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GEOLOGY

The South Tien Shan Belt of Diamondiferous Alkaline Basic Rocks

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Kimberlite pipes were the major source of diamonds in the 19th century. Previously, diamonds were mainly extracted from placers associated with the kimberlite pipes. However, diamonds were discovered in several nonkimberlitic rocks in the 1960s–1980s [1–3 and others]. Large diamond deposits were discovered in Australian lamproites, which are considered a specific variety of basic rocks [2], ultrabasic rocks, picrites, carbonatites, impactites, and high-pressure metamorphic rocks.

The study of alkaline (subalkaline) basic rocks in the central southern Tien Shan (Tajikistan) revealed some specific features of their diamond potential. The region incorporates approximately 90 diatremes of various Lower Mesozoic alkaline basic rocks (table) with mantle nodules (see [4] for their distribution in the structures of the Tien Shan). Mantle inclusions are mainly composed of rocks of the spinel and garnet–spinel facies (16–22 kbar, 1000–1170°C). The rocks are characterized by a high rate of depletion and abundance of mantle-related metasomatism (fluid-rich magmatism) with the formation of potassic ultrabasic rocks (pyroxenites, glimmerites, anorthoclasites, and others) and high-pressure metacrystals of phlogopite, K-kaersutite, sanidine, Al-augite, chrome diopside, apatite, spinel, and other minerals, which are products of the disintegration of mantle pegmatites. Some rock bodies include chromites (Cr_2O_3 up to 58–60%), moissanite, native metals, and sulfides (pyrrhotite and others). The magnetite content is low. Some xenoliths contain graphite. The frequency of its occurrence in concentrates of host basic rocks (43–49%) indicates their crystallization in a carbon-saturated reducing environment.

Within the framework of the *Lamproite* program (1985–1989), we carried out prospecting for diamonds in 44 pipes and 750 dikes of alkaline basic rocks in the southern Tien Shan. Unfortunately, the results turned out to be negative, because the methods applied were designated for the discovery of large kimberlitic diamonds. Only in 1989 did the application of thermochemical analysis according to the method proposed by M.D. Isaeva and V.P. Bocharnikov make it possible to detect small diamond crystals in eight pipes and dikes [5]. The diamond crystals can be divided into three types (types 1 and 2 are similar in terms of some specific features).

(1) Fragments of transparent and translucent, colorless and gray, isotropic octahedrons (0.05–0.12 mm, up to 0.5 mm in some cases) with adamantine luster and hardness >9.5. Some crystals have dull faces and cleavages. The edges also reveal traces of etching. One can see growth triangles, blue cathodoluminescence, and weak orange-red luminescence in the IR beam.

(2) Irregular grains (0.05–0.07 mm) composed of intergrowths of white and gray, transparent and translucent, octahedron faces with adamantine luster. This variety is characterized by blue, pale yellow, and yellow-green types of cathodoluminescence.

(3) Light yellow and yellow grains of cubic (sometimes, distorted) crystals and combination of plane-faced cubes and octahedrons with adamantine luster. The grain size is 0.02 or 0.03 mm (maximum 0.05 mm). This variety is characterized by a knobby–pitted surface of faces and the etching of edges. Cathodoluminescence is absent.

The XSA analysis confirmed the identification of diamonds. In addition, various analyses performed in two laboratories confirmed the presence of five diamond grains in one of the pipes of the study region.

The identified minerals are similar to diamond crystals from the alkaline basic and ultrabasic rocks [2, 3] in terms of the small size of grains and the abundance of octahedral and combined shapes. However, they differ from the tiny diamond grains (usually, intergrowths with graphite) in high-pressure metamorphic rocks (analog of type 3 diamonds). Subsequently, the authors of [7] found such diamond crystals in our xenolith sam-

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Average chemical (wt %) and rare element (ppm) compositions of Lower Mesozoic alkaline basic rocks in the southern Tien Shan

Component	1	2	3	4	5	6	7	8	9
SiO_2	34.9	41.3	47.4	45.8	41.2	41.8	44.6	21.7	4.2
TiO_2	0.8	1.1	1.0	1.2	1.9	1.8	2.4	0.6	0.4
Al_2O_3	9.1	13.3	14.5	16.2	11.0	12.7	16.1	6.2	0.5
Σ FeO	6.5	8.5	8.2	8.2	9.4	10.1	11.8	11.2	4.6
MnO	0.2	0.2	0.14	0.2	0.2	0.2	0.2	0.4	0.4
MgO	17.8	11.2	6.8	4.2	16.0	11.0	5.3	3.1	1.8
CaO	9.1	11.4	10.3	8.4	8.3	10.1	6.8	29.4	45.6
Na_2O	0.7	1.5	2.3	2.4	2.0	2.2	4.0	1.3	0.2
K_2O	1.4	2.3	3.0	3.8	1.6	1.9	2.8	1.6	0.1
P_2O_5	0.5	0.5	0.5	0.5	0.7	0.8	0.9	1.5	1.8
L.O.I.	14.8	7.1	5.7	8.6	6.7	7.2	4.5	19.0	39.4
CO_2	5.8	1.8	2.7	4.7	–	4.1	1.0	17.1	34.1
F, %	0.21	0.15	0.12	0.15	0.06	0.08	0.07	0.14	–
Rb	57	88	107	153	62	79	91	38	9
Sr	–	715	610	602	–	1150	1064	995	3236
Ba	–	634	985	1100	–	400	2040	1333	1.87%
Nb	–	15	25	18	–	89	131	30	65
Zr	–	158	208	205	–	355	420	48	–
Ni	750	290	290	27	260	189	78	15	–
n	2	38	43	11	2	74	7	29	1

Note: Sectors of the southern Tien Shan: (1–7) central sector (Tajikistan), (8, 9) western sector (Uzbekistan) [12]. Rocks: (1–4) absarokite–shoshonite series: (1) subalkaline picrobasite, (2) absarokite, (3) shoshonite, (4) latite; (5–7) intraplate alkaline (subalkaline) basic rocks: (5) subalkaline picrobasite, (6) slightly differentiated basic rocks, (7) differentiated basic rocks; (8, 9) alkaline basic–carbonatite series: (8) silicate–carbonate rocks, (9) carbonatites. (*n*) Number of samples; (–) no data.

ples of graphite pyroxenites. The scanning electron microscopic and microdiffraction analyses revealed that the diamond is developed as micrometer-sized cubic and octahedral crystals intergrown with graphite. According to [7], the formation of diamond crystals is related to the shear flow of graphite under the impact of local thermal explosions and high pressures (up to 60 kbar).

We believe that the major portion of diamond grains formed in a carbon-supersaturated reducing medium of the upper mantle under the impact of high stationary pressures. Two versions of thermodynamic parameters of their crystallization are proposed. The tiny cubic and combined (intergrown with graphite in some places) diamond crystallites were likely formed in a metastable state at the spinel or garnet facies of the mantle due to a local rise in pressure and/or impact of reducing fluids. At the same time, detailed study of diamonds in kimberlites [8] demonstrated that they are primarily xenogenic products, because they often occur in mantle xenoliths or make up intergrowths with minerals of the ultrabasic and eclogitic parageneses. Findings of xenogenic intergrowths of diamond with chromites in Tien Shan [9], which are presumably related to depleted peridotites, indicate that some centers of alkaline basic rocks could reach upper levels of the diamond depth facies.

Numerous diamond grains of the similar habitus and dimension were found later in Lower Mesozoic pipes and dikes at the western extension of the South Tien Shan Belt in Uzbekistan [9, 10, and others]. The polychronous nature of diamondiferous bodies was revealed in this region, where Lower Mesozoic pipes are supplemented with shonkinite–camptonite diatremes and dikes intruded by granodiorites, syenites, and other rocks. Hence, the diamondiferous bodies are obviously not younger than the Permian. The diamonds are associated with chromite, Cr-grossular (up to 11% Cr_2O_3), moissanite, and other substances [10 and others]. The absence of metastable polycrystalline dark varieties suggests mineral crystallization under conditions of the diamond facies of the mantle [3, 10].

According to [1, 11, and others], older (Carboniferous) diamondiferous pipes and lamproite-type volcanic sheets are found in the central Tien Shan. They contain plane-faced diamond octahedrons (0.0*n* mm, rarely up to 0.8–0.9 mm) associated with chromite (up to 64.4%

Cr_2O_3), garnet, native metals, and carbides of Si, Fe, Ti, V, and W. The $\delta^{13}C$ value in such diamond grains is 6.2‰. Their composition is as follows (%): N_2 50.3, CO_2 10.3, H_2O 9.8, CO 4.4, and CH_4 4.2 [11].

The western sector of the southern Tien Shan also includes unique pipes and dikes of K-silicate rocks and carbonatites (table) related to the liquid immiscibility of Lower Mesozoic alkaline basic melts [12]. These rocks are characterized by the coexistence of two explicitly heterogeneous mineral associations. High contents of magnetite (3–15 kg/t) are associated with native metals, moissanite, and diamonds. The concentrates of some large samples (20–25 kg) contain as much as 150–200 yellow-green diamond octahedrons (0.05–0.2 mm). The calcite-rich carbonatites (sövites) contain only a few diamond grains [12].

Thus, numerous findings of small (technical-grade) diamond grains in pipes and dikes in the study region make it possible to outline the South Tien Shan Belt of diamondiferous alkaline basic rocks, one of the world's large diamondiferous alkaline basic zones (900 × 300 km in size). The assessment of the practical significance of the Tien Shan diamondiferous belt needs further investigation.

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