Diamondiferous eclogites from Udachnaya: a subducted component in the Siberian upper mantle

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Many years of study of South African mantle samples have demonstrated the existence of a component related to suduction which is exemplified by eclogite xenoliths which are interpreted to represent parts of metamorphosed subducted Archean oceanic crust (e.g. Jagoutz *et al.*, 1984; MacGregor and Manton, 1986). It is not clear if these interpretations apply worldwide because detailed studies have until very recently been restricted to South African samples. We have investigated eight diamond-bearing bimineralic eclogite xenoliths from the Udachnaya Mine, Yakutia, Siberia in terms of major elements, $^{87}Sr/^{86}Sr$-, $^{143}Nd/^{144}Nd$- and oxygen isotopic ratios in order to elucidate Siberian mantle history, to compare it with that of the South African craton, and to investigate the homogeneity of eclogite-forming processes on a global scale.Analytical methods:Oxygen isotope ratios were measured on mineral separates with the new laser-fluorination technique (Mattey and Macpherson, 1993). Ongoing work on mantle eclogites and diamond inclusions (Lowry *et al.*, 1993 and Lowry *et al.* in prep.) has produced an identical range of $\delta^{18}O$-values compared to the conventional method. $^{143}Nd/^{144}Nd$- and $^{87}Sr/^{86}Sr$-ratios were obtained from the same ultraclean mineral separates of fresh garnets and clinopyroxenes.

Results

The $\delta^{18}O$-values differ from mantle values and range between 5.19 and 7.38‰ with an average error of 0.08‰. Thus, very heavy or light values, as reported from South African eclogites (between 2.2 and 8.0: (Garlick *et al.*, 1971; MacGregor and Manton, 1986) are not observed. However, the oxygen isotope data are significantly heavier than average mantle values (5.5: Kyser, 1991 and Mattey, unpubl. data), and allow classification of the samples as Type A eclogites after Jagoutz *et al.*, 1984 or as Group I after MacGregor and Carter, 1970. Sr and Nd initial isotopic ratios for cpx, recalculated to 350 Ma are between 0.70226 and 0.70699 and 0.51170 and 0.51257 respectively, and those for garnet between 0.70319 and 0.70895 and 0.51158 and 0.51297. In comparison to the data from Snyder *et al.*, 1993 our data for cpx yield a larger variation in $^{87}Sr/^{86}Sr$ but a more restricted range in $^{143}Nd/^{144}Nd$-ratios for both garnet and clinopyroxene.The $^{87}Sr/^{86}Sr$-ratios of garnet overlap with the range observed by Snyder *et al.* (1993).

The Pb-Pb isotopic system (Jacob *et al.* in prep.) yields an age of 2.76 ± 0.1 Ga for the recalculated whole-rocks which is identical within error to the late Archean age of the South African eclogite suite from Roberts Victor (2.7 Ga: Jagoutz *et al.* 1984; Jacob and Jagoutz, 1994).

Discussion

Chemically and petrographically, the Siberian eclogites are very similar to the South African eclogite suites from Roberts Victor or Bellsbank, the most important similarities being the late Archean age (2.76 Ga) and the $\delta^{18}O$-values that deviate from mantle-values. However, differences exist in detail, as no samples with $\delta^{18}O$-values appreciably lower than mantle-values have been reported from Siberia, and the Cs-concentrations of the Siberian eclogites are generally lower than those of the Roberts Victor eclogite suite. Furthermore, we could not establish the influence of admixture of sedimentary material in the genesis the Siberian eclogites as was proposed for some members of the South African eclogite suite (e.g. Jacob and Jagoutz, 1994).

The data obtained from the Udachnaya eclogite suite are best explained by a model proposing an origin from Archean oceanic crust

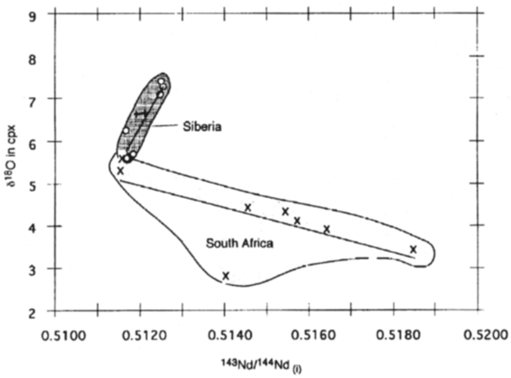

FIG. 1. $\delta^{18}O$ versus $^{143}Nd/^{144}Nd$ for clinopyroxenes from this study (o), cpx from Roberts Victor (+, Jacob and Jagoutz, 1994, and Jacob *et al.*, unpubl. data), and from Bellsbank (x, Neal *et al.*1990). All values are recalculated to eruption age of the respective kimberlite.

that was intensely altered prior to subduction to mantle depths. It is well established from comparison of data from South African eclogites with data from modern altered oceanic basalts and ophiolites that the range of oxygen isotopes observed in mantle eclogites is produced by seawater alteration of the protolith at different temperatures at or close to the surface of the Earth. Therefore, correlations of element concentrations, elemental or particularly isotopic ratios with high-precision oxygen isotopic values must be caused by the same process. We observe positive trends between $\delta^{18}O$ and FeO, Sm/Nd-ratios, $^{87}Sr/^{86}Sr_i$, $^{143}Nd/^{144}Nd_i$ and a negative trend for CaO *vs.* $\delta^{18}O$ in the Siberian eclogites. All of these trends are mirrored by eclogites with $\delta^{18}O$-values lighter than the mantle value from Bellsbank and Roberts Victor, South Africa, creating two wings of a 'butterfly-diagram' (Fig. 1).

The model for the genesis of diamondiferous eclogites from the Siberian craton proposes that oceanic crust was subducted to mantle depths at 2.76 ± 0.1 Ga after having experienced low-temperature hydrothermal alteration to variable degrees that changed the composition of the rock suite by reaction with seawater and formation of secondary minerals. The changes that are now detectable in the Udachnaya eclogites include an increase of formerly uniform oxygen isotopic values, enrichment of Fe, Rb, Cs and Na in the ocean floor, while Ca (and Sr) were depleted. During subduction, the altered crust lost a considerable part of its incompatible element (e.g. Rb, Cs, U) and *LREE* budget, due to dehydration and/or possibly partial melting. Over time the modified Sm/Nd-ratios in the restite led to growth of distinct $^{143}Nd/^{144}Nd$-signatures, related to the extent of alteration of the protolith (Fig.1). Subduction also resulted in resetting of the Sm-Nd isotopic system and cessation of growth of the U-Pb and Rb-Sr isotopic systems, since both were stripped of their isotopic mother elements. Therefore, the Pb-Pb isotopic system delivers age information about the time of subduction, while the $^{87}Sr/^{86}Sr$-ratios reflect the altered protolith prior to subduction, since most of the measured Rb-concentrations in the minerals today are too low to account for the elevated Sr-isotopic values.

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