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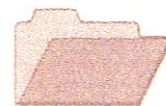
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MINERALOGICAL AND GEOCHEMICAL STUDIES OF GOSSAN AND WALL ROCKS, BOTTLE CREEK, WESTERN AUSTRALIA

Graham F. Taylor

CRC LEME OPEN FILE REPORT 13

September 1998

(CSIRO Division of Exploration Geoscience Report 36R, 1989.
Second impression 1998)

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RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" (1987-1993) had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program included the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.

The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented "an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains". This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.

The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration. Leader: Dr C.R.M. Butt.

The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

This report (CRC LEME Open File Report 13) is a first revision of CSIRO, Division of Exploration Geoscience Restricted Report 036R, first issued in 1989, which formed part of the CSIRO/AMIRA Project P241.

Copies of this publication can be obtained from:

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PREFACE

The CSIRO-AMIRA project "Exploration for Concealed Gold Deposits, Yilgarn Block, Western Australia" has as its overall aim the development of improved geological, geochemical and geophysical methods for mineral exploration that will facilitate the location of blind, concealed or deeply weathered gold deposits.

This report presents results of research conducted as part of Module 2 of this project (AMIRA Project 241): "Gold and Associated Elements in the Regolith - Dispersion Processes and Implications for Exploration".

The objectives of this module are:

- i. To obtain a better understanding of the nature and genesis of lateritic and supergene gold deposits.
- ii. To determine characteristics useful for exploration, especially in areas of transported overburden, for: a) further lateritic and supergene deposits, and b) primary mineralization - including that with no expression as appreciable secondary mineralization.
- iii. To increase knowledge of the properties and genesis of the regolith.

In particular, this report addresses the mineralogy and geochemistry of the mineralized gossan and weathered wall rocks and dispersion into overburden as a guide for exploration for additional deposits of the Bottle Creek type. Application of this and studies of other weathered sulfide - hosted Au deposits in the Yilgarn Block will lead to a predictive model for Au grades and distribution within gossan profiles.

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ABSTRACT

Samples of surface gossan from Emu, VB and Boags (VB South) prospects, and of subsurface gossan and mineralized weathered wall rocks from diamond drill core at Emu and VB prospects have been examined mineralogically and geochemically.

Mineralogy consists of quartz, muscovite, kaolinite, goethite, hematite in variable quantities with subordinate talc, rutile, tourmaline and manganese oxides. Secondary minerals of the jarosite and alunite supergroups are common in the gossans and wall rocks respectively. Pyrite is the predominant sulfide in protore with minor tetrahedrite, sphalerite, arsenopyrite, marcasite and magnetite.

Anomalous concentrations of Ag, As, Au, Cu, Pb, Sb and Zn in protore are reflected in gossan and mineralized wall rocks, although there is a marked depletion at the surface. These elements are therefore considered to be reliable pathfinder elements. Concentrations of Hg, Te and Tl are also considered anomalous, but because of low absolute values and difficulty of analysis, are not considered to be viable pathfinder elements. The nature of concentrations of Mn, Ti, B and Ba within the mineralized horizon is not yet established and analysis of both mineralized and unmineralized country rocks is necessary before they can be considered as pathfinder elements.

Lack of geochemical anomalies in soils supports previous observations (van der Heyde, 1988) that the regolith stratigraphy at VB is transported and represents colluvial/alluvial material on the floor of a drainage channel. Additional research relevant to present and longer-term exploration is indicated.

INTRODUCTION

The Bottle Creek gold deposit is located 210 km north northwest of Kalgoorlie and 77 km northwest of Menzies at longitude 120° 27'E and latitude 29° 10'S. It occurs within the Archaean Coolgardie-Mt. Ida greenstone belt to the west of the Norseman-Wiluna greenstone belt.

Mineralization occurs within altered and metamorphosed easterly-dipping basaltic volcanics which have been intruded by quartz porphyry. Massive sulfides, hosted by a possible graphitic shale, have been weathered to a depth of approximately 85 m, to form a gossan which outcrops sporadically over a strike length of 26 km.

The deposit is situated within a broad valley flanked by BIF to the west and lateritic breakaways to east. Bottle Creek drains to the south. The essentially flat valley floor has a covering of alluvium and colluvium consisting of red soil, variously cemented pisolitic hardpan, calcrete and a lag of surface pisolites. Fragments of BIF occur to the west. The climate is semi-arid with an annual rainfall of about 300 mm.

Bottle Creek was visited by a group of CSIRO geologists in August 1986 when the deposit was subject to a mining feasibility study. Prior to commencement of the AMIRA/CSIRO W.A. Gold Project, Electrolytic Zinc Company of Australasia Limited granted permission for the CSIRO Division of Mineral Physics and Mineralogy (now CSIRO Division of Exploration Geoscience) to conduct mineralogical and geochemical studies of the gossan and weathered wall rocks. The objectives were to study mineralogical and geochemical characteristics of the weathered profile in relation to those of fresh rock and protore, to provide a basis for understanding the geochemistry of laterite and other surficial material and to assist in future exploration.

Subsequently, the AMIRA/CSIRO W.A. Gold Project was initiated and the proposed study was incorporated into Project 241 - Weathering Processes, with Norgold Limited being a sponsor.

This report summarizes initial mineralogical and geochemical analyses of gossans and mineralized wall rocks from Emu, VB and Boags

prospects and of soils from VB. It forms the basis for suggestions concerning geochemical exploration in the leases surrounding the Bottle Creek deposit.

SAMPLING AND METHODS

In addition to the surface gossans from Emu, VB and Boags (VB South) prospects collected in August 1986, near-surface gossans were sampled in the four 5-m deep costeans during June 1987. Five vertical profiles on the north face of the costean at 12967.5 N were also sampled. One of these profiles representing gossan has been studied for this report.

The majority of samples collected in June 1987 are from diamond drill core from Emu and VB North prospects. Selection of Emu drill core was based upon proximity to sections incorporating DDH's EMU 1 and EMU 4 studied by R.A. Binns. VB North diamond drill cores selected are in the vicinity of the costeans at 12962.5 N and 12762.5 N, both of which have been extensively sampled by Dienneke van der Heyde for a Ph.D. study in collaboration with AMIRA/CSIRO Project 240.

Soils to a depth of 300 mm were sampled across the mineralized horizon at 12895 N between the two large costeans at VB prospect (Figure 1). The sampling interval was 2.5 m for 10 m on either side of the mineralization and then at 5.0 m intervals for an additional 20 m. Samples were wet sieved into three fractions ($-180\text{ }\mu\text{m}$; $+180\text{ }\mu\text{m}$ to -4 mm ; $+4\text{ mm}$) and ground for neutron activation analysis (Becquerel Laboratories, Lucas Heights, N.S.W.).

Sampling localities and diamond drill hole collars are indicated in Figures 1-6.

For this preliminary study, gossans and mineralized, ferruginized wall rocks were selected. Portion of each sample was crushed and ground to $-200\text{ }\mu\text{m}$ in a Mn-steel jaw crusher and Mn-steel ring mill. The resultant powder was used for mineralogical analysis by X-ray powder diffractometry and chemical analyses by a variety of techniques

(Appendices 1 and 2). A check on gold assay values is detailed in Appendix 3.

To ascertain the composition of primary sulfides, concentrates were made from fresh portions of core from DDH's EMU 7, EMU 27 and EMU 28, using gravity and electromagnetic techniques, and analysed by ICP and OES techniques.

RESULTS

Sulfide Concentrates

All fractions derived during concentration of the sulfides (floats, sinks, magnetic, non-magnetic) were subjected to X-ray diffraction. Pyrite was the predominant phase in each fraction with subordinate tetrahedrite, sphalerite, arsenopyrite, marcasite and magnetite occurring in some fractions. Tetrahedrite invariably was most concentrated in the heavy magnetic fraction. Neither galena nor pyrrhotite were detected. One sample (74693 from 133.0 m in DDH EMU 28) contained significant arsenopyrite. Minor gangue silicates (kaolinite, muscovite, quartz, chlorite) and carbonates (siderite, dolomite and calcite) were also detected.

Chemical analytical data for five pyrite and one pyrite/arsenopyrite concentrate (Table 1) show that Ag, As, Au, Pb, Sb and to a lesser extent Cu and Zn are anomalous. There are no major differences between the pyrites and the one arsenopyrite-containing sample. It would appear that some anomalously high MnO contents in weathered rock (see later) are not derived from sulfide as a concentration factor of up to 100x is necessary. Where comparison can be made, the average compositions are significantly higher than for the very pure pyrite concentrate from deep within DDH EMU 1 (Binns, 1988).

Gossans

The gossan samples have been divided into two groups representing surface and sub-surface (from diamond drill core). Generally, the

mineralogy of the two groups is similar, with goethite, hematite, quartz, kaolinite, muscovite and beudantite being common. Hematite tends to be more common at or near the surface whereas goethite is more common at depth, possibly reflecting more acid conditions. Rutile was detected in a number of sub-surface gossans.

The secondary mineral beudantite, $\text{PbFe}_3(\text{SO}_4)(\text{AsO}_4)(\text{OH})_6$, is one of the alunite-jarosite minerals commonly associated with gossans (Scott, 1987). Although it has not yet been possible to determine the composition of these secondary minerals they are known to incorporate a wide variety of elements such as Ag, As, Ba, Cu, Pb, Sb and Zn within the structure which is extremely stable under normal weathering conditions. This would explain the high levels of these elements in both surface and sub-surface gossans (Tables 3 and 4).

Even though the concentrations of Ag, As, Au, B, Bi, Co, Cu, Hg, Mo, Ni, Pb, Sb, Te, Tl, V, Y, Zn, TiO_2 and MnO are significantly greater in sub-surface gossans (Table 1), the levels of these elements at the surface are sufficiently anomalous to attract attention during exploration. Because of the extremely high mobility of Ag, it is seldom found at surface (Table 3) and is therefore of limited significance during exploration. The lowest Au content (50 ppb) in surface gossans is substantially higher than background values (~5 ppb), but because of its patchy distribution may be absent from otherwise mineralized horizons.

The one element which is significantly concentrated at the surface is Ba (Tables 3 and 9), whereas other lithophile elements (B, Cr, V and Y) are higher in sub-surface gossans. One possible explanation is that Ba occurs as secondary barite, formed recently by precipitation with evaporite-derived sulfate in ground waters.

Four samples from 2.55 to 3.3 m below the surface at 12937 N show values similar to those of surface gossans but with higher As, Pb, Sb and lower Ba contents (Table 2).

Weathered Biotite Schists

Biotite schists commonly occur to the west of, or host the mineralization. It has therefore been necessary to divide this group of samples into weathered biotite schists (Table 5) and gossanous biotite schists (Table 6), the latter consisting of gossanous veins up to 150 mm thick within the schist.

Mineralogy of these samples consists of quartz, kaolinite, muscovite, talc and traces of rutile. Goethite \pm hematite occur as minor phases in the weathered biotite schists but are major components of gossanous biotite schists. Whereas Pb- and As-bearing jarosites occur in gossanous biotite schist, the Pb- and As-bearing alunites are common in the weathered biotite schist.

At greater depths, the carbonates calcite, siderite and dolomite are often major components. In sample 74667 from 118.1 m in DDH EMU 27, the carbonate is aragonite which is unusual as either an Archaean alteration mineral or as a supergene product. Detailed petrographic examination of this and other samples is planned.

Because of their close proximity to mineralization, concentrations of Au, Ag and pathfinder elements within the biotite schists are elevated. The very erratic but high Ag contents together with substantial abundances of the elements Ba, Cd, Co, Cu, Sr and Zn in the weathered biotite schists (Table 5) suggests dispersion of more mobile elements into immediate wall rocks and initially high values of lithophile elements Ba and Sr. However the marked concentration of Pb in weathered biotite schist is not readily explained, as it would be expected to report with Au, As and Sb in the gossanous biotite schist.

Levels of TiO_2 (average = 1.00% for both groups) are higher than for other rock types (Table 9) but are less than for fresh basalts (Columns C and D) and non-retrogressed biotite schist (Column H) of Table 1 in Binns (1988). It is therefore difficult to imply that anomalous levels of Ti are associated with mineralization.

On the other hand, highest average values of B (tourmaline) occur in sub-surface gossans, gossanous biotite schist and chert/shales (Table 9) suggesting a close correlation between tourmaline and mineralization. Verification would require additional examination of both mineralized and unmineralized rocks.

Weathered Porphyry

The weathered porphyry intimately associated with mineralization is Type 2 (Binns, 1988) with large quartz phenocrysts set in a fine-grained groundmass of quartz and muscovite. Accessory minerals include goethite (particularly in the highly ferruginized sample 74652), kaolinite and occasionally tourmaline (74771 and 74865).

Apart from the higher SiO_2 and lower Al_2O_3 contents, the composition of weathered porphyry does not differ significantly from weathered biotite schist, except perhaps for the low TiO_2 content. This may reflect an overall lessening of the intensity of mineralization, supported by relatively low Au and Ag contents. Other trace element contents generally fall within range of average values for other weathered rock types (Table 9).

The highly ferruginized sample 74652 (DDH 26, 103.6 m) is poorly mineralized (Table 7) but has a significantly higher TiO_2 content than other weathered porphyry, throwing further doubt as to the significance of TiO_2 to mineralization.

Weathered Silicified Shales/Cherts

This group of samples represents highly silicified mineralization. The nature of the precursor rock type is at present the subject of conjecture, with graphitic shale or altered porphyry being considered. Although some of the silicification is primary, considerable silicification has occurred as a result of supergene processes. The mineralogy is therefore dominated by quartz with minor goethite, and subordinate muscovite, kaolinite, rutile, tourmaline and beudantite.

Composition of these samples is dominated by high SiO_2 contents with values in excess of 95% not uncommon (Table 8). There are again some relatively high TiO_2 contents coinciding with high Au values. Whereas the effect of silicification has been to diminish major element contents, concentrations of chalcophile elements have not been correspondingly reduced (except for Cu). Those elements (Mn, Cr and Ni) used to distinguish fresh cherts (Binns, 1988) are not significantly enriched in weathered chert.

Soils

In each of the three fractions, the levels for Ag, Au, Mo, Se and Zn are below the limits of detection indicated in Appendix 2. Values of Co and W reflect contamination from the tungsten carbide ring mill used to grind the samples for analysis (Figure 7) with greatest concentrations occurring in the quartz-rich finest fraction. Some Co occurs in the coarser fraction. Only four elements, As, Ba, Cr and Sb, exhibited sufficient variation to be plotted (Figure 8). Apart from a possible two point As anomaly in the +4 mm fraction there are no indications of underlying mineralization. Arsenic and Sb contents are highest in the coarser fractions confirming previous observations that such elements are mechanically dispersed as gossan fragments (Taylor et al., 1984), rather than by hydromorphic dispersion. Neither Ba nor Cr exhibit anomalies over the mineralization. The significantly higher levels of Ba in the -180 μm fraction probably reflect precipitation of barite from solution onto clay surfaces.

DISCUSSION

The purpose of this study was to characterize significant pathfinder elements associated with gold mineralization at Bottle Creek, which will be of benefit to exploration within the existing leases and for similar deposits elsewhere in the Yilgarn Block. Because of the depth of weathering, present geochemical exploration programmes utilize some part of the regolith rather than fresh rock. The samples chosen for this preliminary study are therefore of gossan, weathered wall rocks and soils. Samples of hardpan and lateritic nodules have been collected

and analysed by members of CSIRO/AMIRA Project P240 - Laterite Geochemistry.

Analysis of the six sulfide concentrates indicates that Ag, As, Au, Cu, Hg, Pb, Sb and Zn are anomalous. Other potentially anomalous elements (Se, Te, Tl and W) have either not been determined or are below the limit of detection of the analytical techniques used.

Except for Se and W, these same elements are present in anomalous concentrations within gossan samples from all three prospects (Table 9). Although the levels of Hg, Te and Tl are low, such values have been used in gold exploration particularly in the United States, but the analytical techniques are difficult and costly and the anomalies are no more significant than for other pathfinder elements.

As would be expected, the concentration of the pathfinder elements is greater within sub-surface gossans, reflecting greater leaching at or near the surface. However, values in surface gossans are sufficiently high for these elements to be considered as pathfinders. The significantly higher concentrations of Ba in surface gossans is discussed below.

This same suite of elements occurs in anomalous concentrations within weathered and gossanous biotite schists, weathered porphyry and weathered chert/shales (Table 9), and is therefore of significance in defining the mineralization. Of particular interest are the lower values for Ag, Cd, Co, Cu, Hg, Pb, Tl and Zn and higher values for As, Au, Mo, Ni, Sb, Sn and Te in gossanous biotite schist compared with weathered biotite schist. In part, this reflects the greater mobility of some elements under acid-oxidizing conditions, but cannot explain the apparent behaviour of Ni and Pb. Nickel is normally relatively mobile whereas Pb (except in the pH range 8.3-10) would normally occur together with As and Sb as stable alunite-jarosite minerals.

Although values for Mn, Ti, B and Ba are elevated in many samples it is not yet possible to determine whether they form primary haloes associated with mineralization. Whereas Mn, Ti and Ba can readily be determined by XRF, B analysis is difficult and costly, and detection of

tourmaline by XRD or optical microscopy is considered more suitable.

By comparison with volatile element levels in gossans associated with volcanogenic massive sulfide (VMS) deposits elsewhere in the Yilgarn Block (Smith et al., 1983), the levels in Bottle Creek gossans, except for As and Sb, are significantly lower. This may well indicate that despite its setting in volcanic host rocks, the Bottle Creek mineralization is not of classic VMS origin.

In her reports on lateritic material at Bottle Creek, van der Heyde (1987, 1988) noted marked differences between the regolith stratigraphy at VB (North) and that at Emu and Boags (VB South). These include

- massive and laminated hardpan at VB and absence of hardpan at Emu and Boags
- massive calcrete at Emu and Boags but at VB the carbonate occurs along laminations in the hardpan, and
- the nature and shape of clasts at VB indicate that the regolith stratigraphy is colluvial/alluvial, whereas at Emu and Boags it is largely residual.

These suggest that VB corresponds to the floor of a drainage channel which was active for a long period and is still present today as a topographical low. The implication is that the mineralization and wall rocks have been subjected to greater hydromorphic activity than elsewhere along strike, as reflected in the geochemistry of regolith materials.

Van der Heyde (1988) found that surface nodular lateritic material at Emu and Boags exhibited Ag, As, Au, Pb, Sb and possibly Zn anomalies associated with the mineralization. No such anomalies were found at VB. Similarly, soils at VB show no anomalies for a range of target, pathfinder or lithophile elements, confirming that the regolith stratigraphy at VB is probably transported, or, less probably, too thick to allow for geochemical dispersion.

Comparison of geochemical data for surface gossans from the three prospects (Table 10, derived from Table 3) indicates that the concentrations of many elements are higher at VB than at Emu and

Boags. This does not support greater leaching at VB, but is evidence of erosion of the upper part of the gossan to expose the sulfate-arsenate zone (Taylor et al., 1980) with higher values of SO_3 , Ag, As, Au, Bi, Hg, Mo, Ni, Pb, Sb, V and Zn (c.f. Table 9 for surface and sub-surface gossans).

The higher Ba values in near-surface gossans and the finest soil fraction indicates that Ba has been precipitated from groundwaters, probably as barite due to high sulfate content. Many of the pathfinder elements are derived directly from mineralization and occur as highly stable secondary alunite-jarosite minerals.

CONCLUSIONS

In this preliminary study samples of gossan, ferruginized/mineralized wall rocks and soils have been analysed by X-ray powder diffraction and a variety of chemical techniques. No attempt has been made to:

- relate geochemistry (including Au and Ag grades) to gossan type
- relate the distribution of target and pathfinder elements to the mineralogy of fresh sulfide, gossan and weathered wall rocks, or
- statistically analyse geochemical data

However, as a result of these studies, the following conclusions can be drawn.

- Whereas pyrite is ubiquitous, the distribution of pyrrhotite is patchy as sulfides selected from three DDH's contained no pyrrhotite. It has therefore not been possible to ascertain the geochemistry of pyrrhotite concentrates. The apparent absence of pyrrhotite may result from leaching of this unstable mineral immediately below the base of complete oxidation with the formation of secondary pyrite.
- Pyrite concentrates are anomalous in Ag, As, Au, Pb, Sb and to a lesser extent Cu and Zn. In the absence of microprobe data, these anomalies are presumed to reflect, at least in part, small inclusions

of argentian tetrahedrite (Binns, 1988), galena, arsenopyrite, sphalerite and occasional marcasite.

- Occasionally high MnO contents in weathered rocks do not derive from sulfide as the concentration factor (x100) is too great. Manganese was probably contained within carbonates, and is present in weathered rocks as oxides. Manganese oxide mineralogy has not been ascertained.
- Mineralogy of gossans and weathered biotite schists, porphyry and silicified shale/cherts consists of quartz, muscovite, kaolinite, goethite, hematite in variable quantities with subordinate talc, rutile and tourmaline.
- Secondary minerals of the jarosite supergroup are common in gossans and the silicified shale/cherts whereas Al-rich analogues (alunites) occur in weathered wall rocks. These minerals are rich in Pb and As and may have a wide range of elements substituting in the lattice (Ag, Sb, Cu, Zn, Ba). They are extremely stable under normal weathering conditions, and are excellent indicators of base metal mineralization.
- Under similar semi-arid conditions, geochemical anomalies around the Elura deposit, New South Wales, are due to mechanical dispersion of secondary minerals of the alunite-jarosite series (Taylor et al., 1984). The possibility of mechanical rather than hydromorphic dispersion from the Bottle Creek mineralized horizon is indicated by soil geochemistry at VB.
- The absence of anomalies in soil and nodular laterite (van der Heyde, 1988) at VB indicates that this overburden is transported. Anomalies are expected in the coarse fraction downslope from mineralized horizon and possibly in underlying saprolite (cf. Taylor et al., 1984).
- High but erratic levels of TiO_2 may be associated with mineralization. Much of this titanium occurs as rutile, but some could be associated with biotite (Binns, 1988).
- Both Au and Ag occur in sub-surface gossans, gossanous biotite schist, porphyry and silicified shales/cherts. In biotite schist, the Ag content is erratically high but Au is low, whereas in surface gossan, Ag is low and Au content is moderate. This confirms previous

- studies (Legge et al., 1987) of near-surface depletion of Au and Ag.
- All lithologies studied are significantly anomalous in As, Ba, Cu, Pb, Sb and Zn, with near-surface depletion for all except Ba.
 - Occasionally anomalous B (tourmaline) cannot, on the basis of this preliminary examination, be directly related to mineralization. Even if found to be an indicator of mineralization, B analysis is difficult and costly and mineralogical examination for tourmaline (by XRD) may be more cost-effective.

RECOMMENDATIONS

The following recommendations address both immediate needs for on-going geochemical exploration in the vicinity of the Bottle Creek deposit and suggested research, which will be of longer term benefit to Norgold.

- The mineralization and immediate wall rocks are characterized by anomalous concentrations of Ag, As, Au, Cu, Pb, Sb and Zn, which except for Au, probably occur in secondary alunite-jarosite minerals (e.g. beudantite, hidalgoite). Although there is some surface depletion of these elements, and the extent of their incorporation into overlying hardpan, soils and pisolites is not known at present, further geochemical exploration should analyse for these elements. Mercury, a commonly used pathfinder element, occurs at levels too low to be cost-effective.
- Mechanical dispersion by sheet wash may be extensive (cf. Elura) so that detection of broad anomalies should be followed by detailed analysis for the less mobile Au to locate drilling targets.
- Until such time as dispersion into overlying material is understood, sampling should be directed to saprolite using RAB or RC drilling.
- Additional studies of the relation of Ti, Mn, B (tourmaline) and possibly Ba to mineralization are urgently required to determine whether these elements should be added to the geochemical package.
- Until detailed electron optical studies of morphology and composition of gold are undertaken, it is not possible to ascertain whether gold in the weathered profile is primary or secondary. Initial reports (Legge et al., 1987) suggest it is secondary, thus strongly indicating that

there may be supergene enrichment of gold and silver at the base of weathering. Assay data for DDH VB 281, the one hole examined which intersects mineralization at the base of oxidation (Figure 5), suggests there has been marked enrichment of Au. Additional work is needed to determine whether there has been residual or supergene concentration of gold higher in the profile.

- Following petrographic, mineralogical and geochemical analyses of country rocks and comparison with data on fresh rocks (Binns, 1988), it is intended to provide guidelines for the characterization of weathered rocks. This will be of use in selection of geologically favoured environments for mineralization.

- Additional studies to determine the best sampling medium are warranted. Emphasis must centre on determining whether overburden is residual or transported (in collaboration with Module 1).

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APPENDIX 1 ANALYTICAL TECHNIQUES UTILIZED AND DETECTION LIMITS (in ppm)

SiO ₂	XRF	-
Al ₂ O ₃	XRF/ICP	-
Fe ₂ O ₃	XRF/ICP	-
CaO	XRF/ICP	-
MgO	XRF/ICP	-
Na ₂ O	ICP	-
K ₂ O	XRF	-
TiO ₂	XRF/ICP	-
P ₂ O ₅	XRF/ICP	-
MnO	XRF/ICP	-
SO ₃	Leco/ICP	-
Ag	ICP	5
As	XRF	2
Au	ICP-MS*	0.002
B	OES	0.1
Ba	ICP	10
Bi	XRF	3
Cd	ICP	5
Co	ICP	5
Cr	ICP	5
Cu	ICP	10
Ca	OES	1
Hg	Flameless AAS	0.01
La	ICP	20
Mo	ICP	0.3
Ni	ICP	20
Pb	ICP	50
Sb	OES	30
Sn	OES	1
Sr	ICP	5
Te	ICP [†]	0.01
Tl	ICP [†]	0.05
V	XRF	5
W	XRF	5
Y	ICP	1
Yb	ICP	1
Zn	ICP	5
Zr	ICP	5

*By Analytical Services (WA) Pty. Ltd.

†By USGS, Denver, Colorado

APPENDIX 2 ELEMENTS DETERMINED BY NEUTRON ACTIVATION ANALYSIS AND
DETECTION LIMITS (ppm)

Ag	5
As	2
Au (ppb)	5
Ba	100
Br	2
Co	1
Cr	5
Cs	1
Eu	0.5
Hf	1
Ir (ppb)	20
La	0.5
Lu	0.2
Mo	5
Rb	20
Sc	5
Se	5
Sm	0.2
Ta	1
Th	0.5
W	5
U	2
Yb	0.5
Zn	100

APPENDIX 3 CHECK ON GOLD ASSAYS

Approximately 10 g sample was sent to Analytical Services (WA) Pty. Ltd. for determination of Au content by fire assay and ICP-MS. Eight samples (10% of total) were duplicated and three standards submitted.

	<u>Original</u> (ppm)	<u>Duplicate</u> (ppm)
74753	0.120	0.140
74804	0.094	0.066
74821	0.390	0.440
74864	0.040	0.032
74787	16	17
74805	0.040	0.020
74695	4.5	0.160*
74965	7.3	7.0
STD7	0.170	0.220
STD10	0.030	0.032
STD11	3.8	3.2

*Presumed sampling error

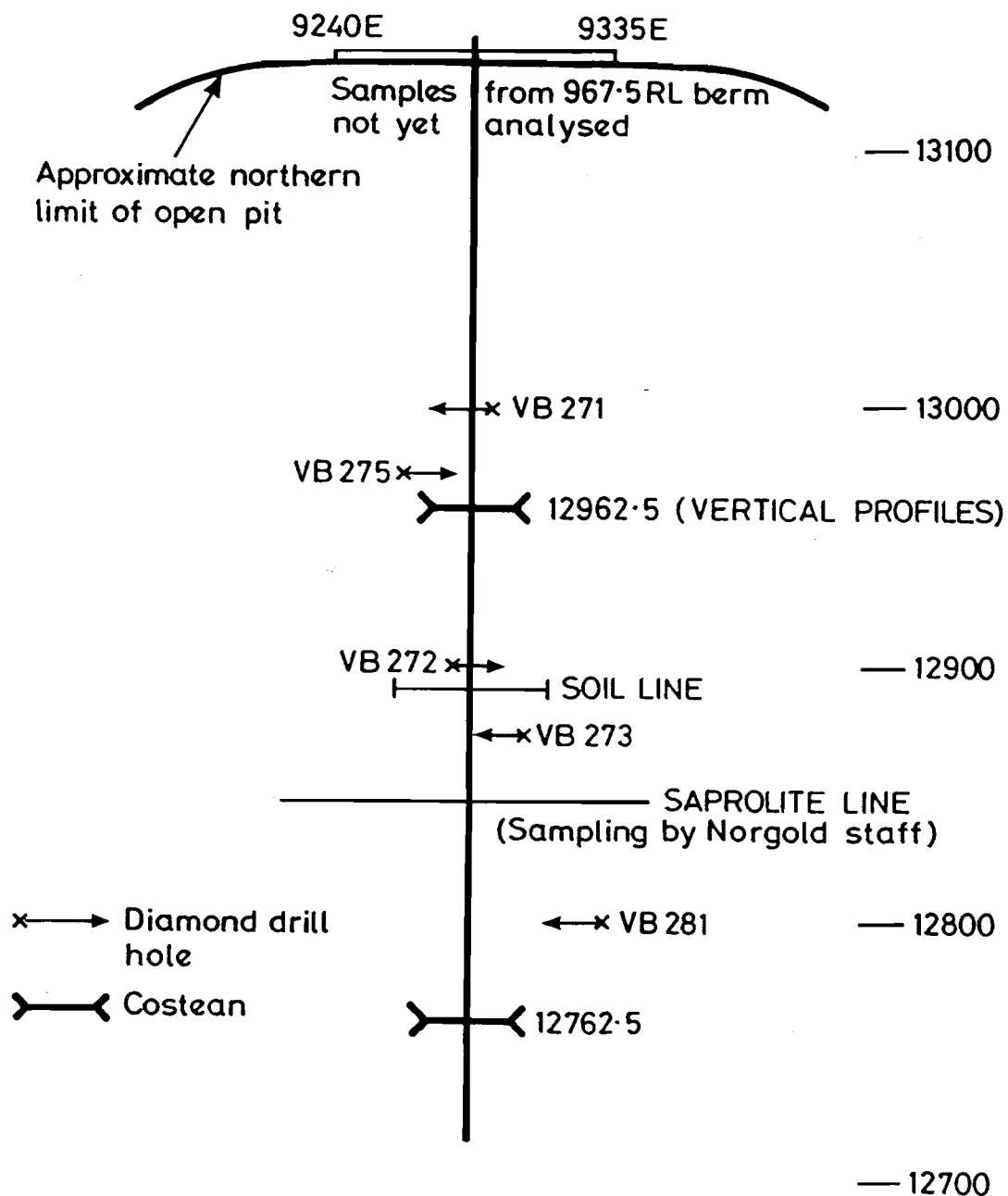


FIG. 1 LOCATION OF SAMPLING LINES AND DRILL-HOLE COLLARS AT VB PROSPECT

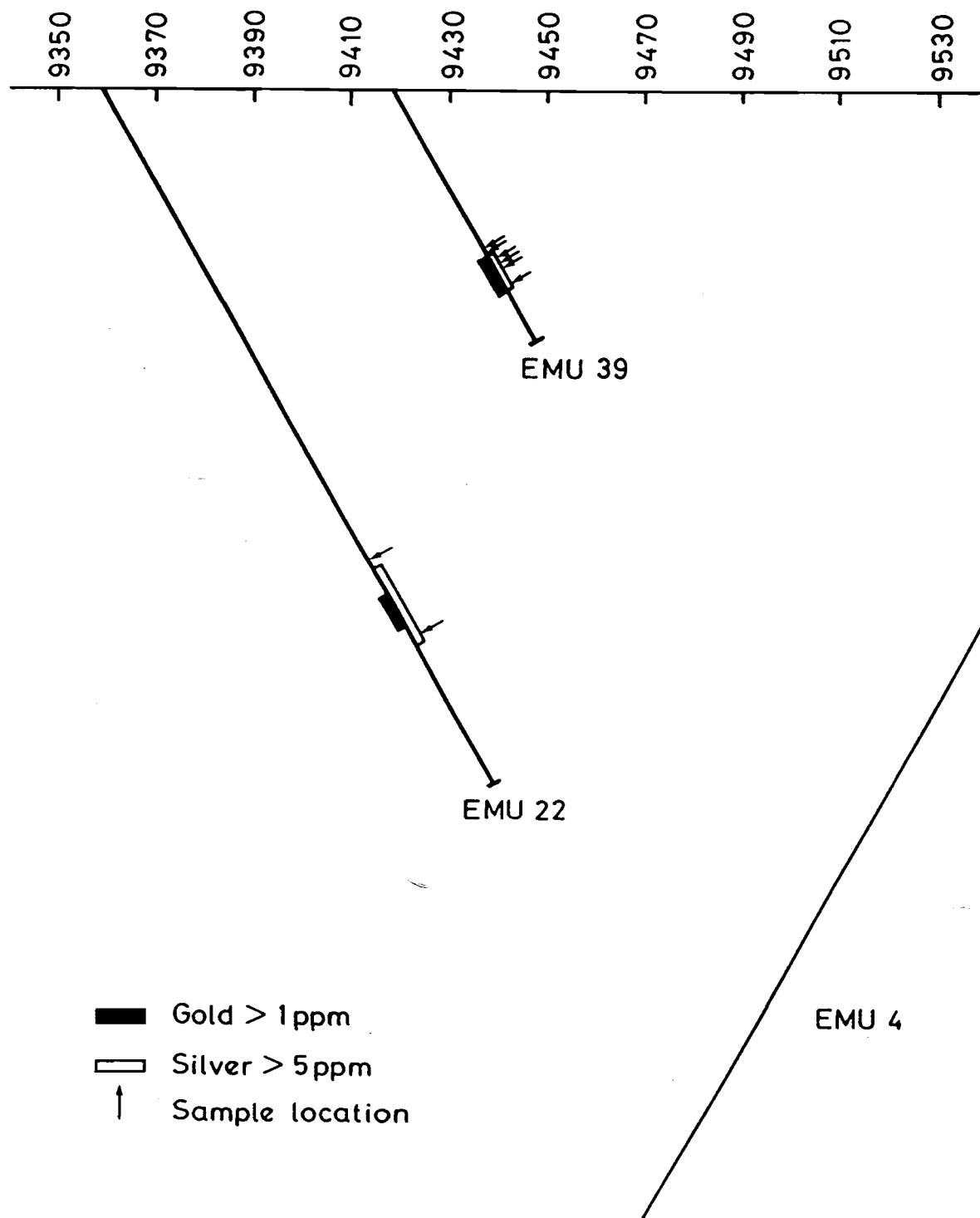


FIG. 2 SECTION AT 15000N SHOWING SAMPLE LOCALITIES IN DDH's EMU 22 AND EMU 39

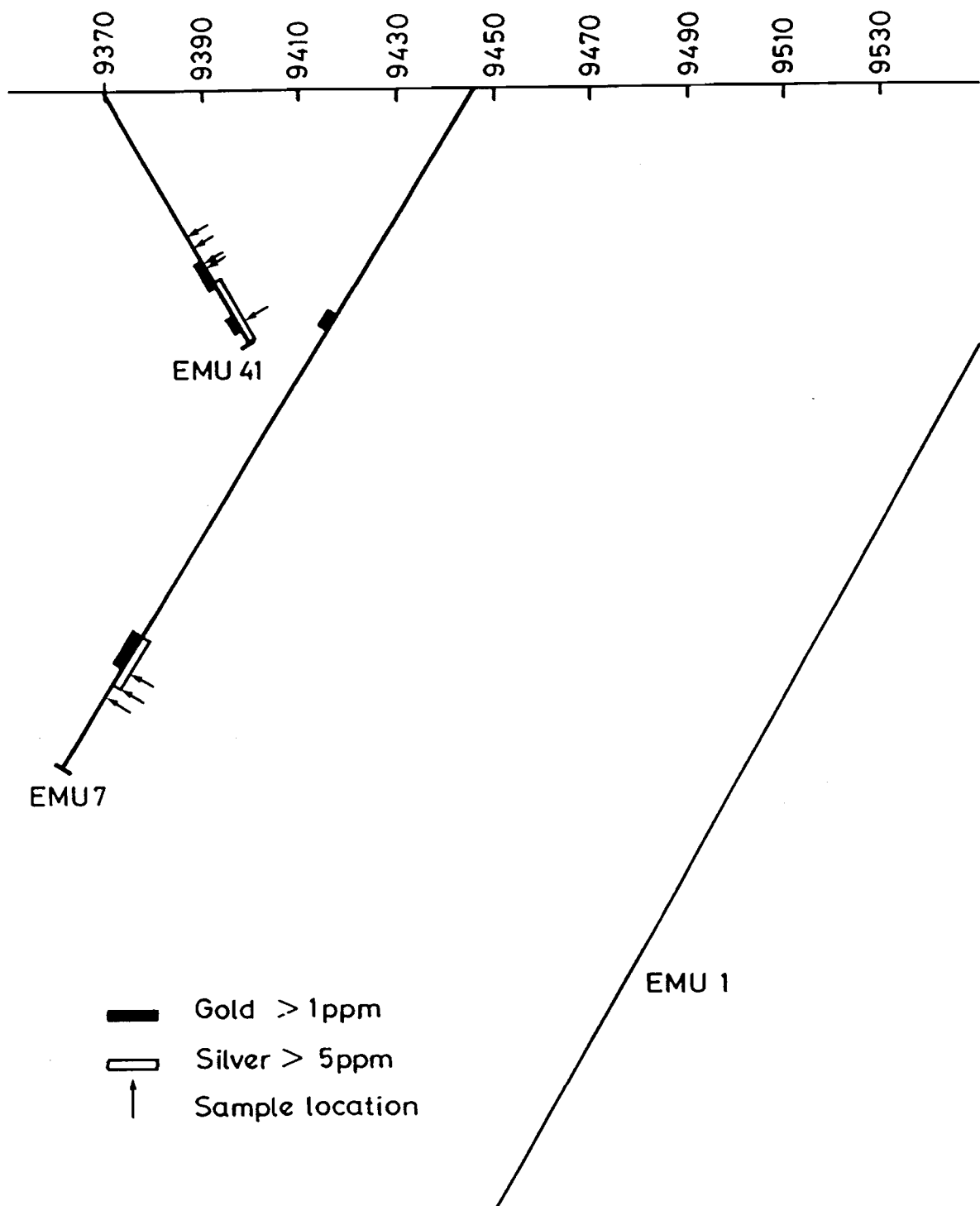


FIG. 3 SECTION AT 15200N SHOWING SAMPLE LOCALITIES IN DDH's EMU 7 AND EMU 41

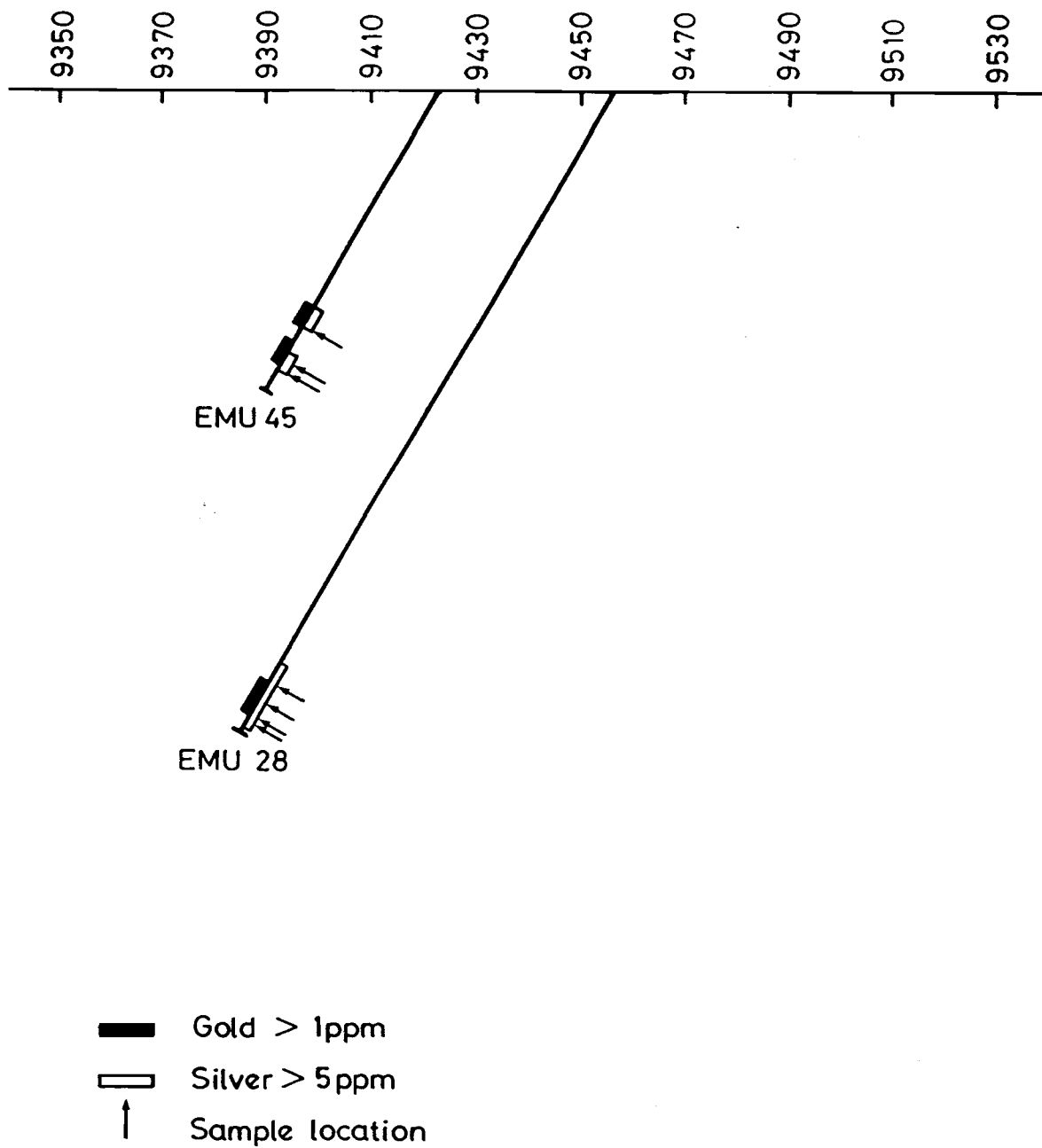


FIG. 4 SECTION AT 15350 N SHOWING SAMPLE LOCALITIES IN DDH's EMU 28 AND EMU 45

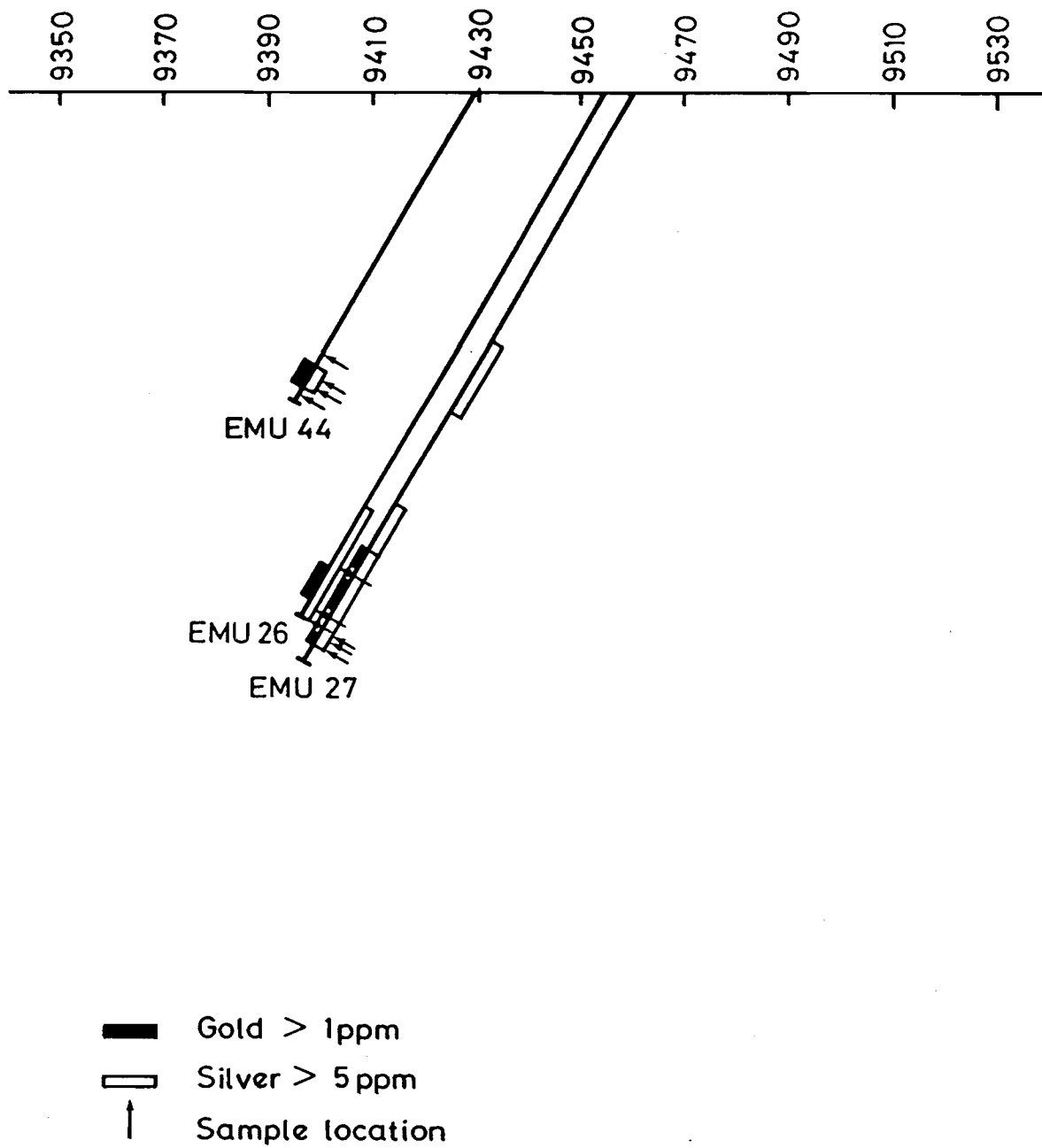


FIG. 5 SECTION AT 155000N SHOWING SAMPLE LOCALITIES IN DDH's EMU 26, EMU 27 AND EMU 44

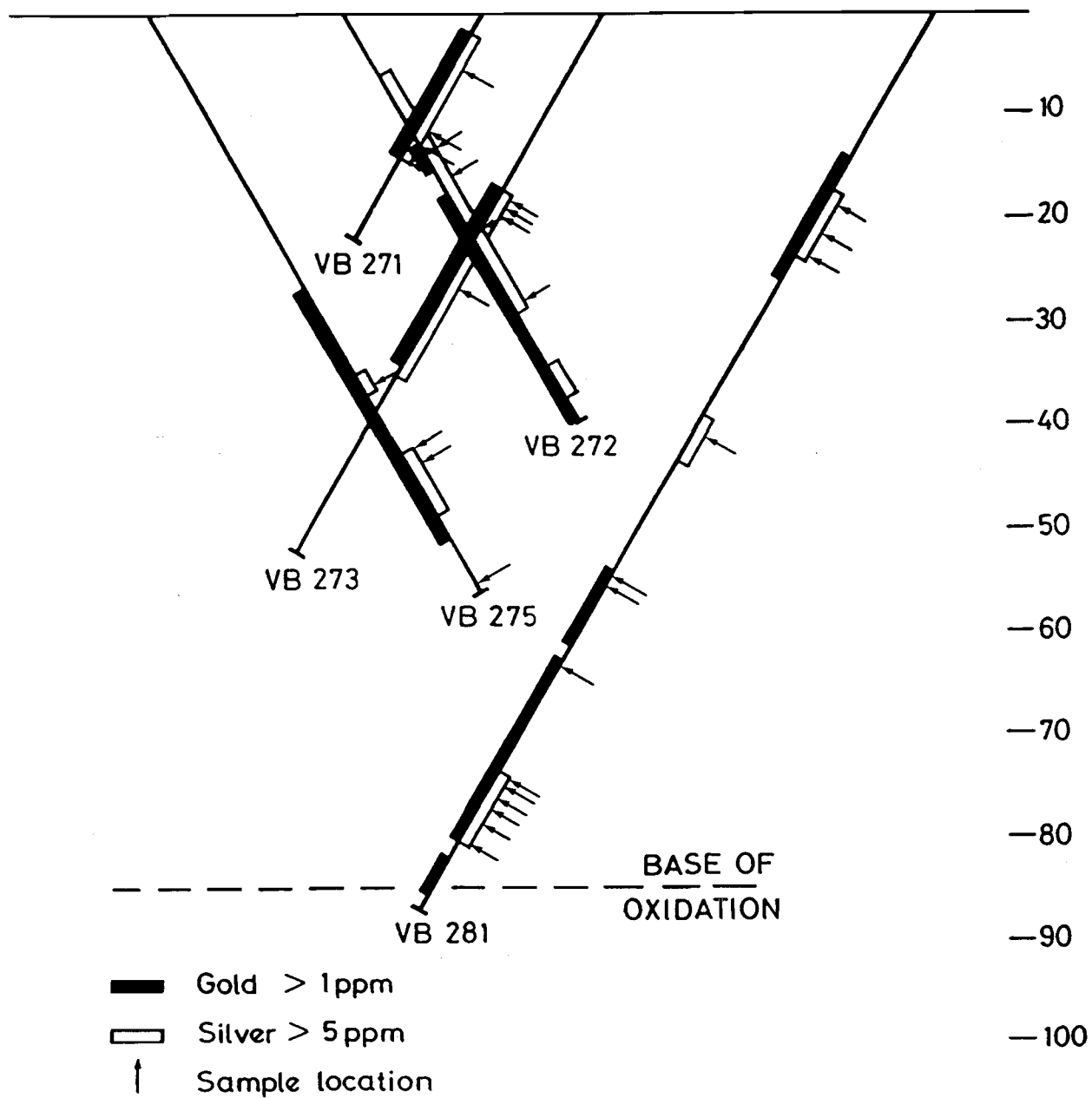


FIG. 6 COMPOSITE SECTION AT VB NORTH SHOWING SAMPLE LOCALITIES
IN DDH's VB 271, VB 272, VB 273, VB 275 AND VB 281

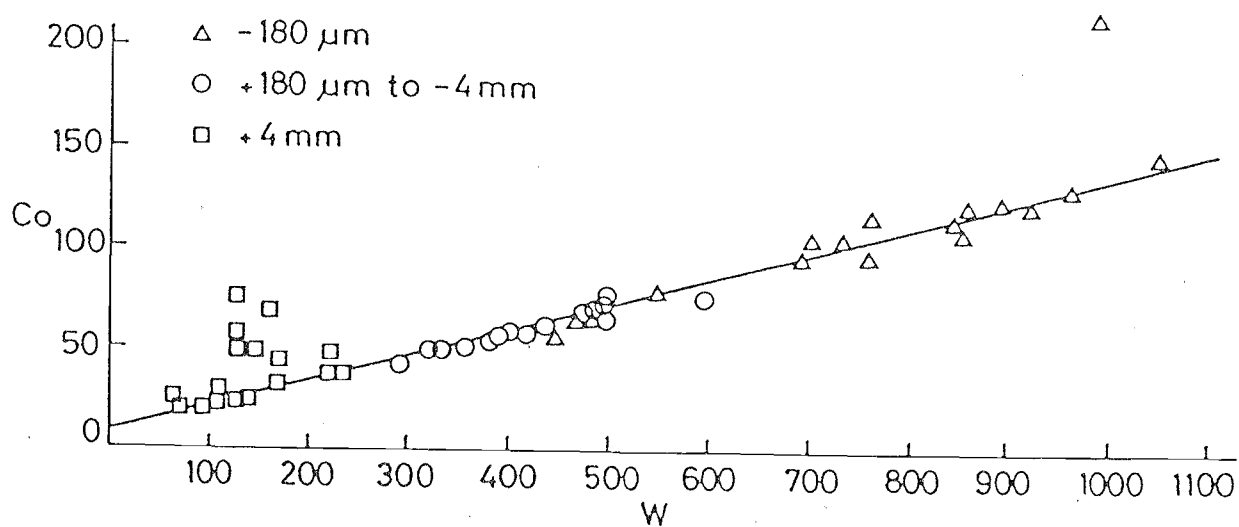


FIG. 7 PLOTS OF C_0 vs W FOR THREE SOIL FRACTIONS FROM VB PROSPECT

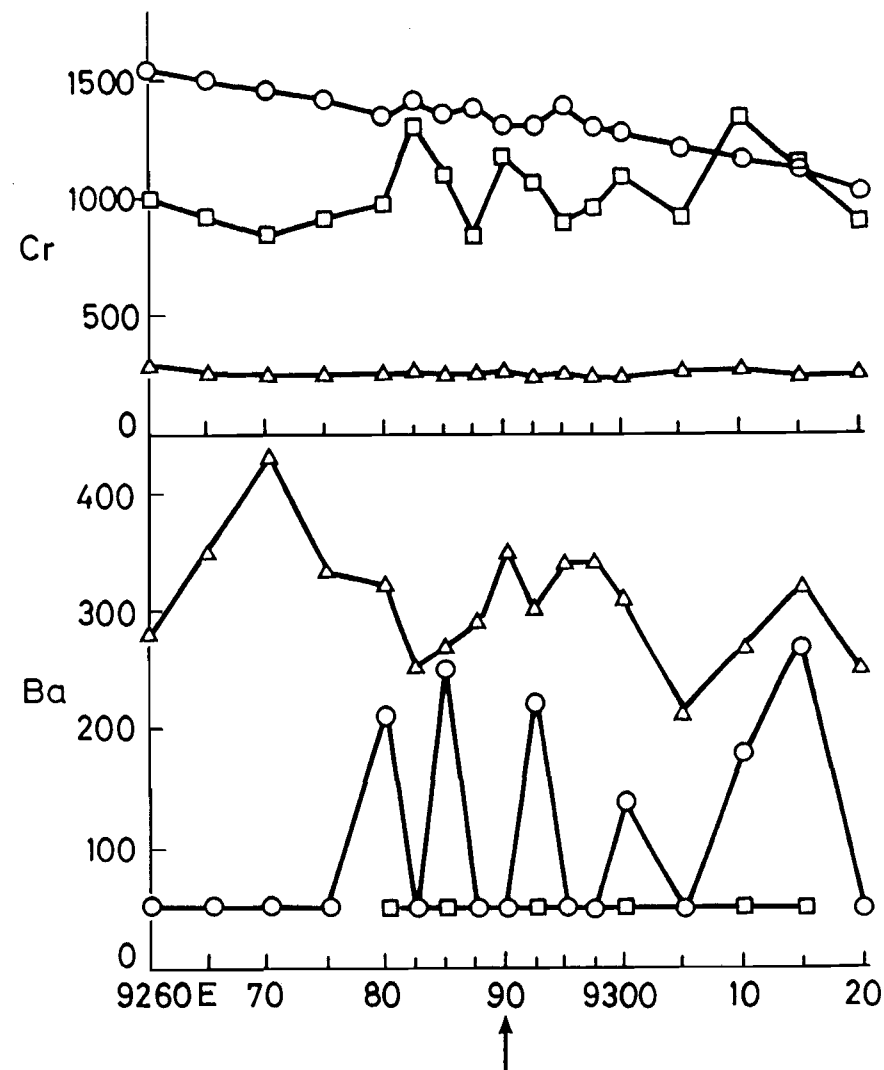
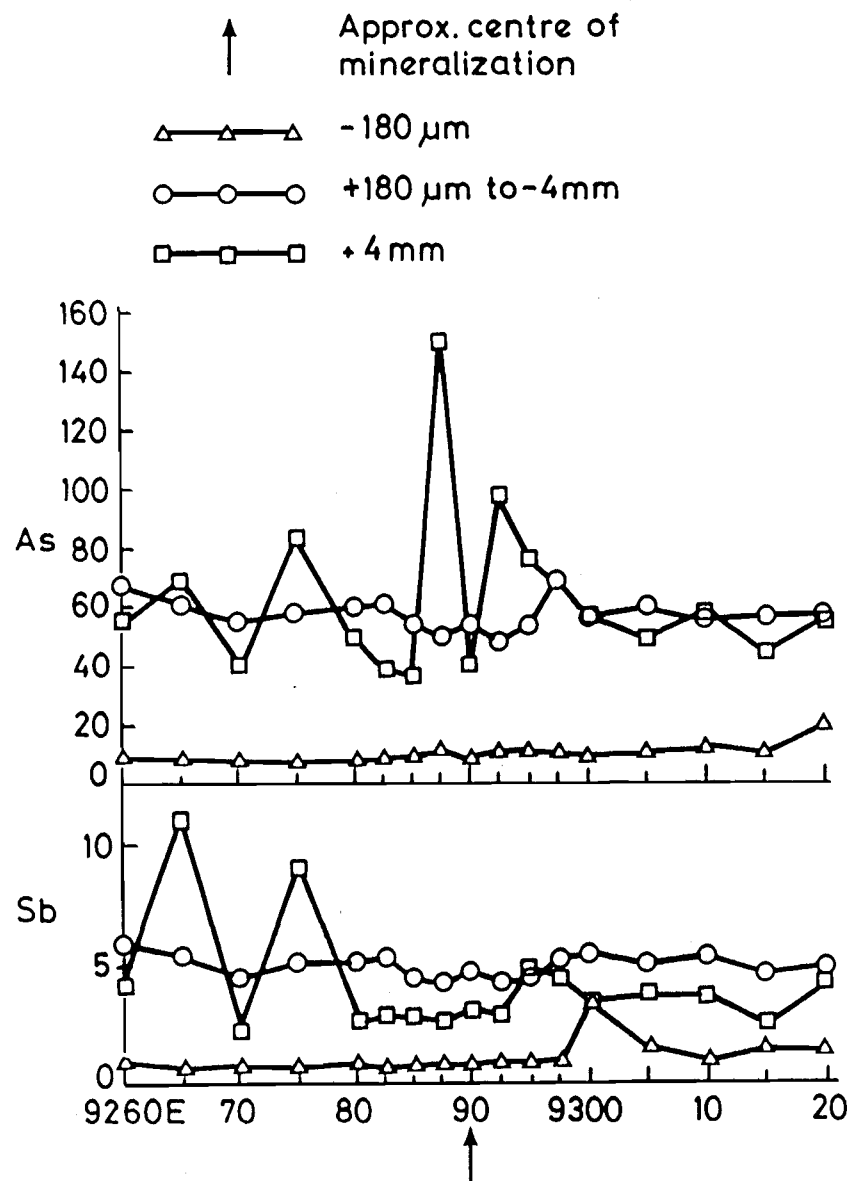


FIG. 8 PLOTS OF As, Sb, Ba AND Cr IN THREE SOIL FRACTIONS FROM VB PROSPECT

TABLE 1. Compositions of sulfide concentrates (majors in wt %; traces in ppm)

DDH	EMU7	EMU7	EMU27	EMU28	EMU28	EMU28
Depth (m)	137.95	143.95	120.70	129.10	136.0	133.0
Lab. No.	74716	74720	74669	74691	74694	74693
	py	py	py	py	py	py/asp
SiO ₂	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Al ₂ O ₃	0.80	0.11	0.54	0.77	1.04	0.94
Fe	45.0	44.7	45.2	44.5	44.8	43.5
CaO	0.01	0.12	0.01	0.01	0.04	0.02
MgO	0.02	0.11	<0.01	0.02	0.04	0.03
Na ₂ O	0.93	0.07	0.77	0.81	1.63	1.25
K ₂ O	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
TiO ₂	0.03	<0.02	<0.02	0.03	0.02	0.03
P ₂ O ₅	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
S	51.9	51.7	52.1	51.7	51.7	48.5
Ag	32	71	10	11	66	16
As	5000	2000	5000	2000	8000	>>1%
Au	2.1	n.d.	1.3	1.1	2.1	3.7
Ba	<10	<10	<10	11	<10	11
Bi	<3	<3	<3	<3	<3	<3
Cd	<5	<5	<5	<5	<5	<5
Co	65	360	215	130	13	35
Cr	<5	<5	<5	6	<5	12
Cu	100	170	360	50	65	37
Hg*	35	100	25	20	120	65
Mn	60	300	25	15	270	95
Mo	<0.3	3	<0.3	<0.3	<0.3	<0.3
Ni	55	150	80	95	35	80
Pb	1390	6400	195	170	1630	1130
Sb	150	100	70	250	70	200
Sn	<1	1	<1	<1	<1	1
Sr	<5	<5	<5	<5	<5	<5
Tl	<3	<3	<3	<3	<3	<3
W	<10	<10	<10	<10	<10	<10
Zn	460	740	30	30	100	300
Zr	145	15	125	120	230	180

n.d. = not determined * Hg in ppb

TABLE 2. Compositions of four gossans from vertical profile at 12957 N 9292 E (majors in wt %; traces in ppm).

Depth (m) Lab. No.	Lithology			
	2.55 74912	2.75 74913	3.0 74914	3.3 74915
SiO ₂	35.9	19.2	21.4	24.9
Al ₂ O ₃	9.72	5.06	9.83	8.14
Fe ₂ O ₃	38.8	59.2	49.8	47.8
CaO	0.36	0.36	0.39	0.46
MgO	0.45	0.71	0.52	0.53
Na ₂ O	0.15	0.17	0.17	0.15
K ₂ O	0.86	0.10	0.30	0.16
TiO ₂	1.72	0.52	0.77	1.42
P ₂ O ₅	<0.1	<0.1	<0.1	<0.1
MnO	0.97	<0.1	0.66	2.19
CO ₂	n.d.	n.d.	n.d.	n.d.
SO ₃	0.21	0.29	0.21	0.35
Ag	7	<5	<5	<5
As	6940	1.02%	1.16%	1.33%
Au	6.8	12	1.1	14
B	100	800	100	50
Ba	340	135	155	170
Bi	14	36	48	31
Cd	<5	<5	<5	<5
Co	19	35	30	35
Cr	130	70	95	120
Cu	390	380	530	490
Ga	10	10	30	15
Hg [†]	60	25	60	85
La	<20	<20	<20	<20
Mo	8	10	20	8
Ni	25	45	60	45
Pb	1370	900	880	3250
Sb	1500	2000	>>1%	1500
Sn	30	40	50	30
Sr	70	50	50	80
Te	0.26	0.27	0.26	0.26
Tl	0.07	0.15	0.20	0.15
V	155	225	245	255
W	11	<5	<5	<5
Y	20	18	17	25
Yb	<1	<1	<1	<1
Zn	300	490	570	630
Zr	270	155	170	260

*As elements and not as oxides

†Hg as ppb

TABLE 3. Compositions of surface gossans (majors in wt %; traces in ppm).

Prospect Northing Lab No.	EMU 15300 74960	EMU 15300 74961	EMU 15487 74962	EMU 15300 74972	- 14400 74963	VB 12962 74964	VB 12762 74965	VB 12762 74967	Boags 11587 64968	Boags 11587 74969	Boags 11587 74970	Boags 11587 74971
SiO ₂	5.26	11.8	2.61	3.71	10.5	18.3	30.4	1.73	5.68	7.08	2.86	1.33
Al ₂ O ₃	2.35	7.46	2.71	2.48	9.67	4.89	7.18	2.25	2.32	4.41	2.74	1.57
Fe ₂ O ₃	84.7	65.4	87.6	82.6	69.8	58.8	47.8	89.8	80.1	76.3	81.0	85.1
CaO	<0.04	0.72	<0.04	<0.04	0.07	0.29	0.31	<0.04	<0.04	<0.04	0.10	0.05
MgO	0.38	0.86	0.32	0.43	0.58	0.44	0.53	0.40	0.36	0.32	0.38	0.34
Na ₂ O	2.26	1.71	2.07	0.06	1.58	0.81	0.92	0.06	0.05	0.05	0.08	0.04
K ₂ O	0.05	1.23	0.12	0.23	1.83	0.11	0.14	<0.04	<0.04	<0.04	<0.04	<0.04
TiO ₂	0.41	0.67	0.32	0.14	0.30	0.37	0.48	0.06	0.17	0.11	0.13	0.18
P ₂ O ₅	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	<0.1	0.14	0.27	0.11	<0.1
MnO	<0.1	<0.1	<0.1	<0.1	<0.1	0.38	0.29	<0.1	<0.1	0.16	<0.1	<0.1
SO ₃	0.36	0.20	0.66	0.22	0.23	0.60	0.20	0.51	0.15	0.26	0.29	0.35
Ag	<5	<5	<5	<5	<5	25	<5	9	<5	<5	<5	<5
As	1930	1910	800	3390	5070	1.51%	1.12%	7870	4820	4220	4350	4420
Au	4.4	0.05	0.05	1.2	0.32	10	7.3	0.84	0.07	2.1	2.2	1.8
B	50	150	40	8	40	50	60	4	15	8	20	10
Ba	7200	2190	2490	190	3940	1490	1900	4490	85	730	90	95
Bi	6	<5	<5	<5	10	18	13	8	<5	7	<5	6
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	6	10	<5	8	<5	30	20	8	30	50	15	10
Cr	105	130	70	195	125	90	95	160	220	75	170	70
Cu	240	520	180	180	120	620	360	210	440	400	430	520
Ga	4	20	6	3	15	5	6	10	15	6	20	3
Hg [†]	100	35	45	25	35	180	50	75	15	35	30	35
La	<20	<20	<20	20	<24	<20	<20	<20	<20	20	<20	<20
Mo	7	8	3	1	4	7	8	31	2	2	2	2
Ni	<20	<20	<20	30	<20	60	55	35	40	30	25	25
Pb	170	50	115	95	300	5200	810	310	170	620	195	155
Sb	200	60	60	150	300	1000	800	1500	1500	800	200	800
Sn	15	6	5	1	5	4	4	<1	4	1	1	3
Sr	160	90	75	13	120	145	115	30	<5	12	15	10
Te	0.27	0.26	0.27	0.30	0.14	0.26	0.27	0.26	0.27	0.16	0.16	0.08
Tl	0.05	1.25	0.15	0.40	2.3	1.25	0.10	0.05	0.05	0.05	0.05	0.05
V	55	125	105	60	115	155	160	85	115	105	25	20
W	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Y	5	13	2	5	7	15	15	5	10	9	2	4
Yb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zn	45	35	<5	125	35	510	360	50	310	300	60	75
Zr	140	165	65	18	60	70	85	15	40	25	35	30

†Hg as ppb

TABLE 4. Compositions of sub-surface gossans (majors in wt %; traces in ppm).

DDH Depth (m) Lab. No.	VB271 12.3 74785	VB271 14.0 74786	VB271 15.5 74787	VB272 15.7 74800	VB272 24.7 74854	VB273 21.0 74866	VB281 23.9 74896	VB281 46.5 74804	VB281 89.8 74825
SiO ₂	17.8	34.4	20.5	21.0	30.2	33.0	38.4	29.4	41.1
Al ₂ O ₃	5.66	7.23	2.57	5.43	4.08	2.93	7.66	8.59	1.31
Fe ₂ O ₃	59.7	43.1	61.6	57.7	45.0	51.1	41.7	51.9	51.0
CaO	0.23	0.18	0.16	0.26	0.24	0.19	0.16	0.09	0.05
MgO	0.46	0.29	0.35	0.50	0.48	0.47	0.42	0.46	0.32
Na ₂ O	0.07	0.08	0.05	0.19	0.20	0.19	1.52	0.13	0.14
K ₂ O	0.13	0.18	<0.04	0.26	0.10	<0.04	1.21	0.67	0.08
TiO ₂	0.26	0.26	0.18	0.72	0.62	0.10	1.80	0.79	0.35
P ₂ O ₅	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MnO	<0.1	0.32	0.75	0.10	4.70	<0.1	0.65	0.67	0.17
SO ₃	0.17	0.35	0.23	0.26	0.16	0.21	0.21	0.34	<0.1
Ag	<5	19	13	<5	37	29	39	<5	<5
As	1.19%	1.25%	1.05%	9810	1.36%	1.56%	8760	5660	5260
Au	90	1.7	15	50	4	0.03	0.16	0.09	0.05
B	60	70	40	50	40	60	70	700	40
Ba	20	450	240	105	730	290	3340	105	260
Bi	9	24	18	11	13	27	9	27	5
Cd	<5	<5	<5	<5	15	13	18	8	<5
Co	65	80	180	50	1350	35	60	65	7
Cr	400	180	270	820	220	420	280	140	110
Cu	860	530	580	510	1660	1290	540	1090	135
Ga	5	8	2	3	1	2	30	25	20
Hg [†]	60	55	30	90	170	185	65	8	410
La	<20	<20	<20	<20	<20	<20	<20	<20	<20
Mo	2	6	8	15	20	10	2	1	15
Ni	200	90	135	140	1050	110	65	80	25
Pb	235	2680	310	245	460	750	1040	820	800
Sb	200	800	20	2000	600	600	200	50	3000
Sn	5	15	5	6	8	5	4	3	15
Sr	30	150	30	35	70	65	145	105	30
Te	0.43	0.42	0.43	0.45	0.28	0.26	0.09	0.22	0.26
Tl	0.2	0.9	2.5	0.2	2.0	0.7	6.9	6.8	0.25
V	117	485	115	105	70	175	325	865	75
W	<5	<5	<5	<5	<5	<5	<5	<5	<5
Y	33	22	25	25	60	45	10	24	3
Yb	<1	<1	<1	<1	2	<1	<1	<1	<1
Zn	810	750	700	990	1300	870	840	980	280
Zr	55	55	25	55	45	16	110	40	75

†Hg as ppb

TABLE 5. Composition of weathered biotite schists (majors in wt %; traces in ppm).

DDH Depth (m) Lab. No.	EMU7 142.7 74718	EMU22 128.0 74753	EMU26 112.8 74658	EMU26 114.3 74659	EMU27 118.10 74667	EMU39 37.4 74763	EMU44 65.8 74685	VB275 63.6 74886	VB281 49.5 74805	VB281 62.35 74808	VB281 63.5 74809	VB281 72.4 74814	VB281 85.3 74822
SiO ₂	51.3	69.7	46.6	55.3	64.0	60.8	40.3	63.8	65.7	55.5	52.8	59.5	61.8
Al ₂ O ₃	16.1	2.21	13.5	19.5	0.18	14.1	15.2	6.29	20.0	24.7	23.5	14.9	4.29
Fe ₂ O ₃	14.1	15.9	27.5	6.15	3.04	13.9	32.0	19.7	4.60	5.10	7.03	7.89	25.1
CaO	4.04	<0.04	0.10	0.23	17.3	0.09	<0.04	0.11	<0.04	0.13	0.05	0.15	0.09
MgO	4.69	0.82	0.33	0.27	0.19	0.51	0.17	0.35	0.25	0.29	0.31	2.80	0.38
Na ₂ O	0.40	0.02	0.21	0.89	0.02	0.21	0.09	0.27	0.10	0.16	0.17	0.10	0.19
K ₂ O	3.31	0.47	4.01	0.77	<0.04	3.23	0.24	1.97	0.97	0.39	1.53	5.50	0.96
TiO ₂	1.47	0.08	1.17	1.36	0.37	1.41	1.12	0.73	0.37	1.57	1.02	1.68	0.67
P ₂ O ₅	0.17	<0.1	0.11	<0.1	<0.1	<0.1	0.13	0.12	0.15	<0.01	<0.1	0.16	0.11
MnO	1.46	0.22	<0.1	0.64	<0.1	<0.1	1.65	<0.1	<0.1	0.27	<0.1	0.80	<0.1
SO ₃	2.41	22.8	0.76	5.12	<0.1	<0.1	0.13	1.17	0.46	0.23	9.94	5.88	0.38
Ag	<5	<5	<5	27	540	<5	<5	31	<5	<5	670	<5	710
As	100	5830	5020	1520	865	3450	1660	8040	1290	1000	325	2220	4330
Au	0.01	0.12	0.01	0.12	1.3	0.01	0.24	2.7	0.04	0.47	0.07	0.27	73
B	25	8	50	70	6	150	100	15	50	70	100	20	25
Ba	450	20	580	110	<10	350	620	510	420	85	175	225	130
Bi	<5	8	5	<5	<5	8	<5	45	7	<5	<5	9	8
Cd	<5	<5	<5	<5	<5	<5	<5	13	<5	7	<5	185	<5
Co	40	35	10	14	7	10	90	<5	<5	7	45	45	6
Cr	130	25	240	160	290	195	210	55	35	190	215	80	290
Cu	45	250	280	290	200	55	1000	225	175	225	3850	95	235
Ga	25	4	20	30	0.8	25	30	8	25	25	25	25	25
Hg [†]	10	55	10	20	2000	20	15	90	10	5	1735	95	310
La	<20	<20	<20	<20	<20	<20	<20	<20	<60	<20	<20	<20	<20
Mo	1	3	0.4	1	2	3	2	2	2	1	2	1	10
Ni	57	120	<20	42	55	<20	95	<20	<20	25	80	75	25
Pb	100	170	85	125	1820	150	65	6400	510	150	270	2900	850
Sb	<30	200	30	<30	200	200	30	700	60	80	100	60	600
Sn	2	<1	1	1	2	2	2	2	<1	1	1	3	30
Sr	65	7	165	380	1050	35	55	270	360	50	100	110	130
Te	0.01	0.25	0.02	0.01	0.24	0.13	0.14	0.24	0.015	0.025	0.025	0.09	0.22
Tl	4.3	1.15	2.45	1.0	0.05	1.9	10.8	2.0	0.3	0.2	1.2	4.9	1.4
V	350	25	395	220	5	330	435	185	95	155	200	390	105
W	<5	<5	<5	6	<5	16	<5	11	6	<5	15	>5	<5
Y	22	4	3	9	3	12	8	3	9	7	4	85	5
Yb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	11	<1
Zn	230	1400	100	60	185	35	145	350	290	770	590	1.332	390
Zr	80	30	55	80	75	75	52	50	120	60	45	90	170

†Hg as ppb

TABLE 6. Composition of gossanous biotite schist(majors in wt %; traces in ppm).

DDH Depth (m) Lab. No.	EMU39 38.7 74764	EMU41 34.0 74727	EMU41 36.7 74729	EMU41 39.55 74732	EMU41 40.5 74733	EMU45 60.1 74701	VB271 5.3 74781	VB281 84.4 74821	VB281 92.0 74826
SiO ₂	48.0	24.4	37.0	55.7	49.3	38.2	49.6	50.7	26.8
Al ₂ O ₃	7.24	21.5	7.67	3.29	5.86	14.2	6.21	7.16	2.32
Fe ₂ O ₃	34.2	38.4	41.9	30.9	33.1	33.0	33.0	30.3	57.3
CaO	0.15	<0.04	0.08	0.09	0.11	0.06	0.14	0.13	0.14
MgO	0.31	0.26	0.67	0.31	0.37	0.45	0.35	0.54	0.51
Na ₂ O	0.10	0.18	0.20	0.12	0.27	0.35	0.11	0.18	0.45
K ₂ O	0.46	0.17	1.18	0.15	0.37	3.75	0.24	1.95	0.29
TiO ₂	0.45	1.60	2.11	0.94	0.62	1.31	0.94	0.68	0.42
P ₂ O ₅	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	0.31
MnO	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	<0.1	0.20
SO ₃	0.23	0.13	0.15	0.17	0.16	0.13	0.10	0.34	0.31
Ag	12	<5	<5	<5	<5	<5	<5	510	<5
As	8990	6730	7740	6210	8740	5630	4800	6070	5500
Au	0.39	0.02	0.01	0.06	0.18	0.03	13	0.39	0.16
B	150	40	700	150	100	200	150	20	50
Ba	800	12	95	65	190	310	75	250	310
Bi	18	8	7	9	11	<5	18	9	<5
Cd	<5	<5	<5	<5	<5	<5	<5	10	<5
Co	17	12	15	25	15	22	22	<5	7
Cr	190	500	330	390	750	500	75	185	135
Cu	250	1050	480	480	460	360	290	135	80
Ga	15	25	10	8	70	50	7	30	50
Hg	95	15	35	20	60	115	20	195	15
La	50	<20	24	<20	<20	<20	<20	<20	95
Mo	25	0.3	1	20	20	2	20	6	10
Ni	65	110	75	155	150	55	65	<20	65
Pb	380	100	270	155	350	180	550	530	650
Sb	200	150	60	1000	2000	40	2000	500	1000
Sn	1	6	7	8	8	3	50	15	4
Sr	400	11	40	40	85	80	55	125	200
Te	0.23	0.29	0.28	0.27	0.29	0.13	0.44	0.23	0.26
Tl	0.65	0.2	2.0	0.3	0.6	3.8	0.35	1.4	0.55
V	215	440	415	170	245	430	75	165	75
W	<5	<5	16	<5	25	<5	5	<5	<5
Y	24	9	26	43	55	26	20	4	7
Yb	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zn	115	80	165	260	240	210	340	390	720
Zr	125	90	135	90	95	70	165	185	155

TABLE 7. Compositions of weathered porphyry (Type 2)* (majors in wt %; traces in ppm).

DDH	EMU26	EMU27	EMU39	EMU44	VB273	VB273	VB281	VB281
Depth (m)	103.6	117.8	46.3	45.9	20.0	20.6	20.8	26.5
Lab. No.	74652	74666	74771	74678	74864	74865	74894	74898
SiO ₂	24.8	83.5	82.4	68.1	72.1	61.4	73.0	74.6
Al ₂ O ₃	4.21	0.22	6.23	8.43	7.89	2.76	6.07	9.07
Fe ₂ O ₃	60.4	14.3	5.56	15.3	13.3	26.6	15.1	8.21
CaO	<0.04	<0.04	<0.04	<0.04	0.05	0.13	<0.04	0.05
MgO	0.26	<0.1	0.22	0.26	0.30	0.33	0.12	0.45
Na ₂ O	0.09	0.01	0.06	0.12	0.18	0.18	1.29	1.05
K ₂ O	0.90	<0.04	1.41	2.46	1.88	0.06	0.33	2.71
TiO ₂	1.20	<0.04	0.67	0.13	0.33	0.22	0.36	0.51
P ₂ O ₅	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MnO	<0.1	<0.1	0.26	<0.1	<0.1	<0.1	<0.1	<0.1
SO ₃	0.47	<0.1	<0.1	0.58	<0.1	0.19	<0.1	0.17
Ag	<5	<5	11	<5	<5	23	<5	<5
As	5640	1310	1350	5000	3880	9280	3640	3570
Au	0.10	0.31	n.d.	0.03	0.04	7.9	5.9	0.18
B	20	6	250	20	60	150	15	100
Ba	125	390	145	1310	490	320	3110	2550
Bi	<5	7	8	11	11	19	<5	8
Cd	<5	<5	<5	<5	<5	<5	8	20
Co	6	<5	13	<5	10	25	20	<5
Cr	225	75	110	18	40	140	170	90
Cu	310	25	120	120	270	690	410	115
Ga	50	8	8	25	50	4	60	20
Hg [†]	20	25	250	25	35	150	30	30
La	<20	<20	<20	<20	<20	<20	<20	<20
Mo	8	2	2	2	2	10	1	2
Ni	<20	<20	35	<20	<20	80	35	<20
Pb	820	150	<50	1210	1000	1120	780	2180
Sb	1000	200	50	40	200	700	70	150
Sn	10	<1	2	1	6	10	<1	8
Sr	30	<5	18	450	60	80	95	100
Te	0.24	0.25	0.30	0.50	0.30	0.27	0.12	0.23
Tl	0.80	0.05	16	2.4	1.3	0.15	2.3	1.5
V	160	7	80	15	65	65	175	110
W	<5	<5	19	<5	13	10	<5	<5
Y	3	3	19	11	15	30	5	8
Yb	<1	<1	1	<1	<1	1	<1	<1
Zn	165	30	45	110	135	370	450	175
Zr	90	50	125	95	85	35	35	130

*As defined by Binns (1988). †Hg as ppb

TABLE 8. Compositions of weathered shales and cherts (silicified mineralization) (majors in wt %; traces in ppm).

DDH Depth (m) Lab. No.	EMU39 40.1 75766	EMU39 41.0 75767	EMU39 42.7 74768	EMU41 54.2 74739	EMU44 61.6 74682	EMU44 63.6 74683	EMU45 50.5 74698	EMU45 57.8 74699	VB272 18.8 74851	VB272 18.8 74852	VB272 32.8 74855	VB273 29.5 74868	VB275 42.4 74869	VB275 49.1 74881	VB275 50.6 74881	VB281 86.9 74823	VB281 88.2 74824	VB sub-surface 74993
SiO ₂	97.2	92.7	75.7	95.3	69.0	70.6	86.6	91.2	97.7	96.6	94.2	96.8	70.6	83.0	94.5	54.1	66.8	59.0
Al ₂ O ₃	0.63	2.28	10.4	1.73	1.01	3.21	3.96	0.69	0.36	0.22	0.57	0.17	7.64	1.83	0.36	1.00	0.49	6.42
Fe ₂ O ₃	0.34	2.41	6.36	0.56	22.7	14.4	1.91	5.99	2.11	2.94	4.00	2.61	15.6	11.9	4.93	36.2	27.5	24.2
CaO	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.12	0.06	0.12
MgO	<0.1	0.31	0.18	0.21	<0.1	0.19	<0.1	<0.1	<0.1	0.11	<0.1	<0.1	0.30	0.14	<0.1	0.32	0.22	0.40
Na ₂ O	0.24	0.10	0.04	0.08	0.06	0.04	1.33	0.03	0.14	0.13	0.12	0.15	0.21	0.13	0.12	0.16	0.14	0.11
K ₂ O	<0.04	<0.04	1.76	<0.04	0.10	0.10	0.09	0.04	<0.04	<0.04	0.12	<0.04	1.68	0.49	0.05	<0.04	<0.04	0.57
TiO ₂	1.33	0.62	0.84	1.62	0.22	3.36	2.12	0.21	0.07	0.10	0.05	<0.04	0.54	0.35	0.06	0.66	0.20	0.28
P ₂ O ₅	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MnO	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1	<0.1
SO ₃	0.15	<0.1	<0.1	<0.1	0.69	0.82	0.58	<0.1	<0.1	<0.1	0.35	0.71	0.13	<0.1	0.18	<0.1	<0.1	<0.1
Ag	5	230	<5	<5	33	27	11	<5	<5	<5	154	62	<5	<5	89	27	18	11
As	30	515	1740	120	8520	7440	3270	1610	355	545	1090	600	2770	2010	1800	4600	3530	4310
Au	17	3.4	1.3	6.8	1.3	40	0.12	4.0	1.4	12	1.5	0.06	0.03	0.05	9.7	42	2.8	10
B	6	1500	15	600	15	400	60	70	6	4	6	4	30	10	8	25	8	60
Ba	70	80	120	35	3460	1040	1430	47	260	240	290	290	460	310	440	250	250	360
Bi	<5	<5	8	<5	15	21	10	<5	<5	6	6	<5	9	<5	8	<5	12	6
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	<5	<5	<5	<5	<5	9	22	<5	<5	9	<5	<5	<5	10	<5	6	6	11
Cr	70	45	75	80	55	590	70	75	25	25	25	15	190	20	35	330	135	45
Cu	5	25	70	10	200	165	75	80	25	35	75	25	230	130	90	190	95	110
Ga	<1	2	8	2	2	8	20	2	<1	<1	<1	<1	8	4	1	25	4	8
Hg [†]	110	785	20	140	100	60	80	45	15	15	540	330	45	30	40	255	450	30
La	<20	<20	<20	<20	<20	<20	95	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Mo	1	2	4	2	20	20	2	2	1	2	2	1	6	2	1	15	4	5
Ni	<20	40	30	<20	33	<20	22	23	<20	<20	<20	<20	<20	<20	<20	50	45	55
Pb	<50	<50	<50	80	2990	1.06%	2330	75	<50	50	85	50	440	140	1290	310	260	300
Sb	<30	30	30	60	150	1500	300	50	40	100	60	40	150	50	30	1500	600	200
Sn	2	6	2	<1	5	25	25	1	<1	<1	<1	<1	4	1	<1	50	3	4
Sr	6	10	30	35	175	190	1300	6	8	10	15	10	150	13	60	20	15	35
Te	0.01	0.27	0.27	0.29	0.46	0.46	0.45	0.34	0.16	0.24	0.18	0.07	0.22	0.22	0.19	0.24	0.28	0.23
Tl	0.05	0.05	1.9	0.05	0.30	0.25	0.25	0.05	0.05	0.10	0.10	1.1	1.4	0.25	0.20	0.05	0.70	0.70
V	40	25	110	35	25	95	<5	15	6	15	10	<5	85	20	7	80	25	70
W	25	23	<5	69	10	77	18	6	9	9	10	15	<5	<5	6	<5	<5	<5
Y	6	<1	12	11	6	55	25	11	2	3	3	1	18	16	2	4	3	17
Yb	2	<1	1	2	<1	7	4	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Zn	11	11	30	15	225	680	185	90	45	70	55	20	150	90	50	550	460	320
Zr	123	18	100	195	18	570	250	20	10	15	8	<5	165	260	20	120	40	55

TABLE 9. Average compositions of various rock types (majors in wt %; traces in ppm).

	Sulfide concentrate (5)	Surface gossan (12)	Sub-surface gossan (9)	Weathered biotite schist (13)	Gossanous biotite schist (9)	Weathered porphyry (7)	Weathered chert/shale (18)
SiO ₂	n.d.	8.44	29.5	57.5	42.2	73.6	82.9
Al ₂ O ₃	0.70*	4.17	5.05	13.4	8.38	5.81	2.39
Fe ₂ O ₃	44.6	75.8	51.4	14.0	36.9	14.1	10.4
CaO	0.04	0.14	0.17	0.09	0.10	0.04	<0.04
MgO	0.04	0.45	0.41	0.87	0.42	0.25	0.15
Na ₂ O	0.91	0.80	0.30	0.22	0.22	0.41	0.19
K ₂ O	n.d.	0.32	0.30	1.80	0.95	1.27	0.24
TiO ₂	0.02	0.28	0.56	1.00	1.00	0.32	0.70
P ₂ O ₅	<0.02	<0.1	<0.1	0.10	<0.1	<0.1	<0.1
MnO	125*	<0.1	0.92	0.40	<0.1	<0.1	<0.1
SO ₃	51.3*	0.34	0.22	0.63	0.19	0.16	0.23
Ag	34	<5	16	155	60	6	38
As	5300	5425	1.04%	2740	6710	4000	2490
Au	1.65	2.53	18	0.45	1.58	2.39	8.53
B	n.d.	38	125	53	170	80	160
Ba	<10	2075	615	285	235	1190	525
Bi	<3	7	16	8	9	11	7
Cd	<5	<5	7	18	<5	<5	<5
Co	135	16	210	24	15	11	6
Cr	5	125	315	165	340	92	105
Cu	130	350	800	530	400	250	90
Ga	n.d.	9	11	20	30	21	5
Hg [†]	60	55	115	340	65	75	170
La	n.d.	<20	<20	<20	<20	<20	<20
Mo	0.3	4	9	2	12	3	5
Ni	82	28	210	47	85	<20	22
Pb	1800	270	815	1045	350	925	500
Sb	140	615	830	175	770	200	275
Sn	<1	4	7	4	11	4	7
Sr	<5	65	75	215	115	115	115
Te	n.d.	0.22	0.31	0.10	0.27	0.28	0.25
Tl	n.d.	0.50	2.25	2.45	1.09	1.33	0.38
V	n.d.	95	260	220	250	75	37
W	<10	<5	<5	6	7	7	16
Y	n.d.	7	25	13	24	13	11
Yb	n.d.	<1	<1	<1	<1	<1	<1
Zn	275	160	835	380	280	185	170
Zr	135	62	55	75	125	80	110

* As elements and not oxides

n.d. Not determined

† Hg as ppb

TABLE 10. Average compositions of surface gossans from Emu, VB and Boags prospects (derived from Table 3) (majors in wt %; traces in ppm).

	Emu (4)	VB (3)	Boags (4)
SiO ₂	5.85	16.8	4.23
Al ₂ O ₃	3.74	4.77	2.76
Fe ₂ O ₃	80.1	65.5	80.6
CaO	0.20	0.20	0.05
MgO	0.50	0.46	0.35
Na ₂ O	1.52	0.60	0.05
K ₂ O	0.41	0.09	<0.04
TiO ₂	0.39	0.30	0.15
P ₂ O ₅	<0.10	<0.10	0.14
MnO	<0.10	0.24	<0.10
SO ₃	0.36	0.44	0.26
Ag	<5	12	<5
As	2000	1.14%	4450
Au	1.43	6.05	1.54
B	62	38	13
Ba	3010	2630	250
Bi	<5	13	5
Cd	<5	<5	<5
Co	7	20	25
Cr	125	115	135
Cu	280	400	450
Ga	8	7	11
Hg#	50	100	30
La	<20	<20	<20
Mo	5	15	2
Ni	<20	50	30
Pb	105	2100	285
Sb	120	1100	825
Sn	7	3	2
Sr	85	95	10
Te	0.27	0.26	0.17
Tl	0.45	0.45	0.05
V	85	135	65
W	<5	<5	<5
Y	6	12	6
Yb	<1	<1	<1
Zn	50	305	185
Zr	95	55	32