PROGRESS EXPLORATION REPORT - GEORGINA BASIN N.T.

PA 2857 (EL 226) Mt. Hogarth N.T.
PA 3084 Mt. Hogarth East N.T.
PA 3085 Mt. Hogarth South N.T.
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. GEOLOGY</td>
<td>1</td>
</tr>
<tr>
<td>3. STRUCTURE AND GEOLOGICAL HISTORY</td>
<td>8</td>
</tr>
<tr>
<td>4. MINERALIZATION</td>
<td>10</td>
</tr>
<tr>
<td>5. MISSISSIPPI VALLEY TYPE LEAD-ZINC DEPOSITS</td>
<td>12</td>
</tr>
<tr>
<td>6. REGIONAL B.M.R. GRAVITY SURVEY: PRELIMINARY INTERPRETATION</td>
<td>13</td>
</tr>
<tr>
<td>7. REGIONAL B.M.R. AEROMAGNETIC SURVEY: PRELIMINARY INTERPRETATION</td>
<td>16</td>
</tr>
<tr>
<td>8. EXPLORATION WORK CARRIED OUT OVER THE AREAS</td>
<td>18</td>
</tr>
<tr>
<td>9. CONCLUSIONS</td>
<td>21</td>
</tr>
<tr>
<td>10. FURTHER WORK</td>
<td>22</td>
</tr>
</tbody>
</table>

Appendix: The Use of Geochemical Exploration Techniques in Locating Mississippi Valley Type Lead Zinc Deposits by Layton & Assoc. Pty. Ltd. May 1971

Maps and Figures in Rear Wallet (ALL PRELIMINARY)

Map A Location Map
Map B Aeromagnetic Interpretation and Geology
Map C Regional Gravity
Map D Regional Aeromagnetics
Figure 1 Interpretation Aeromagnetic Depth Contours PA 2857
Figure 2 Air Photography Interpretation PA 2857
1. **INTRODUCTION**

Prospecting Authorities have been granted in the southwestern Georgina Basin, N.T., over three adjacent areas occupying a total of almost 3,000 square miles as shown in Map A.

Details of the Prospecting Authorities are listed below:

<table>
<thead>
<tr>
<th>PA No.</th>
<th>Name</th>
<th>Date of Granting</th>
<th>Area (sq. miles)</th>
<th>Holder</th>
</tr>
</thead>
<tbody>
<tr>
<td>2857</td>
<td>Mt. Hogarth</td>
<td>22.11.70</td>
<td>793</td>
<td>Pictavia P/L</td>
</tr>
<tr>
<td>3084</td>
<td>Mt. Hogarth East</td>
<td>3.2.71</td>
<td>1,003</td>
<td>Aberlour P/L</td>
</tr>
<tr>
<td>3085</td>
<td>Mt. Hogarth Sth.</td>
<td>3.2.71</td>
<td>1,188</td>
<td>Aberlour P/L</td>
</tr>
</tbody>
</table>

Pictavia and Aberlour Pty. Ltd. are now wholly owned subsidiaries of Metals Investment Holdings N.L. PA 2857 is now Exploration Licence No. 226 (application).

2. **GEOLOGY**

Detailed locations and geology are shown on Map B. The adjoining areas are in the vicinity of the intersection of the Elkedra, Sandover River, Huckitta and Tobermory 1:250,000 Map Sheets.

The major portion of PA 2857 and PA 3084 is located on the southwestern and southern regions respectively of the Sandover River Sheet. About 70 square miles of PA 2057 extends westward onto the Elkedra Sheet and about 150 square miles of PA 3084 extends southward onto the Tobermory Sheet. The majority of PA 3085 occupies the north west corner of the Tobermory Sheet, the remaining 100 square miles extends north onto the Sandover River Sheet beneath PA 2057.
The geology is described in the Explanatory Notes relating to the relevant Map Sheets. The south-west Georgina Basin has also been treated in Part III of an extensive report on the geology of the Mississippi Valley Type Deposits prepared for Metals Investment Holdings N.L. This has been submitted to the N.T. Mines Branch and is available on request.

Little attempt has, however, been made to describe the geology of the four adjoining map sheets in order to obtain a picture of the regional setting. This is done, briefly, below with special reference to those formations out-cropping within or believed to underlie the areas.

**Arunta Complex**

The Archean Arunta Complex crops out extensively on the lower third of the Hackett Sheet and as small isolated outcrops on the north-west Elkedra Sheet. This complex consisting of gneisses, schists and metagranites which have been intruded by basic rocks and granites which also crop out. Within the Arunta Complex and associated granites numerous pegmatite veins are present.

Bore B.M.R. 13 (Sandover) 4 miles west of PA 2857 on the Elkedra Sheet penetrated gneiss between 3304 and 3328 feet. The grade of metamorphism suggests its inclusion within the Arunta Complex. Immediately below this Lower Proterozoic granite was encountered.

**Lower Proterozoic to Middle Cambrian Sediments**

Rocks of this age do not outcrop within the Prospecting Authorities. On the southern region of the Hackett Sheet the Upper Proterozoic to Lower Cambrian Mopunga Group overlies
the Arunta Complex. This Group consists of a sequence of three formations; namely the Elyuah, Grants Bluff, and Mt. Baldwin Formation. The basal unit is the Elyuah Formation consisting of arkose and shale resting unconformably on Archean metamorphics and Lower Proterozoic granites. The Elyuah Formation is overlain conformably by the Grants Bluff Formation consisting of quartz sandstone, greywacke, siltstone and thin dolomite. The Formation is in turn conformably overlain by the Lower Cambrian Mt. Baldwin Formation comprising dominantly sediments with some green shale and yellow dolomite.

B.M.R. 13 (Sandover) encountered units of dolomite and red sandstone in the interval 3097 to 3304 feet. The lithology at this depth resembles the Mt. Baldwin Formation on the Huckitta Sheet.

On the eastern part of the Huckitta Sheet the Mt. Baldwin Formation is conformably overlain by the Author Creek Beds of Middle Cambrian age. These Beds consist of fossiliferous shale, dolomite, limestone and sandstone. On the Tobermory Sheet fossiliferous Lower to Middle Cambrian shale and siltstone rest unconformably on various beds of Upper Proterozoic age and the Mt. Baldwin Formation is absent.

On the Elkedra Sheet the Arunta Complex is unconformably overlain by the Lower Proterozoic Hatches Creek Group which outcrops strongly on the Davenport Ranges to the north-west of this sheet. (See Summary Report on PA 3228 Elkedra for Metals Investment Holdings). The Hatches Creek Group was not regionally metamorphosed but has been intruded by granite, porphyry and dolerite.

In the central region of the Elkedra Sheet the Middle Cambrian Sandover Beds crop out unconformably on the Pre-
Cambrian. These beds consist of friable mudstone, laminated fine grained sandstone, shale and chert. B.M.R. 13 (Sandover) penetrated these beds in the interval 2235 to 3097 feet. The Sandover Beds which have been neither metamorphosed nor intruded are one of several Lower Middle Cambrian sequences which commonly form the base of the Palaeozoic succession around the margins of the Georgina Basin and it is probable that sedimentation in this part of the Basin began with these beds and their approximate equivalent the Author Creek Beds.

Meeta Beds

In the central region of PA 3084 the oldest outcropping rocks are the Meeta Beds, believed to be of Upper Cambrian Age but the possibility of a younger age up to a Lower Ordovician cannot be excluded. These consisting of dolomite with interbeds of oolitic limestone, siltstone and some lenses of clean sandstone up to 75 feet thick. North-east of the Sandover River Sheet these Beds are more than 1,000 feet thick (Lake Nash No.16). The Meeta Beds also crop out on the north-west Elkedra Sheet as a series of south-west trending ridges with a total exposed thickness of 300 feet.

The Meeta Beds were deposited in a shelf area covered by shallow warm waters, mainly characterized by chemical precipitation. Periodic stromes or disturbances of the sea floor, possible with minor regressions, produced intra-formational conglomerates. Highly saline waters rich in magnesium have combined with slow subsidence to cause pre-contemporaneous dolomitization.

The Meeta Beds underlie the Tomahawk and possibly part of the Ninmaroo Formation which crop out in the held areas.
The Arrinthurunga Formation

The Middle to Upper Cambrian Arrinthurunga Formation consists of a thick sequence of dolomite, algal dolomite, limestone with interbedded siltstone and sandstone which lies stratigraphically between the Author Creek Beds below and the Tomahawk Beds above.

The Arrinthurunga Formation does not crop out within the areas but occurs on the Elkedra Sheet over a small region east of Oorratippra Creek with a maximum exposed thickness of 300 feet. B.M.R. 13 (Sandover) penetrated about 2,200 feet of this Formation, the basal part of which (1464 to 2235 feet) outcrops strongly on the eastern part of the Huckitta Sheet. Dips on this Formation are generally low and outcrop ranges from prominent to poor.

The Arrinthurunga Formation contains the Eurowie Sandstone Member which has been used as a marker formation and could have significance as a cap rock. This member also crops out on the north-east Huckitta Sheet and lies between the top unit of a dominantly blue, grey and purple oolitic and algal limestone and dolomite; and the base of the top sequence of the Arrinthurunga Formation. The base of the Eurowie Sandstone Member usually shows a sharp conformable contact with the underlying dolomite and limestone of the Formation and the top, usually grades into the overlying dolomite. The upper beds of the Member, sometimes grade laterally into dolomite. The Eurowie Sandstone Member, itself, generally consists of a medium grained reddish-brown quartz sandstone with beds of fine siltstone near the base.

The basal unit of the Arrinthurunga Formation and the Meeta Beds were deposited on the eastern third of the Elkedra Sheet during extensive shallow water marine sedimentation which began in early Upper Cambrian. The westward extension of both
these units is unknown. Because there are no surface contacts between the Middle and Upper Cambrian formation and because the youngest Middle Cambrian sediments in B.M.R. 13 (Sandover) cannot be dated precisely, it is not known whether the Arrin thrunga Formation lies conformably or disconformably on the Middle Cambrian sediments.

The upper boundary of the Arrin thrunga Formation with the Tomahawk Beds appears to be gradational and conformable to the west of the Huckitta Sheet but to the north-east of the authority areas it is often faulted. Also in this region the top dolomite unit of the Arrin thrunga Formation is less than 300 feet thick and being half its normal thickness may indicate a disconformity. Additional information supporting a disconformity comes from drilling in this region. A water bore (4 miles north-east of the Lucy Creek Crossing on the Lucy Creek-Sandover River road) penetrated 170 feet of the Tomahawk Beds before entering the Arrin thrunga Formation; the interval 180 to 220 feet consisted mostly of caves in dolomite of which the largest was 9 feet deep. The occurrence of these caves may indicate old near surface conditions and therefore a disconformity prior to deposition of the Tomahawk Beds.

The cavernous nature of the Arrin thrunga Formation may also be significant with regard to Mississippi Valley Type Ore Formation.

**Tomahawk Beds**

The richly fossiliferous Upper Cambrian to Lower Ordovician Tomahawk Beds succeed the Arrin thrunga Formation. These Beds crop out over a large part of PA 2857, the southern half of PA 3085 and sporadically over PA 3084. They consist of a sequence of dolomite, dolarenite, sandstone, siltstone with minor limestone; lateral gradations between dolarenite and sandstone are common.
Immediately to the south-west of PA 2857 the Tomahawk Beds crop out as prominent peaks and mesas. Their maximum thickness in this region is about 300 feet but the base is not exposed due to down faulting against the top dolomite unit of the Arrinthurunga Formation.

The Tomahawk Beds accumulated in shallow water, rich in carbonate in a shelf region. Uplift and erosion of adjacent land probably caused later widespread deposition of sand and silt as well as some lateral variations in the sandstone and dolomite units.

Ninmaroo Formation

The Ninmaroo Formation is believed to be the same age as the Tomahawk Beds and crops out on the south-eastern region of the PA 3084 on the Sandover River Sheet and the south-eastern corner of PA 3085 on the Tobermory Sheet.

This Formation has a maximum thickness of 425 feet and consists of dolomite, siltstone and sandstone. Units mapped as the Ninmaroo Formation on the Sandover River Sheet overlie lithologically similar units in the Meeta Beds, but are also similar with units mapped as the Ninmaroo Formation on the Tobermory Sheet. Since these two Formation cannot be distinguished by fossils or lithology the inferred boundary on the Sandover River Sheet is doubtful geological significance.

The Ninmaroo Formations appear to pass laterally into the lower part of the Tomahawk Beds on the southern region of PA 3084.

Sediments of the Ninmaroo Formation accumulated in warm shallow water rich in calcium and favourable to the growth of stromatolitic and columnar algae. Periodically quartz, silt
and sand were deposited.

**Mesozoic and Cainozoic Sediments**

In places within the held areas the Palaeozoic sediments are sometimes overlain by a masking Mesozoic and Cainozoic cover.

About 40% of FA 2857 is overlain with Quarternary sand and alluvial material and small isolated outcrops of Mesozoic quartz sandstone and conglomerate. The total thickness of this cover within FA 2857, where it occurs, should not exceed 60 feet.

About 60% of FA 3084 is similarly covered to a depth believed to be not greater than 100 feet. FA 3085 is more extensively covered (about 80%) and thickness in places may exceed 100 feet.

3. **STRUCTURE AND GEOLOGICAL HISTORY**

The number of orogenies and accompanying metamorphisms in the Pre-Cambrian rocks is unknown. Considerably folding and faulting took place in Pre-Cambrian times and from late Pre-Cambrian to Carboniferous or Permian. Faulting in the Pre-Cambrian basement rocks seems to have largely controlled the development of sediments in the Rucketta Sheet area. There are two dominant structural trend-lines representing the major lines of weakness on the late Pre-Cambrian and most of the Palaeozoic. These trends are in a north-east and north-west direction. Most of the faults mappable in Palaeozoic sediments trend north-west as do many of those which have faulted Upper
Protoerozoic sediments against older Pre-Cambrian rocks, a subsidiary trend is north-east. Similar trends extend on to the adjoining Elkedra, Sandover River and Tobermory Sheets.

On the Sandover River Sheet regional dip of the Palaeozoic formations is from 1 to 5 degrees south-west. Most outcrops are horizontally bedded in the northern and central region of this Sheet. Elsewhere broad anticlines and synclines may be present although fold axes cannot be accurately mapped. The dolomites on the Sandover River Sheet are well jointed in the two major directions with a minor set of joints striking east-west.

In the south-west Georgina Basin Palaeozoic sediments were effected by a strong orogeny which was probably of the same age as the Carboniferous Kanimblan orogery in the Tasman Geo-
syncline. The visible effects in the Elkedra areas are slight and confined to faults trending north-west and some steep dips are associated with this faulting. These effects are seen in the Arrinithunga Formation, Tomahawk Beds, and Meeta Beds in the south-east where faults are part of a system, much stronger in the Huckerita Sheet area, with down-thrown blocks consistently on the east side. Faults in the Sandover Beds may have originated during this orogery, but they could also be associate with epirogenic movements during the Middle Cambrian.

The three areas held are part of a region in which zones of deposition were probably controlled by oscillation of basement rocks along active fracture zones. Sedimentation was essentially continuous during the Middle and Upper Cambrian times when a thick sequence of carbonate rocks were deposited in shallow water in a slowly subsiding basin.
4. MINERALIZATION

On the Pre-Cambrian Shield areas in the southern Huckitta Sheet an increasing number of mineralized areas are being discovered.

For some time small barite deposits have been known within the Jinka Granite and micas have been mined commercially in the pegmatites of the Plenty River Mica Field. Recently Central Pacific Minerals N.I. has geologically mapped and sampled 321 square miles of the Jinka Plains area and has reported a number of quartz-barite-fluorite veins containing copper values.

Also on the shield is the south-east Huckitta Sheet lead occurrences have been noted and copper has been mined commercially in the Jervois Ranges. Petrocarb Exploration N.I. (Australian Miner 21st June, 1971) has reported an upgrading of their Attutra base metal mine within the Jervois Ranges. This Company sunk 44 diamond drill holes and delineated two mineralized zones. In the northern zone 600,000 tons of ore are inferred with average grades of 3% copper, 4.4 oz. silver and 2 lbs. bismuth. The southern zone yielded an inferred ore reserve of 650,000 tons averaging 11.6% lead, 2.4% copper, 10.2 oz. silver and 2 lbs. bismuth.

The authority areas are in close proximity to the shield and within the sediments of the south-west Georgina Basin a number of occurrences of lead mineralization have been noted.

At Box Hole Bore on the Huckitta Sheet about 40 miles south-west of FA 2857 an extensive galena occurrence has been discovered. The galena occurs as lenses within partly silicified Cambrian dolomites of the Arrinthuranga Formation. These lenses are restricted to two horizons with the main lense
averaging 20 feet in thickness and extending discontinuously about 8,000 feet along strike. Cavities are present in the mineralized zone and algal structures are common immediately beneath it. Mineralization in the region appears to be concentrated near the pinching out of a bed, probably due to a lateral facies change. (Enterprise Exploration Pty. Ltd. and Conzinc Riotinto of Australia Ltd. have drilled this deposit without success. Recently Central Pacific Minerals N.L. carried out 12 line miles of I.I. in this region, detecting a number of weak anomalies.

At Coratippra Station (Elkedra Sheet) about 5 miles west of PA 2857 Centamin N.L. encountered surface occurrences of lead, silver mineralization. The host rocks are the Cambro-Ordovician Tomahawk Beds (outcropping extensively in the authority areas) with galena occurring as small veins and lenses within the limestone which again is commonly silicified in the region of occurrence. The mineralized outcrops extend over an area of about 3 square miles north of Trackrider Bore. Some shallow pitting has been done, near the galena outcrops and Centamin N.L. has recently reported encouraging results from a geochemical survey in this region.

Also on the Elkedra Sheet B.M.R. 13 (Sandover) encountered six favourable dolomite horizons ranging in depth from 200/260 feet to 2320/2440 feet. These zones are characterized by low resistivity values on the long normal (18' 8") well log and in general are overlain by shale/sand horizons. They invariably have associated pyrite mineralization and copper has been detected in several assays carried out by the B.M.R. These assays gave copper values ranging from 20 to 100 p.p.m. and persisting over an interval of about 800 feet.

Within PA 2857, 11 miles east-north-east of Argadargada
Homestead on the Sandover River Sheet detrital copper and metallic minerals were noted within limestone and dolomite at 80, 130 and 393 feet (Tolley's Bore).

Although mineralization is probably much more widespread the noted occurrences form approximately linear trend in a north-east direction through the held areas. This trend direction being one of the two major structural directions in this region of the Georgina Basin.

5. MISSISSIPPI VALLEY TYPE LEAD-ZINC DEPOSITS

An extensive report on this type of deposit has been prepared previously by the company. A brief summary is included below for reference.

Lead-zinc deposits of the Mississippi Valley type have a world wide occurrence. The unifying characteristics of these deposits are:-

(a) They occur in limestones and dolomites and their age ranges from Upper Cambrian to Tertiary.

(b) They consist primarily of bedded replacements, veins and cavity fillings. The ore shows great selectivity for certain favourable beds.

(c) Mineralogy is simple and the precious metal content is low, viz: galena, sphalerite, pyrite, fluorite, with minor Co, Ni, Ag, Cu, Cd, In, Ge, Ga. Gangue is white sparry dolomite, calcite, jasperoid, chert and quartz. Traces of hydrocarbons are common. There is usually little wall rock alteration.

(d) There is a general absence of igneous rocks as potential sources of ore solutions.
(e) Ore bodies are most common in passive structural regions. Faults are common in the Appalachian province, Illinois-Kentucky field, North Africa and Ireland.

(f) Ore is frequently related to positive structures including basement "Knobs", calcareous sand banks, algal reefs and domes. Dips of 20 degrees - 40 degrees in off reef beds are common.

(g) Solution activity, brecciation, slump, collapse, and thinning are commonly in evidence, including old karst topography.

(h) Ores occur at shallow depths (generally less than 1,000 feet) relative to the present surface. This is probably a function of both ease of exploration and mode of formation from brines following porous horizons out of the basin.

(i) On a world wide basis the stratiform ore deposits occur in narrow horizons, (often less than 200 feet), regardless of their regional geologic settings and the thickness of the sequence at the location. Furthermore, deposits are commonly near basin margins.

6. REGIONAL B.M.R. GRAVITY SURVEY: PRELIMINARY INTERPRETATION
(refer map C at scale 1:500,000)

The relevant 1:250,000 map sheets have been surveyed in a B.M.R. regional gravity programme. In the vicinity of the authority areas the regional gravity pattern shows a complex super-position of large scale anomalies. The anomalies could result from a variety of subsurface density contrasts, the
main possibilities being listed below:-

(a) Density variations within the thick limestone sequence.

(b) Density contrasts between the sediments and an underlying variable depth crystalline basement.

(c) Lateral density variations within the basement.

Although no density information is available correlations at widely spaced bores suggest that the contribution to the measured anomalies from type A sources is likely to be small.

Also there is not likely to be a large density contrast between the overlying limestone sequence and an acid igneous-metamorphic basement provided the entire sedimentary section is not highly cavernous. Anomalies from type B sources can therefore be expected to be of relatively low amplitude. They are important however, in that by correlation between such anomalies major tectonic lineations and structures within the basement may be revealed. Recognition of such features is often of major significance in ore-body location particularly in the case of non-outcropping stratiform lead-zinc deposits.

Anomalies due to type C sources will probably be of large amplitude, and relatively isolated from the overall anomaly patterns due to type B sources. When such anomalies form positive closures they are likely to be due to intermediate to basic intrusive within the basement. Where they form isolated negative closures or lows a probable explanation is granite (possibly much younger granite) intrusion at depth.

Qualitative and semi-quantitative interpretation of the gravity results has been done and it appears that the authority areas are portion of large "shelf" region of generally shallower basement within the Georgina Basin with much deeper
basement to the north-east and west as depicted in map C.

The complex gravity closures in the vicinity of the authority areas suggest that tectonic and igneous activity has been much more intensive than on the larger part of the shelf extending south-east onto the Tobermory Sheet.

The interpreted shelf is truncated abruptly to the west of a major positive closure immediately west of PA 2857. The large, roughly circular and 15 milligal anomaly probably represents a major basic intrusion within the basement. Using Skeels maximum depth method and a density contrast of 0.1 gm/cc a depth to the top of a vertical cylindrical model representing the supposed source was calculated at about 5 Km. Larger density contrasts gave depths in the vicinity of 9 Km. A similar although much smaller positive closure occurs north-east of the larger anomaly. Major north-west transverse faulting between these features is suggested. Another more elongate positive anomaly near the north-west corner of PA 3085 could be attributed to a similar basic intrusive at depth.

Apart from these relatively isolated anomalies further interpretation over the authority areas suggest a series of alternative north-east trending highs and lows which could be attributed to shallowing and deepening of the basement within the shelf region. An alternative hypothesis is that these linear features represent banding within the basement with more dense intermediate basic and less dense acid rocks alternating in a regular manner with intrusion along major north-east trending zones of weakness.

Another major north-west trending transverse fault is suggested bisecting PA 2857 and suggesting southern movement of a basement block on the western side of PA 2857.
A major fault trending north-west transects PA 3084 with the shelf to the east continuing for some distance to the east beyond this very prominent feature but at a greater depth.

Considering the number of unknowns present this interpretation must be regarded as tentative but when viewed in large scale tectonic terms the features delineated may be very significant for Mississippi Valley Type ore localization.

7. **REGIONAL B.M.R. AEROMAGNETIC SURVEY: PRELIMINARY INTERPRETATION** (refer map D at scale 1:250,000)

The four adjoining map sheets have been flown by the B.M.R. on east-west lines using a line spacing of 2 miles and on average height of 500 feet along ground surface. The results have been manually contoured at 10 gamma intervals.

Magnetic relief is considerable and the resulting anomaly patterns differ markedly on each of the 1:250,000 map sheets; with numerous anomalies relating to sources with a variety of strikes and a number of depths within the basement. In such circumstances and as a result of manual contouring the complex anomaly pattern is difficult to interpret in all but the most general terms.

The general features interpreted from the magnetic contour maps are shown on Map B with possible sources indicated. As with the gravity map major tectonic activity has occurred in the vicinity of the authorities with the two predominant north-east, north-west trends again visible. The north-east fault trend is somewhat more prominent on the Sandover River
and Elkedra Sheets while the north-western trend dominates the Huckitta and Tobermory Sheets. Several narrow linear magnetic highs, presumably due to basic dykes occur in the vicinity of PA 2857 and a large basic intrusive occurs west of PA 2857 corresponding to the +15 milligal gravity closure.

A major north-west, south-east predominantly transverse fault, appears to dissect PA 2857 as on the gravity map and a second major NW-SE fault zone truncates the shelf zone, which again appears to continue eastward for some distance at a greater depth.

The agreement between the gravity and magnetic maps is generally good with gravity highs usually corresponding with magnetic highs and supporting the north-east south-west trending ridge-valley and shelf concepts as well as the postulated isolated more dense and magnetic basic intrusives at depth.

A notable exception to this correspondence occurs in the southern region of PA 3085 where a broad east-west striking magnetic high corresponds to a similar gravity low. This is ascribed to an acidic intrusion within the basement.

Also it should be noted that the north-east south-west trending gravity lows in the north-west corner of PA 3085 trending across the southern region of PA 2857 and the central region of PA 3084 are more difficult to attribute to basement depressions. The magnetics in this region while giving relatively low values are somewhat disturbed and it may be that the sources of the gravity anomalies are granitic basement highs rather than depressions.

Quantitative interpretation of the magnetic anomalies on PA 2857 was done by applying Peters Method assuming basement
sources to be vertically magnetized flat topped vertical prisms. The results of this are shown in Figure 1 (scale 1:250,000) and have revealed a basement high of substantial dimensions on the southern region of PA 2857 and another possible high in the southern region of PA 3084. The presence of the basement knobs may enhance the possibility of Mississippi Valley type deposits within these areas. Quantitative interpretation was not applied to PA 3085 and a large part of PA 3084 but the possibility of similar features within these areas cannot be ignored.

8. EXPLORATION WORK CARRIED OUT OVER THE AREAS

Most exploration has been carried out over PA 2857 and has consisted of detailed air-photo interpretation, track and water bore location, preliminary sampling and geochemical analysis as well as a proposed geochemical survey programme.

(i) Airphoto Interpretation PA 2857 (refer figure 2)

The dominant feature of the area is that of climate. It is of low humidity, low rainfall, and high temperatures. The annual rainfall is usually less than 10 inches with summer temperatures above 115°F. The nearest inhabitants are the owners of "Argadargada" Homestead, located on the western central lease boundary.

The lease area consists mainly of red semi-desert with altitudes ranging from 580' - 1100' where mesas and bluffs may use up to 150' above valleys.

The dominant topographic feature of the area is an arcuate divide striking east-west which separates the area into two drainage basins. That to the north is
drained by the Sandover River through a broad, ill-defined flood plain which eventually reached the Georgina River to the North-east. The southern river system consists of the Imbordjodu and Bloodwood Creeks, both of which flow outside the lease area to the west. Other creeks within the area drain south through moderately entrenched courses until they are lost in the sand and semi-desert.

Air-photo interpretation of the lease area allowed the following topographic and physiographic divisions to be made (see figure 2).

**Area 1:** This is located along the southern margin of the area and is characterised by generally good outcrop associated with numerous entrenched water-courses. Hills are generally of mesa or ridge nature and 100' - 200' in elevation.

This appears to be the only area in which detailed mapping may be carried out and special attention should initially be focused on areas marked A1, A2 on the map. The first of these should provide a good section through the Tomahawk Beds in the east of the area while the other area to the west appears to contain marked facies changes within the same formation.

Soil and/or stream geochemistry also appears to be feasible within this area except on the southern margin where wind blown sand from the south has filled stream courses.

**Area 2:** This has restricted distribution to the east of the area and represents a transition zone between (1) and (3) which is governed mainly by topography.
This area appears to occupy the topographic divide in the area and as such acts as a water shed for streams flowing north and south. Because of this, and because of the non-perennial nature of the streams, drainage here is still widespread but poorly developed. Outcrop also appears to be poor due to lack of fluviatile activity. It is thought however, that this area could still be suitable for most types of stream and soil geochemistry.

Where the margin of areas (1) and (2) coincides with the sand spinifex zone (No.4) contamination of creek beds by wind blown sand becomes obvious.

Area 3: This area has a large extent to the north where drainage patterns are poorly developed and relief difference low. As such it is mainly one of sand/spinifex surrounding either residual soil zones or else isolated outcrops of the Tomahawk Beds. Where access permits, this area should be geologically mapped and while testing of alluvial thickness should be carried out it is not thought that a deep soil sampling survey would be initially warranted. There appears also to be no possibility of stream geochemistry being successful here.

Area 4: By far the most extensive, this zone is also the least interesting. It is dominantly sandy from either wind blown dunes or the alluvial flats surrounding the Sandover River. Outcrop is extremely scattered and access generally is poor and it is suggested that no immediate attention be given to this area.

(ii) Track and Bore Location - Preliminary Sampling TA 2857

A detailed compilation of 74 water bores on the Sandover River Sheet has been made and the data are currently being studied.
Preliminary field studies have located tracks etc. and a number of surface samples have been collected and geochemically analysed. Access to the area is generally good and it is probable that work could continue throughout the year.

The analyses so far received are too few to interpret definitively, but Sample A, a complex ore, collected near the north-western boundary of PA 2857 gave 2440 p.p.m. zinc and about 10,000 p.p.m. manganese.

9. CONCLUSIONS

1. Prospective limestone-dolomite horizons for the formation of Mississippi Valley type lead-zinc orebodies occur throughout the stratigraphic column within the authority areas. Many of these horizons are well within the range of current prospecting methods.

2. The geophysical evidence suggests considerable deep igneous activity and faulting in two major directions. In addition the occurrence of basement knobs within the held areas is indicated and when combined with known mineralization in the vicinity could be very significant for stratiform ore-body localization.

3. On the basis of the geological and geophysical information available at present these areas are regarded as prospective for the occurrence of Mississippi Valley type lead-zinc deposits and thus warrants considerable further attention.
10. **FURTHER WORK**

The feasibility and utility of close line spacing, saturation airborne geophysical coverage are being considered. The aim of such a survey would be to obtain structural information from a high resolution magnetic system and endeavour to obtain subsurface conductivity information (or more strictly speaking the product of conductivity and thickness of the causative bodies) from suitable electromagnetic systems with requisite penetration. In this way conductive strata, fault and shear zones etc. could possibly by mapped, possibly with a VLF unit combined with a multi-channel time domain or dual frequency quadrature electromagnetic system designed to emphasise broad scale features. Thermal mapping with an infra-red unit scanning in the 8-14 micron wave band (flown pre-dawn) may provide much useful additional information. Conventional differential or integral gamma-ray spectrometer surveying might also provide valuable data. The new mercury spectrometer systems could also yield airborne geochemical information of direct or indirect use in the search for sulphide targets.

However preliminary costings of such surveys show that although comprehensive coverage and data would be obtained, a very large exploration expenditure would be required for data gathering, information processing and interpretation. Accordingly the advantages and disadvantages of this type of survey are being subject to careful and thorough consideration prior to committing funds for this purpose.

Ground geochemical methods are considered to be of immediate applicability in the authority areas. A consultant's opinion and proposal on the geochemical approach to exploration for targets sought is appended to this report.
Pictavia Pty. Ltd. (PA 2857)
and
Aberlour Pty. Ltd. (PA 2084, 5)

October 1971

P.O. Box 579 Crows Nest N.S.W. 2065
and
P.O. Box 3520 Darwin N.T. 5794
THE USE OF
GEOCHEMICAL EXPLORATION TECHNIQUES
IN LOCATING MISSISSIPPI VALLEY-TYPE
LEAD-ZINC DEPOSITS

FOR

METALS INVESTMENT HOLDINGS N.L.

May, 1971.
TABLE OF CONTENTS

INTRODUCTION 1
GEOLOGY 2
SOIL 6
GEOCHEMICAL PROSPECTING 11
INTERPRETATION 18
FIELD LABORATORY 19
THE USE OF GEOCHEMICAL EXPLORATION TECHNIQUES

IN LOCATING MISSISSIPPI VALLEY-TYPE

LEAD-ZINC DEPOSITS

INTRODUCTION

The aim of this report is to assess the possibility of using geochemical methods to locate the presence of flat-lying Mississippi Valley-type lead-zinc mineralisation.

A brief description of this type of deposit is given, with possible modes of formation. The mineralogy of such deposits is considered, with a view to the possible use of indicator elements, in conjunction with the main base metals being sought.

The specific area of interest is in the Georgina Basin, Northern Territory, and the climate and soil characteristics of this area are described.
An attempt has been made to assess the value of geochemical prospecting techniques in searching for this type of deposit in the Georgina Basin. The general trace element geochemistry of the area is discussed, and a number of indicator elements are suggested.

Details that should be considered during an Orientation Survey are given, and it is recommended that such a survey be carried out under the supervision of a geochemist.

GEOLOGY

Zinc-lead deposits of the Mississippi-Valley or Tri-State type are generally regarded as telethermal ores, and may be formed by hydrothermal fluids that have migrated great distances from their source. These fluids have lost most of their heat and most of their capacity to react chemically with the surrounding rock. The deposits generally cannot be definitely correlated with known igneous activity, and an alternative hypothesis is that they are deposited from meteoric water.
The Tri-State deposits of the Mississippi Valley form a very large zinc district (of about 2,000 sq. miles) of low-grade zinc ores. Lead is also recovered from these ores, but no other metals are present in commercial quantity.

The host rocks consist of the flat-lying sediments, particularly limestone and chert, of the Boone Formation, which is overlain unconformably by Pennsylvanian shales. Karst topography was developed on the pre-Pennsylvanian erosion surface; solution channels and sink-holes formed in the underlying limestone and along the interface with chert.

Shear zones are prominent and, with brecciated cherts, give rise to localised ore-shoots. The beds generally are barren except where favourable structures for ore localisation have developed. The main ore-bodies, however, are near-surface deposits infilling shallow
solution channels and encircling sink-holes.

A characteristic of these deposits, as of all teleothermal deposits, is the paucity of wall-rock alteration features.

The main mineral is sphalerite, with subordinate galena and minor amounts of wurtzite, marcasite, pyrite and chalcopyrite. Enargite ($3\text{Cu}_2\text{S}\cdot\text{As}_2\text{S}_5$) and millerite ($\text{NiS}$) have also been identified. The gangue minerals are quartz, chert, calcite, dolomite and some barytes. Oxidation of the ores is well developed and a large group of oxidation products is present, which may include representatives of the uranium, vanadium and copper oxides that are a frequent occurrence in telethermal deposits.

A similar series of zinc-lead deposits, although with some difference in the mineral assemblage, occurs in Upper Silesia and these are also regarded as telethermal deposits. In this
example, volume changes in limestone caused by
dolomitisation have resulted in brecciation, making
the host rock accessible to mineralised fluids.

The primary minerals include sphalerite,
wurtzite, galena, pyrite, marcasite, together with
small amounts of arsenic and antimony sulphides,
jordanite \((4\text{PbS} \cdot \text{As}_2\text{S}_3)\) and meneghinite \((4\text{PbS} \cdot \text{Sb}_2\text{S}_3)\).
Minor amounts of silver and cadmium may be present
in the galena and sphalerite respectively.

Deep weathering has resulted in oxidation
of the ores and separation of zinc from iron, so that
a surface zone of relatively pure iron oxides overlies
a zone enriched in zinc (and also cadmium). The
chief oxidation products are smithsonite,
hemimorphite, cerussite and limonite, but other
minerals may be present in minor amounts, such as
anglesite, goslarite \((\text{ZnSO}_4 \cdot 7\text{H}_2\text{O})\), tarnowitze
\((\{\text{Ca, Pb}\} \cdot \text{CO}_3)\), and phosgenite \((\text{PbCl}_2 \cdot \text{PbCO}_3)\).
Bedded zinc-lead deposits are also known in the McArthur River region of the Northern Territory of Australia. In this case, however, they are generally regarded as being of syngenetic origin, with the ore-minerals having been formed by chemical precipitation. The deposits that may be present in the Georgina Basin are thought to be of similar origin.

Although deposits of the McArthur River type may differ in origin from those of the Mississippi Valley and Upper Silesia, they nevertheless share many features in common and are susceptible to similar methods of exploration.

**SOIL**

The dominant factor in soil formation is normally the climate. In the Georgina Basin the rainfall generally averages 4 to 10 inches per year. The average winter minimum temperature is approximately 70°F, and the average summer maximum
100°F. Under these conditions, arid, near-desert-type soils have formed, with little horizon development.

According to published maps, the soils of the area are shallow sandy lithosols, red earthy soils and red earths.

Lithosols are essentially stony or gravelly soils, with little or no horizon development, except possibly a shallow $A_1$ horizon due to the accumulation of organic matter. They frequently contain large amounts of relatively unweathered fragmented rock.

Weathering and leaching are slight, and much of the matrix of these soils consists of finely ground rock fragments. The pH of the soil varies from neutral to slightly acid.

These soils occur on slopes where erosion is sufficient to maintain only a shallow soil cover over the area. Highly resistant rocks will
produce lithosols under less severe conditions of erosion.

*Earthy sands* are generally finer and more uniform in texture than lithosols. They have a uniform profile, with little or no horizon development. The name derives from the earthy appearance of the sand, which results from the coating of clayey material and iron oxides on the siliceous sand grains.

There is commonly a weakly differentiated surface of loose, brown to reddish brown sand overlying a uniform profile: there may be ironstone nodules and sesquioxides throughout. The soil varies in depth from shallow to very deep.

The main soil-forming processes are leaching from the surface, accompanied by the incorporation of any available organic matter, to form an $A_1$ horizon. The soil has an acid reaction, and carbonates and other salts are absent. However, leaching is mild, and there is generally a uniform distribution of clay material throughout
the profile.

These soils occur on low, flat-lying ground, in the hot dry areas of Australia.

Red earths are probably less dominant than the above two soil types in the area. The type covers soils with a wide range of properties, but the common distinguishing features are their sandy texture, moderate porosity, and earthy fabric. They are red to red-brown in colour and have an almost uniform profile with little horizon development. The exception is a pronounced A₁ horizon which is dark, with an acid to mildly alkaline reaction. There is generally a slight increase of clay content with depth. Most of these soils are neutral to acid, with a tendency for the pH to decrease with depth; however, some may be very mildly alkaline. They occasionally contain ferromanganiferous nodules throughout the profile. The soils are normally deep, ranging up to 20 feet, but may be as shallow as 3 feet in layers.
The main process in the formation of these soils has been weathering of siliceous parent material and the segregation of sesquioxides, particularly at depth, the lesser segregation of manganese oxides, and minor clay illuviation. Leaching has occurred but is slight.

The soils occur under a wide variety of climatic conditions and on a variety of land surfaces. The parent material from which they are formed generally has a high silica content, and includes granites, sandstones and unconsolidated sediments.

Red earths form under less arid conditions than lithosols or earthy sands. Alternating wet and dry periods lead to the formation of kaolin clays and unsaturated bases.

Discussion

These soil types are all ones in which there will have been some leaching of base metals.
The mobility of these base metals will be greater and more uniform than in more alkaline soils. However in view of the large areas of dolomite and dolomitic rock the soils are likely to contain appreciable amounts of carbonates. This is likely to interfere with the dispersion of base metals, and must be borne in mind in the interpretation of results from geochemical surveys in the area.

GEOCHEMICAL PROSPECTING

The area is such that geochemical exploration techniques could prove to be one of the more useful methods of locating hidden mineralisation. It is strongly recommended, however, that the area be visited by a geochemist, and the viability of such a programme be assessed once the specific details of the area have been seen in the field.

A detailed Orientation Survey should then be undertaken. If possible an area of known
mineralisation in the same or similar environment should be selected, and a detailed study of it should be made. As no suitable area is known within the lease, the possibility of using an area outside the lease should be considered.

Failing the availability of an area of known mineralisation the area chosen should be one that includes outcrop, shallow soils and deeper soils. Use should be made of an area or areas where the geology is already known and all the rock types on the lease should be included.

The Orientation Survey should be aimed at determining the nature of the dispersion patterns produced by the individual elements, and the optimum sampling depth and inter-sample interval.

Orientation samples should be taken from the different soil types present, from flat ground,
hill slopes and hill crests. They should be collected from lines at right angles to the strike direction of outcrop or suboutcrop and from fairly close horizontal spacings. This latter can best be assessed once details of the selected locality are known. At this stage, and bearing in mind the possible carbonate content of the soil, a suggested distance is 25 feet. Samples should be taken at regular intervals from surface to bedrock. This also can be better assessed in the field and will depend on the nature of the soil profile, changes of soil type etc.

A number of elements are known to occur in this type of deposit, and these include:

- Zn sphalerite, wurtzite etc.
- Pb galena, jordanite, gratonite etc.
- Cu chalcopyrite, enargite
- Ni millerite
- As enargite, jordanite, gratonite
Ag  galena
Cd  sphalerite
Sb  meneghinite

Some of the many minerals in which they occur are also listed.

Copper, lead and zinc should be determined on all samples, and possibly nickel and cobalt. Possible indicator elements include silver and arsenic, and these should also be determined. Cadmium may be present, and could act as an indicator for zinc. Use has been made of this association in stream sediment surveys for zinc, but it is not a normal procedure. Antimony has also been used as an indicator in other areas, but only in exceptional cases.

There are likely to be three major problems when carrying out a geochemical programme in this area. Firstly, much of the ground may be covered
by transported material, largely eolian sand.

A second problem results from the presence of
large concentrations of carbonates in the soil.

Finally, it is possible that migration of trace
elements occurs along the bedding planes, and
that the surface expression of the anomalies
indicates the location of outcrop of the
mineralised beds, rather than the site of
mineralisation within these beds.

To obviate the first problem a constant
check must be maintained in the field to indicate
the areas of considerable sand cover, and care
should be taken that samples are taken from below
this if possible. A map should be drawn up
indicating the relevant areas, and this information
used to assess the significance of the presence or
absence of anomalies.

If carbonates occur regularly distributed
throughout the area the major effect is likely to
be the restriction of mobility of the trace
elements. If, however, their occurrence is patchy,
it is likely that some secondary concentration of base metals, particularly zinc, will occur. For this reason note should be taken of changes in the carbonate distribution.

With respect to the third point it is clearly desirable to relate the geochemical results to the known geology. A possible, although unusual, way of circumventing this problem is discussed below.

Hydrocarbons are frequently associated with this type of deposit. It would be a relatively novel approach, but the possibility of investigating the hydrocarbon content of the soil could be considered. Effective results will depend on the concentration and types of hydrocarbons present.

In this environment, there will be a general tendency toward horizontal migration, following the structure. This applies to any
hydrocarbons present and to metallic species. However, in so far as the movement of the metal ions in solution is along concentration gradients and hydrocarbon movement along pressure gradients it is possible that there would be greater vertical movement of hydrocarbons through the beds than of metal ions and hence surface anomalies of the former would bear a closer relationship to the site of mineralisation at depth than the latter. Analysis of soil samples for hydrocarbons can readily be arranged.

It must be stressed that, as far as the writer is aware, this is an untried idea and it may well be unproductive. However, many features of the proposed exploration present difficulties and the possibility of using new methods can only increase the chance of success. Good control must be applied when they are initiated.
INTERPRETATION

Interpretation of the results of this survey is likely to be complex. Variations in soil type, carbonate content, etc. must be taken into account and the normal considerations must be given to other environmental changes. In addition there may not be a high contrast between anomalous and background concentration ranges. For this reason it is recommended that statistical methods be used. The use of cumulative frequency curves should help to indicate threshold concentrations.

A method described by Tripp (1948) has been suggested by the client to estimate the significance of low-intensity anomalies. This method has the effect of eliminating erratic single-sample anomalies and is similar to rolling mean analysis. Since the paper by Tripp was written (1947), there has been a vast improvement in computer techniques and highly sophisticated methods of operating this type of approach have been developed. A method that can be used to eliminate
general variations in background concentrations is trend surface analysis and its use might also be considered.

A number of inter-element ratios can be calculated and have provided valuable information in a wide variety of problems. A paper by Cachau-Herreillat (1968) describes the use of such ratios in relation to syngenetic stratiform deposits.

It is suggested that use should be made of cumulative frequency methods to estimate threshold concentrations and that the use of ratios should be considered. The value of more complex, and costly, approaches could be considered once the data are available.

FIELD LABORATORY

It has been suggested that use might be made of a mobile field laboratory. The use of such a facility does mean that the analytical results can be made rapidly available to field crews, and
that interpretation can readily be carried out on the spot. In addition any further sampling can be done before field crews leave the area. A possible disadvantage is that accuracy control may not be so great under field conditions when compared to an established laboratory. This is particularly important as the range of significant concentrations in this project may be small, necessitating a close control over the analytical methods.

An alternative possibility is the use of portable chemical kits that enable rapid colorimetric tests to be made in the field. A number of these kits are commercially available. Some have the possible disadvantage that only the cold-acid-extractable fraction of each element can be determined and this should be considered before investing in them.
REFERENCES


Tripp, R.M., 1948, "Is it an anomaly?" Client's reprint.
A→P 2857 Mt Hogarth
Air Photo Interpretation

Figure 2

SCALE. 1:250,000.