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Ravna E.J.K., Kullerud K., Ellingsen E. (2006) Prograde garnet-bearing ultramafic rocks from the Tromsø Nappe, northern Scandinavian Caledonides // Lithos. 92, 336–356.

Ravna E.J.K., Roux M.R.M. (2006) Metamorphic evolution of the Tønsvika eclogite, Tromsø Nappe - Evidence for a new UHPM province in the Scandinavian Caledonides // Intern Geol Review. 48, 861–881.

Kuzyura A.V., Litvin Y.A. Peritectic reaction of olivine in the system olivine-jadeite-diopside-garnet ±(C-O-H) as a clue mechanism of ultrabasic to basic evolution of the upper mantle magmatism (experiment at 6.0 GPa). UDC 552.11

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Abstract. Experimental researches at 6.0 GPa and 1200–1650°C of phase relations at melting of systems Ol–Jd–Di-Grt and Ol–Jd–Di-Grt–(C-O-H) were carried out with using of polythermal sections Ol-Omph and $Ol_{95}(C\text{-}O\text{-}H)_5$–$Omph_{95}(C\text{-}O\text{-}H)_5$. A peritectic reaction of olivine and a melt enriched in Jd-component with a formation of garnet was found out. Fractional magmatic evolution occurs at ultrabasic to basic compositions, it is controlled by a set: cotectic L+Ol+Cpx+Grt → peritectic Ol+Jd-L with a formation of a garnet Grt → cotectic L+Omph+Grt. Peritectic L+Ol+Cpx/Omph+Grt is like "a physico-chemical bridge" providing a transformation from ultrabasic magmas to basic ones, from peridotite/pyroxenite rocks to eclogite ones. C-O-H-fluids don't change phase relations of ultrabasic-basic system Ol-Jd-Di-Grt-(C-O-H), lowering solidus and liquidus temperature on 120 and ~60-80°C and raising a composition of the peritectic reaction concerning Mg- и Fe-components on ~10 wt. %.

Keywords: *eclogite; peridotite; fractional crystallization; ultrabasic to basic evolution; peritectic reaction; olivine garnetization; C-O-H-fluid.*

Mineralogical and petrological studies of xenoliths in kimberlites indicate physicochemically unified processes of formation of peridotite-pyroxenite-eclogite series of magmatic rocks of the garnet-peridotite facies of the upper mantle. Thus, petrochemical trends of increasing concentrations of Ca- and Fe- components in garnets, Fe and Na in clinopyroxenes and omphacites (Sobolev, 1974), Ca and Al - in coexisting garnets and clinopyroxenes of both olivine-normative garnet peridotites and garnets and omphacites of silica-normative eclogites (MacGregor, Carter, 1970), as well as Al and Fe - in peridotite and eclogite rocks (fig. 1) demonstrate continuous, (without jumps) transitions between peridotite-pyroxenite and eclogite rocks. Moreover, the compositions of minerals in diamond-forming rocks show an increasing content of Cr in peridotite garnets and jadeite component in eclogite clinopyroxenes. A large volume of mineralogical and physicochemical experimental data allow to researchers to conclude about the existence of a certain mechanism of eclogite genesis, when minerals of peridotite and eclogite parageneses were formed sequentially as a result of ultrabasic-basic evolution of parental melts with a transition from peridotite to eclogite rocks. Generalization of analytical data on the chemical and phase compositions of rock-forming minerals of the upper mantle and paragenic inclusions in diamonds shows that they belong to a single multicomponent system-complex olivine - garnet - clinopyroxene - corundum - coesite (Litvin, 1991).

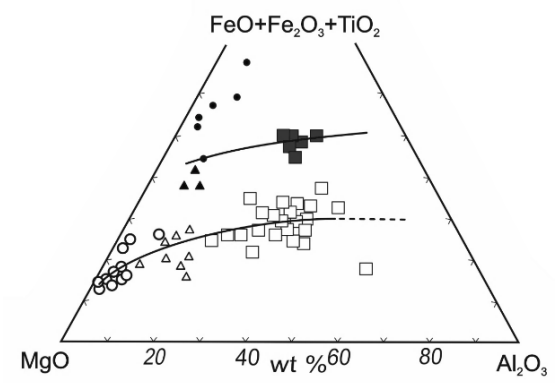

Fig. 1. Petrochemical diagram for ultrabasic and basic rocks of the upper mantle xenoliths in kimberlites according to the data of Marakushev (1984). Mg-Al rocks (white symbols): circles - garnet dunites and peridotites; triangles - garnet pyroxenites; squares - bimineral eclogites and Ky-eclogites. Fe-Ti rocks (black symbols): circles - phlogopite-ilmenite peridotites; triangles - phlogopite-ilmenite pyroxenites; squares are rutile eclogites.

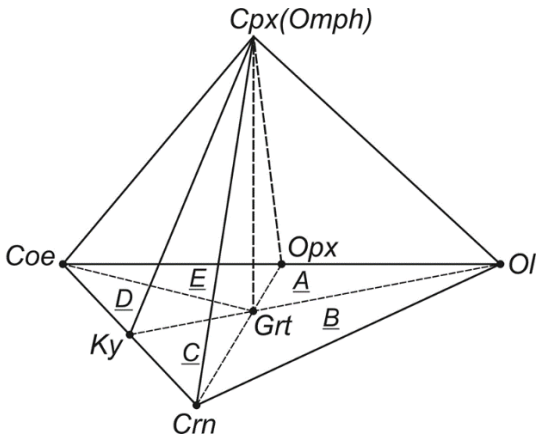

Fig. 2. Generalizing diagram-complex of compositions. It consists of ultrabasic simplexes: (A) peridotite-pyroxenitic Ol-Opx-Cpx (Omph)-Grt; (B) Ol-Crn-eclogitic Ol-Cpx (Omph)-Grt-Crn and basic simplixes: (C) Crn-Ky-eclogitic Crn-Cpx(Omph)-Grt-Ky, (D) Ky-Coe-eclogitic Ky-Cpx(Omph)-Grt-Coe, (E) Coe-Opx-eclogitic Coe-Cpx(Omph)-Grt-Opx

The diagram-complex of compositions of the upper mantle garnet-peridotite facies (Fig. 2, Litvin et al., 2016) makes it possible to study ultrabasic-to-basic petrological and mineralogical objects of the upper mantle within a single physicochemical system.

Analysis of equilibrium structure of the liquidus of Ol - Cpx – Crn – Coe system (Litvin et al., 2019) reveals the existence of temperature maxima in the Opx – Cpx(Omph) – Grt system, corresponding the "eclogite thermal barrier" (O'Hara, 1968) that separates ultrabasic and basic compositions. Therefore, ultrabasic-to-basic evolution is impossible at equilibrium conditions. But factional crystallization of garnet lherzolite material of the upper mantle gives a physicochemical possibility of such a paragenetic peridotite-eclogite transition, it is effective in the interior of the Earth. As liquidus silicate phases crystallize, residual melts and continuous solid solutions (Cpx↔Omph) becomes enriched in the jadeite component, and the overall composition of the system changes from olivine-saturated rocks to silica-saturated ones.

The study of the mechanisms of ultrabasic-basic evolution of mantle systems is carried out in a physicochemical experiment using methods of physical chemistry of multicomponent multiphase systems (Rhines, 1956; Palatnik and Landau, 1961).

Experimental studies at high pressure of phase equilibria of the multicomponent peridotite-pyroxenite system olivine Ol - orthopyroxene Opx - clinopyroxene Cpx - garnet Grt showed that Opx disappears in peritectic reaction Opx + L → Cpx (Litvin, 1991). As a result, it was found that the invariant peritectic association Ol + Opx + Cpx + Grt + L of the ultrabasic system is transformed into a monovariant cotectic association Ol + Cpx + Grt + L. Experimental studies at pressures above 4.5 GPa revealed the reaction of olivine and jadeite with the formation of garnet (Gasparik and Litvin, 1997).

The aim of this work is determination of physico-chemical mechanisms of fractional ultrabasic-to-basic magmatic evolution of material of garnet-peridotite facies with a transition from olivine-containing peridotite-pyroxenite compositions to silica-saturated eclogite-grospidite compositions in both, a dry system and at fluid presence.

Experimental studies of phase relations were carried out at 6 GPa during melting of "dry" magmatic system Ol - (Di / Cpx) - (Jd / Omph) - Grt in its polythermal section Ol – Omph (= $Di_{38}Jd_{62}$) (Litvin et al., 2019). Secondary metastable phases, which were formed during the quenching solidification of the same melts as the liquidus phases, were estimated critically.

The reaction of components of olivine and jadeite-containing melt is detected with a formation of garnet and its liquidus field Grt + L at temperatures not lower than 1650° C in the range of contents of Ol from ~ 40 to ~ 50 wt %, (Fig. 3). There is a quasi-invariant peritectic point Ol + (Cpx / Omph) + Grt + L at temperature increasing 1380 - 1420 ° C and a content of Ol ~ 30 wt%.

At the point, after complete reactionary disappearance of olivine components ("garnetization of olivine"), a regressive monovariant cotectic Omph + Grt + L appears.

Experimental studies of phase equilibria with volatile components is necessary to solve problems related to processes of melting and distribution of substance in the Earth's mantle. This allows studying their influence on the phase relationships in mantle rocks at high pressure. In this regard, the phase relations during melting of the system olivine - jadeite - diopside - garnet - volatile (C-O-H) were studied in a physicochemical experiment at a pressure of 6 GPa (conditions of the upper mantle) and temperatures of 1200-1650°C. The studies were carried out within polythermal section $Ol_{95}(C\text{-}O\text{-}H)_5$ - $Omph_{95}(C\text{-}O\text{-}H)_5$.

SEM photos of the samples (Fig. 4) indicate the efficiency of the peritectic reaction with Ol disappearing in the system (point "P" in the plane of the boundary ternary system Ol - Jd - Cpx- (C-O-H) (Fig. 5)) as a result of the reaction. Thus, monovariant cotectic L + Ol + Cpx / Omph + Grt of ultrabasic-basic system-simplex Ol - Jd - Cpx - Grt - (C-O-H) in the liquidus structure (Fig. 6) serves as a kind of "physicochemical bridge" providing evolutionary transition from ultrabasic to basic magmas in the upper mantle.

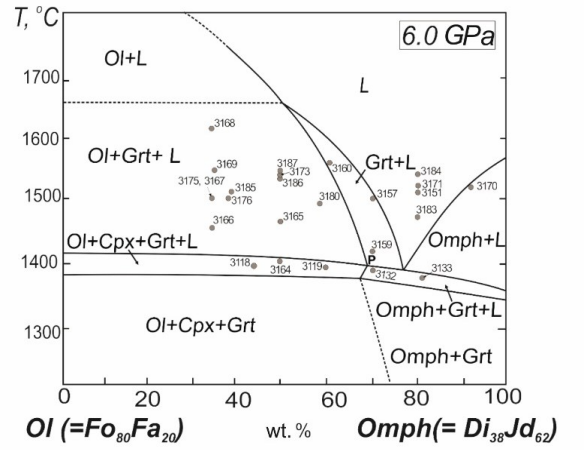

Fig. 3. Diagram of phase relations during melting of ultrabasic-basic system Ol-Di-Jd in its polythermal section Ol-Omph

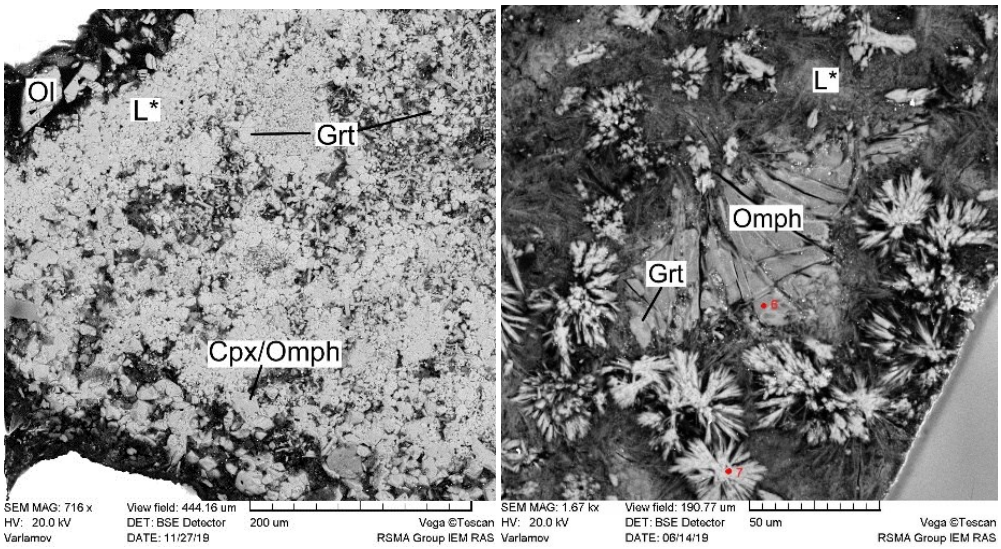

Fig. 4. Experimental samples partially melted at 6 GPa: (4a) - ultrabasic association L + Ol + Cpx / Omph + Grt with quenching phases of melt L* (sample 3233, 6 GPa, 1300°C); (4b) - basic mineral association L + Omph + Grt with quenching melt L* (sample 3223, 6 GPa, 1290°C).

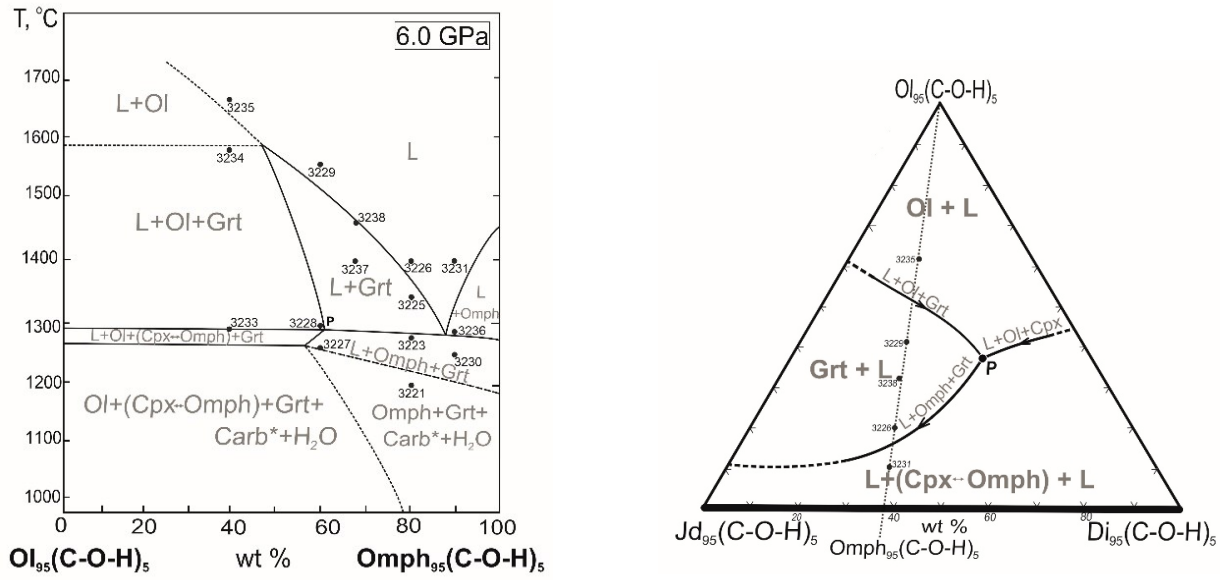

Fig. 5. Phase relations at melting within polythermal section $Ol_{95}(C\text{-}O\text{-}H)_5$ - $Omph_{95}(C\text{-}O\text{-}H)_5$ of the ultrabasic-basic system Ol – Jd – Di – Grt - (C-O-H) at 6.0 GPa.

Fig. 6. Liquidus structure of the ultrabasic-basic system Ol - Jd - Di - Grt - (C-O-H) with reactional Grt. A participation of fluids in composition of the Ol – Jd - Di - Grt - (COH) system leads to quantitative topological changes of the parameters of its liquidus structure - a decrease in the temperatures of the solidus and liquidus boundaries, respectively, by 120 and ~ 60-80°C, as well as a shift of the composition of the peritectic reactions of olivine with increasing concentrations of olivine Mg- and Fe-components by ~ 10 wt. %.

Phase reactions at presence of C-O-H volatiles are characterized by metasomatic CO_2-carbonatization of silicates and dissolution of H_2O in formed completely miscible silicate-carbonate melts. At the same time, the influence of C-O-H-fluid (at its content of 5 wt% with equimolecular amounts of H_2O and CO_2) on composition and temperature of the quasi-invariant peritectic reaction of olivine and jadeite-containing melt with formation of garnet was found.

Since the used concentrations of (C-O-H)-fluid components do not introduce radical qualitative changes in the phase relations during the melting of the ultrabasic-basic system olivine - jadeite-diopside – garnet - volatile (C-O-H) at 6 GPa, the peritectic reaction of olivine remains of paramount importance. It is the main element of the liquidus structure of magmatic silicate-fluid and diamond-forming silicate-carbonate-carbon-fluid systems. The value of this reaction is in its control of final stages of ultrabasic-to-basic evolution of magmatic and diamond-forming melts of the upper mantle.

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Limanov E.V., Butvina V.G., Safonov O.G., Van K.V., Vorobey S.S. K-richterite formation in the presence of K_2CO_3-Na_2CO_3-CO_2-H_2O fluid. Experiment at 3 GPa. UDC 552.4

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Abstract. The reaction 8En + Di + [1/2K_2O + 1/2Na_2O + H_2O] = K-Rct + 2Fo was studied experimentally the presence of a K_2CO_3-Na_2CO_3-CO_2-H_2O fluid a temperature of 1000°C and a pressure of 3 GPa. The amphibole formation was possible at a weight ratio (K_2CO_3 + Na_2CO_3) / (CO_2 + H_2O) = 3/7, at Na_2CO_3/K_2CO_3 = 50/50 and 70/30. In a situation where potassium dominates over sodium, amphibole is formed only at (K_2CO_3 + Na_2CO_3) / (CO_2-H_2O) = 10/90. Amphibole becomes unstable with an increase in the content of alkaline components in the fluid, a large amount of alkaline melt is present in the system. The regularities obtained in the work reproduce well the features of mineral associations and variations in component compositions in the upper mantle peridotites.

Keywords: *mantle metasomatism, experiment, fluid, upper mantle, K-Richterite*

Studies of xenoliths from alkaline kimberlites and basaltoids indicate the presence in the mantle of a multistage process of alteration of mantle rocks during their interaction with fluids and melts of various compositions and origins, referred to as mantle metasomatism (O'Reilly & Griffin, 2013). In the course of this process, there is a change in the mineral composition of rocks, the component composition of primary minerals, as well as the generation of new minerals, such as ilmenite, titanite, carbonates, sulfides, etc., which are not characteristic of the primary paragenesis. A typical mineral indicator of modal mantle metasomatism is phlogopite, the formation of which is accompanied by the decomposition of alumina-containing minerals such as garnet and spinel. A further increase in the activity of alkaline components in the fluid leads to the decomposition of pyroxenes and the formation of K-richterite (Aoki, 1975; Erlank et al., 1986), a specific low-alumina alkaline amphibole that is stable over a wide range of temperatures and pressures (Trønnes, 2002). Its generation occurs during the reaction

$$8En + Di + [1/2K_2O + 1/2Na_2O + H_2O] = \\ = K\text{-}Rct + 2Fo \qquad (1)$$

with the participation of aqueous-carbonic fluids containing salt components. We carried out an experimental study in the enstatite-diopside system in the presence of the K_2CO_3-Na_2CO_3-CO_2-H_2O fluid, at a temperature of 1000 ° C and a pressure of 3 GPa. 3 series of experiments were carried out, differing in the ratio of Na_2CO_3 and K_2CO_3 by weight: I - 50:50; II - 70:30, III - 30:70 and the total content of alkaline components to the H_2O-CO_2 fluid. The work was carried out at the Institute of Experimental Mineralogy, IEM RAS, using a high-pressure anvil with a hole NL-40.

In the first series of experiments, the formation of amphibole was found to be possible when the ratio (K_2CO_3 + Na_2CO_3) / (H_2O + CO_2) = 30/70 by weight. Along with the newly formed amphibole, olivine, a by-product of reaction (1), is present among the experimental products. An increase in the activity of alkalis in the fluid leads to a decrease in the tremolite component in amphibole, which is accompanied by a change in the calcium content of both pyroxenes (Fig. 1 a). The amphibole composition shifts towards K-richterite. The high activity of alkaline components in the fluid leads to the retention of clinopyroxene mainly in the form of inclusions in olivine.

In the second, sodium series of experiments (Na_2CO_3 / K_2CO_3 = 70/30), amphibole is also formed at the ratio (K_2CO_3 + Na_2CO_3) / (H_2O + CO_2) =