KARARI AND WHIRLING DERVISH GOLD DEPOSITS, WESTERN AUSTRALIA

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LOCATION

The Karari (formerly Carosue Dam) Au deposit is approximately 110 km NE of Kalgoorlie and 6 km W of the Mulgabbie Mining Centre at 30°10'S, 122°22'E; Kurnalpi 1:250 000 map sheet (SH51-10). With change of ownership from Aberfoyle Resources Ltd to Pacmin Mining Corporation Ltd in 1999, the exploration lease was renamed Carosue Dam and the deposit Karari. Ownership has since passed to Sons of Gwalia Ltd and thence to St Barbara Mines Ltd. The Whirling-Dervish deposit lies 1.5 km N of the Karari pit (Figure 1).

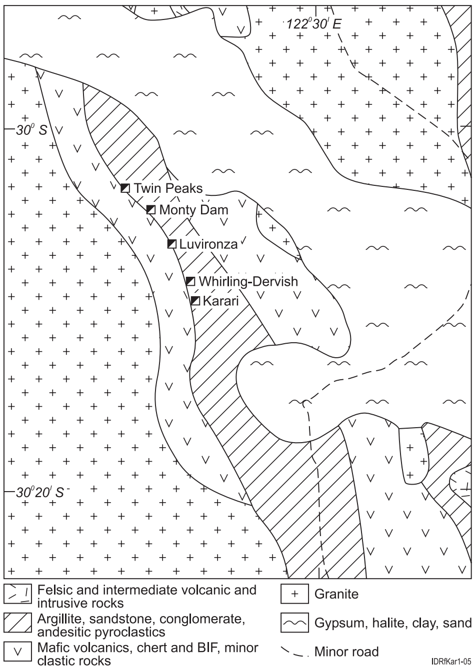

Figure 1. Geology and locations of deposits (after AGSO geology).

DISCOVERY HISTORY

Mineralization at Karari was discovered in 1997 by Aberfoyle Resources Ltd, who followed up Au anomalies identified by auger sampling targeting calcareous soils. Exploration drilling identified a series of mineralized lenses within felsic volcanic rocks along a 14 km zone. Several lenses extended more than 300 m at the Luvironza prospect. The Karari deposit began production in early 2001 and, by mid 2003, produced 240,000 ounces of Au (Sons of Gwalia, written communication, 2003). Drilling along strike of the Karari deposit located mineralization at Whirling Dervish (D. Hammond, personal communication, 2004).

PHYSICAL FEATURESAND ENVIRONMENT

The Karari and Whirling Dervish deposits lie towards the top of a sloping plateau, blanketed by alluvium and colluvium. The slope falls gently N, locally dropping about 8 m over 1000 m, towards the NW arm of Lake Rebecca. An extensive breakaway forms the S and SE margins of the plateau. There is a minor watershed S of the deposits, and the slope is reversed, becoming steeper and more incised towards the SW arm of the playa. Here, and to the E, strike-ridges of Archaean rocks chiefly volcaniclastic sandstone with minor dacite (Morris, 1994), protrude through the Cainozoic sediments,. The present climate is semi-arid, with a variable rainfall throughout the year (mean <250 mm). Mean minimum and maximum temperatures are 3-17ºC in July and 18-35ºC in January. Vegetation is dominantly an open wood- and shrub-lands of *Eucalyptus*, *Acacia* and *Maireana* (bluebush).

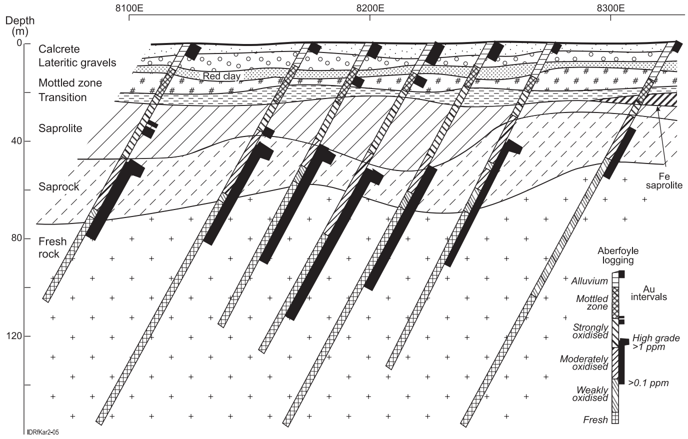

Figure 2. Regolith stratigraphy and Au geochemistry on section 3125 mN, Karari deposit.

GEOLOGICAL SETTING

The Karari and Whirling-Dervish deposits are in the E part of the Norseman-Wiluna greenstone belt of the Archaean Yilgarn Craton. They lie within the Gundockerta Formation, on the western limb of the regional Yilgangi Syncline. They are hosted by sandstones and siltstones in the hanging wall of the regional Kilkenny-Yilgangi Fault. The deposits occur within a 8 x 1.5 km zone, which contains high-K intermediate intrusions of monzonite, syenite and related porphyries, and lamprophyre. The area is also cut by a swarm of N-S faults, and all deposits occur on or close to faulted contacts between intrusions and sedimentary rocks. The deposits occur within a district-scale hydrothermal alteration system that has a distal chlorite zone, a medial muscovite zone and proximal zones of potassic (biotite) and sodic (albite) alteration in and around the intrusions. Chlorite-calcite alteration also occurs within N-S oblique and NNW bedding-parallel faults that cut across the alteration system (W.Witt, personal Communication, 2004). Both deposits are now covered by colluvial gravels, sands and alluvium.

REGOLITH

The regolith in the area is commonly 50-75 m thick, with 5-20 m of transported overburden (colluvium-alluvium, lacustrine clays and quartz sands) covering the entire area. The regolith stratigraphy for a drill section through Karari at 3125mN is shown in Figure 2. Saprock (approximately 25 m thick), containing relatively fresh, green or greyish bedrock fragments grades upwards into a cream-coloured saprolite that is ferruginized in places in its upper part. Above this, the saprolite is transitional to a mottled zone. Red clay between the residuum and the transported overburden commonly marks a zone of mixing. Red colours, magnetic ferruginous nodules and polymictic fragments show the transition to transported cover, which consists of ferruginous gravels, cemented to calcrete in the upper part.

At Whirling Dervish, weathering extends to 39-93 m depth and is deepest in the W. The felsic rocks hosting the mineralization weather to a kaolinite-rich and Fe oxide-poor saprolite. This is overlain by about 12 m of massive, puggy to mottled valley-fill clay, 10 m of red-clay colluvium-alluvium, with lenses of maghemite-bearing nodules. This unit is silicified (hardpanized) near its base and cemented by carbonates in the top 1-6 m. The unconformity with the residual profile is difficult to distinguish due to the similarity of the clays and some retexturing by pedoplasmation and/or diagenesis. A combination of careful logging of quartz and clay fabrics, infra-red determination of kaolinite crystallinity and clay particle size analysis was needed to determine this important

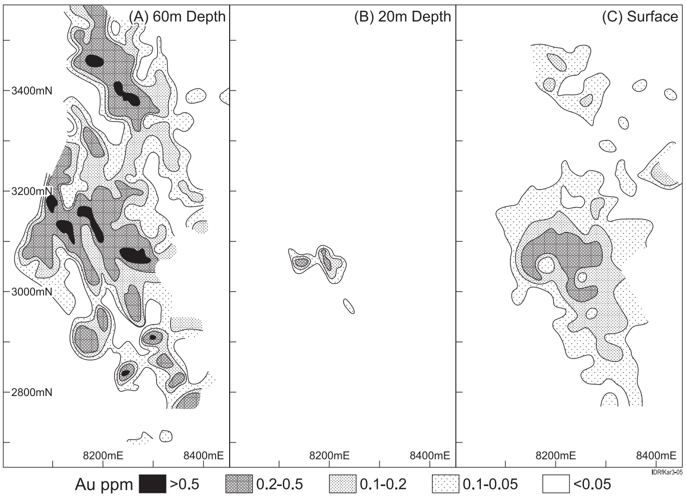

Figure 3. Contoured Au data: (A) Below depleted zone at approximately 60 m depth; (B) Depleted zone at approximately 20 m depth; (C) Surface.

boundary. Clays in the transported materials are generally less well crystalline than those of the saprolite, which lacks the <0.2 µm clay fraction.

Although the Carosue Dam area is close to the northern limit of pedogenic carbonate (the Menzies Line, Butt *et al.*, 1977), calcification extends to 1-6 m, much deeper than in the Kalgoorlie area.

MINERALIZATION

Gold mineralization in the felsic rocks is hosted principally by volcaniclastic sandstones and, to a lesser extent, by trachytes and/or dykes. It is associated with albite, K-feldspar, silica, hematite, carbonate, and pyrite alteration. Mineralization in the fresh rock occurs in multiple lodes, with two orientations; (i) sub-parallel to lithological contacts, striking NNW and dipping moderately to the NE, and (ii) higher grade WNW striking and dipping shallowly to the NE with a gentle northerly plunge (generally silica-albite-pyrite rich). Mineralization is controlled by faults, shears and contacts. To the W, the mineralization is truncated by a N-trending fault against shales and siltstones (distal volcaniclastics). To the E, another fault terminates the mineralized sequence; further to the E there is an intrusive complex. Late-stage, post mineralization, E-W trending faults disrupt the NW striking lithologies and their associated mineralization; the northern blocks are upthrown. An inferred resource of 5.5 Mt at 3 g/t Au was reported for the Karari deposit in September 1997 (H. Rowlands, personal communication, 1999). Reserves calculated by PacMin Mining Corporation Ltd for the Whirling Dervish deposit are approx. 6.9 Mt at 1.88 g/t Au (405 000 oz Au) (Craig, 2001).

REGOLITH EXPRESSION

Gold distribution

The Karari deposit has a strong surface expression of over 400 x 1000 m in calcareous soils, with maximum concentrations >200 ppb Au, developed on essentially barren transported overburden. This overlies saprolite which, over mineralization, is generally depleted, to less than 200 ppb, to 30 m below surface, except in a central silicified zone (Figures 2 and 3). Ore grade supergene mineralization (>1 g/t Au) occurs in the lower saprolite and saprock, above the primary sulphidic lodes. Modelling indicates that mean Au concentrations increase by 40% from fresh rock to the lower saprolite, with a major decrease in the upper, oxidized saprolite and mottled zone (22% and 13% of the fresh rock, respectively). The upper oxidized and mottled zones (with a combined thickness greater than 25 m) are approximately 90% depleted relative to the lower saprolite. The sediments are also relatively Au-poor, though there is a significant increase from the alluvium (13% of fresh rock) to the overlying calcrete (26%, mean 60 ppb).

The anomaly in the calcrete (Figure 3C) is offset to the S of the underlying mineralization, with >100 ppb Au extending laterally for several hundred metres. In this area, the mineralized zone has a near-

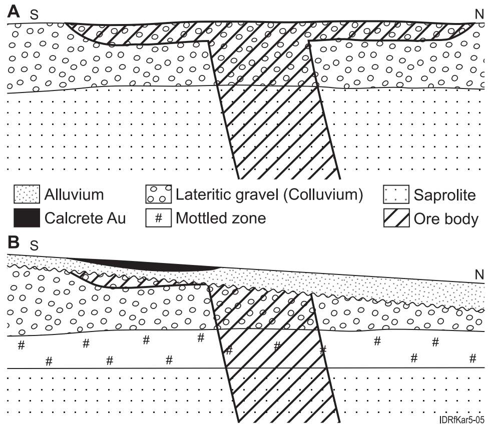

Figure 4. Proposed origin of surface Au anomaly at Karari. (A) Tertiary weathering with dispersion of Au into laterite; (B) stripping of laterite to the N, deposition of alluvium with soil Au anomaly in the S, and leaching of buried Au above strongly to moderately oxidized transition.

complete residual profile and, locally, less than 5 m of transported cover. A proportion of the surface Au is as relict primary grains, indicating at least some residual Au concentration and mechanical transport near the surface. In comparison, the northern part of the mineralized zone has a truncated residual profile, thick transported cover and weak Au expression at surface.

The proposed mechanisms to explain supergene Au distribution at Karari are shown diagrammatically in Figure 4. During weathering in the Tertiary, Au would have been dispersed into the surface laterite away from the ore body (Figure 4A). Later, the laterite cover was partially eroded, followed by deposition of sediments (Figure 4B). To the N, the greater truncation of the residuum and thicker alluvial cover (> 10 m) has resulted in a very poor surface expression whereas, in the S, the more complete residual profile and thinner transported cover has led to a stronger surface Au signature. As a parallel process, Au from the upper saprolite has dissolved in the acid, saline groundwaters and precipitated in the lower saprolite and saprock have dissolved, and moved it downwards to the reduced saprock. Thus, the major Au depletion occurs around the strongly oxidized saprolite and the ferruginous zone.

At Whirling-Dervish, there is an anomaly (15-50 ppb Au) in calcareous materials in the upper 3 m of the transported regolith (Figure 5), displaced 50 m E and NE towards the drainage (Cornelius *et al.*, 2005). This is effective despite 10-20 m of cover. Carbonate hosts the Au in the upper 1-2 m and both carbonate and ferruginous materials host the Au at 2-4 m depth (Figure 6), suggesting intermediate behaviour between Golden Delicious (Au in ferruginous gravels at 10 m depth) and Safari (Au in calcrete from surface to 3 m depth) deposits (both *this volume*). Laser ablation ICPMS investigations indicate that calcite veins and the calcrete matrix host Au in near-surface material. In the saprolite, Au is hosted by barite contained in siliceous opaline material (Cornelius *et al.*, 2005).

Hydrogeochemistry

Groundwaters in the Karari mine lease are saline to hypersaline (2.5-11.6% TDS; cf seawater 3.5%), and acid (pH 3.2-6.0), except for a single neutral (pH 7.1) location SW of the deposit. These ranges are similar to groundwaters in the Kalgoorlie district(Gray, 2001), although 2-3 times less saline. Because of the strong salinity and acidity, very few elements give hydrogeochemical signatures useful for exploration. The best (though patchy) correlation with mineralization was for dissolved Au (Figure 7). Groundwaters at Carosue Dam are ideal for Au dissolution as the chloride ($AuCl_2^-$) or iodide (AuI_2^-) complexes. The groundwaters range from moderately to highly oxidizing: two of the groundwaters are sufficiently oxidizing to dissolve more than 2 µg/L Au, with another three groundwaters containing >0.2 µg/L Au (Gray *et al.*, 2000). These concentrations of dissolved Au are high, relative to other sites on the Yilgarn (Gray, 2001).

DISPERSION MODEL

TBA

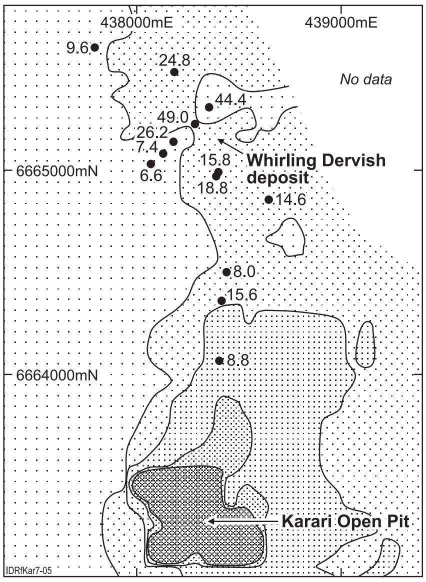

Figure 5. Gold concentrations from auger drilling (Box-Cox normalized and kriged using ArcGIS) and from AC drilling (Cornelius et al., 2005), 2-3 m intervals only. Note the absence of a discreet anomaly over Whirling Dervish in the auger results and, by contrast, anomalous Au concentrations from AC drilling targeting specifically carbonate in soil.

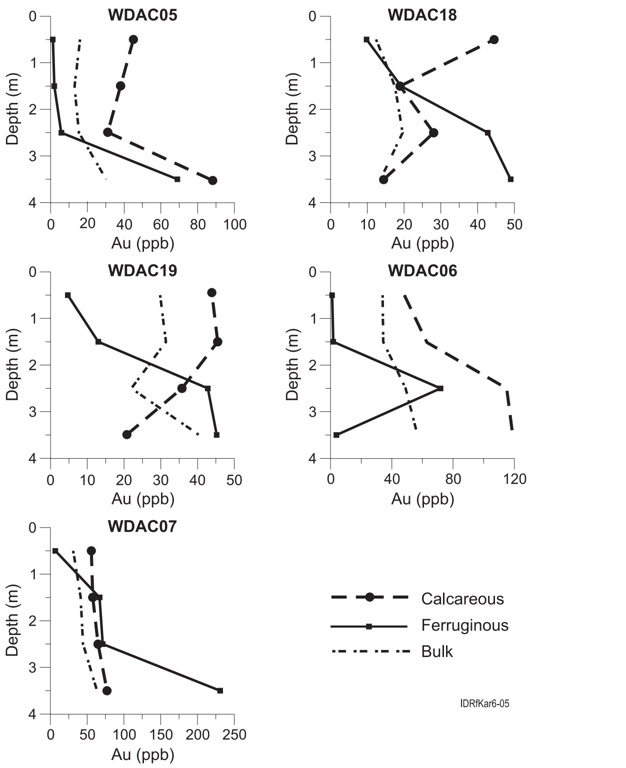

Figure 6. Gold concentrations in the bulk, ferruginous and calcareous material in the upper 4 m from Whirling-Dervish. (Cornelius et al., 2005).

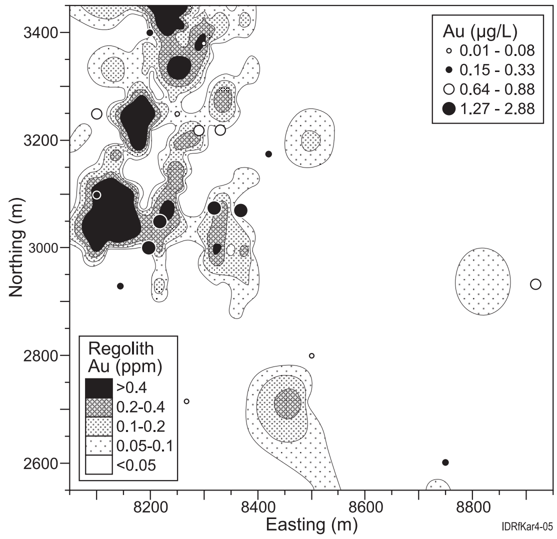

Figure 7. Distribution of dissolved Au with calculated Au distribution for 30-45 m depth shown as solid fill.

ACKNOWLEDGEMENTS

Aberfoyle Resources Ltd., through Michael Joyce and Hugh Rowlands, provided access to the Carosue Dam lease and to exploration data. Pacmin Mining Corporation provided access to later drilling data. Sons of Gwalia Ltd provided data on the Whirling-Dervish lease. St Barbara Mines Ltd gave permission to use company information.

REFERENCES

Butt, C.R.M., Horwitz, R.C.H. and Mann, A.W., 1977. Uranium occurrences in calcretes and associated sediments in Western Australia. CSIRO Australia, Division of Mineralogy, Perth. Report FP16. 67 pp.

Cornelius, M., Singh, B., Robertson, I.D.M., Anand, R.R., Hough, R. and Cornelius, A., 2005. Gold anomaly formation in areas of cover at Karari and Northern Leonora, and implications for exploration. CRC LEME Restricted Report 214R., Perth. 57 pp.

Craig, A.M., 2001. The origins and setting of the Archaean host rock succession to the Karari gold deposit, Carosue Dam, Western Australia – with relevance to the style and timing of mineralization. BSc Honours thesis, Monash University, Clayton (unpublished).

Gray, D.J., 2001. Hydrogeochemistry in the Yilgarn Craton. Geochemistry: Exploration, Environment, Analysis, 1: 253-264.

Gray, D.J., Sergeev, N.B. and Porto, C.G., 2000. Characteristics of gold distribution and hydrogeochemistry at the Carosue Dam prospect, Western Australia. Report No. 664R, CSIRO Exploration and Mining, (CRC LEME Report 121 R) Perth. 105 pp. + CD.

Morris, P.A. 1994. Geology of the Mulgabbie 1:100 000 sheet. Geological Survey of Western Australia Explanatory Notes. 18 pp.

SAMPLE MEDIA - SUMMARY TABLE

Sample media	Indicator elements	Analytical method	Detection limits (ppb)	Background (ppb)	Threshold (ppb)	Maximum anomaly (ppb)	Dispersion distance (m)
Primary	Au						
Saprolite (Whirling-Dervish)	Au	ICP-MS *	0.2	0.2	?	2600	Minimal
Soil (Whirling-Dervish)	Au	ICP-MS*	0.2	Range 1.6 – 4.8			Not enough data
Calcrete (Whirling-Dervish)	Au	ICP-MS*	0.2	<5	10	64	100-200
Groundwater (Karari)	Au	ICP-MS*		0.01-0.08	0.15	2.88	100-200

* After aqua regia dissolution