ORA BANDA SILL PLATINUM PROSPECT

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LOCATION

The Ora Banda sill is centred about 55 km NNW of Kalgoorlie; this prospect is 1 km S of the Ora Banda town site, at 30º24'00"S, 121º03'30"E; Kalgoorlie map sheet SH 51-9 (Figure 1).

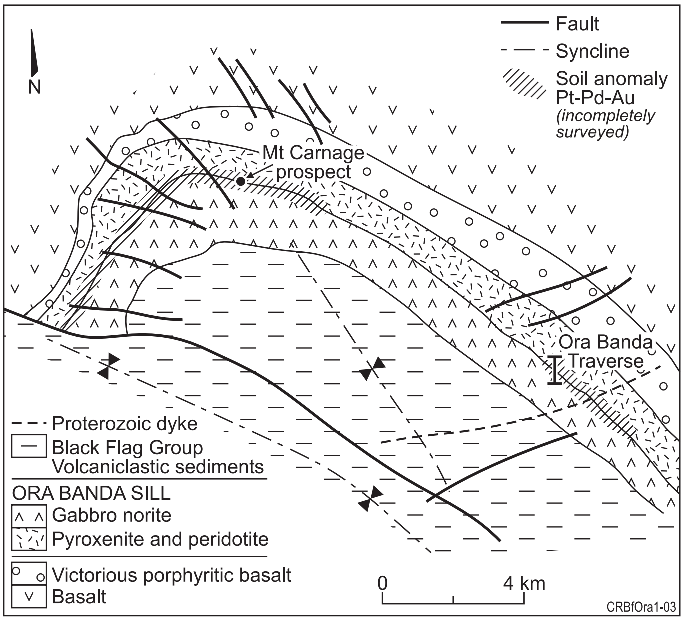

Figure 1. Regional geological setting of the Ora Banda Sill, showing locations of the Mt. Carnage and Ora Banda PGE prospects (after Menzies, 1988a).

DISCOVERY HISTORY

Much of the sill was explored by Carbine Gold N.L. during 1987-1990 at their Ora Banda and Mt. Carnage prospects, S and W of Ora Banda, respectively (Figure 1). Initial exploration was by soil surveys for Au, Pt and Pd, followed by rotary air-blast (RAB) drilling (Menzies, 1988a, 1988b). Overlapping angle holes (inclination 50-65°) were drilled to a downhole depth of 40 m on selected lines across strike. At Ora Banda, the principal drill section was on line 12500E (Figure 2), which intersects the strike of the inferred pyroxenite-peridotite contact at approximately 40°. This drilling confirmed concentrations of up to 2 ppm PGE in lateritic duricrust developed on pyroxenites, with some localized concentrations deeper in the regolith, but none in economic tonnages. Similar results were obtained by BHP Exploration on adjacent areas of the sill. Carbine Gold N.L. tested possible primary mineralization with two diamond drill holes, oriented approximately normal to the strike, drilled to intersect the pyroxenite-peridotite contact beneath 12500E. The drilling found general PGE enrichment in the pyroxenite, but no economic concentration. Much of this account is derived from detailed study undertaken as part of CSIRO-AMIRA project 252 (Butt *et al.,* 1992).

PHYSICAL ENVIRONMENT

The geomorphology of the Ora Banda site is controlled by the lithology of the sill. To the S, a prominent hill of unweathered norite rises above the duricrust-capped surface on the pyroxenites. There is an eroded zone along the pyroxenite-norite contact; in places, the contact forms a dip slope capped by an erosion scarp (breakaway). There is an undulating, locally dissected, lateritic surface on the pyroxenite, with a gentle slope across the peridotite to broad-floored drainages N of the site. The peridotite thus underlies slightly lower, less dissected ground. The area has a low acacia woodland, with scattered eucalypts; casuarinas are common on exposed duricrusts. The climate is semi-arid, with a mean annual rainfall of 250 mm and mean maximum and minimum temperatures of 35 to 20ºC (January) and 17 to 5ºC (July).

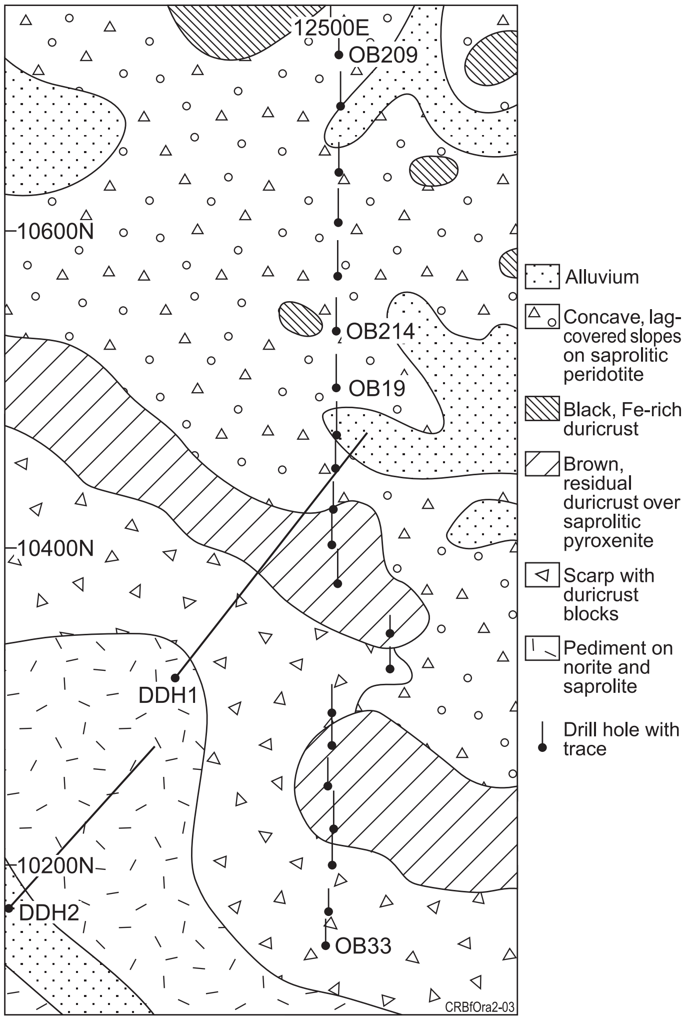

Figure 2. Regolith geology of part of the Ora Banda PGE prospect, indicating sites of lag sampling and drilling.

GEOLOGICAL SETTING

The Ora Banda sill is a 2 km thick high-Mg, mafic-utramafic intrusive body emplaced near the contact between tholeiitic volcanic rocks and the felsic to intermediate volcaniclastic rocks of the Black Flag Group (Witt and Barnes, 1991). The sill has six principal lithological units (Table 1); it is well exposed in its upper part, but the weathered basal peridotite and overlying pyroxenite rarely outcrop and are known principally from the two diamond drill cores. Low angle faults of small displacement have resulted in local repetitions of the peridotite-pyroxenite contact.

REGOLITH

Peridotitic and pyroxenitic rocks are generally weathered to 40-60 m depth. In contrast, the norite tends to be unweathered in outcrop. Essentially complete lateritic profiles are extensively preserved over

Table 1. Principal lithological units (after Witt and Barnes, 1991)

Zone	Thickness (m)	Lithology
Top		
6.	50-100	Pegmatoid gabbro, granophyre.
5.	540	Pigeonite-bearing gabbro-norite cumulate.
4.	315	Bronzite-bearing gabbro-norite cumulate. Some mm-scale layering; local lenses of anorthosite.
3.	90	Norite; massive equigranular plagioclase orthopyroxene adcumulate, grain size 1-2 mm.
2.	165	Orthopyroxenite; massive equigranular bronzitite adcumulate, grain size 1-2 mm.
1.	830	Peridotite. Olivine bronzite orthocumulate.
Base		

the pyroxenite, which is therefore characterized by tracts of lateritic duricrusts and derived soils. Duricrust is rare or absent over the peridotite, and soils are derived from saprolite. Massive, blocky duricrusts developed locally on the peridotite appear to lie directly on saprolite, and may be partly transported in origin. The top 1 to 4 m of the regolith contain pedogenic carbonate. Much of the lag is residual and shows excellent preservation of primary fabrics (Robertson, 1996). Typical profiles are:

Pyroxenite

Lag: coarse, brown, clay-rich granules, with dull, cellular surface, derived from duricrust.

0-2 m: Gravelly, calcarous soils; numerous lateritic nodules and pisoliths.

2-7 m: Massive, nodular and pisolitic duricrust, cemented near the surface; friable with depth.

7-13 m: Mottled clay zone; nodules and pisoliths in a ferruginous clay-rich matrix.

13-16 m: Clay saprolite, commonly ferruginous with some nodules; some green clays.

>16 m: Saprolite; yellow green, soft and clay-rich near the top, harder with depth.

Peridotite

Lag: dense, dark brown to black, ferruginous granules with a vitreous surface; some moss agate.

0-2 m: Calcareous, clay-rich red earths.

2-5 m: Non-calcareous red earths.

5-11 m: Clay saprolite; red clays becoming brown and green with depth.

>11 m: Clay saprolite; brown, khaki and yellow green saprolite; abundant silica and/or magnesite.

MINERALIZATION

Fresh pyroxenite has a broad zone of sulphide, PGE and associated Cu enrichment (as chalcopyrite), with mean concentrations of 130 ppb Pt (maximum 300 ppb), 80 ppb Pd (maximum 215 ppb) and 215 ppm Cu (maximum 3940 ppm) The distribution is rather uniform, with a possible antipathetic relationship between PGE and Cu contents indicating successive cycles of PGE-enriched sulphides. The base of the pyroxenite appears to correspond to the onset of sulphide saturation and the appearance of cumulate sulphides (Witt and Barnes, 1991). Peridotite has mean concentrations of 40 ppb Pt (maximum 235 ppb), 55 ppb Pd (420 ppb) and 30 ppm Cu (180 ppm). A peak value of 980 ppb Pd was not reproduced on re-analysis.

An apparently continuous PGE-enriched "stratigraphic unit" was intersected in saprolite, close to the top of the peridotite (Table 2). This unit has maxima of 3000 ppb Pt + Pd, 52 ppb Ru, 114 ppb Rh, 6 ppb Os, 20 ppb Ir over intervals of 1 to 3 m in three RAB holes. The high abundances of all PGE suggests that this represents a primary mineralized layer but, due to faulting or lack of continuity, the unit was not intersected by the diamond drilling.

REGOLITH EXPRESSION

The overall abundances of PGE and Cu in the regolith reflect the primary distribution, i.e., weathered pyroxenite is PGE- and Cu-rich compared to equivalent units in weathered peridotite. Distributions in the regolith are illustrated in Figure 3. High concentrations of PGE at Ora Banda occur particularly in lateritic residuum over the pyroxenites; this contains 300-400 ppb Pt and 110-190 ppb Pd i.e., 2 to 3 times that in fresh rock. At Mt. Carnage, PGE concentrations are greater, mostly 1000-1950 ppb Pt+Pd over thicknesses of 2-8 m, representing an enrichment of 4 to 7 times (wt/wt). The data also suggest that some enriched zones transgress regolith horizons; such zones dip gently S, sub-parallel to the presumed dip, and may therefore represent primary layering. There has been some apparent fractionation of Pt and Pd during weathering, with gradual depletion of Pd towards the surface. Thus, over the pyroxenites, the Pt/Pt+Pd ratio increases from a mean of 60-65% in the unweathered rock and saprolite to 70-75% in the lateritic horizons; the ratio increases to 90% in lag. There are no lateritic horizons preserved over the peridotites, but the data suggest

Table 2

PGM concentrations of enriched zones from RAB holes OB 19, 20 and 21, and possible source intervals in DDH1.

Hole/sample no.	Depth (m)	Lithology	Pt (ppb)	Pd (ppb)	Pt % (Pt+Pd)	Ru (ppb)	Rh (ppb)	Os (ppb)	Ir (ppb)
Detection Limit			2	2		2	1	2	2
OB 19	0- 4	Peridotite	260	475	35	21	11	2	4
OB 20	17-18	Peridotite	820	440	65	34	49	2	10
OB 21	26-27	Peridotite	1800	1200	60	52	114	6	20
DDH 1 00-5447	106.2-106.5	Pyroxenite	420	360	54	8	15	6	4
DDH 1 00-5448	106.5-106.7	Peridotite	170	118	59	6	11	4	2

Fire Assay NiS collection

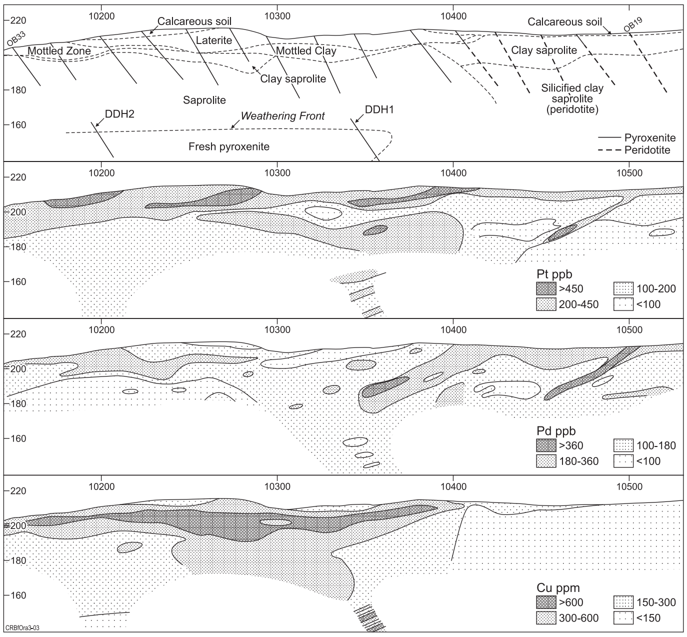

Figure 3. Drill section 12500E, Ora Banda, indicating regolith and bedrock geology, and distributions of Pt, Pd and Cu. Tracks of diamond drill holes show where they pass through the section (compare Figure 2).

Table 3

PGEs in complete laterite profile on pyroxenite (OB 27)

Depth (m)	Horizon	Pt (ppb)	Pd (ppb)	Pt % (Pt+Pd)	Ru (ppb)	Rh (ppb)	Os (ppb)	Ir (ppb)
Detection		2	2	-	2	1	2	2
1	Calcareous laterite	285	80	78	6	14	2	2
3	Laterite	440	124	78	8	26	4	4
5	Mottled clay	310	82	79	8	16	4	4
9	Mottled clay	170	52	77	8	17	4	6
14	Saprolite	145	64	69	4	7	2	2
20	Saprolite	215	82	72	4	10	2	2
25	Saprolite	300	98	75	4	10	<2	2
30	Saprolite	145	84	63	6	9	4	2
35	Saprolite	116	70	62	4	8	2	2
40	Saprolite	150	90	62	4	10	2	2

Analysis: Fire assay, NiS collection

that there may be some surface enrichment associated with calcareous soil and saprolite, perhaps equivalent to that known for Au in this region. However, selective leaching analyses have not confirmed such an association and the enrichment may be due to the residual accumulation of ferruginous lag.

The Cu content in the regolith developed on the peridotite is commonly <30 ppm. In comparison, all regolith units on pyroxenites have Cu contents >200 ppm and concentrations increase upwards through the saprock (mean 205 ppm) and saprolite (mean 315 ppm), to maxima of 700-1095 ppm in the saprolitic and mottled clays and the lower (nodular) horizon of the lateritic residuum. These high Cu concentrations form an approximately sub-horizontal zone of enrichment and are attributed to secondary accumulation with Fe oxides. The Cu distribution is accordingly similar to that of Fe, with which it is associated. Higher in the profile, in the upper lateritic horizons, the Cu and Fe contents decline (<600 ppm Cu); this corresponds to concentration of Al (20-28% Al_2O_3), as gibbsite and in aluminous goethite and hematite, during the further evolution of the lateritic duricrust and, ultimately, formation of the present soil. Copper is probably leached, rather than diluted, during the process of Al accumulation, and may contribute to the Cu enrichment of underlying regolith units. Equivalents of the narrow intervals in fresh pyroxenite having >3000 ppm Cu are not recognized in the regolith.

Ruthenium, Rh, Os, Ir also show upward increases in concentration through the regolith on pyroxenite, although abundances of Os and Ir are very low (Table 3). The highest contents are in the ferruginous horizons (mottled clay zone and lateritic residuum) and are probably due to residual accumulation as immobile elements. The enrichment is of the same order as that of Cu, Cr and Zr.

No separate, PGE-enriched, minerals were identified, despite detailed physical and chemical investigation (Gray *et al.,* 1996). Most PGE are in the <2 µm fraction, mainly in Fe oxides; Pt is hosted by hematite and some Pd by Al-rich goethite. This separation may reflect differences in primary host minerals, with Pt in an easily weathered phase, leading to early release and incorporation in hematite, and Pd in a more stable phase, to be incorporated in later formed minerals such as Al-goethite.

In lag, the Pt and Pd contents clearly reflect those of the parent pyroxenite and peridotite, and the regolith developed from them (Figure 4).

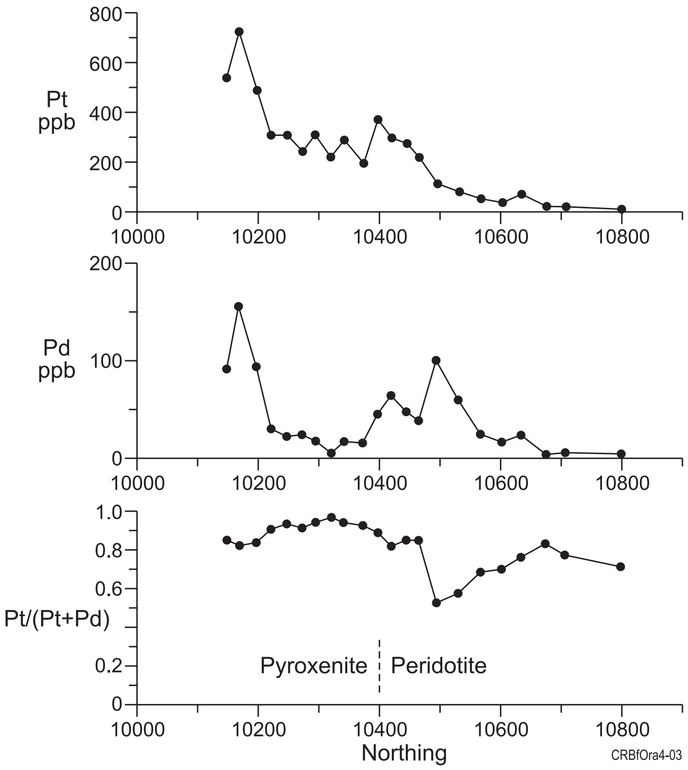

Figure 4. Platinum and palladium concentrations in lag, section 12500E, Ora Banda.

SAMPLE MEDIA - SUMMARY TABLE

Mean concentrations of selected elements in the regolith on peridotite and pyroxenite (from Butt *et al*., 1992).

Horizon	n*	Pt (ppb)	Pd (ppb)	Pt % (Pt+Pd)	Cu (ppm)	Ni (ppm	Cr (ppm)	Fe (%)	Al_2O_3 (%)	MgO (%)
Peridotite										
Ferruginous lag	18 (18)	53	11	78	50	745	32680	47.7	6.2	0.3
Calcareous soil	12 (2)	345	530	40	45	1420	6950	16.6	4.7	6.5
Clay saprolite	31 (44)	175	220	44	39	2175	4900	14.6	3.0	7.6
Silicified clay saprolite	22 (23)	200	165	36	24	1955	4310	12.4	3.0	9.9
Silicified saprolite	17 (52)	105	120	42	27	1840	4445	11.8	2.2	10.7
Saprolite	13 (47)	90	130	42	26	1760	4815	12.1	2.3	12.2
Fresh peridotite	8 (198)	42	55	45	33	1170	4570	12.2	1.8	32.4
Pyroxenite										
Ferruginous lag	26 (26)	400	50	90	485	745	12270	37.5	18.7	0.3
Calcareous laterite	7 (9)	315	110	74	300	405	5100	15.4	18.3	3.6
Laterite	13 (21)	360	120	75	495	535	7560	24.1	22.5	2.1
Nodular laterite	12 (24)	435	180	71	670	500	8380	28.8	19.8	0.85
Mottled clay	13 (34)	265	135	64	675	655	9085	24.6	18.7	2.0
Clay saprolite	13 (28)	265	170	60	660	1740	7110	17.8	8.4	4.8
Saprolite	62 (184)	215	145	62	325	1085	4520	10.3	4.1	15.7
Saprock	8 (72)	165	110	63	145	785	4342	9.9	2.5	27.34
Fresh pyroxenite	12 (160)	130	80	63	610#	1110	2965	11.1	3.3	26.55

Pt and Pd analyses by fire assay fusion, ICP MS. Detection limits 2 ppb

Al_2O_3 and MgO analyses by Li borate fusion and ICP-ES. Detection limits: 0.01%

Cu, Cr, Ni, Fe analyses by XRF pressed powders. Detection limits: Cu, Cr, Ni 10 ppm; Fe 0.01%.

* Numbers in parentheses refer to Pt and Pd analysis.

Data from Cu-rich section of core. Mixed acid ($HClO_4$-HF-HNO_3) analysis of 160 samples gives mean 215 ppm Cu.

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