

Australian Carbonatites: Their Resources and Geodynamic Setting

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Carbonatites are known from each of the megacrustal elements comprising the Precambrian Australian Shield (Figure 1). Australian carbonatites are of interest because – like their counterparts elsewhere – they contain high abundances of LREE, Nb, Ta, P and, in a number of cases, U. Current high prices for U and increased demand for REE (magnets, electronics, automobiles) have renewed exploration interest. Most of the carbonatites lie near major structural features evident in continent-scale aeromagnetic and gravity data and/or seismic tomographic models. The carbonatites fall into two types 1) those associated with kimberlite and/or ultramafic lamprophyres, and 2) carbonatites occurring in alkaline complexes or discrete bodies.

Carbonatites within kimberlite fields

The oldest confirmed Australian carbonatites – the 2020 Ma Mount Weld and Ponton Creek intrusions – lie within the late Archean granite-greenstone terranes of the Eastern Goldfields of the Yilgarn Craton and form part of an alkaline suite including kimberlites and melnoites. Isotopic and trace element evidence suggest they were derived from metasomatised lithospheric mantle that may have also given rise to a contiguous belt of earlier ~2.66 Ga syenites (Graham et al., 2004). All lie along a major structure in the lithosphere evident in regional seismic tomographic models.

The **Mount Weld Carbonatite** comprises an annulus of brecciated wall-rock and fenitic alteration surrounding a ~3 km wide carbonatite (mostly sovite) plug (Duncan and Willett, 1990). The carbonatite is overlain by a thick regolith containing high grade rare earth oxide (REO) deposits and accumulations of apatite, and Nb and other 'rare metals'. The Mount Weld carbonatite hosts the world's richest lanthanide deposit with the central lanthanide deposit (CLD) containing 12.24 Mt @ 9.7% REO (2.5% REO cut off; Lynas Corp. Ltd, 2008). Open pit mining of the central high grade secondary monazite zone (4.7 Mt @ 13.8% REO) is producing feedstock for concentration and shipping to Malaysia for processing with a view to producing 10,500t REO in 2009. In addition to the CLD Mount Weld hosts the southern ore zone containing 2.78 Mt @ 4.0% REO (richer in HREE), and the Crown and Coors polymetallic deposits containing Nb, P, REO, Ta, Zr, Y and Ti resources.

The **Ponton Creek (Cundeelee)** carbonatite is a major stock or plug ~10km across overlain by 500m of

Permian tillite lying ~200km ESE of Mount Weld. Graham et al. (2004) included this body within the ~2020 Ma Eastern Goldfields alkaline suite. It has a central core of ultramafic cumulates (mostly olivine-pyroxenite) cut by narrow veins of apatite-rich carbonatite. Peralkaline syenites are also associated.

Carbonatite veins have been reported from the Granny Smith and Wallaby gold mines, respectively ~15 km NW and ~28km W of Mount Weld. Gold at both is associated with ~2.66 Ga monzodiorite-syenite stocks and dykes and carbonate-rich rocks. These include skarn and hydrothermally altered rocks, post-ore carbonatites and ultramafic lamprophyres (Granny Smith) correlated with the Mount Weld carbonatite, and disputed late-stage 'carbonatites' associated with 2.66 Ga syenites (Mueller et al., 2008).

The **Yungal carbonatite** dyke and the associated Speewah fluorite deposit lie near the major Greenvale Fault at the eastern margin of the Kimberley Craton and adjacent Paleoproterozoic Halls Creek Orogen in the North Australian Craton. The carbonatite is spatially associated with Neoproterozoic (~800 Ma) kimberlites and lamprophyres, including the andradite-carbonate-bearing Bow Hill lamprophyre dyke (Jaques et al., 1986) but its intrusion age is unknown.

The **Walloway carbonatite** is part of suite of small dykes and plugs of carbonate-rich and chemically evolved kimberlite and ultramafic lamprophyre of Jurassic age (~170 Ma) in the Orroroo (Euralia) region at the eastern margin of the Gawler Craton in South Australia (Tucker and Collerson, 1972; Ferguson and Sheraton, 1979). Walloway has similar C, Nd and Pb isotopic compositions to carbonatites elsewhere but more radiogenic Sr and heavier O (Nelson et al., 1988).

Alkaline provinces and discrete complexes

Other carbonatites are either spatially separate or differ in age from known kimberlite fields. Most are associated with other alkaline igneous activity.

The **Copperhead 'carbonatite'** which intrudes the Paleoproterozoic Halls Creek Orogen consists of a small alkaline intrusion with a syenite core and fenitised syenite outer zone containing localised 'carbonatite' breccia pods (Rugless and Pirjano, 1996). Recent U-Pb dating indicates it was emplaced at ~1821 Ma and thus predates the Neoproterozoic suite of kimberlites and lamprophyres in the region.

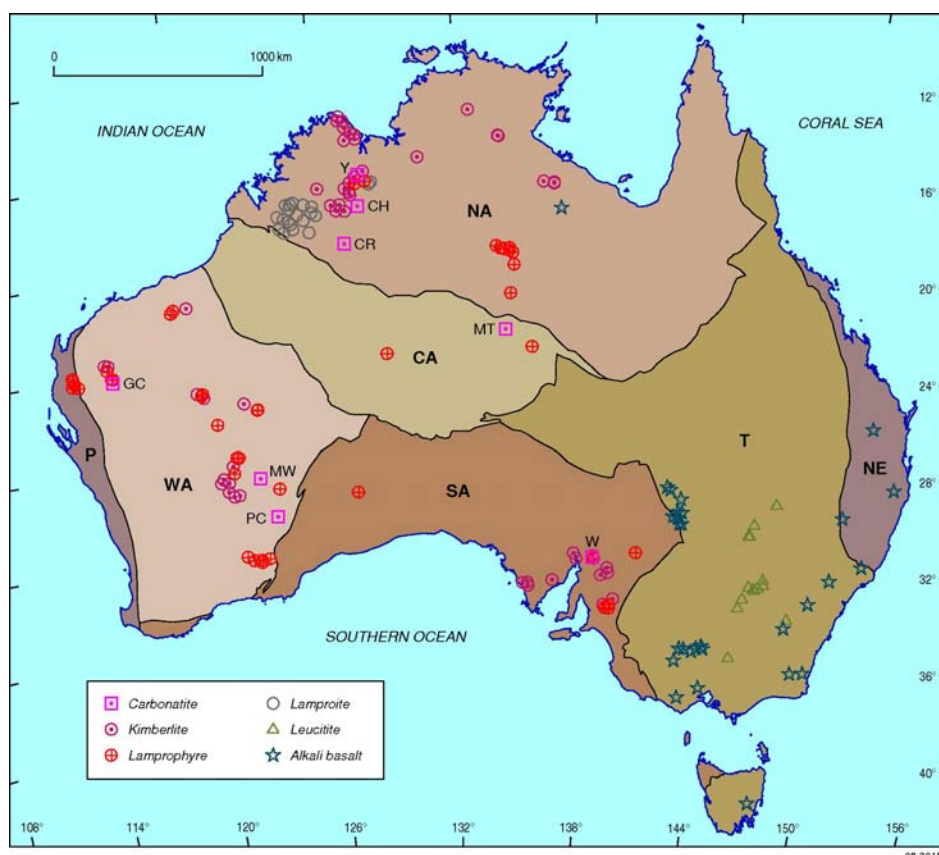


Figure 1. Simplified map showing distribution of Australian carbonatites in relation to kimberlites, lamprophyres, and other alkaline igneous rocks and the crustal mega-elements. WA, NA, CA, and SA refer to the west, north, central and southern Australian mega-elements, T = Tasman, NE = New England. Carbonatites shown are Copperhead (CH), Cummins Range (CR), Gifford Creek (GC), Mud Tank (MT), Mount Weld (MW), Ponton Creek (PC), Walloway (W), and Yungah (Y). A map at 1:5 million scale is available online (Jaques, 2008).

The **Cummins Range Carbonatite** lies at the southern margin of the Halls Creek Orogen surrounding the Kimberley craton. The carbonatite comprises a composite, zoned sub-vertical vertical stock ~2 km across with a central carbonatite core and an eastern plug of carbonated mica pyroxenite (Andrew, 1990). Isotopic dating (1012 ± 12 Ma U-Pb zircon and 905 ± 2 Ma Rb-Sr) indicates that the carbonatite pre-dates the ~800 Ma kimberlites of the North and East Kimberley regions but may be coeval with the Bow Hill lamprophyre (Jaques et al., 1986). An enriched regolith zone over the carbonatite and the pyroxenite phases hosts REO, U, Nb and P mineralisation. Recent company drilling has outlined a resource of 3.55 Mt (1% REO cut-off) @ 2.0% REO, 11.2% P_2O_5 , 216 ppm U_3O_8 and 36 ppm Th. Included within this is a higher grade zone (+2% REO cut-off) of 1.1 Mt @ 3.5% REO and a partially overlapping zone of 1.3 Mt @ 414 ppm U_3O_8 (Navigator Resources Ltd, 2008). Economically significant levels of Nb, Ta, Zr, Ti and Th have also been reported.

The Mesoproterozoic **Gifford Creek alkaline complex** in the Gascoyne Complex of the Capricorn Orogen of WA lies ~70km south of the Barlee Range field of kimberlites and lamprophyres (see Jaques, 2008). The complex comprises an older (~1.68 Ga) swarm of ultrabasic sills accompanied by a extensive belt of

fenite that have affinities with carbonate-rich kimberlites and ultramafic lamprophyres, and a later (~1.25 Ga) set of REE-bearing ferrocarnate-magnetite-hematite dykes (Yangibana ironstones) and other magnetite-bearing alkaline rocks (Pearson and Taylor, 1996).

The 732 Ma **Mud Tank Carbonatite** lies within the Strangways alkaline igneous province in central Australia (Figure 1). It occurs as a series of carbonate-rich lenses surrounded by mica-rich zones and was emplaced into granitoid cataclasites, and mafic aluminous granulites at mid-crustal levels in a active ductile shear zone and remobilised, with part of its Na-rich metasomatic aureole, to higher crustal levels (Currie et al., 1992). Vermiculite is mined at Mud Tank with 8,900t produced in 2006/07. Mud Tank is also a source of gem quality zircon.

Carbonate-rich vein and dykes occur in the 1130 Ma Mordor Igneous Complex. ~50km SSE of the Mud Tank carbonatite. This alkaline complex comprises fractionated suite of co-magmatic alkaline felsic and mafic rocks (syenite-monzonite-shonkinite) and spatially associated phlogopite-bearing ultramafic rocks. Apart from being significantly older than the Mud Tank Carbonatite the Mordor Complex has distinctly more radiogenic Sr isotopic compositions

than the carbonatite (Black and Gulson, 1978). Both however are located on the Woolanga Lineament, a deep seated NW-trending crustal structure that appears to have controlled the emplacement of alkaline rocks in this province throughout much of the Proterozoic.

Implications

The distribution of kimberlites, lamproites and other related alkaline volcanics in Australia is related to the structure of the lithosphere with many intrusions located on discontinuities and gradients evident in continent-scale seismic tomography and potential field data (Jaques and Milligan, 2004). The known carbonatites lie near the margins of cratons and in most provinces there is evidence of deep crustal (and potentially lithospheric) structures that control the distribution of carbonatites and potentially other alkaline suites. Some of these structures have been active over extended periods of time with multiple intrusion events. The geodynamic setting for most is uncertain and may be controlled by far-field stresses. Some may be related to extension events: for example, the Mud Tank carbonatite may have been emplaced during development of the Neoproterozoic Amadeus Basin. Emplacement of the Cummins Range Carbonatite may, as has been suggested for the Neoproterozoic kimberlites in Northern Australia, be linked to structures associated with the break-up of Rodinia (Jaques and Milligan, 2004).

Available trace element and isotopic data for the carbonatites and their co-magmatic counterparts are consistent with derivation as small volume melts from asthenospheric mantle and/or refertilised sub-continental lithospheric mantle (Nelson et al., 1988; Graham et al. 2004). An apparent lack of association between Australian carbonatites and kimberlites carrying economic grades of diamonds suggests that the fluids associated with the refertilisation process were hostile to diamond preservation and/or that these kimberlites were derived from relatively shallow levels in the mantle.

Australian carbonatites, like those elsewhere, have intrinsically high abundances of REE as well as other large-ion-lithophile elements and high-field strength elements such as Nb and Ta. However, economic and potentially-economic concentrations of REO, U, P, Nb, Ta and other 'rare metals' in the regolith developed over the carbonatites result from supergene enrichment. Weathering with pronounced vertical and lateral groundwater flow resulted in leaching and dissolution with enrichment in resistate minerals and formation of secondary REE-rich phosphates and aluminophosphates under conditions of high fluid/rock ratios, long fluid rock residence times, and a range of pH and alkalinity conditions (Lottermoser, 1990).

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