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Mt. Fubilan (Ok Tedi), Papua New Guinea, looking southwest. The scars are drill sites and helicopter landing pads. Photograph by W. V. Hewitt, Ok Tedi Project Geologist.
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Abstract

The Ok Tedi porphyry copper-gold deposit in western Papua New Guinea was discovered and tested by a subsidiary of Kennecott Copper Corporation in 1968-1971. Exploration lapsed in 1972-1975 while Kennecott and the government of Papua New Guinea sought agreement on terms which would apply to any future mining operation. Negotiations failed in March 1975. Over the following fifteen months, the government carried out further testing and in 1976 entered into an agreement with an international consortium of companies led by The Broken Hill Proprietary Company Limited of Australia for final feasibility investigations and studies.

Introduction

Little is written about the historical sequence and interplay of events and circumstances that culminate in exploration and development of a major mineral deposit. The events or hunches that lead to acquisition of a mineral property, the factors that determine expenditures, exploration programs, and development concepts, the different and sometimes conflicting goals and expectations of the mining industry and host governments—all these aspects when drawn together can make an interesting document.

This paper traces the history of the Ok Tedi porphyry copper-gold deposit in Papua New Guinea from its discovery in 1968 to present-day feasibility investigations and studies. Its history could be said to be much older, for reported indications of mineralization in the Ok Tedi region date as far back as July 1875 when the D’Albertis and Hargraves expedition penetrated the Fly River and its tributaries to within approximately 50 km of the deposit. Hargraves examined sand from the river bank and “found a speck of gold, also a specimen of copper” (Goode, 1977).

The striking geographical features of the Ok Tedi deposit are its remoteness and its wetness. It is centered at Mount Fubihan (elevation 2,080 m) about 5 km west of the Ok Tedi (ok meaning river) in the undeveloped northwest corner of the Western Province of Papua New Guinea (Fig. 1). The deposit is approximately 600 air km northwest of the national capital of Port Moresby. Access during exploration is by light aircraft to the project base camp at Tabubil, thence by helicopter to Mt. Fubihan, 10 km to the northwest (Fig. 2). The major Fly River system is navigable by coastal vessel as far as Kiunga, 110 air km south of Tabubil. The distance by river from Kiunga to the mouth of the Fly River in the Gulf of Papua is roughly 870 km. Annual rainfall in the Mt. Fubihan area is between 10,000 and 15,000 mm (400 and 600 inches). The area is known as Cloudlands, with visibility being less than 50 meters for much of the time.

During the period of initial exploration and negotiations on possible development of the deposit, Papua New Guinea itself was undergoing the change from colonial rule to self-government and finally to full independence in September 1975. It was during this period that the deposit came to the attention of the mining fraternity, when in March 1975 the government announced that prospecting authorities containing the deposit which had been held by a subsidiary of Kennecott Copper Corporation since 1968 would not be renewed.

This paper reviews the history of early exploration and the events leading up to the government action in 1975. It then looks at the subsequent period culminating in the Mining (Ok Tedi) Act of 1976 covering resumption of investigations. After the 1975 disappointment for both the Papua New Guinea government and Kennecott, the act represents the evolution of a minerals policy which reflects the willingness of a foreign investor to continue putting up risk money in a young country and the agreement of the government to give practical aid and concessions for the development of a remotely located mineral resource. The story is incom-
plete to the extent that some source material in confidential files is inaccessible and that no attempt has been made to define the role or contribution of the individuals concerned.

Part I. The Years 1966 to 1976

Background—Bougainville Renegotiation

Papua New Guinea was, until December 1973, a territory administered by the Australian government. In December 1973 the Australian government transferred all governing powers to the elected National government, with the exception of foreign affairs and defense, which powers were in turn transferred at the time of independence in September 1975.

Ok Tedi was one of two mining-related problems which came to a head during the 21-month interval between self-government and independence. The other was the renegotiation of the agreement governing the Panguna porphyry copper-gold mine on Bougainville Island. Because the two stories are to some extent intertwined, it is worthwhile to review briefly the Bougainville renegotiation before proceeding farther.

The Australian administration of Papua New Guinea had negotiated the original Bougainville agreement with the would-be developer (a subsidiary of Conzinc Riotinto) in 1967, while exploration and development drilling were still in progress. The initial agreement contained concessions which are generous by today’s standards, including a three-year tax holiday, provision for accelerated depreciation which could extend the tax holiday to six or seven years, and exemption from tax for 20 percent of all income from sales of copper (Faber, 1974).

The mine was brought on-stream at full production in April 1972 at a total cost of about A$430 million. In the period since negotiations were completed in 1967, estimated ore reserves had doubled to over 800 million metric tons. In addition, copper and gold prices had risen to three and four times the levels of 1967. In the first full year of production (1973) Bougainville Copper Limited declared a profit of A$158.4 million. The Government share of this was limited to earnings from a 20 percent paid equity in the company, a 1 1/4 percent royalty on the value of metal in concentrates, and a 15 percent withholding tax on dividends transferred out of the country (effective from July 1972).

In 1972 a report sponsored by the United Nations Development Program and World Bank urged that the fiscal provisions of the 1967 agreement should be

\[ A = \text{Australian dollars, US} = \text{United States dollars}. \]
tional profits tax would come into effect only if annual earnings exceeded A$5.2 million and would result in an overall tax rate of 50 percent, if annual earnings reached A$16.6 million, or 60 percent in the unlikely event that annual earnings reached A$320 million.

Discovery and Early Development

The Ok Tedi story begins in January 1963 when government patrol officer Des Fitter led the first government patrol into the Star Mountains and brought back samples of copper mineralization from Mt. Ian, 6 km north of Mt. Fubian (Pratt, 1977). In August 1966 patrol officer G. C. Young recorded yellow and green encrustation along the entire length of a creek in the Kawarzepi area near Mt. Ian. This encrustation was presumed to be sulphide (more likely iron oxide and hydroxide) and copper minerals (Young, 1966). Unfortunately these significant observations were allowed to pass unnoticed and it was not until June 1968 that Kennecott geologists D. Flishburn and J. Felderhoff on helicopter reconnaissance exploration discovered mineralized float at the Ok Tedi-Ok Menga confluence and traced this back to its source in the Mount Fubian region.

At this time the area was a wilderness with no accurate maps, few aerial photographs, and no access other than by foot or helicopter. It lagged behind most of Papua New Guinea in terms of social services and economic development.

Kennecott was to make a significant impact. Within months a base camp was established. Fuel, supplies, and drilling rigs were shipped from Port Moresby to the river port at Kiunga, thence by light aircraft to Ningerum and by helicopter to Ok Tedi. Drilling started in February 1969 and continued for almost three years until October 1971. In this time a total of 32,860 meters was drilled. In addition the company initiated a number of civic projects including the establishment of a medical clinic and, in February 1971, a boarding primary school. Funds totaling about US$13 million were expended to the end of 1971.

In 1970 the administration of the Territory of Papua and New Guinea recognized Ok Tedi as a potential major project and initiated a series of joint meetings involving the administration and the company. The first meeting was held in August 1970, the second and third in March and August 1971.

At the first two meetings information was exchanged. At the third, discussion progressed to such matters as security of tenure, transition to a Special Mining Lease, and government contribution to infrastructure in addition to government equity participation. The company sought an agreement along the lines of the Bougainville agreement which had
been negotiated in 1967 when the Panguna prospect was at a comparable stage of investigation. While appreciating the company's concern about tenure, the government was unwilling to close off too many options by entering into negotiations at this stage, especially with national elections in the offing (February 1972). Instead an exchange of letters of intent was mooted.

Discussions continued more or less along these lines in meetings held in November 1971, April and August 1972, and in the less formal exchanges which developed between company and government personnel through 1972. While the company sought an agreement before it would commit more funds to the project, the government was reluctant to enter into any agreement until the project was better defined by the proposed next stage of development drilling and metallurgical tests. The government would not commit itself to contribute to infrastructure because there were insufficient data, and such data as were available could be interpreted to indicate a much better return on investment than that determined in company calculations.

Although negotiations proper had not yet begun, some of the main issues were already clear.

While the meetings between government and company were proceeding through 1972, the company continued to be active at Ok Tedi. A consultant engineering study was completed in June 1972 and copies lodged with the government in July. The engineering report (McKee-Pacific, 1972) quoted reserves of only 137 million metric tons of open-pit copper ore averaging 0.88 percent copper, and 100 million metric tons of ore lying beyond the limits of the projected pit. Skarn ore reserves were estimated at 13 to 27 million metric tons averaging 2.5 percent copper. Construction of an airstrip at the base camp (Tabubil) was continued and completed in July 1972. Preparations were begun for the development drilling program to start in October; two large drills were purchased, a mud distribution system constructed, and a contract let for helicopter services. It was intended that the development drilling program would recover large diameter core which, while giving closer control on the composition of the orebody, would also provide sufficient material for bulk metallurgical tests.

**Exploration Halted**

The development drilling program was never undertaken. In the first instance it was delayed by the drought of 1972 which reduced the Fly River to below navigable levels and thus prevented equipment and supplies from reaching the property. In the second instance, after the Fly became navigable in mid-December, the program was postponed because the company apparently considered it unwise to continue with further investment. By January 1973 the entire project had been placed on a standby basis. No further technical work was undertaken, but most of the staff was retained and civic projects were continued. Even on a standby basis costs continued to accrue at a rate of about US$500,000 annually, in large part because of the extended lines of supply.

The decision in December 1972 or January 1973 not to proceed with the development drilling program was the clearest indication up to that time that the company was less than happy with the prospect of investing further funds in mineral exploration in Papua New Guinea. However, there had been warnings twelve months previously when the company had terminated a drilling program at the Yandera prospect and had ceased exploration at Yandera, the Tifalin prospects, Woitape, and other promising areas. In mid-1972 the company had begun the process of farming out all of the areas which it held under prospecting title, with the exception of Ok Tedi and the Tifalin prospects.

There were a number of events which may have led the company to reduce exploration activity in Papua New Guinea. First the expropriation of profitable company operations by the Chilean government in 1971 must have led to some soul-searching with regard to the wisdom of investing in developing countries and must have had some impact on company finances. Second the company's attempts to have the Papua New Guinea government commit itself to negotiate a special agreement, contribute to infrastructure, and participate on an equity-earning basis had been unsuccessful. Third the large tax-free profits earned by Bougainville Copper Limited in its first months of operation in 1972, and higher profits projected for 1973, were leading to agitation for renegotiation of the Bougainville agreement, a move which was supported in public statements by the Minister for Mines in July 1972. Fourth, with self-government scheduled for December 1973, and independence to follow as soon as practicable thereafter, there was an increase in expressions of nationalist sentiment and a questioning of past practices, including a first review of mining policy by the House of Assembly in September and November 1972.

The government for its part had granted a renewal of the prospecting authorities covering Ok Tedi for the two years commencing December 1972, on the understanding that the development drilling would proceed. From its own assessment of data provided by the company, the government believed that the company had presented an unduly pessimistic picture of the economics of the project and had provided insufficient data to establish that there was a need
for government support in terms of infrastructure. Beyond this, the government was newly elected and was fully occupied with the many aspects of approaching self-government and independence. It had yet to develop a firm policy with regard to major mining projects, especially in such key areas as taxation, government participation, and government contribution to infrastructure. In addition the retirement of many long-serving government officers in 1972 and 1973 and the lack of expert consultant advice were other factors which must have reduced government capacity to respond positively at this time. (The appointment of an expert consultant had been recommended by a government working group in 1971 but had not been acted upon.)

In response to company approaches in March 1973 the Minister for Mines gave an assurance that the company's prospecting authorities both at Ok Tedi and in the Tifalmin area (25 km to the north) would remain in force without further work commitment for as long as negotiations continued. At the same time the Minister sought assistance and advice from the governments of Zambia, Zaire, Peru, and Chile. In March-April his special adviser visited Peru and in June-July a three-man team of Peruvian mining experts visited Australia and Papua New Guinea to review available information and to advise the government.

In May 1973 the government adopted a policy with regard to major mining ventures which included the following main points: the government to receive 50 percent of the profits of major mining ventures through taxes and royalties; the government to have the option to purchase equity; and all projects to be self-supporting with regard to infrastructure development.

Negotiating teams representing government and company met for the first time in August 1973 and frequent meetings followed until late 1974. One of the points raised by the government was the favorable impact on the subject of higher gold prices, up from US$35 to US$130 to US$140 at that time. The report by the Peruvian consultants was received late in 1973, and early in 1974 another consultant, Professor Willard C. Lacy, was commissioned by the government. Among other points, Lacy noted the large front-end capital requirements of the project and suggested that a satisfactory return on investment could be achieved if the projected mining rate were increased from 30,000 to 40,000 metric tons of ore per day. This would require establishment of additional open-pit reserves or adoption of underground block-caving mining methods either from the outset or at some stage during the life of the mine.

During 1974 legal documents were drafted and exchanged and most points were agreed on so that by November it was possible for the parties to announce that agreement was expected in the new year. Preparations were made for a resumption of drilling early in 1975; geologist vacancies were advertised and tenders called for a helicopter contract. The term of the prospecting authorities was extended for a further three months to 13 March 1975, in anticipation that agreement would be finalized by that time. However, a number of major issues remained unresolved, including the finer details of the tax package and the means of resolving any disputes which might arise from the agreement.

It had been agreed from the outset of negotiations that the project would be liable for company tax from the time of commencement of a profitable mining operation; company tax currently stands at 33 1/3 percent and an upper limit of 40 percent was agreed. In addition a dividend withholding tax of 15 percent would apply to dividends transferred out of the country, and a standard royalty would be payable amounting to 1 1/4 percent of the value of metal sold, less transport and smelting charges.

In late 1974 it was also agreed that an additional profits tax would apply to any windfall profits; this followed the pattern established in the renegotiated Bougainville agreement (Paber, 1974). However, the additional profits tax would come into effect only after the Investment Recovery Period, i.e., it would not apply until such time as the company had recouped an amount equivalent to its total capital investment, including loan funds, plus interest, and then only to windfall profits.

Negotiations Fail

A meeting in Port Moresby in January 1975 was attended by senior company specialists, including representatives of a potential farm-in partner. All parties were hopeful that agreement on the tax package and other matters would be reached quickly. However, it soon became obvious that the government and company concepts of a reasonable rate of return (i.e., the level at which the additional profits tax would cut in) were some distance apart. In addition the company was concerned about the effect of high rates of inflation on the invested capital base used in the calculation of reasonable rate of return, and about the unfavorable effect of such a tax scheme in the event that earnings fluctuated markedly from year to year.

Apart from taxation, the company would not accept the government position that disputes arising from the agreement should be settled under Papua New Guinea law with, if necessary, reference to an arbitrator to be appointed by a disinterested party such as the United Nations Economic and Social Commission for Asia and the Pacific or the Asian
Development Bank. The company sought to have disputes referred to an international authority such as the International Center for Settlement of Investment Disputes, or to an ad hoc panel of arbitrators not appointed under Papua New Guinea law, and in either case for the dispute to be determined according to "general principles of commercial law and international law accepted by developed nations."

Attempts to reach a compromise continued through February and early March. Faced with a breakdown of negotiations and under national and regional political pressure to ensure a resumption of activity at Ok Tedi, the government offered to finance the next stage of investigation, thereby providing a breathing space during which negotiations could proceed. This offer was rejected. By March 12 it was obvious that agreement could not be reached before expiration of the current term of the prospecting authorities. In the House of Assembly the Chief Minister announced that negotiations had been unsuccessful, that the prospecting authorities would expire at midnight on 13 March, and that the government would proceed with the next stage of investigation on its own initiative, at the same time seeking to interest other major companies in eventual mine development. He paid tribute to the work done by Kennecott and noted that relations with the company continued to be cordial and that the door was still open in the event that further discussions might be warranted.

The government proceeded immediately to resume exploration activity at Ok Tedi and in the Tifalmin area. A senior consultant, Behre Dolbear and Company, Incorporated, was appointed to plan, direct, and supervise the government program, and support services were provided by the government geological survey. The company gave every possible assistance in terms of making available reports, maps, computer records of assay data, etc.

The government-owned operating company (Ok Tedi Development Company) was established and offered continuing employment to all former Kennecott staff. Most accepted this offer, thereby ensuring a smooth transition and efficient resumption of field operations and providing evidence of continuity which must have been reassuring for the village people of the Ok Tedi region. Government personnel were at some pains to explain the changed circumstances to the village people, many of whom expressed resentment that the government had "thrown the company out." The villagers pointed out that it was the company, and not the government, which had constructed the airstrip, school, clinic, and store and had brought the opportunity to work for cash income.

In March to November of 1975, a government-sponsored study into alternative infrastructure schemes to serve the Ok Tedi-Frieda River region (Reuel and Partners, 1975) confirmed that it would be most economical to move concentrates from Ok Tedi by truck or pipeline to a port on the Fly River and that hydroelectric power was the only element of infrastructure which could be efficiently shared with any mine at Frieda River (90 km to the northeast of Mount Fubilan).

In January 1976 drilling resumed at Mount Fubilan under the auspices of the Ok Tedi Development Company, following a Behre Dolbear program which bore some resemblance to the original plan for development drilling prepared by Kennecott 3 1/2 years previously. The program of 4,000 meters was completed on schedule and within budget in April 1976 and a report released in June (Behre Dolbear, 1976).

Meanwhile the government had continued to hold discussions with major mining companies and in March 1976 announced that conditional agreement for the further testing and possible development of the prospect had been reached with the Dampier Mining Company Limited, a subsidiary of The Broken Hill Proprietary Company Limited. One of the conditions was that the company should form a consortium. The other condition was that ore reserves should be shown to be not less than 250 million tons containing not less than 0.85 percent copper and accessible to open-pit mining. The Behre Dolbear (1976) report indicated reserves of this order.

At the same time the government sought to find some means whereby Kennecott's contribution to the discovery and exploration of the Ok Tedi prospect could be recognized in the event that a successful mine were established. Such recognition would need to be in a form and at a level which would not impose unduly onerous financial commitments on the project and would thus be acceptable to incoming participants. The offer of a continuing contributing interest was rejected by Kennecott. As an alternative the government offered an ex gratia reimbursement of all expenses incurred by Kennecott in exploring the property, if a successful mine were established. This would take the form of U. S. dollar bonds issued by the government to Kennecott which would bear interest from the start of construction at a rate per annum 1 1/2 percent above the six months' London Inter-Bank Offered Rate. Interest on the bonds would be paid semiannually and principal would be paid in four equal amounts in 1987 to 1988, 1990 to 1991, 1992 to 1993, and 1994 to 1995. If this proposal is accepted, then the government will be rewarded with equity in the project to the value of the bonds made over to Kennecott. It is understood that discussions are continuing.
Part II. The Years 1975 to 1978

The Reassessment

At the time of the breakdown in negotiations between the Papuan New Guinea government and Kenncott in March 1975, The Broken Hill Proprietary Company Limited (BHP), through its wholly owned subsidiary, Dampier Mining Company Limited, was active elsewhere in mineral exploration in Papua New Guinea. At the Yanderra porphyry copper prospect (Tilley et al., 1978; Wanni, 1978), 430 km east of Ok Tedi, BHP was undertaking a major drilling and evaluation program under an option agreement with Triako Mines N.L. and Buka Minerals N.L. of Sydney.

BHP, asking other companies, had been invited by Kenncott in July 1974 to consider participation in development of the Ok Tedi project. For various reasons it did not at that time pursue the farm-in offer.

Following Kenncott's withdrawal, several international companies commenced negotiations with the Papua New Guinea government on ways to continue evaluation and development of the Ok Tedi deposit. Triako-Buka set in motion their own investigations to determine if the deposit could be more favorable than previously indicated. Their answer was yes and their solution lay in the significant gold reserves known to be contained in the copper-riched rocks capping the main copper body.

The 1972 McKee-Pacific evaluation had made no allowance for these gold reserves, but from 1972 on world gold prices had increased dramatically from US$35/oz to over US$165/oz by mid-1975. Although by the end of 1973 Kenncott were taking into consideration the growing economic value of the gold, ore-handling schedules in their planned mining campaign called for simultaneous copper and gold processing. This meant that most of the gold ore would have to be stockpiled and reclaimed for processing, since the gold-bearing copper rocks were classified as copper overburden to be removed prior to the start-up of a copper operation.

The Triako-Buka plan was to accelerate development of the gold reserves in the shortest possible time as a relatively small low-cost gold-only operation to generate an early front-end cash flow which would help finance development of the larger, more costly copper facilities.

Triako-Buka outlined the idea at a meeting with their Yanderra partner, The Broken Hill Proprietary Co. Ltd., in June 1975. BHP personnel had doubts about the concept; the small gold operation could well be swamped in the prestripping for copper, and worse, the early gold development could retard copper development, which still remained the prime asset of the Ok Tedi deposit. In addition, a Kaiser Engineers' study of the concept indicated considerably higher capital costs than those initially calculated by Triako-Buka. But, although the concept was to diminish in importance relative to other possibilities, there is no doubt that the Triako-Buka initiative provided the catalyst which prompted BHP to turn its attention again to Ok Tedi.

To understand the BHP thinking which then developed from examining available data, it is perhaps best to summarize briefly the setting and geometry of the Ok Tedi deposit and the distribution and reported reserves of the various ore components. The word "ore" is here used in the sense of significant mineralization and not in the strict sense of economic mineralization. The geology of the deposit as known before the current program is more fully described by Bamford (1972).

The geological setting of Ok Tedi is a late Pliocene monzonite to diorite multiple intrusive complex intruded into Upper Cretaceous to Miocene sedimentary rocks (Fig. 3). The sediments generally comprise fine-grained clastic rocks but also include a 300-m-thick massive limestone member.

Most of the Ok Tedi porphyry copper mineralization occurs within a monzonite porphyry intrusive phase centered on Mt. Fablia and measuring approximately 850 m east-west by 900 m north-south. Chalcopyrite is the dominant primary sulfide with lesser pyrite, marcasite, and minor molybdenum. The sulfides are fairly evenly distributed within the monzonite porphyry body as disseminations and veinlet fillings.

Mineralization is associated with potassic alteration which is characterized by biotite and lesser secondary alkali feldspar. A central area of intense...
quartz stockwork about 250 by 120 m tends to coalesce into a pluglike massive quartz body at its center.

The distribution of primary copper mineralization is masked to a large extent by deep leaching and the formation of a major supergene enrichment zone (Fig. 4). The thickness of the leached capping in which copper values are generally about 0.05 percent is from 15 to 200 m. The leached zone passes downward through a sharp interface into the secondary copper blanket where chalcocite is the dominant mineral, replacing and coating chalcopyrite. The blanket varies in thickness from about 50 to 300 m, in which much of the copper grade is over 1 percent. The lower boundary of the blanket is more diffuse with a gradual transition from chalcocite coatings into primary chalcopyrite grades of 0.2 to 0.4 percent copper.

The deposit contains significant amounts of gold. Higher gold values of greater than 1 g/metric ton, and sometimes upward of 3 g/metric ton, occur in
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Fig. 4. Generalized cross sections of the Ok Tedi deposit showing geology and distribution of copper and gold mineralization.
the upper portions of the body, mainly in the leached
capping rocks, forming a annulus around the cen-
tral quartz stockwork plug.

Numerous skarn bodies occur on the margins of the
intrusive complex. The best defined is the Gold
Coast skarn (Fig. 3), which is a semi-tabular mas-
seve magenite that calcsilicate body 10 m to 150 m
thick dipping steeply to the west. The massive mag-
netite contains copper grades of 1.5 percent or more,
and the intrusive and calc-silicate rocks on the hang-
ing-wall side are also mineralized.

The McKee-Pacific engineering evaluation report
of 1972, on which much of the Kennecott-Papua New
Guinea government negotiations were based, quoted
conservative porphyry reserve estimates of 137 mil-
illion metric tons of 0.88 percent total copper recover-
able by open-pit methods. The pit design utilized
final slopes of 35° and an overall stripping ratio of
2.22 to 1, which included about 45 million metric
tons of leached capping as overburden. The mine
life was 15 years with a 27,000 metric ton per day
concentrator throughput.

Overall minimal capital cost for this size operation
was estimated at US$1329.9 million inclusive of 10
percent contingency and 1972 costs escalated by a
5 percent annual rate in the development years. On
the basis of indicated open-pit minable copper reserves
and the development costs involved, Kennecott con-
cluded that the deposit was marginal in economic
viability.

The McKee-Pacific study also reported additional
reserves which did not figure in the feasibility evalua-
tion of the deposit. Porphyry reserves of 100 million
metric tons assaying 0.74 percent copper outside the
planned pit were estimated, of which it was con-
sidered substantial amounts might be recoverable by
underground methods or by extending the pit limits
as the end of the initial mine life was approached.
Underground reserves of between 14 and 27 million
metric tons of Gold Coast skarn ore assaying 2.5
percent copper were inferred from limited drilling.
The McKee-Pacific report acknowledged that the
anticipated value of the gold content of the copper
concentrate product was significant, but no values
were given.

Although not quoted in the report, the Kennecott
estimate of the gold reserve in the leached capping
was 16.7 million metric tons of 3.9 g/metric ton at a
cut-off of 2 g/metric ton.

After reviewing the data, BHP personnel con-
cluded that there was considerable potential for
making the deposit more economically attractive.
None of the three main components of the deposit—
the total porphyry copper system, the skarn high-
grade copper mineralization, and the gold in the
leached capping—had been drilled out. There was
also the possibility of increasing open-pit reserves by
deepening slope angles in the final pit design.

In many respects, this technical analysis of the
project was similar to Kennecott’s thinking as indi-
cated in a proposed final evaluation program pre-
pared by Kennecott’s Papua New Guinea and Aus-
tralian staff in May 1974. Certainly, it was recog-
nized by all that if the project were to be viable, an
increase in total reserves was essential to support a
much higher daily concentrator throughput.

The possibility of the Tifulmin copper prospects
(Arnold and Griffin, 1978 v), 25 km to the northeast,
having an impact on the economic viability of Ok
Tedi and the idea of increasing total reserves of the
project from that source were still apparently being
seriously considered by Kennecott and a potential
farm-in partner at the end of 1974. The BHP
staff did not consider that the Tifulmin mineralization
would have a significant impact and decided to con-
fine their main investigations for additional reserves
to the Ok Tedi area.

The concept of an early gold-only operation and
the exclusion of the Tifulmin prospects from immedi-
ate consideration appeared to be the two main tech-
nical differences between the Kennecott and initial
BHP/Triako-Buka approaches.

The Negotiations

In July 1975, having clarified their position with
Kennecott, BHP and Triako-Buka jointly entered
the list of applicant companies bidding on Ok
Tedi. Although there were differences in emphasis,
they presented to the government positive and optim-
istic proposals for the project based on four main
possibilities: (1) the attractiveness of proving and
mining at an early stage the leached capping gold
reserves; (2) the potential for increased open-pit
porphyry reserves within the planned Kennecott p.i.
from the margins of the deposit and by increasing
pit slopes; (3) the possibility of mining high-copper
skarn material to maintain or boost copper grades;
and (4) the belief that acceptable terms for the
granting of a special mining lease and the associated
taxation and development conditions could be negoti-
ated with the Papua New Guinea government. The
first three were to be tested in a small exploration
program.

The proposals were favorably received and
BHP commenced negotiations with the government
on behalf of BHP/Triako-Buka. An important
breakthrough came in these negotiations on taxation
and development terms, Agreement was reached on
the main obstacles which reportedly had thwarted
the Kennecott negotiations. In particular, the defini-
tion of a reasonable rate of return above which an
additional profits tax would apply including indexa-
tion of capital for additional profits tax calculations and the mechanism for arbitration in any disputes were resolved.

Negotiations were complex and protracted and it became clear to both BHP and the government that what was required was a full-scale feasibility study, rather than the earlier proposal of an initial small exploration and metallurgical test program. In March 1976, a Concession Agreement providing for further investigations and studies, the submission of development proposals, and eventual mining was signed. The agreement was ratified by the Papua New Guinea Parliament in June 1976 and became the Mining (Ok Tedi) Act of 1976.

The agreement represents a practical compromise between government and investor. The government recognized that one of the major problems for the developer would be the raising and servicing of the very large capital finance needed for development. Since this was of vital importance for continued investigations at Ok Tedi, the government made significant tax concessions designed to help the project’s early cash flow. If Ok Tedi is developed, these are the concessions.

**Additional Profits Tax**

An Additional Profits Tax will be payable once the project earns a specified and agreed Discounted Cash Flow rate of return, set at 20 percent or 10 percentage points above the annual rate of interest on domestic corporate borrowings rated AAA in the U.S., with the project having to select one or the other at the time production commences. All subsequent years of positive cash flow will then be subject to an Additional Profits Tax at the rate of (70% - n), where n is the normal company tax rate. However, two realistic concessions were made in this area.

1. Allowance or compensation is made for any subsequent bad years in which a negative cash flow is incurred. In this event, the process of accumulation used to calculate the Discounted Cash Flow rate of return will recommence from those negative cash flow years and no additional profits tax will be paid until such time as the accumulated cash flows are again positive.

2. The Additional Profits Tax will not apply during the investment recovery period. Taxation during this period will be at the normal rate of company tax up to a maximum of 35 percent.

**Accelerated depreciation**

In lean cash flow years before capital payback is achieved, an accelerated depreciation of assets for income tax purposes is allowed which will redistribute some of the tax liability to latter years.

**Withholding tax**

A dividend withholding tax not exceeding 15 percent will apply for the life of the project to all dividends remitted to overseas shareholders. As a concession, the government undertakes not to impose a withholding tax on interest payments made on loans raised to finance initial development of the deposit.

**Life of mine**

For the purpose of calculating tax deductions, the life of the development will not be more than 15 years. After the tenth year of operations, the Chief Collector of Taxes’ discretion under the Income Tax Act to determine the life of the mine will be restored.

**Other factors affecting return on investment**

**Foreign exchange regulations:** Although the project will be subject to normal Papua New Guinea foreign exchange regulations, a comfort clause in the agreement indicates that these controls will not be unreasonable or restrictive.

A machinery clause also allows a certain proportion of the proceeds from the project, to the extent of three months’ sales if needed, to be kept offshore to enable the project to meet regular overseas foreign exchange commitments and obligations, including payment of interest, capital and loan repayments, and dividends. Where sums of foreign currency in excess of three months’ sales are required, special arrangements would be made by the government to guarantee availability of the required sums at the prevailing exchange rate.

**Royalty and export tax:** The project will pay royalty of 1 1/4 percent of FOB revenue from all minerals sold. However, no export tax, levies, or excise duties will be imposed.

For its part, some of the conditions accepted by BHP in the event of development of Ok Tedi are:

**Law applicable:** All matters of the agreement will be governed by and construed in accordance with the law of Papua New Guinea.

**Arbitration:** In the event of disputes, arbitration clauses are provided which are similar to those included in the amended Bougainville Copper Agreement. If agreement of an independent arbitrator cannot be reached, that arbitrator will be appointed by mutual consent from nominations by the Asian Development Bank.

Any question of law in a dispute can be referred to the National Court of Papua New Guinea for opinion, and any opinion would be subject to normal right of appeal.

**Infrastructure:** Generally, the developer will be responsible for the cost, construction, and operation
of all infrastructure associated with the project. If the government provides any infrastructure, it can elect to have the capital cost involved credited against its share of equity in the project.

Social provisions: The project undertakes wherever possible to employ and train Papua New Guinea nationals, to use Papua New Guinea services and supplies, and to encourage and assist nationals to establish businesses supporting the mining operations and associated town. The project also undertakes to carry out an environmental survey of the region and to include an environmental management program in any proposals for development of the deposit.

The Consortium

The Concession Agreement when signed in March 1976 was conditional upon BHP forming a consortium of companies to undertake the next stage of exploration and feasibility work. BHP believed that the investigations and studies should be carried out by a strong international consortium. Such a consortium would be needed to bring together the very large sums required to establish the project and to share the risks inherent in big investments in a remote area of a country which had recently achieved nationhood in September 1975 and which despite a sound political record to date had yet to prove its long-term economic and political stability.

Long discussions took place with a number of international companies and negotiations continued beyond the original deadline of 30 June 1976 set in the Concession Agreement. By this time, the estimated cost of proposed comprehensive investigations and studies had risen to US$13.1 million and Triako-Buka withdrew. On the other hand, encouragement that had been gained by the results of the government-initiated Behre Dolbear drilling program which confirmed the potential for increased porphyry and gold reserves. These results indicated open-pit mineable reserves of 250 million metric tons of 0.85 percent total copper based on a cut-off grade of 0.49 percent copper, a waste to ore-stripping ratio of 2:1, and a pit slope of 45°. Gold reserves in the leached capping were estimated at 25 million metric tons of 2.86 g/metric ton above 1.55 g/metric ton.

Finally on 25 October 1976, a Consortium Agreement was executed, partners to which, with their respective share of consortium expenditure, were: Dampier Mining Co. Ltd., (subsidiary of The Broken Hill Pty. Co. Ltd.), 37.5 percent; Mt. Fubilan Development Co. Pty. Ltd., (subsidiary of Amoco Minerals Co., itself a subsidiary of Standard Oil Co. of Indiana,), 37.5 percent; and Kupferexplorationsgesellschaft mbH, (consortium of West German companies comprising Metallgesellschaft A.G., Siemens A.G., and Kabel und Metallwerke Gutehoffnungshutte, A.G.), 25.0 percent.

Dampier Mining Co. (Danco) is the manager of the exploration and feasibility study program and takes the lead in relations with the Papua New Guinea government. Danco's management of the program is supervised by an operating committee representing the participating companies.

Under the Concession Agreement the Papua New Guinea government may take an equity interest of up to 20 percent in the development of the deposit if it has the funds available, either as a direct investment or by providing infrastructure for which it would earn an appropriate interest. There is no provision in the agreement for compulsory acquisition or for carried interest.

The government has already accumulated equity as credit for money spent directly on the project to continue investigations after March 1975. As of June 1976, this amount totaled about US$3.8 million. Further credit against its share of equity would accrue to the government in any ex gratia settlement between the government and Kennecott in recognition of that company's past contribution to the discovery and exploration of the Ok Tedi deposit.

The Program

The consortium took over the management and running costs of the government-formed Ok Tedi Development Co. Pty. Ltd. In so doing, the project inherited immediate administrative facilities in Port Moresby and an experienced team of people, many of whom had worked in the Kennecott and Behre Dolbear drilling campaigns. Their knowledge of materials handling in difficult and remote conditions enabled field operations at Ok Tedi to swing into action within days of the signing of the consortium agreement.

The remoteness of the deposit means that about 25 percent of the total investigations and studies budget is spent on materials handling from Port Moresby to the site. The bulk of inward cargo is shipped by chartered coastal vessel from Port Moresby to the river port of Kiunga, where fixed-wing aircraft conduct a shuttle service to Tabubil. From there all plant and supplies required on site have to be transferred by helicopter.

However, by the end of November 1976, contract diamond drilling by United Geophysical Corporation of Madang using three Longyear 38 rigs had commenced, and by March 1978 a total of about 22,000 meters had been drilled in 86 holes.

The first 3,830 meters, completed in January 1977, were to test and define more closely the margins of the porphyry orebody, to test for depth extensions of copper ore in the porphyry body, and to test for
continuation of the gold-rich material in the leached capping. This phase of the program was successful.

Since then, drilling has included approximately 11,500 meters of infill drilling of the porphyry orebody and overlying gold-bearing leached capping, and nearly 6,000 meters in the Gold Coast skarn. From this drilling, a preliminary open pit as of March 1978 contains about 265 million metric tons of porphyry ore grading 0.82 percent total copper, 0.65 g/metric ton of gold, and 0.011 percent molybdenum, based on a copper cutoff of 0.5 percent copper, variable pit slope angles of 35° to 40°, and a waste to ore ratio of just under 2:1. The supergene copper enrichment blanket near the top of the deposit would enable ore grades in the early years of production to be in excess of 1 percent copper.

Gold reserve estimates in the leached capping are 30 million metric tons of 3 g/metric ton gold and 0.02 percent copper above a gold cut-off of 1.5 g/metric ton. Reserves in the Gold Coast skarn and mineralized porphyry hanging-wall contain about 40 million metric tons of 1 percent copper which may be recoverable in an open pit adjoining the main porphyry pit.

Bench scale metallurgical testwork on drill core composites of material from within various ore types has been carried out for flow-sheet development. Testing of flow-sheets by short pilot plant runs at Amdel in South Australia is being undertaken on bulk samples taken from adits driven into the gold capping, porphyry ore, and skarn ore. Total adit development to date is 700 meters in four adits, from which 300 metric tons of porphyry material, 30 metric tons of gold capping ore, and 40 metric tons of skarn ore have been transported to Australia. Heap leach testing on 110 metric tons of gold capping ore has been carried out on site, and further testing is underway.

In October 1977, Bechtel Pacific Pty. Ltd. was appointed as overall coordinating engineering consultant for the project. Some of the important decisions and critical factors to be brought together, and on which the viability of the project will depend, include: project capital cost estimates, operating costs, and economic analyses; optimum economic plant capacity; ultimate pit limits and attainable pit slopes; the availability and suitability of waste dump and tailings disposal areas in steep terrain and high rainfall situations; optimal development and scheduling pattern for the porphyry, skarn, and gold reserves; optimum metallurgical flowsheet and processing for the most economic recovery of the various mineral values; viability of cyanide heap leaching of the gold ore and dump leaching of low-grade copper ore; secure and economic transportation system for the concentrates from the deposit to an ocean terminal; evaluation of the project’s power requirements and provision of an adequate secure source; and, environmental impact study.

The consortium has 31 months from 1 November 1976 to 31 May 1979 to complete investigations and to submit development proposals, if any, to the Papua New Guinea government.

Because of the location of the Ok Tedi deposit in such a remote and undeveloped area, infrastructure required for the construction and operation of a large mining complex would be very expensive. In 1975, McKee-Pacific updated figures from its 1972 Kennecott preliminary engineering study, with concentrator throughput being increased from 27,000 to 40,000 metric tons/day. The result was a capital cost estimate of US$486 million. McKee-Pacific (1975) noted that overall capital costs had increased 58 percent since 1972.

Capital costs have since continued to inflate sharply, but at the same time world copper prices have failed to keep pace. The present investigations at the Ok Tedi deposit are designed to determine whether or not what was originally considered in 1972 to be an economically marginal orebody can be made into a profitable mine.

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REFERENCES
Faber, M. L. O., 1974, Bougainville re-negotiated: an analysis of the new fiscal terms: Mining Mag., Dec., p. 446-452.
Kaiser Engineers, 1975, Amdex gold mine study: Rept. to Amdex Mining Ltd., Sydney (unpub.).
McKee-Pacific, 1972, The Ok Tedi project, an engineering evaluation: Rept. to Kennecott Pacific Pty., Ltd., Sydney (unpub.).

1975, Ok Tedi project, order of magnitude up-date of capital cost estimate: Rept. to Ok Tedi Devel. Co., Pty., Ltd., Port Moresby (unpub.).
Rendel and Partners, 1975, Transportation systems for Frieda, Ok Tedi, and Tifalain mineral prospects: Rept. to Dept. Transport, Port Moresby (unpub.).
Young, G. C., 1966, Olsohup patrol report no. 1 of 1966-67: Dept. of the Prime Minister, Port Moresby (unpub.).