

Chemical and isotopic variations in volcanic rocks from the Rungwe Province: Constraints on the development and scales of source heterogeneity beneath the African Western Rift

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Introduction

The chemical and isotopic compositions of volcanic rocks erupted in continental rifts reflect contributions from the asthenosphere, the continental lithospheric mantle, and the continental crust. In particular, enriched or metasomatized subcontinental lithosphere may be an important source for alkaline mafic volcanism (Lloyd and Bailey, 1975; Hawkesworth *et al.*, 1990; Rogers *et al.*, 1992); however, the chemical composition of this reservoir is not well characterized and is likely to be spatially heterogeneous. Both experimental and petrological evidence suggests that small volume CO₂- and/or H₂O-rich magmas can affect the chemistry and mineralogy of the

subcontinental lithosphere, both on regional and local (vein) scales (Wass and Rogers, 1980; Lloyd *et al.*, 1985; Green and Wallace 1988; Harte *et al.* 1993). The migration of volatile-rich mafic silicate melts may produce significant fractionation in trace elements pairs such as Rb-Sr, Sm-Nd and (U+Th)-Pb (Hawkesworth *et al.*, 1984). Heterogeneous and extreme isotopic signatures can potentially develop in metasomatized lithosphere if it remains tectonically stable for time periods of 100 million years or more. Alkaline rocks from continental rift settings can thus provide a window into the nature of interactions between lithospheric and asthenospheric sources. In this study we present the results of geochemical and Pb, Sr, Nd and He isotope analyses of alkaline lavas from the Rungwe province in the western branch of the East African Rift, designed to identify and characterize the chemical signatures of the contributing source regions.

Geochemistry of Rungwe mafic lavas

The Rungwe province is the southernmost of the four volcanic areas of the Western Rift. Rungwe contains five major trachyte-phonolite shield volcanoes located between border faults, and numerous satellite explosion craters aligned along NW-SE trending fractures (Fig. 1). Samples analyzed in this study are representative of each of the major volcanic centres, ranging in age from 8.4 million to historical time (Ebinger *et al.*, 1989; Furman submitted). Mafic lavas from the Rungwe province include alkali basalts, basanites and nephelinites with up to 12 wt.% MgO. The distribution of rock types is geographically controlled to a large extent; for example, the degree of silica undersaturation in mafic lavas increases from northwest to southeast. Nephelinites are found almost exclusively at Kiejo while basanites are abundant at Tukuyu. The disconti-

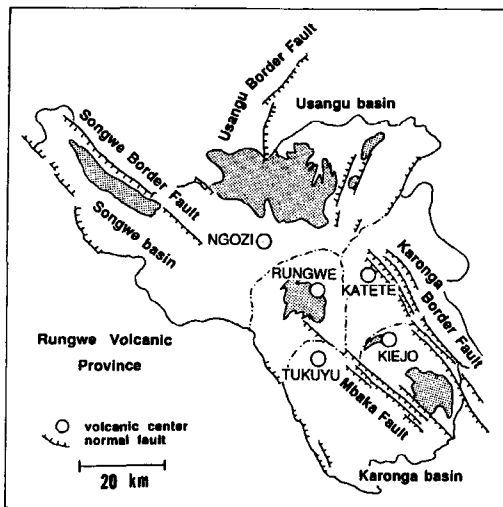


FIG. 1. Map of the Rungwe volcanic province modified after Ebinger *et al.* (1989). Areas of volcanism are outlined, and Holocene lavas are shaded.

nity between Kiejo nephelinites and Tukuyu basanites occurs at the Mbaka transfer fault. Alkali basalts are present in lesser amounts at each volcano except at Ngozi where they are the dominant mafic lava.

Compared to ocean island basalts Rungwe lavas are enriched in all highly incompatible trace elements except Cs, Rb, and K, and show enrichments of REE relative to HFSE. Nephelinites are characterized by higher abundances of incompatible trace elements compared to alkali basalts and basanites of similar MgO content. Many incompatible trace elements (P, REE, Y, Th, Ba) correlate negatively with MgO among nephelinites but positively with MgO among alkali basalts and basanites. Some incompatible trace element ratios, such as Zr/Nb, Ba/Rb and Sr/Ce, have constant values throughout the range of mafic lava types. Other ratios, such as Ba/Nb and La/Nb, vary by a factor of 2 or more within each mafic lava group, and preclude derivation of the Rungwe suite from a homogeneous source. The Rungwe source is best characterized as metasomatized garnet peridotite which contains minor amounts of apatite, zircon, amphibole and ilmenite (Furman, submitted). The accessory phases influence the trace element geochemistry of liquids derived by very small degrees of melting, especially that of the mafic nephelinites. The pattern of trace element enrichment observed in the Rungwe lavas suggests the source was metasomatized by carbonatite magma.

Pb-Sr-Nd-He isotope variations at Rungwe suggest the involvement of at least three end-members, two located in the mantle and/or lithosphere and one possibly located in the crust. There are no simple relationships between isotope compositions and rock type, although nephelinites range to higher $^{206}\text{Pb}/^{204}\text{Pb}$, and alkali basalts have consistently lower $^{206}\text{Pb}/^{204}\text{Pb}$ than either basanites or nephelinites. $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}\text{Nd}/^{144}\text{Nd}$ of the mafic Rungwe rocks are negatively correlated, and lie slightly above the East African carbonatite line (Bell and Blenkinsop, 1987) and the extension of the Sr-Nd correlation for kimberlitic diopsides from South Africa (Menzies and Murthy, 1980). $^{87}\text{Sr}/^{86}\text{Sr}$ ranges from 0.7046 to 0.7055 and ϵNd from -0.4 to -4.5 in the mafic lavas, similar to the range for lavas and xenoliths from the Katwe-Kikorongo field in the northern part of the Western Rift (Davies and Lloyd, 1989). This suggests that widespread (> 1000 km) regional enrichment of the subcontinental lithosphere may have occurred. Two trends are observed on the $^{208}\text{Pb}/^{204}\text{Pb}$ - $^{206}\text{Pb}/^{204}\text{Pb}$ diagram for Rungwe lavas. These trends suggest the involvement of at least three components. One

component may be an asthenospheric source which has relatively radiogenic Pb ($^{206}\text{Pb}/^{204}\text{Pb} > 18.9$) and upper mantle He ($^3\text{He}/^4\text{He} \cong 9 R_A$), as measured for a nephelinite from Kiejo. Lavas having lower $^{206}\text{Pb}/^{204}\text{Pb}$ ratios and located on the 'high' $^{208}\text{Pb}/^{204}\text{Pb}$ trend include a nephelinite from Kiejo ($^3\text{He}/^4\text{He} < 6 R_A$), two alkali basalts from Ngozi, and all of the evolved lavas analyzed to date (phonolite, trachyte and trachybasalt). These same lavas also have unusually high Rb abundances, suggesting either an enriched lithospheric source or some influence of crustal contamination. Samples with less radiogenic $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ may have either a lithospheric or shallow, enriched mantle origin. Oxygen and helium isotope work is underway to further delineate these components.

Summary

The incompatible trace element abundances of Rungwe mafic lavas require melting of an enriched and metasomatized peridotite source. Lavas of varying degree of silica saturation and erupted from a single volcano also appear to have experienced different degrees of interaction with the crust. At the same time, the helium isotopes measured in olivine and clinopyroxene phenocrysts suggest an asthenospheric contribution to magmatism in the Western Rift. Heterogeneities in trace element and isotope composition and, by inference, in minor phase mineralogy of the source regions, occur at scales of 10 km or less, similar to that beneath the Katwe-Kikorongo field in southwest Uganda (Davies and Lloyd, 1989) and beneath the Virunga province (Rogers *et al.*, 1992; Williams and Gill, 1992).

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