LITHOSPHERE EVOLUTION IN THE ARCHANGELSK KIMBERLITE PROVINCE

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Major- and trace-element compositions of diamond indicator minerals (satellite minerals) from kimberlites have been used to map lateral and vertical variations in the composition and thermal state of the mantle beneath the Zimni Bereg area of the Archangelsk kimberlite province. The study includes the diamondiferous kimberlites of the Al-series in the Zolotitsa Field, and the diamond-poor to barren kimberlites of the Fe-Ti series in the Pachuga field and the An-734 group, ca. 50 km to the east.

Major element compositions have been determined by EMP, and trace elements by proton microprobe; ca.1000 grains of Cr-pyrope garnet and 300 grains of chromite from 12 kimberlites have been analysed. Temperatures have been estimated for each garnet grain, using the empirical Nickel Thermometer (T_{Ni}) and for each chromite, using the Zinc Thermometer (T_{Zn}) (Griffin et al., 1994; Griffin and Ryan, 1995; Ryan et al., 1995). Garnet Geotherms (Ryan et al., 1995; this conference) have been determined for each area; individual grains of garnet and chromite have then been placed in stratigraphic context by referring T_{Ni} and T_{Zn} to the relevant local paleogeotherm.

The two areas show striking differences in geotherm and lithospheric structure at the time of kimberlite intrusion (mid-Paleozoic). The mantle beneath the Zolotitsa field had a relatively cool paleogeotherm, lying near a 37 mW/m^2 conductive model between 800-1100°C. In contrast, the mantle sampled by the Fe-Al kimberlites had a geotherm significantly steeper than a conductive model. The base of the lithosphere, as defined by the maximum depth of Y-depleted garnets (Ryan et al., 1995), lay at ≈180 km depth beneath both areas, but the temperature at this depth was ≤1100°C beneath the Zolotitsa field and ≈1300°C beneath the areas intruded by Fe-Ti kimberlites.

There are also marked differences in the extent of metasomatic processes beneath the two areas. The lithosphere beneath the Zolotitsa field is relatively depleted; phlogopite-related metasomatism is prominent at depths of 125-150 km, affecting up to 50% of the volume, but melt-related metasomatism is minor and essentially restricted to depths >160 km. Beneath the areas intruded by Fe-Ti kimberlites, depleted garnets make up ≤30% of the total, and melt-related metasomatism affects ≥50% of the mantle volume over the entire depth range sampled.

The abundance of subcalcic harzburgitic ("G10") garnets is similar in the diamond-rich kimberlites of the Zolotitsa field and in some low-grade to barren kimberlites of the Fe-Ti series. This reflects the similar abundance (<30%) and stratigraphic distribution of harzburgite, which extends over depths of 130-180 km beneath both areas. The differences in diamond grade between the two kimberlite series reflect both metasomatism and the thermal structure of the lithosphere. Beneath the Zolotitsa field, the diamond stability field in the lithosphere extends from 130-180 km, a depth range that encompasses most of the harzburgitic rocks. Beneath the Fe-Ti kimberlite fields, the diamond stability field extends only from ca 150-180 km, and many of the harzburgitic rocks lie in the graphite stability field. Equally importantly, the lithosphere beneath the Fe-Ti kimberlite fields has been strongly affected by asthenospheric, presumably oxidising, metasomatism. Empirical evidence from many kimberlite fields worldwide indicates that this style of metasomatism is destructive to diamonds.

The thinning, heating and metasomatism of the lithosphere beneath the Fe-Ti kimberlite fields is attributed to the intrusion of asthenosphere-derived magmas; this intrusion may be responsible for some of the major domal structure associated with the Archangelsk kimberlite province (Kaminsky et al. 1995). The heat input from these magmas resulted in a progressive steepening of the geotherm with depth, indicating that heat transport was at least partly non-conductive.

Chromites are moderately abundant in the kimberlites of the Zolotitsa field, where they occur to depths of ≈160 km, but are absent in most of the Fe-Ti series kimberlites. The similarities in the rock types and stratigraphy beneath the two areas, derived from the analysis of garnet concentrates, suggest that chromite originally was present in the rocks beneath both areas. Its rarity in the Fe-Ti series kimberlites therefore is ascribed to the effects of the intense metasomatism of the lithosphere. The Solokha kimberlite of the Pachuga field contains a range of chromites with moderate to high Cr contents, but low Mg and high Ti. They show a wide range of T_{Zn} which is not reflected in the T_{Ni} distribution of the garnets from the same kimberlite, and these chromites are interpreted as largely a magmatic population.

High-Mg, Cr ilmenites are abundant in the concentrates from the kimberlites of the Fe-Ti series. Although their compositions normally would be regarded as favourable for diamond preservation, they occur in barren or very low-grade kimberlites. These ilmenite suites show good magmatic fractionation trends (cf. Griffin et al., this conf.), and probably are related to the asthenospheric melts that caused the metasomatism of the mantle and the elevated geotherm. The presence of these ilmenites, and of strongly metasomatised peridotite, in the finely comminuted mantle material of the kimberlite, may account for the distinctive high-Fe,Ti nature of the kimberlites of the Pachuga and An-734 kimberlites.

The traditional use of "G10" garnets, chromites and picroilmenites to evaluate diamond prospectivity can give misleading results in this region, but the methods described here (Griffin and Ryan, 1995), based on both major- and trace-element data, appear to give a reliable basis for prioritisation of exploration targets and for recognition of potentially diamondiferous kimberlite fields, both in this area and in other regions of the Baltic Shield.

References

Griffin, W.L. and Ryan, C.G. (1995) Trace elements in indicator minerals: Area selection and target evaluation in diamond exploration. *In* W.L. Griffin, Ed., Diamond Exploration: Into the 21st Century. Jour. Geochem. Explor. 52 (in press).

Griffin, W.L., Ryan, C.G., Gurney, J.J., Sobolev, N.V. and Win, T.T. (1994) Chromite macrocrysts in kimberlites and lamproites: geochemistry and origin. *In* H.O.A. Meyer and O.H. Leonardos (eds). Kimberlites, Related Rocks and Mantle Xenoliths. CPRM Spec. Publ. 1A/93, pp. 366-377.

Griffin, W.L., Kaminsky, F.V., Ryan, C.G., O'Reilly, S.Y., Win, T.T. and Ilupin, I.P. (1995) Thermal state and composition of the lithospheric mantle beneath the Daldyn kimberlite field, Yakutia. Tectonophysics (in press).

Kaminsky, F.V, Feldman, A.A., Varlamov, V.A., Boyko, A.N., Olofinsky, L.N., Shofman, I.L. and Vaganov, V.I., (1995) Prognositcation of primary diamond deposits. *In* W.L. Griffin, Ed., Diamond Exploration: Into the 21st Century. Jour. Geochem. Explor. 52 (in press).

Ryan, C.G., Griffin, W.L. and Pearson, N., 1995. Garnet Geotherms: a technique for derivation of P-T data from Cr-pyrope garnets. Jour. Geophys. Res. (submitted).