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PETROLOGY, GEOCHEMISTRY AND GEOCHRONOLOGY OF VOLCANIC ROCK SUITES OFTHE DODOLA AREA, SOUTHEASTERN ETHIOPIA

by

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The Dodola area is located in the southeastern Ethiopian plateau, and is built of two co-existing bimodal alkaline magma series. This includes the Late Oligocene Lower (pre-rift) basanite-phonolite lineage and the Mid Miocene-Late Pliocene Upper (rift-type) basanite/alkali basalt-trachyte/rhyolite lineage. The rocks are fairly porphyritic to aphyric; the essential minerals are olivine, clinopyroxene, and plagioclase in the mafic lavas, and feldspars, clinopyroxene, and titanomagnetite in the salic lavas with minor apatite and ilmenite in some rocks. The petrological and geochemical data imply that fractional crystallization is the major process responsible for the evolution of both lava series. Major element chemistries display features agreeable with extraction of olivine, clinopyroxene, and plagioclase from mafic magmas followed by feldspars, titanomagnetite, and apatite from felsic ones. The chondrite-normalized REE patterns show gentle to moderate slopes and small positive Eu-anomalies in mafic and intermediate lavas (plagioclase accumulation) and strongly negative Eu-anomalies in felsic lavas (feldspar fractionation). Primitive mantle-normalized profiles of felsic rocks verify fractionation of plagioclase, clinopyroxene, apatite, and titanomagnetite. Moreover, the reverse zoning in olivine and feldspars and inverse/oscillatory zonation in clinopyroxene are attributed to minor mafic magma mixing.

In the Upper series, the lavas mainly demonstrate initial Sr and Nd ratios of 0.70344–0.70441 and 0.51280–0.51265, respectively and positive epsilon Nd values. In the Lower series, $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of 0.70395–0.70398 and 0.51276–0.51270 were measured on mafic rocks and 0.70450–0.70663 and 0.51271–0.51268 on the phonolites, respectively. The strong similarities in Sr and Nd isotopic compositions of these lavas to basalts from western Ethiopia, the Afar, main Ethiopian rift, and Salali (Kenya) evidently suggest the existence of similar mantle beneath Ethiopia and Kenya. The mafic lavas show within-plate continental volcanic province. The fact that the Sr and Nd isotopic signatures and trace element abundance patterns of the rocks are closely similar to those of OIBs reinforces the assumption that they are derived from mantle plume. For a few felsic lavas, little crustal contamination and prolonged fractionation might have modified this distinct OIB geochemical characteristic.

In the Upper series, major element modelling using mass balance calculation reveals that removal of 87% olivine-clinopyroxene-plagioclase-titanomagnetite yields 13% hawaiite melt from basanitic magma. Taking the maximum enrichments of 4, 3.2, 3, and 2 respectively, for Rb, Nb, Zr, and Y, a trachyte melt obtained when the remaining melt (F) was 28%. In the Lower series, major element modelling indicates that extraction of 61 wt.% olivine-clinopyroxene-plagioclase-titanomagnetite produces 39% phonotephrite melt from basanitic magma. Fractional crystallization is further tested considering enrichments of 3, 2.7 and 2.4 respectively, for Rb, Nb, and Zr; and a phonotephrite residual formed when F was 36%.

Therefore, from all the available indications, it is concluded that the Dodola volcanics represent cogenetic suites, which possibly differentiated through repeated magmatic activities from OIB-type common 'picritic' ancestral magma (s) by means of low-pressure crystal fractionation, with less than 10 Ma repose period between the two major episodes.