Ofioliti, 1999, 24 (1a), 106-107

REACTIVE CRACK FLOW IN THE OCEANIC MANTLE: AN ION PROBE STUDY ON CPX FROM VEIN-BEARING ABYSSAL PERIDOTITES

E.W. Hellebrand*, J.E. Snow*, H.J.B. Dick, C.W. Devey***** and **A.W. Hofmann***

* *Max-Planck-Institut fuer Chemie, Abt. Geochemie, P.O. Box 3060, D-55020 Mainz, Germany.*

** *Woods Hole Oceanographic Institution, Woods Hole, Massachussetts 02543, U.S.A.*

*** *Formerly Geol. Institut, Universität Kiel, now at Fachbereich 5 Geowissenschaften, Universität Bremen, 28334 Bremen, Germany.*

ABSTRACT

Abyssal peridotites are valuable melt migration indicators in the oceanic mantle. They are often cut by magmatic veins of variable thickness and a broad range of compositions. Magmatic veins are much more common in the oceanic mantle than generally assumed. Based on our estimates, between 20 and 30 percent of the global abyssal peridotite database contains veins of magmatic origin. We are primarily interested what the effect is on the host peridotite as a function of vein width and composition. This may place important constraints on the pressure and temperature conditions during which melt is transported in open channels in the shallow oceanic mantle.

For this purpose, we have studied vein-host rock systematics in abyssal peridotites from four fracture zones along the Central Indian Ridge (Engel and Fisher, 1975) and one along the Mid-Atlantic Ridge (collected during ME41/2 cruise in 1998 with R/V Meteor). Unaltered vein and host peridotite phases were analyzed by electron and ion microprobe. In addition, detailed profiles were made in order to quantify the chemical effect in the host rock as a function of the distance from the vein. The vein thickness in our sample set ranges from <100 microns to 2 cm.

Based on the mineralogy and mineral compositions, the veins can be divided into two groups: veins that crystallized from (1) (near-) equilibrium liquids and (2) (highly) evolved liquids.

The first group consists of 4 samples (2 from Ascension FZ and 2 from Marie Celeste FZ). They have simple gabbroic compositions, in which cpx and plag form the only crystallizing phases. Their cpx Mg# has near-mantle values and ranges between 0.88 and 0.91, (distal cpx of the host peridotite has Mg# of 0.91). The Ascension FZ gabbro veins have low Al and Cr clinopyroxenes (Al_2O_3 = 1.8-2.6 wt%; Cr_2O_3 = 0.1-0.4 wt%), indicating spinel fractionation prior to injection. The very thin gabbroic veins in the Marie Celeste FZ are less fractionated, as indicated by their vein cpx compositions (Al_2O_3 = 2.8-3.6 wt%; Cr_2O_3 = 0.5-0.6 wt%). We interpret these veins as unfractionated melts that were trapped in the upper lithospheric mantle. Limited porous flow is required to produce the observed cpx composition in the reaction zone.

The second group consists of 1 gabbro-noritic (cpx, plag, opx, ±ilmenite ±apatite), and two ferro-gabbroic (cpx, ilmenite, Ti-magnetite, plag) veins. The chemistry of the vein phases is consistent with their modal compositions. Vein cpx is characterized by Mg# between 0.7 and 0.8, and very low aluminium and chromium concentrations. (Al_2O_3 = 1-2 wt%; Cr_2O_3 < 0.1 wt%).

All veins have reaction zones, in which the host peridotite composition is modified. Evidence for such a reaction zone is rarely visible in thin section. Chemically, the phases in the reaction zone, especially the clinopyroxenes, show strong deviations from the host peridotite composition. Strong core to rim zonations occur within individual grains. Towards the vein a strong decrease in Mg#, Al and Cr content, as well as a Ti and Na increase is observed.

So far, detailed ion probe profiles are only available for Vema FZ (CIR) peridotites. Here, depleted harzburgites contain evolved veins that are rich in Fe-Ti-oxides. The host peridotite has cpx with LREE depleted patterns ($(Ce/Yb)_N$ = <0.005 - 0.02; $(Sm/Yb)_N$ = 0.1 - 0.5; Yb_N = 1.5 - 5) similar to other strongly trace element depleted oceanic peridotites (Johnson et al., 1990). Cpx in the oxide-rich veins are extremely REE enriched (La_N = 10 - 20; Yb_N = 60 – 120), and have pronounced negative Sr and Ti anomalies as depicted in the extended REE diagram in Figure 1. In a reaction zone which is wider than 5 mm and smaller than 30 mm, the host cpx is modified. A strong LREE-enrichment is observed, but also a significant HREE increase at constant Sr and Ti concentrations. The presence of these anomalies in the reaction zone cpx supports that the melt was evolved prior to injection. Further, the modification of the reaction zone cpx requires limited porous flow, combined with crack flow. More ion probe analyses are needed to distinguish the emplacement conditions of group 1 from group 2 veins.

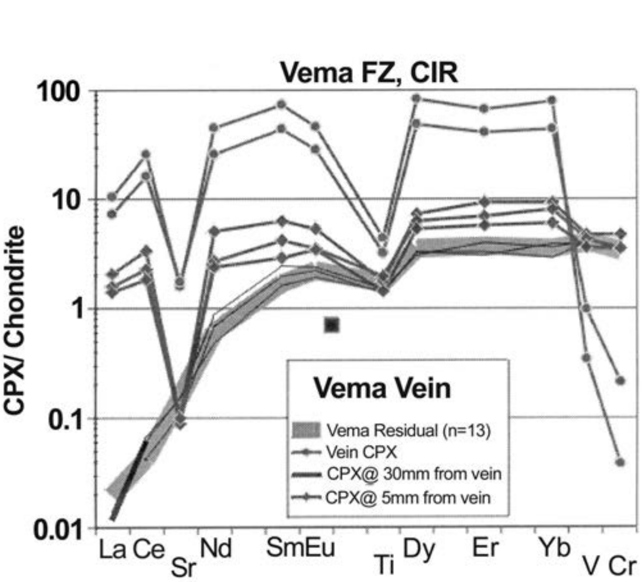

Fig. 1 - Extended REE diagram showing chondrite-normalized cpx composition determined by ion probe in oxide-bearing vein, at 30 mm from the vein, and in the reaction zone (5mm).

The ubiquity of these thin, almost invisible magmatic veins in abyssal peridotites has important implications: (1) whole rock analyses not only give strongly biased information as a result of the intense alteration of abyssal peridotites, but represent a mixture of depleted host peridotite and enriched veins, should therefore only be used in combination with mineral analyses. (2) Reaction zones are chemically modified host peridotite and cannot be used to assess the primary nature of the peridotite. The actual vein may not be visible in the hand sample, because its different rheology makes it an ideal breaking plane in the often highly fractured dredge samples. (3) Open melt transport channels are common in the oceanic mantle and may play an important role as feeders in crustal formation.

REFERENCES

Johnson K.T.M., Dick H.J.B. and Shimizu N., 1990. J. Geophys. Res., 95: 2661-2678.