OXYGEN ISOTOPE COMPOSITION OF MANTLE ECLOGITES

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INTRODUCTION

Oxygen isotope geochemistry has provided useful insights into the origins of mantle eclogites that occur as xenoliths in kimberlite. Many workers now consider eclogites that have anomalously high or low oxygen isotope ratios, relative to typical mantle peridotite ($\delta^{18}O_{VSMOW}$ = +5.37 ± 0.36‰ in peridotite garnet; Mattey et al., 1994), as representing altered ocean lithosphere (e.g., MacGregor and Manton, 1986; Jacob et al., 1994). The number of eclogite xenolith suites that have been studied is relatively small, however, and fewer still have been investigated using high precision laser fluorination (LF) techniques. In order to broaden the oxygen isotope database for mantle eclogite xenoliths, we have begun a systematic study of eclogites from a variety of kimberlite occurrences, world-wide. Here we present our findings to date.

RESULTS

Using LF methods, we have determined the oxygen isotope composition of garnets from mantle eclogite xenoliths from 12 kimberlites located in South Africa (Blaauwbosch, Roberts Victor, New Elands, Lace, Newlands, Premier, Frank Smith, Balmoral, Kimberley, Jagersfontein, Bobbejaan, Monastery), and four kimberlites in the U.S.A. (Schaffer, Sloan, Iron Mountain, Hamilton Branch). Based on electron probe data, we have chosen samples that cover most of the compositional range in many of the suites. The data are shown in Figure 1, which also includes data from eclogitic garnet xenocrysts from the La Ceniza kimberlite in Venezuela (Schulze et al., 2003).

At each location at least some samples have anomalous values of $\delta^{18}O$ (i.e., above or below the typical mantle peridotite garnet value). Suites with some of the more extreme anomalies include Blaauwbosch ($\delta^{18}O$ = +3.31 to +7.39‰), Newlands ($\delta^{18}O$ = +3.15 to +6.07‰), Frank Smith ($\delta^{18}O$ = +3.03 to +4.83‰) and Sloan ($\delta^{18}O$ = +5.22 to +8.19‰). Garnets in alkremites from Jagersfontein and Bobbejaan are all anomalously low ($\delta^{18}O$ = +3.57 to +4.87‰).

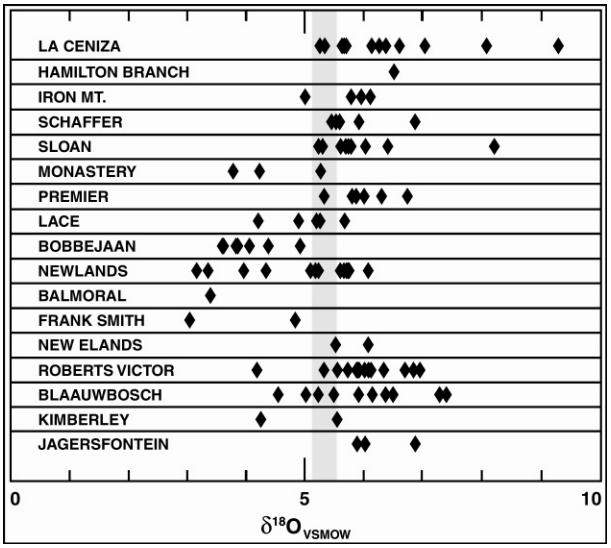

Figure 1. Variations in oxygen isotope ratios for garnets from eclogites in this study. The shaded region represents the approximate range in oxygen isotope composition of garnets from diamond-free peridotite xenoliths (Mattey et al., 1994), considered to represent $\delta^{18}O$ of "normal" upper mantle.

Correlation between oxygen isotope ratios and major element composition or mode is poor overall. Kyanite eclogites and coesite eclogites can have either anomalously high or low oxygen isotope compositions. There is not a correlation between anomalously high values of $\delta^{18}O$ and Group I eclogite garnets (i.e., those with Na_2O above 0.07 wt %) as suggested previously for Roberts Victor. Most suites, in fact, are not even readily divisible into two groups on the basis of sodium content of garnet.

DISCUSSION

Evidence for the presence of subducted altered oceanic basaltic material exists in all regions of the subcontinental upper mantle from which we have eclogite xenoliths. There are, however, hints of regional variations. Eclogites with $\delta^{18}O$ values below typical mantle, representing basaltic material that has undergone exchange with heated seawater, are common in many of the South African suites, but almost unknown at the other locations. No garnets with low values exist in the Venezuelan suite, and only a single garnet from the U.S.A., from an Iron Mountain, Wyoming eclogite ($\delta^{18}O$ = 4.99‰) has a value below

5‰. Within the South African population, all of the kimberlites located north-west of Kimberley (Frank Smith, Bobbejaan, Balmoral, Newlands) have a significant population of eclogites with anomalously low $\delta^{18}O$, though more data are needed from some of these locations to confirm this. The single eclogite from the Hamilton Branch kimberlite (which was intruded through Grenville-age basement) has an anomalously high $\delta^{18}O$ value (+6.50‰).

The oxygen isotope data link alkremites to mantle eclogites, and support earlier suggestions that alkremites are derived from protoliths with origins in altered oceanic crust (e.g., blackwall chlorite – Helmstaedt and Schulze, 1989 or Al-rich pelagic sediments – Exley et al., 1983).

Complexities in the relationships between oxygen isotope ratios and mineral chemistry and mode suggest that correlations between eclogite geochemistry and inferred oceanic basalt protoliths are not straightforward. Furthermore, the range in anomalous oxygen isotope values, although extremely significant in terms of modelling mantle eclogites as subducted oceanic basic rocks, is much narrower than that of basic rocks in ophiolites and modern oceanic lithosphere. This suggests that, following subduction, the eclogites have had their oxygen isotope anomalies smoothed by processes in the upper mantle such as fluid exchange and diffusion

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