

## COMPOSITIONAL EVOLUTION OF THE MONASTERY MEGACRYSTS AND PARENT MAGMA

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The Monastery kimberlite, South Africa, contains a spectacular suite of Cr-poor megacryst minerals recording a wide range of compositional evolution in the subcontinental mantle. The nature of the megacryst parent magma is uncertain and an important problem in upper mantle petrology because of possible links to kimberlite. We have initiated a study which seeks to model in quantitative detail a variety of possible petrogenetic processes responsible for megacryst production and coexisting liquid evolution. A large number of such processes, including some that are open-system, may operate. We have begun by modeling the simpler, closed system processes and will consider other processes as modeling progresses and as the data dictate. In this study we report the initial results of fractional and equilibrium crystallization models for the compositional evolution of this Monastery megacryst suite.

The Monastery megacryst suite is characterized by very regular correlated variations major and trace element chemistry, suggesting the operation of a coherent petrologic process (Gurney et al 1979, Moore et al 1992). The basis for the study is provided by the chemical compositions and coexisting mineral relationships examined in several hundred megacryst samples. Electron-, proton- and ion-microprobe analyses of major and trace elements are used to define the compositional evolution of the megacryst suite minerals. Compositional relationships between the minerals were described by a parameterization of all coexisting megacryst data (i.e., observed intermineral partitioning) and individual mineral trends, so that the composition of any solid phase can be determined from that of any other. Ion-microprobe analysis of coexisting megacryst minerals revealed a systematic change in intermineral REE and other trace element partition coefficients as a function of composition/temperature. These imply large changes in mineral-liquid partition coefficients for certain elements (e.g. a 3-fold decrease in  $D_{gt-L}$  for Ce, and illustrate the degree of complexity required in accurate quantitative modeling of magmatic systems.

We calculated the composition of a hypothetical magma, proposed to be parental to the most magnesian megacrysts by using the composition of the Monastery Quarry kimberlite (Smith et al 1985) as a starting point, and correcting for assimilation of peridotite and megacrysts, as revealed by petrography. This approach emphasizes the importance, in our view, of the admixture and partial melting/assimilation of solid mantle peridotite into kimberlite magma during ascent as a process in kimberlite evolution. However, our initial calculations do not examine the effects of AFC-type processes on

megacryst evolution (cf. Neal and Davidson 1989, Neal 1994). The initial composition used in the modeling was adjusted slightly to ensure that magma and first-formed megacryst mineral compositions were consistent with expected partitioning relationships as revealed by laboratory studies. It was found that subtraction of petrographically observed peridotite proportions yielded a magma in Fe-Mg exchange equilibrium with Fo 88-90 mantle olivine at high pressure.

Crystallization of the Monastery suite begins with olivine (Fo88), orthopyroxene, clinopyroxene and garnet and is replaced at lower temperature by the assemblage orthopyroxene-clinopyroxene-garnet-ilmenite. The relationship of these minerals to more evolved megacrysts of olivine and Fe-rich zircon, and to phlogopite, Nb- and Cr-rich ilmenite and Ca-rich clinopyroxene is presently ambiguous, as is the possible role of a carbonate phase. In simulating the fractional crystallization process, solid phases are incrementally removed from the calculated liquid, in a proportion which allows the residual liquid to precipitate megacrysts which follow the observed trend of the natural samples. In these calculations, either the mineral proportions, or the mineral-liquid partition coefficients may be specified (or varied continuously). The other variable emerges as a product of the calculation. Solid-liquid partition coefficients are initially those used to determine the magmatic composition.

Initial results using fixed mineral proportions show that fractional crystallization of the observed solid assemblage in peridotite-like proportions can produce the chemical variations observed in the first stages of crystallization. Incompatible element abundances suggest that this stage, up to ilmenite entry, requires 20-30% crystallization. However, it appears that equilibrium crystallization is also able to reproduce the compositions under certain conditions. We are presently testing the limits of these conditions, as well as performing runs with pre-specified partition coefficients, which aim to specify mineral proportions more precisely.

## References

- Gurney, J.J., Jakob, W. R. O. & Dawson, J. B. 1979. Megacrysts from the Monastery kimberlite pipe, South Africa. In: Boyd, F. R. & Meyer, H. O. A. (eds.) *The Mantle Sample: Inclusions in Kimberlites and Other Volcanics*. AGU; Washington, 227-243.
- Moore, R. O., Griffin, W. L., Gurney, J. J., Ryan, C. G., Cousens, D. R., Sie, S. H., Suter, G. F. 1992. Trace element geochemistry of ilmenite megacrysts from the Monastery kimberlite, South Africa. *Lithos* 29, 1-18.
- Neal, C. R. & Davidson, J.P. 1989. An unmetasomatized source for the Malaitan alnoite (Solomon Islands) : petrogenesis involving zone refining, megacryst fractionation, and assimilation of oceanic lithosphere. *Geochim. Cosmochim. Acta* 53, 1975-1990.
- O'Neill, J. and Neal, C.R. 1994. Magma-wallrock interaction and the key to reverse fractionation in megacryst petrogenesis. *Eos* 74, 749.
- Neal, C.R. 1994. Megacryst petrogenesis. *Eos* 74, 749.
- Smith, C.B., Gurney, J.J., Skinner, E.M.W., Clement, C.R. and Ebrahim, N. 1985. Geochemical character of southern African kimberlites: a new approach based on isotopic constraints. *Trans. Geol. Soc. S. Afr.* 88, 267-280.