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THE MINERALOGICAL AND GEOCHEMICAL EFFECTS OF WEATHERING ON VOLCANICS FROM THE PANGLO DEPOSIT, EASTERN GOLDFIELDS, WESTERN AUSTRALIA

K.M. Scott

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September 1998

(CSIRO Division of Exploration Geoscience Report 143R, 1990.
Second impression 1998)

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CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining
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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 24) is a Second impression (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report 143R, first issued in 1990, which formed part of the CSIRO/AMIRA Project P241.

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SUMMARY

Profiles above ultramafic and mafic volcanics at Panglo are characterized by the development of a surficial ferruginous calcrete zone which is not present above shales. This zone bears Au ~0.05 ppm and is generally characterized by elevated As, Ba, Cr, Mo, Sb, Sr, V and Zr contents relative to underlying rocks. Higher levels of Au and associated elements (As, Mo and Sb) are present directly above Au mineralization at depth.

Ultramafic rocks generally have high Mg, Cr and Ni contents reflecting the presence of chlorite-vermiculite and talc through the weathered profiles. Where weathering is particularly intense these minerals may be destroyed and smectitic clays developed. Mafic volcanics profiles show greater development of micas and hematite than those above ultramafic rocks. Substantial paragonite is present in the barren profiles but not in the mineralized profiles.

Within both ultramafic and mafic rocks the mineralization is associated with elevated levels of S, Ag, As, Co, Mo, Sb, W and Zn. Sometimes these elements may be found for 5 m vertically above mineralization in ultramafic profiles. However mineralized mafic volcanic profiles may have very high levels of As and W for ~50 m above mineralization.

1. INTRODUCTION

Although mafic and ultramafic volcanic rocks on the western end of the Section 4200N show near surface Au enrichment (Scott, 1989b), insufficient Au mineralization was present in the studied drill holes to allow proper evaluation of the geochemical and mineralogical associations of Au in volcanics (as done for shales from the eastern edge of the deposit; Scott 1989a). To remedy this situation this report compares mineralogical and geochemical features of profiles through mineralized volcanics along Section 4300N (PSRC 226 and PSRC 227) and Section 3900N (PSRC 239) with, those from barren volcanics from Section 3900N (PSRC 238) and Section 4200N (PSRC 309).

The report also defines criteria which can be used to differentiate mafic rocks from ultramafic rocks. Results from all the studied holes through volcanics (including PSRC 230 and PSRC 231; Scott, 1989b) have been utilized to describe idealized profiles through ultramafic and mafic rocks. Features of alteration and mineralization which persist in weathered rocks are also identified.

2. SAMPLES AND METHODS

One metre composite samples collected by Pancontinental Mining Ltd during exploratory reverse circulation drilling of the Panglo deposit were used during this study. As with most of the initial drilling at Panglo, these holes were inclined at 60°E and throughout this report distances along the drill holes are reported rather than true depths below the surface.

Material from the top 66 m was collected from PSRC 226 with 70 m, 69 m, 79 m and 64 m of material sampled from PSRC 227, PSRC 238, PSRC 239 and PSRC 309 respectively. Eight samples of unweathered-volcanics from the diamond drill holes PSRCD 232, PSRCD 306 and PSRCD 309 have also been sampled. Locations of these holes are shown in Fig 1.

Samples have been analysed mineralogically by X-ray powder diffractometry and on the basis of the mineralogical zonation present within the holes, 81 samples from PSRC 226, PSRC 227, PSRC 238 and PSRC 239 and 5 samples of unweathered volcanics have been analysed chemically using the XRF, ICP and ES methods outlined by Scott (1989b). Vanadium contents of these samples have also been determined by ICP. Only ICP analyses have been done for 11 samples from PSRC 309. Caution is required in using some of the results from PSRC 309 because resistate minerals may not have fully dissolved during sample preparation (see below).

Detailed mineralogical study was also conducted on 10 weathered samples (mainly from PSRC 226, PSRC 227, PSRC 238 and PSRC 239) and 3 "fresh" volcanics using a Camebax wave-length dispersive electron microprobe to determine the compositions of silicates and oxides, especially their trace element contents (cf. Scott, 1989b).

3. RESULTS

3.1 PSRC 226 (Section 4300N - Poorly Mineralized)

Mineralogy and geochemistry down this hole is shown in Fig 2 and Table 1 respectively. The mineralization in this hole is sub-economic because of its inconsistent development, but individual 1 m composites may have quite high Au contents (e.g. sample 38062, Table 1).

In PSRC 226 the minerals, quartz, hematite, goethite, calcite ± dolomite, muscovite, chlorite-vermiculite, kaolinite, smectitic clay, talc, halite and rutile were identified using X-ray diffractometry (XRD). Electron microprobe study also reveals ilmenite and pseudorutile as accessory minerals and the Mn oxides (lithophorite and cryptomelane) between 18 and 21 m. Because rutile cannot be identified with complete confidence by XRD (due to the overlap of its major peak with one of the halite peaks), its distribution is not shown in Fig 2.

Using Ti/Zr ratios >60 and Cr contents >700 ppm (cf. Hallberg, 1984), the talc-rich samples between 1 and 19 m appear to be weathered ultramafic rocks (Table 1). Samples with Ti/Zr <60 oocur at 0-1, 20-21 and 61-64m with the surface sample relatively Zr-rich for an ultramafic rock (Table 1) apparently due to surficial enrichment processes (see below). The 20-21m interval represents a high Mn oxide content sample and is Ti-poor relative to underlying mafic rocks but fragments from the 61-64m interval have well developed cleavage and appear to represent a thin shale band.

Within the ultramafic rocks to 19 m there is an upper calcrete zone (0-2 m). The uppermost sample is brown coloured due to its soil component and the lower sample white coloured. Hematite, calcite ± dolomite, talc and chlorite characterize this zone. The underlying kaolinite/goethite zone (2-19 m) is light brown in colour and characterized by abundant goethite (which is often Al-rich), kaolinite, talc and chlorite and smectitic clay (Fig 2).

The mafic rocks below 19 m are hematite-rich and talc- poor relative to the ultramafic rocks above (Fig 2). The uppermost zone within the mafic rocks is kaolinite/muscovite-rich (19-36 m). It is dark brown in colour and contains Al-rich goethite as well as hematite. Between 36 and 44 m the rocks are dark brown to red in colour and muscovite is less abundant and quartz is poorly developed. Chlorite and smectitic clay are completely absent from this zone. The kaolinitic zone from 44 to 58 m is similarly coloured to the zone above but quartz is more abundant and halite is also well developed. Muscovite is only present in minor amounts. Low grade mineralization occurs between 58 and 61 m in dark brown rocks which tend to have more muscovite but less kaolinite than the zone above. The thin shale band (61-64 m) is also dark brown in colour and apart from a slightly lower Fe oxide content and some development of smectitic clay is mineralogically similar to the mineralized volcanics above. Volcanic rocks of the footwall are dark brown in colour and mineralogically similar to mineralized rocks but chlorite is also present in the zone (Fig 2) and the Au contents lower (Table 2).

The ultramafic rocks above 19 m are characterized by higher Mg, Cr and Ni contents and generally lower Al, K, Ti, Mn, Co, Cu, Ga, Rb, Sc, V and Zr contents than the mafic rocks (Tables 1 and 2). The surficial calcite (calcrete) zone has higher Fe, Ca, Ba, Mo, Sr, V and Sr contents relative to underlying weathered ultramafics of the kaolinite/goethite zone. Au is present in anomalous amounts in the calcrete zone (Table 2).

The kaolinite/muscovite zone of the mafic rocks has high Al, K, Ti, Mn, Ag, As, Ba, Co, Pb, Rb, Sc, W, Zn and Zr (Table 2). Many of these trace element contents occur within the high Mn content sample (Table 1) and have been actually detected within cryptomelane and lithiophorite (Section 3.7). Quartz-poor rocks have high Al, Ti, Pb, Sc and low Si contents. The kaolinitic hanging wall to the mineralization has high Na and S but low As and Cr. Low grade volcanic-hosted mineralization is associated with high Si, Na, K, Mn, As, Ba, Co, Rb and W. The shale-hosted mineralization has higher Si, Zn and Zr but lower Al, Fe, Ti, Mn, Co, Ni, Sc and V than its volcanic equivalent (Table 2). The chloritic footwall has very high Si and W, high K, As, Ba, Co, Rb and low Fe, Cr and Ni relative to other mafic volcanics in the profile (Table 2).

3.2 PSRC 227 (Section 4300N - Mineralized)

The mineralogy and geochemistry of this hole is shown in Fig 3 and Table 3 respectively.

The range of minerals identified in this hole by XRD is similar to that found in PSRC 226 (cf. Fig 3 and 2). However ultramafic rocks are present to a greater depth in this hole, with the abrupt decrease in talc and chlorite-vermiculite abundances below 56 m (Fig 3), reflecting the change from ultramafic to mafic volcanics. Ti/Zr ratios >60 and Cr contents >700 ppm (cf. Hallberg, 1984) confirm the ultramafic nature of the rocks above 56 m although the 0-1 m sample again appears to be Zr-rich (Table 3) as found in PSRC 226.

Within the ultramafic rocks five mineralogical zones are recognized. The uppermost is a calcrete zone (0-3 m) characterized by the development of calcite ±dolomite with hematite, muscovite and talc. The surface sample is brown coloured due to its soil content but the other two samples are yellow-white coloured. An extensive zone from 3 to 49 m is characterized by the strong development of chlorite-vermiculite and talc. However its colour changes from yellow to light brown above 27 m to a more khaki colour below 27 m. Apart from more goethite and kaolinite from 3 to 8 m, the mineralogy is similar through the whole interval, consisting of assemblages dominated by chlorite-vermiculite and talc but also characterized by low quartz, muscovite and kaolinite contents (Fig 3). The goethite in this zone tends to be Al-rich. The hanging wall (49-54 m) and mineralized (54-56 m) zones are both brown coloured, reflecting greater development of goethite than in the overyling chlorite-vermiculite/talc zone. Kaolinite and smectitic clay are also better developed than in the overlying rocks (Fig 3).

Although the mafic volcanics below 56m are readily distinguished from the overlying ultramafic rocks by their darker colours and lesser chlorite-vermiculite and talc, the presence of hematite and muscovite and greater quartz, goethite, kaolinite and halite (Fig 3), the difference between mineralized (56-65 m) and footwall rocks (65-70 m) in the mafic volcanics is only obvious on the basis of geochemistry (Tables 3 and 4).

Chemically the calcrete zone is rich in Fe, Ca, Ba, Cr, Mo, Sr, V and Zr and depleted in Mg, Mn, S and Co relative to other zones within the ultramafic rocks (Table 4). The chlorite-vermiculite/talc zone has abundant Mg, Cr and Ni contents but low Fe, Mn, K, As, Ba, V and Zr contents. Si contents of this zone are quite high despite its low quartz content due to its high talc content (Fig 3). Major element contents of the hanging wall zone are similar to those of the overlying chlorite-vermiculite/talc zone, although the slightly elevated Fe, Mn and Na contents reflect the increased goethite and smectitic clay contents of this zone. S, As, Au and Zn contents are however significantly different from in the overlying zone (Table 4). Mineralization at the base of the ultramafic sequence has high Fe, Mn, Ag, As, Au, Ba, Co, Cu, W and Zn contents (Table 4). It also shows some effect of its proximity to mafic rocks by its variable Mg and Ni contents (Table 3).

The mafic rocks have generally higher Al, K, Ti, Ga, Rb, Sc, V and Zr contents but lower Mg, Cr and Ni than the ultramafic rocks (Tables 3 and 4). Gold mineralization is associated with elevated K, Ba, Rb, As, Co, Cu, W and Zn contents. Cr and Ni may also be elevated in the mineralized samples (Tables 3 and 4).

3.3 PSRC 238 (Section 3900N - Barren)

Mineralogy and geochemistry through this hole is shown in Fig 4 and Table 5 respectively.

In addition to the mineralogical suite present in the preceding holes, this hole shows substantial paragonite development and traces of alunite (Fig 4). Talc is not as well developed and muscovite is more extensively developed in this hole than in the preceding holes further to the north (cf. Figs 2, 3 and 4). Calcite extends down to 8 m i.e. to a greater depth than in the preceding holes. On the basis of Hallberg's (1984) criteria, the interval 0 to 8 m (or at least the top 4 m of it) is Zr-rich (Table 5) as found in PSRC 226 and PSRC 227 (Tables 1 and 3). (The remainder of the profile is mafic using Hallberg's criteria.) Although it is possible that this upper portion of the profile may not have developed in situ, it is herein assumed to be in place because the inverse relationship between calcite and muscovite (Fig 4) is consistent with simple carbonate replacement.

Material of the ferruginous calcrete zone is brown in colour and characterized by the presence of calcite ± dolomite, talc and smectitic material. Halite is not developed in this interval (Fig 4). Strongly kaolinized mafic volcanics are present in the hole from 8 to 63 m. Such rocks also have abundant mica and both hematite and goethite. Smectitic clay is only intermittently developed but calcite and talc which characterize the ferruginized calcrete zone are not present. On the basis of the dominant mica type, the interval is divided into a kaolinite/muscovite zone from 8 to 48 m and a kaolinite/paragonite zone from 48 to 63 m (Fig 4). Below 63 m, kaolinite and mica are not so strongly developed and talc and smectitic clay are more persistent. Thus the interval 63 to 69 m is defined as a talc/smectite zone (Fig 4).

Ferruginized calcrete from 0 to 8 m is characterized by high Fe, Ca, As, Cr, Mo, Sb, Sn, V, W and Zr contents and low Si, Al, Na, K, Ti, Mn and Zn contents. Au is also elevated above background values in this material (Table 6). The kaolinite/muscovite zone (8-48 m) has high Al, Fe, V and W and low Si, Ba, Co and Sr contents. The kaolinite/paragonite zone (48-63 m) has higher Na, Ba and Zn contents but lower K and As contents than the zone above. Talc/smectite zone material (63-69 m) has high Si, As, Cu, Zn and W contents (Table 6).

3.4 PSRC 239 (Section 3900N - Mineralized)

The mineralogy and geochemistry of the hole PSRC 239 is shown in Fig 5 and Table 7 respectively.

The mineralogical components present are similar to those found in the nearby barren hole, PSRC 238 (cf. Figs 4 and 5) although paragonite is only found between 7 and 12 m in this hole. Thus talc is not well developed and muscovite is more abundant in this hole than in PSRC 226 and PSRC 227 from the Section 4300N (cf. Figs 2 and 3). On the basis of Ti/Zr ratios >60 and Cr <700 ppm (Hallberg, 1984) the intervals 12-60 m and 72-79 m are mafic volcanics, although the latter interval has Cr contents ~700 ppm (Table 7). Low Ti/Zr contents above 12 m reflect surficial Zr-enrichment, similar to that within PSRC 238 (Table 5) and this interval is probably composed of ferruginized mafic volcanics. The low Ti/Zr ratios in the interval between 60 and 72 m appear to reflect lower Ti-bearing rocks which, because they are mineralized and have well developed cleavage, may well represent a similar situation to that in PSRC 226 where some of the low grade mineralization is associated with a thin shaly band (Table 1, Section 3.1). The presence of thin bands of carbonaceous material in the rocks below 72 m lends support to such an interpretation.

The ferruginous calcrete zone (0-7 m) is red-brown in colour and characterized by the presence of calcite (± dolomite), both goethite and hematite and traces of chlorite and talc (Fig 5). Underlying mafic volcanics between 7 and 60 m (kaolinite/muscovite zone) are grey-white to yellow-brown and khaki in colour. Muscovite and kaolinite are the dominant minerals of this zone but paragonite is present to 12 m. Smectites are present in trace amounts through the interval and halite is strongly developed below 46 m. The goethite of this zone is generally Al-rich. Sedimentary material between 60 and 72 m is khaki to red-brown in colour and is mineralogically similar to the volcanics except that hematite is not as strongly developed (Fig 5). The footwall to mineralization, i.e. rocks below 72 m, consists of mafic volcanics which are khaki- and brown-coloured (thin bands of black carbonaceous material also occurs in this interval but were not chemically analysed). Talc and chlorite are present but hematite and smectites are not well developed at the base of this drill hole, otherwise this footwall zone is relatively similar mineralogically to the sedimentary rocks immediately above it and the mafic volcanics above them (Fig 5). Low grade mineralization persists into the footwall (Table 7).

Ferruginous calcrete from the top 7 m is very rich in Fe, Ca, As, Ba, Cr, Mo, Sb, Sr and V and depleted in Na and K. It also contains low grade Au mineralization (Table 8) as generally found in the surficial calcrete zone in the other drill holes (Sections 3.1-3.3). Kaolinized mafic volcanics (7-60 m) are enriched in Al, K, Ti, Mn, As, Ba, Sr and V but depleted in Si, S, Au, Co, Cr, Cu, Ni, Pb and Zn relative to the poorly mineralized mafic volcanics from below 72 m (Table 8). Mineralized sedimentary material (60-72 m) is enriched in Mn and B relative to the volcanics. It also has high As, Au, Co, Cu, Mo, Ni, Sn, W and Zn, although some of these elements are also present in high amounts in the footwall mafic volcanics (Table 8), especially in sample 39257 which also contains anomalous Ag and Sb (Table 7)..

3.5 PSRC 309 (Section 4200N - Barren)

Mineralogy and geochemistry of selected samples through the hole PSRC 309 are shown in Figure 6 and Table 9 respectively.

Because Ti, Ba and Zr are determined by ICP after a dissolution (instead of by XRF), these determinations must be regarded as minimum values, not necessarily total values because of the possibility of incomplete dissolution. Thus Ti/Zr ratios cannot be used with confidence for these samples. However high Cr contents suggest that the samples from 0 to 23 m are ultramafic, with the lower Cr content of the deeper samples consistent with mafic volcanics.

The initial metre of material (calcrete zone) is brown coloured and readily distinguished from other ultramafic material by the presence of calcite. Ultramafic material between 1 and 23 m (kaolinite/Al goethite zone) is brown to dark-brown in colour and characterized by assemblages of quartz, kaolinite, Al-rich goethite ± hematite and often smectitic clay and halite. Muscovite contents are generally low (Fig 6).

Mafic volcanics between 23 and 36 m (kaolinite/muscovite zone) are dark brown in colour and are mineralogically similar to the overlying ultramafic rocks although the goethite is not so Al-rich, smectite less well developed and muscovite tends to be more abundant (Fig 6). Between 36 and 64 m (kaolinite/paragonite zone) the rocks are again dark brown in colour and as well as abundant muscovite, significant paragonite is present and halite abundance increases relative to the muscovite-bearing zone above (Fig 6).

Chemically the calcrete zone ((0-1 m) is characterized by high Fe, Ti, Cr and V and low Na, K, Mn, Ba, Cu, Ni and Zn. Despite the presence of calcite in this zone Ca is not conspicuously higher than in other zones down the hole. However surficial Au enrichment (as seen in the previously considered profiles through volcanics) is also present in this calcrete zone (Table 10). The kaolinite/Al goethite zone (1-23 m) of the ultramafic rocks has higher Na, Mn, S, Ni and Zn but probably lower Ti than the surficial calcrete zone. Its Cr content is high. Besides their higher Cr contents, the ultramafic rocks have generally lower Na, K, (Ti), Mn, Co, Cu, Sc, Sr, Y and Zn contents than the mafic volcanics (Table 10). The kaolinite/muscovite zone in mafic volcanics (23-36 m) has higher Fe, P and Cu but lower Na, Mn, Co and Sr than the kaolinite/paragonite zone below (36-64 m) with the Co being directly related to Mn in sample 48239 (Table 9) (see also Section 3.7 below).

3.6 Fresh volcanics

Five samples of fresh mafic volcanics have been mineralogically and chemically analysed. Samples 108064, 66, 67 from diamond drill holes PSRCD 232 and PSRCD 306 consist of assemblages of quartz, albite, chlorite, talc, carbonates, (calcite, dolomite and siderite) ilmenite, rutile, apatite and traces of smectitic clay. The samples from PSRCD 306 (108066 and 108067) also contain muscovite and traces of pyrite, chalcopyrite, and Fe-, Ni-rich cobaltite. Samples 108070 and 108071 from diamond drill hole PSRCD 309 are comprised of quartz, albite, chlorite, actinolite, epidote, sphene, carbonates (dolomite or calcite) and rare chalcopyrite. The presence of smectitic clay, muscovite and pyrite and absence of actinolite and epidote in the samples from PSRCD 306 suggests that they are slightly altered. Despite these mineralogical differences, variations in K, Ba and B contents (reflecting the presence of muscovite) and variable Ca and Mg (reflecting variable carbonate development), chemical compositions of these samples are quite similar (Table 11). Ti/Zr ratios ~110 and Cr contents ~170 ppm are consistent with all the rocks being mafic volcanics (cf. Hallberg, 1984).

The presence in the altered sample (108066) of siderite and calcite with higher Fe and Mn contents than in the unaltered sample (108071; Table 12) is consistent with Fe enrichment in the carbonates associated with alteration/mineralization (e.g. Phillips, 1986). The Fe contents of dolomite in the unaltered samples is also considerably less than in samples associated with mineralization at the Hunt Mine, Kambalda (Table 12).

3.7 Trace element contents of minerals

Trace element contents of phyllosilicates in ultramafic rocks show that substantial Cr and Ni and lesser amounts of Cu and Zn are present in chlorite. Zn contents are lower in vermiculite but Cr, Ni and Cu contents are similar to those in chlorite. However when chlorite weathers to kaolinite most of the base metal content is lost (Table 13; Scott, 1989b). Talc has high Ni contents but low Cr contents relative to chlorite (Table 13).

Goethite and rutile in ultramafic rocks generally have high Cr contents, however ilmenite has much lower Cr contents (Table 13). Pseudorutile, which occurs associated with rutile, also tends to have lower Cr contents than rutile (Table 13). Spinel present in one sample is quite Cr-rich.

Chlorites from mafic volcanics have lower Cr and Ni contents than those from ultramafic volcanics (cf. Tables 13 and 14). Actinolite, epidote and sphene within fresh mafic volcanics tend to have low trace element contents although Sr is preferentially concentrated in epidote and some Cr occurs in sphene (Table 14). Muscovite and illite in mafic volcanics have low Cr and Ni contents but may have ~200 ppm Cu and Zn. Substantial Ba and detectable Sr is also present in these K-rich phyllosilicates (Table 14). Paragonite has substantially more Sr but less Ba than muscovite from the same sample (Table 14). Kaolinite again has low trace element contents.

Goethite, ilmenite and rutile in weathered mafic volcanics have much lower Cr contents than their equivalents in weathered ultramafic rocks (cf. Tables 13 and 14). Spinel from mafic volcanics does however contain substantial Cr although much less than in spinel from ultramafic volcanics (cf. Tables 13 and 14). Comparison of disseminated (or residual) goethite with colloform goethite in sample 38021 indicates that the colloform variety has greater Ni, Cu, Zn, Co, As, V but lesser Cr and W than disseminated goethite (Table 14). However at least some of the high base metal contents in the colloform variety may reflect its substantial Mn content especially as the more Mn rich disseminated goethite from sample 39235 has higher Cr, Ni and As than the less Mn rich colloform variety (Table 14). High chalcophile element contents (especially As) in goethite generally reflect its derivation from sulfides, as also found in similar rocks at Callion (Llorca, 1989).

Relative to goethite from the same sample, Al and Ni are consistently lower but Sb is higher in hematite. Other trace components of the Fe oxides show no preferential occurrence with a particular Fe oxide type. The two Mn oxides, cryptomelane and lithiophorite, contain substantial Ni, Cu, Zn and Co contents with Ba ~1.5% and Pb ~0.1% also occurring in cryptomelane (Table 14).

4. DISCUSSION

4.1 Ultramafic rocks

By using the Ti/Zr and Cr content criteria of Hallberg (1984), lithological changes within these five weathered drill hole sections can be recognized. In particular ultramafic rocks were delineated between 0 and 19 m in PSRC 226, between 0 and 56 m in PSRC 227, and between 0 and 23 m in PSRC 309. Results from these drill holes are also compared with results from ultramafic rocks in PSRC 230 and PSRC 231 (Scott, 1989b).

In each of these holes, except PSRC 231, a surficial calcrete zone with calcite ± dolomite is present. It is generally only one or two metres thick and is characterized by higher Fe, Ca, Ba, Cr, Mo, Sr, V and Zr than the underlying ultramafic rocks. Au is also elevated in this zone (e.g. Tables 2, 4 and 9). Detailed study of such calcrete zones reveals a general association of the Ca, Sr and Ba with Au (Lintern, 1989; pers. comm., 1989). Mo (and As, Sn and W) may also be associated with Au in this zone (Scott, 1989b). The other elements, Fe, Cr, V and Zr, are associated with Fe oxides and/or resistate phases (e.g. zircon, Cr-rich spinel). Residual concentration of zircon could explain the Zr enrichment and hence low Ti/Zr ratios often found in this zone (e.g. Tables 1 and 3). This zone probably forms by the concentration of Fe oxides and resistate phases at the surface during laterization and subsequent carbonate infilling of the voids under the current arid conditions. The association of Au with this carbonate (Lintern, pers. comm., 1989) would thus imply mobility of Au subsequent to the original lateritic profile development.

The chlorite-vermiculite/talc zone is 46 m thick in PSRC 227 and characterized by its high Mg, Cr and Ni contents (Table 2). Relative to the overlying calcrete zone apart for the absence of carbonate, it generally has lesser development of goethite, although the upper 6 m of this zone does have greater goethite and kaolinite contents than below (Fig 3). Other profiles through ultramafic rocks (e.g. PSRC 226, Fig 2 and PSRC 309, Fig 6) are more intensely weathered and show even stronger development of kaolinite and goethite than in

PSRC 227, possibly due to their location (see below). This interval is specifically identified as the kaolinite/goethite zone in these profiles. In the least weathered profile (PSRC 227), Mg is present in vermiculite-chlorite and talc, Cr mainly in vermiculite-chlorite, goethite, rutile, ilmenite and pseudorutile and Ni mainly in vermiculite-chlorite (Table 13). Thus in PSRC 309 where neither vermiculite-chlorite nor talc is present, only high Cr is present (Table 9).

The five metres immediately above mineralization in PSRC 227 has slightly elevated Fe, Mn and Na contents (Table 4) reflecting increased goethite and smectitic clay contents relative to the overyling kaolinite/goethite zone within ultramafic rocks (Fig 3). Even more significant are the elevated S, As, Au and Zn contents (Table 4) which can be related directly to sulfide-rich mineralization. The actual ore zone within ultramafic rocks also tends to be more ferruginous and manganiferous than higher in the profile and to have high Ag, As, Ba, Co, Cu, W and Zn associated with Au (Table 4). The association of Ba and Co (and possibly some of the Cu and Zn) may be explained by their incorporation into Mn oxides (cryptomelane and lithiophorite; cf. Section 3.7) but the other elements are as found associated with low grade mineralization and its hanging wall in PSRC 231 (Scott, 1989b).

In summary, study of profiles through ultramafic rocks shows that chlorite-vermiculite and talc are characteristic minerals which persist almost to the surface with calcrete present in the uppermost few metres (e.g. Fig 3). Thus high Mg, Cr and Ni contents are maintained through the profile during weathering of ultramafic rocks (e.g. Table 4). Mica contents are generally low in such profiles. These features are summarized in an idealized profile through ultramafic rocks at Panglo (Fig. 7). The surficial calcrete zone is characterized by the presence of calcite ± dolomite and is quite ferruginous, bearing both hematite and goethite. Ba, Cr, Mo, Sr, V and Zr are abundant in this zone and low grade Au (~0.05 ppm) is also present. Mineralogical changes within the chlorite-vermiculite- and talc-dominated rocks are subtle but a discrete kaolinite/goethite zone may be present in its upper portion and a thin hanging wall zone may extend for ~5 m above mineralization where the latter is developed. The kaolinite/goethite zone is well developed in PSRC 226 (Fig 2) and less well in PSRC 227 (Fig 3). Enrichment of goethite and kaolinite also defines the hanging wall and mineralized zones within the chlorite-vermiculite- and talc-rich rocks (Fig 3). The elements S, Ag, As, Cu, Mo, Sb, W and Zn are found associated with the Au mineralization and often into the hanging wall (Table 4; Scott, 1989b). Ba and Co present in the mineralized zone are probably contained within Mn oxides (cf. Table 14). The footwall material has considerably lower contents of the Au-associated elements than the mineralized zone (Scott, 1989b).

Although these features are generally true, several profiles containing ultramafic rocks at Panglo do not show retention of chlorite-vermiculite and talc. Ultramafic rocks within these holes (PSRC 309 and PSRC 230) can however be identified by their Cr contents >700 ppm and often the more persistent presence of smectitic clay than in mafic volcanics. The absence of chlorite-vermiculite and talc in these holes probably reflects more intense weathering in the holes PSRC 309 and PSRC 230 than in PSRC 226 and PSRC 227. Indeed, if Mg content reflects the intensity of weathering, PSRC 226 (which has some smectite and lower mafic phyllosilicate content i.e. Mg content than PSRC 227) would appear to be more intensely weathered than PSRC 227. Thus the degree of weathering of the ultramafic rocks appears to increase in the order -

PSRC 227, PSRC 231 > PSRC 226 > PSRC 230, PSRC 309.

A possible reason for this may be the location of the holes PSRC 230 and PSRC 309 within the intensely weathered central shear zone at Panglo whereas the other holes were collared west of it (Fig 1).

4.2 Mafic rocks

Mafic rocks are identified by Ti/Zr ratios >60 and Cr contents <700 ppm (cf. Hallberg, 1984). On this basis the most extensive profiles are provided by PSRC 226 (19-61 m and 64-66 m), PSRC 239 (0-60 and 72-79 m), PSRC 238 (0-69 m) and PSRC 309 (23-64 m).

Weathered mafic rocks have more abundant muscovite and kaolinite than the weathered ultramafic rocks. Hematite is also well developed in mafic profiles but not in ultramafic profiles except in the surficial ferruginized calcrete zone (cf. Figs 5 and 2).

The upper calcrete zone in PSRC 238 and 239 is identified by its calcite and dolomite content and by its abundant Fe oxides. Talc is also present in this zone but halite is absent (Figs 4 and 5). Besides Ca, Mg and Fe which relate directly to the carbonates and the Fe oxides, As, Ba, Cr, Mo, Sb, Sr, V and Zr are high in this zone. Au is also present in this zone (Tables 6 and 8). Apart from As and Sb which are not so abundant in the calcrete zone above ultramafic rocks, the features of the calcrete zone are similar over both mafic and ultramafic rocks.

Beneath the calcrete zone, barren and mineralized mafic volcanic profiles are readily differentiated. In the barren profiles (e.g. PSRC 238), the kaolinite/muscovite zone contains paragonite (Fig 4). It has high Fe, Al, K, Ti, V, Zn and W but low Si, Na, Ba, Co and Sr relative to rocks lower in the profile (Table 6). Lower in the profile paragonite becomes more dominant as reflected by the higher Na and lower K contents of the kaolinite/paragonite zone (Table 6). Ba and Zn are also high in this interval and As low. At the base of PSRC 238 mica and kaolinite are less well developed and talc and smectitic clay more consistently developed. Si, As, Cu, Zn and W are relatively high in this zone (Table 6).

In the mineralized profiles PSRC 226 and PSRC 239, paragonite is at best only poorly developed in the kaolinite- and muscovite-rich interval (Figs 2 and 5). Furthermore within PSRC 226, which is only poorly mineralized, the kaolinite- and muscovite-rich interval gives way to quartz- and muscovite-poor zones above the thin interval of mineralization. The kaolinite/muscovite zone of this hole is characterized by high K, Mn, As, Ba, Co, Ni and Zn contents, reflecting its abundant muscovite and Mn oxide content. The quartz-poor zone has low Si, K and chalcophile element contents relative to the zone above but intermediate values relative to the lower kaolinite zone (Table 2). No significant enrichment in Au-associated elements is present above the mineralization. The more highly mineralized PSRC 239 shows no additional zonation in the kaolinite/muscovite interval or zone (Fig 5). A possible reason for this difference is suggested at the end of this section. Compositionally it is similar to its equivalent in PSRC 226 although Mn is not so well developed (Tables 2 and 8). The long interval of elevated As and W contents (Tables 7 and 8) may be regarded as indicating a thick hanging wall. However the mineralization in this hole is entirely shale-hosted (Table 8).

Mineralization in PSRC 226 is also associated with shale but some is present within mafic volcanics. Such volcanics have more abundant mucovite and elevated Si, K, Mn, As, Ba, Co, Cr, Sr, W and Zn relative to its hanging wall (kaolinite zone; Table 2). This suite of elements reflect both the association of chalcophile elements with Au and the presence of Mn oxides in the mineralized horizon (cf. mineralized shale PSRC 239, Table 8 and mineralized ultramafics, Section 4.1). The Mn at this level in the profile was probably derived mainly from dolomite and calcrete (cf. Table 12). The footwall to mineralization is characterized by the presence of chlorite (Figs 2 and 5). Chalcophile elements like As, Co, Cu, Ni, Pb, Zn may also still be high in the footwall (Tables 2 and 8).

Idealized profiles through mineralized and barren mafic volcanics consist of a surficial calcrete zone above kaolinite-, mica- and Fe oxide-rich rocks. The higher K and lower Mg and Cr readily distinguish such rocks from ultramafic volcanics at similar depths, cf. Figs. 7, 8 and 9. The development of hematite in addition to goethite is also a characteristic of mafic volcanics but not ultramafic volcanics and is an useful mineralogical check on the chemical differentiation method of Hallberg (1984).

The ferruginous calcrete zone shows some enrichment of Au to values ~0.05 ppm with enrichments of As, Ba, Cr, Mo, Sb, Sr, V and Zr also present, as found for calcrete above ultramafic volcanics (Section 4.1). In highly mineralized profiles a thick kaolinite/muscovite zone is present above mineralization. This interval (~50 m in PSRC 239) is characterized by high K, Ba, As and W contents (Table 8). The less highly mineralized profile PSRC 226 has quartz-poor and muscovite-poor zones below its kaolinite/muscovite zone. These zones have lesser chalcophile element contents than in the kaolinite/muscovite zone (Table 1). Mineralization in these holes is associated, at least in part, with shale bands but that in mafic volcanics in PSRC 226 is characterized by high Si, K, Mn, As, Ba, Co, Cr, Mo, Sr, W and Zn. The Au-associated elements (e.g. As and W) are strongly associated with mafic volcanics forming the footwall to mineralization. The footwall volcanics also have chlorite present and show some retention of chalcophile elements.

Barren holes, exemplified by PSRC 238, have paragonite within the profile above the level where mineralization generally occurs (i.e. above 60 m). Such peripheral development of paragonite is also found in shale profiles (Scott, 1989a; 1990) and because no paragonite has been found in fresh rocks at Panglo (Section 3.6), it appears to form as a weathering product under saline groundwater conditions (Scott, 1990). Although chalcophile elements may be present in barren profiles, due to their incorporation into Fe oxides (e.g. 39153, Table 14), their abundances are generally lower than in the mafic volcanics above mineralization (cf. Tables 6 and 8).

When unweathered and "unaltered", mafic volcanics consist of quartz, albite, chlorite, actinolite, epidote and carbonates. However alteration results in development of muscovite and sulfides and destruction of actinolite and epidote (Section 3.6; see also Phillips et al, 1983; Groves and Phillips, 1987). Epidote and actinolite are not found in any of the weathered profiles at Panglo, probably due to their susceptibility to weathering (e.g. Loughnan, 1969). However the widespread occurrence of muscovite (which is not easily weathered) in weathered mafic volcanics suggests that pervasive alteration of volcanics at Panglo is common. Furthermore the association of muscovite (and its associated elements, K, Ba and Rb) with chalcophile elements in portions of mafic profiles and low muscovite and low chalcophile element contents elsewhere (e.g. PSRC 226, Table 2 and Fig 2) suggests that the pre-weathering alteration of mafic volcanics is patchy. In addition the presence of only a thin interval of mineralization in PSRC 226 and thicker, high grade mineralization in PSRC 239 where muscovite (i.e. alteration) is more extensive (Fig 5) may imply that the mineralization at Panglo is related to pre-weathering alteration. If this is so, the Au has probably not moved far and potassic alteration (mica-development) associated with primary Au mineralization would appear to be unaffected by subsequent weathering and may indicate areas where secondary Au mineralization may be expected at Panglo. Similarly chalcophile elements (including pathfinder elements like As and W) are retained within secondary oxide phases, especially goethite (Table 14), and hence still show a relationship to Au.

4.3 Calcrete zones

As no calcrete was found above shale profiles at Panglo (Scott, 1989a), calcrete appears to be restricted to mafic and ultramafic profiles at Panglo. Thus a model involving movement of the alkaline earths (derived from weathering volcanics) to the surface and their deposition as carbonates under arid conditions appears to be a reasonable explanation for the surficial carbonate formation (cf. Lintern, 1989).

The greater thickness of the calcrete zone in PSRC 238 and PSRC 239 (i.e. along Section 3900N) that at other locations probably reflects the higher topographic level at the top of these holes (RL=346m) than at the other locations along Sections 4200N and 4300N (RL=343-344m). If this is so, these profiles are the most complete at Panglo, with the others being partially stripped subsequent to calcrete formation.

Because the reverse circulation drilling was inclined at 60°E for the holes reported by Scott (1989b) and in this report, the calcrete zone of PSRC 226 (Au = 0.11 ppm) occurs almost directly above mineralization in PSRC 227 (Fig 10; Section 4300N). Similarly along Section 3900N the calcrete zone in PSRC 238 (Au = 0.12 ppm) occurs vertically above mineralization in PSRC 239 (Fig 10). Because these calcrete sections have higher Au content than adjacent calcretes which overlie barren rocks, the results are similar to those reported along Section 4200N (Scott, 1989b). Thus Au values ≥0.10 ppm in calcrete appear to overlie Au mineralization at depth at Panglo although further study is required to more fully evaluate this feature.

If the calcrete is formed from alkaline earth metals derived from underlying rocks, as suggested above, the presence of higher grade Au and associated elements, As, Mo, Sb, Sn and W (Tables 2 and 6; Scott, 1989b), in the calcrete directly above mineralization may imply similar derivation for these elements. Thus Au ≥0.10 ppm in surficial calcrete could be a significant guide to underlying mineralization in predominantly volcanic rocks at Panglo (see Lintern, 1989 for a more detailed discussion of the calcrete-Au association).

5. CONCLUSIONS

Mafic and ultramafic volcanics in the Panglo area generally have a calcrete zone developed above them. This zone is generally ferruginous and is characterized by elevated As, Ba, Cr, Mo, Sb, Sr, V and Zr, with low grade Au (~0.05 ppm) also present. However where mineralization occurs at depth higher Au grades (>0.1 ppm) and higher levels of As, Mo, Sb, Sn and W occur.

Ultramafic rocks generally show retention of chlorite and talc throughout the profile, although they may be somewhat diluted in abundance in the calcrete zone and chlorite may degrade to vermiculite in the upper part of some profiles. Thus ultramafic profiles are generally characterized by abundant Mg, Cr and Ni throughout (e.g. Fig. 7). (However the location of the holes PSRC 230 and PSRC 309 within the intensely weathered central shear zone at Panglo leads to destruction of chlorite-vermiculite and talc within these holes.) The elements S, Ag, As, Cu, Mo, Sb, W and Zn are found associated with the Au mineralization within ultramafic volcanics and sometimes for ~5 m into the hanging wall. Mn oxides may also be present in the mineralized zone.

Beneath the calcrete zone in mafic volcanics the rocks often have abundant mica and hematite is present as well as goethite. Talc, chlorite-vermiculite and smectitic clays which characterize ultramafic rocks are not well developed in mafic rocks.

In highly mineralized mafic volcanic profiles, a thick kaolinite/muscovite (or leached saprolite) zone is present above mineralization and is characterized by high K, Ba, As and W contents (e.g. Fig. 8). Barren holes show extensive development of paragonite which is especially abundant low in the profile (e.g. Fig. 9). Although chalcophile elements may be present in the more muscovite-rich upper part of the profile their abundances drop in the paragonite-rich part. Mineralization in mafic volcanic profiles is at least partially associated with high Si, K, Mn, As, Ba, Co, Cr, Mo, W and Zn contents. These associations are, at least in part, due to the association of muscovite and Mn oxides with the gold but the significant pathfinders for Au (e.g. As and W) are present in Fe oxides.

The association of secondary Au mineralization and extensive muscovite development (a primary alteration feature) in weathered volcanic profiles at Panglo has obvious exploration potential and hence should be investigated further.

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Table 1. Chemical composition of samples, poorly mineralized drill hole PSRC 226 (majors, wt%; minors, ppm)

Sample No.	38000	38001	38003	38007	38011	38017	38019	38021	38028	38033	38035	38039	38041	38043	38045
Depth (m)	0-1	1-2	2-3	6-7	10-11	16-17	18-19	20-21	24-25	30-31	32-33	36-37	38-39	40-41	42-43
SiO_2	47.5	45.3	56.7	47.7	40.9	34.6	78.7	34.8	37.6	37.3	40.0	31.9	34.9	34.1	31.1
Al_2O_3	7.15	8.85	10.2	14.0	16.6	18.2	6.03	19.5	28.6	29.6	22.8	27.0	27.5	26.5	25.0
Fe_2O_3	28.4	17.7	11.9	16.0	19.9	18.6	8.27	21.9	12.4	11.5	13.7	18.7	20.8	18.4	18.6
MgO	1.92	7.88	6.73	7.69	2.80	5.94	0.12	0.52	0.59	0.55	0.74	0.41	0.19	0.57	0.48
CaO	2.72	1.82	<0.04	<0.04	0.13	<0.04	<0.04	0.05	<0.04	<0.04	0.13	0.07	<0.04	<0.04	0.07
Na_2O	0.42	1.40	1.40	1.09	3.14	3.14	0.63	2.63	1.74	2.21	3.11	2.88	1.08	2.26	5.00
K_2O	0.25	0.10	<0.04	→	→	→	→	1.16	3.47	2.90	1.97	0.36	0.97	0.94	0.31
TiO_2	0.50	0.59	0.55	0.50	0.56	0.42	0.16	0.70	1.76	1.61	1.27	1.23	1.29	1.24	1.11
MnO	0.06	0.06	<0.04	0.06	0.09	0.09	1.06	3.08	0.54	0.25	0.47	0.34	0.33	0.18	0.19
SO_3	<0.1	→	→	→	0.31	0.30	<0.1	0.27	0.19	0.17	0.46	0.34	<0.1	0.24	0.40
Ag	0.1	0.1	<0.1	→	→	→	0.7	2	0.1	0.5	0.2	<0.1	0.2	<0.1	<0.1
As	260	95	84	65	220	270	560	1480	680	350	790	240	180	240	55
Au	0.07	0.14	0.10	0.01	0.02	0.02	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Ba	690	160	61	28	<5	12	510	1750	630	720	530	72	270	260	68
Co	26	33	23	32	35	38	800	1960	150	93	180	44	79	45	41
Cr	1780	2510	2410	2270	4730	4750	950	150	330	330	400	260	280	320	250
Cu	92	49	33	66	83	86	180	420	93	130	140	140	170	130	130
Ga	20	15	7	7	7	5	3	7	20	20	15	15	15	15	10
Ge	1	2	1	1	1	2	2	1	1	1	1	2	2	<1	3
Mo	4	1	2	0.6	1	<0.3	2	2	0.3	<0.3	3	<0.3	→	→	→
Ni	240	710	550	960	920	1160	640	1380	320	280	400	250	300	220	230
Pb	<50	<50	<50	63	64	77	51	95	100	110	94	110	110	79	63
Rb	11	6	<5	→	→	→	→	35	91	78	53	10	28	28	7
Sc	24	23	17	37	45	57	30	64	85	72	68	63	66	75	65
Sn	5	5	5	3	6	8	2	5	3	2	5	1	1	<1	1
Sr	70	40	11	6	17	13	8	26	24	18	32	17	13	12	21
V	520	210	140	190	230	180	95	220	480	430	360	360	420	400	380
Y	7	5	2	4	5	9	7	16	19	13	13	15	14	13	10
W	<10	→	→	→	→	→	30	200	10	<10	20	<10	→	→	→
Zn	45	47	31	51	62	88	100	530	230	160	150	120	280	110	100
Zr	59	43	33	26	25	33	14	89	100	91	70	67	69	63	61
Ti/Zr	51	81	100	120	130	76	64	47	110	110	110	110	110	120	110

Note P_2O_5 <0.1% except 38021 where P_2O_5 = 0.13%

Table 1 Cont'd

Sample No.	38047	38049	38053	38055	38059	38061	38062	38063	38064	38065	38066	38067	38068	38069
Depth (m)	44-45	46-47	49-50	51-52	55-56	57-58	58-59	59-60	60-61	61-62	62-63	63-64	64-45	65-66
SiO_2	44.7	42.9	42.8	44.4	46.6	43.5	57.5	52.3	45.2	57.9	64.5	56.8	68.4	64.5
Al_2O_3	20.9	16.8	21.9	20.4	19.7	20.7	13.9	18.9	14.8	14.2	12.5	10.7	12.4	12.5
Fe_2O_3	16.2	12.8	17.3	14.8	14.1	14.6	11.4	15.0	14.6	12.3	8.64	8.86	10.2	10.2
MgO	0.35	0.86	0.34	0.46	0.47	0.60	0.45	0.44	0.80	0.67	0.62	0.95	0.22	0.49
CaO	<0.04	0.10	<0.04	0.05	<0.04 →				0.08	<0.04 →				
Na_2O	2.76	6.34	2.55	3.15	3.05	3.11	3.60	1.13	6.58	2.49	2.56	5.68	0.44	1.85
K_2O	0.04	0.07	0.08	0.33	0.33	0.81	1.78	2.47	1.47	2.38	1.96	1.46	1.45	1.33
TiO_2	0.94	0.75	1.02	0.93	0.88	0.96	0.60	0.87	0.65	0.50	0.44	0.37	0.54	0.55
MnO	0.17	0.17	0.29	0.29	0.34	0.33	0.49	0.62	0.43	0.45	0.21	0.20	0.50	0.44
SO_3	0.22	0.65	0.20	0.39	0.29	0.31	0.19	<0.1	0.48	0.22	0.19	0.50	<0.1	0.15
Ag	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.6	0.2	0.1	0.1	0.1
As	29	41	40	130	65	230	270	360	380	280	220	320	710	850
Au	<0.01	0.01	0.01	0.02	<0.01	0.02	2.80	0.29	0.29	0.16	0.48	0.54	0.05	0.06
Ba	9	36	36	91	89	210	590	780	620	800	670	690	640	710
Co	24	35	130	85	90	92	380	110	85	160	110	82	250	160
Cr	190	170	240	200	190	260	440	260	350	360	290	260	140	230
Cu	130	120	200	160	150	140	230	140	140	180	110	110	150	180
Ga	20	10	15	15	40	30	20	25	20	25	20	20	20	20
Ge	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mo	<0.3 →				0.4	0.8	1	0.8	0.8	0.8	2	2	2	1
Ni	170	170	240	200	200	230	260	230	160	190	130	120	180	160
Pb	61	<50	64	61	60	59	<50	55	<50	52	56	<50	75	57
Rb	<5	<5	<5	12	12	24	57	70	54	71	57	51	40	38
Sc	53	48	67	64	59	61	46	57	49	39	28	33	39	37
Sn	1	1	1	1	1	2	3	1	1	2	5	1	<1	1
Sr	11	25	12	19	15	15	21	19	38	20	20	23	11	15
V	330	240	290	290	250	300	240	330	280	190	130	160	210	210
Y	5	3	7	9	8	10	12	15	14	14	10	10	11	10
W	<10 →					15	30	20	25	25	30	40	60	200
Zn	66	55	130	93	73	110	150	110	200	470	250	220	110	110
Zr	52	40	53	50	46	53	46	52	47	63	66	50	39	39
Ti/Zr	110	110	120	110	120	110	78	100	83	48	39	44	85	85

Table 2. Average compositions for zones with PSRC 226 (majors, wt%; minors; ppm)

Rock type	ULTRAMAFIC		MAFIC				SHALE	MAFIC
Zone	Calcrete	Kaol/goe	Kaol/musc	Qtz-poor	Kaol	Mineralized	Mineralized	Footwall
Depth (m)	0-2	2-19	19-36	36-44	44-58	58-61	61-64	64-66
No of samples	2	4[1]	4[2]	4	6	3	3	2
SiO_2	46.4	44.9	37.4	33.0	44.2	51.7	59.7	66.5
Al_2O_3	8.00	14.8	25.1	26.5	20.1	15.9	12.5	12.5
Fe_2O_3	23.1	16.6	14.9	19.1	15.0	13.7	9.93	10.2
MgO	4.90	5.79	0.60	0.41	0.51	0.56	0.75	0.36
CaO	2.26	0.05	0.06	0.05	0.04	0.04	<0.04	<0.04
Na_2O	0.91	2.19	2.42	2.81	3.49	3.77	3.58	1.15
K_2O	0.18	<0.04	2.38	0.65	0.28	1.19	1.93	1.39
TiO_2	0.55	0.51	1.34	1.22	0.91	0.71	0.44	0.55
MnO	0.06	0.07	(0.42)	0.26	0.27	0.51	0.29	0.47
SO_3	<0.1	0.18	0.27	0.26	0.34	0.24	0.30	0.10
Ag	0.1	<0.1	0.7	<0.1	<0.1	0.1	0.3	0.1
As	180	160	(610)	180	89	340	270	780
Au	0.11	0.04	<0.01	<0.01	0.01	1.13	0.39	0.06
Ba	430	26	(630)	170	79	660	720	680
Co	30	32	(140)	52	76	190	120	210
Cr	2150	3540	300	280	210	350	300	190
Cu	70	67	(120)	140	150	170	130	170
Ga	18	7	16	14	22	22	22	20
Ge	2	1	1	2	2	2	2	2
Mo	3	0.9	1.4	0.3	0.3	0.9	1.6	1.5
Ni	480	900	(330)	250	200	220	150	170
Pb	<50	57	100	90	55	<50	<50	66
Rb	9	<5	64	18	9	60	60	39
Sc	24	39	72	67	59	51	33	38
Sn	5	6	4	<1	1	2	2	1
Sr	42	8	20	14	15	24	19	13
V	360	190	370	390	280	280	160	210
Y	6	5	15	13	7	14	11	11
W	<10	<10	(12)	<10	<10	25	32	130
Zn	46	58	(180)	150	88	150	310	110
Zr	51	29	88	65	49	48	60	39

[1] Qtz-rich sample (38019) excluded from average

[2] Data from Mn-rich sample (38021) excluded from averages in parentheses

Table 3. Chemical composition of samples, mineralized drill hole PSRC227 (majors, wt%; minors, ppm)

Sample No.	38070	38071	38073	38075	38079	38081	38085	38089	38091	38093	38095	38099	38103	38105
Depth (m)	0-1	1-2	3-4	5-6	8-9	10-11	14-15	18-19	20-21	22-23	24-25	28-29	31-32	33-34
SiO_2	50.3	42.3	46.7	47.1	50.7	49.4	47.6	49.1	48.8	49.6	50.0	62.1	47.7	48.8
Al_2O_3	8.69	8.40	11.3	11.9	8.13	6.65	7.62	7.90	6.57	7.41	6.85	7.45	7.81	6.75
Fe_2O_3	27.7	25.8	13.3	13.5	13.0	11.2	11.9	11.9	11.2	11.7	11.4	10.7	11.5	11.1
MgO	1.34	6.32	11.6	12.4	16.2	17.5	16.8	17.0	18.3	17.8	18.3	8.72	17.7	18.9
CaO	2.21	2.59	0.05	<0.04	→		0.04	<0.04	→					
Na_2O	0.24	0.97	2.04	1.73	0.75	1.52	1.59	1.00	1.75	1.35	1.17	1.27	1.62	1.54
K_2O	0.46	0.39	0.08	0.06	<0.04	→								
TiO_2	0.57	0.48	0.39	0.43	0.34	0.34	0.37	0.41	0.33	0.37	0.35	0.35	0.39	0.34
MnO	0.08	0.08	0.05	0.06	0.08	0.25	0.41	0.15	0.33	0.19	0.15	0.19	0.23	0.17
SO_3	<0.1	0.13	0.16	0.11	<0.1	<0.1	0.17	<0.1	→					
Ag	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1	→			0.1	0.1	0.1
As	150	200	56	37	17	8	17	13	29	15	19	29	26	32
Au	0.03	0.04	<0.01	→										
Ba	150	200	56	37	17	8	17	13	29	15	19	29	26	32
Co	22	37	45	47	63	210	250	110	150	120	110	78	120	100
Cr	1440	2070	2750	2520	2200	2300	2030	2170	2400	2170	2640	1650	2110	2190
Cu	66	62	38	50	73	71	57	60	61	66	59	35	75	48
Ga	25	20	15	20	15	15	10	8	6	10	10	15	10	8
Ge	2	2	2	2	2	2	3	2	5	2	2	2	2	2
Mo	3	6	<0.3	→								0.3	<0.3	<0.3
Ni	170	510	920	1080	1350	2240	2840	2640	2470	2080	2090	1060	1940	1600
Pb	<50	→												
Rb	19	7	<5	→										
Sc	25	28	31	36	32	27	27	31	25	28	27	24	30	30
Sn	5	4	3	5	3	3	3	2	8	3	4	4	2	3
Sr	71	64	14	10	<5	9	16	6	10	9	7	9	10	10
V	440	410	140	130	110	89	120	120	130	120	120	130	140	120
Y	10	7	2	2	4	3	11	9	9	10	8	11	11	13
W	<10	→												
Zn	47	42	42	48	63	130	130	110	90	79	81	72	84	69
Zr	81	49	22	20	18	16	21	23	16	19	18	16	19	19
Ti/Zr	42	80	110	130	110	130	110	110	130	120	120	130	120	110

Table 3 Cont'd

Sample No.	38107	38111	38115	38119	38123	38125	38128	38129	38131	38133	38135	38137	38138	38139	38141	38143
Depth (m)	35-36	39-40	43-44	47-48	51-52	53-54	54-55	55-56	57-58	59-60	61-62	63-64	64-65	65-66	67-68	69-70
SiO_2	50.9	49.1	48.7	45.0	41.1	44.2	46.3	50.4	46.2	46.4	35.2	37.4	36.4	44.0	47.6	42.2
Al_2O_3	5.73	5.84	5.85	9.04	9.41	9.08	7.49	12.1	16.7	21.1	20.8	21.0	23.5	20.9	19.4	21.7
Fe_2O_3	10.6	10.6	10.9	12.1	14.1	14.0	11.9	21.8	18.8	15.4	16.2	16.9	20.6	16.3	16.2	16.7
MgO	20.1	20.1	19.2	18.4	12.7	17.9	20.1	1.85	0.48	0.37	1.14	1.07	0.45	0.44	0.35	0.60
CaO	<0.04	0.26	0.25	<0.04	→	→	→	→	→	→	0.05	<0.04	→	→	→	→
Na_2O	1.16	1.17	1.56	1.31	4.23	1.28	1.28	1.55	2.10	1.60	4.68	3.79	2.20	2.20	2.04	2.36
K_2O	<0.04	→	→	→	→	→	→	0.35	0.71	0.71	1.25	1.24	0.72	0.42	0.13	0.75
TiO_2	0.31	0.32	0.31	0.47	0.46	0.40	0.30	0.41	1.05	1.35	1.26	1.30	1.51	1.39	1.27	1.38
MnO	0.17	0.18	0.20	0.21	0.34	0.27	0.20	0.43	0.39	0.41	0.46	0.29	0.27	0.34	0.28	0.26
SO_3	<0.1	→	→	→	0.30	<0.1	→	→	0.20	0.12	0.49	0.26	0.18	0.21	0.18	0.17
Ag	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
As	32	41	51	35	220	230	140	1380	760	1050	460	530	150	52	39	190
Au	<0.01	→	→	→	0.01	0.21	0.64	1.88	0.03	0.71	2.52	1.84	0.93	0.08	0.01	0.15
Ba	32	41	51	35	220	230	140	1380	760	1050	460	530	150	52	39	190
Co	95	97	93	94	110	98	130	220	130	190	67	73	59	45	48	51
Cr	2180	2320	2430	2210	3130	2770	2790	1600	290	180	460	550	310	220	220	350
Cu	40	47	34	39	70	59	60	350	150	130	100	120	120	86	94	110
Ga	6	6	8	15	15	10	10	30	50	50	40	40	50	40	40	40
Ge	2	2	2	2	3	3	3	4	4	6	2	2	6	2	2	3
Mo	<0.3	→	→	→	→	→	→	2	2	1	1	2	0.3	0.3	1	2
Ni	1620	1530	1600	1940	1490	2500	3270	970	450	360	250	310	350	290	170	250
Pb	<50	→	→	→	→	→	→	→	58	75	67	73	71	66	60	72
Rb	<5	→	→	→	→	→	→	11	21	18	45	40	21	13	<5	22
Sc	26	27	29	35	40	32	30	39	54	55	63	57	62	55	50	54
Sn	3	3	2	3	5	3	2	3	2	2	4	4	3	2	1	2
Sr	8	9	10	5	16	6	<5	10	12	14	29	21	17	17	13	16
V	120	150	110	160	150	150	130	220	350	350	350	350	410	350	340	360
Y	4	2	6	10	14	6	4	19	27	23	18	18	19	12	8	15
W	<10	→	→	→	→	→	→	100	30	30	30	40	20	<10	<10	10
Zn	67	66	71	76	91	290	440	420	170	140	160	190	90	97	73	110
Zr	14	14	16	25	24	20	17	41	62	79	85	92	89	85	76	87
Ti/Zr	130	140	110	64	110	120	110	61	100	100	88	85	100	100	100	95

Table 4. Average compositions for zones within PSRC227 (major, wt%; minors, ppm)

Rock type	ULTRAMAFIC				MAFIC	
Zone	Calcite	Chlorite-vermiculite/talc	Hanging wall	Mineralized	Mineralized	Footwall
Depth	0-3	3-49	49-54	54-56	56-65	65-70
No. of samples	2	15*	2	2	5	3
SiO_2	46.3	48.6	42.7	48.2	40.3	44.6
Al_2O_3	8.55	7.69	9.25	8.80	20.6	20.7
Fe_2O_3	26.8	11.7	14.1	16.9	17.5	16.4
MgO	3.83	17.4	15.3	10.0	0.70	0.46
CaO	2.40	0.07	<0.04	<0.04	<0.04	<0.04
Na_2O	0.61	1.42	2.76	1.42	2.87	2.20
K_2O	0.43	<0.04	<0.04	0.18	0.93	0.43
TiO_2	0.53	0.36	0.43	0.36	1.29	1.35
MnO	0.08	0.19	0.31	0.32	0.36	0.29
SO_3	<0.1	<0.1	0.15	<0.1	0.25	0.19
Ag	<0.1	<0.1	0.1	0.5	0.2	0.1
As	180	29	230	760	590	93
Au	0.04	<0.01	0.11	2.26	1.21	0.08
Ba	350	8	20	200	360	93
Co	30	110	100	180	100	48
Cr	1800	2300	2900	2200	360	260
Cu	64	54	65	210	120	97
Ga	23	11	13	20	46	40
Ge	2	2	3	4	5	2
Mo	5	<0.3	<0.3	1	1	1
Ni	340	1900	2000	2100	340	220
Pb	<50	<50	<50	<50	82	66
Rb	13	<5	<5	7	29	13
Sc	27	29	36	35	58	53
Sn	5	3	4	3	3	2
Sr	55	8	3	5	15	13
V	430	130	150	180	360	350
Y	9	7	10	12	21	12
W	<10	<10	<10	52	30	<10
Zn	45	80	190	430	150	93
Zr	65	19	22	29	81	83

* Excluding qtz-rich sample 38099

Table 5. Chemical composition of samples, barren hole PSRC238 (majors, wt%; minors, ppm)

Sample No.	39102	39105	39110	39115	39131	39137	39147	39153	39163	39173
Depth (m)	0-1	3-4	8-9	13-14	27-28	33-34	43-44	48-49	58-59	68-69
SiO_2	26.6	33.1	36.7	37.5	37.6	42.0	46.7	56.8	46.3	55.2
Al_2O_3	9.69	14.9	20.9	28.4	26.3	24.9	19.8	18.8	18.2	16.2
Fe_2O_3	39.8	37.9	29.1	16.7	19.2	18.0	15.9	13.1	14.2	14.9
MgO	0.84	0.43	0.26	0.22	0.30	0.24	0.39	0.31	0.63	0.38
CaO	8.79	0.74	<0.04 →							0.07
Na_2O	0.18	0.41	0.53	0.71	2.40	1.58	2.46	1.75	4.07	2.26
K_2O	0.23	0.56	2.00	1.19	1.25	1.58	0.24	1.49	0.15	1.26
TiO_2	0.54	0.49	0.92	1.21	1.09	1.04	0.81	0.84	0.79	0.89
MnO	0.04	<0.04	<0.04	0.06	0.16	0.30	0.32	0.15	0.27	0.24
SO_3	0.10	0.22	0.19	0.34	0.26	0.13	0.22	<0.1	0.37	0.20
As	390	700	370	370	440	260	84	260	35	660
Au	0.19	0.05	0.11	0.01	0.01	0.01	<0.01 →			
B	80	150	60	40	50	60	60	60	60	50
Ba	380	490	530	280	520	330	150	1220	86	500
Co	15	21	11	47	23	15	29	18	81	79
Cr	790	620	520	240	330	160	200	220	230	280
Cu	100	90	60	210	150	160	130	150	170	220
Ga	15	20	15	20	30	20	15	15	15	15
Ge	1	1	2	2	2	2	2	1	2	1
Mo	3	3	<0.1	0.3	0.3	0.3	0.5	0.3	0.8	1
Ni	110	120	110	250	260	210	190	130	350	190
Pb	53	<50 →								
Sb	20	10	10	10	<10 →					
Sc	43	44	52	69	74	73	52	51	50	52
Sn	3	3	1	0.5	0.3	0.3	0.3	0.3	0.6	1
Sr	74	40	26	26	69	71	26	73	86	62
V	730	490	470	410	390	370	270	320	270	270
W	10	15	15	20	15	10	10	10	10	15
Y	7	5	8	10	10	11	11	13	18	20
Zn	26	22	25	84	210	63	69	69	190	130
Zr	110	86	62	64	60	54	41	40	42	39
Ti/Zr	29	35	89	110	110	120	120	130	110	140

Note P_2O_5 <0.1%; Ag <0.1 ppm

Table 6. Average compositions for zones within PSRC238 (majors, wt%; minors, ppm)

Rock type	MAFIC VOLCANIC			
Zone	Calcrete	Kaol/musc	Kaol/paragonite	Talc/smectite
Depth (m)	0-8	8-48	48-63	63-69
No of Samples	2	5	2	1
SiO_2	29.8	40.1	51.6	55.2
Al_2O_3	12.3	24.1	18.5	16.2
Fe_2O_3	38.8	19.8	13.6	14.9
MgO	0.64	0.28	0.47	0.38
CaO	4.77	<0.04	<0.04	0.07
Na_2O	0.30	1.54	2.91	2.26
K_2O	0.40	1.25	0.82	1.26
TiO_2	0.52	1.01	0.82	0.89
MnO	<0.04	0.17	0.21	0.24
SO_3	0.16	0.23	0.19	0.20
As	550	310	150	660
Au	0.12	0.03	<0.01	<0.01
B	120	50	60	50
Ba	440	360	650	500
Co	18	25	50	79
Cr	710	290	230	280
Cu	95	140	160	220
Ga	18	20	15	15
Ge	1	2	2	1
Mo	3	0.3	0.6	1
Ni	120	200	240	190
Sb	15	<10	<10	<10
Sc	44	64	51	52
Sn	3	0.4	0.5	1
Sr	57	44	80	62
V	610	380	300	270
W	13	14	10	15
Y	6	10	16	20
Zn	24	90	130	130
Zr	98	56	41	39

Note P_2O_5 <0.1%; Ag <0.1, Pb <50 ppm

Table 7. Chemical composition of samples, mineralized hole PSRC 239 (majors, wt%; minors, ppm)

Sample No.	39175	39179	39181	39183	39191	39201	39223	39235	39243	39249	39251	39257
Depth (m)	0-1	3-4	5-6	7-8	15-16	25-26	46-47	56-57	64-65	70-71	72-73	78-79
SiO_2	29.1	26.5	26.2	37.0	34.8	38.3	49.4	46.6	54.4	72.3	48.5	53.1
Al_2O_3	10.2	11.9	15.3	28.3	29.8	27.1	20.8	21.3	15.2	7.87	17.3	13.8
Fe_2O_3	35.9	40.1	43.6	20.2	19.2	18.2	11.1	9.69	16.0	12.3	15.4	20.6
MgO	0.86	0.82	0.33	0.17	0.21	0.35	0.52	0.70	0.55	0.23	0.68	0.50
CaO	9.33	5.89	0.27	<0.04	→	→	→	→	→	→	→	→
Na_2O	0.23	0.35	0.37	0.85	0.97	0.96	2.72	3.57	1.95	0.88	3.38	0.78
K_2O	0.23	0.19	0.20	0.59	2.32	3.59	2.16	3.58	1.82	1.08	1.11	1.96
TiO_2	0.49	0.46	0.36	0.92	1.77	1.66	1.19	1.22	0.57	0.27	0.78	0.86
MnO	0.04	<0.04	→	→	→	0.14	0.15	0.17	0.40	0.33	<0.04	0.05
SO_3	<0.1	0.12	0.36	0.24	0.23	0.13	0.24	0.33	0.19	<0.1	0.30	0.40
As	300	420	590	610	530	2450	380	670	460	760	310	340
Au	0.08	0.09	0.02	0.01	<0.01	0.01	<0.01	0.01	3.72	0.84	0.47	0.61
B	60	100	120	120	200	80	80	80	280	40	60	100
Ba	410	400	550	200	240	560	300	700	510	350	180	280
Co	18	21	15	10	18	13	19	62	97	80	19	260
Cr	760	700	530	450	360	380	260	250	630	310	620	750
Cu	110	110	67	42	160	170	110	150	170	180	80	390
Ga	30	15	15	30	30	20	15	15	15	8	8	20
Ge	1	0.5	1	2	2	0.1	1	1	1	0.3	1	2
Mo	3	3	2	1	0.8	0.2	0.5	0.2	10	1.5	1.5	3
Ni	140	140	100	120	400	290	160	200	290	320	140	780
Pb	51	58	<50	→	→	→	→	→	58	<50	<50	140
Sb	15	15	15	<10	→	→	→	→	→	→	→	30
Sc	49	51	36	34	75	93	48	57	35	23	45	45
Sn	1	2	1	3	1	1	1	1	5	1	1	5
Sr	94	76	32	31	39	25	27	34	24	12	17	16
V	650	660	610	410	510	510	320	370	200	110	260	270
Y	10	10	10	20	20	30	10	10	60	30	10	40
W	8	8	4	7	19	17	15	26	19	14	13	31
Zn	28	27	42	14	69	110	37	64	320	240	170	1530
Zr	100	120	98	150	110	93	70	73	79	43	60	82
Ti/Zr	30	23	22	37	96	110	100	100	43	37	78	62

Note P_2O_5 < 0.1%; Ag <0.1 ppm except in 39257 where Ag = 10 ppm

Table 8. Average compositions for zones within PSRC 239 (majors, wt%; minors, ppm)

Rock type	MAFIC		SHALE	MAFIC
Zone	Calcrete	Kaol/musc	Mineralized	Footwall
Depth (m)	0-7	7-60	60-72	72-79
No of samples	3	5	2	2
SiO_2	27.3	41.2	63.4	50.8
Al_2O_3	12.5	25.5	11.5	15.5
Fe_2O_3	39.8	15.7	14.1	18.0
MgO	0.67	0.39	0.39	0.59
CaO	5.16	<0.04	<0.04	<0.04
Na_2O	0.32	1.81	1.42	2.08
K_2O	0.21	2.45	1.45	1.54
TiO_2	0.44	1.35	0.42	0.82
MnO	0.04	0.10	0.37	0.04
SO_3	0.18	0.23	0.12	0.35
As	440	930	610	330
Au	0.06	<0.01	2.28	0.54
B	90	110	160	80
Ba	450	400	430	230
Co	18	24	89	140
Cr	660	340	470	690
Cu	96	130	180	240
Ga	20	22	12	14
Ge	0.8	1	0.7	1.5
Mo	3	0.5	6	2
Ni	130	230	300	460
Pb	<50	<50	<50	82
Sb	15	<10	<10	18
Sc	45	61	29	45
Sn	1	1	3	3
Sr	67	31	18	17
V	640	420	160	270
W	10	18	45	25
Y	7	17	17	22
Zn	32	59	280	850
Zr	110	99	61	71

Note: Ag <0.1 ppm

Table 9. Chemical composition of samples, barren hole PSRC309 (majors, wt%; minors ppm)

Sample No.	48174	48178	48187	48197	48205	48209	48215	48225	49233	49239	48248
Depth (m)	1-2	4-5	11-12	15-16	22-23	26-27	32-33	42-43	48-49	54-55	63-64
Al_2O_3	19.5	21.5	21.2	19.8	20.0	16.6	19.1	18.4	18.1	15.2	18.2
Fe_2O_3	26.3	14.0	13.5	13.7	16.3	33.5	15.9	20.0	17.7	15.6	15.0
MgO	0.22	0.15	0.42	0.20	0.39	0.34	0.18	0.54	0.15	0.46	0.27
CaO	0.07	0.04	0.12	0.07	0.09	0.04	0.04	0.14	0.05	0.09	0.06
Na_2O	0.33	0.73	0.92	0.69	1.05	1.19	1.23	3.57	0.69	2.79	1.62
K_2O	0.11	0.04	1.14	0.16	0.33	2.06	0.65	1.18	1.06	1.29	0.90
(TiO_2)	0.95	0.70	0.43	0.39	0.55	0.34	0.93	0.74	0.71	0.59	0.88
P_2O_5	0.03	0.03	0.04	<0.02	0.03	0.29	<0.02	0.05	0.06	0.10	0.10
MnO	0.01	0.08	0.07	0.17	0.11	0.11	0.24	0.31	0.24	0.68	0.30
SO_3	0.08	0.15	0.25	0.15	0.24	0.26	0.14	0.45	0.07	0.32	0.16
Au	0.05	<0.01	<0.01	0.01	0.02	0.01	0.01	<0.01	0.01	0.02	0.22
(Ba)	130	89	920	190	250	340	64	280	340	440	140
Co	10	11	12	13	13	38	11	30	18	280	74
Cr	1330	820	960	770	990	570	240	430	400	280	280
Cu	64	150	84	100	120	610	140	180	160	230	300
Ni	84	220	150	140	350	250	190	200	170	180	180
Pb	<50	→	→	61	<50	53	<50	→	→	→	→
Sc	34	40	56	38	40	51	52	46	48	52	55
Sr	11	6	9	7	14	25	47	53	58	47	50
V	450	210	270	220	240	250	340	340	320	220	320
Y	4	7	8	5	6	12	10	12	9	15	19
Zn	34	120	71	50	110	430	66	250	240	530	130
(Zr)	54	43	52	44	53	100	68	79	67	82	67
Ti/Zr	110	98	49	53	62	19	82	56	64	43	79

Note: All analyses except Au by ICP, thus limits of detection may be different from other analyses in preceding tables.
Values in parentheses possibly affected by incomplete dissolution of sample (see text)

Table 10. Average compositions for zones within PSRC309 (majors, wt%; minors, ppm)

Rock type	ULTRAMAFIC		MAFIC	
Zone	Calcrete	Kaol/goe	Kaol/musc	Kaol/parag
Depth (m)	0-1	1-23	23-36	36-64
No.of samples	1	4[1]	2	4[2]
Al_2O_3	19.5	20.6	17.8	17.5
Fe_2O_3	26.3	14.4	24.7	17.1
MgO	0.22	0.29	0.26	0.36
CaO	0.07	0.08	0.04	0.09
Na_2O	0.33	0.85	1.21	2.17
K_2O	0.11	(0.18)	1.36	1.11
TiO_2	0.95	0.52	0.64	0.73
P_2O_5	0.03	0.03	0.15	0.08
MnO	0.01	0.11	0.18	0.38
SO_3	0.08	0.20	0.20	0.25
Au	0.05	0.01	0.01	(0.01)
Ba	130	(180)	200	300
Co	10	12	25	100
Cr	1330	890	410	350
Cu	64	110	380	220
Ni	84	220	220	180
Sc	34	44	52	50
Sr	11	9	36	52
V	450	240	300	300
Y	4	7	11	14
Zn	34	88	250	290
Zr	54	48	86	74

Note: [1]Data from mica-rich sample 48187 excluded from averages in parentheses

[2]Data from gold-bearing sample 48248 excluded from averages in parentheses

Table 11. Chemical composition of fresh mafic volcanics, Panglo (majors, wt%; minors, ppm)

Sample No. Drill Hole Depth (m)	108064 PSRCD232 136.5	108066 PSRCD306 128.5	108067 PSRCD306 147	108070 PSRCD309 129.3	108071 PSRCD309 130	Average
SiO_2	45.1	44.3	47.0	47.6	46.4	46.1
Al_2O_3	14.4	15.7	15.2	14.8	15.3	15.1
Fe_2O_3	12.9	9.98	9.21	11.7	11.2	11.0
MgO	11.2	3.53	6.74	6.94	6.45	6.98
CaO	3.80	10.6	7.78	11.9	13.3	9.48
Na_2O	1.71	2.40	2.02	2.31	1.82	2.05
K_2O	<0.04	1.52	0.92	<0.04	<0.04	0.50
TiO_2	0.79	0.75	0.71	0.72	0.73	0.74
MnO	0.13	0.23	0.14	0.19	0.18	0.17
SO_3	<0.1	0.70	<0.1	0.15	0.17	0.22
Ag	0.3	0.2	0.2	0.2	0.1	0.2
As	52	87	43	13	13	42
Au	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
B	5	30	30	8	10	17
Ba	10	260	130	9	15	85
Co	54	45	46	48	49	48
Cr	220	170	180	150	150	170
Cu	92	100	74	120	110	99
Ga	30	20	30	20	30	26
Ge	3	1	2	2	2	2
Mo	1	1	1	1	1	1
Ni	160	160	160	160	170	160
Sb	0.8	0.3	0.7	5	8	3
Sc	50	43	43	35	39	42
Sn	2	1	1	1	1	1
Sr	21	53	68	140	170	90
V	260	220	230	230	230	230
W	3	7	<2	2	<2	3
Y	10	10	9	15	15	12
Zn	73	79	64	73	72	72
Zr	44	39	37	40	41	40
Ti/Zr	110	120	120	110	110	110

Note: Au, Sb and W contents determined by Neutron Activation Analysis
Fe and S quoted as Fe_2O_3 and SO_3 to facilitate comparison with oxidized rocks.

Table 12. Carbonate compositions, fresh mafic volcanics, Panglo (mol % cations)

Sample No	Carbonate type	Ca	Mg	Fe	Mn
108064	Dolomite	52.1	36.5	9.36	1.97
108066	Calcite	92.2	2.2	4.03	1.53
108066	Siderite	11.3	16.8	71.5	0.35
108071	Calcite	98.2	0.34	0.85	0.56
108071	Dolomite	49.2	46.0	3.42	1.35
Hunt Mine, Kambalda*	Calcite	93.7	3.2	2.36	0.74
Hunt Mine, Kambalda*	Dolomite	50.8	33.6	14.5	1.09

* Data from Neall and Phillips (1987)

Table 13. Trace element contents of minerals in ultramafic rocks, Panglo (ppm, unless otherwise indicated)

Mineral	Sample No.	Drill hole/ depth(m)	Cr	Ni	Cu	Zn	Sr	Ba
a) Silicates								
Vermiculite	38081	227:10-11	1800	480	230	<100	<100	<100
Chlorite	108062	232:127.5	2500	330	140	<100	<100	<100
	38125	227:53-54	3400	1100	270	250	<100	<100
	38466	231:60-61	2600	890	180	360	220	<100
	38472	231:66-67	1900	1100	150	410	<100	<100
Talc	108062	232:127.5	<100	560	200	<100	<100	<100
	38081	227:10-11	360	260	100	<100	<100	<100
	38125	227:53-54	240	410	<100	<100	<100	<100
	38466	231:60-61	<100	990	150	350	180	<100
	38472	231:66-67	<100	1000	<100	110	<100	<100
Kaolinite	38404	231:2-3	240	<100	<100	<100	<100	<100
	38466	231:60-61	190	<100	180	270	120	<100
b) Oxides								
Goethite	38081	227:10-11	8400					
	38125	227:53-54	8700					
	38404	231:2-3	4500					
	38466	231:60-61	4300					
Rutile	38081	227:10-11	3900					
	38125	227:53-54	4900					
	38404	231:2-3	500					
	38466	231:60-61	4200					
Ilmenite+	38466	231:60-61	180					
Mn ilmenite*	38081	227:10-11	160					
	38125	227:53-54	340					
	38466	231:60-61	340					
Pseudorutile	38081	227:10-11	730					
	38125	227:53-54	340					
	38404	231:2-3	330					
Spinel	38466	231:60-61	4.3%					

+ Mn content < 1 wt%

* Mn content > 4 wt%

Table 14. Trace element contents of minerals in mafic volcanics, Panglo (ppm, unless otherwise indicated)

(a) Silicates

Mineral	Sample No.	Drill hole/ depth(m)	Cr	Ni	Cu	Zn	Sr	Ba
Actinolite	108071	309:130.0	100	<100	<100	<100	<100	<100
Epidote	108071	309:130.0	<100	<100	120	<100	250	<100
Chlorite	108064	232:136.5	950	<100	<100	<100	<100	<100
	108066	306:128.5	230	<100	<100	150	<100	<100
	108071	309:130.0	1400	220	<100	190	<100	<100
Muscovite	38368	230:48-49	110	<100	170	260	120	890
	39153	238:48-49	<100	<100	120	<100	<100	6200
	39223	239:46-47	<100	<100	<100	<100	<100	680
	39235	239:56-57	310	<100	<100	<100	<100	1600
Paragonite	39131	238:27-28	<100	<100	130	280	120	150
	39153	238:48-49	<100	<100	180	<100	280	1000
Illite	38368	230:48-49	<100	<100	160	240	280	560
	39131	238:27-28	<100	<100	130	280	<100	270
Sphene	108071	309:130.0	220	<100	<100	<100	<100	<100
Kaolinite	39131	238:27-28	<100	<100	210	310	<100	160
	48225	309:42-43	<100	<100	<100	<100	<100	<100

(b) Oxides

Mineral		Sample No.	Drill hole/ depth(m)	Cr	V	Ni	Cu	Zn	Co	As	W
Ilmenite		108066	306:128.5	<100	-	-	-	-	-	-	-
Rutile		108064	232:136.5	1600	-	-	-	-	-	-	-
		108066	306:128.5	600	-	-	-	-	-	-	-
		38368	230:48-49	360	-	-	-	-	-	-	-
		39131	239:27-28	300							
		39235	239:56-57	570	-	-	-	-	-	-	-
		48225	309:42-43	210	-	-	-	-	-	-	
Spinel		38368	230:48-49	7700	-	-	-	-	-	-	-
Goethite	diss[1]	38021	226:20-21	300	100	250	210	480	330	2700	1200
	coll[1]	38021	226:20-21	<100	650	1400	3900	1600	560	1.03%	<100
	diss	38368	230:48-49	490	-	-	-	-	-	-	-
	diss[2]	39131	238:27-28	750	-	440	790	780	-	1900	-
	coll & diss[2]	39153	238:48-49	400	-	900	2500	600	-	3100	-
	diss[2]	39223	239:46-47	610	-	590	810	340	-	3200	-
	coll[3]	39235	239:56-57	160	-	450	390	270	-	1500	-
	diss[3]	39235	239:56-57	840	-	720	420	270	-	4900	-
	diss[2]	48247	309:62-63	580	-	340	2400	890	-	880	-
Hematite		39131[4]	238:27-28	790	-	220	440	760	-	2100	
		39223[4]	239:46-47	350	-	360	890	270	-	3700	-
Cryptomelane[5]		38021	226:20-21	-	-	5900	5200	2300	1.44%	-	<100
Lithiophorite		38021	226:20-21	-	-	1.75%	1.09%	1800	2.84%	-	<100

[1] Disseminated goethite: Mn = 0.09%; colloform goethite: Mn = 2.33%

[2] > 10 mol% Al in goethite

[3] Colloform goethite: Mn = 0.12%; disseminated goethite: Mn = 0.42%

[4] Low Al content in hematite: Sb ~ 110ppm

[5] Ba = 1.5% and Pb = 1000 ppm also present

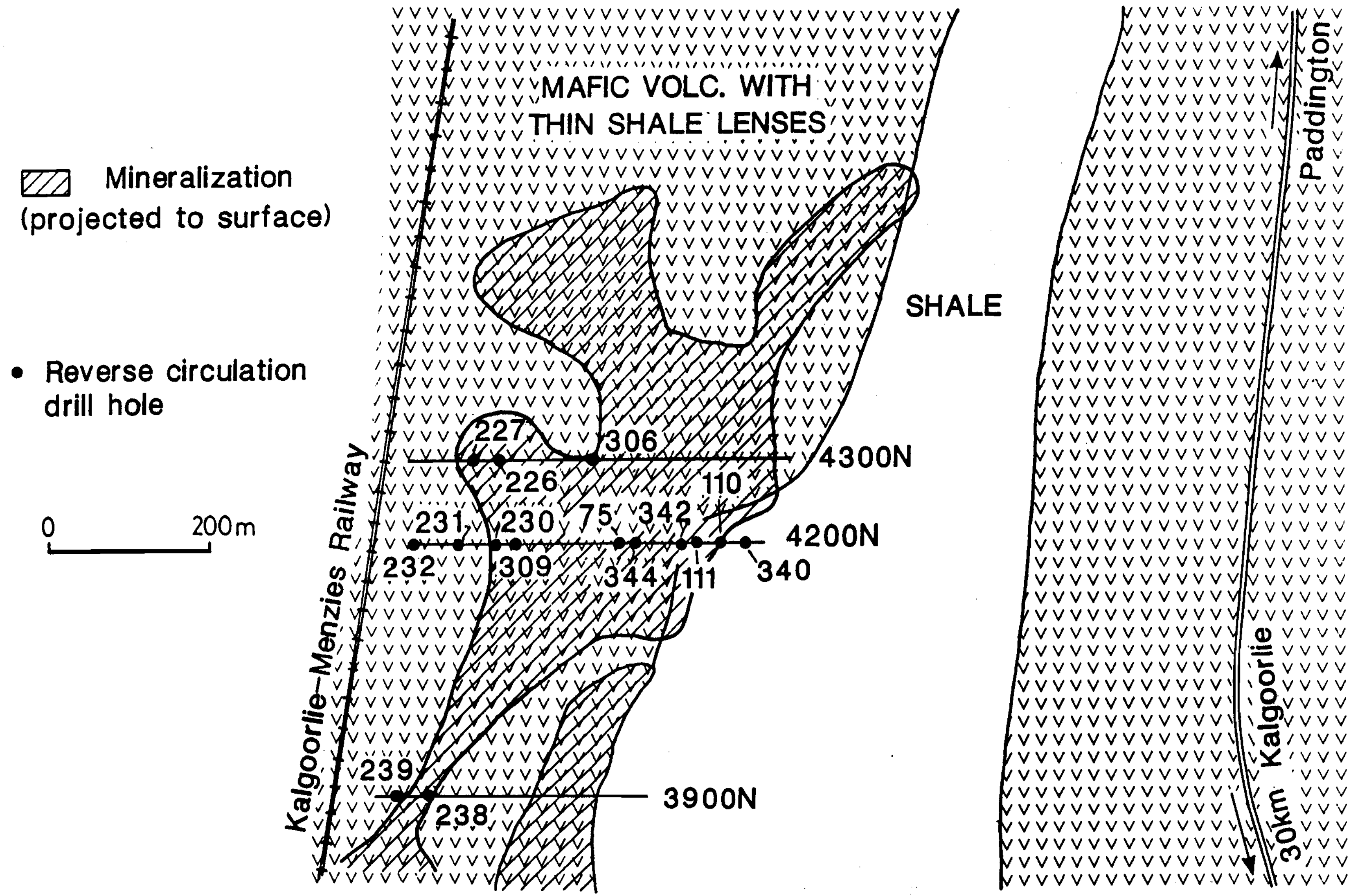


Fig 1. Location of sampled drill holes, Panglo (after mapping by Pancontinental Mining Ltd).

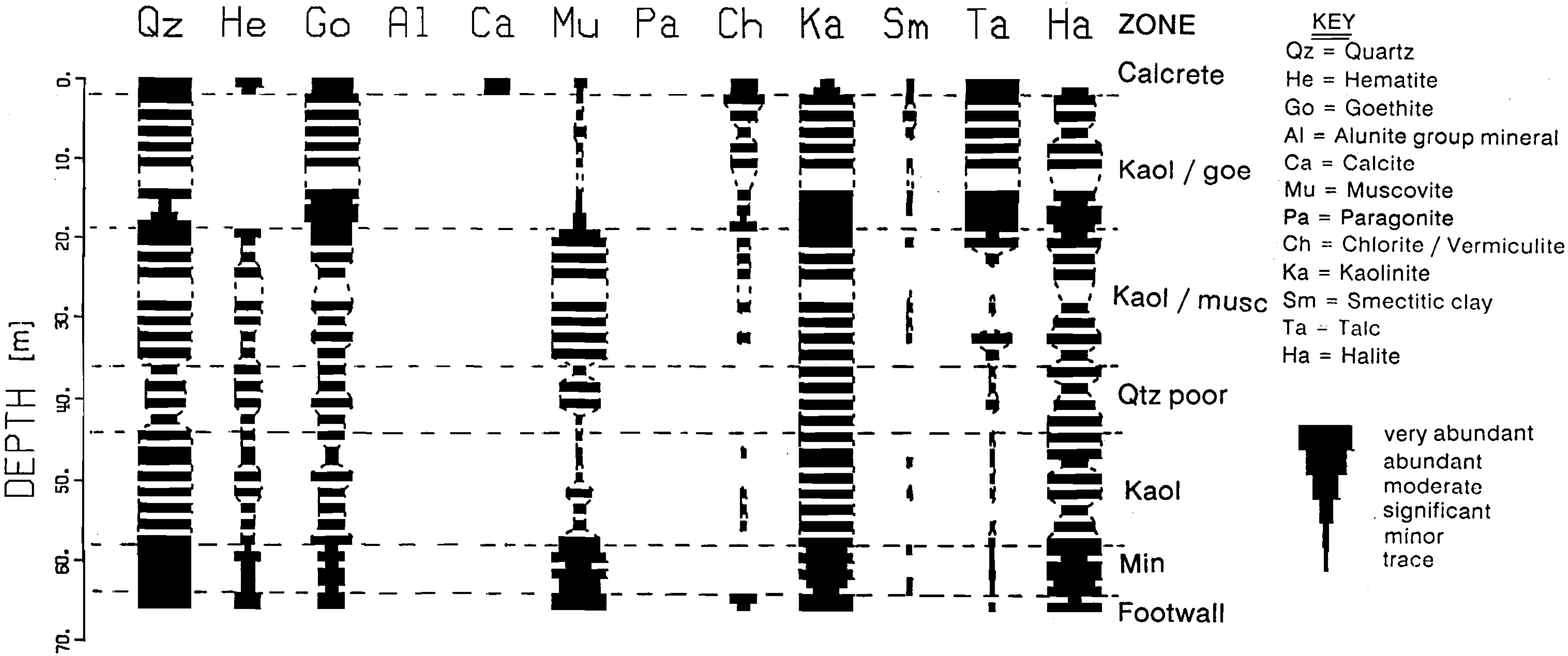


Fig 2. Mineralogical profile through poorly mineralized drill hole, PSRC 226.

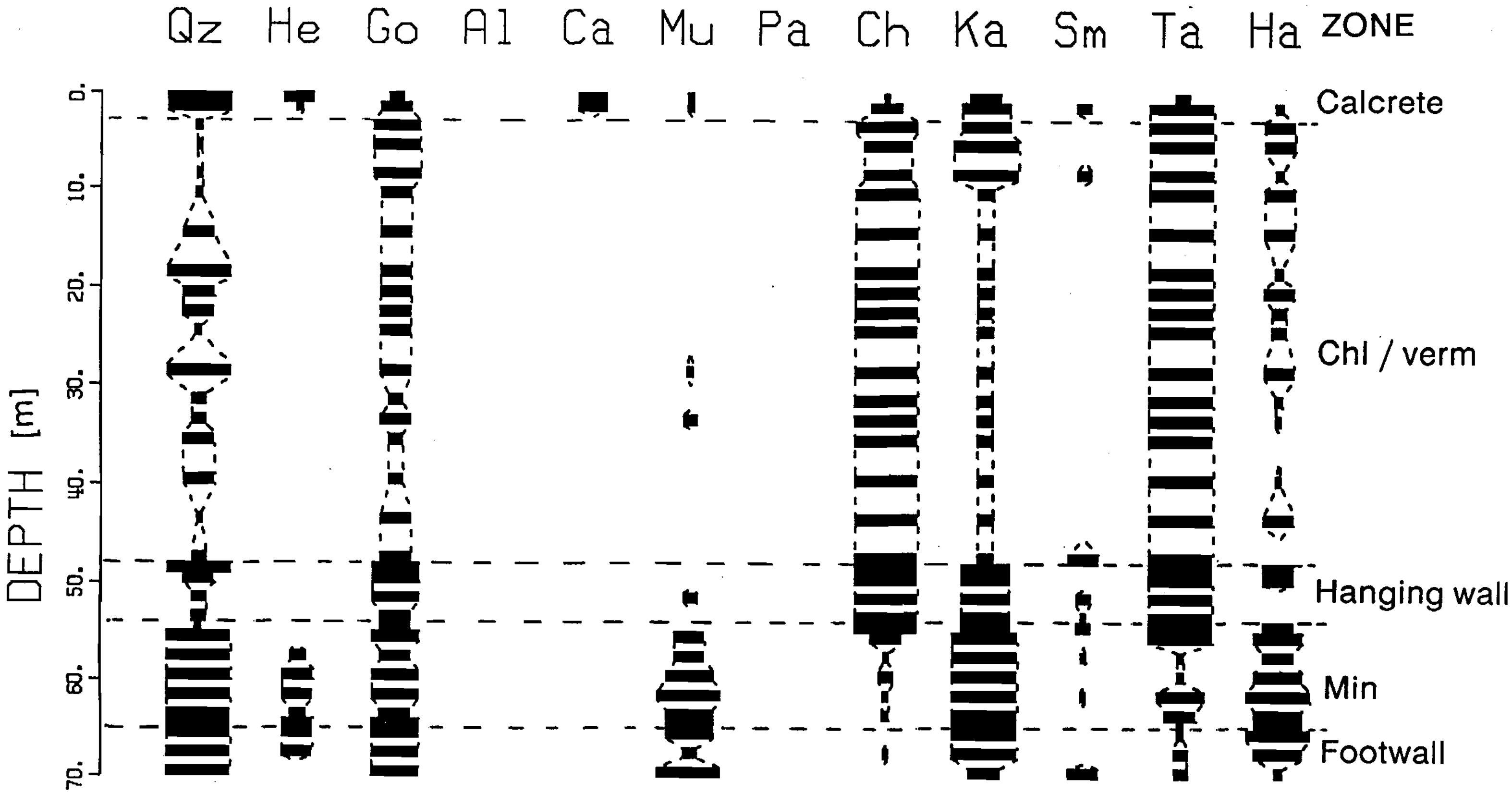


Fig 3. Mineralogical profile through mineralized drill hole, PSRC 227.

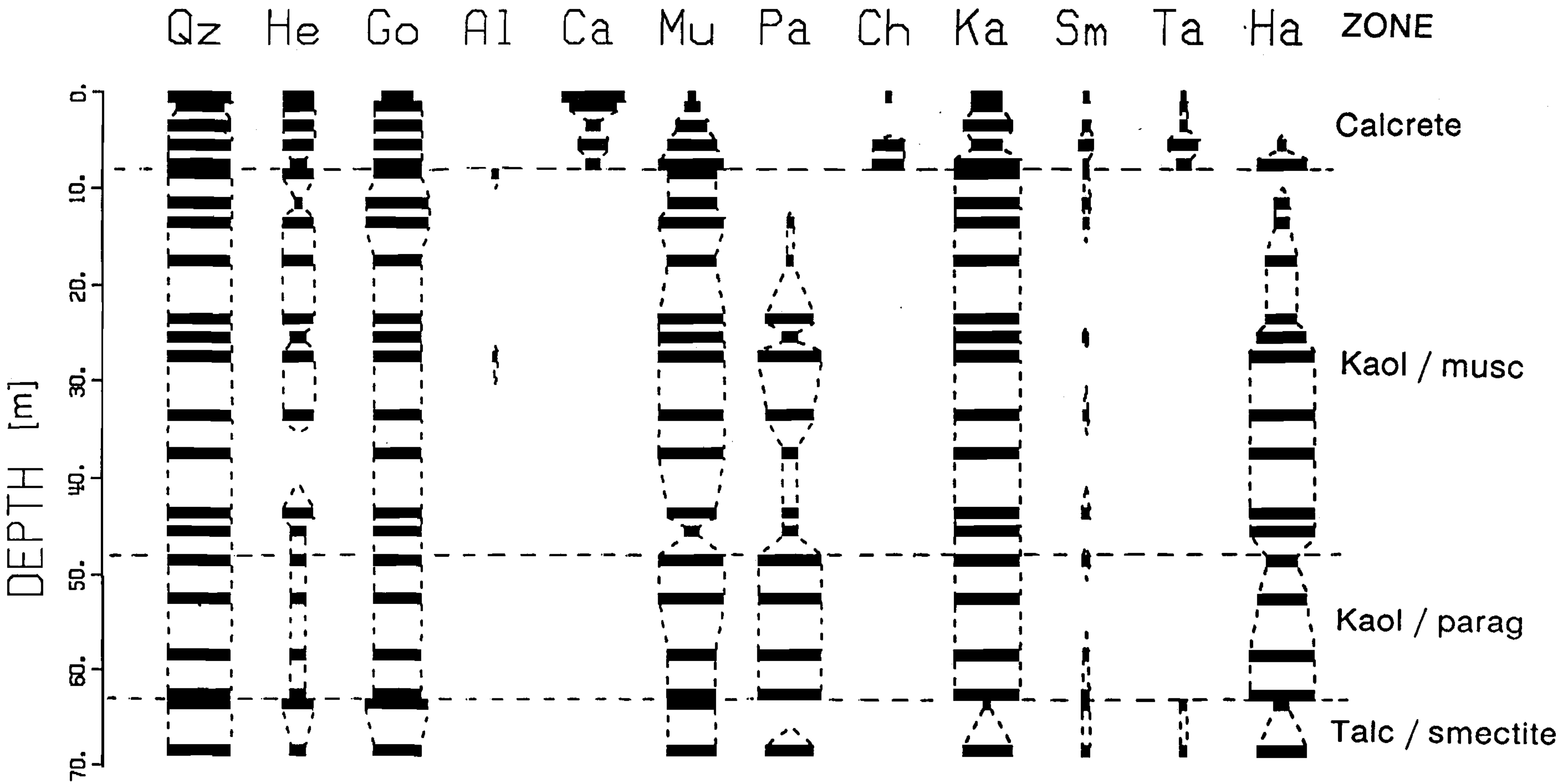


Fig 4. Mineralogical profile through barren drill hole, PSRC 238.

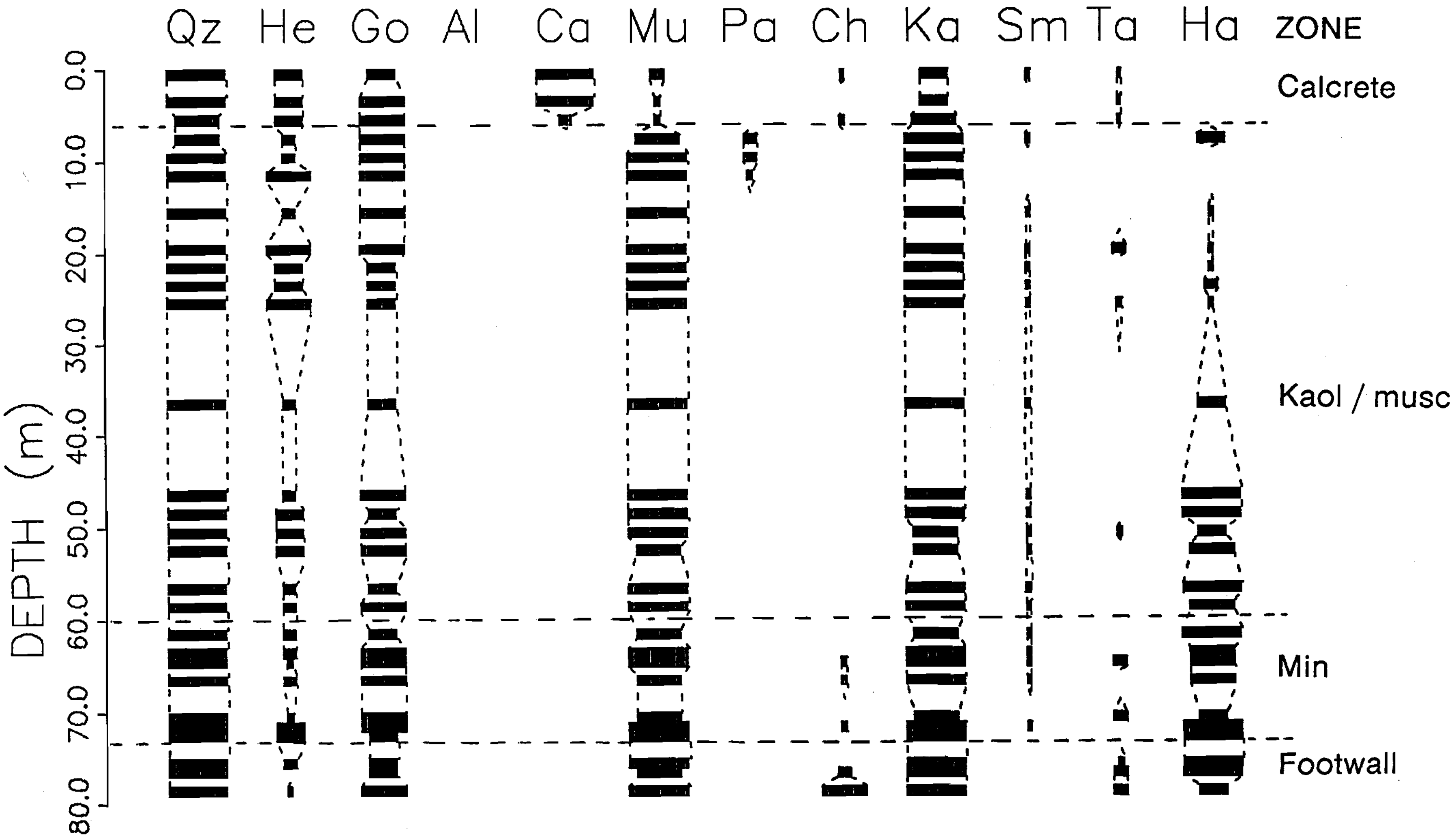


Fig 5. Mineralogical profile through mineralized drill hole, PSRC 239.

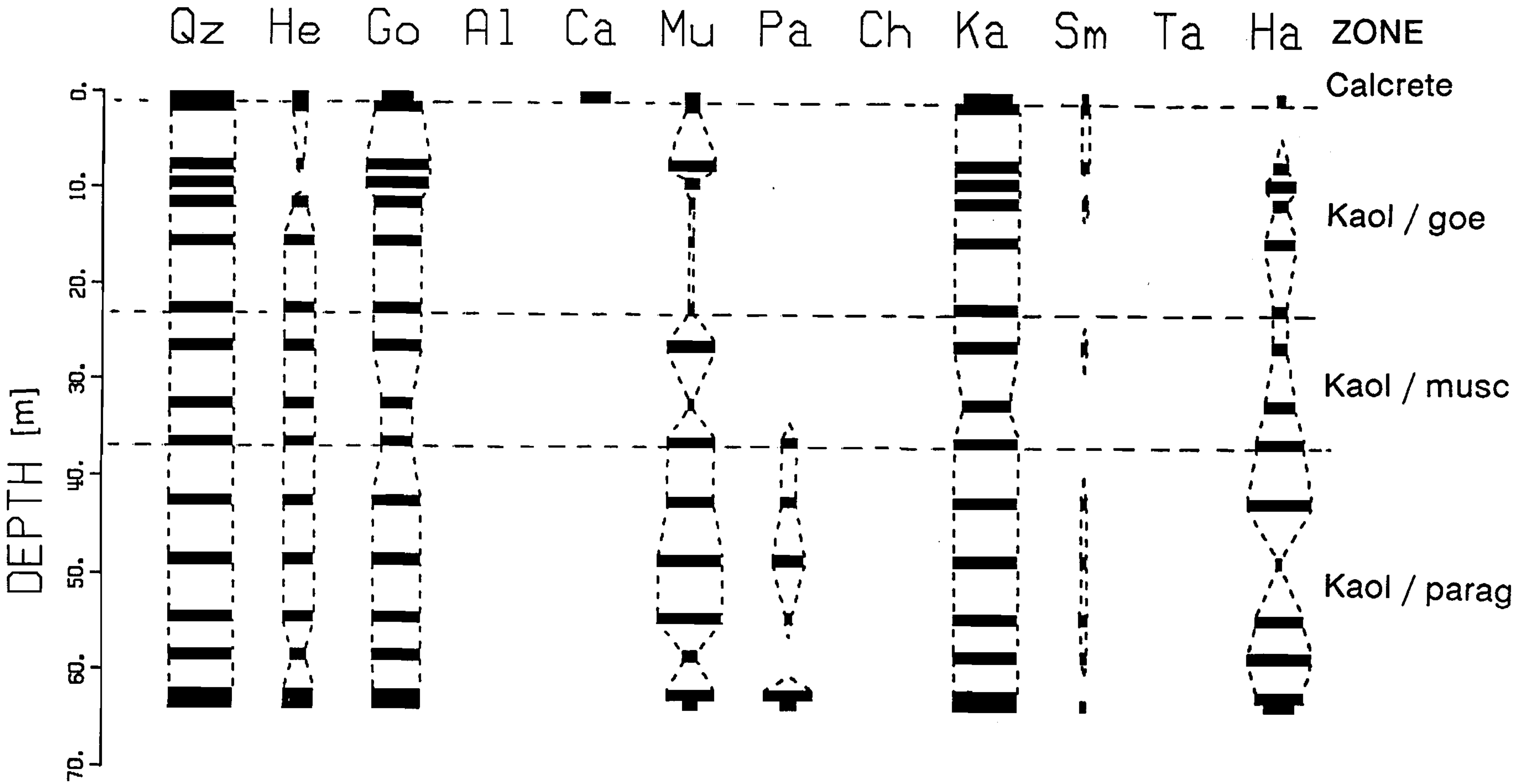
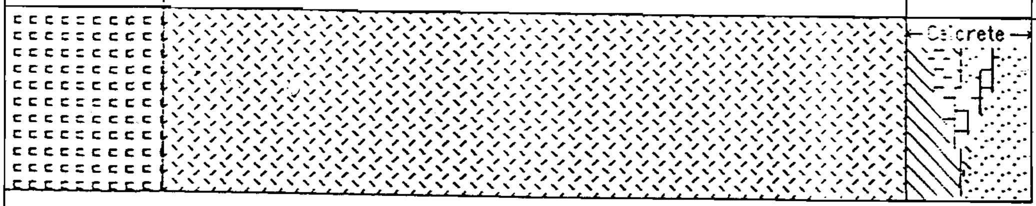
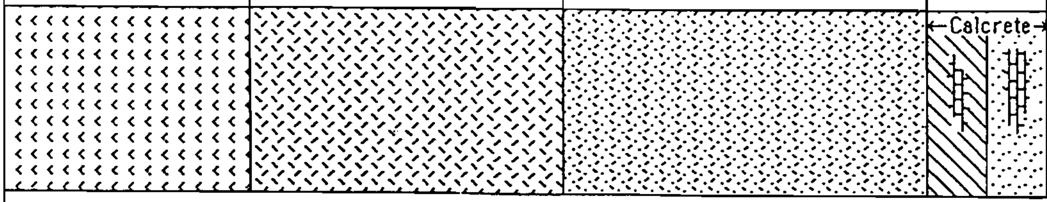


Fig 6. Mineralogical profile through barren drill hole, PSRC 309.



	Fresh Rock	Saprolite				Transported laterite	Soil
Thickness (m)		60-70				0.2-12.0	
Qtz	●	●	●	●	●	●	●
Calc						●	●
Dol	●						
Hem						●	●
Gte		●	●	●	●	●	●
Magh							●
Musc						●	●
Chl/V	●	●	●	●	●	●	
Talc	●	●	●	●	●	●	●
Kaol		●	●	●	●	●	●
Hal		●	●	●	●	●	
Colour	Grey	Khaki to brown	Khaki	Yellow to khaki	Yellow to lt brown	Brown-yellow	Brown
Cr ppm	-	2700	2200	2300	2400	2100	1100
Ni ppm	-	2300	1600	2400	1200	500	160
K_2O %	<0.1	<0.1	<0.1	<0.1	0.1	0.4	0.7
MgO %	19	17	18	18	11	4	1
Fe_2O_3 %	13	13	11	11	13	25	16

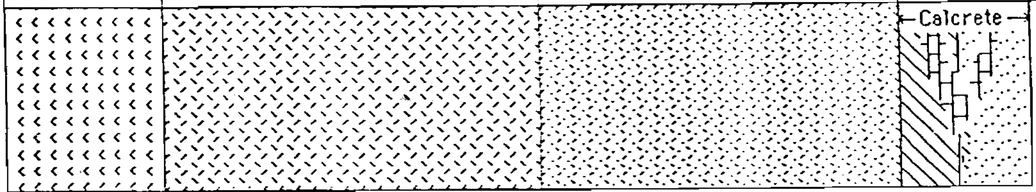
Fig.7. Idealized profile through ultramafic rocks, Panglo



Thickness (m)		20-30	aprox 40		0.2-12.0		
	Fresh Rock	Saprolite	Leached Saprolite		Transported laterite	Soil	
Qtz	●	●	●	●	●	●	Qtz
Plag	●					●	Plag
Calc	●				●	●	Calc
Dol							Dol
Hem		●	●	●	●	●	Hem
Goe		●	●	●	●	●	Goe
Magh						●	Magh
Musc	●	●	●	●	●	●	Musc
Parag						●	Parag
Chl/V	●		●		●	●	Chl/V
Talc		●	●		●	●	Talc
Kaol		●	●	●	●	●	Kaol
Smec				●	●	●	Smec
Amph	●					●	Amph
Pyrite							Pyrite
Hal	●	●	●	●			Hal
Colour	Grey	Dark brown to red	Dark Brown	Grey-brown	Red-brown	Brown	Colour
Cr ppm	180	260	300	400	660	320	Cr ppm
Au ppm	0.01	<0.01 to 3.0	<0.01	0.01	0.10	0.03	Au ppm
K_2O %	1.2	1.3	1.5	2.2	0.2	0.6	K_2O %
MgO %	5	0.5	0.5	0.3	0.7	1.5	MgO %
Fe_2O_3 %	9	15	17	19	40	17	Fe_2O_3 %

Fig. 8. Idealized profile through mafic volcanics (mineralized) Panglo

	Fresh Rock	Saprolite	Leached saprolite		Transported laterite	Soil
Thickness (m)		20-30	approx 40		0.2-10.0	



	Fresh Rock	Saprolite	Leached saprolite		Transported laterite	Soil
Qtz	●	●	●	●	●	●
Plag	●					●
Calc	●				●	●
Dol	●					
Hem		●	●	●	●	●
Goe		●	●	●	●	●
Magh						●
Musc		●	●	●	●	●
Parag		●	●			●
Chl/V	●				●	●
Talc	●	●			●	●
Kaol		●	●	●	●	●
Smec		●	●	●	●	●
Amph	●					●
Ep	●					
Halite		●	●	●	●	
Colour	Grey	Dark brown to brown	Dark Brown	Red brown	Brown	Brown
Cr ppm	170	240	230	500	700	320
K_2O %	<0.1	0.8	1.2	2.0	0.4	0.6
MgO %	7.0	0.5	0.3	0.3	0.6	1.3
Fe_2O_3%	11	14	18	30	38	16

Fig. 9. Idealized profile through mafic volcanics (barren) Panglo

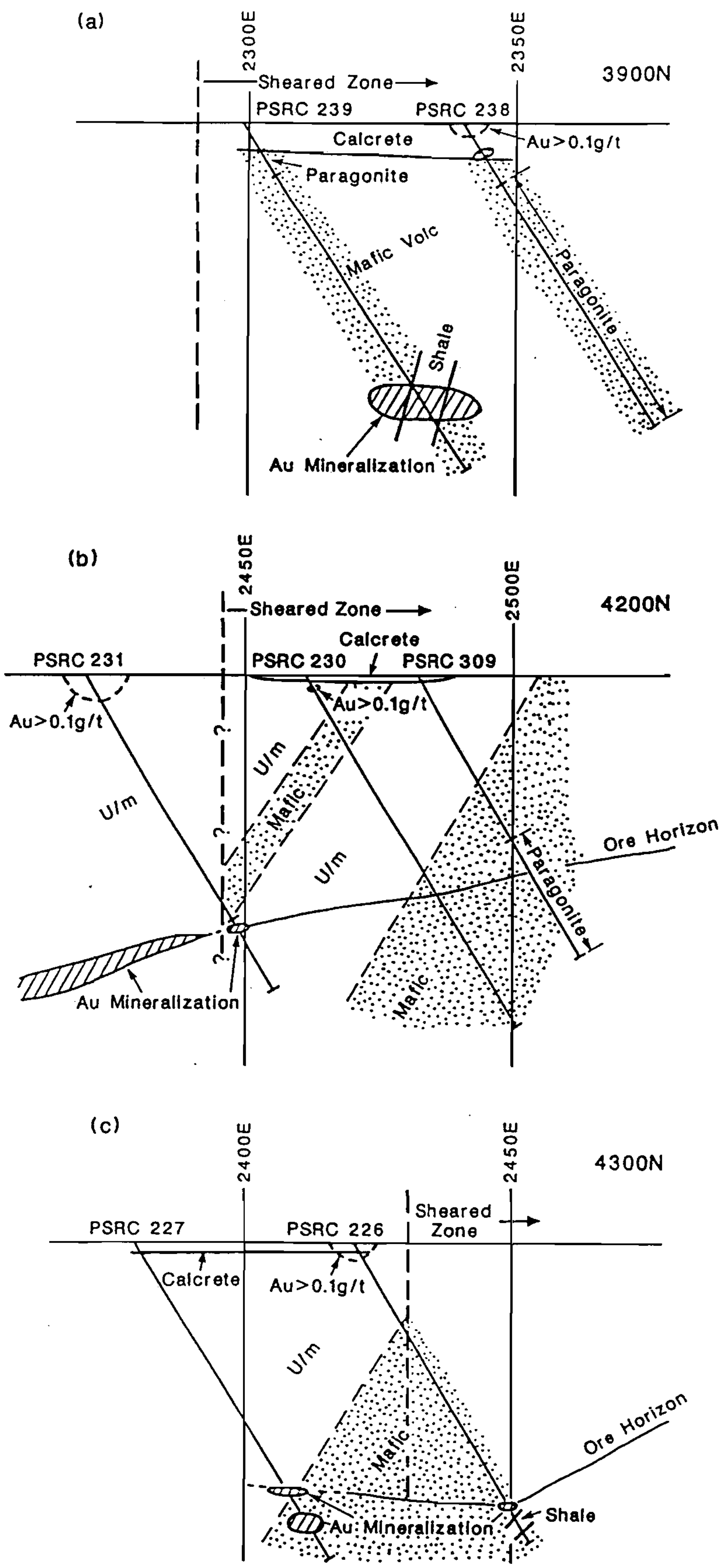


Fig 10 Sections through volcanics at 3900N, 4200N and 4300N, showing significant mineralogical zones and lithologies distinguished during study and locations of near surface gold anomalies > 0.1 g/t relative to mineralization (> 1 g/t) at depth.