ISOTOPIC EVOLUTION OF THE KIMBERLEY BLOCK, WESTERN AUSTRALIA

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Previous studies of the isotopic characteristics of the Miocene olivine and leucite lamproites of the Fitzroy area of the West Kimberley have demonstrated the existence of ancient ($\geq$2000 Ma) mantle sources beneath the southwestern margin of the Kimberley Block (McCulloch et al., 1983; Fraser et al., 1985; Nelson et al., 1986). In this paper we report Sr and Nd isotopic data on a various suites of basic to ultrabasic intrusions ranging in age from early Proterozoic (~1900 Ma) to Miocene (20 Ma) from different parts of the Kimberley to assess the extent and timing of enrichment processes of the subcontinental lithosphere.

The Kimberley Block of Western Australia is bounded by the Halls Creek and King Leopold Mobile Zones which consist of early Proterozoic eugeo-synclinal sediments and volcanics which have been folded and metamorphosed to comparatively high grade, and intruded by granites and basic and ultrabasic rocks. Early to middle Proterozoic platform cover clastic sediments of the Kimberley Basin partly overlie the 1920-1815 Ma basement rocks of the mobile belts and elsewhere are presumed to be underlain by Archaean basement.

EARLY PROTEROZOIC MAFIC-ULTRAMAFIC ROCKS IN THE HALLS CREEK MOBILE ZONE

LREE-depleted, MORB-type Woodward Dolerite has initial εNd = +5 falling on the growth curve of the depleted convecting mantle. In contrast, LREE-enriched basalts and basic intrusives of the Hart Dolerite and Lamboo Complex showing depletion of Nb and Ti have εNd = 0 to -2. These suites may be derived by either melting of ancient enriched mantle or interaction of magma derived from depleted convecting mantle with Archaean crust and/or lithosphere. Significantly, both imply the existence of Archaean crust and lithosphere in this area.

MID-PROTEROZOIC ARGYLE (AK1) LAMPROITES

The richly diamondiferous Argyle lamproite pipe (Atkinson et al., 1984) intrudes the mid-Proterozoic sediments of the Halls Creek Mobile Zone. The pipe is composed of three main lithologies: largely vitric, essentially monogenetic lapilli tuffs (NST = "non-sandy tuffs"); polygenetic lapilli ash tuffs and ash tuffs (ST = "sandy tuffs") with abundant accidental quartz; and olivine (-phlogopite) lamproite dykes (OPLD).

An emplacement age of 1178 Ma is estimated for the Argyle pipe by a Rb-Sr mineral isochron defined by phlogopite and the heavy mineral fraction (dominated by apatite) from an OPLD sample. The phlogopite has $^{87}Sr/^{86}Sr$ = 0.92114 ± 6 and $^{87}Sr/^{86}Sr$ = 12.701. The heavy mineral fraction has $^{87}Sr/^{86}Sr$ = 0.70645 ± 6 and $^{87}Rb/^{86}Sr$ = 0.0114. The sample has $^{87}Sr/^{86}Sr$ and εNd initial ratios of 0.7063 and -5.3 respectively at 1178 Ma. Whole rock Rb-Sr isotope data of OPLD and clasts from "sandy-tuffs" are consistent with this age of 1178 Ma; whereas "non-sandy tuffs" of AK1 pipe give younger Rb/Sr ages which suggest a younger disturbance.

NST samples have εNd values - 3.6 to -4.0 at 1178 Ma consistently higher than εNd values obtained for the OPLD (-4.6 to -5.3). One clast from a ST analyzed has an εNd value similar to that of the OPLD. Nd isotope data suggest that OPLD and NST were derived from slightly different mantle sources or by a different magma generation processes such as different degree of partial melting and varying degrees of wall rock reaction. Sm-Nd model calculation suggest that these lamproites were derived from enriched mantle sources of probably early proterozoic or posssibly late Archaean age.

LATE PROTEROZOIC CUMMINS RANGE CARBONATITE

The Cummins Range carbonatite (Andrew et al, this volume) is located some 350 km SW of Argyle at the intersection of the Halls Creek Mobile Zone and King Leopard Mobile Zone. A Rb-Sr mineral isochron based on an apatite-phlogopite pair gives an

age of 905 ± 2 Ma. Carbonatite sampels analyzed have low but variable $^{87}Sr/^{86}Sr$ initial ratios ranging from 0.7028 to 0.7032 suggesting crustal contamination may be responsible as inferred from other studies of carbonatite intrusives. The three samples studied have similar εNd initial ratios (+1.6 to 2.4). These Nd and Sr isotope initial ratios are typical of carbonatites of world-wide occurrences and suggest that Cummins Range carbonatite is likely to be derived from ocean island basalt (OIB) type source originated from within the depleted convecting mantle.

LATE PROTEROZOIC MICACEOUS LAMPROPHYRE DYKES OF BOW HILL

Bow Hill lamprophyre dyke swarm (Atkinson et al., 1984; Fielding and Jaques, this volume) is located some 22 km west of the Argyle pipe. Preliminary Rb/Sr and Sr isotope data of whole rock samples with $^{87}Sr/^{86}Sr$ initial ratio (0.7057) defined by a clinopyroxene give an age of 900 Ma. Four Bow Hill samples analyzed have εNd initial ratios about +2.0. Similar to Cummins Range carbonatite.

MIOCENE (20 Ma) LAMPROITES OF THE WEST KIMBERLEY REGION

Lamproites from this region show a large range of variation in εNd and $^{87}Sr/^{86}Sr$ initial ratios: εNd from -7.4 to -18.9 and $^{87}Sr/^{86}Sr$ from 0.7104 to 0.7208 (McCulloch et al., 1983; Fraser et al., 1985; this study). On the εNd versus $^{87}Sr/^{86}Sr$ plot, olivine lamproites, chemically similar to micaceous kimberlites, define a field of εNd (-7.4 to -13.8) and $^{87}Sr/^{86}Sr$ initial ratios (0.7104 to 0.7123) which is distinct from the leucite lamproites (εNd = -10.2 to -18.9 and $^{87}Sr/^{86}Sr$ = 0.7123 to 0.7208). At the same εNd value leucite lamproites have higher $^{87}Sr/^{86}Sr$ initial ratios. Such difference could be interpreted in terms of mixing of two mantle components - mixture of enriched and depleted components within the non-convective lithosphere (e.g., McCulloch et al., 1983; Jaques et al., 1984) or mixing of the enriched lithosphere with the relatively depleted convecting mantle. In either model the olivine lamproites contain a larger amount of material from the depleted convecting mantle. Only minor isotopic heterogeneity was observed among samples from individual pipes except at Ellendale 7 where olivine lamproites (εNd = -7.6 and $^{87}Sr/^{86}Sr$ = 0.7104) and leucite lamproites (εNd = -15.4 and $^{87}Sr/^{86}Sr$ = 0.7168) occur in the same pipe.

DISCUSSION

The oldest exposed rock in the Kimberley Block is of early Proterozoic age (about 2000 Ma). However, Nd isotope data of Early Proterozoic mafic-ultramafic volcanics and clastic sediments from the Halls Creek Mobile Zone suggest the existence of Archaean continental crust and lithosphere in this region.

Chemical data of lamproites from Argyle and west Kimberley (Jaques et al., 1984; and this volume) suggest that these lamproites were derived from a strongly depleted refractory mantle source (poor in Al, Ca, Na, V, Y and Sc) which was subsequently enriched in incompatible elements.

Modelling of Sr, Nd and Pb isotope data of Miocene lamproites from west Kimberley (Fraser et al., 1985; Nelson et al., 1986) suggest that they were derived from ancient ($\geq$2000 Ma) enriched mantle sources or at least contained an ancient enriched component.

Calculation of the Sm-Nd evolutionary trajectories of the source regions for the Miocene lamproites at 1178 Ma (the age of the Argyle pipe) gives εNd (1178 Ma) values about +2 for the olivine lamproites with relatively high εNd (-7.8 at 20 Ma); whereas most other olivine and leucite lamproites (εNd = -12 to -15 at 20 Ma) give εNd (1178 Ma) values of -3 to -5. These latter values are similar to the initial ratios of AKl lamproites at that time, consequently mantle sources for lamproites of different ages from east and west Kimberley could have been formed at about the same time and by similar processes. Combined chemical and isotopic data of these lamproites can be best explained by reactivation of the enriched but formerly refractory continental lithosphere formed during early pre-cambrian.

The fundamentally different isotopic characters observed in the Cummins Range carbonatite and Bow Hill dykes of late Proterozoic ages indicate distinctly different magma sources to the lamproite magmas. Carbonatites are generally associated with

lithospheric rifting which could have lead to tapping of deeper convecting mantle as major magma sources.

In conclusion, we consider that the Kimberley craton has developed a thick refractory lithosphere in the early pre-cambrian following extensive subalkaline magma extraction. The timing of the initial enrichment of the subcontinental lithosphere since late Archaean is not well constrained, but it could be partly related to the rifting and magmatism associated with the formation of the early proterozoic Halls Creek Mobile Zone. Subsequent alkaline magmas represent small volume melts extracted from zones of enrichment in this refractory lithosphere at depth of diamond stability (lamproites) or result from direct input from the convecting mantle (carbonatites and Bow Hill lamprophyre). Enrichment of the lithosphere may be due to a number of processes including lithosphere subduction and/or mantle metasomatism and could have resulted from discreet events(s) or continuous processes since the Archaean.

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