GEOCHEMICAL AND GEOPHYSICAL MANTLE DOMAINS.

O'Reilly, [1]Suzanne Y.; Griffin, [2]W.L. and Chen, [1]Y.D.

(1) School of Earth Sciences, Macquarie University, Sydney, NSW 2109, Australia;

(2) CSIRO Div. of Exploration Geoscience, Box 136, N. Ryde, NSW 2113, Australia.

Geochemical Domains

Geochemical Characteristics

Four mantle domains within the spinel lherzolite stability field have been characterized geochemically using a large sampling base of xenoliths entrained in basaltic rocks. Regions sampled are from eastern Australia and eastern China; xenoliths analysed range from spinel lherzolite (metasomatized to varying degrees) to granulites and pyroxenites (frozen basaltic magmas and cumulates thereof).

Three regions of eastern Australia define isotopically distinct domains in $\varepsilon Nd/^{87}Sr/^{86}Sr$ space. The most comprehensive data set, from western Victoria, shows a wide spread of values from around $\varepsilon Nd=6.5$, $^{87}Sr/^{86}Sr= .703$ extending in a mixing hyperbola to extremely "enriched" values ($\varepsilon Nd= -8$, $^{87}Sr/^{86}Sr= .716$). The NSW and Qld domains trend off the mantle array towards high $^{87}Sr/^{86}Sr$ values but define separate fields. Additional constraints for models of geochemical evolution are provided by the isotopic characteristics of suites of granulites and pyroxenites. Many of these formed within the mantle by crystallization of melts with a crustal isotopic signature. These melts formed within a mantle volume already metasomatized and imprinted with "subduction-type" isotopic signatures. This ties in with eastern Australia's tectonic history which has involved multiple rifting and collision episodes during the Phanerozoic.

Xenoliths from the Nushan (China) region show a high degree of modal metasomatism. However, these xenoliths shows no pronounced $^{87}Sr/^{86}Sr$ enrichment;this must reflect the addition of fluids with a primordial or, at least, mantle-array isotopic signature.

Metasomatic processes

To assess the significance of the geochemical characteristics of continental lithospheric mantle, we have carried out a detailed study on a suite of spinel lherzolite xenoliths from the western Victoria domain, southeastern Australia (O'Reilly et al, 1991). These xenoliths are samples of the lithospheric mantle, showing varying degrees of metasomatism. Forty carefully selected whole rock spinel lherzolites have been analyzed (using a variety of techniques) for major and trace elements and over thirty for Nd and Sr isotopic composition. Twelve of these were chosen for proton-microprobe analysis to establish the distribution of trace elements in coexisting phases of cryptically and modally metasomatized lherzolites. To assess mass balance, the modes of the spinel lherzolites analyzed by proton-microprobe were calculated using the whole-rock composition and electron-microprobe analyses of constituent minerals. Mass balance was established within error limits for all rocks where interstitial glass was not present. This indicates that few of the LIL elements reside in "interstitial sites" or as grain-boundary coatings, but are contained in metasomatic phases.

(i) This work demonstrates that the trace-element abundances and patterns of mantle rocks are controlled primarily by the crystal chemistry of metasomatic phases (cryptically-metasomatized clinopyroxene + amphibole, mica, apatite). The variable distribution of these volatile-bearing phases in space and time results in a decoupling of major, minor and trace elements during metasomatism, mainly reflecting crystal/fluid partitioning. For example, Nb is restricted to amphibole or mica-bearing rocks and Sr, REE, Pb, U and Th are most enriched in rocks containing modal apatite.

(ii) Open-system crystallization has taken place, with the mode of the rock determining the bulk KD between rock and fluid. If no volatile-bearing phases are formed (amphibole, mica or apatite), uptake of LIL and HFS elements is limited by the capacity of clinopyroxene to accept these elements.

(iii) The trace element characteristics of some of the mantle rocks are similar to those typically ascribed to "crustal contamination" of melts. This applies to LREE, Zr and Ba abundances, and even isotopic signatures, for the western Victorian mantle.

These results have important implications for contamination of small-volume, apparently primitive or primary magmas, including most continental alkali basaltic types. The LIL and HFSE trace elements in modally metasomatized mantle rocks are concentrated in phases which are less refractory and more easily broken down in heating events (e.g. along magma conduits). When these phases break down, the trace elements cannot be accepted into the residual lherzolite phases and are therefore partitioned into melt, providing very easy contamination of ascending or infiltrating magmas. Therefore, the heterogeneity observed in the trace element patterns of sequences of continental basaltic rocks does not necessarily reflect source heterogeneity. It may merely be the cumulative imprint of varying degrees of contamination by different types of metasomatized lithospheric mantle.

Geophysical Domains

Data from xenoliths are also crucial in interpreting remotely-sensed (geophysical) information on the lithospheric mantle including thermal, magnetic, seismic, gravity, electromagnetic properties. Measurements of acoustic velocities of mantle xenoliths (O'Reilly et al., 1990) and characterization of thermal states have allowed realistic modelling of seismic profiles to define the fine structure of the crust-mantle boundary and lower crust/upper mantle stratigraphies in cratonic and non-cratonic lithosphere sections.

Results show that the thermal profiles of lithospheric sections must be known to model Vp profiles realistically. In addition, the conventional use (by seismologists) of dunite as a generalized mantle wall-rock results in overestimates of mantle Vp. The variable anisotropy (up to 10%) in acoustic velocities measured in moderately foliated mantle rocks may account for enigmatic seismic reflectors in mantle regions, especially at boundaries of large-scale tectonic blocks.

Integration of petrologic, geochemical and geophysical data can provide a holistic models for the structure and evolution of different lithospheric domains ..Many significant mantle events appear to be coupled to tectonic episodes observed in crustal layers. This methodology can be used to identify large continental blocks with contrasting chemical and physical properties relevant to the formation and preservation of diamonds.

References

O'REILLY, S.Y., JACKSON, I., and BEZANT, C., 1990. Seismic and thermal parameters of upper mantle rocks from eastern Australia: implications for seismic modelling. Tectonophysics, 185, 67-82.

O'REILLY, S.Y., GRIFFIN W.L., and RYAN, C., 1991. Residence of trace elements in metasomatized spinel lherzolite xenoliths: a proton-microprobe study. Contrib. Miner . Petrol. in press.