Kimberlite magmatism and origin of K-rich metasomatic melt-fluid

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The experimental study indicates that high-K magmas and kimberlites are in equilibrium with metasomatic minerals, such as phlogopite, richterite, and apatite during their formation in the mantle; i.e., metasomatic processes played a decisive role in their genesis.

In the uppermost part of the mantle, K is entirely concentrated in plagioclase. With increasing depth the K budget is determined mainly by clinopyroxene and, to a lesser extent, garnet. A further increase in pressure causes pyroxene and garnet to react to form majorite, which has K and Na partition coefficients equal to 0.015 and 0.39, respectively [1]. In the depth interval of 410–660 km, majorite is associated with wadsleyite (410–500 km) and ringwoodite (500–660 km), neither of which incorporate K or Na into their structures. At deeper levels, below 660 km, the majorite–ringwoodite assemblage is replaced by the ferropericlase–bridgmanite–Ca-perovskite paragenesis. Here, the modal content of Ca-perovskite is ~8%. The K partition coefficient for Ca-perovskite is relatively high (0.39), and that of Na is even higher (2.0) [2]. The hexagonal NAL phase content up to 1.1 and 6.2 wt% K2O and Na2O respectively. Thus, practically all K and Na will be concentrated in Ca-perovskite and the NAL phase in the upper parts of the lower mantle. When a mantle diapir ascends from a depth more than ~660 km, Ca-perovskite and NAL becomes unstable and reacts with bridgmanite and ferripericlase to produce majorite and ringwoodite, and, with a further decrease in pressure wadsleyite becomes stable. The K partition coefficient in Ca-perovskite is 26 times higher compared with that of majorite. The K partition coefficient of NAL is unknown. The remaining K likely remains excluded from the lattices of minerals in this mantle zone. Majorite may be an important concentrator of Na in the uppermost part of the lower mantle and transition zone. Experimental data indicate that 12 molar % sodium can be incorporated in majorite solid solutions. The chemical composition of the natural majorite contains 0.27-1.12 wt % Na2O. Taking into consideration values of the K partition coefficient for Ca-perovskite and majorite, it can be confidently stated that the thermodynamic activity of K2O in the system increases by more than an order of magnitude with the transition of the bridgmanite–Ca-perovskite–ferripericlase – NAL association to the majorite–ringwoodite paragenesis. This is evidence that majorite will markedly fractionate K and Na, resulting in conditions favorable for the transfer of K into a melt or fluid phase at the boundary between the lower mantle and the transition zone.