

K-rich clinopyroxenes as mantle conveyers of crustal-derived components

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Recent experimental studies (Edgar and Vukadinovic, 1993; Schmidt, 1996; Harlow, 1997) converge to demonstrate that K can reside in the cpx structure at high-pressures (4-14 GPa). To investigate the role of K-rich cpx in controlling the alkali, Sr, Ba, Nd and Pb contents in upper mantle, these elements were determined with REE, Th and U on specimens from two reported geological occurrences: K-rich diopsides from the ultra-high pressure (UHP) Kokchetav Massif and K-rich omphacites inclusions from the Argyle lamproitic diamonds. The Laserprobe ICP-MS was used to achieve *in-situ* microanalyses on these cpx which generally occur as tiny inclusions in other UHP mineral phases or as remnants within retrograde parageneses.

All Kokchetav K-rich cpx correspond to high MgO diopsides with low jadeite and Ti-Cr contents. Those found in the matrix range from 0.2-0.6 K₂O wt.%. They often show regular, tiny (1-5 µm) to large (0.7-1mm width), K-feldspar lamellae that testify of reequilibration during decompression. The K-rich cpx from garnet clinopyroxenites have unusually high, crustal-like, Cs (0.8-2.3 ppm), Rb (1-25 ppm), and Pb (1-17 ppm) concentrations (Fig. 1), but normal Ba and light rare-earth contents, in comparison to K-poor lithospheric mantle diopsides. In contrast, their Sr content is rather low : 2-54 ppm. They display unwonted Rb/Cs, Ba/Rb and Ce/Pb, all much lower than the uniform values of upper continental crust material (Fig. 1) and K/Rb (>500) higher than crustal value (K/Rb=250-290). K-rich cpx from pyroxene-dolomite rocks also incorporate geochemical anomalies (Ba/Rb<1.5; K/Rb>4000; Ce/Pb<4), but lower Rb enrichment, and undetectable Cs contents. In contrast, the K-rich diopside inclusions within garnets are free of any visible exsolutions at the resolution of the back-scattered electron imagery. Their K₂O content is either homogeneous (but extremely variable from one inclusion to another: 0.4-1.3 wt.%) or decreasing from core (1.1 wt.%) to rim (0.4 wt.%). Their high K content is coupled to very high Rb and Cs abundances (Fig. 1).

The analyzed Argyle omphacite compare closely to the Kokchetav diopsides by their Ba-Zr depletions as well as their Rb, Cs, Pb enrichments approaching the crustal abundances. They just differ by their much higher Sr concentrations. All K/Rb, Rb/Cs, Ba/Rb and Ce/Pb are different from those expected for Mid Ocean Ridge Basalts (MORB) (Fig.1), but the Rb, Cs data recall those of South African diamondiferous eclogitic cpx.

Our study indicates that both diopsidic and omphacitic K-rich cpx accommodate crustal-like amounts of Rb, Cs and Pb under some peculiar geological conditions that also favor unusual alkali-Pb redistributions. The K-rich fluids continuously released from subducted rocks from 2GPa to 9GPa are the most appropriate vectors to efficiently mobilize those elements. Fluids related to the 2GPa-dehydration of a subducted oceanic crust could however be ruled out because the element mobility in those fluids would generate low Pb/Sr and high Ba/Rb in the residual cpx, just the opposite of what is observed. The outstanding restriction of K-rich cpx to diamond-bearing lithologies implies a growth from fluids with high K and C activities. Phengite breakdown in a Kokchetav-like carbonate-rich environment is thus inferred as a potential mechanism to imprint the alkali-Pb signature on both K-rich diopside and omphacite. In the Kokchetav Massif, UHP phengite is absent from rock matrix but has been often recognized as inclusions in garnet, sometimes

coexisting with K-rich diopside. This demonstrates that phengite and K-rich diopside were stable together, at some stage during the prograde UHP metamorphism, in agreement with experimental results (Schmidt, 1996). During progressive heating, phengite should melt at around 800°C (at 4GPa) and 900°C (at 6GPa) (Schmidt, 1996), with K-rich cpx and dolomite probably remaining behind as refractory phases. This should make phengite-derived major (K) and trace (Rb-Cs-Ba-Pb) elements available for repartition between dolomite (Ba, Pb), K-rich cpx (Rb, Cs, Pb) and a fluid enriched in K-Rb-Cs-Pb. This scenario is consistent with the dolomite geochemical features (Fig. 1), especially their high Ba/Rb values which appear complementary to those of K-cpx in terms of crustal balance.

Under UHP conditions (>6.5 GPa), most continentally derived materials are probably dense enough to penetrate the upper mantle with eclogites (Irifune et al., 1994). Subduction of UHP K-cpx-rich rocks (such as the Kokchetav garnet clinopyroxenites made up of 70-80 vol.% of cpx) is therefore proposed as an ideal mechanism to recycle supracrustal K, Rb, Cs, Pb, Sr, and Nd to the mantle. However, the narrow range of Rb/Cs, Ba/Rb, Ce/Pb values in oceanic basalts (Fig. 1) precludes any large contamination of ordinary mantle by subducted K-cpx-rich materials. Owing to their low Rb/Cs, K-cpx from diamondiferous eclogites, Argyle diamonds, and UHP metasediments appear complementary to MORB-OIB mantle sources with respect to the chondritic value. They could thus help to close the global balance of those elements with the lithospheric mantle, the depleted mantle, and the continental crust. A similar conclusion could be reached for Ce/Pb in terms of the bulk silicate earth stock of Ce and Pb. Our dataset is thus consistent with the existence of one or several, old (at least Proterozoic according to the Argyle specimens) concealed diamondiferous-metasedimentary-eclogitic (DIME) mantle reservoirs in addition to the depleted mantle and the continental crust. This emphasizes storage of "MORB-OIB" and "DIME" reservoirs in two essentially unmixed regions from the mantle.

Our results support the idea of occasional exchanges between "MORB-OIB" and "DIME" reservoirs as an explanation for the OIB isotopic features. K-cpx have Rb/Sr 1-20 fold higher than the primitive mantle values (0.03), but U/Pb-Th/Pb 100 times lower than the mantle ratios (0.114 and 0.46). Little admixture of a K-cpx-rich component to a "MORB" source would therefore destroy the magmatic derived correlation between these ratios, with the capacity of causing the well-known lack of correlation for Sr-Pb isotopes in OIB. The Kokchetav K-cpx-rich rocks display radiogenic Sr and Pb signatures ($^{87}\text{Sr}/^{86}\text{Sr}$: 0.78-0.79; $^{208}\text{Pb}/^{204}\text{Pb}$: 41.8-44.4) and unradiogenic Nd compositions ($^{143}\text{Nd}/^{144}\text{Nd}$: 0.51110-0.51238). Owing to their very low Sr contents, if they were recycled in limited amounts (1 to 5 wt.%) within a depleted mantle source, they would produce a source with HIMU-like Sr-Nd-Pb isotopic features (Fig.2). However, there is no Kokchetav mixtures with a depleted mantle that could fit the EM1-EM2 Pb isotopic characteristics (Fig. 2b). Proterozoic or Archean analogs might do, if they have remained isolated for a long time in a DIME reservoir to evolve a sufficiently retarded radiogenic Pb growth compared to the depleted mantle.

References

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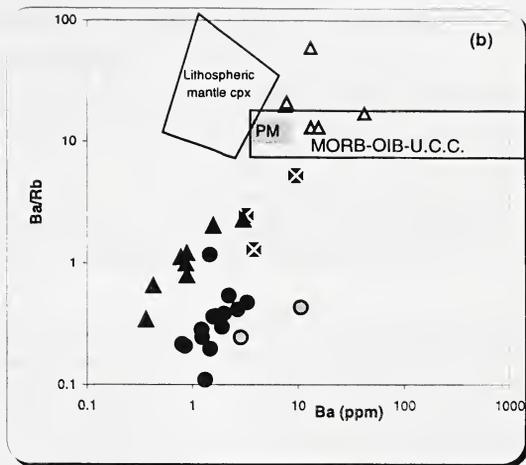
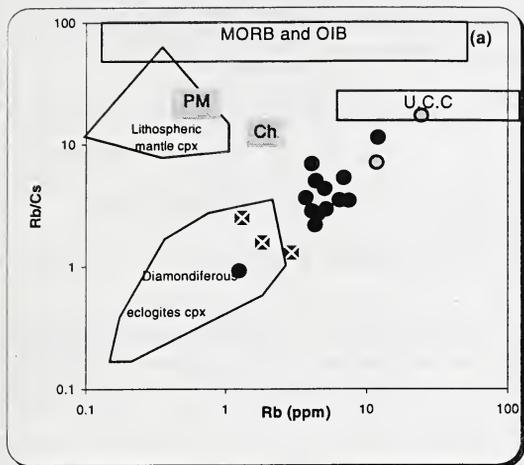


Figure 1 (a) Rb/Cs vs. Rb and (b) Ba/Rb vs. Ba for the overall Laserprobe ICP-MS database on K-rich cpx: Argyle (square with white crosses), Kokchetav garnet clinopyroxenites (matrix: black circles; inclusion: grey circles) and pyroxene-dolomite rocks (black triangles) compared to fields for MORB-OIB and upper continental crust (U.C.C.) reservoirs and cpx data from lithospheric mantle (lherzolites and clinopyroxenites), and from Siberian and South African diamondiferous eclogites. The primitive mantle (PM) and chondrites values (Ch.) are shown for reference. The open triangles display the compositions of Kokchetav dolomites.

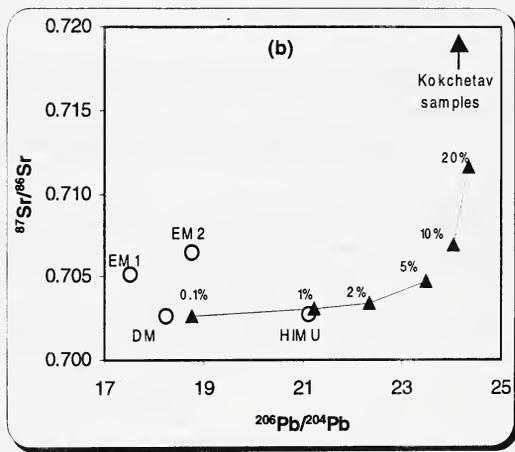
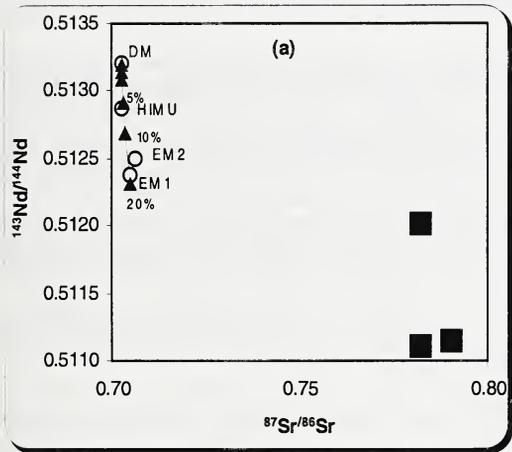


Figure 2 (a) Nd-Sr and (b) Sr-Pb isotopic admixture models between a depleted mantle (DM) source and Kokchetav clinopyroxenites (black squares). The small black triangles on the mixing curves indicate the wt% of Kokchetav samples in the mixture. The open circles illustrate the location of the four main mantle isotopic end-members.