PETROLOGY OF DIAMONDIFEROUS MAGMATISM

Marakushev[1] ,A.A., Pertsev[1] ,N.N., Zotov[1] ,I.A., Paneyakh[1] ,N.A.

1. Institute of Geology of Ore Deposits, Petrology, Mineralogy and Geochemistry Russian Academy of Sciences, b. 35, Staromonetnyi per., Moscow, 109017, Russia

The diamondiferous rocks in genetic aspect can be divided into (I) the primary (the parental in relation to diamonds included) and (II) the secondary which inherited the diamonds of the primary rocks during transformations of the latters.

I. The primary diamondiferous rocks are presented by two genetic types: a - the depth ones connected by their origin with the magmatic chambers of the mantle diamond facies, and b - the shallow products of the fluid explosions of high energy level in ring structures (impactogenic).

a. The depth diamondiferous rocks are polyfacial by their nature. The diamonds and minerals paragenetic with them form the early (intratelluric) generation of magma crystallization products in deep-seated chambers. Crystalization of the minerals precedes the intrusion of the diamondiferous magmas to higher levels of mantle and into the earth crust where their final solidification takes place. Diamondiferous rocks are different by the degree of intratelluric crystallization of melts in deepseated chambers. In some magmatic rocks (dolerites, gabbros, chromite-bearing peridotites) diamonds are present in accessory quantity only but in others (such as eclogites, garnet pyroxenites, pyrope peridotites) they can reach the economic significance. The diamonds in the rocks are presented by two generations. The early defectless diamonds poor in nitrogen form very little crystals and fragments included into rockforming minerals and in the bigger diamond crystals of the second generation. The latters have defect structure and a more essential admixture of nitrogen and other gases. They contain inclusions of the rock-forming minerals which define the peridotite and eclogite-pyroxenite types of diamonds. Rare coexistence of two types of paragenesis (eclogitic and peridotitic) in a diamond crystal reflects the layering of primary magma and movement of growing crystals from one magmatic layer to the other.

The difference in the fluid regime of the pyroxenite-eclogite and peridotite systems are traced in variations of the isotop composition of the carbon of diamonds. The diamond of the pyroxenite-eclogite type is characterized by the wide variations of isotope composition of carbon ($\delta^{13}C$,%o) from -20 to +5. On the contrary, the isotope composition of the peridotite type diamond varies within narrow diapason near $\delta^{13}C=5‰$. This is explained by different fluid regime of the basic and ultrubasic melts. The initial reduced transmagmatic fluids became oxidised in basic melts generating CO_2 which migrates in transmagmatic fluids tending to decrease the carbon heavy isotope content in early small crystals of diamond. The opposite tendency of increasing of $\delta^{13}C$ is connected with accumulation of CO_2 in the same basic melts in next stage due to transformation of the reaction of the diamond formation: $1{,}5\ CH_4 + (CO - CO_2) = 3{,}5\ C(diamond) + 3H_2O$. These opposite effects producing wide variation of carbon isotope composition of diamonds crystalizing in basic melts, are absent in the ultrabasic magmas where the initially reduced character of transmagmatic fluids remains practically unchanged.

This explains the stable isotopic carbon composition of the peridotite type diamonds.

Many scientists (e. g. Javoy et al.,1986) called upon degassing of eclogitic melts (with CO_2 removal) as an efficient mechanism for the enrichment in the light carbon isotopes. On the basis of experimental data as was expressed by Mattey et al.(1990) uncertain remaned only the scale on which this mechanism can operate. Our model overcomes these difficulties because it clames the continuous enrichment effect in the light carbon isotope due to filtering of transmagmatic fluids through the pyroxenite-eclogite melts.

b. The origin of impactogenic diamonds is explained by the fast ascent of fluid plumes to the surface probably from the core of the Earth. The explosions are restricted by domes of the platform basement and accompanied by increasing of temperature up to very high values. It induces the isochoric melting of rocks and minerals with developing of the high pressure (by the "autoclave effect") that is large enough for formation of diamond, coesite and stishovite. Extremely high temperature of the diamond magmatism of this type is proved by the isochoric melting of the individual mineral grains (quartz, plagioclase and others) which are pseudomorphly replaced by melt of corresponding monomineral compositions (diaplect glasses) and formation of lonsdeilite and chaoite along with diamond, lechatelierite and maskelynite. This endogenic impactogenesis is not limited by the shallow depths of the Earth. Kimberlite and lamproite tubes contain nodules of the impactly transformed (cataclastic and partly melted) pyrope peridotites and eclogites. Amasing is the wealth of breccia structures of their diamond-bearing rocks, which formed within a broad range of depth. Some of the breccias formed at the diamond depth facies and consist of fragments of diamond and accompanyed minerals, which are included in larger diamond crystals. We think that their origin is connected with the deep fluid explosions in diamond-bearing intrusives which generate the kimberlite and lamproite magma chambers.

Conceivably, the origin of diamondiferous magma chambers and their further evolution is related to impulses of rapid ascent of extremely dence fluids from the Earth core to the upper mantle. Being partly liquid, the core is capable of retaining hydrogen and some other volatiles (Marakushev,1992). These impulses of ascending fluid flows (mantle plumes) resulted in explosions and, consequently, seismic waves.

II. Kimberlite and lamproite magmas belong to the secondary diamond-bearing type. They inherit diamond mineralization of primary diamond-bearing pyrope peridotites, pyroxenites and eclogites. The main contribution in their genesis gives magmatic replacement of the diamondiferous dunites and peridotites by a basic melts. The process provide both ultrabasic deviation of the magma and the increase of its alkalinity as a result of the acid-base interaction of the components in accordance with the Korzhinskii's principle. The magmatic replacement appears to be the only possible mechanism of kimberlite-lamproite genesis with inheritence of the diamond mineralization of the peridotite-pyroxenite-eclogite intrusives. Their explosive intrusion in upper levels of the crust is completed by the formation of the diamondiferous surface tubes (diatrems).

Eclogite-peridotite intrusive bodies in the lower crust play the role of the substrate for developing kimberlite-lamproite magmatism. It is evidenced by developing kelefitic rims around pyrope grains which demonstrate moderate (crustal) pressures. The kelefitic rims can be cut, broken and replaced by phlogopite which is induced by kimberlite magma.

Peridotite-eclogite intrusions bearing intratelluric diamond mineralization can form the concordant bodies in the evgeosinclinal volcanic-sedimentary formations. Together with them they were deformed and subjected to granitization, migmatization, allochemical metamorphism, and diaphthoresis with inheritence of their diamond mineralization by all these metamorphic products. Minor diamond crystals inclused in the rockforming and accessory minerals of the primary diamondiferous rocks (garnet, pyroxene, zircon) are well preserved whereas bigger grains of diamond suffered breaking down with formation "diamond dust" of its skeletal crystals.

Inclusions of primary diamonds preserved in relict rock-forming minerals afford a unique opportunity to examine inherited diamonds, which have almost not been affected by metamorphism. Examination of these diamonds (Shukolyukov et al.,1993) provide evidence for the mantle genesis of them in the Kokchetav metamorphic rocks. An unusually high helium content of $^3He = 3{,}17 \times 10^{-7}$ g/cm^3, $^4He = 5{,}43 \times 10^{-4}$ g/cm^3 was detected in well-preserved 14Å diamond crystals. These crystals also have unusual ratio $^3He/^4He = 5{,}84 \times 10^{-4}$ which is one order of magnitude higher then even the values specific of kimberlitic diamonds. Because of ^3He is not accumulated in any natural earth processes these data conclusively establish the mantle genesis of the diamonds in the Kokchetav metamorphic rocks.

Metamorphic rocks show the main specific features of diamond-bearing clinopyroxenes: they have elevated potassium contents. Clinopyroxene that occurs, together with diamond, as tiny euhedral inclusions in garnet contains up tj 0,8 wt % K_2O. This points to the significant depths of the mantle chambers to which the Kokchetav diamondiferous magmatism is related. The polyfacial nature of the eclogites and clinopyroxenites is validated by the fact that thier clinopyroxenes show variable K_2O contents. To illustrate this, adress the data obtained from a clinopyroxenite sample from the Kumdykul' area. The garnet ($Mg_{0,77}Fe_{1,15}Ca_{1,14}$-$Mn_{0,05}Al_{0,94}Ti_{0,01}Si_{2,98}O_{12,00}$) contains tiny cristals of potassium-rich clinopyroxene ($K_{0,04}Na_{0,01}Ca_{0,90}Mg_{0,86}Fe_{0,18}Al_{0,05}O_{6,00}$) whereas the clinopyroxene from intergrowth with garnet in the rock matrixis almost potassium-free ($Na_{0,01}Ca_{0,94}Mg_{0,85}Fe_{0,19}Al_{0,04}Si_{1,98}O_{6,00}$). This demonstrates specific compositional features of clinopyroxenes from polyfacial diamondiferous rocks. If these rocks have been affected by allochmical metamorphism, thier clinipyroxene contains thin perthitelike inclusion of potassium feldspar, which are restricted mainly to the crystal core.

The regular position of the diamond-bearing metamorphic complexes formed in this way in the system of the so called coupled metamorphic complexes is determined by occuring them in outer belts rimming of granite-gneiss domes.