

# COMPOSITIONAL AND PHASE RELATIONS OF GARNET AND OMPHACITE: EXPERIMENTAL RESULTS AT 4.0-7.0 GPa IN COMPARISON WITH NATURAL DATA

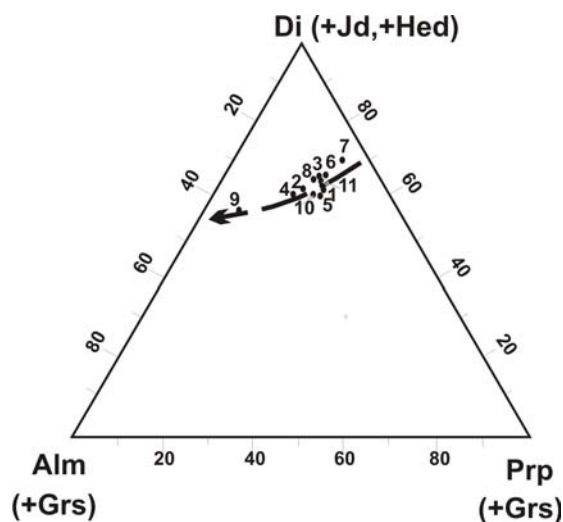
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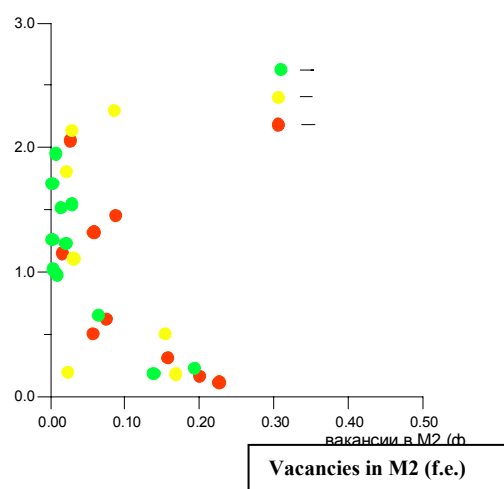
We previously published the results of experiments in some garnet (pyrope-almandine and pyrope-grossular-almandine) [1] and eclogitic (almandine-omphacite, pseudo-ternary system pyrope-almandine-omphacite, and polythermal join garnet-omphacite) [2] systems. In the present study, we suggest an analysis of the experimental and natural data. They are exemplified by eclogites from the “Udachnaya” (our data) and “Mir” kimberlite pipes [3, 4].

From the study of diamondiferous eclogites of the “Udachnaya” kimberlite pipe, we constructed a petrochemical trend on the diopside-pyrope-almandine diagram (Fig.1), which closely resembles the garnet-clinopyroxene cotectics. Pseudo-ternary melting diagram for the omphacite-pyrope (+grossular) – almandine (+grossular) shows the cotectic relations, as well [2]. A perfect correspondence of the natural and experimental data support an idea that bimineral eclogites should be the most abundant rock type among the magmatic eclogites.

The  $\ln K_d$ , where  $K_d$  is a equilibrium constant of the exchange reaction  $\text{Hed} + \text{Prp} = \text{Di} + \text{Alm}$ , for garnet-clinopyroxene pairs from the experiments in the omphacite-garnet join at 7.0 GPa shows a distinct dependence on the Ca-Eskola content in clinopyroxene (Fig. 2). Thus, this dependence must be included into the procedure of temperature calculation for the garnet-clinopyroxene paragenesis formed at high pressures (e.g., inclusions in diamonds). Nevertheless, no dependence between the Ca-Eskola content in clinopyroxene on temperature was found. Apparently, pressure is a major factor influencing on the Ca-Eskola content in omphacites [5, 6].



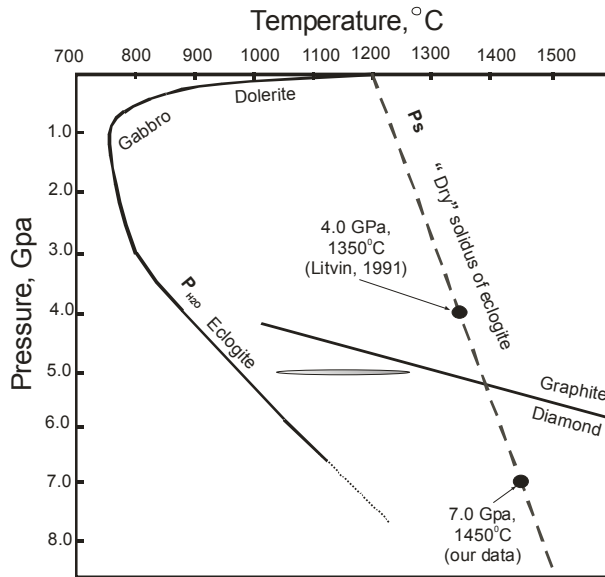
**Fig.1.** Petrochemical trend of garnet-clinopyroxene compositions from nodules of kimberlite pipe «Udachnaya».



**Fig.2.** The dependence of  $\ln K_d$  for garnet-omphacite pairs on the content of vacancies in the M2 site of omphacite.

The T - P diagram in figure 3 shows “dry” and “wet” solids of eclogites. In order to construct the “dry” solidus, we used our experimental data on eclogite system at 7.0 GPa and 1450°C, as well as data by Litvin [7] at 4.0 GPa and ~1350°C. Plotting the P-T data for the diamondiferous eclogites of the “Udachnaya” kimberlite pipe, as well as garnet-clinopyroxene pairs included in diamonds from the “Mir” kimberlites [8, 9] indicate that these data are situated deeply in the “dry” sub-solidus of the eclogitic systems. Lowering of temperature of the eclogite crystallization with respect to the “dry” conditions could be related to the increase of water partial pressure owing to reactions of the diamond crystallization in fluidized magmas:  $\text{H}_2 + \text{CO} = \text{C} + \text{H}_2\text{O}$ ;  $3\text{H}_2 + \text{CO} = \text{CH}_4 + \text{H}_2\text{O}$  etc. [12]. Water can be supplied by fluxes of deep-seated carbonic-aqueous fluids [12], which provoke the above reactions. Thus, the experiments in the model system  $\text{Na}_2\text{O}-\text{CaO}-\text{MgO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ , which is close in com-

position to the natural rutile-bearing eclogites, at pressure 7 GPa show that the “dry” solidi of eclogite is located at around 1450°C. This value is much higher than temperatures calculated for natural eclogite assemblages from kimberlites. It could imply a crystallization of eclogites from strongly fluidized magmas.

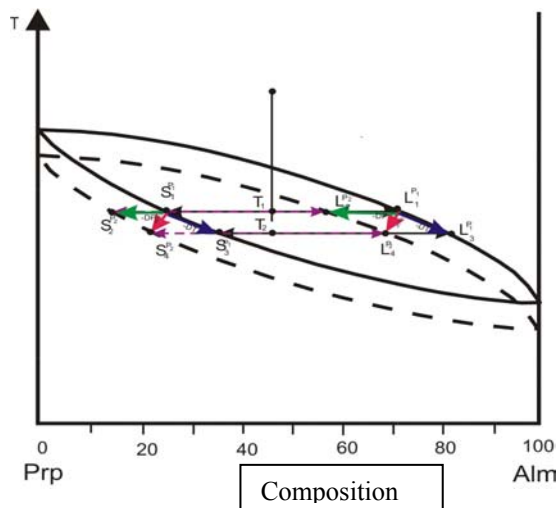


**Fig.3.** Scheme of solidi of basic magmatic rocks under influence of pressure on solid phases ( $P_s$ ) and water pressure ( $P_{H_2O}$ ). Shaded field shows T formation of diamondiferous eclogites of p. «Udachnaya» and garnet-pyroxene association from diamond inclusions of «eclogite» type [9]. Line of eclogite wet solidus: 1) 0-2.5 ГПа [10]; 2) 3.0-6.5 ГПа [11].

Phase diagrams for the binary join pyrope-almandine at 6.5 and 4.0 GPa [1, 2] allow consideration of diverse schemes for variations of Mg-number for garnets crystallizing from a melt under changing either temperature, or pressure, or both parameters simultaneously (Fig. 4). The most interesting situations are related to the decrease of temperature and pressure indicating cooling and uplift of the melt.

(1) **Sub-isobaric cooling** results in the increase of garnet content in the system, i.e. its growth. Thus, a normal crystallization of garnet during cooling at constant pressure would be reflected in a direct zoning in garnet (decrease of Mg-number toward rims). Similar zoning would appear if the cooling rate is higher than the decompression rate.

(2) According to figure 4, a reverse evolution of the garnet Mg-number can be expected during **isothermal decompression**. However, no growth zoning appear in garnet since its amount decreases. In other words, garnet crystals are dissolved in a melt. Similar dissolution would be observed during rapid decompression at slow cooling. Thus, the reverse zoning in garnet can not appear during the normal precipitation from the melt.



**Fig.4.** Scheme of garnet crystallization.

and omphacite Mg-numbers unambiguously reflects its crystallization from a melt, since equilibrium of these phases during cooling and decompression without melt would result in decrease of their Mg-numbers. Equilibrium of above garnet and omphacites included in diamonds with melts is supported

Nevertheless, scheme (2) indicates that crystallization of consequent generations of garnet with the increasing Mg-number is possible during fractional crystallization. If some phase captures precipitated garnet grains, than the Mg-number of these grains would increase from those included in cores of the hosting phase to those trapped into the periphery of the hosting phase. It should be noted that similar evolution would appear for omphacites, as well, if diopside-hedenbergite solid solution is continuous at pressures above 4 GPa. Such regular increase of the Mg-number in garnets and omphacites distributed in the growth zones of diamonds is well described for Yakutian kimberlites [8]. Mutual increase both garnet

by occurrence of melt inclusions in these diamonds [8]. Notable growth of the Mg-number shows that the decompression rate was significantly higher than the cooling rate. This corresponds to the diamond growth during the uplift of the magmatic melt.

Thus, analysis of tendencies in Mg-number variations in garnets of different generations on the basis of the pyrope-almandine join [1] along with independent data reflecting the P-T evolution (for example, variations of Na<sub>2</sub>O and TiO<sub>2</sub> in garnets, Na<sub>2</sub>O and K<sub>2</sub>O in clinopyroxenes) allow in some cases distinguish the magmatic stage for eclogitic assemblages. This conclusion is especially important for inclusions in diamonds, which rarely preserve melt inclusions.

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