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Exploration rock geochemistry in the Rosebery Mine area, western Tasmania

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ABSTRACT

This study reports on the role of rock geochemistry in massive sulphide exploration in the Rosebery mine area. The study involved four aspects: (1) distinction between the host rock and the footwall pyroclastics; (2) geochemical zonality associated with the Rosebery deposit; (3) geochemical haloes around the Rosebery deposit; (4) geochemical evaluation of the host rock.

The difficulty in distinguishing between the host rock and footwall, which have similar lithological characteristics because of the alteration effect within the Rosebery mine area, may be removed by examining their geochemical signatures. The host rock is characterised by the enhancement of TiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, CaO, MnO, P_2O_5, Pb, Zn, Rb, Ba and Tl, and depletion of SiO_2, Na_2O, Cu and Sr. The footwall pyroclastic rocks have enrichment in SiO_2, K_2O, Cu, Rb, and possibly MgO and MnO, and depletion in TiO_2, Al_2O_3, CaO, Na_2O, P_2O_5, Sr, Ba and Tl. Distinction between the host rock and footwall pyroclastics can be made by using the relations between TiO_2, Al_2O_3 and SiO_2. Higher concentrations of MgO, CaO, MnO, P_2O_5, Ba and Tl in the host rock compared to the footwall also play a major role to distinguish it from the footwall.

The Rosebery deposit is associated with significant lateral and vertical (stratigraphic) geochemical zonalities. The lateral zonality sequence (from upper level to lower level along the dip direction) is defined as As-Ba-Sb-Pb-Zn-Cu. The stratigraphic zonality sequence may also be arranged (from top to bottom) as (As, Ba, Sb)-(Pb, Zn)-Cu.

The Rosebery deposit is associated with well-defined surface geochemical haloes (at least 3000×1200 m) of Ba, Mn, Fe, and F which are much larger than the mineralogical alteration zone and which also extend into hangingwall.

The dispersion haloes of K, Rb, Na, Ca, Sr, K/Na and Rb/Sr outline the footwall alteration zone and the host rock of the Rosebery deposit, and also extend into the hangingwall pyroclastics.

Ba, Tl, Ga and V together with Pb, Zn, As, Sb and Ag may be the element association to determine the mineralisation potential of the host rock.

INTRODUCTION

The Mt Read Volcanics are known to be highly prospective for massive sulphide deposits of the Mt Lyell, Rosebery/Hellyer type. Intensive exploration concentrating on the search for blind mineral deposits is being carried out following the discovery of large, hidden, Hellyer deposit in 1983. The delineation of geochemical haloes in wallrocks may enhance the success of exploration for blind deposits.

To the present there are only few exploration-oriented rock geochemical studies of massive sulphide mineralisation in the Mt Read Volcanics terrane, in western Tasmania. Among them Smith (1975), Green *et al.* (1981), Naschwitz (1985), Naschwitz and van Moort (1991) and Green (1990) described geochemistry of host rock and geochemical characteristics of wallrock alteration zone associated with the Rosebery deposit. Large and Huston (1986) and Huston and Large (1987) found that the 'zinc ratio' can distinguish the styles of mineralisation, and is of use in determination of bedrock anomalies and drill intersections at an early stage of exploration. Sheppard (in Govett, 1983) carried out a detailed study of the geochemical dispersion patterns around the Mt Lyell deposits and investigated the element and mineralogical variation related to sulphide deposits. The recent study of Smith and Huston (1992) found that there are three elemental suites associated with the different positions of massive sulphide mineralisation in the Rosebery deposit. They also mentioned the physicochemical conditions in which the elements were deposited and defined pathfinder elements such as Tl and Hg to locate blind deposits.

As the cost of massive sulphide exploration, particularly exploratory drilling, is escalating, a more selective basis for defining targets is essential. Rock geochemistry in conjunction with careful geological study may provide this.

This paper presents a summary of current research on exploration rock geochemistry in the Rosebery mine area., including 203 analyses of Smith (1975) (for major elements and Tl only) and Naschwitz (1985), unpublished AAS and XRF analyses of 123 drill-core samples, re-analyses of 76 surface samples (collected by Naschwitz) using PIXE/PIGME (Proton Induced X-ray Emission and Proton

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Induced Gamma ray Emission) analysis, and additional analyses of 135 drill core samples by PIXE/PIGME.

GEOLOGY AND MINERALISATION

The geology and mineralisation of the Rosebery deposit has been comprehensively described by many workers (Brathwaite, 1969, 1972; Green *et al.*, 1981; Naschwitz, 1985; Corbett and Lees, 1987; Khin Zaw *et al.*, 1988; Corbett and Solomon, 1989; Huston and Large, 1988; Large 1989; Green, 1990; Lees *et al.*, 1990, Khin Zaw, 1991) and will not be described in detail. The Rosebery deposit is the major volcanic-hosted Zn-Pb-Cu-Ag-Au deposit in the Cambrian Mt Read Volcanic belt. The mineralisation occurs within a tuffaceous shale at the contact between the footwall and the hangingwall pyroclastic rocks. The mineralisation has a stratigraphic zonation typical of volcanogenic massive sulphide deposits, characterised by pyrite-chalcopyrite rich zones at the lower portion and sphalerite-galena-pyrite rich zones at the upper portion. A barite-carbonate rich zone occurs at the top of the ore horizons.

The footwall pyroclastics consist of ignimbritic feldspar-phyric pumiceous flow tuff which has been altered to quartz-sericite-chlorite schist. The host-rock shale with disseminated pyrite is commonly siliceous, sericitic and chloritic, and is normally overlain by pyritic black slate. The hangingwall rocks are sericitic quartz-feldspar-phyric epiclastics which are lithologically different in detail from the footwall pyroclastics (Corbett and Lees, 1987; Lees *et al.*, 1990). The Mt Black Volcanics, mainly composed of weakly sericitised and chloritised dacitic to andesitic lavas, generally overlie the hangingwall pyroclastics. The Central Volcanic Complex (CVC) containing the above-mentioned rock units in the Rosebery mine area is faulted against the Dundas Group of volcanics and sediments to the west by the Rosebery Fault.

DISTINCTION BETWEEN THE HOST ROCK AND FOOTWALL PYROCLASTICS

The host-rock tuffaceous shale of the Rosebery mine area has been altered to quartz-sericite-chlorite schist with similar lithological characteristics to the footwall pyroclastics. This makes it difficult to distinguish between these two units within the mine area (Green *et al.*, 1981; Lees *et al.*, 1990), particularly in underground exploration and exploratory drilling.

It has been known that the alteration zone associated with the Rosebery deposit is characterised by enrichment in Si, K, Rb, Mn, Fe, Mg, S and H_2O and depletion in Al, Na, Ti, Ca, Sr, Zr, Y and Nb (Green *et al.*, 1981; Naschwitz, 1985; Naschwitz and van Moort, 1991).

We have made an attempt to distinguish host rock from footwall pyroclastics using original geochemical data (203 samples) Smith (1975) and Naschwitz (1985). They focused on the geochemical characteristics of the footwall alteration and distribution of trace elements in host rock and ores, and did not attempt to differentiate in general between the host rock and footwall rock.

The study has revealed that the variation and relation of major, minor and trace elements are undoubtedly useful to characterise the above rock units and to discriminate between them (Aung Pwa, 1990).

The host rock is defined by the enhancement of TiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, CaO, MnO, P_2O_5, Pb, Zn, Rb, Ba and Tl and depletion of SiO_2, Na_2O, Cu and Sr.

The footwall pyroclastics are characterised by enrichment in SiO_2, K_2O, Cu, Rb, and possibly MgO and MnO, and depletion in TiO_2, Al_2O_3, CaO, Na_2O, P_2O_5, Sr, Ba and Tl.

Distinction between the host rock and footwall pyroclastics can be made by using the relations between TiO_2, Al_2O_3 and SiO_2 (fig. 1). Enhancement of TiO_2 and Al_2O_3 and depletion of SiO_2 in the host rock and reverse variation in the footwall is the characteristic geochemical signature. Discriminant analysis also suggests that the use of TiO_2, Al_2O_3 and SiO_2 as variables is one of the best criteria, giving 94.5% classification success when defining the host rock and footwall pyroclastics. Other elements, such as MgO, CaO, MnO, P_2O_5, Ba and Tl, which show enrichment in the host rock, also play a major role in distinguishing the host rock from the footwall.

The current study suggests that the variation of and relation between TiO_2, Al_2O_3, Nb/Y and Zr/TiO_2 are also extremely useful in defining footwall and host rock.

GEOCHEMICAL ZONALITY ASSOCIATED WITH THE ROSEBERY DEPOSIT

Volcanogenic massive sulphide deposits are commonly characterised by mineralogical alteration zones which are associated with significant rock geochemical haloes, It has been known that these geochemical haloes, extending hundreds to thousands of metres away from ore zones, are much larger than observable mineralogical alteration zones (Goodfellow, 1975; Wahl, 1978; Aung Pwa, 1978; Pirie and Nichol, 1981; Govett and Aung Pwa, 1981; Govett, 1983; Lahtinen, 1989) and also form large exploration targets. The delineation of geochemical haloes, characterised by geochemical zonality in geologically prospective ground, makes it possible to detect deeply buried deposits.

The geochemical zonality is commonly associated with hydrothermal and volcanogenic massive sulphide mineralisation (Beus and Grigorian, 1977; Boyle, 1979; White, 1981; Lahtinen, 1989). A significant geochemical zonality from upper level to lower level along dip direction (Ag-Pb-Zn-Cu-(Ni, Co)) has been found to be associated with Bawdwin massive sulphide deposit, Burma (Aung Pwa, 1981). Lahtinen (1989) also mentioned that geochemical zonality can be applied in massive sulphide exploration in the Pukkiharju Zn-Cu prospect, Central Finland.

The Rosebery deposit is characterised by lateral and stratigraphic mineral zoning of the lens system (Brathwaite, 1969, 1972; Green *et al.*, 1981; Naschwitz, 1985; Huston and Large, 1988; Khin Zaw *et al.*, 1988; Green and Iliff, 1989; Khin Zaw, 1991). Shallow-level, post-tectonic granitic intrusion of Devonian age (Lees *et al.*, 1990) has been interpreted from the gravity data in the Rosebery mine area (Large, 1986). Solomon *et al.* (1987) also pointed out that Devonian hydrothermal activity resulted in chemical remobilisation in the Rosebery massive sulphide deposit. Such a process may produce lateral geochemical zonation due to the mobility of elements in the hydrothermal environment. Mobile elements are generally enriched in the upper or outer margins of mineralised systems or the upper level of geothermal systems (White, 1981; Watts and Hassemer, 1989).

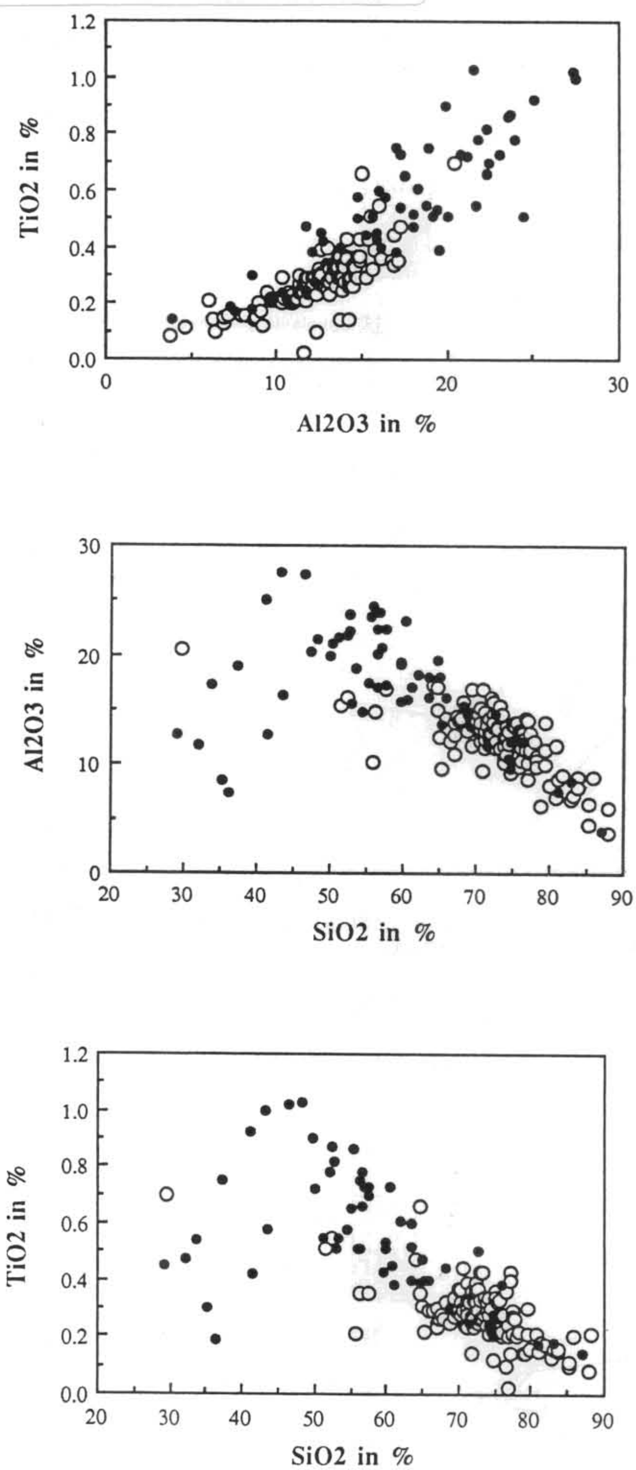

Figure 1

Relation between SiO_2, Al_2O_3 and TiO_2 in the host rock and footwall pyroclastics (based on XRF data by Smith, 1975, and Naschwitz. 1985.

● host rock, ○ footwall

Aung Pwa (1991) studied the variation of Cu, Pb, Zn, Ag, Sb, As and Ba in 123 host rock samples of drill core (with 10 to 20 m sample spacing) from the 270 mS and 300 mN sections to determine the zonality of elements associated with the Rosebery deposit. Ba and Sb were determined by XRF method and other elements were analysed by AAS by Australian Assay Laboratories Group. All drill core samples in this study were taken from host rock with major ore zones. No footwall and hangingwall samples were available.

Smith and Huston (1992) showed that there is a zonal feature of element association:

(1) elements concentrated in the upper portions of the orebody and in the adjacent wall rocks (Pb, Zn, Au, Cd, and Sb);

(2) elements concentrated in the lower portions of the orebody and adjacent wall rocks (Cu, Bi, As, and Fe), and;

(3) elements dispersed well outside zones of strong mineralisation (Tl and Hg). This is probably a stratigraphic zonality feature.

Our study has revealed that the Rosebery massive sulphide deposit is associated with significant lateral (along dip direction of the host rock) and vertical (stratigraphic) geochemical zonality.

Ba, As, Sb, Ag, and possibly Pb, are enriched in the upper portion of and stratigraphically above the ore zones and are considerably depleted in the lower portion of and stratigraphically below the ore zones. In contrast, Cu is enriched in the lower portion of and stratigraphically below the ore zones. Zinc enveloping the ore zone does not show significant variation with depth. The variation of As, Ba, Sb and Cu in the host rock from the 270 mS section is shown in Figures 2–5. Based on the results from both sections (using the coefficient of contrast of Beus and Grigorian, 1977) the lateral geochemical zonality sequence (from upper level to lower level along the dip direction of the host rock) has been arranged as As-Ba-Sb-Pb-Zn-Cu (Aung Pwa, 1990). Silver cannot be included in the arrangement, as the Ag values in the host rock of the lower portion of the section are lower than one ppm (which is the detection limit). However silver, generally similar to As, Ba and Sb, shows remarkable enrichment in the upper portion of the ore zone. Such a lateral geochemical zonality feature may reflect the remobilisation of elements during Devonian hydrothermal activity. The vertical (stratigraphic) zonality sequence may also be similar to the lateral zonality but it is not possible to arrange the sequence as was done for lateral zonality. The general sequence of stratigraphic zonality may be defined (from top to bottom) as (As, Ba, Sb) - (Pb, Zn) - Cu, which is generally similar to the mineralogical zonality. The stratigraphic zonality feature may reflect original depositional condition.

Further investigation to determine the whole picture of geochemical zonality by multi-element analysis should be made.

GEOCHEMICAL HALOES AROUND THE ROSEBERY DEPOSIT

The following are preliminary results of a current project studying distribution of multi-elements in the rocks on the surface of the Rosebery area. The rock samples collected by Naschwitz were re-analysed, after having been leached by hot HNO_3, using PIXE/PIGME analysis. (More detailed sampling and analysis are in progress to examine the present results and to evaluate the geochemical anomalies). This study involved Ca, K, Fe, Na, Al, Mn, Ti, S, Rb, Sr, Zr, Y,

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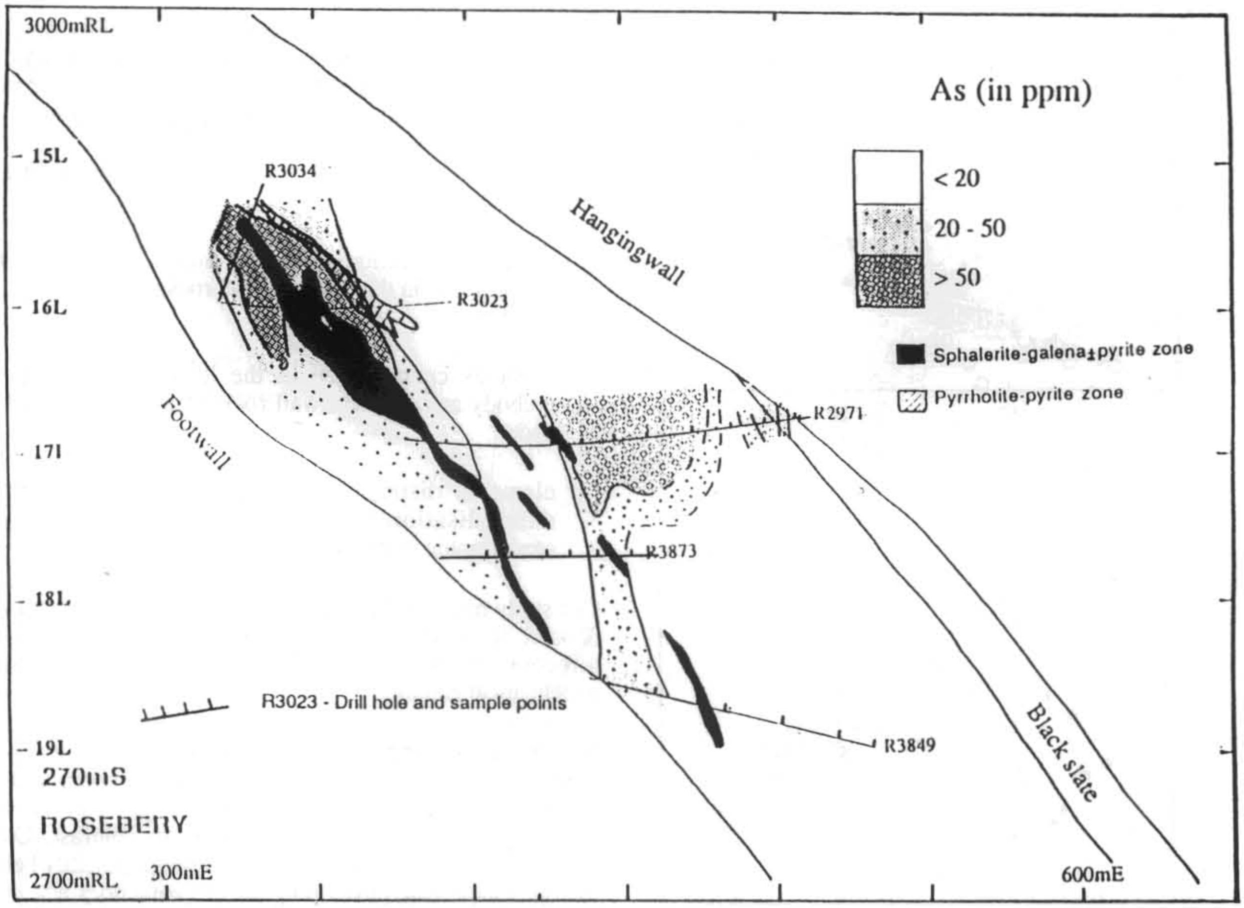

Figure 2. Variation of As in the host rocks from 270 mS section, Rosebery deposit. (Ore zones modified after Khin Zaw *et al.*, 1988).

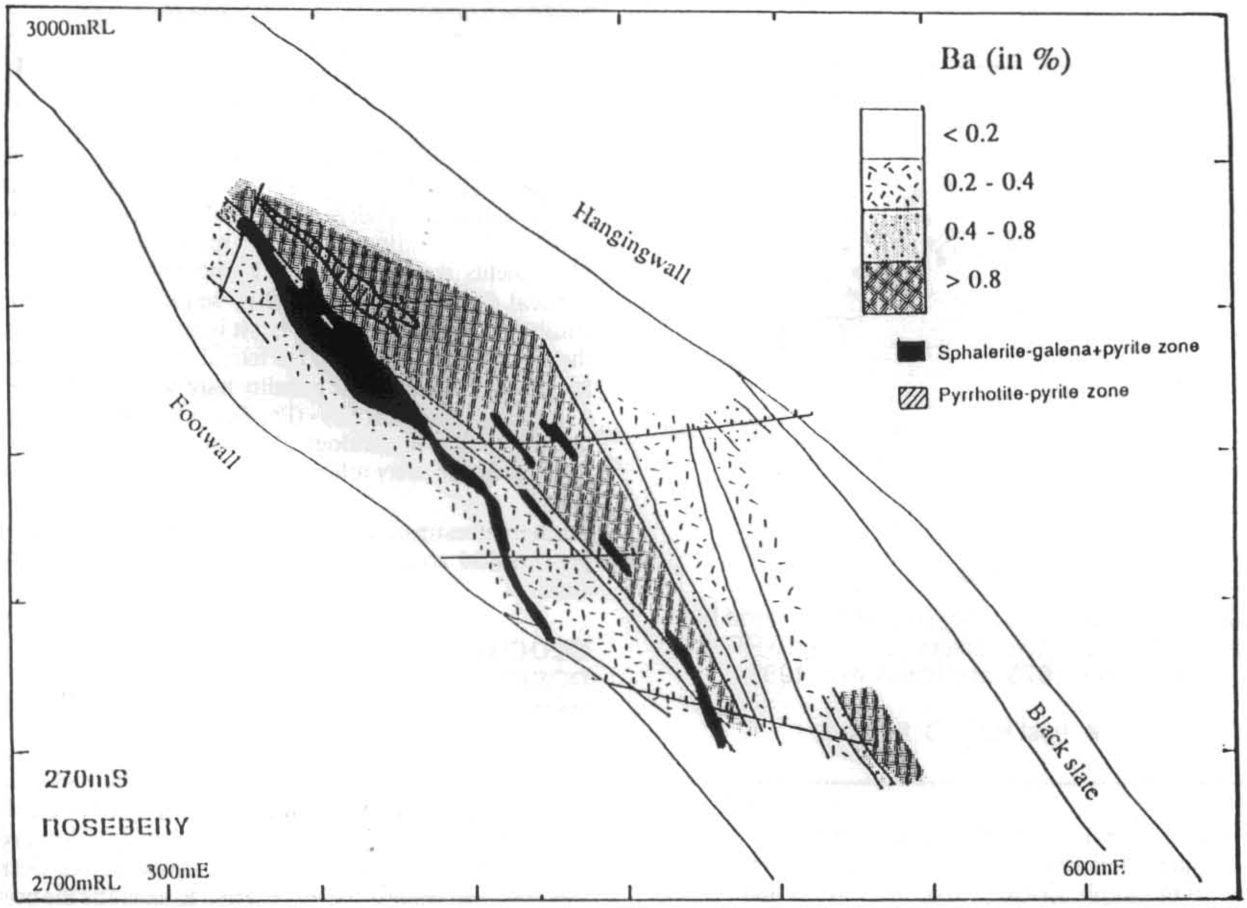

Figure 3. Variation of Ba in the host rocks from 270 mS section, Rosebery deposit.

5 cm

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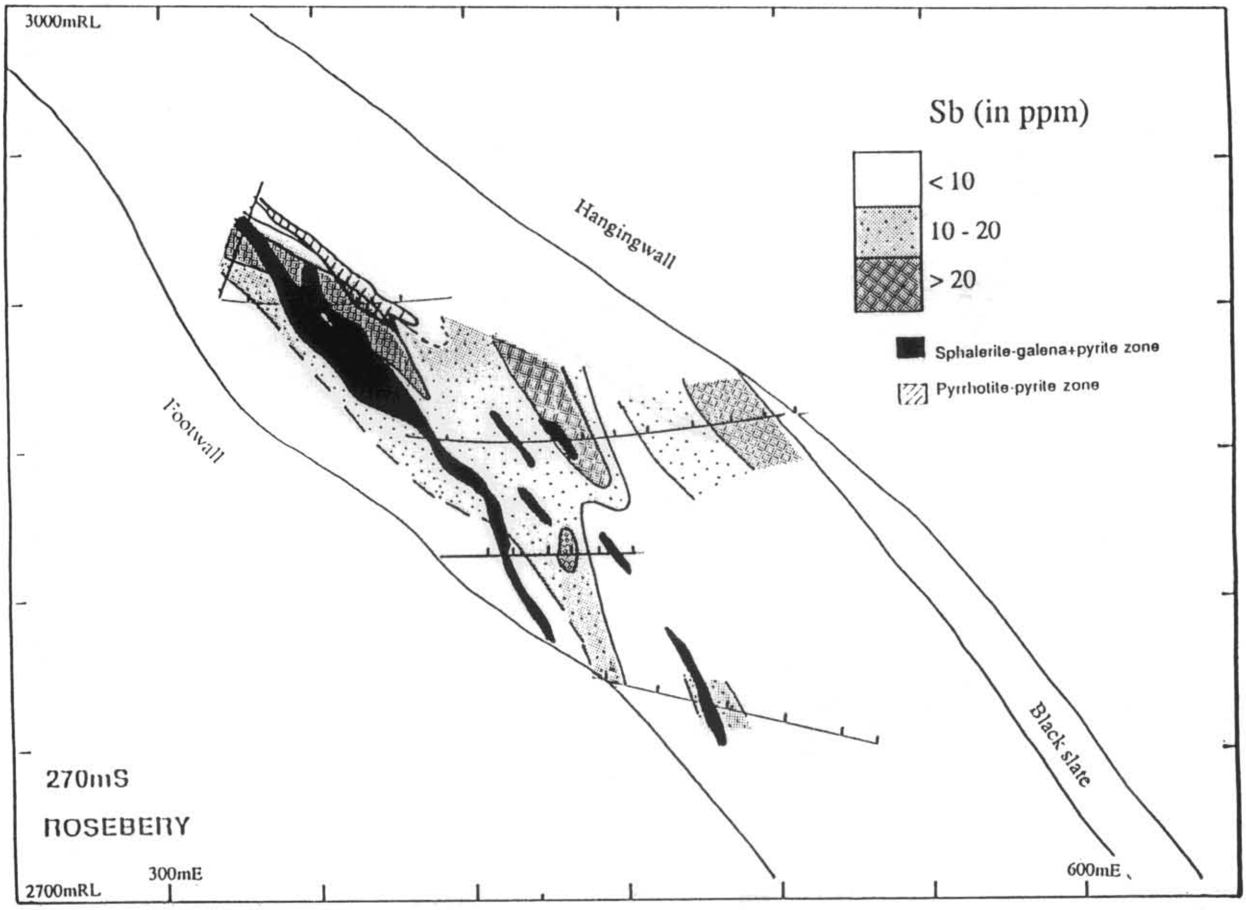

Figure 4. Variation of Sb in the host rocks from 270 mS section, Rosebery deposit.

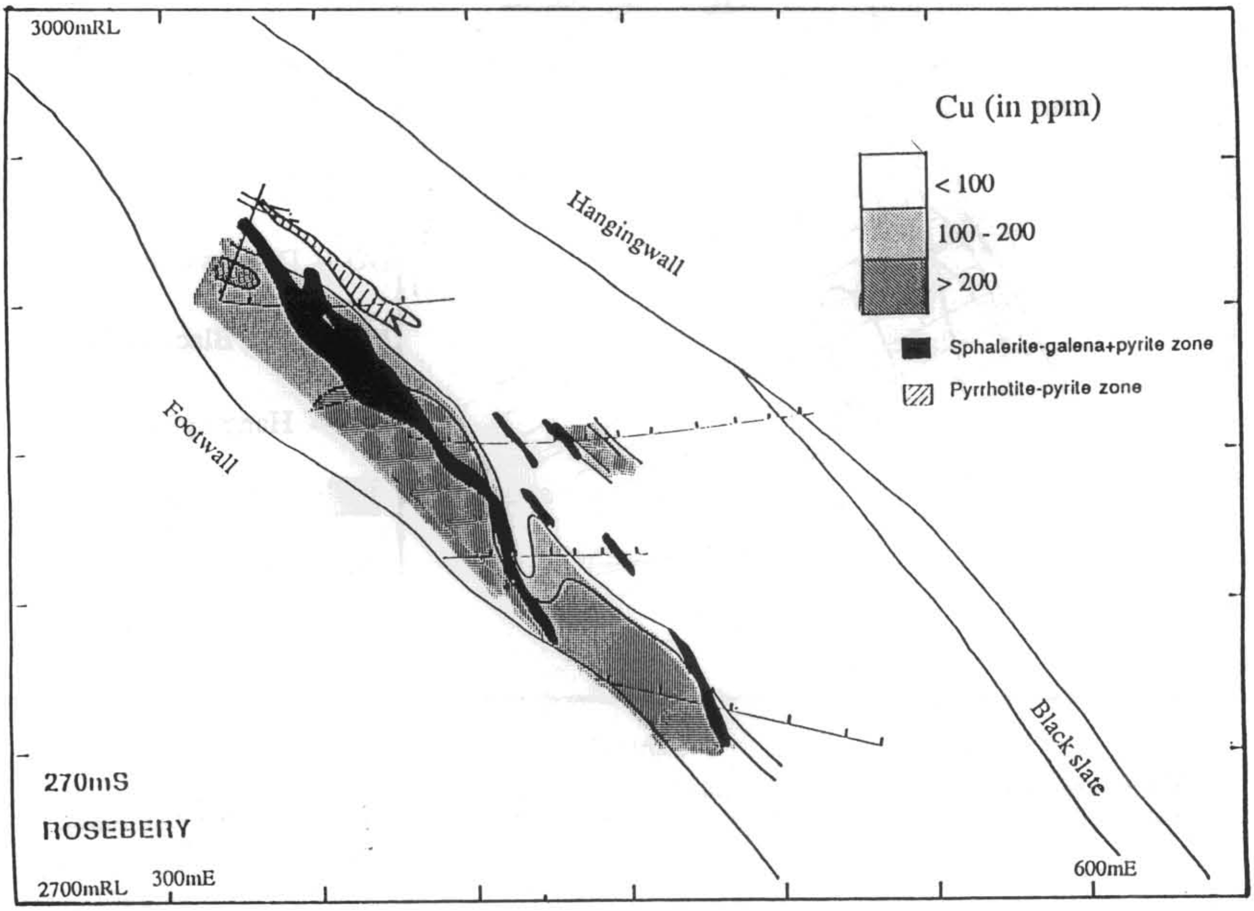

Figure 5. Variation of Cu in the host rocks from 270 mS section, Rosebery deposit.

5 cm

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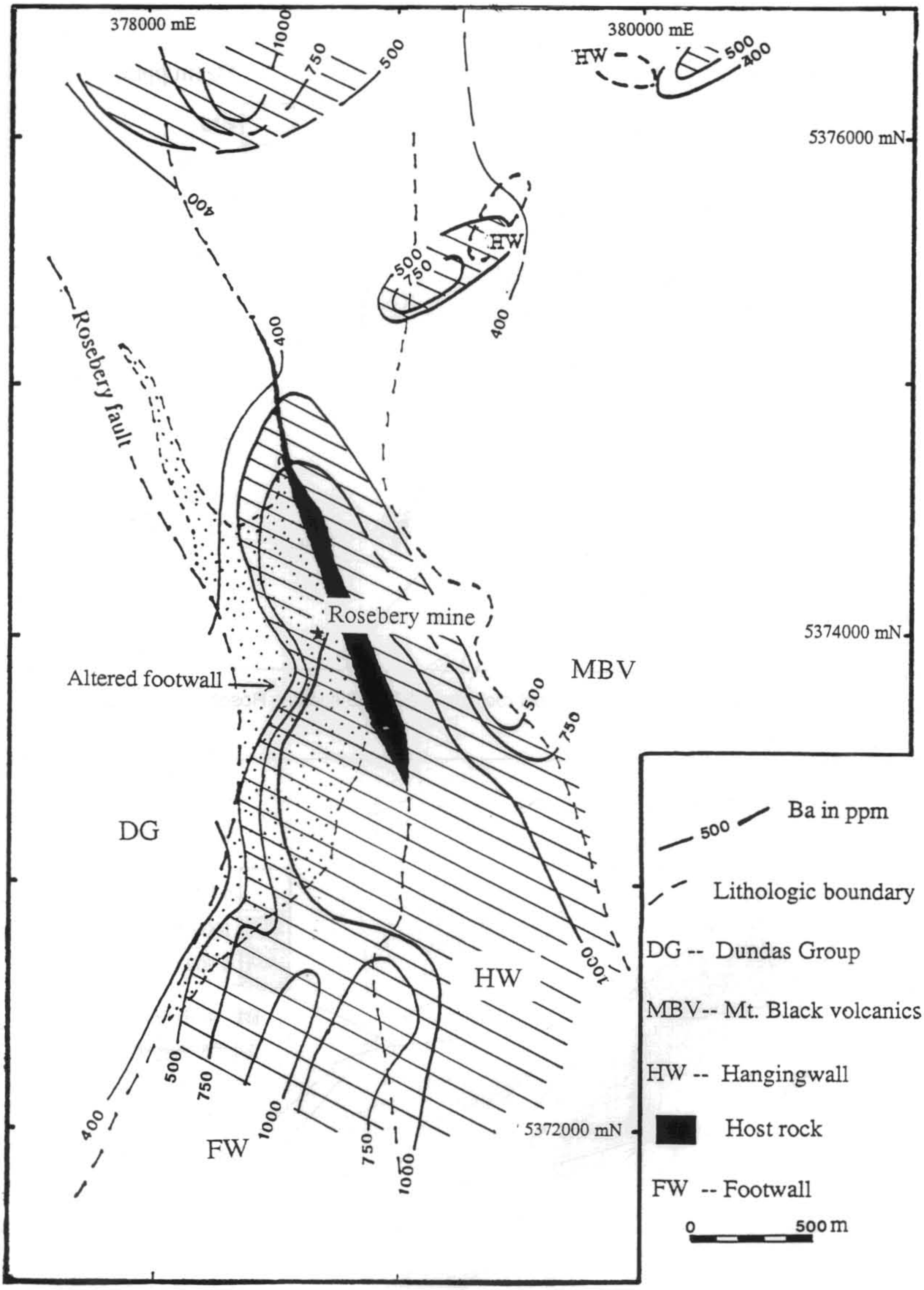

Figure 6

Distribution of Ba in the rocks of the Rosebery mine area. Data based on re-analysis by PIXE of the surface rock samples originally collected by Naschwitz (1985). (Geology modified after Lees, 1986).

5 cm

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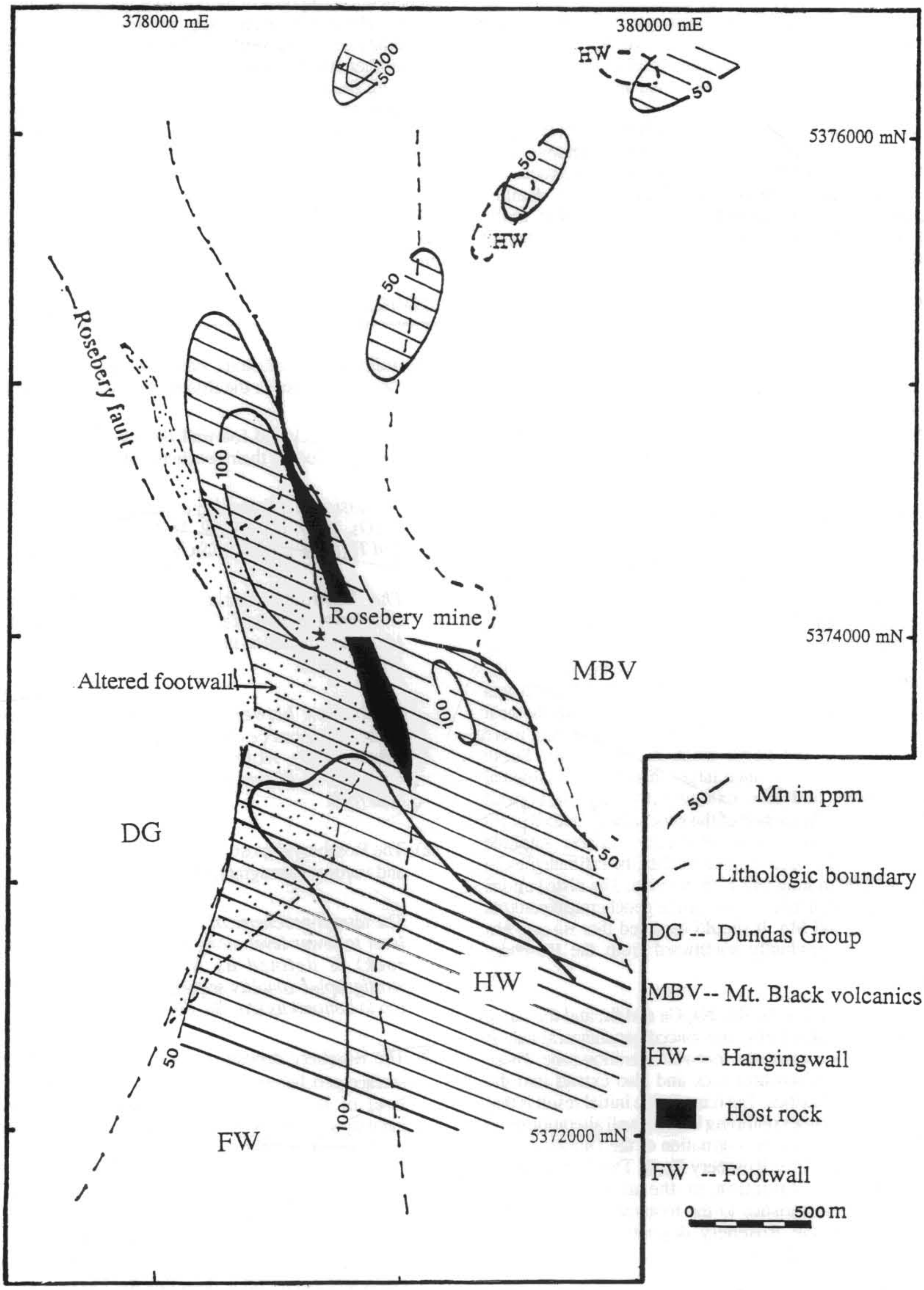

Figure 7

Distribution of Mn in the rocks of the Rosebery mine area. Data based on re-analaysis by PIXE of the surface rock samples originally collected by Naschwitz (1985). (Geology modified after Lees, 1986).

5 cm

Ba, Ni, Co, Pb, Zn, Cu, Ag, *F, V, Cl, Ga, As, Mo, Cd, Cr, Li, Tl, Ge, Sn, W, U* and *Th* (the elements italicised are new elements which Naschwitz did not determine) to determine their spatial distribution around the Rosebery deposit and to define further prospective ground in the area.

The data smoothing technique used by Naschwitz (1985) has the advantage that it presents a statistically valid image of the wallrock alteration pattern. However even the process of smoothing within a small area eliminates the detailed signature of the element distribution. The present study, using hand-contouring, gives more detailed patterns of element distribution and broader geochemical haloes.

The well-defined and large N-S trending geochemical haloes of Ba, Mn, Fe and F outline the mineralised host rock (Rosebery deposit) and footwall alteration zone. Figures 6 and 7 show the areal distribution of Ba and Mn in the rocks of the Rosebery mine area. Well-defined zones of Ba and Mn greater than 500 ppm and 50 ppm respectively outline the host rock of the Rosebery deposit and footwall alteration zone. Although hangingwall samples are not available from the east of the central part of the host rock it is, on the basis of the geochemical data in the east of the southern and northern parts, evident that a Ba halo greater than 400 ppm extends more than 500 m and 700 m into the hangingwall and footwall pyroclastics respectively from the Rosebery ore zones. A halo of Mn greater than 50 ppm also extends more than 500 m each into the hangingwall and footwall pyroclastics. Both haloes (500 ppm Ba and 50 ppm Mn) extend laterally more than 2000 m to the south from the ore zone, but only limited extention, generally the same as the alteration zone, is noted to the north. Although sufficient data are not available at present in the northern part of the host rock, the Ba halo (greater than 400 ppm) may extend more than 1000 m to the north from the ore zone. These geochemical haloes are much larger than the mineralogical alteration zone and also extend into the hangingwall pyroclastics. The dimension of the geochemical haloes of Ba and Mn associated with the Rosebery massive sulphide deposit can, on the basis of present data, be estimated to be more than 3000 m long and 1200 m wide. The distributions of Fe and F also generally show similar geochemical patterns to those of Ba and Mn. It should be noted that Ba and Mn values increase gradually southward from the Rosebery deposit.

Other elements such as K, Rb, Na, Ca and Sr, and the ratios K/Na and Rb/Sr, also form pronounced geochemical haloes which are coincident with the footwall alteration zone. These outline the mineralised host rock and also extend into the hangingwall pyroclastics. The remarkable initial result is that the geochemical haloes outlining the footwall alteration zone extend into the White Spur Formation of the Dundas Group immediately west of the Rosebery Fault. This indicates that the White Spur Formation in the area has similar geochemical characteristics to the footwall alteration zone associated with the Rosebery deposit. More detailed examination is in progress.

GEOCHEMICAL EVALUATION OF HOST ROCK

In surface exploration and exploratory drilling, it is important to evaluate the mineralisation potential of the host rock when it has neither indication of alteration nor trace of mineralisation. One part of the current research, based on the PIXE/PIGME analysis of the host rocks from the drill holes in different parts of the Rosebery mine area, has been to determine whether it is possible to distinguish between the geochemical response of the host rock associated with or near mineralisation, and that without or away from mineralisation. The results so far obtained are encouraging, but further study is still needed. Ba, Tl, Ga and V, together with Pb, Zn, As, Sb, Ag, may be the potential association of elements required to evaluate the mineralisation potential of the host rock in the Rosebery mine area. Smith and Huston (1992) have also demonstrated that Tl, which gives an extensive geochemical halo, may be used in detecting blind deposits, especially on a regional scale in the Rosebery area. The present study reveals that Tl may also be effectively used as a pathfinder element of massive sulphide mineralisation in mine-scale exploration.

CONCLUSIONS

The following conclusions, based on the exploration rock geochemical studies in the Rosebery area, can be made:

(1) The host rock and footwall pyroclastics can be clearly distinguished by their geochemical characteristics.

The host rock is defined by enhancement of TiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, CaO, MnO, P_2O_5, *Pb, Zn, Rb, Ba and Tl and depletion of* SiO_2, Na_2O, *Cu and Sr.*

The footwall pyroclastics are characterised by enrichment in SiO_2, K_2O, *Cu, Rb, and possibly* MgO *and* MnO, *and depletion in* TiO_2, Al_2O_3, CaO, Na_2O, P_2O_5, *Sr, Ba and Tl.*

Distinction between the host rock and footwall pyroclastics can be clearly made by using the relations between TiO_2, Al_2O_3 *and* SiO_2. *Enrichment in* MnO, P_2O_5, *Ba, Tl, Pb and Zn can also be used in defining the host rock.*

(2) The Rosebery deposit is associated with distinct lateral and vertical (stratigraphic) geochemical zonalities.

The lateral geochemical zonality sequence (from upper level to lower level along the dip direction of the host rock) is defined as As-Ba-Sb-Pb-Zn-Cu. The stratigraphic zonality sequence can be arranged (from top to bottom) as (As, Ba, Sb) - (Pb, Zn) - Cu.

(3) The Rosebery deposit is associated with well-defined surface geochemical haloes (at least 3000 × 1200 m in size) of Ba, Mn, Fe and F, which extend into the hangingwall and footwall pyroclastics. The haloes are much larger than the mineralogical alteration zone.

(4) The dispersion haloes of K, Rb, Na, Ca, Sr, K/Na and Rb/Sr outline the footwall alteration zone and the host rock of the Rosebery deposit, and also extend into the hangingwall pyroclastics. These element and element ratios are also useful in detecting the footwall alteration zone related to massive sulphide deposit.

(5) The area within the enrichment zones of Ba and Mn greater than 500 ppm and 50 ppm respectively between the Rosebery deposit and the Rosebery Lodes is of prime interest to focus further detailed exploration. However more detailed study to evaluate these surface geochemical anomalies, to determine the possible source, is necessary and hence is in progress.

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(6) Evaluation of the host rock to determine the mineralisation potential can be made by using the geochemical variation of Ba, Tl, Ga and V together with Pb, Zn, As, Sb and Ag in the host rock being examined.

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