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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Summary Report on Overseas Study Tour March to May, 1969.

by

A. G. L. Paine

SUMMARY REPORT ON OVERSEAS STUDY TOUR

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Countries visited

1. United States of America: 15th March to 13th April
2. Peru 13th April to 18th April
3. Chile 18th April to 25th April
4. England and Ireland 26th April to 23rd May

Purpose

A. 1. To study the geology of large copper and molybdenum deposits in U.S.A. and South America which are associated with igneous intrusions - the "porphyry coppers".

2. To compare the geology of the porphyry copper and molybdenum deposits with the geology of parts of the Burdekin River region in eastern Queensland where I have been carrying out geological mapping for the past six years.

3. To make an assessment of the potential of the Burdekin River region for economic copper and molybdenum deposits of the porphyry type.

B. To study the geology of the tin mineralization in Cornwall, with the main aim of broadening my knowledge of the geology of minerals which are closely associated with granite intrusions (the commonest type of rock in the Burdekin River region); also to compare the Cornish tin occurrences with those in northeast Queensland.

C. To study and report on the geology of the base metal mines in Ireland, and the history of their discovery. Large scale mining of metals is a completely new industry in Ireland, and eight years ago none of the three (3) orebodies now being mined was known to exist.

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* Recreation leave was taken in United Kingdom 5th - 9th, and 19th - 23rd May.

SUMMARY OF MOVEMENTS AND VISITS

15th March: Arrived San Francisco (weekend).

17th March: Visited United States Geological Survey at Menlo Park, and spoke with geologists engaged in research on porphyry copper deposits. Visited geology department at University of California (Berkeley), and spent an afternoon with the Chairman, Professor Charles Meyer. Professor Meyer is a consultant for the Anaconda Company, and is probably the leading expert on the geological evolution and sequence of mineral deposition in porphyry coppers.

18th - 20th March: Visited the Yerington copper mine in western Nevada; was shown some of the geology of the region between Reno and Yerington; was shown over the Nevada Bureau of Mines.

21st March - 1st April: Visited the following 4 copper mines in Arizona and New Mexico; Morenci and Ajo (Phelps Dodge Corporation); Chino (Kennecott Copper Corporation); Twin Buttes (Anaconda Company).

2nd - 8th April: Visited Bingham Canyon copper mine (Kennecott) in Utah, and a small underground copper-lead-zinc-silver-mine (the Lark, United States Smelting, Refining, and Mining Company) next to and related to the Bingham Canyon porphyry.

9th - 12th April: Visited the Climax and Urad molybdenum mines in the Rocky Mountains of Colorado (American Metal Climax); was shown the geology of some of the intrusive rocks in the Colorado Mineral Belt. Visited United States Geological Survey in Denver, and discussed geology of high-level igneous intrusives.

14th April: Visited Geological Survey of Peru in Lima, and learnt something of the regional geology of Peru (no complete map of the country is available as yet).

15th - 18th April: Visited the Toquepala copper mine in south eastern Peru, and the nearby Quellaveco and Cuajone unexploited porphyry copper deposits (all owned by Southern Peru Copper Corporation).

20th - 24th April: Visited the Chuquicamata, Exotica, and El Salvador copper mines in northern Chile.

28th April - 2nd May: Visited all the active tin mines in Cornwall. Brief visit to the geochemical laboratories of Institute of Geological Sciences, London.

12th - 16th May: Visits to the three operating base metal mines in Ireland (all in central western Ireland), preceded by a brief visit to the Geological Survey of Ireland in Dublin.

27th May: Returned to Australia.

OUTCOME

I got a great deal of information from the visits and discussions, and this will be valuable to B.M.R. in several ways:

1. My personal fund of experience has been greatly enriched, and the knowledge acquired will benefit B.M.R.
2. Representative suites of rock and mineral specimens were collected from the mines, and will be available for study.
3. A comprehensive illustrated Record (or Records) will be written summarising the geology of the mines, and containing any other worthwhile geological observations.
4. Many colour slides were taken (some of mine plans and sections).
5. Lectures will be given to B.M.R. staff.

PORPHYRY COPPER DEPOSITS

The porphyry copper deposits occur mainly in the southwestern United States, and in the Andes of Chile and Peru. They have also been discovered in Canada, Mexico, the Carribean, the Phillipines, and New Guinea. The name "porphyry copper" has been coined because, by definition, this type of orebody occurs within or next to an intrusion of porphyritic igneous rock. The intrusions are relatively small, generally between 0.5 and 2 miles in diameter, and they probably represent the deep roots of old volcanoes, which have long since been obliterated by erosion. More copper is produced from porphyry coppers than from any other kind of copper orebody, and the larger deposits of molybdenum occur almost exclusively in orebodies of this type.

Porphyry copper deposits are low-grade orebodies, but their great size (most of them contain several hundred million tons of ore) means that large-scale mining methods can be used, generally in open pits. The average grade of ore in North America is usually between 0.5% and 0.8%, and a cut-off grade as low as 0.4% copper is now commonplace. As an example of how the techniques of mining, crushing, and treating large quantities of rock are being made continually more efficient, the new Brenda Mine in British Columbia is being developed from reserves said to have an average grade of 0.19% copper and 0.087% molybdenum.

The copper minerals occur as disseminations and veins in the intrusive rock and in the host rock against which the intrusion cooled and crystallized. Minor but economically important amounts of molybdenum commonly occur in the cores of the intrusions, and in some places, for example, the famous Climax mine in the Colorado Rockies, molybdenum is the main ore mineral. Intense shattering of the rock, probably caused by forceful upthrusting of successive pulses of magma, is a feature of all of the deposits. The consequent increase in permeability may have been a necessary requirement for the development of economic mineralization, in that it greatly increased the surface area of rock available for precipitation of ore minerals.

The detailed history of intrusion and of primary and secondary alteration and mineralization varies a good deal from one deposit to another, but most of the processes involved appear to have been common to all of the deposits.

In recent years the economic significance of porphyry copper deposits coupled with the U.S.A.'s snowballing requirements for copper and molybdenum has brought about an acceleration in the tempo of research into the origin of porphyry coppers, and the development of new exploration techniques. Experiments with artificial hydrothermal systems show promise of leading to an understanding of the stability-relations between different mineral phases, and of the temperatures and other conditions under which the various ore and gangue minerals crystallize. This work is being done both by the larger mining companies involved (to my knowledge, Kennecott and Anaconda), by the Universities, whose staff commonly consult for the companies, and by the United States Geological Survey.

The large number and density of distribution of known porphyry coppers in Arizona are remarkable. There must have been an abnormally high concentration of copper in that part of the Earth's lower curst or mantle in the early Tertiary, when most of the deposits were formed. It is extremely unlikely that a geological environment containing porphyry coppers in such bonanza-like abundance will be discovered in Australia. However, it is equally unlikely that none at all will be discovered. Porphyry coppers are very low-grade orebodies, and because of this some have not shown up well on the surface, so that they have been missed by prospectors, and have been unearthed only as a result of detailed geological mapping, geochemical sampling, and geophysical surveys. In the search for porphyry coppers attention should be directed to New Guinea, eastern Queensland, eastern New South Wales, southeastern Victoria, and Tasmania. The rest of Australia can be regarded as generally unprospective.

Although Chile is the third-largest copper-producing country in the world, almost all of this coming from porphyry coppers, by no means all of the known deposits are being mined. Copper mining in Chile is largely U.S.-owned or financed, and, owing to chronic uncertainties about the attitude of the government to foreign investment, the large companies seem reluctant to embark on major new development projects. The result is that several large proven orebodies are lying unexploited. The position is even more unsatisfactory in Peru, where a military junta assumed power last October. Firm statements of government policy towards the financing and mining of three large deposits in southeast Peru are awaited by the companies concerned. There is little doubt that if the national economies and politics of Peru and Chile were as stable as, say, those of Australia, the Andes would be the world's major copper-producing area, easily outstripping Arizona or the African Copper Belt. Furthermore, the South American mines, especially in Chile, are sufficiently high-grade to withstand a substantial drop in the price of refined copper (copper grades at the 3 largest mines are 1.8%, 1.2%, and 1.95%). To me this was a striking illustration of the axiom that, in the global deployment of exploration resources by the capital-exporting countries, economics and politics are just as important as geology. So far as copper is concerned, this principle acts greatly to Australia's advantage.

GEOLOGICAL EXPERIENCE OF PERSONNEL IN THE UNITED STATES GEOLOGICAL SURVEY

At the United States Geological Survey in Denver, it was stimulating to talk with several senior geologists, each of whom had about 30 years' experience in geological mapping or other fields of research. The U.S.G.S. has the kind of flexible organization and salary structure that enables this to happen, for promotional procedures in the Survey are not encumbered by a "pyramidal" structure of fixed numbers of positions in each grade, as is the case in B.M.R. In contrast to B.M.R. where a scientist's salary can be raised only if there is a position available into which he can be promoted, in U.S.G.S. salaries are reviewed regularly, and provided a man's efficiency is considered to be increasing, his salary is raised proportionately. This system of efficiency barriers has the happy result of retaining geologists on the staff of the Survey, instead of forcing them to look elsewhere for an increase in salary. It has the further tremendously beneficial effect of building up in U.S.G.S. an enormous fund of geological experience upon which the organisation can draw, and for which it is widely respected.

During discussions with geologists at the laboratories of the Institute of Geological Sciences in London, I was interested to learn that a similar system of efficiency barriers had been introduced there at the time when the British and Overseas Geological Surveys were reorganized recently to form the Institute.

TIN MINING IN CORNWALL

The tin-mining industry of Cornwall, which had been in a more or less static condition for many years, is undergoing a big revival. If all current expansion and development plans come to fruition, Cornish tin production will rise from 1800 to 5000 tons per annum. The two mines which have been producing for many years, Geevor and South Crofty, are being expanded, and a third mine (Nangiles and Wheal Jane) is being re-opened. A new shaft, in what is potentially a fourth mine, has been sunk in relatively virgin country at Pendarves. Exploration continues. The capital employed is mainly South African (Union Corporation and Consolidated Goldfields), although lately interest has been shown also by a Canadian firm.

The mines are all on lodes close to or within the granites. The alluvial deposits have long since been worked out. A fascinating feature of the Cornish tin mineralization is the large difference in age between the tin and the granites which has been established by isotopic dating. Although the tin occurs within or very close to the granites, and is obviously geologically related to it, most of the tin lodes were formed 70 million years after the granites were intruded. This opens up the whole subject of the time relationship between granite intrusion and tin mineralization, which are generally thought of as essentially synchronous events.

It is generally believed that there are still large reserves of tin in Cornwall, mainly at depths greater than those at which mining has taken place up till now. However the estimation of ore reserves is made extremely difficult by the haphazard nature of the lodes. Neither of the two operating mines, Geevor and South Crofty, has ever had proved reserves sufficient for more than 2 or 3 years milling but both mines have been in almost continuous production for over 50 years.

At South Crofy the 15 known lodes each average 4.5 feet in width, but a few (the pegmatite lodes) are up to 100 feet wide. At Geevor the lodes are much narrower.

Current production at Geevor is 800 tons per year of tin concentrate, the average grade of ore being 1 percent Sn. South Crofty produces 1300 tons of concentrate per year, also from 1 percent ore.

BASE METAL MINES IN IRELAND

I visited all 3 operating base metal mines in Ireland. The mines are situated quite close to one another in the central western part of the Republic. Tynagh and Cortdrum, the two open pit mines, are about 40 miles apart, and the new Mogul mine at Silvermines is between Tynagh and Gortdrum, so that the three lie in a north-south line. The Mogul operation at Silvermines, where metals had been mined from time to time since the early 1600's, is the largest underground zinc and lead mine in Western Europe, with a daily throughput of 3,000 tons of ore.

The three orebodies have many features in common, but perhaps the most interesting is their location on east-trending normal faults on which the Lower Carboniferous limestone has been dropped down to the north against the underlying Devonian sandstones and Silurian shales. In each case the limestone is the host rock for mineralization. At Silvermines the ore is zinc-lead-silver, at Tynagh it is lead-zinc-copper-silver, and at Cortdrum it is copper-silver-mercury.

The discovery of these three important orebodies was a triumph for the systematic application of geological, geochemical, and geophysical surveys. Mining had taken place nearly in the past at Silvermines, but apart from this, all the orebodies were completely concealed by glacial drift.

Tynagh was the first entirely new orebody found in Britain or Ireland for over 100 years. The location was one of a number recommended for prospecting by Mr Murrogh O'Brien, then Director of the Geological Survey of Ireland. His recommendation was based partly on a reference to early mining attempts and a report of copper-stained float in the Geological Survey records for 1859, and partly on the recognition of a fault with similar characteristics to the one at Silvermines. Preliminary geochemical soil sampling in 1961 by Irish Base Metals Limited, a subsidiary of a Canadian Company, soon outlined a strong and extensive anomaly. This was followed by an electromagnetic survey that confirmed the existence of a conducting body. A search in the ditches bordering farmers' fields revealed pieces of rock rich in lead. It was decided to drill the anomaly, and as drilling progressed it became clear that the mineralization was economic (1962). Induced polarization was later found to be a suitable method for defining the deposit. Production began in December, 1963.

Silvermines Limited, an Irish Company, was the holder of mineral leases around the old mining village of Silvermines when Mogul Mines Limited, a Canadian mining company, entered the district in 1962. An agreement was concluded between the two companies such that Mogul owns 75% and Silvermines 25% of the resulting Irish incorporation, Mogul of Ireland Limited. Reconnaissance studies of the entire property, comprising geological mapping, geochemical soil sampling, and geophysical surveys, were started in 1962. By 1963, the area of interest has been narrowed down to 3 x 1.5 miles, and modern exploration techniques were applied intensively to this area. By June 1963, a drilling target had been outlined, but initial drilling revealed only marginal and narrow widths of mineralization. However, after a decision had been made to step out to a section in line with the present shaft, excellent grades and widths of mineralization were found. Drilling reached a climax in June, 1964, shaft-sinking was completed by the end of 1966, and the mine went into production in mid-1968.

The operating company at Gortdrum is Gortdrum Mines Limited, a syndicate formed by a group of Canadian companies. The orebody was discovered in 1964 as a result of reconnaissance geological, geochemical, and geophysical exploration, followed by target delineation by I.P. surveys. Production began in 1967. Initially, oriontation studies at Tynagh had shown that such deposits could be readily detected in stream sediments and soils. Numerous areas showing stratigraphic and structural similarities to Tynagh were then selected for reconnaissance geochemical prospecting. One by one these were eliminated, leaving Gortdrum as the most promising prospect.

Ore and production statistics for the Irish mines are as follows:

Current throughput at Tynagh is 2000 tons of ore per day. In 1963 the deposit was known to consist of 5 million tons of secondary ore averaging 9.1% lead, 7.2% zinc, 0.6% copper, and 3.2 oz./ton silver, underlain by 4 million tons of primary (sulphide) ore averaging 4.8% lead, 4.3% zinc, 0.6% copper and 2 oz./ton silver. The dimensions of the secondary ore, which by now has been completely delineated, are 2300 feet long, by up to 550 feet wide, by up to 250 feet thick. By 1968, 8 million tons of primary sulphide ore had been proved in two bodies, over a combined strike length of 4300 feet.

In 1968 the reserves at the Mogul mine, which has a daily throughput of 3000 tons of ore, were 11.5 million tons at 8.2% zinc, 2.8% lead, and 0.8 oz./ton silver, and 2 million tons at 6.0% zinc, 4.0% lead, and 1.0 oz./ton silver. The orebody is strata-bound and wedge-shaped. Its 2 major dimensions are each about 2500 feet; the 2 ore zones have a maximum aggregate thickness of 130 feet, but the average thickness is very much less.

Gortdrum has a daily throughput of 1600 tons of ore. In 1966 the orebody was quoted at 4.2 million tons containing 1.19% copper and 0.75 oz./ton silver, but on my recent visit the mine was said to have a 10 year life, which means the reserves have increased to about 6 million tons. Mercury is being stockpiled, but no figures are available on its grade, although it is very low. The orebody is 2000 feet long. Its width and thickness are very irregular, but maximum width and thickness of 300 feet are quoted.

The Canadian exploration companies were attracted to Ireland by the very favourable taxation conditions offered by the Irish Government (which, incidentally, was described to me as "pretty autocratic"). A situation which is almost incredibly favourable to the companies has recently been created by the declaration of a 20-year tax holiday. The morality of this seems questionable, and in fact reservations were expressed to me by officers of the Geological Survey, and some surprise by mining company personnel.

RENT-A-CARS

Rent-a-cars were used with success in U.S.A., Cornwall and Ireland. Their advantages are considerable. Apart from flexibility and freedom from the restrictions of public transport, another great advantage is that, en route from one mine to another, one is free to examine outcrops and take photographs, and thereby get to know and record for others something of the local geology. Some familiarity with the geology of the surrounding district can be a great help when one comes to discuss and mull over the history of formation of an orebody. A further advantage of rent-a-cars is that one is not dependent on the mining companies for transport from mine to hotel at the mining areas, something which may add to one's acceptability as a guest.

The only reservation I have about rent-a-cars in North America is that sudden immersion in the American world of 70 m.p.h. freeways and driving on the right is not something to be taken lightly, and should certainly not be attempted by inexperienced drivers.

(A.G.L. PAINE)