

CHEMICAL HETEROGENEITIES OF PERIDOTITIC INCLUSION GARNETS AND JUVENILITY OF DIAMONDS.

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Geochemical studies of mineral inclusions in diamonds have contributed to our understanding of mechanisms and timing of diamond formation, and geochemical processes in the continental lithosphere in general (e.g., Sobolev, 1977; Meyer and Boyd, 1972; Gurney et al., 1979; Richardson et al., 1984; Griffin et al., 1993; Shimizu and Richardson, 1987; Rudnick et al., 1993; among others).

There are intriguing features in geochemistry of peridotitic diamond inclusion minerals. For instance, it has been shown that chemical variations among inclusion minerals are very large in individual kimberlite pipes (e.g., Shimizu et al., 1989; Griffin et al., 1993) or even in a single diamond host (Sobolev et al., 1989). Did inclusion minerals (and thus host diamonds) form at a wide range of temperature and/or from chemically diverse media on small spatial and temporal scales? Rare earth element (REE) abundance patterns measured in peridotitic inclusion garnets (Shimizu and Richardson, 1987; Shimizu et al., 1989) are quite dissimilar to those of peridotitic and megacrystic mantle garnets, adding another dimension to the puzzle. Better understanding of these and other geochemical features of diamond inclusion minerals would enhance usefulness of the unique "time capsules".

Emphasis of this study is placed on a detailed documentation of trace element variabilities in peridotitic diamond inclusion garnets on small sampling scales, i.e., within individual garnets, among discrete grains from a single diamond host, and within individual kimberlite pipes.

A Cameca IMS 3f ion probe at Woods Hole Oceanographic Institution was used with a spatial resolution of approximately 20 μm for REE (La, Ce, Nd, Sm, Eu, Dy, Er, Yb) and 8 μm for Ti, V, Sr, Y and Zr. Analytical uncertainties range from 10 ~ 20 % for REE and 5 ~ 10 % for the other trace elements. More than 30 garnet crystals from 15 diamonds from Mir, Udachnaya and Aikhal kimberlite pipes were analyzed; 5 samples were analyzed for more than 2 grains from a single host for possible within-stone heterogeneities, and 18 grains were analyzed on more than 5 spots for possible within-grain heterogeneities.

Salient features of the results are summarized as follows:

- (1) Chondrite-normalized REE patterns vary from strongly light REE-depleted patterns typical of mantle garnets to variably sinuous ones with general light REE

enrichment as observed previously (e.g., Shimizu and Richardson, 1987). Samples from the Mir pipe (MR129/15, Av49, MR92/9 and MR717) cover the entire range, showing large local variabilities. The observed range in $^{147}\text{Sm}/^{144}\text{Nd}$ (0.793 ~ 0.105) for the Mir samples could produce significant variations in $^{143}\text{Nd}/^{144}\text{Nd}$ among samples from individual pipes, depending on the age of diamond formation.

(2) Sr contents are highly variable (a total range of 0.4 ~ 665 ppm) and generally much higher than most peridotitic and megacrystic mantle garnets (< 1 ppm), consistent with the observation by Griffin et al., (1993). The partitioning of Sr between garnet and melt (fluid) suggests either extremely unrealistic crystallization media or disequilibrium distribution of Sr during crystal growth.

(3) Among discrete garnet grains from a single diamond host, REE patterns are broadly similar, but elemental concentrations can vary more than a factor of 5. Largest variations are found for light REE, which are generally mirrored by those in Sr.

(4) Individual garnet crystals are often chemically heterogeneous. Among 18 grains analyzed more than 5 spots, 13 show Sr variations greater than a factor of 2, 7 grains greater than a factor of 5, and 5 grains are found to be heterogeneous by more than a factor of 10. The largest within-grain variation was found in one of 5 grains in Av49 from Mir, in which Sr varies from 2.2 to 665 ppm. An area approximately $50 \times 30 \mu\text{m}$ within a total grain size of $200 \times 150 \mu\text{m}$ appears to have Sr contents greater than 50 ppm, which rapidly decreases to a "base level" of 2.2 ppm within a distance of 50 μm . High Sr is generally accompanied by enrichment in light REE.

The observed large chemical heterogeneities on small spatial and presumably temporal scales can be interpreted as reflecting disequilibrium trace element distribution during fast growth of garnets. The Sr zoning places a limit for a period of time in which diffusional homogenization could have taken place. Based on the experimental data of Sr diffusion in garnet at temperatures appropriate for diamond formation (Coghlan, 1990), it is concluded that a grain with a radius of 100 μm would be homogenized in less than 100,000 years. It is therefore suggested that the peridotitic garnet inclusions from the Siberian kimberlites (and host diamonds) crystallized immediately prior to eruption of kimberlites. The fact that majority of garnets studied here display significant internal heterogeneities strongly support the contention. The "ancient" isotopic signatures (Richardson et al., 1984; Pearson et al., 1995) and the juvenility suggest that garnets were derived from local old lithospheric materials through young metamorphic reactions.

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