

## Stable isotope geochemistry of amphiboles from alkaline igneous complexes

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Several studies have noted that the hydrogen isotope compositions of amphiboles from alkaline complexes not only have an extremely wide range, but also have extremely low  $\delta D$  values in peralkaline to agpaitic rocks. For example, amphiboles measured from complexes of Ilímaussaq (Greenland) and Khibina (Russia) have  $\delta D$  values as low as  $-202$  and  $-178\text{‰}$ , respectively; Tugtutoq Complex (Greenland) has values for amphiboles around  $-137\text{‰}$  and the Canadian Mount Saint Hilaire intrusives about  $-152\text{‰}$ . All of these, however, also values more typical of mantle-derived magmatic rocks (about  $-90\text{‰}$ ). In contrast, amphiboles from the Okenyenya and Messum alkaline complexes (NW Namibia) only have values of between  $-70$  and  $-89\text{‰}$ , supporting a normal mantle origin. The fact that the extremely low values occur in a number of different complexes though, suggests that H isotope compositions of amphiboles in these systems may be controlled by very specific processes. A complete mineralogical and geochemical characterization of selected minerals from a number of petrogenetically well-characterized sites has been undertaken in order to investigate this possibility further. Possible explanations for the wide range and extremely low values include:

1. influence on the hydrogen isotope compositions by hydrocarbons and/or hydrogen derived from organic-rich sediments (e.g., Stevenson et al., 1997),
2. interaction of the magma with low D/H meteoric waters (e.g., Sheppard, 1986),
3. extreme degassing of magmatic water (e.g., Markl et al., 2001),
4. lack of appropriate mineral-water fractionation factors for Fe-rich minerals and/or pressure effects on the mineral-water H isotope fractionations (e.g., Suzuoki and Epstein, 1976; Graham et al., 1984).

Our study concentrates on three well-studied localities - Greenland, the Kola peninsular of Russia, and NW Namibia. The selected amphiboles have compositions typical for calcic, sodic-calcic and sodic amphiboles. These compositions reflect the different geochemical environments in which these amphiboles were formed. The agpaicity index ( $(Na+K)/Al > 1.2$  is defined as agpaitic) of the complexes clearly describes the differences: Ilímaussaq alkaline complex: 1.20-1.77; Kola complexes range between approximately 1.08 and 1.24 and the Namibian alkaline complexes are between 0.72-1.36. Although the index does overlap, it is clear that especially the samples from Ilímaussaq have been formed under extremely alkaline conditions. The

O-isotope compositions, in contrast to those for hydrogen, are quite homogeneous and are compatible with amphibole formation from melts of a normal mantle-type source (values close to 5.5 ‰). Selected amphiboles from all of these complexes have been measured for their Fe<sup>2+</sup>/Fe<sup>3+</sup> by Mössbauer spectroscopy. Preliminary data indicates a rough correlation between Fe<sup>T</sup> and D/H. According to Suzuoki and Epstein (1976), the higher the Fe-content the larger the mineral-water fractionations are. However, no obvious correlation between the low δD values and changes in either the Fe-content or their Fe<sup>2+</sup>/Fe<sup>3+</sup> ratios is observed. Our data do not support interaction with a very reducing fluid as the cause of the low δD values. Profiled analyses of larger amphiboles also exhibit no obvious zonation in δD value, suggesting that late secondary process, such as a diffusive exchange with meteoric water, did not affect these amphiboles. However, a good relationship is observed between the alkali content and the δD values of the amphiboles. This may imply complex fractionation processes in the presence of highly alkaline fluids in these systems and/or a significant control on the H-budget through the appearance of other hydrous phases.

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