

A Development Consequence – Disposal of Mining Waste on Bougainville, Papua New Guinea

Eine Entwicklungsfolge: Die Abraum-Deponie der Kupfergrube von Bougainville, Papua Neuguinea

Une conséquence du développement: le problème des résidus de l'exploitation minière dans l'île Bougainville (Papouasie-Nouvelle-Guinée)

M. J. F. BROWN, Port Moresby*

Abstract: Countries in the South West Pacific face serious environmental pollution resulting from large-scale mining activity. Copper mining on Bougainville, Papua New Guinea, is taken as a case study. This is one of the largest copper mining operations in the world, and copper exports dominate the economy of Papua New Guinea. About 150 000 tonnes of rock waste and tailings are discharged each day from the mine area; the rock waste building up a large dump and the tailings being discharged into the Kawerong – Jaba river system. The tailings have spread out over 1700 ha on either side of the Jaba river, destroying large areas of rainforest and killing fish in the rivers. Pollution from heavy metals also gives cause for concern. The traditional way of life has been disrupted and several villages have been re-located from the tailings lease area. Reclamation is planned, and it is hoped to establish a cattle industry on the tailings deposits. Mining is only a part of a much wider pollution problem affecting Papua New Guinea, and the government should be concerned with enacting effective anti-pollution legislation, and ensuring that there is development without environmental degradation.

Zusammenfassung: Als Beispiel für die schweren Umweltschäden durch den Bergbau im südwest-pazifischen Raum wird der Abbau von Kupfererz auf Bougainville, Papua Neuguinea beschrieben. Täglich gehen 150 000 t Abraum in die Flüsse Kawerong und Jaba. Tropischer Regenwald wird durch Überflutung zerstört; Fische sterben an metallischen Giften. Mehrere Dörfer mußten verlegt werden. Rekultivierung der vom Raubbau betroffenen Flächen ist geplant. Bergbau ist nicht die einzige Ursache für Umweltschäden in Papua Neuguinea. Von der Regierung werden umfassende Schutzgesetze gefordert.

Résumé: Dans les pays du sud-ouest du Pacifique, les activités minières posent de graves problèmes de destruction de l'environnement, comme le montre le cas des mines de cuivre de Bougainville. Ces mines, parmi les plus grandes du monde, fournissent la plus grande partie des exportations de la Papouasie-Nouvelle-Guinée. Environ 150 000 t. de terres stériles et de résidus sont déchargés quotidiennement sur les terrils et dans le système fluvial Kawerong-Jaba. Occupant 1 700 ha sur les deux rives du Jaba, ces résidus ont détruit la forêt tropicale et tué les poissons. Les métaux lourds posent un problème particulier de pollution. Les mines ont bouleversé la vie traditionnelle; plusieurs villages ont dû être déplacés. On projette la restauration des terres ravagées par l'exploitation minière et l'on espère les aménager pour l'élevage bovin. Les activités minières ne constituent d'ailleurs qu'une partie des problèmes concernant l'environnement en Papouasie-Nouvelle-Guinée. Les autorités doivent édicter une législation contre la pollution et assurer le développement économique sans détruire le milieu.

1. Introduction

In recent years conservation of resources and environmental pollution have become important social and political issues. There is a growing awareness of problems concerning the continual and accelerated use of nonrenewable resources, concern over loss of land by mismanagement, the creation of man-made deserts and the degradation of the environment by industrial and urban pollution. The anti-pollution lobby has gained

considerable political influence in the 'western' as well as in the 'socialist' world, and various types of legislation have been passed with the aim of reducing pollution and protecting the environment. In the Third World, however, pollution has not become such a strong political issue.

At the Stockholm Conference on the Human Environment in 1972 there was a considerable divergence of views. At one extreme, there were those who maintained that growth means pollution, and that what we must do is to stop growth and to stop using energy. On the other hand, the underdeveloped countries rationalised that environmental improvement has no meaning to a starving popula-

* Dr. M. J. F. BROWN, Geography Department, The University of Papua New Guinea, Port Moresby, P.N.G.

tion, and that the attainment of levels of material well-being accomplished by the advanced nations must be a primary goal, even if it does result in reduced environmental quality.

In the South-West Pacific, in countries such as New Caledonia, the British Solomons and Papua New Guinea, the development of large scale timber and mineral resources is proving a major source of revenue. An important question, however, is to what extent this revenue can be used to raise the standard of living of the broad mass of the people? Will the development of the mining industry lead to significant economic advancement, or is this development mainly for the benefit of the 'western' world? ZORN (1973) points out that in the case of the copper mining countries of Chile, Peru, Zaire and Zambia, modernisation of the economies has not occurred after more than 50 years of substantial foreign investment. The majority of the people in each country are still living at the bare subsistence level. The export sector is dominated by foreign firms, interested in higher profit situations rather than the developmental needs of the less-developed nations. The experience of copper mining in these areas appears to be development by the rich, for the rich, at the expense of the majority of the people in the poorer nations. Rather than resulting in raising the standards of living, the gap between the developed and underdeveloped nations is widened still further. BROOKFIELD and HART (1972, p. 218) maintain that in Melanesia the revenue earned from the development of non-renewable resources of minerals and timber may merely replace external aid, which might be reduced. Also, in view of the present lack of skilled personnel, only limited Melanesian participation, except as labour, is possible.

In view of this, should the aim of countries in the South-West Pacific with large mineral resources be 'development at any price', with little regard paid to environmental degradation? Even if mining does result in economic development, the notion should be rejected that the exploitation of resources must mean that no consideration is given to environmental pollution. Mining, pollution and land management must be regarded as part of the same ecological process. The land, forests, rivers and fish are regarded as important resources, particularly by those people living at the subsistence level, as much as minerals are regarded as resources by the western world.

2. Bougainville Copper — A Case Study

At Panguna on Bougainville island one of the largest copper mining operations in the world began commercial production on 1st April, 1972 (Fig. 1). The Panguna deposit is a porphyry copper type orebody of about 900 million tonnes containing an average of 0.48 % copper per tonne. The mine is of the open-pit type, and

the ore is treated in a concentrator at the mine site at a rate of about 80 000 tonnes a day. A concentrate of about 30 % copper is slurried through a 26 km pipeline to the port at Loloho, where it is filtered, dried and stored ready for export. The average production will be about 150 000 tonnes of copper, 14 million g gold and 28 million g of silver. The estimated life of the mine is 33 years. The mine will make a substantial contribution to Papua New Guinea's exports. In the 1972/3 financial year the value of copper exports was about A\$ 125 million, or 55 % of the total value of the country's exports (Fig. 2), and for the first time there was a small trade surplus. The main markets for the copper are Japan, Germany (W.) and Spain. The mine is being operated by Bougainville Copper Pty. Ltd., a subsidiary of Conzinc Rio Tinto of Australia, which is itself 80 % owned by the British mining giant Rio Tinto Zinc. The Papua New Guinea government and the Investment Corporation together own a 20 % shareholding in Bougainville Copper, but there is political pressure for a re-negotiation of this equity.

The remote location of the orebody, the rugged mountain topography, dense vegetation and high rainfall (5080 mm a year at Panguna), posed considerable problems of access and construction, which had to be overcome by special engineering techniques. In addition to extensive preproduction operations at the mine site, major facilities that had to be provided included a deep water port at Loloho in Anewa Bay, a 135 MW thermal power station, two new towns, at Arawa and Panguna, and a port-mine access road. Arawa, built on the site of a former coconut plantation, has a population of about 10 000, and has replaced Kieta as the administrative centre of the Bougainville District. There was considerable local opposition to the development of the mine area, and to the provision of land for the port and towns. The mine represents a major capital investment, and in the eight years since preliminary drilling tests began the cost of bringing the mine into commercial production was about A\$ 400 million.

2.1. Sources of Environmental Disturbance

Extensive disturbance and pollution of the natural environment has resulted from the mining operations at Panguna. Before mining could begin about 220 ha of tropical rain-forest had to be cleared and a large thickness of volcanic ash and weathered rock removed to expose the orebody. The vegetation was cleared by poisoning the large trees and spraying the undergrowth with herbicide. The trees were subsequently felled and burnt. The overburden was removed by hydraulicking with powerful hoses, and about 18 million m³ of sediment was discharged directly into the headwaters of the Kawerong river.

The port-mine access road is about 26 km long, and for the final 11 km it has to negotiate the precipitous Crown Prince Range. The steep slopes, high rainfall, high seis-

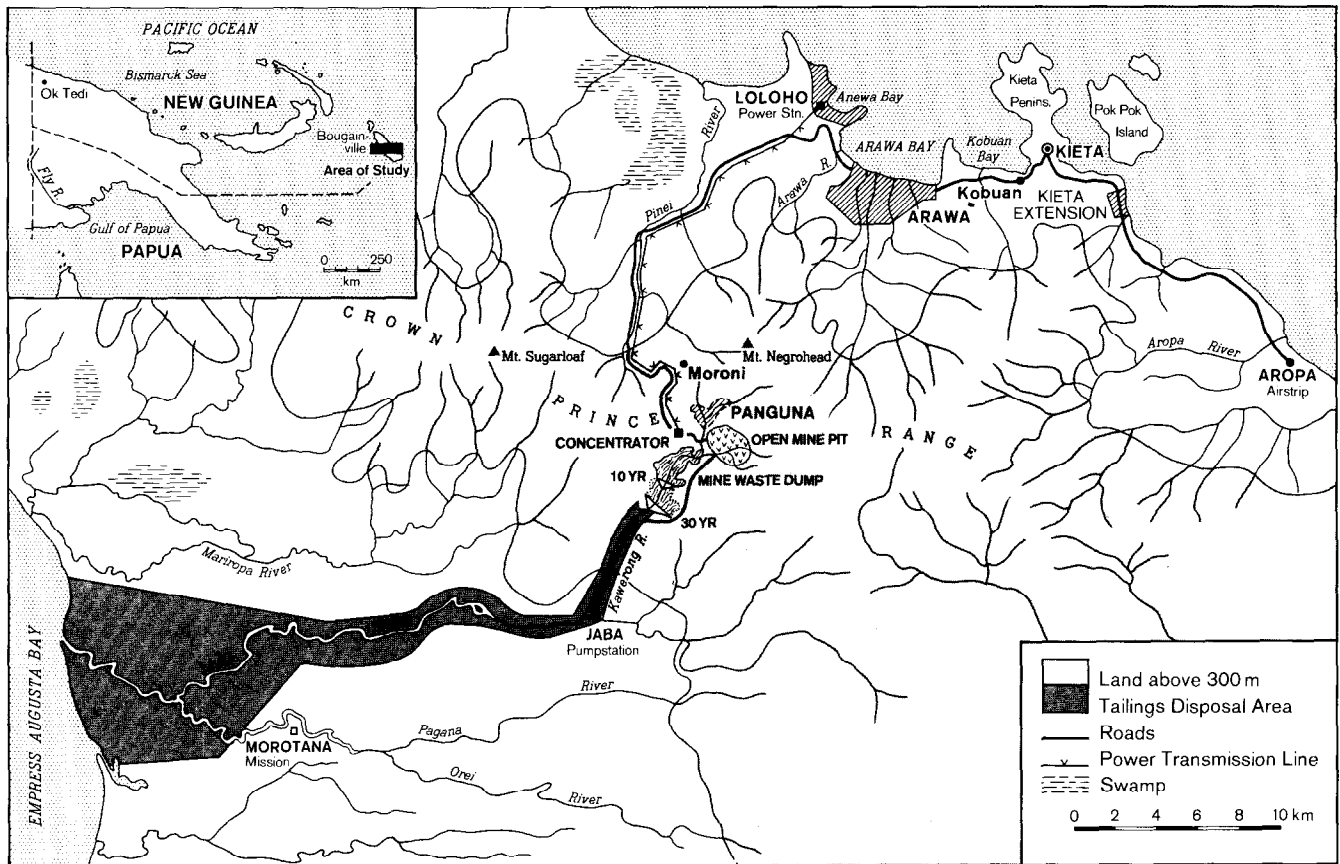
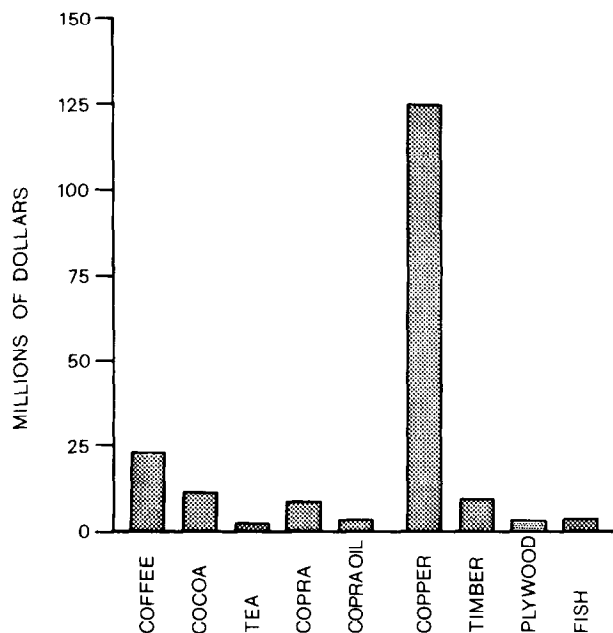


Fig. 1

- Mining operations on Bougainville
- Bergbau auf Bougainville
- L'exploitation minière à Bougainville



micity, and large thicknesses of unconsolidated volcanic ash, mean that the mountain stretch is potentially unstable. Considerable benching and terracing of the hillside was necessary to overcome the threat of landslides, and over 11 million m³ of material was excavated and side-caste into the headwaters of the Pinei river. The sediment load of the river was greatly increased and there was flash flooding, as a result of which two coconut plantations and a cocoa fermentary were inundated. Compensation of A\$ 47 000 was paid for damage to the plantations, a new fermentary was built, and a village was relocated. In

Fig. 2

- Value of principal commodities in Papua New Guinea's exports
- Wert der wichtigsten Exportgüter von Papua Neuguinea
- Valeur des exportations de la Papouasie-Nouvelle-Guinée

addition, levee banks were built and other work carried out to reduce the risk of another flash flood occurring.

The most serious source of environmental pollution concerns the disposal of about 150 000 tonnes of rock waste and tailings a day from the mine area. The rock waste is mainly coarse material and is being deposited in a large dump in the steep, narrow headwaters of the Kawerong valley. It is estimated that after 10 years the dump will extend about 2.2 km downvalley, and after 33 years it will extend to 3.3 km. The surface of the dump is flat, but the face is being actively gullied and suffers a high rate of erosion, the eroded material being carried downstream by the river. The amount of erosion is variable, being related to periods of high rainfall. A total of about 4 million tonnes was eroded in the period November 1970 to October 1971, and the erosion rate is now averaging 539 000 tonnes a month.

The tailings comprise finer grade material and are discharged directly into the Kawerong-Jaba river system, relying on the streamflow to carry the material away. In 1973 the tailings were discharged at a rate of about 70 000 tonnes a day, and a total of 34 376 000 tonnes was discharged into the river in the period January 1972 – June 1973. It was estimated that about 60 % of the tailings would be carried into Empress Augusta Bay and that 40 % would be deposited on the land. Most of the sediment was expected to be deposited in the swampy lowlands near the mouth of the Jaba river (BECHTEL-WKE, 1969). About 8 million tonnes of sediment resulting from mine area erosion entered the Kawerong in the period February 1970 to October 1971. Mine area erosion has since been considerably reduced, and sediment input from this source now averages 49 000 tonnes a month.

The total input of sediment to the Kawerong-Jaba river system in the period October 1968 to June 1973 was 96 099 000 tonnes (Table 1). Of this, it is estimated that about 33 % of the sediment has been deposited on the land and 67 % has been carried to the sea. This corresponds fairly well with the original estimates.

Table 1

- Sediment input to the Kawerong-Jaba river systems, October 1968–June 1973 (millions of tonnes)
- Sedimentzufuhr zum Jaba-Kawerong-System, Oktober 1968–Juni 1973 (Mio. t)
- Apports de sédiments dans le réseau fluvial Kawerong Jaba, octobre 1968–juin 1973 (millions de tonnes)

Hydraulicking (ceased September 1971)	35.255
Mine Area Erosion	9.170
Waste Rock Dump Erosion	17.298
Tailings	34.376
	96.099

(Source: Bougainville Copper)

Of the material entering Empress Augusta Bay, about 25 % has been deposited in a delta at the mouth of the Jaba river. The delta has grown about 1.3 km from the original coastline, with deposition taking place mainly on the northern side.

In addition to the vastly increased sediment load of the Kawerong-Jaba river system, the disposal of tailings has resulted in chemical pollution, particularly by heavy metals such as zinc, copper, cadmium, mercury and molybdenum.

Table 2 shows typical results of analyses of tailings stream water for the period April – June 1973:

Table 2

- Heavy metal concentrations in tailings stream water (parts per million)
- Schwermetallkonzentrationen in Flußwasserablagerungen (Teile in Mio.)
- Concentration des métaux lourds dans les eaux chargées de résidus miniers (parties par million)

Location	Cu	Zn	Pb	Cd	Mo	Hg.	pH
Plant discharge	0.005	0.001	0.002	0.001	0.003	0.001	9.7
Pump station	0.003	0.001	0.002	0.001	0.01	0.001	8.0
6 km below pump station	0.003	0.002	0.002	0.001	0.008	0.001	8.1
Mouth of Jaba	0.005	0.002	0.002	0.001	0.002	0.001	8.1

(Source: Bougainville Copper)

Although, in general, the concentrations of these metals in the river are relatively low, several points should be mentioned. Discharge of metallic wastes from mine areas and metal-processing plants is a matter of serious concern because of their possible toxic properties and other adverse effects. Because of its toxicity, mercury is an undesirable impurity at any concentration. Molybdenum is a rather rare element and is accumulated by vegetation; forage crops raised on land irrigated by water that contains small amounts of the element may become toxic to grazing animals. An upper limit of 0.01 ppm has been set by the U.S. Federal Water Pollution Control Administration (1968, p. 152). High concentrations of copper may be toxic. During the exploration of the Panguna area concentrations of 3 ppm were found. The concentrations of cadmium has a high toxic potential, and a recommended upper concentration limit of 10 µg/l for drinking water has been given (U.S. Public Health Service, 1962). Lead is also a serious, cumulative body poison. It is commonly found in water draining mine or industrial areas, and concentrations should be kept to an absolute minimum.

In addition to chemical pollution of river water, the tailings solids also contain concentrations of various metals and salts. The results of a typical analysis of the solids in the tailings stream is given in Table 3.

Table 3

- Tailings solids — element concentrations in percent
- Feststoffkonzentrationen in Prozent
- Concentration des divers éléments dans les résidus miniers (en pourcentage)

Pb	0.005	Zn	0.013
Mo	0.002	Cu	0.088

(Source: Bougainville Copper)

The rate of liberation of these elements is not known at the present time.

At the port of Loloho the copper concentrate is vacuum filtered and dried to remove the water content, and the filtration effluent is discharged into Anewa Bay. This is another potential source of chemical pollution. Early in the production stage there were fairly high levels of metal concentrations, due to inefficient operation of the plant. However, after corrective action, the concentrations have been reduced. A typical analysis of the filtration effluent is given in Table 4.

Table 4

- Filtration effluent metal concentrations (in ppm)
- Metallkonzentrationen im Filtratabfluß (in ppm)
- Concentration des métaux dans les effluent filtrés (ppm)

Cu	Zn	Pb	Cd	Mo	Hg	pH
0.110	0.002	0.002	0.001	0.009	0.001	8.3

(Source: Bougainville Copper)

2.2. Effects of Tailings and Waste Rock Disposal

The large volume of sediment discharged into the upper Kawerong river as a result of mining activity has had a profound effect on the river system, the vegetation, and the people living within the tailings lease area. The natural flow of the river has been unable to cope with the large sediment input, and there has been a marked change to the river channel and considerable overbank deposition and flooding. As deposition continues, the river is being transformed from a meandering to a braided pattern. Meander bends are being cut off, and the river is leaving its old meander course and becoming straighter and steeper. It is expected that this effect will gradually spread downstream towards the coast. As a result of overbank deposition the tailings have spread out over 1700 ha on either side of the Jaba river, killing large areas of rain-forest (Fig. 3).

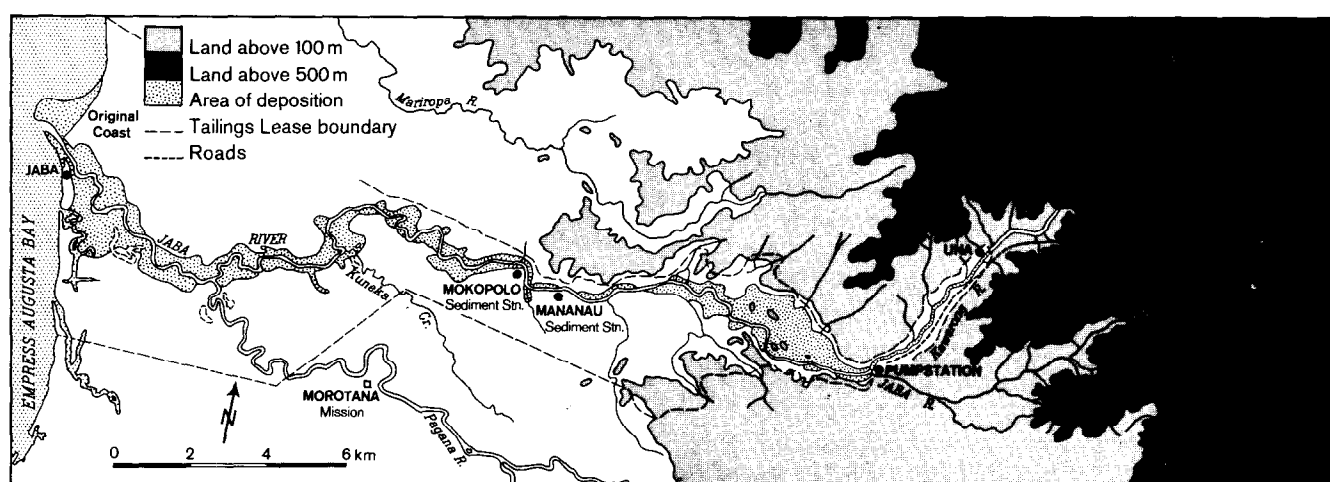


Fig. 3

- Areas of tailings deposition outside original river channel
- Abraum-Deponie außerhalb des alten Flußbettes
- Zones de dépôt des résidus miniers en dehors du lit fluvial original



Fig. 4

- Spread of tailings deposition below the Jaba-Kawerong confluence
- Abraum-Deponie unterhalb des Jaba-Kawerong Zusammenflusses
- Dépôt des résidus miniers en aval de la confluence Jaba-Kawerong

The area of greatest deposition is immediately downstream of the confluence between the Jaba and Kawerong rivers, where the Kawerong leaves its steep mountain course and its gradient is reduced (Fig. 4). Here, about 13 576 000 tonnes of sediment, or 43 % of the total land deposition, has been laid down. The rate of sediment build-up is estimated at 3 m a year and, so far, a thickness of about 8 m of sediment has been deposited. The sediment is almost entirely composed of cobble and pebble gravels.

Another area of significant deposition is in the middle of Jaba river, between Mokopolo sediment station and the junction of Kuneka creek. Here, about 9 648 000 tonnes of sediment has been deposited, or about 30 % of the total land deposition. The rate of build-up averages 80 cm a year, and a maximum thickness of about 5 m of material has been laid down. The sediments in this reach are mainly fine sands and silts.

The areas of least deposition are in the confined, steeper sections of the river about 2 km upstream of Mananau sediment station, and in the swampy lowlands between the Pagana junction and the coast. Although the sediment has

spread furthest away from the river in the coastal lowlands, the volume of deposition in this area is still small.

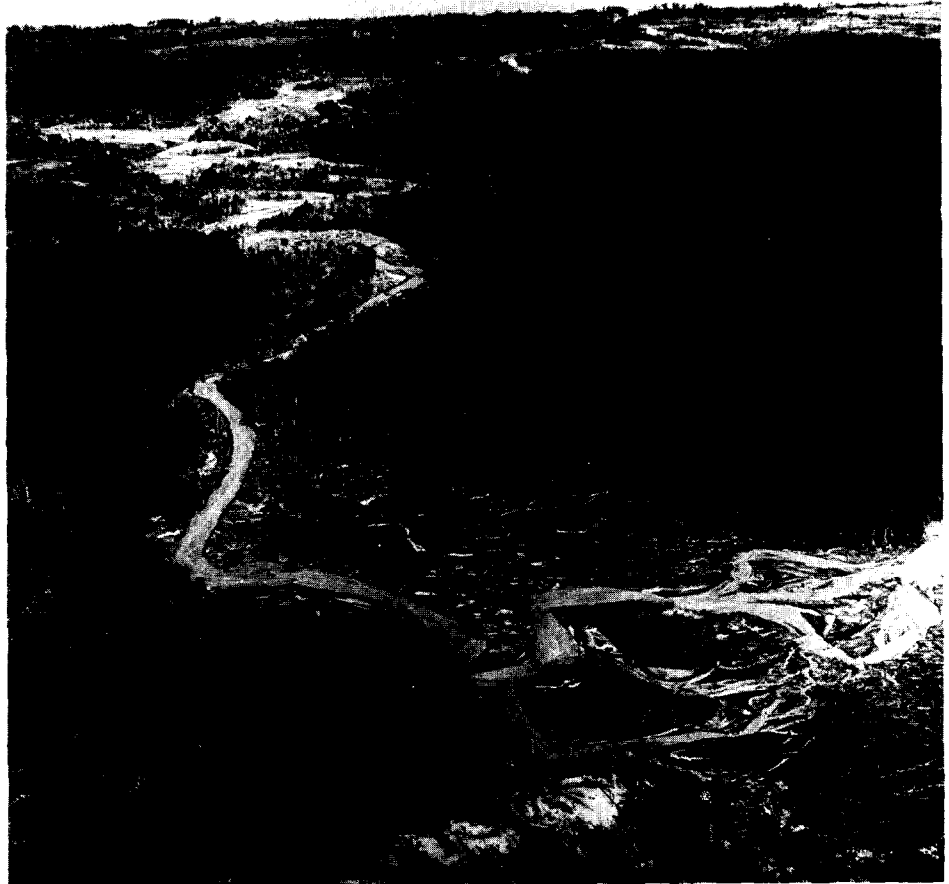
About 3 million tonnes of sediment has been laid down, and thicknesses are generally less than 30 cm. However, the continuing gradual build-up of the river bed and lengthening of the delta is increasing the risk of widespread flooding and a subsequent change in the course of the river. The most likely change is believed to be towards the south, into the old mouth of the Jaba river. This would reduce the present river length by over 3 km and increase the gradient from the Pagana junction by about 25 %.

Increased velocities might enable the river to carry more sediment to the sea.

The behaviour of the river and the spread of the tailings has been completely contrary to what was originally predicted. Rather than deposition occurring mainly in the swampy coastal lowlands, the area of greatest deposition has been where the Kawerong river leaves its mountain course, and the coastal lowlands have been areas of relatively small deposition. The future behaviour of the

Fig. 5

- Spread of sediment on Jaba river indicated by dying trees
- Absterbende Bäume kennzeichnen den Sedimentationsbereich des Jaba-Flusses
- Les arbres mourants indiquent la zone de sédimentation du fleuve Jaba



river and the spread of the tailings is uncertain. It is difficult to predict whether the tailings will spread outside the lease boundary. The absence of any high ground between the Jaba and Mariropa rivers means that it is difficult to assume that the rivers will remain segregated. If there is a danger of the tailings spreading outside the lease boundary retaining levees will have to be constructed.

The disposal of tailings has had a profound effect on the ecology of the river basin. As overbank deposition occurs large areas of rain forest on either side of the river have been destroyed. The progressive spread of the sediment is well indicated by areas of dying trees in the rainforest (Fig. 5). Formerly, the dead trees were left standing above the tailings deposits, but a decision was made to fell the dead trees, leaving large jumbled masses of logs in the river channel.

The sediment-choked Kawerong-Jaba rivers have no more fish living within them. Also, the fish are dying in the fresh tributaries of the Jaba, principally the Pagana and upper Jaba rivers, because they cannot migrate to the sea to spawn. There were plans to introduce exotic fish able to breed in fresh water, but this was not carried out because

it was feared they might spread to other rivers and upset the ecological balance. Mullet fingerlings are being caught in the estuaries of west coast rivers and released in the two affected rivers. This is a major and expensive undertaking, involving the services of a helicopter, and will have to be carried out for a considerable period of time.

The spread of tailings has threatened several villages, deprived the people of both agricultural land and areas of rainforest traditionally important for hunting and building materials, and the people have lost access to fish in the rivers. About 800 people have rights to land within the tailings lease area, though most live in villages outside the lease, and 1400 people have fishing rights on the two rivers. Although only about one-quarter of the lease area has been affected by tailings deposition, the people have lost interest in further agricultural pursuits, and agricultural plots have been abandoned by their owners. So far, four villages on the lease in the Jaba river area have been relocated, and two villages in the lower Kawerong valley have been moved further up the side of the valley because of the danger from waste rock dump failure. In the mine area itself, Moroni village was relocated to make way for the

concentrator. The mining company gives assistance during relocation, including the building of houses, the establishment of gardens, and the provisions of rations until the gardens begin to produce.

A serious consequence of the large volume of deposition in the lower Kawerong valley is that the Jaba pump station is threatened with inundation. The station pumps water from the upper Jaba river to the mine area for industrial uses, and is an essential part of the mine operation. As a result of deposition the Kawerong is now about 6 m above the Jaba at the confluence of the two rivers. To overcome the threat of inundation and back-up of the upper Jaba river a large levee has been constructed, partly out of discarded truck tyres. The levee keeps the sediment out of the upper Jaba and allows the river to enter the Kawerong further downstream. However, if sediment build-up continues at its present rate a very large levee will be required, and the threat of inundation will be greatly increased. Eventually the company may have to relocate the pump station: a very costly operation, which would disrupt the mine operations.

The effect of tailings disposal on marine life is not fully known. About 60 % of the tailings discharged into the river system are carried into the sea and, in addition to building a delta, the sediment has spread north to the mouth of the Mariropa river. There is a potential danger that the tailings, with their heavy metal content, might cause a build-up of metals in the fish food chain. Metals finally accumulate in the bodies of pelagic fish, and there is a potential danger that the rich tuna fishing resources might be affected by chemical pollution of the sea.

2.3. Compensation and Reclamation

Bougainville Copper pays compensation to the village people for a variety of reasons, such as occupation fees, damage caused by mining operations to gardens and livestock, the destruction of cash crop plants, and the destruction or detrimental effect to fishing grounds. The company has about 33 700 acres of land under lease, comprising 1000 acres of Special Mining Lease at Panguna, 22 000 acres of Tailings Lease, and 1700 acres for the port-mine road and Loloho port facilities. In addition, the company has a residence lease in the town of Arawa and an agricultural lease at Kobuan.

Before April, 1973, occupation fees for mining leases were paid on the basis of A\$ 2 per acre or 5 % of the unimproved value of the land, whichever is the greater. However, there was no agreement as to the unimproved value of the land, and the fees were paid at the rate of A\$ 2 per acre, and A\$ 211 000 had been paid to the landowners. In April the unimproved value of the land was set at A\$ 130 per acre, and the annual occupation fees are to be A\$ 6.50 per acre, with back payment of

fees at the rate of A\$ 4.50 per acre. The land value will be re-assessed in March, 1976.

Occupation fees merely entitle the company to occupy land; damages caused to assets on the land must also be compensated. Any flora which bears fruit or other produce is the subject of compensation. For example, A\$ 15 is paid for each coconut palm and A\$ 13.50 for each cocoa or coffee bush. Up to April, 1973 about A\$ 750 000 had been paid in general compensation.

Compensation at a rate of A\$ 20 per person per year is paid for the loss of fish in the Jaba river, and, to date, about A\$ 112 000 has been paid to about 1400 people. Negotiations are also being carried out to reach a settlement on the rate of compensation for killing fish in the Pinei river due to the effects of construction of the port-mine road.

Compensation rates have yet to be agreed upon for the destruction of rainforest due to road-making, mining and tailings disposal. The company is proposing to pay the people A\$ 150 per acre of forest destroyed, in annual instalments of A\$ 1.25 spread over 40 years. This offer has not yet been accepted by the landowners.

In addition to the various types of compensation, gravel and mineral royalties are paid to the people. Mineral royalties entitle owners of land in the Special Mining Lease to 5 % of the royalty paid to the Papua New Guinea government. It is estimated that the landowners will receive about A\$ 75 000 annually, depending on the prices of copper, gold and silver.

In accordance with the Tailings Agreement, the possibility of reclamation of the waste rock dump and tailings deposits is being investigated. It is hoped eventually to be able to convert the tailings into agricultural land and return the area to the local people. A test plot has been established on the waste rock dump, and grasses, legumes and trees are being experimentally grown. In addition, some 30 local families are to be relocated by late 1973 onto a rock waste filled valley. The 2.5 ha of flat land has been top dressed with a 1 m thick overlay of volcanic ash. It is hoped that the people will be able to grow food crops on this reclaimed land. On the tailings, studies are being carried out into the rate of weathering, the rate of nitrogen build-up, and the rate at which vegetation is regenerated on the deposits. A significant tailings experiment has begun on the Jaba river, about half-way between the pump station and the river mouth. The tailings are being pumped onto higher ground, and the solids deposited on an agricultural plot. An experimental livestock station will be established adjacent to this plot and cattle will be grazed experimentally on pasture grown on the tailings. It is hoped that the tailings deposits can be converted to grasslands and a cattle industry established.

3. Conclusion

Copper mining on Bougainville has resulted in serious pollution of the tropical environment. Rivers have become choked with sediment, large areas of rainforest have been destroyed, fish have been killed, and the rivers and seas are being contaminated with heavy metals. After the mine has ceased operations the open pit and waste rock dump will remain as a potential serious source of pollution as a result of erosion and the leaching of soluble oxidation products. This may be particularly heavy in view of the high rainfall in the area. Tailings on the Jaba flood plain may also continue to release metal in solution. A dead mine may remain a very live source of pollution.

Mining is only part of a much broader pollution problem, which may in the near future threaten the whole national environment of Papua New Guinea. Timber mining, the wood chip industry, oil palm and coffee processing, and urbanisation are other potential serious sources of pollution. The government should be concerned not only with the possible re-negotiation of the Bougainville Copper Agreement to gain the best economic returns, and ensuring that the revenue is used to raise the general standard of living of the people. It should also be concerned with the protection of the natural environment, enact legislation so that there can be development without pollution, and ensure that there is a balance between conservation and development.

Comprehensive legislation regarding pollution control should be passed, and control measures should have authority, co-ordination and planning, as well as clearly defined objectives. A Pollution Control Commission should be established, with wide powers to prevent further destruction of the environment. "Pollution has too often been justified by false economics. Easily measured private profits have been used as a facile argument to justify intangible and immeasurable social losses" (Senate Select Committee on Water Pollution, 1970, p. 184). When a new industry is to be established, the government and the company are naturally concerned primarily with the economic success of the industry. Extensive research is made into the economic prospects, the side effects of pollution often receive rather less than detailed consideration.

In the Philippines, an Air and Water Pollution Committee was formed following extensive mining pollution, and strong efforts were made to prevent mining companies from discharging tailings into rivers. As a result several companies built tailings dams to control waste disposal on the land. One of the largest copper mines, Atlas Consolidated, on Cebu island, suffered from a silting up of its deep water port as a consequence of the disposal of tailings into the river, and it was persuaded to discharge its tailings by pipeline into the deeper part of the sea between Cebu

and Negros islands. The volume of tailings disposal, 70 000 tonnes a day, and the distance to the sea, 13.4 km, are both smaller than on Bougainville. With regard to Bougainville, other methods of tailings disposal should be more fully investigated. The method of disposal adopted should not be that which is simplest and cheapest for the mining company, but that which is most effective in reducing environmental pollution.

A body such as a Pollution Control Commission would be particularly important in view of the proposal to exploit large copper reserves at Ok Tedi, at the head of the Fly river in Papua. It is essential that detailed ecological surveys are carried out before mining operations begin, and that there is a thorough investigation of the method of waste disposal. If the tailings are discharged directly into the headwaters of the Fly the consequences would be far more serious than on Bougainville. A much larger river basin would be polluted, and there is the danger that the rich fishing grounds in the Gulf of Papua would become polluted by chemical wastes.

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