

HIGGINSVILLE PALAEOCHANNEL GOLD DEPOSITS, KAMBALDA, WESTERN AUSTRALIA

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LOCATION

The Higginsville palaeochannel deposits are 65 km S of Kambalda and 5 km SSW of the Higginsville Gold Mining Centre at 31°47'28"S and 121°44'34"E; Widgiemooltha 1:250 000 map sheet (SH51-14).

DISCOVERY HISTORY

Resolute Ltd discovered the Higginsville Palaeochannel Deposits (about 300 000 oz) by soil sampling followed by drilling (C. Bonwick, pers. comm., 2001). The soil Au anomaly (>5 ppb Au) over the northern parts of the palaeochannel deposits was broad (>2 km) and may have been due to dispersion from surrounding erosional areas (Figure 1).

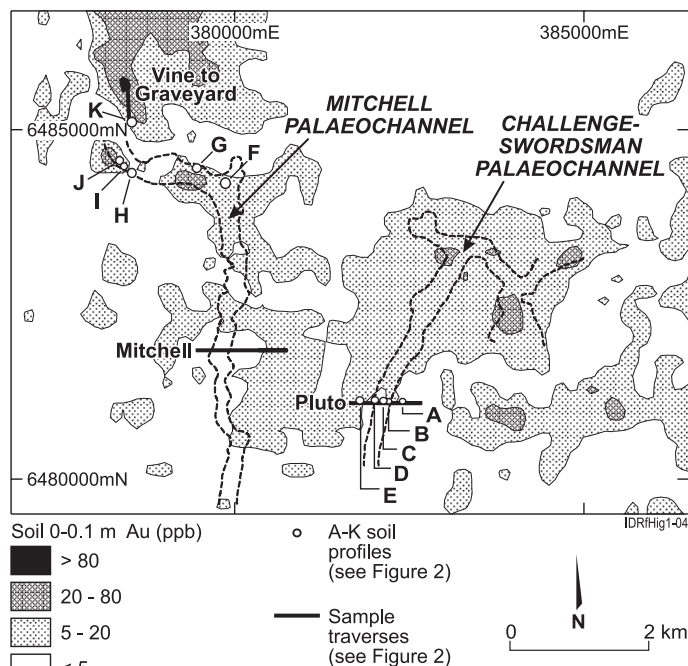


Figure 1. Gold distribution in soil and sampling locations. Mineralization outcrops at Vine but elsewhere is confined to the palaeochannels boundaries.

PHYSICAL FEATURES AND ENVIRONMENT

The terrain is undulating with about 50 m of relief. The palaeochannel deposits are beneath broad valleys with ephemeral drainage. The Mitchell palaeochannel follows the present ephemeral stream that drains the Higginsville Mining Centre. Elsewhere, saprolite of weathered Archaean rocks outcrop. A prominent playa, Lake Cowan, is 3 km to the S and E. The vegetation consists of an open eucalypt woodland of salmon gum (*Eucalyptus salmonophloia*), gimlet (*E. salubris*) and mallee (*Eucalyptus* spp.) and other small trees, possibly boree (*Melaleuca pauperiflora*). The understorey consists of a variety of small shrubs including bluebush (*Maireana* spp.), false bluebush (*Cratystylis conocephala*), saltbush (*Atriplex* spp.) and poverty bush (*Eremophila* spp.). The climate is semi-arid with hot, dry summers and cool to mild winters, with mean minimum and maximum temperatures of 15 and 33°C in January, 5 and 16°C in July (average minimum of 5°C). Mean annual rainfall is 270 mm, with most falling between March and August. Average potential evaporation is about 2300 mm, being greatest in January and February.

GEOLOGICAL SETTING

The Higginsville Gold Mining Centre is at the southern end of the Norseman-Wiluna greenstone belt. The Zuleika Shear is thought to cut the area and primary mineralization is associated with second order fault splays. Two such structures, the Poseidon South Fault and the Mission Fault, bound a major metasedimentary sequence that dominates the area between the Mitchell and Challenge-Swordsman palaeochannels, which host the Au deposits. To the E and W of the metasediments,

forming the limbs of a syncline, is a package of high-Mg metabasalts and ultramafic rocks with minor metasediment, intruded by gabbro, dolerite and felsic porphyry. The Archaean rocks are steeply dipping and have a NNW strike. The sequence is folded into a regional syncline at the NE corner of the Pioneer Dome, which has a generally low angle, northerly plunge (Griffin, 1989). The Mitchell and Challenge-Swordsman palaeochannels, which contain the deposits, are tributaries to the Cowan Palaeochannel beneath Lake Cowan. Both palaeochannels incise the mafic and ultramafic rocks of the limbs of the regional syncline.

REGOLITH

The dominant landform is depositional and comprises 82% of a 25 x 25 km area centred on the deposits (Lintern *et al.*, 1996). It consists of calcareous soil, aeolian sand and remnants of Tertiary lacustrine, fluvial and marine sediments overlying deeply weathered Archaean basement. Erosional landforms occupy 17% and mostly consists of saprolite and slightly weathered rock but outcrop is poor. Relict landforms with lateritic duricrust occupy only 1% of the area. Soils consist of calcareous clays containing abundant lithorelics of a variety of sizes. In depositional areas, the soils also contain detrital fragments of packed or re-cemented duricrust and ferruginous granules.

A typical regolith profile containing palaeochannel mineralization comprises:

- 0-2 m. Dense red, calcareous clays with abundant dark red to black ferruginous granules, some in lenses, with some gypsum. Calcrite occurs within the top 1-2 m as nodules, pisoliths, concretions and as coatings on clay particles;
- 2-6 m. Red, non-calcareous clay with some grey mottling;
- 6-12 m. Multi-coloured clay with abundant ferruginous nodules and some pisoliths;
- 12-18 m. Red and khaki puggy clay becoming paler with depth - some ferruginous nodules;
- 18-34 m. Cream to white, silty, sandy clay;
- 34-40 m. Sandy clay with carbonaceous (including fossil wood) and sulphidic material and
- 40-80 m. Clay saprolite consisting of variably coloured clays with quartz and rock fragments. Fresh rock occurs at a variable depth, generally below 80 m.

MINERALIZATION

Gold mineralization in the palaeochannel occurs at the base of the Tertiary sediments in sands, grit and conglomerates. The source of the Au is unclear, but possibilities are (i) alluvial (placer) Au from an unknown source; (ii) supergene chemical Au weathered from a proximal primary Archaean source or (iii) Au-bearing fluids emplaced from faults in the basement into sands during the Tertiary (Lintern *et al.*, 1996).

REGOLITH EXPRESSION

Regolith materials were sampled from above and adjacent to the Au deposits and analysed for a broad range of elements. No evidence of underlying palaeochannel mineralization was detected in any near-surface sample medium (soil, ferruginous granules, calcrite, vegetation or ferruginous mottles from the upper transported layer) using either total or partial extraction analyses (Lintern *et al.*, 1996). The principal Au results (Figure 2) indicate that:

- (i) There is a general association between Au and Ca (as carbonate) in the soils. The strongest associations occur over outcropping mineralization at Vine and in part of the Pluto traverse. This relationship is also seen in the soil profiles.
- (ii) The Au content of soils is probably only directly related to underlying mineralization at Vine, which is in an erosional area. There

is no relationship over palaeochannel mineralization at Mitchell or Pluto, with the highest concentrations on each traverse occurring in background areas; an apparent relationship at North Graveyard (shallow depositional) is possibly related to higher Ca contents.

(iii) The highest Au concentrations (maximum of 425 ppb) occur in Profile G.

(iv) No Au was detected in many soil samples over mineralization at Mitchell and Pluto (detection limit 5 ppb).

Shallow soils (0-0.1 m) were collected from the Mitchell palaeochannel only; they have less Au than the comparable 0-1 m soils and similarly do not locate buried mineralization unequivocally (Figure 2). Gold concentrations for 0-0.1 m and 0-1 m composite samples are correlated, indicating that, for this traverse at least, samples taken carefully from the surface give similar results to deeper composite samples. However, this relationship may not always be dependable as can be observed from the highly variable Au content of soil samples taken from the soil profiles at Pluto (Figure 2; see also Figure 1).

Partial extractions

Partial extraction studies (using water, iodide, cyanide and MMI) for 0-1 m and 0-0.01 m soil samples for traverses across the Mitchell and Pluto deposits were not an unequivocal guide to buried mineralization. For the Mitchell traverse, the water, iodide and cyanide sequential partial extraction data in the 0-1 and 0-0.1 m samples (Figure 3) indicate that: -

(i) The two 0-1 m samples with the greatest proportion of water-extractable Au (~45%) occur over mineralization. This is not the case with 0-0.1 m samples.

(ii) Mean total Au concentrations are greater in 0-1 m samples (7 ppb) than 0-0.1 m samples (5 ppb). Gold in the 0-1 m soils is also more extractable in water (26% compared to 12%), but there is less total extractable (22% cf. 28%), which may reflect mobile Au in the carbonate.

Ferruginous granules

Fifty individual, wet-sieved ferruginous granules (1-6 mm) were selected at random from a sample containing 400 ppb Au (09-4748 Profile G). Each granule was broken and approximately half was analysed. The Au content of many granules was below 100 ppb, but several were strongly enriched, to a maximum of 51 000 ppb. Petrographic investigations of nine Au-rich (>250 ppb) granules showed

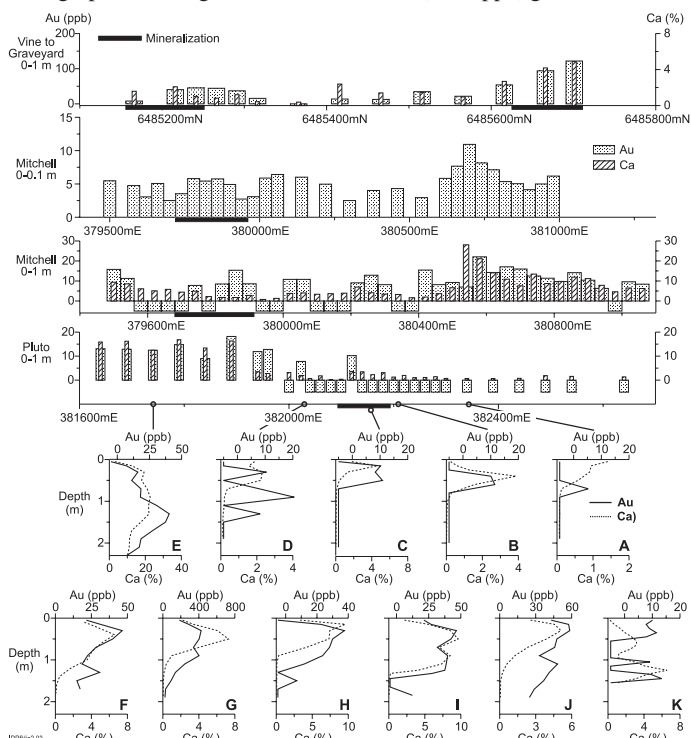


Figure 2. Gold and Ca distributions for soils at Higginsville. Black bar under traverse axis indicates mineralization. Negative Au data indicate concentrations below detection (<5 ppb).

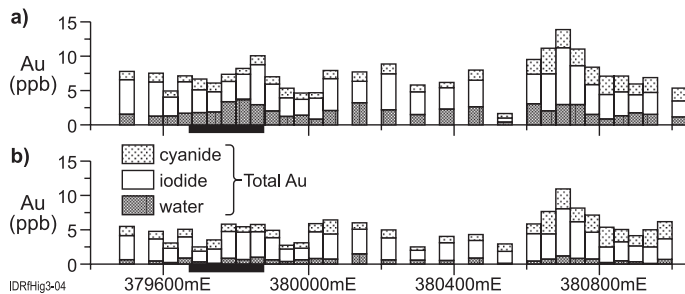


Figure 3. Stacked histograms of partly extractable Au (sequentially using water, iodide and cyanide) for a) 0-1 m and b) 0-0.1 m samples from Mitchell palaeochannel. Black bar indicates location of mineralization. Total Au is the sum of the partial extractions.

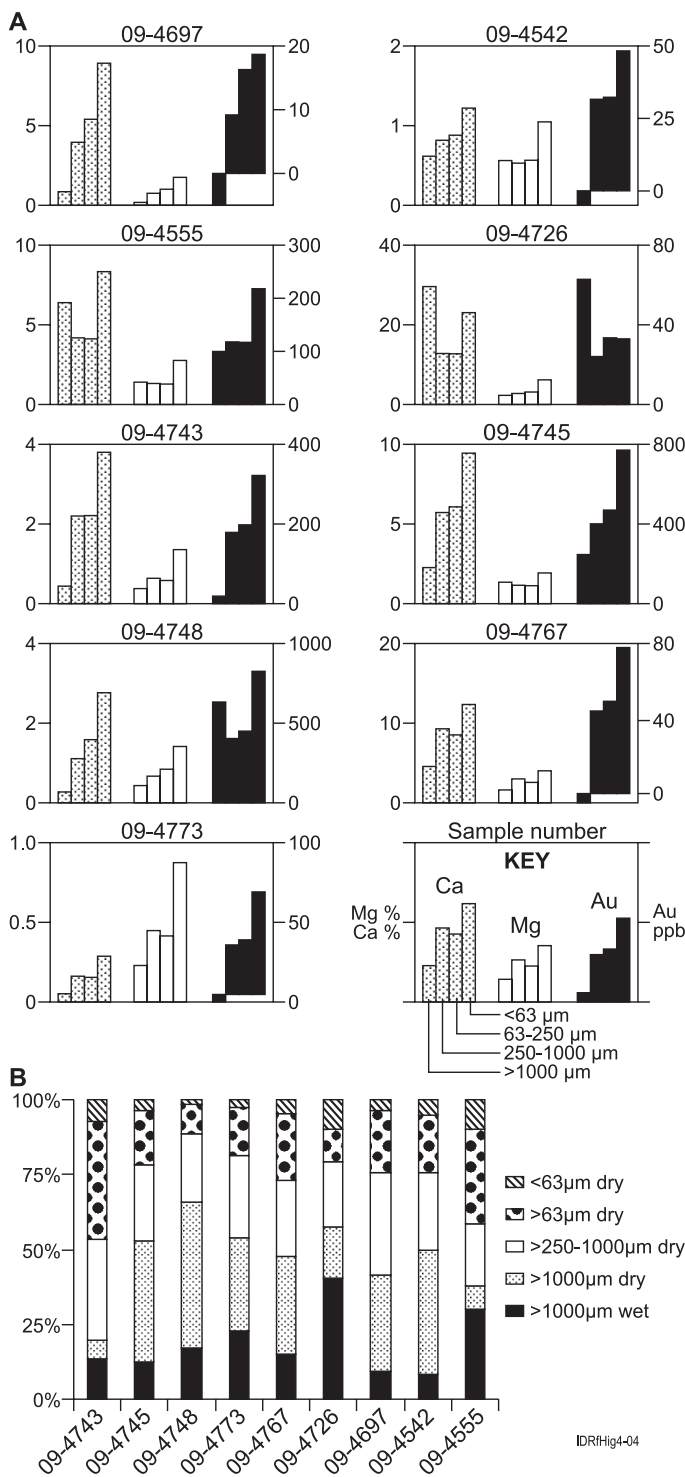


Figure 4. Size fraction analyses of Au-rich samples from soil profiles at Higginsville. A: Gold, Ca and Mg contents. B: Relative proportions of each fraction.

them to be pervasively ferruginized, some with partly-preserved primary lithic fabrics. Each contained particles of free Au (up to 10 µm); the absence of Ag suggests the Au is secondary.

Ferruginous mottles separated from drill cuttings from 2-10 m, above mineralization from Pluto and Mitchell, lacked any detectable Au (<5 ppb), indicating that this material is not a useful sample medium.

Size fraction analysis

Nine Au-rich soil profile samples were dry sieved into four size fractions (<63, 63-250, 250-1000 and >1000 µm; Figure 4); the coarsest fraction was further wet sieved to remove fines. The fractions were analysed for Au and Ca with the following results: -

- (i) For 8 of the 9 samples, the highest Au and Ca concentrations are in the finest fraction.
- (ii) There is a strong association between Au and Ca and a weaker one between Au and Mg.
- (iii) The coarse fraction of sample 09-4748 (which contained a high proportion of ferruginous granules) has a high Au but low Ca and Mg concentrations, confirming the Au-Fe association noted above.

Vegetation

Bluebush has shown potential as a sample medium elsewhere in the Yilgarn (Lintern *et al.*, 1997) and was tested on the Pluto traverse. There was no single representative bluebush species present across the entire traverse, so that two physically similar species (1 and 2) were used. These gave quite different geochemical responses for Au and other elements (Figure 5). Gold concentrations in species 2 follow those in the soil and are greatest on the western part of the traverse. However, concentrations in species 1 are below detection both over mineralization and background to the E, so it is not possible to determine if there is a low-level anomaly. However, results from elsewhere (Lintern *et al.*, 1997) suggest that if concentrations are below 2 ppb, as with most data here, they are unlikely to be significant.

Associations between Au, pedogenic carbonate and ferruginous granules

Much of the Au in soil profiles at Higginsville is associated with pedogenic carbonates (calcite and dolomite). The carbonates form by reaction of Ca or Mg ions with bicarbonate ions in soil water. The Ca and Mg are directly or indirectly derived from bedrock, groundwater, vegetation, dust and rainfall; bicarbonate is from CO₂ from root and microbial respiration and from the air. Carbonate precipitation occurs when concentration by evapo-transpiration causes saturation of soil solution. Drying of the soil probably also controls Au precipitation (Lintern 1989). Chemical adsorption of Au on carbonate surfaces from migrating soil moisture is improbable at the prevailing high pH and, if it did, there would be a Au-enriched zone at the top or base of the carbonate horizon; no such zone is present. Previous laboratory experiments (Gray *et al.*, 1990) and this investigation have shown that Au associated with carbonate is very soluble. In many soils at Higginsville, over 25% of the Au in carbonate horizons is water soluble. Involvement of biota in recycling Au and Ca at the surface is suggested by these metals in plant tissues, although the role of vegetation in the process is probably minor. Both Au and Ca appear to be taken into the plant through the roots, ultimately to be returned to the soil as plant litter. Gold probably occurs in the soil moisture as an inorganic or organic Au complex and is redeposited as an evaporite, with the carbonates.

Some Au is also associated with ferruginous granules. It was probably

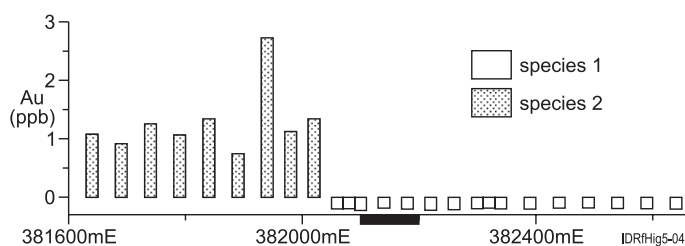


Figure 5. Gold concentrations for 2 different species of bluebush on the Pluto traverse.

incorporated within them during their formation, e.g., during deep weathering in the early Tertiary. Many granules are derived from the breakdown of lateritic duricrust, Fe mottles or Fe-rich saprolite. Gold may be concentrated or preserved in such material by (i) partial weathering of primary host rocks, which later become ferruginized or (ii), Au dissolved during weathering is re-precipitated with neoformed Fe oxides. In both cases, Au grains are encapsulated and protected from dissolution. However, as weathering proceeds under changed conditions, the ferruginous materials may dissolve or disintegrate, releasing the Au grains, which may, themselves, also weather and dissolve.

Ferruginous granules may occur in the calcareous soils or in a distinct horizon deeper in the profile. In some profiles at Higginsville, there is less than a metre separating such gravel-rich and carbonate horizons (e.g., profiles G and H; Figure 2). Any Au dissolved during the weathering of ferruginous granules may be transported across this interval by capillarity, recycling by plants, bioturbation or diffusion. During dry periods, the dissolved Au may precipitate with carbonate, to form the Au anomaly. Some Au remains protected from dissolution within the ferruginous granules for long periods and can thus act as a reservoir to sustain the anomaly, even though the Au in the carbonate is water soluble. The granule behaves like a slow-release garden fertiliser pellet. Eventually, however, all Au in the granules will be released and widely dispersed, weakening and ultimately diluting the anomaly to background concentrations. The strong association between Au in soil carbonate and Au-rich Fe granules is by no means universal. It depends on (i) susceptibility of the granules to weathering, (ii) susceptibility of the Au to be dissolved and (iii) the environment of the soil profile to allow the Au-Ca relationship to develop over the granules.

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SAMPLE MEDIA - SUMMARY TABLE

Sample medium	Indicator elements	Analytical methods	Detection limits (ppm)	Background (ppm)	Max anomaly (ppm)
Soil	Au	INAA*	0.0001	0.005	0.425
Fe granules**	Au	INAA	0.1	0.4	51
Veg 1	Au	INAA	0.0005	0.001	0.003
Veg 2	Au	INAA	0.0005	0.0005	<0.0005
Fe mottles	Au	INAA	0.005	0.005	na

*After pre-concentration on carbon

**Individual granules