

CITATION

Palmer, W. P. (1989). Gold Mining in Papua New Guinea: A Curricular Omission?, *The Journal of the Science Teacher Association of the Northern Territory*, Volume10 (1989-1990), pp. 10-18.

ABSTRACT

What criteria should be used to include or exclude particular topics within a country's science curriculum? It will be argued here that gold/gold mining is a suitable and relevant topic for inclusion in PNG's science curricula and suggestions towards achieving that end will be offered.

The teaching of the mining of copper ore and the metal's extraction are already a well established feature of the science curriculum being taught at Grade 10 and Grade 11. Amongst the reasons for the inclusion of copper were that it was considered to be an appropriate introduction to chemical technology and that it had major economic importance. Other advantages are that there are a wide variety of experiments that can be carried out using copper and its compounds in school laboratories and at least some of its chemistry is relatively straightforward.

In Australian chemistry curricula a little knowledge of industrial chemistry is now required of students, whilst many years ago industrial chemistry made up a considerable proportion of the curriculum. In this context a unit on gold and gold mining might well be a sensible choice at Grade 10 or 11 levels in Papua New Guinea to extend the pupils' knowledge and understanding of the interactions between science, technology and society. Practical work based on the extraction of gold or the chemistry of gold is limited mainly due to its high cost. However the possibilities of school visits to gold mines are greater because there are increasing numbers of gold mines operating. The links between gold mining, society and technology are particularly strong, so there is a good case for the inclusion of unit on the industrial chemistry of gold in PNG curricula.

GOLD MINING PAPUA NEW GUINEA: A CURRICULAR OMISSION

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INTRODUCTION

What criteria are used to include or exclude particular topics within a country's science curricula? It will be argued here that gold/gold mining is a suitable and relevant topic for inclusion in PNG's science curricula and suggestions towards achieving that end will be offered. The teaching of the mining of copper ore and the metal's extraction are already a well established feature of the science curriculum being taught at Grade 10 and Grade 11 (Ponnamperuma and Palmer, 1987). Amongst the reasons for the inclusion of copper were that it was considered to be an appropriate introduction to chemical technology and that it had major economic importance. Other advantages are that there are a wide variety of experiments that can be carried out using copper and its compounds in school laboratories and at least some of its chemistry is relatively straightforward. Owens (1980, p. 135; 1987, p. 161) however argues for a larger number of practical applications of chemistry being included in school curricula. Waddington (1987) points to some of the dilemmas facing science teachers introducing new ideas linking science technology and society and considers that relevance and the ability to inspire future scientists and technologists are important factors in determining science curricula worldwide.

Fensham (1987) expands on the idea of relevance and shows that for Australian chemistry curricula little knowledge of industrial chemistry is now required of students, whereas forty years ago industrial chemistry made up a considerable proportion of the curriculum. In this context a unit on gold and gold mining might well be a sensible choice at Grade 10 or 11 levels in Papua New Guinea to extend the pupils' knowledge and understanding of the interactions between science, technology and society. In general terms students studying a unit on gold would be able to explore these interactions more thoroughly than studying the units on copper, but practical work based on the extraction of gold or the chemistry of gold is limited due to its high cost, the low concentrations of gold present in its ores and the poisonous nature of the chemicals used for extraction. However the possibilities of school visits to gold mines are greater because there are increasing numbers of gold mines operating. The links between gold mining, society and technology are particularly strong. Gold mining has strong historical links to the exploration of the country (Gas and Whitaker, 1975 pp. 245 –274). Politics, law economics, and current affairs link the future of current and prospective mines with the divergence of view about the nature of land ownership in customary (Melanesian) tradition and imposed European law (Times, 23 June 1988, p.6) (Times, 12 January 1989, p.16).

This, for example, is one of the root causes of the disagreements with regard to the copper/gold mine at Panguna. The difficulties of finding sufficient jobs for educated young people is high on the political agenda in Papua New Guinea and the opening of new mines will certainly help to provide employment. On the other hand the opening of mines may well cause environmental damage which prevents farmers and fishermen continuing to provide for themselves in traditional ways.

The sciences of physics, chemistry, geology, geography, engineering, ecology and technology are all interwoven in the study of this topic and this paper will study these linkages. The method chosen will be to give some basic information about gold, explaining the theme from the historically earlier and technologically simpler methods to the more complex modern processes and choosing particular mines as examples of these processes. Background information from books and journals will be supplemented by articles from newspapers, particularly Papua New Guinea newspapers. This is because secondary teachers in Papua New Guinea have very limited resources available to them. This paper aims to act as a model so that teachers can then build up their own collections of cuttings from newspapers. Because the rate of expansion of mining is so rapid, it is a frequent news item for local newspapers and this would allow a file of information to be built up comparatively quickly.

OCCURRENCE

Gold is widely distributed in nature, combined or in the free state, associated with other elements such as sulphur, silver, copper, selenium or tellurium (Aavrimides, 1989). South Africa has the world's largest reserves of gold and currently supplies more than half the world's gold, outside the Eastern block nations (South, January 1988, pp. 11 -12). Indeed political disapproval of South Africa, particularly of its racial policies, may well militate against the inclusion of gold in science curricula worldwide. South Africa's supremacy in the production of gold is being challenged by the emerging nations of Africa, South America and the Pacific which are gradually increasing their production, (South, March 1989, pp. 8 - 11). Figure 1 indicates known mines and projects on the rim of fire.

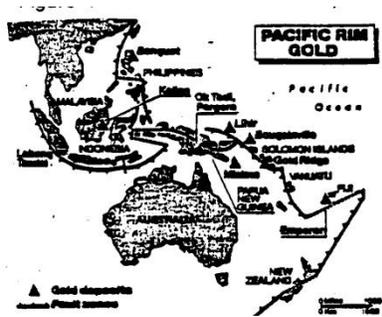
In the countries of the South Pacific on the so called 'rim of fire' (Fig. 2) the plates forming the earth's crust grind together, and complex geological processes bring increased concentrations of many metal ores including gold near to the surface (Jackson, pp. 5 - 10).

Figure 1* Production figures of mines.

*Taken from Times, 9th April 1987, p. 23.

Mines	Countries	Companies	Annual Output Troy ounces
Ok Tedi	PNG	BHP/Amoco	750,000 ozs
Bougainville	PNG	CRA	540,000 ozs
Emperor	Fiji	Emperor/Western	80,000 ozs
Lebon Tandai	Indonesia	CSR	30,000 ozs
Dizon	Philippines	Beuguec	150,000 ozs
Prospects	Countries	Companies	Potential Outputs Troy ounces
Porgera	PNG	Placer/ MIM Renison	1,400,000 ozs
Lihir Islands	PNG	Kennicort Niugini	1,000. 000 ozs
Misima Island	PNG	Placer	200,000 ozs
Hidden Valley	PNG	CRA	200,000 ozs
Gold Ridge	Solomon Is	Cyprus Minerals	??
Kelian	Indonesia	CRA	215.0 ozs

Figure 2* Map of Pacific rim gold.



Historically this area has produced gold since the fourth century AD when Chinese miners were active in Indonesia: gold was found in Fiji in 1868 (Bonato et al, 1987) and was observed in local pottery in Papua as early as 1852 (Healy, 1972). There are currently thirty known mineral sites needing further investigation and at least twelve of these are being mined or under active consideration. (PC, 13 September 1984, p. 13).

Which mines actually develop and which remain as golden dreams depends on many factors, but the factors will be a combination of the economics and the politics of the mine being considered. For example on Bougainville Island the extremely profitable Panguna mine has now shut down due to political disagreement about the distribution of the wealth which it produces. Others may never even start due to local disagreements which usually relate to the compensation to be given for loss of land. The likelihood of a mine being opened quickly increases rapidly if it has a rich vein of gold which can be exploited easily so that capital can be generated to pay for a part of the mine's initial costs. Other factors which affect development are the quantities, type and concentration of the ore, the country's perceived stability and financial standing, labour costs, the terrain, the weather, the risk of earthquakes, proximity to a port etc. These are internal factors but the overall determining factor is the price of gold internationally, both current and predicted. The price of gold has varied widely and is itself determined by supply and demand. Thus it is only mines which are sure to be profitable, even if there was to be a major change in the gold price, that will be developed.

Gold is curious amongst the metals in that it has only a limited number of uses. Most gold is stored as an accepted measure of an individual's or a country's wealth. Gold only has its current high value because people believe it to be valuable. Without that fundamental and widespread belief in gold's value none of the gold mines being considered would be started. A further incongruity in considering gold as a topic for study is that a logical sequence of curriculum development has at its root humanity's illogical desire for gold.

THE MINING OF ALLUVIAL GOLD: WAU AND MOUNT KARE

Gold contained in veins in gold-bearing rock, usually quartz, is called reef gold. When this rock is weathered and eroded the sand and gravel from it contain alluvial gold: these are called placer deposits, which are usually the first gold to be discovered. Prospectors separate the gold from the surrounding material by "panning". The mixture is whirled round and round with water repeatedly discarding the lighter mud, sand and gravel, usually leaving the denser gold with some grains of black sand in the pan. Hard labour is needed to obtain just a few grams of gold as large amounts of gravel must be panned. An improvement on panning is to use a sluice box

which is usually a large wooden construction with transverse strips of wood, riffles, set into its bottom. The box is inclined between 5 degrees and 30 degrees to the horizontal and the gold collects above the riffles (Stewart, 1986). The biography of an early miner in the Morobe goldfields (Sinclair, 1979, p. 33) indicates that even sluicing was hard work: 'As work advanced up the creek, the cleaned bottom was finally dug up with the pick and shoveled into a box to ensure that no gold was left in the cracks or embedded in the bottom itself'.

There are currently about 4,000 small scale PNG miners mainly earning their living from alluvial gold, using either panning or sluicing methods. They obtain their gold as follows. The product of panning or sluicing is mixed with liquid mercury, which dissolves the gold forming an amalgam leaving sand and gravel undissolved. The amalgam is then heated in a furnace, 'retorted' leaving a residue of gold or a gold/silver alloy.

Mercury vapour is extremely dangerous to human health and mercury when dissolved is harmful to the environment. Blowers & Mallard (Times, 22 August 1986, p. 21) carried out a survey to check the effects of mercury on human health and on the environment in the Wau/Bulolo area. They detected very little harm caused by mercury in the environment or in individuals. Mueller (1988), reporting a continuation of the same survey, indicated that there were two individuals with high levels of mercury in their urine.

Recently there has been another gold rush that is unlike the earlier gold rushes at Bulolo and Edie Creek in that the prospectors are PNG nationals. The site is at Mount Kare, near to the proposed Porgera mine (Age, 14 May 1988, p. 1) and village people and other highlanders are randomly digging up the hillside using traditional means. They can continue provided they use hand tools and not machinery (Times, 9 June 1988, p. 20). Overall the situation is said to be 'very, very wild' (Times, 28 July 1988, p. 16), but government still wants its 10% alluvial tax (Times, 14 July 1988), though it provides no health or other facilities (Times 19 May 1988, p. 8).

Large scale mining of the flats of the Bulolo river valley was planned in 1925. (Times, 19 January, 1989, p. 16). Hugh floating dredges were needed to implement these plans and the parts for these dredges were flown in and assembled on site. There were eventually eight working dredges weighing up to 2600 tons each, and these operated from 1938 to 1942. In March 1942 the Japanese captured Lae, so the mining operation was closed (Nelson, 1982) until after the war when mining was restarted. However costs had increased and the price of gold was pegged at \$35 an ounce so the enterprise was less successful than before the war. Dredging was brought to an end in 1965 (Healy, 1972), but the rusting dredges can still be seen today.

Nuigini Goldfields continues to operate successfully in the area (Times, 8 August 1986, p. 23) and Hidden Valley, near Wau, awaits government permission before production can start (Times, 27 April 1989). A further alluvial project in Gulf province near Malalaua at Lakekamu may be developed by City Resources using big dredges like those formerly used at Bulolo (Times 8 September 1988, p. 24). The Lakekamu ore is low grade, but has a large volume and a mine sited there is said to be "viable, affordable and about to happen". (Times, 9 April 1989, p. 25). Thus dredges similar to those that now lie abandoned and rusting may once more be seen in action, perhaps by 1991. Nonetheless it must be hoped that in the new situation more is done to return the land to its former fertility than has been the case at "Dead Valley" Bulolo, where the top soil has been destroyed and is now useless for agriculture (Mueller, 1988) (Times, 25 May 1989, p. 17).

COPPER AND GOLD: BOUGAINVILLE AND OK TEDI

Copper is the main product for both the Bougainville and Ok Tedi mines, but both are also major producers of gold and silver too. The Bougainville deposit was discovered in 1964 (Haddon-Smith) and the mine began production in 1972. Since that time the mine has been of major economic benefit to the PNG economy contributing about one third of the country's GNP. Although there is sufficient ore to continue production until the turn of the century the mine is currently closed due to a dispute with the landowners which has become, for all practical purposes, a civil insurrection against the PNG government. The original agreement was imposed against considerable local opposition and it may be that more generous terms provided for recent mining agreements have caused landowners to feel dissatisfied with their compensation. Certainly good economic management at the mine has made it very profitable in spite of decreasing grades of ore, so over the next few months considerable efforts will be made to resolve the conflict. Apart from financial compensation there is the question of environmental damage. The Jaba River has become badly polluted. The author visited the mine in 1983 and the photographs taken are used in PNG high schools. Apart from details of the mine these slides show the considerable pollution of the river near the outfall from the mine. The sediment from the river has built an estuary and there has been considerable damage to aquatic life which affects the livelihood of local fishermen.

The Ok Tedi mine is in some ways similar but is situated in a more geographically remote area so that any environmental damage is less obvious. A report (Mowbray 1986) did however detail some of this. For example recommendation 8.3, p. 73 states; "Ways must be found to reduce levels of suspended solids immediately and to ensure high levels of copper and free cyanide in the tailings are also reduced". It would appear that little action has been taken on the report's recommendations as recently the Ok Tedi river has been described as a sewer (Times, 1 June 89, p.3). The discharge from mines can pollute rivers in a number of ways. Firstly the crushed rock from which the ore has been extracted can enter the river as a fine mud which the river carries away. Secondly heavy metals normally trapped within the rocks can be released and accumulate in particular aquatic species. Thirdly dangerous chemicals such as sodium cyanide used by the mining company when treating ores may also escape from the mine. Each of these problems can affect local people living below the mine in different ways. The report (Times, 1 June 1989, p. 3) states that the mine waste from the dam has settled as mud in places and blocked the river so that a wide area floods during the heavy rains. The gardens belonging to the Yonggom people are destroyed by the infertile mud deposited, because it prevents crops from growing. They use the water of the Ok Tedi to bathe, wash their clothes, to drink and to fish. Heavy sediment and dissolved heavy metals have made these activities difficult or dangerous. The Yonggom people have received no compensation for the destruction of their way of life.

The initial stage of the Ok Tedi project was to remove the surface layer from "the gold topped mountain" (TEC, June 1983, p. 23). The gold was extracted by the usual carbon pulp-cyanide process and the cash-flow generated used to pay for high initial costs. The sodium cyanide needed for this process was brought most of the way by barge. One barge lost its cargo of cyanide drums in a storm in the Fly estuary. The Post Courier index can be used to tell this story quite dramatically as follows: - CYANIDE LOST NEAR FLY MOUTH (19 June) - WEATHER HAMPERS SEARCH (21 June) - SECOND CYANIDE SPILL SHUTS GOLD PLANT (4 July)

- KEEP SEARCHING ORDER ON CYANIDE (13 July) –RISKY TO SALVAGE DRUMS (30 July) - NOW 138 DRUMS FOUND (18 October) –CYANIDE INQUIRY TO BE SET (5 November) - CYANIDE INQUIRY INDECISION (10 December). This outline story could well be used as an opportunity for imaginative essay writing.

The original design for the Ok Tedi mine included plans for a tailings dam at Ok Ma (TEG June 1983, p. 26), which if built would have obviated the problems described above. It has never been completed due to a mudslide (PIM, March 1984, p. 29) at an early stage of construction (PC, 7 May 1984, p. 3). As an interim measure tailings were treated with hydrogen peroxide to destroy free cyanides and heavy metal cyanide complexes and these soluble products were then precipitated in alkaline solutions (Degussa 2, 1988). Later reports (Times, 1 March 1986, p.3) indicate that the tailings dam will never be built because it is said that the risk to the environment of a tailings dam collapsing due to unstable soils and frequent earthquakes is greater than the known damage caused by the mine waste being dumped in the river. The PNG government and a number of experts, for example Brooks (PC 25 April 1986, p. 5) consider that the damage to the environment is more than balanced by the good the income from the mines does in helping the development of PNG. Others find the environmental cost too high. This is an important area to discuss with students.

THE PORGERA PROJECT AND MODERN GOLD EXTRACTION

Porgera has sixty million tonnes of moderate grade ore containing 6.5g of ore per tonne. (Times, 18 May 1989, p. 21) and will be mined using a combination of open pit and underground mining (Times, 9 February 1989, p. 18). The ore will be ground into a fine powder, after which any free gold will be removed using gravity recovery. The mine's power will come from electricity produced from natural gas from the Hides field. Flotation will remove sulphide ores which will be oxidised by heating in autoclaves. A standard cyanide leaching process will be carried out using carbon in pulp which eventually yields particulate gold and silver. These products are melted and cast into bars of gold-silver alloy ready for further purification.

The major cause of disagreement regarding the plans for the Porgera mine is the provision of a tailings dam. The company believes a tailings dam will always be at risk in an earthquake zone and that a possible collapse poses a greater threat than the continual dumping of waste into the Strickland river system which also, like the Ok Tedi mine, leads into the Fly River (Times 2 March 1988, p. 1). Although there has been considerable political infighting about this (Times 19 June 1989, p. 1) it now appears that mining will go ahead without a tailings dam, but it will have a much less expensive tailings neutralisation plant (Times, 9 February 1989, p. 3).

OTHER MINES, TECHNOLOGY, AND USES OF ORE

Misima was the site of an earlier gold mine which started in 1888 and produced gold until 1950 (Times, 5 September 1986, p. 18). The mine's potential has now been reassessed (Times 12 November 1987, Times, 8 October 1987, p. 33) and agreement between the various parties reached, so that mining can go ahead (Times, 8 October 1987, p. 33). The deposit is of very low grade, 1.38g per tonne of gold and 21 g per tonne of silver (Times, 29 October 1987, p. 3). Production is due to start within the next few months (Times, 18 May 1989, p. 21).

Lihir Island is the projected site for another mine, this time a mine with huge reserves of low

grade ore valued at eleven billion dollars (Age Extra, 12 May 1988). Gold was discovered in Lihir in 1982 (TRS 17 May 1986, p. 3). Exploration has continually upgraded the site and value of the deposits but geological factors present considerable technical problems to mining as the highest grade ores are on the edge of a caldera and are below sea level. The removal of waste without spoiling the environment will also need considerable ingenuity. (Times, 26 September 1986, p. 8).

Future developments indicate promising signs of gold deposits in the Tabar, Tanger and Fenni Island groups, whilst the "Wild Dog" reef in East New Britain is described as a "significant and potentially economic" find, (TRS 17 May 1986, p. 3). There is also a potential gold find at Mount Nakru in West New Britain (Kalowin, 1988, p. 4 and p. 25). At Wapolu on Ferguson Island there are large deposits of low grade ore near the surface which are comparatively easy to mine (NGN 26 January 1987, p. 3). There are also rich gold reserves in Oro province in conjunction with significant platinum at Safia and Embessa (Times, November 1987, p. 1). However technology and economy will determine the future of these mines. Not all the gold can actually be extracted from the crushed rock and it is only recently that recovery of gold from low grade deposits has become technologically and economically feasible. This is partly due to improved technology but also due to a much improved gold price. Over the last few months the supply of gold has increased and the price has fallen. Mines with high cost recovery will be forced to cease mining. There are signs that improved technology will further reduce costs as the following examples indicate. CSIRO scientists have studied the use of thiourea rather than sodium cyanide (CSIRO 1986) in dissolving gold. Reverse phase ion interaction chromatography (RPIIC) may save the gold mining industry considerable sums in reduced chemical costs. Local production of activated charcoal for absorption of gold and silver from the cyanide leach solution could save foreign exchange costs (Afenya et al, 1983). Finally peroxide assisted leach (Degussa 3, 1988) is said to increase the yields and speed of the recovery of gold from the carbon in pulp.

Gold has a low chemical reactivity and good electrical and thermal conductivity. Many of its uses depend on these properties. Gold is used mainly as a store of wealth, for coinage and in the production of jewelry. There are however modern high technology uses for gold in electronics (Puddlephatt, 1979), coating of windows of the lunar module for example to reflect heat (AMIC, 1988), in surgery as wire to provide inert support (Clark and Cook, 1988, p. 3) and for medical applications, particularly in the treatment of arthritis (Ainscough and Brodie 1985).

CONCLUSION

The topic of gold/gold mining contains an admixture of ideas from a variety of disciplines which with further curriculum development can lead to a fully integrated course for year 10 or 11 in PNG high schools. The politics of mining at the present time in PNG might well encourage many companies to help in that curriculum development by providing booklets and other curriculum materials to schools, such as those the mining industry in Australia has already provided for Australian schools.

NOTE

In general newspaper and popular magazine articles will be referenced briefly within the text, whereas books and academic journals will be referenced fully. The following abbreviations will be used.

The Age	Age
New Guinea Nuis	NGN
Pacific Island Monthly	PIM
Post Courier	PC
South	South
The Times of Papua New Guinea	Times
The Times of Papua New Guinea Export Guide	TEG
The Times & Papua New Guinea Regional Survey	TRS

REFERENCES

- AINSCOUGH, E.W. and BRODIE, A.M. (1985). Gold Chemistry and its Medical Applications, *Education in Chemistry*, 22 (1) January, pp. 6-8.
- AFENYA, P. M. and BLOWERS, M. J. (1983). *Research in Mineral Technology and Energy, Chemical Technologists in Industry*, (Editor C. Owens), Papua New Guinea University of Technology, Lae.
- AMIC (1988). Mineral Facts, *Gold sheet no.5*, Australian Mining Industry Council, Dickson, ACT.
- AVRAAMIDES, J. et al (1989). The Production of gold, *Chemistry in an Australian Context Sourcebook*, (Editor I. Irvine). Parkville, Victoria, Australia: Royal Australian Chemical Institute.
- BONATO, J .A. (1987). Gold Extraction. *Chemistry Serves the South Pacific*, (Editors: A. Bonato, J.B. Headbridge and R.J .Morrison). Fiji: University of the South Pacific, pp. 100-107.
- CLARK, I. and COOK, B. (1988). Introduction to Australia's Minerals; Gold. Adelaide: (ITAM 3), S.A. Chamber of Mines and Energy.
- CSIRO (1986). *The Minerals Industry*. Canberra: CSIRO Research for Australia, p. 66.
- DEGUSSA 3 (1988). *Hydrogen peroxide: detoxifying mine effluents containing cyanide. (Company booklet no. 2)*. South Melbourne: Degussa.
- DEGUSSA 3 (1988). *Hydrogen peroxide: Peroxide assisted leach for the cyanidation of gold ores. (Company booklet no. 3)*. South Melbourne: Degussa.
- FENSHAM, P.J. (1987). *Changing to a Science Society and Technology Approach Science and Technology Education and Future Human Needs* (Edited J.L. Lewis and P.J .Kelly). Oxford: ICSU/Pergamon Press, pp. 67-80.
- GASH, N. and WHITTAKER, J. (1975). *A Pictorial History of New Guinea*. Milton, Queensland: The Jacaranda Press, pp. 258-274.

- HADDON-SMITH, K. (undated): *Bougainville Copper*, Bougainville Copper Ltd, PNG
- HEALY, A.M. (1972). Goldfields, *Encyclopaedia of Papua and New Guinea*, (Editor: P. Ryan). Melbourne: Melbourne University Press, pp. 99-501.
- JACKSON, R. (undated). *The Pot of Gold*. Port Moresby: University of Papua New Guinea.
- KALUWIN, C. (1988). Chemistry and mining in PNG, *Chemistry in Papua New Guinea*, 4 (2) November, pp. 6-9.
- MOWBRAY, D.L. (1986). Biological Input of Ok Tedi mine tailings, cyanide and heavy metal on the Ok Tedi, Fly River Ecosystems in Papua New Guinea, *Report to the Bureau of Water Resources. Waigani* (10 September): UPNG.
- MUELLER, N. (1988). *Protecting the Environment: a call for support*. Wau, PNG: Wau Ecology Institute.
- NELSON, H. (1982). *Taim bilong master*. Sydney: ABC, pp. 141-148.
- OWENS, C. M. (1980). Analysis of some chemistry curricula in Papua New Guinea, Unpublished M.Sc thesis University of East Anglia, UK.
- OWENS, C.M. (1986). Chemistry and Everyday Life, *Chemistry in the Service of Papua New Guinea*, (Edited P. Bladon). Goroka, PNG: Papua New Guinea Institute of Chemistry, pp. 153-166.
- PONNAMPERUMA, A.C.W. and PALMER, W. P. (1987). Introducing the chemical industry into the science curriculum in Papua New Guinea, *Education, Industry and Technology*. Oxford: ISCU Press/Pergamon Press, pp. 133-138.
- PUDDLEPHATT, R. J. (1979). Gold chemistry today, *Endeavour* 3(2)78-81.
- SINCLAIR, J. (1979). *Up from South. A Prospector in New Guinea 1931-1937*. Melbourne: Oxford University Press.
- STEWART, DF (1986). Gold recovery in a sluice box: Papua New Guinea Practice, *Chemistry in the service of Papua New Guinea*, (Edited P Bladon). Goroka, PNG: (12-14 September) Papua New Guinea Institute of Chemistry, pp 49-56.
- WADDINGTON, D. J. (1987). Introduction, *Education, Industry and Technology*. Oxford: ICSU Press/Pergamon Press.
- * This paper was presented to the Conference of the Australian Science Education Research Association (ASERA) in 1989.