Geochemistry of Cenozoic basalts in the southern Ethiopian Rift: Implications for evolution of the East African Rift System

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The Ethiopian rift valley, cutting across the uplifted Ethio-Somalia plateau, is part of the great East African intraplate continental rift system. The rift system, having NNE-SSE trend, is connected with the Red Sea and Gulf of Aden oceanic spreading centers through the Afar triple junction in the north, and with the Kenya rift by the broad rift zone of the so-called Turkana depression in the south. Woldegabriel et al. (1990) proposed that the Ethiopian rift valley resulted from mantle upwelling that produced both crustal doming and volcanism. The southwestern Ethiopian basalts are erupted in three major episodes: (1) the pre-rift transitional tholeiites (45-35 Ma) followed by (2) the syn-extensional alkali basalts (19-11 Ma), and (3) the most recent post-rift highly alkaline basalts (e.g., Ebinger et al., 1993; Stewart et al., 1996; Yemane et al., 1999).

The investigated area is situated within the eastern part of the broad rift zone (Turkana depression), between the Ethiopian and Kenya plateaus that can be linked to the Afar and Kenyan mantle Plumes, respectively. We present major and trace element analyses for a suit of basalts (MgO more than 4 %) in this region. Samples have compositions extended from transitional-tholeiite in the Bulal-Elweya area through alkali basalts and hawaiies in Sarite area to more alkaline, basanites-dominated post-rift lavas in the Mega area. These series of rocks appear to correspond to the above mentioned three magmatic activities in the southwestern Ethiopia. All groups are distinct in trace element compositions and highly incompatible element ratios, suggesting the involvement of at least two different mantle sources. The transitional tholeiites have relatively higher Zr/Nb (7.7-8.8), K/Nb (140-191), Ba/Nb (12.0-25.8), Ce/Nb (2.0-2.55) and Ba/Th (100-399), whereas the Sarite alkali basalts and Mega basanites have lower Zr/Nb (4.1-4.3, 2.9-3.9), K/Nb (100-126, 23-122), Ba/Nb (6.7-9.9, 7.0-10.3), Ce/Nb (1.20-1.37, 1.0-1.4) and Ba/Th (98-275, 93-190), respectively. Although the primitive mantle normalized patterns of all groups are broadly OIB-like, distinctive features for these rock suites are apparent. The transitional tholeiites (Bulal-Elweya basalts) show a marked positive anomaly of Ba relative to other LILE and less enrichment of HFSE (e.g. Nb). This pattern in addition to their higher LILE/HFSE ratios is a notable feature for EM I-type source. The significant enrichment of highly incompatible HFSE (e.g. Nb) relative to the LILE and LREE and the relatively low LILE/HFSE ratios in the Sarite and Mega volcanics denote the involvement of HIMU OIB-type source in their genesis. Moreover, the relatively lower Pb/Ce (0.01-0.05) of the Sarite and Mega lavas than the Bulal-Elweya transitional tholeiites (0.04-0.11) supports their derivation from HIMU-type source, as HIMU sources have generally lower Pb/Ce than in EM-type sources (Weaver, 1991).

Previous trace element and isotope studies have proposed a HIMU OIB signature for the Afar mantle plume (e.g., Vidal et al., 1991; Daniel et al., 1994), which can be the possible contributing source for the HIMU component of the Sarite and Mega lavas. The EM type source exhibited by the transitional tholeiites may derived either from the enriched sub-continental lithospheric mantle or a mixture of the plume and lithosphere.