

Parental media for diamonds and primary inclusions by evidence of physicochemical experiment

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Abstract. The mantle-carbonatite conception of genesis of diamond [Litvin, 2007, 2009] is briefly outlined. A generalized diagram of compositions of the multi-component heterogeneous parental medium for diamond and primary inclusions therein is first developed. Boundary compositions of the parental medium diagram are represented by mineral components of the peridotitic and eclogitic parageneses, mantle carbonatites and C–O–H–fluids, phases of accessory type both soluble in the carbonate–silicate melts (chlorides, phosphates, etc.) and insoluble in them (sulfides), as well as carbon. Phase relations of the multi-component eclogite-carbonatite-sulfide-diamond are studied at 7 GPa. “Syngensis diagram” for diamond, paragenetic and xenogenetic minerals (including the solubility curves of diamond in carbonate-silicate and sulfide melts) is constructed. Physicochemical mechanism of formation of diamond and paragenetic minerals is revealed. Genetic classification of primary inclusions in natural diamonds is worked out. Analysis of physicochemical history of diamond formation in the mantle chamber of carbonatite magma is accomplished.

Introduction. The mantle-carbonatite conception of genesis of diamond of kimberlite deposits [Litvin, 2007^{a, b}, 2009] is justified by the complex of mineralogical, experimental and theoretical data. Completely miscible carbonate-silicate growth melts with dissolved elemental carbon (carbon source for diamond) form a basis for the parental media for the dominating mass of natural diamonds and paragenetic minerals. The parental carbonate-silicate-carbon melts are multi-component heterogeneous media with strongly changeable compositions. So, silicate constituents are presented by minerals and components both peridotite and eclogite parageneses [Sobolev, 1974]. It is established in the high-pressure high-temperature experiments that both peridotite-carbonatite-carbon and eclogite-carbonatite-carbon melts are represented as highly efficient diamond-forming media. An example of diamond crystallization in melt oversaturated in dissolved carbon of the eclogite-carbonatite system is demonstrated in the fig. 1.

Composition diagram of parental medium for diamond and primary inclusions. A generalized diagram of compositions of the multi-component heterogeneous parental medium for diamond and primary inclusions therein is developed (Fig. 2). The major composition tetrahedron of the system “peridotite-eclogite-carbonatite-soluble admixture components” is its basic element. Belonging of the mineral assemblage of syngenetic inclusions in natural diamonds to two major parageneses, - peridotitic and eclogitic, - is taken into consideration. The boundary compositions of the parental medium diagram are determined with mineral components of the auxiliary tetrahedrons – peridotitic (Ol–Opx–Cpx–Grt), eclogitic (Cpx–Grt–Crn–Coes), mantle carbonatite (Mg, Fe, Ca, K, Na, etc. carbonates), phases and components of admixed accessory sort – soluble in carbonate-silicate melts (chlorides, phosphates, etc.) including the components of C–O–H-volatile compounds, and carbon too. All the components of the boundary tetrahedrons mentioned above are responsible for formation of paragenetic mineral phases together with diamond and, correspondingly, for capture of the paragenetic inclusions by natural diamonds. At the same time due to physicochemical experiment it turned out that xenogenetic mineral phases are presented within the assemblage of so called syngenetic inclusions. Sulfide minerals which are not soluble in diamond-forming carbonate-silicate melts as well as sulfide melts which are completely immiscible with these are among the xenogenetic phases. In the fig. 2, the auxiliary boundary tetrahedron for sulfide components is positioned out of the major tetrahedron and is

divided by conventional boundary c. l. i. b. (complete liquid immiscibility boundary). This boundary symbolizes xenogenetic nature of sulfides in diamond-forming carbonate-silicate growth media.

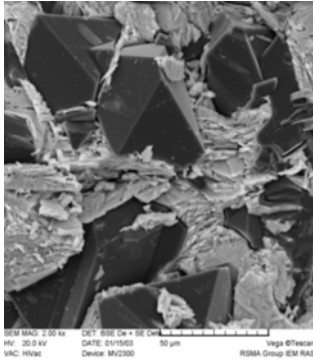


Fig. 1.

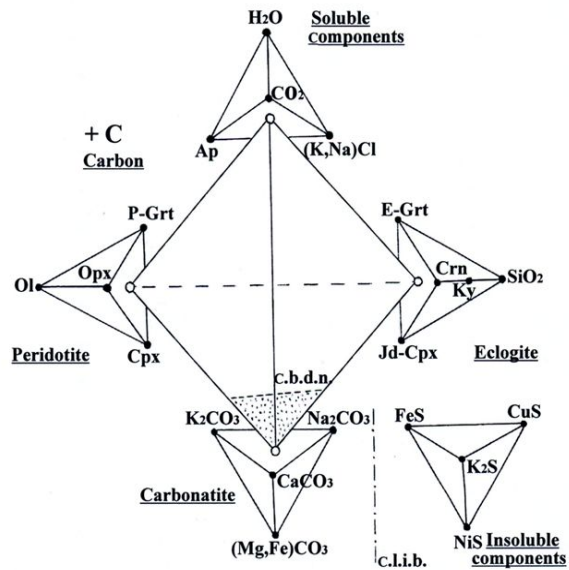


Fig. 2.

The compositions of diamond-forming parental media belongs to carbonatites by experimental estimation of concentration barriers of diamond nucleation, that is limiting for diamond formation compositions in peridotite-carbonatite (30 wt.% peridotite) and eclogite-carbonatite (35 wt.% eclogite) systems [Litvin *et al.*, 2008; Bobrov, Litvin, 2009]. By doing so it has been ascertained that compositions of the peridotite-carbonatite and eclogite-carbonatite growth melts are fell within the carbonatite concentration interval. Primary hermetically included minerals, melts and C-O-H-fluid components in natural diamonds are the fragments of the parental medium which are captured *in situ* by growing diamonds.

Syngensis diagram for the eclogite-carbonatite-sulfide-diamond system. Under the pressure of 7 GPa (diamond thermodynamic stability conditions), melting phase relations of the multi-component heterogeneous system eclogite-carbonatite-sulfide-diamond are experimentally studied. Composition of the system brings into proximity with the parental medium under conditions of eclogite paragenesis. A "syngensis diagram" for diamond, paragenetic and xenogenetic minerals (in respect to diamond) which are presenting at the parental medium is constructed (Fig. 3). Within the diagram, the syngensis diagram for diamond and paragenetic inclusions in the system eclogite-carbonatite-diamond (solid lines) and phase relation diagram for the "xenogenetic" system sulfide-diamond (dashed lines) are combined with the use of the projection method. This makes it possible to obtain a common picture of phase relations in multi-component heterogeneous diamond-forming medium as well as a notion of conditions for joint capture of paragenetic and xenogenetic phases by growing diamonds. For detailed information see [Litvin *et al.*, 2011]. New physicochemical results including diamond solubility curves in completely miscible carbonate-silicate (20–22 wt. % carbon) and sulfide (30–32 wt. % carbon) melts and the solubility curves relationships with the boundaries of phase regions for carbonate-silicate and sulfide phases are obtained. The syngensis diagram gives opportunity to reveal clearly the physicochemical mechanisms of formation of natural diamond and paragenetic minerals. This permits to determine formation conditions of the silicate and carbonate minerals paragenetic in respect to diamond. Also, conditions of coexistence of xenogenetic sulfide minerals and melts with the paragenetic phases are determined. Thereby, physicochemical conditions of *in situ* trapping by growing diamonds of paragenetic and xenogenetic minerals and melts (known in mineralogy of diamond genesis as "syngenetic" or "primary" inclusions) are cleared up. The experimental results and conclusions are essentially important for justification of the mantle-carbonatite conception of diamond genesis [Litvin, 2007, 2009].

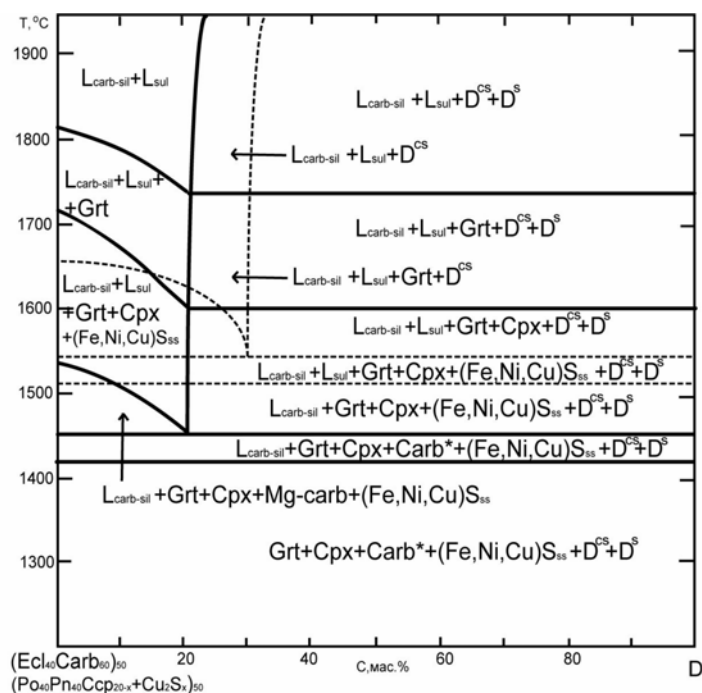


Fig. 3.

Genetic classification of primary inclusions in natural diamond. The data of analytical mineralogy of inclusions and physicochemical experiment, if generalized, allows to work out a genetic classification of primary inclusions in natural diamonds. The classification reveals origin of the inclusions, their physicochemical links with the major components of carbonate-silicate growth melts as well as with soluble and insoluble components and phases containing by the growth melts [Litvin, 2009]. By physicochemical conditions of their origin, the primary inclusions in diamonds could be related to the next groups: (1) major silicate, aluminosilicate, carbonate components and dissolved carbon which are responsible for paragenetic inclusions of Mg–Fe–Ca-silicates, Na–K–Mg–Ca–Fe-aluminosilicates, Mg–Ca–Fe–Al–Si-oxides, Mg–Ca–Fe–Na–K-carbonates, multi-component carbonatite melts, diamond, and unstable graphite; (2) secondary soluble admixed components – oxides, accessory silicates and aluminosilicates, phosphates, chlorides which are responsible for formation of paragenetic minor phases; (3) secondary soluble admixed components of the C–O–H system which are responsible for formation of paragenetic phases of volatile compounds (H₂O, CO₂, etc.) released under solidification of growth melt; (4) secondary phases insoluble and completely immiscible if liquid with carbonatite melts which are responsible for capture of xenogenic sulfides, native metals, etc.

Physicochemical evolution of natural diamond-forming chamber. The syngensis phase diagram for diamond, paragenetic and xenogenetic minerals and melts allows to consider a physicochemical history of diamond formation in the mantle chamber of carbonatite magma [Litvin, 2009] and to approach an estimation of the conditions of their origin in the substance of the Earth's peridotite mantle.

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