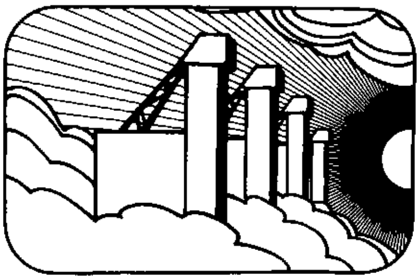

Success in Mineral Exploration: A Matter of Confidence

Based on the first Joubin-James Lecture: University of Toronto, February 25, 1983

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Roy Woodall was the visiting Joubin-James Lecturer at the Geology Department, University of Toronto, in 1982. He delivered three public lectures at this time of which the first is presented here. The remaining two lectures will appear in subsequent issues. We acknowledge support from the Robinson Fund toward the cost of colour reproductions.

Introduction
Western Mining Corporation, incorporated on March 2, 1933, was probably the first company in the world to adopt a deliberate policy of trying to use geological science as an aid to successful mineral exploration. The company is now one of Australia's largest, employing about 5,000 people. It manages operations whose mineral sales last year were valued in excess of $300 million and, in addition, it has a one-third interest in one of Australia's major, integrated alumina-aluminum industries. Moreover, awaiting development is one of the world's largest uranium deposits at Yeelirrie, the world's largest copper-uranium deposit at Olympic Dam and discoveries of gold, oil and natural gas.

Most of what the company has to mine was found by its exploration people. The heart of the company's present Exploration Division is its 155 geologists, geochemists and geophysicists who work both on mines and in regional exploration where scientific exploration and research of the highest standard is encouraged.

The company's history is an outstanding story of successful exploration, success which has resulted from "confidence". But before we can specifically consider the role of confidence in that success we must briefly review the world of mineral exploration, mineral markets within which the mining industry operates.

The World of Mineral Exploration
Scientific mineral exploration is a form of research: we gather data, make interpretations and test those interpretations. In an ideal exploration organisation the mine geologist is as good a scientist and explorer as is the field geologist and, in fact, in some ways the mine geologist has the more exacting position, for he has access to the most data.

Stages of Mineral Exploration. Mineral exploration is the first link in a chain of events which, hopefully, will lead to mineral production. There are two stages of mineral exploration: an early *generative stage* and subsequent *exploration stage.* During the *generative stage* general objectives are set, such as the commodities to be searched for, the level of budget to be applied and the general area to be investigated. During this stage there is reconnaissance both of literature and ground, and empirical and/or theoretical conceptual models are applied in an effort to select favourable search areas. Much of the data assessed at this stage is part of the valuable national, geoscience data base assembled by government geological surveys and universities.

The development and application of an empirical model involves
(i) the observation of geological features commonly associated with mineral deposits;
(ii) a judgement of the likely relevance of the observed associations; and
(iii) the assessment of the mineral potential of some unexplored region in the light of this knowledge.

Because judgement of relevance is an essential stage in the development of an empirical model, empirical models cannot be developed independent of scientific understanding.

Empirical models are particularly valuable when there are large numbers of well documented deposits on which to base an assessment of associated features, but they are unreliable in the search for deposits for which there are few examples. One serious limitation of empirical models is that they cannot predict new deposit types. For example, in 1964 empirical models could not have predicted the importance of Kambalda-type nickel sulfide deposits associated with komatiitic Archean volcanics.

Area selection is enhanced if empirical models can be checked against a reliable body of theoretical data so that a proper judgement can be made about which of the empirically associated features have a critical genetic significance, i.e., which of the observed features relate to the cause of the mineral accumulation or are also products of the cause, and which are probably irrelevant features whose association with ore is purely accidental. Useful theoretical knowledge may be obtained by studying natural systems, laboratory systems and applying physics and chemistry to the problems. Such theoretical studies are concerned with the source of the mineral or metal, the media of its transport, the cause of its movement from source to site of accumulation and factors which result in precipitation, enrichment or trapping. Consideration of theoretical possibilities can result in the discovery of new deposit types, for example, the Yeelirrie uranium deposit in Western Australia (Cameron, 1984).

Our ability to conceive useful conceptual models during the generative stage of exploration is limited only by the density of available, reliable geological, geochemical and geophysical data and our understanding of the physics and chemistry of earth processes.

Once a search area has been defined we enter the *exploration stage* where effectiveness is determined by
(i) the extent to which the search area has been reduced to manageable dimensions during the generative stage;
(ii) the effectiveness of the available exploration methods; and
(iii) the quality, skill and motivation of the scientists and the technicians entrusted with the search.

Government organisations and universities help to provide improved exploration methods and equipment, and it is the universities to whom we entrust the training of would-be explorers in the fundamentals of science. The importance of well trained and motivated explorers cannot be overemphasised, for the Australian exploration scene is littered with the debris of careless and/or scientifically inadequate data collection and data interpretation.

Exploration Activities. Exploration is "going and looking"—just as it was when the great gold discoveries were being made in Australia and North America in the last century. But today we look with more than our eyes. We measure element abundance in stream sediments, soils, rocks and plants as well as the physical properties of the earth. Moreover, we think about what these measurements mean.

In 1964, thinking about unusual amounts of copper, nickel, molybdenum, tellurium and silver in small ironstone outcrops at an abandoned gold mining site called Kambalda led to the discovery of nickel sulfide deposits which now supply 40,000 tonnes of nickel to the world each year and $250 million worth of prosperity each year to the Australian people (Gresham, 1984).

Modern exploration is, moreover, "thinking before we go". Such thinking about how major copper deposits may form, led to drilling in 1975 in a remote part of South Australia, far from any surface signs of copper. As a result, one of the world's greatest copper deposits was discovered at Olympic Dam, hidden beneath 300 metres of barren rock. There were clues in the geologic maps, clues in the magnetic and gravity data and clues on airphotographs (Lalor, in press).

Ingredients of Successful Exploration. Exploration requires people who must be equipped mentally, physically and instrumentally to perform a difficult task. Moreover, it is because people are involved and because they are the most critical component, that success in exploration is, above all else, a matter of confidence.

Exploration also involves the expenditure of large sums of money: money is the second critical ingredient. An in-depth study of metals exploration in Australia between 1955 and 1978 recently has been carried out by Professors Brian Mackenzie of Queen's University and Michel Bilodeau of McGill University, in collaboration with the staff of Western Mining Corporation. During this period the equivalent of $1.62 billion ($1980) was spent on metals exploration and, as a result, 100 discoveries were made. Of these discoveries 43 can be classed as economic discoveries based on estimates of the financial returns which would result from their development under 1980 conditions. The study showed that the average cost of finding an economic metal deposit in Australia is $38 million.

The study also showed that the *average financial return* on metals exploration during this period was most unattractive. Therefore, we have not been exploring in Australia because *on average* it is highly profitable to do so. We have been exploring because either (i) we are in the mining business and wish to try to survive in the business we know best, or (ii) we explore in the manner of a gambler—a short-lived plunge in the hope of a lucky windfall discovery and a bonanza profit, or (iii) we believe our expertise is well above average so that our performance will be significantly more profitable than is the average performance.

If an *average performance* in metals exploration is likely to be a financial loss or an unattractive financial return, the challenge for all involved in mineral exploration is to do what we can to make this vital national activity more attractive as a financial investment. We cannot change commodity prices, we may be able to influence the cost of production and government taxation, but we can influence the cost of making a discovery. Herein lies the challenge. There is no challenge in finding mineral deposits if the cost of discovery is considered irrelevant, for anyone can go through the motions of exploring for minerals, and if you keep at it long enough you must find something. Similarly, doing scientific research is a great way to spend one's time, but cost, relevance and purpose must be kept in mind. People must be motivated to make the most valuable discoveries at the smallest possible cost and those involved must be confident they can do so, if they wish to be truly successful.

The result of any single investment in exploration is likely to be either failure to make a discovery or the discovery of a deposit of insufficient worth to repay the exploration cost and reward the investor for the high risks taken. This fact is relevant to this matter of confidence.

The third critical ingredient of successful exploration is time. It took Western Mining Corporation over eight years to find its first copper-zinc deposit in Palaeozoic volcanic rocks (the Wilga deposit at Benambra in Eastern Victoria). It took seventeen years and $3.4 million ($9.2 million in 1980 monetary terms) to find our first copper deposit in Proterozoic rocks (the Olympic Dam deposit). We have been searching, unsuccessfully, for thirty years for a major copper-zinc deposit in Australia's Archean rocks and we have already spent the equivalent of $13 million. Confidence thus must be soundly based on firm foundations.

The World of Mineral Markets

We explore for minerals from which energy, metals or building materials can be derived, but it is a competitive world. The most critical factor in the economic equation is the price we receive for what we produce, but the price of most mineral commodities in real terms has been constant or has fallen over the past 100 years. The exceptions are petroleum, and the precious and semi-precious metals. There is thus no room for complacency. We must continue to find mineral deposits as cheaply as possible and produce from them efficiently and economically, not by Australian or Canadian standards, but by the standards of the rest of the world. A corollary of this is that we must look for and discover the most economically attractive deposits, i.e., the giant deposits and the rich bonanzas.

Another feature of the world scene is that there does not seem to be any shortage of most mineral resources, with the exception of liquid petroleum. The reserves of the world's copper, nickel, lead, zinc and tin industries have been static for many years (Fig. 1) and, in the case of copper, large numbers of deposits await development. There is no evidence of the so-called depletion of such "non-renewable" mineral resources.

A recent international development is that the market for most mineral commodities has become highly competitive and, as a result, prices have fallen below historical trends. This is in part related to the increasing involvement of governments in mineral production. Only 42% of the world's nickel and 37% of its copper is now produced in a free-market economy. In countries such as the U.S.S.R., its Communist allies and the other socialist-oriented, centrally-planned economies, especially those in the developing world, neither profitability nor the market may control production, particularly if the economy is dependent on the sale of mineral commodities for foreign exchange or for the maintenance of domestic employment.

These facts do not fill us with confidence. On the contrary, they are reasons for concern. But these facts certainly demonstrate what a challenge it is to be involved and to succeed despite the difficulties. In summary, mineral exploration is risky, expensive and competitive, and the prize which continues to motivate the investor is the hope of a bonanza—either in size or grade or both.

The Critical Factor of Confidence

Success in mineral exploration is a matter of confidence. The investor, whether a member of a company's board or an entrepreneur, must have confidence in his exploration manager. The exploration manager must have confidence in his exploration scientists and the scientists must have confidence in their operators, whether they be in the field, the laboratory or the office. The reverse is also true. The field operator must have confidence in and respect for the scientists who design and interpret the surveys, the scientist must have confidence in the judgement and loyalty of his exploration manager and the exploration manager must have confidence in his board or financial backer. Without this chain of confidence there will not be highly motivated people doing good exploration, nor will there be adequate money or enough time.

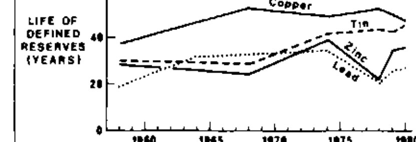

Figure 1 *World metal reserves*

Birth of WMC at Norseman: An Example of Investor Confidence. Western Mining Corporation was formed in 1933 to find and mine gold and other minerals in Western Australia, and events were influenced a great deal by the confidence of the investors and the Board in certain geologists and geological theories, something which was most unusual 50 years ago. Harvard University's professor of geology, Dr. Donald McLauglin, organised a team of geologists to work under Dr. Hugh McKinstry, who later also became a famous Professor of Geology at Harvard. McKinstry's able lieutenants, Terence Conolly, Haddon King and Don Campbell, were sent by that great Australian Sir Lindesay Clark to evaluate a small gold mining area at Norseman in Western Australia. This resulted in the formation of Central Norseman Gold Corporation.

By 1934 the Norseman goldfield had produced 600,000 ounces of gold and the field was considered "mined out" by some experts. One of its main reefs, the Mararoa Reef, had produced 170,000 ounces and the geologists re-mapped the surface exposures and mine workings and drilled some exploratory holes. Only one hole found significant gold but the Mararoa Reef was shown to be a major structure and a complex reverse fault made up of barren, steep shears and flatter, gold-bearing quartz in tension zones or "links" (Fig. 2). There was therefore sufficient confidence in the possibility of ore below barren shear and, therefore, of orebodies repeating at depth that even a single intersection in a drill hole was considered significant.

By 1939 a great deal of underground development had explored at depth and north of the old mines, mainly at the No. 8 and 16 levels, but little ore was found (Fig. 3). Despite the fact that the Company was deeply in debt, effort continued, and eventually the Mararoa No. 2 orebody was discovered ever-so-close to the underground development which initially showed so little ore (Fig. 4).

At this point confidence had increased and was enhanced by the geological concept of a "favourable bed" within which ore would preferentially develop where intersected by the reef shear. A favourable north-plunging zone was shown to be a possibility on the Mararoa Shear, and so driving was continued north on the No. 16 and No. 22 levels for three years, but with no encouragement. But again, confidence in a geological theory prevailed and underground cross-cuts were excavated and expensive underground drilling initiated and, as a result, rich ore was eventually found just below the No. 22 level (Fig. 4).

Meanwhile, the same theory was being tested further north at the Princess Royal Mine. Early drilling gave encouragement, but then over 2 km of barren development consumed profits for 4 years, from 1944 to 1948 (Fig. 5). Eventually confidence in geologic reasoning and "guts and determination" by management found a bonanza, the Princess Royal No. 2 (or North Royal) orebody (Fig. 6).

Central Norseman Gold Corporation not only survived, but it has for over 50 years made a significant contribution to Australia's prosperity, producing 3.6 million ounces of gold valued today at $1.6 billion, and this from an "abandoned" mining field. The Company has rarely had three years of proved ore reserves but has relied, in confidence, on a regular sequence of geologically inspired discoveries to ensure its survival (Fig. 7). One needs to appreciate this long history of management's confidence in geologists to appreciate the subsequent discovery of the great Olympic Dam deposit.

Discovery of the Olympic Dam copper-uranium-gold deposit: an example of confidence in scientists by management. Western Mining had been searching unsuccessfully for copper in Proterozoic rocks for 17 years when a bold decision was made to drill through barren sediments on the Stuart Shelf of South Australia in search of a major copper deposit well away from the accepted areas of copper mineralisation. The decision to risk money and exploration resources in such a high-risk venture was the result of management's traditional confidence in its exploration scientists. One of the most critical factors was the selection of the general area

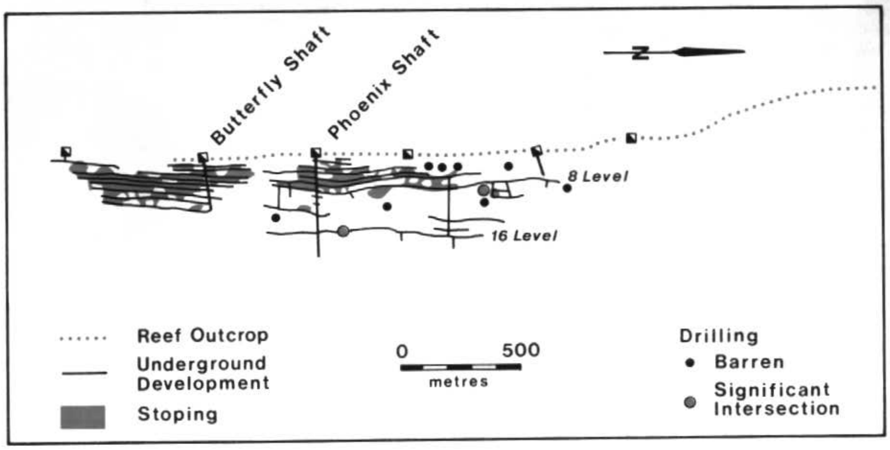

Figure 3 *Composite plan of the Mararoa Shear (1939)*

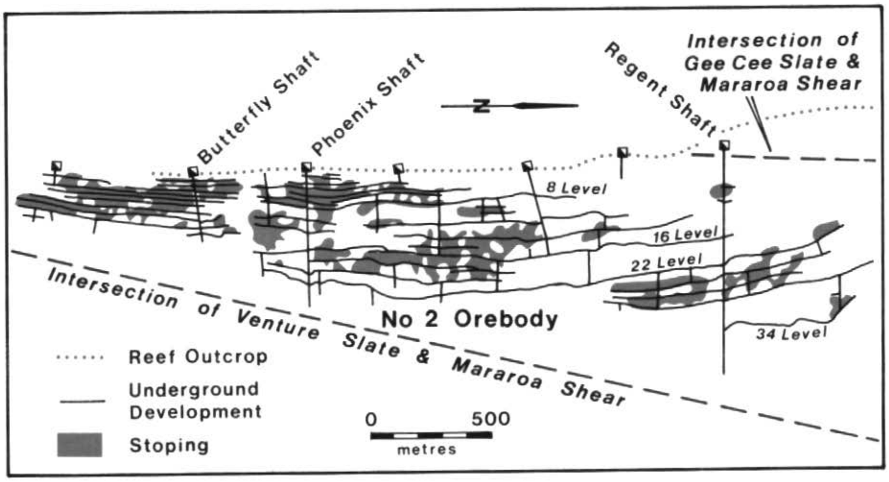

Figure 4 *Composite plan of the Mararoa Shear (1954)*

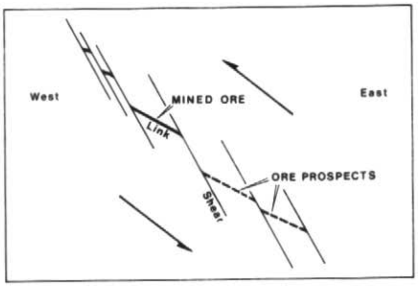

Figure 2 *Cross section of a "Shear-Link" system*

on the basis of studies which showed how copper-bearing solutions could be derived by oxidizing tholeiitic basalts. Others highlighted similarities between the magnetic, gravity and fracture pattern of the area to known copper deposits at Mt. Gunson, and to patterns of lineaments which, worldwide, are associated with mineral deposits. And so one of the world's greatest ore deposits was discovered. It was a matter of confidence, first to start such a venture, and second to persevere when three of the first four holes were barren and ten holes had to be drilled to confirm an economic discovery (Lalor, 1984).

The Discovery of the Benambra copper-zinc deposits: an example of mutual confidence between scientist and field operator. The first signs of mineralization were discovered in this area in 1965-66, but the explorers lacked confidence and failed to follow up the anomalous stream sediment samples they had found. The anomalous samples came from an area which was rugged and only accessible on foot, and follow-up sampling was so difficult that a day of walking might yield only one or two samples.

Western Mining took an interest in the area in 1973 and dedicated, self-assured field personnel confirmed the initial stream sediment results and proceeded with follow-up sampling to outline areas of anomalous copper in soils. But the drilling of geochemical anomalies found nothing of significance and it was realised that some electrical geophysical prospecting technique was needed to scan the geochemical anomalies prior to drilling. A variety of ground and airborne systems were tried but they were ineffective. In the summer of 1977-78, after the drilling of 16 barren holes, it was decided to bring in a ground transient electromagnetic system despite the difficulties of using such a method in the rugged terrain. One area of geochemical response which was checked was at the Wilga prospect, and the one significant result proved to be a single anomalous reading at the northern end of a line (Fig. 8). A tired field crew might not have shown sufficient perseverance to cover exactly the area nominated by their geophysicist and may not have obtained the last reading requested. Moreover, a less than thorough and confident geophysicist may not have judged that one final reading to be sufficiently significant to warrant follow-up in such difficult terrain. After all, we had failed so often in this area. But in this instance the last reading was obtained, its possible significance was checked in a follow-up survey, the first valid transient electromagnetic anomaly in the area was outlined,

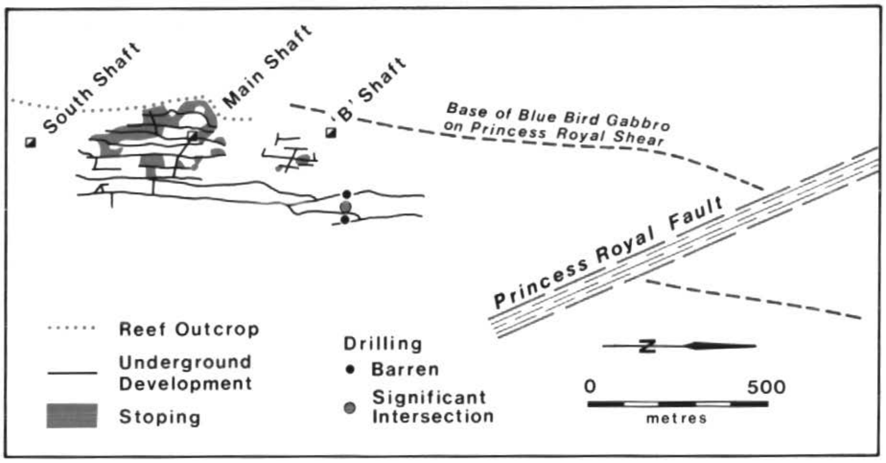

Figure 5 *Composite plan of the Princess Royal Shear (June 1948)*

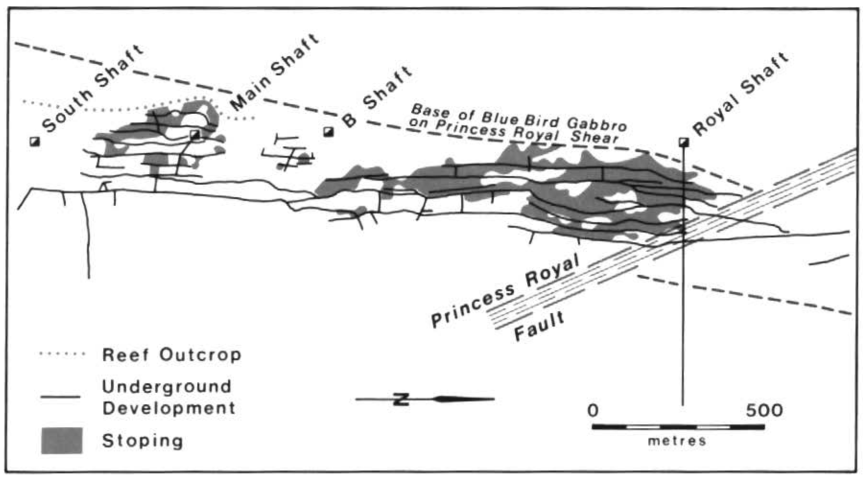

Figure 6 *Composite plan of the Princess Royal Shear (1959)*

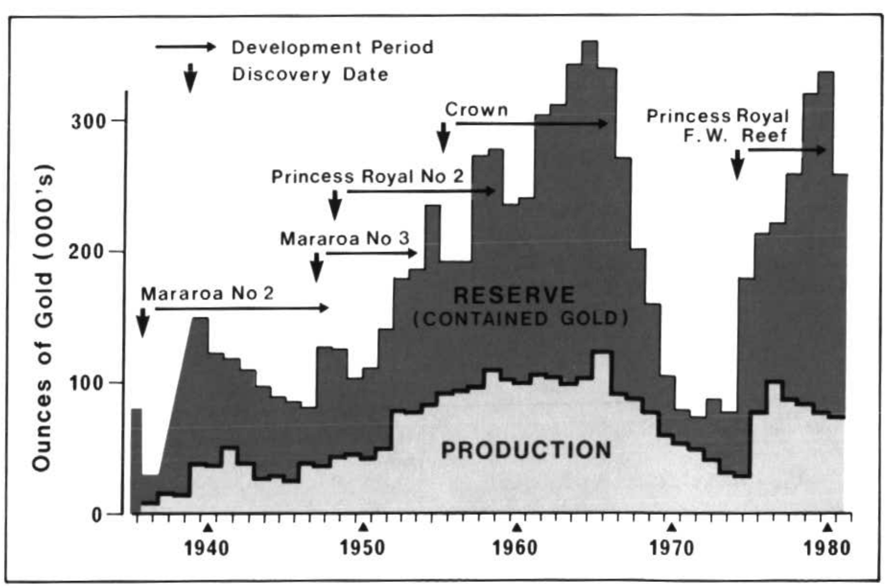

Figure 7 *Annual gold production and reserves—Central Norseman Gold Corporation Ltd.*

and when tested by hole No. 17 a discovery was made (Fig. 9).

A case of present day confidence by a company's board. All those who rely on mining for their revenue know how difficult the present times are, but the Board of Western Mining Corporation has traditionally maintained a strong financial commitment to exploration, even now, when the Company is providing exploration finance at three times the level of its present profit (Fig. 10). This stable continuation of support for an exploration team even in difficult financial times, which in turn is so vital to team morale, is a perfect demonstration of the theme: success in mineral exploration is a matter of confidence.

If confidence is lacking. What if people lack confidence? When Boards of Directors lose confidence they abandon exploration and retrench their exploration staff. When exploration managers and chief geologists lose confidence in their own scientific ability they become self-protective and do not deal honestly with their younger more able scientists, who then lose both their enthusiasm and their respect for their supervisors. When exploration scientists lose confidence they do not speak simply and confidently about their ideas. They follow blindly the latest fad, their field observations and interpretations become unreliable, and their communications lack conviction. When the field staff lose confidence in either their company or their supervisors the best plans can be laid to waste by poor or faulty observations or measurements.

What if there is a lack of confidence at the critical stage of drilling? Without confidence, we fail to persist even though carefully conceived concepts may still be valid despite early disappointment. At Kambalda, the site of the world's first major komatiitic nickel-sulphide discovery, the first drill hole discovered ore. But what if the sequence of holes had been different? Four of the next five holes were barren, and any of these might have been the first hole. At Olympic Dam six of the first nine holes were barren and only the tenth hole found ore grade mineralization, and these were deep and expensive diamond drill holes through 350 metres of cover rocks.

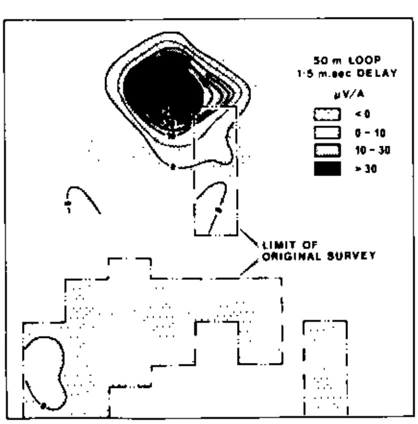

Figure 8 *Wilga T.E.M. (final survey)*

Development of Confidence

How can we develop this critical factor of confidence so that a company's Board of Directors or a financial entrepreneur will have confidence in the exploration manager and the manager will have confidence in the exploration scientist and the scientist will have confidence in the operators, wherever they may be?

Confidence in oneself, i.e., personal confidence, of course comes from success, but it is not helpful to overemphasize this. Success is normally infrequent in the very high-risk business of mineral exploration, and if we rely only on success we will have few confident investors or explorers and, as a result, few discoveries.

But personal confidence can be strengthened by devoting effort to understanding the science and technology which we are entrusted to employ. The acquisition of such understanding begins in school and university and must continue throughout our careers. Personal confidence also develops from self discipline, the discipline which develops fitness of body and mind, a high moral code of behaviour and high ideals.

Mutual confidence is equally important and is fostered when communications are direct and avoid pretence and the use of confusing jargon. The development of mutual respect is essential if there is to be mutual confidence. Confidence also develops between people when there is loyalty, trust, mutual concern, enthusiasm, joy from effort and joy from achievement (even another person's achievement). These qualities are found in many great sporting teams and successful organizations. When mutual respect and mutual confidence are lacking we find poor communications, a lack of trust, selfishness, demands for personal acclaim, disharmony, impatience, as well as lethargic managers, scientists and operators. The result is much wasted exploration effort.

We need to *organize* in such a way as to develop personal and mutual confidence. We organize for orderliness, identity and strength, bringing together a variety of personal skills to bear purposefully on each challenge. But we must not be so organized as to inhibit personal responsibility, personal recognition, personal initiative, personal motivation or personal satisfaction (Schumacher, 1973, p. 201-211). If we do, personal confidence will suffer. An effective organization is an aggregate of small groups, within which each can see and know the other. The effective exploration organization has what the management consultant would call a very flat organizational structure in which, wherever possible, communications are face to face.

Within the successful organization responsibility is delegated downwards to the smallest unit capable of doing a task, down to individual people to whom is given responsibility, recognition and praise. Delegation of responsibility also demands that the manager support the judgement of the persons to whom responsibility is delegated and, except in the most serious circumstances, protect them from damaging external interference or unreasonable criticism.

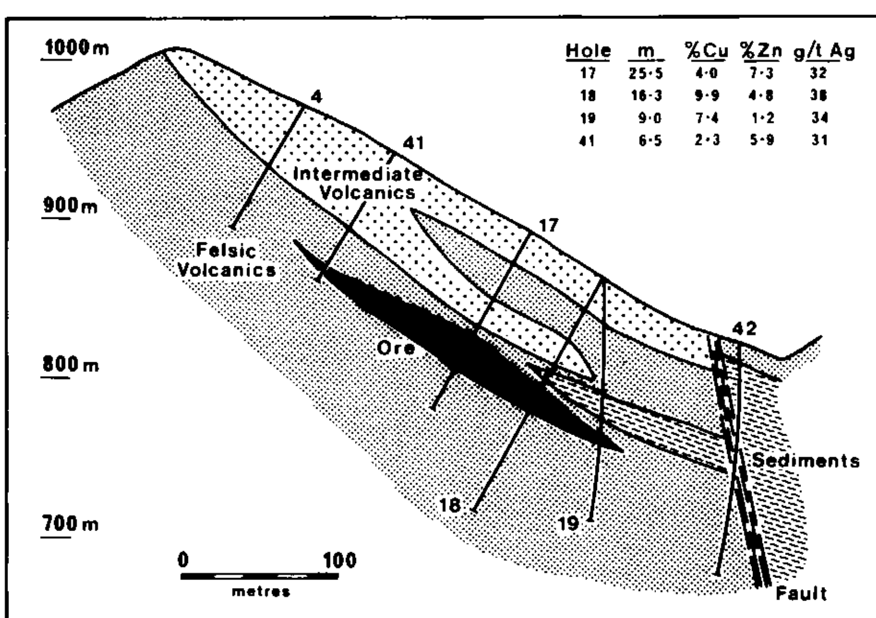

Figure 9 *Wilga cross section 14050E*

Successful mineral exploration cannot be achieved by "on the spot" supervision or direction. The managers must have confidence in their staff. The *action man,* if he is any good, will be miles away from this manager, far beyond any normal management control or enforced discipline. The *thinking man* may be physically close to his manager but, if he is the man the manager needs, he will be mentally distant, breaking new intellectual ground which his manager may have difficulty of either conceiving or understanding.

Reasons for Confidence

We need to stand back at times—especially in difficult times like the present—and view our situation within the fabric of history and, if we do, we will see ample reasons for hope which is so critical to confidence.

The world needs minerals and in historical terms the demand for minerals is still upward even though the rate at which demand is increasing has slackened. This trend will continue upwards as long as there is population increase or a rising living standard for the world's people. We still need metals to construct tools and buildings and to provide means of transport, and also we need energy from minerals to achieve and maintain standards of living. Mineral exploration is vital to the provision of these raw materials; it is essential to the survival of civilization.

Australia and Canada need a minerals industry if they wish to remain prosperous nations. It is not generally realized that until 1914 Australia had the highest average standard of living in the world, as measured by gross domestic product (G.D.P.) per head of population, because until 1914 Australia had essentially a highly productive rural and mining economy which, in turn, supported manufacturing industries.

Since 1914 Australia has felt the need to develop its manufacturing industries regardless of productivity and international competitiveness, and this growth of manufacturing coincides with the country's decline as a prosperous nation for a host of complex reasons.

Increases in national prosperity come from the creation of new wealth, and only 40% of Australia's and Canada's G.D.P. is new wealth, that which is created by the miner, the grower and the maker. Moreover, nearly a quarter of this new wealth is produced by the minerals industry or industries directly dependent on that industry.

The minerals industry is also essential to employment. When the service industries are considered we find that 1.0 million Australians, or 15.6% of the work force, depend directly or indirectly on the industry for their jobs. The situation is similar in Canada. Our countries need a minerals industry and, therefore, vigorous minerals exploration which sustains that industry is also vital.

The size of Australia and Canada also should fill us with confidence, for both are vast. Moreover, much of our countries is concealed: in Australia beneath a complex zone of weathering, which has been, and still is, a great obstacle to mineral exploration, and in Canada by lakes and glacial debris. But the concealment is an exciting challenge to the explorer, for most of the mineral deposits which lie beneath such concealment or beneath thin veneers of sedimentary and volcanic rocks have not been discovered. Australia's greatest ore deposit at Olympic Dam has only recently been discovered beneath just such cover rocks.

There have been great advances over the past 25 years in both exploration technology and in our understanding of earth processes. We have the tools to succeed, they are continually improving and each new generation of explorers is better equipped than were their predecessors.

We should also be encouraged by the continuing success of exploration in both our countries. Australia's greatest ore deposit has only just been discovered, nearly 200 years after colonization and prospecting began. Since 1946 Canada has found 100 economic base metal deposits.

Conclusion

Successful research scientists and exploration scientists worth their "salt" are highly disciplined people of vision and energy, full of faith and hope. They exude confidence, they dream dreams of cities not yet built and gardens not yet planted around some lonely spot where a great mineral deposit will one day be discovered.

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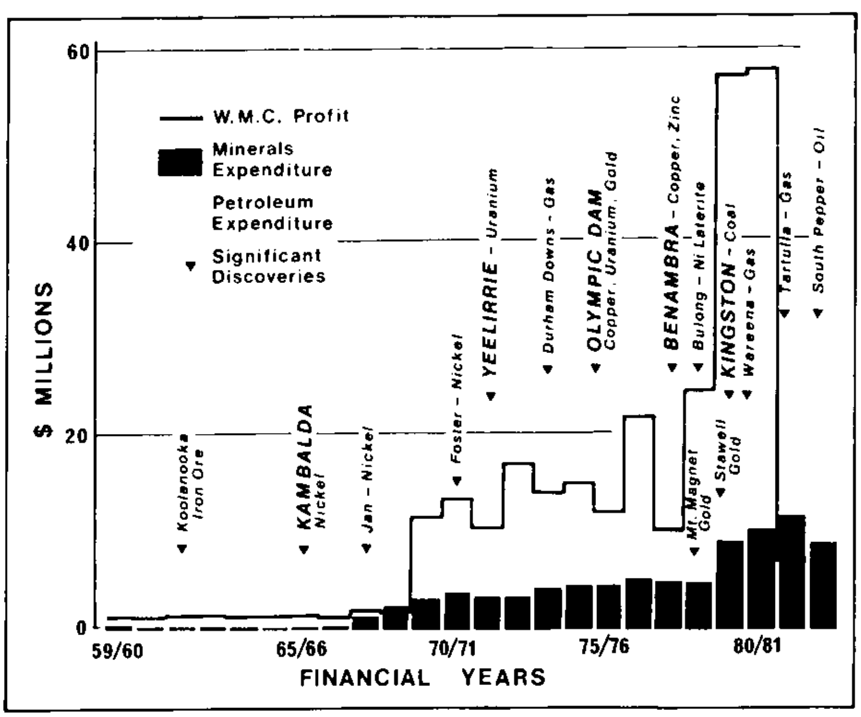

Figure 10 *Western Mining Corporation Limited— profits, exploration expenditure and discoveries.*