

Platinum Group Elements and their host rocks in Tasmania: A summary review

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INTRODUCTION

There are four factors in favour of exploring for Platinum Group Elements (PGE's) in Tasmania:

- PGE's occur in the State, and the areas of occurrence are known;
- Access to land for exploration is dominantly free of restriction;
- Industrial demands are expanding as new products are found in which PGE's are used;
- With changing political and economic situations in South Africa and Russia, traditional supplies are no longer certain.

At present, Platinum Group Elements are currently being used in the petrochemical and automobile industries, in electronics and communications, for medical and dental purposes, in the space industry, in fuel cells, as well as for jewellery and investment bars and coins.

In occurrence and association PGE's can be divided into two groups: IPGE, being iridium (Ir), osmium (Os) and ruthenium (Ru); and PPGE, being platinum (Pt), palladium (Pd) and rhodium (Rh). Gold can be associated with both of these groups.

Platinum Group Minerals (PGM's) mined in Tasmania in the past were commonly known as 'osmiridium', an alloy of Os and Ir with minor amounts of other platinoids, especially Ru. However, when detailed analyses were obtained it was found that a compositional range existed, and the alloys ranged from being dominantly iridosmine to rutheniridosmine with only minor true osmiridium (Ford, 1981; Cabri and Harris, 1975).

Recent work has shown the Tasmanian ultramafic host rocks contain not only Ir-Os-Ru alloys but also Ru-(Ir-Os) sulphide and platinum, as native Pt, as alloys with other PGE's, or in complexes as sulphide minerals (Brown *et al.*, 1988; Creasy, 1990; Peck, 1990; Peck and Keays, 1990; Peck *et al.*, 1992).

In the late 19th century PGM's were obtained as a by-product of gold mining from alluvial and eluvial deposits associated with the ultramafic-mafic complexes. Until c.1900, when a market for osmium and iridium developed, the grains were considered a nuisance and were discarded.

Between 1910 and the end of 1980 approximately 965 kg of 'osmiridium' was recorded as being mined from western Tasmania. Alluvial mining between 1910 and 1925 on the Heazlewood-Mt Stewart-Wilson River complexes (no. 3-5, fig. 1) accounted for ~420 kg of this total. In 1925 the Adamsfield deposits (no. 14, fig. 1) were discovered.

Between 1925 and 1939 ~490 kg of 'osmiridium', including ~430 kg from Adamsfield, were registered. The remaining 55 kg were registered between 1940 and 1980.

The 'osmiridium' alloys were mined from placer deposits spatially associated with olivine-rich ultramafic rocks. Over the last few years, studies of the various areas of ultramafic rocks in Tasmania have shown that there exists a potential for 'hard rock' sources of IPGE's, associated with these high magnesian, olivine-rich ultramafic rocks, as well as a potential for deposits of PPGE's, associated with zones of chromite schlieren in pyroxene-rich ultramafic rocks (Brown *et al.*, 1988; Carthew, 1989a, b; Peck, 1990; Peck and Keays, 1990).

During the late 1940s, exploration for copper-nickel mineralisation in the Cuni area (2 km southwest of Serpentine Hill — no. 7, fig. 1) revealed platinum and palladium in a medium to fine-grained association of magnetite, pyrite, pyrrhotite, pentlandite and chalcopyrite associated with gabbroic rocks.

Relevant land use and access issues, based on the Department of Mines *Mineral Exploration Code of Practice* (Bacon, 1991) are discussed in an appendix to this paper.

KNOWN OCCURRENCE OF PGE'S AND ASSOCIATED MINERALISATION IN TASMANIA

Of the fifteen separate areas of ultramafic rocks which occur in Tasmania, PGE's have been obtained from six. Four areas have produced significant amounts of alloy, with the other two areas producing lesser volumes. A seventh area contained PGE's in alluvial deposits derived from now eroded ultramafic rocks.

The four main areas are:

- the Heazlewood River Complex (no. 3, fig. 1) — also known as 'Nineteen Mile Creek', which includes Fenton's Prospect and the Caudry's workings;
- the Mt Stewart Complex (no. 4, fig. 1) — also known as Laughin's Creek or Ramsay's Prospect;
- the Wilson River Complex (no. 5, fig. 1) — in the north, the Harman River area and in the middle the Wilson River area, and Barnes and Riley Creeks;
- the Adamsfield area (no. 14, fig. 1). Early reports on 'osmiridium' in the Adamsfield area can be found in Nye (1929).

The two areas with smaller output were Boyes River (no. 13, fig. 1) and Rocky Boat Harbour (no. 15, fig. 1) areas. These

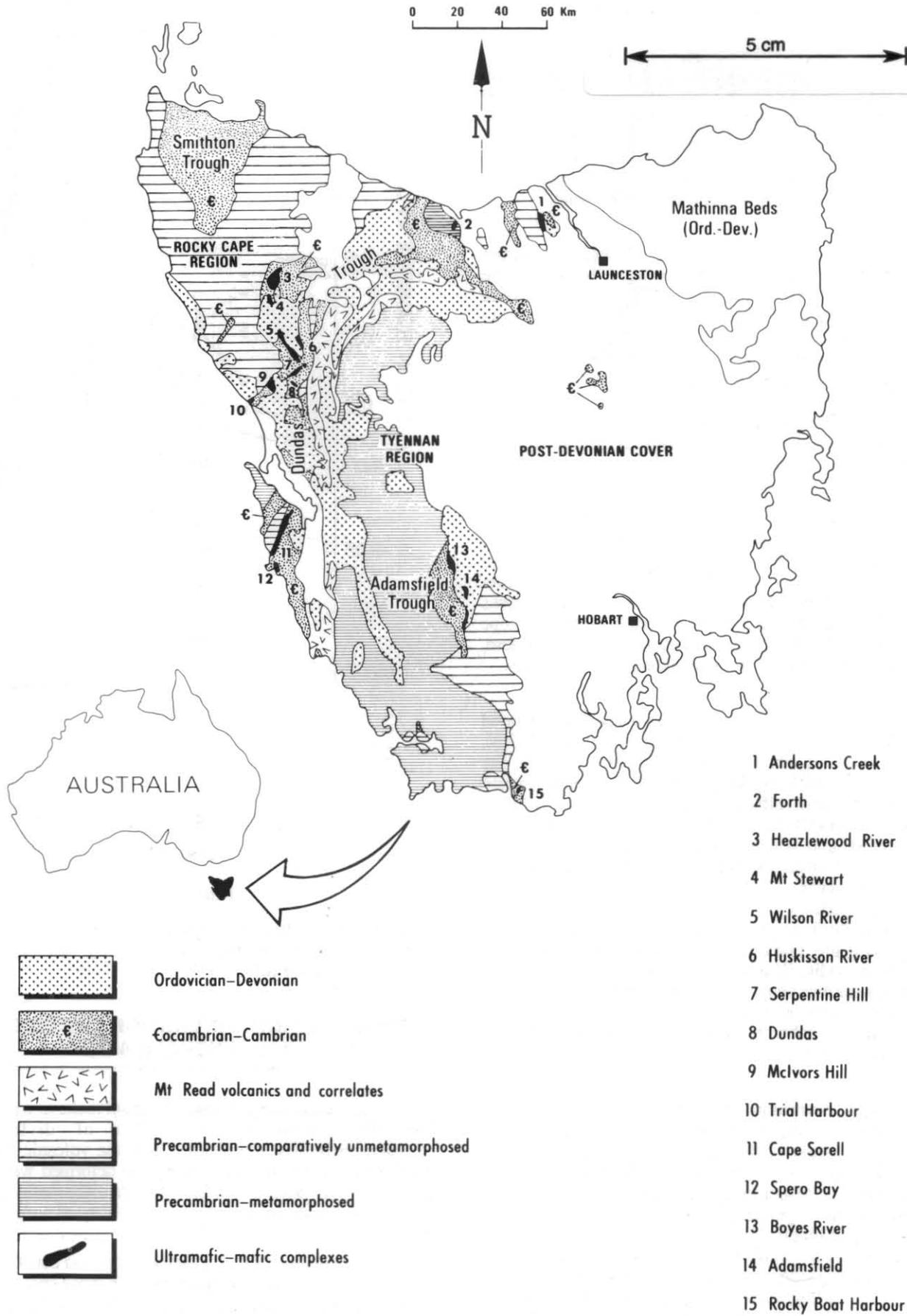


Figure 1

Schematic geological map of Tasmania showing locations of ultramafic-mafic complexes. Rock distribution after 1:500 000 Geological Map of Tasmania (1976).

two bodies are now in the World Heritage Area and are, at present, unavailable for exploration.

The seventh area, containing Keygan and Betts Creeks, is on top of the Meredith Granite (Jack and Groves, 1964). The alluvial deposits were derived from remnants of ultramafic rocks left after granitic emplacement. Prior to emplacement, the ultramafic rocks would have formed a continuous belt from the Heazlewood River area in the north, through the Mt Stewart area, to the Wilson River area in the south.

As well as the areas with historical production, two further areas; the Huskisson River Complex (no. 6, fig. 1), and the Trial Harbour ultramafic body (no. 10, fig. 1); are composed of the same primary ultramafic rock type as the bodies from which 'osmiridium' was produced. A recently completed exploration program over the Huskisson River Ultramafic Complex obtained between 20 and 190 ppb Pt for soil samples from eluvial deposits, as well as grains with varying proportions of Os and Ir \pm Rh, and grains of Pt, as Pt-Fe, Pt-Rh-Fe-Ni and Pt intergrown with Os and Ir (Creasy, 1990).

An average pattern for whole rock PGE contents from the Tasmanian ultramafic rocks was calculated from 42 rock samples analyses for Brown *et al.* (1988). When this average pattern was plotted on a chondrite-normalised PGE diagram (fig. 2), and compared with other areas of ultramafic rocks with known PGE production, the pattern has a similar slope to samples from ophiolite bodies, but, in comparison to these, the Tasmanian 'sample' has anomalously high Pt values.

Outside ultramafic complexes, Pt and Pd have been reported with Cu-Ni sulphide ore in the Cuni copper-nickel field, which is just to the west of Serpentine Hill (no. 7, fig. 1). The ore is a magnetite-pyrite-pyrrhotite-pentlandite solid solution. The first reference from this area was by Reid (1921), who recorded 0.1–0.16 ounces per ton platinum in a Cu-Ni ore sample, which also contained trace gold and ~1.4 ounces per ton silver. A sample of ore from a second mine in the field assayed ~3 g/t platinoïd metals, with Pt and Pd being determined as being in approximately equal proportions (Stillwell, 1946). A third sample from a nearby pit also contains platinum, partly as native platinum and partly as sperrylite (Hughes, 1965). Data obtained from the old mine workings and later drilling indicates that the ore of the Cuni copper-nickel field is contained within, or associated with, gabbroic dykes or sills (Taylor and Burger, 1952; Robinson, 1958).

In the nearby Serpentine Hill Ultramafic Complex, small, cobalt-bearing pentlandite-millerite grains pervade the serpentinitic matrix of the dominantly orthopyroxene-rich ultramafic rocks. Olivine-rich zones within this sequence, consisting of plagioclase-bearing dunite and peridotite, contain chromite grains with laurite [Ru(Os,Ir)S₂] and Os-Ir-Ru alloy grains. Values for Pt (~10–70 ppb) and Pd (~1–10 ppb) from whole-rock samples from the different ultramafic and gabbroic rocks were obtained from this area (Brown *et al.*, 1988; Brown, 1991). The highest values of Pd were obtained from the late-stage gabbroic samples. Values for Pt (17.5 ppb) and Pd (21.5 ppb) were also obtained from whole-rock samples of the associated low-Ti tholeiitic basalt.

Average values of PGE's obtained in the above studies are listed in Table 1.

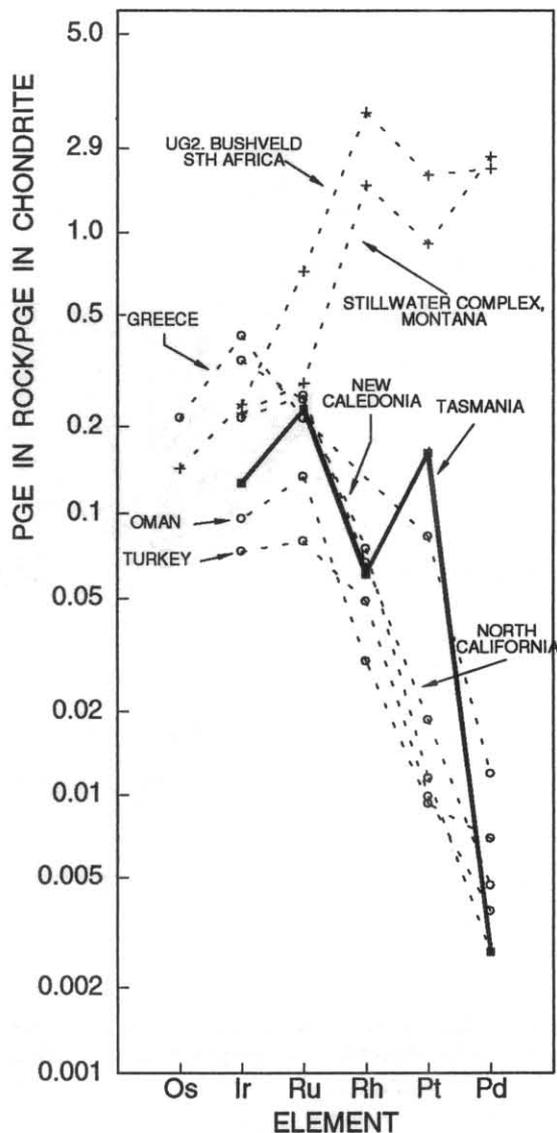


Figure 2

Chondrite-normalised platinum-group element data (after Page *et al.*, 1984) showing average data for 42 samples (after Brown *et al.*, 1988).

ULTRAMAFIC HOST ROCKS FOR THE PGE'S AND ASSOCIATED MINERALISATION

The arcuate belt of Eocambrian–Cambrian rocks in western Tasmania comprises a number of different volcano-sedimentary successions, with the volcanic rocks ranging from mafic to felsic. Along the deformed western margin of this zone a number of ultramafic-mafic rock complexes are exposed (fig. 1).

Using a combination of field characteristics and constituent mineral chemistry, the ultramafic rocks in these complexes have been subdivided into three different successions (Brown, 1986):

- (1) a high-magnesian layered dunite-harzburgite succession (LDH), which contains a tectonic fabric parallel to layering formed during plastic deformation of the cumulate layers;

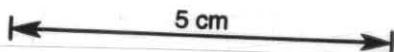


Table 1
Whole-rock analyses of platinum in Tasmanian ultramafic-mafic rocks

	(average values in ppb)		(no. of samples)
Andersons Creek	29.0	±10.3	4
Heazlewood River (North)	16.0	±4.2	4
Heazlewood River (South)	18.3	±2.3	6
Wilson River (North)	16.2	±8.5	5
Wilson River (South)	41.5	±2.1	2
Huskisson River (North)	16.3	±1.2	3
Huskisson River (South)	22.5	±10.6	2
Serpentine Hill Ultramafics	33.1	±17.4	7
Serpentine Hill Chromitite*	44.5	±11.8	6
Serpentine Hill Gabbro	36.0	±19.6	4
Low-Ti basalt, Serpentine Hill	21.5	±13.3	3

* With one chromitite having 1240 ppb Pt (not included above)

(2) a layered pyroxenite-dunite succession (LPD), which is dominated by orthopyroxene; and

(3) a multiply-intrusive ultramafic-gabbro succession (LPG).

The main features of Tasmanian ultramafic rocks are that they are high-magnesian, well-layered, and dominated by olivine and orthopyroxene. Clinopyroxene and plagioclase are subsidiary mineral phases, and only occur as post-cumulate minerals in one of the three different successions recognised. These features separate the Tasmanian rocks from the dominantly clinopyroxene-rich ultramafic rocks which are usually associated with mid-ocean ridge and back-arc environments. The closest correlates to the Tasmanian rocks occur within the Marum 'ophiolite' of Papua and New Guinea (England and Davies, 1973; Jacques and Chappell, 1980; Jacques, 1981) and the Betts Cove area in Newfoundland (Church, 1977).

When considering all areas of ultramafic rocks in Tasmania, the largest volume of rocks belongs to the IPGE-bearing, olivine-rich, LDH succession. This succession consists of well-layered dunite, orthopyroxene-bearing dunite and minor harzburgite. The sequence has a consistent and narrow range of mineral composition, with olivine of Fo₉₂₋₉₄; orthopyroxene of En₉₂₋₉₄, and Al₂O₃ and CaO contents below 0.2 wt% (electron microprobe analyses), indicating an original composition consistent with clinoenstatite. Chrome spinel grains have Cr/Cr + Al (Cr*) = 88–94 (Brown, 1986). Layering is defined by primary mineral alignment of cumulate olivine, orthopyroxene and spinel grains. A tectonic fabric, parallel to layering, pervades the succession. This fabric is defined by a flattening and elongation of the primary cumulate minerals. The LDH succession is considered to have been formed as the magma chamber component of boninitic magmatism (Brown and Jenner, 1989).

The LPD succession is also well layered but dominated by orthopyroxene. The main rock types are orthopyroxenite and olivine orthopyroxenite, with a lesser amount of dunite. Harzburgite layers have not been found within this succession. The mineral chemistry has a wider compositional range, but is also very consistent from area to area. Orthopyroxene grains are En₈₅₋₈₉ with CaO contents between 0.6 and 2.0 wt% and Al₂O₃ between 0.75 and 2.0 wt%. Olivine has a forsterite content of Fo₈₇₋₉₀, and is usually similar to the co-existing orthopyroxene. Subsidiary, post-cumulus clinopyroxene is chrome diopside (Ca:Mg:Fe = 47:49:4), and the chrome spinel grains have an average Cr* of 64. However, the spinel grains have a wide range of chemistry, being Cr* = 58–72, with a tendency of defining two different sequences, one between Cr* = 58–64 and another between Cr* = 68–72. Plagioclase has not been observed in rock from either the LDH or LPD successions.

The third ultramafic succession is characterised by multiple intrusions of various ultramafic and mafic rocks (Brown *et al.*, 1988). The succession consists of an early, well-layered sequence of orthopyroxenite with subsidiary olivine pyroxenite and dunite. This sequence varies from the LPD succession in that dunite layers usually contain an upper, mineral-graded zone, and numerous sedimentary-like structures occur within and across the layering. The mineral chemistry of this early sequence is similar to the LPD succession. The second phase of the LPG succession is characterised by plagioclase-bearing peridotite with plagioclase-bearing oikocrystic harzburgite, and minor plagioclase-dunite with a high chrome spinel content. The second magma phase intruded the first, forming reaction zones. A third magma phase resulted in multiple intrusions which intruded both the earlier ultramafic phases, resulting in the formation of two-pyroxene gabbro with a granular texture.

Overall, the olivine-rich ultramafic rocks with chrome spinel grains having a Cr* between 84 and 94 are IPGE enriched,

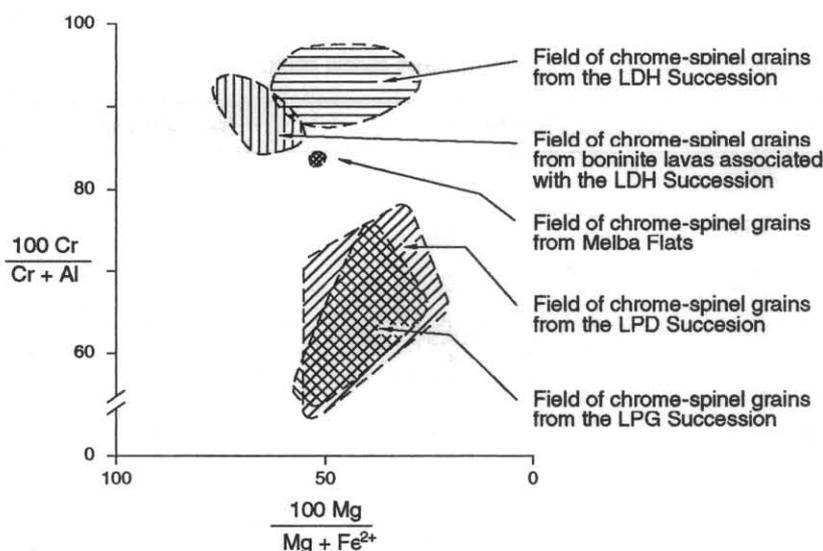


Figure 3

Fields of chrome-spinel grains from Tasmanian ultramafic rocks.

while those which are orthopyroxene-rich or bearing chrome spinel grains have a composition with Cr^* between 58 and 72 are PPGE enriched, especially those with Cr^* between 68 and 72 (fig. 3). This succession is considered to have formed as the magma chamber component of low-titanium, tholeiitic magmatism (Brown and Jenner, 1989).

ASSOCIATED BASALTIC ROCKS

Two basaltic lava varieties have been recognised associated with or within the ultramafic rock complexes. Both lava types contain pillow lava and tabular flows with intercalated breccia units, consisting of volcanic flow detritus, and minor interbedded sedimentary rocks. One of the varieties is chemically and petrographically similar to some of the Western Pacific boninite lavas (Kuroda and Shiraki, 1975; Shiraki and Kuroda, 1977; Hickey and Frey, 1982). These lavas consist of chrome spinel and pseudomorphed clinoenstatite and orthoenstatite phenocrysts in a fine-grained to quenched groundmass of pyroxene microlites. The lavas have anhydrous SiO_2 contents of 53–59 wt.% with an average of 56 wt.%. TiO_2 is less than 0.2 wt.%, MgO is between 18 and 24 wt.%, Zr and Y have average values of ~6 ppm, Nd is less than 3 ppm, and the lavas have concave chondrite-normalised REE patterns with $(La/Yb)_n \sim 1$ (Brown and Jenner, 1989.) The boninitic lavas, which occur mainly in the southern part of the Heazlewood area (no. 3, fig. 1) and to the south of McIvor Hill (no. 9, fig. 1), are considered to have been produced as a second phase melt product (Duncan and Green, 1980), with the early-formed dunite cumulate derived from this magma phase containing the Os-Ir-Ru alloys (Peck *et al.*, 1992).

The second lava variety is a low-Ti tholeiitic basalt. Flows are aphyric, but they contain a large grain-size variation down through a flow. The flows usually have pillow-structured tops, then progress down through fine-grained (1–2 mm); medium-grained (3–5 mm) to coarse-grained (5 mm) basalt, the coarser-grained varieties resembling gabbro in hand specimen, to a chilled base. In places, thin, intercalated, sedimentary rocks occur between flows. Lavas belonging to this group occur on the eastern side

of the Heazlewood and Serpentine Hill area and at McIvor Hill. Good chemical and petrographic correlations occur between the lavas from these three areas. The PPGE-enriched chromitite schlieren in the LPG succession are considered to have been derived from the parental magma of this phase of volcanism.

When chemical data on the basaltic rocks from the Serpentine Hill (Brown, 1991) and McIvor Hill complexes (no. 9, fig. 1) (Olubas, 1989) are combined with earlier data from the Serpentine Hill (Brown 1986) and Heazlewood areas (Creanaune, 1980), they show that the Tasmanian low-Ti basalt and associated gabbroic rocks define a partial melting curve which is almost identical to the curve defined by samples dredged from the Mariana Fore Arc–Bonin Island area (Hickey and Frey, 1982). The Tasmanian boninitic rocks and lavas from Cape Vogel (Jenner, 1981; Hickey and Frey, 1982) define a similarly shaped partial melting curve to that of the low-Ti lavas, but have a slightly different compositional range.

In summary, the PGE-bearing ultramafic rocks in western Tasmania are considered to have formed as magma chamber cumulates from parent liquids which produced boninitic and low-titanium basalt lavas and associated gabbroic rocks. Similar lavas and associated rock are found within the Tertiary to Recent Western Pacific island-arc system between New Guinea and Japan. The present juxtaposition of rock successions in western Tasmania is considered to be the result of obduction of parts of a Cambrian island-arc system onto a continental terrane at the end of the Middle Cambrian, followed by further deformation during a Mid-Devonian orogeny (Brown and Jenner, 1988; Berry and Crawford, 1988).

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APPENDIX

Land tenure and access to land

For exploration and mining purposes in Tasmania, there are three main classifications of land (fig. 4):

1. Land available for exploration without any special conditions

This classification includes all land listed by the Australian Heritage Commission on its Register of the National Estate. The majority of the areas of ultramafic rocks within Tasmania occur within this classification. These areas include the 'osmiridium'-producing areas of Heazlewood (no. 3, fig. 4), Mt Stewart (no. 4), and the Wilson River (no. 5), as well as other areas prospective for both IPGE and PPGE, such as the Huskisson River (no. 6), Serpentine Hill (no. 7), Dundas (no. 8), and Trial Harbour (no. 10).

2. Land available for exploration with special conditions

This classification includes Conservation Areas, Protected Areas and certain Special Reserves. Areas of ultramafic rocks where special conditions for exploration apply include the 'osmiridium'-bearing areas at Adamsfield (no. 14) and Spero Bay (no. 12), as well as the Cape Sorell area (no. 11). The main areas of the Adamsfield ultramafic complex and associated alluvial mineral fields are included in the Adamsfield Conservation Area within the World Heritage Area, and are available for exploration. Application for Exploration Licences and/or Mining Leases are required to be approved by the Mineral Exploration Working Group and the relevant Land Managing Authority.

3. Land, at present, unavailable for exploration or mining

This classification includes National Parks, World Heritage Areas, and Wildlife Reserves. Areas of ultramafic rocks presently unavailable for exploration are the old 'osmiridium'-producing areas of the Boyes River (no. 13) and Rocky Boat Harbour (no. 15), as well as the ultramafic rocks on Macquarie Island.

The Department's *Mineral Exploration Code of Practice* provides an outline of the current procedures which must be followed to obtain exploration approval, and at the same time to give useful, practical information on the expected standards of exploration activities. The Code also details the controls and monitoring procedures which are currently in place.

Conditions under which exploration work may proceed are decided on a site-by-site basis, usually after consultation with other Government departments.

The Department of Mines rigorously enforces a policy of responsible and careful exploration, requiring all proposed exploration activities to be approved in writing before work commences. However, the Department also acts as a facilitator for any exploration company who may wish to apply for an Exploration Licence over areas which require special conditions.

Exploration activities proposed in Protected and Conservation Areas, and other areas considered to be sensitive, must be approved by the Mineral Exploration Working Group, which consists of representatives from the Department of Mines; the Department of Environment and Planning; the Department of Parks, Wildlife and Heritage; the Forestry Commission; and other Departments and interested bodies where required.

The purpose of the Working Group is to examine matters relating to mineral exploration and mining activities within Conservation and Protected Areas, and in other environmentally-sensitive areas, including those parts of the World Heritage Area which are open for exploration.

The fundamental aim of the Working Group is to allow the aims of the explorer to be met without compromising the conservation values of a given area.

An applicant for an Exploration Licence or Special Prospectors' Licence shall submit to the Director of Mines a program of proposed works, and this must be approved in principle before the issue of a licence. The Director of Mines shall submit the programme, and any subsequent variation of it, together with his comments and recommendations, to the relevant Managing Authority, for comment and approval, via the Mineral Exploration Working Group.

The function of the Working Group is to examine the exploration proposals, investigate the impact that any work may have on the historical, archaeological, botanical, zoological or ecological significance of the place, and if need be, impose conditions on the activities so that these values are not permanently adversely affected.

Once approval has been given by the Working Group, the Department of Mines is the Government Agency responsible for the administration and supervision of mineral tenements within Tasmania.

When exploration activity has commenced, supervision of the activities is the responsibility of the staff of the Department of Mines. If considered warranted, field trips may be arranged so that members of the Working Group, or their field representative, can view the progress of work in a particular location.

Further information can be obtained from both the Registrar of Mines and the Manager—Environmental Policy.

