STEINWAY GOLD DEPOSIT, KALGOORLIE, WESTERN AUSTRALIA

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LOCATION

The Steinway Gold Deposit is approximately 25 km S of Kalgoorlie at 30º59'31"S, 121º25'19"E; 1:250 000 Kalgoorlie map sheet (SH51-09).

DISCOVERY HISTORY

Auger soil sampling by Newcrest Mining Ltd in the early 1990s located a number of anomalies (>24 ppb Au). Follow-up RAB and RC drilling discovered the Greenback and Penfold deposits, which have since been mined, and Steinway, which remains undeveloped (Figure 1).

PHYSICAL FEATURES AND ENVIRONMENT

The area around the Steinway deposit is an almost flat lying depositional plain. Rising to the S is an erosional area of mafic saprolite that includes the Penfold Gold Deposit. Drainage is towards White Lake, a playa about 10 km to the N. Locally, there is about 10 m of relief; a range of hills about 5 km S is about 100 m above the plain. Present-day shallow ephemeral channels cross the area and flow N; these channels separate the Steinway and the Penfold soil anomalies (Figure 1). The climate is semi-arid, with an erratic rainfall of about 270 mm pa. The mean daily maximum and minimum temperatures are 33.7 and 18.2°C in January, 16.6 and 4.9°C in July. Vegetation is an open Eucalyptus woodland dominated by salmon gum (*E. salmonophloia*) with an understorey mainly of bluebush (*Maireana* spp.).

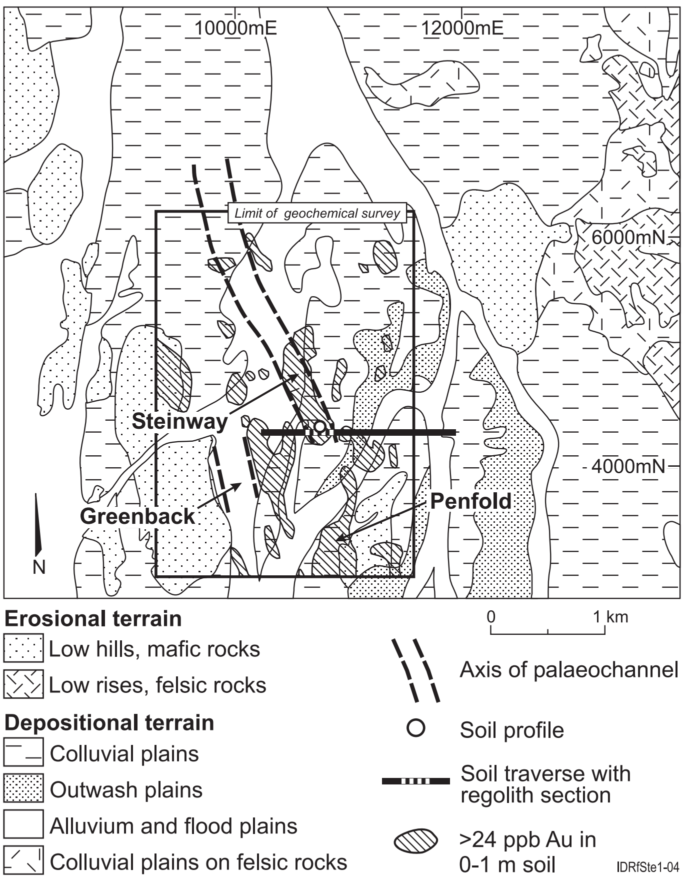

Figure 1. Location of Steinway, soil anomalies, mineralization and study area (after Gardiner, 1993).

GEOLOGICAL SETTING

Steinway lies adjacent to a regional contact between mafic-ultramafic rocks of the Saddle Hills Belt and overlying intermediate to felsic metavolcanic and metasedimentary rocks of the Black Flag Group. It is hosted by saprolites from mafic andesite, trachyte, porphyritic tuff and black shale, below a palaeochannel infilled with Cainozoic sediments (Figure 2).

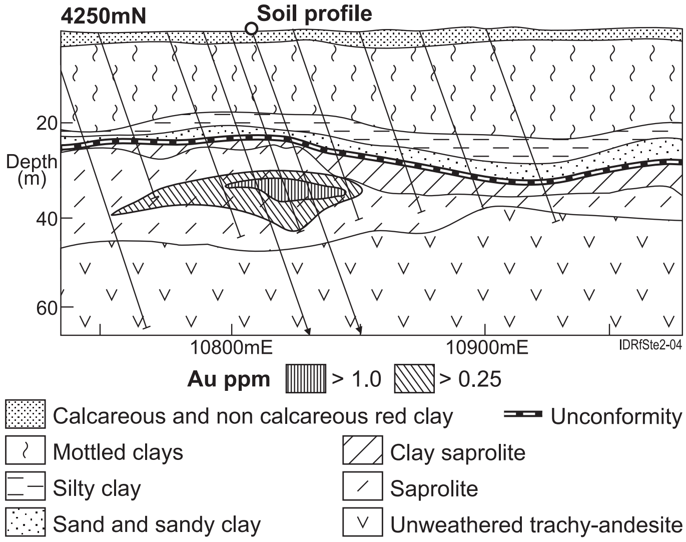

Figure 2. Regolith section across the palaeochannel.

MINERALIZATION

Steinway is a sub-economic Au deposit lying beneath a palaeochannel. There are two types of mineralization at Steinway: (i) sub-horizontal saprolite-hosted supergene mineralization at about 30-40 m, some 5-10 m beneath the unconformity with the sediments of the palaeochannel and (ii) primary mineralization in quartz-stockwork veins within mafic andesite. The andesite has been altered to microporphyritic amphibolites (mainly hornblende), biotite, and lesser feldspar and garnet. Wall rocks near the quartz stockwork are generally silicified, carbonate altered, and veined with tourmaline, quartz and disseminated pyrite.

REGOLITH

Steinway is located beneath a depositional plain on deeply weathered terrain. The central and northern parts of the deposit have a variable thickness (>20 m) of transported overburden, consisting of partly consolidated clays, sands and silts. A typical regolith profile through the palaeochannel consists of the following units: -

- Lag surface of ferruginous ('buckshot') gravels.
- Calcareous clay-rich red soil with abundant ferruginous granules (0-2 m depth).
- Non-calcareous clay with abundant ferruginous granules (2-5 m).
- Clay with zones of ferruginous mottles (5-15 m).
- Variably sandy to silty clay with lenses of coarser sand-rich material; a coarse sand layer overlying mica-rich clay generally marks the unconformity between the base of the palaeochannel and saprolite (25-30 m).
- Saprolite, clay-rich towards the top (30-50 m).
- Fresh rock (>50 m depth).

REGOLITH EXPRESSION

Soil

The soil above the deposit has a Au anomaly (>24 ppb) over 150 m wide E-W, extending for over 1 km to the NW, along the palaeochannel. Few other anomalies in depositional sites in the area have significant mineralization beneath them. The adjacent Greenback mine, for example, about 600 m to the W, lacked a soil anomaly, yet it is buried beneath transported overburden that, in places, is thinner than that at Steinway. Penfold is on a low hill, with residual soil.

Samples of ferruginous lag granules, topsoil (0-0.1 m), augered soils (0-1 m), a soil profile, including bulk samples, palaeochannel sediments, groundwater and vegetation were collected along a section across the

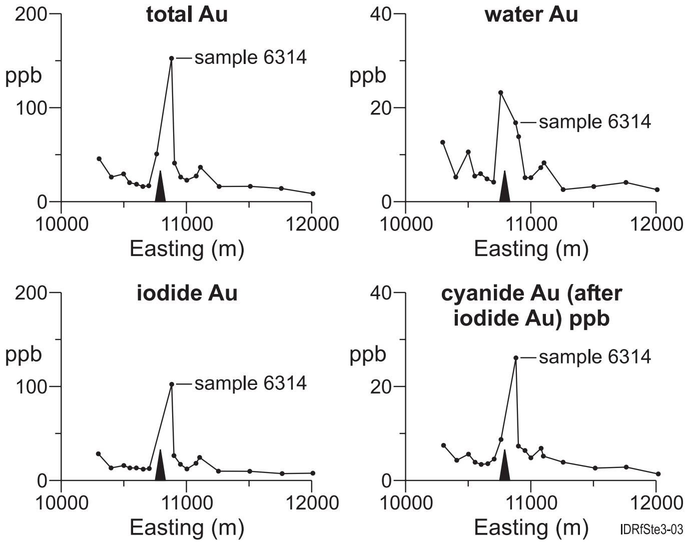

Figure 3. Total, water-, iodide- and cyanide-soluble Au for the auger traverse at Steinway. The cyanide results are for the Au left after the iodide extraction. The shaded area below the plots is the location of mineralization at Steinway.

deposit, intersecting the soil anomaly. The samples were analyzed by INAA (Au, Ag, As, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, Ir, K, La, Lu, Mg, Mo, Na, Rb, Sb, Sc, Se, Sm, Ta, Th, U, W, Yb and Zn.), AAS after digestion in 5M HCl (Ca and Mg) and partial extraction (for water-, iodide- and cyanide-soluble Au).

Gold concentrations of 0-1 m augered samples appear to be related to the underlying Steinway mineralization, reaching a maximum of 152 ppb. Partial extraction of Au from the 0-1 m samples using water, iodide and cyanide (see methods in Gray and Lintern, 1993) produce anomalies largely coincident with total Au analysis (Figure 3).

The comparison of water-extractable Au with total Au indicates the sample with the greatest total Au (sample 6314, 150 ppb; Figure 3) has the lowest proportion of water-soluble Au (11%), compared with all the other samples (mean 27%). The proportions of water-, iodide- and cyanide-soluble Au are approximately the same for all other samples from the traverse. The unusually low concentration of water-soluble Au for sample 6314 may be due to: (i) a high proportion of coarse material, and/or (ii) an association between Au and another phase, such as Fe oxides (see profile and ferruginous granule results), from which the water is less capable of leaching Au. Earlier studies have shown that much of the Au associated with Ca dissolves comparatively readily with iodide and water extraction (Gray and Lintern, 1994).

The highest Au concentration in topsoil (93 ppb) occurs over mineralization and is significantly higher than background (approximately 20 ppb, Figure 4A). The highest concentration for topsoil appears to define slightly better the location of mineralization than for 0-1 m samples, which is displaced slightly to the E (Figure 4A); both augered and topsoil samples show similar anomaly to background ratios (about 7:1).

The soil profile is located close to sample 6314 (described above). Gold concentration gradually increases with depth (Figure 4B), whereas Ca

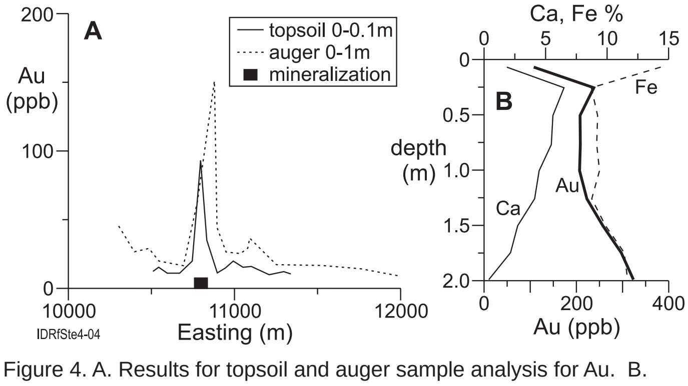

Figure 4. A. Results for topsoil and auger sample analysis for Au. B. Gold, Ca and Fe concentrations for the soil profile at Steinway.

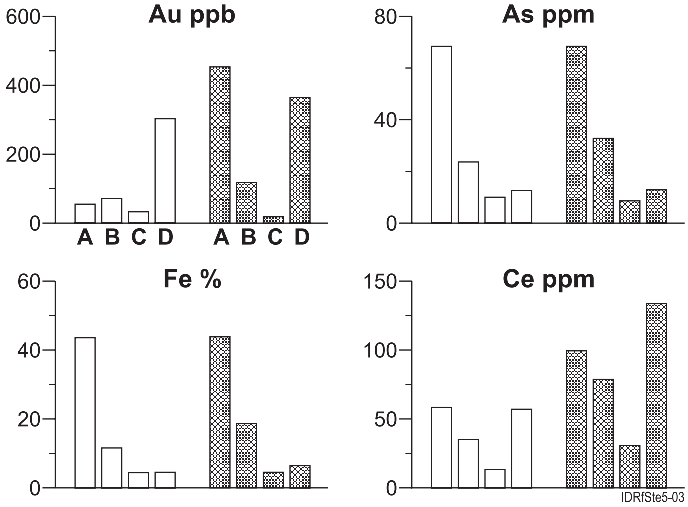

Figure 5. The distribution of Au, As, Fe and Ce in material from four size fractions (A >710 µm, B 710-250 µm, C 250-53 µm and D <53 µm) within two horizons (unhatched 0.2 m; hatched 1.6 m) in soil profile.

sharply increases then decreases; Fe concentration decreases sharply from the surface and then gradually increases with increasing depth due to carbonate dilution. Gold and Ca concentrations are associated in the top 0.5 m, but the Au content appears to be related to Fe in the lower part of the profile.

Soil samples from 0.2 m and 1.6 m were wet sieved (Figure 5). The highest Au concentration is in the coarse fraction (>710 µm) at 1.6 m (450 ppb). This fraction represents 11% of the total weight of the entire sample from this depth and has 17% of the total Au. Most of the Au (80%) is contained in the <53 µm fraction, since this constitutes the largest fraction (63% of total weight). The coarse fraction from 1.6 m is also anomalous in As, Cr, Eu, Fe, La, Sb, Sc, Sm, Th and W.

The soils contain considerable amounts of sub-rounded and polished ferruginous granules (similar to buckshot lag at surface). Analysis of 60 individual granules indicates a wide variation in Au contents from <40 ppb to 15 000 ppb (Lintern and Craig, 1996). Nearly half of the samples had Au concentrations of >100 ppb. The ferruginous granules from the two levels were similar in their Au contents. The pathfinder elements, Sb, As and W, did not vary as much, as Au but there is a moderately strong association between Au and W, with eight of the 15 most Au-rich (>200 ppb) granules having high (>15 ppm) W concentrations. No associations were observed between Au and Sb, or Au and As. Petrographic investigations of 12 individual ferruginous granules containing over 250 ppb Au show that many of the granules preserve primary lithic fabrics that have been pervasively ferruginized. Most of the granules contained visible gold; gold grains >10 µm in size are Ag poor, suggesting they are secondary.

Palaeochannel sediments

Ferruginous material separated from six samples of transported overburden from 6-20 m depth contain less than 20 ppb Au, much less than in surficial ferruginous material. The sample with the most Au (17 ppb) also has the highest Fe, Ba, Ce, Cr, Eu, La, Lu, Mn, Ni, Pb, Sb, Sc, Sm, Th, U and Yb; these elements are probably concentrated within Fe and/or Mn oxides rather than being specifically related to Au. Data from Gardiner (1993) for selected samples from the transported regolith indicate a S-rich unit (possibly sulphate) at about 15 m with high total Au (up to 85 ppb) relative to adjacent sediments (<20 ppb). The patchy distribution of this unit diminishes its suitability as a sample medium.

Vegetation

The Au contents of vegetation (eucalyptus leaves, bark, twigs, mull or bluebush) over mineralization are similar to background areas (Gardiner, 1993; Table 2). Mull, here, is decaying plant matter on the surface. Compared with Zuleika (Lintern, this volume), Au contents in bluebush and mull from Steinway are low (Lintern and Butt, 1992). In comparable depositional terrain at Zuleika, there is up to 7.9 ppb Au in bluebush and 5.8 ppb Au in mull. However, the maximum in eucalyptus leaves (0.8 ppb Au) is similar to that at Zuleika (0.6 ppb) and more than that at Panglo (0.1 ppb; Lintern and Scott, 1990).

Collectively, it would seem that eucalyptus leaves are unsuitable sampling media on thick transported overburden and, at Steinway, none of the organic sample media is suitable.

Groundwater

The Steinway groundwaters are saline (up to 2.5 times sea water) and acidic. They are enriched in Al and Si, the transition metals (Mn, Fe, Co and Ni,), the base metals (Cu, Pb and Zn), Y and the rare earth elements. Such enrichments occur where acidic groundwaters are in contact with mafic rocks (Gray, 1990); these acidic groundwaters are undersaturated with respect to the corresponding secondary minerals for the enriched elements, and may not have any direct exploration significance, aside from indicating mafic lithologies. Chalcophile elements that are enriched in neutral groundwaters in contact with weathering sulphides have very low concentrations in the Steinway groundwaters. Iodine, however, has a high concentration in these groundwaters, as is also observed in other mineralized sites in the Yilgarn Craton. In neutral groundwaters, the most likely mechanism for the dissolution of Au is as the thiosulphate complex, whereas in acid, saline groundwater, such as at Steinway, Au chloride is expected to be important. All but one of the Steinway groundwater samples are insufficiently oxidizing for significant Au dissolution as Au chloride. This one sample was anomalous in Au (0.8 ppb); the others were all Au poor (<0.03 ppb). However, groundwater Eh is very sensitive to a number of factors (such as Fe and Mn contents and the degree of equilibration with atmospheric oxygen), and could vary significantly over time. Under favourable conditions, therefore, dissolved Au concentration could be temporarily high anywhere within the Steinway mineralized area (Lintern and Gray, 1995).

Origin of soil anomaly above mineralization

These data and observations suggest that the ferruginous granules are the immediate source of Au in the soil, and that both the Au and the granules are derived by mechanical dispersion from up slope rather than being vertically derived from underlying buried mineralization. The relatively-soluble Au in the calcareous unit of the soil is probably derived from either (i) the ferruginous granules, which have weathered and released Au, or (ii) direct chemical dispersion from a similar up slope source as the ferruginous granules themselves.

Previous studies have shown that sampling of calcareous units from in situ regolith may accurately define drilling targets. However, in regolith dominated by thick palaeochannel sediments, such as that found at Steinway, there is probably no causal link between Au in calcrete and underlying mineralization. At best, sampling of soil, including calcareous material, may indicate the exploration potential of the (sub-)catchment. It is suggested that, for such landscape regimes, wider sampling intervals could be used, with a follow-up of deeper sampling of basal sediments and/or ferruginous saprolite. Table 1 contains the ranges for different sample media for the Steinway regolith. The data (apart from saprolite and bedrock) reflect weakly anomalous material typical of a depositional regime down slope from mineralization; they are unrelated to underlying mineralization.

REFERENCES

Gardiner, N., 1993. Regolith geology and geochemistry of the Steinway gold prospect, Kalgoorlie, Western Australia. University of Western Australia, unpublished thesis. 165 pp.

Gray, D.J., 1990. Hydrogeochemistry of the Panglo Gold Deposit. (CSIRO/AMIRA P241: Weathering Processes). CSIRO Division of Exploration Geoscience Restricted Report 125R. 74pp.

Lintern, M.J. and Butt, C.R.M., 1992. The distribution of gold and other elements in soils and vegetation at Zuleika, Western Australia. AMIRA P241A: Weathering Processes. CSIRO Division of Exploration Geoscience Restricted Report 328R. 90pp.

Lintern, M.J. and Craig, M.A., 1996 Further geochemical studies of the soil at the Steinway gold prospect, Kalgoorlie, Western Australia. CSIRO Division of Exploration and Mining Report 27R. 21 pp plus Appendices.

Lintern, M.J., and Gray, D.J., 1995. Progress statement for the Kalgoorlie Study Area - Steinway Prospect, Western Australia. CSIRO Division of Exploration and Mining Report 95R. 121 pp.

Lintern, M.J. and Scott, K.M., 1990. The distribution of gold and other elements in soils and vegetation at Panglo, Western Australia. AMIRA P241: Weathering Processes. CSIRO Division of Exploration Geoscience Restricted Report. 129R. 96 pp.

TABLE 1
DATA RANGES

	Au	Ag	As	Se	Sb	Bi	Cu	Pb	Ni	Zn	W
Eucalyptus leaves	<0.0005-0.008	-	-	-	-	-	-	-	-	-	-
Eucalyptus bark	<0.0005	-	-	-	-	-	-	-	-	-	-
Eucalyptus twigs	0.0005-0.0012	-	-	-	-	-	-	-	-	-	-
Mull	<0.0005-0.0044	-	-	-	-	-	-	-	-	-	-
Maireana sedifolia	0.0009-0.0018	-	-	-	-	-	-	-	-	-	-
Lag (>1 mm)	<0.005-0.107	<5	23-146	<5-38	<1-6	-	-	-	-	<100-244	2-32
Soil (0-2 m)	0.008-0.323	<5	15-46	<5	<1-2	<1-4	65-99	10-17	132-258	50-112	<2-14
Ground water	<0.000005-0.00083	<0.001-0.002	-	-	<0.001	<0.002	<0.005-0.399	<0.003-2.121	0.14-1.31	0.04-0.82	<0.001
Transported overburden	0.006-0.23	<1-3	27-57	-	0.9-1.9	<1-1	1-69	2-39	5-199	7-78	3-9
Saprolite	<0.0025-21.4	<5	39-123	<5-12	<0.2-5	<1	10-147	<1-56	60-348	21-211	<2-58
Bedrock	<0.005-0.374	<5	2-304	<5	0.1-0.8	<1-2	16-106	3-15	62-348	33-212	1-43

- Not analysed