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THE SIGNIFICANCE OF CAMPASPE-DOMINATED TERRAINS IN EXPLORATION WITHIN THE MT WINDSOR SUB-PROVINCE N.E. QUEENSLAND

K.M Scott

CRC LEME OPEN FILE REPORT 133

March 2002

(CSIRO Exploration and Mining Report 422R/CRC LEME Report 58R, 1997. Second impression 2002)

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CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, University of Canberra, Geoscience Australia, Bureau of Rural Sciences, Primary Industries and Resources SA, NSW Department of Mineral Resources-Geological Survey and Minerals Council of Australia.
Headquarters: CRC LEME c/o CSIRO Exploration and Mining, PO Box 1130, Bentley WA 6102, Australia

CSIRO/CRC LEME/AMIRA PROJECT P417
GEOCHEMICAL EXPLORATION IN REGOLITH-DOMINATED TERRAIN, NORTH QUEENSLAND 1994-1997

In 1994, CSIRO commenced a multi-client research project in regolith geology and geochemistry in North Queensland, supported by 11 mining companies, through the Australian Mineral Industries Research Association Limited (AMIRA). This research project, "Geochemical Exploration in Regolith-Dominated Terrain, North Queensland" had the aim of substantially improving geochemical methods of exploring for base metals and gold deposits under cover or obscured by deep weathering in selected areas within (a) the Mt Isa region and (b) the Charters Towers - North Drummond Basin region.

In July 1995, this project was incorporated into the research programs of CRC LEME, which provided an expanded staffing, not only from CSIRO but also from the Australian Geological Survey Organisation, University of Queensland and the Queensland Department of Minerals and Energy. The project, operated from nodes in Perth, Brisbane, Canberra and Sydney, was led by Dr R.R. Anand. It was commenced on 1st April 1994 and concluded in December 1997. The project involved regional mapping (three areas), district scale mapping (seven areas), local scale mapping (six areas), geochemical dispersion studies (fifteen sites) and geochronological studies (eleven sites). It carried the experience gained from the Yilgarn (see CRC LEME Open File Reports 1-75 and 86-112) across the continent and expanded upon it.

Although the confidentiality period of Project P417 expired in mid 2000, the reports have not been released previously. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authority 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 133) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 422R, first issued in 1997, which formed part of the CSIRO/AMIRA Project P417.

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PREFACE

The CRCLEME-AMIRA Project "Geochemical exploration in regolith-dominated terrain of North Queensland" (P417) has, as its overall aim, to substantially improve geochemical methods of exploring for base metals and gold deposits under cover or obscured by deep weathering. The research includes geochemical dispersion studies, regolith characterisation, dating of profiles and investigation of regolith evolution.

A variety of sedimentary cover, including Campaspe, Southern Cross and Suttor Formations, occur in the Chaters Towers - North Drummond Basin. Because of the widespread distribution of these cover sequences, there is considerable interest in the use of transported materials as a geochemical sampling medium in the region. In this study, Campase Formation has been characterised to aid its identification. Its possible use as a geochemical sampling medium has been assessed.

The Campaspe Formation is widesparead in the Mount Windsor Sub-Province and is generally underlain by weathered volcanics. The Mount Windsor Sub-province is considered prospective for polymetallic volcanogenic sulfide deposits. However, a sedimentary cover of Campaspe Formation, overlying the prospective volcanics, presents formidable challenges to exploration. On the one hand, it has commonly been considered unsuitable as a sample medium because of its exotic origin and exploration strategy has relied on drilling through the Campaspe Formation into bedrock. On the other hand, it has been subjected to post-depositional weathering and diagenesis because of its age, and it is thought that there could be potential for mechanical or chemical dispersion from underlying mineralisation. This report examines (a) the mineralogical and geochemical critera to distinguish the weathered volcanics from the Campaspe Formation and (b) investigates possible dispersion into the overlying Campaspe formation, based on a number of small studies at the Waterloo, Thalanga East and Brittania prospects.

There are no consistent mineralogical and geochemical criteria but hiatuses in feldspar and kaolinite abundances, rounding of quartz grains and geochemical parameters such as Ti/Zr ratios can be used to distinguish the Campaspe Formation from the basement of volcanics.

At Waterloo and Thalanga East, base metals are mechanically dispersed into the basal 10 m of the Campaspe Formation. The dispersion of Zn and Cu is more restricted (600 x 300m) than that of Pb. At Waterloo, Zn, Cu and Pb anomaly is generally associated with dolomite. At Brittania, there is no dispersion in the Campaspe Formation where quartz-rich sand occurs directly above mineralised volcanics. Thus, dispersion in the Campaspe Formation appears to be contolled by the nature of the sediments so much care is needed in using the Campaspe Formation as a geochemical sampling medium.

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Project Leader

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Deputy Leader

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SUMMARY

Weathered altered volcanics associated with mineralization within the Mt Windsor Sub-province are characterized by very kaolinitic assemblages (sometimes with alunite-jarosite minerals ± barite) derived from alteration of the feldspars. The younger Campaspe Formation is generally characterized by feldspar-bearing assemblages and is not strongly kaolinitic. Thus, the units are easily distinguished on the basis of their kaolinite and feldspar contents. However, where the volcanics are unaltered, feldspars are retained and other criteria must be used to distinguish them from the overlying Campaspe Formation sediments. If the volcanics are intermediate to basic in composition, their lower Si, Cl and higher Al and Ti/Zr relative to the Campaspe Formation can be used to discriminate. Unfortunately if the volcanics are felsic (as at Thalanga) the geochemical parameters, e.g. Ti/Zr do not discriminate between the two units. In these cases, although the unconformity between the two units is commonly associated with Fe oxide enrichment in both units, to accurately define the boundary, the degree of rounding of the quartz grains may be the only reliable parameter for discrimination.

Chalcophile elements (Ba, Cu, Pb and Zn) may be dispersed by mechanical means into the basal 10 m of the Campaspe Formation at Waterloo and Thalanga East. The distribution of Cu, Pb and Zn within thick sequences of the Campaspe Formation at Waterloo reveals that the dispersion of Zn (and Cu) is more restricted (600 m x 300 m) than that of Pb. The usually mobile elements (viz. Zn and Cu) may be stabilized by being associated with dolomite (i.e. an alkaline environment). At Brittania, quartz-rich "sand" occurs directly over mineralized volcanics. Despite its location there is no dispersion observed in this unit, probably because there is no suitable host to immobilize chalcophile elements.

1. INTRODUCTION

The Mount Windsor Sub-province is considered prospective for polymetallic (Zn-Pb-Cu-Ag-Au) volcanogenic sulfide deposits (Berry *et al.*, 1992). However, the occurrence of the Tertiary Campaspe Formation unconformably overlying the prospective volcanics of the region presents a challenge to exploration. Since the 1980's, an exploration strategy relying upon drilling through the Campaspe Formation into volcanic bedrock has been employed. Geochemistry is then used to identity alteration and/or mineralization in the bedrock. However, this approach faces the problem of how to recognize the transition from Tertiary Campaspe Formation into bedrock, especially if the contact occurs where both units are weathered. If drilling is continued until fresh volcanics are obtained, commonly 20 m below the contact, the drilling costs may become prohibitively expensive. Thus a method to accurately define the Campaspe/volcanic boundary during reconnaisance drilling is needed.

Several authors (e.g. Granier *et al.*, 1989; Hartley and Alston, 1995) have contended that the occurrence of relatively local mechanical dispersion of gossanous material within the Campaspe Formation presents a larger geochemical target than the *in situ* weathered mineralization. However, the position of such a dispersion train within the Campaspe sequence is not known prior to drilling, so systematic sampling through the whole Campaspe Formation must be undertaken.

Taylor and Humphrey (1991) studied profiles across the Campaspe/Mt Windsor Volcanics unconformity at Thalanga East but could not clearly define the boundary because of the incorporation of substantial amounts of volcanics into the basal Campaspe Formation. However, Scott (1995) successfully differentiated Campaspe Formation from volcanics at Waterloo using mineralogical (feldspar and dolomite abundances) and geochemical criteria (Ce, Cl, Zr and Ti/Zr). That work indicated that mechanical dispersion of gossanous material occurred at the base of the Campaspe Formation and that a partially stripped lateritic profile is present within the underlying volcanics. This current study further evaluates the use of geochemistry and mineralogy of regolith fragments from drill holes in defining the unconformity by considering deeper (50 m thick) sequences of cover material from Waterloo plus other profiles up to 2 km from the deposit. It seeks to generalize the findings by study of the unconformity elsewhere in the Mount Windsor Sub-province *viz* at Thalanga East and Brittania (Figure 1).

2. GEOLOGY

The Waterloo deposit occurs in andesitic and felsic volcanics of the Trooper Creek Formation. It is a small but high grade deposit (372,000 tonnes at 19.7% Zn, 3.8% Cu, 2.8% Pb, 94 g/t Ag and 2 g/t Au; Berry *et al.*, 1992) and occurs as a steeply dipping lens below 30-60 m of flat-lying Campaspe Formation.

The Thalanga deposit occurs 40 km west of Waterloo in the Mt Windsor Volcanics (i.e. at a slightly lower stratigraphic level than Waterloo; Figure 1). The deposit crops out at Thalanga and is characterized by barite and beudantite (a Pb-Fe-AsO_4-SO_4 mineral of the alunite-jarosite family) with the Fe oxides (Taylor and Humphrey, 1991). Some boxworks and residual pyrite are also in outcrop (Herrmann, 1995). The deposit is Zn-rich with 6.1 M tonnes at 9.3% Zn, 3.0% Pb, 1.6% Cu, 77 g/t Ag and 0.4 g/t Au remaining at June 1994 after the mining of 2.5 M tonnes of higher grade material (Herrmann, 1995). An extensive alteration system characterized by 50 m of intense silification within a 200 m thick zone of feldspar-destructive sericite ± chlorite alteration with disseminated pyrite is developed in the foot wall of the deposit. Wall rock alteration is not well developed in the hanging wall. Thalanga East is a separate lens of about 2 M tonnes at 15% Zn + Pb + Cu occurring beneath about 45 m of Campaspe Formation 600 m to the east of the main deposit (Figure 2). Hartley and Alston (1995) consider that there is both mechanical and hydromorphic dispersion into the Campaspe Formation.

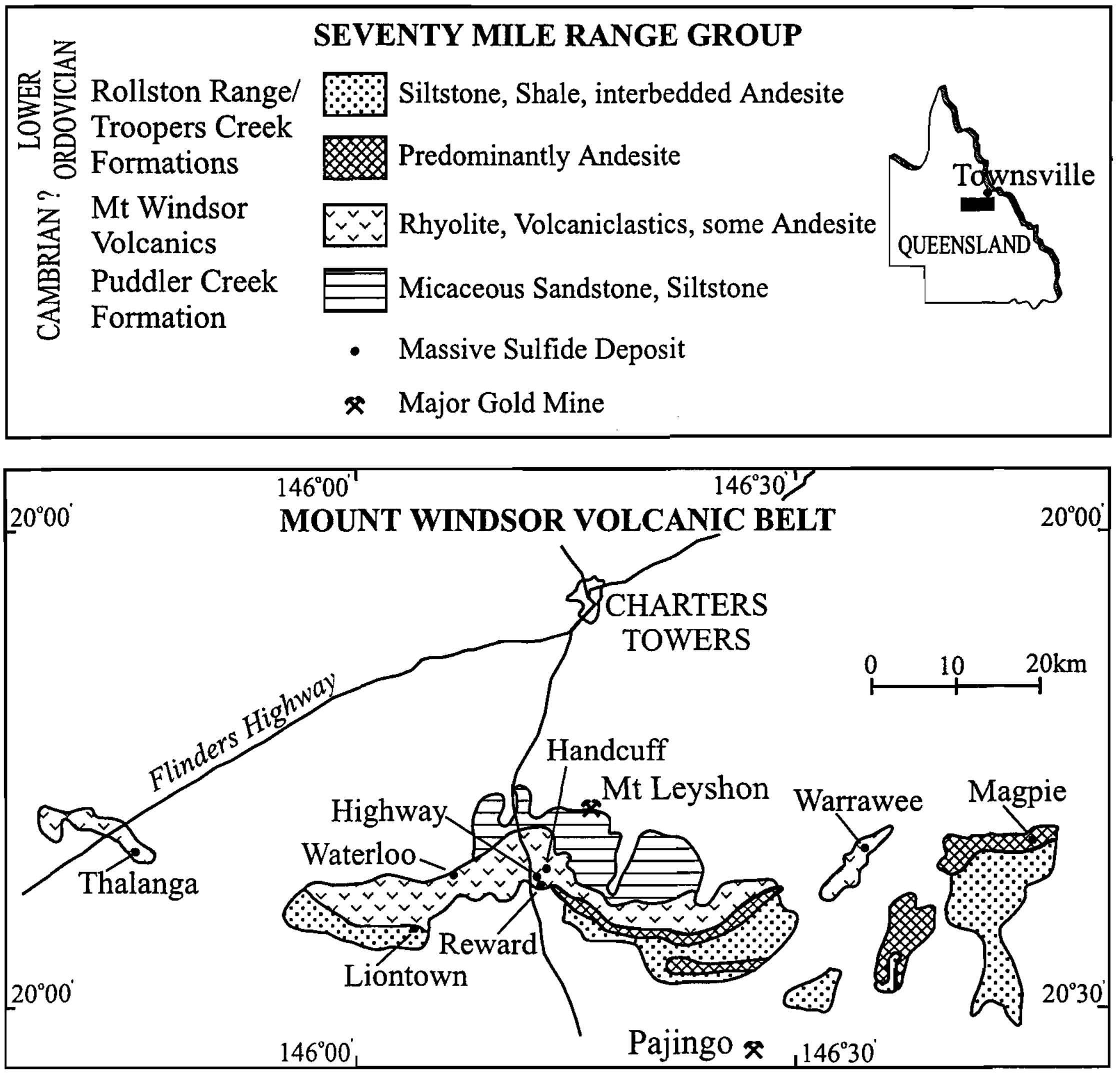


Figure 1 Location map of Mt Windsor Sub-province volcanics and mineral deposits of the region *(after Hartley and Alston, 1995).*

The Brittania mineralization occurs 30 km ESE of Waterloo and is poorly defined but does appear to be Zn-rich mineralization within the Trooper Creek Formation (Sainty, 1994). Mineralization is localized at the contact between a basal dacitic unit and an overlying andesitic unit (which contains jasper exhalites). Synchronous felsic intrusives of Trooper Creek Formation age occur along the dacite-andesite contact (Figure 3). Devonian granodiorite also occurs in the vicinity. The presence of only weak low-temperature alteration in the granodiorite, the close spatial association with the felsic intrusives and Pb isotopic studies suggest the mineralization represents a volcanogenic massive sulfide system (Sainty, 1994).

3. SAMPLES AND METHODS

The main study at Waterloo relied upon 145 three-metre composite pulps from drill holes GY 232-GY 239 which form a section across the deposit (Line 5, Figure 4). No textural information (apart from the original company logging) is available for this section. Thus, using the company Cu, Pb and Zn data as a guide, the mineralogy of 71 of these samples was determined by X-ray diffractometry (XRD), with particular attention being paid to defining where significant mineralogical changes occur. Thirty four samples were analysed by X-ray fluorescence spectrometry (XRF) to determine the major elements plus Ba, Ce, Cl, Co, Cr, Cu, Ga, La, Nb, Ni, Pb, Rb, Sr, V, Y, Zn and Zr. In addition, As, Au, Sb, Th and U were determined for a smaller number of samples by neutron activation analysis (NAA).

A suite of 91 one metre composite samples from reverse circulation drill hole TW 29 (drilled to test the continuity of the Waterloo mineralization at depth) was studied in some detail with a summary derived from logging of fragments presented in Table 1. Geochemical information (As, Bi, Cu, Fe, Mn, Mo, Pb, S and Zn contents by Inductively Coupled Plasma Atomic Emission Spectrometry after an aqua regia digest and Au by cyanide leach, solvent extraction and Atomic Absorption Spectrometry) on these samples was provided by Mt Leyshon Gold Mines. Using the results from examination of the chips and the geochemistry, 8 samples were selected for more detailed mineralogical (XRD) and chemical (XRF/NAA) analysis.

Table 1 Summary log, drill hole TW29, Waterloo

Depth (m)	Colour	Description
0-17	Brown	Contains clear rounded, quartz grains. Lithic fragments (Iron oxide stained sandstone) are often rounded and have a white rim. Some ferruginous pisoliths. White carbonate in basal sample.
17-28	Pink brown	Iron oxide stained clay fragments, quartz is rarer but when present is milky. Carbonate occurs from 17-22 m as white chips.
28-50	Peach	Rare milky quartz grains, clay fragments. Some pseudomorphs after pyrite. No carbonate.
50-75	Pink brown	Rare quartz, casts after pyrite common. Lithic fragments often mauve clay.
75-81	Light grey	Clay-rich material with rare milky quartz. Some lithic fragments are silicified. Some casts after pyrite.
81-91	Yellow brown	Iron oxide stained and grey lithic fragments.

Two reverse circulation drill holes from the Liontown-Waterloo area within 2 km of the Waterloo deposit were studied. Both holes pass through >50 m of Campaspe Formation. Drill hole LLRC 130 (2 km SSW of Waterloo) passes into weathered silica-sericite-pyrite alteration in volcaniclastics and LLRC 138 (2 km SE of Waterloo) passes into volcaniclastics/dacite with no indication of hydrothermal alteration (C. Miller, pers. comm., 1996). After inspection of the coarser fractions in the material within 15 m of the logged unconformity, 5 samples from either side of the unconformity in each hole were analysed by XRD to determine their mineralogy. Using the mineralogical data as a guide, 8 samples from each hole were chosen for chemical analysis by XRF.

At Thalanga East, the boundary between Campaspe Formation and basement volcanics can be readily determined to within a few metres in drill core. Fifteen samples were collected from diamond drill holes TH 358 and TH 424 (Figure 2) about the unconformity. The mineralogical and chemical compositions of the samples were determined by XRD and XRF respectively.

At Brittania, 29 pulps from drill holes BRDD 14 and BRRC 4 (Figure 3) were collected with sampling emphasis placed on the upper 30 m where weathering is significant. The mineralogy of the samples was determined by XRD, with the chemical compositions being determined for 9 samples by XRF.

4. RESULTS

4.1 Line 5, Waterloo

Using the data obtained by XRD, the significant mineralogical variations across the section are shown in Figures 5-9. Together these figures show that plagioclase is abundant down all holes except below about 48 m in GY 232 and GY 233 (Figure 5). Kaolinite and Fe oxides are particularly well developed in this plagioclase-poor zone (Figures 6 and 7). A 10 metre-thick zone containing dolomite, occurs below 27 m in GY 233 to GY 238 (Figure 8). Smectites are ubiquitous through the profiles, but commonly attain their greatest abundance just below the dolomite zone (cf. Figures 8 and 9).

Base metal analyses reveal that Pb is >25 ppm below about 25 m (Figure 10), Cu is commonly >50 ppm at depths between 30-40 m and Zn is generally >100 ppm between 25-45 m (Figures 11 and 12). Very much higher concentrations of these elements occur toward the base of GY 232 and GY 233 (Figures 10-12) where they are accompanied by high Ba contents (Appendix 1) and alunitic minerals (especially between 51 and 57 m in GY 233). Higher Ce, Cr, Zr and lower Al and Ti/Zr contents in the samples above 48 m in GY 232 readily differentiate Campaspe Formation from weathered volcanics below 51 m depth (Appendix 1; Figure 13). However, in the other drill holes, these parameters do not consistently distinguish the different lithologies.

4.2 Drill hole TW 29, Waterloo

Careful logging of the RC fragments from this hole reveals that the quartz grains in the top 17 m are clear and rounded whereas the quartz grains below that level are less abundant, angular and milky in appearance (Table 1). Carbonate is present as discrete white chips between 16-22 m (Table 1; Figure 14).

X-ray diffractometry of samples between 14 and 27 m reveals that material above 17 m contains abundant plagioclase, has montmorillonite (smectite) > kaolinite and some mica and hematite. However below 17 m plagioclase is absent, and mica and kaolinite are quite abundant (kaolinite becoming the major clay below 22 m). The carbonate between 16-22 m is identified as dolomite. Alunite-type minerals and barite are recognized below 18 m and the Fe oxide is goethite rather than

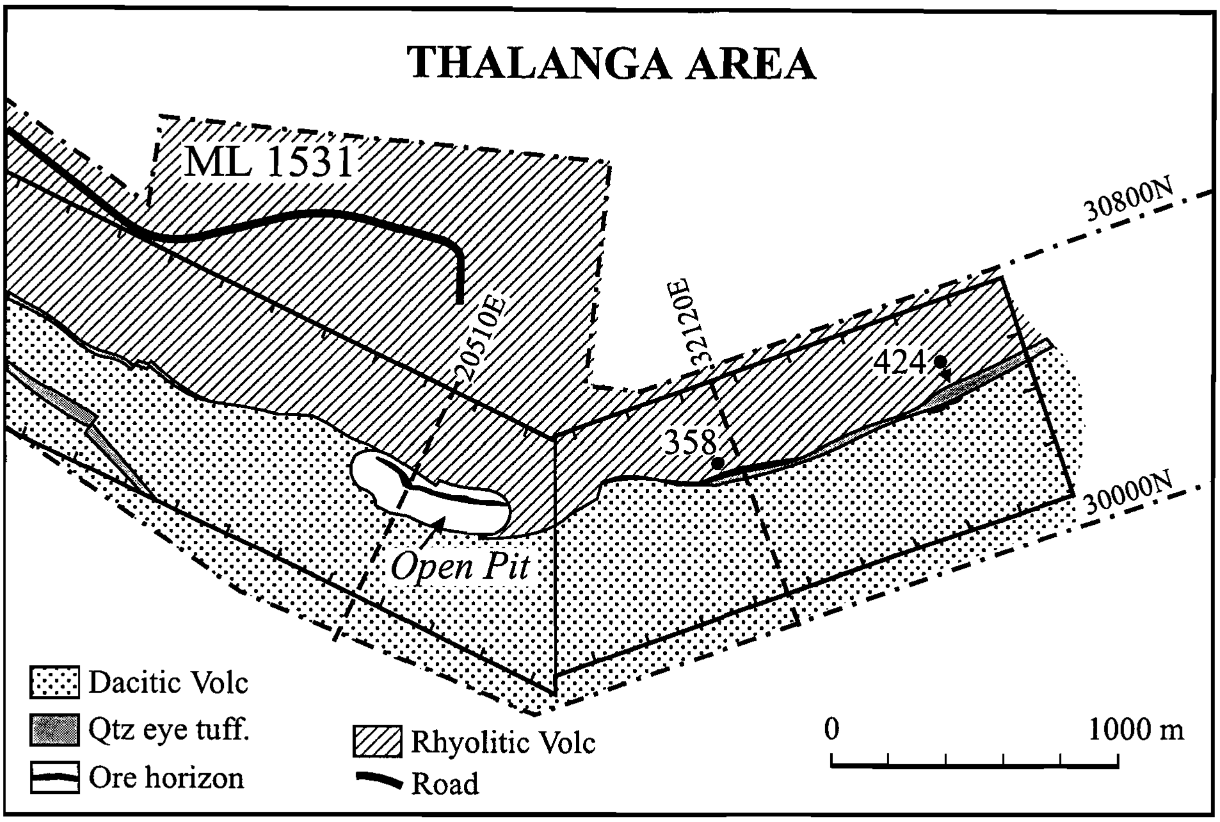


Figure 2 Plan of the Thalanga and Thalanga East deposits, showing drill holes studied *(simplified from Gregory et al., 1990).*

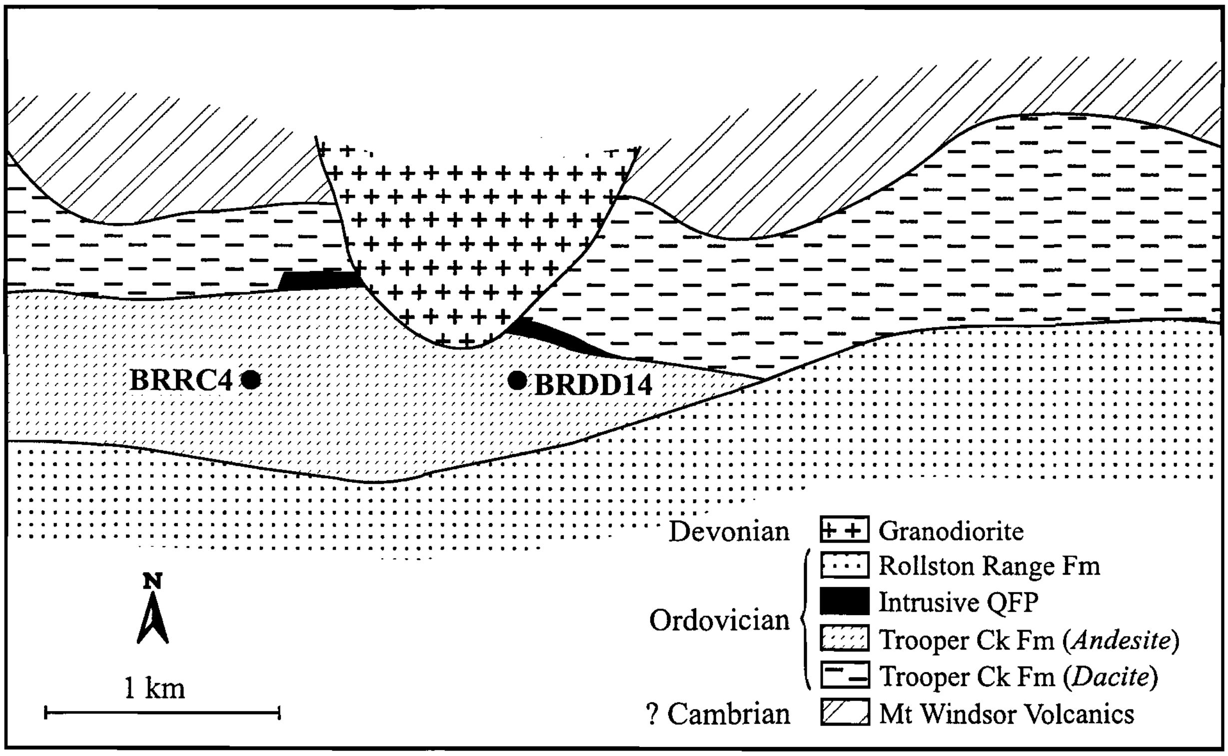


Figure 3 Plan of the Brittania prospect, showing drill holes studied *(after Sainty, 1994).*

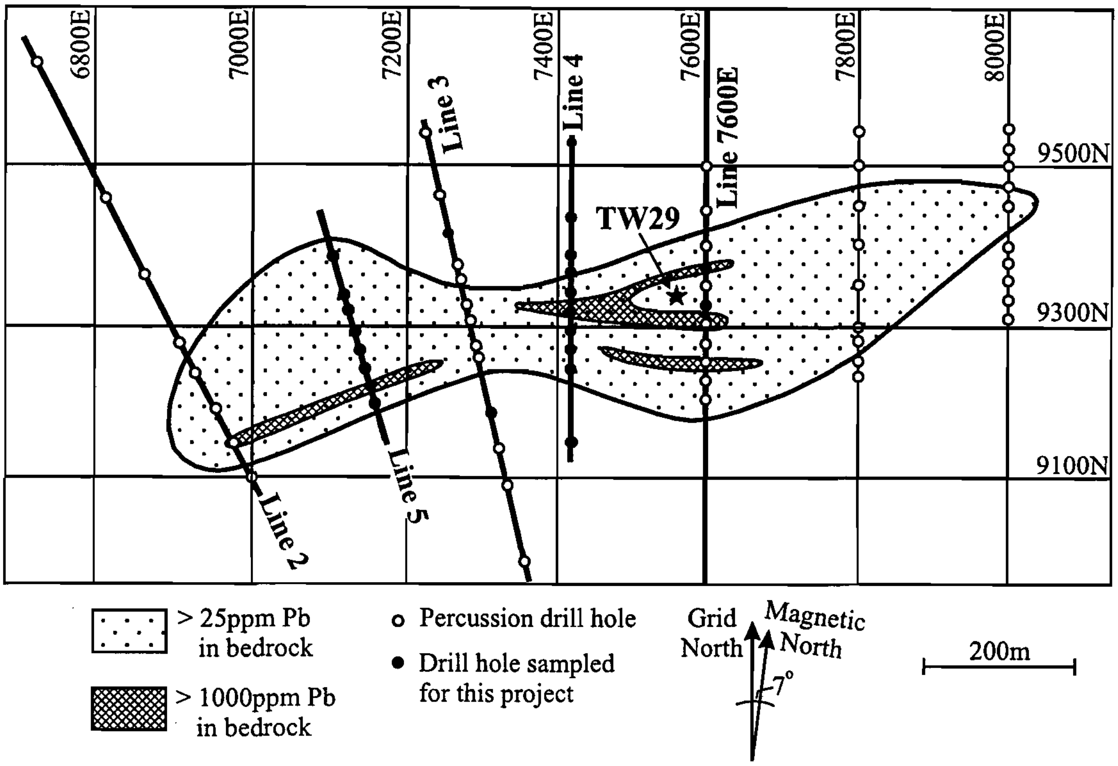


Figure 4a Plan of the Waterloo deposit, showing bedrock Pb contents and location of drill holes *(based on the Penarroya (Aust) Pty Ltd grid).*

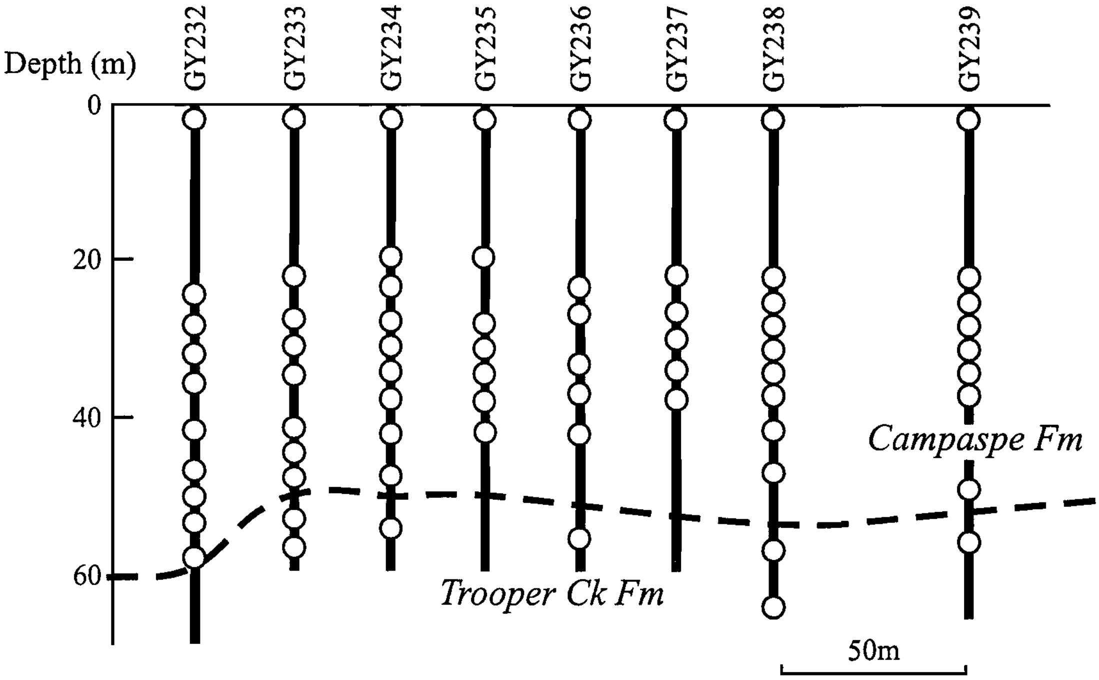


Figure 4b Section along Line 5, showing mapped Campaspe/Volcanics boundary.

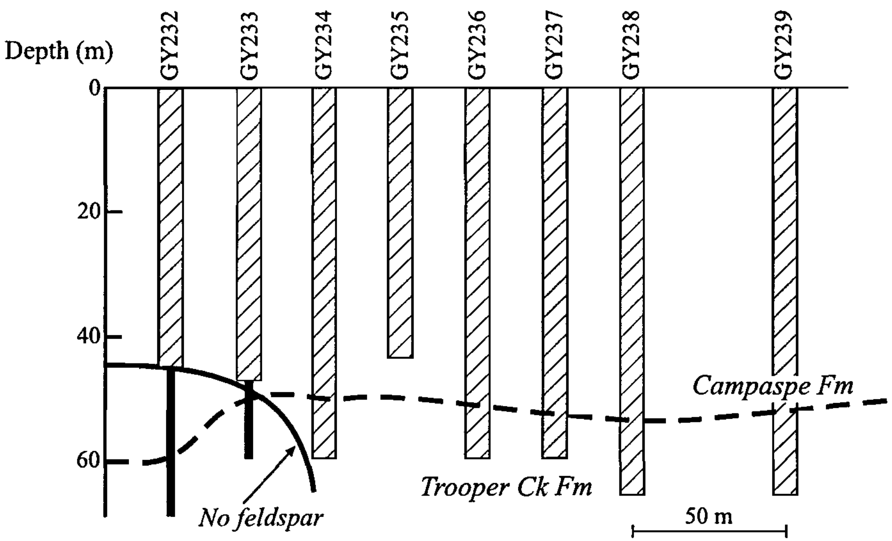


Figure 5 Plagioclase occurrences - Line 5 Waterloo.

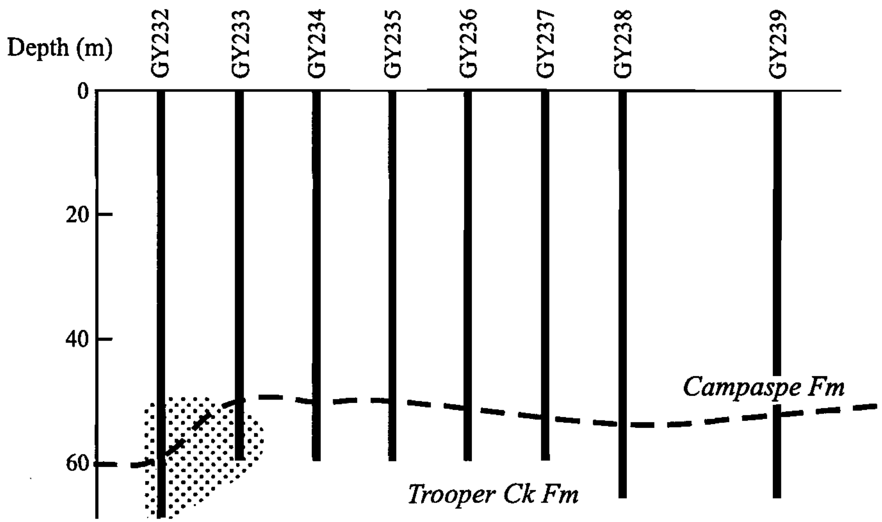


Figure 6 Kaolinite - moderate development - Line 5 Waterloo.

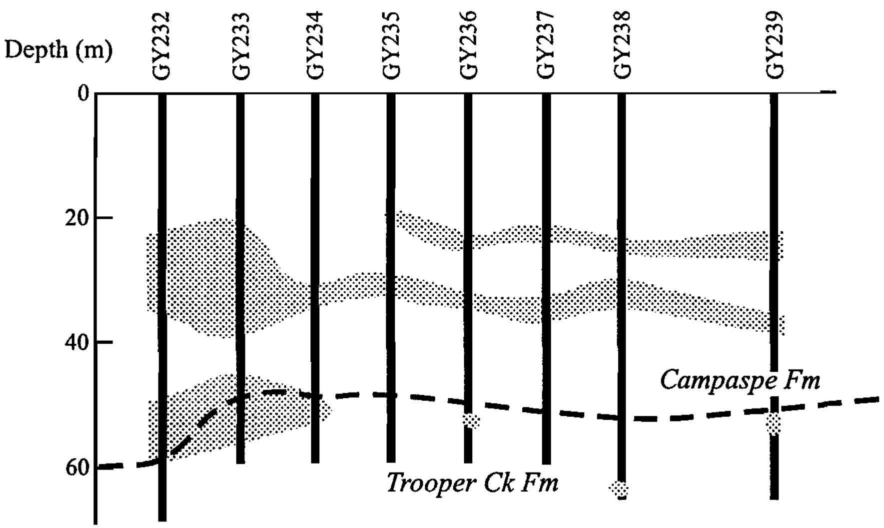


Figure 7 Hematite / Goethite development - Line 5 Waterloo.

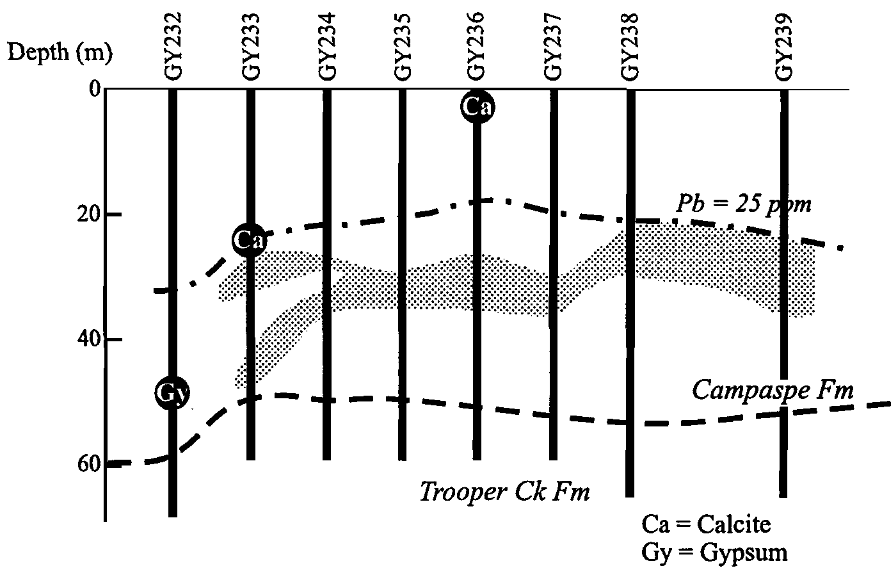


Figure 8 Dolomite occurrences - Line 5 Waterloo.

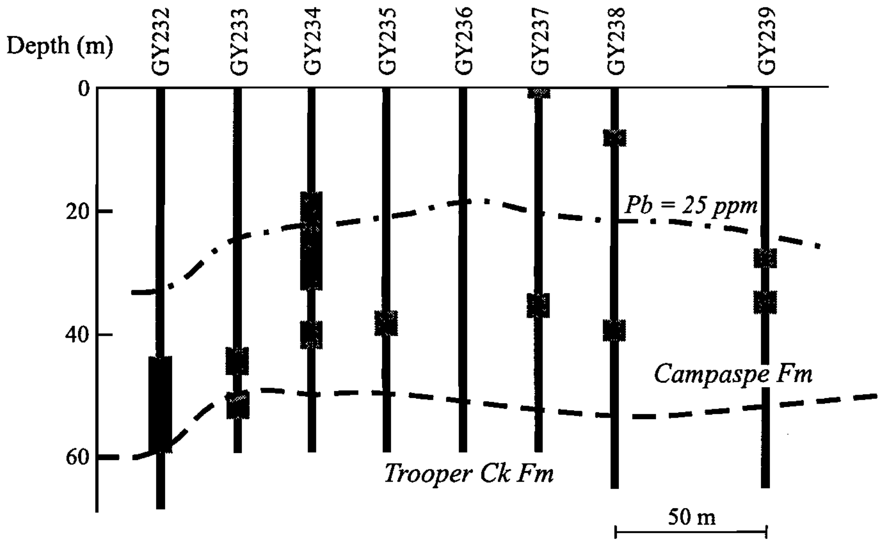


Figure 9 Smectite - abundant development - Line 5 Waterloo.

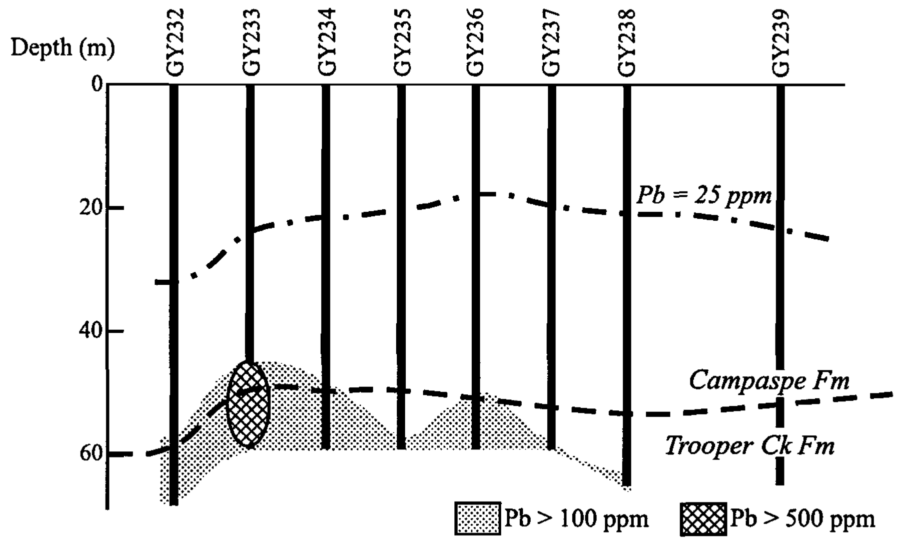


Figure 10 Pb distribution - Line 5 Waterloo.

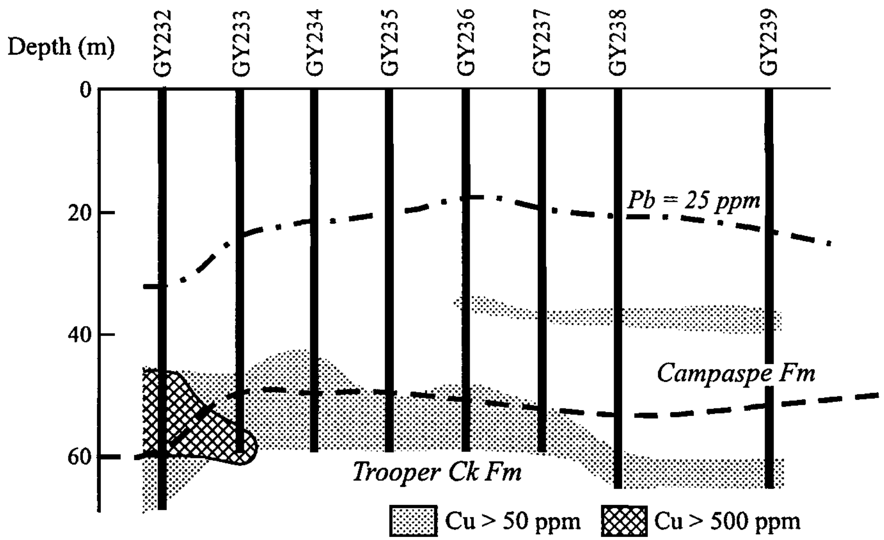


Figure 11 Cu distribution - Line 5 Waterloo.

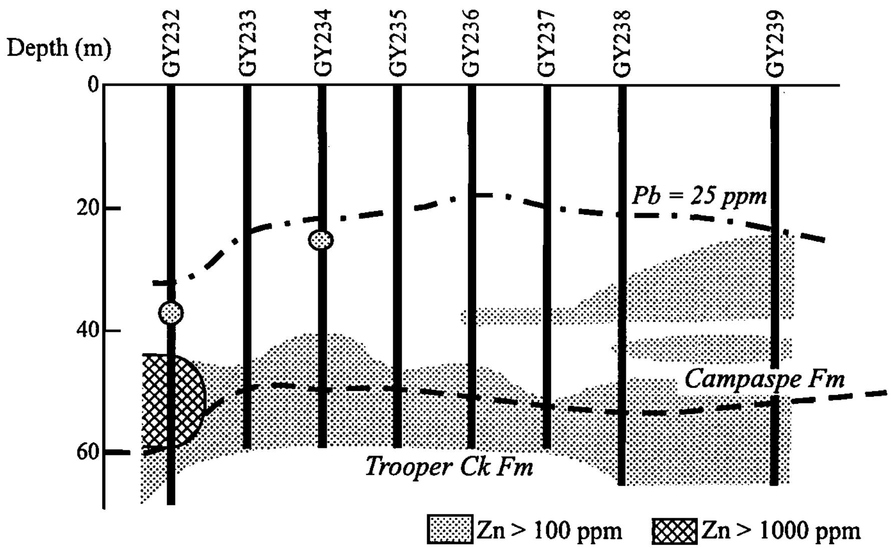


Figure 12 Zn distribution - Line 5 Waterloo.

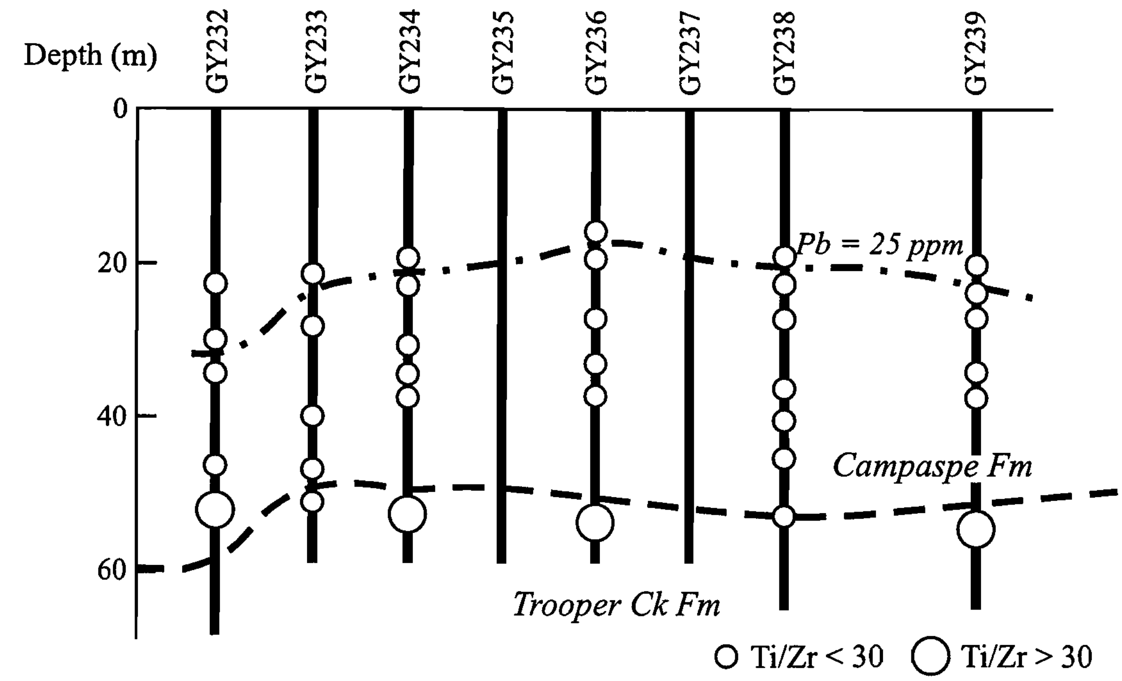


Figure 13 Ti / Zr ratios - Line 5 Waterloo.

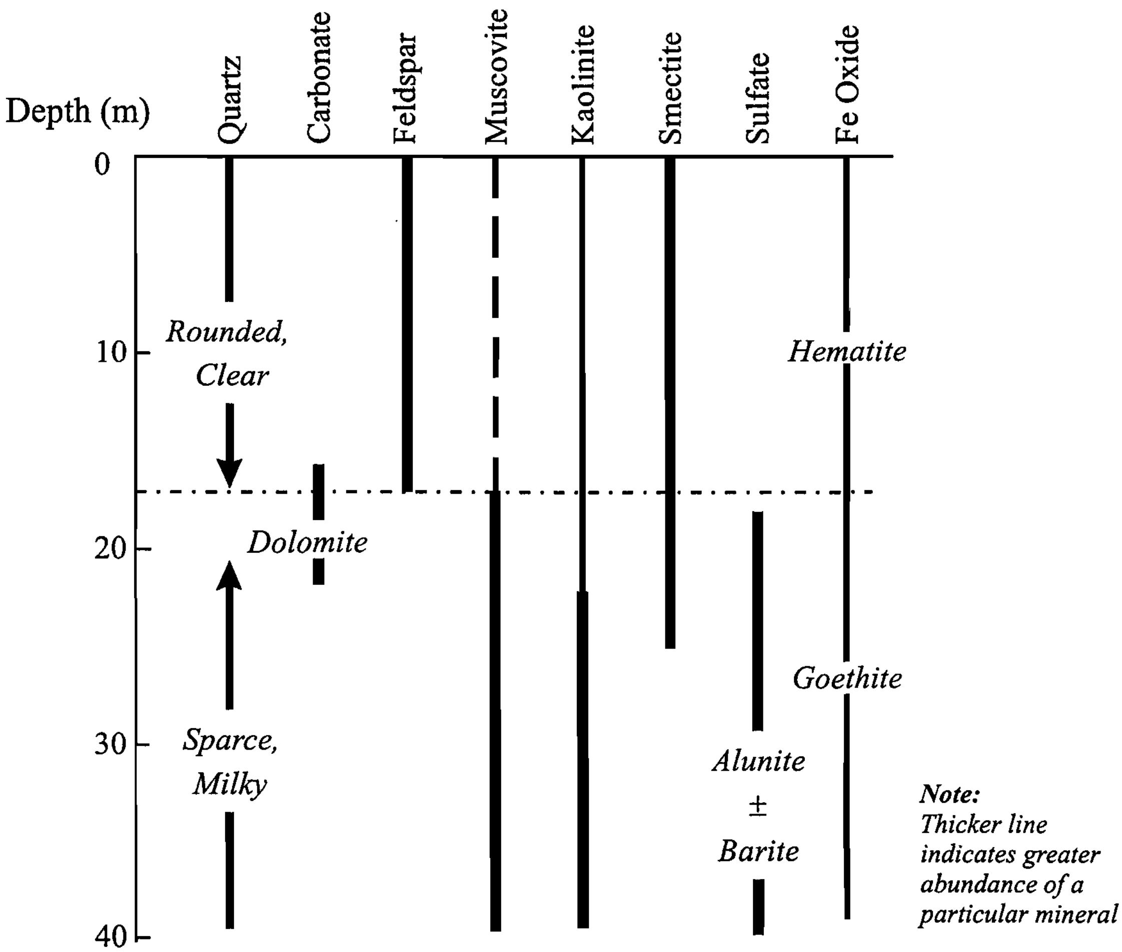


Figure 14 Mineralogical variations in the top 40 m of TW29, Waterloo.

These mineralogical differences are reflected by the whole rock chemistry which shows Si, Na, Cl and Co enrichment and Al, K, S, Ba, Cr, Cu, Pb and Rb depletion in the upper samples (Campaspe Formation) relative to the deeper (volcanic) samples (Table 2). The dolomite zone is readily identified by the samples with elevated Ca and Mg (Table 2). There is also a change in the Ti/Zr ratio at 17 m but the higher values only persist for a few metres within the weathered volcanics (Table 2).

4.3 Liontown-Waterloo area

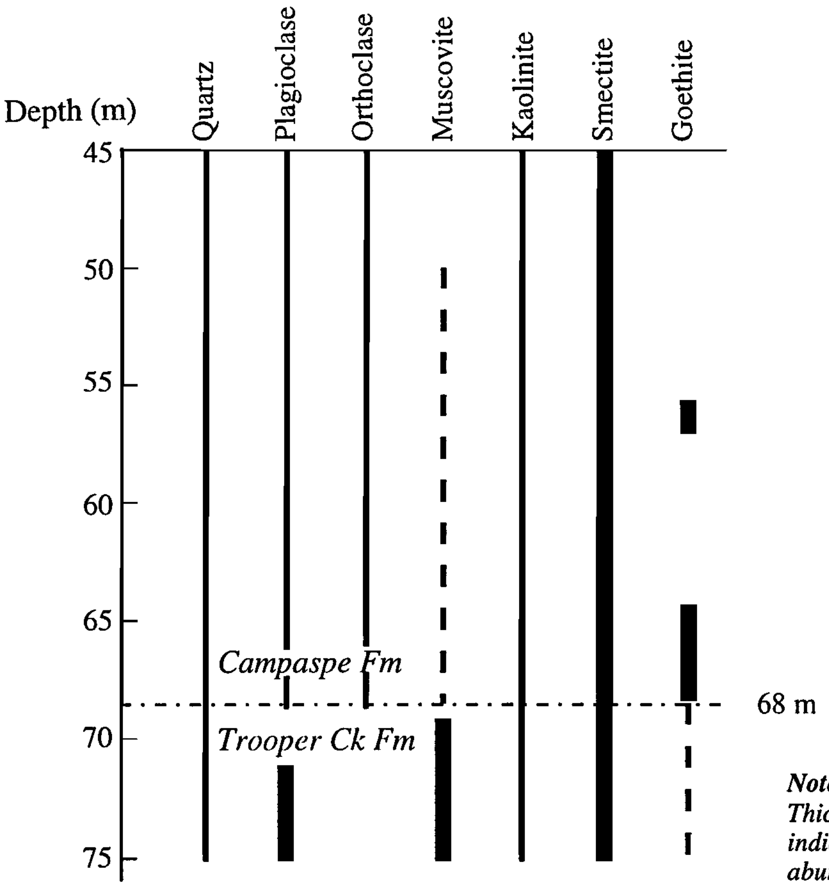
X-ray diffractometry reveals major mineralogical breaks within the two drill holes which intersect hydrothermally altered and barren volcanics. LLRC 130 shows consistent quartz, plagioclase and orthoclase with smectite, kaolinite ± goethite ± muscovite to a depth of 68 m and then an absence of both feldspars before only plagioclase is present below 71 m (Figure 15). Goethite is strongly developed in the interval 65-67 m. Muscovite is especially well developed below 68 m. (This change at 68 m corresponds with the Campaspe/volcanic transition logged by RGC). LLRC 138 shows a change from quartz + kaolinite + muscovite + anatase ± goethite assemblages to anatase-free, plagioclase dominant assemblages at 53 m (Figure 16). Again this transition corresponds with the logged unconformity. Although the presence/absence of anatase, as observed by XRD, may not be significant (due to the obscuring of its X-ray diffraction peaks by feldspars), plagioclase is very much more abundant in this sequence of barren volcanics than previously seen during this study. The absence of feldspars in the Campaspe Formation as observed in this hole has not been seen in the profiles previously studied during this project (Scott, 1995).

The hydrothermally altered volcanics from below 68 m in LLRC 130 have higher Al, Mg, K, Rb, Zn and Zr but lower Si, Cr, V and perhaps marginally lower Ti/Zr than the overlying Campaspe Formation (Table 3; Appendix 2). Material from the basal few metres of the Campaspe Formation is very Fe-rich and has some chemical similarities to the underlying volcanics, e.g. higher Al, Mg, Zn and lower Si and Cr than other Campaspe Formation samples (Table 3). As well as being Fe-rich, such material is also Ti-rich and probably contains a high proportion of highly weathered volcanic-derived material.

Unaltered volcanics below 53 m in LLRC 138 have higher Al, Na, K, Y and Zn and lower Si, Ti, Ba, Cr, Nb, Pb, Zr and marginally lower Ti/Zr than the Campaspe Formation (Table 3; Appendix 3). As indicated above, this volcanic sequence is particularly Na rich, reflecting its very high plagioclase content, but many of the discriminating elements are similar to those in LLRC 130, despite the volcanics being dacitic and rhyolitic respectively.

4.4 Thalanga East

Visual inspection of the drill cores suggests that conglomerate (representing Campaspe Formation) occurs down to 18 m in TH 358 and to 57 m in TH 424 (900 m to the east). Although there are differences in orthoclase abundances between the two drill holes and Fe oxides may be concentrated at the unconformity, there is no distinctive mineralogical break at those intervals (Figures 17 and 18). The composition of the TH 358 profile shows that significant amounts of Ba, Cu, Pb and Zn are present in the basal 10 m of the Campaspe Formation with anomalous Zn extending even further (Table 4; Appendix 4). Base metal contents are lower throughout TH 424 than in TH 358 but Cu, Pb and Zn still appear to be slightly elevated within the Campaspe Formation (Table 4). Although Cr and V contents appear higher in the Campaspe Formation than in the volcanics, Ti/Zr ratios do not discriminate between the two units (Table 4).



Note: Thicker line indicates greater abundance of a particular mineral

Figure 15 Mineralogical variations, LLRC 130 *(determined by XRD).*

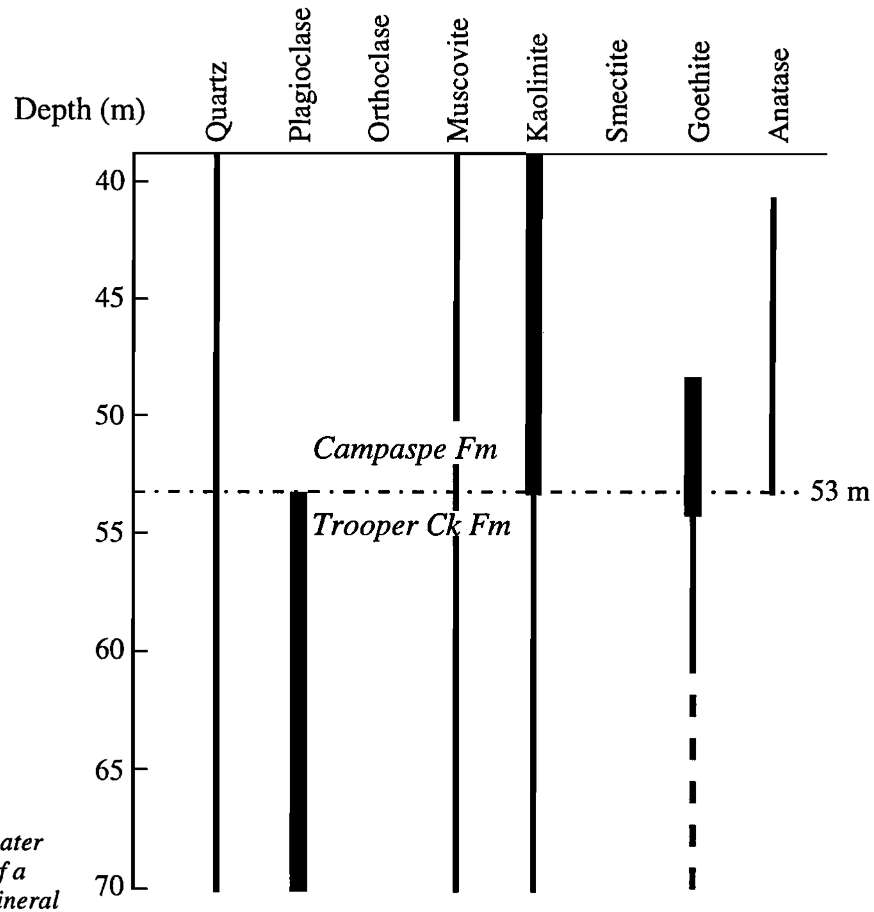


Figure 16 Mineralogical variations, LLRC 138 *(determined by XRD).*

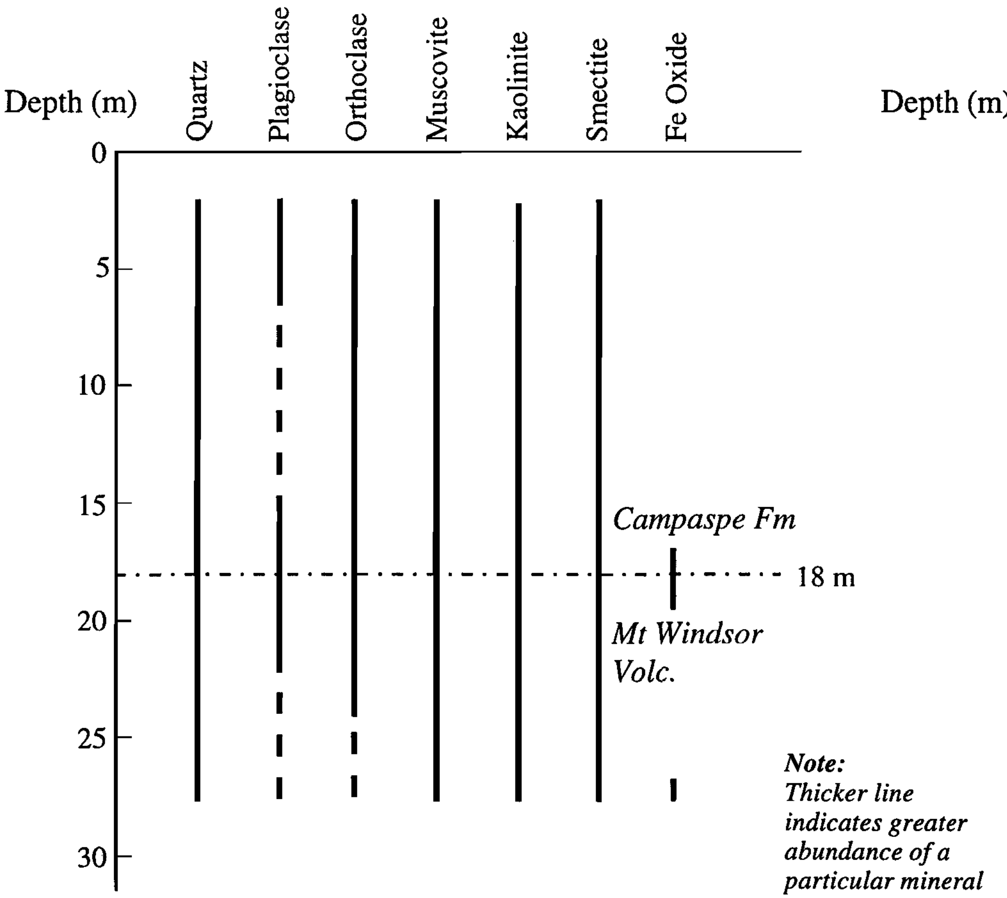


Figure 17 Mineralogical variations, TH 358, Thalanga East *(determined by XRD).*

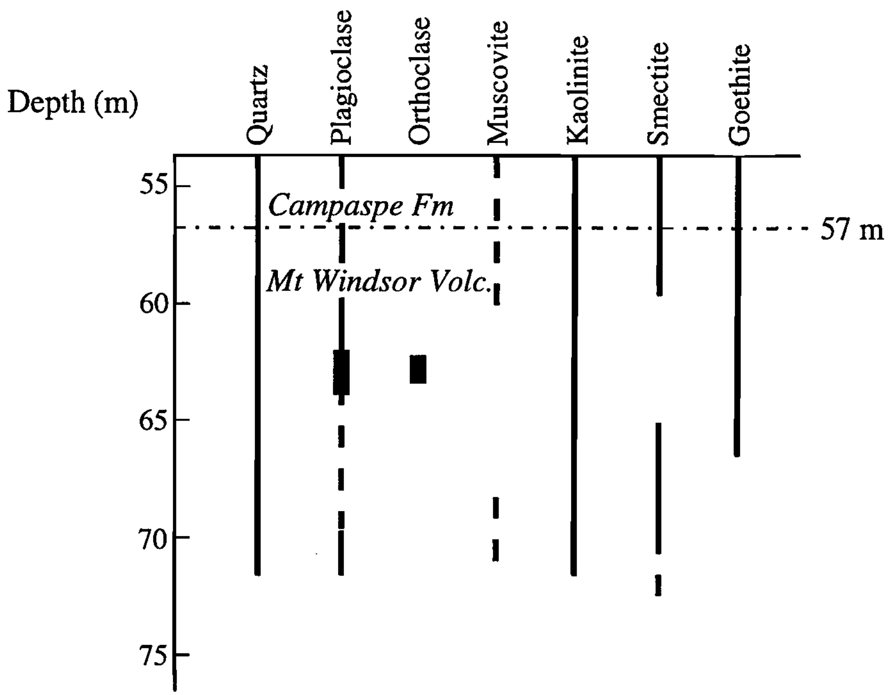


Figure 18 Mineralogical variations, TH 424, Thalanga East *(determined by XRD).*

Table 2 Compositions of samples adjacent to Campaspe/volcanic unconformity, TW29, Waterloo (majors, wt%; minors, ppm)

	129909	129911	129912	129915	129917	129919	129921
Depth(m)	14-15	16-17	17-18	20-21	22-23	24-25	26-27
Unit	Campaspe		------------------------Trooper Ck Fm ------------------------				
SiO_2	69.5	69.9	52.7	59.4	-	53.9	64.8
Al_2O_3	12.4	11.2	14.4	18.1	-	19.2	17.3
Fe_2O_3	5.47	5.46	5.96	4.68	-	10.1	6.42
MgO	1.07	1.57	4.05	2.05	-	0.65	0.50
CaO	0.29	0.94	3.95	1.60	-	0.07	0.05
Na_2O	2.63	2.49	0.28	0.10	-	0.15	0.10
K_2O	0.77	0.82	2.25	3.20	-	3.10	2.52
TiO_2	0.58	0.41	0.58	0.59	-	0.68	0.66
MnO	0.07	0.07	0.13	0.05	0.02	0.01	0.01
P_2O_5	0.03	0.03	0.03	0.03	-	0.16	0.10
SO_3	0.02	0.03	0.07	0.03	0.11	1.25	0.39
As	3	7	13	12	14	24	19
Au(ppb)	0.7	0.8	0.4	0.7	1.3	5.1	3.1
Ba	390	660	1740	910	8400	2.07%	5840
Ce	38	42	22	42	39	46	54
Cl	240	230	140	<20	-	<20	<20
Co	12	11	2	<1	3	<1	<1
Cr	12	12	49	42	53	63	41
Cu	11	14	68	73	160	300	170
Ga	16	14	18	19	-	<3	5
La	27	20	16	16	20	36	17
Nb	8	7	10	8	-	12	12
Ni	7	5	10	5	-	<5	<5
Pb	21	29	110	150	400	2810	1450
Rb	30	27	90	130	84	120	99
Sb	<1	2	4	3	4	-	-
Sr	79	100	150	67	-	170	91
Th	8	8	13	11	12	-	-
V	88	85	110	81	-	140	100
Y	25	20	23	15	-	7	11
Zn	49	42	44	55	58	140	99
Zr	130	110	100	88	-	150	220
Ti/Zr	27	22	33	40	-	27	18

Table 3 Average compositions of Campaspe Formation and underlying volcanics, LLRC 130 and LLRC 138, Waterloo/Liontown (majors, wt%; minors, ppm)

Drill Hole	LLRC 130			LLRC 138	
Depth (m)	46-62	65-66	69-75	39-50	53-70
No of samples	4	1	3	3	5
Unit	----------Campaspe----------		Trooper Ck	Campaspe	Trooper Ck
SiO_2	84.2	63.2	69.3	76.8	68.1
Al_2O_3	6.26	11.2	13.9	13.0	16.3
Fe_2O_3	2.79	11.8	4.57	2.89	4.92
MgO	0.50	1.47	1.95	0.29	0.30
CaO	0.26	0.33	0.27	0.05	0.13
Na_2O	0.77	0.80	0.73	0.13	4.31
K_2O	0.55	0.68	3.01	0.60	1.04
TiO_2	0.24	0.78	0.26	0.94	0.39
MnO	0.03	0.06	0.16	0.01	0.02
P_2O_5	0.02	0.11	0.03	0.04	0.05
SO_3	0.02	<0.01	<0.01	0.02	<0.01
Ba	170	290	840	560	280
Ce	28	50	51	62	75
Cl	520	960	330(90)	400	780
Co	7	22	4	3	10
Cr	13	<10	<10	23	<10
Cu	110(65)	68	72	33(13)	72
Ga	8	14	17	15	13
La	13	24	27	37	36
Nb	<4	5	7	15	5
Ni	26	110	48	110(8)	40(15)
Pb	18	15	15	38	18
Rb	16	9	65	26	18
Sr	37	50	40	74	73
V	46	55	15	87	73
Y	20	30	28	17	29
Zn	37	390	550	34	120
Zr	90	91	160	190	97
Ti/Zr	16	51	11	30	25

Note: Values in parentheses exclude one anomalously high value.
See Appendices 2 and 3 for data from individual samples

Table 4 Average compositions of zones in Campaspe Formation and underlying Volcanics, Thalanga East (majors, wt%; minors, ppm)*

Drill Hole		TH 358		TH 424	
Depth (m)	2.5-4.1	8.5-17.9	18.1-27.6	55.5-56.9	58.0-71.6
No of samples	2	4	7	2	6
Unit	Campaspe Fm		Mt Windsor	Campaspe	Mt Windsor Volc
SiO_2	78.3	76.8	77.5	56.0	70.2
Al_2O_3	13.2	9.77	10.4	7.90	10.1
Fe_2O_3	3.93	8.15(4.77)	4.60	25.1	9.74
MgO	0.90	1.06	0.74	0.41	0.46
CaO	0.25	0.16	0.12	0.26	0.31
Na_2O	0.91	0.71	0.73	0.85	1.16
K_2O	2.21	1.68	1.96	0.57	0.96
TiO_2	0.33	0.30	0.32	0.19	0.35
MnO	0.03	0.08(.03)	0.08(.04)	0.02	0.03
P_2O_5	0.03	0.02	0.01	0.07	0.05
SO_3	<0.01	0.03	0.04	0.01	0.02
Ba	380	700	950(530)	160	420(290)
Ce	-	-	21	20	36
Cl	-	-	<20	65	65
Cr	36	30	<10	23	<10
Co	23	13	6	1	5
Cu	20	140	180	51	34
Ga	-	-	12	9	12
La	24	29	18	<10	16
Ni	<20	<20	<20	<10	<10
Nb	9	11	12	9	10
Pb	38	240	200	130	110(38)
Rb	110	69	68	24	36
Sr	82	42	35	34	33
V	71	110(62)	49	230	90
Y	42	36	24	8	22
Zn	280	1070	700	160	140
Zr	100	130	150	67	110
Ti/Zr	18	14	13	17	17

*Some data taken from Taylor and Humphrey (1991).
Note: Values in parentheses exclude one anomalously high value.
See Appendices 4 and 5 for data from individual samples

4.5 Brittania

At Brittania, the regolith consists of a sequence of alluvial clay overlying "sands" before passing through weathered bedrock andesites of the Trooper Creek Formation (R. Sainty, pers. comm., 1995). The uppermost clay-rich zone is characterized by the presence of plagioclase ± orthoclase, kaolinite, muscovite and trace to minor smectites and goethite (Figure 19). Material from the "sand" zone contains only kaolinite, muscovite and trace goethite with quartz. Both feldspars and smectites are absent from this sand zone. The underlying weathered andesites are indicated by the presence of abundant smectites (Figure 19). Within the andesites, the effects of weathering are seen over an interval of 50 m. Intensive weathering in the top 25-30 m of andesite results in assemblages of quartz ± plagioclase, goethite, muscovite and kaolinite with the smectites. Partially weathered material, with two feldspars (both plagioclase and orthoclase), epidote, chlorite and amphibole retained in the presence of smectites, occurs for another 25 m. Fresh andesites have similar mineral assemblages except that they contain no clay minerals and pyrite and calcite are present in some samples (Figure 19).

Within the regolith at Brittania, the "sand" unit is readily identified by its high Si and quite low contents of other elements (Table 5). The weathered andesite is distinguished from the overlying regolith units by its high Al, Fe, Mg, Ca, K, Ti, Ce, Co, Cr, Cu, La, Ni, Pb, Rb, Sr, V, Y, Zn and low Si, Nb and Zr contents (Table 5). The higher Ti/Zr ratio also distinguishes the andesite from the other units. The similarity between the Ti/Zr ratios for the "sand" and the alluvial clay suggests that both are ultimately derived from felsic rocks.

5. DISCUSSION

5.1 Waterloo-Liontown area

In the two southernmost drill holes along Line 5 (GY 232 and GY 233), the absence of feldspar and increased Fe oxide, kaolinite, smectite (and muscovite) is interpreted as marking the transition across the unconformity at ~48 m (Figures 3-7). Bianchite (Zn, Fe)$SO_4.6H_2O$ and alunite-type minerals occur in the weathered volcanics beneath the unconformity and indicates that these holes pass from Campaspe Formation into weathered mineralization. Elevated Cu, Pb, Zn and Ba contents in the volcanics are consistent with such an interpretation (e.g. Figures 10-12). Although Al is elevated and Si, Cl and Cr lower in the volcanics relative to the Campaspe Formation, other previously determined chemical discriminants (i.e. lesser Ce, Zr and greater Ti/Zr in the volcanics; Scott 1995) are not consistently useful as lithological discriminators in these profiles. (Appendix 1).

In TW 29, the abrupt cessation of feldspar and the increase in muscovite, kaolinite and smectites again reflects the transition from Campaspe Formation to weathered mineralized volcanics, indicated by the presence of alunite-type minerals and barite (Table 2, Figure 14). However, of the potential lithogeochemical discriminants listed above, only the increased Al and Ti/Zr and decreased Si and Cl reflect the change from sediments to volcanics (Table 2).

To the north of the mineralization along Line 5 (i.e. holes GY 234 to GY 239), there is no change in the feldspar, kaolinite, mica or smectite content at the unconformity. Although the volcanics have generally lower Si and Cl and higher Al, Ti/Zr than the Campaspe Formation, geochemical discriminants do not consistently work in these barren profiles. Whether this persistence of feldspar within the volcanics reflects a lack of feldspar-destructive hydrothermal alteration (prior to weathering) or a lack of acid conditions (derived from weathering sulfides) during weathering processes, the northern portion of Line 5, with feldspar through the whole profile, appears to be less

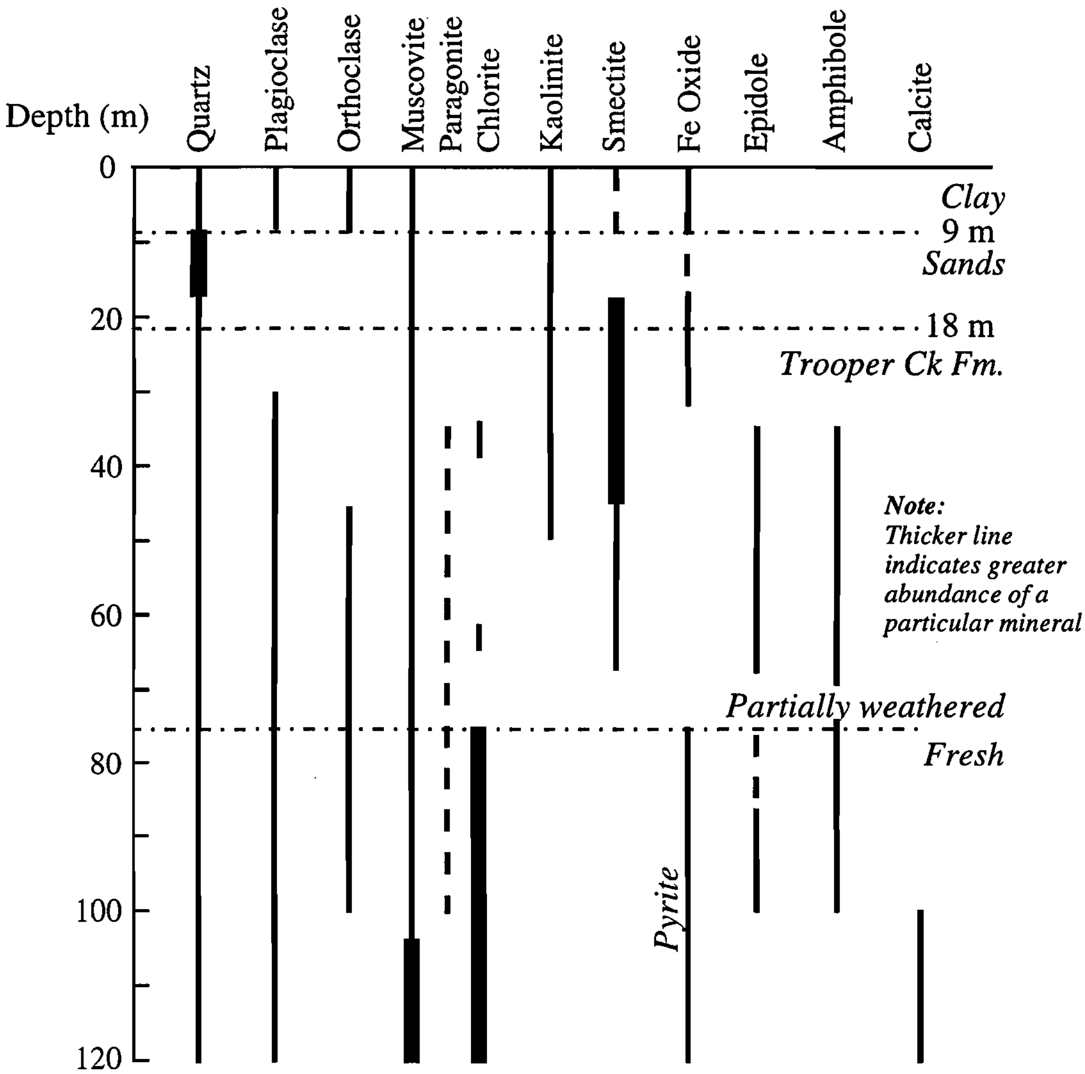


Figure 19 Mineralogical variations BRDD14, Brittania
(determined by XRD).

Table 5 Average compositions of regolith zones, Brittania (majors, wt%; minors, ppm)

Zone No. of samples	Alluvial Clay 2	Sand 3	Weathered Andesite 4
SiO_2	76.1	84.0	49.6
Al_2O_3	12.2	9.84	19.1
Fe_2O_3	3.73	1.35	12.8
MgO	0.35	0.13	1.67
CaO	0.10	0.05	0.55(.21)
Na_2O	0.54	0.09	0.52
K_2O	0.75	0.26	1.32
TiO_2	0.36	0.29	0.77
MnO	0.03	0.01	0.06
P_2O_5	0.02	0.01	0.06
SO_3	0.03	0.02	0.04
Ba	300	160	600(390)
Ce	26	<20	61
Cl	790	400	590
Co	4	2	30
Cr	22	12	76
Cu	<10	12	280
Ga	17	12	17
La	16	10	42
Nb	9	8	4
Ni	<5	8	44
Pb	24	20	36
Rb	27	10	59
Sr	24	10	66
V	47	23	190
Y	21	9	39
Zn	44	23	1100
Zr	140	120	63
Ti/Zr	16	15	76

Note: Value in parentheses excludes one anomalously high value
See Appendix 6 for data from individual samples.

altered/mineralized than Line 4. The relatively low base metal contents in basal samples from drill holes to the north of GY 233 (Appendix 1, Figures 10-12) are consistent with this interpretation. Thus mineralization is unlikely to occur to the north of GY 233 but could occur south of GY 232.

The occurrence of Zn and Cu anomalies at the unconformity along the whole of Line 5 and between 25 and 40 m in GY 236 to GY 239 (i.e. 10 m above the base of the Campaspe Formation and to the north of the weathered mineralization) suggests that hydromorphic dispersion of Zn (and Cu) may have occurred. Comparison with the dolomite distribution (Figure 8) suggests that alkaline conditions leading to dolomite formation/preservation may be responsible for the retention of the normally mobile Zn and Cu. Using information from other sections at Waterloo, the Zn anomaly at 25-40 m depth within the Campaspe Formation is at least 600 m long and greater than 300 m wide to the north of the Waterloo mineralization (Figure 20). Copper >50 ppm within the Campaspe Formation also occurs along Line 5 and Line 3 but does not form such an extensive halo as that of Zn. The location of the Zn and Cu anomalous zones within the broader Pb > 50 ppm zone within the Campaspe Formation (Figure 21) could suggest that all three elements were originally present in mechanically transported gossanous fragments, with Zn and Cu being subsequently mobilized and only stabilized/retained where alkaline conditions are present. The fact that the Pb anomaly is open to the north and southeast suggests that broad Pb anomalies within the Campaspe Formation could be significant in regional exploration. In fact, Hartley and Alston (1995) indicate Pb >25 ppm is anomalous for the Campaspe Formation, with Pb >100 ppm representing meaningful anomalies. Thus the presence of smaller Zn (and Cu) anomalies within large Pb anomalies could provide a vector to mineralization, even though the Zn (+ Cu) anomalies are likely to be slightly laterally displaced from the mineralization. Whether the Zn (+Cu) halo is always associated with carbonate should be investigated further because of the implications for finding such haloes simply by analysing the dolomitic material and not every sample within Campaspe Formation profiles.

As seen along Line 4 (and in TW 29), dolomite occurs at the top of the weathered volcanic profile immediately below the Campaspe Formation (Scott, 1995). There the dolomite was argued by Scott (1995) to represent pedogenic carbonate formed at the top of the pre-Campaspe weathering profile. However, in the barren profiles along Line 5, weathering is less intense (as reflected by the persistence of plagioclase across the unconformity), and the dolomite horizon, if present, occurs much higher in the Campaspe Formation. Thus, a carbonate horizon (although very significant, as seen above) cannot be used as an indicator of the unconformity in barren profiles. Furthermore, although the volcanics have lower Si and Cl and higher Al and Ti/Zr (except in GY 238 where the volcanics are more dacitic than andesitic), the other geochemical parameters do not consistently discriminate between the volcanics and sediments in these barren holes.

Even more felsic volcanics occur 2 km SSW of Waterloo where drill hole LLRC130 passes through 68 m of Campaspe Formation before passing into weakly mineralised rhyolite. Nevertheless LLRC 130 shows the absence of feldspars in the uppermost volcanic samples (at 69 m) and increased muscovite and smectite contents in the mineralized volcanics relative to the overlying Campaspe Formation (Fig. 15). Aluminium is elevated and Si, Cr and perhaps, Ti/Zr, depleted in the volcanics relative to Campaspe Formation (Table 3). Despite the Si content of these volcanics being higher and the Ti/Zr ratio much lower than in most of the volcanics along Line 5 (reflecting a rhyolitic rather than an andesitic-basaltic composition), Si and Al are still good discriminators for volcanics and sediments. The maintenance of such lithological differences reflects a concurrent change in the Campaspe Formation composition. This suggests that the Campaspe Formation here may be locally derived from quite felsic rocks.

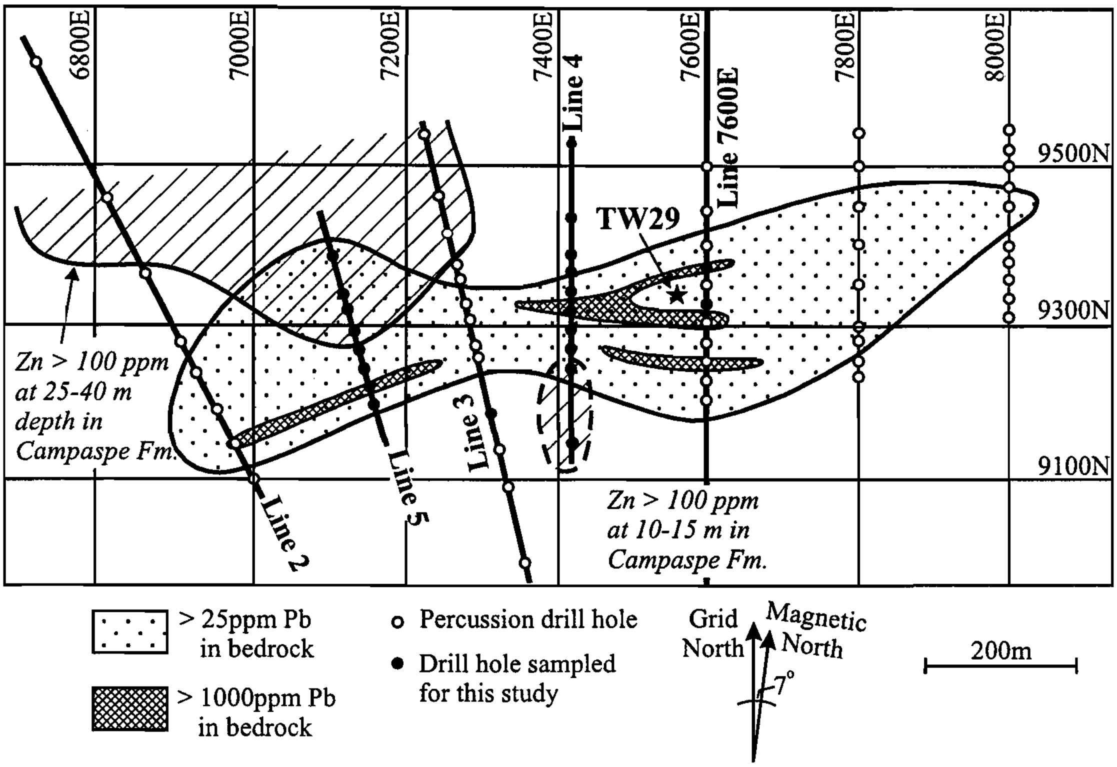


Figure 20 Location of Zn halo in the Campaspe Formation at Waterloo.

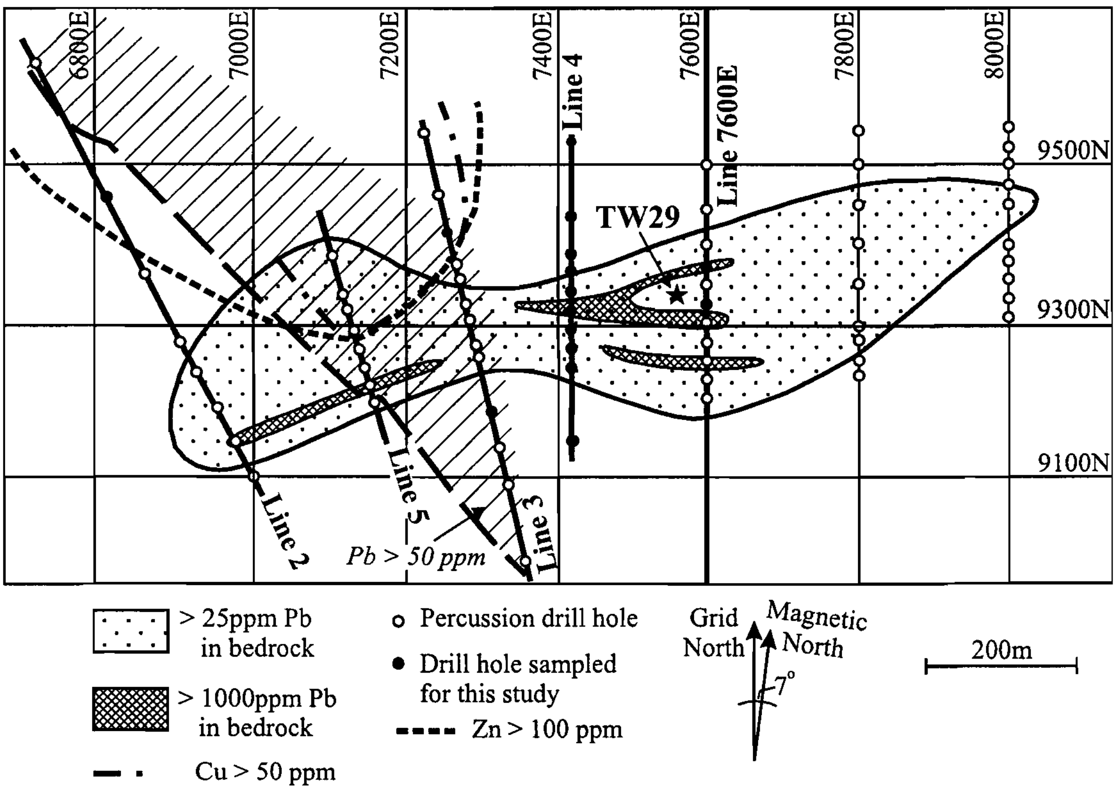


Figure 21 Location of Zn and Cu halos within Pb halo in Campaspe Formation at western end, Waterloo.

The relatively high Ti/Zr within the Campaspe Formation from the profile provided by LLRC 138 (2 km SE of Waterloo) (Table 3) also suggests local derivation from more mafic material than that which generally provides the source for the unit. (The absence of feldspars in the Campaspe Formation immediately above the volcanics is a further reflection of regional variability in the Campaspe Formation). However the presence of feldspars in the volcanics (Figure 16) reflects the absence of acid weathering in the volcanics (i.e. barren volcanics). Thus the mineralogical break between the Campaspe Formation and the barren volcanics is probably fortuitous in this drill hole.

Study of these profiles confirms the observations of Scott (1995) that the transition from the Campaspe Formation into mineralized volcanics at Waterloo is marked by an abrupt cessation of the presence of feldspars and an increased abundance of kaolinite, smectites, muscovite ± alunite-type minerals ± barite. Iron oxides are commonly enriched within this region either at the base of the Campaspe or top of the volcanics. Copper, Pb, Zn and Ba are generally enriched in the mineralized volcanics although some dispersion into the overlying Campaspe Formation by mechanical and/or hydromorphic processes is also possible (e.g. sample 134020, Appendix 2). Chemically the volcanics are enriched in Al and depleted in Si, Cl and Cr relative to the Campaspe Formation. Ti/Zr ratios may be useful in discriminating the two units when the volcanics are dacitic, andesitic or basaltic but not if they are rhyolitic. In the case of such felsic rocks, textural information, such as the rounding of quartz grains, may be the only effective way to define the Campaspe/volcanic contact.

Neither mineralogical (changes in feldspar and phyllosilicate abundances) nor geochemical (Si, Al, Ti/Zr contents) discriminants consistently define the Campaspe/volcanic transition where the volcanics are barren. Thus the textural features (quartz rounding) may be the only way to consistently define the transition. However, once it is known that one is dealing with volcanics (and Ti/Zr ratios may be useful if the volcanics are relatively mafic i.e. andesitic-basaltic), the presence of the feldspars and poor development of kaolinite suggest that such volcanics are unaltered/non-prospective.

5.2 Thalanga East

At Thalanga East there are no distinctive mineralogical differences between the Campaspe Formation and the underlying volcanics in either of the holes studied. Because the volcanics are rhyolitic, Ti/Zr ratios do not help define the boundary either. From visual inspection of the core, it is quite obvious that substantial amounts of the volcanics are incorporated as detrital fragments into the basal portion of the Campaspe Formation (W. Herrmann, pers comm., 1995). Thus, incorporation of mineralized material is likely to account for most of the geochemical enrichment (Ba, Cu, Pb, Zn) in the basal 10 m of the Campaspe Formation in TH 358 (Table 4) with the more extensive development of anomalous Zn probably reflecting superimposed hydromorphic dispersion, as seen at Waterloo (Figure 12). The lack of geochemical/mineralogical criteria (with the possible exception of higher Cr and V contents in the Campaspe Formation: Table 4) indicates that careful logging of textural features (e.g. quartz rounding) may be the only way to define the unconformity at Thalanga.

5.3 Brittania

At Brittania, the absence of feldspars at about 9 m in drill holes reflects the transition from clay-rich to sandy regolith material. Weathered andesitic volcanics are indicated by the presence of smectitic clays below 18 m (Figure 19). Chemically, the weathered andesite is readily distinguished from the overlying units by its higher Al, Fe, Mg, Ti, Co, Cr, V and lower Nb and Zr contents than the overlying regolith units. Higher Ti/Zr ratios also readily differentiate the andesite from cover material. Copper, Pb and Zn contents are also elevated in the andesite, but with the absence of suitable adsorbers/absorbers in the sandy unit, there is no record of any significant hydromorphic dispersion of Cu or Zn into the cover sequence at Brittania.

6. CONCLUSIONS

Differentiating the Campaspe Formation from weathered volcanics in the Mt Windsor sub-province is difficult but mineralogical and chemical parameters may be useful in supplementing textural information. The Campaspe Formation is generally characterized by assemblages of quartz, plagioclase, orthoclase, smectite and kaolinite. When this overlies weathered altered/mineralized volcanics, very kaolinitic and mica-rich assemblages (sometimes with alunite-jarosites and/or barite) with no feldspars are encountered. In such areas, the abrupt change in the feldspar and kaolinite abundances readily define the Campaspe/volcanic unconformity. Elevated base metal and Ba contents may also be present in the basal few metres of the Campaspe Formation as well as in the mineralized volcanics (Figure 22). However, if volcanics are unaltered, although elevated Ba and base metal contents can occur at the unconformity (due to mechanical transport), feldspars are still present in the weathered volcanics (Figure 22) and recognition of the unconformity cannot always be accomplished by the use of simple mineralogical and/or chemical discriminants.

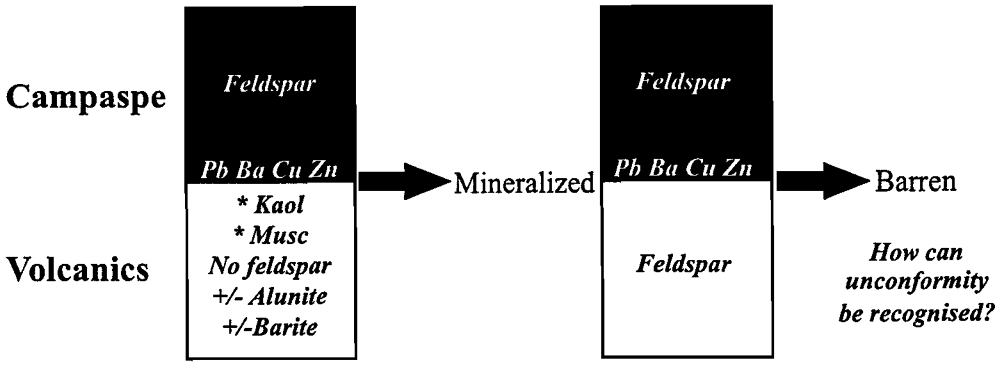


Figure 22 Recognition of the Campaspe/volcanic unconformity in the presence of mineralization

If the volcanics are of intermediate to basic composition, features such as the higher Si, Cl and lower Al and Ti/Zr can be used to distinguish the Campaspe Formation from the volcanics (Figure 23). However, where the volcanics are quite felsic, as at Thalanga East and LLRC 130 (Liontown-Waterloo area), geochemical parameters do not discriminate between the sediments and volcanics (Figure 23). In such cases textural information may provide the only information upon which to decide the rock-type in weathered drill chips.

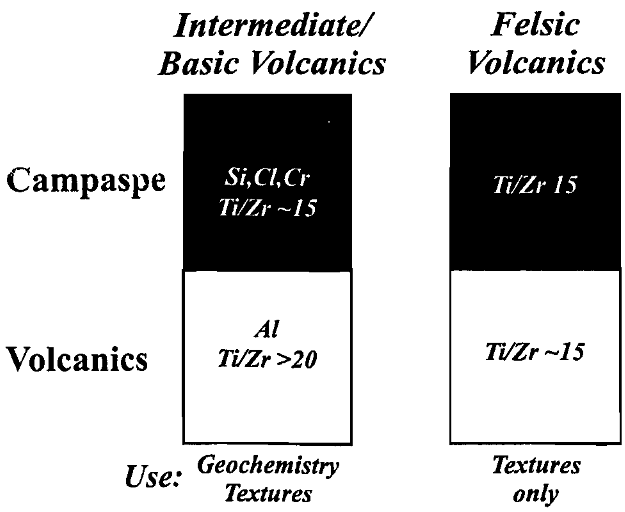


Figure 23 Recognition of the Campaspe/volcanic unconformity in barren profiles

The distribution of chalcophile elements in cover sequences at Waterloo and Thalanga East indicates that Pb and Ba may be strongly dispersed as gossanous fragments into the basal portion (up to 10 m) of the Campaspe Formation. Zinc and Cu are associated with such gossanous fragments, but they are also dispersed further both vertically (at Thalanga East) and laterally (at Waterloo). In the latter case, a Zn >100 ppm halo up to 600 x 300 m is present in the Campaspe Formation to the northwest of the deposit where the cover is more than 40 m thick. Along Line 5 at Waterloo, there may be some association between this anomaly and the occurrence of dolomite. Because dolomite samples can be easily identified in drill chips, the association of Zn and Cu with dolomite should be further investigated.

Quartz-rich "sand" between the more clayey Campaspe Formation and the volcanics at Brittania, does not contain any suitable host to retain/stabilize mobile cations so that no hydromorphic halo appears to be developed/retained in the two holes studied.

7. ACKNOWLEDGEMENTS

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Appendix 1. Composition of samples from drill holes along Line 5, Waterloo (major components, wt%; minors, ppm); except where otherwise indicated

Drill hole	129758	129760	129761 GY232	129765	129767	129778	128780	129784 GY233	129786	129788	129797	129798	129800 GY234	129801	129802	129807
Depth (m)	24-27	30-33	33-36	45-48	51-54	21-24	27-30	39-42	45-48	51-54	18-21	21-24	30-33	33-36	36-39	51-54
Unit	Campaspe				Volc	Campaspe				Volc	Campaspe					Volc
SiO_2	63.2	64.8	68.2	74.0	61.5	67.4	65.6	71.6	76.4	59.7	69.4	67.3	67.5	62.4	74.2	52.4
Al_2O_3	13.2	14.2	12.5	10.3	16.9	13.7	12.3	10.9	8.28	20.6	11.9	13.3	12.9	14.1	11.3	18.1
Fe_2O_3	6.06	7.20	6.78	4.38	7.59	6.37	6.13	6.12	5.57	5.78	6.02	6.35	7.06	7.29	4.74	14.8
MgO	2.14	1.26	1.07	0.85	1.23	0.97	1.65	0.96	0.66	0.61	1.51	1.10	1.14	1.62	0.72	0.67
CaO	1.93	0.51	0.24	0.33	0.23	0.21	1.27	0.29	0.35	0.13	0.51	0.45	0.46	1.10	0.25	0.30
Na_2O	1.13	1.13	1.07	0.87	0.20	1.44	0.85	1.01	0.93	0.81	2.02	0.89	1.19	0.65	0.96	2.29
K_2O	0.83	0.83	0.93	0.87	0.78	0.78	0.68	0.76	0.81	2.49	1.12	0.81	0.91	0.73	1.04	1.18
TiO_2	0.72	0.84	0.78	0.37	0.55	0.78	0.85	0.59	0.44	0.60	0.52	0.85	0.84	0.83	0.57	0.77
MnO	0.04	0.07	0.14	0.02	0.01	0.04	0.11	0.15	0.03	<0.01	0.09	0.04	0.15	0.21	0.07	0.02
P_2O	0.03	0.04	0.04	0.02	0.06	0.03	0.04	0.03	0.08	0.19	0.03	0.43	0.04	0.05	0.03	0.12
SO_3	0.01	0.01	0.01	0.03	0.03	0.01	0.06	0.01	0.09	1.02	0.01	0.02	0.01	0.03	0.01	0.04
As	-	-	11	41	7	-	-	13	49	210	-	-	-	18	9	78
Au(ppb)	-	-	<5	16	76	-	-	8	20	360	-	-	-	19	<5	47
Ba	280	330	480	600	660	260	1200	460	1030	1830	390	270	440	910	310	300
Ce	53	68	77	77	<20	49	69	58	76	130	56	51	72	59	61	43
Cl	130	70	20	<20	<20	240	160	<20	20	<20	330	300	230	100	90	<20
Co	5	10	17	12	8	8	11	11	5	<1	7	1	15	9	9	1
Cr	37	32	37	110	16	53	40	74	84	19	40	32	42	37	89	12
Cu	18	24	32	220	630	49	22	28	59	160	18	21	22	38	17	150
Ga	19	18	16	10	15	17	17	13	6	<3	15	17	18	15	13	17
La	30	35	31	33	13	25	32	14	29	23	28	24	40	33	21	12
Nb	10	15	14	<4	<4	14	18	9	8	5	10	18	15	11	8	7
Ni	14	18	8	14	19	29	<5	7	24	<5	6	14	8	10	<5	20
Pb	20	32	51	170	39	26	43	56	670	3400	15	27	33	66	33	170
Rb	38	37	40	25	24	31	33	30	26	58	38	37	38	39	37	28
Sb	-	-	1	5	1	-	-	1	8	65	-	-	-	1	<1	7
Sr	80	63	56	55	37	60	78	57	110	200	78	53	63	66	48	160
Th	-	-	11	6	4	-	-	7	6	6	-	-	-	9	8	6
V	94	130	110	69	120	120	120	100	69	110	90	110	120	140	82	200
Y	28	31	30	25	22	25	30	23	20	<5	26	25	34	29	20	26
Zn	92	87	76	410	1200	58	67	62	220	290	83	60	76	80	74	500
Zr	170	230	200	99	60	190	200	160	130	130	150	210	230	180	160	140
Ti/Zr	26	22	23	22	55	25	25	22	21	28	21	25	22	27	21	34

NOTE: U < 2 ppm

Appendix 1 (cont.)

	129828	129829	129832	129834	129835	129837	129858	129859	129861	129864	129867	129870
Drill hole			GY 236						GY 238			
Depth (m)	15-18	18-21	27-30	33-36	36-39	54-57	18-21	21-24	27-30	36-39	45-48	54-57
Unit			Campaspe			Volc			Campaspe			Volc
SiO_2	70.0	66.2	64.8	63.5	66.5	59.8	67.0	65.0	58.8	65.1	80.9	79.9
Al_2O_3	12.0	14.2	13.3	13.3	14.0	17.6	13.6	13.8	12.1	13.7	7.37	8.56
Fe_2O_3	5.25	6.47	7.08	8.13	6.58	10.2	6.97	7.04	6.75	8.26	3.56	3.57
MgO	1.15	1.10	1.48	1.43	1.05	0.48	1.27	1.14	3.04	1.22	0.67	0.60
CaO	0.41	0.26	0.76	0.83	0.28	0.22	0.31	0.42	3.27	0.39	0.28	0.23
Na_2O	2.20	1.56	1.20	0.98	1.18	2.48	1.84	0.94	0.87	1.76	1.13	1.23
K_2O	0.67	0.86	0.87	0.64	1.09	2.17	0.93	0.84	0.57	0.72	0.87	0.72
TiO_2	0.67	0.77	0.80	0.80	0.78	1.03	0.62	0.79	0.78	0.68	0.20	0.38
MnO	0.06	0.06	0.10	0.34	0.10	0.01	0.14	0.10	0.10	0.20	0.03	0.02
P_2O_5	0.02	0.04	0.05	0.06	0.04	0.19	0.04	0.04	0.04	0.05	0.03	0.04
SO_3	0.01	0.01	0.03	0.01	0.01	0.10	0.02	0.02	0.02	0.01	0.01	0.02
As	-	5	11	23	13	74	6	7	12	23	11	4
Au(ppb)	-	<5	7	<5	<5	19	<5	<5	<5	10	25	<5
Ba	280	330	690	590	350	500	480	410	450	410	230	360
Ce	45	57	75	62	65	37	67	49	60	55	130	46
Cl	430	470	200	230	140	<20	410	390	270	190	50	<20
Co	6	9	16	20	11	2	12	6	12	15	27	12
Cr	68	44	42	45	49	<10	81	38	27	53	110	72
Cu	14	16	72	42	29	61	16	36	72	48	24	28
Ga	15	17	17	16	17	21	16	19	15	16	10	10
La	34	30	38	23	40	16	26	26	22	22	57	20
Nb	12	10	11	11	10	6	9	9	13	11	<4	<4
Ni	<5	6	49	17	14	7	<5	21	38	9	9	<5
Pb	15	25	52	79	41	160	19	37	32	55	25	62
Rb	26	35	38	28	44	45	35	39	27	27	23	20
Sb	-	<1	<1	1	<1	3	<1	<1	<1	1	<1	<1
Sr	79	64	70	71	63	250	67	59	110	88	50	86
Th	-	10	11	7	11	4	11	11	8	7	4	5
V	82	120	120	150	110	150	110	110	120	140	39	65
Y	28	27	31	27	32	12	28	26	25	32	48	23
Zn	48	72	87	99	112	150	100	82	83	120	72	170
Zr	170	180	180	170	200	130	150	190	180	170	79	89
Ti/Zr	24	25	27	28	24	49	25	23	27	25	15	26

Appendix 1 (cont.)

	129881	129882	129883	129885	129886	129892
Drill hole			GY 239			
Depth (m)	21-24	24-27	27-30	33-36	36-39	54-57
Unit			Campaspe			Volc
SiO_2	71.5	65.2	64.5	59.0	66.1	68.5
Al_2O_3	12.1	13.5	12.5	12.3	12.7	12.4
Fe_2O_3	6.34	6.91	7.70	6.45	8.28	5.66
MgO	0.78	1.43	1.60	3.54	1.19	1.11
CaO	0.19	0.78	1.13	3.63	0.42	0.44
Na_2O	1.49	1.25	0.96	1.17	1.16	1.26
K_2O	0.84	1.02	0.63	1.37	0.63	0.92
TiO_2	0.62	0.70	0.79	0.57	0.75	0.62
MnO	0.06	0.10	0.10	0.18	0.17	0.04
P_2O_5	0.04	0.05	0.05	0.04	0.05	0.08
SO_3	0.02	0.02	0.02	0.03	0.01	0.03
As	-	-	-	-	-	-
Au(ppb)	-	-	-	-	-	-
Ba	350	390	320	1010	370	360
Ce	64	68	69	67	53	70
Cl	130	250	230	170	190	<20
Co	6	10	22	15	19	16
Cr	98	39	40	31	39	84
Cu	21	52	30	42	39	26
Ga	16	17	16	18	16	15
La	30	31	20	39	25	42
Nb	9	9	9	12	10	5
Ni	8	18	7	15	15	9
Pb	22	38	44	39	58	29
Rb	34	36	29	49	26	29
Sb	-	-	-	-	-	-
Sr	53	70	74	92	67	150
Th	-	-	-	-	-	-
V	100	130	130	110	130	120
Y	27	32	24	36	30	48
Zn	56	200	120	110	220	360
Zr	160	170	170	160	170	110
Ti/Zr	23	26	28	22	26	34

Appendix 2 Compositions of samples adjacent to Campaspe/Volcanic Unconformity, LLRC 130, Waterloo/Liontown (majors, wt%, minors, ppm).

	134001	134006	134011	134016	134020	134024	134026	134029
Depth(m)	46-47	51-52	56-57	61-62	65-66	69-70	71-72	74-75
Unit			Campaspe Fm				Trooper Ck Fm	
SiO_2	75.4	89.1	87.4	85.0	63.2	67.3	73.2	67.4
Al_2O_3	9.29	4.76	4.80	6.19	11.2	14.7	12.2	14.7
Fe_2O_3	4.24	1.56	2.67	2.70	11.8	4.80	3.98	4.93
MgO	0.72	0.26	0.55	0.45	1.47	2.03	1.67	2.15
CaO	0.45	0.26	0.16	0.16	0.33	0.21	0.19	0.41
Na_2O	1.20	0.94	0.43	0.51	0.80	0.45	0.75	1.00
K_2O	0.74	0.61	0.87	0.48	0.68	3.66	2.52	2.86
TiO_2	0.36	0.18	0.23	0.18	0.78	0.27	0.23	0.27
MnO	0.04	0.02	0.05	0.02	0.06	0.10	0.10	0.28
P_2O_5	0.02	0.01	0.02	0.01	0.11	0.03	0.03	0.04
SO_3	0.06	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Ba	250	160	120	140	290	980	710	820
Ce	38	29	21	22	50	45	55	54
Cl	920	410	530	220	960	800	60	120
Co	4	8	6	8	22	1	5	7
Cr	22	<10	12	11	<10	<10	<10	<10
Cu	82	61	51	230	68	21	120	75
Ga	12	7	6	7	14	19	16	17
La	18	8	13	13	24	28	26	27
Nb	5	<4	<4	<4	5	5	9	7
Ni	28	38	22	12	110	<5	75	68
Pb	33	11	15	14	15	13	13	20
Rb	24	14	11	15	9	79	54	61
Sr	58	33	28	29	50	27	31	61
V	70	29	43	43	55	16	16	14
Y	15	12	16	37	30	29	27	27
Zn	49	17	34	49	390	520	470	650
Zr	110	87	92	71	91	170	140	160
Ti/Zr	20	12	15	15	51	10	13	10

Appendix 3 Compositions of samples adjacent to Campaspe/Volcanic Unconformity, LLRC 138, Waterloo/Liontown (majors, wt%; minors, ppm).

	134030	134035	134040	134044	134045	134050	134055	134060
Depth(m)	39-40	44-45	49-50	53-54	54-55	59-60	64-65	69-70
Unit	Campaspe Fm					Trooper Ck Fm		
SiO_2	78.0	80.2	72.2	61.4	70.0	65.4	72.5	71.1
Al_2O_3	12.4	12.5	14.1	18.0	15.6	17.9	14.9	15.2
Fe_2O_3	1.96	0.91	5.81	8.20	5.02	5.14	2.90	3.36
MgO	0.24	0.19	0.45	0.45	0.38	0.29	0.22	0.20
CaO	0.05	0.04	0.06	0.13	0.12	0.14	0.13	0.12
Na_2O	0.14	0.12	0.14	0.92	3.35	6.74	4.66	5.86
K_2O	0.40	0.53	0.86	0.76	1.07	0.95	1.38	1.06
TiO_2	0.97	0.95	0.91	0.43	0.39	0.44	0.36	0.35
MnO	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
P_2O_5	0.02	0.04	0.07	0.08	0.06	0.04	0.02	0.03
SO_3	0.03	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ba	510	530	580	270	260	240	400	250
Ce	46	94	45	150	110	40	35	40
Cl	350	430	410	930	240	590	950	1170
Co	3	4	3	21	16	6	5	3
Cr	13	17	40	<10	<10	<10	<10	<10
Cu	12	72	14	38	75	150	66	29
Ga	16	14	16	16	12	17	11	11
La	24	53	33	70	52	24	12	22
Nb	15	13	18	7	5	<4	4	4
Ni	<5	300	15	21	25	140	10	<5
Pb	43	43	29	20	16	22	15	15
Rb	20	21	38	16	18	16	21	17
Sr	46	110	67	49	75	120	110	120
V	72	50	140	85	73	79	65	61
Y	16	17	19	44	47	26	13	15
Zn	47	19	36	190	110	130	75	91
Zr	180	190	200	100	100	110	87	86
Ti/Zr	32	30	27	25	24	25	25	24

Appendix 4 Compositions of samples DDH TH 358, Thalanga East (majors, wt%; minors, ppm)

Sample No	76743	76745	76747	76749	76751	128152	76752	128153	128154	128155a	128155b	76755	76756
Depth (m)	2.5	4.1	8.5	12.1	17. 2	17.9	18.1	18.5	18.9	19.5	19.5	22.3	27.6
Unit			Campaspe Fm						Mt Windsor Volcanics				
SiO_2	73.7	82.9	81.8	82.9	70.7	71.6	79.4	74.1	68.5	79.2	78.7	83.4	79.5
Al_2O_3	16.9	9.45	10.7	10.2	7.69	10.5	11.0	11.9	12.2	7.87	9.02	10.2	10.7
Fe_2O_3	4.89	2.96	2.96	3.72	18.3	7.63	4.53	3.42	5.95	5.51	2.08	2.63	8.05
MgO	1.27	0.53	1.74	1.06	0.83	0.61	0.93	0.89	1.08	0.52	0.64	0.69	0.46
CaO	0.28	0.23	0.12	0.10	0.13	0.30	0.17	0.14	0.16	0.12	0.14	0.07	0.06
Na_2O	0.69	1.13	0.35	0.22	0.64	1.61	0.93	0.86	0.84	1.03	0.93	0.43	0.06
K_2O	1.83	2.58	1.87	1.45	1.30	2.11	2.58	2.48	2.03	1.90	1.77	2.07	0.92
TiO_2	0.52	0.15	0.33	0.35	0.28	0.25	0.52	0.38	0.38	0.21	0.27	0.15	0.33
MnO	0.02	0.04	0.22	0.03	0.02	0.03	0.03	0.04	0.04	0.03	0.02	0.31	0.08
P_2O_5	<0.02	0.05	<0.02	<0.02	0.04	0.02	<0.02	0.01	0.01	0.02	0.01	0.02	0.02
SO_3	<0.02	<0.02	<0.02	<0.02	0.06	0.05	0.03	0.03	0.01	0.02	0.17	<0.02	<0.02
As	<10	<10	<10	<10	96	-	11	-	-	-	-	<10	40
Au(ppb)	<5	<5	<5	<5	6	-	14	-	-	-	-	11	<5
Ba	270	490	590	330	740	1200	770	540	440	440	3400	740	260
Ce	-	-	-	-	-	<20	-	25	29	<20	<20	-	-
Cl	-	-	-	-	-	<20	-	90	<20	<20	<20	-	-
Co	14	29	40	8	4	1	6	5	3	<1	2	15	10
Cr	45	27	28	36	47	10	17	<10	<10	<10	<10	18	14
Cu	24	16	45	170	230	130	160	170	220	87	110	210	330
La	24	24	44	38	20	12	14	21	21	10	15	31	12
Ga	-	-	-	-	-	9	-	14	16	6	11	-	-
Nb	13	5	12	12	8	13	13	12	13	9	10	14	10
Ni	<20	<20	<20	<20	<20	<10	<20	<10	<10	<10	<10	<20	<20
Pb	47	30	130	49	510	260	200	140	180	190	79	300	290
Rb	120	96	89	72	52	63	82	88	80	50	55	84	35
Sb	0.5	0.6	0.6	0.8	2.4	-	0.5	-	-	-	-	0.7	0.2
Sr	70	94	45	32	39	50	55	34	34	29	60	25	11
V	78	63	46	63	260	76	69	36	52	54	32	33	70
W	<2	5	18	6	8	-	51	-	-	-	-	6	7
Y	35	48	67	39	18	21	29	25	25	16	18	35	23
Zn	190	370	1700	1200	810	550	760	680	740	370	590	910	850
Zr	150	58	170	160	96	120	170	170	160	110	120	150	150
Ti/Zr	20	15	12	14	18	13	18	13	14	11	14	6	13

Note: data for sample numbers beginning 76--- taken from Taylor and Humphrey (1991).

Appendix 5 Compositions of samples, DDH TH 424, Thalanga East (majors, wt%; minors, ppm)

Sample No	128156	128157	128158	128159	128160	128161	128162	128163
Depth (m)	55.5	56.9	58.0	60.5	63.3	66.2	69.4	71.6
Unit	Campaspe		Mt Windsor Volc					
SiO_2	51.6	60.4	67.0	62.2	74.2	72.0	69.2	76.6
Al_2O_3	5.85	9.95	9.23	9.01	11.1	8.78	11.6	10.7
Fe_2O_3	32.8	17.4	13.6	18.4	4.93	9.10	7.96	4.46
MgO	0.32	0.49	0.43	0.47	0.35	0.47	0.69	0.35
CaO	0.20	0.32	0.35	0.58	0.19	0.21	0.28	0.25
Na_2O	0.32	1.37	2.12	0.95	1.37	0.21	0.51	1.78
K_2O	0.44	0.69	0.74	0.79	1.01	0.61	0.71	1.91
TiO_2	0.14	0.24	0.27	0.33	0.44	0.45	0.39	0.22
MnO	0.02	0.02	0.03	0.06	0.03	0.03	0.02	0.02
P_2O_5	0.08	0.06	0.06	0.09	0.03	0.04	0.04	0.03
SO_3	0.01	0.01	0.02	0.03	0.01	0.01	0.02	<0.01
Ba	110	210	410	260	280	220	270	1070
Ce	21	<20	22	45	29	36	67	<20
Cl	130	<20	<20	<20	120	70	280	150
Cr	20	25	<10	19	12	<10	<10	<10
Co	2	<1	<1	<1	2	9	11	5
Cu	45	57	59	86	26	<10	15	12
Ga	6	12	11	10	10	13	14	14
La	<10	<10	11	<10	14	13	36	15
Ni	<5	<5	<5	<5	<5	<5	14	<5
Nb	9	9	8	7	9	12	12	10
Pb	120	130	250	250	46	31	33	42
Rb	17	31	45	26	37	23	25	57
Sr	28	40	44	49	32	17	23	32
V	250	200	110	190	60	80	75	22
Y	<5	12	9	15	13	29	33	32
Zn	150	160	150	190	93	120	140	120
Zr	45	89	97	93	130	160	160	120
Ti/Zr	18	16	17	21	21	17	16	11
K/Rb	220	180	140	250	230	220	240	280

Appendix 6 Compositions of samples, BRDD 14 and BRRC 4, Brittania (majors wt%; minors, ppm)

Sample No	113456	113457	113458	113459	113470	113471	113472	113473	113474
Drill hole		BRDD14					BRRC4		
Depth (m)	6-9	15-18	24-27	30-33	6-9	9-12	15-18	21-24	27-30
Unit	Clay	Sand	Volcanics		Clay	Sand		Volcanics	
SiO_2	79.0	85.6	56.1	54.0	73.1	83.4	83.0	42.9	45.4
Al_2O_3	9.61	9.03	15.4	18.0	14.8	10.0	10.5	22.9	20.1
Fe_2O_3	4.22	1.29	14.5	10.6	3.24	1.48	1.27	14.4	11.5
MgO	0.37	0.12	0.80	1.69	0.33	0.12	0.15	1.21	2.98
CaO	0.11	0.04	0.13	0.31	0.09	0.05	0.05	0.20	1.55
Na_2O	0.75	0.05	0.23	0.76	0.33	0.14	0.07	0.36	0.73
K_2O	1.13	0.25	0.69	1.43	0.37	0.18	0.35	0.97	2.18
TiO_2	0.30	0.23	0.53	0.91	0.42	0.30	0.35	0.82	0.83
MnO	0.03	0.01	0.03	0.07	0.02	0.01	0.01	0.03	0.10
P_2O_5	0.02	0.01	0.09	0.06	0.01	0.01	<0.01	0.04	0.05
SO_3	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.11	0.02
Ba	340	180	240	360	260	160	140	270	540
Ce	38	<20	60	73	<20	20	<20	<20	97
Cl	710	180	330	590	860	670	350	680	770
Co	4	1	23	44	4	2	2	15	39
Cr	19	15	24	38	24	10	10	130	110
Cu	12	31	330	350	<10	<10	<10	190	260
Ga	14	12	15	17	19	12	12	19	19
La	19	18	46	34	12	<10	<10	11	76
Nb	11	6	<4	5	6	9	8	<4	5
Ni	5	15	38	46	<5	<5	8	32	58
Pb	27	26	36	15	21	19	14	60	31
Rb	39	9	43	75	14	7	13	39	77
Sr	30	11	57	64	18	12	8	41	100
V	54	23	240	160	40	22	24	240	130
Y	26	8	9	45	15	8	12	<5	96
Zn	37	29	440	650	50	20	21	1160	2170
Zr	140	89	69	69	140	100	160	61	52
Ti/Zr	13	16	46	79	18	17	13	81	96