OPEN FILE

NORTHERN GOLD N. L.
COMBINED ANNUAL REPORT FOR
THE YEAR ENDING FEBRUARY 1984
EXPLORATION LICENCES 3006, 3040,
3041, 3055 HOWLEY AREA
NORTHERN TERRITORY

Licensee – Talmira Trading Pty. Ltd.
Operator – Northern Gold N. L.
Licence – EL's 3006, 3040, 3041, 3055
Location – Pine Creek 1:250,000 5052-8
Batchelor 1:100,000 5171
Tipperary 1:100,000 5170
Period – February 1983 – February 1984
Date Submitted – 23/2/84
Author – B. D. Richardson
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SUMMARY.

This report deals with EL's 3006, 3040, 3041, and 3055, four of the seventeen Exploration Licences operated by Northern Gold N.L. in the Howley area.

The leases hold potential for gold deposits associated with alluvials shedding from the mineralised Howley Line and within the prospective rocks of the Gerowie Tuff and Mt. Bonnie Formations.

The main exploration programme during the 1983/84 season involved an alluvial testing programme over part of EL 3040 and 3055. A total of 87 slots were dug across the alluvials and 247 vertical channel samples collected. All samples were processed and the heavy mineral concentrates sent for Au analysis. These results are not available to date.

On EL 3006 a RESIP survey was conducted over a possible anticline structure paralleling the Howley Line. The results indicated a body of disseminated chargeable material, sulphides or graphite, of low volume percent.

In the 1984/85 period, exploration will involve geological mapping, sampling, auger drilling, and costeaming. If results are encouraging percussion drilling will follow.
The Exploration Licences 3006, 3040, 3041 and 3055 were granted to Talmina Trading Pty. Ltd. in 1982. Towards the end of 1983, Northern Gold N.L. became the operator of these and thirteen other Talmina held leases in the Howley area. (Fig 1.)

<table>
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<th>EL 3006</th>
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The Howley area is located 140 kilometres south of Darwin and access to all Licences is via the Stuart Highway. Exploration Licences 3040, 3041 and 3055 are adjoining while EL 3006 occurs 16 kilometres northwest of the southern three.

The licences operated by Northern Gold N.L. contain large areas of the South Alligator Group of rocks, which are hosts to gold mineralization in the Howley area and elsewhere.

A number of significant old mines occur in the area, the most noted of which are the Cosmopolitan, Metropolitan (Big) and Chinese Howleys. These three occur on the Howley Anticline, a major structure in the Pine Creek Geocyncline. Gold mineralization can be traced along this fold axis, termed the Howley Line, from Cosmopolitan Howley northwards through the licence area.

The three southern licences occur to the east or straddle the anticline and contain considerable areas of alluvium shedding from the Howley Line. The old mines are held under lease by Geopeko - Anaconda, who are at present actively exploring the
Cosmopolitan Howley area.

Exploration Licence 3006 occurs to the west of the Howley Line, but may contain a parallel anticlinal structure. In December 1983 Northern Gold N.L. commenced an alluvial testing programme in the northeast corner of EL 3055. A limited geophysical survey (RRMIP) was conducted over part of EL 3006 and results from this programme is presented in this report. A Statement of Expenditure is given in Appendix 1.

One block of EL 3040 and three of EL 3006 were relinquished on the 8th January and 2nd February, 1984 respectively. These areas were regarded as unprospective by the Company.

1.1 HISTORY AND PRODUCTION

Gold was first discovered in the Howley district in 1873 when the Overland Telegraph was being constructed. Gold mining in the tenements was initiated by Chinese during the 1880's from both alluvials and reefs. The largest reef mine, the Metropolitan Howley (sometimes referred to as the Big Howley) operated between 1883 and 1903 and since that time there has been no significant production except for cyaniding of tailings. Officially recorded production from the Metropolitan Howley totals about 1,000 kilograms of gold; however old unofficial reports suggest production may have been considerably more. The workings consisted of an open cut, two three-compartment shafts to depth of 52 and 58 metre and extensive underground workings. 1,300 metres to the southeast the Chinese Howley mine was operated between
1892 and 1896 with official recorded production about 360 kilograms (ore grade 28 g/t). By 1896, problems with sulphide ore treatment, underground water, periodic flooding and mine collapses were encountered in the Chinese Howley mine. During the 1890's medium grade gold ore was produced from dozens of pits along the Howley Line northwest of Metropolitan Howley, but few records are available. At Bridge Creek, in the northwestern part, several shafts are 16 to 33 metres deep. The Howley Line is semi-continuous from the Cosmopolitan Howley prospect and is marked by numerous shafts and pits. Several intermittent sub-parallel reef systems were worked on both sides of the Howley Line.

To the North-east of the Howley Line, other significant lines of reefs were worked, the most prominent known as the John Bull and Britannia Lines. Production usually ceased at the water-table. Below the water-table gold was associated with strong sulphide mineralisation causing treatment problems. The major producers along the John Bull Line were the Zapopan (2,146 kgs of gold) and the Brocks Creek Mine where 40,000 tonnes of ore were crushed for a recovery of 682 kgs. of gold (17.1 g. Au/tonne) and 18,326 tonnes of tailings were treated for 147 kgs. of gold (8 g. Au/tonne).

Production from the large and intensely worked shallow alluvial fields within the tenements is not recorded.

1.2 PREVIOUS EXPLORATION

After the end of mining early this century and prior
to 1976, only limited exploration was conducted over
the Howley area. In the period 1976 - 1981 B H P Co. Ltd.
and Homestake Mining Ltd. carried out an extensive
exploration programme covering the Cosmopolitan to
Metropolitan Howley belt. A summary of exploration
activity, including B H P's work is given below:

Blanchard and Hall (1937) reported on the Howley properties
for Anglo Queensland Pty. Ltd. (which later became Mount
Isa Mines). Costeaining and/or open cut sampling was
carried out at the Metro, Chinese and Cosmopolitan Howley
prospects before exploration in the form of underground
driving was concentrated on the Cosmopolitan Howley.
This work was terminated when it was concluded no
potential existed for a large resource.
In 1954-55 440lbs of uranium was mined by Brocks Creek
Uranium at the Fleur de Lys mine, which is located about
2km north of the Cosmopolitan Howley (Firman, 1955)
Between the early 1950's and mid 1970's a succession of
exploration programmes including diamond drilling were
completed at the Cosmo by the N. T. Mines Branch (Sullivan
and Iten, 1952) B.M.R. (McQueen, 1959; Vanderplanck, 1965),
a private syndicate (Mcmanus and weber, 1969) and United
Uranium N. L. ( Cox, 1972). In each case insufficient
results were obtained to maintain enthusiasm.
In 1976 B.H.P. obtained an option over the Howley Line
deposits and subsequently joint ventured this with
Homestake Australia. An extensive exploration programme
consisting of geological mapping, scree-rockchip sampling,
ground magnetics, costeaining and drilling covered the
areas around the three main deposits (Randall and Diemar
1980). Once again it was concluded that the resources
outlined were to small for viable production rates.
The tenure holdings, which consist of Gold Mining Leases
and Mineral Claims over the 3 main deposits, were optioned
to a joint venture between Peko-Wallsend and Anaconda
Australia in 1982. Exploration by this joint venture is continuing at present and is concentrated at the Cosmo.

In 1982 Talmina Trading Pty. Ltd. carried out limited exploration over the southern area of EL 3006. Work was concentrated on a low ridge of outcropping Mt. Bonnie Formation rocks, and involved general prospecting, sampling and auger drilling (see Annual Report 1982-83). One sample returned an assay of 8.9 g/t Au and samples collected from the alluvials showed trace gold.

Interpretation of Landsat photography indicated a possible anticlinal axis in the lease area and limited mapping supported this. Exploration on the other leases consisted of a shallow reconnaissance, auger drilling and trenching programme, and general prospecting (see Annual Reports 1982-83). The work was concentrated around the old alluvial digging and the results were encouraging enough to warrant further work in the 1983-84 period.

2. GEOLOGY

The Howley area is located within the western part of the Pine Creek Geosyncline and contains rocks of Lower Proterozoic age. In the basin, granitic Archaean basement is successively overlain by:— coarse clastics and carbonates of the Batchelor group; fluvialite and shallow waterplatformation plastics of the Mount Partridge group; and a heterogenous sequence of carbonaceous mudstones, acid tuffs, banded iron formations and siltstone/greywacke turbidities of the South Alligator Group and finally the flysch sequence of the Finnis River Group. The sediments
were intruded by sills of the Zamu Dolerite prior to the major phase of regional deformation, which was accompanied by greenschist facies regional metamorphism. A second, broad, open phase of cross folding is probably related to widespread granite intrusion, which occurred in the early Middle Proterozoic. Sediments of the South Alligator and Finnis River Group and intrusives of the Zamu Dolerite and Burnside Granite occur in the Howley area. The intrusion of the granite during the Middle Proterozoic was responsible for the formation of the major structure in the area, the Howley Anticline, which has a strike length of over 26 km.

The sediments are tightly folded with the western limb dipping at 60° to 80° while the eastern limb is steeply dipping to overturned. The axis runs in a north-westerly direction curving around to the north outside the tenement area. The plunge of the axis is variable, changing from 50° W. in the Cosmo Howley area, to 32° N. at the Metro Howley and 50° south at the Bridge Creek working.

The oldest rocks along the Howley Anticline are the carbonaceous shales, mudstones, iron formations and carbonates of the Koolpin Formation exposed at the Cosmo Howley area. These are overlain by acid tuffs, mudstones and siltstones of the Gerowie Tuff. The Mt Bonnie Formation is a transitional sequence between the Gerowie Tuff and the Burrell Creek Formations, and shows a gradual decrease in volcanic component and increase in clastic component. The Burrell Creek Formation is the basal unit of the Finnis River Group and is comprised of greywackes, siltstones, shales and minor conglomerates.

Sills of the Zamu Dolerite occur along the Howley Line area and
are most common south of Chinese Howley and north of the Bridge Creek area. The sills are generally thin, less than 20 m, but in the north-east corner of EL 3055 a sill over 100 m wide exists (Fig 2). The dolerites only sub-outcrop but are marked by distinctive red soils.

Exploration Licence 3006 occurs to the west of the Howley Line and contains outcropping shales, siltstones and tuffaceous units of the Mt Bonnie Formation. The rock types occur along a low north-south running ridge, the centre of which is formed by a number of quartz veins up to 3 m in width. The only outcrop west of this ridge, occurs along the boundary of the EL, where the Shoobridge Fault has exposed the greywackes and siltstones of Burrell Creek Formation.

In EL 3055, west of the Geopeko leases, the dominant rock types are the shales, siltstone and acid volcanics of the Mt Bonnie Formation. A small area of the underlying Gerowie Tuff and Koolpin Formation occur in the south-east corner with the greywackes and siltstone of the Burrell Creek Formation in the north-west. Limited reconnaissance work has indicated a number of tin bearing pegmatites in the EL, west of the Howley Line. All rock types are folded and steeply dipping and two fold axes paralleling the major anticline axis are indicated from the BMR Geology Map of the area (Fig 1), and interpretation of Landsat photography. In parts of the area the Lower Proterozoic sediments are overlain unconformably by flat dipping Cretaceous sandstones, siltstones and claystones of the Petrel Formation.

East of the Howley Line, EL 3055 contains rocks of the Gerowie Tuff and Mt Bonnie Formations with large sills of the Zamu Dolerite. Exploration Licences 3040 and 3041 contain predominantly
units of the Mt Bonnie Formation with rock types of the Burrell Creek Formation running through their north-eastern corners.

3. EXPLORATION POTENTIAL

The major gold mineralisation within the Howley area is structurally controlled, restricted to the hinge line of the Howley Anticline and concentrated at the nose of tight folds, e.g. Cosmo and Metro Howley. Alluvial workings cover large areas of the shed from the Howley Line with palaeo-channels carrying gold several kilometres east of the Metro and Chinese Howley areas.

Within the eastern area, EL 3055, the potential exists for a gold deposit associated with the Gerowie Tuff and Zamu Dolerites and related to a southern extension of the Chinese Howley mineralised zone. There is also the potential for a second deposit associated with the alluvials shedding from the Howley Line.

The area of EL 3055 west of the Howley Line has the potential for gold mineralisation associated with:

- the anticline paralleling the Howley Line.
- the prospective Koolpin and Gerowie Tuff Formations.
- alluvials shedding westward from the Howley Line and hardrock mineralisation adjoining the Geopeko Leases.

In the Howley area, the major exploration was concentrated along the Howley Line within the Koolpin and Gerowie Tuff Formations. The Mt Bonnie Formation has to a large extent been neglected, yet it is known to carry gold elsewhere in the Pine Creek Geosyncline. Recent prospecting by Northern Gold N.L.
has discovered minor gold mineralisation within this Formation. Given the right structural controls and lithologies, the Mt Bonnie rocks hold good potential for hardrock gold mineralisation. Exploration Licences 3040 and 3041 contain units of the Mt Bonnie Formation as does the north-east corner of EL 3055 and this Formation will be the subject of intensive exploration in the coming year. A preliminary photo-interpretation of these three licences has shown that the units are intensely folded, a number of anticlinal structures exist and cross faulting is common (Fig 2). A second potential gold deposit is within the alluviats shedding from the Howley Line. In the period covered by this report, an alluvial assessment programme was conducted over the north-east corner area, EL 3055. Exploration Licence 3006 has the potential for gold mineralisation associated with a minor anticline paralleling the Howley Line. Gold was discovered along a possible hinge zone previously and further work will be carried out to determine the structure.

4. WORK DONE

4.1 EL 3006
In October 1983 Northern Gold N.L. contracted Scintrex Pty. Ltd. to execute a series of RAPID RECONNAISSANCE MAGNETIC INDUCED POLARIZATION (RRMIP) surveys over various prospects in the Howley area. The objective of these surveys was to locate and define segregations of sulphides as gold is known to be associated with pyrite-arsenopyrite in the Howley area.

The RRMIP method is a recently developed technique that
has proved very successful in locating sulphide bodies beneath very conductive overburden. A brief and simple description is given below with a more complete description given in Appendix 2.

There are two significant electrical properties of rocks and ore bodies which are of great assistance in identifying zones of potential economic interest. The first is resistivity which can be described as the resistance of a rock to the passage of electric current through it. Massive sulphide zones, fault zones, zones of deeper and more intense oxidation and graphite horizons, are examples of units which will allow greater quantities of current to pass. In RHMIP, the measurement of resistivity is made with a very sensitive horizontal field magnetometer. This by virtue of the fact that current is simply the number of electrons flowing, and each of these electrons carries a magnetic field with it as it moves. Thus the magnetic field observed by the magnetometer is proportional to the current flowing through the volume of overburden and rock below the sensor. This measurement is called Magnometric Resistivity (MMR). Positive values define areas of relative conductors, and negative values, areas which are relatively resistive. This property can be used as a method for tracing rocks having different resistivities beneath conductive overburden, as well as to define specific conductors.

The second and more significant property is known as induced polarization. This phenomenon involves the storage of some of the electrical energy at the grain boundaries
of sulphides (or graphite) grains, and the water contained between grain boundaries in rocks and ore bodies. If a pulsed current is used, the sulphide or graphite zones will charge during periods of current flow, and discharge during periods when the current ceases to flow. It is this discharge of stored energy which is the induced polarization effect, and the magnetic sensor is sufficiently sensitive to define these minute magnetic fields. The magnetic induced polarization effects are measured in terms of Relative Phase Shift (RPS). Positive values denote internal polarization from within sulphides or graphite, while negative values generally denote the discharge of the polarization effect external to the source.

The field procedure involved the laying out of a 600 x 600m grid across the strike of the units of interest. Where possible a base line was run along the main zone of interest and cross lines taken off every 100m and extended 300m either side of the base line.

Holes were dug for the electrodes, positioned 1200m apart on the base line i.e. 300m north and south of the array. Readings were taken at 25m intervals but broadened to 33m towards the end of the survey. Two operators were used and one 600m x 600m array could be read in a full day if all gridding was completed and electrode holes dug.

In EL3006 one array was surveyed across the prospective, low, north-south striking ridge with the base line, 7600m, running west of the major quartz veins.

4.2 EL 3040, 3041, 3055

During December and early January an alluvial testing programme was conducted over a small area covering the
corners of EL's 3055, 3040 and 4226. The programme was designed to test alluvials shedding from the Howley Line between Fleur de Lys and Chinese Howley. The more detailed work was concentrated in areas of old alluvial diggings with a broader spaced grid downstream from these areas.

4.2.1 GRIDDING

Five kilometres of gridding across all major alluvial areas with the origin (50,000N / 50,000E) at the surveyed corner peg of EL's 3040, 3055, 4226. Lines were spaced at 100m across alluvial workings and 200m further downstream (Fig 3)

4.2.2 SLOTTING

The Komatsu Excavator was used to dig a total of 85 slots along the grid lines at an average spacing of 30m. Each slot was taken down to bedrock and a vertical channel sample was collected from the slot wall. The depth of slots varied between 2 m and 4.5 m with an average depth of 2.5 m. Each slot was geologically mapped.

4.2.3 SAMPLING

The vertical channel sample collected from each slot was at minimum, 30 cm wide and averaged 1 m in length. Separate samples were collected from each lithological unit and the average sample weight was 8kg. A total of 247 samples were collected.

Each sample was processed in the following manner:

1) Sample weighed
2) Clays and semi-lithified fragment broken up in the bowl of an electric cement mixer.
3) Coarse fraction removed by wet sieving
4) Finer fraction panned and heavy concentrate collected and sent to Fox Laboratories for gold analysis

4.2.4 COSTEANING
A total of 5 costeans were dug in EL 3055 to expose bedrock and to better sample alluvials. The Komatsu Excavator was used and samples were collected as described above with 10 m the average distance between sample points. A total of 92 samples were collected and processed.

4.2.5 GENERAL
1) Prior to the commencement of gridding an attempt was made to locate the eastern boundaries of all Geopeko operated mineral claims in the area.
2) A number of samples were collected and panned from the main creeks draining the test area to determine the northern and eastern extent of the slotting programme
3) A preliminary photo-interpreted map was compiled of the test area and EL's 3040 and 3041. A programme of costeaning and sampling was planned for EL 3041 but heavy rain prevented access to this area.
4) General prospecting, reconnaissance and orientation tour over EL's 3040, 3041 and 3055.

5. RESULTS

5.1 EL 3006
The results of the RRMIP survey are shown on Figs. 4, 5, and
and the Discussion and Conclusions as presented by Scintrex are given in the following pages.

SCINTREX

HOWLEY EL 3006

DISCUSSION

This array is situated on the contact between rocks of the Burrell Creek Formation to the west, and Mt. Bonnie Formation to the east (see 1:100,000 location map).

The MNR data shows an extremely strong conductor of +190% centred at 7700E on line 15900N which by line 16300N has decreased to +70%. It is most likely that the source of this feature is narrow, and shows enhanced conduction from line 16200N and well to the south of the array. The broad fall-off in gradient to the east and west of the axis implies that the source extends to depth (i.e. 400 metres) and probably dips to the west (providing the source is reasonably homogeneous). It should be noted that the source continues to the north past line 16200N but with much reduced contrast to the enclosing rocks.

The RPS data does not reflect the presence of the above conductor axis at all. This implies that the source is wholly due to contrasts in the resistivity of the rock units, and not to interconnection between sulphides (or graphite). The RPS data shows a broad, very low amplitude response of about +0.3° above background, extending for +100 metres from 7600E/15900N, +80 metres of 7550E/16200N, to +50 metres of 7575E/16500N. The chargeability zones lie on the western boundary of this relative conductor, and must consist of very low volume percentage sulphides or even higher mafic mineral content.
CONCLUSIONS

1. The conductor axis defined at 7700E which shows values above +100% on the three southern lines, is interpreted as being due wholly to changes in the geological units.

2. The broad, low amplitude chargeability horizon trending from 7600E/15900N (+200 metres thereof) to 7575E+50 metres on line 16500N, is due to disseminated chargeable material (probably sulphides) of low volume percent (1%). Only geology could enhance the interest of this feature.
A detailed geological map is not available as yet. While gridding the array, the author noted the major north-south striking quartz veins between 7600 m and 7700 m which corresponds to the major conductor axis, Fig. 6. This conductor, or area of relatively low resistivity possibly corresponds to a fault zone. The broad, low amplitude chargeability horizon trending along 7550 m (Fig. 6) may correspond to a mildly carbonaceous horizon noted in this location or to disseminated sulphides. Gossans were found associated with the quartz veins but were most common just south of the array area.

5.2 EL 3040, 3041, 3055

5.2.1 ALLUVIAL TESTING PROGRAMME

Complete results are not available at the time of writing this report. However, visual estimates of gold grades in concentrates are regarded as significant.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 EL 3006

Minor gold mineralisation occurs within EL 3006 as evidenced by assay results and general prospecting. Landsat interpretation and mapping has indicated the possibility of an anticlinal structure running through the lease area. The results from the RRIP survey indicated a narrow zone
of low volume per cent (1/0) disseminated sulphides (or graphite) and a possible fault zone in the vicinity of the interpreted anticlinal axis.

In the 1984/1985 period geological mapping, costeaining, auger drilling and sampling will be used to assess EL3006. The exploration programme on this will be part of an on-going programme that has commenced on EL 4208, the adjoining Licence to the south. The expected expenditure for the year is $12,000-00.

6.2 EL 3040, 3041, 3055

At this stage it is not possible to draw any conclusions from the alluvial testing programme as results are not available. Once all assays are completed the area tested will be assessed and gold reserves calculated. During the 1984/1985 period the area covered by the three licences will be geologically mapped at a scale of 1:15,000. Areas of particular interest will be gridded and sampled. Shallow auger drilling and costeaining is planned for areas of alluvium and anomalous zones located by the sampling programme. RRMIP surveys and percussion drilling will follow if results warrant further investigation.

An estimate of expenditure for each licence is given below:-

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weber, C.R.,


Diemar, M.,


and Iten, K.W.B

**STATEMENT OF EXPENDITURE**

**JANUARY 1983 to FEBRUARY 1984**

EL's 3006, 3040, 3041, 3055

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| Total               | 14750| 11950| 17550| 18850|
THE PRESENT APPLICATION
OF THE MAGNETIC INDUCED POLARIZATION (MIP) METHOD
IN THE TIME AND FREQUENCY DOMAIN

INTRODUCTION

Since the Magnetic Induced Polarization (MIP) method was introduced into Australia some six years ago, very considerable field experience has been gained. The purpose of these comments is to discuss the application of the method, the form of the responses observed, and how the standard anomaly forms are generated. This is a simple non-mathematical description designed to enable the geologists to visualise just how the energising and induced polarization currents flow in the ground, and how to interpret these in a qualitative sense, for it is the geologist who is far better qualified to interpret this data in a structural context. It is the author's opinion that MIP data is more often than not, simpler and more diagnostic to interpret than EIP or EM data in the conductive conditions which exist over much of Australia's land mass.

The Uniqueness of the MIP Method ......

It is essential to grasp the very basic differences between the magnetic mode of acquiring induced polarization data (MIP) and the more conventional electrical mode (EIP). As even geophysicists of some experience have had difficulty in appreciating the full significance of this method, it is necessary to state in simple terms some of the unique attributes of the method.

1 - Conventional EIP data monitors ONLY the current flow AT THE SURFACE generated by the storage of charge (IP effect) WITHIN the body. With MIP both the current flow OUTSIDE, but more importantly INSIDE the chargeable
source, are DIRECTLY MONITORED. Thus the external (EIP) polarization from
mineralisation NEED NOT NECESSARILY COME TO THE SURFACE for it to be monitored.

2 - In conventional EIP, the transfer of the induced polarization signal from
the source mineralisation to the surface involves a considerable loss of
energy by "friction" and "chemical reactions" en route, whereas for MIP,
as the movements in current at depth are monitored from depth via their
associated magnetic fields, very much less loss of energy is involved.
Thus, the fall off in response with distance from a chargeable source is
very much less as seen with MIP than that seen with EIP.

3 - With conventional EIP methods, the external induced polarization effect is
monitored via two potential electrodes placed some distance apart (commonly
25 to 100 metres), effectively averaging the response over this distance.
However, as the MIP sensor is about 60 centimetres in length only, in the
MIP method it is essentially a point source measurement which improves
resolution very considerably.

4 - Where conventional EIP techniques are applied to highly conductive overburden/
oxidation regions, the multi-layering within this zone very considerably
reduces or even eliminates the EIP signal en route to the surface. With
MIP, both primary and secondary (IP) current flow within this zone has NO
MATERIAL INFLUENCE on the data. Thus the problems of "masking" are eliminated
with MIP.

5 - As the EIP induced polarization signal flows from source to surface, the
medium through which it passes not only reduces its amplitude (see 2 above),
but also modifies the form of the signal. Thus the decay form observed at
the surface will tend to be that of the medium rather than the source.
However, as the MIP monitors the magnetic field from the decay within
the source itself, no such distortion in the internal polarization decay
form can be expected.

6 - The EIP method is essentially a measurement of absolute levels of apparent
resistivity and chargeability as observed at the surface. However, the MIP
method measures the relative properties of chargeability and resistivity, and is thus more sensitive to these differences.

7 - In the EIP method, the electric field is often severely distorted by local and often insignificant inhomogeneities in resistivity. However, as the primary (resistivity) and secondary (IP) magnetic field measurements are summed over a large volume of rock, they are not distorted or masked by local inhomogeneities.

A Definition of Terms ......

Before going into the detailed qualitative discussion of the principles of operation, it is best to define the terms used in the description.

**Energisation:** The process by which current is introduced into the volume of rock which is the subject of the survey. **Primary Current Flow:** The flow of current through this medium as a result of this energisation. **Primary Magnetic Field ($H_p$):** The magnetic field generated by virtue of the primary current flow in the subsurface.

**Induced Polarization Effect:** The "condenser like" storage of energy on an electronic/electrolytic boundary, for instance on sulphide/electrolyte boundaries. **Internal Polarization:** The induced polarization effect within the body, which is the source of all induced polarization phenomenon, whose discharge is always in the **OPPOSITE DIRECTION** to the primary current flow which caused it.

**External Polarization:** The induced polarization effect which flows outside or external to the causative source which is always of the same sign as it is in the same direction as the energising primary current. **Secondary Magnetic Field ($H_s$):** This is the magnetic field caused by the flow of secondary currents within (internal) and outside (external) of the causative source.

**Decay Form (LM):** This term describes the decay of the energy stored within the body. It may be more rapid than "normal" or slower than "normal". (A detailed description follows on Page 9).
Comparison of the Electrical and Magnetic Modes of Acquiring Induced Polarization Data ..... 

By far the most meaningful way in which to visualise the nature of MIP (and indeed EIP) data, is to consider the energy storage concept and to look at the primary current flow pattern and the resultant equipotential field caused by this energising current, and then the consequent secondary current flow pattern and its associated secondary potential field caused by the decay of the energy stored on electronic/electrolytic contact boundaries, which is known as induced polarization. As this is most easily visualised in the time domain, this description is confined to that domain.

Energisation Process ..... Normally current is applied to the volume to be sampled by means of two electrodes placed semi-parallel to the expected strike of the target mineralisation. In the diagram shown in Figure 1, the fine solid lines represent the current flow pattern so generated. The dashed faint lines represent the equipotential surfaces (lines in the section).

In the electrical mode, the two potential electrodes (see Figure 1) will measure the resistivity of a volume of material defined by the equipotential surfaces which are always at right angles to the current flow.

Energy Storage Process ..... The material through which the current passes will store some portion of the energy in a way determined by the properties of the storage material. The amount of energy stored will depend on the total area of the sulphides (or graphite etc.) presented to the current, and thus, the greater this surface area with respect to the volume of material, the greater will be the energy stored. Finely disseminated material will store substantially more energy than coarse grained material.

The Discharge of Stored Energy ..... On cessation of the energising current flow, the energy stored by the chargeable source will discharge internally within the source as shown by the solid arrows in Figure 2, and externally around the body in the medium surrounding the source as shown by the solid heavy lines in Figure 2. These currents are respectively known as internal and external current flow. The former is of negative sign as it is in the opposite direction to the original energising current, and the latter is of positive sign as it is in the same
direction as the energising current.

In the electrical mode, only the discharge external to the body is investigated. In Figure 2 the thick solid lines show this discharge together with the equipotential surfaces (thick broken lines) which this current imposes. As with the charging process these surfaces must be at right angles to the current lines which impose them. The potential electrodes will therefore measure the stored energy (chargeability) as seen via the secondary equipotential field. It is important to note that (i) this is NOT the same volume as the resistivity measurements and (ii) it is NOT the original IP signal as stored by the body, but a measurement distorted and processed by the environment through which it has passed.

In the magnetic mode a very sensitive magnetometer (Scintrex MFM-3) is used to "sense" the horizontal component of the magnetic field due to the current flow both inside and outside of the source material. This is possible because each electron which flows in the ground carries with it an associated magnetic field. This magnetic field will pass unhindered through the environment and thus both the discharge internally and externally to the source can be monitored on the surface.

The Form of MIP Anomalies ......

In the MIP method, the energising field is normalised with respect to the energising current electrodes. Details of this procedure are given later in this paper. In the description Figures 3 to 6, the magnetic field due to the primary passage of the energising field \( H_N \), can be regarded as "relative bulk conductivity" plotted upwards. In these figures, internal polarization (which is negative in sign because it flows in the opposite direction to the energising current), is plotted upwards, while external polarization (which flows in the same direction as the energising current and is therefore positive in sign) is plotted downwards.

The enclosed Figure 3 demonstrates the theoretical form of an MIP anomaly from a source which has no electrical contrast with the enclosing material, but has the property of retaining charge. (In nature such anomalies are in fact observed from the ilmenite fraction within heavy mineral deposits in beach sands.)
SCINTREX

EIP & MIP
DISCHARGE OF INDUCED POLARIZATION

MIP Sensor

Sum of internal and external fields

EIP potential dipole

Disseminated chargeable source

Magnetic field due to external polarization (Hs)

Magnetic field (H) due to internal polarization

Internal polarization

Fig. 2.
SCINTREX

TYPICAL M.I.P ANOMALY FORMS

THEORETICAL MODEL

CHARGEABLE SOURCE
NO RESISTIVITY CONTRAST

TYPE A
CHARGEABLE SOURCE
RESISTIVE SOURCE

NOTE:
+ External current flow into plane of paper
- Internal current flow out of plane of paper

Fig. 3
Energisation is along strike, into the plane of the paper. In all figures the current flow direction is represented by arrows, with dots representing current flow out of the plane of the paper, and crosses represent the current flow into the plane of the paper.

In Figure 3, over the source, the magnetometer will "see" a surplus of internal (negative) current flow, while on the flanks of the body, the external (positive) current flow will become predominant. The "head and shoulders" MIP anomaly shown is always seen over all sources. It is the distortions in shape, form and zero level that yield vital information as to conductivity of the source, conductivity of the environment above and about the source, the depth to the source and the nature of the mineralisation in and around the source.

**TYPE 'A' (Figure 3).....** shows the typical anomaly form over a chargeable source which is more resistive than the surrounding medium. In such cases the normal "head and shoulders" anomalies coincident with a depression in the $H_N$ are observed. An example of such an anomaly form is chalcopyrite/pyrite in quartz veins itself within a more resistive conductive rock unit.

**TYPE 'B' (Figure 4).....** In this case the chargeable source has no resistive contact with the enclosing material. This example is very similar to the theoretical model. An example of such an anomaly form would be over disseminated sulphides within a homogeneous rock unit.

**TYPE 'C' (Figure 4).....** In this case the source of the chargeable material is itself more conductive than the enclosing rock type. When the observed $H_N$ values are less than 180% - 200%, a normal "head and shoulders" anomaly is observed over the source. In practice, observed $H_N$ values rarely exceed 150% of normal.

**TYPE 'D' (Figure 5).....** In this most important anomaly form which invariably is associated with massive sulphides which are both conductive and electrically continuous, a massive sulphide must be surrounded by a disseminated halo within more resistive host rocks. In this case the disseminated sulphides will naturally store the induced polarization charge far more efficiently than the massive electrically continuous core. Thus, on completion of the energisation process,
SCINTREX

TYPICAL M.I.P ANOMALY FORMS

TYPE B
CHARGEABLE SOURCE
HOMOGENOUS

external
M
0
HN
100%

Geological
cross section

TYPE C
CHARGEABLE SOURCE
CONDUCTIVE

external
M
0
HN
100%

Geological
cross section

NOTE:
+ External current flow into plane of paper
• Internal current flow out of plane of paper

Fig. 4.
the charge stored within the disseminated halo will preferentially discharge through the conductive massive sulphide core. This effect has NEVER been observed where $H_N$ values have been less than 180% of normal. This anomaly form due to its high $H_N$ and coincident predominantly external (positive) current flow, is diagnostic when observed. An example of such a response is the Mt. Windarra pyrrhotite/nickel/copper deposits in Western Australia.

TYPE 'E' (Figure 5) ..... A distorted MIP response curve is generated when a polarizable body is located on a contact between rocks of quite different resistivities. This is rather common in Western Australian nickel deposits. In such a case the return polarization current flow will be concentrated in the more highly conductive rock type instead of being symmetrically distributed on both sides of the body. The resultant MIP response is an asymmetric curve, with its internal (negative) maximum lying on the more resistive side of the body and the external (positive) current peak lying on the more conductive side. Sometimes the asymmetry is so large that the "crossover" is almost directly over the polarizable body. The $H_N$ peak is shifted over the conductive rock side of the polarizable body.

Composite Anomalies ..... 

As can readily be appreciated, the above examples 'A' to 'E', represent single simple bodies. In the field, more often than not, the sources vary in composition and therefore in chargeability and resistivity across strike, along strike and down dip. For example, while the form of Type 'C' and Type 'D' anomalies are very different in appearance, the geological situation which gives rise to them requires relatively little change in conductivity to materially change their form from 'C' to 'D'.

In the interpretation of MIP therefore, the electrical characteristics of known 'Type Deposits' similar to those being sought, together with local information as to the possible range of structure in the area, is of primary importance. In other words, geological input is often of greater importance than quantitative geophysical data.
SCINTREX
TYPICAL M.I.P ANOMALY FORMS

TYPE D
CHARGEABLE SOURCE
VERY CONDUCTIVE WITH
DISSEMINATED HALO

TYPE E
CHARGEABLE SOURCE
ON CONTACT BETWEEN
TWO ROCK TYPES OF
DIFFERING RESISTANCE

NOTE:
+ External current flow
  into plane of paper

- Internal current flow
  out of plane of paper

Resistive rock

Conductive rock

Geological cross section

Fig. 5