Fig. 1. Twisted **quartz**. 8.5 x 8 cm. Puiva.
Mining Museum of Mining University (St. Petersburg)* no. MGS-1731/245. Photo: M.B. Leybov.

* Here and after, Mining Museum of Mining University (St. Petersburg) means
Mining Museum of National Mineral Resource University "Mining", St. Petersburg, Russia.

HISTORICAL REVIEW

"The mineral was transparent like mountain spring water, smooth like the important detail of the most complicated mechanism, and those seeing it for the first time felt mistrust of its natural origin; the rock crystal was an object of search of the expedition in the distant remote massifs of the Subpolar Urals".

A.N. Aleshkov, 1934

The first rock crystal finds at the western slope of the Subpolar Urals near Sura-Iz Mt. were reported in 1927 by P. Terentiev and N. Filippov, reindeer breeders from the Saranpaul village, and were published by A.N. Aleshkov (1935). In 1930 the Council for the Study of Productive Forces of the USSR Academy of Sciences organized expeditions to different regions of the Soviet Union to find optical varieties of quartz to fill the need of industry. One of these expeditions, headed by A.N. Aleshkov, visited the region of Sura-Iz Mt. in 1932 and discovered the first deposit of rock crystal within a year (Aleshkov, 1933, 1937_1, 1937_2). In 1934, they continued working at this deposit and discovered a second deposit, Dodo, at the eastern slope of the Urals in the region of Neroika Mt., where eight tons of quartz crystals had been mined right away (Aleshkov, 1936).

In 1935, the trust "Russian Precious Stones" ("Russkiye Samotsvety") received the government's request for an urgent delivery of a ton of rock crystal needed to replace the two-headed eagles at the Moscow Kremlin towers with stars decorated by seven thousand faceted quartz crystals up to 200 carats. In the same year, the trust organized the mining of rock crystal at the Subpolar Urals at the Dodo and Sura-Iz deposits (Semenov, Shakinko, 1982), where the piezoelectric and optic quartz was discovered. Based on that data, the Trust № 13 of the National Commissariat of the Defense Industry of the USSR organized a Polar Urals expedition, specializing in quartz raw material, in autumn of 1935. In 1936, this expedition discovered the Puiva rock crystal deposit.

Piezoelectric and Optic Quartz Prospecting (1935–1945)

The base for the Polar Urals Expedition was Saranpaul village in the Berezovsky District of the Tyumenskaya Oblast. In those days, one reached Saranpaul from Tyumen by the small steamship "*Petr Shleev*" (*Fig.* 2) up the rivers Tura, Tobol, Irtysh, Ob, North Sosva, and Lyapin. To reach the mountains, the geological parties began their travel by boat to the transit camps (*Fig.* 3, 4), and then went on foot with loaded horses. Initially, the investigations were focused on prospecting rock crystal placers and rock crystal-bearing veins. In some cases, small quarries and short adits were bult for mining of the rock crystal deposits. During this period the Subpolar Urals became one of the main regions of mining for piezoelectric and optic raw material, and its importance increased even more from 1941 to 1945.

Scientific research started at the very beginning of the exploration of the rock crystal-bearing deposits of the Subpolar Urals. Specialists from the leading institutes of Moscow and Leningrad took part in this project. In 1937, this work was supervised by G.G. Lemmlein, the senior scientist of the Crystallographic Laboratory of the USSR Academy of Sciences (since 1944 the Institute of Crystallography), and in 1939 by E.P. Moldavantsev, professor of the Central Research Geological Prospecting Institute of Nonferrous and Noble Metals (TsNIGRI). N.A. Sirin (1945) compiled a map of the Subpolar Urals at a scale of 1:200000 with a description of the stratigraphy, magmatic processes, and structural features; he also gave instructions for prospecting of rock crystal. At this time, the first publications appeared – works by G.G. Lemmlein, I.I. Shafranovskii, M.F. Belyakov, V.A. Vakar, E.M. Bonshtedt-Kupletskaya on the study of piezoelectric and optic quartz and the mineralogy of the deposits, and data on the genesis of the rock crystal-bearing veins in the articles of M.G. Khisamutdinov (1940), G.V. Merkulova (1942), and V.A. Vakar (1943). A large team of geologists and mineralogists investigated the deposits during this period. A.D. Azarnykh, M.F. Belyakov, I.V. Bussen, V.A. Vakar, A.Ya. Galaidin,

Fig. 2.
Steamer "Petr Shleev" in Saranpaul, 1956.
Photo: V.V. Bukanov.

Fig. 3. Departure of geological crew to the mountains, 1956.
Photo: V.V. Bukanov.

Fig. 4. Delivering cargo in the mountains, 1956.
Photo: V.V. Bukanov.

I.I. Ivanov, A.E. Karyakin, V.T. Klochkov, I.N. Korobov, V.I. Malinovskii, V.K. Melnalksnis, G.V. Merkulova, O.A. Novikov, B.A. Osadchev, G.P. Petrunin, E.D. Polyakova, V.A. Smirnova, P.P. Tokmakov, P.A. Tertyshnikov, M.G. Khisamutdinov, M.M. Khotenok, and many others were among them. These scientists discovered the main deposits and found out general genetic and geological features of the deposits of Subpolar Urals.

Beginning of the Prospecting for Piezoelectric Quartz and Rock Crystal for Fusion (1945–1962)

From 1945 to 1947, I.V. Bussen, A.E. Karyakin, G.V. Merkulova, and G.P. Petrunin worked out the stratigraphy of the metamorphic series, made geologic maps of the rock crystal-bearing area at a scale of 1:100000, and summarized data on the geology and genesis of the deposits. They discovered that the rock crystal occurrences were exhausted on the plunges of the Lyapinskii anticlinorium towards the north and the south, and established that the hydrothermal formations, including the rock crystal-bearing quartz veins, are connected to massive granitoids. During the post-war period, especially at the beginning of the 1950s, the scale of exploration and mining of the expedition grew noticeably. It primarily happened due to the increase in demand for quartz used for fusion in the process of optical glass making. Consequently, instead of 10%, now up to 80% of the mined raw material was used. Year-round work with underground mining was organized at the largest deposits. The expedition was reinforced by skilled personnel and was equipped with drilling equipment, compressors, and power plants. Mechanical transport appeared, and roads with landing fields for AN-2 planes (*Fig.* 5) were built in the mountains. As a result of the exploration expansion, two new large deposits were discovered: Pelengichei-3 (in marble) and Zhelannoe (in quartzite). An evaluation of the deposits' depth for the purpose of identifying objects for preliminary survey had also begun at that time.

G.G. Lemmlein, I.I. Shafranovskii, D.P. Grigoriev, A.E. Karyakin, N.Yu. Ikornikova, E.D. Inshin, V.V. Bukanov, V.Yu. Eshkin, and other authors publish new works exploring the results of a special study of quartz crystals, associated minerals, and the genesis of the deposits. G.G. Lemmlein's summary (1954) mentioned data on 26 minerals in Alpine-type veins of the Subpolar Urals. Along with the doctorate of A.E. Karyakin, there was a number of PhD theses (candidate dissertations) defended at that time by: E.D. Inshin (1954), V.A. Smirnova (1956), V.V. Bukanov (1961), and V.Yu. Eshkin (1961).

By the end of this period, a considerable area of the province was covered by geological prospecting maps at scales of 1:25000 and 1:10000; the refinement of geological maps and drawings of discovered quartz veins and placers of quartz crystals on these maps were made. The old geological maps were refined, and new geological maps with scales of 1:5000 and 1:2000 were created. In 1961, the expedition's special party, headed by V.A. Smirnova, made summary maps with a scale of 1:200000: 1) a map of the geological structure; 2) a map of the location of rock crystal-bearing mineralization; and 3) a map predicting future production for the rock crystal-bearing province. They also established the sequence of works on the deposits, according to their prospective value and measured probable reserves. It was the first time that three rock crystal-bearing tectonic zones – Central, Western, and Eastern – were identified, which was especially significant since all magmatic rocks and rock crystal-bearing veins of the Subpolar Urals are located in these zones.

Prospecting on Rock Crystal and Veiny Quartz for Fusion(1963–1980)

During this period, at the industrially promising deposits Pelengichei-3, Zhelannoe, Dodo, and Puiva, a preliminary survey began studying the deep levels to assess the reserves of piezoelectric and optic quartz, rock crystal for fusion, and also a new type of raw material (veined quartz for manufacturing a special type of glass). The prospects for semiprecious stone raw material were assessed: for amethyst at Khasavarka; for citrine and smoky quartz at Zhelannoe; and for rutulated quartz at Cheln-Iz and Skalistoe. The research teams increased veined quartz sampling, as well as that of underground mining, drilling, and geophysical prospecting. A.E. Karyakin and V.A. Smirnova summarized the regularities of formation and location of the piezoelectric and optic quartz deposits at the Subpolar Urals in their monogpraph (1967). G.B. Milgrom formulated the foundations of geological-economic assessment of these deposits in his PhD thesis (1968). A.A. Korago's

PhD thesis (1970) presented the results of study of the geological structure and rock crystal content of the Rosomakhinskii region, including the Cheln-Iz deposit of ritulated quartz. The PhD thesis of A.V. Kozlov (1974) explored the conditions of formation of quartz crystals at the Zhelannoe deposit, while the PhD thesis of E.M. Suchkova (1978) was devoted to the accessory minerals of the rock crystal-bearing veins.

The Tyumenskoe and Ukhtinskoe geological departments began a systematic geological survey of the Subpolar Urals, and organizations of the Ministry of Geology and of the Academy of Sciences began the theme research. Mostly, for the rock crystal-bearing province, this meant a deeper analysis of obtained data, enriched through aerial photograph interpretation, geological-structural analysis, and mineralogical mapping during this period. All of this activity prepared the basis for a new approach to regionalization and a complex assessment of reserves. The Institute of Geology of the Komi Branch of the USSR Academy of Sciences (the executive director of the works was V.V. Bukanov) identified the genetic differences in the prospects of two productive zones of the Zhelannoe deposit. They also discovered that, after gamma irradiation, the rock crystal from the Eastern zone nests became citrine-colored, whereas rock crystal from the big veined nodes of the Western zone became smoky-colored. As a result, low-quality crystals from the Eastern zone were used to irradiation for their subsequent sale as raw material for jewelry. This work was successful for many years.

This period had also brought the identification of the evolutional sequence of the deposits formation for the province as a whole, as well as the identification of the metamorphogenic Alpine-type veins and the hydrothermal-metamorphogenic multiple cavity veined zones. The latter were subdivided into the veined nodes with rock crystal and quartz for fusion and also the veined zones with nests of piezoelectric and optic quartz, citrine, and amethyst.

Final Period of Exploration and Summarizing of Data (1981–1991)

As the state stopped financing further expeditions, this opened the final period for the exploration of the Subpolar Urals rock crystal deposits. Despite that fact, the main goal had been achieved: a preliminary survey of the main deposits (Puiva, Dodo, and Zhelannoe) had been completed, and reserves had been approved in the USSR State Committee for Reserves. Special credit for those accomplishments goes to the chief geologists of the parties: E.V. Burlakov at Puiva, S.A. Gusev at Dodo, and N.A. Pozhidaev at Zhelannoe; to the chief geologists of the expeditions: D.A. Zolotarev, L.S. Skobel, and V.I. Samokhvalov; and to V.V. Bukanov, the chief geologist of the "Severkvartssamotsvety" state association.

Fig. 5. Landing field at Neroika, 1958. Photo: V.V. Bukanov.

Fig. 6. **Quartz** on feldspar. 11 x 11 cm. Subpolar Urals.
Mining Museum of Mining University (St.-Petersburg), no. MGS-1731/287. Photo: M.B. Leybov.

Fig. 10. Sceptre **quartz**. 15 x 9 cm. Khasavarka. Mining Museum of Mining University (St. Petersburg), no. 1733/109.

↗ *Fig. 11.* **Rock crystal**. 7 x 4 cm. Neroika. Subpolar Urals. Fersman Mineralogical Museum, RAS, no. 40903, 1939.

Fig. 12. **Quartz**. 27 x 18 cm. Dodo. Fersman Mineralogical Museum, RAS, no. M31323, 1991.

Photo: M.B. Leybov.

Fig. 13. **Ferroaxinite** crystal (7.5 cm) on matrix. 9.5 cm. Puiva. Specimen: D. Trinchillo. Photo: J. Elliott, FMI.