GRANNY SMITH GOLD DEPOSITS, WESTERN AUSTRALIA

D.J. Gray, M.J. Lintern and C.R.M. Butt

CRCLEME c/o CSIRO Exploration & Mining, P.O. Box 1130, Bentley, WA 6102, Australia

LOCATION

The Granny Smith Gold Deposits, that include the Goanna, Granny and Windich ore bodies, are 25 km S of Laverton (Figures 1 and 2) at 28°49'S, 122°25'E: Laverton 1:250 000 map sheet SH51-02.

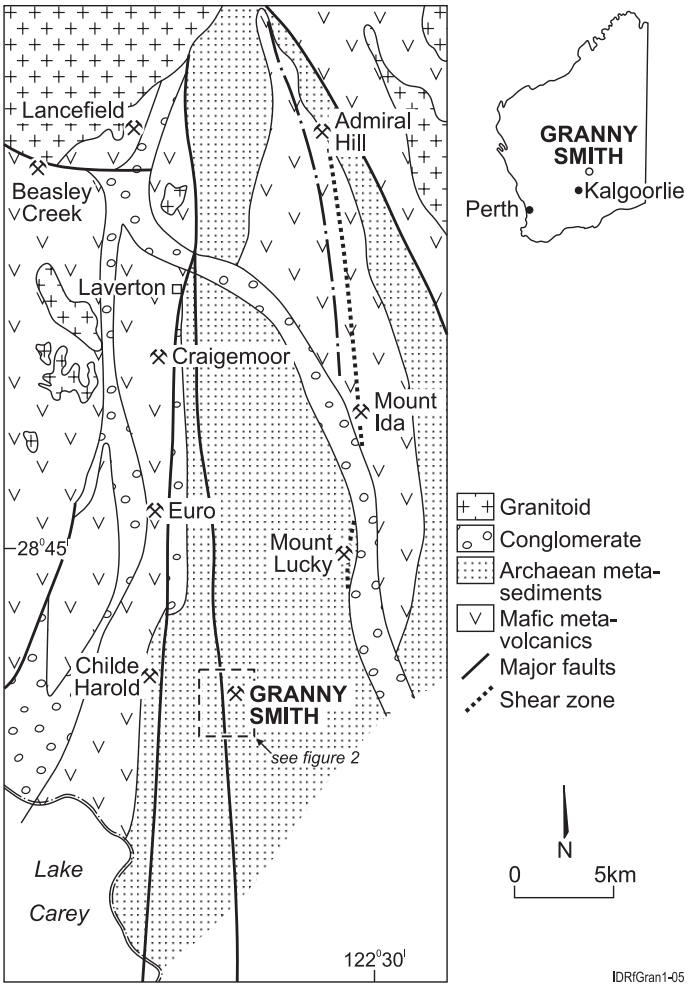

Figure 1. Regional geology and setting of the Granny Smith Gold Deposits (after Hallberg, 1983, and Hall and Holyland, 1990).

DISCOVERY HISTORY

The Goanna and Granny deposits were found by R.L. Smith, a prospector, in 1979 (Hall and Holyland, 1990). They outcrop and contain visible Au. Exploration by Teck Explorations Ltd., Canyon Resources Pty Ltd., and Delta Gold NL, showed that the Au mineralization was partly in a granodiorite and partly in Archaean metasediments (Figures 2 and 3). In 1984, CSR Ltd outlined four soil-Au anomalies (>30 ppb Au), of which two contained the Granny and Goanna mineralizations (up to 750 ppb). In late 1987 and early 1988, successive RC and RAB programmes delineated the Windich, Granny and Goanna ore zones.

PHYSICAL ENVIRONMENT

The surface is mostly flat, at about 410 m, with two BIF-dominated hills. The larger hill (465 m) lies to the W of the Granny deposit, and the smaller (430 m) to the S of Windich. Small, S-flowing ephemeral streams drain into the major Windich Creek to the S (Figure 2) ultimately entering Lake Carey, 10 km SW. The streams flow only after heavy rain, mainly during the summer. The groundwater is saline (about 5% TDS) at the Granny deposit, increasing in salinity with depth and towards Windich Creek, reaching about 20% TDS.

Vegetation is open woodland that becomes dense along creek lines, consisting mainly of mulga (*Acacia aneura*) with a sparse understorey of *Cassia*, *Eromophila* and *Maireana*. Vegetation is largely degraded, due to overgrazing, and the soils are poor in nutrients (N, Ca, K, P) and have high Na/K and Na/Ca ratios. This area lies N of the Menzies Line (Butt *et al.,* 1977). Mean annual minimum and maximum temperatures are 21-36ºC (January) and 5-18ºC (July). The mean annual rainfall is 230 mm, with more than half in January to June.

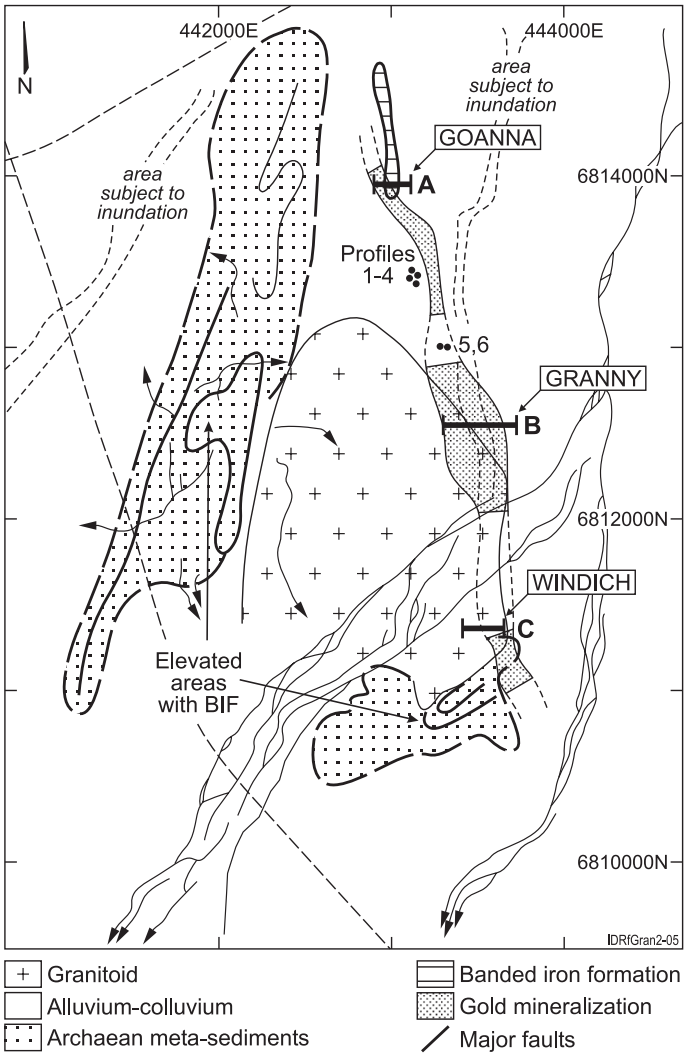

Figure 2. Local geology of the Goanna, Granny and Windich deposits, making up the Granny Smith Gold Deposits, after Hall and Holyland (1990), showing the locations of the sections in Figure 3 and profiles in Figure 4.

GEOLOGICAL SETTING

The Granny Smith deposits occur along a N-trending structural corridor (Figure 1). A granitoid intrusion outcrops W of Granny Smith; it underlies metasediments over much of the area and its eastern contact with the metasediments is the locus of the Granny mineralization (Figure 2). There are mafic metavolcanic rocks to the W and metasediments and felsic metavolcanic rocks to the E. The deposits occur, in the S at Windich, in granodiorite, in the centre within epiclastic sediments and, in the N, within epiclastic sediments and BIF (Hall and Holyland,1990).

Near the Windich mineralization, thick medium- to fine-grained, massive siltstone and shale are capped by BIF and subordinate tuff. To the N and E, close to the Granny mineralization, there is more than 100 m of quartz-rich greywacke, lithic wacke and minor shale and sandstone interbeds, with a basal conglomerate of clasts of shale, quartz, quartzite, BIF and feldspar-phyric volcanic rocks. At the Goanna ore deposit, the sequence is similar, although with more BIF in the hanging wall and no conglomerate (Figure 2).

REGOLITH

The upper portion of the regolith consists of three horizons: -

Topsoil and unconsolidated colluvium. This is gravely, unconsolidated, shallow, sandy and acidic. It varies from a few tens of mm to nearly a metre thick. The gravel is polymictic with coarse clasts, including BIF, ferruginous nodules and quartz.

Hardpan. The hardpan is a cemented unit consisting of red brown colluvium and residual clays up to 3 m thick, commonly grading downwards into brecciated saprolite. The colluvium is variable in composition, consisting of laminated and blocky units with a few friable segregations. In the upper portion, manganiferous coatings and nodules are common. Calcareous segregations occur towards the base.

Saprolite. The upper saprolite consists of subangular blocks of weathered bedrock in red-brown clays that are locally mottled ochre, red and orange. It is commonly calcareous to a depth of at least 9 m, with veins and segregations of calcite dispersed through the clay-rich matrix. The abundance of carbonate in the saprolite is unusual. There is little carbonate in the upper 2-3 m of the regolith, as is common S of the Menzies Line (Lintern *et al.*, 1997).

MINERALIZATION

The proved and probable reserve of the Granny Smith deposits was estimated in 1993 to be 12.22 Mt at 1.69 ppm Au (Gold Gazette, 8th Feb 1993). Although mineralization is continuous over at least 3500 m, it only reaches economic grades at the Goanna, Granny and Windich deposits (Figure 2).

(i) The Goanna Deposit is in a shear, trending NNW, dipping 50°E and striking for at least 1 km. The mineralization is 5-20 m thick and hosted by metasediments (including BIF). The depth of weathering is 70-80 m (Figure 3A).

(ii) The Granny Deposit is 1.5 km S of Goanna and forms a shallow, sub-horizontal blanket along the contact between granodiorite and overlying metasediments (Figure 3B). The contact is sheared and brecciated. The shear strikes for 600 m, is up to 500 m wide, 15-40 m thick and dips 25°E. The depth of weathering varies from 10-80 m. A high-grade zone occurs in the upper part of the mineralization.

(iii) The Windich Deposit is located 800 m S of Granny, and is buried beneath at least 5 m of colluvium-alluvium. The deposit is 400 m long, 150 m wide and 30 m thick, with a dip of 10°E. Mineralization is at or below the weathering front (15-45 m; Figure 3C).

REGOLITH EXPRESSION

Detailed regolith studies were conducted on five shallow profiles. Gold is significantly depleted from the upper 20 m of the regolith, but there is little evidence of widespread supergene enrichment (Hall and Holyland, 1990). It is most abundant in hardpan, and least abundant in unconsolidated topsoil (Figure 4).

Soil and hardpanized colluvium. Gold contents in soil range from 3-18 ppb (Figure 4). The higher abundances in profiles 5 and 6 may be due to inclusion of some hardpan in the sample, since the topsoil is very thin (commonly <500 mm) in both. The unusually high Au content in the topsoil of profile 3 (12 ppb) may be due to particulate Au shed from sub-cropping mineralization upslope, where visible Au was found originally. In general, the Au anomaly in topsoil is weak, considering that profile 6 was located only 20 m from sub-cropping mineralization.

The highest Au concentration in hardpan is in profile 6 (190 ppb at 1.25 m; Figure 4), which is close to sub-cropping mineralization. In profiles 3, 4 and 6, the Au maxima are close to the base of the hardpan, whereas in profiles 1 and 5, they are in the upper part of the hardpan. Hardpanization is a late overprint and the high Au contents may represent earlier enrichment at the interface between the residual and transported materials. Hardpanization probably contributes to preservation of the softer, transported parts of the regolith and, hence, preservation of the unconformity.

Gold in hardpan is partly hosted by lithorelics, but most is in the matrix.

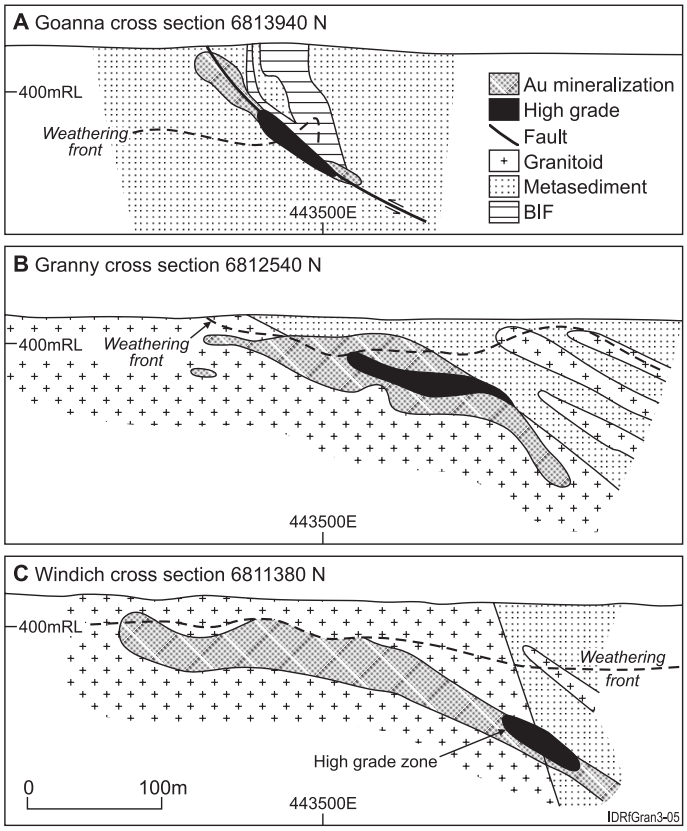

Figure 3. Sections through the Goanna (A), Granny (B) and Windich (C) Au deposits from data supplied by Placer Exploration Ltd. See Figure 2 for locations of the sections.

There does not appear to be any general mineralogical, geochemical or textural associations of Au with other components within the profiles studied. Laboratory experiments on soils from Granny Smith indicate that only a minor part of the Au is associated with Mn oxides, organic material and soluble Si. Most of the Au can be leached with weak extractants such as iodide (Gray *et al*., 1998). Gold is generally soluble in pulverised soil, but it is less mobile in the hardpan, due to encapsulation by the cement.

The Au-Ca association, highly significant S of the Menzies Line, occurs weakly, if at all, at Granny Smith and, therefore, the carbonates should not be sought specifically as an exploration sample medium. Pedogenic carbonates are, in general, uncommon N of the Menzies Line. Carbonates at Granny Smith are probably a type of groundwater calcrete, having a different origin and properties.

Sampling of hardpan at the interface between transported and residual components could be used for Au exploration, though care should be taken in extrapolating to other sites that have hardpan, since only five profiles were sampled at Granny Smith. Identification of this material in drill cuttings is difficult.

Saprolite. The interface between saprolite and colluvium is indistinct. The saprolite becomes brecciated by hardpanization and is composed of sub-angular clasts (lithorelics) supported by a siliceous hardpan matrix; the greatest Au contents of the saprolite occur closest to the contact with the colluvium and may be due to interface enrichment. The greatest Au content of the saprolite occurs in profile 1 (80 ppb at 3.75 m). Most Ca (and calcite) occurs at the top of, or within, the saprolite, dispersed throughout the clay-rich matrix and as veins and concretions. However, although Au occurs in some carbonate segregations, there is no obvious relationship between the distributions of Au and Ca, unlike S of the Menzies line (Lintern *et al*., 1997), suggesting that calcrete is not a good exploration sampling medium at Granny Smith.

In addition to Au, the most significant pathfinder elements are W, Mo and, possibly, Sb. The concentrations of Cu, Pb, Zn and As are moderate to low and unlikely to be diagnostic. Copper and Zn have been detected as sulphides, whereas As appears to be strongly related to the Fe content. The Ba content is variable and, although it may be associated with mineralization, high Ba concentrations in felsic rocks,

such as granodiorite, reduce its potential as a pathfinder.

Although As, W, Mo and, perhaps, Sb are associated with the primary mineralization, only As is retained at presently detectable concentrations in the upper regolith. In the top soil, As concentrations are variable and are likely to be contained within Fe segregations. Hardpan tends to be generally poor in As, although small maxima occur in places near the base (profiles 1, 5 and 6). Arsenic concentrations tend to increase with depth in the saprolite and are greatest (142 ppm) close to mineralization. Arsenic tends to be associated with lithorelics.

Barium, Cu and Zn are weakly enriched in bedrock and are retained in the upper saprolite. The generally low abundances of Bi, Cd, In, Pb, Se and Ag in primary mineralization eliminate them as potential pathfinders.

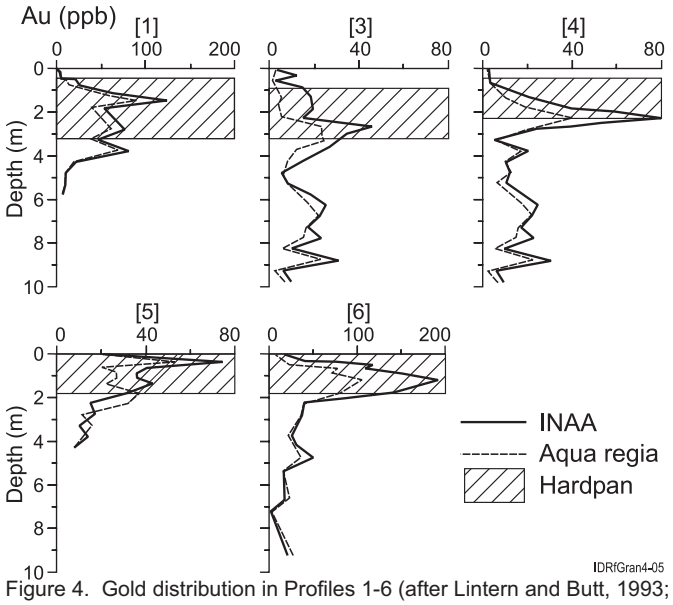

Figure 4. Gold distribution in Profiles 1-6 (after Lintern and Butt, 1993; see Figure 2 for locations of the profiles).

HYDROGEOCHEMISTRY

Groundwaters at Granny Smith are generally neutral, with variable salinity, and highly stratified (Gray, 1993). Samples obtained from bores used to dewater the mining area indicate a deep saline system, whereas samples obtained by bailing untapped drilling provide more shallow, fresher groundwater. Thus, at Windich, mineralization occurs at depth, and water samples obtained by bailer have very low dissolved Au (≤0.01 µg/L).

In contrast, at the Goanna and Granny pits, water samples were obtained from dewatering bores, and presumably are in contact with Au mineralization. The greatest Au concentrations (Gray, 1993) occur in pumped samples from the southern part of Granny (0.07–0.09 µg/L), with the sample from the central part of Goanna also having a moderate Au concentration (0.04 µg/L). These deep water samples in areas of high Au grade are enriched in Au (relative to Windich), As, Co, Mn, Mo, Ni, Pb, Sb, Tl and Zn, apparently reflecting the geochemistry of the Au mineralization. This multi-element association may offer scope for exploration in similar environments and regions. The regional effect is critical: dissolved concentrations of many elements at Granny Smith are low, relative to groundwaters in the Kalgoorlie region, which, for example, have up to 4 µg/L Au and an anomaly threshold of 0.05 µg/L (Gray, 1993; Gray, 2001).

Some soluble and readily dispersed elements associated with mineralization have potential as regional groundwater pathfinders. For example, As, enriched in the mineralized area, could be a regional groundwater pathfinder, but regional sampling would be required to demonstrate this.

In summary, groundwater Au concentrations at this site are generally low, relative to sites further S. There is a particularly poor Au in groundwater response to mineralization at Windich, compared to Goanna and Granny. In a regional Au groundwater survey, this area might well be discounted but there may be scope for a multi-element approach.

ACKNOWLEDGEMENTS

G.C. Hall, S.J. Hunt, P. Silversmith and D. Lord of Placer Exploration Ltd are thanked for assistance and discussions. R. Bilz, J. Crabb, G.D. Longman, M.K.W. Hart, A. Howe, M. Willing and E.H. Nickel of CSIRO contributed to the project. Additional analyses were by R.J. Watling and D. Delev of the Chemistry Centre WA and carbons were analysed by Becquerel Laboratories.

REFERENCES

Butt, C.R.M., Horwitz, R.C. & Mann, A.W., 1977. Uranium occurrences in calcrete and associated sediments in Western Australia. Report FP16, CSIRO Australia, Division of Mineralogy, Floreat Park, 67 pp (Unpublished).

Gray, D.J., 1993. Investigation of the Hydrogeochemical Dispersion of Gold and other Elements from Mineralized Zones at the Granny Smith Gold Deposit, Western Australia. CSIRO Division of Exploration Geoscience Restricted Report 383R. Vols I and II. 93pp (Reissued as Open File Report 93, CRC LEME, Perth, 2001).

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

Gray, D.J., Lintern, M.J. and Longman, G.D., 1998. Readsorption of gold during selective extraction - observations and potential solutions. Journal of Geochemical Exploration, 61: 21-37.

Hall, G.C. and Holyland, P.W., 1990. Granny Smith Gold Deposit. In F.E. Hughes (Editor) Geology of the Mineral Deposits of Australia and Papua New Guinea. Australasian Institute of Mining and Metallurgy, Melbourne pp 519-524.

Hallberg, J.A., 1983. Geology and mineral deposits of the Leonora-Laverton area, northeastern Yilgarn Block, Western Australia. A report and series of 1:50000 scale geological maps. Geological Survey of Western Australia Record 1983/8.

Lintern, M.J. and Butt, C.R.M., 1993. The distribution of gold and other elements in soils at the Granny Smith gold deposit, Western Australia. CSIRO Division of Exploration Geoscience Restricted Report 385R. 73pp (Reissued as Open File Report 53, CRC LEME, Perth, 2001).

Lintern, M.J., Butt, C.R.M., and Scott, K.M., 1997. Gold in vegetation and soil - three case studies from the goldfields of southern Western Australia. Journal of Geochemical Exploration, 58: 1-14.

SAMPLE MEDIA - SUMMARY TABLE

Sample medium	Indicator elements	Analytical methods	Detection limits (ppm)	Background (ppm)	Threshold (ppm)	Max anomaly (ppm)
Fresh bedrock	Au	FA	0.005	-	-	16
	As	XRF	1	-	-	244
	W	XRF	1	-	-	129
	Mo	XRF	0.5	-	-	69
Saprolite	Au	INAA	0.005	-	-	0.08
	As	XRF	1	-	-	140
	W	XRF	1	-	-	4
	Mo	XRF	0.5	-	-	4
Soil and hardpanized colluvium	Au	GF-AAS	0.005	<0.005	0.01	0.09
	As	XRF	1	15	25	27
	W	XRF	1	<1	2	5
	Mo	XRF	0.5	1	3	5
Groundwater	Au	INAA*	0.005	0.01	0.02	0.09
	As	ICP-MS	0.01	0.02	0.06	0.16
	W	ICP-MS	0.001	0.001	-	-
	Mo	ICP-MS	0.002	0.02	0.05	0.093

GF-AAS Graphite furnace AAS after aqua regia digest. FA Fire assay.

* After pre-concentration on activated carbon.