PERIDOTITE XENOLITHS FROM THE UDACHNAYA KIMBERLITE PIPE

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Speculation on the composition and structure of cratonic lithosphere must be constrained by bulk analyses of large xenoliths. Those of sufficient size to provide suitable analytical samples are rare, but a suite of forty-one has been collected at Udachnaya. These include spinel facies peridotites, coarse low-temperature garnet peridotites and high-temperature sheared lherzolites and harzburgites. Bulk analyses have been carried out on samples that are predominantly in excess of 300 grams and these are combined with electron probe analyses to provide modes.

The peridotites from Udachnaya closely resemble counterparts from the Kaapvaal craton in southern Africa. The spinel facies peridotites are characterized by red-brown spinel in symplectites accompanying orthopyroxenes with 1.5-3.0 wt.% Al_2O_3. The garnets in coarse, low-temperature peridotites are rounded to irregular, from < 1 mm to 5 mm, are clustered in some specimens and have Cr_2O_3 contents ranging widely from 1 to 9 wt.%. All but one of the low-temperature spinel and garnet peridotites have mg numbers in the range 92.0-93.0. High-temperature lherzolites and several harzburgites have textures ranging from coarse to (more commonly) porphyroclastic-mosaic, some exhibiting extreme fluidization of enstatite. Their garnets are invariably rounded. These rocks are enriched in Fe and Ti relative to the low-temperature peridotites but have similar ranges of CaO and Al_2O_3.

Udachnaya peridotites have been metasomatized with alteration of major element contents prior to, during and following eruption. Rims of garnets in some high-temperature rocks are enriched in Ti, probably by reaction with melts prior to eruption (Smith and Boyd, 1989). All Udachnaya peridotites contain secondary interstitial diopside believe to have been introduced during eruption. The secondary diopside is extremely variable in composition but is commonly poor in Al, Cr and Na and rich in Fe and Ti relative to primary diopside. It characteristically forms mantles on primary enstatite that texturally pre-date serpentine. The secondary diopside is sometimes accompanied by calcite and rarely by monticellite. Its modal proportion ranges up to 5 absolute wt.%.

Bulk analyses for many Udachnaya peridotites show an excess of FeO over that calculated from the electron probe analyses of primary minerals and the mode (Fig. 1). This "introduced FeO" is as large as 1.5 wt.% and it correlates with loss-on-ignition(Fig. 2). It thus appears to have been introduced along with H_2O and CO_2 during serpentinization, following cooling of the kimberlite and included xenoliths to temperatures of several hundred degrees.

Estimates of the temperatures and depths of equilibration of Udachnaya peridotites form two clusters that plot close to the 40 mW/m^2 conductive geotherm (Fig. 3). There is a gap between points for high-temperature peridotites and those for the low-temperature rocks similar to that which is found in plots for Kaapvaal peridotites (Finnerty and Boyd, 1987). This depth interval may be occupied in part by megacrystalline dunites (Pokhilenko et al., 1993). There is little evidence of an inflection in the Udachnaya geotherm in contrast to Kaapvaal plots, a consequence of the markedly lower Al_2O_3 contents of enstatites in the high-temperature peridotites from Udachnaya. The xenoliths of deepest origin come from about 200 km in both Siberia and the Kaapvaal craton. They must be regarded as a part of the craton root inasmuch as most of their Re depletion ages are in the range 1-3 Ga (Pearson et al., 1995).

A plot of mg number against modal olivine for the low-temperature Udachnaya peridotites differentiates them from oceanic peridotites but shows a wide concordance with Kaapvaal counterparts (Fig. 4). The average mg number is 92.6 for Udachnaya and 92.7 for the Kaapvaal. The average modal olivine (or Mg/Si) is higher for Udachnaya but there is a large variation for both suites and a broad overlap. Moreover, there is a concordance in ranges of Ca/Al. These cratonic peridotites appear to have formed in processes that differ from that in which Phanerozoic oceanic lithosphere has been generated but which may have been very similar for the Kaapvaal and Siberia.

Kinzler et al. (1993) have shown that depleted oceanic peridotites are not simple residues but have been enriched in olivine by upward percolation of melt of later generation. Residues that have failed to interact with later melt may have Mg/Si closer to that of average cratonic peridotite. Such residues might be cumulates and cumulate formation might also provide the wide variation in modal olivine that is characteristic of Udachnaya and Kaapvaal peridotites.

Boyd, F. R. (1989) Compositional distinction between oceanic and cratonic lithosphere. Earth and Planetary Sci. Lett. *96*, p. 15-26.
Finnerty, A. A., and F. R. Boyd (1987) Thermobarometry for Garnet Peridotites: Basis for the Determination of thermal and Compositional Structure of the Upper Mantle *in* Mantle Xenoliths, P. H. Nixon ed., John Wiley and Sons, N.Y. p. 381-402.
Kinzler, R. J., Y-L. Niu and C. H. Langmuir (1993) Modal mineralogy and composition of abyssal peridotites: problems and solutions. EOS, Transactions American Geophysical Union, *74*, p. 623 (abs).
MacGregor, I. D. (1974) The system MgO-Al_2O_3-SiO_2: solubility of Al_2O_3 in enstatite for spinel and garnet peridotite compositions. Amer. Mineral. *59*, p. 110-119.
Pearson, D. G., S. B. Shirey, R. W. Carlson, F. R. Boyd, N. P. Pokhilenko, and N. Shimizu (1995) Re-Os, Sm-ND, and Rb-Sr isotope evidence for thick Archaean lithosphere mantle beneath the Siberian craton modified by multistage metasomatism. Geochim. et. Cosmochim. Acta *59*, p. 959-978.
Pokhilenko, N. P., N. V. Sobolev, F. R. Boyd, D. G. Pearson, and N. Shimizu (1993) Megacrystalline Pyrope Peridotites in the Lithosphere of the Siberian Platform: Mineralogy, Geochemical Peculiarities, and the Problem of their Origin. Russian Journal of Geology and Geophysics, *34 (1)*, p. 50-62.
Smith, D., and F. R. Boyd (1989) Compositional heterogeneities in phases in sheared lherzolite inclusions from African kimberlites. Proceedings of the Fourth International Kimberlite Conference, Vol. 2, Geol. Soc. Australia Special Pub. No. 14, 1989, p. 709-724.

Fig. 1: A plot of FeO in the normalized bulk analyses (observed) against FeO calculated from the electron probe analyses of primary minerals and the modes.

Fig. 2: A plot of "introduced FeO" against loss-on-ignition for Udachnaya peridotites; "introduced FeO" is the difference between FeO in the normalized bulk analysis and that calculated from the primary mineral analyses and the mode.

Fig. 3: Temperature-depth estimates for high-temperature (solid circles) and low-temperature (open squares) garnet peridotites from the Udachnaya kimberlite. Estimates were made with the FB86 cpx solvus thermometer and Al in opx barometer of MacGregor (1974), as recommended by Finnerty and Boyd (1987).

Fig. 4: A plot of modal olivine against Mg/(Mg+Fe) of olivine for low-temperature peridotites from Udachnaya and the Kaapvaal. Both spinel- and garnet-facies peridotites are included. The Oceanic Trend illustrates the compositional path from fertile pyrolite-like peridotites to depleted residues, including abyssal and alpine peridotites and ophiolite tectonites (Boyd, 1989)

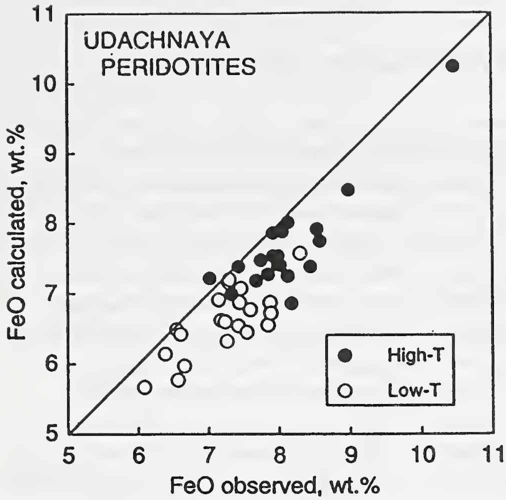

Figure 1

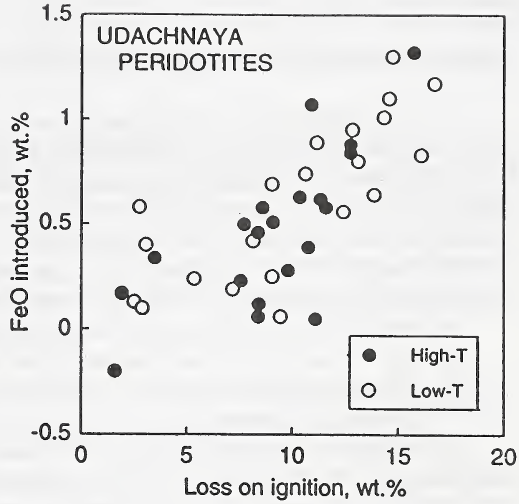

Figure 2

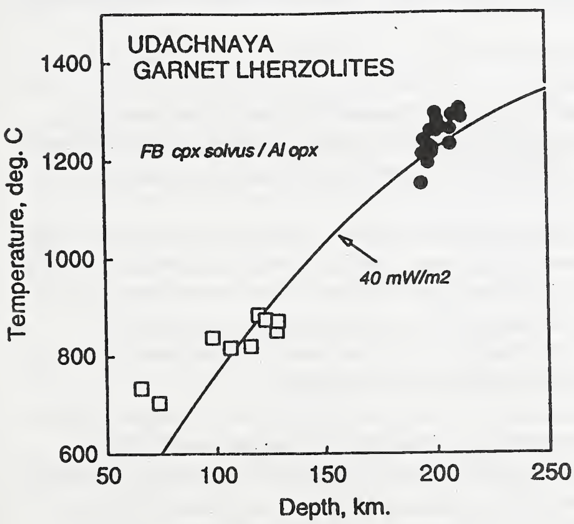

Figure 3

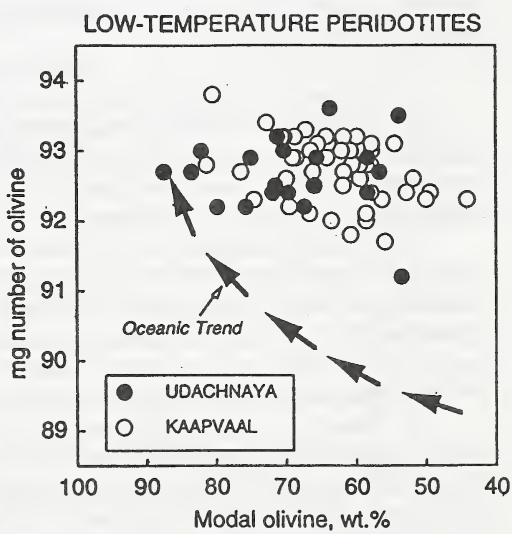

Figure 4