

## Partial melting of fenitized crustal xenoliths in the Oldoinyo Lengai carbonatitic volcano, Tanzania: Discussion

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### ABSTRACT

Morogan and Martin (1985) have proposed that the alkalic carbonatite lavas (natrocarbonatite) of Oldoinyo Lengai were produced by partial melting of a regionally fenitized basement to generate two conjugate immiscible liquids: the carbonatite and the associated silicate lavas. The proposed origin is not viable. The existence of a regionally fenitized basement has not been established nor is it likely, certainly not by the method proposed. Immiscibility is restricted to systems with alkali carbonates, and so even if a regionally developed fenite composed of nepheline + alkali feldspar + clinopyroxene + calcite did exist, it would not produce alkali-rich carbonatite melt and phonolite magma as conjugate liquids. The high F and Cl contents of the carbonatite lava have no obvious source in the alleged fenite basement, nor can the high concentrations of Nb, REEs, Sr, Ba, Th, Pb, or U be explained in this way. Sr- and Nd-isotope values are generally consistent with a mantle origin and offer little support for derivation from Archean basement. The alkalic carbonatite lavas of Oldoinyo Lengai cannot have been formed by partial melting of fenite.

### INTRODUCTION

The unusually alkalic carbonatite lavas of Oldoinyo Lengai volcano in Northern Tanzania have fascinated petrologists for more than 20 years. Two main schools of thought have emerged. One, led by Le Bas (1981, 1987) and Woolley (1982) and based largely on the experimental work of Freestone and Hamilton (1980), contends that the alkalic carbonatite magma (commonly referred to as natrocarbonatite) developed as an immiscible liquid that separated from either carbonated nephelinite or phonolite or from both. The other, led by Gittins, contends that such highly alkalic carbonatite magma is a late derivative developed by fractional crystallization of a more primitive, alkali-poor olivine sovite magma. The latter group sees the alkalic carbonatite magma as one that requires particular conditions to form (probably F-rich and water-deficient parental magma) and so forms rather rarely. Le Bas (1981), in contrast, sought to elevate the alkalic carbonatite magma to a parental status from which all other carbonatite magma can be derived through alkali loss. The debate is laid out in Twyman and Gittins (1987).

### THE MOROGAN AND MARTIN SCHEME

A new and novel variant was introduced recently by Morogan and Martin (1985), who have sought to derive the magma from fenite. Their proposal (p. 1124–1125) is that the lower crust in the Gregory rift valley sustained “fenitization on a regional scale” as a result of its being invaded by “a volatile phase rich in water and carbon dioxide and bearing alkalis” during the formation of the “mantle-derived alkalic basalt melt.” This alkalic basalt, and associated nephelinite, is the pririfting precursor to

the later nephelinite, phonolite, and carbonatite plutonism and volcanism. That fenitization might occur on a regional scale rather than being associated purely locally with individual carbonatite-alkalic rock complexes is a new idea. The alkalic carbonatite magma (natrocarbonatite) is, thus, alleged to have developed, together with phonolitic to trachytic magma, as the result of crustal melting of the fenite to produce two conjugate immiscible liquids.

The alleged regional fenitization is said to have developed fenites devoid of plagioclase because of nephelinitization of the original plagioclase by carbonate-bearing solutions after the manner advocated by Cermignani and Anderson (1983). On the basis of a study of the available fenite xenoliths, the regional fenite foundation is said to consist largely of nepheline + alkali feldspar +1 clinopyroxene + carbonate.

### CRITIQUE

There are many reasons why the proposed origin of alkali carbonatite magma is not viable. It involves an exaggerated interpretation of fenite xenoliths that are found as ejected blocks, some of which have undergone incipient melting and which were derived from granitic and gabbroic parents within the Precambrian basement. No convincing evidence is offered why these xenoliths should have come from a regionally fenitized basement rather than from one fenitized in the immediate vicinity of the volcano Oldoinyo Lengai. Similarly, there is no convincing reason why the mantle should be “degassing” (p. 1125) above a region of partial melting where alkali basalt magma was forming. The mantle is not generally

thought to be a particularly rich source of either water or carbon dioxide on a regional scale, and even if a fluid were produced, it would be more likely to dissolve in the developing silicate liquid than to be driven out above the site of melting. Even less is there any convincing reason why such a  $H_2O-CO_2$  fluid should be so alkali-rich as to be an agent of fenitization. One may conclude, therefore, that the existence of the requisite foundation of regionally developed fenite alleged to underlie Oldoinyo Lengai is not proved, is indeed unlikely to exist, and cannot logically be expected to have formed by the process invoked by Morogan and Martin.

The next stage, that of anatexis of the fenite to produce two conjugate immiscible liquids, is derived from the experimental studies of Freestone and Hamilton (1980), who showed that the alkalic carbonatite and phonolite form immiscible liquids when melted at elevated pressure. What that study did not show is that the carbonatite liquid is actually *derived* from the phonolite. The possibility of anatexis occurring is based on the presence of glasses in the fenite xenoliths where melting is thought to have occurred during their transport in the alkalic carbonatite magma.<sup>1</sup> The authors do not attach any particular significance to the compositions of the glasses, which are, indeed, said to be from disequilibrium melting. Their existence is merely held to confirm that anatexis is possible, which of course we know anyway in that any rock will melt if it gets hot enough. The quantum leap is in accepting that alkalic carbonatite liquids form immiscibly and, hence, that anatexis of a fenite composed of nepheline + alkali feldspar + clinopyroxene + carbonate will produce an alkali-rich carbonate melt and its conjugate silicate liquid, a phonolite.

The experiments of Freestone and Hamilton (1980) prove that phonolite and alkalic carbonatite melts are immiscible at pressures only slightly elevated above 1 bar but prove nothing more than the existence of that property. A derivative relationship of the one from the other is not established. This has recently been argued by Twyman and Gittins (1987). On that basis, the second stage of the Morogan and Martin case is also not proven. There remain, however, many more reasons why the Oldoinyo Lengai alkalic carbonatite lava could not have developed by anatexis of fenite, and they all concern chemical composition.

The lava is extremely rich in F (1.5–3%, with almost 8% in the quenched matrix) and Cl (0.75–4%) (Gittins and McKie, 1980). While little is known about the par-

<sup>1</sup> Morogan and Martin (1985, 1123) commented that "if the blocks of fenite became rheomorphic due to soaking in the natrocarbonatite magma, . . . it would seem likely that the magma's temperature was somewhat higher than the temperature of the anhydrous liquids, 655 °C at 1 kbar, determined by Cooper et al. (1975)." However, the magma is extremely rich in F, the effect of which is to drastically lower the solidus temperature of the xenoliths; it is still possible, of course, that the magma cooled during its ascent and, hence, that the temperature of the magma deeper within the volcano where partial melting occurred was higher than 655 °C.

tioning of F and Cl between silicate and carbonate liquids, there is nothing to indicate that the fenites are particularly enriched in either. Micas and amphiboles of carbonatites and fenites commonly contain F, but in the fenites described by Morogan and Martin, neither mineral is abundant, except for one with 34% hornblende, and that is probably original metagabbroic hornblende rather than a fenitic amphibole. In any case it is almost impossible to concentrate so much F and Cl into a carbonate liquid if the source is only mica and amphibole of fenite. Since the alleged regional fenite is supposed to have been produced by a noncarbonatitic source, it is also distinctly unlikely that the high Nb content of the carbonatite lava could have been produced in this way. Basically similar arguments apply to the contents of Sr (12000 ppm), Ba (8000–11000 ppm), Pb (120 ppm), Th (2 ppm), and U (7 ppm).

Finally, one may look at the isotopic composition of the carbonatite. Data presented by Bell and Blenkinsop (1987) are the best available and give  $^{87}Sr/^{86}Sr = 0.70442$ ,  $^{143}Nd/^{144}Nd = 0.51261$ ,  $\epsilon_{Sr} = -0.7$  to  $-1.1$  and  $\epsilon_{Nd} = -0.5$  to  $-0.9$ , which are values very close indeed to those of bulk Earth. They are generally consistent with a mantle origin and offer little support for an origin by partial melting of fenitized Archean basement. Of course, it is difficult in the present state of isotopic geochemistry to distinguish crust-mantle isotopic signatures from those of metasomatized rocks.

Morogan and Martin (1985) have produced an interesting and thought-provoking proposition for the origin of the highly alkalic carbonatite lavas and pyroclastics of the volcano Oldoinyo Lengai, but on balance it does not seem to be acceptable, and the debate must continue.

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