# ULTRAHIGH-PRESSURE METAMORPHIC ENVIRONMENT OF MICRODIAMONDS

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The Kokchetav massif (Northern Kazakhstan) is known as the type locality of diamonds in metamorphic rocks. The massif has a complex heterogeneous structure. Eclogite and diamondiferous rocks occur only within the deposits of the Zerenda rock series which occupied the central part of the massif. This series is represented mainly by metamorphic assemblages of amphibolite and epidote-amphibolite facies.

A significant spread in P-T parameters of metamorphism was found in the eclogites and country rocks from various sites (Shatsky et.al.,1989) **The diamondiferous rocks and high-temperature nondiamondiferous eclogites** occur within the lowermost unit 1 of the Zerenda series (Dobretsov et.al.,1995). This unit is composed of dominant garnet-bearing quartzofeldspathic gneisses and biotite schists with lesser amounts of garnet pyroxenite, garnet-pyroxene-carbonate rocks and eclogite lenses of basaltic composition.

The mineral parageneses of eclogite, amphibolite and greenshist facies are recognized in diamondiferous rocks.(Shatsky et.al.,1993) **The parageneses of eclogite facies and diamonds are generally preserved only as inclusions in garnets and zircons.** In addition, the diamonds were found as inclusions in kyanite, clinopyroxene and in secondary minerals replacing garnet and cpx (biotite, muscovite, amphibole).

The UHP mineral assemblages of diamondiferous cataclastic biotite gneisses and schists are made up of Gnt ± Cpx ± Bt ± Phe ± Kfs ± Sph ± Ky ± Coe ± Ap The eclogite facies mineral paragenesis of pyroxene-garnet-carbonate rocks and garnet-pyroxenite is composed of Gnt + Cpx + Dol + Cal ± Phl ± Rut ± Sph ± Zo ± Mag.

Evidence of UHP was obtained from specific features of minerals included in garnets and zircons. Potassium-rich clinopyroxene (up to 1.5% $K_2O$), grossular-pyropic garnet (grosspydite type garnet), aluminous sphene (up to 13,8 $Al_2O_3$), Si-rich phengites (up to 3,6 Si p.f.u.) attest to UHP conditions of metamorphism (Sobolev, Shatsky, 1990, Shatsky, Sobolev 1993, Shatsky et.al. 1995). This is confirmed by discovery of coesite as inclusions only in zircons from diamondiferous gneisses in a number of samples (Sobolev et.al., 1991,1994).

The majority of diamonds are crystals with the variably developed of hummocky cuboid faces and flat octahedral faces. As a rule, cuboid faces predominate. The morphology of this type of diamond indicates that crystals have experienced mixed-habit growth (Lang 1979) While the octahedron faces grew by a normal, layer by layer mechanism, the cuboid regions characterize non-faceted abnormal growth. Some cuboids show "fibrous"structure. The octahedral microfacets developed on cuboid surfaces are generally observed in crystals from pyroxene-carbonate rocks. Diamonds showing octahedral morphology (sharp-edged octahedral, twinned crystals), coated diamonds and polycrystalline aggregates are also noted.

**Thus, the morphology of metamorphic diamonds shows no principal morphological differences with diamonds from kimberlites.** On the other hand, there are essential differences between metamorphic and synthetic diamonds. As observed by I. Sunagawa (1984) on natural diamonds, only {111} faces are characteristic of the layer by layer mechanism. Whereas on synthetic crystals, including diamonds, grown under metastable conditions from vapour phase (Sato, Kato, 1992) both {100} and {111} faces grown layer by layer mechanism.

Table 1. Geochemical characteristics of diamondiferous rocks.

| | La/Yb | Th/U | K/Rb | Rb/Cs | Sm/Nd |
|---|---|---|---|---|---|
| n | 44 | 47 | 40 | 45 | 34 |
| X | 3.34 | 1.85 | 197.09 | 43.88 | 0.3071 |
| S | 3.13 | 2.59 | 70.76 | 25.16 | 0.0761 |
| Min | 0.11 | 0.01 | 57.00 | 7.71 | 0.2120 |
| Max | 10.70 | 13.30 | 422.00 | 154.38 | 0.5150 |
| Upper Crust[1] | 13.64 | 3.82 | 250 | 30.3 | 0.1730 |

[1] (after Tailor S.R., Mclennan S.M.,1985).

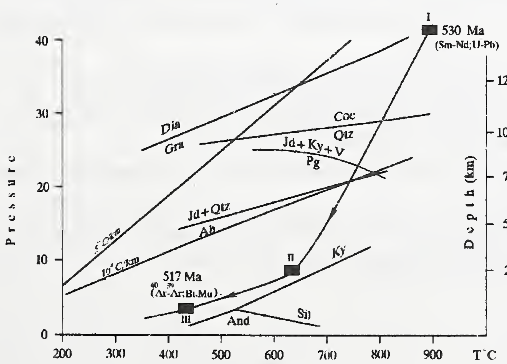
The composition of diamondiferous cataclastic gneisses, mica schists and cataclastic garnet-pyroxene-quartz rocks varies widely. Bulk composition of diamondiferous rocks correspond to marls. The rocks are depleted with respect to the crust in such elements as Ba, Ta, Th, Sr and LREE (Table.1). Most rocks are depleted in U as well. In most of the diamondiferous rocks, the Th/U ratio is lower than in the upper crust. The diamond-bearing rocks are significantly distinct from non-diamondiferous rocks of the Kumdy-Kol and the Zerenda series rocks of the other sites, when the ratios of La/Yb and Sm/Nd are compared.

Wide variations of $\varepsilon_{Nd}0$ values characterize the Zerenda series rocks. These variations are especially significant for diamondiferous rocks which, generally excluding pyroxene-carbonate rocks, have higher $\varepsilon_{Nd}0$ values (−13,5 - +11,7) compared to the other Zerenda series rocks.

On an isochron diagram the Zerenda series rocks form a linear array suggesting an age of 561±31 Ma with the initial $^{143}Nd/^{144}Nd$ ratio of 0,51116 ($\varepsilon_{Nd}T$ - 15,5).

Mineral separates of diamondiferous rocks and migmatite form an isochron with an age 521±11 Ma and initial ratio of 0,511128 ($\varepsilon_{Nd}$ (T) -13). Using the initial $^{143}Nd/^{144}Nd$ ratio obtained by the mineral isochron a 2,3 Ga model age was deduced.

The $^{40}Ar/^{39}Ar$ dating of the biotite and muscovite which replace garnet in the diamondiferous garnet-biotite gneisses give an age of 517 Ma. The obtained data prove that the rate of cooling of the diamondiferous rocks from 530 up to 517 Ma would be 46-42 C°/Ma.
Isotopic-geochemical investigation of the Zerenda series rocks of the Kokchetav massif together with mineralogical-petrological investigations (Sobolev, Shatsky 1990, Shatsky et.al.1993,1995) allow us to distinguish the following stages in the geological evolution of the crustal block in which the ultra-high pressure metamorphism is manifested (Fig.).




The Sm/Nd model age of the Zerenda series rocks proves that the crust of North Kazakhstan was formed in the Early Proterozoic at 2,2-2,3 Ga. According to the available Caledonian paleogeodynamic reconstructions for Kazakhstan, a break of the continent and formation of ocean floor occurred in the Late Riphean Zonenshain et.al., 1990) During the moving apart of the continental fragments, thinning of the continental margin formed by basaltic volcanism occurred. The isotopic-geochemical results on eclogites allow us to propose that the formation of the protoliths occurs at this time referred to this stage (Shatsky et.al., 1993). In the Lower Paleozoic (530-540 my) the collision of microcontinents resulted in the sinking of thinned crust to a depth of about 150 km. During subduction most LREE, Sr, U,Th,Ta, and K was removed from the subducted crust due to partial melting. The uplift of the diamondiferous rocks to a crustal level has proceeded with velocities no less then 10 mm/year. The uplift of a hot plate into the earth's crust must have produced the melting of rocks which earlier underwent a low-grade metamorphism. The interaction of newly formed melts and their related fluids with diamondiferous rocks resulted in the formation of biotite gneisses, schists and migmatite. The rocks attained their final appearance after the superimposed greenschist facies metamorphism.

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