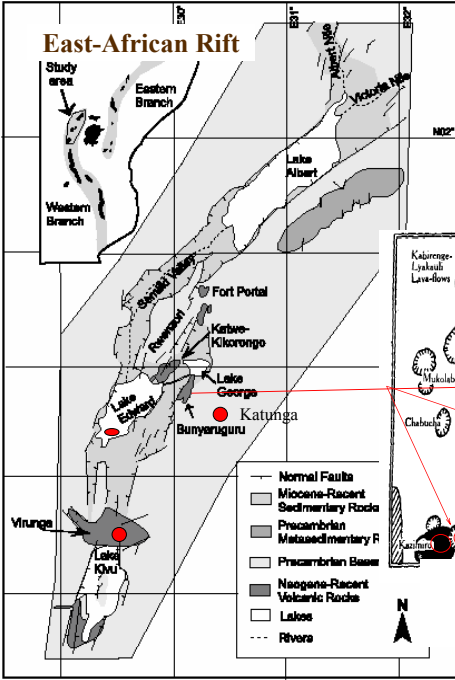


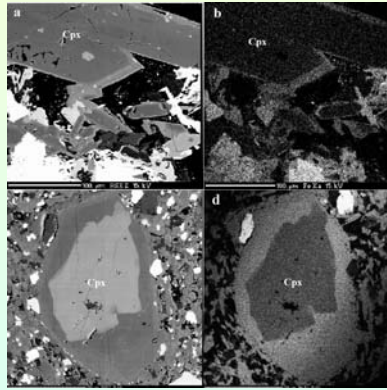
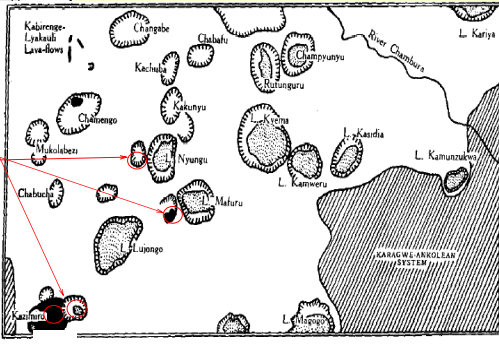
Clinopyroxene-host disequilibrium (Sr-Nd-Pb isotope systematics) in ultra-potassic magmas from East-African Rift

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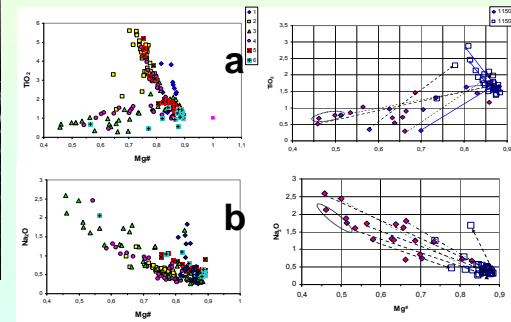
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Bunyuruguru volcanic field



Zoned clinopyroxenes studied - BSE images: (a) in mafurite (11503 sample) Toro-Ankole, (b) in ne-leucite (11641 sample) Visoke volcano, Virunga; (c) large clinopyroxene in mafurite (11503) with clearly expressed reverse zonation; (d) the same grain image in Mg-K α emission. The nature of zoning, overgrowth of the primary clinopyroxene grains that crystallized from the new portions of the melt, indicates a difference in the primary melt composition evolution.



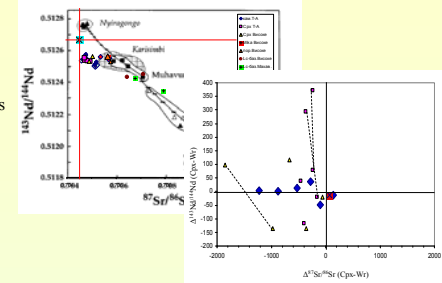
The plots showing the relationship TiO₂ vs. Mg[#] (a) and Na₂O vs. Mg[#] (b) of investigated clinopyroxenes. Two trends are clearly defined, corresponding to various temperature and pressure environments. Symbols: 1 – 11523; 2-11641; 3 – 11503; 4 – 11530; 5 – 11642; 6 - 11497; (c) and (d) - an examples the core (fill diamond) to rim (empty square) clinopyroxene composition changing in the mafurite (sample 11503).

The Sr, Nd, Pb isotopic composition of minerals from ultra-potassium volcanic rocks of the East African Rift.

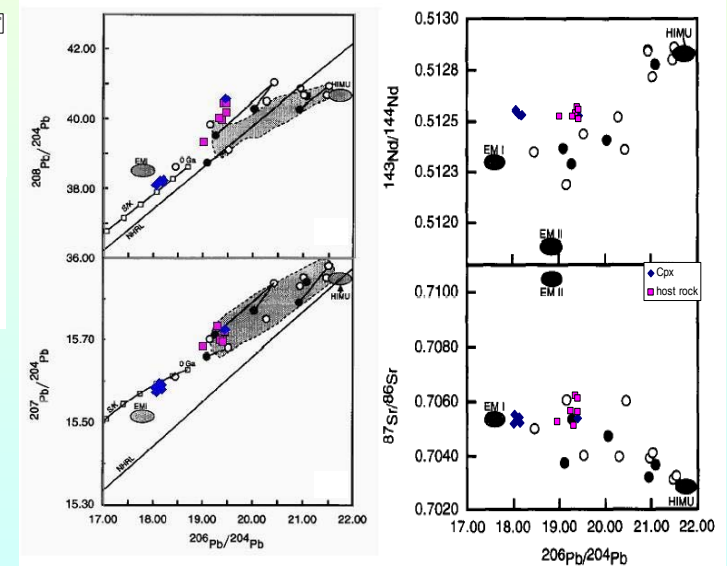
sample	Sm	Nd	¹⁴³ Nd/ ¹⁴⁴ Nd	¹⁴³ Nd/ ¹⁴⁴ Nd±2σ	Rb	Sr	⁸⁷ Rb/ ⁸⁶ Sr	⁸⁷ Sr/ ⁸⁶ Sr±2σ	²⁰⁶ Pb/ ²⁰⁴ Pb±2σ	²⁰⁷ Pb/ ²⁰⁴ Pb±2σ	²⁰⁸ Pb/ ²⁰⁴ Pb±2σ
11497 cpx	36.12	121	0.18096	0.512506±3	19.15	421	0.13146	0.704944±12	18.1574±8	15.5955±7	38.1901±24
11503 cpx	57.25	198	0.17504	0.512511±4	17.21	324	0.15352	0.704725±10	18.1705±5	15.5840±6	38.2308±19
11523 cpx	36.39	145	0.15173	0.512508±4	16.54	366	0.13066	0.704824±8	18.1151±7	15.5971±7	38.2122±24
11641 cpx	27.91	116	0.14491	0.512504±6	24.44	426	0.16614	0.704913±7	19.4257±6	15.7293±6	40.5741±23
11530 cpx	48.59	161	0.18194	0.512525±6	22.51	523	0.12453	0.704705±6	18.0375±9	15.5883±9	38.0899±30
11642 cpx	51.76	136	0.23061	0.512535±4	18.68	382	0.14134	0.705033±8	18.0481±7	15.5772±8	38.1097±23
11642 mica	2.48	24.35	0.06150	0.512527±12	132	96.62	1.28371	0.705703±18	n.d.	n.d.	n.d.

Nd, Pb and Sr isotope ratios have been determined for kamafugite lava and clinopyroxene and phlogopite phenocrysts from Toro-Ankole and Virunga volcanic fields of the East African Rift. The whole rock Sr – Nd isotopic signatures of kamafugites (⁸⁷Sr/⁸⁶Sr: 0.70463 – 0.70536; ¹⁴³Nd/¹⁴⁴Nd: 0.51249 – 0.51255) suggest derivation from an EM1-type mantle source. In contrast, Pb isotopic compositions of the same samples (²⁰⁶Pb/²⁰⁴Pb: 19.00 – 19.57; ²⁰⁷Pb/²⁰⁴Pb: 15.69 – 15.74; ²⁰⁸Pb/²⁰⁴Pb: 39.30 – 40.26) reveal a similarity to EM2-type mantle. New Nd, Pb and Sr isotopic data for clinopyroxene (⁸⁷Sr/⁸⁶Sr: 0.70473 – 0.70503; ¹⁴³Nd/¹⁴⁴Nd: 0.51250 – 0.51254; ²⁰⁶Pb/²⁰⁴Pb: 18.04 – 18.17; ²⁰⁷Pb/²⁰⁴Pb: 15.58 – 15.60; ²⁰⁸Pb/²⁰⁴Pb: 38.09 – 38.23) suggest derivation from an EM1-like source, and indicate Sr and Pb isotope disequilibrium between clinopyroxene and corresponding host rock. Moreover, clinopyroxenes demonstrating a greater degree of isotopic disequilibrium with their host rock are more sodic in composition. The isotopic disequilibrium is corroborated by the presence of chemical zoning within clinopyroxene, which suggests rapid magma ascent rates preventing melt homogenization.

The Pb isotopic ratios for both mineral and corresponding whole rock, together with published data on East African rift-related alkaline centers, define a trend interpreted to represent a mixing line for melts derived from sources such as EM1 and as HIMU. The similar isotopic compositions for clinopyroxene from the different volcanic rocks within the East African Rift suggest the existence of a common, older mantle source for their parental melts. The origin of these melts can be attributed to an enrichment event 400-500 Ma, i.e. significantly prior the younger (Quaternary) ultrapotassic magmatism. Our preferred interpretation for the results reported here involves the mixing of the melts derived from EM1- and HIMU-like sources, which were rapidly transported to the Earth's surface. The primary magmas formed as the result of melting of a heterogeneous (on kilometer scale) mantle source consisting of peridotite and pyroxenite.



Different variants of Sr-Nd isotopic disequilibrium clinopyroxenes (diamonds) and mica (square) with host rocks, expressed as the difference between isotopic data for mineral and whole rock. The isotopic difference $\Delta^{143}\text{Nd}/^{144}\text{Nd}$ and $\Delta^{87}\text{Sr}/^{86}\text{Sr}$ between whole rock (Wr) and clinopyroxene (Cpx) is expressed in parts per million (ppm). The symbols denote: 1 – present work studied ultrapotassic rocks Toro-Ankole and Virunga; 2 – nephelinite lavas from Napak volcano (Simonetti, A., Bell, K., 1993); 3 - nephelinite lavas from the Mount Elgon volcano (Simonetti A., K. Bell, 1995).



HIMU, EM1 and EMII mantle components are from Hart (1988). Symbols: diamond – studied in present work clinopyroxenes from Toro-Ankole and Virunga kamafugites; square – whole rock Toro-Ankole and Virunga kamafugites; dots - diopside phenocrysts from Mount Elgon nephelinites; circles - whole rock Mount Elgon nephelinites.

The main result obtained in our study is the lack of isotope equilibrium between clinopyroxene and the host alkaline, primitive melts, recorded previously in East Africa by Simonetti and Bell (1993; 1995) and Davies and Lloyd (1989). The nature of Sr isotope disequilibrium is correlated with clinopyroxene compositional zonation; isotopic and elemental composition disequilibria indicate a high-pressure trend (primarily in high Na₂O) and corresponds to isotope-enrichment relative to the host rock clinopyroxene, whereas a low-pressure evolution trend is correlated to (Sr) isotopically depleted clinopyroxene compositions.

The second conclusion is the existence of a common source for the parental melts from which the clinopyroxenes crystallized. The isotopic variations of Sr and Pb in clinopyroxenes are confined to a limited range, regardless of occurrence. Keeping in mind the location of volcanoes from which kamafugite specimens were collected (Kyambogo, Nyungu and Kazimiro craters in Bunyuruguru field, Isinga island on Edward Lake and Visoke volcano, Virunga field) we suggest the existence of a common source from which all investigated clinopyroxene-bearing melts have formed. Such a source may be earlier magma chambers or veins within the lower lithosphere, generated during an ancient metasomatic/magmatic event long before the ultrapotassic magmatism. Melts in these locations, where clinopyroxene crystallization took place, have Pb-Sr-Nd isotopic signatures similar to those of EM1 mantle. Later kamafugite magmas, which differ in the isotopic composition of strontium and lead, formed during ascent as mixing between melts entrained the previously formed clinopyroxenes. The rate of mixing was faster than needed to establish the isotopic and chemical equilibrium.

Based on the data reported here, our preferred interpretation is that the ultrapotassic rocks investigated here result from the mixing of melts derived from two different sources (lithosphere and asthenosphere), which took place during rapid ascent of the magmas. The origin of the primary melts themselves is associated with melting of a heterogeneous (kilometer-scale) mantle source in which peridotite and pyroxenite were present in varying proportions.

The variable nature of the Rb-Sr, Sm-Nd and U-Th-Pb isotope systems is likely indicative of the complex processes involved in the genesis of the kamafugite magmas. These processes include enrichment (metasomatic) events by silicate melts and H₂O – F – CO₂ fluids, convecting asthenosphere, ascending plume and magma mixing.

