

A3: ECONOMIC GEOLOGY

CONVENOR: PHILLIP SECCOMBE

KEYNOTE: A 3.1 EMPIRICISM AND CONCEPT IN SUCCESSFUL MINERAL EXPLORATION

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An empiricism is knowledge acquired from experience and observations regardless of theory or scientific principles. Scientific empiricism is the use of descriptive science to develop hypotheses and exploration strategies. A concept is a thought, an idea, or theory and conceptual ore search invokes theories or ore genesis.

It is fashionable to talk about exploration strategy in terms of "models" and to categorise our exploration strategies as either empirical or conceptual. However, we need to be aware that the construction and application of exploration models can narrow the vision and reduce mental agility and flexibility, especially if pursued with excessive religious zeal. Models are often dangerously linked to fads and fashions and can attract such veneration as to be a comfortable substitute for reality.

Factual data collection by geologists, geophysicists and is fundamental to empirical exploration but there is no such thing as completely objective data collection or completely objective data interpretation. They both involve judgement of degrees of of relevance based on experience and beliefs.

"What the evidence prevails upon the mind to believe, depends upon the mind as well as the evidence" Lasky (1948)

"Geologists do much of their work intuitively in their minds based on experience so that.... exploration geology seems as much an art as a science" Adams (1985, p.273).

Geoscientists are reluctant to have their exploration strategies as entirely "empirical" lest this infer their thinking and practice is unscientific. So the empirical explorer searches for a theory to demonstrate that certain observations are relevant, while the conceptualist searches for empirical evidence to justify a theory. Both aim to give their exploration strategies the cloak of integrity. Thus in practice, the

distinction between the empirical and the conceptual (theoretical) becomes blurred and we thus should not expect a clear demarcation between an "empirical" exploration strategy and a conceptual exploration strategy.

A conceptual model, properly used:

- . both constrains and promotes observations and data collection....
- . promotes communication....
- . aids the quantification of risk, and
- . identifies useful avenues of research.

Never-the-less, if we express the way we organise our thoughts and develop- our exploration strategies by referring to conceptual "models" we should do so with great care. Geological theories of ore formation are extremely difficult to prove and geological time and earth processes difficult or impossible to duplicate in a laboratory. Moreover, scientific discussion concerning the evolution of planet Earth is still full of controversy, as is discussion of the processes going on within the Earth today. How less perfect is our knowledge of processes in the past.

No geological research is more critical to the development of an understanding of ore formation and the development of sound exploration strategies, than meticulous, geological mapping, and core logging by mine and field geologists. Such work is however often despised by the academically inclined. Perhaps the most neglected area of documentation and conceptual thinking is research concerned with the tectonic setting of the giant mineral deposits and mineral fields, i.e. observations and theories concerned with features and events at regional and even continental scales.

Exploration for nickel and gold in Australia has largely been based on empirical strategies. The average cost of discovering an economic gold deposit has been \$20 million and the average cost of an economic nickel discovery \$28 million. In contrast,

the cost of discovering an economic base metal deposit has been \$274 million, or an order of magnitude greater. One contributing factor is that empirical methods of exploration: i.e. prospecting, geochemical and geophysical surveys to identify 'anomalies' and programs of pattern drilling have not been as effective in the search for base metals as in the search for gold and nickel.

An Australian Company's Experience

Norseman Discoveries: 1933-1949---

While the development of exploration strategy on the Norseman goldfield has been firmly anchored on empirical observations in the form of detailed surface and underground mapping, there have been conceptual aspects to data interpretation. As early as 1930's concepts which evolved from the modelling experiments of Hans Cloos were relevant. Early exploration was guided by the idea of an east-dipping reef-shear with flatter sections (links) which under the reverse fault movement predicted by Cloos experiments, become zones of dilation and thus the preferred sites of maximum quartz reef formation and gold deposition. The empirical and the conceptual are interwoven into the fabric of over 50 years of successful exploration at Norseman.

Kambalda Discovery: 1957-1986---

It was an empiricism i.e. the recognition of the similarity in geology of the Canadian and Western Australian Archaean which aroused the initial interest in the potential of the Yilgarn Craton for metals other gold. It was conceptual thinking which recognised that nickeliferous ironstones were gossans derived from magmatic sulphides. From then on, empirical exploration i.e. the drilling of geochemical and geophysical anomalies and drilling beneath gossan outcrops dominated nickel exploration in Western Australia and resulted in discoveries which stretched from Norseman to Wiluna. Thus the successful strategies of the nickel boom were like those employed in the gold search at Norseman; they moved from the empirical to the conceptual, and back to the empirical.

"the models used were a mode of travel rather than a destination" Adams (1986, p.296-7).

Yeelirrie Discovery 1971---

The discovery of the Yeelirrie uranium deposit was the successful culmination of an exploration programme initiated in 1968, to explore for sandstone-type uranium deposits in Australia. In common with any discovery Yeelirrie carried its own salutary lessons, not least of which being the necessity to maintain open eyes and an open mind. It strikingly

illustrates the uncertainties in exploration and how a geological conceptual model may be sufficiently correct to take exploration in the right general direction yet lead to the discovery of an unexpected style of mineralisation.

Olympic Dam Discovery 1957 to 1976---

Western Mining began searching for a major copper deposit in Proterozoic rocks in 1957. The initial logic was strictly empirical.

- look for surface indications of copper mineralisation
- major copper deposits occur in Proterozoic rocks worldwide,
- economic copper deposits have been found in Proterozoic rocks in Australia, and
- geological mapping, geochemical stream and soil surveys and geophysical surveys should be effective, empirical prospecting techniques;

By the early 1970s a line of conceptual thinking had been developed by Douglas Haynes during Doctorate research at the Australian National University. From his research came the knowledge that copper is leached from basalt during oxidation and hence the exploration concept was developed that: substantial piles of oxidised continental, thoielitic basalts could source enough copper to form a major sediment-hosted orebody.

A second line of conceptual thinking was being developed in the late 1940's and 1960's by Tim O'Driscoll, while mapping the Broken Hill ore deposit, a programme which subsequently developed into Doctorate and post-Doctorate research at Adelaide University. From this research came the concept that the regional shears (lineaments) were sources and controllers of mineralisation which would be found distributed either syngenetically or epigenetically at points in and along the lineament tracks. In 1972 the ingredients of the structural lineament-ore signature was established as the paradigm for the selection of exploration targets. Two years later it was used to define targets which are now occupied by the deposits of Olympic Dam and Century.

In 1973, a third exploration scientist, Dan Evans, entered the stage. Evans asked for the opportunity to combine the conceptual ideas of the two specialists, Haynes and O'Driscoll, whom he respected. In order to lead the search for Proterozoic stratiform copper in South Australia. In July and August 1974, the small Mount Gunson copper deposit was used both by the project geophysicist Hugh Rutter, and the tectonics team of O'Driscoll and Dave Duncan, as a basis for empirical targeting. In June 1975 the first hole (RD1), was sited on a combined gravity-magnetic-tectonic target and his hole. Intersected the fringe of one of the world's great ore deposits.

In the final analysis, the Olympic Dam deposit

was discovered because minds were prepared to believe in a blend of both conceptual and empirical evidence. i.e. in the power of both theory and observation, and managers were prepared to back the judgement of those scientists, even though many years of disappointment.

Did serendipity play a part in the discovery of the Olympic Dam deposit? Of course it did! The Olympic Dam discovery is in keeping with the words of Pasteur.

"In the fields of observation, chance favours the prepared mind".

The minds which led to this discovery were up to 40 years in preparation and the company's learning experience concerning Proterozoic copper deposits spanned 20 years.

The Road to Discovery---

The road to discovery and successful exploration is neither solely paved with empiricisms nor with concepts. When empiricism is dominant we walk a more certain path. When concept, i.e. theory dominates, the path may lead to the unknown but possibly to the discovery of new ore deposit types.

Earth science and ore deposit models whether empirical or conceptual:

"are only relevant if they give us a sounder basis for confidence, make us bolder and more perceptive explorers, and help us to be more confident in the recognition of either the close proximity of ore or a new ore environment. But we can follow knowledge and reason just so far, then comes the act of faith, the leap beyond the sure path. Whether we are ultimately able to take that step is a test of our ultimate

confidence in science and ore deposit models" Woodall (1984, p. 132)

What distinguishes those who can make "the act of faith, the leap beyond the unknown" from those who cannot? It is intuition. Intuition looks beyond appearances to inner meanings, relationships, interpretations possibilities.

In most intuitive experience....there is an element of prophecy. Those who lack intuition are often paralysed by the search for certainty.

In the final analysis it is not the exclusive possession of observations (empiricisms) or concepts (theories) that distinguishes those who discover from those who fail. What matters is what use the mind makes of the empirical and the conceptual.

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A 3.2 THE EVOLUTION OF A NEW CONCEPT IN AN OLD AREA THE KANOWNA BELLE CASE HISTORY

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Gold was first discovered in the Kanowna area, approximately 20 kilometres northeast of Kalgoorlie in Western Australia, in 1893. Gold mining in the area peaked in 1898 with the production of 152,000 ounces from vein-hosted and alluvial sources. From 1911 production became sporadic and declined rapidly before ceasing in 1946.

Interest in Kanowna surged again in 1979 as the gold price rose, resulting in increased exploration activity and, in 1986, the recommencement of mining at Kanowna. Total gold production from the Kanowna area is approximately one million ounces.

Exploration for additional mineralisation in the Kanowna area focussed on extending, or finding repetitions of known vein deposits and deep leads.

Minor success was achieved on both fronts leading to the open-pit mine on the old Ballarat and Last Chance vein systems (Delta Gold N.L. 67.5%, Pancontinental Mining 32.5%) and the commencement, after the amalgamation of leases to form the Golden Valley Joint Venture (Delta Gold N.L. 50%, Peko Gold Ltd 50%), of mining the deep leads for heap-leach treatment at the QED operation.

Using proven mineralisation concepts for the area, the GVJV employed the established techniques of soil geochemistry and RAB drilling to explore for vein and deep lead deposits.

One other concept did exist in the minds of the joint venturers' geologists however; this paradigm was that the Kanowna area, because of its past production