CONTENTS

Osborne, Queensland, Australia

Deposit Description

Location (Figure 4.1)

Osborne is ~195 km SE of Mount Isa and ~120 km NE of Boulia at latitude 22º 04' S & longitude 140º 34' E on the Boulia (SF 54-10) 1: 250 000 sheet and the Toolebuc (7053) 1: 100 000 sheet. Access to the site is via a 75 km sealed road from the railhead at Phosphate Hill.

Reserve

The Osborne deposit has a total mine-life ore reserve of:

15.2 Mt @ 3.0% Cu and 1.05 g/t Au (Rubenach et al, 2001).

Reserves in 1999 were (Brook Hunt, 2000):

Proven	**9.4 Mt @ 2.96% Cu and 1.00 g/t Au**
Inferred	**0.7 Mt @ 1.97% Cu and 0.80 g/t Au.**

The approval to proceed with development of the mine was made when the reserve was:
11.35 Mt @ 3.04 % Cu and 1.28 g/t Au in June 1994 (Tullemans and Voulgaris, 1998).

The global resource was estimated in March 1992 at:

36 Mt @ 2.0% Cu and 1.0 g/t Au

and clearly a substantial part of that will not be mined under current economic conditions (Tullemans and Voulgaris, 1998).

Climate and Vegetation

Average maximum and minimum temperatures at Boulia Airport (Station 038003) from 1886-2001 were 31.7º C and 16.7º C respectively. The January and July maxima and minima over the same period were 38.5º C & 24.5º C (Jan) and 22.8º C & 7.5º C (Jul). Annual precipitation was 264.7 mm over 115.0 years. Boulia has a distinct wet season from November to March (37.6 mm/month), a transition in April and October as one wet season finishes and the next one starts (14.7 mm/month), and low rainfall from May to September (9.5 mm/month). Mean relative humidity at 0900 hrs was 44% and at 1500 hrs was 26% (Bureau of Meteorology Internet site, 2001).

The principal vegetation types in the open cut area prior to mining were snappy gum (*Eucalyptus leucophloia*), and spinifex *(Triodia molesta)* in an open woodland setting. Creeks draining to the NE support Normanton box (E. normantonensis), acacias and spinifex. Ground to the south of the pit, in the area of the tailings dams is predominantly spinifex hummock grassland. Other trees in the airport area, include western bloodwood *(E. terminalis)* and lesser acacias *(A. chisholmii* (turpentine bush)), *A. acradenia* and *A. spondylophylla)* (Placer Pacific EMOS, 1994).

Topography

Local topographic relief is a flat plain a short distance south of the most SE outcrop of the Precambrian mineral belt of NW Queensland. In the open cut area, the pre-mining RL is 276-280 m. Drainage from the open pit is gently to the NE, and from the tailings dams to the NW and to the east, the latter being on a low mesa (Placer Pacific EMOS, 1994).

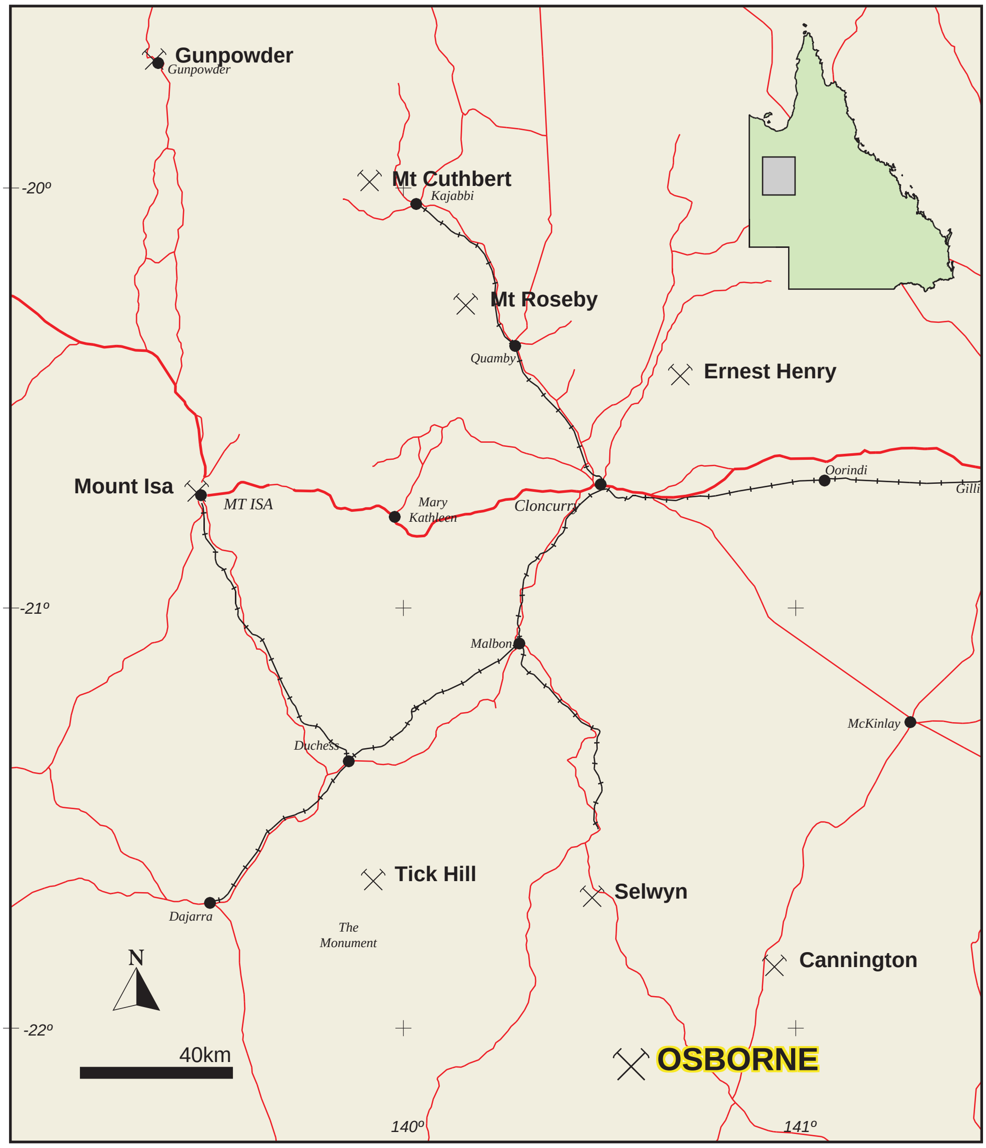

Figure 4.1 Location of the Osborne deposit, Queensland

Geology *(Figures 4.2, 4.3 and 4.4)*

Osborne occurs in the SE extremity of the eastern fold belt of the Pre-cambrian inlier of NW Queensland in amphibolite facies rocks of the Soldiers Cap Group *(Figure 4.2)*. Paragneisses are quartzo-feldspathic to pelitic in composition, being strongly deformed by a D2 event. The orebody host is a suite of metasomatic rocks (D2) that include albitites, sillimanite gneiss, magnetite rich ironstones, biotite schists, cummingtonite and anthophyllite schists and calc-silicates. Abundant pegmatite bodies were intruded syn D2 and a second generation of albitisation and calc-silicate alteration followed (Rubenach et al, 2001).

The area is divided into two domains by the Awesome fault, a western domain of pre metamorphic BIF and schist, and an eastern domain of schists and pegmatites and a fault bounded body of meta-ultramafic rock *(Figures 4.3 and 4.4)*. More specifically the western domain is two stratiform bands of magnetite-quartz-apatite ironstone, striking NW and dipping 25º-55º NE. The ironstones are 10-45 m thick (upper) and 8-15 m thick (lower) and are separated by 6-40 m of feldspathic psammite and lesser peraluminous schist. The eastern domain lacks ironstones, has several pegmatite intrusions and an amphibolitic peridotite measuring 180 m (NE-SW) x 100 m x <65 m, bound by phlogopite shear zones on all sides (Adshead et al, 1998).

Some 25% of the ore is in the ironstone, the remaining 75% being in the highly siliceous rock (HSR). The intense alteration of this unit variously gives it a quartzitic appearance or a milky buck quartz vein appearance (Switzer and Huddy, 1998). In both domains, the high grade mineralisation occurs where the host lithology has been flooded with silica to produce the grey, massive, coarse grained silicification (Tullemans and Voulgaris, 1998).

^{40}Ar-^{39}Ar dating of the D2 event based on actinolitic hornblende from a foliated albitised rock was 1595 Ma (Rubenach et al, 2001), which correlates with U-Pb ages on U-rich titanite of 1595±6 Ma (Gauthier et al, 2001). In addition Re-Os dating on molybdenite from two localities, gave 1595±5 and 1600±6 Ma (Gauthier et al, 2001). ^{40}Ar-^{39}Ar dating on hornblende and biotite from the mineralisation gave a younger age of 1540 Ma (Perkins and Wyborn, 1998).

Alteration

The age dating data suggest two hydrothermal events at Osborne at 1595 Ma and 1540 Ma (Rubenach et al, 2001). The Cu-Au mineralisation was associated with early garnet and pyroxene alteration typical of skarn deposits at 1595 Ma. The calc-silicate alteration, andradite garnet, hedenbergite and magnetite forms a well developed 10-20 m halo around the massive magnetite, chalcopyrite pyrite mineralisation. The magnetite and calc-silicate alteration is overprinted by a later episode of pervasive albitisation (Gauthier et al, 2001).

Structure

The Cu-Au mineralisation was formed early syn-D2 at 1595 Ma (Gauthier et al, 2001). Late stage deformation of pre-existing ironstones and albitic alteration during ore genesis is consistent with the retrograde alteration (Rubenach et al. 2001).

Mineralisation *(Figure 4.5)*

The ore zones consist of massive magnetite, pyrite, chalcopyrite and silica with lesser hematite and pyrrhotite up to 20 m thick. A paragenetic sequence of five events has been established (Gauthier et al, 2001):

- Magnetite + andradite + hedenbergite (oldest)
- Magnetite + pyrite
- Pyrite + chalcopyrite + molybdenite
- Chalcopyrite + silica
- Pyrrhotite (youngest).

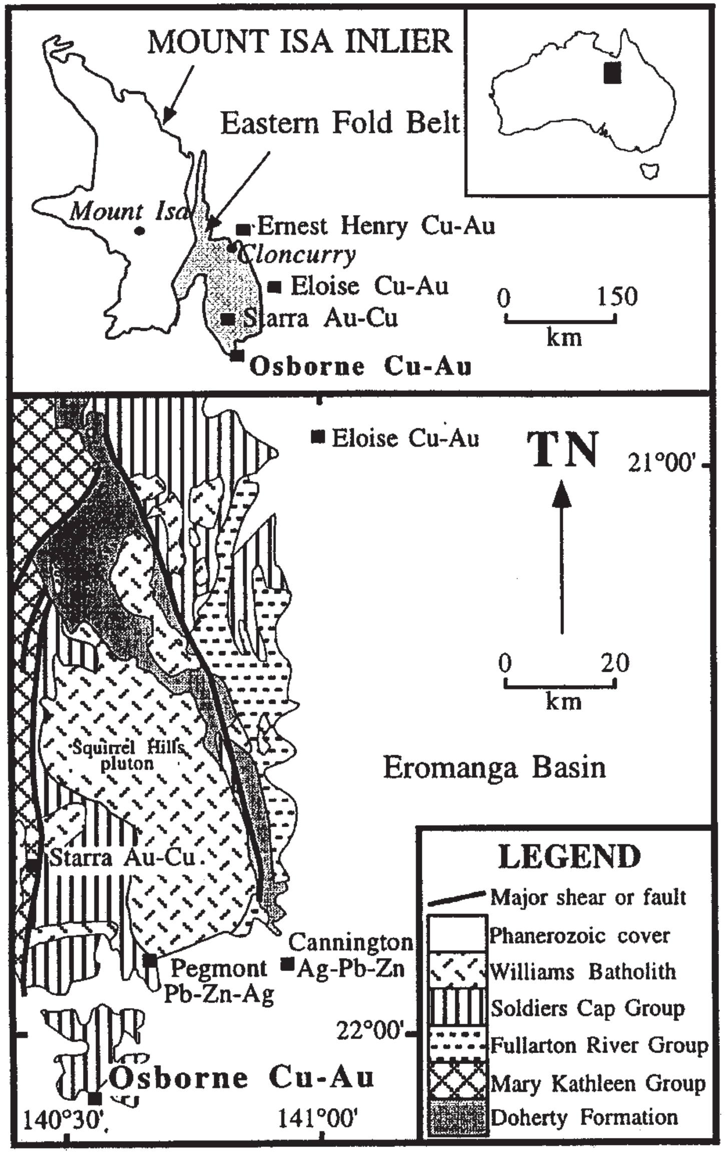

Figure 4.2 **Regional geology of the Osborne-Starra-Eloise area** *(after Adshead et al, 1998)*

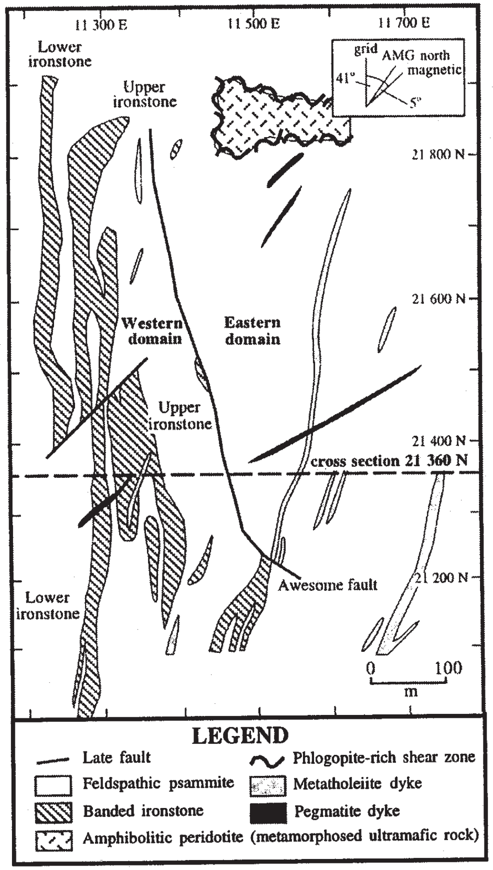

Figure 4.3 **Local geology of the Osborne area**
(after Adshead et al, 1998)

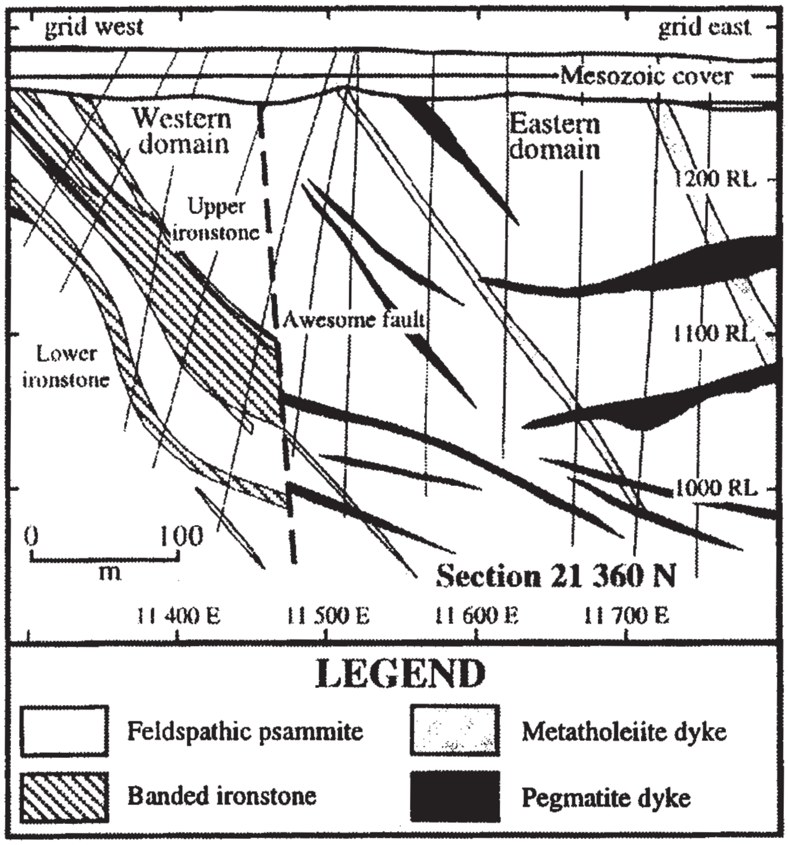

Figure 4.4 **Geological cross section at 21 360 N**
(after Adshead et al, 1998)

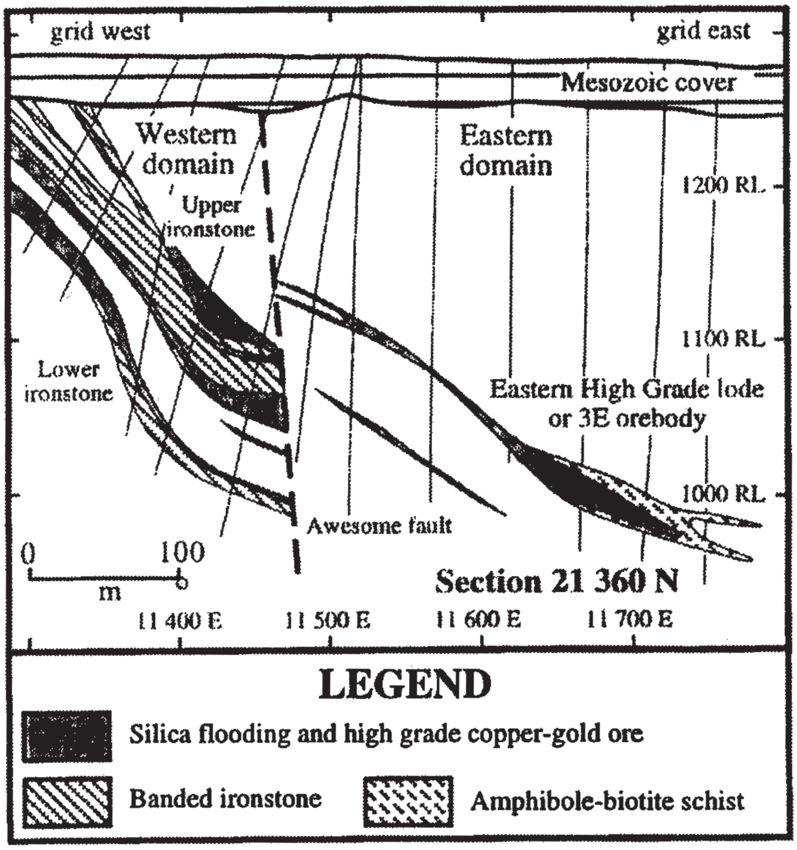

Figure 4.5 **High grade Cu-Au mineralisation on 21 360 N** *(after Adshead et al, 1998)*

The magnetite rich skarn replaced iron tholeiites, but also overprinted sillimanite-biotite para-gneiss, pegmatites and banded iron formations. Gauthier et al (2001) indicate though that regional BIFs throughout the Cloncurry district are not associated with Cu-Au ore genesis of the Osborne type.

Copper is the only primary sulphide mineral and argentiferous gold is the only auriferous phase (fineness 850-950). Anomalous concentrations of Fe, Co, Mo, Ag, Se, Bi, Hg, Te, Sn, F, Cl, HREE, Y and Nb occur in the high grade Cu-Au mineralisation (Adshead et al, 1998). Au occurs as 1-10 micron inclusions in chalcopyrite and as solid solution in pyrite and chalcopyrite (Tullemans and Voulgaris, 1998).

Mineralisation in the Western Domain occurs in the 2M, 2S, 1S and 1S South orebodies *(Figure 4.12)*. The southern and highest grade deposit is the 1S orebody. Sub-economic mineralisation continues up dip to the Mesozoic/Proterozoic unconformity. The Eastern Domain includes the 2N and 3E orebodies, which are hosted by intensely silica-flooded pegmatite and albitic rocks in a close association with schists (Tullemans and Voulgaris, 1998).

Zone of Oxidation

Oxidation in the near surface area created an oxide resource, which contained significant atacamite (Brook Hunt, 2000). The base of complete oxidation (BOCO) is 5-20 m below the base of the Mesozoic sediments. Oxide zone minerals include native Cu, malachite, cuprite, chrysocolla and atacamite. Transitional ore contains chalcopyrite, chalcocite, digenite, covellite and bornite (Tullemans and Voulgaris, 1998).

The ratio of cyanide and/or acid soluble Cu to total S was successfully used to distinguish between the oxide and sulphide resources during the feasibility study *(Figure 4.6)*. A sharp boundary was noted at RL 1215 m between a 35 m upper oxide zone and the underlying transition and fresh ore. Each ore type has vastly different flotation characteristics (Tullemans and Voulgaris, 1998).

Regolith *(Figure 4.7)*

The Precambrian basement is weathered to saprolite to a depth of 15 m below the unconformity, and locally down to 75 m around the mineralised zone. On section 21,937.5 mN, massive sulphides subcrop under a cover of siliceous ironstone gossan at 30 m below the surface. Secondary carbonates, mainly malachite and lesser chrysocolla and atacamite, 5-10 m thick separate the gossan from the primary mineralisation. The Mesozoic cover varies from the 30 m over the gossan on 21,937.5 mN to 100 m to the south of the plunging mineralised zone (Lawrance, 1999).

The Mesozoic cover includes (Lawrance, 1999):

- Soil/duricrust – the soil is only a few centimetres thick, and is covered by abundant rubble of angular ironstone, silcrete, polished rounded coarse, buck shot gravel and quartz scree. The silcrete and ferruginous duricrust can be up to 15 m depth.
- White upper saprolite, which is increasingly mottled towards the surface (0-5 m). Locally this is strongly ferruginous.
- A paleo-redox and Redox zone, where the siltstone is weathered to kaolinite with minor illite, alunite and muscovite. Two laterally extensive sub-horizontal ferruginous zones overprint the oxidised saprolite between 12-18 m depth (the Paleo-redox zone) and 25-30 m depth (the Redox zone). The Redox zone is probably an active perched water table.
- An iron-redox front at 30-35 m depth, which correlates with a shale/siltstone contact, and intersects the basement gossan. The reduced shale, saturated with saline groundwater, consists of dark green-grey smectite, muscovite and orthoclase. It grades upwards into a light grey kaolinitic sediment beneath the redox front. The weathering

change is accompanied by pervasive yellow goethitic staining (3-5 m thick) which is sometimes called the embryo-redox zone.

- Rounded quartz pebbles and cobbles, 1-4 cm in diameter, at the unconformity.

The underlying basement of Precambrian saprolite was weathered in Precambrian/Paleozoic time (Lawrance, 1999).

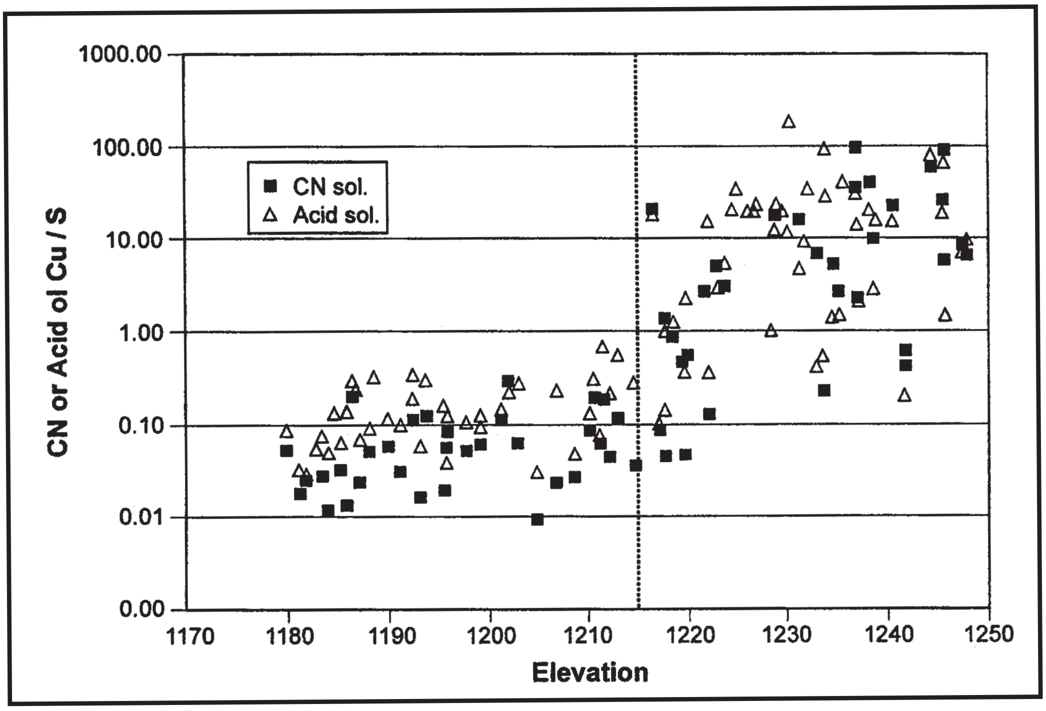

Figure 4.6 **CN or acid soluble Cu versus RL at Osborne** *(after Tullemans and Voulgaris, 1998)*

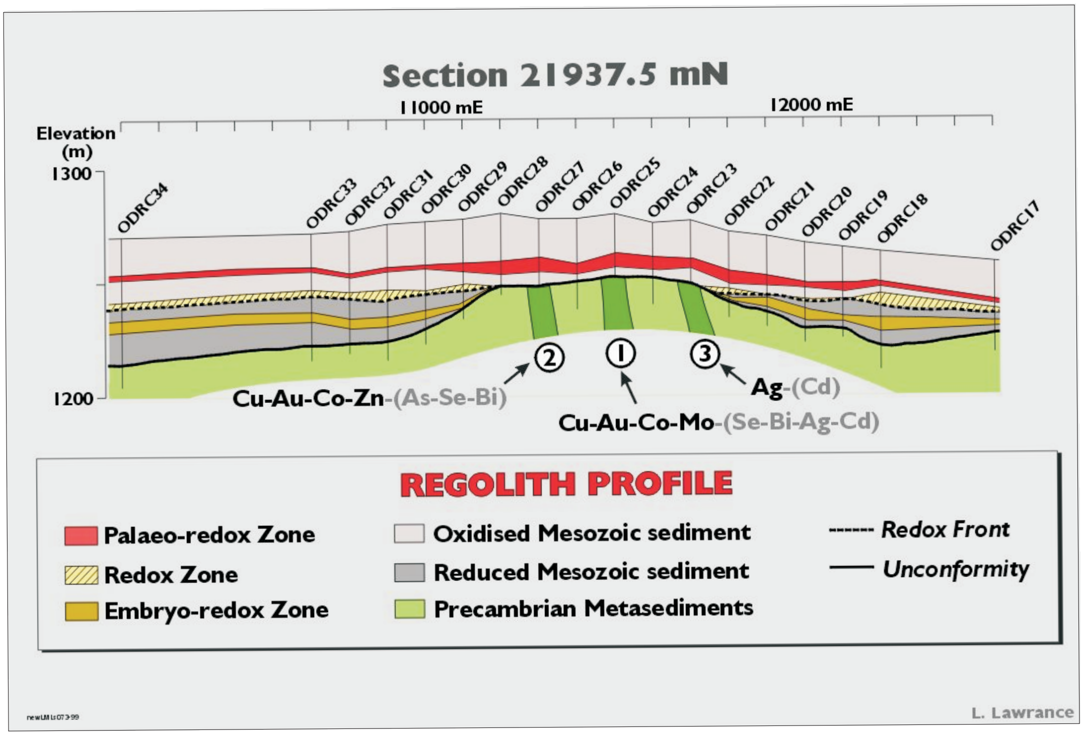

Figure 4.7 **Regolith profile on Section 21 937.5 mN, Osborne** *(after Lawrance, 1999)*

Geochemistry

Stream Sediment (-80#)
The deposit does not outcrop, and no stream sediment geochemistry or regional enzyme leach soil geochemical data has been sighted.

Soil
Results of Placer soil sampling has not been sighted. However Hall advises that many techniques give positive anomalies above the orebody and they are indicating new targets near the airstrip and elsewhere. Osborne gives positive anomalies for MMI, regoleach and Sirogas, but enzyme leach results suffered from biases due to batch effects. Hall indicates that some 15-18 methods have been tried over the orebody and many of them produce positive anomalies above the deposit (Hall – pers.comm. 2001).

The Osborne area was subject to an AMIRA research project, P355A, which was aimed at testing Russian geochemical methods over buried deposits in Australia. In conjunction with this, conventional –1 mm soils from 20 cm depths were collected at 25 m sample spacings on Line 21 140 mN. These samples were split into two parts, and one set was assayed for Cu, Zn, Co, Au and Sb by Analabs, and the other was sent to Chemtronics for MMI analysis.

Conventional –80# sampling on Line 21 140 mN
The ironstones are closest to the surface on section 21 150 mN between 11 220 E and 11,400 E. Above the buried mineralisation, strong single spikes were indicated for Sb (1.6 ppm in a background of 0.6 ppm) and Cu (37.7 ppm in a background of 25-30 ppm). Values for Au, Co and Zn were all background (Ryss et al, 1993).

Mobile Metal Ion (MMI) on Line 21 140 mN
The MMI samples gave positive responses for Cu, Pb, Zn, Cd, Ag and Ni. No responses resulted for Au, Pt, Pd, Bi, Tl, Sb and Sn. Above the mineralised zone a single spike response occurred for Zn (12.25 ppm in a background of 3.5 ppm), but values for Cu, Pb, Ni, Cd, and Ag were background. Cu values were shown to rise strongly towards the western end of the line (3 ppm), which is well above the background of 0.1-0.2 ppm) (Birrell et al, 1993). This coincides with a MPF and CHIM target (see below).

Russian Geochemistry
The Russians employed three techniques. Two were essentially soil sampling methods (MPF & TMGM) and the third was a geoelectrochemical (CHIM) method. MPF involves taking surface samples and selectively removing metals from the organic matter. TMGM involves soil from 20-50 cm deep from which the metals are removed from the Fe-Mn oxides. CHIM involves putting electrodes along the traverse, running direct current for a fixed period and subsequently measuring the amount of metal collected on the electrode. The three traverses across the deposit at a ~400 m separation were at 21 140 mN, 21 535 mN and 21 937 mN.

MPF *(Figures 4.8 and 4.9)*
Over the Eastern domain, the MPF assays were background for Cu/C, Zn/C and Co/C, the MPF data being presented as metal values divided by C. Over the orebodies of the Western Domain, the Cu/C values were anomalous only on the northern line 21,937 mN *(Figure 4.8)*. Co/C seems to show a coincident anomaly with Cu/C, but again nothing is anomalous on the other traverses. No response was apparent in the Zn/C data on any of the traverses over the mineralisation.

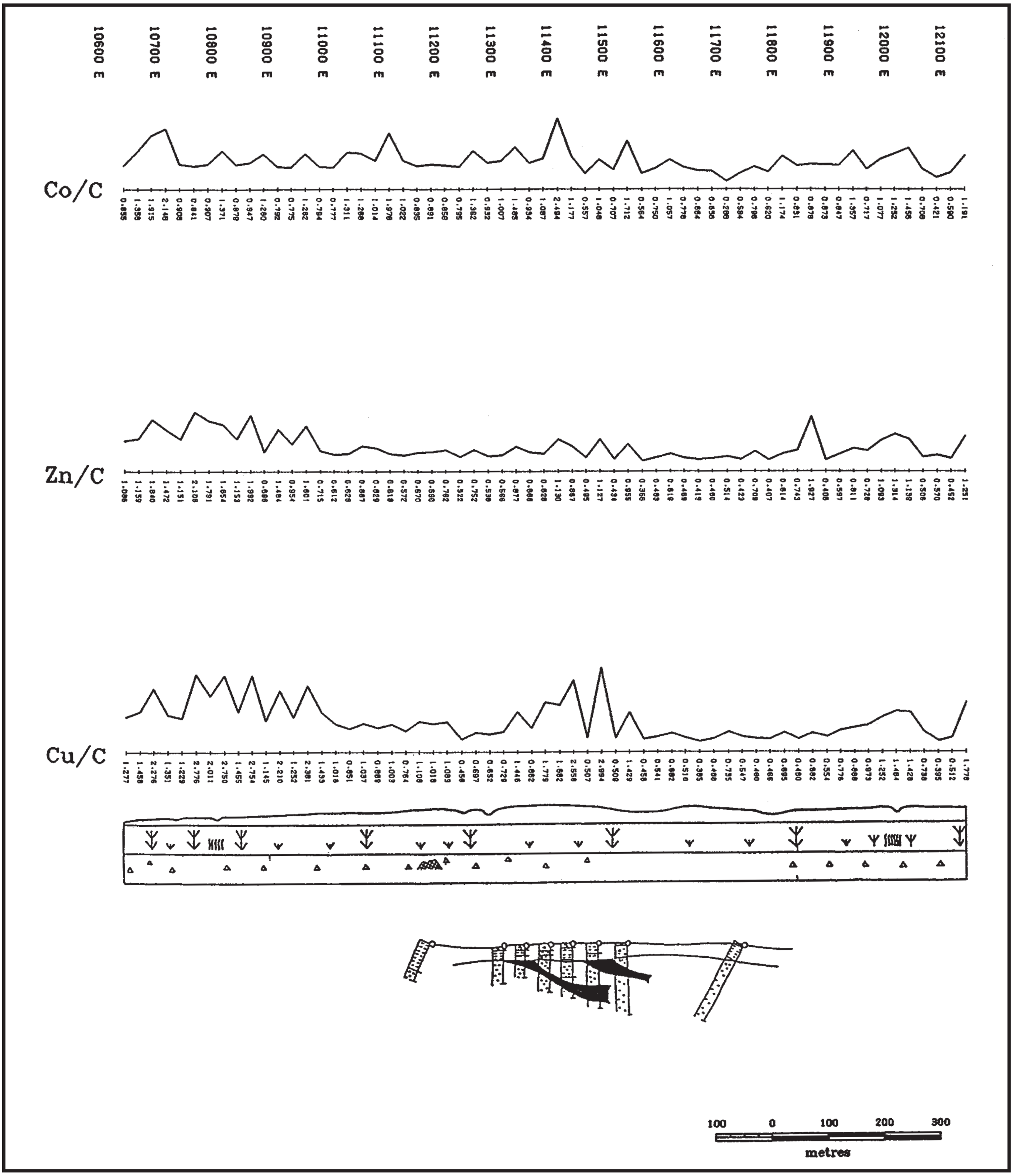

Figure 4.8 MPF geochemical profiles on Line 21 937 mN *(after Ryss et al, 1992)*

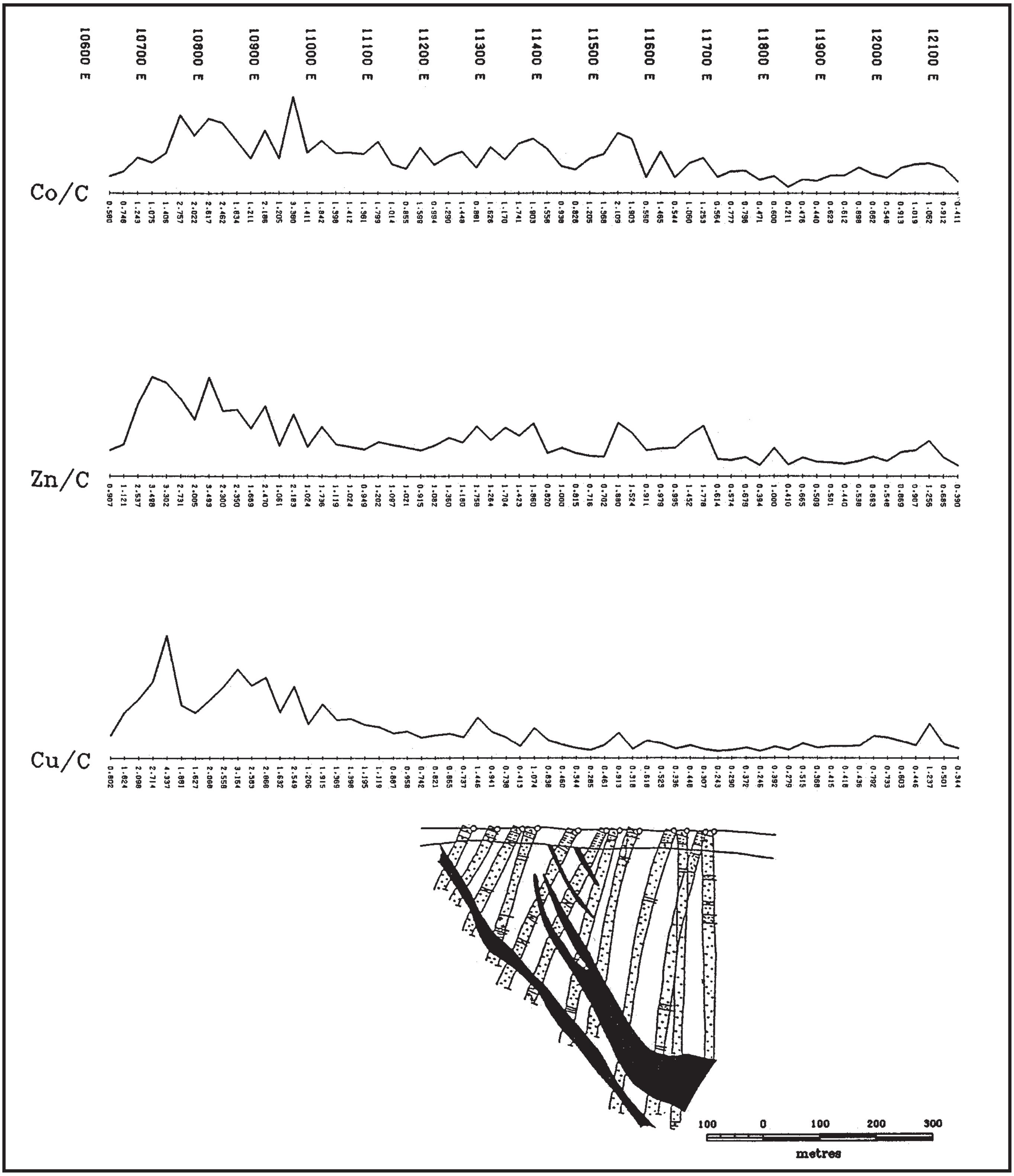

Figure 4.9 MPF geochemical profiles on Line 21 140 mN *(after Ryss et al, 1992)*

Well west of the known mineralisation, the strongest responses for Cu/C and Zn/C were on the southern line 21 140 mN *(Figure 4.10)*. The same anomaly was not evident on the two northern traverses. West of 11 200 mE the topography slopes to the west, which could spread the anomaly in that direction, but it would hardly upgrade it *(Figure 4.10)*. As this work was done in 1992 and no other orebodies have appeared in this position in 1998 papers, it is presumed this footwall area has been drilled and found wanting. At the time though, this western Zone was suggested as a new target by the Russians.

TMGM *(Figures 4.11 and 4.12)*

Without knowing the intimate details, it is thought that the TMGM method and the MOMEO method (see Ernest Henry and Olympic Dam) might be somewhat similar. Both involve removing metal ions that have adhered to Fe oxides.

The TMGM plot on 21 937 mN showed a strong anomaly for Cu, Co and Ag in the soils above the Awesome Fault *(Figure 4.11)*, which separates the Eastern and Western domains on Adshead et al's map (1998), and above the 2N orebody on Tullemans and Voulgaris map (1998) *(Figure 4.12)*. On the other two sections lesser Cu and Co anomalies occurred in this position. No TMGM Cu anomaly appears west of the orebodies in the area of the mysterious MPF Cu/Zn anomaly, although the TMGM Co is increasing at the western end of the line.

CHIM *(Figures 4.13 and 4.14)*

CHIM showed strong but spiky anomalies above the western domain ironstones on the southern two traverses for Zn & Co *(Figure 4.13)*. It also showed a Cu high at 11 425 mE near the eastern domain ultramafic on 21 937 mN. The CHIM also indicated the new western target in the southern traverses, which is presented in their product (Cu x Zn x Co) map *(Figure 4.14)*.

Conclusion

The Russian work is probably insufficient to state for sure that these methods would recognise buried targets under 20-40 m of Mesozoic cover. The supposed target to the west of the known deposits is down slope from those deposits, so maybe it is caused by groundwater seepage down gradient in that direction. If it is has not been drilled, it remains a target. If it has, and has been proved wanting, the negative finding does not seem to have found its way into the literature.

The positive TMGM anomalies above the Awesome Fault and the N2 orebody suggest that this anomaly at least is real. It has a parallel with the MOMEO anomalies that are also derived from metals adhering to Fe oxides. Anomalies for that method have been indicated at Olympic Dam and NW of Ernest Henry, albeit in very broadly spread samples. The implication from the Russian work is that the TMGM method is the most likely to have recognised the buried deposit at Osborne. All methods involving extracting Cu and related metals from Fe/Mn oxides are therefore recommended as avenues worth pursuing. The MPF and CHIM approaches would seem to be of more dubious value. That said, it would be interesting to know what follow up if any has been implemented on the area immediately west of the known deposits.

Cover rocks *(Figures 4.15-4.21)*

Cu and Au and other unspecified elements are dispersed upwards and laterally into the Mesozoic cover rocks during weathering as part of a reduction/oxidation (REDOX) process. This formed a dispersion halo within the Mesozoic cover extending the strike length of the deposit and some 1.5 times wider than the mineralised zone. From this Placer developed geochemical exploration techniques for exploring below the Mesozoic cover (Tullemans and Voulgaris, 1998) (see Lawrance below). A number of exploration prospects resulted, and it is evident from Hall that the geochemistry is in the vanguard of this exciting exploration (Hall, 2001, pers.comm.).

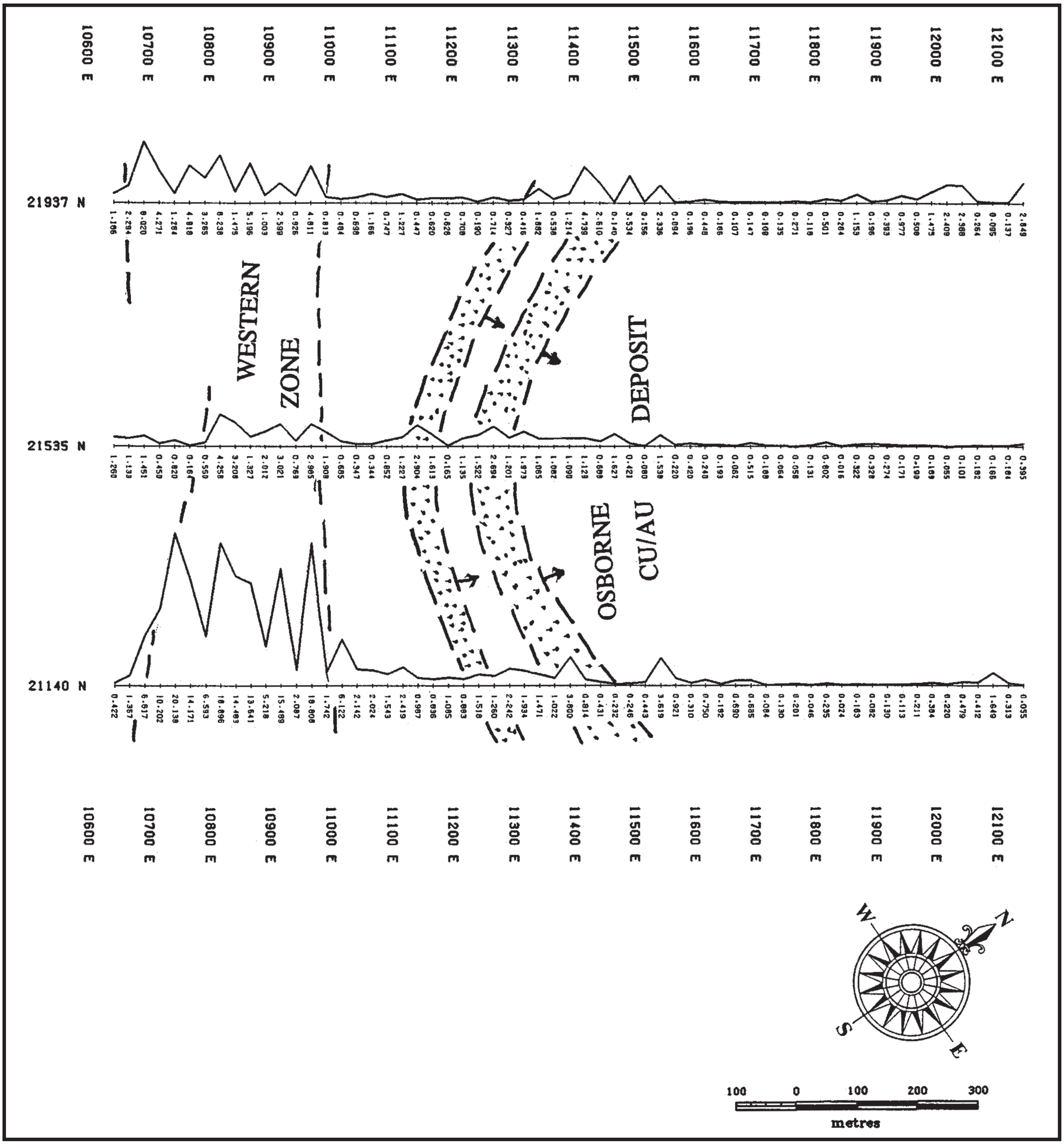

Figure 4.10 MPF Cu/C x Zn/C x Co/C in plan at Osborne *(after Ryss et al, 1992)*

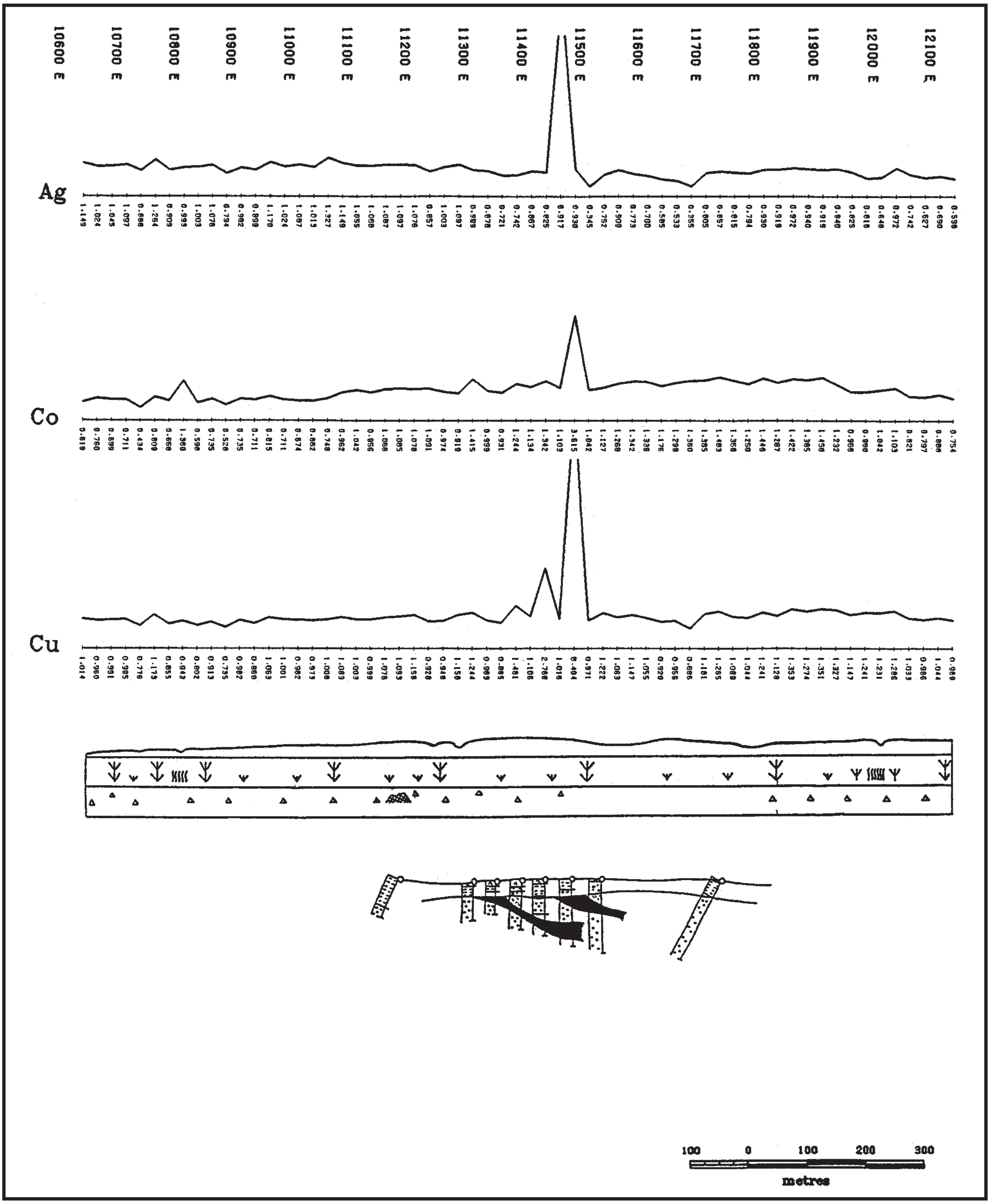

Figure 4.11 TMGM Cu, Co and Ag results on Line 21 937 mN at Osborne *(after Ryss et al, 1992)*

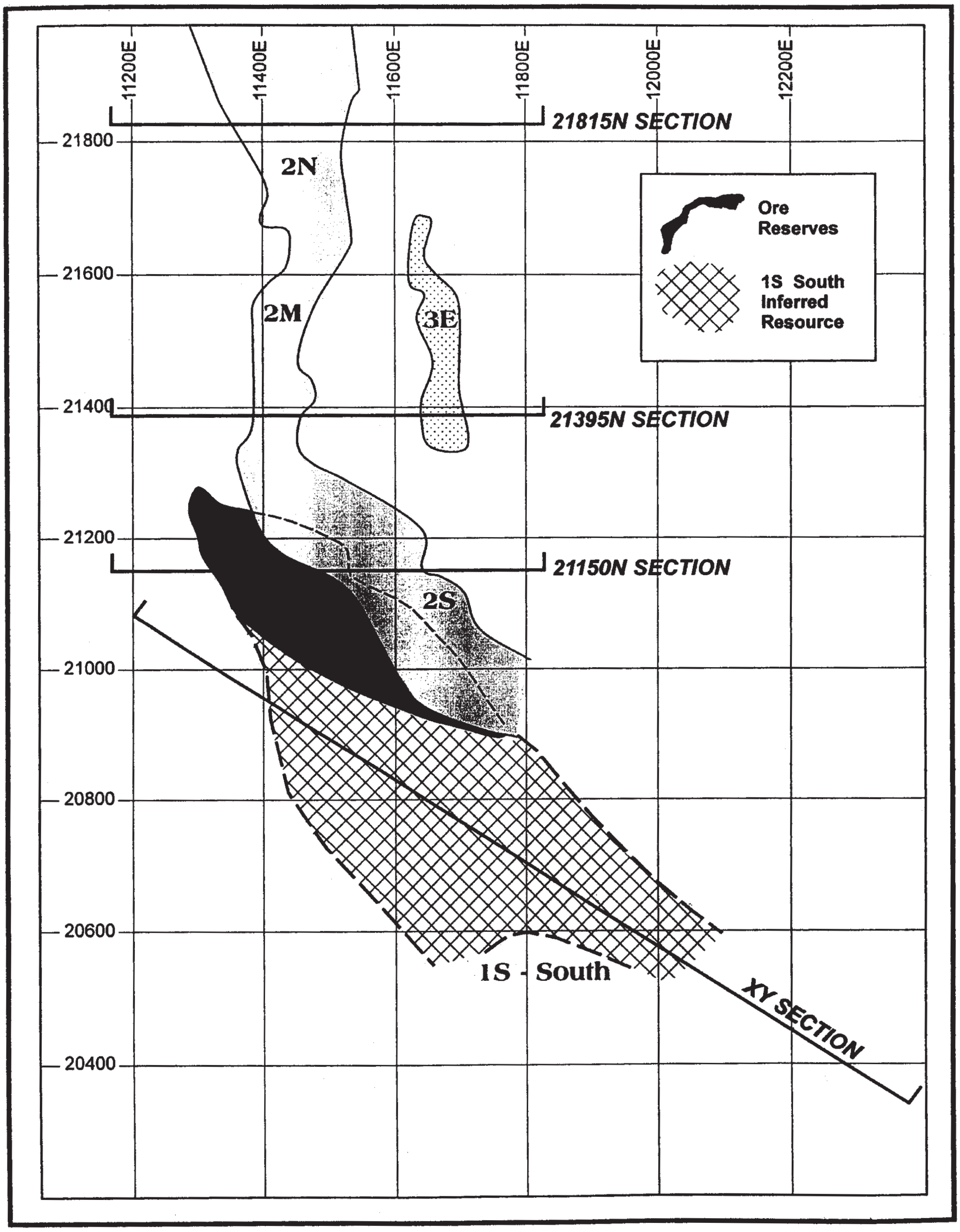

Figure 4.12 Plan of Osborne orebodies *(after Tullemans and Voulgaris, 1998)*

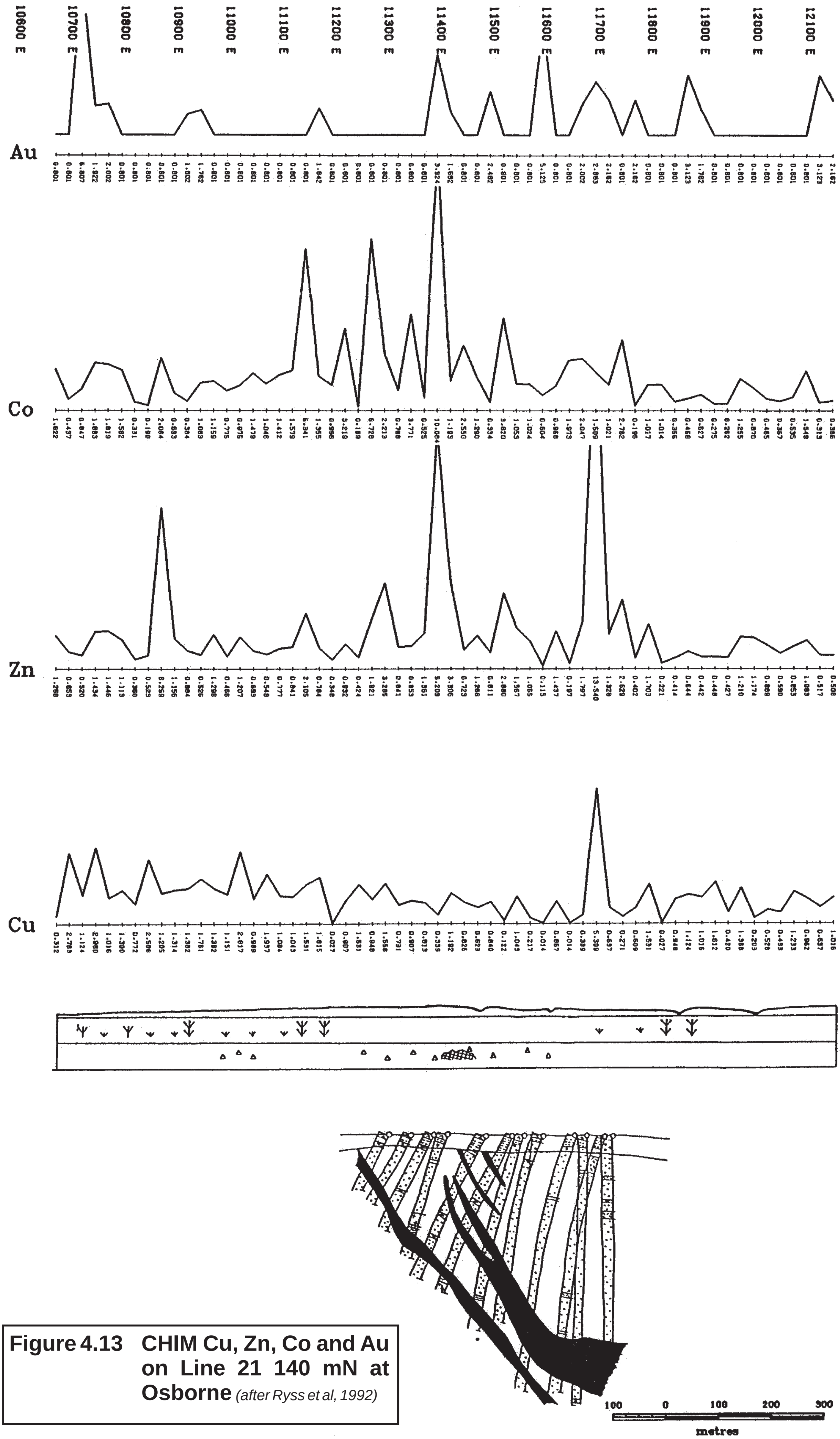

Figure 4.13 CHIM Cu, Zn, Co and Au on Line 21 140 mN at Osborne *(after Ryss et al, 1992)*

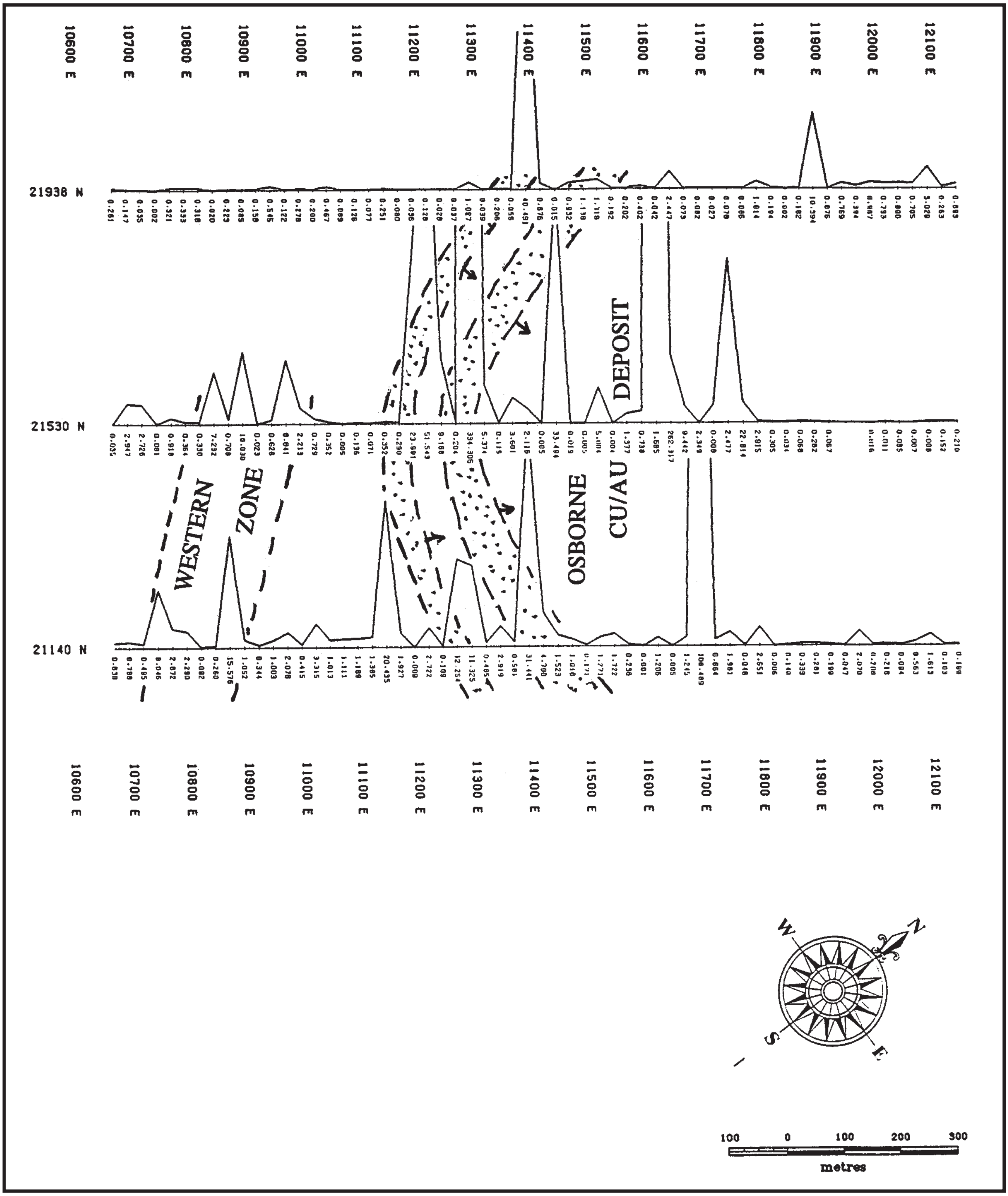

Figure 4.14 CHIM Cu x Zn x Co in plan at Osborne *(after Ryss et al, 1992)*

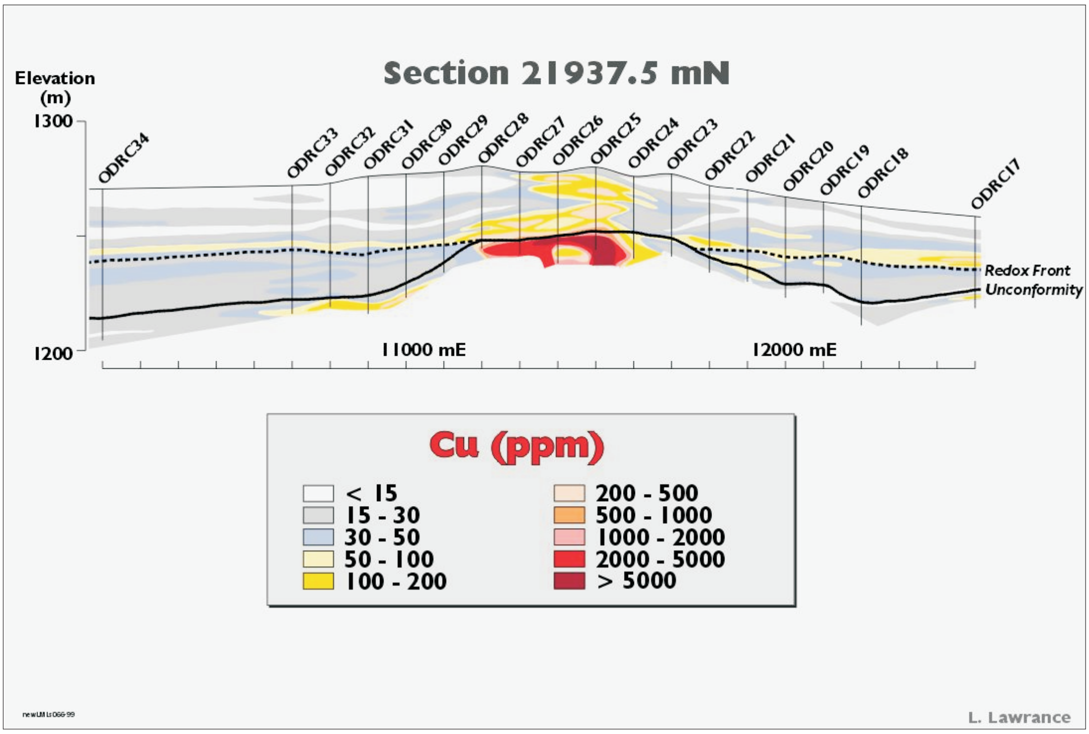

Figure 4.15 **Distribution of Cu within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia** *(after Lawrance, 1999)*

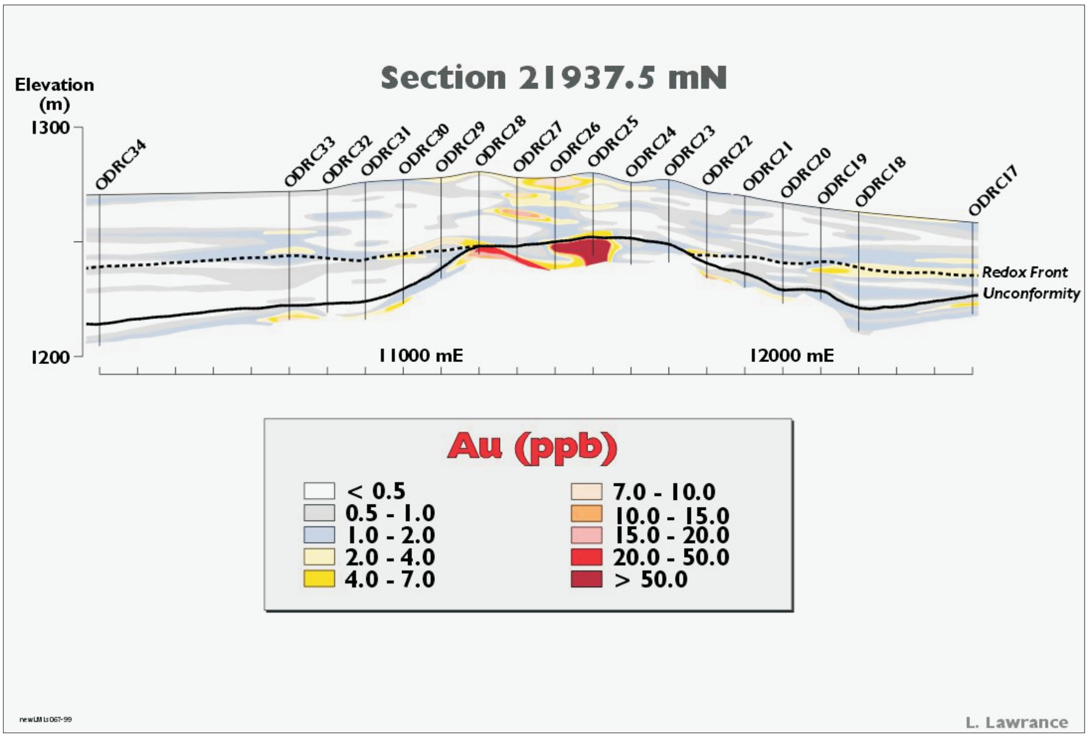

Figure 4.16 **Distribution of Au within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia** *(after Lawrance, 1999)*

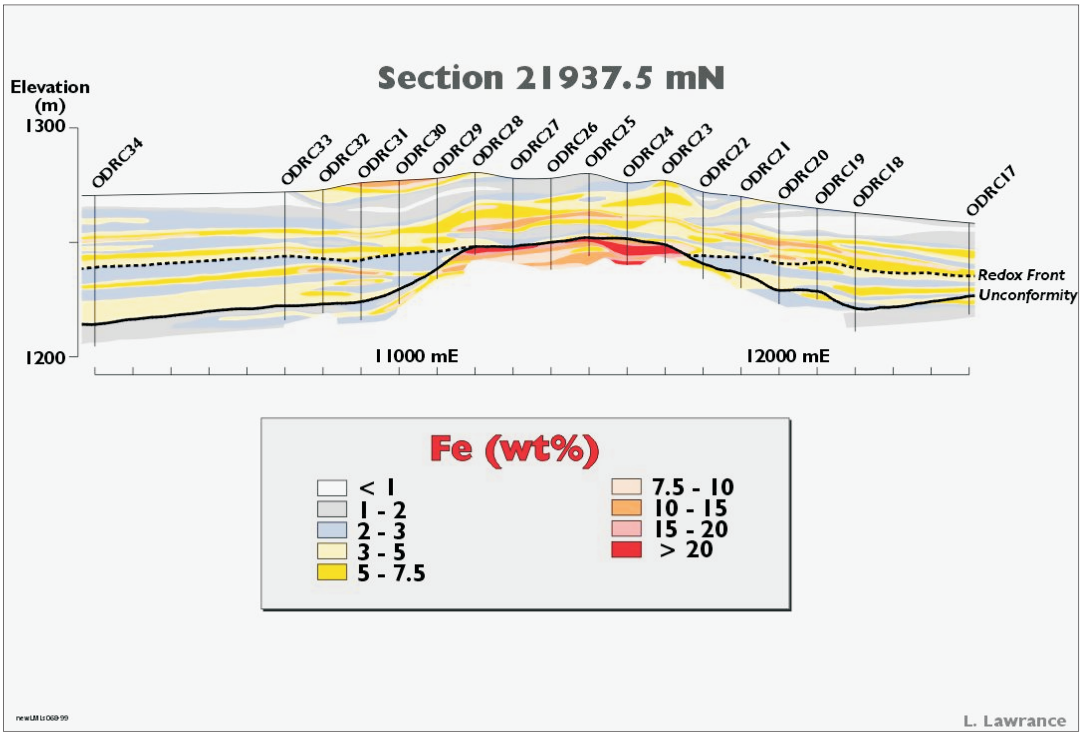

Figure 4.17 **Distribution of Fe within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia** *(after Lawrance, 1999)*

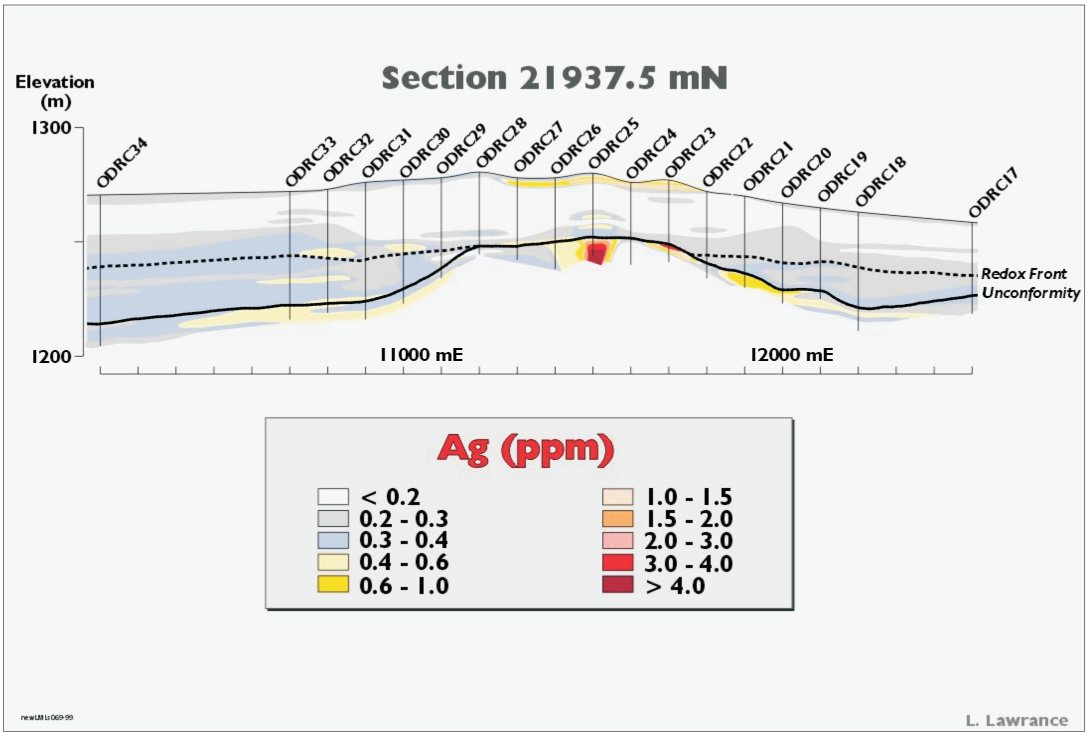

Figure 4.18 **Distribution of Ag within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia** *(after Lawrance, 1999)*

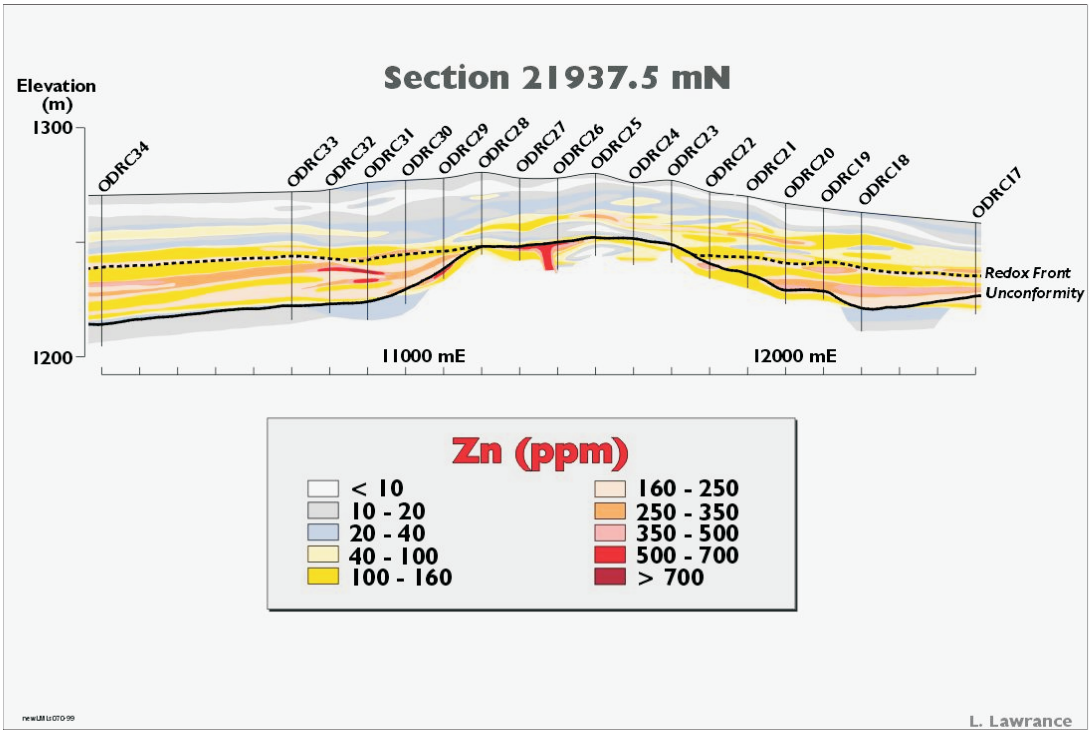

Figure 4.19 Distribution of Zn within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia *(after Lawrance, 1999)*

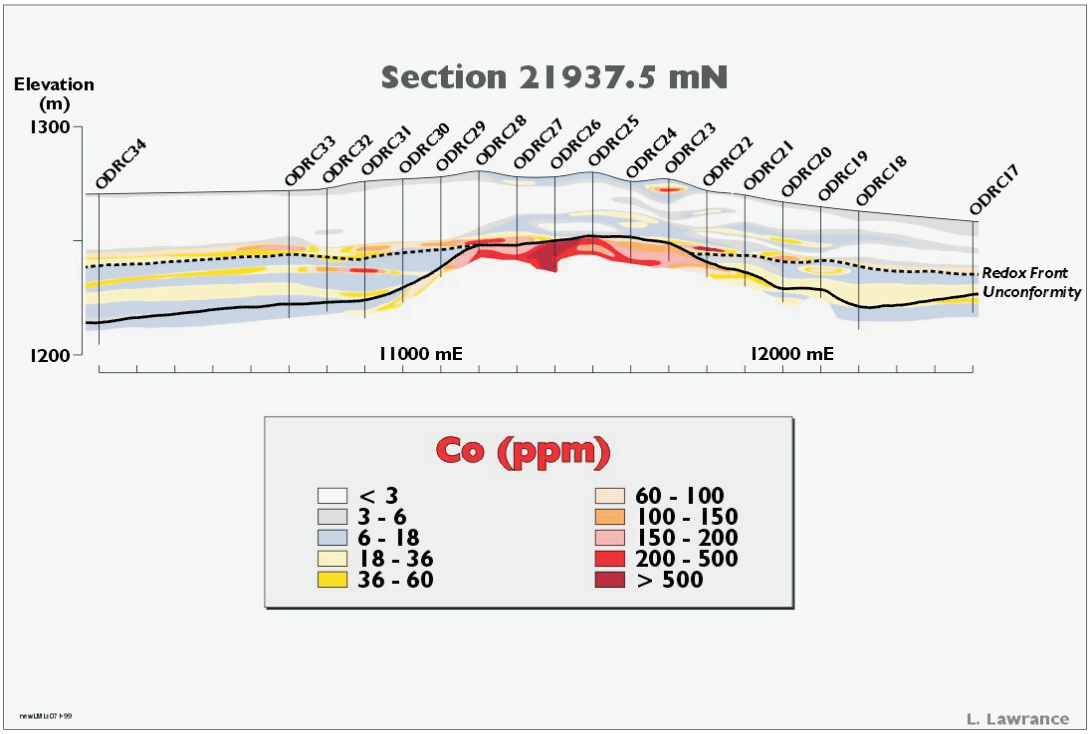

Figure 4.20 Distribution of Co within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia *(after Lawrance, 1999)*

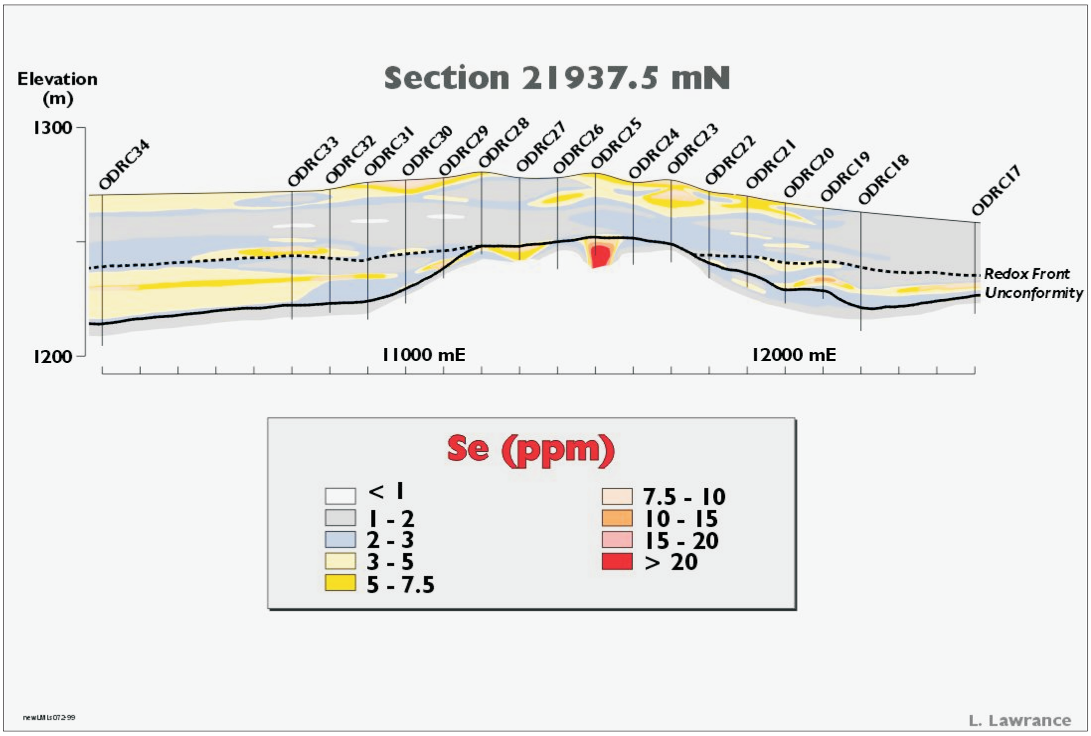

Figure 4.21 **Distribution of Se within Mesozoic cover on Section 21 937.5 mN over the buried Osborne Cu-Au deposit, Northern Queensland, Australia** *(after Lawrance, 1999)*

Lawrance (1999) indicates that three styles of mineralisation were intersected in the basement subcrop.

- The main zone, as intersected in ODRC 25. This indicated Cu (6.4%), Co (1180 ppm), Mo (850 ppm), Se (52 ppm), Bi (35 ppm), Ag (4 ppm), Au (0.5 ppm), Cd (1.4 ppm), Fe (22%) and Mn (0.7%) in both secondary and primary mineralisation.
- A less prominent mineralised zone, exemplified by ODRC 27 with Cu (0.5%), Co (220 ppm), Zn (630 ppm), As (48 ppm), Se (8.5 ppm), Bi (2.8 ppm), Au (0.03 ppm), Fe (17%) and Mn (860 ppm) and
- A subtle zone, exemplified by ODRC 23 with Ag (3.5 ppm) and Cd (1 ppm).

The dispersion of these elements appears to be associated with the paleo-redox zone that intersects the main gossan, but is truncated around the basement subcrop by the unconformity. In the Mesozoic cover, there are five distinct zones of sub-horizontal anomalism (Lawrance, 1999).

- The near surface zone (0-5 m). Anomalous for Au, Cu, Ag, Bi, Se and Mo.
- In the dispersion plume, in the oxidised upper profile, directly above the mineralisation. Anomalous for Au, Cu, Fe and Bi.
- In the paleo-redox zone. Anomalous for Au, Zn, Pb, Fe and Mn.
- In the redox zone. Anomalous for Au, Cu, Ag, Zn, Cd, Pb, Co, Fe, Mn, Se and Mo.
- In the embryo-redox zone. Anomalous for Zn, Cd, Pb, Co, Fe, Mn, and Se.

This dispersions form a "Christmas tree" pattern above the orebody subcrop, especially for Cu and Au *(Figures 4. 15 and 4.16)*. Other elements show stronger lateral dispersion – Fe, Zn, Co and Se *(Figures 4.17-21)*. The goethitic redox zone is the most strongly anomalous and laterally extensive of the anomalous zones. Coherent anomalies for Fe, Mn, Au, Cu, Co, and Zn extend over 1000 m to the limit of the section on both sides of the subcrop. The paleo-redox zone by contrast is the least anomalous in trace elements of the redox zones (Lawrance, 1999).

The strongest concentrations in the near surface are for Cu, Au and Ag at 2-4 m depth, directly above the buried subcrop of the orebody. Mo, Se, Sb and Bi are associated with the ferricrete and As, Pb and Zn are not anomalous near surface. Maximum anomalies directly above the buried subcrop are 370 ppm Cu, 22 ppb Au and 0.9 ppm Ag. Maximum concentrations in the ferricrete were 2.5 ppb Au and 14 ppm Se, but only 16 ppm Cu (Lawrance, 1999).

Development of the plumes above the buried deposit is illustrated in *Figures 4.22-4.25* (Lawrance, 1999). It becomes clear that if the topography sloped away at a reasonable gradient, the redox plumes will reach the surface and contribute to the drainage and the surface soils. Such a mechanism is being suggested for the area NW of Ernest Henry in the Tommy Creek catchment (see elsewhere in this volume).

The Cl content of oxide concentrates was high in the early pit mining averaging ~3,400 ppm, which made the concentrates difficult to sell. The problem was caused by atacamite $Cu_2Cl(OH)_3$. The penalty element had gone unrecognised through the feasibility process, and it affected 270 000 t of oxide ore (Tullemans and Voulgaris, 1998). In the absence of knowledge to the contrary, it is suggested this might have produced a Cl leakage anomaly at surface as occurs at Eloise. Lawrance does not discuss halogens in her paper.

Molybdenite

In the course of age dating, Re concentrations in molybdenite were found to be 338.2±0.3 and 396.2±0.3 ppm and Os was 5724±6 and 6729±13 ppb (Gauthier et al, 2001).

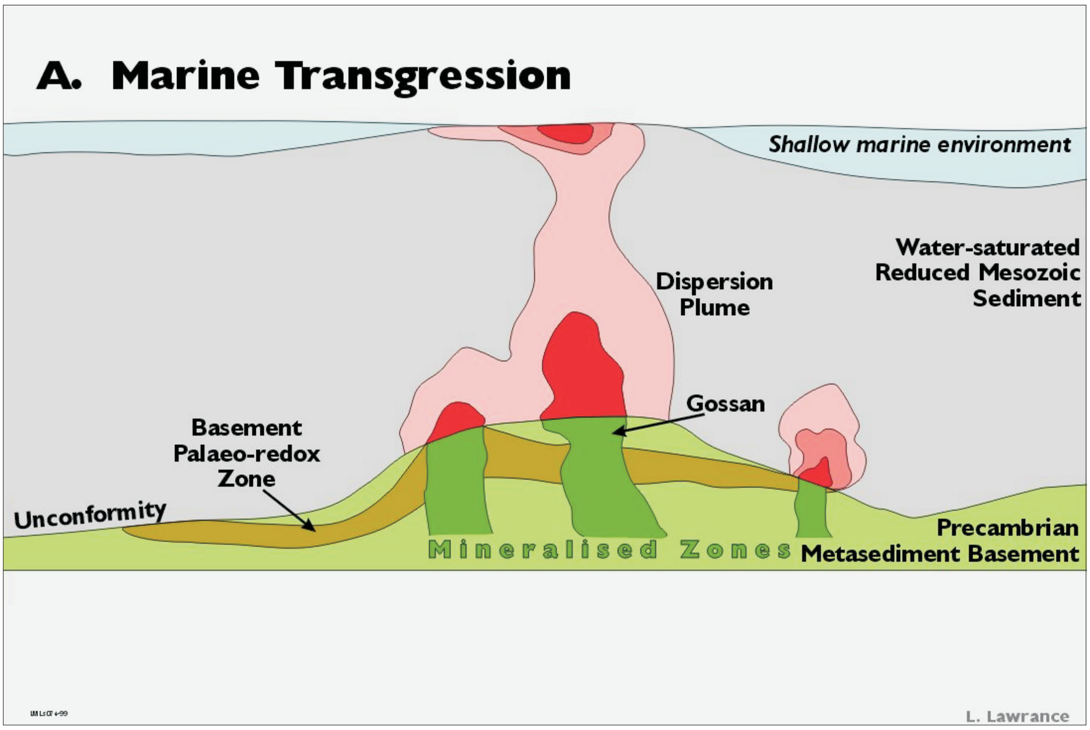

Figure 4.22 Model of trace element dispersion into unmineralised Mesozoic cover over the buried Osborne Cu-Au deposit, Northern Queensland, Australia - A. Marine Transgression *(after Lawrance, 1999)*

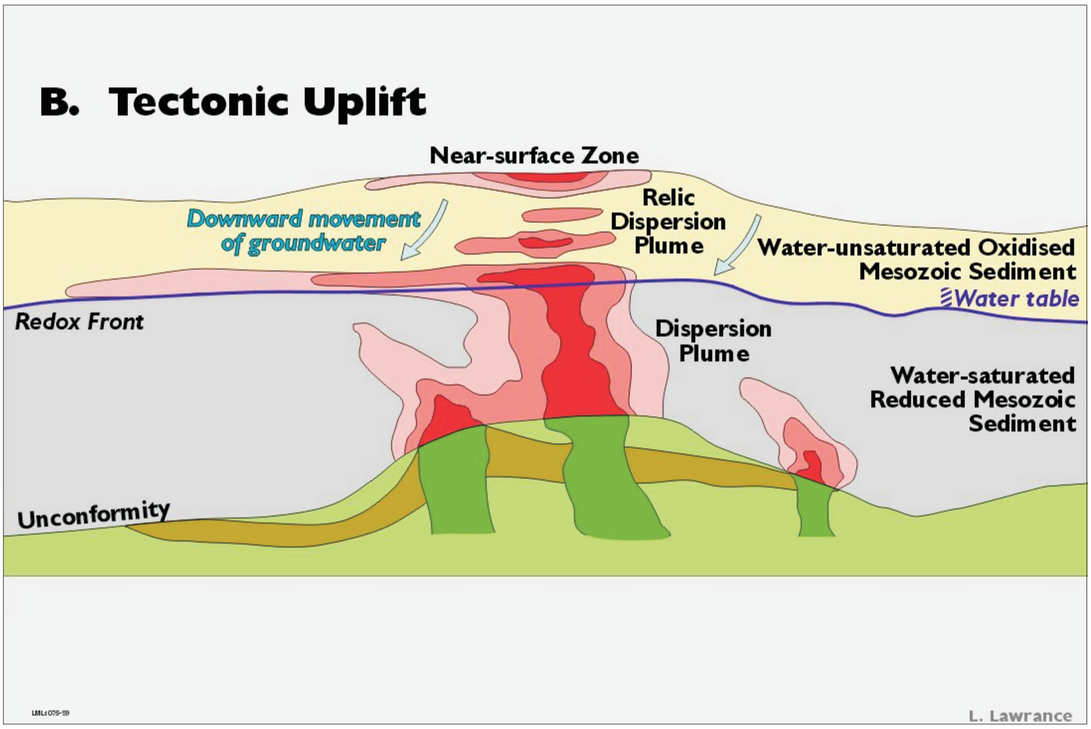

Figure 4.23 Model of trace element dispersion into unmineralised Mesozoic cover over the buried Osborne Cu-Au deposit, Northern Queensland, Australia - B. Tectonic Uplift *(after Lawrance, 1999)*

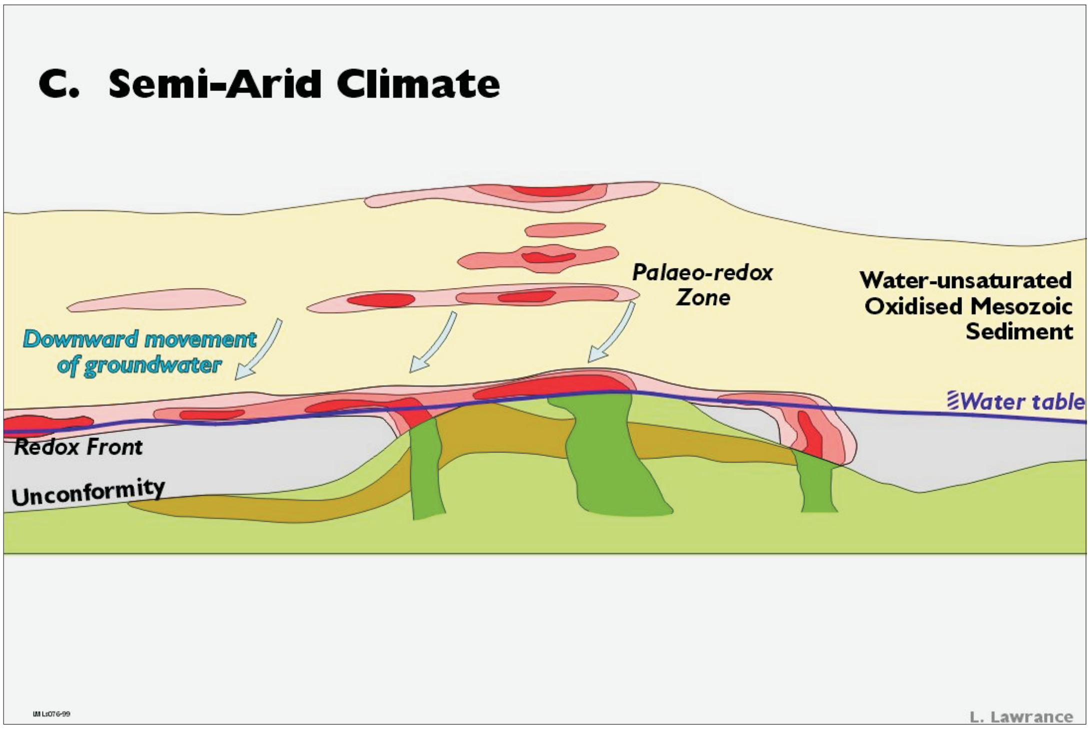

Figure 4.24 Model of trace element dispersion into unmineralised Mesozoic cover over the buried Osborne Cu-Au deposit, Northern Queensland, Australia - C. Semi-arid climate *(after Lawrance, 1999)*

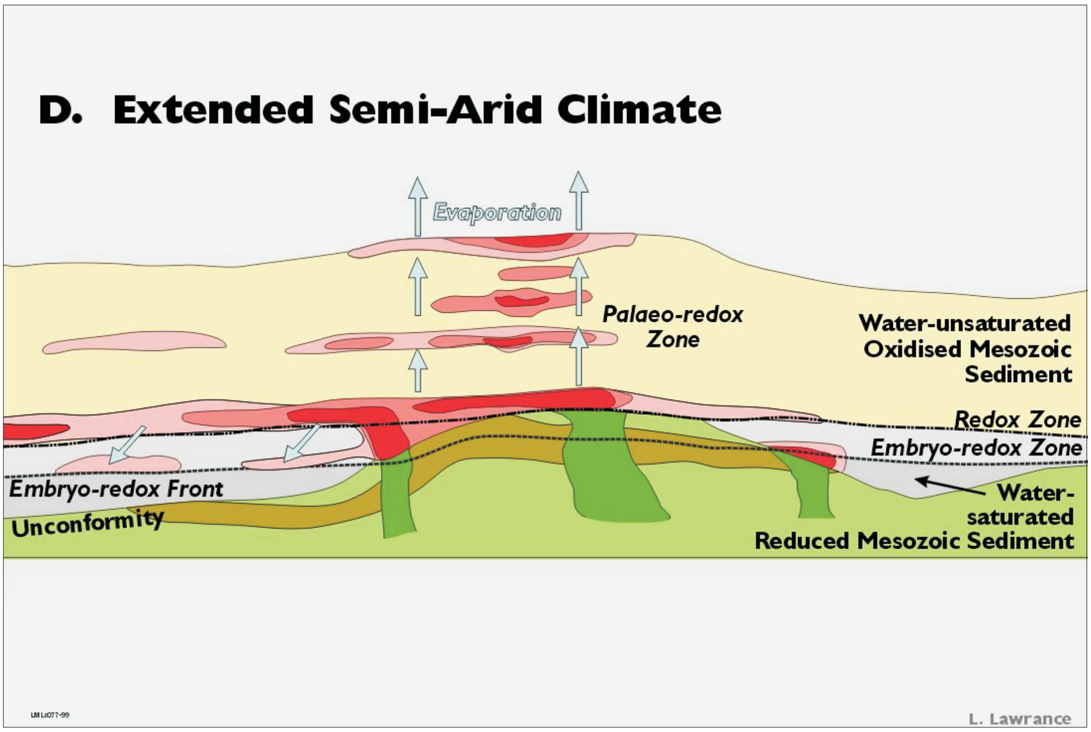

Figure 4.25 Model of trace element dispersion into unmineralised Mesozoic cover over the buried Osborne Cu-Au deposit, Northern Queensland, Australia - D. Extended semi-arid climate *(after Lawrance, 1999)*

Geophysics

Magnetics *(Figures 4.26, 4.27 and 4.28)*

Osborne is near the limit of the MIM NWQ Airborne regional magnetic survey, 1990. Nevertheless it is coincident with a strong total magnetic intensity anomaly (reduced to pole) *(Figure 4.26)*. The detail in the coverage though is less than in other areas. Ground magnetic coverage shows the anomaly to be NNW oriented with two peaks ~540 m apart. The anomaly has a sharp cut-off to the west and a gradual one to the east, which reflects the shallow east dip of the ironstones *(Figure 4.27)* (Anderson and Logan, 1992).

The aeromagnetic anomaly was first recognised by Newmont in 1974, in their search for Pegmont-style base metal mineralisation. They drilled it to find a best intersection of 0.13 ppm Au and 230 ppm Cu, after which they relinquished the area. CSR Limited and Billiton acquired the ground in 1985, and covered the original anomaly with ground magnetics, IP and 16 shallow RC drill holes. The ground magnetics was conducted at a spacing of 5 or 10 m, on lines originally 70 m apart, that were later infilled to 35 m. The instruments used were Geometrics G856 magnetometers. Profiles and geology are shown in *Figure 4.28* (Anderson and Logan, 1992).

TEM *(Figures 4.29 and 4.30)*

Fixed loop TEM involving transmitter loops of 600 m x 300 m, with the long axis parallel to the strike, was undertaken shortly after the magnetics. These and limited follow-up Sirotem moving-loop traverses, indicated a conductive zone coincident with the magnetic anomaly in the southern part of the grid. Down-hole TEM indicated the source to be weakly mineralised ironstone, but it was not clear why the anomaly was restricted to the southern part of the magnetic trend (Anderson and Logan, 1992) *(Figure 4.29)*. Perhaps this had something to do with the enlarging resource to the south that the later drilling revealed (Tullemans and Voulgaris, 1998). Sections at 21 360 mN, where the east dip of the ironstone is relatively steep, and at 21 780 mN, where the east dip is shallower, produce asymmetric and symmetric Sirotem profiles respectively *(Figure 4.30)*.

Down hole EM conducted after drill holes were completed usefully pointed to off-hole conductors up to 200 m away. With hindsight it became clear that with greater use of down-hole EM, some of the discoveries could have been made two to four years earlier than they were (Tullemans and Voulgaris, 1998).

IP

The CSR dipole-dipole IP survey defined a broadly anomalous chargeable zone, coincident with the ground magnetic anomalies (Gidley, 1988).

Gravity

Five detailed gravity traverses indicate close agreement between known density distribution of ironstones and the observed gravity. The gravity highs however do not show coincidence with best Cu-Au grades (Anderson and Logan, 1992).

Mise-à masse

Mise-à masse surveys with the transmitting electrodes placed in high grade intersections, generally indicated a lack of electrical continuity within the mineralisation, suggesting that higher sulphide content does not imply higher conductivity (Anderson and Logan, 1992).

Radio Imaging *(Figure 4.31)*

Hole to hole tomography using a Radio Imaging Technique (RIM) was trialed by Mine Exploration and Technical Services Pty Ltd (METS) *(Figure 4.31)*. It was concluded from the test that the

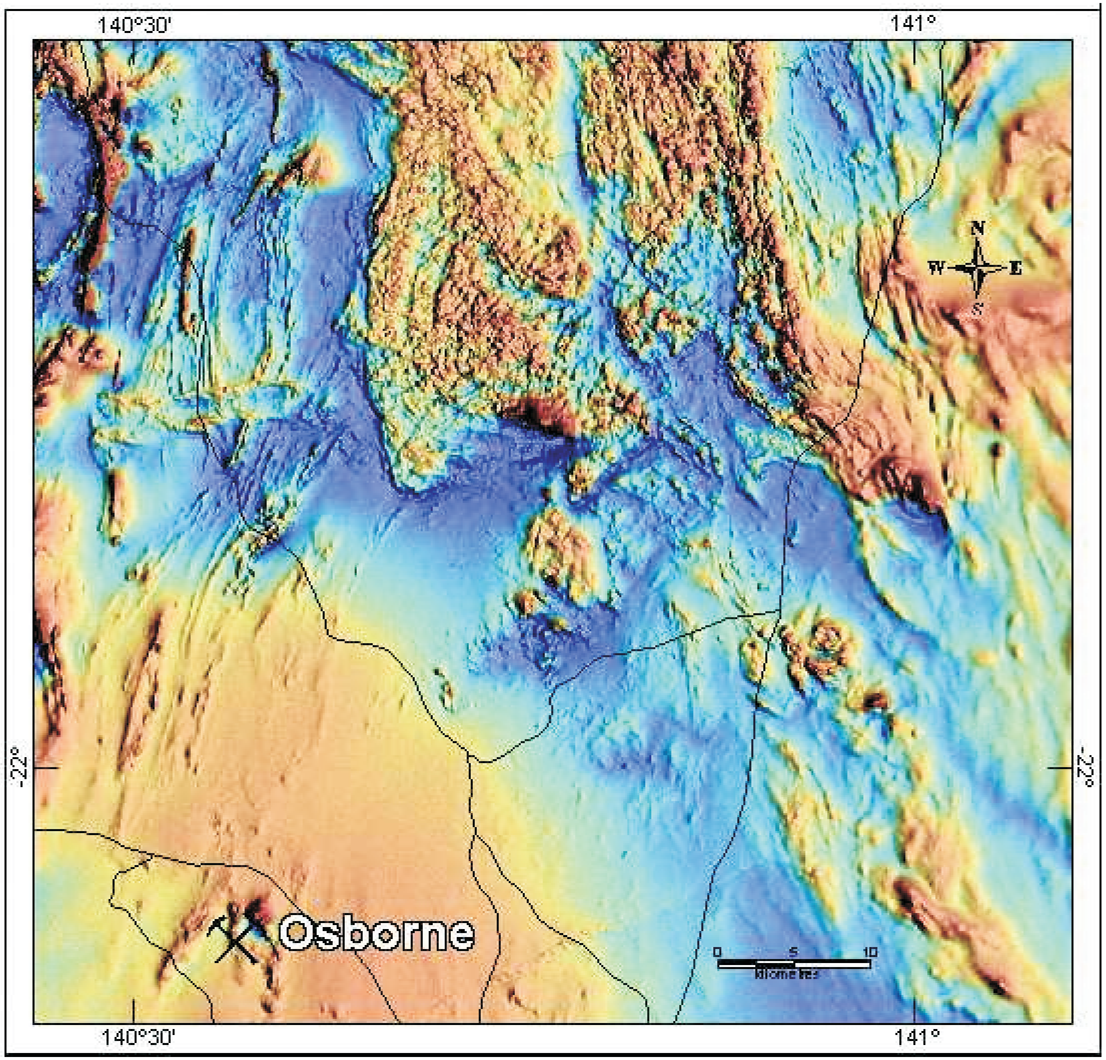

Figure 4.26 Total magnetic intensity reduced to pole at Osborne *(after MIM NWQ Airbourne magnetic survey, 1990)*

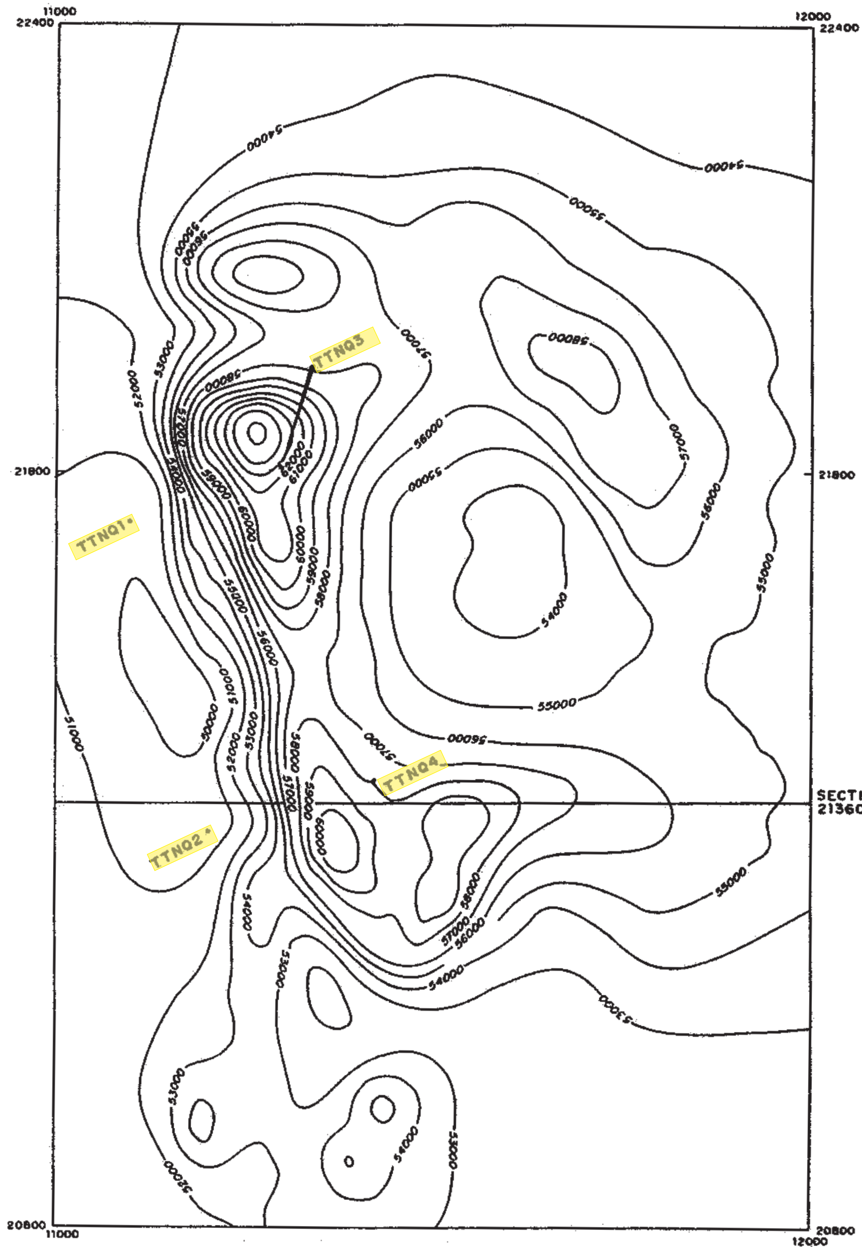

Figure 4.27 Total magnetic intensity for ground magnetic data at Osborne, with early drill holes indicated *(after Anderson and Logan, 1992)*

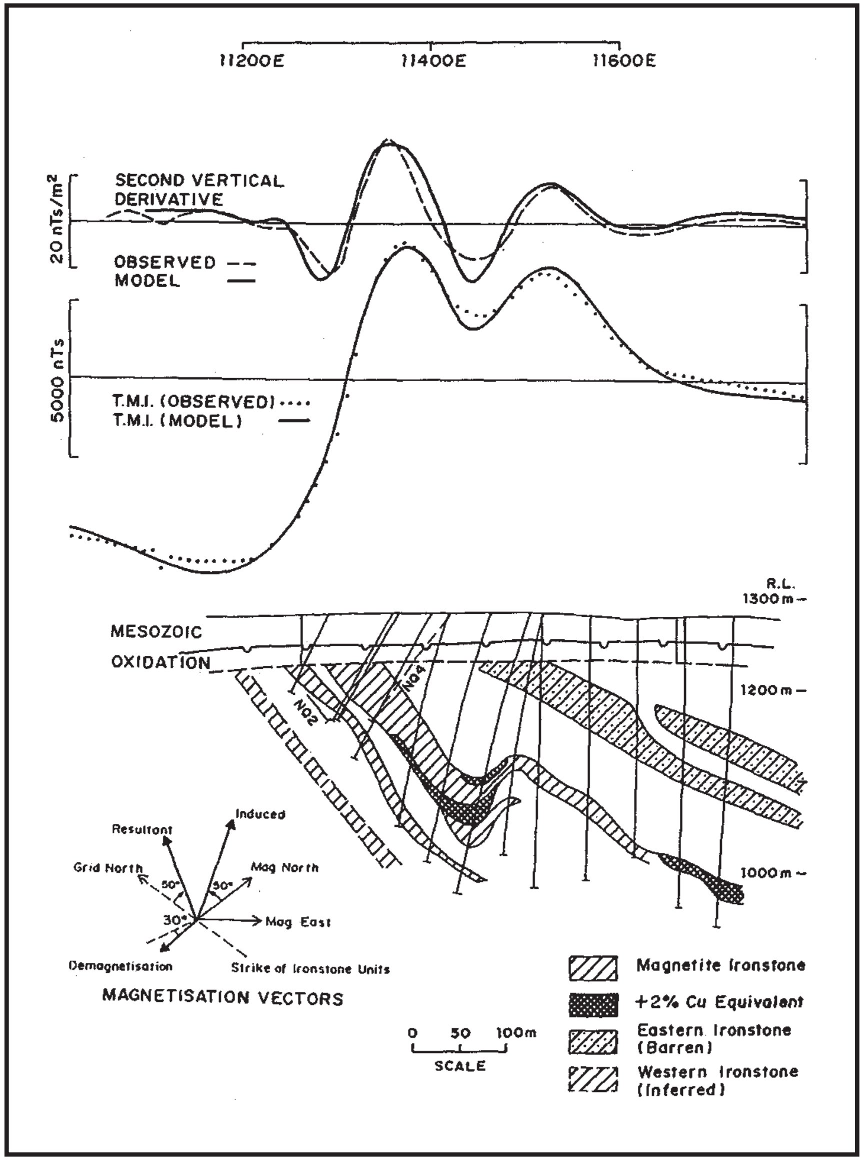

Figure 4.28 Ground magnetic data on section 21 315 mN showing model results, and TMI relative to the geology *(after Anderson and Logan, 1992)*

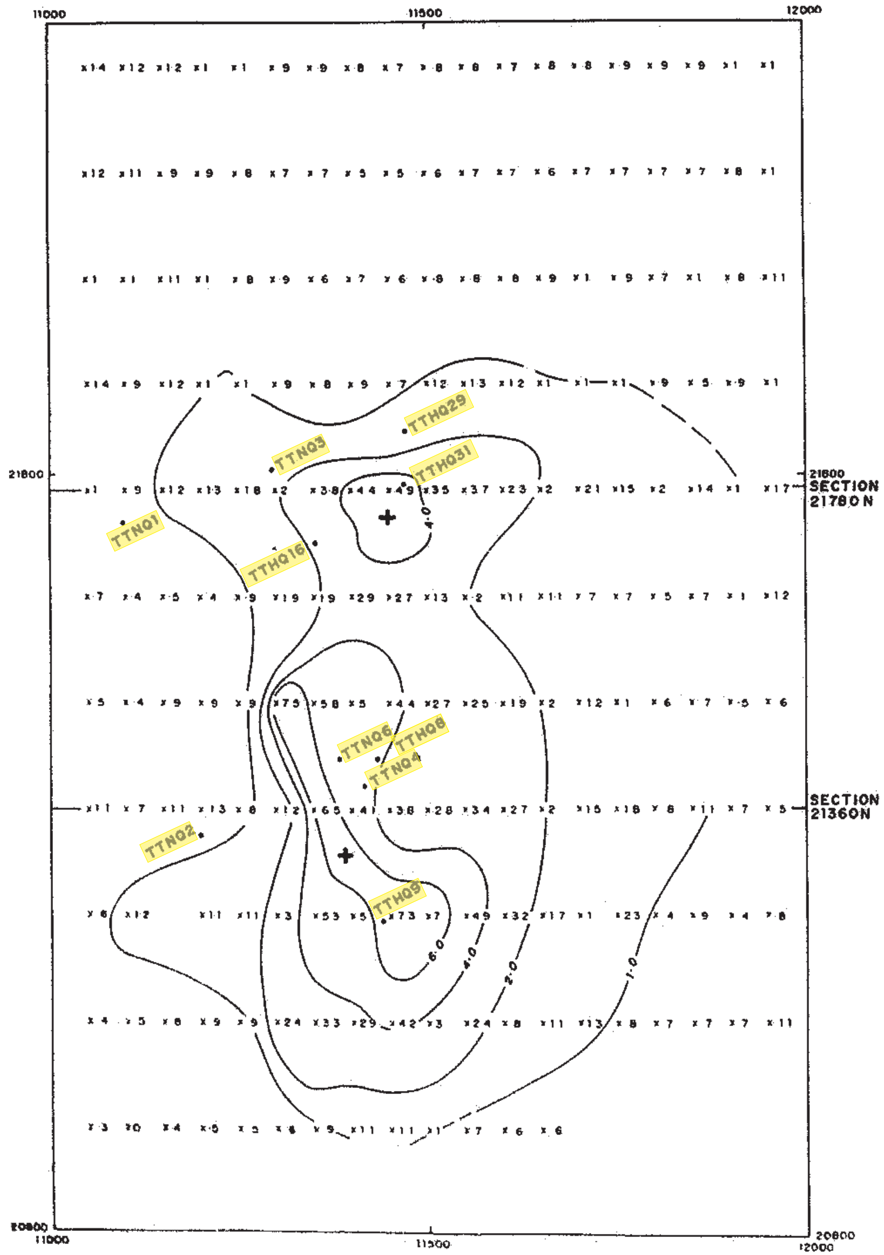

Figure 4.29 Contours for "late-time" moving loop TEM response - Sirotem channel 14 (delay time 11.6 ms) at Osborne *(after Anderson and Logan, 1992)*

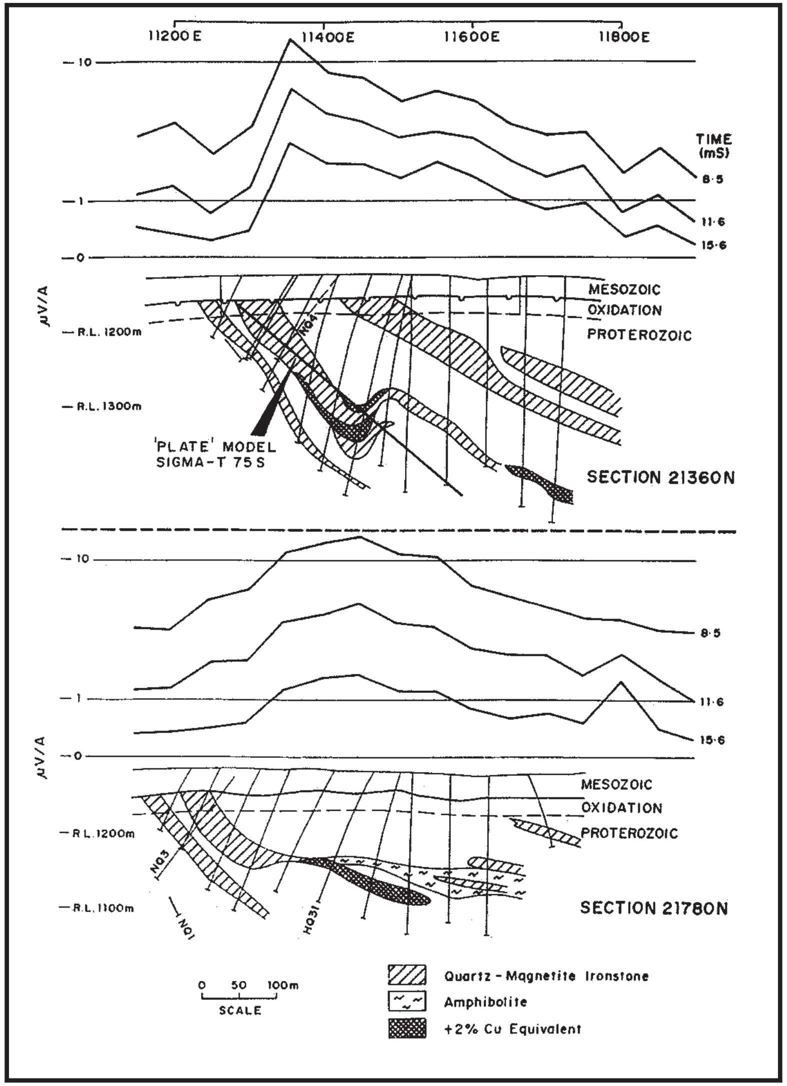

Figure 4.30 **Comparisons between moving-loop TEM responses on sections 21 360 mN and 21 780 mN at Osborne** *(after Anderson and Logan, 1992)*

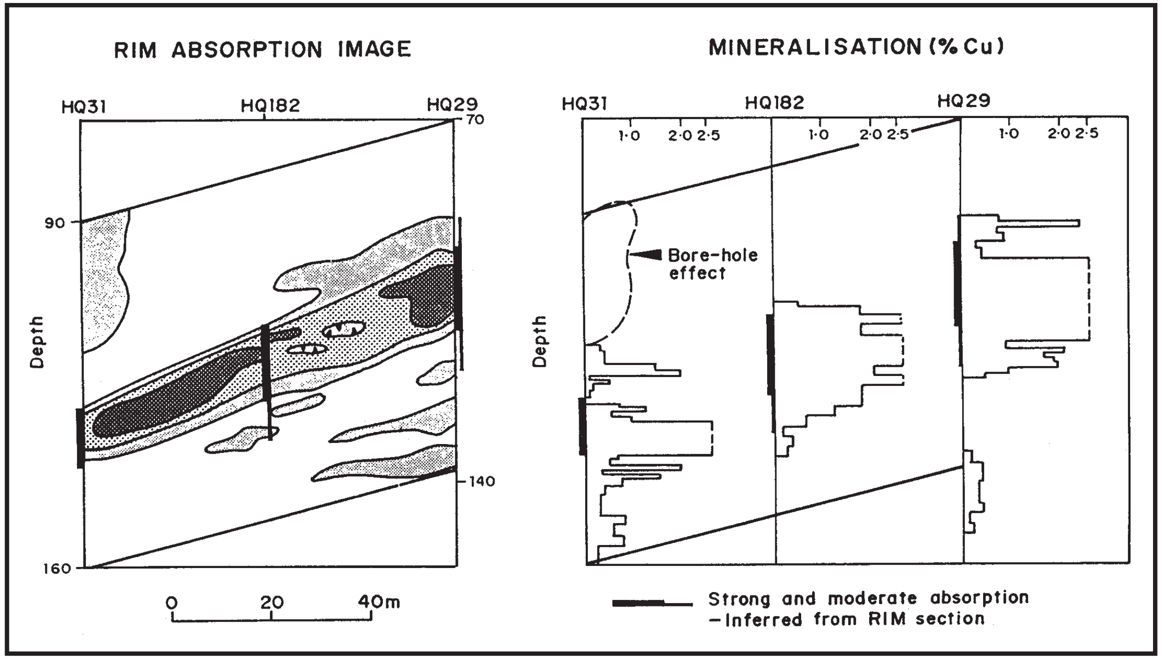

Figure 4.31 **RIM absorption image compared to drill assays in three holes at Osborne** *(after Anderson and Logan, 1992)*

technique might assist in defining the distribution of mineralisation between holes. Further tests were planned in 1992 (Anderson and Logan, 1992).

Self potential
Hall advises that the SP method produces anomalies indicative of the orebody after rain, but SP responses after the ground has dried out are not so impressive (pers. comm. 2001).

Initial Drilling
Early drilling by Newmont and others in 1976 produced a best intersection of 2 m @ 0.13 g/t Au and 0.023% Cu (Adshead et al, 1998).

In 1985 drilling by CSR and Billiton (11 RC holes) indicated a zone of anomalous Cu-Au mineralisation in ironstones (Adshead et al, 1998).

During the second half of 1989, four core holes drilled into the shallower northern part of the North-East anomaly, indicated high grade Cu-Au mineralisation. One of these was the discovery hole TTHQ029, which intersected 32 m @ 5.8 % Cu and 3.2 g/t Au from 98 m. This confirmed potential for an economic deposit within the ironstone sequence (Keough, 1993).

Drilling to bring the project to resource status, required 400 holes (100 km) (Keough, 1993).

The recognition that the preferred host rock was not the ironstone, but the silica flooded rock, provided the impetus for drilling non-ironstone targets. This led initially to the discovery of the 2N orebody and subsequently the 3E deposit in albite altered rocks distal to the weakly mineralised Upper Ironstone (Tullemans and Voulgaris, 1998).

Reasons for the Discovery
The Osborne discovery was made because (Tullemans and Voulgaris, 1998):

- Of the recognition of the connection between Cu-Au mineralisation and ironstones.
- Aeromagnetics was the primary exploration method, and it indicated anomalies in the covered terrain.
- Of the recognition of higher Cu-Au values in drill chips by CSR compared to the drill results of earlier explorers.
- Of the recognition of abundant sub-economic intersections in the ironstone.
- Of the recognition of the significance of the silica flooding and its connection to high grade mineralisation.
- Persistence after four years of drilling involving 80 RC holes (9,811 m) and 36 diamond drill holes (3,310 m) and not getting an economic intersection.

The discovery was delayed because of (Tullemans and Voulgaris, 1998):

- Selective sampling practises in drill holes, which meant some of the critical areas were not sampled.
- A loss of faith in ground and down-hole EM. If the down-hole EM in particular had been implemented from the beginning, the discoveries would have come much earlier.
- An emphasis on drilling the up-dip portions of the target horizons, because of a desire to find open-pittable mineralisation. The better higher-grade mineralisation was at depth.
- The delay in recognising the significance of the silica flooded rock as the main orebody host even when it was sometimes close to the ironstones *(Figure 4.32)*.

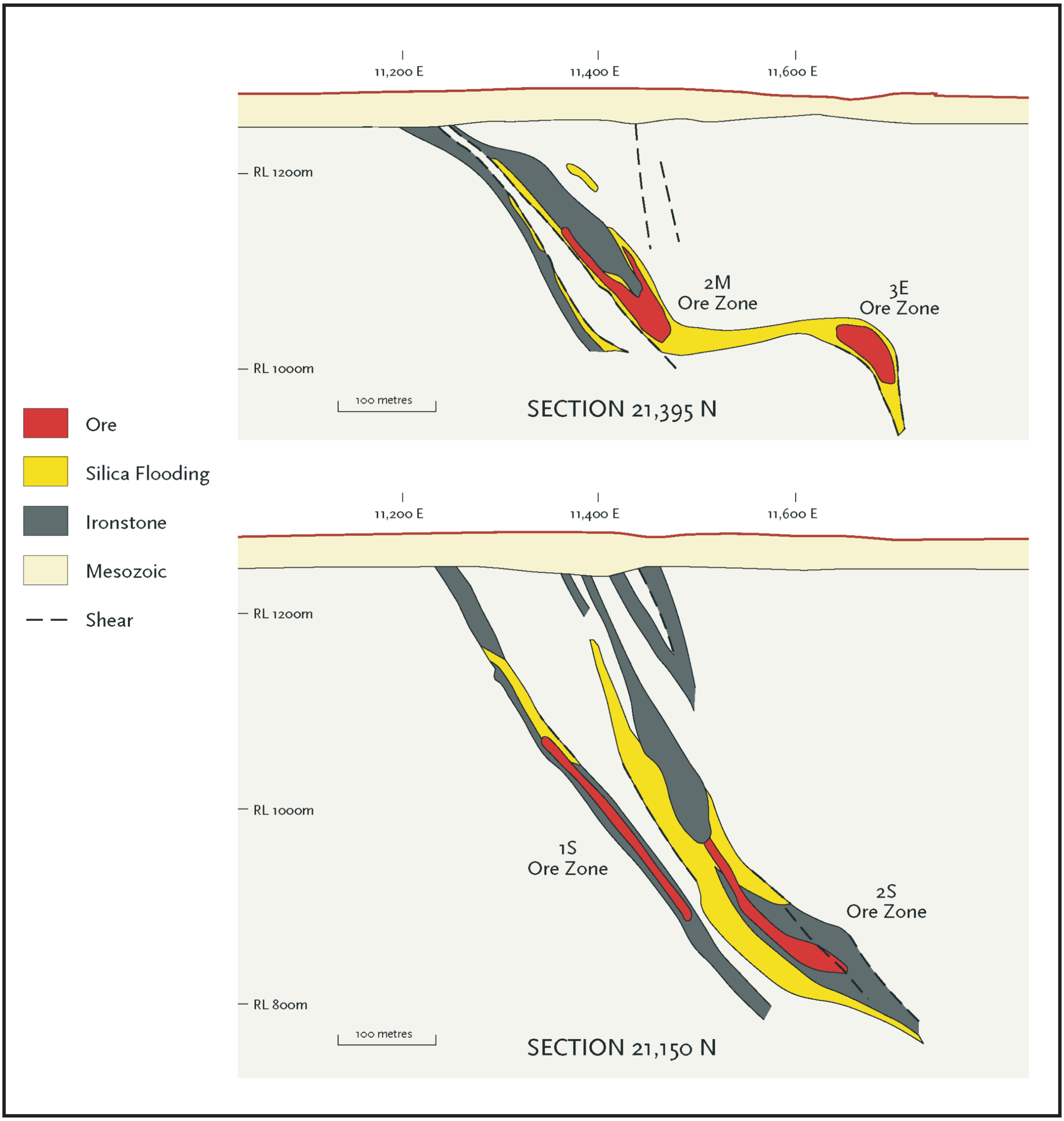

Figure 4.32 Osborne cross sections at 21 395 mN and 21 150 mN showing zones of silica-flooded rock *(after fb_osborne.pdf, at the Placer Dome internet site, 2001)*

Discovery and Development

Discovery Outcrop

The deposit is buried under variably cemented silcrete (up to 15 m thick) and 20-40 m of Mesozoic siltstone and mudstone. Consequently there was no outcrop.

Discovery

An Authority to Prospect was granted to a consortium of Newmont Propriety Limited, ICI Australia Limited and Dampier Mining Company Limited in 1975 to explore in the Osborne area. This resulted in aeromagnetic and electromagnetic surveys being flown, several anomalies being identified including a strong magnetic anomaly at Osborne, and follow-up mapping and shallow percussion drilling in areas of no outcrop. The best intersection was 2 m @ 0.13 g/t Au and 0.023% Cu and the tenement was relinquished in late 1976 (Adshead et al, 1998).

In 1985 a joint venture between Billiton Limited and CSR Limited acquired the area with a view of searching for Starra style orebodies which had been found some 50 km to the NNW. A programme of 11 RC holes found quartz-magnetite ironstone with anomalous Cu and Au. Subsequent airborne and ground magnetic surveys, together with IP indicated four anomalies, the largest of which eventually was shown to host the deposit (Adshead et al, 1998).

In 1998 Placer Pacific Exploration Limited acquired the CSR exploration group, became the manager of the JV, and drilled the coincident ground magnetic and IP anomaly. From 1985-89, 36 core holes (3310 m) and 80 RC holes (9,811 m) had outlined a strike length of 800 m of low grade Cu-Au ironstone. The discovery hole came in 1989, when TTHQ029 intersected 32 m @ 5.8 % Cu and 3.2 g/t Au from 98 m. Concurrently the project geologist, Robert Osborne died, and the previously unimaginatively named Trough Tank Prospect, was renamed Osborne (Adshead, 1998).

By June 1993, Placer had become the sole owner of the property, and a major step-out drilling programme was undertaken. This involved 475 holes for 59,272 m of RC and 30,335 m of core drilling. It resulted in a Measured and Indicated Mineral Resource of 11.2 Mt @ 3.51% Cu and 1.49 g/t Au (Adshead, 1998).

Cost of Operation

Total costs for mining, milling, administration, transport, smelting and royalties in 1999 were US$58.97/t or US$0.52/lb Cu produced (Newmont fb_osborne pdf). Exploration costs are not known.

Development

After acquisition of the property in March 1993, Placer undertook successively pre-feasibility and feasibility surveys. In 1994, A$155M was approved for plant construction and mine development. Production started in August 1995 and by the end of the year, the oxide had been processed and sulphide was being treated. In 1996, underground production started, and excavation of the hoist and ventilation shafts were completed. Shaft equipping continued through 1997 and low-grade oxide stockpile material was milled in 1998. At the end of 1998, mine and mill expansion to 1.5 Mtpa was completed. Throughput in 1999 exceeded 1.5 Mt due in part to installation of an underground crushing system (Brook Hunt, 2000).

Mining

The initial mine plan envisaged open pit mining for 18 months followed by underground operations for 10 years. The open pit mining was by a contactor – Eltin Ltd. (Brook Hunt, 2000).

Underground production started in April 1996. Access to the underground workings was via a decline from the bottom of the open pit. A 700 m deep shaft was completed in 1998, which hauls ore to the surface (Brook Hunt, 2000).

The mining cost per tonne was US$18.82 in 1999 (Placer Dome fb_osborne.pdf).

Metallurgy

Cu and pyrite concentrates are produced by crushing, grinding, gravity concentration and flotation methods. Cu concentrate is trucked to Phosphate Hill, and then railed to Townsville for export to Japan (Brook Hunt, 2000).

The milling cost per tonne was US$7.40 in 1999 (Placer Dome fb_osborne pdf).

Ownership

The property is owned by Placer Dome Inc. (100%).

References

Adshead, N.D., Voulgaris, P. and Muscio, V.N. (1998) Osborne copper-gold deposit, in *Geology of Australian and Papua New Guinean Mineral Deposits* (Ed. D.A. Berkman and D.H. Mackenzie), pp. 793-800 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Anderson, Chris G. and Logan, Keiran J. (1992) The history and current status of geophysical exploration at the Osborne Cu & Au deposit, Mt. Isa, Exploration Geophysics 23: 1-8.

Birrell, R.D., Mann, A.W. and Lawrance, L.M. (1993) Results of a mobile Metal Ions Study, Emu Plains, NT, Menninnie Dam, SA, Trough Tank, Q'ld and Hunters Dam, SA, Appendix VIII in *Geoelectrochemical Test Programme in Australia, P355A*. pp. 25, Ed. Ryss et al (1992).

Blake, D.H., Jaques, A.L. and Donchak, P.J.T. (1983) Selwyn region, Queensland, 1: 100 000 Geological Map Commentary, Bureau of Mineral Resources, Geology & Geophysics, Australian Government Publishing Service, Canberra 1983.

Brook Hunt, Mining & metal industry consultants (2000) Osborne, Australia, in *Copper Mines Cost Study (1996-2014),* Volume 3 of 8, Australasia and Asia, pp. 421-431.

Bultitude, R.J., Blake, D.H., Donchak, P.J.T. and Mock, C.M. (1982) Duchess Region, Queensland, 1: 100 000 Geological Map Commentary, Bureau of Mineral Resources, Geology & Geophysics, Australian Government Publishing Service, Canberra 1982, 35 p.

Gauthier, L., Hall, G., Stein, H. and Schaltegger, U. (2001) The Osborne deposit, Cloncurry District: a 1595 Ma Cu-Au skarn deposit, in *2001: A hydrothermal Odyssey,* Extended Conference Abstracts, Townsville, 17-19th May, 2001, Ed. Patrick J. Williams (James Cook University EGRU), pp. 58-59.

Gidley, Peter R. (1988) The geophysics of the Trough Tank gold-copper prospect, Australia, Bull. Aust. Soc. Explor. Geophys. 19:76-78.

Keough, David (1993) The Osborne Deposit-Its discovery, geology and development, in *Carpentaria and Mount Isa regional development forum, North West Queensland branch of the Australasian Institute of Mining and Metallurgy,* pp.69-70.

Lawrance, Louisa (1999) Multi-element dispersion in Mesozoic Basin sediment over the Osborne deposit, Northern Queensland, Australia: Implications for regional geochemical exploration in buried terrain, in *Exploration under cover Sydney, 1999,* AIG Bulletin 28: 73-81.

Lord, J.R. (1999) Osborne, Queensland, in *Cu-Au-Fe-Oxide Systems: Examples of Mineral deposits from around the world,* Hirlstock Pty Ltd Report for M.I.M. Exploration Pty Ltd, pp. 98 - 109.

Perkins, C. and Wyborn, L.A.I. (1998) Age of Cu-Au mineralisation, Cloncurry district, Mt. Isa Inlier, Queensland as determined by $^{40}Ar/^{39}Ar$ dating, Aust. Jour. Earth Sci. 45:233-246.

Rubenach, M., Adshead, N., Oliver, N., Tullemans, F. and Stein, H. (2001) The Osborne deposit: Geochronology, and genesis of mineralisation in relation to host albitites and ironstones, in *2001: A hydrothermal Odyssey*, Extended Conference Abstracts, Townsville, 17-19th May, 2001, Ed. Patrick J. Williams (James Cook University EGRU), pp. 172-173.

Ryss, Y.S., Voroshilov, N. and Seigel, H.O. (1992) Geoelectrochemical Test Programme in Australia, on behalf of The Australian Mineral Industries Research Association Limited, Project P355A. pp. 35 + VIII Appendices.

Switzer, Cameron and Huddy, Chris (1998) Visit to Osborne Cu-Au mine, MIMEX Technical Memorandum 1998/013, 3 pages.

Tullemans, F.J. and Voulgaris, P. (1998) The role of geology and exploration within the mining cycle at the Osborne Mine, NW Queensland, in *AusIMM '98, The Mining Cycle, 19-23 April 1998, Mount Isa, Queensland.* (The Australasian Institute of Mining and Metallurgy: Melbourne), pp. 159-169.

Williams, P.J., Pollard, P.J. and Blake, K.L. (1997) Osborne in *Short Course on Fe Oxide-Copper-Gold Deposits (The Candelaria-Ernest Henry-Olympic Dam Family)*, James Cook University Economic Geology Research Unit, pp. G-37 to G-41.

Non-authored Reference

_______ (1994) Osborne Project, N.W. Queensland, Environmental Management Overview Strategy, Project PJM 90041, 16 March 1994, Submitted for granting of Mining Lease, Placer Pacific Limited, 58 pages, 3 appendices.

_______ (1990) MIM NWQ Airborne magnetic survey.

Internet Sites

Bureau of Meteorology internet site (2001), Climate averages for Boulia for the period 1886-2001. http://www.bom.gov.au/climate/averages/tables/cw_038003.shtml

Placer Dome Internet site (2001) http://www.placerdome.com/properties/content/main.html

LIST OF FIGURES

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