

DIAMOND CRYSTALLIZATION IN CARBONATE-SILICATE MELTS OF DIAMOND-BEARING ROCKS OF THE KOKCHETAV MASSIF (EXPERIMENT AT 5.5 – 7.5 GPa) Spivak A.V., Litvin Yu.A., Matveev Yu.A.

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Deciphering of the physical-chemical mechanisms of diamond formation in metamorphic complexes, as examples of «non-kimberlitic» diamond formation, is one of the major problems of the genetic and experimental diamond mineralogy. Experimental modeling of diamonds genesis of metamorphic complexes (Kokchetav, Kazakhstan; Dabie Shan, China) was executed. Carbonate-silicate dolomite-garnet-clinopyroxene rock from the Kumdy-Kol, Kokchetav deposit was used in experiments at high pressures. This type of the rocks differs by the extreme contents of diamonds (2000 carat/ton).

The major purpose of the present experiments is a high-pressure diamond synthesis in the carbonate-silicate melts produced from the diamond-bearing rocks of the Kokchetav massif along with an investigation of coexisting carbonate-silicate assemblages.

Diamond synthesis at pressures 5.5 – 7.5 GPa was realized in dolomite-garnet-clinopyroxene melts of the rock from Kumdy-Kol. The melts were supersaturated with carbon of graphite from a starting mixture. The starting mixture was prepared from a natural carbonate-silicate rock powder (Kumdy-Kol, Kokchetav massif), mixed with graphite powder. The experiments were performed using the “anvil-with-hole” apparatus with the cell made of lithographic limestone (Litvin, 1991). Pressure was controlled within the accuracy ± 0.1 GPa. Accuracy of temperature measurement was $\pm 20^\circ\text{C}$. The experimental samples were studied by SEM with the use of a CamScan electron microscope (MSU, operators – E.V.Guseva, N.N.Korotaeva).

Study of the diamond crystallization in the carbonate-silicate melts, produced from the Kokchetav rocks, was carried out at pressures 5.5 - 7.5 GPa, temperatures 1300 - 1800°C and run duration 1 - 40 min.

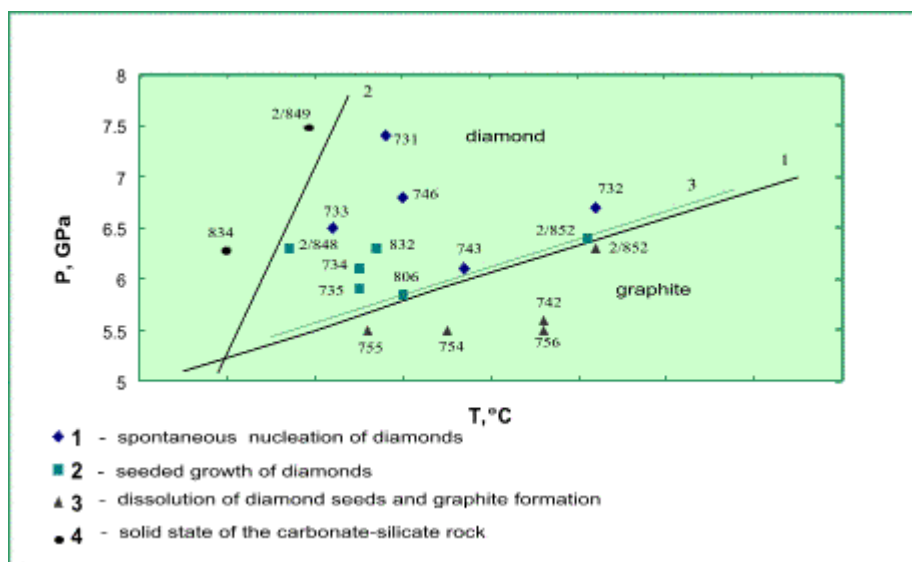


Fig. 1. The PT data points for diamond crystallization in carbonate-silicate melts, produced from the Kokchetav rock. 1 – the equilibrium boundary graphite – diamond (Kennedy C.S. & Kennedy G.C., 1976); 2 – the temperature of melting of the carbonate-silicate rock mixed with carbon (i.e. metastable graphite) in dependence on pressure; FLS – the field labile solution (diamond spontaneous nucleation); FMS – the field metastable solution (seeded growth of diamonds); 3 – the kinetic boundary FLS/FMS (the lower boundary of the field of the diamond spontaneous nucleation). Number of samples is by experimental date point.

At melting temperature, the spontaneous nucleation and intense diamond crystallization occurred during the first 1 - 2 minutes. Nucleation and growth of diamond crystals within the field of diamond thermodynamic stability are conditioned by the following physical and chemical processes. The graphite dissolves in carbonate-silicate melts formed by the partial melting of the rock. As a result, a solution of carbon in the melt, supersaturated with respect to diamond, forms. The following factors determine the formation of such solutions at the PT - conditions of diamond thermodynamic stability: (1) difference in solubility of metastable graphite with respect to stable diamond, and (2) the thermal gradient within the heater. The PT data points for diamond crystallization in carbonate-silicate melts, produced from the Kokchetav rock, are plotted in fig. 1.

The field of diamond crystallization is between the graphite - diamond equilibrium boundary and the line of melting of the carbonate-silicate rock mixed with carbon (i.e. metastable graphite) in dependence on pressure. The kinetic boundary between the labile solution fields of carbon in carbonate-silicate melts of rocks (LSF) and the metastable solution field (MSF) is within this field. The LSF is identified by the spontaneous nucleation and crystallization of diamonds. Within the MSF, the seed growth of diamond proceeds without spontaneous nucleation. The graphite - diamond equilibrium was identified by the partial or complete dissolution of the diamond seed during their transformation to graphite in the carbonate-silicate melts beyond the field of the spontaneous nucleation.

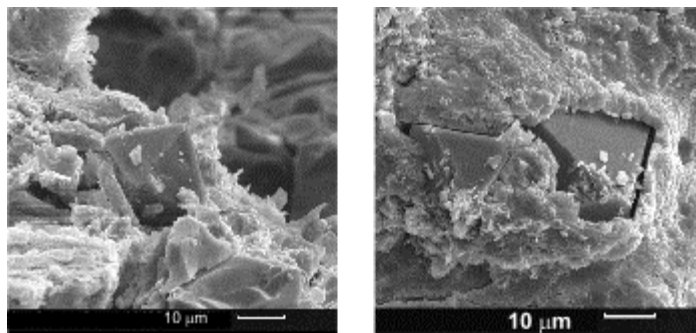


Fig. 2. Diamond crystallization in carbonate-silicate melts of the Kokchetav massif rocks.

Diamonds form single crystals, spinel twins and aggregates of mean size up to 100 µm (fig. 2). The spontaneously crystallized diamonds are octahedral with smooth facets (111), rare cubic with rough facets (100). It is better seen after growth of layers of newly formed carbonate - synthetic diamond on the octahedron (111) and cube (100) facets of the seed (fig.3). The dissolution of diamond in the carbonate-silicate melt is accompanied by the formation of tabular graphite crystals or rarely large blocks of graphite.

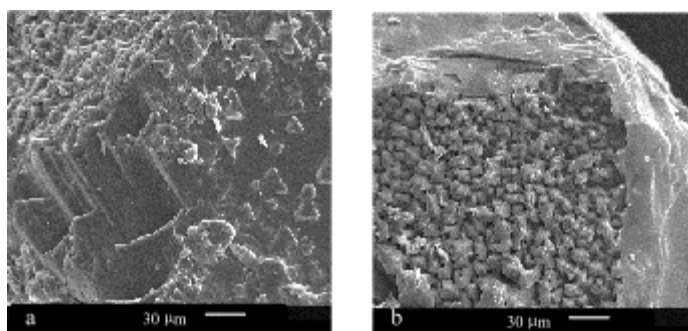


Fig. 3. Seeded growth of diamond: (a) smooth facets on the octahedral (111) (smpl. 731) and (b) rough facets on the cubic (100) facets of the seed (smpl. 733).

Changes in compositions of garnets and clinopyroxenes after experiments with run duration 10 - 30 min. are negligible. These phases, probably, were involved in the melting process only on interfaces

with the partial formation of the carbonate-silicate melt. This melt serves as a solvent for carbon during the diamonds synthesis. Composition of dolomite is approximately similar to the natural, but in one case, i.e. sample № 732 the K_2O content in it increases up to 1.71 wt. %. Newly formed garnets crystallized along with diamonds (fig. 4) differ in composition from the original garnets in the starting mixture. The pyrope content increases, while grossular and almandine concentration decreases. The aluminum content of clinopyroxenes increases, whereas the alkaline content (K+Na) decreases.

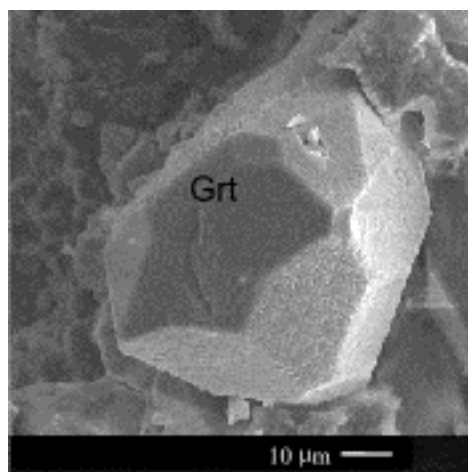


Fig. 4. Formation of garnet and in the same carbonate-silicate melt as diamond crystallizes.

It can be assumed that the processes of natural diamond formation in the carbonate – silicate melts in the mantle conditions are the same as in the experiments, since the chemical composition of the media and the physical parameters of the diamond crystallization coincide. Therefore, it is possible to speculate not only about the experimental modeling of diamond formation in metamorphic complexes, but also about the reproduction of natural processes of diamond formation in the high-pressure experiment with respect to their major constituents, i.e. chemical composition of the parent environment, mechanism of diamond formation, and physical parameters.

Thus, the synthesis of diamonds in the carbonate-silicate melts, produced from the natural diamond-bearing rocks from the Kokchetav massif, is firstly performed. These melts are supposed to be oversaturated with the dissolved carbon. The experiments proved that the carbonate-silicate melts were the highly effective diamond-forming environment at the diamond stability conditions. The rate of diamond crystallization in the carbonate-silicate melts is appreciably high (grain of size up to 100 μm forms during 1-2 minutes). Diamond formation is accompanied by crystallization of syngenetic minerals, such as garnets and clinopyroxenes.