Lithosphere Thickness Control on the Extent and Pressure of Mantle Melting Beneath Intraplate Ocean Islands

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Summary
We have examined island-averaged geochemical data for 115 volcanic islands with known eruption ages and ages of the underlain lithosphere from the Pacific, Atlantic and Indian oceans. These age data allow calculation of the lithosphere thickness at the time of volcanism. After correcting the basaltic (and the alkaline varieties) for fractionation effect to Mg# = 0.72, we found that the island-averaged Sr/Ni and Sr/Y ratios increase with increasing lithosphere thickness. The island-averaged [La/Sr]N and [Sm/Yb]N ratios also increase with increasing lithosphere thickness. The correlations of these petrologic parameters with lithosphere thickness become outstanding when the data are averaged into each of the ten distribution intervals regardless of ocean basins and geographic locations. These correlations of these petrologic parameters with lithosphere thickness become outstanding when the data are averaged into each of the ten 10-km lithosphere thickness intervals regardless of ocean basins and geographic locations. These correlations are most consistent with the interpretation that the extent of melting decreases whereas the pressure of melting increases with increasing lithosphere thickness. This is physically consistent with the active role of the lithosphere plays in limiting the final depth of intra-oceanic mantle melting (i.e., the lid effect). This is, beneath thin lithosphere, a parcel of mantle rises to a shallow level, and thus melts more by decompression with the aggregated melt having the property of low extent and high pressure of melting. By contrast, a parcel of mantle beneath thick lithosphere has restricted amount of upwelling, and thus melts less by decompression with the aggregated melt having the property of high extent and low pressure of melting. This finding confirms the earlier suggestions that oceanic lithosphere thickness variation exerts the primary control on the chemistry of ocean island basalts (OIB). Variation in initial depth of mantle melting as a result of fertile mantle compositional variation and mantle potential temperature variation can influence OIB compositions, but these must have secondary effects because they overshadow the effect of lithosphere thickness variation that is prominent on a global scale.

Figure 1. Island groups: 1, Amsterdam-St. Paul (2); 2, Ascension (1); 3, Austral-Cook (12); 4, Azores (10); 5, Balleny (2); 6, Bouvet (1); 7, Cameroon Line (5); 8, Canary Islands (8); 9, Cape Verde (10); 10, Caroline (10); 11, Cocos (12); 12, Comores (9); 13, Crozet (4); 14, Deception (3); 15, Desventuradas (1); 16, Easter seamount; 17, Faito-Rongai-Norther; 18, Galapagos (23); 19, Gough channel; 20, Good Father; 21, Hawaiian (12); 22, Heard (1); 23, Iceland (4); 24, Juan Fernandez (1); 25, Juan Fernandez (2); 26, Kerguelen (7); 27, Line Island Chain (1); 28, Macquarie (1); 29, Madeira (1); 30, Marion (1); 31, Macquarie (12); 32, Martin Vos (1); 33, Mascarene (1); 34, Mauritius (1); 35, Mid-Atlantic Ridge (6); 36, Pitter Island (1); 37, Picoa; 38, Prince Edward (1); 39, Reunion (1); 40, Reunion Ridge (4); 41, Ross Island (1); 42, Sargasso (11); 43, Seychelles (2); 44, Society (10); 45, St. Helena (1); 46, Swallow (1); 47, Tristan da Cunha (5); 49, Tristan da Cunha (1). On diagram; island chain marked with red circle and number. Islands chains given in alphabetical order and number of islands associated with that chain in brackets. Map courtesy of http://chuma.ca/cas.usf.edu/~juster/volc1/world%20map.gif

Figure 2. Plots of global OIB petrologic parameters as a function of lithosphere thickness at the time of active OIB volcanism. These parameters include major element oxides (SiO2, TiO2, Al2O3, FeO, MgO and P2O5 in weight percent) corrected for fractionation effect to Mg# = 0.72 (denoted by subscript 72) and rare earth element ratios (La/Sm and Sm/Yb) normalized to chondrite values (denoted by subscript N) averaged within 10-km lithosphere thickness intervals regardless of ocean basins and geographic locations.

References
[1] MPI GEOROC data database (http://georoc.mpch-mainz.gwdg.de/georoc/)