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MINERALOGY AND GEOCHEMISTRY OF WEATHERED MAFIC/ULTRAMAFIC VOLCANICS FROM SECTION 4200N AT PANGLO, EASTERN GOLDFIELDS, WESTERN AUSTRALIA

K.M. Scott

CRC LEME OPEN FILE REPORT 14

September 1998

(CSIRO Division of Exploration Geoscience Report 42R, 1989.
Second impression 1998)

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

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

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

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

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

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

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

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

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

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

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

This report (CRC LEME Open File Report 14) is a first revision of CSIRO, Division of Exploration Geoscience Restricted Report 042R, first issued in 1989, which formed part of the CSIRO/AMIRA Project P241.

Copies of this publication can be obtained from:

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PREFACE

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

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

The objectives of this module are:

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

In particular this report (a) documents geochemical and mineralogical associations of gold present in weathered volcanics in the Eastern Goldfields at the Panglo gold deposit, (b) suggests several pathfinders for Au in both lateritic and supergene environments and (c) suggests geochemical discriminants for distinguishing mafic from ultramafic rocks.

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SUMMARY

A total of 62 samples derived from reverse circulation drilling through weathered volcanic sequences on the western edge of the Panglo gold deposit have been analysed chemically and mineralogically. On the basis of their Cr contents they have been classified as either mafic or ultramafic rocks. Higher Cr contents in the oxide phases, goethite, rutile and spinel, also appear to distinguish ultramafic from mafic rocks.

More extensive development of alunite and paragonite which characterize mineralized and barren shale profiles respectively (Scott, 1989a) are not present in the weathered volcanic profiles. However, near-surface Au enrichment (>0.05 ppm) in the volcanics is associated with elevated As and sometimes Mo, Sn and W contents. These elements plus Cu and Sb are also associated with sub-economic mineralization at depth. Thus similar pathfinders are present in both shale and volcanic sequences at Panglo.

1. INTRODUCTION

Changes in the mineralogy and geochemistry through weathered black shale profiles on the eastern edge of the Panglo gold deposit have been reported (Scott, 1989). That study found thicker sequences of alunite above mineralization than in equivalent rocks from barren profiles and more extensive development of paragonite adjacent to mineralization. Mo and Sb were found to be the best geochemical pathfinders for mineralization with As, Tl and W also recognized as useful.

This report details a similar study of samples from reverse circulation drilling through mafic-ultramafic volcanic sequences to the west along the same section (4200N) as the shale profiles (Fig. 1). A complimentary study of ultramafic-mafic sequences located 100 m to the north will be reported separately (Scott, 1990).

2. SAMPLES AND ANALYTICAL METHOD

The top 61 m of material from PSRC 230 and 69 m from PSRC 231 have been sampled. Logging of the holes suggested that, except for the initial 5 to 8 m of material from the holes, samples are weathered mafic volcanics (R.W. Howard, pers. comm., 1987). As both holes were drilled inclined 60° to the east, distances indicated in this report are distances along the drill holes rather than true depths below the surface.

Sixty-eight 1 m composites, prepared and analysed for Au by Pan-continental Mining Ltd., were analysed by X-ray diffractometry (XRD) and 62 of these were analysed chemically using the methods outlined by Scott (1989). However, the As, Ba, Rb, Sr and Zr contents reported herein have been determined by X-ray fluorescence spectrometry, using pressed powders.

Samples 38368 and 38466, representing mafic and ultramafic rocks respectively, have been studied using a Camebax wave-length dispersive electron microprobe to determine the compositions of specific silicate, oxide and residual sulfide phases. Silicates were analysed using a defocussed beam with a beam current of 20 nA and an accelerating voltage

of 15 kV and counting times of 20 seconds. Oxide and sulfide phases were counted at 20 nA, 20 kV using 20 second counting times. Trace elements were counted for 100 seconds at 50 nA, 20 kV, allowing abundances down to 100 ppm to be determined.

3. RESULTS

3.1 PSRC 230

The mineralogy and geochemistry of PSRC 230 is shown in Figure 2 and Tables 1 and 2 respectively.

In PSRC 230 the minerals, kaolinite, quartz, goethite and halite, occur in relatively similar amounts through the profile with variable amounts of muscovite, hematite and chlorite. The relative proportions of these latter minerals generally form the basis for defining the six mineralogical zones within the profile. The top metre is brown coloured and characterized by the presence of calcite and smectitic clay. Between 2 and 7 m samples are brown to dark brown and characterized by abundant muscovite and the presence of smectitic clays (Fig. 2). From 8 to 17 m the samples are consistently darker and contain less muscovite than above. A lower muscovite-rich zone (similar to the one between 2 and 7 m) occurs between 18 and 23 m. A thick dark brown zone with consistent development of hematite, relatively poor development of muscovite and intermittent development of chlorite and talc occurs between 24 and 44 m. From 45 to 61 m samples may be slightly lighter in colour and are distinguished from the zones above by their abundant muscovite and significant hematite and chlorite contents.

The calcite zone (0-1 m) is characterized by abundant Fe, Mg, Ca, As, Ba, Cr and Sr and low Al and Mn. The upper muscovite zone (2-7 m) has high Mo and W contents, anomalous Au and low Mn, Co, Ni and Zn contents. Within the kaolinite/goethite zone (8-17 m), K, As, Rb and Sr are low but in the underlying lower muscovite zone these elements are elevated to levels similar to those in the upper muscovite zone (Table 2). In the kaolinite/goethite/hematite zone (24-44 m) Co, Cr and Cu are high and As is low. The basal muscovite/chlorite zone (45-61 m) has high K, Mn, Ti, Cu, Zn and Zr.

3.2 PSRC 231

Mineralogical and geochemical compositions of PSRC 231 are shown in Fig. 3 and Tables 3 and 4 respectively.

In PSRC 231 the dominant minerals are again kaolinite, quartz, muscovite, goethite \pm hematite and halite but chlorite is much more abundant than in PSRC 230. The top 4 m of the profile is light brown in colour and contains abundant chlorite and smectitic clays. Between 5 and 17 m the rocks are darker than above (being brown to dark-brown) and contain more kaolinite and Fe oxides but less quartz, mixed layer clays and chlorite than in the uppermost zone. The rocks between 20 and 39 m are similar to those above except that quartz is more abundant and chlorite is more consistently developed (Fig.3). From 40 to 55 m the rocks tend to be slightly darker than above and have more abundant hematite and muscovite than the overlying zones. In the zone between 56 and 69 m the rocks are dark brown to brown-grey in colour. Chlorite is particularly abundant, smectitic clay and talc are often present with kaolinite, muscovite and hematite less abundant than immediately above. The upper 7 m of this chlorite-rich zone is poorly mineralized and tends to be slightly more grey in colour than the deeper unmineralized rocks.

The surface chloritic zone (0 to 4 m) has high Fe, Mg, As, Cr, slightly elevated Au content but low Mn and Cu contents. Quartz-poor rocks between 5 and 17 m have high Al, Fe, K, Ti, As, Ga, Sc and Zr but low Si. The kaolinite/goethite zone (20-39 m) has a high Sc content and particularly low Mg and As contents. Muscovite/kaolinite/goethite assemblages (40-55 m) are characterized by high Mn, Ba, Co, Cu and Y. The mineralized portion of the chloritic zone has high Mg, Na, Au, Cr, Mo and Ni and low Al, K and Sr. Unmineralized equivalents have a relatively similar geochemistry although Mg, As, Au, Cr, Ni and Mo are significantly lower than in the mineralized samples.

4. DISCUSSION

4.1 Lithologies within PSRC 230 and 231

Inspection of the data in Tables 1 and 3 reveals two samples with SiO_2 contents $>60\%$ - sample 38367 at 47-48 m (PSRC 230) and 38457 at 51-52 m (PSRC 231). The lack of observed quartz veining in these samples (R.W. Howard, pers. comm., 1987) suggests that the high silica content is not simply due to quartz. Whereas all other samples from the two profiles have $\text{Ti/Zr} > 70$, these two samples have lower values (Tables 1 and 3), implying that they are more felsic than the other samples (cf. Hallberg, 1984; Robertson & Gall, 1988) - sample 38457 possibly containing both mafic and felsic material.

Unfortunately Ti/Zr ratios are similar for both mafic and ultramafic rocks but high Cr contents may indicate ultramafic rocks provided Cr has not been extensively mobilized during weathering (Hallberg, 1984). Preliminary electron microprobe studies of Cr hosts in weathered mafic and ultramafic rocks indicate that significant Cr occurs mainly in chlorite, goethite, rutile, ilmenite and spinel (Table 5). Of these components only chlorite is likely to be substantially affected by weathering thus, provided Cr freed during the decomposition of chlorite is adsorbed onto/incorporated into Fe oxides, Cr would appear to be substantially retained during weathering at Panglo.

On the basis of $\text{Cr} > 700$ ppm (as recommended by Hallberg, 1984) the samples from 0-9 and 16-46 m in PSRC 230 and 1-6 and 54-69 m in PSRC 231 represent ultramafic rocks. Although the upper portions of each hole corresponds well with the interval identified during the initial logging of the drill holes, the deeper intervals were not so identified. Study of ultrabasic rocks from PSRC 226 and 227 show that abundant chlorite and talc persist to the surface (Scott, 1990). Whereas the PSRC 231 profile shows good correlation between Cr and chlorite (and, to a lesser extent talc) the Cr rich rocks in PSRC 230 do not generally contain substantial chlorite or talc (Figs. 2 and 3). Possibly the location of PSRC 230 within the more intensely weathered central shear zone at Panglo with the other holes being located outside the shear zone may explain the lower abundance of mafic phyllosilicates in this hole.

Higher abundances of the elements Mg, Ni and lower abundances of Sc, Sr, V and Y may distinguish fresh ultramafics from mafic rocks (e.g. Wang, 1988). However in the weathered sequences at Panglo only the Mg, Sc and Y contents are useful discriminants, especially in PSRC 231 where weathering is less intense than in PSRC 230.

The higher Cr contents in goethite, rutile and spinel from the ultramafic rock relative to equivalent minerals from the mafic rock and the higher Ni content of residual sulfides in the ultramafic rock also suggest a possible means of distinguishing individual weathered mafic and ultramafic rocks. However, the whole-rock chemical differences (discussed above) are, of course, less time consuming.

If the lithological differentiation above is correct, the presence of over 40 m of mafic rocks between bands of ultramafic rocks in PSRC 231 suggests that the mafic and ultramafic rocks are probably closely associated genetically. Thus in the following section, apart from excluding the rocks with felsic components, differences in lithology are ignored, with the elements Cr, Mg, Sc and Y which may reflect lithological differences generally not being considered further.

4.2 Mineralogical and geochemical zonation within weathered volcanics

Mineralogy and geochemistry generally correlate within the profiles. Thus elevated K, Ba and Rb contents in PSRC 230 characterize the muscovite-rich zones (Table 2) and high Mg and Cr in PSRC 231 define the chlorite-rich zones (Table 4) - Ba being seen to be concentrated in muscovite and illite and Cr within chlorite (Tables 5 and 6). On a smaller scale, elevated Mn contents occur associated with anomalous Ba, Co, Cu and Zn contents in some samples especially in the muscovite/kaolinite/goethite zone in PSRC 231 (Tables 3 and 4). Such associations suggest adsorption onto/incorporation into Mn oxide phases as in PSRC 226 (Scott, 1990), although such phases were not positively identified by XRD in these samples (probably due to poor crystallinity and overlap of Mn oxide diffraction peaks by kaolinite - see also Robertson and Gall, 1988).

Textural relationships reveal some of the weathering processes, e.g. kaolinite replacing chlorite (Fig. 5). The kaolinite retains some of the parent mineral's major components, i.e. Fe, Mg and Na (Table 6) as well as some of the trace components, e.g. Cu, Zn and Sr although others like Cr and Ni are substantially lost (Table 5). Mn freed during such decomposition of the chlorite may form the Mn oxides which appear to be developed in the muscovite/kaolinite/goethite zone above the mineralized chlorite zone in PSRC 231 (Fig. 3, Table 4).

Alunite which was particularly abundant in the shale sequences above mineralization and paragonite which was strongly developed laterally to mineralization (Scott, 1989a) are only poorly developed in the volcanics. They therefore cannot be used to discriminate between mineralized and unmineralized volcanic sequences. Furthermore the low grade of mineralization in PSRC 231 also makes difficult the recognition of any mineralogical association with Au. However, significant geochemical features in the profiles do exist (as discussed below).

In the near surface zones (calcite and upper muscovite zones, particularly in the top 3 m) of PSRC 230, anomalous Au contents occur (Tables 1 and 2). These occurrences are accompanied by slightly elevated As, Mo and sometimes W contents and lower Mn, Co, Cu, Ni, Sc and Zn contents than elsewhere in that drill hole. The top 6 m (i.e. the chloritic zone and top of the quartz-poor zone) of PSRC 231 also show elevated Au with high As, W and Sn and low Mn, Co, (?Cu) relative to the barren kaolinite/goethite and muscovite/kaolinite/goethite zones below (Tables 3 and 4).

Thus the volcanics show a general near surface enrichment in Au accompanied by elevated As and often Mo, Sn and W relative to barren rocks lower in the profile. However whether the occurrence of higher Au and As contents in PSRC 231 than in PSRC 230 can be specifically related to mineralization vertically below the former occurrence (Fig. 4) is not currently known. The presence of detectable Ca with the anomalous Au close to the surface could suggest an association of Au with calcrete, as found at the Peach Tree and Lady Gladys deposits (C.R.M. Butt, pers. comm. 1989).

In the chlorite-rich material below 55 m in PSRC 231 the low grade Au zone (56-63 m) has higher Mg, As, Ba, Cr, Cu, Ni, Zn and possibly Mo than the underlying barren material (Table 4). Of these elements Ba reflects the presence of muscovite in the upper part of the zone (cf Table 5, Fig. 3). The Mg, Cr, Ni and Zn could reflect greater chlorite development here (since all are abundant in chlorite; Table 5) or a more magnesian chlorite here than below. The elevated As, Cu and Mo in this zone and with accompanying detectable Sb for approximately 7 m and W for 5 m into the muscovite/kaolinite/goethite zone above (Table 3) suggests that these elements may form a dispersion halo about the Au zones at depth, as found in the shale sequences at Panglo (Scott, 1989).

5. CONCLUSIONS

The mafic and ultramafic rocks within PSRC 230 and PSRC 231 can be differentiated on the basis of their Cr contents. Other discriminants (Mg, Sc and Y) are also useful in PSRC 231 but not where weathering appears to be more intense as in PSRC 230. Preliminary electron microprobe studies suggest that higher Cr contents of the oxide phases, goethite, rutile and spinel and higher Ni content of residual sulfides may also distinguish ultramafic from mafic rocks.

No mineralogical differences between mineralized and barren sequences were recognized, possibly due in part to the low Au contents within these two sequences. Near-surface Au enrichment is associated with As and sometimes Mo, Sn and W. Deeper in the profile in PSRC 231, elevated As, Cu and Mo occur with Au with Sb and W occurring for about 5 m above. Thus similar geochemical pathfinders for Au are present in both shale and volcanic sequences at Panglo.

6. RECOMMENDATIONS FOR FURTHER WORK

(1) Further electron microprobe studies should be done to determine the compositions of oxides and the chlorite in the unmineralized chloritic zone at the base of PSRC 231 to determine whether there are any significant differences between mineralized and barren rocks having similar mineralogy.

(2) Because of the common occurrence of felsic rocks in the mines of the Eastern Goldfields, the compositions of minerals in the felsic rock 38367 (PSRC 230: 47-48 m) should be determined and compared with equivalent minerals from the mafic/ultramafic rocks.

(3) Compositions of Mn oxides should be determined to verify their Ba, Co, Cu and Zn associations postulated above.

7. ACKNOWLEDGEMENTS

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Table 1. Chemical composition of samples, drill hole PSRC 230 (majors, wt%; minors, ppm).

	38317	38319	38321	38323	38325	38329	38331	38333	38335	38337	38339	38341	38343	38345	38347	38349
Depth (m)	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31
SiO ₂	50.0	57.5	53.7	49.1	53.6	54.0	55.1	50.9	50.0	51.8	54.0	50.6	50.4	47.7	50.8	51.7
Al ₂ O ₃	11.8	15.7	19.7	22.2	20.3	19.5	19.8	19.7	21.2	21.2	20.1	21.6	21.8	21.6	22.0	21.7
Fe ₂ O ₃	20.4	15.2	12.5	13.4	12.7	13.6	13.4	14.6	15.0	13.0	12.1	13.3	13.9	15.1	13.5	13.0
MgO	1.18	0.31	0.34	0.30	0.14	0.17	0.19	0.21	0.18	0.31	0.48	0.22	0.18	0.19	0.20	0.19
CaO	2.15	0.09	<0.04													
Na ₂ O	0.96	0.74	0.90	1.05	0.87	0.81	0.87	0.90	0.87	0.87	1.06	0.97	1.06	0.94	1.00	1.02
K ₂ O	0.75	0.64	1.69	1.08	0.15	0.11	0.09	0.18	0.29	1.24	2.69	0.76	0.39	0.13	0.09	0.27
TiO ₂	0.63	0.77	0.62	0.69	0.68	0.86	0.75	0.82	0.79	0.64	0.68	0.83	0.67	0.68	0.66	0.66
MnO	0.05	<0.04	0.05	0.09	0.08	0.12	0.26	0.86	0.22	0.31	0.26	0.24	0.23	0.34	0.29	0.19
SO ₃	0.12	<0.1	0.10	0.12	0.12	0.12	0.13	0.13	0.15	0.11	0.12	0.15	0.13	0.12	0.12	0.12
Ag	<0.1							0.8	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1
As	130	61	110	97	35	14	<10	27	68	79	93	83	31	35	28	28
Au	0.06	0.21	0.03	<0.01												
Ba	410	290	250	170	43	47	110	380	92	280	1140	210	120	61	30	79
Co	10	<5	6	7	7	7	8	47	15	58	23	40	43	110	48	21
Cr	1330	1030	850	730	1140	620	530	430	710	720	800	790	890	920	730	850
Cu	97	38	74	98	86	100	130	100	110	97	72	100	110	84	93	100
Ga	25	25	20	20	25	30	25	20	25	25	20	30	40	30	25	25
Ge	2	2	2	2	2	2	2	2	3	2	2	2	3	2	3	3
Mo	7	4	20	8	5	3	3	3	2	5	1	5	2	3	2	4
Ni	170	52	83	110	91	100	100	63	130	190	130	180	170	140	190	210
Rb	25	17	35	26	7	6	5	7	8	28	62	19	13	6	5	11
Sc	28	29	36	44	42	44	40	50	40	41	46	48	40	43	39	47
Sn	4	4	3	2	3	3	2	2	3	2	2	2	3	3	2	2
Sr	38	18	24	14	8	9	9	16	9	24	34	19	13	10	10	15
Y	4	2	2	2	3	6	4	5	4	5	4	4	3	4	3	4
W	<10	40	10	50	50	<10										
Zn	79	23	38	48	56	60	58	52	120	100	160	86	66	150	83	100
Zr	55	38	29	39	33	54	37	42	38	33	33	110	35	32	37	38
Ti/Zr	70	120	130	110	120	100	120	120	130	120	120	130	120	130	110	100

Note P₂O₅ < 0.1% except 38367 where P₂O₅ = 0.15%. Bi <3, Pb <50, Sb <30, Tl <3 ppm.

Table 1 (Cont'd)

	38350	38353	38355	38357	38359	38361	38363	38365	38367	38369	38371	38373	38375	38377	38379	38381	
Depth (m)	31-32	33-34	35-36	37-38	39-40	41-42	43-44	45-46	47-48	49-50	51-52	53-54	55-56	56-57	58-59	60-61	
SiO ₂	51.4	51.2	50.4	53.1	51.9	52.2	55.2	51.8	65.3	54.5	50.5	48.0	46.6	51.5	49.9	51.9	
Al ₂ O ₃	22.1	22.1	23.5	21.3	20.8	20.5	17.3	19.7	8.11	18.8	20.6	20.8	21.9	17.4	22.6	22.3	
Fe ₂ O ₃	13.4	12.5	12.6	13.6	13.5	14.2	15.5	15.1	17.9	14.0	15.8	17.7	18.0	17.7	14.6	12.8	
MgO	0.19	0.36	0.17	0.17	0.19	0.20	0.24	0.24	0.19	0.35	0.29	0.25	0.25	0.30	0.25	0.25	
CaO	<0.04																
Na ₂ O	0.98	1.43	0.82	0.74	0.94	0.77	0.71	1.02	0.28	0.89	0.78	0.61	0.71	1.08	0.86	0.90	
K ₂ O	0.24	1.02	0.46	0.13	0.20	0.05	0.05	0.48	1.65	2.00	1.20	1.22	0.91	1.34	1.98	2.10	
TiO ₂	0.74	0.76	0.77	0.70	0.68	0.75	0.68	0.77	0.36	1.03	1.23	1.30	1.46	0.99	1.55	1.44	
MnO	0.22	0.21	0.36	0.28	0.23	0.21	0.55	0.32	0.66	0.25	0.31	0.38	0.48	0.51	0.21	0.28	
SO ₃	<0.1	0.16	<0.1					0.10	0.12	0.10	<0.1				0.18	<0.1	<0.1
Ag	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.8	0.2	0.1	0.2	0.2	0.3	0.1	0.1	
As	16	45	28	26	29	19	100	91	68	45	14	54	68	58	91	250	
Au	<0.01																
Ba	110	320	180	81	86	20	73	200	540	130	130	120	110	180	140	150	
Co	38	46	76	85	68	73	210	98	220	67	54	53	44	82	19	37	
Cr	890	730	850	840	950	1010	1390	1180	370	250	250	280	230	390	290	280	
Cu	120	110	140	180	130	130	250	270	360	210	170	150	120	200	110	100	
Ga	30	30	30	30	30	25	20	25	20	30	30	30	40	25	50	40	
Ge	3	3	2	4	2	4	2	3	2	2	2	2	2	2	2	2	
Mo	2	8	4	8	15	7	6	20	8	6	10	2	3	5	3	2	
Ni	190	190	210	320	250	210	630	400	200	130	170	170	150	170	150	140	
Rb	11	21	13	6	7	<5	<5	14	38	43	27	29	24	31	48	52	
Sc	50	49	57	51	49	56	50	56	37	61	59	64	56	54	52	49	
Sn	2	2	2	2	2	2	3	2	3	2	1	2	2	2	2	2	
Sr	13	19	18	12	12	11	16	14	31	23	24	24	26	30	38	35	
Y	4	4	6	7	7	7	9	8	10	6	7	6	6	8	4	6	
W	<10									15	<10						15
Zn	150	110	97	170	130	120	360	190	730	380	190	300	180	380	270	160	
Zr	36	40	55	35	32	43	55	40	52	75	80	78	87	66	77	76	
Ti/Zr	120	110	80	120	130	110	70	120	40	80	90	100	100	90	120	110	

Table 2. Average values for zones within PSRC 230 (majors, wt%; minors, ppm)

Zone Depth (m) No. of Samples	Calcite 0-1 1	Upper musc 2-7 3	Kaol/goe 8-17 5	Lower musc 18-23 3	Kaol/goe/hem 24-44 11	Musc/chl 45-61 8*
SiO ₂	50.0	53.4	52.7	52.1	51.6	50.6
Al ₂ O ₃	11.8	19.2	20.1	21.0	21.3	20.5
Fe ₂ O ₃	20.4	13.7	13.9	12.8	13.7	15.7
MgO	1.18	0.32	0.18	0.34	0.19	0.27
CaO	2.15	0.04	<0.04	<0.04	<0.04	<0.04
Na ₂ O	0.96	0.90	0.86	0.97	0.95	0.86
K ₂ O	0.75	1.14	0.16	1.56	0.28	1.40
TiO ₂	0.63	0.69	0.78	0.72	0.70	1.22
MnO	0.05	0.05	0.31	0.27	0.28	0.34
SO ₃	0.12	<0.1	0.13	0.13	<0.1	<0.1
Ag	<0.1	<0.1	0.2	0.2	0.1	0.2
As	130	89	30	85	35	84
Au	0.06	0.08	<0.01	<0.01	<0.01	<0.01
Ba	410	240	130	540	110	150
Co	10	5	17	40	74	57
Cr	1330	870	690	770	910	390
Cu	97	70	110	90	130	150
Ga	25	22	25	25	29	34
Ge	2	2	2	2	3	2
Mo	7	11	3	4	6	6
Ni	170	82	97	170	230	190
Rb	25	26	7	36	9	34
Sc	28	36	43	45	48	56
Sn	4	3	3	2	2	2
Sr	38	19	10	26	14	27
W	<10	33	14	<10	<10	<10
Y	4	2	4	4	5	6
Zn	79	36	69	120	130	260
Zr	55	35	41	33	40	72

*Sample 38367 omitted from average

Note: P₂O₅ < 0.1%; Bi < 3, Pb < 50, Sb < 30, Tl < 3 ppm

Table 3. Chemical composition of samples, drill hole PSRC 231 (majors, wt%; minors, ppm)

	38401	38403	38405	38407	38409	38411	38415	38418	38422	38424	38430	38432	38436	38437	38439
Depth (m)	0-1	1-2	3-4	5-6	7-8	9-10	13-14	16-17	20-21	22-23	26-27	28-29	31-32	32-33	34-35
SiO ₂	48.9	51.4	33.6	32.8	32.8	33.3	32.2	34.8	49.7	50.8	52.1	50.1	49.0	46.8	51.3
Al ₂ O ₃	20.6	16.0	25.6	27.7	28.5	27.7	27.1	26.6	20.0	19.4	20.1	21.2	21.3	21.4	19.4
Fe ₂ O ₃	15.2	20.2	25.2	22.5	20.4	21.4	23.2	21.6	17.1	16.8	14.7	15.5	16.3	16.9	17.3
MgO	5.30	0.57	0.48	0.37	0.32	0.31	0.37	0.35	0.28	0.18	0.29	0.22	0.25	0.40	0.29
CaO	<0.04	0.21	0.07	<0.04											
Na ₂ O	0.67	0.70	1.00	1.17	1.09	1.35	1.18	1.16	0.90	0.81	0.92	0.90	0.78	1.02	0.85
K ₂ O	1.07	0.18	1.11	1.24	1.18	0.84	1.65	1.00	0.82	0.20	0.71	0.66	0.68	0.87	1.05
TiO ₂	1.37	0.52	0.84	0.76	1.41	1.66	1.73	1.70	1.41	1.43	1.31	1.40	1.36	1.36	0.86
MnO	0.08	0.05	0.08	0.05	0.06	0.09	0.17	0.13	0.09	0.13	0.20	0.17	0.18	0.20	0.34
SO ₃	<0.1	0.15	0.13	0.13	0.27	0.14	0.14	0.16	0.10	0.12	0.11	<0.1	<0.1	0.11	<0.1
Ag	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2
As	73	530	390	400	400	200	290	260	26	14	18	<10	20	49	99
Au	<0.01	0.26	0.12	0.24	<0.01	<0.01	<0.01	0.04	0.01	0.02	0.03	0.02	0.01	<0.01	<0.01
Ba	64	210	260	140	160	62	180	110	70	24	94	80	120	170	280
Co	23	13	22	18	22	36	17	14	9	14	37	25	32	30	74
Cr	300	2460	2220	1940	510	370	320	270	270	330	250	270	260	300	240
Cu	71	58	41	83	130	140	140	140	83	150	130	120	120	110	160
Ga	40	25	30	30	40	40	50	50	40	30	40	30	40	40	30
Ge	3	5	7	5	3	4	4	2	2	1	2	2	3	4	3
Mo	5	6	2	1	0.3	2	2	2	5	8	3	8	6	5	3
Ni	190	310	300	260	220	510	330	180	110	190	190	230	160	190	280
Rb	31	11	31	32	29	23	38	25	23	8	21	19	21	25	29
Sb	<30														
Sc	52	20	41	42	64	52	58	66	52	61	59	58	61	56	55
Sn	2	7	6	5	2	2	2	2	2	2	2	2	2	2	2
Sr	17	20	14	12	46	13	17	13	17	13	19	16	14	14	13
Y	10	3	5	5	8	10	10	8	11	8	9	8	7	7	8
W	<10	100	<10	15	<10	<10	<10	<10	15	<10	<10	<10	15	15	<10
Zn	240	30	50	150	250	210	87	130	60	120	85	100	89	130	170
Zr	80	44	62	57	79	87	89	84	80	78	68	74	70	89	50
Ti/Zr	100	70	80	80	110	110	120	120	110	110	120	110	120	90	100

Note: P₂O₅ < 0.1% except 38424 and 38430 where P₂O₅ = 0.12 and 0.11% respectively. Bi < 3, Pb < 50, Tl < 3 ppm

Table 3 continued

	38443	38445	38447	38451	38453	38455	38457	38460	38462	38464	38466	38468	38470	38472	38474
Depth (m)	38-39	40-41	42-43	45-46	47-48	49-50	51-52	54-55	56-57	58-59	60-61	62-63	64-65	66-67	68-69
SiO ₂	49.0	49.3	49.7	53.4	50.7	51.2	60.4	56.0	56.8	53.2	49.6	51.1	57.0	53.5	53.1
Al ₂ O ₃	18.8	21.3	19.6	18.5	19.5	18.3	15.6	14.3	15.4	11.2	11.4	14.0	14.0	14.1	16.3
Fe ₂ O ₃	19.3	15.6	16.3	15.3	16.6	16.9	11.4	15.5	14.5	14.1	15.0	14.7	15.2	14.2	14.1
MgO	0.40	0.42	0.39	0.35	0.38	0.41	0.48	0.61	1.23	8.49	10.4	6.35	1.67	6.10	3.01
CaO	<0.04														
Na ₂ O	1.13	0.97	1.13	1.28	1.28	1.17	1.47	1.90	1.47	1.21	1.52	1.59	1.71	1.39	1.74
K ₂ O	0.38	1.48	1.00	0.65	0.24	0.81	1.15	0.54	0.76	0.05	0.05	0.33	0.04	0.09	0.58
TiO ₂	0.92	0.98	0.93	0.90	0.93	0.87	0.67	0.74	0.75	0.54	0.59	0.73	0.58	0.57	0.73
MnO	0.33	0.73	0.79	0.41	0.46	0.95	0.25	0.35	0.27	0.24	0.17	0.23	0.29	0.27	0.24
SO ₃	0.12	<0.1	0.12	0.13	0.11	0.11	0.12	0.19	0.13	<0.1	<0.1	0.13	0.16	0.11	0.13
Ag	0.2	0.5	0.2	0.1	0.1	0.8	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.7
As	73	200	120	<10	25	80	78	200	140	140	240	150	170	110	92
Au	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.12	0.23	0.48	0.36	0.08	0.13	0.06
Ba	55	410	330	110	100	440	450	150	260	31	26	120	24	49	130
Co	78	190	160	88	83	160	74	120	110	100	82	84	97	91	75
Cr	280	260	210	270	300	330	440	970	1060	1830	2630	1560	900	1380	980
Cu	160	1250	160	130	120	180	130	130	140	81	100	100	92	68	86
Ga	30	25	20	25	25	25	25	20	25	20	20	20	20	20	20
Ge	4	2	2	3	2	3	2	2	2	2	2	2	2	2	2
Mo	5	6	6	6	3	6	6	4	8	6	7	5	6	3	6
Ni	370	290	280	210	160	260	220	450	470	790	770	640	440	600	340
Rb	12	38	24	18	8	22	31	17	22	8	9	14	5	10	20
Sb	<30					50	30	40	<30						
Sc	48	58	54	52	51	54	42	45	44	35	36	41	35	31	37
Sn	2	1	1	2	2	3	2	4	3	8	8	4	4	5	5
Sr	11	16	16	19	12	26	15	15	11	10	11	10	15	13	16
Y	7	9	13	11	13	16	10	12	10	4	4	7	5	4	6
W	<10	25	20	<10	<10	<10	15	15	15	<10	<10	<10	10	<10	<10
Zn	130	820	100	69	39	86	110	120	160	120	130	140	83	120	120
Zr	77	53	47	67	51	41	65	37	46	25	28	40	30	29	43
Ti/Zr	70	110	130	80	110	130	60	120	100	130	130	110	110	120	100

Table 4. Average values for zones within PSRC 231 (majors, wt%; minors, ppm)

Zone Depth (m) No. of Samples	Chlorite 0-4 3	Qtz-poor 5-17 5	Kaol/goethite 20-39 8	Musc/kaol/goe 40-55 6*	Chl(min) 56-63 4	Chlorite 64-69 3
SiO ₂	44.6	33.2	49.9	51.7	52.7	54.5
Al ₂ O ₃	20.7	27.5	20.2	18.6	13.0	14.8
Fe ₂ O ₃	20.2	21.8	16.7	16.0	14.6	14.5
MgO	2.12	0.34	0.29	0.43	6.62	3.59
CaO	0.10	<0.04	<0.04	<0.04	<0.04	<0.04
Na ₂ O	0.79	1.19	0.91	1.29	1.45	1.61
K ₂ O	0.82	1.18	0.67	0.79	0.30	0.24
TiO ₂	0.91	1.45	1.26	0.89	0.65	0.63
MnO	0.07	0.10	0.21	0.62	0.23	0.27
SO ₃	0.11	0.17	<0.1	0.12	<0.1	0.13
Ag	0.2	0.1	0.2	0.3	0.1	0.3
As	330	310	38	110	170	91
Au	0.13	0.06	0.02	<0.01	0.30	0.09
Ba	180	130	110	260	110	68
Co	19	21	37	130	94	88
Cr	1660	680	280	390	1770	1090
Cu	57	130	130	330	110	82
Ga	32	42	35	23	21	20
Ge	5	4	3	2	2	2
Mo	4	1.5	5	5	7	5
Ni	270	300	220	280	670	460
Rb	24	29	20	21	13	12
Sc	38	56	56	52	39	34
Sn	5	3	2	2	6	5
Sr	17	20	15	17	11	15
W	37	<10	<10	18	<10	<10
Y	6	8	8	12	6	5
Zn	110	170	110	210	140	110
Zr	62	79	73	49	35	34

*Sample 38457 omitted from average

Note: P₂O₅ < 0.1%; Bi < 3, Pb < 50, Sb < 30, Tl < 3 ppm

Table 5. Trace element contents of minerals within mafic and ultramafic rocks, Panglo (ppm unless otherwise indicated)

Mineral	Sample No.	Rock Type	Cr	Ni	Cu	Zn	Sr	Ba
Chlorite	38466	U/m	2600	890	180	360	220	<100
Talc	38466	U/m	<100	990	150	350	180	<100
Muscovite	38368	m	110	<100	170	260	120	890
Illite	38368	m	<100	<100	160	240	280	560
Kaolinite	38466	U/m	190	<100	180	270	120	<100
Goethite	38368	m	490	-	-	-	-	-
Goethite	38466	U/m	4300	-	-	-	-	-
Rutile	38368	m	360	-	-	-	-	-
Rutile	38466	U/m	4200	-	-	-	-	-
Ilmenite	38466	U/m	180	-	-	-	-	-
Mn-ilmenite	38466	U/m	340	-	-	-	-	-
Spinel	38368	m	7700	-	-	-	-	-
Spinel	38466	U/m	4.3%	-	-	-	-	-
Pyrrhotite	38466	U/m	-	2.92%	<100	<100	-	-
Pyrite	38368	m	-	1100	<100	<100	-	-

Table 6. Average compositions of silicates (determined by electron microprobe)

38466: PSRC 231:60-61 m

Chlorite-(Mg_{5.53} Al_{3.09} Fe_{2.26} Na_{.12} Cr_{.07} Ca_{.04} Ni_{.02} Mn_{.01} K_{.01} Zn_{.01} Ti_{.01})(Si_{6.64} Al_{1.36}) O₂₀(OH)_{15.87} Cl_{.10} F_{.02}

Talc-(Mg_{4.90} Fe_{.79} Si_{.09} Al_{.06} Na_{.02} Ni_{.02})(Si_{8.00})O₂₀(OH)_{3.92} F_{.05} Cl_{.01}

Kaolinite-(Al_{3.76} Fe_{.12} Mg_{.14} Si_{.04} Na_{.02})(Si_{4.00})O₁₀(OH)_{7.96} F_{.02}

38368: PSRC 230: 48-49 m

Muscovite-(K_{1.71} Na_{.14} Ba_{.01})(Al_{3.69} Mg_{.18} Fe_{.10} Ti_{.03})(Si_{6.36} Al_{1.64})O₂₀(OH)_{3.95} Cl_{.02} F_{.01}

Illite-(K_{1.36} Na_{.08} Ba_{.01})(Al_{3.60} Mg_{.16} Fe_{.08} Ti_{.03})(Si_{7.16} Al_{.84})O₂₀(OH)_{3.97} F_{.03} Cl_{.02}

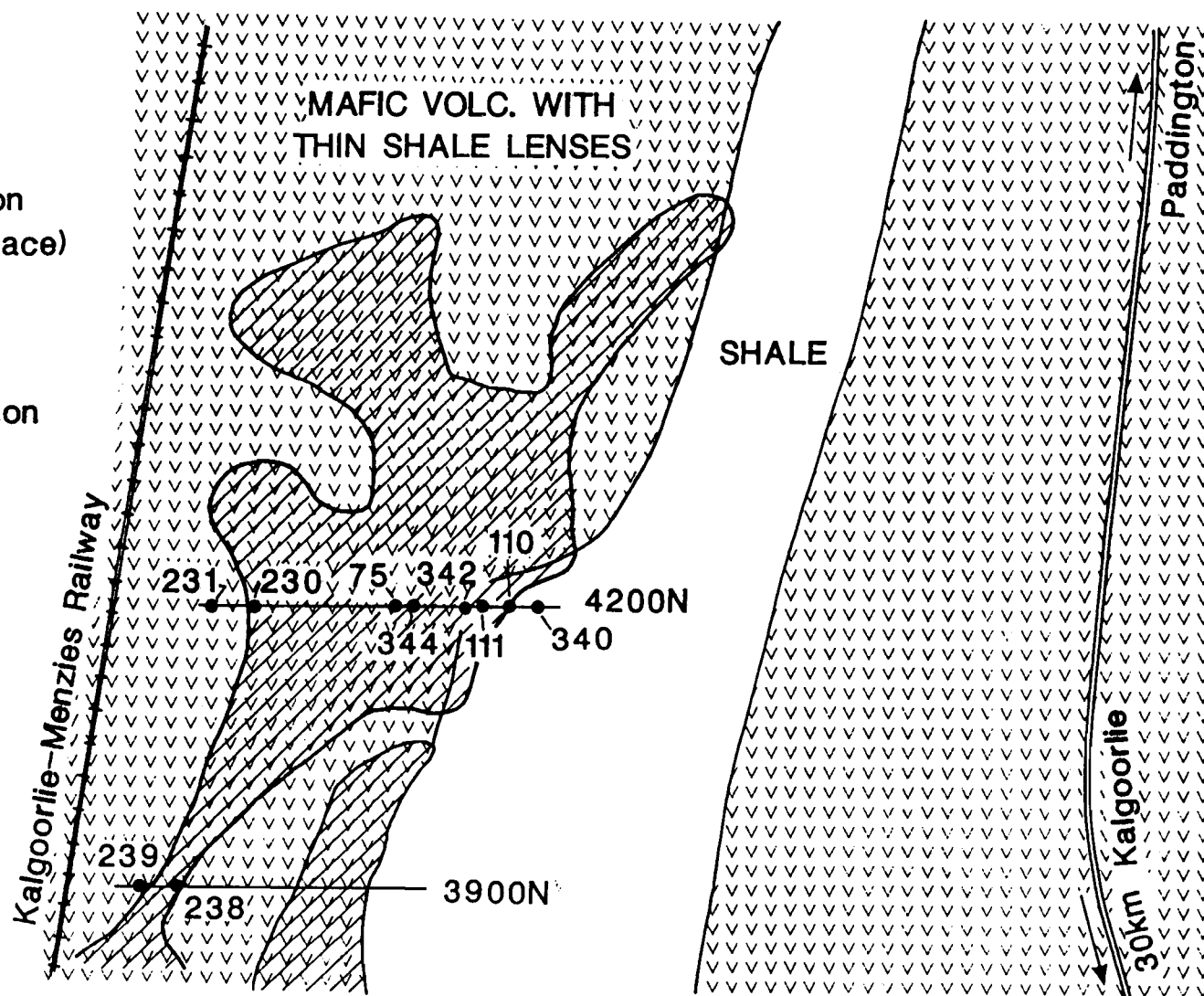


Fig. 1 Plan of mineralization at Panglo (after mapping by Pancontinental Mining Ltd.)

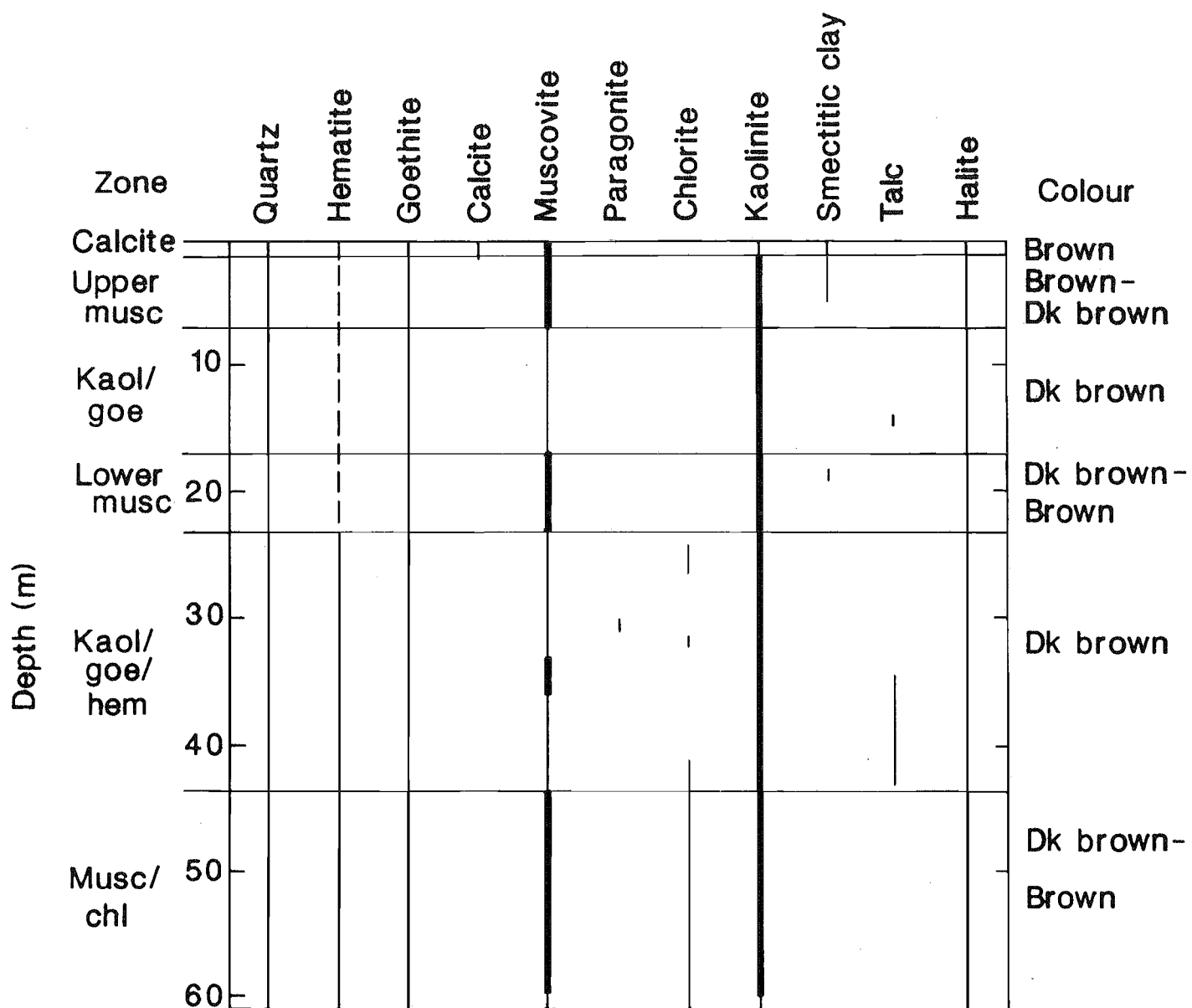


Fig. 2 Mineralogical profile through drill hole PSRC 230

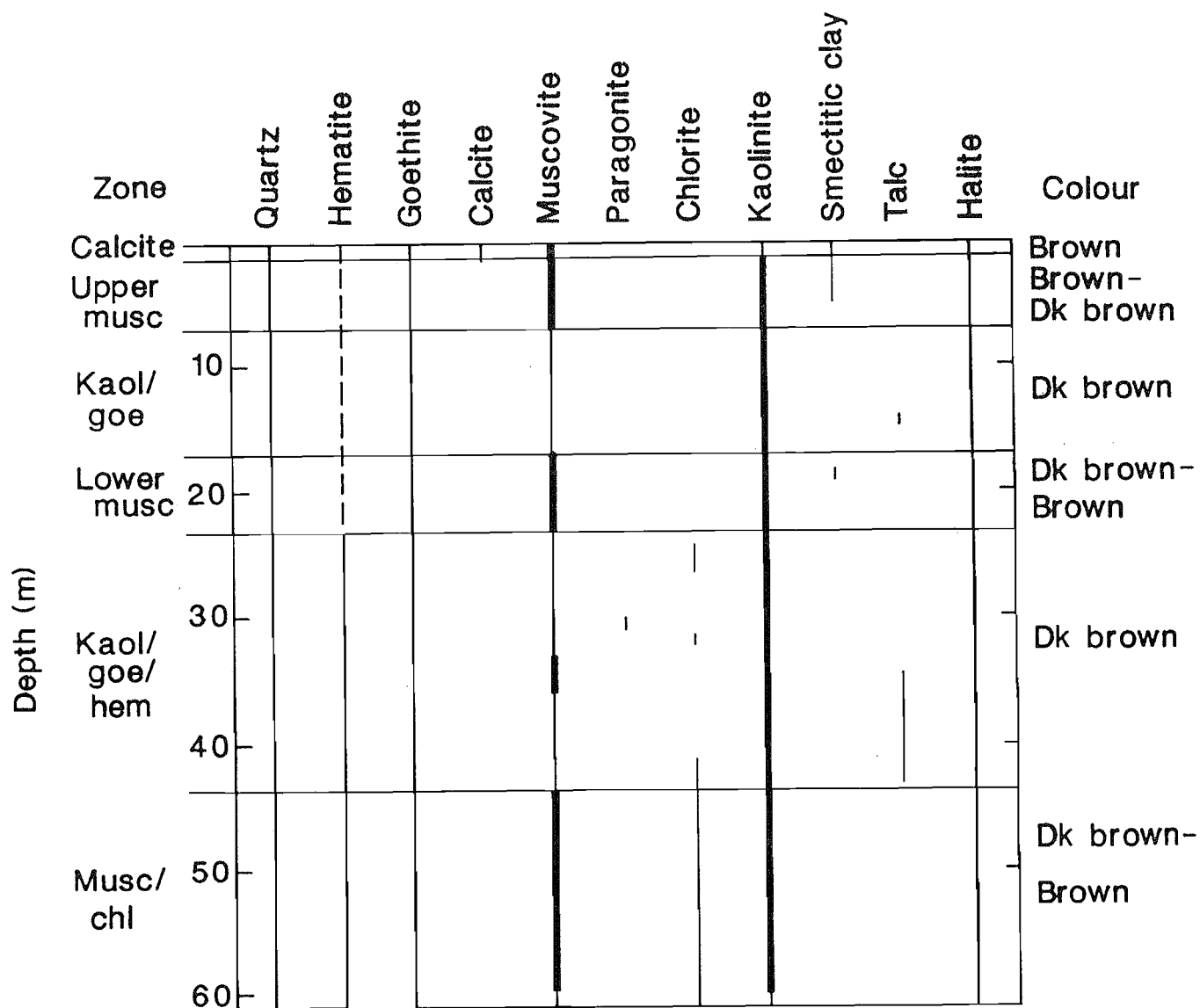


Fig. 2 Mineralogical profile through drill hole PSRC 230

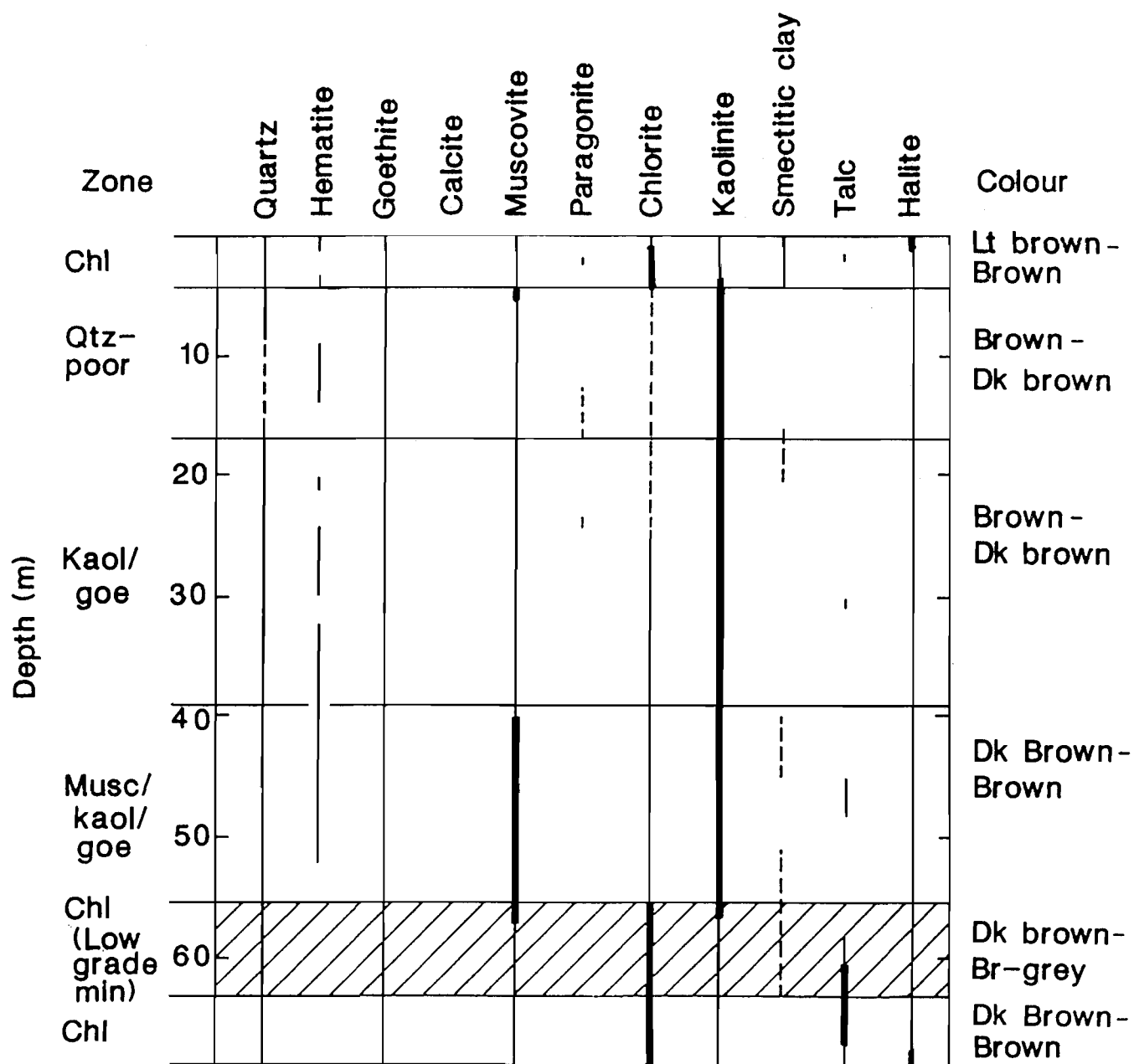


Fig. 3 Mineralogical profile through drill hole PSRC 231

PANGLO SECTION 4200N (WEST)

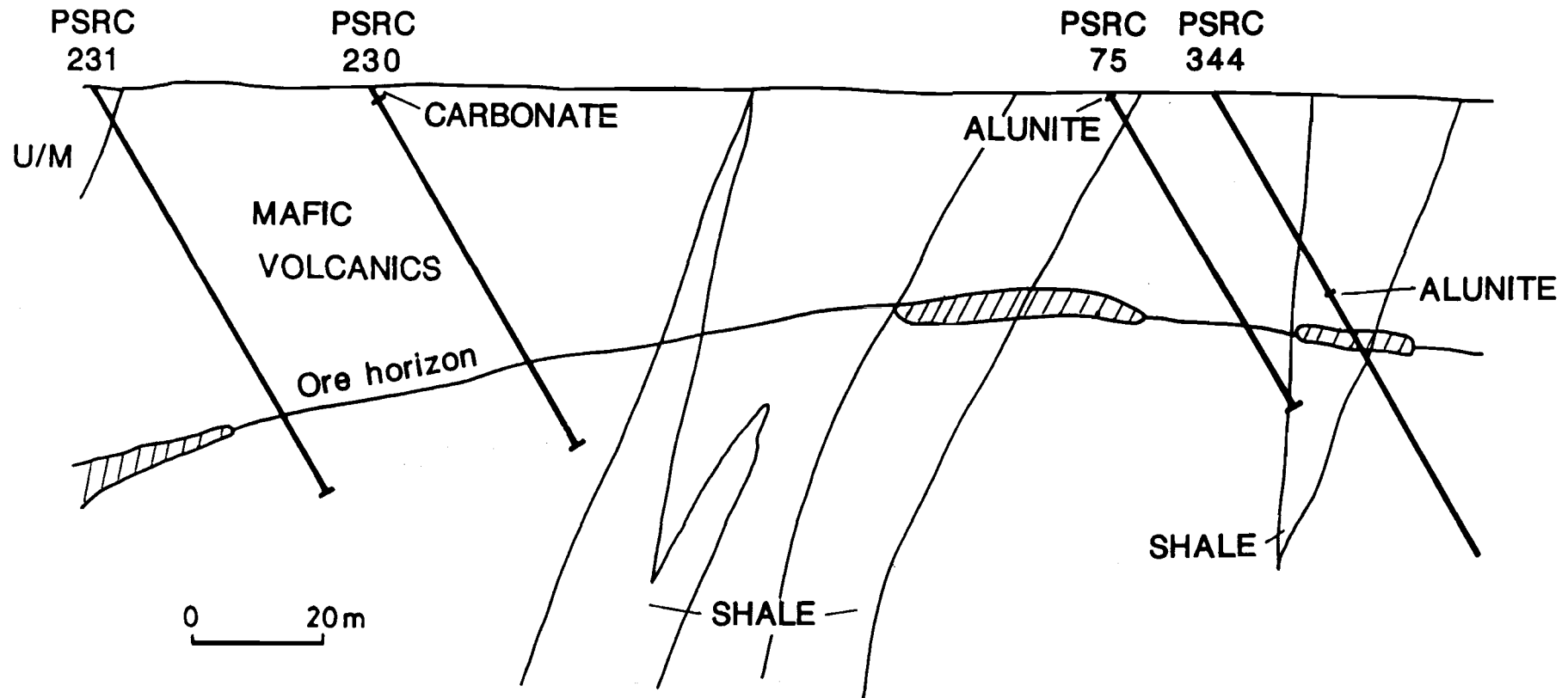


Fig. 4 Section showing the location of mineralization relative to PSRC 231 and 230
(modified from section drawn by Pancontinental Mining Ltd.)



Fig. 5 Kaolinite (light grey) pseudomorphing chlorite (White dots indicate analysed spots. Back scattered electron image. Scale Bar = 100 μm . Sample 38466).