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BACKGROUND TO GOLD EXPLORATION

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Introduction

In 1986, world-wide production of gold was 1967 tonnes. The largest non-communist producers of gold were South Africa, USA, Canada and Australia. The 1987 Consolidated Goldfields survey ranked Papua New Guinea as the seventh largest producer.

Whilst this Papua New Guinea ranking is impressive, its largest producing mine, Ok Tedi, will experience declining gold production in the near future as gold grades fall and copper increases. This mine is the largest producer outside of South Africa and Russia and the decline highlights that a region's production is dynamic and new mines need to be discovered to replace depleted reserves.

Gold exploration is an ongoing process on a global scale. Many companies have been attracted to the prospective geological setting of Papua New Guinea and other southwestern Pacific islands. The number of companies working in the region has intensified over the last five years.

There are many national incentives to encourage the successful development of a producing gold mine. Access to cash flow, foreign exchange reserves, employment and infrastructure and other development opportunities are just a few of the socioeconomic benefits. Political benefits are an additional consideration. As an example of the financial benefits, the gold/copper mine at Bougainville contributed K815 million in dividends and direct taxation to the Papua New Guinea economy from 1972 to 1986.

However, exploration incentives and rewards cannot exist without risk, planning and long-term commitment. The time taken from exploration, through to mine development and production is typically from ten to twenty years. Whether or not a successful revenue outcome is derived from gold exploration and development depends upon the geology, timing and financing elements of the project.

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Geology. Exploration interest in gold has been sparked with discoveries of large low-grade gold deposits along the Pacific 'Rim of Fire', an irregular chain of volcanic islands stretching along the southwest margin of the Pacific Ocean. This chain corresponds to the boundary of the collision zone between the Australian and Pacific crustal plates. It stretches from Papua New Guinea (New Britain, New Ireland, Lihir and Bougainville), through to the Solomon Islands, Vanuatu, Fiji, Samoa, Tonga and the Kermadec Islands. Table 1 illustrates that this region holds several world-class deposits. These include alluvial (placer), epithermal and porphyry deposits.

Table 1 Some major Pacific island (and Canadian) mines

	Reserves (million *tonnes*)	*Grade*	1986 gold production (*ounces*)
PAPUA NEW GUINEA			
Bougainville	580	0.46 g/t gold 0.40% copper	530,000 e 178,600
Ok Tedi	400	0.66 g/t gold 0.76% copper	700,000 e 20,000
Misima	147	3.38 g/t	750,000 e
Porgera	83	5.1 g/t gold	600,000 e
Lihir	147	3.38 g/t gold	400,000 e
Lakekamu	40m cu m	0.3 g/t gold	100,000 e
SOLOMONS			
Gold Ridges	50	2.0 g/t gold	150,000 e
FIJI			
Vatukoula	1	6.4 g/t gold	100,000 e
AUSTRALIA			
Telfer	31	2.3 g/t gold	250,000 e
Kidston	36	1.7 g/t gold	215,000 e
INDONESIA			
Kasongan	147m cu m	0.3 g/cu m gold	20,000 e
CANADA			
Hemlo	50	7.0 g/t gold	1,000,000 e

cu m - cubic metres; g - gramme; t - tonne; c - copper tonnes; e - estimates.

Alluvial deposits such as Kasongan are concentrations of heavy minerals, including gold, buried in ancient river channels. They have been formed as a result of gold-bearing rock weathering and decomposing. This leaves behind the inert gold which is washed into rivers and subsequently buried by sand, gravel and clay. The current economic limit for mining these with a dredge is a depth of 100 metres of loose barren material. An epithermal deposit is the term for those deposits formed within a volcano as a result of ascending hot fluids from deep in the earth's crust depositing gold within 300 metres of the surface. These fluids dissolved gold from its natural background concentration of a few parts per billion, depositing it at a concentration of a few parts per million (grammes per tonne). Each gramme of gold may well have required between 500 and 1000 tonnes of fluid. In the harsh tropical climate, these deposits are eroded away within a million years of formation. Examples of these deposits may be found at Lihir and Vatukoula. Porphyry deposits such as Bougainville are also formed by volcanic activity. This occurs at greater depth which can vary from 2 to 8 kilometres below ground level. However, these deposits are eroded within five million years in a harsh tropical climate. In contrast, similar deposits at Kidston, in Australia, have taken four times as long to be exposed.

Since intense exploration activity within the southwest Pacific region has been recent, there has been little chance to build a well-developed geological data base. Initially, grassroots exploration areas are selected for detailed work by small teams. They issue geological survey maps where scanty data have been extrapolated and interpolated over wide areas. Remote sensing can also be used at this early stage to pinpoint target areas. Data such as changes in the earth's conductivity, magnetism, density and other parameters are analysed. Information that is anomalous to the earth's background level highlights areas which are worthwhile for further investigation. Subsequent exploration stages are more labour and capital in-

tensive. They range from sampling streams and rivers by panning for gold and other indicator minerals to sampling exposed rocks. If positive finds result, trenches are dug and soil samples are taken with the objective of outlining a drilling target.

If the prospect is encouraging after sampling surface material, the property progresses to the next stage. This involves drilling holes in the ground to take samples to gain an understanding of the geology and to determine the presence and grade of mineralization. Drilling also enables a mineable reserve to be calculated. If the results are positive, bulk samples are excavated for metallurgical and mine-planning feasibility studies. The entire exploration program to this stage could cost up to $100 million with no guarantee that the reserves will be economic. The definition of an economic ore body changes over time. For example, the gold price was around $US650 per ounce and copper in excess of $US1 per pound in 1981 when the Ok Tedi exploration was completed and the decision had been made to construct the mine. However, by the time all of the facilities were ready for production in 1985, gold price had fallen to $US300 per ounce and copper to $US0.60 per pound. This made the project's viability look doubtful at the time. With gold prices now close to $US450 per ounce and copper prices near $US1.00 per pound, the prospects look more hopeful.

The whole process of exploration and mine development can be extremely slow, risky and time consuming. In Australia, where the risks and geology are better understood, it is possible to start a small-scale gold operation (producing at an annual rate of 10,000 ounces) within twelve to eighteen months of commencing exploration. This operation would cost between $5 million and $10 million. In fact, the time period is usually from four to six years.

Time. By contrast, this time scale can be factored up by two or three times in the Pacific area. The terrain is less hospitable, supporting infrastructure is lacking, data bases are scanty, the deposits bigger, the geology not always understood and there may be complex metallurgical and environmental problems to solve. Delays are also influenced by both the explorers' and governments' attitude towards negotiations of operating agreements and the willingness of traditional landowners to negotiate access and compensation terms on the exploration areas.

Alluvial deposits are usually the quickest to discover and bring into production since river valleys are more accessible than volcanic mountainous areas and the plant can be constructed on site. The presence of gold can be determined cheaply, easily and quickly by panning river gravels. However, these deposits are extremely complex with fickle grade distribution that can easily fool the unwary prospector. Evaluation and construction of the Wau/Bulolo placer field in Papua New Guinea took five years from 1927 to 1932 and was mined continuously for thirty-four years, producing over two million ounces of gold worth $US930 million at today's gold price. This area is currently being re-evaluated to determine if it is worthwhile re-treating previously mined gravels which were excavated to 15 metres. The area may be mined down to greater depths in excess of 90 metres. The Panguna porphyry copper/gold deposit on Bougainville island took nine years from exploration to production. Ok Tedi in the Star Mountains, some 18 kilometres east of the Papua New Guinea/Irian Jaya border, took sixteen years. Porgera has taken longer, with several groups not prepared to wait out the search. It took twenty years of sporadic effort to trace alluvial gold to the main deposit and a further twenty-two years to move the project to a stage where bulk sampling can now be taken for ore reserve confirm-

ation, metallurgical testing and mine planning. The mine is unlikely to come into production before 1990.

Successful explorers need to be patient and have extremely strong financial backing if they are to see an exploration project turned into a mine. As a consequence of the long exploration and proving up period, the explorer is exposed to structural changes to the supply and demand for the target commodity, as well as to political risk brought about by possible changes of government.

The non-geologist needs to recognize that mineral deposits are difficult to find. Only a few are worth developing, and not all of these developments are profitable. Governments should not have unreal expectations that a financial bonanza can be brought about by the current high level of exploration activity. Development can only occur in suitable geological and economic environments.

Finance. Different kinds of finance are appropriate to a gold development project at various stages of development and risk level.

During the initial stage, exploration companies that have been set up with the specific aim of exploration are generally funded by individual shareholders. This is the most risky period of the project and it is impossible to borrow funds for the work. In the event that there is no discovery, or the find may be too small to be of economic significance, there is no obligation to repay capital to investors who have accepted the risk.

Once ore reserves have been confirmed and the economic viability of the project demonstrated, there is a wider range of financing alternatives available for mine construction. Funding for Misima is expected to be $280 million, whereas Ok Tedi cost $1400 million. Ok Tedi development has had two loan syndications, with the second one in 1984 becoming more difficult as banks became disillusioned with both country and project risk. The lead bank had to provide $US100 million out of the $US200 million syndicated. The 1986 syndication of a $US125 million multi-option facility for Bougainville took proposals to fifty banks before being completed. The main reason behind this reluctance is that Bougainville is regarded as a copper producer and banks are now averse to commodity-based countries.

Traditionally there has been a shift from debt to equity. However, over the past five years, gold backed debt instruments have become popular. It is recognized that any transaction achievable with paper money can be accomplished with gold. One option is to use a gold loan where a financier advances gold to the project owners who in turn sell it, purchasing goods and services for mine construction. The gold advance is repaid out of production with a small interest component of between three and four per cent per annum. Other sources of finance include export credits from countries where equipment is purchased. Multilateral agencies such as the World Bank could play a more dominant role in financing the fruits of the current exploration activity.

After production has begun there is a revenue distribution between the miner and the government. The miner needs to cover the costs of production as well as make a satisfactory return on investment. Incentives for exploration need to be maintained whilst adequate compensation is given to the original owners of the wealth. Governments view the benefits of mine development in a wider social context, where maximum benefits should flow through to the domestic economy. This can be achieved by the government holding part ownership, specifying local content of goods and services in addition to settling appropriate levels of royalties, duties and taxes. (See editors' note, 'The Papua New Guinea Mineral Resources Stabilization Fund', in this issue).

Conclusion

This article has canvassed the issues pertaining to a successful revenue outcome from gold exploration and production. After consideration of the geology, the time involved in project construction and the difficulties of financing, the new producing mine is not always 100 per cent successful. Despite vast amounts of money and technology in all phases of the program, a successful outcome requires good will between government and explorer, together with good luck.