REGOLITH EFFECTS AND AU EXPLORATION IN THE BLAYNEY-ORANGE DISTRICT, NSW

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ABSTRACT

Au mineralization in the Blayney-Orange district, 180km west of Sydney in the Lachlan Fold Belt, may have significant associated As, Cu, Pb, Sb and Zn contents. Such potential pathfinders are retained in gossanous outcrop, where present, and may also be retained in residual soils. Study of residual soil at Osborneville (10km south of Blayney) suggests that the fine (<63μm) fraction of the soil contains higher concentrations of Au and base metals than the coarser soil fractions. However aeolian material is also known to be deposited in the Lachlan Fold Belt during the last 260,000 years. Aeolian successions produce red soils with > 80% of their weight having a grain size <63μm and having consistent Ti/Zr≈12. Furthermore, many soils of the region contain an aeolian component which is not immediately apparent except after sieving and chemical characterisation.

If a significant amount of aeolian component is present in a soil, the magnitude of any Au or base metal anomaly (associated with residual material) could be substantially reduced. Thus sampling based on the use of the fine fraction of soils may not have fully tested the economic potential of the region. Instead, use of the coarse (>2mm) fraction of the soils is recommended, preferably after inspection of such material for homogeneity. The use of pisoliths in the district is also briefly discussed.

INTRODUCTION

Weathering of Au-bearing rocks may lead to the dispersion and concentration of the Au within specific portions of the regolith profile. In the Yilgarn Craton of Western Australia, the concentration of Au in ferruginous lag and at palaeowatertables with zones of depletion in between has been well documented (e.g. Butt, 1988). There the weathering history reflects development of a lateritic profile during a long period of tectonic stability followed by the imposition of more arid conditions. However, in Eastern Australia, tectonism is more active with multiple periods of erosion within and since the Palaeozoic often resulting in only a thin sequence of regolith materials being present. Such regolith can have a quite complex history but is relatively poorly documented although Chan (1998a, b) has recently added substantially to our understanding of Mesozoic and Tertiary events in the Bathurst 1:250 000 sheet area. This paper considers aspects of the Quaternary regolith development, particularly aeolian deposition in the Blayney-Orange district of NSW, 180km west of Sydney (Figure 1), and its implications for exploration strategies.

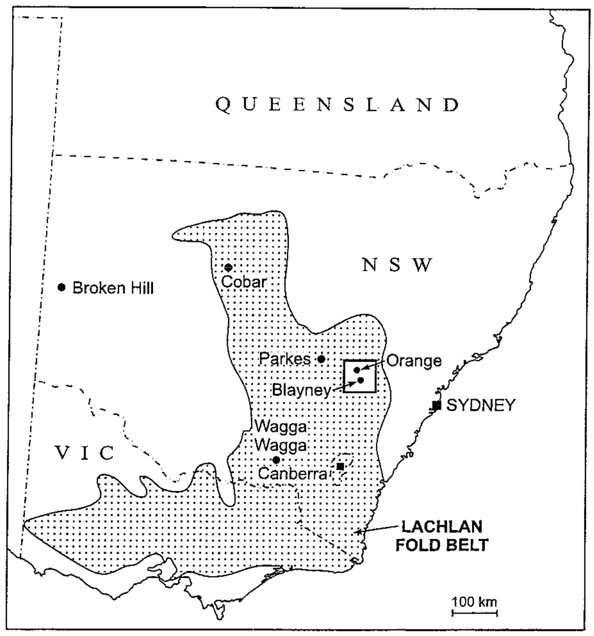

Figure 1. *Locations within the Lachlan Fold Belt, SE Australia.*

REGOLITH GEOLOGY AND AEOLIAN DEPOSITS

Palaeozoic rocks of the eastern Lachlan Fold Belt have been folded and uplifted by a series of tectonic events during the Silurian through the Devonian and into the Lower Carboniferous. Together these events result in the North-South zones seen today. Since that time, weathering, erosion and sedimentation have occurred. Upwarping associated with pre-rifting along south-eastern Australia in the late Cretaceous and formation of the Murray Basin in the early Tertiary induced an anti-clockwise rotation of drainage from its northerly Jurassic direction to the north west and then westerly (Chan, 1998b). In the Blayney-Orange district, lavas from the eruption of the Mount Canobolas volcano during the late Tertiary (11-13 m years ago: Middlemost, 1981) blanketed in the landscape often covering pre-Miocene weathering profiles with the associated doming inducing a new radial drainage pattern about it (Chan, 1998a, b) thus further complicating drainage systems. Subsequently alluvial and aeolian deposition has occurred in gullies and on topographic rises respectively.

Aeolian deposition over south-eastern Australia occurred in a number of discrete episodes over the past 260,000 years (Wasson, 1987) and is well recognised in western NSW and the Riverina (e.g. Williams et al., 1991; Chen, 1997). Such deposition extends well out into the Pacific Ocean (Bowler, 1976; Kiefert and Mctainsh, 1996). However in the erosion-dominated areas of the highlands of the eastern Lachlan Fold Belt its significance has often not been fully appreciated, partly due to its occurrence in hybrid profiles i.e. where aeolian material is mixed with other (often residual) material. In such cases, detailed oxygen isotope studies have allowed recognition of an aeolian quartz component in soils developed above granites (Chartres and Chivas, 1987; Charters et al., 1988). That study relied upon the differences in the temperature of formation of the residual and introduced quartz and suggests that the aeolian component is derived from weathered felsic rock and homogenised during transportation (Chartres et al., 1988). Although objective criteria for recognising aeolian components in other environments have not been defined in the eastern Lachlan Fold Belt, the presence of quartz in soils above Tertiary basalts near Bathurst (e.g. Craig and Loughnan, 1964) may give a clue to the presence of an aeolian (or, at least an introduced) component. However, the recognition of a "pure" aeolian profile within a road cut 1.5km east of Browns Creek (Figures 2 and 3) enables the features of aeolian material in the eastern Lachlan Fold Belt to be documented. This profile was initially recognised as aeolian by Garry Johansen (formerly of Newcrest Mining Ltd) an the basis of its soil colour, fine grain size and position in the landscape. Subsequent chemical and mineralogical characterisations of the aeolian material here indicates that it has a consistent Ti/Zr value ~12—a value much lower than the volcanic saprock (Dickson and Scott, 1998). Such a consistent felsic value reflects the marked uniformity of such material as is also reflected by oxygen isotope ratios in their quartz grains in other accessions throughout the eastern Lachlan Fold Belt (Chartres et al, 1988). When sieved the aeolian material reveals its fine grain size (83% of it is finer than 63μm) and the presence of Fe nodules in the coarse fraction. This latter feature and the presence of Fe/Mn mottling in portions of the profile indicate that Fe and Mn mobilisation processes have operated to produce visible changes by indurating the porous regolith since the deposition of the aeolian material (i.e. 20-260 ka).

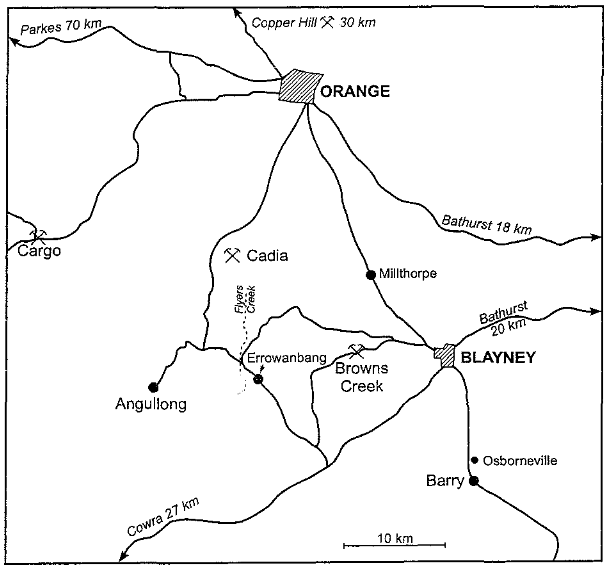

Figure 2. *Locations within the Blayney-Orange district*

ECONOMIC GEOLOGY

Although the potential for porphyry Cu mineralization in Central NSW has been recognized since the 1970's when Cargo, Cadia and Copper Hill were all investigated (Stevens, 1974; Welsh, 1975; Chivas and Nutter, 1975; Scott, 1978) the recognition that such mineralization was Ordovician rather than Siluro-Devonian led to the discovery of Cadia Hill and Ridgeway porphyry Cu-Au deposits (Newcrest Mining Limited, 1997). Structurally controlled vien deposits also occur within alteration systems controlled by shear zones within the Ordovician volcanics (e.g. Doepel, 1997). Skarn mineralization is also present at Browns Creek where a limestone lens in the Ordovician volcanics is introduced by a Silurian granodiorite (Creelman et al , 1980) All three styles of mineralization can potentially be affected by weathering and erosion processes since the Mesozoic leading to deep weathering profiles up to 50m deep as at Copper Hill (Scott, 1988), where the rate of chemical weathering was greater than the erosion rate Elsewhere, erosion has rapidly removed weathering products and fresh rock with disseminated sulfides with only minimal weathering can be found on the surface. Silicification associated with the hydrothermal alternation events can also lead to preservation of relatively unweathered material at the surface

Figure 3: *Aeolian material above hardpan and saprolite at Browns Creek*

Table 1: *Compositions of ironstones/gossans, Blayney-Orange area (ppm, unless otherwise indicated)*

Mineraliz Type	**? Shear Related**		**? Skarn**		**Skarn**	
Location	**Blayney**		**Osborneville**		**Browns Creek**	
Sample No.	**134396**	**134397**	**134400**	**134404**	**135951**	**135952**
Fe_2O_3 %	57.3	82.0	86.1	94.6	79.2	68.7
MnO %	0.36	0.43	0.05	0.04	0.65	0.09
P_2O_5 %	1.01	0.81	0.10	0.11	0.44	0.67
SO_3 %	<0.01	<0.01	0.04	<0.01	<0.01	<0.01
As	38	17	9	6	220	140
Au (ppb)	75	<5	69	15	26	93
Co	130	72	180	71	420	68
Cr	240	41	52	16	170	280
Cu	580	<10	600	79	220	1300
Ni	92	74	29	<10	310	160
Pb	500	4	<3	9	6	16
Sb	40	9	0.4	<0.2	4	15
Zn	160	260	26	31	960	480

EXPLORATION ORIENTATION STUDY

Weathering of probable shear-and skarn-related Cu-Au mineralization 1km north west of Blayney, at Osborneville (10km south of Blayney) and Browns Creek (9km west of Blayney) results in gossanous ironstones which may contain elevated levels of As, Au, Cu, Pb, Sb and Zn (Table 1). However the presence of these potential pathfinder elements is highly variable with only Au and Cu consistently anomalous. Furthermore because outcrop is not extensive in this grazing district, soil geochemistry is a widely used exploration technique. At Osborneville a thin soil is present above gossanous outcrop (Figure 4). Sieving tests indicate that Au, Cu, Pb and, perhaps, Zn are concentrated in the fine relative to the coarse fraction (Table 2). Similar enrichment in Au in the fine fractions of soils is seen elsewhere in the Lachlan Fold Belt e.g. in the Parkes region (B. Cruikshank, pers. comm. 1997) and appears to offer a good sampling medium. However aeolian material is known to be within the district and, as well as forming "pure" aeolian successions as at Browns Creek, it often occurs admixed with residual soil. Such cases may be difficult to recognize in the field e.g. in a road cut 1km south of Millthorpe where red soil occurs above andesitic to basaltic volcanics (Figure 5). When this soil is sieved it shows a high proportion of fine material and no tendency for any of the potential pathfinder elements except, perhaps Zn to strongly concentrate in the fine fraction (Table 3). Furthermore the Ti/Zr ratio is very much lower (17) than that in the coarsest fraction (42). Here it is suggested that the fine fraction represents aeolian and admixed residual material whereas the coarsest fraction consists of lithic fragments (Table 3). Similar cases where the different soil fractions appear to have different origins are reported by Dickson and Scott (1998) in this region.

Where aeolian material is present within a soil, it will dilute any geochemical signatures present in the residual component of the soil, with the dilution problem being compounded if a fine fraction of the soil is used during the geochemical survey. However, as indicated above, as well as its fine grain size, aeolian material is characterised by a consistent Ti/Zr ratio ~ 12 (Dickson and Scott, 1998). The high Ti/Zr ratio (=94) for the 1-2mm fraction of the soil at Osborneville reflects its derivation from basaltic volcanics (e.g. Hallberg, 1984) but the intermediate value in the fine fraction of soil suggests that even it is likely to be contaminated by aeolian material. In this case the Au and Cu contents are sufficiently high that the anomalism is readily seen. However, where a greater proportion of aeolian material is present, anomalous values may be substantially diluted.

Table 2: *Composition of Osborneville soil fractions (ppm, unless indicated otherwise)*

SOIL FRACTION	+ 2 MM	- 2+1 MM	- 63 µM
PROPORTION %	36.1	7.3	20.2
DESCRIPTION	MAGNETIC FRAGMENTS	MAGNETIC FRAGMENTS	-
Fe_2O_3 %	89.8	91.1	32.8
TiO_2%	0.10	0.11	0.72
SO_3 %	<0.01	<0.01	0.20
As	29	33	31
Au (ppb)	17	33	130
Cu	150	140	260
Pb	<3	16	46
Sb	1.1	1.8	1.3
Zn	29	35	58
Zr	<5	7	200
Ti/Zr	-	94	22

Figure 4: *Thin soil associated with gossanous material at Osborneville*

Figure 5: *Red soil composed of aeolian and residual components, Millthorpe (profile depth 2 5 m)*

Table 3: *Composition of Millthorpe soil fractions (ppm, unless indicated otherwise)*

Soil Fraction	+ 2 mm	- 2+1 mm	-63 µm
Proportion %	23.1	3.6	61.2
Description	Lithic Frags	Magnetic Fe Concretions	-
Fe_2O_3 %	13 2	25 9	7 65
TiO_2%	0.31	0.80	1.16
SO_3 %	<0.01	<0 01	0 08
As	19	35	10
Au (ppb)	<5	<5	<5
Cu	73	130	60
Pb	26	82	28
Sb	1	3	1
Zn	17	47	42
Zr	44	170	410
Ti/Zr	42	28	17

Because it is impractical to determine the extent of aeolian contamination at all soil survey sites in order to be confident that no anomalies have been overlooked, use of coarse soil fractions representing largely residual saprolite fragments may represent an appropriate alternative strategy. The +2mm fraction is more practical than the 1-2mm fraction because of its greater abundance (Figure 6) This however means that the levels of Au and Cu may be much lower than would be present in the fine fraction of totally residual soil

One potential way of generating higher concentrations of target elements in the coarse fraction of a soil might be to preferentially sample and analyse its most ferruginous portion A multitude of studies have shown that such material is likely to bear high concentrations of chalcophile and other potential pathfinder elements (e g Taylor and Scott, 1982; Carver et al , 1987; Smith et al , 1992; Anand et al , 1993). A practical and effective way to sample such ferruginous material is by pisolith sampling (e g Smith and Perdrix, 1983) if it is present In the Blayney-Orange district some pisoliths are present but, with the complex history of erosion and deposition since the Mesozoic, an understanding of where such

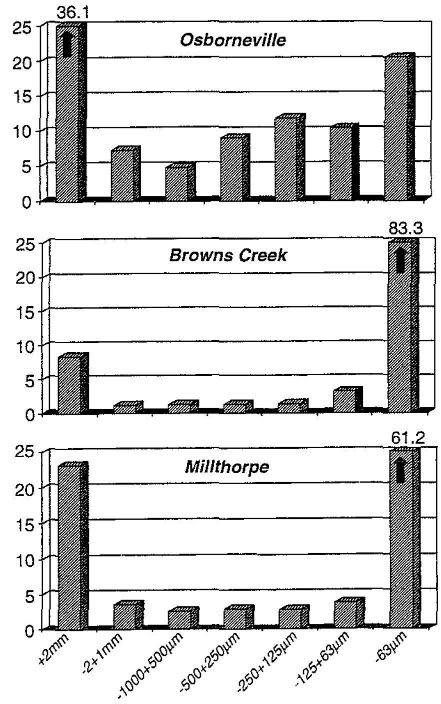

Figure 6: *Distribution of size fractions in soils, Blayney-Orange area.*

TABLE 4: *Compositions of pisoliths and saprolite, Errowanbang and pisoliths, Flyers Creek (ppm, unless indicated otherwise)*

LOCATION	ERROWANBANG		FLYERS CREEK
SAMPLE	TYPE PISOLITHS (3)	SAPROLITE	PISOLITHS
Fe_2O_3 %	15.3	10.4	16.1
MnO %	0.37	0.24	4.39
TiO_2 %	0.97	0.73	1.08
As	46	44	100
Au (ppb)	<5	<5	<5
Cu	57	150	63
Cr	170	320	75
Pb	84	21	150
Zn	32	130	230
Zr	450	71	420
Ti/Zr	13	62	15

(Ba = 2300 ppm)

material fits within the regolith landscape must be developed For example, pisoliths are present overlying basaltic/andesitic saprolite at Errowanbang (13km west of Blayney). Their position on a slight ridge in a broad valley makes it likely that they are either transported or developed in transported material (R. Chan, pers. comm, 1997) Indeed only Pb is elevated and the As, Cu and Zn contents are depleted in the pisoliths relative to the saprolite (Table 4) i e the pisoliths show no enrichment in potential pathfinder elements Furthermore the introduced nature of the pisoliths material is readily reflected by the discrepancy in Ti/Zr values Although other felsic sources are possible, the low Ti/Zr value could even suggest that the pisoliths reflect development in aeolian material

Similarly Mn-stained pisoliths adjacent to alluvial Au workings along Flyers Creek (4km north of Errowanbang) have a relatively low Ti/Zr ratio (Table 4), again consistent with a large component being derived from aeolian material The lack of Au and Cu but relatively high As, Pb and Zn contents in this material may well reflect hydromorphic dispersion and incorporation into neo-formed Mn oxides

Because pisoliths formed from aeolian material would be included in the coarse fraction of a soil, careful inspection of the coarse fraction for homogeneity prior to its analysis is warranted. In particular, cases where the coarse material consists of both angular lithic saprolite fragments and rounded ferruginous material should be treated cautiously Where there is doubt about the origin of the coarse material and the amount of possible introduced material is far greater that the certain residual saprolite, Ti and Zr should be determined to try to firmly establish the nature of the material

Partial leaching techniques also preferentially target Fe-Mn-rich material and have identified targets through thin transported cover in western N S W (e g Cohen et al , 1996). The mobility of Fe and Mn in the Blayney-Orange district is reflected by the mottling and staining seen in profiles Thus the applicability of these methods should also be pursued further

CONCLUSIONS AND RECOMMENDATIONS FOR EXPLORATION

Gossans developed from different types of Cu-Au mineralization in the Blayney-Orange district may be enriched in As, Au, Cu, Pb, Sb and Zn but only Au and Cu are consistently present. These elements also appear to be retained in the soils developed on outcrop and are particularly well concentrated in the fine fraction of the soil However, that fraction is susceptible to contamination by aeolian material, with the effect of diluting the intensity of any geochemically anomalous element contents Thus the use of the coarser material, particularly the +2mm fraction of the soil (which effectively represents fragments of saprolite) is recommended for orientation studies prior to drilling. Such material can itself incorporate neo-formed Fe-Mn concentrations (including pisoliths) which may in fact represent aeolian material so considerable care must be exercised when interpreting the results of geochemical surveys in the district

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