BRONZEWING - THE ROLE OF REGOLITH-LANDFORM CONTROL AND REGOLITH GEOCHEMISTRY IN THE DISCOVERY OF A LARGE GOLD DEPOSIT

J.H. WRIGHT, E. ESHUYS, R.R. ANAND

J.H. WRIGHT, Great Central Mines Limited, 10 Richardson Street, West Perth, Western Australia, 6005
E. ESHUYS, Great Central Mines Limited, AWI House, 210 Kings Way, South Melbourne, 3205
R.R. ANAND, CRC LEME, CSIRO Exploration and Mining,, Underwood Avenue, Floreat Park, Western Australia, 6014

ABSTRACT

The discovery in 1992 of the large Bronzewing gold deposit in the Yandal greenstone belt of the Yilgarn Craton is an example of using an integrated surface and drilling geochemical approach to exploration in a "greenfields" location (Eshuys et al., 1995). Regional geological assessment was followed by regolith mapping, surface geochemical programmes and RAB drilling in areas of transported cover. The prime geochemical sampling media were the various ferruginous lags, outcrops and lateritic pisoliths and nodules recovered from RAB drilling. Ferruginous materials from the surface sampling and drilling and four metre composites from all drilling were analysed for Au.

Mineralisation at Bronzewing was overlain by discontinuously preserved lateritic residuum and by 20 m of transported overburden. Samples of the residuum and areas of saprolite under the residuum were strongly anomalous in Au. In the discovery hole, the Au concentration in residuum was 0.3 ppm whilst an intersection of 12 m at 1 ppm Au was recorded in deeper sections of the saprolite.

Subsequent investigations and production have outlined a Au endowment of approximately 4 million ounces (Phillips et al., 1998) in two separate ore systems, Discovery zone and Central zone. The surface sampling also indicated anomalous Au concentrations at other locations in the SW corner of the tenement which were subsequently found to indicate Au mineralisation.

INTRODUCTION

Bronzewing is located 385 km north of Kalgoorlie and 105 km south west of Wiluna in the Yandal greenstone belt of the northern portion of the Archaean Yilgarn Craton of Western Australia (Figure 1). Within the last 10 years Bronzewing (GCM, approximately 4 m ounces; Phillips et al., 1998), the Jundee/Nimary (GCM, approximately 8.4 m ounces), Centenary (Plutonic Resources, approximately 2.1 m ounces; Bucknell, 1997) and Mt McClure (approximately 1.1 m ounces, Australian Resources, 1997) Au deposits have been discovered. The discoveries made so far in the Yandal greenstone belt confirm this as a major gold producing belt. Exploration development is at a relatively early stage with potential for numerous additional large Au resources.

Historically, the belt has produced small amounts of Au from small quartz-hosted, outcropping ore zones, the most extensive of which were located around Darlot in the southern portion of the belt. Previous exploration had concentrated on the base metal and nickel sulphide potential of suitable host environments and gossan outcrops. Some relatively extensive gold exploration programmes were carried out in the 1980s revealing some small, uneconomic resources but, in general, the applied exploration methodology did not adequately account for the deeply weathered greenstones and the extensive alluvial covered greenstones. This required a better appreciation of regolith terrains and a better appreciation of the belt geology. Recent spectacular exploration success has spurred intense exploration activity in the Yandal belt.

REGIONAL GEOLOGY

The Yandal greenstone belt (Figure 1) lies in the segment of granite/greenstone terrains generally referred to as the Norseman-Wiluna belt (Gee, 1979). It is characterised by mafic to ultramafic basal units and calc-alkaline, dacitic felsic upper sequences (Messenger, unpublished data, 1996). Banded iron formation units are scarce, but a prominent banded, ferruginous, siliceous rock occurs on the western side of the belt.

Basal units of the belt consist of thick, generally pillowed, tholeiitic basalts with lesser, fine- grained sediments and komatiitic basalt. Upper units consist of dacitic lava and volcaniclastics with interflow sediments (Messenger, unpublished data, 1996). Porphyry and lamprophyre hypabyssal intrusives are common. "Internal" granites occur on the eastern side of the belt and prominently to the south of Bronzewing. Coarse diorite to granodioritic intrusive "dykes" occur to the east of Bronzewing.

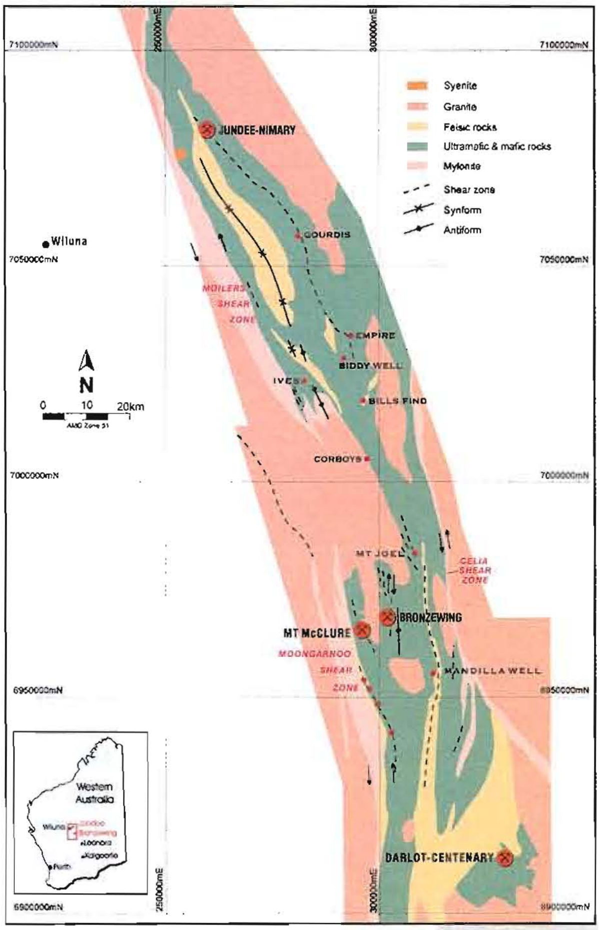

Figure 1: *Geology of the Yandal Greenstone Belt.*

The structure of the belt is not well understood. In the north, outcrop distribution and magnetics suggest a belt-parallel synclinal fold with a western shear termination at the belt margin. To the east, contacts other than the prominent Celia Shear zone appear to be intrusive or sheared intrusive (Figure 1). Significant belt-parallel shearing is recognised, e.g. Mt Joel and Yandal shears. Mineralisation at Bronzewing is at the brittle-ductile structural transition whereas at Jundee it is predominantly associated with brittle fracturing.

Metamorphism in the belt varies from lower greenschist to amphibolite grade, with the higher grades associated with granitoid margins (Clough, unpublished data, 1997). At Bronzewing, the metamorphic grade is upper greenschist to lower amphibolite whereas the Jundee deposit occurs in predominantly mafic host rocks at the lower greenschist facies.

The Bronzewing deposit lies centrally in the belt. Ore is located in a narrow N-S structural corridor between the mafic/ultramafic Bapinmarra Sill in the west and a fault/granite intrusion zone in the east. Host rocks are pillowed, iron-rich, tholeiitic basalt and dolerite with intrusive porphyry and minor lamprophyre. Ore is associated with quartz veins and sulphide-quartz-mica alteration zones in a brittle-ductile structural framework. Gold is predominantly as free grains associated with pyrite (pyrrhotite and minor to trace amounts of chalcopyrite, scheelite and tellurides.

GEOPHYSICS

Magnetic surveys around the Bronzewing Mine indicate a lack of susceptibility contrast between ore and host. The complex, relatively strong magnetic effects of ferruginous granules in palaeodrainage networks dominate the near-mine magnetics and mask basement magnetic responses in the mineralised areas and obscure the details of stronger magnetic contrast in bedrock. However, the basic geological framework, revealed by a combination of gravity and magnetics, is a shallow, south-plunging, open antiform in the mafic dominated sequence. To the west of the mine, the basaltic and ultramafic rocks terminate against a magnetic granite wedge (Starkey, 1997: pers com). The termination is probably a reverse or thrust fault.

GEOMORPHOLOGY

The Bronzewing district is broadly undulating with the low relief typical of the Yilgarn Craton. It ranges in elevation from 460 m to 575 m above mean sea level. The Bronzewing Mine site is at about 500 m and is situated on an alluvial flat, adjacent to the Bates Creek drainage, and slopes very gently west-southwest. A few hills of secondarily silicified and ferruginised or relatively unweathered Archaean greenstones form strike ridges. Greater relief variation, such as at breakaway scarps, occurs where there has been differential stripping of the regolith. Below the breakaways, gentle slopes of main valleys are produced by active but intermittent drainage and by localised deposition of sediments.

Bates Creek and its tributaries in the south and west form drainage channels trending east and northeast toward Lake Maitland and associated playas. Creek beds are variable in definition. In places, they may be 15 m wide and 2 m deep but, both upstream and downstream, become a complex of merging anabranches.

REGOLITH

An early, rudimentary photo interpretation of the regolith was used to control sampling. Later, post-discovery mapping by Varga (1994) and Crawford (1994) is presented in this paper. Their map was based on interpretation of aerial photographs and Landsat TM imagery and was thoroughly checked by field investigations. The terminology is based on the CSIRO terminology (Anand and Butt, 1988; Anand and Smith, 1993).

The Bronzewing and Alf Well exploration licence areas (Figure 2) consist of a series of low rises and lateritic hummocks within and bounding an extensive area of exotic transported alluvium (some granitic in origin) overlying extensive and deep alluvial palaeochannel deposits of the products of lateritic profile reduction. Ferruginous lateritic residuum occurs as exposed and buried remnants of pisolitic and nodular duricrust and extensively ferruginised upper saprolite on the interfluves between these palaeochannels.

The relict regime occupies topographically higher parts of the landscape and comprises broad crests flanked by long, gentle slopes. Here, ferruginous lags (nodules, pisoliths) are either residual or of local derivation, whereas on the transition into and on areas of alluvium, they are of transported origin.

The erosional regime contains ferruginous saprolite, saprolite, bedrock and minor nodules and pisoliths. The slopes are covered with a lag of ferruginous gravel derived from lateritic residuum, ferruginous saprolite, iron segregations and some quartz vein material. In large parts of the exposed areas, lag occurs over eroded saprolite which contains iron segregations and pervasively ferruginised clay saprolite. Ferruginous fragments in this type of lag consist of fragments of ferruginous saprolite rather than pisoliths and nodules. Exposures in Central Pit show that, where the lateritic residuum is partly eroded, pockets of pisoliths and nodules are preserved.

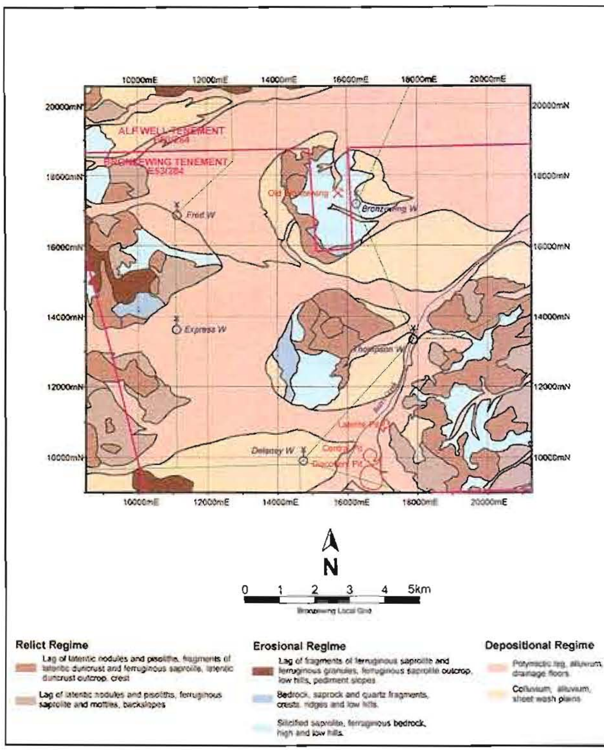

Figure 2: *Interpretative regolith map based on grouping of regolith materials and associated geomorphic features (after Varga, 1994 and Crawford, 1994).*

Depositional regimes are characterised by broad, low topographic features which are underlain by colluvial and alluvial deposits. Beneath alluvial cover are concealed:-

(a) earlier depositional regimes, consisting of megamottled, clay-rich sediments, confined to palaeochannels;

(b) areas where lateritic residuum is present; and

(c) areas where saprolite is present. (Varga, 1994 and Crawford, 1994).

The residual profile beneath the colluvium and alluvium has up to 5 m of lateritic residuum consisting of lateritic nodules and pisoliths, set in a silty clay matrix (Figure 3). In part, nodules were formed by fragmentation and collapse of the underlying ferruginous saprolite and thus preserve the chemical composition of the underlying bedrock. The ferruginous saprolite, a few metres thick, grades downwards into saprolite. Fresh rock is encountered at 80-120 m depth.

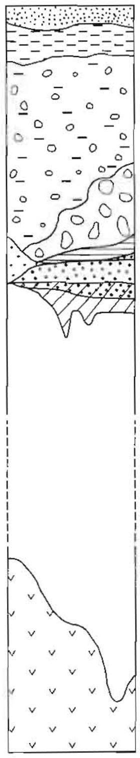

Figure 3: *Schematic regolith profile at Bronzewing.*

The infillings of palaeochannels consist of mottled smectite and kaolinite-rich clays with basal dolocrete. Away from these channels, the transported materials consist of gravelly and silty alluvium and colluvium. Drilling over Bronzewing has shown that there are Au anomalies within the lower part of the alluvial cover. These are probably due to incorporation and dilution of locally derived auriferous lateritic gravels rather than secondary, hydromorphic dispersion.

Near-surface, silty, alluvial sediments generally have been transported from outside the immediate catchment; some have a distinctly granitic provenance and are typically hardpanised. Lag and soil here do not reflect the local bedrocks.

SAMPLING

A rapid geochemical assessment of the potential of the Bronzewing area was made on the basis of the following strategy.

1. Collect rock chip samples, exposed ferruginous duricrust, ferruginous saprolite and quartz.
2. Collect ferruginous gravels, preferably nodules and pisoliths from the lateritic residuum, from the lag over areas of relict and erosional regimes (Anand and Smith, 1993). Nodules and pisoliths from the lateritic residuum were the preferred sample medium.
3. Drill wide spaced RAB holes (nominally 400 m along tracks and wide-spaced grid lines) to fresh rock under areas of depositional materials and sample as follows:-
   a) any pisolitic or nodular lateritic residuum (hand-picked samples); and
   b) all four metre composites down the drill hole to fresh rock.

   The model of the regolith stratigraphy and the criteria for distinguishing between residual and transported regolith materials in depositional environments were based on Anand et al. (1991).
4. Attempt limited soil sampling in areas of residual soil over potentially mineralised corridors.

Surface sampling commenced in May, 1992 and drilling started on 4th July, 1992. The discovery RAB hole (Number 65) was drilled on 15th July, 1992.

ANALYTICAL METHODS

All surface samples and the hand-picked ferruginous drill samples were assayed for Au to ppb level by Aqua regia extraction/carbon rod finish at Analabs in Perth. All drilled composite samples were analysed by Aqua regia/AAS by Australian Assay Laboratories to a detection limit of 0.01 ppm.

RESULTS

The Au analyses (in ppb) are shown for lateritic ferruginous materials (Figure 4) and for quartz-bearing ferruginous saprolite, duricrust samples and lags (Figure 5).

The lateritic, ferruginous materials consist of lag, ferruginous saprolite or duricrust and RAB drilled lateritic residuum samples containing pisoliths and nodules and ferruginous saprolite. Statistical populations approximated to log normal distribution and were subdivided according to selected percentile level Au concentration (50th, 75th, 90th, 95th, 99th). Strong Au responses were obtained in the south east corner of the map at the current Bronzewing Mine and at Bob's Find north of Bronzewing (Figure 4). Other single response anomalies have not proved to indicate significant Au mineralisation as yet.

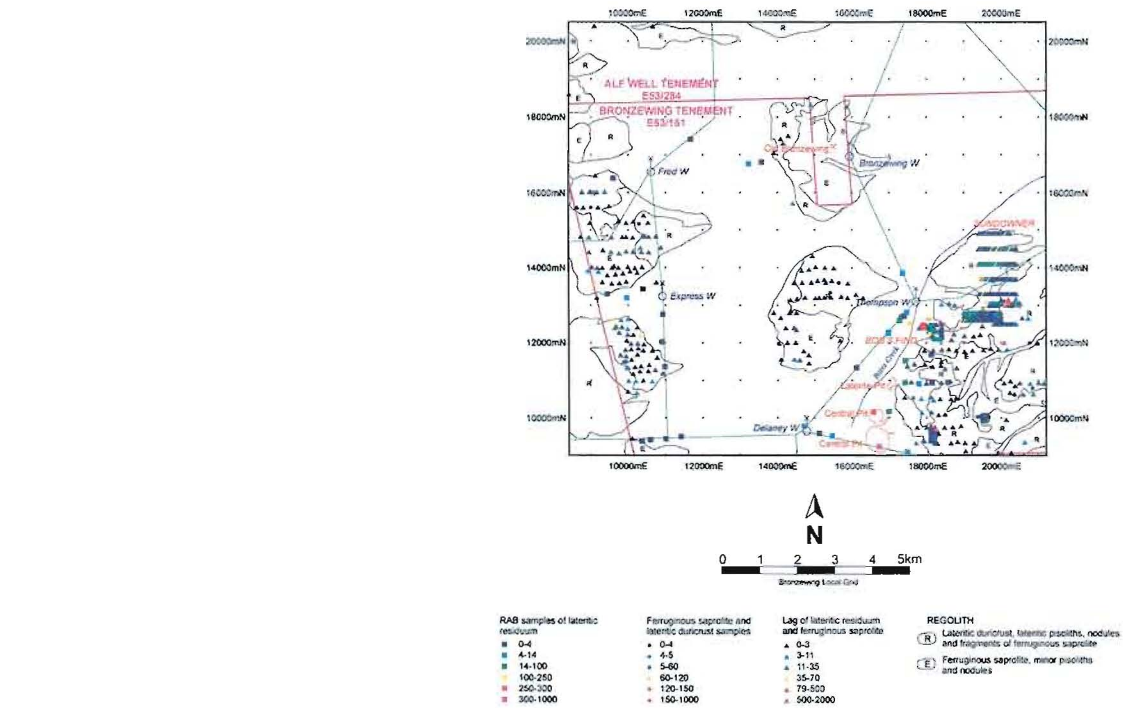

Figure 4: *Gold (ppb) in lateritic pisoliths and nodules, ferruginous saprolite outcrop and ferruginous lag samples.*

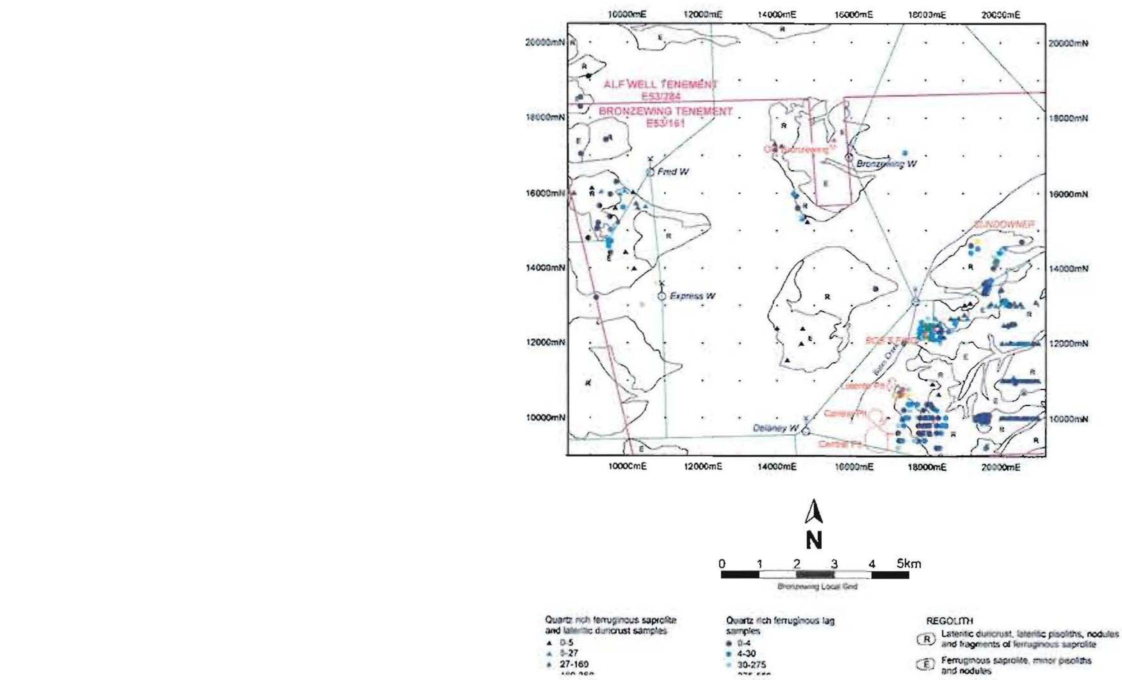

Figure 5: *Gold (ppb) in quartz-rich ferruginous lag, ferruginous saprolite and duricrust samples.*

	Rock Samples	Lag Samples
Lateritic ferruginous materials	60 ppb	35 ppb
Lateritic ferruginous materials and quartz	275 ppb	160 ppb

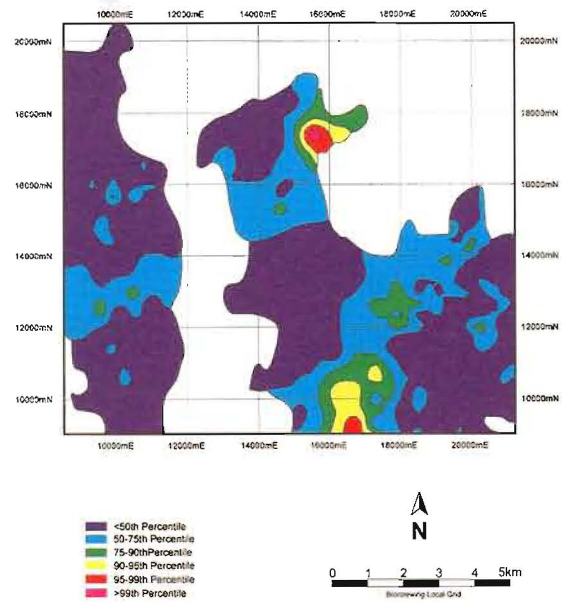

Figure 6: *Gold distribution from lateritic materials after normalisation to percentiles of distribution of the lag, ferruginous saprolite, lateritic duricrust and RAB sample population.*

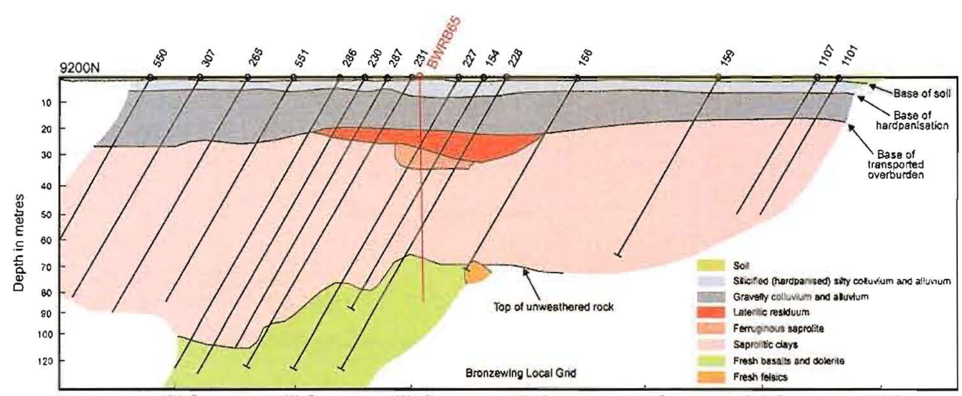

Figure 7: *Regolith section along Line 9200N in the Discovery Pit area (Modified from Varga, 1994). The discovery RAB hole is projected onto the section.*

The Au values of quartz-bearing rock and lag samples strongly highlight the Bob's Find location; show scattered high values in the Sundowner area; and show strongly elevated values immediately SE of the location of the Laterite Pit. The Au concentrations of the quartz vein-bearing materials in lag and ferruginous outcrop materials are much greater than for the equivalent ferruginous sample types without vein quartz. At the 90th percentile level:-

A combination of sample types by percentile scores (Figure 6) shows a clear north west trend through the Bronzewing Mine locality and the Old Bronzewing Mine locality. The north south orientation and alignment of the Bronzewing and Old Bronzewing anomalies could reflect ore location at the intersection between north south shear zones and a north east to south west structure.

The drill section in Figure 7 shows the discovery RAB drill hole plotted onto a detailed drill section of the Discovery Pit. Early RAB holes were drilled nominally 400 m apart and only one of these is present on the section. The drill intersection in hole BWRB 65 contained up to 0.3 ppm Au in the remnants of the lateritic residuum and 12 m at 1 ppm Au further down in the saprolitic part of the intersection.

CONCLUSIONS

The geochemical strategy adopted at Bronzewing clearly identified the Discovery and Laterite zones of the Bronzewing deposit. The Central Zone was discovered soon after by follow-up grid drilling in the corridor north of the Discovery location. It was clearly demonstrated that a successful geochemical approach to exploration challenges in deeply weathered terrain depends on a good initial appreciation of surficial geology, careful selection of sampling materials, a "mix and match" approach to obtain area coverage, geologically controlled sampling and determination to drill deep and assay all intervals of the hole. Employment of appropriate geochemical methods and careful selection of elements for assay should be based on the best available model of primary and secondary dispersion for selected elements.

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REFERENCES

Anand, R.R. and Butt, C.R.M., (1998). The terminology and classification of the deeply weathered regolith. CSIRO Australia, Division of Exploration Geoscience Report (not numbered), 29p.

Anand, R.R., Churchward, H.M., Smith, R.E., and Grunsky, E.C., (1991). Regolith-landform development and consequences on the characteristics of regolith units, Lawlers district, Western Australia. CSIRO Australia, Division of Exploration Geoscience Report **166R,** 160p.

Anand, R.R. and Smith, R.E. (1993). Regolith distribution, stratigraphy and evolution in the Yilgarn Craton - implications for exploration. In: P.R. Williams and J.A. Haldane Ed. *An International Conference on Crustal Evolution, metallogeny and exploration of the Eastern Goldfields,* pp 187-193. AGSO Record 1993/94, Extended Abstracts.

Australian Resources, 1997. Quarterly Report, December, 1997.

Bucknell, W., 1997. The Discovery of the Centenary Gold Deposit, Darlot, Western Australia. *New Generation Gold Deposits '97,* November 1997, Australian Mineral Foundation, Adelaide, pp 13.1-13.8.

Crawford, R., 1994. Regolith-Landform relationships and geochemical dispersion in regolith from the Bronzewing Au prospect W.A. and its immediate environments. Honours Thesis, CODES, University of Tasmania, 92p.

Eshuys, E., Herbison, I.D., Phillips, G.N., Wright, J.H., 1995. Discovery of Bronzewing gold mine. In proceedings, *New Generation Gold Mines : Case Histories of Discovery,* Perth 27-28 November, 1995, Australian Mineral Foundation, Adelaide, pp. 2.1-2.15.

Gee, C., 1997 Structure and Tectonic Style of the Western Australian Shield. *Tectonophysics*, **58,** 327-369.

Phillips, G.N., Vearncombe, J.R., Blucher, I. and Rak, D., 1998. Bronzewing gold deposit, In: D.A. Berkman and D.H. MacKenzie Ed. *Geology of Australian and Papua New Guinea Mineral Deposits*, pp 127-136 The Australasian Institute of Mining and Metallurgy Monograph **22.**

Plutonic Resources, 1996. Annual Report

Varga, Z.S., 1994 Regolith landform relationships and geochemical dispersion in regolith about the Bronzewing Au deposit, Western Australia. Honours Thesis, CODES, University of Tasmania, 110p.

Varga, Z.S., Anand, R.R. and Wildman, J.E., 1997 Regolith landscape evolution and geochemical dispersion about the Bronzewing gold deposit, Western Australia, CSIRO Australia, Division of Exploration and Mining, Restricted Report **308R,** 85p.