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# CHINESE CHIM ELECTROGEOCHEMICAL METHOD: FIELD TRIALS 2005, SOUTH AUSTRALIA

*Adrian Fabris, John Keeling, Roger Fidler, Baohong Hou,  
Xianrong Luo and Nanshi Zeng.*

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# CONTENTS

ABSTRACT .....	1
1. INTRODUCTION .....	2
2. BACKGROUND .....	2
3. SOUTH AUSTRALIAN TRIALS .....	6
3.1 Methodology .....	8
3.2 Challenger Au Mine .....	8
3.2.1 Challenger Au Mine Survey.....	9
3.3 Kalkaroo Cu-Au-Mo Prospect.....	15
3.3.1 Kalkaroo Cu-Au-Mo Survey.....	16
3.4 Goulds Dam U Prospect .....	18
3.4.1 Goulds Dam U Prospect Survey.....	18
4. DISCUSSION .....	25
5. CONCLUSION .....	31
6. RECOMMENDATIONS .....	31
ACKNOWLEDGEMENTS .....	31
APPENDIX A: PLOTS OF CHIM AND SOIL SURVEY RESULTS FROM THE CHALLENGER GOLD MINE .....	38
REFERENCES.....	65

## FIGURES

<b><u>Figure</u></b>	<b><u>Title</u></b>	<b><u>Page No</u></b>
Figure 1	Component and field set up of the CHIM (a) Original Russian CHIM (b) 'Chinese' CHIM	4
Figure 2	Location map showing CHIM survey field sites	7
Figure 3	Plan showing the location of the CHIM survey sites in relation to the known subsurface extent of the Challenger Au ore shoots M1, M2 and M3. (i) Plan view (ii) Long-section (ore shoots projected onto section)	11
Figure 4	Plots of CHIM analyses (cathode plus anode) and soil surveys at the Challenger Au Mine. Soil results for samples from the bottom of CHIM electrode pits (~0.2 m depth) and digested using aqua regia, and soil samples collected during an earlier survey for Dominion Mining Ltd and digested by aqua regia and LocatOre (proprietary method). Two surveys ('A' and 'B') were completed perpendicular to the down plunge projection of M1, M2 and M3 ore shoots. Sections include drill holes projected onto the section. (i) Au, (ii) As, (iii) Ag	12
Figure 5	Plots of soil analyses at the Challenger Au Mine. Conductivity and Hg measurements are on samples taken from the bottom of electrode pits (~0.2 m depth). sections include drill holes projected onto the section	17
Figure 6	Kalkaroo location map (a) CHIM lines and recent drillholes overlaid on an orthoimage, (b) CHIM lines overlaid on an aeromagnetic image of the Kalkaroo South Dome	20
Figure 7	Plots of CHIM analyses along Line A at the Kalkaroo Cu-Au-Mo Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~ 0.2 m depth). (i) Au, Ag, Ad and Rb, (ii) Mo, Cu, Zn and W, (iii) U, V, Cd and Bi	21
Figure 8	Plots of Hg, conductivity, Fe, Mg and Ca analyses over Kalkaroo Line A	24
Figure 9	Plots of CHIM analyses along Line B at the Kalkaroo Cu-Au-Mo Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~ 0.2 m depth). (i) Au, Ag, Ad and Rb, (ii) Mo, Cu, Zn and W, (iii) U, V, Cd and Bi	27
Figure 10	Plots of Hg, conductivity, Fe, Mg and Ca analyses over Kalkaroo Line B	30
Figure 11	Goulds Dam locating map showing CHIM line and historic drill holes	32
Figure 12	Plots of CHIM analyses over the Goulds Dam U Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~ 0.2 m depth). (i) As, Rb and V, (ii) Zn, W and Cu. (iii) U, Mo and Ag, (iv) Au, Bi and Cd	33
Figure 13	Plots of Hg, conductivity, Fe, Mg and Ca results from the Goulds Dam survey line	37

## **PREFACE AND EXECUTIVE SUMMARY**

The electro-geochemical 'CHIM' technique developed by Chinese researchers was trialled in South Australia as a potentially useful surface technique to detect 'blind' mineralisation either in bedrock or buried by younger sediment cover. Trials form part of a larger study into potential exploration methods effective in areas of thick regolith cover (Program 1 - Curnamona MinEx). These surveys were the first time that the Chinese CHIM technique has been tested under arid conditions in Australia.

Two survey lines were completed over projected extension of ore shoots at the Challenger Mine. Although results were not conclusive, they were encouraging when compared with results from soil samples. Results from the Kalkaroo Cu-Au-Mo Prospect recorded elevated levels of Au, U, Cu, W and Bi over mineralisation but the response was such that anomalies could not be interpreted with confidence. An elevated As response was recorded over mineralisation at the Goulds Dam U Prospect but any relationship of As to underlying mineralisation has yet to be established.

It is recommended that further trials of the CHIM technique are undertaken, although with minor modifications to the equipment to suit local conditions.

Adrian Fabris  
Project Leader

## **ABSTRACT**

A version of the CHIM electro-geochemical prospecting technique, developed at Guilin University, China was trialled in field surveys at the Challenger Au Mine, Kalkaroo Cu-Au-Mo and Goulds Dam U prospects, in South Australia. These surveys were the first time that the Chinese CHIM technique has been tested under arid conditions in Australia. The method employed in these surveys used simple independent dipole electrodes buried in the soil and powered by a 9 volt DC battery. Mobile ions drawn to the carbon electrodes were captured on specially-prepared foam coatings wrapped around the electrode. The electrodes were exhumed and the coatings removed and analysed to determine the concentration of metal ions. The method relies on the leakage of ions from an ore body to the surface where the applied current has potential to collect the ions from a larger volume than would be feasible with traditional soil sampling methods.

Two survey lines were completed over projected extension of ore shoots at the Challenger Mine. Although results were not conclusive, they were encouraging when compared with results from soil samples. Elevated levels but inconsistent results for Au and As were obtained over ore shoots projected from between 200 and 400 m below the surface. At Kalkaroo, elevated levels of Au, U, Cu, W and Bi were recorded over mineralisation but the response was such that anomalies could not always be interpreted with confidence. An elevated As response was recorded over mineralisation at Goulds Dam but any relationship of As to underlying mineralisation has yet to be established.

Modifications to the equipment are required to make the system more robust and to allow monitoring of the current while in use. This would ensure that dipoles are operating as intended and would assist with fine-tuning to optimise current and collection time to suit local conditions.

## 1. INTRODUCTION

The electro-geochemical 'CHIM' technique developed by Chinese researchers was trialled in South Australia as a potentially useful surface technique to detect 'blind' mineralisation either in bedrock or buried by younger sediment cover. The surveys were the first time that the Chinese CHIM technique has been tested under arid conditions in Australia. Trials were part of a collaborative research project in South Australia, developed between Professor Xianrong Luo, Guilin University of Technology, China and Dr Baohong Hou, Senior Principal Geologist, PIRSA, supported by Primary Industries and Resources, South Australia (PIRSA) and integrated with current activities of the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME), in which PIRSA is a core participant. Future scientific exchange with researchers at Guilin University of Technology is facilitated by a travel grant from the Australian Government through the Australia-China Special Fund for Scientific and Technological Cooperation administered by Department of Education, Science and Training.

## 2. BACKGROUND

CHIM (**CH**astichnoe **Iz**vlechnyye **M**etallov) is an electro-geochemical method for collecting ions by placing appropriately prepared electrodes in the soil and applying a current for a sustained period (Fig. 1). While CHIM's beginnings were in the USSR in the 1930s, it wasn't until the early 1970s that the method was really developed by Ryss, Goldberg and others at the All-Union Research Institute of Exploration Technology at Leningrad (Alekseev et al., 1996; Hoover et al., 1997). Early versions of CHIM focussed only on collection of positively charged ions while negatively charged complexes were ignored. In the 1980s, the method was taken up, particularly in China but also in Israel and India where local variants subsequently arose. In the early 1990s, with improved knowledge of the effect of redox conditions on ion mobility around conductive ore bodies (Govett and Atherden, 1987; Thornber and Taylor, 1992) and an increased focus on detection of deeply buried ore deposits, interest in the technique spread to western countries including USA and Canada. Trial surveys with CHIM were conducted in various countries, including Canada, US (Leinz, et al. 1998) and Australia (via AMIRA). An outcome of these trials was the development by the United States Geological Survey (USGS) of a modified version of CHIM named 'NEOCHIM', that addressed some of the problems identified in Russian designs in particular, acid loss from electrode collectors and the necessity for both anion and cation collection at each sample site.

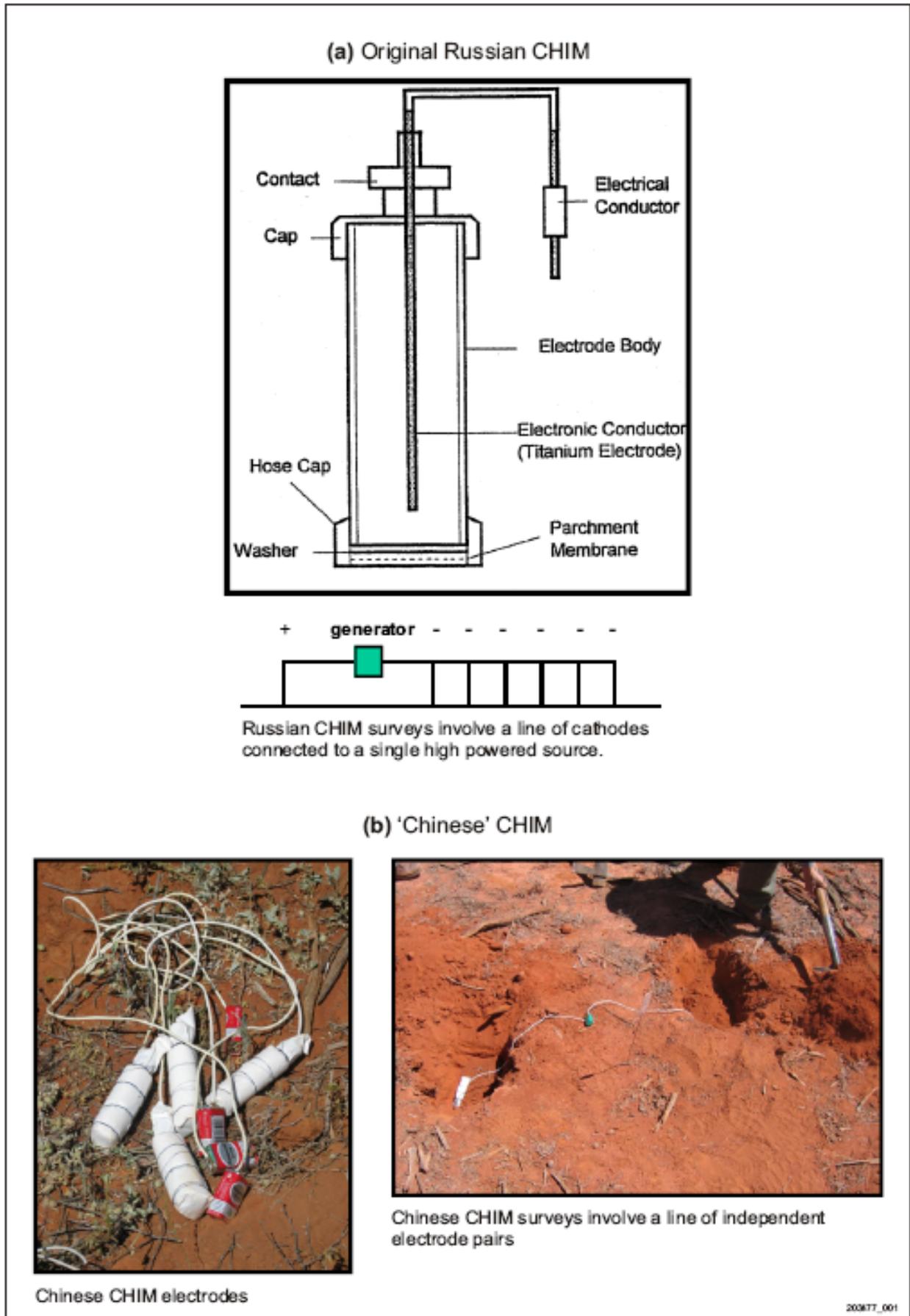
The many variations of CHIM fall broadly into two categories. In the first, the object is to extract ions directly from the ore body (the 'logging' methods). These are distinguished by having a larger power input than those of the second style, where the object is to collect ions already dispersed from the orebody by other mechanisms ('aureole' methods). While there is some discussion as to the validity of this demarcation, it is useful as an indicator of intent. The method used in the current trial is of the aureole style.

Although both the objectives and the manner of operation are quite different, a traditional CHIM survey has something in common with a pole-dipole IP survey in having a distant but substantial current source and a series of ion collectors, resembling IP receiver pots. A dipole version of CHIM has also been proposed (Levitski et al., 1996). In China, the same equipment has been used for both IP and CHIM surveys, which were done consecutively.

The method used in the current surveys was developed by Professor Luo at Guilin University, Guangxi Province, southern China (Luo, 1996; figure. 1). This version of CHIM is a minimalist approach using very portable, light-duty equipment consisting of a series of independent electrode pairs powered by individual dry cells. The electric current draws mobile ions from the surrounding soil and sub-surface to be captured on the specially coated carbon electrodes placed in the soil. The method relies on the leakage of ions from an ore body to the surface where the applied current has potential to collect the ions from a larger volume than would be feasible with traditional soil sampling methods. Surveys are conducted over a period of hours through to several days so as to allow time for sufficient quantities of slow-moving ions to reach the electrodes.

A consequence of the prolonged sampling period is that chemical changes occur at the electrodes causing complications to the technique. The following discussion is based on an unpublished review of the CHIM technique produced by Hoover and Leinz, formerly of the USGS (Hoover pers comm., 2005). Many of the complications arise from the nature of water. Water electrolyses. The specifics of the reaction vary in detail with the salt content but in essence, hydrogen ions are released at the anode and hydroxyl ions at the cathode. This has a number of consequences. The most obvious is that this competes with the transportation of ions by consuming current. Hydrogen and hydroxyl ions travel particularly quickly relative to other ions, which coupled with their high relative abundance, results in them monopolising the current to the detriment of the ions of interest.

There may be important chemical consequences too, because many metals have sparingly soluble hydroxides. As a consequence, positively charged metallic ions on their way to the cathode may first reach hydroxyl ions being expelled from the cathode, resulting in the metals of interest being precipitated some distance short of the collector and therefore not being measured. The simplest solution is to apply acid to the soil in vicinity of the cathode to offset hydroxide production. A more elegant solution to this problem is a double-chambered electrode with a salt bridge devised by Leinz et al. (1988) that minimises the release of acid to the soil.



**Figure 1. Components and field set up of the CHIM. (a) Original Russian CHIM (b) 'Chinese' CHIM.**

Outside the countries where it is well established, CHIM tends to be regarded with a degree of reserve. Among the more contentious issues are the discrepancy between laboratory measurements of ion mobilities and those required to move ions from great depth to the electrodes and the relative importance of the roles of diffusion and electrochemistry in the CHIM process.

The first issue is largely whether or not a more rapid mechanism of ion transport exists in addition to the movement of an ion in an applied electric field. Estimates of the volume of soil that would be sampled under 'normal' operating conditions, though approximate, fall several orders of magnitude short of what is required to move ions from an orebody to the surface in a practical time. Russian practitioners, particularly, infer that this occurs and indeed is the intended basis of the logging methods.

The second issue has a number of component aspects not all of which are problems and in fact has given rise to a new technique, MDI (**M**etoda **D**iffuzionnogo **I**z vlecheniya). The effect depends on the generation of hydrogen (and hydroxyl ions) and their great mobility rather than their chemical properties. Hydrogen ions are approximately five times more mobile than most other ions, and in particular, their corresponding anions, apart from hydroxyl. For instance, at 25°C, H<sup>+</sup> has an ionic diffusivity of 9.34 x 10<sup>-5</sup>cm<sup>2</sup>/sec while Cl<sup>-</sup> has an ionic diffusivity of 2.03 x 10<sup>-5</sup>cm<sup>2</sup>/sec, a difference of a factor of 4.6. As a result, even an electrode containing an acid (as is usually the case) but with no applied current, loses hydrogen ions by diffusion into the soil more quickly than chloride ions. Ultimately, this increasing separation of charge sets up a field that retards the further, rapid movement of hydrogen ions and accelerates the chloride ions. As a result, the acid overall migrates into the soil at a rate determined by both anion and cation.

Experimental work done by Vinogradov and McBain (1941) where 0.1N HCl diffusing into a 0.1N KCl solution was found to move K<sup>+</sup> ions 2.51 times more quickly than when the same solution diffused into water. This is considered to be an indication of the effect of the field produced by the separation of the charge. For other acids, the difference is greater again as other anions tend to be slower than chloride. In the context of the CHIM, any acid in the collector will diffuse into the soil and in so doing generate a field. On the other hand, cations present in the soil but not represented in the electrode fluids, tend to diffuse in the opposite direction, into the collector as their concentration gradient has the opposite sense. These cations are apparently also influenced by the field resulting from the separation of hydrogen ions and their anions which further accelerates them toward the collector. In mixtures of ions, such as would occur in surveys, the rate of migration of ions is a little greater than would have been predicted from theory.

Since CHIM electrodes are commonly filled with acid and will generate additional hydroxide at the cathode as a consequence of electrolysis, this effect should be expected to be part of the CHIM process. Hoover and Leinz (pers comm., 2006) would contend that this is overwhelmingly the more important process whereas most Russian sources assume the migration of ions under the applied current is more important. The MDI

method mentioned above, takes advantage of this diffusive effect to drive ions from the soil into a suitable collector (such as a sausage skin filled with acid) without recourse to an externally applied electric field. While some of these conjectures are beyond the scope of the initial project, which was intended simply as a demonstration of the Chinese CHIM technique under field conditions, they need to be taken into consideration in any future modification to the technique that aims to improve reliability and reproducibility of results.

### **3. SOUTH AUSTRALIAN TRIALS**

During September and October 2005, demonstration surveys were conducted at Dominion Mining Ltd's Challenger Au Mine, Havih Resources NL's Cu-Au-Mo prospect at Kalkaroo, and at Southern Cross Resources Uranium One Inc's Goulds Dam U Prospect (Figure. 2). Survey lines were designed to test the technique over different styles of mineralisation and a range of cover types and thicknesses. These include; thin transported cover but with mineralisation at 100–400 m in bedrock at the Challenger Au Mine; 50 m of transported cover including a 40 m thick unit of

Tertiary lacustrine clay, with primary mineralisation at approximately 110 m depth at the Kalkaroo Cu-Au-Mo Prospect; and mineralisation near the base of 110 m of transported Tertiary sediments at the Goulds Dam U Prospect.



Figure 2. Location map showing CHIM survey field sites

### **3.1 Methodology**

The Chinese variant of the CHIM technique is used in China principally as a brownfields exploration method to test for extension or repetition of known mineralisation or to improve anomaly definition identified from other techniques. The approach of the team at Guilin University is to take shallow soil samples over the area under investigation and determine conductivity and mercury (Hg) content. Conductive sites showing elevated Hg content are followed up with closer spaced sampling before planning a CHIM survey. Conductivity in microsiemens per cm is determined on 1 gm dried sample ultrasonically dispersed for 60 seconds in 100 ml distilled water and allowed to settle for 30 seconds. Mercury is determined by heating an accurately weighed, hand-ground, 0.1 gm air-dried sample to 800°C and measuring the amount of Hg vapour using a propriety analytical technique. This approach has proved effective at several locations in China (Luo et al., 2004) and appears to be well suited to polymetallic ore deposits, with elevated Hg content, in the subtropical Dachang Mineral District in northwest Guangxi Province.

For the South Australian surveys, all sites were chosen over mineralisation identified or inferred from drilling or, in the case of Challenger, by extrapolation of the structures controlling the distribution of Au ore bodies. The CHIM method developed by Professor Luo is based on the extraction of electromobile forms of metals from the regolith into element-collectors using low voltage and extended collection times. The setup comprises specially coated carbon electrode pairs connected by a disposable 12 or 9 volt DC power supply. The electrodes were buried at around 0.2 m depth and 0.6 m apart, the area moistened by the addition of 1 litre of 30% HNO<sub>3</sub>, and then covered over by soil. These were left for around 48 hours after which time the electrodes were exhumed. The electric current causes any mobile positively charged metallic ions to move towards the cathode and negatively charged ions, including negatively charged complex of metallic ions, to move towards the anode under the influence of a potential field. The ion and ionic complexes accumulate in a specially prepared absorbent coating the electrodes. The absorbent coatings are removed and digested in warm concentrated HNO<sub>3</sub>. The concentration of elements in solution is determined by ICP-MS, and reported as µg of contained metal per electrode. Prior to placement of the electrodes, a soil sample was collected from the base of the electrode pits at each site. These were crushed and sub-sampled for analysis of selected elements by ICP MS following aqua regia digest, and for measurement of electrical conductivity and Hg analysis at Guilin University using techniques outlined above.

### **3.2 Challenger Au Mine**

The Challenger Gold Mine is located 740 km northwest of Adelaide and 240 km northwest of Glendambo (Figure. 2). The objective was to identify a surface geochemical expression that would map the three main ore shoots M1, M2 and M3. Survey lines were located 50 and 450 m from the present open pit. At these distances, the tops of the shoots are estimated to be between 120 to 210 m and 320 to 410 m below ground surface respectively (Figure. 3).

The Challenger lode system is within Archaean Christie Gneiss where Au in the host sediment was mobilised and concentrated during migmatite-grade metamorphism at ~2440 Ma (Poustie et al., 2002). Gold mineralisation is largely structurally controlled within a series of shoots that plunge at ~30° towards 030°. The shoots occupy dilation zones associated with asymmetric folding. Drag folds having multiple separate fold closures define individual shoots. The largest shoot, M1, has folds of average amplitude 25–30 m and wavelengths varying from 5–20 m with the overall shoot width being 40–50 m (Poustie and Abbot, 2006). Mineralisation is coarse Au with minor sulphides arsenopyrite, lollingite and pyrrhotite, with traces of bismuth minerals, tellurides, chalcopyrite, pentlandite and sphalerite (Poustie et al., 2002).

### **3.2.1 Challenger Au Mine Survey**

The Challenger survey was conducted using 49 electrode pairs. These were laid out at 20 m intervals along two surveyed lines that crossed the projection of the ore shoots at approximately 50 m and 450 m out from the open pit margin (Figure. 3). Thickness of transported cover on the survey lines was absent to <3 m as low dunes of orange-brown to red-brown slightly clayey, fine to coarse sand. Where the sand was thin or absent, laminated massive calcrete in weathered bedrock usually persisted to the full depth of the 0.2 m excavation. Thickness of saprolite in the mine area is reported to be around 20–30 m (Lintern and Sheard, 1999). Minor perched water is present at the base of saprolite at around 30 m, with the water table at around 110 m and showing very low flow rates (Poustie, pers comm., 2006).

At each CHIM site a bottom-of-hole sample was collected prior to the placement of the electrode. The bulk sample was crushed to minus 80 mesh and analysed for selected elements using aqua regia digest and ICP-MS (Australian Mineral Development Laboratories — AMDEL). Subsamples were taken to Guilin University for conductivity measurement and for Hg determination.

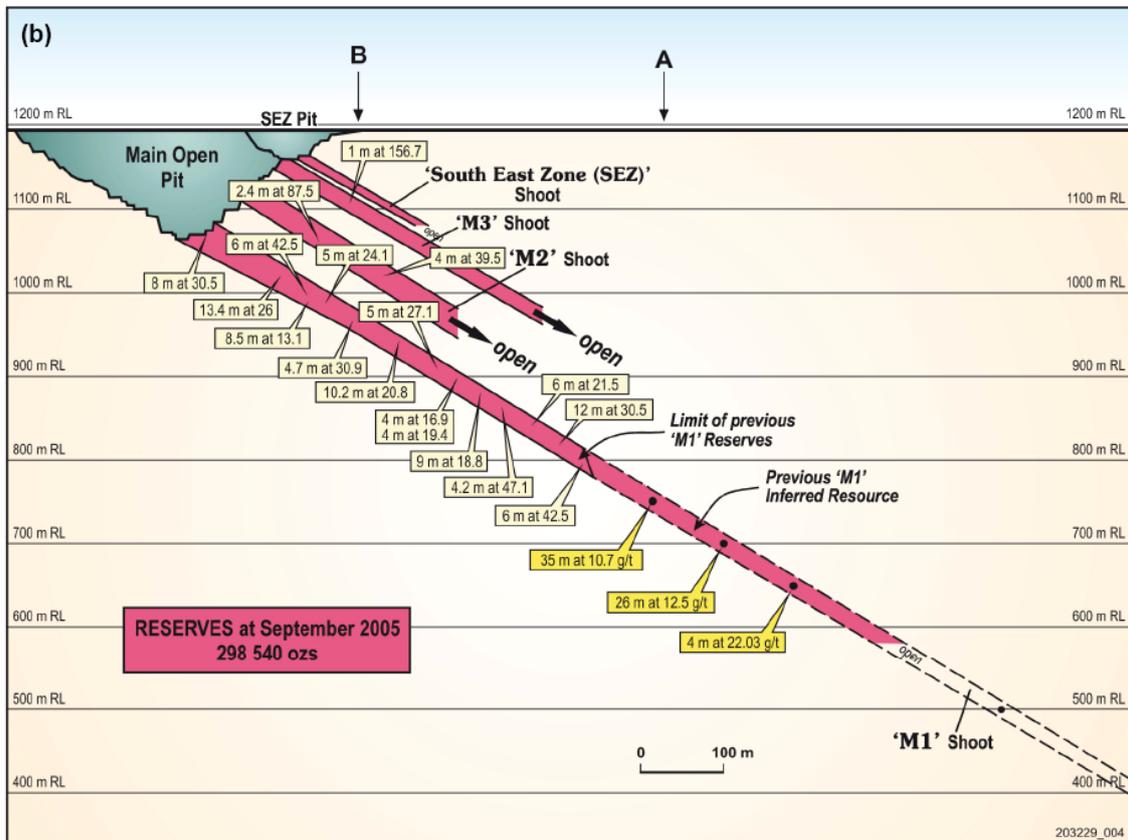
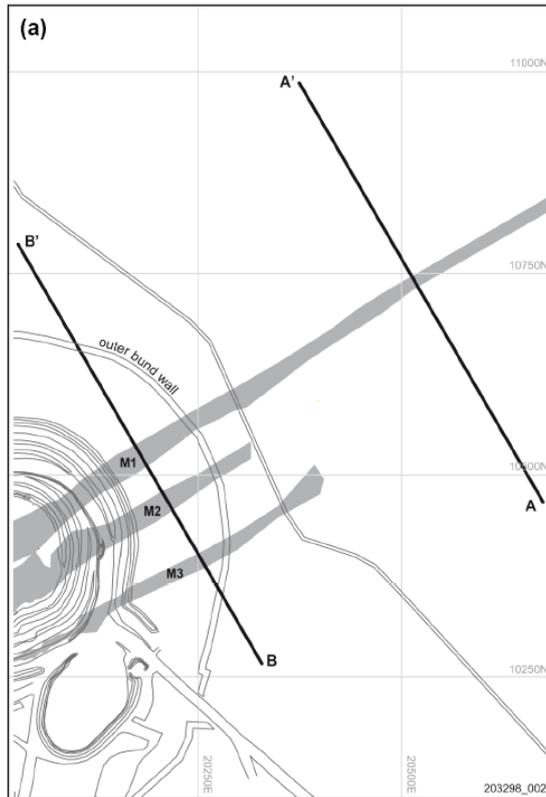
At the time of the CHIM survey, a vegetation survey based on mulga litter was also completed along the survey lines. Samples were forwarded to CRC LEME in Perth to be included with vegetation samples from other surveys being prepared for analysis. At the time of preparation of this report, the analytical results are still outstanding and will be included in a future report.

The sites chosen for the CHIM survey at Challenger Au Mine had been established for an earlier survey supported by Dominion Mining Ltd that trialled the LocatOre bacterium-based leach technique (SoLogic Ltd). Results of analyses from that survey were provided by Dominion and selected analyses have been included in graphical presentations of data in this report for comparison purposes only. The full detail of results and interpretation of the LocatOre survey are confidential to Dominion Mining Ltd and further details should be sought directly from the company.

### 3.2.2 *Results and Discussion*

Selected plots of CHIM results obtained from each site and comparison with soil survey analyses are shown in Figure 4. Full results are given in Appendix A. Analyses of CHIM electrode coatings were elevated but somewhat spiky for Au, As and Ag over the projected ore shoots. CHIM Au values on Line B-B', closest to the pit, show elevated but consistent values of around 60  $\mu\text{g}$  (Figure. 4i). This may simply reflect the high Au results from this area (up to 100 ppb) and be due to mechanical dispersion down-slope from sub-cropping ore (Lintern and Sheard, 1999). Alternatively, the Au results for Line B may have been affected in some way during sampling or analytical preparation but in either case, should be disregarded. The sampling procedure precludes cross-check analyses, and repeat analyses of selected prepared solutions gave similar results. Other elements analysed in the digest solutions for Line B do not appear to have been similarly affected. For instance, As on Line B shows some correlation with the known position of ore (Figure. 4ii). Highest As value of 164  $\mu\text{g}$  was recorded over the M2 shoot. The M2 shoot is also highlighted by elevated values for Rb, V, and W (Appendix A). High Ag values at the northwestern end of Line B and while one value of 192  $\mu\text{g}$  corresponds with the position of ore shoot M1, similarly elevated values elsewhere on the line are not associated with any known mineralisation (Figure. 4iii). Results for As on Line A indicate that there is no correlation with ore shoots predicted to be present at depths greater than 320 m (Figure. 4ii). Irregular As values of  $>60$   $\mu\text{g}$  from the south-eastern end of Line A may be due to the M3 shoot which is estimated to be at the shallowest depth of around 320 m. Shoots M2 and M1 show no response in As that can be detected above background levels. The Au levels on Line A also show no clear correspondence with the projected position of the ore shoots with the exception of one sample over shoot M3 which reported the highest Au value of 162  $\mu\text{g}$  (Figure. 4i). Two spikes for Ag on Line A show approximate correlation with the projected positions for shoots M1 and M2, but there is no corresponding high value over shoot M3 (Figure. 4iii).

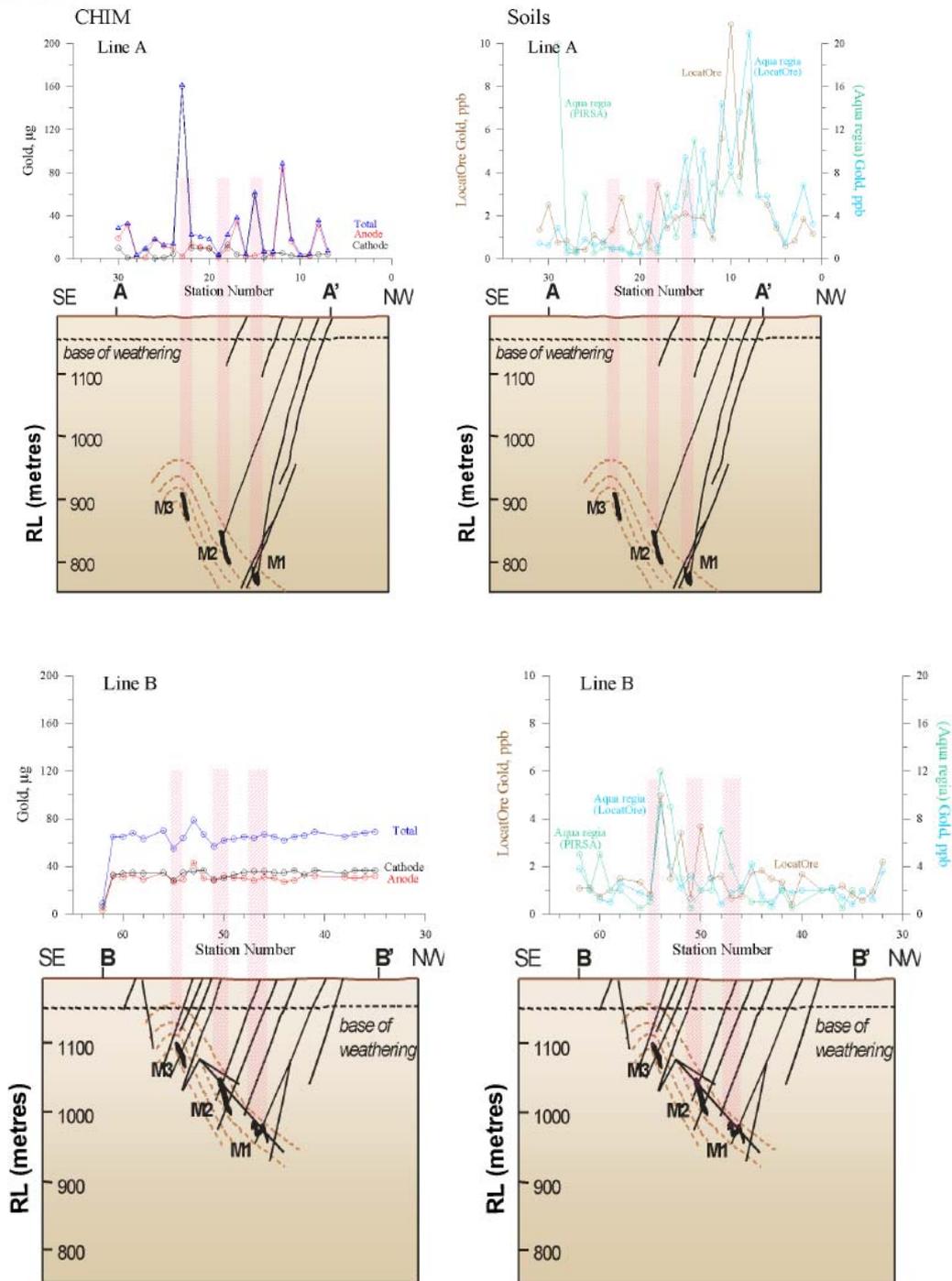
Analyses of soil samples from the base of the electrode pits showed very little correlation with anomalous element values and the projected position of Au ore shoots, and surprisingly, no correlation with CHIM results. A notable exception is Ag on Line B where anomalous values



**Figure 3. Plan showing the location of the CHIM survey sites in relation to the known subsurface extent of the Challenger Au ore shoots M1, M2 and M3. (a) Plan view (b) Long-section (ore shoots projected onto section).**

## Challenger CHIM Test

GOLD



**Figure 4 (i)** Plots of CHIM analyses (cathode plus anode) and soil surveys at the Challenger Gold Mine. Soil results for samples from the bottom of CHIM electrode pits (~0.2 m depth) and digested using aqua regia, and soil samples collected during an earlier survey for Dominion Mining Ltd and digested by aqua regia and LocatOre (proprietary method). Two surveys ('A' and 'B') were completed perpendicular to the down plunge projection of M1, M2 and M3 oreshoots. Sections include drill holes projected onto the section. (i) Au, (ii) As, (iii) Ag.

# Challenger CHIM Test

## ARSENIC

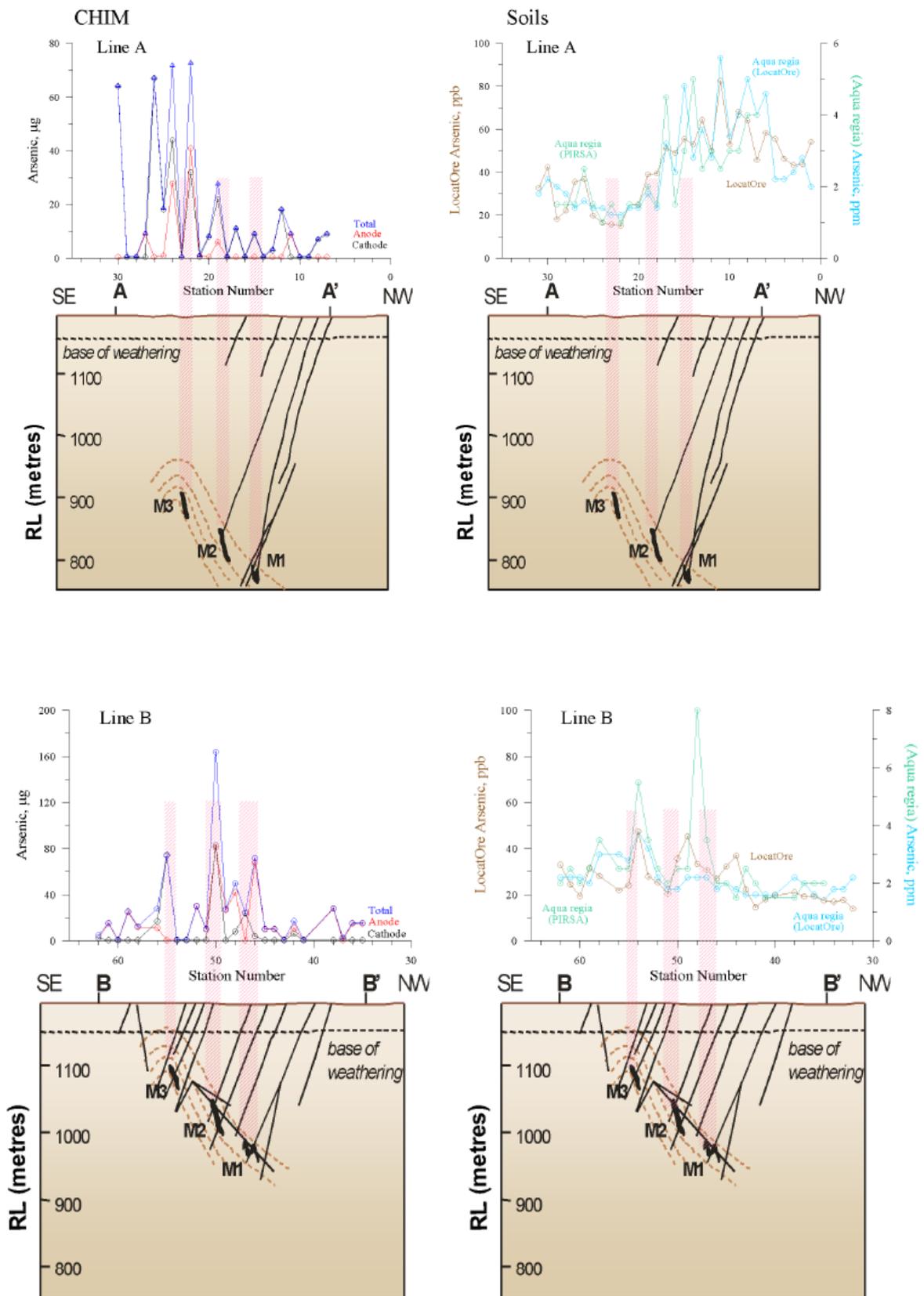


Figure 4 (ii)

# Challenger CHIM Test

## SILVER

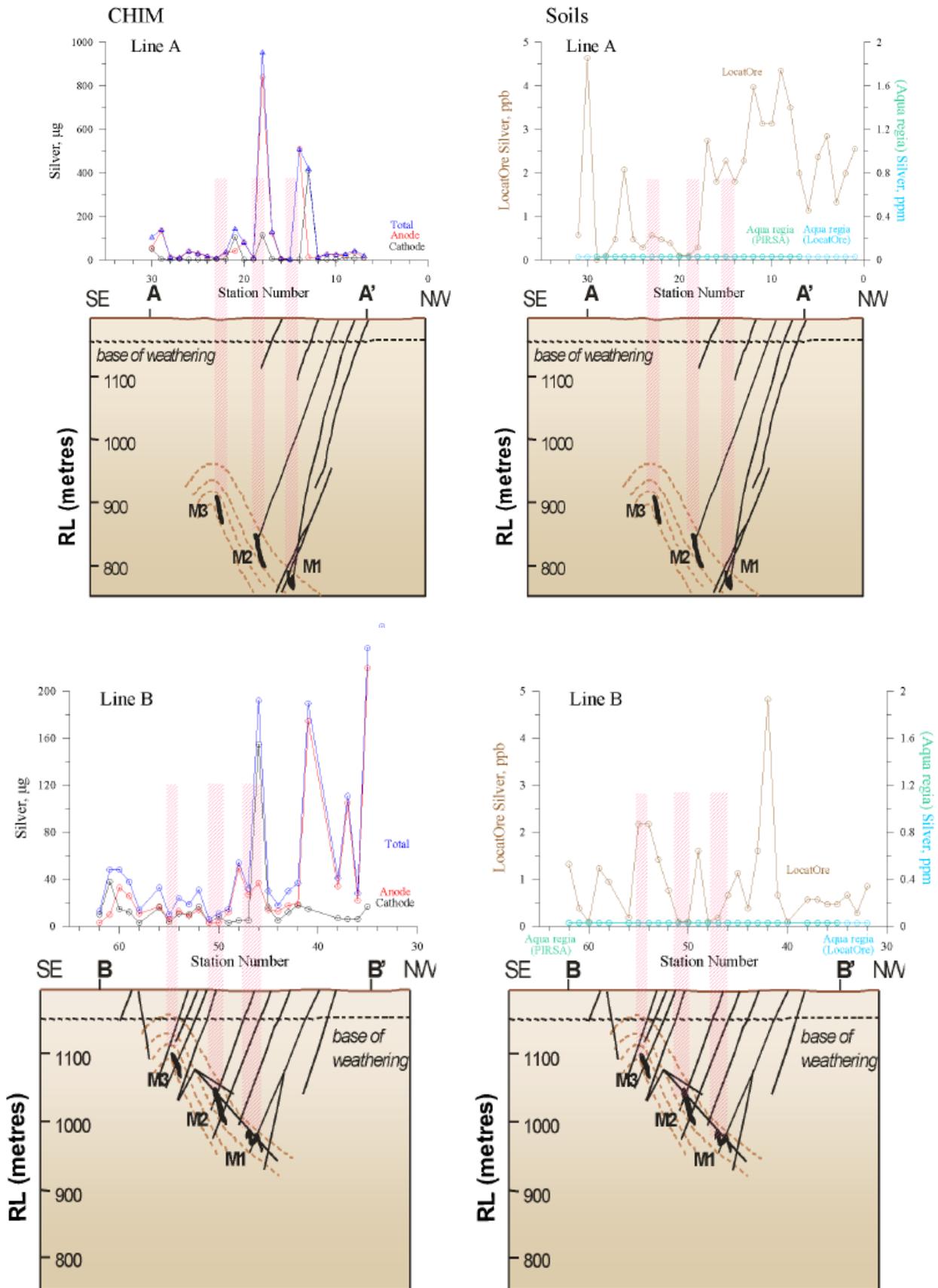


Figure 4 (iii)

correspond to projected positions of ore shoots M1 and M3. Highest Au value of 20 ppb was recorded from calcrete on Line A, southeast of the projected position of M3 shoot (Figure 4i).

High Au, Ag, As, Cu and U values on the northwestern end of Line A are all from massive laminated calcrete (Appendix A). Anomalous Au values overlying ore shoots M3 on Line B are also associated with increased carbonate content in soils.

Data for Hg on Line B gives weak correlation with the positions of the shallowest shoots M2 and M3 with values over 60 ppb, against a background of 20 ppb (Figure. 5). Similar high values for Hg on Line A did not correspond with the projected position of mineralised shoots. Conductivity data showed no obvious pattern that could be related to mineralised shoots at depth (Figure. 5). Dune sand (dry) generally had a lower conductivity than that for carbonate soils.

LocatOre samples gave mostly ambiguous results. However, elevated lead values corresponded to M1 and M2 on Line A and M3 on Line B (Appendix A).

### **3.3 Kalkaroo Cu-Au-Mo Prospect**

The Kalkaroo Prospect is situated 400 km north-east from Adelaide and 60 km north-north-east of Olary (Figure. 2). The two survey lines were across areas of significant mineralisation as defined by drilling (Figure. 6). The northern line was situated to cross the central region of an elongate zone of Cu-Au mineralisation defined by drilling and containing an indicated resource of 70 Mt at 0.47% Cu, 0.46 g/t Au and 124 ppm Mo ([www.havilah-resources.com.au](http://www.havilah-resources.com.au)). The southern line was sited over supergene mineralisation identified in drill traverses on the western edge of the Kalkaroo South Dome (Figure. 6).

The Kalkaroo Prospect is covered by 40–70 m of transported cover including Tertiary fluvial sands, lacustrine clays and Quaternary to recent alluvial clayey sand. Basement strata dip at approximately 40° around a dome structure (named the ‘Kalkaroo South Dome’ by Havilah Resources; Figure. 6). Primary mineralisation is stratabound with shallowest intersections at around 110 m depth in Palaeoproterozoic, albite-rich metapelites and psammopelites +/- pyrite. The mineralised sequence is overlain by carbonaceous metapelites and underlain by albite-altered scapolitic metasediments which are strongly magnetic and pyrite poor (Law and Terrill, 2001). Cu-Au mineralisation is typically chalcopyrite-dominant, occurring as stratabound replaced carbonate bands and nodules, and within fractures and veins (Busuttill and Law, 2003). Supergene enrichment of the primary mineralisation shows typical zoning from chalcocite coated chalcopyrite in the lower portion of the profile to malachite-dominant towards the top of the profile where a gossanous material may exist (Dawson, 2000). Native copper in the supergene zone is common proximal to the highest primary Cu grades. Down hole geochemistry indicate an As-Mo association with the Kalkaroo Cu-Au mineralisation (Law and Terrill, 2001).

### **3.3.1 Kalkaroo Cu-Au-Mo Prospect Survey**

#### *LINE A*

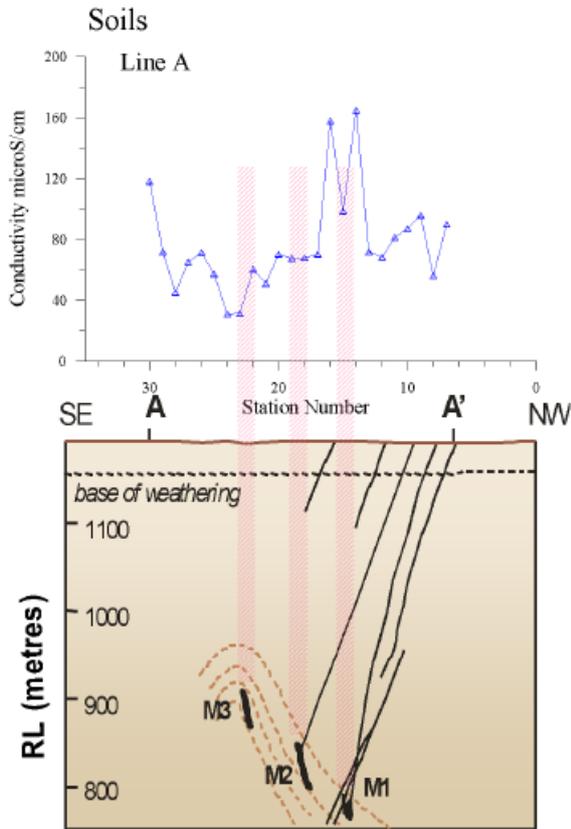
Line A of the Kalkaroo survey used 17 electrode pairs to make a line 440 m in length. Electrode pairs were laid out at 20 m intervals directly over mineralisation and at 40 m intervals away from mineralisation. Thickness of transported cover and saprolite is approximately 65 m and 60 m respectively. Mineralisation was intersected in holes KKRC 002, 003, 006 and 007 by Havilah Resources (Figure. 7). Mineralisation is open to the north. Highest combined Cu-Au grades were intersected in the supergene zone in hole KKRC006 (39 m of 1.6% Cu and 0.93 g/t Au) and, in primary mineralisation, in hole KKRC003 (21 m of 0.8% Cu and 0.17 g/t Au). Highest Mo concentrations of up to 2500 ppm were intersected in KKRC006. Assuming the formation of an anomaly at surface occurs directly above primary mineralisation, surface anomalism is expected between electrode pairs KA6 and KA12.

#### *Results and Discussion*

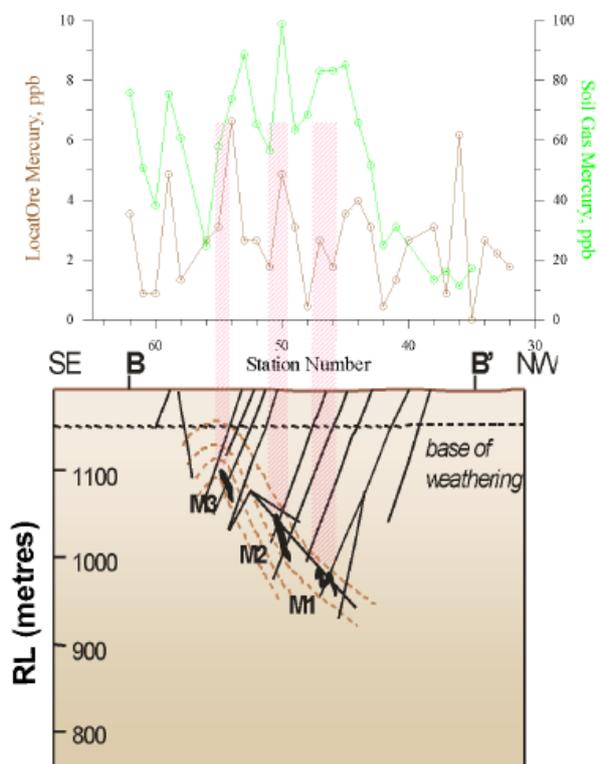
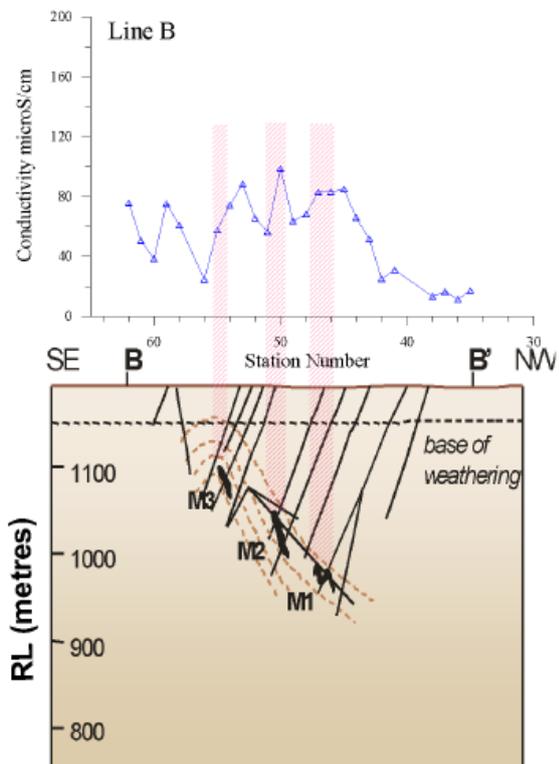
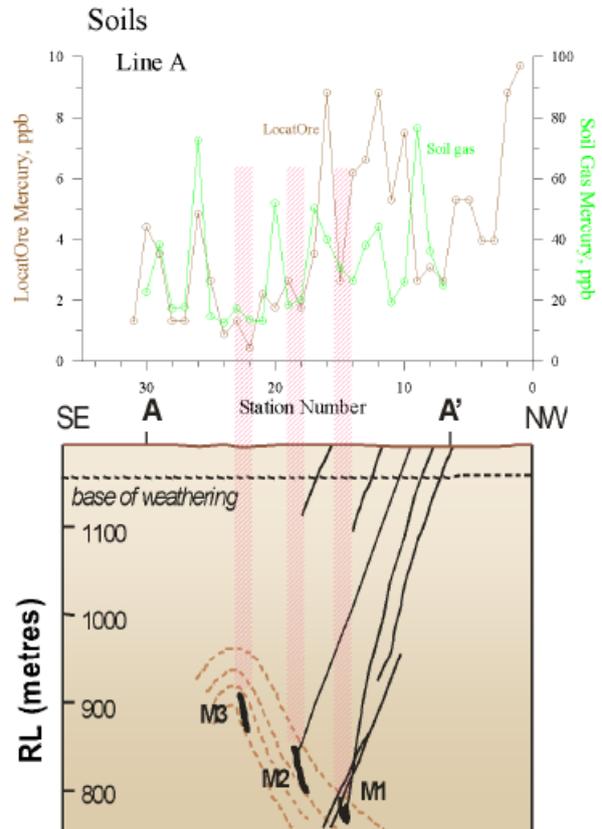
The CHIM technique recorded weakly anomalous levels of Au, Cu, U and Bi above highest grade mineralisation (Figure. 7). Anomalies for Au, U and Cu are based on single point analyses only and therefore need to be interpreted with caution. Of these elements, only the Cu value reached a level of more than twice background (minimum required to be considered anomalous). Acid attack of the Cu wire connected to the electrode is a potential cause of the singular 10 times background anomaly, but corrosion of the copper wire in this instance was not observed when the electrodes were exhumed. Elevated levels for V and W do not correlate to areas of identified mineralisation. The coincidence of high values for elements Au, U, Cu and Bi over an area of known basement mineralisation, while not strikingly anomalous, gives encouragement for detecting some chemical expression, at the near surface, of mineralisation buried by thick sediment cover. Bottom-of-hole soil and conductivity results show no relationship to mineralisation. Mercury analyses gave some elevated values, >20 ppb, over the area of mineralisation, however, the survey did not extend sufficiently far as to reach background and determine whether these values are regionally significant (Figure 8).

# Challenger CHIM Test

## CONDUCTIVITY



## MERCURY



**Figure 5. Plots of soil analyses at the Challenger Gold Mine.** Conductivity and Hg measurements are on samples taken from the bottom of electrode pits (~0.2 m depth). Sections include drill holes projected onto the section.

## *Line B*

The southern Kalkaroo survey used 16 electrode pairs to make a line 400 m in length. Electrode pairs were placed at 20 m intervals directly over mineralisation and at 40 m intervals away from mineralisation (Figure 9). The thickness of transported cover and saprolite beneath the survey line was approximately 50 m and 60 m respectively. Significant Cu mineralisation (3 m of 1.15% Cu) was discovered by drill hole KKRC063 within the supergene zone, and the primary mineralisation source is predicted to be proximal and down dip to the west.

## *Results and Discussion*

Au and W anomalism was recorded on Line B (Figures 9i and 9ii). Anomalies of two and a half times background for Au and four times for W occur directly over mineralisation intersected by drilling. The anomaly is most evident at the anode for Au, inferring Au mobility as a negatively charged complex, while the W anomaly occurred at the cathode. Elevated levels of Zn were recorded over mineralisation. A Au-Mo anomaly at the western end of the line and Ag-Zn anomaly at the eastern end of the line, apparently unrelated to mineralisation, imparts uncertainty to the validity of CHIM element responses.

Bottom-of-hole soil, Hg and conductivity results show no relationship to mineralisation at depth (Figures 9 and 10).

### **3.4 Goulds Dam U Prospect**

The Goulds Dam Prospect has an indicated resource of approximately 2 million kilograms  $U_3O_8$  at 0.12%. The mineralisation is hosted by Tertiary (Eyre Formation) sand channel infill within a palaeovalley incised into Cambrian siltstone (Billeroo Palaeochannel). The palaeovalley as defined by drilling and airborne EM (TEMPEST), is up to 10 km wide and extends for over 80 km (Southern Cross Resources, 2000). At the Goulds Dam prospect, the Billeroo Palaeochannel is approximately 2 km wide (Skidmore, 2003). Sediment cover comprises approximately 100 m of unconsolidated Tertiary clay, sand and silt overlain by 20 m of Quaternary sand and silt.

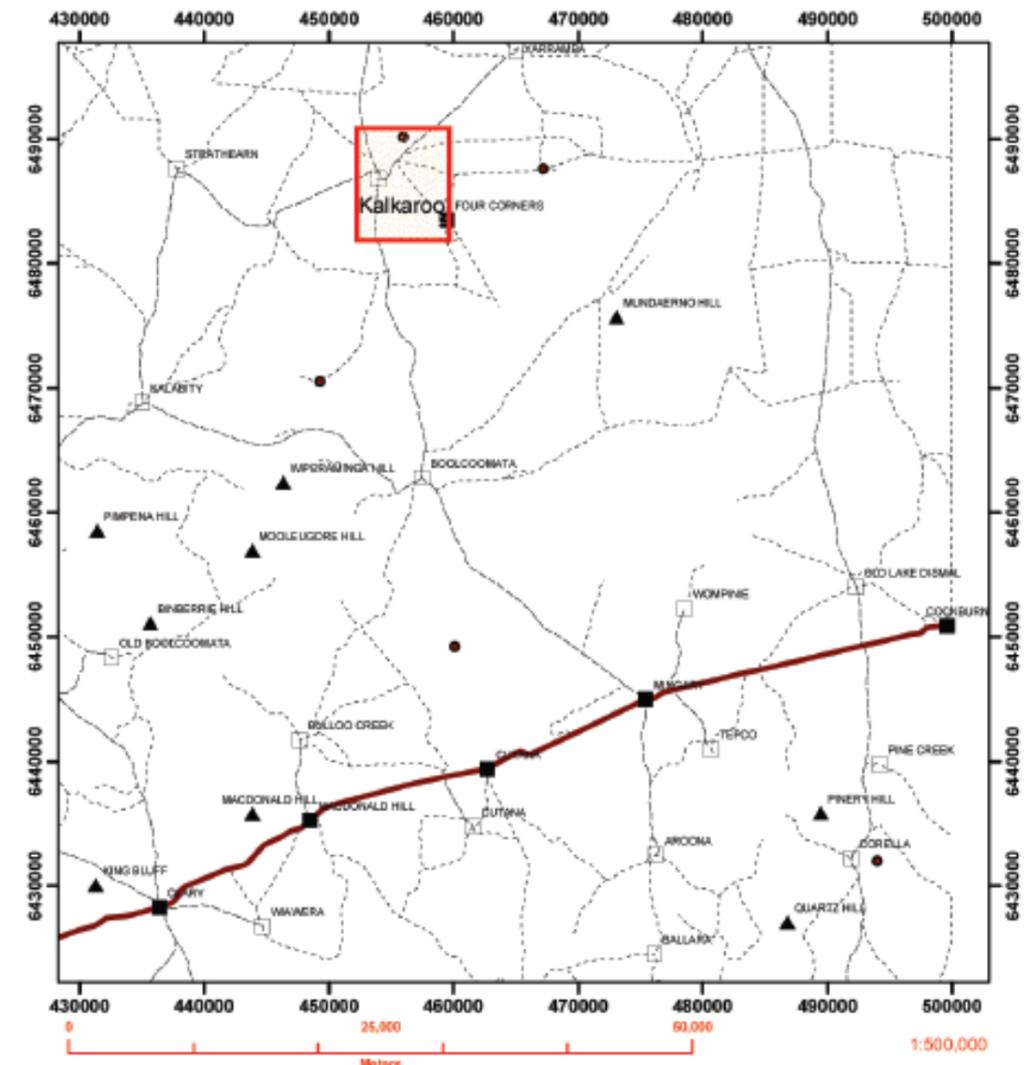
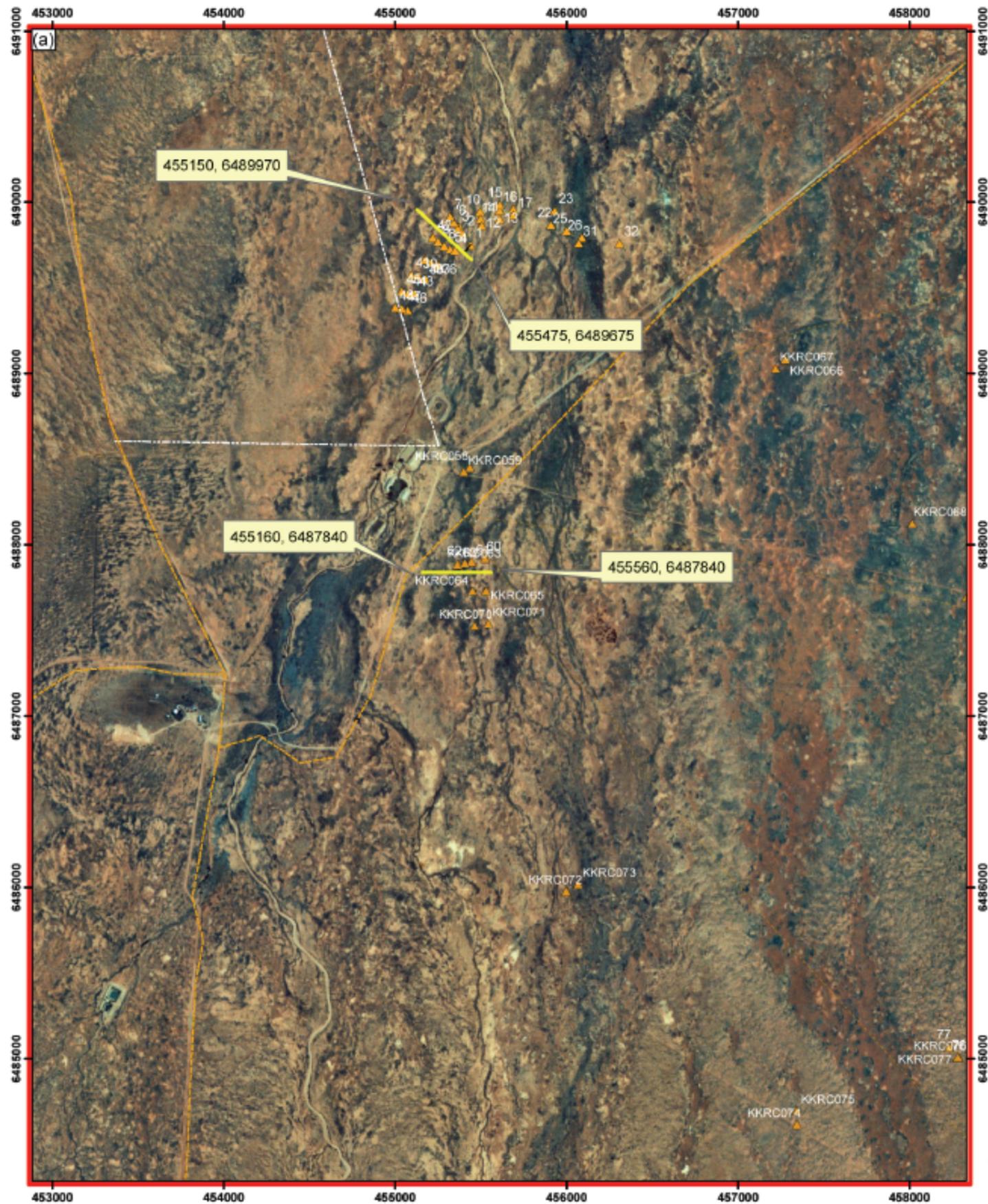
The Goulds Dam sedimentary U 'roll front' style mineralisation is associated with a bend in the Billeroo Palaeochannel, that may be related to a basement fault, indicated in regional airborne magnetics, reactivated at the time of sediment deposition.

#### **3.4.1 Goulds Dam U Prospect Survey**

Immediately prior to the survey, resource definition drilling at the Goulds Dam Prospect, increased the likelihood of surface contamination. The CHIM survey line was therefore sited approximately 700 m north of the indicated uranium resource (Figure 11). Uranium mineralisation of up to 646 ppm was intersected at

this site in reconnaissance drilling in the 1970s, and was thought likely to be an extension of the main mineralised zone to the south. The continuity of mineralisation along the channel could not be established by infill drill holes and subsequent work was focussed on the main prospect. The CHIM survey was offset some 20 m south from the 1970s drill traverse.

The Goulds Dam survey consisted of 17 electrode pairs making a line 460 m in length. Electrode pairs were placed at 20 m intervals over the area of known mineralisation and at 40 m intervals away from mineralisation (Figure 12).



**Legend**  
 ▲ Recent drillholes  
 — CHIM Lines

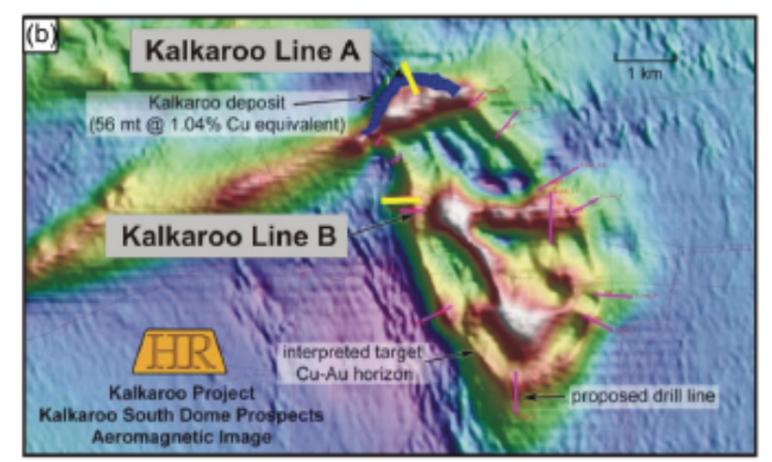
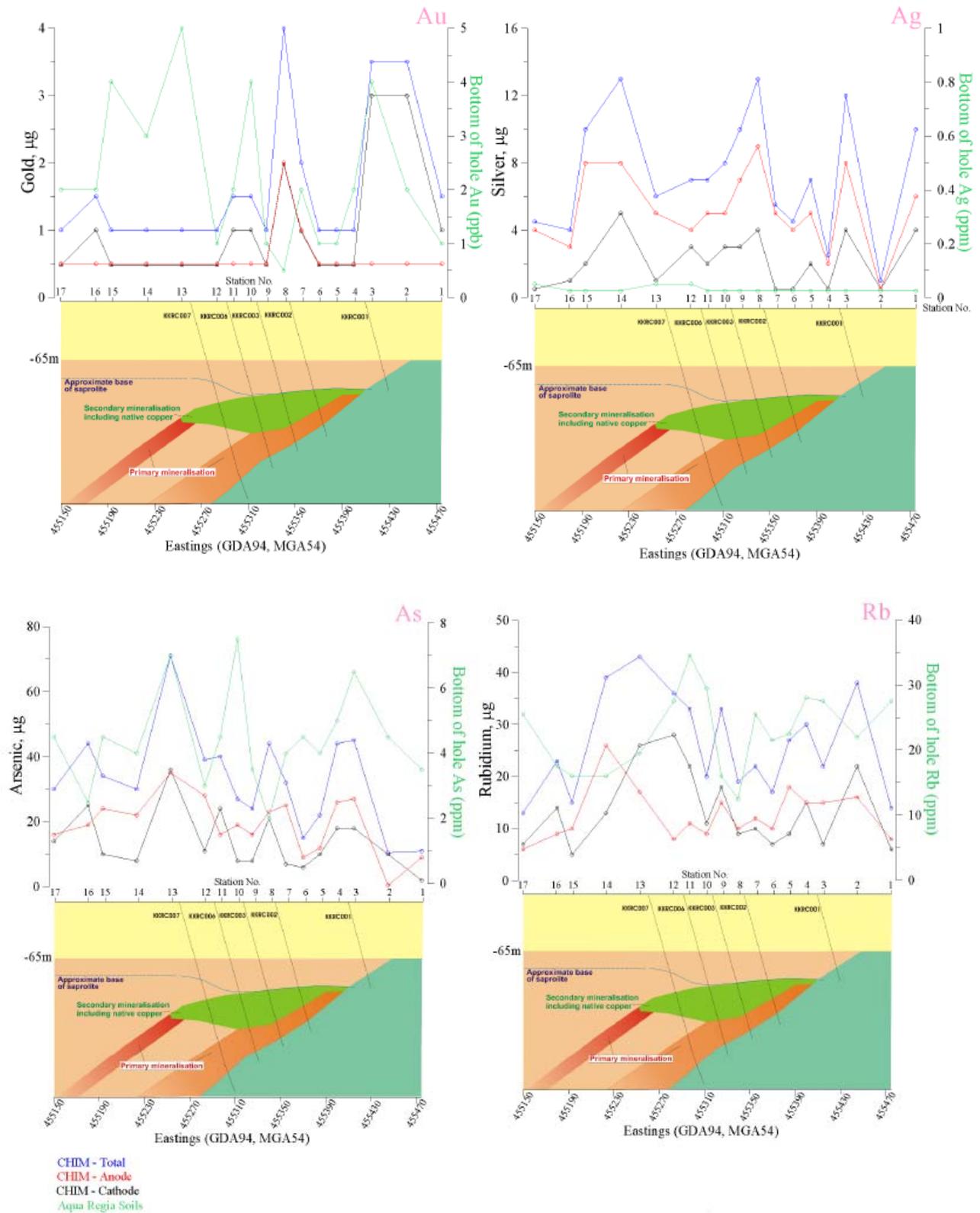


Figure 6 - Kalkaroo location map (a) CHIM lines and recent drillholes overlaid on an orthoimage (b) CHIM lines overlaid on an aeromagnetic image of the Kalkaroo South Dome (after havilah-resources.com.au). (GDA94, MGA54)



Figure 6. Kalkaroo location map (a) CHIM lines and recent drillholes overlaid on an orthoimage, (b) CHIM lines overlaid on an aeromagnetic image of the Kalkaroo South Dome.

## Kalkaroo CHIM Line A



**Figure 7 (i).** Plots of CHIM analyses along Line A at the Kalkaroo Cu-Au-Mo Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~0.2 m depth). (i) Au, Ag, As and Rb, (ii) Mo, Cu, Zn and W, (iii) U, V, Cd and Bi.

# Kalkaroo CHIM Line A

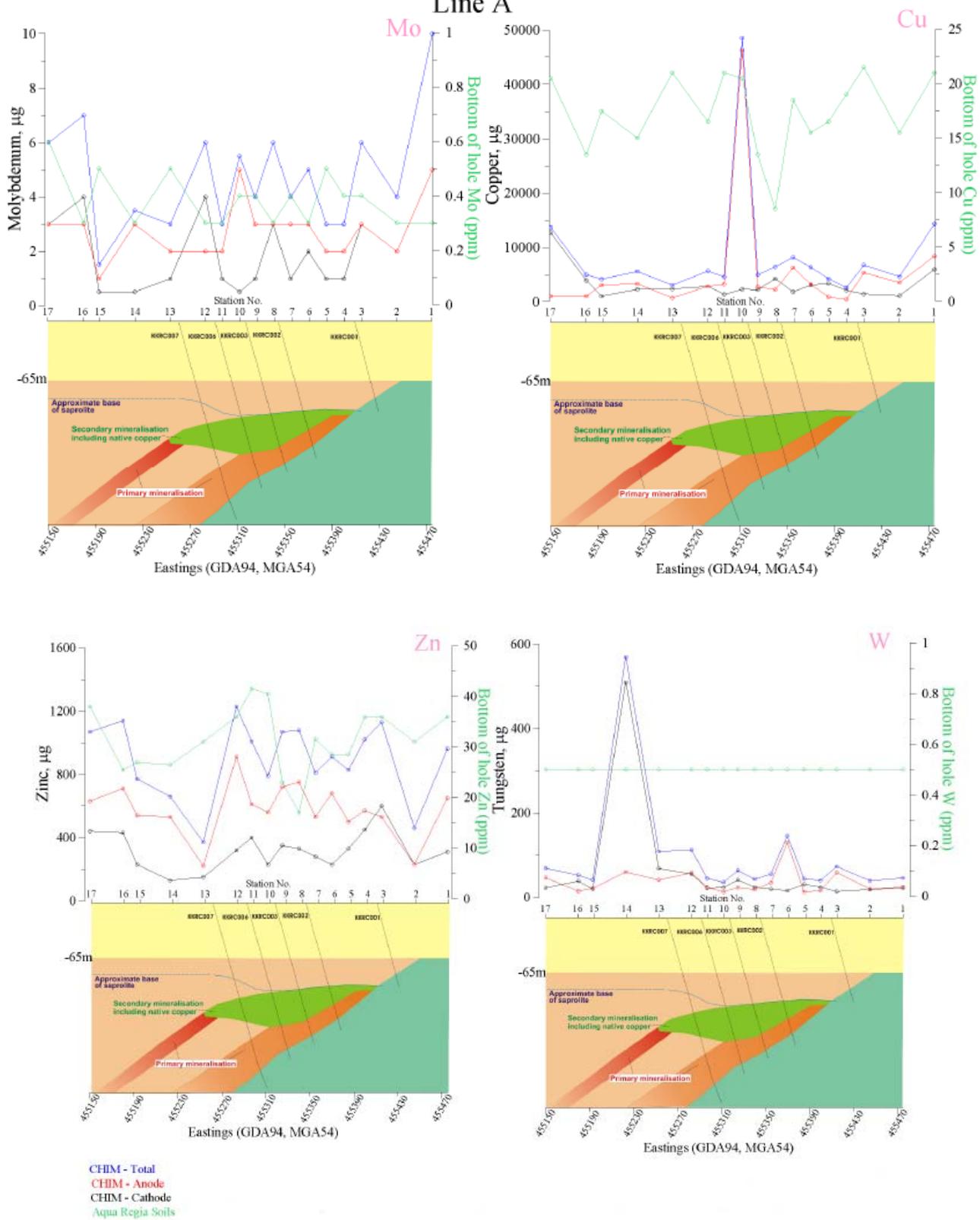
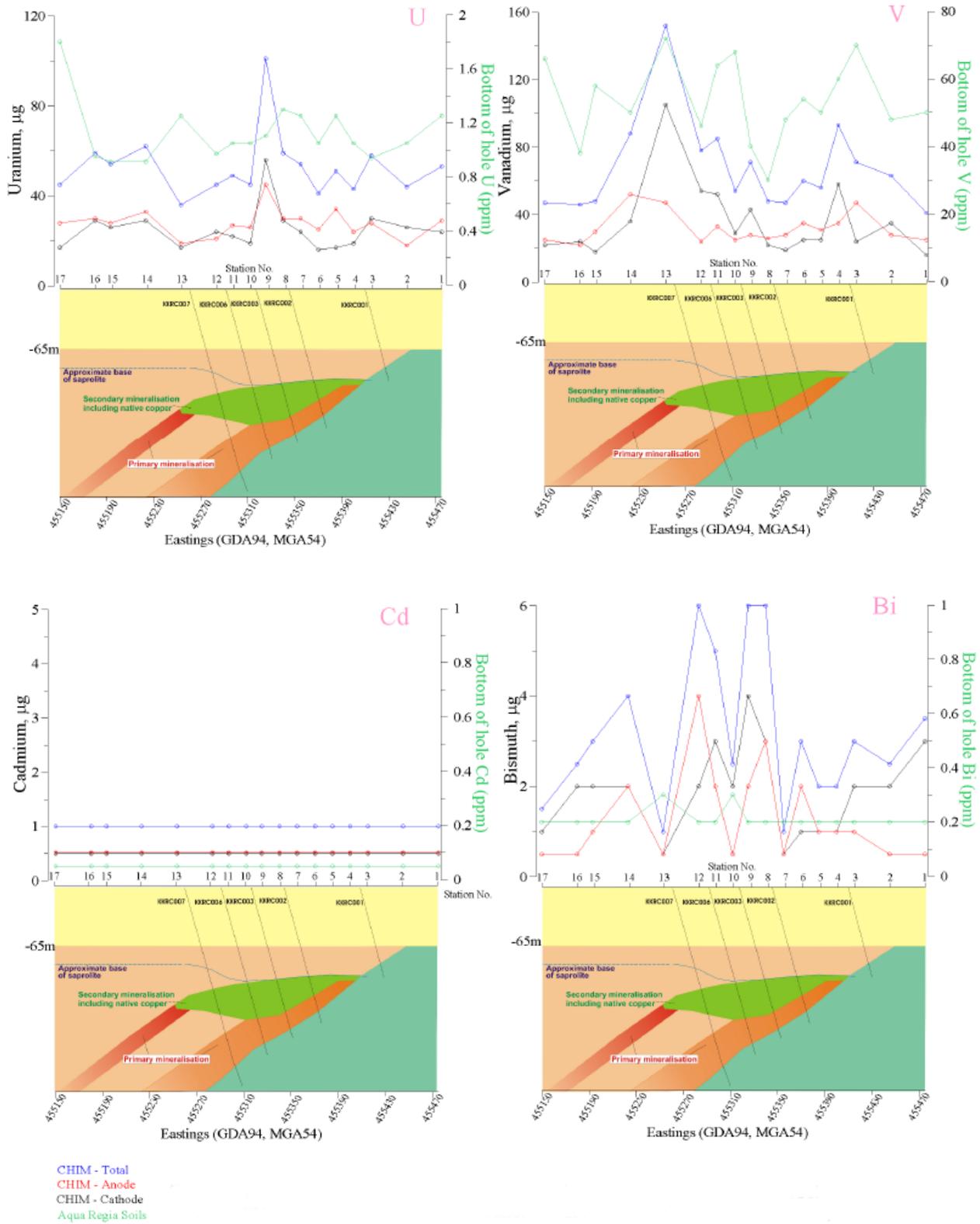


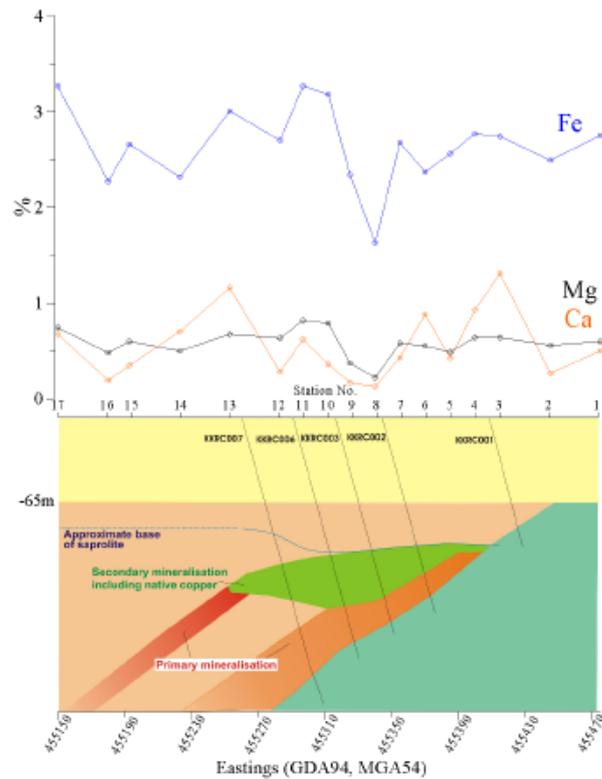
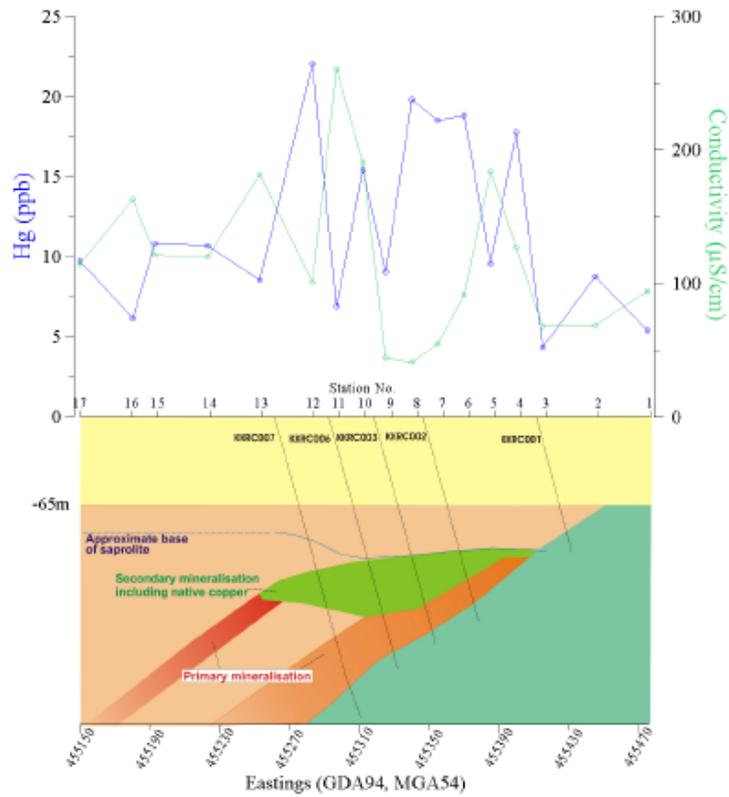
Figure 7 (ii).

## Kalkaroo CHIM Line A



**Figure 7 (iii).**

## Kalkaroo CHIM Line A



**Figure 8. Plots of Hg, conductivity, Fe, Mg and Ca analyses over Kalkaroo Line A**

### 3.4.2 *Results and Discussion*

An anomaly of 4 times background in As was recorded over known mineralisation (Figure. 12i). The elevated value was recorded at the anode. Arsenic has no known relationship to the Goulds Dam mineralisation and is therefore most likely coincidental. Elevated levels were recorded in Rb, Cu, W and V over mineralisation, but are not considered to be sufficiently above background to be significant (Figure. 12). High Ag, Mo and U levels at the eastern end of the survey line can not be disregarded as the extent of uranium mineralisation in this part of the palaeochannel is poorly defined by the small number of drill holes.

Bottom-of-hole soil results show no relationship to mineralisation. The conductivity and Hg measurements were slightly higher over the area of mineralisation but the survey did not extend far enough to determine whether these elevated values are significant (Figure. 13).

## 4. **DISCUSSION**

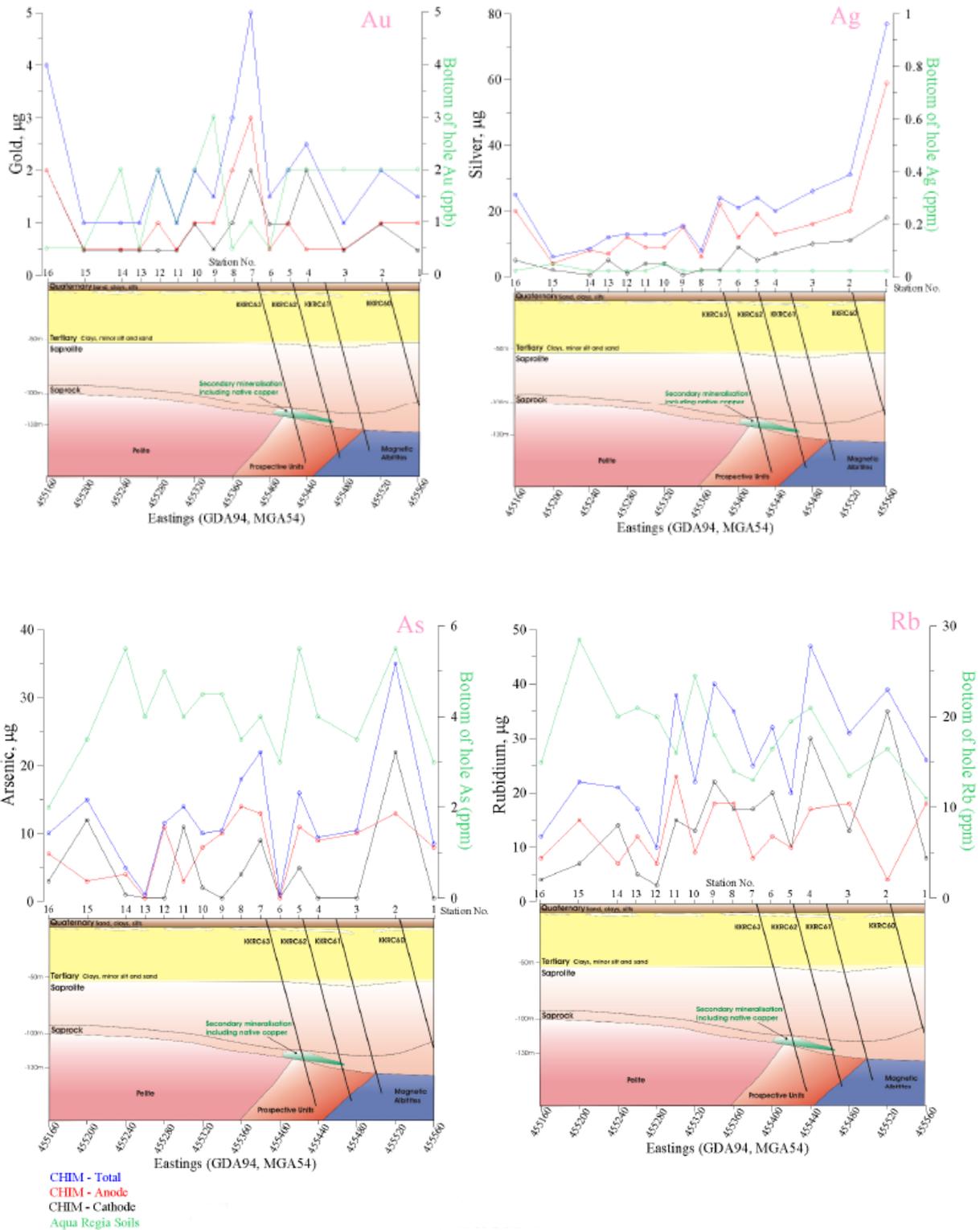
The Chinese CHIM is compact and portable but has requirements that limit the scope of potential applications. In particular, the requirement to supply acid and to leave the electrodes in place for around 48 hours mean that this type of survey is best suited to brownfields exploration where targets are reasonably well constrained. In this respect the use of CHIM is similar to some ground electrical geophysical surveys, with which it is also comparable in terms of logistics and cost.

Previous CHIM surveys have reported a surface response directly over mineralisation or above crosscutting structures that act as conduits for ions to migrate to the surface (Leinz et al., 1998; Antropova et al., 1992). In order to maximise a potential response, the spacing between pairs of electrodes needs to be compatible with the size of the target and not rely on an inferred broader chemical dispersion halo. This means that for shear-hosted, structurally-controlled or steeply dipping, stratigraphic-hosted mineralisation, the spacing between electrode pairs may need to be under 10 m to ensure that more than one sample point is over mineralisation. During field trials of the CHIM, a number of issues were identified that may have impacted on results of the surveys. Acid attack on the copper wires connecting the battery to the electrodes was noted. Any exposure of the copper wire during the electrolysis process would result in its gradual digestion and therefore an effect on recorded copper levels. It is for this reason that all copper results recorded by the current CHIM technique must be interpreted with caution. This makes detecting copper mineralisation difficult. An additional concern is where the acid may dissolve sufficient copper wire so as to break the electrical connection. If the electric current is an important factor for the accumulation of metal ions by the CHIM method, as suggested, any electrode that has been disconnected for a period could invalidate any comparison with results obtained from other electrode pairs used in the survey.

The addition of  $\text{HNO}_3$  around each electrode acts to liberate ions from surrounding soil and improve electrical conductivity. In soils that contain high carbonate content there will be significant variation in the effect of acid addition, due to neutralisation. Although carbonate content can be monitored by analysis, there is no effective way to quantify the effect and to factor this into the interpretation of results.

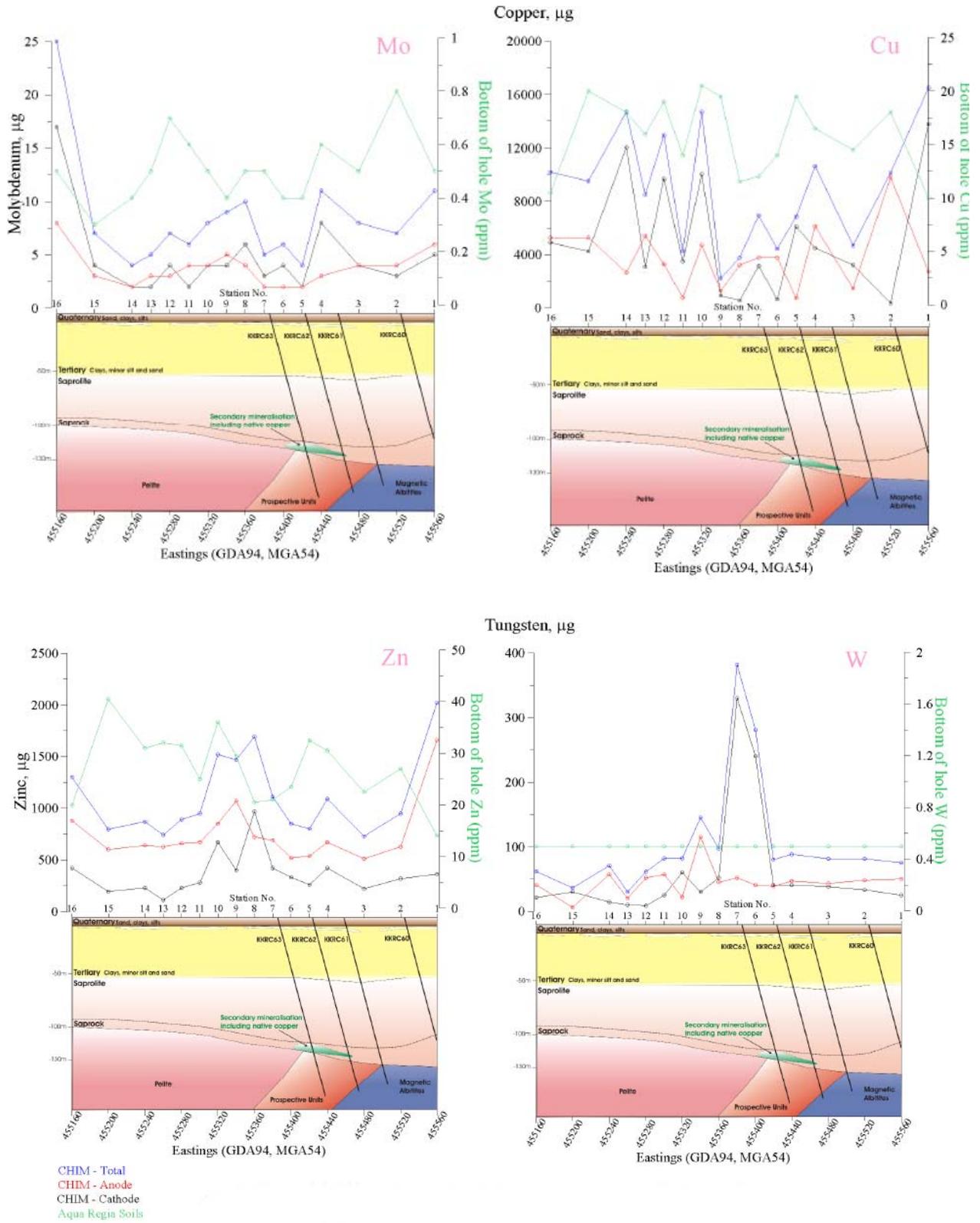
Future collaboration with Professor Luo will look to address these issues, and to examine other variations and modifications of the CHIM technique that have been developed in China with a view to their potential application in Australia.

## Kalkaroo CHIM Line B



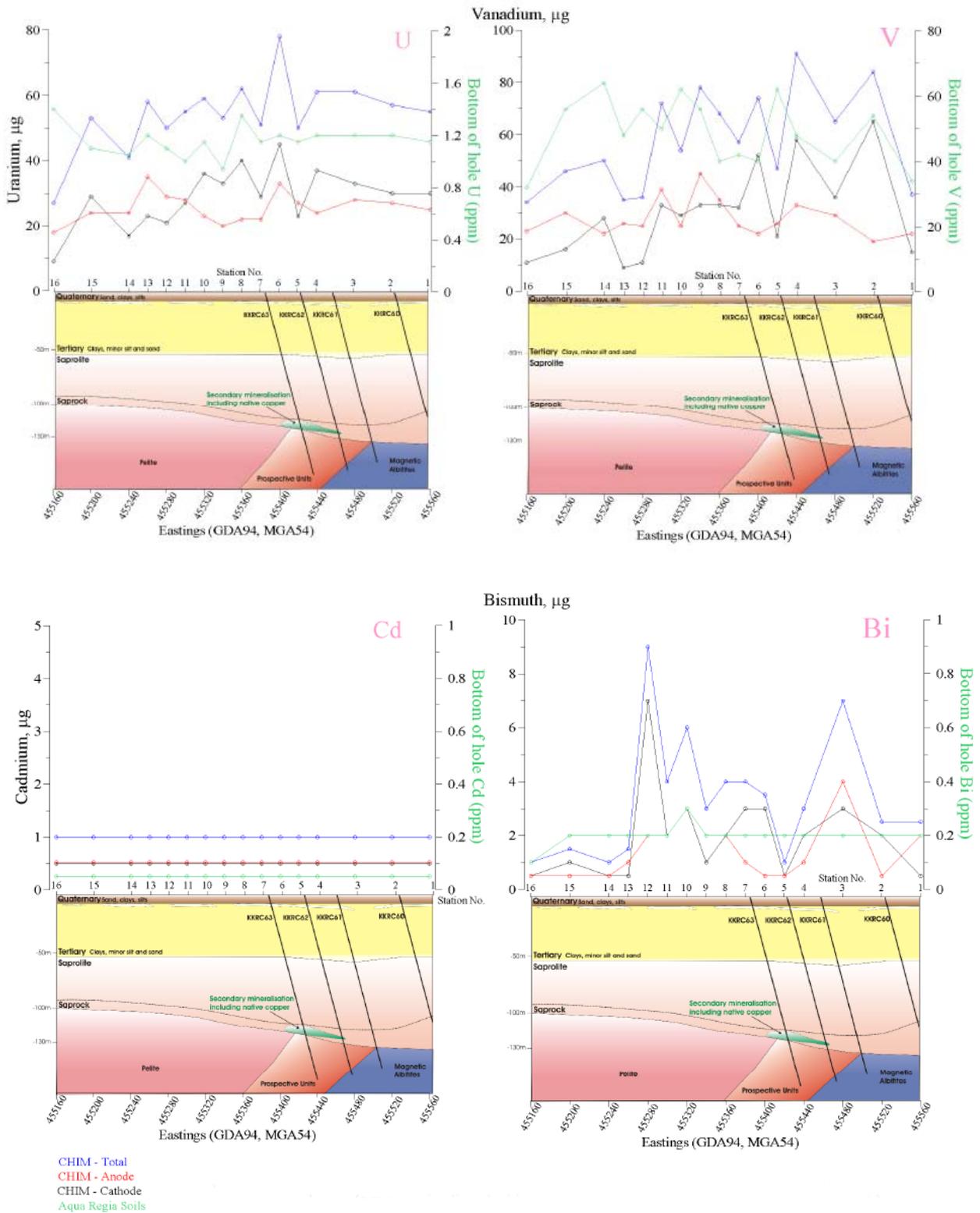
**Figure 9 (i).** Plots of CHIM analyses along Line B at the Kalkaroo Cu-Au-Mo Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~0.2 m depth). (i) Au, Ag, As and Rb, (ii) Mo, Cu, Zn and W, (iii) U, V, Cd and Bi.

# Kalkaroo CHIM Line B



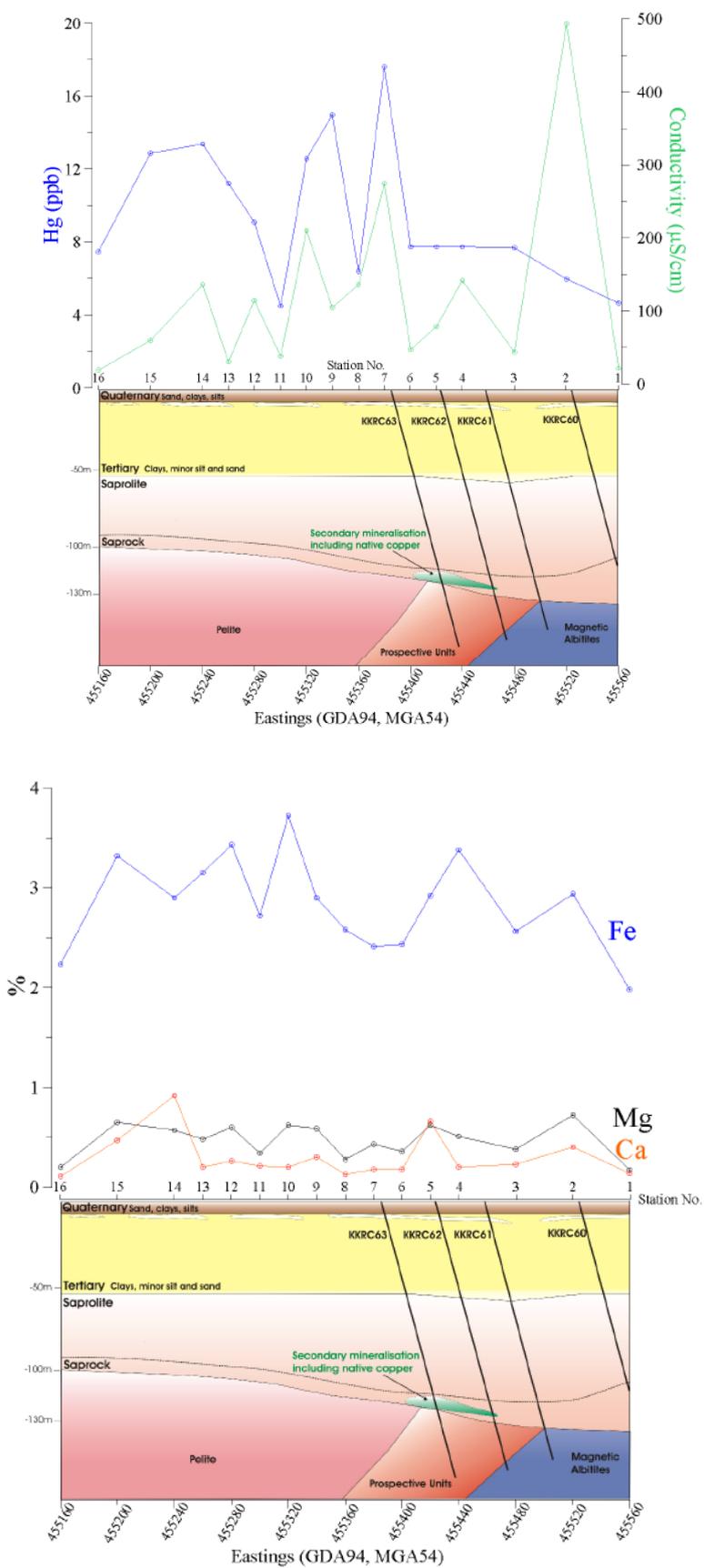
**Figure 9 (ii).**

# Kalkaroo CHIM Line B



**Figure 9 (iii).**

## Kalkaroo Line B



**Figure 10. Plots of Hg, conductivity, Fe, Mg and Ca analyses over Kalkaroo Line B.**

## **5. CONCLUSION**

While promising relative to other methods trialled, the results of CHIM surveys did not give a reliable relationship between surface geochemistry and the location of underlying mineralisation. Of the three locations and styles of mineralisation tested, the Challenger Au Mine produced the most encouraging results. In particular for As on Line B, where point anomalies appeared to map the underlying ore shoots. The lack of response on the deeper section on Line A may indicate that the method was applied beyond its practical limit.

Elevated levels of Au, U, Cu and Bi on Line A and for Au and W on Line B of the Kalkaroo survey define the zone of highest-grade mineralisation. Results from the Goulds Dam survey were less encouraging. A lack of constraint on the extent of mineralisation at the Kalkaroo and Goulds Dam prospects broadens the zone of potential underlying mineralisation and thus also the area where an anomaly may be significant. Survey lines over these prospects were probably not of sufficient length to establish true background levels for elements targeted in the CHIM surveys.

There is sufficient encouragement in the CHIM data to suggest that some modification to the technique could improve the overall result. The use of a longer record time or increased current may help to sharpen up any weak anomaly that might be present.

## **6. RECOMMENDATIONS**

- The technique warrants further experimentation for near mine extensions to ore at the Challenger Au mine. Some modifications are needed to improve the robustness of the system and to allow monitoring of current input so as to be able to optimise the system for the dry soil conditions often encountered in the Australian outback.
- The use of wires that will not contribute to an anomaly in elements of interest is recommended.
- The CHIM was tested in challenging conditions. Future surveys should include sites that provide a range of transported cover thickness and various styles of primary mineralisation, including shear-hosted deposits.

## **ACKNOWLEDGEMENTS**

Guilin University of Technology, China, and CRC LEME, PIRSA provided financial and logistical support for field operations. The assistance of Tony Poustie and Andy Giles of Dominion Mining Ltd with accommodation and field activities at the Challenger Mine is gratefully acknowledged. Havilah Resources Ltd and Southern Cross Resources Ltd. Pty. (now SRX Uranium One Inc.) provided data and encouragement that made surveys at Kalkaroo and Goulds Dam prospects possible.

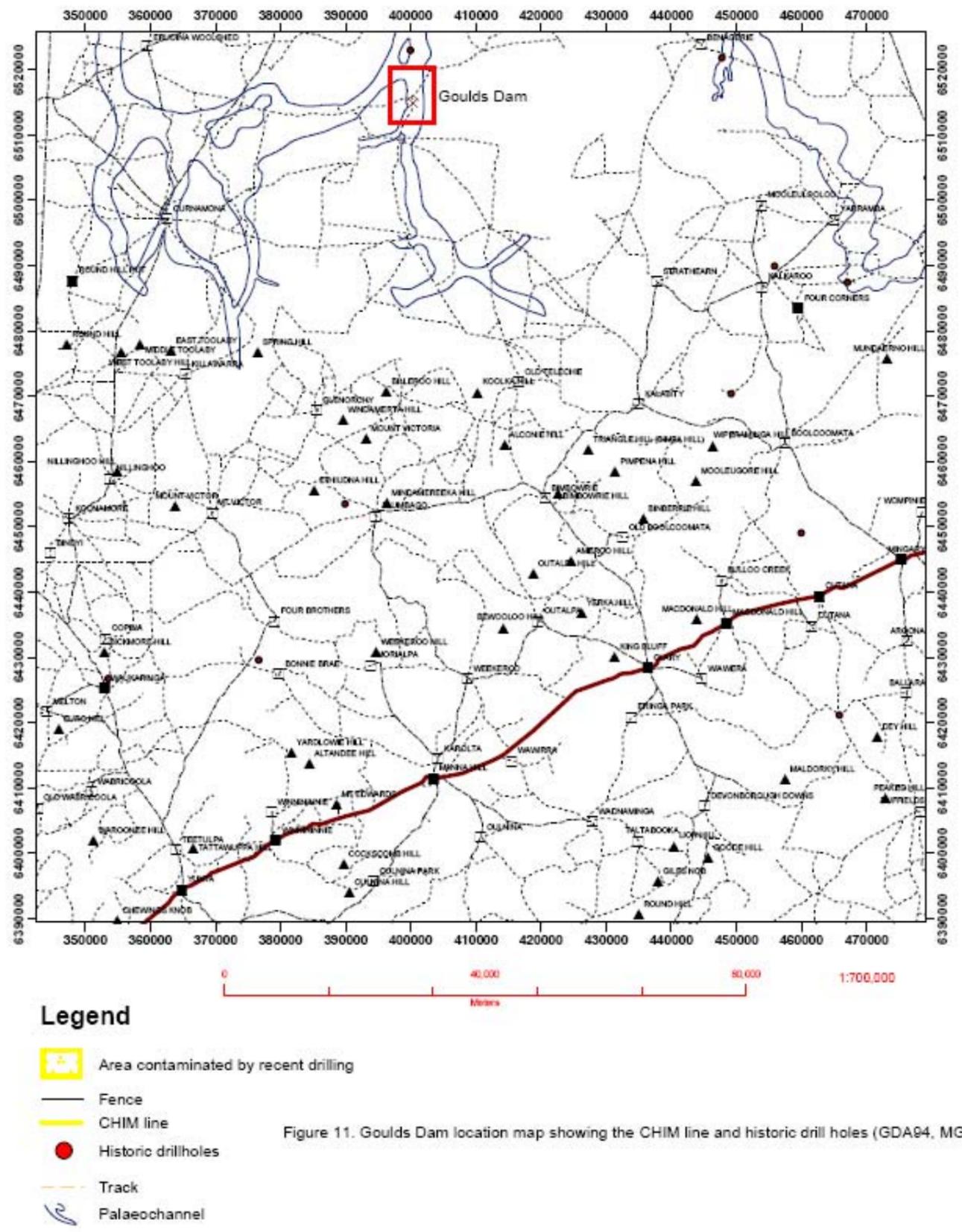
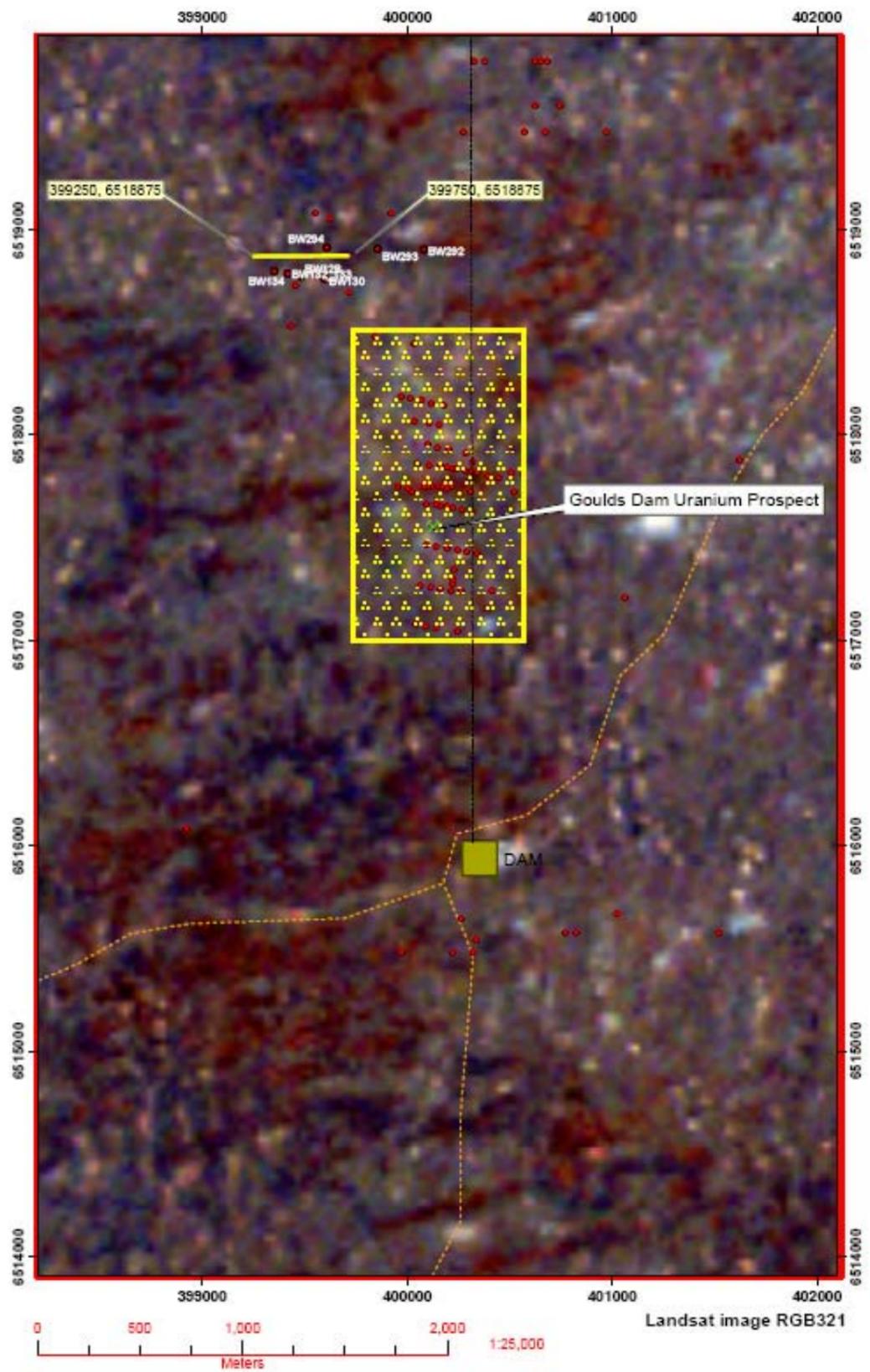


Figure 11. Goulds Dam location map showing the CHIM line and historic drill holes (GDA94, MGA54).

Figure 11. Goulds Dam location map showing CHIM line and historic drill holes

**Figure 12. Plots of CHIM analyses over the Goulds Dam U Prospect plus soil analyses (aqua regia digest of bottom of CHIM hole soil samples ~0.2 m depth). (i) As, Rb and V, (ii) Zn, W and Cu, (iii) U, Mo and Ag, (iv) Au, Bi and Cd.**

Fig 12

Fig 12

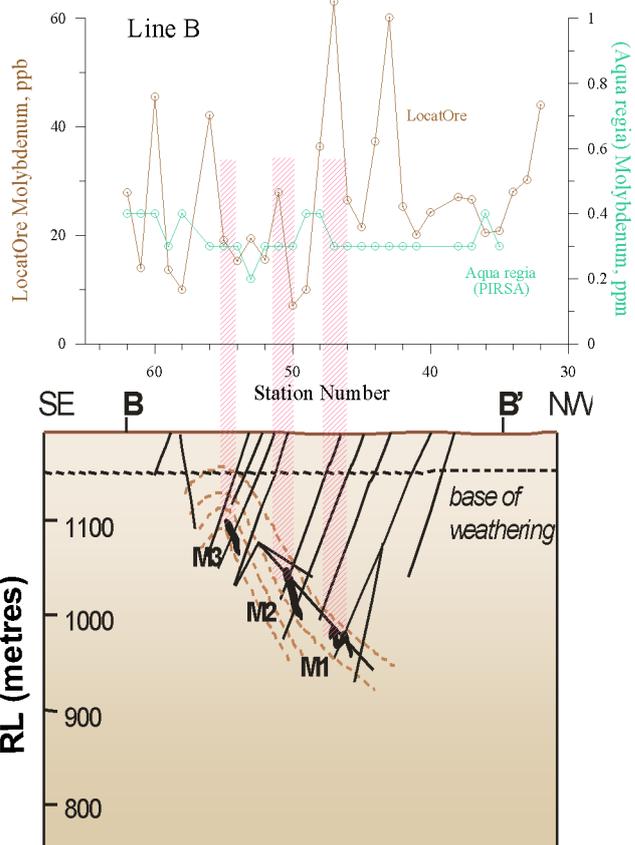
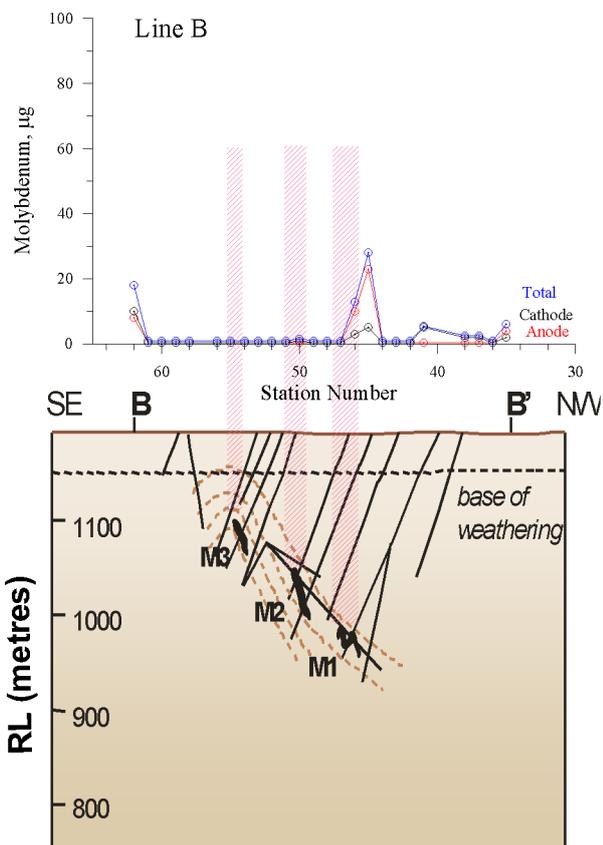
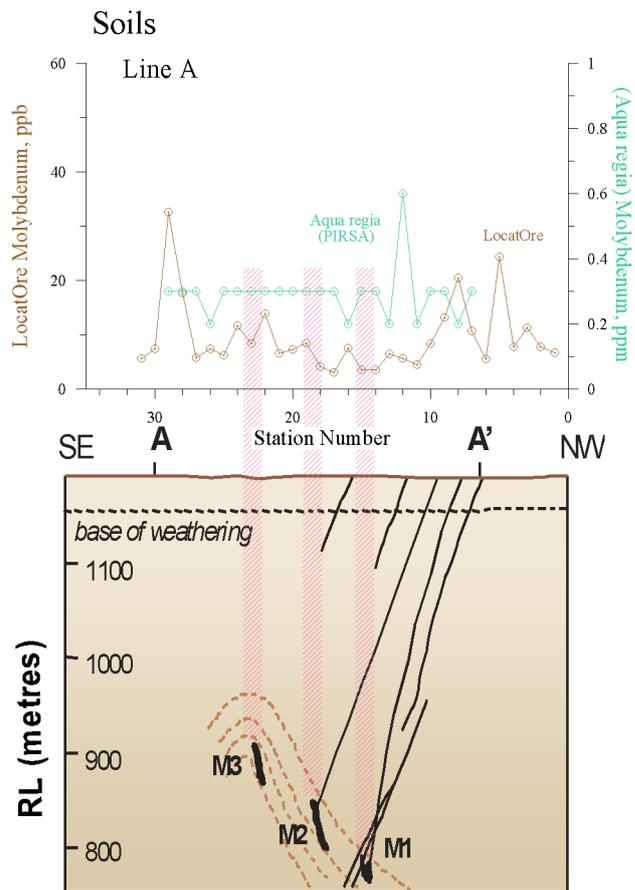
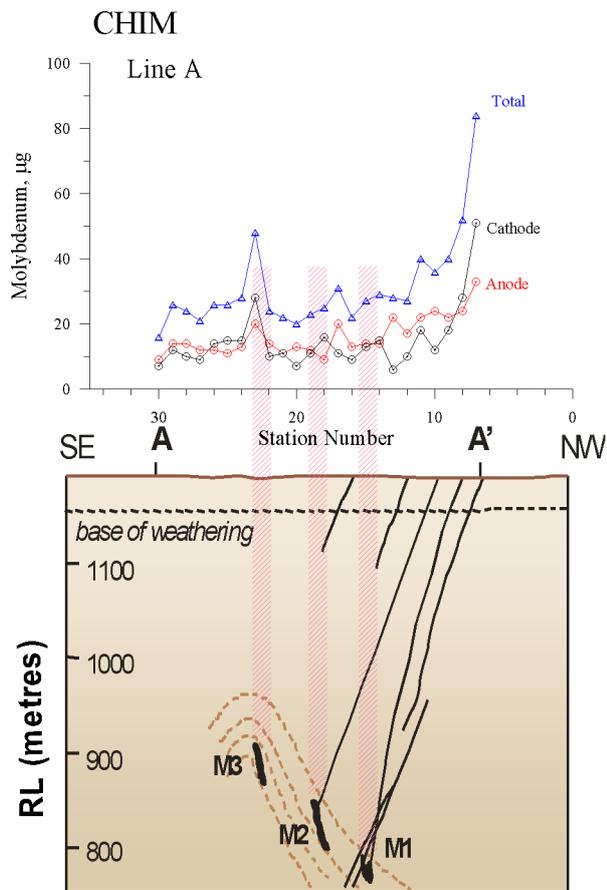
Fig 12

**Figure 13. Plots of mercury, conductivity, iron, magnesium and calcium results from the Goulds Dam survey line**

**APPENDIX A. PLOTS OF CHIM AND SOIL SURVEY RESULTS FROM THE CHALLENGER GOLD MINE**

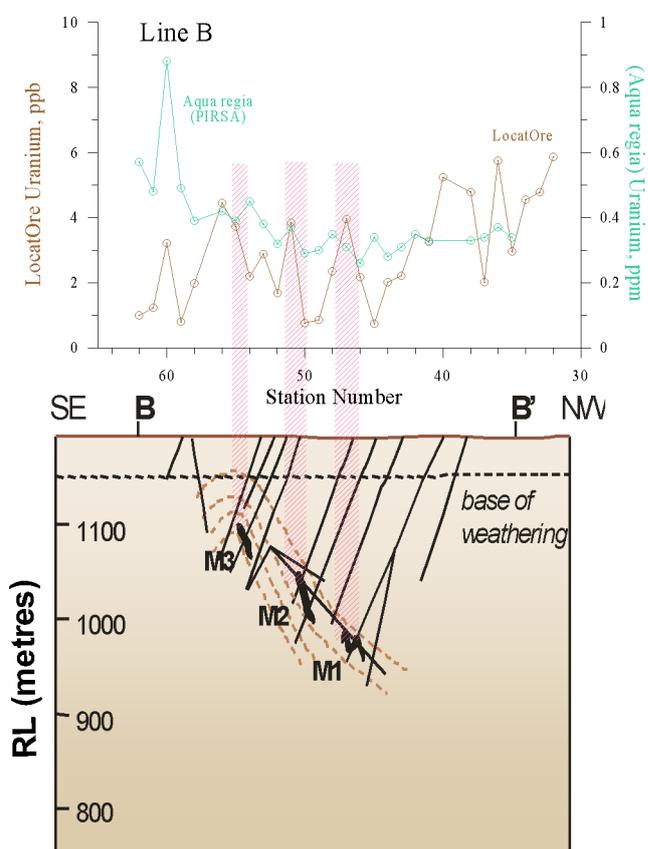
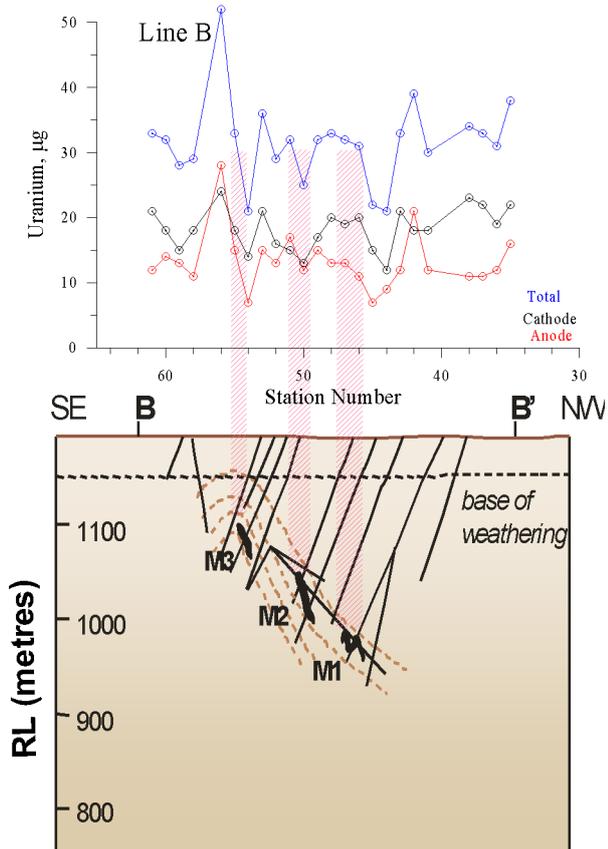
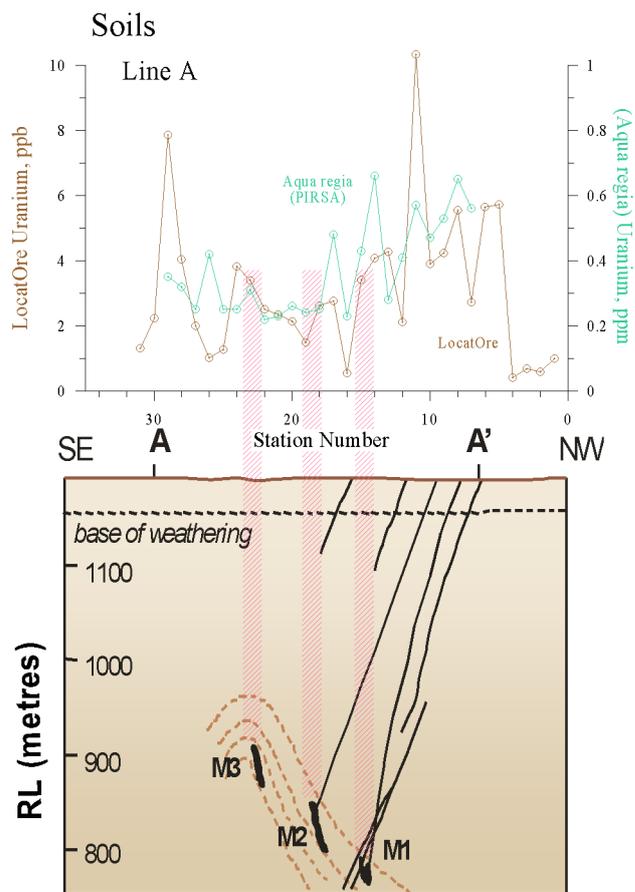
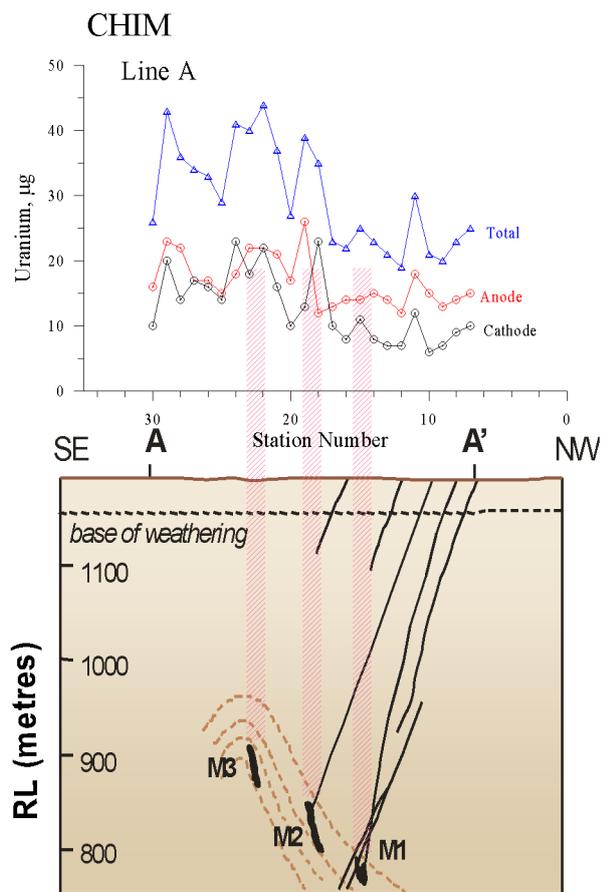
# Challenger CHIM Test

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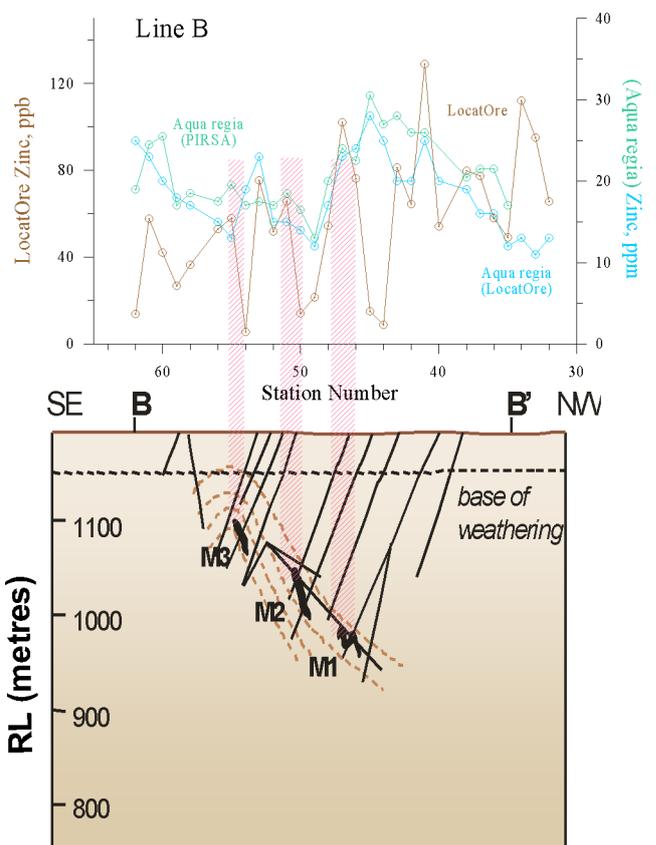
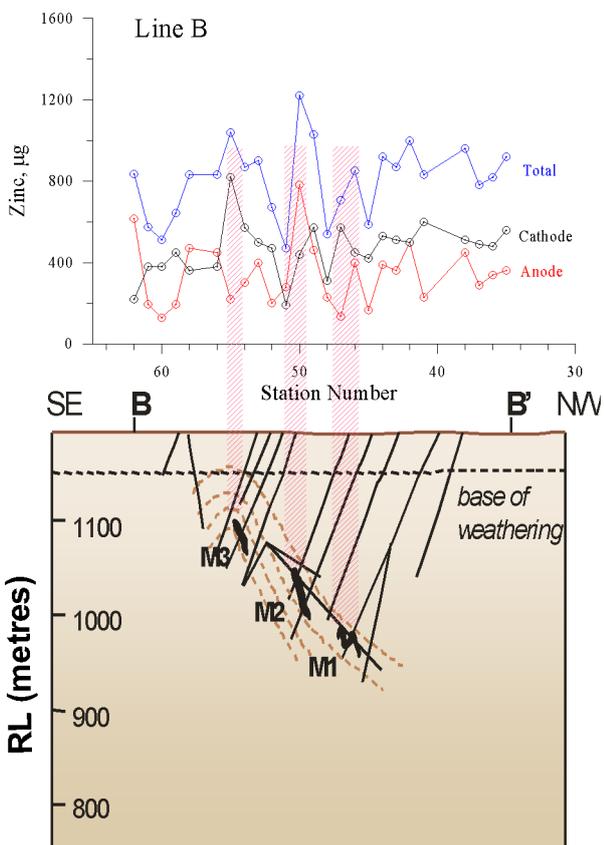
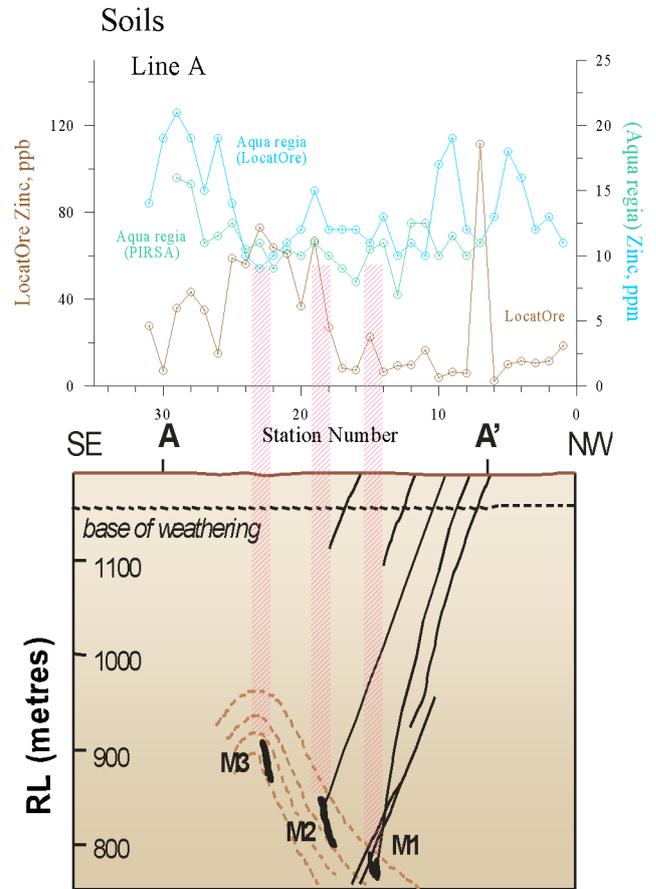
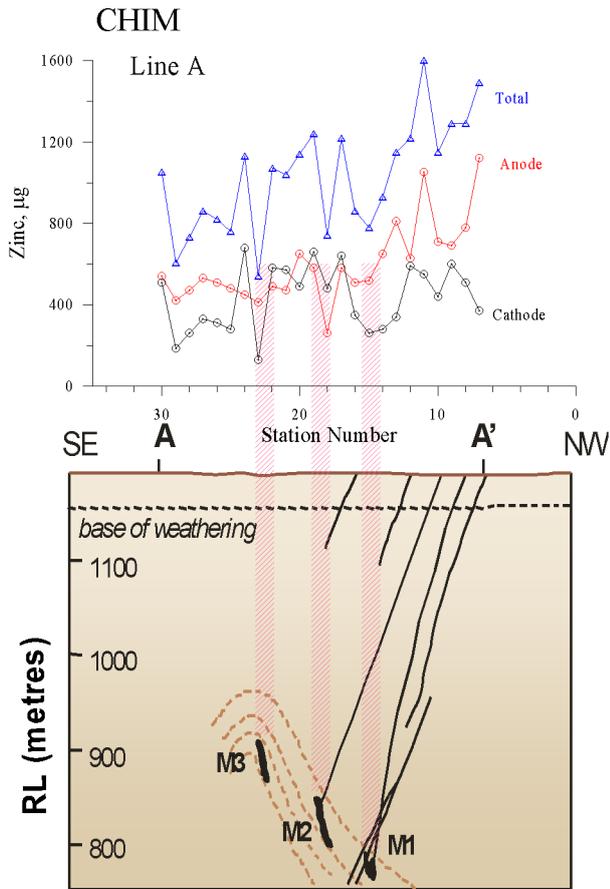
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## URANIUM



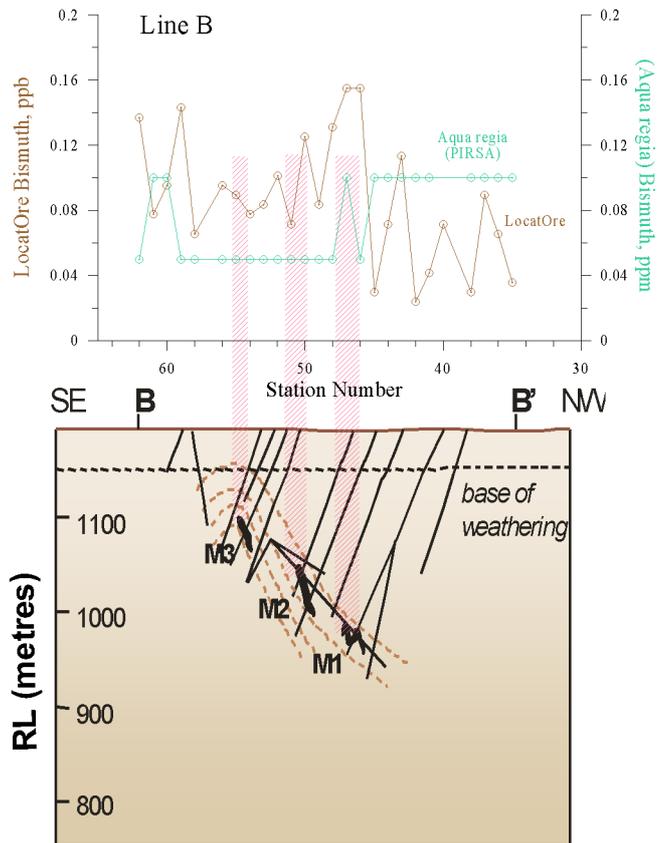
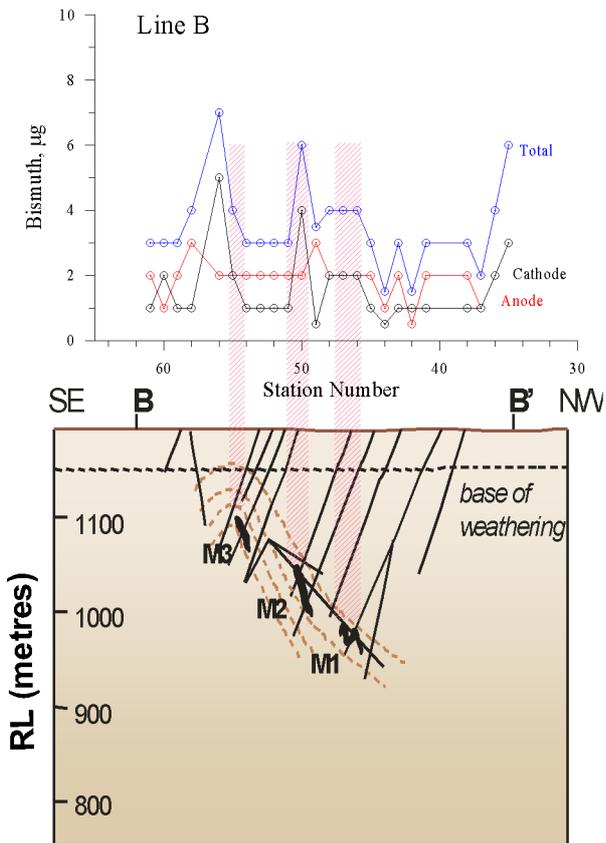
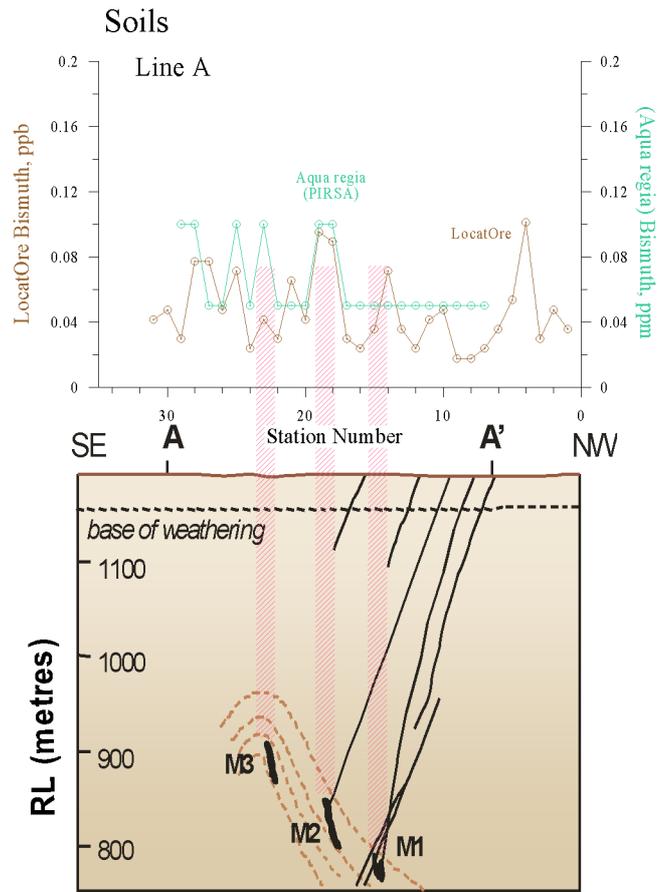
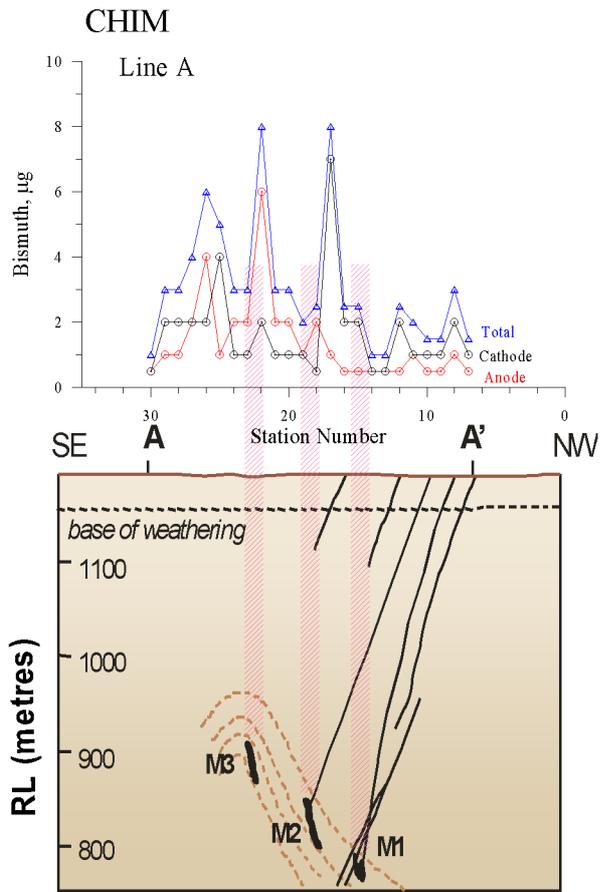
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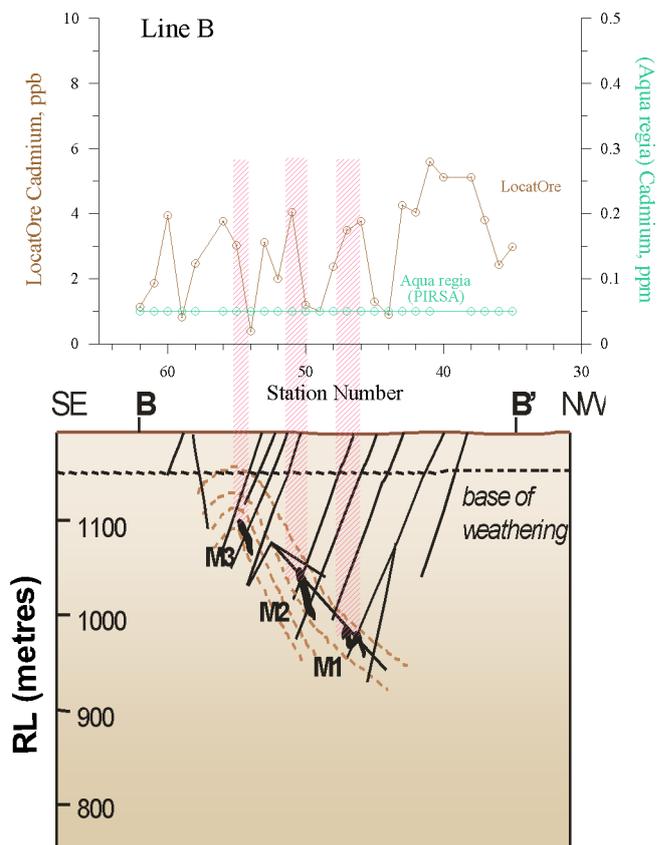
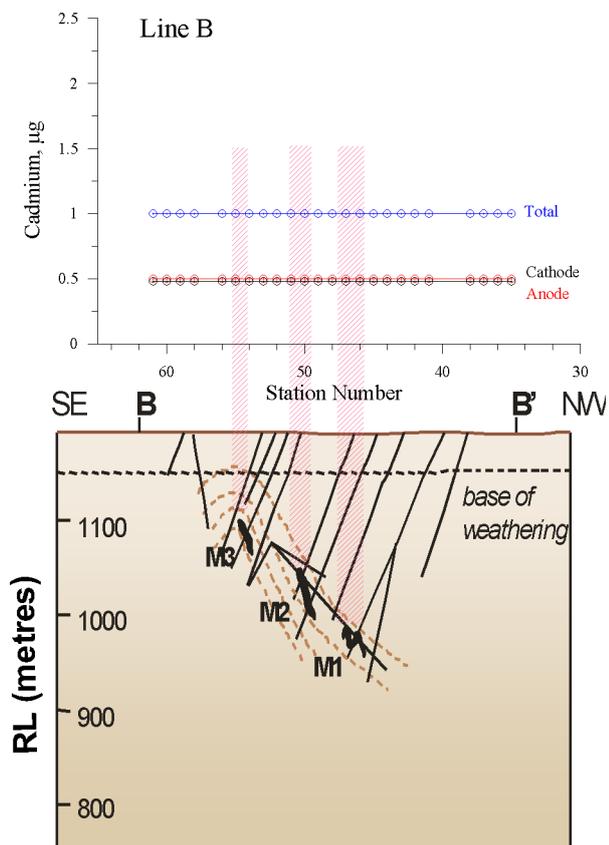
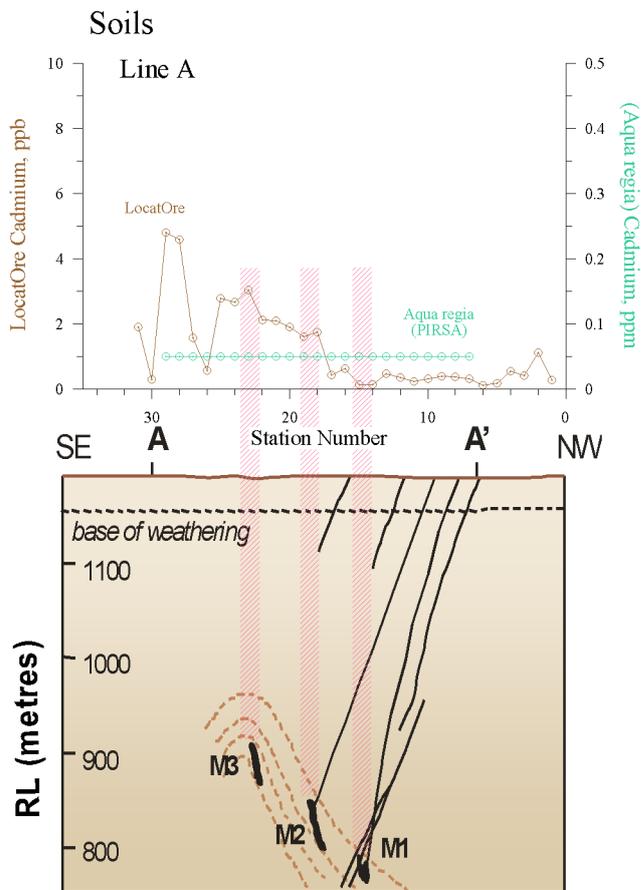
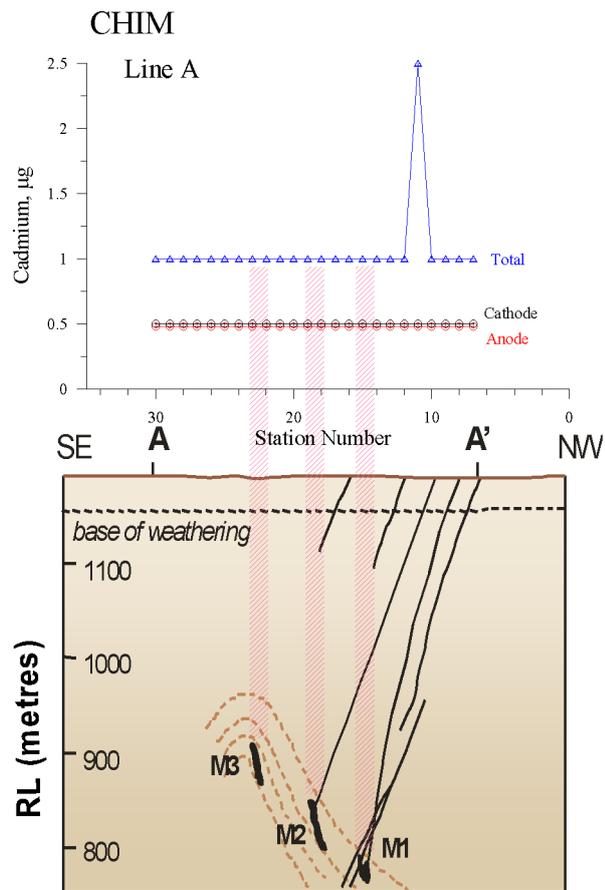
# Challenger CHIM Test

## BISMUTH



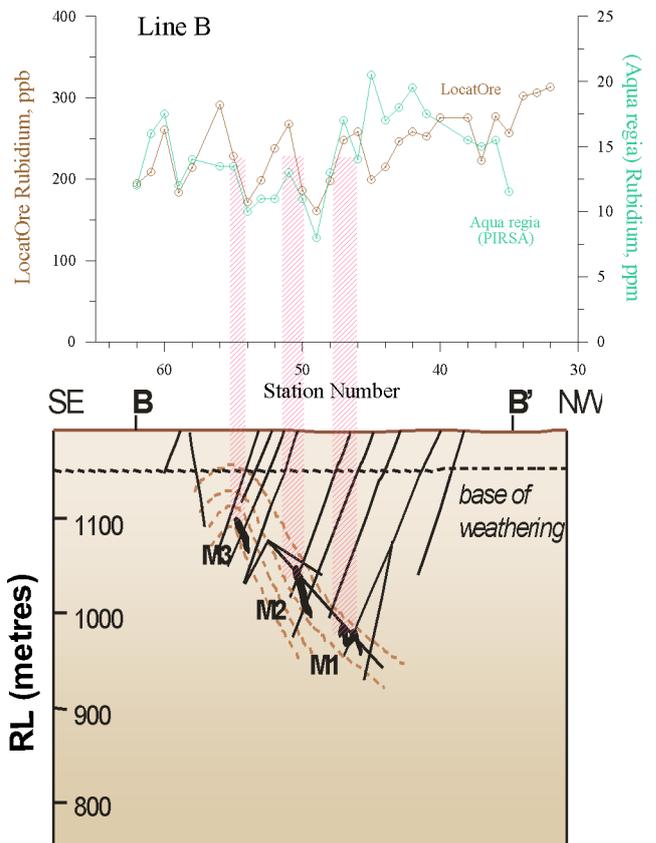
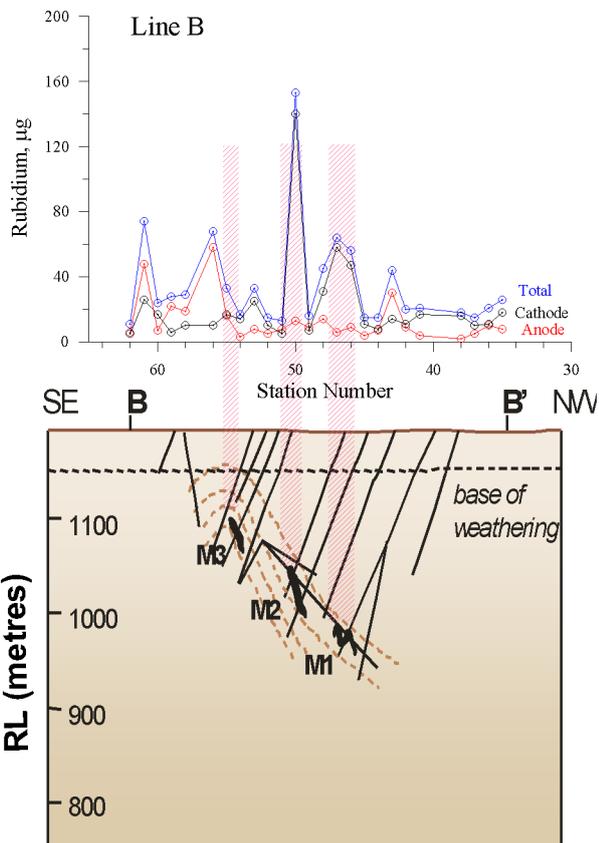
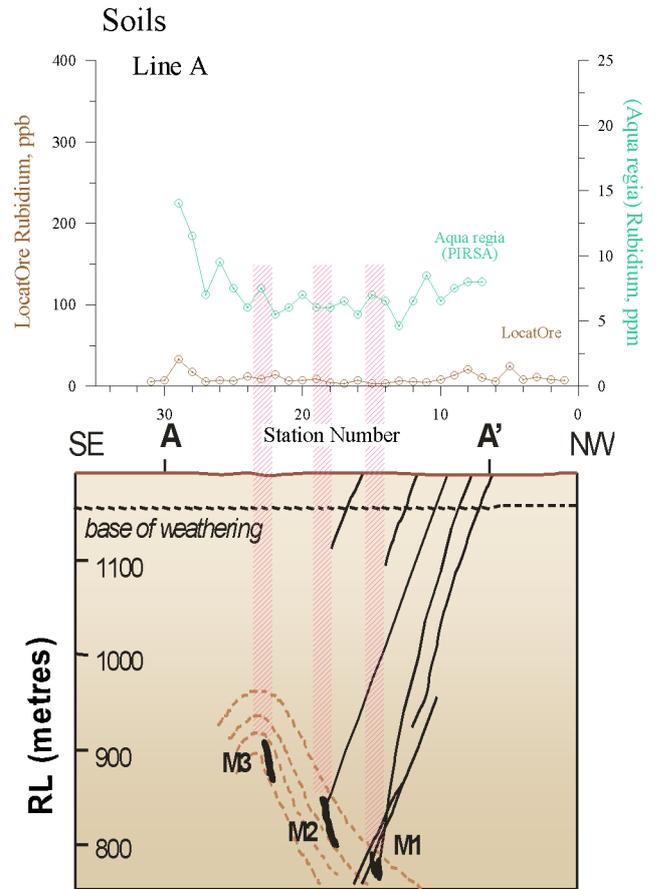
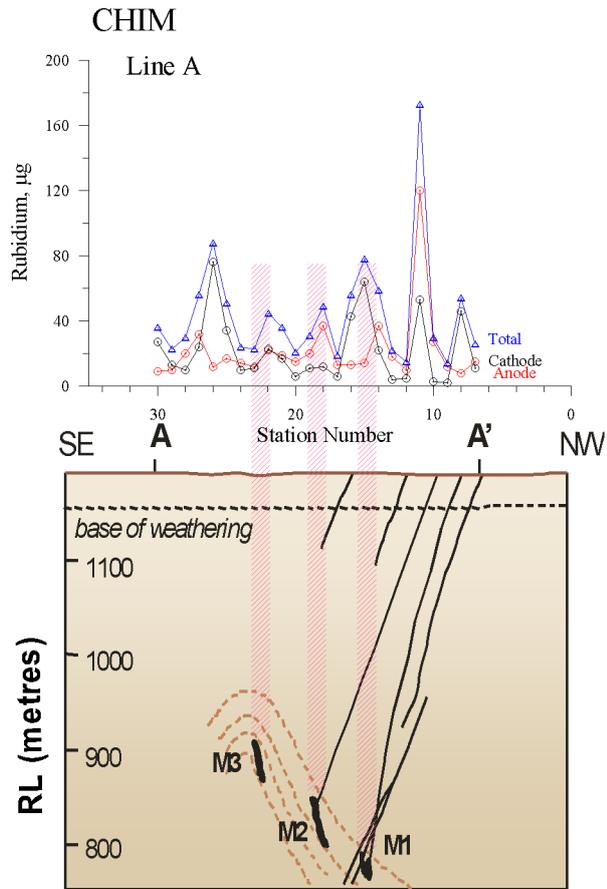
# Challenger CHIM Test

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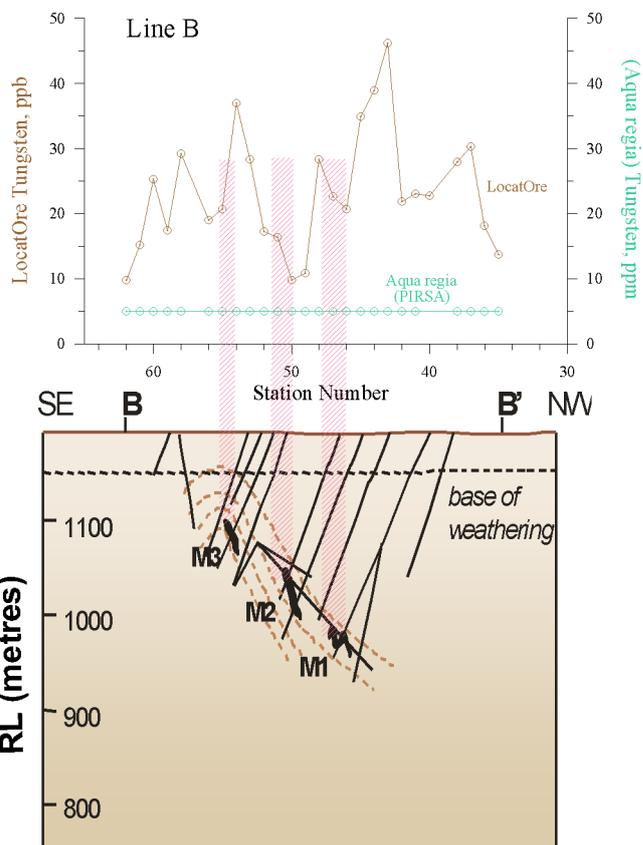
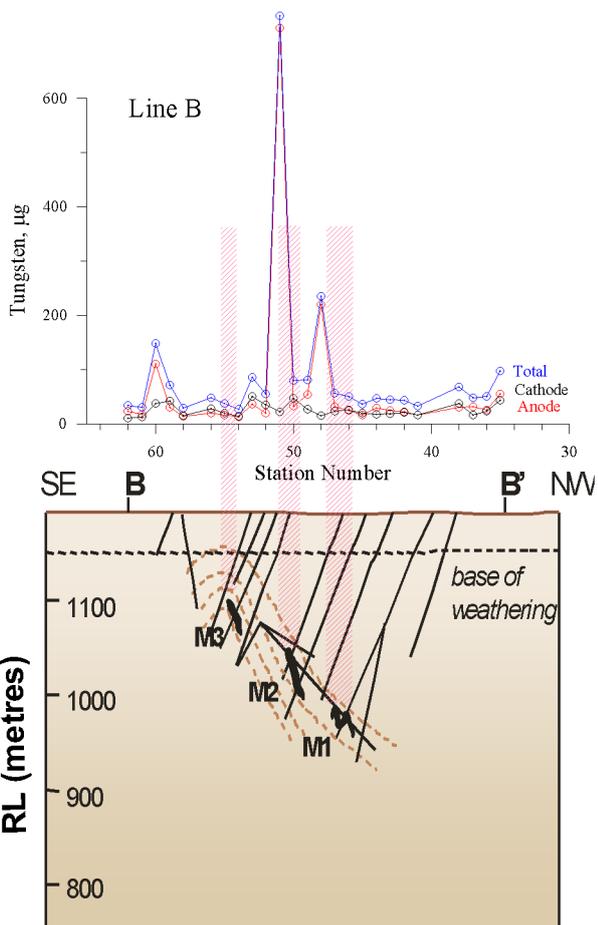
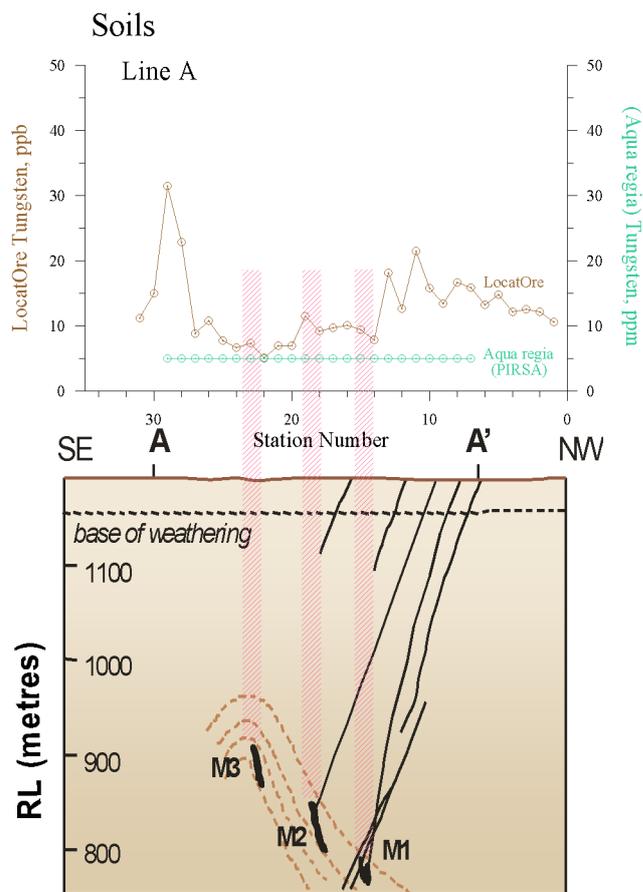
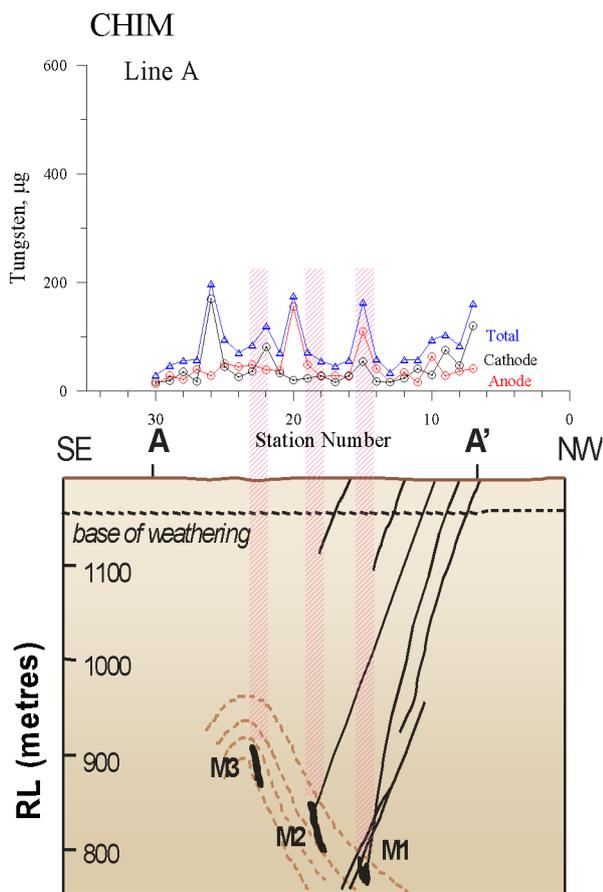
# Challenger CHIM Test

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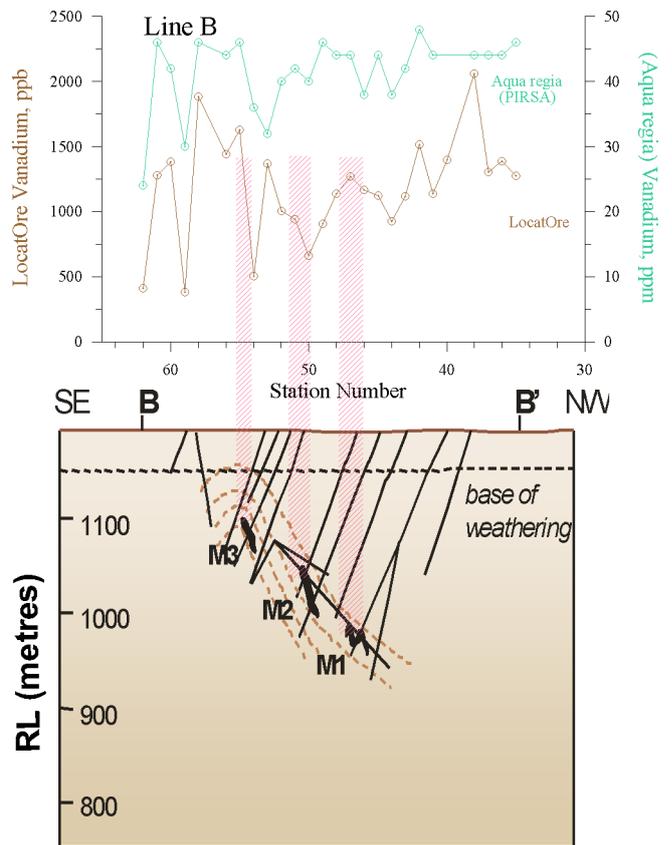
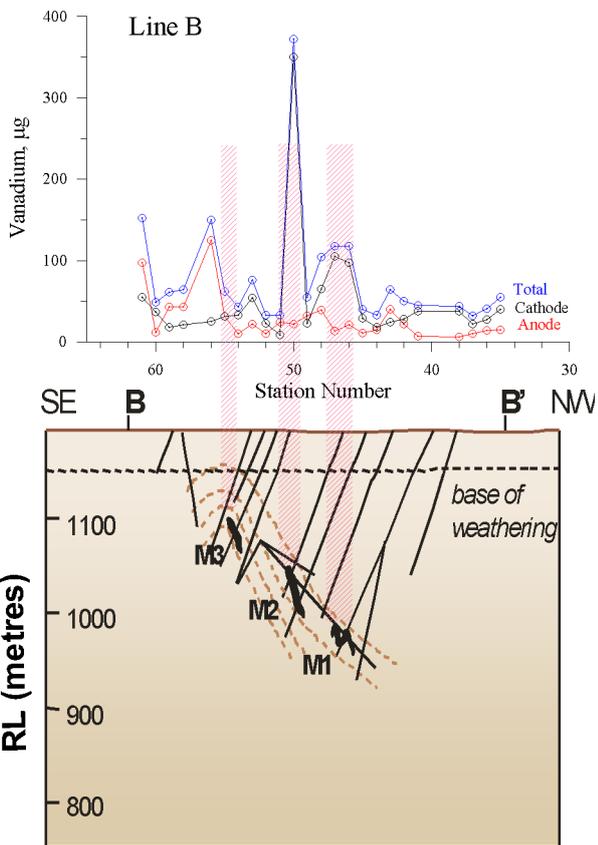
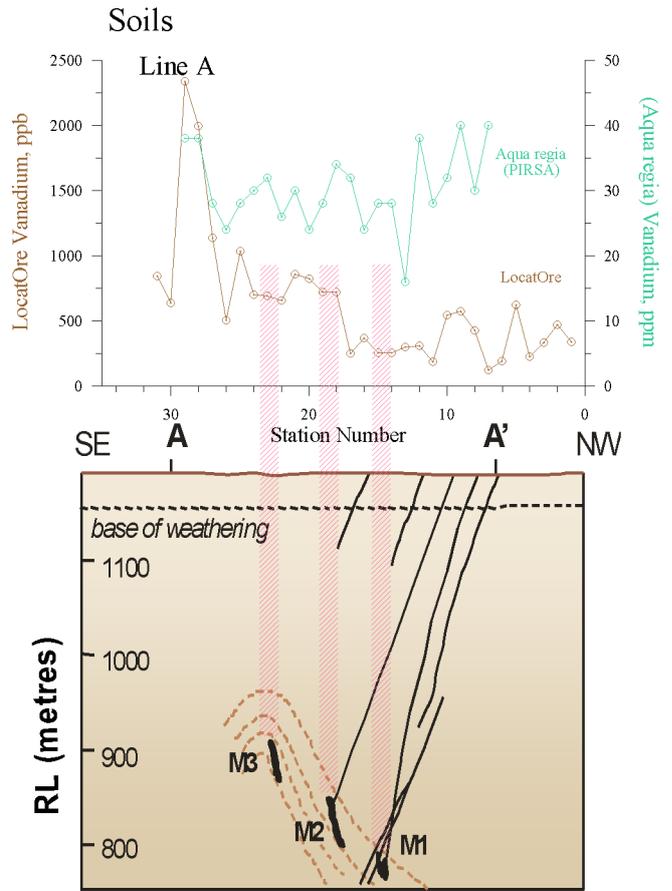
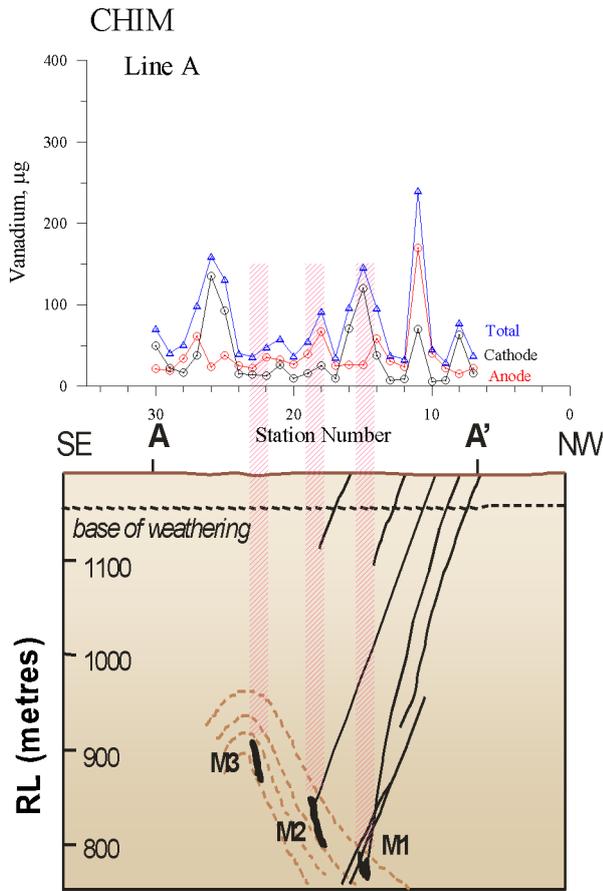
# Challenger CHIM Test

## TUNGSTEN



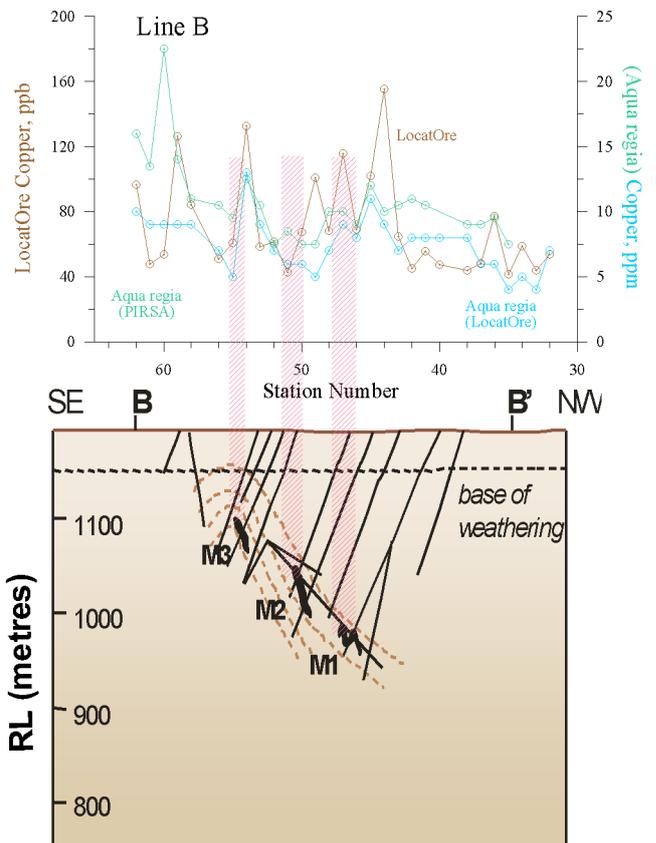
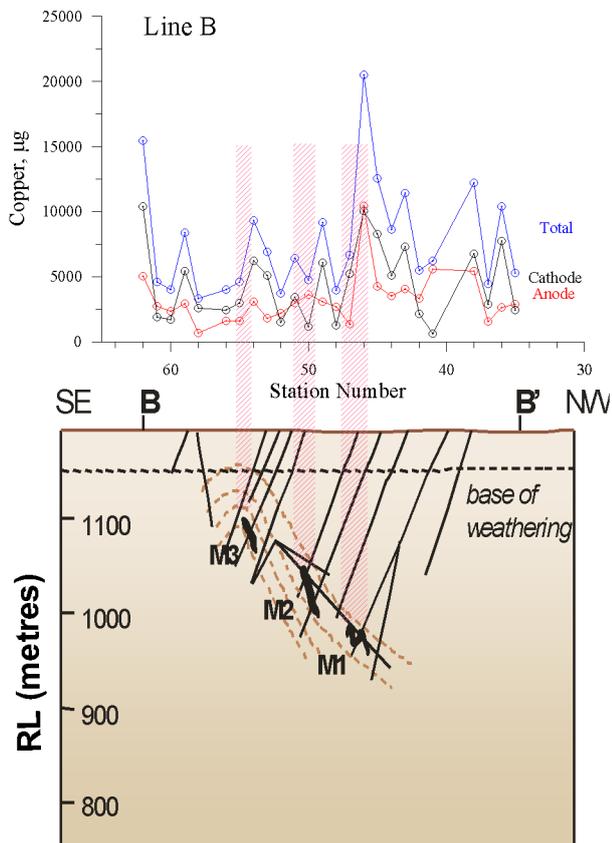
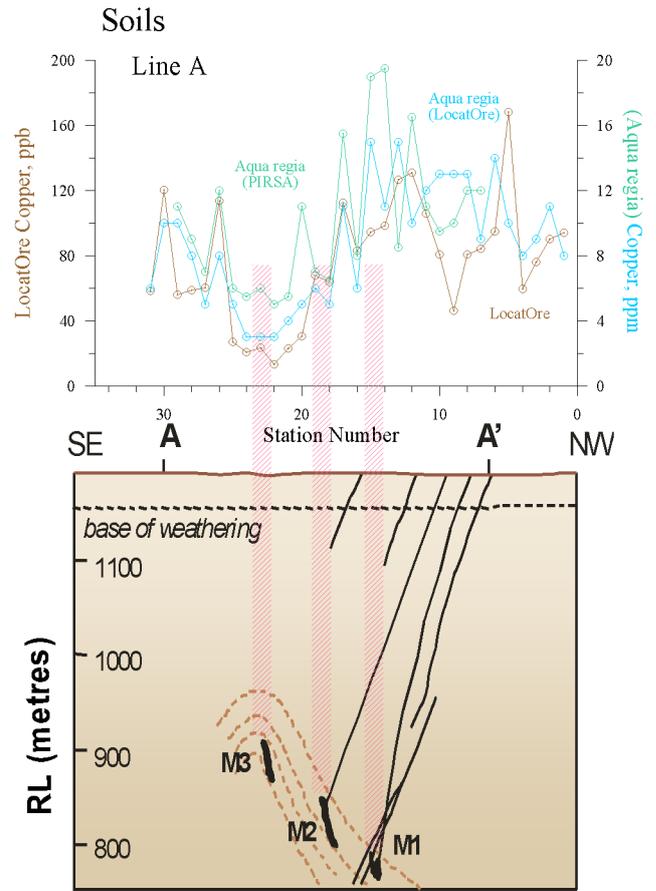
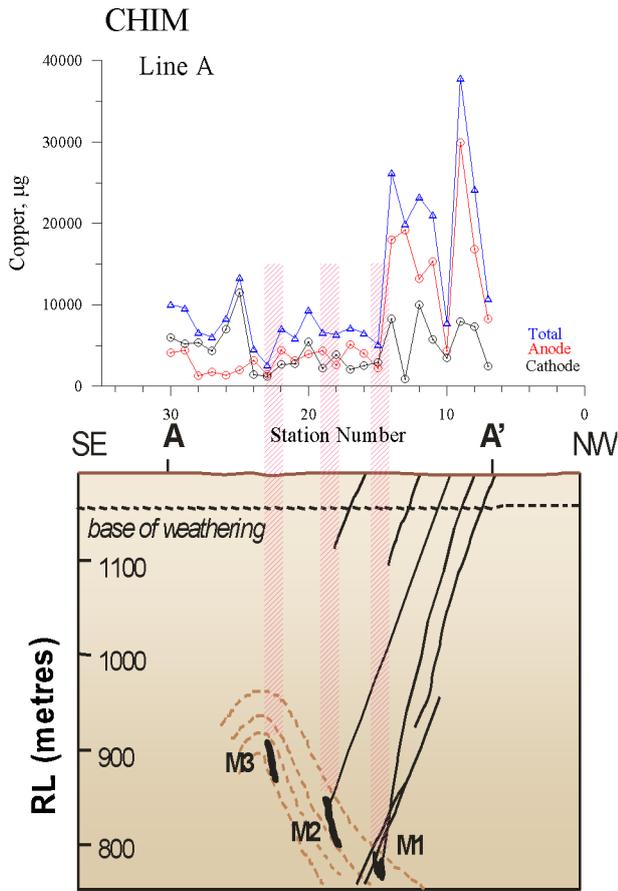
# Challenger CHIM Test

## VANADIUM



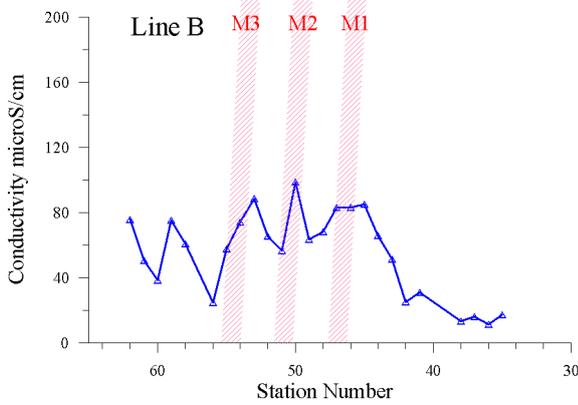
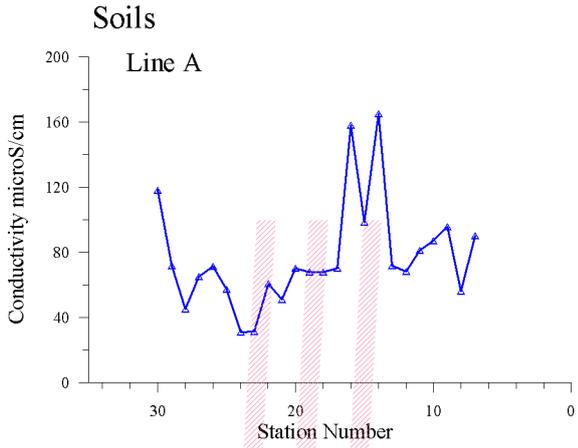
# Challenger CHIM Test

## COPPER

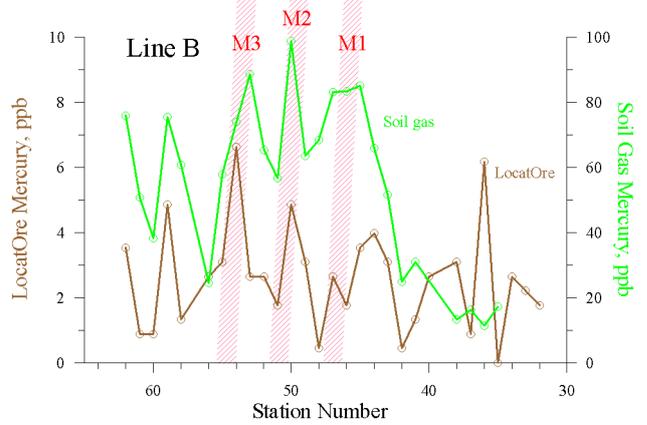
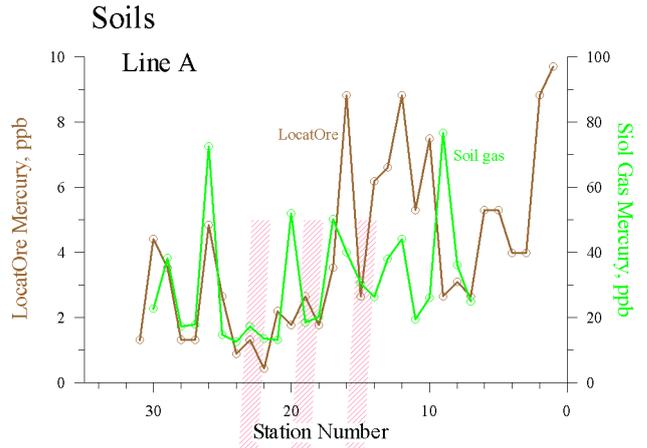


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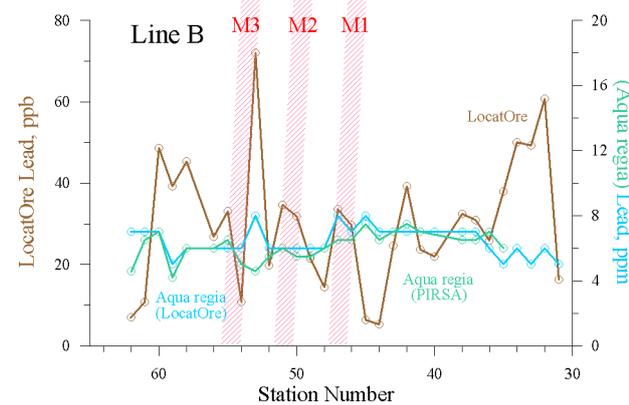
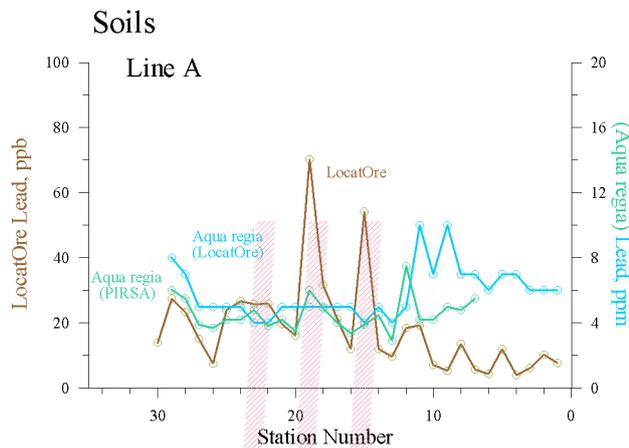
## CONDUCTIVITY



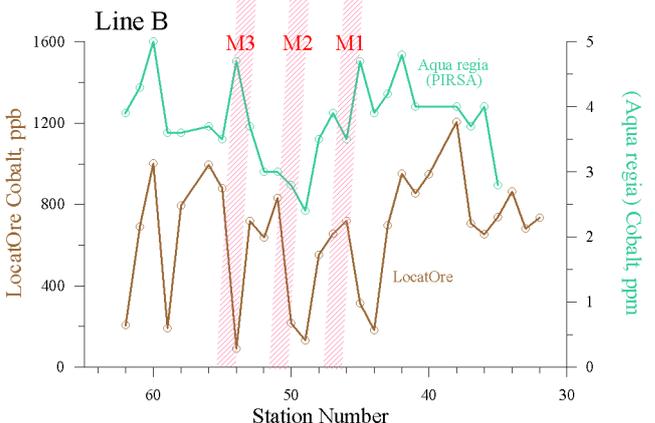
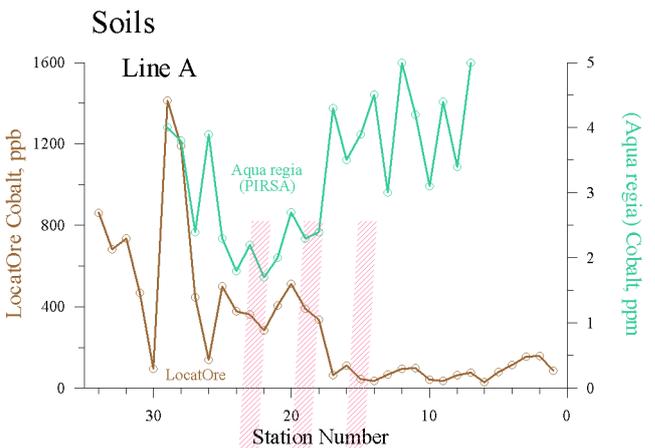
## MERCURY



## LEAD

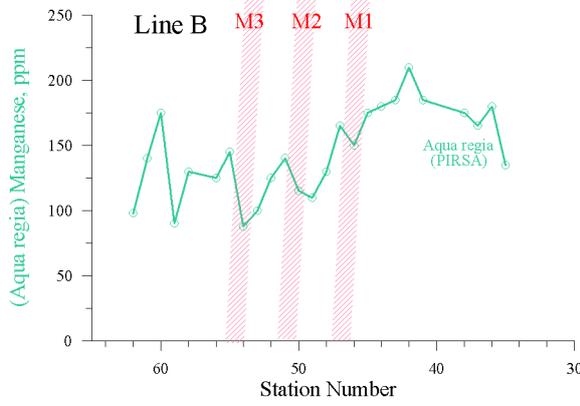
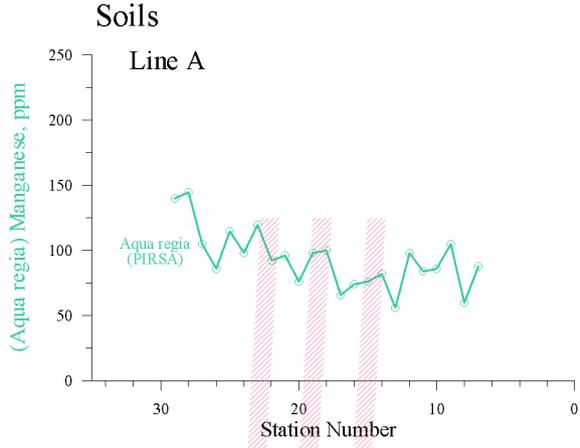


## COBALT

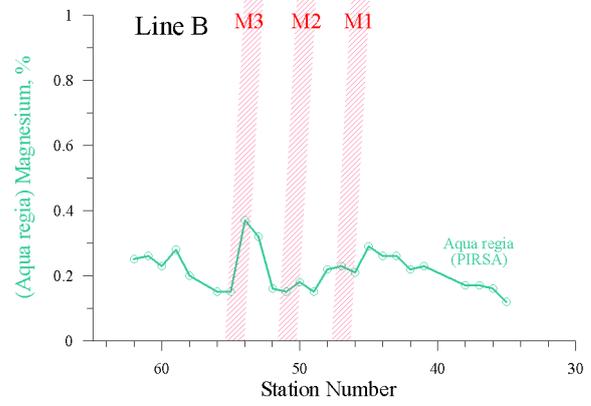
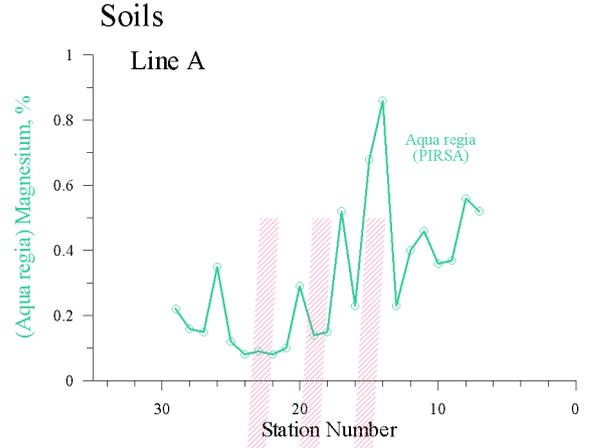


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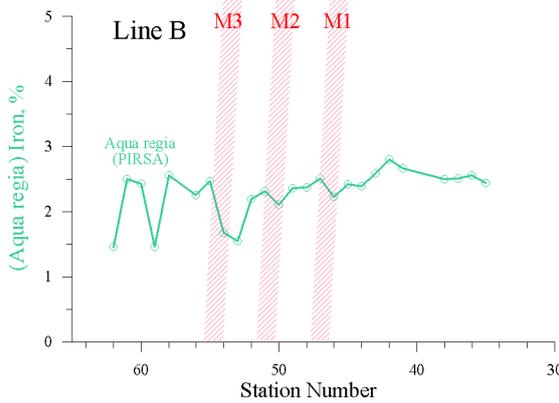
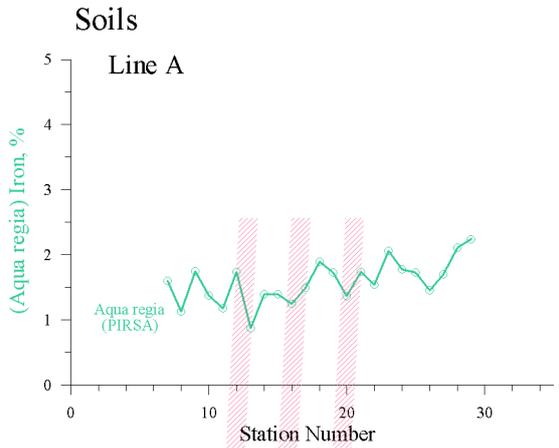
## MANGANESE



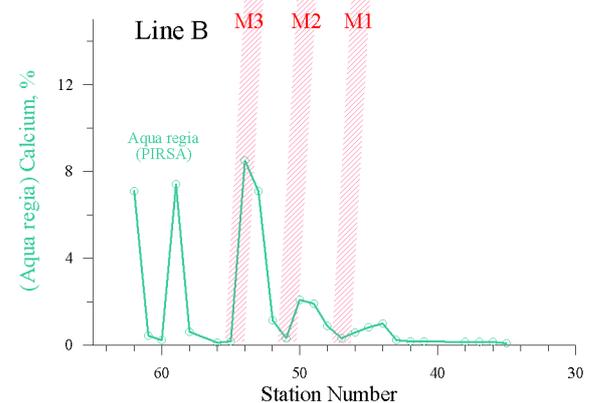
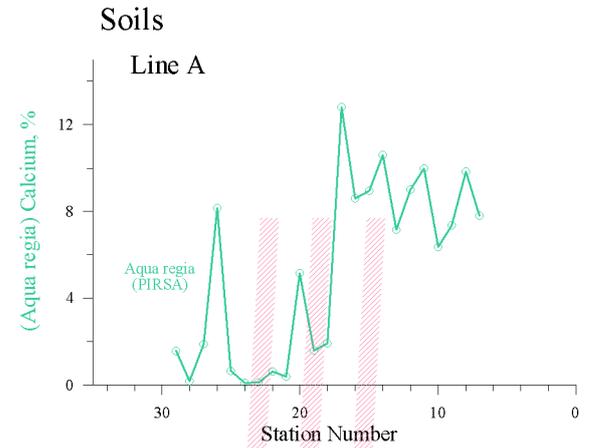
## MAGNESIUM



## IRON

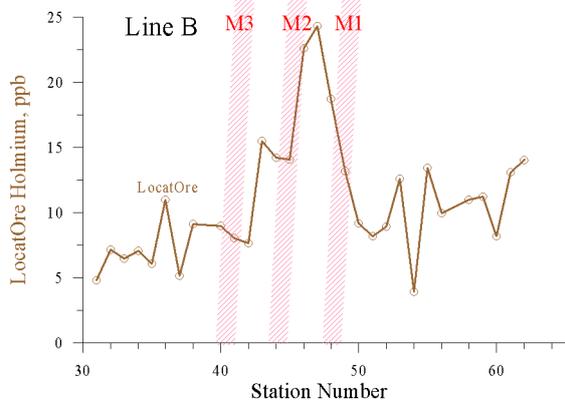
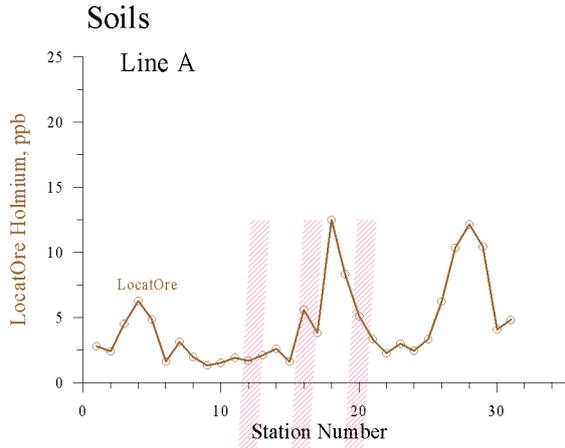


## CALCIUM

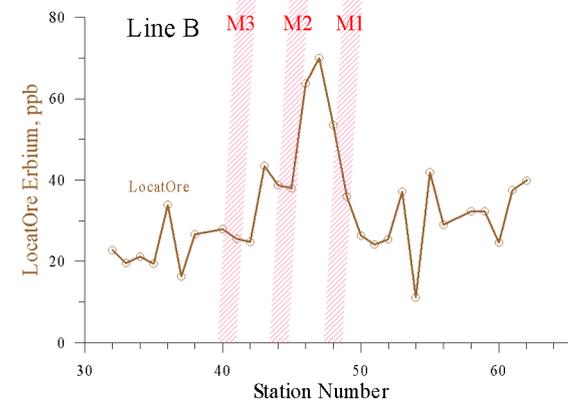
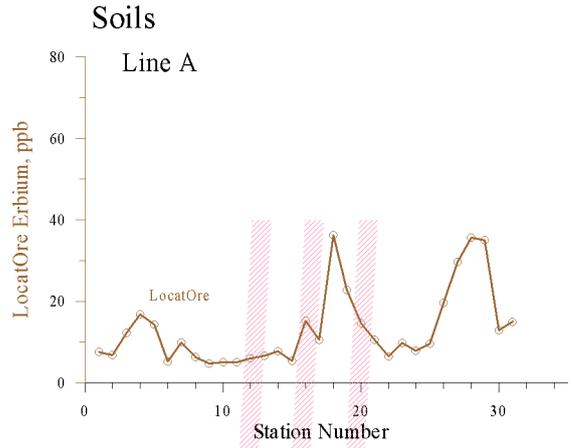


# Challenger CHIM Test

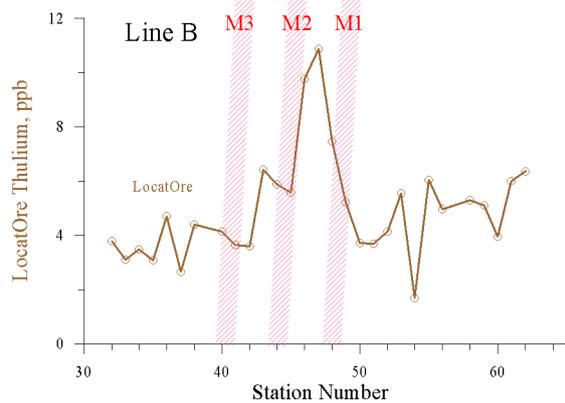
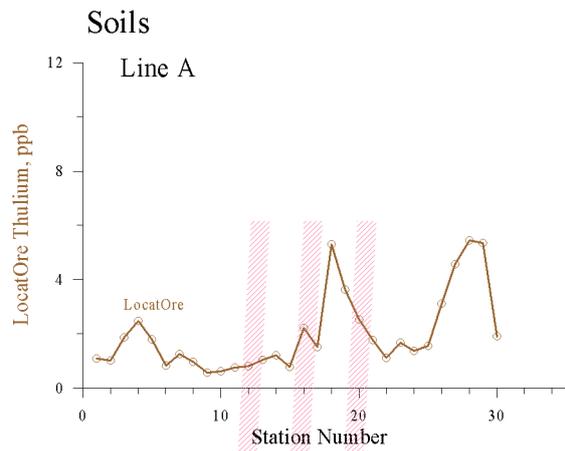
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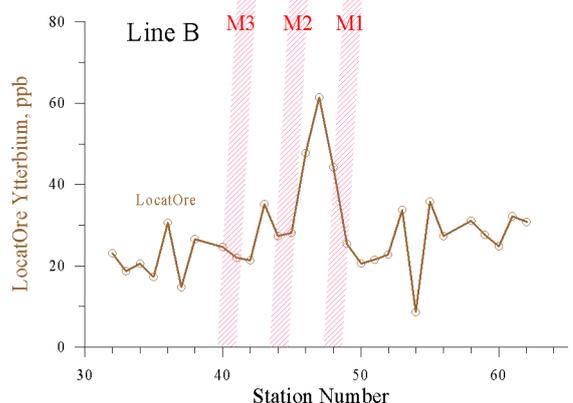
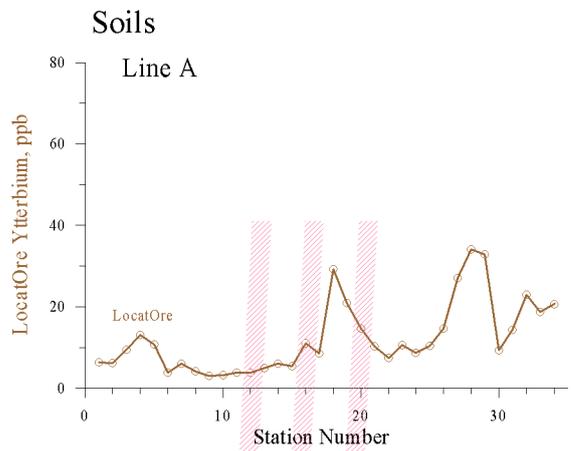
## ERBIUM



## THULIUM

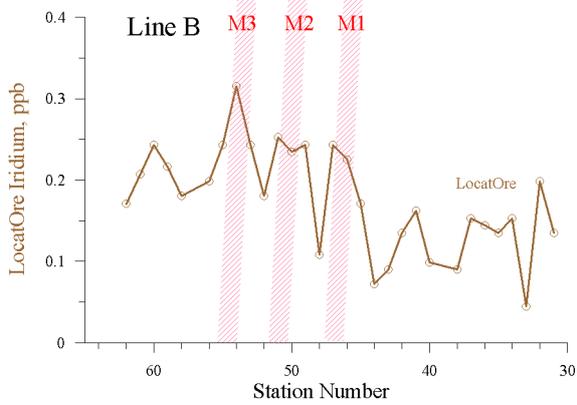
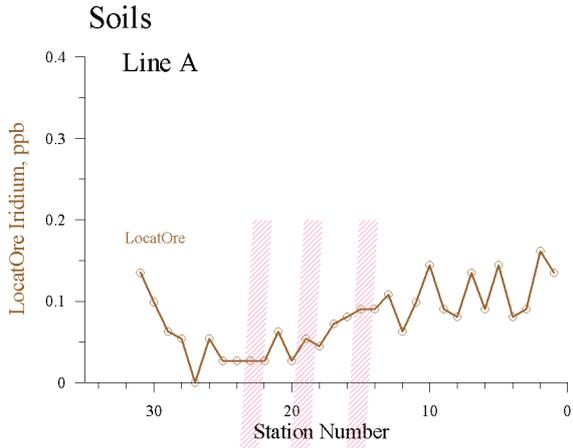


## YTTERBIUM

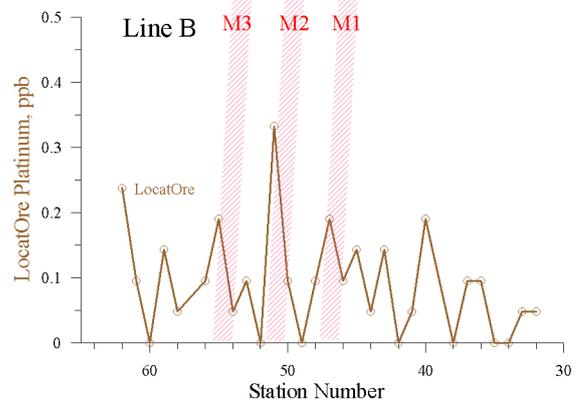
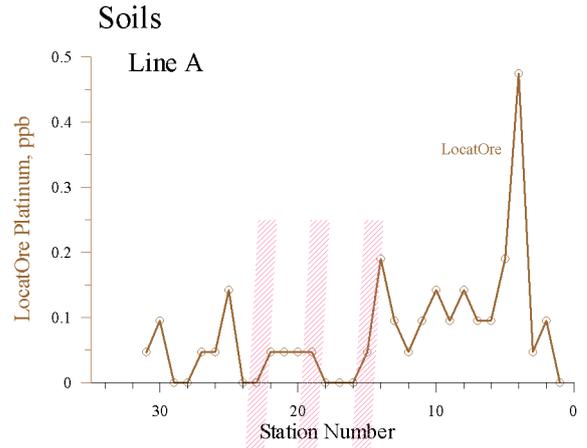


# Challenger CHIM Test

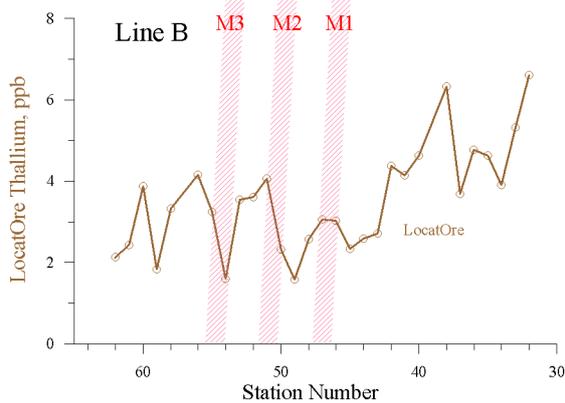
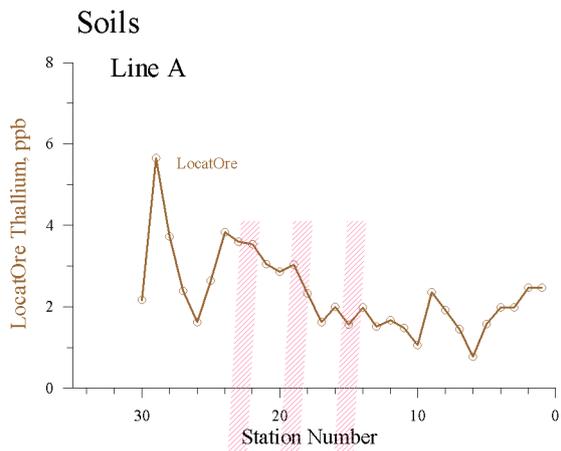
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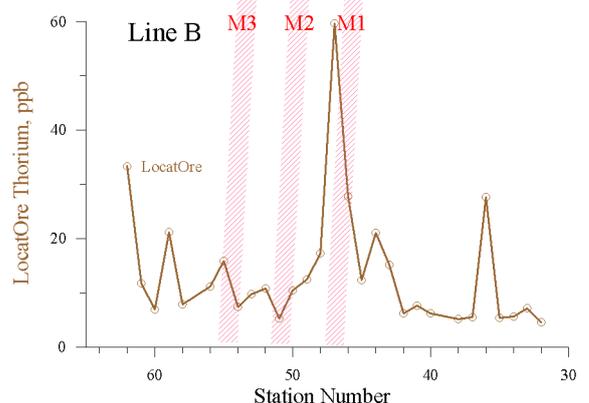
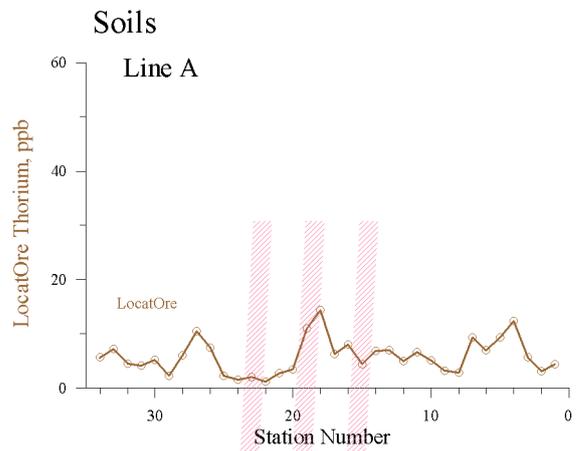
## PLATINUM



## THALLIUM

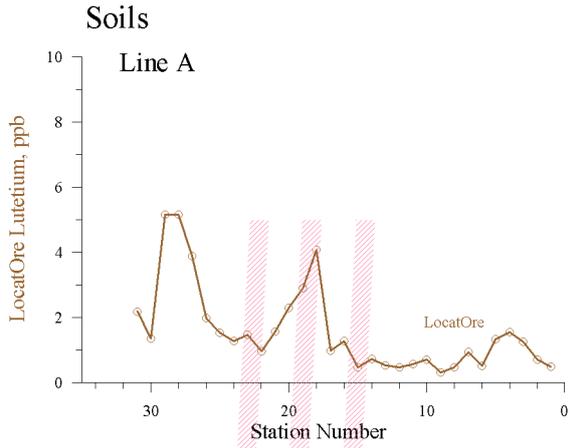


## THORIUM

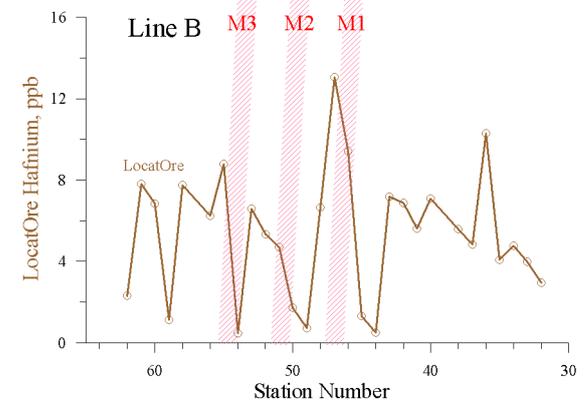
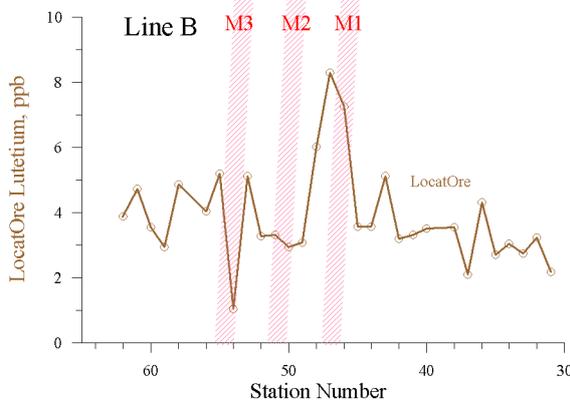
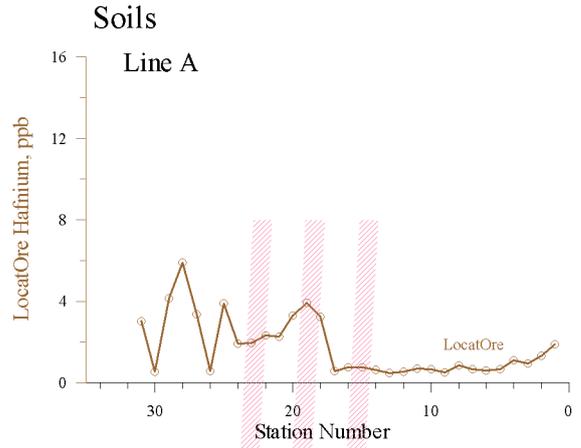


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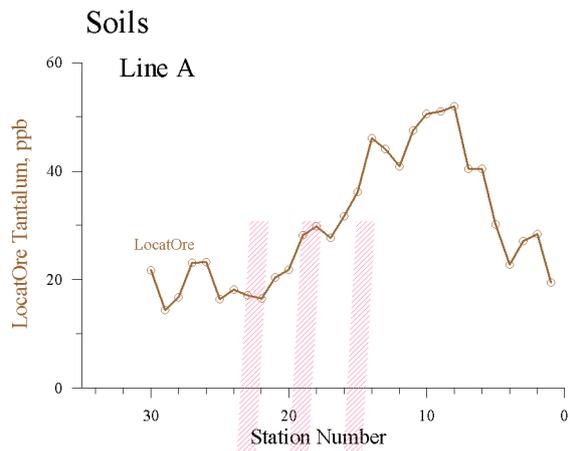
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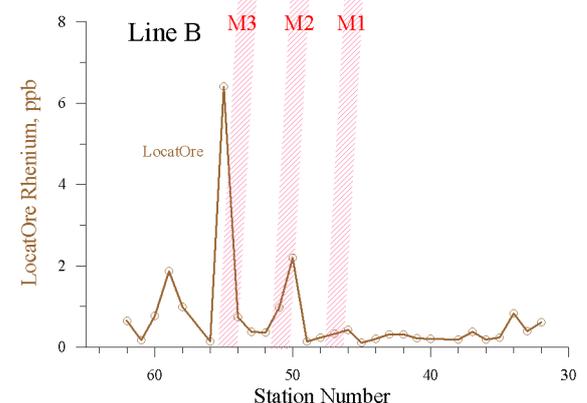
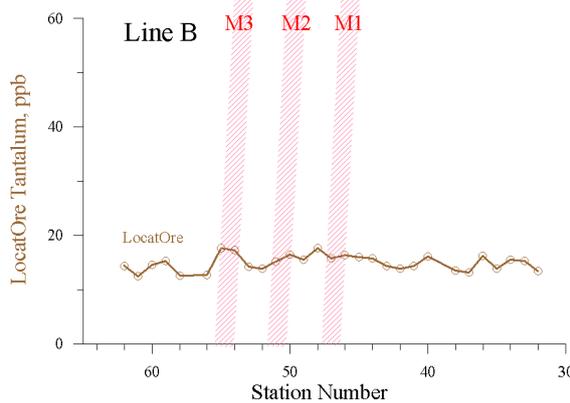
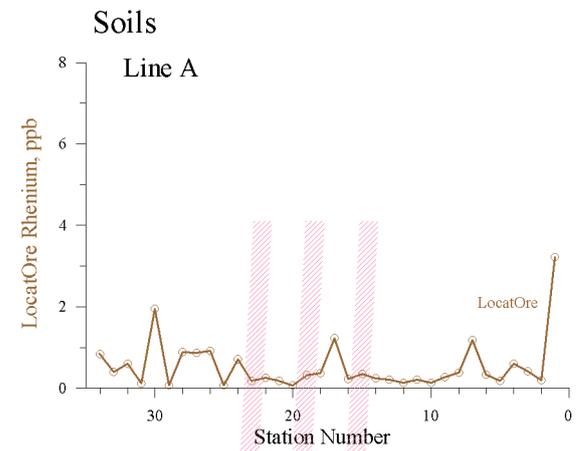
## HAFNIUM



## TANTALUM

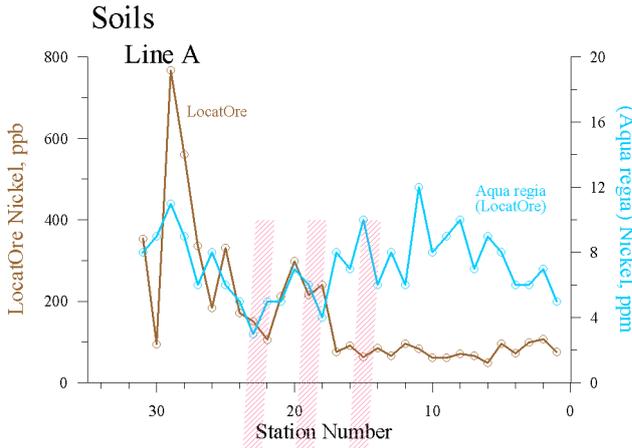


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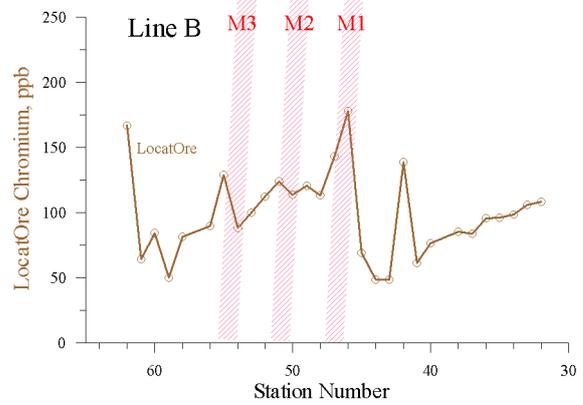
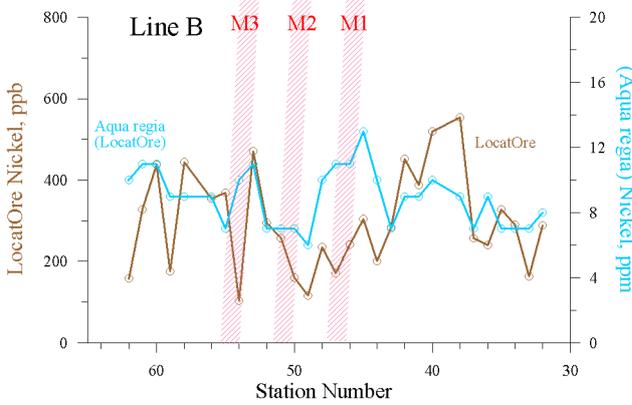
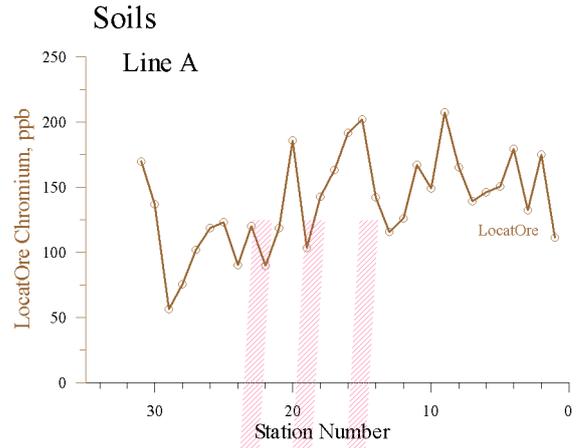


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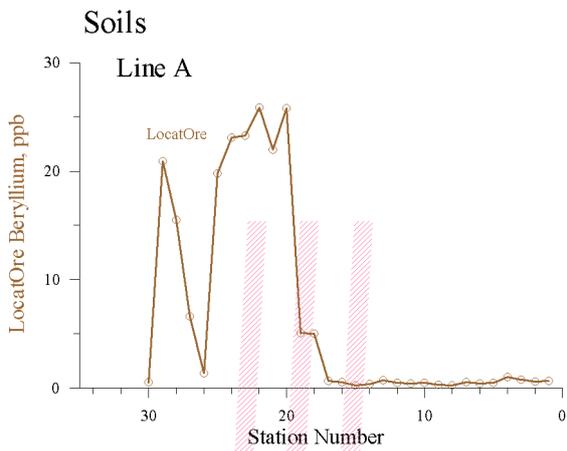
## NICKEL



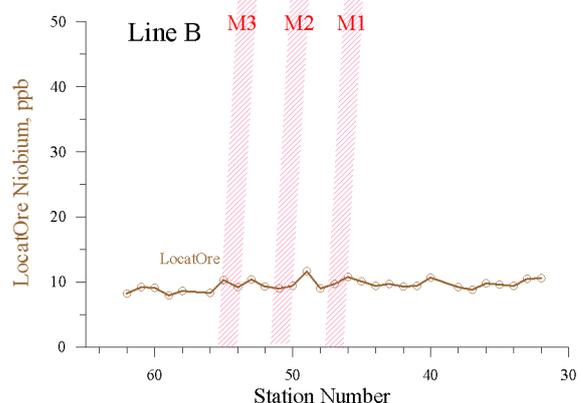
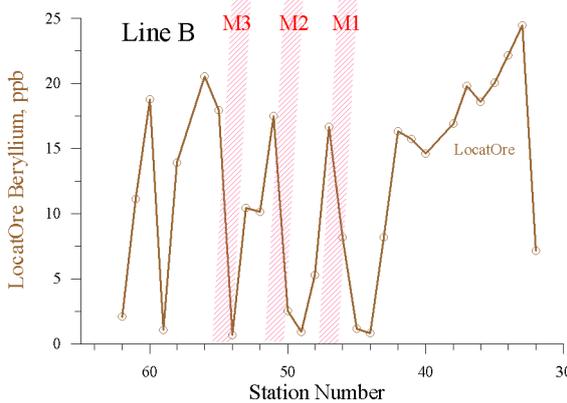
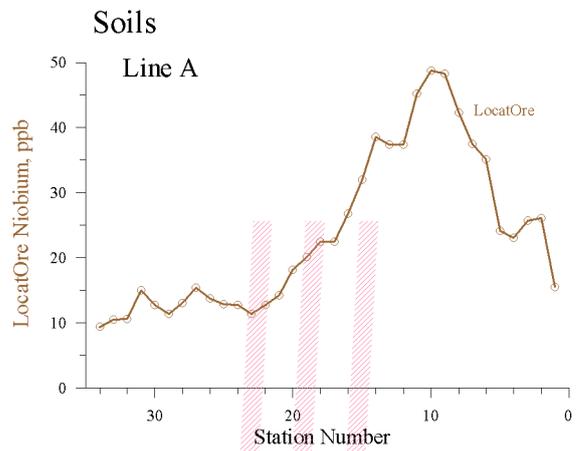
## CHROMIUM



## BERYLLIUM

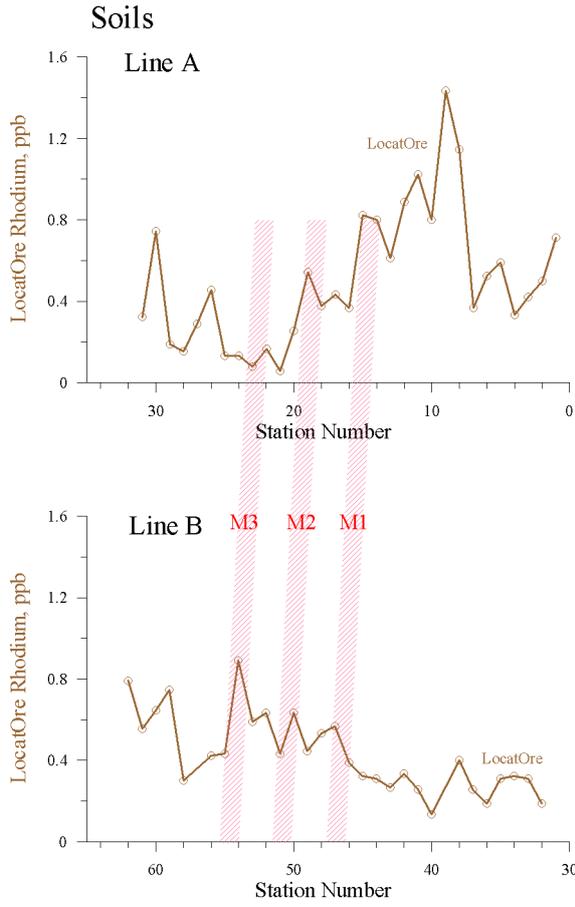


## NIOBIUM

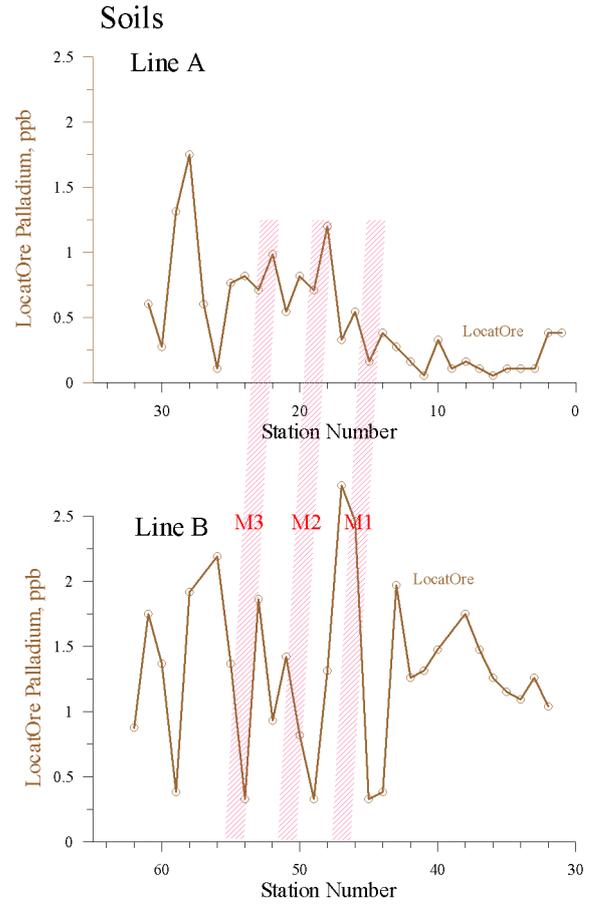


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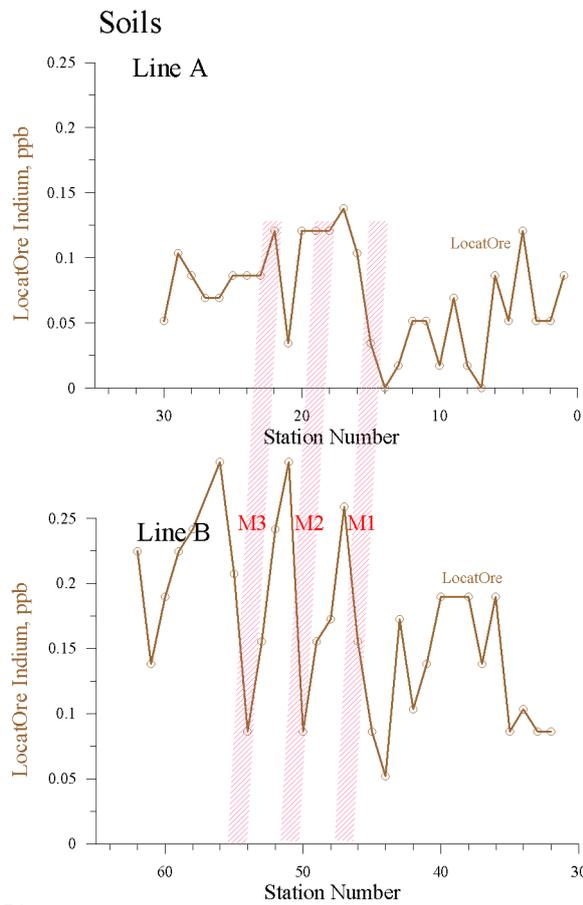
## RHODIUM



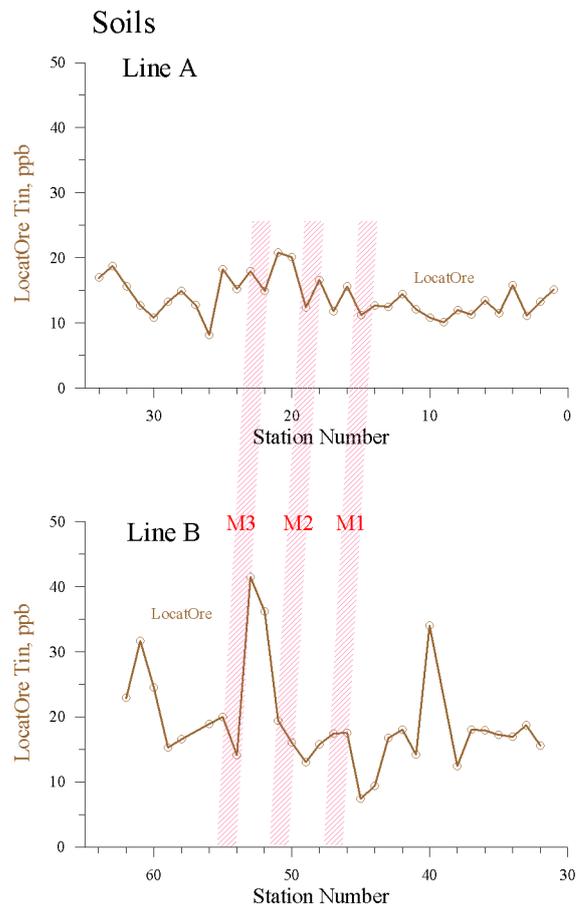
## PALLADIUM



## INDIUM

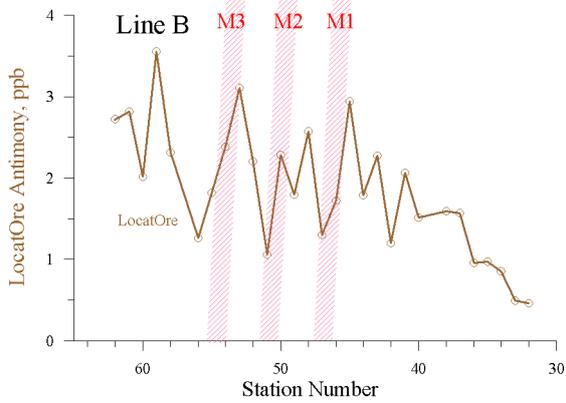
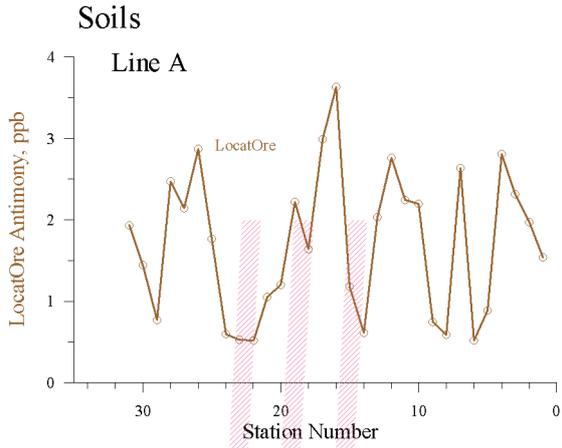


## TIN

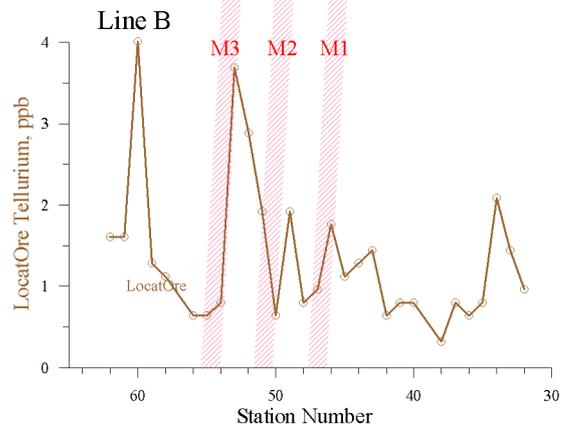
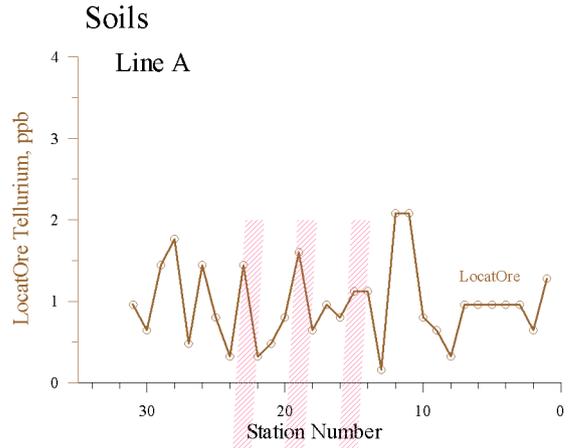


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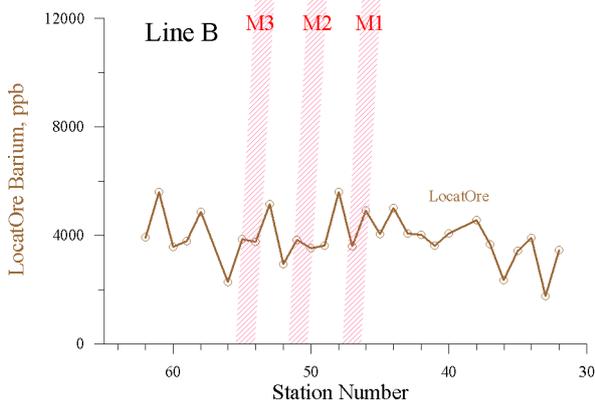
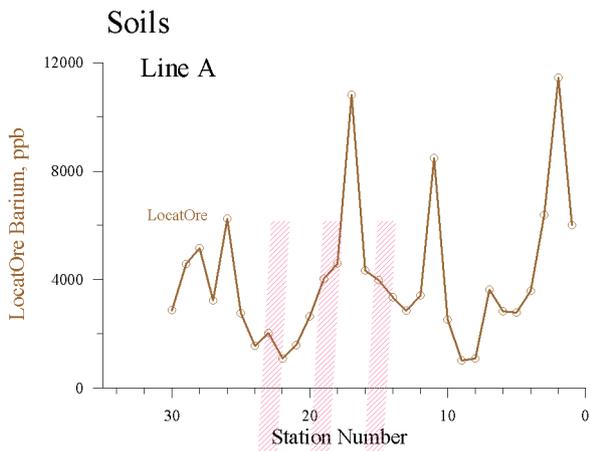
## ANTIMONY



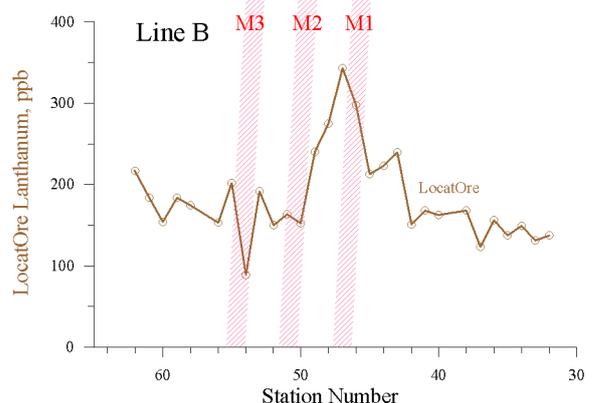
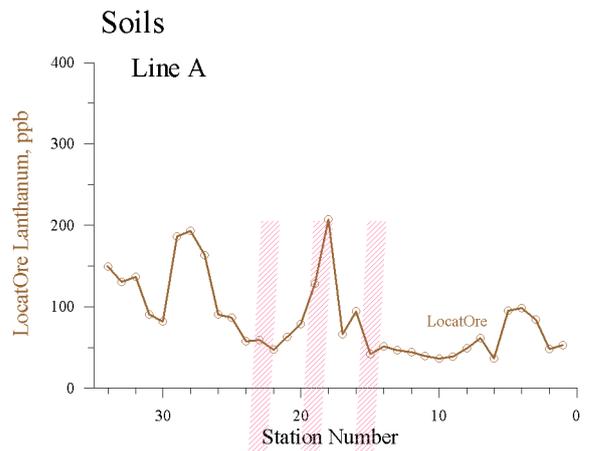
## TELLURIUM



## BARIUM

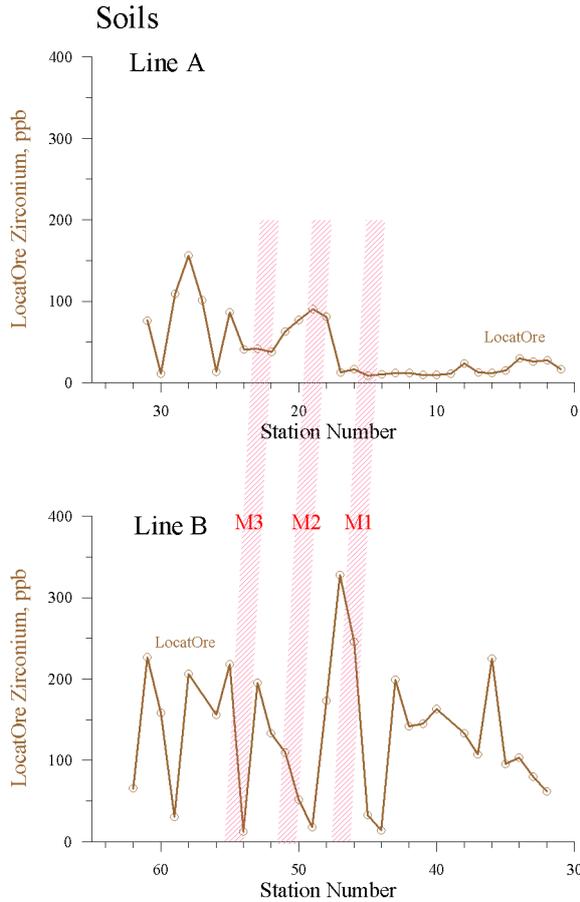


## LANTHANUM

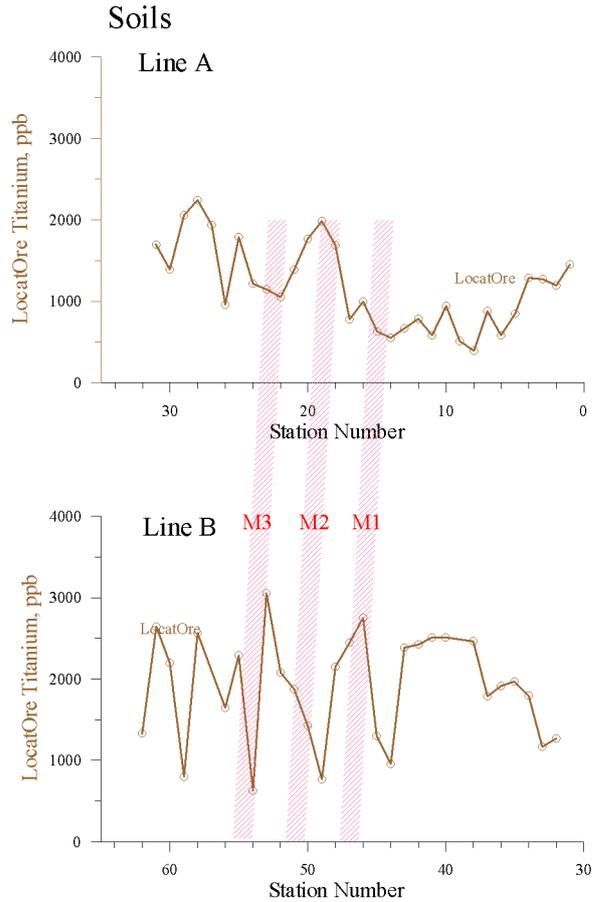


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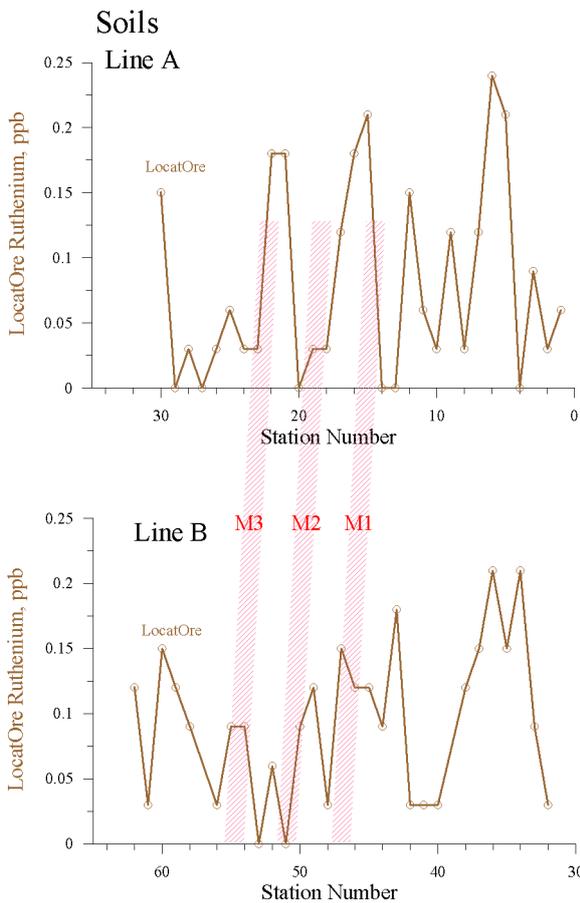
## ZIRCONIUM



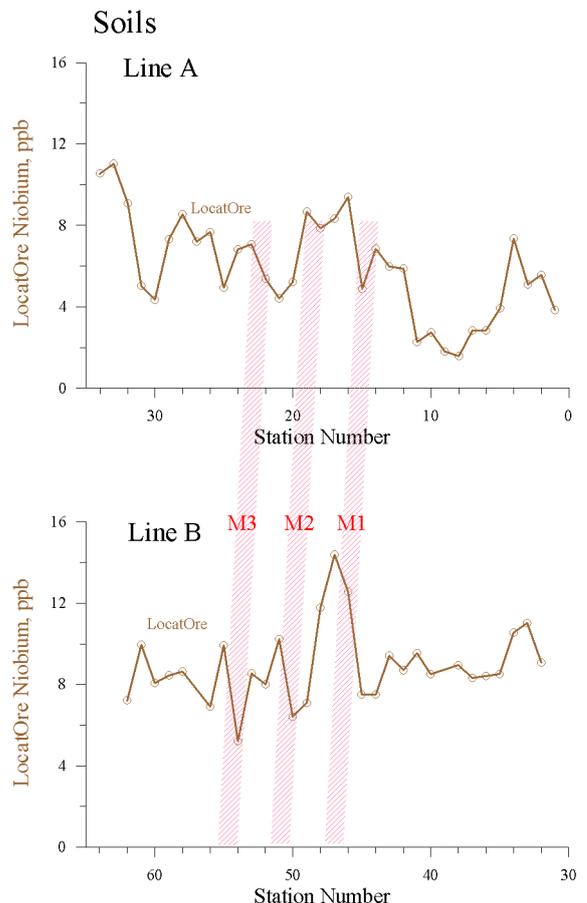
## TITANIUM



## RUTHENIUM

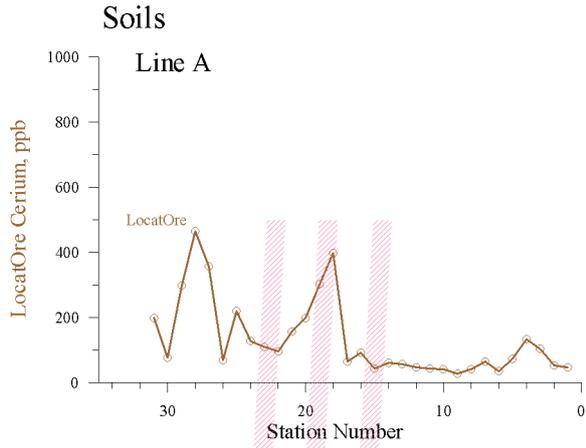


## GALLIUM

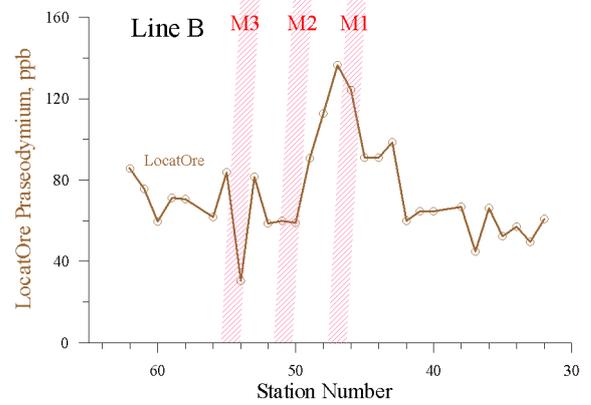
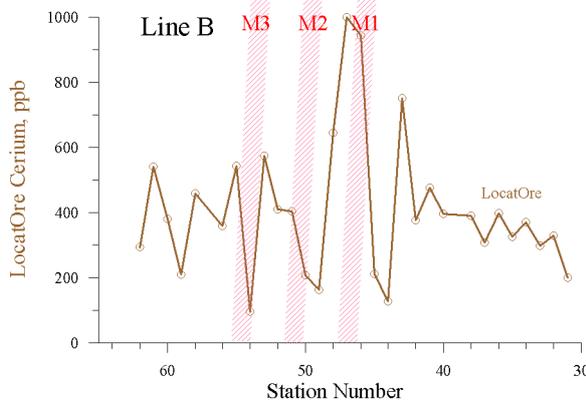
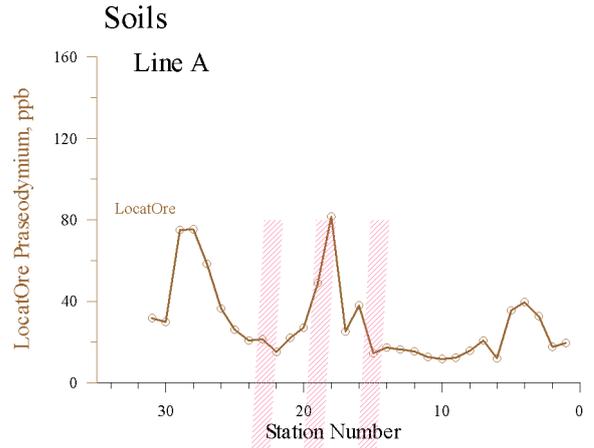


# Challenger CHIM Test

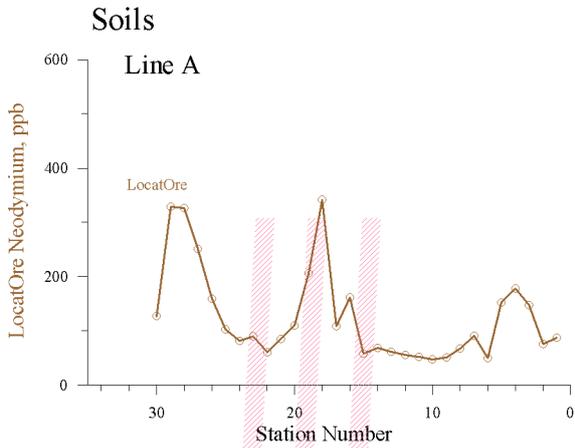
## CERIUM



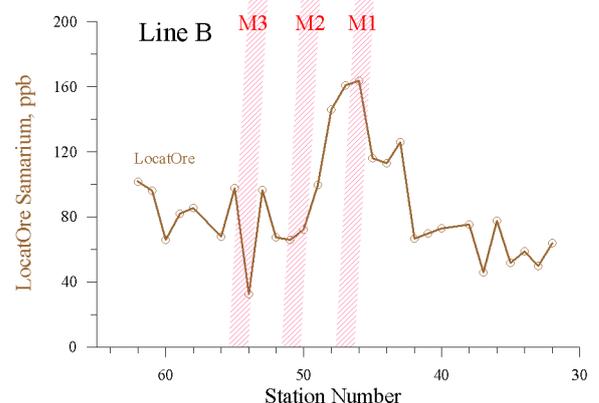
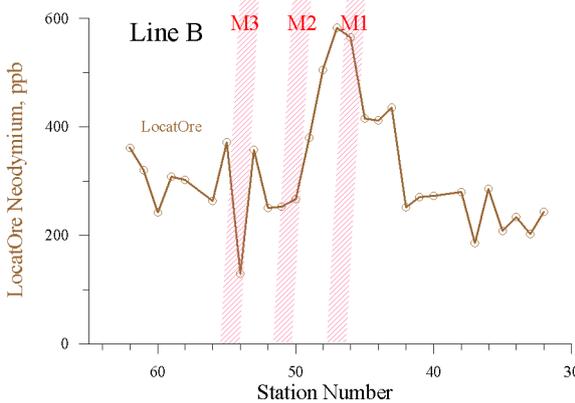
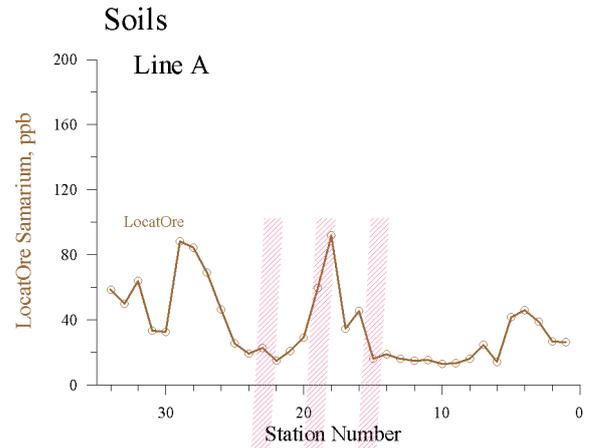
## PRASEODYMIUM



## NEODYMIUM

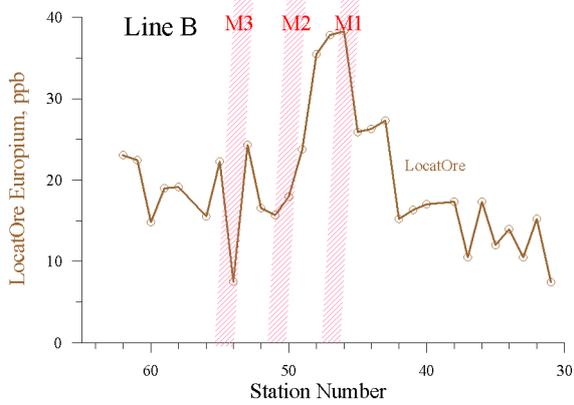
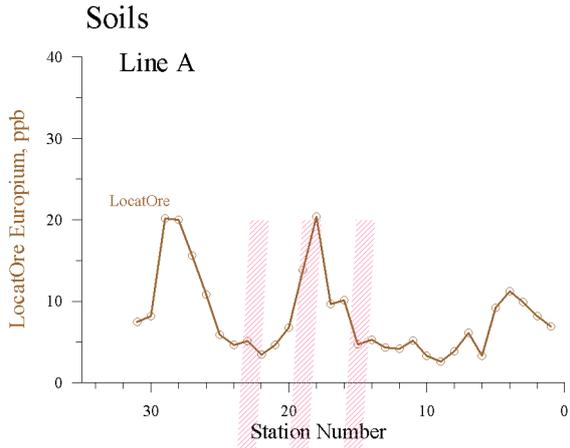


## SAMARIUM

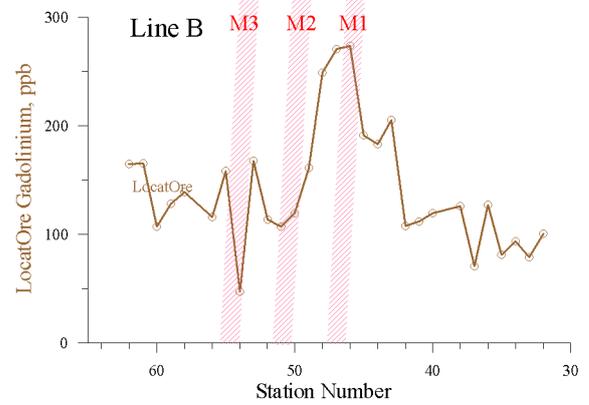
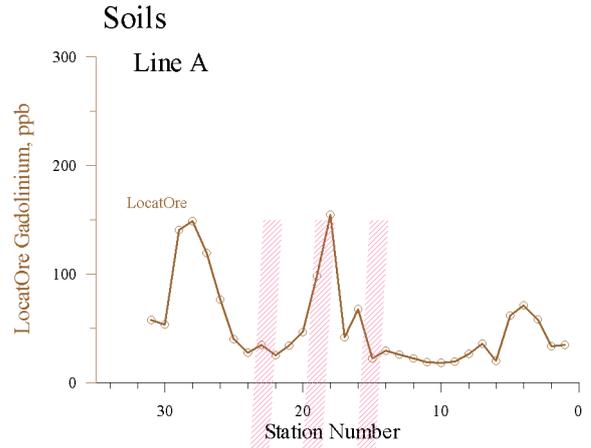


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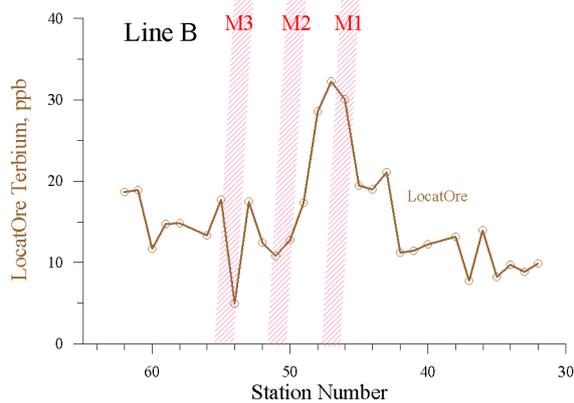
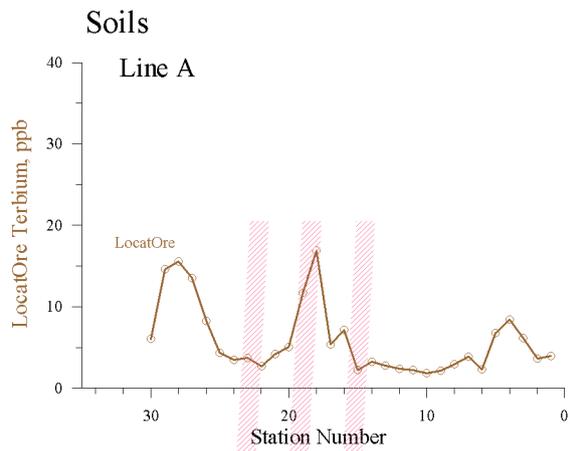
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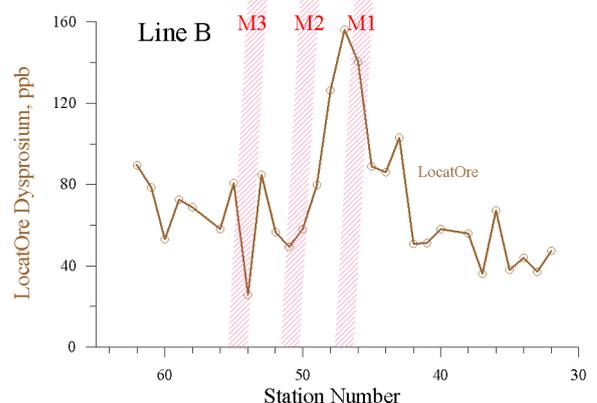
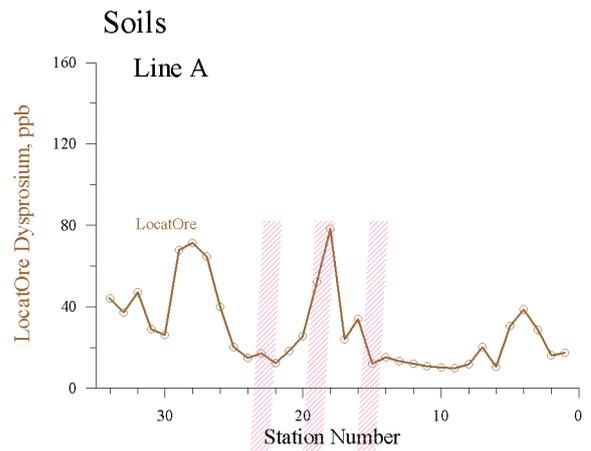
## GADOLINIUM



## TERBIUM

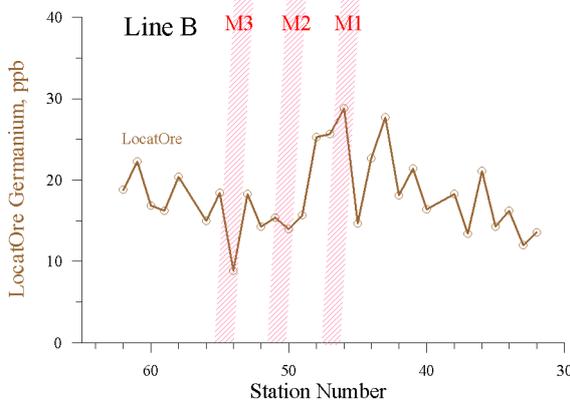
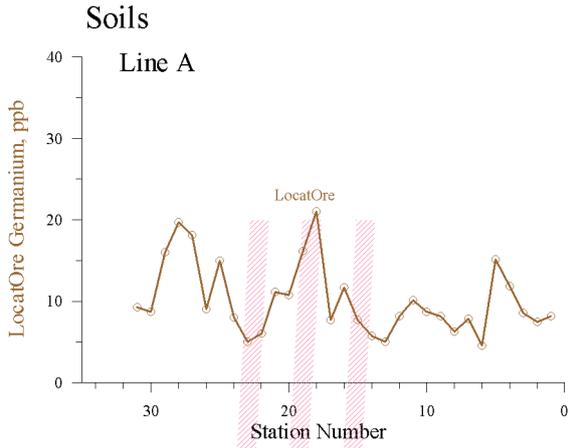


## DYSPROSIUM

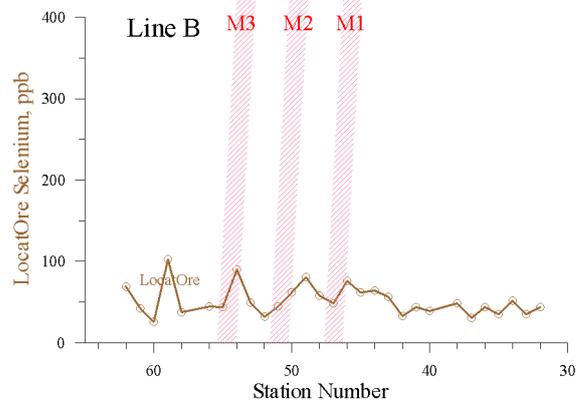
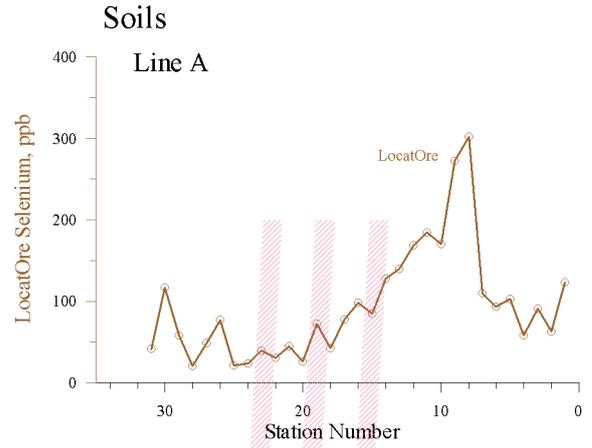


# Challenger CHIM Test

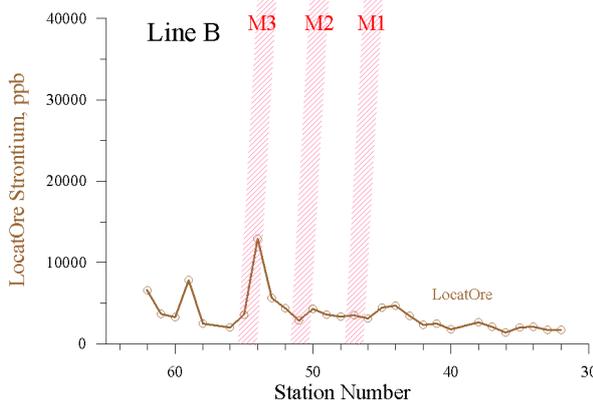
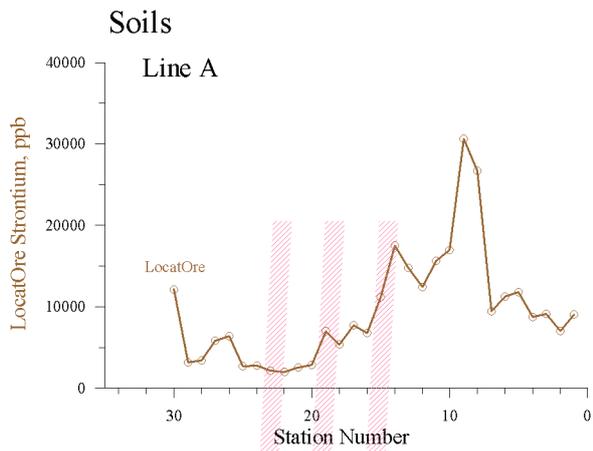
## GERMANIUM



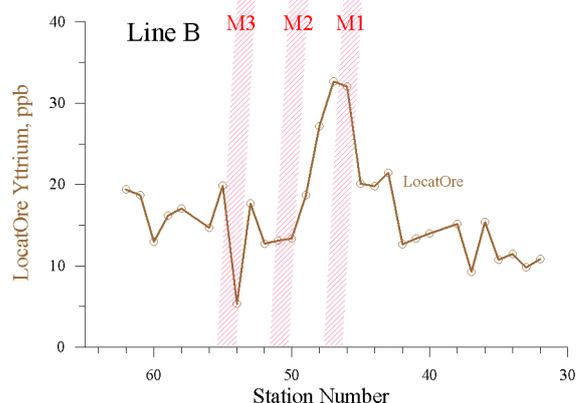
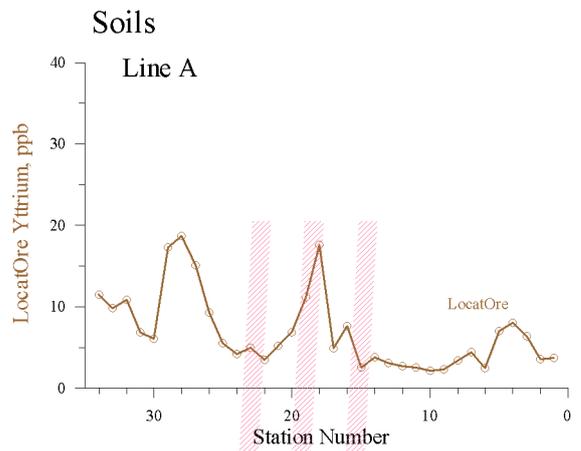
## SELENIUM



## STRONTIUM



## YTTRIUM



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