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An integrated petrological, geochemical and Re–Os isotope study of peridotite xenoliths from the Argyle lamproite, Western Australia and implications for cratonic diamond occurrences

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ABSTRACT

An integrated study of the petrology and Re–Os geochemistry of a suite of peridotite xenoliths, some carrying abundant diamonds, from the richly diamondiferous Argyle AK1 lamproite pipe provides definitive evidence for a depleted lithospheric root of Neoarchean age (T_{RD} eruption ~2.2–3.1 Ga) beneath the Proterozoic Halls Creek Orogen at the margin of the Kimberley Craton, Western Australia. The microdiamonds from the peridotitic xenoliths are similar in their properties to the minor population of small, commercial sized, peridotitic diamonds from Argyle, both formed in the Archean from isotopically mantle-like carbon. The major element bulk chemistry and mineral chemistry of the Argyle peridotites are slightly less depleted than Archean cratonic peridotites as a whole but similar to those reported from Neoarchean–Paleoproterozoic cratonic provinces. The Argyle peridotite xenoliths were derived from within the diamond stability field (1050–1300 °C and 4.9–5.9 GPa) near the base of the lithosphere (typically 160–200 km depth) with a geothermal gradient of 41.5 mW/m^2. This thick diamondiferous lithosphere, estimated at up to 225 km thick from present day seismic S-wave tomography, appears to have persisted since the time of eruption of the Argyle lamproite (~1180 Ma).

The existence of late Archean age lithosphere beneath the Argyle diamond pipe, in a region where no crustal rocks of Archean age are known, suggests a decoupling of the crust and mantle in the region of the Halls Creek Orogen, perhaps as a consequence of Paleoproterozoic (~1.85 Ga) reworking and/or subduction at the margin of the Kimberley Craton. The confirmation of an Archean lithospheric root beneath the Argyle pipe at the margin of the Kimberley Craton seemingly conforms with “Clifford's Rule”, regarding the restriction of economic diamond deposits to those underlain by Archean cratons. However, Argyle owes its rich diamond grades not to its Neoarchean mantle roots but to the presence of richly diamondiferous eclogitic material accreted to the craton root during the Proterozoic.

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1. Introduction

The Argyle mine, one of the world's largest diamond mines, is the only major diamond deposit found in an early Proterozoic mobile belt. It is hosted by the Argyle AK1 lamproite pipe and lies within the Halls Creek Orogen (HCO) at the southeast margin of the Kimberley Craton in Western Australia (Fig. 1). Archean mobile belts such as the Limpopo Belt contain diamondiferous pipes (e.g. Venetia, River Ranch). However, with a few exceptions such as the Prairie Creek (USA) lamproite (Lambert et al., 1995), Buffalo Head Hills (Canada) kimberlites (Carlson et al., 1999), Pimenta Bueno and Juina (Brazil) kimberlites (Bulanova et al., 2008a,b), kimberlites and other alkaline ultrabasic volcanic rocks (including lamproites) intruding post-Archean mobile belts at the margins of cratons are mostly barren of diamonds, presumably having been derived from shallower depths and thus sampled lithosphere in the graphite stability field (Janse, 1994). A number of studies of the Southern African (Kalahari and

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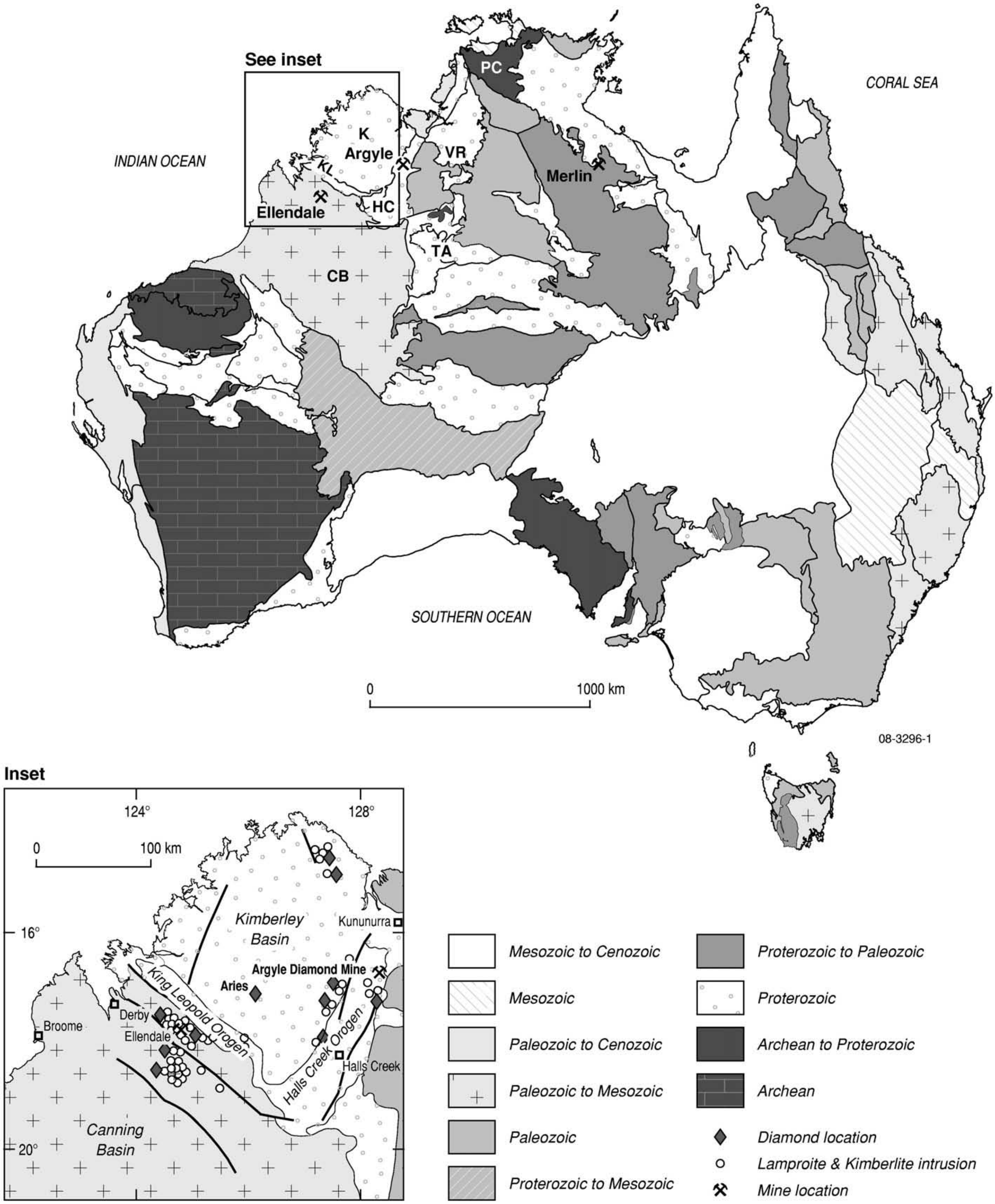

Fig. 1. Simplified geological map of Australia showing location of Argyle mine, the Halls Creek Orogen and the Kimberley Craton in relation to major geological regions by age. The inset shows the distribution of kimberlites and lamproites in the Kimberley Craton and the Argyle and Ellendale diamond mines. CB=Canning Basin, K=Kimberley Craton, PC=Pine Creek Inlier, TA=Tanami Province, and VR=Victoria River Basin.

Kaapvaal) Craton, the Siberian and North Atlantic Cratons, have demonstrated a general correspondence between the age of the crust and the age of its underlying mantle (e.g. Carlson et al., 2005 and refs. within) and provided compelling evidence that cratonic lithospheric mantle is typically coupled with its overlying crust (Helmstaedt, this issue). It is therefore important to constrain the depth and the age of

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