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A NEW VIEW OF THE ZEEHAN KINERAL
FIELD - EL 28/88
ALLEGIANE MINING- M.MCKEOWN

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ALLEGIANE MINING N.L.
ZEEHAN PROJECT

A NEW VIEW
OF THE
ZEEHAN MINERAL FIELD

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ALLEGIANE MINING N.L.

98-4184

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ABBREVIATIONS

Allegiance	Allegiance Mining N.L.
CRA	Conzinc Rio Tinto Australia Ltd
CRAE	CRA Exploration Pty Ltd
EL	Exploration Licence
EZ	The Electrolytic Zinc Company Ltd
MRT	Mineral Resources Tasmania
Renison	Renison Ltd
RGC	RGC Ltd
RGCE	RGC Exploration Pty Ltd
PGE	platinum group element
PGM	platinum group metal

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1 INTRODUCTION

The Zeehan mineral field, more or less bounded by the Cuni area in the north, Dundas in the east, the Oceana mine in the south, and Trial Harbour in the west, has been the focus of continuing prospecting and exploration since the first discovery of galena at Zeehan by Frank Long in 1882.

Allegiance Mining N.L., in its own right or in Joint Venture with Rio Tinto Exploration Pty Ltd, is currently exploring on three Exploration Licences stretching from the immediate vicinity of the Zeehan township westwards to Trial Harbour:

EL28/88 in several parts, one of which lies immediately south-west of Zeehan, another at Trial Harbour

EL2/96 immediately to the north-west of Zeehan

EL22/97 in two parts, to the west and south-west of Zeehan.

A compilation of the existing exploration data, covering the area from Zeehan to Trial Harbour, which covers EL 28/88 and parts of the other three Licences, has been made, the area being shown on Plans 1 and 2.

Within the compilation area, there are two areas excluded from Exploration Licences:

- four contiguous Mine Leases at Comstock, held by Sundew Holdings Pty Ltd and Merseylea Mining Pty Ltd,
- a Retention Licence at Queen Hill, held by Aberfoyle Ltd.

These are shown on Plan 1.

This report describes the conclusions which have been made concerning the geology in the compilation area, taking into account the recent discovery of nickel sulphides by Allegiance on the Avebury grid, summarises the results of the data synthesis, and presents a holistic view of the geology, structure and mineralisation.

2 PHASES OF EXPLORATION

The area from Zeehan to Trial Harbour has been subjected to more or less continuous, if sometimes desultory, exploration, since 1882.

During early prospecting from 1882 to World War I, many prospectors scoured the countryside seeking any mineral occurrence which might be exploited for a profit. Many mineralised zones, nearly all silver-lead-zinc, were discovered and many of these were exploited. Unfortunately, most of the mines in the area immediately around Zeehan were short-lived, closing after exploitation to only shallow depths. Only three mines have recorded significant production since 1915: the Oceana and the Montana, which closed in 1960 and 1954 respectively, and, more recently, the Comstock, which is still subject to Mining Leases, although production has ceased at the present time (King and Blissett, 1967).

The nickel boom of the late 1960s inspired EZ Exploration to explore the outcropping ultramafic at Trial Harbour for nickel. This was not successful.

The most recent major exploration efforts were almost exclusively driven by the search for specific commodities, often based on specific geological models. This marked a distinct change from the attitude of the early prospectors who were not constrained by such preconceived ideas.

In the 1970s and 1980s, Renison Ltd and RGC Exploration Pty Ltd explored around the southern and eastern margins of the Heemskirk granite for tin, hoping to find a Renison style tin deposit. Several small deposits were located, some with metallurgically refractory tin minerals, and the search was abandoned. During the same period, Aberfoyle Ltd drilled the stannite lodes at Queen Hill, at the western end of the Zeehan township. A significant quantify of mineralisation was identified - 7.3 million tonnes at 0.75% Sn (Anderson, J.A., 1989) - and is now covered by a Retention Licence.

Amoco Minerals Australia Pty Ltd explored for carbonate hosted silver-lead-zinc deposits around Zeehan during the 1970s and 1980s. This exploration effort was focused on the Ordovician Gordon limestone which outcrops to the south of Zeehan around the Strahan Road. A relatively small resource of lead-zinc mineralisation was identified at the old Oceana Mine, at the foot of Mount Zeehan. In 1983, the resource was estimated to be 4 million tonnes at 19.4% Pb, 4.0% Zn and 106 g/t Ag (Taylor and Mathison, 1990).

CRA Exploration Pty Ltd, partly in joint venture, first with Major Mining Ltd and later with Allegiance Mining N.L., began exploring around Zeehan in the early 1990s. Exploration was driven, but not absolutely exclusively, by four ore deposit models: stratabound shale hosted lead-zinc deposits, carbonate hosted lead-zinc deposits, ultramafic hosted low grade nickel sulphide deposits, and lead zinc skarns. In the early stages of exploration, the

possibility of other occurrences, such as tin, were not completely discounted, but exploration was soon concentrated on five particular areas:

- stratabound shale hosted lead zinc on the Stonehenge grid which lies to the east of the Comstock group of mines,
- carbonate hosted lead-zinc in the Myrtle and Pyramid areas, to the south of Zeehan,
- ultramafic hosted nickel sulphide deposits at Trial Harbour, and
- a potential lead-zinc skarn beneath a lead-zinc soil anomaly on the Avebury grid, between the Trial Harbour Road and the Little Henty River.

Apart from the exploration for carbonate hosted lead zinc deposits, all this CRAE exploration effort is relevant to the compilation area.

3 DATA SYNTHESIS

A large amount of data exists in the compilation area, contained in a large number of Company and State reports. The bibliography lists many, but not all, the reports, and includes those which contained relevant geological data used to plot two 1:10000 scale plans which are attached. The two plans abut and cover the Trial Harbour and the south-western Zeehan areas and are named accordingly. For convenience of reference, an A3 size, small scale copy of the South-western Zeehan sheet is included as Figure 2.

Ground and aerial magnetics surveys have been the principal geophysical exploration tool in the compilation area. Allegiance recently completed a new high resolution aerial magnetic survey, controlled by GPS, over the Zeehan to Trial Harbour area. The results of this survey will be technically superior to any existing data and, so, only passing reference is made to the results of old geophysical data in this report.

4 THE ROCK UNITS

4.1 INTRODUCTION

The principal Precambrian and Palaeozoic rock units in the compilation area are described briefly below from youngest to oldest. This is not the same as the sequence from the base to the top of the rock pile in the area because the oldest rock unit, the Precambrian Oonah Formation has been thrust over the younger Cambrian rock units.

disconformity

Devonian	Heemskirk granite	leucocratic granites and adamellites
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*disconformity**unconformity: Tabberabberan orogeny*

Devonian	Florence quartzite	sandstones and minor siltstones
Silurian	Austral Creek siltstone	siltstones and interbedded sandstones
Silurian	Keel quartzite	sandstones
Silurian	Amber slate	fissile siltstones and mudstones
Ordovician	Gordon limestone	dark grey carbonates and minor mudstone and sandstone
Ordovician	Zeehan conglomerate	quartz conglomerate and minor sandstone

disconformity

Cambrian	Ultramafic complex	dunites, gabbros, basalts, serpentinites
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disconformity

Cambrian	Crimson Creek Formation	interbedded volcanoclastics, basalts, mudstones and shales
Cambrian	Dundas Group	chert conglomerates, gritty sandstones, siltstones and basalts

unconformity: Penguin orogeny

Precambrian	Oonah Formation	quartzites, micaceous quartzites, siltstones, shales, graphitic shales and dolomitic units
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The Oonah Formation, the oldest of the rock units in the area, has been thrust over the Cambrian sedimentary rocks by the low angle Tenth Legion Fault. The recognition of the Tenth Legion Fault as a thrust by Findlay and Brown (1992) was important in finally enabling the resolution of previously contorted and complex fault patterns.

The Cambrian ultramafic complexes are fault bounded sheets, sometimes described as allochthonous sheets, which, perhaps, have been thrust over the top of the other Cambrian sedimentary rocks from the east (Berry and Crawford, 1988). In previous interpretations, the ultramafic complexes are never shown extending far beyond their outcrop pattern, for example, refer to the cross sections shown on the Zeehan 1:50000 geological map sheet.

4.2 A NEW VIEW OF THE CAMBRIAN ULTRAMAFICS

It is now proposed by the author that there is a possibility that, beyond the outcrop of the Heemskirk granite, the entire area from Trial Harbour to Zeehan is underlain by Cambrian ultramafics. This proposition is supported by four strands of evidence: the outcrop pattern of ultramafics over the area, all five drill holes at Avebury, two diamond drill holes west of Avebury, and the existing magnetic surveys.

Two large areas of ultramafic outcrop occur at Trial Harbour and south of McIvor Hill. However, separate from these occurrences, there are three smaller areas of ultramafic outcrop shown on MRT maps, and three references to smaller ultramafic occurrences are noted in old reports:

- three pods of serpentinite outcrop have been mapped on the Avebury grid (Trial 1:25000 sheet and Zeehan 1:5000 sheet)
- four pods of porphyritic basalt have been mapped to the south-west of the Swansea mine (Trial 1:25000 sheet and Zeehan 1:50000 sheet)
- a pod of serpentinite has been mapped to the west of the Central Balstrup mine (Oceana 1:25000 sheet and Zeehan 1:50000 sheet)
- a dyke of pyroxenite was reported between the Swansea and Silver Duke Mines (Reid, 1922)
- a dyke of serpentinite was reported to the west of the Spray mine (Waller, 1904)
- a dyke of gabbro was reported near the Central Balstrup mine, in the Comstock Tramway Summit cutting (Twelvetrees and Ward, 1910)

Five diamond drill holes have been drilled at Avebury, three by CRAE and two by Allegiance: DD96ZA1, DD96ZA2, DD96ZA3, and A001, and A002. All five holes intersected serpentinite which have been described as altered ultramafics, originally dunites or peridotites (Ashley, 1997 and Fander, 1998). In addition, two holes drilled by Renison Limited at Area D, to the west of Avebury, intersected serpentinitic rocks: TH1 and TH2. These serpentinites were also described as altered ultramafics.

Existing magnetic surveys suggest the existence of ultramafics beneath Avebury (Tear and Tesselaar, 1996), the Stonehenge area (Roberts, 1986a), and the area between Avebury and Stonehenge (Kilpatrick, 1982). Recently, Allegiance has flown a new helicopter based magnetic survey over the entire area but these results are not yet available to the author.

5 FOLDING

Very recently, Upton (1996) made a study of the structure in the Stonehenge area. He identified five sets of folds. The dominant folds were the last, generated during the Tabberabberan orogeny, and very evident in the folding of the Silurian and Devonian sedimentary rocks immediately to the south of the Little Henty River (Figure 2). The axes of these folds strike more or less north-west and Upton suggested that the wavelength of the folds is about 2 kilometres.

This pattern of folding is also evident in the detailed mapping of the Oonah Formation in the Comstock to Stonehenge area (near the centre of Figure 2), and is also in the Cambrian ultramafics just north-west of the Avebury grid. The pattern of folding also helps to explain the distribution of the outcrop of both the Cambrian ultramafics and the Oonah Formation remnants. The author's first pass suggestion of the location of the major fold axes is shown on Figure 3.

The shape of the concealed ultramafics will be more complicated than is suggested by this generation of folding alone. The unfolded ultramafics would not have consisted of a simple regular sheet, having been emplaced by thrusting and, consequently, having faulted boundaries, as is evident at the contacts of the outcrop of the Trial Harbour ultramafic. The picture would also be complicated by other generations of folding which would have structurally interfered with the major north-west folds. There are insufficient data to resolve this problem at the present time but the sketch cross-sections indicate some possibilities (Figure 4).

6 FAULTING

The major faults in the north of the area are the Tenth Legion, Balstrup and Sylvester faults. The Tenth Legion Fault is a low angle thrust fault between the older Oonah Formation and the younger, but underlying, Cambrian rocks, both sedimentary and ultramafic in origin. The

Balstrup and Sylvester faults are normal faults which strike slightly south of east and which have significant throws (Figure 2). There are several other faults, less significant structurally but important as pathways and traps for ore bearing fluids, which strike either side of north, some of which offset the Tenth Legion Fault.

To the south of the compilation area, a significant fault, or series of faults, separates Cambrian rocks from Ordovician, Silurian and Devonian sedimentary rocks.

7 MINERALISATION

Sphalerite and galena were the source of the zinc and lead won from the Zeehan mines. Sphalerite and galena occur as veins and veinlets in fault fissures with pyritic and sideritic gangue, or as sphalerite-galena replacement of carbonate rocks.

Since 1910 (Twelvetrees and Ward, 1910), the distribution of mineralisation around the Heemskirk granite in the Zeehan area has been considered a classic example of mineral zoning. The explanation of the zoning has been refined somewhat to take into account the tin mineralisation at Queen Hill, and to reflect the third dimension to the buried granite beneath Zeehan. Moving progressively further away from the granite the zones are:

- within the Heemskirk granite: cassiterite associated with tourmaline and pyrite,
- the contact metamorphic zone: ironstones, sphalerite, galena,
- the pyritic belt: sphalerite and galena in fissure lodes with a pyritic gangue,
- the sideritic belt: sphalerite and galena in lodes with a sideritic gangue.

This zoning, taken together with the occurrence of a granite cupola or dyke beneath Queen Hill, allows nearly all the known mineralisation to fit into a pattern and traditionally, the Heemskirk granite has been regarded as the source of all mineralisation around Zeehan.

However, this model of the mineralisation does not explain the known nickel occurrences, and recent analyses of lead-isotope data from holes drilled by CRAE on the Stonehenge grid have introduced some doubt that the granite is the only source of all the lead-zinc mineralisation.

8 NICKEL MINERALISATION

8.1 NICKEL OCCURRENCES

The presence of nickel in the area from Trial Harbour to Zeehan and Melba Flats has been known for a hundred years. In fact, until the nickel boom of the 1960s which directed exploration and investment attention to Western Australia, the area around Zeehan was considered to contain the most significant nickel occurrences in Australia. Total nickel production in Tasmania has come from the Cuni area, near Melba Flats, where 576 tons of nickel were produced from about 5400 tonnes of ore between 1913 and 1938 (McLeod, 1966).

In the compilation area, exploration for nickel has been concentrated within the ultramafic outcrop at Trial Harbour. During the early 1970s, EZ drilled 11 short diamond drill holes and during 1973, CRAE drilled nine diamond drill holes. None of these holes intersected economic nickel mineralisation.

Nickel sulphide mineralisation on the Zeehan field was first reported by Waller (1904) and later by Twelvetrees and Ward (1910), Petterd, (1910) and Reid (1922). However, this nickel prospectivity was ignored during exploration from the 1970s to the mid-1990s when exploration effort was directed at tin and silver-lead-zinc targets.

In 1996/97, CRAE drilled beneath coincident lead-zinc soil and magnetic anomalies on the Avebury grid, the target being a possible lead-zinc skarn. No lead-zinc mineralisation was found but all three holes intersected significant nickel sulphide mineralisation. Subsequently, following a recommendation by Newnham (1997), Allegiance drilled two holes closer to one of the main magnetic anomalies, both holes intersecting significant nickel mineralisation. The results of these drilling programs have been summarised elsewhere (McKeown, 1998).

The known nickel occurrences are described briefly below, their locations are shown on Figure 5, and the mineral species which have been recorded are listed in Table 1.

TABLE 1

NICKEL MINERALS REPORTED FROM THE ZEEHAN FIELD

annabergite	$\text{Ni}_3\text{As}_2\text{O}_8 \cdot 8\text{H}_2\text{O}$
breithauptite	NiSb
chloanthite	NiAs_2
garnierite	$\text{H}_2(\text{Ni},\text{Mg})\text{SiO}_4 \cdot n\text{H}_2\text{O}$
gersdorffite	NiAsS
hauchecornite	$\text{Ni}(\text{Bi},\text{Sb},\text{S})?$
heazlewoodite	Ni_3S_2
maucherite	Ni_3As_2
millerite	NiS
niccolite	NiAs
pentlandite	$(\text{Fe},\text{Ni})_9\text{S}_8$
rammelsbergite	NiAs_2
ulmannite	NiSbS
violarite	$(\text{Ni},\text{Fe})_3\text{S}_4$

On the Avebury grid, nickel has been intersected in five holes and the intersections are summarised below:

DD96ZA1	151.6m to 59.6m	8m down hole at 0.61% Ni
	188.5m to 198.5m	10m down hole at 0.34% Ni
DD96ZA2	68.9m to 72.7m	3.8m down hole at 1.67% Ni
	90.5m to 93.1m	2.6m down hole at 0.59% Ni
	102.1m to 105.8m	3.7m down hole at 0.77% Ni
	183.1m to 185.3m	2.2m down hole at 0.57% Ni
	189.6m to 190.7m	1.1m down hole at 0.98% Ni
DD96ZA3	185.6m to 186.0m	0.4m down hole at 1.09% Ni
	189.3m to 190.0m	0.7m down hole at 1.12% Ni

A001	243.9m to 316.3m	72.4m down hole at 0.36% Ni, 0.52% S
	including 243.9m to 254.6m	10.7m down hole at 1.15% Ni, 1.61% S
	including 243.9m to 244.3m	0.4m down hole at 15% Ni, 20.4% S
A002	118.3m to 120.3m	2.0m down hole at 0.14% Ni, 0.08% S

Nickel minerals which have been described from these drill holes include niccolite, millerite, gersdorffite and pentlandite which was, notably, the only nickel mineral identified in A001 (Ashley, 1997 and Fander, 1998). These intersections are referred to again in the next section of this report (8.3 THE AVEBURY NICKEL SULPHIDE MINERALISATION).

On the **Area D** grid, immediately to the west of the Avebury grid, Renison drilled three diamond drill holes, two of which intersected what may be low grade nickel mineralisation. No nickel assays were carried out but parts of all three holes have recently been submitted for nickel assay (McKeown, 1998). Nickel minerals were identified in samples submitted for petrographic descriptions and Wally Fander's (1998) relevant descriptions are summarised below:

- hole TH1 at 68m: metasomatised serpentinite with primary and secondary magnetite and pyrrhotite, chalcopyrite and ilvaite, some of the pyrrhotite contains very occasional pentlandite inclusions
- hole TH2 at 388.5m: magnetite replaced by pyrrhotite with patches of chalcopyrite and occasional bladed grains of ilvaite and rare grains of heazlewoodite? up to 10 μ across in magnetite

South of the Tenth Legion mine, on Renison's East Heemskirk grid, several outcrops of ironstone were sampled for nickel. Analyses ranged from 20ppm to 1400ppm with the highest on line 3000N at 930E and 1415E: 770 and 1400ppm respectively (Stephenson, 1978).

From the **Sylvester mine**, sphalerite and galena with small inclusions, up to 20 μ across, of ulmannite have been described (Both and Williams, 1971).

From the **North Tasmanian mine**, minute grains of rammelsbergite or para-rammelsbergite in galena have been described (Both and Williams, 1971).

From the **Tasmanian mine**, small inclusions, up to 15 μ across, of rammelsbergite or para-rammelsbergite were recorded in galena, and of breithauptite in galena or intergrown with pyrrhotite in sphalerite (Both and Williams, 1971).

Between the Swansea and Silver Duke mines, garnierite, millerite and pentlandite were described in a pyroxenite dyke (Reid, 1922).

At the Central Balstrup mine, in an exposure in the Comstock Tramway Summit tunnel, Waller (1904) and, later, Twelvetrees and Ward (1910) described an occurrence of niccolite and ruby tin in a gabbro dyke. Petterd (1910) described breithauptite and chloanthite from the same mine. Both and Williams (1971) described niccolite as mosaics of interlocking grains 0.1 to 0.3mm in diameter intergrown with patches up to 0.5mm wide of maucherite, with gersdorffite as long irregular veinlets up to 150 μ across, and with rammelsbergite, gersdorffite and ulmannite associated with the niccolite, and a narrow veinlet of violarite, after pentlandite, and small areas and veinlets of hauchecornite in some niccolite aggregates.

From the Austral Mine, rammelsbergite? as small inclusions in galena was reported (Both and Williams, 1971).

To the west of the Spray mine, further west of Moyle's lode, a dyke of serpentinite with associated nickeliferous and cupriferous pyrites was described by Waller (1904).

At Trial Harbour, traces of pentlandite occur in the outcropping serpentinite. A grab sample from the dump at the Nickel Reward mine assayed 4.3% Ni (Poltock, 1987).

8.2 THE AVEBURY NICKEL SULPHIDE MINERALISATION

After study of the results of the three holes drilled by CRAE at Avebury, Lindsay Newnham suggested a remobilisation model to explain the genesis of the nickel sulphides not only at Avebury but also at Cuni, to the north of Zeehan:

"... a situation exists in this area where a nickeliferous ultramafic has been intruded and intensely altered by a granitic intrusion. This intrusion both remobilised the nickel and added sulfur to the system, giving rise to the potential formation of nickel sulfide deposits" (Newnham, 1997).

This explanation conforms with the conclusion of Poltock (1987) that, at the Nickel Reward mine, the pentlandite bearing pyrite-magnetite lode, in a localised brecciated and silicified zone of the serpentinite, was a result of the intrusion of the ultramafics by the Heemskirk granite.

The model has parallels with a summary of the key factors in the genesis of world-class nickel deposits which was recently published (Naldrett, 1997). Naldrett concluded that the key factors in the genesis of such deposits were:

- "the segregation of large amounts of sulfide at one time ... (with) the addition of sulfide from an external source..."
- sulfides must also have had the opportunity to react with sufficient magma in order to scavenge adequate quantities of Ni, Cu and PGE"
- "concentration of the sulphides in restricted localities so that the deposit is of economic grade"

The Heemskirk granite is a possible **sulphur source**, having provided the sulphur in many deposits, including:

- the endogranitic tin mineralisation such as at the Federation, Sweeney's and Globe Mines,
- most of the silver-lead-zinc deposits around Zeehan,
- the tin bearing pyrrhotite deposits at Queen Hill,
- the tin bearing pyrrhotite deposits at Renison Bell.

This view is reinforced by the mapping of pyrrhotite bearing rocks on the Area D grid, around the Tenth Legion mine, and the several pyrrhotitic zones in the Cambrian sedimentary rocks in A001 (McKeown, 1998).

Petrological examination of drill core from holes drilled on the Avebury grid have been undertaken by Ashley (1997) and Fander (1998). Ashley considered that the proportion of sulphide present suggested that it was introduced from a source external to the serpentinite, perhaps the Heemskirk granite. Wally Fander considered that the nickel sulphides were introduced after the serpentinisation of the ultramafic, implying an external source for the sulphide content of the mineralisation.

The ultramafics in the compilation area are a potentially large **nickel source**. The background nickel content of the ultramafics at Trial Harbour is generally in the 1000 to 2000 ppm range (Parkinson, 1993b). A cubic kilometre of this material, at a bulk density of 2.5 tonnes per cubic metre and 1500ppm Ni, would contain over 3.5 million tonnes of elemental nickel. It is now proposed (section 4 A NEW VIEW OF THE CAMBRIAN ULTRAMAFICS) that the ultramafics occur over an area of over 40 square kilometres, stretching 14 kilometres east-west from Trial Harbour to Zeehan, and at least 3 kilometres north-south in the Stonehenge to Avebury area. Even at low nickel concentrations, this ultramafic could be a potential source of large amounts of nickel.

The best nickel intersection to date has been that in serpentinite in A001 but the shape of the nickel mineralisation intersected in this hole has not yet been defined by drilling. The greatest concentration of nickel sulphides occurred at the top of the intersection of magnetite rich serpentinite, and the nickel concentration gradually decreased down the hole which stopped in low grade nickel sulphide bearing serpentinite (Figure 6). A tight, circular, magnetic anomaly (Plan 1), with its peak just to the east of this intersection, certainly results from the magnetite rich serpentinite in A001. Considering all these features, it is difficult not to imagine the nickel sulphide occurring in a domal trap, the nickel sulphides having accumulated at the top of the altered ultramafic, beneath impervious Cambrian sedimentary rocks (Figure 7) and that this nickel sulphide concentration is not a vein deposit.

A remarkable feature of the nickel sulphide mineralisation in A001 is the lack of elevated levels of other elements:

A001 243.9m to 254.6m	1.15% Ni
	1.61% S
	261ppM Co
	73ppM Cu
	36ppm Pb
	156ppm Zn
	19ppm As
	<1ppm Ag
	6ppb Au
	<5ppb Pt
	<1ppb Pd

8.3 DISCOVERY OF THE AVEBURY NICKEL SULPHIDES

It is always interesting to consider why new mineral discoveries were not made earlier. In this case, there are several possible reasons.

After the early prospecting period, in the Zeehan area outside the Trial Harbour serpentinite, there was no exploration for nickel.

As suggested above, some nickel sulphide concentrations may occur in domal traps, but the probability of the ground surface coinciding exactly with the apex of a dome is low. However, the possibility of such outcrop should not be completely disregarded and there are reported nickel occurrences which warrant further investigation, for example, at Central Balstrup mine.

In addition, it is unlikely that domal traps are the only sites for nickel sulphide accumulations which could also be expected in fault fissures. Some of the many gossanous outcrops which occur in the compilation area may be the surface expressions of fault fissures and some may contain anomalous nickel but there are no records of nickel sampling of such outcrops.

At Avebury, nickel sulphide concentrations are not associated with elevated levels of other elements, apart from sulphur. There is no non-nickel signature to these concentrations which could have been detected in a soil anomaly, no associated gold or PGMs which could have left an alluvial signature. The only reliable chemical guide appears to be nickel. Around Zeehan, analyses of soil and stream samples for nickel have never been routinely undertaken.

Eventually, the Avebury nickel sulphide occurrence was discovered as the result of drilling planned to test a lead-zinc soil anomaly. It is now thought that this anomaly resulted from a low grade lead-zinc skarn developed in the Cambrian sedimentary rocks overlying the ultramafics at Avebury (McKeown, 1998).

8.4 THE TRIAL HARBOUR NICKEL OCCURRENCES

EZ explored the Trial Harbour serpentinite from 1968 to 1972, during the nickel boom. Geological mapping, soil sampling, and ground magnetics and IP surveys were followed by 11 diamond drill holes. Although soil samples returned assays up to 1% Ni, the best diamond drill intersection was 11 metres down hole at 0.54% Ni in hole TH136. The nickel occurred as veinlets and disseminations of pyrrhotite-pentlandite-pyrite.

A brief exploration program, commissioned by M.G. Creasy in 1988, concluded that relatively high grade nickel in the pyrite-magnetite lode at the Nickel Reward mine occurred in a localised zone of brecciation and silicification of the Trial Harbour serpentinite were a result of the intrusion of the ultramafics by the Heemskirk granite (Poltock, 1987).

CRAE explored the outcropping serpentinite at Trial Harbour during 1992/93. Detailed mapping, soil and rock chip sampling, and nine shallow diamond drill holes were completed.

The soil and rock chip samples returned assays up to 1.6% Ni but, as is the case at Avebury, there were no associated high levels of other metals. CRAE geologists concluded that the lack of associated copper suggests that the nickel sulphide mineralisation is not a primary feature of the ultramafic (Parkinson, 1993b).

Except near the surface, most diamond drill holes returned nickel assays <0.2% Ni, but the best results were:

ZT3	4.0m to 11.0m	7.0m down hole at 1.0% Ni
	11.7m to 16.7m	5.0m down hole at 0.38% Ni

There was no significant sulphide logged in this hole suggesting that the nickel may be present in a silicate species, however, subsequent petrological studies identified the nickel bearing sulphides pentlandite and heazlewoodite. The petrological work also indicated that the nickel sulphides were not primary segregations but had been introduced during serpentinisation, presumably during the emplacement of the Heemskirk granite (Parkinson, 1993b).

It is now proposed by the author that the outcropping Trial Harbour serpentinite represents the root zone of an Avebury style deposit (Figure 7). It is suggested that drilling for nickel sulphides in this area be directed to the faulted contacts of the serpentinite where nickel sulphides may have accumulated.

9 LEAD ZINC MINERALISATION

9.1 INTRODUCTION

CRAE geologists had targeted stratiform lead zinc deposits on the Stonehenge grid. An area at the eastern end of the grid was selected for initial exploration because of the occurrence of limestone and sulphidic black shale within the Oonah Formation. Also, RGC had intersected several metres of significant zinc mineralisation, in brecciated zones, in nearby drill hole TH12 (Roberts et al, 1983):

TH12	32.0m to 42.0m	10.0m down hole at 2.49% Zn, 1.0% Pb, 32g/t Ag
	79.0m to 82.0m	3.0m down hole at 10.3% Zn, 1.5% Pb, 261g/t Ag

In 1993, two diamond drill holes were completed to test the ground where Grubb's Shear cuts through a sequence containing black shales. The best results from this drilling were:

ZS1	119.2m to 121.4m	2.2m down hole at 7.8% Zn, 10.1% Pb, 191g/t Ag
ZS2	100.5m to 112.0m	11.5m down hole at 4.1% Zn, 1.1% Pb, 10g/t Ag
	190.3m to 190.5m	0.3m down hole at 20.0% Zn, 12.3% Pb, 415g/t Ag 2.9% Cu, 2.2% Sb

These intersections were made in dolomites, siltstones and shales, where sphalerite veining occurred within brecciated zones of ankerite/siderite alteration.

A third diamond drill hole, ZS3, was drilled to test the black shales away from any known shear. This was less successful, the only significant mineralisation - 1.1m down hole at 3.5% Zn, 0.1% Pb and 19g/t Ag - coming from a 5mm true thickness dolomite vein parallel to the core axis (Parkinson, 1993b).

In 1995, 27 air core holes were drilled on grid lines in the area around these previous diamond drill holes. Several significant shallow intersections were made:

ZS5	9m to 26m	17m vertically at 2.82% Zn, 2.06% Pb
ZS6	0m to 6m	6m vertically at 2.79% Zn, 1.22% Pb
ZS8	12m to 15m	3m vertically at 1.43% Zn
ZS10	3m to 12m	9m vertically at 2.42% Zn

The mineralisation in these intersections consisted of galena and dark brown sphalerite, with intergrown pyrite, in black shale. A diamond drill hole, ZS31, was drilled to test for possible down dip extensions of the mineralisation in the black shale (Figure 8). This hole intersected three significant mineralised zones:

ZS31	34.0m to 40.5m	6.5m down hole at 6.3% Zn
	66.2m to 67.5m	1.3m down hole at 3.5% Zn
	153.0m to 156.2m	3.2m down hole at 2.5% Zn

The first and third of these intersections was made in sheared, pyritic, black shales, and the second came from a quartz vein in brecciated sandstone. In an attempt to find the surface trace of the intersections in ZS31, 163 wacker samples were taken, drilled to an average depth

of 4.9 metres. These samples located the upper black shale mineralisation from ZS31 and defined a 600 metre long, east-west Zn anomaly, open to the west. It was not clear whether the mineralisation in black shales was stratiform or discordant (Tear, 1995a).

A geological and structural analysis of all the available the data was undertaken during 1996 (Upton, 1996). The conclusion of this work was that, in the Comstock Stonehenge grid area, pyrite, sphalerite and galena occur as:

- hydrothermal veins in fractured and faulted zones, a Tabberabberan event
- minor skarns, a Tabberabberan event
- stratiform deposits in black shale horizons, origin unknown

Further drilling suggested for the Stonehenge area did not proceed due to budgetary constraints (Tear and Russell, 1996a).

9.2 A NEW STYLE OF LEAD-ZINC MINERALISATION

The identification of stratiform lead-zinc mineralisation stratiform in black shales on the Stonehenge grid represents the discovery of a mineralisation style previously unknown on the Zeehan field. Figure 9 shows Upton's (1996) interpretation of the structure of the black shale horizons around the diamond drill holes on the Stonehenge grid.

Four samples from the air core program on the Stonehenge grid were submitted for lead isotope analyses.

The lead isotope ratios of these samples have been plotted on a $^{206}\text{Pb}/^{204}\text{Pb}$ vs $^{207}\text{Pb}/^{204}\text{Pb}$ graph (Figure 10). The results plot as a tight cluster which is isolated from the accepted fields for both Devonian veins and Cambrian volcanogenic massive sulphides. There is a suggestion that differences in analytical techniques is responsible for the difference; ICP-MS was used for these analyses, and thermal-ICP for the others (Tear, 1995a). However, the origin of the lead in these samples is still not clear (Green, 1998).

10 GOLD MINERALISATION

Reported gold occurrences are uncommon in the compilation area, but the following have been reported.

A stream sediment sample from **Stonehenge Creek**, just above the junction with Comstock Creek contained 2.98ppm Au (Komysan, 1984a).

A stream sediment sample from **Comstock Creek**, just above the junction with the Little Henty River contained 0.38ppm Au (Roberts, 1985a).

A sample from the **Nubeena mine** contained gold inclusions in ore and quartz rich gangue (Both and Williams, 1971).

In diamond drill hole **ZS31** drilled on the **Stonehenge grid** traces of gold were intersected in a faulted zone (Tear, 1995a):

ZS31	152.95m to 154.5m	0.269ppm Au
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This is not a lot of evidence for the presence of gold in the area, but, considering the extremely small number of gold assays undertaken, the possibility of gold occurrences, perhaps as invisible gold, should be pursued.

11 RECOMMENDATIONS FOR FUTURE WORK

Priority should be given to those tasks which may most immediately lead to the definition of an orebody, that is, further diamond drilling at Avebury to follow up the nickel sulphide intersection in A001, and drilling on the Stonehenge grid to pursue the lead-zinc target outlined by CRAE.

The following suggestions for future work are numbered for convenience of reference but are not listed in order of importance.

1. No specific mention has so far been made to access to the compilation area, the author has assumed the reader's familiarity with the problems of access, especially south of the Trial Harbour Road. Nevertheless, it is recommended that vehicle access be established to the Avebury grid to facilitate further drilling.
2. There should be further drilling to test the nickel sulphide mineralisation at Avebury.

3. There should be further drilling to test the lead-zinc target on the Stonehenge grid.
4. All core from existing diamond drill holes should be located and the core re-logged and re-assayed with a view to identifying nickel occurrences. There are diamond drill holes in the Tenth Legion, Comstock and the Spray mine areas.
5. Once the results of the recent aeromagnetic survey are received, the concealed ultramafic complex should be modelled as a deformed sheet. Modelling to date has assumed the ultramafics as steeply dipping sheets (for example, Tear and Tesselaar, 1996).
6. A gravity survey over the areas where the results of the aeromagnetics suggest that the ultramafic might be deeply buried may clarify the location and shape of the buried ultramafic.
7. Gossanous outcrops should be sampled and analysed for nickel, including:
 - the ironstones in the Tenth Legion and Kynance mine areas
 - a gossan near line 24E, 00N on Area D grid which coincides with a magnetic anomaly, and which could be located on a fault (Lees and Newnham, 1974)
8. The recorded mineralised outcrops of ultramafics and altered ultramafics should be sampled and analysed for nickel, including:
 - the Orient Mine, just west of the Area D grid, where aggregates of hornblende associated with serpentinitised olivine, magnetite and pyrrhotite have been reported (Blissett, 1962)
 - the reported exposure of nickel sulphides in the Summit cutting of the Comstock tramway (Waller, 1904 and Twelvetrees and Ward, 1910)
 - the altered serpentinite dyke reported to the west of Moyle's lode (Waller, 1904)
 - the nickel occurrence in the pyroxenite dyke between the Swansea and Silver Duke mines (Reid, 1922)
9. Both and Williams (1971) examined a limited number of specimens, not samples, from museums, collections and dumps; if they had examined more specimens maybe they would have identified more nickel occurrences. So sampling and nickel analyses should be undertaken on material from all existing mine dumps in the area now presumed to be underlain by ultramafics.
10. Detailed geological mapping of the Avebury grid should be undertaken.

11. The preparation of comprehensive geological base plans for the compilation area should continue. 1:5000 coverage should be completed by preparation of plans which cover the quadrangles which contain the areas around

- the Tenth Legion mine
- Avebury to Area D
- the Swansea, Silver Duke and Austral mines

12. Digital topographic data should be acquired to enable adequately detailed control of all geological data and preparation of good geological plans.

13. All existing drill hole data should be converted to computer based, digital format for use with exploration and mining software such as DATAMINE or SURPAC.

12 CONCLUSION

This year's drilling at Avebury and the completion of this data compilation have resulted in the generation of several novel ideas which point to new exploration targets in the compilation area:

- the entire area from Trial Harbour to Zeehan is underlain by Cambrian ultramafics (section 4.2)
- the concealed ultramafic is probably folded along north-west striking axes (section 5)
- nickel mineralisation is known over the whole of the compilation area (section 8.1)
- remobilised nickel sulphides exist at Avebury (section 8.2)
- nickel sulphides may have accumulated in domal traps (section 8.2)
- potential exists at Trial Harbour for the discovery of nickel sulphide accumulations, away from the area traditionally explored (section 8.4)
- stratiform lead-zinc mineralisation occurs on the Stonehenge grid (section 9.2)

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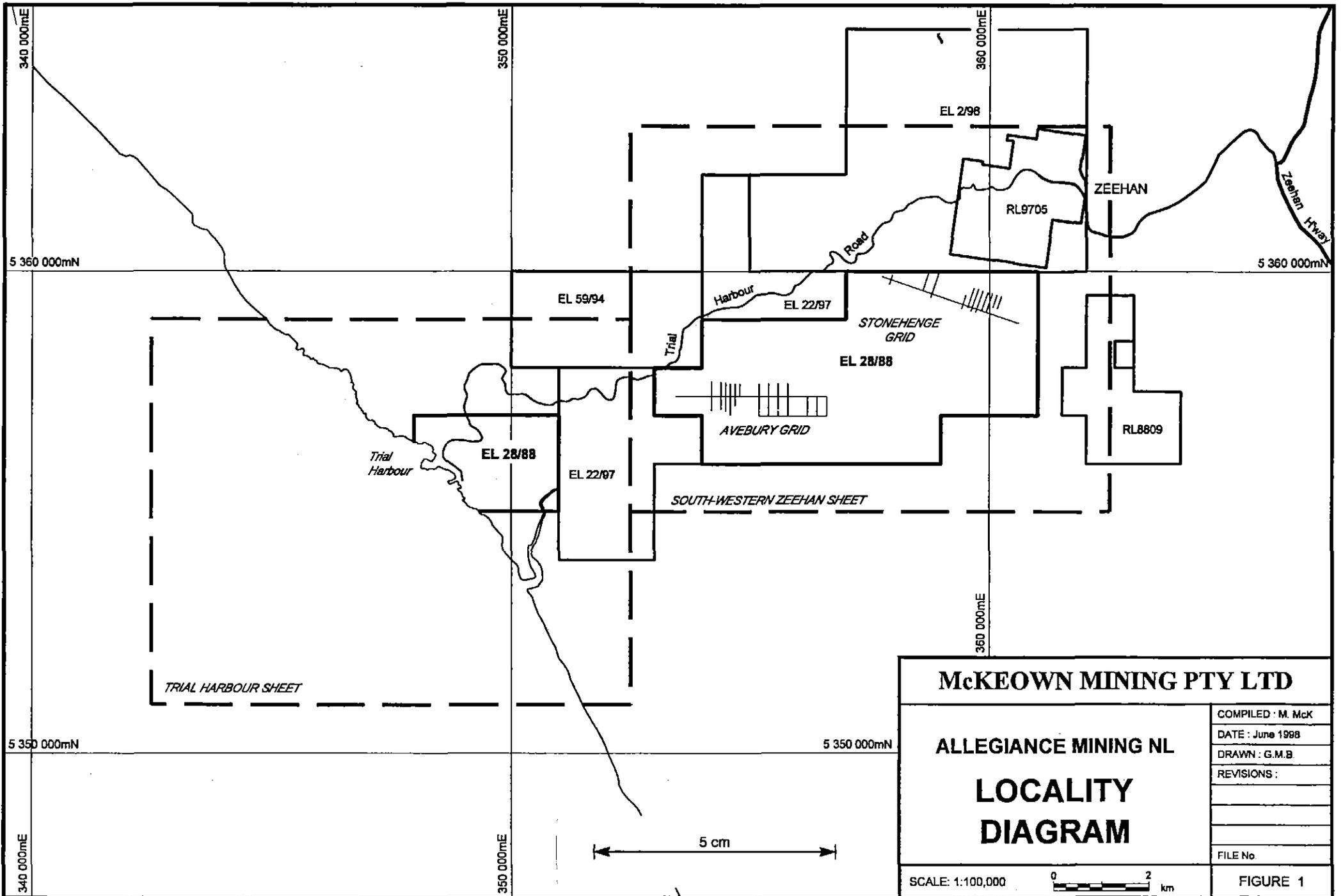
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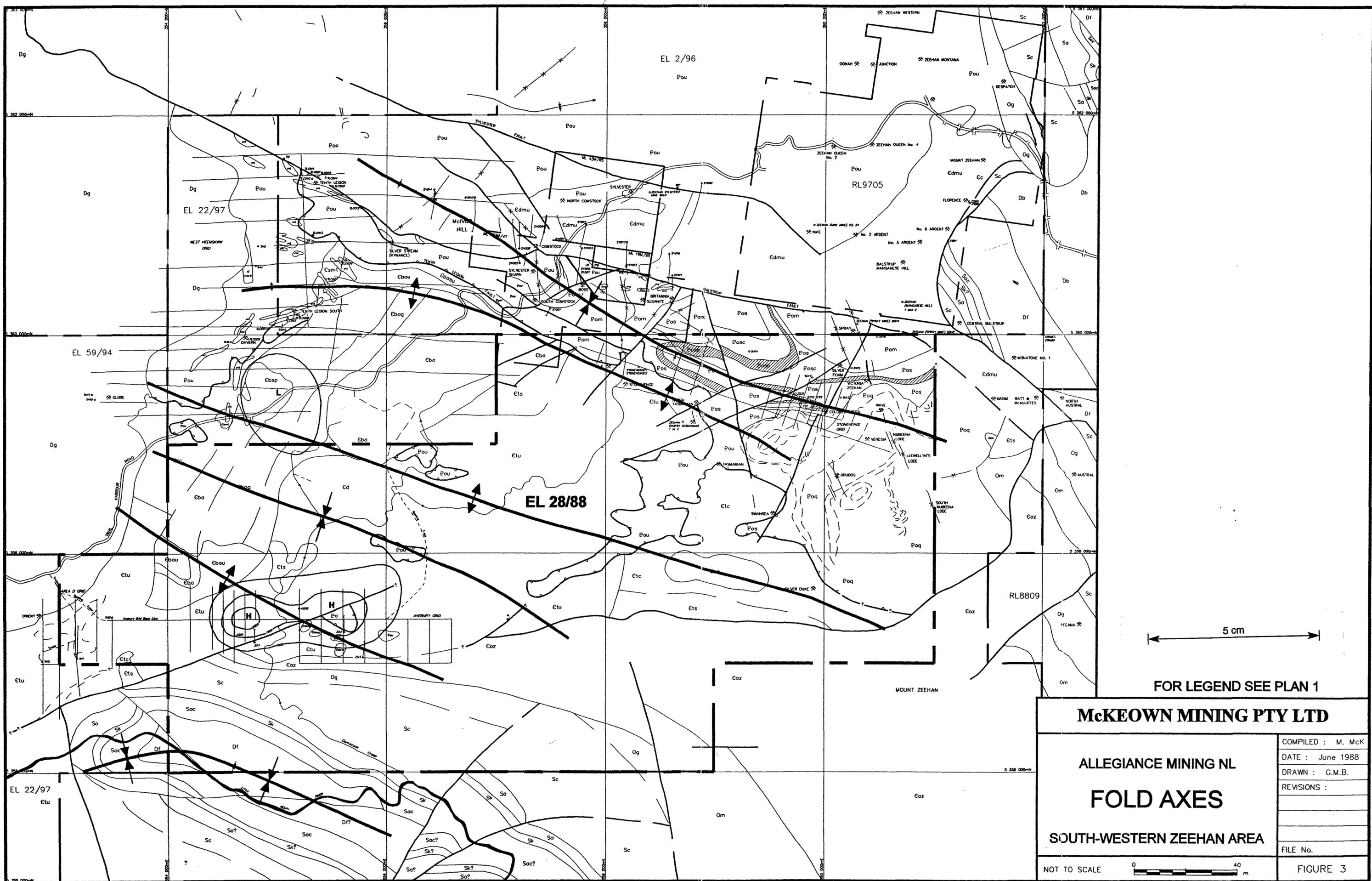
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443032



5 cm

FOR LEGEND SEE PLAN 1

McKEOWN MINING PTY LTD

ALLEGIANCE MINING NL

FOLD AXES

SOUTH-WESTERN ZEEHAN AREA

COMPILED : M. McK

DATE : June 1988

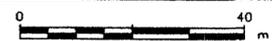
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REVISIONS :

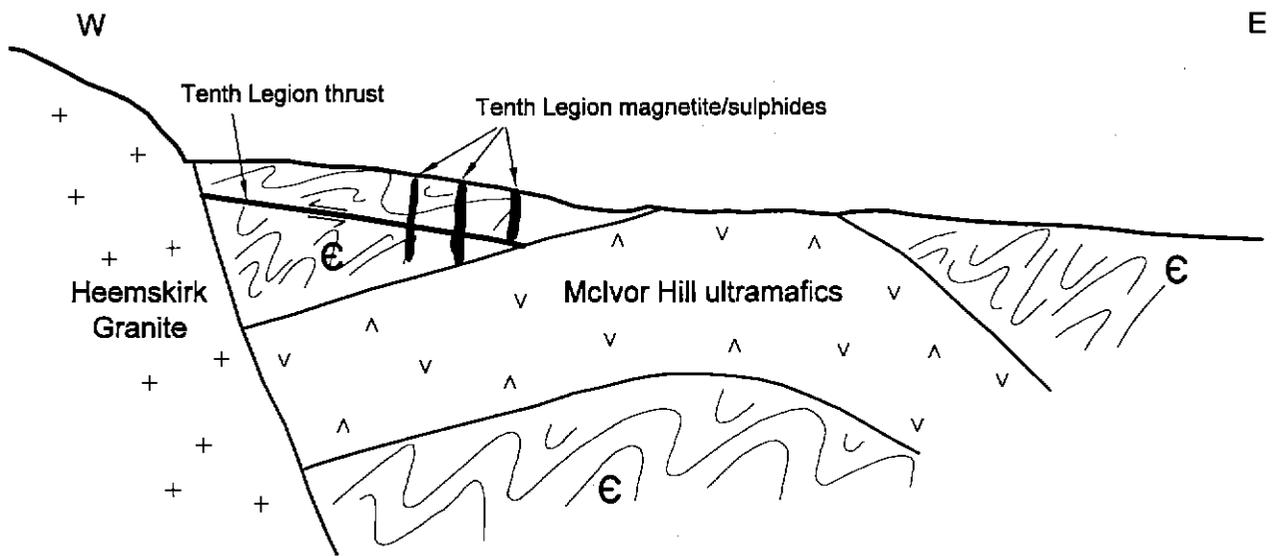
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FIGURE 3

NOT TO SCALE



SKETCH SECTION THROUGH TENTH LEGION AREA



SKETCH SECTION THROUGH STONEHENGE

GRID AREA

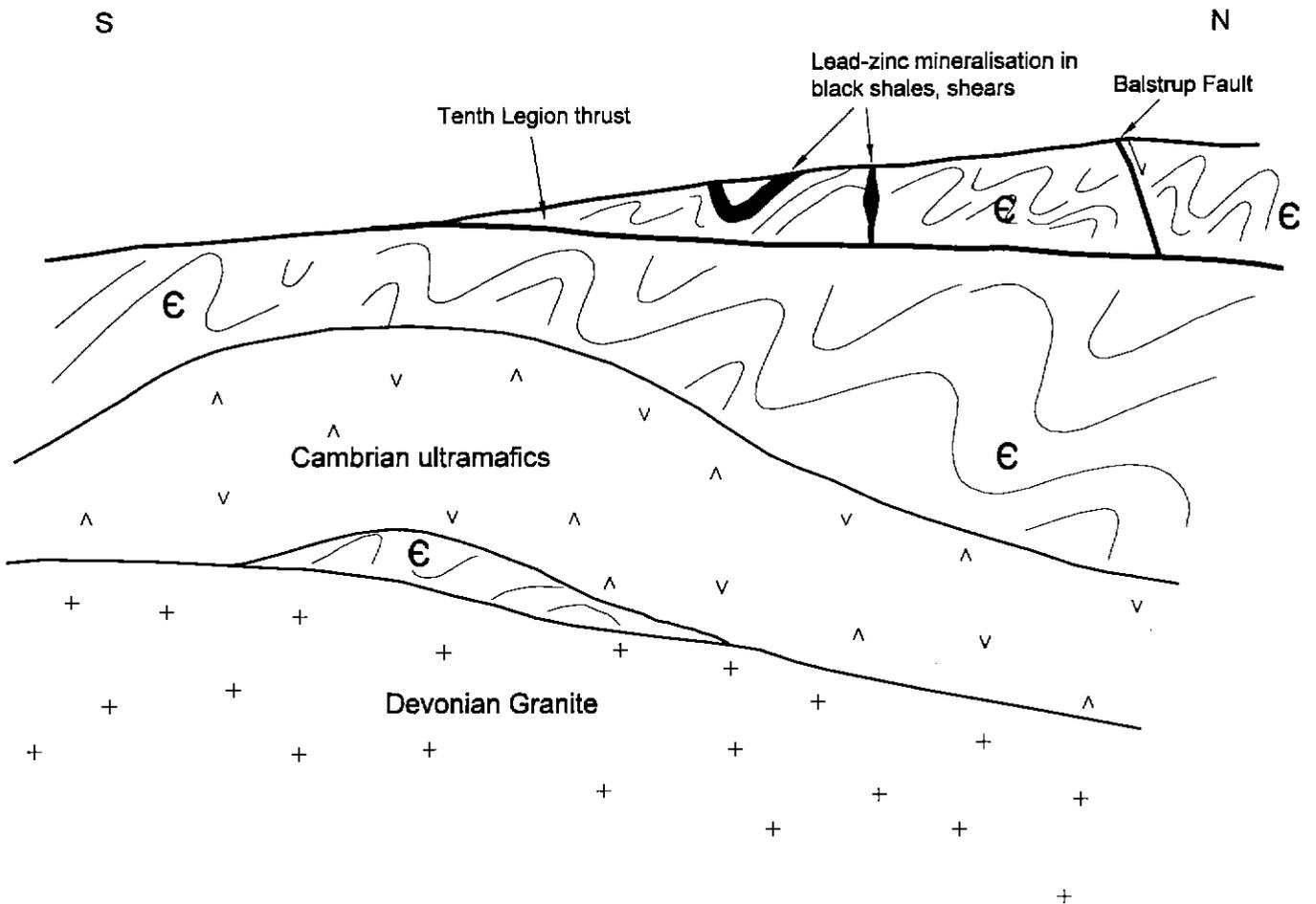


FIGURE 4

A001 - %Ni vs depth

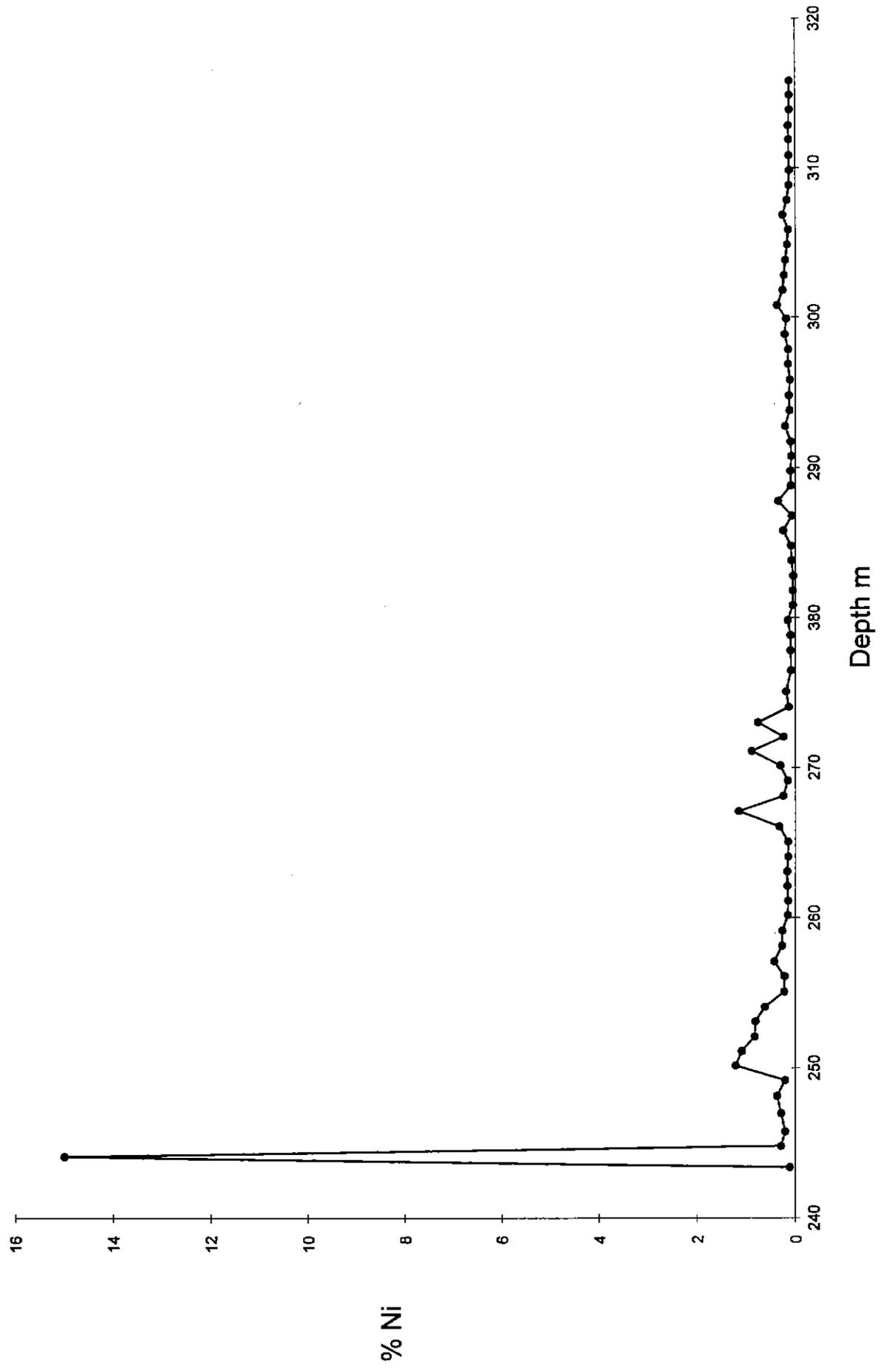


FIGURE 6

AVEBURY NICKEL SULPHIDE MODEL

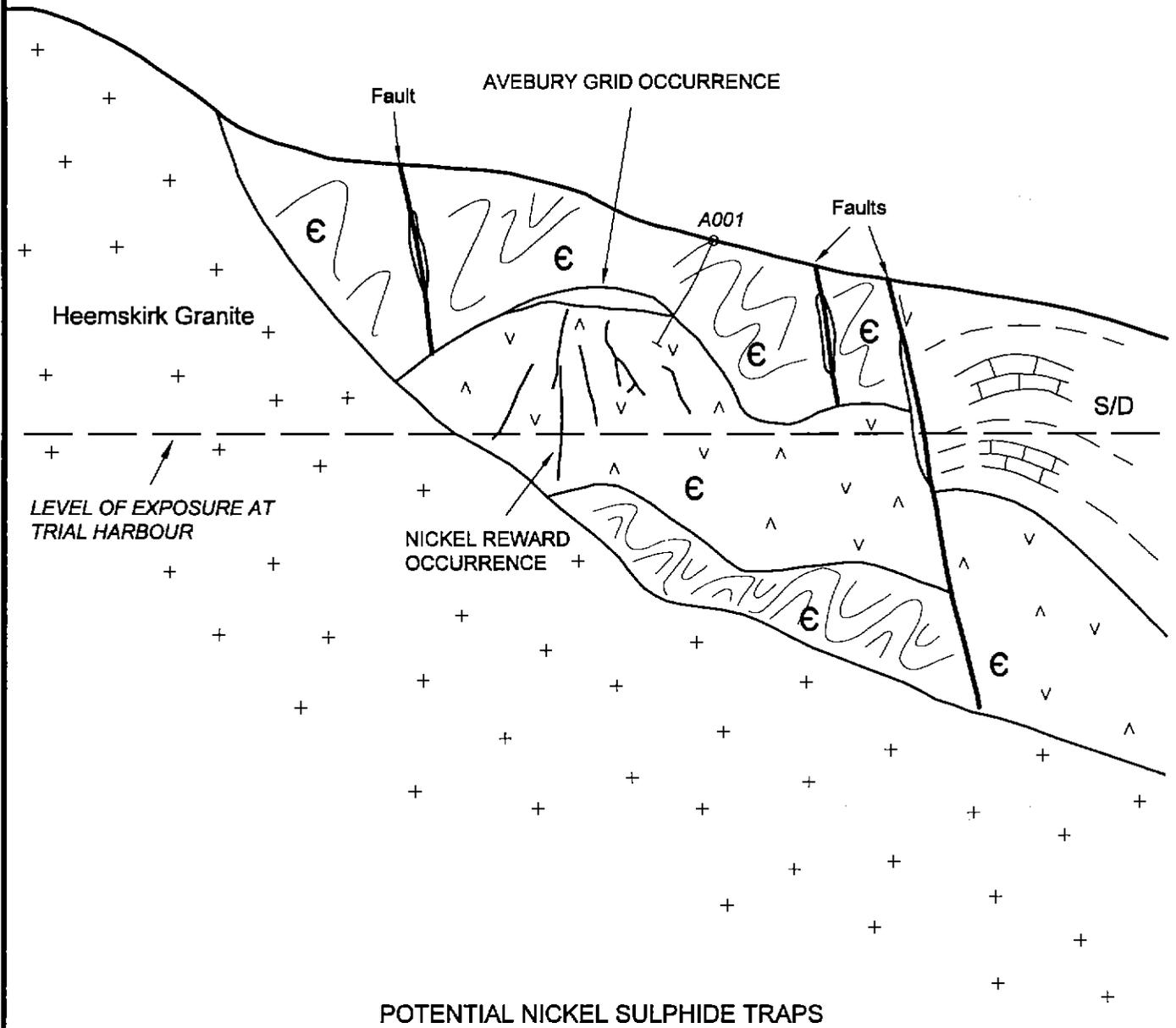


FIGURE 7

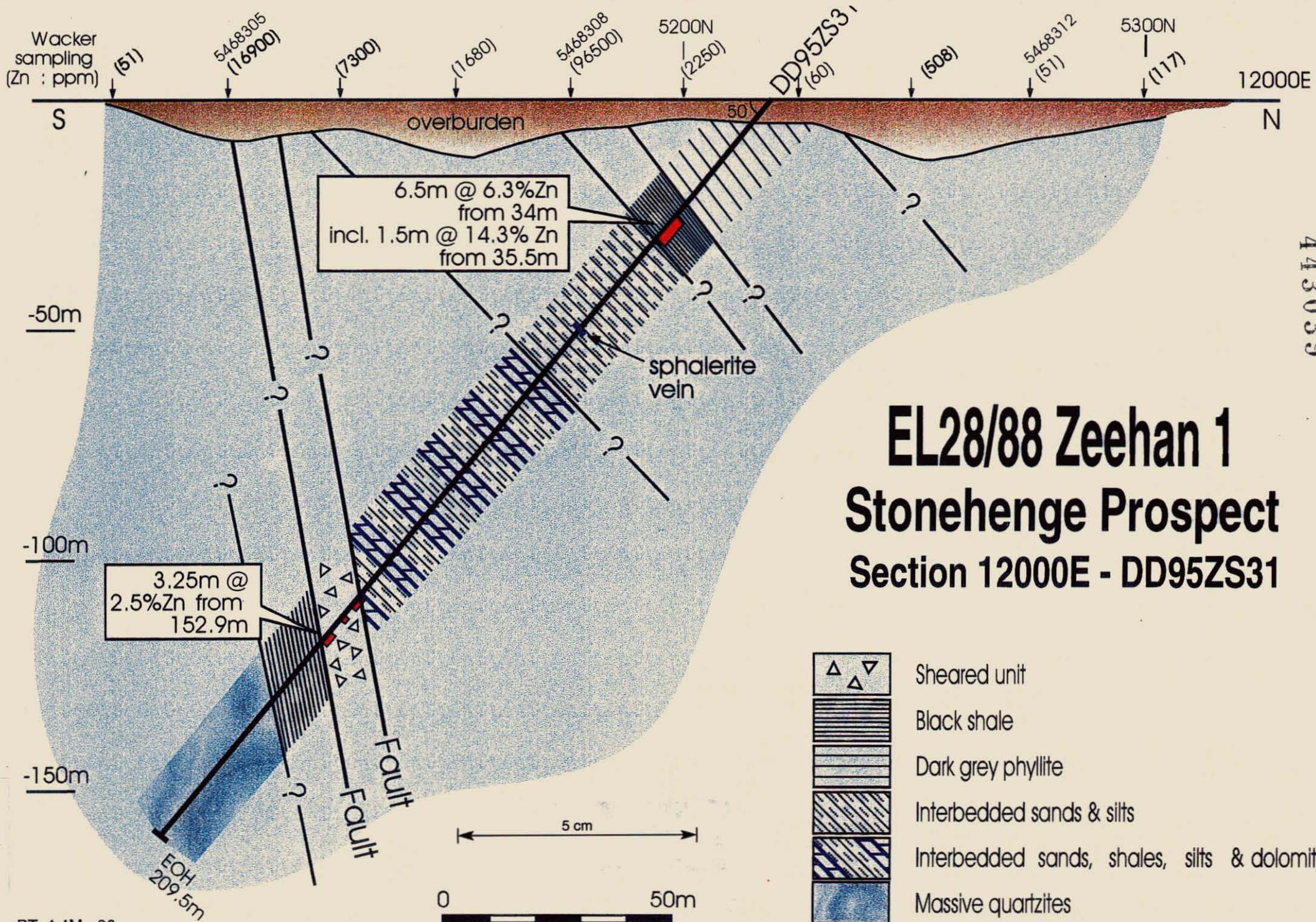


FIGURE 8

INTERPRETATIVE MODEL OF BLACK SHALE HORIZONS SURROUNDING THE MINERALISED HORIZONS AT STONEHENGE

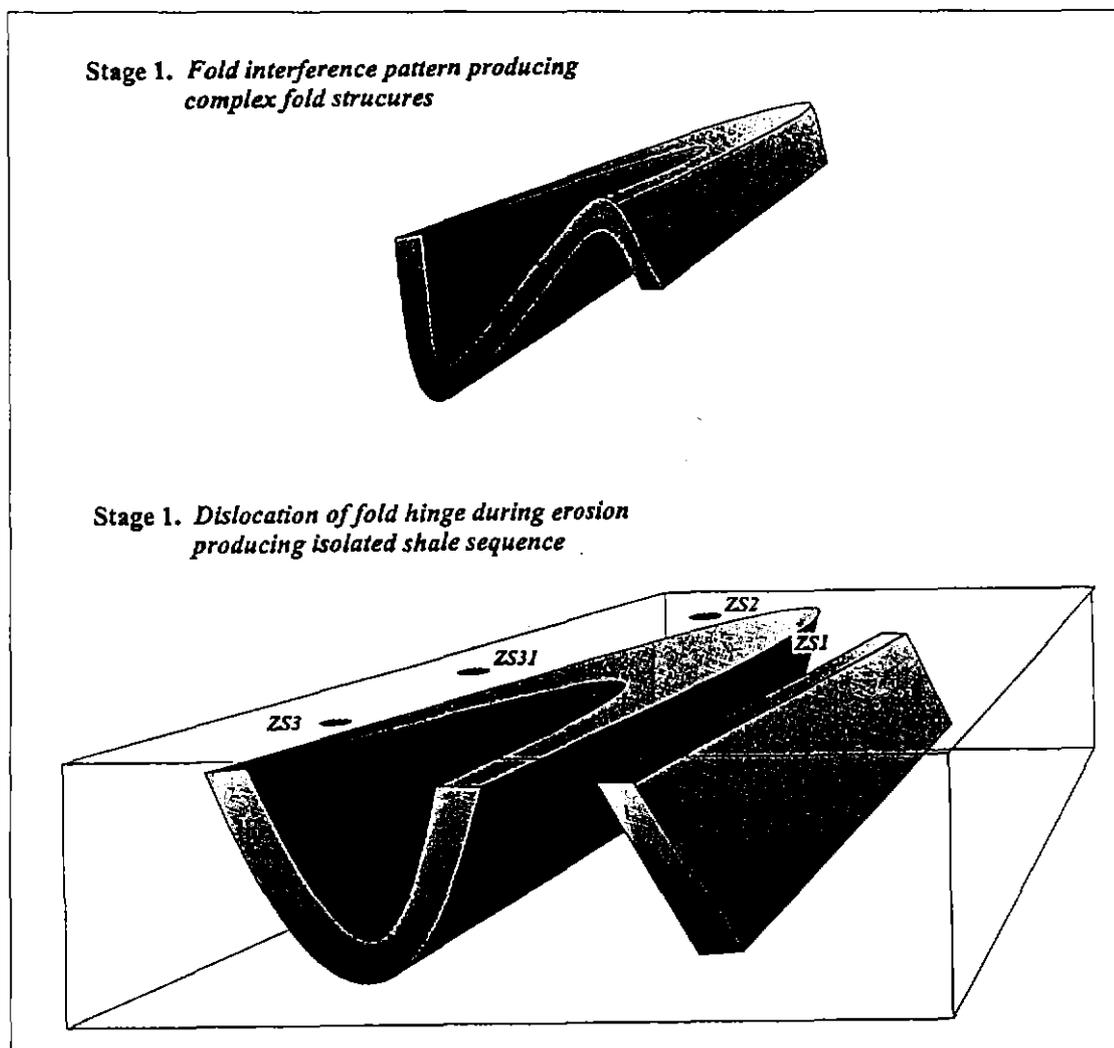
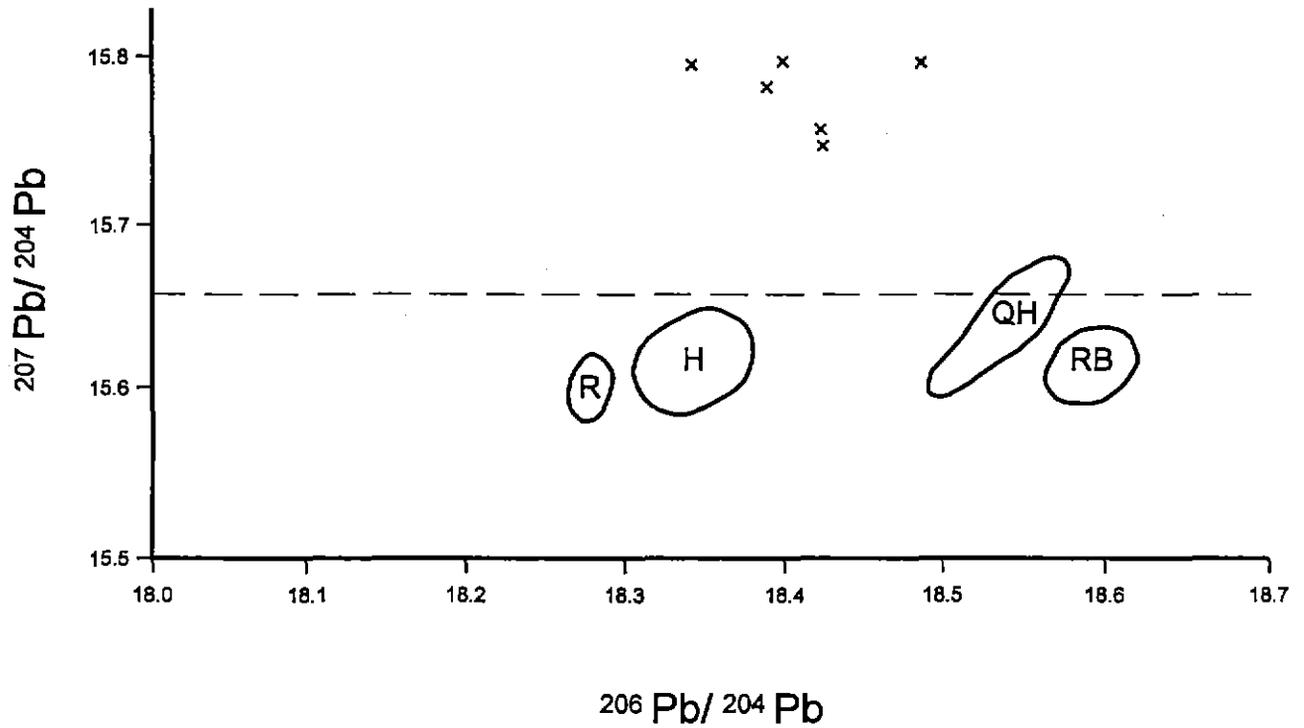
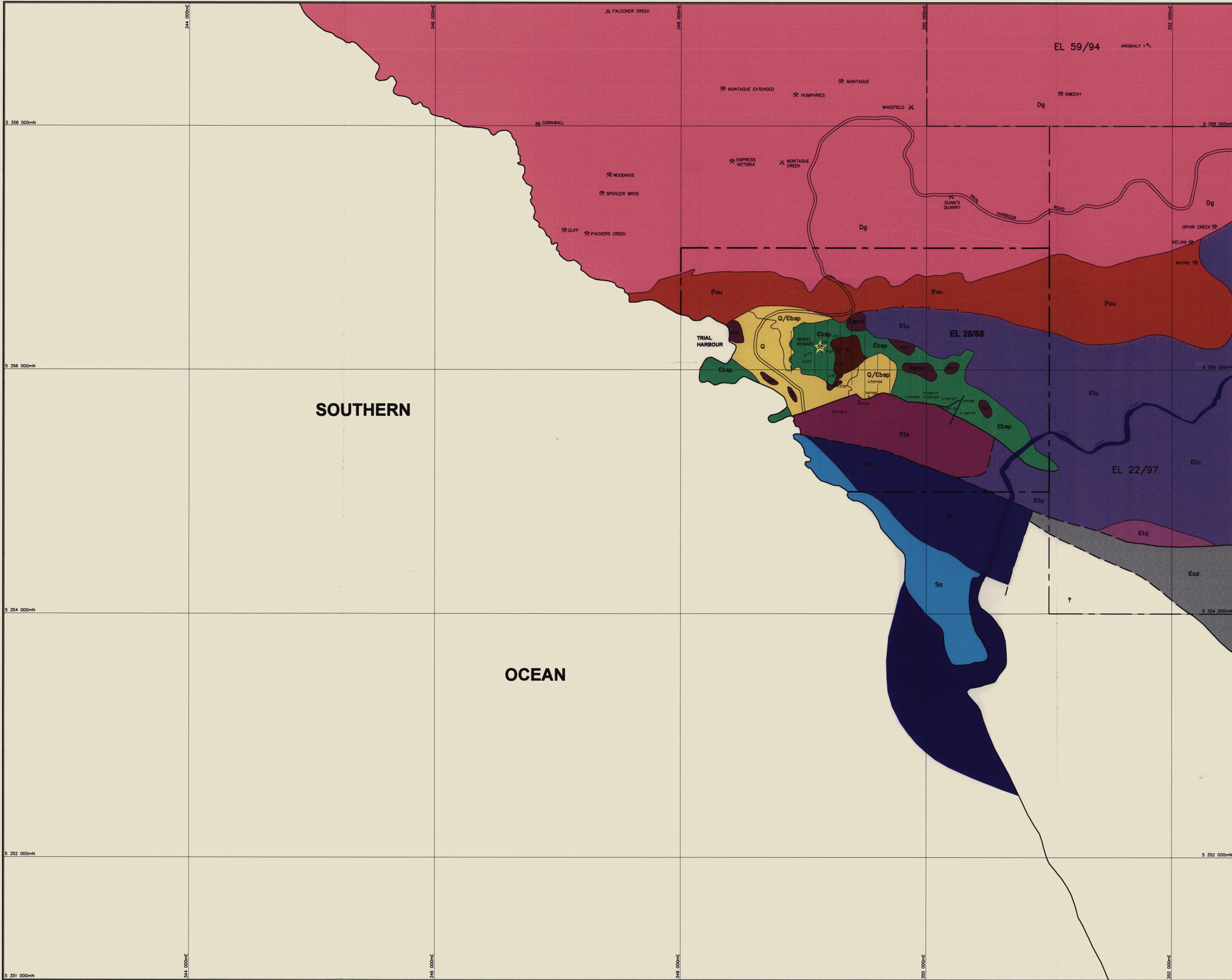


FIGURE 9



- R ROSEBERY - HERCULES
H HELLYER - QUE RIVER
QH QUEEN HILL
RB RENISON BELL
× STONEHENGE GRID

LEAD ISOTOPE RATIOS - STONEHENGE GRID



LEGEND

- QUATERNARY**
 - Q Quaternary sand, beach deposits
- TERTIARY**
 - T Tertiary ironstone
- SEDIMENTARY ROCKS**
 - Df Florence quartzite
 - Ac Austral Creek siltstone
 - Kl Keel quartzite
 - Am Amber slate
 - Cq Crofty quartzite
 - Gd Gordon limestone
 - Mn Maina sandstone
 - Mz Mt Zeehan conglomerate
 - Ch Chert, siltstone and lithicwacke
 - Includes
 - Chc Chert
 - Chl Siltstone and lithicwacke
 - Chm Siltstones and magnetite
 - Chq Siltstone and quartzwacke
 - Vc Volcaniclastics, chert, siltstone
- PRECAMBRIAN**
 - Pou Oonah Formation
 - Includes
 - Pom Micaceous units
 - Pon Siltstone and shale
 - Poc Calcareous units
 - Pps Graphitic shale
 - Pqs Quartzite
- IGNEOUS ROCKS**
 - Dg Heamskirck granite
 - Dm Felsic dyke
 - Cba Basalt flows
 - Gab Gabbro
 - Mif Mafic igneous rock
 - Mf Mafic rock
 - Serp Serpentine
- MINERALISATION**
 - M Magnetite
 - ms massive sulphide
- BOUNDARIES**
 - Geological boundary
 - Concealed geological boundary
 - Fault
 - Thrust fault
 - Fissure lode
- STRUCTURAL**
 - Syncline, plunge indicated
 - Anticline, plunge indicated
 - Bedding trace
 - Pyrrhotitic zone
 - Magnetic high
 - Magnetic low
 - Reported Nickel Occurrence
- OTHER**
 - Mine or prospect
 - Alluvial workings - abandoned
 - Diamond drill hole collar
 - Diamond drill hole trace
 - EL boundary
 - ML or RL boundary

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A NEW VIEW OF THE ZEEHAN KINERAL FIELD - EL 28/88
 ALLEGIANCE MINING - MCKEOWN

5 cm

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	PLAN 2