REGOLITH STRATIGRAPHY AND GOLD DISTRIBUTION AT THE BIRTHDAY GOLD PROSPECT, GAWLER CRATON, SOUTH AUSTRALIA

M J LINTERN[1] AND M J SHEARD[2]

[1]*Cooperative Research Centre for Landscape Evolution and Mineral Exploration CSIRO Exploration and Mining c/o PIRSA, GPO Box 1671, Adelaide, SA 5001, Australia*

[2]*Regolith Terranes Team, Minerals Group PIRSA, GPO Box 1671, ADELAIDE SA 5001, Australia*

ABSTRACT

Our knowledge of geochemical dispersion in the Gawler Craton (South Australia) is poor since there have been very few research or orientation studies In this study at the Birthday Gold Prospect, the application of geochemical dispersion models identified in Western Australia to sites in the Gawler Craton were investigated The specific objectives of the study were to (i) undertake a detailed orientation survey, (ii) establish a regolith framework, (iii) identify potential sample media, and (iv) determine the most appropriate ways to explore in this area A 1 5 km line (the "regolith traverse") was chosen for the study of geochemical dispersion and regolith stratigraphy in a known area of mineralisation

The Birthday Gold Prospect occupies an area of low topographic relief in a semi-arid environment approximately 750 km north west of Adelaide (South Australia) Regolith stratigraphy indicates a complex, deeply weathered regolith. The upper regolith (0-6 m) is characterised by the development of silcrete and calcrete on a thin (<2 m) horizon of locally transported materials, overlying Archaean rocks deeply weathered to clay-rich saprolite to about 30-40 m depth The geochemical results confirmed the presence of 2 main zones of mineralisation at about 30 m depth Of most significance is the anomalous Au concentrations in calcrete above mineralisation (maximum of 13 ppb) However, concentrations are also high in another area (14 ppb) where no mineralisation has been identified Anomalous concentration of Au above mineralisation also appear to persist in the upper regolith (beneath the calcrete) and it is this feature that distinguishes the false anomaly from the true

Recommendations for Au exploration at Birthday and in areas with similar regolith are:

i at the prospect scale, maximum calcrete sampling at 200 x 200 m spacing with follow-up calcrete sampling, or augering at 50 x 50 m spacing from surface to 1 or (preferably) to 2 m or more (compositing the cuttings);

ii calcrete nodules to be analysed for pathfinder elements, since their signatures may be retained within the upper regolith and may be broader or more contrasting;

iii limited deep drilling (<5 holes, to RAB blade refusal) in areas with strong Au in calcrete maxima, particularly if there are concomitant maxima associated with anomalies derived from shallow augering; and

iv use of regolith-landform mapping and regolith stratigraphy to assist with interpretation of the geochemical results

INTRODUCTION

A series of CSIRO-AMIRA Projects (P240, P240A, P241, P241A) in the Yilgarn Craton in Western Australia from 1987 to 1993 (Butt et al, 1991; Smith et al , 1992; Butt et al, 1993; Anand et al, 1993) investigated the geochemical expression of primary and supergene Au mineralisation in the regolith. These studies demonstrated that in relict (laterite intact) and erosional (saprolite or bedrock exposed) landform regimes, carefully directed, shallow sampling of specific regolith materials (e g. calcrete) was generally more cost- and technically-effective than routine drilling to deep saprolite or fresh rock in regional- and prospect-scale exploration. In contrast, our knowledge of geochemical dispersion in the Gawler Craton (South Australia) is poor, with very few published research or orientation studies In this study at the Birthday Gold Prospect, geochemical dispersion models identified in Western Australia were investigated to determine whether they can be applied in the Gawler Craton

The specific objectives of the study were to (i) undertake a detailed orientation survey, (ii) establish a regolith framework, (iii) identify potential sample media, and (iv) determine the most appropriate ways to explore in this area. A 1 5 km line (the "regolith traverse") was chosen for the study of geochemical dispersion and regolith stratigraphy and is centred on 2 zones of mineralisation (termed zones 1 and 2) The Birthday Gold Prospect is located about 750 km NW of Adelaide (South Australia) at AMG 395600E 6689700N (Figure 1) This study of Au is part of a larger project investigating multi-element distribution at this location

SITE DESCRIPTION

Mineralisation

The local geology at the Birthday Gold Prospect includes Archaean quartz-feldspar-garnet gneiss, mafic gneiss and ultramafics with significant levels of sulphide (Daly et al , 1998). The prospect was located by drilling to blade refusal after regional calcrete sampling identified a broadly anomalous area in Au Subsequent infill sampling located a coherent Au anomaly peaking at 68 ppb Early shallow (0-60 m) rotary air blast (RAB) drilling by Minotaur Gold NL outlined a series of parallel bands of Au mineralisation located at about 30 m within saprolite; one metre samples returned 1.2, 0 5, 0 7 and 1 1 g/t Au from each respective band (Figure 1) Anomalous Au appears to be associated with ultramafic lenses and their contacts (faulted or folded) with surrounding gneissic lithologies Follow-up deeper RC drilling (Figure 1) intersected altered contact zones with quartz, feldspar, carbonate, and sulphide development (Anon, 1996) The area is currently being actively explored using RC and RAB drilling

Landforms

The Birthday Prospect occupies an area of low topographic relief To the north and west, a low arcuate rise of variably silicified basement outcrop is partly covered by Quaternary dunes South and east of this rise is a broad area of alluvial plain and minor sand spreads A low-angle erosional escarpment has developed on the southern and eastern sides to this rise; the escarpment upper flanks are clad with silcrete gibber and blocks A subdued drainage to the south and east of the rise has developed with some minor clay pans evident An undulating palaeo-land surface was established from identification and interpretation of drill cutting material (Figure 2)

Regolith stratigraphy

The regolith is complex and consists in its lower parts of variably weathered clay-rich saprolite (5-10 m thick) overlying saprolite (20-30 m thick) grading into fresh rock Silicified saprolite is exposed at the far western end of the study area whereas, over the middle to eastern end, it is buried by a variety of thin (<2 m) alluvial sediments An irregular upper surface of the saprolite was revealed by 6 m deep RC holes drilled for this investigation (Figure 2). This surface is variably silicified, locally forming a silcrete, and is overlain by calcareous silcrete and/or calcrete These are, in turn, overlain by soil, aeolian sand and sandy or clayey alluvium, within which younger nodular, platy to massive calcrete may occur The silicified upper surface of the saprolite probably represents a palaeo-land surface; the saprolite probably formed prior to and during the silicification event

Weathering has yielded kaolinite, kaolinite after feldspar, sericite after mica and feldspar, smectite and illite clays, calcite, hematite and goethite/limonite in the upper saprolite. Soil and upper saprolite material are also variably cemented with silcrete, silicified saprolite, ferruginous materials, calcrete, calcite, gypsum, celestite and combinations of these.

Soils

Soil terminology used herein follows that of Northcote (1979) and Stace et al (1968) A variety of soils have developed from several surficial units over the study area A detailed pedological examination of the area was beyond the scope of this study; the following descriptions provide a general framework only

Primitive lithic-rich profiles include stony, coarse-textured Uniform (Uc) and stony Duplex (Dr) lithosols. These are restricted to the tops and flanks of the low escarpments at the western end of the area, and to drainage lines Sand spreads, related to Quaternary red dunes and creek flood-outs, have medium textured Uniform soils (Um 1, Um 2) and some earthy Gradational profiles (Gn 2) More mature profiles, displaying well differentiated soil horizons, are also present in the lower topographic locations, as red Duplex soils (Dr 1 and possibly Dr2). All soils in this area are within the AS2 unit described as alkaline, strongly sodic and sodic with sandy and loamy textures (Northcote and Skene, 1972).

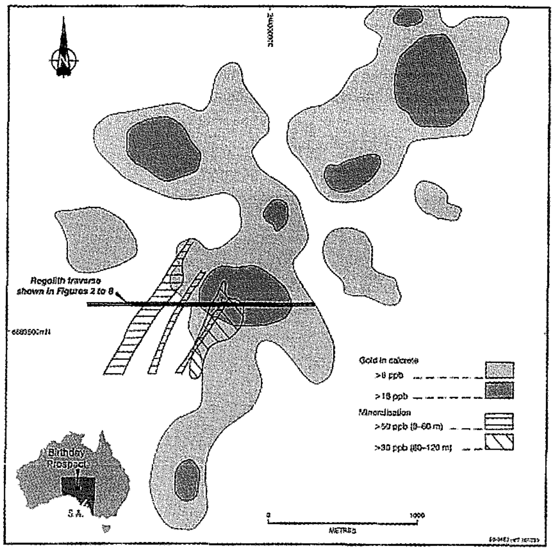

Figure 1: *Mineralisation, gold in calcrete anomaly (prior to detailed in-fill), regolith traverse and location of study at Birthday Gold Prospect, South Australia Data courtesy of Minotaur Gold NL*

Calcium carbonate (calcrete) is present in the B horizons throughout the area, and all soil profiles are either fully alkaline or at least alkaline in the lower parts, although some of the sands have neutral to weakly acid A horizons. Calcium carbonate occurs as pisoliths, nodules, plates, coatings and hard-pan within the lower A or upper B horizons. All forms appear to have undergone pedogenic and biogenic modification from a likely original aeolian, earthy/silty form (Crocker, 1946; Quade et al., 1995)

VEGETATION

Vegetation consists of chenopod shrubland and open woodlands of mulga and sheoak, with chenopod understorey. The shrubland consists of members of the Family Chenopodiaceae, principally *Maireana sedifolia*, *Atriplex vesicaria* and *Scleroleana obliquicuspis*. Other vegetation identified include *Helipterum floribundum* (Asteraceae), *Ptilotus* sp (Amaranthaceae), *Senna artemisioides* (Caesapiniaceae), Erodium sp (Geraniaceae), *Acacia ?aneura* (Mimosaceae), *Eremophila scoparia* and *latrobei* (Myoporaceae), *Casuarina* sp (Casuarinaceae), *Lycium australe* (Solanaceae) and lichens and grasses including *Enneapogon avenaceous* (Poaceae) and *Xanthoparmelia* sp (Parmeliaceae). Plant communities vary across the traverse but *Maireana sedifolia* is ubiquitous to varying densities throughout the area

3. METHODS

3.1 SAMPLE COLLECTION

All sampling was restricted to the regolith traverse within 10 m of northing line 6689700N from 394765E to 396296E (chosen as mineralisation had been intersected by the company) along an existing RAB drilling line undertaken by Minotaur Gold NL prior to our visit. A variety of samples were taken at 80 m intervals along the traverse

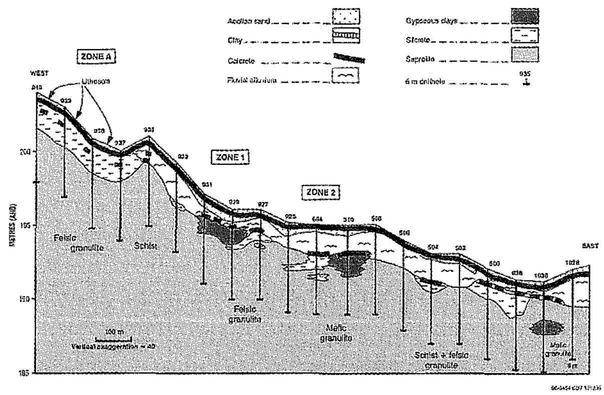

Figure 2: *Regolith traverse showing upper regolith as revealed by twenty 0-6 m RC drill holes using geochemical, mineralogical and lithological data*

One hundred and twenty samples (1-3 kg) were collected at one metre intervals from 0-6 m from 20 holes, using a reverse circulation-equipped (RC) drill rig. The drilling method enabled accurate sampling to be undertaken with minimal down hole contamination. The first 10 cm (approximately) of the surface was removed prior to drilling to reduce the possibility of aeolian dust contamination, albeit remote, caused by previous drilling activity; a soil sample from this interval was collected separately <10 m away from the drilling activity

Twenty soils (0-10 cm) weighing 1-2 kg were carefully collected using geological pick and plastic dustpan from uncontaminated ground

Twenty lag samples (1-2 kg) were collected from the surface using a plastic dustpan and brush. These were separated into coarse (>2 mm) and fine (>0.5 mm to <2 mm) lag. The coarse lag was highly variable in terms of type and quantity. Towards the western end samples consisted of silcrete, whereas to the east, they were highly ferruginous. Several samples near the centre of the traverse consisted of calcrete, presumably brought to the surface by either burrowing animals or tree throws. Fine lag consisted of polymictic material predominantly siliceous

Twenty carbonate nodule samples were hand picked from drill spoil and the sides of the open RC drill holes

Twenty leaf and outer branch samples of bluebush *Maireana sedifolia* were collected in calico bags from two bushes per site.

Pulverised RAB drill cuttings (146 samples) up to 59 m depth from 20 holes from the regolith traverse were analysed to examine the identity, dispersion and geochemical characteristics of elements closely associated with Au within the regolith The samples were supplied by Minotaur Gold NL from a previous drilling programme

Sample preparation and analyses

Mineral samples

The preparation regime for each sample type varied Soil samples and RC drill cuttings were pre-prepared in the laboratory by weighing, mixing on a plastic sheet, then incrementally extracting approximately 200 g of material for external laboratory sample preparation and analysis (AMDEL Laboratories Ltd) Calcrete samples were washed in a coarse sieve, retaining the >2 mm size fraction. Lag samples were washed through a coarse then fine sieve, retaining the >2 mm and >0 5mm to <2 mm size fractions Approximately 60 g of pulverised RAB drill cuttings from the company's drilling programme were extracted and analysed. At the laboratory, samples were dried, jaw-crushed (if required) and pulverised in a Cr-free ring mill Samples (25 g) were analysed for Au by graphite furnace AAS after aqua regia digest and DIBK extraction; the detection limit was 1 ppb Calcium and Mg determinations were made using ICP-OES following mixed acid digest (HF+HNO3+HCl) Other elements were analysed for but are not reported here.

Vegetation samples

Vegetation samples were prepared within two days of collection to prevent mould growth Samples were vigorously washed with hot then cold water in individual fine-mesh nylon, zippered bags (to remove as much aeolian dust contamination as possible) before air drying. Samples were weighed, then dried at approximately 80°C for at least 24 hours, to prevent smearing during grinding Samples were ground using a 3 blade cutting mill The samples were then re-weighed and ashed using the following step-heating programme: 4 hours at 200°C, 4 hours at 400°C and then 15 hours at 550°C before being re-weighed Samples were analysed as above for mineral samples The detection limit for Au was 0 3 ppb (dried weight)

GEOCHEMICAL RESULTS

Introduction

The geochemical results revealed three principal zones of interest (Figure 3, zones 1, 2, and A) which are discussed in detail below Zones 1 and 2 are related to mineralisation and zone A is related specifically to a Au in calcrete anomaly at the western end of the traverse.

Upper regolith (0-6 m)

Gold is found to be associated with pedogenic carbonate occurring throughout the top 1 to 2 metres Adjacent 0-1 m samples had the highest Au concentrations of 16 and 15 ppb respectively and are located above mineralisation near the centre of the section (zone 2, drill holes 664 and 925, Figure 3,); the associated calcrete nodules contain 13 ppb Au A broad zone (400 m) of elevated Au concentrations (>5 ppb Au) is located at 0-2 m depth in the central and eastern part of the regolith traverse and persists, partly, to lower depths (zone 2, 2-6 m) but at decreasing concentrations Calcrete nodules in the western part of the section (zone A) contain 11 ppb Au, but the drill cuttings (0-1, 1-2 m, etc.) all contain <5 ppb. A technique that is often used by the Australian exploration industry is to normalise the Au concentrations with respect to either Ca and Mg contents or usually just the Ca contents; this is because Au has been found to accumulate in calcrete (Lintern, 1989, Lintern et al., 1997) Normalising the Au data with respect to the alkaline earth metals and Ca only (Figure 4) had the effect of smoothing and enhancing the Au response for the 0-1 m samples above mineralisation The "new" maximum at hole 937 (Figure 4) can probably be ignored since the Au concentration is close to detection (2 ppb) and Ca is also low (0.4 %) Normalising with respect to "total Au and Ca" in the upper regolith (by adding individual metre Au and Ca concentrations together) for the 0-6 m samples did not produce any significant maxima (Figure 5). Calculating "total Au" in the upper regolith (summing the Au concentrations from 0-6 m) had a smoothing effect on distribution and resulted in maxima over mineralised zones 1 and 2 (Figure 6). There is little evidence to suggest any significant Au anomalism in the gypseous clays

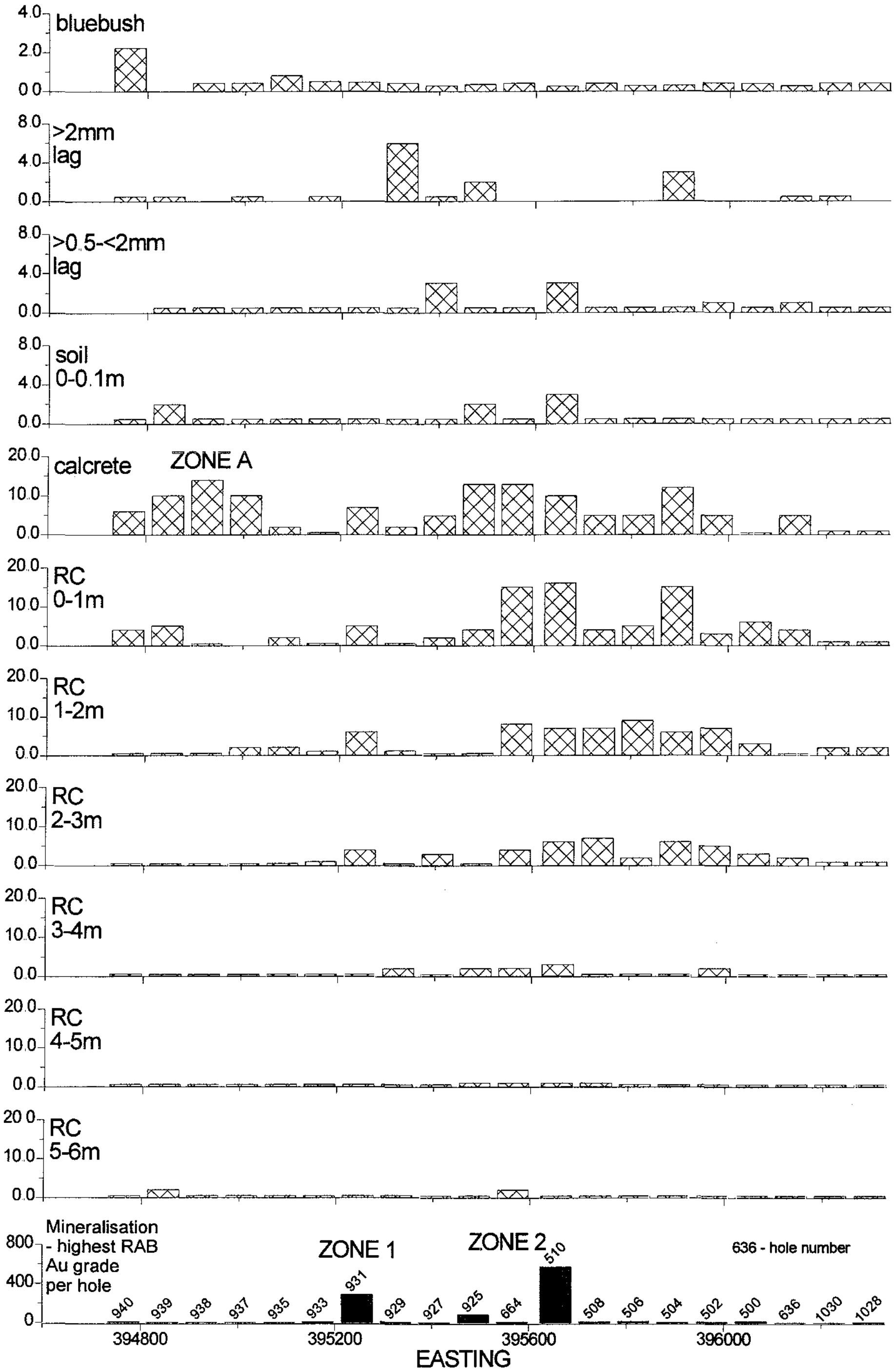

Figure 3: *Regolith traverse Au distributions (ppb) of various sample media compared across mineralisation on 6689700N at Birthday Prospect The three zones are referred to in the text Y axes show concentration*

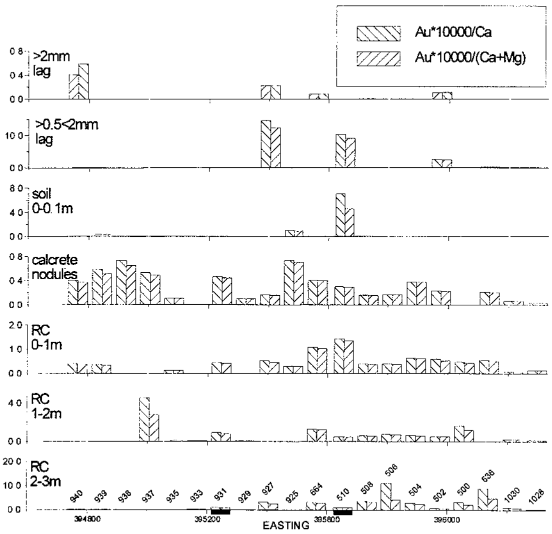

Figure 4: *Regolith traverse Au distributions normalised with respect to Ca and Mg in various sample media across mineralisation on 6689700N at Birthday Prospect Black rectangles indicate mineralisation (zones 1 and 2) Y axes show concentration (ppb/ppm)*

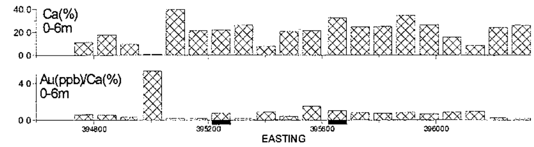

Figure 5: *Regolith traverse normalised Au distribution using summed Au and Ca for 0-6 m at Birthday Prospect Black rectangles indicate positions of mineralisation (zones 1 and 2) Summed Au and Ca was calculated by adding individual metre Au and Ca concentrations together Y axes show concentration.*

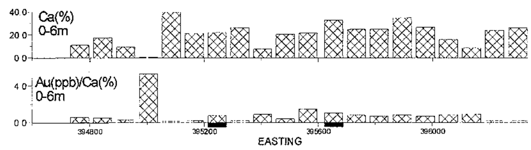

Figure 6: *Regolith traverse total Au concentrations (ppb) for 0-6 m (RC) and 0-10 m (RAB) at Birthday Prospect Black rectangle indicates position of mineralisation (zones 1 and 2). Y axes show concentration*

Lower regolith (up to 60 m depth)

Calculating "total Au" concentrations for RAB cuttings from 0-10 m produced a maximum over one area of mineralisation (zone 1) but not over the second area (zone 2); this is in contrast to the same technique used for the 0-6 m samples and suggests inhomogeneity in the Au distribution Across the regolith traverse section, there appears to be a region with low Au concentrations (<1 ppb) extending from near the surface to about 30 m depth (Figure 7); at about 30 m, Au concentrations from about 4 to 20 ppb occur The highest Au concentration recorded was 580 ppb at 35-36 m (zone 2, hole 510)

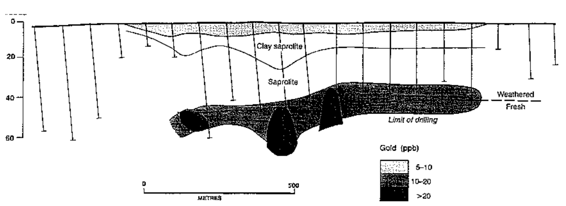

Figure 7: *Regolith traverse Au distribution (ppb) in section as defined by RAB drill cuttings Y axis shows depth*

Soil (0-0.1 m)

Gold contents are generally below or just above detection (1 ppb, Figure 3). The highest concentration recorded was 3 ppb and occurred over zone 2 Normalising the Au data with respect to the alkaline earth elements produced a stronger, single point maximum over mineralisation (Zone 2, Figure 4)

Coarse and fine lag

The highest concentrations for coarse and fine lag were 6 and 3 ppb respectively, although most Au concentrations were below 1 ppb (Figure 3) Coarse lag was scarce and samples were not collected at 10 of the sites One fine lag and two coarse lag samples with particularly high Fe contents sampled in the eastern and western ends of the traverse had Au contents below detection, indicating that Fe oxides are not strong trap sites for Au in this environment

Calcrete

Of most significance is the anomalous Au concentrations in calcrete, particularly over mineralisation (zone 2, maximum of 13 ppb, Figure 3). However, concentrations are also high in zone A (14 ppb) where no mineralisation has been identified Normalising the Au data with respect to the alkaline earth metals had limited effects in enhancing the response over mineralisation, and did not remove the apparent spurious anomaly at zone A (Figure 4). Zone A calcretes have higher Mg contents compared with the rest of the sample set: 4 samples with a mean concentration of 2 1% compared with a mean of 1.0% for the entire set (Figure 8) One calcrete sample (hole 500) had particularly low Ca (and Au) concentrations (Figure 3); this sample, whilst effervescing with dilute acid, was composed primarily of silicified clay-rich saprolite with minor carbonate coatings, emphasising the need to analyse calcrete samples for Ca

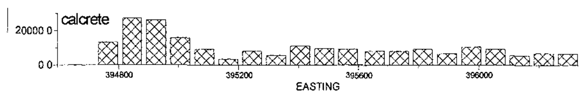

Figure 8: *Regolith traverse Mg concentrations (ppm) in calcrete nodules at Birthday Prospect Y axis shows concentration*

VEGETATION (BLUEBUSH)

Gold concentrations for bluebush were close to detection (0 3 ppb) save one sample (2 2 ppb dry weight) in background at the western end of the traverse (Figure 3) These concentrations are not significant when compared with data from Western Australian studies (Lintern et al , 1997)

DISCUSSION

The results indicate that Au in calcrete successfully locates mineralisation (zone 2); and there is a weaker Au enrichment in calcrete at zone 1 (7 ppb) However, calcrete samples in zone A also have high Au concentrations but here there is no associated mineralisation Zone A differs from zones 1 and 2 in a number of other ways:

i the presence of high concentrations of Mg in calcrete (Figure 8);

ii 1-6 m samples have no detectable Au (Figure 3);

iii the Au anomaly in 0-1 m samples is removed after normalising with respect to Ca (Figure 4);

iv zone A is located on relatively steeper sloping terrain (Figure 2)

The Au in calcrete results at Birthday are similar to those found in Western Australia for regolith types where saprolite outcrops or subcrops (e g Lintern, 1989; Lintern and Scott, 1990; Lintern and Butt, 1992) The calcrete is considered to be a recent aeolian addition to the landscape (Quaternary) as a result of a shift in the climate to greater aridity (Crocker, 1946; Quade et al., 1995) The variety of forms, pedological features and location of calcrete observed at Birthday and elsewhere suggests that the calcrete has been re-worked into the upper regolith as a result of rainfall (dissolution) and evaporation (precipitation) Thus, the calcrete is a cementing material within the upper regolith (soil, laterite and saprolite) and will contain diluted elemental signatures (including Au) reflecting the host rock on which it is formed In addition, it has been demonstrated that some of the Au in calcrete is water soluble, suggesting that there is also some potential mobility of Au in the calcrete (Gray and Lintern, 1998)

Due to the apparent mobility of Au, it should be expected that some of the gold in calcrete anomalies have been re-located both chemically and physically due to topographical effects At Birthday, this appears to be an explanation for the anomaly at zone A The position of zone A at the foot of a slope may suggest the presence of mineralisation further to the west and that the Au has been transported to this site by mechanical and/or chemical means The Au in calcrete anomalies at zones 1 and 2, however, are located over relatively flat-lying areas and do not appear to have moved away from their source. Furthermore, the presence of Au in the upper regolith in zones 1 and 2 (and not zone A) indicates that leaching of the regolith by groundwaters has not led to the removal of all of the Au here This Au not only provides a clue to the explorer, of the possibility of mineralisation at depth in the unweathered zone i e an exploration target, as demonstrated here, but also provides a source for the Au in the calcrete The process is akin to a "slow-release" fertiliser (the saprolite) providing nutrient (Au) to the soil (calcrete) The Au in calcrete anomaly will persist above mineralisation, providing that it is still being "fertilised" by the Au from within the upper saprolite, at a greater rate than its removal by erosion or dispersion

RECOMMENDATIONS FOR EXPLORATION

Orientation studies of this type are more useful from multiple economic-level, drill intersections whereas the Birthday Gold Prospect is sub-economic However, there are recommendations and lessons to be learnt from Au exploration at Birthday and in areas with similar regolith These are:

i at the prospect (in-fill) scale, perform maximum calcrete sampling at 200 x 200 m spacing with follow-up calcrete sampling, or augering at 50 x 50m spacing from surface to 1 or (preferably) to 2 m or more (compositing the cuttings);

ii that calcrete be analysed for pathfinder elements, since signatures may be retained within the upper regolith and may be broader or more contrasting;

iii to undertake limited deep drilling (<5 holes, to RAB blade refusal) in areas with strong Au in calcrete maxima, particularly if there are concomitant maxima associated with anomalies derived from shallow augering; and

iv to make use of regolith-landform mapping and regolith stratigraphy to assist with interpretation of the geochemical results

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