

Melting Relations of Natural Eclogite at High Pressures: Contrasting Trends of Eclogite Fractionation

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New data on melting of natural eclogite and garnet pyroxenite are presented and applied to model the generation of the eclogite layer associated with garnet lherzolite in the Bohemian Massif, and to the origin of eclogites in general. Melting of eclogite (B16 - Bečváry) at 2.3 GPa revealed multiple phase saturation with a spinel lherzolite assemblage at about < 5% crystallization. The first phase to appear on the eclogite liquidus is olivine. According to the series of peritectic reactions melt + ol = opx + cpx, and melt + ol = opx + cpx + sp; olivine is joined by opx, cpx and sp. At about 45% crystallization, ol and opx dissolve back to the melt by peritectic reaction ol + opx + melt = cpx + sp and cpx + sp crystallize until about 94% crystallization when garnet appears. Sp dissolves on the subsolidus by peritectic reaction melt + cpx + sp = gar. Therefore, ol + opx + melt = cpx + sp and cpx + sp + melt = gar reaction relationships were observed during crystallization of a melt with natural eclogite composition at 2.3 GPa.

According to the experimental results, the eclogite (B16) is a product of partial melting of a depleted spinel lherzolite at $\sim 2.0 < P < 2.5$ GPa. It is suggested that the melt was initially segregated from a parental depleted spinel lherzolite to form thin layers in the host peridotite, and the peritectic reactions of minerals with the melt occurred in the layers as crystallization proceeded. The assemblage of a clinopyroxenite with Ca-poor garnets and spinel was formed close to the solidus, and the final eclogite assemblage of the bimodal garnet and pyroxene was formed by disappearance of spinel by reaction and recrystallization at subsolidus temperatures, at which Ca-rich garnets were formed at the expense of clinopyroxenes. Two distinct trends of eclogite fractionation for melts projected onto the $Al_2O_3 - (Fe,Mg)O - CaO$ ternary were established experimentally at 2.3 and 2.8 GPa. The olivine - orthopyroxene - clinopyroxene (+spinel) fractionation trend for 2.3 GPa moves toward the $Al_2O_3 - CaO$ join and reaches a reaction point where both olivine and orthopyroxene dissolve to form garnet + clinopyroxene. Beyond this reaction point the garnet-clinopyroxene (+spinel) fractionation trend remains the same, i.e., toward the $Al_2O_3 - CaO$ join. On the contrary, the garnet - clinopyroxene fractionation trend of liquid with the same composition at 2.8 GPa moves toward the $Al_2O_3 - (Mg,Fe)O$ join with decreasing temperature, which is opposite to that observed in the iron-free system at about 3.0 GPa. Therefore, the trends of eclogite fractionation as determined at 2.3 and 2.8 GPa are opposite.

The pressure at which a change occurs from one trend to another is about 2.4 GPa.

The origin of bimodal garnets in the eclogite (B16) can be explained by the recrystallization of primary clinopyroxenite with Ca-poor garnets at subsolidus temperatures. Ca-poor garnets in the eclogite are, therefore, most probably relics from the original clinopyroxenite, which crystallized within the garnet peridotite host as a dyke, whereas the Ca-rich garnets were formed during recrystallization of the clinopyroxenite to the eclogite assemblage at subsolidus temperatures.

Melting reactions of garnet pyroxenite (Sm - Borek) were studied at a pressure of 2.8 GPa. The first phase to appear on the liquidus is opx and at about $\sim 27\%$ the crystallization is joined by cpx. Garnet appears below $\sim 30\%$ crystallization and with further crystallization, peritectic reaction opx + melt = gar + cpx causes opx to dissolve to the melt to form gar + cpx. The opx-fractionation trend tends to move toward the $Al_2O_3 - CaO$ join, and is therefore opposite to the trend of the gar - cpx fractionation as determined by the partial melting of eclogite at 2.8 GPa in this system. The garnet pyroxenite (Sm) does not represent a melt but is probably a cumulate, formed most probably at higher pressures than the eclogite (B16).

Except eclogite (B16), all the other samples studied are cumulates formed at higher pressures (probably close to or higher than ~ 3.0 GPa).

These cumulates (garnet+orthopyroxene+clinopyroxene) crystallized at different stages of a fractional crystallization process from melts initially in equilibrium with the assemblage of garnet lherzolite. During fractionation, olivine and orthopyroxene dissolved back to the melt to form the final garnet + clinopyroxene cumulates at least at pressures near 3.0 GPa. The peritectic reaction opx + melt = gar + cpx was observed experimentally for melting of garnet pyroxenite (Sm) at 2.8 GPa. Probably, a similar kind of such process, under limited P,T conditions, took place widely in the Bohemian Massif and produced garnet pyroxenite and eclogite cumulates. The eclogitic melt with composition of (B16) was generated by lithospheric extension with a stretching factor of $1.5 < b < 2.0$ when the potential temperature of the mantle was ~ 1480 °C. The formation of eclogite within the peridotite host was most probably related to the extensional regime in the marginal basin during the Devonian. A partial melt of depleted spinel lherzolite intruded into the host lherzolite and underwent near isobaric cooling followed by an uplift to a depth of ~ 50 km.