Impact−Cosmic−Metasomatic Origin of Microdiamonds from Kumdy−Kol Deposit, Kokchetav Massiv, N. Kazakhstan

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Introduction

Any collision extraterrestrial body and the Earth had left behind the "signature" on the Earth's surface. We are examining a lot of signatures of an event caused Kumdy-Kol diamond-bearing deposit formation, best-known as "metamorphic" diamond locality among numerous UHP terrains around the world. We are offering new impact-cosmic-metasomatic genesis of this deposit and diamond origin provoked by impact event followed prograde and retrograde metamorphism with metasomatic alterations of collision area rocks that have been caused of diamond nucleation, growth and preserve.

Brief geology of Kumdy-Kol diamond-bearing deposit

Kumdy-Kol diamond-bearing deposit located within ring structure ~ 4 km diameter, in the form and size compares with small impact crater (Fig. 1). It is important impact event signature.

Figure1: Cosmic image of Kumdy-Kol deposit area [http://map.google.ru/].

Diamond-bearing domain had been formed on the peak of UHP metamorphism provoked by comet impact under oblique angle on the Earth surface. As a result, steep falling system of tectonic dislocations, which breakage and fracture zones filling out of impact and host rock breccia with blastomylonitic and blastocataclastic textures have been created. Diamond-bearing domain has complicated lenticular-bloc structure (1300 x 40-200 m size) and lens out with deep about 300 m. Compositions of diamond-bearing rocks are dominate garnet-biotite gneisses and discontinuous lenses of carbonate, quart, garnet-pyroxene rocks, amphibolised eclogites, that alternated with lenses of diamondless not altered garnet-biotite gneisses and granite. Diamond-bearing rocks are characterize strong metasomatic alteration with the strongest contrast revealed in a gneissose substrate. Ages of these rocks are: Grt-Bi gneisses – Proterozoic, diamond-bearing rocks−Cambrian, granites Later Cambrian – Ordovician. Spatial diamond distributions have not precise lithological lines. [Tretiakova, Lyukhin, 2016 and references there in].

Feasible scenario of impact event

Comet core was consisted from chondritic matter with abundance of carbon and possible nano-diamonds, having abnormal value of noble gases (He, Ne, Ar, Xe) + IDPs (SiC, graphite and diamonds with high contents of noble gases) + carbonaceous matter presolar grains, including diamond and graphite, SiC, Si_3N_4, Al_2O_3, $MgAl_2O_4$, $CaAl_{12}O_{19}$, TiO_2, $Mg(Cr,Al)_2O_4$, silicates, TiC, Fe-Ni metal, noble gases and trace elements [Clayton, Nittler, 2004]. These evaporated comet substance under high pressure was injected into previously metamorphic host rocks appeared to be impact-cosmogenic source of diamond seeds and/or nanodiamonds. Water-vapor comet cloud with H_2O, C, CH, CH_4, CN, HCN gases and fine dispersed comet core, survived during comet passing through Earth dense air, mixed with vapor and melting target rocks and produced complicated carbon saturated fluid–melt [DeNiem, 2002] that was a source of epitaxial diamond growth (CVD) on carbonaceous matter seeds imported by a comet.

Signatures of impact metamorphism

Collision of huge velocity comet and the Earth had been caused of rapid shock wave compression (pressure peak > 50 GPa) and multiple complex mineral transformation, among them: 1. Presence of UHP minerals: diamond↔lonsdaleite, coesite, omphacite. The formation of hexagonal diamond (lonsdaleite) is interpreted as a direct transformation (solid to solid) of cubic diamond by a kinetic mechanism due to the shear stress and enhanced temperature induced by the rapid shock wave compression [He, 2002], Microdiamond (~10 - 50 μm size), graphite and coesite crystals distributed within the grains of all rock-forming minerals and also associated with fractures in rocks and minerals; 2. Delivering by comet moissanite (SiC) and graphite spheruls; meteoritic matter: magnetite, hematite, iocite, troilite, ∝-Fe, Ni-Fe; 3. Annealed metallic globules having various fanciful forms (globules, small dump-bells, drops, spherules and so on) in host rock and rock-forming minerals; 4. Dislocation and birefringence in diamonds, planar structure in quartz, inclusions UHP minerals in rock-forming minerals.

Signatures of progressive metamorphism

1. Mineral association: dolomite + diopside + garnet ±diamond observed in dolomite marble; 2. High concentrations: Na, Ti in garnets, K, Na in clinopyroxenes, K in amphiboles, Al, Si in titanite, Al in phengite [Zwang et al., 1997]; 3. Cation's exchange in shock-activated phases by displacement: $2Al^{3+} \rightarrow [(Mg, Fe)^{2+}+Ti]$ or (Ca+Al) → (Na+Ti) in garnets, Si → (Mg^{2+} +Na +Al^{3+}) in clinopyroxenes, and so on; 4. Solid phase transformations: K-feldspar and phengite exsolution in diopside; coesite lamella in titanite and diopside, quartz lamella in eclogitic clinopyroxene, and so on; 5. HP and low P mineral inclusions in zoned garnets and zircons.

Signatures of regressive metamorphism

Sharp drop pressure and slowly decrease temperature after impact created conditions of regressive metamorphism. Fluid/melt also acted on intensive metasomatic alteration of diamond-bearing rocks. Metasomatic changes characterize by presence graphite rims on diamond crystals; quartz pseudomorphs after coesite; biotite–K–feldspar and plagioclase–amphibole symplectite-like intergrowth around clinopyroxenes and garnets; a replacement garnet by biotite are the marker of amphibolite metamorphic phase (~ 650-680°C, <10 GPa); solid to solid phase transformation dolomite to calcite and chlorite-actinolite in matrix of host rocks are markers of greenschist (~ 420°C, ~2–3 GPa) metamorphic phase.

Inclusions in diamonds

Polycrystaline nano-inclusions in diamonds represented by oxides Si, Ti, Fe, Cr with trace element impurities: Mg, Ca, Al, K, Na, S, P, Pb, Nb, Cl, Zn, Ni [Dobrzhinetskaya et al., 2003], and also Si-P-K-containing glasses and K-Si-COH fluid inclusions [Hwang, 2006]; mineral inclusions also captured by diamonds-bearing garnets and zircons in both progressive and regressive metamorphic stages. Inclusion compositions have similarity to extraterrestrial matter.

Carbon, Helium, Nitrogen, Hydrogen and Nickel in diamonds

Carbon represents by graphite, diamond↔lonsdaleite, chaoite, ∝- and β-carbines, X-ray amorphous skeletal forms. Diamonds have different forms: cubes (dominated), distorted forms, skeletal and spheroid crystals, octahedra, twins. Core and rim differ on morphology, C and N isotope compositions in cube forms. Symplectite-like diamond-graphite intergrowth, coated diamonds with graphite rim and graphite crystals are observed. Diamond carbon isotope composition of $\delta^{13}C$ (–8.9 to –27 ‰) compare with $\delta^{13}C$ (−5 to −31 ‰) in meteorites; diamonds from gneisses have lighter $\delta^{13}C$ relatively to those of pyroxene-carbonate and garnet-pyroxene rocks that suggest to discrete carbon sources. Values $\delta\ ^{13}C$ of graphite are lighter than those in diamonds that do not supported the hypothesis of transformation graphite to diamond for this deposit. Carbon matter composition compared with those presolar nanodiamonds.

$^3He/^4He$ isotopic ratio ($7x10^{-1}$ to $8x10^{-9}$ ‰) of diamonds [Shykolukov et al., 1996] is significantly higher than $^3He/^4He$ ratio of IDP (> 10^{-4} ‰), the Earth's atmosphere ($1.4x10^{-6}$), Solar wind ($4.3x10^{-4}$), MORB ($1.1x10^{-5}$), OBI ($0.7x10^{-4}$). ^3He occur in diamond lattice and inclusions, it means that ^3He was trapped by diamonds during its formation outside the Solar System, more likely ^3He is primordial galactic component. ^4He, Ne, Ar, Xe also present in these diamonds.

High N (up to 10000 ppm), high enriched $\delta^{15}N$ (+5.3 to + 25 ‰), high H in diamonds compare with value coma comet gases (CN, HCN), diamonds from chondrites and presolar diamond grains. N aggregation state are Ib+IaA (Ib > IaA). Presence of Ni-N centers in diamonds identified by PLS. So, diamond crystallization occurred by CVD growth process on carbonaceous matter seeds from over saturated carbon fluid/melt. Small diamond sizes, low N aggregation state and diamond preservations suggest to short-term diamond grown process.

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