THE DEVELOPMENT OF THE MINERAL RESOURCES IN TASMANIA

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INTRODUCTION

The value of mineral production in Tasmania reached a peak in 1956 when the total value of minerals produced was £14,375,000. Due to lower metal prices the value of production for 1961 was £13,380,000. In addition to this, the value of the metals and their oxides produced by the Mining Industry from interstate or imported ores during 1961 totalled £16,930,000.

The number of employees in the Mining and Metallurgical industry for 1961 averaged 8493. It is interesting to note that the Mining and Metallurgical industry consumed 57% of the electric power generated in Tasmania in 1958.

The increase in the standard of living in the more advanced countries brings with it increasing demands upon the mining industry, for without adequate metals, minerals and fuels, our civilization would rapidly vanish The continued supply of the necessary minerals demands that adequate reserves should be maintained. Ore bodies once mined cannot be regenerated, so that there must be a constant search to discover and to develop new reserves to supply this ever increasing demand for metals and minerals.

The problem of the development of mineral resources in Tasmania is being investigated by three main groups.

1. Producing Mining Companies in Tasmania who wish to replace the ore reserves they mine from year to year, and in so doing, maintain a reasonable tonnage of ore in reserves; or expand their operations outside their existing mines. Most working mining companies plan their development programme to maintain their ore reserves at a somewhat steady figure if this is physically possible.
2. Outside exploration groups and mining companies, who wish to expand their activities or invest in new areas.

These investigation groups usually have a comprehensive exploration staff with adequate finance and equipment.

3. The Tasmanian Department of Mines, which has a responsibility to see that the mineral industry progresses, and to see that the mineral resources of the State are adequately and properly developed.

TYPES OF OREBODIES IN MINERAL DEPOSITS

Not all mineral deposits are valuable enough to warrant their mining although changing conditions or metal prices may make this so at a future time. At this stage we should consider - What is "ore"? "Ore" has been defined as a naturally occurring mineral substance which can be mined and treated at a profit. Mineral deposits are divided geologically into many types, but for the sake of simplicity we can divide them into ore bodies associated with igneous activity such as lode deposits, stratified deposits such as coal seams, and deposits due to weathering and erosion such as alluvial tin deposits. In the search for mineral resources, a different sub-division is important.

1. Surface Deposits or deposits that outcrop.

It appears that most surface outcropping deposits have been located already by prospectors or companies although many were regarded as being of no significance at the time of their discovery. Economics change with time - accessibility improves, mining and treatment methods improve, prices change; and many deposits discarded as valueless in the past now become valuable. The re - assessment of old deposits is therefore necessary in the light of changing conditions.

2. Buried Deposits

Until the advent of geophysics the discovery of mineral deposits was principally restricted to such deposits as were exposed upon the surface or whose presence could be deduced from geological studies of structure and by the identification of favourable horizons. The geologist rather than the prospector took the leading part. In the search for oil in particular, the geological deductions became more important, and the cumulative knowledge that resulted from the number of petroleum geologists engaged in oil search rapidly built up a geological practice, which is an important asset in the industry.

Nevertheless geological methods could not meet all the conditions, nor did the mining geologists in the metalliferous field find their methods comprehensive enough to meet the needs brought about by covered deposits which showed no clue to their presence. Something more than speculation based as geological knowledge was needed. The churn drill and the diamond drill could be used to test speculative inferences, but the probabilities of failure were large and the cost of the work limited it seriously.

In more recent years geophysical methods have been used extensively in the search for mineral deposits. A background of geological knowledge is required for the successful interpretation of the measurements that are made, but the combination of geophysics and geology is now standard practice in the search for hidden deposits.

It must be understood that geophysics is a limited tool and not an answer to every problem. The surface cover over an orebody seriously blankets the characteristics of the orebody, and in many methods the results of the geophysical tests represent only the conditions very close to the surface.

<u>THE PRELIMINARY INVESTIGATIONS</u>

1. <u>Favourable Geological Conditions</u>

In a general way certain associations of rocks and mineral deposits have been noted. Where deposits are of a nature genetically associated with igneous rocks we must expect them to be in areas characterized by these rocks. Tin is usually associated with granite or acidic rocks and in fact most of our ore deposits of note in Tasmania are associated with the widespread granite occurrences, although there are some notable exceptions to this. In considering mineral producing localities individually, valuable generalizations often can be made and are made. There is another consideration of importance and that is rock alteration. It has been observed that where solutions of deep seated origin have been at work they have in many cases attacked the wall rock of fissures, and have caused more or less extensive alteration. Surface rock areas which show alteration such as kaolinization sericitization and silicification are important. The almost universal presence of pyrite in close association with ore minerals, the readiness with which this mineral weathers and the highly coloured nature of its residue often mark the weathered area in the vicinity of an outcropping deposit and serve to distinguish it from areas which are devoid of mineralization.

Structure of the surrounding rocks and districts is important in the emplacement of orebodies. Uplift, faulting, shearing and folding are significant and many orebodies have been located by the study of structural control.

2. Geological Mapping

The basic step in the development or search for mineral resources is a knowledge of the rocks of the area. Geological field parties closely map the area or district and the mapping usually extends well outside the limits of the area selected for mineral search. The Department of Mines in Tasmania is mapping the whole of the State in reasonable detail and the results of this mapping are published in the form of 1 mile to the inch series regional geological maps.

It is usually on the basis of the regional mapping that favourable geological series or districts are selected for further detailed geological mapping, or a programme of geophysical work may be prepared.

Geological mapping will give outlines of favourable areas for search by revealing the presence of favourable rocks, suitable rock structures - Dr. Campana's postulation of a rift valley on the West Coast of Tasmania, and the zonal distribution theories of deposition at Zeehan and Moina area notable examples.

The discovery of coal at Stanhope and the discovery of dolomite near Smithton resulted from geological mapping.

3. <u>Aerial Search</u>

A. Aerogeophysics

Airborne geophysics may be used in conjunction with regional geological mapping, to select areas for close investigation. Airborne geophysical work has considerable advantages for the rugged Tasmanian landscape, where ground work is often laborious and expensive, if not impossible. Instruments may be carried by smaller commercial planes such as the DC3, in light aircraft or by helicopter. The basic tool is the airborne magnetometer and already approximately one third of Tasmania's land surface has been covered by this method, with flight lines at approximately $\frac{1}{4}$ mile intervals. In addition the whole of Bass Strait has been covered with flight lines at a greater interval in the preliminary work in the search for oil.

In addition to aeromagnetic cover, large areas of Tasmania have been covered by airborne electromagnetic survey and airborne scintillometer survey.

Aerogeophysics requires a large amount of expensive preparatory work. In surveys over land the procedure is as follows :-

(a) Air photography of the whole of the area to be studied.

(b) Compilation of mosaics to enable the pilot of the survey aircraft to fly a correct course - such mosaics may be controlled or uncontrolled.

(c) The actual survey which incorporates -

(i) The recording of instrument results

(ii) The position of the plane at that time (usually by photography).

(d) The compilation of the integrated plan in which results are usually presented as contours on a base map.

In the case of surveys over sea, photography is not required but the plot of the aircraft is fixed by shoran stations.

It should be noted that aeromagnetic and airborne scintillometer are the more useful phases of airborne geophysics. The Savage River iron ore deposits were outlined by airborne magnetometer survey and the preliminary survey of Bass Strait for oil was made by airborne magnetometer.

B. Photo-interpretation

An examination of aerial photographs will often reveal structural features which require further investigation. The occurrences of faults and fold patterns can be recognised and the plotting of favourable rock types and features can be done accurately from the study of photographs by a trained observer. The location of the extension of the Lyell Shear which is associated with favourable mineralization was postulated after such a study.

The investigation at Moore's Valley in Western Tasmania resulted from the postulation of suitable geological structure after comprehensive photo interpretation studies.

4. Ground Search

A. Transport

As mentioned earlier, the difficulties of transporting ground parties in parts of Tasmania are great, but the advent of the helicopter has accelerated ground investigations in recent years. Field parties and their equipment can be set down in otherwise inaccessible areas with little difficulty, and many areas previously considered as too difficult to investigate are now included in investigational programmes. The helicopter has proved invaluable for transporting diamond drilling equipment to inaccessible and mountainous locations and in the case of the first two diamond drill holes at Savage River all drilling and camp equipment was transported by helicopter.

A four-month field season by an exploration company using helicopter transport of field parties gave the following interesting figures :-

Number of completed flights	638
Number of flight sections	1844
Flying time	454½ hours
Passengers carried	1135
Freight carried	432,202 lb.
Cost per lb/minute flown	0.603 pence

B. Geophysics

As mentioned earlier geophysics is a limited tool, and is not an answer to every problem. Various methods are used based on electrical conductivity, magnetic field etc. as discussed later, but all methods of analyses of results are based on the examination of anomalies or a departure from normal. The cause of this anomaly whether it be an orebody, a structural change, a petroleum deposit or other mineral mass or an unusual condition resulting from such occurrences is the object sought. Upon the accuracy of this identification hinges the success of geophysical prospecting. Usually the determination of an anomaly with reference to both position and depth is insufficient and needs to be interpreted with reference to all the geological facts about structure that can be obtained. In addition boring is usually necessary to test the theory that has been postulated.

A considerable degree of success has been obtained with geophysical methods, and some of their limitations are now known. The cost of geophysical work varies between wide limits depending upon the methods used and the thoroughness of the work. Although the cost unit may not be very great, the area to be covered may be great, and the aggregate cost of most surveys is high enough to limit their application.

It is important to note that the results of one geophysical method may be quite meaningless as anomalies can be due to a number of causes, many of which are of no economic interest. It is usual to survey an area of interest using a number of methods and confirmining anomalies can then be regarded as outlining an area worthy of further testing.

A brief outline of the various methods is listed below.

(a) Magnetic Method

This method involves the detailed measurement of the earth's magnetic field over the area of interest using a sensitive instrument. The earth's normal field is practically uniform on small areas but will be disturbed locally if there are geological formations containing magnetic minerals such as magnetite or pyrrhotite. The magnetic (magnetometer) method is one of the most generally useful geophysical methods, as it can give valuable structural information and is also applicable to the direct detection of orebodies containing magnetic minerals. At Savage River, grid magnetometer surveys were extremely useful in planning a diamond drilling programme. Many non-mineralized rocks such as basalt are extremely magnetic and will give large magnetic anomalies.

(b) Electrical Methods

All these methods depend upon measuring the electrical conductivity of the ground and are particularly suited to the search for orebodies whose conductivity is either much greater or much less than that of the neighbouring geological formations. Electrical methods are used in the search for sulphide orebodies but other conductors such graphitic shales or water bearing fault zones will often give results similar to those from sulphide deposits.

(i) Resistivity - the resistance between two electrodes driven into the ground is measured directly. The observed resistance is an average value for the ground, to a depth which depends upon the distance between the electrodes. By varying this distance the resistivity of the ground can be explored to different depths. This method is particularly useful when the surface is underlain by geological formations lying almost horizontally. As orebodies tend to occur in regions of disturbed geology, the resistivity method does not have a wide application to prospecting for mineral deposits, but can sometimes be usefully employed in the search for deep leads.

(ii) A.C. Methods depend upon the application of a low frequency electromagnetic field to the ground and the measurement of the resulting distribution of electrical potential. The presence of a formation whose conductivity is markedly different from that of the surrounding rocks will cause an anomaly in the field. Various forms of the method are used such as the electromagnetic (E.M.) method which is most useful for detecting conductors such as orebodies of sulphide minerals, or the potential drop ratio which is considered to be particularly useful for detecting poor conductors (e.g. quartz reefs). The electromagnetic method is the one most generally used in prospecting for base metal deposits, but has the limitation that it cannot explore the ground to a very great depth.

(iii) The Self Potential method depends upon measuring the natural potential distribution in the ground. An irregular potential distribution may be due to a number of causes which are imperfectly understood. However, it has been found empirically that a body of sulphide minerals which lies partly below water level is often associated with an anomaly of characteristic form. The practical application of the method is restricted to deposits of this type.

(iv) Induced Polarization where-by an electrical current is passed into a long conductor on the ground which is earthed at intervals. The field thus created is read with an earthed coil. The method is being developed at the present time and is capable f detecting sulphide orebodies at greater depthds than was possible by other electrical methods. Induced polarization was used at Moore's Valley with remarkable results. However, diamond drilling to date indicates that the anomaly was caused by effects not associated with the type of orebody sought.

(c) Gravity Method

This method uses detailed measurement of the earth's gravity field which may be disturbed locally by the presence of geological formations of higher density than the surrounding rocks. The method is mainly applicable to structural problems (oil search) as most orebodies are not large anough to cause measurable gravity anomalies. However, very large bodies such as certain iron orebodies may be directly detectable by this method. The method was used in some deep lead studies at St Helens.

(d) Radiometric methods

This is used to measure the gamma ray intensity at the surface. Many geological formations and some orebodies contain sufficient radioactive materials to produce measurable gamma radiation and this can be useful in geological mapping. The value of the method is limited, because the radiation is absorbed by a small thickness of soil or rock, so measurements can only be made over outcropping rock. Radiometric methods are widely used in the search for Uranium.

(e) Seismic Method

This method measures the velocity of propogation of waves in the various formations in the ground. The effective use is restricted to areas in which the geological formations do not dip steeply, as it cannot be applied where dips are steep or the geology is complicated. The only application in prospecting for metallic mineral deposits is in the search for deep lead deposits as shallow depths only are involved, the refraction seismic method being used.

Seismic refractive methods have been used extensively in Tasmania to determine the course of alluvial tin leads beneath the surface.

C. Geochemical Prospecting

Most metallic mineral deposits are surrounded by a halo of the metals of the deposit, but the halo may contain only minute quantities of the metal. Early work in geochemical prospecting emphasized the analyses of soils for traces of ore metals, but the present practice emphasizes the importance of studies of geochemical patterns in all natural materials - rock soil, ground and surface water, vegetation and lake and stream sediments. The elements measured are most commonly the commercially important metals. As in geophysical work the analyses of results are based on the concept of an anomaly or departure from normal. A geochemical anomaly is an area of unusual metal content or some other chemical chracteristic of a naturally occurring material. However, other naturally occurring phenomena, e.g. glaciation, sub-surface water, surface water, biological dispersions, cause local enrichments, so that a geochemical anomaly does not necessarily represent a mineral deposit.

Trace analyses of stream water are a useful form of geochemical prospecting. This was donein the search for Uranium near Rossarden.

Any technique giving a qualitive or quantitive indication of the distribution of elements may be applicable to geochemistry. Most techniques applied in exploration today are concerned with trace detection (parts per million) and include colorimetry, chromatography, spectrochemical analyses, X-ray and fluorescence methods. Some, especially colorimetry and chromatography, lend themselves to field use. Special care is necessary in translating analytical techniques to practical use for each geological environment. The best sampling practice and the sensitivity of the proposed method must be determined to allow for proper interpretation of results.

The area to be tested is laid out on a grid pattern, and the results expressed as a contour plan, anomalous areas being readily detected. The interpretation of results may be difficult, and involves a knowledge of the many factors involved.

THE DETAILED SEARCH

1. Exploration

When an area of interest has been indicated by the presence of old prospector's workings, by geologically favourable conditions, by confirming geophysical or geochemical methods, by other favourable circumstances, or a combination of these factors, then actual testing of the area should commence. As was suggested earlier even confirmining geophysical results are not necessarily indicative of commercial mineralization. Magnetic anomalies may be due to fault zones which may contain uneconomic pyritic mineralization or even water bearing zones which will give electrical anomalies.

Selected areas of interest may be tested in a number of ways.

A. Detailed geological mapping is required in many cases to outline rock types, geological structures and any surface mineralization that occurs within the selected area. Such mapping is made on aerial photographs if they are available, preferably on a scale of 20 or 30 chains to the inch, the results of the mapping being transferred later to a detailed map.

Such detailed mapping may reveal the cause of a geological anomaly and may result in an area being regarded as not being worthy of further testing. On the other hand it may allow the following exploration programme to proceed with a better idea of the target area and therefore a greater chance of a successful result. Favourable geological structures may be located, faults outlined and a trend of mineralization postulated.

B. As a result of A, surface trenches or costeans may be cut across the anticipated strike of the mineral deposit to enable it to be outlined, and samples would be taken for assay to determine whether the lode formation was of economic value or not. An examination of the exposed lode can also give significant information as to the type of deposit that has been located.

. Drilling of a deposit outlined by B or postulated by A is usually commenced - this will enable some idea of the size of the lode to be determined and its length and depth below the surface to be assessed.

C. Diamond drilling is used extensively in this type of work, but other types of drilling are used in particular cases - Wagon drilling or churn drilling is used to outline shallow or flatly bedded deposits. Such a drilling programme can be costly and require a considerable expenditure, but the results are so important to the future of the prospect that this expense should not be bye-passed. Samples obtained from the boring are accurately split and sampled, the results being plotted on cross sections that are prepared from the drilling work.

In this manner an estimate of the tonnage and grade of indicated ore can be prepared.

Boring results will enable an outline of the deposit and its grade to be plotted, but it must be remembered that although drilling is necessary, care must be taken in the way that the results are used. Diamond drilling results especially can be very misleading, but the greater the number of drill holes used to test a deposit the greater the chance of obtaining an accurate assessment.

It is a statutory requirement in Tasmania, that the Department of Mines must be notified of all bore holes drilled on mines, and in addition all diamond drill cores or material recovered from bores must be preserved and the Department of Mines given a detailed accountof the material drilled. Mines usually store their diamond drilling core in boxes, stacked in suitable racks to enable the staff to re-examine the core with a minimum of difficulty. The preservation of bore holes cores is of utmost importance in the re-assessment of old mines or prospects that have been examined in the past.

D. Development work, in the form of shafts, adits, drives and crosscuts, is then required to outline the boundaries of the deposit. This is the most expensive stage of the investigation, and is usually left until the less expensive preliminary work is completed, although it may be co-ordinated with the drilling and boring programme. Development headings are carefully sampled and the samples assayed as the work proceeds - in this way the drilling and other results can be checked. Development work gives reliable information about the orebody itself, and this enables the future mining method to be planned. The development programme may commence by sinking shafts in the deposit itself, and then driving to the extremities, most of the headings remaining in the deposit. Such headings may not, and often cannot be incorporated in the later production layout, as the planned layout of a mine for the production stage requires a considerable knowledge of the outline of the orebody, the nature of the ore and the metallurgical treatment that will be required. Should the diamond drilling stage, indicate a substantial orebody, the development stage may be partly incorporated in the mine layout. The permanent shaft and levels may be used as a basis for this development programme, but every case introduces its own problems, and the planned programme must be regarded as flexible.

2. Metallurgical Research

Many mineral deposits that have been examined in the past have been found to be uneconomic due to many difficulties encountered in extracting the valuable minerals from the lode.

Ore dressing methods have been improved dramatically since the development of froth flotation and in more recent years ion exchange methods have been developed to a high degree of efficiency.

It is usual for samples of lode material to be tested in the early stages of the investigation of a deposit, with the object of determining the most suitable ore treatment method, the anticipated percentage recovery and the probable cost.

The Tasmanian Department of Mines has its own Chemical and Metallurgical Research Laboratory which is constantly investigating these problems, both for new deposits and for existing mines. Research may cover many aspects - crushing and grinding, the fineness of grinding required to release the economic minerals from the gangue, gravity and flotation methods of concentration, hydrometallurgical problems and mill design.

Such work by the Department of Mines Research Branch has developed a method of preparing clay suitable for paper manufacturing from deposits in the North-East of Tasmania which were previously regarded as useless.

Pilot plant equipment is available to enable field conditions to be repeated in the research laboratory, and in many cases this is essential, if reliable information is to be given to the mining industry.

In addition, some of the larger operating mines have their own research sections which are constantly investigating local metallurgical problems.

Chemical and Metallurgical Research has many aspects, and the problems are always changing, but continued research is essential if the mining industry is to provide us with the raw materials that are required continuously if we are to maintain our high standard of living.

3. Ore Reserves

It is opportune to mention ore reserves at this stage. The satisfactory exploration programme requires the proving of sufficient ore reserves of satisfactory grade to enable mining to commence.

Ore reserves have been divided into four groups by a committee approved by the Australasian Institute of Mining and Metallurgy.

(a) Proven Reserves - are those in which the ore is fully developed or so well known that the tonnage and grade estimates have a high probability of being accurate.

(b) Measures reserves are those for which although the tonnage and grade is computed from dimensions revealed in outcrops, pits, trenches, workings and/or drill holes, and the grade from the results of detailed sampling, and tonnage and grade are as well known as they will be prior to extraction, nevertheless the geological character of the orebody and the method of mining are such that tonnage and/or grade estimates do not have a high probability of being accurate within close limits.

(c) Indicated reserves are those for which tonnage and grade are computed partly from specific measurements, samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement and sampling are too widely or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

(d) Inferred ore is ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the spatial limits within which the "inferred" ore may lie.

The grade of ore reserves is calculated using assay information from the sampling of development openings, surface pits and trenches and diamond drill bore holes and must be a weighted average.

The commencement of productive mining operations requires that sufficient ore of satisfactory grade is available, and that sufficient capital is available to bring the ore deposit into production.

CONCLUSIONS

At all times it must be kept in mind that except in times of natural emergency, a mine is developed with the express purpose of making a profit. If the reserves are insufficient or the grade of material is too low, then the searcher has not achieved his object. However, the information he has obtained is not wasted - emergencies arise, economics change, and the information so laboriously collected and collated will be useful at a later date.

It is important that information so collected should not be lost, and it is for this reason that the Department of Mines requires that copies of the results of investigations should be lodged with them for future use. Such information, even if negative, assists the future searcher to plan his programme and to save much useless expenditure, and thereby allow a greater amount of investigation to be done with the money available.

At this final stage it must be conceded that serendipity "the faculty of making happy discoveries by accident" is important in mineral search. The Golden Gate Mine at Mathinna is a Tasmanian case. The Mount Isa field is another notable example. Silver-Lead-Zinc ore was discovered in a surface outcrop in 1923, and the various difficulties of finance, transport etc. were sufficient to discourage all but the most tenacious. In 1930 diamond drilling to test the downward continuation of the Black Star lead orebody, accidentally discovered a separate mineable copper orebody. The further testing of the copper lode has proven the existence of enormous deposits of high grade copper ore. Although small copper lodes are known on the surface at Mt Isa, drilling beneath them would have produced no encouraging results and the prospects would be distinctly less promising than many of the copper prospects in the Cloncurry mineral field. Dr. Raggatt, Secretary of the Department of National Development wrote in 1958 "The conclusion must be that it is unlikely that any company would have been prepared to drill the prospect with sufficient intensity to have any hope of success. In other words under today's conditions an orebody known to contain hundreds of millions of tons of copper sulphide ore, and which at one point lies within 600 feet of the surface is unlikely to be discovered".

Exploration techniques are improving rapidly, and it is certain that future methods of search will give even more satisfying rewards.