

ABUNDANCES OF TRACE ELEMENTS IN CLINOPYROXENES FROM THE HOROMAN PERIDOTITE COMPLEX: EVIDENCE OF REACTION WITH EXOTIC MELT/FLUID

Eiichi Takazawa*, Frederick A. Frey** and Nobumichi Shimizu***

* Department of Geology, Niigata University, Niigata, 950-2181, Japan.

** EAPS, Massachusetts Institute of Technology, Cambridge, MA 02139, U.S.A.

*** Woods Hole Oceanographic Institution, WHOI, MA 02543, U.S.A.

ABSTRACT

The Horoman peridotite, a fault-bounded 8 x 10 x 3 km orogenic lherzolite exposed in the high-T and low-P Hidaka metamorphic belt of Hokkaido, Japan, experienced a partial melting event in the oceanic mantle at 831 Ma (Yoshikawa and Nakamura, 1998), which created the main lithologies of plagioclase lherzolite, lherzolite and harzburgite (Takazawa et al., 1998). Subsequent metasomatic events in the lithospheric mantle partially modified the Horoman peridotite (Takazawa et al., 1992; 1996; Yoshikawa et al., 1993). The spatial variations of trace element abundances and Sr-Nd isotopic systematics in clinopyroxenes within the 140 m Bozu stratigraphic section reflect the spatial variations of the metasomatic reactions.

The Bozu stratigraphic section belonging to the Main Harzburgite Lherzolite suite of Takahashi (1991) has a layered sequence from plagioclase lherzolite (57 m thick) through lherzolite (60 m thick) to harzburgite (>43 m thick). The lherzolite and harzburgite layers have an interstitial-phlogopite-bearing sub-zone (10 m thick) and Type II mafic granulite layers (Takazawa et al., 1998), respectively. Abundances of REE, Ti, V, Cr, Sr, Y and Zr in clinopyroxenes from 68 peridotites along the Bozu section were analyzed using Cameca IMF 3f ion probe at Woods Hole Oceanographic Institution. Previous study demonstrated that the compositional zoning in clinopyroxene porphyroclasts was created by uplift of the Horoman complex from garnet- to plagioclase-stability field (Ozawa and Takahashi, 1995; Takazawa et al., 1996). Thus we analyzed porphyroclast clinopyroxene cores which were equilibrated with garnet. These cores are relatively enriched in incompatible elements, such as light REE, thereby showing that the metasomatic event occurred within the garnet-stability field.

Important features of the spatial compositional variations in the clinopyroxene cores are: (1) At the lherzolite-harzburgite boundary clinopyroxenes are strongly enriched in REE, Sr, Zr and Y and have $[La/Yb]_{CN} > 1$. Their chondrite-normalized patterns display a “~” shape. Abundances of La, Ce, Sr at the boundary are forty times greater than those in lherzolite clinopyroxenes 2.5 meters from the boundary; (2) The lherzolite clinopyroxenes near the harzburgite-lherzolite boundary are enriched in light and middle REE and have a “~” shaped chondrite-normalized pattern whereas further from the contact clinopyroxenes are only enriched in light REE ($[La/Nd]_{CN} > 1$) and have a “√” shaped pattern. (3) Abundances of highly incompatible elements in the lherzolite clinopyroxenes gradually decrease toward the lherzolite-plagioclase lherzolite boundary, but middle and heavy REE abundances are almost constant.

To explain chondrite-normalized REE patterns for

clinopyroxenes in the Horoman peridotite, in particular, the strongly inflected v-shape patterns in some lherzolites,

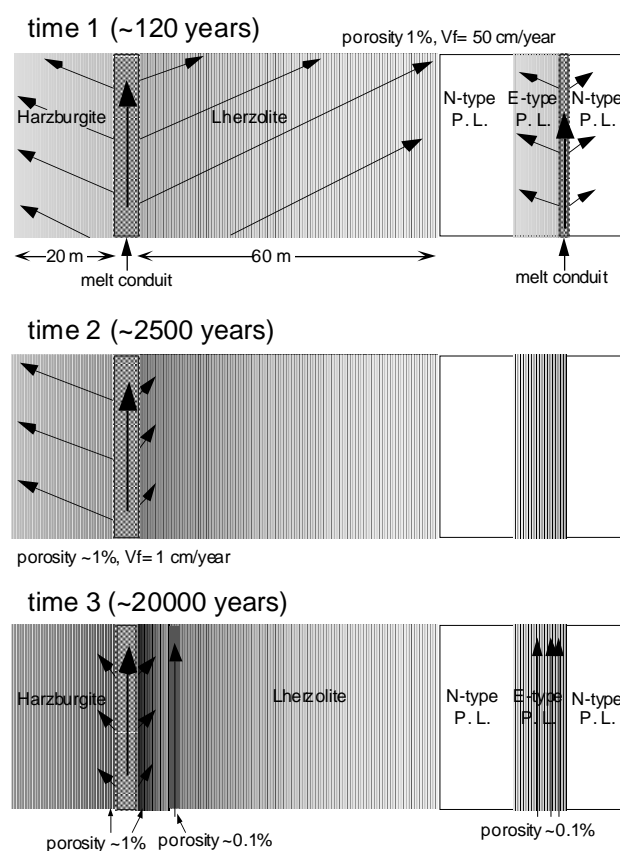


Fig. 1. Schematic model showing the proposed sequence of melt-peridotite reaction occurring in the Bozu section. In each panel, arrows indicate direction and region of melt flow. Graded shading indicates relative abundance of LREE in clinopyroxenes. At time 1, a melt percolated from a melt conduit located at the harzburgite-lherzolite contact into wallrocks with porosity of 1% and velocity of 50 cm/year. Another melt conduit was located at the boundary between E-type and N-type plagioclase lherzolites (garnet lherzolite at this time). At time 2, melt flow in the harzburgite and lherzolite contracted and percolated for ~3 meters from the melt conduit into lherzolite, but over 20 meters in harzburgite due to a difference in permeability. There was no melt flow in the E-type plagioclase lherzolite at time 2. At time 3 melt flow contracted further in both lherzolite and harzburgite. Clinopyroxene located near the melt conduit (<1 m) reacted with the melt for longer duration. Also at time 3 another melt channel parallel to the main conduit was present at 3 to 10 meters from the harzburgite-lherzolite contact. This melt flow was characterized by low melt fraction (~0.1%), long percolation distance (~100 meters). A similar melt channel with low melt fraction of 0.01% and shorter percolation distance (~10 m) was present in the E-type plagioclase lherzolite layer.

Takazawa et al. (1992) used the model of Bodinier et al. (1990) and Vasseur et al. (1991) in a two-stage calculation; (1) partial melting of fertile peridotite, and (2) ion-exchange reaction between depleted peridotite and an exotic melt with high LREE/HREE and Sr and Nd isotopic ratios that differ from the peridotite matrix. Subsequent to Takazawa et al. (1992) new observations summarized above enable more detailed evaluation of the suitability of an ion exchange model.

An alternative model is that the harzburgite was produced by reaction between lherzolite and an exotic melt/fluid. This hypothesis was tested using an AFC model (Kelemen et al., 1992) and the model of Godard et al. (1995), but we could not identify permutations of these models that provided satisfactory explanations of the incompatible element abundance trends in the Horoman peridotite. The clinopyroxene chondrite-normalized patterns in the Bozu section can be best explained by an ion-exchange reactions between percolating exotic melt and peridotite without changes in modal mineralogy. The model requires, however, a specific spatial and temporal evolution of melt flow in a stratigraphic context. Fig. 1 schematically summarizes a proposed sequence of melt-peridotite reactions occurring in the Bozu section. This scenario is consistent with Sr and Nd isotopic ratios of lherzolite clinopyroxenes. The exotic melt/fluid had present day $\epsilon_{Nd} \sim -6$ and $^{87}Sr/^{86}Sr \sim 0.703-0.704$.

REFERENCES

- Bodinier J.-L., Vasseur G., Vernieres J., Dupuy C. and Fabries J., 1990. Mechanism of mantle metasomatism: Geochemical evidence from the Lherz orogenic peridotite. *J. Petrol.*, 31: 597-628.
- Godard M., Bodinier J.-L. and Vasseur G., 1995. Effects of mineralogical reactions on trace element redistributions in mantle rocks during percolation processes: A chromatographic approach. *Earth Planet. Sci. Lett.*, 133: 449-461.
- Kelemen P. B., Dick H.J. and Quick J. E., 1992. Formation of harzburgite by pervasive melt/rock reaction in the upper mantle. *Nature*, 358: 635-641.
- Takahashi N., 1991. Origin of three peridotite suites from Horoman peridotite complex, Hokkaido, Japan; Melting, melt segregation and solidification processes in the upper mantle. *J. Min. Petrol. Econ. Geol.*, 86: 199-215.
- Takazawa E., Frey F.A., Shimizu N. and Obata M., 1996. Evolution of the Horoman peridotite (Hokkaido, Japan): Implications from pyroxene compositions. *Chem. Geol.*, 134: 3-26.
- Takazawa E., Frey F.A., Shimizu N. and Obata M., 1998. Whole-rock compositional variations in an upper mantle peridotite (Horoman, Hokkaido, Japan): Implications for melt segregation, migration and reaction. Submitted to *Geochim. Cosmochim. Acta*.
- Takazawa E., Frey F. A., Shimizu N., Obata M. and Bodinier J.-L., 1992. Geochemical evidence for melt migration and reaction in the upper mantle. *Nature*, 359: 55-58.
- Ozawa K. and Takahashi N., 1995. P-T history of a mantle diapir: the Horoman peridotite complex, Hokkaido, northern Japan. *Contrib. Min. Petrol.*, 120:223-248.
- Vasseur G., Vernieres J. and Bodinier J.-L., 1991. Modeling of trace element transfer between mantle melt and heterogranular peridotite matrix. *J. Petrol. (Special Lherzolites Issue)*, p. 41-54.
- Yoshikawa M. and Nakamura E., 1998. Geochemical evolution of the Horoman Peridotite Complex: Implications for melt extraction, metasomatism and compositional layering in the mantle. Submitted to *J. Geophys. Res.*
- Yoshikawa M., Nakamura E. and Takahashi N., 1993. Rb-Sr isotope systematics in a phlogopite-bearing spinel lherzolite and its implications for age and origin of metasomatism in the Horoman peridotite complex, Hokkaido, Japan. *J. Min. Petrol. Econ. Geol.*, 88: 121-130.