WATERLOO BASE METAL DEPOSIT, MT WINDSOR SUB-PROVINCE, NE QUEENSLAND

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LOCATION

The Waterloo Zn-Cu-Pb-Ag-Au deposit is located 35 km SW of Charters Towers at 20˚22'S, 146˚07'E; Charters Towers 1:250 000 map sheet (SF 55-02).

DISCOVERY HISTORY

Polymetallic massive sulphide mineralization was first discovered at Liontown in 1905. However, it was the 1975 discovery of the 8.6 Mt Thalanga massive sulphide deposit (Herrmann, 1995), within the volcanic rocks of the Mt Windsor Sub-province (Figure 1), that encouraged modern exploration for volcanogenic sulphide deposits in the Charters Towers region (Berry *et al.,* 1992; Beams and Jenkins, 1995). Deposits found prior to 1981 were at least partially outcropping and discovered either by prospectors or by modern, conceptually based gossan searches and stream sediment geochemistry. However, in 1981, mineralization was found below Tertiary cover (Campaspe Formation) at East Thalanga by Penarroya (Australia) Pty Ltd by RAB drilling. In 1985, the Waterloo deposit was found, 40 km E of Thalanga, by drilling through the Campaspe Formation into the underlying volcanic rocks (Berry *et al.,* 1992; Hartley and Alston, 1995), after a small outcrop of altered volcanic rock was recognised in an adjacent creek by P. Gregory of BHP Minerals.

Hartley and Alston (1995) identified a laterally extensive Pb anomaly at 25-30 m depth within a 50 m thick regolith sequence, which they thought to be Campaspe Formation, above the Waterloo deposit. They argued that this represents mechanical dispersion, from a previously outcropping gossan, during deposition of the Campaspe Formation, and recommended systematic sampling of the complete Campaspe Formation profile during exploration.

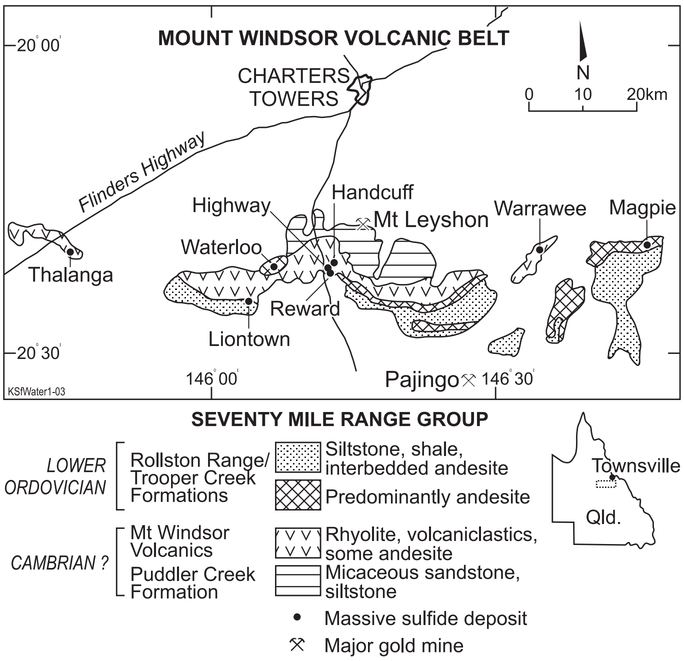

Figure 1. Location map of the Mt Windsor Sub-province volcanic rocks and mineral deposits (after Hartley and Alston, 1995).

PHYSICAL FEATURES AND ENVIRONMENT

The climate is tropical with hot, wet summers and warm, dry winters with a few frosts. The mean annual rainfall is 660 mm and falls mainly during December-March, associated with local thunderstorms or rain-bearing depressions. The mean daily maximum and minimum temperatures are 35°C and 21°C in December, and 25°C and 11°C in July.

The deposit occurs beneath eucalypt woodland and savanna within the catchment of the Burdekin River, a perennial stream which may be reduced to a string of waterholes during very dry seasons. Smaller streams, like the one exposing altered volcanic outcrop, a few hundred metres from the deposit, are ephemeral (Clarke and Paine, 1970). These streams have cut several metres into flat-lying alluvium adjacent to the deposit.

GEOLOGICAL SETTING

The Cambro-Ordovician volcanic rocks of the Mt Windsor Sub-province form a 160 x 30 km belt flanking the southern edge of the Ordovician-Permian Lolworth-Ravenswood granitoids, to the S of Charters Towers. The Waterloo deposit occurs within andesitic and felsic volcaniclastic rocks of the Lower Ordovician Trooper Creek Formation, in the upper part of the volcanic sequence (Berry *et al.,* 1992; Figure 1). Other volcanogenic deposits of the region occur in a similar stratigraphic position, except for Thalanga. This occurs within the more felsic Cambrian Mt Windsor Volcanics at or close to their contact with the overlying Trooper Creek Formation (Gregory *et al.,* 1990). These prospective Palaeozoic rocks are overlain unconformably by the flat lying Pliocene Campaspe Formation (Henderson and Nind, 1994), consisting of poorly consolidated gravels, grits and claystones derived from both the Lolworth-Ravenswood granitoids and volcanic rocks. Quaternary alluvium and colluvium also occur near the deposit.

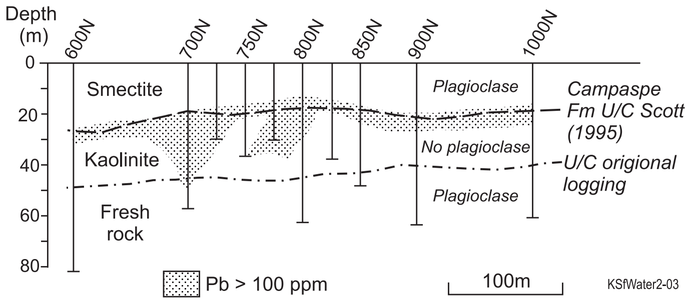

Figure 2. Lead distribution on line 4 with regolith mineralogical variations and revised position of the unconformity (after Scott, 1995).

REGOLITH

Weathering at Waterloo extends to about 50 m depth, penetrating about 20 m into the basement with breakdown of feldspar, chlorite and pyrite to saprolitic kaolinite and Fe oxide assemblages (Scott, 1995). This residual material is unconformably overlain by approximately 30 m of poorly consolidated gravels, grits and claystones of the Campaspe Formation. Because Campaspe Formation sediments and the residual profile beneath are not conspicuously different in drill cuttings, the original logging mistakenly identified the fresh rock/saprolite boundary as the unconformity (see Figure 2). However, these flat-lying sediments conceal an undulating basement surface (Hartley and Alston, 1995),

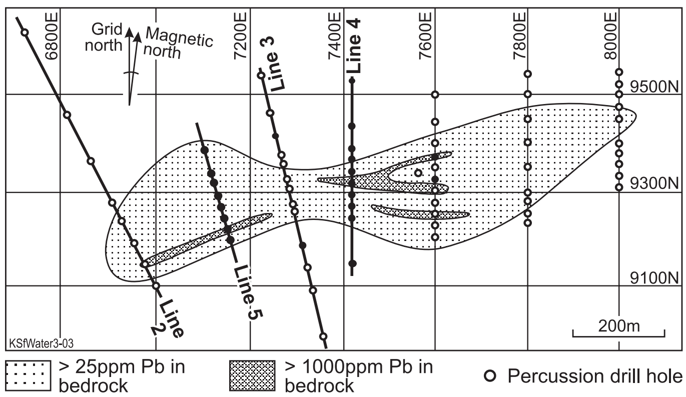

Figure 3. Plan of the Waterloo deposit, showing bedrock Pb contents and location of drilling (based on Penarroya (Aust) Pty Ltd grid).

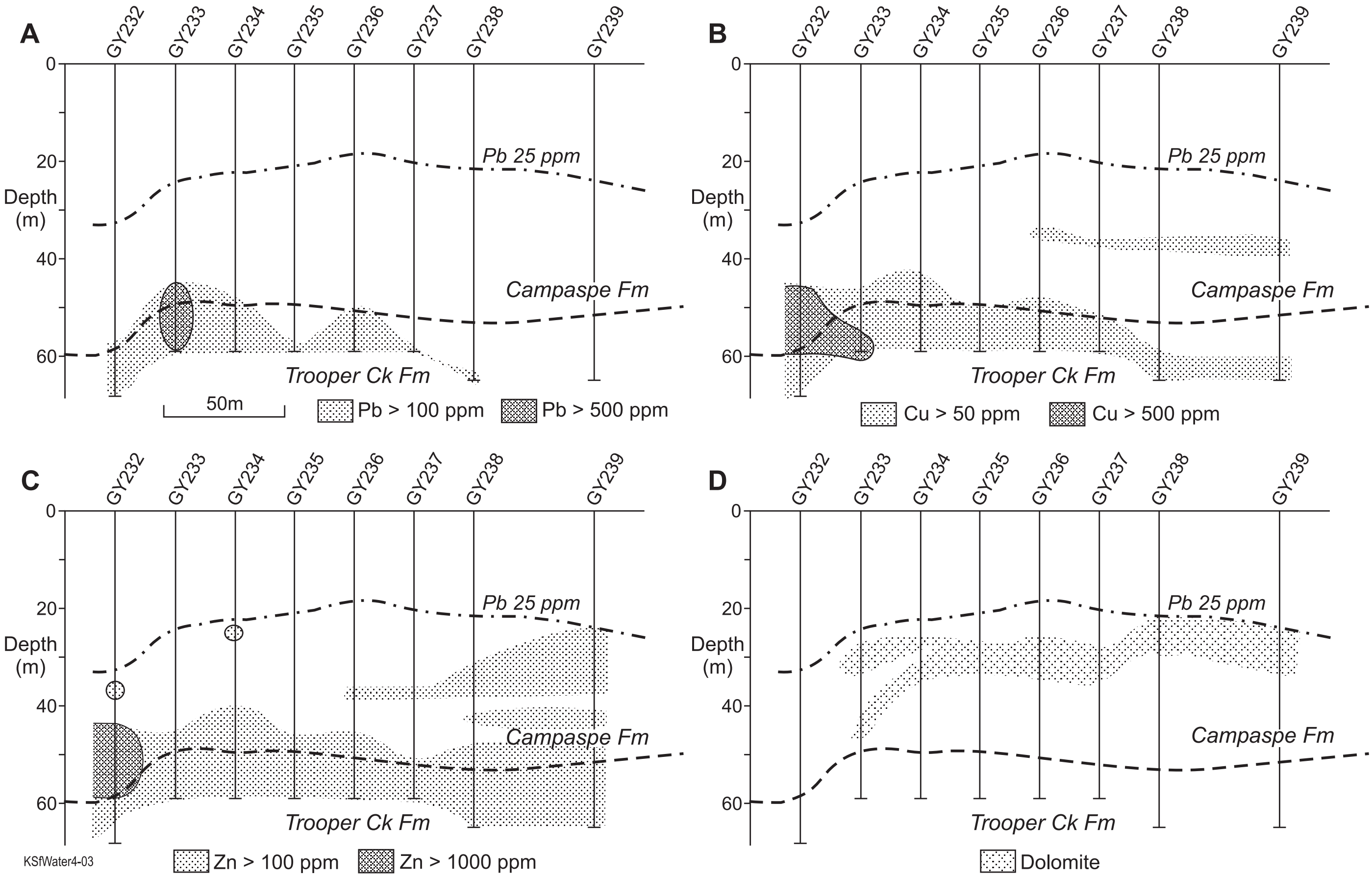

Figure 4. Distributions of Pb (A), Cu (B), Zn (C) and dolomite (D) on line 5.

with a deeper palaeochannel (65 m) over the NW of the deposit, quartz in the transported material is clear and rounded but, in the residual saprolite, is sparse and milky (Scott, 1997). Up to 10 m of dolomite occurs at about 30 m depth in the regolith, either in residual saprolite, in the central part of the deposit, or within the Campaspe Formation on the NW edge of the deposit (Scott, 1995; 1997). Several metres of Quaternary alluvium and colluvium, commonly containing pisoliths, also occur locally.

MINERALIZATION

The Waterloo deposit is hosted by andesitic and felsic volcaniclastics of the central portion of the Trooper Creek Formation. It is small (372,000 t) but high-grade (19.7% Zn, 3.8% Cu, 2.8% Pb, 94 g/t Ag and 2 g/t Au) and is sphalerite-, pyrite- and chalcopyrite-rich (Berry et al., 1992). Alteration associated with mineralization is to sericite, pyrite and quartz and extends 50 m into the footwall (R. Sainty, pers comm., 1995). The deposit is 300 m long, 5 m wide and dips sub-vertically beneath the Campaspe Formation sediments (Hartley and Alston, 1995).

REGOLITH EXPRESSION

Penarroya (Australia) Pty Ltd outlined a 700 x 150 m zone with Pb >1000 ppm within a broader 1100 x 250 m halo with Pb >25 ppm in saprolite (Figure 3). There are also extensive haloes for Cu and Zn in the saprolite, but these are much more variable due to mobility of these elements during weathering and/or primary variability (Hartley and Alston, 1995). Thus, they recommended Pb as the best indicator of mineralization in both fresh and weathered residual material.

Hartley and Alston (1995) described a dispersion train of Pb within the Campaspe Formation above the central part of the deposit (Figure 2). However, Ti/Zr ratios and feldspar and clay abundances indicate that the unconformity is higher than previously thought and that the Pb anomaly is at the base of the Campaspe Formation rather than midway within it (Scott, 1995; 1997). Hence interface sampling (*cf.* Robertson, 2001) for Pb would indicate at least a 400 m wide anomaly. Further to the W, the Campaspe Formation is deeper and Pb again is anomalous at its base (Figure 4A). However, Cu and Zn are anomalous within the cover rocks, 10 m above the unconformity (Figures 4B and C), in the area where dolomite occurs lateral to the mineralization (Figures 4D). Scott (1997) suggested that alkaline conditions around the dolomite precipitated any Cu and Zn that was hydromorphically dispersed in the Campaspe Formation, whereas Pb was mechanically dispersed.

LEAD ISOTOPES

The Pb isotopic ratios (Dean, 1995) for a selection of Pb-rich samples from both the Campaspe Formation and volcaniclastic rocks of the Trooper Creek Formation (Figure 5) indicate that Pb in both rock types within 100 m of the mineralization has a ^{206}Pb/^{204}Pb ratio of 18.06-18.11, typical of volcanic-hosted massive sulphide deposits in the Mt Windsor Sub-province. However, the Campaspe-hosted material from more than 100 m away from mineralization has greater ^{206}Pb/^{204}Pb ratios (18.12-18.21) suggesting incorporation of extraneous Pb from the country rock. However, because Pb contents are low in the Campaspe Formation, away from the mineralization, uncertainties due to possible contributions of radiogenic Pb developed *in situ* may have affected these samples more than others. Thus Pb isotopic ratios could provide a vector to mineralization at Waterloo but additional testing is needed.

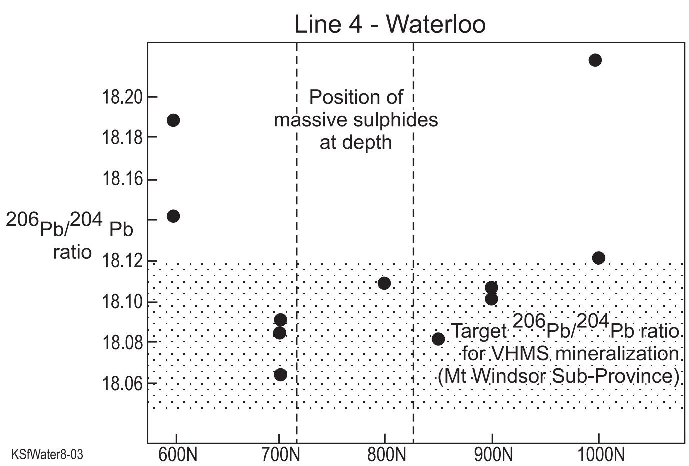

Figure 5. 206Pb/204Pb ratios and Pb contents along line 4 (after Dean, 1995).

ACKNOWLEDGEMENT

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SAMPLE MEDIA - SUMMARY TABLE

Sample medium	*Indicator elements*	*Analytical methods*	*Detection limits*	*Background*	*Threshold*	*Maximum anomaly*	*Dispersion distance*
Primary mineralization	Pb	AAS	5 ppm	<25 ppm	100 ppm	4.04%	400 m
	Cu	AAS	2 ppm	<50 ppm	100 ppm	4.98%	>400 m
	Zn	AAS	2 ppm	<100 ppm	1000 ppm	29.9%	>400 m
Saprolite	Pb	AAS	5 ppm	<25 ppm	100 ppm	2.96%	400 m
	Cu	AAS	2 ppm	<50 ppm	50 ppm	3900 ppm	300 m
	Zn	AAS	2 ppm	<100 ppm	100 ppm	850 ppm	200 m
Interface/unconformity	Pb	AAS	5 ppm	90 ppm	-	1500 ppm	>300 m
Tertiary cover (Campaspe Formation)	Cu	AAS	2 ppm	50 ppm	-	160 ppm	200 m
	Zn	AAS	2 ppm	100 ppm	-	290 ppm	200 m

AAS analysis followed dissolution with $HF/HClO_4/HNO_3$ and HCl