Tasmania

Tasmanian Geological Survey

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

by A. V. Brown

INTRODUCTION

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

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

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, and for jewellery and investment bars and coins.

PGE's can be divided into two groups based on their occurrence and association:

- 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 that the alloys ranged from being dominantly iridosmine and rutheniridosmine, with only minor true osmiridium (Ford, 1981; Cabri and Harris, 1975).

Tasmanian ultramafic rocks host 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; Peck and Keays, 1990).

In the late 19th century PGM's were obtained in Tasmania 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 discarded.

Between 1910 and the end of 1980 approximately 965 kg of 'osmiridium' was registered as having been been mined from western Tasmania but a greater quantity was probably recovered but not registered. Alluvial mining between 1910 and 1925 on the Heazlewood River–Mt Stewart–Wilson River complexes (fig. 1) accounted for ~420 kg of this total. The Adamsfield deposits (fig. 1) were discovered in 1925, and 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. During the 1980s, studies of the various areas of ultramafic rocks in Tasmania showed that there existed a potential for 'hard rock' sources of IPGE's, associated with 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, 1986; Anon., 1987; Brown *et al*., 1988; Peck and Keays, 1990).

Exploration for copper-nickel mineralisation in the Cuni area (2 km southwest of the Serpentine Hill Ultramafic Complex; fig. 1) during the late 1940s revealed platinum and paladium in a medium to fine-grained association of magnetite, pyrite, pyrrhotite, pentlandite and chalcopyrite within gabbroic rocks. A review of PGE mineralisation in the Cuni field is included in Brown (1991).

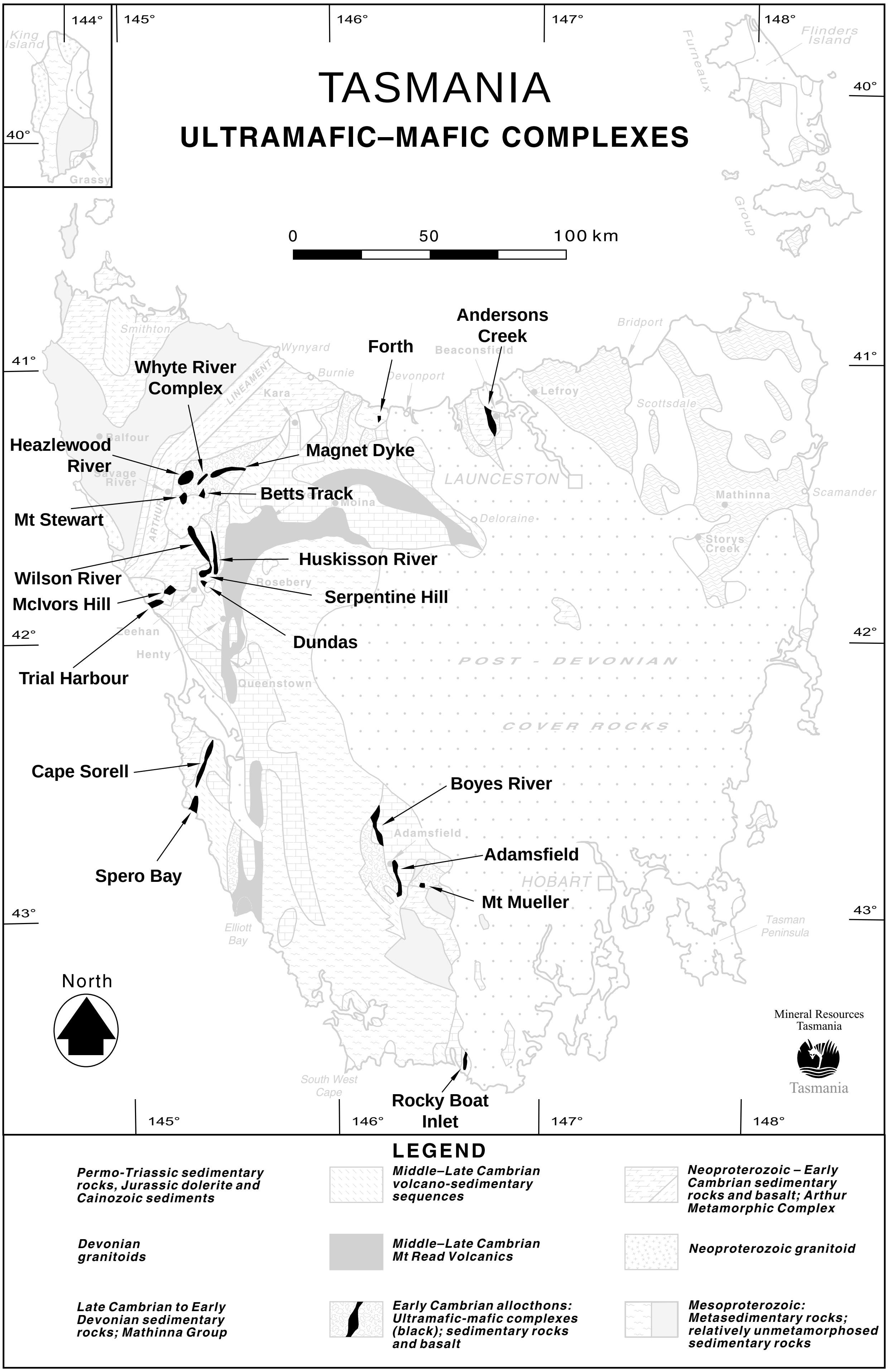
TASMANIA
ULTRAMAFIC–MAFIC COMPLEXES
0
50
100 km
144°
145°
146°
147°
148°
40°
41°
42°
43°
King Island
Grassy
Flinders Island
Furneaux Group
Tasman Peninsula
Smithton
Wynyard
Burnie
Kara
Devonport
Beaconsfield
Bridport
Lefroy
Scottsdale
LINEAMENT
ARTHUR
Balfour
Savage River
Moina
LAUNCESTON
Deloraine
Mathinna
Scamander
Storys Creek
Rosebery
Zeehan
Henty
Queenstown
POST - DEVONIAN
COVER ROCKS
Adamsfield
HOBART
Elliott Bay
South West Cape
Andersons Creek
Forth
Whyte River Complex
Heazlewood River
Magnet Dyke
Betts Track
Mt Stewart
Huskisson River
Wilson River
Serpentine Hill
McIvors Hill
Dundas
Trial Harbour
Cape Sorell
Spero Bay
Boyes River
Adamsfield
Mt Mueller
Rocky Boat Inlet
North
Mineral Resources Tasmania
Tasmania
LEGEND
Permo-Triassic sedimentary rocks, Jurassic dolerite and Cainozoic sediments
Middle–Late Cambrian volcano-sedimentary sequences
Neoproterozoic – Early Cambrian sedimentary rocks and basalt; Arthur Metamorphic Complex
Devonian granitoids
Middle–Late Cambrian Mt Read Volcanics
Neoproterozoic granitoid
Late Cambrian to Early Devonian sedimentary rocks; Mathinna Group
Early Cambrian allocthons: Ultramafic-mafic complexes (black); sedimentary rocks and basalt
Mesoproterozoic: Metasedimentary rocks; relatively unmetamorphosed sedimentary rocks

Figure 1

KNOWN OCCURRENCE OF PGE'S AND ASSOCIATED MINERALISATION IN TASMANIA

Of the fifteen separate areas of ultramafic rocks known to occur in Tasmania, seven have so far been associated with the production of PGE's and PGM's, with an eighth area having alluvial deposits following the erosion of remnant ultramafic rock after granitic emplacement. Four of the areas produced significant amounts of alloy, with the other four areas producing lesser volumes.

The four main areas (fig. 1) are:

- the Heazlewood River Complex, also know as 'Nineteen Mile Creek', which includes Fenton's Prospect, the Caudry's workings;
- the Mt Stewart Complex,also known as Laughin's Creek or Ramsay's Prospect;
- the Wilson River Complex — the Harman River area in the north, and the Ahearne, Berkery, Kershaw, Barnes and Riley Creeks in the middle section north of Riley Knob; and
- the Adamsfield area.

The four areas with smaller output are at Boyes River and Rocky Boat Harbour, which are now in the Tasmanian World Heritage Area and, as such, are not available for exploration, and the areas around Keegan and Betts creeks, which are on top of the Meredith Granite. The latter areas contain alluvial deposits derived from remnants of ultramafic rocks after granitic emplacement. Prior to granitic 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 and the Trial Harbour ultramafic body; are composed of similar primary ultramafic rock type as the bodies from which 'osmiridium' was produced.

An exploration programme over the Huskisson River Ultramafic Complex during the late 1980s obtained between 20 and 190 ppb Pt for soil samples from eluvial deposits, as well as grains with varying proportions of Os and Ir ± 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 rock was calculated from analyses of 42 rock samples (Brown *et al.*, 1988). When this average pattern is plotted on a chondrite-normalised PGE diagram and compared with other areas of ultramafic rocks with known PGE values, the pattern has a similar slope to samples from ophiolitic bodies but with anomalously high Pt values.

Outside of the 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 (fig. 1). At Cuni 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 of 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 platinoid metals, with Pt and Pd being determined as being in approximately equal proportions (Stillwell, 1946). A third sample from a nearby pit also contained Pt, partly as native Pt and partly as sperrylite (Hughes, 1965). Data obtained from the old mine workings and later drilling indicates that the ore at Cuni is contained within, or associated with, peridotite dyke or sills (Taylor and Burger, 1952; Robinson, 1958).

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

ULTRAMAFIC HOST ROCKS FOR THE PGE'S AND ASSOCIATED MINERALISATION

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

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 three different successions. 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 New Guinea (England and Davies, 1973; Jaques and Chappell, 1980; Jaques, 1981) and the Betts Cove area in Newfoundland (Church, 1977).

The ultramafic rocks of western Tasmania have been subdivided into three different successions using a combination of field and constituent mineral chemistry (Brown, 1986). These three sequences are:

- a high-magnesian layered dunite-harzburgite succession (LDH), which contains a tectonic fabric formed by plastic deformation of cumulate layers;
- a layered pyroxenite-dunite succession (LPD), which is dominated by orthopyroxene; and
- a multiply-intrusive ultramafic-gabbro succession (LPG).

The largest volume of ultramafic rocks belongs to the 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 Fo_{92-94}; orthopyroxene of En_{92-94}, and Al_2O_3 and CaO contents below 0.2 wt% (electron microprobe analyses), indicating an original composition consistent with clinoenstatite. Chrome spinel grains have 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. This 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 is 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 En_{85-89} with CaO contents between 0.6 and 2.0 wt% and Al_2O_3 between 0.75 and 2.0 wt%. Olivine has a forsterite content of Fo_{87-90}, and is usually similar to the coexisting 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. Spinel grains have a wide range of chemistry (Cr* = 58–72) with a tendency to definine two different sequences, one with a range of Cr* = 58–64 and another Cr* = 68–72. Plagioclase has not been observed in rock from either of the LDH or LPD successions.

The third ultramafic succession is characterised by multiple intrusions of various ultramafic and mafic rocks (Brown *et al.*, 1988). This 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 of 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 Cr* between 84 and 94 (fig. 2) are IPGE enriched, while those which are orthopyroxene-rich or orthopyroxene-bearing with chrome spinel grains having a composition with Cr* between 58 and 72 are PPGE enriched, especially those with Cr* between 68 and 72 (fig. 2).

This succession is considered to have formed as the magma chamber product associated with the phase of low-titanium, tholeiite magma (Brown and Jenner, 1989).

ASSOCIATED BASALTIC ROCKS

Two basaltic lava types have been recognised within the ultramafic rock complexes. Both 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 chrondite-normalised REE patterns with $(La/Yb)_n$ ~1 (Brown and Jenner, 1989). The boninitic lavas occur mainly in the southern part of the Heazlewood River area (fig. 1) but fault-bounded blocks also occur to the south of McIvor Hill (fig. 1) and in the Moores Pimple area to the northeast of Dundas.

The second lava variety is a low-Ti tholeiitic basalt. These flows are aphyric but contain a large grain size variation down through a flow. The flows usually have pillow-structured tops, then progress down through fine (1–2mm), medium (3–5mm) 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

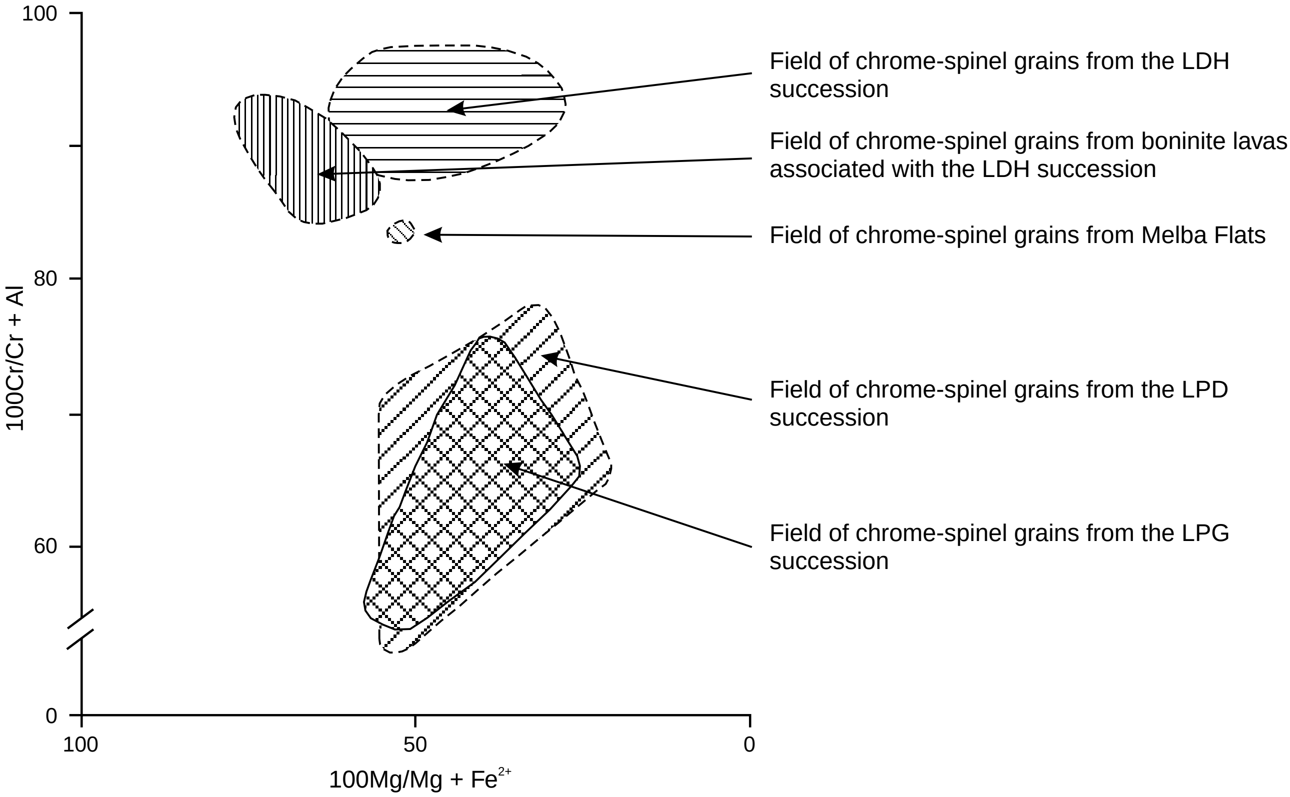

Figure 2

Fields of chrome-spinel grains from Tasmanian ultramafic rocks.

area and at McIvor Hill. Good petrographic correlations occur between the three areas.

When chemical data on the basaltic rocks from the Serpentine Hill (Brown, 1991) and McIvor Hill (Olubas, 1989) complexes are combined with earlier data from the Serpentine Hill (Brown, 1986) and Heazlewood (Creenaune, 1980) areas 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 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. The Western Pacific island arc system between New Guinea and Japan is a Tertiary to Recent setting for the production of similar lavas and associated rocks. The present juxtaposition of rock successions in western Tasmania is considered to be the result of an island arc being obducted onto a continental terrane at the end of the Middle Cambrian, followed by further deformation during a mid-Devonian orogeny.

BACKGROUND REPORTS

Further information on PGE and their host rocks in Tasmania can be found in a number of background reports, including:

- Report on the osmiridium 'lode' at the head of Main Creek, Adamsfield (Nye, 1930);
- Geological Survey Bulletins *Osmiridium in Tasmania* (Reid, 1921) and *The osmiridium deposits of the Adamsfield district* (Nye, 1929), both of which were reprinted as a single volume in 1991;
- Notes on the history of mining and exploration at Adamsfield (Bacon, 1992);
- Platinum Group Metals. Supply, uses and future (Stait, 1987);
- Geology and economics of platinum-group metals in Australia (Hoatson and Glaser, 1989);
- Bibliography on mineralogy, geochemistry, metallogeny, analytical procedures and exploration of the Platinum-Group Elements (de Oliveria *et al.*, 1991);
- International strategic minerals inventory summary report — Platinum-Group metals (Sutphin and Page, 1986).

REFERENCES

ANON., 1987. *Adamsfield prospects, South West Tasmania, EL4/85. Annual Report for the period ending 25 July 1987.* Metals Exploration Ltd [TCR 87-2729].

BACON, C. A. 1992. Notes on the history of mining and exploration at Adamsfield. *Report Mineral Resources Tasmania* 1992/20.

BROWN, A. V. 1986. Geology of the Dundas–Mt Lindsay–Mt Youngbuck region. *Bulletin Geological Survey Tasmania* 62.

BROWN, A. V. 1991. Revocation Report on the Melba Flats Exempt Area, SR 1987, No. 216 of 11 km^2. *Report Division of Mines and Mineral Resources Tasmania* 1991/10.

BROWN, A. V.; JENNER, G. A. 1989. Geological setting, petrology and chemistry of Cambrian boninite and low-Ti tholeiite lavas in western Tasmania, *in:* CRAWFORD, A. J. (ed.). *Boninites and related rocks*. Allen and Unwin : London.

BROWN, A. V., PAGE, N. J.; LOVE, A. H. 1988. Geology and platinum-group-element geochemistry of the Serpentine Hill Complex, Dundas Trough, Western Tasmania. Canadian Mineralogist. 26: 161–175.

BROWN A. V.; FINDLAY, R. H.; GOSCOMBE, B. D.; MCCLENAGHAN, M. P.; SEYMOUR, D. B. 1994. Geological Atlas 1:50 000 Series, Sheet 50 (7914S). Zeehan. *Department of Mines, Tasmania*.

CABRI, L. J.; HARRIS, D. C. 1975. Zoning in Os-Ir alloys and the relation of the geological and tectonic environment of the source rocks to the bulk (Pt:Pt + Ir + Os) ratio for placers. *Canadian Mineralogist* 13:266–274.

CHURCH, W. R. 1977. The ophiolites of southern Quebec: oceanic crust of Betts Cove type. *Canadian Journal Earth Sciences* 14:1668–1673.

CREASY, M. G. 1990. *John Lynch Creek, Annual Report 28 October 1989–27 October 1990, EL18/86*. [Unpublished] [TCR 90-3183].

CREENAUNE, P. J. 1980. *The volcanics of the Heazlewood River complex*. B.Sc. (Hons) thesis, University of Tasmania : Hobart.

DUNCAN, R. A.; GREEN, D. H. 1980. Role of multistage melting in the formation of oceanic crust. *Geology* 8:22–26.

ENGLAND, R. N.; DAVIES, H. L. 1973, Mineralogy of ultramafic cumulates and tectonites from eastern Papua. *Earth Planetary Science Letters* 17:416–425.

FORD, R. J. 1981. Platinum-group minerals in Tasmania. *Economic Geology* 76:408–186.

HICKEY, R. L.; FREY, F. A. 1982. Geochemical characteristics of boninite series volcanics: implications for their source. *Geochemica et Cosmochimica Acta* 46:2099–2115.

HOATSON, D. M.; GLASER, L. M. 1989. Geology and economics of platinum-group metals in Australia. *Resource Report Bureau of Mineral Resources, Geology and Geophysics Australia* 5.

HUGHES, T. D. 1965. Nickel mineralization in Tasmania, *in:* MCANDREW, J. (ed.). Geology of Australian ore deposits. *Proceedings Eighth Commonwealth Mining and Metallurgical Congress* 1:523–524.

JAQUES, A. L. 1981. Petrology and petrogenesis of cumulate peridotites and gabbros from the Marum Ophiolite Complex, northern Papua New Guinea. *Journal of Petrology* 22:1–40.

JAQUES, A. L.; CHAPPELL, B. W. 1980. Petrology and trace element geochemistry of the Papuan Ultramafic Belt. *Contributions Mineralogy and Petrology* 75:55–70.

JENNER, G. A. 1981. Geochemistry of high-Mg andesites from Cape Vogel, Papua New Guinea. *Chemical Geology* 33:307–332.

KURODA, N; SHIRAKI, K. 1975. Boninite and related rocks of Chichi-jima, Bonin Islands, Japan. *Report Faculty Science Shizucka University* 10:145–155.

MATHEZ, E. A.; PEACH, C. L. 1989. The geochemistry of the Platinum-Group Elements in mafic and ultramafic rocks, *in:* WHITNEY, J. A.; NALDRETT, A. J. (ed.). Ore deposition associated with magmas. *Reviews in Economic Geology* 4:33–43.

NYE, P. B. 1929. The osmiridium deposits of the Adamsfield district. *Bulletin Geological Survey Tasmania* 39.

NYE, P. B. 1930. Report on the osmiridium "lode" at the head of Main Creek, Adamsfield. *Unpublished Report Department of Mines Tasmania* 1930:121–125.

DE OLIVEIRA, A. M.; JOST, H.; DE LIMA, C. V.; MERKLE, R. K. W. 1991. Bibliography on mineralogy, geochemistry, metalogeny, analytical procedures and exploration of the Platinum-Group Elements. *Research Report Institute for Geological Research on the Bushveld Complex, University of Pretoria* 92.

OLUBAS, P. E. 1989. *The geology of the McIvor Hill Complex*. B.Sc.(Hons) thesis, University of Tasmania : Hobart.

PAGE, N. J.; ENGIN, T.; SINGER, D. A.; HAFFTY, J. 1984. Distribution of platinum-group elements in the Bati Kef chromite deposit, Guleman-Elazig Areas, eastern Turkey. *Economic Geology* 79:177–184.

PECK, D. C.; KEAYS, R. R. 1990. Geology, geochemistry and origin of platinum-group elements-chromitite occurrences in the Heazlewood River Complex, Tasmania. *Economic Geology* 85:765–793.

REID, A. M. 1921. Osmiridium in Tasmania. *Bulletin Geological Survey Tasmania* 32.

ROBINSON, R. G. 1958.; Recent drilling of the Cuni deposit, Zeehan. Technical Report Department of Mines Tasmania 3:11–27.

SHIRAKI, K.; KURODA, N. 1977. The boninite revisited. *Journal Geography (Tokyo)* 86(3):34–50.

STAIT, B. 1987. Platinum Group Metals. Supply, uses and future. *Current Issues Brief Legislative Research Services Department of the Parliamentary Library Australia* 7.

STILLWELL, F. 1946. Copper-nickel ore from Zeehan District, Tasmania. *CSIRO Mineragraphic Investigation* 342.

SUTPHIN, D. M.; PAGE, N. J. 1986. International Strategic Minerals Inventory summary report — Platinum-group metals. *Circular United States Geological Survey* 930-E

TAYLOR, B. L.; BURGER, D. 1952. The Five-Mile copper-nickel deposits. *Unpublished Report Department of Mines Tasmania* 1952:72–97.

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