Genesis and timing of ignimbrites (Alaji ignimbrites) associated wirh trap basalts from the northern Ethiopian plateau

A. Dereje — CRPG-CNRS, B.P. 20, 54501 Vandoeuvre Les Nancy, France and Geol. & Geophys. Dept., AAU, P.O. Box 1176, Addis Ababa, Ethiopia

B. Marty, P. Barbey — CRPG-CNRS, B.P. 20, 54501 Vandoeuvre Les Nancy, France

Y. Gezahegn — Geol. & Geophys. Dept., AAU, P.O. Box 1176, Addis Ababa, Ethiopia

L. Reisberg, R. Pik — CRPG-CNRS, B.P. 20, 54501 Vandoeuvre Les Nancy, France

The northern Ethiopian traps (30 Myr) are thought to be related to the arrival of a mantle plume (Afar plume) and the break-up of the continental crust (Red sea, Gulf of Aden and Ethiopian rift). These traps display a strongly bimodal basalt-rhyolite association, but the basalts being dominant over the rhyolites in volume (4: 1). The explosive mode of eruption and the large volume of Alaji ignimbrites suggest that they had a very important effect on the environment at the time of their formation.

The acidic rocks, termed as the Alaji formation, are common in the upper part of the volcanic succession. They are composed essentially of ignimbrites with subordinate obsidian flows. The ignimbrite formations are usually several hundred meters in thickness (<500 m), but are much thinner in the south (<1 m).

Systematic sampling of acidic rocks from the northern Ethiopian plateau showed that these rocks are dominantly rhyolites with a few trachytes. They display weakly peralkaline affinities and can thus all be described as comendites. Three types of geographically and chemically distinct rhyolites are recognized:

(1) The Lima Limo rhyolites (30 ± 0.2 Myr; Ar-Ar plateau age) that crop out in the NW part of the plateau are intercalated within the low-Ti basalts. They are characterized by high ratios of Zr/Nb (15–17) and La/Nb (1.7–2.5) and low Ce/Pb (7.5–8.7) ratios. They also possess negative anomalies in Th, Nb and Ta. The initial $^{87}Sr/^{86}Sr$ ratios (0.704–0.707) are more radiogenic and the initial $^{143}Nd/^{144}Nd$ ratios (0.5126–0.5128) less radiogenic than those of the associated low-Ti basalts. The $\delta^{18}O$ values (+8.7 to +9.2) are relatively high. The chemical and isotopic data indicate that the Lima Limo rhyolites were produced either by partial melting of lower crustal materials or by concomitant crustal assimilation and crystal fractionation from the associated low Ti-basalts.

(2) The Wegel Tena rhyolites (28.9 ± 0.2 Myr; Rb-Sr isochron age) form the main part of the ignimbrite pile and crop out in the eastern sector of the plateau close to the rift margin. They overlie the basalts, which are of high-Ti affinity in this region. They have trace element ratios, such as Zr/Nb (7–8.5), La/Nb (0.8–1.4) and Ce/Pb (10–25), and $\delta^{18}O$ (+5.5 to +7.0) which are in the range expected for rhyolites derived from basalts. (One exceptional sample has $\delta^{18}O = +4.7$, which may reflect minor incorporation of hydrothermally altered material.) The initial $^{87}Sr/^{86}Sr$ ratios (0.7046) are slightly more radiogenic than those of the associated coeval basalts whereas the initial $^{143}Nd/^{144}Nd$ ratios (0.5128) are similar to the basaltic values. The Wegel Tena rhyolites are thought to be produced from mantle derived basalts by fractional crystallization accompanied by small amounts of crustal contamination.

(3) The Debre Birhan rhyolites (Miocene), located south of the Wegel Tena rhyolites, are more differentiated and have very low Sr concentrations (<10 ppm) reflecting plagioclase removal. They have trace element ratios, such as Zr/Nb (8–8.9), La/Nb (<1) and Ce/Pb (9–17), that are typical of rhyolites derived from basalts by fractional crystallization. The $\delta^{18}O$ values are within the mantle range (+5.6 to +6.0). The initial $^{87}Sr/^{86}Sr$ ratios (0.706) are more radiogenic than those of mantle-derived basalts. This probably results from very small amounts of crustal contamination, which can produce a large effect on

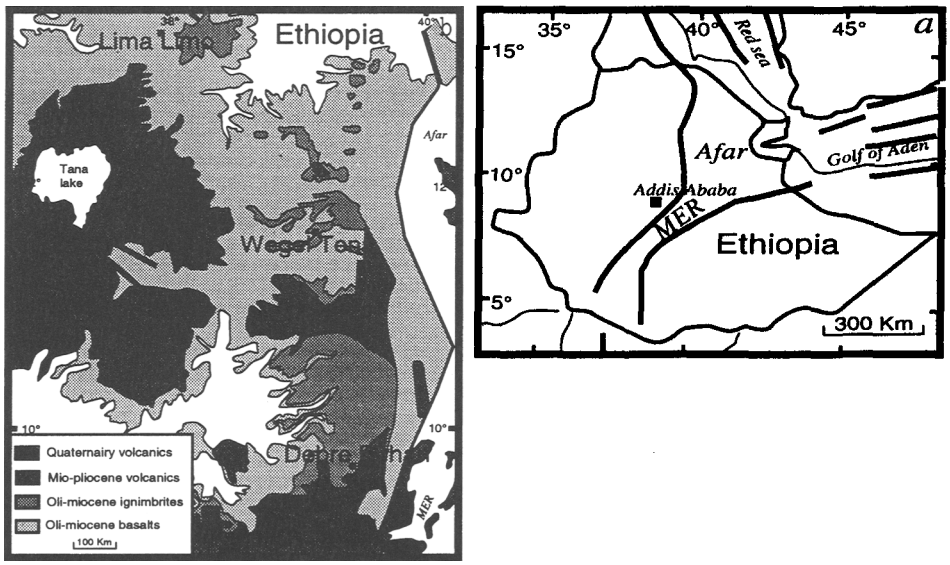

FIG. 1. (a) Location map of the triple junction (Red Sea), Gulf of Aden and Ethiopian rift). (b) Geological sketch map of the northern Ethiopian plateau showing the distribution of the main lithologies and location of the three ignimbrite units (Lima Limo, Wegel Tena and Debre Birhan).

Sr isotopic ratios for low Sr rhyolites. The $^{143}Nd/^{144}Nd$ ratios (0.5127) are somewhat low. (No data are available for the associated basalts.) This may imply that the Debre Birhan rhyolites were derived by assimilation-fractional crystallization of depleted basaltic magma, though the oxygen and trace element data argue that any crustal assimilation was minor. Alternatively the low Nd isotopic ratios may indicate that the source of the parental basaltic magma was somewhat enriched.

The acidic rocks from the northern Ethiopian plateau are thought to be produced from the associated mantle-derived basaltic magmas through combined assimilation and fractional crystallization processes. They were extruded just after the main phase of basaltic trap emplacement.

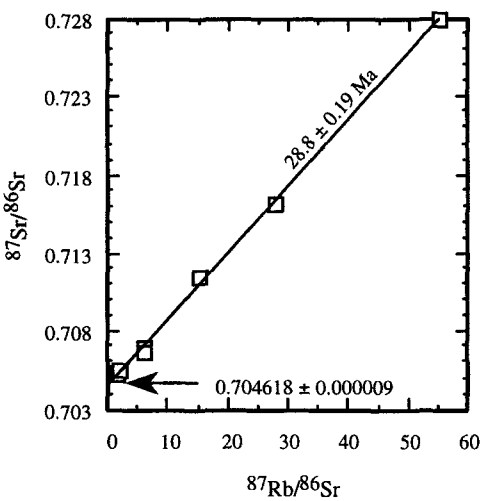

FIG. 2 Rb-Sr isochron formed by ignimbrites from the Wegel Tena unit that is associated with the high-Ti basalts. The age of these ignimbrites is 28.8 ± 0.19 and initial $^{87}Sr/^{86}Sr$ ratio is 0.704618 ± 0.000009.