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Early-Middle Jurassic mafic dykes from western Dronning Maud Land (Antarctica): Identifying mantle sources in the Karoo large igneous province

T.R. RILEY[1], P.T. LEAT[1], M.L. CURTIS[1], I.L. MILLAR[1] AND A. FAZEL[2]

[1] British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK (t.riley@bas.ac.uk; p.leat@bas.ac.uk; m.curtis@bas.ac.uk; ilm@bas.ac.uk)

[2] Department of Earth Sciences, Open University, Milton Keynes, MK7 6AA, UK (A. Fazel@open.ac.uk)

Dolerite dykes in the Ahlmannryggen region of western Dronning Maud Land (Antarctica) form part of the wider Karoo igneous province. The composition of the dykes provides the strongest geochemical evidence to date that the province was, at least in part, related to the arrival of a mantle plume. The dyke compositions extend the geochemical limits of the Karoo volcanic province and include low- and high-Ti magma types, which incorporate both picrites and ferropicrites. Provisional geochronology on the dykes indicate a Mesozoic age peak at 178 Ma, with additional smaller peaks at 187 and 198 Ma. Proterozoic peaks have also been identified in the range 750 – 1100 Ma. Four chemical groups have been identified in the Ahlmannryggen region based on ~ 90 dykes and sills. The groups are defined on the basis of TiO_2 and Zr contents, but are reinforced by rare earth elements, $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$. Group 1 is interpreted to be largely Neoproterozoic in age, whilst groups 2 – 4 are Mesozoic. Group 1, low TiO_2-Zr dykes overlap in composition with the ~1000 Ma Borgmassivet Intrusives, with the exception of four dykes that are distinct to the other Proterozoic intrusive rocks and overlap with the low-Ti, Kirwanveggen lavas, which are Middle Jurassic in age. Group 2 rocks have moderate TiO_2-Zr contents and are interpreted to be the result of mixing between plume-derived melts and continental crust. Group 3 rocks form the most distinct magma group and are largely picritic with E-MORB-like chemistry (high TiO_2, Zr, flat REE patterns, $^{87}Sr/^{86}Sr_i \sim 0.7038$, $\varepsilon Nd_i \sim 8$). The E-MORB-like magmas of group 3 are derived from deep-seated (garnet stability) depleted mantle. The group includes several high Mg-Fe dykes (ferropicrites), which are interpreted as melts of Fe-rich streaks in a mantle plume starting head. Initial geochronology suggests that the ferropicrites are significantly older at 198 Ma than the main Karoo peak. Group 4 is the most enriched magma group with OIB-like chemistry and is dominated by picrites. Magma groups 3 and 4 are interpreted as representing the depleted and enriched components of a mantle plume.

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Nd, Sr and Pb isotopic and trace element data support a subduction origin for the Dufek layered mafic intrusion, Antarctica

S.B. MUKASA AND A.V. ANDRONIKOV

Dept Geological Sciences, University of Michigan, Ann Arbor, MI 48109-1063 (mukasa@umich.edu)

Mantle plumes provide an attractive and plausible mechanism for the break-up of supercontinents and the often contemporaneous, and short-duration, generation of voluminous magmas in large igneous provinces (LIPs). Therefore, such a mechanism is being debated at present for the origin of the Dufek layered mafic intrusion and associated lavas of the Ferrar Magmatic Province (FMP), both in the Transantarctic Mountains, Antarctica, and with the Shona, Bouvet and Discovery hotspots implicated as the possible culprits. Emplacement occurred in the mid-Jurassic during fragmentation of the supercontinent Gondwanaland.

Plagioclase and pyroxene separated from various rock types from the intrusion have initial $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$ and Pb isotopic ratios that exhibit a wide range (e.g., $^{87}Sr/^{86}Sr$ = 0.70609 ±2 to 0.71656 ±1; $^{143}Nd/^{144}Nd$ = 0.51213 ±1 to 0.51233 ±4; and $^{207}Pb/^{204}Pb$ = 15.544 to 15.873). These ratios can vary both between one mineral type in different rocks and between different mineral types in the same rock. Differences between minerals in the same rock become more pronounced towards the top of the intrusion, explicable by the assimilation of a small amount of the area's Precambrian to Permian metasedimentary rocks. Even for samples exhibiting the least upper crustal contamination, there is little overlap between the isotopic ratios for the Dufek intrusion (and associated volcanic rocks) and those for the hotspots with which the intrusion has been linked.

Chilled margins of FMP dikes and sills near the Dufek intrusion have primitive-mantle-normalized trace element abundance patterns nearly identical to those of Bushveld parental magmas and West Pacific boninites. These characteristics are best explained by having a magma source of once-melted harzburgitic mantle subsequently enriched in large ion lithophile elements by subduction processes. While it is possible that a plume close by destabilized an already weakened East Antarctic cratonic margin causing further thinning of the Antarctic lithosphere, and hence promoting decompressional melting of the upper mantle, the geochemical evidence does not support magma production for the FMP directly from a plume. The upper mantle source region probably acquired the subduction signature exhibited by the Dufek intrusion and lavas in its immediate vicinity during Paleozoic and Mesozoic subduction along the proto-Pacific margin of Gondwanaland.