BOUGAINVILLE ...

THE ESTABLISHMENT OF A COPPER MINE

PAPUA NEW GUINEA
NATIONAL PARLIAMENT

Mr. Lawrence J. Daveona
Clerk Asst- Parliamentary Committees

P.O. Parliament House, Waigani. NCD
Tel: (675) 327 7759 Fax: (675) 327 7466
email: ldaveona@yahoo.com.au

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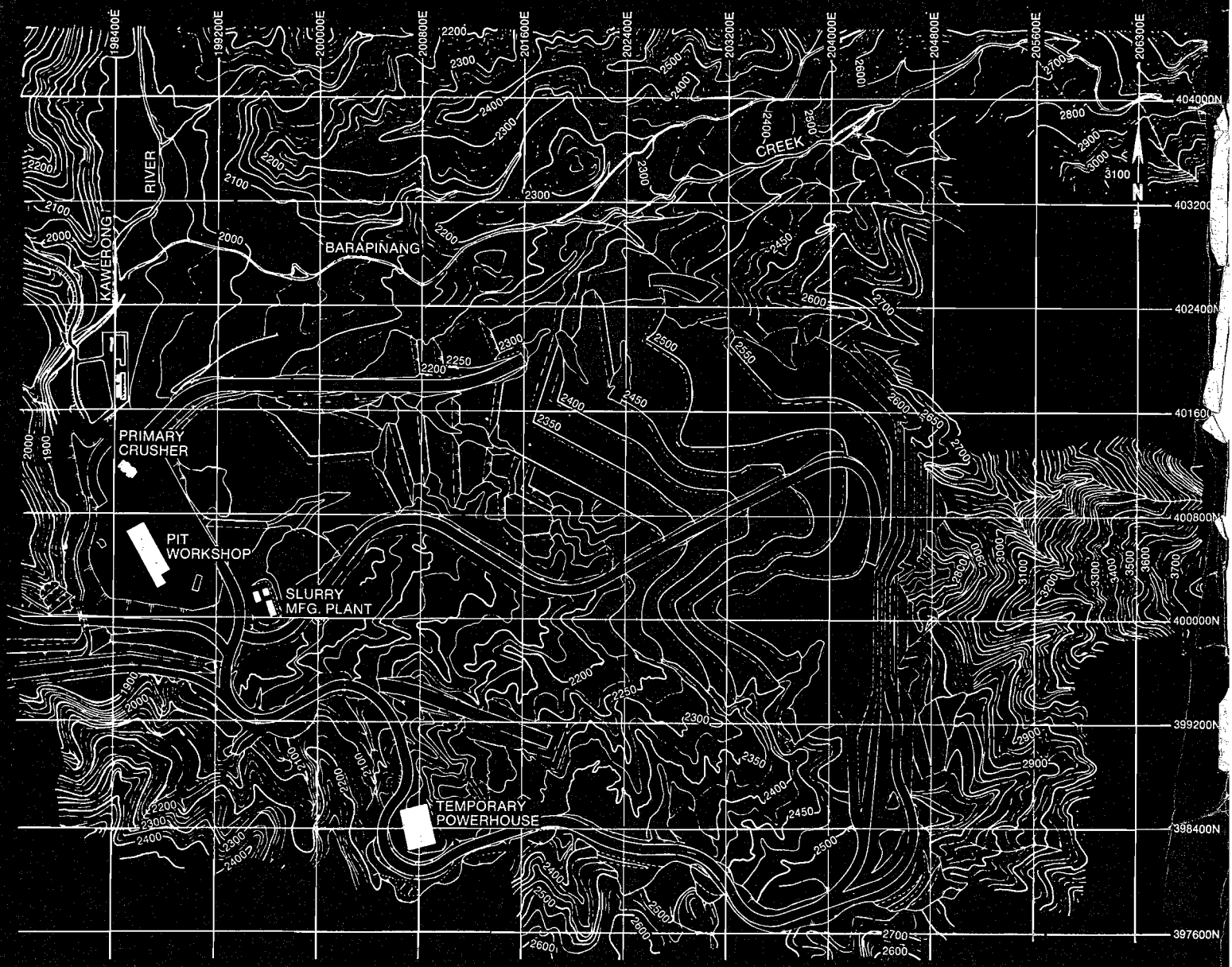

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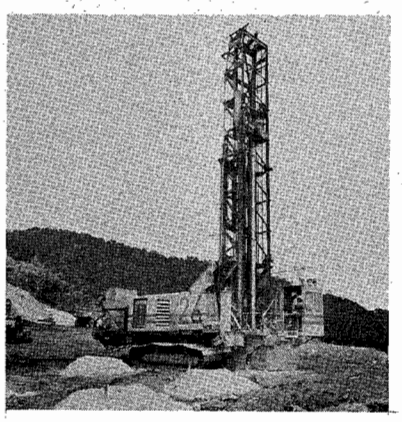

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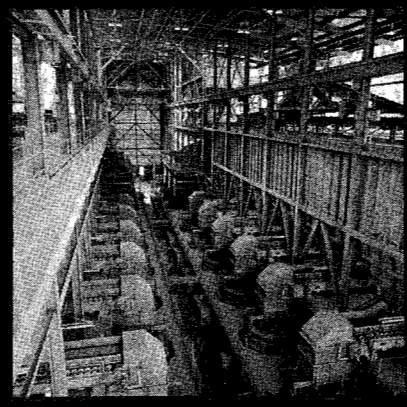

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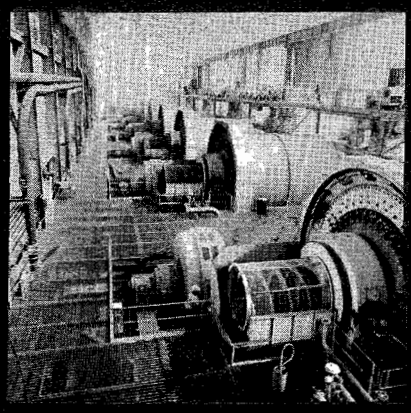
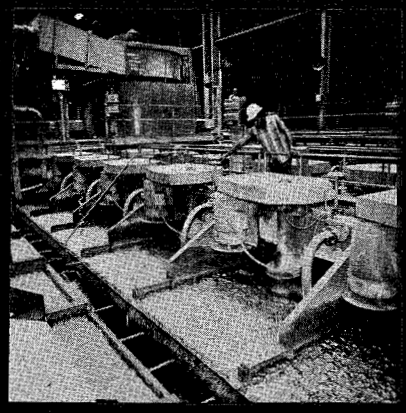
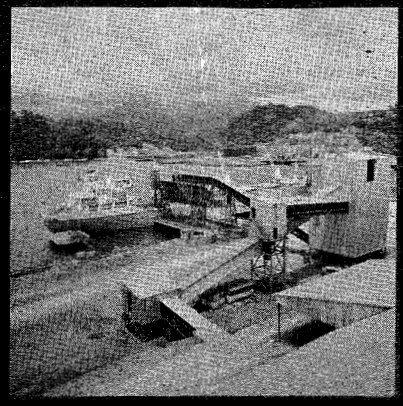

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This Book

The discovery of the Panguna deposit and its identification as one of the world's largest porphyry copper ore bodies initiated evaluation studies, planning and design, which led to the construction of the giant $400,000,000 Bougainville Copper Mine.

The story of this magnificent Engineering and Construction achievement is told in the following pages by the planners, consultants, designers, contractors and suppliers themselves, who, on a tropical island of mountains, jungle and swamp, created and brought into full scale operation – ahead of schedule and within budget – the world's largest start-up copper mine, with essential supporting services of Port, Access Road, Fuel Oil Storages, Power Station, Transmission Line, Telecommunications System and two Towns with Housing, Schools, Hospitals and Supermarkets.

The articles bear dates or otherwise indicate the period of the mine's development at which they were written. No endeavour has been made to up-date them, the Editors preferring that facts, figures and the authors' impressions of that time should remain.

Two articles, which appear on pages 362–379, should rightfully have been placed at the commencement of the book – "The 1936 Report" by Dr. N.H. Fisher and Mr. J.E. Thompson's" 1962 Report". Unfortunately they were received only after printing was well advanced and there was no alternative but to place them as appendices.

Throughout the book there are references to B.C.P. (Bougainville Copper Pty. Ltd.), B.C.L. (Bougainville Copper Ltd.) and B.M.L. (Bougainville Mining Limited). The changes in company structure which have occurred, and the current shareholdings are as under.

PARTNERSHIP AND OWNERSHIP

The original groups that explored the Panguna deposit, Conzinc Riotinto of Australia Limited and New Broken Hill Consolidated Limited, had interests divided two-thirds C.R.A. and one-third N.B.H.C. A partnership existed from the beginning.

The operating Company, then named Bougainville Copper Pty. Limited, was established on Bougainville in 1967. Its partnership with Papua New Guinea was incorporated, in the same year, in an Agreement which placed specific responsibilities on both the Company and the Government and set the pattern for joint development of the project. The P.N.G. House of Assembly ratified the Agreement in 1967 and the Government consolidated the partnership by subscribing for a 20% equity interest in the Company in 1970. The remaining 80%, owned by C.R.A. and N.B.H.C., was held by their subsidiary, the holding company, Bougainville Mining Limited.

Further subdivision occurred in 1971, widening participation still more. Bougainville Mining Limited offered a proportion of its shares to members of the public in Papua New Guinea and Australia. The response to this share issue fully reflected the general confidence in the mining operation.

Especially significant was the response from Papua New Guineans. The size of the public issue in P.N.G. broke new ground and it was not known if such an offer would interest people who had had little opportunity to comprehend shares, the stock exchange or how companies operated. A carefully planned share education programme, conducted in conjunction with Government authorities, was carried out throughout P.N.G. centres in early 1971 in an endeavour to help overcome some of these problems. In the event, the majority of the one million shares offered in P.N.G. were subscribed for by indigenous organisations and individuals. Some 9,000 Papua New Guineas became shareholders.

During 1973 Bougainville Copper Limited replaced Bougainville Mining Limited as the public company for the Bougainville project. Through a scheme of arrangement approved by the relevant Courts, shareholders exchanged their shares in Bougainville Mining Limited for shares in Bougainville Copper Limited, so gaining a direct interest in the company operating the mining project.

The ownership structure of Bougainville Copper Limited is now:–

Government of P.N.G. and Investment Corporation of P.N.G.	20%
Public shareholders	26.4%
C.R.A.	53.6%

The company's issued capital is $133,687,500 in 267,375,000 ordinary shares of 50 cents.

Two million Bougainville Copper shares are held in trust by the Panguna Development Foundation Limited for later distribution to P.N.G. residents.

In the meantime, these shares represent a significant earning potential for the Foundation to be applied to the promotion of business ventures designed for participation by Papua New Guineans.

The work of the Panguna Development Foundation fits readily into the context of progressive localisation throughout P.N.G. To date the Foundation's principal activities have been at Arawa and Panguna on Bougainville, where new towns and new centres of population have created business opportunities. Here the concept of indigenous ownership in business is growing in a spirit of multi-racial co-operation and partnership.

An Introduction

Two of the most stimulating elements in the Australian scene today are the ever increasing explosion in minerals discovery and the role Australia is playing in bringing the Territory of Papua and New Guinea to nationhood. Both project themselves strongly into the future.

A fusion of these two elements is taking place at Bougainville in the T.P.N.G., where Bougainville Copper Pty. Limited has developed a large porphyry copper orebody, and is contributing to the development of the economic and social fabric.

The copper orebody on Bougainville is located in challenging terrain at Panguna in the precipitous and jungle covered Crown Prince Range. After thorough exploration and proving of the deposit, we have developed the site and accompanying facilities and commenced copper production in 1972.

Development, once begun, takes on a definite course which inevitably brings some dislocation and disturbance. This is applying also to Bougainville Island which has previously had little contact with the world of industry. The Company is mindful of these factors – the upheaval both in the physical sense and upon the lives and customs of the indigenous population – and has framed careful policies to minimise unwanted effects and maximise long term benefits.

The futures of both T.P.N.G. and the Bougainville Copper project are identical in many respects. The two are partners in the best sense and from this partnership will flow benefits in terms of prosperity and welfare that should materially assist the Territory in its move towards nationhood. Bougainville Copper is proud to be part of that movement and to make a full contribution as a citizen of the Territory.

F.F. Espie,
Managing Director,
Bougainville Copper Pty. Limited.

IN BRIEF

Bougainville Copper's orebody consists of 900 million tons of ore with an average grade of 0.48% copper and 0.36 dwt. gold per ton. Several additional millions of tons of lower grade material are situated on the perimeter.

It is suitable for open-pit mining, and for efficient, economic operation is being worked on a very large scale. To illustrate the necessity for big tonnage throughputs, with the estimated recovery rate of 95%, 1,000 tons of the 0.48% copper ore have to be treated to produce about 4.5 tons of copper.

Thirty million tons of ore will be mined and treated annually to make the operation the largest in the world in terms of start-up tonnages. This will give an average annual production rate of some 150,000 tons of copper in concentrate, 500,000 ozs. of gold, and 1,000,000 ozs. of silver, this rate being attained within six months of start-up. Long term sales and finance have been finalised. Sales have been arranged for the first 15 years of production with 1,025,000 tons going to Japan (which has an option to an additional 75,000 tons), 787,500 tons to Germany, and 180,000 tons to Spain. The Japanese and German contracts are the largest ever arranged for the supply of copper concentrate to these countries. Most of the copper will be paid for at the free world price, with a guaranteed floor price of US30c per lb.

Cost of establishing the operation was approximately $400 million. Part of this came from the Group's own resources, part from the general public in return for an equity interest, with the major portion coming under two credit agreements. The first was arranged with the Bank of America National Trust and Savings Association, and the Commonwealth Trading Bank of Australia, under which Bougainville Copper borrowed $US246.4m. in Eurodollars. The second was arranged with two major Japanese trading companies which provided $US60m., of which $US30m. was made available specifically to finance equipment purchases from Japanese suppliers.

Benefits to the Territory

The conditions under which the operation is proceeding were laid down in the Mining (Bougainville Copper Agreement) Ordinance 1967 passed by the Territory's House of Assembly on 30th August, 1967. A schedule in the Ordinance said the Administration was satisfied the development of such a large scale operation would bring significant benefits to the Territory in respect of:–

> revenues from royalties and other forms of taxation, overseas trade balances, the economic and social development of the people through employment opportunities, training in new skills, purchase of local supplies, community development, improved communications and the extension of education and health services.

The project will directly or indirectly provide employment for some 2,500 indigenes of the Territory, rising to perhaps 4,000 after 10 years. The Territory's exports which at present are mainly agricultural will be more than doubled, and the Administration estimates that during the first 10 years of operation, it will receive total revenues from Bougainville Copper, including the 1¼% royalty, of between $200m. and $300m., depending on the price of copper. A three-year tax free holiday has been granted, after which a tax ceiling of 50% will apply from the fourth to the 25th

year of production. A 20% equity interest in the operation has been accepted by the Administration on behalf of the people of the Territory.

The Bougainville Copper operation will thus be an important addition to the economy of the Territory.

THE ISLAND

Bougainville is the principal island of the northern group of the Solomon Islands, and is about 120 miles long by 30 miles wide. An island of great beauty, it features a steep mountain range in parts 8,500 ft. high, which can fall rapidly to the sea over a distance of 10 miles. It has active volcanoes, fast streams that rush along like rapids, native villages clinging to mountain ridges, plantations, even elusive fish.

It is an island which was occupied by Germany before the First World War and by Japan's armed forces during part of the Second World War, but in peacetime, has known little haste.

Bougainville is the most eastern of the islands controlled by the Administration of T.P.N.G. Being at the "end of the line" it has been outside the stream of tourism, and its development until now has been mainly agricultural. Flat land is a rarity except in the northern, and in the western coastal areas. Its volcanic soil gives great fertility although the quality of the land deteriorates to swamp, waste areas in the west. Its fertile areas coupled with a rainfall which rises to 200 ins. a year in the mountain areas, allows copra and cocoa to be produced efficiently, and some rubber also. Plantations range up to 4,000 acres and are owned or leased by expatriates and expatriate companies, various religious denominations which are principally Roman Catholic, and also indigenes.

The indigenes are Melanesians and are virtually jet black in colour. They take pride in being the darkest in the Pacific area, and are easily distinguishable from the lighter skinned mainland natives.

Political self-determination has come progressively to the Territory and to Bougainville. The island elects three electroal representatives to the 94 member House of Assembly, which meets in Port Moresby, the electorates being the island as a whole, Bougainville North and Bougainville South. Tribes also elect members to local councils, and an association of tribes called the Napidakoe Navitu represents indigenes politically and in business negotiations.

The Administration is represented by a District Commissioner assisted by Assistant Commissioners who have responsibility for prescribed areas of the island.

THE DISCOVERY IS MADE

The discovery of the Panguna deposit and its identification as one of the largest porphyry copper orebodies in the world was a major geological achievement. It was by no means a chance discovery, but was the rewarding result of geological reasoning, a comparison of characteristics elsewhere in the world where similar deposits were known and worked, and perseverance.

The character of exploration in the C.R.A. Group had undergone several changes since the last World War. At first, the company's exploration programme consisted largely of looking at prospects, mostly outcropping, which had been brought to its notice by prospectors, leaseholders and others. This situation changed to one in which the company made its own choice of areas.

By 1959, this had changed further to a position of trying to visualise what kind of deposits could exist in particular areas in accordance with available understanding of geology, but which had not and probably could not be discovered by prospectors. Now, however, the chances of discovering them had been increased by later techniques principally geochemical.

C.R.A. started looking for porphyry copper in Queensland in 1961, and is still looking there. It was necessary to suppose that any outcropping low grade orebody would have been seen by prospectors who could have worked on the high grade sections of it, but not recognised its low grade potential. Panguna proved a perfect example of this. It had been worked previously for its gold between 1933 to 1951 and because of visible surface signs was known to contain some copper.

During its search for porphyry copper within Australia, C.R.A. found two copper occurrences which at first appeared interesting but after being diamond drilled proved to be too low in grade. Their discovery was significant, however. Firstly it removed the general feeling that copper deposits were to be found only among the young granites of the Americas. Secondly from the experience gained in the search, it enabled C.R.A. to upgrade a somewhat loose, qualitative geochemical technique of exploration into a reliable, efficient and quantitative tool which could cover large areas rapidly. The Company resolved to continue the search, but to move it to areas where young rocks were present. This meant the Territory of Papua and New Guinea, and New Zealand.

The geologist in charge of porphyry copper work, Ken Phillips, visited the Atlas mine in the Philippines while returning from a holiday, and found this was porphyry copper in a fine grained quartz diorite intruding andesite volcanics. (The Panguna deposit later proved almost identical). The next logical step was to search the records of the Mines Department in Port Moresby for references to copper in granites, and three were traced – at Bundi, south of Madang, and at Kupei and Panguna on Boungainville Island. A further prospect at Laloki, 18 miles from Port Moresby, which had been examined and drilled by the company first in 1950 and in 1957, was again investigated.

Bundi and Laloko proved disappointing so Phillips went to Kupei in April, 1964, but this also failed to show promise. His party crossed over the Crown Prince Range and walked into the Panguna area taking stream samples and soil testing as they went. It was apparent from the start that the area had considerable interest.

There were few signs of copper at the surface, as large sections of the deposit were effectively concealed by layers of volcanic tuff up to 200 ft. thick. Consequently it was at first believed that the Panguna Ridge area which had the highest assays, comprised the entire orebody. However, the decision was made to drill a line of widely spaced holes to test for extensions. These proved that the deposit was greater than at first thought. The testing of the deposit then followed the normal exploration pattern.

GEOLOGY OF THE DEPOSIT

The Panguna deposit is a porphyry copper type, which means its copper content is low and disseminated through rocks which are igneous in origin. It is situated in the Kawerong Valley on the western fall of the Crown Prince Range in south central Bougainville (see map), and occupies an irregular oval measuring about 5,000 ft. by 7,000 ft. The valley is a natural amphitheatre, with some of its natural slopes being in excess of 45 degrees.

The evaluation programme was completed after the diamond drilling of more than 200 holes for a total footage of 274,000 ft. As a result, ore reserves within the limits of a designed open cut were estimated to be 900 million tons of 0.48% Cu and 0.36 dwt per ton gold, around which there are additional quantities of lower grade ore. The mineralisation continues to an unknown depth beneath the bottom of the planned open cut. Silver and molybdenum are also present in small amounts. Two long exploratory adits were excavated to obtain bulk samples, and to provide ore for metallurgical testing. The correlation of bulk samples with drillhole results showed that the evaluation of the orebody based on the diamond drill core studies was conservative.

Bougainville Is. is essentially an uplifted Cainozoic successsion of older volcanic rocks, limestone, and younger volcanic rocks, and is surrounded by a coral reef. (Cainozoic is the youngest of the four great geological eras). The island is part of the volcanic belt which virtually encircles the Pacific Ocean, and several volcanoes are situated along its north-west-south-east axis. One – Mt. Bagana – is highly active, but 24 miles from the deposit, while two are dormant. The activity and temperatures of the volcanoes are checked regularly by company geologists, who are convinced that they will not affect the operation.

The surface extent of the Panguna copper mineralisation was defined by analysing both stream silt and soils, and by the chip sampling of exposures in creeks. Mineral indications were sufficiently positive to warrant the previously mentioned diamond drilling programme, which was escalated as further results came forth until 16 drills were in operation. The jungle covered mountains and ridges made the transportation of equipment and the movement of drills a major problem which was overcome by helicopters in the earlier stages, and later by cutting a road from the coast through a 3,500 ft. pass over the Crown Prince Range. This was a major reason why the proving of the deposit was one of the costliest ever undertaken.

The Panguna mineralisation is predominantly in the form of chalcopyrite with some bornite (two copper-iron sulphides) mostly along thin veins. Some of the intrusive rocks have minor amounts of chalcopyrite disseminated within the rock fabric. Gold and silver are contained in the chalcopyrite, but free gold is rarely to be seen. Pyrite (iron sulphide) and magnetite occur along veins and in disseminated form, and there are also small amounts of molybdenite along veins. The primary ore is covered by layers of secondary and oxidised ore, and in places by boulders, volcanic ash, alluvium and soil. This overburden varies in thickness from 0-200 ft. and must be removed as well as the vegetation cover in the pre-production period prior to mining.

The deposit extends into ridges bordering the valley such as the Panguna Ridge – one of the highest grade areas – but in the main lies below the valley floor.

WHETHER TO PROCEED

A great deal of evaluation work was done on the Bougainville Project. This basic homework added up to one of the most thorough investigations of a mining prospect ever carried out, and followed in the main, sophisticated, computer-based procedures.

A bewildering array of variables had to be considered. Some could be controlled by management, others such as the market for copper concentrates, equipment costs and the availability of finance could not be controlled, while others varied unpredictably, the chief intangible here being the future price of copper.

To evaluate the interaction of these variables, a high capacity computer was used from the start of the investigations. It covered a wide range of evaluation work from geological assessments to financial studies, and in three years was used between 120 and 150 hours.

In the early days, drilling information was incomplete, and knowledge of other factors was far less precise than it was later on. Consequently all conclusions had to be periodically reviewed in the light of more up-to-date information as it came to hand.

The stages in the evaluation work were roughly as follows: first, the mineral values of the orebody and their spatial relationship were expressed in a numerical form or model, which allowed the computer to simulate the mining operation; second, the physical limits of mining were determined, having in mind the distribution of mineral values and the characteristics of the surrounding rock mass; third, by simulating the variations in those factors which could be controlled, such as pit output, concentrator throughput and cut-off grade, the Company could evaluate different modes of attack and hence decide what operational strategy should be followed.

From the answers obtained to these questions, the Company was then able to determine the financial outcome of the proposed scale of operations, the manner in which the orebody was to be developed, and the cut-off grade policy.

In the final stages of the evaluation work, management was also able to obtain an assessment of the risk involved in its investment. No absolute statement of risk was possible, but by establishing the sensitivity of financial results to the many factors involved, B.C.P. did obtain a yardstick whereby it could determine the consequences of its decisions.

PREPARATIONS

Once the decision was made to proceed with the project, all the various production components, the services, preproduction planning, the accommodation for personnel, the 10,000 and 1 items needed before production can commence, had to be provided in accordance with a strict time schedule. This constitutes the construction phase of the operation, which on Bougainville, will extend over two years.

Construction for a project as big as this is basically an exercise in planning and logistics. The requirements are to have everything that is wanted for a job on hand when it is needed, and to dovetail each stage into the next. The construction phase thus becomes a progression of completed stages, all integrated with each other. It is like a great river which starts small, then builds up as tributaries add strength at various intervals, and then finally its entry into the ocean marks its high point, and its end.

Bougainville's construction phase can be summed up as follows: clear the land – provide the services – build the production components.

All three categories were completed before one dollar can be earned, and cost approximately $400m. This points up the fact that mining companies attempting big projects must be big in themselves, and capable and free to command great skills and attract capital funds. The joint venture of Bechtel-Western Knapp Engineering was responsible for all construction management except mine preparation work such as pre-production stripping.

Bougainville Copper looked after these aspects itself.

CLEARING

The first requirement in an open pit operation like this is to uncover the orebody. In Panguna's case, this involved the removal of –

1. a vegetation cover of towering trees and jungle undergrowth in terrain which in parts is only a little less steep than the Matterhorn and
2. a volcanic tuff and weathered rock overburden varying from nil to 200 ft. in depth but averaging about 50 ft. Nature has ensured that few things are easy in this operation. One redeeming feature is the softness of the volcanic tuff. This can become a churned, muddy mess, in five minutes, but can be removed more easily than consolidated material.

All large trees were poisoned and the undergrowth sprayed with herbicide during May and July, 1969. A method of clearing known as high-lead logging started late that year with the clearance of the pit area, this amounting in the first stages to about 500 acres.

High-lead logging is a faster, more sophisticated version of the ball-and-chain method of clearing and is very effective in rough areas. The principle is to draw a 2¾ ins. diameter steel hawser through an area like a giant scythe, keeping it moving at about 900 ft. a minute and off the ground so it will exert greater leverage when it hits anything and also to keep out of the way. A swathe 600 to 800 ft. can be cleared at a time. The hawser is drawn in by two 450 h.p. winches which exert their pull through 110 ft. high masts, hence the name of high-lead logging. Three days are needed to set the gear up to clear one section, and a further three days for the actual work. At the first pass all but the biggest trees are knocked over and these are blasted from the ground. The hawser is pulled back to its original position by return hawsers and then used to draw everything into a natural depression such as gullies for burning. Large trees are carried to the piles by rubber tyred skidders.

The sap run in the trees and vegetation has long since ceased and everything dried out, but in an area where inches of rain can fall each day, burning is not easy. The piles of dead wood can be burned only by providing near furnace conditions, and this is done by powerful fans blowing a stream of air onto the piles, and the addition of diesel fuel.

This is clearing jungle areas on a scale and in a manner which Bougainville Copper believes has never been attempted in the world before. Jungles certainly have been cleared but usually with plenty of assistance from natural rotting, and this takes longer than Bougainville was prepared to wait. This had to be a quick and a clean sweep.

HYDRAULICKING

The next stage in uncovering the orebody is to remove the overburden of volcanic tuff and weathered rock by hydraulicking. A cheap, quick method of removal, but useable only in sparsely populated areas because of its reaction on stream flows, it is carried out by monitors capable of flinging 12 tons of water each minute for a distance of 100 ft. or more. In other terms, 725 h.p. motors operate three-stage pumps, capable of pumping 2,500 gallons of water each minute to a height (or head) of 650 ft. through 3½ in. nozzles.

An impact such as this, however, would merely punch holes in the tuff which does not flow freely, so the monitors are serviced by bulldozers which push the material down to the monitor jets. Removal rates of 280 cu. yds. per bulldozer hour were being obtained, and when three bulldozers are feeding each of the company's monitors, the landscape changes rapidly.

A total of 28m. cu. yds. of material was removed by the hydraulicking operation which was also used to establish flat areas for the concentrator, stockpile areas, workshops and lay-down areas.

The dislodged material went mainly into the Kawerong River, a fast-flowing mountain stream which quickly washed it away. Build-ups did occur but were usually scoured out by the frequent flood conditions which follow heavy rain. Regular checkpoints were established down the course of the Kawerong River to keep a check on the river flow.

SERVICES IN SUPPORT

ACCESS ROAD

A new 16-mile access road between Loloho and Panguna built under contract is the most spectacular and far reaching of the services installed. Except for a few major deviations, it follows the route of the first access road which was built by C.R.A. with assistance from the Snowy Mountains Authority, and which has been a rough but essential lifeline for the operation.

The new road is 24 ft. wide with shoulders of varying width, and is one of the finest in the entire Territory. It replaced the 20% maximum gradient of the access road with a more gradual 12% and its first function was to enable heavy construction mine and concentrating equipment to be taken through the mountains to Panguna. Its construction posed many problems. Starting from the coast, it immediately meets swamp conditions so great tonnages of fill were required. It then traverses relatively flat land for about eight miles and meets the fast flowing Pinei River. This was crossed first by a low level bridge which served until a permanent steel bridge was completed in 1970.

After leaving the coastal plain, the road climbs rapidly into the mountains where the challenges are the precipitous nature of the country and the problems of erosion, landslides and slippery surface conditions which the heavy rain creates.

A mammoth earth moving operation was needed here. Ridge tops were cut off and sometimes used to fill ravines to provide a gradually ascending route for the road. A complicated bench system often rising 200 ft. above the road was necessary in some sections to protect it against landslides and to divert water from it. A guiding principle in design has been to "keep as much water as possible off the road". Culverts, channels and drains route flow-off to the natural drainage systems of creeks and rivers.

The road designers also had to allow for the effect of earth tremors in the area. It is inevitable that landslides will take place occasionally but the broad width of the road plus its shoulders, and protection from the benches, should minimize the effect.

The road was built in phases. It became trafficable in October 1970, so enabling heavy equipment to move to Panguna.

POWER GENERATION

B.C.P. constructed a 135 MW steam power station at Anewa Bay which in size is almost double the entire generating capacity (70 MWs) of the T.P.N.G. Besides servicing the copper project, it also supplies bulk power to the Electricity Commission of Papua and New Guinea for use in Kieta and Arawa districts.

The power comes from three steam turbo-generators each of 45 MWs, and is reticulated to the Panguna operation by a 132,000 volt line. This was installed on transmission towers built sufficiently high to clear the biggest trees of forest areas, and to prevent undergrowth from interfering with the lines. The towers follow the same approximate route as the road.

The Anewa Bay power station is totally enclosed because of the high rainfall. A shortage of flat land with a suitable rock base for foundations was a problem which was resolved only through a massive excavation exercise. 1,000,000 cubic yards of material were carved out of a hillside to provide a proper site for the station.

PANGUNA AND ARAWA

A mountain town, Panguna, and a coastal town, Arawa, provide comfortable accommodation and all the community needs for a good, well balanced life. Both cater for expatriates and indigenes living on an integrated basis.

Panguna is adjacent to the mine operation but out of sight from it. It was built in two adjoining valleys, the Kawerong and Karoona valleys which come together to form a broad V. Key production personnel and their families are accommodated here and give the town a population of about 3,000.

The steep valleys add beauty to Panguna but severely restrict its size. Houses have been built on slopes up to 1 in 3. The company would have liked to accommodate all its mine and mill personnel at Panguna but was forced to establish a second town, Arawa, on the coast, in conjunction with the Administration, from which workers commute the 32 miles round trip to Panguna and back by bus each day.

Arawa eventually will be bigger than Panguna with a population of upwards of 10,000 to make it one of the principal towns in the Territory. It will also be the Administrative capital of the Bougainville District. But whereas Arawa will be an open town and subject to business and trading influences from many quarters besides the mining project, Panguna will be a company town administered by B.C.P. Arawa will accommodate Panguna personnel who can't be quartered at the mine site, and workers from the coastal industrial area and Anewa Bay port area besides non-company personnel.

Both Panguna and Arawa have been laid-out by consultants in accordance with the latest town planning principles. The cost to B.C.P. of establishing Panguna, and its share in establishing Arawa ran to about $30 million. Under the terms of the Mining Agreement, the Administration will bear the cost of schools, medical services, postal and police services.

Some details of the two communities are as follows:

Panguna: 320 homes have been built and an increase to 400 is probable. Many are of two levels with carport, play area, laundry and utility rooms at ground level. They have three or four bedrooms, with the upper level area ranging between 10 and 15 squares, and are all-electric.

Panguna's height above sea-level is 2,200 ft. where the temperatures are moderate, consequently air-conditioning is not needed. With land at such a premium, 24 two-bedroomed flats were built and single-men's accommodation is three-storied. 36 self-contained motel type suites were built for unmarried senior personnel.

Non-company personnel cannot be accommodated at Panguna, and visitors will be required to stay at Arawa. Shopping and community facilities will be most adequate. A supermarket, department store and line of shops face onto a pedestrian mall, and a hall caters for club activities, social and film nights. An interdenominational church with 500 seats has been built.

Sporting facilities include an oval, tennis and squash courts and an Olympic-sized swimming pool. For the socially inclined, a club with its own bars and sporting facilities makes an ideal gathering place. A primary school will be built near the community centre for 600 students, both expatriate and indigene. Indigenous children from nearby villages will also be taught.

Street names have already been selected, taken from the names of local creeks and tribes.

Arawa: Many years of growth lie ahead of Arawa, which is designed to follow a separate, suburban style of development with each area having its own school and shopping facilities. It will eventually have several primary schools, a high school and a technical school.

Services will be correspondingly larger and the first of these to be built was the hospital, which has 250 beds, and serves as a district hospital. The beach area is flanked by recreational facilities.

MINING

The task of establishing Bougainville Copper as the biggest copper mining and treatment operation in the world in terms of start-up tonnages would be complicated enough in itself without the physical difficulties so evident in

Panguna. Some are temporary and can be disposed of in a few years such as the vegetation cover and volcanic tuff. Others must be borne throughout the life of the operation such as the monotonously regular rainfall and the slush it creates. Steep terrain makes transportation difficult and puts a premium on flat ground. A mining engineer once summed up the position: "There are problems everywhere. Certainly there are logical, practical solutions to them all, but on Bougainville, boy – they cost a lot of money."

The following are some notes on the mining operation and on a few of the problems being encountered.

Clearing the vegetation by logging and removing the tuff by hydraulicking have been dealt with in the previous section on preparations for the operation. Hydraulicking has also been used to help construct the haul roads which traverse the Panguna-Kawerong Valley area. These are 100 ft. wide and give access to three main areas – first to Panguna Ridge where mining commenced because the copper grades are highest in this area; second to the primary crusher site by the side of the open pit, and third to the waste disposal area in the valley. The roads have 70 ft. pavements, 15 ft. of safety mounds and a further 15 ft. for drainage channels. They are used by a fleet of 41 – 1000 h.p. trucks carrying 100 tons in a single load, and which have both front and rear drives to handle the muddy conditions experienced during the early years of mine development.

The ore to waste ratio at Panguna is approximately 1:07, which is low for a porphyry copper deposit. About 40% of all material mined will be dumped in a 1½-mile section of the Kawerong Valley, which proved the only economical disposal area nearby. Over the years about 400 million tons of material will end up in the valley. But what will happen to the Kawerong River which flows through it? The solution is a complicated, fascinating one, and worth describing in detail.

Dumping will start in the section of the valley nearest the open pit and will gradually extend down it. For a while the course of the Kawerong River will not be affected, but as the sides of the valley are filled and then the centre, the dumping will encroach on the river and lift the level of its bed. Its present gradient is about 8%. Dumping will eventually raise it to 1%. The dumping will be so arranged that there will always be a channel across the top for the river to follow, but as the dumped material is rock, and free draining, most of the water should percolate through it. The dumped material will be bound or supported by the valley walls. Stability studies of this dumping arrangement have been carried out and the project has been designed with adequate safety factors.

The waste material going to dump still has copper values, and B.C.P. has conducted an interesting and imaginative exercise into the practicability of leaching these values. The main problem would be to prevent the dilution of the copper, rich liquor by water draining from the sides of the valley. If the rain could be kept off the dump, so much the better, but this would be an impossibility. A number of leaching tests have been conducted, but the project is essentially one for the future.

Actual mining was preceded by an intensive period of pre-production development which included the previously mentioned logging, hydraulicking and stripping by shovel and truck. All these operations were aimed at having available for the concentrator a continuous supply of ore.

The activity is centred on Panguna Ridge under which a high grade section of the orebody lies. The open pit is being developed by the shovels and 100-ton capacity trucks working to the normal open cut principle of 50-ft. high benches.

Excavation over the years will extend from the top of the ridges which are about 3,400 ft. above sea level, to about 900 ft. below the valley floor – a total vertical distance of some 2,900 ft. The mineralised rock is intensively fractured and together with the seismicity of the area and high rainfall, make the stability of the pit slopes a critical factor. A decision on the slopes of the final pit will not be necessary for several years, when the open pit becomes better defined, but already, a programme is being carried out by a team of geologists and hydrologists to collect and analyse data on the distribution and frequency of fractures in the rock mass, rainfall and run-off groundwater behaviour and seismicity.

The mine will not take on the familiar appearance of an open cut with its concentric bench pattern until about the third year of production. It will not expand to its full pit area of a rough oval 7,000 ft. by 5,000 ft. until towards the end of its life, which could be in excess of 25 years.

The accurate separation of waste material from ore will be critical to the economics of the operation, and will be achieved by the sampling of ore cuttings from blast holes, and by reference to the highly detailed ore reserve plans prepared from the diamond drilling results. Strict control will be exercised over these functions by the mine supervisory staff, aided by geologists.

Panguna's rainfall varies between 180 ins. and 200 ins. each year. Usually there is a heavy downpour each afternoon. With the removal of the vegetation cover and overburden, run-off is expected to increase by 50%. Drainage of the mine area will thus be a critical problem which would fill few plumbers with joy.

For the first three years of operation, mining will be concentrated in ridge areas above the level of the pit, and a gravity system will be used to drain these areas. It will consist of an interlocking system of channels, ditches and culverts which will be adjusted according to need as the configuration of the mine changes.

In future years as the mine develops below surface level, it will be necessary to develop another drainage system to remove water accumulating in the pit from rainfall and from the substantial seepage of ground water. Investigations are proceeding into a tunnel system below the pit bottom which would be connected to it by a series of vertical shafts. The collected water would then either be pumped out or drained away by a shaft. A simple analogy to this method would be the drainage of a kitchen sink. A further alternative would be to remove the water from the pit bottom by pumps. A final choice on method is not required immediately.

CONCENTRATE FROM ORE

As with many low-grade metalliferous ores, examples being lead, zinc and nickel, the copper ore of Panguna needs to be upgraded to a concentrate before smelting. A

concentrate of 30% Cu is being produced, after which it is pumped in slurry form through a 5½ ins. diameter pipe to the export port of Anewa Bay 15 miles away. It is filtered, dried to reduce its moisture content to about 7%, then placed in a covered storage of about 60,000 tons capacity to await shipment.

Concentrating is a key stage in the Bougainville operation. The grinding and flotation stages are the biggest in the world to be accommodated under one roof. In flat terrain this would present few problems, but at mountainous Panguna, it had to be created by large scale earth works.

The Panguna concentrator is also the biggest in the world in terms of start-up tonnages. Other concentrators such as Kennecott's at Bingham Canyon handle larger tonnages, but with a number of concentrators built over a period.

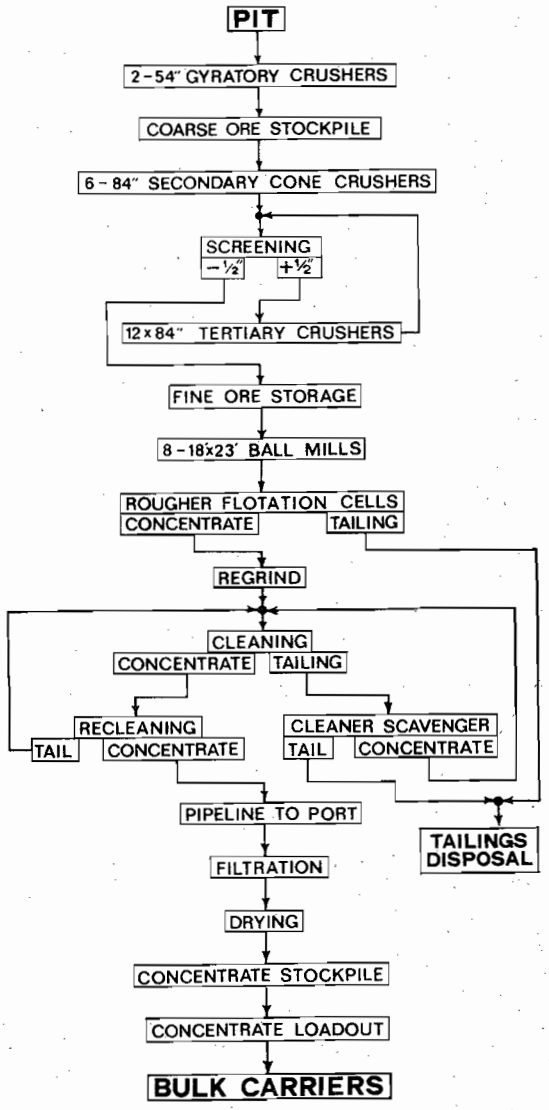
Treatment of the ore presents no abnormal metallurgical difficulties. The overriding need is to handle huge tonnages continuously without falter. The concentrator treats 90,000 tons of ore daily, seven days a week throughout each year, this rate being required to reach the annual production target of 150,000 tons of contained copper and 500,000 ozs. of gold (included in the concentrate).

Concentrating involves the three stages of crushing, grinding and flotation. Because of the scarcity of flat, open ground in the Panguna Valley, the only operation carried out there is primary crushing to minus 8 ins. by two 54 ins. gyratory crushers. A coarse ore conveyor, covered against the rain, takes the ore 400 ft. above pit level to a coarse ore stockpile, capacity 50,000 tons, on the Moroni Ridge.

Then follows further crushing and screening, which progressively reduces the ore to minus ½ ins. size when it is ready for grinding. The principle behind flotation is to grind the ore to fine particle size, to release the valuable minerals from the rock and agitate in water to which collecting and frothing reagents have been added. The mineral particles then rise with the froth of bubbles and the waste material sinks. Through such separation a product of higher mineral grade is obtained.

The minus ½ ins. crushed product enters the grinding section from an 80,000 ton capacity storage shed. It is fed to eight single stage ball mills each 18 ft. in diameter and 21 ft. long and powered by a 4,250 h.p. motor. Forged iron balls in the mills of 2 ins. to 3 ins. diameter grind the ore to a particle size of 73 microns – about coarse powder size. In grinding the ore, the balls themselves are gradually worn away and between 16,000 and 20,000 tons of balls will be consumed in a year. As these have to be imported, the freight bill is high. Autogenous grinding, a method whereby the ore grinds itself was examined as an alternative, but did not prove feasible because it required considerably more power per ton of ore.

The flotation plant is equipped with process control and has two sections, each containing 96-300 cub. ft. and 117-100 cub.ft. flotation cells. Total nominal flotation capacity is thus 72,000 cub. ft. which is quite immense. Although perhaps a little unfair because of the different ores and grades handled, it is neverthless interesting to compare this capacity with established operations. The Zinc Corporation, a C.R.A. Group mine at Broken Hill, has a total concentrating capacity of 3,800 cub. ft. New Broken Hill consolidated has 7,065 cub. ft.



FLOW CHART OF THE OPERATION

Bougainville Copper's cells are in rows of 14 with a back-to-back configuration. The dividing walls between the cells are removed so the end result is two cells working as one 600 cub. ft. unit. This has never been tried before with this size of machine.

The concentrate from the flotation section is pumped as a slurry through a 5½ ins. diameter carbon steel pipe to Anewa Bay. Up to 2,000 tons of concentrate is pumped daily for 360 days a year, the pipeline being installed by the side of the road. The use of the pipeline is novel, this being only the second application of the method in the South-West Pacific, the first being the Savage River (Tasmania) iron ore operation. It was selected on the grounds of economy after consideration of a variety of methods including trucking.

At Anewa Bay the final stage before shipment is to reduce the water content of the slurry. This is carried out in two stages, the first being vacuum filtering which cuts the moisture content to about 12%, and the second being

rotary kiln drying which reduces it further to 7%. A covered storage of about 60,000 tons capacity holds the concentrate for shipment. This is carried out in cargoes of between 15,000 tons and 25,000 tons. Ship loading rate is 1,000 tons per hour. Huge quantities of chemical reagents are needed in the flotation process. To control alkalinity levels in the circuits, between 25,000 to 30,000 tons of hydrated lime will be used each year. 900 tons of frother reagents will be required and 300 tons of collector reagents.

The latter could be likened to the supply of 300 tons of fine quality oil to lubricate watches, and that would go a long way.

RELATIONS WITH THE INDIGENES

In its relations with the indigenes of Bougainville Is., the Company's policy has three main objectives:

- to work harmoniously with the established order of life on the island.
- to employ and to train as many indigenes as possible.
- to achieve a high degree of integration between indigines and white expatriates.

This policy has been followed resolutely. It has had rough passages but to date has been successful. The main problem has been one of communication, of advising the indigenes what the company's plans and intentions are in such a way that they are understood and remembered.

How do you convince a local people who speak 19 different languages that the Company's diamond drills will not release a flood of subterranean water which will drown the island, OR that the drills are not sucking out the copper wealth from the ground, OR that they are not interfering with the spirits of their forefathers? The answers are patience, a knowledge of the lingua franca "Pidgin", and help from others with experience in such matters, including officers of the Administration.

To see how other companies handled similar problems, two senior executives of B.C.P. visited Zambia in late 1966 where selection and training programmes for indigenes were operating. It employed anthropologists, psychologists and sociologists, so it might better understand the background and culture of the Bougainvilleans, their beliefs and values, likes and dislikes, and so formulate plans for better relations. B.C.P's. operations have caused a certain amount of interference with established land holdings, although published assessments have often exaggerated the scale of such interference and the inconvenience it has caused. The Administration responsible for providing the Company with its "reasonable land requirements" and for fixing the level of compensation.

Where land is purchased, the purchase price is fixed after negotiation. Where land is leased, the indigenes compensated not only for the temporary loss of the use of the land, but for the loss of hunting grounds, tribal tracks and other inconveniences. Where re-settlement has been necessary, alternative accommodation to European standard has been provided, and assistance given to help the indigenes re-establish industries of their own. Some of these such as market gardens, transportation, stores, are being used to service the operation, so there will in practice be a "multiplier effect" among the direct and indirect benefits the operation will bring.

The great majority of indigenes accept the Company's operation, and appreciate the benefits it is bringing. Of these, employment and training opportunities are by far the most important.

B.C.P. recruits as many skilled and unskilled indigenes as it can in regular campaigns on the island and in other parts of the Territory. Many skilled Bougainvilleans have returned to their island home without prompting because of better opportunities available.

The amount spent by the Company on scholarships and training escalates each year, the budget figure for 1970 being in excess of $500,000. This allows better education to be offered to all levels of indigenes, from those straight from the village to skilled technicians wanting to take out diplomas and degrees. There are no bonding requirements applied.

B.C.P's. induction book states: "As soon as an indigene progresses to take his place in the integrated community, he will be welcomed into it. The Company does not seek to rashly force the pace of integration, nor will it tolerate the deliberate obstruction of this movement. The expression of racial prejudice by any employee whether he be indigenous or expatriate will be regarded as a serious matter."

It would be hard to expect a native steeped in village ways, with little education or sense of modern hygiene, to take his place without preparation among the modern facilities of a mining town. It would be embarrassing to him, to his fellows who had already made the transition, and to expatriates. Consequently his entry into integrated messes and integrated towns follows a careful plan. He need not progress at all if he doesn't want to, but the opportunity is there. The plan revolves mainly around the Company's camp and mess system. On joining the operation an indigene with little but his village background would join the indigenes mess where the food is mainly native, where h. becomes accustomed to sleeping in a bed, and where he learns personal and community hygiene. He can receive schooling at various levels.

Next he may enter a transit camp where the conditions are more similar to those in expatriate quarters, where his development progresses a stage further, but where he still mixes with his fellows.

Finally, when he is ready and when he has assumed responsibility in the operation, he comes to the integrated quarters – either in the single men's or in a house in an integrated section of the town. This progression has been most successful. It is not new to the Territory, but is in advance of what is common practice.

Papua New Guinea & Bougainville

COMPETING NATIONALISMS AND THE CRISIS OF EXPECTATION

Antony Martin,
Economic Journalist

One hundred years ago, New Guinea was the last unknown. Books of total fantasy which purported to describe its interior had to be taken seriously, because nobody knew what it was like. Then, in 1885, Britain and Bismarck's Germany agreed to divide up the island, in a fashion familiar from African history. By that time a few traders and missionaries had established themselves on the coast. But when the powers met in Berlin to draw their imaginary line through the middle, they were parcelling out territory that no European had ever seen.

All unknown to these Stone Age people, their political status in the world at large had been going through continuous change in the half-century before they were 'discovered'. If their homes lay to the north of the mythical line, they were New Guineans, living successively in a territory administered by the German New Guinea Company, an imperial German colony, an Australian possession under military rule, and a League of Nations mandate run by Australia. If they lived to the south of the line, they were not New Guineans at all but Papuans, and following a period as British protected persons they became, after a fashion, Australian citizens. None of this made any impact on their lives. What mattered much more, when it came, was the introduction of new technology (steel axes for stone ones), new and useful goods, colonial law and order, and the moral and religious ideas of the Western world as expressed by missionaries. At the political level, the status of the territory was determined by the military ambitions and fears of Western powers, the results of world wars, and the search of Europeans for profits and raw materials. It was only after the second world war that the economic, social and political development of the local people began to be seen as worthwhile objectives, partly for their own sake and partly because world opinion on such matters had become a factor that the Australians, like other colonial powers, felt they had to take into account.

Full internal self-government is now scheduled for December, 1973, with independence expected to follow not long afterwards.

More than most former colonies, Papua New Guinea suffers from a clash between history and geography. To begin with, the main island (the biggest in the world after Greenland) is split down the middle, from north to south, by one of those suspiciously straight lines. To the west of it lies West Irian, the former Dutch colony which the late President Sukarno of Indonesia managed to incorporate into his sprawling domains.

The frontier was hardly decreed by nature and its existence is likely to pose diplomatic problems, if nothing more serious, for the government in the east.

Papua New Guinea itself consists of the eastern part of the main island, plus numerous smaller islands of which New Britain and Bougainville are the most significant. The government's first task is to build a nation out of this variegated material, and there are many potential sources of division.

Papua and New Guinea have always been separate administrative units, Papua under British and Australian rule and New Guinea under German and Australian rule, with a short interlude under the Japanese. Although the two are now going forward together, New Guinea is still constitutionally speaking a United Nations trust territory, whereas Papua is an Australian territory. The tone of government has also differed between the two segments. In Papua, the emphasis was on benevolent, high-minded protection of the natives from exploitation by business interests. In New Guinea, perhaps partly because of the German legacy, there was greater scope for European planters and commercial operators, with correspondingly greater economic development and worse race relations. Whatever the explanation, the numerically fewer Papuans fear domination by the New Guineans. Antagonism manifests itself in occasional riots and is reflected in jealousies at the political level.

There are divisions, too, between coastal people and highlanders. They look different; they have a different history, notably so far as length of contact with Europeans goes. The Highlanders in particular, to the extent that they identify with a larger group than the clan, may well think of themselves as Highlanders rather than as Papuans and New Guineans. But there are still more immediate potential threats to national unity. The most important concerns Bougainville, the copper-rich island which lies nearly 600 kilometres to the east of New Guinea proper. The Bougainvilleans, 80,000-odd in number, look strikingly different from the rest. They are jet black in appearance, as opposed to coffee-coloured, and refer to all other Papuans and New Guineans as 'red-skins'. Geographically, they are the northern end of the Solomon Islands and not a part of the New Guinea complex at all. They find them-

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selves in Papua New Guinea because of another 19th century deal between Britain and Germany under which Germany got Bougainville and Britain took the rest of the Solomons (themselves today being prepared for independence in 1975).

For several years there has been an active secessionist movement on Bougainville, which has agitated for a referendum to let the people decide whether they want to stay with Papua New Guinea, go it alone, or go in with the British Solomons. The old argument that Bougainville would not be a viable entity has lost most of its force with the opening of the huge copper mine last year. On its own, Bougainville would be rather a rich country. The trouble is that Bougainville's copper would be the mainstay of the national economy, which explains why any administration, whether the Australians or their successors, has resisted and will go on resisting a referendum with the utmost determination. Many new nations, as Africa knows all too well, face these divisive pressures. Papua New Guinea may seem to have even more of them than most and one could add to the list without trouble: the potential split between town and countryside, the enigmatic but powerful movement towards some form of separate political identity for the formidable Tolai people, who live on the overpopulated Gazelle peninsula of New Britain. The big unknown is what happens in a country which is not just divided into largish tribes, as in most of Africa, but fragmented into a myriad of tiny clans.

As in all developing countries the leaders face dilemmas to which there are no immediate solutions. One is the future of the agreement between Papua New Guinea and Bougainville Copper Pty. Ltd., which lays down the terms on which the company can operate its major new open-cast mine. Voices are being heard to say that the agreement is too favourable to the company and that an independent Papua New Guinea would have to renegotiate it.

Australian development policy has concentrated on increasing exports, encouraging subsistence farmers to enter the cash economy by producing tropical cash crops for which there is a world market (even if an uncertain and limited one), and providing the administrative framework and infrastructure needed for these purposes. If the test is growth in the modern sector, the policy has been highly successful. Gross monetary sector product (which excludes the value of subsistence output) grew at an average rate of over 15 per cent a year in money terms between 1966 and 1970, accelerating towards the end of the period under the massive stimulus of the A$400 million investment required to bring the Bougainville copper project on-stream.

Bougainville apart, the prime cause of these achievements has been Australian aid. Over the past ten years, Canberra has pumped very large and increasing sums of money into the place, and the level of financial aid last year – A$140 million of budget grant and Australian government expenditure – works out at well over A$50 for every man, woman and child in the population. It is claimed that this is the highest level of aid per head enjoyed by an underdeveloped country in the world. There may be room for dispute over how much of this is really 'aid'. What is clear is that it has not brought the country anywhere near financial self-sufficiency, and the question arises how long the Australians will be prepared to go on paying up to support a country for which they will no longer have direct responsibility.

A draft report, unpublished but extensively leaked, by a World Bank–United Nations Development Project team invited to suggest guidelines for the next five-year plan due to start this year, had some sharp things to say about former policies, and it made recommendations. One of which was that Papua New Guinea ought to think seriously about renegotiating the Bougainville copper agreement.

This was a deal hammered out between the company, and the colonial administration, and ratified by the then House of Assembly in 1967. Very briefly it provides that the company should have a tax holiday for the first three years of production and that after writing off its capital expenditure it should start paying company tax at a rate starting at 25 per cent of income in the first year (the territory's normal rate), then rising in four years to 50 per cent and subsequently by degrees to 66 per cent. The company is not expected to pay tax before 1978, but this depends on the level of profits which in turn depend on unknowns such as the copper price. The Government has exercised an option to take up 20 per cent of the equity at par, on present evidence the best investment it is ever likely to make. It also gets a royalty of 1¼ per cent of gross revenue, 5 per cent of which goes to local landowners around the mine area near Panguna in Bougainville.

This is not the palce to assess the merits of that agreement. Its opponents have attacked it on a variety of grounds, among them that the tax holiday is too generous, the Government's equity too low, or that the copper should be exported after smelting and refining instead of in concentrates. They are inclined to point to recent developments in other copper-exporting countries such as Chile, Zambia, Zaire and Peru, drawing the conclusion that Papua New Guinea gets less from Bougainville than those countries do from their mineral resources. The company might reply that Bougainville is a new mine financed largely with medium-term loan capital and that until the loans are paid off there is only a limited amount of net revenue to be divided between the Government and the shareholders. For that and other reasons, it might add, comparisons with other copper producing nations are not necessarily in order. In legal terms it could claim that the agreement was freely ratified by a previous House of Assembly. To which the reply might be that the House was a colonial rubber-stamp in no position to pass judgement on such a crucial matter, still less to bind its successors. Whatever the merits of such arguments on both sides (and I have only mentioned a few of the most obvious ones), potential investors are possibly more interested in the nature and strength of the forces at work. They could do worse than begin by noting that the pressure against the agreement derives from two distinct sources: dissatisfaction on the island of Bougainville itself and the general hunch that Australia may not have struck as hard a bargain with the company as it could have done. Both play their part, but my impression is that the purely local pressure may be the more potent at the present time.

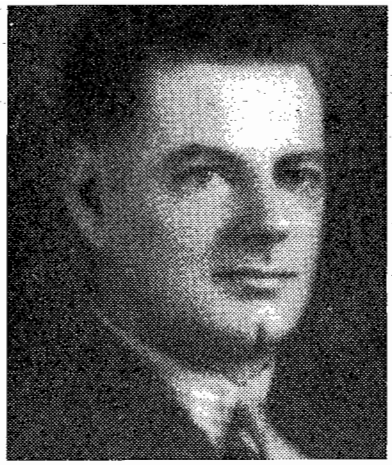
Many Bougainvilleans, especially among those directly affected, remain on the whole very unhappy about the new mine in their midst. Whatever its material benefits, in terms of cash compensation, employment opportunties, new markets for produce and general economic development, they see it as an intrusion on their way of life. Its social consequences have certainly been drastic. To mention only one, alcoholism is now a serious problem, whereas drink was previously unknown in these parts. The mine is

also hard to reconcile with traditional attitudes to land. For Bougainvilleans, as for many others in Papua New Guinea, land is far more than a commodity. In fact, it is not a commodity at all, but a guarantee of livelihood and security, a status symbol, and a sacred abode of ancestors. In short, it is central to their whole world. Holding such beliefs about land, the people whose resettlement was required by the project were not to be easily persuaded that cash and other forms of compensation, at higher than market rates, were an acceptable substitute. Much more than the old lady whose home is threatened by a new highway, they deeply resented being compelled to move. They knew too, that their accustomed social life was in for massive disruption through the influx of Europeans, 'redskins', money and machinery. Nothing in their experience had prepared them to assess the trade-off between economic gain and social upheaval. Here, in its starkest form, was the confrontation between pre-industrial society and the implacable modern world – a clash which, as we shall see, has almost always produced bizarre results in Papua New Guinea. The lack of a common ground can be seen symbolically in the still unresolved dispute over compensation for virgin bush. The company's final offer of A$150 a hectare was met by the local community with a demand for A$2,500 per hectare per year. This was tantamount to saying 'not at any price'.

No doubt such conflicts are inevitable whenever large industries establish themselves in areas which have never known them before. But when they happen in a situation as fluid as that of Papua New Guinea today, they have political consequences. It is important that the two indigenous leaders who have spoken out against the agreement are both from Bougainville. Mr. Paul Lapun, the Minister of Mines, has said that, after independence, Papua New Guinea will re-negotiate all its agreements with foreign investors, including that with Bougainville Copper. And Father John Momis, the influential young Catholic priest who is deputy-chairman of the constitutional planning committee, has urged forcefully that the Government should acquire at least 51 per cent of the mining company's share capital. Mr. Lapun, at least, is primarily a champion of the Bougainville people. He is a member of Pangu, which stands above all for national unity, but has been associated with the Bougainvile secessionist movement. He embodies the pull of conflicting nationalisms, Father Momis, an intellectual, may well be influenced by a wider economic nationalism as well as by his Bougainville connections, but in his case, too, it might be misleading to discount the importance of the local factor. What has to be borne in mind is that these Bougainvilleans have staked their claim at a time when the whole constitutional future of the nation (including the place in it of a Bougainville with secessionist tendencies) is still in the melting pot. In the play of political forces that will determine both the constitutional future and policy towards foreign investment, the claims of Bougainville itself will exert an influence not necessarily smaller than that of theories about the proper relationship between Papua New Guinea and large mining companies. Mr. Lapun will not have forgotten that he waged a long and ultimately successful battle against the Australian administration to have a portion of the nation's royalties allocated to his island – an achievement for which he won the honoured title of 'Mr. Five Per Cent'.

When I asked Mr. Somare whether the statements of the Mines Minister and Father Momis should be taken as Government policy, he stressed that the two had spoken in their capacity as members for Bougainville constituencies and that the issue had not come up before the Cabinet. He went on to say that Papua New Guinea needed foreign capital but wanted to be sure that any given investment would actually benefit the people. "We are communalists, not capitalists", he explained, "and we hope to get the best of both worlds". That useful phrase about keeping one's options open seems appropriate. The ambiguities involved were neatly illustrated in October 1972, when it was announced that the official opening of the Bougainville mine, scheduled for November 30, was to be cancelled. The cost of the ceremony would thus be saved, allowing A$100,000 to be donated towards famine relief for the 130,000 Highlanders who had just been afflicted by the unusual and horrible combination of drought and frost. It is not too cynical to conjecture that Mr. Somare might have been embarrassed to fulfil the engagement he had accepted to open the mine, which could have implied endorsement of the terms under which it operates. The emotional force behind Bougainville separatism showed itself vividly in January, 1973, when Mr. Somare visited the island. He met such hostility that there were fears for his safety, and at one point he had to make a rapid and unscheduled departure by helicopter. The reason had nothing to do with copper: it was that two civil servants from Bougainville who were stationed in the Highlands had just been murdered there when their car was involved in a fatal accident and they got out to render assistance.

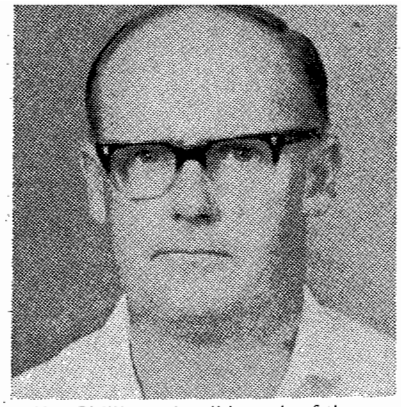
Two final points need to be made about the Bougainville agreement and foreign investment generally. One is that the coalition government contains important elements – notably the Finance Minister, Mr. Chan, and his People's Progress Party – who are sensitive to the susceptibilities of foreign investors and convinced of the country's need for private overseas capital. The coalition's ability to rule appears to depend on their support. The other is that if Papua New Guinea is to achieve financial independence in the sense of being able to balance its own budget at anything like the current level of public spending, or its foreign payments at the current normal level of imports, it may have to think hard about ensuring that further large mining and other natural resource projects are brought into production: Bougainville alone won't do the trick. And, in fact, such possibilities are in the cards provided that the Government maintains an appropriate climate. Kennecott, for example, has already spent something like A$15 million proving a copper orebody at Ok Tedi, in the remote mountains hundreds of kilometres up the Fly River near the West Irian border. Although no decision to go ahead has been taken, it is generally thought there is a viable mine provided the company judges that it can strike an acceptable bargain with the Government. In this case the social problems seem likely to be minimal, since the local population is very small and scattered. There are other promising copper deposits; large amounts of natural gas have been found in the Gulf of Papua; and Japanese investors are showing keen interest in the timber and fishing industries – both surprisingly undeveloped. So far as export prospects go, the establishment of major natural resource enterprises like these seems to offer the only hope of breaking out of the constraints imposed by oversupplied and volatile world markets for such tropical staples as coffee, copra and cocoa.



Jack Comb, one of Bougainville's pioneers.

Discovery

Pacific Islands Monthly, published in Sydney and circulated throughout the Pacific Islands for more than 40 years, has reported the developing story of the Bougainville copper mine from the beginning. The material reproduced here is copyright, Pacific Publications (Aust.) Pty. Ltd., GPO Box 3408, Sydney.



Ken Phillips, who did much of the early exploratory work for CRA

The huge carpet of dark moss ranging over the creekbed looked pretty uninteresting to the two tired prospectors. The moss was long and scraggy, and it looked as if it had been growing in the spot undisturbed since time immemorial. Nevertheless, Jack Comb and Captain Bob Palmer elected to give it another try.

So far their daylong panning expedition up the twisting Bougainville creek had revealed only small traces of gold flakes — hardly the rich ore locals had talked of, a few days before, in nearby Kieta.

Both men climbed onto the slippery bank and started chipping the moss from the rock. Their picks and shovels easily ripped off long sheets of moss to expose the naked rock.

"We had cleared a big patch when we saw it," Mr. Comb said many years later. "Long, shiny streaks of gold-bearing lode running along interspersed with darker, greenish signs of copper.

"The copper wasn't as shiny as the gold, but it was there all right."

By turning over that moss way back in 1929, the two prospectors made the first real find of gold on Bougainville and so started the island's small Kupei goldmines which flourished through the 1930's.

Nearly $60,000 in gold was taken out of Kupei and nearby spots in the rugged, Crown Prince Ranges of Bougainville, before production petered out in the 1950's.

Today, with the gold-producing days largely forgotten, the Crown Prince Range area is the location of huge copper operations which make Bougainville the site of one of the world's biggest copper mines.

Every enterprise in PNG in the 1970's and probably also the 1980's is overshadowed by Bougainville's mineral exports.

But back to the beginning . . . .

After uncovering the moss, the jubilant Mr. Comb and Captain Palmer, both veterans of the Edie Creek goldrush three years before, marked the spot and quickly packed their gear.

They retraced their steps 3,500 feet down the Crown Prince Ranges to the creek mouth and Iwi Plantation, then run by the popular Jimmy Joyes. They told him of their find.

Mr. Joyes had hired Mr. Comb and Captain Palmer through the Bougainville Syndicate which he had formed with a group of Adelaide businessmen early in 1929 to look for gold behind his plantation. He had met the two men during the Edie Creek goldrush.

Now that he knew there was gold in the area, Mr. Joyes wasted no time in relaying the news to his Australian partners. A mining consultant and metallurgist, Mr. E.G. Banks, was dispatched to Kupei to evaluate the find.

Mr. Banks and an assistant made tests on extracted concentrates of gold-bearing ore and yields indicated a commercial find.

Kupei gold was proclaimed in May, 1930. Word was soon out and prospectors quickly drifted in to try their luck.

Miners like J.H. Ellis, P.A. Logan, C.W.M. Evans and W.R. Sergeyeff arrived. Mr. E.P. Holmes, Secretary for Lands in Rabaul for the mandated territory, arrived to take ore samples.

Two mining experts from the Australian steel maker, Broken Hill Pty. Ltd., Messrs. F.R. Hockey and K.C. Church, inspected Kupei sites in 1931. They found too little had been done by that stage to warrant further BHP interest.

Meanwhile, Mr. Comb and Captain Palmer, working for the Bougainville Syndicate, got busy.

Mr. Comb sunk several small adits to test more ore. He found one major problem — it was difficult to extract the gold from its less-profitable neighbour, copper.

Perhaps the best summary of Bougainville's gold came from the famous "Sharkeye" Park, who wasn't slow to show his face at Kupei.

Park had a good look around, and left, saying: "There's gold there, but there's too much bloody Bougainville in it."

Mr. Comb wasn't discouraged, however, and he travelled to Sydney to build a two-head battery to work the Kupei diggings. He returned to Kupei and won over $2,000 of gold with the tiny battery.

About 1933 the Bougainville Syndicate pulled out its interest in the small goldmine and sold its holdings to Mr. Comb and Captain Palmer, who decided to work the mine in partnership.

Six months after the partnership began, Captain Palmer, an experienced Islands skipper, died suddenly on a visit to Rabaul.
Mr. Comb, who now lives in retirement in Sydney, worked on alone for a short period and then sold out, for $12,000 to a second Bougainville Syndicate.

Before leaving, he installed a larger five-head battery for the mine's new owners, who stepped up operations.

By 1934, two other nearby gold deposits had been located at Moroni, south of Kupei, and at Panguna, east of Moroni. Both were high up in the Crown Prince Ranges and were discovered separately by two miners, Mr. C.W.M. Evans and Mr. G.A. Myers.

Mr. Joyes, as interested as ever in ore, took out a prospect at Panguna in 1935.
A geologist for the PNG Administration, Mr. N.H. Fisher, made a report on the three areas in 1935, and said Kupei had lower-grade ore but cheaper mining costs than the two later discoveries.

No figures are available for gold production before 1935, but it is likely about $10,000 in gold was won up to this period. Production rose five fold in 1937 to 598 ounces, but in 1938 it was 100 ounces less.

Between 1930 and 1940, about $50,000 in gold was found. After World War II, production didn't start again until 1948, and then only lasted about three years.

A syndicate including Mr. R. Watson and Mr. R. Doyle won some alluvial gold near Atamo, and two prospectors Hetherinton and Gleeson, made small finds between 1949 and 1954.

Small finds were also made at Atamo and Karato to the north-west of Kupei, along the Kavarong River and in other spots in the ranges.

But by 1960 mining in Bougainville seemed over. During that year a startled traveller reported that he had seen a large colony of bats in one of the dormant mine adits.

Then in 1961 a report on the Panguna gold-copper prospect was released by the Australian Bureau of Mineral Resources. It was compiled by Mr. J.E. Thompson, then a geologist working out of Port Moresby.

"The difficulties of access to the mineralised areas of the Crown Prince Range could possibly be borne by a large-scale copper-gold mining operation, but for small operators, interested only in gold, the area is not attractive," Mr.Thompson said in his report.

"From a regional aspect, the Kupei—Panguna—Moroni area is a province of copper-gold mineralisation which warrants reconnaissance investigation," he said.

"The area of particular interest for copper mineralisation is the northern fall of the Crown Prince Range from Atamo to the foothills behind Kieta."

Mr. Thompson's report on Kupei's copper possibilities came out at a time when the big, British-owned mining company, Conzinc Riotinto, was searching eastern Australia for low-grade deposits of copper.

A company geologist, Mr. K. Phillips, 32, took a trip to the Philippines in May, 1963, and inspected a huge copper mine in operation at Cebu Island.

To Mr. Phillips' thinking there were many geological differences between Cebu and the type of country CRA was looking at in Australia for copper.

He suggested it would be better to look in the New Guinea Islands, or the Solomons. A few months later he was sent to have a look at a mineral prospect in the NG Highlands.

Nothing came of this trip but CRA was still interested in two copper occurrences in NG — at Kupei, Bougainville, and Bundi, south of Madang.

CRA re-read the Thompson report and promptly applied for prospecting rights over 130 square miles behind Kieta — a request which was granted in December, 1963.

In January, 1964, as a senior geologist for CRA Exploration Ltd., a wholly-owned subsidiary of CRA, Mr. Phillips went to Keita for a few days to obtain advice from Administration officers regarding contact with Bougainville Islanders.

Two months later he was back with a geo-chemist, Edgar Mucenie kas, 40, two field assistants, Rex Brooks, 18, and Ian Wilkie, 18, and a representative of the PNG Department of Mines, Port Moresby, Neville Robinson, 35.

The party stayed in Kieta only to buy supplies and then wasted little time hiring a small boat which took them around to Arawa Plantation.

With a few Bougainville guides and carriers they walked up into the Crown Prince Ranges and reached the site of the old Kupei goldmine.

Heavy undergrowth, bushes and long vines covered up any exposures or outcrops of minerals.

The party operated from Kupei until April, examining sediment samples from nearby creeks and rivers. Then headquarters were changed to Moroni Village, four miles away on the western slopes of the Crown Prince Ranges.

Mr. Muceniekas was able to analyse most sediment samples on the spot, but urgent specimens were rushed to Kieta by runners. CRA quickly set up an improvised laboratory at Kieta.

Meanwhile, the explorations extended to nearby Panguna.

Mr. Phillips was convinced after preliminary investigations that the area contained big copper deposits. In his reports to top CRA executives in their Melbourne headquarters he argued that the terrain closely resembled areas of Cebu Island.

Sediment samples held very strong positive copper responses, scattered over a large area of several square miles. Results were deemed "encouraging", and CRA decided that findings warranted diamond drilling.

CRA's chief geologist, Mr. Clem Knight, arrived at Kupei in mid-1964 and called for a small one-ton rig, capable of drilling to 100 feet, to be brought in from Kieta.

The trouble CRA experienced getting the rig into Kupei, part by part, by small boat and Bougainville carrier, convinced the company that helicopters were the only answer for getting heavy and bulky equipment in to the area, and CRA began airlifting all its heavy equipment.

When the Kieta-Panguna access track was completed early in 1967, helicopters were gradually phased out. The last copter airlift was completed early in 1968.

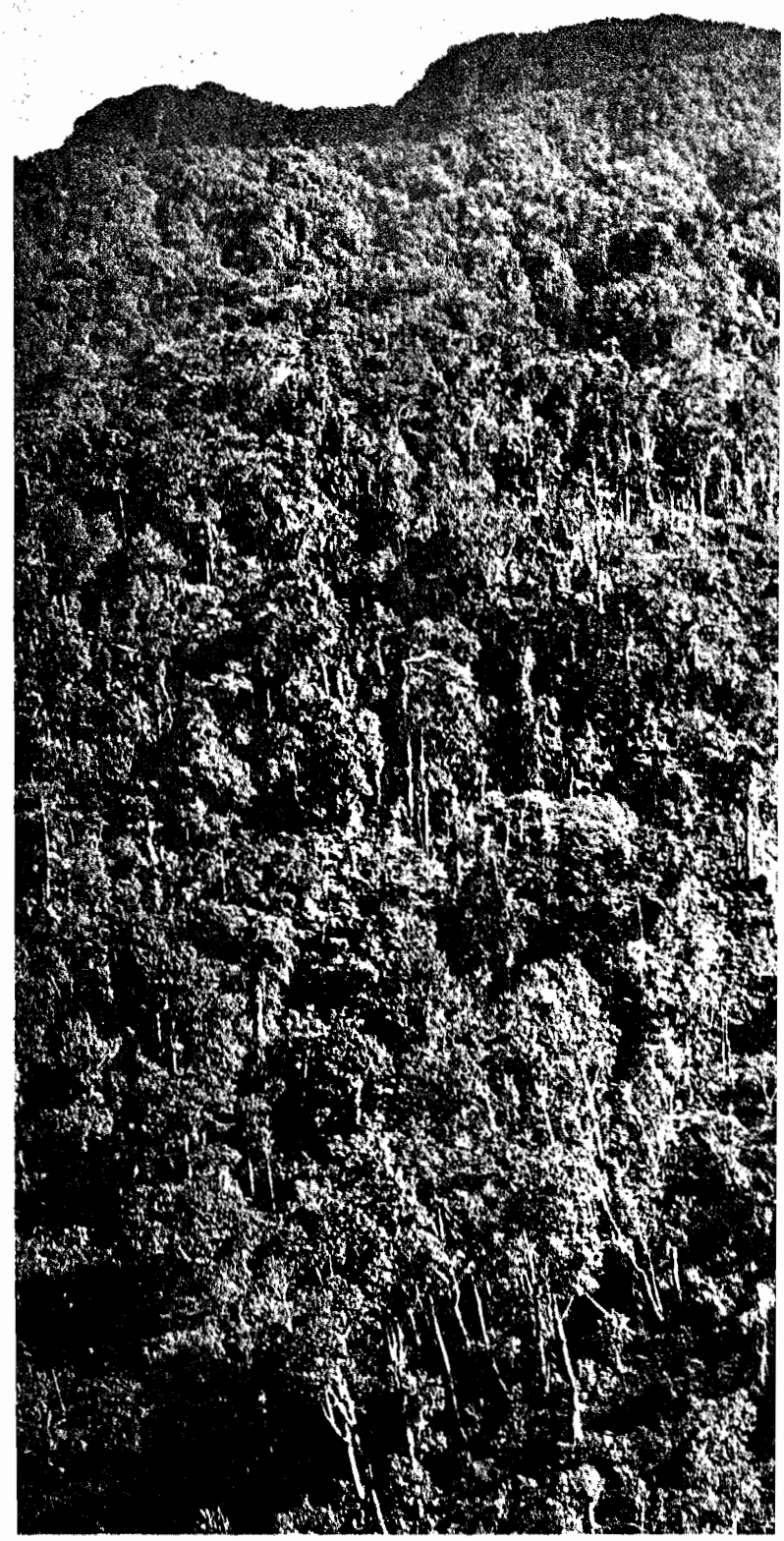
The first rig was too small, and it was quickly followed by two bigger rigs, both capable of drilling to 600 feet.

Operations started to build up fast during 1965. Extra field assistants and geologists arrived, and hundreds of local people found part-time or full-time work, first under Mr. Phillips, who remained in charge of operations until September, 1966, and then under Mr. Colin Bishop who took over.

In May, 1965, CRA announced its "interesting copper prospect" near Kupei.

During the next three years this report was followed by others which estimated the copper-bearing ore at 90 million tons, 100 million tons and 200 million tons.

And in May 1968 Mr. Val Duncan, chairman and chief executives of Rio Tinto-Zinc Corporation, told the company's shareholders: " . . . We believe that Bougainville . . . will prove to be one of the low-cost copper producers when the final evaluation has been completed, and will moreover be a substantial gold producer. We hope to bring it into production by 1972".

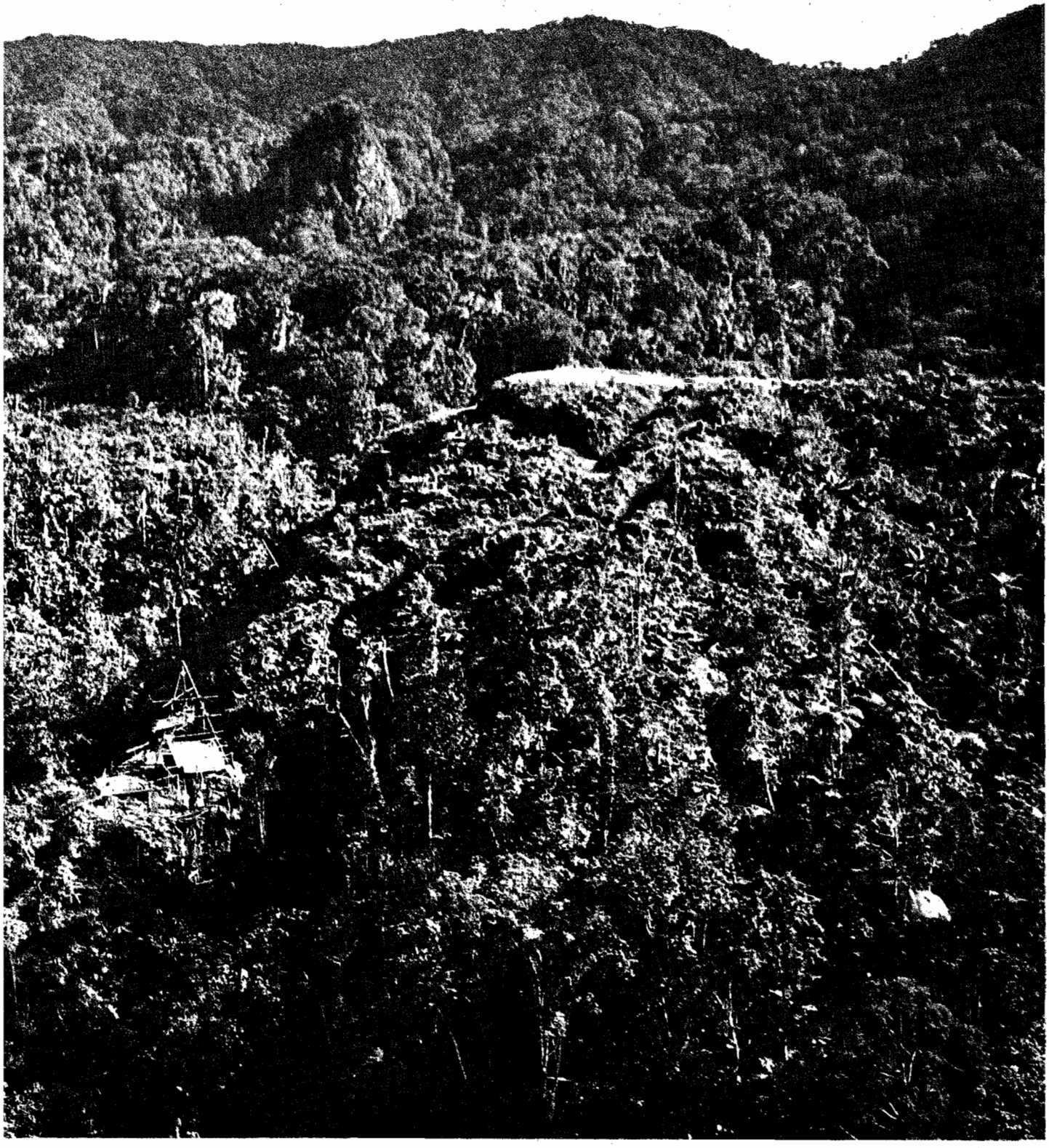


EXPLORATION DRILLING

C.R.A. geologist, Ken Phillips who was in charge of an exploration team, walked into Panguna Valley on 1st April, 1964.

Light drills were manhandled across the 3500 ft. divide by the exploration crew in November 1964 to do initial drilling.

Here, in the lush tropical Panguna Valley, one of the early drill sites is illustrated.



The Bougainville Copper Project

F.F. Espie

Paper presented at
The Australasian Institute of Mining and Metallurgy,
August 1970.
Illustrations, maps and political comments apply as at January 1971.

FRANK FLETCHER ESPIE

Mr. F.F. Espie, O.B.E. is Chairman of Directors of Bougainville Copper Limited and of Bougainville Mining Limited.

As an Executive Director of Conzinc Riotinto of Australia Limited he has Board responsibilities for the Bougainville operation. He is also Chairman of N.B.H.C. Holdings Limited, Australian Mining and Smelting Co. Limited and Mary Kathleen Uranium Ltd., and a Director of Australian Fluorine Chemicals Pty. Ltd. In addition Mr. Espie is a Director of the Rio Tinto Zinc Corporation Limited, London. He is a mining engineer by profession and is stationed at 95 Collins Street, Melbourne.

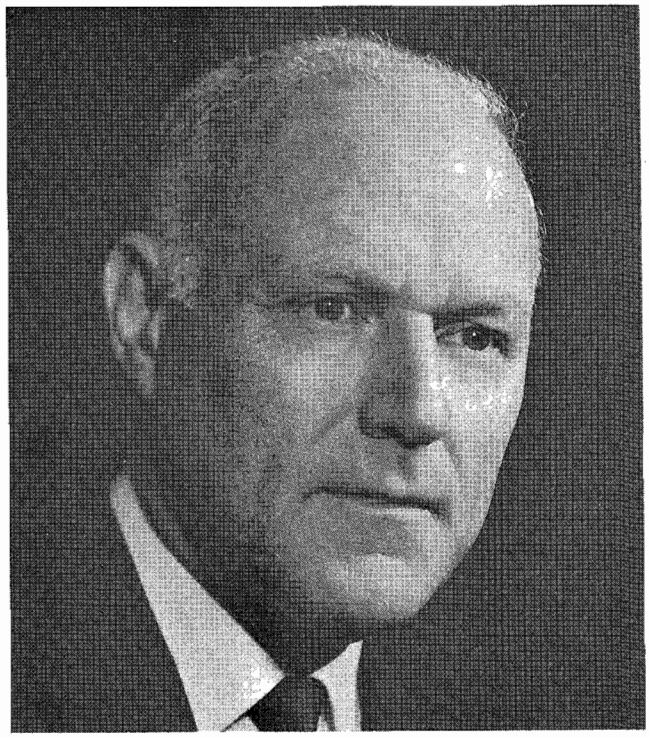
Mr. Espie was born 56 years ago at Bawdwin in Burma where his father was General Manager of the Burma Corporation. He was educated at St. Peter's College, Adelaide, then went to the Adelaide University to study Mining Engineering. He joined the AIF in 1940 and served with the 9th Division in the North African Campaign and New Guinea rising to the rank of Captain. After demobilisation he returned to his mining engineering studies and graduated at the end of 1946.

Mr. Espie had 14 years with the Zinc Corporation/New Broken Hill Consolidated mines at Broken Hill being respectively Underground Manager of ZC and Mine Superintendent before being appointed Assistant General Manager (Production) in March 1957. In March 1961 he transferred from lead/silver/zinc mining to aluminium, and became General Manager of Comalco Products at Yennora, Sydney, with responsibility for the semi-fabricating operation and sales of products.

In August 1962 he went to the Group's Sydney Office before transferring to Melbourne Office in January 1964 to become General Manager of the Group's newly formed Industrial Division, which embraced coal, quarrying, timber and bricks.

Towards the end of 1965, he took charge of the Bougainville investigations, later becoming the project's Executive Director, then Managing Director, then Chairman of Directors, He was appointed to the Board of CRA on February 21, 1968;

Mr. Espie is married with four children, and is a keen golfer and surfer.



ABSTRACT

The mining operations of Bougainville Copper Pty. Limited are located at Panguna on the Island of Bougainville which is part of the Territory of Papua and New Guinea.

C.R.A. Exploration Pty. Limited first established mineralization in the Panguna area in 1964. Exploration work since then has established ore reserves estimated to be 900,000,000 long tons of ore assaying 0.48 per cent copper and 0.36 dwt/ton gold. An economic feasibility study completed in July, 1969 enabled a decision to be made to proceed with a major mining operation. The ore will be mined by open cut methods and will be treated in a conventional concentrator with a nominal capacity of 90,000 short tons/day. The concentrate will be pumped as a slurry through a 16 mile long pipeline to a port established on the east coast where it will be filtered and dried ready for export. Other supporting facilities for the mine include two towns, a 135 MW steam power station, and access roads.

Original manuscript received at The Australasian Institute of Mining and Metallurgy 7th April, 1970. By agreement with the author and The Institute this paper was brought up to date at the end of January, 1971. An earlier version of the paper was presented at the Annual Conference of The Institute held in Melbourne, Vic, 9th-14th August, 1970.

INTRODUCTION

Bougainville Island is part of New Guinea which is a United Nations Trust Territory administered by the Australian Government in conjunction with the Australian Territory of Papua. Of volcanic origin, the island is approximately 130 miles long by 40 miles wide at its widest point. Along the main axis of the island there is a chain of mountains between 6,000 and 8,000 ft. high. The Panguna orebody is on the western slope of the Crown Prince Range at an elevation between 2,000 and 2,500 ft. The climate is tropical with little variation throughout the year. Rainfall is greater than 200 in./year.

Under a Prospecting Authority issued in 1963, indications of copper mineralization were confirmed in the Panguna area. The indications were sufficiently promising to justify the commencement of a drilling programme in 1964. Based on the good drilling results obtained the investigation programme was expanded to include metallurgical testing, development of exploratory underground adits, and engineering studies. The culmination of the investigation programme was the preparation of a feasibility report in July 1969.

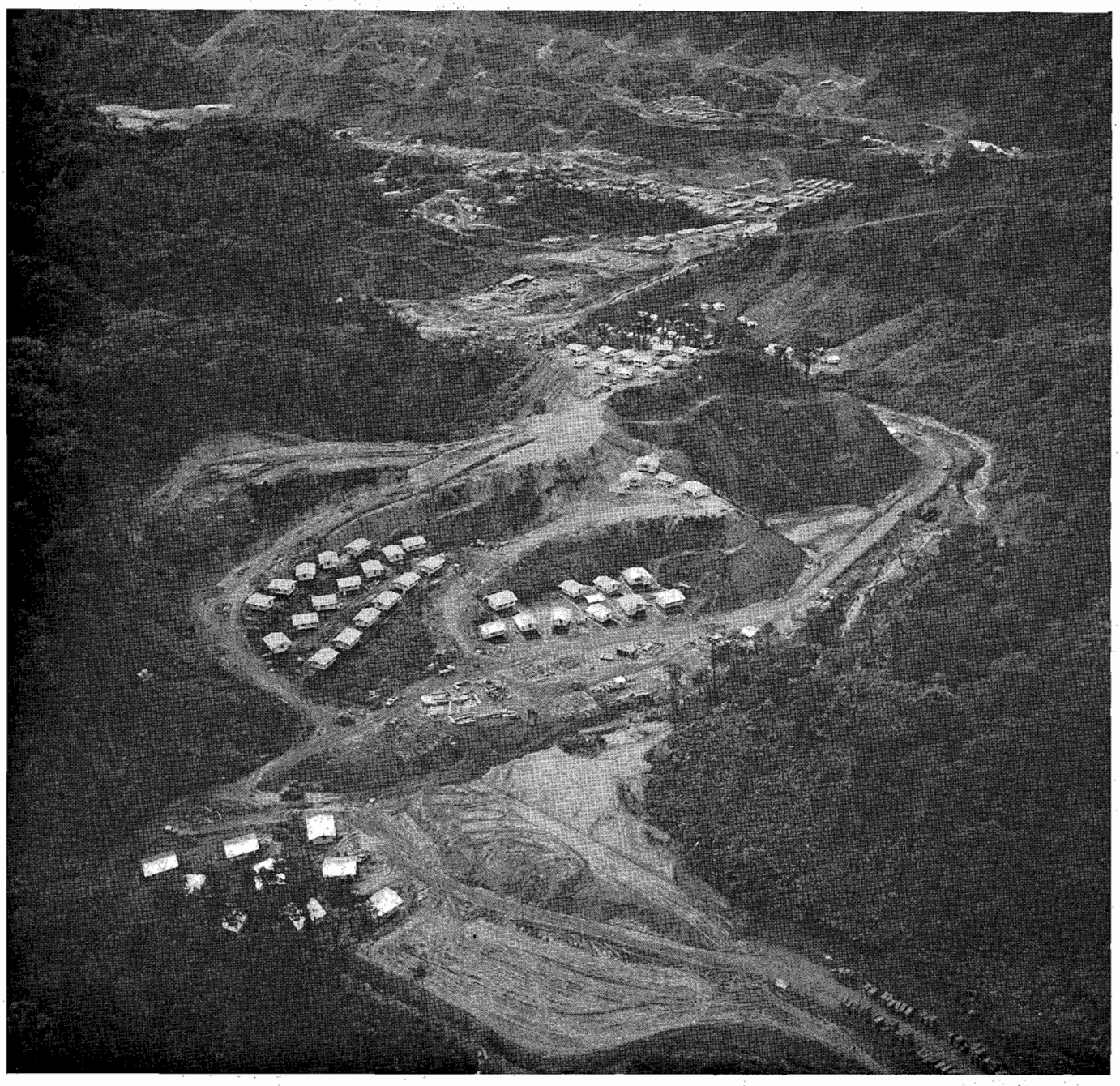


Fig. 2 – General view of the mine area and facilities at Panguna. Part of Panguna town stands in the foreground of the picture. The concentrator area is out of the picture at top right, and construction camps lie in the valley extending left. The original camp can be seen in the background, and is partly encircled by the first mine haul road.

Commercial production of copper concentrate began in mid-1972. By that date 8 years had been spent in exploring and investigating the deposit and in constructing the mine and its facilities.

Fig. 1 shows the location of the operations of Bougainville Copper Pty. Ltd., and Fig. 2 is a general view of the mine area and facilities at Panguna.

GEOLOGY

The Panguna copper deposit is a porphyry copper type situated in the Kawerong Valley on the western fall of the Crown Prince Range in South-central Bougainville. The geological structure was described in detail by Macnamara (1968) (This article is on pp 36–46. Ed.)

Copper-gold mineralization with small amounts of silver and molybdenum is associated with a group of acid to intermediate intrusives which have invaded a pre-existing sequence of andesitic volcanics. The intrusives, and the invaded rocks near the contacts, are mineralized in zones associated with pervasive alteration. Faulting and intense fracturing, particularly of the andesitic rock, are features of the mineralized area. The orientations of intrusives and quartz veining appear to be controlled by pre-mineralization fault-joint patterns in the intruded rocks.

The discovery resulted from investigation of old gold prospects which had been worked in the 1930's, and in which copper had been reported by government geologists. The surface extent of the copper mineralization was defined by geochemical drainage and soil sampling, and chip sampling of exposures in creeks.

The andesitic volcanics form part of the Kieta Volcanics of middle to upper Tertiary age, which make up most of the Crown Prince Range. The Kieta Volcanics consist mainly of andesitic and basic flows and pyroclastics (agglomerates, tuffs, tuffaceous shales). In the mineralized area the principal member is the Panguna Andesite, consisting of massive flow rocks, which have been exposed and drilled over a thickness of some 3,000 ft. Dips in the Panguna Andesite are no more than 10° to 20°.

The Panguna Andesite is intruded by a series of diorite-granodiorite rocks. These are regarded as co-magmatic and there appears to be a tendency for the younger members to be more porphyritic and quartz-rich, and to occur near the margins of the main intrusion. The main intrusion is the Kawerong Quartz Diorite, which is typically a pink hornblende diorite. The quartz content varies from nil to about 10 per cent, and hornblende forms 15 to 25 per cent of the rock. Marginal differentiates, or facies of the quartz diorite, some of which are late stage, include biotite diorite, biotite granodiorite, leucocratic quartz diorite, and quartz feldspar prophyries. These intrusives and the invaded rocks near the contacts are mineralized in zones associated with pervasive alteration.

The types of alteration are characterized by processes of biotitization, chloritization, quartz-kaolin-pyrite alteration, pyrite alteration, and propylitic alteration. Biotitization appears to be related directly to the ore formation, but other types appear to be developed at a later stage.

As expected in a high sulphur-type porphyry copper deposit, chalcopyrite is the dominant primary copper mineral, being accompanied in places by bornite and a little molybdenite and silver. Gold content varies sympathetically with the copper, and pyrite is widely distributed. Chalcopyrite occurs principally in the Panguna Andesite, in and about the leucocratic quartz diorite, and in the biotite diorite.

Mineralization occurs mainly in quartz veins which normally contain the chalcopyrite in a central zone with quartz crystals growing inwards from the straight vein walls. Chalcopyrite also occurs disseminated in the Panguna Andesite and in the quartz and biotite diorites.

The degree of jointing is greater in the mineralized area than outside it. As there is a general decrease in the amount of veining, the degree of alteration and percentage of copper away from the biotite diorite intrusives types, there can be little doubt that the diorite is the source of the copper mineralization.

Oxidized and secondary zones occur at the Panguna deposit. The oxidized zone ranges from nil to 260 ft. thick, and averages about 100 ft. The base of the zone may be defined mineralogically by the upper limit of chalcocite, chalcopyrite, or bornite and the downward limit of the minerals malachite, cuprite, and limonite.

Secondary enrichment is restricted, generally being confined to areas of combined high topography and relatively high grade mineralization. The maximum known thickness of the secondary zone is 250 ft.

The evaluation drilling programme was completed after drilling more than 200 holes for a total footage of 240,000 ft. Ore reserves are estimated to be 900,000,000 long tons assaying 0.48 per cent copper and 0.36 dwt/ton gold.

MINING

Mine planning began in early 1966. Initially the mine planning team was primarily concerned with establishing the overall economic viability of the mine and determining the optimum operational strategy.

The two basic alternatives of underground block caving and open pit mining were studied. Economic analysis showed the latter method to be more favourable.

Detailed investigation of open pit mining followed. This entailed analysing the economic consequences of changes in the various factors subject to management control. These were

1. Pre-production stripping,
2. pit output,
3. concentrator throughput,
4. cut-off grade and hence head grade, and
5. waste to ore ratio.

These variabales were altered subject to the independent parameters which affect the economics of the project. The parameters considered were

1. The distribution of mineralization within the rock mass,
2. marketing constraints,
3. operating and capital costs, and
4. metal prices.

Continual reassessment of the various factors took place as more information became available from the exploration programme. To assist in analysing the large volume of data and complex inter-dependence of the factors involved, ex-

tensive use was made of computer and operations research techniques.

Thus the governing philosophy in this initial stage was that these broad studies, judging alternative strategies by a yardstick of net present value, incorporated more refined data as these became available and established indicative planning criteria for the project.

Investigation of the physical problems of mounting an open pit operation in the highlands of Bougainville proceeded in parallel with the economic studies. Testwork was undertaken to determine the optimum methods of dealing with these problems and to establish cost data. Considerable time, effort, and money was devoted to evolving methods for clearing the jungle cover, removing the unconsolidated over-burden and determining stable pit slopes. The importance of careful analysis of the latter factor arises from the potential adverse effect of slope stability of the highly fractured nature of the rock mass, the seismic environment, and high rainfall.

In fact, geotechnical studies were among the more important facets of mine evaluation, as the results affected not only pit slopes but also the stability of waste dumps, haul roads, and all other fill structures. As the presence of underground water is critical to slope stability and the whole area has abundant underground water supplies, exhaustive studies were made into the behaviour of the watertable.

Concurrently with the open pit mining investigations two horizontal adits, Panguna and Western, were driven into the orebody. These adits provided sufficient bulk samples to

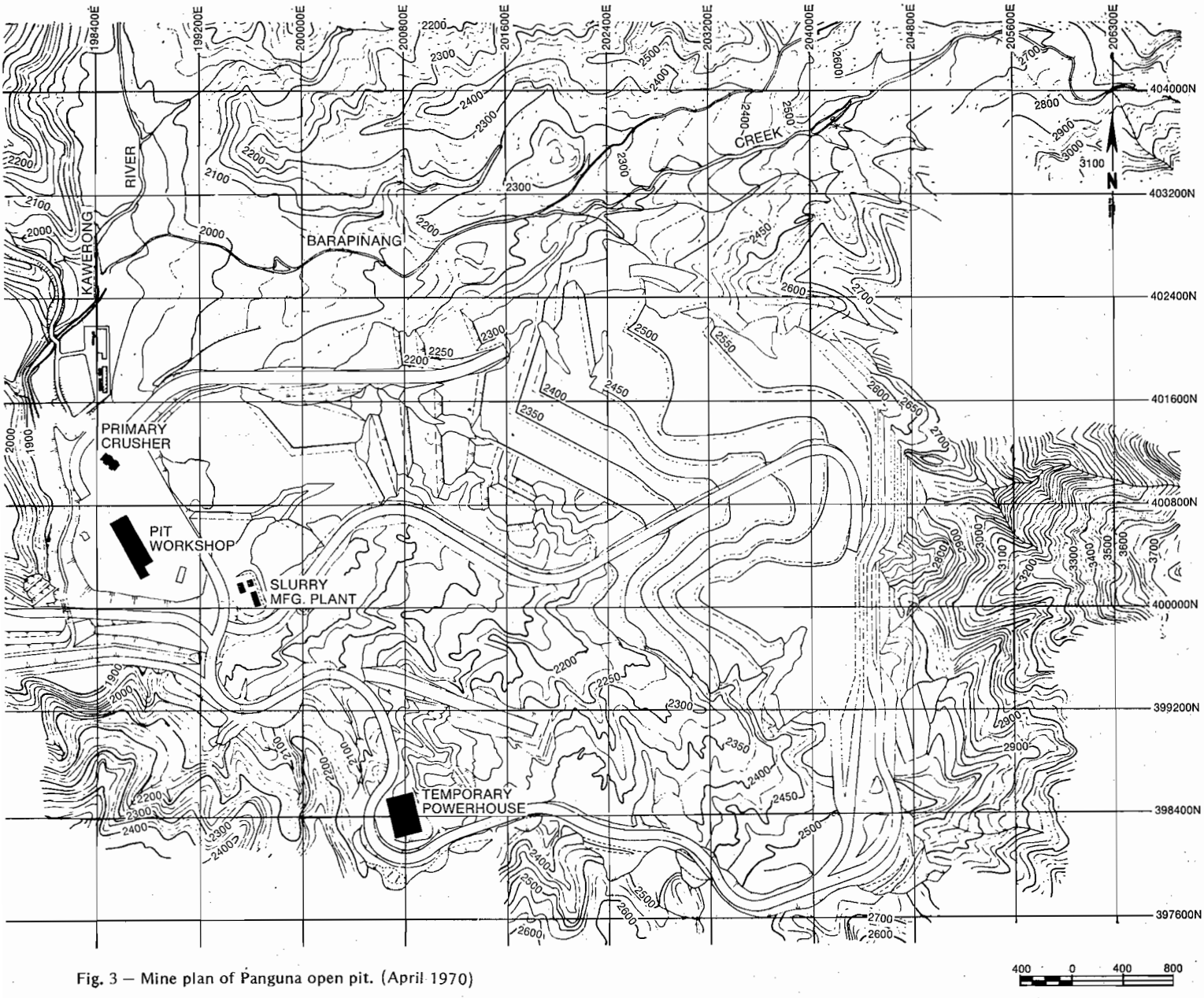


Fig. 3 — Mine plan of Panguna open pit. (April 1970)

check the accuracy of the drill core assays and at the same time produced ore for the metallurgical investigation programme. While both adits were open the opportunity was taken to study their effect on the watertable.

The criteria which emerged from the mining studies were a mine excavation rate of 159,000 short tons a day (a waste-to-ore ratio of 0.68) for a concentrator throughput of 90,000 short tons a day.

Mining and concentrating operations will be based on working three 8-hour shifts a day, 21 shifts a week.

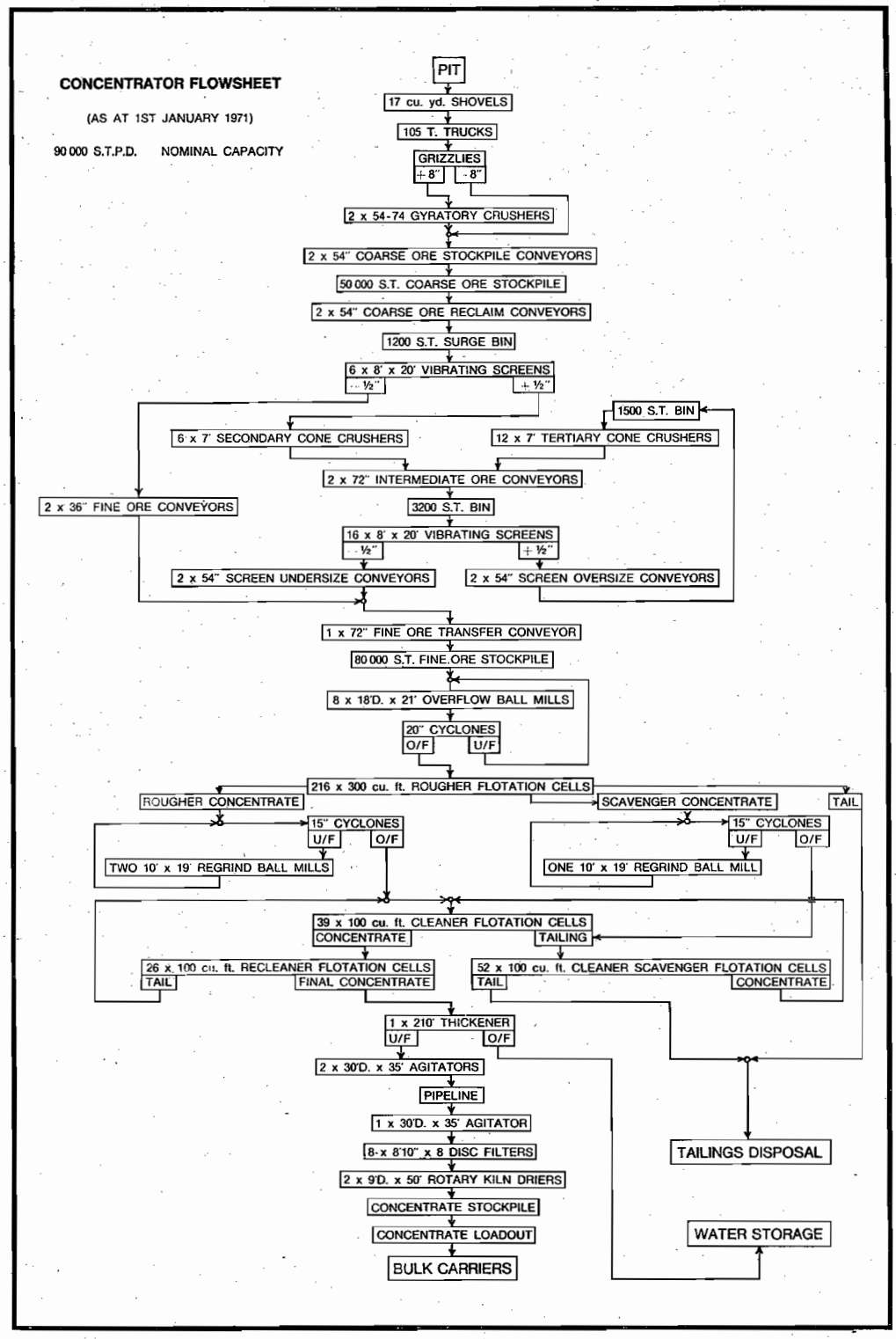


Fig 4 — Concentrator Flowsheet of Bougainville Copper Pty. Ltd.

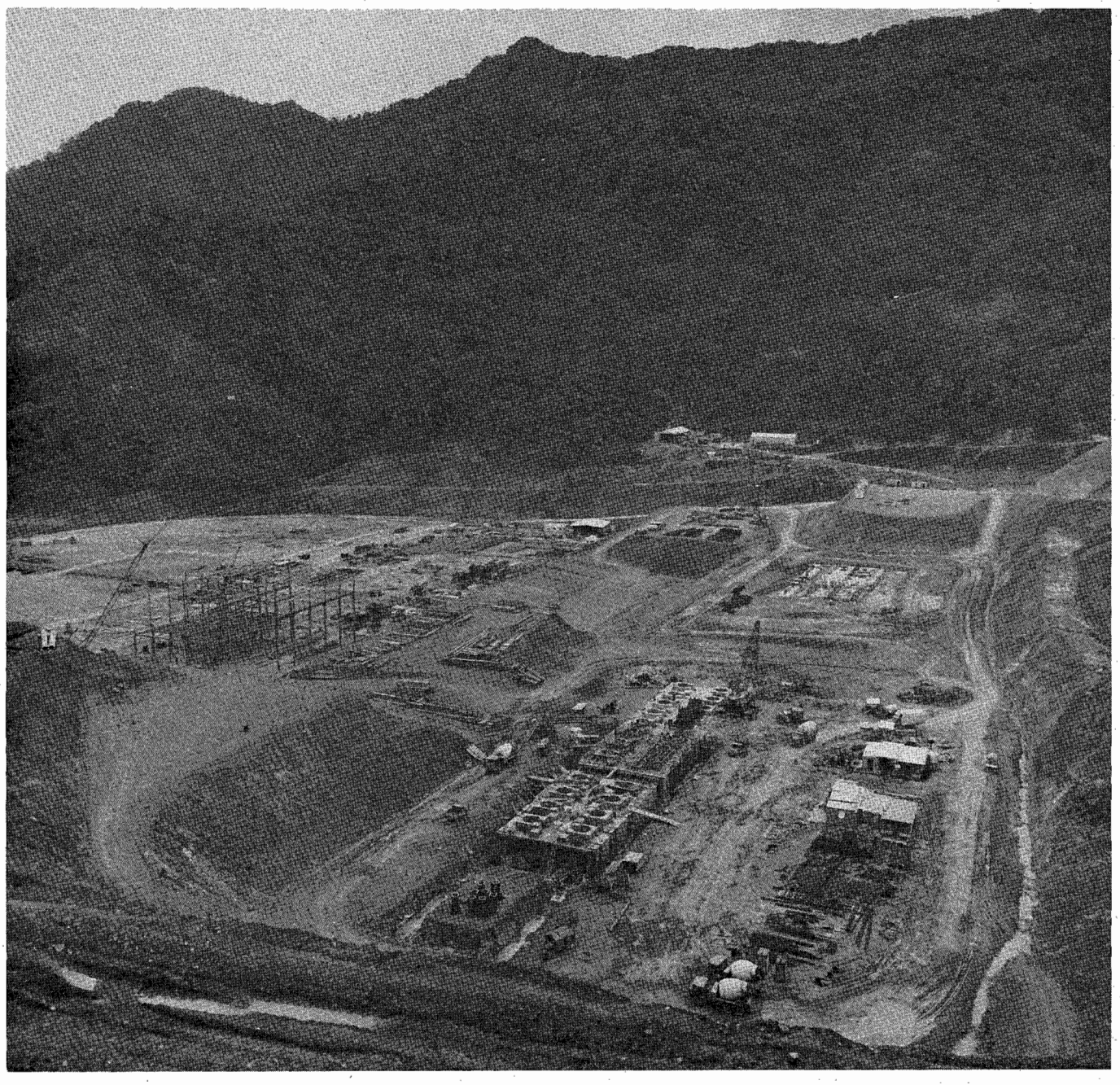


Fig. 5— General view of the concentrator area showing the secondary and tertiary crushers in the foreground and the screening plant base slabs behind it. The steelwork for the concentrator under construction is at the left of the picture.

The final stage of the mine investigation was the selection of mining equipment. Economic analysis demonstrated the advantage of selecting equipment of the largest possible size. Basic equipment will include.

1. six 17 cu.yd. electric shovels,
2. forty-one 100-130 ton trucks, and
3. five 9 7/8 in. diameter electric rotary drills.

Pit ancillary equipment will include

1. four rubber tyred dozers,
2. seven track dozers,
3. one 6 cu.yd. front end loader,
4. six 10 cu.yd. dump trucks,
5. three graders, and
6. one sprinkler truck.

The plan of the open pit at the beginning of commercial production is shown in Fig. 3.

METALLURGY

Metallurgical assessment of the Bougainville orebody began in the middle of 1966. Initially the work was based at the Metallurgical Research Laboratories of The Zinc Corporation Limited using drill cores sent from Bougainville. These were considered to provide the most representative

metallurgical sample of the whole orebody, irrespective of how much underground development was carried out.

The metallurgical laboratory tests showed that the primary sulphide copper and gold values were particularly amenable to recovery by flotation. The most important feature was the ability to achieve above 90 per cent copper flotation recoveries at head grades down to as low as 0.15 per cent Cu at coarse grinds of 40-50 per cent minus 200 mesh, and high flotation pulp densities of up to 45 per cent solids. Concentrate grade was strongly correlated with head grade varying from approximately 33 per cent Cu at head grades of the ore of 0.7 per cent Cu and above, down to 25 per cent Cu at 0.25 per cent Cu.

Gold and silver recoveries were also strongly correlated with head grade and tended to be in the range of 70-80 per cent and 40-50 per cent respectively.

Molybdenum analyses of the ore were of only marginal economic interest and production of a molybdenum concentrate has not been investigated to date.

Spectrographic analyses of ore and concentrates did not show any other elements in sufficient quantity to be of economic importance or deleterious to subsequent processes.

Magnetite analyses of flotation tailings averaged between 3 and 4 per cent and production of a magnetite concentrate with an iron content above 62 per cent is feasible using a simple magnetic concentration circuit but will not be pursued at this stage.

In 1967 a 20 ton/hr bulk sample plant was commissioned at Panguna. Tests using this plant showed that the major rock types crushed easily without any abnormal fines production. However, some problems are expected with contact zone materials which usually contain gouge.

The leaching of oxide ores is not economical but the possibility of dump leaching of waste is being studied.

A 5 ton/hr sulphide flotation pilot plant was built at Panguna and a test programme was begun in October 1968 using ore from the Panguna and Western adits. The results of the pilot plant programme confirmed the trends shown in the laboratory pattern but showed that a large variation in the hardness could be expected throughout the orebody.

Run-of-mine semi-autogenous grinding tests were technically successful but because of the large hardness variation of the Bougainville ore and the inability of the process to produce a coarse product, power and media requirements were high and the economics compared with conventional crushing and grinding were questionable.

Proposed Concentrator:

It is currently planned that primary sulphide ore will be treated in a flotation concentrator of a nominal rated capacity of 90,000 short tons/day using the flowsheet shown in Fig. 4. Concentrator facilities under construction are shown in Fig. 5.

Economic analysis demonstrated the advantage of large equipment and the concentrator is expected to employ.

1. primary crushing of pit ore by two 54 in. gyratory crushers preceded by grizzlies,
2. secondary and closed circuit tertiary crushing with six 7 ft. secondary and twelve 7 ft. tertiary cone crushers producing a minus ½ in. feed to the concentrator.
3. apart from surge capacity within the crusher circuits, coarse and fine crushed ore stockpiles are included, with a nominal capacity of 50,000 short tons and 80,000 short tons respectively,
4. fine grinding by eight 11,500 short tons/day lines each consisting of one 18 ft. diameter by 21 ft. by 4,250 h.p. overflow ball mill in closed circuit with 26 in. cyclones.
5. flotation with a total of 216 by 300 cu.ft. rougher flotation cells and 117 by 100 cu.ft. cleaner flotation cells.
6. regrinding of rougher concentrates in three 10 ft. diameter by 16 ft. ball mills,
7. transportation of concentrates after thickening to the port site filtration plant by pipeline,
8. at the port, filtration in seven 9 ft. 10 in. diameter by 8-disc filters, rotary kiln drying, and stockpiling under cover.

Principal technical data for the concentrator are as follows.

Average work index –	10.4
Economic optimum grinding power consumption at a grind of 50 per cent minus 200 mesh –	5.8 kWh/s. ton
Economic optimum flotation time –	18 min.
Total power consumption –	13 kWh/s. ton
Total ball consumption –	1.2 lb/s. ton
Flotation reagents –	S3501 0.015 lb/s. ton Frother 0.09 lb/s. ton Lime 1.5 lb/s. ton

ENGINEERING

Engineering of the various facilities and services required for the development of the Panguna orebody began in the middle of 1966. The first requirement for the project was the construction of a temporary access road from the base camp on the east coast near Kieta to support the exploration and drilling programme. Until the road was completed in late 1967 the exploration camp at Panguna was supplied by helicopter.

Construction of the access road (Fig. 6) was made difficult by the instability of the volcanic tuff covering the Crown Prince Range which separates Panguna from the east coast of Bougainville. The difficulties associated with access from the east coast made the apparently more easily accessible west coast route appear attractive. However, the lack of a good port site on the west coast led to the decision to construct the permanent access road from the east coast where there was a good port site available at Anewa Bay.

One of the major bottlenecks – road access from port to mine – was eliminated early in 1971. The temporary track to Panguna, which had been in use since early 1967, was replaced by a new 2-lane highway 24 ft. wide and having a maximum gradient of 12 per cent (compared with up to 27 per cent in mountain sections on the old track). This highway involved over 13 million cu.yd. of excavation.

The new road became fully trafficable in December 1970. It is designed for speeds up to 50 m.p.h. on the flat coastal area. In the Crown Prince Range section the design speed is generally 30 m.p.h. to 20 m.p.h. in some difficult areas.

The road (Fig. 6) allows improved transport of materials between the port and the mine area. Transportation of the concentrate was originally to be by truck but, as mentioned

Fig. 6 — A comprehensive picture of the mountain section of the highway put through the Crown Prince Range to connect port and mine. The old access track can be seen to the right. (Nearing completion of road, December 1970)

previously, it is now intended to install a slurry pipeline system along the length of the access road. Other roads vital to the project include mine haul roads, the Jaba River access road, and the existing road from Anewa Bay to Kieta, the present administrative capital of the island.

The Jaba River road will pass through 7½ miles of rugged terrain along the pipeline from the water pumping station near the junction of the Kawerong and Jaba Rivers to the concentrator.

The port at Anewa Bay (Fig. 7) began receiving shipping at its permanent wharf in August 1970. It is dredged to accommodate vessels of up to 45,000 tons dead weight. In the decision to locate the port at Anewa Bay possible exposure to tsunamis was considered. It is expected that only tsunamis from the area of Alaska will enter the harbour. All the port facilities are located well above the expected maximum height of the wave which will have been greatly reduced by the travel distance and the off-shore protecting reefs.

To supply the electrical power demand of the mine and concentrator a 135 MW steam station burning fuel oil is

being constructed at the port. Economic investigation showed that it would be more economic to transmit power at 132 kV to the main load centre at Panguna from Anewa Bay rather than pump fuel oil from the coast over the Crown Prince Range to a power station at the mine. Temporary power facilities of 11 MW were established at Panguna in 1970 to allow operation of shovels and drills to begin in the latter part of the year.

To house the total workforce of over 2,500 men with, in many cases, their families, two towns have been built. The first, Panguna, is located close to the mine on the special mining lease and consequently is a company town. The other town, Arawa, is on the coast between Anewa Bay and Kieta and is a public town.

When C.R.A. Exploration Pty. Ltd commenced operation on Bougainville, there was no internal communication system on the island and the only external link was a poor quality HF link from Kieta to Rabaul which operated for a limited time on certain days.

A project of this magnitude required a completely integrated communication system between its centres of operation on the island, and telex and voice communication to the international communication system.

A decision was made by the Post and Telegraph Department to install a high quality troposcatter-microwave system to cover internal communication on Bougainville and to connect Bougainville into the international communication system via the SEACOM cable at Madang. As this system would not be operational until first half of 1971, it was necessary for Bougainville Copper to install an interim communication system, to cover the project construction requirements. This system consists of the three main centres of operation, coupled together by a U.H.F. radio link.

At the same time, the off-island H.F. radio link between Kieta and Lae has been updated by the Post and Telegraph Department, part of the cost being contributed by Bougainville Copper.

Engineering investigation of the project was initially carried out by Central Engineering Services, a Division of C.R.A. Engineering Pty. Limited. In addition to preparing the first engineering study of the project, Central Engineering Services was also responsible for all engineering activities associated with the exploration and investigation programme.

In December 1966 a joint venture of Bechtel Corporation and Western Knapp Engineering (W.K.E.) both of San Francisco, was commissioned to prepare a second engineering study which was completed in August 1967. During the remainder of 1967 and 1968 engineering investigations were continued by both Central Engineering Services and Bechtel-W.K.E.

After initial construction was authorized at the end of 1968 Bougainville Copper Pty. Limited appointed Bechtel-W.K.E. as managers of engineering, procurement and construction and established a team of owner's representatives, a substantial number of whom were seconded from Central Engineering Services.

At the end of 1970 the construction programme was approximately 45 per cent complete. In addition to completion of the road and the opening of the port, construction of crushing and concentrator facilities at Panguna and of the 135 MW power station at Anewa Bay were well advanced and pit pre-production was well under way. Housing and accommodation facilities at Panguna were about 75 per cent complete.

POLITICAL SITUATION

The island of Bougainville, although geographically part of the Solomon Islands, is politically part of the Australian Territory of Papua and New Guinea (T.P.N.G.) which is administered by Australia under a United Nations Trusteeship.

When it became apparent that the Panguna orebody was a potential mine, Bougainville Copper Pty. Limited negotiated an agreement with the Administration of T.P.N.G. to provide security of tenure.

The agreement provides for the Administration to issue the company with a special mining lease for an initial period of 42 years with provision for two extensions of 21 years. In addition 20 per cent equity at par was taken up by the Administration on behalf of the people of Papua-New Guinea. A 3-year tax holiday will operate from the commencement of commercial production of copper concentrates at the end of which period the company will begin to pay taxes increasing to an amount equivalent to 50 per cent of taxable income. This rate of tax is twice that current in the Territory at the time of the agreement. In addition the Administration will receive dividends from its 20 per cent equity participation in the project and also royalties equivalent to 1¼ per cent of the F.O.B. value of the concentrate sold. These receipts will ensure that over 60 per cent of the taxable income of the operation will remain in the Territory.

This agreement was ratified as the Mining (Bougainville Copper Agreement) Ordinance 1967 by the House of Assembly of the Territory in August 1967.

As well as maintaining close contact with Administration personnel on Bougainville and in Port Moresby, the company has continually tried to explain its activities to the local people who will be directly affected by the mine operations.

A great deal of the opposition originally expressed by portions of the local population has been replaced by support for the project. This support has been gained by officers of the company visiting the main towns and villages on the island and by inviting groups of people to visit Panguna. This has enabled the indigenes to gain a better appreciation of the company's activities. In addition several members of the Administration and House of Assembly have been taken to inspect some of the company's mining operations in Australia. The main political problem has been the acquisition of sufficient land for the construction of all the facilities required for the mine town and port. On Bougainville, as in other parts of Melanesia, there is a strong spiritual tie between the people and the land which is usually owned communally, and it is not surprising that a people with relatively recent contact with the western world have some trouble in comprehending all facets of the introduction of a very large mining project.

Under the agreement between the company and the Administration the latter is responsible for acquiring sufficient land for the reasonable needs of the company.

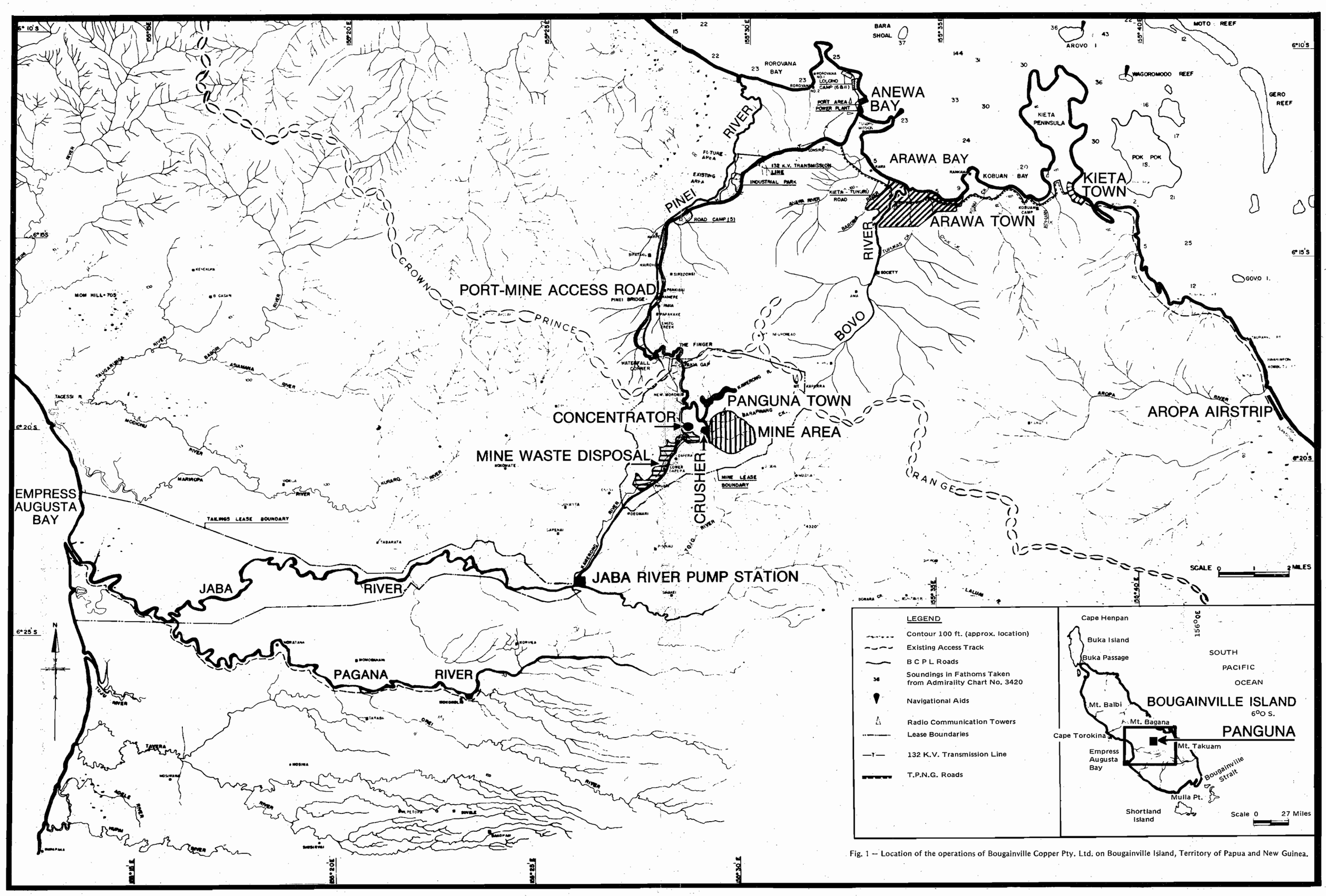


Fig. 1 -- Location of the operations of Bougainville Copper Pty. Ltd. on Bougainville Island, Territory of Papua and New Guinea.

Fig. 7 — General view of Anewa Bay area. Concentrate dewatering and filtering facilities will be located on the area adjoining the wharf. The site for the 135 MW power station is in the centre of the picture.

Papua-New Guinea is an underdeveloped country and as such has many problems in common with other countries at similar stages of economic development around the world. The company became aware of these problems during its early exploratory work and has studied the steps taken to overcome these problems in countries with large mining industries such as Zambia. Based on these investigations the company has formulated a policy of localization of the workforce as quickly as possible.

To carry out this policy an extensive training programme has been introduced. This programme provides for the training of local people to fill all positions from labourers to tradesmen and supervisors, many of which will initially be filled by expatriates. As indigenes become qualified they will eventually fill technical and management positions.

CONCLUSION

The Bougainville copper project will be one of the largest copper operations in the world producing annually an average of 150,000 tons of contained copper and 500,000 oz. of gold in concentrate. Anticipated capital cost is approximately $400 million and start-up date was in mid-1972.

Rock Types and Mineralization at Panguna

P.M. Macnamara,
Senior Field Geologist,
C.R.A. Exploration Pty. Ltd.

Paper presented at
The Australasian Institute of Mining and Metallurgy,
December 1968.

ROCK TYPES AND MINERALIZATION AT PANGUNA PORPHYRY COPPER PROSPECT, UPPER KAVERONG VALLEY, BOUGAINVILLE ISLAND

ABSTRACT

A large body of porphyry-type copper mineralization occurs at Panguna in southern Bougainville. It is associated with the intrusion of quartz diorite/granodiorite into andesites, particularly with the contact zone. Metasomatism of both intrusives and andesite resulted in the formation of biotite pseudomorphing hornblende and the veining of the resultant biotite diorite and biotitized andesite by quartz-chalcopyrite veins with pink orthoclase and dark biotite selvages, respectively.

The orientation of intrusives and veins appears to be controlled by premineralization fault-joint patterns in the intruded andestic Kieta Volcanics.

INTRODUCTION

Bougainville, at the northern end of the Solomons chain, is a north-west trending island about 130 miles long by a maximum of 40 miles wide and forms the easternmost part of the Trust Territory of New Guinea (Fig. 1).

The area of copper-gold mineralization around Panguna lies

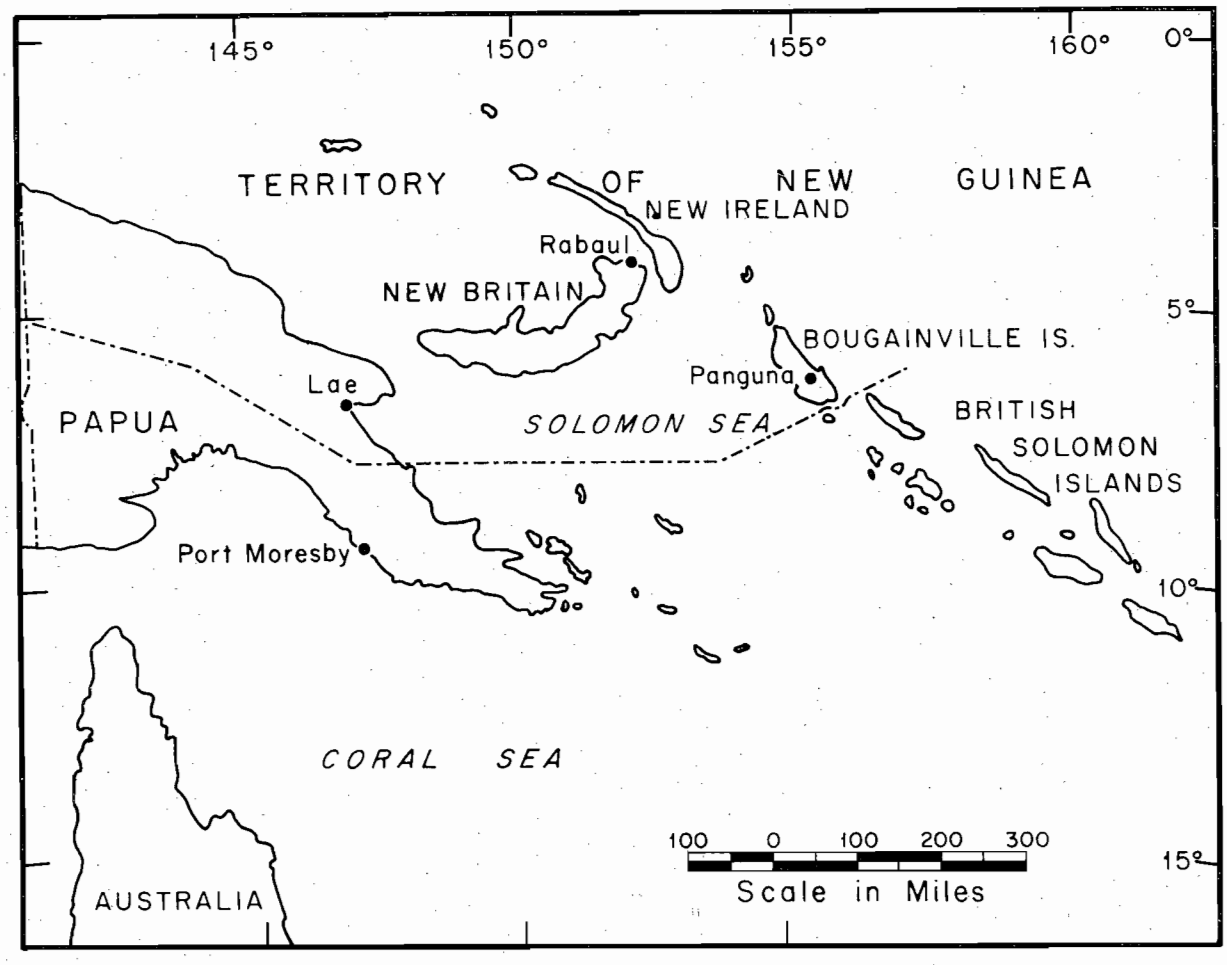


Fig. 1 — Locality map, showing Bougainville Island, Territory of Papua and New Guinea.

within the Kaverong Valley which drains westwards from the Central Crown Prince Range of southern Bougainville. Access is from Kieta on the coast, 12 miles to the north-east.

Gold was discovered at Kupei near the crest of the Crown Prince Range in 1930, where an elliptical shaped body of about 230 ft. by 160 ft., consisting of a network of copper-bearing auriferous quartz stringers, grading about 8-10 dwt/ton gold was subsequently worked (Fig. 2). Shortly afterwards a similar but much smaller occurrence of faulted quartz-sulphide veins, averaging an estimated 15-20 dwt/ton gold, over 18 in. width was discovered at Panguna, and worked until the onset of the Japanese invasion in 1941. N.H. Fisher (1936) visited the area for the New Guinea Administration, and described the occurrence of gold and copper in association with porphyry and agglomerates. J.E. Thompson (1962), Senior Resident Geologist for Papua and New Guinea, visited the Panguna-Moroni area and suggested reconnaissance geochemistry and mapping over a wide area of the Crown Prince Range in the search for large, low grade centres of copper-gold mineralization.

In 1963, the Atlas Copper mine at Toledo in the Philippines was visited by K.M. Phillips of C.R.A. Exploration Pty. Limited, who suggested that a similar geological environment of diorite intrusive into Tertiary andesite might be found in New Guinea. The copper mineralization of Kupei and Panguna, recorded by Fisher and Thompson in particular attracted his attention because of the close apparent similarity in age, rock types, and quartz veining with the occurrence at Toledo. From April to July, 1964, K.M. Phillips and his party outlined an area of widespread copper mineralization by geochemical stream sediment and soil sampling. The rocks exposed at Panguna were found in fact to be similar to those at Toledo (viz. diorite intruding very fractured andesite rocks), and the recognition of significant porphyry-type copper mineralization led to the commencement of a testing programme.

By July 1965, eleven diamond drill holes to depths up to 800 ft. had been completed, mainly on Panguna Hill. These had all cored copper mineralization of significant grade.

Subsequent escalation of diamond drilling followed, so that by July, 1967, 81 holes had been completed to an average depth of 1000 ft. and an estimated 200 million long tons of ore of average primary zone grade of 0.63 per cent copper and 0.5 dwt/ton gold had been indicated.

CLIMATE AND TOPOGRAPHY

Bougainville has an equatorial climate with a poorly defined wet season. At Panguna the temperature ranges between mean monthly maxima and minima of 84°F. and 57°F., with high relative humidity. Up to about 200 in. per year of rain fall on the prospect area around Panguna.

The terrain is deeply dissected, and side slopes of 30° to 45° are common. The Kaverong Valley is surrounded by hills up to 5,000 ft., while elevations within the prospect area vary between 2,000 ft. and 3,000 ft. above sea level. The area is covered by tropical rain forest, with fairly thin undergrowth except in areas of dense secondary growth.

REGIONAL GEOLOGY

The Kieta Volcanics, which are the oldest rocks exposed on Bougainville, form the Crown Prince Range and the Deuro Range in southern Bougainville (Blake and Miezitis, 1967).

They are separated from the Emperor Range in the north by active volcano Mt. Bagana, 5730 ft., and the extinct volcanoes Billy Mitchell, Numa Numa, and Reini, and bounded on the south by the Mt. Taroka-Mt. Takuan volcanics.

The buff-coloured Lower Miocene Keriaka Limestone uncomformably overlies the Kieta Volcanics. Darker fine grained, organic limestone occurs in the Kieta Volcanics near Pakia and in the Karato-Mainoko area, 9 miles WNW of Panguna.

The Kieta Volcanics consist mainly of andesitic and basic flows and pyroclastics (agglomerate, sandstone, and siltstone). In the Pakia Gap-Panguna area the beds and flows dip SSE generally at 10° to 15°, but around Kieta there appears to be a general low northerly dip. About 1 mile south of Pakia, dips to 30° occur locally. An overall anticlinal arching is therefore inferred between Kieta and Panguna.

A stratigraphic sequence in the area between Nairovi and Panguna, modified from McQueen (unpublished report to C.R.A. Exploration Pty. Ltd. 1966) and Fountain (unpublished report to C.R.A. Exploration Pty. Ltd., 1967), is shown in Table 1. Correlation of the rocks of the Kaverong Valley and those on the Pakia Gap-Nairovi Village road is uncertain, as contacts are obscured by younger rocks, particularly the Pakia Gap Tuff. An overall SE dip in the rocks between Pakia Village and Panguna (Fig. 3) supports the sequence outlined in Table 1.

TABLE 1

Stratigraphic column
*Nairovi to Panguna, Bougainville**

Age	Rock unit
Quaternary	River gravels 0-50 ft Volcanic ash 0-100 ft Boulder terraces 50 ft
Pliocene ?	*Intrusives* Nautango Andesite Karoona Porphyry and other porphyry dykes Biuro Granodiorite *Marginal phases* Kaverong Quartz Diorite and its marginal mineralized phases (1) leucocratic quartz diorite (2) biotite diorite (3) biotite granodiorite
Miocene ?	Pakia Gap Tuff (+600 ft)
	Unconformity
Oligocene ? to Lower Miocene ?	Kieta Volcanics † (Fm) Undifferentiated welded tuffs and agglomerates Binivan Andesite Breccia Member +1000 ft Panguna Andesite Member +3000 ft Pinei Agglomerate Member +1500 ft Nairovi Siltstone Member +1500 ft

* Modified from A. F. McQueen, unpublished report, 1966 and R. J. Fountain, unpublished report, 1967.
† Blake and Miezitis (1967).

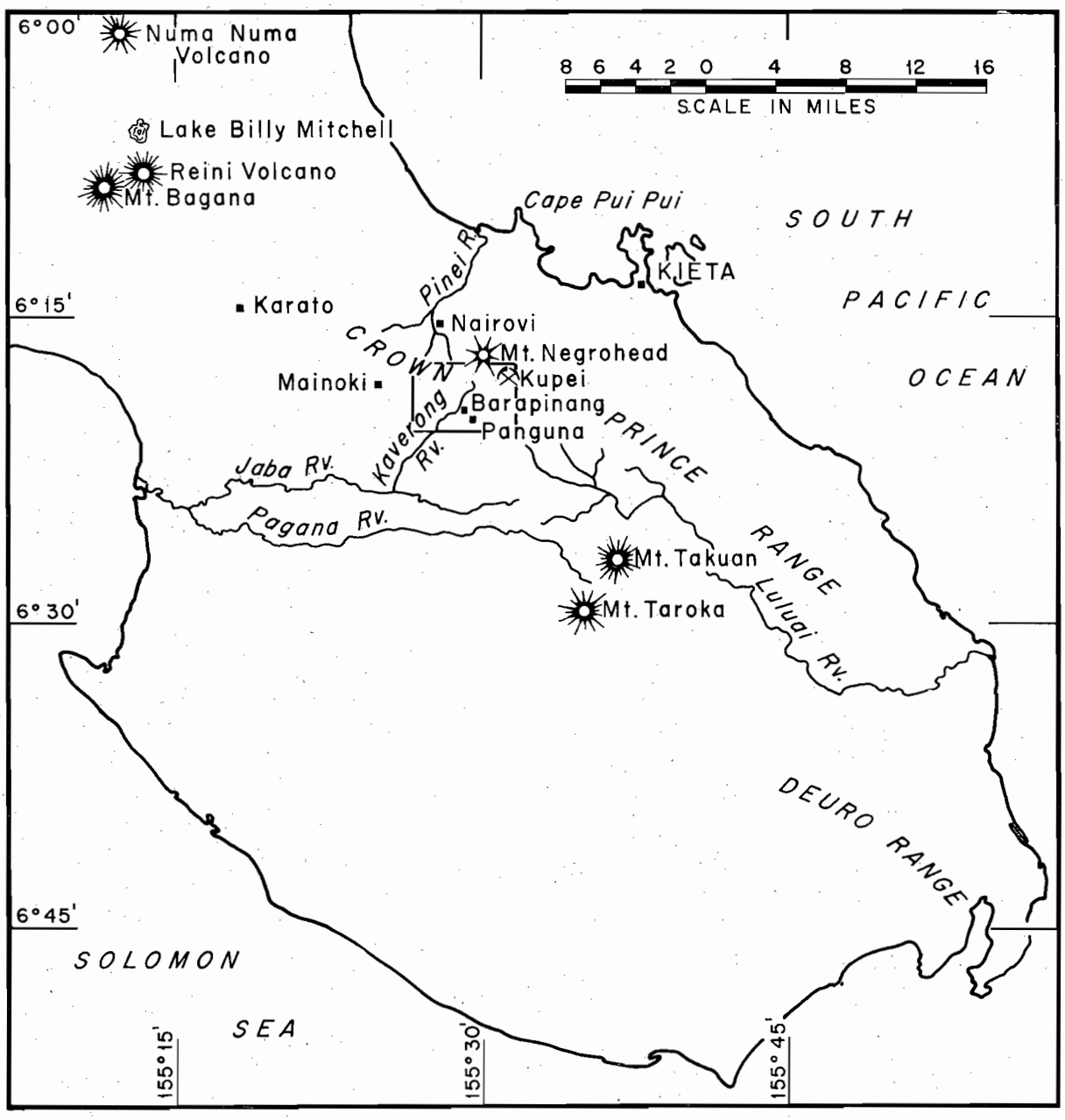


Fig. 2 — Locality Plan, showing Panguna, Bougainville Island.

ROCK UNITS IN THE VICINITY OF THE MINERALIZED AREA

Volcanics and minor dykes

The volcanics and dykes are described in ascending order of age.

Nairovi Siltstone (new name)

It is inferred that the Nairovi Siltstone is the oldest unit in the area examined. It is exposed near Nairovi to an elevation of about 1700 ft. above sea level at the type section on the Pakia road, and also between Nairovi and Cape Puipui. It is made up mainly of finely bedded, buff-coloured tuffaceous siltstones, with some interbedded massive tuffaceous sandstones and sporadic impure limestone. The limestone is fine grained, grey and (?) unfossiliferous. Dips are generally low, of the order of 0° to 20° to the north or south. In places the unit is intruded and deformed by basaltic dykes.

Pinei Agglomerate (new name)

The Pinei Agglomerate crops out at the type section on the northern side of the main divide between 1700 ft. and 2500 ft. above sea level along the Pakia Gap-Nairovi road. In mass appearance it is similar to the rocks seen around Kieta and is equally fairly well indurated.

The agglomerate is composed mainly of greenish andesite fragments, with lesser red andesite and pale cherty inclusions. Lenses of buff-coloured tuffaceous siltstone are common.

Dips are normally about 15° SSE. Above 2500 ft. above seal level, the Pakia Gap Tuff is exposed in road cuttings. It probably unconformably overlies the Pinei Agglomerate and the Panguna Andesite.

Panguna Andesite (new name)

The Panguna Andesite is the oldest unit exposed in the Kaverong Valley, and it has been demonstrated by drilling

to extend in depth at least to an elevation of 200 ft. above sea level near Panguna. The type section is exposed along Panguna Creek, between the Kaverong River and Panguna. It is mineralized around Panguna and elsewhere, where adjacent to mineralized diorite.

The few dips seen in the Kaverong Valley in Panguna Andesite are at 10° to 20° SE to SSE, and the equivalent rocks are probably covered by Pakia Gap Tuff on the northern side of the main divide, where they pass down into the Pinei Agglomerate.

The bulk of this rock in the Kaverong Valley is texturally and compositionally a hornblende microdiorite and appears to have been a lava flow. It shows no sign of vesicularity. In some places there are fine grained, banded sections, whilst in others xenolithic inclusions make up a large percentage of the rock. It is possible that some sections, especially these latter types, are hard welded agglomerates, but the field relationships indicate that they are flows.

The Panguna Andesite, then, is composed of the following elements.

1. Hornblende microdiorite. This occurs as either a main rock type of itself, or as a "matrix" in the xenolithic sections. 1·5 to 2 mm euhedral hornblende crystals form 15 to 20 per cent of the rock, the remainder being mainly plagioclase laths of smaller dimensions. The hornblende is commonly grouped in glomeroporphyritic clumps.

2. Xenoliths. These may form up to about 80 per cent of the rock and range in size from 2 mm to several cm. There are apparently two main types, which are

a. A dark grey or blue-grey porphyritic (2 to 5 mm) hornblende-augite andesite, which is the most common xenolith type, and

b. A light coloured hornblende felspar rock of dioritic appearance.

The xenoliths are usually irregular in outline, but in some places are sub-rounded. Reaction rims have been seen around some of them.

3. Banded fine grained and very fine grained ("cherty") hornblende andesite, pale green in colour. The banded sections may be of limited extent only. They form less than 10 per cent of the diamond drill core around Panguna, but may be more common elsewhere where the andesite is less xenolithic.

Binivan Andesite Breccia (new name)
This is a crudely banded andesitic rock with pale green pyritic-epidote-chloritic material as inclusions and joint coatings which were probably formed by deuteric alteration. The rock is similar in places to the (?) xenolithic sections of the Panguna Andesite which it immediately overlies, but it may be partly agglomerate. There is occasional quartz veining, and fine grained red (?) andesite inclusions occur in places. It has been intruded by diorite dykes, presumably associated with the Kaverong Quartz Diorite.

The Binivan Andesite Breccia crops out in the higher parts of Binivan Creek (the type section), and in the high hills around the Kaverong Valley where it is normally associated with a steepening of slope due to its more massive character. Joints are commonly spaced at 5 ft., contrasting with the more closely spaced joints in Panguna Andesite.

Welded chloritic agglomerate and tuff
These rock types occur around the headwaters of Barapinang Creek and towards Mt. Negrohead, and lie above the Binivan Andesite Breccia. Various irregular andesite fragments, 1 to 8 cm in diameter, occur in a greenish chloritic matrix.

Pakia Gap Tuff (new name)
Indurated tuff occurs around the type section at Pakia Gap and in road cuttings towards Nairovi to about 2,600 ft. above sea level. It (?) unconformably overlies the Panguna Andesite and the Pinei Agglomerate and appears to be thicker on the northern side of Pakia Gap.

No bedding has been observed in it, nor have equivalent rocks been recognized elsewhere in the Kaverong Valley. The rock is grey where fresh, with a greenish-grey chloritic matrix, but is commonly highly weathered to pink and yellow mottled clayey soil containing residual angular cherty pieces and broken quartz.

The rock is cut by quartz-felspar porphyry and some quartz veins.

Nautango Andesite (new name)
The Nautango Andesite is a pale grey, fine grained andesite with acicular hornblende crystals 1 to 4 mm long. It intrudes the Panguna Andesite and the Kaverong Quartz Diorite in the Nautango area where the type section is exposed as a knoll of plug-like appearance. Other types of subvolcanic andesite dykes occur also, such as those on the road west of Barapinang, but do not appear to be very common or extensive.

Volcanic ash
Most of the volcanic ash has been weathered to a brown clayey montmorillonitic matrix with black and green, 1 to 2 mm hornblende, some felspar crystals and squashed pumice fragments. Crystal ash, mainly felspar, with some hornblende, occurs in bands and lenses and makes up about 10 per cent of the total.

The clayey type ash occurs in extensive sheets, and has loosely bonded water which causes the ash to liquefy if disturbed by road plant. This has led to instability of road beds, and the need to place quantities of river gravel on roads in these sections.

The ash forms a capping on the tops of some ridges and at the flattening of slopes. In the past it has formed terraces on top of creek boulder terraces, and remnants of these terraces occur in the Panguna-Barapinang-Kaverong River systems. It varies in thickness from nil to a few feet on steep slopes, and increases to about 50 ft. thick on lower ground.

River gravels and boulder terraces
River gravels are more evident around the Pakia Village area, but there are also reworked gravels in the boulder terraces around Panguna and Barapinang. Some of these terraces may have been formed by the stripping action of ash mixed with rain water as it moved from the higher slopes into the valleys. Very large blocks of Binivan Andesite Breccia, some reaching 15 to 20 ft. in size, occur in the lower Panguna Valley remote from the nearest outcrop and were possibly deposited in this way.

Diorite-granodiorite intrusives associated with mineralization, and subsequent intrusives
The rocks of this group are co-magmatic, and there appears to be a tendency for the younger members to be more por-

phyritic and quartz rich, and to occur near the margins of the main intrusion. The intrusives are discussed in order of their apparent sequence from oldest to youngest.

Kaverong Quartz Diorite (new name)
This is typically a pink hornblende diorite, with granodiorite phases in places. It is exposed over much of the Upper Kaverong Valley and is similar to the diorite in the Luluai River area. The type section occurs in the Kaverong River about ¼ mile below its junction with Kompooma Creek.

The quartz content varies from nil to about 10 per cent generally, and is usually interstitial, but composite grains up to 3 mm have been noted. Hornblende forms 15 to 25 per cent of the rock with 1·5 to 3 mm subhedral and euhedral forms and occasional 5 mm stumpy euhedral crystals. The remainder of the rock is normally plagioclase of even grain size but occasionally phenocrystic.

Some orthoclase, up to 15 per cent, has been seen in thin sections and may account for the overall pink appearance of the rock.

The hornblende is commonly chloritic and in these cases may contain few fine spots of chalcopyrite. The felspars are occasionally slightly sericitized, and a little epidote is present in places. Numerous small dark chloritic inclusions and large very dark biotitic zones in the Kompooma and Karoona Creek areas probably represent partially assimilated country rock, presumably Panguna Andesite. In diamond drill core in and around Panguna, about 3 to 5 per cent of the diorite consists of these dark clots.

The Kaverong Quartz Diorite has the following marginal differentiates or facies.

Biotite Diorite. This rock is light grey with 0·5 to 5 mm brown biotite pseudomorphs after hornblende, and irregular biotite patches forming 15 to 25 per cent of the rock.

Felspars are grey-white to cream. A little magnetite is also present.

In texture the rock resembles Kaverong Quartz Diorite in which biotite has replaced hornblende. No definite contact between these two rock types has been seen and it is probable that there is a gradational change from Kaverong Quartz Diorite in the north through biotitized hornblende quartz diorite to biotite diorite in the south.

In places, the boundary between biotite diorite and Panguna Andesite is gradational though a darker variety of biotite diorite and a biotitized hornblende microdiorite.

Biotite granodiorite. The biotite granodiorite may be a variant of the biotite diorite containing more granular quartz. It is recognized as a separate rock type on the basis of the quartz content visible in hand specimen, although this may not be a significant difference, as the biotite diorite also has granular quartz in places, as well as finer groundmass quartz which becomes more evident macroscopically when the rock is kaolinized.

Leucocratic quartz diorite. The leucocratic quartz diorite includes microdiorite and porphyritic varieties, but is essentially similar to the biotite diorite except that it is more heavily quartz veined and carries more copper and orthoclase vein selvages. It occurs in Panguna Hill and at Kupei and forms the strong, weather-resistant feature on these ridges due to abundant sheeted, 2 mm to 8 mm wide, quartz veins. These veins are parallel to the dyke-like intrusive walls of the diorite.

The sheeted quartz-veined type of intrusion may be part of an elongated cupola which exhibits the most intensive veining in the roof and hood. The amount of veining and the intensity of mineralization in the leucocratic quartz diorite decrease in depth in both Panguna and Kupei. At depth, the leucocratic quartz diorite resembles biotite diorite where unchloritized, except for a larger amount of pink orthoclase selvage on vein walls.

The ferromagnesian minerals are mainly chloritized, probably as a result of post mineralization alteration, but pseudomorphs after hornblende remain in places. It is not known if these were biotitized before replacement by chlorite, but biotite is common throughout the leucocratic quartz diorite.

Barren late stage diorite intrusives

Biuro Granodiorite (new name). The Biuro Granodiorite is a light coloured granodiorite with 10 to 20 per cent of 1 mm quartz, 10 per cent of 1 to 5 mm hornblende, generally black and fresh, and commonly 10 to 15 per cent of 3 mm felspar phenocrysts set in a somewhat finer felspar matrix. The rock generally contains a very low percentage of copper (of the order of 0·02 per cent Cu), except where it is contaminated by pre-existing mineralized rocks into which it intrudes. The rock intrudes both Panguna Andesite and the biotite diorite phase of the Kaverong Quartz Diorite.

Karoona Porphyry (new name). The Karoona Porphyry is a light coloured rock with large distinctive quartz and felspar phenocrysts in a hornblende-felspar microdiorite or andesite matrix. 2 to 5 mm euhedral quartz grains form 10 to 15 per cent of the rock with similar sized and amounts of felspar phenocrysts, but grain size of phenocrysts and groundmass can vary considerably. The rock occurs marginal to the Kaverong Quartz Diorite, near or at its contact with the Panguna Andesite. It contains no obvious copper. The type section is in Karoona Creek.

Felspar porphyry and quartz felspar porphyries. Various types of these porphyries occur in the area. They are all generally marginal to the Kaverong Quartz Diorite or as dykes traversing Panguna Andesite.

A felspar porphyry with a rather dark, fine grained groundmass intrudes the Nairovi Siltstone in places near Pakia.

ALTERATION

The following types of alteration appear to have taken place in the mineralized area.

1. biotitization
2. chloritization
3. quartz-kaolin-pyrite alteration
4. pyrite alteration
5. propylitic alteration

Biotite appears to be related directly to the ore formation (Fig. 3) as is possibly chlorite to a lesser extent.

The other alterations appear to be of a later post-ore, retrograde nature.

Biotitization

The apparent pseudomorphing of hornblende to form the biotite of biotite diorite and leucocratic quartz diorite appears to be related directly in time and space to the

mineralization. This probably took place by the introduction of K-SiO_2-Cu resulting in the formation of pink orthoclase and chalcopyrite as well as biotite. Simultaneously, in the Panguna Andesite, alteration of fracture walls to form a dark biotite selvage or intensely biotitized zones where fractures are closely spaced was followed by the emplacement of quartz and copper. In places chalcopyrite occurs as specks with the biotite in both the altered andesite and the biotite diorite.

The occurence of biotite pseudomorphing hornblende, with the assemblage quartz-albite-orthoclase-muscovite-biotite is present in some porphyry coppers elsewhere such as Bagdad, Morenci, Ely, and Bingham (Titley and Hicks, 1966).

Chloritization

This appears to be associated with a late stage alteration and is particularly noticeable in Panguna Hill, where (?) biotite and hornblende in leucocratic quartz diorite have been altered to chlorite in association with the kaolinization of felspar. In the biotite diorite/granodiorite intrusives, a further stage of alteration results in the formation of a blue-green chlorite or chloritic clay, which turns brown on exposure to air. This alteration is fairly widespread and the blue-green colour of the chlorite is quite distinctive.

Elsewhere, as at Kupei, chlorite forms a halo in the Panguna Andesite around an intrusion, and sometimes occurs with pyrite and quartz replacing biotitized andesite.

Quartz-kaolin-pyrite alteration

This is a late alteration, generally confined to fracture zones in the Panguna Andesite at Panguna and Kupei. The rock alters to a white or grey soft pyritic clay with quartz and occasionally a little chalcopyrite. The controlling fractures may be flat and irregular, or steep. A similar alteration occurs along fracture zones in diorites. Early alteration of ferromagnesian minerals to chlorite and the incipient kaolinization of felspars appears to be an early stage, in some cases, of this type of alteration. The largest crystals appear to be the least altered and ferromagnesian minerals are probably affected more readily than felspar. The biotite granodiorite mass immediately north of Panguna Creek has been intensely altered in places. Intense silica-pyrite metasomatism along fractures and replacing the chloritized ferromagnesian minerals of the kaolinized granodiorite leads to an end product of quartz-pyrite-kaolin-chlorite, separated by harder zones and patches with strongly kaolinized felspar and chlorite. The larger felspar crystals in both zones are commonly represented now by large yellow phenocrysts of kaolin after felspar.

Pyrite alteration

The disposition of pyrite in rocks around the edge of the area of copper-gold minerlization suggests the presence of a pyritic halo. The contact zone between diorite and andesite is normally biotized, and it is usually very thin if it is pyritic also.

As a corollary, an increasing pyrite to chalcopyrite ratio in the ore usually accompanies a decrease in copper grade for that particular area.

Propylitic alteration

There are some indications of zones of propylitic alteration in the host Panguna Andesite around the orebodies at Panguna and Kupei, represented by patchy pyrite-epidote-chlorite alteration. The overlying Binivan Andesite Breccia, with its typical steep topographic expression tends to coincide with and mark these areas in many places. In addition, the inclusions in the Vinivan Andesite Breccia appear to have been (?) deuterically altered to a chlorite-pyrite-epidote mass.

Trends of alteration

While the process of alteration is not restricted to the formation of one "indicator" mineral, but affects the different minerals in the same rock in different ways according to their nature, grain size, the pressure and temperature conditions, and the presence or absence of overlapping metasomatic changes, the following trends appear to exist.

1. Hornblende→biotite→chlorite→chloritic clay

   $\rightarrow +SiO_2 + FeS_2 \rightarrow$ pyrite

   $-$chlorite $-$ quartz

2. Felspar→incipient white kaolinization→cream kaolinitic felspar→yellow kaolin

3. The coarser crystals and coarser grained xenoliths in the Panguna Andesite are the last to be altered, so that common commonly a coarse grained hornblende-bearing xenolith has chloritic ferromagnesian minerals, while the surrounding finer grained andesite is biotitized.

Similarly, in the pyrite-silica replacement of granodiorite, the large yellow kaolinized felspar phenocrysts are the last to be replaced.

MINERALIZATION

In all mineralized rock types, chalcopyrite is the dominant primary copper mineral, associated in places with some bornite, and a little molybdenite and silver. Magnetite occurs as an alteration product due to the biotitization of andesite and as a primary mineral in quartz veins.

Pyrite is widely distributed, but, when intimately associated with the copper mineralization, appears to vary antipathically with it. Traces of sphalerite and galena have been found.

Gold appears to vary sympathetically with the copper content and there is a suggestion that this ratio varies slightly in different rock types.

The base of oxidation rises under the ridges from the level of the main creeks to a depth below the ridge tops that reach, in places, several hundred feet. Cuprite and malachite are common oxide zone minerals. A thin chalcocite zone occurs in places.

Kaverong Quartz Diorite

The Kaverong Quartz Diorite carries weak copper mineralization throughout the Kaverong Valley, mainly as chalcopyrite, with occasional bornite, which occurs mostly in chloritic hornblende. Economically significant concentrations of copper mineralization occur in the three marginal facies.

Biotite Diorite. The biotite diroite is the host rock of most of the disseminated mineralization north of Panguna, and is apparently the source of mineralization in the adjoining Panguna Andesite.

The rock is usually veined by irregular, thin quartz-chalcopyrite veinlets with pink orthoclase selvages. This type of veining is characteristic of the mineralized diorites and granodiorites. The additions of SiO_2-Cu-K seems to be involved in the mineralization process. In addition, diss-

eminated chalcopyrite, sometimes with bornite, replaces biotite, or is associated with the replacement of pre-existing hornblende by biotite.

Biotite granodiorite. On present evidence,the biotite granodiorite facies appears to be similarly but more weakly mineralized than the biotite diorite.

Leucocratic quartz diorite. The amount of quartz veining in the leucocratic quartz diorite intrusion appears to control the degree of veining in the adjacent Panguna Andesite and the amount of copper in both rock types. Bornite tends to be more abundant in this rock type, and this may be a reflection of the association of bornite with this particular type of veining.

Panguna Andesite mineralization. The Panguna Andesite is intruded by all the diorite rock types. It is the most strongly mineralized extrusive rock in the area, due to its close spatial relationship with the Kaverong Quartz Diorite. The degree of jointing is greater in the mineralized area than outside it.
Mineralization at Panguna and Kupei in the Panguna Andesite occurs mainly in straight walled quartz veins 2 mm to 25 mm wide, which normally carry the chalcopyrite in a central zone with quartz crystals growing inwards from both walls. An altered wall zone composed of fine grained dark brown biotite forms a selvage to the veins. Closely spaced parallel quartz veins occur in the andesite adjacent and parallel to the vein-sheeted leucocratic quartz diorite dykes. The veins tend to be wider than usual (up to 5 cm) in these cases, and their width appears to be controlled to some extent by the proximity of the intrusion.

Occasionally thick quartz veins up to a few feet wide occur, but large (fracture-controlled ?) zones of biotite alteration of the andesite with irregular quartz-chalcopyrite veins are more usual. This biotite alteration leads to replacement of hornblende by biotite in the first stage but, with increased intensity, finally results in the formation of a fine-grained dark brown mixture of biotite-skeletal, kaolinized felspar-magnetite-chlorite rock with very little of the original texture remaining. This is the main type of alteration associated with the mineralization phase, and is most extensive where economically significant mineralization occurs in the andesite.

Considering the amount and width of veining, the percentage of copper and degree of alternation in the andesites, and the general decrease of these features with increasing distance away from the biotite diorite intrusive types, there can be little doubt that the intrusion is the ultimate source of the copper mineralization.

Some weak copper-zinc mineralization has been observed in the Binivan Andesite Breccia, above the Panguna Andesite, in the Panguna and Barapinang Creeks.

FAULTING

Whilst the island of Bougainville is aligned roughly in a NW-SE direction, the major joints and faults in the Kieta Volcanics trend at 120°. Mt. Bagana actually distorts this trend, and joint trends in the Kieta Volcanics appear to "wrap around" the volcano. Bureau of Mineral Resources mapping (Blake and Miezitis, 1967) shows this trend on a regional scale, whilst in the Kaverong Valley a fault along Panguna Creek and another through Pakia Gap are in the same direction. Faulting at 050° to 070° is also common, and may control the direction of stream channels in parts of Barapinang and Pankiranku Creeks.

Both the above trends coincide with premineralization jointing directions. This is shown by

1. minor quartz veins,
2. the dyke at Kupei (130°), and
3. Panguna Hill quartz diorite dykes (110° and 050°).

Brecciation and recrystallization in diorite shown by chlorite wrapping around granulated felspars has been observed in some diamond drill cores.

CONCLUSIONS

The rocks of the Kaverong Valley are made up of a group of andesite extrusives of the Kieta Volcanics sequence and a major intrusive called the Kaverong Quartz Diorite, which is the ultimate source of the copper mineralization in the adjacent Panguna Andesite.

Late metasomatic changes in the biotite diorite resulting from the introduction of K-SiO_2-Cu were apparently responsible for the following features.

1. The formation of irregular quartz-chalcopyrite veinlets with pink orthoclase selvages.

2. The pseudomorphing of hornblende by biotite in the diorite-type rocks, and the replacement of this mineral by copper minerals.

3. Biotitization associated with quartz-chalcopyrite veins in Panguna Andesite. The biotite occurs as selvages to veins and also in zones. Biotite and orthoclase appear to be the alteration minerals associated with ore. The later siliceous-pyritic argillic alterations are probably not related to ore formation. The leucocratic quartz diorite of Panguna Hill is generally more intensely altered than the biotite diorite in the area, both in the quartz-orthoclase-copper phase and later. This is evident from the greater degree of mineralization, pink orthoclase, quartz veining and argillic alteration seen in this area. At both Kupei and Panguna, the mineralization may be associated with elongated cupola vein sheets, the directions of which parallel regional joint/fault directions in the Kieta Volcanics.

Large and small zones of siliceous pyritic-argillic alteration, which are not unusual features in other porphyry copper deposits, occur in the area.

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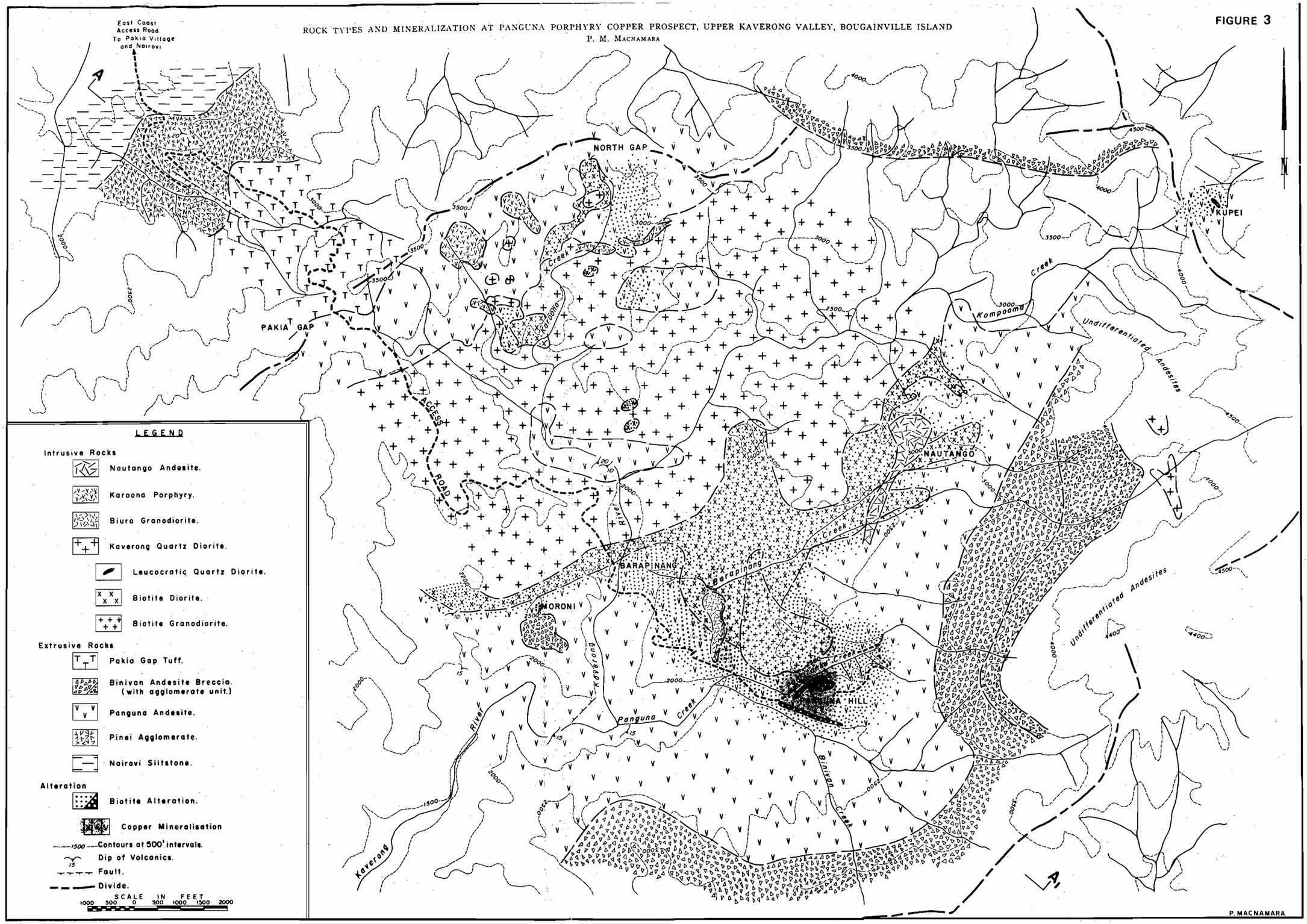
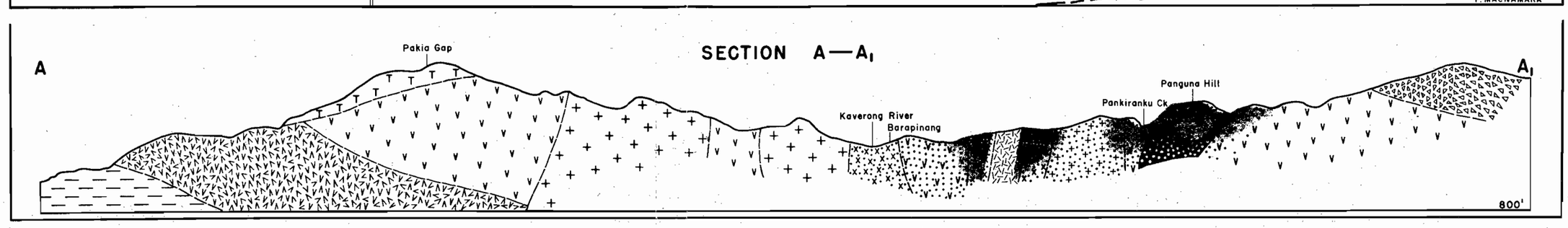
FIGURE 3

ROCK TYPES AND MINERALIZATION AT PANGUNA PORPHYRY COPPER PROSPECT, UPPER KAVERONG VALLEY, BOUGAINVILLE ISLAND

P. M. MacNamara

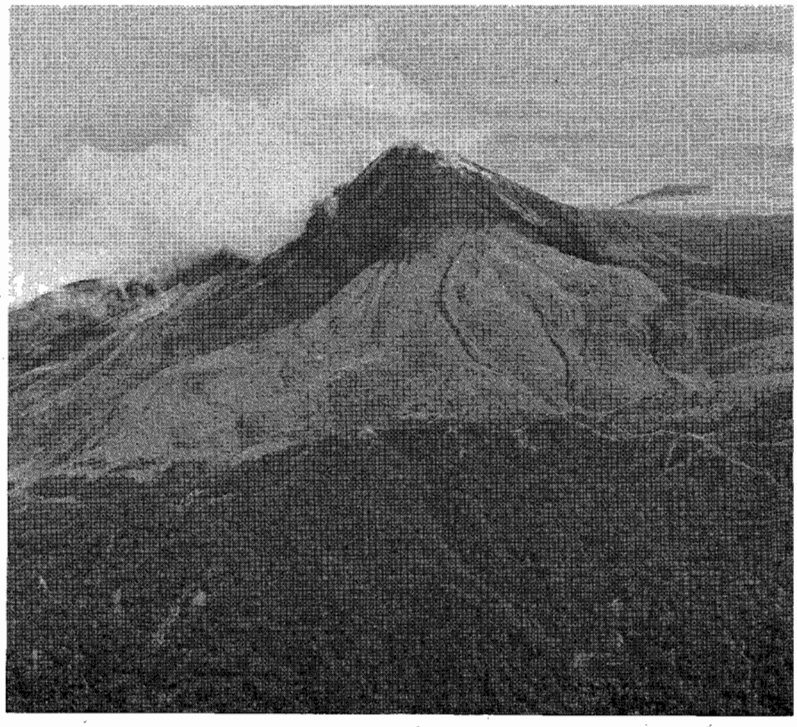




Volcanoes

VOLCANOES – WHAT THEY MEAN TO PANGUNA

Adrian Baumer, B.C.P., Chief Geologist



Mt. Bagana

Bougainville is a volcanic island with a row of mostly extinct volcanoes along its north west–south east axis.

One of the most active volcanoes in Papua New Guinea, Mt. Bagana, is 24 miles north west of Panguna. Two volcanoes Mt. Balbi and Mt. Loloru, are dormant.

Balbi is 44 miles north west of Panguna and Loloru 16 miles south east.

As far as the Bougainville copper project is concerned, it may be safely assumed that an eruption of Bagana would not affect the mine operations due to the distance between the volcano and the mine and the existing topographical barriers.

However, under certain circumstances, ash falls may occur if the prevailing wind direction during and following an eruption is from north west to south east.

Eruptions in volcanic centres which have been inactive or dormant for a longer time are usually very sudden and violent. The dormant volcano, Loloru, consists of a dome, surrounded by a crater with a diameter of about 1.5 miles part of it filled by a crescent shaped lake.

There are patches of fumarole activity, mainly on the northern slopes of the dome where the otherwise dense vegetation has been destroyed.

It is assumed that changes in behaviour of the volcano will be preceded by changes in temperature of the fumaroles and hot springs as well as the water in the lake.

BCP geological staff have been monitoring these temperatures at regular intervals and also report on any visual changes from the previous inspections.

These inspections, which have been in progress for the past four years, have not indicated any significant variation in temperatures to indicate that Mt. Loloru is making preparations to erupt.

Following are the changes in temperatures measured to date:

Fumaroles 93°C–98°C
Hot springs 64°C–70°C
Water of the lake constant 21°C

A hazard associated with some types of erupting volcanoes is the "nuee ardente" – a laterally directed and explosive gaseous eruption.

However, these eruptions usually follow the drainage systems. It appears therefore that there is no threat to Panguna from either Bagana or Loloru.

Earthquakes associated with volcanic eruptions are generally localised in the vicinity of the centre of eruption, the intensity rapidly decreasing with increasing distance from the vent. Therefore seismic activity associated with eruptions should not affect operations at Panguna.

Seismic Affects:

The stability of the rock slopes of the open pit is affected by changes in the forces acting upon the rock mass generated by seismic shock waves.

Bougainville Island is in a zone of high seismic activity due to its location within the circum-Pacific Belt.

Records are available for shocks of felt intensity until 1967, when the first two strong motion accellerographs were installed, initially at Kobuan near Kieta and later at Panguna.

A seismograph of Kobuan, with a Willmore Mark 11 seismoneter, came into continuous operation in August, 1969.

Some 100 shocks have been felt and reported at Kobuan and Panguna since October 1966. Only one shock was of intensity 5, after the modified Mercalli scale, the remaining shocks being of intensity four to five or less.

Shocks were most strongly felt in houses built on high stumps situated on hills or ridges consisting of intensely weathered rock and unconsolidated volcanic ash so an accelerograph was placed in such a position.

This unit has been triggered by shocks of intensity four to five or stronger. The "felt" shock of intensity five which occurred on March 28, 1970, showed on this accelerograph a maximum acceleration of 0.15g.

This confirms that accelerations and felt intensities are considerably smaller on rock than on unconsolidated or weathered material.

However, for the stability analysis of the open pit, horizontal accelerations in rock of 0.13g were used.

Groundwater Survey

WATER ON BOUGAINVILLE

Australian Groundwater Consultants Pty. Ltd.

Of the many problems encountered during the development of the Bougainville Island copper orebody, the most bothersome and 'always present' difficulty, has been water. In the mountainous region of the Crown Prince Range, one can depend on a drenching downpour every day to swell the numerous rivers and creeks, making already difficult access almost impossible.

The Crown Prince Range stretches some 50 miles across the island in a south easterly direction. The northernmost point of the range starts at a volcanic complex, including the Bagana Volcano, reputedly the most active in the New Guinea area with manifestations of activity reported as recently as 1963 to 1965. The range has as a centrepiece, the majestic Mt. Negrohead rising to over 5,200 feet, from which can be seen the extensive mine at Panguna, some two air miles distant. At Panguna, once exploration had proved the viability of the orebody as an economic proposition, attention was turned to the services necessary to support a mining complex.

It was calculated that to ensure maximum throughput of the concentrator at the mine, water would be required at the rate of 35 million gallons per day – about one tenth of the quantity consumed in Sydney each day! In summarising the water requirements of the project, a division was made of industrial process water, and town and general purpose water. The table following shows the demand for each requirement.

WATER REQUIREMENTS – Bougainville Copper Pty. Ltd.	
TYPE OF WATER	UTILISATION
Industrial process	Concentrator at Panguna Mine
Town and General	Panguna townsite – domestic
	Arawa townsite – domestic
	Port and Industrial area
	Domestic
	Make up water, power station
	Cooling water, power station
	Slurry washing
	General purpose
	Panguna Mine and industrial area
	General purpose

One would think water would not be a problem at the mine site with very high daily rainfall, or at the Arawa Bay coastal development area, with an average rainfall of 10 inches per month. In fact, the problems were considerable. In the mountains, turbidity in the fast flowing streams prevented efficient pumping, while on the coastal area, pollution from villages upstream and sediment build-up made treatment essential before the water could be used for domestic purposes. A firm of Australian consultants were engaged to study the problems involved in securing water supplies for the project and to suggest alternative schemes to those suggested by the damming of nearby rivers.

The Consultants studied the hydrology of the island by helicopter, and found evidence of large artesian water deposits. This discovery opened the way to possible development of the vast quantity of water required for the concentrator, and at a moderate cost. Preliminary investigation indicated that artesian pressures were such as to enable groundwater, once tapped, to rise to the surface with no mechanical assistance. The prospect of drawing the entire concentrator supply from groundwater was not established as there has never been any deep exploration, although indications of the existence of suitable aquifer types – vesicular basalts, flow partings and porous fanglomerates – were found.

In the event of groundwater not being able to supply sufficient water to the concentrator, the Consultants planned to recharge the aquifer system by diverting nearby streams into the wellfield system, thus using surface waters to augment the groundwater supply.

Drilling at the concentrator site would have meant the water bores would be in excess of 2,000 feet deep – an expensive drilling job, and one made more difficult with the problem of continuing seismic activity. The decision was made, however, against the utilisation of artesian groundwaters for the concentrator, due to the technical drilling problems involved, and the time of development. Start up date for the mine in 1972 was all important, and delays due to difficulties with deep artesian drilling could not be tolerated. The fact remains that a vast untapped supply of good quality water awaits future development for this or other projects in years to come.

Water was also required for the project's coastal installations, and so a combined programme of groundwater geophysics and aerial infra-red sensing was drawn up by the consultants to locate the areas where groundwater could be developed for domestic and industrial process requirements.

The geophysical programme was designed to evaluate groundwater depth and salinity, and in conjunction with the aerial sensing survey, to locate prime bore sites in areas close to the supply points on the coast. Specifically designed to cope with Bougainville's geology, three variations on the basic geophysical technique of electrical resistivity traversing were used.

Schlumberger traversing produces a continuous graphical display of average resistivity patterns down to the depth of current penetration – water bearing strata record low resistivities, while unsaturated, or massive rock strata will record high resistivities. This technique indicates the existence of groundwater, but not depth. The second variation, double dipole traversing, does indicate quantitative depth through resistivity values, and also information on extent and relative salinity. The third variation, vertical electrical sounding, also produces data on depth of anomalous zones, and also changes in geological formations, provided they produce an electrical effect. These three variations were carried out by the Consultants using a four man geophysical team in both the Port area, around Loloho, and the Arawa townsite region. Interpretation of the data so collected, indicated the existence of shallow alluvial sand and gravel aquifers (water bearing sub-surface zones) in both areas.

These aquifers were found to contain fresh potable water very close to the surface and down to a depth of 75–100 feet. Deeper than this, saline waters were recorded which would present considerable problems of intrusion, if overpumping of the fresh water zones was permitted.

The aerial sensing survey was undertaken in conjunction with the geophysical survey to give the consultants data on groundwater outflow into the South Pacific Ocean, as well as identification of spring flow into streams and vegetation conditions. A combination of the recording of thermal infra-red radiation and reflected infrared were decided upon as most fitting the area, and the services were obtained of Qasco Air Surveys of Brisbane, and the Department of Physics at Newcastle University, headed by Professor C. Ellyet. Thermal infrared radiation (far) cannot be detected by photo-chemical means, but instead requires a detector using a liquid nitrogen cooled Cadmium-Mercury-Tellurium conductive sensor. This sensor, after filtering, records an output on magnetic tape installed in the aircraft. Ground processing converts the output to film at a later date. The purpose of the thermal imagery survey was to detect and locate thermal anomalies both on and offshore, associated with major groundwater movements – onshore would be represented as deep seated springs, and offshore, as fresh water outflow.

Reflected infrared radiation (near), due to its wave length, can be recorded by a photo-chemical process. This technique is based on the photography of reflected infrared radiation detected by a film which is sensitive to infrared radiation in the short wave length band between 750 and 950 umicron. The prime purpose of using this technique in the consultants' investigation was to provide ground control for the thermal imagery, and data on the local hydrology and geology through the surface vegetative conditions.

The two aerial techniques were flown over the coastal region from Rorovana to Kieta at differing altitudes and times of day to achieve the best possible results.

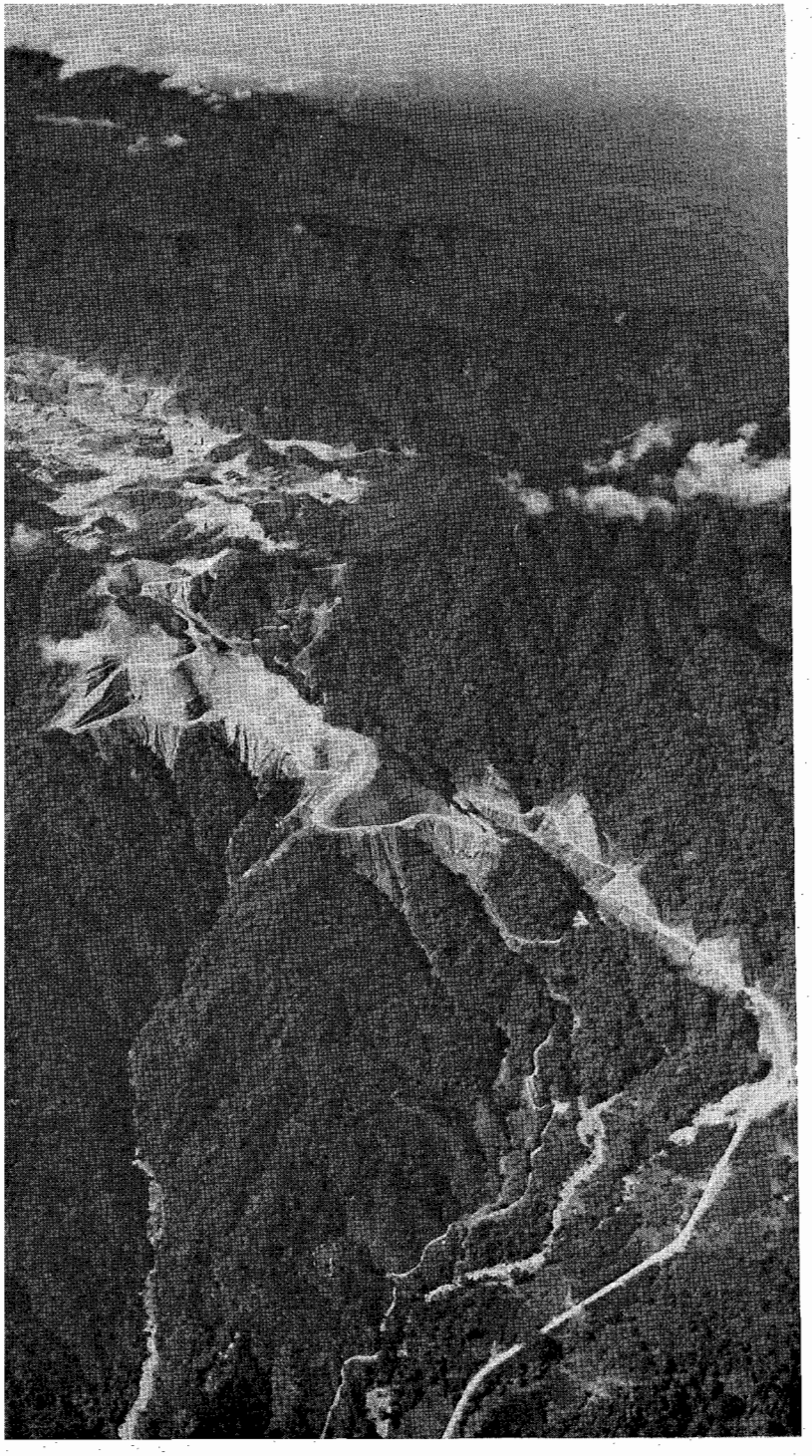
Combined interpretation of the aerial data resulted in the detection of both shallow and deep groundwater outflows.

The shallow outlfows – of common occurrence – are from the alluvial aquifer systems delineated by the geophysical investigations, and are mainly adjacent to the coastline of Arawa Bay and to a lesser extent around Rorovana Bay.

Of significant importance was the discovery of major groundwater outflows from deep volcanic aquifers by the aerial technique. These occur into Kieta Harbour, off Rorovana Bay and off Arawa Bay. The volumes of water discharging into these areas is enormous and promises a reliable, potable water supply for future requirements on the island.

It is interesting to note that this survey was the first of its type undertaken in the Southern Hemisphere. The immediate success in locating groundwater outflows gives some indication of the usefulness of this technique in island environments in years to come.

The groundwater investigations carried out by the consultants on Bougainville indicate strongly that the island possesses sufficient groundwater resources to satisfy the largest water requirements foreseeable in the future. Both geophysical and aerial sensing surveys have provided proof that further investigations, including test drilling and pumping tests (to determine aquifer potentials), are justified. It is a pity that the construction of the copper complex was so urgent that development of underground water resources was passed over. The groundwater is still there – all it needs is a requirement large enough to warrant its development and utilisation in the future.



Mountain section of the road

Opposite –

Earthworks at Pakia Gap

Port–Mine Access Road

P.R. Pettit, D.F.C., B.E., F.I.E. Aust., M.I.E. Canada,
Laurie, Montgomerie & Pettit Pty. Ltd.,
Consulting Engineers.

The development and operation of the Bougainville Copper Project required the establishment of a transportation link between the coastal area and the mine, located some 16 miles inland at an elevation of about 2500 ft. It was necessary to plan an all-weather road to provide access for heavy mine equipment (17 cu.yd. shovel and 105 ton dump trucks) and a means of transporting materials and personnel to and from the coastal area where the port, power plant, major townsite at Arawa and the town of Kieta and the air-port are located.

In 1968 Laurie & Montgomerie and Coffey & Hollingsworth were separately commissioned by Central Engineering Services (a division of Conzinc Riotinto of Australia Ltd.) to carry out pre-investment studies for order of magnitude costs and alternative routes. These consultants were subsequently commissioned and worked in close collaboration to carry out feasibility studies for final route selection, detailed investigation and design and construction monitoring for geometry, slope stability and construction materials.

The client stipulated that the road should be of sufficient standard to provide safety for personnel and equipment using the road, to incorporate the concentrate pipeline within the road bench and minimum interference to mine operations and communications between the port and mine. The road as finally designed had the following characteristics:–

Two lane (24ft.) highway from port area to copper mine.

16 miles long – 9 miles Valley and 7 miles Mountain Section.

Design Speeds. Valley – 50 mph. Mountain – 30 mph (20 mph difficult sections).

Ruling Grade – 12%. Maximum Elevation – 3300 ft.

The consultants encountered and overcame very many problems including rugged jungle covered terrain with sharp ridges and valleys and steep side slopes; complex geology with structurally disturbed volcanic rocks frequently deeply weathered and overlain by up to 30 feet of volcanic ash with thixotropic properties; stability problems with unstable natural slopes and earthquake activity; an annual rainfall of 200 inches leading to major drainage and groundwater problems; deleterious mineralisation causing low durability of rock for pavement materials.

The solution to these problems required studies for alternative locations using photogrammetry and stereoscopic examination of aerial photographs followed by ground reconnaissance; a total of 5 routes totalling 75 miles in

length were investigated; detailed engineering geology and rock mechanics studies; field examination of existing failures and the existing access track followed by stability analyses; design generally in cut material (with only fill at creek crossings) with batter slopes and benching up to 400 ft. above road level; careful attention to drainage of battered slopes and road with adequate catch drains and culverts (in certain areas horizontal drains were installed in batter slopes to relieve seepage water pressures); detailed design of subgrade and pavement; intensive exploration and testing for suitable materials for the pavement.

In the valley section approximately three miles of the road were through swamp areas with soft soil problems and water of high acidity.

Earthworks involved about 13 million cubic yards of excavation and cost was approximately $14 million.

A recent investigation has shown that the road and drainage system is generally performing well. The pavement is at present being sealed to achieve a further improvement in performance.

In order to improve the appearance of the landscape and to preserve the batter slopes, a program of seeding, planting and fertilizing has been undertaken. Trial plots have been sown to test various imported and indigenous species of grasses, legumes and creepers and planting of benches and slopes has been carried out. This program has generally met with success although it has proved difficult to establish growth in some clay benches.

Planning and Development of New Towns

I.C. Miller, B.C.E., L.S., F.I.E. Aust., M.I.S. Aust.,
Gutteridge, Haskins and Davey Pty. Ltd.,
Consulting Engineers.

Section of a paper presented in May 1971.

INTRODUCTION

About $40 million is being spent on the planning and development of two new towns, to house and provide facilities for the people who will work directly for Bougainville Copper Pty. Ltd., those in subsidiary services, the Territory Administration and other public authorities.

The towns are being built to provide accommodation and facilities for both indigenous and expatriate peoples in single quarters and various classes of houses and flats.

One town is on the east coast of the Island, named Arawa, to provide for a design population of some 10,000 persons, whilst the inland mine town, named Panguna, is presently being constructed for a planned population of some 3,000 persons.

This paper primarily considers the standards and basis of design adopted in the planning and provision of services to these new towns, with some information on the people of Bougainville and the mining operations.

Although the basic design criteria may not differ greatly from that adopted for developments on the mainland of Australia, consideration has to be given in planning for the integration of peoples of different cultural and social backgrounds; and in the design, to the technological problems associated with extreme tropical climatic conditions, steep unstable jungle lands and remoteness of the site.

TOWN PLANNING

Panguna

There was little choice available in the selection of the site for the mine town.

Practically the whole of the Panguna valley, in which is located the houses, camps and field plants for the exploratory works, is within the limits of the mine pit area. Surrounding valleys are limited in their suitability for development because of the narrowness of the floor and the steeply sloping sides.

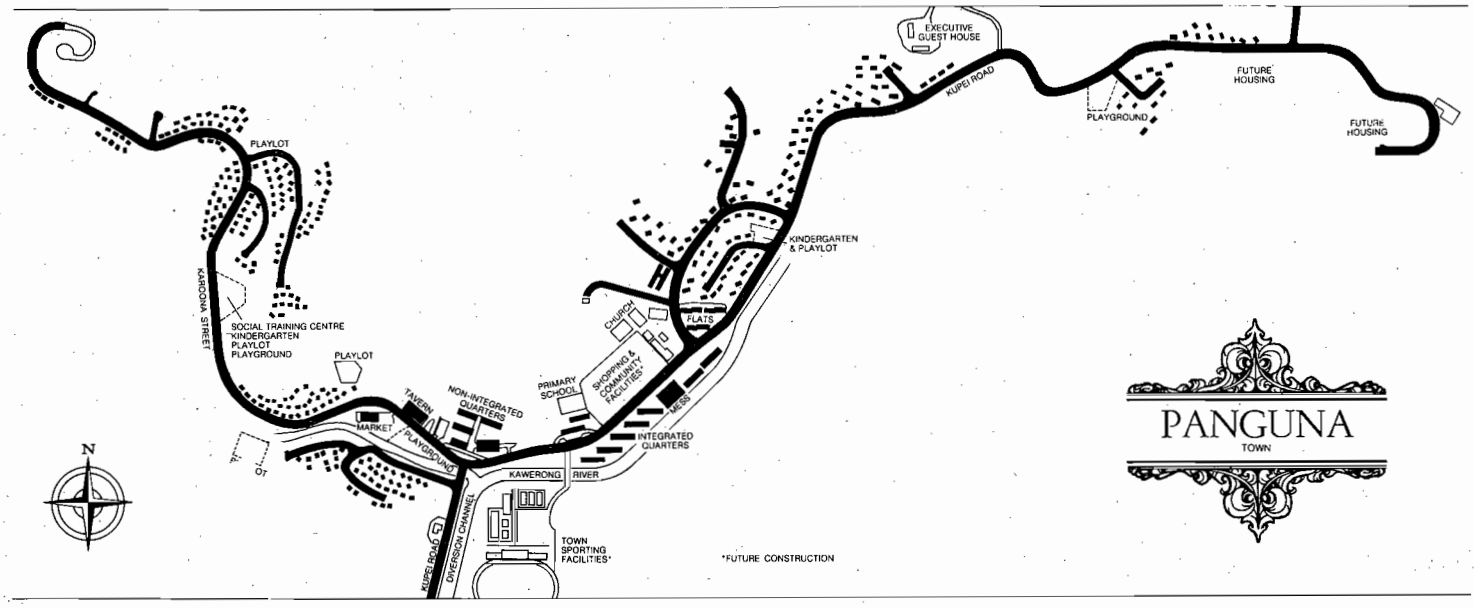
The Kawerong River valley area was selected as the site for the mine town, as it provided sufficient area to accommodate the essential personnel required at the mine site.

The town houses about 200 homes for indigenous workers, and 200 homes for expatriates, as well as single dormitory accommodation for about 800 workers.

The layout of the town is shown below, for which the design population is 3,000 persons.

The town centre comprises a shopping complex, club buildings for both expatriate and indigenous peoples, church building, school, market and recreation facilities including oval, swimming pool, tennis and squash courts.

The valley is narrow with a maximum width of about 500 feet and with steeply sloping and heavily forested sides and



has the same vegetation and soil composition as the mine area. The ash must be disposed of by dumping or spreading over the slopes and eventually being washed into the streams.

The valley sides reach slopes of 1 to 1, and a limit of development was placed on land with slopes up to 1 (vertically) to 2½ (horizontally) and the topography has led to the ribbon type development of the town.

As Panguna is a company town, it was not necessary to design the layout to a minimum allotment size. The general criteria adopted was to allow for a spacing between adjacent houses of twenty feet and front to back of at least forty feet in steep slopes and up to seventy feet in the lower slopes.

As the integrated houses had double the floor area of the indigenous houses, (12 squares to 6 squares) and are raised with a level platform underneath for carport, laundry and play area, the excavation limits determined the spacing in most cases.

The average area of each allotment is 3,000 square feet for indigene housing and 5,000 square feet for integrated housing.

Considerations taken into account when siting houses were firstly, orientation in an east-west direction to make maximum use of sunlight for drying purposes, and secondly, to face down the valley for aspect and to take advantage of the slight but welcome breeze up the valley.

The noise level at the town due to the large ore trucks and the crusher plant was calculated from theoretical considerations, and as a result it was decided that buildings such as the school or hospital would not be placed in the town below the junction of the Karoona and Kawerong Rivers.

It was estimated that a noise level of 70 db.A could be reached at the nearest buildings, which is a level experienced by some householders on major traffic roads in the inner city suburbs.

The level however can be reduced at the source by effective mufflers, barrier walls at the crusher, and protection by a green belt of trees and jungle.

ARAWA

The new coast town of Arawa has been planned to meet the requirements of the remainder of the work force of Bougainville Copper Pty. Limited, and also the supporting populations of persons providing town subsidiary services, and people from the Territory Administration and other public authorities.

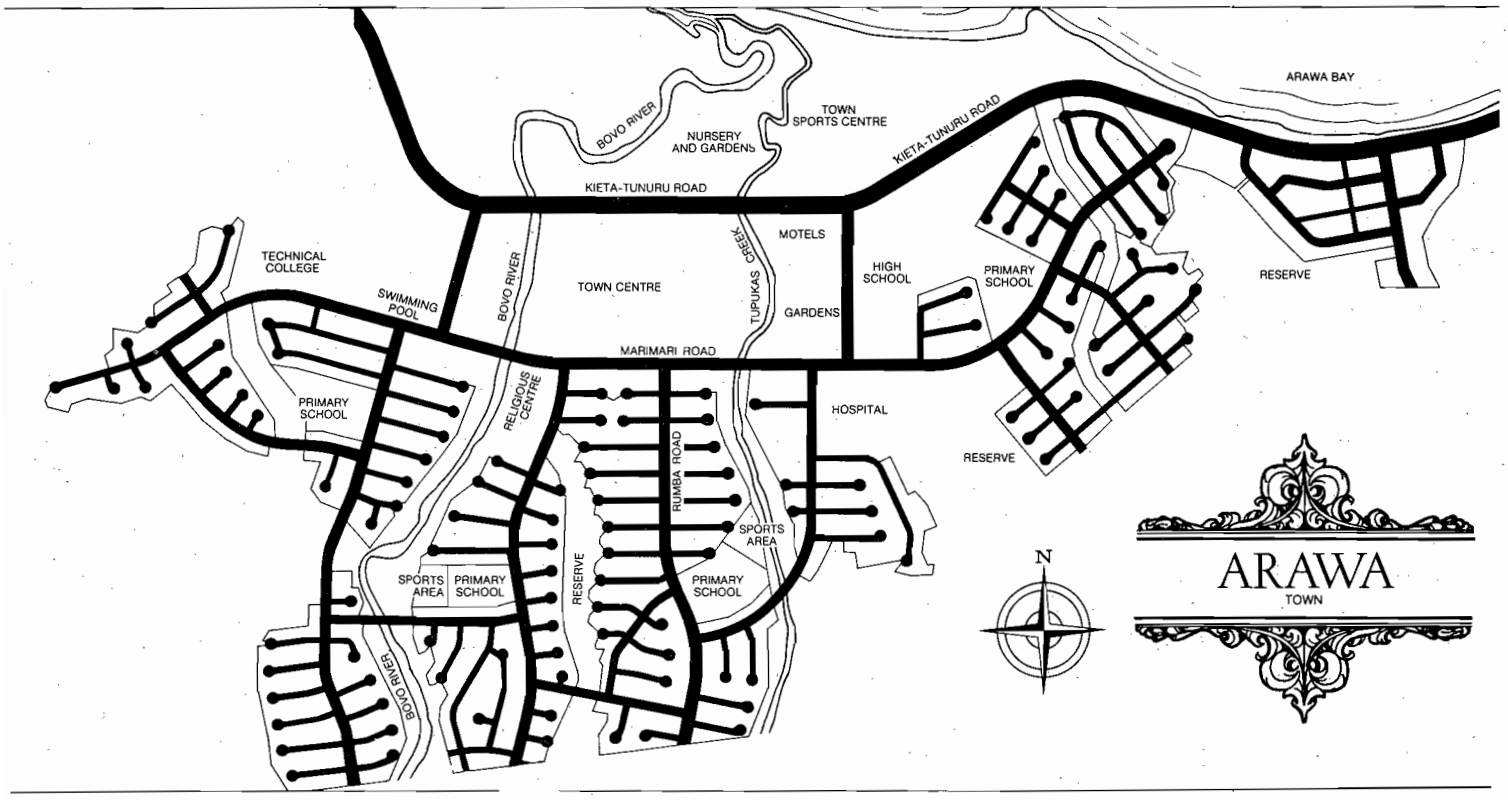
The planning target is for 2,000 houses to meet these needs, of which about forty per cent are required by the Company. The present area available at Arawa for town development is about 1,400 acres, which can provide for this requirement. For the purpose of calculating capacities of the various services to the town, a figure of four persons a house has been adopted, giving an ultimate population of 10,000 persons.

A number of different class houses will be allocated to indigenous and expatriate employees depending on the level of employment, and these will have varying allotment sizes.

It is the intention not to group houses of the one class in large separate and distinct areas, but rather to scatter each class in small groups throughout the whole town area.

A minimum allotment area of 4,000 square feet has been adopted, with larger blocks for the higher class houses.

Most of the Arawa land has been a copra and cocoa plantation, owned by an Australian, with the remaining un-



developed land owned by the Arawa tribal people.

The area has an annual rainfall of about 120 inches, and is gradually sloping from near sea level to about 100 feet higher.

The proposal plan for the town development is shown on page 53.

Basically, the plan provides for recreational areas to the north of the main road, which connects Kieta to the new port and the mine area, with the town centre, community facilities and residential development to the south of this road.

It is envisaged that most houses will be located in courts leading off collector roads. At the ends of many courts pedestrian access is provided to the river reserves or into walk-way reserve areas.

The primary schools will be located to provide accommodation of up to 700 pupils each. The grouping of the different classes of houses has been arranged so that each school will receive pupils from each class of house.

The town centre will provide all facilities such as supermarkets and department stores, banks, cinemas, medical and dental clinics. Other community facilities will include churches, motels, markets, clubs, hospital, secondary and technical schools.

Recreational facilities will include swimming pools, golf course, small boat berthing, ovals and squash, basketball and tennis courts.

It is envisaged that the area will be cleared of most trees and vegetation and sections will be regraded to improve the topography and drainage pattern. The banks of the rivers will be cleared, graded and landscaped as development proceeds and some river improvement works will be carried out to assist in the dissipation of flood waters.

TOWN SERVICES:

WATER SUPPLY

Sources – The source of supply for Arawa is the Bovo River, and for Panguna, the Kawerong River.

The minimum flows recorded at gauging stations in both rivers exceed the maximum demand, so that no water storage will be provided.

The water is usually clear and odourless, but heavy rains increase turbidity and bacterial pollution can be expected as the catchment areas include some native villages.

Treatment Works – The purification plants will comprise coagulation and sedimentation, filtration, chlorination, fluoridation and clear water storage for plant operation.

In Arawa, the plant has been designed for 75,000 gallons per hour, and at Panguna, for 30,000 gallons per hour.

Schemes – A gravity system could be implemented at Arawa provided that it is possible to utilise a suitable site for off-take and treatment works upstream and outside of the town boundary, otherwise it will be necessary to pump from the Bovo River

In Panguna, a gravity scheme has been provided for most of the town, with pumping to small areas unable to be served by gravity.

Reticulation – In general, asbestos cement pipes have been used for reticulation mains.

The requirements per capita adopted were

Average Daily Demands – 100 galls/cap/day
Maximum Daily Demands – 150 galls/cap/day

Rainfall is fairly constant throughout the year, so that garden watering is not a heavy user as is the case in areas of Australia where the maximum demand can be many times the average demand.

It is considered that the consumption figures for the indigenous population should be the same as for expatriates, as their houses will have similar facilities for the use of water, and are being integrated into a new and high standard development.

The minimum pressures in mains will be 60 feet in residential areas and 100 feet in commercial areas. The mains will be checked to provide a minimum fire flow at these heads of 200 gallons per minute in residential areas and 400 gallons per minute in commercial areas.

The maximum pressures in the mains will be limited to 300 feet to allow use of normal household fittings.

SEWERAGE

Flows – The sewers have been designed to carry peak wet weather flows without surcharges, and to produce self-cleansing velocities at peak dry weather flows.

The peak wet weather flows will include an allowance for infiltration and could approximate to four times the average dry weather flows, which have been taken as 50 galls/cap/day.

Minimum grade of sewers will be such as to obtain a cleansing velocity of 2 ft/sec with the pipe flowing full and will be

6" diameter	1 in 150
9"	300
12"	500
15"	700
18"	800
21	1000

The generally adopted maximum number of tenements connected to sewers at minimum grades will be

6" diameter	130
9"	550
12"	900

Reticulation – In general, asbestos cement pipes have been used for both sewers and rising mains.

At Arawa sewers are located in road reserves and generally at the back of lots where it is more economical to provide one reticulation sewer to connect houses on either side of the rear boundary.

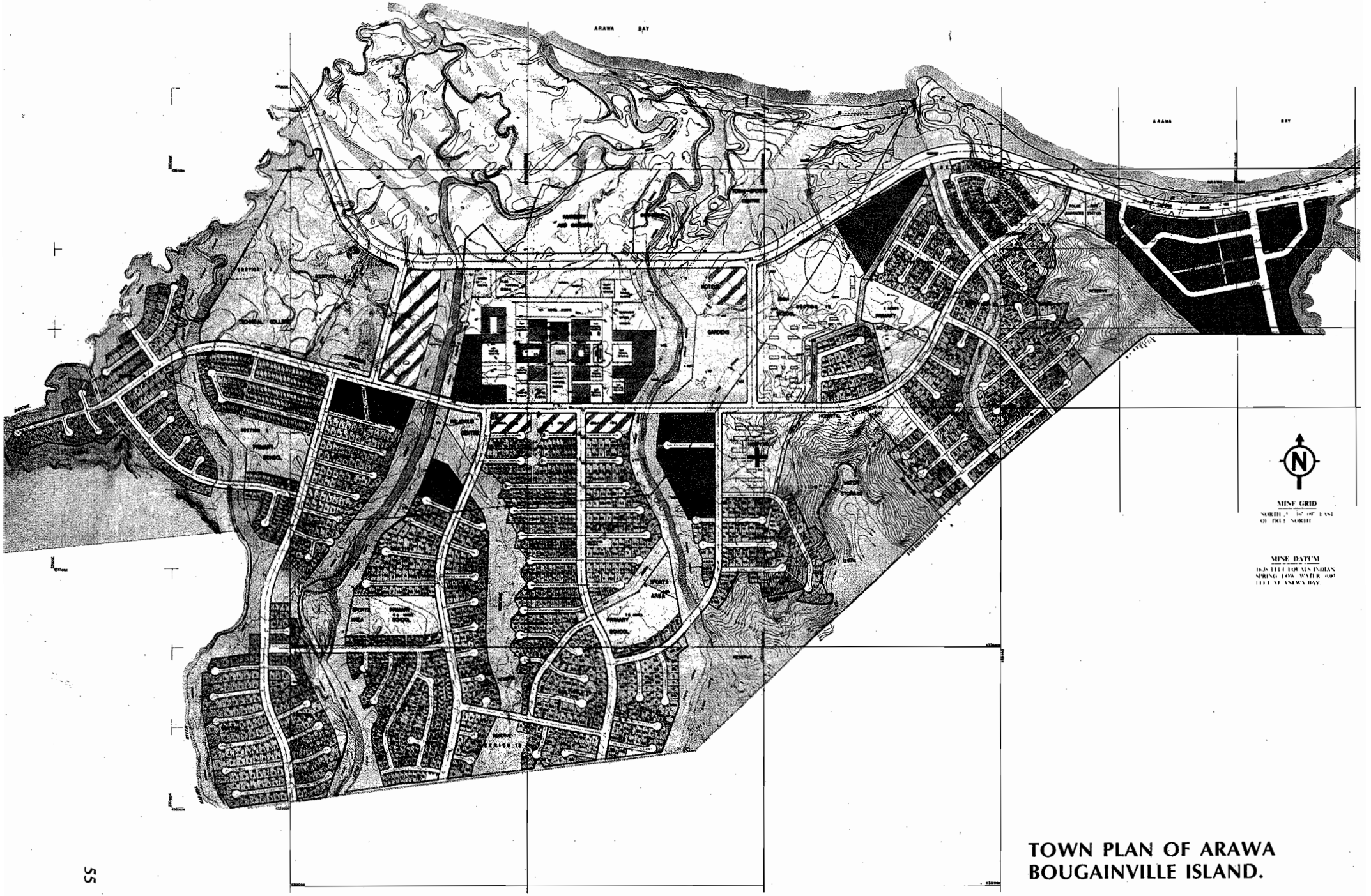
At Panguna, sewers are in road reserves and as close as possible to the houses.

House connections are 4 inch diameter asbestos cement pipes from the junction with the main.

Minimum cover over pipes is –

House connections	1'6"
Sewers in properties	2'6"
Sewers under roads	3'6"

The maximum spacing of manholes is 400 feet, and if appreciable savings can be achieved, sewers are designed



TOWN PLAN OF ARAWA BOUGAINVILLE ISLAND.

↑ Panguna Town showing the rugged terrain and the "ribbon" type development caused by the scarcity of flat ground. This photograph was taken as construction was nearing completion.

↓ Portion of Arawa Town on Bougainville's East Coast. It was built on the site of a former expatriate plantation and is headquarters for Bougainville District. This photograph was taken in May 1971.

with horizontal curves. This has applied frequently in Panguna where lines are irregular in location and steeply graded.

Disposal – At Panguna, a prefabricated type of treatment plant will be installed. The plant is to be a contact stabilisiation type with separate aeration and clarification. Effluent from the clarifier will be discharged to the stream downstream of the town.

At Arawa, disposal will be by an ocean outfall after comminution of gross solids and passing the flow through a scum tank. Provision will be included in the design so that treatment could be provided if this proved necessary.

ROADS

Cross Sections – Typical road sections adopted are as follows –

Location	Reserve Width	Pavement Width
Residential Streets	50 feet	18 feet
Collector Streets	75 feet	24 feet
Through Collector Streets	100 feet	36 feet

In order to fully utilise these minimum width pavements, fully mountable concrete kerbing will be used where needed to permit parking off the pavements, also bus bays will be provided on bus routes.

Road sections and parking areas in the town centre will incorporate non-mountable kerb and channelling with fully paved footways.

Gradients – Maximum grades for roads is 20 per cent and the minimum grades 0.5 per cent.

Pavement – At Panguna, the subgrade has in most cases a high content of volcanic ash, which, combined with the high rainfalls and steep grades, makes construction difficult.

As soon as cutting of a road section is completed, a sub-base of coarse rock material, generally andesite which is obtainable close to the town site, of 18 inch thickness is placed. This sub-base course is then used as a construction platform for further works, and extends over the full formation width. After trafficking, the material firms up and a top course pavement of crushed rock of 6 inch to 8 inch thickness can be placed.

Some areas of Arawa require the same treatment but where the natural material is better a pavement thickness of 9 inches to 13 inches of crushed rock is used.

The top 4 inches of the pavement will consist of fine crushed rock or gravel suitable for sealing.

The final pavement sealing will be determined only after field tests on actual materials used, but it is expected that an initial primer seal followed by a two coat hot bituminous seal will produce the most satisfactory results.

DRAINAGE

Scheme – At Panguna, due to the poor soil conditions and risk of scouring by high flows and velocities, a piped underground drainage system has been designed to take maximum flows.

At Arawa, minimal underground drainage will be provided in the residential areas. In the residential courts, the drainage flows will be contained within the road pavement and channels. Piped drainage of up to 30" diameter will be provided in the collector roads to take the low flows, with the roadways being depressed in relation to the residential land so as to act as floodways to contain the major flows which are discharged to the rivers by grassed floodways.

Within the commercial areas full capacity underground drainage will be provided in the immediate vicinity of buildings.

Design – There are little meteorological records available in the area to develop reliable rainfall intensity – duration frequency curves.

The design adoptions were made after consideration of the information contained in various hydrology reports of the mine area, and consideration of factors determined by the Commonwealth Bureau of Meteorology.

The curves were compared with the limited records available on the island, and also with area of similar climate in North Queensland and the north-eastern coast of New Guinea, where more extensive records are available.

Design recurrence intervals vary extremely from 20 years for commercial areas to about 1 year for non critical areas. Run-off coefficients used are

1.00 for paved and roofed areas and
0.60 for residential areas and catchment areas.

Corrugated metal pipes are used for all drains.

ELECTRICITY

Source – the main generating station is located at the new port site. It is an oil fired steam station, with 3 x 45 Megawatt output.

The high tension line to the mine is 132 KV and 22 KV. to Arawa.

Reticulation – High voltage electricity at 22 KV. is reticulated through Arawa with 415/240 volt low voltage distribution. For Panguna 6.6 KV. was chosen for the high voltage reticulation again with 415/240 volt distribution.

Design – Reticulation of both high and low voltage is primarily overhead except for Arawa town centre and some service connections at Panguna.

System design has been based on the standards of Papua and New Guinea Electricity Commission with 8" x 8" x 30 lbs/ft universal beams hot dip galvanised selected for all poles and 61/1878 steel cored aluminium conductor used for both high and low voltage distribution.

Distribution design for Arawa presented no difficulties and involved standard procedures normally encountered in urban and suburban systems. The topography of Panguna introduced a number of design difficulties many of which could only be solved on site during construction. The steep slopes and winding roads dictated an aerial distribution system of closely spaced poles and slack stringing to avoid excessive use of anchor guys. Kiosk type substations of either 150 K.V.A. or 300 K.V.A. have been used as standard at Panguna and generally 200 K.V.A. pole type substations at Arawa. Some larger substations were necessary at main load centres.

Aerial house services have been used generally although underground services were found necessary in certain areas. For low voltage services P.V.C. two or four core insulated and sheathed cable is run in galvanised water pipe.

Street lighting is by fluorescent mercury vapour type lamps for main road and 2 x 20 watt fluorescent for minor roads.

Planning and Building in Bougainville

D.V. Dunn, F.R.I.B.A., F.R.A.I.A., F.A.I.M.,
Stephenson & Turner, Architects.

PLANNING AND BUILDING IN BOUGAINVILLE

To support ore mining operations of Bougainville Copper Pty. Ltd., it has been necessary to plan and construct two separate townships.

Panguna is located about 2,500 feet above sea level in mountainous country on the mine site.

Arawa, which is designed to accommodate the bulk of the commercial and residential activities for the operation, is located at sea level where a population of 10,000 or so will live.

In designing buildings for Bougainville, there are many of the problems associated with tropical conditions such as high humidity, excessive rainfall, occasional cyclonic donditions, all of which have an affect on the choice of building materials and systems. Seismic design rules apply to structures and availability of materials is governed by limited local manufacturing facilities and the normal restrictions of imports.

In Panguna almost every building site had to be carved from the side of a mountain or created by filling. Arawa on the other hand, is low lying, swampy ground with all the problems associated with foundations, drainage, flood water clearance and so on.

In this article, four buildings are illustrated typical of the diverse types included in both developments. In addition, there are, of course, groups of houses designed for residents at all levels and in all occupations, there are department stores, utility buildings, recreation areas and all the roads and services associated with such developments.

ADMINISTRATIVE

One of the main difficulties encountered at Panguna was the shortage of reasonably level sites for building.

Every building or group of buildings required some site work in levelling and grading.

Panguna fans out from an administrative centre along two very narrow valleys forming watersheds for two creeks which almost fill the narrow floor of each valley. In the wet season these creeks can become raging torrents.

The sides of each valley quickly become precipitous, so that the higher the building, the more difficult the excavation.

The soil is comparatively loose after the removal of the jungle cover and it is not unusual to step back for several hundred feet up the mountain face after excavating a building shelf.

It is in one of these locations that Stephenson & Turner have located the guest flats and Mine Manager's house, with a magnificent view down the valley to the mine site.

The guest flats are to accommodate visitors to the mine site and comprise self-contained bedroom units with a central guest lounge, dining room and kitchen.

They are constructed in concrete block and, because of the site, the floors are in timber well clear of the ground. The roof is steel tray decking.

The whole complex is air-conditioned.

CHURCH

The non-denominational church building at Panguna reflects Stephenson & Turner's basic philosophy in building for the tropics.

There are open sides to take advantage of any air movement, with open louvres screening any areas where privacy is required.

Wide roof overhangs without gutters protect these open sides. Wide concrete drains at ground level receive stormwater from the roof and carry it away.

The floor is monolithic concrete on fill for cleanliness and coolness.

The roof in colorbond trimdeck is opened at the apex with louvres to induce air movement through the building.

The roof is framed in timber trusses of special design which are left exposed. All roof loads are transmitted to the foundations through four cruciform reinforced concrete columns.

THE ARAWA TOWN CENTRE

The Centre

Arawa is a new town developed on a site of approximately 60 acres, five miles west of the Port of Kieta. The eventual population is estimated to be 10,000, but the town will provide regional facilities for a total population of the order of 50,000.

The Town Centre serves four neighbourhood units each accommodating up to about 2,500 people, these being grouped around the south and east sides of the Town Centre. Each neighbourhood unit has its own primary school and local minor shopping facilities.

The Town Centre has its focal point in the garden plaza located in the main shopping area which contains four department store/supermarkets, each located on a corner, and these are flanked by blocks of lock-up shops on the east and west and by shops, offices and professional rooms on the north side. The Community Centre, Library and Creche complete the enclosure on the south side. Verandas and covered pedestrian ways, which will conform to broad design standards and uniform heights, and appearance, link the building masses and provide uninterrupted

shelter for shoppers.

The western end of the retail area is occupied by a group of trade stores each of which contains residential accommodation on the first floor level; adjacent to these are a tavern and cinema.

A site has been provided for a residential hotel on the eastern side of the Centre. There are also sites for private commercial offices, a community centre and service station and an air conditioned cinema. The TPNG administration offices, post office, library, police station, court house and town council facilities are all located around the Centre.

The traditional market, the principal outlet for local produce, will be located on the east boundary where it will serve as a social meeting place for the indigenes and will probably become quite a tourist attraction, as in other places.

The proposals for staging the various building priorities are based on three controlling factors:

a. Adequate provision of facilities for the growing population.

b. Development of facilities in a rational and visually acceptable manner by establishing a central area to give identification to the Town Centre.

c. Prevention of spasmodic or irregular development of commercial areas.

Initially, site works and services work will be carried out followed by the first stage which will include basic facilities such as the post office and telephone exchange, the first of the department stores, some of the public and community buildings and the first stage of the shops. The market, court house, administration offices and other utility requirements will also be provided.

Progressively, the various department stores, lock-up shops and other accommodation will be developed as the population expands.

Flood Control

Arawa is in the centre of heavy rainfall area and flood control has been a primary consideration in planning the Town Centre. It will be protected from river flooding by the construction of levees adjacent to the Bovo River and Tupukas Creek and by Main Road No. 1. The internal underground branch system will accommodate flows having a return frequency of once in five years, but larger flows will be accommodated by utilizing the internal north to south road ways, parking areas, etc., as flood ways. The buildings will be constructed on raised platforms to obviate internal flooding.

Utilities

The Town Centre plans make full provision for water supply and fire services, drainage and sewerage and for electric supply and reticulation. Oil is the fuel for power generation. All cables will be run underground as will the telephone distribution system.

Design Standards

The report makes provision for certain mandatory requirements to apply to all leases for individual sites and some of the principles involved include the establishment of "envelopes" for buildings in the Town Centre, discussion with the planning consultant prior to the preparation of preliminary designs, approval of sketch plans by the Building Board within the limits of the prescribed "envelope". Controls over points of access, materials, lighting, street furniture and fixed signs are recommended to be established.

Car Parking

The principle of segregation of pedestrians and vehicular traffic within the Centre has been adopted, but on the principle that integrated car parking space is desirable.

MESS

Among the various amenity buildings designed by Stephenson and Turner for the Bougainville Copper Project is the Integrated Bachelor Quarters Mess at the new coastal town of Arawa.

This building is part of a larger complex, housing the various integrated bachelor quarters.

The floor is ceramic tile on concrete above fill for easy vermin free maintenance. It is raised above the surrounding ground level to overcome the danger of flash flooding in this area, which is at the confluence of two rivers.

To give some relief from the high humidity in this coastal region the walls are no more than flyscreens supported by an aluminium framework between concrete block columns with poured concrete cores.

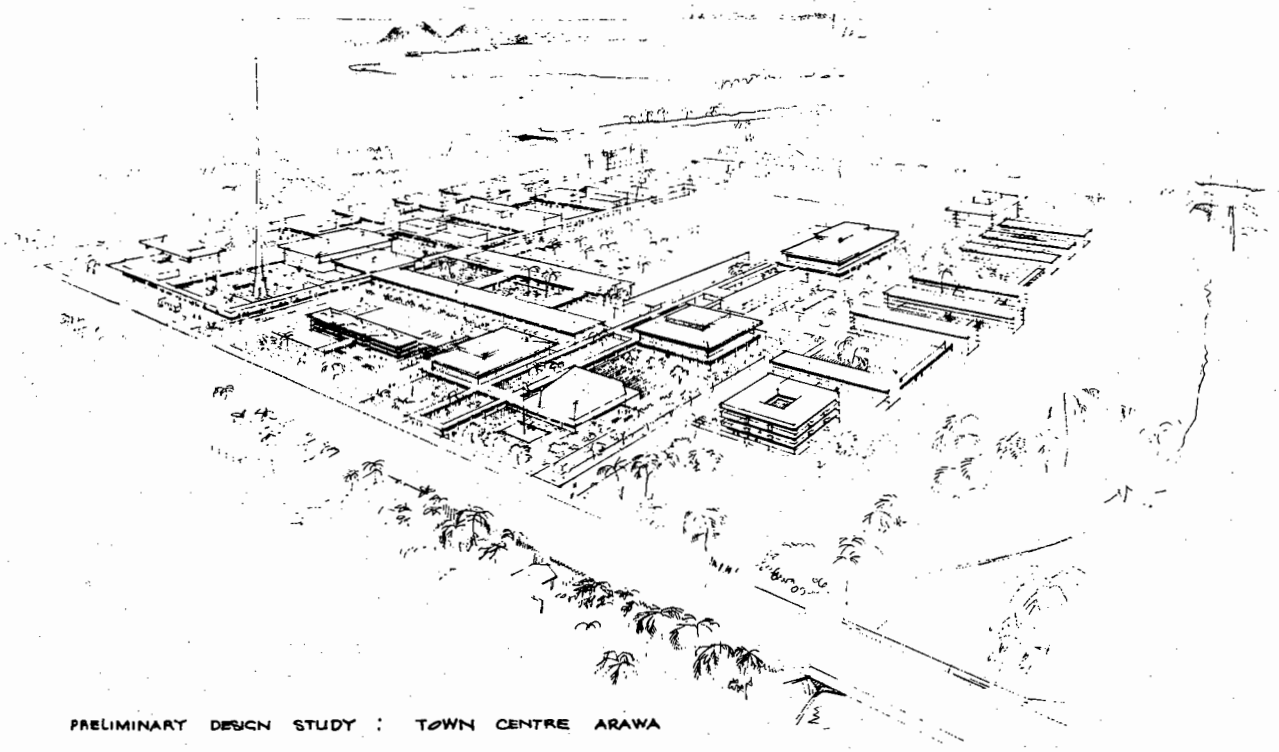
This allows the natural movement of air essential for comfort in tropical conditions. This movement is further assisted by fans and the exhaust of a central plant room which rises to open louvres above the apex of the steel truss, "Decramastic" metal tiled roof.

The walls are set well back under this roof providing a continuous verandah overhang for protection against the heavy tropical downpours.

The eaves overhang and the ceilings are timber lined.

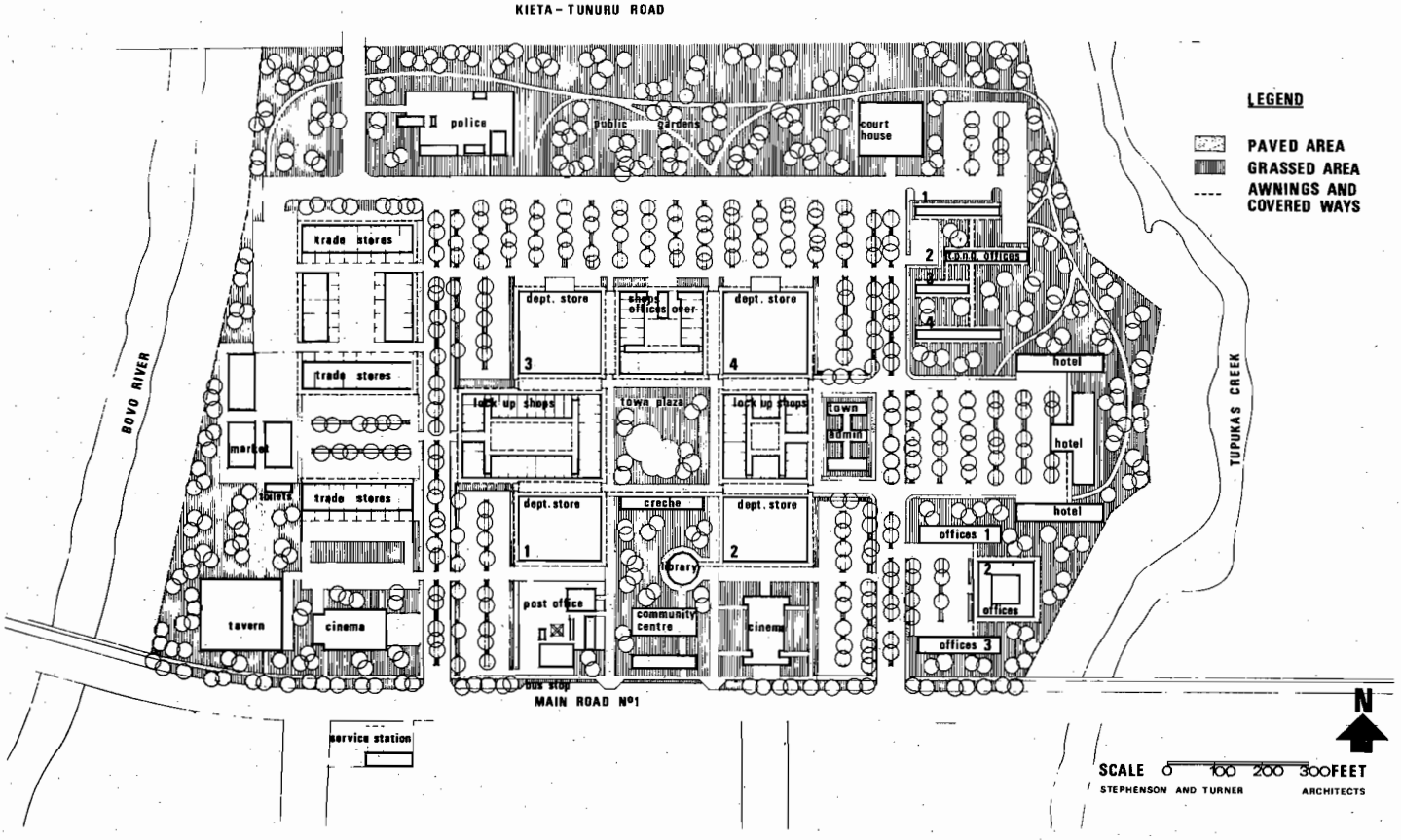
In addition to a fully equipped and thoroughly engineered kitchen catering normally for some 240 diners, a games room, a reading room and a general lounge are provided for the integrated personnel.

ARAWA TOWN CENTRE

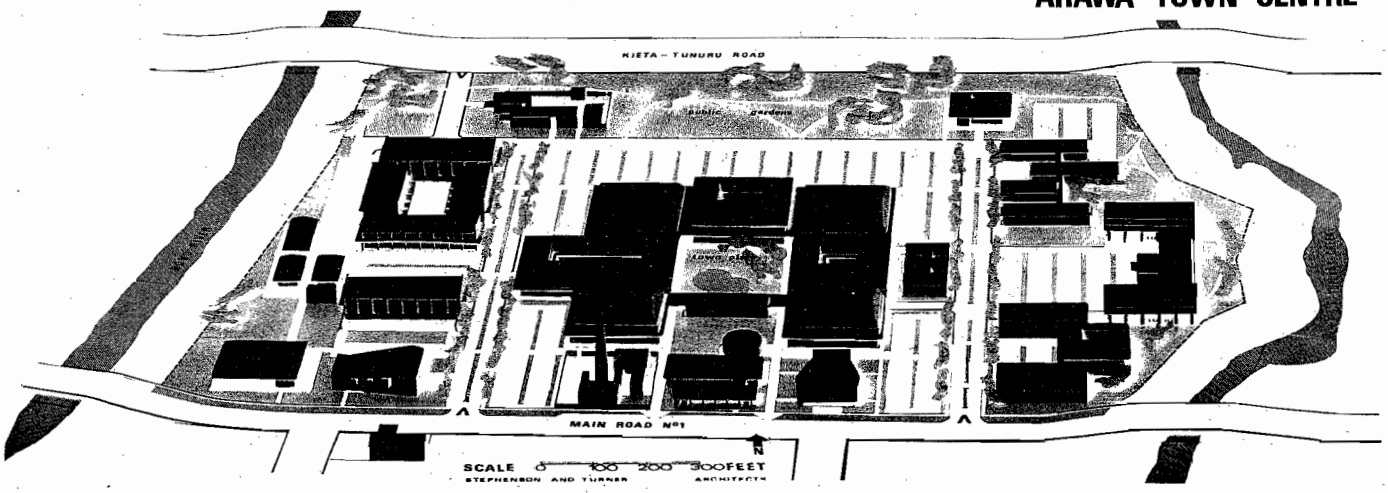


PRELIMINARY DESIGN STUDY : TOWN CENTRE ARAWA

MAIN ELEMENTS

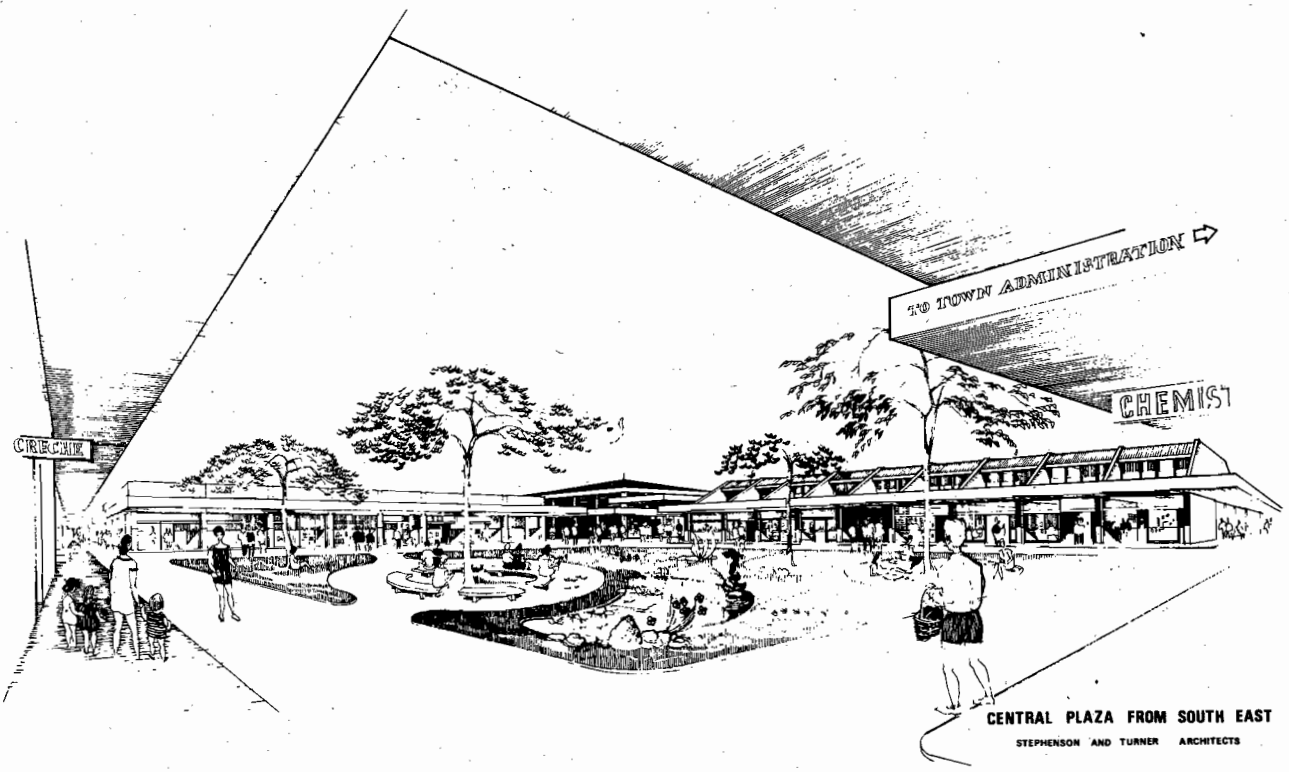


ARAWA TOWN CENTRE



VIEW FROM MAIN ROAD 1.

STEPHENSON AND TURNER ARCHITECTS



CENTRAL PLAZA FROM SOUTH EAST

STEPHENSON AND TURNER ARCHITECTS

Financing the Project

C.R. Wilshire, A.A.S.A., A.C.I.S., A.B.I.A., F.C.I.V.,
Assistant General Manager,
Commonwealth Trading Bank of Australia.

In January, 1969, Lou Mulkern, senior vice-president of the Bank of America, walked into Fred Butcher's office at the Commonwealth Bank in Sydney and said, "We want to put a deal together and we want Australian banks to be part of it."

Only six months later, on July 28, Mr. Butcher, the general manager of the Commonwealth Trading Bank, flew to San Francisco to sign the Bougainville Copper credit agreement which began what was then the largest single international financial and mining operation ever attempted.

"Two centuries ago," he told that meeting of international bankers, "Louis Antoine de Bougainville, the French lawyer, soldier and sailor, circumnavigated the world. Although he has long been forgotten except by historians, his distinguished name lives again today in another international venture – Bougainville Copper. This is a new star in the Pacific, a revolutionary development that will drastically change the history, economy and life of an island, a region and a territory."

And how right he was. In money alone, apart from planning, management and sweat, it cost $400 million to get this undertaking, in a remote mountain valley on Bougainville Island in the Solomons, into operation.

The financing of this great mine, with its 900 million ton ore deposit, was an immense and complicated financial job.

Bougainville Copper Pty. Ltd., which is owned 80 per cent by Bougainville Mining Ltd. and 20 per cent by the Papua New Guinea Administration and the PNG Investment Corporation Ltd., was formed by Conzinc Riotinto of Australia Ltd. and New Broken Hill Consolidated Ltd. (now NBHC Holdings Ltd.).

Financing really began with a meeting between Mr. L. J. Mulkern and Sir Mark Turner, vice-chairman of RTZ London, and the Reserve Bank of Australia in Sydney when the need for a strong Australian role in the undertaking was emphasised.

The Bank of America was appointed financial manager and asked to arrange international finance which at that stage was estimated at $A300 million, divided into shares of $A100 million and loans of $A200 million.

Heading a consortia of 27 American, British, Canadian, French, Dutch, Italian, Japanese and Bahaman banks and institutions, the Bank of America raised $A125 million and also another $A75 million on Euro-dollar money markets in Europe. It then lent this $A75 million ($US92.4 million) to the Commonwealth Trading Bank which in turn lent it to Bougainville Copper.

Although the Commonwealth Trading Bank did not have to find the funds, it was responsible for final repayment to the Euro-dollar lenders.

The borrowing arranged by the Bank of America and the Commonwealth Trading Bank was supported by a Credit Agreement which pledged all shares in Bougainville Copper to the major lenders. This gave the lenders overall control of the operation and it was this agreement that was signed in San Francisco.

Although the Commonwealth Trading Bank, to spread its risk, formed a consortium of Australian trading banks and the Australian Resources Development Bank, it still took 40 per cent of the primary risk and also provided a bridging loan of $A25 million and much working capital.

The Commonwealth Savings Bank also lent $A12.5 million to help build the new town at Arawa on Bougainville Island and for housing at the mine site at Panguna.

Final loans to Bougainville Copper, after the original estimated cost of development was increased to $A400 million, were: Bank of America syndicate, $US110 million; Commonwealth Trading Bank syndicate, $US67.4 million; Japanese cash and equipment loans, $US60 million; U.S. Export-Import Bank equipment loan, $US56.8 million; Equipment loans from Australian suppliers, $A25 million; Commonwealth Savings Bank housing loan, $A12.5 million. And capital subscribed by shareholders was increased to $A130 million.

As Fred Butcher added, that day in San Francisco: "Speaking for all the trading banks in this Australian bank consortium ..... and speaking as an Australian deeply concerned for the future of my own area of the Pacific and its peaceful development, may I say ..... this is an exciting day."

History has proved the accuracy of that statement. Bougainville Copper began commercial operation in April, 1972, and in its first year to December 31, 1972, its net profit was $A27.7 million.

Bank Establishment

by
F.E.J. Butcher, A.A.S.A., F.A.I.M.,
General Manager,
Commonwealth Trading Bank of Australia.

Commonwealth Trading Bank at Panguna.

From the air Bougainville in the northern Solomons is a romatic island. Lush and rugged, surrounded by reefs and an emerald sea. Cloud sits on the rain forest that mats the mountains. The tall volcanic cones of Bagana and Balbi smoke sullenly and glow at night.

But along the Crown Prince Range and down on the flat country, life has not always been as romantic as it seems from a passenger's window.

Rain, mud, dust, heat, boredom. These are deep in the memories of the men who established the Commonwealth, the first Bank in Bougainville, only a few years ago. But deeper in their consciousness is another feeling, almost of pride, that they were part of a tremendous and exciting adventure. That they were pioneers.

The Commonwealth Bank has a long link with Bougainville, the island that carries a distinguished French navigator's name. Almost back to the time when Bougainville was part of German New Guinea. The Commonwealth Savings Bank established an agency at the little port of Kieta in 1916 and continued this for the next half century.

Then change came like a cyclone to this remote island where nothing will ever be the same again.

In the mid-1960's, Bougainville Copper's 900 million ton ore deposit was proved at Panguna, in a 2000 feet high valley on the western side of the range, and in June, 1967, the company was incorporated in the Territory of Papua New Guinea and an agreement made with the Administration to mine the ore.

The Commonwealth Banking Corporation had already decided to move in and to become part of the evolution of this tropical mine that is one of the largest in the world.

But a Bank does not move in. People move in. So how the Commonwealth Bank was established in Bougainville is largely the story of the men, most of them young, who sweated on the spot.

Mark Roden served with the Commonwealth Bank at Rabaul from 1965 to 1967. In January, 1967, there were problems with the old agency on Bougainville and he flew the 275 miles to Kieta to iron them out and to study how a sub-branch could be established.

The original plan was to replace the agency – in a small waiting room at the Kieta Hotel – with a sub-branch housed in a fibro shed on the beach, but the shed was so small and light that it was a open invitation to Bougainville Copper's hard-drinking workforce to carry the bank away after a spree. Another office had to be found.

The sub-branch was opened at the Hotel on July 27, 1967, in a partitioned storeroom at one end of the Boi Bar. It had a door to the street, a door into the native bar and a door into the European Bar. The small population of Kieta agreed that it was the most convenient bank they had ever seen.

Dick Watkins was the first officer-in-charge – on his own, of course – but he resigned after a few months and was succeeded briefly by Tony Evans and then, in February, 1968, by Trevor McDonald who was there for the rest of the year.

The sub-branch had moved, in December, 1967, to a small room at the Local Government Council building where a rough counter was built by two freelance carpenters, "Blue", an Australian, and "Double Whisky", an eastern European. Nobody in Bougainville could ever pronounce his name. The room was so small and windowless that in the afternoon if it rained, and it generally did, it was so dark after 2 p.m. that McDonald had to requisition for a kerosene lantern. Electric power at Kieta came on only at meal times and never after 11 p.m. There was also no water supply, except from tanks.

Trevor McDonald has vivid memories of his time at Kieta. He lived first at the Hotel and then in the back of a warehouse. There were about 90 Europeans in the town, including two single girls. It rained every day. The mud stained everything. At the pictures there was a ten minute interval every time a reel was changed, so few of the audience ever saw the end of a film.

But what he remembers most were his flights to Panguna or Barapinang, pronounced "Barrapeena", as the area was originally called.

Two days every week he closed the Bank at Kieta and went by helicopter to the present mine site, a flight over the Crown Prince Range that took only 12 minutes. The mountain valley where the mine was established was still jungle. A few native-type huts in a clearing, a prefabricated building or two and that was about all in 1968. And when it rained, at an average of one inch a day through the year, Panguna was a foot of grey-brown mud.

His bank was a native hut in the morning and the construction canteen in the afternoon. But because of cloud cover, he had to get out as early as possible after lunch or the chopper could not fly and he could not return to Kieta and his bank until next day.

Some of the early chopper pilots were erratic fellows. One, an American, packed a gun in a hip holster and told his passengers, "Touch the joystick and I'll shoot you." Another, determined to park his chopper in a hanger at the strip at Kieta, reversed in, but his machine was caught in its own down-thrust. It lifted suddenly and took the roof off. A total loss.

All the early Bank men on Bougainville remember the chopper flights and the 16 miles of mountain road built between August, 1969, and December, 1970.

Once, when his chopper was grounded by weather, Trevor McDonald came down the mountain in a jeep. The hillsides were slipping. There were wash-aways. The mud was like glass. The 12-minute chopper flight became a terrifying land journey that took four hours – and he never once let go the tin box holding the cash from Panguna. But the record down trip was seven hours – to cover 16 miles.

When Kieta became a full branch on July 1, 1969, (under Keith Weissel) and Jack Small, chief manager for the Territory, flew in for the opening celebration from Port Moresby with Bruce Dixon, manager at Rabaul, the Bank's office had moved to the front of a warehouse occupied by Breckwoldt and Company and the South Pacific Brewery.

Stuart Grieve, who was there for three months to July, 1969, remembers how in heavy rain water and silt sometimes covered the floor of the Bank and how a new safe sent from Port Moresby sat for a month on a copra trolley in the street outside waiting for a locksmith to open it. The safe had been shipped door upwards as deck cargo on an island trader and had filled with salt water during the voyage.

Grieve lived in a Bank-rented house – with permanent duckboards to negotiate the garden after rain – and ate at the Kieta Hotel. A diet mostly of meat and boiled vegetables, since practically everything fresh had to be flown from Rabaul and didn't last long.

There was little to do. The pub was the main gathering place. The sports club – with practically no sporting activities on the island – had one billiard table. The Bank's only transport, one motor cycle, was used at weekends to explore bush tracks around Kieta. And once he and several others nearly lost their lives when, at sea in a dinghy on a

fishing expedition, they were hit by a violent storm and bailed all the way back to Bougainville and safety.

Jim Goodwin, who became manager in August, 1969, recalls how chaotic communications were from Kieta. It took two days to get a phone call to Rabaul or Port Moresby or Sydney and it was often quicker to drive to Panguna than to try to phone or relay a message. Reception was generally poor and if it improved a bulldozer driver would almost certainly cut the main cables.

But communications did not only mean the telephone. Goodwin was at Aropa, the Kieta grass strip 13 miles from town, after heavy rain, when a Trans Australia Airlines pilot commandeered a kombi van and raced up and down the strip putting the vehicle into violent skids. Goodwin thought the pilot had gone troppo until he returned, called his passengers together and said, "She's still a bit slippery but we'll get off."

A real problem for all staff in those days was the total lack of any organised sport. The closest golf course was on Buka Island, an hour by light plane to the north, but at twenty dollars return Jim Goodwin found it expensive golf, even for a long weekend.

But tremendous changes were on the way and life in Bougainville was altering drastically as Bougainville Copper's workforce, which came from all over the Territory and islands and from Australia and New Zealand, was rising to its 10,000 peak, and as the mine was developing and on the coast the new town of Arawa, six miles from Kieta, and the mine port at Anewa Bay, were building. Anewa was originally called Loloho which was popularly known as "Lollypop".

A new prefabricated-in-Brisbane Bank building and seven bedroom staff quarters was completed at Kieta in July, 1970, but when Bill Salthouse established a new branch among the mud and dust of rising Arawa, once a beautiful copra plantation, in May, 1971, life was still primitive.

When he opened the branch in a small separate building, near the post office and a supermarket, the ledger desk was five packing cases, stores were in boxes, he didn't have a chair for a fortnight, the interior was being painted and he had to live with his assistant and the Kieta manager in a one room flat at Kieta for the next two and a half months before moving into metal huts at a construction camp for another four. Then he went suddenly deaf with a local infection and because there was no pharmacy on Bougainville, ear drops had to be flown from Rabaul. When he left Arawa in June, 1972, it was a fully serviced functioning town and the administrative centre for Bougainville. But he had plenty of troubles between arrival and departure.

A water truck backed into his Bank one Saturday night and took away a corner. A three and a half ton safe would not go into the Bank and had to be lifted by crane and lowered into the building through a hole made in the roof. Then the Bank, which had two smaller safes began to sink in the mud and had to be jacked up.

He also had problems with strikes. The big workforce struck because someone started a silly rumour that the Bank planned to close its agency at Loloho. The men were out for two days before a shop steward took the trouble to ask Salthouse if the rumour was true. But the strike that made all Bougainville laugh was when a ship was delayed and there was no Victorian Bitter beer. Plenty of other brands, but no V.B.

The servicing of the Panguna agency by helicopter and then road ended on January 8, 1970, when a full branch was established under J. W. Stephenson, but the man who holds the record as manager, from November 9, 1970, to September 16, 1972, was Peter Doolan who saw the great mine develop from its early construction stage to production, first shipment of copper concentrate and beyond.

His branch was in the lowest part of the 2,000 feet high Panguna valley, below what was known as the "Pink Palace", the mine company's main office. The branch was either surrounded by mud or, if rain did not fall for a day or two, covered in dust churned by the heavy construction trucks. And often in the afternoons when the mountain weather closed in a cloud would drift right through the Bank and work had to stop until it left by the back door.

The days were always hot, and muddy or dusty. At night, in the construction camps where he and his staff lived, a blanket was needed. And the rain on some days was almost solid, with a tremendous run off from the heights which swirled around the Bank.

Panguna branch was the only Bank in the Territory, and probably anywhere, to open on Saturday afternoons. This was necessary because mine and construction workers were spread widely over the great valley and native workers were paid on Saturdays.

Earlier at Panguna, and at Kieta, many of the black Bougainvillians were cautious about money. They shunned notes and demanded silver, especially on market days. But the tremendous amount of money earned during the establishment of the mine and more and more contact with banking led them to change so rapidly in their attitude that today, any local will accept and bank a cheque like any European. During construction particularly native workers were banking up to forty dollars a fortnight and large sums for land and tree compensation from the mine were paid in. There is more money held by the local population of Bougainville today than in any other area of Papua New Guinea.

The men of the Commonwealth who helped establish their Bank on the island regard themselves as an elite force. They were carefully selected for their character and stability and they were not sent to Bougainville unless they had first served in some other part of the Territory. Their record as bankers and men is magnificent.

As Peter Doolan says: "We all felt, as we watched the mine, the towns and the Bank grow, that we were part of a great achievement under at times trying conditions. Any officer, for example, who has served at Panguna is known as a Panguna Pioneer.

"I used to tell the youngsters on my staff: 'You're seeing things you'll never see again. They're building something here – not pulling it down.' "

Evaluation and Planning

SOME ASPECTS OF THE EVALUATION AND PLANNING OF THE BOUGAINVILLE COPPER PROJECT.

M.R.L. Blackwell
Chief Mining Engineer – Bougainville Copper Pty. Ltd.
(formerly Consultant with RTZ Consultants)

This paper was presented at the 9th Internation Symposium for Decision Making in the Mineral Industry (Montreal, June 1970) and is reprinted by permission of the Host Sponsors – Canadian Institute of Mining and Metallurgy, from their publication "DECISION MAKING IN THE MINERAL INDUSTRY"

ABSTRACT

Bougainville is a large-scale, open-pit prospect which has been developed and planned in considerable detail over the last three years.* Various techniques have been employed for ore reserve estimation, optimum pit planning and economic investigations. These have included several computer programs which have contributed significantly to improving the efficiency of the total planning process. The paper describes the techniques, with emphasis on their practical role.

* The work reported here was undertaken during the period 1967 through 1969.

INTRODUCTION

The methods described here are, in part, similar to other relatively new but well documented approaches to the problem of evaluating and planning an open-pit operation. Nevertheless, it is hoped that interest and discussion will be stimulated by those aspects of the analysis which are novel or unusual, together with the physical magnitude of the proposed operation which emerged from the evaluation phase.

The venture is being undertaken by Bougainville Copper Ltd., with Conzinc-Riotinto of Australia as the majority shareholder. That it is spectacular in scale and engineering challenge may be judged from descriptions of the location and environment. †

The body of the paper describes the stages in the evaluation process and two appendices deal with certain theoretical aspects. The latter are included because the approach adopted to the evaluation problem is influenced by the economic analysis described therein.

† Mr. Blackwell's references to ore deposit, location, topography, climate and exploration have been omitted, as they are covered elsewhere in this book. Ed.

Outline of Evaluation Process

In broad terms, the economic analysis of the prospective operation had three stages:–

- Modelling the orebody from exploration drilling results;
- Determining the final pit limits on the basis of drilling results available and current cost estimates;
- Establishing and evaluating the operating strategy within these pit limits which provided the most attractive economic return, subject to various constraints.

Initially, with exploration drilling continuing, the data flow necessitated repeated revision and consequently the whole process was iterative. Thus each cycle took as a starting point the conclusions of the previous cycle and repeated the process incorporating additional and refined data. As might be expected, the economic return from successive exercises showed an upward trend, but the rate of improvement decreased, that is, the return on exploration expenditure diminished. Furthermore, field investigations and refined estimating consistently improved the data on which the analysis were based. Ultimately, these tendencies converged at the point where management was satisfied that the proposed exploitation strategy was not only the best possible under the circumstances, but also that the economic return was acceptable, both in magnitude and likelihood of attainment. In this latter regard, to allow reasoned judgement on the risk associated with the venture, the economic outcome of the proposal was subject to extensive sensitivity analysis.

THE MODEL OF THE OREBODY

Summary

In the initial evaluation work, the normal practice of attributing grades to specific blocks of ground was not followed. Instead, zones of roughly homogeneous value

were defined by equal grade contour surfaces. Within each such zone, grade was described by a frequency distribution of "mining units" estimated from the distribution of values observed in diamond drilling results. The term "mining units" refers here to that sized volume of ground which it is feasible to mine selectively and discard to waste.

Rationale

This particular model, which is described more fully below, was selected for three main reasons:—

- Firstly, because in defining the shape of zones, it materially assists in geological interpretation and planning the drilling campaign. This was well illustrated early on, when from limited drilling results, a particular hypothesis had been advances as to the nature, shape and attitude of the orebody. However, on processing the data in the manner described, it immediately became obvious that the geometry of the orebody was significantly different; moreover, predictions as to possible orebody extensions based on this contouring were substantiated by subsequent drilling.
- Secondly, the values of individual lengths of drill core are only indicative of the value which will be encountered in a particular portion of the orebody. This is merely a reflection of the relatively violent fluctuations in value which small volume sampling units can exhibit due to the nature of mineralisation. Nevertheless, these fluctuations, together with the absence of perfect serial correlation laterally, do mean that drill core values provide a fairly doubtful basis for attributing specific values at particular points throughout the rock mass.
- Thirdly, the disparity in size between drill core and mining units gives rise to potential hazards in estimating the effect of applying a cut-off grade if blocks are valued from the grade recorded in portions of drill core. The difficulty here is that one is interested in the distribution of mining units to assess the effect of selective mining. However, one has the distribution of a much smaller volume sampling unit, the use of which must tend to overstate the grade above a cut-off grade, since the variance of sampling units will be larger than that of mining units. This can be overcome by interpolative combination of neighbouring values as is frequently done. However, it was felt that a more logically consistent approach was to determine the distribution of units of a known size and adjust this distribution to take account of size difference.

Derivation of the Orebody Model

The procedure followed was in two stages:—

- Division of the orebody into grade zones;
- Estimation of the frequency distribution of values displayed by mining units.

Division of the Orebody into Grade Zones

By a process of simple linear weighting and interpolation between neighbouring drill hole values, a grade value was calculated at a matrix of regular points through the rock mass. These points were transferred to level plans and the zone boundary contours were then interpolated between the calculated grid point values. The choice of contours to divide the orebody was empirical. The purpose was to isolate zones in which the values were roughly homogeneous, that is to minimise serial correlation between successive samples due to value trends within the zone. (see below).

The contour surface defined in this manner showed a strong persistence and coherence both vertically and horizontally which, not unnatrually, corresponded fairly closely to various geological features observed in the area.

The contours and subsequent grade determination were based purely on vertical drill holes. Subsequent inclined and horizontal holes in one portion of the orebody substantiated both the geometry of the zones and the estimated grade for these zones in a most gratifying manner.

Estimation of Grade Distribution Within the Zones

Prior to attempting any determination of grade distribution, an analysis of all drill hole results was undertaken to discover the extent of serial correlation. The object of this analysis was to assess whether the results would lead to statistical bias in estimating the variance. In practice, the mean-square-successive-difference test used showed strong serial correlation between the original assays taken at 10 ft. sampling intervals. However, it was found that this effect could be eliminated by combining contiguous results into 50 ft. composite samples. As a by-product, this analysis indirectly supported the selection of a fifty-foot bench height, by indicating that selectivity would probably not be improved by selecting a lower bench height.

After this tedious but necessary digression, the fifty-foot composite results were used to determine, by conventional statistical procedures, the type and parameters of the distribution of these units for each zone, using all such units located in a particular zone. The resulting distributions were used as a basis for deriving the distribution of mining units, that is units which were considered to be the minimum size that can be selectively mined. The method of derivation used was that proposed by R. F. Shurtz[1]. Mr. Shurtz's description will not be duplicated here. Sufficient to say that he provides a method for estimating the smaller variance of the distribution of the larger mining from that of 50 ft. core composites.

Once established in this manner, the model of the orebody lends itself very readily to evaluating different cut-off grade policies and despite the apparently complicated procedure required, the use of a computer reduces it to a simple and rapid process.

To Summarise

The orebody and surrounding rock mass was divided into zones and the distribution of values of mining units within these zones described by frequency distributions. This model thus far is confined to copper which is the primary economic constituent. Minor quantities of gold and silver also occur and their concentrations are sympathetic to those of copper. Accordingly, the grades of these materials were estimated from regression relationships established between these metals and copper in each zone.

It is worth noting that the predictive capability of this model was checked by conventional manual ore-reserve calculations performed independently by the geological staff, as well as by interpolative combination of neighbouring holes to compute block values. The results were at all times close, reflecting the high degree of local homogeneity shown by the orebody. In the final analysis, of course, the most satisfactory model will only be determined by operating experience.

DETERMINATION OF FINAL PIT LIMITS

The determination of the economic limits to open-pit mining and subsequent evaluation of alternative mining strategies were accomplished using an open-pit design program developed by RTZ Consultants. Again, the nature and use of this program has been described elsewhere[2]. Essentially, this program allows simulation of the mining operation, calculating the tonnage by classified material types for any specified mining plan. As input the program requires a level by level plan of the orebody with different material identified by a numerical index code. In this instance, the grade zones and other geological types were identified in this manner.

Final Pit Limits

In principle, the mechanics of pit limit determination were similar to that described by Carlson, Erickson, O'Brian and Pana[3]. That is, starting from an economically feasible open-pit, the existing pit walls were incrementally extended by a series of cones around the pit perimeter. The acceptance or rejection of each cone was decided on the basis of a simple break-even equation. Thus, after applying a cut-off grade to an incremental cone, the resulting head grade and waste to ore ratio determined whether the cash flow generated by ore in the cone balanced the cost of mining it, making allowance for difference in haul cost for elevation differences.

Two points are worth noting:—

- Firstly, the cut-off grade applied was the current estimate of that which would be in force towards the end of the operating life. The question of cut-off grades will be discussed in Appendix I — here it will merely be noted that this cut-off grade calculation contained no minimum profit nor depreciation.
- Secondly, because of the pit configuration, the ore in a particular incremental cone will be won later than the associated waste to be stripped. Thus, recognizing the time value of money, the revenue generated by the ore in the cone was discounted by a present value discount factor. In practice, this is tantamount to including a variable profit in the breakeven calculation.

EVALUATING ALTERNATIVE OPERATING STRATEGIES

The factors which determine the economic outcome of an investment in a mining venture may be conveniently divided into two groups. Those which are susceptible to control by management, and those which are not. The latter include the product prices, the market demand for the product, the amount of finance available and, to a large extent, the costs of exploitation. These factors effect the financial return both directly as in the case of price and costs, but also as constraints, as in the case of market demand and availability of finance. Within the framework of these "external" factors, the profitability of the project will be substantially determined by management policy on:—

- The sequence in which material is mined;
- The physical capacity of the various stages in the production process;
- The cut-off grade applied and the resulting waste to ore ratio.

Arriving at an overall optimum combination of these factors is clearly not simple since the factors are multi-dimensioned and interdependent. The line of attack adopted in this instance was essentially heuristic. The basic steps were:—

- Produce an inventory of ore reserves through time by simulating mining according to a pre-determined plan;
- Select a set of values for the parameters which can be controlled by management;
- Given the selected values and external constraints, determine the cut-off grade policy which provides the maximum present value from the operating cash flow.

Thus, for a particular set of assumptions an optimal operating strategy was determined and its economic outcome quantified. (See appendices).

Time Inventory of Ore-Reserves

Using the open-pit computer program the material within the final pit limits was divided into increments of a specified size, corresponding to the material to be mined in successive time increments. Generally speaking, the early increments were made to correspond to about a year's production, while the later increments were much larger.

The program computed the tonnage of each grade zone and geological type to be excavated from each increment. Applying the distribution of values to each zone and combining the results, these provided a statement of the quantity of material within each grade interval for the increment. (This is illustrated, as a hypothetical example in Table 1

TABLE 1 — Illustration of Ore Reserves Inventory for a Single Increment
(tons in millions)

Grade Intervals	<0.1%	0.1 — 0.199%		0.2 — 0.299%		0.3 — 0.399%		>0.4%	
Bench Level	Tons	Tons	Grade	Tons	Grade	Tons	Grade	Tons	Grade
2100	2.4	2.1	0.13	1.8	0.23	1.6	0.36	3.2	0.68
2050	0.7	0.8	0.15	1.9	0.23	2.4	0.34	4.1	0.63
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
TOTAL	11.4	6.8	0.14	8.4	0.24	9.80	0.33	18.6	0.60

Selection of Parameter Values

The selection for a particular case depended naturally on the purpose of the series of trials. The first target was to establish the sequence in which the orebody should be mined. As can be imagined, an orebody of this size gives fairly considerable scope for different permutations. In simple terms, however, there were two obvious extreme possibilities, which consisted of commencing operations at either end of the pit. The one possibility having a high grade and stripping ratio, the other extreme having these parameters with lower values.

The choice of strategy was made by simulating these two extremes together with intermediate combinations. Each such trial, of course, produced a different time inventory of ore-reserves. For each such mining sequence, defined by a particular time inventory of ore-reserves, the optimum cut-off grade policy was computed for various pit and concentrator capacities. In all, four mining sequences were considered, each at the six different combinations of production rates shown in Table 2:—

TABLE 2

Production Rates m.t.p.a.	
Pit	Concentrator
32.4	10.8 & 16.2
37.8	10.8 & 16.2
43.2	10.8 & 16.2

A typical case is illustrated in Table 3 below with the relative profitability shown by expressing the present value of each sequence as a percentage of Sequence 1.

TABLE 3

Concentrator Capacity — 16.2 m.t.p.a.
Pit Output — 43.2 m.t.p.a.

Sequence	Index of Profitability
1	100.0%
2	106.3%
3	103.6%
4	96.3%

The strategy selected was on the basis of the highest present value. This was Sequence 2 in which operations commence on the high grade portion of the orebody and development of the lower grade portion is delayed until roughly 100 million tons of ore had been excavated from the high grade portion of the body. At this stage, in view of the relatively imprecise nature of estimates and knowledge of future price, this study was only intended to give a crude working rule for further planning.

Determination of Optimum Scale of Operations

Having established the sequence of development, the next stage was to determine the best scale of operations within the constraints of finance availability and market limitations. It is perhaps worth dwelling briefly on the latter.

A management decision had been taken to market the product as concentrates rather than copper metal. As a result, the potential market was somewhat narrower than would otherwise be the case. Moreover, both the decision to commence operations on the high grade portion of the orebody and the optimum operating strategy tended to produce a declining profile of copper output. However, there was a limit to which such a declining pattern could be accommodated in marketing strategy. Therefore, to achieve a more acceptable pattern of metal production, it was necessary to place a market constraint in the early years whilst determining the optimum strategy. Thus, subject to these constraints, the procedure was similar to that outlined above, with more attention being paid to the details of the configuration of the developing pit. Figure 1 illustrates the form of the final results obtained.

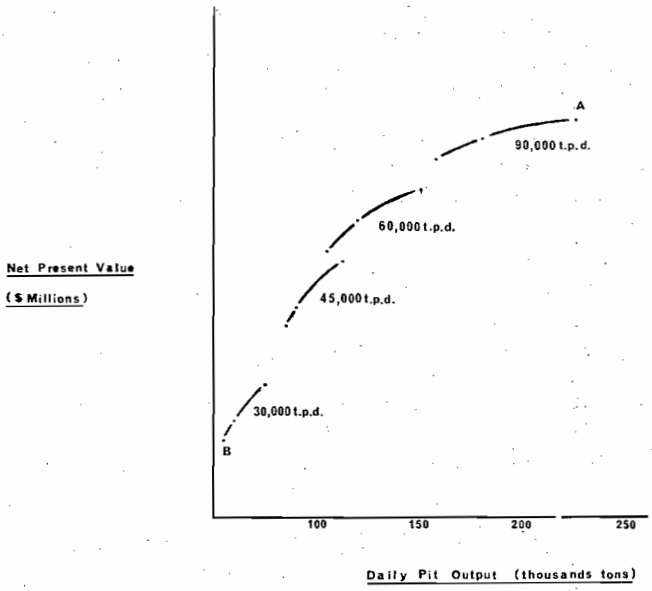


FIGURE 1 — Graph showing the economic effect of increased pit output for various concentrator areas.

Impact of Increased Scale on Project Economics

It will be observed that the overall tendency of the set of curves is a diminishing response to increase in scale. The point at which this envelope reaches a maximum, for given assumptions and estimates of price and costs, is a function of the tonnage of ore-reserves — thus the effect of increasing ore-reserves, proved by drilling during the course of evaluation was to increase the scale at which this maximum occurred.

The magnitude of the impact of increasing scale has on project economics may be gauged from the fact that the highest NPV on the graph in Figure 1 — i.e. point A is about 250% of the lowest — i.e. point B (at the price and discount rate adopted in evaluating the project).

Referring to the appendices, it will be seen that the optimisation procedure, of which the points on the above graph are the final result, gives rise to a cut-off grade which varies — normally declining monotomically. The effects of such a policy are evident from the Table 4 , which compares the financial outcome of a fixed cut-off grade policy to a variable one in one of the cases analysed.

TABLE 4

	Cut-off constant at 0.2%	Cut-off declining from 0.35% to 0.2%
D.C.F. return on total capital at risk.	11.2%	12.9%
N.P.V. of total cash flow	$20.9m	$46.9m

This effect is evident in Figure 2 from the increased return obtained for each concentrator capacity by higher mining rates.

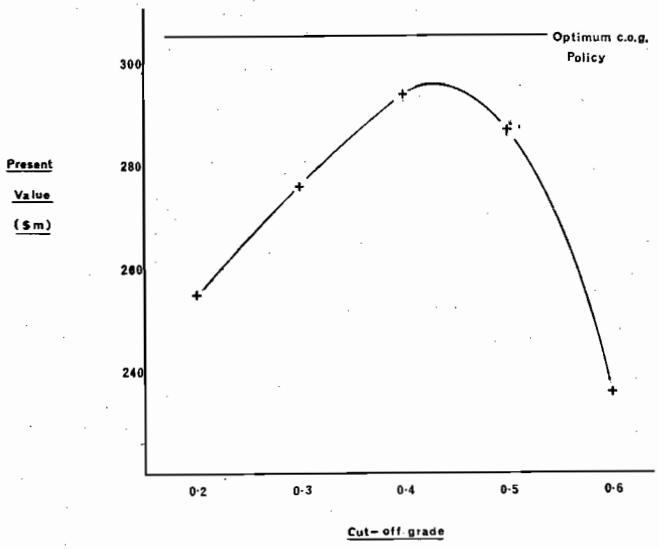


FIGURE 2 – Comparison of economic effect of different cut-off policies.

GENERAL DISCUSSION

Broadly speaking, the results of the conceptual evaluation and planning of the Bougainville project was that both concentrator throughput and pit output should be as large as possible. The final configuration arrived at – 165,000 tons from the pit and 90,000 tons through the concentrator was not optimal in the sense that a larger scale would theoretically have improved the overall Net Present Value of the operation. The size, however, was constrained by other considerations not the least of which were the practical problems associated with achieving a pit production in excess of 165,000 tons per day from the outset.

The optimum cut-off grade policy for this proposed strategy was used as a framework within which to carry out more detailed pit planning in which the development of the pit, the haul road alignments and similar operating details were more precisely defined. The most important ground rules distilled from earlier analyses were:–

- Firstly, that production should be concentrated on the high grade portion of the orebody for the first three years.
- Secondly, that the cut-off grade should be maintained as high as pit production output allows during the first 15–20 years of production.
- Thirdly, the overall working slopes should be maintained as steep as possible, consistent with operating efficiency; the aim here being to utilize production capacity in maintaining as high a cut-off grade as possible by delaying removal of the peripheral low grade material.

As mentioned earlier, the unrestrained application of these criteria, together with a natural outward decrease in grade, gives rise to a metal production profile through time, which presents marketing difficulties. In terms of the cut-off grade analysis given in the appendices, the market becomes the limiting constraint, giving rise to a staged build-up in pit output and concentrator throughput. In detailed planning these criteria were modified to give a more acceptable metal output by not concentrating pit production exclusively on the high grade – that is the time inventory of ore reserves was modified. This led to the proposed strategy which entails a cut-off grade declining from about 0.3% copper to 0.2% or less at the end of the operation's life with pit output being maximised, thus producing an essentially constant waste to ore ration.

As might be expected, problems did arise on occasions. Probably the most serious was that of data preparation, not only the normal one of miscoding, which was contained by a series of checks at each stage, but more serious was that of data volume. This was particularly true of the input data for the open-pit program. The problem was one of time – the whole evaluation cycle was a relatively long affair, and by the time a cycle was completed, the twenty diamond drills in the field had generated a significant amount of new data. At the time there was no access to any automatic digitizing equipment and manual coding was a tedious and time consuming activity, taking about 2–3 man days per 30,000 matrix cells (one level). Ultimately a solution to this was found by evolving a new coding procedure. This involved coding only the interfaces between different types on to a transparent plastic sheet from which cards were punched, which only takes about 2 man hours per level. This procedure had the additional advantage of allowing selective updating only of those parts of the matrix in which new information was available.

The second major problem was the understandable professional engineering reserve towards the novel aspects in the analysis. This has two facets – the communication barrier in explaining the reasoning where new ground is broken, and a certain reserve in accepting results derived by an unfamiliar process. The only apparent solution to these difficulties seems to be a continual process of explanation and periodically carrying out comparative calculations, both of which, being time consuming, add to the time necessary for the evaluation process.

APPENDIX I

OPTIMUM CUT-OFF GRADE POLICY

A number of aspects of the procedure outlined above were influenced by work on mine economics initiated by K.F. Lane[4], Managing Director of RTZ Consultants. Basically, this work has applied accepted economic principles to the mining situation and in doing so has taken explicit account of the two features which distinguish a mining venture from its industrial cousins.

These features are, of course, the flexible device available to management for changing unit profit in the form of the cut-off grade; and the fact that the resource on which the venture is based has a finite life.

The conclusions arrived at differ from conventional practice in two regards:—

- Firstly, in the concept of cut-off grade which emerges from the analysis.
- Secondly, in providing a method of determining analytically the cut-off grade policy which will produce the highest present value of the operation's future cash flow for a given set of assumptions on product price, operating costs and capacities of various links in the production chain.

Taking these two in turn:—

The Cut-Off Grade

Conventional practice is to determine the cut-off grade as a breakeven point at which revenue is balanced against all costs. The costs included in practice vary slightly from person to person, but typically include one or more of the following:—

- Mining cost.
- Depreciation.
- Some minimum profit element.

It will be seen that none of these appear in the determination proposed here. The reason for excluding minimum profit is discussed in the following section headed Maximum Present Value, but it is relevant to discuss the exclusion of mining costs and depreciation here. The omission of depreciation is simply explained on the basis that depreciation is an accounting device which will only rarely reflect replacement expenditure which is the only relevant legitimate economic cost. Mining costs, on the other hand, are not relevant to a marginal breakeven analysis because the decision is unaffected by these costs — they will be incurred whatever the cut-off grade adopted, unless production is to cease. (Ignoring cost differences in waste and ore mining to simplify the argument).

A further feature of marginal analysis is the importance of recognizing explicitly that in a mine, as in an industrial complex, there are a number of interdependent links which make up the production chain. Each element — for instance, the pit, the concentrator, the smelter, the refinery and the market — has or can have, a capacity limit. Normally on a mine this will be the concentrator, however this is not necessarily true and a coherent theory must cater for all possible circumstances.

The relevance of constraints arises from the aim of maximising the cash flow. Thus, if the pit output is the constraint on the whole operation, in order to maximise the cash flow, it is necessary to maximise the gross margin or profit per ton of material. Similarly, if the concentrator or market are the constraints the aim is to maximise the "profit" per ton of ore and metal respectively. The argument may be clearer algebraically:—

If: P is "Profit" or gross margin
Q_m is material mined at \$m/unit
Q_c is ore concentrated at \$/unit
Q_r is product refined/smelted/sold at \$/unit
s is selling price of product \$/unit
f is time cost \$/unit time
y is recovery proportion
g is cut-off grade with subscript identifying stage which is constraining production.

$$P = (s-r)\,Q_r - c.\,Q_c - m.\,Q_m - f.T$$

The length of time under consideration when the next Q_m of material is mined is determined by which element constrains the whole system thus:

If the Pit is the Constraint

$$T = \frac{Q_m}{M}$$

where M is the pit output per unit of time, then

$$P = (s-r)\,Q_r - c\,Q_c - (m + \frac{f}{M})\,Q_m$$

and to maximise the profits

$$\frac{dP}{dg_m} = (s-r).\ \frac{d\,Q_r}{dg_m} - c.\ \frac{d\,Q_c}{dg_m} \quad \text{as,}$$

Q_m is constrained w.r.t. g_m

This has maximum if

$$(s-r)\,\frac{d\,Q_r}{d\,Q_c} = c$$

But $Q_r \gg y.\ Q_c.\ g_m$

Therefore, $\frac{dQ_r}{dQ_c} \gg y.\ g_m$

Thus, $g_m \ll \frac{c}{y(s-r)}$

and the maximum is given when

$$g_m = \frac{c}{y\ (s-r)}$$

Similarly if the concentrator is the constraint

$$T = \frac{Q_c}{C}$$

where C is the concentrator throughput per unit of time

$$P = (s-r) - m.\,Q_m - (c + \frac{f}{C})\,Q_c$$

Differentiating w.r.t. g_c and setting $\frac{dV}{dg_c} = 0$ we have

$$\frac{dQ_r}{dQ_c} \gg y.\ g_c$$

and, $g_c \quad \lessgtr \frac{c + \frac{f}{C}}{y(s-r)}$

with $g_c = \frac{c + \frac{f}{C}}{y(s-r)}$ for maximum

and, if say the market is the constraint

$T = \frac{Q_r}{R}$

where R is the market demand per unit of time

$P = (s-r - \frac{f}{R}) \quad Q_r - c.Q_c - Q_m.m$

and differentiating w.r.t. g_r

$g_r \quad \lessgtr \frac{c}{(s-r-\frac{f}{R}) \quad y}$

with the equality giving the maximum.

Thus, the expression for calculating a cut-off grade to give maximum profits varies according to which element constrains production. The derivation above also shows the logic of omitting the unit mining cost from the cut-off determination.

Multiple Constraints

In practice it is likely that the operation will not be constrained by one stage only. It could be limited simultaneously by two or more stages in the whole process.

When this is the case, it is obviously not possible to operate at one of the points derived above and the nearest approach is to balance whichever stages are limiting the complex at their maximum capacities. The relevant balancing point may be directly determined from the grade distribution within the next Q_m of material.

Maximum Present Value

It is perhaps appropriate to break off at this point and introduce a further concept before passing on to the determination of the optimum cut-off grade policy from the ground rules laid out above. In order to do so the problem will be re-stated:—

> An important characteristic of a mining operation is that the resource on which the operation is based is not only finite in extent, but also is being depleted by that operation. Thus, the fundamental problem arises of choosing a compromise between high returns over a short period and lower returns over a longer period. Clearly, in circumstances of this kind, decisions affecting the rate at which the resource is exploited have major economic consequences. The problem is a multi-stage decision problem which can be mathematically formulated and solved. This procedure is shown in Appendix II. The important feature of the solution is that when "present value" is accepted as the criterion of optimality, the strategy for obtaining a maximum present value can be obtained by the inclusion of one additional cost element in the cut-off grade determination. This "cost" can be regarded as an additional time cost, so that the determination of an optimum present value, reduces to repeated maximisation of an expression of the form:
>
> $P - f't$
>
> where the f' is the sum of the normal time cost and the additional "cost" mentioned above.

Obviously, this additional, if you like, "artificial" cost is analogous to the profit element which is commonly included in cut-off grade calculations. (See for instance J. D. Erickson[5], where the need to balance life and profits for an optimum policy was also recognized). The distinction between the two lies in the method of derivation. This difference in turn gives rise to a further difference in practice:—

> A breakeven cut-off grade determination which includes a fixed figure for minimum profit gives rise to a constant cut-off grade assuming prices/cost are constant. The above method, in contrast, adds on a decreasing "cost" (since this cost is a function of present value — see Appendix II) and this results in a declining cut-off grade as the Present Value decreases with diminishing ore reserves. It is possibly helpful to think of this cost as analogous to an amortisation charge which diminishes as the capital investment is recovered.

Optimum Cut-off Grade

Reverting to the cut-off grade determination, it will be seen that procedures discussed earlier are essentially unaffected by incorporating the additional time cost. All that happens is that the f becomes f' and the calculation proceeds as before.

The actual choice of the optimum cut-off grade at any particular point in the mine's life is readily determined by considering the stages of the operation in pairs. (See K. F. Lane[4]).

An algorithm for solving the present value maximisation, formulated in the Appendix, has been combined with the cut-off grade calculations in a commercially available computer program developed by RTZ Consultants, to apply to open-pit mining problems. The object of this program is to establish the annual operating decisions (quantity mined, cut-off grade etc.) which will give the maximum present value for a particular set of assumptions on product price, costs and capacities. It was this program which was used in the evaluation and planning described at the start of this paper.

The effect of this maximisation procedure is illustrated below by comparing the economic result of the optimum policy with those obtained by applying a range of fixed cut-off grades. These comparisons are based on a hypothetical mine with:—

Pit Capacity	40 m.t.p.a.
Concentrator Capacity	15 m.t.p.a.
Concentrator Recovery	85%
Unit pit costs per ton material	25c.
Unit mill costs per ton ore	50c.
Selling cost per ton copper	$50
Time cost	$6.0 m.p.a.
Copper price	39c.

and with ore reserves as tabulated in Table 5 The results of the different strategies are summarised in Table 6 showing the optimum cut-off grades through time; Table 7 summarising the results of the different policies; and in Figure 2

TABLE 5 — Ore Reserve Inventory by Mining Increments

Showing the tonnage, in millions of tons, in each grade interval, with the grade above 0.6% Cu given in the final column.

Grade Intervals to:	<0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	>0.6	Grade >0.6
Increment 1.....	6.5	0.8	0.8	0.8	0.8	0.8	0.4	0.8	1.0	1.1	7.5	0.99
" 2.....	5.7	1.1	1.1	1.1	1.1	0.9	1.0	0.9	1.2	1.2	6.6	0.96
" 3.....	7.7	0.9	0.8	0.9	0.8	0.8	0.6	0.6	1.1	1.1	7.5	0.94
" 4.....	7.8	0.9	0.9	0.9	0.9	0.9	0.6	0.7	1.2	1.1	7.1	0.90
" 5.....	6.9	1.1	1.2	1.1	1.1	1.1	0.5	1.1	1.0	1.1	7.1	0.93
" 6.....	49.6	4.5	4.5	4.3	4.6	4.1	4.8	4.5	4.5	4.2	38.0	0.81
" 7.....	57.0	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	25.3	0.96
" 8.....	18.7	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	19.7	1.05
" 9.....	26.6	7.0	7.0	7.0	7.0	6.9	6.9	6.9	6.9	6.9	26.6	1.11

TABLE 6 — Summary of Optimum Strategy

Present Value of Cash Flow $305.5m
Total Cash Flow $797.3m

Year	Cut-off Grade %	Quantity			Annual Profit (US) $.10⁶
		Mined x 10⁶ tons	Conc. x 10⁶ tons	Produced x 10³ tons	
1.....	.54	38.63	15.00	116.63	61.98
2.....	.54	40.00	15.00	111.63	57.99
3.....	.51	40.00	15.00	106.77	54.44
4.....	.48	40.00	15.00	96.07	46.63
5.....	.48	40.00	15.00	96.07	46.63
6.....	.48	40.00	15.00	96.07	46.63
7.....	.39	40.00	15.00	90.92	42.88
8.....	.38	40.00	15.00	90.75	42.75
9.....	.38	40.00	15.00	90.75	42.75
10.....	.42	40.00	15.00	98.25	48.22
11.....	.46	37.46	15.00	106.19	54.65
12.....	.41	33.39	15.00	100.94	51.84
13.....	.37	30.25	15.00	98.59	50.91
14.....	.32	27.10	15.00	92.94	47.57
15.....	.27	24.44	15.00	87.56	44.31
16.....	.22	22.17	15.00	82.36	41.08
17.....	.17	8.56	6.36	32.76	16.05

TABLE 7 — Comparison of the Economic Effects of Different Cut-off Grade Policies

Cut-off Grade % Cu	Annual Pit Output		Time to Reach Max. Pit Output, years	Total Present Value of Cash Flow, $ millions at 15%	Total Cash Flow, $ millions	Life, years
	Initial M. tons	Maximum M. tons				
0.2	22.9	27.2	11	255	910	25
0.3	25.7	32.7	10	276	860	21
0.4	29.9	40.0	9	294	819	18
0.5	34.4	40.0	4	287	717	15
0.6	40.0	40.0	0	236	548	15
Optimum	38.6	40	3	305	797	16

which shows the Present Value comparison graphically.

From the results it will be seen that the optimum policy has a gross advantage of $9 million over the highest present value obtainable by a fixed cut-off grade strategy.

This margin reduces to about $8 million, net of mining equipment capital cost differences, to take account of the difference in pit outputs.

The significance of an improvement of this order should, of course, be judged against the Present Value net of all capital expenditure. This expenditure was ignored in computing the above results since it was the same for all cases apart from the marginal difference for mining equipment at different pit outputs. For an operation of this size, the total investment could be in the region of $250 million and an increase of $8 million in N.P.V. is equivalent to about an 18% improvement. Furthermore, compared to the results of a calculated breakeven cut-off grade at less than 0.2% the improvement is more striking still.

The description and discussion of the theoretical background to the evaluation of the Bougainville projection in this and the subsequent Appendix may be considered disproportionately lengthy. However, it was felt that the approach has sufficient potential to merit more than the somewhat meagre attention paid to it to date. It is worth pointing out that besides the work of Lane, there are numerous examples in mining literature of recognition by various authors of the importance of the ideas discussed in this paper. For instance, Halls, Bellum & Lewis[6] recently, and Soderberg[7] earlier showed the limitations of thinking only in terms of a single calculated cut-off grade, while as noted earlier, Erickson[5] appreciated the need to balance high profit and the operation's life. All that has been done within RTZ is to link up these ideas into what is, hopefully, a coherent and logical framework.

APPENDIX II

MAXIMISING THE PRESENT VALUE OF A MINING VENTURE

Criterion for Optimum

The criterion for determining the optimum pattern of cash flow is an economic problem beyond the scope of this paper. Here, it will be assumed that the proper criterion is maximum present value.

The definition of present value is:—

$$V = \sum_{n=1}^{N} P_n / (1+r)^n$$

where r is the cost of capital to the operation, expressed as a proportion, and P_n is the cash flow in year n.

Again, discussion of appropriate values for cost of capital are beyond the present scope, but a figure of the order of 8—15% net of tax applies in most industrial contexts.

Mathematical Statement of the Problem

It is now possible to state the general problem explicitly in mathematical terms. At any time during the life of the operation, there will be a certain amount of resource remaining at the beginning of the year and the profit which can be realised during the year will be a function of this, the amount of resource consumed, and possibly several other parameters, i.e.

$$P_n = P_n \quad (Q_n, q_n, a_{n1}, a_{n2} \ldots . a_{nm})$$

where P_n is the profit in the nth year.

Q_n is the resource remaining at the beginning of the year.

q_n is the resource consumed during the year, and

$a_{n1}, a_{n2} \ldots . a_{nm}$ are other parameters affecting the profit.

The problem, therefore, is to determine a sequence of values

$$q_n, a_{n1}, a_{n2} \ldots . a_{nm} \quad n = 1,2 \ldots . N$$

such that

$$\sum_{n=1}^{N} q_n = Q_1 \text{ and}$$

$$V = \sum_{n=1}^{N} P_n / (1+r)^n \text{ is a maximum.}$$

Development of Solution

A considerable simplification can be achieved by restating the problem in a different form. Calling the maximum present value at the beginning of the nth year V_n^*, this can only depend upon the amount of resource available, Q_n, i.e.

$$V_n^* = V_n^* (Q_n)$$

In fact, dropping the suffix n and introducing time as a continuous variable T, the maximum present value at any stage of the operation can only be a function of the amount of resource remaining and the time i.e.

$$V^* = V^*(Q, T)$$

Now a structural equation for V can be derived by considering an increment of resource, q. If the time necessary to consume this increment is t, then, provided t is small:—

$$V(Q, T) = P(Q, T, q, t, a_1, a_2 \ldots . a_m) + V(Q-q, T + t) / (1 + r)^t$$

In words, the present value at any stage can be regarded as the sum of the profit earned in the next small time interval and the present value at the end of that interval discounted back.

Applying the dynamic programming principle of optimality:—

$$V^*(Q,T) = \underset{t, A}{\text{Max}} \left(P(Q,T,q,t,A) + V(Q-q, T+t)/(1+r)^t \right)$$

where A represents all the parameters $a_1, a_2 \ldots . a_m$. Since t is small this can be written in the form:—

$$V^*(Q,T) = \text{Max} \left(P(Q,T,q,t,A) + \left[\frac{\partial V^*(Q,T)}{\partial T} - rV^*(Q,T) \right] t \right\} + V^*(Q-q,T)$$

or simplifying the notation:—

$$V^*(Q,T) = \underset{t,A}{\text{Max}} \left(P + \frac{\partial V^*}{\partial T} - rV^* \right) t + V^*(Q-q,T)$$

Interpretation

Despite its apparent complexity, the last equation has a remarkably simple interpretation. The overall maximisation problem has been reduced at any stage to maximising.

$$P + \left(\frac{dV}{dT} - rV\right) t \qquad \text{(dropping the asterisks)}$$

Here, the important observation is that the expression in brackets, $\left\{ \frac{\partial V}{\partial T} - rV \right\}$ is independant of the parameters t, A. This means that it is fixed during the maximisation process at a particular stage. In fact, $\left\{ rV - \frac{\partial V}{\partial T} \right\}$ can be regarded as an additional time cost to be borne by the operation, and for the want of a better term, it can be called an opportunity cost.

Thus, the solution to the problem involves repeatedly maximising an expression of the form

$$P - ft$$

and then fitting the pieces together so to speak, into a whole for the life of the operation. **At each stage, it should be noted, the maximisation is no more difficult than maximising the profit P.** If the structure of the profit function is such that the problem of maximising it for a given increment in resource is soluble, then certainly the stage by stage maximisation is soluble and the only remaining difficulty is that of integrating the stages into a whole.

Before discussing this, it is instructive to examine the nature of the opportunity cost

$$rV - \frac{\partial V}{\partial T}$$

more closely. It consists of two components both of which, in a sense, measure the penalties of doing nothing.

(i) rV. If operations were to cease for a period, the time at which future profits would be realised would be delayed and the present value now would decline because of the effect of discounting. The rate of decline would be:—

$$(V - V(1 + r)^{-t})/t) \longrightarrow rV$$

Hence rV measures the discounting penalty per unit time of doing nothing.

(ii) $\frac{\partial V}{\partial T}$ The present value of the operation can be changing with time purely because of changing economic circumstances such as prices, costs and markets. The rate of decline, if no resource were consumed, would be:—

$$(V(Q, T) - V(Q, T + t))/t = -\frac{\partial V}{\partial T}$$

Hence $-\frac{\partial V}{\partial T}$ measures the penalty per unit time of changing economic circumstances if nothing is done. It can, of course, in particular circumstances, be a bonus rather than a penalty.

Algorithm for Solution

A computer based algorithm for the solution of this problem in the mining context has been developed by RTZ Consultants. This solution is by an iterative procedure which has proved remarkably efficient. The number of iterations depends upon the extent to which the economic parameters — particularly price — vary, but four or five is normal with an extreme of about 30. Even the latter is not really time consuming and can be accomplished at a cost of $5–10.

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Mine Operations at Bougainville

R.L. Kay,
Assistant Pit Superintendent – Production,
Bougainville Copper Pty. Limited.

Paper prepared in mid-1972, shortly
after commencement of mining operations.

The presence of copper at Bougainville was first reported during the mid 1930's by a government geologist who visited gold exploration prospects in the Panguna area and noted presence of copper mineralisation. Subsequent investigations in 1964 by a geological team working for Conzinc Riotinto of Australia Limited culminated in the discovery of the Panguna deposit.

The surface of the orebody is located at an elevation between 2,000 and 3,000 ft. above sea level. Topography in this area is extreme with a cover of dense vegetation. The climate is tropical with little variation throughout the year. Rainfall at Panguna averages about 185 in. per year.

Pre-production, construction and development were completed by the end of 1971, while commercial production of concentrates commenced on April 1, 1972.

The Panguna orebody is a porphyry type copper deposit contained within a surface area of approximately one square mile. The host rock is a sequence of andesitic volcanic and volcanoclastic rocks with dip angles generally less than 20 deg. These volcanic rocks were later intruded by acid to intermediate rocks with both the intrusives and the host rock mineralised in the area of the contacts. The latest event in this intrusive sequence was the placement of granodiorite stock which is essentially unmineralised. The geology of the deposit was described in detail by Macnamara (1968).[1]

The principal structural feature which affects the engineering aspects of ore extraction is the intensity of faulting and fracturing of the orebody. These discontinuities, both filled and open, are in general closely spaced and steeply dipping.

Copper, the predominant economic metal, occurs mainly as chalcopyrite in quartz veins and, to a lesser extent, disseminated through the rock mass. Values diminish outward from central high grade zones. Apart from copper, the other economically significant metals are gold and silver.

The primary orebody is partially overlain by an oxidised zone which in those areas with relatively high copper content phases into a zone of secondary enrichment. The oxide zone varies up to 260 ft. in thickness. The underlying secondary zone, which is noticeably restricted to beneath the tops of ridges, has a maximum depth of 250 ft. Treatment of the oxide zone and part of the secondary zone is not profitable because of metallurgical problems.

Superficial materials overlying the deposit include river boulder terraces, screes, alluvium and a mantle of unconsolidated volcanic ash produced by intense volcanic activity in recent geological time. This volcanic ash mantle varies up to 200 ft. in thickness and is often interbedded with large boulders, sometimes exceeding 20 ft. in diameter.

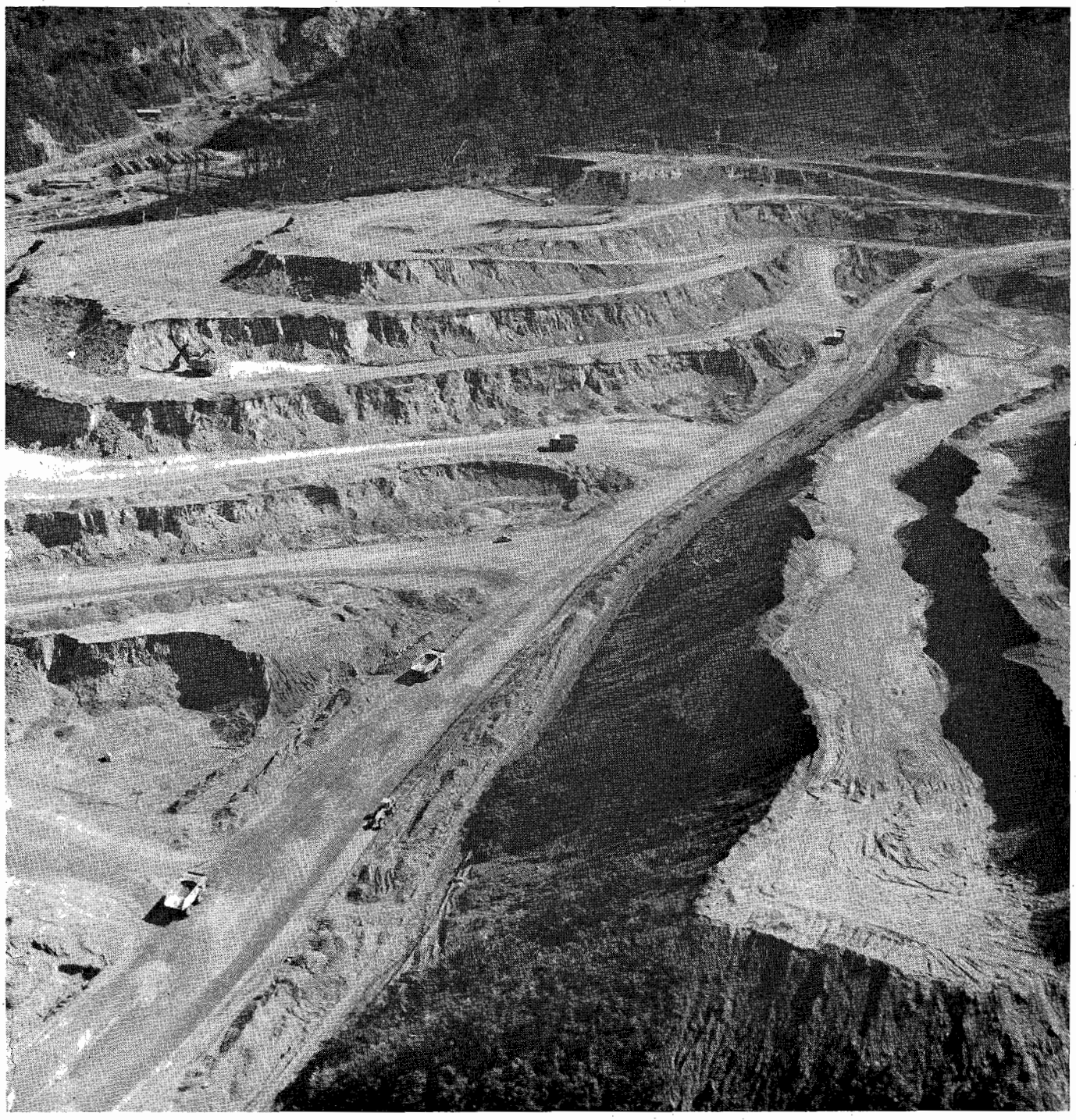
Preliminary evaluation

In early 1964, geochemical investigation had indicated the presence of widespread copper mineralisation. The resulting exploration drilling program was completed in 1969, by which time information from 277 diamond drill holes was available, totalling over 230,000 ft. of drilling.

The results of this drilling were checked by underground development on two horizons within the orebody. This work involved 12,500 ft. of horizontal development plus a further 1,800 ft. of vertical rising coaxial with exploration drill holes. As well as showing that diamond drill core assays had indicated a conservative prediction of orebody grade, this underground development was a convenient source of material for metallurgical testing.

Ore reserves were estimated at 900,000,000 long tons assaying 0.48% copper and 0.36 dwts per ton gold.

The ultimate limits of the open pit were determined by breakeven analysis of incremental extensions of the pit walls and deepening of the pit bottom. Slope stability investigations had shown that a maximum slope of 45 deg. decreasing to 35 deg. as the depth below the rim of the pit increased, would provide adequate stability with a conservative factor of safety. The pit boundaries were extended by increments until economic breakeven was reached between the value of the ore and the cost of mining both the ore and the necessary waste. A discount of 30% was applied to ore revenue in recognition of the time lag be-



Aerial view of the Panguna open-cut pit area. Euclid R105 trucks travel along one of the 80 ft. wide mine haul roads which provide access to the benches.

tween the removal of waste in the upper section of the increment and the generation of revenue from sale of the concentrate. This procedure resulted in an irregular pit outline which was smoothed out for operational consideration.

Detailed planning of pit development was preceded by a series of evaluatory studies aimed at establishing future production strategy. Of considerable benefit at this stage was the orebody model developed for the Panguna deposit (Blackwell, 1972),[2] which permitted alternative mining strategies to be quickly evaluated by computer. The basic criteria emerging from these studies were:

Mine excavation rate – 159,000 dry short tons per day, based on a 20 shift week.

Long term waste to ore ratio–0.68.

Design concentrator throughput–90,000 dry short tons per day.

Mine planning, initiated in early 1966, had proceeded concurrently with and provided input for the broader studies which defined basic production strategy. Once optimum scale of operations for both concentrator and mine, cut-off grade policy and equipment sizing had been selected, planning emphasis shifted to development of the pit through time.

The design criteria upon which pit development was based were:

Bench height–50 ft.

Final benches–25 ft. minimum width with 1:2 bench face slope.

Standing benches–50 ft. minimum width.

Working benches–125 ft. minimum width.

Haul roads–70 ft. wide.

Maximum internal ramp gradient –12%.

Minimum quantity of stripped ore in front of each shovel–one month supply.

A cut-off grade which reduced over the life of the pit and so maintained a constant waste: ore ratio.

This last design criteria was developed after several cut-off grade studies and, subject to constraints such as marketing, resulted in maximisation of project present value.

As exploration data was accumulated, continuous revision of project economics was necessary. Each new study entailed refinement of previous estimates of:

Capital expenditure on preliminary stripping, mine, concentrator and port facilities, community and other support facilities.

Operating expenditure on mining operations, concentrate production and transport, operation and maintenance of all facilities throughout the life of the pit, taxation, financing obligations, etc., and revenues from sale of concentrate.

The financial implications of various strategies were examined using computer assistance in marshalling the large volume of data involved. Economic sensitivity to variation of factors, both those subject to management control and independent factors such as metal prices, was also examined.

The economic viability of the operation was confirmed by July, 1969, leaving the way clear to proceed with the financing necessary to launch the project.

About 560 acres of dense tropical rain forest had to be cleared before mine facilities could be constructed and stripping of the orebody commenced. Simple burning off of the vegetation was precluded because of high rainfall and humidity. Removal of all vegetation from the area was necessary as the next phase of the development program in the pit area was hydraulic sluicing of the unconsolidated ash. A clearing technique was developed which effectively permitted a thorough approach to clearing without any delays to critical development schedules.

The larger trees were poisoned and the undergrowth sprayed with a herbicide four to five months before felling. This allowed the sap to dry out and partially prevented saturation during heavy rain.

Standing dead trees were felled either by hand, or dozer, or a logging technique known as "hi-lead yarding". Stumps were removed with dozers or explosives.

All vegetation was collected by dozer or yarder into piles and burned. Combustion even during heavy rainfall was maintained by using large diesel driven fans into the air stream of which a spray of diesel fuel was injected.

A workforce of 17 expatriates and 117 indigenous personnel was involved using the equpment listed below.

Two Skagit BU98 yarders.
Two Franklin 190 BPS log skidders with 82 in hydraulic grapples.
Four D8 dozers with logging winches.
Ten Briggs and Stratten cyclone fans.
Four Lister SR3 fans.
Chain saws and miscellaneous items.

The hi-lead yarding method used employed two yarders each consisting of a 450 hp engine, a series of winches and a telescopic tower which extended 110 ft., all mounted on dozer tracks. The yarders were installed on the tops of ridges with tail pulleys some 2,000 to 3,000 ft. in front of the units. Steel hawsers were connected to the winches through the sheaves at the tops of the towers and thence through tail pulleys with the line returning to another winch on each machine. Between the main lines, one from each yarder, was connected a heavy wire rope which was drawn towards the machines by their main winches. This hawser progressed across the area to be cleared at up to 10 m per hour, knocking down trees and generally pulling out most of the roots as well. The machines were also used to drag the trees into valleys where they were collected for burning.

Once the yarders were set up, the rate at which vegetation was felled and transported was exceptionally quick. Clearing was accomplished ahead of schedule, taking about five months to complete instead of the planned eight months.

Hydraulic overburden removal

Conventional excavation of the unconsolidated volcanic ash covering the orebody was considered impractical because of the nature of the material. The ash contains 40% to 50% water by weight and is similar in appearance to sandy clay. When disturbed and wet, it rapidly deteriorates into a rich mud. This latter property precluded the use of rubber tyred excavation and haulage equipment.

The method chosen to remove this surface material from the pit area was dozing to hydraulic monitors. The

slurried material then flowed down natural drainage channels into the river system and thence to the sea.

The impact of a 2,000 gal/min. jet of water through a 2¼ in nozzle at a pressure of about 100 lb/sq. in merely punched a hole in undisturbed ash. But once the ash had been broken up by dozers it rapidly formed a slurry capable of flowing down gradients in excess of four per cent. This slurry was dense enough to support large unbroken pieces of ash and to some extent broken weathered rock and interbedded scree material.

A typical equipment requirement to maintain hydraulic sluicing activities at the rate achieved is listed below.

Seventeen D8H dozers.
Two D6C dozers.
Two Terex TS14 scrapers.
Seven Thompson pump sets (rating 2,500 gal/min at 650 ft. head).
Six 6 in Stang monitors with 2¼ in nozzles.
One 4 in Stang monitor with 1½ in nozzle.
Miscellaneous pipelaying equipment and smaller monitors.

Initial estimates of hydraulicable material in the pit area indicated 18,590,000 bank cu yd to be removed in 16 months. The actual volume removed 15,757,000 cu. yd. over an operating period of 17 months. Two factors contributed to the difference between predicted and actual volumes and excavation rates:

The occurrence of boulder terrace material was more frequent than had been predicted from exploration drilling.

In several areas the lower level of hydraulicking was higher than anticipated.

It was recognised at an early stage of pit planning that considerable attention to pit maintenance facilities was necessary to ensure that mine production performance and cost targets could be met. Construction of the Pit Workshops commenced in 1970, and together with the Pit Fueling Station, was operational by mid 1971. Design criteria in building these facilities included capability of maintaining haulage trucks of up to 200-ton capacity and provision for expansion if required at some late date.

A contract for the supply of explosives for pit blasting operations was awarded to Ireco Chemicals in 1969. Construction of a facility capable of supplying the pit with up to 18 million lb. of explosives per year was commenced in 1970 and completed four months before commencement of blasting operations in the pit.

Conventional mining operations with electric shovels and drills commenced 12 months before completion of the permanent power generation station at Anewa Bay.

During the intervening period power was supplied by a temporary diesel plant capable of generating 11 mW at 6.6 kV. This facility has since provided useful back-up during commissioning of the permanent station at the port. Capital expenditure on purchase and installation of the 10 1.1 mW generating sets in the temporary facility exceeded $1,000,000.

Mine haul roads

Pit operations were initiated at the highest sector of the five-year pit rim which is also the furthest from the waste dump. Access to this area was gained by December 1970 when construction was completed of the South Haul Road, a 9,600 ft. road involving 1,447,000 cu. yd. of excavation.

Because of difficult terrain, design criteria for this road were less stringent than normally expected for a major mine haul road. The criteria used were:

Road width – 60 ft.
Maximum gradient – 10%
Minimum radius of curvature – 250 ft.
Minimum base thickness – 4 ft.
Road safety berm height (where necessary) – 8 ft.

The 4,800 ft. long Pankiranku Haul Road through the centre of the pit was completed in April, 1971. For this road, design width was increased to 80 ft. and the base thickness to a minimum of 8 ft. Maximum road gradient is 10.5%.

The remaining major pit road, the 4,200 ft. long North Ore Haul Road, was completed in December, 1971. Road construction was based on a design of 90 ft. with a minimum base thickness of 10 ft. Road gradient does not exceed 10%. A total of 526,000 cu. yd. of material was excavated mainly by hydraulicking with over 300,000 cu. yd. of rock fill supplied direct from waste rock excavation in the pit. The combination of hydraulic excavation method and direct waste haulage from the pit resulted in extremely low road building costs.

The first shipments of major pit equipment arrived at Bougainville Island in mid 1970. Tranport to the mine site and erection preceded shovel and truck operations which commenced in November, 1970. All major items of equipment were received, erected and in operation by mid 1971. The final major equipment numbers were identical with the fleet as at April 1972 outlined under Pit Operations below.

Initial performance efficiency was reduced to train both supervisors and operators. The ability of selected Papua New Guinean personnel to rapidly master the 100-ton capacity Euclid trucks helped achieve production objectives.

By the end of the pre-production stage a work-force had been created which maintained pit operations satisfactorily. By then operations within the pit were fully localised below the supervisory level. Reliance on personnel from outside Papua New Guinea was restricted to mine maintenance tradesmen and a comparatively few other skilled categories.

In several areas the surface of the orebody was found to be closer to the natural surface than had been estimated. The quantity of material excavated by conventional shovel and truck operations to December 31, 1971, was 32,766,000 dry short tons against a 1971 target of 33,954,000 short tons.

The responsibility for ensuring continuity and control of production operations at Bougainville Copper has been subdivided between two mine engineering functions, planning and production control.

The mine planning engineer is responsible for the preparation of medium and long term plans for the development of the orebody. Currently, monthly plans within the scope of the mine planning section is included. The rationale behind this arbitrary subdivision is that the planning function is forced to recognise and allow for the practical

problems arising in planning and scheduling the detailed equipment duties and moves within the monthly period. The result is that recognition of practical details is injected into the longer term broad pit development studies.

Planning for each succeeding month is based on the assay data obtained from rotary drill hole assays. Forward planning beyond one month is based on the orebody model derived from the results of the exploration diamond drilling. Forward planning is based on grade zones and not on the individual block values usually developed for long term planning.

The production control function is responsible for:

Translating short term plans into daily and weekly schedules which specify major equipment locations and duties.

Monitoring daily production performance.

Co-ordinating pit production within geological and equipment maintenance constraints.

Variation in copper grade, degree of oxidation and hardness are also recognised in balancing the various ore locations to ensure maximum concentrator throughput and recovery.

Pit operations

Pre-production operations in the pit area were completed by the end of 1971.

The major pit equipment as at April 1972 is:

6 P & H 2100B electric shovels.
5 Bucyrus Erie 45 R drills.
41 Euclid R-105 haulage trucks.
14 Cat. D8 tracked dozers.
2 Cat. D9 tracked dozers.
2 Cat. D6 tracked dozers.
1 Cat. D4 tracked dozer.
3 Cat. 16 graders.
2 Cat. 14E graders.
2 Cat. 824 rubber tyred dozers.
1 Cat. 988 front end loader.
1 Cat. 992 front end loader.
1 Terex 72-81 front end loader.
1 Cat. 955 Traxcavator.
2 Terex TS14 scrapers.
3 Cat. 769B water tankers.
4 Cat. 769B dump trucks.
3 I.R. Crawlair with compressors.
4 Compactors (road construction and maintenance).
2 Backhoes.
1 Franklin logger.
1 Autocar low loader.

Figures given here refer to the first four months of 1972, as compared with those predicted in June, 1969.

Except for public holidays, operations in the pit and concentrator are continuous, based on three 8-hour shifts a day, seven days a week. Personnel working to shift schedules in the pit observe a 20-minute lunch break (within the 8-hour shift) while those working day shift only (tradesmen, blasting and construction workers, etc.) have a 30-minute lunch break.

All tons quoted in this section are wet short tons. The average moisture content for the four months to April 30, 1972, was 6.9% by weight.

At an early stage in preliminary planning, it was recognised that problems would be encountered in maintaining equipment due to the isolation of the project. To some extent this problem has been alleviated by a policy of encouraging equipment suppliers to set up warehouse and repair facilities on Bougainville Island. By April, 1972, back-up facilities were being operated by the suppliers of mine haul trucks, tyres and most of the ancillary pit equipment. (dozers, front-end loaders, graders, etc.)

All five Bucyrus Erie 45R rotary blast hole drills are electric powered. In addition to blast hole drilling, 100 ft. deep exploration holes are drilled on an 83 ft. square grid. Experience has shown that short and medium term grade forecasting and ore/waste boundary definition are considerably enhanced by these exploration holes. The need for this additional drilling was not appreciated during the preliminary planning phase.

Drill performance estimates were based on several manufacturers' estimates following test work done on rock samples from underground development during the exploration phase. The predicted drill performance of 216 ft. per 8-hour shift has been exceeded by a considerable extent in actual operation. Average drill performance for the first four months of 1972 has been 745 ft. per drill shift. The gross disparity between actual and estimated performance is due to:

All material is drilled and blasted in order to optimise shovel loading rates even the volcanic ash overburden remnants where this material has not been completely removed.

Near the surface of the orebody weathering of material has resulted in outstanding performances in the oxidised zone.

The intensely fractured nature of most material within the pit, although recognised prior to drilling test work by several drill manufacturers, probably was not taken into account.

The mechanical availability of the Bucyrus Erie 45R blast hole drills has been 94.8% in contrast to a 1969 estimate of 82%.

Drill utilisation will increase as pit excavation deepens. As at the beginning of May, 1972, drilling two shifts a day, seven days a week, is more than sufficient to satisfy requirements in the pit.

The explosive used for primary blasting is an Ireco non-metallised slurry which forms an impervious gel within minutes of mixing. The constituents are blended together in a pump truck immediately prior to pumping into the blast holes. Problems usually associated with conventional ammonium nitrate – fuel oil explosives in wet humid climates are thus avoided.

Blast hole burden and spacing in the major rock type, a well fractured andesite, is 30 ft. x 35 ft. This pattern is reduced to as close as 20 ft. x 20 ft. for quartz diorite. "Hard toe" conditions during shovel loading are minimised by subgrade depths of 7 ft. to 10 ft.

The actual powder factor achieved of 0.24 lb. slurry per ton mined exceeds the 1969 feasibility estimate of 0.20 lb. per ton. Blasting cost per ton mined is less than estimated because feasibility estimates were based on metallising the slurry for greater strength. Experience has shown this to be unnecessary.

Secondary blasting is seldom required because of the characteristic pre-fracturered nature of the orebody.

Loading

The six P & H 2100B electric shovels purchased by Bougainville Copper were among the first shovels of this size to be manufactured under licence in Japan. Selection of 17 cu. yd. dippers followed the determination of bulk loose density of ore at 1.32 short tons per cu. yd.

Shovel production per shift for the first four months of 1972 was 13,025 short tons in comparison with the feasibility estimate of 13,800 short tons per shovel shift. To achieve maximum productivity, attention is currently directed towards reduction of truck queueing delays at the shovel. Hence, although higher average shovel production rates are achievable, overall shovel/truck productivity considerations are taken into account in setting shovel performance objectives.

Mechanical availability for the P & H 2100B shovels was 84.6% compared with the feasibility estimate of 80%. The first major shovel overhauls are not scheduled until late 1972. Actual and estimated shovel utilisation were close at 65.4% and 67% respectively.

In contrast to recent trends in large pits elsewhere, the trucks selected for pit haulage at Bougainville Copper were mechanical transmission 100 short ton capacity Euclid R-105 units. Apart from commercial and service back-up considerations, the factors which influenced the decision to purchase mechanical drive trucks instead of the more usual electric wheel driven trucks for this capacity were:

Balanced tyre loading with dual 24:00 x 49, 42 ply rating tyres mounted on both axles.

Superior retarding and braking characteristics.

Positive drive to both axles – initial working benches being very soft underfoot.

Unresolved doubts as to the suitability of electric wheel units under local conditions.

Truck haulage productivity for the first four months of 1972 was 1,845 short tons compared with an average 2,176 short tons per truck shift originally estimated for the whole of 1972.

Two factors contributing to the disparity between estimated and achieved performance are of a temporary nature.

An abnormally high waste: ore ratio existed during the early months of the year while concentrator commissioning was in progress. Waste haul was 33% longer than ore haul.

Mining operations commenced in that part of the pit furthest from both primary crusher and waste dump. The average length of haul profile will decrease significantly during the remainder of the year.

Although mechanical availability of the Euclid R-105 trucks at 70.5% is lower than the estimated 84%, achieved utilisation of 67.7% has exceeded the original estimate of 65% for these trucks.

Since inception of operations it has been expressed company policy to localise the workforce as quickly as possible. Extensive training programmes have provided locally trained personnel at a rate even greater than that envisaged during the preliminary planning phase.

A breakdown of Mining Department manpower for April 1972 is shown :

Manpower Summary (April 1972)

	Expat.	Indig.	Total
Pit Operations	36	318	354
Mine Engineering	18	11	29
Geology	8	9	17
Pit Maintenance	181	225	406
Total – Mining Department	243	563	806

The current rate of localisation is expected to be maintained with many of the supervisory and technical positions planned to be localised by 1980.

Within the pit, the ability of Papua New Guinea employees in operating large equipment has been particularly impressive.

Shovel operators – with intensive training and several months' experience, Papua New Guinean shovel operators have now attained a level of skill comparable with operators in similar operations elsewhere.

Haul truck drivers – the standard expected from and achieved by Papua New Guinean drivers is similar to that required at any other open pit operation. Again, specialised and intensive training of operators paid early dividends.

Drill operators – expatriate supervisors initially operated drills to ensure familiarity with all facets of drill operation while training Papua New Guinean employees on the job. Since mid-1971 these local operators have been used with no significant change in drill performance.

In other areas such as maintenance, pit ancillary equipment operation and pit surveying, much reliance is also placed on locally trained indigenous employees. The results achieved in training Papua New Guinean employees in the operation of pit equipment augurs well for the continuing success of B.C.P.'s localisation program.

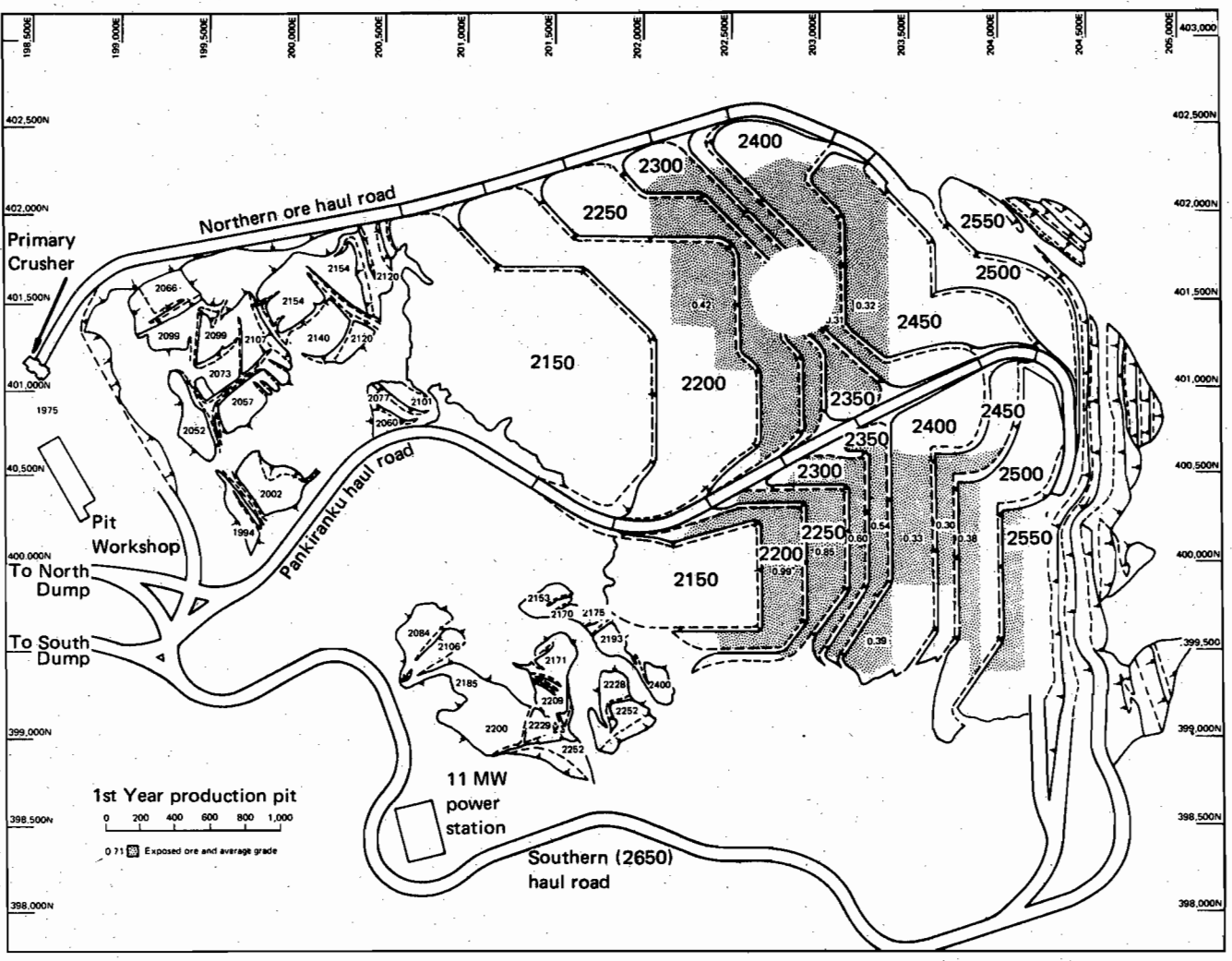
Concentration of the orebody's copper content is achieved in the mill by crushing, grinding and flotation of the primary sulphide mineral. The resulting concentrate, assaying about 30% copper, is transported 17 miles to the coast by pumping as a slurry through a 5½ in. dia. pipeline. After filtering and drying to about 7% moisture content, the concentrate is ready for despatch by bulk ore carriers to Japan and Europe.

Conclusion

From the date of decision to proceed with the Bougainville Project, the pressure on management to commence operations at the earliest possible moment has been intense. The cost of accelerated construction is more than offset by the income gained from beginning production three months in advance of original target.

Current mine productive capability compares well with levels planned for in the 1969 feasibility estimates. Mining cost per ton for the first four months of 1972 differs from the estimate for 1972 based on 1969 price levels. This difference, after allowance for the haulage considerations discussed above, is within the limits of general price inflation over the past three years.

To date the problems in launching a $400 m project ahead of schedule and within budget have been met. Attention is now directed towards optimising the potential of this project. If past achievement can be regarded as a measure of likelihood of success, the outlook for the Bougainville Copper mine is indeed encouraging.



Bougainville mining factsheet and layout of first-year production pit

Orebody dimensions (approx.)	6,000 by 4,000 ft (in plan)
Projected pit dimensions (at rim)	7,000 by 5,000 by 1,000 ft deep
Overburden stripped hydraulically	15,757,000 cu yd over 17 mo.

Equipment used for hydraulic stripping

17 Cat D8H bulldozers	7 Thompson pump sets (2,500 gpm at 650 ft head)
2 Cat D6C bulldozers	6 Stang monitors (2¼-in. nozzles)
2 Terex TS14 scrapers	1 Stang monitor (1½-in. nozzle)

Misc. pipe laying equipment and small monitors

Preproduction waste rock removed	32,766,000 st (to Dec. 31, 1971)
Mine excavation rates	159,000 stpd
Ore	90,000 stpd
Waste	69,000 stpd
Waste: ore ratio	0.68

Mine Design

Bench height	50 ft
Final benches	25 ft minimum; sloped face 1:2
Standing benches	50 ft minimum width
Working benches	125 ft minimum width
Haul roads	70 ft wide; maximum grade 10%
Ramp grade	12% internal maximum
Stripped ore	Minimum one-month supply in front of each shovel

Major pit equipment

6 P&H 2100B electric shovels	1 Cat 992 front end loader
5 Bucyrus Erie 45R rotary drills	1 Terex 72-81 front end loader
52 Euclid R105 trucks	1 Cat 955 Traxcavator
14 Cat D8 tracked bulldozers	2 Terex TS14 scrapers
2 Cat D9 tracked bulldozers	3 Cat 769B water tankers
2 Cat D6 tracked bulldozers	4 Cat 769B dump trucks
1 Cat D4 tracked bulldozer	3 Ingersoll Rand Crawlairs
3 Cat No. 16 graders	4 Compactors
2 Cat No. 14E graders	2 Backhoes
2 Cat 824 rubber-tired bulldozers	1 Franklin logger
1 Cat 988 front end loader	1 Autocar loader

Drill pattern (andesite)	30 by 35 ft by 57 to 60 ft deep
Drill pattern (quartz diorite)	20 by 20 ft by 57 to 60 ft deep
Slurry consumption	0.24 lb per ton mined

Equipment performance at Bougainville Copper*

Equipment	% Mechanical Availability Predicted	% Mechanical Availability Actual	% Mechanical Utilization Predicted	% Mechanical Utilization Actual	Productivity
Blast hole drills	82	94.8	75	23.5	216[1]
Electric shovels	80	84.6	67	65.4	13,025[2]
Trucks	84	70.5	65	67.7	1,845[3]

1. Ft per 8 hr shift. 2. Tons loaded per shovel shift. 3. Tons hauled per truck. *Covers first four months of 1972.

Engineering Management of the Bougainville Project

R.B. Hope,
Engineering Manager,
Bougainville Copper Pty. Limited.

Summary:

The aim of this paper is to demonstrate how the Engineering Management function is being carried out on the Bougainville Copper Project.

A general description of the project is provided and it is shown in a general concept how any large mining project develops from early exploration activities, through what is termed the development phase, to start-up of operations. The sequence of events leading up to the present stage of the Bougainville Project are then presented for compaison to provide an understanding of how the actual situation has affected the engineering management function.

The nature of the project and the particular conditions under which the project is being developed are described to show the situation requiring management control. The main methods of achieving that control are delineated.

Many of the normal problems associated with the development of large projects are magnified on this project. How some of these problems were handled is shown, so that benefits of experience may be shared.

The conclusion provides some suggestions as to what may be considered key factors in the successful development of similar large projects.

1. PROJECT DESCRIPTION

The Bougainville Copper Project will be one of the world's largest copper producing mines, with an annual output of approximately 33 million tons of low grade ore producing some 450,000 tons of copper concentrate (30% Cu).

The principal resource is a large porphyry copper deposit in the Panguna area of Bougainville Island, T.P.N.G. which will be developed by open cut methods. A locality map is given in Fig. 1. Investigations have proved the presence of some 900 million tons or ore with an average grade of 0.48% of copper and 0.36 dwt. gold per ton. The ore will be concentrated near the mine before being piped to the Company owned port at Anewa Bay on the east coast for drying and shipping. Tailings will be transported by pipeline towards the west coast where they will be deposited on swamp plains. A flow chart of the operation is shown in Fig. 2.

Paper No. 2964, presented at The Institution of Engineers Australia Annual Engineering Conference held in Adelaide from 22nd to 26th March, 1971.

The author is Mr. R.B. Hope, Engineering Manager, Bougainville Copper Pty. Limited, Melbourne. Mr. Hope was awarded the MANAGEMENT PRIZE of The Institution of Engineers Australia (1971 Award) for this paper.

Engineering for the project is being carried out in San Francisco, Vernon, Melbourne and Bougainville. Offices for procurement and logistical support have been established in San Francisco, Melbourne, Tokyo, London, Sydney, Brisbane, Panguna and Port Moresby.

Major Facilities:

The project when completed will consist of the following mining, concentrating and service facilities:

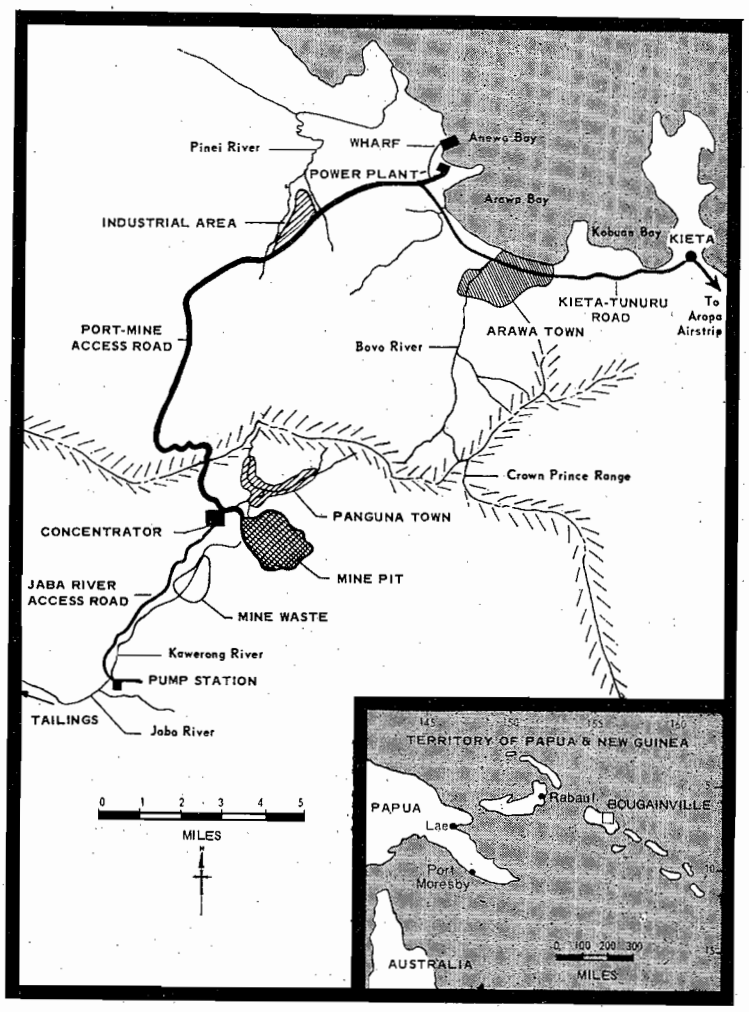


Fig. 1 – Locality Map

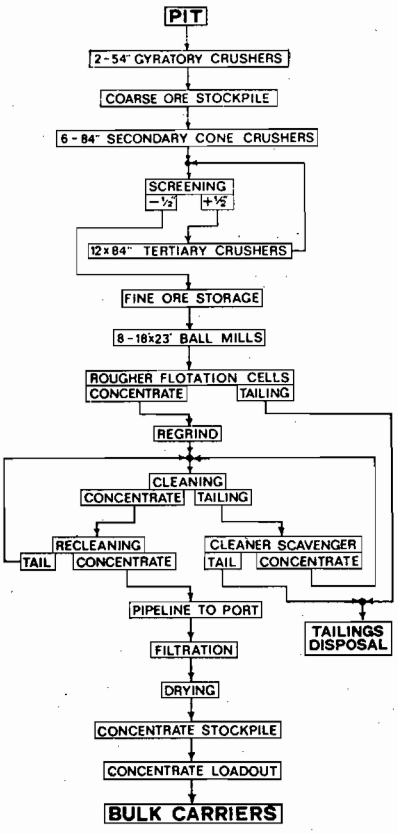


Fig. 2 — Flow Chart of the Operation

(a) **Mine**

The pit, will have rim dimensions of approximately 7,000 ft. by 5,000 ft. and will be some 1,000 ft. in average depth, with a system of mine haul roads 80 ft. wide to accommodate 100-ton haul trucks. Initially some 23 million cu.yd. of volcanic ash and waste rock has to be removed, and as the mine develops a further 400 million cu.yd. of mine waste will be removed.

Mine Service facilities include mine office, pit workshops, pit fueling station, fuel oil storage, slurry manufacturing plant and storage for magazines and detonator.

(b) **Crushers, Mills and Concentrator**

The ore will receive Primary, Secondary and Tertiary crushing to reduce it from an average size of minus 8 in. (ex primary) to minus ½ in. (ex tertiary). In the concentrator it will then be milled down to 45% minus 200 mesh before passing into the flotation cells. The concentrate leaves the concentrator as a slurry of 65% solids which will be pumped through a pipe to the port. The tailings will be disposed of, through a separate pipeline into the Kawerong Valley below the mine waste dump.

Water for the mill will be pumped from the Jaba River (Fig. 1) through a nominal 32-in. dia. pipeline a distance of about 7½ miles. The high head pumps will consist of seven horizontal multi-stage turbine pumps with a capacity of 2,500 g.p.m., against a head of 2,600 ft.

(c) **Towns**

Two new towns are being provided to support the project; Panguna near the minesite and Arawa near the coast. The rugged terrain at Panguna limits the size of this town to about 2,000 people, requiring it to be restricted to company personnel engaged on critical or standby activities in the mine area.

Arawa will be developed jointly by the company and the Administration of the Territory of Papua and New Guinea. Planning provides for a population of at least 12,000 people, and includes a major city centre development of commercial and administrative facilities.

(d) **Port**

Located in the port area are the filtering and drying facilities for the slurry, and a concentrate load out on a tubular steel pile wharf with capacity to load 40,000 D.W.T. carriers. The permanent power plant, fuel tank farm and some warehouse facilities are also located in this area.

(e) **Power Plant**

A steam-electric power station is under construction with initial installed capacity of 135,000 kW, consisting of three boiler/turbine-generator units having a name plate rating of 45,000 kW each. The plant, which will be cooled by sea water is an indoor type burning fuel oil.

(f) **Access Highway**

With the assistance of a team from the Snowy Mountains Authority, a single lane track was constructed for the exploration phase. This road climbs steeply at gradients up to 27% from the coast to Panguna over the Crown Prince Range, and has frequent hairpin bends and a rapidly weathering gravel surface.

This road has now been replaced by a new two lane highway, designed for speeds of 50 m.p.h. in the valley section of seven miles and reducing to 20 m.p.h. in a limited number of places in the mountain section and has a maximum ruling gradient of 12%. Some 13 million cu.yd. of excavation are involved in the construction of this road, which rises from sea level to a maximum elevation of 3,300 ft. at Pakia Gap. An example of the cuts involved in this work is given in Fig. 3.

(g) **Temporary Facilities**

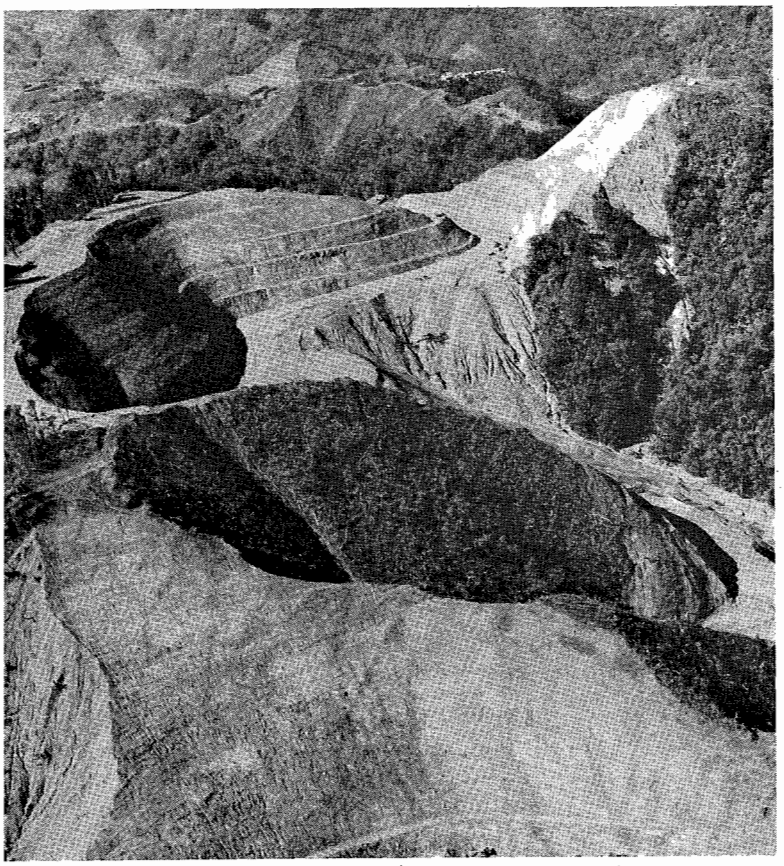
The provision of temporary facilities is a major item for this project, and includes accommodation for some 10,000 men in eight separate camp areas; construction warehouseing (110,000 sq.ft.); maintenance shops (23,000 sq.ft.); temporary power (20MW); aggregate and concrete plants for the port and mine areas; a temporary wharf and heavy construction equipment.

(h) **Industrial Area**

An industrial area will be provided to supply the necessary services and facilities for the support of the mine, mill and communities.

Cost:

The capital required for the construction phase of this project is estimated to be in the order of $350 million. During the first 20 years of operations an extimated further $100 million will be required, for additions and equipment replacement.



Earthworks at the Pakia Gap which forms part of the 16-mile access road leading from Anewa Bay to the Panguna minesite. (May 1970)

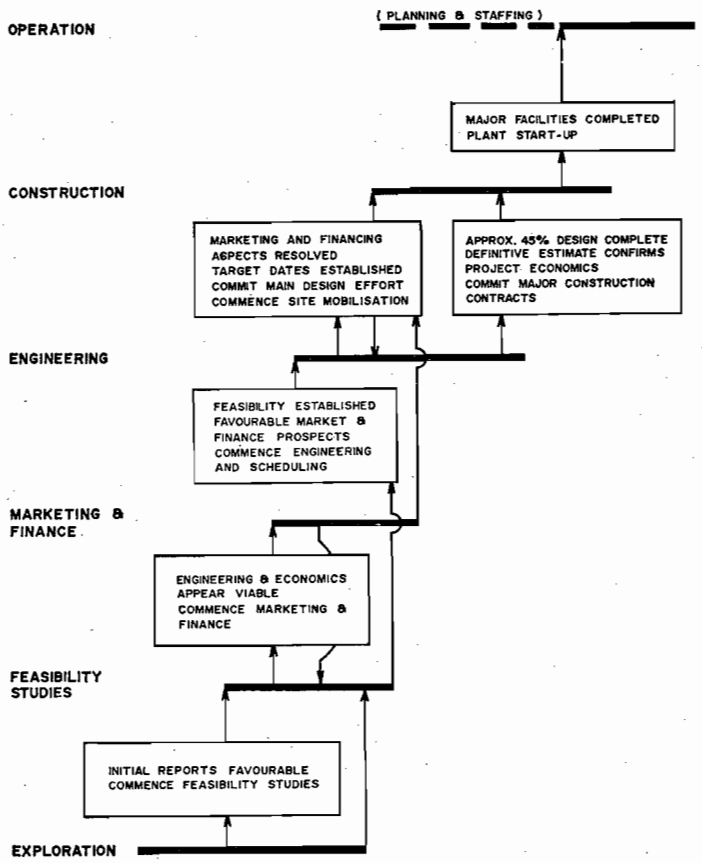


Fig. 4 — Relationship between Key Development Stages

2. PROJECT DEVELOPMENT

In most large mining projects there is a general pattern of development consisting of a series of stages which are executed from exploration, feasibility studies, design and construction through to plant start-up. Certain key decisions are inherent in this process and presage the moving from one stage to the next. Whilst these stages are common to most projects, it will be found that the length and relative timing may vary from one project to another. The stages and key decisions are shown diagramatically in Fig. 4.

It can be seen, that key decisions are made to initiate each subsequent stage and that some overlap of stages can occur with feedback of information from one to the other. Throughout this development process, there is a deepening physical and financial commitment on the part of the mining company. With that deepening commitment comes increasing pressure on management to shorten the time involved in each stage and to make the decision to commence the next activity.

The key events in the B.C.P. project are listed in Appendix 1 and from these Fig. 5 has been compiled. This figure shows how each phase actually developed and graphs the costs incurred during the exploration phase and also projects expenditure through the development phase to start-up of operations.

The development phase is the area of main concern to engineering management and consists of two main activities design and construction.

Under ideal circimstances design is taken to at least "Definitive" stage prior to commencing the major construction activities (Fig. 4). By "Definitive" is usually meant that a minimum of 45% of the design effort is completed, all major engineering problems are solved, costs can be estimated to within say 10% of the ultimate project cost, and completion time for the project can be accurately forecast. Under these conditions, it is assumed that designs are completed on a particular item before calling tenders. Prior to the definitive stage being reached, "on site" activities would normally be limited to mobilization of camps, preparation of laydown areas and provision of some logistical support facilities.

On this project the high costs involved have resulted in great pressure being placed on reducing the time involved in each of the various phases and activities. As shown on Fig. 5 the "Definitive Estimate" for this project was produced when only approximately 25% of the Engineering was complete. The June, 1970, Quarterly Project Forecast provided an estimate of the total project cost, closer to a definitive estimate but because of the overlapping of activities, the construction effort had already been committed to a great extent by that time, so it could not act as a major control point.

It is considered that the tight time schedule with its overlap of activities has placed a far greater demand on the management effort than any other single factor affecting the project and is a constant discipline on all personnel and activities.

Effective management under the above described situation is certainly harder to achieve than under more normal circumstances, and requires that the management systems provide for close monitoring and tight control of all project activities.

4. MANAGEMENT CONTROL

In establishing the basic management controls, considerable attention was paid to other recent major developments, particularly those at Palabora and Churchill Falls. Visits were made to various projects by a B.C.P. Management and Engineering team to study the management structures and controls.

A project management contract, providing for a Principal-Agent type of relationship, was established between B.C.P. and B-WKE* which allows for maximum use of the B-WKE resources in the fields of management, engineering design, procurement and construction, whilst still retaining ultimate control of project scope, engineering standards, finance and expenditure in the hands of B.C.P. This is similar to the relationship between CFL Co.+ and A.C.B.** on the Churchill Falls project.

In preparing the organisational structures, controls, etc., due cognisance had to be taken of the need to define and tie together the activities of each of the major centres of engineering. It was also necessary to clearly establish the relationship of B.C.P. managerial and technical personnel to those of B-WKE. A description of the organisational structures, procedures, planning and cost control systems follows.

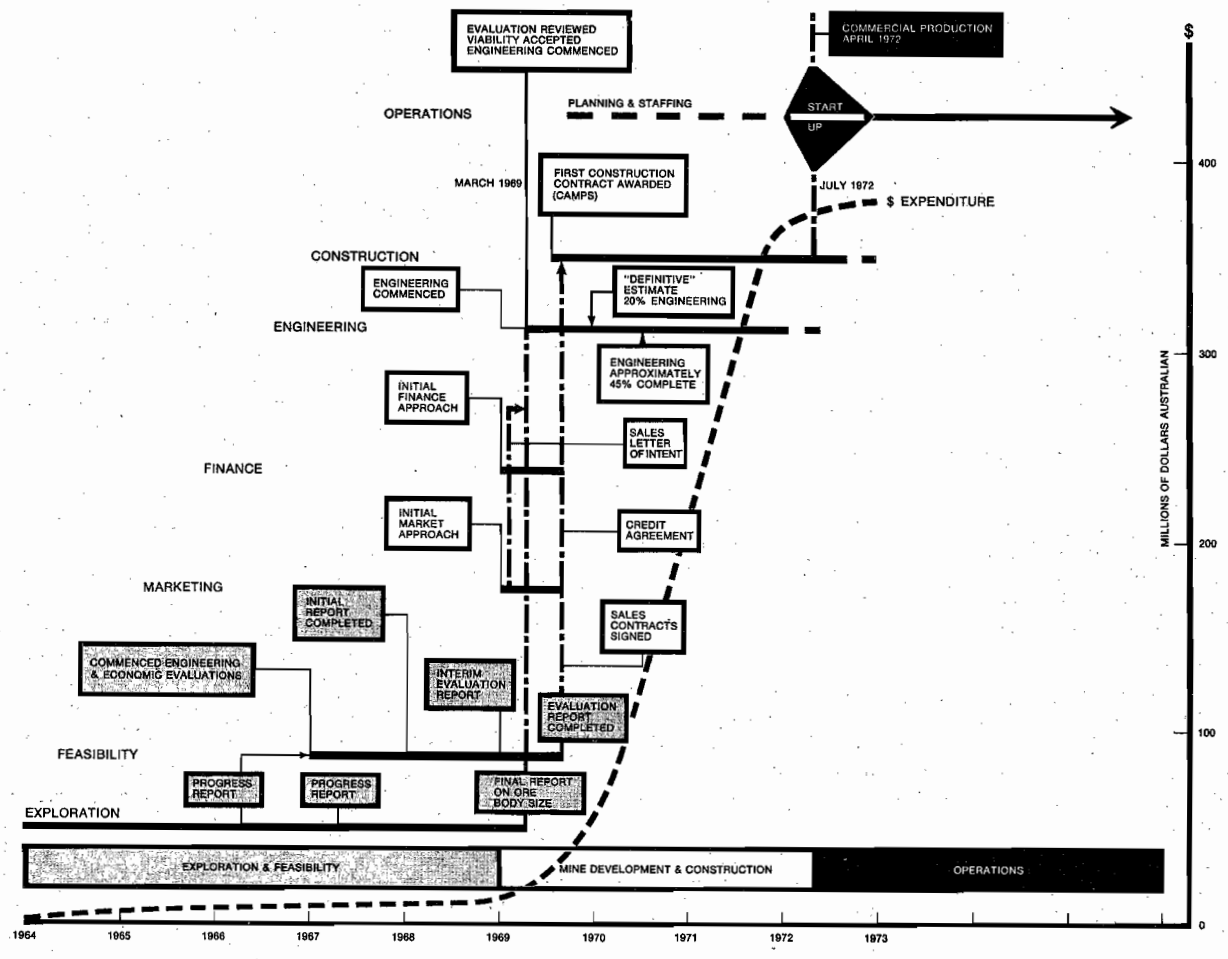
Organisation:

In order to rationalise the complicated situation of the B.C.P.—B-WKE relationship, the various centres of activities and the broad scope, it was decided that the B-WKE project organisation should provide the basic structure, with B.C.P. establishing a team in each engineering centre to monitor and approve the particular activities. The day to day joint efforts are based on the principle that the B.C.P.—B-WKE personnel should work together as a team with the common aim of achieving a well engineered project within agreed limits of time and cost.

* A joint venture of Bechtel Pacific Corp. Ltd. and Western Knapp Engineering.
† Churchill Falls (Labrador) Corp. Ltd., Canada.
** Acres Canadian Bechtel of Churchill Falls.

DEVELOPMENT AND EXPENDITURE CHART

TIME AND MONEY WERE OUTSTANDING ELEMENTS IN BOUGAINVILLE COPPER'S PLANNING.



The B-WKE Project Organisation (Fig. 6) is divided into three major groups, covering the basic areas of San Francisco, Melbourne and Bougainville, with the Vernon power group coming under the control of the Assistant Project Manager in San Francisco. Brief details of the responsibilities of the various centres are as follows:

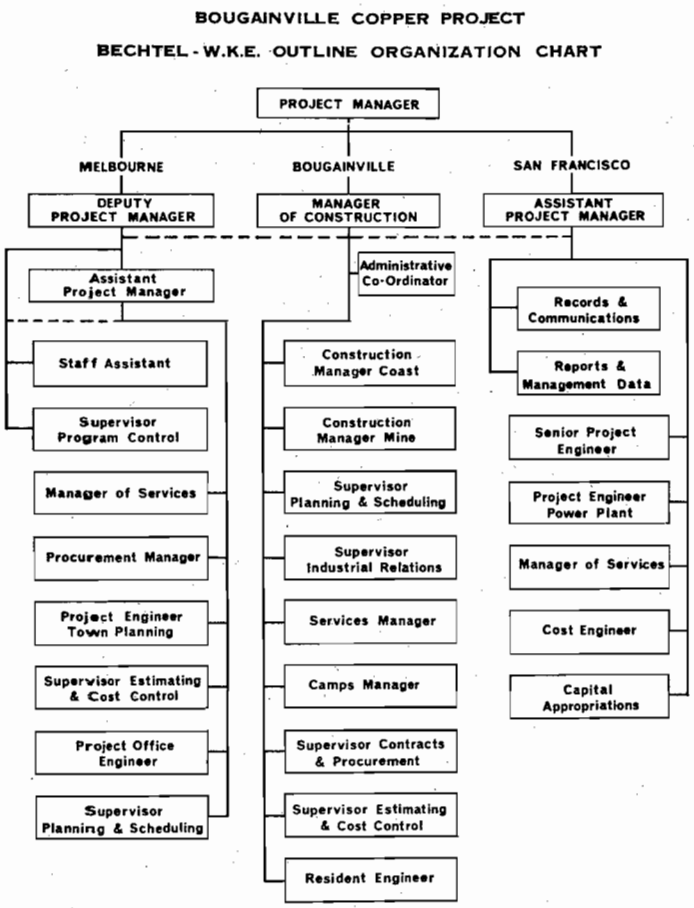


Fig. 6 – B-WKE Project Organisation

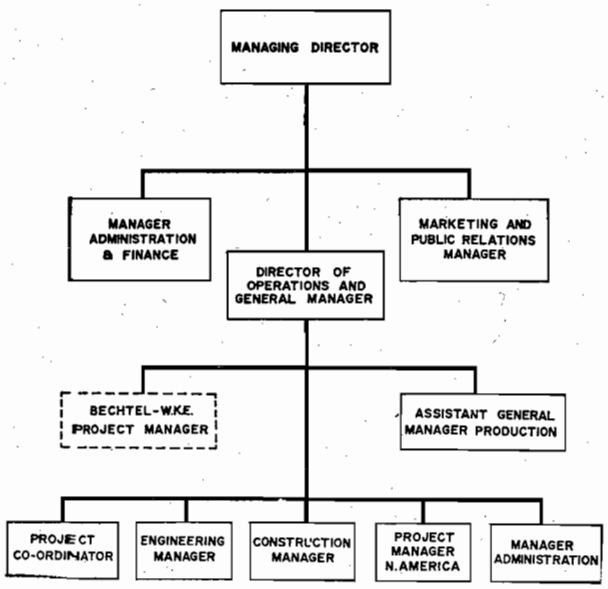


Fig. 7 – B.C.P. Interim Organisation

(i) **San Francisco**
Design and procurement of the process plant and facilities. Design of the port and mine service areas. Design of the power plant, using the Bechtel Power group in Vernon. Purchasing of major equipment associated with the foregoing responsibilities is distributed through the San Francisco procurement organisation to an office in London for the United Kingdom and Europe, and to Melbourne for obtaining quotes from Australian and Japanese suppliers.

(ii) **Melbourne**
Design of town and support facilities. Detailed engineering design of civil works as required. Design of temporary facilities, including camps and services. Preparing all contract packages, tendering, review and award of contracts. Assisting San Francisco with procurement by providing direct contact with suppliers. Providing logistical, administrative, shipping and expediting support for on-island activities. Planning and cost control centre for the project until December, 1970, when the centre transfers to the site.

(iii) **Bougainville**
Control of all construction activities, field planning and engineering. Design of access roads. Stores control and warehousing. Plant maintenance. Surveying and soils investigations.

(iv) **B.C.P. (see Fig. 7)**
The B.C.P. Interim Organisation will operate until project start up, at which time a permanent organisation suitable for operating the project will come into being.

Direct contact with B-WKE is maintained through the Project Manager (North America) in San Francisco, the Engineering Manager and the Project Co-ordinator in Melbourne, and the Construction Manager at Bougainville. A specialized staff assists each Manager in carrying out his responsibilities, and senior B.C.P. operating personnel provide support in depth for review and approval of designs and specifications.

The Project Manager – North America has an assigned staff, a Senior Electrical Engineer and a Civil Engineer. The function in this group is primarily one of plant design and equipment selection, and support is provided by the Concentrator Manager and the Senior Metallurgist on a part-time basis and the Power Plant Superintendent, the Mill Superintendent and the Assistant Mill Superintendent (Milling) full time until completion of design of the facilities within their particular zone of responsibilities.

The Engineering Department has a specialist for each of the following areas of responsibility: Estimates; Bid Documents and Contracts; Town Planning, Civil; Mechanical; Electrical: Architectural; Operational Planning; Engineering Co-ordination.

The Project Co-ordinator is responsible for establishing the requirements for project cost control, planning and scheduling, and the necessary monitoring and reporting on these aspects. He has a team of five accounting and computer specialists who keep close watch on the cost and time situation.

The Construction Manager on site is assisted by a

Project Engineer and an Assistant Project Engineer for each of three defined areas of construction. These areas are the process plant, mine services and coast area. The Construction Manager monitors all construction activities, ensures that adequate supervision and quality control procedures are being provided and maintained, approves onsite purchases, contracts and changes within specified authority.

Project Procedures:

The assembling of a large team under the project organisation within a relatively short period brings together mostly for the first time a large number of personnel of all levels and skills, experience and interests. The organisational structure delineates their position in the team, but there is an obvious need to provide guidance and ground rules for the day to day running of the project.

This need is provided for by the Project Procedures which delineate zones of responsibilities and authority, and provide the basis for an orderly and professional conduct of the project. They ensure uniformity of operation between the various offices and establish the guidelines and discipline to ensure that the overall project requirements are fulfilled. Sufficient flexibility is provided to allow for individual judgment under special circumstances providing certain control measures are observed. The procedures also set the guide lines and provide the controls for the relations between B-WKE and B.C.P. and with bodies outside the project organisation.

The procedures are subdivided into the several main divisions; including Management, Administration, Cost and Progress, Engineering, Procurement and Contracts, Finance and Accounting, Field. Each section of the actual procedures also contains exhibits which show the precise format to be followed for all standard forms, schedules, tabulations, etc.

Planning and Scheduling:

Control of the many activities involved in the development phase cannot be achieved without a sound, practical and detailed strategy. Once developed, close monitoring and updating is necessary to take corrective action as required, and to avoid unnecessary crashing of activities no longer on the critical path.

On this project two separate computerized systems are being employed for planning and scheduling. The first system employed is for drawing controls and reporting on procurement and expediting. The second is based on critical path methods for control of the contracting and construction activities. Information from the first is transferred manually into the CPM networks which provide the basis for the second system. These transfers are shown as target dates or percentage completion for drawings relating to a particular facility or major part thereof, and act as start dates for contracting or construction activities.

To be effective any network, for a facility and ultimately the whole project, must present a feasible and logical plan of work, which is achievable under the actual project conditions. Accordingly, as any network is being developed, input is required from the many specialists that will be involved in the various activities. In most cases this requires input from San Francisco, Melbourne and Site. For example, during the preparation of the power plant schedule up to 20 advisory experts were involved from the three centres and were concentrated in the Melbourne Office for approximately one week until agreement was reached on the network plan.

Once agreed, information from the networks is fed into the computer on an I.C.L. P.E.R.T. system programme. The project is currently split into 15 major facilities, each having between 2,000 and 4,000 activities with a project total in the order of 40,000.

Constant monitoring and updating is essential, and this is achieved by a planning and scheduling team resident on site feeding information back to the main team in Melbourne. Up-date information is fed to the computer and reforecasting of the whole network takes place at regular intervals.

The most important report for management control is the project exception report, which highlights the areas where there are difficulties in meeting scheduled dates. This effectively concentrates management's attention where it is needed most, and a report on proposed corrective action which accompanies the exception report provides a basis for reaching quick and sound decisions. Other reports are sorted by responsibility, start date, facility etc., and give the engineer only those activities for which he is responsible.

The combination of time-scaled networks and the computer print-out reports is considered to be essential to the proper planning and scheduling control of the project. The CPM networks provide an immediate visual relationship of activities which can more readily be used for discussions or for amplification to facilitate day to day planning than the computer print-outs, whereas, on the other hand, the computer provides the flexibility and comparative reporting so necessary for detailed analysis and reporting.

Cost Control:

No management decision can properly be made without consideration of its effect on cost. Therefore it is essential that accurate and current reporting and forecasting is available throughout the life of the project. With the high rate of expenditure on this project, proper cost control becomes more critical than ever, and so considerable thought and cost has gone into developing the Project Cost Control System. This system is computerised, and is based to a large extent on the programme developed for the Churchill Falls project.

The project extimate is cost coded, and all expenditure incurred must be related back to a particular cost code classification. The basic form of control is by client approval of an appropriation against the cost code budget to meet the tender amount of a particular contract package, procurement action or field expenditure. Any short fall from the amount provided for that item in the control estimate is made good from the contingency fund, whilst any over budget is transferred into contingency. Clearly the size of such transfers is a measure of accuracy of the estimate, and hence an analysis of the transfers to and from contingency can provide a forecast of the final cost. These transfers occur at two levels, the actual transfers made on appropriating or returning unused funds at the completion of a contract, together with forecast under-runs and over-runs arising from a review of each contract on a monthly basis.

The actual transfers and forecast transfers expressed as ratios of appropriated funds give an accurate picture of

whether an overall project over-run (or under-run) is likely. This, of course, must be related to the overall accuracy of the estimate to give the "degree of confidence" in the forecast final cost of the whole project. The main area of inaccuracy of the forecast final cost is in the unknowns of the work still to be awarded and (at the early stages of the project) still to be designed and finally estimated.

This is in part overcome by pre-packing and budget extraction of the unawarded work as far in advance as possible so that as engineering design reaches completion, forecast transfers to and from contingency can be made at the earliest possible stage, and hence improve the degree of confidence in the forecast final cost of the project. A typical appropriations status reporting sheet is attached as Fig. 8.

It is vital in all of the cost control reports that the correct definition of "incurred costs" is used. Too often only invoiced or paid costs are reported, and this invariably means that reporting is lagging some six to seven weeks behind construction activities. Incurred cost must at all times be understood and reported as work done. Separate reports on paid or invoiced costs may be required for accountancy purposes, but should never be allowed to confuse the issue at project management level.

Project Meetings:

Project review meetings are held on a regular basis, and are in addition to the many other meetings held as necessary on particular subjects at all levels of contact within the project organisations. These meetings are held each fortnight between B.C.P.'s Engineering Manager and the B-WKE Deputy Project Manager (Melbourne), with selected staff members of each organisation in attendance. At these meetings B.C.P. presents an agenda covering outstanding project problems for discussion and resolution as to required action.

Formal minutes of each meeting are produced in tabular form setting out topic, action required, action by (person) and date action to be completed. A follow-up procedure ensures the actions are taken as required.

5. MAJOR PROBLEMS

The combination of broad scope, tight time schedule, rugged terrain, thick jungle, unstable soil, high rainfall, seismic activity, tropical climate, initial lack of facilities and remoteness of the site from major centres of supply has created some very major problems and called for special solutions. Some of these problems, and details of how they are being handled are described in the following paragraphs.

Design and Construction:

On any project it often becomes necessary to "crash" the design of some portion to meet a particular deadline but it is another problem and a difficult one to effectively crash the design of the whole of a project. Normal methods of reducing the time involved in the design process are to assign more personnel to the design team and to place the team on an overtime basis, however on the Bougainville Project, this was not sufficient.

In the early planning on our project it was evident that even allowing for a major "crashing" of the design effort,

BOUGAINVILLE COPPER PROJECT JOB 6406
CAPITAL APPROPRIATIONS STATUS ($000's)

Month of May 1970 — Appropriated $200,000 — Report No. 7 Page 8 of
Definitive Estimate $300,000 — Unappropriated $100,0

Contract or Purchase Order No.	Approp. No.	Description		Appropriations			Incurred Cost To Date	Forecast Final Cost	Forecast Approp. Under Run (Over Run)	Uncom Approp Balance Remainir
		Activity	Contractor	Definitive Estimate	(To) from Con-tingency	Total Approp.				
M-C101	121 thru 121-2	Clearing and Burning Mine Area	A	300	(100)	200	100	190	10	10
Blanket	122 thru 122-2	Lighting Cable Transformers and Equipment	B	400	—	400	50	400	—	350
M-C143	123	Housing—Arawa Town	C	7000	—	7000	—	6500	100	400
MC-110	124	Sheet Piling—Power Plant	D	100	(50)	50	—	50	—	10
M-C127	125	Integrated and Non-Int. Bachelor Qtrs.—Panguna	E	2500	400	3000	20	2900	100	50
M-211	126	Initial Piping—Power Plant	F	20	(10)	10	—	10	—	—
M-208	127	Cooling Water Heat Exchangers	G	20	50	70	—	80	(10)	—
M-203B	128	Condensate Pumps	H	50	(30)	20	—	20	—	5
SE 7 E 201	129 thru 129-2	Auxiliary and Station Service Transformers	I	200	(50)	150	—	150	—	10
SE 7 E 201	130	Main Power Transformers—Power Plant	J	1000	100	1100	—	1100	—	10
M-C155/ 6/7	131	Fabricate, Deliver, Erect Struct. Steel	K	5000	1000	6000	—	6000	—	—
MY 327	132	Charter Hire—Shinkai Maru	L	500	200	300	100	300	—	—
M-C151	133	Panguna Health Centre	E	150	(50)	100	—	100	10	20
M-C134	134	Steel Sheeting Roofing and Siding	M	600	(100)	500	—	500	—	50
Blanket	135	Handtools and Expendables	N	250	—	250	—	250	—	—

NOTE: Figures quoted are for illustration purposes only and are not true values.

Fig. 8 — Typical Page from Capital Appropriations Status Report

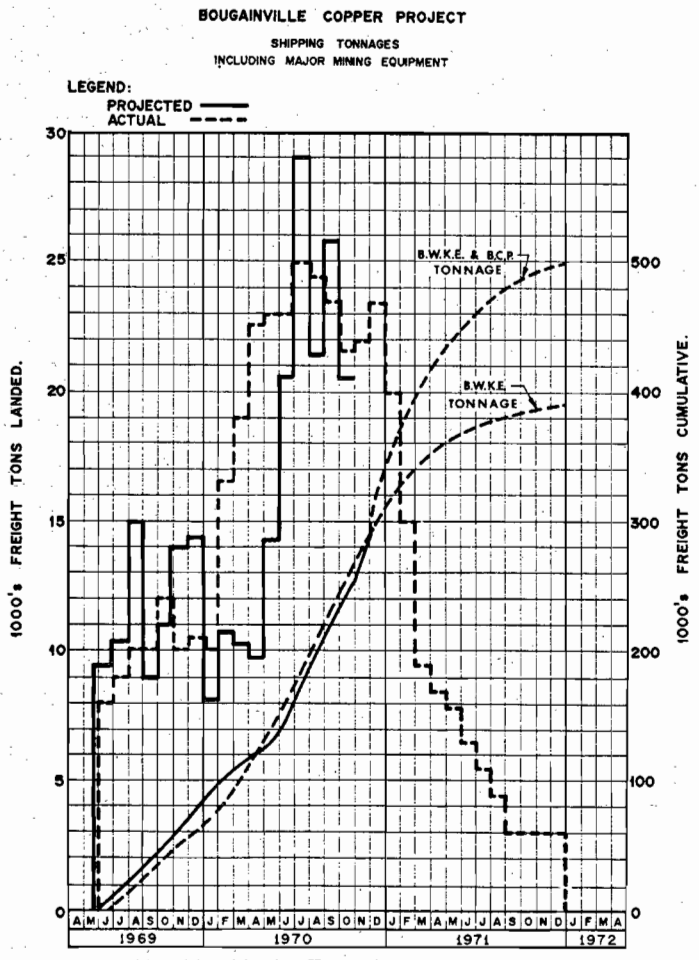


Fig. 9 — Monthly Shipping Tonnages

the end date of project was not achievable without considerable overlap of design and construction. It was therefore decided to call tenders on certain major bid packages before design was complete and in some cases, before detail design was even commenced.

This was achieved by making up bid packages with a general description of the scope of work, and general specifications with plans of a similar facility drawn from another project. The form of tender listed quantities based on a "best guess" and the contractor bid on a unit price basis for those quantities. The contract was awarded to the lowest bidder and as the actual designs became finalised and real quantities known the unit rates bid were applied to the new quantities.

The contracts usually provided that in case of a 20% or greater over or under-run in quantities, then the unit rates would be subject to re-negotiation. This approach has not been without its problems, but in general has been successful in making possible the necessary design-construction overlap.

Logistics:

Solving logistic requirements is perhaps the most critical and widespread of all problems on major construction projects and is certainly critical on this project. It is estimated that some 400,000 "tons" of goods will have been delivered to the island to complete this project of which some 100,000 of these will need to be removed.

Fig. 9 shows the estimated monthly tonnages. The high monthly tonnages early in the project are largely due to mobilizing the materials for temporary facilities and heavy earth moving equipment and these have had to be handled with insufficient time for detailed planning and development of adequate wharves and laydown areas.

In order to co-ordinate, allocate priorities and make maximum use of long term charters, it was decided that B-WKE would arrange the shipping of all materials destined for the project. This includes all contractors supplies and equipment from Australian Ports.

The existing wharf at Kieta, while capable of accepting 7,000 DWT ships, was completely inadequate for holding the tonnages involved. The company therefore purchased a 400-h.p. tug, 75-ton landing craft and two 200-ton dump barges and later hired a 300-ton dump barge to enable ships to be unloaded in Anewa Bay before the permanent company wharf was completed.

While land might seem to be readily available in a relatively undeveloped island this has not been the case on Bougainville and the development of laydown areas has been expensive and time consuming.

The access road problem has been a real logistics bottleneck. For the first six months of the project the round trip for a semi-trailer from Kieta to Panguna commonly took over 24 hours even with bulldozer assistance.

In the early days of the project one airline only operated and this was a DC3 Service to Kieta. Travel from Melbourne to Kieta took part of three days and air freight backed up at Rabaul and on average took over two weeks to reach the island. The services have steadily improved with increased traffic, the introduction of a second airline and daily flights to Kieta. The airport has now been upgraded to Fokker Friendship standard.

The logistic problem was greatly reduced upon the opening of the new port-mine access road, the completion of the company's wharf and the establishment of daily Friendship flights.

Accommodation:

Accommodation has been and continues to be one of the major problems. The rapid build-up and high number of workmen required, called for an equally rapid supply of accommodation (Fig. 10). It has been desirable to erect the necessary accommodation without adding unduly to the large number of workmen required for the main construction effort. The aim has been to minimize the amount of temporary accommodation and to make maximum use of permanent housing. This has been achieved by a constant monitoring of actual build-up of accommodation requirements and availability against forecast needs.

Communications:

Communications problems are being experienced at both the technical and human levels. Those at technical level being the most damaging to the project and least easily resolved. The two problems presented themselves as follows:

(a) **Technical**
With the three main project centres being so far apart and the construction site in such a remote location, there is a tremendous need for constant and effective communications. Unfortunately and with great detri-

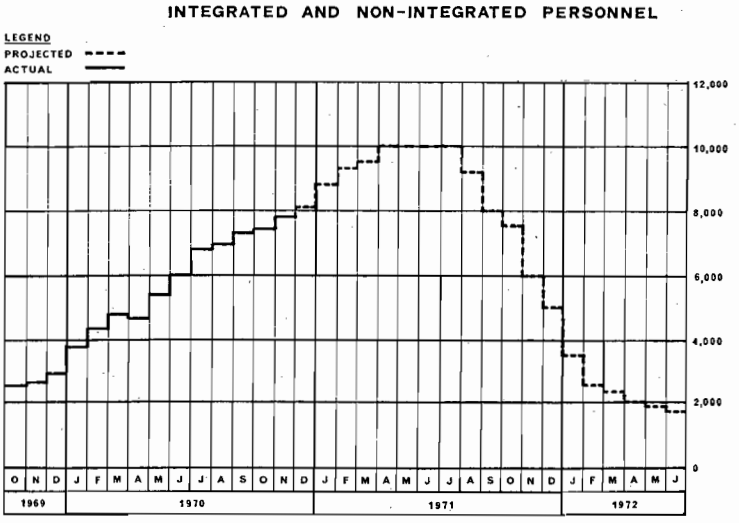


Fig. 10 – Manpower Forecasts and Build-up

ment to the smooth running of the project the communications between Melbourne and site have been most inadequate.

Up to the present time these have consisted of a T.P.N.G. Post and Telegraphs Four Channel H.F. System between Kieta and Lae, and a V.H.F. System from Lae to Madang, where it joins into the Seacomcable. The unreliability of this system has been compounded by the heavy traffic demand and the limited hours of operation.

As a partial solution to this problem company correspondence to and from the island is placed in air freight bags which leave Melbourne and the island daily. Copies of telexes are sent per the mail bag, and quite often arrive before the original message sent over the machine.

The long term outlook is somewhat brighter, as early in 1971 the P & T will have in operation a high quality troposcatter-microwave system which it is hoped will eliminate this particular problem.

(b) **Human**

The human communication problem is somewhat more complex, but in brief is the tendency of persons, sections or departments to inadequately communicate with other persons or areas of the organisation on matters of common interest and importance. On this project it is fact that this has been caused by:

(i) The three major centres being so widely separated.
(ii) The newness of the project organisational structure.
(iii) Heavy work load on all involved in the project.

These have produced a tendency to "compartmentalised thinking," whereby not enough thought was being given to who else may be interested in, or affected by, some particular decision or situation. In some instances decisions have been made in a "vacuum" and as a result failed to fully appreciate all the factors

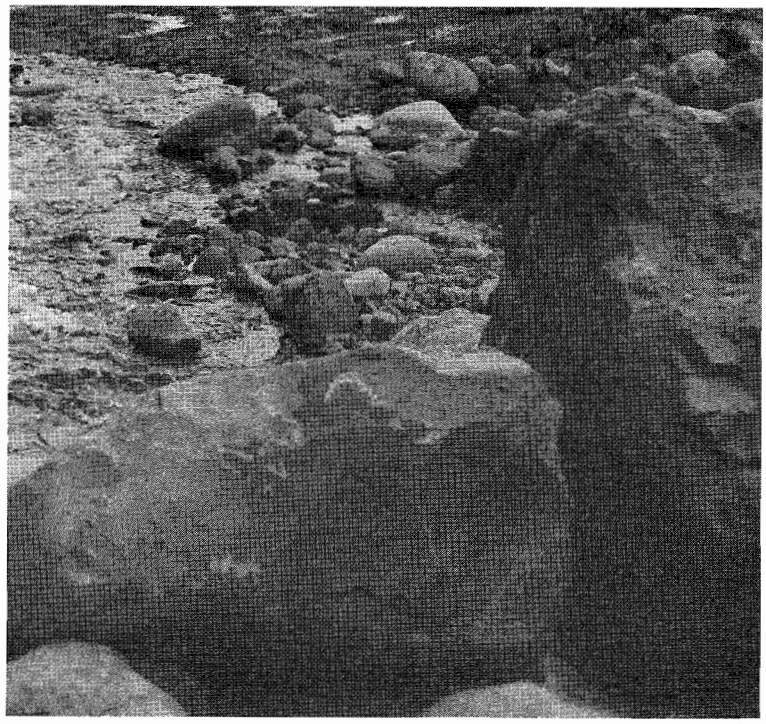


Fig. 11 – 12 ft. Boulders Transported by Mud Flow

that were involved. The steps taken to overcome this problem include:

(i) Indoctrination briefing for new personnel covering a description of the project, the organisation, procedures and the particular person's place in the organisation and responsibilities.
(ii) Wide mandatory distribution of correspondence per lists in the procedures.
(iii) Regular staff meetings and wide distribution of minutes.
(iv) Regular visits between major centres by key personnel.

However, the major step in preventing or overcoming this problem is to recognise its existence.

Port-Mine Access Road:

The timely and proper construction of the port-mine access road has constituted one of the most constant and major problem areas on the project. This road was constructed, to rural highway standards, through extremely rugged terrain, without the advantage of a lengthy pre-design investigation and with design and construction running concurrently.

The problems arising out of this situation started with determining the type of contract to handle the situation and have continued through construction in many forms. To solve the contracting problem the construction contract was let as a "cost plus incentive fee" basis. A base fee is nominated in the original tender and is paid as a percentage of a target estimate, that is also submitted in the tender. At the end of the work, the target estimate is to be adjusted against actual quantities of work done and used as a yardstick for comparison with actual costs. One quarter of any savings, thus shown, are to be added to the contractors base fee. Any over-run of costs will be shared between the client and contractor on a pre-negotiated basis. As an additional incentive there is a substantial bonus-penalty amount for timely completion.

A major problem experienced was the occurrence of landslides and mud-flows. The landslides lead to a re-design of the road, incorporating more conservative batter slopes and some realignment which resulted in more than doubling the original estimated quantity of earthworks in the mountain

section, the volume for the whole work now totalling some 13 million cu.yd. The mud-flows occurred as a result of the build-up in the valleys of side cast spoil which after becoming saturated by heavy rain flowed down the valleys and transported debris and boulders up to 12 ft. diameter (Fig. 11) and cut-off the road lower down and threatened local villages. To combat this, levees to protect villages have been built and footbridges provided for access.

6. CONCLUSION

The tremendous pressure to bring this project into production within such a short period is no doubt common to many, if not all, large modern day projects. This is certainly a situation that is not likely to improve or change within the foreseeable future.

What then are the essentials to success for a company developing a major project under such conditions? It is suggested, the following will play a large part in the successful prosecution of any project.

(i) A recognition of the phases to be passed through and the risks inherent in reducing the time required to properly carry out the tasks in each.
(ii) Early appointment of key project personnel including the project manager.
(iii) Using operating personnel to provide support in depth for the project development group.
(iv) Developing a sound organisational structure and proper procedures.
(v) Proper and adequate planning of the project schedule prior to making irrevocable major commitments.
(vi) Paying particular attention to the timely production of drawings and preparation of contract packages.
(vii) Setting and adhering to realistic target dates.
(viii) Exercising good engineering management skill in determining the proper balance between quality of engineering and speed of construction.
(ix) Management developing the project organisation into a team and imbueing that team with a sense of dedication and a constant understanding at all times of the need to "keep things moving."

Finally it is suggested success is in sight when all concerned accept the principle "that nothing is simple" and plan accordingly.

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APPENDIX I

Timetable of Developments (April 1964 to Nov. 1970 only. Ed.)

1964	April	Exploration for copper ore commenced on Bougainville at Kupei and Panguna.
1965	July	Rate of Panguna exploration stepped-up, orebody described as large and low in grade.
	Dec.	Orebody reported to contain 90 million tons averaging 0.63% copper, and 0.58 dwt. gold per ton.
1966	Dec.	Orebody reported to contain 230 million tons averaging 0.63% copper and 0.45 dwt. gold per ton. Engineering study commenced based on a plant to process 30,000 tons of ore per day. Expenditure on exploration reached $4½ million.
1967	June	Bougainville Copper Pty. Ltd. incorporated in T.P.N.G. Agreement reached with the T.P.N.G. Administration concerning conditions for development of the project.
	Aug.	Engineering study, including capital and operating cost estimates, concluded that the project was not viable based on assumed output.
1968	Mar.	Following further evaluations the C.R.A. Board stated "...confident that Bougainville a viable proposition..."
	Dec.	(a) Interim Evaluation Report completed, based on processing 80,000 long tons per day. (b) Preliminary Market approaches were made in Japan. (c) Comprehensive Evaluation Report commenced, based on processing 90,000 short tons of ore per day.
1969	Jan.	Meeting with representatives of Bank of America to discuss financial aspects of the Bougainville Project.
1969	Feb.	(a) Seven Japanese smelters signed a letter of intent for 950,000 tons of contained copper over 15 years from 1972. (b) Orebody now 760 million tons – 0.47% copper, and 0.4 dwt. gold per ton.
	Mar.	Although the final evaluation report was not yet complete it was decided that the economics were sufficiently favourable, that a full programme of design engineering, and construction of critical support facilities, could be undertaken.
	June	(a) First construction contract, the supply and erection of temporary camps, awarded. (b) Contract for construction of general Portsite work, awarded.
1969	July	(a) Letter of Intent and notice to proceed issued for construction of Port-Mine Access Road. (b) Credit agreement for up to $US 246.4 million in Euro-dollars signed with Bank of America and Commonwealth Trading Bank. (c) Further sales arranged with German and Spanish smelters. (d) The Evaluation Report for the Bougainville Copper Project was completed.
	Aug.	Letters of intent were issued for Boilers and Turbine Generators.
	Sept.	(a) The contract for dredging and construction of the permanent wharf awarded. (b) Letter of Intent issued for supply and erection of 184 houses at Panguna Townsite.
	Nov.	(a) $US60 million in loans arranged with Japan, half for equipment purchases from Japanese suppliers. (b) Decisions taken for the purchase of major process equipment including Crushers, Mills, and Flotation Cells.
1970	Jan.	"Definitive Estimate" completed.
	April	Agreement for Services between B-WKE and BCP signed.
1970	May	Export Import Bank Loan Agreement executed.
	June	Engineering and procurement approxiamtely 50% complete. Construction approximately 20% complete.
	July	Dedication of Kieta Aerodrome by Australia's Prime Minister.
	Aug.	First ship berthed at partially completed wharf at Anewa Bay.
	Sept.	(a) Slurry Manufacturing Plant became operational. (b) 11-MW Plant generated power for operation of shovels.
	Oct.	The 100-ton ore trucks drive over the new Highway to the Mine Site.
	Nov.	Mining commences with the trucks and shovels on removing the overburden waste.

The Winds of Change

DOUGLAS OLIVER
Professor of Anthropology, Harvard University.
Pacific Islands Professor of Anthropology, University of Hawaii.

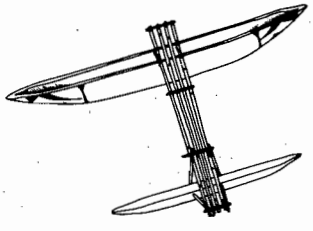
Just ten years ago the obscure western Pacific island of Bougainville was classified by New Guinea standards as 'undeveloped'. Now unimagined wealth is being released by a vast copper mining project which has brought about profound changes in the islanders' traditional ways of life.

What will be the future for the proud, intelligent Bougainville people? As Papua New Guinea races towards political independence, what will become of the island on which the full weight of the pressures for change is focused?

An eminent anthropologist who has known Bougainville for thirty-five years, Professor Oliver is uniquely qualified to foreshadow the future. Sensitively, and with the ease and simplicity of familiarity, he evokes an ancient society, its two centuries of contact with alien European influences, and its current dilemma. Events are moving apace.

Douglas Oliver is Emeritus Professor of Anthropology at Harvard University and Pacific Islands Professor of Anthropology at the University of Hawaii. His continuing study of Bougainville and the Pacific islands began in 1938-9. Since 1968 he has been employed occasionally by Bougainville Copper Pty. Ltd. to advise on the enormous social problems associated with the mine and to organize a research programme which, hopefully, will temper the effects of the mine's presence upon the Bougainvillians while ensuring that they benefit from it.

This article "The Winds of Change" is reprinted, by permission, from Douglas Oliver's book "BOUGAINVILLE – A PERSONAL HISTORY" published in 1973 by Melbourne University Press. Other books by the same author include "A SOLOMON ISLAND SOCIETY" and "THE PACIFIC ISLANDS".



The gold fever that gripped mainland New Guinea in the twenties and thirties spread to Bougainville Island as well, where small quantities of the mineral along with traces of copper were discovered in the mountains inland from Kieta. Beginning in 1933 a gold mine was operated at Kupei, but on such a very small scale that it was regarded by most expatriate officials and planters as a pathetic pipe-dream.

Then in 1960 an administration geologist re-examined the country around Kupei and confirmed the presence of intensive low-grade copper mineralization. Meanwhile, post-war mineral discoveries in Australia stimulated exploration for minerals in the nearby islands, and when new technologies demonstrated the profitability of mining low-grade copper ores, provided these occurred in sufficiently large quantities, two companies formed a joint enterprise in 1964 to test the feasibility of mining the Bougainville deposits. These were Conzinc Riotinto of Australia Ltd (CRA) and New Broken Hill Consolidated Ltd, the former contributing two-thirds of the venture capital, the latter one-third.

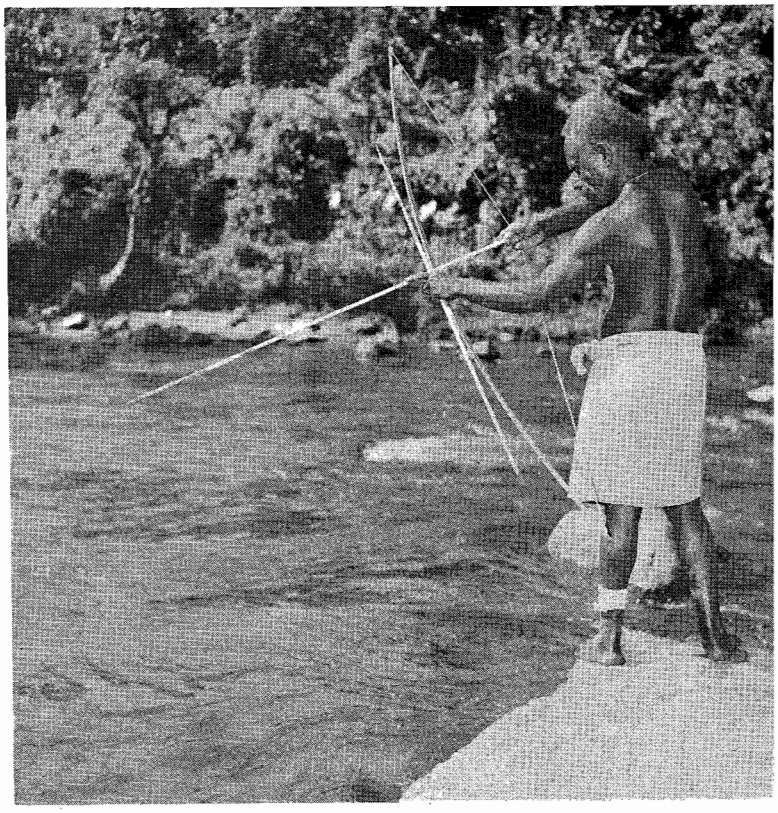
In contrast to the miniature Kupei enterprise the new venture was carried out with large capital resources, experienced management, great technical expertise, and the most modern of equipment. By the use of ground parties, the most promising area for further exploration was delimited in the Panguna valley, about 1.5 kilometres from Kupei. Panguna is only 14.5 kilometres from the coast by direct flight but those kilometres cover some of the island's most rugged terrain – swamps, streams subject to torrential deepening and widening, a 1200 metre mountain range, and a deep and unstable topsoil thickly overgrown with rain-forest vegetation. While a temporary access road was being constructed, helicopters had to be used to move in the first test-drilling equipment and supporting supplies. By mid-1966 diamond-drilled holes dug to 300 metres depths indicated the presence of a huge ore body of copper and significant quantities of gold.

While testing was underway a mining agreement was negotiated with the administration. According to its terms, if and when the company decided to go ahead with actual mining the administration would be offered 20 per cent of the enterprise's equity capital – an option which the administration subsequently exercised by acquiring 20 per cent of the shares issued by the company – plus a royalty

at the rate of 1.25 per cent on the free on board value of its revenues from sales of copper concentrates during the 42-year term of the initial mining lease. In addition, after three years of commercial operation the company was obliged to pay territorial taxes on its profits beginning at the rate of about 25 per cent per annum and increasing over the years to a maximum rate of 66 per cent.

Guaranteed markets had to be found for the mine's products, and financeing for construction of its mining and support facilities, a cost initially estimated to be in excess of $A300 million and eventually reaching $A400 million. The first requirement was assured by letters of intent exchanged with Japanese, German and Spanish smelters; the second by means of cash and equipment loans from companies in Australia, Japan and the United States, and from proposed sale of shares. Among the facilities needed for the enterprise as finally planned were crushers and a concentrator at the mine site, a port for concentrate storage and ship-loading, a 26 kilometre high-speed highway linking mine and port, and living etc. accommodation for some 3000 employees and their families. (As one indication of the size of the project, the company's electric power plant would have to generate about 135 megawatts – almost twice the amount generated throughout the rest of the Territory in 1971.) And all this on a small remote and rugged island with an indigenous population which though largely illiterate, technologically primitive and economically marginal, was nevertheless being moved toward self-government and political independence at a very rapid rate. In the words of one writer, this copper project ('unquestionably . . . one of the biggest mines in history') constitutes the most formidable industrial management task ever undertaken by Australians, or, one might add, by any mining company anywhere.

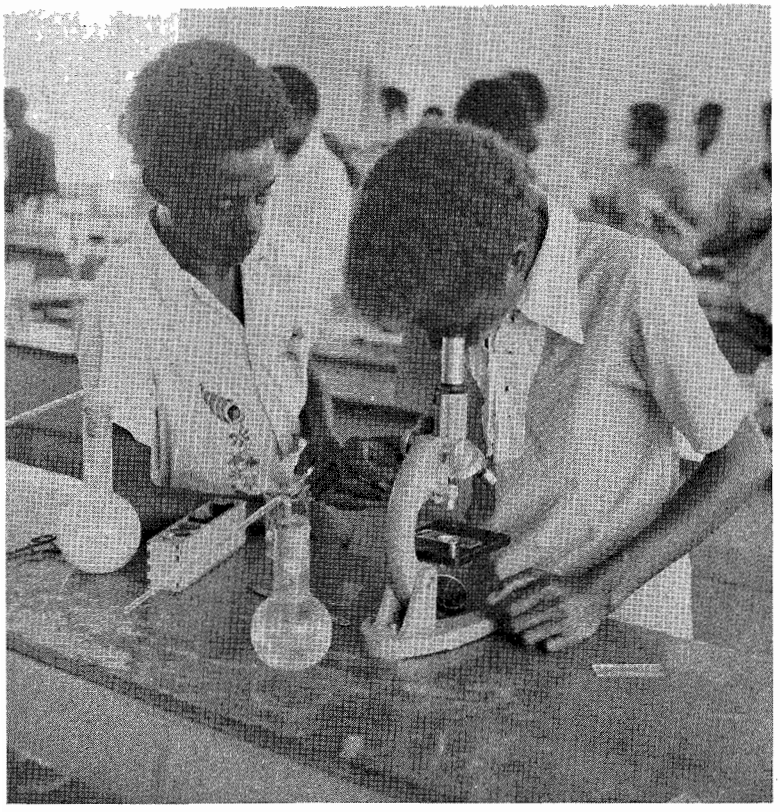
The decision to go ahead with mining was made in 1969, after an expenditure of over $A21 million in testing. By this time the ore body had been found to contain over 1000 million tonnes of variable quality; for economic reasons it was decided to mine only those locations containing about 900 million tonnes which had an average content of 0.48 per cent of copper and 4389 milligrams of gold per tonne. The open-pit mine will eventually become one of the largest man-made holes in the world; 2 kilometres wide, 2.4 kilometres long, and a minimum of 300 metres deep. Mountainous terrain along one side of the pit will produce benched terraces reaching in places as much as 800 metres in height. To reach the mineral-bearing ore it will be necessary to remove, initially by hydraulic lifting and by truck haulage, about 42 million tonnes of waste overburden. The ore itself will initially be processed at the mine site by crushing and concentration,and then moved by pipe line, in the form of a slurry, to Loloho the company's port some 26 kilometres away. When in full operation the concentrators' throughput will reach 90000 short tons of ore a day.



Using a floating cane shaft, traditional mountain stream fishing is still practised.

On the basis of the trend in current world copper and gold prices (copper $US0.50 per pound) the company will produce metal exports averaging $A170 million per annum to be compared with the value of all the Territory's other commodity exports which is estimated to be $A84 million by 1972-3. According to one calculation, the direct revenue which this project will eventually yield to Papua New Guinea's administration, including company taxes, royalties and dividents, employees' personal income taxes, customs duties, etc., will amount to about $A50 million a year. This is an amount equal to about one-third of the administration's total budgeted expenditure for the fiscal year 1970-1, and equal to the revenue obtained by the administration during that period from all other local, that is non-Commonwealth government, sources.

In addition to these financial yields to the administration, the operation of the Bougainville copper mine will continue to provide cash incomes for the indigenes on its own payroll as well as for numerous others who profit monetarily as land lessors, produce growers, and other participants in the mine's inevitable 'multiplier effects'. The company has encouraged indigenes' participation in these economic developments in a number of ways, including the large-scale purchase of foodstuffs (totalling $A300000 during the 1970-1 fiscal year), and assistance in the establishment of business enterprises. To facilitate



Bougainville Copper Pty. Ltd. provides in excess of $500,000 yearly for indigene education up to diploma and degree level.

the latter the company set up the Panguna Development Foundation Ltd, initially capitalized by a company-guaranteed loan of $A8 million, to set up commercial ventures in which indigenes would be encouraged to assume management and ownership as rapidly as possible. And finally, of the 1114000 Bougainville Copper shares reserved for sale within the Territory, 893000 were sold to individual indigenes or to largely indigenous groups, the remainder going to missions or long-resident expatriates, individuals or corporations. No breakdown is available showing the number of shares held by Bougainvillians, but the company made a special effort to publicize the offering locally.

Less tangible, but in the long run of perhaps equal importance to the Territory's economy, will be the opportunities which the project will provide to numerous indigenes to acquire new skills; company policy from the beginning has been to give preference in employment to the Territory's indigenes in both technical and staff positions. This policy has been reinforced by means of large-scale on-the-job training, by liberal donations of tertiary school scholarships (with no requirement for eventual company employment), and by deliberately rapid replacement of expatriate employees.

At the peak of the construction period there were some 10189 employees on the payrolls of the copper company and its associated contractors – 3861 expatriates and 6328 indigenes. It is expected that this number will drop to about 3000-3500 in normal post-construction times, and that the replacement (of expatriates by indigenes) will proceed at the following rate:

Percentage of indigenes, by job category

	1972	1975	1980
Managerial and professional	1	7	30
Sub-professional	4	25	70
Supervisory and skilled	36	75	95
Semi-skilled	95	100	100
Unskilled	100	100	100
Total	70	87	94

Internally as well, the company has sought to narrow the economic gap between indigenous and expatriate employees by paying the former with the highest wages deemed practicable; but wages present a different kind of problem, with political overtones. For even if the company would like and were able to pay indigenous and expatriate employees the same rates for the same jobs – and there is no evidence that this is not the case – it is constrained from doing so by its view of the economic realities of Papua New Guinea as a whole and its wider responsibilities as a leading employer there. Undoubtedly this policy will provoke scepticism and criticism from indigenous politicians and their sympathizers, but it is apparently based on the assumption that until conditions throughout Papua New Guinea permit a general and economically feasible wage rise to that level it would be irresponsible, even havoc-making, for the copper company to make such a move.

The company's offical social policies have been suffused with the same principles of ethnic equality – or indeed, pro-indigenous bias – as examplified in its effort to promote 'integrated' messing, housing and recreation, and in its stern sanctions (i.e. immediate dismissal) against inter-ethnic brawling.

Undoubtedly an ingredient of disinterested humanitarianism motivated the company officials most responsible for the pro-indigenous bias of these economic and social policies (none of these top officials had worked previously in Papua New Guinea), but candid acknowledgement was made by the company's management of the motivating factor of 'intelligent self-interest'. Situated as it is among a populace moving rapidly towards self-government and then independence, the company would invite almost certain political trouble by following policies that were neutral or pro-expatriate. At stake is not recovery of its $A400 million investment – that should be realized within a relatively short time and before any presently conceivable political events could radically after the company's ownership or management – but the prospect of decades of attractive profits, for present and future share-holders (including indigenes), after the original investments have been paid off. Company

management evidently intends to do all it can to avoid the nationalization or expropriation that has befallen many expatriate enterprises in other parts of the ex-colonial world. As the senior executive put it, 'If we cannot convince the first indigenous leader [of a self-governing Papua New Guinea] that the mine is in the interests of the country then we have failed.'

Unfortunately from the company's standpoint, and despite its relatively enlightened policies, several factors have intervened during its first few years of operations to create dissatisfaction and even hostility among some of its indigenous neighbours. Some of this ill-will was bought on by ignorance on the part of company personnel or ineptness on the part of administration officials during the early stages of exploration and land resumption. Some has been operations when at several stages in the exploration and testing the scope of the project has had to be expanded. Still other frictions have been engendered by the mine's mode of financing, by management's need to commence revenue-earning production as rapidly as possible in order to retire heavy-interest loans. And still others stem, probably inevitably, from the very nature of the enterprise and of its geographic and cultural setting: a privately owned and managed profit-seeking business with large manpower and land requirements situated among a remote, commercially underdeveloped and, by European standards, culturally archaic populace.

Predictably, the factor that has led to most discontent among Bougainvillians has been the company's acquisition of land -- land for the mine itself, for roads and power lines, for disposal of tailings, for port and storage facilities, and for employee housing. The troubles began with the appearance of the first prospectors and became worse when mapping and test-drilling proceeded. It resulted in physical threats to company personnel and removal of survey markers. At one point the administration felt obliged to send in police to safeguard further testing and mapping.

By the time that land had to be acquired, and not just camped on, for the larger-scale delineation of the ore body's extent and content, the indigenous population in the vicinity of Panguna had been compelled to acknowledge the presence of the vast new enterprise in their midst. A few of the villagers near the mining complex seem to have greeted events with pleasurable anticipation of the material rewards they would reap from it, while a few others became and remained implacably hostile, Most of them however appear to have become resigned more or less disconsolately to what they regard as another example of the white men's cupidity, deceit and irresistible power.

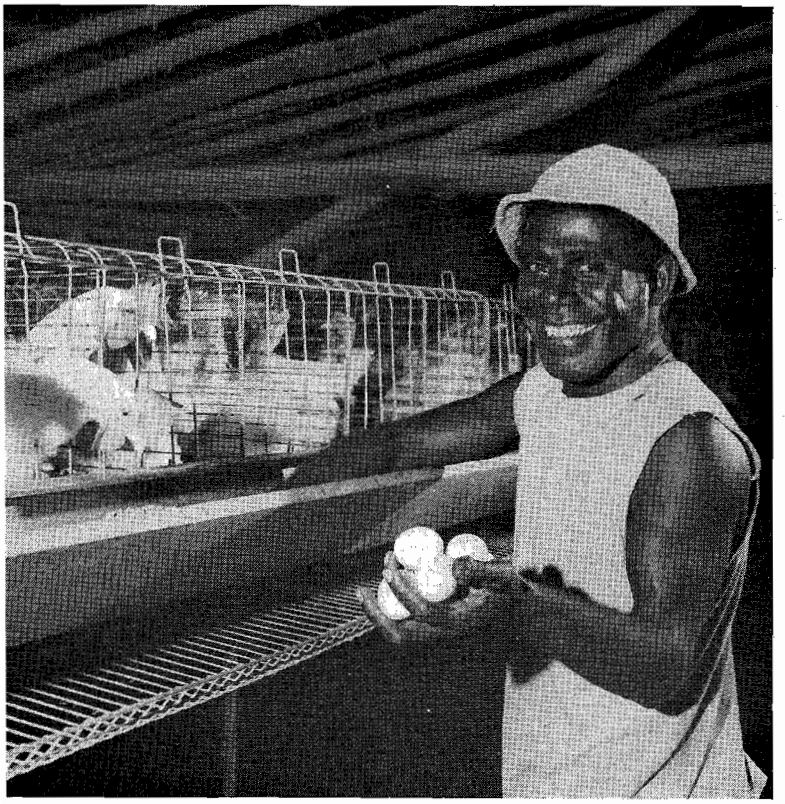
The first company prospectors to enter the large Panguna valley itself reported it to be uninhabited and only sparsely utilized; but to conclude from this that the land itself was only loosely owned and socially inconsequential was tragically misguided. One can excuse reasoning of this sort on the part of company personnel, most of whom were

White residents and indigenes shop side by side, for locally grown produce in a native market place.

new to New Guinea; however, after a half century of New Guinea experience one would expect that the administration might have gained more insight into the complexities and imponderables of indigenous land ownership, and would have acted accordingly.

Perhaps no two language communities on Bougainville-Buka have exactly the same ideas about land ownership, but they all share certain rules in common. For example, there is probably no tract of land anywhere (including areas of fresh water and enclosed areas of the sea), however remote or economically useless by European standards, that is not identified more closely with some persons than with others. In other words, in Bougainvillians' terms there is no such thing as wholly free, unowned land on their islands. For example, on one occasion in 1939, when the author visited Puruata Island just off the coast of Torokina and within sight of smoking Mt Bagana, he was informed that the reason his Banoni-speaking hosts did not venture up the slopes of the volcano, despite their lively curiosity about it, was that it was the abode of Rotokas-speaking spirits. Some other traditional rules respected by all or most Bougainvillians concerning land ownership are as follows:

1. Different features of a landscape may be 'owned' by different persons or categories of persons, for example, soil may be owned separately from the plants growing in it. (However, it should be noted that Bougainvillians do not traditionally distinguish surface from sub-surface features



Modern poultry farming techniques are replacing the old custom of village fowls who fended for themselves and hid their eggs in the scrub.

of land in terms of ownership.)

2. The persons owning any feature of a tract of land tend to be multiple rather than individual, especially with regard to the more permanent features such as soil and long-lived economically useful trees.

3. In instances of multiple ownership of any land feature, the tenure rights are truly 'joint'; some individuals among the joint owners, male or female, may tend to exercise more decisive authority than others in their land's use, but disposal of it usually requires consensus.

4. Ownership of the more permanent features of a tract of land changes mostly through the process of inheritance and mainly through women. In some places the ownership of such features may become transferred in consideration of gifts or services of some kind, but this is rarely, probably never, carried out in a commercial spirit of buying and selling, and such exchange transactions are invariably between kinfolk.

5. In general, Bougainvillian landowners are a jealously opposed to unauthorized trespass as are Europeans, but if properly requested they are usually most generous in granting to others the temporary use of their lands, including the right to plant short-lived food crops on them.

Just contrast these principles with those under which the copper company was officially authorized to operate.

According to the terms of the Territory's 1928 mining ordinance under which the company's initial prospecting took place, no permission was needed either from the mining warden or the indigenous owners, and the only compensation due to the latter was for damages to their property resulting from the prospecting. Also, under Australian law, ownership of certain precious metals in the Commonwealth (and thus, in the Territory) is vested in the administration. In mid-1966, an amendment was made to the 1928 ordinance requiring the company to pay an 'occupation fee' to the owners of land actually occupied in the course of mining, but this amounted to only $A2 an acre per annum, or 5 per cent of the assessed unimproved value of the land, whichever is greater. Moreover, no change was made in the provision that all royalties would go to the administration for use throughout the whole of the Territory.

Some local landowners fatalistically accepted the payment of the occupation fees, while others refused them on the grounds that acceptance of payment meant approval of the transaction. (Persons in the latter category have their moneys held in trust by the administration on their behalf, but whether they or their heirs will ever accept them is problematical.) The principle that royalties paid on the treasure from one's own land would be used for the Territory as a whole, and not for the land's owners, or even for Bougainvillians in general, was considered by some Bougainvillians to be insanely alien, or transparently deceitful. This reaction was reinforced by the belief held by many of the landowners that the revenue in question would be spent not on mainland New Guinea indigenes, which would be bad enough, but on more luxuries for the already affluent expatriate bureaucrats. Eventually Bougainville's House of Assembly member, Paul Lapun, succeeded in persuading enough of his elected fellow members to defeat the administration and allocate 5 per cent of the expected mine royalties – that is 5 per cent of 1.25 per cent of total copper revenue – to the Panguna landowners themselves. It is safe to predict that the royalty issue, both its proportion to total company revenue and its ultimate disposition, will continue to disturb the company's local public relations for many years to come.

Bougainvillians have been affected in various ways and to widely differing degrees by the company's land acquisition. Some have been deprived of actual or potential food-garden sites. Others have lost cash-producing cocoa trees or coconut palms. In still other instances individual homes or whole hamlets have been demolished or moved to make way way for the mine and its attendant activities.

In instances involving arable land or crop-bearing trees, claims for damages and losses have been negotiated between owners and the company be administration officials. By current, market-fixed economic standards most such payments would probably be characterized as 'liberal' – but to an indigenous owner unaccustomed to evaluating land in monetary terms, such standards have little or no meaning.

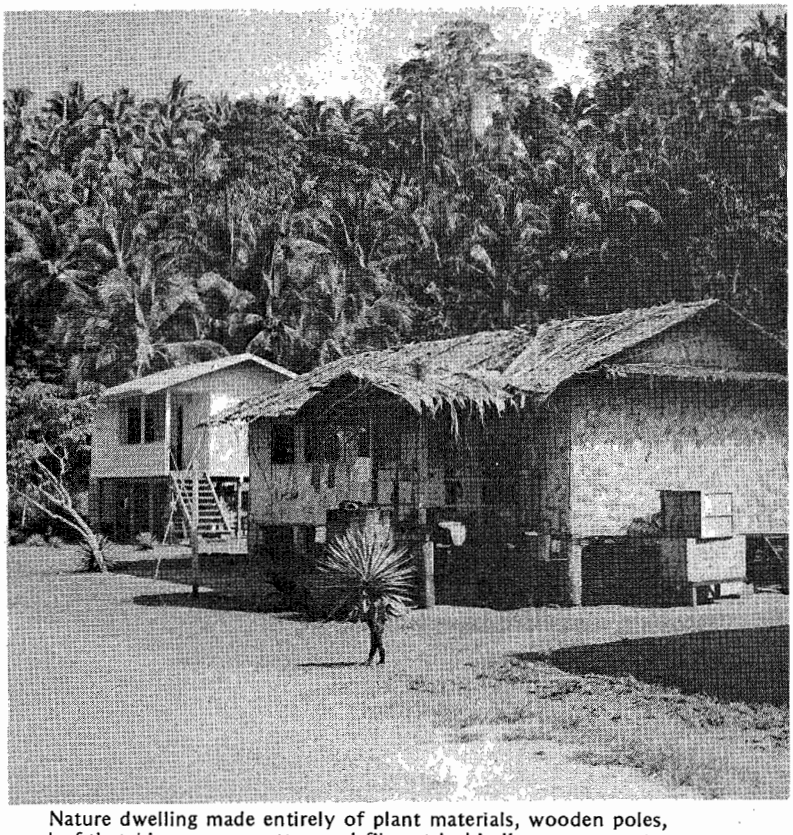
Where resettlement has been necessitated, the company has usually borne most or all of the monetary costs of moving and rebuilding, But again, for people whose ties to residence are deeply sentimental and even religious, the costs of moving involve much more than money.

The most conspicuous instance of resettlement was that of the village of Moroni, whose residents were moved into new houses built on a bulldozed mountain top overlooking the mine site. These costly prefabricated, multi-room dwellings might seem to be a rich fulfilment of many Bougainvillians' expressed wish for European-style housing, but whether Moroni villagers consider them an adequate exchange for their former place of living would be difficult to discover. Casual questioning would undoubtedly elicit statements both pro and con, but it would require much more study to uncover the effects of this revolutionary change in the community's whole way of life.

The mountaineer Moronis accepted more or less peacefully the changes forced upon them; not so the Rorovanas, who dwell north of Kieta along the coast. Some permanent housing for company personnel has been built in a narrow valley directly adjacent to the ore body, but elsewhere around Panguna the land was too steep-sided to house the numerous employees and their families who would make up the company's permanent workforce. Hundreds of acres were needed, for houses, stores, schools, recreation places, a hospital, etc., and not for short-term transients willing to put up with camp-like conditions in return for high pay, but for a demanding, and hopefully contented, long-term staff. And while the company's policy called for rapid localization of its personnel, it had to be acknowledged that expatriates would continue to occupy the higher-ranking jobs for years to come.

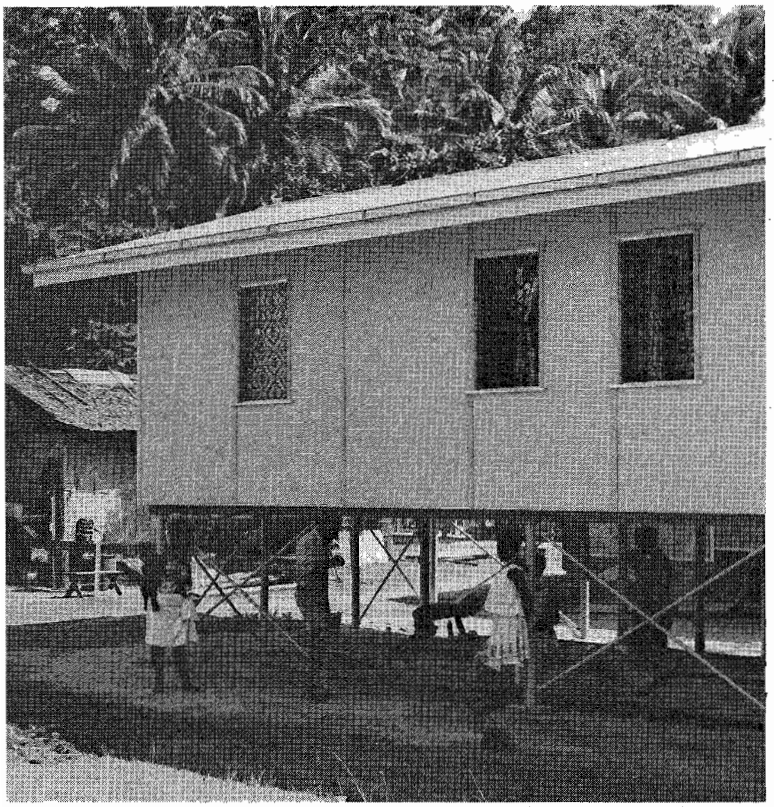
One possible place for the future town was found in the foothills near the highway and about mid-way between mine and coast, an ideal site in terms of location and climate. However, acquisition of the site would have required resettling scores of indigenes, including some already moved from homes near Panguna, and this the responsible officials were unwilling to do. Instead it was decided to establish the new town on and around the tract occupied by the European-owned coastal plantation of Arawa. This was a low-lying, sun-baked flat some sixteen kilometres by road from the mine where most of its residents would work, but having the humanitarian and, ultimately, political advantage of alienating only relatively small areas of indigenous-owned land.

Acquisition of the expatriate-owned plantation involved a large price but no major political hazards for administration or company, but when moves were made to acquire some nearby indigenous-owned properties for the port, their owners, the Rorovanas, refused to sell it, and it was reported that they were encouraged in their stand by one or more of their Marist missionaries and by the foreman of the plantation. In the end, the administration had to assert its overriding powers to force the sale, and even then police were required to remove some protesting Rorovana women from the paths of the incoming bulldozers — a confrontation which predictably, attention upon the event, and which led more or less directly to some local political developments.



Nature dwelling made entirely of plant materials, wooden poles, leaf-thatching, woven rattan and fibre-strip bindings.

Another large-scale effect of company operations on indigenous land holdings has begun to take place to the west of Panguna. Although the port and town site (and hence the road, pipe-line, and powerlines) are located east of the mine site, the latter is west of the island's watershed at this point, and its streams carry the ore body's overburden, and eventually the ore tailings, down the Kawarong and Jaba rivers to the west coast outlets. By mid-1971 these naturally clear streams were already silted, and it was openly acknowledged by the company that the flow of tailings would eventually raise the river beds significantly and cover large adjoining areas with sediment. Fortunately this part of the island is only sparsely inhabited, but it became necessary to move a few settlements to higher ground, and to resettle all the inhabitants of the coastal village situated near the Jaba's outlet. The company acknowledged its responsibility to pay damages to indigenes whose fishing grounds were being spoiled by the water's silting, although lack of records of previous catches made it difficult to support or refute the amounts of such claims. And finally, soil scientists and agriculturalists were commissioned to survey the tailings



Modern company-built indigene occupied, all-electric 3 and 4 bedroom houses range between 10 and 15 squares.

area and draw up plans for rehabilitating it, so that it is 'possible' (probable' may be too optimistic a word) that this large area may someday be capable of supporting a larger population than ever before.

Thus, a considerable number of Bougainvillians living in areas directly within the area of the company's operations have had their lives changed in numerous, and sometimes disagreeable, ways. To many whose homes and gardens have not had to be moved, the construction of this huge enterprise has brought some physical discomfort and psychological stress. Households bordering the new roads have been subjected to the constant jarrring noise of large trucks and the clouds of dust raised by them. In many places the privacy normally enjoyed by the indigenous settlements has been violated by strangers sightseeing, curio-seeking, or in search of women. Both company and administration have sought to discourage this practice, but without much success. (For one thing, some of the younger villagers themselves have abetted the nuisance, for the profit they can derive from hosting, selling, and pimping.) So far this alien invasion has kept mainly to places accessible by motor vehicle from the company's several camps of construction workers, but some of the more enterprising visitors have begun to visit villages as far away as Siwai, thereby raising doubts, incidentally, in some indigenes' minds about the desirability of island-wide roads.

The principal anxiety aroused by the excursioning aliens is the real or imagined sexual threat they pose towards their womenfolk. And although fellow blackskins from distant parts of Bougainville and Buka also take part in these excursions, they seem to arouse less anxiety than whites or redskins. The redskins are generally imagined to be sharper witted and more combative, and the whites, being of course 'masters', have power on their side. Some of this anxiety may derive from the occasional known instance of Bougainvillian girls having indeed shown preference for the more sophisticated, freer-spending foreigners. In any case, this sexual threat should not be minimized when listing the losses suffered by many in consequence of the mining enterprise.

Other observers, including some Bougainvillians themselves, consider that the mining enterprise is greatly accelerating the destruction of that which was good in indigenous society – by dispersing families, weakening parental authority, encouraging sexual immorality, disdaining native customs, etc. Evidently, much of this kind of criticism is generational, and hence somewhat biased in evaluation, but whether one considers the changes destructive or otherwise, the fact remains that the existence of the mine has already begun to speed up these changes.

In addition to all these deprivations, real or imagined, some Bougainvillians regard the mining as the unwarranted removal of a valuable and irreplaceable natural resource. The more sophisticated indigenes voicing this sentiment acknowledge that they themselves are not now in a position to develop the enterprise on their own. They argue, however, that the ore could either have been left in the ground until they themselves were capable of mining it; or that the administration should have sought capital from elsewhere and operated the mine for the exclusive profit of Papua New Guineans in general (or Bougainvillians in particular), instead of granting mining rights to a private, profit-making, expatriate company. Whether or not these recriminations are justified, they will undoubtedly persist and probably gain weight as a political issue for a long time to come.

Some of the advantages, present or projected, for the Bougainvillians have already been mentioned. They include the large increase in individual cash incomes as a result of direct company employment or of the industry's various 'multiplier effects'; the construction of new roads and increased external communications; and the acquisition of new skills. To these might be added the arguable gains accruing to the islanders as a result of their having been ushered out of economic and cultural stagnation into modernity by means of a relatively benevolent form of colonialism. But whether the gains offset the losses is a matter for debate. At the present time Bougainvillians themselves, including some not yet directly affected by the industry, differ widely in their estimates. A decisive answer to this question will have to await later judgement, if indeed it will ever be possible to answer it by applying criteria acceptable to most of the Bougainvillians themselves.

Bechtel in Australasia

In 1959, Bechtel established a permanent office in Melbourne to bring to this country, a new concept in comprehensive engineering, procurement and construction service. In the ensuing years this concept has been well received by Australia and New Zealand and a substantial number of engineering and construction programmes have been undertaken. These are diverse in size and type ranging from studies to projects ranking with the largest ever undertaken in the southern hemisphere.

The Melbourne office of Bechtel is now staffed with approximately 100 people with a similar number of personnel assigned to site project offices in the field. A full complement of technical and service departments including engineering, estimating and procurement, administration and accounting and manpower services is maintained in Melbourne, and the local operating entity, Bechtel Pacific Corporation Limited, is an affiliate of the world-wide Bechtel organization from which support is drawn in all phases of its activities.

In the course of its work, Bechtel has become a substantial employer of labour as well as of other contractors and subcontractors throughout Australia and New Zealand. It therefore possesses greater than usual knowledge of labour practices, wage patterns, union negotiations and worker productivity. Its relationships and experiences with other contractors and subcontractors, both local and international, who perform construction in Australia give to Bechtel intimate knowledge of their identities, capabilities and effectiveness.

The following brief descriptions of a number of important projects illustrate Bechtel's work in Australia.

AMPOL REFINERIES Ltd. – Engineering, procurement and construction of Ampol's 45,000 BPSD Lytton Refinery, near Brisbane.

CLIFFS W.A. MINING CO. ROBE RIVER PROJECT – Feasibility studies, engineering, procurement and construction of iron ore development and associated facilities.

CONTINENTAL CARBON CO. (Aust.) Pty. Ltd. – Engineering, procurement and construction of 30 million pounds per annum carbon black plant.

FREEPORT INDONESIA Inc., West Irian – Bechtel-sponsored joint venture for development of substantial copper ore deposit in West Irian.

INTERCONTINENTAL HOTELS Corp. – Planning, design, construction of Melbourne's "Southern Cross" Hotel. One of 32 such projects for client.

LAPORTE TITANIUM (Aust.) Pty. Ltd. – Engineering, procurement and construction of 10,000 LTPA titanium dioxide plant near Bunbury, W.A.

MINISTRY OF WORKS, N.Z. – Engineering, procurement and management of 700,000 KW Manapouri Hydroelectric Project, and 240 MW Marsden Point Power Station.

MONSANTO CHEMICALS (Aust.) Ltd. – Engineering, procurement and construction of 1969 Chemical Plant of Year Award plant at Footscray, Vic.

MOONIE PIPELINE Co. Pty. Ltd. – Feasibility study and engineering management of Moonie-Lytton 190 mile oil pipeline.

Mt. NEWMAN MINING IRON ORE PROJECT, W.A. – Management responsibility for 30 million LTPY iron ore development.

NATURAL GAS PIPELINES AUTHORITY OF SOUTH AUSTRALIA – Feasibility Study, engineering and management of 480 mile, 22 inch gas pipeline.

PICKANDS, MATHER & Co. International – Study, engineering, procurement and construction for development of Savage R. iron ore complex.

WEST AUSTRALIAN PETROLEUM Pty. Ltd. – Feasibility study, design, construction, supervision of WANG 258 mile gas pipeline system.

WESTERN MINING Corp. Ltd. – Feasibility study, engineering, procurement and construction of 15,000 LTPY nickel concentrate leading plant, W.A.

SYDNEY B. FORD

SYDNEY B. FORD, Bechtel-WKE Project Manager, has been associated with the Bechtel organisation for over twenty years in various capacities including Project Engineer, Manager of Engineering, Manager of Business Development and other assignments in connection with specific projects ranging in the various fields within the Mining and Metallurgical industries, including iron ore, aluminium, alumina, copper and nickel. Since his assignment as Project Manager on the Bougainville Copper Project, Mr. Ford has returned to San Francisco Home Office of Bechtel Corporation as Manager of Operations for the Mining and Metals Division.

LAMAR F. HUTCHISON, is Vice-President and Resident Manager of Bechtel Pacific Corporation, Melbourne. During his three years in Australia Mr. Hutchison has been involved in such major projects as Bougainville Copper, Mt. Newman, Robe River and the Kurnell Refinery expansion. He is a graduate in Mechanical Engineering.

LAMAR F. HUTCHISON

Project Management

DESIGN ENGINEERING, PROCUREMENT and CONSTRUCTION MANAGEMENT of all facilities for the BOUGAINVILLE COPPER PROJECT

Bechtel—WKE, a joint venture of
Bechtel Corporation and Western Knapp Engineering,
San Francisco.

by Lamar F. Hutchison,
Vice-President and Resident Manager,
Bechtel Pacific Corporation, Melbourne

and

Trevor A. Pfeiffer,
Senior Cost Engineer,
Bechtel Pacific Corporation, Melbourne.

TREVOR A. PFEIFFER, is Senior Cost Engineer with Bechtel Pacific Corporation, Melbourne. Since joining the Company in 1965 he has completed assignments on such major projects as Bougainville Copper, Monsanto Chemicals and Petroleum Refineries in Australia.

INTRODUCTION

If you can let your imagination run wild to the extent that you can visualise a huge pile of houses of 15 squares each — a pile of 125,000 houses, then you can come close to envisioning the total amount of earth works, excavations and fill, required to get the Bougainville Copper Project completed.

If that is too much for you, imagining such a pile of houses, try it another way. In an area equivalent to that bounded by Spring, Latrobe, Spencer and Flinders Streets in Downtown, Melbourne, imagine a uniform, vertical walled excavation deep enough to easily bury six storey buildings, and you will have come up with approximately the same volume as the pile of houses. The Bougainville project required some 43 million cubic yards of excavation and 25 million cubic yards of fill — a total of 68 million cubic yards of earth moving to bring it into being.

It is with good reason that the Bougainville Copper Project is recognised as the largest grass roots project of its kind in the world to date.

If you need more convincing as to the size of the project consider 980,000 sq.ft. of roofing and wall cladding, 4,000 tons of plate work, 10,600 tons of structural steel. Getting the job done required 760,000 sq.ft. of concrete form work and 184,000 cubic yards of concrete were mixed on site. To complete the job it took 275,000 lineal feet of piping, 83,000 lineal feet of cable tray, 102,000 feet of conduit and 1,850,000 feet of wire and cable.

Materials, equipment and tools are far from being the total requirement for constructing a huge industrial complex such as Bougainville. You can better understand this if you know that personnel on site consumed 1,800 tons of fruit, 4,000 tons of meat, fish and poultry, 4,200 tons of vegetables, 43,000 gallons of ice cream and 6,000,000 eggs.

About the only other item of information available to demonstrate how big is big is to tell you that the beer consumption amounted to 22,250,000 cans of 13 oz. (equivalent) each.

It was a tough job beating the rain and isolation to the point where films became boring, tall stories lost all credulity and there was never enough mail from home. Normal 60 hour work weeks, with varying requirements for overtime, still left many men with time on their hands; but work they did, and during 1971, the peak work year, there were 30,486,035 manhours expanded on the job.

The job consisted of engineering, procuring and constructing all of the facilities necessary to process 90,000 tons per day of copper ore to produce a concentrate dried and ready for shipment to clients around the world. Bougainville Copper Pty. Limited is the visionary mining company that brought it about, Bechtel-WKE, a joint venture of Bechtel Corporation and Western Knapp Engineering, both of San Francisco, had full responsibility for engineering, procurement and construction management of all facilities (see Attachment 1).

There were dozens of contractors involved — most from Australia, several from Papua New Guinea and some from

other countries around the world. Each of the contractors has their own story to tell; only the mining company can adequately express the 'owners' point of view. In the following pages we will attempt to point up some of the interesting details of the job as encountered by Bechtel-WKE, the engineers and project managers.

LOCATION

The Copper Project site is located on Bougainville, the principal island of the northern group of the Solomon Islands; politically a part of Papua New Guinea. The island is approximately 120 miles long by 30 miles wide and is distinguished by the steep Crown Prince mountain range which reaches elevations of over 8,000 ft. The range drops sharply to the east and west coasts, thus providing only very limited areas of level land.

Bougainville Island is part of the volcanic belt which virtually encircles the Pacific Ocean. Several volcanoes are situated along its North-West/South-east axis. Mt. Bagana, located 24 miles from the deposit, is highly active; others less active or are dormant.

Bougainville is the most eastern of the islands controlled by the Administration of Papua New Guinea. Papua, a British Protectorate since 1884, became Australian Territory in 1905. New Guinea, a German Territory until World War 1, was mandated to Australia in 1921 and became a United Nations Trusteeship Territory administered by Australia after World War 11. Since that time the two Territories have been administered as one.

Political self-determination was coming progressively to Papua New Guinea even as the mining project was born, and as a step towards self-government, elections were held in February/March 1972, for the 100 member Papua New Guinea House of Assembly. No one party achieved a controlling majority of seats, however, a Government was formed comprising a coalition of five groups (National Coalition) headed by the Pangu Party. In addition to the 100 elected members, there were three expatriate Australian Official members of the House who were not subject to election and who participated in an advisory capacity only.

Bougainville Island elects four representatives to the House of Assembly, which meets in Port Moresby. Tribes also elect members to local councils and associations of tribes which represent indigenes politically and in business negotiations.

The 70,000 people of Bougainville and adjoining Buka Island are Melanesians and are virtually jet black in colour. They take pride in being the darkest group in Papua New Guinea. The Bougainvillean is strongly family oriented, most often religious and of generally high moral standard. There are nineteen main language groups, but Pidgin is becoming increasingly well known and the one which allows the most widespread communication.

The temperature on the island's coast varies from daily highs of 90°–95°F to nightly lows of 70°–75°F. Temperatures at Panguna (2,300 ft. elevation) vary from highs of 84°–90°F to lows of 60°–65°F. Panguna was the more congenial working area for most expatriates. However, rainfall at Panguna averages about 190" per year, with as much as 25" per month in the period of December through April. Rainfall on the coast totalled 120" in 1971.

Prior to the advent of the Copper Project, developments on Bougainville had been mainly of an agricultural nature. Copra and cocoa were produced efficiently on plantations either owned or leased by expatriates with single areas of up to 4,000 acres being under cultivation. Subsistence gardening was the main occupation of villagers and a large trade was initiated by the mining company with these villagers to provide food for construction camps and fresh produce for the townsite markets.

Road transportation on Bougainville was limited to about 60 miles of road from Panguna to approximately 20 miles beyond Aropa airstrip. Main locations of the Project connected by road were Panguna (Mine site), Anewa Bay, (Port site), Arawa (coastal town newly constructed) and Kobuan. Kobuan, an early construction staging camp, was located some three miles east of Kieta which was the Administration headquarters before removal to Arawa in 1972. Kieta had existing dock facilities capable of berthing ships up to 5,500 dwt.

Aropa aerodrome, located a further ten miles south of Kieta, was originally capable of handling aircraft no larger than DC-3's. In mid-1970, the Administration completed lengthening and paving the runway so that Fokker Friendship F-27's and cargo planes including Hercules type aircraft could be accommodated. The runway then had a sealed gravel surface, 5,400 feet long and 100 feet wide.

The 596 mile flight to Port Moresby took approximately three hours, and connected directly with daily services to Australia. Total flight distance from Kieta to Melbourne was 2,811 miles one way and required 12 to 14 hours total travel time for the one day through trip.

ORE BODY

The ore deposit is located at Panguna, approximately 16 miles inland in the Kawerong Valley, on the western fall of the mountain range in the south central area of the island, at an elevation of 2,300 feet. The Panguna mineralisation is predominately in the form of chalcopyrite with some bornite along thin veins. Gold and silver are contained in the chalcopyrite but free gold is rarely to be seen. Pyrite and magnetite occur along veins in disseminated form, and there are also small amounts of molybdenite. The primary ore was covered by layers of secondard and oxidised ore and, in places, by boulders, volcanic ash, alluvium and soil.

ENGINEERING

By the mid-1960's Conzinc Riotinto of Australia, the parent company of Bougainville Copper Pty. Limited had carried out extensive exploration work and feasibility studies which permitted them to carry forward with confidence and zeal the projected new mine. Their exploration work actually began in 1939 and in June 1967 Bougainville Copper Pty. Limited was incorporated for development of the ore body.

In August, 1966, Bechtel-WKE engineers first visited the mine site as a preface to assisting in the carrying out of studies and providing competent reports. In the following years the relationship flourished and April 1969 saw the beginning of the first project engineering work in the San Francisco offices of the Bechtel-WKE joint venture (table No. 2).

In the San Francisco project office engineering was performed for all facilities of the project except townsites and the power plant. Work on the townsites was handled by Australian Town Planning consultants under the management of Bechtel-WKE.

The mining company had reserved for their own direct action the continuing exploration programme, pre-production development of the mine, the purchase of mine equipment, the build up and training of operating staff and the operations of both the port and the mine towns.

A very close liaison was maintained between Bougainville Copper and Bechtel-WKE to avoid areas of overlapping activity and to assure completion of all the engineering programmes and construction requirements in a timely fashion. Specifically, the joint venture had full responsibility for:

Process facilities — ore crushing, screening and concentrating, thickening, pipe line transport, filtering, drying and storage.

Port, wharf and concentrate ship loading facilities.

Power production and transmission.

Port and Mine townsites.

Service facilities such as roads, bridges and site communications.

Temporary construction facilities including camps and buildings, ship freight handling and personnel transportation.

A specialist group from Bechtel's Los Angeles Power Division designed and provided services for the construction of the 135 mw steam power station. The design group peaked at about 40 men and carried on their work with direct responsibility to project management.

The San Francisco Project office approached their work from two points of view, these being process and non-process facilities. A staff reaching approximately 220 engineers, draftsmen and non-technical personnel which produced a total of 5,200 drawings and the corresponding specifications for the procurement of materials and equipment.

A Project office in Melbourne was set up to handle the miscellaneous engineering functions and to supervise the town planners. One of the prime functions was that of contracting the major parcels of work involved in the project. To perform these tasks an additional 190 technical and non-technical employees provided services.

A field engineering office was established at the mine site very early in the project. The engineers at this location were responsible for interpreting drawings and specifications for Bechtel-WKE inspectors and for the multitude of contractors performing work. They were also responsible for handling many of the miscellaneous design tasks, especially for temporary facilities, which are inevitable and unavoidable on a project of such magnitude as that of Bougainville Copper. At the peak of activity the site engineering office had a permanent staff of over 30 people supplemented periodically by technical personnel from other engineering offices, contractors and suppliers from all over the world.

Engineering for the Bougainville Copper Project was one of those nearly unbelieveable exercises in collaboration and understanding which are so necessary to successfully accomplish an undertaking of this magnitude. The interchange between San Francisco, Los Angeles, Melbourne and Site engineering offices of corresponence, sketches, drawings, specifications, photographs, reports, telexes and telephone calls demanded constant attention and control that can only be achieved through the inspiration of a common cause and a total understanding of mutual problems and goals.

Beyond the purely productive engineering activities there were intertwined close liaison relationships with the client technical organisations at each of the project offices; the shoulder to shoulder co-operative efforts of engineers, procurement personnel, estimators and schedulers; the continuing dialogue with suppliers of equipment and materials; and the indefatigable search for total understanding of work methods and goals with contractors' engineers and planning staffs.

The Bougainville Copper Project was one of numbers — all sorts of numbers — of tremendous magnitude. Total engineering effort for the job conformed, and rounded off at approximately 1,000,000 manhours or the equivalent of 500 qualified technicians working full time for a year.

PROCUREMENT AND LOGISTICS

The multitude of finely co-ordinated procurement activities were conducted by the Project offices established by Bechtel-WKE in Melbourne, Bougainville, Los Angeles and San Francisco. By maintaining close collaboration between these offices and the area offices of Bechtel Corporation, San Francisco (serving the U.S.A., Canada, Japan and South Africa) and Bechtel International Ltd. London, England serving the British Isles and the European Continent), the advantages were realised of direct contact with vendors in the areas in which tenders were solicited or orders placed.

Major process equipment for Bougainville was covered by some 700 purchase orders issued in the United States to suppliers in Japan, England, Sweden, Finland, Canada and the U.S.A. In addition, there were approximately 200 purchase orders issued for major power plant and switch yard equipment principally from England, Japan and the U.S.A.

There were almost 11,000 purchase orders written for the Bougainville Copper Project. More than 1,000 of these were handled through a sub-office of procurement and logistics in Port Moresby and almost 3,000 were issued by procurement personnel permanently located on project site. The Melbourne office emitted just under 6,000 purchase orders for materials, equipment and food coming out of Australia, New Zealand, Singapore, Japan, United States, England and Canada.

The Bougainville Copper Project offered many challenging and interesting problems in logistics. The ocean freight portion began in earnest in June, 1969, with shipments from west coast, U.S.A. direct to Kieta, Bougainville.

As freight for the project increased in volume, several charter vessels handled large single shipments, such as the nineteen 100-ton capacity Euclid trucks shipped ex-Cleveland in May, 1970, and in September 1970, twenty-two similar units. The loading of the second lot of trucks on the "Yanagi Maru" was one of the largest shipments the Port of Cleveland had ever handled. The unusual size and weight of these trucks necessitated the manufacture, by the steamship line, of a special lifting device for loading and unloading.

In June, 1971, the charter vessel "Golfo di Palermo" of 20,000 ton capacity was loaded with 11,239 short tons of bulk grinding balls at Sault Sainte Marie — the largest ever

export shipment of grinding balls from Canada.

To obtain direct port of call shipping service to Kieta from the east, gulf and west coasts of North America it was necessary to ship in minimum lots of 500 short tons as inducement to the shipping companies which service this area. Toward the latter part of the project it became necessary to embark material from North American ports direct to Sydney because of lack of minimum tonnage. Trans-shipment to Kieta was accomplished through the long-term charter vessels serving the project. At the peak of cargo handling, nine ships were under charter to supply materials, equipment and food to the Bougainville Copper Project.

Some special problems taxed the ingenuity of logistics personnel. On July 1, 1971, a U.S. west coast longshoremens' strike necessitated the diversion of cargo from the west coast to the gulf area, and approximately 500 tons of equipment became strike-bound on the Los Angeles docks. It was necessary to re-order a portion of this strike-bound material and air freight to jobsite. It was felt, in the beginning, that the strike would be of short duration; however, this proved to be incorrect as it lasted 135 days – the longest strike in U.S. maritime history.

Air freight shipments played an important role for the Bougainville project by transporting critical materials to jobsite. Such shipments, in general, were consolidated during a given week in New York, Houston, San Francisco and Los Angeles and flown over a weekend to Sydney; transferred at Sydney for further air carriage to Port Moresby and again transferred at Port Moresby for movement to Kieta. Midway through the project air shipments were consigned directly to Port Moresby, and even to site, from North America and the United Kingdom.

The U.S. west coast longshoremen's strike in October, 1971 necessitated chartering several Hercules L-100 aircraft flights for movement of critical material needed at jobsite.

Air freight was handled at Aropa Airstrip through regularly scheduled airline services. DC-3 aircraft were used until July 1970, at which time improvements to the airstrip completed by the Administration allowed the use of Friendship F-27 aircraft on regular services.

Initial island port facilities consisted only of a wharf at Kieta Harbour capable of berthing ships of 5,500 dwt, with inadequate cranes or other dockside handling gear. An 11-mile coastal road from Kieta to the project port facilities at Anewa Bay existed but was of very poor quality, with steep grades and sharp bends.
To overcome this, a temporary wharf was constructed at Anewa Bay, in 1969, to berth ships of approximately 1,500 tons. Prior to completion of this wharf, freight was landed via a ramp from a ship equipped with bow doors. The permanent Anewa Bay wharf, capable of berthing 50,000 dwt. vessels, was used for freight after its completion in July, 1971, but, until that date, freight from vessels of over 1,500 tons was barged ashore.
Getting back to what has previously been referred to as big numbers for a big project, shipping tonnages certainly qualify for inclusion. There were 553,000 ocean tons of freight shipped into Bougainville Island of which 344,000 tons came out of Melbourne, Sydney and Brisbane, including the North American shipments referred to earlier as being trans-shipped from liners through Sydney. In addition there were 115,000 ocean tons of freight south bound from Bougainville to Australian ports. Most of this was contractor equipment being returned to Australia. The total shipping tonnages for Bougainville – to and from jobsite – amounted to 668,000 ocean tons of freight. Australia provided the bulk of the tonnage, as previously mentioned, followed by 118,000 tons from Japan, 37,000 tons from North America, 8,000 tons from New Zealand and 25,000 tons of inter-island shipping.

In order to round out freight handling information for the project it is well to remember that much of it had to be moved over land surfaces for great distances. Road freight in Australia amounted to 463,000 tons, while on Bougainville 650,000 tons were transported along coastal roads and over the mountains to the mine area.

The efficient and effective handling of logistics for the Bougainville Copper Project must be accepted as a major contribution to its successful and timely completion.

CONSTRUCTION

The Bechtel-WKE supervision/management force was responsible for supervising, inspecting, controlling and approving all on-site contractor work which included the administration of construction contracts, quality of work performed, quantity reporting, co-ordination of schedules, statement of claims and the never ending task of catering to the requirements of people – thousands of people.

Structured under the leadership of the construction manager, project responsibility was divided into two major areas – the mine and the port. Plate No. 3 shows mine facilities with the major exceptions of Panguna town and the Jaba River pump station and pipeline and Plate No. 4 shows permanent facilities installed in the port area.

Ninety three contractors working at various times throughout the life of the project were necessary to complete the operating and support facilities. The expatriate work force at the peak of activity in 1971 totalled more than 6,000 while the integrated force reached its maximum at about 4,000 men. Summing the entire staffs of supervisory, support and labour personnel of Bechtel-WKE, Bougainville Copper Pty. Limited and contractors, the maximum labour force was approximately 10,700 in mid-1971. This force was distributed about 50% at the mine-site, 40% in the port area and 10% involved in the service links such as the access road and communications systems.

Excluding the manhours applied to management, supervision, mine development and other activities of the mining company and excluding the supervisory personnel of Bechtel-WKE and contractors, the labour or manual work force performed 42,000,000 manhours of productive effort. If you work this back to the staid 40 hour work week it would require a force of 1,000 men for a period of more than 20 years to achieve the same effort.

Project Management and Service Departments headquartered at Panguna. Additional construction offices were located in each of the major areas of activity such as mine service area, concentrator area, port-mine access road, port area and Arawa townsite. Bechtel-WKE specialists in engineering, accounting, estimating, planning and scheduling, quality control, contracts administration and construction were distributed among the several offices. Materials handling and warehousing, including the vast laydown areas, operated from the major installation near the power plant at the port.

Earlier on, it was mentioned that looking after people is a major requirement of a construction manager on a remote site. Bechtel-WKE had responsibility for supplying all of

the facilities and amenities for personnel, some of which were handled by contractors and others by appropriate personnel of the joint venture.

At project kick off the mining company had a temporary camp which had been used for exploration work and continued to serve construction until other facilities became available and the land where the original camp was installed became an integral part of the mining operation. All in all there were eleven camps, the largest of which had a nominal capacity of 1,800 men while six of these camps were capable of handling well over 1,000 men each. Providing bedding, maintaining ablution facilities, attending to recreational requirements and, above all, seeing that the men were well fed, was a never ending task. The introductory section of this article contains some examples indicating the magnitude of effort required.

Providing accommodation for personnel and physically erecting equipment and materials were not the only preoccupation of Bechtel-WKE project management personnel. Planning and scheduling to propitiously utilise equpment, machinery, personnel and facilities was a challenge unto itself. Estimating costs, establishing budgets and controlling millions of dollars of effort each month; properly accounting for expenditures and reporting costs and progress to Bougainville Copper entailed the continuous attention of numerous staff specialists.

One of the principal efforts of the Bougainville Project management was to ensure that the highest standards of safety were maintained throughout the several work areas. Establishing co-ordinated effort at each work place, and among the many contractor organisations involved, proved to be well worth every effort it entailed. For example, during 1971, the year of maximum project activity when more than 30,000,000 manhours were worked, 13.07 was the accident frequency rate. This low rate is a testimonial to the efficacy of the project planning and accident prevention work on the part of every organisation involved.

For the life of the project covering some 53,000,000 manhours there were a total of 871 lost time accidents, resulting in 16.44 as the total project frequency rate. This number must be compared with the 65.0 frequency rate during the same period for the Australia-wide construction industry.

Among other services provided by project management was security, first aid, and industrial relations. Here again the job established enviable records for minimising lost time due to industrial disputes. Reference has previously been made to 1971 as the year of maximum activity and to the more than 30,000,000 manhours worked during that year. During this period there were 106 work stoppages totalling less than 90,000 lost manhours divided as follows:

Number	Manhours lost	Dispute
60	39,996	Wages and General Conditions.
7	30,083	Security and First Aid.
17	14,861	Accommodation, messing and amenities.
9	2,147	Demarkation.
3	1,740	Fatality Site.
10	922	Union Business.
106	89,749	

When one considers that the labour force was made up of more than half indigenous personnel from virtually every district of Papua, New Guinea and Bougainville, many of who could not even speak the same language and few who could read and write, and that the remainder of the work force, although predominantly Australian, came from several countries of South East Asia, Italy, Spain, Portugal, Israel, France, Germany, United Kingdom, Canada and the United States, the above figures are, as stated earlier, a monument to management and co-operation among organisations.

A great amount of credit for the successful figures quoted in the preceding paragraphs, with relation to accident prevention and lost time through industrial problems, is due directly to the untiring efforts of Union leaders. Union management in Australia, through the ACTU, greatly assisted in establishing working conditions on site and to bringing about the harmonious environment among the several unions involved. Demarkation disputes were minimal and Union business counted for scarcely more than one percent of the few manhours lost through work stoppages.

The Bougainville General Construction Workers Union was most effective in looking after the requirements of their thousands of members while at the same time, working to minimise problems which could lead to disruption of the common effort.

Attachment 3 is a Union Roster of Representation setting forth the names of the Unions which worked on Bougainville and the principal classifications of personnel who integrated their membership.

About the first year of project life, that is from early 1969 to early 1970 there was little concern expressed by the small number of workers on site about organised Union activity. In January 1970, Bechtel-WKE was approached by an Area Committee, which comprised employees from various contractors, with a demand for Bechtel-WKE to negotiate with them an agreement on a log of claims for wages and conditions. Bechtel-WKE met with the Area Committee on a number of occasions up until March, 1970, by which time no agreement had been reached and the men went on strike.

At the time of the strike it was considered that the Area Committee needed assistance in managing the prevailing industrial situation, and the members of the various unions represented, through their respective union officials, called on the ACTU to handle the dispute. As a result, the ACTU remained the employee representative body on site and each of the unions were represented by the ACTU acting as agent. Each employer at site had at least one Job Delegate who conferred with full time site ACTU represt-atives.

At the peak employment period, August, 1971, there were approximately thirty Job Delegates. Once a month, or as required, these Job Delegates met with their two full time ACTU Site Representatives for the purpose of discussing industrial matters relating to the Project. The meetings were held during working hours.

TOWN SITES

When you start from scratch on a project such as Bougainville you expect to run into the normal complications presented by climate, environment and logistics and you even expect to encounter some difference of opinions among the many experts and specialists on whose wisdom

the facilities are structured. The building of new towns is somewhat different.

When it comes to houses, reticulation systems, supermarkets and bus routes every man is an authority – at least, every man has an opinion. There is good reason for listening to every one who can speak authoritavely because it is difficult to change substantially a town which has been built to plans. Everyone who lives in the town, especially the initial lot of residents, are prone to feel they could have done a better job had they been in charge.

The Bougainville townships of Panguna and Arawa, the first of these to house Bougainville Copper Pty. Limited employees in the mine area and the second the PNG town open to not only the mining company and Government employees, but available to other residents and businesses which wished to establish themselves in that area.

Panguna was located on the slopes of the Karoona Creek and Kawerong River. Plate No. 5 gives an idea of the general layout of roads and houses. This town was developed to ultimately accommodate 3,000 residents, principally families of mining company personnel but including a scattering of Government people, such as teachers and medical personnel.

The rocky terrain and steep inclines made it extremely difficult to locate the initial 384 homes. Commercial services and recreation areas had to be hewn from hillsides and access roads were prone to be rivers during the construction period.

Table 4 shows shows some of the multi-storied structures which were family flats and living quarters for single employees. There were six blocks of flats and ten blocks of single quarters in the initial construction.

Among the facilities built to service the mine town were oval, tavern, tennis courts, basketball courts, volley ball courts, staff club, kindergarten, sports centre, swimming centre and squash courts. There was also a town centre housing a community hall, stores, supermarket, banks, post office, library and doctors offices in addition to the school rooms, medical clinic and church, as well as normal municipal services of police, fire, ambulance and similar.

Panguna had eleven types of residential construction varying from modest houses of 612 square feet to executive type homes approaching 3,000 square feet each.

Arawa, a veritable city carved from an old established coconut plantation, was a joint development by Bougainville Copper Pty. Limited and Papua New Guinea. It was originally designed to house approximately 6,000 persons with expansion to about 11,000 by 1985. At the time of project completion Arawa was so structured as to accommodate approximately 4,400 people in comfort uncommon in new towns in remote areas.

Private enterprise supplied all commercial businesses and services and approximately 20% of the housing was to be the initiative of private individuals. The townsite covered 805 acres and some 2,000 home sites were developed. Much of the Arawa area was a bog and one of the construction problems encountered was the excavation and fill of areas which needed improvement – earth moving amounting to more than 2,300,000 cubic yards.

The mining company constructed 465 houses of timber frame elevated on steel sub structure with external lining of asbestos cement. PNG built another 355 similar houses. In all, there were fifteen basic types of residential structures in Arawa providing an interesting mix of types and sizes in order to avoid monotony and to promote integration of the many and varied residents of the city.
Two primary schools each consisting of eight two-room structures of 1500 square feet were part of the initial construction. In addition, there was a hospital complex of fourteen buildings totalling 86,000 square feet offering full services including operating theatre, x-ray, pathology, dentistry and maternity. The hospital provided bed space for 250 patients and class rooms for student nurses and staff.

The town sites rounded out the project and by the time the process facilities were operative, ample, comfortable, well furnished living quarters were available to Government employees, mining staff and service personnel.

CONCLUSION

There was no single effort that brought about the successful completion of the Bougainville Copper Project. The mining company, Bougainville Copper Pty. Limited, and its associates, must be recognised as the driving force behind the entire venture because, indeed, it was they who put in more than thirty years of exploration, development, imagination, initiative and planning to overcome the untold obstacles which litter the way to major new developments such as these.

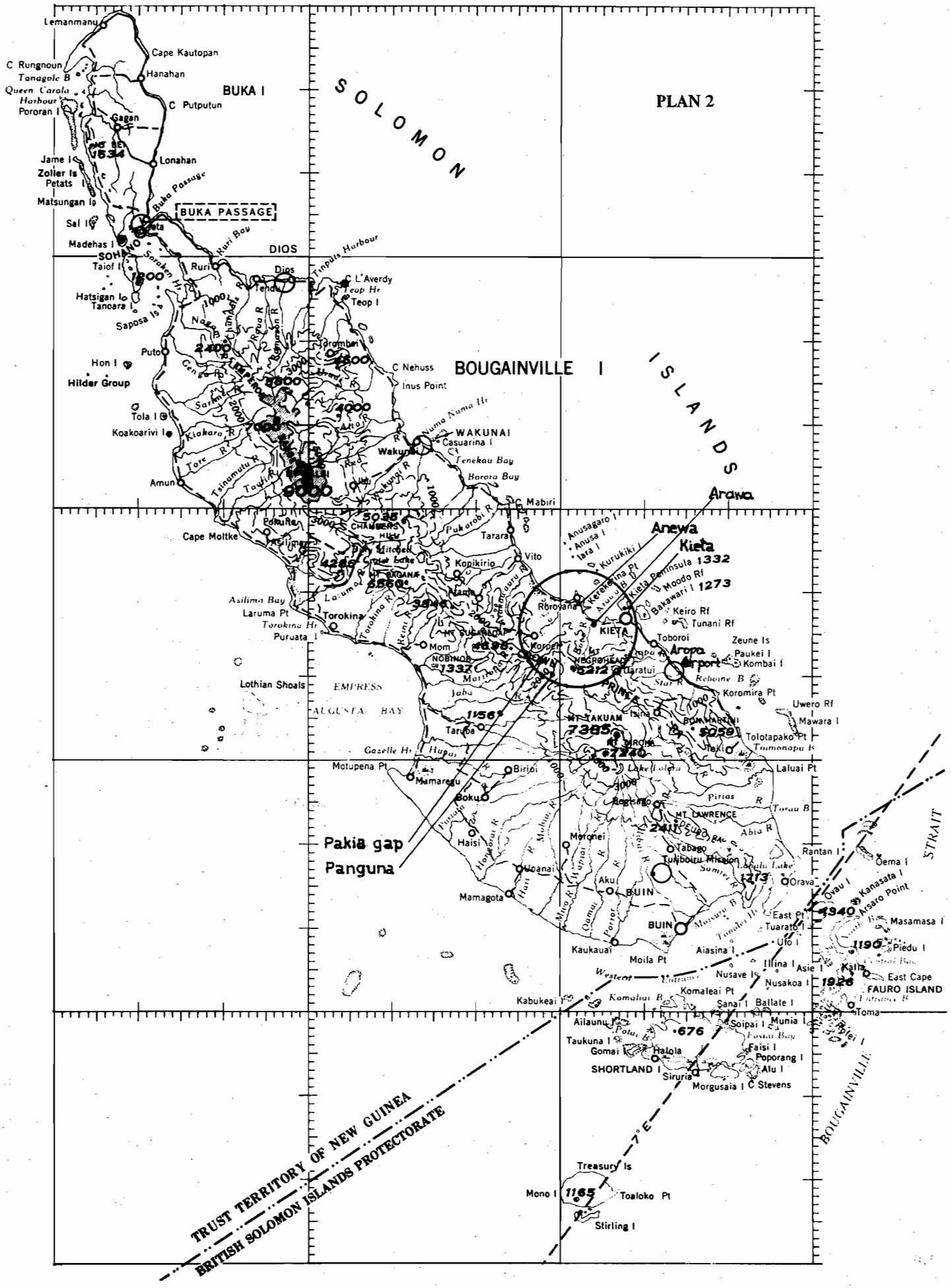
The Australian Government and the Administration of Papua New Guinea surely made their contributions and everyone from the Administrator to the staff of the District Commissioner laboured to protect local interests while ever displaying a constructive attitude and offering a helping hand to advance the project efforts.

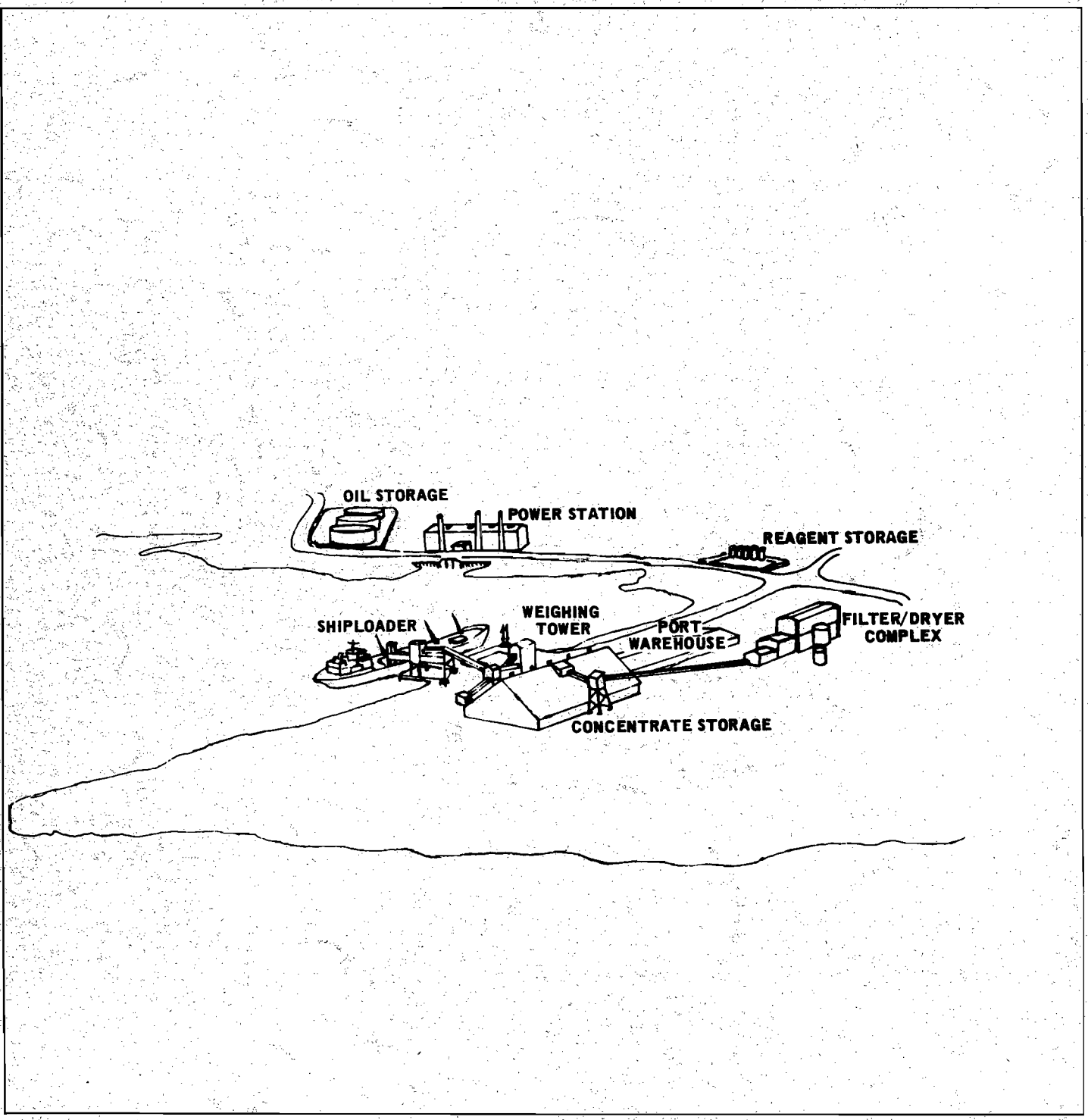
The residents of Bougainville in the vicinity of Panguna, Rorovana and Kieta and those who lived along the route from the airstrip to the Jaba River Pump Station demonstrated an uncommon patience and understanding with the "foreigners" who invaded their lands by the thousands and disrupted their traditional way of life. These local residents were awed by the strangers and their activity as well as the changes which they wrought in the countryside. Always fair in their dealings with project personnel their contribution to the project deserves special attention.

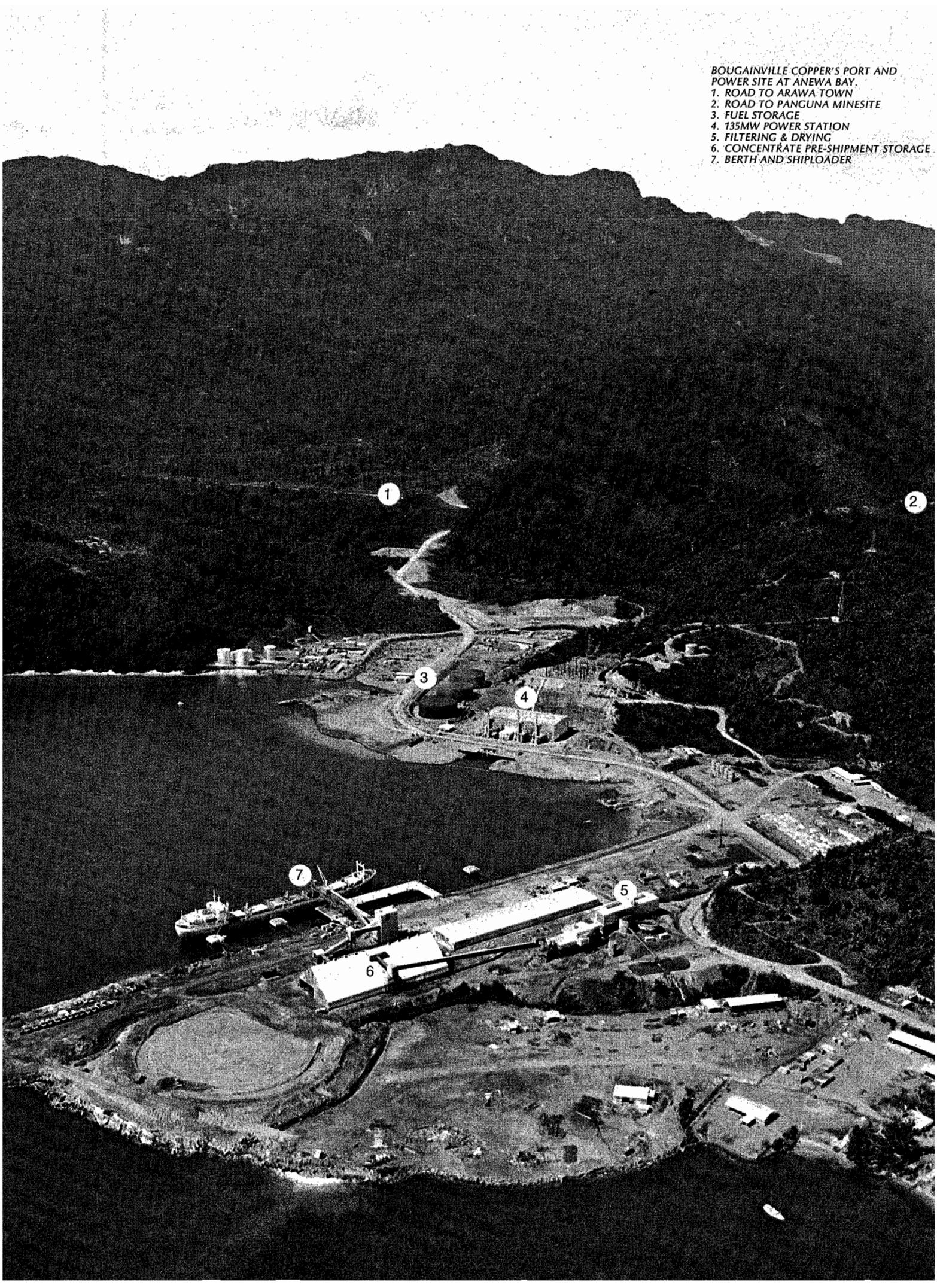
Contractor organisations faced new and challenging conditions and demands, and rose to the occasion with performances and ingenuity that stand as targets at which others can set their sights in the future. The Bougainville Copper Project was built by contractors and their personnel as this publication amply illustrates. Unfortunately, there is never a way to tell the full story and much of the spice disappears with retelling such as is contained in this book.

Bechtel-WKE is extremely proud to have engineered and managed the construction of this great project. As Managers Bechtel-WKE found no less a challenge from Bougainville than that faced by other organisations which, for the first time, faced the exigencies and perplexities of remote project sites. Old friendships were renewed and new relationships were born from the trials by torrential rains, swirling floods, knee deep mud, and the almost incongrous choking clouds of dust.

The Bougainville Copper Project is not only the largest grass roots copper undertaking in the world to date – it is truly a monument to every man who turned his hand toward its successful completion.


PLAN 2
BUKA I
BUKA PASSAGE
DIOS
SOHANO
BOUGAINVILLE I
SOLOMON ISLANDS
WAKUNAI
KIETA
Aropa Airport
Arawa
Anewa
Kieta
Pakia gap
Panguna
BUIN
SHORTLAND I
FAURO ISLAND
EMPRESS AUGUSTA BAY
Lothian Shoals
Cape Moltke
Cape Kautopan
C Putputun
Lonahan
Gagan
Hanahan
C Rungnoun
Tanagole B
Queen Carola Harbour
Pororan I
Jame I
Zoller Is
Petats I
Matsungan Ip
Sal I
Madehas I
Taiof I
Hatsigan Ip
Tanoara I
Saposa Is
Hon I
Hilder Group
Tola I
Koakoarivi Ip
Amun
Puto
Ruri
Ruri Bay
Tinputs Harbour
C L'Averdy
Teop Hr
Teop I
C Nehuss
Inus Point
Casuarina I
Tenekau Bay
Borora Bay
C Mabiri
Tarara
Vito
Kopikirio
Torokina
Laruma Pt
Asilima Bay
Puruata I
Mom
Nobinob
Mt Bagana
Mt Balbi
Mt Takuam
Mt Lawrence
Mt Loloru
Mt Bibiro
Mt Bonis
Mt Bom Martini
Mt Orgoi
Mt Egeregeo
Mt Peuru
Mt Pirias
Mt Abia
Mt Sumi
Mt Ioma
Mt Kabuna
Mt Kaiaka
Mt Kaiaka
Mt Kaiaka


OIL STORAGE
POWER STATION
REAGENT STORAGE
SHIPLOADER
WEIGHING TOWER
PORT WAREHOUSE
FILTER/DRYER COMPLEX
CONCENTRATE STORAGE



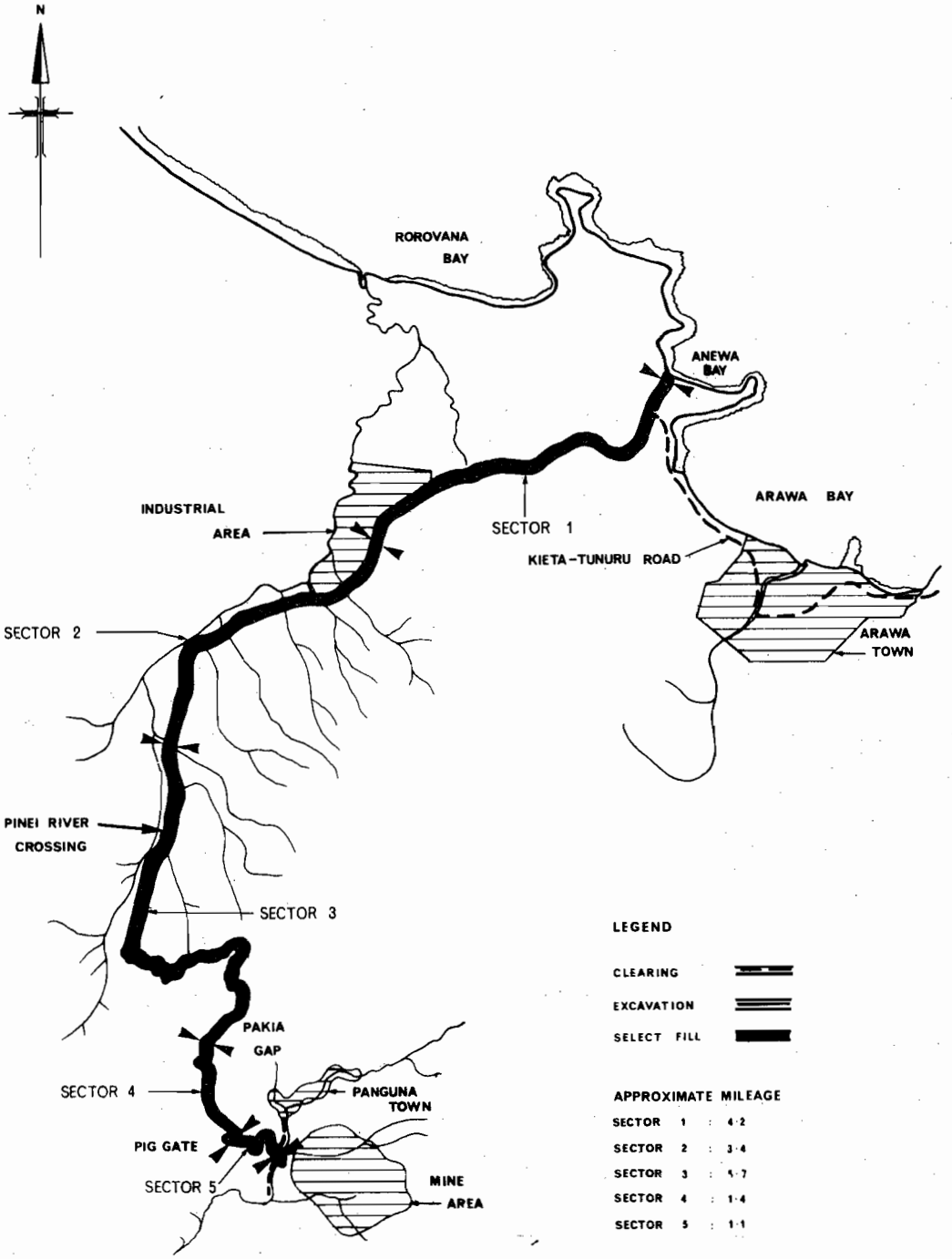
BOUGAINVILLE COPPER'S PORT AND POWER SITE AT ANEWA BAY.
1. ROAD TO ARAWA TOWN
2. ROAD TO PANGUNA MINESITE
3. FUEL STORAGE
4. 135MW POWER STATION
5. FILTERING & DRYING
6. CONCENTRATE PRE-SHIPMENT STORAGE
7. BERTH AND SHIPLOADER

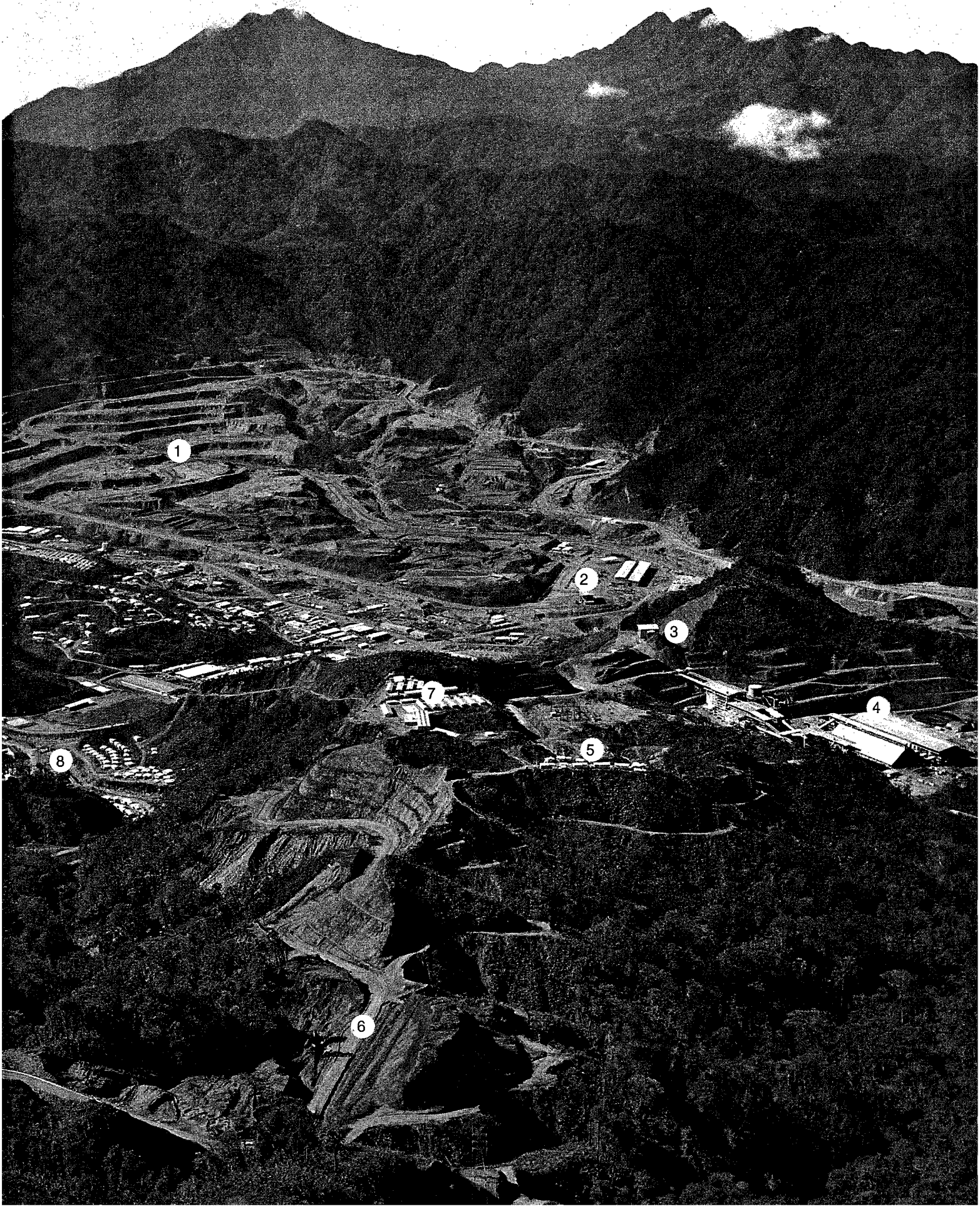
PORT-MINE ACCESS ROAD

Mountain section of the access road with the mine in background and the original access track still visible (July 1971).

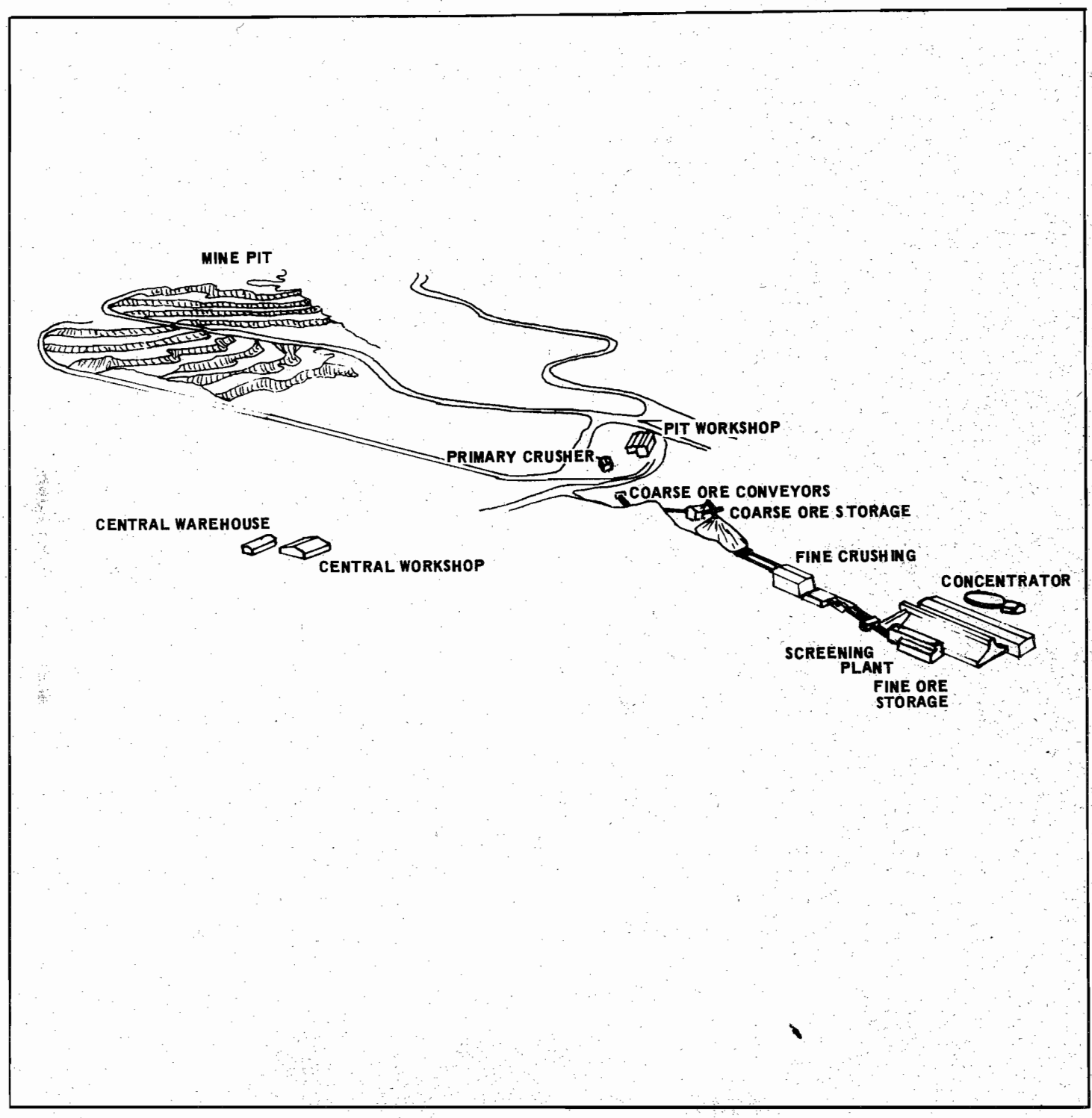
PORT-MINE ACCESS ROAD

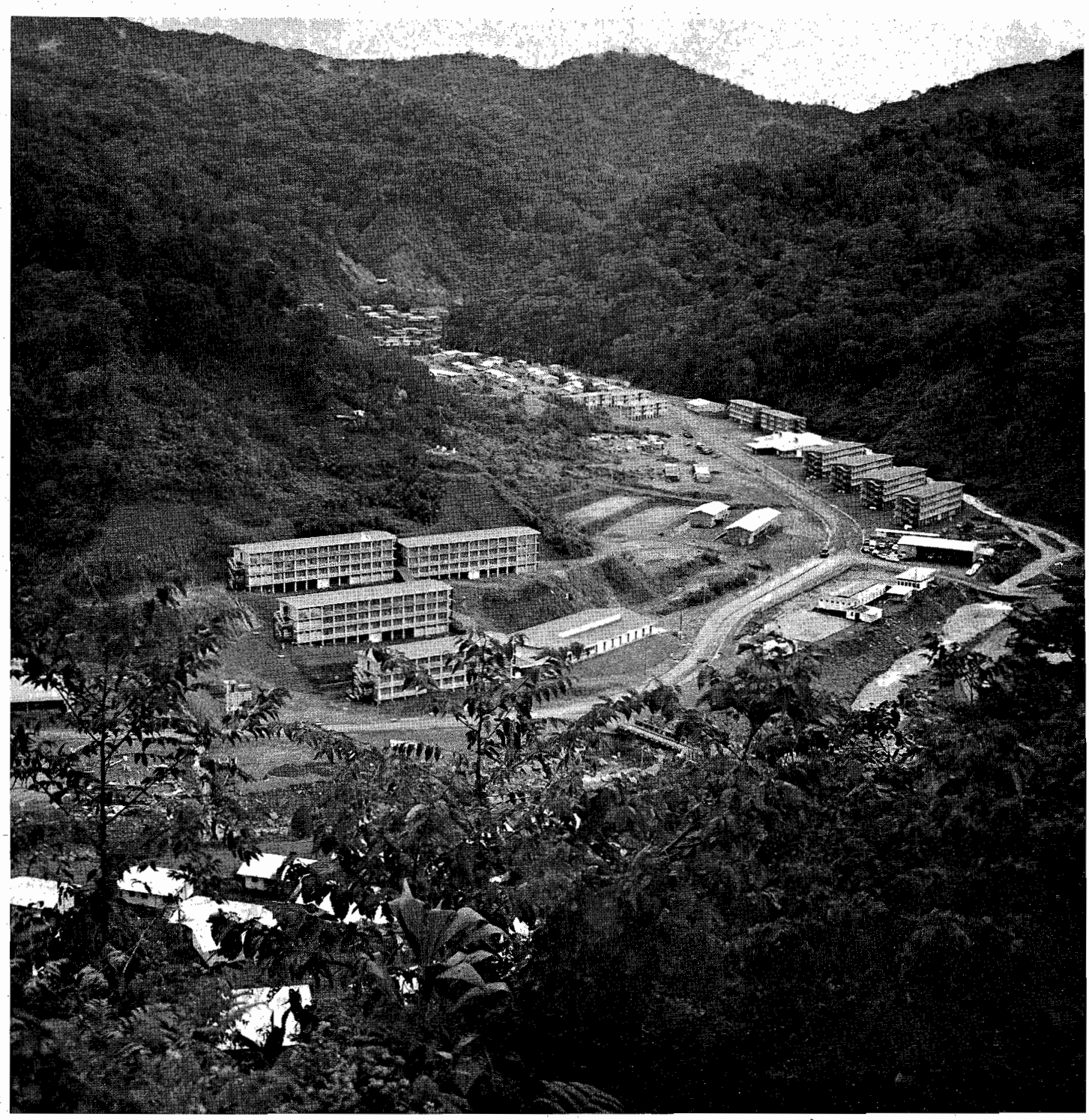
MAJOR EARTHWORKS



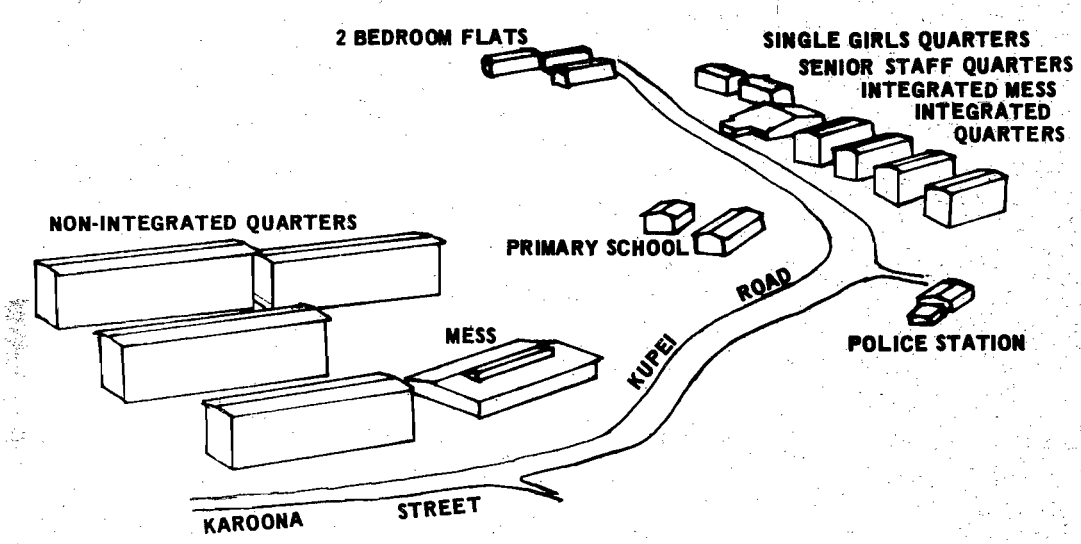


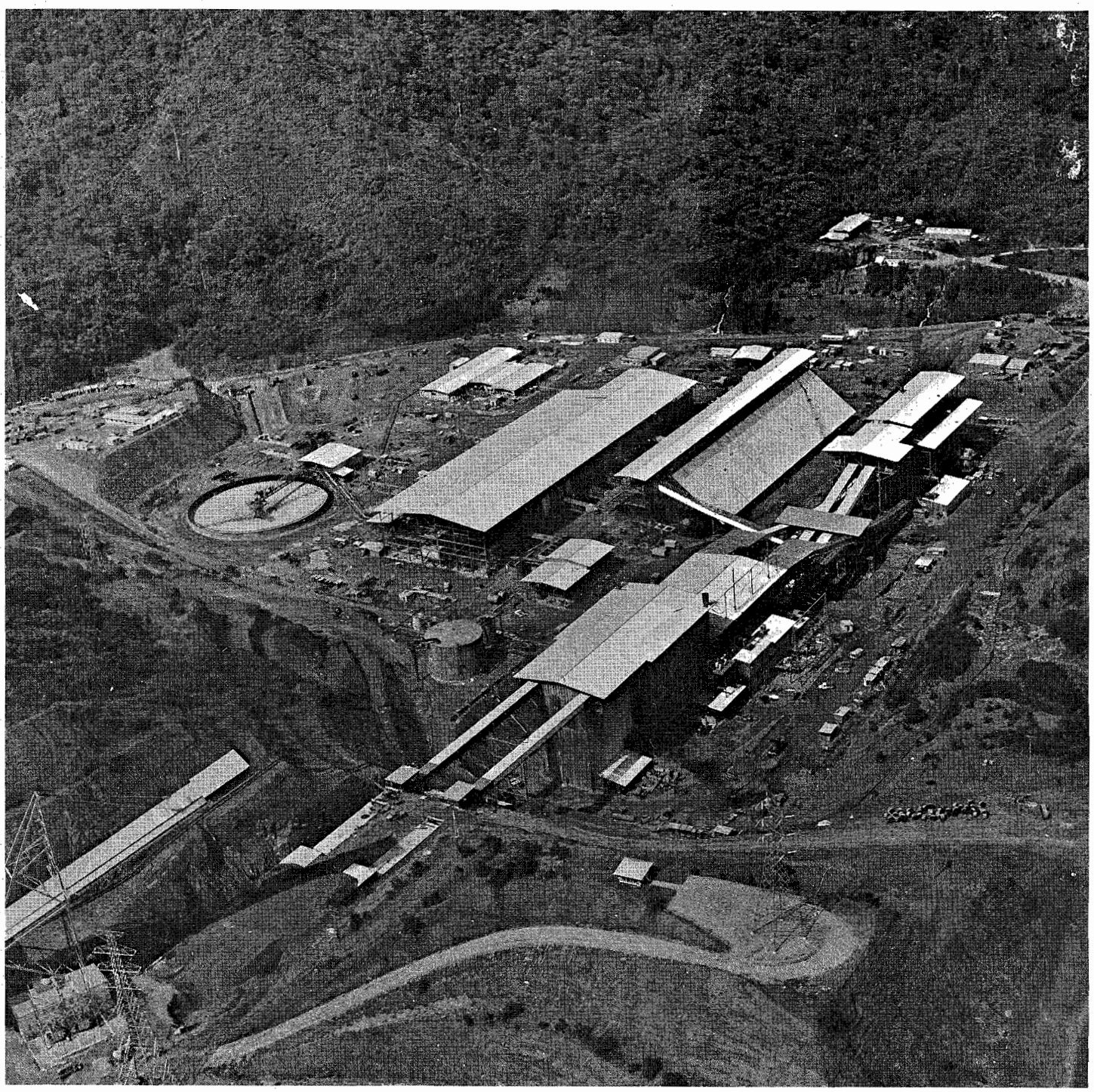
PANGUNA, BOUGAINVILLE ISLAND, 1972.
MINE AREA 1.
PRIMARY CRUSHER 2.
COARSE ORE STOCKPILE 3.
CONCENTRATOR AREA 4.
MORONI VILLAGE (RELOCATED) 5.
PORT-MINE ACCESS ROAD 6.
CAMP AREA 7.
HOUSING AREA 8.


MINE PIT
PIT WORKSHOP
PRIMARY CRUSHER
COARSE ORE CONVEYORS
COARSE ORE STORAGE
CENTRAL WAREHOUSE
CENTRAL WORKSHOP
FINE CRUSHING
CONCENTRATOR
SCREENING PLANT
FINE ORE STORAGE

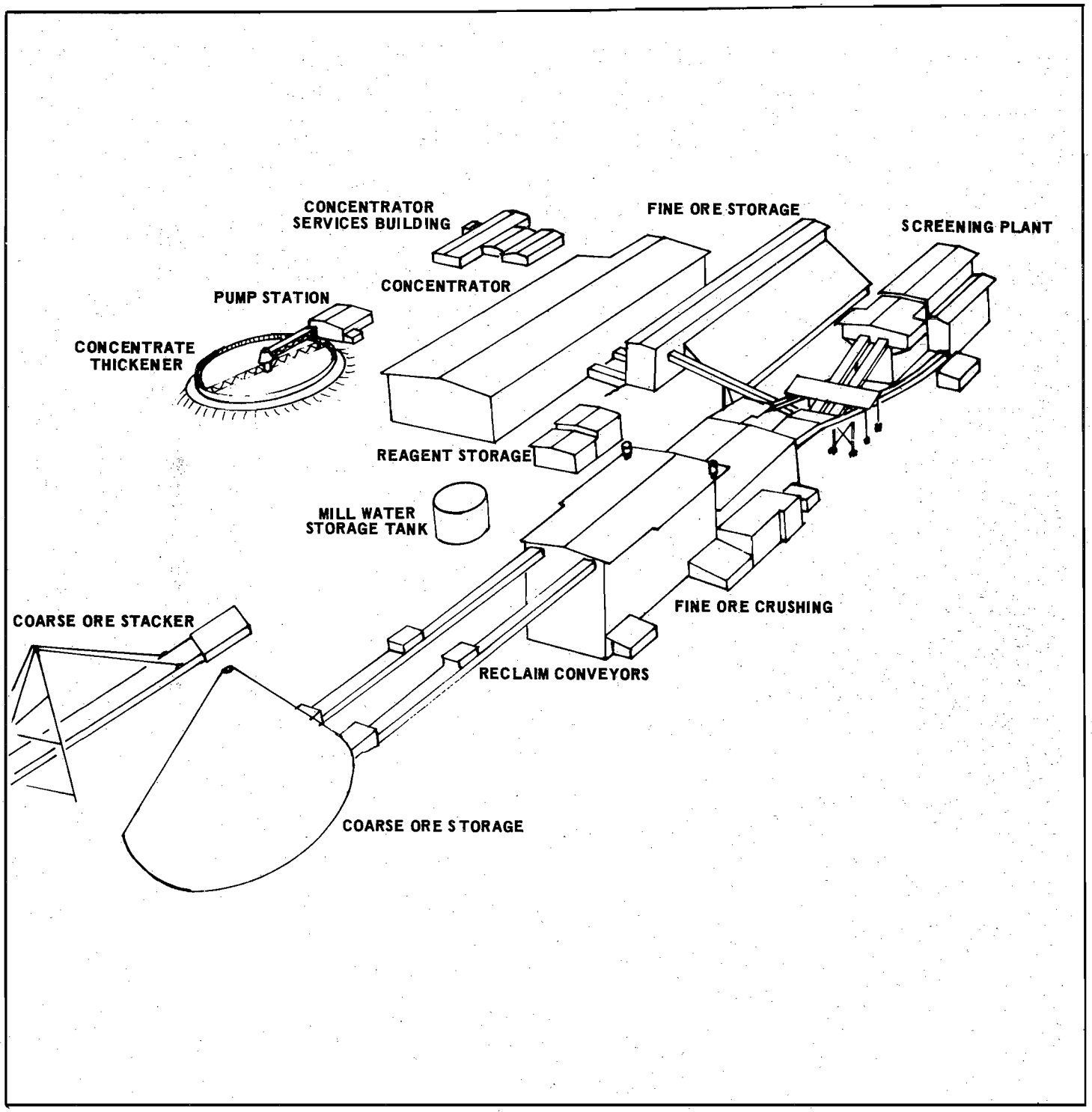


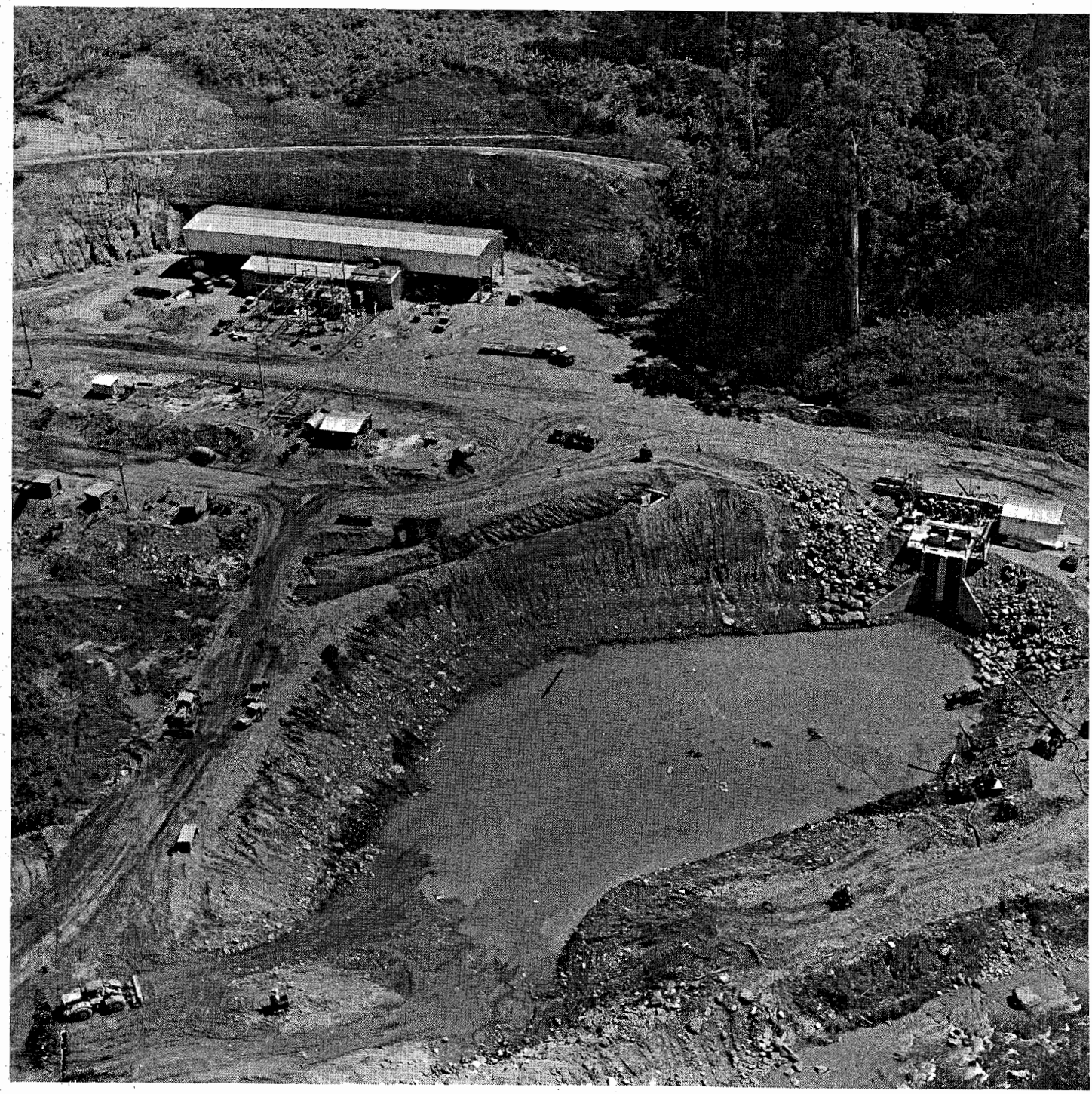
Panguna Township.


2 BEDROOM FLATS
SINGLE GIRLS QUARTERS
SENIOR STAFF QUARTERS
INTEGRATED MESS
INTEGRATED QUARTERS
NON-INTEGRATED QUARTERS
PRIMARY SCHOOL
MESS
KUPEI ROAD
POLICE STATION
KAROONA STREET

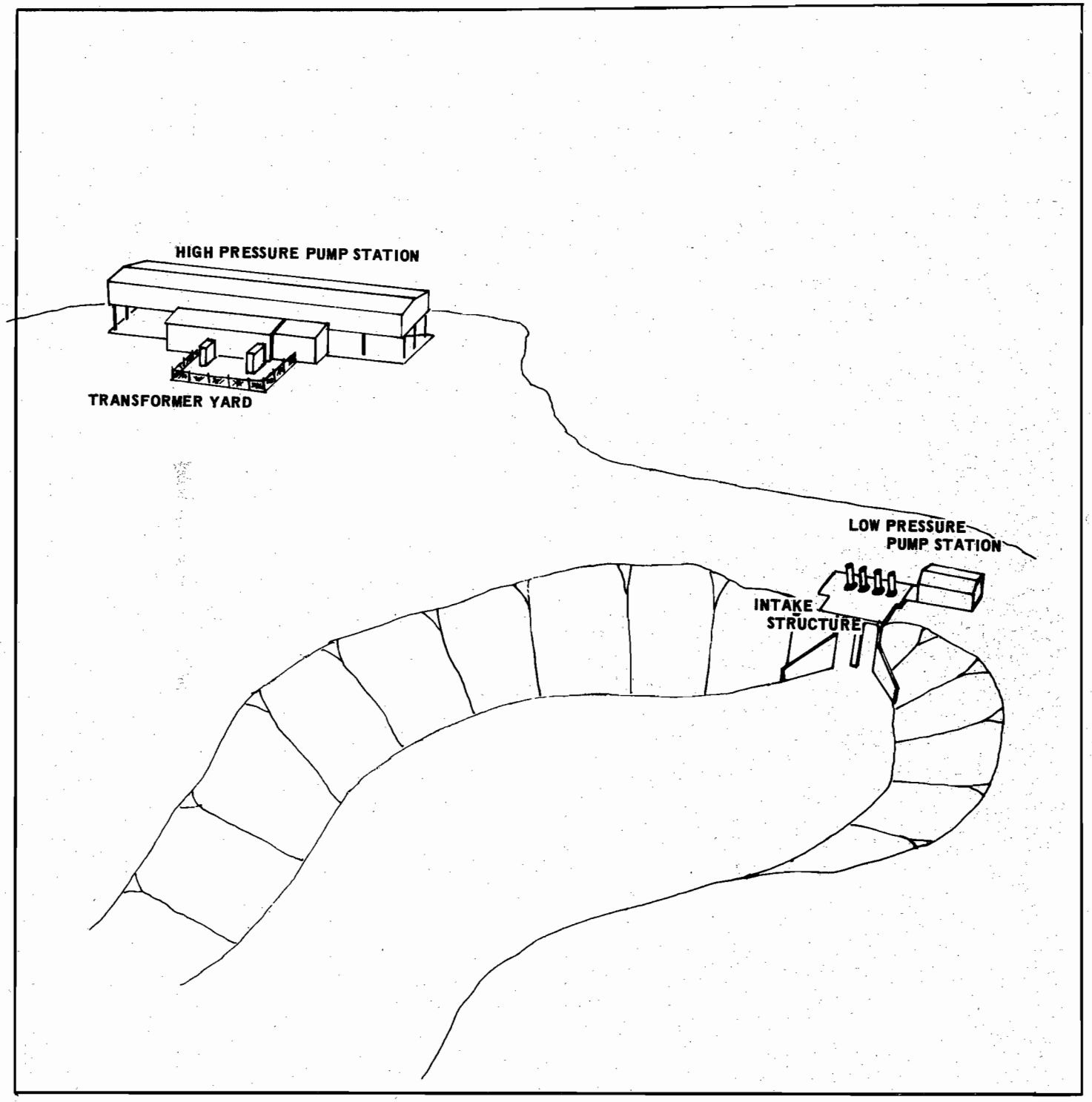


Concentrator Area — Panguna.


CONCENTRATOR
SERVICES BUILDING
FINE ORE STORAGE
SCREENING PLANT
CONCENTRATOR
PUMP STATION
CONCENTRATE
THICKENER
REAGENT STORAGE
MILL WATER
STORAGE TANK
FINE ORE CRUSHING
COARSE ORE STACKER
RECLAIM CONVEYORS
COARSE ORE STORAGE



Jaba River Pump Station.


HIGH PRESSURE PUMP STATION
TRANSFORMER YARD
LOW PRESSURE
PUMP STATION
INTAKE
STRUCTURE

Arawa Townsite — Arawa Bay.

COAST PROCESS AND SERVICE AREAS

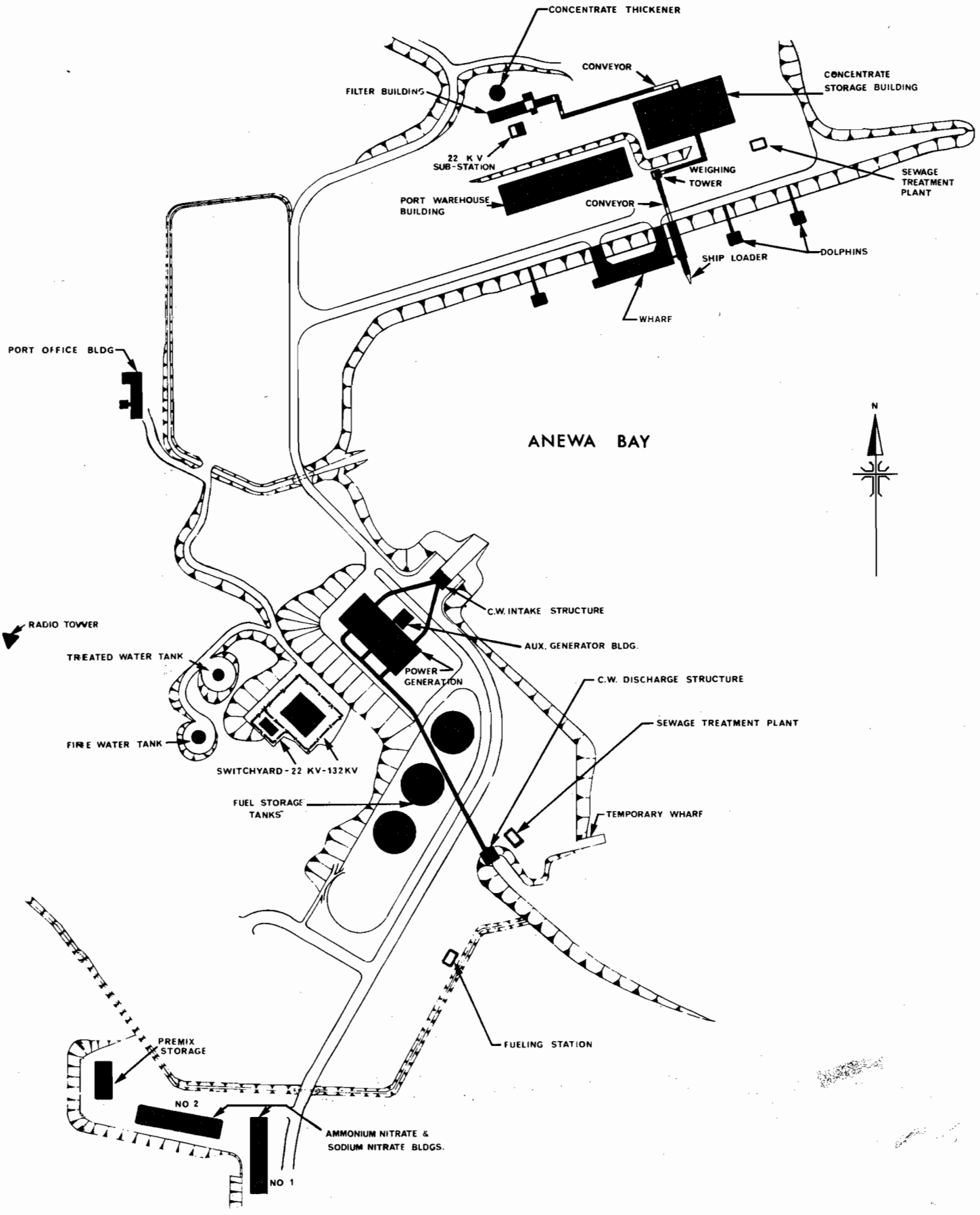


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Table 1 SUMMARY OF MAJOR EQUIPMENT BY PROCESS FACILITY

Primary Crusher
Two 54' – 74" Gyratory Crushers.
Fixed Grizzlies at 8" spacing.
Four 72" Apron Feeders.

Coarse Ore Conveyor
Uncovered storage for 50,000 short tons.
Two reclaim tunnels with five 54" apron feeders.

Fine Crushing and Screening
Six 7' standard Secondary cone crushers.
Twelve 7' short head tertiary cone crushers.
Six 8' x 20' double deck secondary screens.
Twelve 8' x 20' single deck tertiary screens.

Fine Ore Storage
Covered storage for 80,000 short tons.
Eight reclaim tunnels with eight Mexican feeders each.

Concentrator
Eight 18' dia. x 21' primary ball mills.
Three 10' dia. x 19' Regrind Ball mills.
108 x 600 c.f. rougher flotation cells.
39 x 100 c.f. cleaner flotation cells.
26 x 100 c.f. recleaner flotation cells.
52 x 100 c.f. scavenger cleaner flotation cells.

Concentrate Thickener
210' diameter centre-pier thickener.

Tailings Disposal
Two 42" fibreglass pipes approximately 6000' long dumping into Kawerong River.

Concentrate Pipeline
6 inch OD Pipeline 0.344" wall thickness approximately 16.5 miles long.

Concentrate Pump Station
Two mainline slurry pumps (one spare) rated at 150 ST/HR at 65% solids.

Filter and Drying
40' diameter centre-pier thickener.
Eight 9' diameter eight disc filter units.
Two 9' dia. x 50' oil fired rotary driers.

Concentrate Storage and Loadout.
Covered storage for 60,000 short tons.
1200 LT/HR shiploader. Static weighing system with manual and automatic sampling.

Table 2 PROJECT HIGHLIGHTS

August 1966
First Bechtel-WKE party visits Bougainville.

January 1967
Bechtel-WKE commissioned to perform Logistics Study.

November 1968
Interim Feasibility Study produced as joint effort of mining company principals and Bechtel-WKE.

April 1969
Bechtel-WKE joint venture given notice to proceed as engineer manager for project.

First Bechtel-WKE representative took up residence on Bougainville.

May 1969
Bechtel-WKE office established in Melbourne.

August, 1969
Major power plant equipment ordered.

Pilot plant test work completed at site.

November 1969
Orders placed for major process equipment.

July 1970
Kieta Aerodrome dedicated by the Rt. Hon. J.P. Gorton M.P. Prime Minister of Australia.

August 1970
First ships dock at partially completed permanent wharf at Anewa Bay.

October 1970
First mining shovel and 105 ton ore truck used at Mine site.

November 1970
First piece of major project equipment set on foundation (cone crusher).

February 1971
Port-Mine Access Road trafficable over entire length.

August 1971
Unloaded first shipment of heavy fuel oil for power plant.

October 1971
Power plant Unit No. 3 successfully started and power produced.

Jaba River Pipe line completed.

December 1971
Primary Crusher and Coarse Ore Conveyor accepted by Bougainville Copper. Initial ore processed through fine crushing, screening, No. 2 ball mill and rougher flotation circuit.

January 1972
First concentrate slurry produced, pumped to port and processed through filter/drier plant to storage.

February 1972
All mine process facilities accepted by Bougainville Copper Pty. Limited.

Table 3 UNION ROSTER OF REPRESENTATION

Union	Classification
Amalgamated Engineers Union	Fitters Motor Mechanics
Amalgamated Society of Carpenters and Joiners of Australia	Carpenters and Wood Joiners
Australian Builders Labourers Federation	Labourers Steel Fixers Concrete Workers Riggers Drainers
Boilermakers and Blacksmiths Society of Australia	Boilermakers Blacksmiths Pipe Fitters
Electrical Trade Union of Australia	Electricians
Federated Ironworkers Association of Australia	Trades Assistants Riggers
Plumbers and Gasfitters Employees Union of Australia	Plumbers
Transport Workers Union of Australia	Vehicle Drivers
Federated Storemen and Packers Union of Australia	Storemen
Australian Society of Engineers	Fitters Motor Mechanics
Amalgamated Society of Carpenters & Joiners of South Australia	Carpenters Wood Joiners
Australian Workers Union	Labourers
Building Workers Industrial Union of Australia	Carpenters Wood Joiners Bricklayers Bridge Carpenters Tilers
Federated Engine Drivers and Firemens Association of Australia	Plant Operators Powerhouse Attendants
Operative Plasterers & Plaster Workers Federation of Australia	Plasterers Plaster Board Fixers Concrete Floor Finishers
Sheet Metal Working Agricultural Implement and Stovemaking Industrial Union of Australia	Sheet Metal Workers
Operative Painters and Decorative Union of Australia	Painters Signwriters
Federated Miscellaneous Workers Union of Australia	Watchmen Cleaners
Federated Liquor and Allied Industries Employees Union of Australia	Cooks Mess Attendants

W.K.E. in Australasia

Arthur G. McKee & Company was organized in 1905. Since then, the firm has gained world-wide recognition as an engineering and construction organization specializing in production and process facilities for the nonferrous, petroleum, chemical and steel industries.

Western Knapp Engineering Co. was acquired by McKee in January of 1961 and has since become the Western Knapp Engineering division of McKee. WKE initiated operations in 1934 and has completed over 1100 contracts since that time. This backlog of experience, plus the experience background of each individual and the total McKee Company, has resulted in an organization which is particularly adept at supplying design, engineering, construction, and project management services for heavy industrial projects, particularly those facilities relating to the mining and processing of minerals and metals. This experience includes all phases of the mineral-metals industry — primarily it has been in mining, ore dressing, chemical metallurgy and pyrometallurgy.

The general services available from McKee–WKE are: engineering studies; feasibility studies; preliminary installation and operating costs estimates; detailed cost estimates; detailed design for construction; procurement and expediting; project management and construction. The client often uses McKee–WKE for the entire sequence of services on one project and occasionally the sequence is simplified, going from preliminary engineering, feasibility studies and cost estimates as one job to design and construction of the entire facility on a turnkey basis.

McKee–WKE's experience has covered a wide variety of minerals and metals and has involved execution of work concerned with all phases of mineral property development, from preliminary examination to a total facility consisting of a mine, mill, and smelter.

The permanent staff of McKee and subsidiaries numbers some 3000. This figure does not include field construction forces which at times numbers as many as 15,000 workers. Among the staff members are internationally recognized authorities in the design and construction of facilities for the production of nonferrous metals, iron, and steel, the processing of petroleum, petro-chemicals, and chemicals, and for the treatment and handling of raw materials. These men have been called upon to provide facilities for processing almost every commercial mineral commodity from raw aggregates to germanium concentrates and other "exotic" minerals.

McKee Pacific Pty. Ltd., the permanent office of the McKee organization in Australia was established in 1966. And since then has completed 43 contracts ranging from feasibility studies to complete turnkey projects. This has involved more than one million manhours of engineering in the Melbourne office as well as the transaction of procurement contracts to the value of $62 million and construction contracts to the value of $144 million.

Men and Earthmoving Equipment

MEN, EQUIPMENT and the BOUGAINVILLE COPPER PROJECT
A Study of Equipment Usage, Skills and Techniques

by Lawrence J. Weber

This paper was prepared by Lawrence J. Weber and presented for Bechtel—W.K.E. by Lamar F. Hutchison, Resident Manager of Bechtel Pacific Corporation Limited, for discussion during the National Earthmoving, Mining and Construction Congress, on August 30, 1971, at the Southern Cross Hotel, Melbourne, Australia.

Lawrence J. Weber is Managing Director of McKee Pacific Pty. Ltd., Melbourne, a subsidiary of Arthur G. McKee & Company. His previous position was Assistant Project Manager for Bechtel-W.K.E. on the Bougainville Copper Project.

A graduate of University of Notre Dame, Mr. Weber has been a field engineer with Foster Wheeler; a project engineer with Brown-Olds; and Manager of Engineering for McKee's Western Knapp Engineering Division in San Francisco, where he has worked on major mining projects for the past twelve years. He is a member of the Aus. I.M.M., A.I.M.E. and a Registered Professional Engineer in California.

INTRODUCTION

The Bougainville Copper Project is located in the Panguna Highland area on Bougainville Island. The undertaking is one of the largest copper mining operations in the world.

Bougainville Island is 30 miles wide and 130 miles long with its dominant feature a range of mountains which rises to 8,000 ft. and runs the length of the island. This mountainous land is jungle covered and swampy in low lying coastal areas. The terrain formation for the most part consists of volcanic ash and fractured and weathered rock. The weather is tropical with coastal rainfall ranging from 100 in. to 150 in. per year while the mountain areas receive from 150 in. to 300 in. per year.

This paper describes the major earthmoving tasks which were required for the mine development and the related facilities. The type of equipment utilized, labour and special techniques employed and some of the problems which were overcome are discussed. The scope of the work covered included the excavation and fill of over 43 million CY at a cost of 52 million dollars.

THE MINING COMPLEX

Mine: The Open Cast Pit is located at Panguna some seventeen miles from the coast. The planned output of 90,000 STPD of ore will result from the pit which will eventually measure 6,000 ft. in length and 5,000 ft. in width and a depth of 1,000 ft. Ore of approximately ½% copper will be mined using 5 Bucyrus-Erie 45R electric rotary drills, slurry explosive, 6 P & H 17 CY electric shovels and 53 Euclid 100 ton trucks.

Concentrator: This is also located at Panguna and is designed to produce 500,000 LTPY of copper concentrate (30% copper). The concentrate is produced by a process of crushing, fine grinding and flotation. This concentrate is slurried and pumped to Anewa Bay for filtering and drying before shipment on 20-25,000 dwt. ships. The site of the main concentrator is approximately 1500 ft. x 1000 ft. and at an elevation of 2200 ft.

Panguna Township: A modern town is being constructed at Panguna which includes over 300 houses plus several flat units and bachelor quarters. All community amenities are being established. Panguna housing will be for B.C.P. Limited employees required to be housed in the Mine Area. The ultimate population will be approximately 3,000.

Port Site: The Port Site at Anewa Bay is situated in a natural harbour and is seventeen miles from the mine site. The wharf is suitable for 40-45,000 ton ships and is complete with portside stores. The complex at Anewa Bay also includes a 135 MW power station and concentrate filtering, drying and storage facilities.

Arawa Town: Arawa is a public town being built jointly by B.C.P. Limited and the Administration of P.N.G. It will become the largest town in Bougainville and the ultimate population is expected to be 10,000. The town lies along the coast between Anewa Bay and Kieta, and initially covers an area of 700 acres.

PLANNING

During the planning stage from late in 1968 until early in 1969 it became evident that the project schedule dictated a high peak of earthwork in a relatively short period of time. This in turn necessitated a rapid build up of equipment, manpower, supervision and support facilities. A summary schedule showing the scope of the earthwork program is shown in Figure A.

In the case of mine hydraulicking, temporary facilities and road maintenance, it was apparent that the earth moving equipment could be fully amortized during the construction period and the organization and manpower would logically form the nucleus of the final mining operation. Consequently the work was handled on a direct hire labour basis for operating, maintenance and supervision. Equipment was purchased and maintenance facilities were established by B.C.P. Limited.

For the remaining earthworks, because of the demand for a great number of equipment spreads for a short period of time, it was decided to break down the work into a number of packages which would fully utilize the organizational skills, manpower and available plant from several experienced contractors. This resulted in the award of four major contracts as shown in Table 3–1.

Construction camps were established and operated on a central job basis. A contract for all fuel and lubricants was arranged. Each contractor set up his own maintenance facilities close to the centre of his work whilst the various equipment dealers established themselves for servicing assistance and spare parts.

Planning had to be continually updated and resources were modified throughout the program to keep up with significant changes in ground conditions, work quantities, variations and production results. The evaluation of production for all work was done on a weekly basis in order that trends could be identified and corrective action taken whenever required.

ACCESS ROAD

General:

In 1966 an initial seventeen mile access track was constructed by C.R.A. Exploration Pty. Ltd. which connected the mine site at Panguna and Anewa Bay on the east coast. This track served as an access to the mine site until mid 1970. It was not designed to handle heavy truck haulage, nor for the transport of mining and milling machinery, therefore a higher standard road was required. However, the old track had to serve the operations and remain open while the new road was being constructed.

The new road was constructed by a joint venture of Morrison-Knudsen-Fluor at a total cost of $16 million. The road begins with a large box cut at the coast, passes over swamp land, and thereafter through foot-hills in the valley section for a distance of nine miles. The mountain section of seven miles crosses the Crown Prince Range at an elevation of 3,500 ft. before descending to the mine at 2,000 ft. The road in the valley section has a 24 ft. pavement with 8 ft. shoulders and is designed for a speed of 50 mph. In the mountain section the road has a 24 ft. pavement with 3 ft. shoulders and is designed for a speed of 20-30 mph. It provides all weather access between the mine and the coast at a maximum gradient of 12%.

Buried within the road formation lies a 5.5 in diameter steel pipe line which transports copper concentrate in a water slurry from the mine to the coast. The road formation required an 18 in. sub-base of select material with a C.B.R. strength of 20. The pavement base course in 12 in. thick crushed rock. Bridges and structures were designed for an H-20 loading. The road was sealed after construction of the mine was completed.

Construction required a fleet of major equipment which included 24 Cat 769 35-T trucks, 20 Cat D-8 dozers, 7 Cat D-9 dozers, 2 Cat 992 10 CY loaders, 6 Cat 988 6 CY loaders, 6 Cat 14 and 2 Cat 12 graders. A detailed listing of the equipment is shown in Table 4–1.

More than 13 million CY of soil, volcanic ash, and weathered rock had to be excavated. The statistics for the road are:-

1. **Final Quantities**

a)	Clearing and Grubbing	456 acres
b)	Excavation, Unclassified	13,385,000 CY
	Valley Section–Total	2,474,000 CY (9 miles)
	Mountain Section–Total	10,911,000 CY (6.7 miles)
	To Pig-Gate	10,167,000 CY (5.6 miles)
	From Pig-Gate to Mine	744,000 CY (1.1 miles)
	By Dozers	(8,049,000 CY)
	Loaders	(1,826,000 CY)
	Scrapers	(292,000 CY)
c)	Sub-base–Plant Produced (–4")	142,000 CY
d)	Base Rock–Crushed	110,000 CY
e)	Culverts	22,000 LF

2. **Peak Excavation Rate** 1,644,000 CY/month

3. **Timing – 17 months overall**

a)	Work Commenced	August 1969
b)	Access Opened	
	Port to Waterfall Corner	July 15, 1970
	Port to Checkpoint Gap	October 4, 1970
	Pig-Gate to Mine	September 5, 1970
	Full Road	January 1971.

Clearing

The right-of-way was cleared by hand clearing of all vines and small growth, felling trees and cutting into sections, and dozing or winching logs off the right-of-way. Grubbing was done under embankments of less than 2 ft.

Valley Section

Construction in the valley section of nine miles was basically a clearing and filling operation which required the borrowing and hauling of competent materials for the road formation. Although at the beginning of the road there were a few cut situations which produced suitable materials, for the most part the work was over and through poor ground and swamps which had to be displaced by imported materials, or excavated and wasted along the road.

The major valley box cut at the start of the road was cut and hauled by Cat 631B scrapers to swamp fill the first 0.85 miles. At this point a large rock cut was made using Airtracs, loading with 998's, and haulage by 769's to swamp fill for the next two miles. The following five miles were completed using borrow material from the Kumo Pit along the Pinei River. Pit run gravels (–14 in.) were excavated from the river bed by a five cubic yard drag line and stockpiled. This material was loaded out by 988's and hauled by 769's and scrapers. The Kumo Pit also was the source of rock for sub-base (–4 in.) and crushed rock base course materials. The last mile of the valley section was filled from borrow from Emito Creek, being reclaimed and moved with D-8's, 988's and 769's.

Mountain Section

The mountain section (including Pig-Gate to Mine) extends for 6.7 miles over very difficult terrain. Because of the steep slopes and unstable soil conditions, exceptionally high – up to 400 ft. – cut slopes were required. Design called for cut slopes in rock from 63° to 76° from horizontal, depending upon the quality of the material encountered. Cut slopes in overburden and highly weathered material ranged from 45° to 53°. A series of benches were required to control the water drainage and prevent erosion of the cut slopes. Benches 10 ft. wide were called for every 40 ft. of height.

Almost all the material was side-cast with dozers and 992 loaders. Some box cuts and restricted areas were hauled by 961B scrapers to fill or waste, or loaded by 988 and 992 loaders and hauled in 769's Of the total excavation approximately 350,000 CY was hauled.

The major equipment items used in the mountain spreads were as follows:

Av. No.	Type	No. Range	Time
2.4	D-6 Dozers	1 – 4	14 months
10.25	D-8 Dozers	7 – 18	14 months
6.58	D-9 Dozers	5 – 9	14 months
1.7	992 Loaders	1 – 2	11 months
2	631B Scrapers		6 months
1	988 Loader		2 months

No accurate production figures are available as the conditions varied so much from station to station with type of material, depth of cut, distance of drift, etc. It appears however that average rates per operating hour were approximately:–

a)	D-6, D-8 and D-9 Dozers	130 CY/hr/machine
b)	992	333 CY/hr/machine
c)	631B	191 CY/hr/machine

Availability was:–

D-6	– 78%
D-8	– 82%
D-9	– 77%
992	– 80%
631B	– 70%

TECHNIQUES

Pioneering – Mountain Section

Due to the continuous wet conditions, the steep terrain, and nature of the soil, it was extremely difficult to make access to the top of high batters so that equipment could open the cuts. The best results were obtained by starting with a D-4 Dozer with winch, and a crew to anchor and corduroy, gradually working a narrow access. This was then enlarged by D-6 dozer and winch and corduroyed to permit passage of D-8's, D-9's and loaders. The tops of some batters took up to two weeks to obtain access in this manner.

Servicing Equipment – Mountain Section

As batters were opened and equipment reached lower benches and became isolated, it was necessary to either build additional access to bench after bench or service equipment by crews on foot.

Small skid shacks, skid tanks, welders, and compressors were maintained as close as possible to the operating spreads to provide fuel, lube, parts and repair backup.

Fuel tank depots were located on the old Port Mine road at various locations where they could be serviced by bulk trucks. From these depots fuel was hauled to spreads in 1,000 gallon tanks mounted on four wheels and pulled up the steep access to the spreads by D-4 or D-6 tractors (sometimes D-8's were necessary) where they were dumped into 1,000 gallon skid mounted tanks. Many times this could not be done due to inaccessability.

At these times fuel was pumped through plastic flexible pipe to skid tanks located at high points and then fed by gravity to the machines through plastic hoses stretched to the working benches.

Lubrication had to be done by hand in most remote mountain sections. Delivery of oil barrels was a major problem when equipment was isolated.

Personnel often had to hike considerable distances over rough terrain where 6 x 6 manhauls or even tractors could not haul them.

General Construction Comments

a) Ash materials could be dozed quite easily. When wet it could be treacherous and machines were always worked at least in pairs to assist each other in heavy conditions. Winches were used daily.

b) Much of the mountain section was deeply weathered rock which had to be ripped.

c) Rock was drilled by airtracks and shot with gelatinite.

d) When good rocky material was encountered near the bottom of cuts it was left to use later for sub-base on less stable sections as they were completed. The subgrade had to have a 20 C.B.R. strength.

e) Loaders were used primarily in side casting materials from box cuts which required a long drift to side cast. As can be seen, very little was loaded and hauled, the majority was walked to the side and dumped.

f) Slides, particularly in the ravines where the material was deeply weathered, and of the side cast waste, were a constant danger and problem particularly on completed benches which were no longer accessible.

g) Rock falls were a constant danger in many areas.

h) House-size volcanic boulders completely enveloped in mushy ash constituted the most difficult work encountered.

i) Heavy erosion of side cast materials causing huge mud flows across lower access roads in creek crossings was a constant problem. Millions of yards of material flowed in this manner across the old Port-Mine road, particularly at Emito Creek, and was a constant source of blockage to mine access.

Manpower:

The peak manpower totalled 400 expatriates and 400 indigenes. The expatriate force was made up of predominantly Australian personnel, with a normal cross section of skills found at remote locations in Australia. The indigenous personnel were trained to the extent possible under a highly intensive construction program.

The road was a major achievement for the Contractor, Morrison-Knudsen-Fluor, and it is a tribute to the dedicated men who made it possible. They battled rain, mud, and more mud. Today the road is a modern link across half of the island.

D-8 Pioneering an access road.

MINE OVERBURDEN REMOVAL

General:

Overlaying much of the mine site was a layer, principally of volcanic ash, varying from nil to 200 ft. in depth – averaging 50 ft. After clearing the mine area – covering 500 acres – of trees and vegetation, this material had to be removed.

The volcanic ash insitu contains 30 to 50% water and once exposed to the rain becomes a slippery and muddy mess which will quickly bog down equipment. However, the ash is thixotropic and once disturbed can be easily slurried with water to form a transportable pulp. It was the foregoing problem and the characteristics of the ash which led B.C.P. Limited in 1968 to develop a method of hydraulicking, which in turn presented a very cheap and quick method of excavation and removal.

In the hydraulicking operation each work area was planned so that the overburden could be dozed a short distance by teams of two to four D-8's and D-9's. The dozers brought the material within range of one or two Stang high pressure hydraulic monitors. These monitors operate at a pressure of 650 ft. head and a capacity of 1,000 to 2,500 GPM through 1 in. to 3½ in. nozzles. The monitors are fed by a pumping station consisting of four 725 HP three-stage pumps, each with a capacity of 2,500 GPM. The water was distributed from the pumping station by a network of six miles of 12 in. and two miles of 16 in. steel pipe. The pipe distribution system was designed for simple assembly through use of bolted flanges and Victaulic couplings. To provide sufficient water pressure at the higher mine elevations, a booster pump station with three 2,500 GPM pumps was installed.

The excavated material, once slurried, flowed down the mine creek valleys at a minimum slope of 4 to 5% to the Kawerong River, which is a fast flowing stream running to the West Coast. Build ups occurred due to the deposition of solid rock materials which were carried along, however these were minimized and flushed away by the frequent high flows which follow heavy rain.

Equipment:

Three Spreads each consisting of 3 to 4 Dozers and 1 or 2 monitors operated during the peak production periods.

Rates up to 280 CY/bulldozer operating hour were obtained, with an average rate of about 200 CY/bulldozer operating hour being maintained throughout the work. For medium hauls the use of Terex TS 14 twin powered scrapers were used effectively.

The major equipment employed included:

4	D-9 Dozers
18	D-8 Dozers
3	D-6 Dozers
2	D-4 Dozers
2	TS 14 Scrapers
7	2500 GPM Pumps
2	Cat 561 Pipelayers
6	3½" x 6" monitors
4	2½" x 4" monitors
6	1" x 2" monitors
14	Floodlight Units
3	Muskateer Pipe Carriers

Availability of dozers was 73% and the availability of the pumps was 75%.

Production figures for a six month period were as follows:

Excavation (BCY) (1)	7,642,000
Dozer Operating Hours	36,700
Rate – (BCY/Dozer Hour)	208
Quantity Water (Gallons – 1000's)	575,000
Rate – (BCY/1000 gallons)	13.3

(1) Ash in place weighed 1.1 to 1.5 ST/BCY wet basis.

A total of 17 million cubic yards was removed by hydraulicking operations. This excavation method was also used to remove ash in the mine workshop area, the lower end of the mine access road, the main switch yard, and in the concentrator site. Work started in May 1969 and was completed in October 1971.

Commentary:

Original planning called for 6 in. monitors working with 2 to 3 D-8's, allowing for a utilization factor on the monitors of 50% because of time of relocation. It was found that the 6 in. monitor was big and cumbersome, therefore the smaller (2" and 4") more portable units were employed.

The topography was difficult to traverse and the ash was generally at the top of ridges. The best results were obtained when the water stream impacted the excavated material as it was leaving the dozer blade. It was futile to cast soil over the sides of benches and attempt to move it from the toes of the spoil pile with monitors. Thus it was necessary to move the monitors as close as possible to the dozer spreads.

It was also found that the piping system was difficult to relocate because of the large sizes used and the difficult terrain. Smaller lines and hoses off the mains combined with smaller monitors minimized this problem. For similar operations there would be merit in considering the use of head tanks and reticulation down to the working benches, rather than the uphill feed system utilized.

The D-8 dozers were selected because of the uncertainty of the ground being able to support heavier units. Ultimately it was found that D-9 dozers were entirely suitable under the conditions and these units operated much more efficiently than the D-8's. All dozers were equipped with wide-tracks and 'U' blades. To get the maximum utilization of equipment, operations were carried out on 2–10 hour shifts, 6 and 7 days per week.

Manpower:

Construction personnel at the peak included the following:

Direct operations	No.
Pipe Laying	48
Hydraulicking	69
Pump Attendants	20
Total Number	137

Direct operating labour hours for a 12 month period averaged 0.025 MH/BCY.

The construction crews were made up of expatriate and indigenous personnel in a ratio of about 1:2.

Indigenous personnel were utilized for operating the monitors and all pipe laying.

Both expatriate and indigenous personnel were used for operating bulldozers and trucks. The utilization of indigenes for these jobs was only limited by the availability of trained personnel. Virtually all mechanical repairs were handled by expatriates, however on the job training of indigenes was carried on whenever possible in the shop and field maintenance operations.

The biggest single problem was obtaining sufficient qualified personnel for the maintenance of equipment.

CONCENTRATOR AND PANGUNA TOWN

General:

Both the Concentrator and Panguna Town are located adjacent to the mine at an elevation of over 2000 ft. and their establishment involved clearing and developing an area of almost 50 acres.

The concentrator site lies along a mountain slope on the Karooma Creek valley. The main site is roughly 1000 ft. x 1500 ft. in plan and is terraced in a series of benches to best utilize the sloping topography in the design of the plant.

The entire site was developed through excavation, as the surface material contained, in some cases, a large amount of ash, and in other cases it was highly weathered material which deteriorated rapidly. Excavated material was spoiled downhill from the concentrator site up to 3000 ft. from the working area. For certain isolated areas, such as stream diversion and the coarse ore conveyor cut, excavated material was side cast to spoil.

Rock amounted to about 10% of the excavated material. Rock not used for hardstanding haulage roads was stockpiled and, once the site was cut to sub-grade and sloped for drainage, it was used for plating the construction work and laydown areas. This provided a good firm working area throughout the construction period, in spite of the heavy traffic and regular torrential rains.

Panguna Township is adjacent to the mine operation and is being built in two adjoining valleys, the Kawerong and Karoona valleys which come together, forming a broad 'V'. The valleys are steep and houses are built on slopes up to 1 in 3. Design of house sites called for cut and fill bench formation. Due to the poor quality of much of the hillside material, a large amount of rock hard-standing materials had to be imported for the house sites and drives. Elaborate drainage channels and pipelines had to be constructed concurrent with the earthwork construction to protect the building sites and streets from washouts.

The contract for this section of the work was awarded to Dumez (Australia). Work started in December 1969 and was completed for the Concentrator by September 1970 and in Panguna Town by March 1971.

Equipment:

Due to the varied nature of the work, virtually every size and type of earthmoving equipment was utilized. An indication of the scope of work and spreads of equipment employed in this work is summarized in Table 6–1. Table 6–2 shows the major items of equipment with availability and productivity where this was known.

Techniques:

a) Machines – most of the equipment used was of the standard type with the exception of the Nisha-Menck Scrapedozers which were very successful when working in soft volcanic ash and mud. These machines combine the abilities of a bulldozer with the carrying capacity of a small scraper. They are approximately 190 HP, mounted on tracks, have a low bearing pressure and carry within their bodies a scraper bowl of about 7 CY capacity. Over short-haul distances (400 – 900 ft.) in the Concentrator area conditions of mud, heavy rainfall

Port to mine access road winding towards Pakia Gap. The bench cuts are at approximately 30' heights. The original road track constructed for access during the exploration can be observed at the upper right side.

and steep grades, these machines were capable of out performing any other form of scraper whether rubber-tyred or tractor drawn. All the excavation work for the coarse ore conveyor which was down the side of a precipitous hill was performed by these machines.

Terex TS 14 twin power scrapers were utilized for a large proportion of the Concentrator excavation and generally gave good service. It is doubtful whether single engine scrapers would have performed under the conditions where traction was of primary importance. However, a major problem with rubber-tyred equipment was the high tyre wear rate resulting from wheel slippage over wet, jagged and abrasive material. Experiments made with fitting chains to the wheels were not successful as there was very little clearance between the wheel and the main chassis member and, with the build up of mud in the chains, excessive wear was caused to the chassis and adjustment parts. There was also the question of safety in that the operator sits immediately above the driving wheels and if a chain had snapped injury could result.

b) Methods – The removal of volcanic ash was extremely difficult and various techniques were tried such as blasting the ash down to a firm surface where conventional loaders could operate. When excavating with rubber tyred loaders into a face of volcanic material it was necessary to bring in one load of rock for every three loads of ash removed, for surfacing the working area.

Of particular interest was the provision of haul roads within the Concentrator area. Generally the main haul roads ran over areas of mud or volcanic ash and although sections were properly constructed with crossfall drainage and side drains, the high moisture content of the sub-base, when combined with high precipitation and heavy traffic flow, caused the roads to disintegrate in a very short period (4 to 10 hours). Also the mud which dropped from wheels caused difficulties with traction. The method used to overcome this was to divert the small creeks which flowed through the Concentrator on to the haul road so that in effect the road became a shallow stream. The continual passage of water over the road washed out the fines and mud from the surface and left behind such gravel and stones as were present in the matrix. Any spillage from equipment was also washed away so that a reasonable surface with good traction was maintained at all times. However one disadvantage of having a loose surface and travelling through running water was an extremely high degree of tyre wear. The production results, however, demonstrated that the method was effective.

Commentary:

The utilization of shovels was not very successful. After poor initial experience with 992 and 988 loaders in the slippery conditions where ash was present, the shovels were chosen because of their ability to handle wet conditions and their digging capability in working faces in bench type excavations. Unfortunately once in operation they were plagued with mechanical problems which resulted in the low availability indicated in the attachments. On the other hand, as working conditions changed and experience was gained, the 992 and 988's gave outstanding performance in the loading operations.

Manpower:

During July 1970 whilst at the peak of the contract, the number employed totalled 626:—

	Construction	Repairs	Supervisory
Expatriate	193	147	101
Indigenous	128	42	15
Total	321	189	116

PORT SITE

General:

This section of the project included the site preparation for the power station; the concentrate filtering, drying, storage and handling facilities; and associated fuel storage and wharf warehousing. Also included were the permanent roads for the port area along with general drainage structures.

The shortage of flat land with a suitable rock base for foundations was a problem which could only be resolved through a massive excavation program. Additionally, a large area for laydown in proximity of the wharf was required. Both objectives were achieved by carving out of the hillsides proper sites for the power plant and the concentrate process facilities, using the excavated materials for fill in swamp and shore areas to develop laydown space. Reference is made to Figure C.

The major construction and cost item involved was the excavation of 1,160,000 CY of rock. The rock was slightly fractured moderately hard tuffaceous andesitic agglomerate, both fresh and moderately weathered types.

All earthwork and drainage was carried out by Dillingham Corporation of New Guinea Pty. Ltd. The construction period was nine months.

The major quantities involved were:—

Excavation — Common	(CY)	585,000
Excavation — Rock	(CY)	1,160,000
Classified Fill	(CY)	640,000
Unclassified Fill and Spoil	(CY)	1,100,000
Culverts	(LF)	1,650
Grouted Stonework	(SF)	13,000

Equipment:

The work method employed utilized drill tracks, wheel and tracked loaders, and 35T and 6 CY dump trucks. There were eight spreads of equipment worked. The units and the performance achieved were:—

Spreads No. 1 and 2

2 D8H Dozers
1 Terex 72-81 9 CY F.E.L.
4 35 T trucks
Average load cycle — 3 minutes
Cut measure 15 CY load in rock
17 CY load in common
Availability 75%
Loads per hour — 15
Rock excavation per hour — 225 CY
Common excavation per hour — 250 CY

Spreads No. 3, 4, 5, 6 and 7

1 D6C Dozer
1 D8H Dozer
1 2½ CY F.E.L.
6 6 CY tip trucks
Average load cycle — 2 minutes
Cut measure 4 CY load in rock
4½ CY load in common
Availability 75%
Loads per hour — 22
Rock excavation per hour — 88 CY
Common excavation per hour — 100 CY

Spread No. 8

6 Crawler Drills
6 600 C.F.M. Compressors
Hole pattern 8 ft. x 8 ft.
Yield per foot drilled — 2.4 CY
Availability 83%
Average drill production — 55 LF/hour
— 130 CY/hour

A listing of all major equipment is shown in Table 7—1 together with availability for each type. As indicated, the large loaders experienced mechanical difficulties which adversely affected the capability of the heavy truck spreads.

Techniques:

Apart from the normal problems associated with a project of this magnitude the following are of interest.

Due to the concentrated nature of the work and the very confined area of operation, careful consideration had to be given to detail scheduling. The schedules were prepared on a two-weekly basis with updating weekly.

Drilling and shooting was a key operation from the overall productivity viewpoint and with so many other construction activities going on it was necessary to give careful consideration to all blasting details. Quarrying operations were scheduled for drilling on two shifts daily six or seven days per week with shot loading and blasting on the day shift only. Blast times were arranged to suit meal break and shift change over periods.

Manpower:

The personnel utilized are summarized as follows:

	Operating	Support	Supervisory
Expatriate	42	24	32
Indigenous	61	12	1
TOTAL	103	36	33

Total — 172

A detailed breakdown by position of these personnel is shown in Table 7—2.

ARAWA TOWN

General

The Arawa Town site is located along the east coast of Bougainville in a former plantation. The town has been completely planned, including establishments in the town centre for Government activities and commercial enterprises, housing areas, sites of schools, hospitals and recreation facilities. The town drainage system is designed to provide orderly run off of storm water with a minimum of flooding during peak periods. The town will be fully reticulated for water and sewerage.

The earthwork contract called for the construction of eighteen miles of streets, preparing 2200 house sites, and developing 150 acres of land for the town centre and other municipal facilities. There are ten miles of storm drains. Excavation work totaled over 2,000,000 CY and fill totaled 600,000 CY.

The conditions encountered in town earthworks varied from swamps or semi-swamps over the lowlands, which constituted 20 to 30% of the town area along the coast to

Site excavation for the concentrator. April 1970

boulder terrace along the higher ground inland.
At the beginning of the work, typical to all earthwork operation on the island, there was a lack of good fill and hardstanding materials which were essential to pioneering in poor ground and wet conditions. This material was developed from borrow pits in the river beds and from a hillside quarry.

Equipment:

Conventional equipment was chosen with the sizing of spreads varying from 2½ CY loaders and 6 CY trucks, to 6 CY loaders and 35T trucks. The Nisha-Menck "Scrapedozers" of 6–8 CY were effectively used in the soft ground for developing house sites. This range of equipment was necessary to suit the varied earthmoving tasks involved.

A list of the spreads employed and average productive capacities are listed below:

a. **Quarry Operation**
   D8H Dozer with single ripper.
   Cat. 966B F.E.L.
   4 White 12 CY Dump Trucks.
   10 Izusus 6 CY Dump Trucks.
   Average productive capacity 9000 B CY "SOLID"/ week single shift only.

b. **River Quarry Work**
   Cat. D8H Dozer (Supplement by D9 ripper if required due to large boulders).
   Cat. 988 F.E.L.
   3 x R35 Euclids.
   G.D. Airtrac and 600 CFM Compressor.
   Average productive capacity 8000 B CY "SOLID"/ week.
   (N.B. this is the **average**, plant suffered standby when large interlocked boulders required drilling and shooting).

c. **Road Stripping**
   2 No. Nisha-Menck SR 264 "Scrapedozers" (Bowl capacity approximately 8 CY)
   Average total productive capacity 200 B CY "SOLID"/ hour on haul of 300 feet approximately.

d. **Normal Cut/Fill Operation on Roads**
   3 x Angle Blade D8H Dozers
   Average total productive capacity in material free of large boulders 8000 B CY "SOLID"/week.

e. **Coconut Log Disposal**
   D6C Dozer with winch
   Kato 750 backhoe with hydraulic "tree grab".
   2 White 12 CY Dump Trucks. (3 required if long haul).
   Average productive capacity 80 trees per day.

The availability of equipment was very good considering the operating conditions. The results obtained are listed in Table 8–1.

Techniques:

The special techniques utilized with regard to plant were as follows:

a. The use of the wide track "scrapedozers" on stripping.
b. The use of Komatsu D50P "swamp dozers" to spread spoil from road works and drainage channels.

c. The use of "end dumping" over swampy ground to build temporary and permanent roads.
d. The boxing out of road formation by dragline on swamp pads or temporary fill. In some areas, "ground contact" track machines could not be used without complete bogging.

All the above requirements were necessitated by the exceptionally heavy rainfall (150 in. per year), the low-lying topography and the soft nature of the soil.

e. The use of hydraulic backhoe and "tree grab" attachment with tip trucks for the removal to disposal of coconut logs (which cannot be burned with much success).

Manpower:

Peak manpower employed was:

	Operating	Support	Supervisory
Expatriate	81	77	16
Indigenous	114	28	1
TOTAL	195	105	17

Note: **Operating** includes all personnel on plant, concrete work and drainage.

Support includes all workshops, clerical and survey.

In general the capability of the expatriate workers was typical of that found in Australia indicating that a reasonable cross section of Australian labour was obtained.

Due to the critical time controls on the contract, training of indigenous personnel was done "on-the-job".

General Advice:

a. **Methods**

A close study of every operation was required, with particular emphasis placed on constructing drainage structures as far ahead of program as possible. The use of all track machinery with special swamp tracks and wide tracks is a recommended necessity in the soft conditions.

Haulage requirements over rough jungle roads almost always dictated the use of "all wheel" drive plant, (e.g. 6 wheel drive Izusu trucks).

The presence of large rock floaters near old river courses meant that any list of plant for major earthworks should include track mounted drills capable of 3–4 in. holes. It should be noted that even a close inspection of coastal jungle terrain may not indicate the presence of rock floaters. These must be handled by tracked dozers equipped with heavy duty blades and rippers, supplemented by "Airtracs".

b. **Cost/Productivity Controls**

Normal controls were employed, with allowance for the overall drop in productivity of rubber and track mounted plant due to wet roads and swampy conditions.

c. **Scheduling**

Account was taken in the drop of plant productivity as per paragraph b) above, and also actual lost time during periods of heavy rain (making all operations impossible) and the associated repair work and clean-up after such storms. The allowance by experience was a loss of one day in six, as an average over twelve months. However, under certain conditions this was modified to take into account dry periods and wet periods during the year if the job was for only a short duration.

Programs had to be finalized as soon as possible, to enable the timely purchase of materials (very few of which are available in PNG) as the 6 to 8 weeks lead time involving shipping from Australia can be critical. This same problem on deliveries applies to spare parts, hence stocks of spares must be much larger than a job with similar plant in Australia.

d. **Recruitment**

Employment of local people was done as needed and without advertising, as the response to any attempt at active recruitment was overwhelming; only a small percentage have skills required. All labouring jobs are easily filled by local hire.

CONCLUSION

In making commentary regarding experience gained on Bougainville, the principal rules involved are all well known in the engineering and construction business. It is emphasized however that on such large undertakings each factor takes on a greater significance in the ultimate results of the operation. Therefore it is appropriate to restate the principles which are so important on a project such as Bougainville Copper.

a. **Design and Planning**

Adapt an engineering and construction schedule which allows time to accurately establish the work requirements, permits maximum utilization of equipment, and allows optimum use of support facilities and manpower. If initial information is not accurate and major revisions are necessary during the work, all other operations can be adversely affected.

Establish camps, personnel amenities, communications and logistics of the highest standard before the work program accelerates.

For areas subject to high rainfall and poor soil at the very beginning, delineate abundant and convenient borrow pits and rock quarries to supply competent embankment and hardstanding materials – especially for the pioneering stage.

Allow large contingencies in quantity estimates for materials which will "disappear" in swamps or will wash away, and for the work involved in the development of temporary support facilities.

Choose experienced contractors who have available the management, experienced supervision, qualified personnel and the resources to furnish top quality equipment.

b. **Plant Equipment**

Standardization of equipment spreads with interchangeability of parts should receive extra special attention for work in remote areas.

Provision for supply and warehousing of spare parts should be carefully planned and established (including logistics and custom procedures) before work begins. Spares far in excess of normal construction practice should be maintained for jobs in outlying areas.

Tracked equipment was successful in the soft conditions when equipped with wide swamp tracks.

Rubber tyred loading and handling equipment performed well in the wet conditions, however high tyre wear should be allowed for. Unfortunately, the new Cat Dystred wheel was not available for the Bougainville earthwork. This

Site excavation for the concentrator – in centre is a 3 CY shovel working with 35 ton trucks. May 1970

wheel appears especially suitable for "island" conditions.

Under similar conditions all-wheel drive units should be mandatory for small haulage units, personnel carriers, service and utility vehicles. For large haulage and transport units all-wheel drives should be favoured if other factors are equal.

Twin powered scrapers operated well under most conditions encountered. Single powered scrapers were less adaptable and tractor drawn scrapers were almost useless.

A greater number of stand-by equipment units must be allowed for than is normally done. This is particularly applicable to key one-of-the-kind plant in spreads e.g. loaders, draglines, shovels, etc. to protect the overall availability of the spreads.

Allow for lower than normal productivity because of time lost due to rain, and inefficiencies occurring from wet conditions, bogged equipment, inexperienced labour, accidents, etc.

c. **Manpower**

Establish labour rates, working and living conditions which will help recruit and keep top quality operators and mechanics.

Maintain on-the-job labour relations to minimize work stoppages. Plant laying idle gets mighty expensive!

Equally important in recruitment is to be selective and thorough in hiring practices. Employees should be checked out through references and/or tested before being mobilized. Turnover and inexperienced personnel are costly in every way.

Currently there are not significant numbers of trained indigenous operators and mechanics in PNG to handle earthwork construction on contracts similar to those awarded on Bougainville without using a predominantly expatriate work force. In fact, under present conditions, it is difficult to recruit sufficient qualified personnel from Australia and New Zealand.

This indicates the need for more training programs, both in Australia and in PNG to develop the skills which will be required for civil works necessary for industrial development and public works projects.

ACKNOWLEDGEMENTS

The writer is grateful to the Contractors, their personnel, and Bechtel–W.K.E. staff for their assistance in providing most of the material presented in this paper.

Special thanks are due to the following.

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– J.F. McKee – Residential Manager, D.W. Teters – Project Manager

Dumez (Australia) – for the Concentrator and Panguna Township
– Louis Mauduit – General Manager, N.G. Allen – Construction Manager

Dillingham Corporation of New Guinea Pty. Ltd. – for the Port Site
– F.W. Hurd – General Manager, J.W. Swan – Project Manager.

Thiess Bros. (Pacific) Pty. Ltd. – for Arawa Town
– A.J. Wells – Branch Manager, N.G. Bowra.

Bechtel – W.K.E. – General Data
– Estimating and Cost Control Department

TABLE 3–1

Major Earthwork Contractors

Contract:	Contractor:
Port–Mine Access Road. Mine haul roads. Jaba River road.	Morrison-Knudsen Fluor (A joint venture)
Concentrator site Panguna Township	Dumez (Australia)
Port Site	Dillingham Corporation of New Guinea Pty. Ltd.
Arawa Town	Thiess Bros. (Pacific) Pty. Ltd.

TABLE 4–1

Major Equipment Employed on Port-Mine Access Road and Support

M-K-F Equipment:

1.	Jersey Rock Spreader
2.	Ambulances
2	Buses
28	Pickups
13	Vehicles
8	8 CY Dump Trucks
6	5 CY Dump Trucks 6 x 6
21	3T Flatbeds
9	7T Flatbeds/Manhauls
1	1T Flatbed
3	Truck Tractors, Prime Mover
4	Fuel Trucks
18	35T Rear Dump, 769
2	125 cfm Compressors
2	250 cfm Compressors
4	365 cfm Compressors
8	600 cfm Compressors
2	Concrete Mixers – 125
8	Air Track Drills
1	5 yd. Shovel, Dragline
1	26T Truckcrane
1	600 Gradall
3	410 AW Cranes
4	3T Cranes
2	12 Graders
5	14 Graders
20	10 KW Light Plants
2	Small Farm Tractor Loader/Backhoe
5	950 Loaders 2½ CY
5	988 Loaders 6 CY
1	992 Loader 10 CY
2	WC17 Wagner Rollers
1	VP20D Roller
1	VP80D Roller
2	66T Rollers
2	600 Raygo Rollers
1	R120 Sheepsfoot
2	619 Scrapers
2	631B Scrapers
1	D-4 Dozer w/winch
1	D-4 Dozer w/winch
3	D-6 Dozers w/winch
2	D-7 Dozers
3	D-8 Dozers w/ripper
5	D-8 Dozers w/winch
2	D-8 Dozers w/slopers
8	D-8 Dozers
6	D-9 Dozers w/ripper
1	D-9 Dozer
1	824 Dozer
1	834 Dozer
3	Farm Tractors
1	40T Lowloader Trailer
2	4000 Gal. Semi-Tankers, Water
5	1000 Gal. Tank Trailers
12	400 A. Dsl. Welders

BCP Equipment:

2	IR Drill Tracks and 600 cfm compressors
2	Cat D-9 Dozers w/rippers
6	Cat D-8 Dozers w/rippers
1	Cat 992 10 CY Loader
2	Cat 988 6 CY Loaders
9	Cat 769B 35T Trucks
1	Cat 14E Grader

Rock Crushing Plant:

1	Dump Hopper & Apron Feeder
1	Vibrating Grizzly
1	36 x 24" Traylor Type H Jaw Crusher
1	36" Belt Conveyor
1	3 Deck Vibrating Screen
1	24" Belt Conveyor
1	Stacker Conveyor
1	Universal Engineering Corp. Portable Plant consisting of: 1 Feed Hopper 1 36" x 12" Jaw Crusher 1 30" x 36" Roll Crusher 1 5' x 14' Deck Vibrating Screen

TABLE 6–1

Concentrator and Panguna Township – Earthworks and Equipment Spreads

Item	Concentrator	Panguna
Clearing & Grubbing (acres)	22	27
Common Excavation (CY)	3,200,000	304,000
Rock Excavation (CY)	385,000	204,000
Class AA Fill (CY)	194,000	131,000
Class B Fill (CY)	180,000	–
Overhaul (CY/Mile)	37,000	136,000
Culverts 12 in. to 54 in. (LF)	–	6,500
Roads – Base Course (CY)	–	98,000

The following equipment spreads were used at the Concentrator site:–

Spread No. 1

1	Cat D9 Dozer
1	Cat D8 Dozer
1	DRM 600 Grader
1	Coates 78T Roller
4	Terex TS 14 Scrapers

Spread No. 2

1	Cat 992 10 CY Loader
2	Cat D9 Dozers
1	Cat D6 Dozer
6	35T Trucks
1	DRM 600 Grader
1	Coates 78T Roller

Spread No. 3

1	Bucyrus 71B 4¼ CY shovel
1	Cat 988 6 CY Loader
1	Cat D9 Dozer
1	Cat D8 Dozer
4	35T Trucks

Spread No. 4

1	Bucyrus 71B 3½ CY shovel
2	P & H 1055 4 CY shovels
1	Cat D9 Dozer
3	Cat D8 Dozers
8	35T Trucks
1	DRM 600 Grader
4	Air trac Drills
4	600 cfm Air Compressors

Spread No. 5

1	Cat D9 Dozer
1	Cat D8 Dozer
4	Terex TS 14 Scrapers

Spread No. 6

6	Nisha-Menck Scrapedozers

The spreads used at Panguna Township were as follows:

Spread No. 7

1	Cat 977 3 CY Traxcavator
1	Cat D8 Dozer
1	Cat D6 Dozer
3	International 9 CY Tip Trucks
3	Izusu 6 CY Backhoes
1	JD 450 F.E.L./Backhoe

Spread No. 8

1	Cat 977 3 CY Traxcavator
1	Cat D8 Dozer
1	Cat D6 Dozer
3	International 9 CY Tip Trucks
3	Izusu 6 CY Tip Trucks
1	Coates 78T Roller

Spread No. 9

1	Cat 977 3 CY Traxcavator
2	Cat D6 Dozers
1	Cat D4 Dozer
3	Mercedes 13 CY Tip Trucks
1	DRM 600 Grader

Spread No. 10

1	Cat 977 CY Traxcavator
1	Cat D8 Dozer
1	Cat D6 Dozer
1	Cat D4 Dozer
3	Mercedes 13 CY Tip Trucks
3	Izusu 6 CY Tip Trucks
1	JCB 3/4 CY Backhoe
1	Coates 78T Roller

Miscellaneous Plant

5	JD 450 F.E.L./Backhoes
5	Cranes
2	250 cfm Compressors

TABLE 6–2

Concentrator and Panguna Township Earthworks – Major Equipment Summary

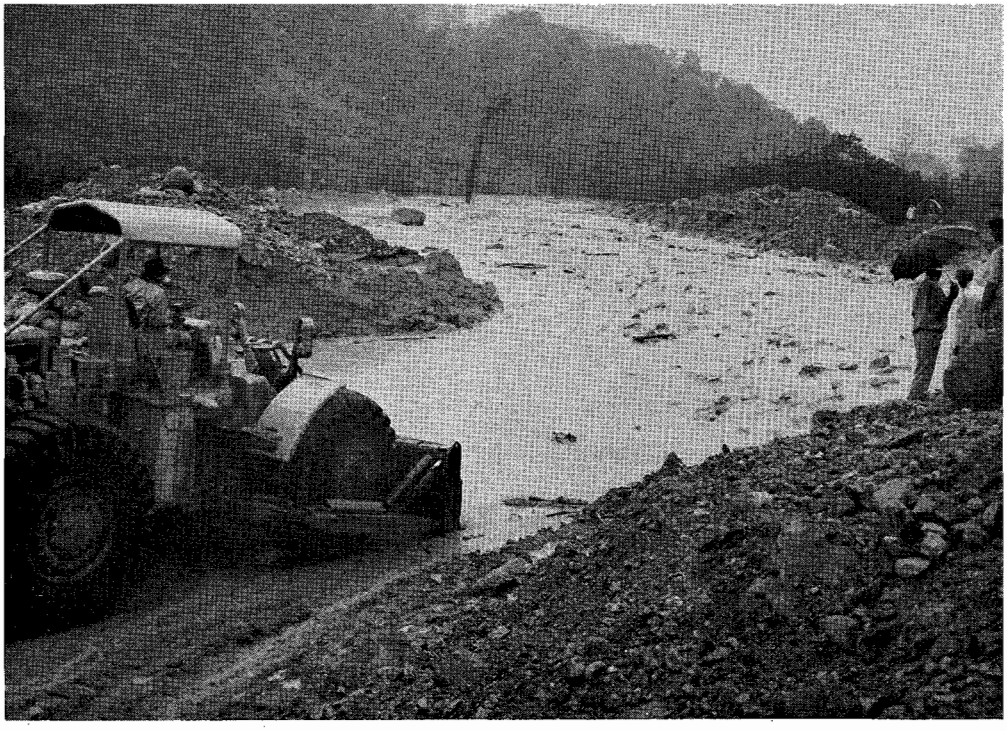
Item	No.	Availability %	*Production/hour (CY) Working	*Production/hour (CY) Working & Repair
Cat 992 Loader	1	80	298	237
Cat 998 Loader	1	80	204	164
Cat 977 Loader	4	64	74	47
Shovels	4	39	183	77
TS 14 Scrapers	8	65	77	50
Scrapedozers	6	72	70	50
Cat D9 Dozers	6	68		
Cat D8 Dozers	8	77		
Cat D4 Dozers	4	75		
35 Ton Dump Trucks	18	62		
Mercedes Trucks	6	70		
International Trucks	6	43		
Izusu Trucks	9	90		
Graders	4	70		

*Productivity is quoted per actual working hour on the shift inclusive of working and repair but not including standing-time when the machine was mechanically available for work.

TABLE 7–1

Portsite Earthworks – Major Equipment Summary

Item	No.	Availability %
Terex 72–81 9 CY F.E.L.	2	60
Cat 950 2½ CY F.E.L.	3	75
Cat 980 5 CY F.E.L.	1	75
Cat D6C Dozer	3	75
Cat D8H Dozer	8	60
Cat 12E Grader	1	75
Cat 14D Grader	1	75
International 175 CY Traxcavator	2	40
Terex R35 35T Truck	4	75
Cat 769 35 T Truck	4	75
Izusu 6 x 6 6 CY Tip Truck	30	60
JCB 6D Crawler Hyd. Backhoe	2	75
Davleco 72T Vibratory Roller	3	75
L.W. Double Drum Roller	1	75
I.R. URD 475 Crawl Air Drill	7	75
Atlas 250 CFM Compressor	1	75
Atlas 350 CFM Compressor	1	75
I.R. 600 CFM	7	75
Lister 7KVA Mobile Light Plant	5	75
Lister 21 KVA Mobile Light Plant	3	75



Washout of Port-Mine access road at EMITO CREEK caused by mudflow consisting chiefly of material washed from sidecast excavations on the mountain section of the road. Aug. 1970

TABLE 7–2

Portsite Earthworks – Manpower

	Expatriate	Indigenous
Operating		
Drillers	12	12
Dozer Operators	12	6
Grader Operators	2	–
35T Truck Drivers	10	6
Loader Operators	6	7
Native Artisens & Labour		30
Support		
Fitters	14	2
Serviceman	4	8
Auto Electrician	1	–
Panel Beater	1	–
Fitter Turner	1	–
Boilermakers	2	2
Electrician	1	–
Supervisory		
Project Manager	1	
Project Superintendent	1	
Shift Superintendent	2	
Earthworks Foreman	2	
Quarry Foreman	2	
Labour Foreman	1	
Shop Foreman	3	
Project Engineer	1	
Office Manager	1	
Accountant	1	
Paymaster	1	
Clerical	2	1
Surveyor	2	
Leading Hand Operators	4	
Leading Hand Drillers	5	
Leading Hand Fitters	3	
Peak Strength	98	74

TABLE 8–1

Arawa Town Earthworks – Major Equipment Summary

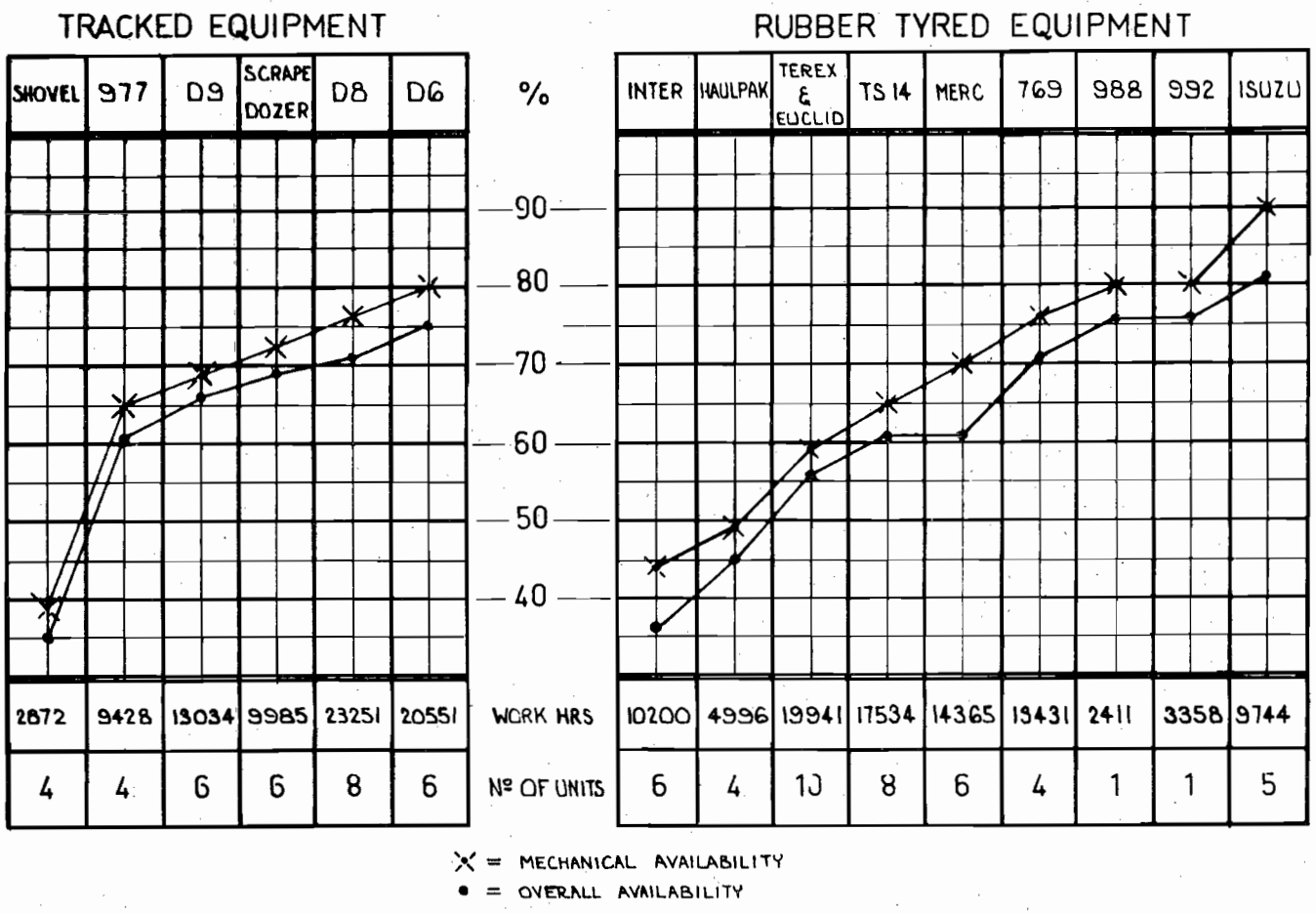
Item		*Availability%
Trucks	35T Euclid Dump	95
	12 CY White Dump	71
	6 CY Izusu Dump	81
F.E.L.	2 Cat 950	91
	1 Cat 966	90
	1 Cat 977	95
	1 Cat 988	85
Dozers	2 Cat D4	93
	4 Cat D6	89
	5 Cat D8	88
	1 Cat D9	82
Dragline	2 P & H 2½ CY	62
Backhoes	2 Kato 350) 1 Kato 750)	85
Graders	2 Cat 14) 2 Cat 12)	92
Cranes	1 Steelweld 23T 1 Austin-Western 7T	
Compressors	2 G-D 600 CFM 1 CP 175 CFM	
Drill Tracks	2 G-D ATD 3100	
Rollers	2 Pacific 33 T.C. Vibrating Self Propelled. 2 Pacific V12D Sheepsfoot Drawn. 1 Pacific V12D Smooth Drawn. 1 McDonald NB11 13T Self Propelled	

* Taken over five month period February – June 1971

Figure 8

CONCENTRATOR & PANGUNA TOWNSHIP EARTHWORKS

FINAL EQUIPMENT AVAILABILITY



NOTE :- ABSOLUTE COMPARISONS OF AVAILABILITY FIGURES SHOWN FOR SIMILAR MACHINES FROM DIFFERENT MANUFACTURERS SHOULD NOT BE MADE BECAUSE OF THE DIFFERENCE IN AGE OF UNITS AND THE AVAILABILITY OF SPARES.

LEGEND

EXCAVATION ——————

HYDRAULICKING - - - - - - - -

FIGURE A

MASS EARTHWORKS PROGRAM

BOUGAINVILLE COPPER PROJECT

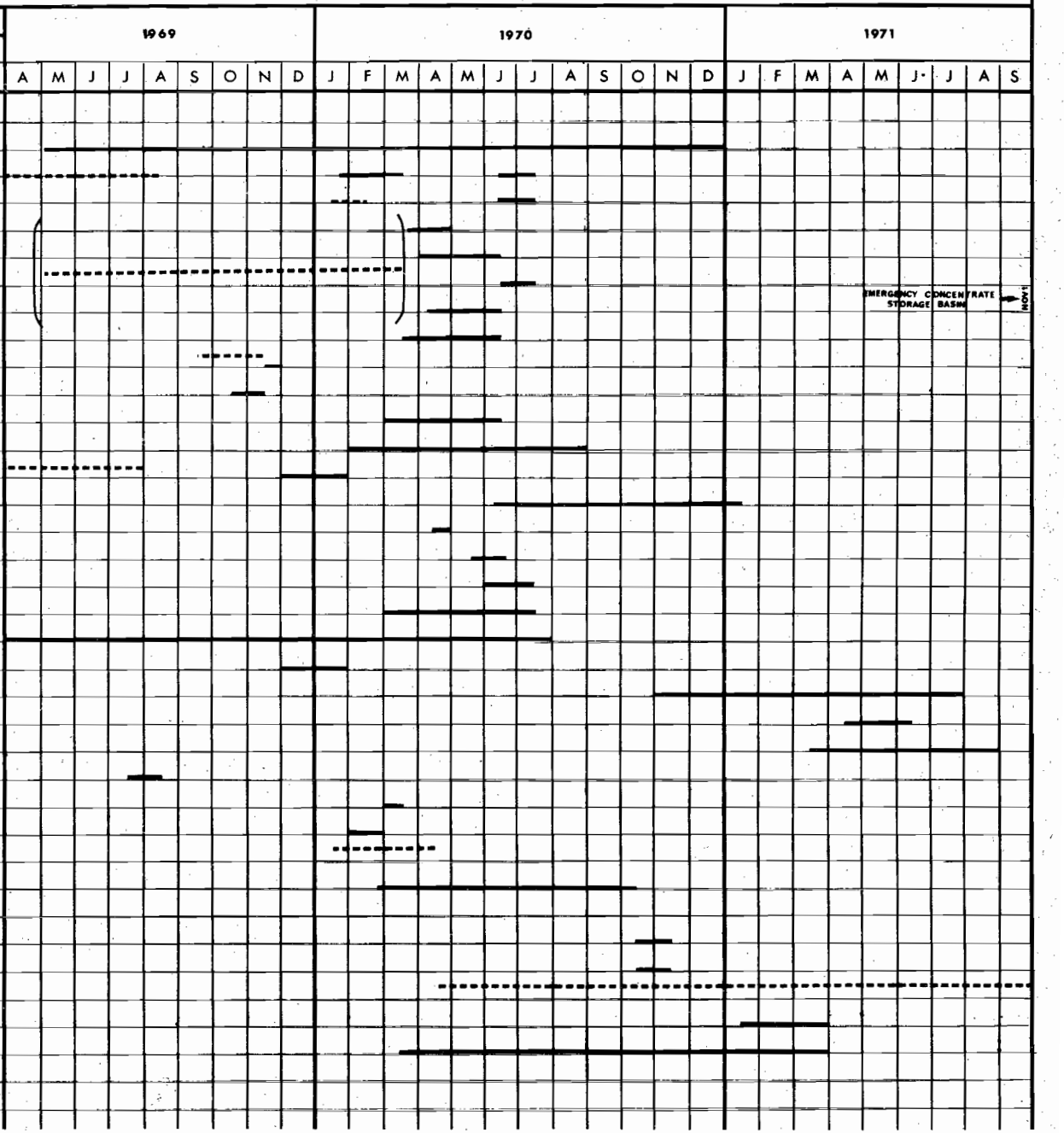
BOUGAINVILLE COPPER PTY. LIMITED

BECHTEL - W.K.E.

A JOINT VENTURE

JOB NO. 6406

	DESCRIPTION	EARTHWORKS, CU. YDS X 1000				
		EXCAVATION			FILL	
		HYDR	COMMON	ROCK	SPOIL	BORROW
1	MINE AREA		300	200	350	150
2	PANGUNA TOWN					
3	PRIMARY CRUSHER					
4	COARSE ORE CONVEYOR	4,000	3,200	300	3,211	374
5	COARSE ORE STORAGE					
6	FINE CRUSHING & SCREENING					
7	FINE ORE STORAGE					
8	CONCENTRATOR					
9	CONCENTRATOR HARDSTAND			40		40
10	SWITCHYARD	200				
11	ADMINISTRATION BUILDING					
12	ROAD & CREEK DIVERSION INCLUDING RIP RAP					
13	CRUSHED ROCK BASE COURSE					300
14	MINE SERVICES AREA INCLUDES PIT WORKSHOP & PIT FUELING STATION	100				
15	KAWERONG DIVERSION INCLUDING RIP RAP					
16	TOWN MAINTENANCE AREA INCLUDES CARPENTER SHOP & CENTRAL FUELING STATION					
17	CENTRAL WAREHOUSE					
18	CENTRAL WORKSHOP					
19	SPORTS RECREATION AREA					
20	CAMPS & LAYDOWN					
21	QUARRY LAYDOWN & ROAD					
22	JABA RIVER ROAD & WATER LINE		700		500	200
23	JABA RIVER PUMP STATION		170	30	100	10
24	CONCENTRATE PIPELINE PIPE ALIGNMENT & ACCESS					
25	TEMPORARY ACCESS ROADS					
26	SLURRY PLANT					
27	1.1 MW POWER HOUSE					
28	MINE HAUL ROADS		1,403	47	1,200	100
29	2650 CH 00 - 4900					
30	2650 CH 4900 - 9877					
31	2600					
32	2550					
33	MINING OPERATION	17,650				
34	PANKIRANKU ROAD					
35	QUARRY WESTERN ADIT			200		
36						
37						
38						



39						
40						
41						
42						
43						
44						
45						
46						
47						
48						
49						
50						
51						
52	SUB-TOTAL MINE AREA	21,950	6,815		5,601	1,214
53	**COAST AREA**					
54	KIETA - TUNURU ROAD		210	100	100	100
55	ARAWA TOWN		1,902	90	1,488	504
56	LAYDOWN AREAS					
57	CONCENTRATE PROCESS INCLUDES FILTERING & DRYING		520		508	208
58	CONCENTRATE STORAGE					
59	PORT WAREHOUSE, WHARF AREA & LOADOUT FACILITIES					312
60	POWER PLANT & SWITCHYARD			926		15
61	PERMANENT WHARF LAYDOWN AREA INCLUDES PORT OFFICE BLDGS					152
62	TEMPORARY WHARF LAYDOWN AREA INCLUDES FUELING STATION				273	265
63	FUEL STORAGE AREA			140		
64	NITRATE & PREMIX STORAGE		152			5
65	CAMPS		100			100
66						
67						
68						
69						
70	SUB-TOTAL COAST AREA		4,184		2,341	1,843
71	**SERVICE LINKS**					
72	PORT-MINE ACCESS ROAD		10,388			
73	CH 130065 - 139600	50				
74	CH 00 - 130065					
75	BASE COURSE & SEALING			110		110
76	INDUSTRIAL PARK		300			300
77						
78	SUB-TOTAL SERVICE LINKS	50	10,788		10,388	440
79						
80						
81						
82	**GRAND TOTAL**	22,000	21,784		21,887	8,667

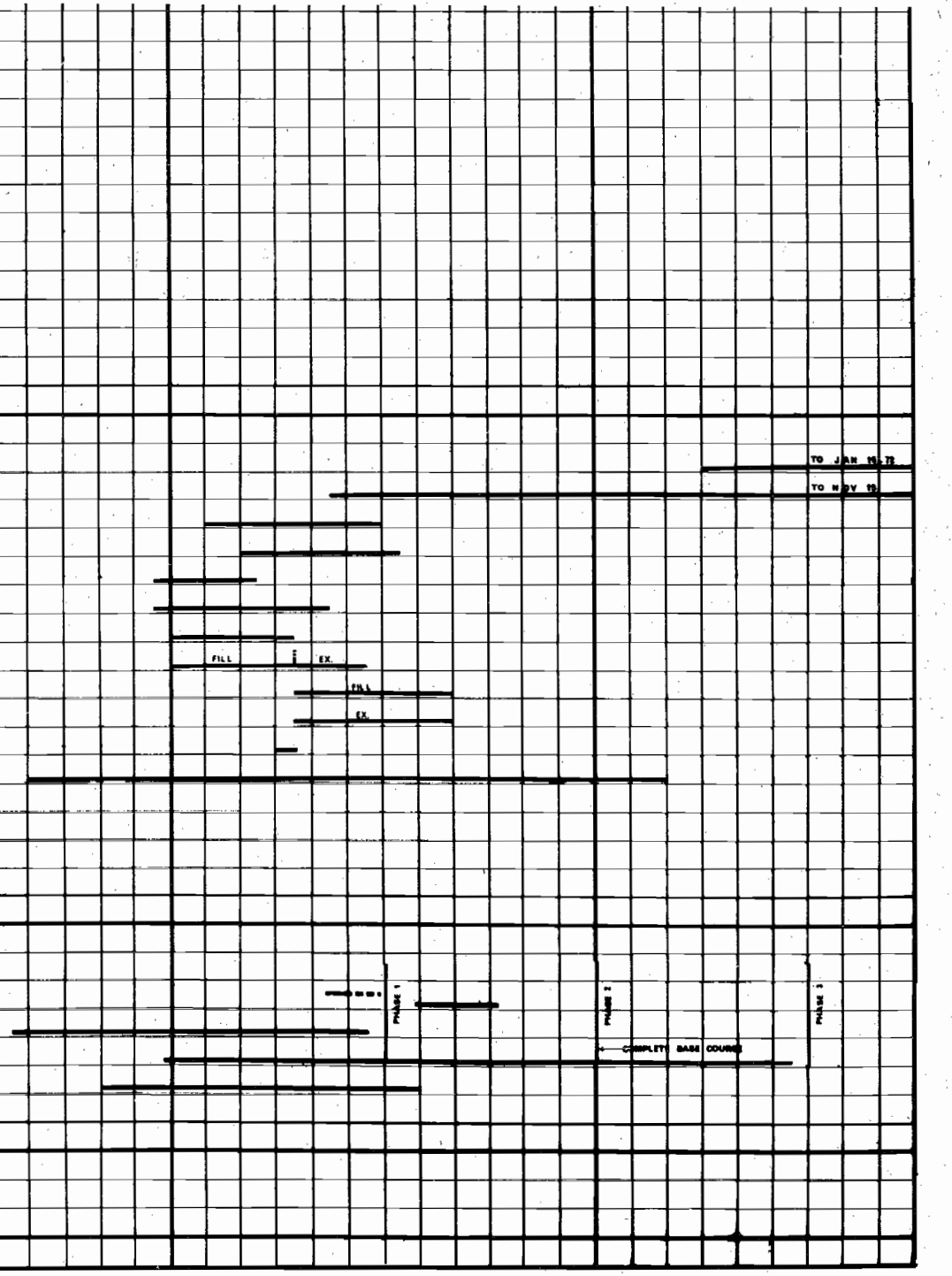
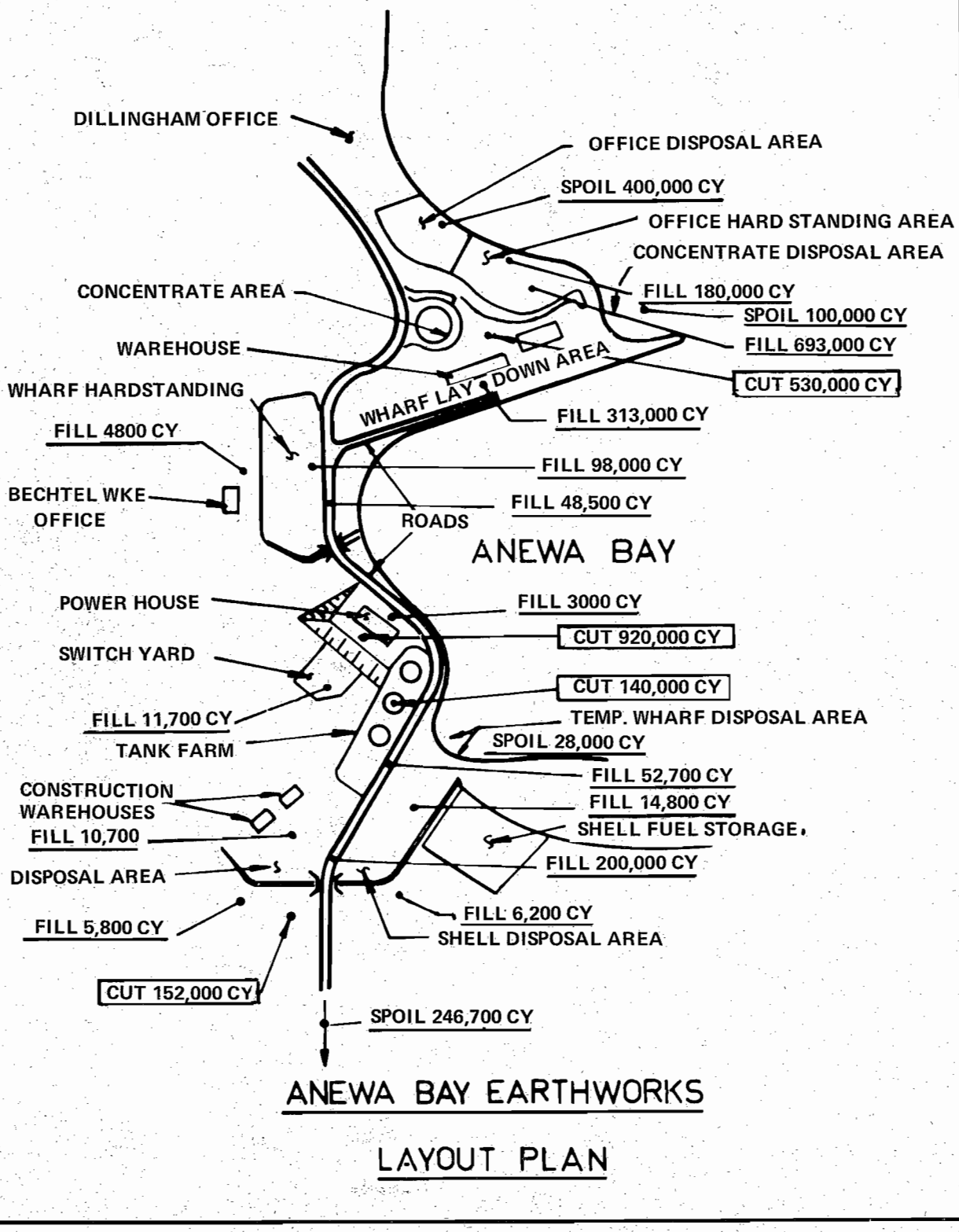


Figure C

PORT SITE EARTHWORKS

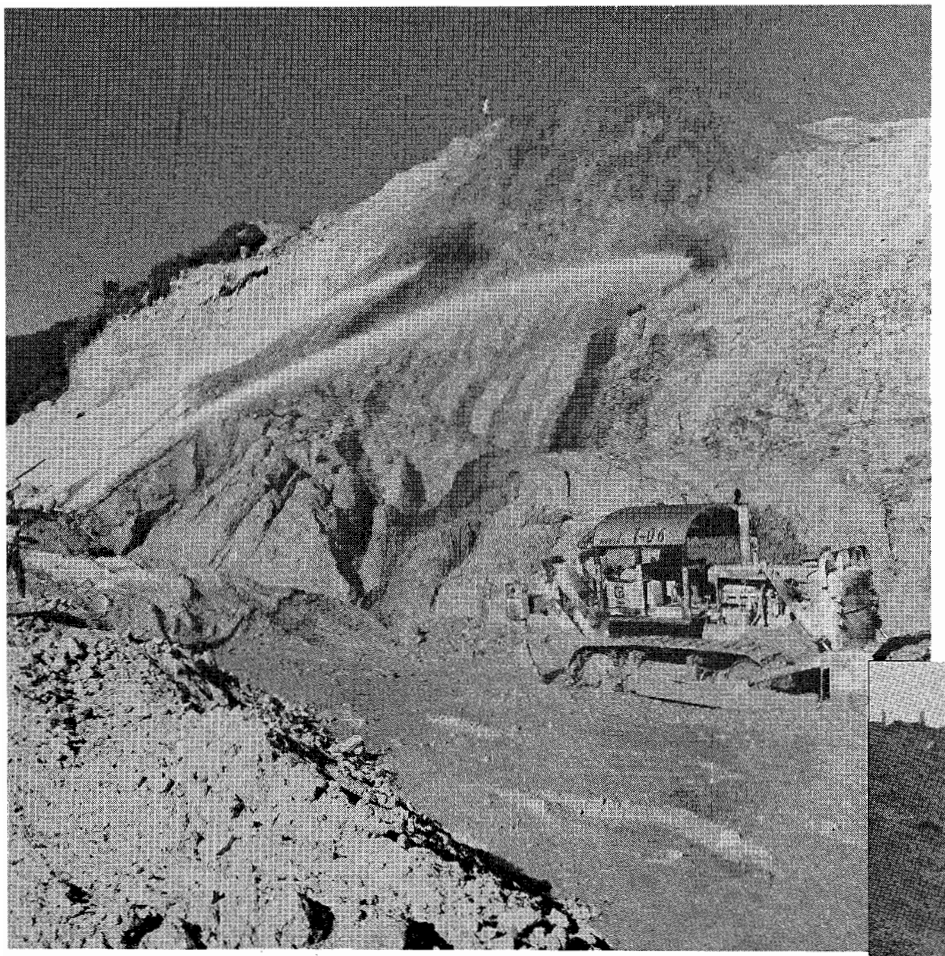


ANEWA BAY EARTHWORKS

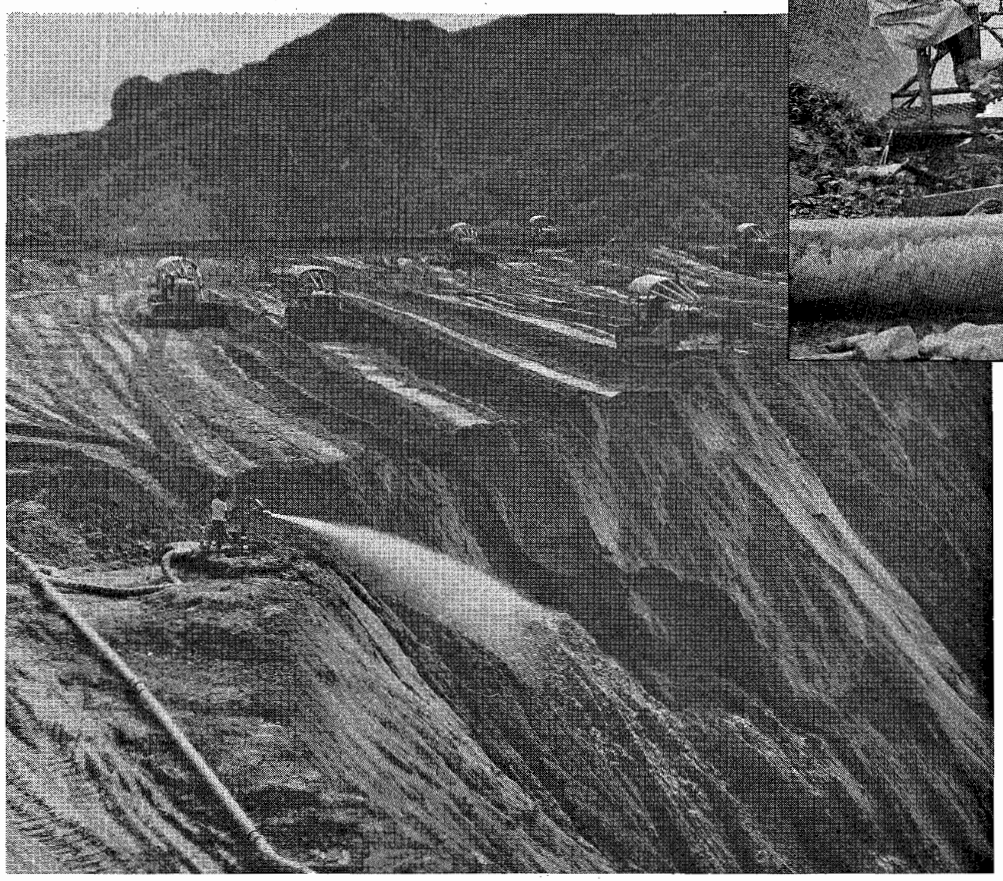
LAYOUT PLAN

Hydraulicking

The volcanic tuff was stripped by bulldozing and hydraulicking. Inteligiants operating at pressures from 200 to 300 pounds per square inch discharged 2,500 gallons of water per minute through 3.0 and 3.5 inch nozzles.



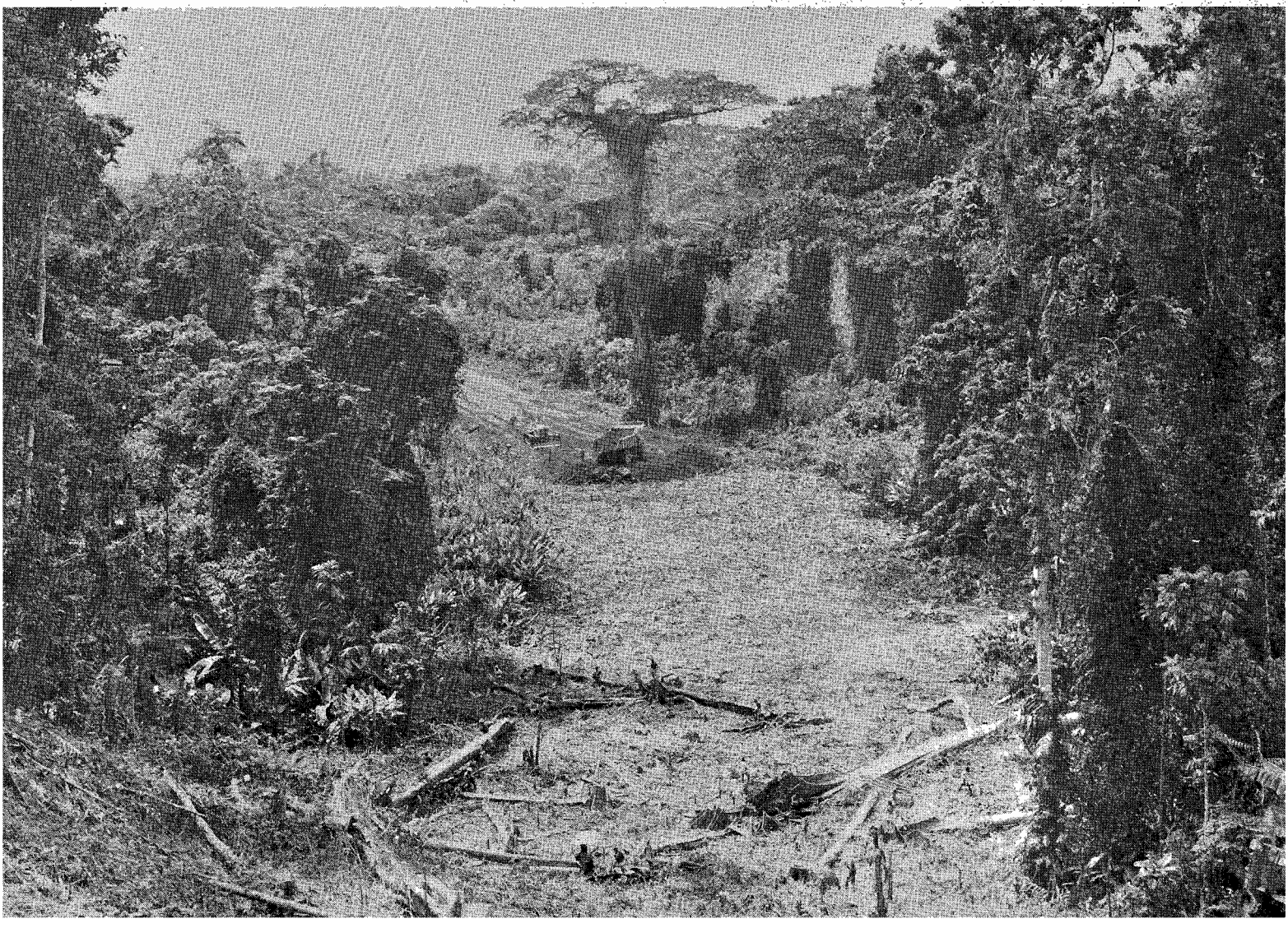
Dozers pushed the tuff to the monitors which slurried the material and washed it into the Kawerong River. Stripping reached 280 cubic yards per bulldozer hour. A total of 16,000,000 cubic yards were hydraulicked.



Roadworks, Structural Excavation and Concrete, Installation of Mechanical Equipment

MORRISON-KNUDSEN COMPLETES THE BOUGAINVILLE PROJECT'S MAJOR WORK CONTRACTS ON SCHEDULE.

Cat 769 end dumping fill as formation pushes through the swamp area. Oct. 1969



Initial pioneering work on a bench in the mountain section.

BOUGAINVILLE

In July 1969 the Joint Venture of M-K-F, composed of Morrison-Knudsen International Company, Inc., as sponsor, and Fluor Australia Pty. Ltd. as co-venturer, received a letter of intent to enter into a contract for the construction of a high standard access road extending from Loloho on the coast to the mine site at Panguna. This contract was supplemented late in 1969 by the winning of the Mine Haul Roads development and again early in 1970 with another contract for the Structural Excavation and Concrete for the port and mine processing facilities. A further successful tender, for the installation of Mechanical Equipment, was lodged late in 1970.

These contracts with their requirements for such a diversity of skills were run concurrently under the management of the sponsoring contractor, Morrison-Knudsen International Company, Inc.

During their 140 week stay on Bougainville, M-K-F completed 26 miles of roads requiring in excess of 15 million cubic yards of excavation; poured 104,000 cubic yards of heavily reinforced concrete; and installed mechanical equipment with an aggregate weight of 15,400 tons.

M-K-F equipment began to arrive on site just 4 weeks after the original letter of intent was received, and the initial group of 10 machines ultimately grew to a multi-million dollar fleet of some 530 major items, all of which were maintained by M-K-F's own forces in their well equipped base and field shops.

During the life of the job M-K-F operated in excess of 10 million man hours with a labour force recruited mainly in Australia, New Zealand and P.N.G., and reaching a peak of 2,400 personnel in March 1971. Of this force, 1,160 men were accommodated in the M-K-F operated Camp 5, the only camp on the project operated by a construction Contractor. Over the life of these contracts M-K-F served 2,219,000 meals and provided accommodation for 702,000 man days.

ROADWORKS

Roads constructed on Bougainville by M-K-F were:

Port-Mine Access Road	16½ miles
Mine Haul Roads	3½ miles
Jaba River Access Road	6 miles
Total	26 miles

ACCESS ROAD

The access road which links Loloho with Panguna traverses 6 miles of swamps, 3 miles of undulating foothills and then reaches up the slopes of the Crown Prince Range at a maximum gradient of 12%. At Pakia Gap, elevation 3,316 ft., the road breaks through into the Panguna Valley and falls 1,000 ft. to the mine site.

Construction requirements for the road were a 24 ft. pavement with 8 ft. shoulders in the valley section and 3 ft. shoulders in the mountains. Sub-base was to be 18 inches of select material with CBR.20 and pavement, 12 inches of crushed rock. Drainage structures and roadside furniture were also required.

Benching proceeds down to formation level on the access road. June 1970

This road, with batter slopes varying from 45° to 76° from horizontal, depending on material, and 10 ft. benches at 40 ft. vertical intervals, resulted in 13 million cubic yards of volcanic ash and rock being excavated.

The major equipment items used by M-K-F were 9 Cat. D-9 Dozers, 25 Cat. D-8's, 2 Cat. 992 10-c.y. Loaders, 7 Cat. 988 6-c.y. Loaders, 2 each 631 and 619 Scrapers, 27 Cat. 769 35-ton Dump Trucks and 9 Cat. Graders.

The valley section of the work was generally a clear and fill operation. Clearing was basically a hand operation using chain saws to fell heavier timber, the debris was then dozed aside as the formation progressed.

Fill material was spoil from two cuttings near the coast, and borrow from Kumo pit, located on the Pinei River, approximately at the 4½ mile point of the alignment. The material was hauled in Cat. 769's and Scrapers and end dumped from the progressing formation to displace swampy ground.

The mountain section of the road is through very steep, unstable terrain and rainfall of 200" per annum caused this to be very susceptible to slips and rock falls which were a constant danger during construction. Pioneering in the mountains was achieved using a D-4 with winch to dead-anchor or to another dozer as anchor, to gradually edge a narrow access up a ridge; this was increased using progressively larger dozers until the production units could be brought in.

Up to 2 weeks work was sometimes required to reach a production stage on a batter. Formation was then brought down by sidecasting material with dozers and loaders.

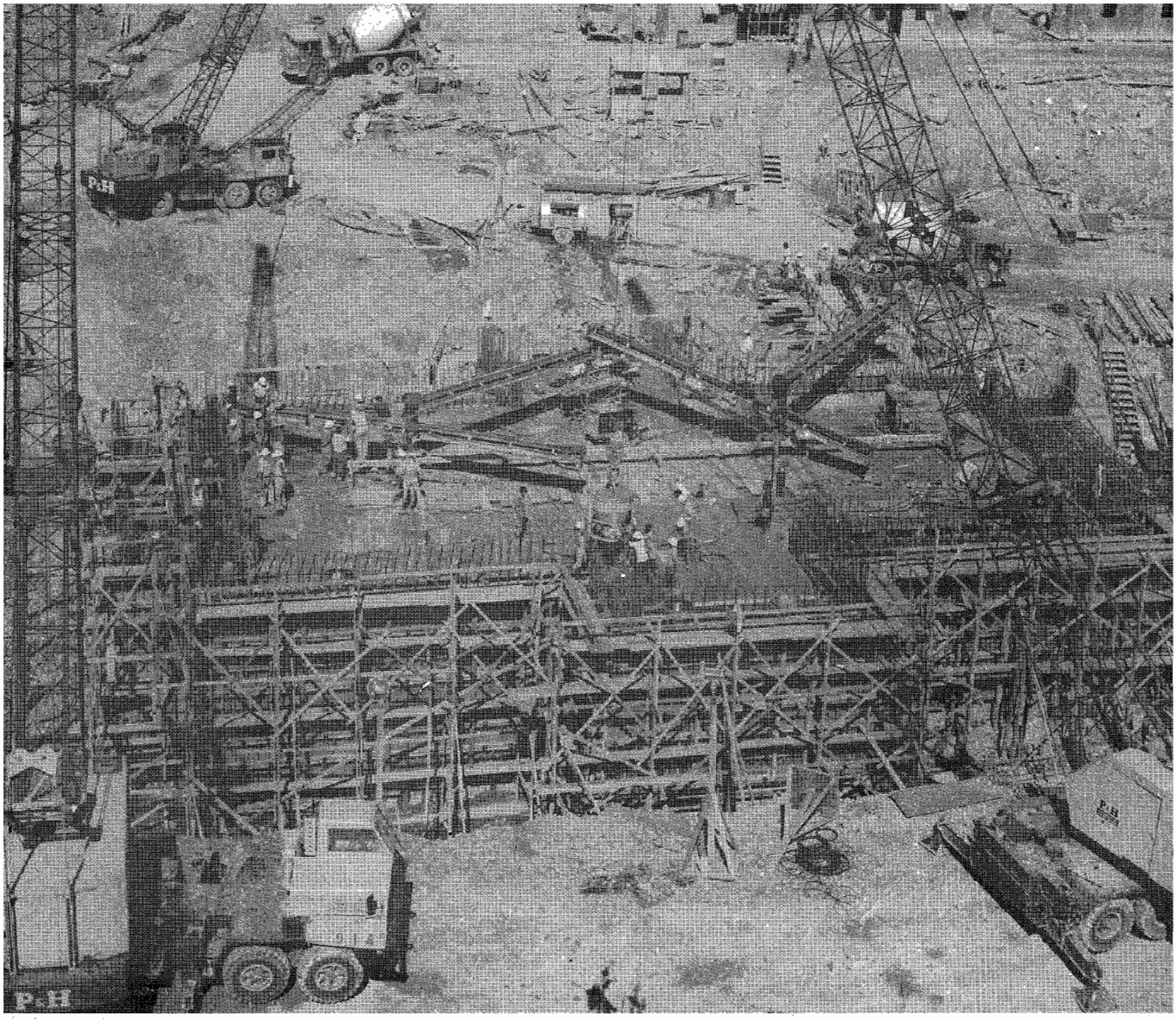
The sub-base and pavement materials were obtained by extending the operation of the Kumo Borrow Pit with the addition of a crushing complex to produce the required −4" and −1½" crushed rock from the −14" pit run gravels. This material was then hauled along the formation in Cat. 769's and Scrapers.

Servicing of equipment in the difficult mountain section was a constant problem with many units having to be attended by foot crews. Fuel could not be delivered by wheel mounted tankers. Skid mounted storages were placed strategically and fuel was pumped to these from the nearest access then gravitated in polythene hoses to the benches on which machines were operating.

The immensity of the task of building the access road can be appreciated when one considers the following statistics:—

Deepest Cut	550 feet
Largest volume of excavation in 1,000 ft. of formation	1.8 million cu. yds.
Total volume of excavation	13.3 million cu. yds.
Total length of drainage pipes	4.1 miles
Peak excavation rate	1.6 million cu. yds./month

After completion of this road the following tribute was paid by Mr. L.F. Hutchison, Resident Manager of the Bechtel Pacific Corporation:



Pouring in the Primary Crusher. Three buckets and the Beltcrete unit were being used on this major pour. Sept. 1970

"The road was a major achievement for the Contractor and it is a tribute to the dedicated men who made it possible. They battled rain, mud and more mud. Today the road is a modern link across half of the island".

MINE HAUL ROADS

These comprise 3½ miles of heavy-duty roads, with a pavement width of 80 ft., complete with drainage structures and safety berms. They run from the proposed pit area to the site of the Primary Crushing Plant, and as their name implies provide the route for the Mining Company's 100-ton haul trucks.

Assembly of crews for this phase of work began in December 1969 and an access and waste dump road were commenced. Earthworks on the haul roads proper were commenced on 15 February 1970. Operations on the haul roads were basically of a load, haul and dump nature. The bulk of material was unsuitable for road sub-base, hence most areas were excavated below sub-grade and backfilled with material from the few rock cuts or from borrow areas. Final excavation quantity on the Mine Haul roads totalled 1.4 million cubic yards including 86,000 cubic yards of rock. Total quantity of embankment placed was 181,000 cubic yards.

JABA RIVER ROAD

This 6 mile road, to provide access from the mine to the mill water supply site at the confluence of the Kawerong and Jaba Rivers, occupied M-K-F crews from 14 October 1970 until 15 June 1971. Upgrading of an existing track through the mountains for equipment access to the start of the valley section was the initial undertaking. On completion of this, construction of the 3½ miles along the Kawerong Valley section began. Construction of the mountain section, from Mine site down into the valley, commenced shortly after.

Methods used for this portion of M-K-F's work were basically identical to those used for the Port-Mine road.

Foundation works for the Secondary & Tertiary Crushing Units. The foundation slab of the Screening Plant can be seen in the background. Jan. 1971

STRUCTURAL CONCRETE

Contract 138/139 was for the completion of structural excavation and concrete work for foundations and substructures in the Mine and Port areas.

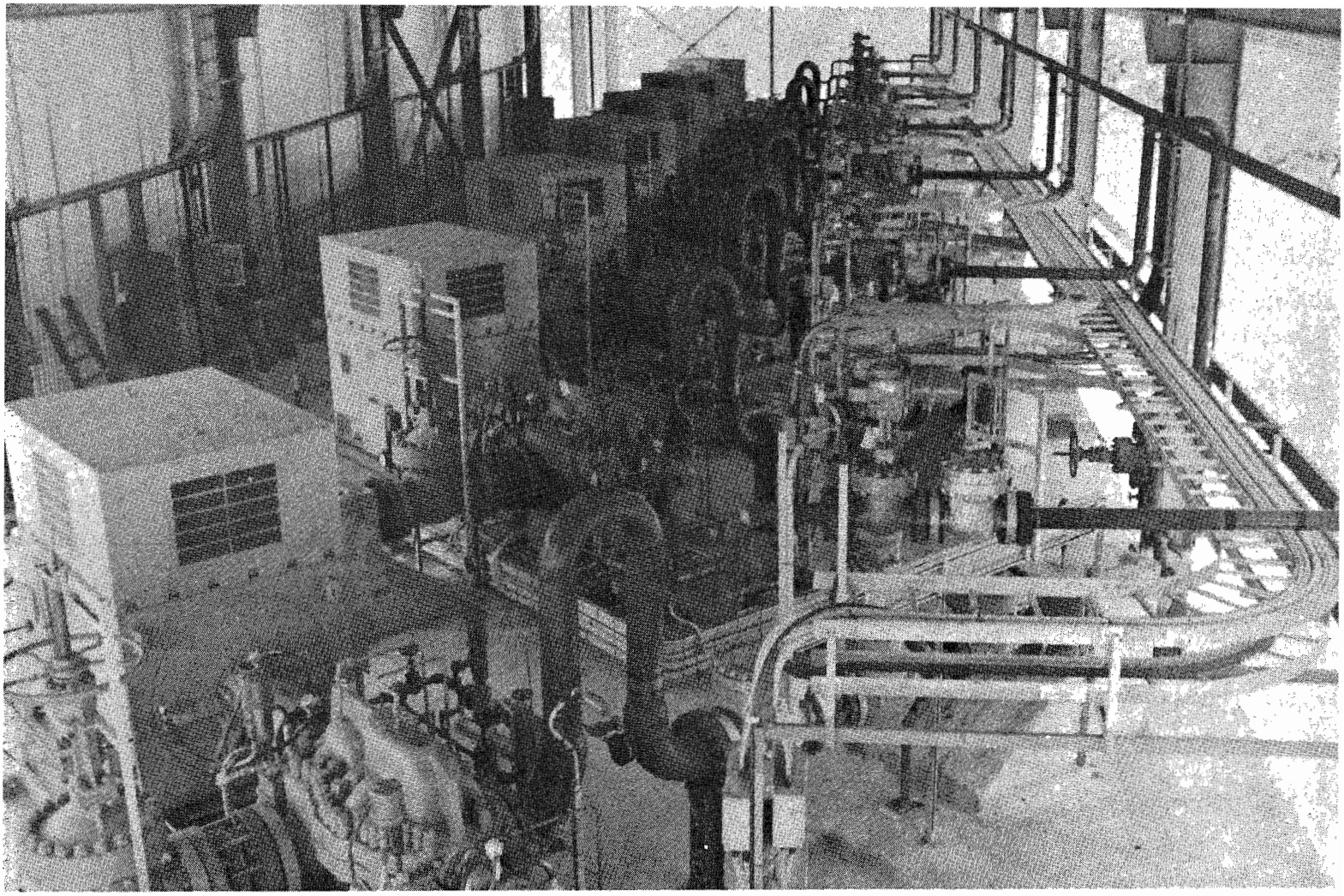
The major structure in this field of M-K-F's work was the 120 ft. high reinforced concrete housing for the twin primary crusher units. This building contains some 12,000 cubic yards of concrete and over 1,000 tons of reinforcing.

Other items completed by M-K-F as part of this contract were foundations and floors for all the ore processing plants, the power plant and various storage facilities.

Formwork with a total contact area of 1,002,000 square feet was generally fabricated by the Contractor in their own shop, with only limited use of patent type systems. This was found to be the best solution to fulfil the needs of the great variety of intricate shapes required.

The remote location of the project, together with the quantity of reinforcing involved also led to the establishment of M-K-F's own rebar fabrication shop. During the job this shop took delivery, cut, bent and delivered to respective locations, 5,500 tons of rebar.

Concrete pours carried out for the contract varied in size from ½ cubic yard foundation pads to 920 cubic yard nonstop pours, most of these being complicated by the inevitable tropical downpours. The numerous locations of these individual pours and the large floor slab areas on the project, required an efficient, readily mobile unit capable of a high concrete delivery rate, with good coverage. This need was fulfilled by the purchase of two belcrete systems consisting essentially of a series of telescopic conveyor belts mounted on a hydraulic crane, and a highly manouverable 'swinger unit' which can cover an area approx. 25' radius from a single set up. Concrete can be delivered at a rate of approx. 90 CY/hour to the pour using this system. By end of job M-K-F had constructed 104,000 c.y. of the foundations on which the Bougainville Copper machinery stands.



The Jaba River High Pressure Pumping Station. All earthworks, concrete, structural and mechanical installations for this station were carried out by M-K-F.

MECHANICAL

The final contract awarded to M-K-F, which indicates best the sponsor's diversity of activities, was MC-194 Mechanical Installation at the Port and Mine sites.

The scope of this contract was that M-K-F should be responsible to unload, inspect, store, maintain, install, lubricate and test run the various pieces of processing equipment. The supply of shims, bolts, nuts, wedges, grout, fastening tools, lifting devices, and any other equipment items was considered part of the same responsibility.

Items installed by M-K-F, with an aggregate weight of 15,400 tons include 5.6 miles of belt conveyors and 3,200 tons of miscellaneous steel shutes, wear plates and rubber components, in addition to the major process machines, viz:—

> Primary, secondary and tertiary crushers; primary and secondary ball mills, Jaba River mill water pumps; floatation cells; concentrate thickener and pumps; filters and dryers; load out machinery.

These machines with their electric motors, some rated up to 4250 horsepower, required the skills of a team of fitters, millwrights, and others, capable of setting individual items weighing from a few pounds up to hundreds of tons each, to tolerances measured to four decimal places of an inch.

M-K assembled and supervised this team.

The completion of these difficult contracts, in a timely and excellent manner, contributed significantly to the success of the overall Bougainville development. This successful undertaking is surely a tribute to many individual "Emkayans" and an indication of the skills and competence developed by the "M-K" organization during more than sixty five years of widespread operations.

The Cleaner Flotation Cells installed in the Concentrator building by M-K-F.

The Shiploader, Shuttle Conveyor and Jet Slinger erected as part of M-K-F's mechanical contract.

The Mining of Mount Nautango

P. Towndrow,
Pioneer Concrete Services Ltd.

Pioneer Concrete Services Ltd. participated in the Bougainville venture through its two contracts with Bechtel-W.K.E., the Managers of the Project, for the supply of Concrete, Quarry Rock and Crushed Rock products. In particular this article deals with the problems associated with the mining of an extinct volcanic plug, named Mount Nautango.

Pioneer made its original Tender Bid on 8th August, 1969 and received its acceptance of Tender by telegram on 24th September, 1969. Pioneer's work was divided between two contracts titled Contract 113 and 114, having a combined value of $8,000,000.

CONTRACT DETAILS

Job 6406 – Contract C113

Quarrying and Aggregate Contract at Panguna

This was for the supply of all plant, labour, materials and equipment for the production of the following:

Crushed Road Aggregates	
Minus 6 inch to Zero	300,000 c.y.
Minus 1½ inch to Zero	350,000 c.y.
Crushed Concrete Aggregates	
Minus 1½ inch to No. 4 Sieve	80,000 c.y.
Minis ¾ inch to No. 4 Sieve	20,000 c.y.
No. 4 Sieve to Zero	50,000 c.y.
Mortar Sand	2,000 c.y.
Quarry Run Rock	350,000 c.y.

The source of rock was to be Mount Nautango, which was to be quarried by the Contractor with the cost of this operation included in the unit rates.

It was conceded that during the initial development stages of Nautango it would be a physical impossibility to produce sufficient quarry rock to meet requirements from this source alone. Accordingly it was agreed that Pioneer could win a poorer quality, but acceptable material for quarry rock, from the adjacent accessible ridge until output from Nautango could meet all requirements. The following equipment was purchased to carry out this work.

1. 200 T.P.H. Crushing Plant.
2. Four Hough 120 Rubber Tyred Front End Loaders (6 c.y. Bucket).
3. Two Caterpillar D8 Dozers.
4. One Caterpillar D7 Dozer.
5. Two Terex Model R-355 Tip Trucks (24 cy capacity).
6. Three Gardner Denver Air-Trac's Model A.T.D. 3200.
7. Three Gardner Denver 900 C.F.M. Compressors.
8. One Gardner Denver 160 C.F.M. Compressor.
9. One 5 ton Conquip Crane.
10. Miscellaneous Items – Workshop, Store, Amenities, Office Buildings, etc.
11. Six Toyota four wheel drive light vehicles (utilities and station wagons).

Job 6406 – Contract C114

This Contract was for the supply of Concrete at Panguna and Concrete and Aggregates at the Portsite.

65 c.y. per hour Plant (Portsite)

3000 p.s.i. Concrete with 1½" Max. Agg. including the supply of Aggregates	30,000 c.y.
3000 p.s.i. Concrete with ¾" Max. Agg. including the supply of Aggregates	30,000 c.y.

100 c.y. per hour Plant (Minesite)

3000 p.s.i. concrete with 1½" Max. Agg.	80,000 c.y.
3000 p.s.i. concrete with ¾" Max. Agg.	20,000 c.y.

The following equipment was purchased to carry out this work.

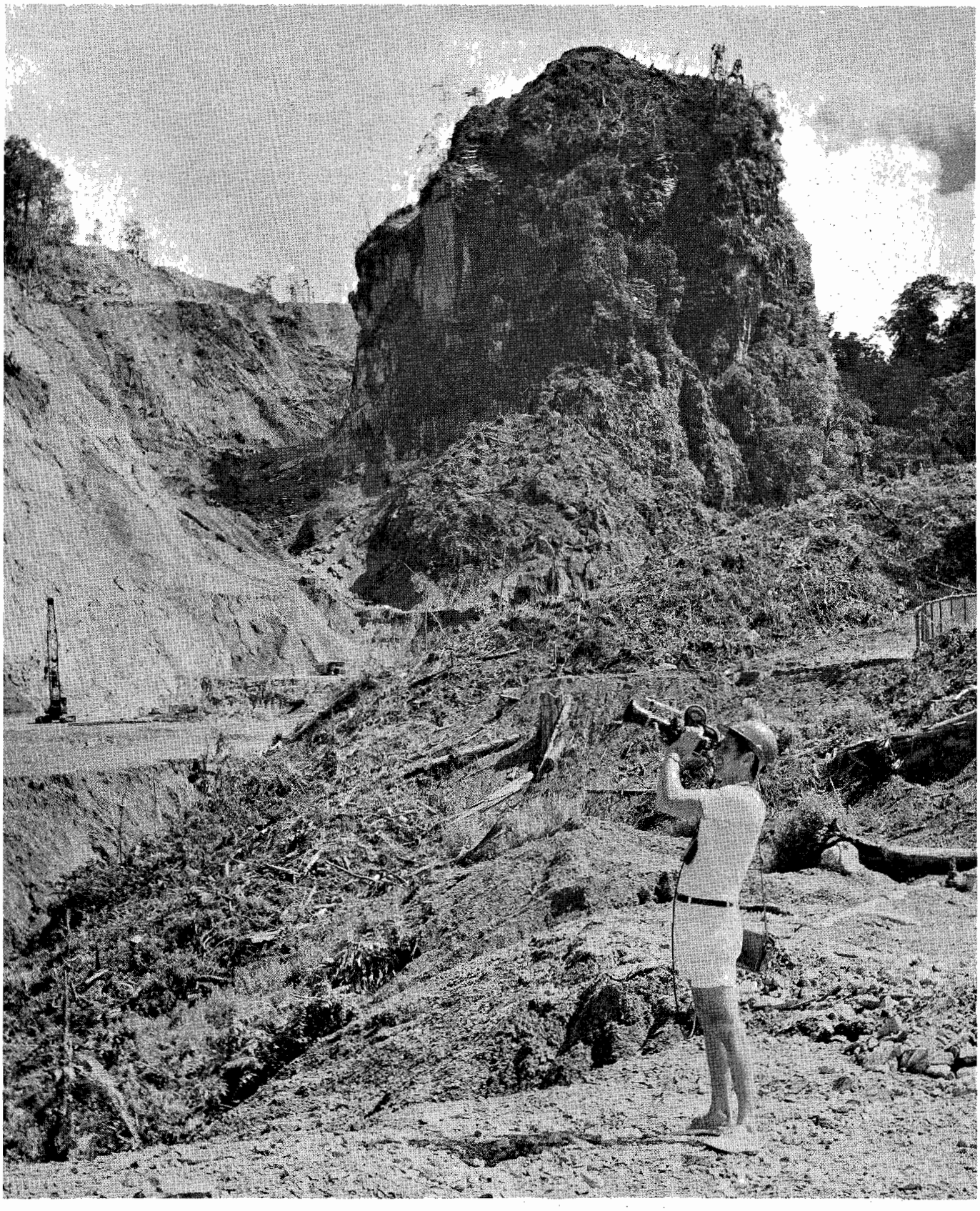
1. Four Fowler Rex 65 c.y. per hour "Hy-Way Batcher" plants.
2. 40 T.P.H. Crushing Plant (Portsite)
3. Four Hough 65 Rubber Tyred Front End Loaders (2½ c.y. Bucket)
4. 25 International Series C1800 Trucks.
5. 25 Moulang 6 c.y. Transit Mixers.
6. Three Compact Model Forklift (2 Ton)
7. One Caterpiller 343 Alternator
8. One Caterpiller 333 Alternator.
9. Four O'Neill Mobile Homes.
10. One International Series C1600 Manhaul.
11. Ten Toyota four wheel drive light vehicles (station wagons and utilities).
12. Miscellaneous items – Workshop (at Portsite), Office, Amenities.

A total of $2,000,000 was expended for the purchase of equipment for both contracts.

Because of the remoteness of the area and shipping delays it was found necessary to carry a large range of spares on the Island, the maximum value of spares held was slightly in excess of $300,000.

Geographically Pioneer's operations were centered around two separate areas, the Minesite and the Portsite, which are separated by some twenty miles of road. For the first half of the Contracts access over the seven mile Crown Prince Range was via a temporary access track. This track climbed to a height of 4000 feet above sea level and had an average grade of approximately 17 per cent with some sections to 25 per cent. Loaded semi-trailers had to be pushed up this track with dozers, frequently the track was impassable because of land slides and at one stage early in 1970 the road was blocked for two weeks. It was over this road that all of Pioneer's equipment for the Minesite operation was hauled. Today a new two lane twenty-four foot wide, with a maximum grade of 12 per cent, roadway is in use.

The Minesite operation is located in the Panguna Valley at an elevation of 2500 feet. Rainfall is very variable and



Mt. Nautango

yearly averages range from 150 to 250 inches. Rain normally commences about mid-day and continues to about 5 p.m. During the wetter season, from November to March, it generally rains every day.

Rain is usually very heavy and frequently stops all work. Whilst in the earthworks stage of construction considerable damage to work is done by rain and one must spend a considerable amount of time the next day cleaning up the mess before a start can be made on constructive work. Frequently the same cycle is repeated the next day and during the main construction stage from December 1969 to April 1970 Pioneer's operators claimed it rained every day. With their contract, as with all others on the Island, "Time is the Essence of the Contract," and no extensions of time could be claimed for time lost because of rain.

The temperature throughout the day changes from cool first thing in the morning to hot at mid-day, thence to hot and steamy during the afternoon rains. Nights are generally very still and starlit and pleasantly cool; the temperature falls from a daytime average of around 75 degrees F. to about 60 degrees F. at night and one blanket is necessary for comfortable sleeping.

Pioneer's operations at the Portsite were located just outside the Arawa Township on the Bovo River, about a quarter of a mile from the ocean. The Arawa Township is the new mining township for the project and is designed to cater for 10,000 people. Here the climate is much warmer with daytime temperatures averaging 85 degrees F., air-conditioning in offices being essential while at home air-conditioning or large overhead fans make life bearable. Rainfall is less than at Panguna and is also very variable. Five yearly averages compiled since 1917 range from 90 to 170 inches per year. There is a definite wet and dry season, the wet season being from November to March.

The initial problems which faced Pioneer were the opening up of Mount Nautango as a quarry, the erection of a crushing plant and concrete batch plants at Panguna, and a crushing plant and concrete plant at the Portsite.

By far the most difficult was the opening up of Mount Nautango.

Mount Nautango consists of a large plug of porphyritic hornblende andesite (Nautango Andesite) which has been intruded into Panguna Andesite and biotite-quartz diorite.

Prior to Pioneer commencing operations on the Island, Mount Nautango was extensively tested as a source for concrete and road aggregates. Several diamond drill holes were drilled into the mountain to determine the rock type, its quality and fracture details. It was found that the rock varied greatly from exceptionally good quality to poor quality. Drilling also showed up considerable jointing and fracturing, a factor which caused many problems and greatly increased quarrying costs throughout the entire operation. Other sources of rock investigated included several similar type volcanic plugs. However, the economics of development and quality showed Mount Nautango to be the most acceptable.

During Pioneer's pre tender visit to site and its inspection of Mount Nautango, it was decided that the best approach to the mining of the mountain was by the use of conventional quarrying methods working from the top down. It was very obvious that gaining access to the top of the mountain for heavy equipment would be a major problem.

At the time several other mining methods were considered, the one which came nearest to ousting mining from the top was the Tunnel Blasting (Cayote) method.

After much consideration this method was abandoned because of the following:

a. Long period required for initial development during which time no rock would be available from the Mountain.
b. The nearness of the Mountain to plant and buildings. The crushing plant was only two hundred feet from the toe of the Mountain and Camp (1) which housed 1500 Europeans, was within 800 feet.
c. In this type of ground results would be unpredictable and one could finish up in a far worse position after the shot than before.
d. Skilled underground miners would be required for driving the tunnels.

Subsequent quarry operations proved beyond any doubt that the Cayote method would have been a disastrous choice.

Having decided to mine from the top the next problem was getting there.

A narrow saddle ridge existed behind the mountain, this terminated some 200 feet below the summit. From here there was little trouble in getting men to the top using rope and timber ladders. However getting essential heavy equipment to the top was another problem. The work of cleaning the jungle vegetation and timber from the top and sides commenced as soon as expatriate supervisors arrived on site in November 1969. Mostly indigenous labour was used for this task at which they proved very adept.

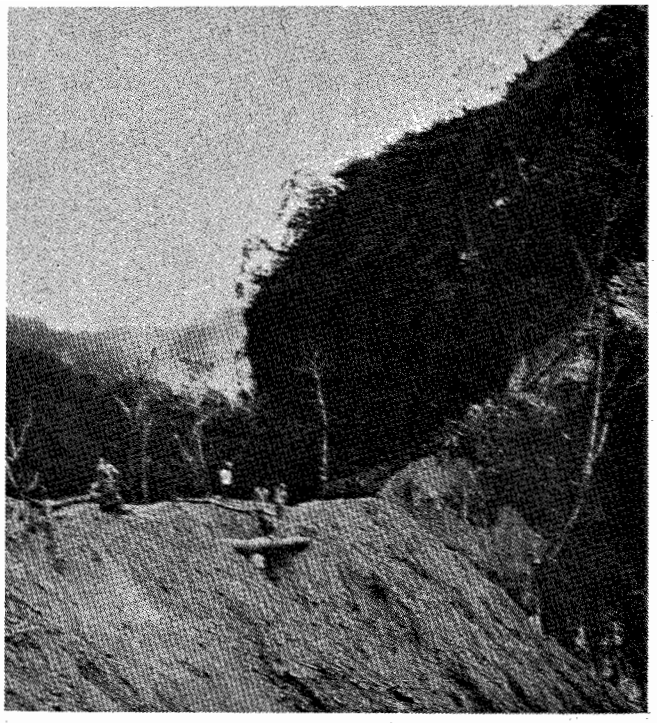
An Air-Trac drilling rig was dismantled and flown to the top using a helicopter, and reassembled there. Its compressor was located on a plateau across the saddle, and an air line was run from here across the saddle to the top. Initial drilling showed a far greater depth of overburden than was originally thought to exist. This was of the order of 30 feet and comprised unconsolidated volcanic ash (tuff) containing many large boulders. This ground was almost impossible to drill and some mechanical means of removing the large quantity of overburden had to be brought to the top of the mountain, fast.

Whilst work on top was in progress dozers were also pushing fill into the valley to widen the saddle to enable heavy equipment such as large dozers, Air-Tracs and compressors to be taken to the top. Two D8 Caterpillar dozers worked non stop day and night for two weeks pushing material across the saddle and eventually linked up with the mountain at a point some 150 feet below the summit.

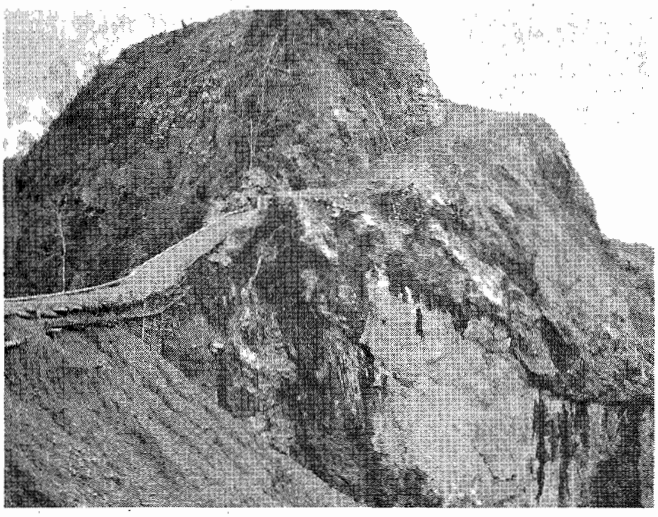
From the link up point an Air-Trac then commenced drilling out a bench around the side of the mountain on a rising grade of 1 in 3 to give access to the top. After firing a few rounds, heavy torrential rains washed away a great deal of the newly formed saddle crossing making it unusable. This halted further work on the access track.

Access across the saddle was the key to the whole operation, and to get the necessary heavy equipment to the top, safe, reliable crossing had to be constructed.

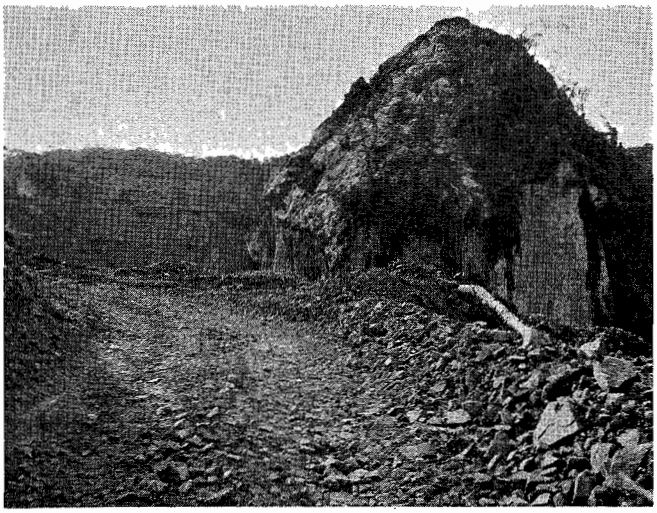
Working off what was left of the saddle fill, logs, two feet in diameter and up to 50 feet in length were placed vertically in two rows fifteen feet apart for the full distance



"Two D8 Caterpillar dozers worked non-stop day and night for two weeks pushing material across the saddle".



"Logs, two feet in diameter and up to 50 feet in length were placed vertically in two rows . . . for the full distance".



The access road to the saddle.

across the saddle, and the tops of these were cut off to form a level top.

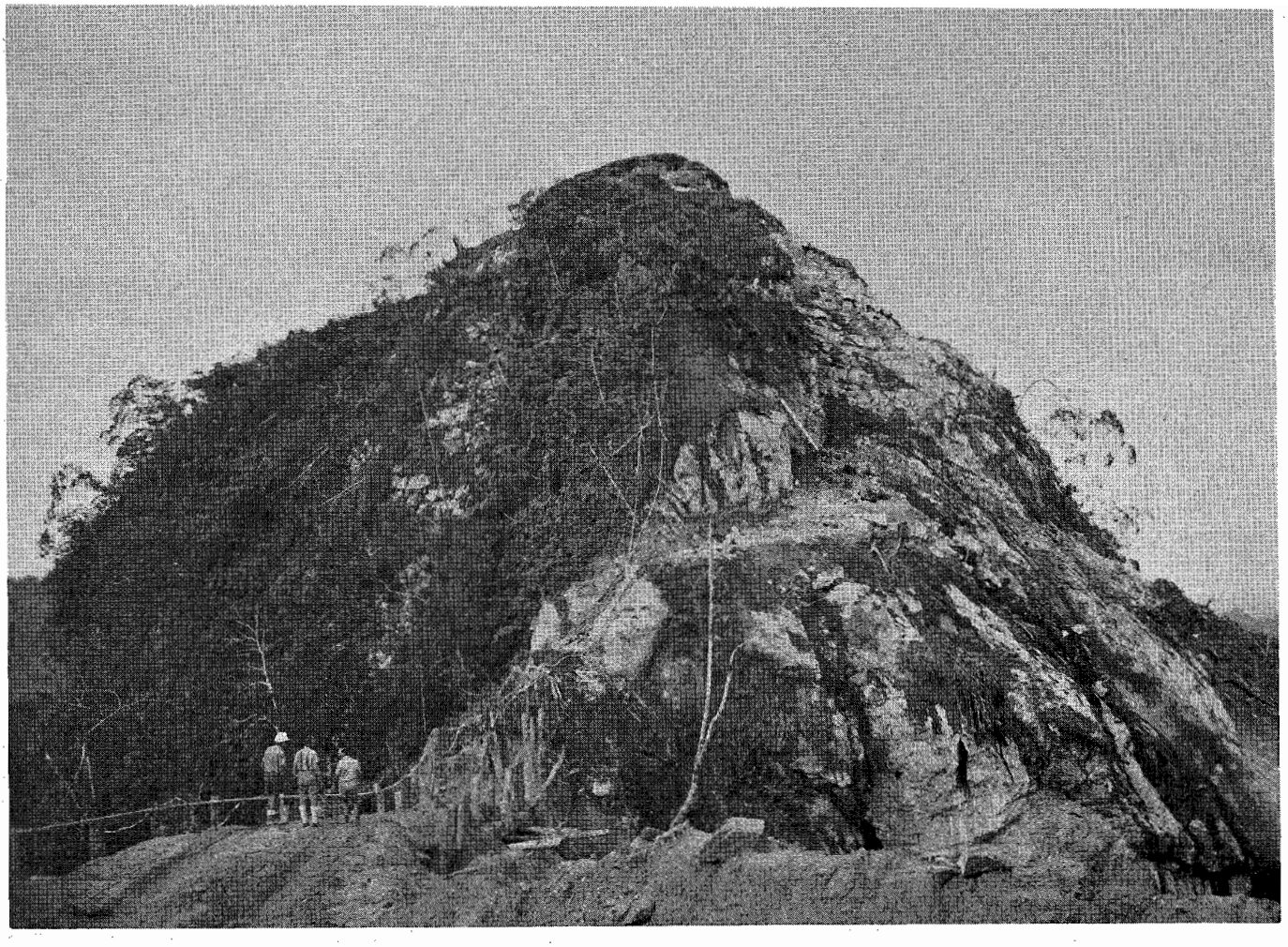
Heavy wire rope was used to tie the two rows of logs together to prevent them from spreading, and the space between the two rows was filled with rock and earth. With fingers crossed, we watched as a Caterpillar D4 dozer slowly made its way across the causeway. It made it and we were on our way again.

After progressing about 150 feet with the access track around the mountain it was decided to attempt to get the D4 dozer onto the top to commence the urgent task of removing overburden. To do this the dozer would have to be winched up the 80 foot vertical face of rock at the end of the access track. A winch was set up on the plateau across from the mountain, a large tree on top was used as an anchor and a set of triple blocks was connected between the anchor point and the dozer. Some six hours later, and after much hard work, the dozer reached the top, still in one piece.

It immediately started pushing overburden over the side, allowing exposed boulders to be fired and progress to take place. The area on top at this stage was about 100 feet in diameter, and the dozer had to take cover behind a rock or dig itself a trench for refuge during firing. It was several weeks before the access track reached the summit, thus the dozer was effectively "locked in" on the top for this period. A Caterpillar D7 dozer had been brought across the saddle bridge and greatly speeded up the work of removing shot rock from the access track. Once the access track reached the top the D4 and D7 dozers soon completed clearing the overburden and production drilling then commenced. Initially drilling in the weathered broken crust was slow and because of the confined space production from each blast was small, the first blast yielding some 3000 cubic yards of material.

Pioneer was now running behind schedule in this phase of the contract and in an effort to catch up, progressively larger blasts were attempted. After some weeks, two 15,000 c.y. blasts were being fired each week. The ground was very broken, causing very slow drilling and considerable bit loss and damage to both bits and drilling rigs, and ground conditions showed no sign of improving as work progressed downwards. There were now three Air-Tracs operating, working two shifts, seven days a week. A D8 dozer had been brought across the saddle and this and the D7 dozer were employed pushing shot rock over the side of the mountain. Operating conditions were extremely hard on dozers, and availability fell to around 50 per cent. Because of this another D8 was ordered and arrived on site in August 1970. This then gave us two D8's and one D7, which proved to be the optimum number. Because of the pressure brought to bear on us for Nautango rock, the size of the blasts continued to increase to a maximum blast yielding 45,000 c.y. The heavy vibration from this blast however, made it obvious we had to change our plan of attack.

Up to this point we had been working the mountain on alternate sides, i.e. North and South with shot rock being dozed from the top into catchment and recovery gully on either side. This allowed dozers and drills to work simultaneously on alternate sides on top of the mountain without interference. Loading out operations on the quarry floor could also be carried out continuously as this operation was able to work below the drills and thus followed them from side to side. At this stage the Mines Inspector



The Saddle and Access Track to the top of Mt. Nautango.

stopped us from recovering any rock from the South side catchment gully for safety reasons. There were about 100,000 c.y. of recoverable shot rock in the gully, and the loss of this at a time when it was most needed was a bitter blow. As we now had to confine all our operations to the north side of the mountain, loading out from the quarry floor could not take place continuously as before, for all personnel and equipment had to be removed from the area when dozers were pushing over. It now also became impossible to work dozers and drills on top of the mountain without interference, and operating times for both operations fell.

As a result of all these restrictions a new mining plan emerged; this plan proved successful and was carried through to the end of the job and was as follows:

Basic Details –

Benches

a. Depth, 30 feet maximum.
b. Width, 60 feet minimum (Set by Mines Inspector).
c. Length, full width of mountain.
d. Yield, 15,000 c.y. maximum per firing.

Boring and Loading

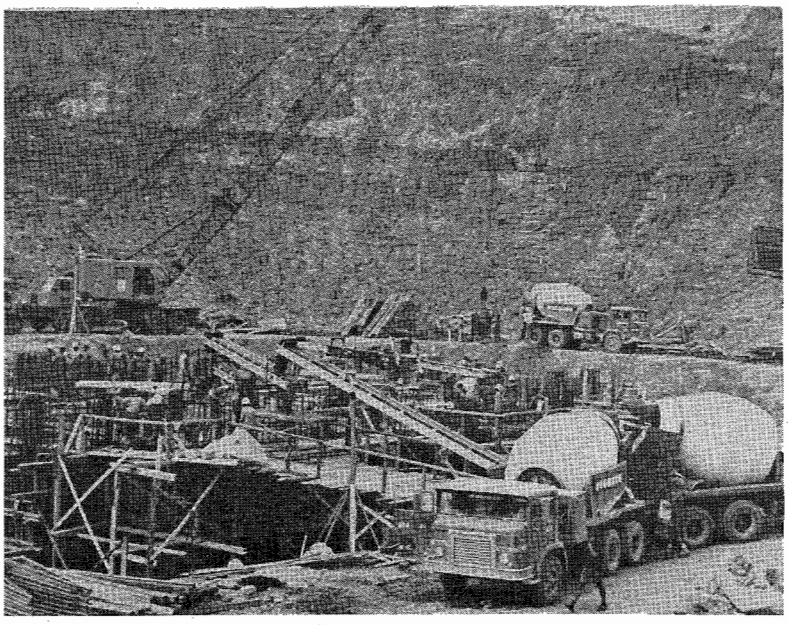
a. Hole diameter 4 inch
b. Hole depth 32 feet.
c. Number of holes per firing 80 to 120.
d. Hole pattern 9' x 9' offset square.
e. Holes drilled 25 deg. off vertical.
f. Top 10 feet uncharged.
g. Loading 0.8 lbs. Nitropril per c.y. broken.
h. Each hole double primed using two separate Cordtex circuits.
i. Polythene tubing for Nitropril used in almost all holes because of water and badly fractured ground.

From June 1970 to October 1970 most quarrying personnel worked ten hours a day, seven days a week, taking one Sunday off each month. By August 1970 we had caught up with the backlog and from then on started to build up substantial reserves of broken rock. At the end of January 1971 we were advised by the Managers of an underrun situation for crushed rock products. At that stage there were estimated to be 200,000 c.y. of recoverable broken rock in the North gully and 250,000 c.y. of broken rock in the South Gully. This was still unrecoverable because of the Mines Departments Requisition. The 200,000 c.y. in the North gully was now sufficient to meet future requirements therefore production work on top of the mountain ceased at the end of January 1971.

Following the cessation of operations on top of the mountain further representations were made to the Mines Department to allow the recovery of rock from the South gully. After some minor blasting on the South side rim to remove loose slabs and extensive barring and cleaning down the Mines Department allowed access to about 80 per cent of this material in April 1971, although quantity wise this material was not required it was of superior quality to that on the North side.

Today Nautango is quite easily accessible and presents an easy mining proposition should further rock be required from that source. Mining operations have lowered the mountain by 305 feet and about one third of its total original volume of 2,500,000 cubic yards has been blasted and dozed off.

Our safety record was good. During the fourteen months of



Pouring foundations for Primary Crushing Plant.

operation on top of the Mountain there was not one lost time accident. Bearing in mind that this would have been one of the most difficult and dangerous operations on the Project, this was an outstanding achievement. Dozers were continually working day and night pushing broken rock over the edge with a 500 foot vertical drop beneath them, one slip or error of judgement would almost certainly mean death for the operator and the complete write off of a machine. We were indeed very fortunate to have extremely competent operators with nerves of steel.

So ended the conquest of Nautango.

During the development and mining of Nautango other aspects of our Contract were being carried out.

At Panguna the 200 T.P.H. Crushing Plant was erected in the shadow of Mount Nautango, after considerable delays were experienced in being given a usable site.

Two 65 cubic yard per hour Concrete Batch Plants were erected at the Minesite. In December 1970 a third 65 cubic yard plant was erected in the Concentrator Area to avoid a two mile haul over steep grades and to increase capacity. Our Contract at Panguna called for a Peak Monthly Output of 10,200 cubic yards – the achieved peak was 10,125 for the month of December 1970. Also we had to supply 100,000 cubic yards of concrete by 1st August, 1971 – at this date we had supplied 101,700 cubic yards.

There was initially some concern expressed over our selection of the International Series C1800 trucks as Concrete trucks, bearing in mind the steep grades encountered, i.e. average 12 per cent. Four of our twenty five trucks were converted to six wheel drive units by the replacement of the original front axle assembly with a front wheel drive conversion kit. When operating, these conversions did improve traction, however, there were many problems associated with the installation and many failures of parts causing low availability. The International trucks which were not converted were performing well and it was found that six wheel drives were not necessary.

At the Portsite a 65 cubic yard per hour Concrete Batch Plant and a 50 cubic yard per hour aggregate Crushing Plant were erected. Feed for the crushing plant was gravel won from the adjacent Bovo River using an Owner supplied Lima 65C – 1½ cubic yard bucket Dragline.

Operations at the Portsite were fairly straightforward, the only problem being that there was only one operating Concrete Plant and should this break down during a critical pour we were in trouble. Fortunately, this never happened. It was Pioneer's responsibility to supply water from the adjacent Bovo River and Power and to avoid downtime both these systems were duplicated.

Our Contract at the Portsite called for the supply of 60,000 cubic yards of concrete by the 1st April, 1972, as at 20th October, 1971, 65,000 cubic yards had been delivered.

Cement for the both areas was supplied by the Manager, Bechtel – W.K.E., and was stored in a warehouse adjacent to the Batch Plant. This was in the form of bagged cement in 96 lb. or 112 lb. bags stacked on pallets of 1½ or 2 tons. As required, the pallets were carried to the de-bagging platform by a Forklift where a team of six to nine Indigenes broke the bags and discharged the contents into a receptive hopper at the bottom of the Cement Silo. Bulk cement was considered, but, it was found more economic to use the bagged product.

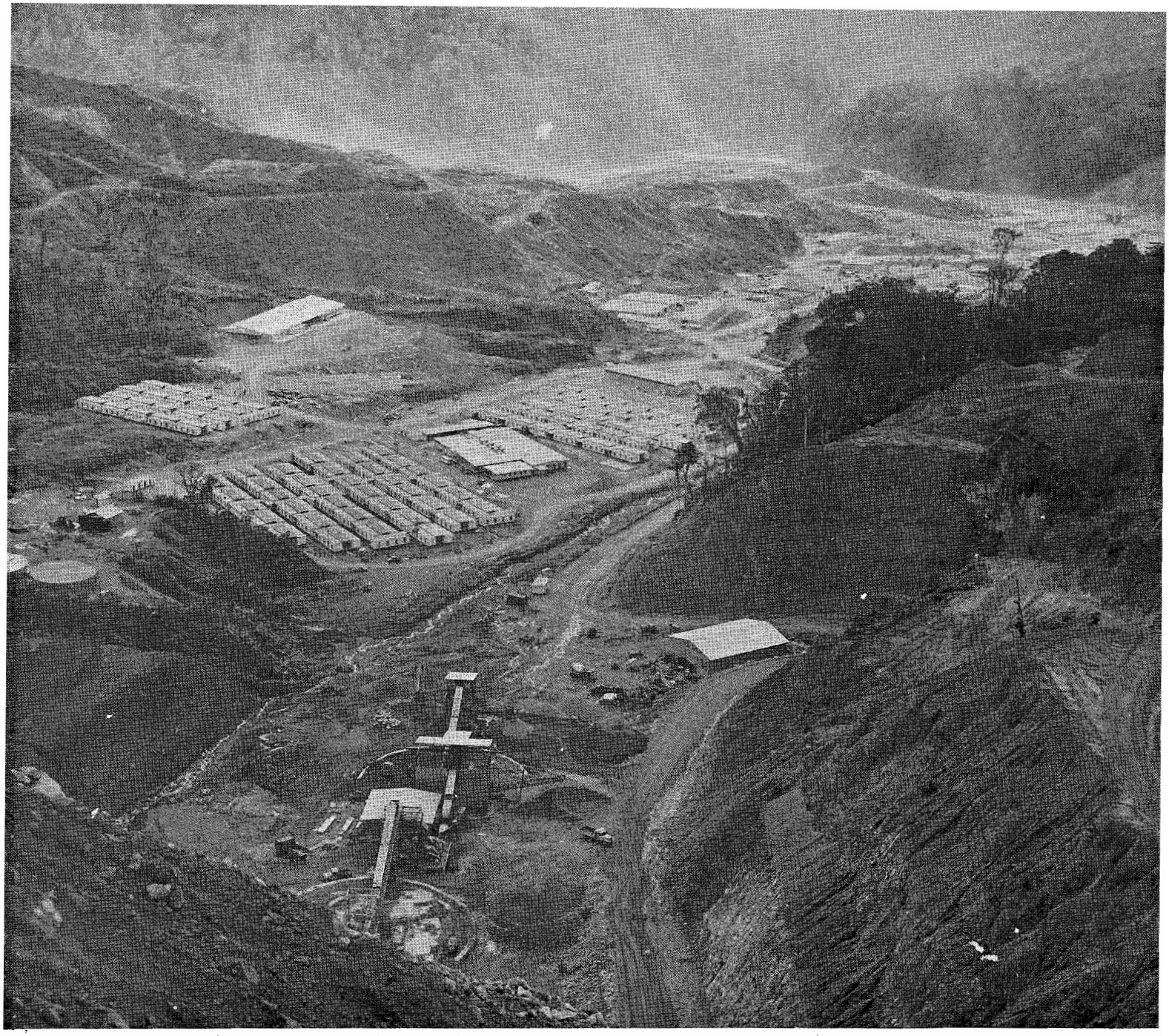
The maximum workforce, in December 1970 was 187 employees of which 92 were expatriates and 94 were indigenous personnel.

Communications were a major problem. Even after two years' operation, there are no phones in Contractor's Offices in the Arawa area where our Head Office was located. To make a phone call to Australia one had to make a six mile journey to Kieta, book a call and wait. If you were lucky it may come through in half an hour, but generally it took several hours. In the early stages phone calls were taken from a phone placed on a filing cabinet on the open verandah of the Post Office. Because of bad reception one had to talk loudly over the phone, and everyone within 20 yards heard your side of the conversation. Later the telephone was located in a modern building with two open phone booths. Everyone nearby still heard your conversation, but at least one did not get wet by rain, or roasted in the tropical sun.

The telegraphic service improved and one could generally get a telegram through from Australia to Arawa in two to four days.

Transportation of goods to site by sea and air was always difficult. A regular charter shipping service operated between Australia and Bougainville with normally two ships in per month. However, because of capacity ship loadings, items were frequently left on the wharf in Australia. Air freighting of emergency spares was frequently resorted to and items ordered via this method generally took one to two weeks to arrive on site. When ordering replacement stock spares it was essential to order at least three months ahead of anticipated requirements.

One unexpected problem was the refusal to grant an Import Licence for redundant equipment which we desired to send to Australia and which was purchased in the U.S.A. and shipped direct to Bougainville. These items included a Caterpiller D8 Bulldozer and Terex Off-Highway Dump trucks.



The crushing and concrete batch plants (foreground), viewed from Mt. Nautango, with a general view of the campsite.

There was single accommodation only for wages employees and non senior staff. This was in the form of mobile units with two men per room. Meals for expatriates were good and were taken in a centrally located mess hall, there being one of these located in each of the six expatriate camps. There was very little integration, indigenies being housed and fed in separate indigenous camps. There were six of these camps which consisted of sixty man Boi Houses with centrally located mess halls.

A 60 hour, 6 day week was normally worked, generally with plenty of overtime. An average wage for an expatriate would be $180 per week, and for an indigene $20 per week. Both got free accommodation and meals. Expatriates signed on for a six month contract. Their air fare from Australia to site was deducted from their pay over a three month period and was refunded in full after the completion of three months satisfactory service. They earned a free return air ticket after completing six months of satisfactory service.

Thus wages and working conditions were very good. However, the absence from one's family, and lack of amenities and outside interests, particularly in the early days, kept many good men away from the Project.

To me the secret of success for a short term Contractor on Bougainville or on any other remote area Project, is to initially flood the job with expatriate labour, for it is almost impossible to initially get quality manpower. Therefore, the only other alternative is to go for quantity. This may seem expensive, but, it is preferable to not meeting your Contractural obligations. Because of union policy, if an incompetent worker was brought to site you were stuck with him for at least six months, thus all employees should be closely screened before appointment, and even then one is forced to take the best of what is offering and this may not be too good.

Export Wharf and other Port Facilities

The Hornibrook Group
(Northern Division)
Brisbane, Australia.

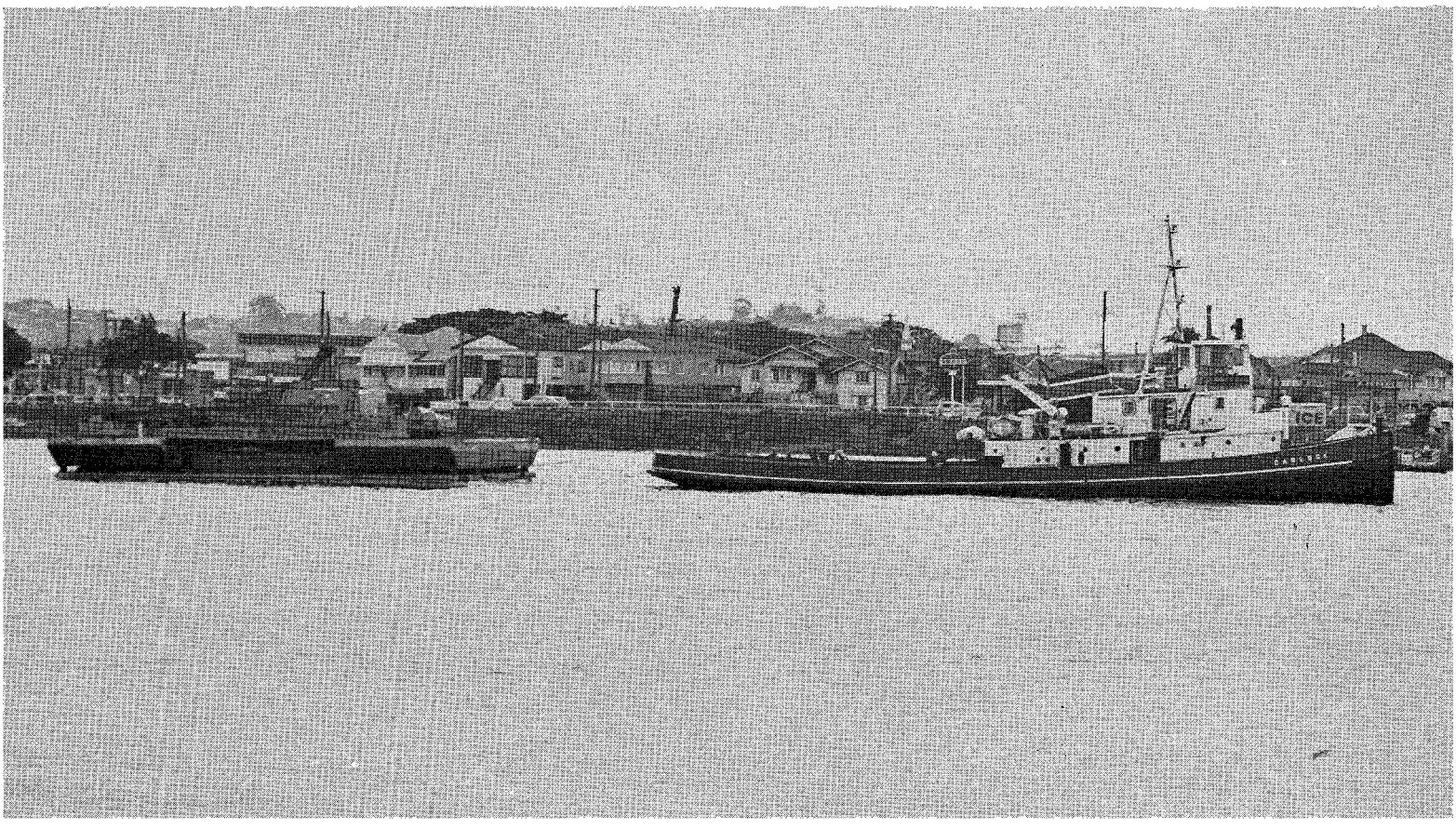
The Hornibrook Group Northern Division, based in Brisbane provided the cargo handling facilities in Anewa Bay for the Bougainville Copper Project, contracts awarded to the Division being for the construction of a barge unloading quay and for the export wharf.

Barge Unloading Quay

We were awarded the contract to construct this quay in May, 1969. It took the form of an artificial island, 90 ft. x 35 ft., in which the fill material was contained by timber planks set between 10" x 10" x 72 lbs. H-section steel piles. At this early stage in the development of the project accommodation was extremely difficult to obtain, the island roads were anything but all weather roads, and communications with Australia were quite inadequate, and our crew of seven men were soon to learn the frustrations which accompanied the execution of urgent works under these circumstances. We were accommodated in a camp south of Kieta which meant we were obliged to cross the Kieta hill twice a day, and as this section of road was often closed by landslides or generally slippery conditions we finally stationed a vehicle on either side of the hill to ensure that the work on the quay could continue.

Despite early shipping delays, and a call to carry out urgent repairs to the existing wharf in Kieta, the barge unloading quay was handed over to the owners in September, 1969, together with an ancilliary platform to accommodate the front-end discharging "Cosmos".

Barge "Anewa" leaving Brisbane in September, 1969, bound for Bougainville.

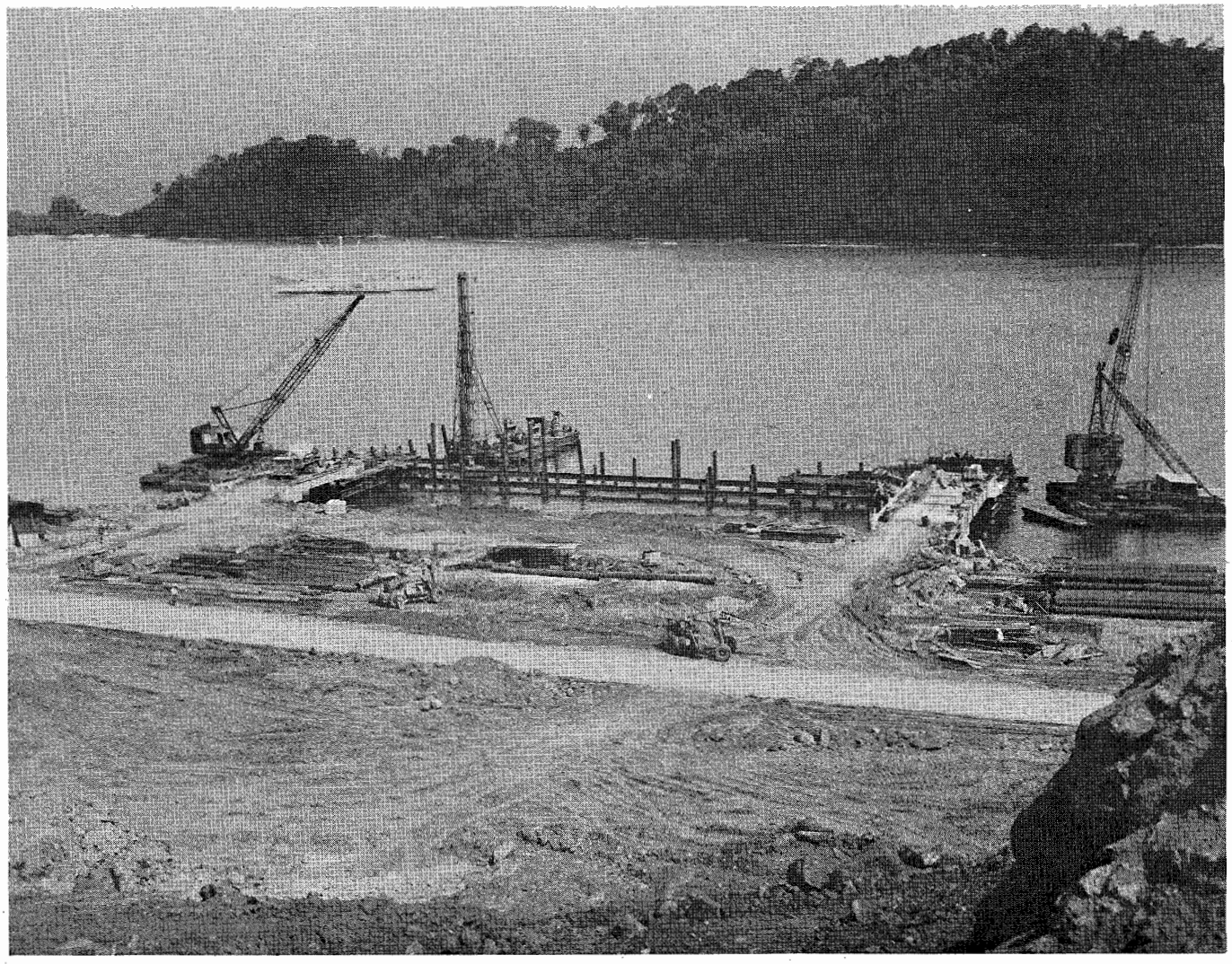


Export Wharf

This consisted of a wharf head, loader platform, and three dolphins, each in itself a reinforced concrete structure supported on concrete filled 18" diameter tubular steel piles. Onshore concrete mooring blocks were also provided and the whole length of the berth required dredging. The prime purpose of this dredging was to reduce the slope of coral inshore of the quay line to improve the stability of this area in times of seismic activity, and only at the very eastern end of the berth was the naturally available depth of water at the quay line less than 40 ft.

To service the dredging operation we provided a 54 RB dragline mounted on a 70' x 50' x 6' steel platform, appropriately named "Anewa", which we made up from two of our existing barges. As this assembly had to be towed to the site, we took advantage of the deck space available to forward other items of plant needed to carry out the contract, and on 27th September, 1969, a well laden vessel proceeded down the Brisbane River under tow by the tug "Carlock" bound for Bougainville. Other major plant items used in the construction of the berth were a 15 ton floating stiffleg derrick crane, and a 70' x 24' x 6' steel pile driving barge which was picked up from Port Alma by the "Carlock" and towed to site in tandem with the "Anewa".

A total of slightly more than 21,000 lin.ft. of piling was driven in the wharf with the average length of pile exceeding 120 ft. A B.S.P. 12b single acting hammer with a ram weight of 6 tons was used throughout, and we did not have to make use of a modified 12b hammer with an 8 ton ram which we carried on site as a spare hammer and to drive any stubborn pile to bedrock. The number of rakers, and their configuration, precluded the driving of all of the permanent piles from floating plant, and falsework had to be constructed to service the pile driving operations. This served also to support the forms for the 3,500 cu.yds of concrete used in the superstructure. Approximately 50,000 cu.yds. of material was removed in the dredging operations and while most of this was handled effectively by the dragline a section of extremely hard coral projected beyond the quay line at the eastern end of the berth, at such a level

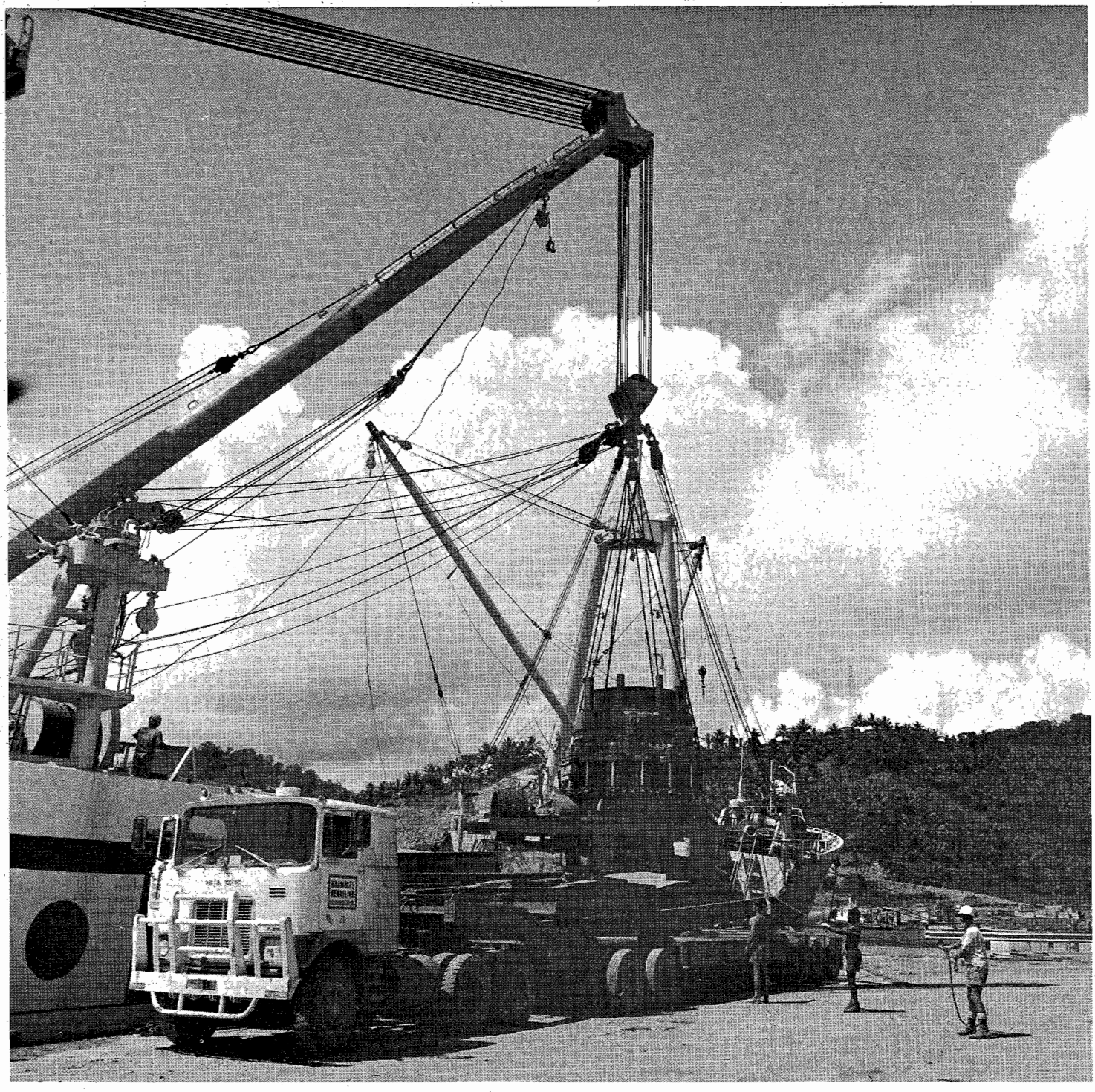


Wharf under construction in April, 1970, showing the dredge, pile driving barge, and 15 ton floating stiffleg crane.

"Yashiwosan Maru" being loaded with copper concentrate at the Anewa Bay Wharf in April, 1972.

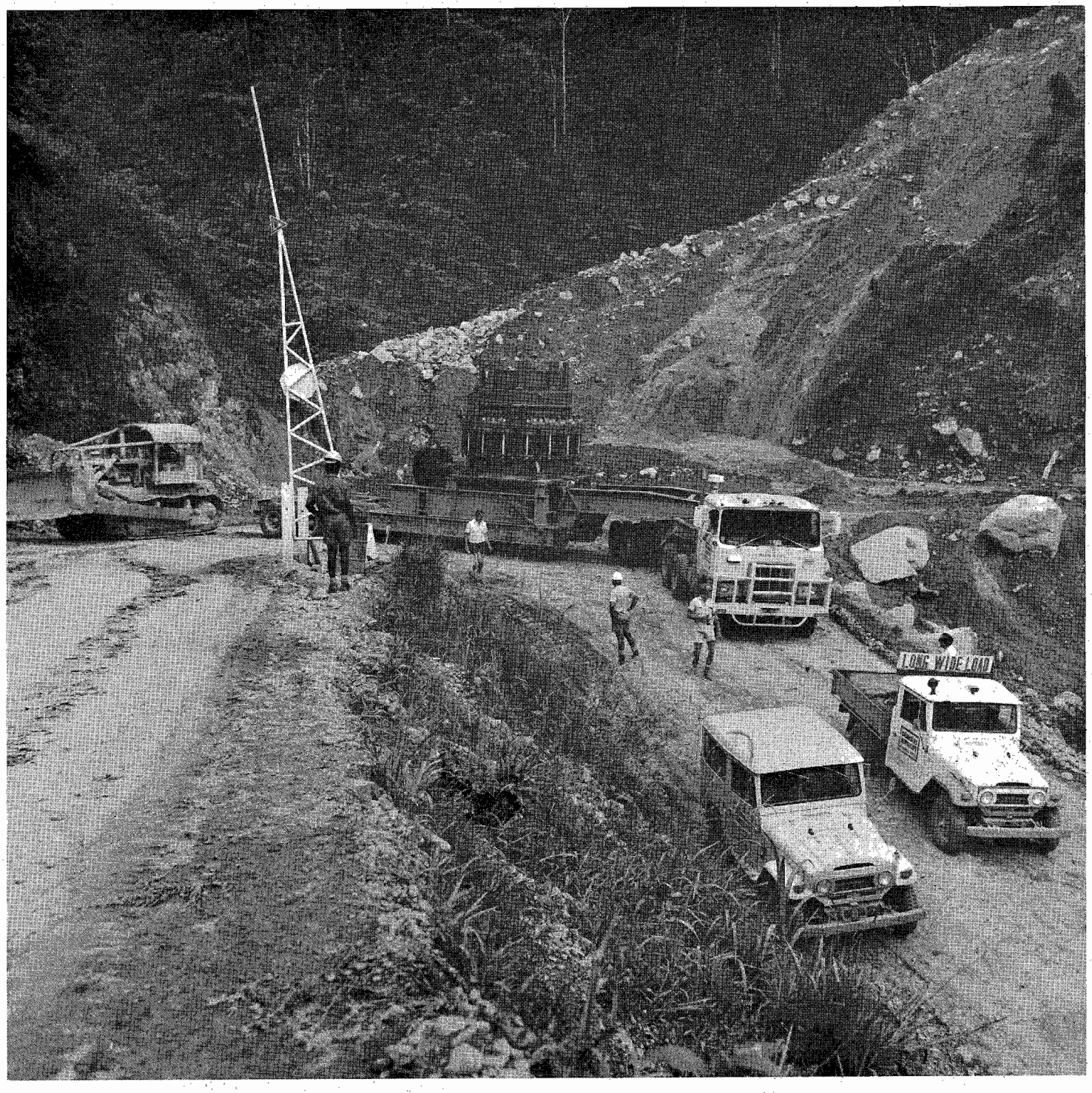
that 40 ft. of clear water was not available at low tide, and this proved too much for this machine. This outcrop was removed by underwater blasting using a technique developed on site. This consisted of driving an 18" diameter mandril into the coral at approximately 8'0" intervals along lines parallel to the quay line, and loading each of the holes so formed with strings of approximately twelve 6 lb. charges of gelignite. This procedure proved effective in splitting the coral and enabling us to peel the outcrop back to the quayline.

The last of our employees left Bougainville early in June, 1971, just two years after the first arrived on the island. The extent of the development of the Bougainville Copper Project in those two years was most impressive, and all those associated with this development must be extremely satisfied with their achievements.



A Symons Cone Crusher weighing 70 tons, is loaded onto a Brambles Kennelly low loader at Anewa Bay for transport over treacherous mountain roads to the mine site. Nov. 1970

Material Handling & Transportation



Some of the typical terrain between port and mine site. A low-loader negotiates a hairpin bend with a bull dozer acting as additional backing power. Nov. 1970

LEADERS IN LOGISTICS

In September 1969 Brambles Industries Limited were appointed to handle the complete material handling and transportation within Australia for all commodities purchased in Australia for the Bougainville Copper Project.

This contract required Brambles to provide complete transport services at all loading ports in Australia and to transport intra-state and inter-state by both road and rail to move approximately 300,000 tons of cargo for shipment to the mine site.

Additionally a joint venture between Brambles Industries Limited and Kennelly's Transport Overseas Pty. Ltd., was appointed to undertake material handling and transportation on Bougainville Island for all the material required to establish the mine, town site and port. In Australia a National Co-ordination Office was established to co-ordinate the activities of all the Brambles branches and to provide close liaison with the Managing Engineers, Bechtel–W.K.E. Warehouse areas were established in each port for the consolidation of consignments and, as warehouse space on Bougainville was at a premium, cargo was containerised

Indigenous stevedores assist the Brambles Kennelly staff to uncouple wires from a crane after unloading the heavy lift from M.V. Cosmos at Anewa Bay. June 1970

or unitised where possible. It was also essential that all necessary documentation, e.g. Certified Customs Invoices, Commercial Invoices, Export Permits and the like, were correctly prepared to facilitate both exportation from Australia and importation into Bougainville.

As part of this total logistics programme, close liaison was necessary with the stevedores to plan the stowage of the vessel, to ensure that cargo was available to maintain the stowage plan, and of course to ensure that the turn around of the charter vessel was expedited. On Bougainville Island the joint venture company established a transport organization with approximately 150 personnel and fully equipped with prime movers, trailers, cranes, low loaders, fork lift trucks and ancillary plant and equipment.

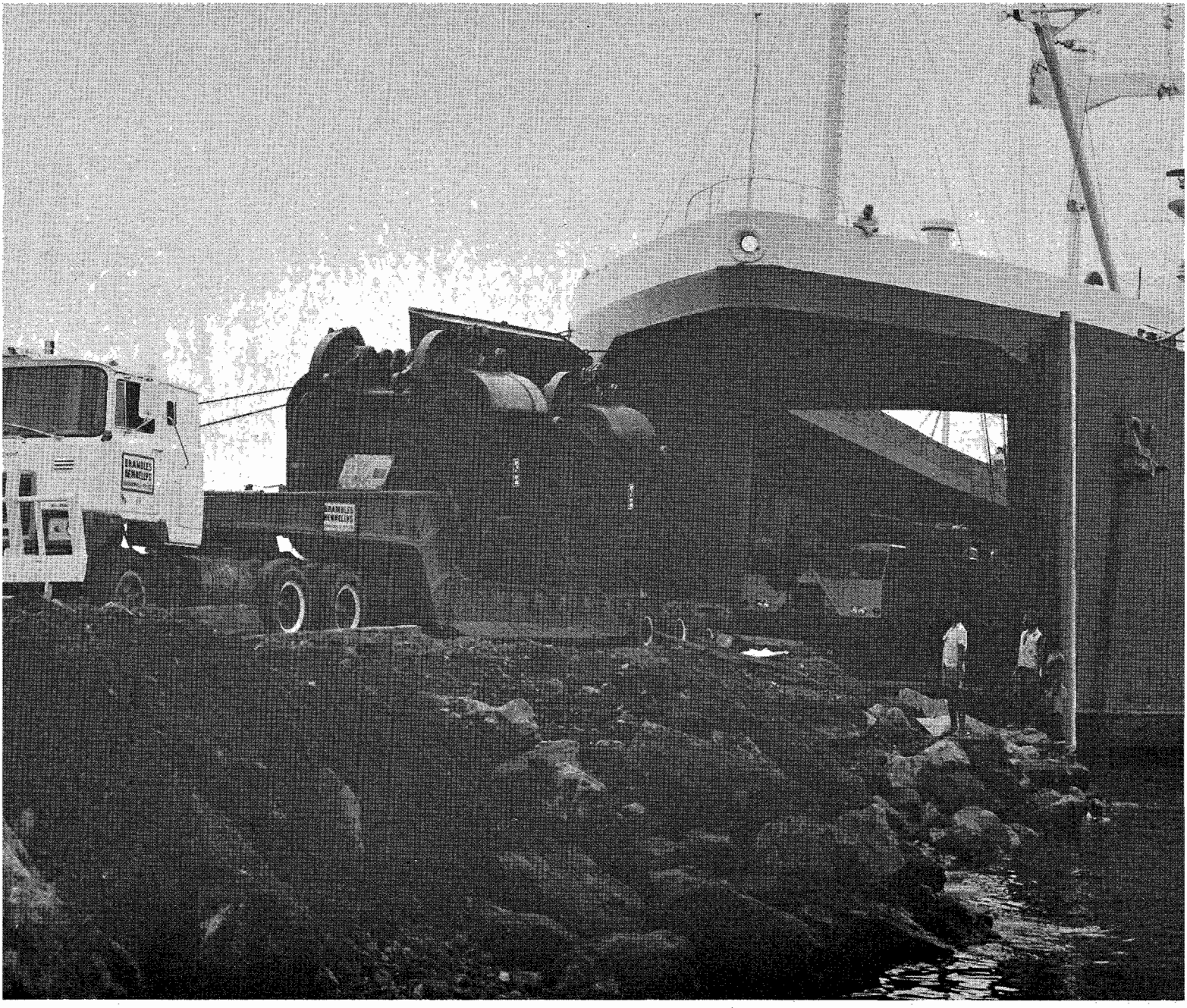
The operations at Bougainville extended from Kieta to Jaba River, a distance of some 33 miles. Kieta was the existing port and was used for the main entry of equipment and materials until the Anewa Bay port facilities at Loloho and the new Port-Mine Road became operative late in 1970.

Kieta to Loloho was a distance of 10 miles, over a very windy, narrow road with two dangerous hills, one within a mile of Kieta, and one four miles further on.

From Loloho to the mine site at Panguna was a further 16 miles, of which 9 miles were flat, but winding, and the other seven miles were over a very dangerous mountain road, climbing to a height of 5,000 feet before descending 2,000 feet to the mine site at Panguna. The mountain section was constantly affected by landslides, and there were dozens of hairpin bends and grades from one in six to one in four.

From Panguna there was a further six miles to Jaba River, but only a very small volume of freight was moved over this road.

From March, 1970 until August, 1970, a 24-hour operation was maintained over the original Port-Mine access track.



Prior to completion of port facilities, Brambles accepted responsibility for the shipping of equipment and supplies in vessels appropriate to varying requirements. Here the M.V. Cosmos is beached to enable unloading of heavy lifts. June 1970.

During the period of the contracts from October 1, 1969 to the completion of the project in April 1972, a staggering total of 126,901 hours of operational machinery was used and more than 300,000 tons of cargo including transportation of foodstuffs from wharfs to various construction centres was moved to sustain a workforce of approximately 5,000 people, which peaked at 10,500.

Equipment

Heavy prime movers Mack F & R Series	x	24
Tray trucks, Mack and Fuso	x	12
Low Loaders, 90 ton capacity	x	1
Tip trucks, Macks	x	12
Hire vehicles – Toyota, 4 wheel drives Cranes, Fork lifts etc.	x	40
Spare parts $A100,000		
Refrigerated Containers	x	4

Earthworks and Drainage

Louis Mauduit, General Manager,
N.G. Allen, Construction Manager,
Dumez (Australia).

INTRODUCTION

In October, 1969, Dumez (Australia) were awarded a Contract for approximately $5 million for earthworks and drainage on Bougainville Island. Four months later the Managers, Bechtel-W.K.E., tripled the scope of our works and a new contract price of $13 million was negotiated with a requirement to maintain the same key completion dates.

To meet this challenge, Dumez drew upon its world-wide resources to assemble a team from France, England, South Africa, Pakistan and, of course, Australasia.

The amount of equipment on site was increased by 150%. Production had to be more than trebled and a peak of 1,120,000 cu. yds. was achieved for the month of August, 1970.

Dumez (Australia) are proud that all relevant key areas were handed over on or before the contract commitment dates.

PROJECT LOCATION

Bougainville Island — steep mountains covered with dense tropical jungle — two active volcanoes located within 30 miles of the Mine Area — a 200 inch annual rainfall with rain storms being virtually a daily occurrence — daytime temperatures constantly around 90°F with extremely high humidity.

Excavations, earthworks and the beginning of construction of Panguna township. Karoona Valley extends through the centre of the picture and the Kawerong Valley is at lower right. (Feb. 1970)

Excavations at Moroni Ridge which overlooks the concentrator area (part of which is at right). The coarse ore stockpile will be located on the clearing at top centre. (June 1970)

By virtue of the location, this project presented a challenge to the client, the managers and the contractors. Extreme isolation, poor communications, heavy rainfall, difficult terrain and several project-wide industrial disputes were all overcome.

SCOPE OF WORKS

Panguna Townsite
Concentrator Area
Primary Crusher
Mine Services Area
Access Roads
Additional Works

PANGUNA TOWNSITE WORKS

Main roads were constructed along the Kawerong and Karoona Creek valleys with access streets to house benches terraced on the valley sides.

This consisted of clearing dense jungle mainly by hand labour then developing access over waterlogged volcanic ash by the dumping of a rock base course.

Excavation was performed with low ground pressure equipment such as Cat D4 and D6 dozers, 977 traxcavators and a JCB Model 6D hydraulic backhoe.

Drainage works consisted of excavating and laying Armco nestable piping and the construction of concrete manholes entry pits and stone pitched headwalls.

CONCENTRATOR AREA

The bulk of the clearing and removal of part of the surface volcanic ash was done by others. The volcanic ash being removed by hydraulicking.

From the post hydraulicked surface we excavated all encountered materials to form benches, on which phases of the copper concentration plant could be erected.

Materials excavated included:

Saturated volcanic ash.
Wet clay.
Boulder terrace material (boulders up to 50 cu. yds. in a clay matrix).
Weathered rock.
Fresh rock.

To provide the flexibility necessary to handle all encountered materials, the following teams were used:

3½ cu. yd. face shovels and 35 ton dump trucks.
TS14 scrapers.

Earthworks near the concentrator area at Panguna. (Sept. 1970)

992 Cat loader and 35 ton dump truck.
988 Cat loader and 35 ton dump truck.
3½ cu. yd. dragline and 35 ton dump trucks.
SR264 scrapedozers.
Cat D8 and D9 dozers and natural hydraulicking.

Diversion of Karoona Creek which flowed through the centre of the excavation area was also carried out.

Because of the soft ground conditions haul roads were constructed in the old creek beds, which had good gravel or rocky bases.

By diverting the Karoona Creek across the excavation area, use was made of heavy rainfall to naturally hydraulic excavated material away. This had the added advantage that any rock in the excavated material was deposited in the watercourse which provided the base for one of the main haul roads through the area.

The excavated area was 2,000 ft. by 2,000 ft. and up to 300 ft. deep.

PRIMARY CRUSHER – MINE SERVICES AREA

The mine services area required the developing of a large flat area on a hillside composed of saturated volcanic ash and wet clays.

This was done with dozers, front-end loaders, trucks and scrapers.

Due to prior work by others one clayey hill was not accessible to any type of equipment.

This was removed by hand augering horizontal holes and blasting with gelignite.

The primary crusher required the excavating of a hole some 70 ft. deep with surface plan dimensions approximately 200 ft. wide and 400 ft. long.

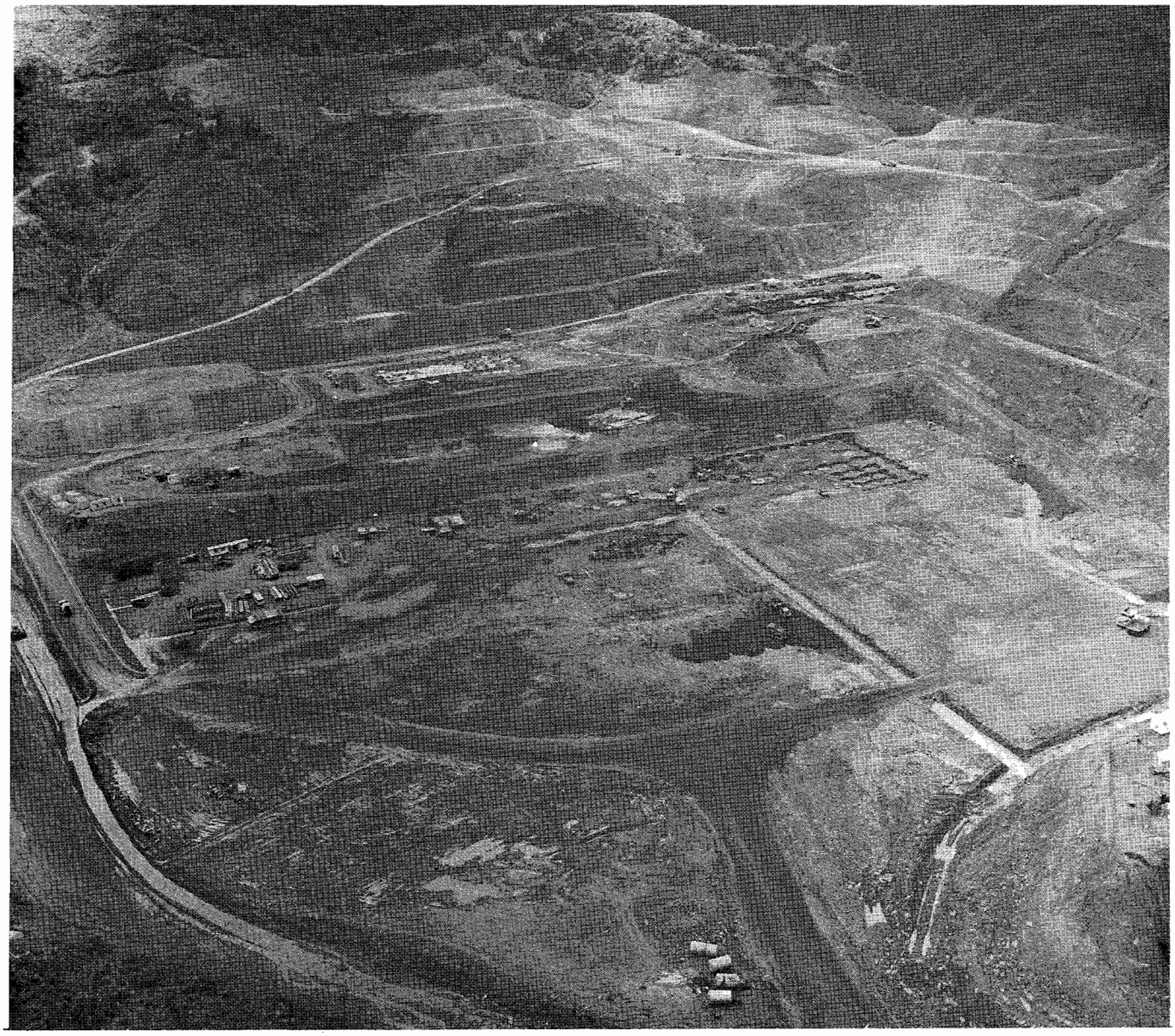
This was done with front-end loaders and 35 ton dump trucks.

ACCESS ROADS

A number of access roads were constructed throughout the works area, consisting of minor earthworks and placement of rock base course material.

REMOVAL OF OVERBURDEN IN THE MINE SITE

After completion of the Concentrator works, Dumez equipment was teamed with the Manager's plant to excavate and remove rippable overburden from the mine-site to various locations within the project area.



Earthworks and excavations at the Panguna concentrator area, the location of the fine crushing, screening, grinding, flotation and thickening processes. (Oct. 1970)

PLANT EMPLOYED ON THE PROJECT

Description	Mobilised in Nov./Dec. 69	Mobilised in Mar./Apr. 70	Total Numbers
Dozers Cat D9	2	4	6
D8	4	4	8
D6	4	2	6
D4	2	–	2
Scrapers TS14	3	5	8
Scrapedozers SR264	–	6	6
3½ cu. yd. shovels 71B	–	2	2
3½ cu. yd. shovels P & H 1055B	–	2	2
Loader Cat 992	1	–	1
988	–	1	1
977	2	2	4
Trucks 35 ton	7	11	18
International trucks	10	–	10
Mercedes trucks	–	6	6
Isuzu trucks	2	7	9
Graders DRM 600	3	1	4
Front-end loaders/backhoes	6	–	6
Cranes	4	1	5
Airtrac drills	4	–	4
600 c.f.m. compressors	4	–	4
250 c.f.m. compressors	2	–	2
78T vibrating rollers	2	1	3
Light vehicles	20	21	41
Plus miscellaneous equipment			

TECHNICAL DATA

Concentrator and Other Areas

O.T.R. Excavation	3,900,000 cu. yds.
Rock Excavation	400,000 cu. yds.
Selected Filling	200,000 cu. yds.

Townsite Area

O.T.R. Excavation	475,000 cu. yds.
Rock Excavation	145,000 cu. yds.
Selected Filling	230,000 cu. yds.
Culverts 12" to 72" diam.	5,700 l ft.

Laying pipes through volcanic ash and boulders in earthquake country

Hardie's Fibrolite AC pipes featured at Arawa and Panguna – with the installation of a water supply and sewage scheme for the townships. In fact, Hardie's participation in the establishment of the Bougainville mine complex was one of the most difficult ever encountered.

The island was remote. Access was poor. There were no facilities on the island. Everything had to be brought in. The whole operation was continually hampered by the heavy rain which is common in the area. And lastly there was the problem of using indigenous labour who, up to the arrival of the construction teams, had been primarily subsistence farmers. To provide a suitable labour force a crash programme was initiated to train these people to perform functions ranging from pipe laying, to laboratory work, to driving the huge 100 ton capacity dump trucks which worked round the clock at the mine site.

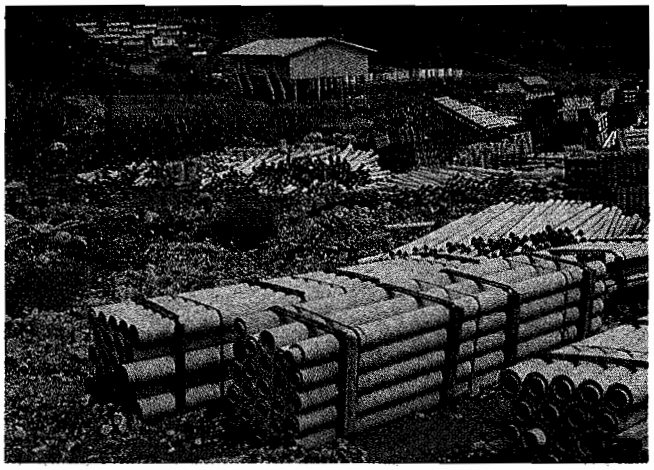
Another problem which the contractors had to "live with" was the incredibly poor landing facilities on the island. At the time the Fibrolite AC pipes were landed the main port of Loloho at Anewa Bay, the site for the Company's permanent wharf, was not operating. Consequently 90% of the pipes used in the townships were landed at an old Copra wharf at Kieta – which was capable of accepting 7,000 dwt.

Panguna, base port of the Bougainville operations, under construction in July 1970.

A typical trench at Panguna for water and sewerage pipes.

ton ships (although it was totally unsuitable for the tonnages involved), and although the wharf itself was small, it was necessary to bulldoze away part of an adjoining hill so that there was even room to unload the ships.

To make matters worse there wasn't even back loading! From the old wharf the semi-trailers had to haul the pipes to Arawa and then on to the company town of Panguna, 16 miles away. The trip up and over the Crown Prince Ranges, often driving through isolated cloud banks, was a hair-raising experience. It was quite common for the round trip from Kieta to Panguna to take over 24 hours. The road was nothing like it is today. The semi-trailers would



Water supply and sewerage pipe storage area — Panguna township.

often jack-knife on the numerous tight "S" bends. They would then sound their enormous Klaxon horns and bulldozers, located near known trouble spots, would come to their assistance, straighten out the rig and send the semis on their way once more. Often the loads were so heavy that the bulldozers would be needed to push the semi-trailers up some of the steeper grades.

9" gravity sewer and 9" water main pipes share common trench at Panguna.

And that was only the start of the problems the contractors had to face. Bougainville is a volcanic island with a row of mostly extinct volcanoes along its north west. The island in reality is one great alluvial boulder field comprised of gravel and silt.

Because of the heavy rainfall (200" at Arawa and 120–140" at Panguna) there is also an enormous amount of ground water. Consequently, as fast as the trenches were dug they began to either cave in or fill with water. The trenches had to be continually pumped to prevent them turning into nothing more than bogholes.

The ground itself was also studded with huge boulders. Some were so heavy that it was common for the trenching equipment to overload the hydraulic systems.

Trial treatment plant during early stages of mine construction.

Indigenous labour was mostly used. While they had received some training they were certainly not familiar with the technicalities of pipe laying or the various grades of pipes required for either sewage or water supply. To avoid confusion the design engineers specified Hardie's Class "D" asbestos cement pipes for both applications – over 120 miles in total were used, in diameters from 4" to 24".

The only variation being in the fittings where cast iron for water supply and AC fabricated fittings in Class "D" material for sewage were supplied. The higher strength pipe offered another advantage. The island is also subject to regular earth-tremors, (Guriers), particularly at Panguna – and it was felt that the Class "D" Fibrolite AC pipe would be more resistant to movement of the ground.

With the introduction of a modern water supply and sewage scheme at Panguna and Arawa, Hardie's, through the supply of their Fibrolite AC pipes, have played an important role in creating two European standard townships in an area where no up-to-date facilities existed before.

Above: Swamp at Industrial Area (Arawa) prior to drainage and construction, 1971.

Right: Building main road No. 2 across swamp, Arawa, 1971.

Roads, Drainage & Earthworks

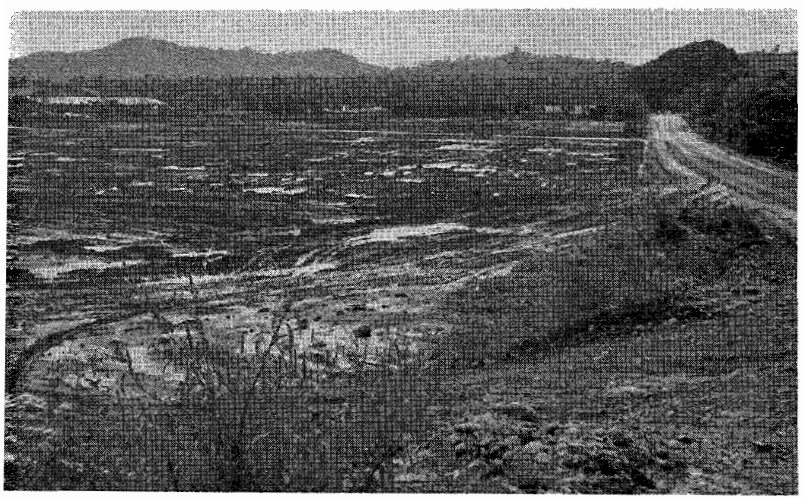
PROJECT:	Arawa Town, Roads, Drainage and Earthworks
CLIENT:	Bougainville Copper Pty. Ltd.
ENGINEER:	Bechtel–W.K.E. Joint Venture
CONTRACTOR:	Thiess Bros. (Pacific) Pty. Ltd.
VALUE:	$6 million approx.
COMMENCED:	1st July 1970
COMPLETED:	Schedule works completed November 1971 Extra works completed 1972
LOCATION:	East coast of Island of Bougainville near the sea coast town of Kieta.

TECHNICAL DATA

- 10 miles of stormwater drains
- 18 miles of streets
- 10 miles of sidewalks
- 750 acres of clearing
- 2,000,000 c. yds. of excavation
- 600,000 c. yds. of fill material
- 150,000 c. yds. of rock excavation
- Preparation of 2,200 house sites

1. Town centre area following clearing, prior to filling, 1971.
2. Arawa township, work in progress, 1971.
3. Establishing channels to drain swamps in township area, 1971.
4. Clearing and site preparation, 1971.
5. Bitumen sealing, main road No. 3.

6 & 7.
Arawa township nearing completion, 1972.



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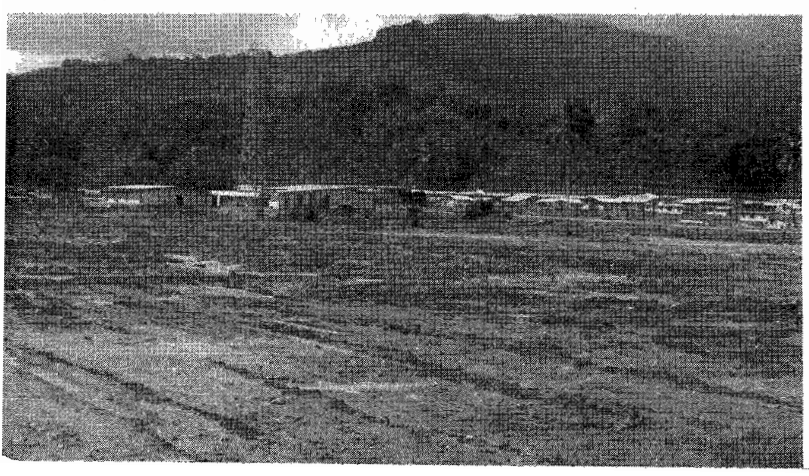

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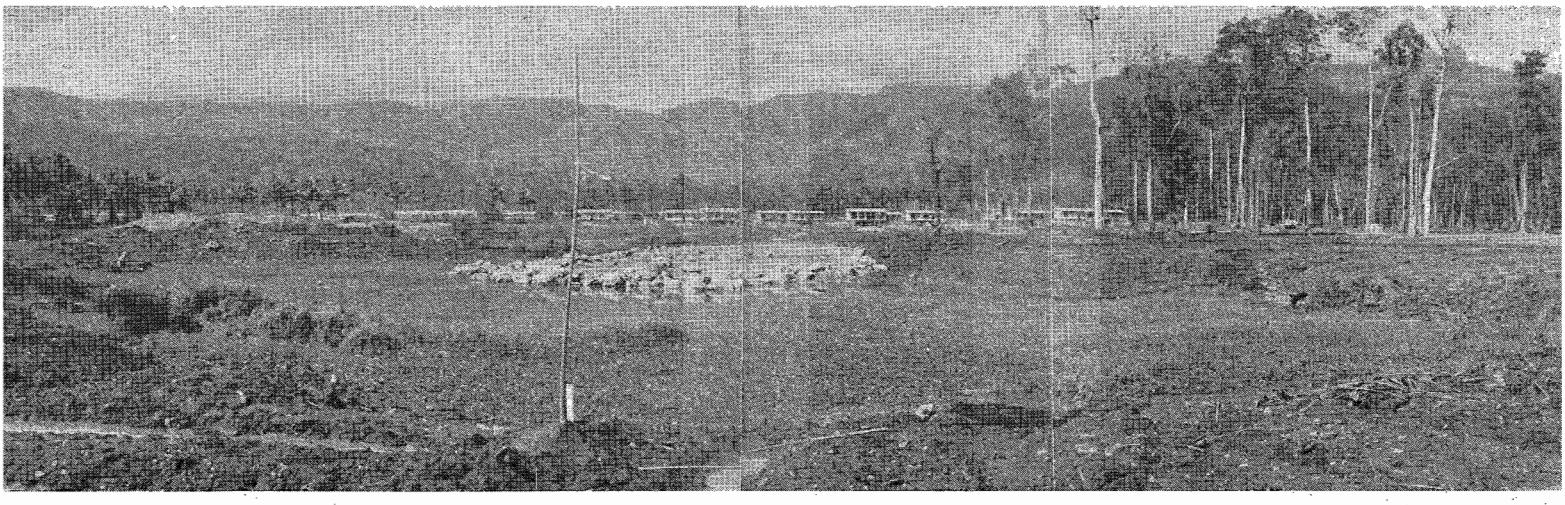
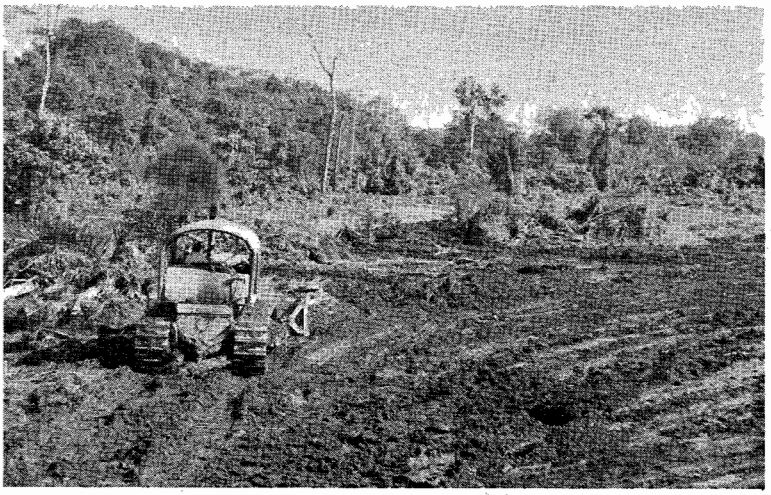


In June 1970 Thiess Bros. (Pacific) Pty. Limited were awarded a Contract for earthworks, drainage, clearing and levelling of house blocks for Bougainville Copper Pty. Ltd. The first part of the Contract had to be finished by mid-November 1971. This phase was brought to a successful conclusion within the time specified. A large amount of extra works plus inclement weather called for another six months of dogged and persistent work. The employment peak was reached about February 1971 with 300 employees in all. Approximately half this number were indigenous personnel.

The Arawa Town Site was laid out on a former plantation on the least precipitous ground in this area of Bougainville and about half the area was very swampy. The other half was covered with giant volcanic boulders known in some parts of the world as "The Devil's Marbles". Both types of terrain were covered with a very dense jungle growth. The rainfall in this area is in the region of 200 inches per year, which when combined with humidity in the high nineties, makes the jungle grow by leaps and bounds. The problems multiplied because of lack of visibility and the huge amount of fast-growing undergrowth which had to be continually cleared before survey lines could be established.

4



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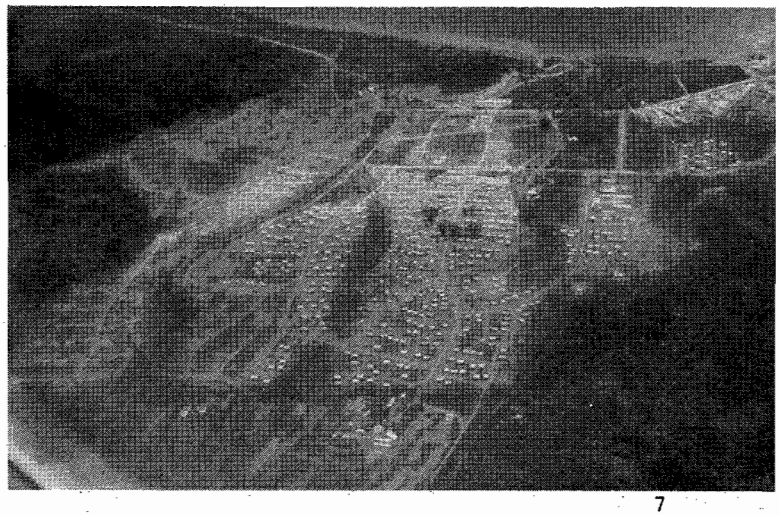
Due to the low elevation thousands of cubic yards of filling had to be excavated from a hillside quarry to raise existing levels so that drainage could be effected and the work organised for full production. Prior to filling being placed the swamp area had to be cleared and deleterious material removed. The contractor instituted a number of novel techniques to overcome the difficulties inherent in swamp excavation.

Specialist equipment such as low bearing pressure scraper-dozers which had never previously been used in Australasia on swamp work were employed on this operation. Despite the severely adverse climatic, topographical and geological conditions, Thiess Bros. completed the works within the time specified and met all interim target dates.

June of 1972 saw the town of Arawa substantially established — by then the trade store, service stations, doctor and dental clinics and all the essential community services were functioning.

Thiess Bros. (Pacific) are proud to have been associated with Bougainville Copper Pty. Ltd. and all other Contractors in bringing to a successful conclusion the town and amenities known as Arawa Township.

6



7

A Town is Born

HOUSING AND SCHOOLING FOR ARAWA

Morobe Constructions Pty. Limited.

For the provision of housing for the employees of Bougainville Copper Pty. Ltd., Morobe Constructions Pty. Ltd., are proud to have participated in the construction of the Arawa township.

From the designs offered to the client, seven different units were selected ranging from 3 to 4 bedroom residences, some fully air conditioned.

The design and construction contract consisting of 446 residences was completed in 20 months employing a peak labour force of 600.

The major part of the labour force consisted of Papuans and New Guineans who were flown to and from the mainland by chartered aircraft.

The contract was hampered by difficulties encountered only in remote tropical conditions. The township was constructed on what was virgin jungle and the clearing contractors experienced extreme difficulties in keeping pace with the construction schedule.

The contract was also plagued by strikes, high rainfall conditions and shipping strikes.

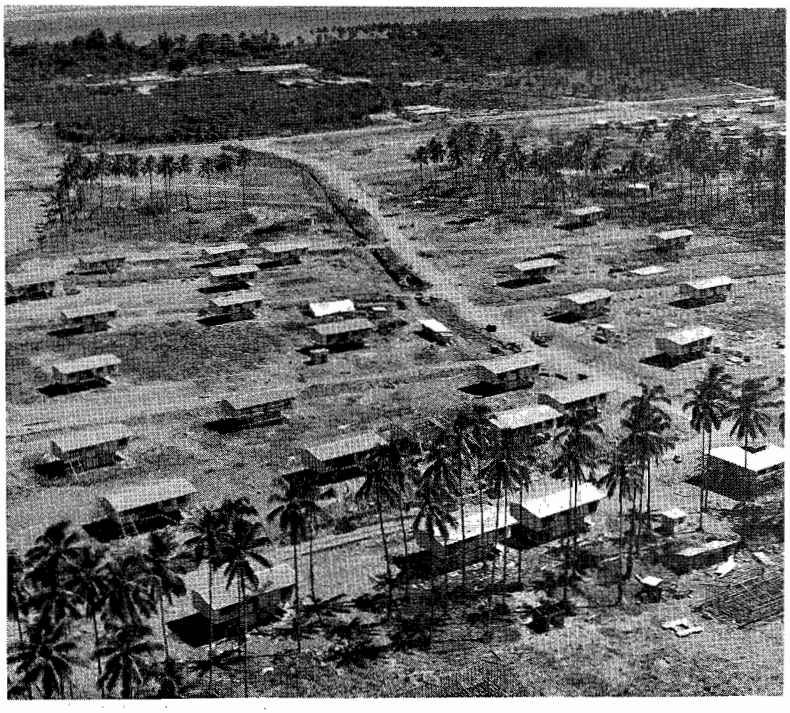
Materials were shipped from the mainland by coastal shipping services; Timber for the project was procurred at Cape Rodney in the central region of Papua. Aluminium windows and components were manufactured in Hong Kong.

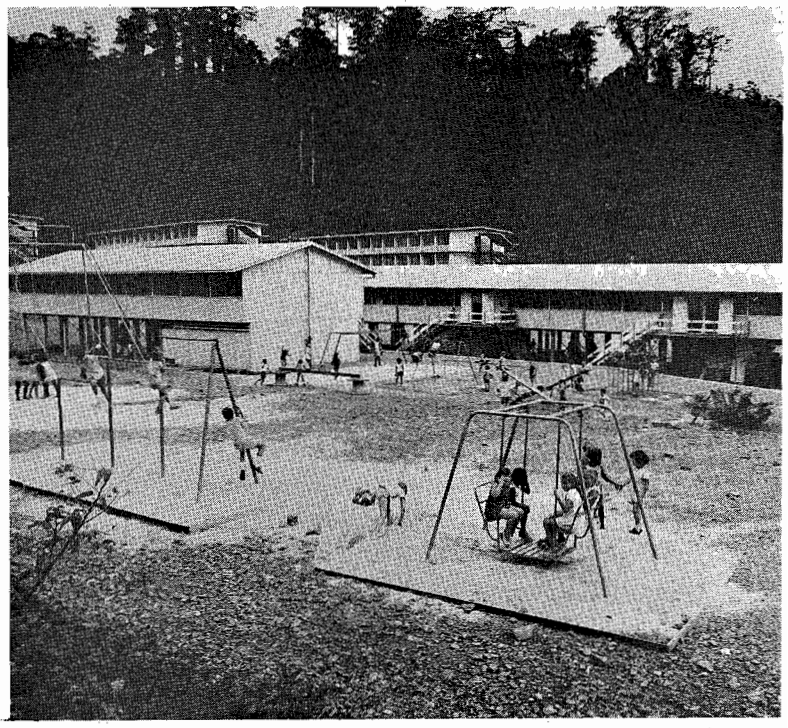
Primitive wharfage and handling facilities contributed to a high loss rate of materials mainly due to breakages, theft and goods lost in transit.

Furniture and Joinery was also manufactured by Morobe Constructions Pty. Ltd., in their workshops at Six Mile, Port Moresby and sea freighted in a "knocked down" condition for assembly in the "on site" workshop.

The electrical work was carried out by Papuan Electrical Pty. Ltd., and plumbing by R.C. Bailey Plumbing Co. both subsidiary companies of Morobe Constructions Pty. Ltd.

The company also constructed the two Primary Schools, stages one and two of the Arawa High School, stages one and two of the Technical School and the Arawa Police Station and Barracks, for the Department of Public Works.





Top:
ARAWA – beginning of the town.

Centre:
Primary School and Playground.

Below:
Indigene and expatriate children in Primary School class.

Fuel Storage and Pipe Installations

By H.C. Laan,
Project Manager,
Matthew Hall (Pty.) Limited.

Matthew Hall (Pty.) Limited's association with the Bougainville Copper Project stems back to 1969 when the Company supplied skilled labour to assemble and erect 6 fuel storage tanks at Loloho. These tanks, of bolted and rivetted construction together with their associated hardware, etc. made up the interim fuel storage and distribution centre for the project. In 1969 Matthew Hall acting as main contractor for Shell Company (Pacific Islands) Ltd. undertook construction of the projects Seaboard Terminal located at Loloho, Anewa Bay. This contract was followed by installation of aircraft fueling facilities at Aropa Airport, plus a mine site distribution depot at Panguna to service the rapidly increasing fleet of construction equipment operating at the actual mine site.

Following successful completion of these facilities Matthew Hall was again engaged by the Shell Co. to construct the heavy fuel oil storage facilities for the Loloho power station. Shortly after commencing site work on this installation M.H. was awarded a contract by Bechtel WKE for installation of all high and low pressure piping for both the power station and port area process facilities at Anewa Bay.

Being one of the first contractors on site gave the company a unique opportunity to witness the rapid acceleration of all phases of the Bougainville Copper project including the development of unilateral industrial relation administration, integration of an indigenous work force, logistics control, and general overall co-ordination of a project, which must rank with some of the most demanding process type projects ever undertaken.

Apart from the obvious satisfaction and sense of achievement gained by being part of a team that helped build this enormous undertaking was the proven fact that at the completion of the project, all sections of the company's organisation had been tested and proven under the most rigorous and demanding conditions that could be experienced in major construction work.

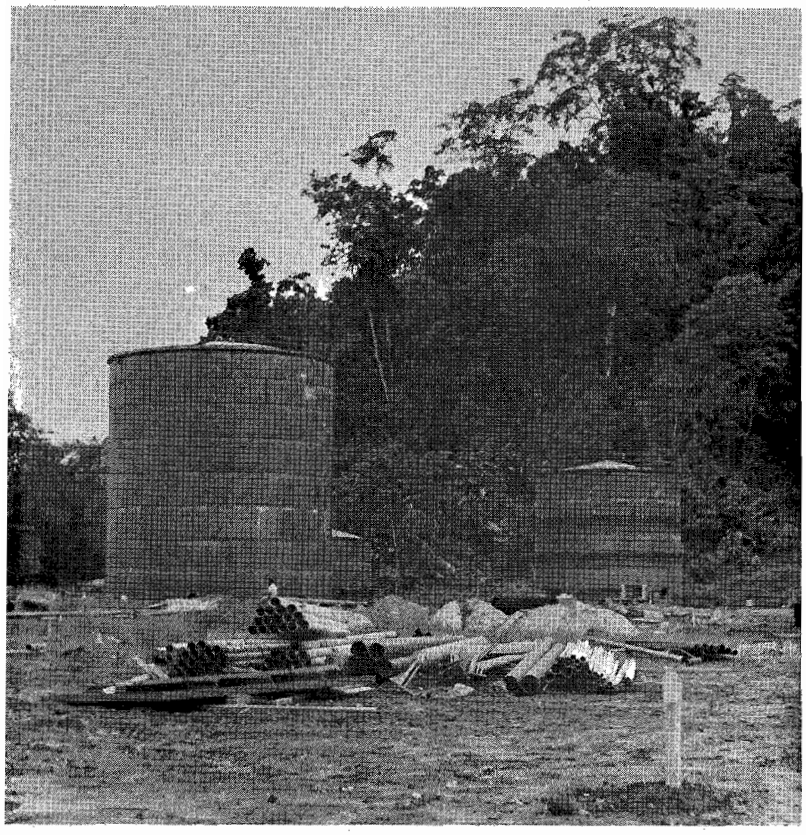
Like all other contractors associated with the Bougainville project M.H. found very early that some of the methods and systems which had long been accepted as standard procedure for general organisation and mobilization of a new site were inadequate on this project. Forward planning prior to mobilization, which has always formed a major part of the company's construction activities, took on a new meaning as planning and construction engineers detailed and organised not only the resourcing of contract materials but also had to accurately take off and send to site all hand tools, consumables, etc. which in the early phases of the project were totally unobtainable on the island. In fact, for the earlier contract the company erected and ran its own camp at Loloho complete with mobile kitchen, bunkhouses, etc.

The success of this forward planning is evidenced in that all target dates for both the Shell Co. and Bechtel WKE contracts were either met or bettered. Completion of the first, most critical phase of the Power House piping contract, was achieved six days ahead of schedule whilst phase 2 "came in" 29 days ahead.

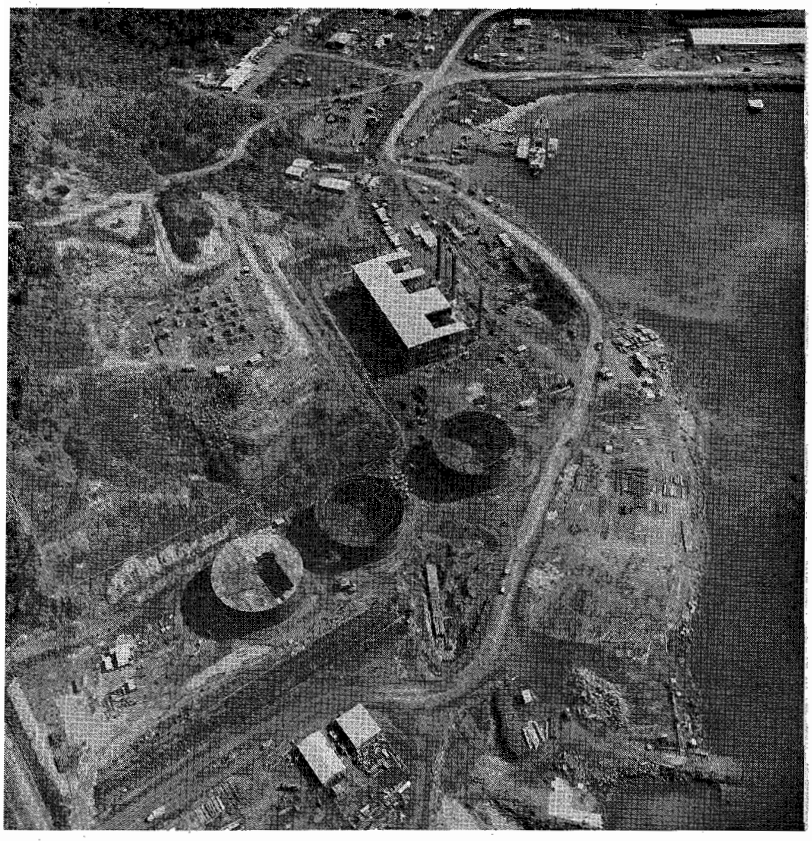
As the company's activities were mainly concentrated at Anewa Bay it was decided to offer all employment opportunities for indigenous personnel to members of local villages and at the peak of construction some 85 indigenous personnel were employed, most of whom were recruited from Roravana village. Under the general direction of indigenous leaders these men made a valuable contribution to the success of the company's contracts.

The company's association with local contractors during the period 1969/1972 was most rewarding if somewhat different from mainland Australia accepted practices. One aspect of working in relatively remote (in a general sense) areas is that if you don't have it, you make it! and to this end the ingenuity of local contractors during the earlier contracts was boundless, no doubt born and developed by years of frustration in trying to obtain items from Australia in any reasonable period of time.

Similarly, for the power house contract Matthew Hall's plant maintenance staff had the unenviable task of keeping equipment running at all times to support the Company's round-the-clock operation with only Sundays available for major repair jobs.



Grass Roots! The first phase of Matthew Hall's work at Bougainville. Indigenous labour played a major part in completing the Shell Company's depot in record time.



Heavy fuel oil tanks under construction.

With the relatively large labour force, personnel transport became a high priority maintenance item, as at the peak of construction all vehicles, manhauls, personnel bus, etc. were fully utilised transporting workmen between the camp and job site.

The "make it" philosophy came to the fore when one of the main personnel transports, a Bedford 37-seater bus, broke a spring. As a result of urgent repairs the company ended up operating what is probably the only Bedford bus fitted with International truck springs and a modified chassis to take spring hangers fabricated from miscellaneous parts.

Some points of interest of the main contracts undertaken in Bougainville are as follows:

Interim Fuel Storage

At the time that these storage facilities were constructed it was extremely difficult, if not impossible, for heavy vehicles to negotiate the roadway between Kieta and Anewa Bay. Part of the facilities required transport of two 30 x 9 tanks from Kobuan to Anewa Bay. This posed a minor problem in logistics until it was decided to seal the tanks and float them, thus enabling the units to be towed to the job site. On arriving at Anewa Bay the vessels were rolled up the beach onto firmer ground where they could be handled by more conventional means.

The bolted storage vessels purchased by the Shell Co. in Singapore arrived via landing craft in an operation reminiscent of war time exploits in the area. The vessels although new required the application of some 500 lbs. of epoxy to seal the various joints.

Although only minor in scope this contract heralded the company's involvement with the Bougainville Copper Project.

Fuel Oil Depot At Loloho

This contract which was completed during 1970 included the erection of storage tanks for both conventional and aviation fuel. A total of five tanks were erected together with an office block, fueling apron, maintenance workshop, etc.

One of the features of this project was laying of a submarine line to enable fuel to be discharged from tankers moored in Anewa Bay.

The underwater topography around most of the islands of Papua New Guinea includes magnificent coral reefs studded with every imaginable form of coral and exotic gorgonia. Normally these reefs run shallow for a relatively short distance from shore and then "drop off" rapidly to, in some cases, 700 fathoms. Laying of the line involved blasting a path through existing coral formations to provide a firm bedding. This blasting etc. was undertaken by a Suva based diver who specializes in underwater construction work for the South Pacific area.

The eight inch line was prefabricated on shore into three (3) sections. Following wrapping and installation of a slatted protective cage around the pipe sections (to avoid damage from coral abrasion) the first section was floated out, anchored, the next section welded on and the joint wrapped, this procedure being repeated for the third section.

Once the floating line was completely run out to its terminal point it was accurately positioned over the prepared bed

and allowed to sink into position following which conventional anchor blocks were installed to permanently locate the line. (The waters of Anewa Bay are generally quite calm thus favouring this particular method).

The entire fuel depot including the submarine line was built in record time and the first cargo of automotive diesel fuel was discharged by a Shell tanker on 15th December, 1969.

Loloho Power House Heavy Fuel Oil Storage Facility

This contract involved the construction of three steel storage tanks and associated piping plus a 22" pipeline from the wharfside unloading point to the tank compound.

The 142' dia. x 48' high tanks were constructed in the conventional manner using a mobile hydraulic crane to position the preformed plates for each strake. Horizontal welds were carried out via an automatic machine whilst vertical welds utilised conventional manual welding techniques.

Total length of the 22" ships discharge line is 2900 ft. The line generally follows the contour of the foreshore roadway. At the tank farm end it is diverted underneath the roadway through a concrete culvert.

Owing to the anticipated temperature changes of the line, as a result of unloading the fuel at a considerably higher than ambient temperature, provision had to be made for expansion. Controlled expansion was achieved by the use of fixed anchor blocks which directed the expansion via roller type pipe supports. The natural contour of the line provided adequate direction for expansion thus precluding the installation of normal loop type expansion facilities which due to space restrictions between the roadway and the water's edge could not have been fitted. As constituents of the fuel oil tend to solidify if reduced to ambient temperature facilities have been provided to clear the line after each tanker's discharge by 'pigging'.

Connection of the line to the discharging vessel is via a pair of Wheaton 12" manual unloading arms. These units, which are the largest that can be manually operated, enable the discharging vessel to hook up with the minimum of delay. The unloading arms are designed to take account of tidal changes plus lateral movement of the unloading vessel.

The system was put into operation in August 1971 when the 36,000 ton tanker "VOLVULA" discharged 33,000 tons of heavy fuel oil.

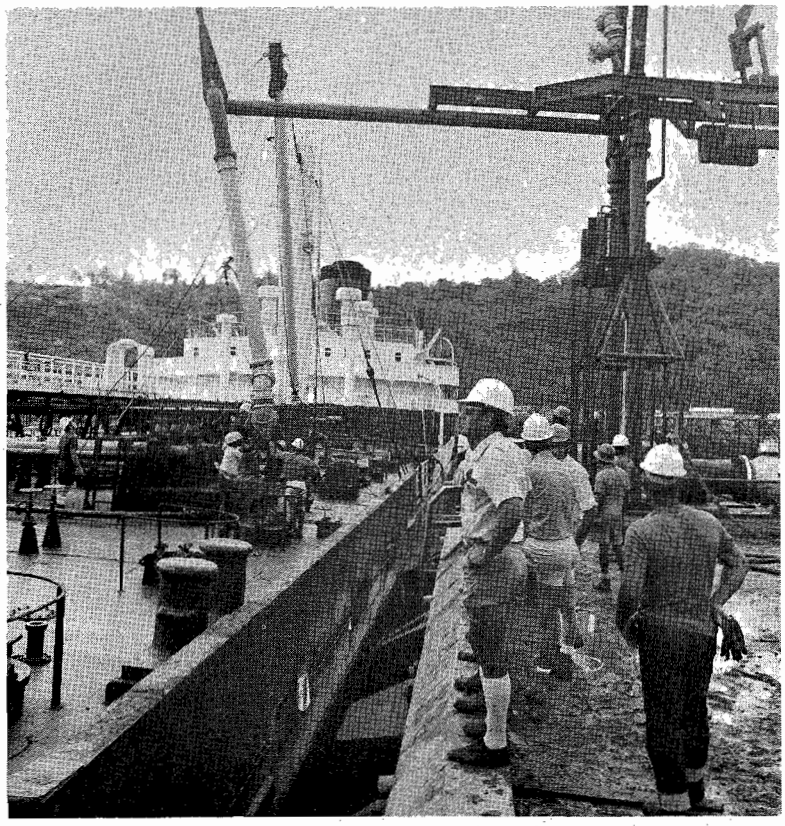
Piping and Port Area Facilities

By far the biggest contract undertaken by M.H. (Pty.) Limited on Bougainville was the installation of all piping for the Loloho Power Station and Port area facilities.

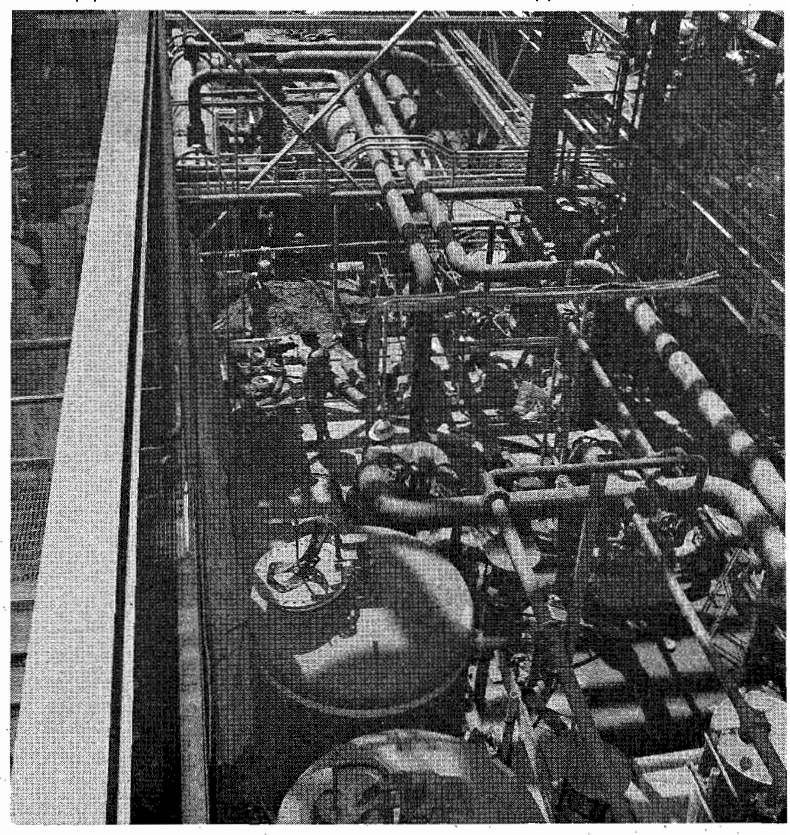
Total footage of pipe installed for this contract approximated 87,000 ft. of both small and large bore piping.

In order to fabricate and install this quantity of pipe in the short time available the company had to mount a crash programme utilizing day and night shifts working 6 days per week, 10 hours per day. However, owing to the number of mainland projects running concurrent with the Bougainville Project the company had difficulty in recruiting sufficient skilled personnel from Australia, and hence it became necessary to draw a section of the workforce comprising pipe fitters and specialist welders from the company's London Office. Altogether a total of seventy-five U.K. expatriates were engaged on this contract.

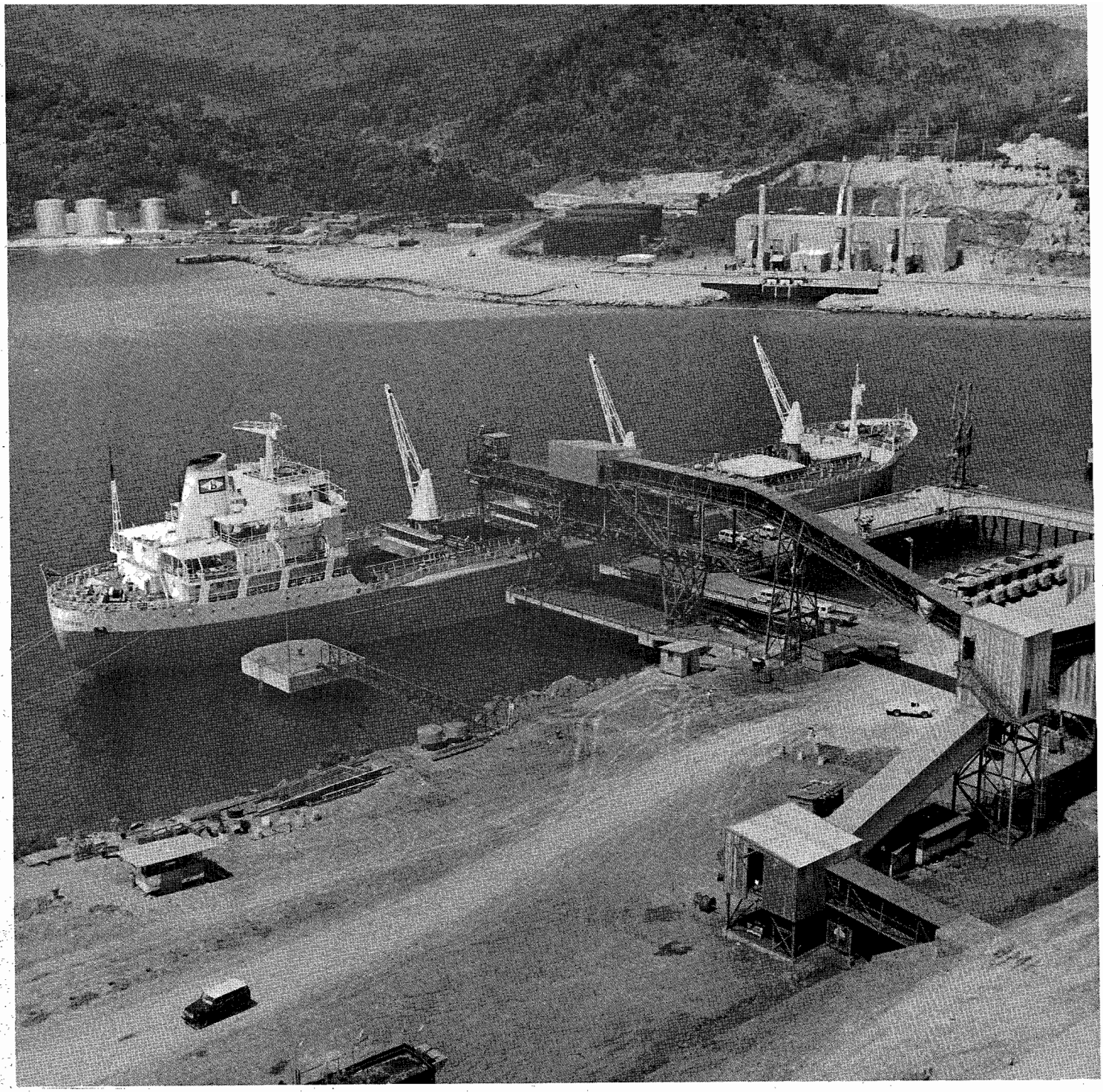
Despite the large workforce employed on this contract



The first unloading of heavy fuel oil using the 12" Wheaton unloading arms. The second arm is still in the 'parked' position at top right of picture. The "pig" launching trap and start of the 22" pipeline can be seen at the bottom of the arm support frame.



Powerhouse piping — general congestion of areas plus multi trade involvement calls for detailed planning of piping installation sequence.



View showing Shell Company Depot at top left. The 22" fuel unloading line runs from unloading arm on right of wharf along foreshore to large storage tanks at centre rear of picture. April 1972

(total at peak was 465 men including staff) industrial unrest was kept to a minimum with only minor stoppages being recorded throughout the course of the contract. This record can no doubt be attributed to unilateral industrial relations controls organised and co-ordinated by Bechtel WKE.

In order to minimize "lost" time due to design queries, changes, etc. the company arranged for all design to be undertaken at site. A team of 14 engineers and draughtsmen was seconded from the company's Sydney office to undertake the preparation of and amendments to detailed construction drawings.

Matthew Hall Staff Welding Inspectors carried out continuous monitoring of weld quality. The high degree of skill demanded of each welder at the pre-employment weld test was reflected in the excellent record achieved in that cut-outs were almost non existent.

Two forms of welding were employed, all high pressure and alloy piping utilized a T.I.G. root run followed by manual arc filler runs. Low pressure piping used manual arc, conventional welding throughout.

In March 1972 the last of the company's personnel returned to Australia having discharged the company's final responsibilities towards completion of what has been an exciting and satisfying series of contracts.

Matthew Hall (Pty.) Limited is proud to have been associated with building of the Bougainville Copper Project.

A far cry from normal home comforts, but for Shell personnel in Bougainville in the early days of the project, this timber, fly-screen and canvas hut was literally "home". "Diving from the back door was not allowed at low water."

Oil Supply

SHELL COMPANY (PACIFIC ISLANDS) LTD.
BOUGAINVILLE STORY.

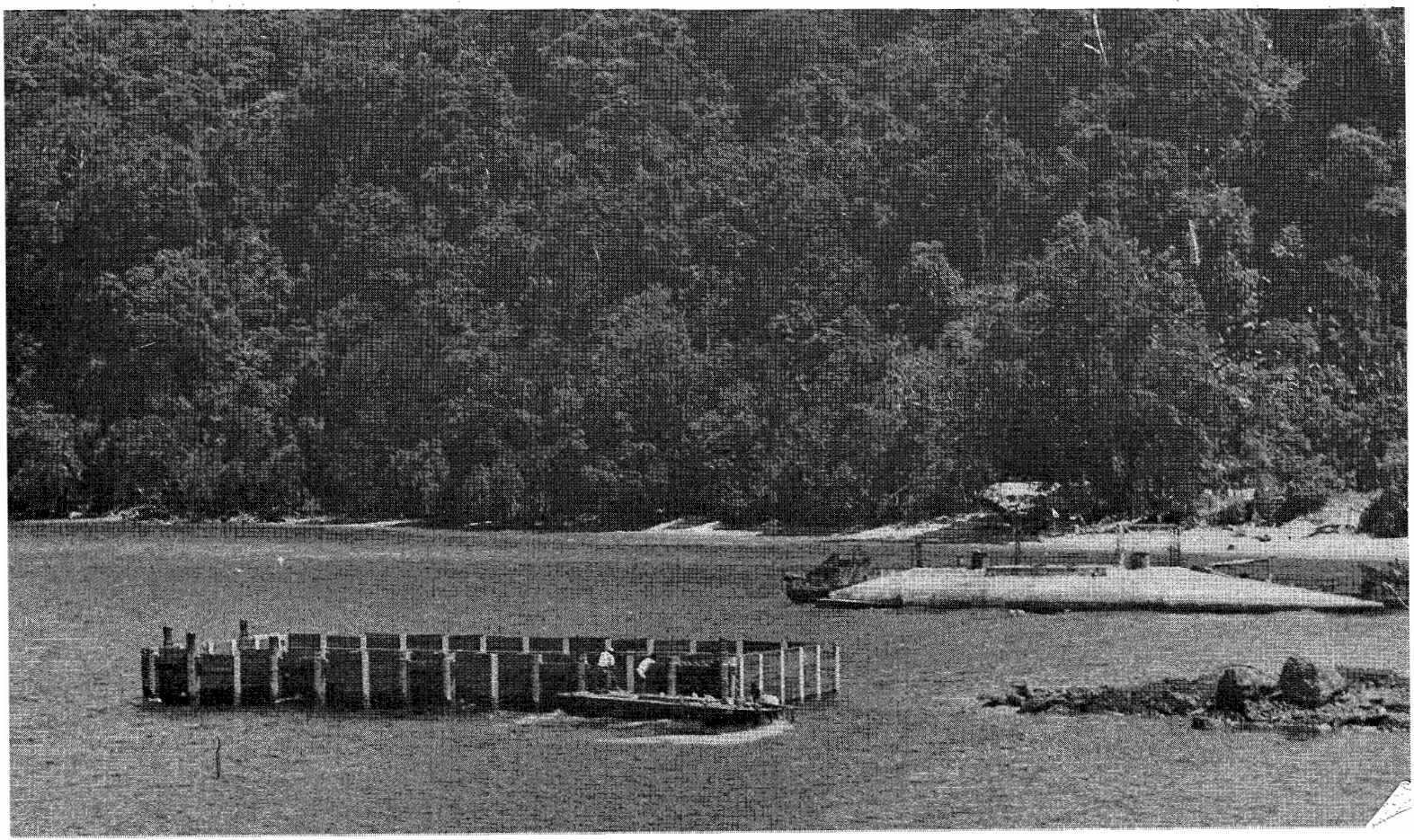
Until the early part of 1969, Kieta, on the south-east coast of Bougainville Island, was just another small Pacific Islands' port, quietly catering to the modest needs of the rural community of the island's South-Eastern Central District.

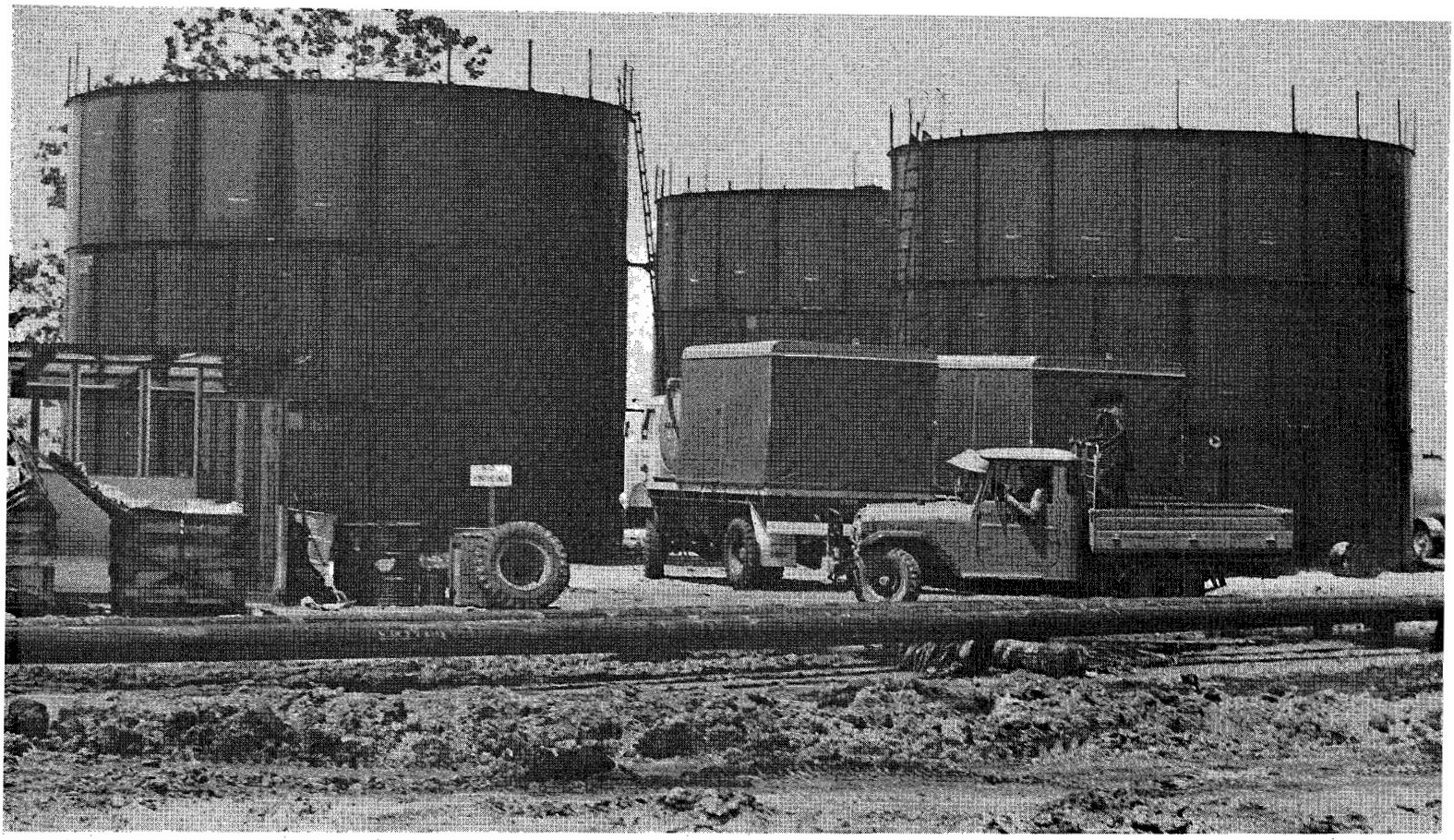
In two-and-a-half years, this little port was to become the focal point of the world's largest quick-start mining development.

Men and machines poured into Kieta on their way to Panguna, site of the vast copper ore body, transforming the little town into a seething cauldron of activity.

After 30 months of intensive work under arduous conditions, the giant mining complex of Bougainville Copper Pty. Limited finally emerged – poised ready to produce copper concentrate for smelters throughout the world and provide a valuable contribution to the developing nation of Papua-New Guinea.

The former war-time Japanese submarine raised from the sea bed off Rabaul, that served as back-up supply transport ex Rabaul for Shell during the early stages of construction, photographed berthed alongside the 600 ton barge "Intrepid" just off the beach at Loloho.





Temporary bolted tanks on the beach at Loloho provided initial bulk storage for the Bougainville project while the permanent installations were constructed. In foreground sections of the submarine pipeline prior to launching.

The first C.R.A. geologists began exploring the Panguna area to assess the extent of the ore body there in the early 1960's and right from the start, Shell lent its support to the operation. Rabaul, on the neighboring island of New Britain, was the stepping off point for Bougainville and local Shell personnel soon developed close relationships with the exploration parties.

Fuel for the early exploration activities – minute quantities compared to the supply required at the height of the construction work in 1970 and 1971 – was supplied by Shell, and from this small beginning grew a massive operation of maintaining supplies and distributing fuel and lubricants throughout the project area.

The operation has been described as "An oilman's greatest challenge . . . ." – keeping the customer supplied in extremely adverse conditions. In fact, the task was reminiscent of maintaining and supplying a war-time beach-head.

And conditions were adverse! Up to 200 inches of rain a year turned the rough tracks over the mountain from Kieta and nearby Anewa Bay to the mine site at Panguna into a quagmire. Sections of the road washed out from time to time; vehicles broke down frequently because of the tough conditions; some were lost in falls from the precipitous road, yet a round-the-clock supply was essential throughout the project area. By 1968 work had progressed from the on-foot exploratory stage to more detailed exploration. Drilling was underway to evaluate the ore body, an access track was under construction and helicopters were being used to shuttle personnel, equipment and stores onto the Panguna jungle.

Shell was now supplying increasing quantities of fuel to support these operations and, so that a continuous supply might be maintained, tanks were installed on the beach at Kobuan Bay. This was supplied from Rabaul by the 200 ton coastal tanker "Kuanua".

Additional transport was provided by using a wartime Japanese cargo submarine salvaged from the Rabaul area and specially reconditioned for the purpose.

At this stage, 20 – 40,000 gallons of gas oil a month were required to support the mining company's activities, and already it was obvious that a continuing fuel supply was the life blood of the project.

Without fuel, machines would be useless, and without the machines the operation would grind to a halt resulting in costly loss of time and serious disruption to the overall co-ordination of the project.

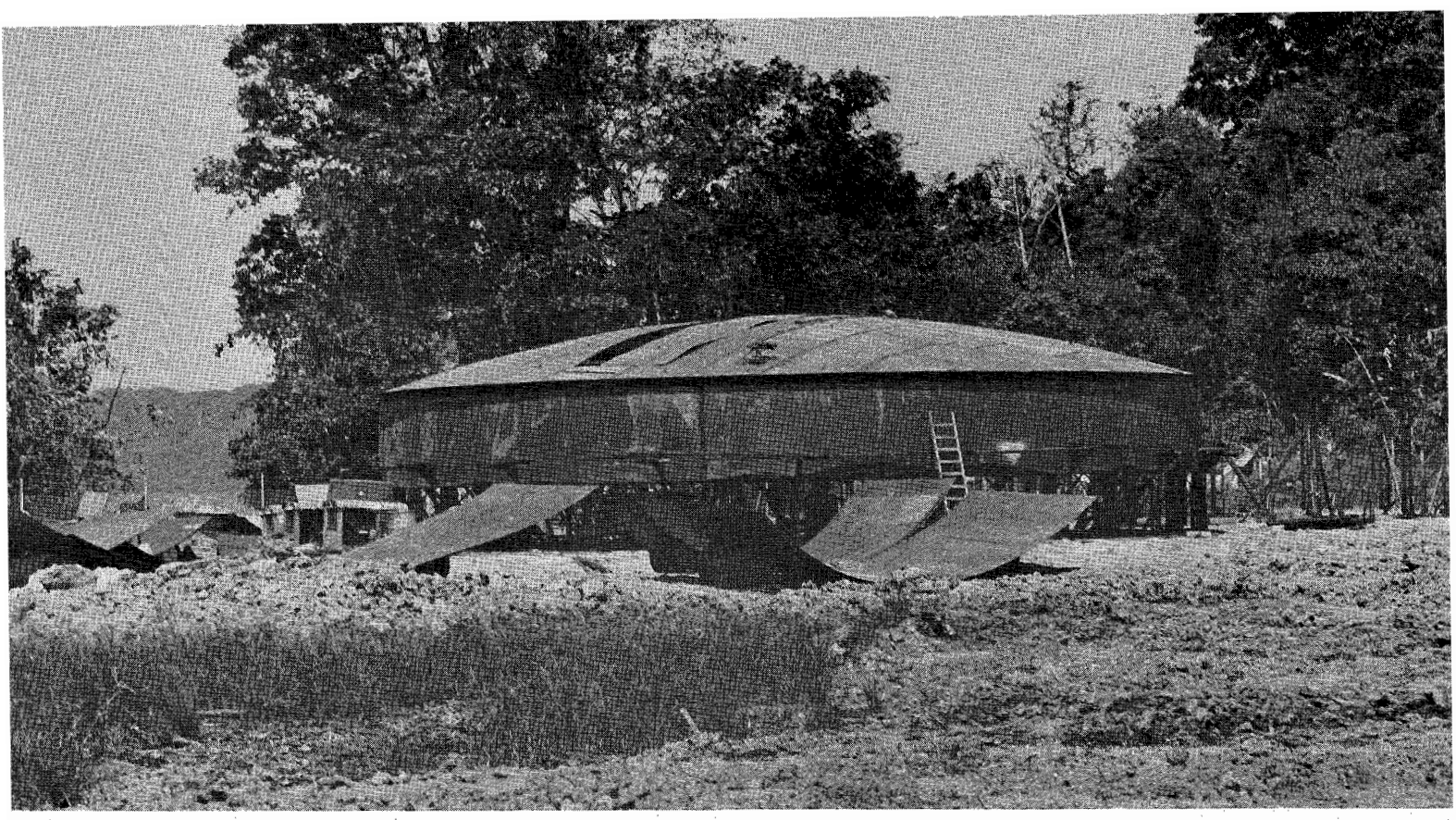
About the middle of 1969, the first major fuel supply contract – for the construction stage – was won by Shell. This contract required the establishment before December of that year, of an oil terminal for the storage of white oil products, the construction of ocean tanker discharging facilities and the supply of 400,000 gallons of automotive diesel fuel a month, rising to just over 1 million gallons a month at the peak of the construction stage.

A Shell "Project Engineering Team" was formed to design a product storage plant and marine facilities tailored not only to the needs of the immediate construction phase, but to ultimately cater for the petroleum needs of Bougainville Island's future.

After designs were agreed, Matthew Hall Pty. Limited was commissioned to construct the white products terminal and tanker discharge facilities on five acres of land having water frontage to Anewa Bay at a place called Loloho.

While the design and preparatory phase was underway, men and machines were pouring into the island; construction camps were going up and construction work was beginning.

With this massive build-up in activity came an enormous escalation in fuel requirements. Problems of supply and maintaining that supply were immediate. The permanent oil storage terminal being built at Loloho would take several



Erecting the tank farm at Loloho using the jack-up method of construction. In the first picture the roof section is shown virtually completed for jacking up for construction of the next level. The method of construction provided dry working conditions for workers during the 1969 wet period. The other picture shows one of the tanks completed and another under construction in the background.

months to complete, but in the meantime the demand for petroleum products was rising rapidly.

To meet the situation, three 500 ton bolted tanks, purchased from the British Army in Singapore were erected on the beach at Anewa Bay and kept supplied by a small coastal tanker. A 600 ton barge – 'Intrepid' – moored off the beach, initially provided supplementary supplies to the temporary shore facilities.

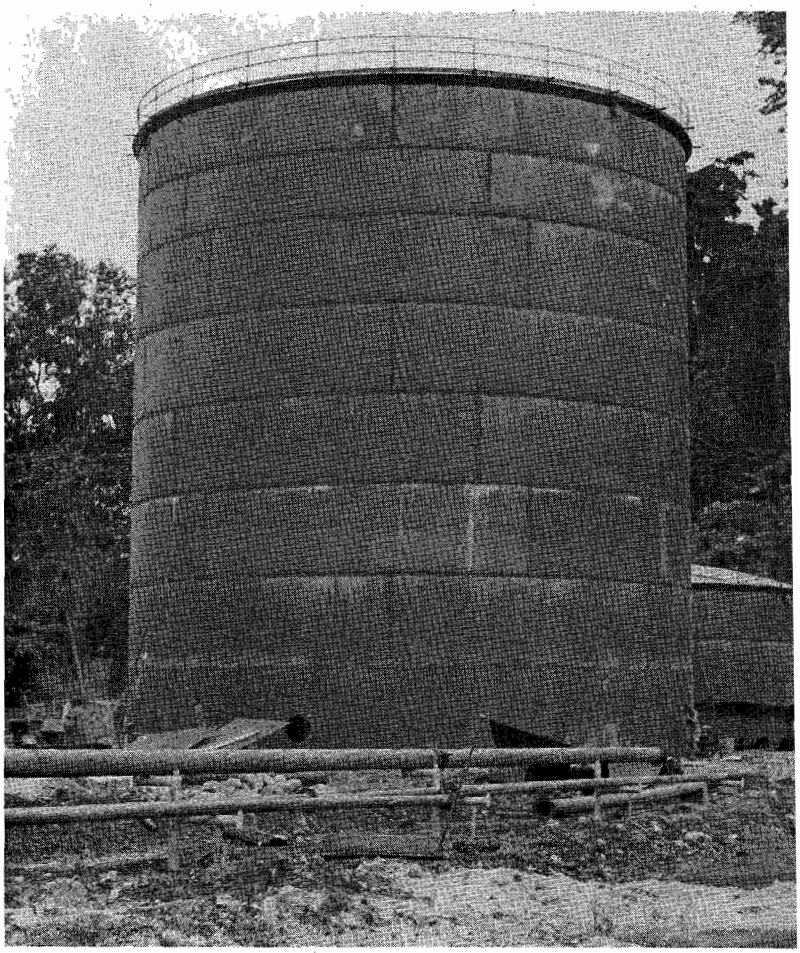
The tanks were obtained with the aid of Shell International Petroleum Company, London, who assisted with the purchase arrangements and the shipping of the tanks to Rabaul.

The storage barge 'Intrepid' was hired from Port Moresby and underwent extensive reconditioning before it was suitable for fuel storage. A Singapore tug was used for the tow to Anewa Bay and its return to Port Moresby at the end of the hire period.

Accommodation for Shell personnel at this stage was also at the temporary stage. A hut was constructed on the beach between the high and low water marks to avoid problems of land ownership. The makeshift structure of timber, fly-screens and a tent-fly roof built on a base of three inch pipe, served the early Shell team well and was still in service beyond most expectations.

Subsequently, a permanent 40-man camp was built by Matthew Hall, on Shell's behalf, consisting of 20 two-man huts, and accommodation was also provided from time to time in the Bechtel W.K.E. camps.

In winning the fuel supply contract Shell had undertaken to maintain fuel and lubricants supplies delivered to user points throughout the mining project area. A fleet of tray trucks with the demountable tanks hauled fuel from the port area to the mine site 17 miles away over the mountains, along a road that almost defied description.



Late 1969 a small chartered tanker in foreground discharges automotive products by floating line to the 600 ton barge "Intrepid" (centreground of picture) and the three 500 ton bolted tanks temporarily erected on the beach at Loloho. On far left of picture the permanent Shell Loloho installation is under construction.

At one stage the construction of a pipeline to carry fuel to Panguna was considered, but ruled out because of time, construction problems and because it was not economical compared to road transport.

Fuel was required throughout the project area 24 hours a day. Shell kept a senior man on the spot during the construction phase to co-ordinate distribution. Long hours, late night and pre-dawn emergency trips to take fuel to machines working in remote corners of the area became regular parts of his job.

But, efforts of this kind played vital roles in maintaining continuous supply which was never broken. On occasions, stocks of fuel on the island dropped to low levels; in fact at one stage only 20,000 gallons remained, but it was just enough to last until the delayed arrival of fresh supplies by ship.

Throughout the second half of 1969, a full engineering team was building the permanent Shell installation at Loloho. Marine specialists from Brown Marine in Fiji were flown to Bougainville to assist with the installation of the mooring facilities and the submarine pipeline for ocean fuel discharge from ocean tankers.

The pipeline itself provided problems. During the laying of the line, 1900 feet of pipe was floated into Anewa Bay, supported by drums. The pipe was secured at the shore end and towed by a launch. When in position, the pipe was lowered to the sea bed by gradually releasing the drums. This operation required great care, as the release of too many drums at once would overstress the pipe and may have led to damage

The buoy mooring facilities involved complications also. The normal delivery period for the buoy, its pendant and anchor chains and the anchors is about 12 months. The project could not wait that long for the equipment and so Shell International was again asked to help. The buoy and all the fittings were obtained in six months, including shipping time, enabling construction deadlines to be met.

In constructing the tank farm it was decided to erect the tanks for the Loloho installation by the jack-up principle. The complete roof of a tank was built first and this was jacked up while the walls were erected underneath, providing dry working conditions for the construction crews during the wet season late in 1969.

In December the job was finished; the white products storage tanks of 7600 tons capacity were commissioned and the 3000 foot submarine pipeline from tanker buoy moorings in the bay was ready to take the first shipment. The white

products installation with a total storage capacity of 7600 tons and valued at about $1 million (including marine facilities) was in operation less than six months from acceptance of the tender – a record time for such a project. On the 15th of that month, the first 18,000 ton deadweight general purpose tanker from Singapore put in to the bay, tied up at the new moorings and discharged its cargo.

One of the major problems in supply and distribution of fuel to the growing project was to maintain a continuous flow of products to Panguna where work was progressing at an ever-increasing rate.

At any time because of weather conditions the road might not be serviceable and vehicles could be held up for indefinite periods while repairs were effected. Under such conditions the chance of a break in supply of fuel at the site was always a real possibility. In one emergency, a river of mud several feet deep, flowed across the road cutting it and blocking all vehicular access. To overcome the problem tankers maintained a shuttle service from Anewa Bay to the mud flow and from the other side of the mud to Panguna. A temporary pipeline was rigged to transfer fuel from one tanker to another across the mud.

In its 17 miles the road climbed 3000 feet up from the coast and then dropped another 1000 feet to the mine site. Tankers wore out tyres every 2000–3000 miles and clutches and gearboxes burned out regularly. During this period road-freighting from Loloho to Panguna was undertaken for Shell by Kennelly's Transport. The operation was extremely arduous but successfully performed, thanks to the almost continuous personal supervision of Mr. John Kennelly, backed by his team of experienced transporters.

To help overcome the problem and to provide an adequate buffer stock of fuel at Panguna, it was apparent late in 1969 that greater capacity storage facilities would be required urgently at Panguna.

It was decided to build a 250,000 gallon storage tank at the mine site and this was done while the Loloho terminal was under construction.

The result after six months from the start of the construction stage was that Bougainville was assured of direct ocean tanker supply and sufficient tankage to ensure a continuous supply of fuel.

In line with Shell's policy in other Pacific Islands' areas, provisions were made for the employment of as high a proportion of local employees as possible. To begin with, tanker drivers were all Europeans, but as indigenes were trained, they took over the work. Other local people were trained for other jobs.

Late in 1970, Bougainville Copper called tenders for the construction of a large tank farm for fuel oil for a 135 megawatt power station scheduled to come on stream during the second half of 1971.

Shell won this contract in October 1970 and, after designs and specifications for the plant had been agreed with Bechtel WKE, work began on a 60,000 ton fuel oil tank farm and a 3000-feet, 22-inch tanker discharge line at Anewa Bay, early in January 1971. Again Matthew Hall Pty. Limited won the position of principal contractor for construction.

The fuel oil tank farm was designed with capacity for taking 40,000 ton cargoes ex tanker and to carry a buffer of one month's supply for the power station.

By this stage, shipping movements in the Bay were increasing and with the eventual production of copper concentrate, even more ships would be using the port and its facilities. To minimise the shipping pattern it was essential that facilities were available for 30–45,000 ton tankers to optimise fuel oil cargo discharges.

The final design work for this contract was finished by Christmas that year and the construction team began work a few weeks later.

Mud everywhere and a tray truck loaded with tanks of fuel bound for Panguna, comes to grief on the old access track. Landslides, washaways and rivers of mud took their toll of vehicles making the long haul from the beach to the mine area.

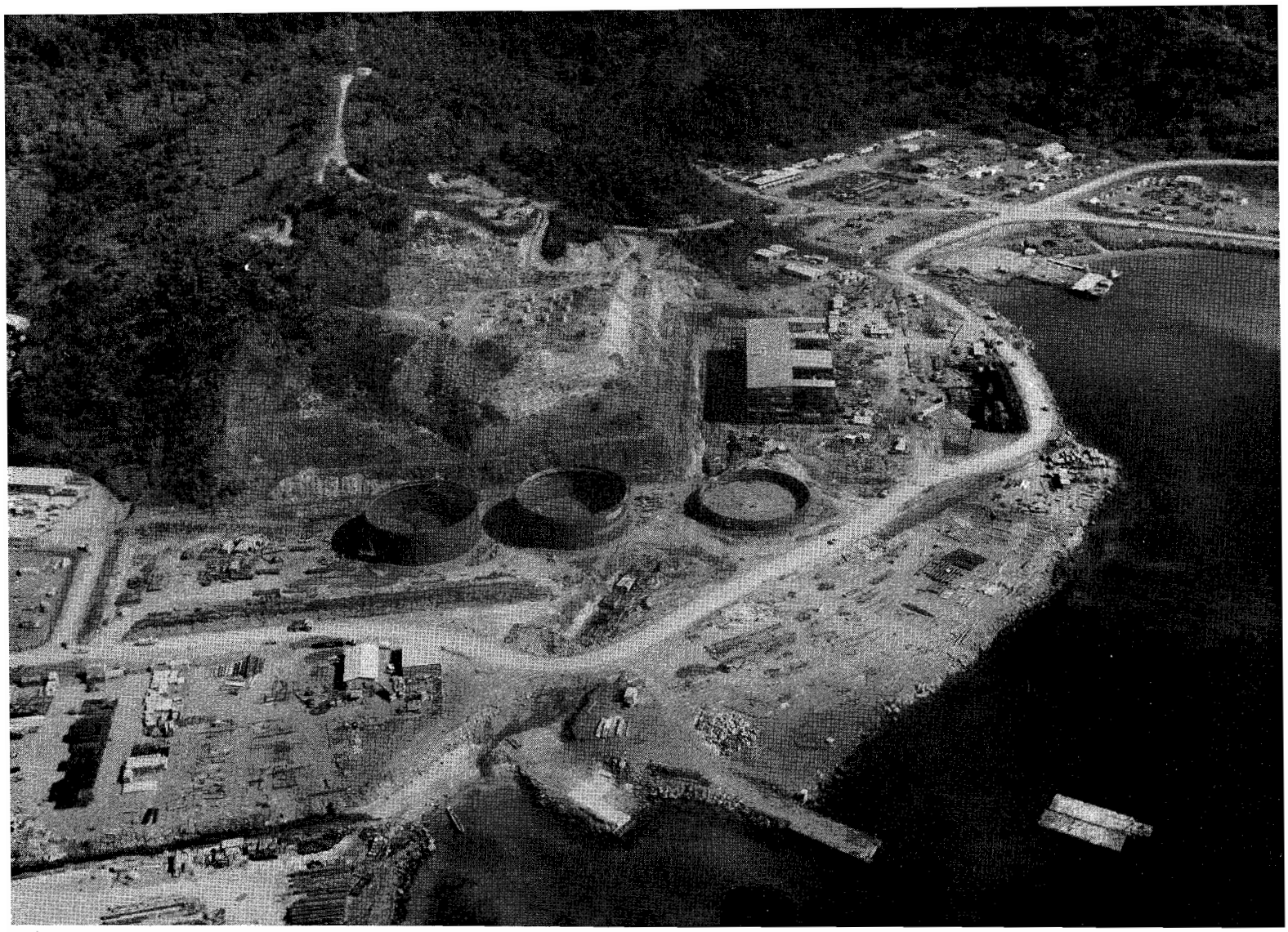
The whole of the Anewa Bay port area was undergoing transformation when this major contract was awarded. A small hill was bulldozed away and the rocks and earth from that area used to reclaim part of the Bay. At the same time, work was under way with the power station and other buildings in the area. Bechtel-W.K.E. was responsible for the entire port area project and the co-ordination of each construction task. Considerable liaison with Bechtel was essential for the successful erection of the tank farm, tanker discharge facilities and pipeline to the storage tanks, to coincide with other development work being carried out at the same time.

Blasting, earth-moving, filling of reclaimed land and the building of access roads all had to be co-ordinated and carefully timed to ensure that each project progressed satisfactorily and was completed on time without impeding the construction of other facilities.

The effectiveness of the liaison operation was borne out when the French Shell tanker "Volvula" arrived in August with the first 33,000 ton cargo of heavy fuel oil. A 36,000 ton dead weight tanker, she was the largest vessel ever to discharge cargo in a Papua-New Guinea port.

The discharge tested the design capacity of the pipeline facilities (3000 feet long and 22 inches in diameter) by pumping cargo at the rate of 3500 tons an hour to complete the discharge within 10 hours, allowing the tanker to sail within 24 hours of its arrival.

To relieve the demand on the Bougainville Copper



The three large fuel oil tanks to supply the Bougainville power station are pictured here in the course of construction. The roof section of the tank on the left is shown under construction while the tank on the right is still at an early stage of building. May 1971

workshops, and also as part of the forward planning to serve the growing town in Panguna, Shell negotiated with the mining company to establish a service station in Panguna itself and this was completed in January 1972.

At the height of the construction period in 1970, the small airstrip of Aropa, 12 miles from Kieta was handling increased traffic, and although not directly a part of the mine development project, constant supply of fuel to the airstrip played a vital role in the project. Shell installed underground tanks and a mini hydrant system of underground pipe to the aircraft apron for refuelling. This work was completed by August 1970 and proved an important factor in improving refuelling facilities for the increasing aircraft traffic to Bougainville.

Throughout the project, communications with Project teams at Bougainville were a constant problem. Only one telephone was available at the Kieta Post Office early in the project and it was necessary to have messages relayed to Australia through occasional radio links, if important, or by mail.

Shell had the advantage of having permanent staff in various parts of Papua-New Guinea and also having its tanker, "Kuanua", plying regularly between Rabaul and Bougainville. This became an important communications link.

Because of this difficulty and because most of the problems that arose on the island needed to be solved very quickly it was essential for staff on the spot to make immediate decisions. Without these decisions the supply of fuel may well have been broken.

Shell's contracts in Bougainville, involving more than $2.5 million investment, called for the establishment of many facilities, but more importantly, the continuous supply and full-scale distribution of fuels and lubricants.

Fuel dispensing equipment, meters, pumps and satellite tanks, minor items compared to the large storage facilities yet just as essential, were supplied as required in the Mine Project area.

Throughout the entire operation, great attention was paid to the up-dating of equipment and modification to constantly improve the supply and distribution system.

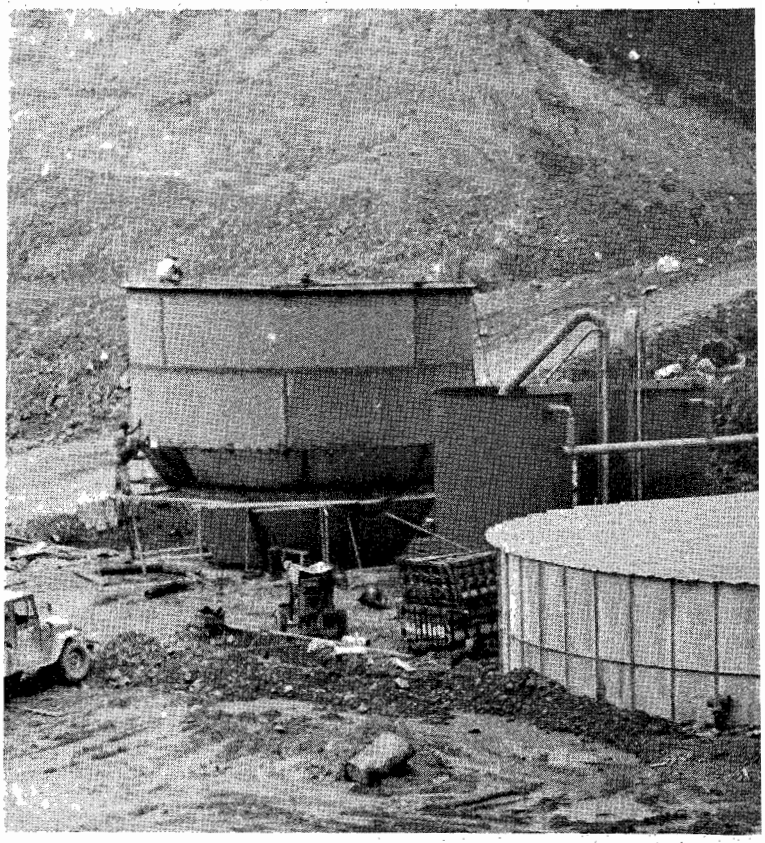
As part of this improvement activity, although at a later stage than the construction phase, Shell installed liquid petroleum gas facilities on the island and has since introduced bulk lubricating oil deliveries to Bougainville and drum filling facilities on the island.

The exercise will be discussed among oilmen for a long time as possibly "the greatest challenge", while in Bougainville the trials and frustrations of the late sixties are virtually forgotten and the 15 or so tanker visits each year have become just another event at the busy port.

Town Water

R.E. Moore,
Product Manager, Water & Waste Treatment,
Sybron (Australia) Pty. Ltd.

Sybron supplies Bougainville's major towns with drinking water.



720,000 I.G.P.D. Sybron water treatment plant under construction at Panguna

With an annual rainfall of more than 200 inches, one might question the need for water treatment plants on Bougainville. But those who have seen the Bovo River at Arawa or the Kawerong River at Panguna after rain in the mountains will know just how quickly a reasonably clear stream can turn into a racing turbid river.

The Bovo wasn't the start of it for Sybron. The initial need for potable water was at Panguna.

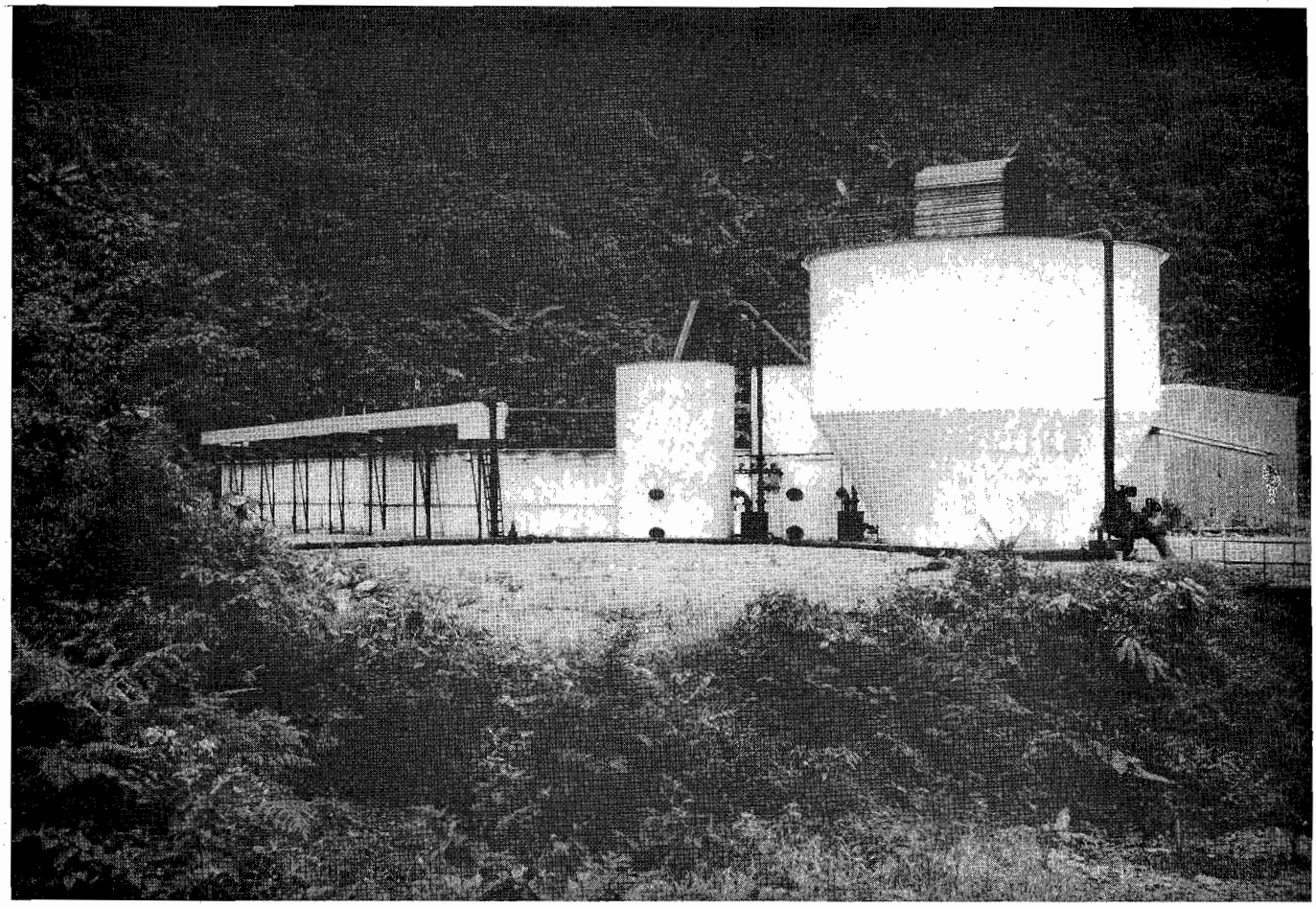
While the Kawerong River did not have far to travel from its source to the mine town, and therefore was likely to have only minimal pick-up of vegetation and soil from its catchment area, clean water could not be guaranteed under all circumstances. Added to this, there was a chance of bacteria entering the water from animal life and possibly from villages upstream of the town.

These two factors justified the need for a water treatment plant, and in January, 1970, Sybron was successful in its tender for the design, supply, supervision of erection and commissioning of the Panguna Water Treatment Plant.

The plant's initial capacity was to be 480,000 imperial gallons per day with a future expansion to 720,000 imperial gallons per day.

Reliability of operation was an essential requirement for this plant, as it was for any equipment on Bougainville, and the Sybron design met this need by utilizing natural hydraulic laws to reduce the use of mechanical or electrical components. Gravity flow from plant inlet to clearwater storage via automatic filters ensured not only reliability, but simplicity of operation. In fact the only pumps necessary for the plant were for general purpose water and chemical dosing.

The plant basically consisted of a 22'–6" top diameter x 14'6" bottom diameter x 22'–0" high vertical double



The completed 720,000 gallon per day Sybron water treatment plant at Panguna.

cone clarifier, utilizing the solids contact upflow sludge blanket principle and sized for the ultimate plant capacity, followed by two 10'–0" diameter x 15'–0" high automatic valveless gravity (A.V.G.) sand filters, with a third to be added at a future expansion.

The clarifier was provided with a four speed drive agitator, adjustable automatic sludge blowdown gear, and a swing-arm sludge blanket sampler to give complete control in forming and maintaining a sludge blanket.

Aluminium sulphate with sodium carbonate were selected to produce a floc, and sodium carbonate for pH correction. Chlorine dosing in the clarifier and in the filtered water removed the risk of bacteria in the final product and kept the formation of algae at bay.

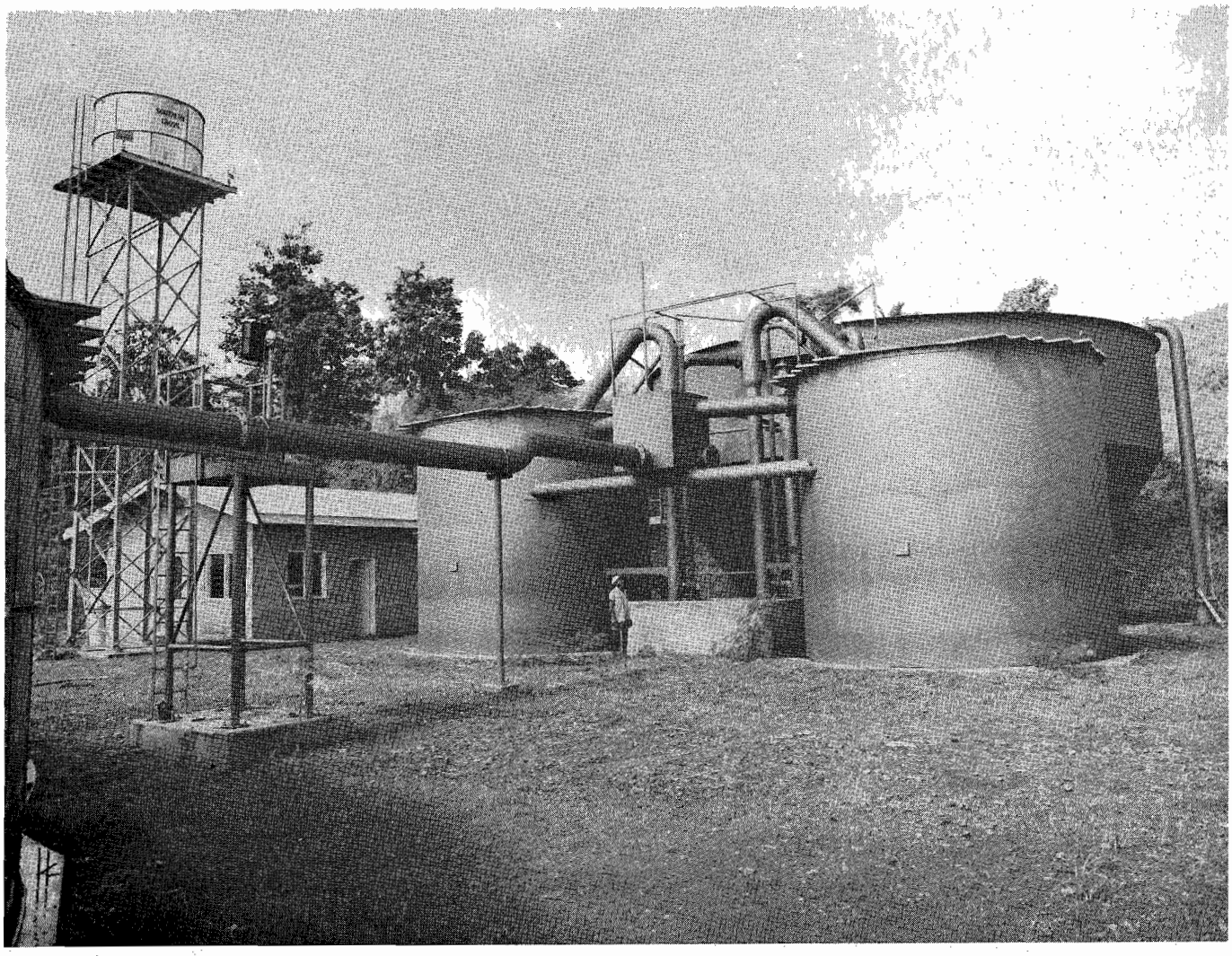
The Sybron Automatic Valveless Gravity Filters were and are complete within themselves. They include their own filtered water backwash storage compartment and automatically backwash by means of siphonic action when the head loss through the sand bed reaches its design level. No pressure switches, timers or valves are necessary to initiate or to stop the backwash cycle, thus giving complete simplicity and reliability of performance.

The ancillary gear that formed an integral part of the plant included a parshall flume and instrument for total plant flow measurement, flow measuring devices for each filter, chemical mixing and solution tanks, chemical dosing pumps, a gas chlorinator, and a service water pump.

Manufacture of the plant was carried out in Brisbane, and it was shipped to site with the clarifier in a knocked-down condition, and the A.V.G. filters fabricated complete. Bechtel–WKE erected the plant with part supervision by Sybron, and it was successfully commissioned in April, 1971.

While on the Island, Sybron's commissioning engineer was able to evaluate more closely the condition of the Bovo River which was to be the source of supply for the next water treatment plant to be built; the Arawa Town water supply.

In June 1971 Sybron was successful in tendering for the design, supply and commissioning of the Arawa Town Water Treatment Plant.



Two million gallon per day Sybron water treatment plant at Arawa.

At Arawa the need was for 2,000,000 imperial gallons per day; a plant almost three times the size of the Panguna plant.

Again simplicity of operation was required and the Arawa plant was basically the same design, but a larger version of the Panguna plant.

The Clarifier was 43'–6" top diameter x 25'–0" bottom diameter x 22'–0" high and was followed by two 16'–0" diameter x 15'–0" high Automatic Valveless Gravity Filters. Alum and soda ash were again used for floc formation, and sludge blanket control facilities as at Panguna were also provided.

The complete plant was shipped from Sydney in a knocked-down condition in October, 1971, and was erected by others ready for commissioning.

Sybron's commissioning engineer was on site to inspect the final stages of erection and installation and to start-up the plant in April, 1972. Unexpected sub-surface boulders had caused a few delays to the civil contractor in laying the pipeline from the intake weir and pump house to the Sybron plant, but eventually the plant was filled with water and commissioning proceeded well during the first day.

During that night the Bovo turned into a racing torrent that left its mark from the intake structure to Arawa. Sections of the six inch steel pipe main to the town were bent or missing, growth along the banks of the river had been completely flattened; and large sections of the concrete intake weir had been washed away.

Needless to say, the Bovo was highly turbid at this stage, as it is each time rain falls anywhere in its catchment area.

After civil repairs and modifications had been made to the intake weir, the plant was successfully commissioned and handed over to Bougainville Copper Pty. Ltd. who in turn handed it over to the Public Works Department.

Panguna and Arawa, the two major water treatment plants on Bougainville, plus a smaller plant at Loloho, broadened Sybron's Experience in a most difficult environment where too much water is a problem, but where consistently potable water is essential for support of the population that is needed to develop the wealth of Bougainville.

Plastics

NYLEX AT BOUGAINVILLE

Nylex Corporation Limited, the largest plastics manufacturer in Australia, played an important role in the establishment of Bougainville Copper Pty. Ltd.

Nylex Fabrics Division and General Products Division, with the three associate companies, Armstrong-Nylex, ACI-Nylex and Olex Cables, supplied a wide range of products to this vast operation. Not only were materials supplied but service was provided by product specialists, technicians and the resident Nylex sales staff in P.N.G. to meet all technical requirements of joint construction managers Bechtel and Western-Knapp Engineering.

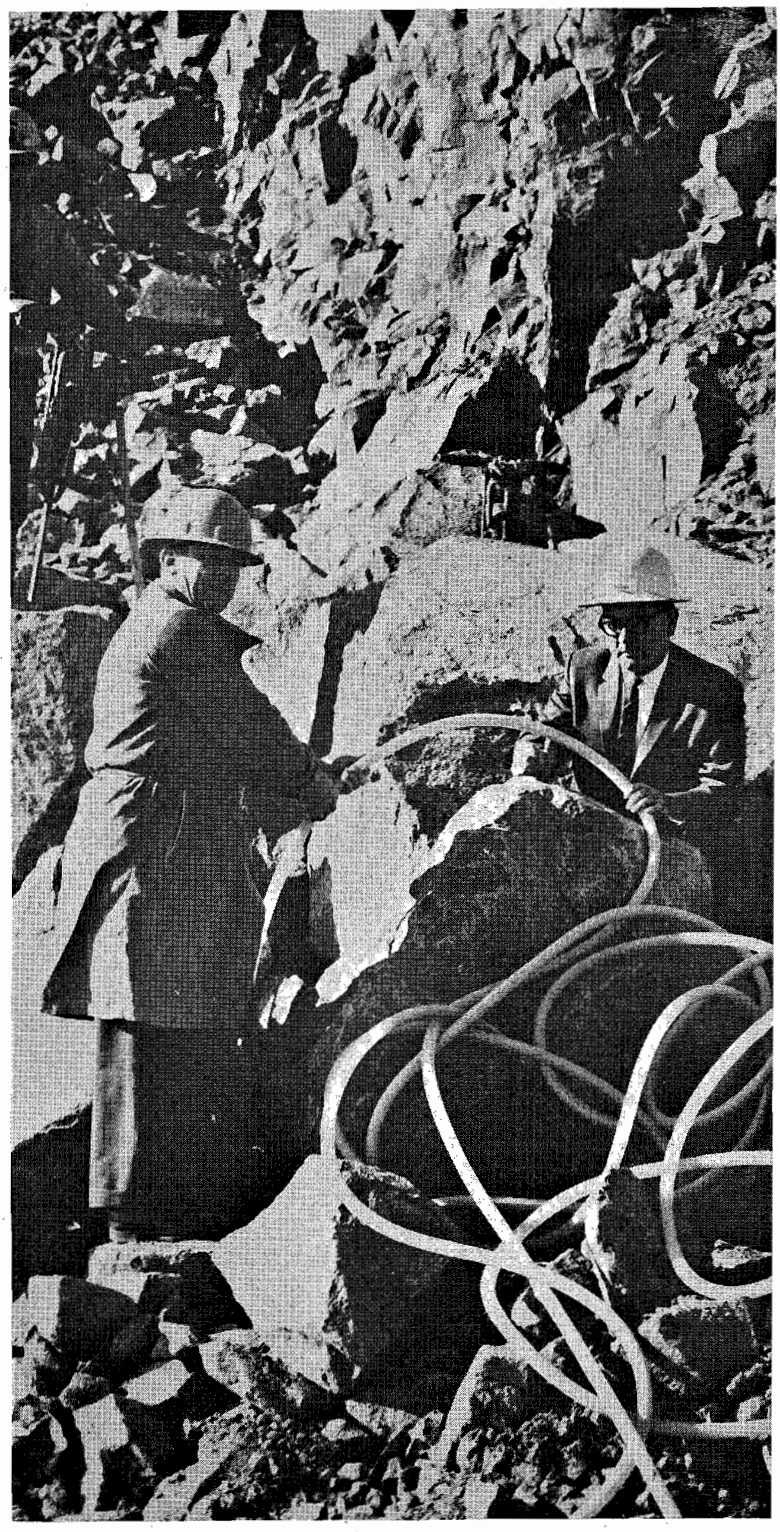
A costly, involved project such as the Bougainville development requires a great deal of ingenuity and advanced technology, which, in the field of plastics, Nylex is well qualified to provide.

The Company's involvement in the project began during the initial planning stage, several years before the establishment of the first construction camp, when Nylex representatives began work in P.N.G. on specifications that would suit the demanding requirements of the project, and of the environment.

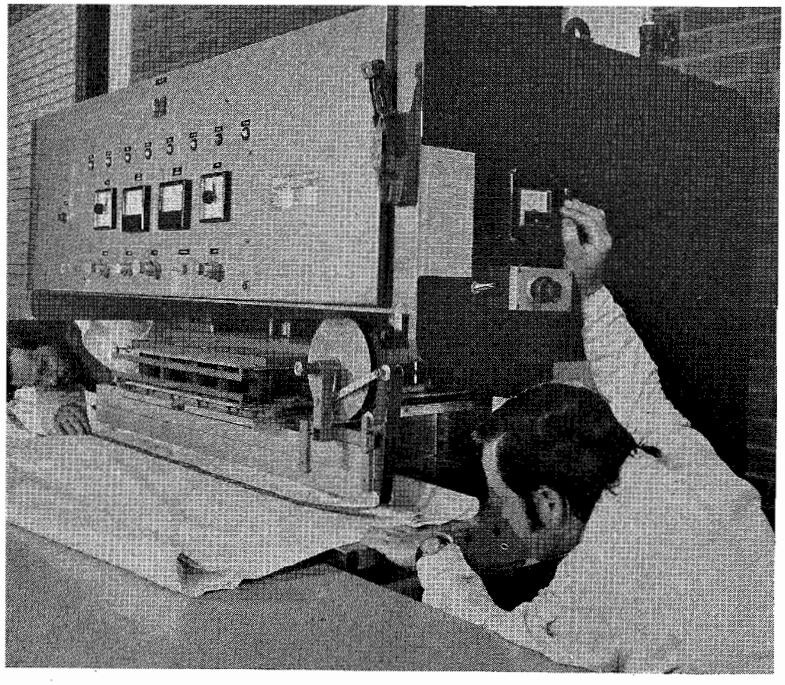
During the early stages of construction, one of the most urgent needs was to protect both men and equipment from the elements. Two Nylex products, Wavelock and Vynaprufe, proved eminently suitable for this purpose.

Nearly all the rain-wear required by the labour force was manufactured from Wavelock. This is an extremely lightweight, flexible and completely waterproof fabric, with a unique interlocking nylon reinforcement. It is made by sandwich construction with nylon material between two layers of specially formulated vinyl. High tear strength enables it to withstand the rigours of use on construction sites, and in fact the qualities of the fabric make it highly popular for constant wear in the hot, humid and muddy conditions encountered at Bougainville.

Similar to Wavelock in construction is another nylon reinforced vinyl, Vynaprufe, which is used for heavy duty applications where high tear strength and resistance to



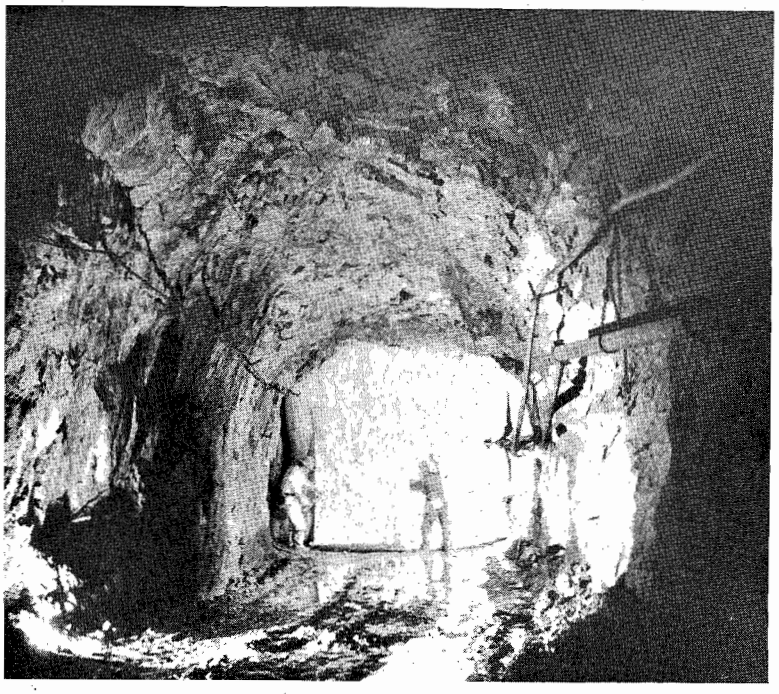
Nylex pressure hose used in test drilling operation.



A 10kw welder with tape dispensor being used at Nylex Fabrication Development Centre to weld reinforced vinyl sheet. A number of grades were used at Bougainville – "Wavelock" for rain-wear and "Vynaprufe" for heavy duty tarpaulins and covers. (Top)

An inflatable ventilation barrier, known as "Mulane", designed to act as an air barrier in mine drives, adits and tunnels. (Centre)

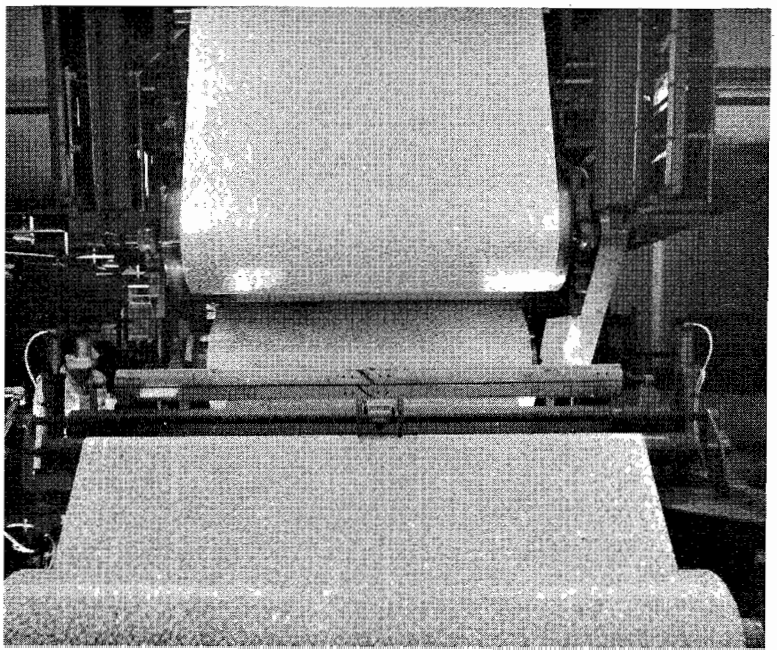
Manufacturing Armstrong–Nylex flooring which was used extensively in housing, offices and public buildings. (Bottom)



rotting and mould are required. An advantage of using this product is that it can be welded, eliminating water penetration through stitched seams, although stitching may be employed where necessary.

A number of grades and qualities of Nylex Vynaprufe are designed to provide optimum protection, depending on the application involved. Its main uses are for tarpaulins and covers, and in addition to wide use on the Bougainville project, Vynaprufe is often used for truck and shipping container tarpaulins. At Bougainville, large reinforced vinyl covers and tarpaulins, some measuring over 53 square metres in area were supplied, complete with fittings.

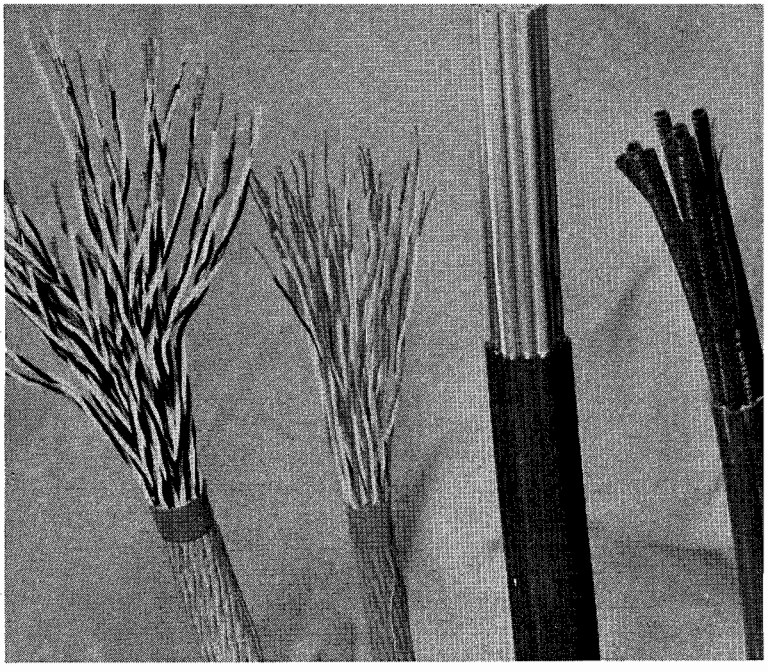
The demand for Vynaprufe covers proved so great that Nylex arranged for manufacture to be carried out by two local fabricators: Arrowel Pty. Ltd. of Lae, and Canvas and Cordage Pty. Ltd. of Rabaul. Apart from the obvious advantage of ready availability, the arrangement provided the added benefit of helping to expand industry in Papua New Guinea. The two fabricators were required to install high frequency welding equipment to join pieces of reinforced vinyl, and the result of this is that both companies have now developed prosperous businesses for the manufacture of all types of vinyl covers, and are employing a considerable number of indigenous staff.



The Bougainville construction programme naturally included the building of houses as well as of mine offices and in all cases extensive use was made of Armstrong Nylex flooring.

In conditions of high humidity it is essential that building components are not affected by moisture or fungus growth and the vinyl flooring does not deteriorate in any way under such conditions. A most servicable and decorative floor covering, it has great durability coupled with resistance to moisture and chemicals, hence its wide use in hospitals and offices as well as for domestic applications. The range of floor coverings supplied includes Excelon vinyl asbestos tiles and Poly-Flor flexible tiles and sheet.

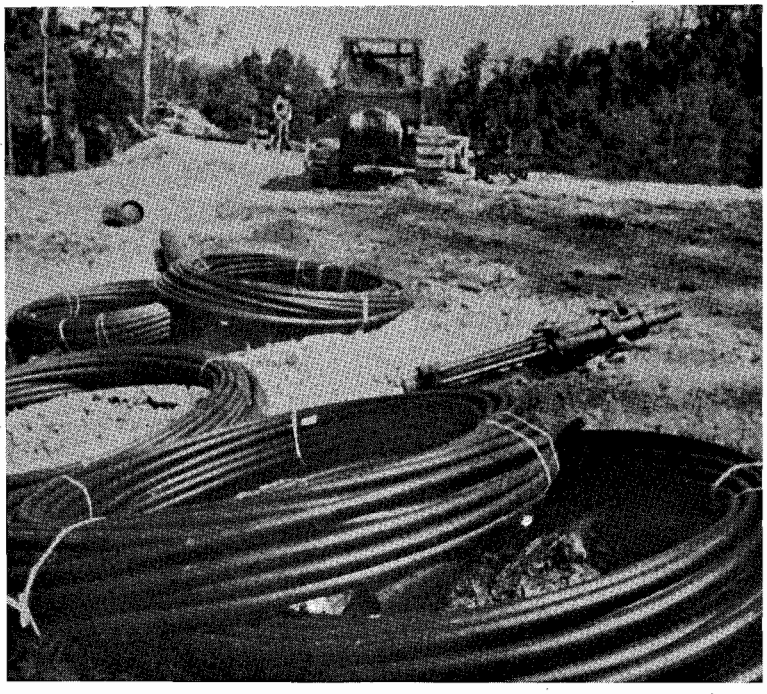
Armstrong-Nylex, supported jointly by the technology of Armstrong-Cork of the U.S.A. and of Nylex, has supplied



Dekoron instrumentation wire and cable, now manufactured under licence by Olex Cables Pty. Ltd., a company formed by a merger between the cables operations of Olympic Consolidated Industries Ltd. and Nylex. The types of Dekoron illustrated are, from left to right, a multi polyethylene tube bundle for instrument air supply, for use in severe corrosive or adverse weather conditions; multi-pair thermocouple extension cable with overall aluminium-mylar screen and copper drain wire; and multi-pair instrumentation cable showing individually screened pairs and overall aluminium-mylar screen, and finned copper drain wire with every screen. (Top)

ACI — Nylex polyethylene pipe used for fast water supply to drilling rigs. (Centre)

Power and Control Cables in ore handling plant. (Bottom)



most of the flooring used in connection with the Bougainville project and continues to supply additional quantities as new houses and facilities are built.

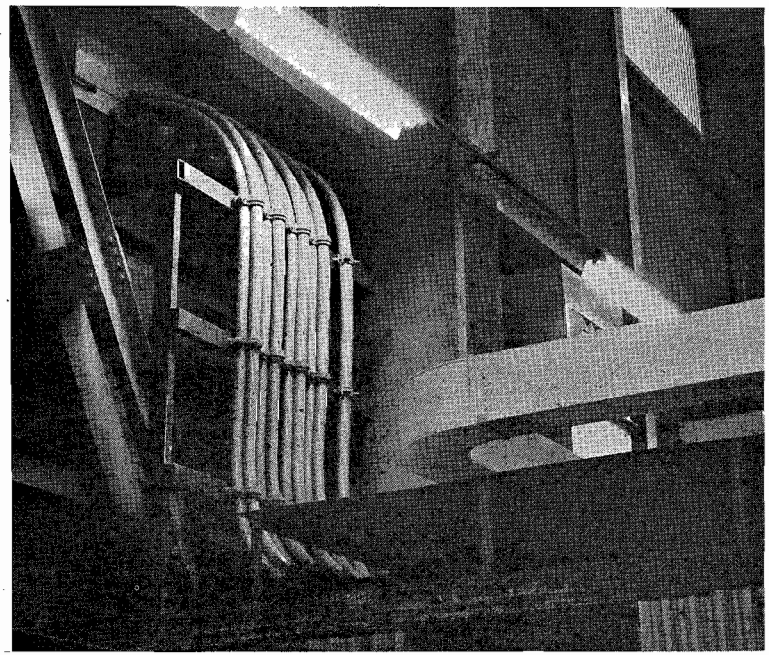
Power is another essential in the Bougainville operation, and accurate and reliable transmission is vital. A number of different types of insulated cables and wires were manufactured and supplied, to custom requirements, by the Lilydale plant of Nylex, before the formation of Olex Cables (the joint venture company owned by Nylex and Olympic Consolidated Industries Limited).

Types of cables range from house wiring to high tension cables and Dekoron, a specialised product used in process instrumentation, and in electronic and computer applications. Dekoron can be supplied as a series of metal or plastic tubes bundled and sheathed for pneumatically controlled instruments, electronic instrument wire and cable or thermocouple extension wire and cable. Dekoron, available in a wide range, from multi-pairs to multi-triads, will economically deliver clean and accurate signals back to the control room and is ideal for any application where external electrostatic noise is a problem. Industrial and process control cables are extensively used in workshops and milling operations at Bougainville, as well as in flotation cells and the power house.

ACI-Nylex supplied a considerable amount of large bore polyethylene pipe, up to 6" in diameter, which was used for water and temporary de-watering services.

A variety of PVC pressure hose was supplied by the General Products Division of Nylex and quantities were used in high pressure air and water supply in the workshops, and for general air tool work. High pressure nylon tubing was supplied for various instrumentation applications and control equipment.

Nylex has been concerned in almost every sector of the Bougainville project from the mining operation and auxiliary services to the welfare of the people working in the area. This is a continuing role demanding a thorough understanding of environmental conditions, and the full use of Nylex's extensive resources in technology, marketing and manufacturing skills.



Communications for Bougainville

LAE/BOUGAINVILLE WIDEBAND TELECOMMUNICATIONS SYSTEM

M.W. Dobbin, A.R.M.I.T., M.I.E. (Aust.), M.I.R.E.E. (Aust.)
Page Communications Engineers Pty. Ltd.

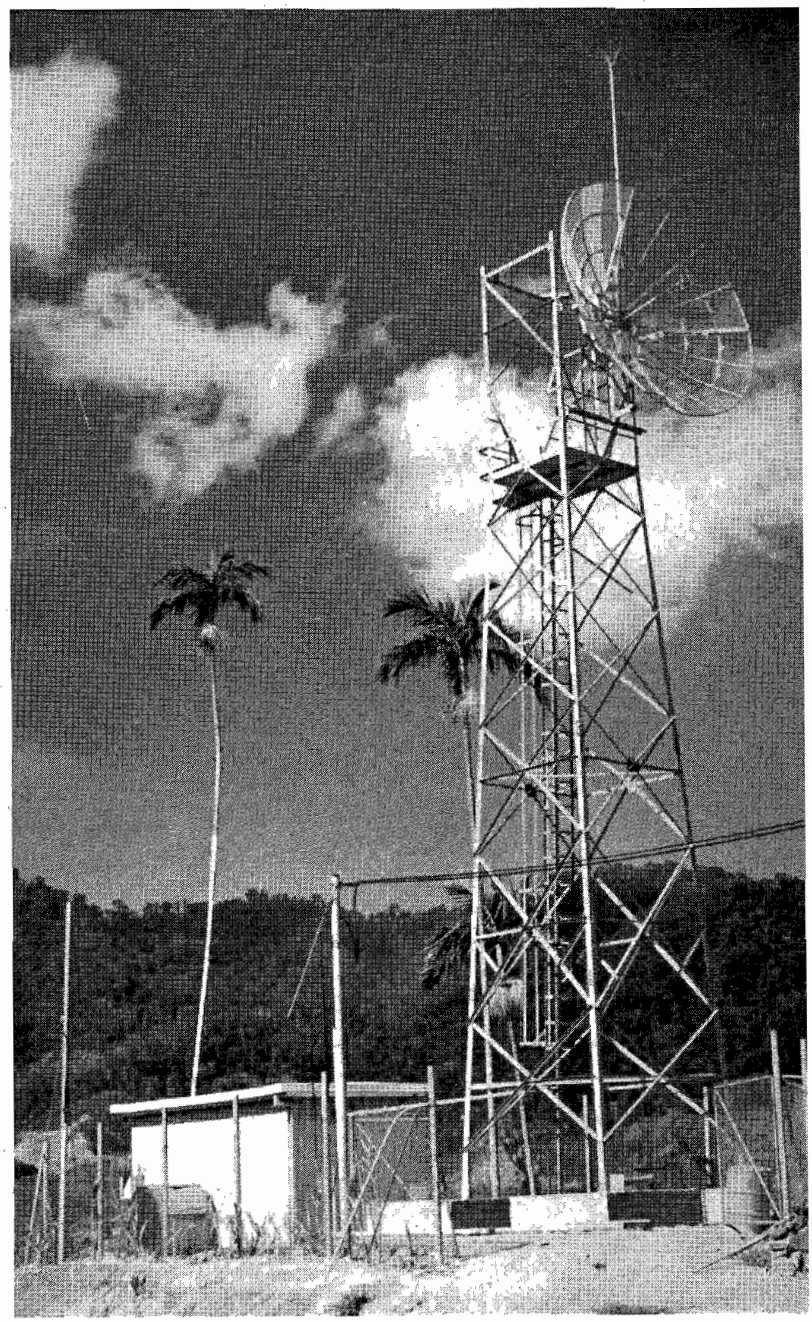


Fig. 1 — Interim communications installation at Road Camp Construction Site.

INTRODUCTION

When CRA Exploration Pty. Ltd. commenced operation on Bougainville there was no internal communication system on the island and the only external link was a temporary HF link from Kieta to Rabaul available for limited times during certain days.

A project of the magnitude contemplated by CRA required a completely integrated communication system between its centres of operation on the island and telex and voice communication to the international communication system. A decision was made by the Posts and Telegraphs Department to install a high quality tropo scatter-microwave system to cover internal communication on Bougainville and to connect Bougainville into the international communication system via the SEACOM cable at Madang.

As this sytem was not planned to be operational until the first half of 1971, it was necessary for Bougainville Copper to install an interim communication system to cover the project construction requirements.

On 25th October 1969 a contract was awarded to PAGE Communications Engineers Pty. Ltd. for the design, supply, installation and commissioning of an Interim Communication System for Bougainville.

The system consisted of three automatic telephone exchanges interconnected by a multi-channel radio bearer trunking network linked to the long haul HF network operated by the Department of Posts and Telegraphs. The system offered all the advantages of crossbar switching and provided automatic dial exchange service among major locations within the mining complex, terminating at an international exchange.

The interim system was commissioned by PAGE during May 1970. However, during January 1970, the contract for the Lae – Bougainville Broadband System was also awarded to PAGE, the scope of this contract far exceeded that of the Interim Communication System. A total of 145 men were employed by PAGE during 1970-71 in the construction phase of the project. The system was finally accepted by the Posts and Telegraphs during August 1971.

PAGE Communications was also involved in a third construction program on Bougainville, this being the installation for BCP of permanent telephone reticulation on the island. All of the construction programs involved some form of continuing maintenance requirement and thus, although PAGE first arrived on the island during 1969, PAGE still has employees on the island today, assisting in the maintenance of the permanent communications network.

LAE-BOUGAINVILLE WIDEBAND TELECOMMUNICATION SYSTEM

Of all the construction programs the Lae-Bougainville Wideband Telecommunications System was the most demanding in terms of both design and implementation. This can best be understood by considering the geography of the system. Between Lae and Bougainville are a total of 715 radio route miles; 539 miles of that total comprising water span tropospheric scatter links, the remainder LOS microwave. The system installed is among the most technically sophisticated in the world and yet it is located in one of the most primitive and inaccessible areas on earth.

The bearer-multiplex system design permits a maximum capacity of 120 voice channels throughout the system, except for one span between Rabaul and Bougainville which supports a maximum capacity of 60 voice channels. The transmission performance and interface characteristics of the system, fully comply with the applicable recommendations of the C.C.I.R. for international grade service. The system is fully automatic, designed for continuous service without operating attendants. The radio bearer, multiplex and power generation system at all terminals and repeater sites are continuously monitored by an automatic fault detection and alarm system which provides a read-out of the operational status of all major active components, including power plant, at Lae Tomavatur, and at Arawa, for Bougainville sites only.

The fault detection and alarm system is essential to the concept of automatic unattended operation since the overall system reliability is a function of both mean-time-between-failure (MTBF) and mean-time-to-repair (MTTR). All sub-systems common to one or more 12-channel groups are at least 100% redundant to maximise MTBF; the MTTR is minimised by employment of the automatic fault detection system to provide timely advice of major component failure.

Another measure to improve reliability and minimise maintenance requirements was taken during the system design; wherever a trade off was feasible to exchange prime power consumption for other parameters, this exchange was performed to the maximum extent. Thus the electrical configuration of many links is characterized by unusually large antenna, and very low transmitter power output levels, resulting in an all-solid state electronic configuration of the radio bearer, except for the single long span between Rabaul and Bougainville, and the absolute minimum power plant size.

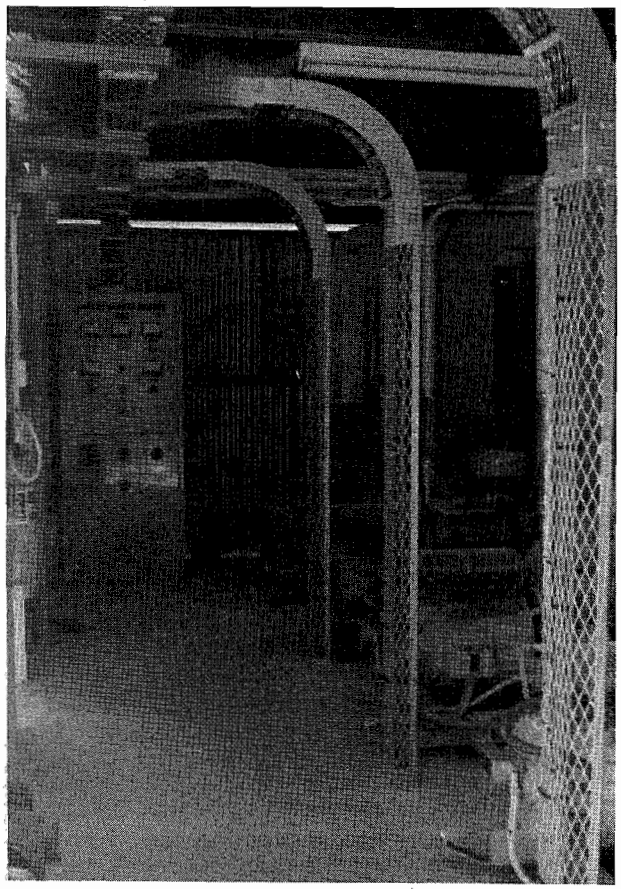


Fig 2. Power generators of typical Repeater Station, including Auto Control Cubicle.

Except for the AC prime power supplies for the Tomavatur-Torokina plants the power subsystem design utilises a generator or ac mains-rectifier plant to charge or float charge storage batteries; this design approach also maximises system availability through the intrinsic "no break" feature of battery power supplies and buys valuable time while repairs can be accomplished on defective prime-movers or the ac mains source.

Bearer Route and Geography

The 715 mile route of the microwave radio bearer required 10 repeaters and seven terminal stations located between the westernmost terminal at Lae and the easternmost terminals at Arawa, Panguna and Kieta (see Fig. 2). Seven of the ten repeaters are active baseband repeaters and require

power, supporting systems and shelters; the remaining three are passive devices consisting of back-to-back parabolic-reflector antenna (Kieta-Anewa) or plane reflectors (Arawa to Panguna and Arawa to Torokina). The terminal stations at Lae, Kimbe, Tomavatur, Arawa, Anewa, Kieta and Panguna are readily accessible and present no unusual or difficult logistic support requirements, however, the repeaters are without exception located in isolated remote terrain which in some cases are extremely difficult of access.

Equipment Configuration

Although each site imposed specific requirements on the configuration of individual stations, all were built around a common basic equipment type, generally differing from station to station only in the number or arrangement of major components.

Radio Bearer Plant

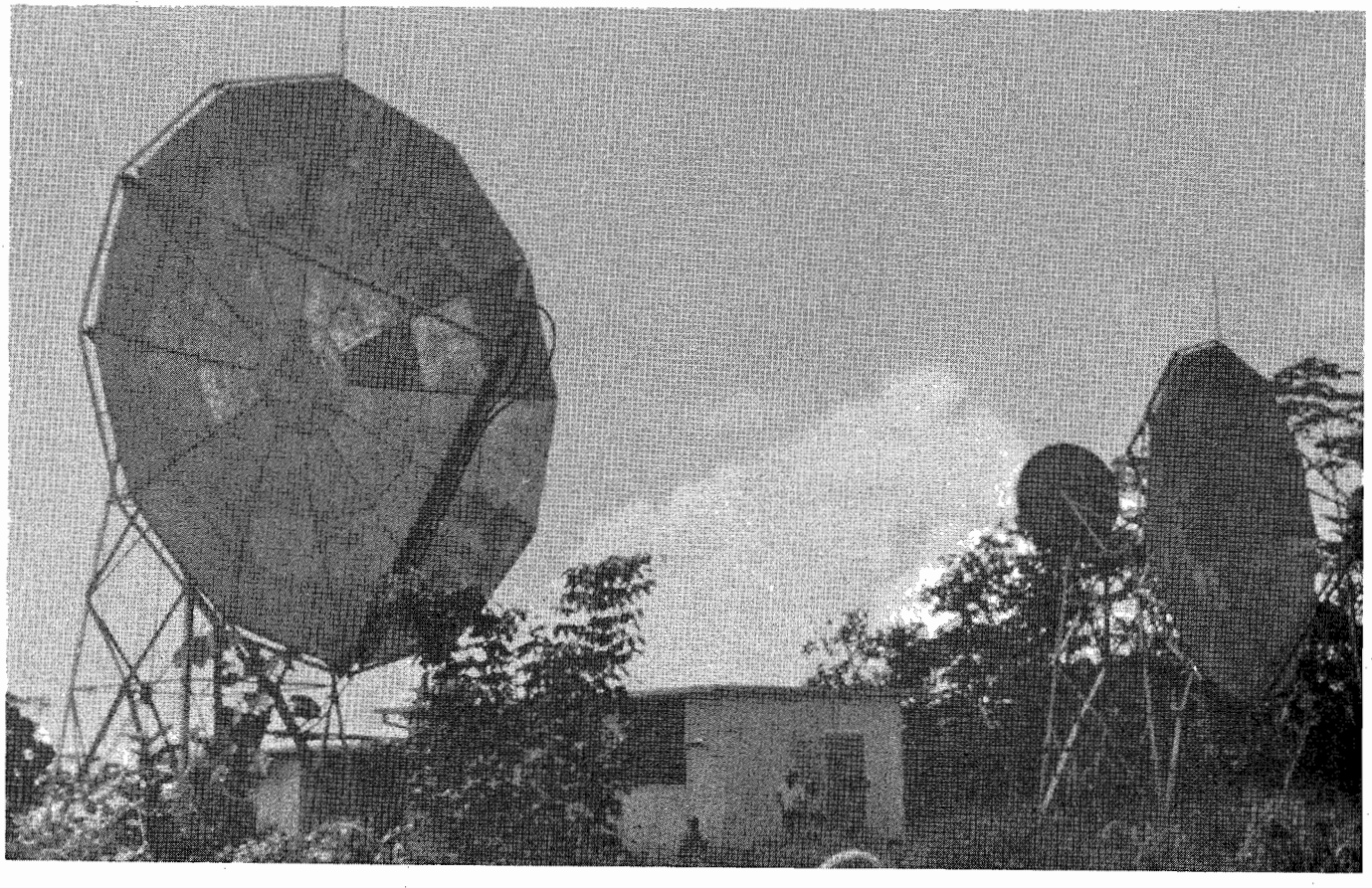
The radio bearer equipment throughout the system is capable of a maximum capacity of 300 voice channels and in fact although the ultimate capacity of the system is 120 channels all equipments for line of sight links were supplied, installed and adjusted for 300 channel operation to minimise the complexity of maintenance instructions and procedures.

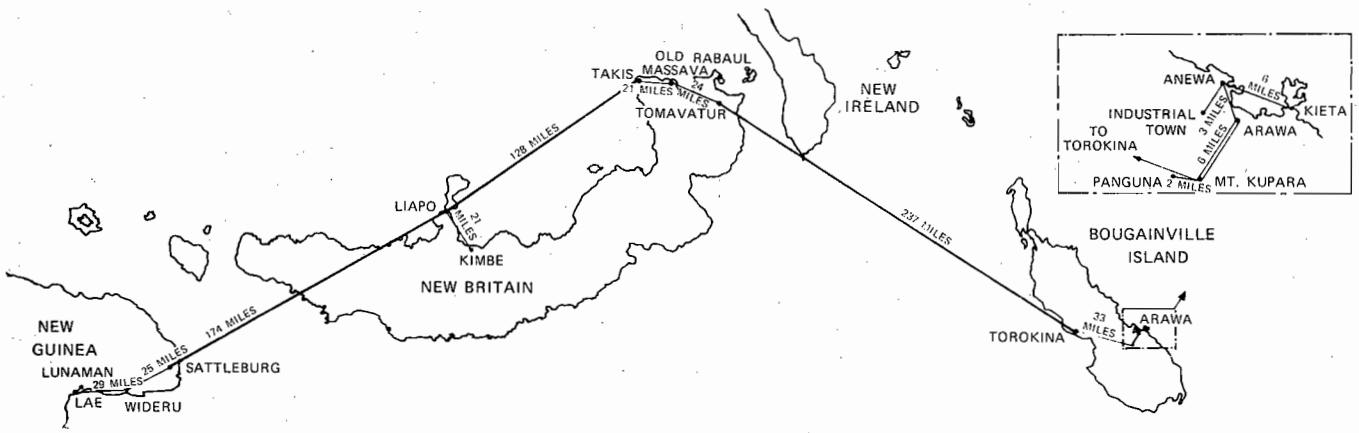
A number of modifications are made to this basic terminal for troposcatter spans. Tropospheric scatter links, are in general limited in maximum capacity by the propogation mechanism itself. Because the maximum design capacity of the Sattelburg-Liapo-Takis tropospheric scatter links is 120 channels, and since the RF carrier fading on tropo links generally prohibits the high threshold associated with 300 channels' I.F. filters, a number of internal modifications to the basic 300 channel LOS terminal are necessary. As the tropospheric scatter links are operated in quadruple diversity, the combiner shelf is modified by operating two dual combiners with a common constant current generator source. Some sites also required additional external transmit RF power amplification to enable the design parameters to be met.

Traffic Multiplex Plant

The multiplex equipment for trunk traffic service is located at Lae, Liapo, Kimbe, Tomovatur, Arawa, Anewa, Kieta and Panguna. The multiplex plan utilises CCIR Super-group 1 for Lae-Tomavatur (Rabaul) traffic Supergroup 2 for Kimbe-Tomavatur (Rabaul) traffic and Supergroup 1A for Tomavatur-Bougainville traffic. Supergroup 1A equipment relocates the fifth (top) group of Supergroup 1 to a position just below the first (bottom) group of Supergroup 1, i.e., to the baseband spectrum 12-60KHz; this transposition of one group is often necessary (or at least highly desirable) due to the rapid deterioration of performance of some tropospheric scatter link configurations with increasing top baseband modulating frequency. That is, the design configuration of a tropospheric scatter bearer is often critically dependent upon the maximum baseband modulating frequency (due to frequency-selective fading), and the Tomavatur-Torokina link would require the next larger nominal antenna size (60 ft.) to handle CCIR Supergroup 1. The other, short configurations of tropospheric

Fig. 3 — Takis — tropospheric scatter/LOS repeater.





Location	Installation
Lae	Exchange
Wideru	Repeater
Sattelburg	Transhorizon repeater (Vic Finschhafen)
Liapo	Transhorizon junction station (Vic Talasea)
Kimbe	Terminal & Exchange

Location	Installation
Takis	Transhorizon repeater (Gazelle Peninsula West)
Old Massava	Repeater (Gazelle Peninsula North Coast)
Tomavatur	Transhorizon Repeater (Gazelle Peninsula East Coast)
Torokina	Transhorizon Repeater (West Bougainville)
Rabaul	Terminal & Exchange

Location	Installation
Panguna	Terminal & Exchange
Anewa Bay	Terminal & Exchange
Mount Kupara	Plane Reflector
Arawa	Terminal & Exchange
Kieta	Passive Repeater
Kieta	Terminal & Exchange

Fig. 4 — The 715 mile route of the micro-wave radio bearer.

scatter bearers (Sattelburg-Liapo-Takis) happen not to be profoundly affected by top baseband modulating frequency, and therefore are configured for Supergroups 1 and 2.

The Power Plants

The greatest variation in equipment configurations among the thirteen active sites appears in the power plants; this variation is necessary to accommodate the rather substantial dissimilarities in power requirements, accessibility, and logistics of fuel delivery among the sites. At all sites, storage batteries are employed to provide a "no-break" operating power reserve for all equipment loads (except

Fig. 5 — Tomavatur — terminal station for Rabaul.

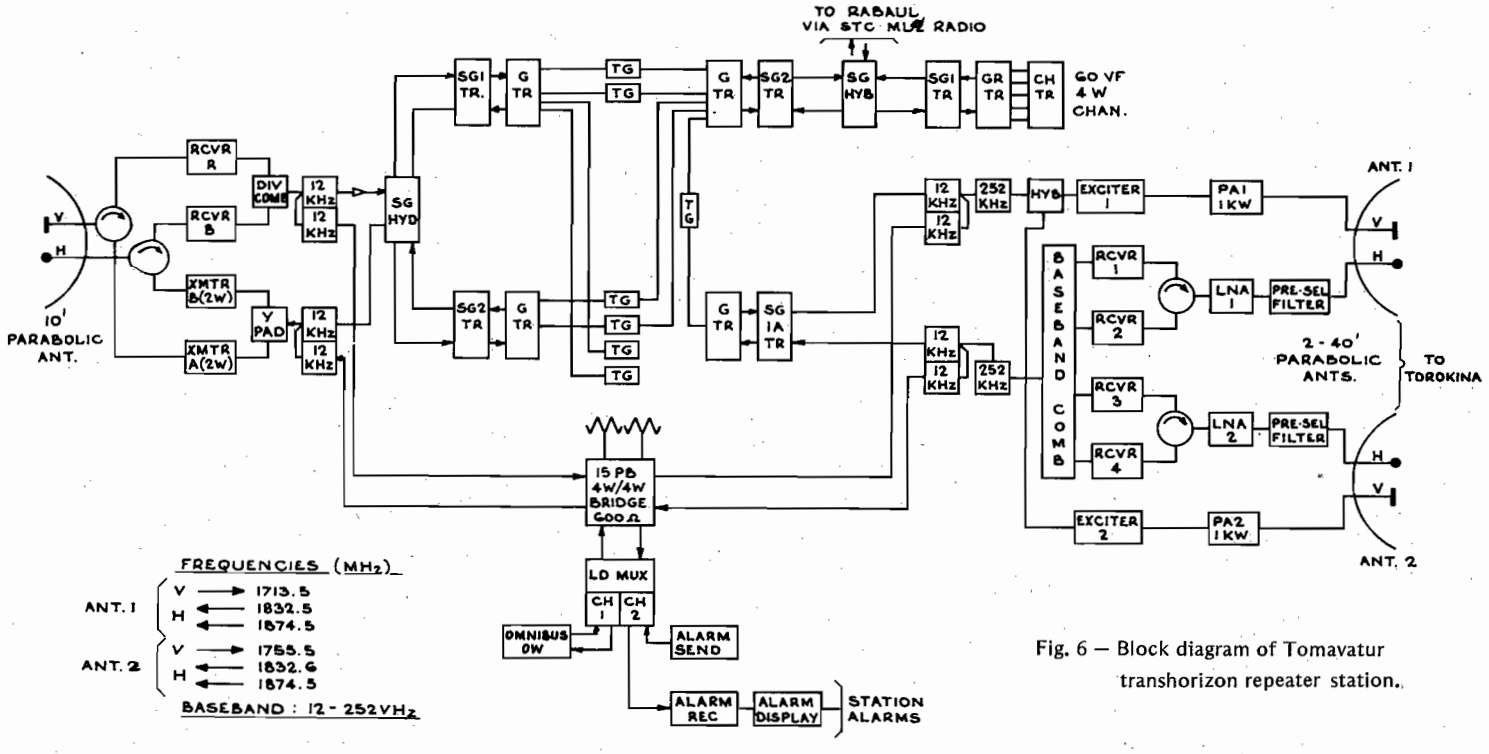


Fig. 6 — Block diagram of Tomavatur transhorizon repeater station.

the klystron high power amplifiers at Tomavatur and Torokina which require direct connection to a.c. mains). Rectifier suites are employed at nine of the sites to charge the batteries and supply the d.c. load; these rectifier suites are fed by a.c. mains at seven sites, and by engine-alternator sets at two others. At the remaining four sites, engine-generator sets are employed for direct supply of the d.c. load and battery charging.

The power plant configurations of Sattelburg and Torokina represent the most general case, at which all of the components described above are employed; certain of these components are omitted at the other sites, as indicated in Fig. 7. At Sattelburg and Torokina, engine-alternator sets supply prime a.c. power to the connected a.c. load and to a rectifier suite; the rectifier suite is used to charge the station batteries and supply the a.c. load. At Lae, Kimbe, Toma-

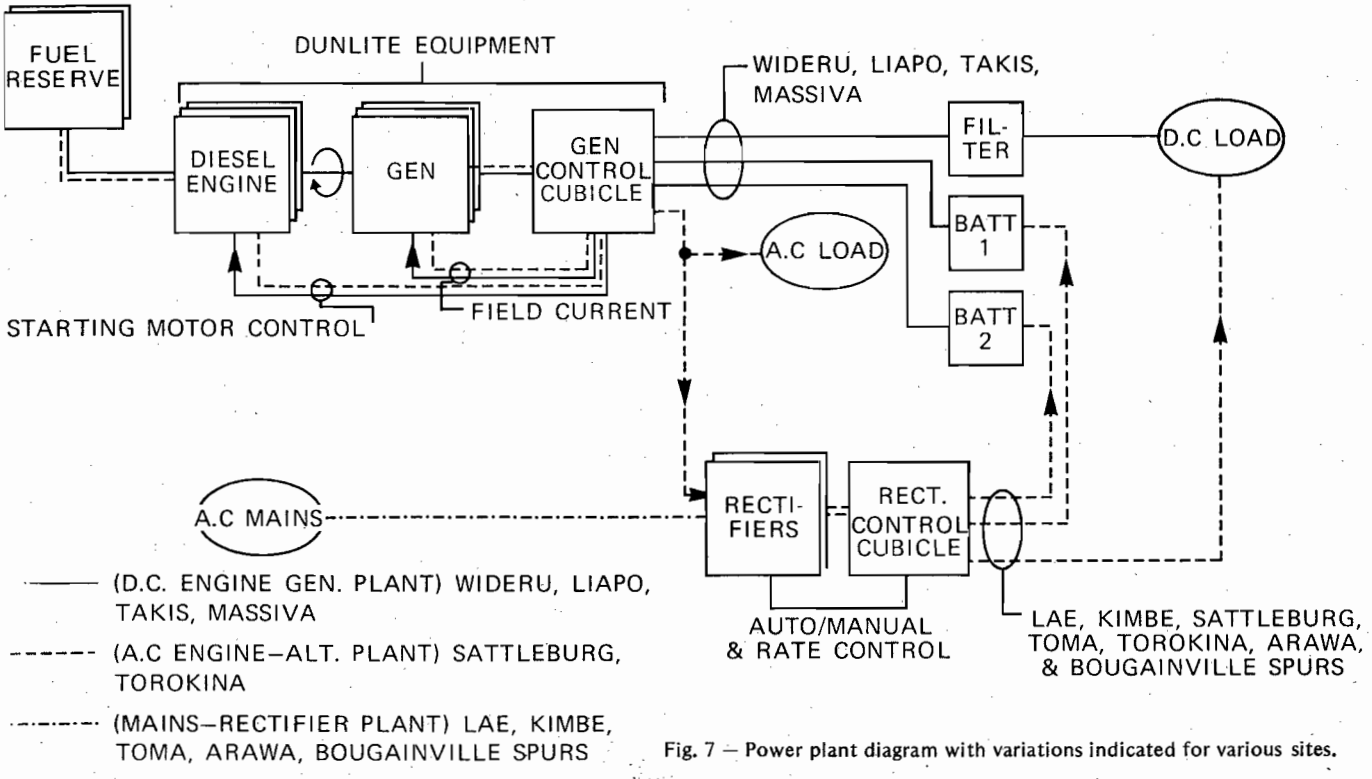


Fig. 7 — Power plant diagram with variations indicated for various sites.

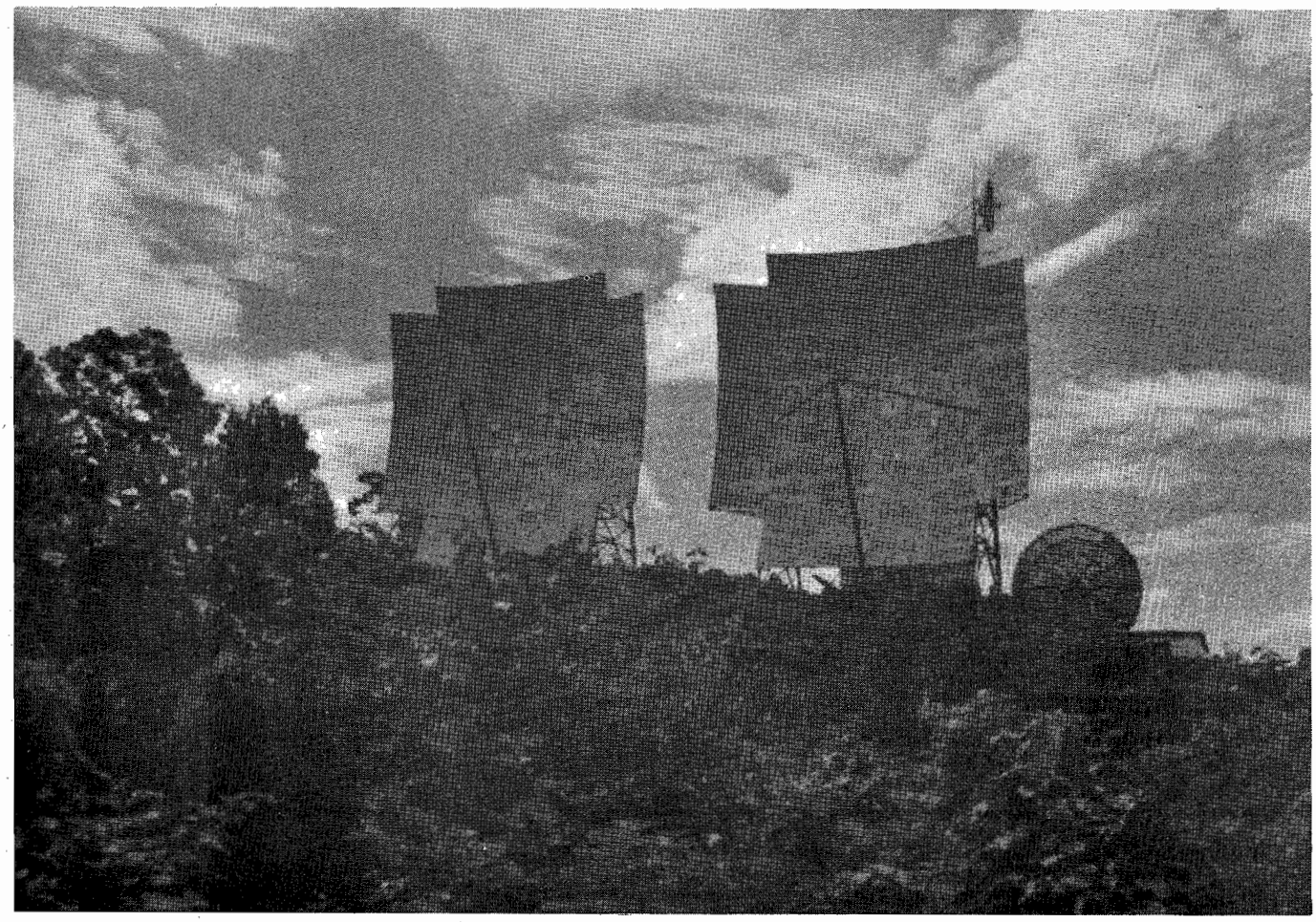


Fig. 8 — Liapo — tropospheric scatter repeater with LOS spur to Kimbe.

vatur. Arawa and the Bougainville spur stations, the engine-alternator sets are omitted and prime power is obtained from a.c. mains. At Wideru, Liapo, Takis, and Massava the rectifier suites are eliminated and engine-generator sets are directly connected to the batteries and d.c. load.

All power plants in the system are thus built up of two or more of the following basic components:

(a) storage battery sets
(b) d.c. line filters
(c) rectifier suites
(d) engine-generator or engine-alternator sets
(e) fuel storage facilities

The configuration employed was selected to provide a source of power optimised to the unique electrical, physical, and logistical requirements of each site.

Remote Supervisory Alarm System

A remote fault detection system is included in the Lae-Bougainville broadband system to transmit alarm conditions sensed at radio stations to the maintenance centres. The alarm system provides early warning of system failures and also a means of identifying specific equipments in alarm condition, prior to maintenance visits to unattended stations.

Each radio station on the system is equipped with a 28-channel sender. These 28 channels are allocated in accordance with the requirements of the particular radio station in which it is situated, e.g. Wideru has 19 alarms allocated, while Liapo has 28 alarms allocated (being the maximum available). At the applicable maintenance centres a 28-channel receiver is installed for each station to be received; each receiver is mounted with its associated display panel to key display lamps for each of these channels carrying alarms.

Typical alarms for each station cover all contributing plant on site including radio receivers, transmitters, power amplifiers, multiplex common alarms, battery voltage, engine or rectifier interlock control, diesel-engine control, and fuel systems. The specific alarms for each station are listed elsewhere and are engraved on each keyed alarm display lamp at the receiving terminals.

The equipment installed is of 28-channel capacity and future allocation of alarm channels, as may be required from time to time, requires only radio station wiring additions, i.e., the running of a single pair of suitably filtered wires for each alarm, which, when shorted, will produce a keyed lamp display at the maintenance centre.

To satisfy the maintenance requirements of the overall system, all the stations from Lae to Torokina have their alarms displayed at Lae and also at Tomavatur. Only the stations on Bougainville Island are displayed at the Arawa Maintenance Centre.

Mobile Communications

MOBILE COMMUNICATIONS VITAL FOR BOUGAINVILLE VENTURE

G.C.K. West, Commercial Manager.

Philips Telecommunications Manufacturing Co. Ltd.,
Melbourne. Australia.

Back in 1967 there were no proper roads in Bougainville, only rough tracks through the jungle, so moving about was difficult, unless you went by helicopter. Everything was just beginning.

If it had not been for the helicopter, Philips Telecommunications of Australia Limited, would not have been able to carry out the task entrusted to it by C.R.A. Exploration Pty. Ltd. The task was to survey the proposed operational area to ascertain the requirements for a radio communication system, which was to cover the entire mining operation, including Panguna through to the coast, and give limited and temporary telephone access to the outside world.

Initially the communication system was to serve the needs of the exploration team. It was to provide them with normal telephone facilities (over the radio) between Barapenang and Kieta and thence via HF (High frequency) radio to Rabaul and thence into the Posts and Telegraphs network.

The mobile radio system was to provide communication to vehicles and base camps for control, supervision and safety, and also to give vehicle to vehicle communication.

From the modest interim needs of both the exploration and construction phases, the system changed and expanded until, at the time of going to press, it comprised nearly 400 VHF mobile 2-way radio installations and 6 talk-through-repeater stations on 6 separate channels. The system now caters for the needs of the many operations of the company including administration, mining, fire, ambulance, medical, security, rescue, civil engineering, electric power distribution, ship-to-shore communication and also independant contractors.

From the May 1967 survey it was evident that, to ensure good communication to areas on both sides of the Crown Prince Range, it would be necessary to install VHF (Very high frequency) talk-through-repeater-stations at an elevated site which would command a good "radio view" of the operational areas.

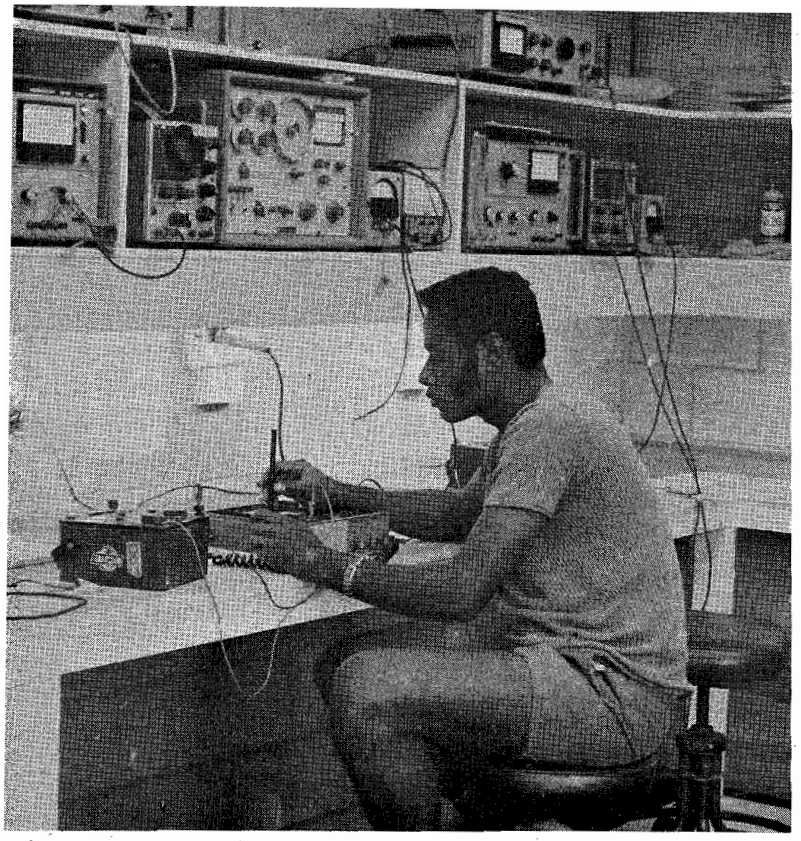
Though not directly accessible by road, Pakia Gap was the site finally chosen for best coverage. Access was possible by helicopter and materials could also be carried in by personnel on foot. A helipad was provided.

Other factors considered included the form of housing required for the equipment, the antenna supporting structures and antennas.

Because all equipment was to be battery powered it was necessary to ascertain the best method of charging the batteries. Solar generators, wind generators, thermo-electric generators and diesels were all considered. For reasons of economy and practicability of fuel supply, a diesel driven 240 volt A.C. generator was selected for the task. It was to be installed below Pakia Gap near the road, and the 240 volt A.C. power transmitted by cable to the equipment hut. This would provide bench lighting, power for test equipment and be converted to 12 volts D.C. by means of a regulated battery charger.

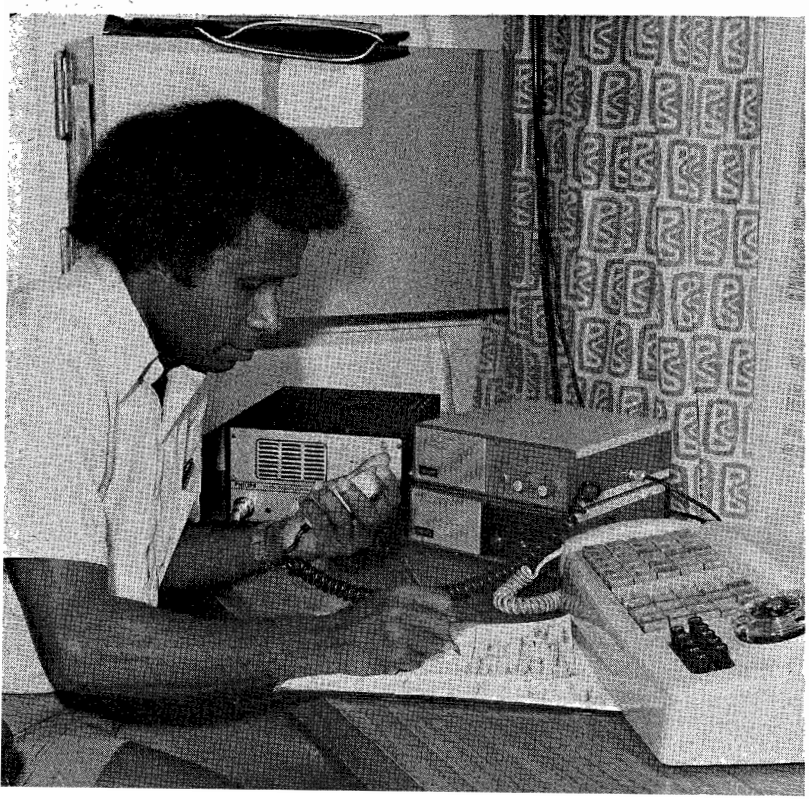
As a result of the survey and subsequent system design, which was provided by Philips Telecommunications, C.R.A. Exploration Pty. Ltd., ordered a communication system, in 1968, which was to provide for basic needs.

Shortly after the system was installed a teleprinter system was also added to the circuit to provide full communication facilities to the outside world.



Indigenous technicians are being trained by Philips personnel to maintain the various communication equipments.

One of the many radio control points. This office maintains communication between headquarters and the company's helicopter and aircraft.



It was soon realised that the temporary link now established between the mining project and the outside world, needed to be duplicated to provide backup against communication failures and also, to expand communication to the various projects now being undertaken in the area. Thus, during 1969, the communications expanded from the simple voice link from Barapenang to Kieta – Kobuan, to a number of installations which provided links into the Post and Telegraphs radio telephone system and teleprinter facilities. Other simplex systems were provided for communication to scattered project sites, and to mobile units travelling on the original road between Barapenang and the coast, and also to the airport. To this was later added a maritime communication system for harbour and lighter operations, and later still communication to the Company's aircraft.

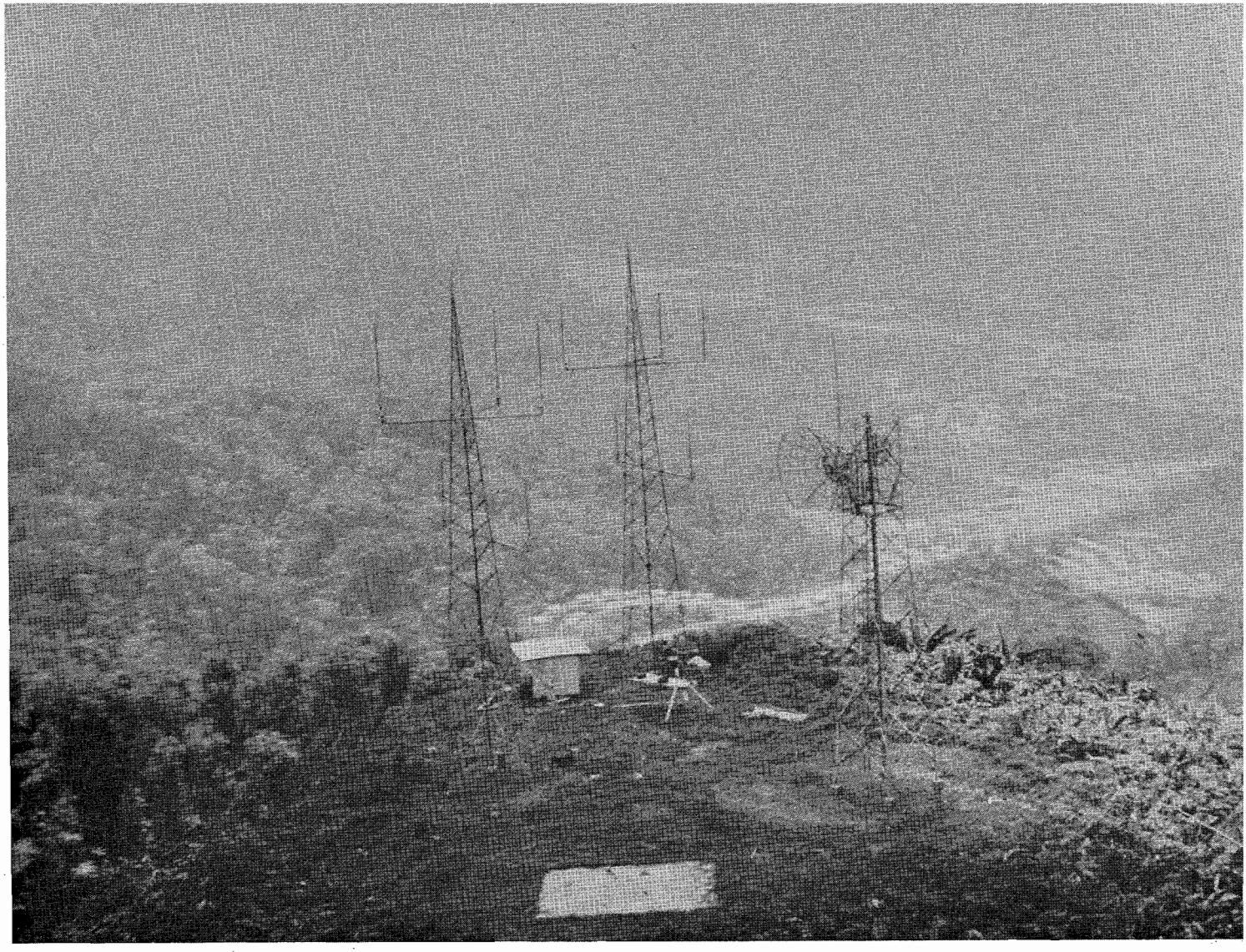
This entailed the siting of new base stations at Anewa Bay, and a site on the Jaba River at Daranai, which provided communication to the west coast of Bougainville.

By this time the system had grown to considerable proportions and being the only communications available, was of the utmost importance to the entire mining operation. During the initial 6 months of its growth, Anewa township depended on a single VHF radio telephone link to provide all telephone communications into the general telephone circuit. The equipment has proven itself time and time again for reliability, in fact when cyclones in the area have completely disrupted the internal telephone network the VHF communication system has been the only method of communication available.

Equipment reliability was such that there was insufficient work to keep a technician fully occupied, however, discussions between the companies resulted in Philips providing a resident maintenance technician to provide service, not only for the communication system, but also for other electronic equipment being used on the project.

At the time of publication there is still a Philips technician on site. However, in line with company policy indigenous personnel are being trained in the maintenance of the equipment, and have shown considerable aptitude in that direction.

With the eventual installation of permanent telephone networks for the Post and Telegraphs Department, part of the interim telephone communications provided by the VHF system became redundant but some of the communication facilities were retained as a backup in case of an emergency.



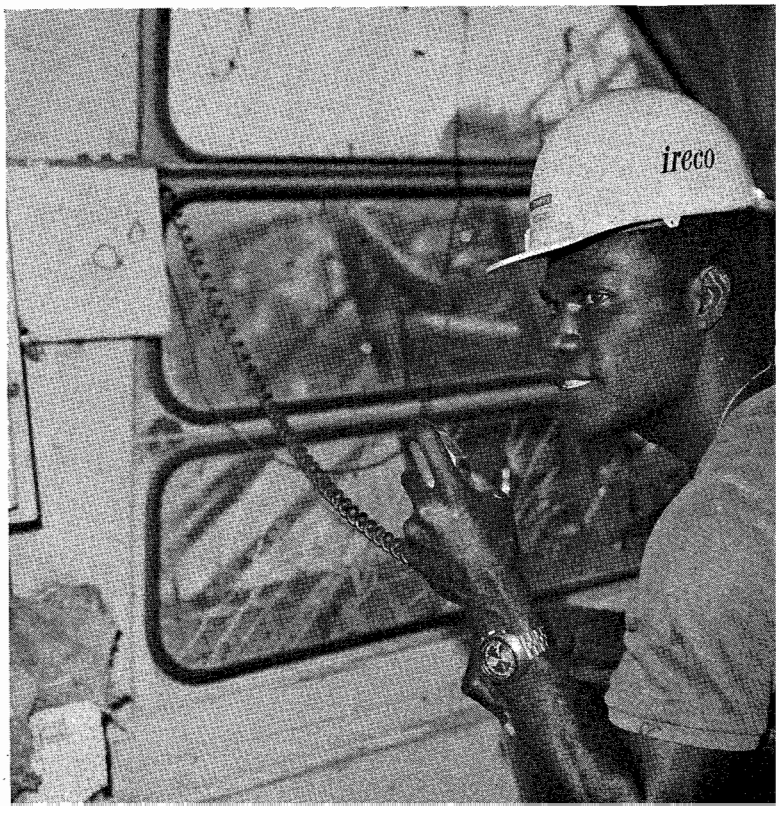
An aerial view of the Pakia Gap equipment building which houses five VHF talk-through repeaters. The transmitting and receiving aerials are mounted separately on towers either side of the building. Panguna can be seen in the distance. The tower on the right is a passive repeater for UHF telephone circuits and is not associated with the mobile radio network.

All the equipment supplied for the communication system was designed and made in Australia at the Philips plants in South Australia, and later at Clayton in Victoria. System design and overall co-ordination and the development and manufacture of special apparatus was by the Special Projects Division of Philips Telecommunications of Australia, and later by Philips Telecommunications Manufacturing Company Limited.

The present VHF system used in the Bougainville mining project has expanded to provide communication for sub-contractors and suppliers to the project such as catering, vehicle tyre services, building contractors, civil engineering, the electricity commission, and the Panguna Police Department.

The number of mobile units is now nearing 400. Although the character of the communication requirements have changed somewhat since the early development days, the present Philips VHF mobile radio communication network is more than ever a vital tool in the overall mining complex.

Philips VHF 2-way radio units have been installed on all manner of vehicles and earth moving equipments. This operator is using a unit installed on a Bucyrus Erie mobile electric drill.



Crossbar Telephone Systems

PABX SYSTEM AT BOUGAINVILLE

L M Ericsson Pty. Ltd.,
Melbourne. Australia.

The three automatic telephone exchanges which formed an integral part of the Interim Telecommunications System specified for the project were designed, manufactured and supplied by L M Ericsson Pty. Ltd. of Melbourne.

The exchanges were required to service and to interconnect three central offices, one each serving the mine site, the road camp and the port site.

Interconnection supplied by others was by means of a multi-channel radio bearer trunking network linked to the Department of Posts & Telegraphs HF radio network.

All incoming and outgoing calls connecting to the public network at Kieta, which were intended for or originated from any extension at any of the three offices were to be handled by operators at the Port site. There were to be no operators in attendance at Road Camp or Mine Site.

Automatic dial access was required to the operators at Port site by any extension at any of the three offices. Automatic dialling extension to extension calls was also required, irrespective of whether the extensions were connected to a common exchange or located at different exchanges.

The proposed capacities were as follows:—

	Port Site	Road Camp	Mine Site
Extension Lines (initial)	110	60	180
" " extendable to	180	90	270
Internal connections	14	6	14
Connections to Port Site		4	8
" " Road Camp	4		4
" " Mine Site	8	4	
Operator Positions	2		

Transportable shelters for accommodating the equipment on site were to be provided and each exchange was to be installed in the shelters at the factory and pre-tested before shipment.

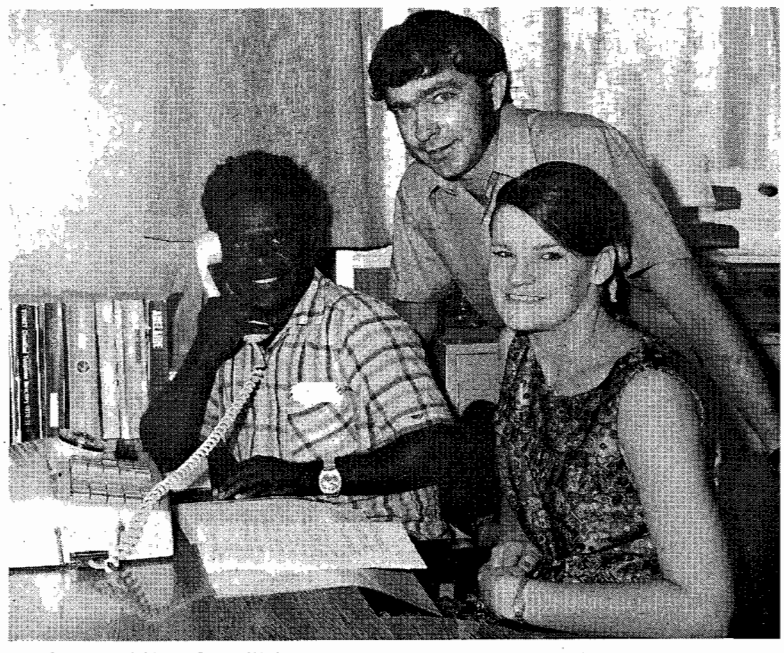
Following a detailed study and evaluation of the technical specifications it was decided that the equipment to be supplied should be basically the ARD 561 Crossbar PABX system which offered various advantages.

The crossbar switches, relays and components were the same as those used in the L M Ericsson main exchange equipment adopted by the Australian Post Office in 1959 as standard for the development and automation of the Australian Telephone Network.

Several hundred of these systems were already in operation throughout Australia and Papua New Guinea, and had developed a reputation for outstanding reliability.

Various sophisticated facilities available with the ARD 561 but not required for the interim system could be effectively and economically designed out through appropriate modifications. At the same time, the modifications did not preclude the provision of fully integrated PABX facilities at some future date with the minimum of inconvenience when permanent PABX systems might be required.

The design of the system permitting relay sets to be plugged into pre-wired racks would greatly facilitate pre-delivery testing at the factory, final installation and testing on site, as well as future expansion.



Raymond Utep from Wakunai and Shirley Beatson at BCP's Loloho exchange. Standing is Communications Supervisor, Neville Dipell.

The transportable buildings (shelters) in which the equipment was to be housed were, of course, subject to quite stringent specifications in respect of vibration free construction, dust control, lighting, ventilation, tropic proofing etc., etc.

Here again, the Company had some years of experience in the provision of buildings for various types of transportable exchanges forming an integral part of telephone networks in both Australia and Papua New Guinea and were able to comply with the requirements at short notice.

For the more technically-minded, the following extract is taken from the original specification for the Port Site (Anewa Bay) exchange:—

The automatic switching equipment shall provide the following essential facilities:

Initial installed capacity for inter-connecting ninety lines with expansion capability to an ultimate of 180 lines without disturbing the original unit.

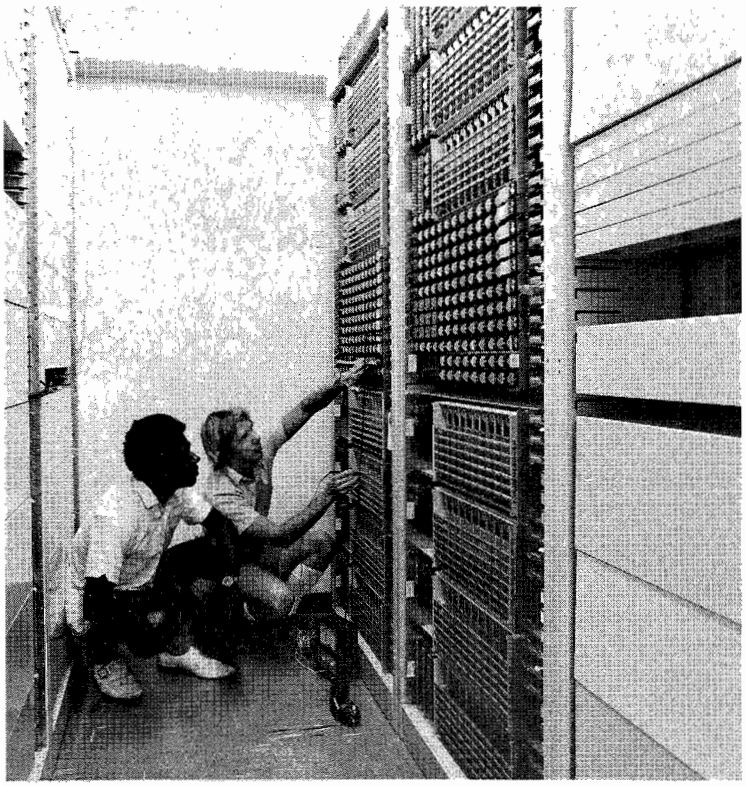
Initial provision for at least ten simultaneous internal calls (links) and at least twenty simultaneous external calls (exchange lines). The equipment shall be safeguarded against the possibility that exchange lines are switched together.

Extension to extension calls dialled directly.

Extension calls to extensions in other two exchange via exchange lines to be dialled directly.

Extension to operator dialled directly.

Any two extensions shall be able to communicate without the possibility of being overheard, or interfered with by a third extension.



The automatic exchange equipment at Bougainville.

Dial tone shall be provided to indicate switching equipment is ready to receive dial pulses. Dial tone shall be a 360 hz to 440 hz continuous voltage. The tone level measured across a 600 ohm resistive termination on any telephone circuit shall be within the limits of –18 dbm minimum and –15 maximum.

Access to any extension already in use shall be prevented automatically and when attempted, a busy tone of 360 hz to 440 hz interrupted 335 milliseconds to 415 milliseconds on and 335–415 milliseconds off shall be transmitted automatically to the extension making the attempt. The level of the busy tone measured across a 600 ohm resistive termination on any telephone circuit shall be between –9 dbm minimum and –6 maximum.

Ringing of extension bell shall be controlled automatically from the switching equipment, avoiding necessity for a ringing key, button, or handle at any telephone. Ringing shall be cut off from called line immediately upon removal of handset at the called extension. Ringing current shall be between 15 and 27.5 hz interrupted with the periodicity of 360 to 440 milliseconds on and 1.8 to 2.2 seconds off. Full load output ringing voltage shall not rise above 100 volts.

Ringing of bell at called extension shall be indicated to extension calling by a distinctive audible tone of 360 hz to 440 hz interrupted in accordance with the ringing current supply specified in 4.129 above. The level of the ring tone measured across a 600 ohm resistive termination on any telephone circuit shall be within the limits of –9 dbm minimum and –6 dbm maximum.

Only a single pair of wires shall be required between each extension and the switching equipment. The switching equipment shall operate satisfactorily with extension lines having a loop resistance of 1000 ohms maximum, including the telephone set.

"Talking" battery shall be furnished from the switching equipment. Local battery-type telephone instruments shall not be required.

First party release shall control the switch train so that either party is free as soon as his receiver is replaced.

Equipment shall operate satisfactorily when used with dials having a speed of operation varying over a range of 8 to 12 impulses per second with a make/break ratio between 33/67 and 50/50.

Equipment shall operate on 48 volt nominal direct current over an approximate range of 44 to 56 volts.

Terminal blocks shall be furnished for connection to all external circuits.

Provision to intercept by the attendant all calls placed to non-existant or unassigned directory numbers.

An Operator's Manual Assistance Position shall be furnished to operate with the Switching Equipment but shall be located in a separate room. It shall consist of a two-position switchboard and be capable of allowing an operator to perform all functions normally associated with manual assistance including the following:

Receive and distribute to any extension at any of the three central offices all incoming calls from the public exchange at Kieta. It shall not be possible for the operator to connect an exchange line to a call in progress.

Place all outgoing calls from any extension at any of the three central offices to the public exchange at Kieta with the ability to either hold, or subsequently revert, to the originating extension while the call is put through. A test key or some other means shall be provided to allow the operator to select an exchange line not in use so as not to interrupt those in use. Call automatically will clear when extension finishes call. Ringing equipment to signal the public exchange shall be provided.

Two information circuits to allow operator access to and from all extensions connected to any of the three central offices.

Automatic operator recall to indicate to the operator that the required extension has not answered within 30 to 45 seconds.

Alarm Facilities shall be provided to warn of selected malfunctions in the switching equipment. Alarms shall be classified as urgent, non-urgent or supervisory.

The following equipment conditions shall operate an alarm classified as urgent:

(i) Operation of any fuse, circuit breaker, heat coil or any other electrical protective device.
(ii) Failure of the ring and tone supply to any part of the equipment when no further alternative supply is available.
(iii) Low voltage or failure of the battery supply to the equipment.
(iv) Low voltage or failure of the rectifier except where the cause of the condition is due only to an interruption to the electricity supply mains.
(v) A switching magnet continuously energised, with the exception of those magnets which are guaranteed by the manufacturer to be self-protecting against electrical overload.
(vi) Failure of a subsidiary power supply to the equipment.
(vii) Failure of the alarm circuitry.

The following equipment conditions shall operate an alarm classified as non-urgent:

(i) Interruption to the electricity supply mains feeding to the equipment.
(ii) Ring and tone source automatic change-over to alternative supply.

A supervisory alarm shall be operated when any abnormal condition of an extension line, tie line, or exchange line causes the automatic switching equipment to be held for a period from one to three minutes or when line lock-out occurs.
Urgent alarms shall be reset to normal only by manual operations of the control. Non-urgent and supervisory alarms shall be self-restoring. Urgent alarms shall light a red lamp and sound a bell or buzzer. Non-urgent and supervisory alarms shall light appropriate warning lights.

Maintenance Facilities shall provide adequate access and connection facilities for the individual testing of all relay sets and integral circuits without the need to remove covers from the equipment. Each exchange circuit shall have a break type jack in the exchange line path for testing back into the switching equipment. Each traffic carrying circuit shall be provided with the following facilities:

(i) Access Jack
(ii) Occupation Lamp
(iii) A make busy key or control

Designations – All equipment shall be adequately designated to permit ease of operation and guidance for service activities. The designations shall provide contrast with equipment surfaces and be of sufficient size to be legible.

Main Distribution Frame – Distributing frame or frames shall be of sufficient capacity to accommodate all wire interconnections expected for ultimate expansion of the system.
It shall be possible to test all lines and trunks from the distributing frame.
Carbon gap arrestors and heat coils shall be used to protect all external metallic circuits.

Power Plant and Common Services – A complete power plant suitable for the operation of the ultimate capacity of all telecommunications equipment shall be supplied as part of the central office.

Mains voltage will be 220 volt AC $\pm$ 10%, single phase, 50 hz $\pm$ 2 hz. 415 volt AC $\pm$ 10%, three phase, 50 hz $\pm$ 2 hz will also be available.

Nominal operating voltage shall be 48 volts DC.

A regulated, smoothed, full wave rectifier of all solid-state construction shall be supplied as the DC power source. Output capacity shall be sufficient to provide adequate power under peak traffic conditions. The rectifier plant shall be suitable for battery charging and float duty.

A battery shall be furnished, designed to last a minimum of five years of float service life and shall have a discharge capacity sufficient to operate the central office for ten hours.

The battery shall be mounted in such a manner that it will not endanger personnel and with sufficient surrounding air space to prevent the accumulation and concentration of battery gases.

Battery and charger control switches, DC voltmeter, DC ammeter, fuses or circuit breakers and supervisory circuits shall be provided as necessary.

Rectifier output noise when measured with a suitable measuring set under rated load conditions shall not exceed 28 dba, FIA weighted.

The rectifier shall be designed so that neither rectifier or central office equipment shall be subject to damage in case the load circuit is opened for any value of load within normal limits.

Ring and tone generator equipment shall be supplied with adequate standby equipment which will automatically be placed in operation upon failure of regular equipment. If mains power is used as the primary power source for this equipment, provision shall be made for continuity of service during power failures. Electronic equipment shall be solid-state.

A positive busbar connected to the positive terminal of the battery and positive terminal of the rectifier shall be connected to the telecommunications earth on the main distribution frame. The telecommunications earth shall not be connected to an earth connection to be used by any other electrical source.

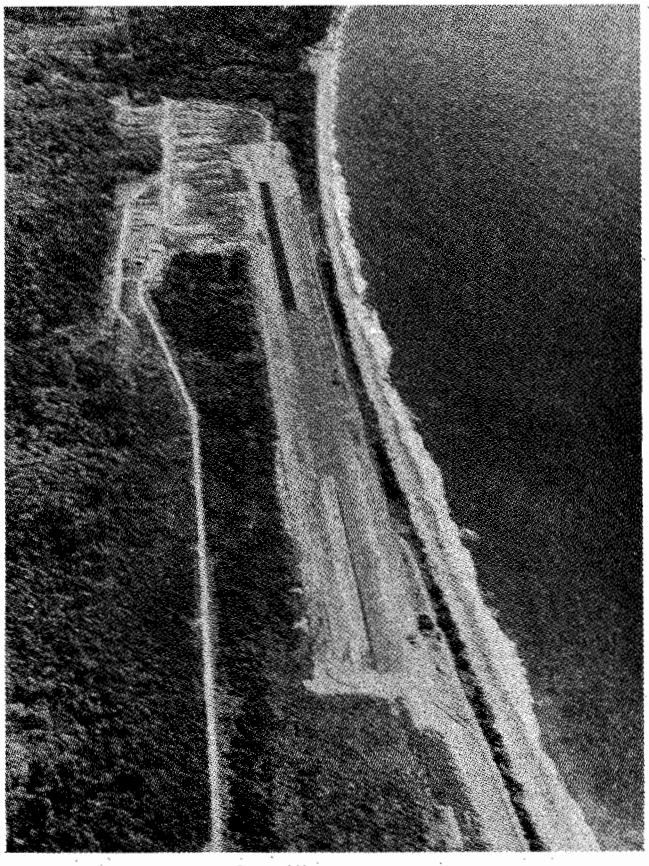
A power distribution panel consisting of battery and distribution fuses, appropriately alarmed shall be provided.

Power equipment and wiring shall comply with Australian Standard CC1, SAA Wiring Rules.

The Head Office and chief manufacturing plant of L M Ericsson Pty. Ltd. is located at Broadmeadows, Victoria. The company, which has a substantial Australian equity, is a member of the world-wide Ericsson group which was formed by Lars Magnus Ericsson in the year the telephone was invented.

In Australia, where the company has played a major role in the development of communications, it manufactures automatic crossbar switching equipment for rural telephone exchanges, city telephone exchanges, trunk exchanges, telex exchanges, private exchanges and other products of the telecommunications field.

The Role of Aircraft



Aropa airstrip, 14 miles from Kieta

TAA AND THE BOUGAINVILLE COPPER PROJECT

Communication or the lack of it has been one of the main problems associated with the establishment of the Bougainville Copper project. To TAA, solving communication problems is part of its business, so it was natural that the airline should become involved with the project and help to make it one of the most exciting and successful technological undertakings of the decade.

The completion of the 16-mile road to Panguna showed an imaginative and adventurous use of engineering and scientific expertise. The thousands of tons of heavy equipment, vehicles, complex machinery and technical equipment transported by ship from all over the world to Bougainville was an object lesson in co-ordination. And by air came the personnel; the hundreds of qualified engineers, geologists, scientists, surveyors, architects and a host of experienced workmen from America, Australia, New Zealand and Papua New Guinea, to build Panguna and start it producing copper. Also by air came the supplies of perishable foods, mail and the urgently required machine parts arriving in all shapes and sizes.

TAA was the only regular air link with Bougainville up to 1968 when Ansett Airlines started operating into Bougainville. TAA had taken over the original Qantas services and flew one DC3 a week to the island. The airline did not have its own office but was represented by the Kieta Trading Company in Kieta.

At the end of the Pacific war in 1945 there was only one operational airfield in Bougainville suitable for DC3's – this was at Torokina – away from most centres of population on the south-west coast. However, it was used for several years by Qantas as a stopping and refuelling place on its British Solomon Islands service.

Then came the "great" days of the flying boats – first Catalinas and later Sunderlands. The service ran from Rabaul to Buka Passage, Inus, Kieta and Buin.

Pressure brought a slow development of airstrips and eventually the flying boat services gave way to DC3's into Aropa airstrip, south of Kieta.

Until CRA moved into Bougainville and turned it into a major world mining project TAA was flying a handful of passengers into Aropa once a week. Its DC3 flew from Rabaul on Sunday and arrived at Kieta via Buka. Two years later the airline was flying hundreds of people a week into Aropa on 20 regular flights. In 1966 there were only about 60 CRA personnel on Bougainville and by the end of the decade Panguna was a new and thriving mining town of more than 2000 expatriate Europeans and several hundred indigenes from throughout Papua New Guinea.

Together BCP and TAA provided the potential for Bougainvilleans to learn new skills and add new dimensions to their way of life; helping to prepare them for an important place in the future independence of Papua New Guinea.

Although there were three airstrips on Bougainville before BCP arrived – Wakunai, Kieta and Buin, Kieta was to be the focus of attention as it was closer to the mine site and the projected BCP port at Anewa Bay.

By early 1969 the potential of the Panguna operations began to have an impact on airline services to Bougainville and by the end of that year TAA had seven DC3's a week flying from Rabaul to Kieta, four special DC3's from Rabaul and one Fokker Friendship from Port Moresby to Buka with a DC3 connection to Kieta.

Early in 1970 an extension to the Aropa airstrip was undertaken by the Department of Civil Aviation to allow Fokker Friendships to fly direct from Port Moresby to Kieta, so busy had the BCP traffic become.

The work on the strip lasted about eight weeks and meant a serious restriction to Kieta air services. It meant the DC3 could not operate until the work was finished. However, TAA got over the problem by flying all passengers and cargo to Buka and then using the Twin Otter aircraft into Kieta. This short take-off and land aircraft has proved invaluable

A TAA Twin Otter on a grass landing strip in Papua New Guinea.

in many parts of Papua New Guina and on the Australian mainland.

The upgrading of the Aropa strip meant a rapid acceleration of BCP personnel travelling to Bougainville to work at Panguna, Anewa Bay and Arawa. The entire copra plantation at Arawa had been bought to provide space for the new township and tall waving palms still bow gently among the prefabricated houses.

BCP estimated that between November 1969 and July 1970 about 5,500 staff flew into Bougainville.

With limited and infrequent shipping service in the early stages the carriage of all types of goods by air into Kieta from Rabaul and Port Moresby played a very significant part in the development of the project. TAA Friendships and freighters flew in almost daily supplies of perishable foods, mail, urgently needed machinery spares, equipment of all types to supplement the project supplies arriving by sea. Two pure cargo flights operated each week between Port Moresby and Kieta.

The TAA flights connected directly at Port Moresby with flights from the mainland and so provided a virtual overnight service from Australian capital cities to meet the many emergencies which occurred during construction, and the initial stages of the operation. About 120 tons of air cargo were flown in during 1970, which by air cargo standards, is a big uplift.

In 1969 it was estimated by Bechtel-WKE, the construction managers, that 20,000 pounds of cargo a week was coming into Kieta, largely by Bechtel-WKE chartered boats. Naturally the majority of project supplies continued to arrive by ship but by January 1970 there were 15–20,000 pounds of cargo being flown into Kieta a month by TAA.

Towards the end of 1970 Aropa was a tremendously busy airstrip for its size and isolated location. Both in passengers and cargo the port of Kieta kept appearing on the top of TAA's performance charts.

In that year TAA had 20 regular passenger flights each week to Bougainville. Eight Fokker Friendships flew to Buka direct from Port Moresby or via Lae or Rabaul, seven DC3's flew Rabaul/Buka/Kieta and three special DC3's a week flew between Buka and Kieta. And these aircraft were being fully utilised, for the airline was operating them with an astonishing 85 per cent load factor into Bougainville as a whole, and 94 per cent into Kieta.

In 1971 the demand for air travel from BCP staff in Kieta was so great that in March TAA established a one-man office at the Panguna mine site. This office turned out to be a huge portable packing case and was used to write out thousands of domestic and international tickets before TAA established an office in Kieta in November 1971.

From October 1971 to May 1972 TAA had its busiest period to date when it won a contract to fly out the thousands of expatriates and indigenes who had been working on the various construction jobs – the wharf, roads, power station, living quarters and recreational facilities. To the local TAA staff this was known as the "big Exodus" when tickets were written for 3,000 expatriates and more than 4,500 indigenes.

BCP and TAA had worked together for many weeks to ensure as little disruption as possible to working schedules and to try and fly the returning contract workers home as quickly and conveniently as possible. They left Kieta over the space of seven months on their way to Australia, New Zealand, North America and all parts of Papua New Guinea.

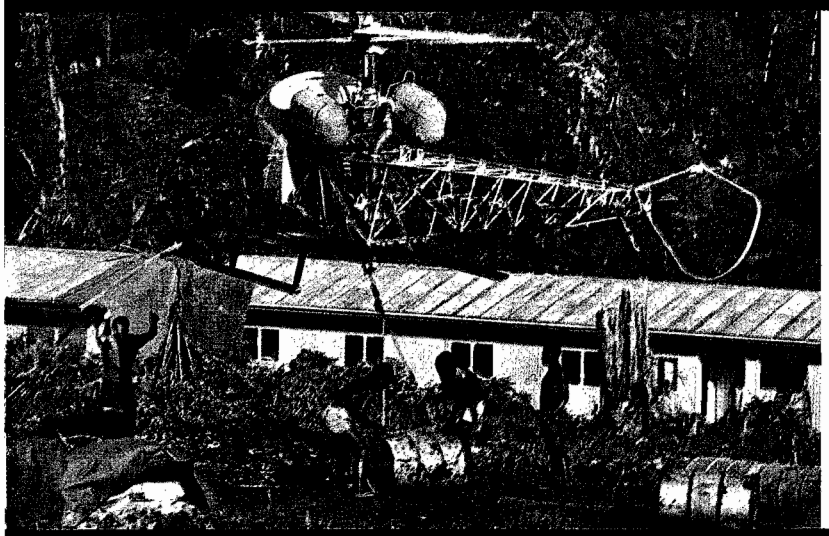
Aircraft returning to Bougainville over this period brought other BCP staff who became permanent workers at the copper production plant.

In April 1972 Bougainville Copper started piping slurry to its port at Anewa Bay at the rate of 90,000 tons a day. By this time TAA had built a new air-conditioned office next to its last agent in Kieta – Breckwoldt and Co. Kieta had established itself as a fully fledged TAA port with cargo handling, international travel and traffic facilities.

Today, the pace of the Bougainville copper project has stabilised with the construction projects completed and the copper production underway. TAA services to the island have also stabilised to ten flights a week – six Rabaul–Kieta and four Fokker Friendship flights direct from Port Moresby to Kieta. The project is not only ensuring a constant stream of technical personnel to Kieta but this year, for the first time, certain North American tour agents are making Kieta a stopover on their Pacific tour programmes.

Air travellers to Bougainville in 1973 will find an island flourishing with activity. The Bougainville Copper Project has made an indelible mark upon the island in a way which has given an impetus to employment and cultural and economic development. And this is a development of which TAA is proud to be a shareholder and a major contributor.

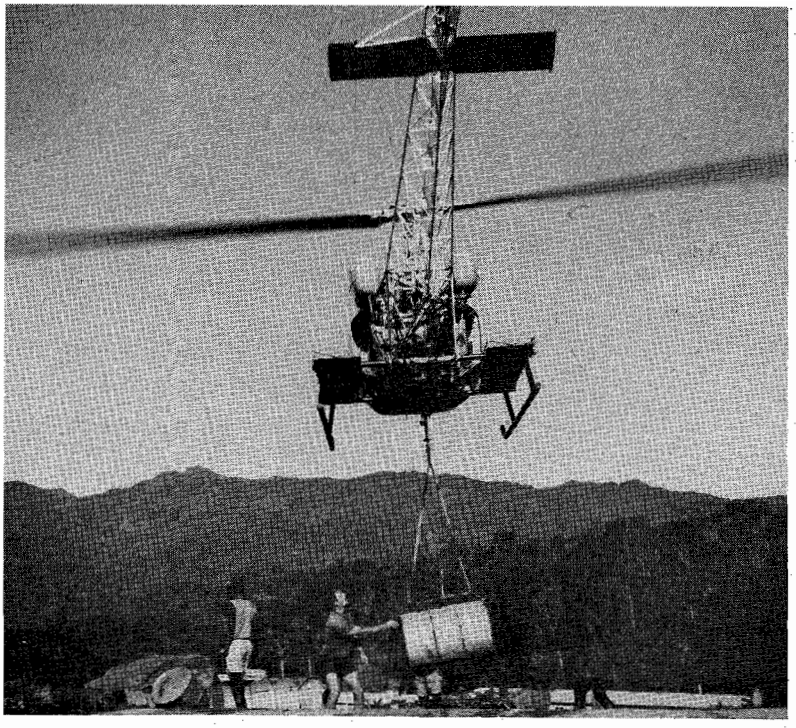
One of the most versatile airline aircraft in the world today is the Quick Change (QC) Fokker Friendship. TAA has six of these aircraft which fulfill a dual role with the airline. The QC Friendship can be operated either as a passenger aircraft or as a freighter whichever is needed in the circumstances. As a passenger aircraft its seats are mounted in groups on six separate aluminium bases or pallets which are locked down over a roller system in the cabin floor. When conversion is required the seats are rolled out and stored leaving an empty cabin. The aircraft can carry more than 5 tons of cargo, which is placed inside containers then rolled in through a big door at the front of the aircraft. The containers have aluminium pallet bases of the same dimensions as those on which seats are mounted. It's simply a matter of rolling out seats, floor and all, and rolling in cargo, complete with its own floor.

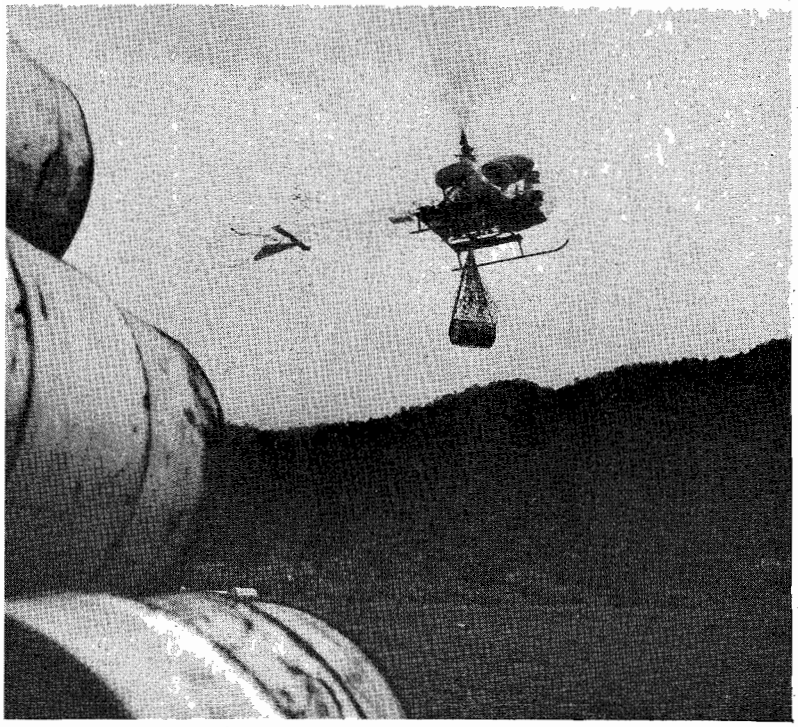


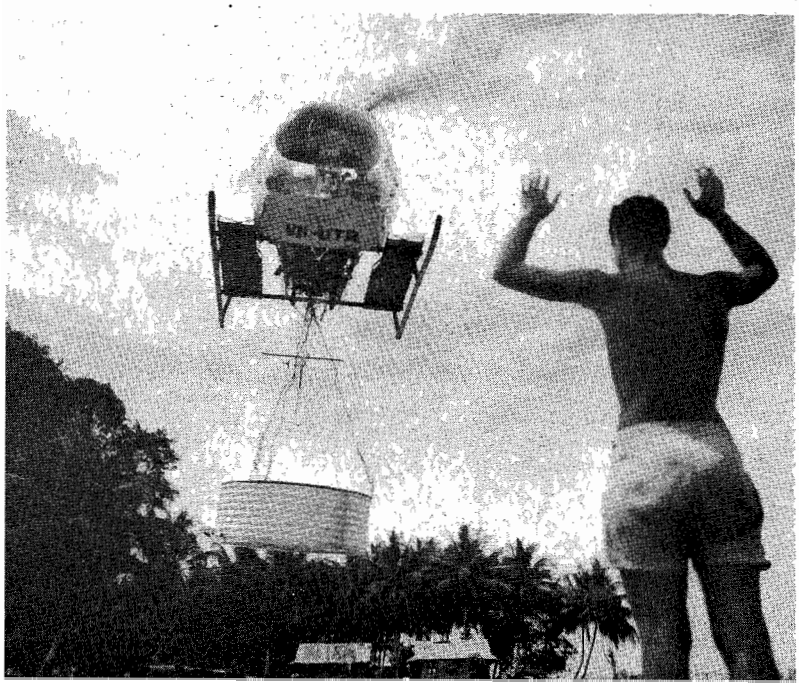
Transporting equipment and supplies to the Panguna area, by helicopter (left) and by trucks along a temporary track was a continuing priority for effective planning.

Airfast Helicopter Utilities Pty. Ltd.
All States of Australia, P.N.G. and South Pacific.
Member Company of Airfast Services Group.

Above: Airfast Bell Helicopter 47G3B1 resupplying a camp on Bougainville.







Helicopters at Bougainville

Helicopter operations in Bougainville have been a classical example of the way in which helicopters help in mineral projects from the exploration stage through feasibility studies to production.

Inaccessibility to interesting areas made exploration difficult. First the geologists moved through the mountainous terrain exploring on foot. Then they got a motorbike to get along the tracks and progress speeded up. From the time the first helicopter arrived in 1963 things began to move fast.

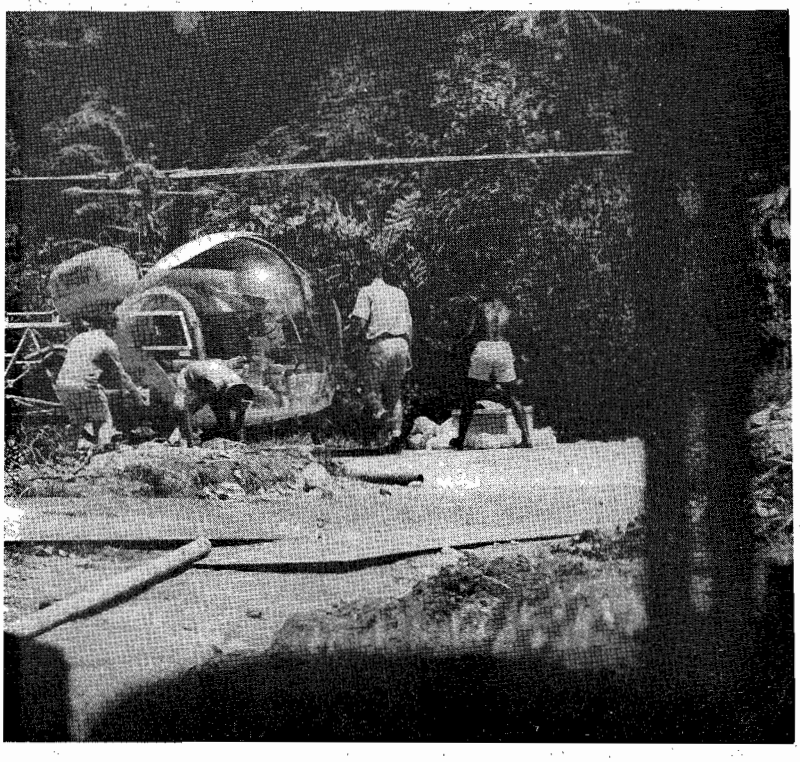
Geologists' time was used for exploration, not for walking. Radius of action increased. It was at last possible to get a bird's eye view of outcrops and anticlines in the valleys, to mount a systematic programme, and to bring back a sizable load of samples. Then to return quickly with precision to an interesting area, and to move light drilling equipment in and the cores out. When the chief arrived for a look, the helicopter was there to fly him into the camp and to get him away again, without wasting his time climbing mountains.

As exploration progressed, geologists used the helicopter to prospect in many directions. Fresh food delivery meant a daily run from Kieta. The volcanologist had to visit the slopes of Mount Bagana. Surveyors needed transport to survey points.

The prospect looked promising but there was a lot to do. Heavier drills were needed for evaluation. These had to be flown in and moved about. This meant larger helicopter capacity. The helicopter type that had been used for the first few years was the Bell 47G-3B-1 with 270 HP turbo-supercharged piston engine and seating for pilot and two passengers. This is the most universal type of helicopter used in Australia and throughout the world for geological exploration.

The cargo was carried on cargo litters or slung from the quick release hook, but load was limited to about 600 pounds.

For heavier loads, a Sikorsky S58 with about two-ton capacity was brought in. Airfast Helicopter Utilities' staff had used the type before in Papua to move oil rigs in sections and assemble them on site. The Company also operates twin-engined Sikorsky S58T's in various parts of the world. The S58's work was to be mainly conveying heavy items between Kieta and Panguna and then moving the drill from point to point. A hangar for helicopter stores and maintenance was erected on the coast not far from the wharf, where the equipment could be uplifted and flown nine miles over the ridge to the drill site. Later on a ten seat turbine-engined Bell 204 replaced the S58. The smaller Bell 3B1 was retained for the lighter duties of commuting and support.



Helicopter Utilities Pty. Ltd. helicopters performed a multiplicity of duties through the exploration and construction phases of the Bougainville Project. Here, illustrated, are typical assignments.

There was still no road to Panguna but if feasibility studies were to be made in depth, a road was needed to get crushers and graders on to the site, and to keep the work going when weather interrupted flying. Although it subsequently proved the reverse when the weather interrupted the road traffic!

Possible routes to the East and West Coasts were explored by helicopter, maps made and soil and rock structure analysed. Sub-contractors used the helicopter to assess the size of the job. Until a temporary access road was completed in 1967, the helicopter supplied entire requirements of the geologists and surveyors and camp crews for four years and flew out all the data.

Improvements were needed in radio communications. The Company's helicopters had been used for some time in Papua New Guinea to site and service the Post and Telegraph microwave repeater stations on mountains across the country. Similar work was carried out for BCP's sub-contractors on Bougainville, and again time was saved by providing ready accessibility.

The exercise shows how the helicopter reduces by years the length of exploration and feasibility phases of mineral search in remote areas, improves the economics by enabling financial decisions to be made in good time, firstly on whether to commit further funds on the project, and secondly, on whether production is warranted. It provides quick transport to base for the injured and sick when used as an aerial ambulance. Such saving in time, and thus money, between exploration and production, the more efficient use of manpower, the assistance in on-the-spot assessment and the improvement in camp conditions due to quick transit time to base, make helicopters essential tools in this type of operation.

Brief specifications of three helicopter types used at Bougainville.

	BELL 47G–3B–1 270 h.p. turbo-supercharged piston engine	SIKORSKY S58	BELL 204
All up weight	2,950 lbs.	12,700 lbs.	9,500 lbs.
Disposable Load	980 lbs.	4,695 lbs.	4,000 lbs.
Fuel Capacity	48 imp. gal.	234 imp. gal.	191 imp. gal.
Consumption	16 i.g.p.h.	75 i.g.p.h.	80 i.g.p.h.
Endurance	178 minutes	188 minutes	143 minutes
T.A.S.	60 knots	95 knots	100 knots
Range	133 Naut. miles.	226 Naut. miles	178 Naut. miles (with 45 minute reserve)
Pay load available	468 lbs.	2,794 lbs.	2,050 lbs.
Passenger Seating	2	12	9

Activity—Early '70

Stuart Inder,
Editor,
Pacific Islands Monthly.

Pacific Islands Monthly, published in Sydney and circulated throughout the Pacific Islands for more than 40 years, has reported the developing story of the Bougainville copper mine from the beginning. The material reproduced here is copyright, Pacific Publications (Aust.) Pty. Ltd., GPO Box 3408, Sydney.

"Let's leave it here. We'll get a new one from equipment pool!"

On previous flights from Rabaul, down the island chain to Kieta, on the east coast of Bougainville, I felt I was leaving a metropolis for a sleepy, charming island backwater where I could relax. This time I knew it would be different.

Even the gateway to Bougainville, the airstrip at Buka, was humming with earth-moving machinery that would lengthen and strengthen it to take the big increase in air traffic that has followed Conzinc Riotinto's vast copper development in the mountains behind Kieta. Ansett Airlines had finally to be given rights to fly into Bougainville, for TAA couldn't handle the upsurge in business.

Half-a-dozen natives, the inevitable airline bags over their shoulders, climbed aboard the aircraft, headed for Kieta, where the big money is. Some of them may have left plantations, which today in Bougainville can't keep labour in competition with better conditions and pay in the copper area. District Commissioner Des Ashton already fears a squatter problem, similar to Port Moresby's.

Aropa airstrip, a few miles sough of Kieta and the closest you can get by conventional aircraft to the copper project, was a sea of mud and bulldozers when our DC3 landed in a tropical downpour. Soon even a DC3 will be too big to land at Aropa, as the dozers make their final attack on the strip, to bring it to Fokker standard. A Fokker a day will then come in direct from Moresby.

I didn't recognise the road from the airstrip to Kieta. Three years ago, when I was last here, it was a wheel track. Now, bridges are being widened or replaced, new grades have been found. Ten years ago there was not a single bulldozer on the whole of Bougainville; now equipment jams the new roads, and 60 new motor vehicles of all kinds are being registered every month.

We passed by a new Administration town, temporarily named St. Michael's, with houses rising from the scrub. This is Kieta's first suburb, for it will eventually link with the old town.

Further towards Kieta, the overseas wharf, hardly completed, is already inadequate. Burns Philp's Islands trader, Tulagi, whose arrival was once an event, is not seen these days — but ships come in from all compass points and compete for berths. Although there is no wharf yet at Anewa Bay, site of the new copper port north of Kieta, CRA ships unload supplies on the beach there to avoid the congestion.

Kieta was not merely congested when we drove in — the pretty town was a shambles. Several months of wet weather — the worst stretch in 10 years — had made it a sea of mud, and construction gangs were adding to the morass. A bulldozer driver the previous day had ploughed up the telephone cables three times, adding to the air of harassment that now hangs over Kieta.

"We're suddenly a frontier town," said Mrs. Greg. Wall, of Island Casuals, planned as Bougainville's first women's fashion shop. But on this new frontier her biggest demand is for quality work clothes for men. Opposite her shop, which she can't extend until she can coax a carpenter from somewhere, Burns Philp is quickly erecting a store — perhaps a sure sign that the frontier will widen into permanent prosperity.

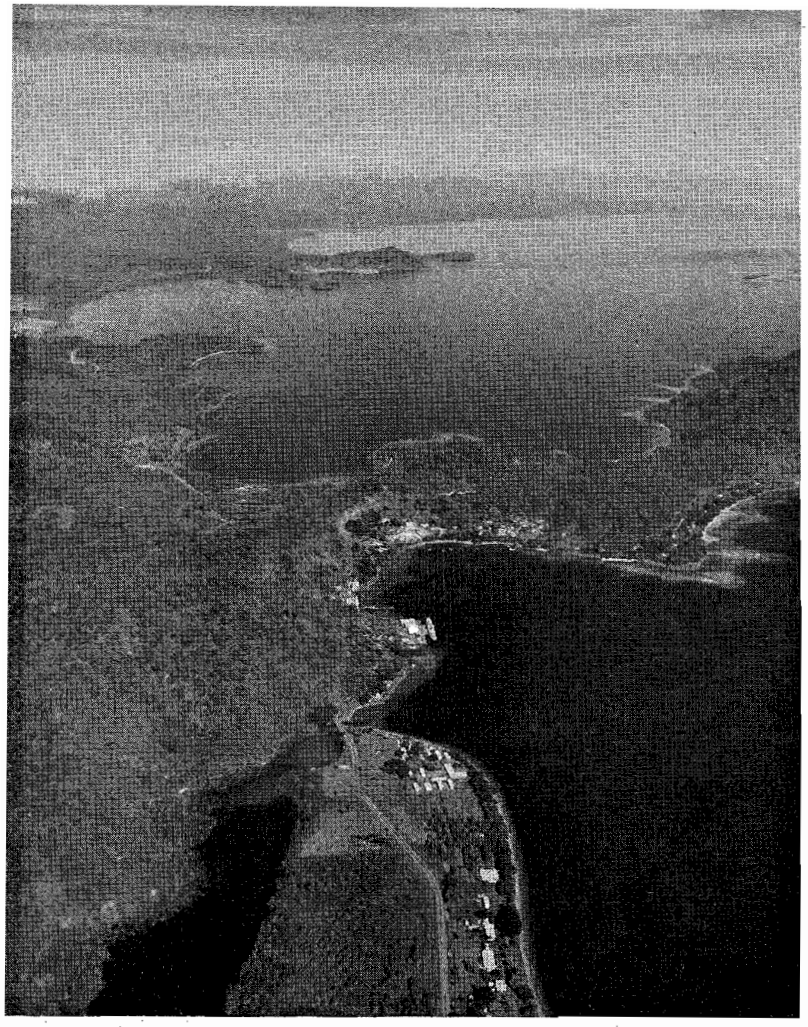
The big bar at the Hotel Kieta is crowded with men from the mine, and from the big construction and transport contractors whose know-how is developing this remote stretch of New Guinea. They can get a drink at their own messes, but they want a change of scene.

The hotel has been over the plimsoll with travellers for months, the humid dining-room is virtually standing-room-only, and manager Si O'Donnell like a cat on hot bricks as he waits for the first stage of $800,000 worth of extensions (final total, three wings, 80 self-contained units) to be finished in a few weeks.

"The day we can put a bulldozer through this building I'll bung on two 18-gallon kegs to celebrate," he says. His guests, sharing two to a room, endorse his impatience.

In town, everything you want to buy is either sold out or not yet arrived.

Almost 4,000 men, scattered in workers' camps in an arc around Kieta, have brought this boom to the backwater township. They have nowhere else to go — and they won't go anywhere else until they build the mining plant and housing at Panguna, the port at Anewa, the two new towns at Arawa and St. Michael's, and the roads that link them. And then they will go home, to Australia, America, or the



Bougainville east coast. Kieta (centre), Arawa (top left) and Anewa Bay (top centre).

New Guinea mainland, and their places will be taken by the permanent staff who will man the mine and the port and live in the new towns, and by the shopkeepers and public servants who will service them.

There will be 7,000 construction workers at the peak, this year and next – less than half of them New Guineans. The total will drop to 3,500 by 1973 – but that figure will already have been matched by the permanent staff and their families living in only one of the new towns – Arawa. Arawa, a few miles out of Kieta, will have 8,500 people within the next five years as the real business of treating 900 million tons of ore over the next 30 years gets into giant stride.

Meanwhile, Kieta is the reluctant confused midwife to one of the world's largest copper mines.

The frontier conditions have not so far brought an increase in crime to Kieta. "The men are all working too hard," says Inspector John Ring, in charge of the Bougainville police district.

Everybody shares in the development bonanza; most of the earlier native opposition to the project has dispersed with growing prosperity. At nearby Kobuan, coastal depot for the mine, six drivers and four other men for five days each week spend an average of $1,000 a day in silver pieces, buying fruit and vegetables in the villages. Record day's silver outlay was $1,400. The famous Buin basketware, made further south, is bought up as soon as it is woven. Locals say they have seen CRA helicopters leaving Buin with baskets lashed to their undersides.

You need permission from Bougainville Copper Pty., CRA's operating company for the project, to visit the mine site at Panguna, in the Crown Prince Range. And preferably a four-wheel drive vehicle and a driver-guide.

BCP managing director, Frank Espie, who happened to be "up the hill"on his 36th visit in four years, sent down permission, and Ian Williams and Frank Nicholson, at Kobuan, supplied the Toyota. Three years earlier I had set out from Kobuan by helicopter, for the 16 mile road then was still being pushed over the ranges. Cloud at 3,500 ft. had forced us back.

Now it was dusk, and raining steadily, as I set off more hopefully. We ploughed our way along the coast through Arawa, before turning inland on a new stretch of two-lane, 24 ft. wide road elevated across swamp.

The bulldozers had only just started to root out the cocoa and coconuts at Arawa, most of the famous orchid collection had been shipped off to the Lae botanical gardens, and the plantation was doomed. A $47.5 million town will soon begin to rise on the site.

Nearby, at the site of the massive power station for the whole area, and of the new deepwater port, where the 40,000 ton dw ore ships will berth, heavy equipment was pushing hills into the sea and wharf piles were being driven.

Nearly 900 men were encamped there in portable aluminium huts – with canteens and open-air movies. Mountains of supplies were stacked at Palm-tree height on both sides of the road, awaiting transport up the hill. It was like the war.

But in this war the fight was clearly against time. Time was money and no time was to be lost in mounting this carefully-planned assault on the ranges and in bringing the spoils to the coast.

Since the ore is low grade, profits require mining on a large-scale. BCP will extract 30 million tons of ore a year by open pit, to produce concentrates for export containing about 150,000 tons of copper, 500,000 oz of gold and 1 million oz of silver.

By the beginning of 1972, when the company begins production, it will have spent $353 million in development –most of it on short-term loan. If a few extra million dollars in the meantime will get the mine producing faster, that's money well spent.

As our Toyota headed up the new highway to the clouds, we dodged trucks and bulldozers and unshaven men who work two 10-hour shifts, day and night, to get the road through. Powerful portable lights often blinded us. In places the new road diverted us to the old, narrower, steeper, access road.

The new road is being designed for 50 mph speeds on the flat, 20 to 30 mph in the ranges. It will be sealed. But now we left it altogether, and ploughed at 3 mph in axle-deep mud through a series of climbing zig-zags.

Only the previous week, near here, the new road had collapsed, taking eight men to their deaths. There were grumbles about safety, and many men were on strike. We slithered and slid, but the driver kept control. Numbered posts at short intervals beside the track were not there to prevent us sliding over, but to quickly identify the trouble spot to the bulldozer driver should we slide over, or be stopped by a fall of rock ahead.

We were now enveloped in fog, our headlights stabbing only a few yards ahead. But it wasn't fog, the driver explained. It was cloud; we were at 3,000 ft. In this weather, on this road, at this hour, it was an eerie experience.

We were over the top, and began to descend to the Panguna Valley floor, 1,000 ft. below. As the Toyota ground its way down, we negotiated a series of bends, to suddenly face a huge battery of lights, men and machines moving a mountain aside to make way for the site of the ore concentrator.

And far off below, in the misty distance, were the exciting lights of a large town. This was Panguna – 2,200 workmen in the remote middle of nowhere – 100 women, 75 with husbands or families, 30 children in the new school.

Here was the focal point of Papua-New Guinea's most massive development – one that has occurred with such swiftness that few people have yet been able to grasp its extraordinary significance.

From this valley in the first 10 years of production, $400 million will flow to the P-NG Administration alone – without taking into account the benefits from a rapid growth in export income.

In this valley one of the real worries is whether the P-NG Administration, and the House of Assembly, do in fact understand the implications of a mining development of this magnitude and speed of progress, and can move quickly enough to meet the government's share of construction and staffing responsibilities.

Big new towns can't suddenly rise as Bougainville's new towns are rising, without a strain on government works and services – on the need for teachers, police, doctors, nurses, and clerks, and for homes and buildings to house them.

The difficulty of government keeping pace with private enterprise had just been brought home to some of the women in the valley. The Administration school had not long been built – erected by BCP, in eight weeks.

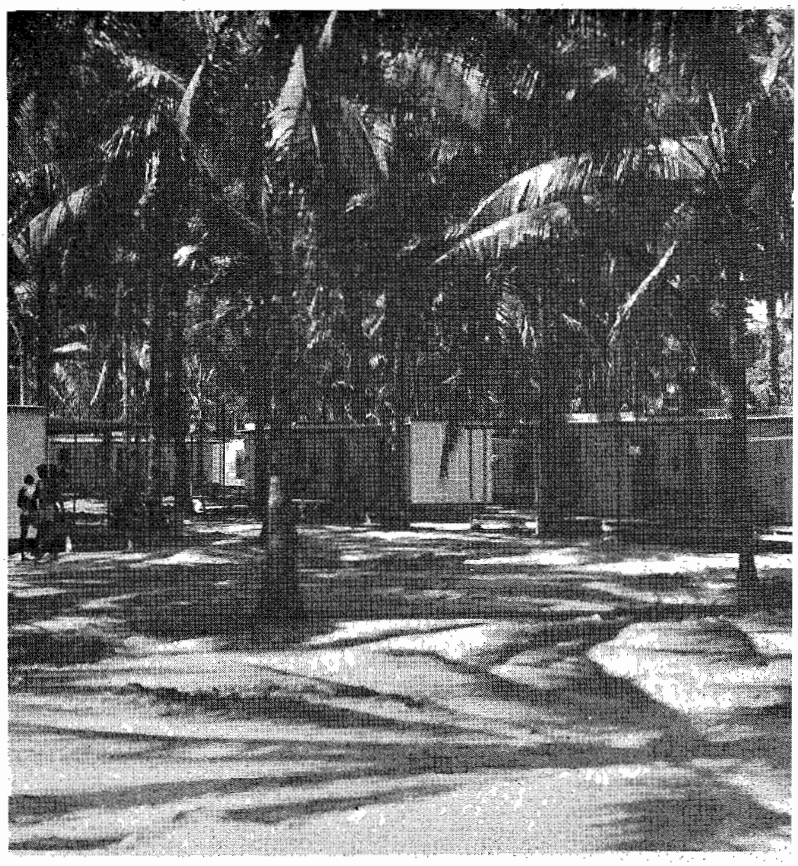
It was quicker for the company to do the job. But the roof was unlined, according to the Administration specfications, and when it rained the class couldn't hear the teachers speak for the noise. In any case the teachers, man and wife, had now resigned.

Mrs. Colin Bishop, wife of the copper company's area manager, has been longer in Panguna than any of the women – since July, 1967. Her three children took their lessons by correspondence. For her, life at Panguna has become civilised since 1967.

Fine new houses that any Sydney or Melbourne family would be proud to own are being erected and occupied; there is a supermarket and milk bar and far more social life. Messes for the single men are modern, comfortable, fitted with batteries of washing machines and driers. Some messes are integrated, and nowhere is there a colour bar.

Sales at the company store reflect wages paid. All business is in cash, and in one month recently the store sold $26,000 worth of radios and electrical equipment and then placed an order for $28,000 worth. A single order for $19,000 worth of hi-fi equipment was sold before it arrived.

Native workmen buy $45 watches, $420 motor bikes, $150 Polaroid cameras. The camera purchases are good value for their owners – who soon recover their outlay by selling



Camp 5, at Loloho.

snapshots of their fellow toilers at $1.50 each.

The company subsidises food prices, milk sells for only 1c over cost. Store profits go into an amenities fund.

I met Henry Moses, a local villager who returned to Panguna in 1967 after teaching at a Christian mission school on the coast for seven years. Henry, 33, now manages and inspects work camps for the company, lives in a company house in the valley, sends three of his four children to the new school, and owns and operates on the side two trade stores, a cocoa and copra plantation, and two trucks.

Meanwhile, Panguna is a company town, and development is planned entirely around the site of the pit – which happens to occupy the only flat piece of land in the valley. Houses and amenities spread themselves around the hills.

The current development is in clearing sites and erecting permanent buildings, including the concentrator, and in preparing the way for the giant 17 cu. yd. shovels and 100 ton trucks that will have the main task of getting at the ore, when up to 120 ft. of overburden is removed from the pit site.

The highway from the coast – to be finished by mid-year – is not designed to get the concentrate out, but to get this massive equipment in. The concentrate will go to the port as a slurry through a pipeline that roughly follows the road, and will be stockpiled there for shipment.

Bougainville today vibrates to its very core with men and equipment dedicated to getting that first shipment out in 1972.

Fire Protection

Brian Barnabas
Fire Fighting Enterprises Ltd.
Melbourne & Sydney

FIRE PROTECTION FOR THE BOUGAINVILLE PROJECT

Approximately 98 per cent of the portable, fixed and mobile fire protection equipment at the Bougainville Copper Project was designed and installed by Fire Fighting Enterprises Limited, one of Australia's largest organisations specialising in the production of fire fighting equipment and systems, through its subsidiaries Fire Fighting Equipment, May-Oatway and Presha Engineering. In co-operation with Bechtel-WKE, fire prevention system engineers of the FFE Group worked to identify the type

Bougainville Copper maintain their own fire fighting force, and the FFE Group has supplied numerous items of equipment for the fire stations which were erected in the mine area and in the port area.

of fire that is likely to occur, minimised the inherent risk of outbreak, and designed systems which will isolate and extinguish any fire that does break out.

Protection of the Bougainville Project against damage and loss by fire began early in 1971, when representatives of Fire Fighting Enterprises Ltd. established liaison with the Chief Fire Officer of Bechtel-WKE, Brian Barnabas, in order to determine suitable equipment to protect the project during construction stages.

The immediate requirement was for protection of construction camp facilities and equipment, a matter of considerable urgency due to the fact that no units of the local fire brigade were on hand or immediately available to fight an outbreak.

From the outset it was clear that adverse climatic conditions on the island would be a major factor in determining the type and suitability of equipment. Another was the remoteness of the site from centres where advanced maintenance could be carried out.

EARLY PROBLEMS OVERCOME

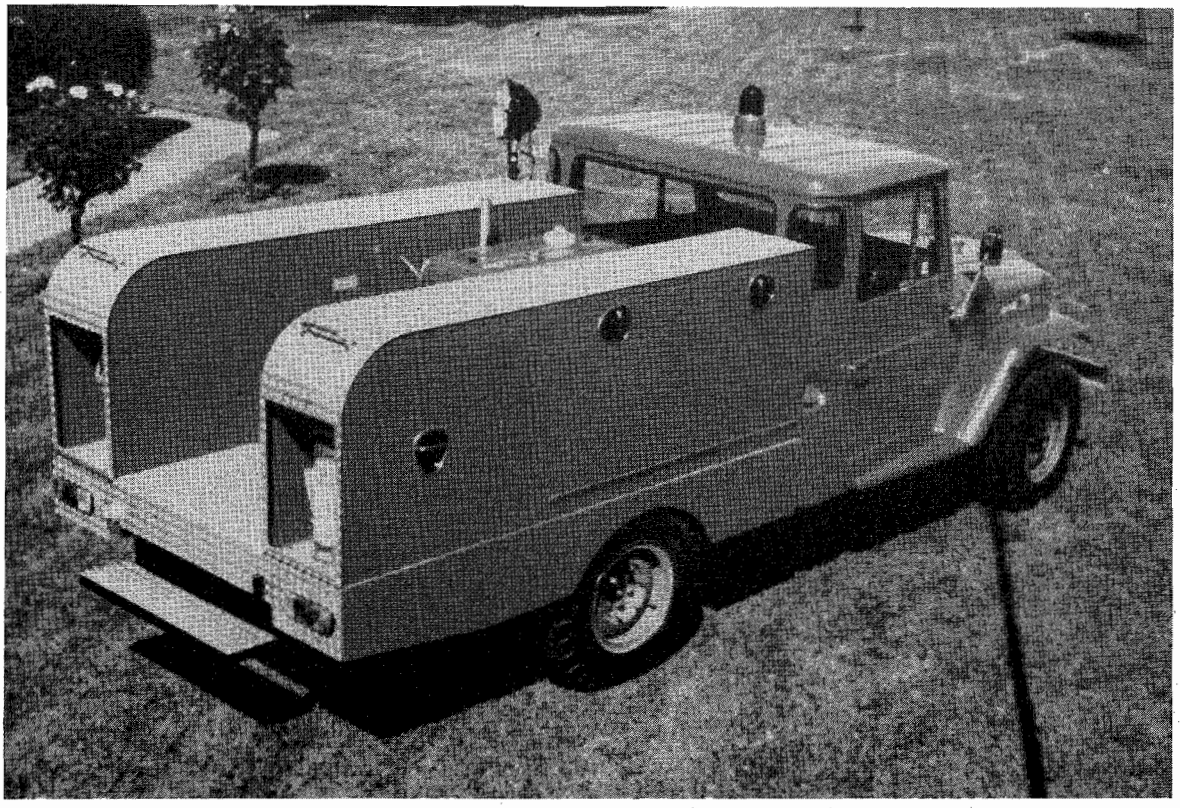
The effect of high speed corrosion of metals in tropical conditions and the destructive attack of mildew on other materials were two of the early problems that FFE engineers tackled without hesitation and progressively overcome.

Mildew attack accelerated by ambient high humidity would have made short work of conventional canvas fire hose. Suitable alternatives were sought, and subsequently Duraline "Flame Fighter" synthetic hose was installed throughout the entire project. The all-synthetic fibre construction of the hose combines strength with lightness, flexibility and durability; additionally, with drying no longer an essential part of hose maintenance, the cost of drying towers and equipment was saved. Duraline hose was also extensively used for construction pumping work and in the training of locally recruited personnel, with complete success.

The FFE-"Quell" water-filled air-pressurized fire extinguisher, with its 2-gallon capacity and its ability to throw a jet 30 feet, was an obvious choice for fighting ordinary combustible fires which might occur in construction camp areas.

To best withstand the rigours of the Bougainville climate, the unit with body constructed of 18 SWG drawn copper was selected. In this unit an internal overflow prevents overfilling; pressure recharging is obtainable from any 100 psi compressed air system; operation is controlled by a simple squeeze-grip valve which also serves as a carrying handle; and a recessed pressure gauge indicates the state of readiness of the unit at all times.

Simple to use and easily rechargeable, the "Quell" air/water extinguisher proved more acceptable than either the soda/acid type, which required too frequent inspection, or the CO2 type which was considered impractical on



Fast personnel rescue tenders are fitted with all necessary equipment for cutting and forcing entry into burning vehicles and buildings.

Bougainville because of recharging problems and gas discharge due to heat expansion.

The types of extinguisher favoured for flammable liquids and electrical fire risks were the "Quell" BCF (bromochlorodifluoromethane) and "Quell" Dry Chemical units. BCF units were installed on transport vehicles requiring protection in preference to dry powder extinguishants tended to tamp down and malfunction as a result of the constant motion. By comparison, BCF required minimal checking and was quite unaffected by movement.

The FFE "Quell" range of portable, fixed and mobile equipment eventually accounted for approximately 98 per cent of fire protection installations at Bougainville.

FIRE STATIONS EQUIPPED

For the Fire Stations which were erected in the mine area and in the port area, a fire truck and two rescue vehicles were designed and built by Presha Engineering Division of the FFE Group to specifications which again had to allow for severely adverse climatic conditions.

The cross-country fire truck, equipped with a six-man cabin, a 100 gal. foam tank and an 800 gal. water tank with four hand lines, is a rugged vehicle powered by a 210 h.p. diesel. The general purpose personnel rescue vehicles are equipped with means for cutting and forcing entry into burning vehicles or buildings, and carry special flood lighting. In all three vehicles, cooling of the engines under all conditions has been an important design consideration.

Breathing apparatus and portable pumps were also supplied by FFE for the fire stations, and members of the Fire Brigade were instructed in their use. Again, due to the remoteness of the site, equipment was chosen that required little or no maintenance and could be recharged or even repaired on the site.

FIXED FIRE PROTECTION

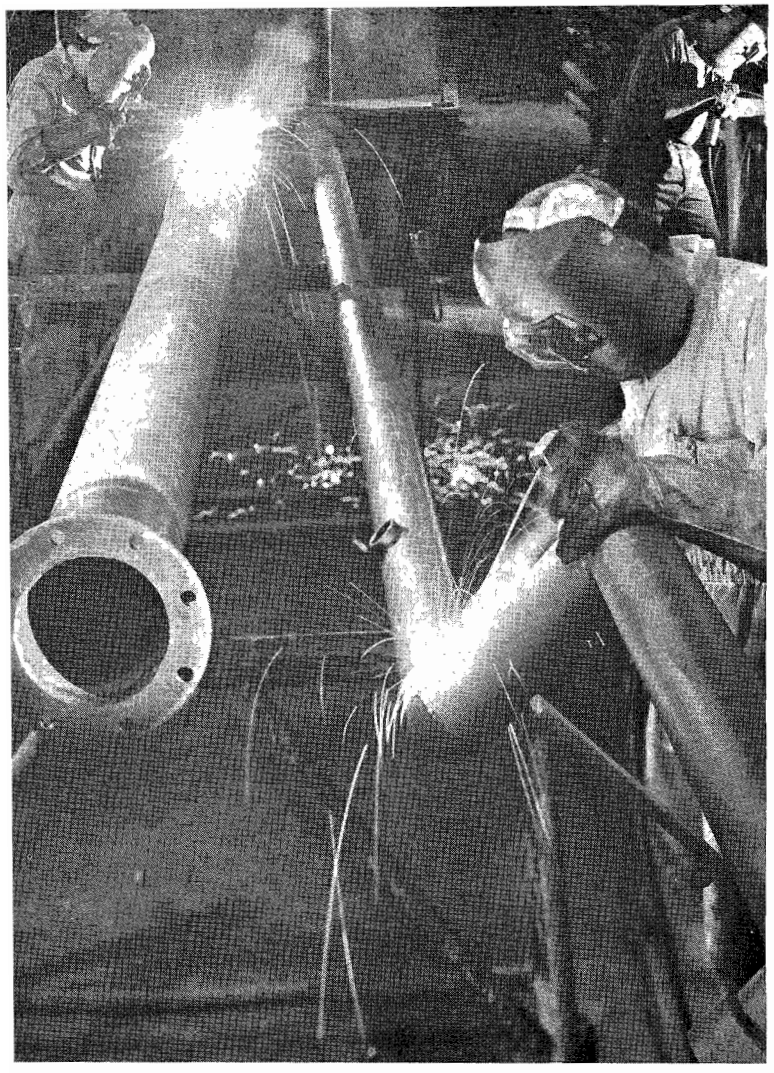
In 1972, when construction work was well advanced, the company was commissioned to design and install the fixed fire protection system for the entire Bougainville Project.

Each area was evaluated with particular regard to provailing conditions and level of risk, and types of protection were decided upon by FFE experts in consultation with the Chief Fire Officer.

PROTECTING THE PORT AREA

In the port area, it was decided that the warehouse and explosives store, would best be protected by a standard wet pipe sprinkler system, and the power house transformers by a deluge spray. At once a problem arose. The existing emergency water supply system in the port area allowed for introduction of sea water when domestic supplies of fresh water being introduced to a live transformer could prove hazardous. A separate fresh water supply was designed for the sprinkler systems and, at the same time, a manual spray protection system was provided to cover the boiler fronts and generators.

The fire engine supplied by the FFE Group has a six-man cabin and is fitted with a pump, 800 gallon water tank and 100 gallon foam tank. It is powered by a 210 hp diesel engine.



Fabrication and welding of pipe to carry the water supply for fire protection systems installed at Bougainville.

The three five-million-gallon oil storage tanks are also protected by manually-operated spray systems which are designed to cool the tanks in the event of a fire in the area.

For actually extinguishing an oil fire, foam is used. Fixed foam protection, as sometimes installed on flammable liquid tanks, was not thought desirable because an explosion could destroy the apparatus. Instead, two handlebar type "Quell" Monitors, each with a foam output of 460 gallons per minute, were provided to protect the bund areas and pipelines around the tanks where fire is more likely to occur.

"Quell" hose reels are fitted inside all buildings, and 145 of them are installed throughout the project. Each reel has 120 ft. of ¾ in. hose and a "Quell" T.B. Fog Nozzle, and can be operated swiftly and easily by one person. For secondary attack on interior fires if necessary, a 2½ in. fire hose is stored outside buildings.

PROTECTING THE MINE SITE

At the mine site, fire protection by fixed sprinkler installations concentrated on the conveyor system and in the slurry manufacturing building.

The possibility of covering the full length of conveyors with a protective sprinkler system was discounted due to the high costs involved. As a result, protection was concentrated on the transfer towers and drive houses. The normal practice of locating sprinkler heads at ceiling level had to be abandoned because the roof heights and weather intrusion (through the open sides of the structures) made such a design impracticable. Instead, the discharge nozzles and fusible links of the system were engineered around the conveyor drive rollers and other parts, where fire is more likely to occur.

The slurry (explosives) manufacturing building is protected by a deluge system which required careful planning because of the nature of the manufacturing components stored there and also because of the possibility of a change in storage layout.

Two of the stored components, carbon black and sulphur, require copious quantities of water in the event of fire, whereas the third component, aluminium powder, will explode violently if water is applied.

It was decided, therefore, to install spray system pipework and fittings throughout the entire building but to fit blank plugs instead of water discharge heads in the aluminium powder area; these plugs can be replaced with operational heads on re-location of the powder.

PROTECTION AT JABA RIVER

Protection of the remote automatic pump station at the Jaba River is of major importance because this facility is not manned and it is imperative that the pumps work without interruption.

The main pump house is protected by a "Quell" deluge system, but, because of the high roof area, the fusible link detection system has been replaced by a faster-acting Heat Activating Device system which operates on the expansion-of-air principle. The transformers there are protected by a spray system similar to that installed at the port area.

The two rooms housing equipment to control operations at Jaba River are covered by an automatic BCF system, incorporating explosive discharge controls which are activated by May-Oatway smoke ionised detectors. May-Oatway is another of FFE's many specialist divisions. Twenty-eight 200lb BCF cylinders are strategically located to totally flood the area in the event of fire, and at the same time an alarm is signalled to the concentrator control room.

Before discharge of the BCF into the rooms, alarm bells and visual flashing signs give personnel a 20 second warning. The doors then automatically close and air-conditioning is shut off to fully utilize effectiveness of the BCF.

The May-Oatway control panel makes for easy testing by Fire Brigade personnel and, like all fire fighting systems installed at the project, is engineered to code alarms to the company fire station, ensuring a major concentration of fire fighting effort if an outbreak should occur.

The overall fire protection system, supplied and installed by Fire Fighting Equipment at Bougainville at an estimated cost of about $400,000 is one of the largest in the Southern Hemisphere.

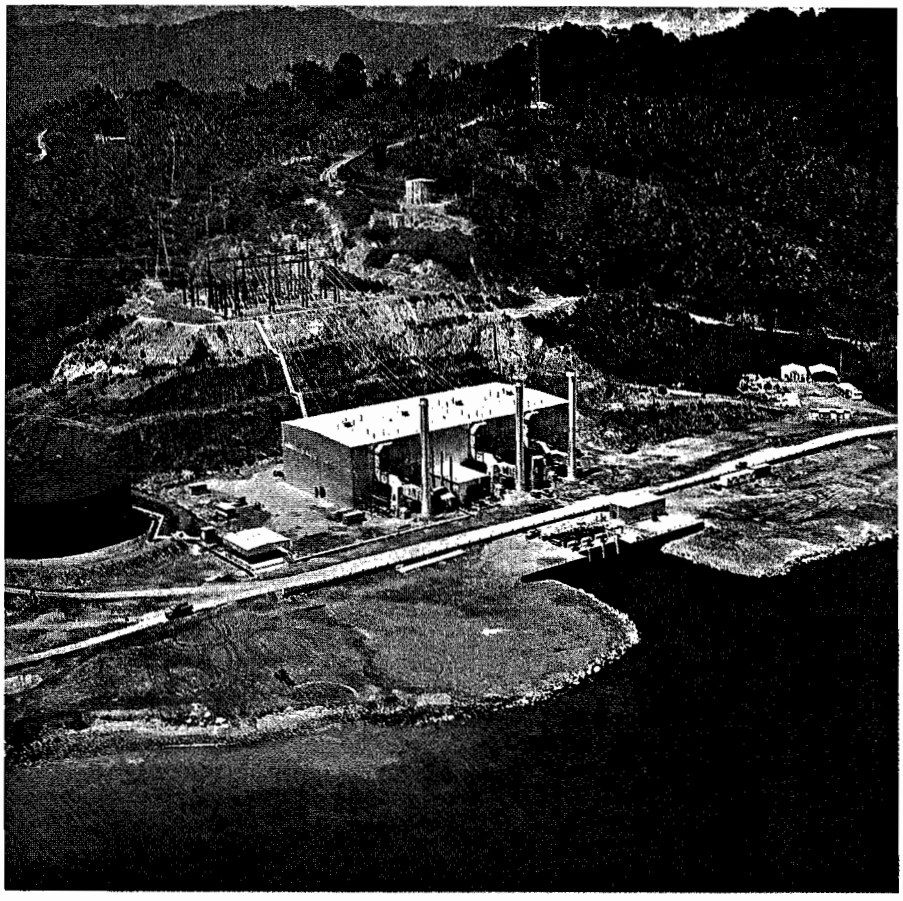
The complete safety of personnel, plant and equipment is of paramount importance at this remotely-located mine. Careful planning and installation of the most modern and efficient equipment available has ensured maximum protection of the multi-million dollar Bougainville project against loss and damage by fire.

Boiler Erection & Power Plant Mechanical Installation

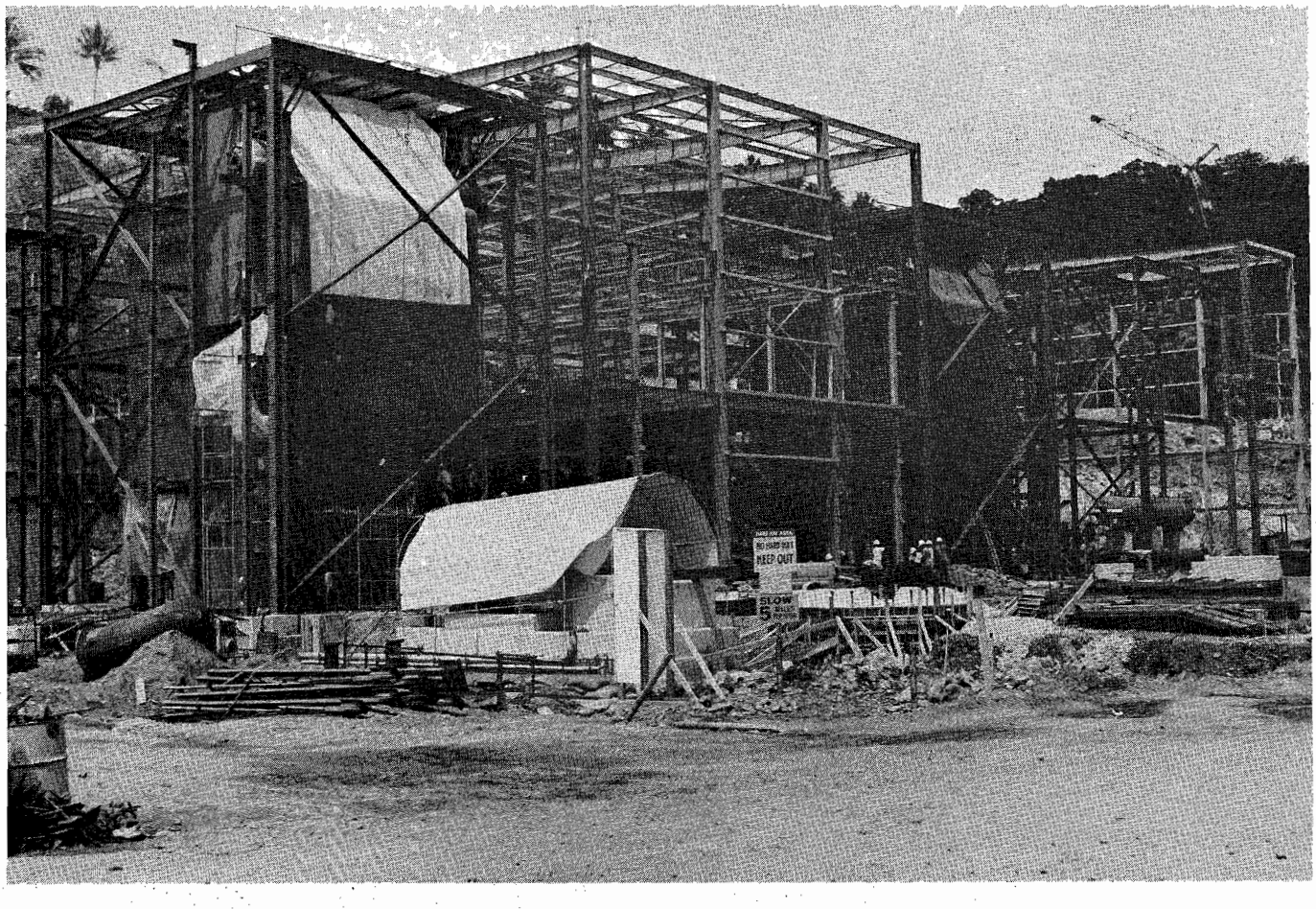
G. Sostheim,
Senior Project Engineer,
World Services & Construction Pty. Ltd.

In June 1970, World Services & Construction Pty. Ltd., were commissioned by Bechtel–W.K.E. to erect three Babcock and Wilcox–Hitachi Bi-Drum pressurized water cooled furnaces, having a continuous rating of 441,000 lbs/hour at 1,325 p.s.i.g. 950°F at superheater outlets. These oil fired steam generators, together with three non-heat steam turbine electric generators (installed by others) rated at 45MW each and the necessary associated complex, constituted the power plant, whose function it was to supply power to the copper concentrator, mine, portsite facilities and townships of Arawa and Panguna via a 132 KV transmission system. In December 1970, W.S. & C., were awarded a further contract for the installation of ancilliary mechanical equipment for the power house complex.

Although W.S. & C., is part of the large Dutch V.M.F. group of companies which has built petro-chemical and power plants all over the world, it was the first time that W.S. & C., the Australian subsidiary, had ventured outside the mainland of Australia to undertake a multi million dollar project. The contract represented a particular challenge as local availability of consumables, spare parts for construction equipment and vehicles and other logistics vitally essential for a project of this size were virtually unavailable on the



Power Station at Anewa Bay, Bougainville, completed by World Services & Construction Pty. Ltd. in 1972, showing intake structure in foreground, switch yard at rear of power station and fuel oil storage tank at left.



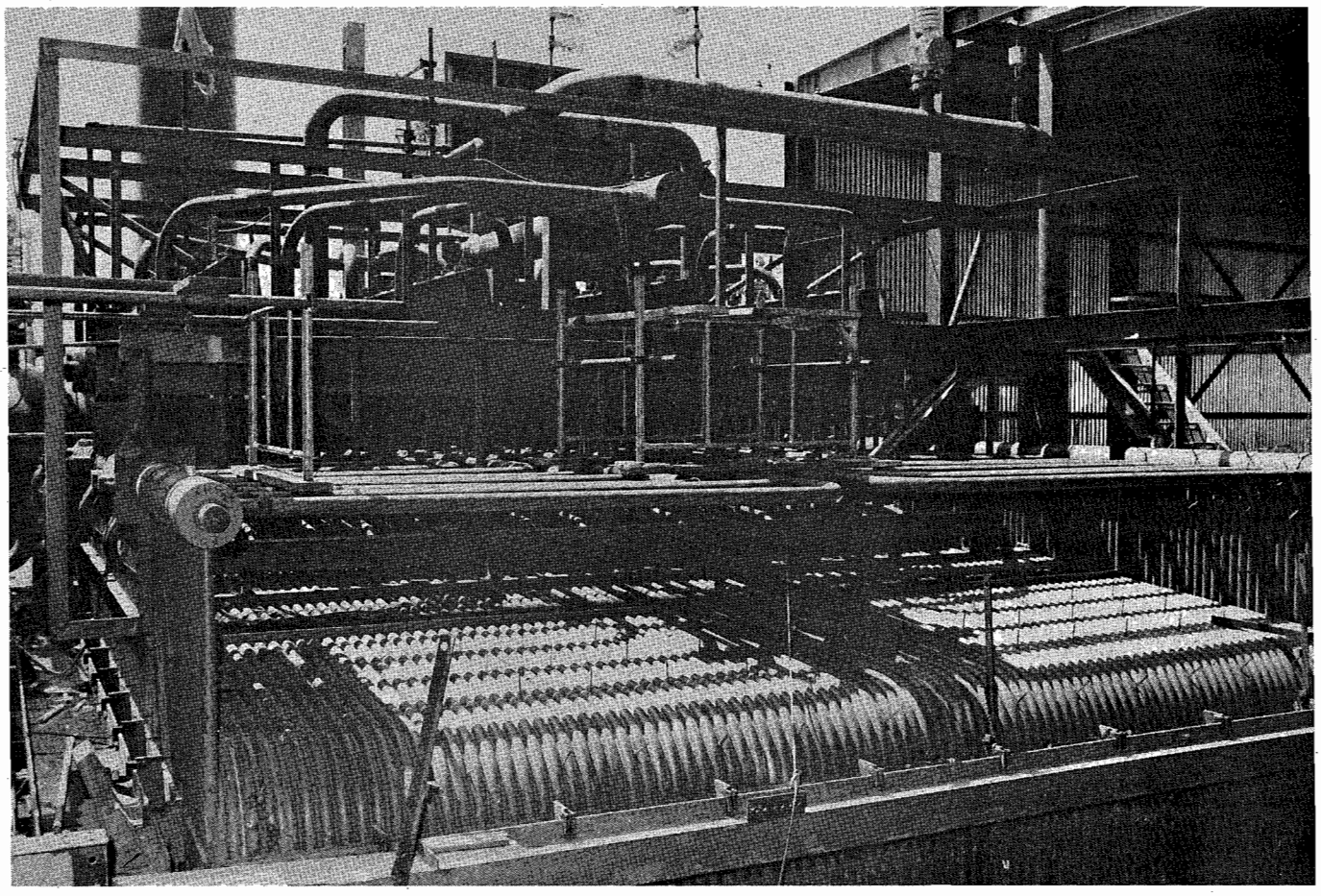
Power Plant Boiler No. 3 left side, forced draft fan foundation with white canopy. Boiler No. 2 right side. First drum for Boiler No. 1 far right. February, 1971.

island of Bougainville. A senior representative was sent to Papua–New Guinea to investigate the supply position in Port Moresby, Rabaul and Lae, but his report indicated that the specialized equipment required was in limited supply or not available at all. The W.S. & C. management therefore decided to supply everything down to the last bolt, nut and washer from Australia, and by August 12th, 1970 only a short 6 weeks after award of Contract, most of the site establishment, construction equipment including cranes, tools and the initial construction crew had arrived on site.

In the meantime, a complete management team had been assembled consisting of a Site Manager, Project Engineer, Deputy Project Engineer, Planning Engineers, Mechanical, Piping, Rigging, Welding and Instrument Supervisors together with the necessary back-up of Store Supervisors to handle the mammoth task of receiving nearly 2,500 tons of Boiler Material and Equipment from Japan in readiness for the erection of the Power Plant.

Whilst this initial phase of construction was being carried out at Bougainville, the training of welders for the specialized task of welding the boilers was being undertaken at W.S. & C. Workshops in both Melbourne and Sydney including the qualifying of 20 different welding procedures which had been established by W.S. & C. and approved by Bechtel–W.K.E. Both Argon Arc and Manual Metallic Arc welding was to be employed in the construction of the Boilers, the former being used on all Boiler Tubes including Superheater Bundles and Attemporator piping and the latter for the welding of Refractory and Insulation studs to the Boiler, welding of Buckstays to Boiler Side Walls and seal welding.

As is normal in the erection of this type of Boiler a specially designed temporary drum support structure was first erected to suspend the 50 ton steam drum approximately 45'0" in the air to permit the exansion of generating tubes, Roof panels and Floor panels into this drum and the lower water drum. At the same time the temporary structure permitted the lifting and lining up of the Side Wall panels and subsequent vertical welding of these panels to one another and to the Front panels. All Tube and Pipe welds were 100% radiographed and in addition the Superheater, Attemporator and Steam Piping welds had to be stress relieved. More than 14,000 ½" dia. studs per boiler had to be welded to boiler tubes and other parts of the boiler for the subsequent installation of insulation and refractory materials which also formed part of W.S. & C.'s contract. The use of stud guns for welding of the studs was not feasible as experiments had indicated that embrittlement of the boiler tube material might occur.



Roof and burner panels and superheaters nearing completion — Unit 2. May 1971.

Although the Furnace with its drums, tubes and panels forms the heart of the Boiler, it constitutes only part of the Boiler proper with its Buck Stays, galleries, stairs, air and gas ducting, Air Preheater, Forced Draft Fan, 110'0" high Exhaust Steel Stack, the inner and outer skin of the Boiler, Soot Blowers, Air Registers, Burners, integral piping, insulation and refractories. In addition, there are of course the ancillaries that form part of the power plant e.g. Water Intake Structure with its travelling screens and circulating water pumps condensors, Boiler Feed Pumps, etc., which were all installed by W.S. & C.

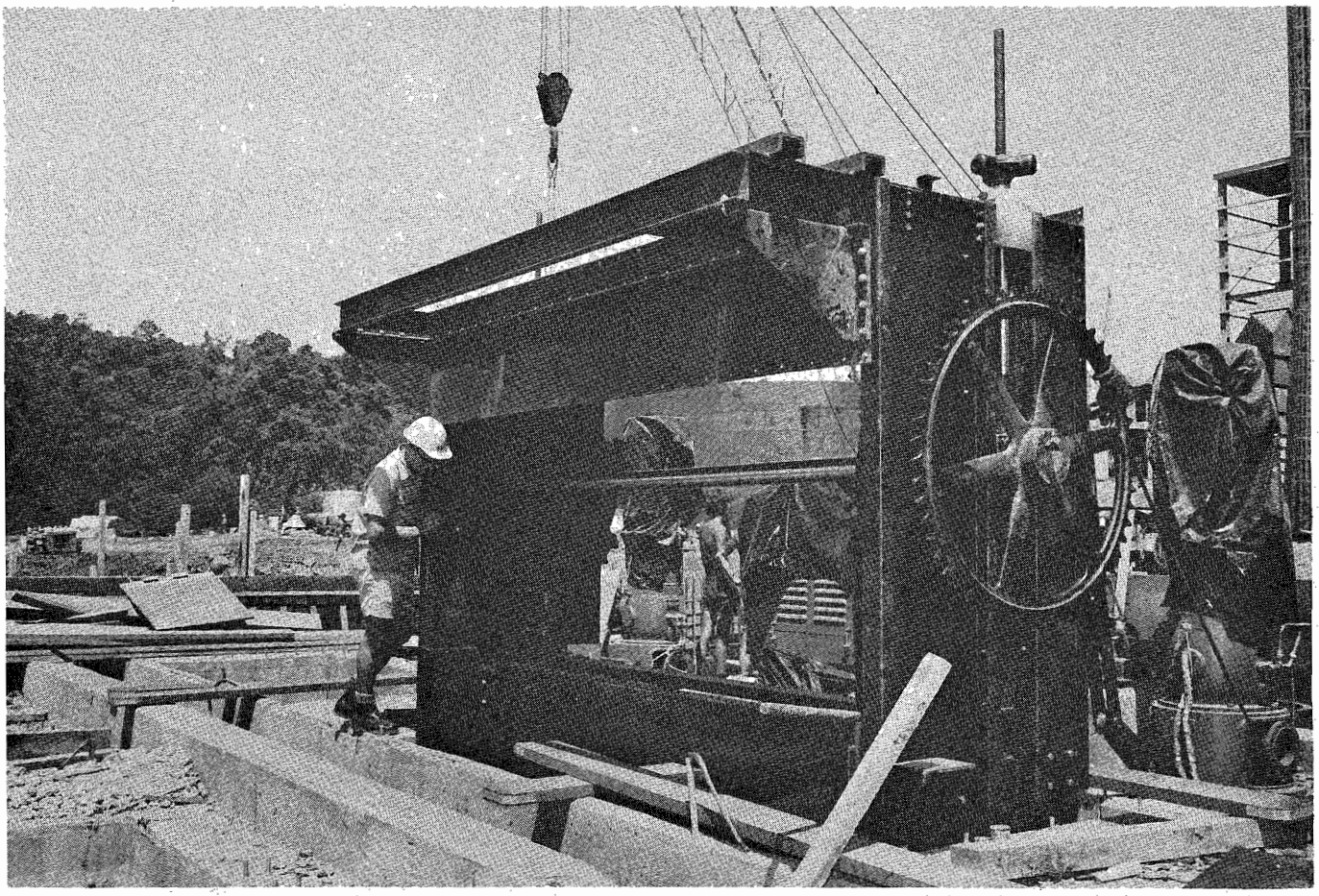
The erection of the three Boilers was started off at intervals of six weeks, so that soon all Boilers were being worked on at the same time. The peak crew of approximately 140 expatriates was augmented by 35 Indigines who formed a valuable part of the work force in the field and in the office. Despite the heat, humidity and often very heavy rain which is peculiar to the island of Bougainville, very little time was lost due to weather. Even more satisfying was the virtual absence of industrial unrest in spite of a six (6) days a week 10 hours a day work week with frequently Sunday work thrown in for good measure.

As each Boiler neared completion, it was subjected to two tests, the first being a hydrostatic test where the tubes, drums, water tube panels and pipes were pressurized with water to 800, 1,500 and 2,250 p.s.i.g. respectively. As each progressive stage was reached, the boiler was checked visually for leaks by representatives of B.C.P.L., Bechtel–W.K.E., the Boiler Manufacturer and W.S. & C.

After the hydrostatic test the boiler was subjected to an air leak test whereby the boiler casing and ducting were pressurized with air to 20" Water Gauge. Maximum permissible pressure loss was 2" Water Gauge in 10 minutes. None of the three boilers exceeded a loss of 1¼" W.G. during this specified period.

The final phase in the erection of the boilers was reached at the end of November 1971, when the boilout of the individual boilers took place. Under the direction of the Boiler Manufacturers Start-Up Engineer, each system was first flushed with water. After drying the boiler, the ignition system was lit and a three day Soda boil-out commenced. After cooling down, both steam and water drums were washed out, and the whole system steam flushed. The last item was the setting of the Main Steam Safety Relief Valves and ensuring the correct operation of these valves.

Thanks to a resourceful and competent Site Organization all difficulties were overcome and the Project successfully completed three weeks ahead of Schedule.



Above: Installing Travelling Screens in Intake Structure. May 1971.

Below: Intake Structure – installing transition piece. May 1971.

Turbo–Generator Units and Control Equipment

TOSHIBA AT BOUGAINVILLE

We, Toshiba, Japan's largest manufacturer of electrical equipment are justly proud of our association and participation in "Bougainville" a large copper mining complex by world standards today.

Copper the electrical equipment manufacturer's master metal occupies a vital and important role in his manufacturing processes and it is without doubt that in the very near future our manufactured products will contain elements and components of Bougainville copper.

This knowledge provided us with an added incentive to ensure that the electric power generating equipment supplied by us would live up to our motto "quality first".

In designing this equipment it was essential to take into consideration certain specific requirements for the plant.

1. Reliability

The power plant supplies power into an isolated power system and the mining complex is located in an isolated and remote area in which outside service facilities are non-existent. Therefore reliability of plant is essential.

2. Climate

The climatic conditions are typically island tropical, high rainfall, high humidity associated with high temperature which necessitated special attention to detailed tropic proofing of the plant.

3. Power System Frequency Control

Since the power plant supplies electric power into an isolated distribution system comprising both mining and township domestic loading, and the mining load is somewhat cyclic, it was essential to provide a quick response automatic frequency control system so as to maintain set frequency at all times within acceptable commercial limits.

The equipment provided by Toshiba was limited to the base turbo-generator units and their associated control equipment; a total of three units, each of 45 MW capacity, being supplied under the contract.

The contract administered by Bechtel–WKE, imposed upon Toshiba the responsibility of providing design parameters for the auxiliary equipment, as well as the provision of site supervision for the site erection of the base contract equipment.

Machine erection presented unusual difficulties in that due to the isolation of the area, common articles of hardware and consumable materials of any nature were almost unprocurable from local sources. General erection labour from local sources was in extremely short supply, and the high rainfall and lack of conventional hard base road systems, made transportation an extreme difficulty.

The absence of adequate station crane facilities imposed a difficulty in lifting the 120 ton alternator stator from the basement floor to the machine hall floor, a lift of approximately 30 feet. This lift was accomplished utilising a slab lifting steel framework, to which was added a centrally controlled sequentially operated jacking system.

The design of the lifting rig allowed the stator laden semi-trailer to be driven into the lifting area, to be unloaded by the rig. Having taken the rotor weight, the rig rose in a series of 9 inch lifts, each lift taking approximately 20 minutes, until the stator reached a point where it could be skated sideways off the rig platform over a beam bridge onto the foundation block. The rig was then shortened and repositioned on each foundation block in turn, to lower the stators onto their respective foundation locations.

The auxiliary equipment comprising L.P. heaters, H.P. heaters, deaerators, condensers and evaporators, were supplied by other manufacturers under separate contracts also administered by Bechtel–WKE.

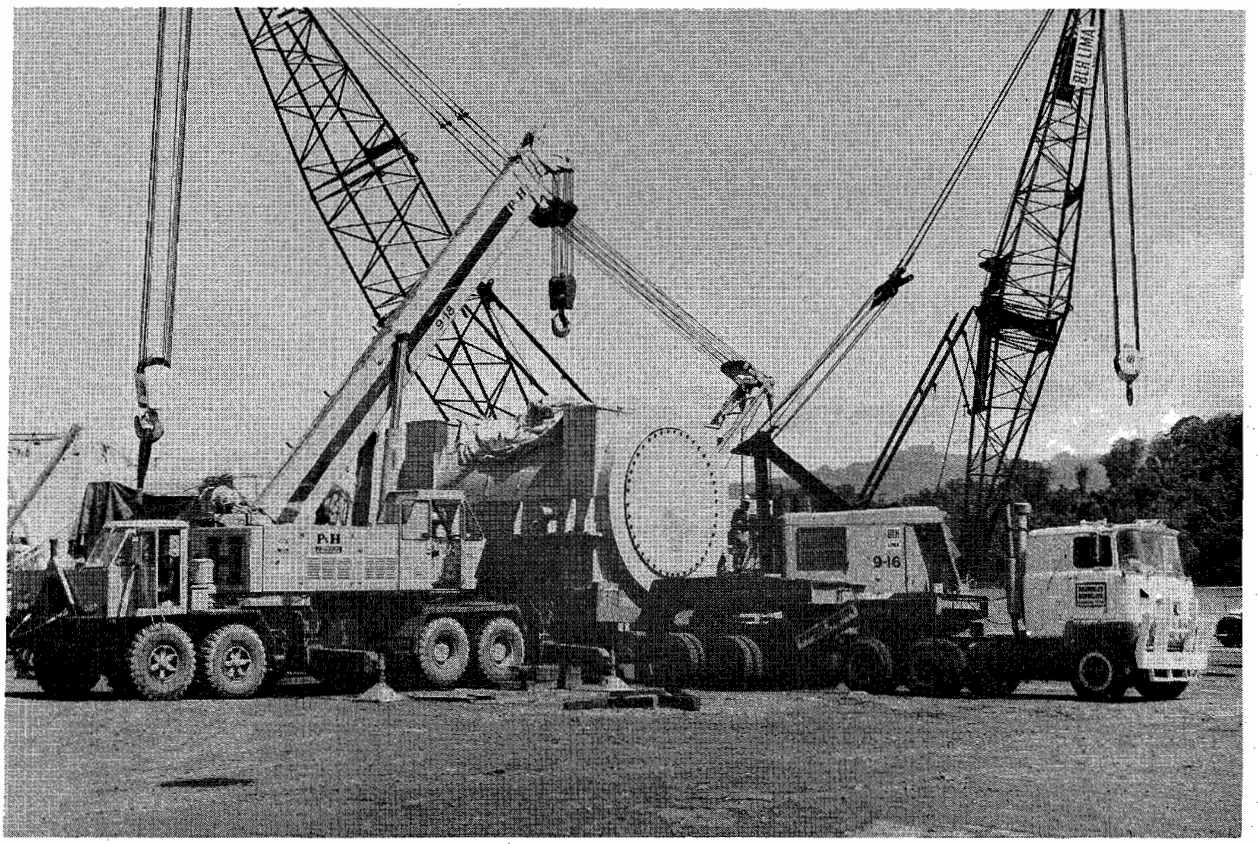
(II) TURBINE

The steam turbine is designed under a preferred standard steam condition for industrial-use steam turbines. The initial pressure and temperature are restricted to a relatively higher level; however, the structure is of simple design, aimed at increasing the reliability and thermal efficiency during continuous operation.

The turbine heat cycle is a regenerative cycle with 5-stage extraction. Construction is restricted to TCSF 23" from the extraction point and manufacture process.

Steam from the boiler is induced to the turbine through two lead pipes, and after flowing through the main stop valves, it is regulated by shell-mounted control valves on the upper and lower casing.

The steam expands adiabatically in the steam path, generating power and being extracted to feed the water heat-



Off loading 120 ton Stator for Power Plant Generator.

ing system, is then exhausted down to the condenser, and finally condensed.

The main design aspects are listed below.

Type of Turbine

Single-cylinder, impulse type, single-flow exhaust, 5-stage extraction, regenerative condensing turbine.

Rated Output	45000KW
Rated Speed	3000 rpm
Direction of Rotation	Counterclockwise (viewed from turbine front end)

Steam Condition

Main Steam Pressure	1250 psig
Main Steam Temperature	950°F.
Exhaust Pressure	2.75 Hg abs
No. of Extractions	5 stages
No. of Stages	18 stages
Critical Speed	2100 rpm (Multispan flexible support condition)
Final-stage Blade Length	23 inch

The turbine assembly is illustrated in Fig. 1.

1. Casing

The casing consists of cast alloy steel, high-pressure casing and steel plate-fabricated, low-pressure casing which are jointed vertically at the No. 4 extraction point.

The high pressure casing is made of Cr-Mo cast steel to endure a high-pressure and high-temperature steam condition.

Moreover, the casing head has been selected to permit using an inserted-chamber-type control valve bowl casing head to avoid high thermal stress induced by the contact of high-temperature steam with the low-temperature metal casing section.

Regarding the inserted-chamber-type casing head, the control valve bowl room is enveloped by first-stage exhausted steam whose termperature and pressure is relatively lower than that of the control valve bowl steam.

Since the first-stage shell pressure is lowered when steam flows through the Curtis stage, the high-pressure casing is of single-shell construction.

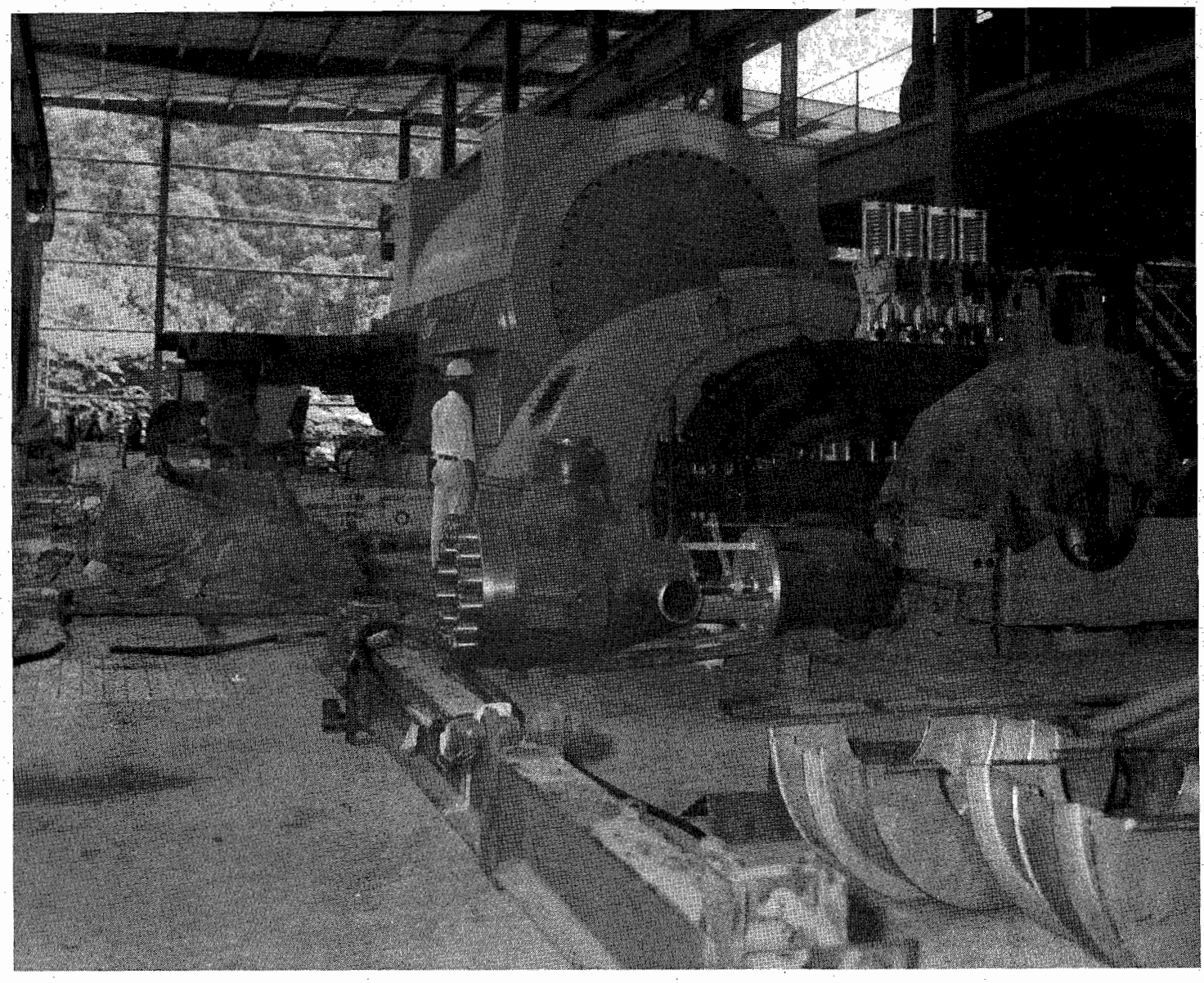
The increased volume gradually flows through the enlarged annular area, and the casing outer diameter is enlarged exactly at the extraction point, thus contributing to carry-over energy availability.

The low-pressure casing is of carbon steel plate fabricated structure to improve reliability.

The low-pressure casing is of double-shell construction having an inner shell as one body with an outer casing.

This design provides sufficient space for an extraction chamber for the feed water heating system and improves rigidity of the shell. An atmosphere relief plate and a manhole are provided in the upper half of the casing which prevent casing deformation normally caused by condenser system trouble.

2. Rotor



Toshiba Turbo Generator equipment in course of erection.

The rotor is of forged alloy steel of Cr-Mo-V. The wheel is machined from raw material in one body. After being subjected to a nondestructive inspection and thermal stability test, it is machined.

Dynamic balance is checked by a high-speed balancer. The rotor is assembled, and a dynamic balance test is finally conducted at high speed.

3. Blade and nozzle

The material is chrome steel, not only resistant to erosion and corrosion, but also able to suppress vibration. The vane section is of proven high-efficiency design and the flow pattern follows a free vortex pattern.

The last stage blade, stellite-clad to protect it against drain erosion, is 23" long and silver brazed with lacing wire to prevent vibration.

The nozzle is fabricated of chrome steel.

The diaphragm is made of steel plate to facilitate repair should trouble arise after long-time operation.

The diaphragm is provided with a labyrinth packing seal to restrict shaft leakage.

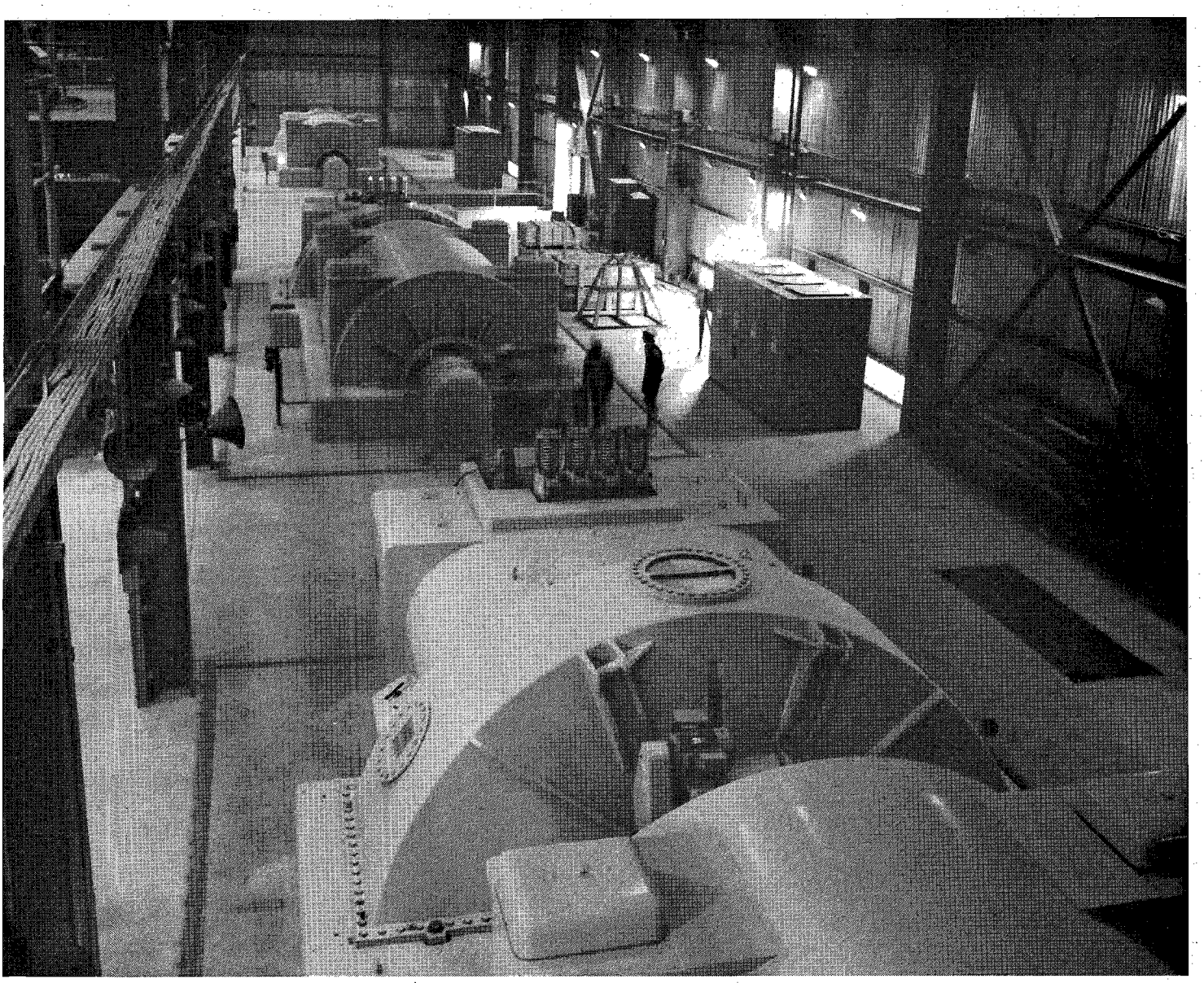
(III) TURBO-GENERATOR

Generator Type

Three-phase, totally enclosed, forced air-cooled, horizontal, direct-coupled to turbine type synchronous generator with cylindrical rotor.

Rating:

No. of Poles	.....	Two (2)
Capacity	.....	55,000 kVA
Speed (rpm)	.....	3,000 r.p.m.
Voltage	.....	11,600V
Frequency	.....	50Hz
Power Factor	.....	0.9 (lag.)
Short-circuit Ratio	.....	Not less than 0.66
Insulation Class	.....	B
Excitation System	.....	Static excitation system with saturable current transformer and power potential transformer.



Three 3,000 r.p.m. Toshiba Turbines, each generating 45,000KW are shown operating in the 135MW power station at Anewa Bay. The station supplies power for the Panguna mine site (via a 132KV line) and Arawa town (via a 22 KV line).

Special features of the 55MVA turbine-generators and accessories for the Bougainville Copper Pty. Ltd. are as follows.

1. Easy Maintenance

Taking into consideration that they were installed on Bougainville Island, we exerted efforts to obtain generators that require a minimum of maintenance.

As a result, the generators are an air-cooled type (although we would normally select hydrogen gas-cooled type generators from the viewpoint of economy). They are the largest air-cooled type generators that Toshiba has ever produced.

A static excitation system which has no rotating parts was applied, thus anticipating less maintenance.

2. Tropicalized Treatment

Bougainville Island has a tropical climate. Generally speaking, such climate is not suitable for electrical equipment. However, Toshiba has had much experience with such equipment, since many locations in Japan have similar moist climates. Based on past experience, we gave special consideration to the selection of materials, exterior finish, and plating.

(IV) INSTRUMENTATION & CONTROL

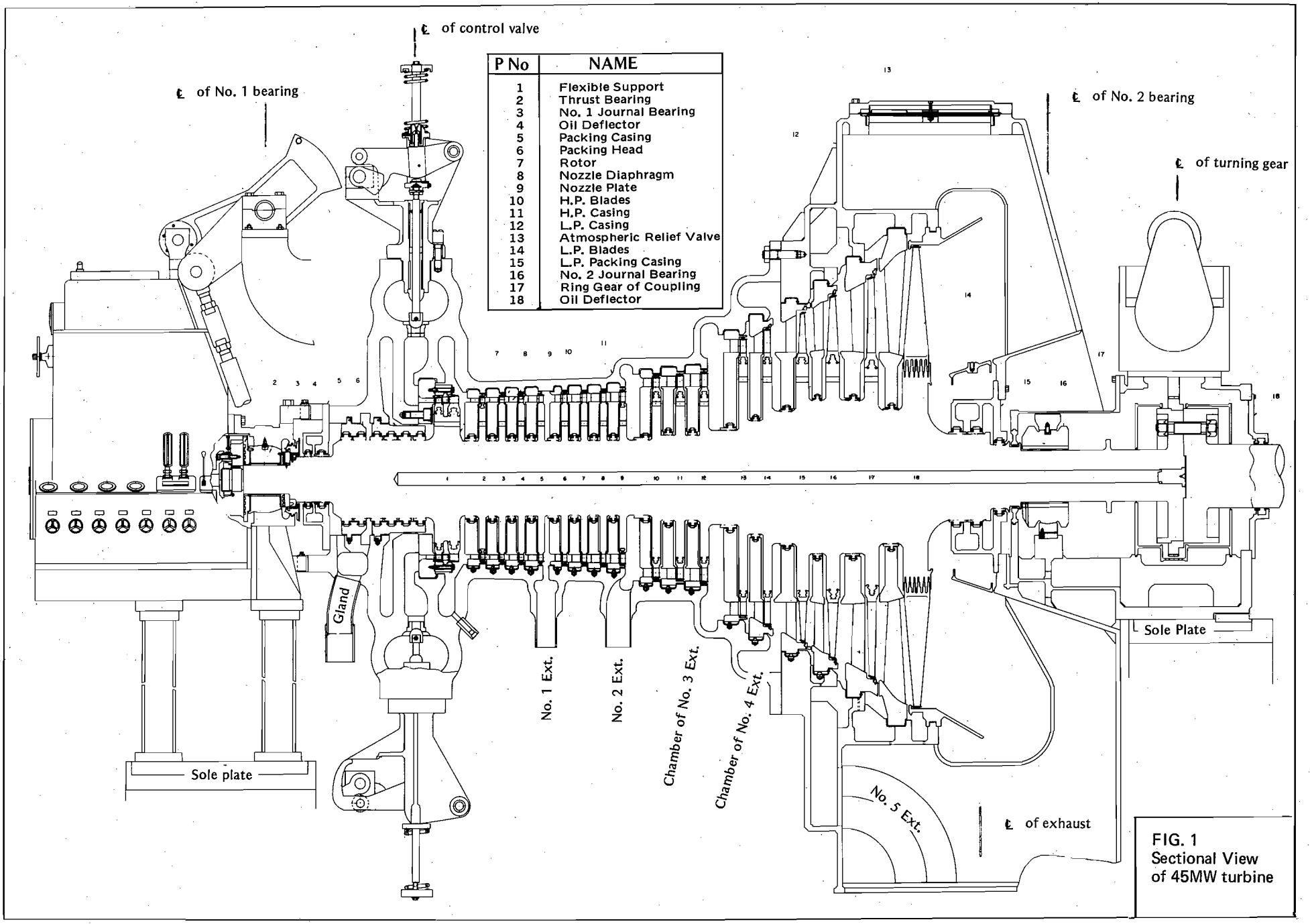
The turbine is started from the turbine starting panel installed adjacent to the turbine; load control is subsequently effected at the turbine control board. Turbine safe operation is also supervised at the board.

Turbine supervisory instruments with high reliability are supplied and installed on the turbine control board. The system consists of the following.

1. Recorder

Eccentricity, speed, valve position recorder .... single-point inking recorder which records rotor eccentricity when the turbine is turning, speed when the turbine accelerates to the rated speed, and valve position when the generator is in line.

Shell and differential expansion vibration recorder .... Six-point printing recorder with two tracks which records



P No	NAME
1	Flexible Support
2	Thrust Bearing
3	No. 1 Journal Bearing
4	Oil Deflector
5	Packing Casing
6	Packing Head
7	Rotor
8	Nozzle Diaphragm
9	Nozzle Plate
10	H.P. Blades
11	H.P. Casing
12	L.P. Casing
13	Atmospheric Relief Valve
14	L.P. Blades
15	L.P. Packing Casing
16	No. 2 Journal Bearing
17	Ring Gear of Coupling
18	Oil Deflector

FIG. 1
Sectional View
of 45MW turbine

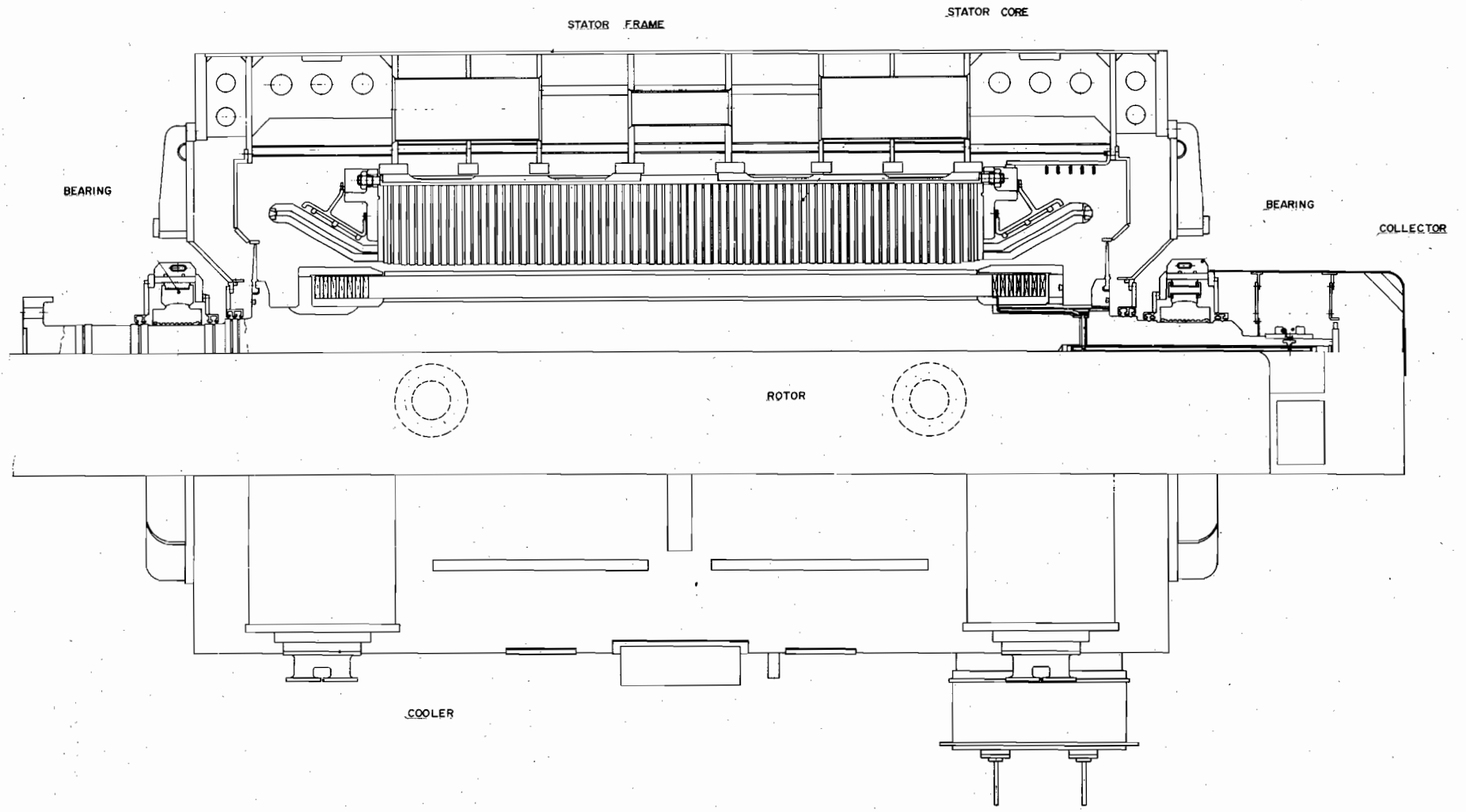
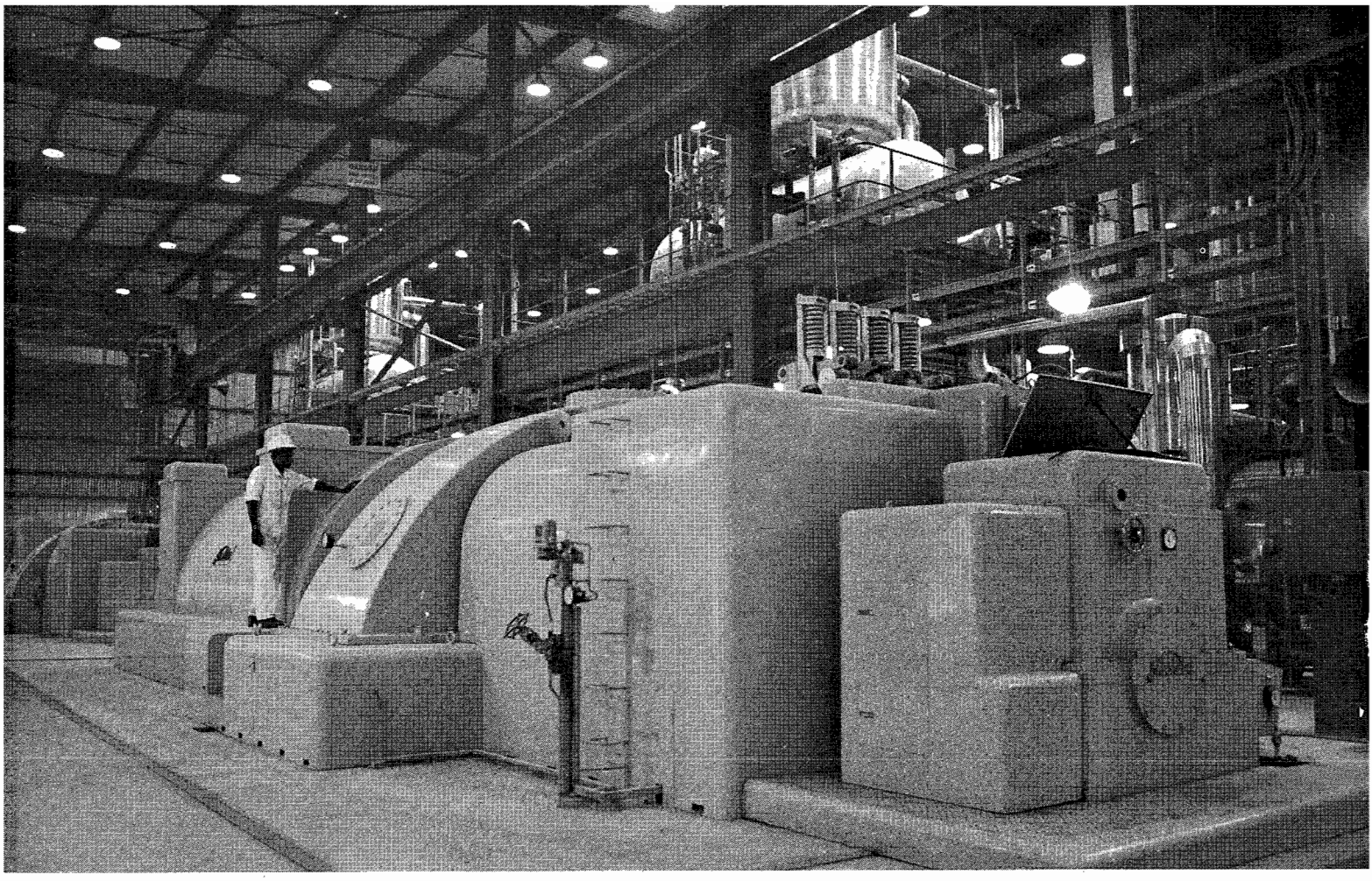


FIG 2 SECTIONAL VIEW OF 45MW GENERATOR



Another view of the Toshiba-Turbines at Bougainville.

casing expansion, relative expansion between rotor and casing, and peak-to peak amplitude of vibration of the turbo-generator bearings.

2. Amplifier

Eccentricity, speed, valve position amp. . . . . Feeds the proportional DC signals of each measurement to the recorder.

Shell and differential expansion amp. . . . . Feeds the proportional DC signals of each measurement to the recorder.

Vibration amp. . . . . Feeds the proportional DC signals of 4T/G bearing vibrations.

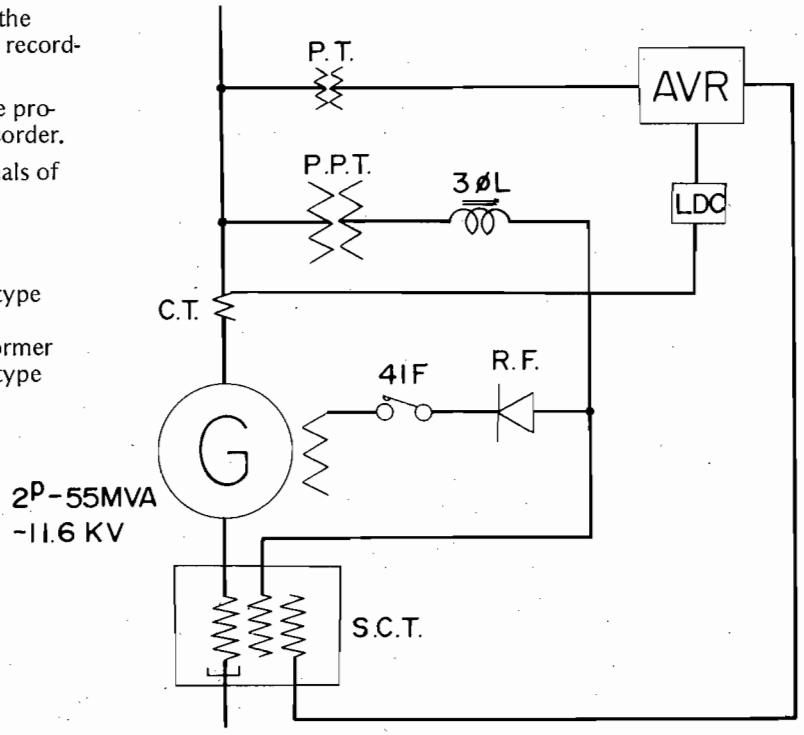
3. Detector

Speed detector.....Tachogenerator
Eccentricity detector..... Impedance bridge type
Valve position detector ..... Potentiometer
Shell expansion detector ..... Differential transformer
Diff. expansion detector ..... Impedance bridge type
Vibration detector ..... Dynamic type

<<ABBR.>>

P.T.	:	Potential Transformer
AVR	:	Automatic Voltage Regulator
P.P.T.	:	Power Potential Transformer
S.C.T.	:	Saturable Current Transformer
L.D.C.	:	Line Drop Compensator
R.F.	:	Rectifier
3øL	:	Three Phase Reactor
41F	:	Field Switch

EXCITATION SYSTEM



Motor Control Centres

BATEBILT PROVIDES "POWER UNDER CONTROL"

The steam power station which provides power for the Bougainville project can supply 135,000 kW of power for the various mining and treatment plants and ancillary services.

More than 1,000 motors consume this power. These motors are divided into groups and controlled by motor control centres which receive the signals from the sophisticated automatic control devices and provide the "muscle" for switching individual motors or large blocks of power as required by the ore production and treatment processes.

The control of this power is entrusted to the "Batebilt" withdrawable type motor control and distribution centres made by the manufacturing division of Barker & Taylor Pty. Ltd. of Melbourne, Australia who won the contract against world-wide competition. Barker & Taylor also manufactured the low voltage main switchboards and the relay panels.

The Batebilt motor control centres have many novel and patented features but the special features which influenced their selection for this project are firstly their proven and tested high short circuit performance and secondly their flexibility and adaptability to accept the inevitable last minute changes in design.

Barker & Taylor are justly proud of their proven ability to design and manufacture such high performance equipment and deliver it on schedule under the high pressure conditions which invariably apply with major projects of this type.

Their successful performance with the Bougainville copper project exemplifies the steady and widespread progress the group has made in the electrical engineering field since the inception of the company in 1951.

Wholly Australian owned, the company has steadily expanded its capacity in the complementary fields of electrical contract installation and switchboard manufacture, with emphasis on the professional engineering and management approach necessary to achieve its acknowledged leadership in both fields.

The Batebilt Draw-out Motor Control Centre is the result of an extensive programme of research and development, taking into account the latest overseas trends and the demands of modern process industries where centralized control of motors is fundamental to the efficient operation of the electrical system.

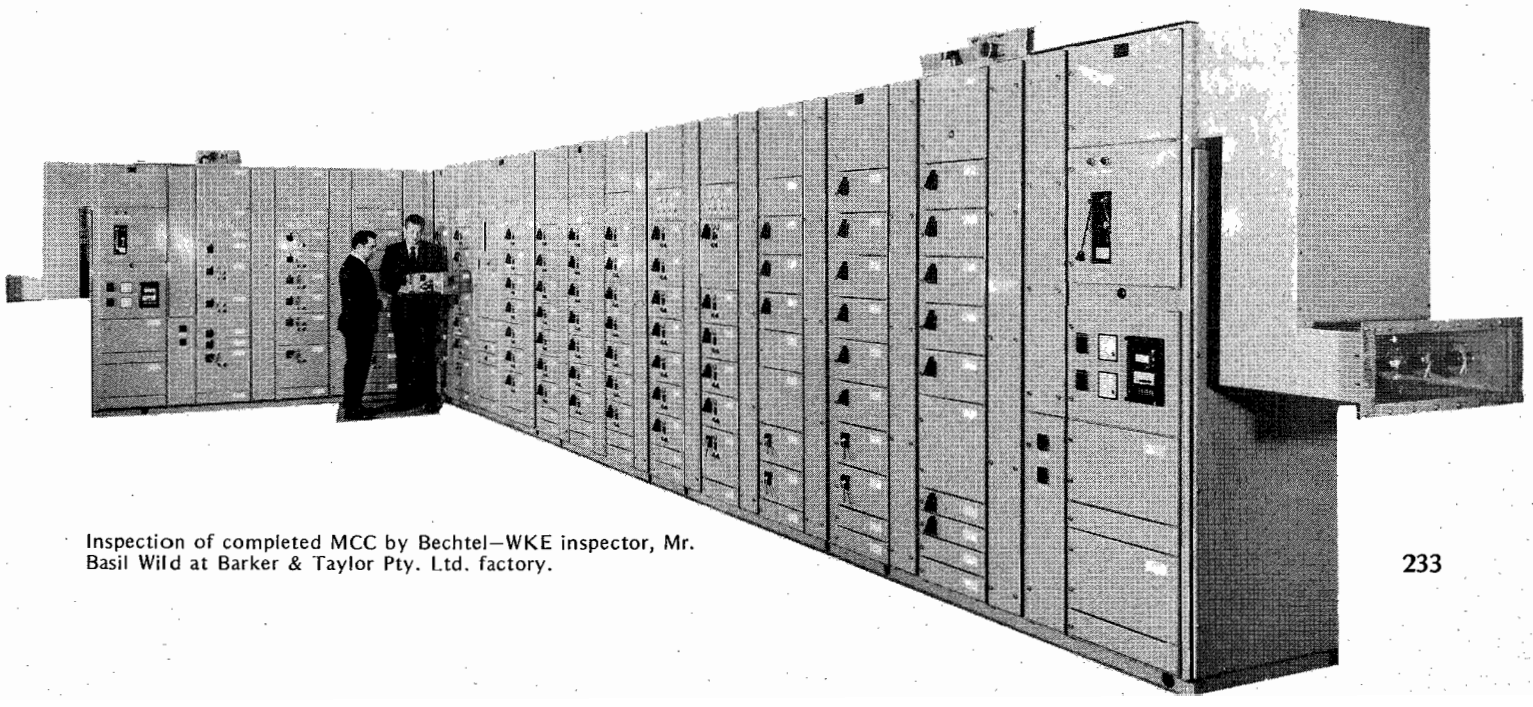
It is a completely Australian development, designed by engineers with intimate experience of the special requirements of major industrial projects where remote sites, extreme ambient conditions, rush programmes, last minute changes and sophisticated automation techniques demand the utmost in reliability, flexibility of arrangement and facilities for safe and speedy operation and maintenance.

Great emphasis is placed on the ability of the equipment to withstand, confine and control the effects of electrical energy on the rampage under short circuit conditions.

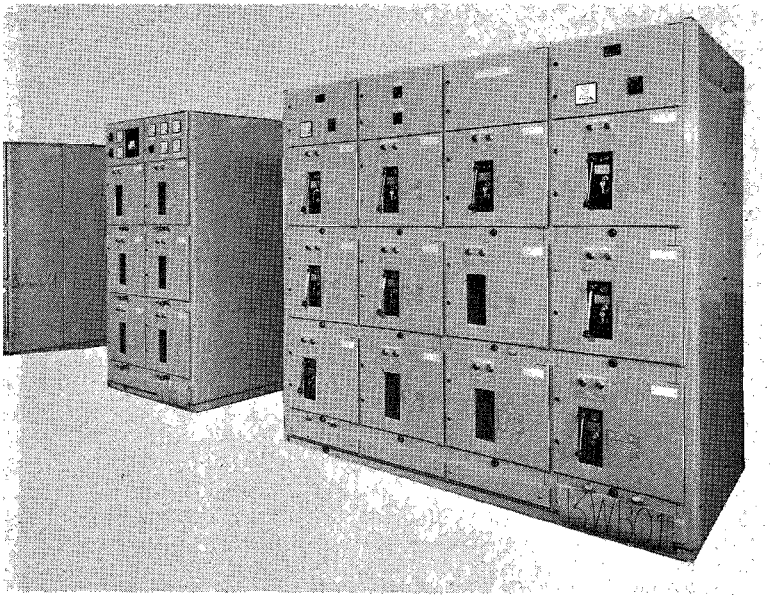
The Batebilt motor control centre is of attractive, flush fronted modular design with unequalled compactness.

The front access, fully withdrawable "in-depth" arrangement gives minimum frontal area per unit and minimum length with resultant savings in switchroom floor space.

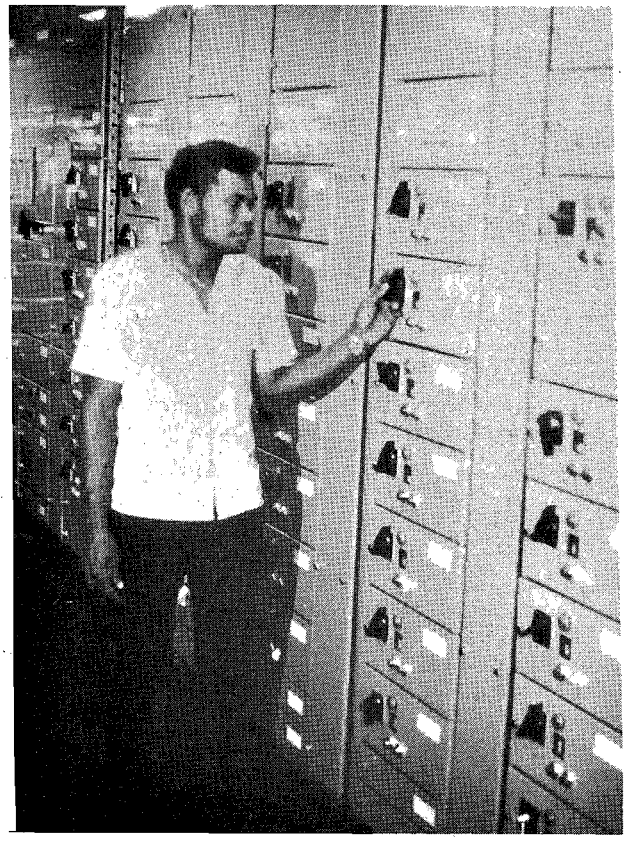
Accessibility is a feature – all load circuit components, cables and terminations are accessible from the front. Units are easily withdrawn for inspection, testing, maintenance or replacement – complete shut-down is unnecessary. Cable entry is from above or below, and special attention has been given to provide ample space for laying and terminating the large multicore control and power cables used in large automated projects.



Inspection of completed MCC by Bechtel–WKE inspector, Mr. Basil Wild at Barker & Taylor Pty. Ltd. factory.



Low voltage main switchboards at Barker & Taylor Pty. Ltd. factory.



Typical MCC in service at Bougainville.

Typical MCC with direct busbar connection to transformer.

The freedom of access provided by the fully withdrawable double isolation units allows operation and maintenance staff to work under fundamentally safe conditions. The separate motor isolating switch with rugged interlocks ensures that the compartment is closed and sealed before the equipment can be energised. The motor isolating switch is tested to break stalled motor currents.

The fixed portions of the cubicles are identical regardless of the modular arrangement of starters or CFS units so that great flexibility is achieved to allow re-arrangement at short notice on site. The only tools required to change the modular arrangement are two spanners and one screwdriver.

The welded base channel and side frames, heavy gauge structural members and solid bolted assembly provides inherent strength and robustness and all steel-work is fully tooled and jig-built to ensure inter-changeability to allow for speedy replacement or re-arrangement.

Each standard direct-on-line motor starter draw-out unit is complete with motor isolating switch, contactor, thermal overload relay and HRC fuse cartridges, the latter being contained in a moulded carrier which plugs directly onto the vertical bus. Control devices such as local and remote push buttons are provided to meet specified requirements on site.

Outgoing connections both for power and control dircuits are made by robust self-aligning contacts at the side of the unit, immediately adjacent to the cabling area and outgoing cable terminations are made at the side of the unit on a cable terminating plate, which can when desired, be withdrawn to allow terminations to be made off in front of the cubicle.

The combination switch and fuse units supplied are also fully withdrawable, and are similar to the starter units.

All equipment is tropicalized to meet the onerous climatic conditions on site, and special circuitry is provided in the motor control centres to automatically supply a low voltage supply for anti-condensation heaters in the motors whenever they are idle.

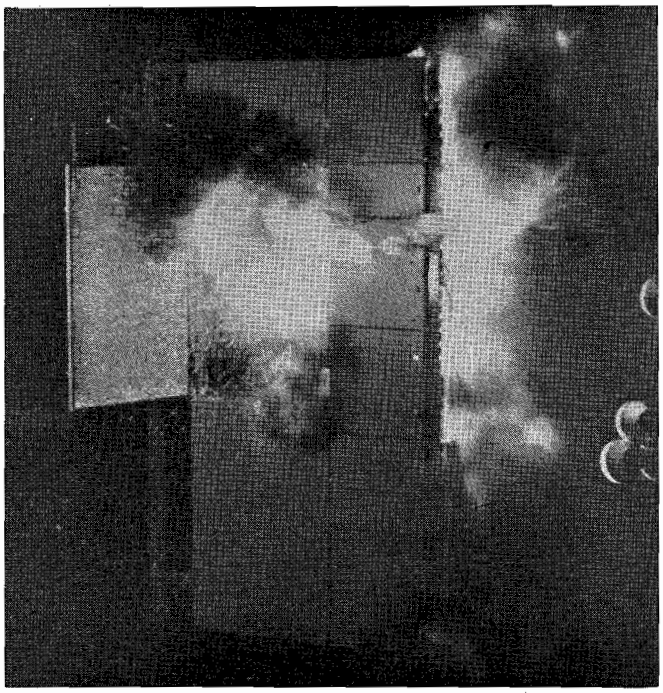
Short circuit performance

The massive scope of a project such as Bougainville, whilst providing cost benefits due to the scale of production, brings in its train other problems such as larger concentrations of power and consequently higher short circuit currents.

If a major electrical short circuit occurs at Bougainville then 135,000 kw of rotary energy at the turbines is available to pour itself into the fault, limited only by the natural resistance of transformers and transmission lines. Short circuit currents up to 40,000 amperes or more can occur on the low voltage system and, until protective devices operate to clear the fault, electrical energy goes on the rampage, twisting, melting and vapourizing copper and steel and creating hazard to life and property.

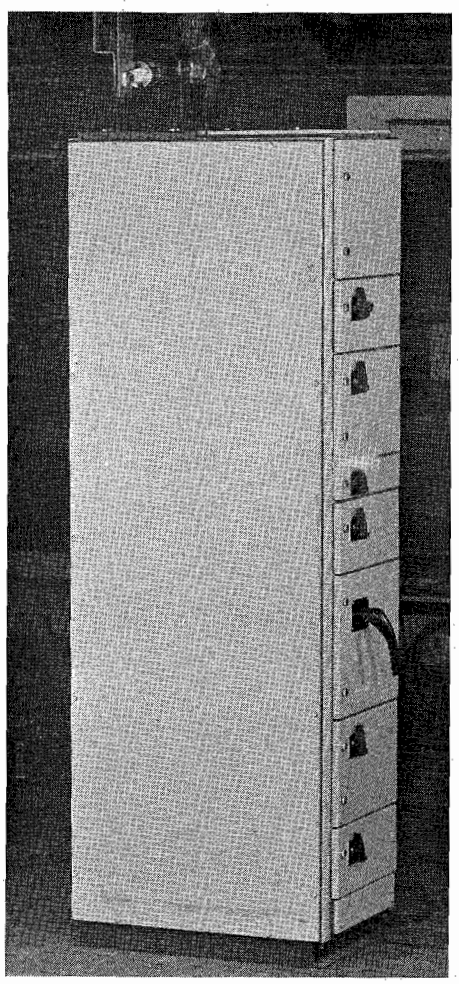
The effect is spectacular but the spectacle of plant lying idle for weeks awaiting the re-building of a switchboard is not pleasing to the eye of a project manager when the value of production can be measured in thousands of dollars per hour.

The problem is not new and short circuit performance and type testing of switchboards is a subject of major importance to engineers.



Photograph "A" during uncontrolled arcing fault.

Photograph "B" controlled arcing fault.



Until recently the stress was laid upon such items as busbars and circuit breakers, but greater recognition is now given to the importance of confining and controlling short circuits, especially arcing short circuits which can occur within the switchboard itself.

The Batebilt Motor Control Centre complies with British Standard Specification BS 4070 (Class 3CF) which classifies the degree of damage to be expected or tolerated in the event of both internal and external short circuits and includes stringent test clauses to prove the short circuit capacity of the switchboard and its components as a complete assembly.

The equipment was fully short circuit type tested to all relevant clauses of BS 4070 – 1966, Class 3 CF including:–

(a) BUSBARS
Bolted faults to 43 kA for 3 seconds, 50 kA for 1 second, at 415 volts. These tests prove the integrity of the busbar system and the general strength and robustness of the cubicles.

(b) MOTOR STARTERS
External bolted faults on prospective 43 kA to prove the short circuit co-ordination of fuses, plugging contacts, contactors, overload relays, isolating switches and inter-connections.

(c) COMPARTMENTS
Internal arcing faults on prospective 43 kA at 415 volts (open wire fuses) to prove the overall strength of construction and the ability to confine damage to the faulty compartment.

The busbars, load circuit equipment and cables are in separate enclosed zones to prevent internal electrical faults from spreading within the board.

Photograph A illustrates the spectacular effect of an uncontrolled arcing short circuit which occured during testing of a prototype motor control centre in 1968 at Sydney County Council Testing Laboratories. The arcing current in this test was 20,000 amperes and the fault lasted for 11 cycles (1/5 second) until cleared by the master circuit breaker on the testing station.

Photograph B was taken during a later series of successful tests on a production model motor control centre. The photograph B, taken at the same relative instant as Photograph A shows the dramatic improvement in control and confinement of the arcing short circuit, achieved by the Batebilt gas venting system. This was one of a series of five similar tests carried out on this cubicle, all in one day, following which the M.C.C. was still in servicable condition.

Such built-in safety features, allied with the proven advantages of fully withdrawable motor control equipment, provides real advantages on remote mining projects where staff turnover is high and operating labour is inexperienced or unskilled. These and other features of the Batebilt motor control centres have been proven not only at Bougainville, but also at Nabalco, Gove, Western Mining Co., Kwinana, Mount Isa Mines, Robe River, Greenvale Nickel, and many other projects where profitable operation depends in large degree on the reliability of the electrical system.

Australian and overseas patents have been awarded to Barker & Taylor for the principal design features, and the company has arranged manufacturing licencees in many other countries.

Transformers

Tyree Industries (Vic.) Pty. Ltd.,
Thomastown, Victoria, Australia.

TYREE TRANSFORMERS FOR 3300 VOLT DISTRIBUTION SYSTEM

The treatment plant at Bougainville uses a large number of 415 Volt motors supplied from switchboards strategically located throughout the plant. Each switchboard is fed from the 3300 Volt distribution system via a transformer and Tyree is proud to be selected by Bechtel-W.K.E. as the supplier of the vital link between the 3300 Volt system and the 415 Volt system.

The contract involved over 30 transformers, ranging from 200 kVA to 1000 kVA, including 18 rated at 1000 kVA, all supplied by the Specialty Division of Tyree Industries Ltd., from the Keon Park, Vic. works.

An order of this nature highlights one of the factors behind the growth of the Division by the supply to industry of a product especially tailored to meet the exact requirements of a specific industry, whether they relate to the electrical requirements of the transformer, its mechanical construction or to economic factors such as reliability and ease of maintenance.

Some of the distinguishing features of the transformers supplied on this contract were:

Sealed Construction

For the tropical conditions encountered at Bougainville, Bechtel-W.K.E. specified sealed construction. This was achieved by using a gasketted and bolted top cover with the tank height arranged so that there is always an air space above the level of the insulating fluid, irrespective of the temperature of the insulating fluid.

As the fluid is never in contact with the outside air, the transformers should operate for many years without deterioration of the fluid in normal operation.

A pressure relief vent in the form of a rupturable diaphragm is fitted to guard against an excessive internal pressure.

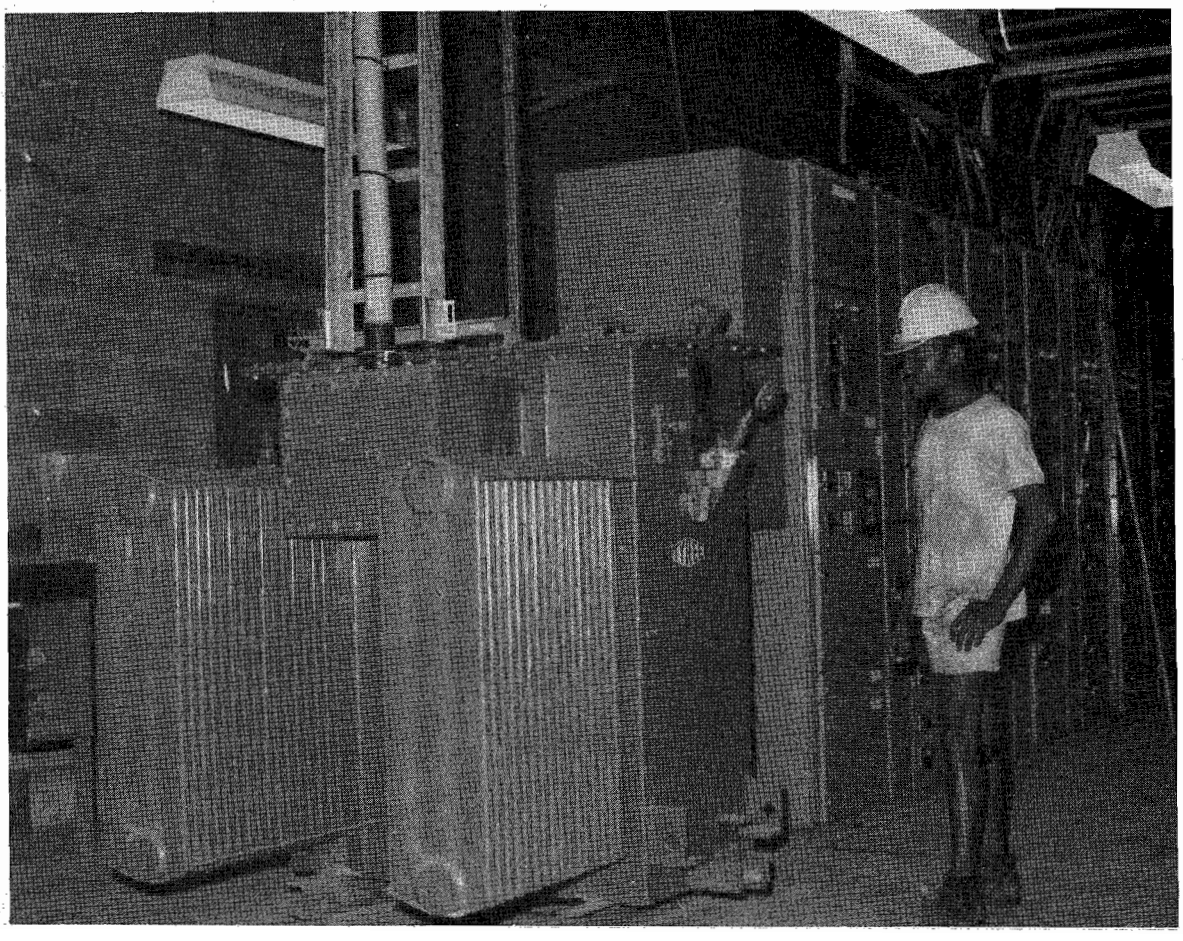
Air Insulated H.V. Cable Box

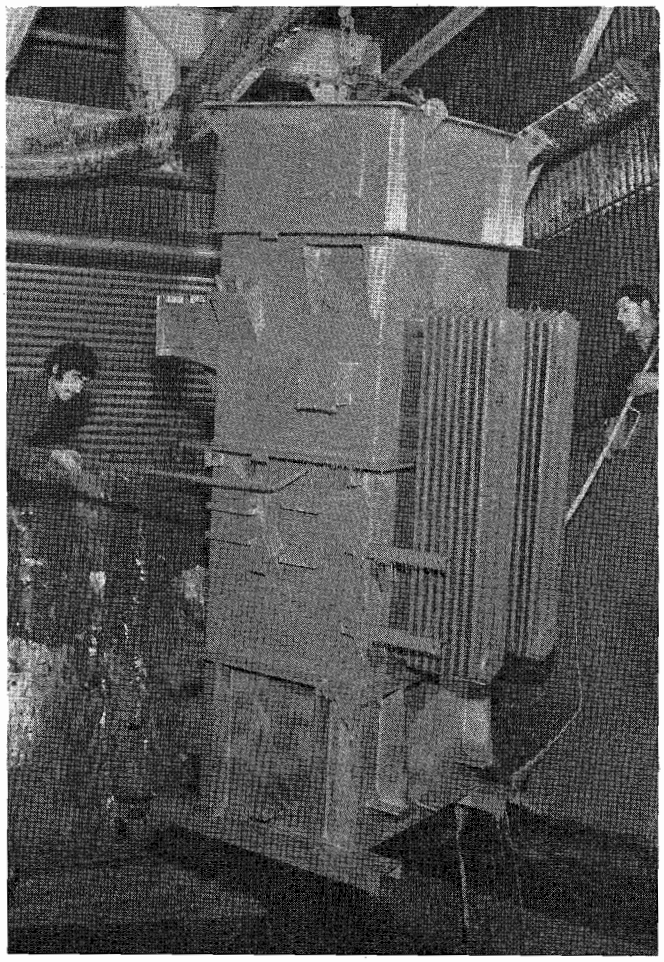
With one or two exceptions, all the 3300 Volt cables enter the cable box from above, the cables being run overhead, dropping down to the transformers. Instead of the more usual compound filled cable box, an air insulated box is used, with bushings spaced to give the necessary clearances in air. This type of cable box facilitates the cable termination procedures and also makes any subsequent removal of the cable easier.

Bus Duct Flanges for L.V. Bushings

The busbars from the 415 Volt bushings to the switchboard are enclosed in ducting which terminates in a flange which bolts onto a corresponding flange on the transformer. This feature makes it possible to mount the transformer close to the switchboard and at the same time provides an easy method of removing the transformer.

To make the transformers readily interchangeable, only 3 different bushing heights and flange dimensions were used for the complete range of transformers.





GENERAL CONSTRUCTION

The transformers were 'Spacemiser' design as developed by Westinghouse of U.S.A. (Tyree is a member of the Westinghouse Group, and the sole Australian licensee for Westinghouse transformers).

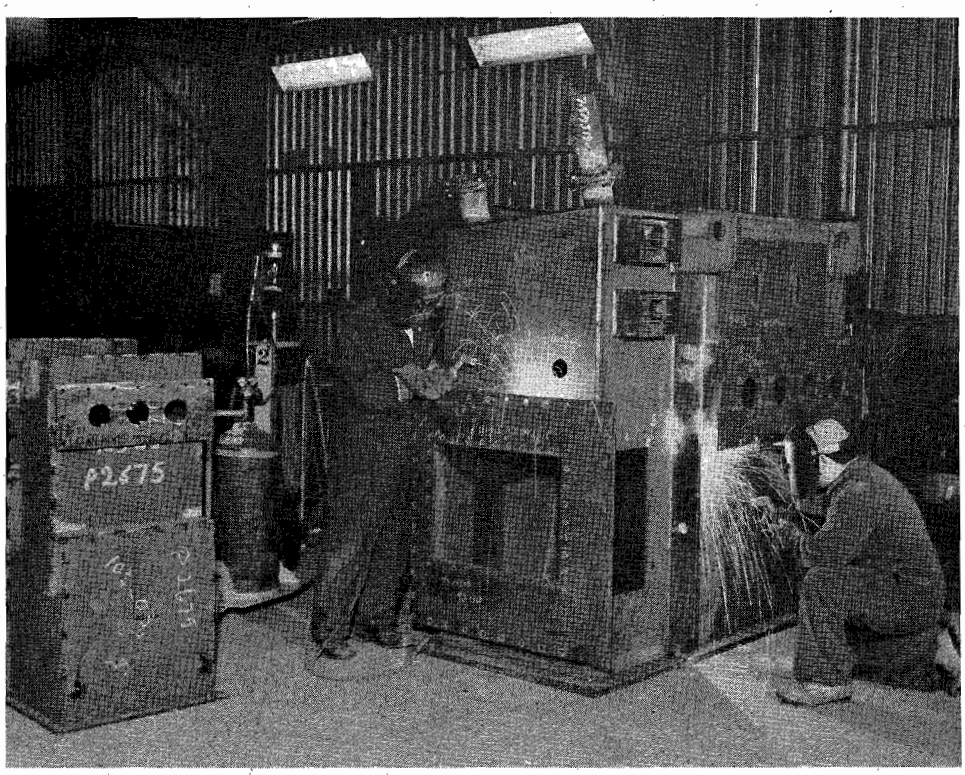
The 'Spacemiser' design uses a rectangular section core with mitred interleaved joints. This gives low magnetising currents, low and consistent iron losses and low noise levels.

Coils are wound on a rectangular former with the L.V. winding made from sheet conductor, using a thermo setting stableized insulating paper for interturn insulation. The H.V. winding, using rectangular section paper covered conductor, is then wound over the L.V; again the interlayer insulation uses the specially prepared insulating paper. The complete coil is then cured so that the H.V. and L.V. windings are bonded together and as a result, no shrinkage of the coil is possible during service.

The tanks are designed and braced to meet the conditions experienced during vacuum testing, transport and in service. The external surfaces are abrasive blasted before application of the priming coat and finishing coats. These are applied by the flow coating process which gives a uniform coat on all surfaces with excellent adhesion.

OTHER TYREE TRANSFORMERS AT BOUGAINVILLE

Under separate contract to Bechtel-W.K.E. Tyree supplied two 500 kVA 13200/3300 volt ratio transformers for the electrical reticulation at Panguna and since the initial installation have supplied a 7500 kVA transformer 13200/3300 volt ratio for the Concentrator Substation.



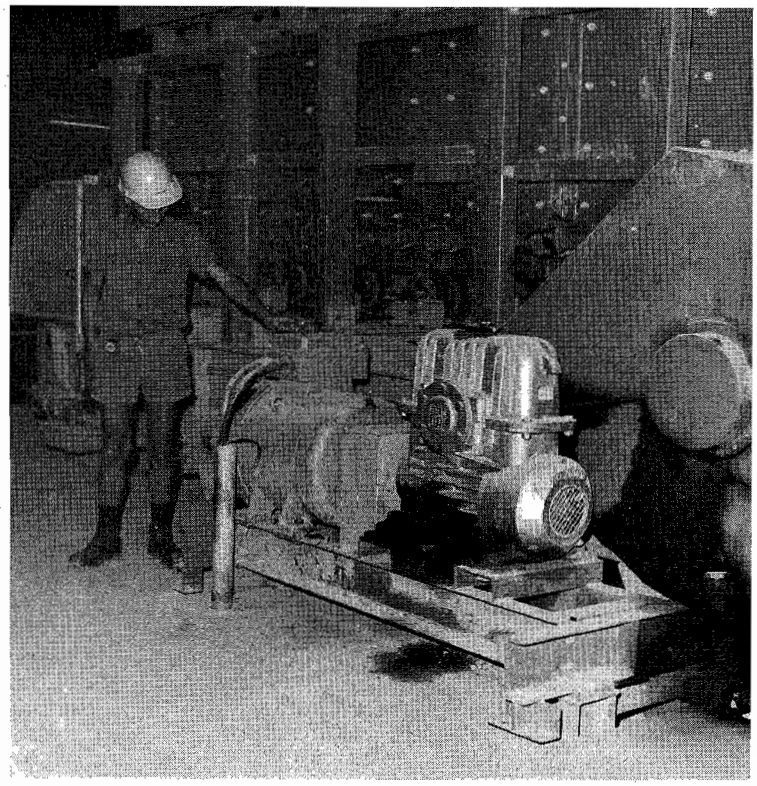
Left: 500 kVA Transformer in fine crushing plant area.

Above: Application of priming coat by the flow coating process, to the abrasive blasted transformer tank.

Right: Typical tank fabrication.

Variable Speed Drives

Electric motors, variable speed drives and hoists from ASEA.



ASEA DC motor—type LAC250
driving Apron Feeder for Secondary Crushers.

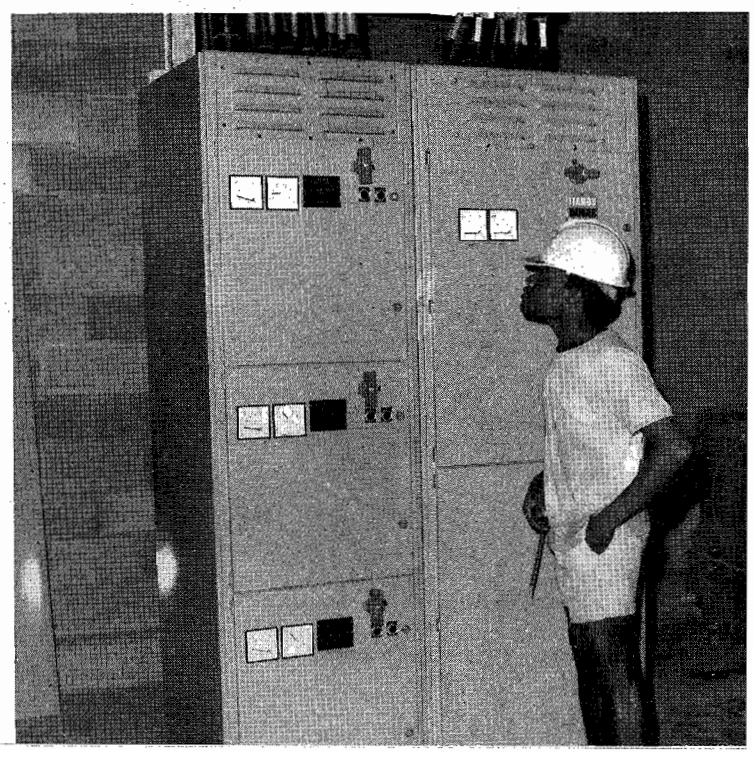
ASEA variable drives are playing an important role in powering the primary apron feeders in the primary crusher, the reclaim apron feeders and the secondary apron feeders.

Four 50 h.p. variable speed drives are used on the primary apron feeders. The motors are located at the second lowest level of the primary crusher, with cubicles in the primary crusher switch-room. The drives, which are controlled from the Primary Crusher control room, can be operated either manually or automatically.

The 50 h.p. motors involved are Type LAC 315, foot-mounted, totally enclosed, with heat dissipated through the casing. Special labyrinth seals are fitted for the very arduous operating conditions. Each motor is fitted with a BD 2510 tacho-generator.

The converters are Type ARWE 500/100, input 415v, 3 h.p. 50 HZ; output 0-460v DC, 100A continuous. Each is fitted with an internal fan and filter for dusty conditions. Facilities for remote control via 4-20mA signal and for controlled acceleration are provided.

Thyristor convertors for Reclaim Apron Feeders.



Of the sixteen ASEA 20 h.p. variable speed drives supplied, 10 are used on the reclaim apron feeders located in tunnels under the coarse ore stockpile some distance from the control room, while six are located on the secondary apron feeders above the secondary crushers.

The motors are Type LAC 250, as for 50 h.p. motors, but are rated at 20 h.p., 1500 r.p.m.

The converters are Type ARVG 350/90, input 415v, 1 ph, 50 HZ; output 0-350v DC, 90A DC continuous, as for 50 h.p. drives.

In addition to the DC drives, ASEA has also supplied eleven hoists with cable wheels and cables, ranging from ½ to 5 ton capacity for various applications on the fine crushing plant. All equipment including switchgear controls and hoists were tropic-proofed to very strict specifications laid down by the project managers Bechtel–W.K.E.

Electrical Equipment

F.P.E. Australia Pty. Ltd.,
Sydney, Australia.

FPE ELECTRICAL EQUIPMENT AT SITE

An essential commodity at all large project sites is the ready availability of electrical power. Major considerations in the selection of the power generating and distribution equipment are prompt delivery to meet site programmes and service reliability when installed.

For the Bougainville Copper Project, the Designer/Builders, Bechtel–W.K.E. chose FPE Australia Pty. Ltd., to supply the 20 panel 6,600 volt, 250 MVA Oil Circuit Breaker Switchgear for the initial power station installation.

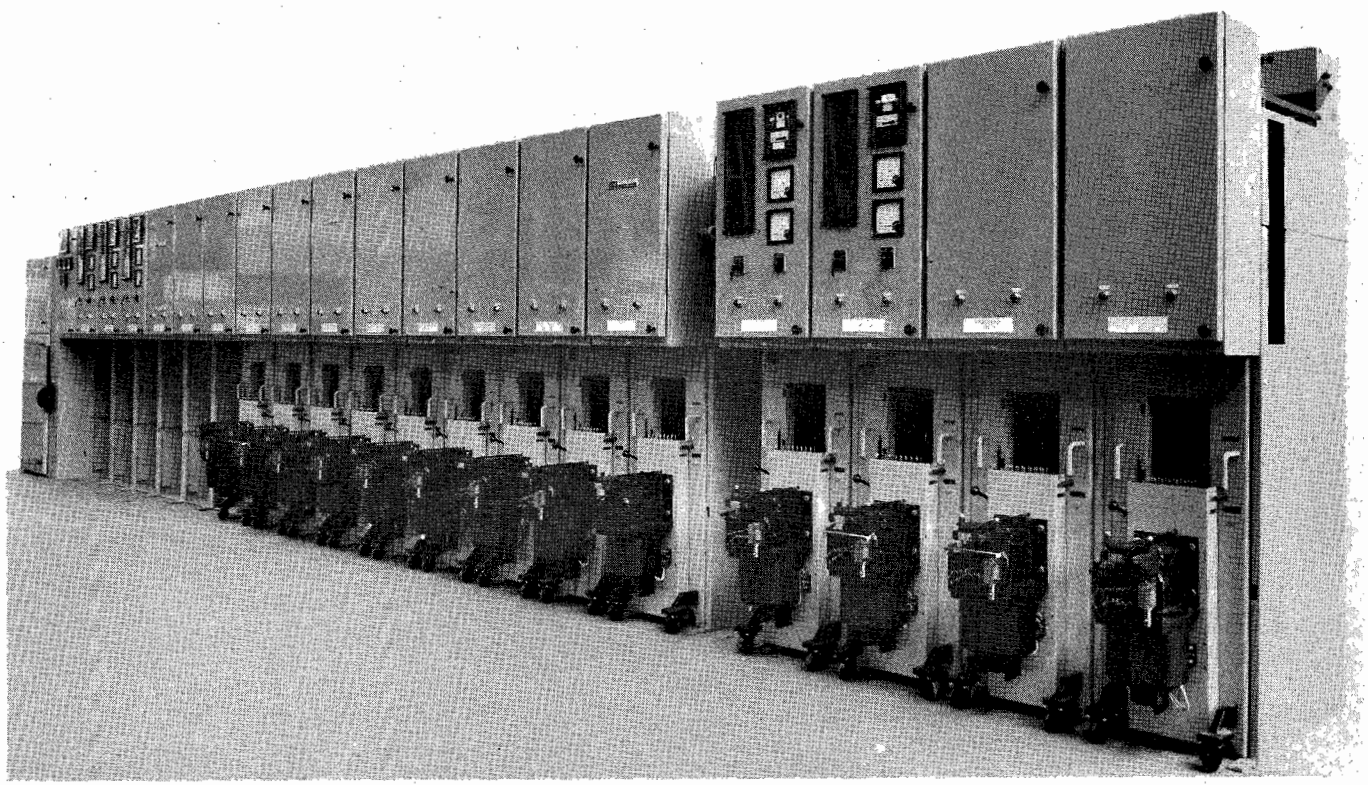
The power station comprised ten–1100 KW Diesel powered generating sets and the FPE Switchboard consisted of ten Generator Unit Panels, two Bus-Tie Panels and eight Feeder Panels, Circuit Breakers being the type PDB16/B fitted with solenoid closing mechanisms. The board was tropic proofed to suit local conditions. A large quantity of the initial power produced was used to supply the electric power shovels employed in loading the 100 ton haul trucks associated with removal of overburden.

At the purchase date the shortest possible shipping date was of major importance and, in all the switchgear was completed and despatched in just over ten weeks from order. At a later date, to coincide with site construction a team of FPE technicians was sent to site to complete installation and commissioning of the equipment.

In addition to the above switchgear supplied for the construction section of the project, as part of the major plant equipment FPE supplied some 300 feet of indoor and outdoor 3,300 volt bus duct of various current ratings. These ranged from 1200 through to 3000 amps and utilized copper conductors of rectangular section. The busducts were installed to distribute the 3.3kV power system from each of the step down power transformers to the various 3.3kv load centres.

All enclosures were constructed from light gauge sheetmetal which was specially treated to withstand the adverse climatic conditions associated with tropical regions. All ducts were totally enclosed non ventilating types and were provided with space heaters to minimise condensation within the duct. Where ducts passed through external walls of buildings fire barriers were provided.

20 panel 6,600 volt 250 MVA type AG16 oil circuit breaker switchboard shown during final assembly at the Liverpool plant of FPE Australia Pty. Ltd.



Water Supply and Treatment

M.J. Stevens,
The Permutit Company of Australia Pty. Ltd.

Before any serious work can begin on a new project in a remote location such as Bougainville, a palatable water supply must be provided. Natural water supplies, even if they are abundant, are seldom suitable for many uses and the river waters available at Bougainville contained suspended particles and organic matter, typical of this type of supply and varying in quantity according to location and season.

Initially, several mining camps were set up at different locations and each needed a safe water supply for drinking and general domestic use. Each camp had to be provided with its own water treatment plant to remove the suspended particles and organic matter, and produce sterile water. The locations of the camp sites meant that the treatment plants had to be supplied as completed units where possible, with a minimum of on-site assembly work. They also had to be very simple to operate and have foolproof controls.

The PERMUTIT Company of Australia Pty. Ltd. has had considerable experience with every type and size of water treatment system, and especially with jobs in difficult locations, where there are limited operating and maintenance personnel available. A basically conventional treatment system was designed into a packaged treatment unit, made and fully works-assembled in Sydney, then shipped in skid-mounted sections to Bougainville.

The treatment system is firstly to deliver the raw water into a small open holding tank where it is dosed with three chemicals. Aluminium sulphate is used for coagulation, with soda ash added to produce the correct pH for complete flocculation of particles and organisms. For sterilisation liquid sodium hypochlorite is used – this being the simplest and safest method bearing in mind the operating conditions of the plants. The chemicals are prepared and stored in polythene tanks and injected by a triple-headed diaphragm pump driven by a single motor.

From the holding tank, the water is pumped into a pressure sand filter, where the floc particles which have been formed by the coagulation process, are removed. The filter incorporates a retention section above the sand bed to give time for this process to occur, thus avoiding the usual large separate flocculation tank.

To ensure that the treated water is always sterile, regardless of variations in the incoming water, it is necessary to add sufficient chlorine to always leave a residual and the final stage of treatment is to remove this residual chlorine.

The water from the sand filter, still under pressure, is passed through another filter which contains a bed of activated carbon where this occurs. The treated water is then delivered to an elevated storage tank and this provides a volume of clean water at a high flow rate which is needed for backwashing the sand filter, also the carbon filter, although its washwater requirements are much less. This system eliminates separate washwater storage and pumping equipment, again simplifying the treatment system.

Controls are simple and automatic; a balanced float valve controls the incoming raw water into the holding tank, a level switch in the treated water tank controls the main pump and this in turn is linked to the chemical feeder so that chemicals are dosed only when the plant is operating.

The end result of this system is to remove from the incoming water, turbidity, colour, organisms, iron and colloidal matter.

PERMUTIT initially supplied three versions of this system – one for an output of 20,000 gallons per day, two for 60,000 gallons and one for 400,000 gallons. The two smaller units were completely assembled, piped and wired on steel skids, 8 feet wide by 13 feet and 16 feet long respectively, so that there was no difficulty with either road or sea transportation. The 400,000 gallons plant consisted of a skid, fitted with the holding tank, pumps, chemical dosing equipment and control centre, with the filters supplied separately. As there were two 9 feet diameter sand filters and a 7 feet diameter carbon filter, it was obviously not practicable to supply this plant in one piece. Following the successful installation and operation of these first four treatment units, PERMUTIT subsequently supplied two more of the 400,000 gallons per day systems and another two 60,000 gallons packages.

As well as domestic water, the project involves other specific water demands for processes, which require different methods of treatment. One such application is for feed water to the evaporator at the Power Station which was specified to be free from turbidity and hardness. PERMUTIT supplied a system comprising three Pressure Filters charged with anthracite and having fully automatic control of backwashing, followed by two Water Softeners, also with fully automatic controls for regeneration.

Another application is the provision of chemically pure water which is essential for the initial start-up of the Power Station. PERMUTIT was able to supply, on immediate delivery, a packaged Mixed-Bed De-ioniser which is simply connected to the available water supply and instantly produces water of extreme purity.

Bougainville is, in fact, another of the many industrial and developmental projects where various water treatment skills are called for and met by the complete range of equipment designed and made in Australia by PERMUTIT.

Pollution Control

George I. Kaldor
Epco Pty. Ltd.,
Melbourne, Brisbane and Sydney.
Australia

THE PROVISION OF SEWAGE PURIFICATION PLANTS AT BOUGAINVILLE

Environmental Conditions

Well before the beginning of large scale construction work on the project, the need for effective protection of the island's environment and prevention of pollution of waterways and beaches was recognised. Villages and future camps were relying on water supply from the same streams, where others were to discharge their sewage. If these streams become polluted, it would create a serious health hazard for downstream native villages and camps. Some construction camps were located on the seashore, and the personnel used the beach for swimming. Pollution of waters on the seashore would therefore create serious health hazards.

Pollution Hazards

The elimination of various nuisances associated with sewerage became an important consideration. If raw sewerage is discharged into streams or offshore waters, the banks would be covered with sewerage solids, and in addition in turbulent streams by virtue of atmospheric aeration a biological process similar to treatment would take place on a reduced scale, and solids would coagulate, and also finely divided suspended solids would cover the banks. Likewise tidal currents may wash masses of coarse and suspended solids ashore. These solids deposited would not only generate intolerable, offensive odours, but also be a hot bed of disease producing bacteria, flies, mosquitoes, and other insects, and may become a source of serious epidemics.

Pollution Control by Sewage Purification Plants

The only way to control the discharge of raw sewage contributed by the construction camps and establishments associated with the project was by the installation of purification plants, which are sized to receive all wastewater discharged, and by virtue of effective treatment process remove all the polluting contents and potential from the sewage to such a degree, that it can be safely discharged into the streams and offshore waters without creating health hazards, thus the effluent after treatment was not to contain appreciable quantity of suspended solids, biochemical oxygen demand, coliform organisms, nutrients.

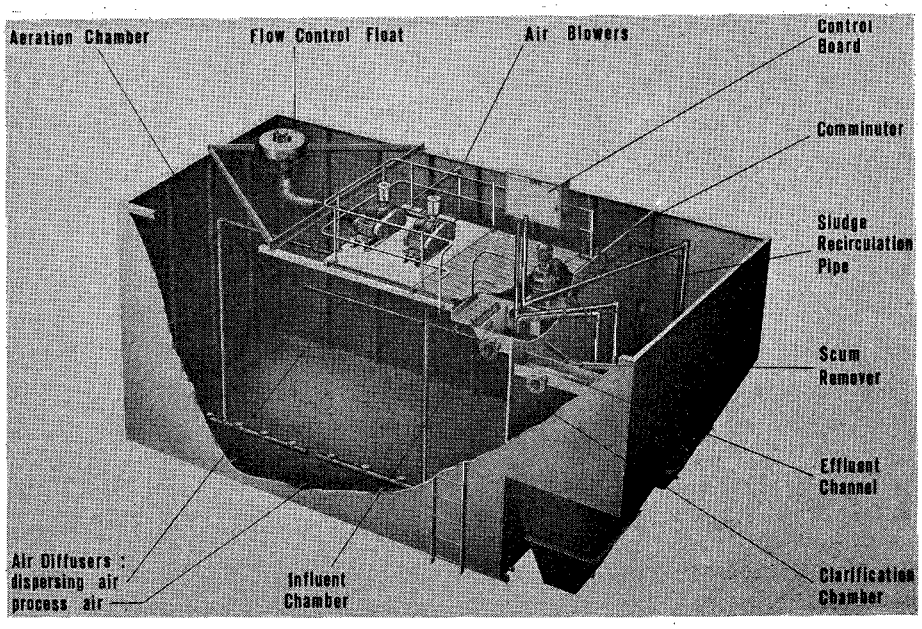
As the mine site was not easily accessible, and even the coastal construction camps had limited area available, the construction of permanent treatment plants would have taken too long and capital expenditures high. Also relocation of various camps envisaged brought up the necessity of using portable purification units, which can be transported on the construction roads available according to the programme of camp movements. As the personnel in the camps were subject to fluctuation, and the capacity of treatment units relocated could not be expected to match the next camp size, it was essential, that the process used should be capable of being underloaded, and to take periodical overloads without detriment to the quality of effluent produced. It was also essential, that the treatment plant unit and process should be capable of instantaneous start-up at full efficiency after installation or relocation.

Treatment Process and Plant

The extended aeration process utilised by portable packaged sewage purification plants was selected to fulfill the numerous requirements. The process builds up its treatment potential by developing a colony of bacteria within the treatment plant, accommodated by a mass of suspended solid particles, and the incoming raw sewage is mixed with the mass of suspended solids within the plant, and the bacteria consumes the organic polluting solids in the raw sewage in the presence of abundant air supply diffused. After 24 hours of aeration of the mixture of organic solids and bacteria (called "mixed liquor suspended solids"), the mixture passes a settling tank, where the mixed liquor suspended solids separate by settling and are recirculated to maintain the continuity of the process, and purified effluent evolving on the surface of the settling tank is discharged through the effluent weir. The effluent received tertiary treatment by chlorination to sterilise the effluent before discharge into the receiving body of water.

The treatment plant unit utilising the extended aeration process is portable, compact and relatively simple to install in any locality. The incoming raw sewage is immediately mixed in the influent compartment with the recirculated mixed liquor, establishing instant contact between the bacteria and organic pollutants. It passes a comminutor, which disintegrates coarse solids and is discharged into the aeration chamber, where diffused air supplied by blowers maintains the oxygen supply of the bacteria and keeps mixed liquor in turbulent suspension. After 24 hours of aeration the mixed liquor passed a flow

EPCO Pty. Ltd. are represented overseas in Great Britain, Fiji, India, Ceylon, Philippines, Indonesia, Singapore, Thailand and Malaysia.



Rectangular Portable Plant 2,500–60,000 G.P.D. capacity range.

control device reducing transfer flow leaving the aeration chamber and the moderated flow enters the settling chamber, where sludge containing the bacteria settles to the inclined hopper floor and is recirculated by air lift pump and the purified effluent overflows the outlet channel weirs and leaves the settling tank. In the subsequent chlorine contact chamber the chlorine injection sterilises the effluent before final discharge from the plant.

There are a number of advantages in the selection of the extended aeration treatment process and purification plant, especially at projects like the Bougainville scheme. It is capable of being periodically overloaded, or underloaded, in the latter case the aeration system is adjusted to the actual load conditions. The treatment process functions without the necessity of operational handling or constant attendance, which is also of considerable advantage, as qualified operating personnel are not readily available. High efficiency yields 95%-97% removal of biochemical oxygen demand and suspended solids from the raw sewage and produces clear, stable effluent. Tropical conditions increase the efficiency of the process, as higher temperature aids the bacteriological activities during biochemical decomposition in the aeration chamber and settling efficiency in the clarification tank. The process can be quickly started, and in case of controlled seeding assumes its full potential within a very short time, approximately 1 - 2 weeks. The process does not produce any by-products, such as sludge or scum which would require separate disposal and is free of any nuisances like flies, insects, odours. Very high inflow rates aggravated by heavy rainfall and high infiltration rate entering the plant is reduced by flow control system before entering the settling tank, therefore the plant is insensitive to extreme flow conditions.

Installation

The type of treatment plant selected is delivered in a fully assembled condition to the point of installation, and after connecting incoming and outgoing piping, electricity to the switchboard, it can be readily started up sometimes a few days after delivery. All units were installed at primitive conditions, site preparation consists of pouring a flat concrete plinth for the plant. Disconnection before relocation is also simple, transport was normally effected by loaders and prime movers.

Sizing of Treatment Plants

Although a variety of standard plant sizes are available from the supplier, two main sizes selected were 20,000 and 60,000 gallons per day (imperial). After the installation of the first treatment plant units, field measurements indicated the following parameters:

Hydraulic loadings:

Construction camp personnel: 65 gpd/capita ADWE (average dry weather flow).
Note: Initially 60 gpd/capita design flow was adopted, but measured rating was 65 gpd/capita.
Shaft housing establishment: 60 gpd/capita ADWF.
Peak Flow: 4 times ADWF, can increase to 6 times ADWF.

Biological loading:

Biochemical Oxygen Demand: 0.2-0.25 lbs./day/capita
Note: Due to food wastage at construction camps.

Aeration Requirements:

Aeration volume 2,500 cu. ft./lb. BOD minimum

Installation Programme

The number and size of treatment plants required was determined from the anticipated number of camp sites, periods of their existence, staff fluctuation over various periods.

The following tabulation shows the initial period of the project, while the construction staff was increasing, necessitating the installation of treatment plant units reaching full capacity:

Population to be served and Treatment Plant Sizes

	August 1969	January 1970	August 1970	August 1971
Panguna Town Site – Staff Houses	300 persons 20,000 gpd – 1 unit	300 persons 20,000 gpd – 1 unit	300 persons 20,000 gpd – 1 unit	300 persons 20,000 gpd – 1 unit
Panguna Camp 1-3 Constr. Camp	1300 persons 20,000 gpd – 1 unit 60,000 gpd – 1 unit	1300 persons 20,000 gpd – 1 unit 60,000 gpd – 1 unit	1300 persons 20,000 gpd – 1 unit 60,000 gpd – 1 unit	1300 persons 20,000 gpd – 1 unit 60,000 gpd – 1 unit
Panguna Camp 7 Constr. Camp	1000 persons 60,000 gpd – 1 unit	1000 persons 60,000 gpd – 1 unit	1000 persons 60,000 gpd – 1 unit	1000 persons 60,000 gpd – 1 unit
Loloho Camp Constr. Camp and Staff Homes	–	1000 persons 60,000 gpd – 1 unit	1000 persons 60,000 gpd – 1 unit	2000 persons 60,000 gpd – 2 units
Camp 5 Constr. Camp	300 persons 20,000 gpd – 1 unit	600 persons 20,000 gpd – 2 units	600 persons 20,000 gpd – 2 units	300 persons 20,000 gpd – 1 unit
Arawa Constr. Camp	–	–	1000 persons 60,000 gpd – 1 unit	2000 persons 60,000 gpd – 2 units

Sewerage System

At the Panguna construction site the mountainous terrain permitted the adoption of gravity sewerage systems, also at the Camp 5 site there was sufficient fall available. At the Arawa and Loloho camps the terrain was flat, and pumping stations had to be provided. The raw sewage pumping stations had unusually high maintenance requirements, the variety of articles entering the sewerage system causes blockages and breakdowns.

Duplicate submersible sewage pumps were provided, the pumping rate of 6 times the ADWF is essential due to peak loadings amounting to 5 times ADWF.

Infiltration particularly affected the gravity sewerage systems, especially at Camp 5. Open or cracked manholes received considerable volumes of rainwater, and at times washed out all the suspended solids from the treatment plant. It is advisable to construct manholes in such areas with the top projecting at least 12" above ground level to prevent ingress of stormwater flooding such areas.

Special care is recommended to be taken at similar projects to arrest grit and clay before reaching the treatment plant by suitable traps, which can be easily cleaned. High volumes of grease are discharged from kitchens with the waste food, and the provision of grease traps is imperative. Pumping stations are to be provided with trash screens to have 1½" clear opening between bars.

Organisation of Operation

The Panguna treatment plants were operated by the staff of the project management organisation, who maintained the units from the time of commissioning. The Camp 5 units were placed into the hands of contractors, but due to frequent changes and staff fluctuations the arrangements were unsatisfactory. The Loloho treatment plants were maintained by contractors initially.

Following the recommendations of the suppliers of the treatment plants, the overall control of the operation of the plants was reorganised and placed into the hands of the project management organisation, with one person in charge and operating staff attending the plants. Central storage of chlorine and spare parts was organised. Regular contact and personal assistance of the suppliers improved the operating standards of the treatment plants, despite being overloaded most of the time of their operating period.

Co-operation of Suppliers

The suppliers of the treatment plants Epco Pty. Ltd. (Melbourne) and the project management co-operated closely in respect of the treatment plants and all problems associated with pollution control.

The commissioning of the first four treatment plants at Panguna and Camp 5 was done by engineers from Epco Pty. Ltd., who also instructed the project management and the operating staff of the plants in respect of operation and maintenance. Subsequently several visits were made by Epco engineers, testing the effluent produced by the plants, carrying out adjustments, negotiating with health authorities and reporting to project management. For start-up of subsequent treatment plants, and carrying out periodical service, the Epco service staff was made available for several months also to assist in the stage of re-organisation at the time of centralising the control over the operation of the plants.

The extended aeration type portable packaged sewage treatment plants proved satisfactory at the project for controlling water pollution by the purification of sewage from the various contributing sources. For similar projects it is advantageous to use these plants, and it is advisable to consult the suppliers of the plants regarding the incorporation of the plant(s) into the sewerage scheme, special provisions, operating requirements, and negotiation with health and pollution control authorities.

Skilled Tradesmen

Skilled Engineering (Contract Labour) Pty. Ltd.

SKILLED TRADESMEN – A BACK-UP WORKFORCE, READY TO GO.

One of the most time consuming and frustrating activities which major contractors faced was the recruiting of skilled tradesmen for Bougainville.

The situations vacant columns included weekly, advertisements for electricians, riggers, fitters, boilermakers and the like to work for contractors for anything from three to six months.

Many top executives found themselves interviewing hundreds of men daily, and screening and checking employment histories.

Skilled Engineering, however, played a significant role in assisting one major contractor, in particular, to recruit a suitable large team of men.

From a back-up workforce of approximately 300 permanent employees, they were able to offer, proven, reliable and adaptable tradesmen, many of whom had already worked in remote places and on mining sites in particular.

Within a few weeks, sixty men were selected and assembled, the necessary entry permits arranged, travel and accommodation organised. Their client was able to concentrate on their own specific technical matters, prior to departure. Executives valuable time was saved and there was no need to advertise and travel interstate to secure men.

Supervisory staff, leading hands and foremen were included in the team of men, ensuring efficient liaison betwen the workforce and the project management staff, once on-site.

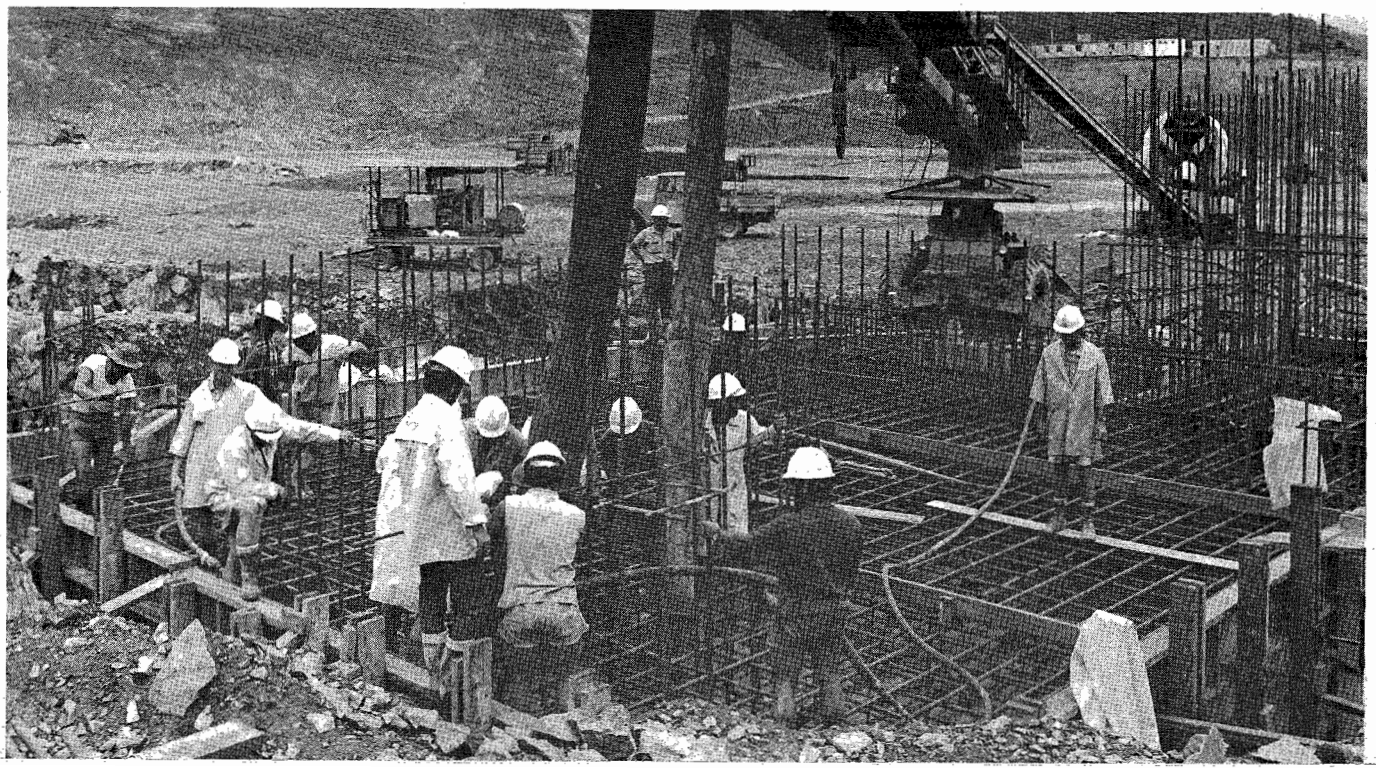
Most contractors involved in Bougainville were faced with labour problems constantly. Many tradesmen just couldn't adjust to the climate and working conditions and returned home, adding great expense to the contractors' project, and creating work delays, as it was weeks usually before their company could organise replacements. By using skilled tradesmen from Skilled Engineering's pool of labour, they could have had back-up replacements, almost immediately.

Many leading companies engaged in construction, installation and maintenance of plant and equipment for mine complexes rely on this method of acquiring labour. Staff can be provided for short or long term projects, at realistic hourly rates, on short notice. Travel and accommodation are arranged as an extra service. Alternatively a regular employee can be repalced if absent due to illness or holidays.

The hourly hire rate includes extras like workers compensation, sick pay, public risk insurance ($200,000 coverage) pay roll tax, public holidays, overalls and tools.

Skilled Engineering have been providing teams of men for work of this nature for almost ten years and were pioneers in the field of labour-hiring in Australia. Their men have been engaged in some part of most of the major mine complexes completed in this time, Mt. Tom Price, Kambalda, Weipa, Paraburdoo, Port Lincoln, Groote Eylandt, Barraba and Port Latta, as well as Bougainville.

Preparing reinforcing for a concrete pour.



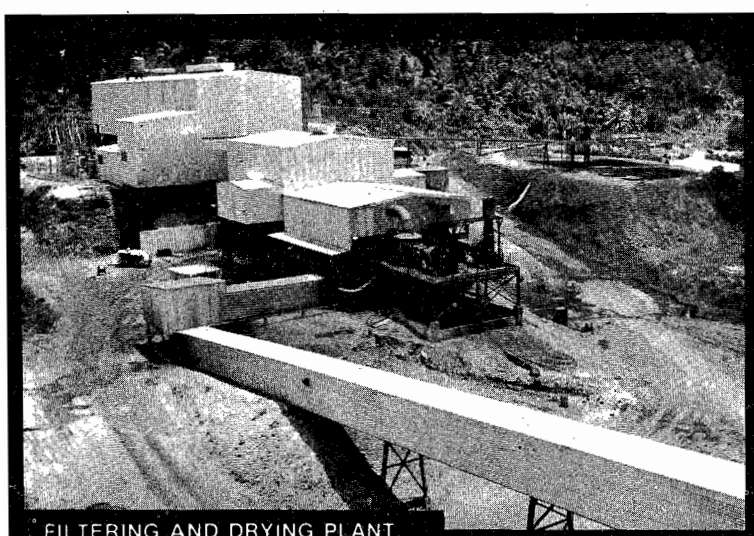
Roofing Bougainville

1,250,000 square feet of roofing. That was the requirement for the Bougainville Copper Mine. A lot of roof . . . . and most of it in difficult locations . . . . in mountainous, tropical terrain . . . . required to conform to a tight construction schedule.

Steel Deck Industries accepted the challenge, not only for the actual construction, but for the development and procurement of materials. One item — the special manufacture of 750,000 special stainless steel fasteners of H3 alloy with "Weather Seal" washers — another, .032 V rib stucco finish aluminium sheeting in lengths of 45 feet.

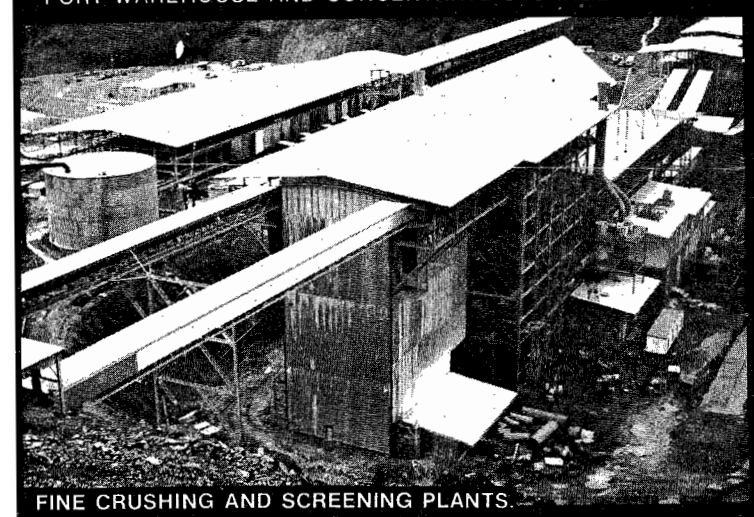
In this high rainfall, tropical area almost everything required roofing — process buildings, conveyor systems, bulk storage areas and office blocks. And with gale force winds to drive torrential rain horizontally, a great deal of wall areas required cladding.

Roofing Bougainville was an exciting and challenging exercise performed to an exacting schedule. Steel Deck's know-how and experience on earlier major roofing projects enabled them to successfully tender, plan and complete the entire contract.

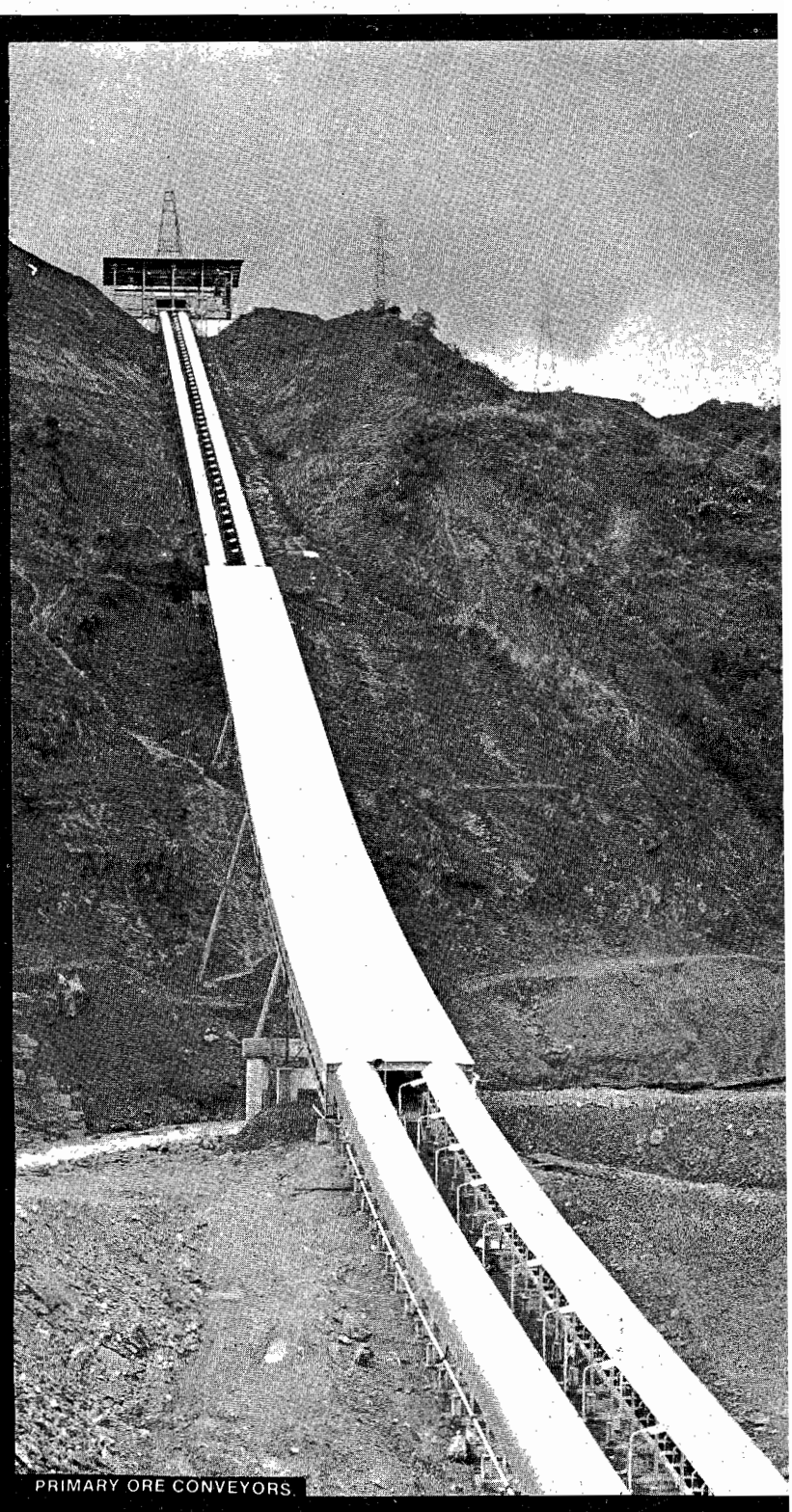


FILTERING AND DRYING PLANT.

PORT WAREHOUSE AND CONCENTRATE STORAGE BUILDING.



FINE CRUSHING AND SCREENING PLANTS.



PRIMARY ORE CONVEYORS.

Arawa Hospital

by R.H. Deacon, A.R.M.I.T., M.I.E. Aus.
Bechtel—W.K.E. Hospital Project Superintendent.
Contractor: Barclay Bros. (New Guinea) Pty. Ltd.

The 220 bed Hospital is located on 56,000 sq. ft. site at Arawa and is the base Hospital for Bougainville Island which has an indigene population of 79,000 and a European population of 5,000. The remainder of the Island is served by a network of medical aid posts.

Description

The Arawa Hospital complex consists of 14 single storey and two storey buildings with a total floor area of approximately 120,000 sq. ft. The complex provides for major and minor surgery, outpatient examination and treatment, maternity service, mortuary, x-ray laboratory, pathology, psychiatric facilities, dental service, approximately 220 ward beds, quarters and messing facilities for students, nurses and staff and classrooms plus auxiliary facilities like plant rooms, laundry processing, storage incineration and offices.

Buildings

The building blocks are of steel portal frame construction with reinforced concrete, ground floor and suspended floor slabs. The roof and end walls are lined with vinyl covered corrugated galvanised iron sheeting and the sides are constructed with timber framed window panels. The internal walls are of timber framed construction lined with either prepainted hardboard or tilux sheeting.

The passage way floors to the wards are lined with vinyl tiles, and the theatres, labour and delivery rooms including adjacent areas are lined with welded conductive vinyl tiles. All internal walls to the theatres, labour and delivery rooms are lined with welded sheet vinyl.

The Hospital grounds have been landscaped and grassed. Also the surfaces to the car park and service roads has been sealed.

Air Conditioning

The air conditioned areas in the Hospital are Blocks 4 and 5 which house the operating theatres, laboratory, pathology, x-ray, class room and the labour and delivery rooms. Also the minor theatre in the out patients (Block 1).

The air conditioning system consists of three separate air handline units providing cool de-humidified air to various areas. Cooling and de-humidification is achieved by a complex of three inter-coupled Email PBO—60W Package chiller sets which chill water the secondary refrigerant to cool the air.

Furnishings and equipment of high standard make Arawa Hospital the most modern in the entire Territory of Papua-New Guinea.

Arawa's 220-bed hospital built by Barclay Bros. Pty. Ltd. was opened in 1972.

Hot Water reheat units are provided to ensure that there is dehumidified air at all times.

Three inter-coupled Marley cooling towers located at the end of building 5, which provide cooling for the condenser water that cools the twelve Westinghouse Compressor motors.

Five major exhaust ventilator systems are installed in Blocks 4 and 5 to extract the contaminated air from the building as well there are small wall air extractor units to exhaust small isolated areas. The remainder of the Hospital is kept cool by circulating the air with ceiling mounted fans and exhaust fans extract stale air from small isolated areas.

Fire Protection

A fixed temperature sprinkler system is provided to protect the buildings. 212°F. sprinkler heads are located below ceiling level and are fed by a system of galvanised threaded pipes. Isolating ball valves are located at the system entry to each building. Flow switches are located at the entry point to Building No. 5 and 8. In the case of building 5 the switch is used to isolate the air conditioning equipment. In the case of Building 8 the switches are used to isolate the discharge fans associated with the cooling equipment.

A 4" dia. sprinkler control valve set is provided within a valve cabinet at the end of the building which is connected to the remainder of the buildings by a 3" pipe.

There is a water driven local alarm bell which operates on the Pelton wheel principal. Also there is a direct alarm connected to the local Fire Brigade Station.

Medical Gases

The oxygen and nitrous oxide storage cylinders and the compressed air compressors for the suction and suction exhaust systems are housed in the end of Block 5 plant room.

The oxygen, suction and suction exhaust systems are reticulated to several of the wards in Blocks 2 and 3 and to the operating theatre, labour and delivery wards in Blocks 4 and 5. Nitrous oxide is also reticulated to the above rooms in Blocks 4 and 5.

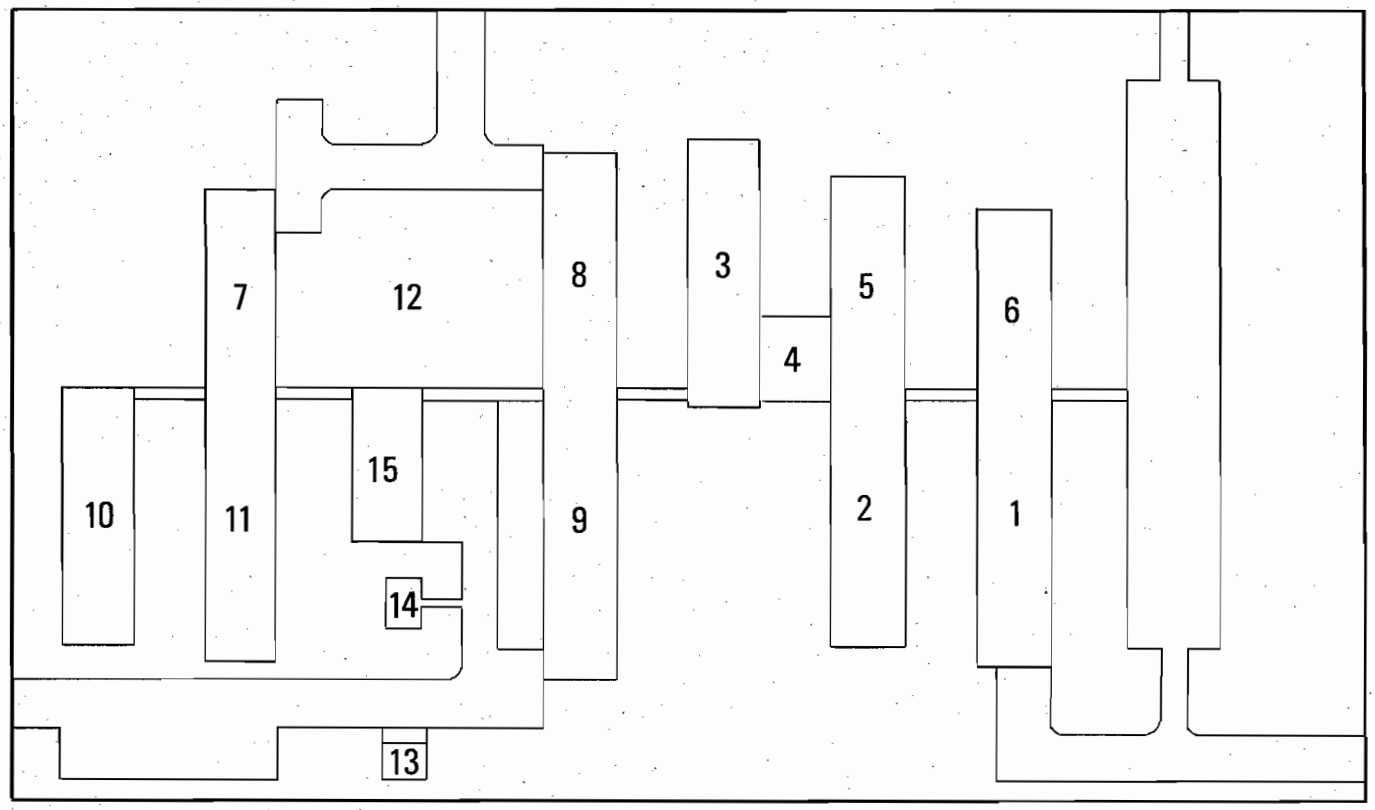
The system is duplicated with one group on duty and the other on standby.

Laundry

The laundry equipment is operated by steam and compressed air. The equipment consists of three commercial washing machines, 2 hydro extractors, commercial drying machine, flat work ironer, steam press and mattress sterilizer.

The steam is supplied from two diesel fired boilers in the boiler house, connected in series, each having a capacity of

ARAWA HOSPITAL – BLOCK PLAN



1. Outpatients.
2. 120 Bed Ward.
3. 100 Bed Ward.
4. Block 4
5. Operating Theatre, Laboratory, Pathology & X–Ray.
6. Dental Laboratory, Office & Dispensary.
7. Class Room & Medical Store.
8. Kitchen & Mess Hall.
9. Laundry, Store & Autopsy.
10. Nurses' Quarters.
11. Students' Quarters.
12. Boiler Room & Maintenance Shop.
13. Inflammable Liquid Room.
14. Incinerator Room.
15. Block 15.

2500 lbs/hr of steam at 212°F. with one boiler on duty and the other on standby. The boilers are horizontal, multi pass, fire tube, fully automatic type using diesel fuel oil.

Kitchen

The kitchen is designed to cater for 350 people comprising 220 patients and 130 staff. The dining hall has a seating capacity of 90. The patient's food is transported from the kitchen to pantries located in each ward block and is distributed to the patients from there.

The kitchen is fully electrically operated and the latest in equipment design has been installed.

Water Supply and Mechanical Service

Water for the Hospital is supplied from the Arawa Town water supply system and enters the Hospital reticulation system at approximately 125 psi and is reduced through a pressure reducing station to 60 psi for use throughout the Hospital. There are two emergency water storage tanks with a capacity of 28,000 gal. for raw water storage and 5,000 gal. for soft water storage.

The water softener equipment has a soft water capacity of 3,000 gal. per hour. The water passes through a filter and then the softening media and discharges into either the soft water storage tank or the soft water reticulation feeding the hot water boilers. A salt and brine tank for the softening media is connected to the softener vessel.

The emergency water supply is operated via two pressure units. Normally one unit is on duty and the other on standby. The duty unit supplies soft water feed to the hot well, hot water boilers and water softener during water softener back wash.

During emergency conditions, when the town's mains have failed both units come into operation and one draws from the raw water tank and delivers to the hospital water supplying main and the other draws from the soft water tank and delivers to the hot well and hot water boilers.

Hot water for the reticulation system originates from two automatic, hot water boilers, one on duty and the other on standby.

The boilers are of the horizontal, multi pass, fire tube, fully automatic type using diesel fuel oil.

The system also has two hot water circulating pumps, one on duty and the other on standby.

The Contract included the supply of the dental equipment, hospital sterilizing equipment, x-ray film viewing boxes, drying cabinets, developing tanks, autopsy table and mortuary refrigerator.

Electrical Supply

The Arawa Hospital has a 415–240V – 50 cycle per second alternating current permanent supply which services the whole hospital. In addition there is AC and DC emergency power supplied.

The essential power supply (emergency AC power) is generated by an emergency diesel generator located in the boiler house, with an output of 250 KVA. The generator is automatically cut in when the mains power supply fails.

The emergency supply for lights to the operating theatres, aneathestising room, labour and delivery rooms is supplied from three battery operated lighting consoles which have an output of 24 volts DC. The batteries are lead acid type with a capacity of 200 AH on a 10 hr. rate. Constant voltage charging is by a full wave rectifier.

Construction

The construction and commissioning of the Arawa Hospital was a real challenge, as the site was located approximately 2500 sea miles from Brisbane, Australia and all the personnel, equipment and material had to be either shipped or flown in to Bougainville Island.

The scheduled construction period was 80 weeks commencing on January 18, 1971 and finishing on 30 July, 1972. For various reasons the commencement of the contract was delayed for several weeks. However, the client still required the facility to be handed over on the original finishing date. In actual fact the Hospital was completed and handed over to the Client 4 months ahead of schedule.

The early completion of this facility was achieved by a tremendous team spirit and co-operation between the personnel of the various organisations involved.

The peak work force comprised of 200 indigines and 60 European construction workers, including staff. The average site ratio was 5 indigenes to 1 European.

Listed below are some of the difficulties and challenges encountered during the course of construction.

The Hospital was scheduled to be constructed and handed over in three stages, namely:

Stage 1 — consisting of 100 bed ward, laundry, kitchen, plant room and student nurses living quarters.

Stage 2 — outpatients, dental dispensary and Administration Block.

Stage 3 — Operating Theatre, laboratory, pathology, x-ray, 120 bed ward, classroom, medical store and nurses quarters.

This in itself created many problems as a substantial portion of Stage 3 housed the equipment and services which had to be completed so that Stage 1 would be operational.

Stage 1 was completed on schedule.

Stage 2 was completed four weeks ahead of schedule and the outpatients section was opened in early February.

Stage 3 was completed the first week in April, being 16 weeks ahead of schedule.

Site conditions were very wet and boggy. Before construction could be commenced the site had to be drained. This was achieved by forming a series of open earth drains.

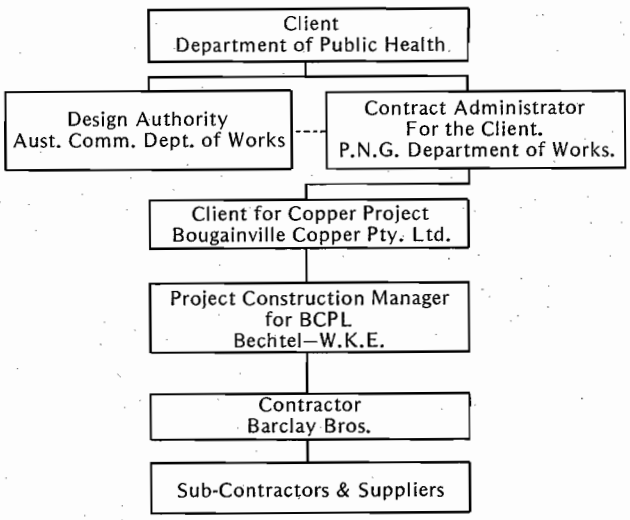
All shipping, Island road transport, concrete, sand, aggregate, fuel, camp accommodation and housing for the Bougainville Copper Project, including the Arawa Hospital, were furnished by Bechtel–WKE. The Contractor was charged a nominal rate for these supplies and the camp accommodation was supplied free of charge.

The delivery of the above items had to be scheduled to coincide with the overall project control schedule.

The overall project shipping programme was scheduled to slow down to two company chartered ships calling, from January 1972 onwards. In June 1971 both the Bechtel–WKE and the Contractors (Barclay Bros.) site Management carried out a feasibility study and drew up a revised detailed construction, procurement and manpower schedule to complete the project approximately four months ahead of the original schedule finish date to enable the majority of supplies to be landed on site prior to the proposed shipping cutback and to utilise services of Bechtel–WKE's expediting section.

The above revised programme was a very ambitious one and its success is attributed to the team work and efforts of everyone associated with the Project.

The Management and Administration of the Arawa Hospital Contract required liaison with 7 separate organisations including three Government Agencies:



HOSPITAL ADMINISTRATION

Hospital Staff

The Hospital is staffed and administered by the PNG Department of Public Health and the hospital staff comprises:

1 European Hospital Superintendent.
7 European doctors.
1 European dental surgeon.
2 Indigene Dental assistants.
1 European matron.
1 European Hospital Secretary.
150 nursing staff including clerical with a ratio of 5 indigene staff to 1 European staff member.
80 Maintenance staff which includes 2 Europeans.

The nurses quarters provide accommodation for 120 people. The remainder of the staff live out in private accommodation with the exception of a few officers who live in housing supplied by the Administration.

The Barclay Story

Barclay Bros. (New Guinea) Pty. Ltd.
an associate company of
Barclay Bros. Pty. Ltd.,
Brisbane, Australia.

Mr. C.I. Barclay,
Chairman and Managing Director,
Barclay Group of Companies.

Barclay Bros. Pty. Ltd., a Queensland founded company servicing Australia in the building and construction field through its New Guinea company – Barclay Bros. (New Guinea) Pty. Ltd. – contracted in 1969 to carry out work for Bechtel-W.K.E. and Bougainville Copper Pty. Ltd. a complex approximating $22 million. This work was completed in 1972.

Work was performed in some of the toughest terrain in the world and initially, access was by helicopter only. Despite all these problems, Barclays performed in the words of Bechtel-W.K.E. 'in a most superb manner'.

Barclays completed with some of the world's largest companies – French, American, British and Italian – and demonstrated throughout the whole of the project their expertise and experience which was of extreme value having worked in New Guinea for a period of some 17 years.

Major Barclay undertakings in Bougainville were:

Port facilities
Roads
Bridges
Electrical power transmission lines
Hospitals
Office Complexes
Warehouses
Housing

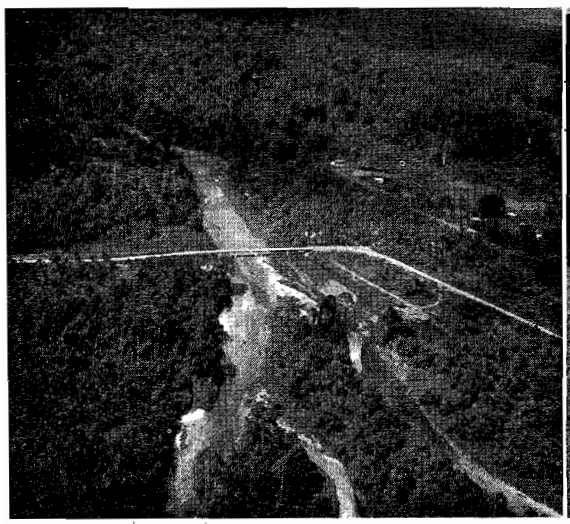
These were but a few of the many installations required by Bougainville Copper Pty. Ltd. and its ancillary operations. The extent of Barclays participation is also depicted in the accompanying illustrations.

Over the period 1969/72 a work force of up to 2,000 was engaged, and in total a force of 8,000 went through the pay system for the 3 years. Additionally, it is worthy to mention that the company received an Award (A Certificate of Safety) for having achieved 973,832 accident-free manhours, an achievement that was not bettered on the entire Project.

It must be appreciated that in the early stages of the contract facilities were almost non-existent. This presented a problem for the personnel initially engaged to carry out the first stages of the Mine Development. Quite frequently our personnel worked 7 days a week, 3 shifts per day in order to meet and keep up with the requirements of our programme. However, in the overall, contracts were completed ahead of schedule and to the satisfaction of both Bechtel-W.K.E. and Bougainville Copper Pty. Ltd.

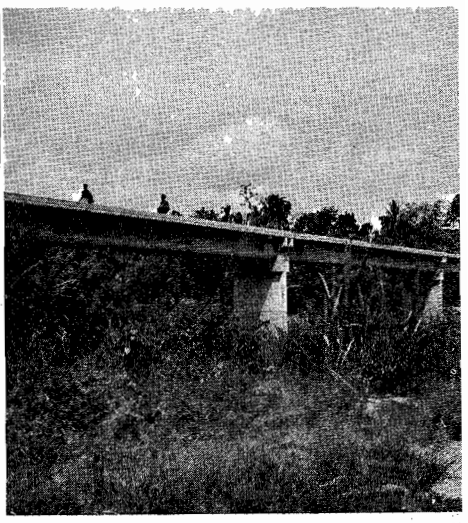
Further to this, equipment such as motor vehicles and other mechanical items were subjected to some of the most torturous conditions imaginable, and often worked in water and mud until such time as service facilities, bridging and roads were made available.

Barclay Bros. Pty. Ltd. were pleased to be a part of the world's largest start-up Copper Mine which came into full scale operation ahead of schedule and within budget.

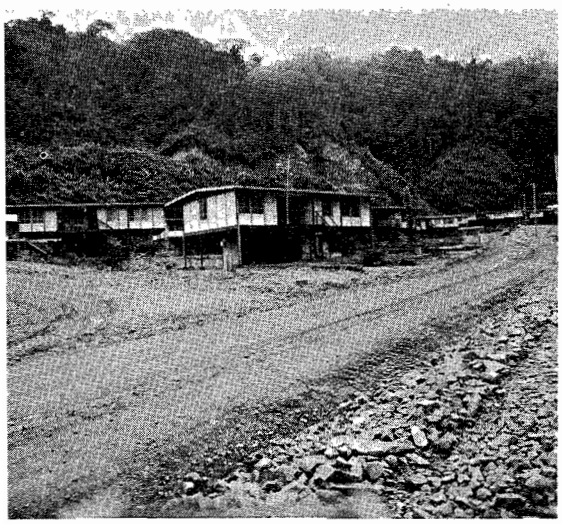


River crossing, Buin to Boku, Bougainville.

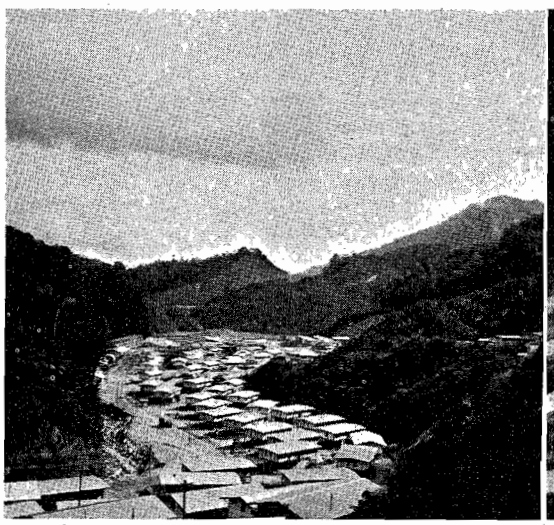
Buin to Boku road, with multi-pipe culverts.



Buin—Boku Road Bridge.



Housing at Panguna.



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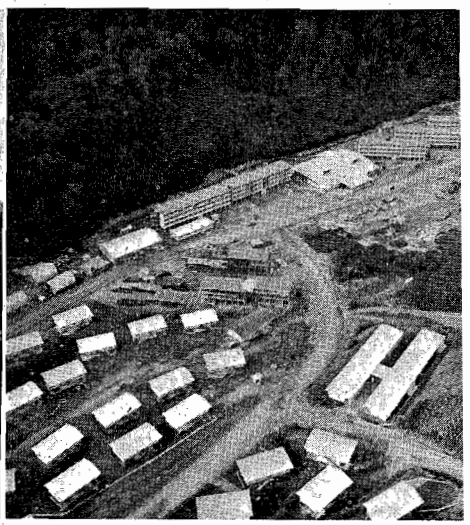
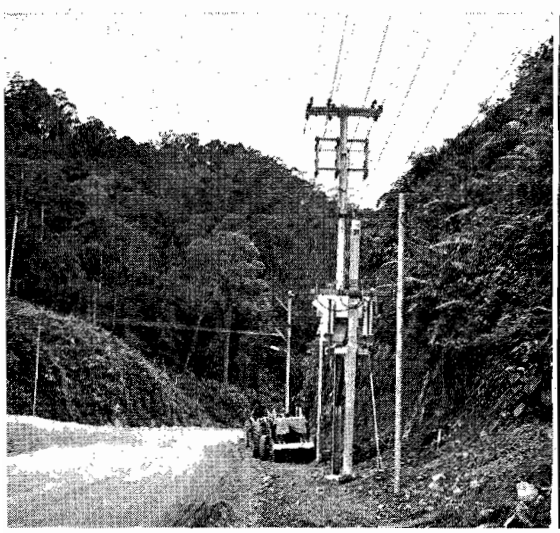
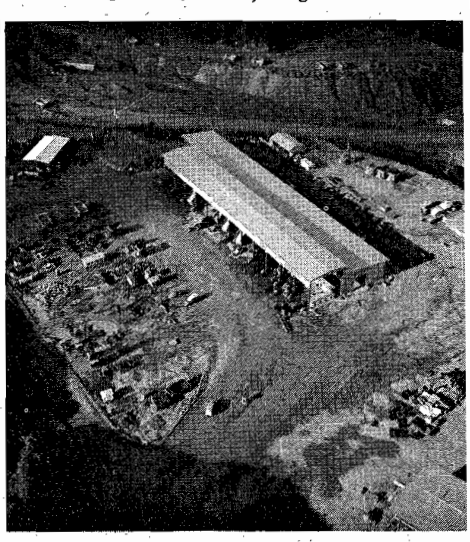


Integrated Quarters, Panguna.



33 kV Transmission Line, Panguna.

6.6 kV Transmission Line, Panguna.



Heavy Plant Workshop Foundations

Feeding, Housing and Camp Management

B.F. Brown Company, Inc.
International Caterers
Frankston, Vic., Australia
(Incorporated in Chicago, U.S.A.)

16,900,000 MEALS FOR 9,000 MEN IN JUNGLE CAMPS, 1250 MILES FROM SUPPLY PORT.

September 1969 saw the commencement of Brown's involvement in the Bougainville Copper Project. Initially their commitment required the catering for members of the original Exploration Camps, followed by the build-up of a wide variety of services, as the project excalated.

Within three months (December 1969) the work force had grown to 2900 (2000 indigenes and 900 expatriate whites) and a peak of 9000 (5000 indigenes and 4000 expatriates) was reached in the second half of 1971, with a decline to a little below 5000 (2750 indigenes and 2000 expatriates) at conclusion of the construction phase in April 1972.

Throughout this period, Brown's services had to keep pace with the numbers of people and the location of their camps.

The operation involved considerably more than the preparation of meals. With a staff of 900 (one tenth of the entire project workforce at peak) Brown's responsibilities included:

- Requisitioning of all food and associated items
- Receiving from ship, transporting, warehousing and distribution to camps
- Preparation and serving of all meals in 10 locations
- Operation of Bakery
- Complete laundry service for workforce
- Camp and dependent housing maintenance and janitor service to project offices
- Management and staffing of 10 Wet Canteens and 10 Dry Canteens
- Motion picture theatre management and operation at 10 locations
- Native market supervision
- Hygiene sanitation, garbage collection, removal and disposal for all camps, canteens and dependent housing areas
- Complete maintenance of all plant and equipment used in Refrigeration, Cooking, Bakery, Laundry, Canteens, Theatres, own Trucks & Transport and operation of spare parts and replacement store. (Spare parts for Camps, Kitchens and Laundry were greater than manufacturers would hold in an Australian Capital city.)
- Camp security service
- Managerial, clerical, payroll and employees relations staff.

Some kitchens for the ten camp locations were designed by Browns and served workforce populations of from 250 to 2000 situated along a 30 mile circuit accessible only by rough, 4-wheel vehicle tracks. Six of the kitchens were all-electric, three had oil-fired steam cooking and one temporarily relied on wood burning.

Refrigerated storage of 80,000 cu. ft. (20 x 4,000 cu. ft. units) was located 60% at portsite and 40% at minesite, and all camps had additional refrigerated storage to meet their requirements.

Brown's fleet of 40 trucks and passenger buses handled the transport of their employees and all supplies between wharf, warehouses, refrigerated storage and camp sites – an item not without its problems at a time when road construction was in progress and construction vehicles had priority.

One one occasion the port–mine road (under construction) was cut by a landslide and trucks had to be driven as far as the break, unloaded by hand and the goods carried around the slide to waiting trucks on the other side.

If a truckload of timber went over the side, the workers waiting for it weren't greatly concerned, but if a truck of food went over, that was different – they still had to feed them that night!

There was a crisis almost daily, or as was said, there were three a day, breakfast, lunch and dinner.

Due to the extreme isolation of the project, Bechtel–WKE had insisted that meals for the men should be of the very highest standard. No effort was to be spared to provide the very best.

After discussion with the Project Management, three menu types were adopted – Menu 1 for expatriate whites, Menu 2 for indigenes who had already become accustomed to European type food and cooking, and Menu 3 for P.N.G. and Bougainville natives who had come directly from their own villages and were accustomed only to locally produced and prepared foods.

The menus, typical extracts from which are listed below, were changed daily.

MENU 1

BREAKFAST

Chilled Fruit Juices
Assorted Dry Cereals
Assorted Hot Cereals
Stewed Fruit
Grilled Bacon – Lamb Chops
Spaghetti in Tomato Sauce
Eggs – Fried, Scrambled, Boiled or Poached
Toast, Butter, Jam, Honey
Assorted Beverages

LUNCH

Soup de Jour
Grilled Pork Chops & Piquant Sauce
Beefsteak & Mushroom Pie w/Flaky Pastry
Whipped Potatoes
Buttered Asparagus Tips
Carrots Vichy
Cold Collation
Assorted Sweets
Bread Rolls, Butter, Jam, Honey
Assorted Beverages
Fresh Fruit, Cheese Board

DINNER

Scotch Broth
Roast Leg of Lamb w/Mint Sauce
Curried Prawns w/Condiments
Baked Jacket Potatoes
Baked Pumpkin
Green Peas
Spring Salad
Assorted Sweets/Ice Cream
Bread Rolls, Butter, Jam, Honey
Cheese Board
Assorted Beverages

MENU 2

BREAKFAST

Chilled Juice or Cordial
Fresh or Tinned Fruit
Grilled Lamb Chops
Fried Fresh Eggs
Baked Beans
Hot Cakes – Jam
Bread – Butter, Vegemite
Assorted Beverages

LUNCH

Chicken Noodle Soup
Roast Beef, Brown Gravy
Brown Rice
Green Beans
Cold Collation
Assorted Sweets
Bread – Butter, Jam
Assorted Beverages

DINNER

Beef Barley Soup
Grilled Steak
Brown Potatoes
Baked Pumpkin
Creamed Carrots
Assorted Sweets
Cheese & Biscuits
Bread – Butter, Jam
Assorted Beverages

MENU 3

BREAKFAST

Tinned Meat
Rice
Navy Biscuits
Fresh Fruit
Assorted Beverages

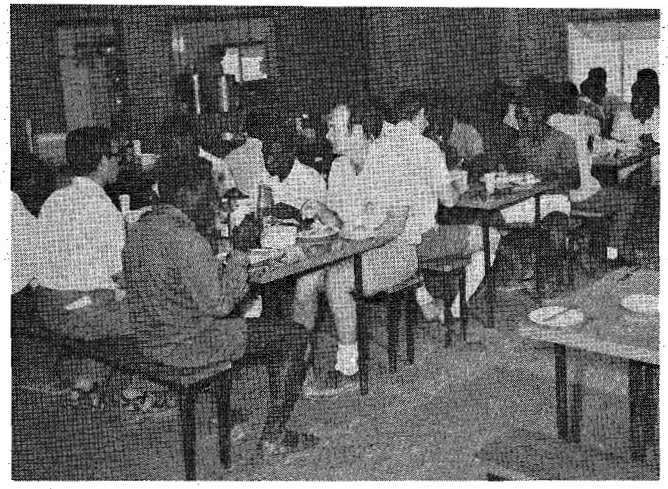
LUNCH

Mackeral Pike with Vegetables
Rice – Fresh Vegetables
Wholemeal Rolls
Fresh Fruit
Assorted Beverages

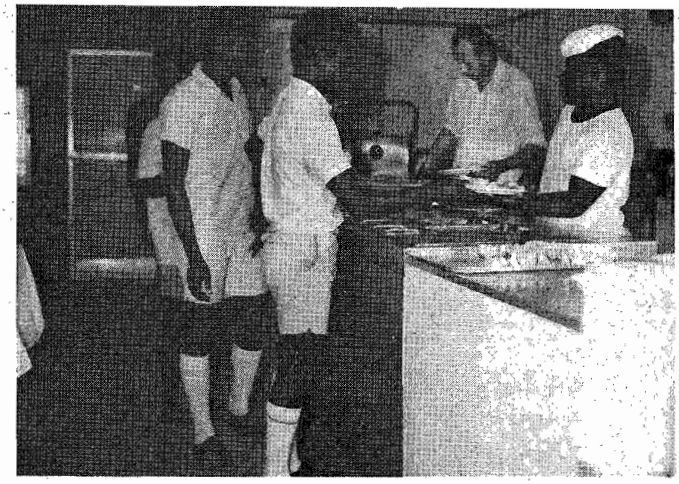
DINNER

Savoury Beef Stew
Green Vegetables
Kau Kau (Sweet Potatoes – Yams)
Rice
Wholemeal Rolls
Fresh Fruit
Assorted Beverages

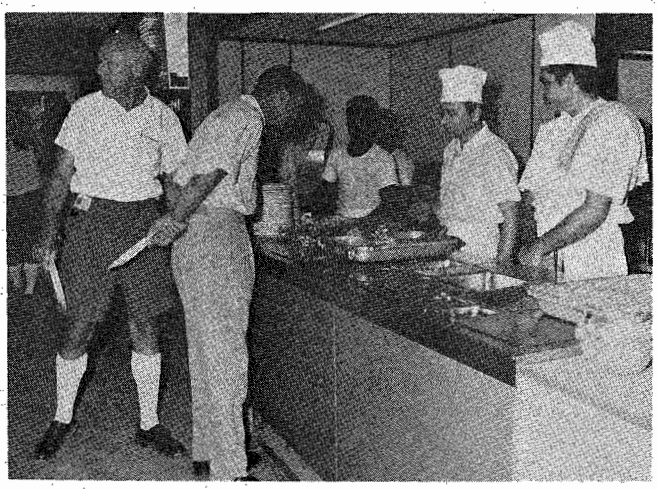
Camp 1 Mess, Panguna, October 1970.



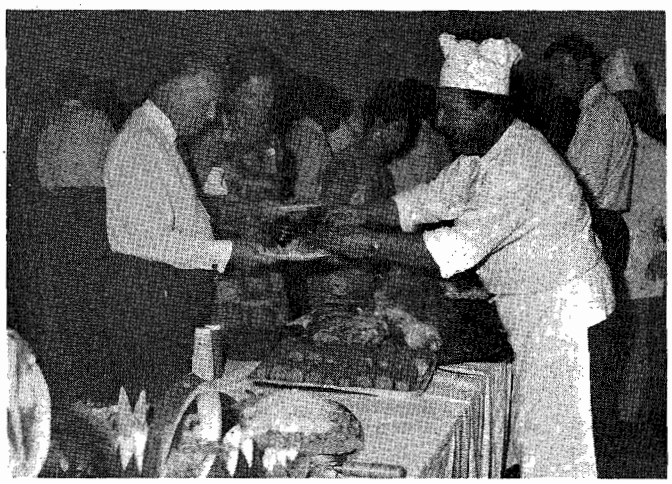
Rigu students at Camp 2 Mess.



Camp 2 Food Servery.



H.R.H. Prince Philip, Duke of Edinburgh, with Mr. F.F. Espie, O.B.E., Chairman of Directors, Bougainvile Copper Ltd. during the Prince's visit to Papua-New Guinea in March 1971.



Sir Val. Duncan, Chairman and Chief Executive of Rio Tinto-Zinc Corporation, London, and Mrs. Ballmer, wife of Manager, Bougainville Mining Ltd., being served at an official function.

The stores ordered by Brown's for fortnightly deliveries included such quantities as:

250,000 lb.	Meat, Chicken & Fish
90,000 lb.	Potatoes
30,000 lb.	Onions
8,000 lb.	Prawns
18,000 doz.	Fresh Eggs
1,500 gals.	Ice Cream

The total quantities of some items used for the duration of the project were:

Fresh Meats	6 million lb.
Tinned Meat & Fish	3 million lb.
Vegetables	18 million lb.
Dry Staples	20 million lb.
Beer	25 million 13 oz. cans
Rice	4½ million lb.
Ice Cream	60,000 gals.

At the commencement of the project, very little locally grown produce was available, but the Bougainvilleans were encouraged to plant additional crops for sale – which they proceeded to do with a great deal of enthusiasm. On one occasion a group of natives arrived with six tons of cucumbers. No bananas or coconuts – six tons of cucumbers. Browns bought them all, but they don't recall what they did with them.

The Brown workforce of 900 included 760 indigenes (mostly P.N.G. men – Bougainvilleans are subsistence farmers and they generally preferred their own way of life). This represented the highest ratio of indigenes to expatriates employed by any contractor on Bougainville. And they were all trained by Browns, in a wide range of skills.

Carpenters, Plumbers, Electricians, Motor Mechanics, Cooks, Bakers, Laundrymen, Cleaners – you name it, Browns trained them. Today they are working in Bougainville, New Guinea, the Solomons and elsewhere, good workmen, using the skills taught to them.

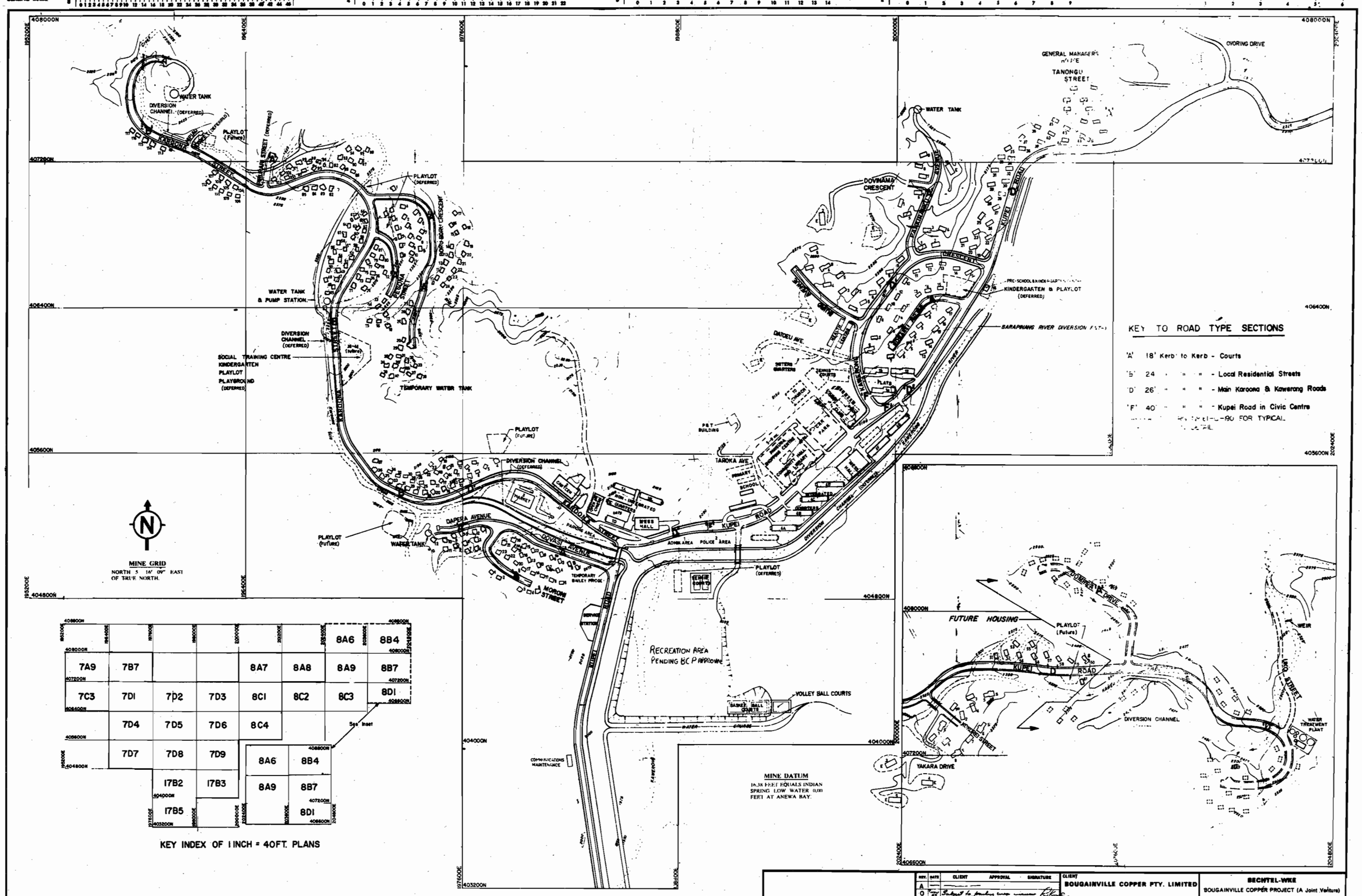
Brown's staff worked a mammoth total of 5,300,000 man days and prepared a total of 16,900,000 meals.

On the successful completion of their contract in April 1972, the workforce were handed A$50,000 Airline tickets to fly them to their homes.

May 2nd 1972 saw the last Brown personnel fly out of Bougainville, when thirty management staff chartered a TAA "Friendship" for the three hour flight to Port Moresby. Naturally Browns took over the catering, for what was to become known as the "Champagne Flight", and it is unlikely that ever before or since have passengers and crew on an airline flight enjoyed such gourmet service. They had cause to celebrate. They had completed to the unqualified satisfaction of B.C.P., Bechtel–WKE and every man on the workforce, what might well be the largest civil catering contract, ever undertaken anywhere in the world.

At Bougainville, the entire workforce was fed and housed for the duration of the project, whereas on some great construction jobs a large percentage of the workforce is recruited locally and engaged on a day-labour basis, returning to their homes nightly for meals and accomodation.

SCALING RULES



REV.	DATE	DESCRIPTION	DR.	CH.	SPV.	APPROVED

REV.	DATE	DESCRIPTION	DR.	CH.	SPV.	APPROVED
—	—	SCOUT HALL PLOTTED GENERAL REVISION.				
4	7-7-71	SCOUT HALL REMOVED				
5	"	" "				
6	17-7-71	SERVICE				
7	3-12-71	ADDED HOUSE NUMBERS				

REV.	DATE	DESCRIPTION	DR.	CH.	SPV.	APPROVED
A	—	—				
0	7 NOV 69	ISSUE FOR CONSTRUCTION				
1	16 MAR 70	COMMUNITY AREAS & AS BUILT HOUSES REVISED				
2	18 MAY 70	LOWER KAROONA AS BUILT ADDED NOWN				
3	CANC TO	INFORMATION TRANSFERRED FROM PLAN W-C-101				

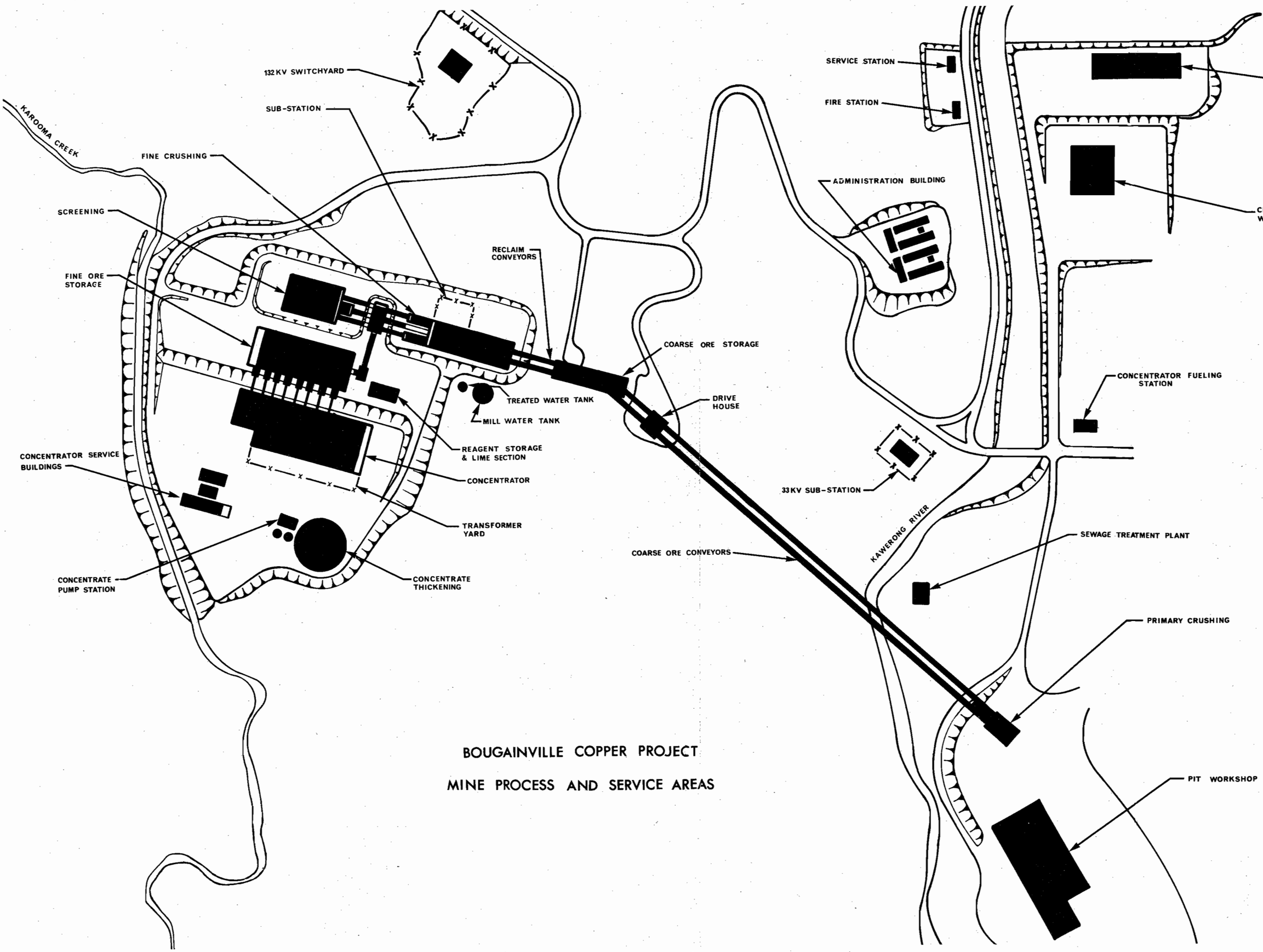
REV.	DATE	CLIENT APPROVAL SIGNATURE
A		
0	7/11/69	Subject to further comments
1	16/3/70	
2		
3	7/5/70	

CLIENT
BOUGAINVILLE COPPER PTY. LIMITED
BOUGAINVILLE ISLAND
TERRITORY OF PAPUA AND NEW GUINEA

BECHTEL-WKE
BOUGAINVILLE COPPER PROJECT (A Joint Venture)
BECHTEL CORPORATION — WKE DIVISION ARTHUR G. McKEE & CO. MELBOURNE

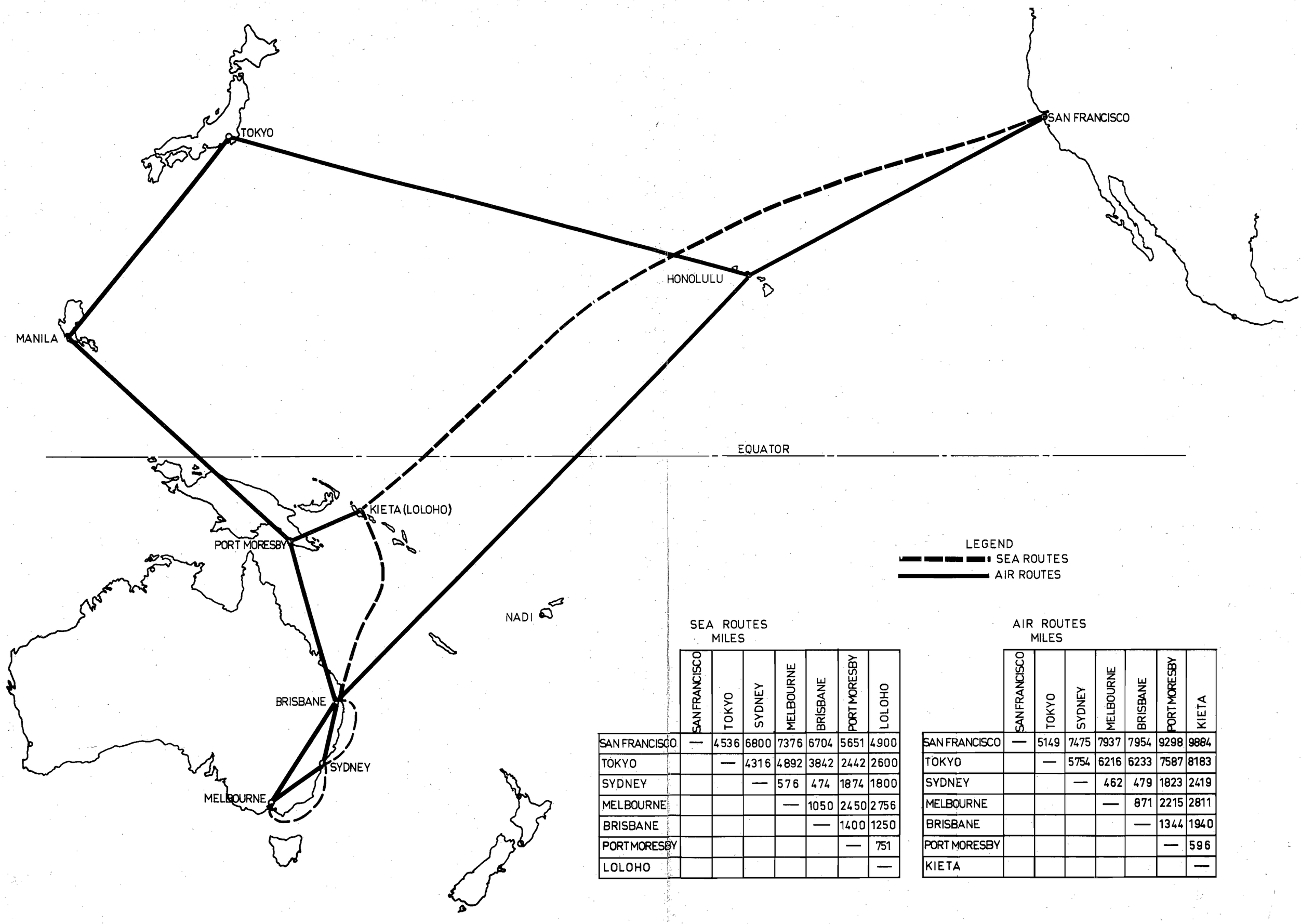
TITLE
PANGUNA TOWN
TOWN PLAN & ROAD LAYOUT

SCALE 1INCH = 200FEET
JOB NO. 8406-2306
DRAWING NO. 91 - C - 102
REVISION 7



BOUGAINVILLE COPPER PROJECT

MINE PROCESS AND SERVICE AREAS



SEA ROUTES
MILES

	SAN FRANCISCO	TOKYO	SYDNEY	MELBOURNE	BRISBANE	PORT MORESBY	LOLOHO
SAN FRANCISCO	—	4536	6800	7376	6704	5651	4900
TOKYO		—	4316	4892	3842	2442	2600
SYDNEY			—	576	474	1874	1800
MELBOURNE				—	1050	2450	2756
BRISBANE					—	1400	1250
PORT MORESBY						—	751
LOLOHO							—

AIR ROUTES
MILES

	SAN FRANCISCO	TOKYO	SYDNEY	MELBOURNE	BRISBANE	PORT MORESBY	KIETA
SAN FRANCISCO	—	5149	7475	7937	7954	9298	9884
TOKYO		—	5754	6216	6233	7587	8183
SYDNEY			—	462	479	1823	2419
MELBOURNE				—	871	2215	2811
BRISBANE					—	1344	1940
PORT MORESBY						—	596
KIETA							—

Plate 1

THE PUMKUNA COPPER - GOLD PROSPECT

BOUGAINVILLE ISLAND
NEW GUINEA

154°00′ 154°30′ 155°00′ 155°30′

5°30′ 6°00′ 6°30′ 7°00′

TRUE NORTH
MAG. NORTH
6½°

Buka I.

Sohano

BOUGAINVILLE I.

NUMA NUMA

MT. BALBI 9000′

WARANAI R.

MT. BAGANA 6560′

ATAMO

KARATO

CROWN

KORPEI

RORONANA

ARAWA BAY

Kieta

MORONI

KUPEI

PUMKUNA

GUAVA

JABA R.

KAVARONG

PRINCE

RANGE

MT. TAKUAM 7385′

MT. TAROKA 7240′

EMPRESS AUGUSTA BAY

FOR DETAIL SEE 1B.

Buin

A LOCALITY MAP
SCALE 1:100,0000

10 5 0 10 20 30 40 Miles.

TO MORONI ½hr walk.

Pungirungu Ck.

JOINS KAVARONG CK. THENCE JABA R.

T.N. M.N. 6½°

Pung'gana Creek

Konungipa Ck.

2300′

2700′

50°

OLD BALL MILL

FOR DETAIL SEE 1C

Buriuwa Ck.

CAMP

TO GUAVA ¾ hr walk.

B PUNG'GANA CREEK
SCALE
200 0 400 Feet

TRUE NORTH
MAG. NORTH
6½°

C THE PUMKUNA LODE AND OLD WORKINGS
SCALE
20 0 40 Feet

PLAN

2370′
2360′
2350′
2340′
2330′
2320′
2310′

F 80° 50°

50°

LODE 18" to 24" WIDE

Chalcopyrite within lode

B

75°

30°

CU STAIN

60°

F 70

2" chalcopyrite stringer

Cu stained wall rock

Quartz with limonite stains

55°

Lode outcrop

Cu staining

Mullock

A

Pung'gana Ck.

DIAGRAMMATIC SECTION

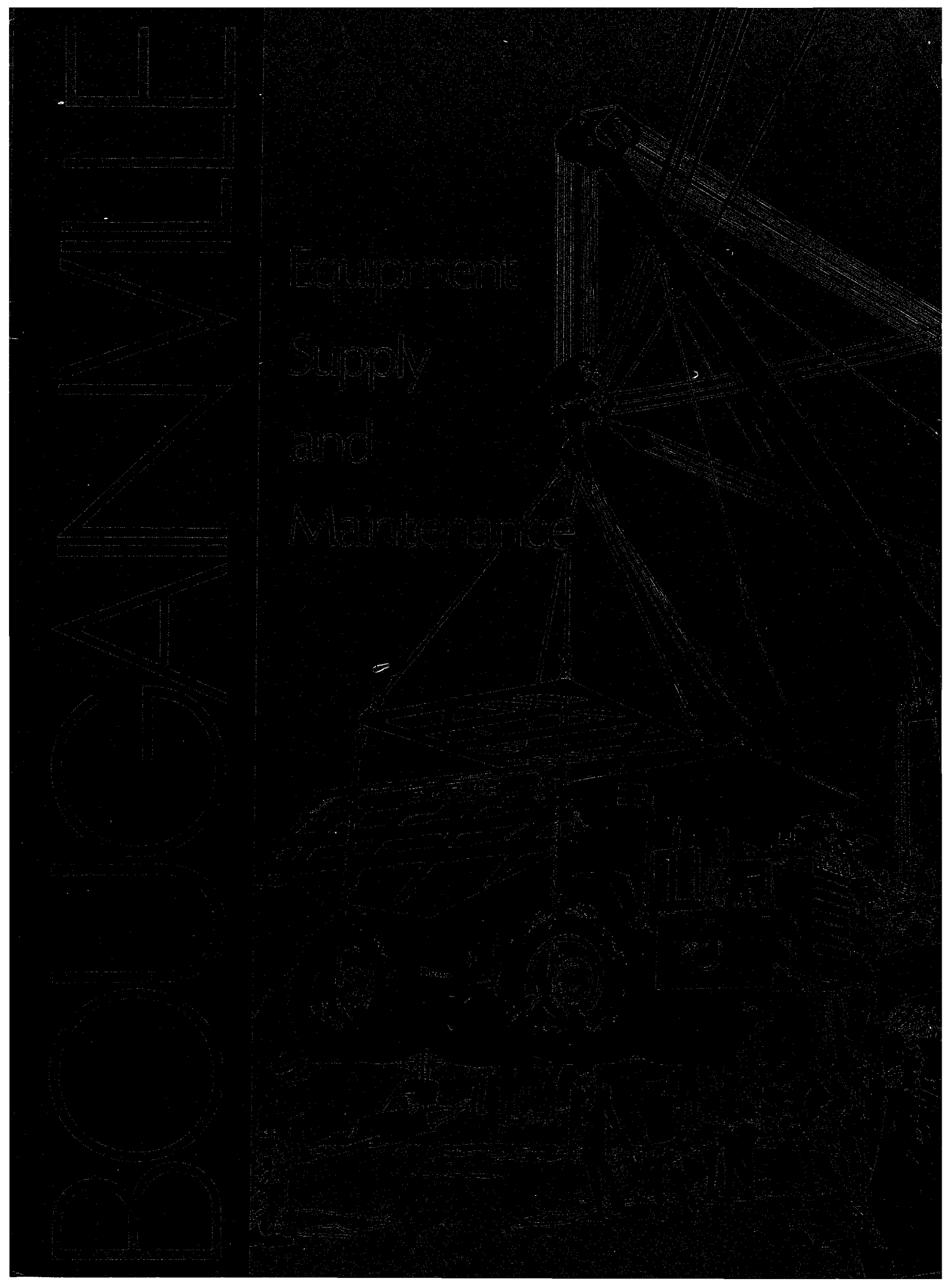
A B

Scale
40 0 80 Feet

● OLD BALL MILL

Bureau of Mineral Resources, Geology & Geophysics Canberra A.C.T. Nov. 61

PNG 13/7 Gr.


Equipment
Supply
and
Maintenance

PROFILE OF A SUPPLIER

Early in the planning stages of the project, a San Francisco based equipment distributor recognized an opportunity. An opportunity to participate in the development of the Bougainville Project from its inception to completion and beyond. With Bechtel–WKE at their doorstep, Morgan Equipment Company became immediately involved.

Primarily, Morgan Equipment sought to fulfill the need for haul trucks required to deliver the ore from the pit to the primary crusher. Prior to the awarding of that order, Morgan was able to place 12 pieces of equipment with several contractors during the construction phase. Their service people delivered each unit and put them into service. Working out of cargo containers was a general rule of thumb.

CONTINUOUS MAINTENANCE

When Bougainville Copper placed the order for 41 Euclid haul trucks, Morgan's permanent relationship with the project began. A tremendous maintenance facility was required to service the fleet of 105-ton haulers. Each truck is powered by a 1000 HP Detroit Diesel engine. The hydro-mechanical transmissions are the largest of their kind in the world. Morgan Equipment opened their maintenance facility on the Island in mid-1969 to back up the Euclid haulers and keep them in continuous motion.

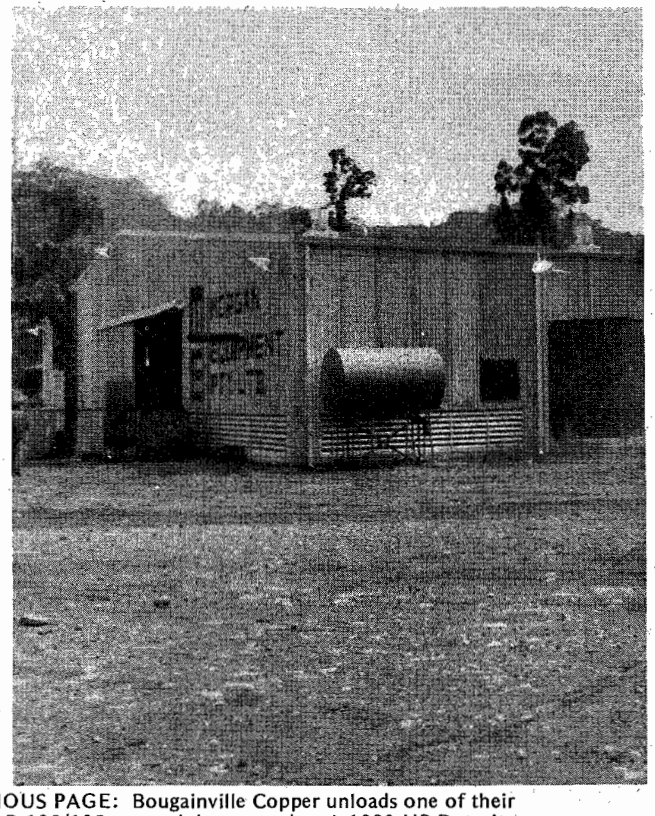
Today, 74 people work two ten-hour shifts per day, 365 days a year. The most sophisticated shop equipment is utilized. The staff is reported to be the most technically qualified service organization in the area. A completely rebuilt 1000 HP diesel engine or hydro-mechanical transmission can be turned out every four days.

The shop and warehouse is located on a two acre plot in Bougainville's Industrial Park and occupies 24,000 sq. ft. Overhead cranes, jib cranes and forklift trucks facilitate the movement of exchange components through the shop. A 2000 HP engine dynamometer, the largest of its kind in the South Pacific, is used to test every engine. The transmission test stand can check out the largest hydro-mechanical transmission in production. The injector room is complete with the most modern testing equipment. The shop has the latest tools including magneflux equipment.

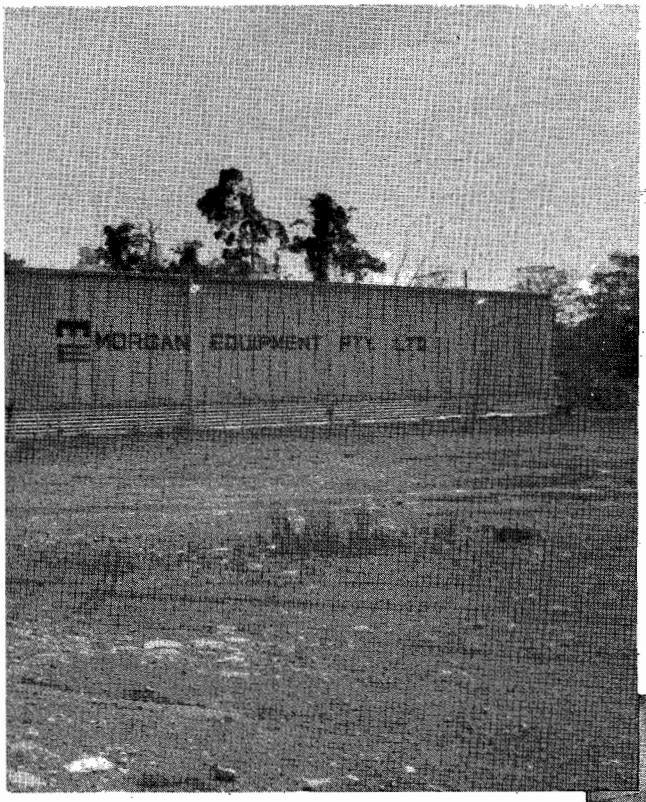
Bougainville Copper is assured of a constant and dependable source of parts. Morgan Equipment's inventory level is valued in excess of $3 million. When normal suppliers are half-way around the world, parts availability is a must to eliminate the possibility of costly downtime.

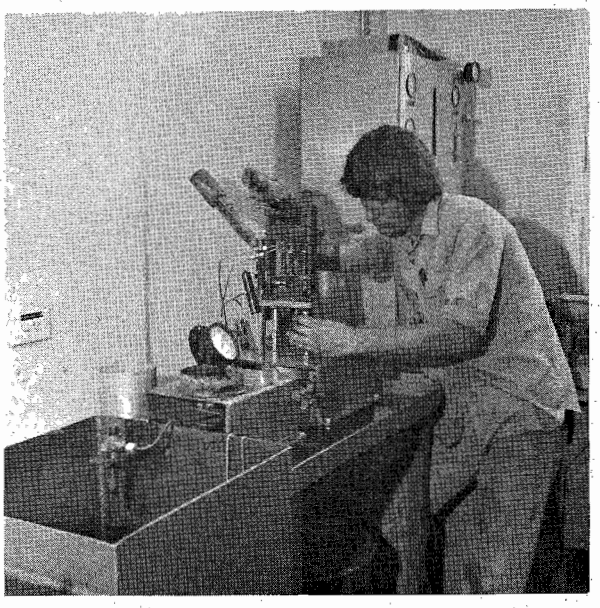
In addition to Morgan's maintenance capacities on the Island, they still remain a major supplier of equipment. Specifically, Morgan represents: Euclid/off highway rear dump and bottom dump haulers; P & H/ truck cranes, hydraulic truck cranes, crawler cranes, rough terrain cranes, hydraulic hoes and power shovels; Michigan/ scrapers, front end loaders, rubber tired dozers and log skidders; Sullair/ diesel, electric and gas compressors, trac drills and air tools; Detroit Diesel Allison/diesel engines from 20 to 1650 horsepower and powershift transmissions for mining and construction.

Morgan Equipment Pty. Ltd. regards itself as much more than a source of equipment. Many suppliers have left the Island. Morgan will remain as long as they can fulfill their function. A pledge to help keep Bougainville Copper in continuous motion.

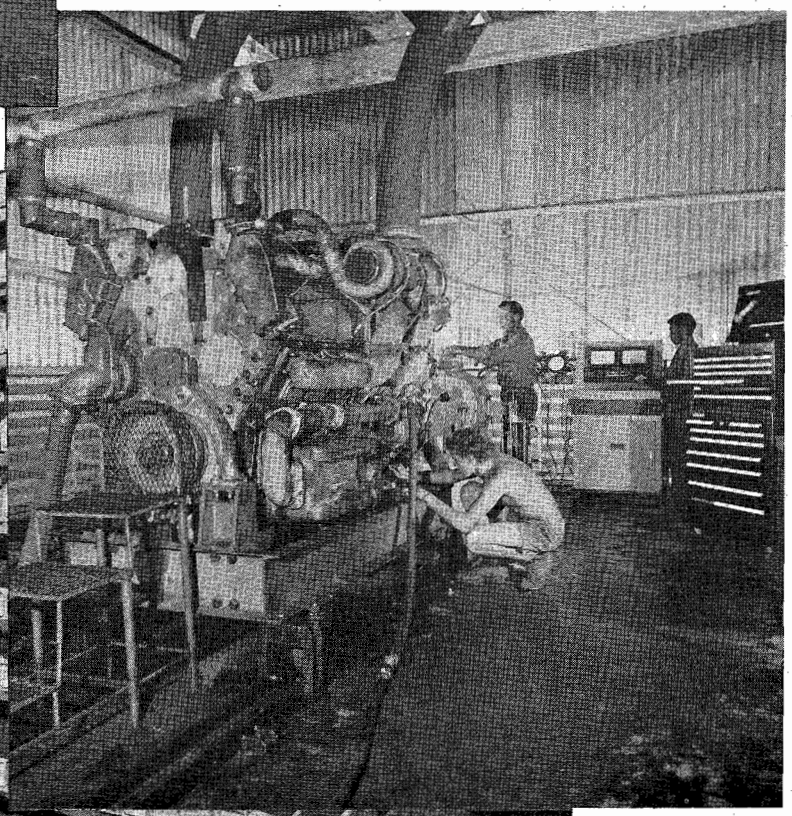


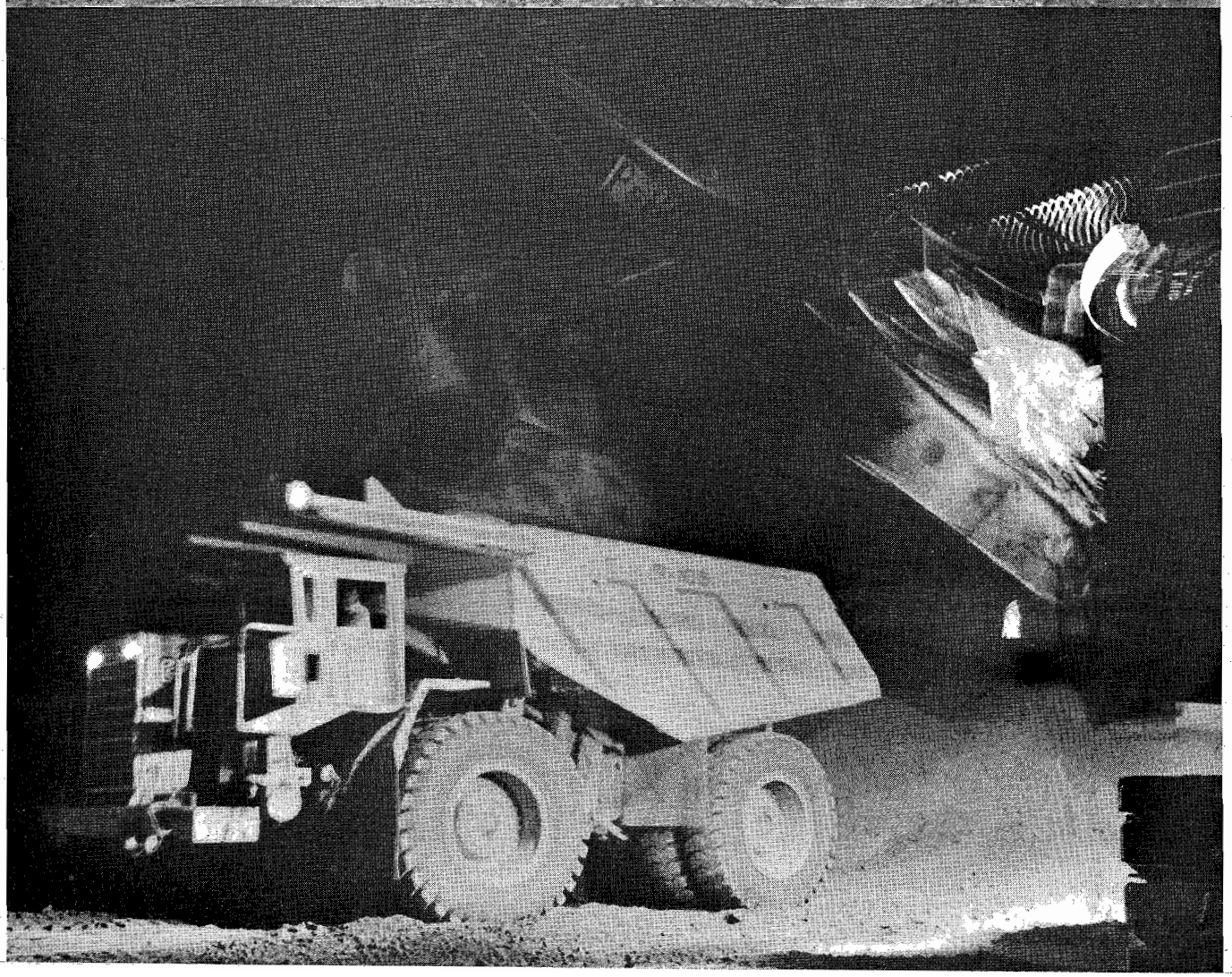
PREVIOUS PAGE: Bougainville Copper unloads one of their Euclid R-105/105-ton end dump trucks. A 1000 HP Detroit Diesel 12V–149T powers each Euc. An Allison dual path, six speed, full powershift transmission drives all four wheels.
TOP: Morgan Equipment Pty. Ltd., Bougainville Island. Twenty-four thousand square feet of shop and warehouse.
BELOW: An indigene apprentice being instructed by our shop foreman.
CENTRE RIGHT: Each engine is tested on a 2000 HP dynamometer, the largest dyno in the South Pacific.
BOTTOM RIGHT: A portion of our $3 million parts storage area at Bougainville.
NEXT PAGE: P & H Shovels and Euclid R.105's never rest on Bougainville. They work around the clock, 365 days a year .... rain or shine.





TOP RIGHT: Each engine sub-assembly is tested and rebuilt if necessary. In the contamination-free injection room, injectors are overhauled.

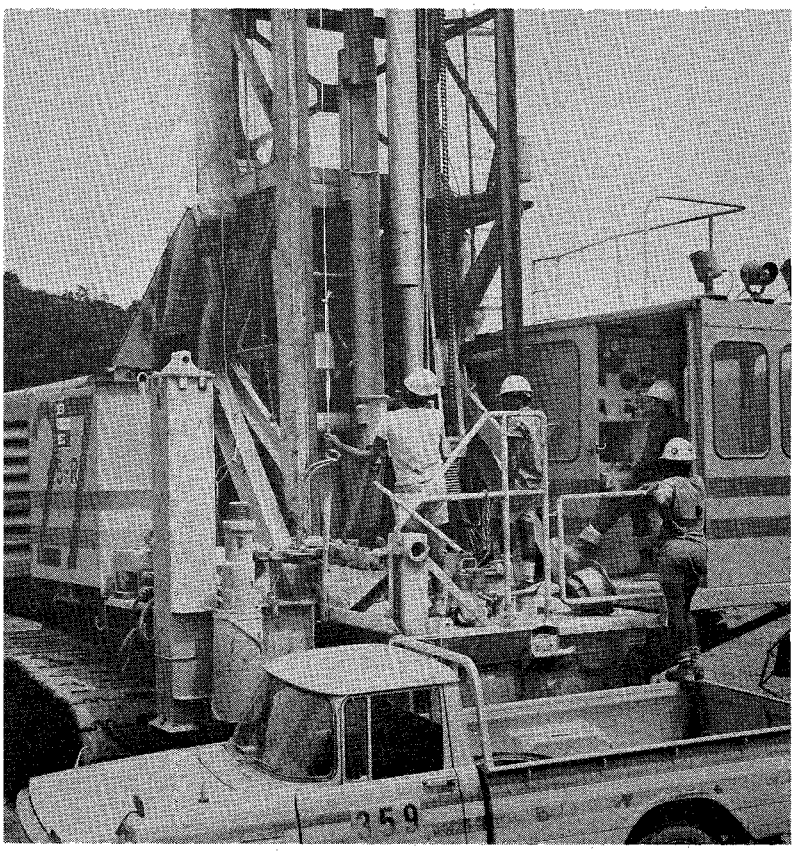


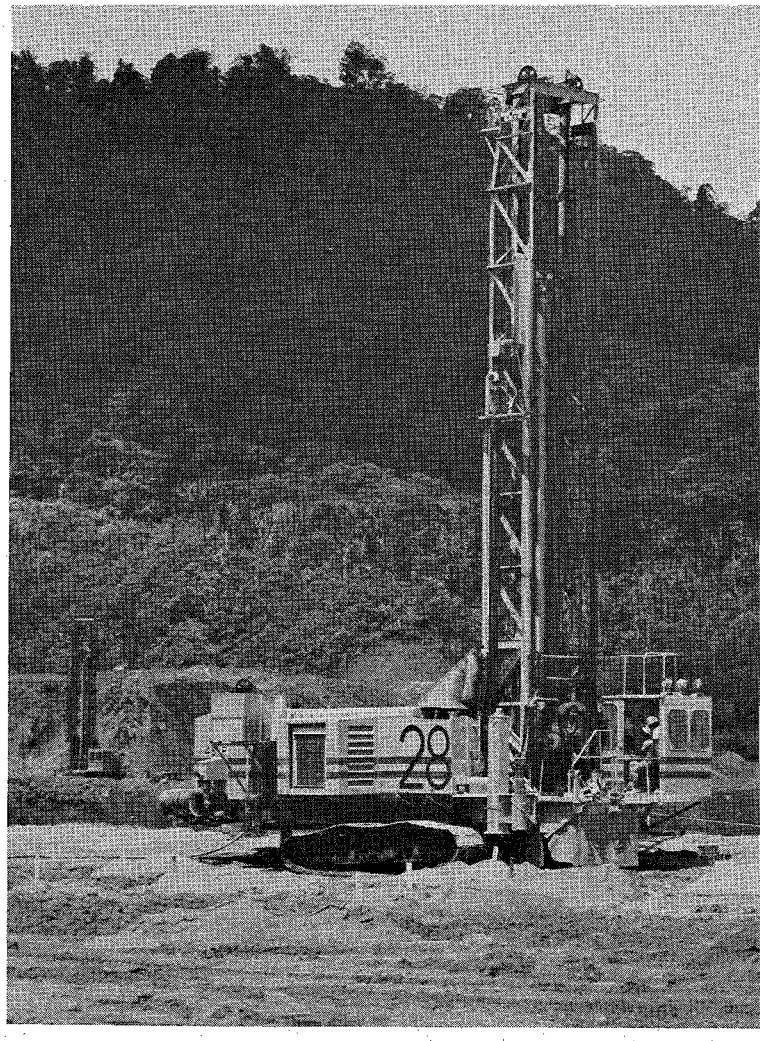


The Bougainville Drills

BUCYRUS-ERIE 45-R Blast Hole Drills at Panguna

BUCYRUS-ERIE master erectors supervised assembly and testing of each Bougainville drill — and trained local crews in their operation and maintenance.





Five B-E 45-R all-electric drills do the drilling at Bougainville Copper Pty.'s Panguna mine.

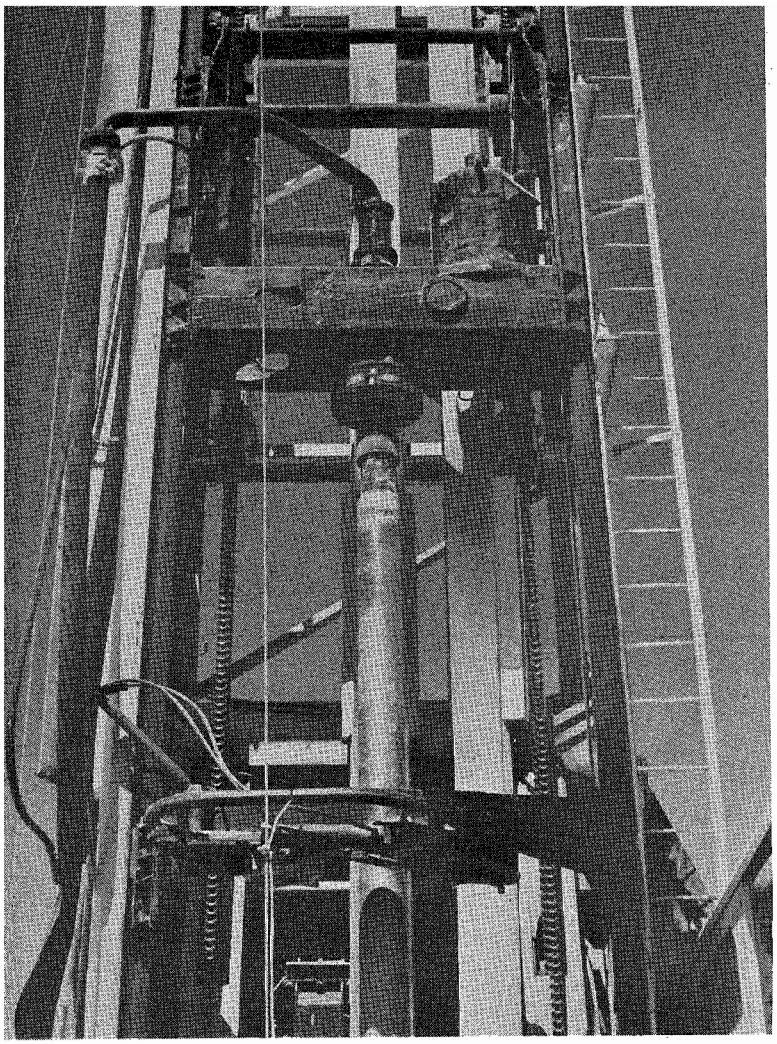
Plans at Panguna call for moving more than 1½ billion tons of earth in the mine itself, not to mention site and roadway building. After the initial hydraulic clearing was done, just about 99% of that total remained for drilling and blasting.

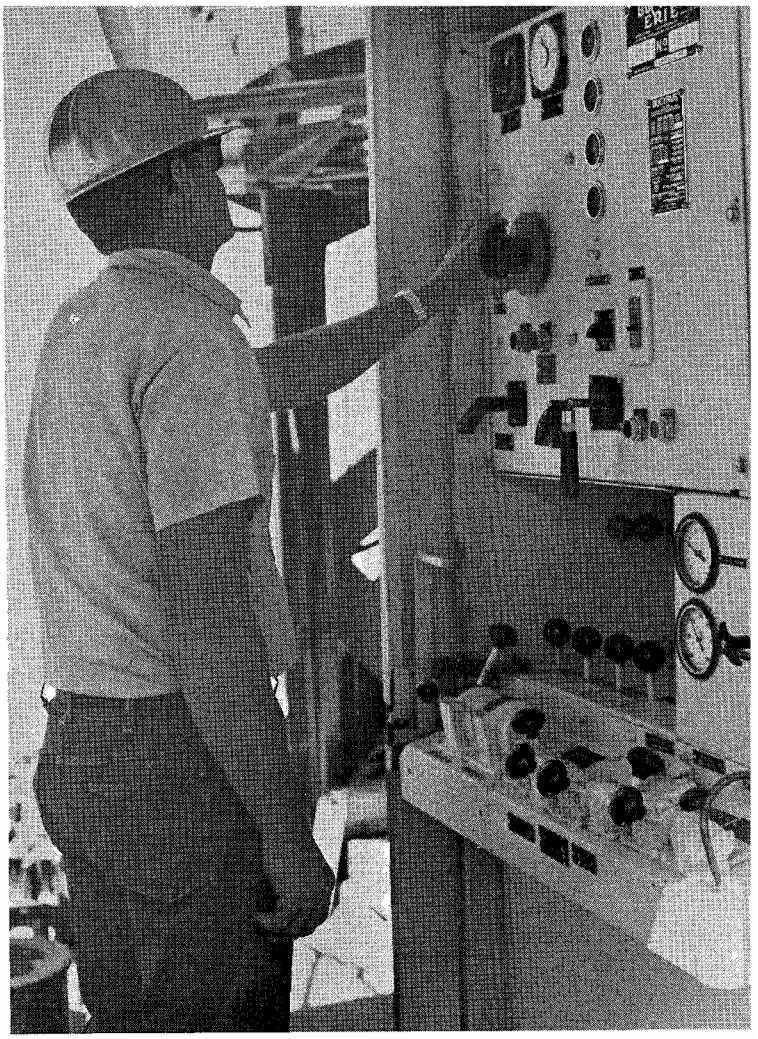
Five identically-equipped BUCYRUS-ERIE 45-R rotary blast hole drills are handling this immense drilling job.

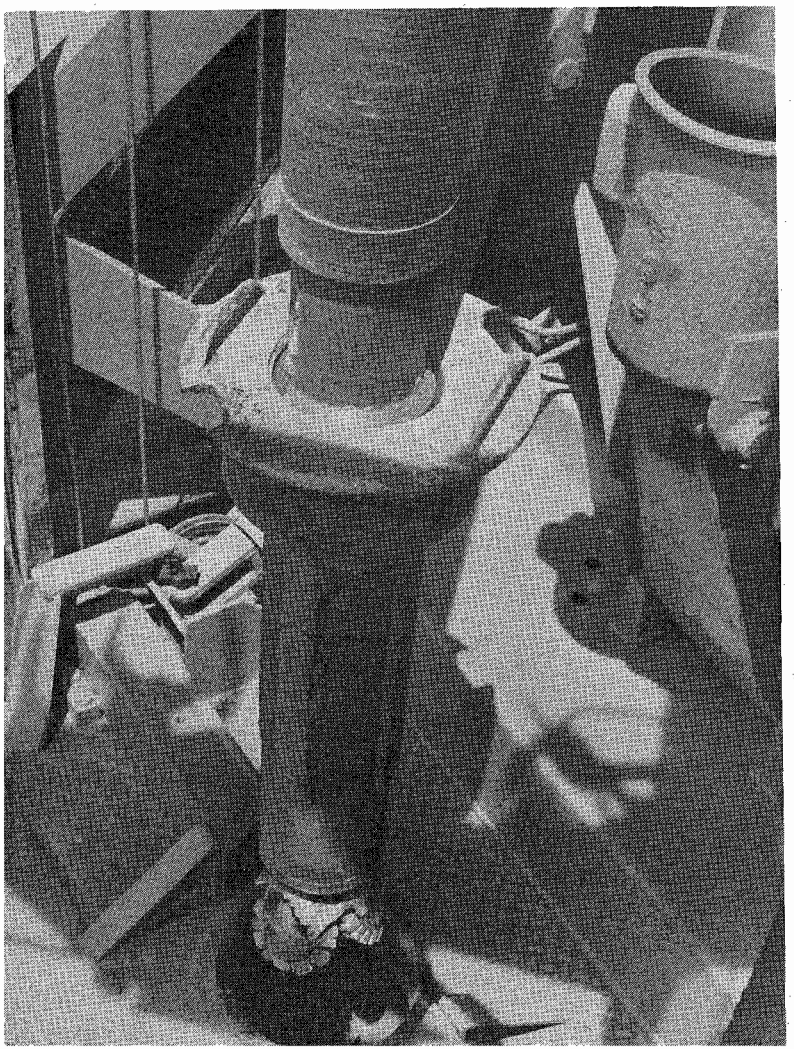
As ordered by Bougainville Copper Pty., Ltd., each drill carries a pair of 32½-foot drill pipes in its 57-foot mast, and uses 9-7/8 inch drilling bits. The all-electric power system features a variable 25/50 horsepower DC rotary drive motor, mounted in the mast, and a 50-hp AC hoist/propel motor. Each drill is capable of generating 70,000 pounds of pulldown force.

The 45-R's at Panguna sink holes from 57 to 60 feet deep, drilling in two basic patterns: 20' by 20' in the quartz diorite areas, and 30' by 35' in the andesites which predominate in the region. The deep holes provide ample toe depth below the 50-foot benches, for stability in the wet materials.

For better flotation and maneuverability under the wet tropical conditions, all five Bougainville drills walk on extra-wide 42-inch crawler pads. Independently controlled hydraulic jacks quickly bring the machine into level drilling position. Water-injection into the drilling hole suppresses dust, while an air compressor powered by a







The 45-R's exclusive mast-mounted Electric Rotary Drive gives the operator instant, infinitely variable control of both RPM and pulldown force. Twin 32½-foot pipes are racked in the mast, which can be hydraulically set up to 30° off horizontal for angle drilling. (Top left)

Remote-controlled tool wrench (A) and utility hoist, along with infinite low-speed rotary control in both forward and reverse, are used to change the bit. Remote hydraulic pipe handler (B) automatically positions each pipe directly over the hole for hookup, and returns to rack after use. (Bottom left)

The operator's cab is insulated, with tinted safety glass, for comfort and convenience. Fingertip control of all machine functions and all-round visibility keep 45-R's operator in full command. Electric, hydraulic and air controls are functionally grouped in easy reach. (Above)

150-hp motor keeps the bit clear by bailing the cuttings out of the hole during drilling.

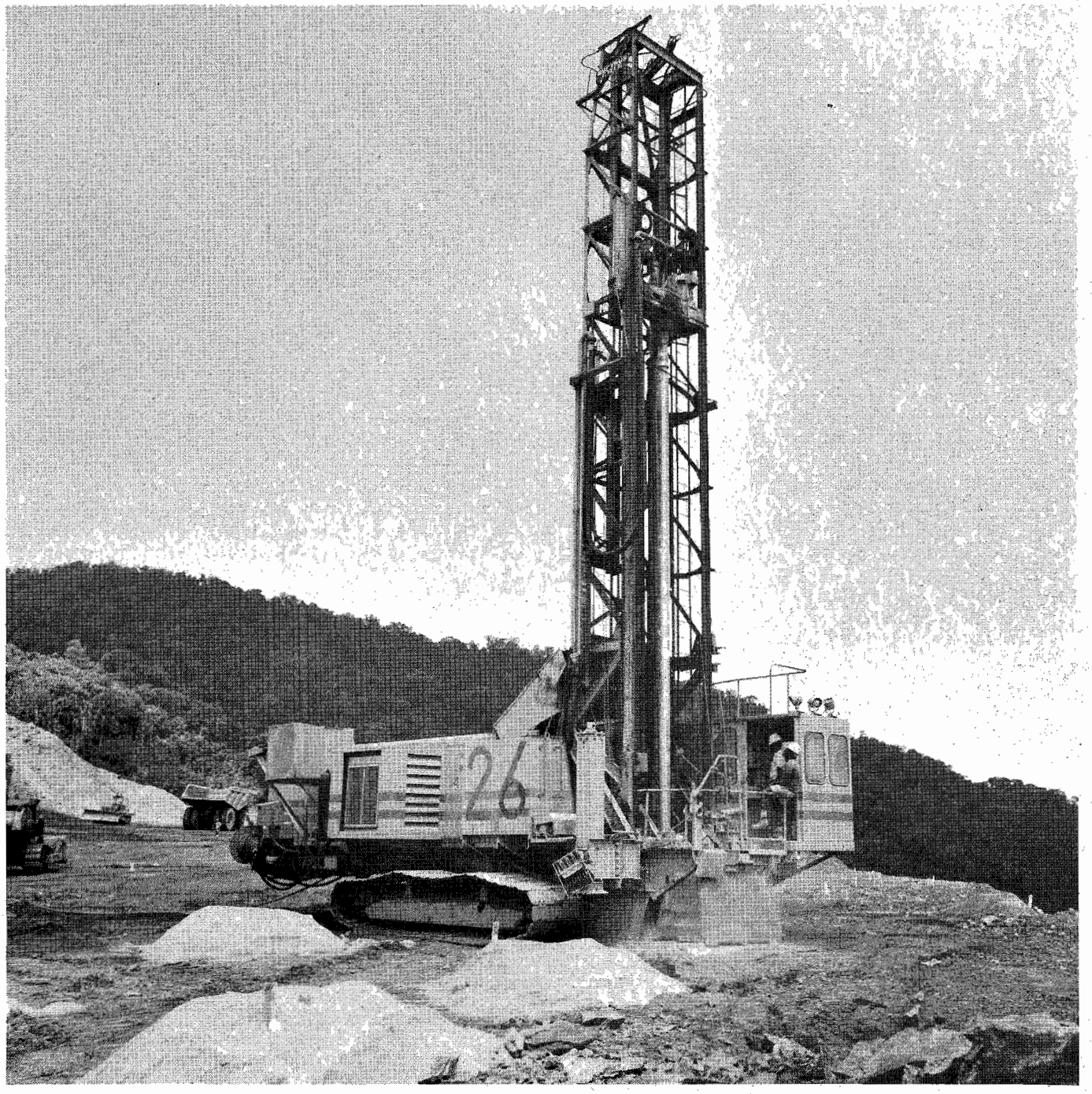
There are more than 100 other 45-R's at work in mines around the world, and in the seven years since the pilot model went to work in an Arizona copper mine B-E's 45-R has won recognition as the industry standard. First to introduce electric rotary drive and the end-mounted, hydraulically-positioned mast, B-E's rotary blast hole drills have long been the most popular choice of surface miners.

In March, 1970, the first two Bougainville drills left BUCYRUS-ERIE's main plant in South Milwaukee, Wisconsin, where all B-E blast hole drills are manufactured. Taking up four rail cars apiece, they travelled overland to Cleveland, Ohio, where they joined a chartered shipload of Bougainville equipment for the long trip to the Solomon

Islands. The other three 45-R's followed, by various routes, that summer and fall.

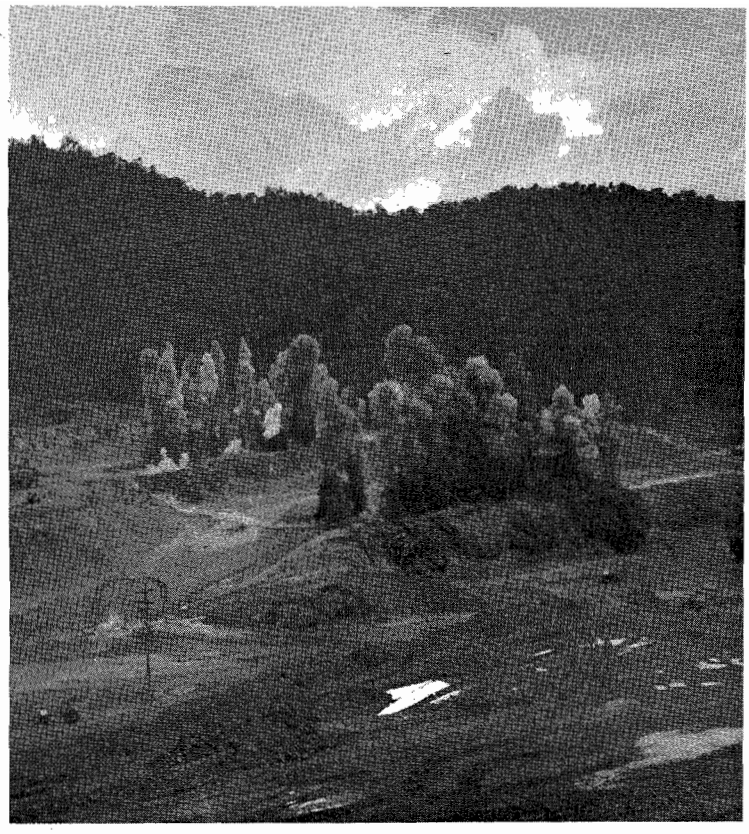
When they reached port at Kieta, the drills were hauled by truck up the winding 16-mile road to the Panguna site. There, a B-E master erector spent an average of four weeks supervising assembly and testing of each drill. In keeping with Bougainville Copper Pty's policy to localize the work force as quickly as possible, the B-E erector also conducted on-machine and classroom training schools for the Panguna crews.

In their first year, the B-E 45-R's were contributing outstandingly to Panguna's production: running at better than 90% mechanical availability, they were achieving an average of over 740 feet drilled per shift (as against 216 feet predicted in the mine plan). The drilling will get tougher as the pit gets deeper, to be sure; but the five Bougainville drills will be equal to the task.



With special protection against the tropical climate for all motors and solid-state controls, the five Bougainville 45-R drills have reached average outputs as high as 100 ft. per hour.

Blasting at Bougainville



Blasting at Bougainville

Rock Types

Blasting at Bougainville has been designed to effectively and economically break the specific rock types peculiar to that mine.

The porphyry copper ore body lies in the Panguna andesite of upper tertiary age. The medium grade disseminated zones in the andesite have a cubic fracture pattern with typical joint systems at 8 to 12 inch intervals. The higher grade ore is usually associated with leucocratic quartz diorite and biotite diorite intrusives in the andesite flow.

The ore body is associated with pyroclastic deposits such as tuffs, tuffaceous shales and agglomerates. An oxidized zone typical of porphry copper deposits exists to depths of 260 feet, averaging approximately 100 feet. The average rock density is 1.32 short tons per cubic yard. Average rainfall at Panguna Hill is about 200 inches per year.

IRECO Site-Mixed-System (SMS)

Because of the unusual climate and rock conditions at Bougainville, special slurry formulations for use with the IRECO Site-Mixed-System were developed and tested by IRECO Chemicals for use in this mine. Initially the IREGEL 300 B Series was used. In March 1973, a simpler system, the IREGEL 600 B Series was introduced. Both systems use non-explosive ingredients that are safely and easily handled and stored. These ingredients are unloaded from ships at the port, stored in warehouses until they can be trucked up the 16-mile road to the mine. There they are stored at the staging plant.

The IRECO staging plant is located on a piece of ground approximately 100,000 square feet. In this area are located all facilities for storage of dry ingredients, preparation of liquid ingredients, maintenance, loading of SMS Pump Trucks, and other offices and buildings for personnel amenities. Figure 1 shows the general layout of the staging plant. The operation is as follows:

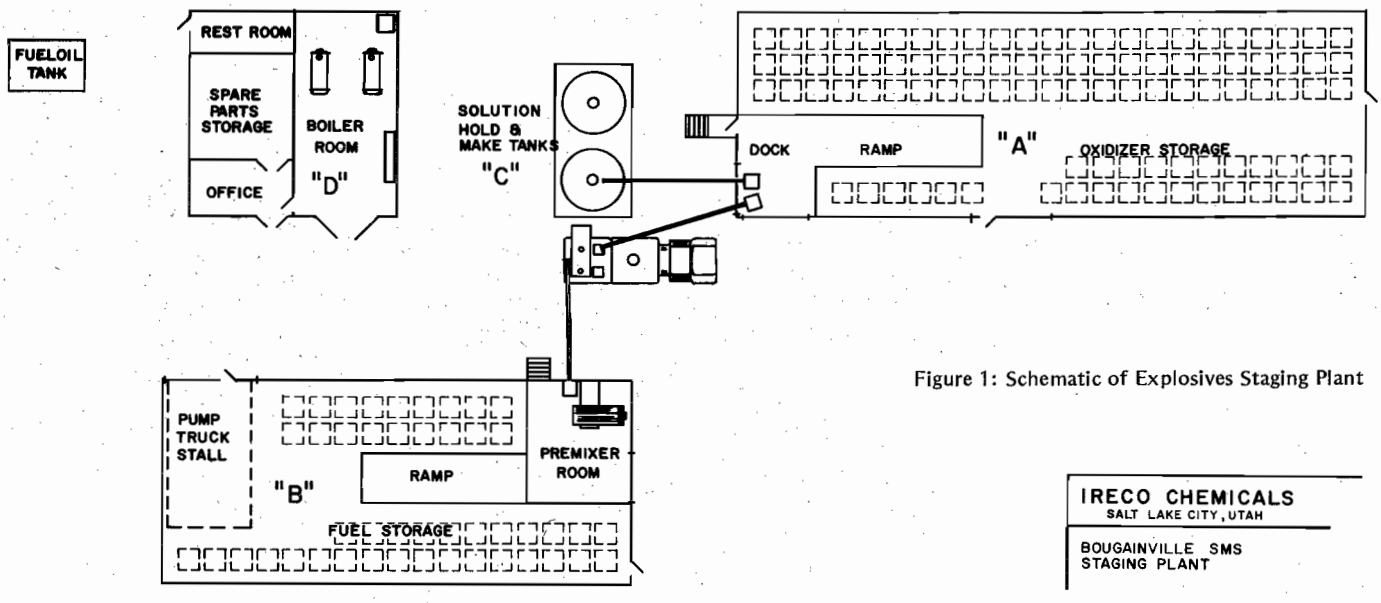


Figure 1: Schematic of Explosives Staging Plant

The dry ingredients arrive at the staging site by truck. Oxidizers are stored in **Building A** (40' x 120') and dry fuel ingredients are stored in **Building B** (40' x 80'). This permits convenient handling of the materials during preparation of the oxidizer solution and loading of the SMS Pump Trucks while minimizing degradation due to weather conditions.

Three times each week, 100,000 pounds of oxidizer solution are prepared in one of the two 12,000 gallon tanks shown in **Area C**. These tanks are of fibreglass construction and are insulated to minimize heat loss as the solution is stored at an elevated temperature. Each tank contains a mixer, steam coils and a temperature sensing thermostat which maintains the solution at a constant temperature. Steam is supplied by two 30 boiler horse power boilers located in the **Utilities Building D.** The utilities building also contains all electrical distribution panels, as well as the office and lavatories.

One of the major considerations in the design and subsequent operation of the Bougainville plant was providing for adequate maintenance. Equipment was chosen not only for its reliability but for its ease of maintenance. A comprehensive preventative maintenance program is carried out to insure consistent supply of explosives to the mine. Building B contains a garage where the maintenance is performed. Spares are stored out of the weather in Building D.

When slurry is required, one of three 25,000 pound pump trucks is brought to the staging plant and loaded with the three component ingredients; liquid oxidizers, dry oxidizers, and fuels. The plant is designed so as to load liquid and dry ingredients simultaneously. Normal loading time is 20 minutes for a 25,000 pound load. Figure 2 shows a truck in the loading area. The canopy is to protect the dry oxidizer salts from rain during loading. The Fuel Storage Building is shown on the left and the Oxidizer Storage Building on the right. Loading takes place by a skip on the left and screw conveyors on the right. Located above the truck is the control panel for operating the conveyors. Also on the right can be seen the oxidizer solution tanks.

An important safety aspect in the design of the SMS pump truck was separation of fuels and oxidizers until such time as the explosive is required in the borehole. Each fuel, oxidizer, or thickening agent is stored and transported on the truck in its own container. Once at the borehole, these ingredients are fed continuously by pump or screw convey-

Figure 2: IRECO pump truck at staging plant

or into a special mixing chamber, mixed, and pumped into the borehole. The main slurry pump will deliver slurry to the borehole at a rate of 500 pounds per minute.

Another aspect of safety with the SMS pump truck is that the critical diameter of the slurry (e.g. the diameter at which it will detonate) is larger than the diameter of the delivery hose. At Bougainville, 100 feet of one and one-half inch diameter hose is used. The critical diameter of the slurry is five inches. Thus, the slurry is virtually non-explosive until it is placed in the borehole. Figure 3 shows the slurry loaded into a borehole.

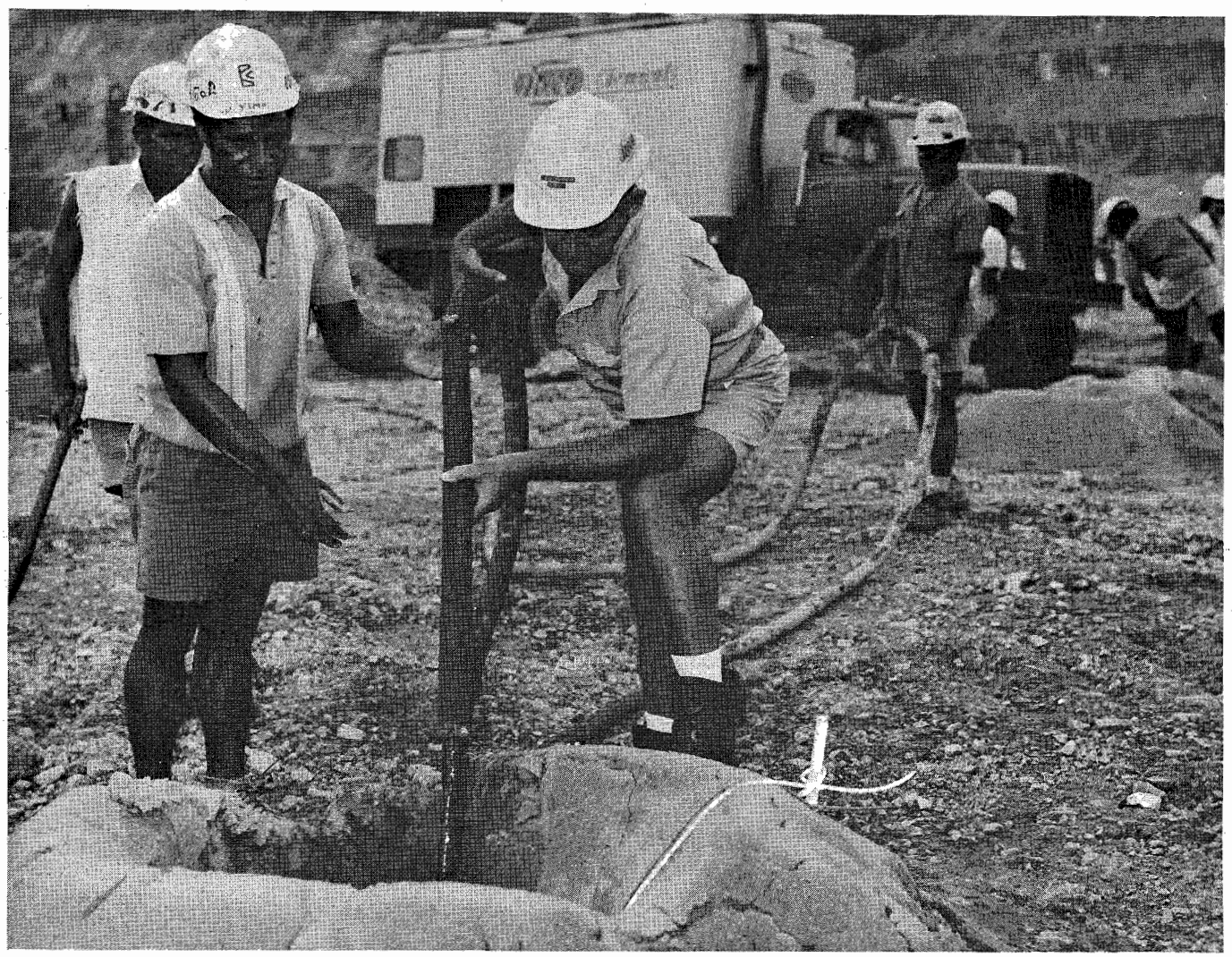
When the hose is placed at the bottom of a borehole, a predetermined quantity of slurry is programmed into the truck's automatic control panel. These panels have four channels with a capability of delivering four different products (of different energies and densities) sequentially into the same borehole. By adjusting the control switches, the operator can select and produce the explosive he desires for the specific rock conditions of each borehole. Thus, a site-mixed slurry is matched to ground conditions by the IRECO operator. The control panel also contains instrumentation to monitor the flow rate of each ingredient. If required, the automatic sequences can be by-passed for manual control. Figure 4 shows the operator in the rear of the pump truck. Above his head can be seen the control panel.

Products

Basically IRECO slurry blasting agents contain oxidizing agents and non-explosive fuel materials. The explosive energy derived from these unique explosives is the result of extremely rapid oxidation-reduction reactions producing highly exothermic products of detonation. Initiation of the slurry explosive is made by means of a high explosive primer. A slurry explosive consists of two phases, a dispersion collodial solution phase and a dispersed phase. Slurry explosives were invented in 1956 by M. A. Cook, present Chairman of the Board of IRECO.

The IREGEL slurries selected for use at Bougainville have excellent water resistance and variable density control. In addition the weight strength of these explosives can be easily varied when a change of energy is required for certain rock conditions. IREGEL slurries are in a liquid phase when pumped and fill the borehole, thus ensuring a perfect coupling with the rock for maximum explosive efficiency.

Figure 3: Loading of IREGEL slurry into borehole



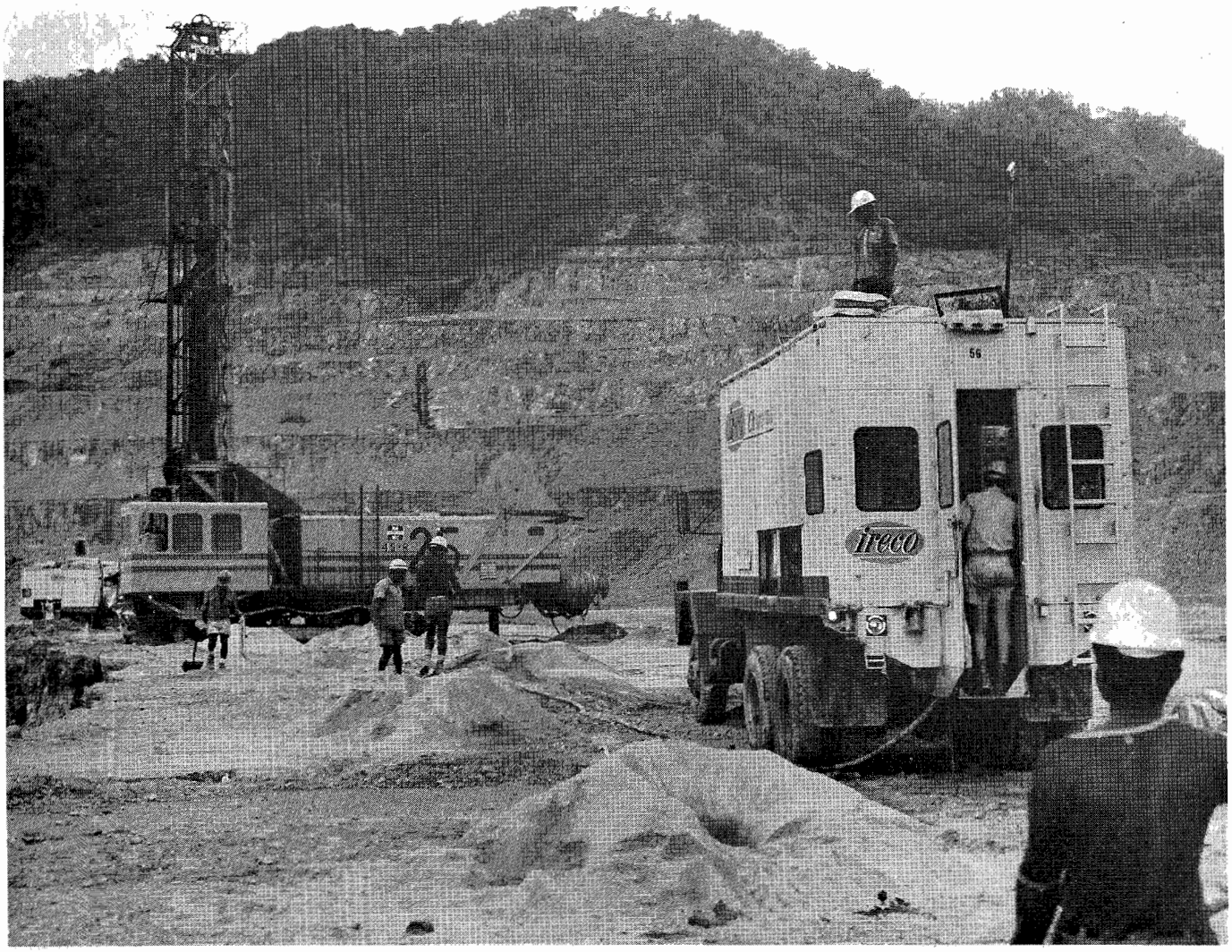
Mine Blasting

Open pit mining as currently planned at Bougainville will excavate ore to a depth of 1000 feet from an elliptical zone 6000 feet long by 4000 wide. The pit was designed with benches 50 feet high. Bucyrus-Erie 45 R rotary drills are used with 9 7/8" tricone bits to drill blast-holes 56 to 60 feet deep. Burden and spacing vary considerably depending on joint and fracture conditions in the rocks. Typical patterns are 30 feet by 35 feet in andesite and 20 feet by 20 feet in quartz diorite. Blast-holes are loaded with 36 to 45 pounds of slurry per foot of borehold with densities varying from 1.05 to 1.30 g/cc. Bulk strengths vary from 1.05 to 1.6 times the bulk strength of ANFO.

Since the andesite is prefractured, moderate energy such as that provided by the base IREGEL 606B mix is adequate to obtain suitable fragmentation. In the harder quartz veins, however, aluminum is sometimes added for additional strength.

Slurry loading factors range from 0.5 pounds to 1.35 pounds per cubic yard. Two cast pentolite boosters are strung on two 50 grain per foot detonating cord downlines for bottom priming. Tie lines are 25 grain detonating cord with millisecond delay connectors. The slurry column rises about 32 feet in the normal hole leaving an average stemming height of 25 feet. When aluminized bottom loads are used they generally make up one-third of the column load. Rock fragmentation at Bougainville has been excellent with practically no secondary blasting required.

Figure 4: IRECO pump truck operator loading pattern



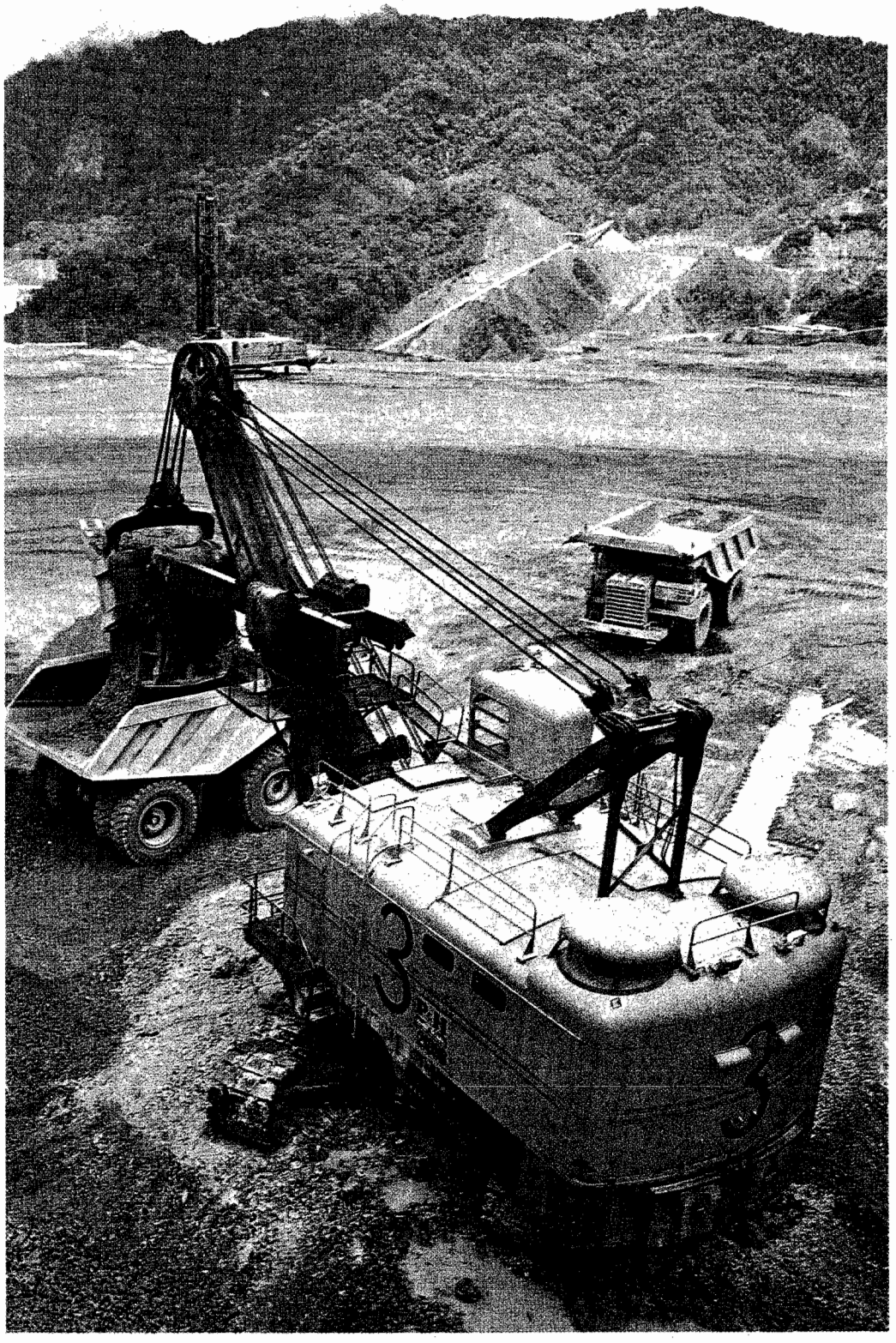
Electric Mining Shovels

BOUGAINVILLE . . .
another all P & H pit.

Harnischfeger,
Milwaukee, Wisconsin, U.S.A.

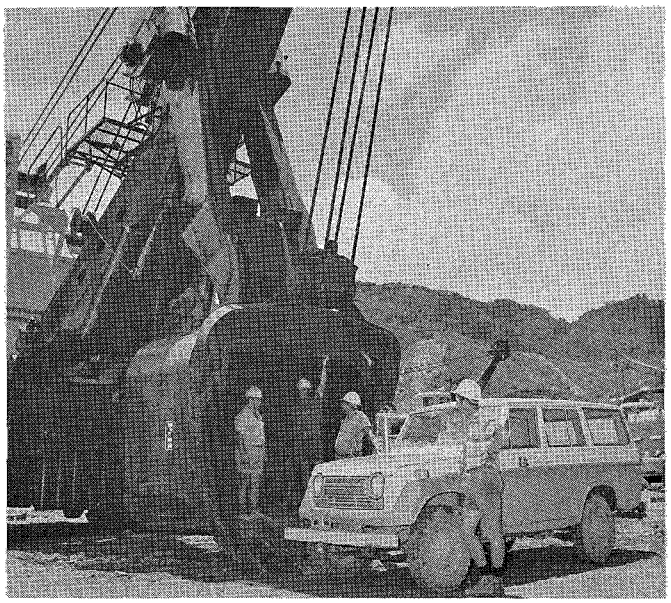
The largest open pit copper mine ever built in a single stage and projected to be the world's 4th largest open pit mine in output by 1973. That's the new Bougainville mine, open since April 1972.

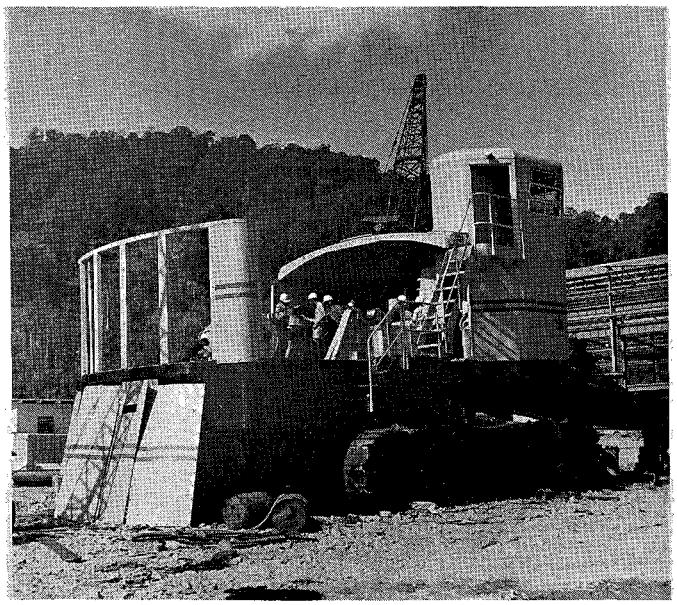
And from the mine's commencement of production, it's been going all out with P & H. The pit uses P & H shovels – exclusively. P & H 2100 B 17-yard Electric Mining Shovels, built by Kobe Steel Ltd.



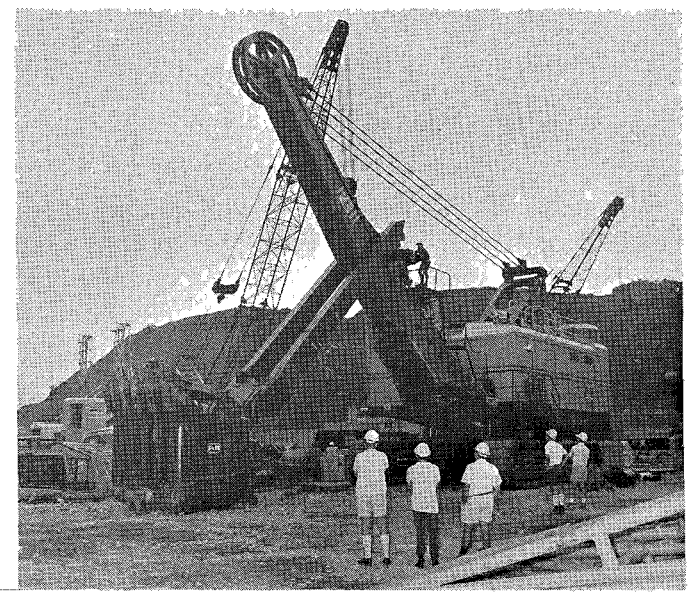
The six P & H 2100 B electric shovels purchased by Bougainville Copper were amongst the first shovels of this size to be manufactured under licence in Japan. Selection of 17 cu. yd. dippers followed the determination of bulk loose density of ore at 1.32 short tons per cu. yd.

Mining equipment was based on an estimated production of 13,000 tons per shovel shift, 12 shovel shifts per day — nine to ore and three to waste. Mechanical availability for the six P & H 2100 B shovels has been 84.6% compared with the feasibility estimate of 50%.



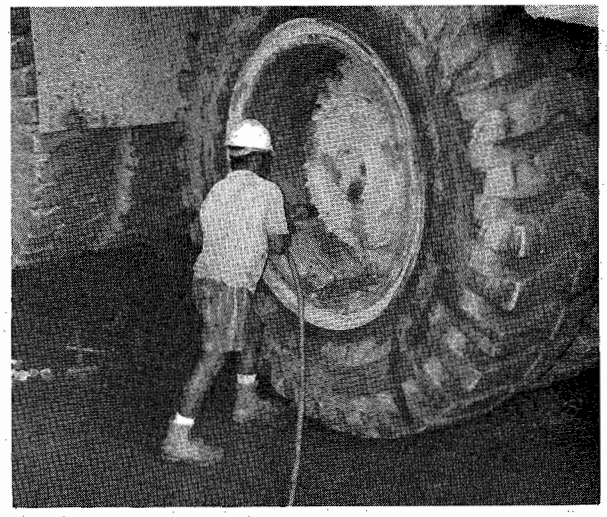


P & H electric shovels undergoing final assembly by P & H engineers at Panguna mine site.



Tyres

Dunlop Australia Ltd.



It all started when Jim Quealy went for a walk in the jungle. Not a tourist stroll through the lush, tropical vegetation, but a two-week footslogging trek over bush tracks and back-breaking mountain climbs. Dunlop Australia had come to Bougainville.

That was in 1969 and the task looked like being tagged 'mission impossible'. But at stake was the biggest single tyre contract in world mining history.

Everything seemed to point to giving the Bougainville project a wide berth. There was no port to unload equipment and material. Just the sleepy fishing village of Kieta — peaceful and primitive but an unlikely beachhead for a multi-million dollar operation.

A 16-mile road had to be carved out of the virgin jungle to the proposed mining site. On the face of it, a not unduly tough job until it was realised that the road could bog vehicles axle deep in mud, that sudden rain storms could wash away the surface — annual rainfall is 200 inches — and that the road would have to follow a razorback ridge with a cliff-hanging one-in-four climb. Mission impossible, indeed.

But not for Dunlop's go-ahead Jim Quealy. His report back to Dunlop's executive in Melbourne was terse and to the point, "We can do it". And he got the go-ahead.

The challenge was on, but Quealy and his men had done their homework the hard way — in the field. Early in 1969 Dunlop took part in helping to force a new 100-mile beef road through virgin scrub in the MacArthur River area of the Northern Territory.

This was an exercise in logistics for project boss Tom Gill and his men — tyre performance in rough unforgiving terrain, supply problems in the vast Outback, keeping the construction vehicles running without the benefit of workshops, working long, hard hours in energy-sapping heat. This was the Commando-like work-up for Operation Bougainville. It lasted a year then Gill and a 19-man handpicked crew headed north for Bougainville. And even bigger problems than the beef road.

At Anewa Bay all equipment had to be brought ashore by barges until a proper port could be built. Everything had to be manhandled — no easy job with giant earthmover tyres weighing up to a ton each — until cranes were set up to help with the unloading. Then the 16-mile road to the mine site had to be pushed through.

As the road sliced into the jungle up to $750,000 worth of tyres were stored at nine points along the way in bark humpies and under trees — the only available cover. And they were needed. Conditions were so bad that 30-ton low-loaders carrying equipment to the mine site bogged to their axles in mud. Bulldozers had to pull them out then push them up the dizzy mountain track while the trucks churned their wheels with up to 100% wheelspin. It was not unusual for a set of tyres to last a mere 80 hours — scraped, torn and hacked by the rocky outcrops of the mountain ridge. Finally, the road was finished, gradients eased to 15 per cent from a heart-stopping 27 per cent and bitumen or concrete surfaces laid in the worst stretches.

Time for a breather, but not for the Dunlop men. Their job was just starting. Faced with servicing the biggest concentration of rubber-tyred earthmoving equipment in the world working around the clock seven days a week, there was no time to sit back and take in the scenery.

With 42 Euclid R105 dump trucks in constant use — this number later rose to 55 — and each truck having eight tyres some problems were expected, particularly as the site conditions were virtually identical to those found in underground mining . . . . soft, mud overlay on jagged rock. At the start of mining operations tyre life in some cases was an alarming four hours. This was traced to misuse or driver inexperience with the Euclids, which carry a load of 105 short tons. And with each tyre costing close to $2,000 each, a solution was needed — in a hurry.

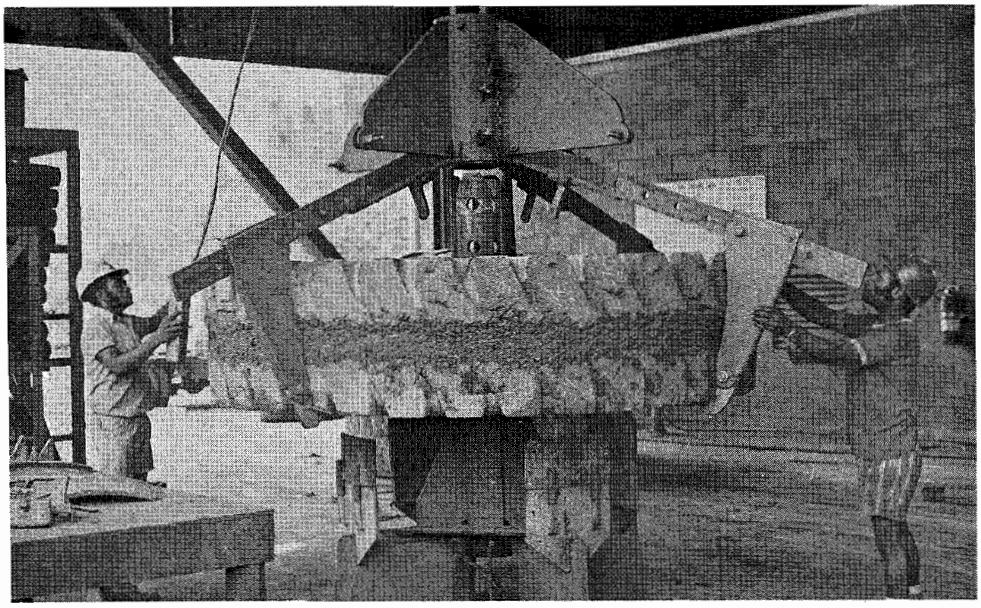
All the Euclid drivers are specially trained, hand-picked Bougainvillians. Sitting high up in the cab it's not easy for an experienced driver to estimate his travel speed. How much harder must it have been for those local boys whose first encounter with motor vehicles was driving the big ones.

So a programme was started to check and maintain speeds within 20 miles an hour on the ore haul and 15 miles an hour on the waste haul. The ore haul is a short distance run, but the waste haul covers more than 1½ miles. This way, the Dunlop men could keep a constant check on tyre life — and abuse — as well as play a continuing part in the driver training programme.

And as a double check load cell weighbridges were set up which can tell instantly whether either the front or rear axles are being overloaded. This information can be relayed on the spot to tell the shovel operator that he is not putting a balanced load in the dump trucks. The weighbridges — accurate to one per cent and not requiring the trucks to stop for the load to be checked — also record the gross vehicle load, enabling an overload analysis to be carried out.

This combination of driver training and electronic load cells has been a major factor in controlling speeding and overloading — the two most severe causes of tyre failure.

Special Fork-lift taking a tyre and wheel assembly off one of the big Euclids.



Demounting a worn tyre from its wheel with the giant Dunlop tyre fitting machine.

Exacting conditions like those at Bougainville demand specialised knowledge and tyres tailor-made for the job. There's no room for a 'she'll-be-right' approach when a $200,000 Euclid is standing idle for want of proper tyres and servicing instead of earning its keep. That's why Dunlop Australia right from the early beginnings of the Bougainville project has carried out an intensive program of constant improvement to increase tyre life and cut operating costs.

At first tyre mortality was high, but by using a feedback system of information to Dunlop's technical centre in Melbourne and by using a computer to analyse the data and performance of several rival brands of tyres — fitted as initial ex-factory equipment on some of the dump trucks — tyre wear has been slashed dramatically. Each month tyre performance is evaluated and new compounds are being introduced in a bid to give longer tyre life. With a tyre contract this big, you don't stand still.

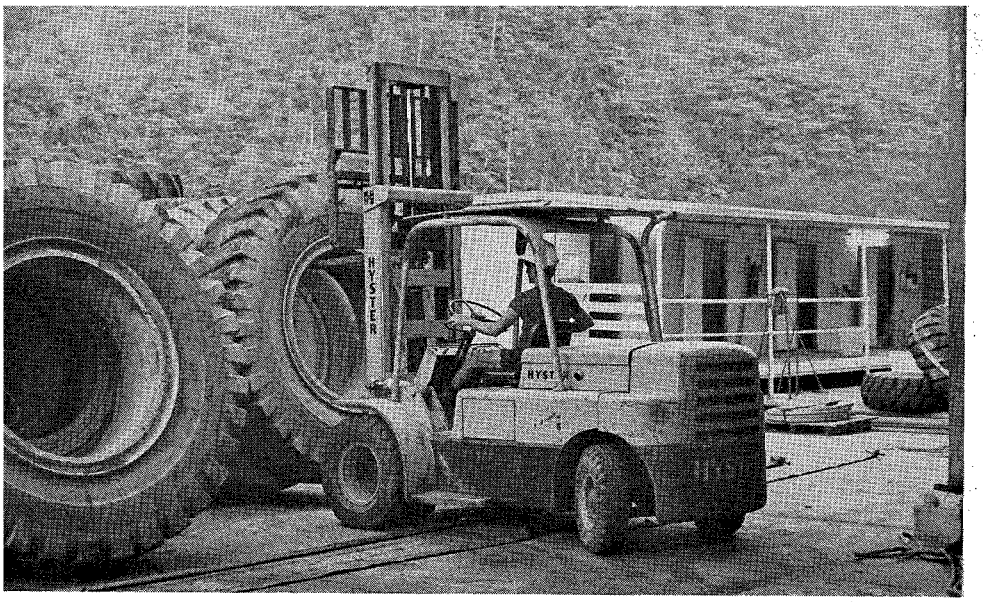
Until a proper Dunlop servicing building could be put up on the mine site, all work on tyres was done on the spot. Tom Gill's crew of 19 Australians and 30 indigenes had to make do until special equipment was brought in. Like changing giant earthmover tyres all of 100 inches in diameter and weighing a ton apiece on the spot and having to use concrete slabs to stop the jacks from sinking in the mud. Or having to sweat for hours in the clinging humid heat to change a tyre on a wheel.

That's all changed now. From stockpiles of tyres under trees and in bark shelters, a modern 20,000 sq. ft. warehouse has risen at Nairovi, five miles from the one-time fishing village of Anewa, now transformed into a bustling port and power station site.

Dunlop Australia's on-the-job equipment includes five cranes mounted on four-wheel drive trucks, three fwd light commercials, four personnel carriers and service trucks, four forklifts, a materials handler, a specially-designed forklift for handling ultra-large tyres and an $11,000 giant tyre removal unit which allows a tyre to be removed and replaced in 20 minutes instead of 1½ hours manually. They've come a long way since those early days in the jungle.

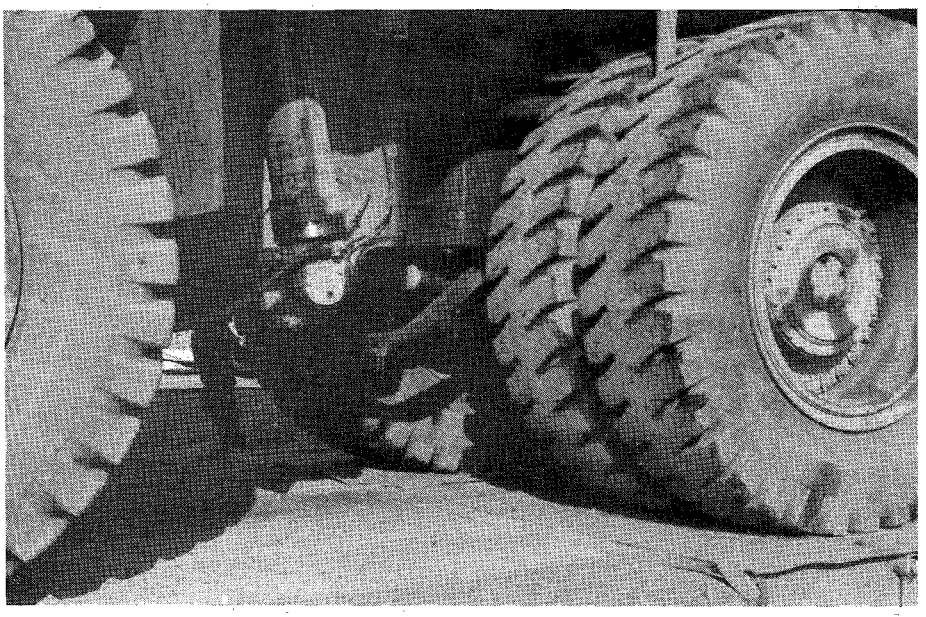
Total investment in equipment is $2 million and tyre stocks carried usually run to more than $1.5 million.

But as well as the money investment, Dunlop Australia believes in investing in the future by training local labor. That is why the new streamlined operation in Bougainville now totals 11 Australians and 22 indigenes. The company runs a three-month training course for local labor. This scheme has worked so successfully that one complete shift



Handling new tyres, already mounted on rims.

Truck passing over weighbridge.



of servicemen, including the foreman, are all indigenes.

That alone is a big step forward since Jim Quealy went bush in 1969 . . . . . .

But Dunlop Australia's involvement in the Bougainville project was not solely confined to tyre supply and servicing. Two of the company's major offshoots were called in to lend their expertise. They were the Industrial Products Division and the Battery Division.

Ore crushing is done by 21 secondary and tertiary crushers at the Panguna mine site and a Dunlop subsidiary, Pulleys (Aust.) Pty. Ltd. designed a quick removal motor pulley hub made of cast steel. This contrasts with the cast iron type of hub normally supplied for smaller equipment and represented an important technical development.

Each crusher motor has a 25" pitch circle diameter x 14 E grooves pulley giving an overall 25" face. Each crusher pulley is a 42" P.C.D. x 14 E groove pulley having a similar face width of 25". Weight of one P.C.D. pulley and hub is about a ton. The cone crushers at Panguna have 21 motor pulleys and 21 crusher pulleys.

Choice of these pulleys and the supply of 14 matched sets of 252 300 E-section Dunlop V-belts was a tribute to the technical services and skills of the Dunlop Industrial Division.

As well, Dunlop Skega linings have been supplied for three regrind ball mills which grind fine ore into fine particles. In this section 9 primary and three regrind ball mills in all will use 20,000 tons of steel balls a year.

The Battery Division was faced with its share of problems as the mine site was opened up. Because of vehicle vibration and high temperatures, expected life for ordinary batteries was around four months.

The Battery Division, based at Sandringham in Victoria, provided a special bonded element type battery with the plates in each cell secured to the base of the battery.

Each group of plates was specially packed to stop horizontal and vertical movement, keeping internal damage to a minimum.

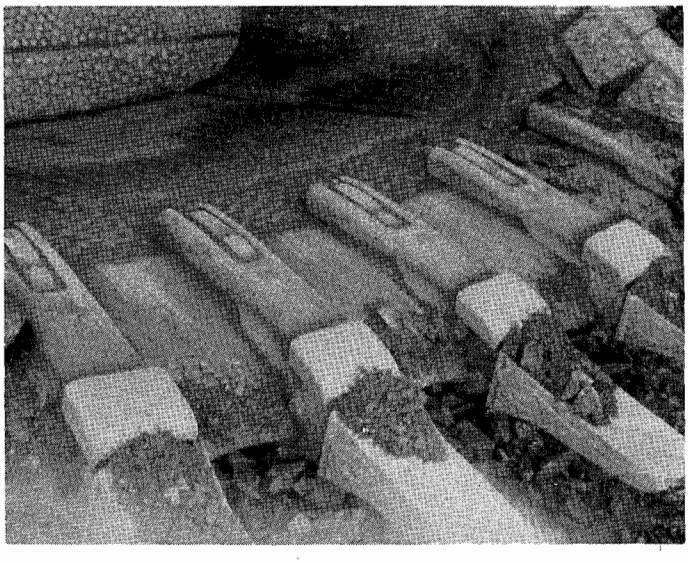
Battery life in this area was further prolonged by using a special lower specific gravity electrolyte to suit the high working temperatures at the mine site and cut down dramatically the excessive rate of battery plate corrosion.

Illustrated on page 292 is a short head tertiary cone crusher being positioned at the fine crushing plant.
Pulleys Australia Pty. Ltd. supplied the special pulleys.
Matched V-belt drives are by Dunlop.

Earth Engaging Tools

Unprotected lip, between teeth of shovel dipper. This area was a major problem for Bougainville.

Between teeth area of shovel dipper is now protected with high hardness weld on lip shrouds.



Since the start of operations by Bougainville Copper Pty. Ltd. on Bougainville Island in 1967, "wear" has been one of the biggest factors in the use of equipment. To overcome this problem ESCO with its various abrasive resistant alloys has been used on all types of earthmoving equipment operated not only by B.C.P.L. but also by the contractors who were engaged in earthmoving and road building.

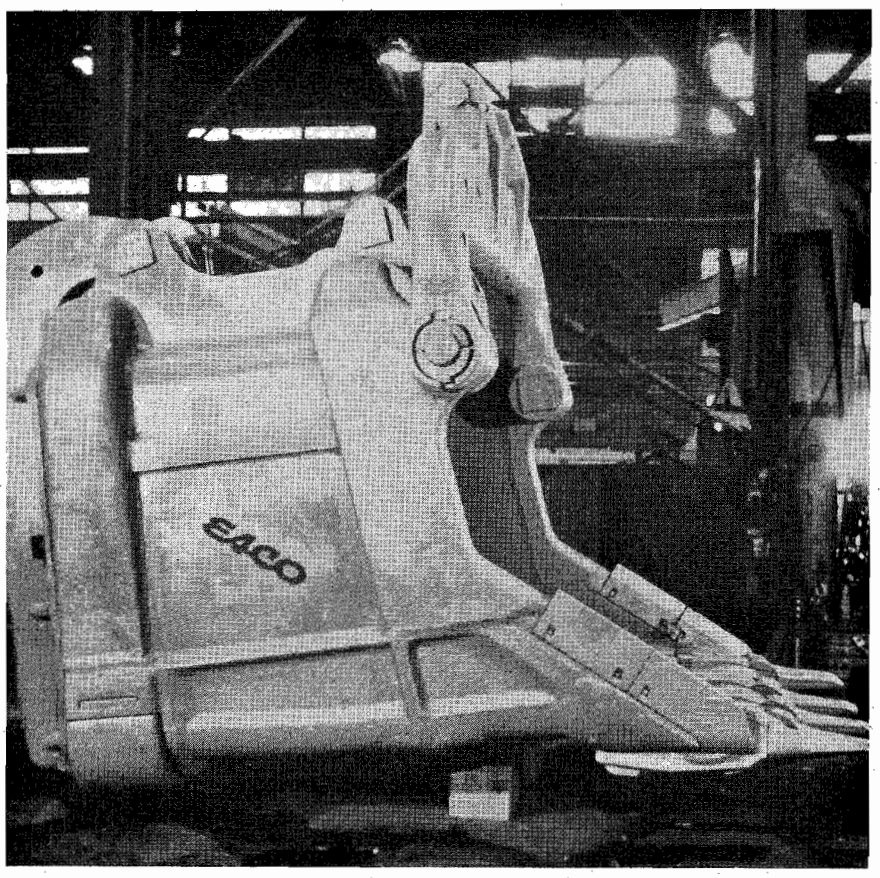
Companies such as Morrison-Knudsen-Fluor were familiar with the qualities of ESCO from previous projects, thus Equipment Distributors Pty. Ltd. who are the licencees for ESCO in the South Pacific were one of the first suppliers of earth engaging tools to this part of the world.

The wear problem was most acute with the shovels used in winning the ore as both teeth and lips were particularly vulnerable to this abrasive wear. To overcome the tooth problem, production of ESCO's Alloy 12S was started in Australia. Alloy 12S is a medium carbon steel containing over 4% alloy and it is hardenable to a depth of five inches and possesses high strength and hardness. Impact resistance is excellent in relation to hardness and the use of this alloy has considerably extended the life of the points in comparison to that previously obtained.

The next problem to overcome was that of wear in the lip section between the adaptors, as shown in Figure 1. This was solved by designing shrouds to fit between the adaptors and protect the leading edge of the lip (Figure 2). The shrouds are cast in ESCO Alloy 12 and to date have given extremely good life.

Other items of the ESCO range used on site are cutting edges and end bits for dozers and scrapers, rippers for dozers and smaller teeth for the loaders and backhoes used on the various jobs. The success of these units has led to the purchase of an ESCO 17 cu. yd. WCW Series II Shovel Dipper.

This unit will be fitted to a P & H 2100B electric shovel. The prime function of this dipper is the removal of the ore body for processing to copper concentrate.



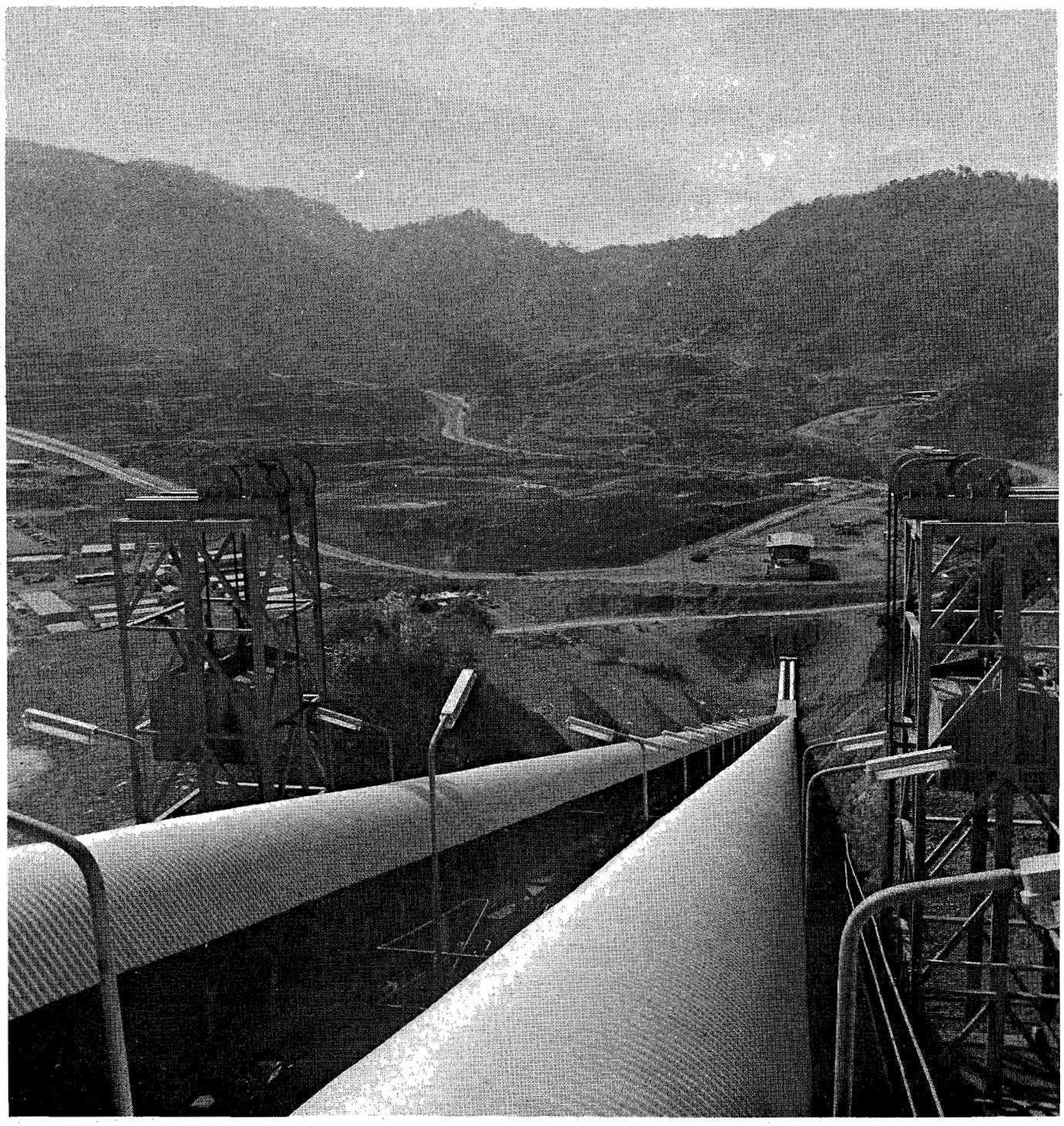
Side profile of latest Esco wide cast weld series II shovel dippers.

About the dipper –

The Series II shovel dippers from ESCO have been designed and produced over the last two years from experience gained over many years on the iron ore and copper sites throughout the world. Special features of this dipper are its curved lip, its low height and, in particular, the mechanically attached shrouds or wear pieces. From observations taken throughout the mining industry, it became apparent that the older style of shovel dipper was not suited to the modern excavator. As a result of this, the latest design from ESCO is now wider and lower so as to ensure that a full dipper is obtained with every pass. The curved lip design was chosen for its ability to load with less power requirement. This, coupled with the low, wide profile of the dipper, ensures faster and easier loading.

The shrouds on the ESCO dipper are attached by means of fluted spools and wedges or rubber locks and pins and are located in critical wear areas of the shovel dipper. These wear areas occur in between teeth in the shovel dipper wings and in the corner heel section. As the shrouds are mechanically attached and therefore do not require welding to retain them in position, they can be produced in alloy steel with a Brinell of 500. The high Brineil of this steel ensures maximum time between shroud changes.

These features ensure the ESCO dipper gives maximum production and minimum down time.

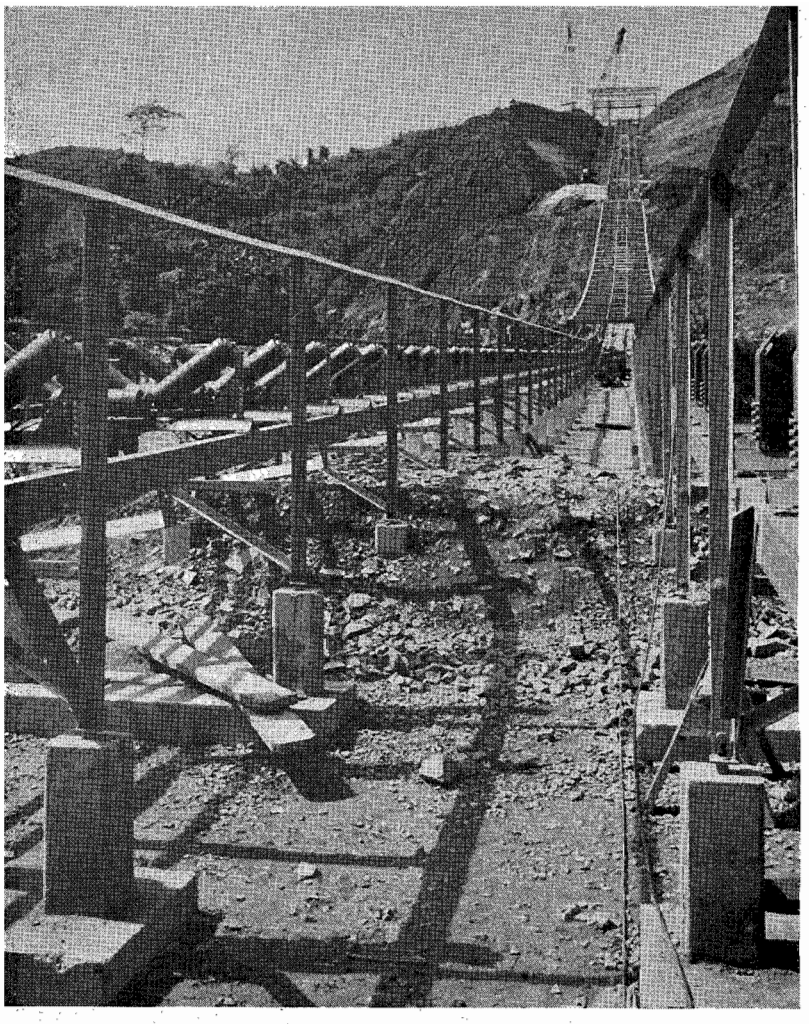


Coarse Ore Conveyors with Primary Crusher and Mine Pit in background.

Conveyors

FOX CONVEYORS HASTEN BOUGAINVILLE'S GIANT OUTPUT

Conveyor head of the two 54" belt conveyors which lift 3,500 tons per hour, a vertical height of 525 feet to the coarse ore stockpile.



One of the toughest and most adventurous assignments for Fox Manufacturing Company's conveyor equipment is in Papua New Guinea where millions of tons of ore are being processed in the giant project operated by the Bougainville Copper organisation.

This tremendous engineering job involves logistical planning on a grand scale.

The immense loads of ore are carried by almost 60 Fox conveyors from point to point in the processing treatment, maintaining the speedy output and the economy of operation which the project demands.

Fox Manufacturing Company supplied all conveyor hardware including conveyor rollers, drives, pulleys, gear boxes and couplings.

In all, 54 belt conveyors are operating in the mill complex at Panguna, whilst a further 15 have been installed in the port area. It is a tribute to Fox Manufacturing Company's reputation that such a large order, worth more than $A3.3 million, was secured and successfully fulfilled.

Continuous processes are used in all stages of the ore treatment and it is logical that continuous interstage material transport be used, with buffer storages in the form of stockpiles or surgetank capacity in case of breakdown of any component. Fox Manufacturing Company's continuous belt conveyors meet these requirements in all ways, due to the company's wide experience in design and manufacture of this form of equipment.

The wide range of conveyors included innovations in both idlers, pulley and drive sections. Special-feeder, shuttle and tripper conveyor types were required in many differing lengths, belt widths, delivery rates and other parameters.

One aspect of the processing operation required two large converyors each to elevate 3,500 tons per hour up a vertical height of 525 feet.

The environment in which these conveyors operate is not a kind one. The site is only 6 degrees south of the Equator, and tropical conditions of extreme humidity and heavy rainfall exist. This, coupled with the fact that sulphide ores are being handled, promotes highly corrosive conditions, so thorough protection of all equipment was essential. All bearing of conveyor idlers and pulleys are provided with triple layrinth seals and the steel frames are painted. All conveyors outside the buildings are covered against the weather.

At this point a change occurs in the movement of the ore. The discrete 100 ton loads which are tipped into the primary crushers turn into a continuous flowing stream, carried forward from one treatment stage to the next along a network of conveyors. In the two main areas of operation the mill and concentrating sections at Panguna and in the dewatering and shiploading sections at the Port area belt, conveyors are used.

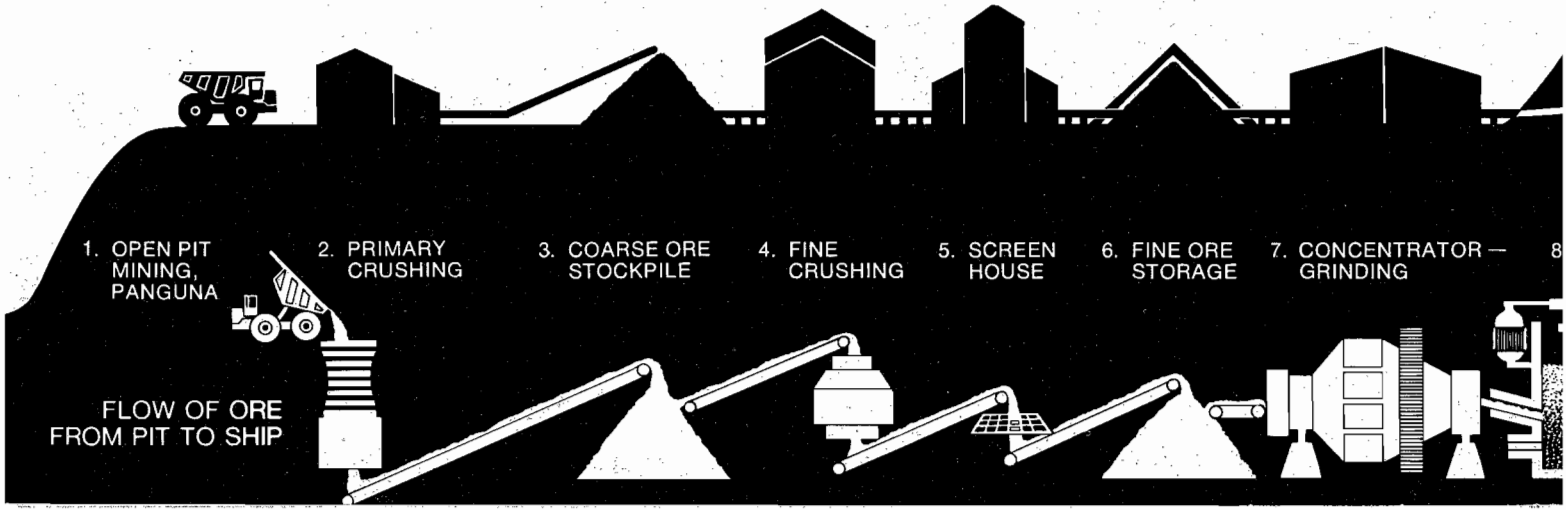
The flow diagram at foot of page shows in outline the paths taken by the product in its various forms as it progresses through the various treatment stages from open cut to ship. The conveyors supplied and where they fit in the general flow diagram is indicated below.

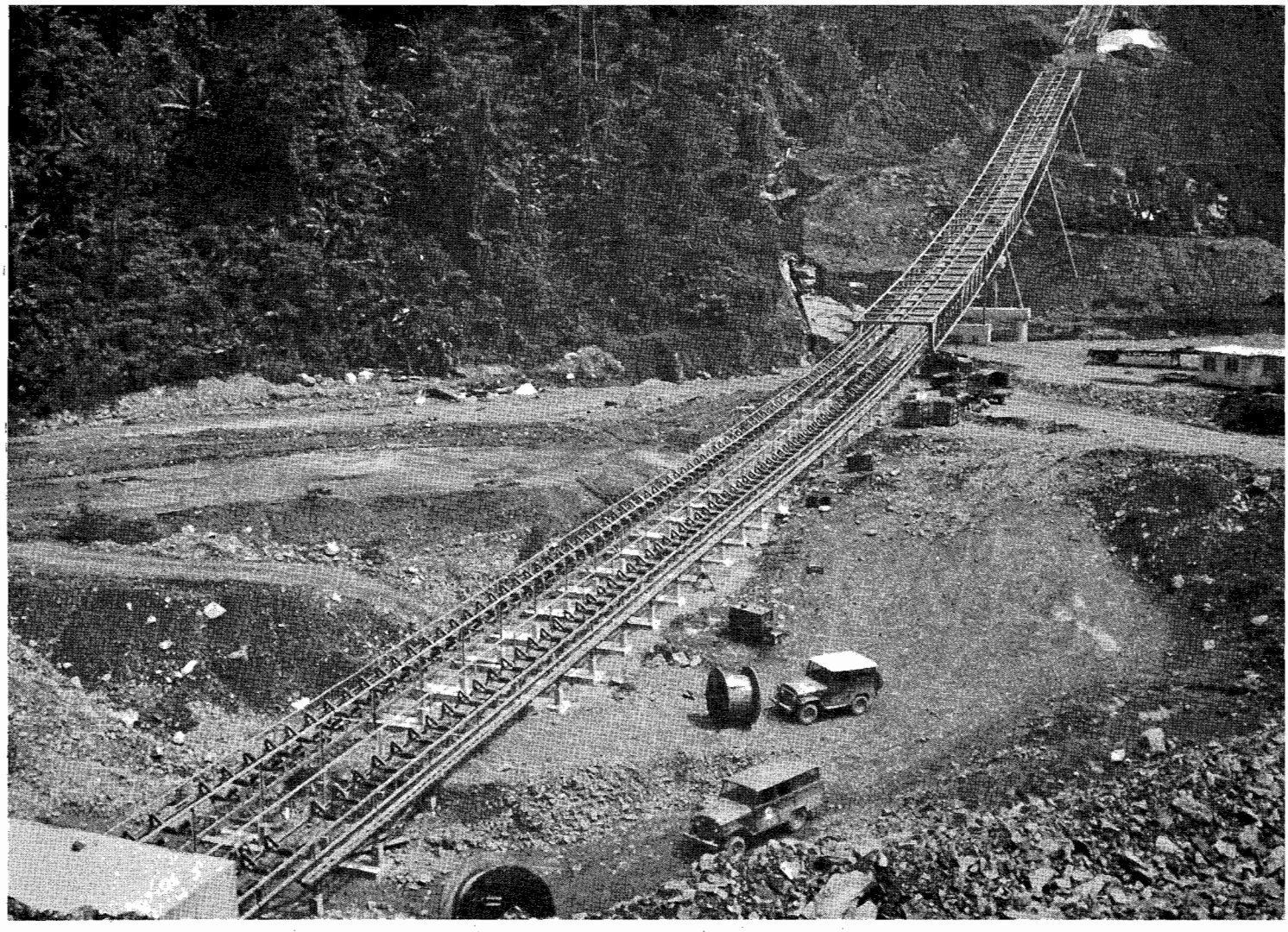
Stage 2 to Stage 3

In the mill section at Panguna are Coarse Ore Stockpile Feed Conveyors. Two large external conveyors carry ore from the primary crushers to the coarse ore stockpile. Belt width is 54", conveyor length 2400 feet approximately, belt speed 598 fpm, capacity 3500 stph and initial drive horsepower 2700.

Stage 3 to Stage 4

Secondary crushing feed conveyors. Two shuttle conveyors carry ore from coarse ore stockpile to secondary crushers in fine crushing plant. Belt width 54", conveyor length at maximum extension 676 feet, belt speed 441 fpm, capacity 2665 stph, drive horsepower 150.





Twin Conveyors each elevate 3,500 tons per hour up a vertical height of 525 feet

Stage 4 to Stage 5

A complex of conveyors involving:

(a) Crushed ore collecting conveyors. Two conveyors carrying product from secondary and tertiary crushers to discharge into:

(b) Two 72" crushed ore conveyors each fitted with a tripper travelling to distribute the product into a group of surge bins which feed the tertiary screens via

(c) Sixteen 84" tertiary conveyor belt feeders driven by a variable hydraulic drive remotely controlled to give a belt speed of 18 ft. to 36 ft. per minute and a capacity up to 648 stph each.

(d) Two 54" screen oversize collecting conveyors carrying oversize from the tertiary screen back to

(e) Two 54" tertiary crusher conveyors with a capacity of 2743 stph at a belt speed of 467 ft. per minute each fitted with a tripper travelling to distribute the product into tertiary crusher surge bins which feed onto

(f) Twelve 48" tertiary crusher belt feeders driven by a variable hydraulic drive remotely controlled to give a belt speed of 25 to 50 feet per minute and a capacity up to 457 stph.

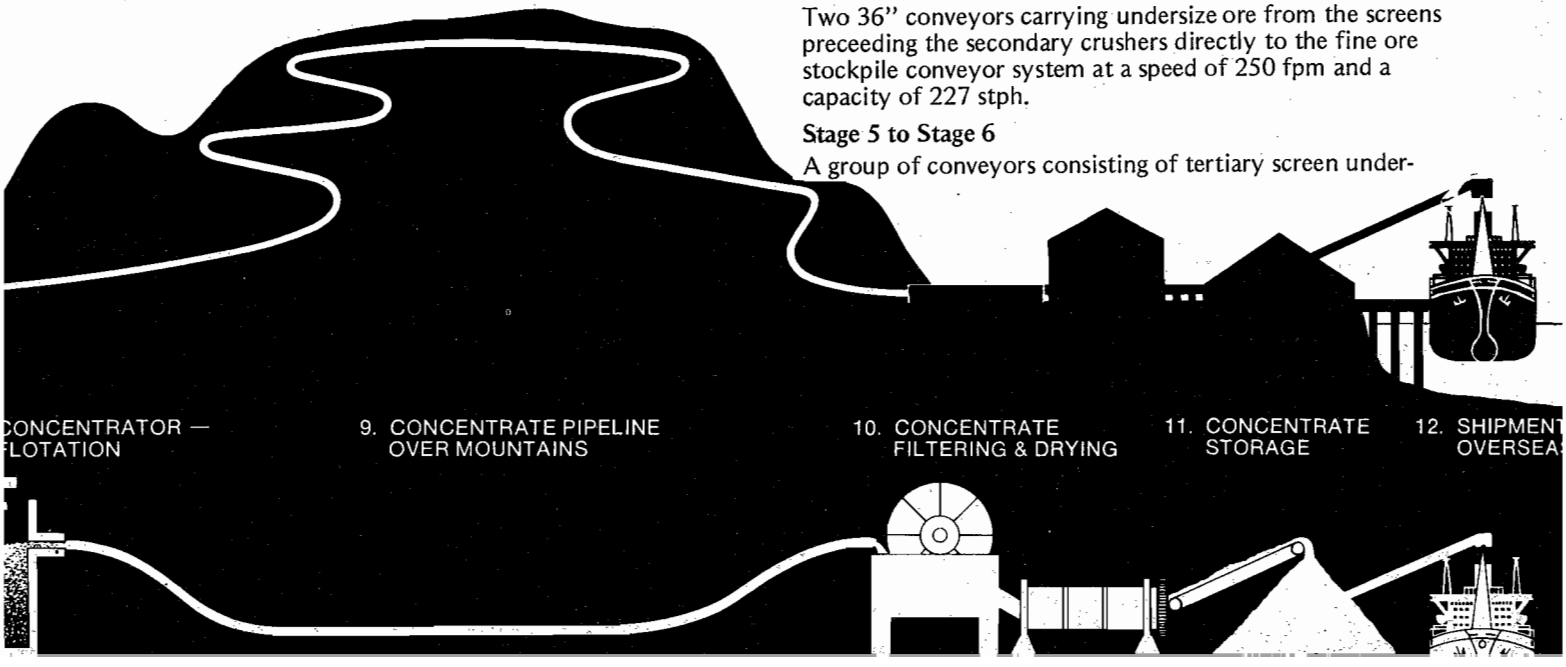
Stage 4 to Stage 5

Primary fines collecting conveyors.

Two 36" conveyors carrying undersize ore from the screens preceeding the secondary crushers directly to the fine ore stockpile conveyor system at a speed of 250 fpm and a capacity of 227 stph.

Stage 5 to Stage 6

A group of conveyors consisting of tertiary screen under-



size collecting conveyors, fine ore transfer conveyors and fine ore tripper conveyor which transport the end product from the fine ore crushing plant to the fine ore stockpile.

The tertiary screen undersize conveyors are 54" wide a length of 375 feet with a belt speed of 442 fpm a capacity of 2439 stph and a drive horsepower of 200.

The fine ore transfer conveyor is 72" wide with a length of 272 feet and an elevation of 71 feet. The belt speed is 499 fpm, the capacity is 5330 stph and the drive horsepower is 700.

The fine ore conveyor is 72" wide and is fitted with a tripper travelling back and forth over 345 feet distributing the fine ore onto the fine ore stockpile.

This belt travels at 499 feet per minute and has a capacity of 5330 stph driven by a 400 horsepower electric motor.

Stage 6 to Stage 7

Ball mill feed conveyors. Eight 36" conveyors are installed under the fine ore stock pile and are fed by Mexican feeders. Their length is 226 feet with an elevation of 26 ft. and have a 60 horsepower variable hydraulic drive to give a belt speed from 125 to 250 feet per minute. Each belt has a capacity of 483 stph. The speed of each belt is remotely controlled and each belt is fitted with a weigh scale.

CONVEYORS IN THE PORT AREA

Stage 10 to Stage 11

A group of conveyors of varying capacities, sizes, lengths and types whose function is to move the concentrate through the dewatering and drying processes to the concentrate stockpile.

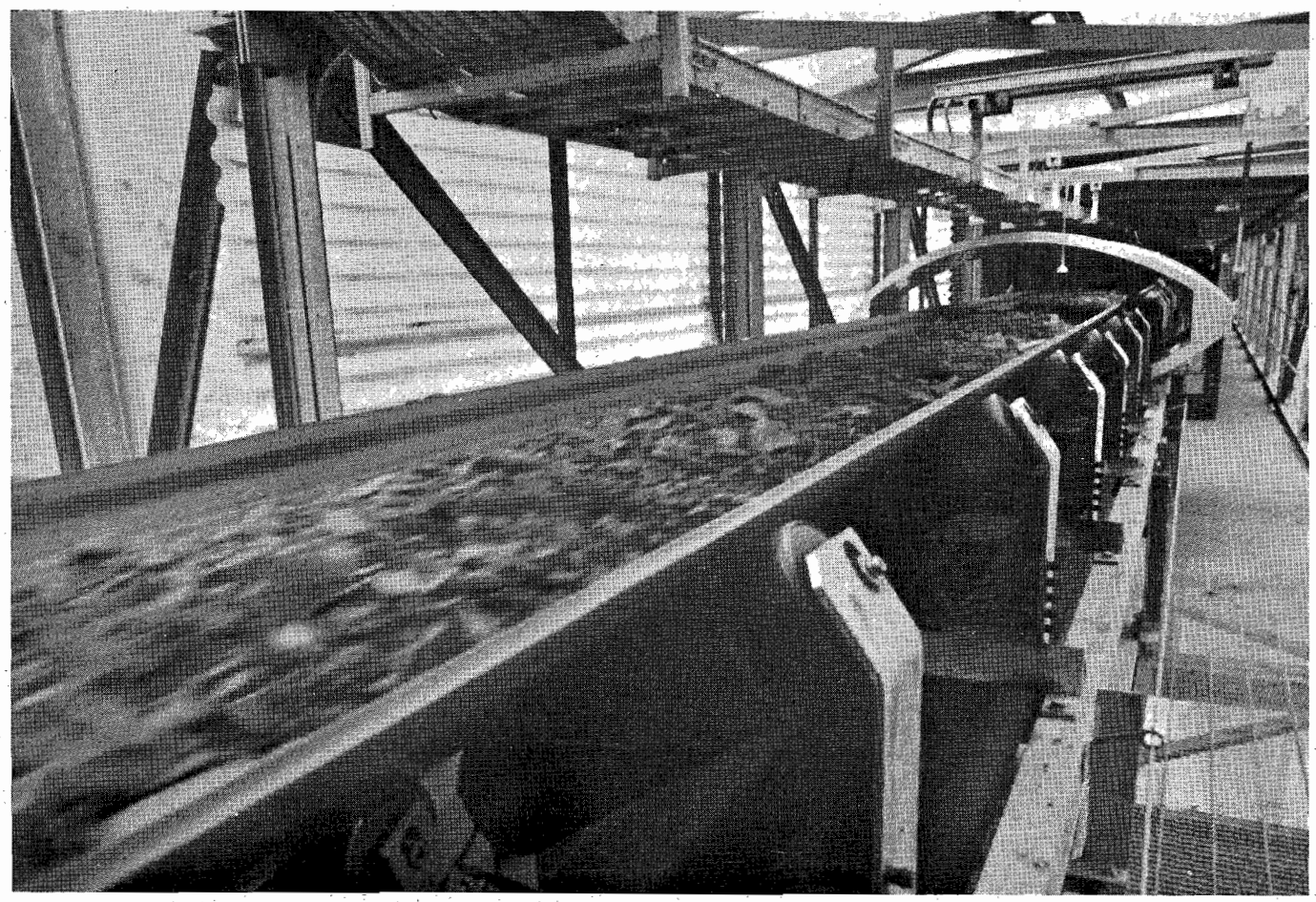
Capacities range from 75 to 160 stph with belt speeds of 200 fpm and drivehead horsepowers ranging from 5 to 60.

Stage 11 to Stage 12

Ship loading system. This final group of conveyors moves the concentrate from the stockpile adjacent to the wharf into the ship. It consists of a ship loader belt feeder, shiploader feeder and shiploader shuttle conveyor.

Capacities of all three units are equal, 1345 stph. The belt width of the feeder is 84", that of the other two is 36". Drivehead horsepowers vary from 60 to 150.

The final shiploader shuttle conveyor functions to spread the load across the ship. To distribute the load fore and aft, the ship is winched along the wharf.



Fox Conveyors move 90,000 tons per day at Bougainville.

Cyclones

KREBS CYCLONES AT BOUGAINVILLE

Krebs Engineers has supplied a large number of cyclones for the Bougainville project, all spares having been supplied by the Australian manufacturing licensees, United Development Corporation Pty. Ltd., a company in the Sala group.

For this contract, 76 D20LB cyclones, 24 D15B and 2 D20B Krebs cyclones were supplied manifolded in groups to operate in closed circuit with the 8 grinding mills.

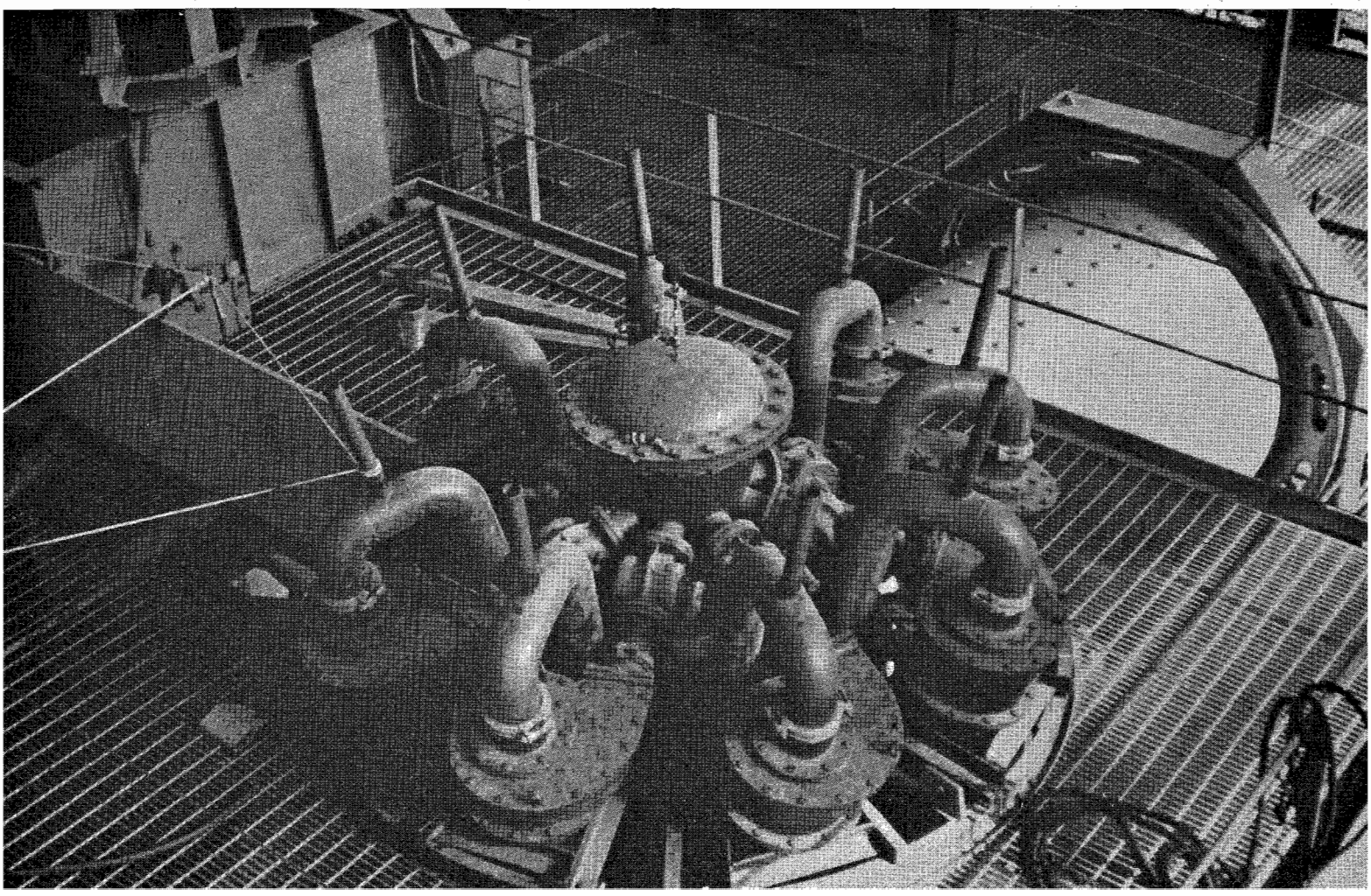
Krebs cyclones are available in sizes ranging from 3" to 50" diameter and a wide variety of configurations is possible, depending on the particular application. Krebs cyclones are used in the mining industry throughout the world, and are used by most major Australian mining operations.

Smooth discharge from the apex is essential for satisfactory operation of cyclones, and a variety of apex assemblies is available for all sizes of Krebs cyclones. It is often best to install a variable type controlled by pneumatic or hydraulic pressure. The largest apex valve will pass over 250 tons per hour of solids.

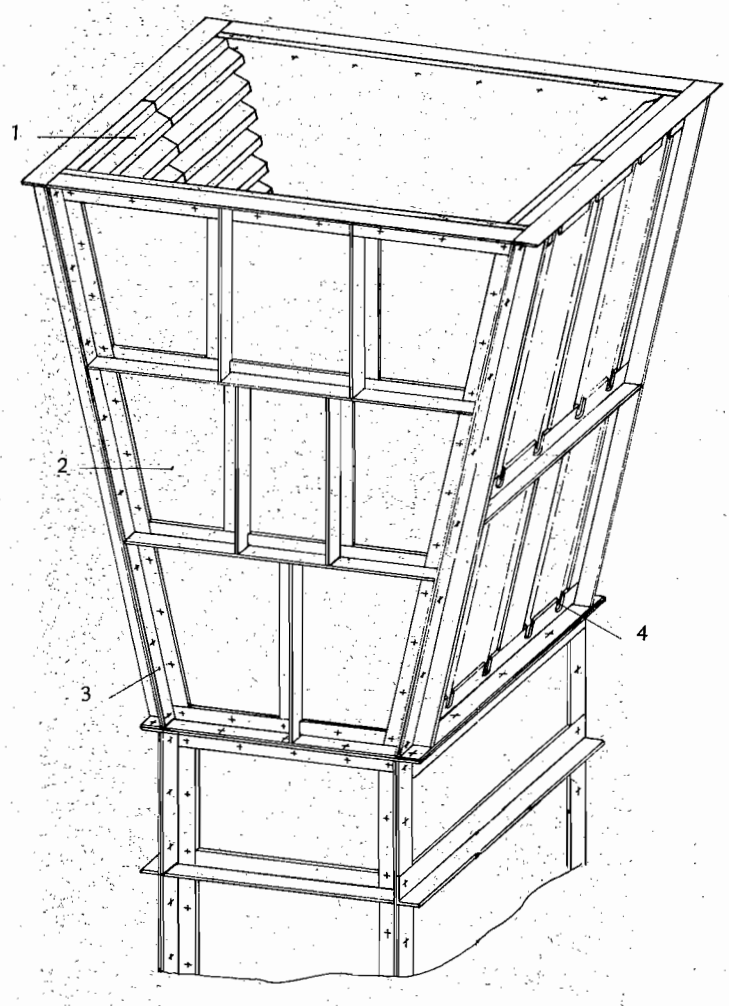
The most important applications of Krebs cyclones are:

1. **Sizing of particles.** With properly designed cyclone systems, the overflow sizing can be very precise. Maximum size is about 500 microns and minimum about 10 microns.
2. **Degritting of suspensions.** Coarse solids can easily be removed from suspensions such as metallurgical mill tailings, milk of lime, paper pulp and fruit juices. They normally operate at low pressure and the equipment is compact and economical in operation.
3. **Desliming.** The removal of particles smaller than 10–20 microns is effected by using a hydrocyclone fitted with a 'Cyclowash'. This provides water injection to replace the slime carrying water in the underflow and products relatively free of slimes can be obtained. Sands for mine backfill or tailing dams are produced in this manner.
4. **Closed circuit grinding.** This is one of the most important uses for hydrocyclones and the Krebs Cyclone is widely used for this application.

An installation of Krebs Cyclones at Bougainville Copper Pty. Ltd.



Self–Supporting Rubber Chutes



1. Trellex Elements Type VP.
2. Trellex Wear Resistant Rubber.
3. L-iron.
4. Slots for fastening VP elements.

TRELLEBORG SELF-SUPPORTING CHUTE CONSTRUCTIONS AT BOUGAINVILLE COPPER MINE.

Trelleborg Mining Service Department during the last decade has developed the self-supporting rubber chute system. It was selected by "World Mining" for the magazine's Blue Ribbon award in 1966.

This Blue Ribbon award is designed "to mark outstanding technological performance in conjunction with development of equipment for the world mining industry."

Trelleborg had previously received this award three times – in 1963 for the Duenero Rubber Screen Cloth and in 1964 for the rubber shaft closing bladder and for mill linings.

One of the largest installations in the world of Trelleborg self-supporting chutes is the one at Bougainville Copper mine, for which Trelleborg has supplied sixteen tertiary and six secondary self-supporting chutes underneath screens.

The main advantages of the Trelleborg self-supporting rubber chute versus a conventional steel chute is long life compared with steel liners, ease of fitting and, therefore, short installation time and reduced maintenance costs.

The rubber chutes also result in lower noise level (normally a reduction of more than 50% of hearable noise), eliminate build-up of material due to their very flexible construction and, as rubber is relatively soft, create less fines and dust.

The Trelleborg self-supporting chutes are built up by the following components: Trellex wear and impact resistant elements – type PU, PP, VP or VM (see illustration), with Trellex wear-resistant rubber sheeting, T-bolts, elevator volts and the same construction as in steel.

The fact that Trelleborg supplies the elements for all impact areas with a metal-to-metal fastening system or, in certain cases, also with metal backing, makes the whole construction very rigid and stable. On all areas not exposed to heavy impact – so called "safe areas" – Trellex rubber sheeting is used. The principle of the Trelleborg self-supporting chute is shown in the sectional drawing.

This construction is very light and provides excellent facilities for quick and easy maintenance, as each 5 ft. long impact element is fastened with a maximum of six T-bolts, and especially as replacement of elements can be done from outside the chute, thereby increasing safety and reducing downtime.

All chutes are built up in sections which are bolted together. Trelleborg normally supplies the steel frame section already rubber-lined with sheeting or elements on two sides in readiness for final installation.

The Bougainville Copper Pty. Limited secondary chutes are 27 ft. high and the tertiary chutes are 23 ft. high, all lined with VP elements on impact areas and Trellex sheeting on vertical safe areas.

The chutes have been operating continuously since January 1971, the total life of impact plate being estimated at 14 to 16 months.

Trelleborg also supplied self-supporting rubber launders to BCP.

TRELLEX LINER UNIT TYPES

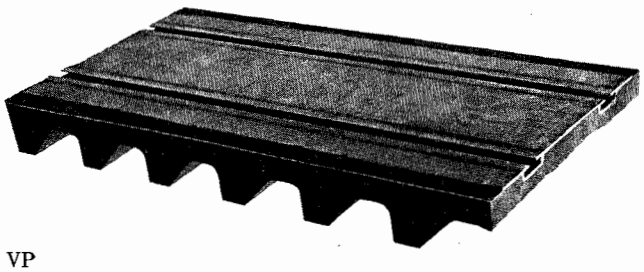
PR

PP

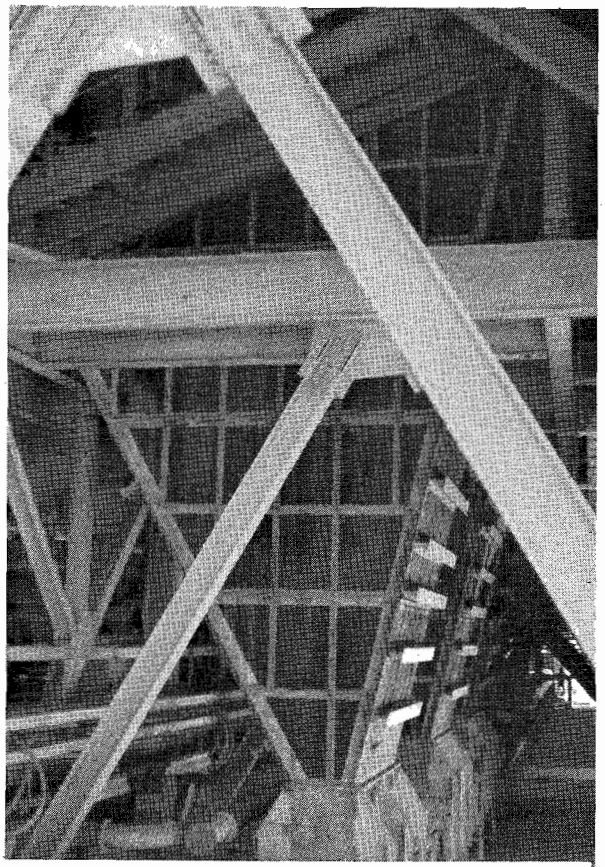
PU

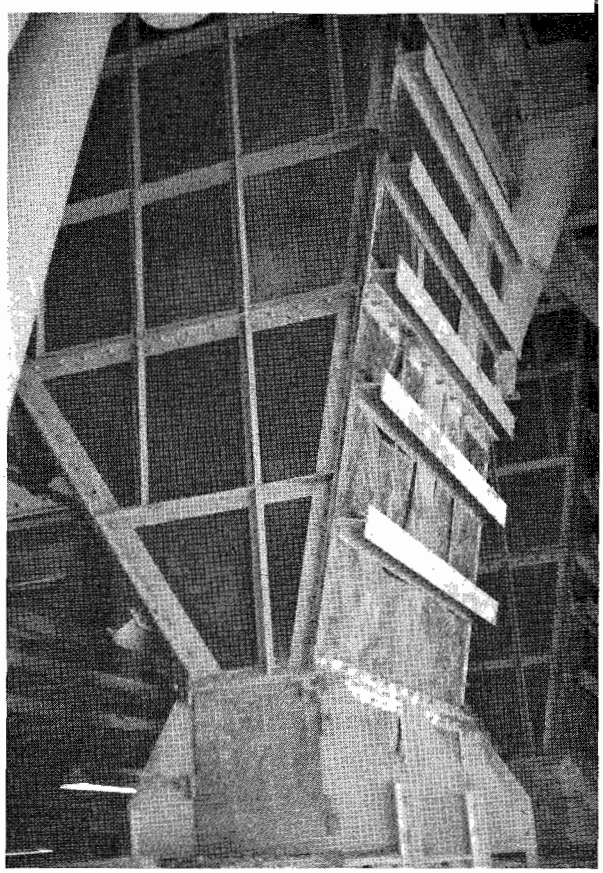
LU

VP



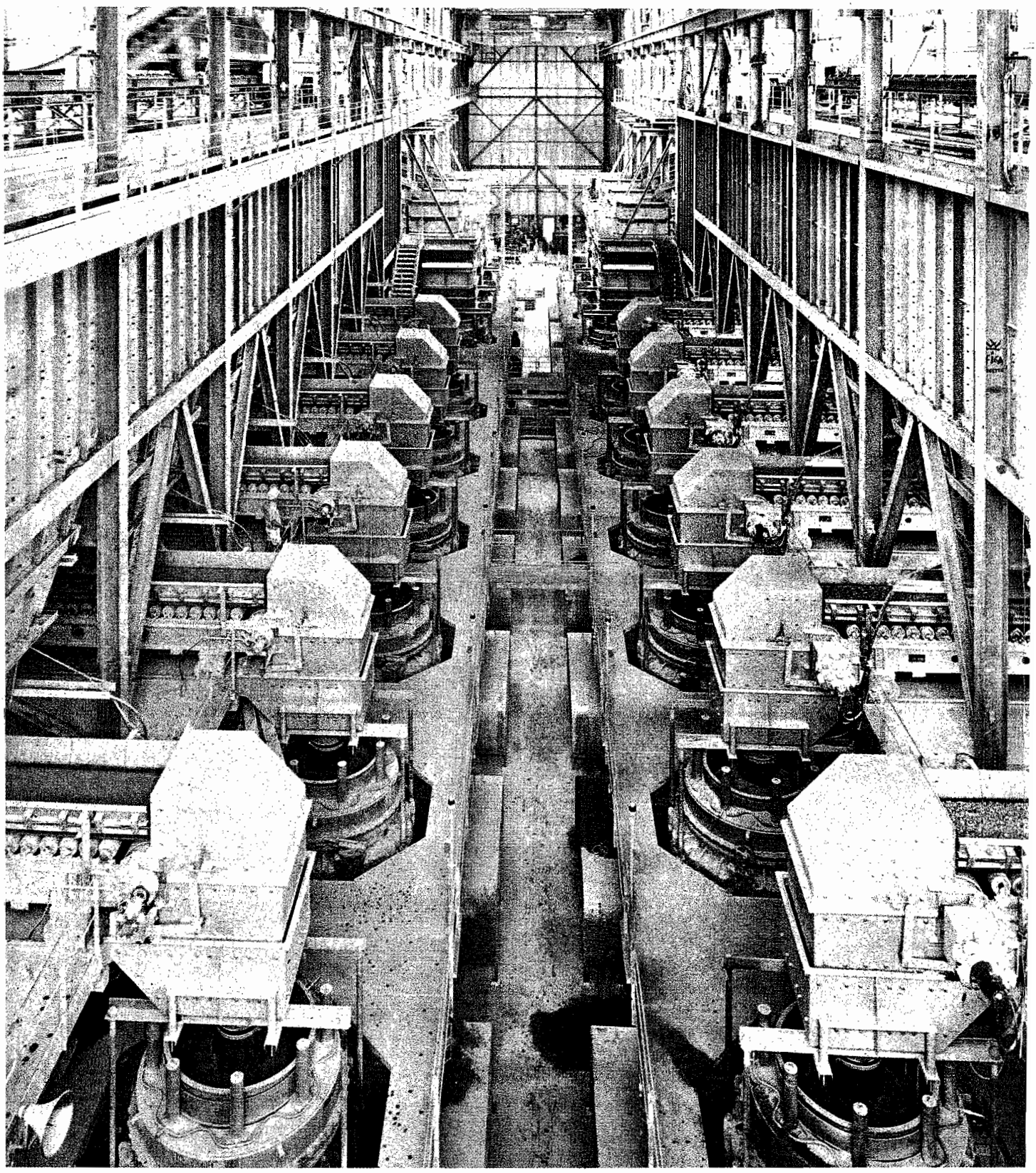
VP





Above — Wear-resistant impact elements and Trellex wear-resistant rubber sheeting.

Right — Trelleborg Self-supporting Rubber Chutes at Bougainville.



Twelve Vickers Ruwolt built 7 ft. Symons Short Head Tertiary Crushers operating in the fine crushing building at Bougainville.

Crushers

VICKERS RUWOLT CRUSHERS PROCESS UP TO 90,000 TONS OF COPPER ORE PER DAY AT BOUGAINVILLE.

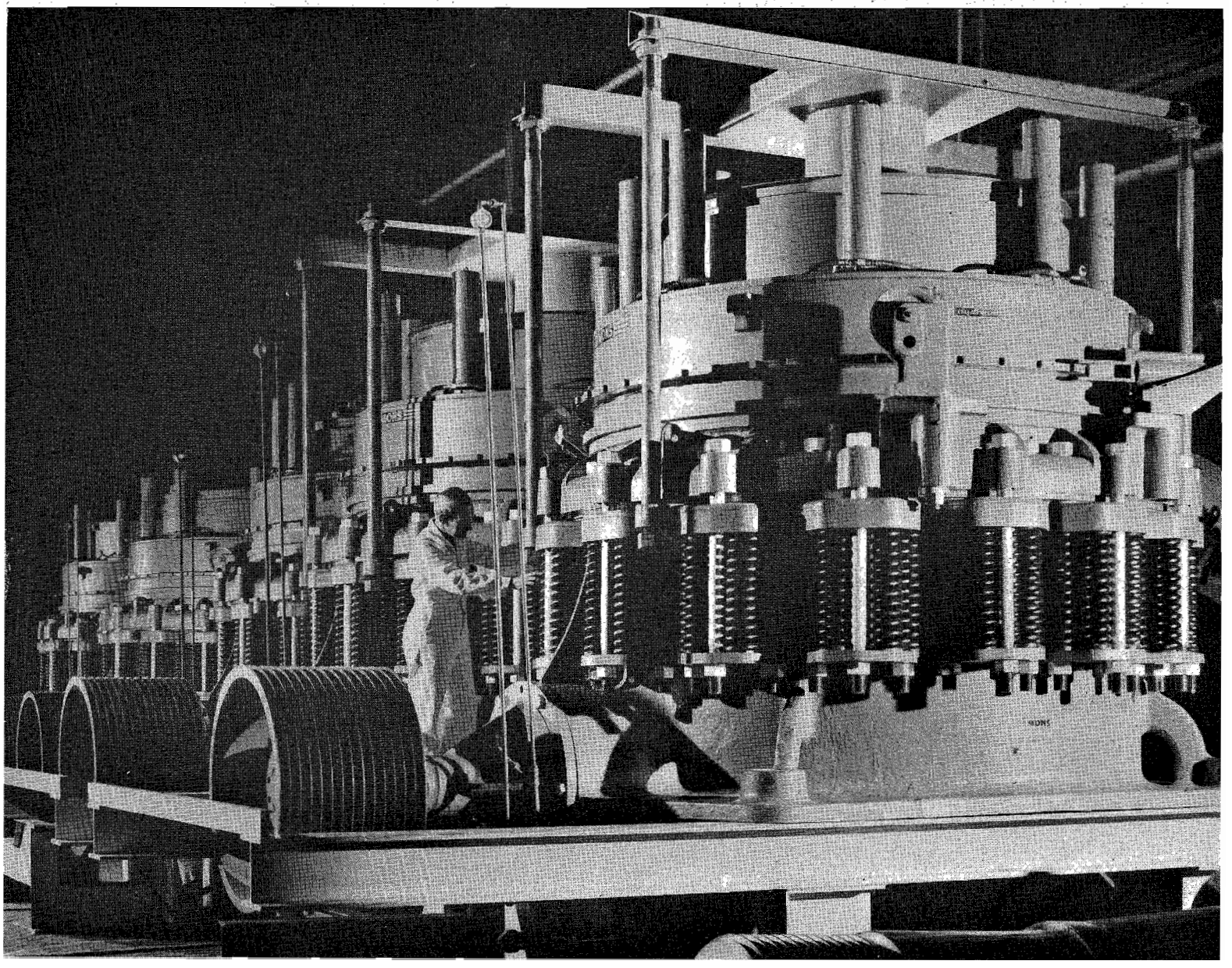
During the mineral boom of the early 70's, Vickers Ruwolt Pty. Ltd. became deeply involved with the manufacture of all types of primary and secondary crushers, and grinding mills for the reduction of ores. This included auxiliary equipment such as feeders and mineral pumps.

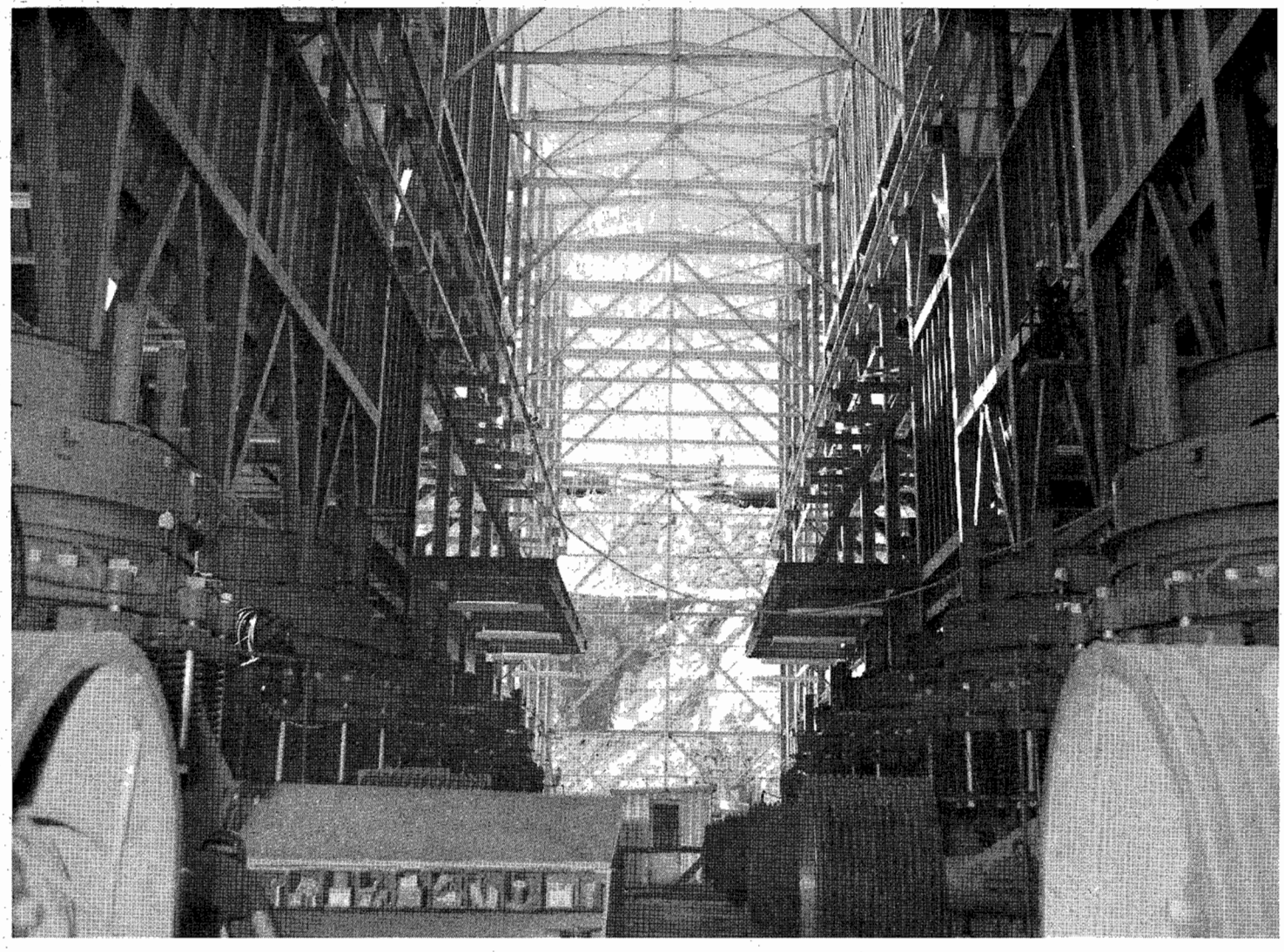
Conservative government estimates forecast a $2,000 million boom a year in export revenue for minerals and metals.

At that time Vickers had orders in excess of $4 million for mineral processing equipment. Part of these orders was for the supply of eighteen 7 ft. Symons cone crushers for the Bougainville copper project.

Today in the "great hall" at the Bougainville Copper Pty. Ltd. crushing plant, are the 21 crushers Vickers Ruwolt built as part of a $1.75 million export order from Bechtel-W.K.E., consultants to the mine owners.

Five 7 foot Symons Crushers at Vickers Ruwolt factory, Melbourne, Australia.





An interior view of construction progress on the fine crushing plant at Panguna. Crushers are shown in position (June 1971).

The six 7 ft. Symons Standard Heavy Duty cone crushers and twelve 7 ft. Symons Short Head tertiary crushers were built under licence from the Nordberg division of Rex Chainbelt Inc. U.S.A. The company has since changed its name to Nordberg Machinery Group, Rexnord.

The six secondary and twelve tertiary rock crushers have the capacity to process 90,000 tons of copper ore each single day.

This order was the largest single order ever placed for crushers of this type in Australia, and was won by Vickers Ruwolt in the face of intense overseas competition.

Specially chartered vessels took the crushers – each weighing 74 tons – to Anewa Bay, at Bougainville Island. They were then trucked 16 miles over the mountain access road to the crushing plant at Panguna.

Working around the clock, 100-ton capacity dump trucks drive up and deliver their load every 90 seconds to the ore conveyor line.

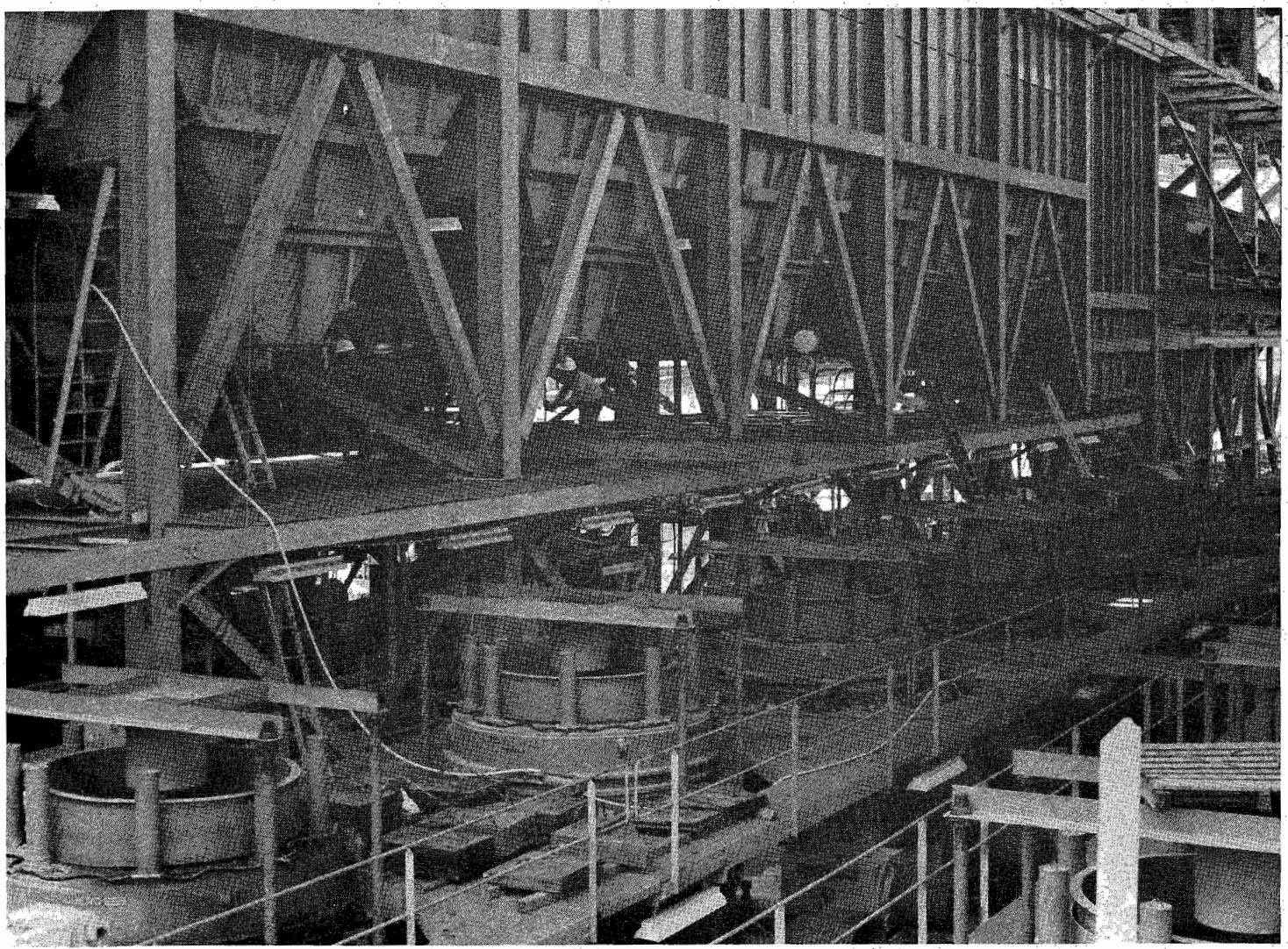
Product ore from the primary grizzlies and primary crushers is minus 8-inches. It is elevated up a 30 per cent incline, belt-weighed and drops on to the 50,000 ton coarse ore holding stockpile.

The following description applies to either of the crushing lines. Ore is reclaimed from the coarse stockpile by five apron feeders to a 672 foot long horizontal 54 inch wide conveyor. Ore is weighed on the belt which is equipped with an overhead magnet and a metal detector.

A shuttle head on the conveyor keeps three 300 ton surge bins full of ore at the secondary crushing circuit. Ore from each bin is withdrawn by a 54 inch by 15 ft. variable speed apron feeder. Ore is dropped onto an 8 by 20 foot double deck vibrating screen. Undersize is conveyed to a covered 80,000 ton fine ore stockpile. Oversize from the top two decks drops into a 7 ft. Symons standard crusher for reduction.

Crusher product is conveyed to a screening plant on a 72 inch wide 623 foot long conveyor. A 241 foot long tripper conveyor distributes ore into eight 200 ton surge bins. An 84 inch wide hydraulically driven (ease of speed control) belt feeder withdraws ore from the bin and drops it onto an 8 by 20 foot single deck vibrating screen.

Screen oversize (tertiary feed) is weighed on a tripped belt equipped with a magnet and fed into six 200 ton surge bins. Hydraulically driven belt feeders withdraw the ore from the surge bin and feed it at a rate which produces choke feeding to a 7 foot Symons Short Head crusher.



An interior view of construction progress on the fine crushing plant at Panguna. Symons 7-ft. cone crushers are shown in position (August 1971).

Tertiary crusher product joins the secondary crusher product on a 72 inch wide belt. Thus open circuit primary and secondary crushing is followed by closed circuit tertiary crushing.

The secondary crusher surge bins are fed by two shuttle belts. The tertiary crusher bins and the tertiary screen bins are fed by trippers.

By using this system, maximum capacity is achieved without one bin being short of ore while the adjoining bin is overflowing.

Belt scales are Ramsay, magnets are Dings Magnetic, and metal detectors are from Outokumpu. Hydraulic drives are Lucas Staffa.

Ore has unusual crushing and screening requirements

Firstly, extra screening capacity was added to the tertiary section because the ore is wet. Average run of mill ore contains 5.0 per cent water, which is mainly surface moisture since Panguna experiences an annual rainfall of about 200 inches.

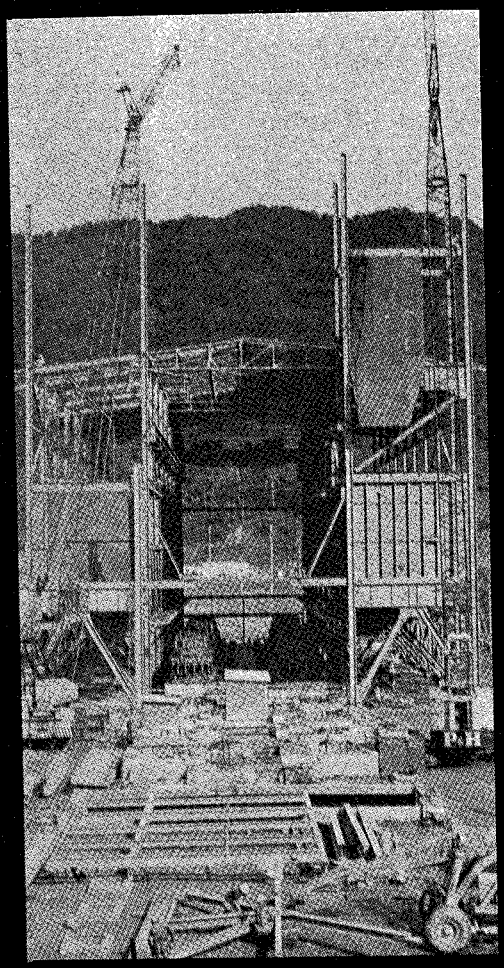
Secondly, because of the thick crushed ore bed on the vibrating screens, the screen area had to be very high in the secondary and tertiary crushing plants in comparison to other porphyry ores.

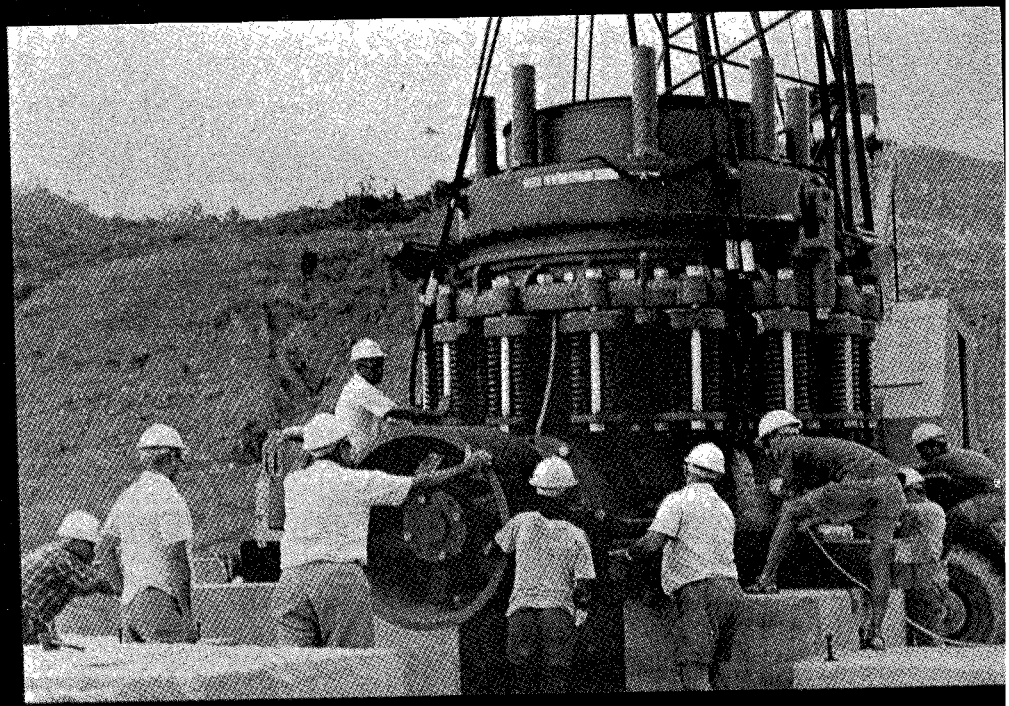
Primary crusher feed was estimated to be 10 to 20 per cent minus ½-inch. However it has been as high as 40 to 50 per cent.

Thirdly, nature did not provide a suitable flat terrain adjacent to and below the ore body to accommodate all of the crushing complex on one site.

As a result, the primary crushing plant was built in a valley on the north rim of the final pit, and the large secondary and tertiary fine crushing complex built on bulldozed shelves on the north side of Moroni Ridge – both plants on reclaimed terrain.

Incidentally, the primary crusher dumps were built large enough to handle 200 ton capacity trucks in the future; the secondary and tertiary crushing plant had extra foundations poured to accommodate two additional secondary and four additional tertiary crushers. Within 9 months of the original commissioning date, Vickers Ruwolt received an order for a further three crushers, which have now been installed. This indicates Bougainville Copper's satisfaction with the Company's equipment and back-up service.



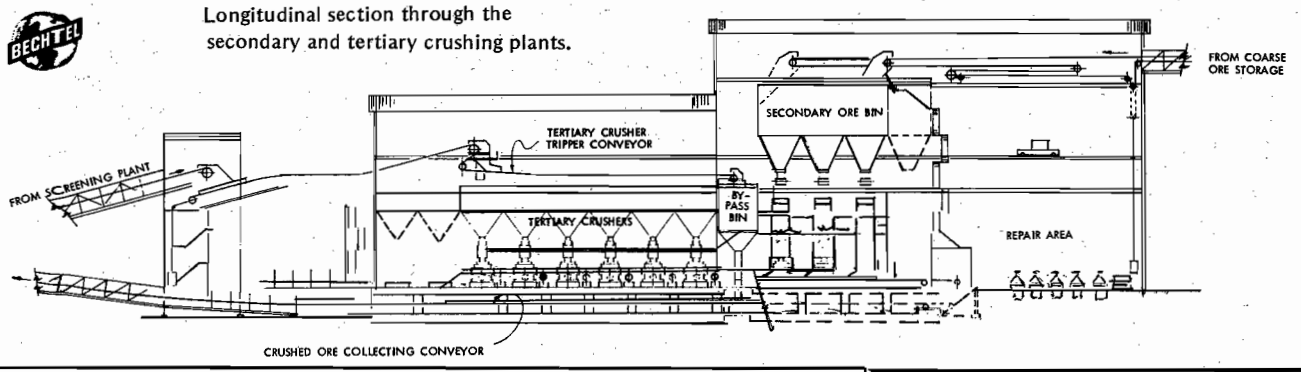


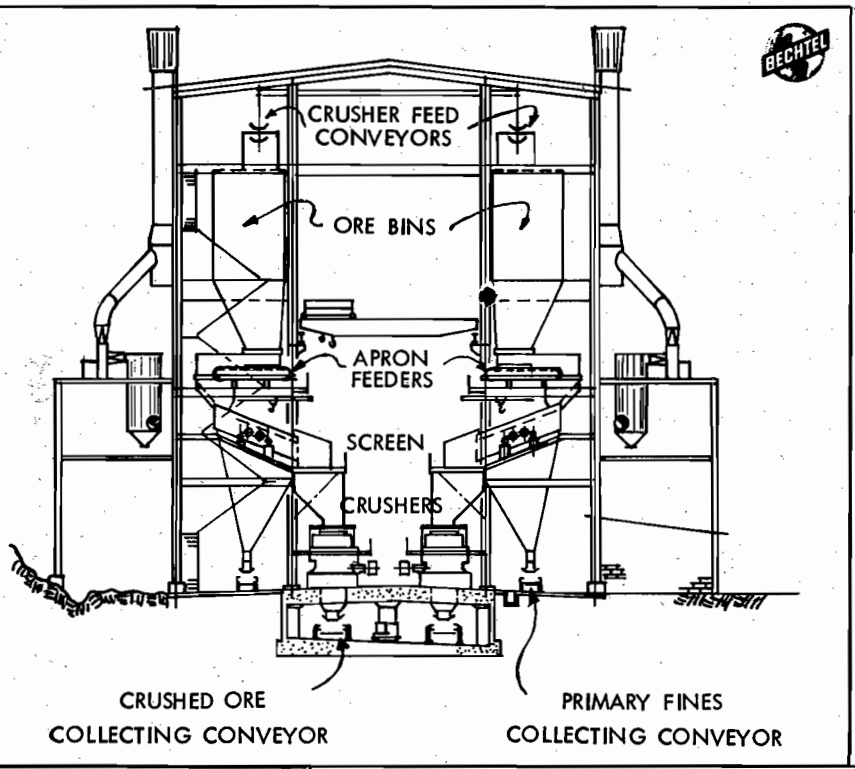
Top: A general view of the Panguna minesite. The concentrator area, with treatment facilities under construction is at centre right.

Left: The fine crushing plant under construction. Six secondary cone crushers and twelve tertiary crushers will reduce the coarse ore to —½" before grinding and flotation.

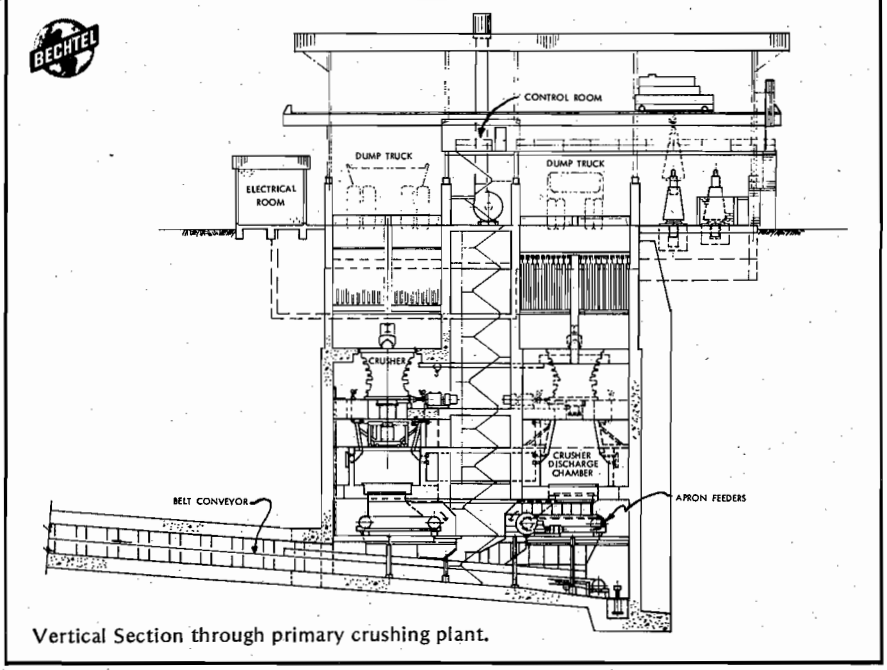
Above: One of the short head tertiary crushers being positioned on concrete slabs at the site of the fine crushing plant.

Longitudinal section through the secondary and tertiary crushing plants.



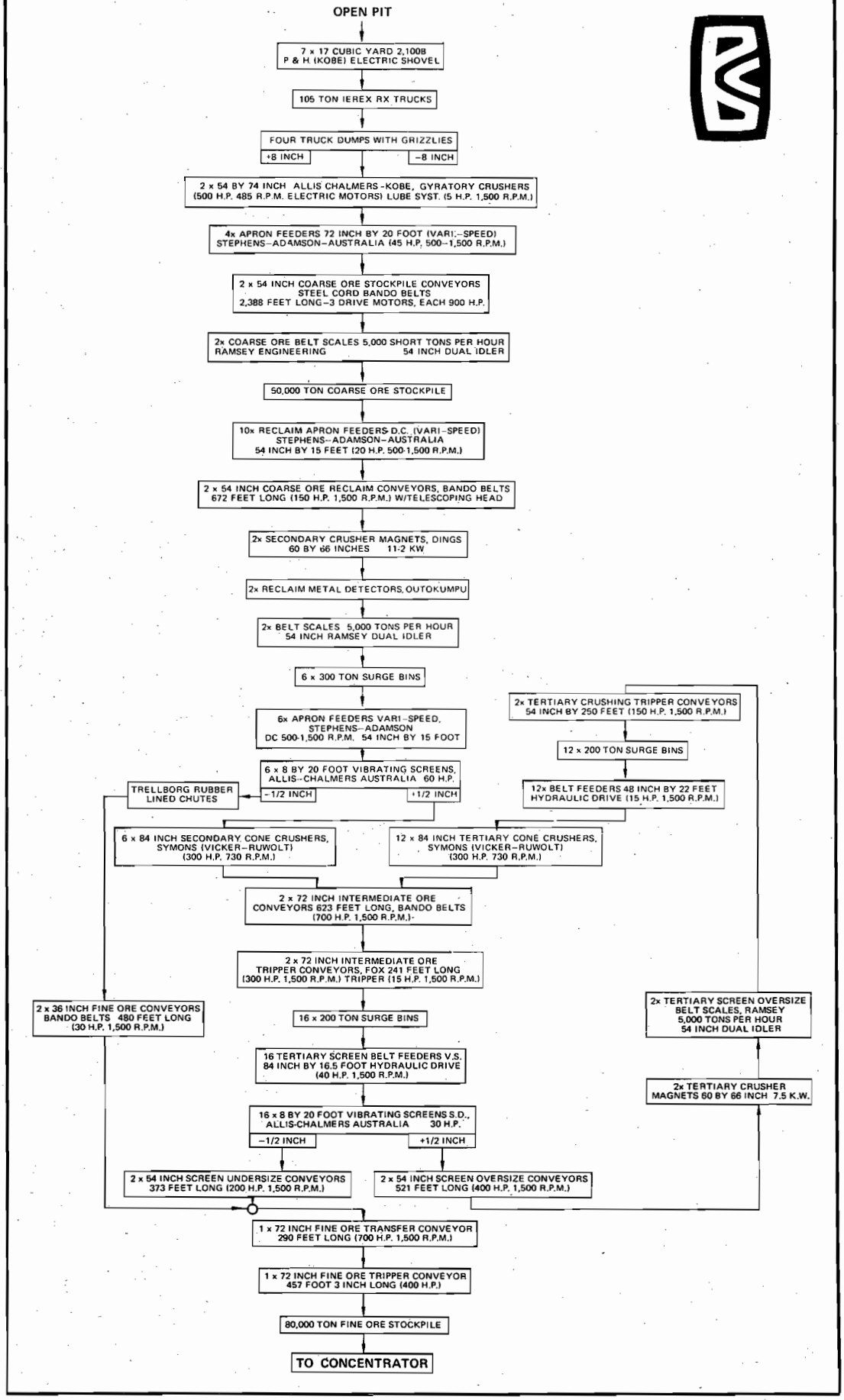


Cross Section through the secondary crushing plant.



Vertical Section through primary crushing plant.

CRUSHING & ORE STORAGE FLOWSHEET



Hard Metal Slurry Pumps

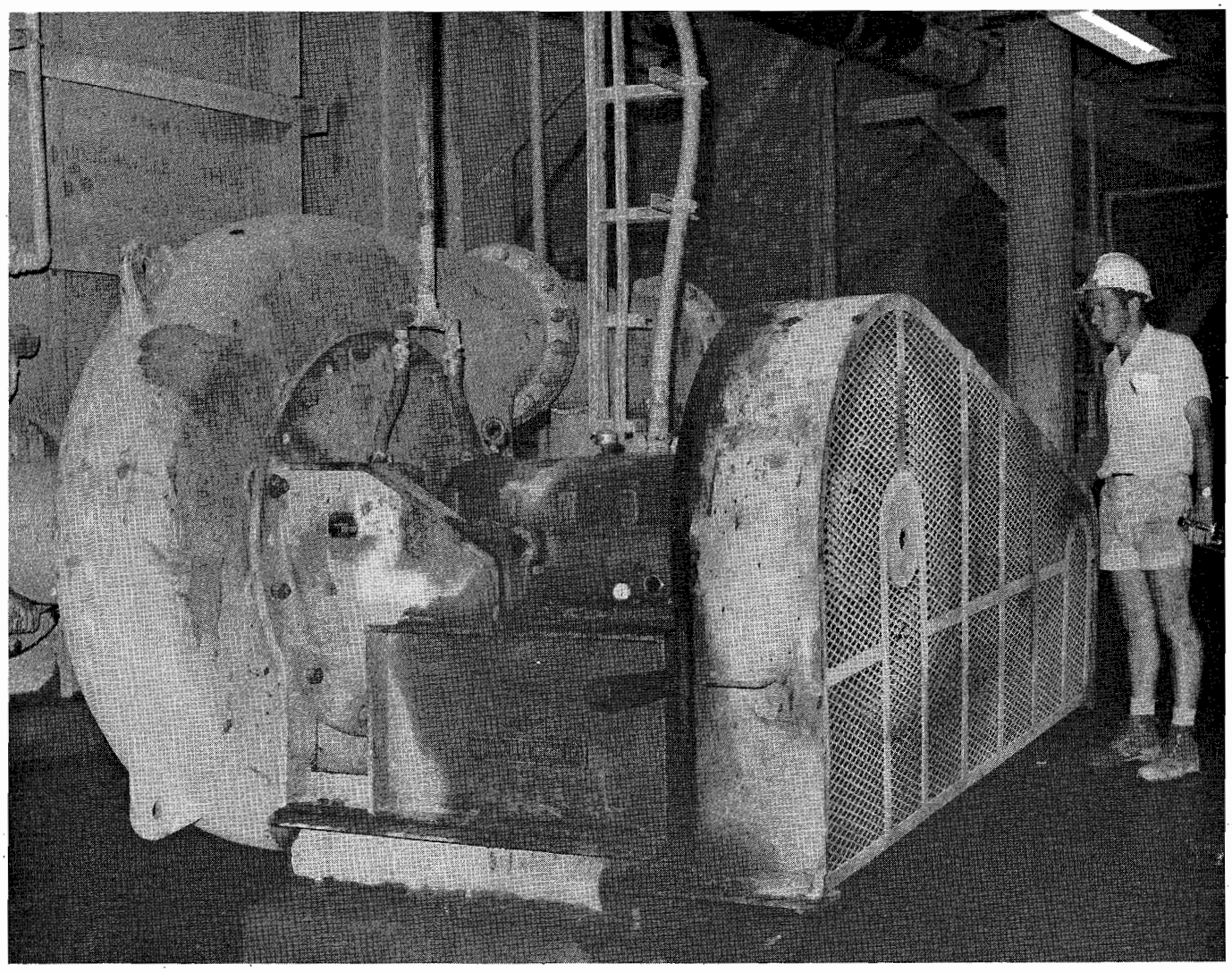
KELLY & LEWIS – GIW HARD METAL SLURRY PUMPS HANDLE A TOUGH JOB AT BOUGAINVILLE.

The Primary Cyclone Feed Pumps for this project were supplied as a joint venture by Georgia Iron Works of Grovetown, Georgia, USA, and their Australasian and South-East Asian Licensee, Kelly & Lewis Pty. Ltd. of Springvale, Victoria, Australia.

The pump units are installed in the concentrator area. Each pump takes its slurry from a sump installed directly beneath the discharge of each of the nine large ball mills. The total discharge of the mills is pumped by the KL-GIW slurry pump units to the primary cyclones. Here classification of the ground ore is carried out. Oversize ore from the classification returns to the ball mills for further grinding, whilst the balance continues through the further processes in the concentrator.

Taking into account the recirculating load and new ore feed the daily throughput of each primary cyclone feed pump in the concentrator is in the order of 13 million U.S. gallons

One of nine KL–GIW Slurry Pumps in operation at Bougainville.



of pulp per day. This amount of slurry contains approximately 50 to 60 thousand tons of ore with the maximum sizing around ½".

The original order for the first stage of the mine consisted of eight 16" x 16" LSA39 (400 x 400 mm) GIW hard metal slurry pumps, each having a duty capacity of 9,200 U.S. GPM (2,100 cu. m/h) against a total head of 50 feet (15 m). These fixed speed units are vee-belt driven by electric motors of 350 Hp/960 Rpm rating with a final pump speed of 310 Rpm.

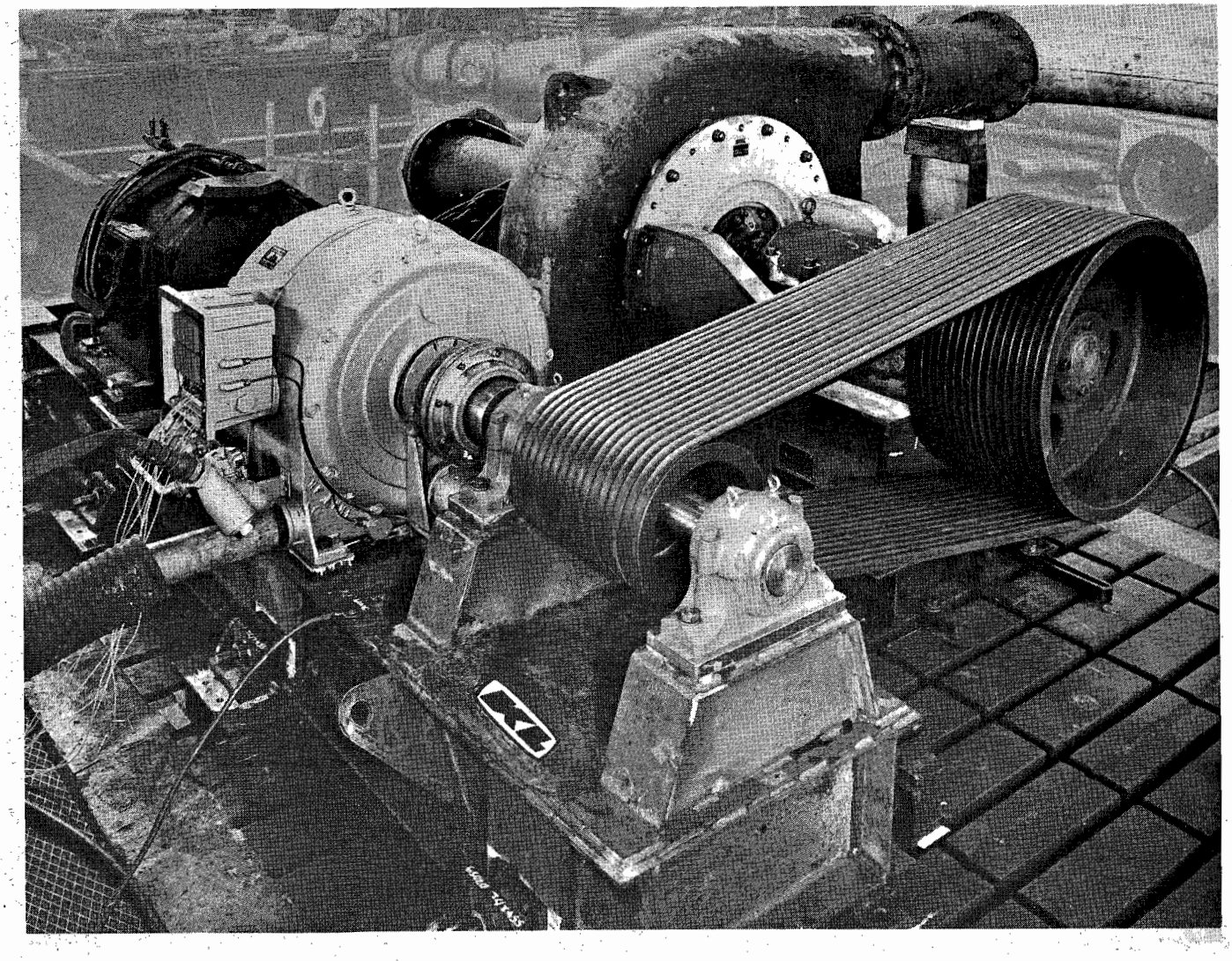
Kelly & Lewis also supplied from Australia the pump unit for the 9th ball mill which was brought into service in 1973. This ninth operating unit was supplied fitted with variable speed control. The 500 Hp/960 Rpm electric motor is direct coupled to a variable speed Eddy current coupling with the final drive being by vee-belts to give a pump operating speed range from 250 to 370 Rpm.

The pumps selected for this vital pumping job are to advanced engineering standards. It was important that robust construction features, coupled with abrasion-resisting materials were employed to ensure long trouble-free service under arduous operating conditions.

All components directly exposed to the extremely abrasive slurry are made from really tough metal. The material of wetted parts such as shells, impellers and suction liners, are of "Gasite", a special alloy developed by GIW. Hardness of these "Gasite" parts is 650–700 B.H.N. "Gasite" is a material with resistance to fracture under repeated impact and one which gives a longer working life and lower replacement cost.

The advanced design innovations include a pump shell which eliminates wear at the cut-water and a replacable suction liner which can be rotated at intervals to increase

Works test of variable speed KL–GIW Slurry Pump at Kelly & Lewis plant in Springvale, Australia prior to despatch for Bougainville.



wear life. The impeller is of the dredge type which increases parts' life by reducing velocity and turbulence and has wide passageways to handle solids.

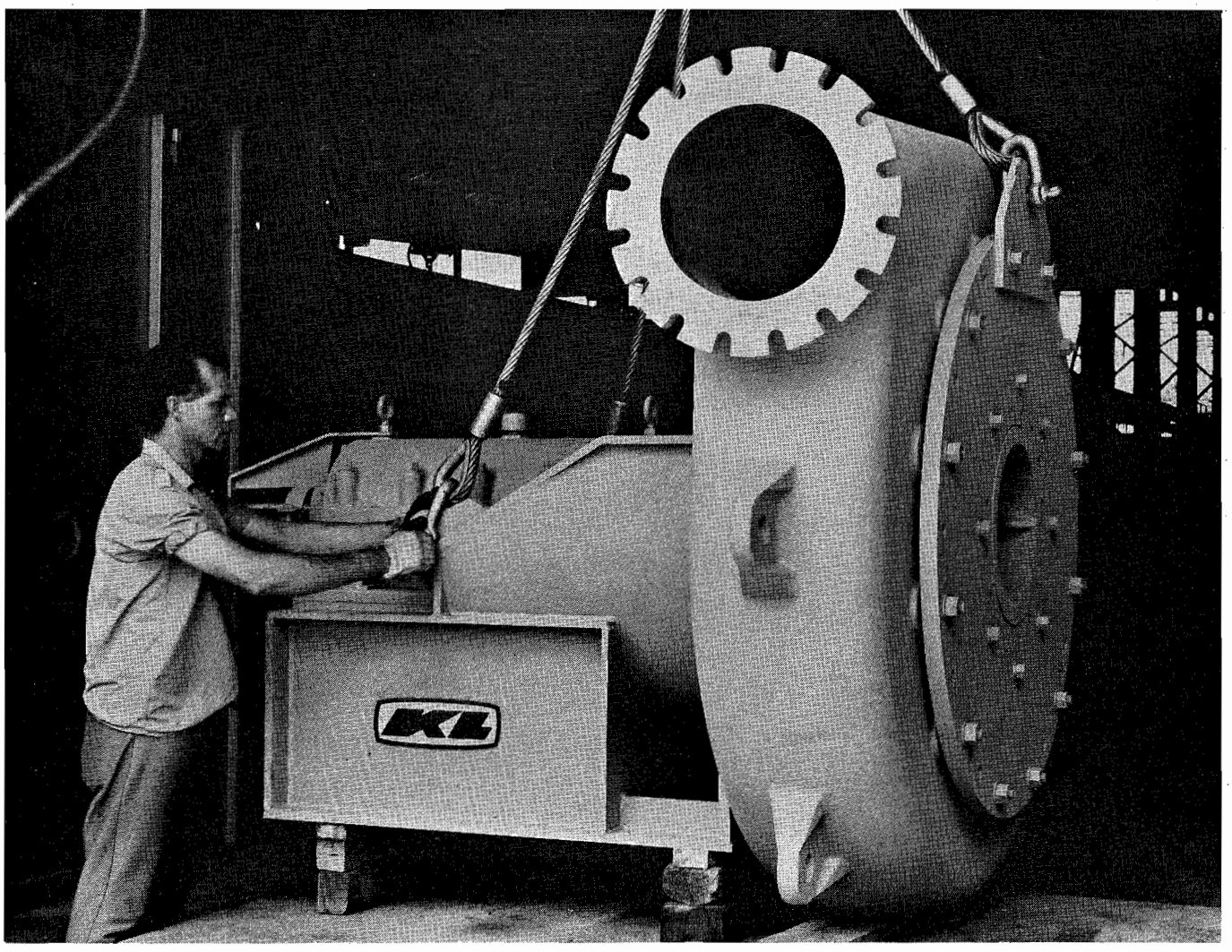
The sturdy fabricated pedestal frame incorporates a simple mechanism to adjust the clearance between impeller and suction liner for continued efficient performance. The stuffing box, gland and lantern ring are split for ease of maintenance. A heavy duty split cartridge type bearing assembly, with oil lubricated self-aligning radial and thrust bearings support the high tensile steel shaft. A replaceable fused carbide shaft sleeve has the dual advantage of giving longer packing life and a stuffing box comparatively free of maintenance. Alignment of the pump shell and wetted parts with the shaft and bearing assembly is automatically obtained through accurate machined fits into the pedestal.

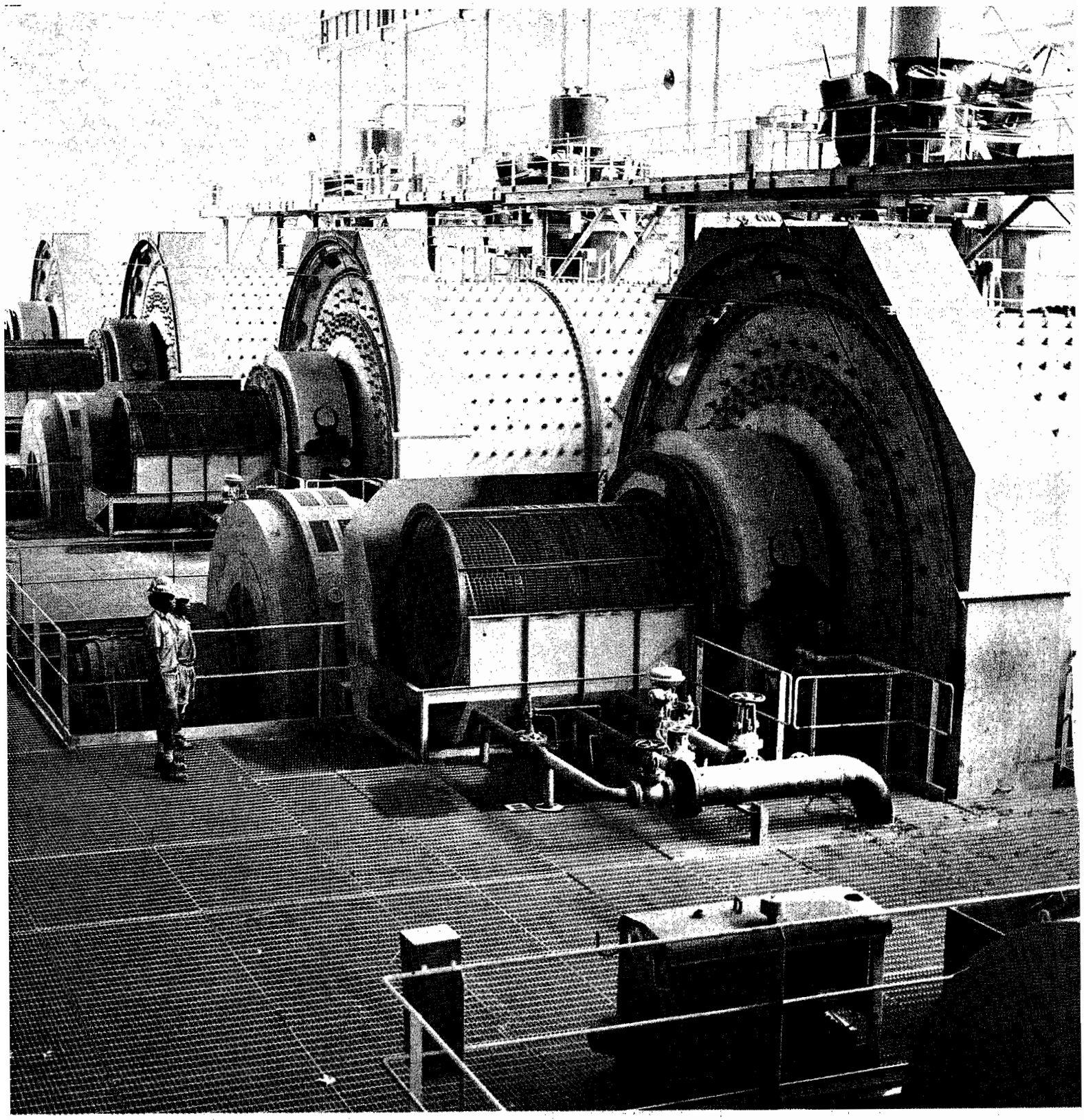
Down-time is critical and costly and, to achieve the minimum in lost time, Bougainville Copper Pty. Ltd. have purchased two spare 16" x 16" LSA 39 KL-GIW bare pumps to enable a quick and efficient pump change-out during a mill shut-down. Maintenance is carried out by completely removing a pump due for scheduled inspection and installing a unit reconditioned from parts held in stock.

Reports from Bougainville Copper Pty. Ltd. Engineers indicate that the KL-GIW slurry pumps are giving excellent performance with each pump handling approximately 8 million tons of ore before replacement of the pump shell is required. Impellers and suction liners have approximately half of this life.

All spare parts for the eleven KL-GIW pumps are manufactured and supplied by Kelly & Lewis Pty. Ltd. Springvale, Victoria, Australia.

A massive KL–GIW Slurry Pump leaving Kelly & Lewis for Bougainville.



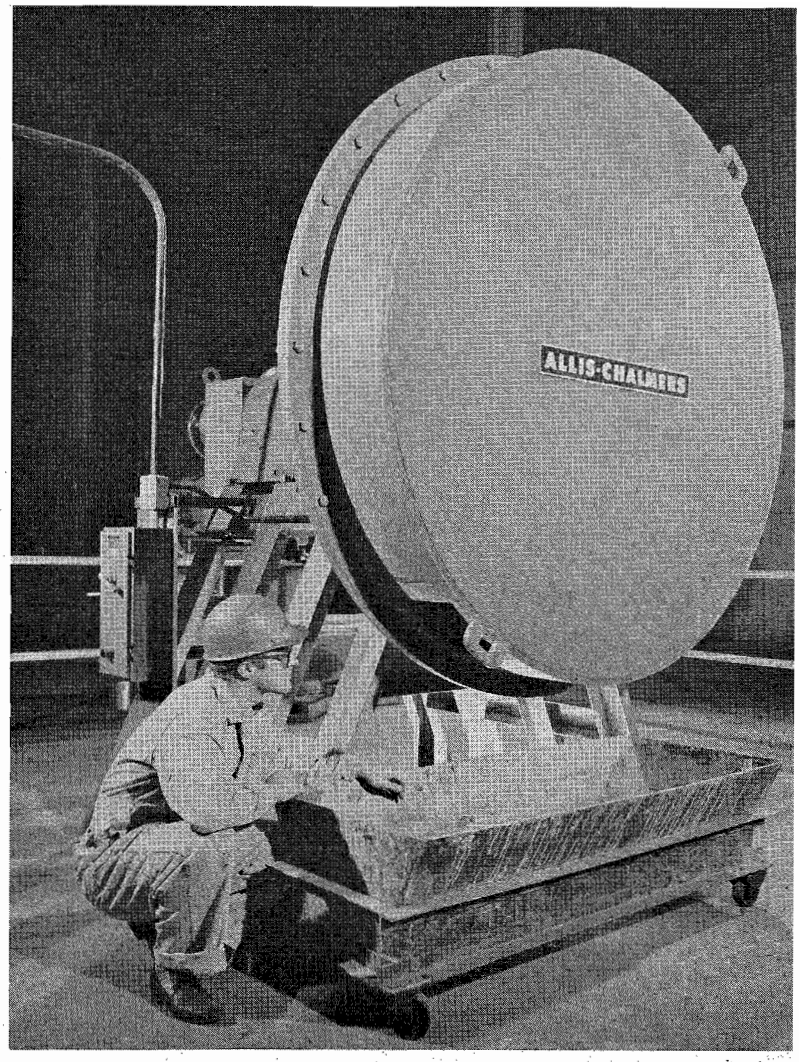


"PART VIEW OF EIGHT Primary 18' x 21' Overflow Ball Mills designed by Allis-Chalmers specifically for the Bougainville Project.
Each mill is driven by a 4250 HP motor through a single pinion and ring gear.
These are the largest single pinion drives supplied on mills to any industry.

BALL MILLS

THE ROLE OF ALLIS-CHALMERS IN SUPPLYING THE BALL MILLS TO BOUGAINVILLE COPPER

by C.A. Rowland
Senior Process-Project Engineer,
Cement & Mining Systems Division,
Allis-Chalmers Corporation,
Milwaukee, Wisconsin.



Autogenous media competency tester at the A–C Process Research and Test Centre.

"What are the largest ball mills that you have built for grinding copper ore?" and "What are the largest size rod and ball mills that you are prepared to build for grinding copper ore?" The answers – "16½' x 19' overflow ball mills for the Duval Corporation at their Sierrita Plant in Arizona" and "15' diameter rod mills and 18' diameter ball mills." This was part of an informal discussion held early in May 1968 at 95 Collins Street in Melbourne. This was the first of many discussions which lead to the installation of eight 18' x 21' 4250 hp Allis-Chalmers overflow ball mills in the Bougainville Copper Company's copper ore concentrator at Panguna, Bougainville. When purchased these were the largest diameter and highest horsepower ball mills ever purchased for grinding copper ore. The mills were built by Allis-Chalmers licensee in Japan, Kobe Steel Co., Ltd.

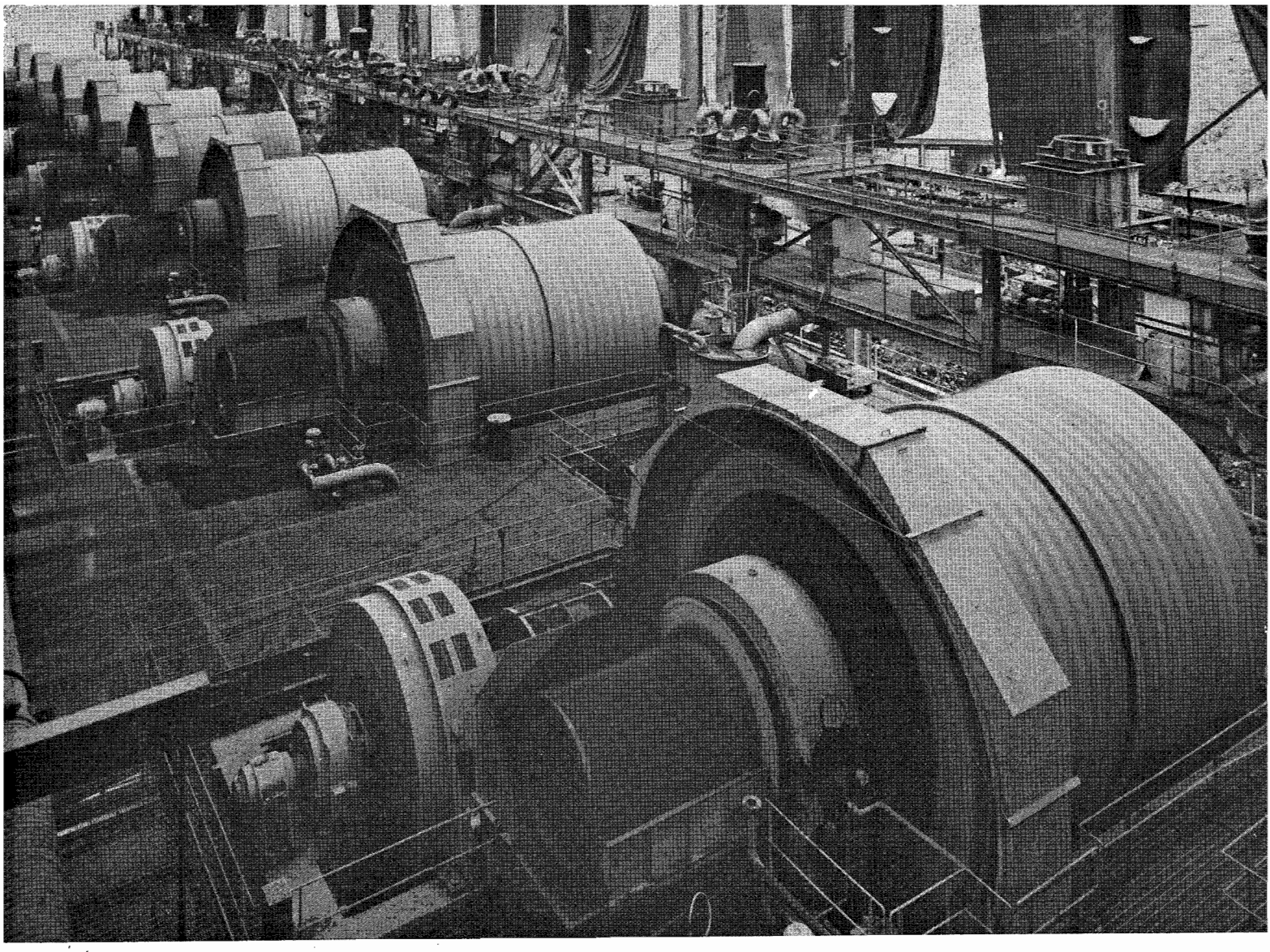
While the actual recovery of the copper minerals occurs in the flotation section of a copper ore concentrator, making flotation the heart of the plant, the grinding circuit, which is the final step in preparing feed for the flotation section, is the most expensive to build, consumes the most power and has the highest operating cost of any section in the ore processing part of the complete operation.

Selection of the proper grinding circuit to process 90,000 tons of ore per day in the centre of the rather remote Island of Bougainville would be difficult. A different emphasis on the many factors involved in the selection was required compared to selecting mills for a concentrator in a developed and established area.

Imaginative thinking, expanding on proven principles and designs so as to obtain the largest equipment possible of a proven design, was called for. Process, equipment and plant design should keep capital and operating costs to a minimum, yet avoiding the risk of using processes and equipment that would be difficult to repair or would require a long shut down while waiting for new parts or new equipment.

In designing a copper ore concentrator, the concentrating circuit is developed first. The fineness of the grind at which the copper mineral is freed from the host rock, is established which is the product size to be produced in the grinding circuit. Studies are required to establish the characteristics of the ore that will control the selection of the crushing and grinding circuits and equipment to be used to prepare feed for the concentrating circuit. To develop the concentrating circuit and to obtain grinding data on the Bougainville ore, Bougainville Copper decided to obtain representative bulk samples of the ore which would be treated in a pilot plant to be built at the mine site. This sampling and pilot plant program to be co-ordinated with an extensive core drilling program so that the pilot plant results and bench scale tests on cores from the drilling program could be compared, evaluated and developed into an overall analysis of the ore body. The pilot plant was commissioned in September of 1968.

In early October 1968, two representatives of Allis-Chal-



Installation of eight 18' x 21' Allis-Chalmers Overflow Ball Mills at Bougainville Copper.

mers, one from Australia and one from the United States, visited the pilot plant. Pilot plant operations were observed and studied and an inspection was made of the Panguna Adit. Mr. W.J.N. Davis extended the invitation that he did to all visitors for a morning's climb up the soon to be removed Panguna Ridge.

Discussions were held concerning grinding theory and practice with the staff responsible for the operation of the pilot plant and the evaluation of the results of the work. The amount of copper recovered from the ore and the amount of and grade of concentrates produced in the pilot plant would establish the size analysis required from the grinding circuit. Careful recording of the following data obtained from the pilot plant ball mill should be made when running grinding tests:

1. Feed rates.
2. Power drawn by the grinding mill.
3. Screen analyses of the new feed to the grinding circuit.
4. Screen analyses of the ball mill discharge-feed to the cyclone classifier.
5. Screen analyses of the classifier oversize being returned to the mill.
6. Screen analyses of the classifier fines – the circuit product.
7. Pulp density of the ball mill discharge.
8. Pulp density classifier feed.
9. Pulp density classifier oversize.
10. Pulp density classifier fines.

This data would permit evaluating the pilot plant operation and establishing data for selecting and designing the grinding circuits.

The Bond Third Theory of Comminution with its Formula would be used to evaluate the pilot plant data and establish the work indices for each of the ore types and areas in the mine. The Bond Formula is:

$$W = \frac{10Wi}{\sqrt{P}} - \frac{10Wi}{\sqrt{F}}$$

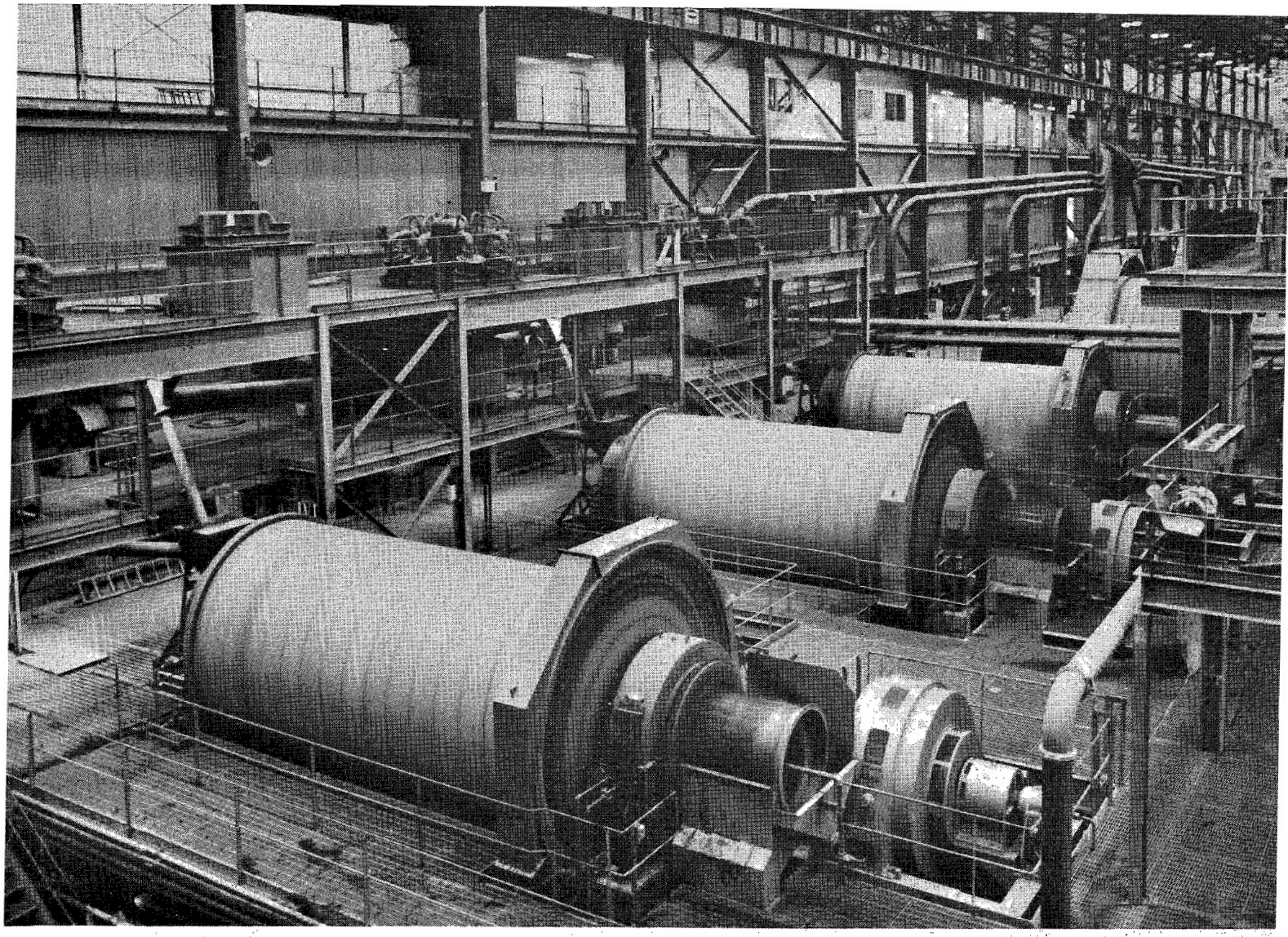
where W = KwH per short ton of new feed

Wi = Work Index

P = Product size 80% passes in microns

F = Feed size 80% passes in microns

Work index, defined as the work required to grind one short ton of ore from an infinitely large feed size to 80% passing 100 microns, gives the grindability of the ore. Work index as obtained from the Bond Formula relates to standard conditions, and takes into account variations in feed and



Installation of three 10' x 20' Allis-Chalmers Regrind Ball Mills at Bougainville Copper.

product sizes giving a standard reference point making the work index an accurate method for measuring grindability (resistance to grinding).

To check the work indices calculated from pilot plant data, Bond grindability tests are run on samples from the pilot plant ball mill feed. With the application of appropriate factors to the work indices obtained from the pilot plant data, putting it on the same basis as the work indices obtained from grindability tests, the two sets of work indices can be compared and with the grindability test as the basis for comparison pilot plant ball mill performance evaluated. Bougainville Copper set up a procedure to run grindability tests. Arrangements were made to send some samples to the Allis-Chalmers Process Research and Test Centre for grindability tests.

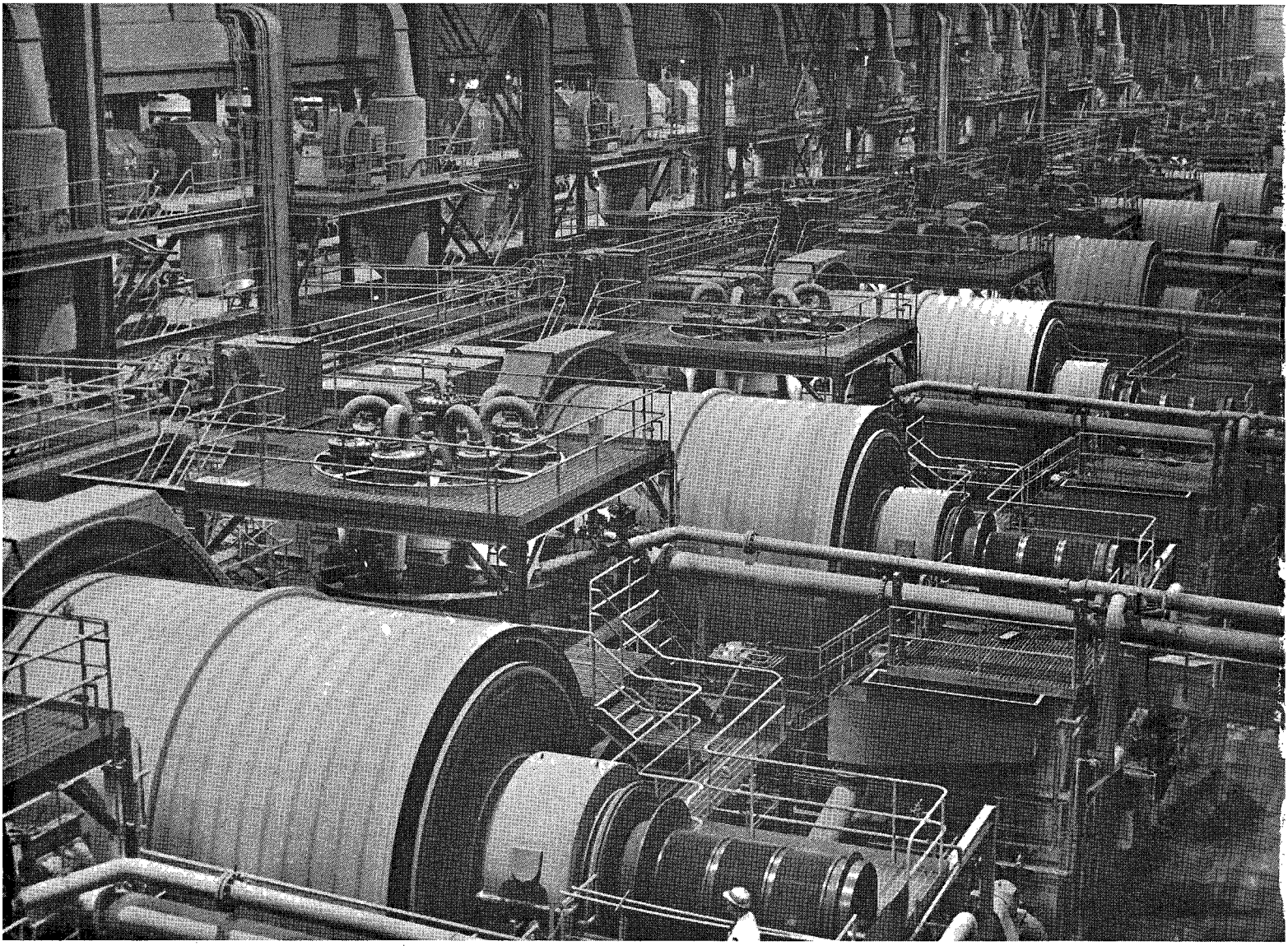
All metallic grinding media needed by the grinding mills would have to be shipped into Bougainville. Eventually a foundry to make grinding balls might be built, however, it would always be necessary to ship in grinding rods since they are produced in steel rolling equipment. Grinding methods and circuits eliminating the use of either or both grinding rods and balls were discussed.

The most efficient, power-wise, proven grinding circuit for preparing concentrating circuit feed is the rod mill-ball mill circuit with the rod mill grinding in open circuit producing feed for closed circuit ball milling. Use of the rod mill-ball mill circuit would be a proven approach for grinding Bougainville ores.

Grinding rods are bulky and difficult to handle. The longest grinding rods of acceptable quality available are 20 feet long. A 4 inch diameter, 20 foot long rod weighs about 850 pounds. Special facilities would be needed to unload rods from ships and transport them from the port to Panguna. Rod consumption could be from 30 to 40 tons of rods per day.

Charging rods to rod mills requires from a one to two hour shutdown every other day. Broken pieces of rods and thin rods are removed from the mill and new rods are put into the mill at this time. New rods are charged through the discharge trunnion of rod mills. Space equal to the overall length of the mill is required at the discharge end of the mill for a rod charger and a rod storage rack.

The maximum size of rod mills available is limited by the length of acceptable quality rods available. Large rod mill capacity is limited by the flow rate of pulp through the void space available in the rod charge. These factors indicated that at least eight rod mills and eight ball mills, a total of sixteen mills, would be required to grind 90,000



16½' x 19' Overflow Ball Mills used for single stage grinding of copper ore.

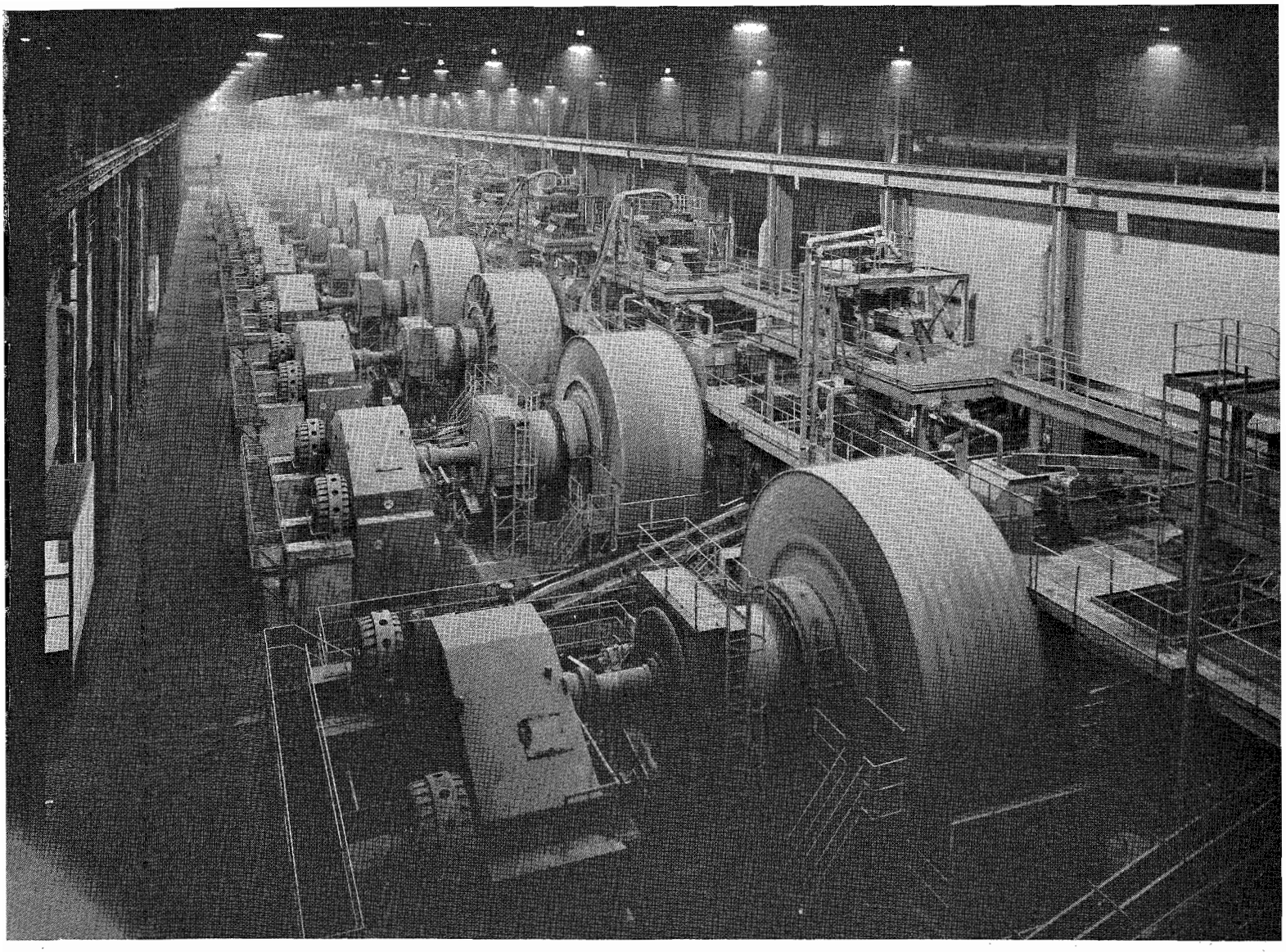
tons of Bougainville ore per day. No limits had been established on ball mill sizing so if single stage ball milling could be used, it appeared that eight large ball mills of the largest design being contemplated would perform the required grinding.

The advantages of the lower operating and capital costs by eliminating rod mills, even though a rod mill-ball mill circuit would be more efficient, power-wise, in this case, pointed out the need for proving out single stage ball milling in the pilot plant. This would include crushing and screening tests to be sure the wet and sometimes sticky ore could be crushed in closed circuit to all passing ½ inch square mesh as required for feed to a single stage ball mill. All the recent successful applications of single stage ball mills grinding copper ore had been in arid and semiarid areas, so closed circuit crushing of wet ore such as would be encountered on Bougainville did not occur and was not a problem. Pilot plant ball mill performance for single stage ball milling would also have to be evaluated by pilot plant testing. It was decided to run the pilot plant on the basis of single stage ball milling.

The facilities for supplying grinding balls to Bougainville Copper were located in Australia, Japan, Canada and the United States. Based upon single stage ball milling, the assumed ball consumption was between 40 and 45 tons per day. Obtaining and handling this quantity of balls becomes a supply and transportation problem. Autogenous grinding, where the grinding media is the ore itself, would eliminate the need for balls in the primary grinding mills. The use of semi-autogenous grinding where a small amount of large size grinding balls are used as supplemental grinding media, could reduce considerably the quantity of grinding balls required.

Successful use of autogenous grinding depends upon the ore containing a sufficient quantity of competent ore media. Field testing of breakage patterns in blasting and primary crushing would be required to establish if primary autogenous mill feed would contain the required 35-40% of plus 4 inch material. Allis-Chalmers runs media competency tests on the media size fraction of an ore to evaluate its suitability to be grinding media. These two steps would establish if a sufficient quantity of suitable rock media were available. The size distribution of the product from an autogenous is dictated and controlled by the structure of the ore and can be quite different than the product from a ball mill. The only way to develop this data and to prove the suitability of the autogenous mill product for the next processing stage is to run pilot plant autogenous grinding tests.

Arrangements were made to ship samples to the Allis-



Installation of ten 24' x 8' Allis-Chalmers "Rockcyl" Mills (Primary Autogenous) with trunnion drives.

Chalmers Process Research & Test Centre for media competency tests. Visual inspection of the ore along the walls of the Panguna Adit were not encouraging toward the possible use of autogenous grinding. Later Bougainville Copper decided to install a pilot plant size auogenous mill to check both autogenous and semiautogenous grinding and the suitability of the products from each as feed to the concentrating circuit.

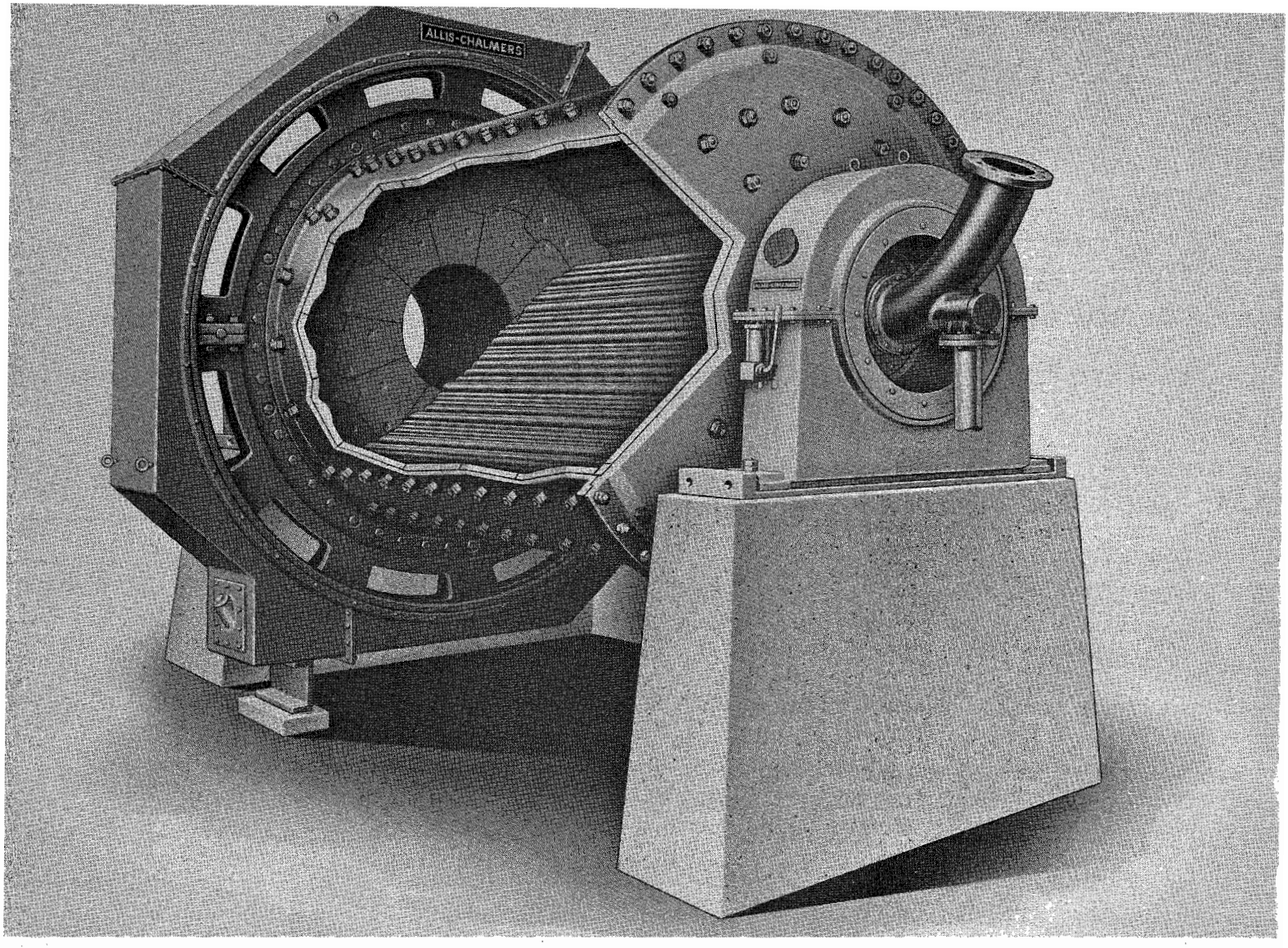
In early 1969, with Allis-Chalmers assistance, arrangements were made for Mr. W.J.N. Davis of Bougainville Copper to visit installations with large diameter Allis-Chalmers ball mills and primary autogenous mills in the copper ore and iron ore mining areas of the United States.

A visit was also made to the West Allis, Wisconsin plant of Allis-Chalmers for a detailed discussion on procedures for designing grinding mills particularly mill heads, shells, trunnion bearings and drives. The development of the present design formulae used was reviewed along with the verification of and the constant up-dating of these formulae through extensive stress measurements made during manufacture, erection and mill operation. It was shown how 18 foot diameter ball mills could be designed. Mechanically and structurally, while the 18 foot diameter ball mills would be the largest of their type, they fell well within proven grinding mill designs. It was shown that the purchase of this size mill would not entail any above the ordinary risk on the part of Bougainville Copper.

Shipping and handling delays caused a delay until mid-1969 in running the test work at the Allis-Chalmers Process Research & Test Centre. Pilot plant testing verified that single stage ball mills could be used for grinding Bougainville ore. With work indices calculated from pilot plant operating data, 18' x 21' overflow ball mills for single stage ball milling were selected and preliminary mechanical specifications were prepared.

World-wide sourcing for these grinding mills was investigated. Allis-Chalmers licensees in South Africa and Japan and subsidiaries in Canada, Great Britain and Australia, were sent specifications and drawings for the 18' diameter mills so that they could study the possibility of building these mills in their areas, and prepare preliminary quotations.

In early June 1969, three representatives from Allis-Chalmers, two from the United States and one from Australia, visited Bougainville to witness autogenous grinding tests and study data collected in pilot plant autogenous grinding tests. For most ore types, the power requirements were higher than for single stage ball milling and the product produced did not make as suitable a concentrating circuit feed as the product of single stage ball milling. The



Typical rod mill with spout feeder and wave liners.

variations in mill peformance were quite great even with semiautogenous grinding. At best, Bougainville Copper could only have installed semiautogenous grinding with a high degree of risk. This was verified by the results of the Allis-Chalmers media competency tests.

The results of the Bond grindability tests run by Allis-Chalmers were checked by Bougainville Copper with the work that they had done and with pilot plant results. As a result, they prepared the final specifications for selecting the single stage ball mills.

Work index 10.1

Feed size 80% passing 9400 microns

Product size 45% passing 200 mesh — 80% passing 220 microns

Mill sizing using these specifications confirmed the selection of the 18' x 21' overflow ball mills. In November 1969, the mills were purchased from the Kobe Steel Company, Ltd. who manufacture Allis-Chalmers grinding mills under license. All detailed engineering design calculations, basic layout drawings and basic specifications were prepared by Allis-Chalmers. The Kobe Steel Company made the detail drawings and manufactured the grinding mills. The first mill was assembled in Kobe Steel's shops and was inspected by Allis-Chalmers design engineers.

During the manufacture of the mills, there were discussions concerning the design of head and shell liners to be supplied with the mills and as replacement parts. Conservative proven designs were selected recognizing that changes based upon actual wear patterns developed during mill operation could be required. Study of actual wear patterns and recommendations on replacement liner designs are part of the service to be given after the mills had been in operation.

During this period, meetings were also held concerning mill design, mill operation and mill maintenance with supervisory, operating and maintenance personnel from Bougainville Copper. Meetings were held with the contractor responsible for mill erection to outline erection procedures and to assure that all mill parts would be properly handled, stored and installed.

For part or all of the mill erection, engineers from Kobe Steel, Allis-Chalmers, Allis-Chalmers Australia Limited and the Falk Corporation were at the site to supervise and assist in mill erection and to inspect the erection of the mills and the installation of the gears and pinions for driving the mills. The Falk Corporation supplied the gears and pinions for driving the mills. The presence of these specialists helped ensure that the mills were properly installed and aligned.

Being within proven design, the mechanical requirements for the mills could be easily established and designed for.

PRIMARY CRUSHER. Close-up view of one of Bougainville Copper Pty. Limited's two Allis-Chalmers 54"-74" gyratory crushers in the primary crushing building at Panguna. These crush the copper ore to minus 8 inches.

The process performance of the mills was based upon test work extrapolated up to the 18' diameter and was also based on experience in similar operations using other size mills. There are a number of factors involved in grinding mill performance. Many of these factors are influenced by a change in mill diameter. Each factor has a different relationship to change in mill diameter. The range of exponential factors applied to mill diameters varies from 0.5 to 2.5. It is not possible to build a scale model of a grinding mill and obtain the same condition as in a large mill. To study the performance of the 18' mills and to assist with process operation of the mills and with any possible operating problems, Allis-Chalmers agreed that after the mills went into full production that a process engineer would visit the plant. In April and October 1972, such visits were made and future visits are being considered.

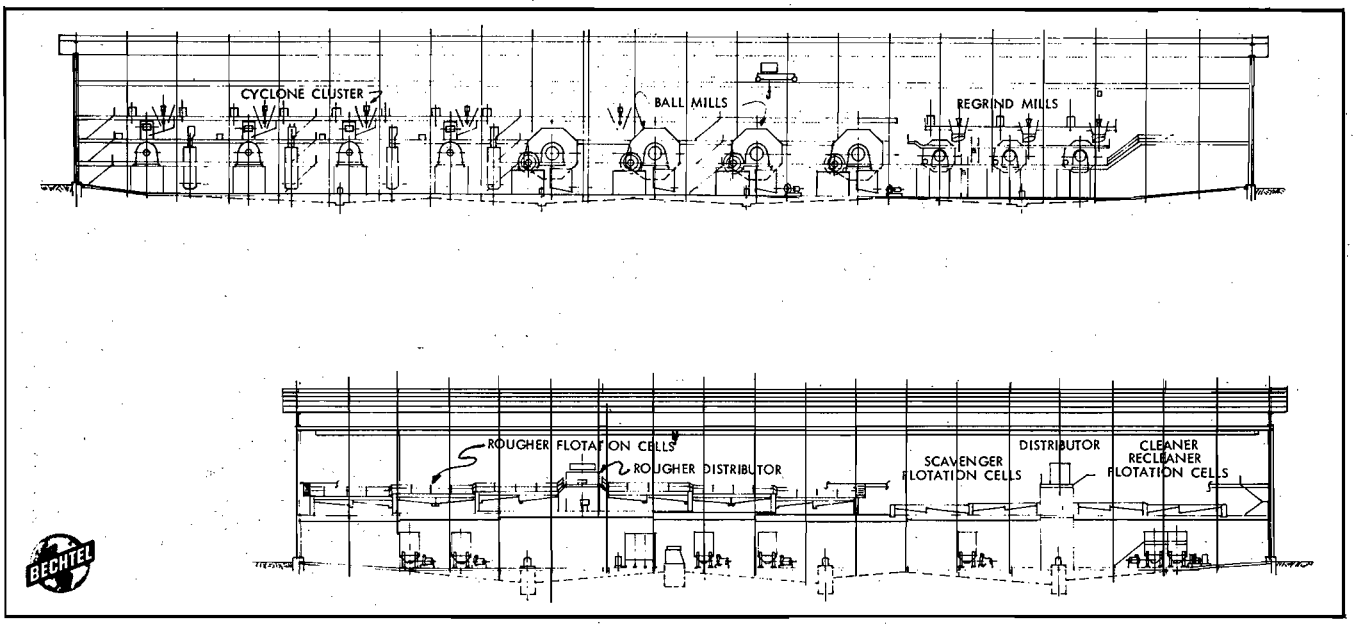
As a manufacturer of grinding mills, Allis-Chalmers involvement in the furnishing of the 18' x 21' ball mills to Bougainville Copper consisted of:

1. Assistance in selecting the grinding circuit.
2. Assistance in selecting the size of mills required.
3. Assistance in recommending the type of data to be accumulated for the ball mill in the pilot plant and means to evaluate the accumulated data.
4. Running Bond grindability tests and media competency tests.
5. Preparing mechanical specifications for the mills.
6. Establishing world-wide sourcing for the manufacture of the grinding mills to suit financing.
7. Designing the mills and assisting licensee with the manufacture of the mill.
8. Assisting with the erection of the mills.
9. Assisting with any mill problems either mechanical or process after start up of the mills.

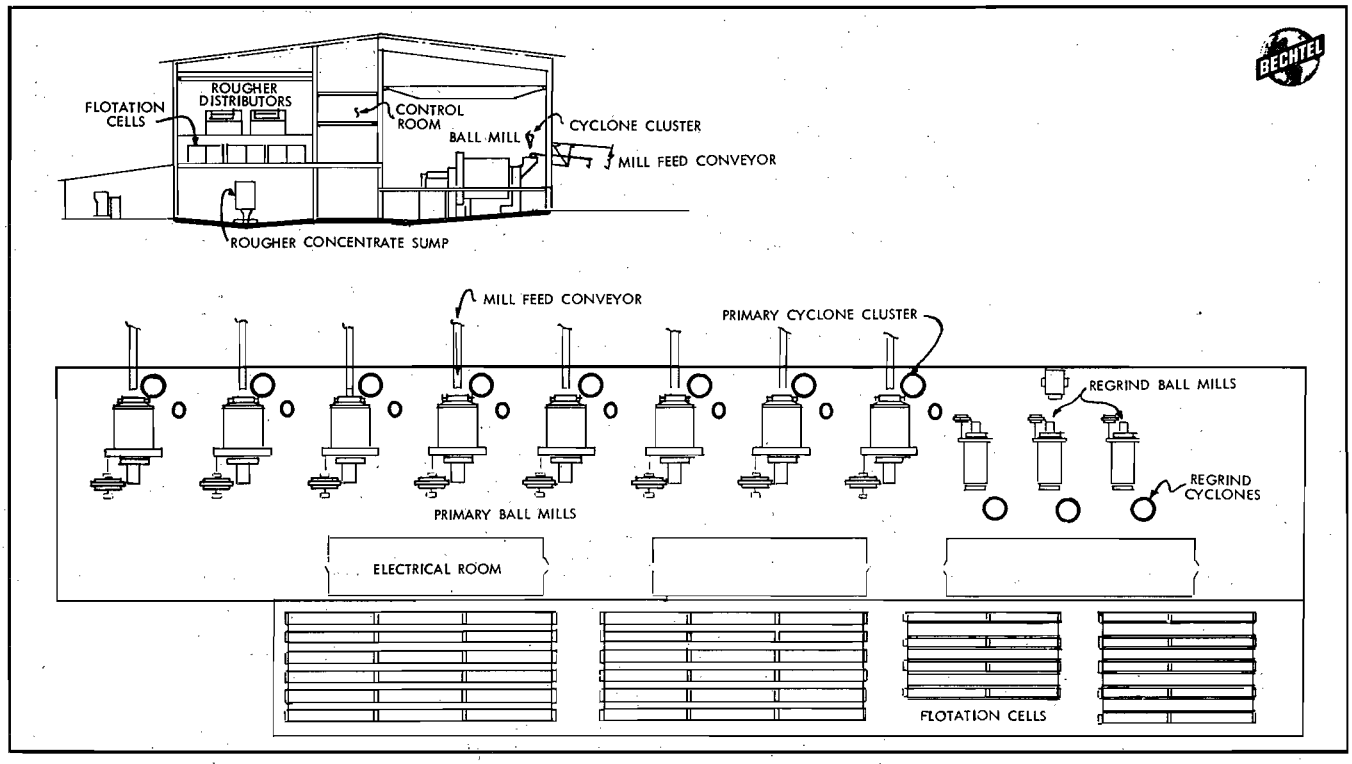
To obtain the most efficient degree of copper recovery and copper content in the concentrates, the concentrates from the rougher flotation section are ground farther to obtain a greater liberation of the copper minerals. Data for sizing regrind mills was obtained in the pilot plant. Allis-Chalmers Australia Limited obtained the contract for the three 10' x 20' wet grinding overflow ball mills installed for regrind service.

The concentrates are dried at the port in two 9' x 50' dryers with wet scrubber dust collectors designed by the Stansteel Corporation, an Allis-Chalmers subsidiary, and supplied by Stansteels' Australian licencee, Armstrong-Holland.

Other Allis-Chalmers equipment supplied for Panguna Concentrator were two 54—74 Superior Gyratory Crushers built by Kobe Steel, six 8' x 20' Double Deck Extra Heavy Duty Model XH Ripl-Flo Vibrating Screens and sixteen 8' x 20' Single Deck Heavy Duty Model SH Ripl-Flo Vibrating Screens by Allis-Chalmers Australia Limited.

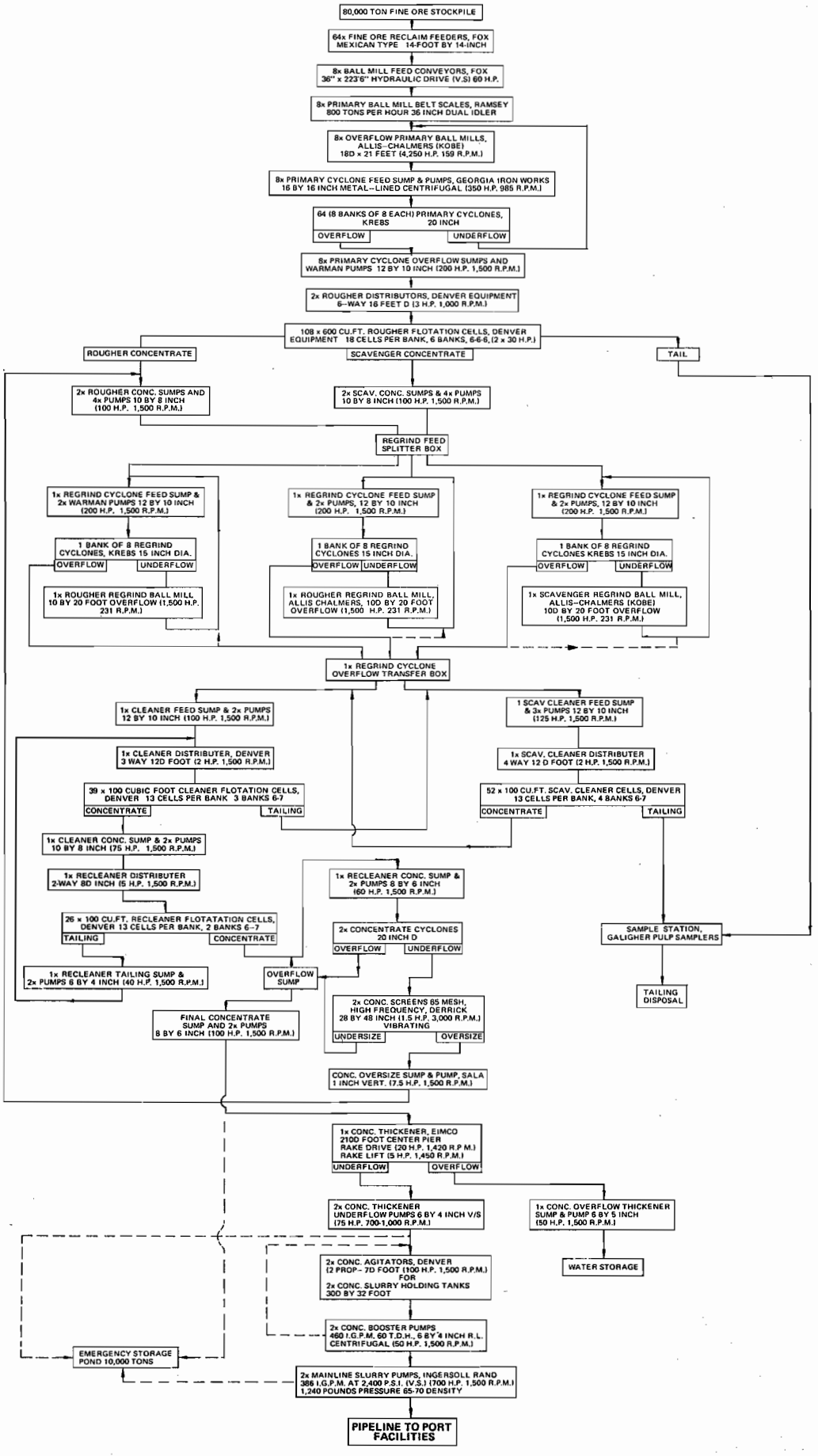


Longitudinal sections through grinding bay and flotation bay.



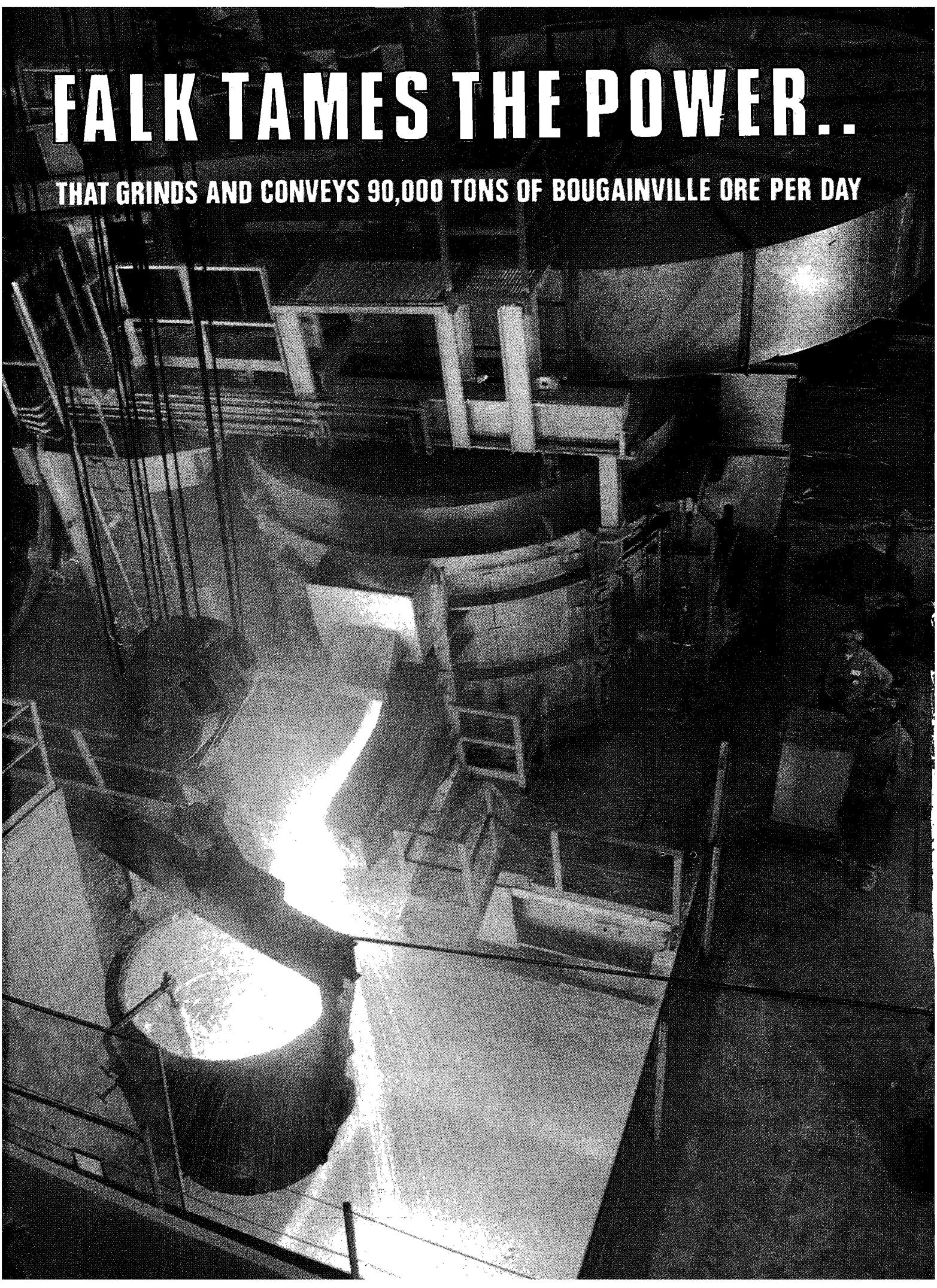
Section and plan of grinding and flotation circuits.

CONCENTRATOR FLOWSHEET



FALK TAMES THE POWER..

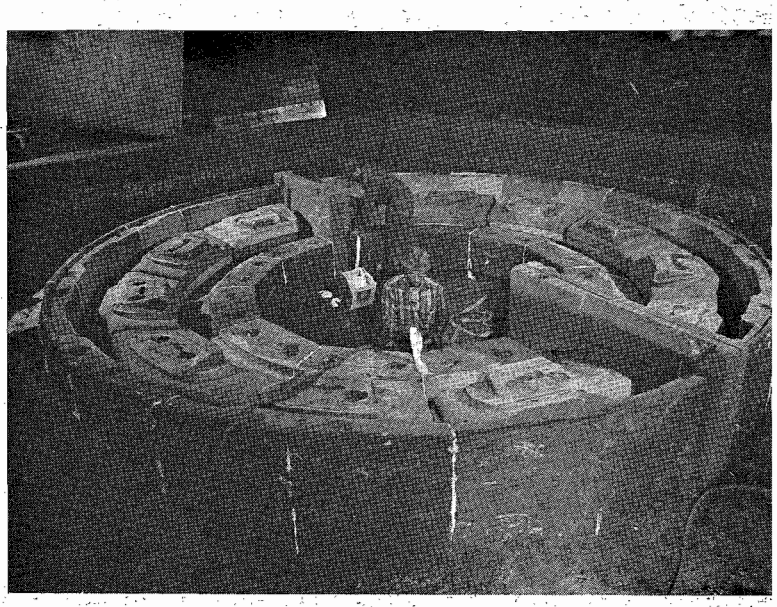
THAT GRINDS AND CONVEYS 90,000 TONS OF BOUGAINVILLE ORE PER DAY



1. Core making
2. Drilling the Splits
3. Pinion cutting

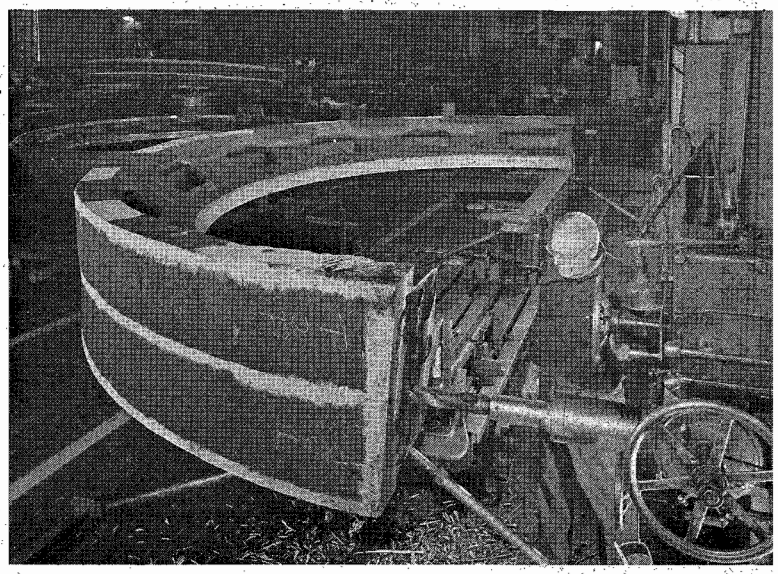
Ball Mill Drives

1.



FALK FURNISHES DRIVE SYSTEM FOR LARGEST DIAMETER, HIGHEST HORSEPOWER BALL MILLS, SUPPLIED TO DATE FOR GRINDING COPPER ORE

2.

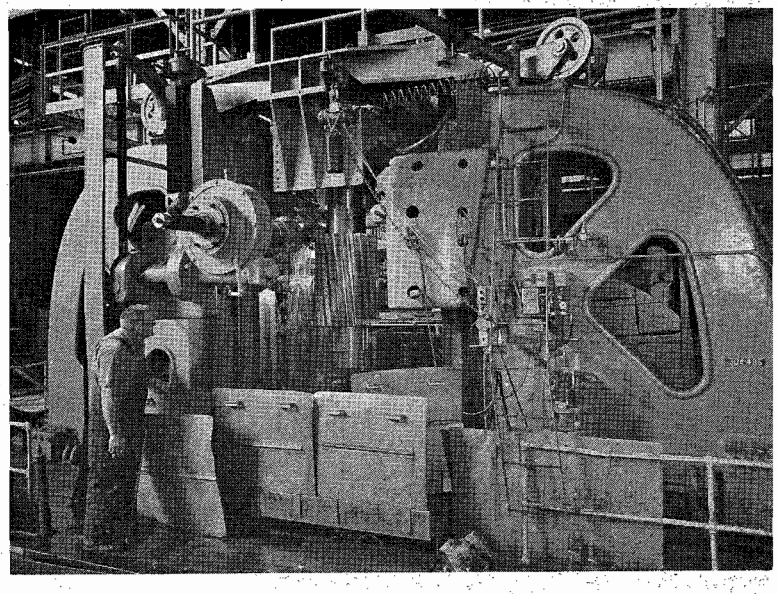


By
William G. Saar
Project Manager
International Sales Division
The Falk Corporation
Milwaukee, Wisconsin
Subsidiary of Sundstrand Corporation

The Falk Corporation is indeed pleased and fortunate to have played a role in the supply of nine ball mill gear sets for the primary grinding apparatus of copper ore for Bougainville Copper Pty., Ltd. Papua-New Guinea. Our role as a component supplier to Allis Chalmer's licensee, Kobe Steel in Japan, was a task which we accepted with a great deal of enthusiasm. At the time the gear sets were furnished, the overflow ball mills were the largest in diameter and highest in horsepower that had ever been sold for the purpose of grinding copper ore.

The original installation totalled eight gear sets and one more gear set has been furnished since then. The ball mills are 18' x 21' each driven by a 4,250 horsepower 158 rpm electric motor through air clutches to the Falk gear sets, each consisting of one gear and one pinion.

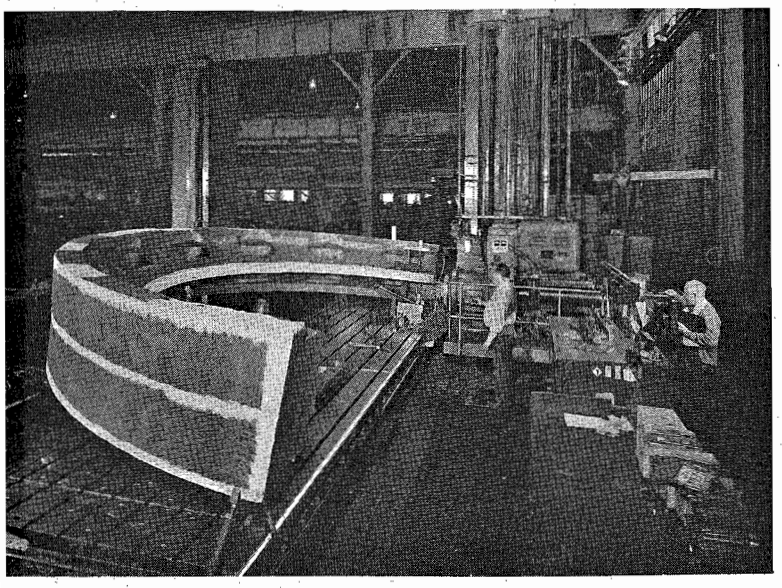
3.



The final mill speed is 12.46 rpm. Illustrations of the mills gear sets can be seen in the Allis Chalmers paper on ball mills, immediately preceding this article. Each gear set had the following size parameters:

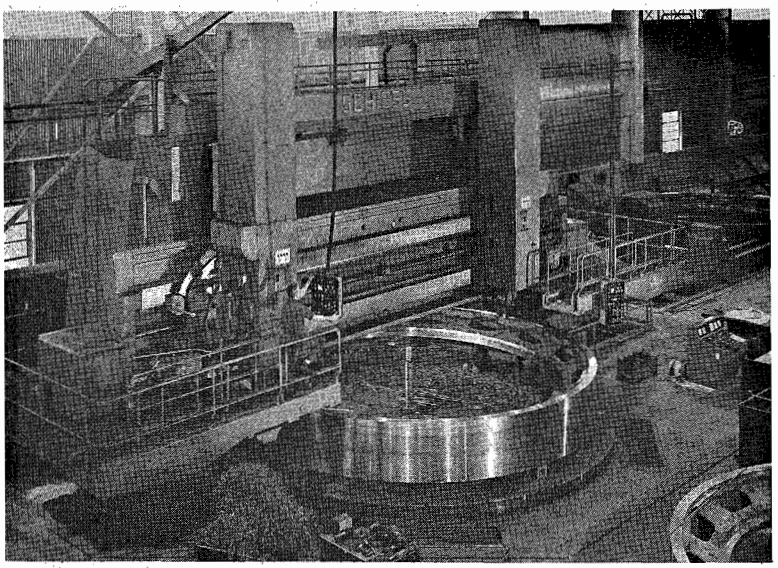
Gear –

Material – Alloy cast steel cast in two halves
Outside diameter – 282"
Face Width – 39"
Bore – 227.50"
Weight – 82,500 pounds



4. Milling the Splits
5. Trim, Bore and Face
6. Gear cutting

4.



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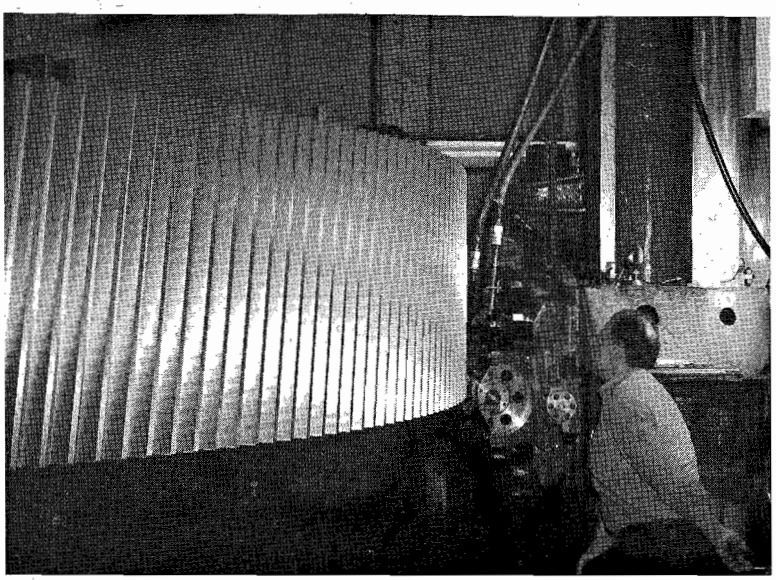


6.

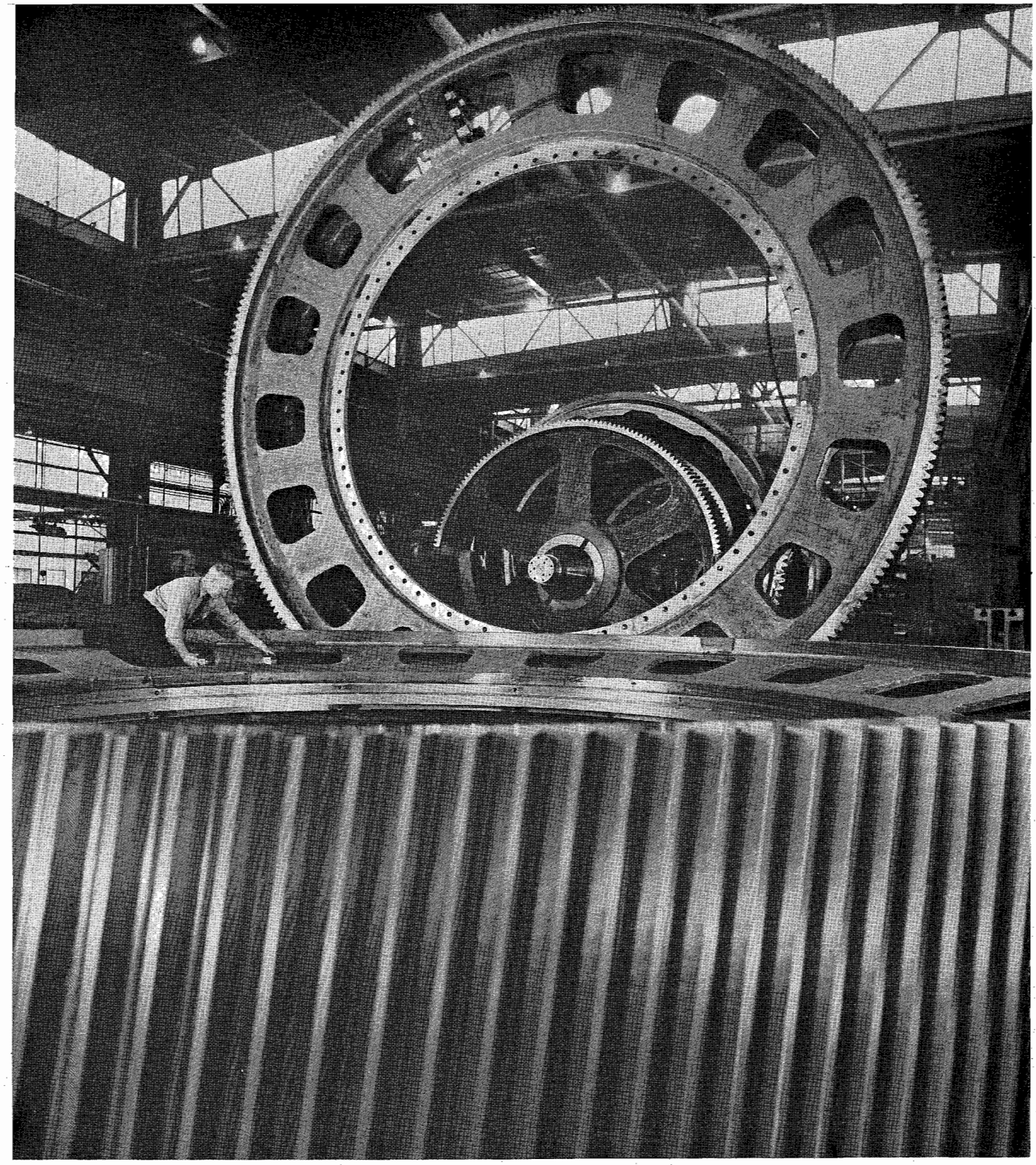
Pinion –

Material – Alloy steel forgings
Outside diameter – 24"
Face Width – 39"
Length – 138"
Weight – 7,900 pounds

For any order of this magnitude, quality standards play an important role in determining a gear supplier. Falk quality and reliability is world renowned and it was this superior quality along with the ability to maintain shipping schedules that was the determining factor in our being selected to supply the gear drive system to the mill builder.

Many quality standard factors went into the supply of these gear sets. In recent years the trend in grinding mill drives has been both higher horsepowers and higher pitch line velocities. Based upon many years of experience in the grinding mill field, Falk realized that the developing trend required gears having a higher degree of precision. The Falk Corporation was prepared to meet this challenge with its long-established metallurgical and manufacturing capabilities which, coupled with design engineering and gear technology know-how, enables The Falk Corporation to provide large ring gears having unexcelled accuracy and performance.

Quality control is initiated at the design stage by developing in-house process and inspection specifications which direct the necessary control during all phases of gear manufacture. The initial quality control begins in the Falk steel foundry which employs a modern 50 ton electric furnace and an automatic spectrometer which monitors the percentage of all elements used for control of the steel melting and casting process, as well as for the determination of the final chemical composition. A Materials Engineering Department and well equipped Materials Chemical and Sand Laboratories, in addition to technical production engineers, all participate in developing scientifically engineered specifications for materials, pattern design, riser design, sand properties and final production and quality control procedures. Modern inspection equipment affords quality certification for checking during the process and for final inspection. A 20,000 ampere Duovec instrument is used for wet fluor-



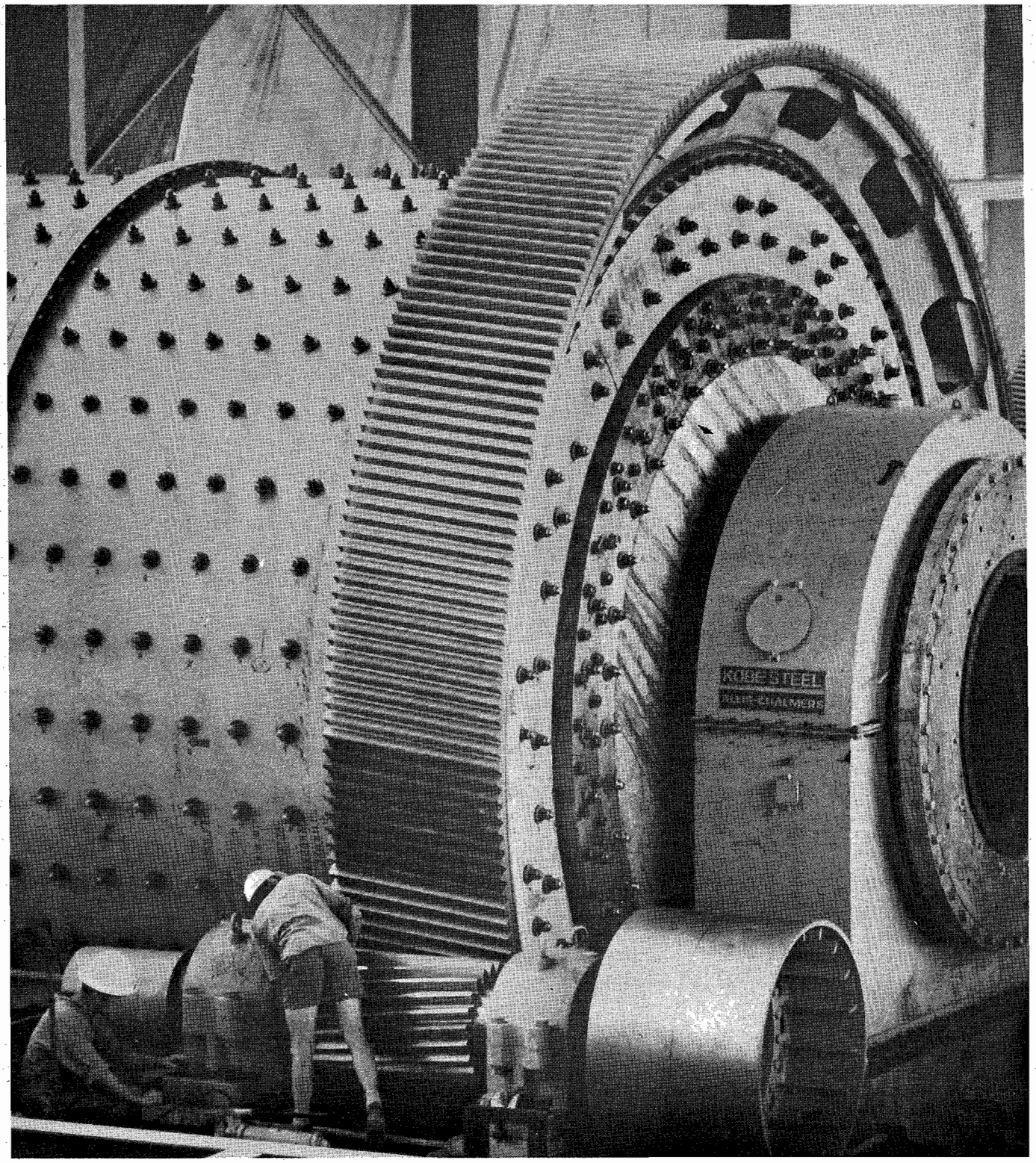
Ball Mill Ring Gears ready for despatch.

escent magnetic particle inspection for in-process control and final inspection. A radio-active Cobalt 60 and a 25,000 Betatron (x-ray) are available for radio-graphic examination to ensure the internal soundness of castings. The large heat treat furnaces are all automatically controlled with some monitoring as many as 12 points around the gear.

Falk gear manufacturing facilities include large Falk-designed heavy duty hobbing machines, which have designed into them a unique compensating dividing system offering the maximum in index accuracy. This is a proprietary design not available in commercially manufactured gear hobbers.

The many years of experience in the specialized large gear design field has enabled the development of capabilities to properly evaluate the accuracy of commercially available gear machines. Many recommended improvements and changes have been incorporated in the large special generating machines which have been purchased, such as those made by Maag and Schiess.

The Falk quality control system also includes a special Engineering Gear Technology Department whose salient assignment is to audit preventive maintenance programs to ensure the continued accurate performance of Falk gear

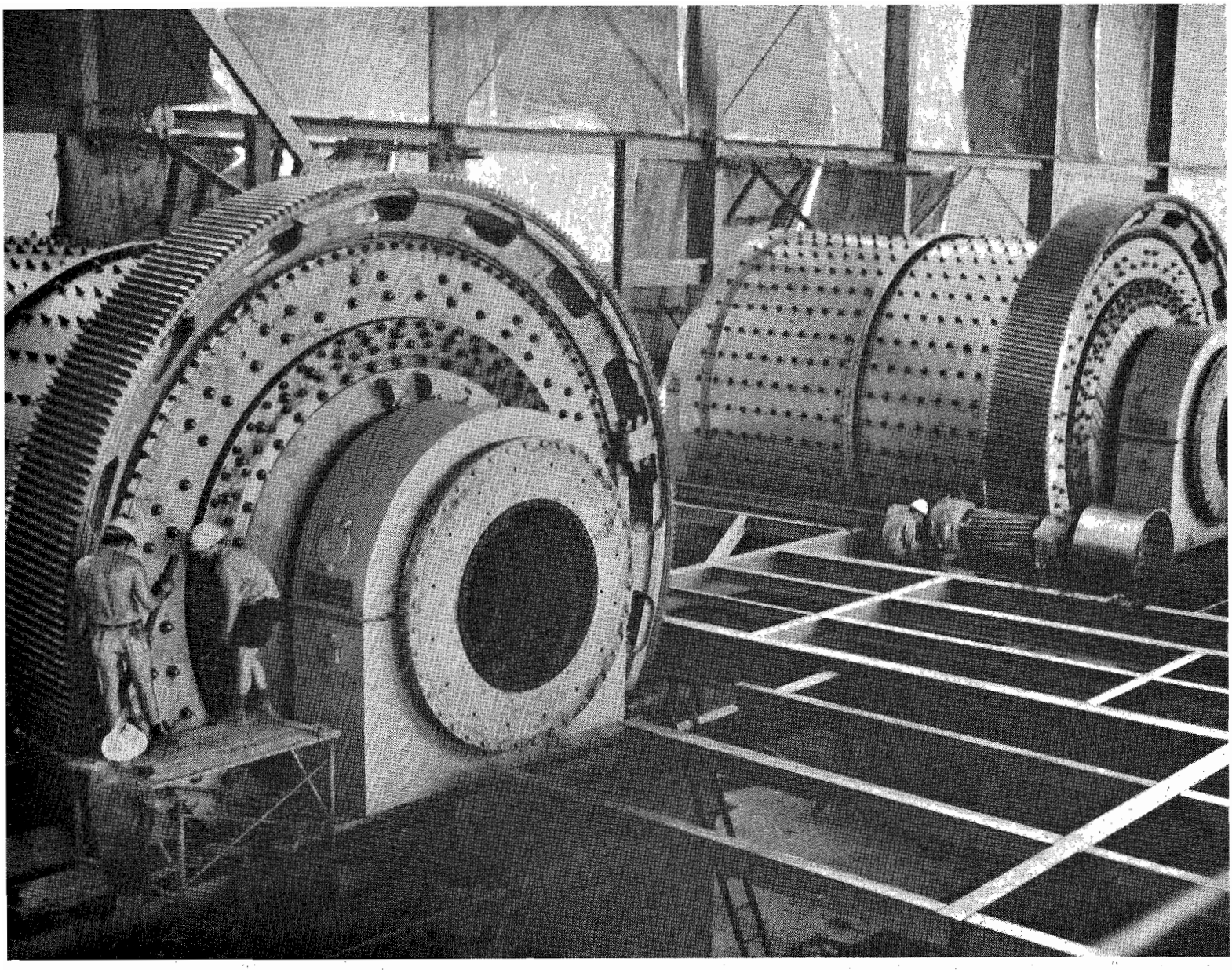


Installation of Ball Mill Ring Gears at site.

hobbing, shaving, lapping, balancing, and contact testing machines. Engineers and technicians trained in the skills of manufacture and inspection procedures have available all of the special laboratory instruments needed to evaluate all phases of gear geometry which might affect the ultimate accuracy of gears of this large size. This includes unique testing equipment like the Hofler automatic pitch tester which has the capability of measuring to .000020". We also employ very sophisticated angular velocity dynamic displacement testers for gear machine certification which can measure angular velocity changes of a shaft or relative angular velocity changes between rotating shafts to within one microradian.

Relating our accuracy capabilities to a specific AGMA quality class, we are confident of meeting Class 10 or better for gears 200" and larger. The tolerances specified in AGMA Classification Manual 390.03 are: runout, pitch, lead and profile.

Runout accuracy is the result of machine accuracy and set-up control. Our machine certification and setup control procedures guarantee a result well within the .010" tolerance for a 200" gear and Falk's own production specification is approximately one-half this value. Pitch tolerance for this



Installation of Ball Mill Ring Gears at site.

size and class is .0013" and with our specially designed machines we are consistently able to meet or better this value and certify its quality. Lead tolerances again are controlled by machine accuracy. Accurate instruments for lead measurements for gears of this size are not available. However, we not only certify the machine capabilities, but evaluate this result by contact checking. Accurate profile measuring instruments for gears this size also are not available; however, our process control system does assure that we have the required accuracy to satisfy the application.

We use Class A hobs and certify their tolerance on our hob checking instruments. We also test and measure the involute on smaller gears produced by these hobs and thus are able to extrapolate values for larger gears.

Falk manufacturing, inspection controls, engineering and technology provide the confidence that grinding mill gears will be furnished which will meet AGMA Quality Class 10. It also affords the customer the additional assurance that with the aid of our computer data retrieval system we can, without delay, furnish spares with duplicate design specifications and quality standards to satisfy complete interchangeability.

Own own rigid quality specifications and those of our customer, the mill builder, enabled Falk to supply gear sets that met or exceeded the parameters as set forth by both Bougainville Copper Pty., Ltd. and Bechtel/WKE.

After sales service also played an important part in Falk securing this order. Supervision of installation was provided and performed by one of our several technical service engineers. This took several trips and many man hours of work but was well worth the additional effort when translated to complete customer confidence in our product. These same service engineers are also on recall and on very short notice can be put into service to assist in customer problems associated with our equipment. These services are provided at added cost and this cost is minimal when compared with the benefits derived. The Falk Corporation is one of the only corporations in its field capable of providing this much needed assistance.

As supplementary equipment Falk supplied the gear drive systems for three 10' x 20' regrind ball mills furnished by Allis Chalmers Australia. This equipment was supplied with the same stringent quality control standards used in the manufacture of the primary ball mill gear drives.

Conveyor Drives

FALK PLAYS AN IMPORTANT ROLE AS COMPONENT SUPPLIER TO CONVEYOR MANUFACTURER FOR BOUGAINVILLE COPPER

By
William G. Saar
Project Manager
International Sales Division
The Falk Corporation
Milwaukee, Wisconsin
Subsidiary of Sundstrand Corporation

One of the larger conveyor drive installations of its type in the Western Pacific is now in operation in Papua-New Guinea where Falk drives are assisting in the conveying of millions of tons of ore for Bougainville Copper Pty., Ltd.

The Falk Corporation is extremely proud to have assisted its licensee, Sonnerdale Richardson David Brown Pty. Ltd. in the selection, engineering, and manufacture of Falk speed reducers.

But one might ask the question, why Falk drives on this particular project? The answer, we at Falk, believe, is basic and quite easily understood. Falk quality and precision are known the world over and whether we emphasize such features as all steel housings, precision hobbed gearing, or tandem seals, we get down to the basics – proven quality and reliability. Add this to our association with Sonnerdale Richardson David Brown Pty. Ltd., Australia's largest and best known gear manufacturer, and you come up with a team that was able to manufacture, with all of its ramifications, the complete requirement of drives from the smallest shaft mounted helical gear drive transmitting 1.5 horsepower, see Figure 1, to the largest 127" centres dual input pinion parallel shaft conveyor drives. Each of these drives is capable of transmitting 1,800 horsepower continuously for the two large external conveyors carrying ore from the primary crushers to the course ore stockpile, see Figure 2. The majority of the 40 conveyor drives furnished by Falk/SRDB are standard catalogue gear drives with time proven performance records.

This unique relationship between Falk and SRDB enables Falk to send engineering and manufacturing details to SRDB and thus ensure that the gear drives furnished would meet consistent rigid quality standards and be completely interchangeable with Falk Milwaukee equivalents. The reputation and manufacturing ability of SRDB is unquestioned and this has played a major role in our ability to provide gear drives to meet and exceed the rigid specifications of the conveyor manufacturer, Fox Manufacturing Company of Australia.

One function that Falk/SRDB insists upon is the task of after sales service. Many times a component drive supplier sells the drives and fades out of the picture. This is not so in the case of Falk/SRDB. Supervision of installation was handled at the jobsite, as well as periodic on site inspections, by a Falk trained SRDB Service Engineer. In-plant maintenance seminars have also been held with Bougainville Copper personnel as well as helping to determine proper spare parts backup. These are continuing educational and service functions that we feel must be included as part of our product package. These additional services are performed at added cost, but this is minimal when compared with the obvious customer benefits derived. Falk/SRDB are two of the few corporations of this type that are capable of providing this service.

The following briefly summarizes Falk/SRDB participation, thus far, on this project:

Conveyor drives mine site area:

Total number of drives furnished – 25

Largest drive – 127" total centres dual input shaft capable of transmitting 1800 horespower continuously. Torque at low speed shaft is 2,984,200 lb. in. Drive centres are 63.500" plus 63.500".

Smallest drive – 507J24 shaft mount that transmits 30 horsepower continuously, torque at low speed shaft is 49,736 lb. in.

Total accumulated horespower – 8570.

Total accumulated torque – 19,425,000 lb. in.

Conveyor drives at port site area:

Total number of drives furnished – 15

Largest drive – 2170Y3 parallel shaft that transmits 60 horsepower continuously. Torque at low speed shaft is 625,000 lb. in.

Smallest drive – 307J24 shaft mount that transmits 1.5 horsepower continuously. Torque at low speed shaft is 12,000 lb. in.

Total accumulated horsepower – 589.

Total accumulated torque – 1,732,000 lb. in.

Figure 1 — Falk/SRDB 307J24 shaft mounted drive

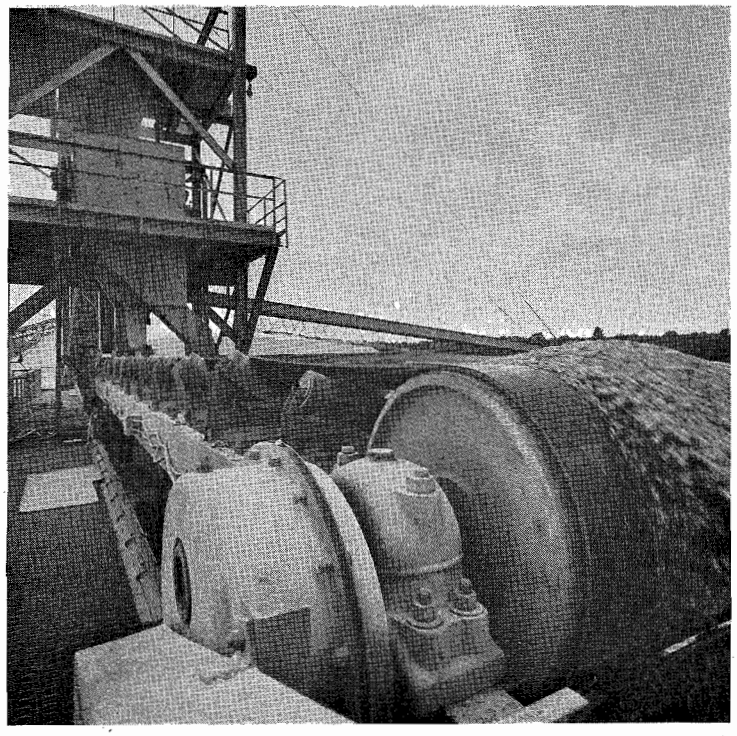
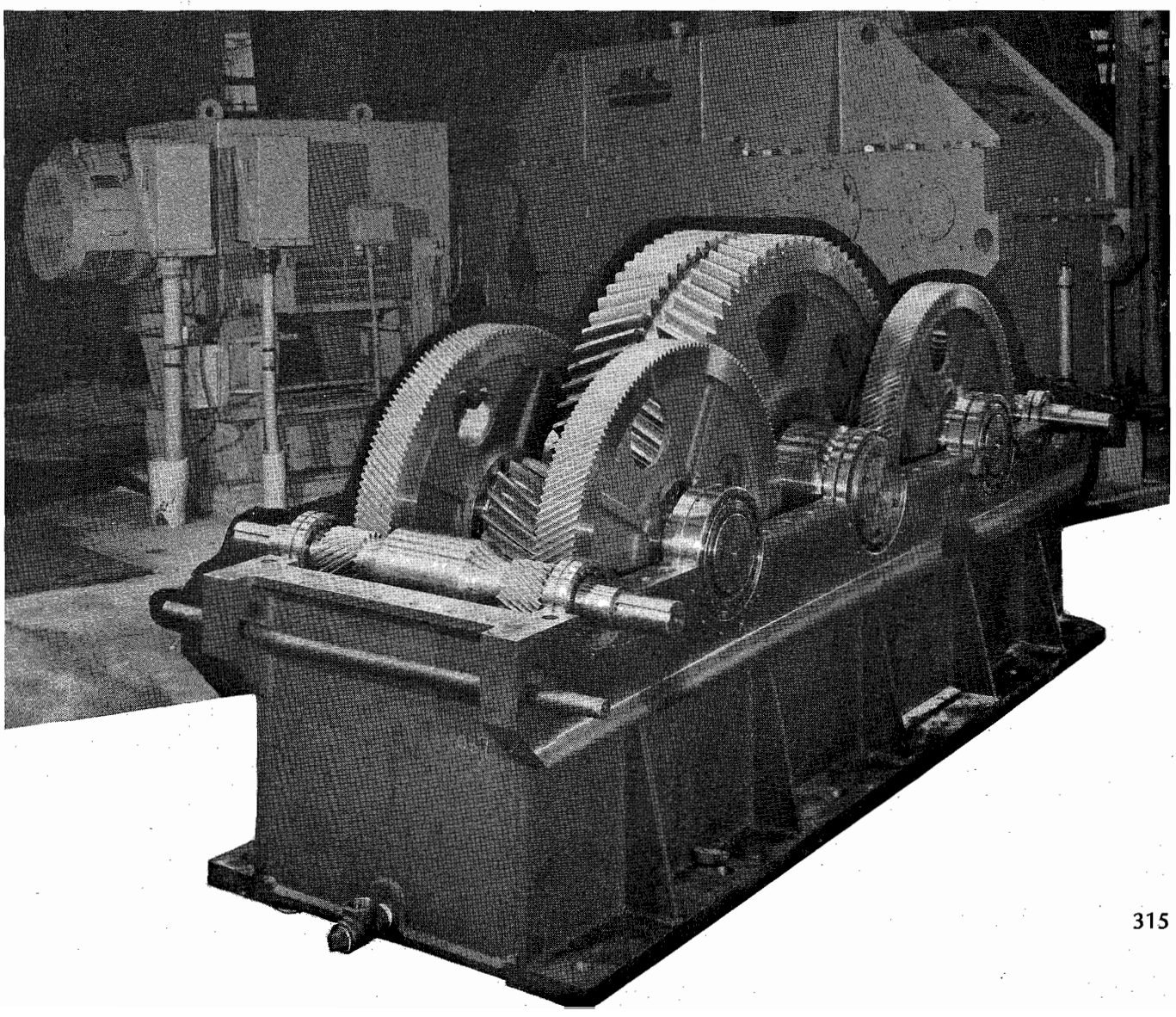
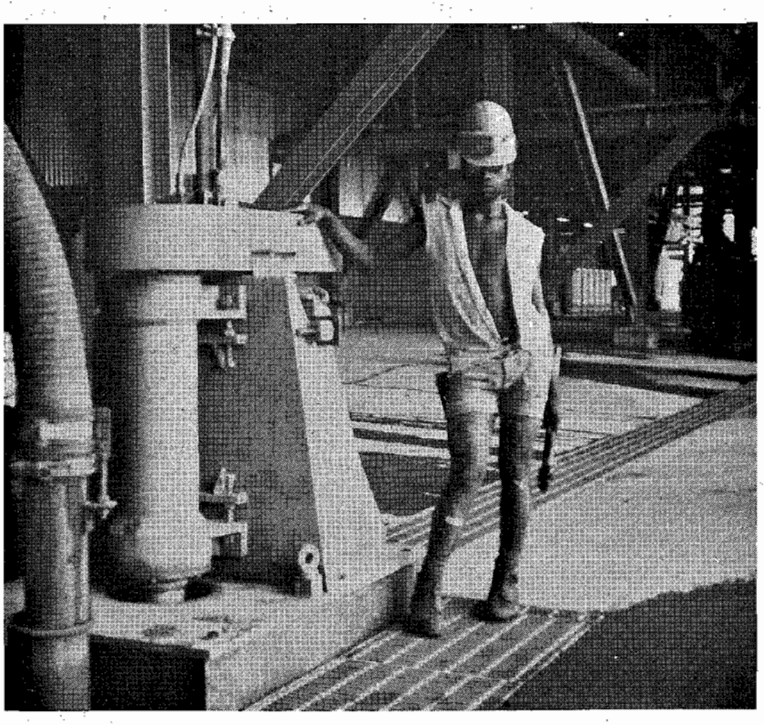


Figure 2 — Falk/SRDB 127" total centre dual input drives



Sump Pumps



Sala 6" sump pump installed at Panguna, Bougainville.

SALA EQUIPMENT AT BOUGAINVILLE

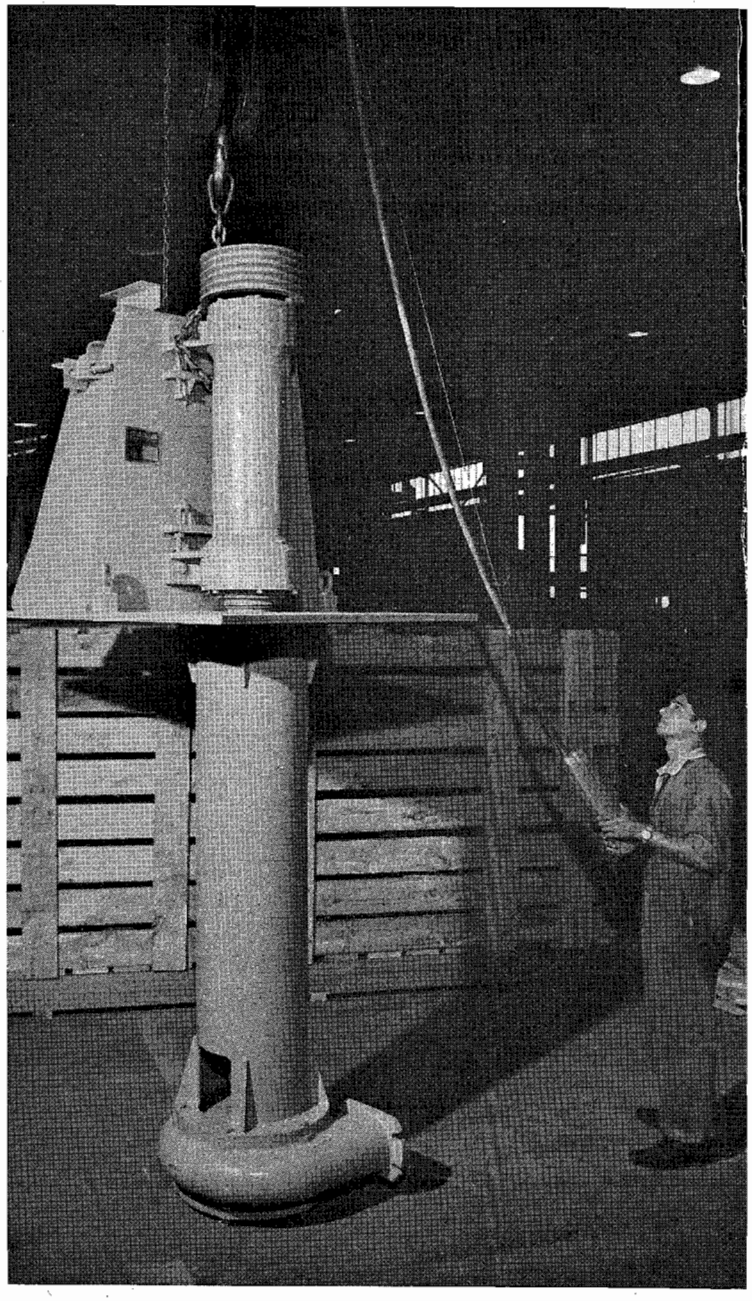
Sala Australia Pty. Ltd. supplied a total of 34 sump pumps for the Bougainville Copper project. These pumps were in 1", 3" and 6" sizes with varying shaft lengths up to 6'.

The pumps were provided with wear parts in Ni-hard and the 3" and 6" units were of the special GS design, which incorporates spray holes in the pump casing through which part of the liquid sprays back into the sump, preventing settlement of solids and airlocking of the pump.

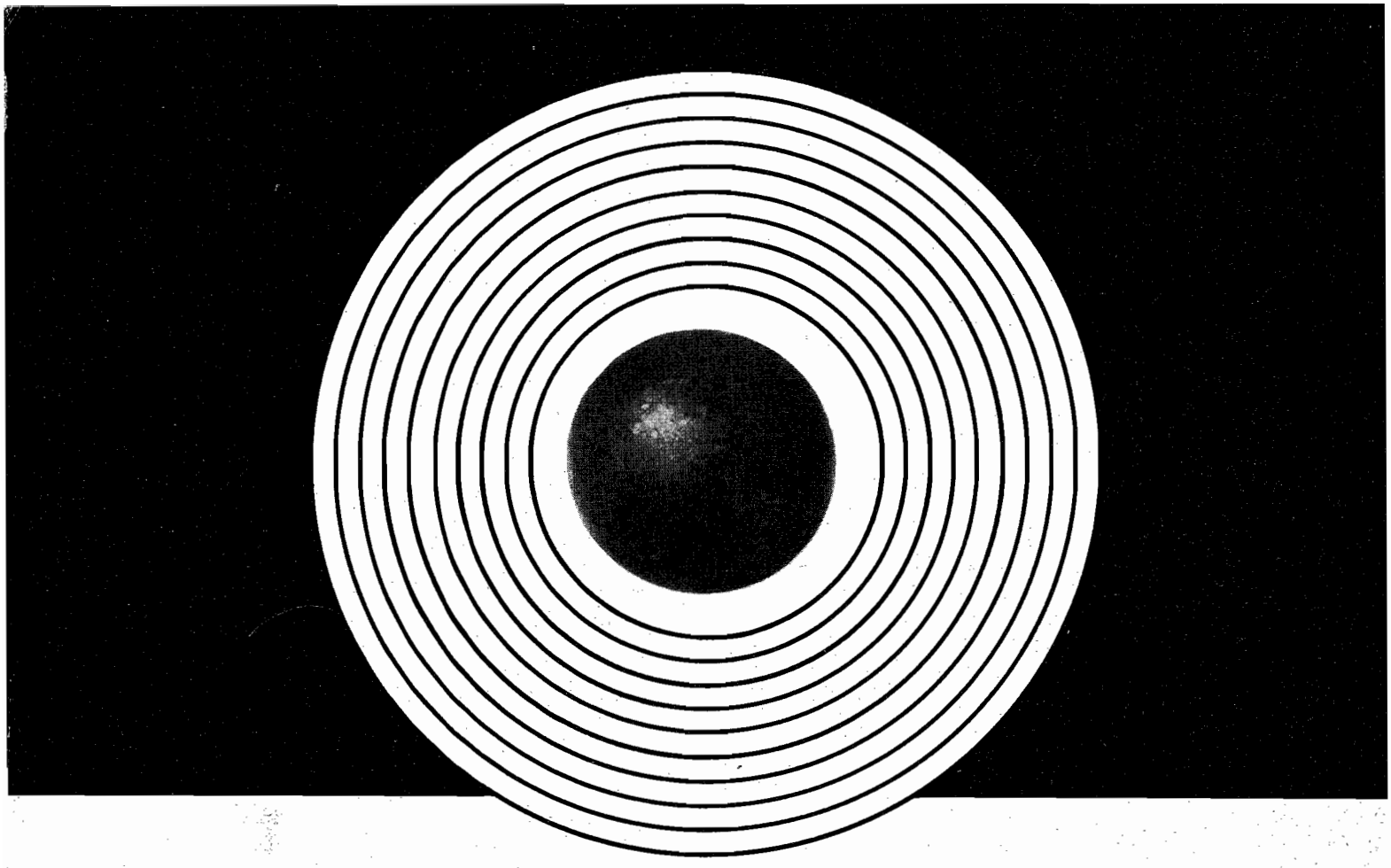
All of the pumps are glandless and have no submerged seals or bearings. The impellers are of the open type with auxiliary vanes on the back, preventing liquid from leaking out around the shaft. No parts are ruined if the pumps are idling without liquid in the sump.

Sala Australia Pty. Ltd. is the supplier of a wide range of specialised pumps for mining and industrial use. The company's offices are situated at Pendle Hill, Sydney.

Sala Australia's manufacturing program has recently included magnetic separators, type BFR flotation cells, type SPV pumps, thickeners, drum and disc filters, all destined for use in Australian mining operations.



One of the Sala 6" x 6' shaft sump pumps installed at Bougainville being prepared for shipment in Sala's Sydney plant.



Bougainville starts up on Algoma Steel grinding balls

Forged steel grinding balls from The Algoma Steel Corporation, Limited of Canada, were ordered for start up of the Bougainville mine production. Over 11,000 tons of balls, ranging in size from 1½" to 3" in diameter, were shipped late in 1971 for the beginning of production early the following year.

Algoma is one of Canada's largest steel producers. Annual raw steelmaking capacity is more than two and one half million tons (more than two and a third million metric tons). When present expansion plans are complete by the mid-1970's, Algoma's capacity will approach 4 million tons (3.6 million metric tons). At the Sault Ste. Marie plant, a wide variety of steel products is produced. Algoma is one of Canada's leading suppliers of forged steel grinding balls and hot rolled grinding rods.

Algoma Steel was founded in 1902 at Sault Ste. Marie, Ontario. Situated on the St. Mary's River between Lakes Superior and Huron, the plant enjoys direct access to the St. Lawrence Seaway system, two major trans-continental railways and the Trans-Canada highway.

Algoma forged steel grinding balls raw materials

The manufacture of grinding balls begins long before forging and heat treatment stages. Like the origin of all Algoma steel products, it starts with careful processing of raw materials from Algoma's own mines: coal, limestone and iron ore. Coal is used for making coke. Then, together with iron ore, it provides the charge for the blast furnaces.

Blast furnace

In the blast furnace the iron ore, consisting of iron oxide, is reduced by carbon and carbon monoxide from the coke, to iron. This then dissolves silicon, carbon and other elements. The result is a 94% iron liquid called hot metal. Together with scrap steel, it is the basic material for the oxygen steelmaking furnaces. Iron composition is controlled by sizing and blending of the charge materials, which are analysed regularly.

Steel

Steel is made in the basic oxygen furnace from a charge of about 75% hot metal and 25% scrap. All silicon and parts of other elements are removed by an oxidation process. At the same time, carbon content is reduced to the level suitable for grinding balls — about 0.75%. The oxygen source is a high velocity jet of 99.9% pure oxygen, which impinges upon the metallic charge material in the furnace. For each heat the process parameters — such as hot metal temperature, oxygen input, flux in the form of lime — are calculated from pre-determined equations for the reactions' physical chemistry. This results in the optimum tapping temperatures and oxidation state. A final temperature measurement is made before tapping. During tapping, calculated additions of ferromanganese and other alloys adjust the steel analysis to the desired ranges for grinding ball hardness.

After tap, the steel is poured into hot-topped moulds. All grinding ball steels are fully killed and hot-topped to ensure uniform composition and freedom from "pipe" lamination in the body of the ingot.

Rolling

After a pre-established waiting time, the moulds are removed from the ingots. The ingots are then transferred to soaking pits, where they are brought up to rolling temperature (2350°F) at a controlled rate. The ingots are then rolled on a blooming mill. At this stage any visible surface defects are removed by an automatic oxygen-gas flame machine. The blooms are immediately rolled on a continuous mill into billets. The billets are transferred to a continuous bar mill, where they are reheated and rolled into rounds.

Forging

The rounds are now transferred to the Ball Mill. Here they are reheated, sheared into short lengths and forged into ball shape in automatically operated forging die equipment. The balls proceed next to a rounding mill where satisfactory shape and surface are ensured.

Heat treatment

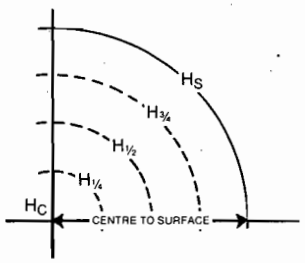
From the rounding mill, the balls enter the rotating quenching drum which contains water as a quenching medium at its exit. Control over the temperature of the ball before quenching is maintained and the quenching rate in the water is controlled. Immediately on leaving the water, the ball is brought to the desired tempering temperature in order to obtain the right microstructure and hardness. Parameters such as furnace temperature, water flow rate, drum speed and tempering temperatures are monitored to maintain consistency of quality.

Structure, sizes & characteristic properties

Algoma Steel grinding balls are composed of high carbon steel. For some sizes they also contain chromium for added hardenability and abrasion resistance. On quenching, the structure is transformed from the austenitic phase to acicular martensite. Martensite, which derives its hardness from iron carbide, has high hardness and resistance to wear but in the acicular condition has poor resistance to impact. To improve its toughness, the balls are tempered, which spheroidizes the iron carbides. The resultant structure, termed tempered martensite, has excellent hardness and toughness.

In larger balls, the structure deeper below the surface consists of bainite. Bainite is similar to tempered martensite but of slightly lower hardness. The centres of large balls, which may be subject to high impact forces in grinding, are of pearlite, which is relatively soft and may provide a cushioning effect to impact.

The following diagrams show schematically representative cross-section microstructures and hardness values expressed as Rockwell 'C.'



† It is considered that Volumetric Hardness figures give a better measure of wear performance than Surface Hardness figures.

Average Volumetric Hardness values can be derived from the following expression:

$AVH = .008H_C + .063H_{¼} + .203H_{½} + .437H_{¾} + .289H_S$

Approximate equivalent hardness numbers

Rockwell C-Scale Hardness No.	64	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34	32	30	28	26	24	22	20
Brinell Hardness No. 10mm ball, 3000 Kg. Load Tungsten Carbide Ball	722	688	654	615	577	543	512	481	455	432	409	390	371	353	336	319	301	286	271	258	247	237	226

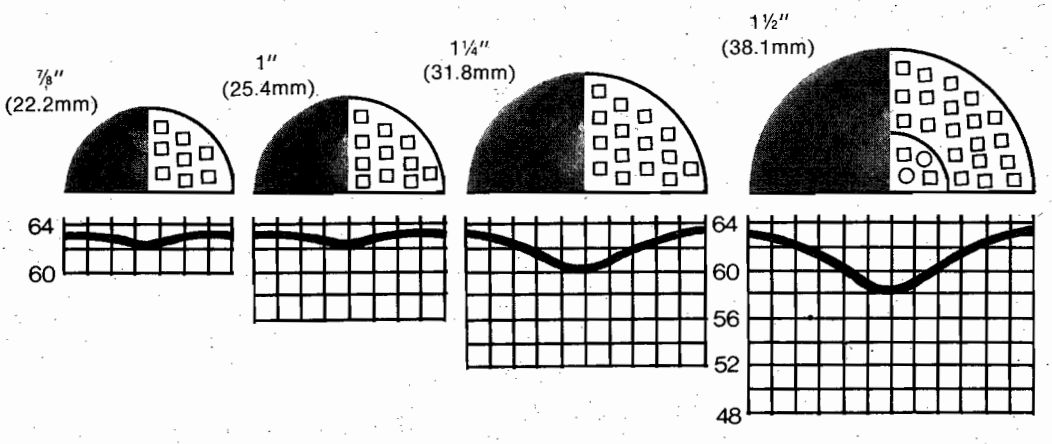
Diameter*		Nominal Unit Weight		Approximate Number of Balls		Approximate Number of Balls**		These are Calculated Figures Only						Typical Hardness Rockwell C-Scale	
								Unit Volume		Unit Surface Area		Grinding Surface**			
												Per Cubic Foot	Per Cubic Metre		
in.	mm.	Lb.	Kg.	Per ton (Short)	Per ton (Metric)	Per Cubic Foot	Per Cubic Metre	in.³	cm³	in.²	cm²	in.²	m²	Surface***	Volumetric†
⅞	22.2	0.099	0.045	20,200	22,270	2,630	92,750	0.3507	5.748	2.4053	15.518	6316.1	143.94	63	62.9
1	25.4	0.148	0.067	13,510	14,900	1,760	62,070	0.5236	8.582	3.1416	20.269	5519.8	125.81	63	62.9
1¼	31.8	0.290	0.132	6,900	7,600	900	31,670	1.0227	16.760	4.9088	31.670	4403.1	100.30	63	62.5
1½	38.1	0.501	0.227	3,990	4,400	520	18,330	1.7671	28.963	7.0686	45.604	3668.6	83.60	63	61.5
2	50.8	1.187	0.538	1,680	1,860	220	7,730	4.1888	68.654	12.5664	81.073	2752.0	62.71	62	59.0
2½	63.5	2.318	1.051	860	950	110	3,960	8.1812	134.090	19.6350	126.677	2199.1	50.18	62	59.0
3	76.2	4.005	1.817	500	550	65	2,290	14.1372	231.709	28.2744	182.415	1837.8	41.83	62	58.5
3½	88.9	6.360	2.885	310	350	40	1,440	22.4494	367.944	38.4846	248.287	1577.9	35.86	61	58.2
4	101.6	9.493	4.306	210	230	27	970	33.5104	549.235	50.2656	324.294	1357.2	31.36	61	58.2
5	127.0	18.541	8.410	110	120	14	490	65.4500	1,072.726	78.5400	506.709	1099.6	25.08	59	56.0

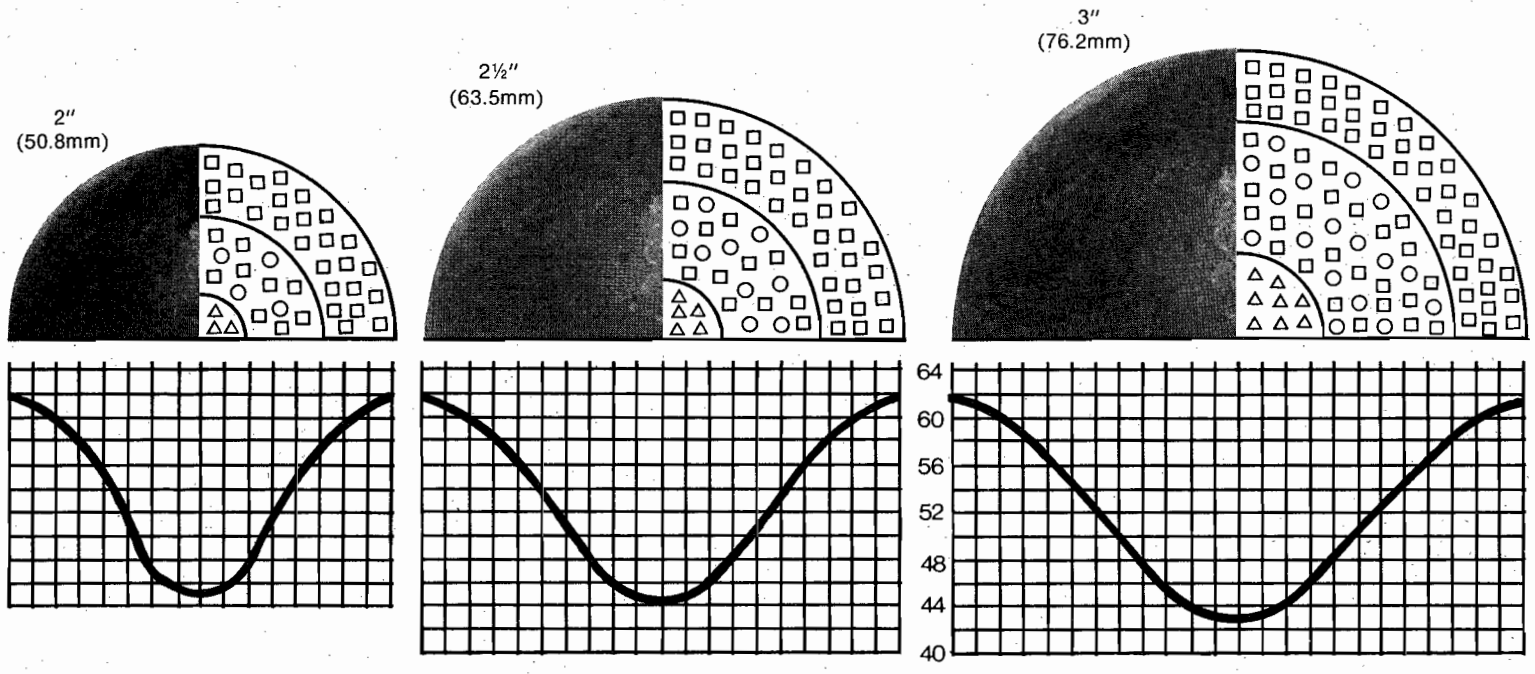
*Sizes of balls other than shown are available subject to negotiation.

**Over the complete size range, an average weight of loose balls is taken as 260 lb. per cu. ft. or 4164.68 kg. per cu. metre.

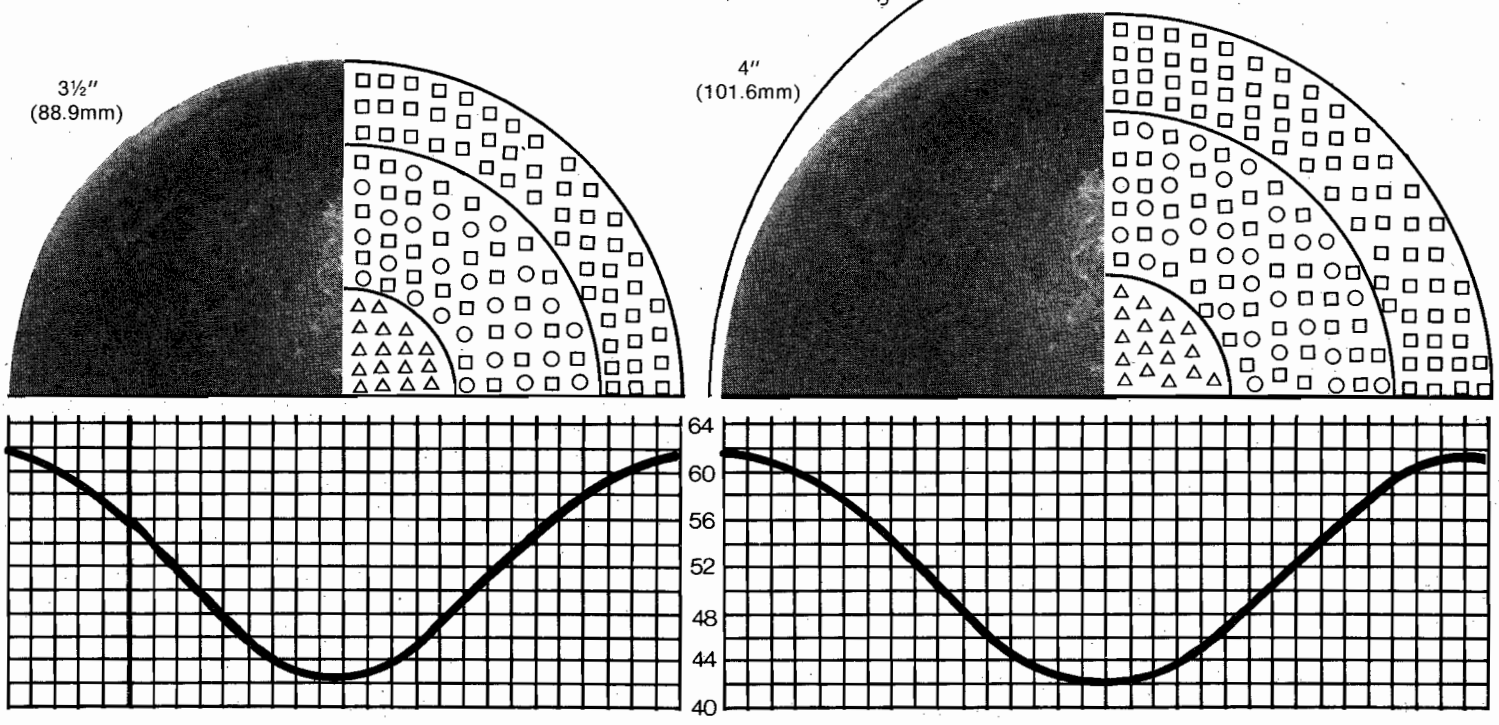
***Algoma also supplies a special annealed ball with a typical hardness of 50 Rc (481 BHN)

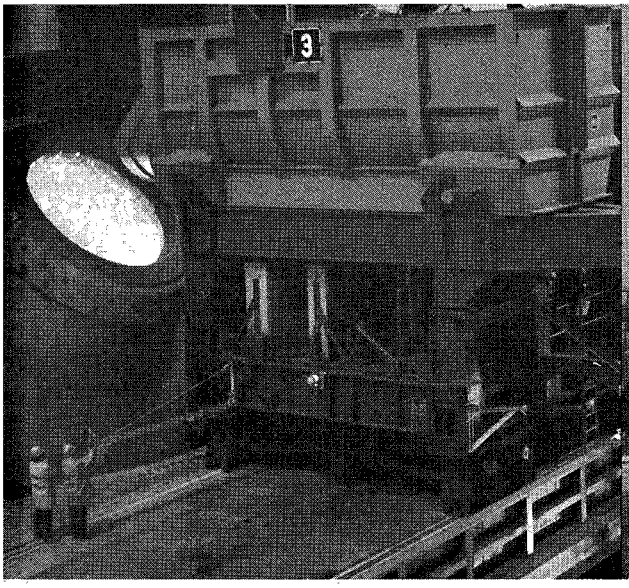
Symbol	Structure	Typical Hardness Rockwell 'C'
□□□□□□ □□□□□□	Tempered Martensite	60 / 65
○○○○○○ ○○○○○○	Bainite	48 / 60
△△△△△△ △△△△△△	Pearlite	35 / 48



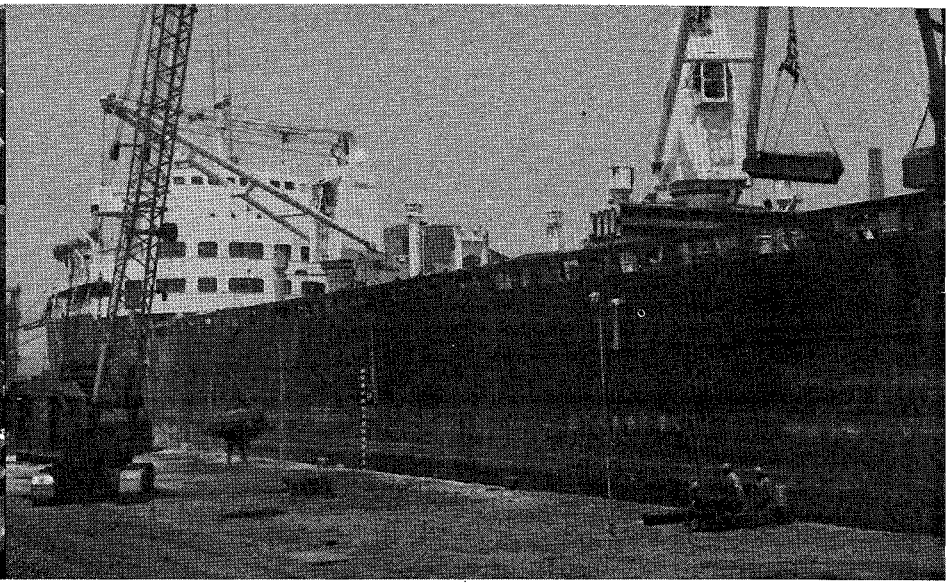


5″ (127.0mm) balls also available subject to inquiry

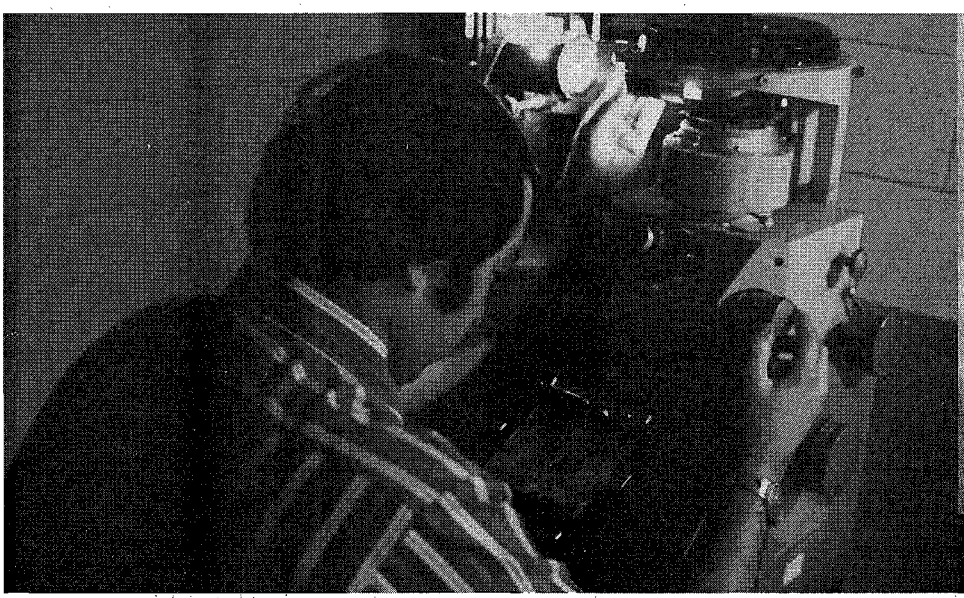




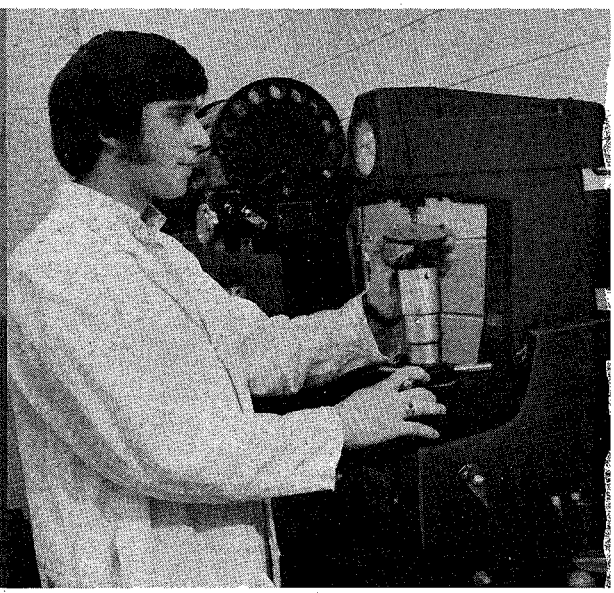
Scrap-charging machine unloading scrap into new 250 ton B.O.S.P. steelmaking vessel.



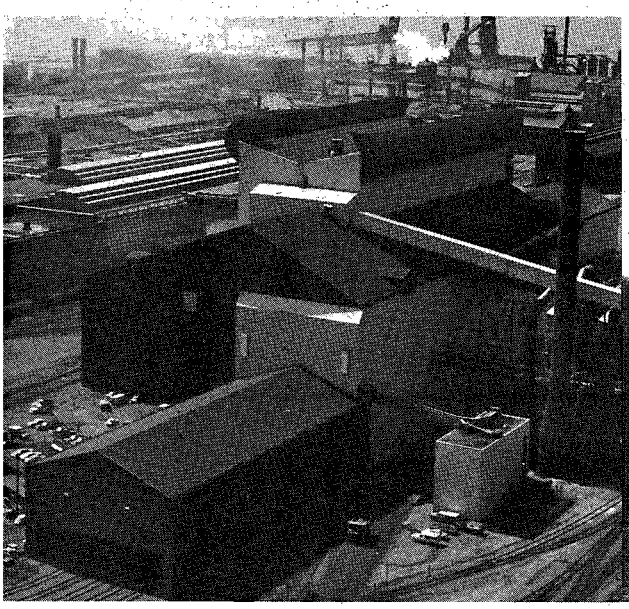
Loading loose grinding balls by magnetic crane and skip into ocean-going vessel.



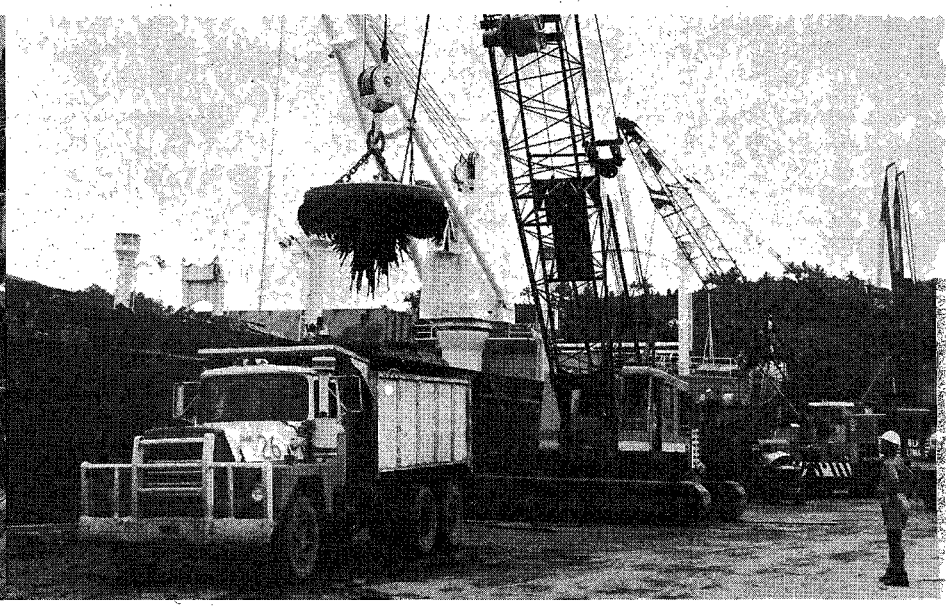
Metallographic examination of grain structure being carried out by skilled technician.



Cross-section hardness testing to ensure a high level of quality control.



Aerial photograph of Algoma steelworks at Sault Ste. Marie, Canada.



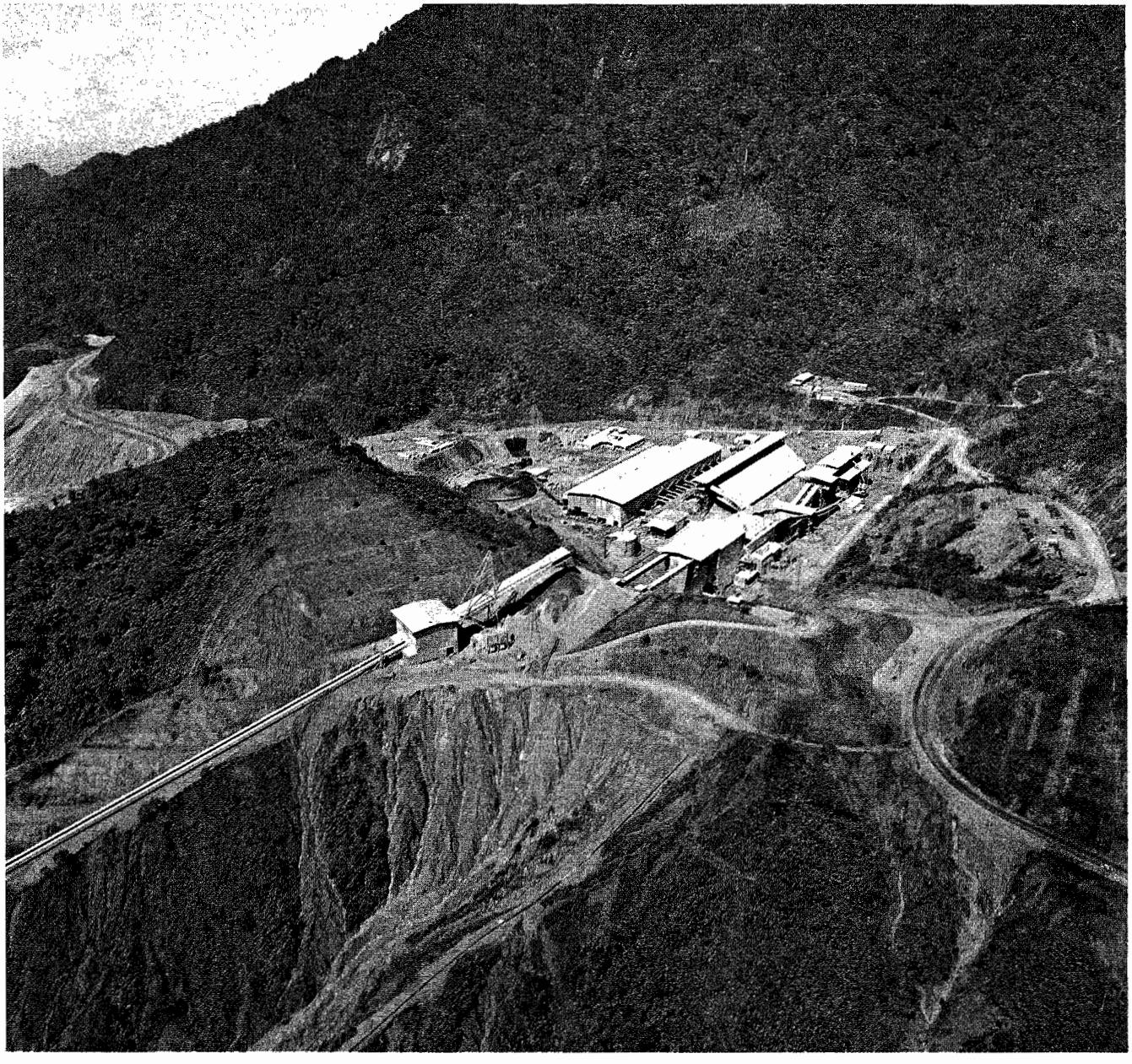
Unloading Algoma forged steel grinding balls by magnetic crane at Bougainville Island.

The Concentrator

DENVER Rotating Pulp Disbritutors and Flotation cells in operation at Bougainville.

C. Otis Staples,
Manager, Denver Equipment Division,
Joy Manufacturing Co., Australia.

The Panguna Concentrator facilities of Fine Crushing, Screening, Grinding and Flotation treat some 80,000 tonnes of ore each day. The operation is continuous.



Foreword

The Bougainville Copper project is the largest "Grass Roots" development for copper concentration in the world. The Management of C.R.A. who were responsible for the conception and completion of a scheme of this magnitude are to be congratulated on their achievement. All of the contributing contractors and engineers must also receive much credit for the parts they played in this $400,000,000 project.

Location

The mine and concentrator are located at Panguna on the Island of Bougainville at approximately 7°S—156°E. This island is part of Papua-New Guinea but in the past was classed as one of the Solomon Islands. There is a townsite for some of the employees at Panguna and there are others at Loloho and Arawa. The port at Loloho in Anewa Bay has been dredged to receive large bulk carriers up to 45,000 tons, for shipping the concentrates. Supplies for the mine and mill are received here and oil storage for the 135 MW power plant are provided adjacent to the power plant.

A modern highway about 25 km. long connects the port with Panguna. This crosses the Crown Prince range and at the highest point is 1,000 metres above sea level. The elevation of the plant at Panguna is almost exactly 700 metres A.S.L. In this area annual rainfall is 5,000 mm.

History

The modern investigation of the Panguna ore body commenced in 1963 when an exploration team was taken to the old gold workings by helicopter. Geochemical sampling results were such that drilling rigs and crews were called in to provide core samples which were tested in the laboratories of Zinc Corporation at Broken Hill, N.S.W. Good grades and recoveries were achieved. With the drilling and metallurgical results it was possible to arrange financing by credit agreements with American, Australian and Japanese banks. Batch testing at Broken Hill was followed by the establishment of a pilot plant at Panguna where the test work was carried out by C.R.A. metallurgists.

Geology and Mineralization

The porphyry copper ore contains chalcopyrite as the major primary copper mineral which is accompanied by some Bornite, a little Molylodenite and Silver. The gold values are associated with the copper. Pyrite is found throughout the ore body. In the upper levels some oxidized copper minerals are present but they are not found at depth.

The chalcopyrite is principally found in the Panguna Andesite, with some in the leucocratic quartz diorite and biotite chlorite.

The ore reserves at this time stand at 600,000,000 tonnes at a grade of 0.48% Copper and 0.559 of Gold per tonne.

Flotation Cells under construction.

Mining

Mining is by open cut pit which on completion will be 2140 metres long by 1520 metres wide by 300 metres deep. Haul roads to the primary crushers are 25 metres wide for the 88 tonne Euclid R105 Trucks. Benches are drilled by 5 @ 250 mm. electric drills and loading is done by six @ 13 M^3 electric shovels. Overall mining is at 150,000 tonnes per day of which 82,000 tonnes goes as feed to the concentrator and 68,000 tonnes of over burden is hauled to waste.

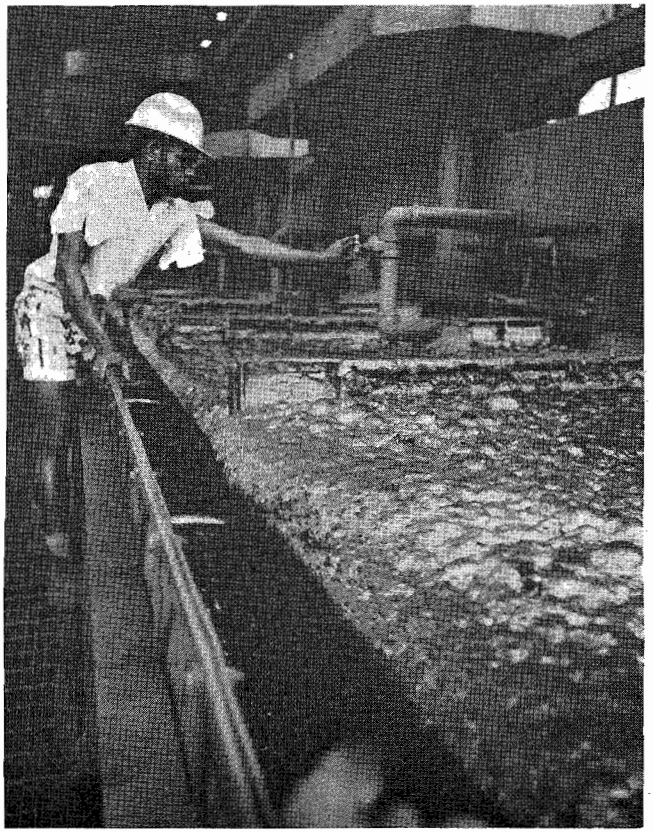
Milling

The flowsheet is straight forward with stage crushing and screening followed by grinding and flotation.

In the primary gyratory crushers the ore is reduced to — 200 mm. and then is conveyed 740 metres by twin conveyors to a 49,000 tonnes live capacity surge pile. From the surge pile the ore is conveyed, again by twin conveyors, to secondary and tertiary crushing and screening.

The final crushed product at minus 12.5 mm. is distributed in a covered storage area with a total capacity of 225,000 tonnes. From this fine ore storage pile 9 @ 915 mm. feeder conveyors, each unit with 355 mm. square Mexican feeders deliver ore to the grinding mills. The feeder conveyors are each equipped with Ramsey weightometers and with hydraulic drive motors for speed control

Nine 5.5 m x 6.5 m Allis Chalmers ball mills with 3170 KW synchronous motors operate in closed circuit with either batteries of 5 @ 760 mm. or 10 @ 555 mm. cyclones. The mills are overflow type and fitted with discharge trommels having 25 mm. openings. At 13 RPM the mills operate at 68% of critical.



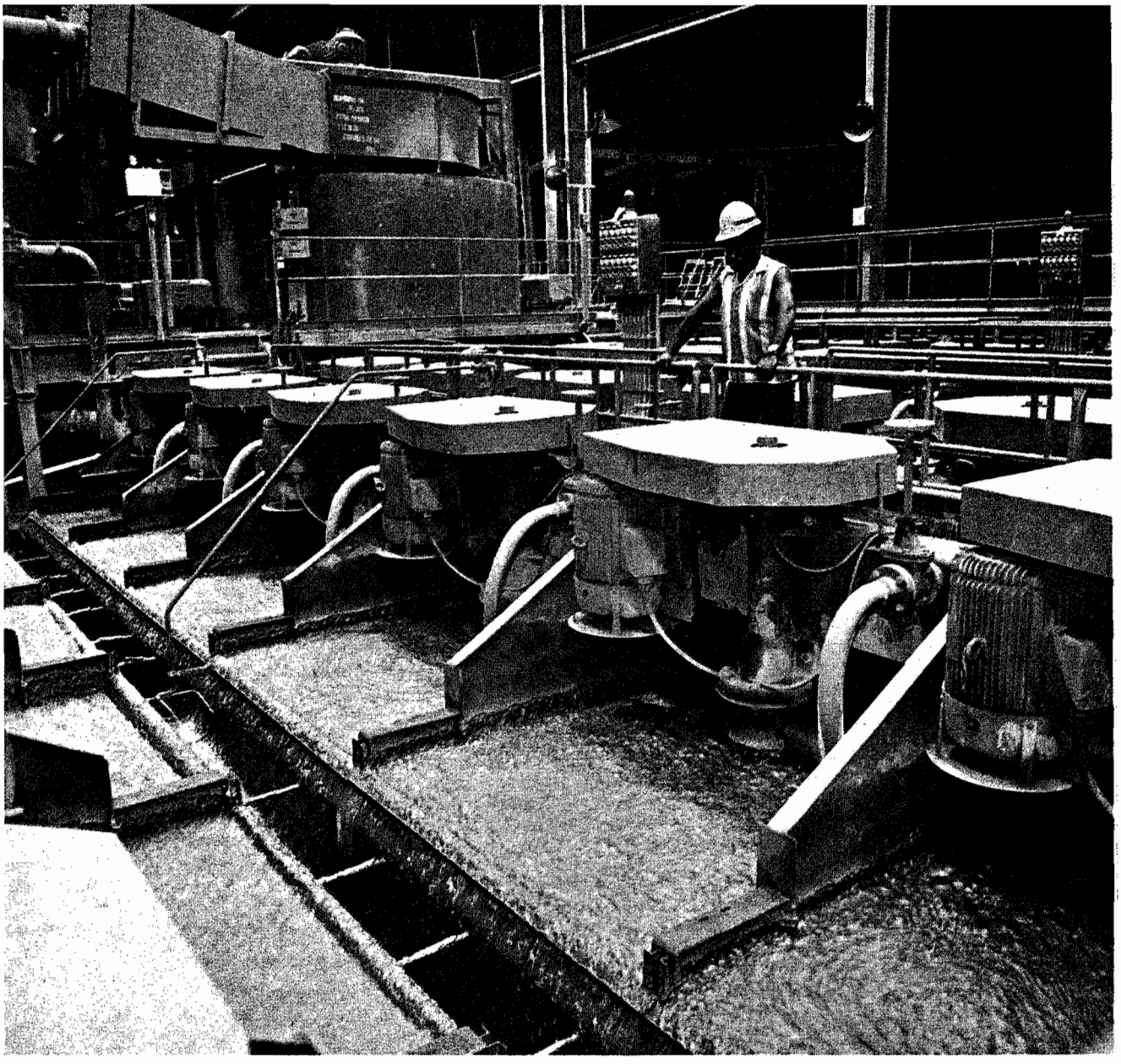
Flotation Cells in Panguna Concentrator.

SCREEN ANALYSIS CHART

% PASSING

Tyler Mesh	Ball Mill Feed	Ball Mill Discharge	Cyclone Over-flow	Cyc-lone Sands	Final Concen-trate	Flot-ation Tail
¾"	85.9	98.9		96.6		
4 mesh	48.0	91.0		86.1		
8 mesh	29.4	82.1		74.5		
14 mesh	20.8	69.2		59.0		
28 mesh	16.2	52.9	95.0	40.5	100.0	94.6
35 mesh			88.7		100.0	88.1
48 mesh	12.9	37.2	79.2	23.2	100.0	78.1
65 mesh			69.0		99.7	67.1
100 mesh	10.5	28.9	58.9	16.3	98.9	56.4
150 mesh			49.5		96.9	46.8
200 mesh	8.4	22.9	41.2	12.0	92.0	37.9
270 mesh			36.9		86.8	33.2
Cyc. 1			33.0		70.5	31.7
Cyc. 2			27.5		56.9	27.0
Cyc. 3			21.7		32.0	21.3
Cyc. 4			17.0		31.6	16.5
Cyc. 5			14.4		24.9	13.3

Denver Equipment's 18 cell banks
for roughing and scavenging in the
Flotation Bay of Panguna's Concentrator



Mill discharge is pumped to the cyclones by 400 mm x 400 mm G.I.W. pumps each with 260 KW motors. Cyclone overflow density is read by Gammagauges and maintained at 50% solids by water control to the pump sumps. Under these conditions the grind will be 40—42% minus 74 microns.

The cyclone overflow is pumped by 300 mm x 250 mm Warman pumps to the flotation feed distributors.

Flotation

The two 5 metre diameter 6-way Denver Rotating pulp distributors each feed a rougher scavenger section which consists of 3 banks of 18 cells Denver No. 600—H—D.R. flotation cells. Each cell has two mechanisms with 838 mm. moulded rubber impellers and matching moulded rubber diffusers. A 22 KEW motor is used for each mechanism. This 108 cell circuit provides a total of 1835 M^3 of flotation capacity. In each of the 18 cell banks, roughing is done in the first six cells, with the balance of the cells for scavenging. From the flowsheet, it can be seen that these two products are reground separately and each goes to a separate section of the cleaner circuit. The regrinding for the rougher concentrates is done in two at 3 m. dia. x 6.1 m. long overflow A—C ball mills in closed circuit with batteries of 380 mm. cyclones. The scavenger concentrates are reground one 3 m. x 6.1 m. mill with the same cyclones as for the rougher product. The cyclone overflow is about 85% minus 325 mesh and has a maximum of 2% + 100 mesh. All of these mills have 1125 KW drive motors, and operate at 70.8% of critical.

The reground rougher concentrate is split between three banks of 13 cell Denver No. 30 (100) DR flotation cells by a 3.7 m. 3-way dia. Denver Distributor. The tailings from this circuit are combined with the feed to the scavenger cleaner circuit. The first cleaner concentrates are next split between two @ 13 cell banks of Denver No. 30 DR cells which make a final concentrate and a tail which is returned to the head of the cleaner circuit.

The primary scavenger concentrates are split four ways by a 3.7 m. 4-way Denver distributor to four @ 13 cell banks of Denver No. 30 DR cells. The tailings from this circuit are combined with the primary scavenger tailings as final tails. The concentrates are returned as feed to the head of the rougher cleaner circuit. Total flotation cost is 6.2 cents per tonne. Transfer of concentrates and tailings in these circuits is done by 300 mm. x 250 mm., 250 mm. x 200 mm., 200 mm. x 150 mm., 200 mm. x 150 mm. pumps. All of these pumps are in duplicate. To avoid any problems with pipeline erosion and wear in the main-line slurry pumps, the cleaned concentrates are cycloned in 500 mm. cyclones, with the undersize going to the 67 m. dia. thickener. The cyclone underflow is passed over a pair of 700 mm. x 1200 mm. vibrating screens from which the oversize is returned to the rougher regrind circuit.

The No. 600H DR flotation cells receive supercharge air at a pressure of 140 mm. mercury. 21 M^3 per minute is provided for each cell. In the cleaner circuit the supercharge air pressure is 82 mm. Hg. and 3.5 M^3 per minute is provided per cell.

Plant air at 5.6 Kg. sq. cm. is stepped down as necessary to actuate the air motors for the level control dart valves of the cells.

The Denver DR flotation cells, the pulp distributors and reagent agitators for Bougainville Copper were all manufactured in Australia and approximately 300 tons of steel were required for the fabrication.

Reagents

Reagent used in the circuit is shown in the tabulation. These are mixed in a separate building and pumped to the use points in the plant.

In this section four @ 2.4 m. x 2.4 m. and one 3.3 m. x 3.3 m. propellor agitators and two @ 5.5 m. x 5.5 m. paddle Agitators were supplied by Denver Equipment Division.

REAGENTS	QUANT	LOCATION
M.I.B.C.	51 g/t	Cyclone O/F
P.Amly Xanthate	6 g/t	Cyclone O/F, Scavenger Feed
Lime	500 g/t	Mills

Concentrate Handling

Following the final classification of the cleaned flotation concentrates, they are pumped to the 67 m. dia. thickener. The overflow is returned to the circuit. The underflow at about 65% solids is transferred to two Denver 9 m. dia. x 10 m. high, double propellor surge agitators. From these agitators the pulp is fed by centrifugal pumps to one of the two Ingersoll Rand positive displacement pumps feeding into the 150 mm. pipe line which carries the concentrates 25 Km. over the mountains and to the filter, drying, storage and loading plant at Loloho. The piston pumps operate at 85—92 kg. cm. 2 and deliver about 1750 L/min. The 520 Kw. motors are connected to the pumps by variable speed drives.

PRODUCTION — September 1973

Days Operated	30
Ore Milled/Day	83,398 tonnes
Ore Total	2,501,930 tonnes
Ore Grade — Cu%	.72
— Au g/t	.93
— Ag g/t	2.14
Recoveries % Cu	87.3
Au g/t	32.7
Ag g/t	76.0
Metal content Cu tonnes	15,626
Au KG	1,777
Ag KG	4,124

Filtering at the port is done using 2.7 m. dia. x 8 disc Eimco Agidisc filters. Two stage wet vacuum pumps give 580–650 mm. Hg vacuum. Average filter cake moisture is 14%. From the filters the concentrates can be delivered directly to the 60,000 tonne storage area or can be fed to two Armstrong Holland 16 m. x 2.8 m. dia. oil fired rotary dryers.

From the storage area the concentrates are delivered by a conveyor system where the product is weighed and sampled prior to final loading into the holds of the ships. Stowing is done by a remote controlled jet slinger. The grade of concentrates shipped are within the following range:

Cu	28–32"	
Au	23–37 gm. per tonne	
Ag	68 gm. per tonne	
Fe	26% total	
S	31% total	
Moisture	6–8%	
Sizing	–270 mesh	75–90%
	–200 mesh	95–100%

Tailings Disposal

From the concentrator the tailings are allowed to run into the Jaba River system which carries them out into swampland. The frequent and rather severe earthquakes makes the establishment of conventional tailings disposal dams impossible.

Power

Bougainville Copper has its own oil burning power station at Anewa Bay capable of producing 135 MW. This power is transmitted to the plant at 132 KV 50 hz. Four diesel generators at Panguna can provide 11 MW at 6.6 KV. as standby power.

POWER CONSUMPTION

	KWH/T
Crushing	2.05
Grinding & Classification	7.2
Flotation	2.4
Thickening & Filtering	0.1

Water

Water for the plant operation is pumped from the Kawerong and Jaba rivers to the mill head tanks. The flow rate is 1.7 cu. metres per second. The only reclaim of water possible is from the concentrate thickener.

Laboratory and Assay Office

Flotation circuit samples are cut manually once an hour and analyses are made with Atomic Absorption and XRF as well as fire assaying and classical wet analysis. Shift samples are done by XRF and require about 20 minutes for results to be available. These analyses are done in the plant. Production analyses are done in a separate laboratory.

Pilot Plant

A pilot plant is now under construction, in which grinding and classification circuits flotation cell configurations and other aspects of plant operation can be studied and evaluated.

Personnel

The total labour required per shift is remarkably low for such a large operation. Both indigenous and expatriate labour run the plant as is shown in the chart. Much work is being done at this time to educate and to train indigenous labour to eventually replace a majority of the expatriate operators in all sections of the plant.

CONCENTRATOR LABOUR ESTABLISHMENT

Indigenous

1	Jaba Pump Operator
2	Kawerong Pump operator
2	Concentrator Pump Station
1	Regrind Operator
1	Flotation Floor
1	Grinding Bott. floor
1	Tunnel
3	Lime shed
4	Rougher Flotation (2 x 2)
2	Cleaners
2	Control room (1 trainee)
4	Grinding
1	Driver

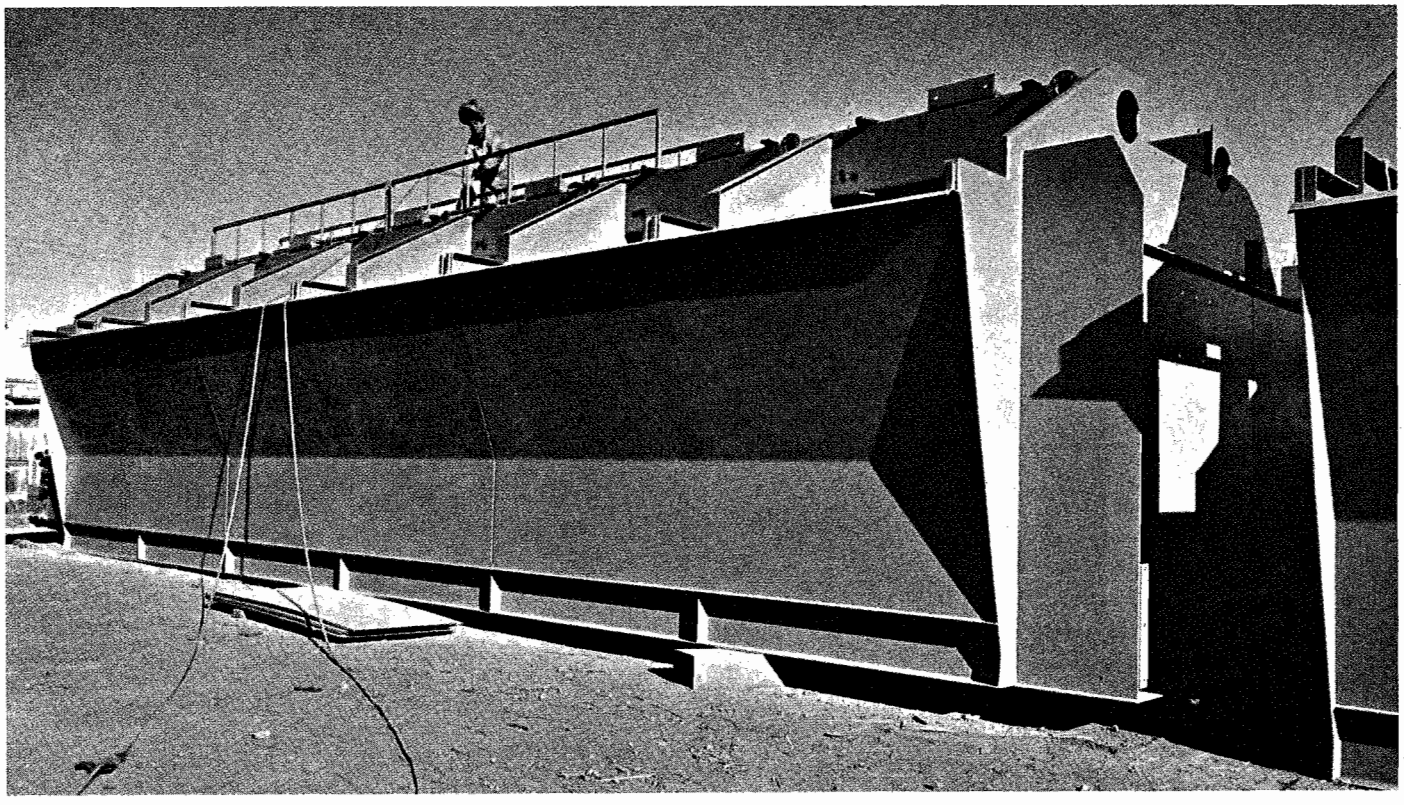
Expatriate

1	Shift foreman
1	Station operator
1	Flotation operator
1	Mill operator
1	Mill Supervisor

Assistant Superintendent Concentrator
Plant Metallurgist
Concentrator Superintendent (including Crusher)

Acknowledgement

Denver Equipment Division of Joy Manufacturing Company wishes to thank the Management and Staff of Bougainville Copper Limited for permission to prepare this record of the plant and also for supplying the various data.

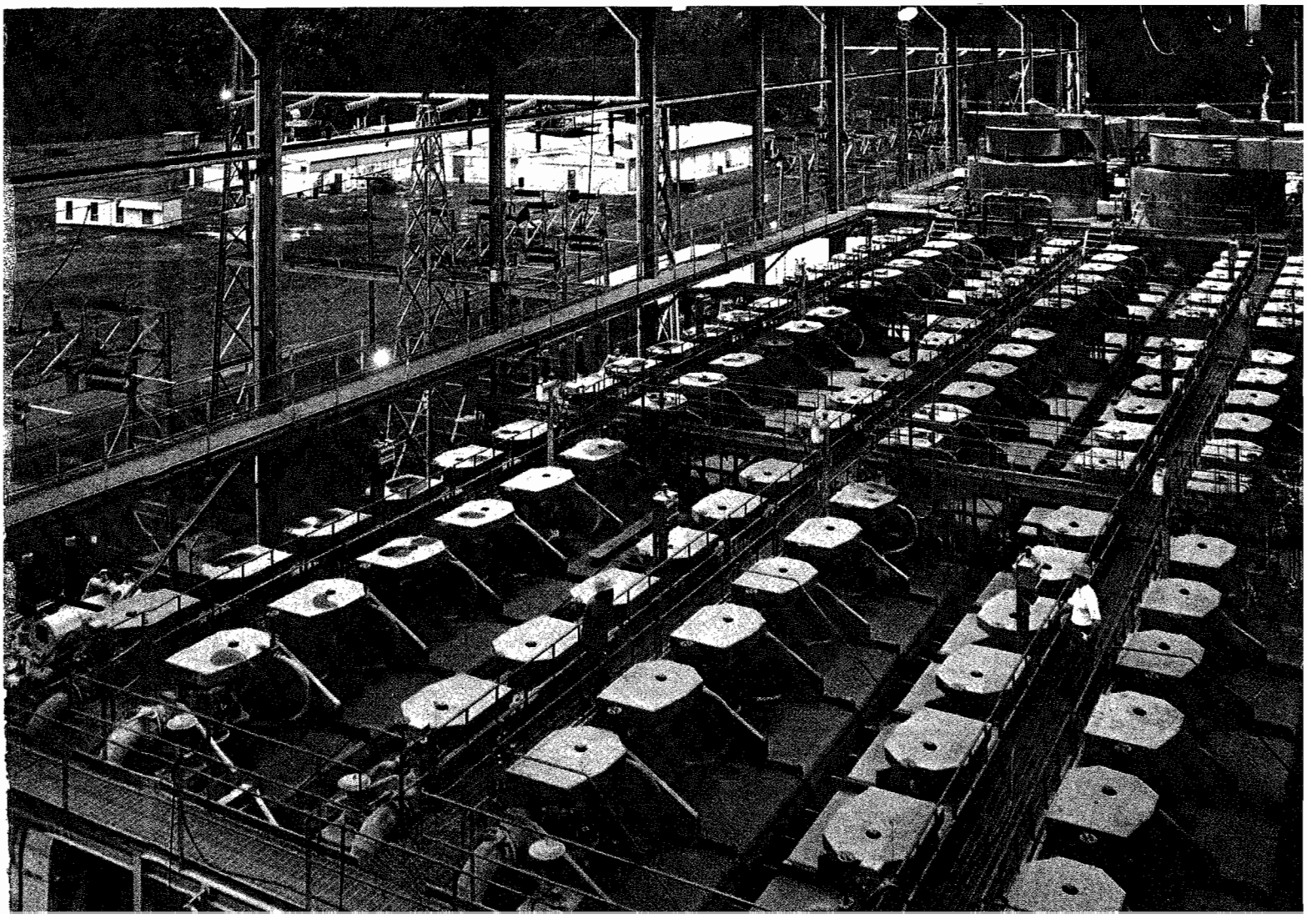


Above:

The 600 cu. ft. cells above, are part of the six 18-cell No. 600-H D-R Denver Flotation Machines which were shipped to Bougainville.

Below:

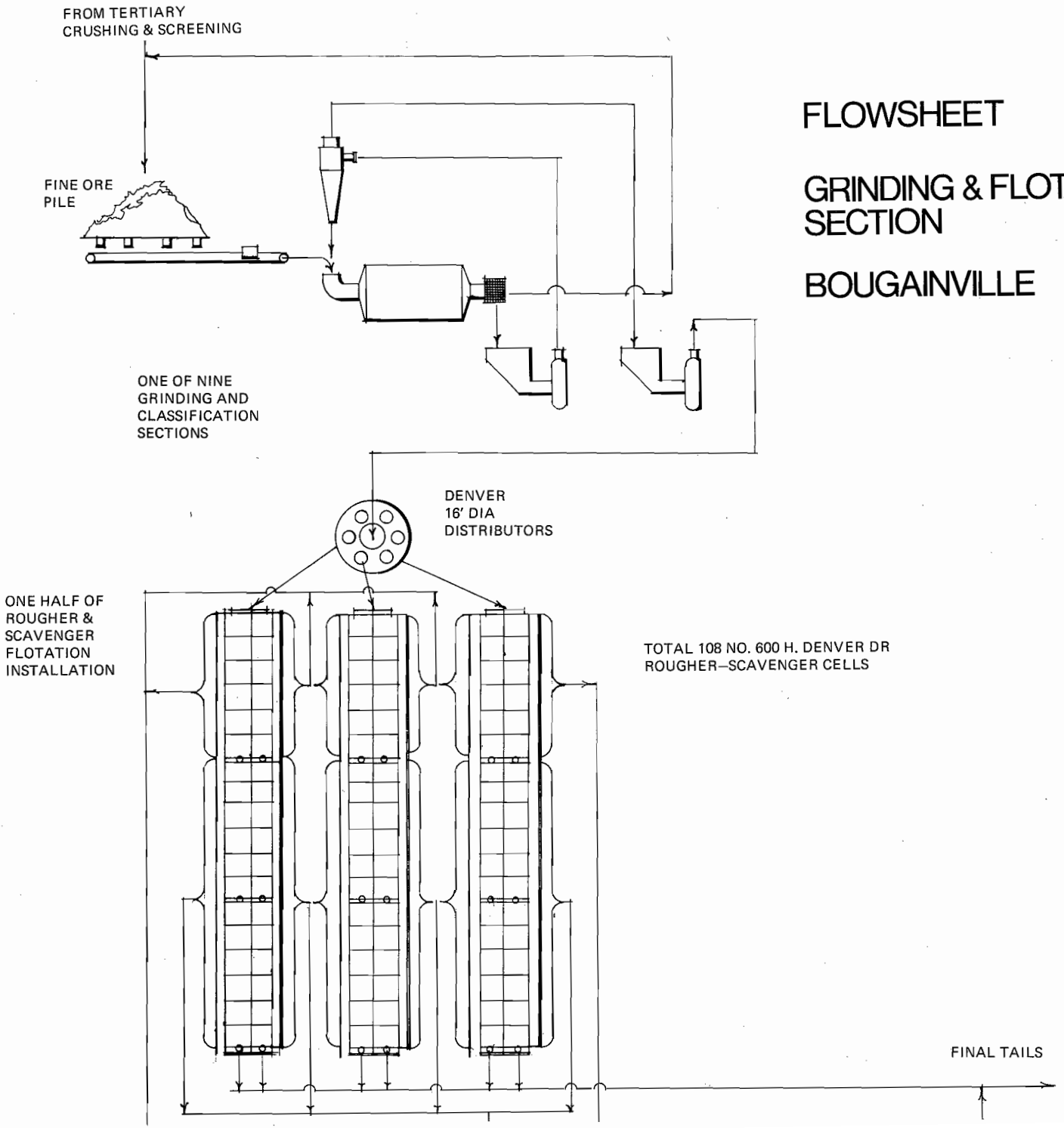
A general view of Flotation section at Panguna.

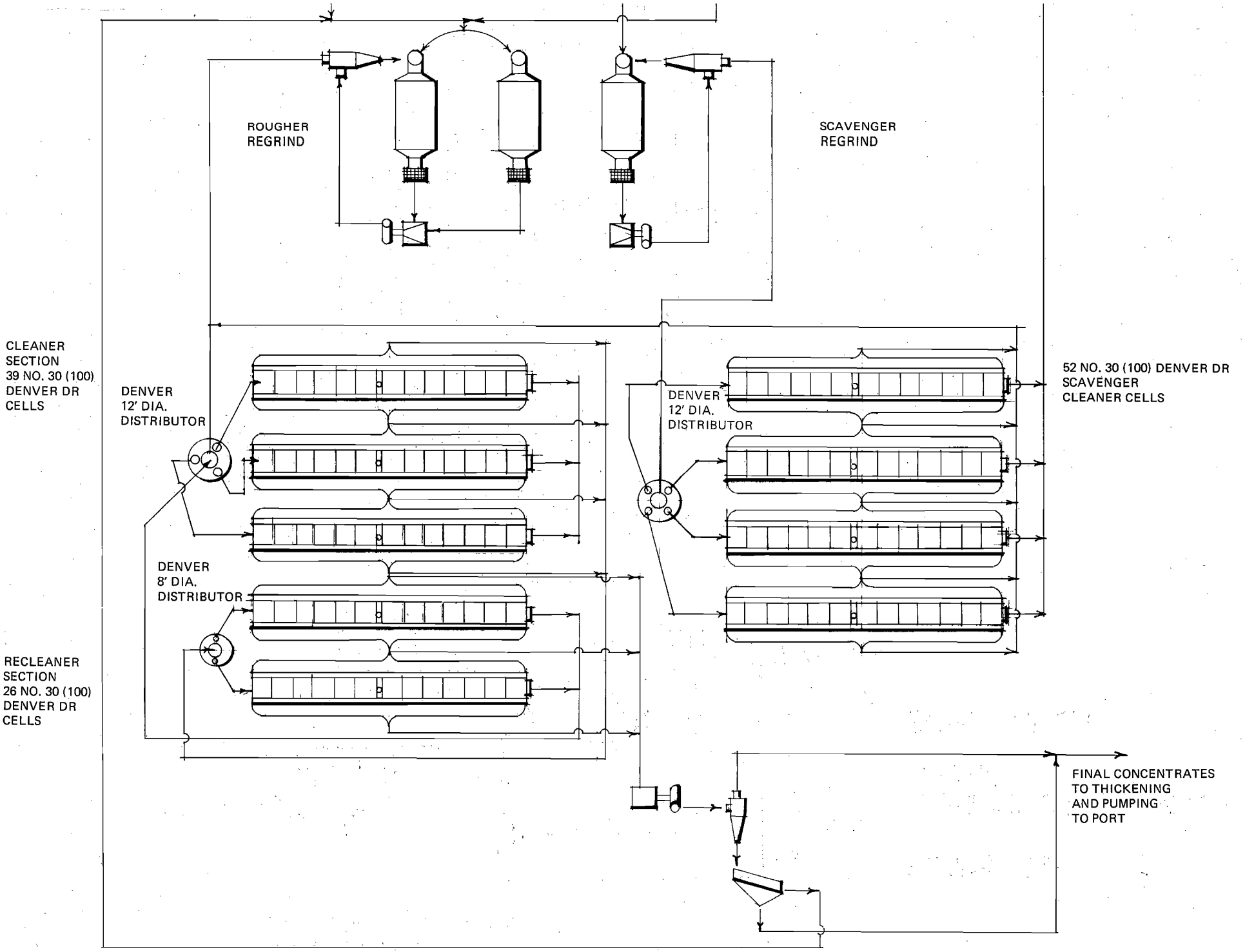


FLOWSHEET

GRINDING & FLOTATION SECTION

BOUGAINVILLE

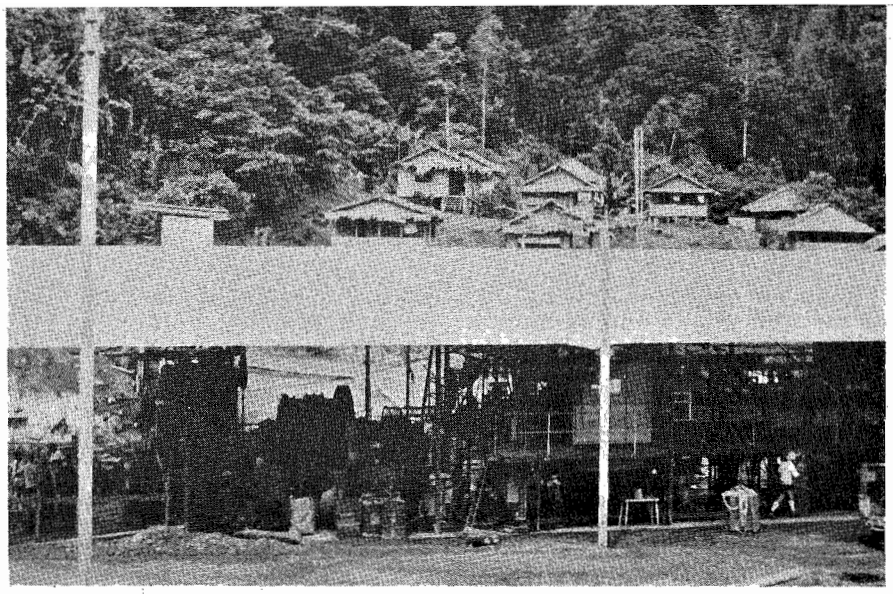



ROUGHER
REGRIND
SCAVENGER
REGRIND
CLEANER
SECTION
39 NO. 30 (100)
DENVER DR
CELLS
DENVER
12' DIA.
DISTRIBUTOR
DENVER
8' DIA.
DISTRIBUTOR
DENVER
12' DIA.
DISTRIBUTOR
52 NO. 30 (100) DENVER DR
SCAVENGER
CLEANER CELLS
RECLEANER
SECTION
26 NO. 30 (100)
DENVER DR
CELLS
FINAL CONCENTRATES
TO THICKENING
AND PUMPING
TO PORT

REAGENTS

THE ROLE OF CYANAMID AUSTRALIA PTY. LTD., IN SUPPLYING REAGENTS TO BOUGAINVILLE COPPER.

Bruce E. Ashton,
Manager,
Industrial Products Division,
Cyanamid Australia Pty. Limited.



Exterior view of Metallurgical pilot plant.

American Cyanamid Company's involvement with the mining industry commenced with the formation of the company in 1907 when crude calcium cyanide designated AERO Brand Cyanide was produced and sold for the cyanidation of gold. Since that time, Cyanamid's interest in various facets of mineral benefication has grown until, as at present, an extensive range of products are available for the cyanidation of gold, sulphide and non-sulphide mineral flotation and solid/liquid separations.

Technical representation in Australia began in the late 1920's, and was gradually expanded to cater for the growing needs of the mining industry, particularly in the areas of gold cyanidation and sulphide flotation. Initially this was provided through the then North American Cyanamid Company until in 1954 Cyanamid Australia Pty. Limited was created to co-ordinate and control the overall activities of American Cyanamid Company in Australia and adjacent countries.

When preliminary investigation work on the Bougainville project began, Cyanamid Australia was one of the companies invited to offer recommendations for flotation of the copper minerals. From a number of flotation collectors and frothers submitted and extensively tested in the Zinc Corporation laboratories, one collector, AERO Promoter 3501 was chosen as the most effective Cyanamid product.

Although a relatively new product, this collector was already showing promise overseas particularly on coarsely ground porphyry copper type ores. AEROFROTH 65 Frother was also used extensively in early test work as this water soluble material allowed good control of frothing in laboratory scale tests. By the time the decision had been made to design and build a metallurgical pilot plant at Panguna on Bougainville Island the choice of flotation collectors had been reduced to three products, one of which was AERO Promoter 3501.

The close liaison of Cyanamid Australia's metallurgical staff with C.R.A. and Zinc Corporation personnel seconded to the Bougainville project over the laboratory evaluation period was continued through the pilot scale testing. The pilot plant operated for a period of several months treating ore from two adits driven into the ore body. The plant itself was probably the most sophisticated ever built in the South Pacific area and with its capacity of 5 tons/hour gave information which could be extrapolated satisfactorily for scale up design purposes.

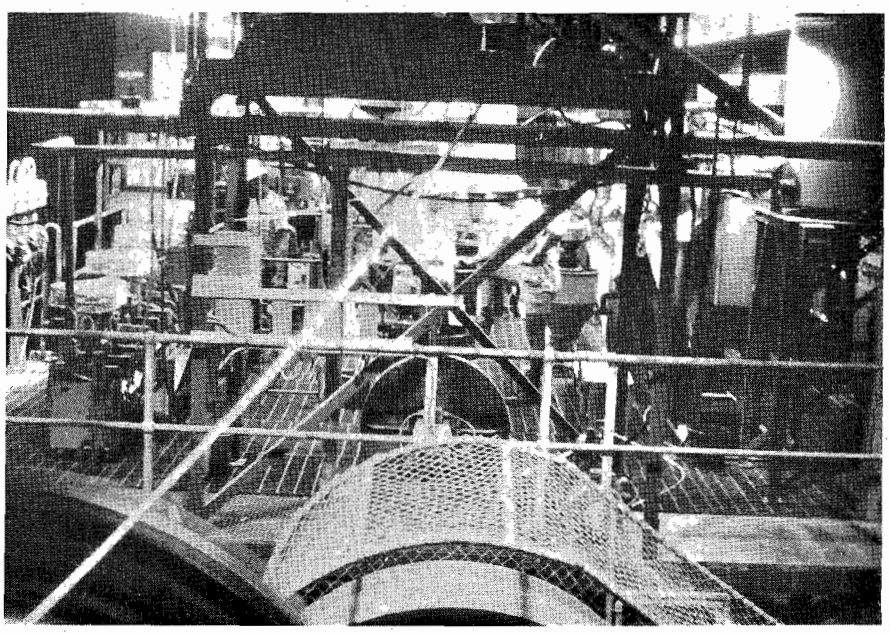
Many of the variables tested in the laboratory were checked in this plant, including a study of collectors. Cyanamid staff continued to work closely with the Bougainville metallurgical staff both on site and in Australia on collector evaluation. Detailed evaluation of the three collectors, as defined by laboratory work, was carried on for a considerable period of time and final results showed that AERO Promoter 3501 gave metallurgical results which were slightly but significantly superior to those obtained with the other collectors.

Of particular interest was the improvement in concentrate grade, an important factor due to the long shipping distances to Japanese and European markets. As a result of this testing the above collector was chosen for use in start up of the full scale concentrator.

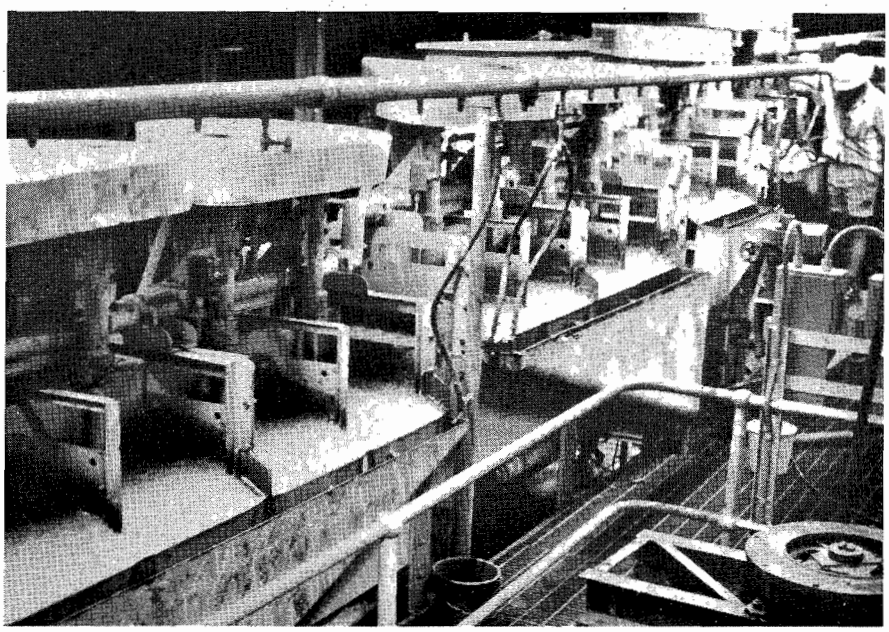
Although test work on the pilot plant was carried out on underground ore it was appreciated that in opening up the deposit a large quantity of upper zone, partially oxidized, ore would have to be mined and treated before reaching the primary sulphide ore. Since this ore has different flotation characteristics, Cyanamid metallurgical staff have been working closely with Bougainville personnel in an attempt to determine the most suitable collector or collectors for the tarnished upper level ore. Much has been done and further work is still required on this aspect. The main approach recommended by Cyanamid is the use of physical mixtures of dithiophosphate acid and xanthate type collectors. Recent work overseas in the Stamford Research Laboratories of American Cyanamid Co. and on site at various mining operations has shown that a mixture of these two types of collectors will often give better metallurgical results than the use of either when used alone. This "synergistic" effect is not new in flotation although the concept has seldom been tested in recent times. It is thought a mixture of this type could prove to be the most satisfactory for the currently milled ore at Bougainville.

In addition to the flotation collector study, Cyanamid and Bougainville staffs have studies the use of frothers in the flotation circuit, the application of synthetic flocculants in copper concentrate thickening and the use of emulsions for dust control on roads.

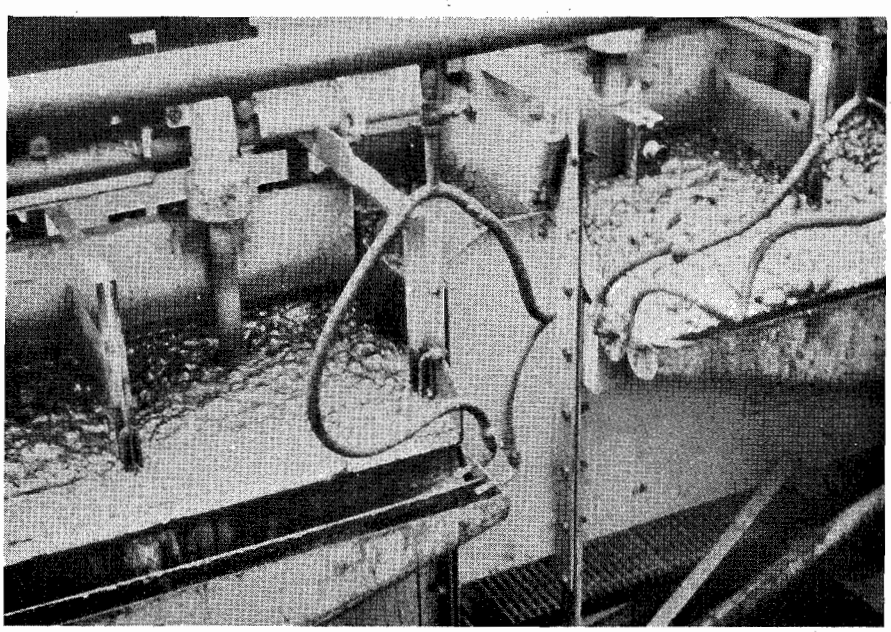
With an operation of the magnitude of Bougainville copper and in view of its location in a tropical, high rainfall area there are many problems to be solved where the use of chemicals can play a part. Since American Cyanamid Company has for many years offered a very wide range of chemical products for use in mineral benefication and mining, technical liaison and co-operation between Bougainville Copper and Cyanamid Australia Pty. Ltd., staff will continue.



Internal view of pilot plant, showing grinding and flotation sections.



Pilot plant flotation cells, showing cleaner, rougher and scavenger banks.



Close up view of flotation cells in operation, using AERO Promoter 3501 and AEROFROTH 65 Frother. (At Pilot Plant)

Heavy Duty Slurry Pumps

Warman Equipment (International) Ltd.

Warman Pumps operate at Bougainville

Sixty Warman Series 'A' heavy-duty slurry pumps were supplied to fulfill the initial purchase order from Bechtel – W.K.E. for the Bougainville Copper project.

Pumps sizes ranged from 2/1½ Warman Series 'A' Frame 'B' Type 'M' fitted with a 7½" diameter impeller to 12/10 Warman Series 'A' Frame 'F' Type 'AM' fitted with a 32" diameter impeller. Typical process slurry duties handled by the pumps consisted of primary cyclone overflow, rougher and scavenger concentrates, final concentrate, thickener underflow, mainline booster concentrate and distributor feed.

Submerged gland sealed pumps were also supplied, with the initial consignment and each removes filtrate from a filtrate receiver under a vacuum of twenty five inches of mercury. The Warman submerged gland sealed pump for filtrate duties features a double gland seal submerged in water to give a positive seal when operating under high vacuum conditions.

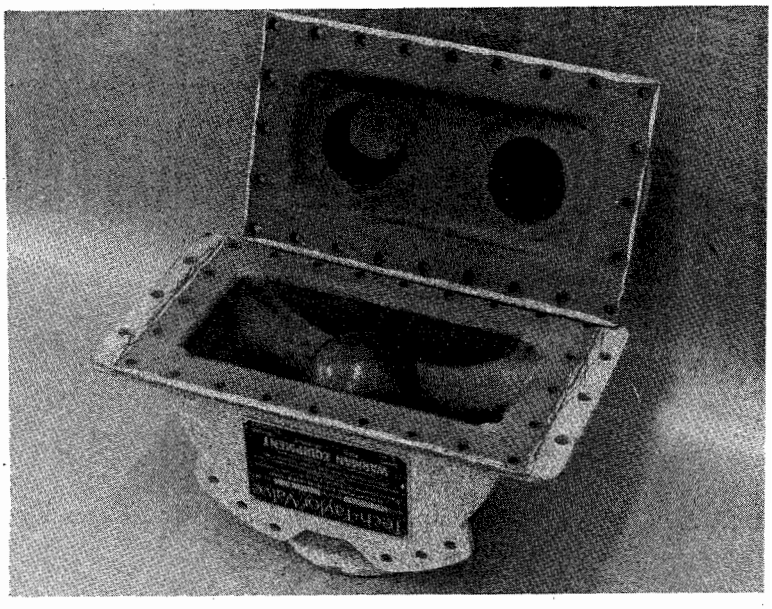
All process slurry pumps were gland sealed and fitted with moulded rubber lines and ni-hard impeller. The gland sealed pumps are provided with a supply of clean gland sealing water at a pressure in excess of the pump delivery pressure to prevent solids entering the stuffing box and causing excessive wear to the shaft sleeve and gland packing.

Drive components provided with the pumps consisted of beta and delta section pulleys fitted with taper-lock bushes. Spacesaver wedge-belts were fitted and the drive protected by a closed mild steel guard.

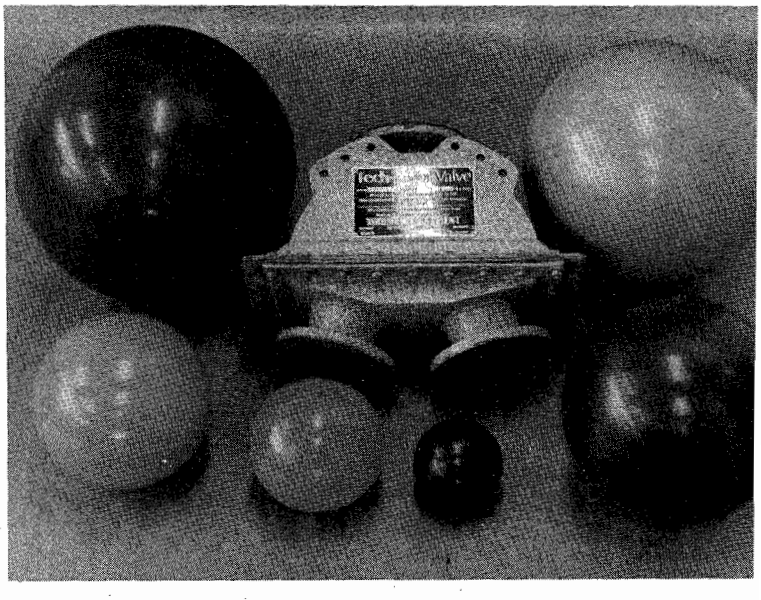
Baseplates for mounting the units were of rolled and folded mild steel construction. Drive arrangements consisted of the overhead mounted motor (CV), reverse overhead mounted motor (ZV) or the side by side arrangement (CL) depending on the horsepower and frame size of the installed motor.

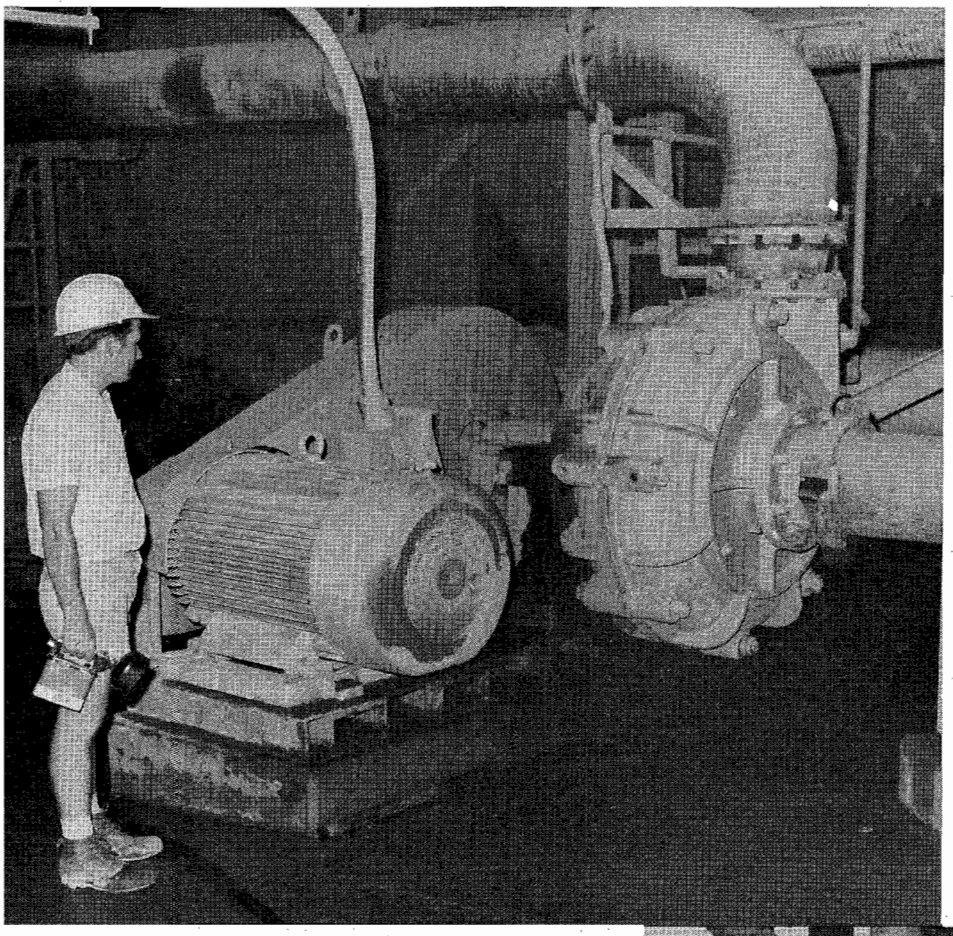
To assist with the installation of the pipework all pump units were filled with mild steel flanged adaptors to match the intake and discharge of the pump, with the ends collared for victaulic couplings.

Tech-Taylor valves were installed in the delivery lines of duplicate pumps delivering into a common line to give automatic changeover from one pump to the other. The valves are fully rubber lined and were developed to solve the problems of switching quickly from one pump to another when handling highly abrasive slurries.

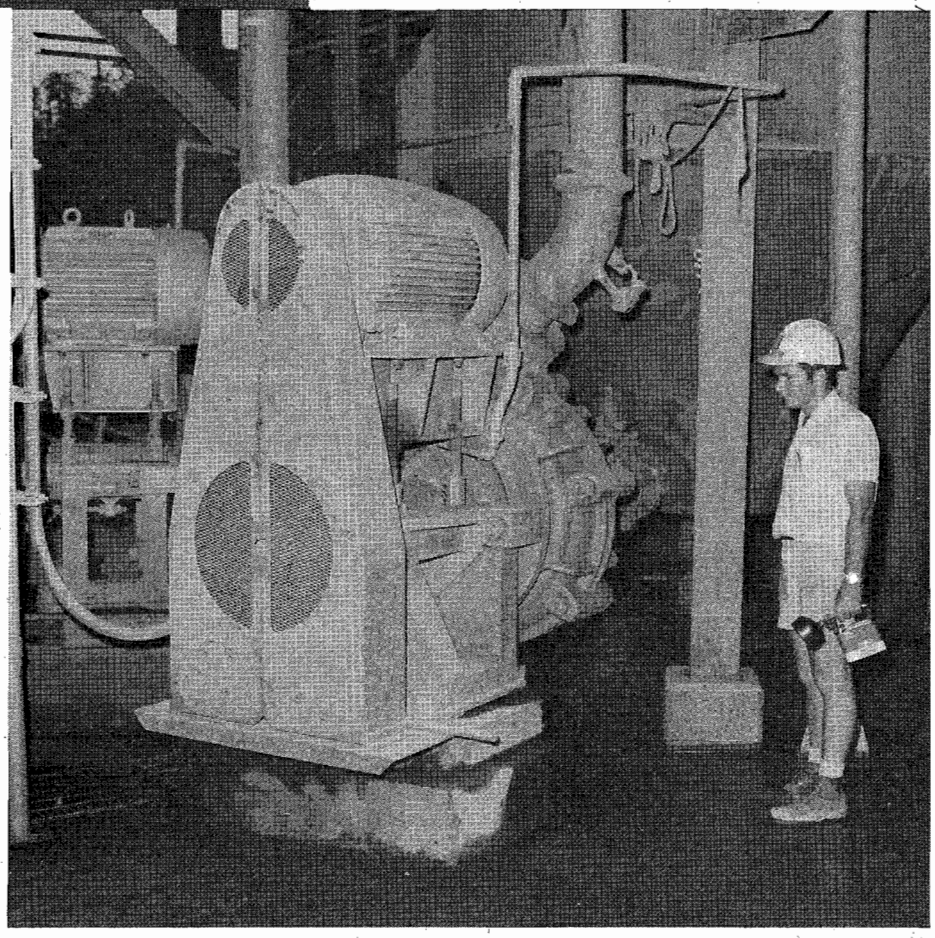


Tech-Taylor Valves

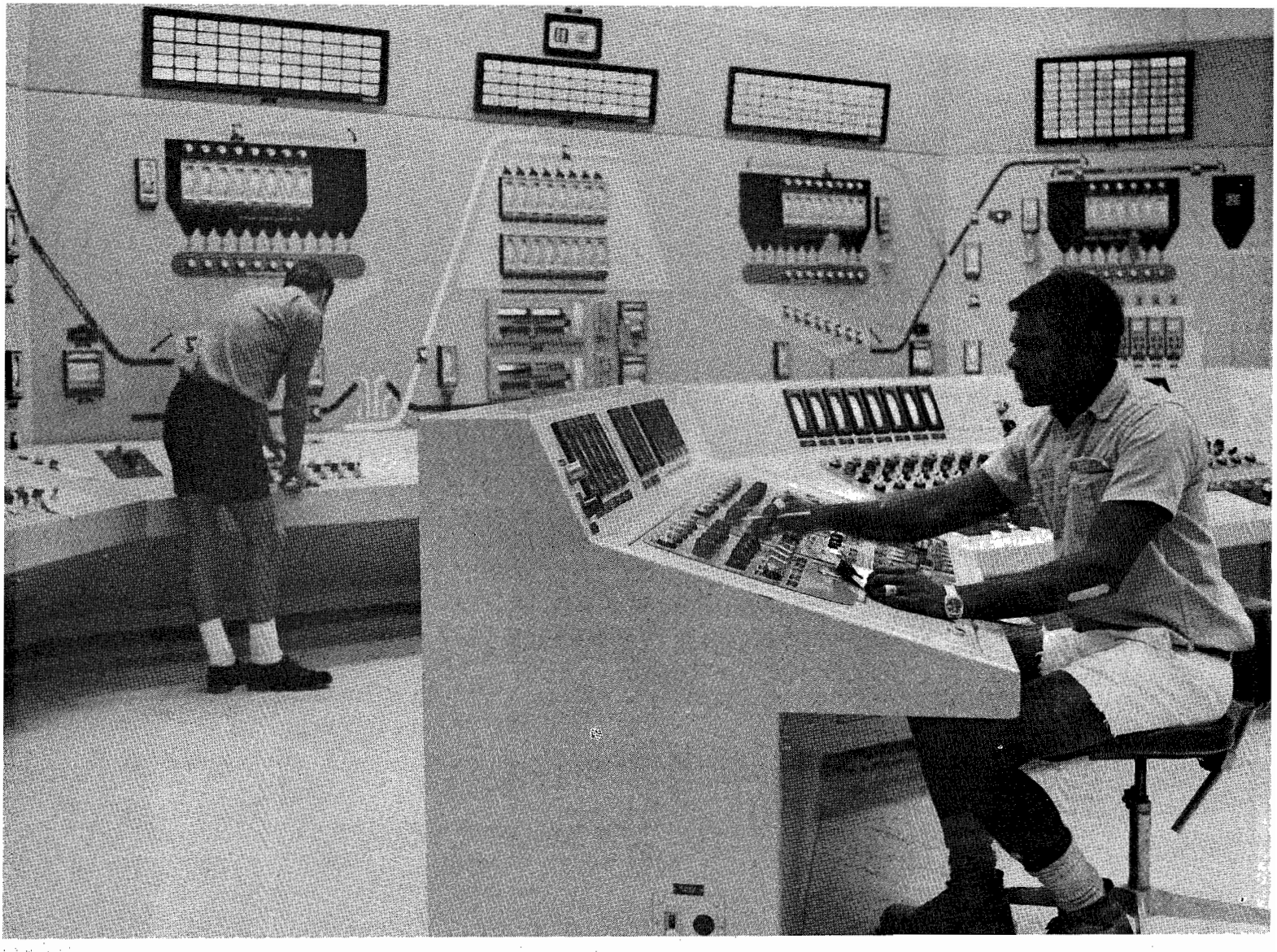




Warman Slurry Pump.



Scavanger Concentrate Pump No. 1.



The Fine Crusher Control Room at Panguna, Bougainville.

Instrumentation & Control Systems

Foxboro Proprietary Limited supplied, installed and commissioned instrumentation and control systems, panels, and alarm systems for the fine crushing and screening plant, concentrator and slurry pumping station at Panguna; for the water pumping station at Jaba River; and for the filters and rotary driers at Loloho.

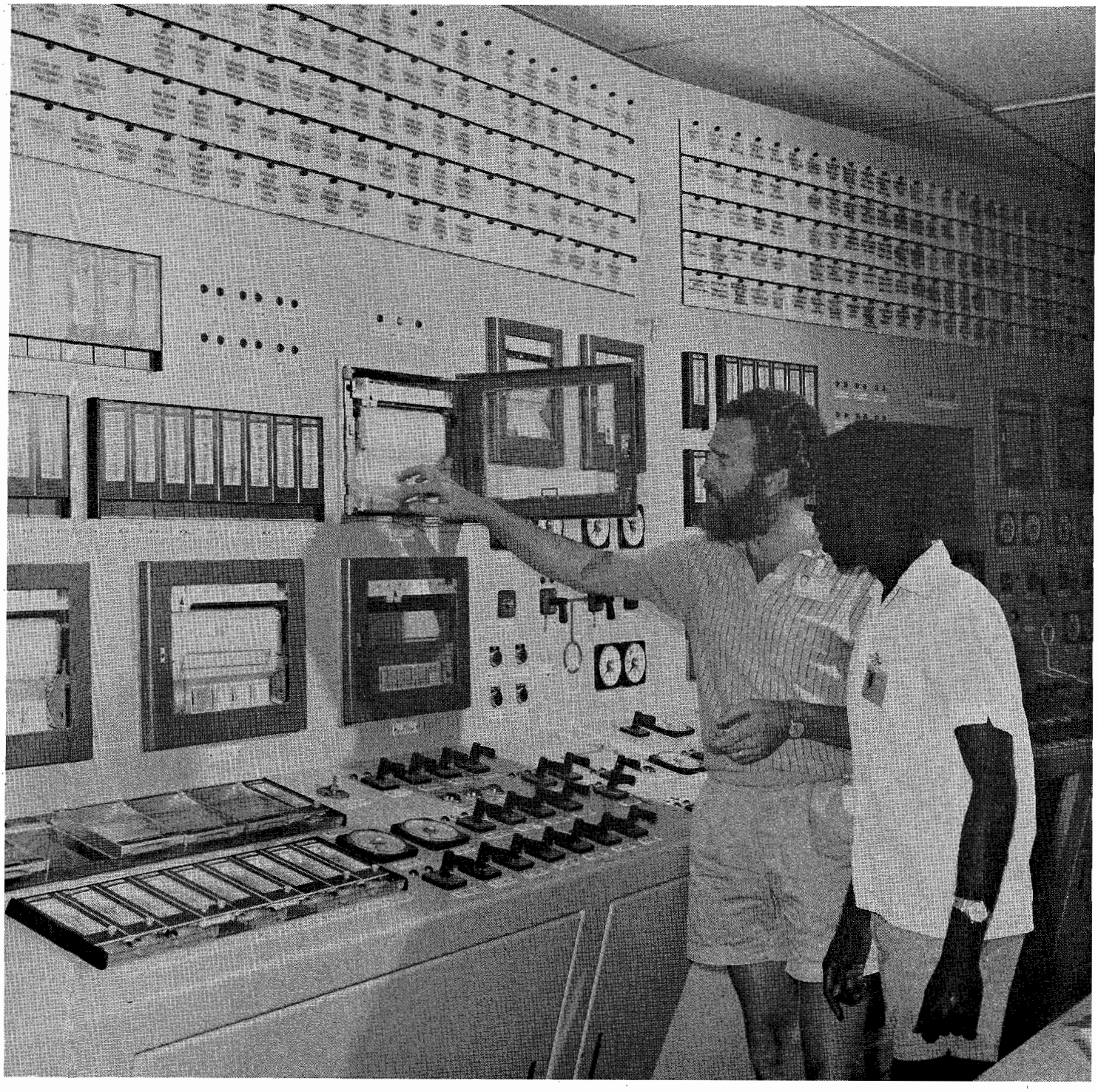
All instrumentation is electonic, except for some local pneumatic loops on the disc filters at the port site. A transmission signal of 10-50 mA DC is used between local transmitters and control room on each plant. Process parameters measured and controlled include pH, electrical load, pressure, temperature, level, belt speed and liquid flow.

One of the problems associated with the control of mineral processing plants, is the large distance velocity lags due to the long transport time on conveyors. This problem was overcome by Foxboro at Panguna, by the use of controls with dead time compensation. Some of the pH control loops used on the island have the same features.

Other advanced control techniques include ball mill controls which maintain optimum circulating load and therefore maximum efficiency. The control system on the rotary driers at Loloho also includes multiple element loops for high efficiency operation.

Full graphic control panels which were manufactured by Foxboro Proprietary Limited at their Panel Fabrication Plant in Victoria, Austalia, were supplied for some of the major plants, notably the fine crushing and screening plant, manual controls are located on the high density operator's console. An extension of the graphics in the console simplifies correlation of auto-manual switches and manual controls with the automatic controls on the main panel.

Due to the "crash" nature of the project, the design and construction phases of panel manufacture frequently overlapped. Because of this, special emphasis was placed on functional testing of the completed panels at the factory. All multiple element control loops and analog computers



The Control Room at the Power Station at Loloho, Bougainville.

were scaled, calibrated and functionally tested as operating systems in the panels before despatch. All alarm systems were functionally checked after assembly in the panels and given a "burn-in" period. The thoroughness of the works tests significantly reduced site work and contributed to the smooth startup of the plant.

Instrumentation for the Power Station at Loloho was supplied by Yokogawa Electric Works, Foxboro's licensee in Japan. Instruments are Foxboro's "100-line" pneumatics, plus YEW analytical instruments. Control panels for the three units are grouped in the central control room, and are of walk-through cubicle construction.

Combustion controls for the oil fired boilers include parallel metering and control of oil and air for stable and accurate control of combustion conditions, with automatic cross-limiting to maintain safe air-fuel ratios during transient conditions.

Boiler feed water is controlled by a 3-element drum level control system.

Installation and commissioning of all instrumentation at Panguna, Jaba River and Loloho were carried out by Foxboro Proprietary Limited. For this purpose Foxboro established fully equipped site offices which included stores, installation workshops and technician workshops at both Panguna and Loloho.

Concentrate Pipeline

CONCENTRATE PIPELINE

COPPER CONCENTRATE CHARACTERISTICS

Mineralogical composition
Principally chalcopyrite with minor amounts of bornite, pyrite, and quartz.

Specific gravity of solids
From 3.72 to 4.26.

Sizing (expected)

Tyler Mesh	Weight Percent Passing Expected	Design
65	100	100
100	100	98
150	99	95
200	97	88
270	90	77
325	84	70
400	77	65

Rheology

Wt. Percent Solids	Slurry Viscosity	Yield
65	10.24 centipoises	21.2 dynes per square centimeter
70	19.43 centipoises	44.0 dynes per square centimeter

PIPELINE

Length	88,700 feet
Elevation: Inlet	2,080 feet
Maximum	3,200
Outlet	80
Diameter external	6.00 inches
Wall thickness	0.344 inches
Line volume	13,650.9 cubic feet
	85,318.3 imperial gallons
Line cross sectional area	22.16 square inches
	0.1539 square feet
Slurry tons to fill at 65 percent solids and SG 4.0 = 1.96	836 tons
Solids	543 tons
Corrosion allowance	0.99 inch
Steel tonnage	915 tons
Design flow rate	386 Imperial gallons per minute
Maximum operating pressure range	1,590 pounds per square inch
Normal operating pressure range	1,250 to 1,590 pounds per square inch
Pipeline allowable pressure, maximum	
1st year	4,290 pounds per square inch
33rd year	3,060 pounds per square inch
Maximum pipeline velocity	10.4 feet per second

Flow Velocity Range: (4.26 solids specific gravity)

Solids Tonnage, per hour	Weight percent solids 65	70	Time to port, minutes
150	6.7 feet per second	5.7 feet per second	220.6
125	5.6	4.9	264.0
90	4.0		370.0

Limiting Capacities: (Tons per hour of concentrate)

Weight percent solids	Limiting capacity tons per hour Minimum	Maximum
70	125	172
65	90	150
60	77	129
55	65	110

PUMPS

Number pump stations:	One
Type:	Ingersoll-Rand Triplex vertical plunger, reciprocating positive displacement
Number:	One operating
	One standby
Maximum operating horsepower:	600 per pump

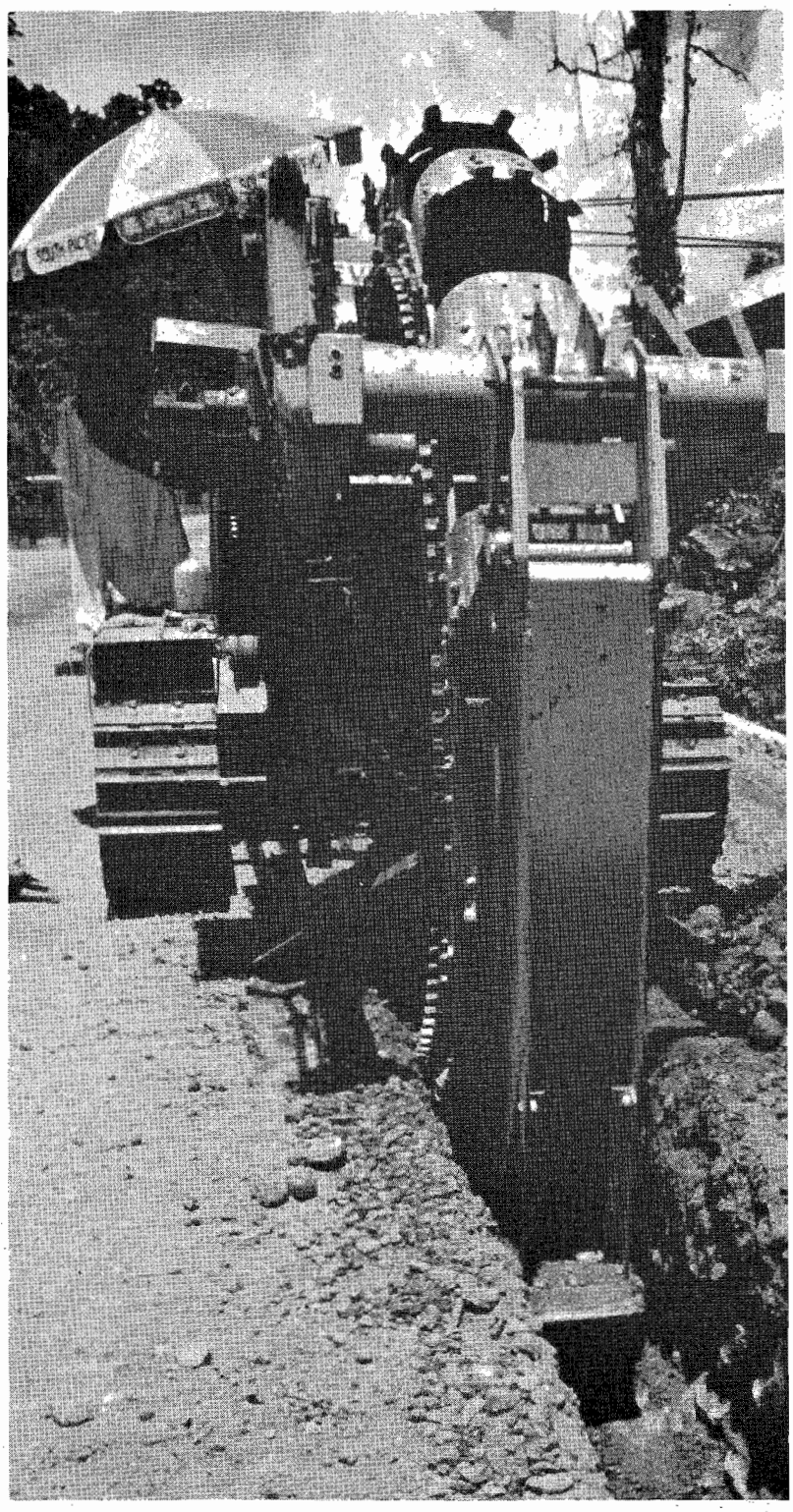
SLURRY PIPELINE – Panguna to Anewa Bay

Bougainville operates the world's first copper concentrate line where pulp is pumped an appreciable distance against a high head.

The pumping plant and 17 mile concentrate pumping system is designed to deliver 2,000 tons of concentrate per day from the mine to the filtering and drying plant at Anewa Bay. Flotation concentrate is screened to approximately 100 per cent minus – 100-mesh, density regulated to 65 to 70 per cent, and stored in two 750 ton capacity agitated slurry holding tanks.

The concentrate pipeline, buried on the cut side of the Panguna–Anewa Bay road and provided with cathodic protection, starts with a test loop to determine viscosity and density. The rate of erosion is also monitored. This is a routine and regular test. Viscosity is tested separately for every holding tank, 32 ft. diameter by 30 ft. high. Density is held between 65 and 70 per cent solids; fineness is 65 to 90 per cent minus – 325-mesh. Lime is added to the tank to control pH of slurry to prevent pipe corrosion which takes place above a pH of 11. Slurry with a high pH is hard to pump. If it meets specifications for density, size and viscosity it is fed to an Ingersoll-Rand vertical Triplex plunger pump. The slurry, under a pressure of 1240 pounds per square inch is fed into a 5.312 inch internal diameter carbon steel pipeline and elevated 1,120 feet to the top of the Crown Prince Range from where it flows by gravity to the concentrate storage tank at Anewa Bay.

Accessory items in this system include two booster pumps to provide the required intake head to the mainline pumps and the test loop. Instrumentation includes thickener torque, level and meter amps indication; underflow density controller; holding tank level indication; pipeline density, flowrate, pH, test loop differential pressure; and pumps discharge pressure and amps. The latter is used as a guide to pump wear.



Trenching, March 1971, for the Concentrate Pipeline.

Concentrate Pipeline Pumps and Compressors

INGERSOLL-RAND AT WORK FOR BOUGAINVILLE COPPER

On Bougainville Island the capabilities and economies of Ingersoll-Rand equipment such as vertical positive displacement pumps., oil free air compressors, workshop compressors, pneumatic tools, self propelled rock drills and portable compressors are operational throughout the mine and port site at Bougainville Copper Pty. Ltd.'s huge copper mining complex at Panguna and Loloho.

The CM250–URD475 Crawlair rock drill and DR600 portable compressor for example were used by contractors engaged in what must surely be one of the toughtest, most adventurous and seemingly impossible construction projects undertaken by man. Much of the rock excavated could be ripped but 12 Crawlairs using the 4¾" bore universal rotation drifter were employed on the hard rock sections.

The Crawlair is also used for secondary drilling in the mine. Primary blasting generally produces good fragmentation of the ore but large "floaters" or boulders not broken up by the primary blasting are often encountered and must be drilled by the Crawlair and blasted for the mining operation to progress. (Fig. 6 shows this application).

Ingersoll-Rand compressors also provide vital auxiliary services. Owing to the mountainous terrain and relative location of mine, concentrator, power station, ship loading etc. the feasibility of piping air from one central location was neither economic nor practical so individual systems employing separate compressors at each location including oil free air where required were called for. The individual size of compressors used range from 80 cfm to over 1000 cfm, providing a total in excess of 6000 cfm at pressures of between 100 and 125 psig. This does not include the considerable number of portable air compressors in use.

Oil free air is used for instrumentation purposes throughout the concentrator at Panguna as well as the power station and the drying and ship loading facility at Loloho. This oil free air is supplied by a number of non-lubricated, double acting, single stage, vertical, water cooled, reciprocating electrically driven air compressors. These units are fitted with patented channel valves with teflon guides and wear strips which require no lubrication. Piston rings are also of teflon and the cylinders do not require oil. Piston rod packings also operate without oil and special oil wiper rings next to the crankcase ensure that no oil passes along the piston rod from the crosshead. Initially two Model 7" x 5" ESV NL–2 compressors were installed at the con-

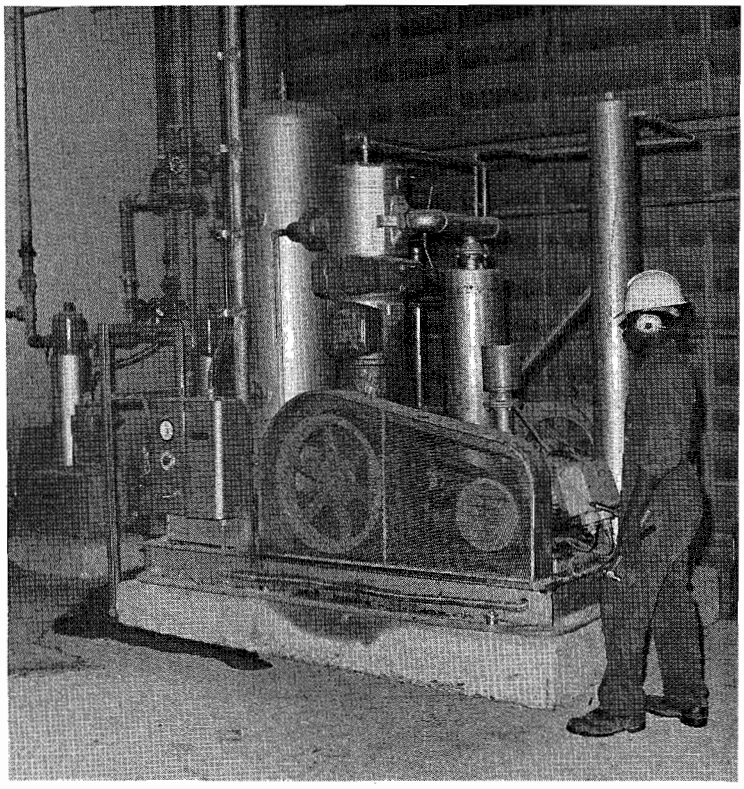
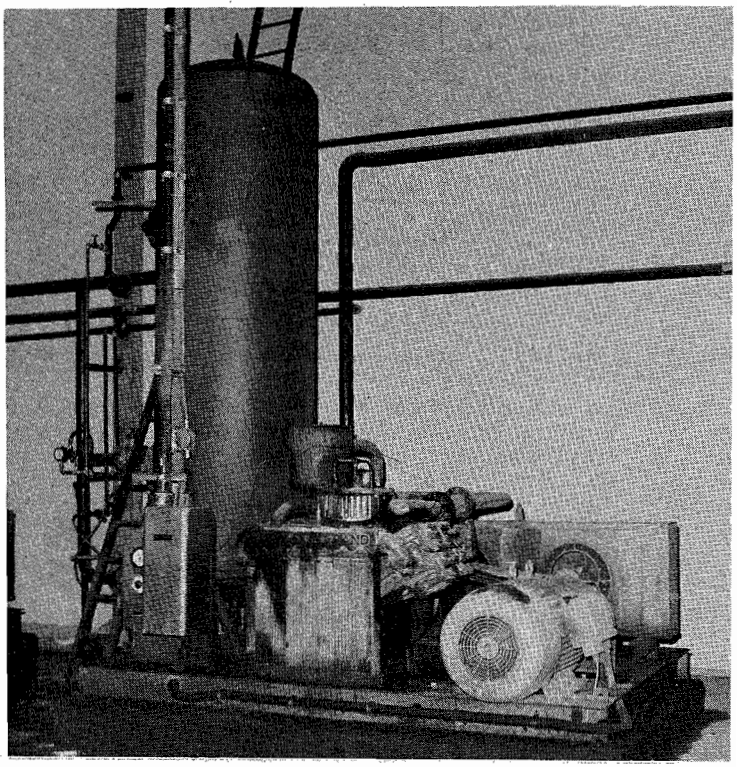


Fig. 1 A workman checks a non-lubricated compressor in the concentrator.

Fig. 2 A 400 cfm type 40 supplies 125 psi compressed air to the clutch bags on the primary overflow ball mills.



centrator and the recent addition of another primary overflow ball mill has increased the demand for oil free air resulting in a 12" x 11" ESV NL–2 non-lubricated compressor being installed. Also there are three 12" x 11" ESV NL–2 compressors in the power station and another two 7" x 5" ESV NL–2s at the drying and loading complex at Loloho. (Fig. 1 shows an ESV NL–2).
For applications not requiring oil free air there is a separate system at the concentrator which apart from general purpose air is used to actuate the air clutch bags in the primary ball mills. Two 75H Type 40 two stage, single acting, air cooled, reciprocating, electric air compressors were installed to supply a total of 800 cfm at 125 psig. (See Fig. 2). Similar units to these are also installed in the mine and light vehicle workshops as well as the central workshop and ship loading area. Again due to the additional ball mill plus the ever increasing demand for general purpose compressed air as a means of providing a safe low maintenance source of power for pneumatic tools and other air operated equipment, larger XLE compressors have recently been installed to cope with the large base load with the smaller units handling the peak requirements. These units are two stage, double acting, reciprocating, water cooled, electrically driven machines providing 1030 cfm at 125 psi. They are slow reving easily maintained units requiring a minimum of attention. This is particularly important where there is a shortage of skilled labour.

Perhaps the major installation of Ingersoll-Rand equipment is in the pump house in the concentrator area at Panguna. (See colour plate). It contains two Ingersoll-Rand Aldrich vertical pumps (Fig. 3) which pump the copper concentrate in a slurry for 16 miles through a 6" diameter pipe from the concentrator to the port at Loloho on Anewa Bay.

The use of vertical positive displacement pumps instead of the usual horizontal type for this kind of mineral service is one of the outstanding features of the Bougainville mine project. Positive displacement pumps were preferred over centrifugal pumps because of the high casing pressures and large number of stages that would have been required. Of the types of positive displacement pumps available plunger pumps were selected over piston pumps because of the former's capability for continuous plunger flushing. This maintenance saving feature in which the plungers are synchronously flushed with clear water during the suction stroke, prevents the abrasive concentrate slurry from causing excessive wear on the internal parts, such as plungers, packing, and stuffing box bushings.

This application is believed to be the first installation of vertical positive displacement pumps in the mineral or concentrate ore slurry service. The inverted plunger vertical configuration was chosen in preference to the more usual horizontal units because of:

(a) The elimination of eccentric wear of plunger, packing and bushings due to plunger weight.

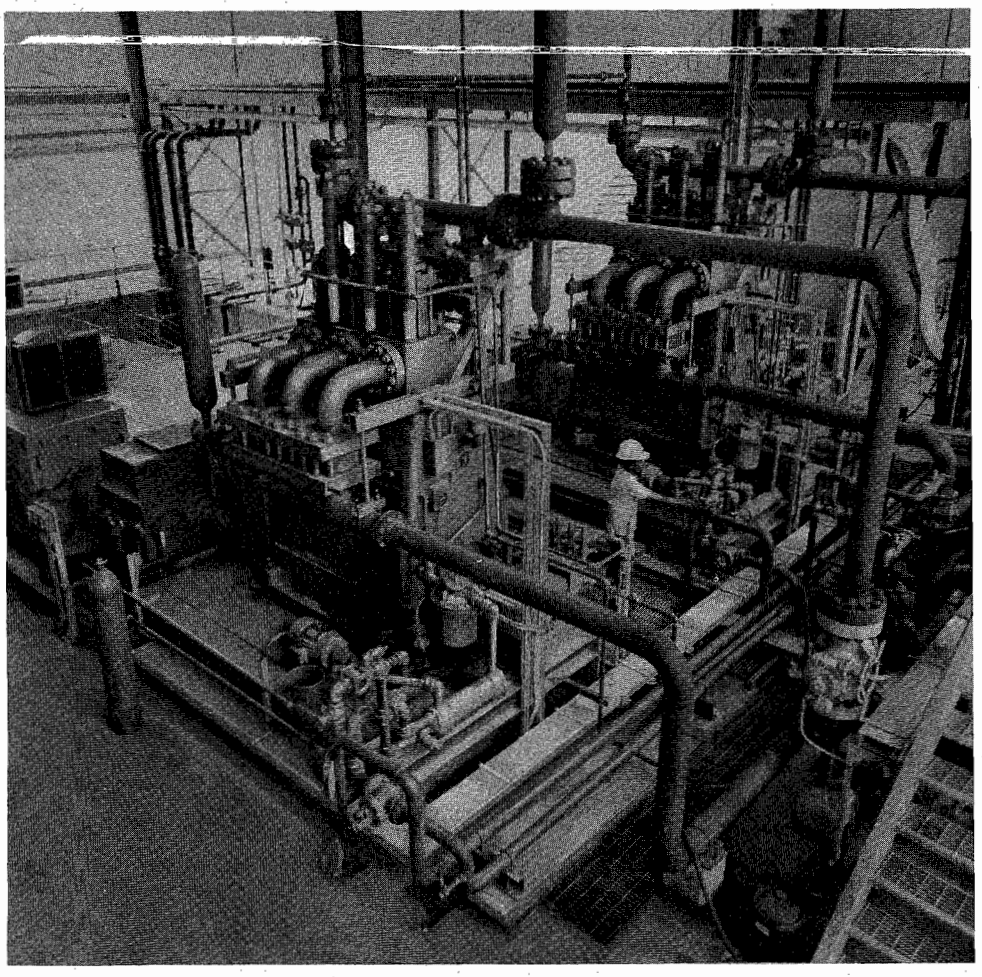


Fig. 3 Two high pressure slurry triplex pumps designed for handling copper ore slurry, 60% by weight solids at 240 psi discharge pressure, installed at Panguna.

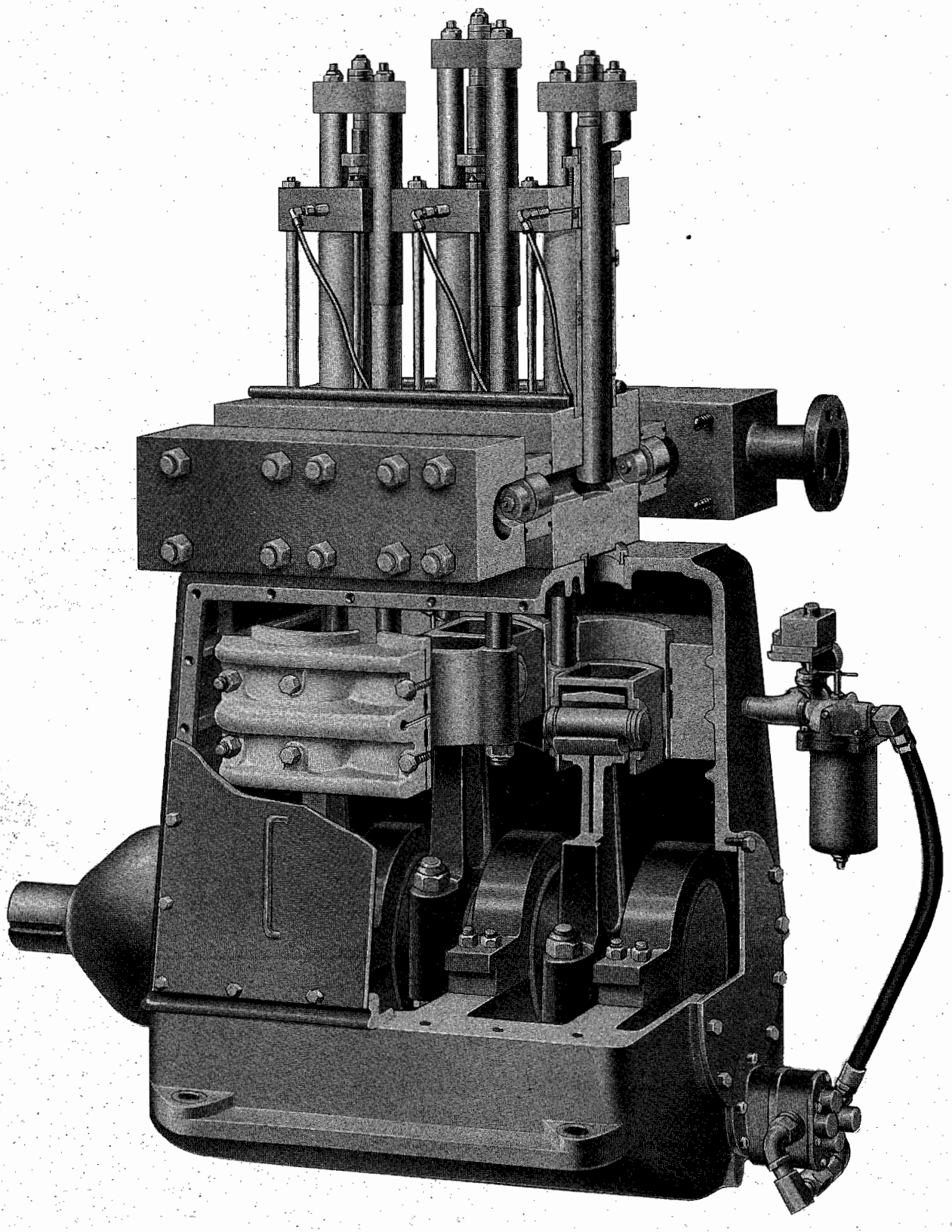
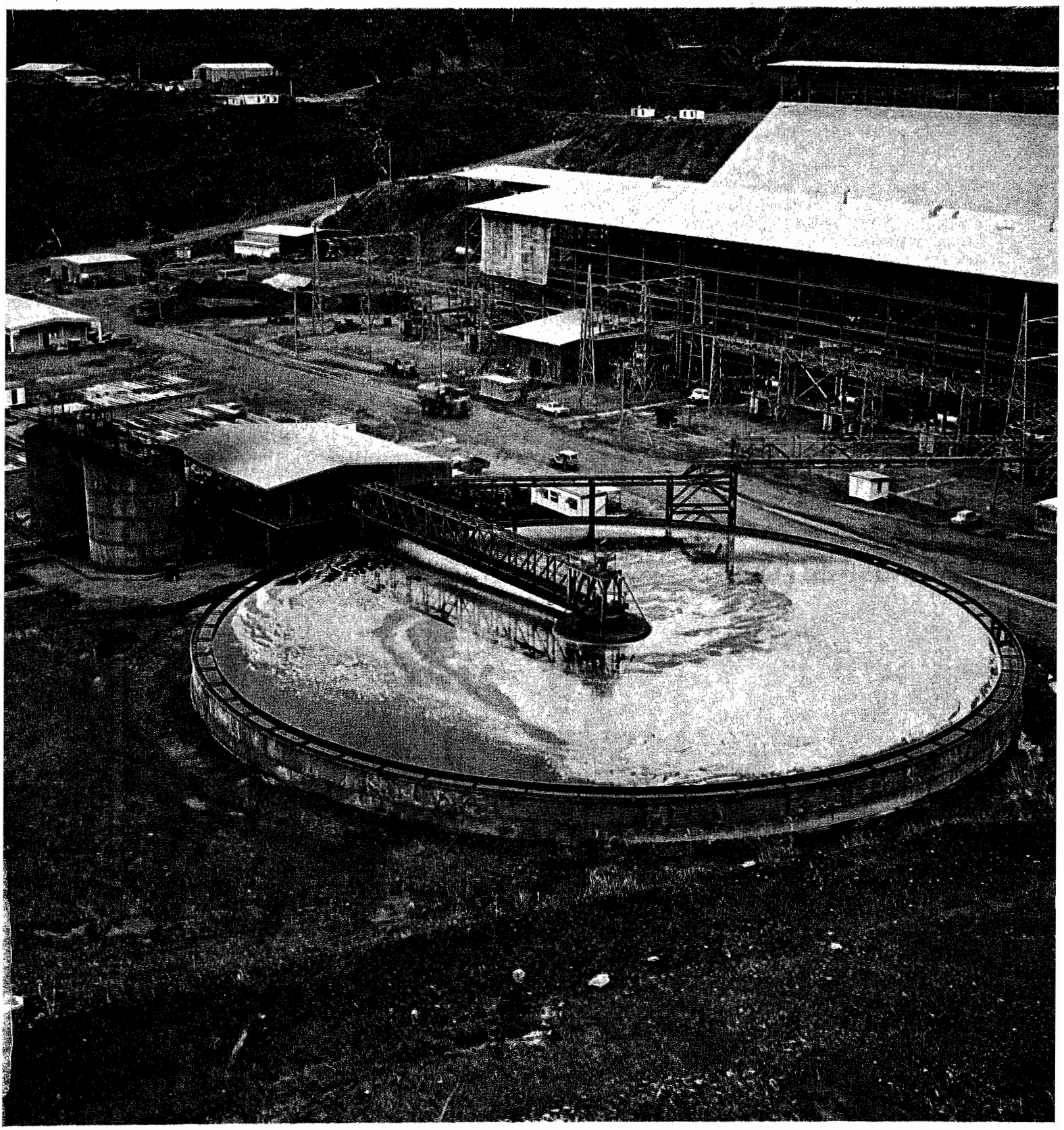


Fig. 4 A vertical Aldrich Pump for general service showing the heavy-duty power end and the straight through valve bore of the fluid end.



View o f the concentrator area, showing the pump house at the beginning of the 16 mile long concentrate pipeline.

(b) The increased flexibility for the designer to optimize stuffing box design in respect to throat bushing length and clearance for most efficient plunger flushing.
(c) The self-aligning features of the vertical plunger connections to the yoke.
(d) The accessibility of the plungers and packing for routine maintenance.

Flexibility of design allows for pumps to be built for a specific application rather than to use a standard design pump in slurry service. The vertical pump affords maximum design flexibility enabling special custom fitted process pumps to be built from standard components that have been field tested in hundreds of applications all over the world. For example Fig. 4 shows a fluid end design which might be used in a non-abrasive non-corrosive liquid whereas the fluid end shown in Fig. 5 is for slurry service, the difference in the construction of the fluid ends can readily be seen. A different design again would be used for chemical service.

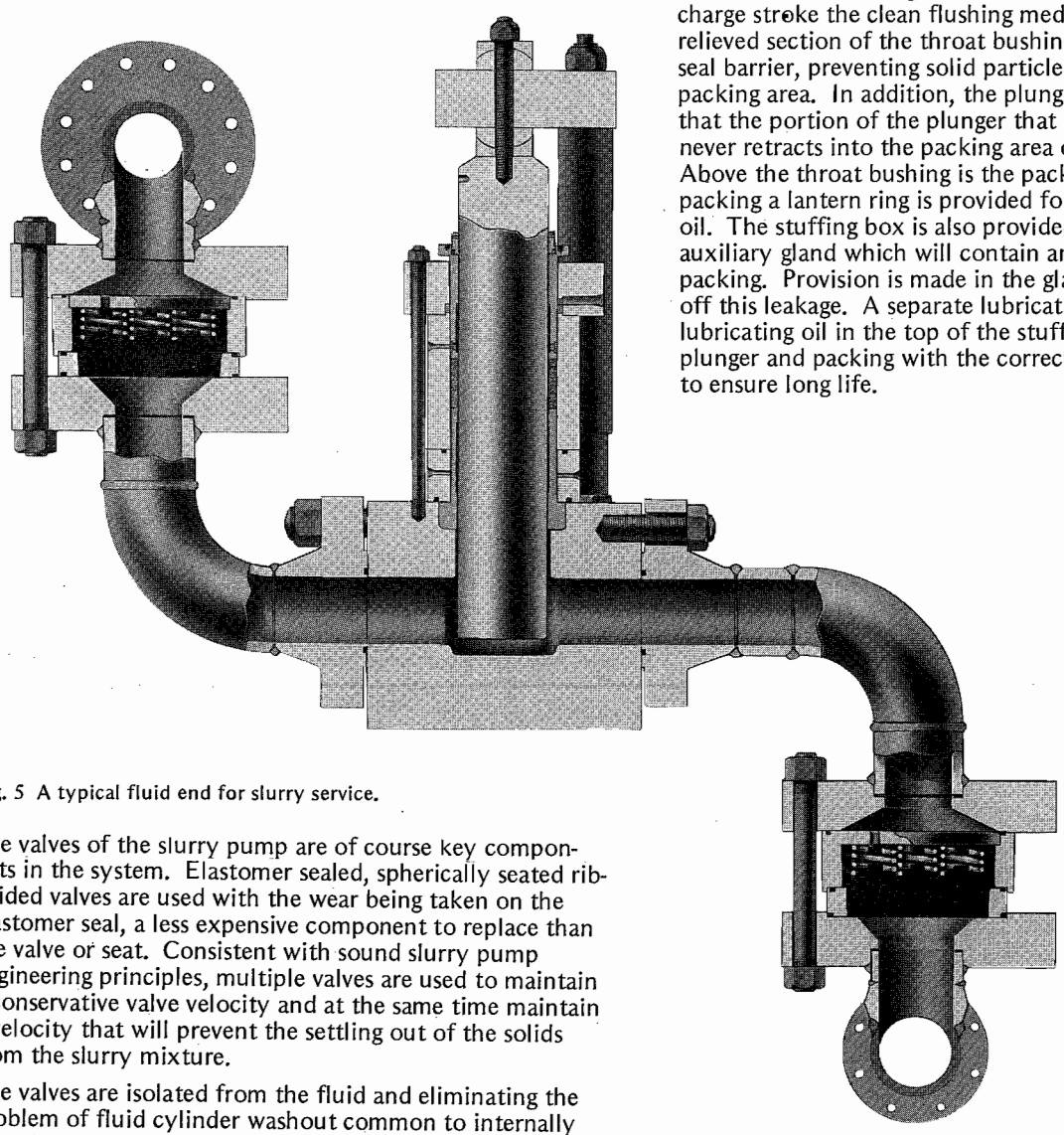


Fig. 5 A typical fluid end for slurry service.

The valves of the slurry pump are of course key components in the system. Elastomer sealed, spherically seated rib-guided valves are used with the wear being taken on the elastomer seal, a less expensive component to replace than the valve or seat. Consistent with sound slurry pump engineering principles, multiple valves are used to maintain a conservative valve velocity and at the same time maintain a velocity that will prevent the settling out of the solids from the slurry mixture.

The valves are isolated from the fluid and eliminating the problem of fluid cylinder washout common to internally valved pumps. The location of the valves in separate cannisters affords ease of inspection and replacement, eliminating the need for valve seat pullers and special tools. The separate cannister design also provides for easy conversion to ball valves without any change to the fluid cylinder.

The uniquely designed stuffing box incorporates all the design features which Ingersoll-Rand knows from experience are necessary to insure minimum downtime on a slurry handling pump. An extra deep stuffing box with a flushed throat bushing in the bottom of the box prevents the abrasive solids from getting into the packing where they could lodge and eventually score the plunger. A relieved section on the inside diameter of the throat bushing is provided along with a connection to the outside of the stuffing box to permit clean water or other compatible liquid to be injected. On the suction stroke of the pump the wash liquid is injected into this relieved area surrounding the plunger. The injected liquid washes all solid particles from the plunger as it retracts into the packing. A check valve is installed in the flush line to prevent flow back from the stuffing box to the source. On the discharge stroke the clean flushing medium is trapped in the relieved section of the throat bushing and forms a liquid seal barrier, preventing solid particles from entering the packing area. In addition, the plungers are extra long so that the portion of the plunger that dips into the slurry never retracts into the packing area of the stuffing box. Above the throat bushing is the packing and above the packing a lantern ring is provided for injecting lubricating oil. The stuffing box is also provided with a gland and an auxiliary gland which will contain any leakage past the packing. Provision is made in the gland ring for draining off this leakage. A separate lubricator is provided to inject lubricating oil in the top of the stuffing box to provide the plunger and packing with the correct amount of lubrication to ensure long life.

A triplex plunger pump provides synchronized flushing to the main pump stuffing boxes. The flush pump is coupled to and driven off the outboard end of the crankshaft of the main pump. The flush pump crankshaft is 180° out of phase with the main pump crankshaft, ensuring that the flush pump is on discharge stroke when the main pump is on suction stroke. The assembly is complete with check valves, relief valves and individual lines piped from the flush pump to each stuffing box of the main pump.

A heavy duty power end design incorporates a high tensile cast iron main frame totally enclosing all moving parts and providing a generous oil reserve. The crankshaft is ground webbed balanced and precision machined from a solid high carbon steel forging with rifle drilling for lubrication. All bearings are precision factory adjusted sleeve type with bronze backed babbit lined main bearings and crankpin bearings. The crosshead pin bearing is solid bronze. If maintenance is required the main bearings can be rolled out without removing the crankshaft.

Connecting rods are dropped forged steel rifle drilled for lubrication. Crossheads and crosshead guide are high tensile cast iron. The crankheads run in bored guides with one half of the crosshead guide cast integral with the frame and other half removable and shim adjustable. The crosshead guides have renewable cast iron shoes which are easily replaced in the event of wear.

Fig. 6 Secondary drilling with CM 250 Crawlair. Boulders like these are frequently not broken by primary drilling.

Filters

Envirotech Australia Pty. Limited.

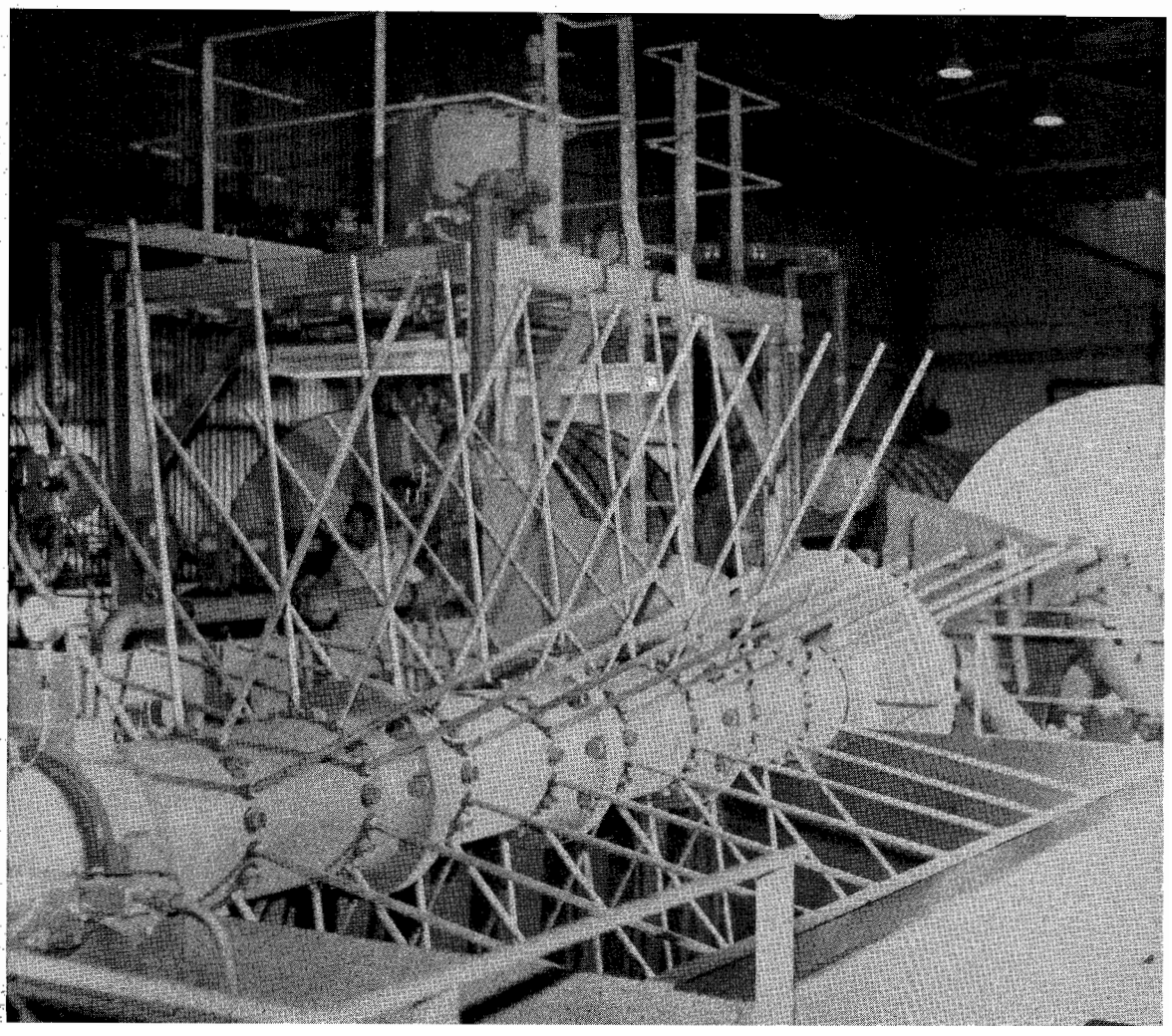
Dewatering of the final mill concentrate is carried out at the port installation. The concentrate is received at the port as a slurry containing 65% solids. To effect dewatering Bougainville Copper selected Eimco Agidisc Rotary Vacuum Filters which were designed and built in Australia by Envirotech Australia Pty. Limited under licence to their associate company Eimco Corporation of Salt Lake City, Utah, U.S.A.

The filter plant installation has 8 Eimco filters giving it substantial reserve capacity under normal operating conditions. In the agidisc filter design, the filtering area is the radial surface of a series of rotating discs and on these units the discs are 8'10" diameter and each filter has 8 discs giving it a total filter area of 880 sq. ft.

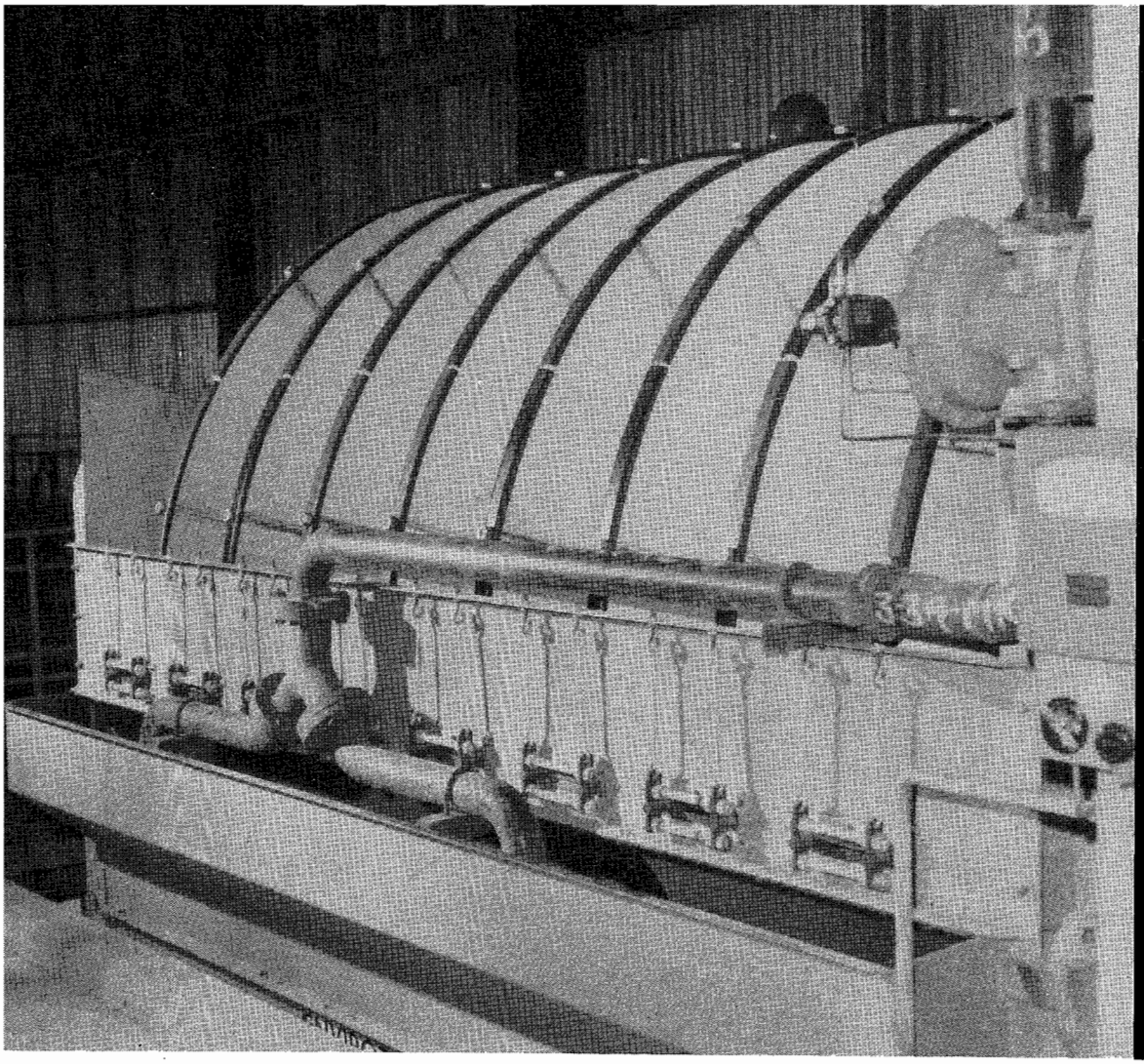
Each disc is made up of ten sectors each hydraulically independent of the other which are connected hydraulically and mechanically to a rotating centre barrel. Two stationary valves on the end of each centre barrel regulate the filter cycle and each valve is used to supply vacuum to and collect filtrate from 4 discs. The valves are connected to Eimco 72" diameter x 72" high vacuum receivers through which vacuum is applied and in which the vacuum air and the filtrate are separated.

The disc sectors on these filters are made of Eimcomet, a specially formulated injection moulded polypropylene. This construction was selected to provide the required resistance to both erosion and corrosion and because of its lightness allows it to be easily handled by one man for filter media replacement. In addition, it is resistent to damage and distortion through dropping or knocking.

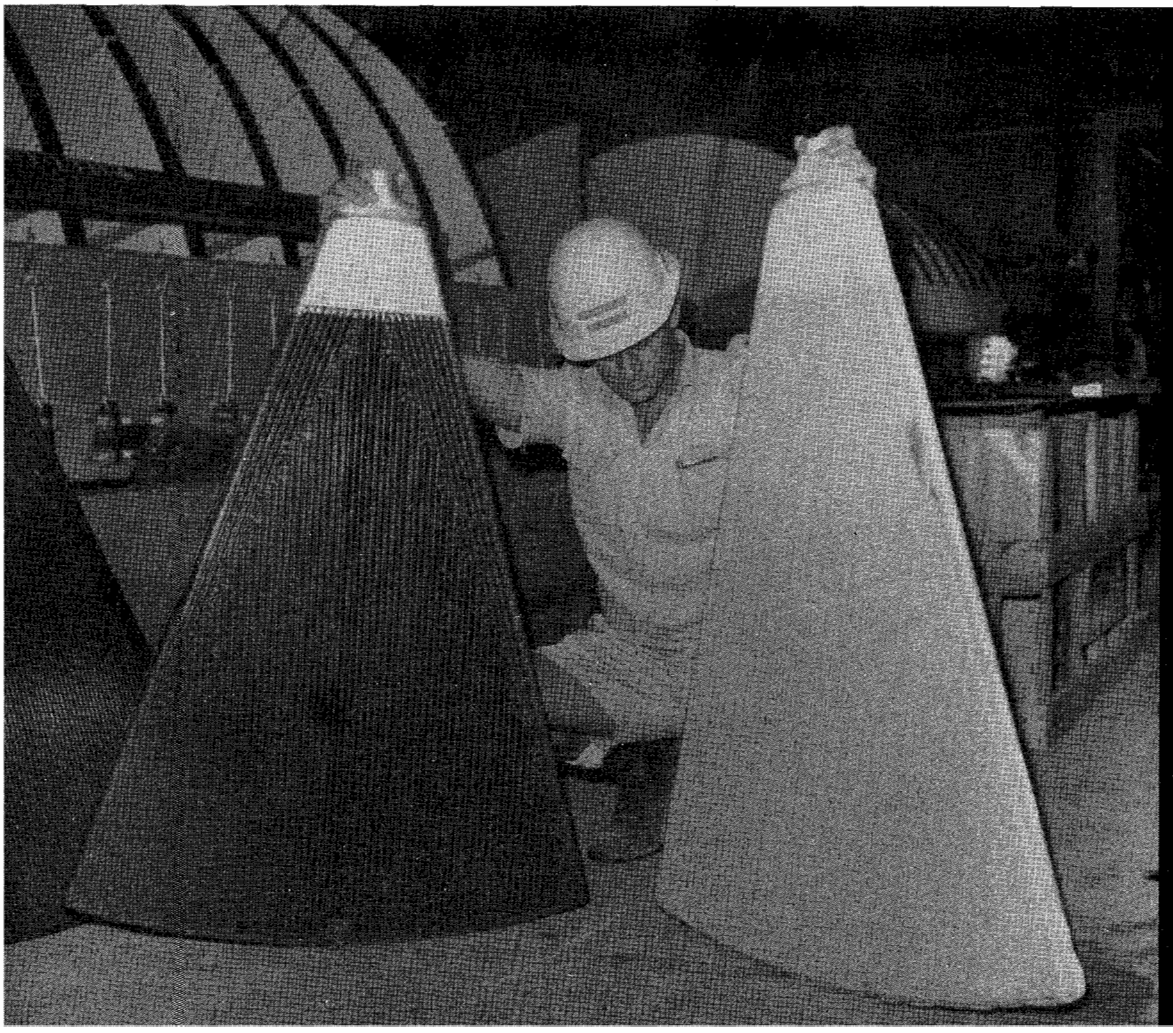
At all times the slurry pool in the filter vats are agitated by a full length agitator in the bottom of the tanks. This ensures uniform size and distribution through the slurry pool and ensures that an even filter cake is produced. An uneven filter cake will give rise to short circuiting of dry vacuum air and resulting in an inefficient filter drying cycle. The filters operate at vacuum levels between 22 and 23" in mercury and each filter handles up to 1,100 tons of dry concentrate per day. The moisture level of the final filter cake averages 14% moisture and can be down to 10% moisture under reduced throughput conditions.



Filter before installation of sectors, showing centre barrel and radial rods.



General view of filter ready for operation, showing filter discs, adjustable discharge scraper, anchors, the feed pipe and feed box.



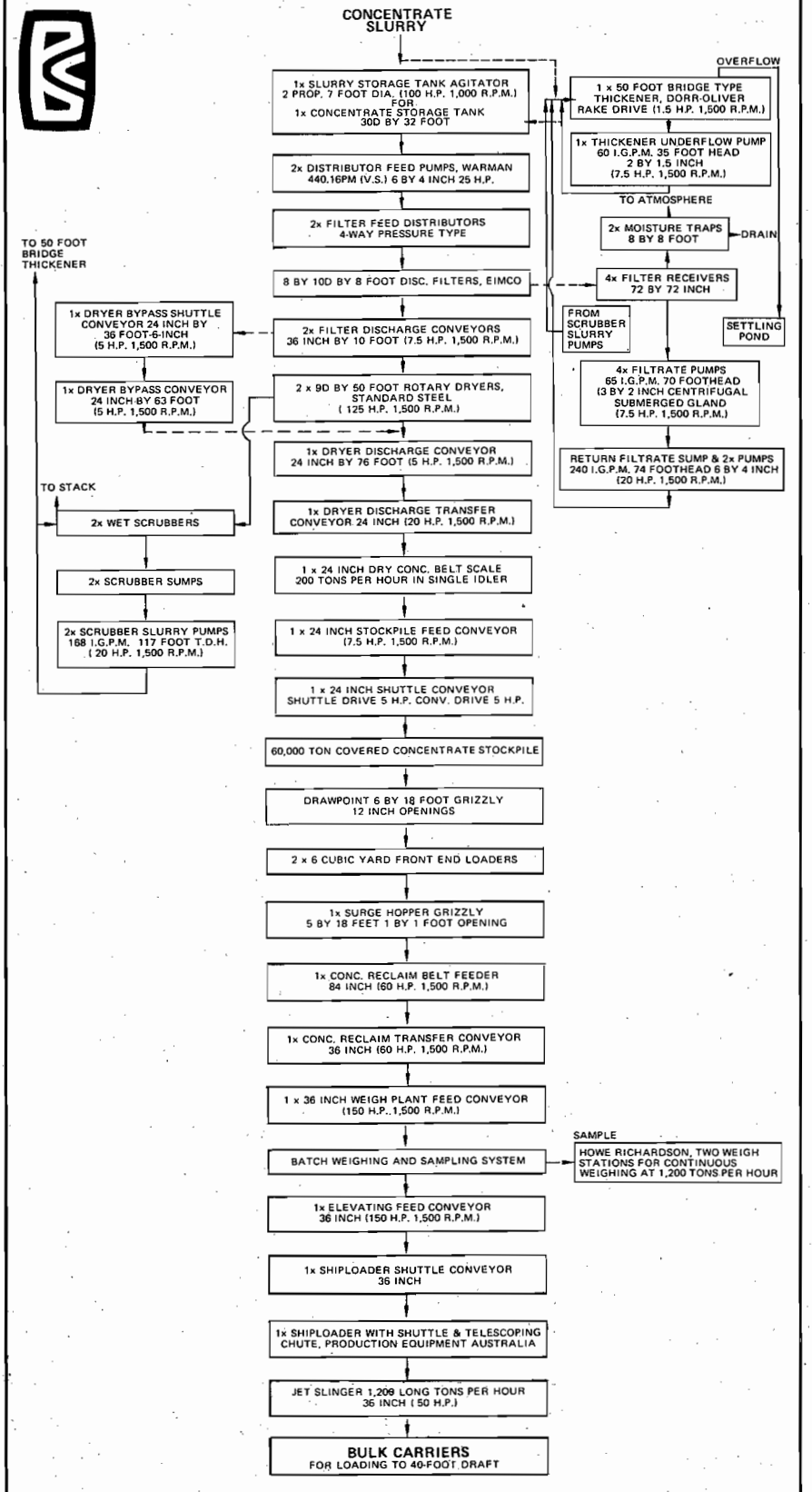
Sectors constructed of moulded Eimcomet, before and after fitting of the filter bags.

Filtering, Drying & Loadout

From the slurry holding tank, the concentrate is pumped to one of eight 10 ft. diameter eight-disc filters where moisture is reduced to about 11 per cent. Filter cake is delivered to two 9 ft. diameter by 50 ft. long oil fired rotary kilns where moisture is further reduced to 7.0 per cent.

Dried concentrate is stored in a covered building holding 60,000 tons. It is reclaimed by 6 cu. yd. front end loaders, transferred to belt conveyors, weighed and sampled, and delivered into ship holds by a fixed point shiploader with shuttle belt and telescoping chute. A jet slinger at the end of the chute loads and trims the ship's holds at a rate of 1,200 long tons per hour.

FILTERING, DRYING, & LOADOUT FLOWSHEET



Slurry Sampling at Bougainville

The Galigher Company,
Salt Lake City, Utah, U.S.A.

Sampling of slurries follows the same accepted procedure as outlined for dry materials. Extraction is accomplished by means of a cutter progressing through "the whole of the stream, part of the time", at a fixed rate of speed. Cutters may be sized with openings to extract a percentage of the flow rather than only three times the particle size as in dry sampling.

Samplers used on slurries entail mechanical sampling devices for extracting a sample from stationary or moving liquids in open launders, pipes, and flumes. Galigher total sampling provides standard off-the-shelf machines with type "A" and "B" cutters for launders and special-duty samplers. Newly developed and tested machines include injection-type pipe samplers, stationary pipe samplers, stationary launder samplers, and open-stream effluent samplers.

Today plants are producing new materials with strict emphasis placed on quality control. Representative sampling at critical stages of processing is an accepted must and is possible with Galigher sampling systems.

Sampling systems have become more and more complex to comply with changing conditions and increased tonnages. It is not uncommon to have tonnages ranging up to 10,000 TPH of dry product with particle size exceeding eight inches and slurry flows such as at Bougainville, exceeding 15,000 GPM.

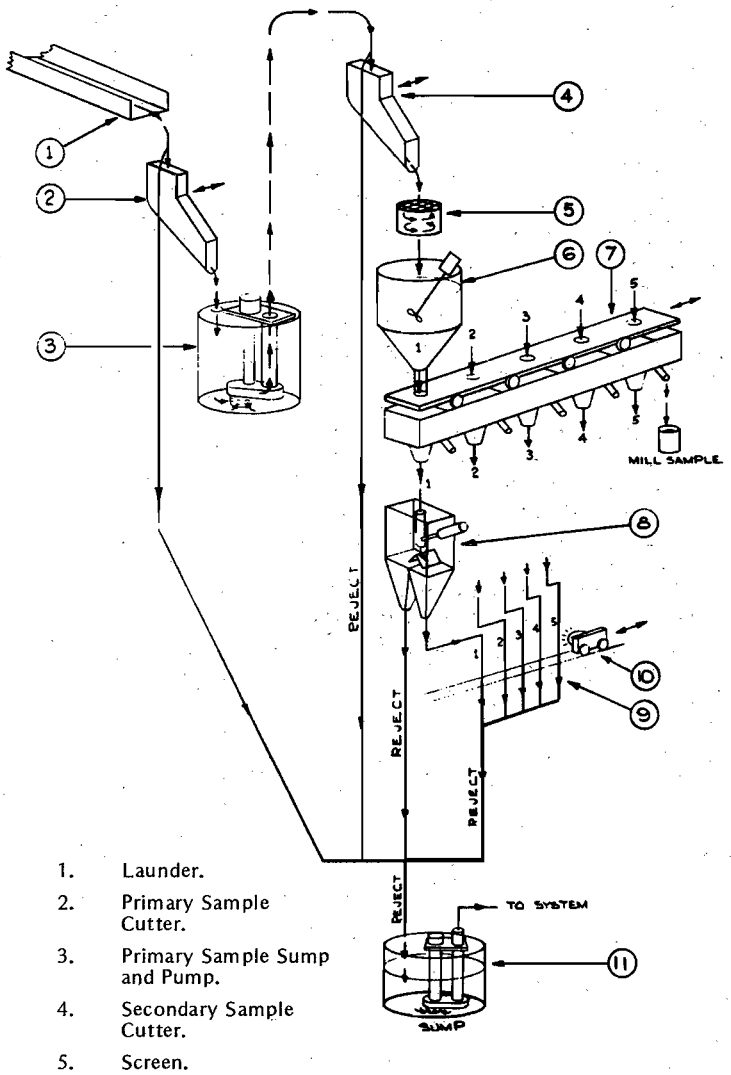
X-ray systems for product analysis and quality control as well as dust-tight and moisture-tight systems which prevent sample contamination are other areas of Galigher's activities in this ever-changing field of sampling. In the past just one or two sampling stations were required to do the job. Today, the entire system must be taken into consideration. This "total sampling" Galigher concept requires specialized procedures to avoid problems in developing sampling systems. All services and machines should be obtained from one source that provides total system responsibility.

Galigher Company follows these guide lines and provides all sampling services as well as manufacturing and producing all hardware and related components required for sampling flows from minimal amounts to the higher feed rates.

The application of pulp sampling equipment in the concentrates at Bougainville is an example of successful slurry sampling under the most difficult of conditions.

The sampling system at Bougainville has been designed to effectively and economically furnish a reliable sample from the flows of solids and pulps at the concentrate building under extremely difficult conditions.

TYPICAL FLOW DIAGRAM WITH X-RAY SCANNER



1. Launder.
2. Primary Sample Cutter.
3. Primary Sample Sump and Pump.
4. Secondary Sample Cutter.
5. Screen.
6. Agitator
7. Gang Sampler
8. Tertiary Sampler.
9. Plastic Pipes in X-Ray Scanner.
10. X-Ray Scanning Head.
11. Sump Pump.

Galigher Sampling equipment is located in the concentrator building at an elevation of 2,100 feet where it is required to operate in conditions of high ambient temperature, 70–100 degrees, and with relative humidity ranging between 80 and 90 per cent. High humidity, corrosion, severe splash problems, and oversize material reporting from the grinding circuit were some of the problems that were initially overcome.

The overcoming of the severe problems at Bougainville was largely due to the careful initial planning of the plant, the carefully designed and properly manufactured sampling equipment, and the efficient and thorough maintenance program that supported the sampling system.

Many applications require a drive mechanism capable of handling small to medium direct mounted cutters or cart-mounted cutters as in the Bougainville concentrator, where the Galigher CS-400 Mechanism is well suited for this application. Machines may be set up for timed or continuous operation, both of which apply at Bougainville, where type "B" horizontal sample cutters and type "D" cutters with 30 degree offset to the vertical are utilized. Cutters here were fabricated from 1/8" stainless steel, having an overall body length of 20", 26", or 30", and a cutter length of 10" or 15", with adjustable stainless steel cutter lips varying from 0–2" cutter opening. The number of cuts per hour vary from 4–12, with cutter speeds set at 6.6 IPS or 11.6 IPS.

The modular design of the rotary arcual Vezin sampler was chosen as a Secondary Sampler because it offered several unique advantages:

A. Dust and moisture-tight.

B. No additional chutework to design and fabricate.

C. No additional fit-up or installation problems.

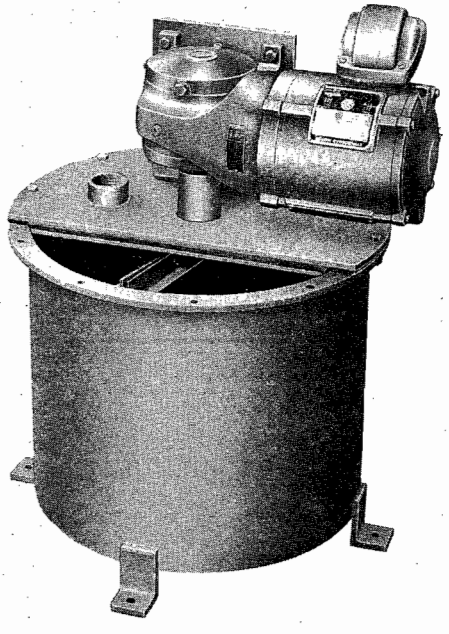
D. Ease of installation.

E. Sampler is isolated and represents good sampling design with sampling chamber isolated from the main stream.

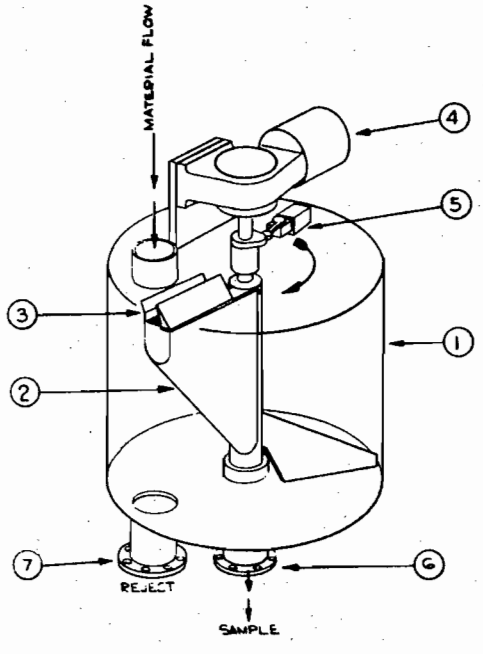
The external shell of the arcual, Vezin-type sampler is fabricated of mild steel, with cutter fabricated from type 304 stainless steel. Adjustable cutter lips were used in order to provide some adjustment features after the unit is installed if the particle size should change or the amount of material per cut requires changing.

The arcual-type samplers and the Secondary Chain Drive Samplers were wired for continuous operation and were designed for taking 5% of the primary sample at an operating speed for the arcual samplers of 41 RPM, because of the severe climatic conditions; otherwise, standard machines were fitted with tropic-proofed gearmotors and anti-condensation heaters.

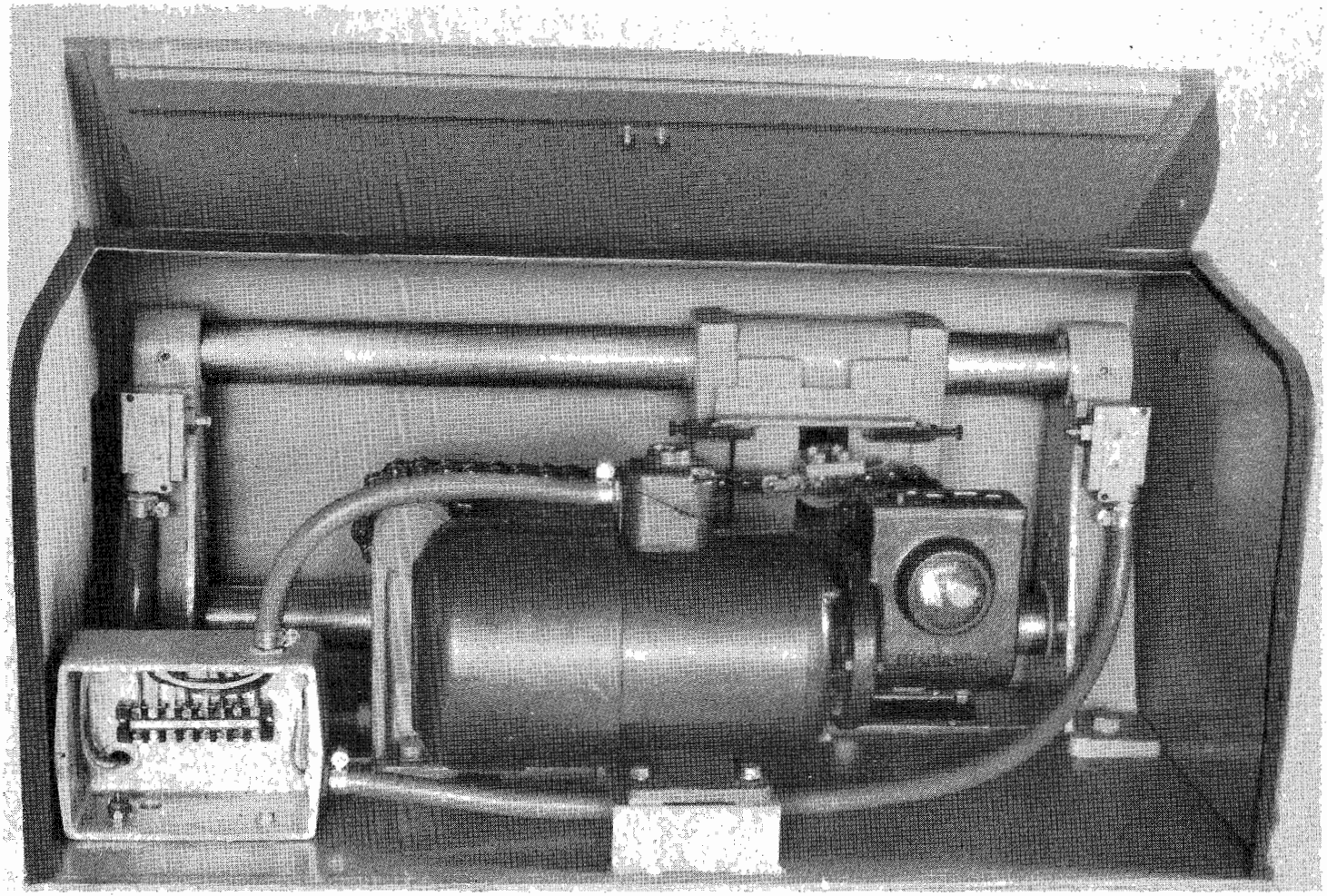
In summary, Bougainville Copper Pty. Ltd. has proved that a successful sampling system is dependent on careful initial plant design and properly engineered and manufactured sampling devices. Even as important is the program established for the operating personnel that will insure the continuous operation of the system through a planned program for protection and maintenance of the sampling system.



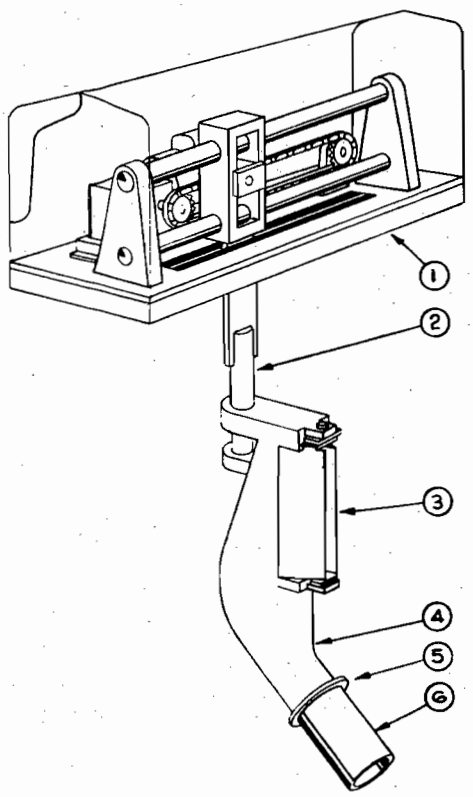
ROTARY ARCUAL SAMPLER – MODEL GM-500.



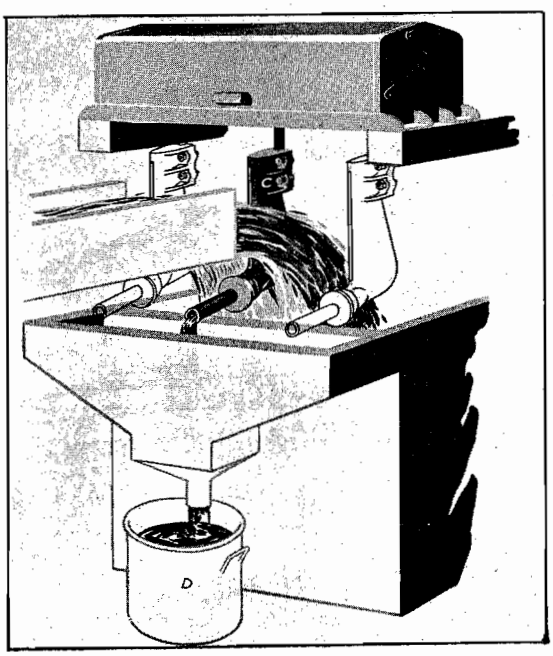
1. Housing.
2. Cutter.
3. Adjustable Lips.
4. Electric Gearmotor.
5. Solenoid Switch.
6. Flanged Sample Discharge.
7. Flanged Reject Discharge.



CHAIN DRIVE SAMPLER – MODEL CS-400.



1. Electro-mechanical drive.
2. Cutter Support Arm.
3. Adjustable Cutter Lips.
4. Cutter Body.
5. Drip Ring.
6. Discharge Spout.



Shiploader

1,200 TON PER HOUR COPPER CONCENTRATE SHIPLOADER FOR BOUGAINVILLE COPPER PTY. LTD.

F.J. Nott, M.I.E., (Aust.) Dip. M.E.
Design Engineering Manager,
Production Equipment Ltd.

The shiploader installed at Bougainville was designed, constructed and erected by Production Equipment Ltd., Melbourne, Australia, to the performance specifications laid down by Bougainville Copper Engineering Administration.

The submission by Production Equipment Ltd. was governed by the need for a robust and reliable unit for the fast handling of bulk ore carriers and by the climatic and seismic conditions which apply to the Bougainville area.

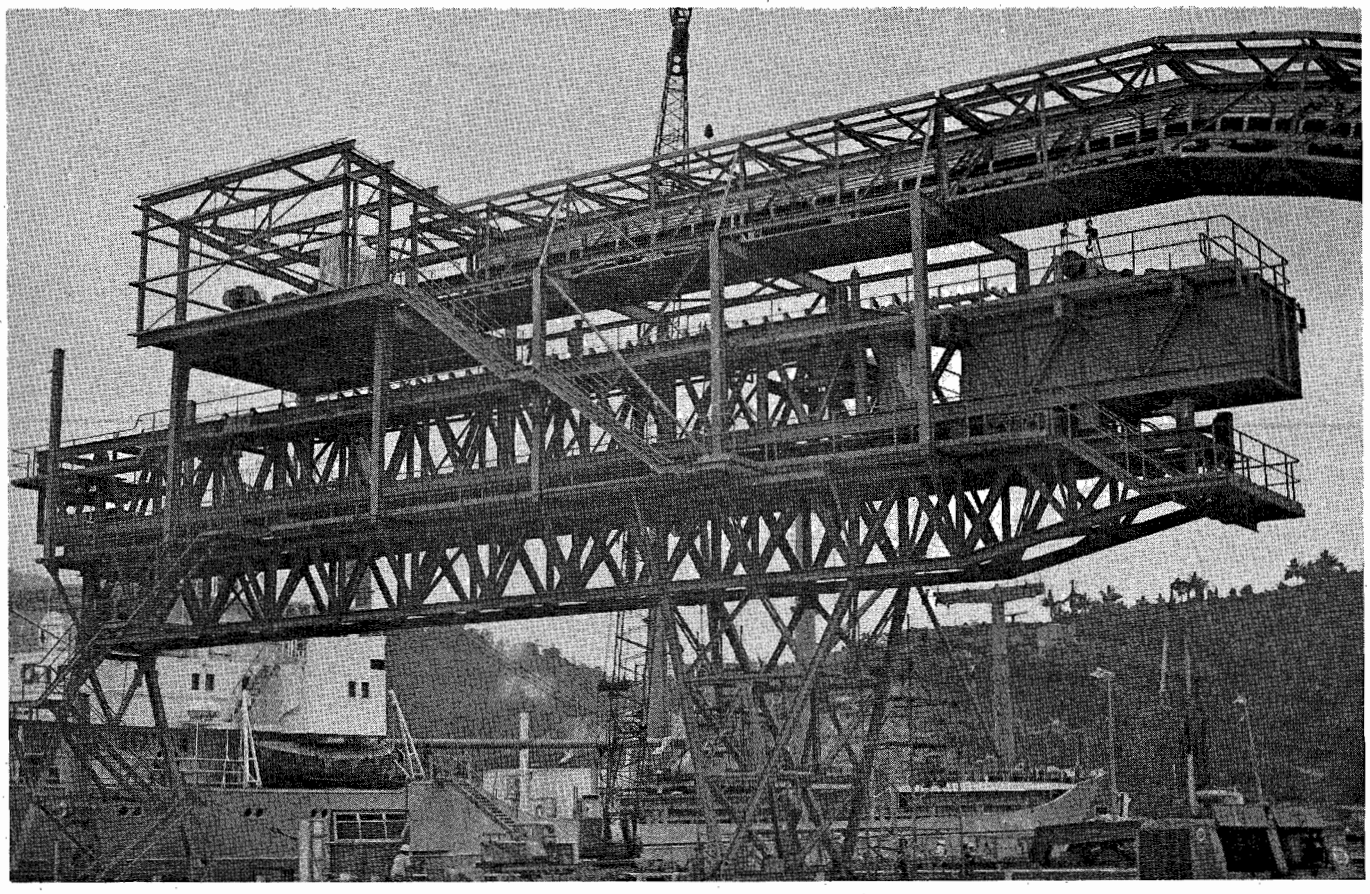
Based upon the proven concept that the degree of reliability for any equipment is often in inverse proportion to its complication, a design was developed for a loader comprised of a fixed support structure on which was mounted a retractable lattice girder boom.

This design was also considered preferable for the Bougainville area since it provided a low squat unit without masts or other high structures necessary for a shiploader with a luffing boom action. With the prevalence of cyclonic winds and possible earth tremors, the avoidance of such structures was considered an advantage.

The main structure of the shiploader comprises a lattice type box girder mounted on a rigid trestle at the landward end to provide lateral and longitudinal rigidity and a flexible trestle at the seaward end to accommodate bridge length variation due to thermal and other causes.

This arrangement maintains maximum clearance for general wharf traffic beneath the shiploader.

Shiploader in course of construction.



Shiploader in operation at Anewa Bay, Bougainville.

A retractable lattice girder boom runs on the main bridge structure and supports at its seaward end, a telescopic loading chute operator's cabin and a supplementary chute hoist system for the accommodation of ore carriers larger than normal traffic.

The boom travel permits the passage of a ship along the wharf when it is fully retracted and provides a maximum reach for shiploading of 65 feet from the wharf fenders.

The loading boom travels on four pairs of travel wheels, two pairs of which are attached to the main bridge at the seaward end and two pairs of which are attached to the travelling boom. All pairs of wheels are bogey mounted to ensure load sharing and wheel flanges maintain guidance of the boom.

To counterbalance the extended boom and loading chute, a counterweight is incorporated in the landward end and this also ensures ample traction on the driving wheels attached below this counterweight to the boom.

The electric motor drive transmits power to a drive pinion at the bogey pivot centre and the pinion in turn meshes with ring gears on both trackwheels in each driving bogey.

To provide smooth starting and stopping of boom travel, the drive unit incorporates a traction type fluid coupling carefully matched to the drive characteristics.

This drive also incorporates electrically released spring applied shoe brakes to stop and hold the boom at any required loading position. Oleo type buffers are provided as safety stops in the event of over-travel.

The telescopic loading chute is raised or lowered as required by a rope system, the operating winch for which is located adjacent to the boom counterweight and operable from the driver's cabin.

The lower end of the chute is provided with a rotateable belt type slinger for hold trimming and with a flap to bypass the slinger for general loading. The slinger, which is rotateable through 360 degrees, can be used for trimming, as and when required, from the control cabin.

In order to ensure maximum facility of operations, the control console was designed to require a minimum of operator functions and numerous automatic interlocks were included throughout the electrical control system.

The retractable boom design permitted the use of a single conveyor for transport of the material over the boom to the loading chute without the complication of accommodating slack belt usually associated with luffing boom types.

The conveyor belt is 36 inches wide operating at 500 feet per minute and both drive and tension take-up are located at the landward end so that the discharge pulley is retained at the optimum position for feeding the telescopic chute.

To avoid over-run of the conveyed load, an automatic thruster released brake is interlocked with the drive motor so that immediately it is de-energised, the brake is applied.

The provision at the seaward end of the boom for the accommodation of the largest ore carriers is comprised of a small tower into which the telescoped chute may be hoisted to provide additional height for "warping" the ship along the wharf.

The hoisting of the chute is performed by a combination of motor operated screw jacks and rope hoists. To achieve this additional lift, the discharge pulley of the conveyor is carriage mounted and the chute hoist ropes are reeved through a series of sheaves.

Operation of the hoist moves the conveyor pulley clear of the chute, raises the chute, and by means of movable sheaves, maintains tension in the main chute ropes. This ensures that all components are correctly positioned for operation when the unit is returned to its working position.

In keeping with the simple construction of the shiploader, the electrical system was kept as simple as possible.

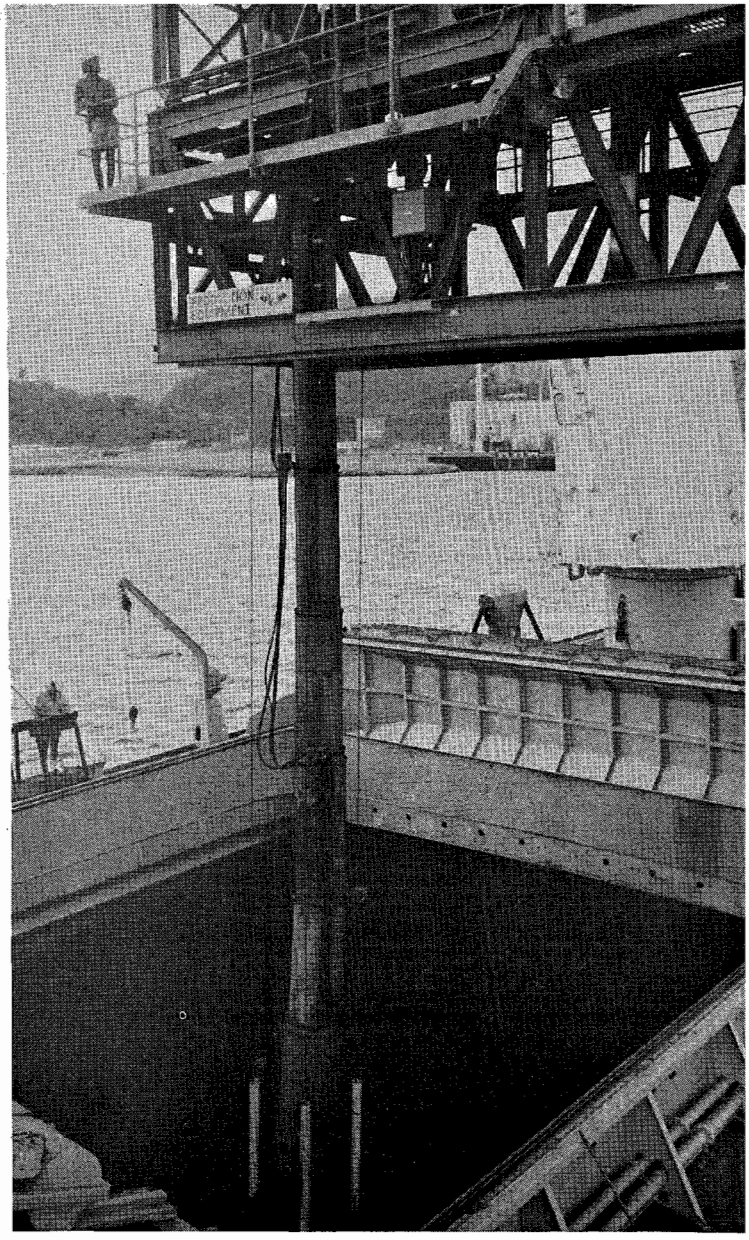
As all drives consisted of squirrel cage type motors, it was decided that standard control circuits, utilising solenoid operated contactors and auxiliary relays, be incorporated.

These were housed in a weatherproof cubicle which was located inside the retractable boom at the landward end.

The complete controls were located on a console deck in the driver's cabin and from this point it was possible to control in sequence, the complete conveyor system leading up to the shiploader together with all shiploader drives.

A system of neon proving lights was incorporated to prove that all circuits were healthy and to indicate that in the case of a fault, the protective device had operated.

Interlocking is provided to ensure that the conveyor system cannot run with the slinger in the fully raised position and standard travel limit switches are located at the extremities of all moving parts.



Telescopic Loading Chute (fully extented)

A P.I.A.B. tension indicator complete with over and slack tension limit switches, was installed in the telescopic winch rope system, which, as well as protecting the operation of the chute against malfunction, also senses a blocked chute.

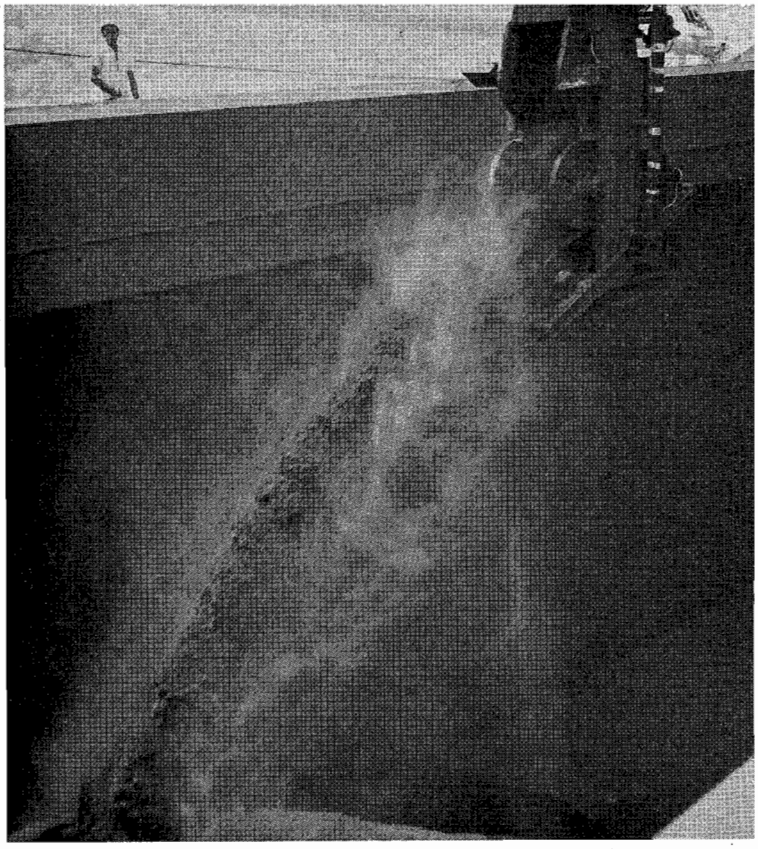
All electrical equipment, including the drives, are located on the retractable boom which keeps the number of circuits to be run to associated plant, to a minimum.

It was only necessary to install a four bar collector system for the connection of the main power supply to the boom, together with a six core flexible cable supported by a catenary wire for the sequence interlocking to other plant.

From the foregoing it will be appreciated that the Bougainville shiploader has been designed and constructed to perform the required duty with a minimum of complication.

This was the initial aim, bearing in mind the remote area in which it was to operate, so that

a) the potential for operational fault was minimised.
b) in the event of a fault occurring, the simplicity of design and control would permit speedy correction without the need for specialist personnel on site.



Rotatable Belt Slinger for hold trimming.

TECHNICAL DATA

Capacity: 1200 long tons per hour.

Material: Copper Concentrate.

Properties:

Density:	Loose	140 lb./ft.^{3}
	Compacted	170 lb./ft.^{3}
Moisture Content:	7% (max.)	
Angle of Repose:	Loose	37°
	Compacted	46°

Telescopic Boom:

Range of position of centre line of jet slinger.	70'0"
Minimum operating position from wharf edge.	13'6"
Maximum operating position from wharf edge.	65'0"
Parked position behind edge of wharf.	—4'6"
Travel speed.	46 ft./minute
Travel wheel bogies	2 fixed 2 drive
No. of wheels in fixed bogie	2 x 2
No. of wheels in drive bogie	2 x 2
Dia. of travel wheels	22"

Travel Drive:

Motor horsepower	15
Motor RPM	1440 nominal
Motor type	Squirrel Cage
Input coupling	"Schroeder & Holland" single rotor fluid coupling size A with brake
Brake	"SRDB" JK8
Gear reduction	"Falk" 7CB4—12 with two output shafts 76—62/1 ratio
Output coupling	"Falk" 13F Steelflex
Final drive	Open gearing
Final drive ratio	64 : 25

Belt Conveyor:

Width	36 inches	
Speed	500 ft. per minute	
Trough angle	35°	
Drive pulley diameter	23¼"	
Head pulley diameter	23¼"	
Capacity	@ 140 lb. per cubic ft. material	1700 short ton/hour
	@ 170 lb. per cubic ft. material	2100 short ton/hour

Conveyor Drive:

Type		Tail Drive
Belt Centres		106'6"
Take up length		3'0"
Motor H.P.		20
Motor RPM		1440 nominal
Motor frame		Squirrel cage
Couplings	Input	"Falk" 8BW Steelflex
	Output	"Falk" F11 Steelflex
Brake		"SRDB" JK8
Gear Reduction		"Falk" 6C2—02/17.51 : 1 ratio

Jet Slinger:

Make		"Link Belt"
Type		B
Size		36"
Capacity		1200 long tons/hour
Belt width		36"
Belt speed		500 ft./minute
Trajectory	max.	+45°
	min.	+15°
Slinger Motor H.P.		50 H.P.
Slinger Motor R.P.M.		1440 nominal
Drive		Vee belt C—105/4
Trajectory Control Motor		0.5 H.P. at 960 R.P.M.
Trajectory Control		"Prok" 2 ton Motorized Screw Jack
Slew Drive Motor		0.5 H.P. 10 RPM output

By Pass Chute Flap Gate

Drive motor	0.5 H.P. Gear Motor 10 RPM output
Torque control coupling	Reynold No. 646421

Telescopic Chute:

Range	45'0"
Lifting speed	30 ft./minute

Telescopic Chute Winch:

Rope speed	60 ft./minute
Motor Horsepower	15
Gear Reduction	"Falk" 8C302/109.98 : 1 ratio
Winch Drum R.P.M.	11.3

Weights: (long tons)

Service Weight	212 tons

Shipping–the Island's Lifeline

John R. Hall,
Shipping Supervisor,
Bougainville Copper Pty. Ltd.

The requirements involved in the construction stages of building a mine, two townships, a port and supporting utilities such as a power station, roads, water pipelines etc.; were apparent when the initial feasibility studies were undertaken for the Bougainville Copper Project.

Every item of equipment could only be supplied by sea to an island with a rugged mountainous tropical forest hinterland with an established commercial port at Kieta, some fourteen miles from the intended new port at Anewa Bay.

It was therefore essential at the outset, to commence operations at Anewa Bay using a beach-type operation whereby specialised Japanese vessels, with bow doors, could discharge heavy earth moving equipment direct to the beach in order to clear sufficient space for essential equipment, portable housing and foodstuffs to be discharged. A small temporary barge wharf was rapidly constructed so that larger vessels could discharge their cargoes into barges and a more conventional discharging operation utilised.

Given the basic facilities of an open roadstead and a barge wharf plus the use of a commercial port where possible, equipment and supplies were unloaded in large quantities, construction effort on the port site increased and a temporary road was cut through the Crown Prince Range to the intended mine site at Panguna.

The problems encountered in the initial construction stages were not only caused by the type of equipment moved and the lack of facilities at the discharging area; the weather also had a serious effect on operations as Bougainville has a rainfall of some 200" of rain per year and it is not unusual to experience some 6" of rain in one hour consequently delaying discharge of equipment.

A pattern soon evolved which made the Project's dependence upon containerisation a high priority for most mining supplies and foodstuffs. As the construction period of over two years continued, and facilities ashore improved, so did the type of tonnage that was chartered, in that larger and more sophisticated vessels capable of very flexible cargo handling of all types were obtained and utilised for longer periods during this phase of construction.

Basic requirements on such vessels were heavy lift capacity of 70—90 tons 'tween deck space for unitised cargoes, reefer plug points for about twenty refrigerated containers, suitability for fork lift truck operation within the holds and clear deck and hatch space for the carriage of hazardous cargoes.

The eventual completion of the berth at Anewa Bay and its supporting facilities such as warehousing etc., gave an impetus to the arrival of equipment and supplies for the project all of which assisted the mine contractors in maintaining their construction schedule. Thus the excessive pressures put on vessels in carrying the goods to Bougainville, were relieved considerably as the initial supplies were built up to reasonable levels.

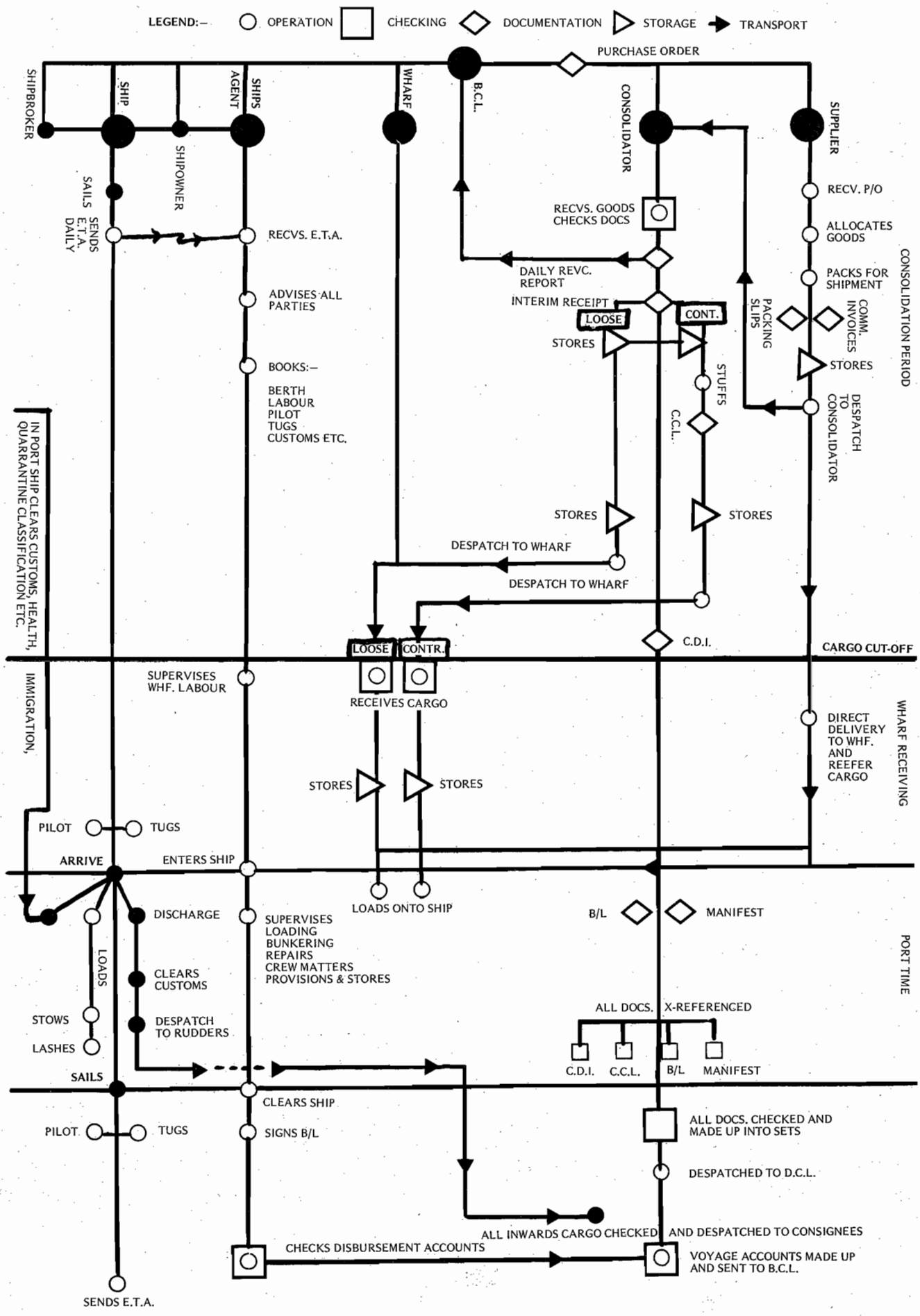
It was at this time, during the final construction phase of the project, that even larger vessels were chartered on a worldwide basis to bring stockpiles of supplies for the mine.

The completion of the construction phase and the advent of the mining operation brought problems that had hitherto not been encountered during the construction period, in that the type of cargo changed drastically from heavy equipment and bulk supplies, to more conventional containers and unitised cargo.

Preparing for this operation, cargo consolidators were appointed at Melbourne, Sydney, and Brisbane, to consolidate cargo at specified warehouses and pack into containers in a manner suitable to operational requirements and to the satisfaction of the Customs and Quarantine Authorities of Papua New Guinea.

Of the many vessels used to date, it has been found that the container feeder ship has been most suitable type of vessel required. Two ships, both German flag, of modern 'tween deck construction with larger holds and hatches, are utilised as support ships for the project. These are carrying homogenious cargoes successfully to the island using, thanks to the co-operation of both owners, indigenous crews on deck thus assisting Papua New Guinea with the training of a potential mercantile marine.

CONSOLIDATION OPERATION CHART



Ship Chartering

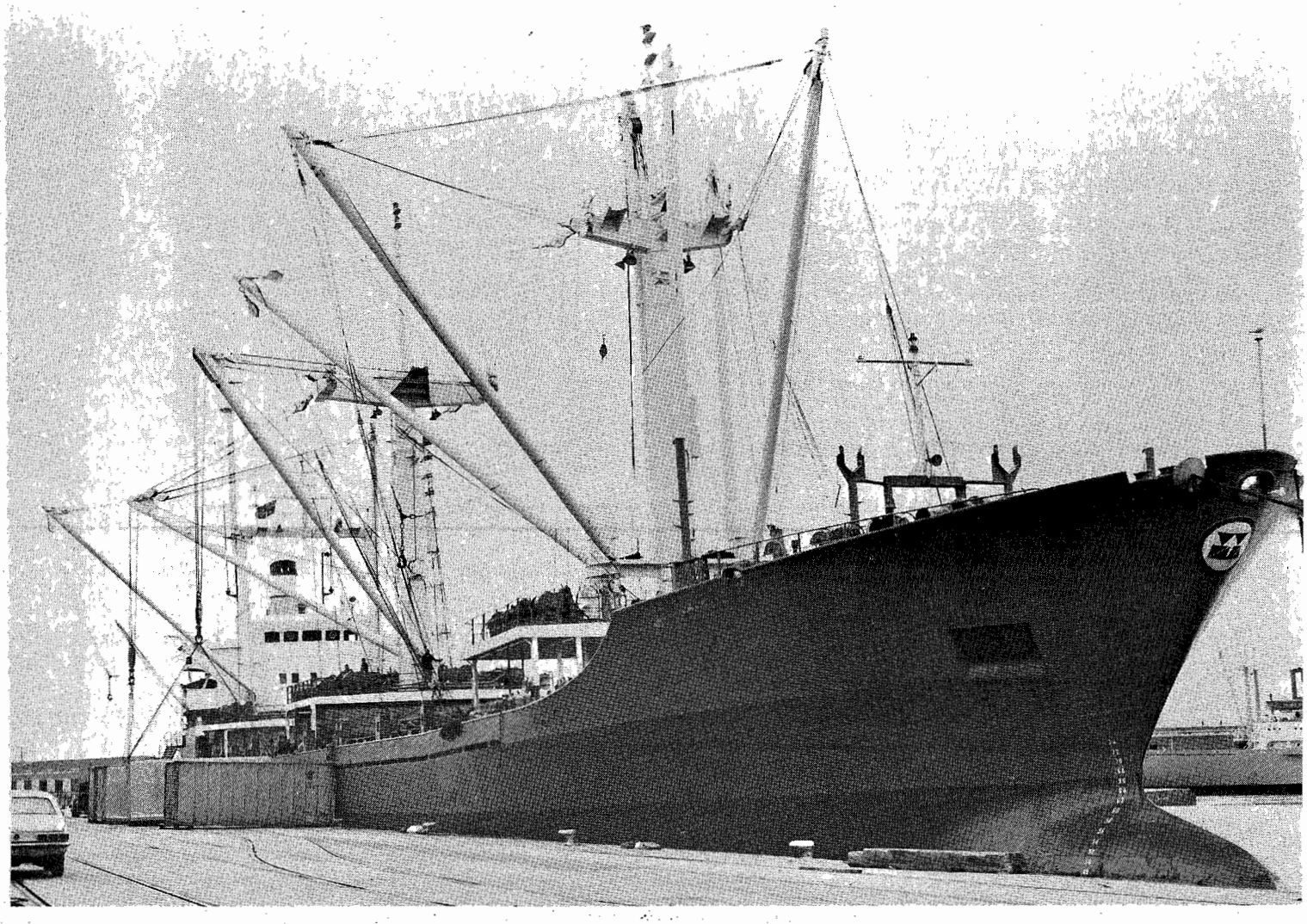
The provision of special-purpose vessels to meet the changing requirements of the Bougainville project as it developed through construction stages.

ELDER—AUSTRAL Chartering Co.,
Melbourne, Australia.

M.V. "Weser-Carrier", a modern cargo container vessel, launched February 1971, is one of two craft currently under charter to Bougainville Copper Pty. Ltd. with a speed of 15 knots and 5,000 ton capacity, the "Weser Carrier" has a container (20' x 8' x 8'6") intake of 183, with 40 electric connecions for refrigerated containers.

The cargo gear makes the vessel almost independent from port facilities.

The two vessels, "Weser-Carrier" and "Pacific" maintain a continuous service between Australian ports (Brisbane, Sydney, Melbourne) and Anewa Bay, Bougainville.



The early development of the Bougainville Copper Project was followed with great interest by our Company and as a result of this we became actively involved as Shipbrokers/ Consultants in this project. Our task was to assist in overcoming the problems of transporting and discharging equipment into Bougainville, which resulted in our arranging the chartering of more than twenty different vessels, most of them specialised heavy lift carriers able to handle the large construction equipment and materials needed in Bougainville.

In order to cope with the initial very limited port facilities at Anewa Bay, it became apparent that a highly specialised vessel was needed and this led to the chartering of m.s. "COSMOS", owned by Tokyo Shipping Co. Limited, who are well known for their ability and experience to successfully undertake difficult projects of this type. This 2,170 tons deadweight vessel, has the unusual facility of being able to discharge directly onto a beach by way of bow doors and ramp.

Of the vessels contracted a number were on fairly long term timecharter while others were involved in occasional single voyages.

The largest heavy lift vessel chartered was m.v. "YANAGI MARU" with derricks capable of lifting items up to 180 tons each, independently of shore facilities. While the principal movement of cargo was from Australia's East Coast, an appreciable quantity of earthmoving equipment and construction material was moved to Bougainville from West Australia. Some shipments were quite unique in their composition and complexity and included the largest cargo of grinding balls ever shipped in bulk from the Great Lakes, and crushers from Japan and Australia. Another unusual cargo transported consisted of 41 Euclid Dumptrucks each of 105 tons capacity, also from the Great Lakes.

As the labour force built up in Bougainville, so the demand for more refrigerated supplies increased considerably. To help cope with this need the refrigerated vessel "KEMPHAAN" was chartered in October 1969, eventually completing 18 months employment.

Since the hectic activity during development lessened, charter shipping requirements for equipment into Bougainville have of course been somewhat reduced. However, the volume of goods still needed to maintain the operation is considerable, as a result of which two charter vessels were engaged for this purpose in 1971, and will continue over the next few years, moving cargoes between Australia and Bougainville. These two ships are German flag vessels of modern design suitable for general cargoes, bulk cargoes and containers, and have the special ability to take refrigerated containers which 'plug in' to the ships' power during the voyage from Australia.

We are proud to have been associated with Bougainville Copper Limited in such an eminently successful operation. For Elder-Austral Chartering Co., it was a classic exercise in the use of shipping skills available in Australia by Companies with the rare ability to grasp the essentials of a difficult shipping requirement and to act swiftly.

A First in Logistic Support

CONSOLIDATION AND FREIGHT FORWARDING

Rudders (a division of TNT Management Pty. Limited)
Custom Brokers & International Freight Forwarders.

In April 1972, TNT, the largest freight forwarding organisation in the Southern Hemisphere, was appointed by Bougainville Copper Pty. Ltd. to provide a logistic support programme for the Bougainville Island Copper project.

This service was assigned to Rudders, the international Freight Forwarding Division of the TNT Group with 77 years of experience in all phases of documentation, transport, warehousing and distribution.

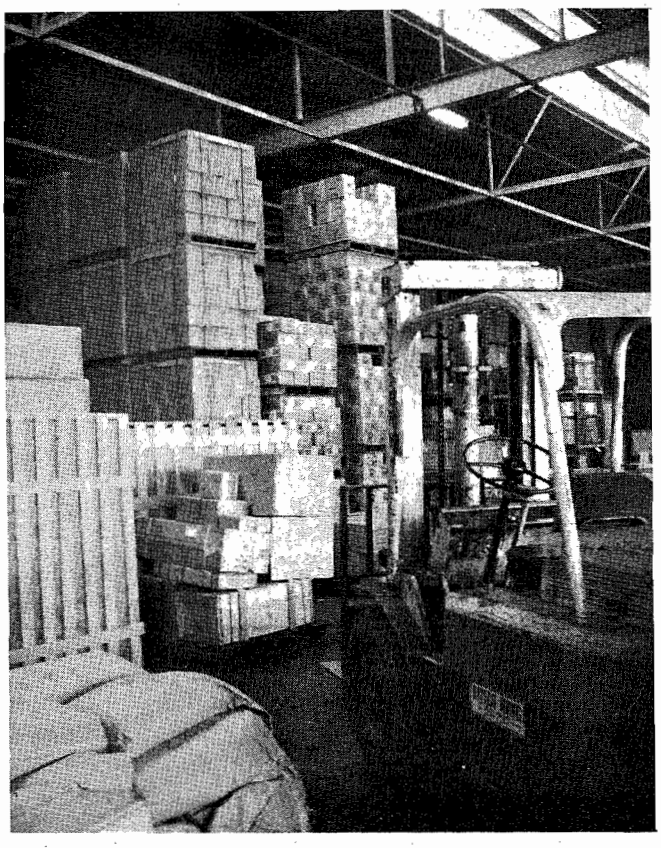
The programme involves the movement of over 60,000 tons of freight per annum from Australian manufacturers located in Brisbane, Sydney and Melbourne to Bougainville. Rudders are responsible for the consolidation of this freight to meet the fortnightly shipping schedules and specific additional services supplied cover stevedoring, ships agency, local transportation, intra and interstate freight forwarding services. Further, a complete customs clearance documentation service is provided in accordance with the P.N.G. legislation.

In addition, the company has offices on all major airports and is fully geared to handle emergency and perishable air cargo to the project. This is a 24 hour—7 day a week service.

The necessary management expertise between these various services and Bougainville Copper personnel has been provided by the establishment of Project Divisions in all States and this has resulted in Bougainville Copper personnel dealing with the 'one company' only – a first in logistic support programmes for major projects.

Rudders have established in major departure ports for B.C.L's. two charter vessels, "Wesser Carrier" and "Pacific", Bougainville Wharehouses, into which are received, at suppliers convenience, all goods ordered by B.C.L. for shipment by the next sailing.

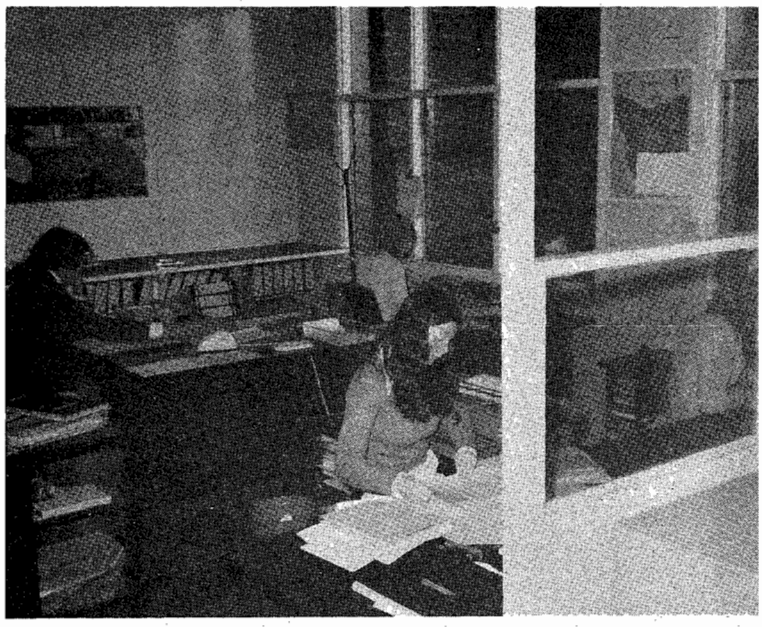
The goods, after having been checked against purchase orders, are prepared by Rudders for loose shipment, dry containerisation or refrigerated containerisation, as may be specified, and a daily report of goods received is supplied to B.C.L. At an appropriate time prior to Cargo Cut-off Date, all goods are despatched by Rudders to wharf with all necessary documentation.



A variety of goods stored in the Melbourne "Bougainville Warehouse", prior to containerisation or loose shipment.

A section of Rudder's "Bougainville Warehouse" at Melbourne
A load of cartons arrives for consolidation

Loading "loose" cargo on M.V. "Wiser Carrier"
Documentation at Rudder's "Bougainville Warehouse" office in Melbourne



Containerisation

Chep Packaging & Container Division
Sydney and Melbourne, Australia.

Containerisation of goods for transport by road, rail, air and sea has won almost universal acceptance since its relatively recent introduction. Standardisation of container sizes and the development of special handling and conveying equipment has added to the more obvious advantages of the system, which include more economical factory packaging of goods for transport, protection from the elements and from damage or pilfering, speedier and more economical bulk handling, temporary warehousing in containers in areas that are congested or where adequate storage facilities are lacking and in the case of perishable goods, door to door transport at specified and rigidly controlled temperatures.

The Bougainville operation, requiring the shipment of tons of goods from Australian ports annually, uses two continuous charter vessels which were designed for 'Container shipping'. Whilst they do, of course, carry loose cargo, the majority of their freight is containerised.

CHEP Packaging and Container Division are currently supplying to the freight forwarders, Rudders, 300 'Dry' containers and 60 'Reefers' (refrigerated containers) each of nominal 20 long tons rating. This latter quantity represents the largest refrigerated container operation out of Australia.

CHEP containers are manufactured in Melbourne by Freighter Industries Ltd. and the specifications of the refrigerated unit are as follows:

20' x 8' x 8'6" REFRIGERATED CONTAINER ALUMINIUM/STEEL CONSTRUCTION FOR THE CARRIAGE OF REFRIGERATED CARGO.

DIMENSIONS (External)
Length — 19'10½"
Width — 8'0"
Height — 8'6"

DIMENSIONS (Internal)
Length — 17'9" (with integral refrigeration plant)
Width — 7'4"
Height — 7'2-7/8"

CUBIC CAPACITY
945 cubic feet

GROSS WEIGHT RATING
(20 long tons)

CONTAINER HEAT LEAKAGE
50 B.T.U./hr/°F.

REAR DOOR OPENING
88" wide x 80¾" height.

BASE FRAME
Welded assembly of rolled steel sections. 'C' section crossmembers on 16" centres.

END FRAMES
Austen 50 steel, loop frames, suitable for six-high stacking.

FRONT & SIDE PANELS
.048" satin finish aluminium alloy 5052—H36.

•SIDE POSTS
5" x 1¼" top-hat extruded aluminium 6061—T6 pillars on 24" centres.

FRONT POSTS
'Z' section, high tensile steel pillars on 12" centres.

ROOF SHEETS
One-piece, .048" aluminium 3003—H14, bonded to roof bows. All rivetting along sides to exterior.

TOP SIDE RAIL
Inset design extruded aluminium 6061—T6 section.

ROOF BOWS
Top-hat extruded aluminium 6061—T6 sections on 24" centres.

LININGS
Each wall, roof and doors, lined with corrugated 20 gauge, pre-painted aluminium alloy 5052—H34 panelling.

On the side walls, corrugations vertical, and on the roof longitudinal, to maximise air circulation.

The linings are fastened to rigid P.V.C. angle extrusions, set into the insulation, and are fastened to the posts.

BATTENS
P.V.C. angle type extrusions.

FLOOR
2" deep extruded aluminium alloy airflow floor, with extruded perimeter side gutters.

INSULATION
3" thick slab-stock polyurethane (density of 2.0 lbs./ft.K= .15) on all walls, and 2" in doors.

REAR DOORS
Sandwich construction of 1" alumply, insulation and linings.

DOOR SEALS
Each door is bordered by an outer flexible vinyl dust seal and an inner foam-filled neoprene heat seal.

LOCKING MECHANISM
Each door is fitted with two lines of "Bloxwich" model BE2500 locking mechanism. All fittings hot dip galvanised.

PROTECTION PLATES
Triangular steel plates at each top corner for protection against lifting equipment.

FORK POCKETS
Two sets of fork pockets are incorporated in the base, viz..

A "reefer" (refrigerated container) after being held under refrigeration at Rudders Melbourne "Bougainville Warehouse" is transported to shipside for loading aboard for re-connection to refrigeration point.

(i) 18" x 5" internal on 78" centres.
(ii) 12" x 3" internal on 33" centres.

TIMBER TREATMENT
All timber and plywood is treated in accordance with the requirements of the Commonwealth Department of Health.

PAINTING
All external steelwork is grit blasted and painted with one coat of zinc rich paint and one coat of chlorinated rubber enamel.

SIGNWRITING
The containers are signwritten with the CHEP insignia, serial numbers, ratings, etc., in accordance with I.S.O. and Lloyds requirements. Data plates affixed to the rear frame.

DOCUMENT HOLDER
A document holder is affixed to the rear door.

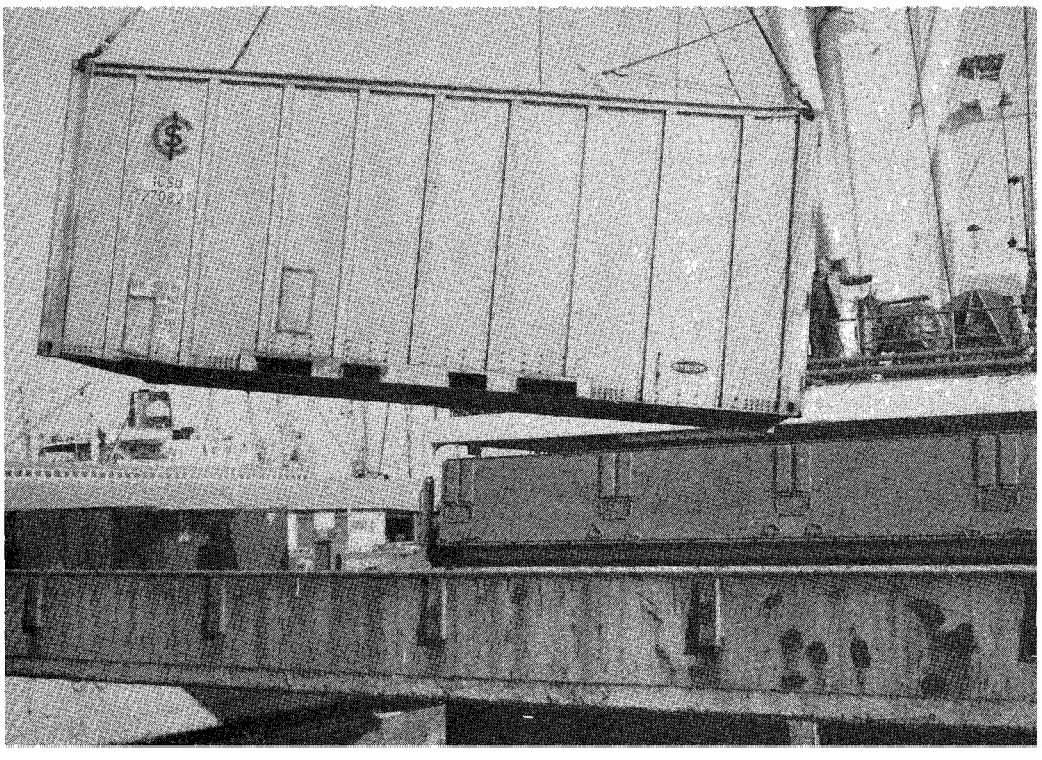
REFRIGERATION
The front frames are designed to suit the refrigeration plant.

The units are delivered to Luke Systems, who manufacture and instal the refrigeration unit.

The Luke Systems Division has specialised in the transport refrigeration field for many years and is one of the relatively few companies in the world engaged in the design and manufacture of Refrigerated Systems for Containers.

Both Luke Systems and Freighter Industries Limited have Lloyd's approved factories and all units are built under Lloyd's supervision. Luke Systems has a Lloyd's approved laboratory facility which is used for heat leakage and refrigeration system performance data compilation. Freighter Industries Limited have all the necessary equipment to fully test containers for stacking, racking strength, etc. including taint testing facilities.

A "reefer" (refrigerated container) being loaded aboard the M.V. "Wesser Carrier" at Melbourne.



The N.H. Fisher Report 1936

GEOLOGICAL REPORT
KUPEI GOLDFIELD, BOUGAINVILLE, T.N.G.

Dr. N.H. Fisher,
Director,
Bureau of Mineral Resources, Geology & Geophysics,
Canberra, Australia.

We are grateful to Dr. N.H. Fisher for supplying this hitherto unpublished (except in "Rabaul Times") report on the Kupei Goldfield. Dr. Fisher's report was written immediately after he visited the area in March—April 1936. He was accompanied by Mr. L.C. Noakes, then Assistant Geologist, Territory of New Guinea, now Assistant Director – Mineral Resources, of the Bureau of Mineral Resources.

Location, Transport, etc.

This report deals mainly with the three known gold-bearing areas in the Kieta Goldfield, namely Kupei, Pumkuna and Moroni, and the adjacent country. The time of examination was unfortunately limited to two weeks, so that detailed work was confined to these three areas, and a wider investigation of the geology of the district, except as revealed by the roads and streams between these areas and the coast, was not possible.

Kupei is situated about seven miles S.S.W. from the beach at Arawa Bay, which is 5 miles west of Kieta. It is 3,600 feet above sea-level, near the crest of the Crown Prince Range which, though much closer to the Kieta side of the island, forms the divide between waters flowing north-east and those flowing south-west to Empress Augusta Bay. On the Kupei property the range is 4,000 feet above sea-level, but it rises to considerably greater heights elsewhere.

The topography of the inland portion of Bougainville is exceedingly rugged. Mountains rise to a maximum height of 10,000 feet and in general the country consists of streams occupying steep-sided gorges between mountain ridges. In many places, some near Kupei, sharp peaks or knobs occur with nearly vertical bare rock faces. The mountainous country is bordered by a coastal flat usually a few miles wide on the north-east side of the island, while on the south-west, at Empress Augusta Bay, this coastal flat comprises an extremely large tract of country, which is separated from the Moroni, Pumkuna area by a series of river gorges. In the upper reaches of the Kavarong, a reasonable extent of river flats and terraces is found. Climate at Kupei is generally warm in the morning, wet in afternoon, cool at night. Average annual rainfall at Kieta is 125 inches, at Kupei probably rather more. Rainfall is distributed evenly throughout the year.

Moroni is 3 miles W.S.W. of Kupei and Pumkuna a similar distance S.S.W., both on the south-western fall of the range and at an elevation approximately 2,900 feet above sea level. Climate on this side is similar to Kupei but less extreme.

Water throughout the district is generally plentiful, with the streams falling rapidly in their upper portions. The supply at Kupei is naturally limited by its close proximity to the top of the range. Kupei creek which flows through the lease has normally less than one cusec of water. Further down, however, where the volume has increased slightly, it passes over a waterfall which it is considered could be adapted to work a small electric power generating plant.

Pumkuna is particularly well served by a stream carrying upwards of 4 cusecs flowing right through the property.

Timber on the coastal fall of the range is mostly small, with thick secondary growth. It is apparent that the greater portion of this area has been used at some time or other in the past for native gardens and the trees have not since had time to regain their normal stature. Near the top of the range, however, and on most of the western fall, virgin forest is found, with a plentiful supply of trees of all sizes and comparatively little undergrowth.

Transport to the field is effected entirely by native labour and pieces of machinery weighing up to 3¼ tons have been brought in by this means, after months of arduous work. Cargo is landed on the beach at Arawa Bay, where anchorage exists for ships but no wharf for unloading. Road

construction is in progress and a rough motor road should soon be available almost as far as Kaino, elevation 800 feet, more than half-way to Kupei Mine. From there to Kupei village, the track is even now probably adequate for mule traffic. The last part of the road, from here up to Kupei, climbs very steeply and is merely a footpath winding up the side of the mountain. With comparatively little work, however, this could be made into a mule track, and this form of transport is strongly to be recommended. Carrying by boys is becoming increasingly more expensive, for although casual labour is fairly abundant, it is practically impossible to get boys to carry cargo from the beach at Arawa Bay to Kupei for less than 2/-, or about ½d. per pound, and carrying by indentured labourers is little, if any, cheaper. Similar advantages would accompany the construction of a mule track to Pumkuna and Moroni, which are at present (April 1936) connected with Kupei by a rough bushroad.

History

Gold was first discovered at Kupei by J. Comb, who was granted a Reward Prospecting Claim. 660 x 120 metres, at the beginning of 1930.

The Kieta Goldfield was proclaimed in May of the same year.

In December, 1932, the Tapu Reward Claim at Moroni was pegged by C.W.M. Evans, who had prospected up to this area from Empress Augusta Bay.

The Pumkuna Reward Claim was granted in February, 1934 to G.A. Myers. Other claims and leases have been applied for at various times, but most of them have been abandoned. The following list comprises all the mining tenements at present in force on the field —

Number	Name	Present Owner	Area	Date of Grant	Location
P.C. No. 1.	Kupei Claim	Bougainville Syndicate	7.92 ha	21.2.30	Kupei
P.C. No. 22.	Tapu Reward	C.W.M. Evans	7.92 ha	19.12.32	Moroni
P.C. No. 24	Pumkuna Reward	Bougainville Syndicate	7.92 ha	27.2.34	Pumkuna
GML. No. 4	Kupei No. 1	"	18.9 ha	31.8.35	Kupei
GML. No. 5	Kupei No. 2	"	18.55 ha	31.8.35	Kupei
GML. No. 6	Pumkuna No. 3.	"	17.50 ha	24.8.35	Pumkuna
GML. No. 7	Pumkuna No. 4.	"	10.00 ha	31.8.35	Pumkuna
GML. No. 8	Pumkuna No. 5.	"	10.00 ha	31.8.35	Pumkuna
GML. No. 10	Ejel	J.H. Ellis P.A. Logan C.W.M. Evans J.M. Joyes	4.00 ha	31.8.35	Pumkuna
GML. No. 17	Said to be No. 1	W.P. Sergeyeff	6.60 ha	15.2.36	Pumkuna

(The Bougainville Syndicate was owned (or at least financed) by the late Archbishop Duhig of Brisbane).

In May, 1931, the Kupei Reward Claim was transferred to Bougainville Gold Options N.L., who carried out development work in the shape of drives and crosscuts. Later, however, the property reverted to Mr. Comb, who installed in 1934 a two stamp battery run by a Pelton wheel. In March, 1935, the claim was sold to the Bougainville Syndicate, who have since been proceeding with the development and testing of the lode. The two head battery, operated by an oil engine, has been working on ore from slip material beneath the lode, and has produced gold to the value of nearly £1,000. At present a five head stamp battery is being constructed and it is hoped to crush 25 to 30 tons per day when it is completed.

The pegging of the Moroni reward claim was the result of a long period of prospecting by Mr. Evans, and two gold mining leases were applied for in the same area shortly afterwards. These leases — known as Webel No. 1 and No. 2 — were tested for alluvial gold by southern mining engineers but the company was unable to proceed with them. A small amount of alluvial gold has been won from the reward claim.

The Pumkuna lode was found as a result of attempts to work alluvial in the creek lower down. A small amount of costeaning work has been done and a short drive put in on the lode at creek level. A small two head battery worked by a water wheel has crushed a few tons of ore. This claim was also sold to the Bougainville Syndicate, who subsequently pegged gold mining leases adjoining.

An area of 1280 acres is now being taken up on behalf of Oriomo Exploration Ltd. on the Kavarong River near Moroni, as an exclusive prospecting licence, with a view to testing for alluvial gold.

General Geology

The only rocks observed in the Kupei district were porphyrites and a series of derived agglomerates. The porphyry is exposed only where the overlying agglomerates have been removed by erosion and most of the north-eastern fall from Kupei consists of agglomerates, often forming bare upstanding crags. At Kupei itself, the porphyry is exposed and also along the Kavarong River on the south-western side and in Pumkuna and Corona Creeks, the lower portions at least. Higher up, and along the ridges, the agglomerate is found overlying the porphyry, which appears to grade up continuously into the agglomerate. A gradual change takes place from porphyry with a few included rock fragments to a coarse agglomerate which higher up becomes much finer, with gritty and tuffaceous matter filling the interstices. The agglomerate is very hard and compact and often the individual fragments are so merged with one another that it is difficult to define their boundaries. The constituents of the agglomerate are all igneous in origin, mainly corresponding in composition to the underlying porphyry, but containing also doleritic and andesitic types which were not observed in situ.

The character of the porphyry itself shows a wide range of local variations but the alteration from one phase to another, though often fairly abrupt, is always continuous. The normal porphyry is a finegrained rock with a light grey to greyish-green ground mass, numerous small crystals of plagioclose and elongated hornblende crystals in lesser quantities, though often prominent. Where mineralisation has occurred there is usually present an acidic phase which looks like a finegrained sheared granite. The ferromagnesian mineral in this type, often occuring as large phenocrysts, shows a subparallel orientation. Felspars, mainly plagioclose, are abundant, while magnetite, pyrites and a yellowish-green mineral, probably epidote, in veins and clusters, are also present. The association of this rock with the presence of mineralisation in at least three gold-bearing areas in the district suggests that it may form a useful guide to likely areas in future prospecting work. Often adjacent to this type and grading continuously into it over a short distance is a dark fine-grained silicified form, with small felspar crystals, augite and hornblende irregularly distributed, magnetite, pyrites, epidote and occasional dark inclusions.

The nature of the porphyry and the variations in its composition suggest that it is part of a large mass which has been intruded near the surface and that accompanying or subsequent explosive activity has been responsible for the formation of the agglomerates, part of which at least were laid down under water. Many of the constituent pebbles and boulders are rounded and the upper portions have often a definite sedimentary aspect. At Kieta itself a tuffaceous conglomerate occurs in association with a porphyritic augite andesite, and these rocks have a rather later appearance.

The porphyry wherever exposed is frequently faulted, the faults often being accompanied by small intrusions of a later acidic porphyry which is silicified and strongly mineralised with pyrites and which sometimes carries small amounts of gold.

Economic Geology – Kupei
Ore Geology

The Kupei lode consists of a mass of closely set gold-bearing quartz stringers in mineralised copper-bearing porphyry. The surface outcrop of the lode occupies an area of 1500 square metres (.35 acre) the maximum length being 70 metres (231 feet) in a more or less north south direction and maximum width 32 metres (106 feet) from east to west.

On the No. 1 level, over 100 feet below the highest outcrop, the width of the lode is much reduced from the surface thickness, giving here a horizontal width of only 14 metres (46 feet). The ground surface slopes steeply from the western side of the outcrop down to No. 1 level, so that an oblique section of the lode is exposed. The area of the lode on No. 1 level has been reconstructed from underground work and surface mapping and occupies only 268 sq. metres, so it will readily be seen how the extent of the mineralised area has diminished.

No. 2 level was driven at a slightly lower elevation in an area where the mineralisation is weak and failed to cut the lode, though mineralised stone is beginning to show up in the end of the drive.

No. 3 drive (37.5 metres (124 feet) below No. 1), has apparently passed entirely beneath the higher grade ore, as it reveals only an indeterminate area of the low-grade mineralisation typical of the area surrounding the lode, as well as a few thin mineralised stringers along faults.

Sections across and along the lode have been constructed from the data available to show the approximate extent of what will probably be commercial ore. These sections and the plans show the lode as a wide irregular lens on the surface which rapidly diminishes in size with depth and plays out somewhere between Nos. 1 and 3 levels. The general shape of the lode, then, approximates to an elliptical inverted cone, which has been cut obliquely by the present surface of the hillside. It is readily seen that this shape of orebody is ideal for mining by open cut or glory-hold methods and mining costs should be remarkably low.

The quartz veins in what is regarded as lode material consist of two main series, roughly vertical and horizontal respectively. The vertical veins are the larger and stronger series, up to three inches in width, but generally about an inch, set a few inches apart, and roughly parallel to each other. Their strike more or less corresponds to the margin of the lode at any particular place, varying in direction from 100° to 190°. They bifurcate and pinch out and join each other again irregularly, or are connected by oblique smaller veins, but the proportion of quartz in most places is fairly consistent. The more or less horizontal series of veins are smaller, ½ inch width, more irregular and less consistent, and tending to form a network between the main vertical angles. Occasionally other veins cut across the general direction of these two series. At one place on the No. 1 level, a thickness of several feet of almost solid quartz occurs.

The quartz veins occupy a series of fractures which may have been caused by some compressive or tensional stress or possibly by shrinkage due to cooling of the porphyry mass.

The most prominent minerals in the quartz are bornite and chalcopyrite, both sulphides of copper and iron, distributed evenly in small blobs and patches. Pyrites, galena and zinc blende occur in appreciable quantities, though irregularly. Impure malachite, green copper carbonate, from the oxidation of the copper sulphides is exceedingly abundant. Magnetite is plentiful in the concentrates obtained from the mill but probably comes mainly from the country rock. The porphyry between the quartz veins is also mineralised, usually by copper minerals.

Fineness of the gold in the bullion sent away from the mine has varied from 830 to 896 parts per 1000 with a silver content of 65 to 175 parts per 1000. High comparative silver values in samples of ore assayed show that silver exists in other minerals as well as alloyed with the gold.

Outside the lode the strength of the mineralisation diminishes fairly sharply and the lode is surrounded by an indefinite zone of much weaker mineralisation, gradually passing outwards into unmineralised porphyry. This low grade area consists of silicified and copper stained porphyry carrying irregular widely spaced small quartz stringers, ½ inch in width, and the gold content is not considered to be nearly sufficient to warrant treatment. Outside this area again the porphyry is hard and silicified, and carries only a very occasional quartz vein or copper stain.

A structure typical of the quartz veins is the presence of a narrow streak of mineralisation, usually bornite, less than 1/8 inch wide along the centre, showing that the quartz vein after its formation has opened up again along the centre to allow the later copper mineralisation to take place.

The lode is cut by several faults striking more or less east west and dipping nearly vertically or slightly to the south. They usually carry mineralised clayey or pyritic mineralised material. All seem later than the ore and one fault at the south side of No. 2 drive displaces the lode a few metres.

Tonnage and Grade of Ore

An approximate estimate of the amount of ore was arrived at from the areas on the surface and on the No. 1level and allowing for the present contour of the ground. A figure of 20,777 cubic yards is indicated, which, allowing 15 cubic feet per ton for the ore in situ, gives a total tonnage of 37,400.

Information on the grade of the ore is limited, particularly with regard to the copper content. Three samples were taken across the lode in No. 1 level in order to get a check of the value, but results are not yet available.

Sampling of this level by W.P. Sergeyeff gave an average value across the lode of 12 dwts. Au. per ton and the total average of all samples taken on the level was just over 10 dwts.

In January, 1930, Mr. E.P. Holmes brought back some specimens of ore from the lode which were sent for assay to the New South Wales Mines Department. The sample was described as quartz with yellow sulphide and graan carbonate of copper, and returned 15.25 dwts Au. per ton, 28.28 dwts Ag. per ton and 4.56% copper.

1100 lb. of copper-gold were sent south by J. Comb to be assayed by O.T. Lempriere & Co., but contained only 0.95% Cu., 0.8 dwts. Au. and 4 dwts Ag. per ton. However, it is not known from which part of the mine this was taken.

Perhaps the most reliable guide to values is the results which have been obtained from the ore put through the two head battery. Up to 14.9.35, 127 tons had yielded 60 ozs. 2 dwts. retorted bullion giving 39.41 ozs. fine gold, while later crushings of 88 tons gave 30 ozs. 17 dwts. bullion. The indicated recoverable average grade from the total of this ore is thus between five and six dwts. per ton, not allowing for the gold in the concentrates. Calculated recovery over the plates up to the present has not been better than 70% and it is anticipated that this figure will be improved upon when the new mill gets into operation.

Method of Treatment

The two head battery, operated by a 4-6 h.p. oil engine, has put through up to six tons every twentyfour hours. The ore has been selected from the dump of ore and rock beneath the lode, railed a short distance and tipped down a bank to a dump near the mill. It is then carted in boxes to a breaking shed where it is broken to 3 inch pieces by boys with sledge hammers and then fed to the stamps. Treatment consists of amalgamation with mercury in the battery and in wells, followed by amalgamation plates, further mercury wells, a corduroy table and two boxes fitted with corduroy and ripples. A certain proportion of the gold is not amenable to amalgamation with mercury and most of this has been saved in the concentrates from the corduroy and the boxes. This reluctance to amalgamate is apparently due to the presence of a surface film on the gold, which is said to be destroyed by roasting.

The new five head battery now under construction will be run by a 35 h.p. engine and is expected to crush 25 to 30 tons a day. In addition to amalgamation on plates the ore will be treated by passing over a Wilfley table and also through an amalgamating barrel.

Pumkuna

The Pumkuna lode also occurs in porphyry which is well exposed over the steep cleared hillside forming the right bank of Pumkuna Creek. The origin of the ore and the associations are similar to Kupei, but the type of lode is different. The main Pumkuna lode is a fissure vein fairly consistent in thickness and composition over an exposed length of 70 metres (231 feet). Width varies up to 44 inches and averages between 20 and 24 inches. Dip is from 40 to 65 degrees to the north east and the direction of the lode on the surface 57° west of north. The true strike of the lode on a horizontal plane however is from 30 to 50 degrees west of north.

The lode material is principally quartz with a certain amount of copper minerals throughout, and local strong developments of chalcopyrite, hornite, and malachite, at two places particularly, one near the east end of the outcrop, the other near the west end. Molybdenite in small silver-grey flakes is found in patches associated with the copper minerals and pyrites and magnetite are also present.

A bulk sample was obtained by sampling the reef at frequent and regular intervals, dollying and quartering. The gold, silver and copper content will be made available when results are to hand.

In addition numerous samples, taken along the reef and dollied, suggested an average gold content of about 15 dwts. and 1 oz. per ton. Mineralisation is consistent but the gold content increases slightly at the eastern end. The average of 7 samples taken by W.P. Sergeyeff was almost exactly 1 oz. Au. per ton.

24 ozs. of gold have been declared from Pumkuna, ranging in fineness from 904 to 946, but averaging about 935, and in silver content from 42 to 82 parts per thousand.

The length of the reef at present exposed practically continuously along the hillside is 70 metres (231 feet). At both ends, however, the reef is still showing up strongly with no visible signs of pinching out. The eastern end passes under Pumkuna Creek, and is hidden by a considerable thickness of river wash and alluvial terraces, while the western end is masked by slip ground and overburden. Even on the exposed length of 230 feet, taking the average width at 20 inches and allowing 15 cubic feet per ton of ore in situ, about 25 tons of ore are available per foot of depth, or, assuming a recoverable grade of 15 dwts. per ton 18.75 ounces (£150) per foot of depth. Possible continuations of the lode at either or both ends will most likely increase these figures and it is reasonable to assume the lode will persist for at least a few hundred feet in depth. It should be noted, however, that assuming the dip remains constant, parts of the lode will pass at a depth varying from 250 feet to 400 feet into G.M.L. No. 10, known as the "Ejel".

In addition to the main reef several smaller lodes occur scattered about the hillside and the adjacent country. They are mostly small, from 3 to 9 inches in width, and the principal ones are roughly parallel to the main lode in strike and the dips, though in the same direction, are usually slightly steeper – about 70°. In type and composition they are exactly similar to the main lode; consisting of quartz veins along fissures with local strong development of copper minerals. The gold content of these veins as indicated by dollying samples is probably rather less than the main lode and this circumstance, combined with their small size, will prohibit their being extensively worked.

It is obvious then that the principal direction of shearing and fissuring, which has resulted in the formation of lode channels for the later mineralising solutions, is in a N.W. –S.E. direction. Another lesser series of nearly vertical faults and fissures, some carrying mineralised material, occurs more or less at right angles to the main series. At one place near the west end of the main lode a small vertical gold bearing reef, 12 inches wide, meets the lode at right angles. Some of these faults are later than the ore and in one place the lode is displaced a few feet.

A short drive has also been put in on the bank of a small tributary which comes into Pumkuna Creek from the left just below the principal workings, apparently on a gold-bearing reef. The drive has fallen in, however, and the stone could not be inspected in situ.

The porphyry at Pumkuna is undoubtedly continuous with that at Kupei, and shows the same interesting variation in composition in the vicinity of the mineralised area. Most of the porphyry on the hillside is the dark fine-grained more basic variety, but it occasionally gives way to the lighter coloured acidic phase, which occurs in irregular patches. The country rock here, too, away from the lode, contains as at Kupei and elsewhere, an occasional small quartz stringer with often a thin central vein or bornite and chalcopyrites, as well as a few irregular copper strains.

On the whole, then, the Pumkuna lode is of higher grade than the Kupei lode, but it will be much more expensive to work. Its average width is less than the minimum stoping width and a certain amount of country rock will have to be broken with the ore. Moreover, the ore will all have to be hoisted to the surface, and not mined by gravity methods as at Kupei. The problem of underground water, too, may be considerable, owing to the fractures which traverse the porphyry forming channels for the circulation of surface waters, especially at the eastern end of the lode where it lies under the water logged gravels and terraces of Pumkuna Creek.

On the other hand, water power is more readily available here than at Kupei.

Moroni

On the Tapu Reward Claim a large area exists which carries gold in surface prospects varying from good tails in a small dish down to very fine colours. At the place where the best results are obtained in the surface material, Mr. Evans has exposed a rock face for several hundred feet up to the top of the Mountain and gold can be obtained in small quantities on the surface almost to the top. The rock exposed is porphyry at the bottom which changes continuously over a distance of several feet into the overlying agglomerate.

The top portion of the porphyry contains large included boulders, and alters continuously into a coarse agglomerate succeeded by a finer material. The top of the porphyry and the bottom of the agglomerate both for a considerable distance below and above the transition are silicified and strongly mineralised by pyrites and a little quartz in

minute veins and vugs. Here on the surface the best dish prospects are obtained, though it has not yet been possible to obtain gold from dollied specimens of the actual stone. Higher up the hillside the agglomerate is similarly mineralised in irregular patches. There seems little doubt that the gold is associated with this mineralisation, but the only way to test its possibilities would be to trench the surface and sample and assay the material obtained. Gold is mostly fine though coarse pieces have been found. A few rock specimens showing gold have been obtained, mostly in agglomerate, and in one case the gold is actually in association with crystalline cubes of pyrites. Bornite and zinc blende were also observed. A small amount of alluvial gold has been won from the creek below, of a fineness of 824.

Boulders of porphyry, showing rich gold veins, have also been found in the adjacent creeks. These, however, are similar in nature to the porphyry near the mineralised areas at Kupei and Pumkuna, and the gold is contained in small quartz veins in the rock. Though impressive in appearance, the economic significance of this gold is not great for they undoubtedly come, not from an appreciable lode formation, but from a small chance vein in the country rock, such as might be found anywhere over a large area of the porphyry.

Considerable faulting has occurred in this area and many of the fault fissures are filled with a silicified porphyritic material carrying abundant pyrites and often a little gold. This is a type of occurrence which is common throughout the district, though none has yet been found to be of workable grade.

Alluvial

Since most of the eastern fall of the Crown Prince Range consists of agglomerate which on the whole is apparently not goldbearing, little chance exists of working alluvial gold on this side. On the western fall, however, prospects are slightly better. Many of the streams are known to carry gold and small amounts have been recovered at times in the past. Extensive flats and terraces occur along the Kavarong River. Small amounts of gold are obtained in dish prospects. In the higher portion of the river and in the tributary streams, such as Corana and Pumkuna Creek, the abundance of huge boulders would make working difficult. Along the Kavarong, however, near its junction with the Corana Creek, where an exclusive prospecting licence has recently been pegged, is a fairly extensive series of river flats and terraces with comparatively few large boulders. Values appear to be low, only one or two colours, generally very fine, being obtainable in most dishes.

The flats at the bottom of Corana Creek, then pegged as Webel No. 2 lease, but since abandoned, were tested in 1934 by southern interests. Eighteen test holes were put down to an average depth of eight feet, though only 50% of them found bottom. The average value was given as 8d. per yard, gold at £4.0.0 an ounce, and the fineness of the gold as 842. As these flats were formed by a creek shedding from a definitely known gold bearing area, the chances of payable gold along the flats of the Kavarong, the material for which is contributed from a much wider area, much of it barren, cannot be regarded as hopeful.

Conclusion

The Kupei lode is a low-grade proposition of limited extent but cheap mining costs. The amount of commercial ore in the present exposed ore body could be defined fairly accurately by surface sampling, but mill recoveries and underground samples suggest that at least 5 dwts. gold per ton should be recovered, and that the life of the mine should be at least five years. The chances of this area becoming a large producer are not great but depend on the possible location of an extension of the present ore body or a similar deposit in depth. So that it may be desirable at a later stage to continue underground exploration by driving or by diamond drilling if extension of the present lower drives gives any indication of further ore.

The Pumkuna lode is a more normal type of occurrence, a narrow but persistent fissure vein. Its higher grade is offset by the fact that it will be much more expensive to work and its value depends on its continuation in depth and along the strike. There is quite a good chance that further similar lodes of this type may be located by future prospecting. The small irregular quartz veins through the porphyry similar to those in the vicinity of the Kupei and the Pumkuna lodes, are found in places wherever the porphyry is exposed throughout the district.

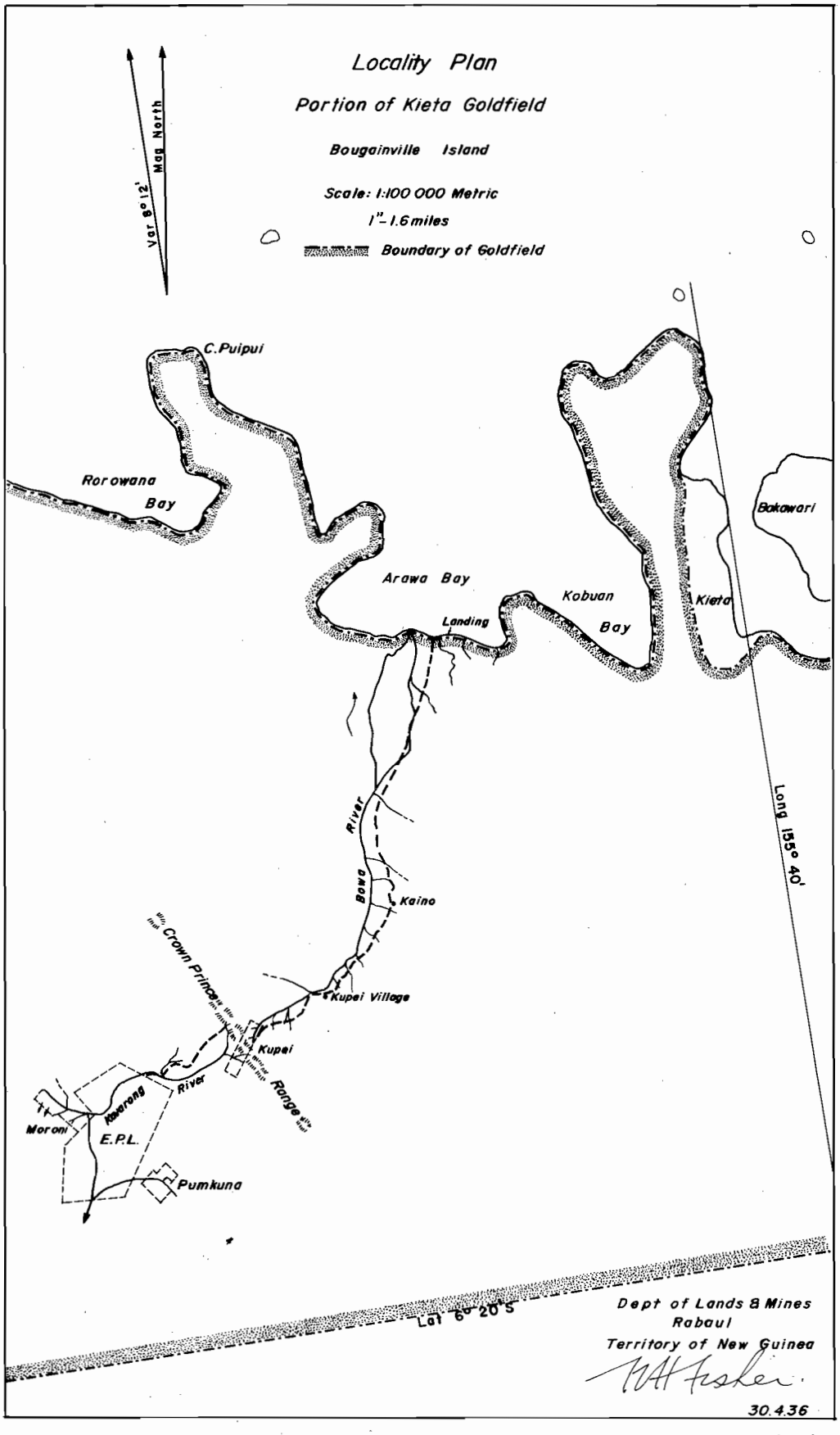
If conditions should occur to localise this mineralisation into a single fissure lode, as at Pumkuna, or any other form of concentration, payable lodes are likely to exist. Consequently, though prospecting will be difficult, it is not considered impossible that a prospector with experience and capital should by systematic work locate small new lodes of the Pumkuna type.

In view of the proved existence of values by Kupei and Pumkuna, and the possibility of opening up new country, it is strongly recommended that all assistance possible be given towards the construction at least of a mule track connecting Moroni, Pumkuna and Kupei with the coast.

SUMMARY

1. Mineralised area in rugged country. elevation 2,500 to 4,000 feet, seven to twelve miles from the coast, transport by natives only.
2. Country consists of felspar-hornblende porphyry overlain by agglomerate.
3. Kupei lode consisting of mass of quartz veins carrying gold and copper in mineralised porphyry. Grade of ore low, mining costs very cheap, limited tonnage.
4. Pumkuna fissure lode, quartz carrying gold and copper, 20 inches wide, at least 70 metres (231 feet) in length, dip to north-east at 40 to 65 degrees, value possibly 15 dwts. to 1 oz. Au. per ton.
5. Large area at Moroni of mineralised porphyry and agglomerate associated with gold on surface. No definite lode formation.
6. Alluvial flats and terraces mostly too low grade to be worked.
7. Possibility of new finds being made.
8. Assistance recommended in opening up country by roads and mule tracks.

N.H. Fisher,
Geologist.


Locality Plan
Portion of Kieta Goldfield
Bougainville Island
Scale: 1:100 000 Metric
1"-1.6 miles
Boundary of Goldfield
Var 8°12' Mag North
C. Puipui
Rorowana Bay
Arawa Bay
Kobuan Bay
Landing
Kieta
Bokowari
Long 155° 40'
Bova River
Kaino
Crown Prince Range
Kupei Village
Kupei
Kaverong River
Moroni
E.P.L.
Pumkuna
Lat 6° 20' S
Dept of Lands & Mines
Rabaul
Territory of New Guinea
30.4.36

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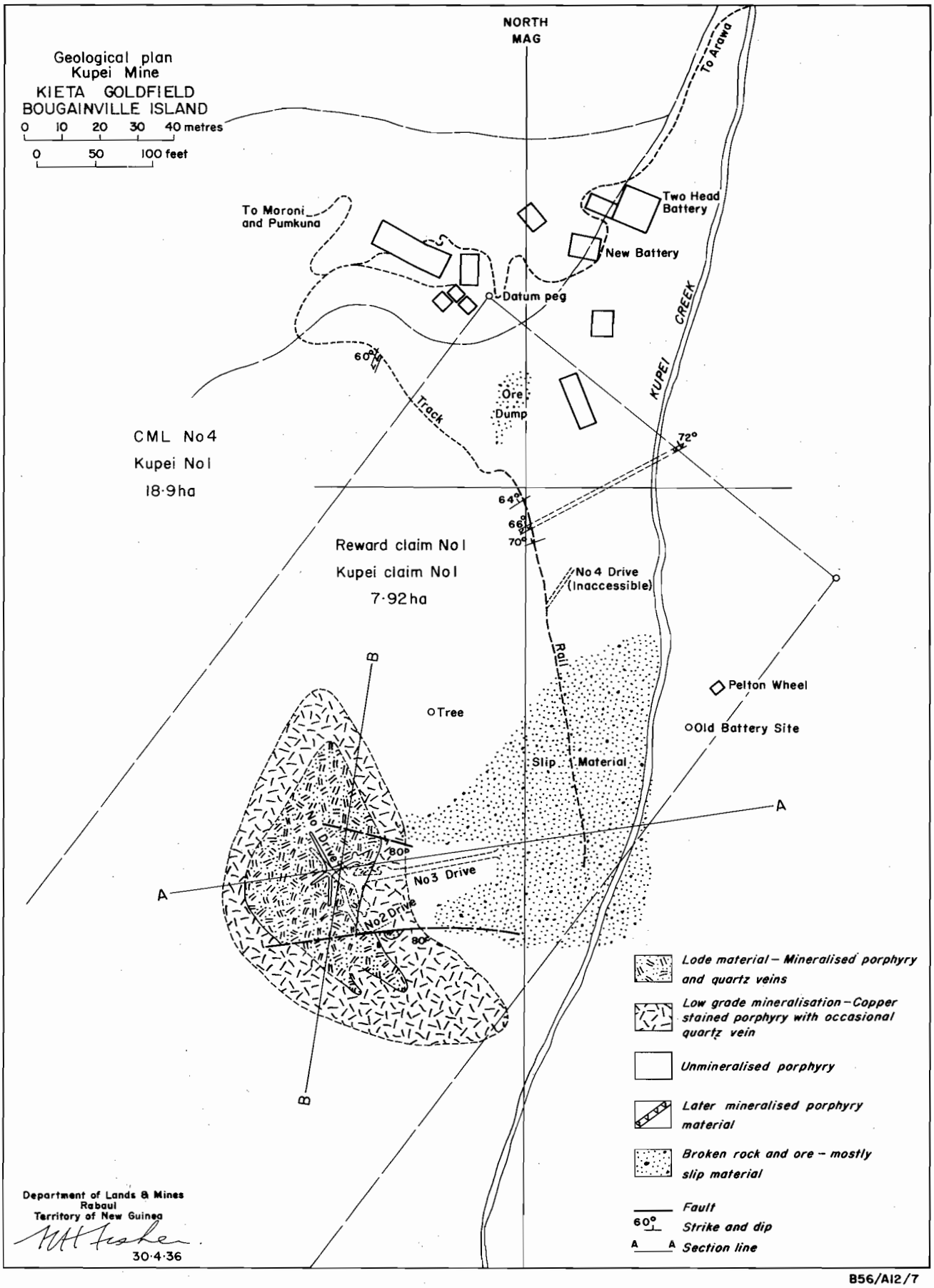
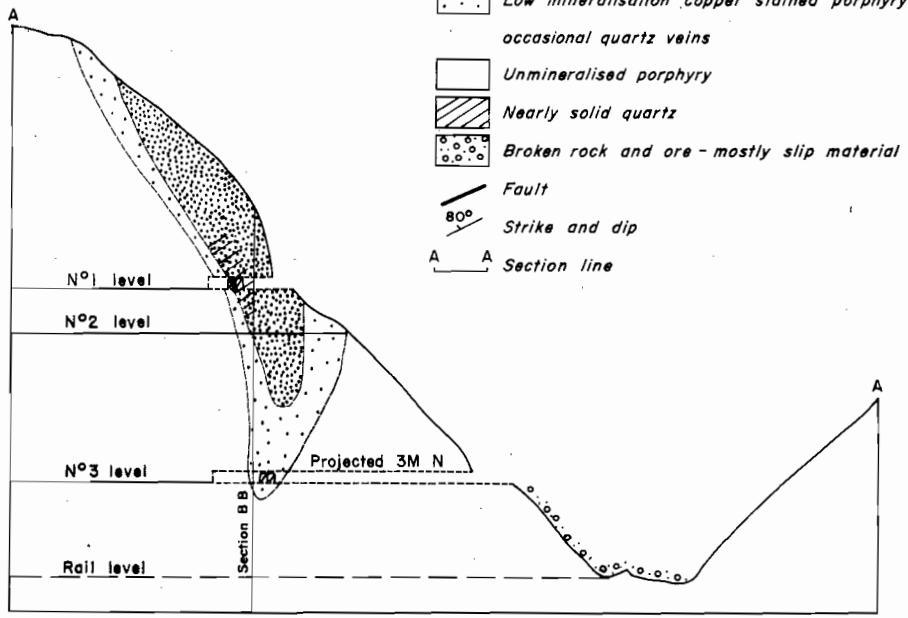

Geological plan
Kupei Mine
KIETA GOLDFIELD
BOUGAINVILLE ISLAND
0 10 20 30 40 metres
0 50 100 feet
NORTH
MAG
To Arawa
To Moroni and Pumkuna
Two Head Battery
New Battery
Datum peg
KUPEI CREEK
60°
Track
Ore Dump
CML No4
Kupei No1
18·9ha
72°
64°
66°
70°
Reward claim No1
Kupei claim No1
7·92ha
No4 Drive (Inaccessible)
Rail
Pelton Wheel
Old Battery Site
Tree
Slip Material
B
A
No1 Drive
80°
No3 Drive
No2 Drive
Lode material – Mineralised porphyry and quartz veins
Low grade mineralisation – Copper stained porphyry with occasional quartz vein
Unmineralised porphyry
Later mineralised porphyry material
Broken rock and ore – mostly slip material
Fault
Strike and dip
Section line
Department of Lands & Mines
Rabaul
Territory of New Guinea
30·4·36
B56/A12/7

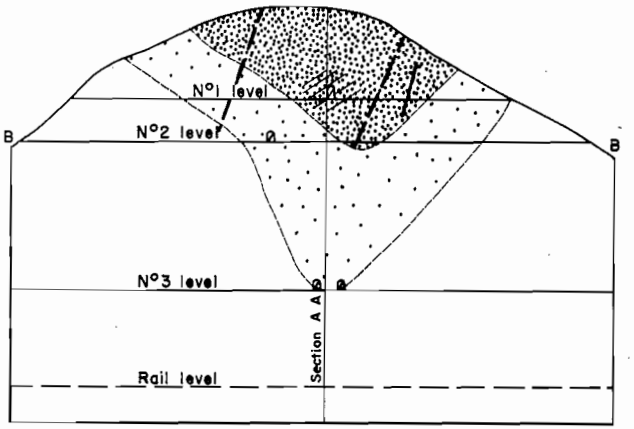
Geological sections and level plans
Kupei Mine
KIETA GOLDFIELD
BOUGANVILLE ISLAND

0 10 20 30 40 metres
0 50 100 150 feet

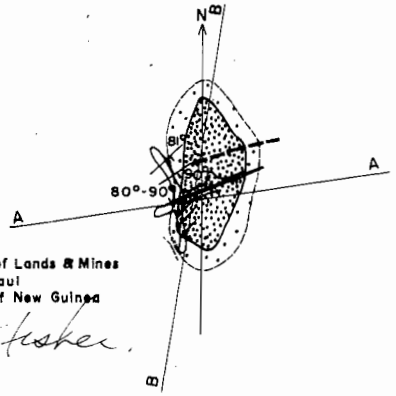
Lode material – mineralised porphyry & quartz veins
Low mineralisation copper stained porphyry with occasional quartz veins
Unmineralised porphyry
Nearly solid quartz
Broken rock and ore – mostly slip material
Fault
80° *Strike and dip*
A A *Section line*



Section A A (looking North)

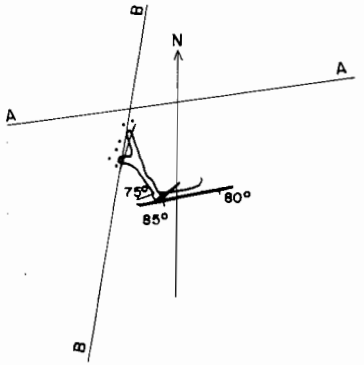


Section B B (looking West)

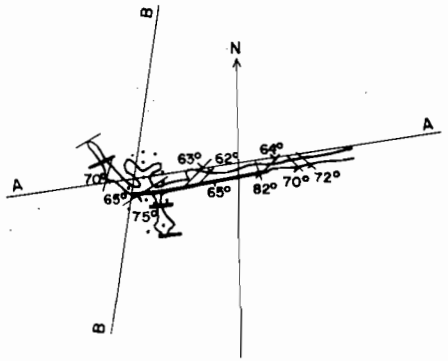


Department of Lands & Mines
Rabaul
Territory of New Guinea
M H Fisher.

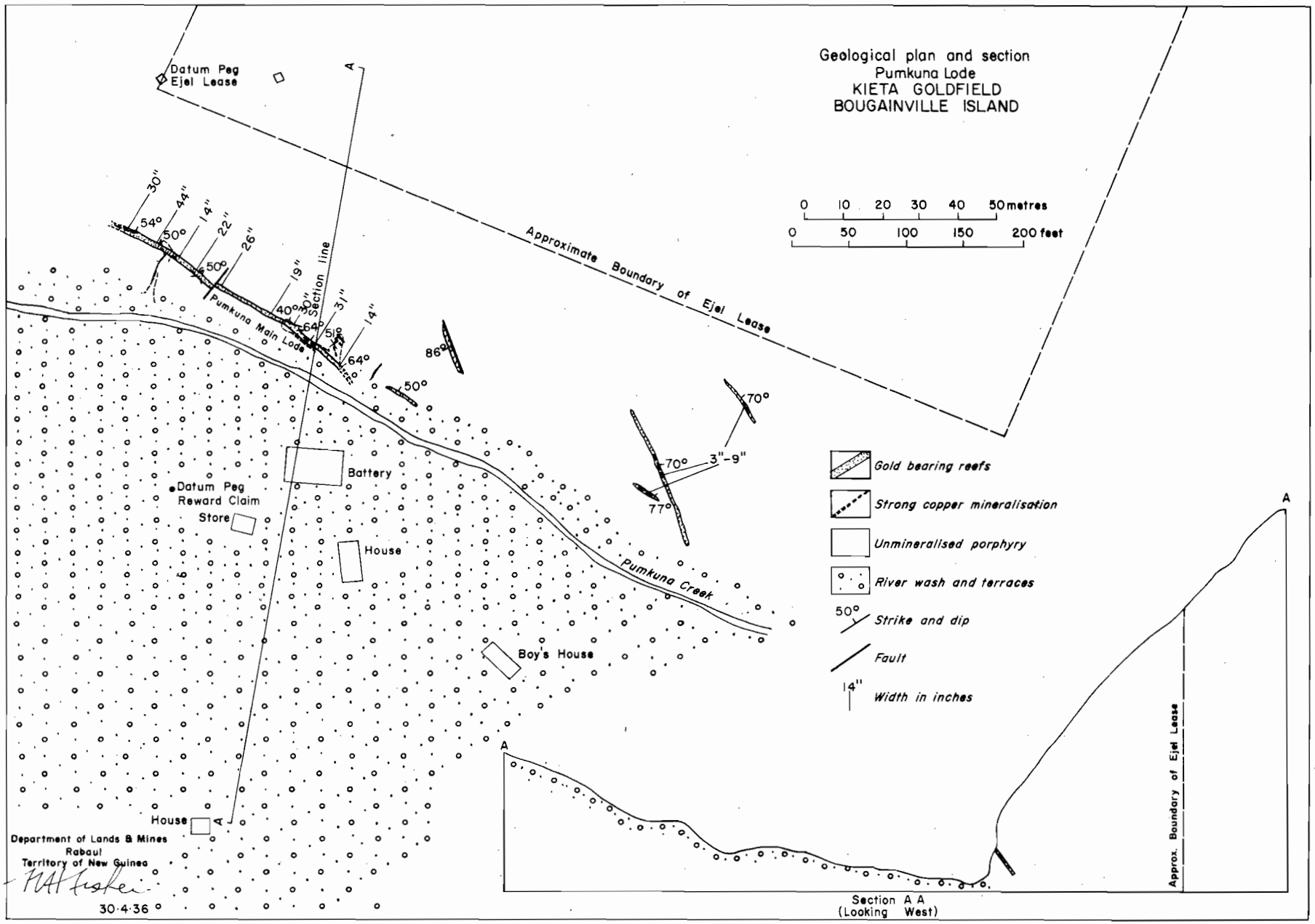
30·4·36 Plan N°1 Drive



Plan N°2 Drive



Plan N°3 Drive


Geological plan and section
Pumkuna Lode
KIETA GOLDFIELD
BOUGAINVILLE ISLAND
Datum Peg
Ejel Lease
Approximate Boundary of Ejel Lease
0 10 20 30 40 50 metres
0 50 100 150 200 feet
Section line
Pumkuna Main Lode
30"
54°
44"
50°
14"
22"
50°
26"
19"
40°
30"
64°
31"
50°
14"
64°
86°
50°
70°
70°
3"-9"
77°
Battery
Datum Peg
Reward Claim
Store
House
Pumkuna Creek
Boy's House
House
Gold bearing reefs
Strong copper mineralisation
Unmineralised porphyry
River wash and terraces
50° Strike and dip
Fault
14" Width in inches
A
A
Approx. Boundary of Ejel Lease
Section A A
(Looking West)
Department of Lands & Mines
Rabaul
Territory of New Guinea
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Pumkuna Goldfield Report

I went into the area in March 1960 in response to a request to the Mines Department, Port Moresby, by Michael Morgan for assistance in the prospecting and development of the old Pumkuna, (as it was then called) gold lode. He accompanied his request by some very spectacular copper (chalcopyrite and bornite) specimens which contained significant gold. I was also interested in checking out magnetite sands on the south-west and north-east coasts of Bougainville and on learning something about the basement rocks on which the conspicuous young volcanoes of Bougainville had been built.

I spent three or four weeks on Bougainville and about 10 days of this period in the Moroni-Pumkuna area; the remainder of the period I was travelling making geological observations and sampling magnetite sand deposits along the coast and for a short distance inland.

On completion of this survey I prepared a report on the Pumkuna gold lode for the Mines Division, the contents of which were, I believe, relayed to Michael Morgan. This would have been a confidential report. As I recall, I downgraded the gold prospect as a small operation but drew attention to the possibility of developing the prospect on the basis of a large tonnage low grade combined copper-gold operation.

Michael Morgan had neither the capital nor the know-how to proceed and made no serious attempt to follow through on this recommendation. I understand he died before C.R.A. came into the picture in 1964.

Ivo Wood, then Chief of the Division of Mines, visited me at my Pumkuna (phonetically it was called Pung'gana by the Moroni villagers in those days) camp for a few days. He would have stayed longer had he not been bitten on the hand by either a centipede or a scorpion – the culprit was never sighted. He was very sick for two days and one night and very gamely struggled back to Kieta with help from the local people.

Early in 1961 I was transferred from my position of Senior Resident Geologist, Papua-New Guinea, to a posting in the Bureau of Mineral Resources, Canberra. There I wrote a more formal report on the Pumkuna copper-gold prospect and on the magnetite beach sands of Bougainville. These were subsequently released as Records 1962/39 and 1961/97, respectively, and thereafter were publicly available through the Bureau of Mineral Resources library and distribution system. A copy of Record 1962/39, without maps, is included with this letter.

The above extracts are taken from a letter received from Mr. J.E. Thompson, October 22nd 1973. It was Mr. Thompson's report on the Pumkuna Copper-Gold Prospect, Bougainville Island (which is reprinted following) that influenced Mr. K. Phillips, C.R.A. Company Geologist to visit the area in January 1964, and March 1964, and as a direct result of his favourable report to C.R.A., the giant Bougainville Copper Project was initiated.

The possibility that that copper-gold mineralisation might be of porphyry copper type occurred to me on reading Dr. N.H. Fisher's 1936 account of his investigation of the Kupei Goldfield (which includes Pumkuna and Moroni) before I went into the area. I wrote to Dr. Fisher, probably early in 1960, seeking his opinion on whether the geological and mineralogical associations he had described at Kupei in 1963 might fit the porphyry copper classification, which at that time had not been recognised outside of North America. He did not discourage this suggestion. Ivo Wood was also very much aware of the possibility of significant low-grade copper-gold mineralisation in the area and we discussed it at length in camp, before he was bitten.

After Michael Morgan's demise, and my return to Canberra, the Pumkuna copper-gold prospect was discussed freely by Ivo Wood, Dr. Fisher and myself with geologists and principals of several major mining companies including C.R.A., Kennecott and others, who I cannot now recall. In 1962 we were successful in attracting the attention of a Mr. Ted Scholey, independent American mining engineer and promoter, resident in the Philippines. Ted Scholey was seeking prospects in New Guinea and gold prospects in the Kainantu area and the Pumkuna copper-gold mineralisation appealed to him. I thought he actually applied for a Prospecting Area (a one square mile concession) over an area including Pumkuna-Moroni and Kupei in 1962, then went back to the Philippines and Japan to raise finance for exploration. He did not return and I presume his efforts to raise capital were unsuccessful. The application would have either been withdrawn or otherwise invalidated.

The Pumkuna lode was a quartz vein, originally exposed on the flank of what was later to be known as Panguna Hill, the richest part of the Panguna orebody, the old alluvial gold workings at Moroni are probably also within the presently defined orebody. The Pumkuna lode was intersected by a short adit from slightly above the level of Pumkuna Creek, then driven on for about 140 ft. Details of this are given in the enclosed report.

My camp was on a site previously occupied by Mike Morgan on the left bank of Pumkuna Creek, opposite the portal of Pumkuna adit. Mike Morgan, although he claimed to have been in the area on several occasions, had not won any ore from the Pumkuna lode, nor had he cleaned out the workings. The underground workings were still standing when I mapped them, but the walls were extensively leached and unsuitable for sampling without thorough cleaning, for which I did not have the equipment.

Despite the ruggedness of the country, outcrop conditions were poor because of thick rainforest cover, soil and scree; reconnaissance geological mapping was fairly hopeless. I was impressed with the amount of copper carbonates leaching into the adit and drives on the Pumkuna lode and with the pale green staining in many of the porphyry boulders in Pumkuna and nearby Punkirunku Creek.

The following extracts from the 1962 report on my 1960 investigation indicate my awareness of the porphyry-copper possibilities of the prospect, though at the time I was reluctant to label it as such on the basis of only a cursory examination:—

Page 376, para 8: "The transport of heavy mining equipment over the routes described above would be impractical (in the context of a small gold operation) and only the incentive of very large returns could justify large scale development of a prospect in this area (Pumkuna). Should the Kupei-Pumkuna-Moroni area be considered as a large scale porphyry copper prospect with by-product gold and other minerals (as it turned out), only then could serious appriaisal of the access problem be justified."

Page 378, para 13: "From a regional aspect, the Kupei-Pumkuna-Moroni area is a province of copper/gold mineralisation (with the emphasis on copper) which warrants reconnaissance investigation. The rugged topography, dense forest cover and paucity of outcrop severely limit coverage by conventional surface mapping methods. The most fruitful method of mineral exploration would be by geochemical survey using either stream sediment (as was done by C.R.A. in 1964-65) or stream water analyses. The known association of molybdenum in the ore would be of value in tracing the copper mineralisation geochemically. Geochemical methods based on molybdenum dispersion in stream sediments have been successfully applied by the Kennecott Copper Corporation in the search for "Porphyry" copper deposits in British Columbia."

Page 378, para 16: "The difficulties of access to the (Pumkuna-Moroni-Kupei) mineralised areas of the Crown Prince Range could possibly be borne by a large scale copper-gold mining operation but, for small operators interested only in gold, the area is not attractive."

Page 374, para 6 (Summary): "Reconnaissance geochemical prospecting for copper using trace molybdenum in stream sediments as an indicator might indicate areas of copper concentration worthy of closer attention as copper, and possibly gold, prospects."

You will find some information on access and topographic conditions in 1960 in the enclosed report.

I have used "Pumkuna" throughout because of the precedence established by Dr. Fisher in his 1936 report. "Pung'gana" is the way the locals pronounced it and this is not far from C.R.A.'s "Panguna".

Jack E. Thompson

The J.E. Thompson Report 1962

THE PUMKUNA COPPER-GOLD PROSPECT BOUGAINVILLE ISLAND, TERRITORY OF PAPUA AND NEW GUINEA.

J.E. Thompson,
formerly Senior Resident Geologist, Papua-New Guinea and
Supervising Geologist, Bureau of Mineral Resources, Canberra.

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Mr. J.E. Thompson's report, Record 1962/39 is published with the permission of the Director, Bureau of Mineral Resources, Geology and Geophysics, Canberra, Australia.

SUMMARY

The Pumkuna lode in mountainous central Bougainville was mined for gold on a small scale throughout the 1930's. The prospect was abandoned in 1941 at the onset of the Japanese invasion and has not been worked since.

The lode is a quartz vein, ranging from a few inches to two feet in width, in microgranodiorite which is overlain by volcanic agglomerate containing both basaltic and andesitic components. Chalcopyrite and bornite in the lode have weathered to produce green staining of soluble copper salts in the old underground workings. Chalcopyrite, bornite, chalcocite, covellite, magnetite and molybdenite were observed in small stringers in the surrounding country rock.

The lode crops out on the steep valley slope north of Pung'gana Creek. It can be traced at the surface for about 150 feet and has been mined at shallow depth by a drive about 100 feet long. The total length of the lode in the drive is about the same as the outcrop length mapped in 1936, indicating that much of the lode was mined from the surface.

The lode strikes north-west and dips to the north-east at 30° to 60°. In all faces of the underground workings the lode is only a few inches wide and faulted. At the time of abandonment ore reserves were apparently low. It is estimated that only about 600 tons of ore remain between the drive and the surface. The grade of the ore is not known with any certainty but individual assays from samples taken before 1936 suggest an average grade between 15 dwts and 1 oz. gold per ton.

The Pumkuna lode is not an attractive gold prospect under present conditions.

The extent of copper mineralization in the vicinity of the Pumkuna lode is unknown. However, chalcopyrite-bearing stringers and boulders are common. Copper mineralization is also associated with gold lodes at Kupei and Moroni nearby in a similar geological environment. Reconnaissance geochemical prospecting for copper using trace molybdenum in stream sediments as an indicator might indicate areas of copper concentration worthy of closer attention as copper and possibly gold prospects.

INTRODUCTION

Early in 1960, attention was drawn to the Pumkuna lode in central Bougainville by part-time prospector, Michael Morgan, engineer, of Kieta and Rabaul, who forwarded specimens of rich copper-gold ore to the Division of Mines in Port Moresby. In correspondence Mr. Morgan stated that the specimens had not been taken from previously known mine workings.

HISTORY

Gold and copper mineralization has been known on Bougainville at least since 1930, when the Kieta Goldfield was proclaimed. During the early 1930's three principal areas were prospected, namely, Kupei at 3600 feet above sea level on the steep north-eastern fall of the Crown Prince Range overlooking Arawa Bay; Pumkuna at 2300 feet above sea level about three miles south of Kupei and on the south-western fall of the Range; and Moroni, also on the south-western fall, near the head of the Kavarong River.

In 1936, the Kieta Goldfield was examined by N.H. Fisher, then geologist for the New Guinea Administration. His unpublished report (Fisher, 1936), which is the only available account of pre-war mining on Bougainville, is the source of information on pre-war mining at Kupei, Pumkuna and Moroni used throughout this report.

Total recorded gold production from Bougainville has been 2282 fine ounces. Annual production is shown in the accompanying table.

GOLD PRODUCTION – BOUGAINVILLE ISLAND

Year	Gold Fine oz.	Value £
1935	45	
1936	113	
1937	598	
1938	487	
1939	297	19,497
1940	217	
1941	32	
1942–1948	no production	
1949	166	
1950	126	1,880
1951	95	1,469
1952	78	1,214
1953	6	94
1954	15	240
1955	5	80
1956–1958	no production	–
1959	2	36
Total	2,282 oz.	£24,510

Peak production was attained during the years 1937 and 1938, that is, subsequent to Fisher's examination of the field. The relative contributions of Kupei, Pumkuna and Moroni to production after 1936 are not known, but Kupei was the principal producer.

The Kupei lode is a lenticular concentration of fractured quartz veins containing interstitial chalcopyrite, bornite and gold within a feldspar-hornblende porphyry which is overlain by a volcanic agglomerate with porphyry components.

The lode is elliptical in plan, has an outcrop length of 230 feet and a maximum width of 106 feet. At the time of Fisher's inspection the lode had been intersected on three adit levels but on the lowest level, about 220 feet below outcrop, it was represented by a narrow zone of slightly mineralized porphyry containing only few small gold-bearing quartz stringers. Fisher estimated that about 7,400 tons of easily mined gold ore were available. A reliable estimate of the grade of this ore could not be made, but production figures indicate an average grade between 8 and 10 dwts per ton. The Bougainville production from 1936 to 1941 suggests that about a third of the ore reserve estimated by Fisher had been consumed by 1941. There is no record of production from the Kupei mine after the war.

At Pumkuna, Fisher mapped the outcrop of a well-defined quartz-gold lode containing chalcopyrite and bornite over 231 feet. The average width of the lode was between 20 and 24 inches and its estimated average grade was 15 dwts to 1 oz gold per ton. In 1936, underground development at Pumkuna was restricted to a short drive at creek level at the south-eastern end of the outcrop. Recent mapping by the writer indicated that much of the original lode outcrop as mapped by Fisher has since been removed and that the lode was subsequently intersected at shallow depth by a 50 foot adit and followed for about 100 feet by a drive from this adit. This work was done before the evacuation in 1941.

At Moroni, eluvial gold occurs over a large area near the crest of the Crown Prince Range on its south-western fall, near the contact of porphyry with overlying agglomerate, but up to 1936 no definite lode had been located.

The flats of the lower reaches of the Kavarong River were tested by drilling as possible gold dredging areas in 1937 and again about 1953, apparently with poor results.

For a few years after the war, a syndicate comprising R. Watson, now of Lae, R. Doyle of Lahang Plantation near Sohano and others, won a small quantity of alluvial gold from near Atamo on the north-eastern fall of the Crown Prince Range and Karato on the opposite fall.* Mr. Doyle could not recall seeing copper minerals in these areas.

Small parcels of alluvial gold were won from several localities in the Crown Prince Range by Messrs. Hetherington and Gleeson, prospectors, between 1949 and 1954, but as far as is known they made no important new finds.

Mr. M. Morgan, Mr. E. Tull and other residents of Kieta have, during the past few years, made short prospecting trips to the known gold-bearing areas, but they have won very little gold.

There is no record of any serious testing of the copper mineralization which commonly is associated with the gold in this region.

THE PUMKUNA LODE

Access and Climate

The Pumkuna lode crops out on the steep northern flank of the valley of Pung'gana Creek, an eastern headwater tributary of the Kavarong River which joins the south-westerly flowing Jaba River. The prospect, about 2300 to 2500 feet above sea level, is deeply enclosed within mountains up to 4500 feet above sea level. Rainfall is high; probably of the order of 150 to 200 inches per year and

*(See Plate 1a)

morning mists are common. Clouds usually accumulate around the mountain peaks, but, even on cloud-free days sunshine penetrates to the valley floor only between 10 a.m. and 3 p.m. Nights in the prospect area are cold and day temperatures are mild.

That small part of the steep hill slope which has been disturbed by former mining operations is now thickly covered with low, dense, secondary bracken. The rest of the area is covered by thick, perpetually wet, rain-forest.

The prospect adjoins a walking track between Moroni and Guava villages which is kept clear by local villagers for the use of patrolling Administration officers.

Access from the coast to the Pumkuna prospect is extremely difficult and the only means of transporting supplies and equipment to the area is by porterage. The pre-war feats of transporting heavy equipment and regular supplies from the north-eastern coast by the use of native carriers could not be repeated nowadays because of the changed attitude of natives towards this type of work. Even on a short visit to the area, arrangements for native carriers should be made well in advance and the services of the mountain people from the Guava area should be sought in preference to villagers from Moroni; the coastal inhabitants understandably object to carrying supplies in the rugged mountains.

On this inspection, access to Pumkuna was achieved by chartered launch from Kieta to Rorawana, thence by a good track and using Rorawana carriers, to Korpei where the night was spent in the Government rest house. On the following morning, using carriers from Korpei and the nearby village of Pakia, the Crown Prince Range was crossed after a steep climb up to a saddle about 3500 feet above sea level. At Moroni on the south-western fall, carriers were changed. The Pumkuna prospect was reached late in the afternoon after a half hour walk from Moroni.

It is possible to make this journey in one day, but the overnight stop is strongly recommended so that the steep climb up to the divide on the Crown Prince Range can be tackled after a good rest and during the cool of the morning.

There is a more direct route from Pumkuna to Kieta by way of Guava village and the Kupei mine which is regularly traversed by natives in one day, but which, from all accounts, is very difficult going.

The transport of heavy mining equipment over the routes described above would be impractical and only the incentive of very large returns could justify large scale development of a prospect in this area. Should the Kupei-Pumkuna-Moroni area be considered as a large scale porphyry copper prospect with by-product gold and other minerals only then could serious appraisal of the access problem be justified. In this case the use of aerial rope-ways from mineralized areas in the mountains inland from Arawa Bay to the coastal flats would seem the most feasible method of transport, though the source of power for operating such a system is not readily apparent. Approach from the north-eastern coast would be preferable to an approach from the south-western coast, not only because of the shorter direct distance but because of the advantage of natural harbours on the north-eastern coast at Arawa and at Kieta.

In the improbable event of the Pumkuna lode being developed as a gold producer without support from Kupei then road access from many possible airstrip sites on the lower Kavarong River might be considered. Such airstrip sites could be linked to vehicle tracks maintained by the Administration and the Roman Catholic Mission which lead to a beach landing point near the mouth of the Jaba River and to Buin.

Geological Environment

The present investigation can add little to the observations of Fisher (1936) as most of the prospect area has been covered by thick secondary growth since pre-war abandonment and much of the steep hillslope made unstable by surface mining operations has since been further disturbed by successive small landslips.

The host rock of the quartzose lode is a medium-grained leucocratic intrusive rock (?microgranodiorite) which is darker in colour away from the main lode. The darker phase of the intrusive rock about 800 feet upstream from the Pumkuna lode is notably less quartzose than the main lode and contains more chalcopyrite, bornite, covellite, magnetite and molybdenite. This mineralization occurs in at least three widely separated fracture fillings up to 9" wide with no wall-rock alteration. Although gold assays up to 2 ozs per ton have been obtained on specimens from these veins they are individually too small for profitable mining. It was from one such vein that Mr. Morgan's specimen containing a high copper and gold content was obtained.

Volcanic agglomerate and breccia with components similar to the host rock of the Pumkuna lode and some vesicular basaltic components bonded with a fine fragmental matrix were seen as boulders in Pung'gana Creek and as talus accumulations near the mineralized area.

The relationship of the agglomerate to the intrusive rock could not be determined from outcrop but similarity of components of the agglomerate to the intrusive rock which contains the Pumkuna lode suggests that the agglomerate is the younger. A similar relationship for "porphyry" and agglomerate was observed by Fisher in the Kupei area and adopted by him for the Pumkuna area. However, exposures at Pumkuna are so poor and topographic relief so abrupt that detailed surface mapping and probably drilling would be necessary to determine the true relationship.

At Moroni, Fisher noted a gradational contact between "porphyry" and agglomerate through a transitional "porphyry" boulder zone. This contact was silicified, pyritized and contained bornite, sphalerite and gold, with gold more particularly on the agglomerate side.

Thus it appears that mineralization is younger than the deposition of the volcanic agglomerate.

The fineness of gold in the region ranges from 830 at Kupei to 946 at Pumkuna. This is anomalously high fineness for gold associated Tertiary volcanic rocks or high-level intrusives in the Territory of Papua and New Guinea (Fisher, 1945) but there seems little doubt that the intrusive rock, the agglomerate and the mineralization are co-magmatic members of a complex volcanic pile now deeply eroded to form the crest of the Crown Prince Range in the mineralized area. The age of this volcanic pile is unknown but the low-angled easterly regional dip of agglomerates near Kieta indicates little tectonic deformation which suggests no great antiquity. An Upper Tertiary age is therefore proposed tentatively.

Steeply dipping, grey, bedded marl was seen at a creek

crossing on the north-eastern fall of the Crown Prince Range between Pakia and Moroni villages. These marls appeared unfossiliferous but their steep dip suggests that they are older than the volcanic agglomerate on the crest of the range. A limestone boulder with diagnostic Lower Miocene "e" stage large foraminifera was collected by A.K.M. Edwards in 1951 from the Wakunai River on the route from Numa Numa to Mount Balbi and described by Crespin (1951). It is possible that the steeply dipping marl mentioned above may also be of Lower Miocene age.

Active and recently active vulcanism on Bougainville is expressed by the volcanic cones of Mount Balbi (9000 feet) which dominates the northern half of the island, Mount Bagana (6560 feet) an active vent on the south-western flank of the Crown Prince Range near the centre of the island, and the complex of eroded cones including Mount Takuam (7385 feet) and Mount Taroka (7240 feet) which dominate the southern half of the island. The pyroclastic products from this vulcanism are only loosely compacted and cannot be mistaken for the older, well lithified pyroclastics in the mineralized areas.

In brief, the Crown Prince Range is composed of Lower Miocene marine sediments including limestone and bedded marl which have been folded, and, after a period of erosion, subjected to severe andesitic and basaltic vulcanism with the accumulation of large pyroclastic piles which were later intruded by numerous volcanic plugs and near-surface intrusives ranging in composition from granodiorite to quartz diorite.

In the Kupei-Pumkuna-Moroni area the margins of these plugs and intrusives have been favourable sites for quartz, copper, iron and gold mineralization introduced at a late stage in the volcanic cycle. Subsequent uplift and erosion has exhumed the Miocene marine sediments, exposed volcanic necks and intrusives and has isolated remnant agglomerate outlier cappings to form the rugged Crown Prince Range to which large recent volcanic mountains have been accreted.

(The occurrence of ultramafic pebbles in streams draining the southern end of the Crown Prince Range (Thompson, 1961) suggests that deeply penetrating faulting may have preceded the earlier vulcanism but, as this area has not been closely examined, further deduction is not possible.)

Lode Dimensions and Disposition (Plate 1c)

The outcrop of the lode mapped by Fisher (1936) was described thus:—

..."a fissure vein fairly consistent in thickness and composition over an exposed length of 231 feet. Width varies up to 44 inches and averages between 20 and 24 inches. Dip is from 40° to 65° to the north-east and the direction of the lode on the surface is 57° west of north".

This description does not quite fit the present-day outcrop which must have been modified by mining after Fisher's visit. The lode outcrop could be traced discontinuously for about 140 feet and the width of massive quartz ranged up to 18 inches. The strike and dip of the lode conform with that recorded by Fisher. Thus it appears that the thickest parts of the lode outcrop were removed.

At the time of Fisher's inspection, the short drive from creek level at the south-eastern end of the lode outcrop was the only attempt to follow the main lode underground. Later an adit was driven beneath the lode outcrop apparently on the 1 foot wide near-vertical quartz vein mentioned by Fisher at the western end of the lode and striking across it. This vein terminated against post-mineralization faults within a short distance of the portal. The adit was driven about 60 feet where it encountered a lode with strike and direction of dip comparable with that of the exposed lode but its correlation with the outcrop requires an unnatural projection of the surface dip which may be explained by downhill movement of the surface with adjustments along fault planes observed in the adit.

The main lode was followed to the north-west for 70 feet where it terminated against a cross fault and to the south-east where there is minor displacement by post-ore faulting. At both faces in the drive the quartz lode was only about six inches wide and apparently not sufficiently rich to warrant underground search for the displaced portions. Along strike the lode width is irregular, with bulges up to 2 feet 6 inches wide but averaging about 1 foot. The extent to which gold mineralization extended beyond the limits of the quartz lode into surrounding wall rock has not been checked by assay but except for a few small stringers the wall rock looks barren although it is stained pale green in places by the impregnation by soluble copper salts.

The short drives at the south-eastern end of the lode also indicate irregular width and faulting complications which discouraged further work.

The picture construed from the mapping is one of a small marginal mine which, while on average width and grade ore, may have yielded small profits but which could not tide over lean periods when width and/or grade dropped below average nor could it support underground probing for displaced lode segments. Thus it appears that the mine was abandoned primarily because of the lack of ore reserves and not because of the war threat.

The underground workings are not timbered but there have been no serious collapses and the workings are completely accessible, though very wet from surface drainage moving along the fractured quartz lode system. This water has leached the copper sulphides in the lode and pale green and pale blue copper salts encrust the walls and roof in some sections of the crosscut and drive. Green algal slime which is also prevalent may be mistaken for copper staining. In places the slightly weathered microgranodiorite wall rock is very pale green from the impregnation of copper salts which selectively stain the slightly weathered feldspars.

The mine is inhabited by a colony of bats which may cause some alarm on first entry but which soon disperse.

Lode Mineralization and Tenor

The main lode is white, fractured quartz containing chalcopyrite and bornite which appear to have followed the quartz, in some instances occupying the central portion of the lode. The copper minerals are localized within the lode but show no relationship to faulting. The small north-easterly striking quartz lode on which the main adit was driven shows only limonite staining.

No unweathered specimens suitable for mineragraphic examination could be obtained either from the outcrop of the main lode or from the underground workings. The small quartzose veins about 800 feet upstream from the main lode, had a central band of copper-iron sulphide minerals, magnetitie and molybdenite.

A mineragraphic description by G. Greaves of two specimens (P436a and P436b) from this locality is appended. He recognized, in order of decreasing abundance, the copper minerals, bornite, chalcopyrite, chalcocite, covellite and minor digenite and noted ex-solution lamellae of chalcopyrite in bornite.

A specimen of ore from the Old Kupei mine was also examined and described by Greaves – following this paper – (specimen P437). The Kupei ore and the specimens from near Pumkuna show marked mineragraphic similarity and indicate a comparable, if not a common, genesis.

No samples were taken for assay from the Pumkuna lode because of extensive leaching and contamination by copper salts. From information available in 1936, Fisher estimated that the main Pumkuna lode contained from 15 dwts to 1 oz gold per ton. The fineness of the Pumkuna gold produced before 1936 ranged from 904 to 946.

The only ore reserve that can be calculated with any degree of confidence is that block between the underground workings and the surface. Assuming a connection through average width ore (1.2 feet) between the two workings, this block contains about 600 tons of quartz lode material which, for the most part, is considerably less than minimum stoping and driving width.

The lode cannot be confidently projected beyond any of the faces in the underground workings and in all faces the lode is less than average width.

The narrow quartz chalcopyrite fracture fillings in (?)quartz diorite which crop out in the bed of Pung'gana Creek upstream from the main lode, are too small to support a mining operation even though specimens taken from the veins may give high assays for both copper and gold.

Green staining of the country rock was seen not only in the immediate vicinity of the known lode but also on many stream boulders and in the boulders of some talus accumulations downstream from the exposed lode. This staining was seen in both agglomerate and microgranodiorite. In the agglomerate, malachite occurs in small round voids which look like vesicules but are more probably spaces left after selective removal by weathering of a particular mineral. In the microgranodiorite, a faint green colouration has selectively stained slightly weathered feldspar but, except for very minor chalcopyrite in accessory magnetite, no copper minerals could be identified microscopically. It would appear that this staining has come from leaching of copper minerals nearby.

Method of Treatment of ore from pre-war mining

The Pumkuna mine was not being worked at the time of Fisher's visit in 1936.

The remains of a small ball mill were found on an alluvial flat on the left bank of the Pung'gana Creek opposite the main adit, and about a hundred feet from the creek (presumably above flood level.) Ore and mullock were probably trucked out of the main adit; the ore hand-picked and the mullock dumped on the right bank of the creek. The selected ore must have been transported to the opposite bank by a "flying fox", put through the ball mill and the gold concentrated from the crushings by some crude gravity method followed by amalgamation. It is indeed surprising that even such a rudimentary treatment plant could have been established in this remote area when it is considered that all equipment was carried from the north-eastern coast over a rugged 4000 feet range by native labour. Under present day labour conditions, this feat could not be repeated; some other means of transportation would have to be found.

CONCLUSIONS

Difficult access conditions would make any mining venture in the Pumkuna area very costly. The Pumkuna lode as seen from outcrop and the old underground workings is much too small for consideration as a gold-mining prospect under present access and labour conditions.

Underground mapping has indicated that, contrary to popular rumour, the mine was abandoned primarily because of shortage of ore and not necessarily because of the Japanese advance.

In none of the underground faces is the lode wider than 1 foot and at both ends of the main drive the lode is displaced along faults. There is insufficient ore in sight to justify re-opening the mine even on a small scale.

From a regional aspect, the Kupei-Pumkuna-Moroni area is a province of copper/gold mineralization which warrants reconnaissance investigation. The rugged topography, dense forest cover and paucity of outcrop severely limit coverage by conventional surface mapping methods. The most fruitful method of mineral exploration would be by geochemical survey, using either stream sediment or stream water analyses. The known association of molybdenite with the ore would be of value in tracing the copper mineralization geochemically. Geochemical methods based on molybdenum dispersion in stream sediments have been successfully applied by the Kennecott Copper Corporation in the search for "porphyry" copper deposits in mountainous British Columbia.

In such an investigation stream sediment sampling and field mapping of available outcrop could proceed concurrently. The area of particular interest for copper mineralization is the northern fall of the Crown Prince Range from Atamo to the foothills behind Kieta; about 80 square miles with a high density drainage pattern.

On a broader scale, the entire Crown Prince Range, about 250 square miles, is worthy of reconnaissance surface mapping and reconnaissance sampling and analysis of stream sediments to determine whether the Kupei-Moroni-Pumkuna area is the only province of copper mineralization.

The difficulties of access to the mineralized areas of the Crown Prince Range could possibly be borne by a large scale copper-goldmining operation but for small operators interested only in gold the area is not attractive.

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APPENDIX TO J.E.THOMPSON REPORT

MINERAGRAPHIC DESCRIPTION OF THREE SPECIMENS OF COPPER ORE FROM BOUGAINVILLE, NEW GUINEA.

by G. Greaves.

Following are descriptions of three specimens of copper ore from Bougainville. These were submitted by J.E. Thompson.

P436b – Pung'gana Creek near Pumkuna lode, headwaters of Jaba Creek, Bougainville.

The hand specimen consists of a massive, fine-grained, grey rock intersected by a green-stained brecciated quartz vein which in turn encloses a brassy yellow and black sulphide vein about 0.5 cm wide.

Sulphides form roughly 30% of the specimen. Of these, chalcopyrite forms over 50%, bornite 40%, and chalcocite and covellite 10%.

Inclusions of quartz, hydrous iron oxides and malachite up to 1 m.m. long are found in the sulphide vein, and fracture fillings of these minerals up to 0.2 m.m. wide, also cut the vein.

The chalcopyrite has numerous elongated inclusions of bornite up to 6 m.m. long; these are generally parallel to the margins of the vein.

Some bornite grains have exsolution lamellae of chalcopyrite in the (111) planes. Peripheral alteration of bornite to covellite has proceeded along two crystallographic directions. Bornite has been altered to chalcocite and covellite to a greater extent than has chalcopyrite.

The green colouration in the quartz vein is due to malachite. Hydrous iron oxides and small amounts of magnetite, chalcopyrite and bornite are also present. The chalcopyrite occurs both as irregular inclusions in magnetite and as separate grains marginally altered to covellite. The bornite is partly altered to chalcocite and subordinate covellite.

P436a – same locality as P436b.

The hand specimen is massive and consists of equidimensional grains of black sulphide, quartz, smaller grains of brassy yellow sulphide, and interstitial green oxidation products.

Sulphides form roughly 30% of the specimen. Of these, bornite forms about 65%, chalcopyrite 20%, and chalcocite and minor digenite and covellite 15%. The textures are similar to those of specimen P436b.

Irregular grains of cahlcopyrite up to 3 m.m. long have been altered along grain boundaries and quartz-filled fractures to chalcocite.
Bornite grains up to 7 m.m. diameter have been extensively shattered, and subsequently recemented with quartz. Bornite is considerably altered to chalcocite and covellite along these fracture fullings and around the margins; it also contains inclusions of digenite up to 0.05 m.m. diameter.

Hydrated iron oxides and malachite have formed around the quartz grains and to a lesser extent the sulphide grains.

P437 – Old Kupei Mine, 10 miles S.W. of Kieta, Bougainville.

The hand specimen consists of irregular grains of black and brassy yellow sulphides in quartz.

The sulphides form roughly 10% of the specimen. Of these, chalcopyrite forms about 45%, bornite 50% and covellite and minor chalcocite 5%.

Grains of chalcopyrite up to 2 m.m. in diameter are generally associated with the bornite.
Bornite forms rectangular grains up to 4 m.m. long and exsolution lamellae of chalcopyrite occur in the (111) planes of bornite. Very fine veins of chalcopyrite in some of the bornite grains are just visible at a magnification 1,050 X. Bornite, more so than chalcopyrite, is altered to covellite and chalcocite around the margins and along fracture fillings of quartz. The exsolution – lamellae of chalcopyrite are unaltered, although the enclosing bornite is partly altered to covellite.

Irregular magnetite grains form less than 0.5% of the specimen and have a maximum diameter of 1.6 m.m.

Summary

The sulphides present are bornite, chalcopyrite, chalcocite, covellite and very minor digenite in order of decreasing abundance.

Chalcopyrite and bornite have been fractured and recemented by quartz and supergene alteration to chalcocite and covellite has taken place.

The presence of exsolution lamellae of chalcopyrite in bornite indicates that the temperature of deposition of these two sulphides was greater than 475°C (Schwartz, 1931)*.

The complete absence of pyrite and the presence of minor amounts of magnetite is notable.

Surface weathering of the copper minerals has produced malachite and hydrous iron oxides.

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* Schwartz, G.M., 1931 : Econ. Geol., 26, 186-201.

1971
REVIEW OF OPERATIONS

BY MANAGING DIRECTOR
OF BOUGAINVILLE COPPER
PTY. LIMITED

Construction work on the Bougainville project during 1971 continued ahead of schedule and was nearing completion by the end of the year.

Total expenditure on mine property and capital works in progress at 31st December, 1971, was $357 million. This was financed by shareholders' equity to the extent of $125 million and the balance by borrowings. The estimated overall total cost of the exploration, development and construction programme remains approximately $400 million.

ORE RESERVES: No exploratory drilling to define further ore reserves was undertaken during the year. Estimated ore reserves within the limits of the planned open pit thus remain approximately 900 million tons of ore averaging 0.48% copper and 0.36 dwt. gold per ton. When full production of copper concentrate is achieved, production of ore from the mine will be at an annual rate of approximately 28.9 million tons.

MINE DEVELOPMENT: The stripping of waste rock and overburden to expose the orebody and the establishment of mining benches and haul roads continued in 1971 and are on schedule for the commencement of open-cut mining operations. During the year under review 8,140,000 cubic yards of soft overburden and 26,700,000 tons of waste rock and oxidised material were removed. Daily production on a fully operational basis will be 80,000 tons of ore, plus waste rock. Bougainville Copper's fleet of major mine equipment now comprises five 9⅞ inch diameter drills, six 17 cubic yard capacity electric shovels and forty-one 100 ton capacity trucks, all of which are operational.

POWER: The power station was one of the most critical items of construction to be completed during 1971. The 135 megawatt steam power station, situated near the wharf at Anewa Bay, comprises three turbine-generator units rated at 45 megawatts each. It is designed so that two of these units will be able to supply the power requirements of the mine and port areas.

Completion of the power station enabled the testing and running of heavy machinery to commence in December 1971.

TREATMENT FACILITIES: The concentrating process involves three stages of crushing, grinding and flotation. By the end of December 1971, the two 54 inch gyratory primary crushers and one half of the fine crushing and screening plants were commissioned. In addition, the installation of eight ball mills, each 18 feet in diameter and 21 feet long, which will grind the crushed material in a single stage to the size required for flotation, was completed. The flotation section, comprising two hundred and sixteen 300 cubic foot rougher flotation cells and one hundred and seventeen 100 cubic foot cleaner flotation cells, was 95% complete at the year end.

Water requirements for the concentrator have been met by building a pump station on the Jaba River capable of supplying 30 million gallons of water daily and by laying 7½ miles of 30 inch pipe.

Testing has been completed on the 5½ inch diameter pipeline which will carry the concentrate in slurry form 16 miles from the mine site at Panguna to Bougainville Copper's port installation at Anewa Bay. At the port, filtering and drying facilities and covered storage of about 60,000 tons capacity were in an advanced stage of construction at the year end. It is expected that the concentrate to be shipped will contain approximately 30% copper, 1 ounce gold per ton and some silver.

During 1971, whilst the large treatment structures were under construction, strong earthquakes were recorded off the west coast of Bougainville Island. Seismic effects were felt at Panguna but no damage to any plant or buildings occurred.

PORT: The port at Anewa Bay has been dredged to provide berthing for ships up to 40,000 dead weight tons. The 250 foot wharf, which was completed in August 1970, handled 210,000 shipping tons of material and equipment required for the construction and mining programme during 1971.

Copper concentrate will be shipped directly from storage into vessels by belt conveyor. Shipments are expected to be in quantities of up to 25,000 tons of concentrate. Erection work on the shiploader was nearing completion at the year end.

TOWNS: Because of the scarcity of flat ground at Panguna, it was necessary

for Bougainville Copper to provide two residential areas to accommodate company personnel.

At Panguna 323 houses have been built and were available for occupation by employees and their families at 31st December,1971. Other accommodation includes a number of two bedroom flats and ten three storey blocks providing quarters for single personnel.

The town of Arawa is situated on the coast some eighteen miles by road from Panguna. Bougainville Copper is developing Arawa in conjunction with the Government. Housing construction progressed satisfactorily in 1971 and 399 houses were available for occupation by company employees and their families at the end of the year. Erection of the 250 bed Arawa Hospital is nearing completion and construction is well advanced on the high school, technical college and other civic facilities.

ACCESS ROADS: The sixteen mile port-mine access road has been open to traffic since December 1970. During the year a road was constructed to provide access to the Jaba River pump station area and to facilitate the laying of the water pipeline to the concentrator. Bougainville Copper has agreed to assist the local government councils in western Bougainville to extend this road to give agricultural producers in the Buin area of south Bougainville full road access to Panguna and the established port of Kieta.

WORKFORCE: During the year the workforce rose to over 10,000 at the peak of construction activity. Demobilisation following the completion of construction contracts reduced the figure to 7,553 at 31st December, 1971. Bougainville Copper's operational workforce is expected to be approximately 3,200 persons, of whom approximately two-thirds will be Papua New Guineans.

Training facilities were expanded during the year and a new modern training centre is nearing completion. Bougainville Copper continues to place strong emphasis on education and training of local people. Just under 2,500 persons participated in company training during the year, including 95 students sponsored to scholarships in tertiary institutions of Papua New Guinea.

MARKETING: No new sales agreements were entered into during 1971. Bougainville Copper's total sales at present aggregate 1,992,500 tons of contained copper for delivery over fifteen years. In addition, vendor's options have been negotiated to sell to Japanese smelters up to an additional 82,500 tons of contained copper over production years 6-10 inclusive. Details of Bougainville Copper's present annual contracted sales of contained copper in concentrate are as follows:

PURCHASER	ANNUAL DELIVERIES YEARS 1-5	6-10	11-15	TOTAL OVER 15 YEARS
JAPAN:				
Japanese smelters				
Firm sales	95,000	80,000	30,000	1,025,000
Vendor's options	—	16,500	—	82,500
	95,000	96,500	30,000	1,107,500
WESTERN GERMANY:				
Norddeutsche Affinerie	52,500	52,500	52,500	787,500
SPAIN:				
Rio Tinto Patino	15,000	15,000	6,000	180,000
Total including options	162,500	164,000	88,500	2,075,000

R. W. BALLMER,
DIRECTOR

24th February, 1972.

1972 REVIEW OF OPERATIONS

BY MANAGING DIRECTOR OF BOUGAINVILLE COPPER PTY. LIMITED

ORE RESERVES: No further drilling to define further ore reserves was undertaken in the period and at the end of 1972 estimated ore reserves stood at approximately 900 million tonnes of ore averaging 0.48% copper and 0.55 grams of gold per tonne.

PRODUCTION: During 1972 a total of 46,753,200 tonnes of ore and waste was extracted from the mine. Of this 21,885,252 tonnes of ore were milled, and 123,961 tonnes of copper were produced.

Production for the nine months of commercial production ended 31st December is set out in the table below.

PRODUCTION*	Nine Months Ended 31st December, 1972	
Ore milled	18.75	millions of dry tonnes
Grade—copper	0.78	per cent
—gold	0.81	grams/tonne
—silver	2.08	grams/tonne
Concentrate produced	395,092	dry tonnes
Grade—copper	28.20	per cent
—gold	27.50	grams/tonne
—silver	69.25	grams/tonne

*Comprises commercial production. Pre-commissioning production of 3.135 million tonnes (43,023 dry tonnes concentrate) is excluded from the above figures.

The incidence of non-sulphide ore in the crust of the ore-body which affected production results in the early months has continued to diminish with the penetration of the ore-body beyond the oxide zone.

The progressive improvement in ore quality and concentrator performance during the year has enabled the April 1972 forecast of 120,000 long tons (121,920 tonnes) of copper contained in concentrate, to be achieved.

Operation of the processing facilities has been generally satisfactory but, as should be expected with any new mine, minor problems were encountered in the first months of operation. Modifications have been made to ball mill circuits and the installation of an additional ball mill, scheduled for completion in the latter part of 1973, will ensure greater concentrating capacity in future years.

The fleet of mine haul trucks was brought to its full complement of 52 by the delivery of eleven additional trucks during the year.

The mine and concentrator operated on a seven day week throughout the year except for two occasions when cyclonic conditions brought extremely heavy rain to the Panguna area. Measures taken to correct the defects have proved adequate in subsequent storms.

SHIPPING: During the year there were 23 concentrate shipments totalling some 471,120 wet tonnes, the largest of which was 27,690 wet tonnes destined for discharge at Hamburg. The port handled 766,790 freight tonnes, making it the largest port in Papua New Guinea in terms of cargo handled.

WORKFORCE: With the institution of the operating phase, Bougainville Copper ended 1972 with a workforce somewhat in excess of 3,000 employees, of which 70% were Papua New Guineans.

There were no serious industrial disputes during 1972.

In mid-year, a new two-year agreement was reached with the Bougainville Mining Workers' Union relating to wages and working conditions.

TRAINING & EDUCATION: A new training centre was opened at Panguna early in the year to cater for apprenticeship training in all trades used on the mine site. Apprentices currently in training total 240 with a planned increase to 340 in 1973. Company scholarship holders attending tertiary institutions throughout Papua New Guinea include 22 at the University, 28 at the Institute of Technology and 38 at the Lae Technical College. Training courses for skilled, semi-skilled and junior supervisory personnel were continued throughout the year.

CONSTRUCTION OF FACILITIES: Construction of key operational facilities was completed by April 1972. The major items of construction associated with original project planning still outstanding are the sealing of the port - mine access road and the construction of additional amenities and recreational facilities at Panguna, including a new interdenominational church.

These items are scheduled to be completed during 1973.

The final cost of the original project including exploration and development costs is expected to be within the overall budget of $400 million.

At Arawa, the jointly developed company and Government town, construction has commenced on an additional 190 company residences.

MARKETING:

SALES

Discussions with the Japanese buyers, Norddeutsche Affinerie (Germany) and Rio Tinto Patino (Spain) to consider their requests for revision of smelting and refining terms were successfully concluded in March and April on a basis satisfactory to all parties. The buyers had sought changes to the smelting and refining terms to assist them in meeting extra anti-pollution costs and cost disadvantages arising from the realignment of international currencies in late 1971.

The Japanese buyers had also requested that Bougainville Copper reduce contractual deliveries during 1972 and 1973 by 20%. However, following discussions, they agreed to accept deliveries of the full contractual tonnage from 1st April, 1972, but to toll smelt and refine 10% of this tonnage for sale of the tolled copper by Bougainville Copper outside Japan. This tolled copper metal has been sold. The tolling arrangement will continue until the end of 1973 when the Japanese buyers will revert to purchasing the full contractual tonnage.

Three new copper concentrate sales agreements were concluded by Bougainville Copper during the year. The first, with Norddeutsche Affinerie, covered a total of 40,000 wet tonnes of concentrate, 20,000 wet tonnes of which was subject to two buyer's options each of 10,000 tonnes. The first option was exercised while the second remains open.

Two other sales agreements were signed for the delivery of between 150,000 and 200,000 wet tonnes of concentrate in the period 1973-1976.

PRICES

Prices for copper remained at low levels throughout the year, despite a recovery in demand for copper metal in the U.S.A., Japan and Europe towards the end of the period. A major reason for the depressed prices was the increase in the availability of supply of copper during 1972. Apart from Bougainville Copper, two other major mines commenced production during the year and there were additions to capacity at many existing mines.

While the rise in the price of gold during 1972 provided higher revenue receivable from gold sales, this increase provided only a partial offset for the low prices prevailing for copper on the London Metal Exchange.

R. W. BALLMER,
DIRECTOR.

12th February, 1973.

HIGHLIGHTS 1972

JANUARY:

First concentrate run through pipeline to port.

MARCH:

Commissioning of plant completed.

APRIL:

Commercial production commenced.
First commercial shipment made.

JULY:

Net earnings of $6.593 million for half-year to 30th June announced.

DECEMBER:

Production for year 1972:—	
Tonnes of copper in concentrate:—	123,961
Consolidated net earnings for 1972:—	$20,853,957
Net earnings per share:—	11.7 cents
Funds of Bougainville Mining shareholders:—	$127,962,000

1973 BOUGAINVILLE MINING LIMITED HALF YEARLY REPORT

The Directors of Bougainville Mining Limited present the following (unaudited) financial results and production figures of the Company and its 80 per cent owned subsidiary, Bougainville Copper Pty. Limited (now Bougainville Copper Limited), for the six months ended 30th June, 1973, together with results to June 1972.
Bougainville Copper Pty. Limited did not commence commercial production until 1st April, 1972; therefore the figures shown below relate to different periods of operation and are not directly comparable.

FINANCIAL RESULTS:

	SIX MONTHS ENDED 30TH JUNE 1973 $'000	SIX MONTHS ENDED 30TH JUNE 1972 $'000
Value at Mine of Products	98,136	31,854
deduct: Costs of production and financing costs	47,960	23,365
: P.N.G. Government royalty	1,155	309
	49,021	8,180
add : Exchange gain realised on loan repayments	2,935	—
Net earnings—Bougainville Copper Pty. Limited	51,956	8,180
deduct: Interest of P.N.G. Government in earnings of Bougainville Copper Pty. Limited	10,391	1,636
	41,565	6,544
add : Bougainville Mining Limited—Net earnings (loss)	(12)	49
Consolidated net earnings before dividend withholding tax	41,553	6,593
deduct: Dividend withholding tax*	3,209	—
Consolidated net earnings of Bougainville Mining Limited	38,344	6,593

*Provision for Papua New Guinea dividend withholding tax is based on the present corporate structure and assumes that the dividend paid out of the first six months' earnings by Bougainville Copper will be received by Bougainville Mining and that dividend withholding tax thereon will be borne by Bougainville Mining. If the Scheme of Arrangement, referred to later, becomes effective, the dividend will be paid directly to shareholders who were previously Bougainville Mining shareholders. Under these circumstances withholding tax will be deductible from dividends payable to shareholders resident outside Papua New Guinea; no withholding tax will be deductible from dividends payable to shareholders resident in Papua New Guinea.

PRODUCTION STATISTICS:	SIX MONTHS ENDED 30TH JUNE 1973	SIX MONTHS ENDED 30TH JUNE 1972
Ore milled (millions of tonnes)	13.230	8.630
Grade — Copper (per cent)	0.76	0.67
— Gold (grams/tonne)	1.09	0.59
— Silver (grams/tonne)	1.95	2.01
Concentrate Produced (dry tonnes)	304,285	154,565
Grade — Copper (per cent)	28.22	27.79
— Gold (grams/tonne)	31.40	22.80
— Silver (grams/tonne)	66.10	70.00
Metal Content		
Copper (tonnes)	85,861	42,954
Gold (kilograms)	9,554	3,524
Silver (kilograms)	20,116	10,819

OPERATIONS: Oxidised ore is becoming less significant as a proportion of material mined and the percentage of oxidised ore to be processed is expected to continue diminishing as the orebody is developed.
A ninth ball mill was installed ahead of schedule and became fully operational in the latter part of July. This should ensure that 175,000 tonnes of copper contained in concentrate will be produced in 1973 as forecast in the last Annual Report.

CONSTRUCTION: The final major items of construction associated with original project planning—the sealing of the port-mine access road and the construction of additional amenities and recreational facilities at Panguna— were essentially completed in the first half of the year.

MARKETING: During the six months ended June, fourteen shipments containing 277,281 wet tonnes of concentrate were made. The concentrate contained 71,800 tonnes of copper, 7,869 kilograms (252,984 ounces) of gold and 16,888 kilograms (542,960 ounces) of silver.
Copper prices rose strongly during the period, reflecting supply difficulties in some major producing countries, buoyant economic conditions in the major industrial countries and international currency uncertainties. The London Metal Exchange official cash seller's price for electrolytic copper wirebars averaged £588.12 per tonne (A$1,050 per tonne) during the period compared with £429.56 per tonne (A$865 per tonne) in the previous six months' period, July to December, 1972. Since the end of June copper prices have increased further to reach new record levels.
In the six months to June gold prices almost doubled, with the London Gold Market price for fine gold increasing from a low of US$64.30 per ounce on January 19, 1973 to US$123.33 per ounce on June 29, 1973. The average price for the half year was US$89.41 per ounce (A$2.073 per gram). The average price for silver on the London Silver Market was UK91.53 pence per ounce (A5.3 cents per gram). Monetary instability has been the main reason for the higher gold and silver prices.

ARALGON CITY LIBRARY

Who is buying Bougainville copper concentrate?

The initial purchase contracts for concentrate were negotiated with the Japanese Smelter Group, Norddeutsche Affinerie GmbH, and Rio Tinto Patiño S.A. In 1971 Bougainville received vendor's options for sales of up to an additional 82,500 tons of contained copper over production years six through 10. In 1972 a contract was signed with a United States purchaser for sale of 7,370 to 11,000 tons of contained copper in concentrate for each of four years starting 1 January 1973. A second contract was also signed for delivery of 17,550 contained tons of copper for delivery in the January 1, 1973, to June 30, 1975, period. A summary of sales contracts is shown in adjoining table.

However, modifications have been made in all the original contracts to reduce payments to Bougainville because of added smelting costs, currency devaluations, and increased capital cost to minimize pollution. The Japanese cut their purchase by 10 percent through 1973, but they did agree to smelt this 10 percent for Bougainville to sell resultant blister outside Japan.

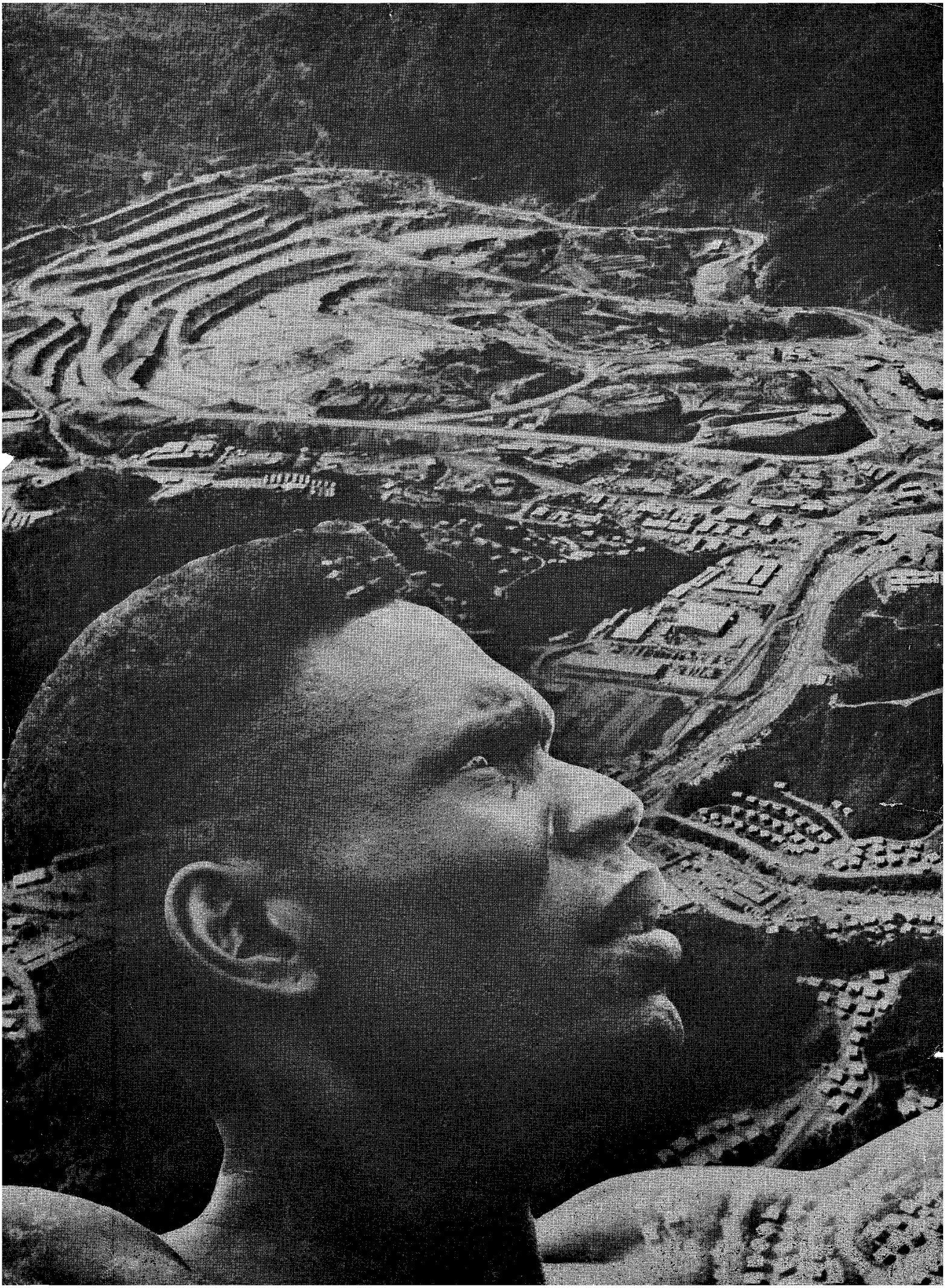
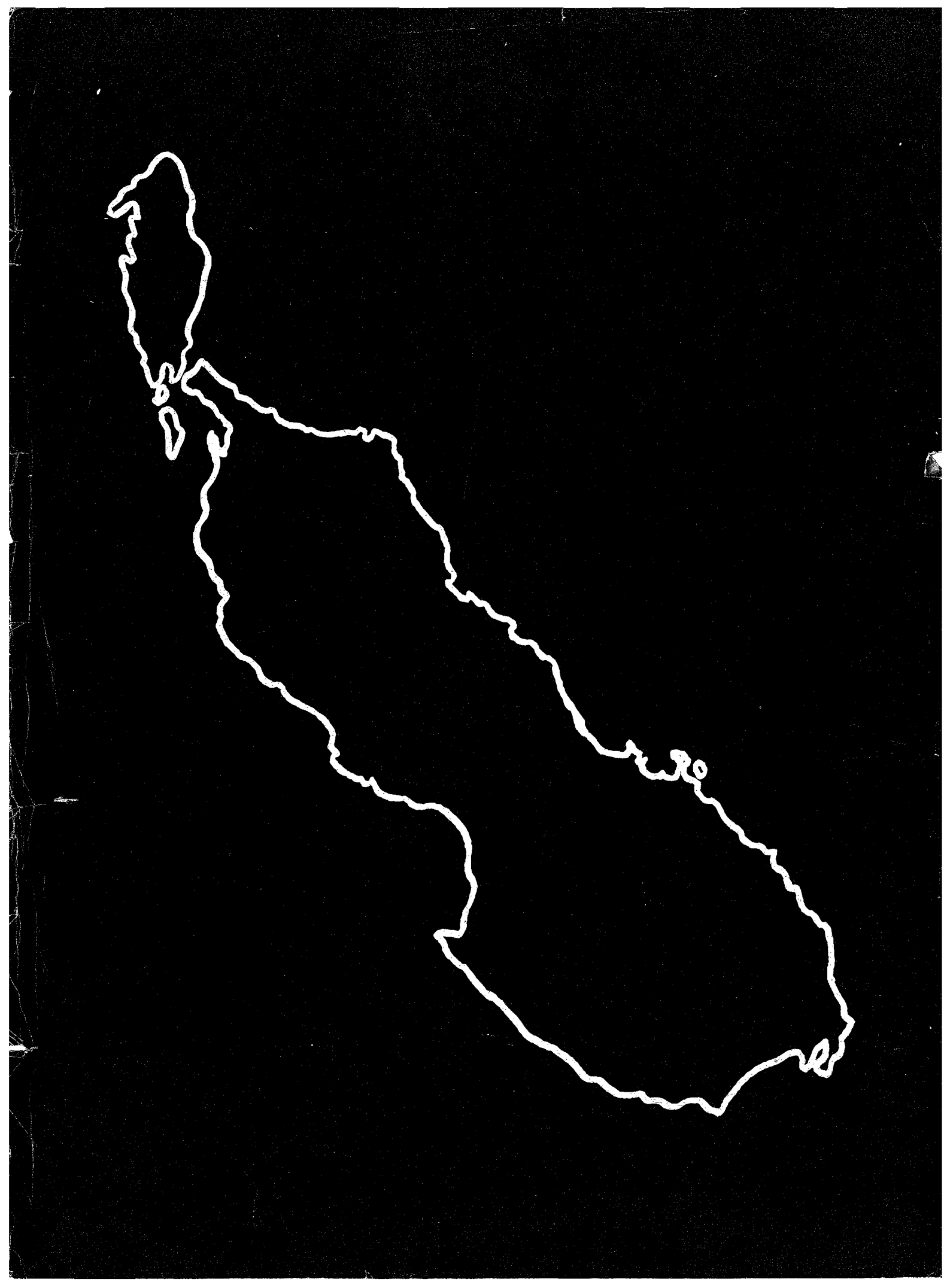
As a part of the contracts the payable gold and silver contents will be priced on the free market London price. Copper will be priced on the London Metal Exchange's cash sellers price for electrolytic wirebars. The concentrate will incur refining and smelting charges, deductions for impurities and any excess moisture, and freight charges to European buyers. The Japanese buy f.o.b. A floor price of $0.30 per pound of copper applies before charges and deductions.

Bougainville Copper's Contracted Contained-in-Concentrate Copper Sales

Purchaser	*Annual Deliveries, Tons in Years 1 to 5*	*5 to 10*	*10 to 15*	*Total Over 15 Years*
	JAPAN			
Japanese Smelter Group				
Firm sales	95,000	80,000	30,000	1,025,000
Vendor's options	—	16,500	—	82,500
Total	95,000	96,500	30,000	1,107,500
	WEST GERMANY			
Norddeutsche Affinerie GmbH	52,500	52,500	52,500	787,500
	SPAIN			
Rio Tinto Patiño S.A.	15,000	15,000	6,000	180,000
	UNITED STATES			
First sale	7,370 to 11,000	—	—	7,370 to 11,000
Second sale	17,550	—	—	17,550
Total	24,920 to 28,550	—	—	24,920 to 28,550
Grand total	187,420 to 191,050	164,000	88,500	2,099,920 to 2,135,550

Production and Cost Estimates

Bougainville Copper Pty. Ltd. Production and Cost Estimates for 1972 through 1976

Item	*1972*	*1973*	*1974*	*1975*	*1976*
Ore milled, per day	78,000	90,000	95,000	100,000	105,000
Ore grade					
Copper, percent	0.65	0.65	0.60	0.60	0.55
Gold, ounce	0.02	0.03	0.027	0.02	0.02
Recovered grade					
Copper, percent	0.553	0.56	0.53	0.54	0.59
Gold, ounce	0.0167	0.025	0.023	0.017	0.017
Metal prices					
Copper, cents pound	$ 0.50	$ 0.50	$ 0.55	$ 0.55	$ 0.60
Gold, per ounce	$62.00	$65.00	$65.00	$70.00	$70.00
Metal value per ton					
Copper	$ 5.53	$ 5.60	$ 5.83	$ 5.94	$ 5.94
Gold	$ 1.04	$ 1.62	$ 1.49	$ 1.19	$ 1.19
Total	$ 6.57	$ 7.22	$ 7.32	$ 7.13	$ 7.13
Ore milled per year, tons	22,000,000	32,400,000	34,200,000	36,000,000	37,800,000
Operating cost per ton[1]	$ 2.80	$ 2.30	$ 2.00	$ 2.00	$ 2.00
Operating profit per ton	$ 3.77	$ 4.92	$ 5.32	$ 5.13	$ 5.13
Less royalty	$ 0.10	$ 0.11	$ 0.11	$ 0.11	$ 0.11
Less administration	$ 0.04	$ 0.04	$ 0.04	$ 0.04	$ 0.04
Less interest	$ 0.50	$ 0.45	$ 0.40	$ 0.35	$ 0.25
Less depreciation and amortization	$ 0.90	$ 0.80	$ 0.75	$ 0.75	$ 0.70
Less taxation	0	0	0	0	0
Other costs	$ 0.10	$ 0.09	$ 0.05	$ 0.05	$ 0.05
Total other costs, per ton	$ 1.64	$ 1.49	$ 1.35	$ 1.30	$ 1.15
Possible profit, per ton	$ 2.13	$ 3.43	$ 3.97	$ 3.83	$ 3.98

1. Base year is 1972: mining, $0.30; milling, $0.85; transportation, $0.10; smelter and marketing, $0.15.