REGIONAL-SCALE METASOMATISM AND THE EVOLUTION OF CRATONIC MANTLE LITHOPHERE

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ABSTRACT

Considerable importance has been attached to the role of metasomatism in determining aspects of modal mineralogy, minor and trace element abundances, and isotopic compositions in peridotitic mantle xenoliths. However there have been many uncertainties about the nature of the metasomatic fluids (or melts?) involved, and of the scale of these metasomatic processes; although arguments have been made for the considerable mobility of small melt fractions (McKenzie, 1989), and the possibility that many metasomatic fluids may evolve from the melts responsible for megacryst crystallisation in the deep lithosphere (Harte et al., 1993).

Peridotite xenoliths from the Jagersfontein kimberlite pipe, South Africa, show a wide range of characteristics and give pressure-temperature estimates spanning a wide range of conditions and potential mantle depths (Fig. 1). Recent detailed studies of these xenoliths have shown that evidence of their geochemical evolution is often preserved by chemical heterogeneities or zonations in garnets within the peridotites (Burgess, 1997; Burgess and Harte, 1999). The garnet zonations most commonly involve variations in Cr, Ti and Al which change lherzolite garnet compositions directly towards (Type I) or away from (Type II) the compositions of megacryst garnets.

In the case of harzburgite garnets, zonations of Type III bring rim compositions close to those of lherzolite garnets. Fig. 2 reconstructs the distribution of the metasomatised peridotites.

Ion microprobe determinations of trace element compositions in the rims of the garnets show gradual changes in the co-existing melt composition, demonstrating increasing LREE and La/Lu with decreasing depth. Modelling of these variations, shows that the necessary variations in melt composition must involve processes of fractional crystallisation, and cannot be produced by exchange alone (as in a chromatographic exchange model). Thus the trace element data support the peridotite evolution model derived from consideration of major-minor element data as shown in Fig. 2, and also support the ideas of regional-scale mobility of small melt fractions (McKenzie, 1989), and the evolution of metasomatic melt compositions by a process of percolative fractional crystallisation (Harte et al., 1993).

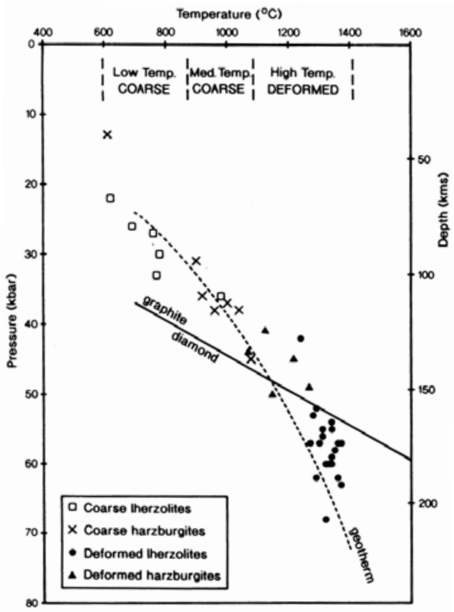

Fig. 1 - P-T estimates for Jagersfontein peridotite xenoliths analysed in this study (Burgess, 1997). Xenoliths divided into lherzolites/harzburgites on basis of presence/absence of clinopyroxene. Division into low, medium and high temperature following Winterburn et al. (1990); but pressure calculations use Brey and Kohler (1990) barometer, with temperature either from Brey and Kohler (1990) cpx-opx solvus (for lherzolites), or from O'Neill and Wood (1979) Mg-Fe garnet-olivine exchange (for harzburgites). The solid black line is the graphite-diamond equilibrium of Kennedy and Kennedy (1976), the dashed line is the $44 mW/m^2$ conductive geotherm calculated by Kohler and Brey (1990) from the data of Chapman and Pollack (1977).

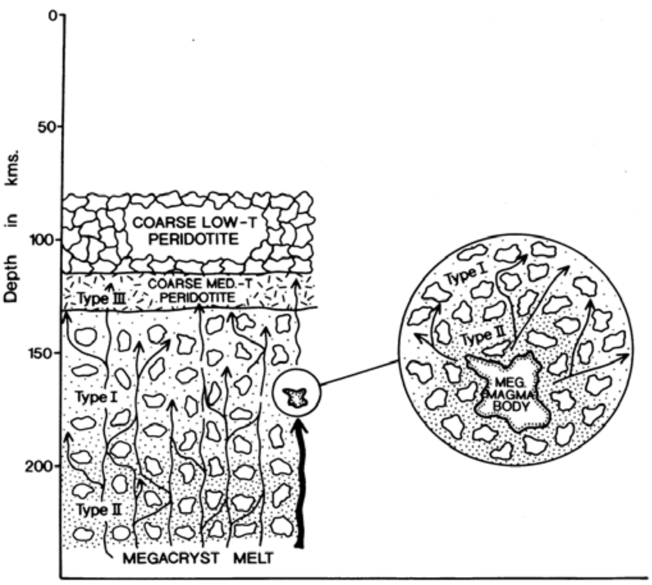

Fig. 2 - Model of evolution of the sub-cratonic lithosphere. The left hand side of the diagram shows the preferred model for Jagersfontein, with melt (initially in equilibrium with Cr-poor megacrysts) infiltrating upwards and progressively causing the Type II, I and III garnet metasomatic zoning phenomena noted in text; deformed peridotites occupy the mantle depth range below 130, and the pervasively infiltrating melt is indicated by the arrowed lines.
The right hand side of the diagram illustrates a potential situation where melt intrusion gives a higher level body of megacryst magma, and a metasomatic aureole is formed about it (such a situation could be associated with an inflected geotherm, unlike that shown in Fig. 1).

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