THE AKHMATOV MINE IN THE SOUTH URALS: Notes on Mineralogy

Vladinir A. Popov
Institute of Mineralogy, Ural Branch of Russian Academy of Science, popov@mineralogy.ru

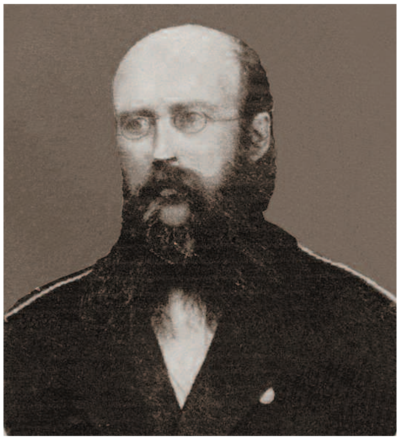


Fig. 1. Efim Fedorovich Akhmatov (1769–?), manager of the Kusa plant (portrait from the Zlatoust museum; photo: N.I. Arsent'ev).

In the 18–19th centuries in Russia, the ores for metallurgical plants were intensely prospected, predominantly in the Urals. The Ural prospectors and locals were finding numerous occurrences; many of which became economic deposits, where mining followed.

The Akhmatov mine is the most famous among known mines in the Shishim-Nazyam (Nazmin) Mountains in the South Urals. This mine is located close to the Europe-Asia geographical boundary at the eastern slope of the Chernaya Rechka ridge which is a branch of the Nazyam (Nazmin) ridge (*Fig. 3*) 16 km north of the Zlatoust railway station, Chelyabinsk region (55° 18′15′′ N., 59° 39′22′′ E.) (*Fig. 2*). It is reached by car from Zlatoust or from the settlement of Magnitka 4 km north of the mine. The extensive dumps of the mine (*Figs. 4, 8*) are situated 350–350 m south of the Medvedevka-Magnitka and road Zlatoust-Magnitka railway crossing. A sign was installed on the road (*Fig. 5*).

According to Yakov Nesterovsky, the Akhmatov mine was opened in 1811 by Efim Fedorovich Akhmatov (1769–?) (*Fig. 1*), bailiff and later a steward of the Kusa plant. This mine was named in honor of Akhmatov (Zlatoust..., 1994). While ores in the vicinity of the Kusa plant were prospected, an occurrence of garnet-bearing rock and mineral specimens was found, where Akhmatov decided to begin mining. According to one version, the mine was opened because of the abundant rock-forming garnet that was used as an abrasive in processing cast-iron and steel products.

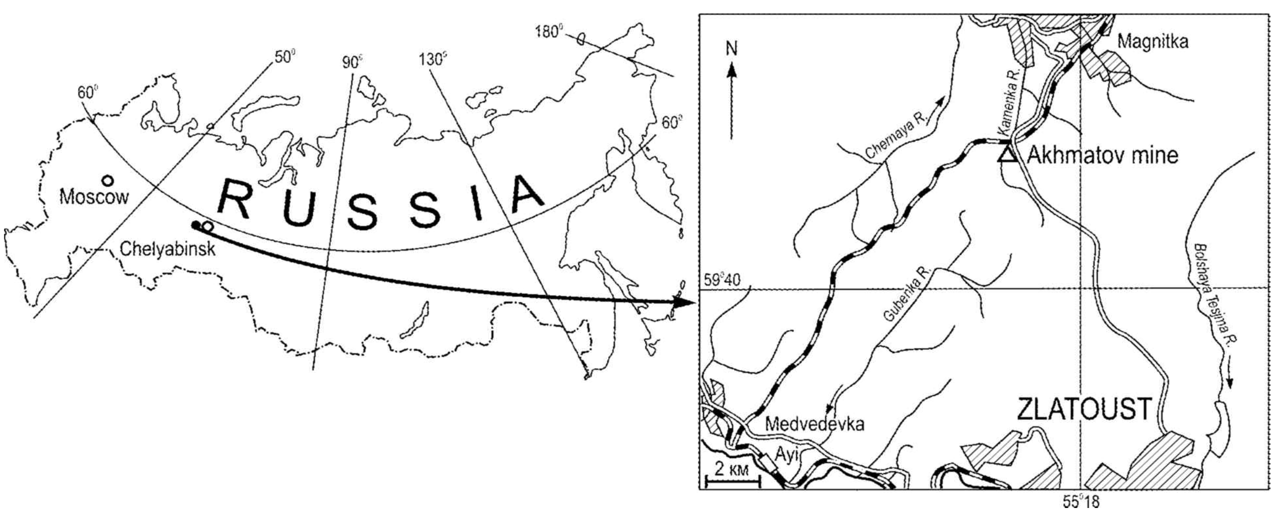


Fig. 2. Geographic location of the Akhmatov mine.

Fig. 3. View of the Taganai Ridge from the Nazyam Mountains.

Photo: Vladimir A. Popov

Fig. 4. Dumps of the Akhmatov mine.

Fig. 5. Sign of the *Taganai* National Park close to the Akhmatov mine.

Fig. 6. Crystals of **perovskite** embedded in calcite. 3 x 8 x 10 cm. Mineralogical Museum of St.-Petersburg State University, No 34/1899. Photo: M.B. Leybov.

Fig. 7. **Garnet** embedded in chlorite rock. 6 x 9 cm. Fersman Mineralogical Museum RAS, No K1378, M.A. Tolstopyatov collection. Photo: M.B. Leybov.

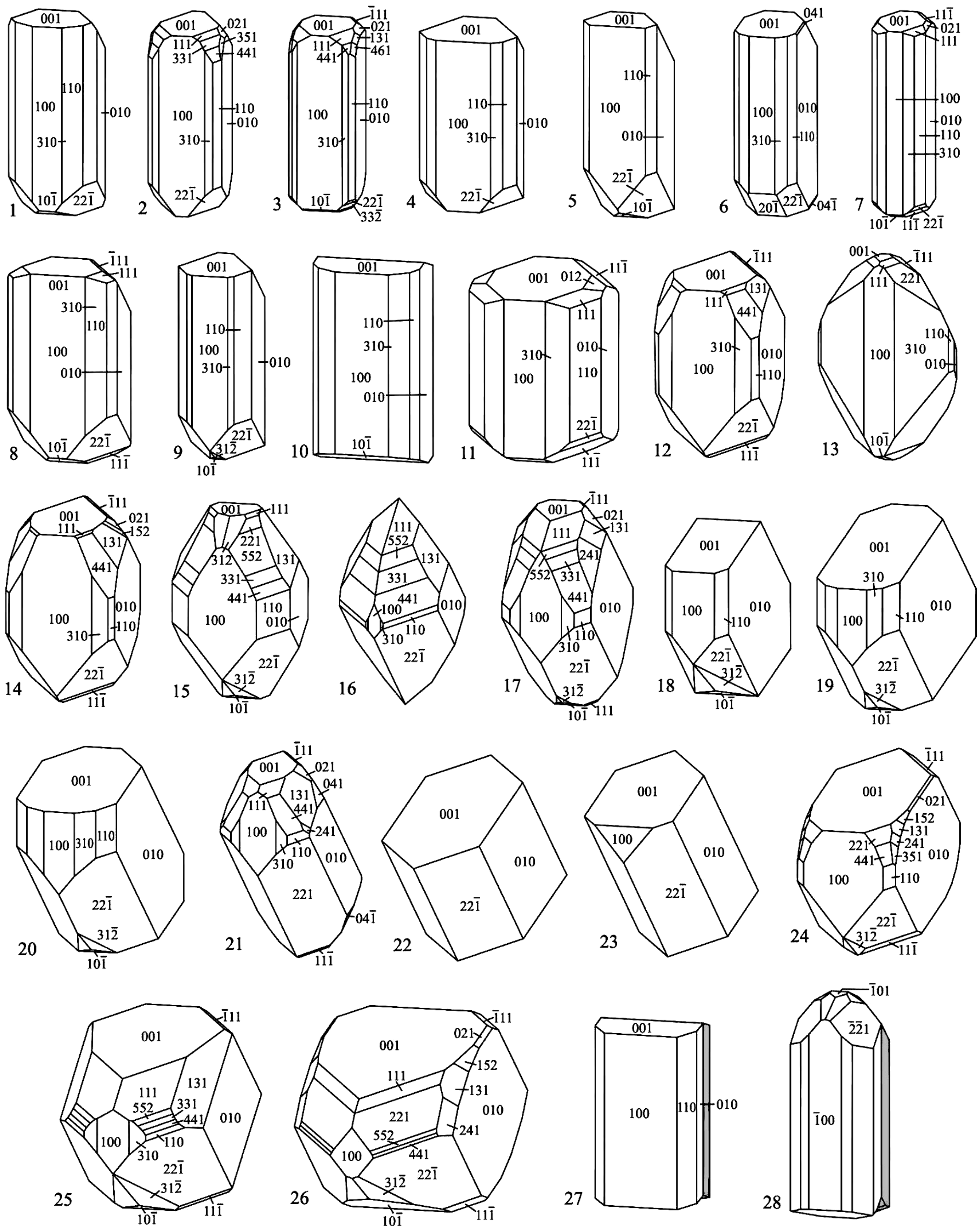
Fig. 8. A dump of the major pit.
Photo: V.A. Popov.

This version is convincing enough. However, it should be noted that P.P. Anosov, outstanding metallurgist and geologist, in 1820 used corundum deposits not far from Zlatoust in the region of Miass. Later, V.S. Myasnikov (1954) noted that the initial study of the Akhmatov mine was focused on mineralogical problems. The most famous discovery happened in 1839, when Gustav Rose described the new mineral perovskite from the Akhmatov mine.

The magnificent specimens from the Akhmatov mine beautify the collections of most old museums and universities worldwide and private collections. Many mineralogists and crystallographers were charmed by the large crystals of garnet, pyroxene, magnetite, perovskite, epidote, and titanite. Gustav Rose, Nikolai Koksharov, Pavel Eremeev and other well-known researchers readily measured and described the complicated crystals. Victor Goldschmidt organized all of the plots of crystals into a multivolume atlas (1913–1923), from that Yu.L. Voitekhovsky (2002) selected data on the crystal shape of minerals from Russia with many specimens from the Akhmatov mine.

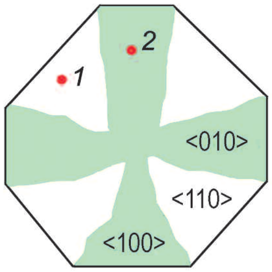
For 200 years of the mine's existence (the pits and dumps occupy an area of 50 x 100 m), a great amount of mineralogical, in particular crystallomorphological, material was accumulated. Unfortunately, because of the absence of regular mineralogical mapping (documentation), it is very difficult to report the whole history of the minining and the findings of unique specimens of minerals. However, an idea of complex (multistage) formation of the minerals is possible.

Currently, the district of the Akhmatov mine is a part of the *Taganai* National Park and the mine is a national heritage and important geological monument. It is of mineralogical and historical interest like the other mineral mines in the vicinity: Nikolae-Maksimilianovskaya, Zelentsovskaya, and Eremeev, located north of Akhmatov, and Perovskite, Praskov'e-Evgen'evskaya, and Shishim, located south of Akhmatov mine.



1 001 110 100 010 310 $10\bar{1}$ $22\bar{1}$
2 001 021 351 111 331 441 100 110 010 310 $22\bar{1}$
3 001 $\bar{1}11$ 021 131 111 441 461 100 110 010 310 $10\bar{1}$ $22\bar{1}$ $33\bar{2}$
4 001 110 100 010 310 $22\bar{1}$
5 001 110 100 010 $22\bar{1}$ $10\bar{1}$
6 001 041 100 010 310 110 $20\bar{1}$ $22\bar{1}$ $04\bar{1}$
7 001 $11\bar{1}$ 021 111 100 010 110 310 $10\bar{1}$ $11\bar{1}$ $22\bar{1}$
8 $\bar{1}11$ 111 001 310 110 100 010 $10\bar{1}$ $22\bar{1}$ $11\bar{1}$
9 001 110 100 310 010 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$
10 001 110 310 100 010 $10\bar{1}$
11 001 012 $\bar{1}11$ 111 310 010 100 110 $22\bar{1}$ $11\bar{1}$
12 001 $\bar{1}11$ 131 111 441 310 010 100 110 $22\bar{1}$ $11\bar{1}$
13 001 $\bar{1}11$ 111 221 110 100 310 010 $10\bar{1}$
14 $\bar{1}11$ 001 021 111 152 131 441 010 100 110 310 $22\bar{1}$ $11\bar{1}$
15 001 111 221 312 552 131 331 441 110 100 010 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$
16 111 552 131 331 441 100 010 110 310 $22\bar{1}$
17 $\bar{1}11$ 001 021 131 111 241 552 331 441 010 100 110 310 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$ 111
18 001 100 010 110 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$
19 001 310 010 100 110 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$
20 001 100 310 110 010 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$
21 $\bar{1}11$ 001 021 041 131 111 441 100 241 110 010 310 221 $04\bar{1}$ $11\bar{1}$
22 001 010 $22\bar{1}$
23 001 100 010 $22\bar{1}$
24 $\bar{1}11$ 001 021 152 131 221 241 441 351 010 100 110 $22\bar{1}$ $31\bar{2}$ $11\bar{1}$
25 001 $\bar{1}11$ 111 131 552 331 441 010 100 110 310 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$ $11\bar{1}$
26 001 021 $\bar{1}11$ 152 111 131 221 010 552 241 100 441 $22\bar{1}$ $31\bar{2}$ $10\bar{1}$ $11\bar{1}$
27 001 100 110 010
28 $\bar{1}01$ $\bar{2}21$ $\bar{1}00$

a



b

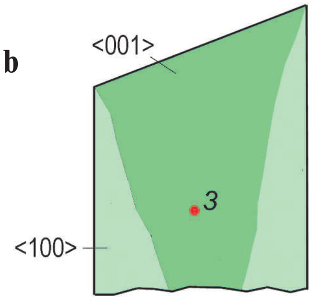


Fig. 48. Sketch of sector zoning of **diopside** crystals: (a) section perpendicular to [001], (b) section along {010}.
Numbers menas points of electron-microprobe analyses.

Crystal Morphology of Minerals

It is wonderful that Goldschmidt assembled in his "*Atlas*" nearly all drawings of crystals from the Akhmatov mine drawn by researchers from many countries for long period. The author of this study has processed all of these drawings, changed all the symbols of crystal forms to Miller indices, and redrawn crystals in the setting corresponding to the unit cells. The initial description may be found in Goldschmidt, 1913–1923.

The most morphological illustrations are devoted to **diopside** whose crystals (*Fig. 47*) in various assemblages are elongated along the [001] axis, pseudo-isomteric, or slightly elongated along the [10–1]. The crystals are typically flattened parallel to {100} and less frequently on {010}. Twins parallel to {100} are frequent. The acicular white crystals of diopside strongly flattened parallel to (100) and elongated parallel to [001] were not previously described. A few crystals have abundant forms. The color of diopside is variable; there are colorless, white (nearly opaque), greenish, light bluish green, and grayish green crystals (*Fig. 32*). In the case of significant plastic deformation, clear pyroxene parting parallel to {001} and steps on the faces of the *h k 0* zone. Consistent with crystal block slipping parallel to {001} along the [100] axis are observed in diopside crystals.
In one of the diopside crystals in the sections parallel to (010) and perpendicular to axis [001], sectoral distribution of Al and Fe is displayed. An admixture of Al_2O_3 up to 0.5 wt.% (*Fig. 48*, point of analysis 1) and less than 3 wt.% FeO were measured in the

⇦ *Fig. 47.* **Diopside** crystals from the Akhmatov mine. Most drawings are given from Goldschmidt atlas; No 10 after E.P. Shcherbakova; No 13 after V.A. Popov. All crystals are drawn in the setting correspon-ding to the unit cells; all symbols of crystal forms are changed to the Miller indices.

Fig. 49. Crystal of **diopside** (2 cm) on druse of **clinochlore**. 4 x 6 x 8 cm. Vernadsky State Geological Museum RAS, No MN-50410. Photo: M.B. Leybov.

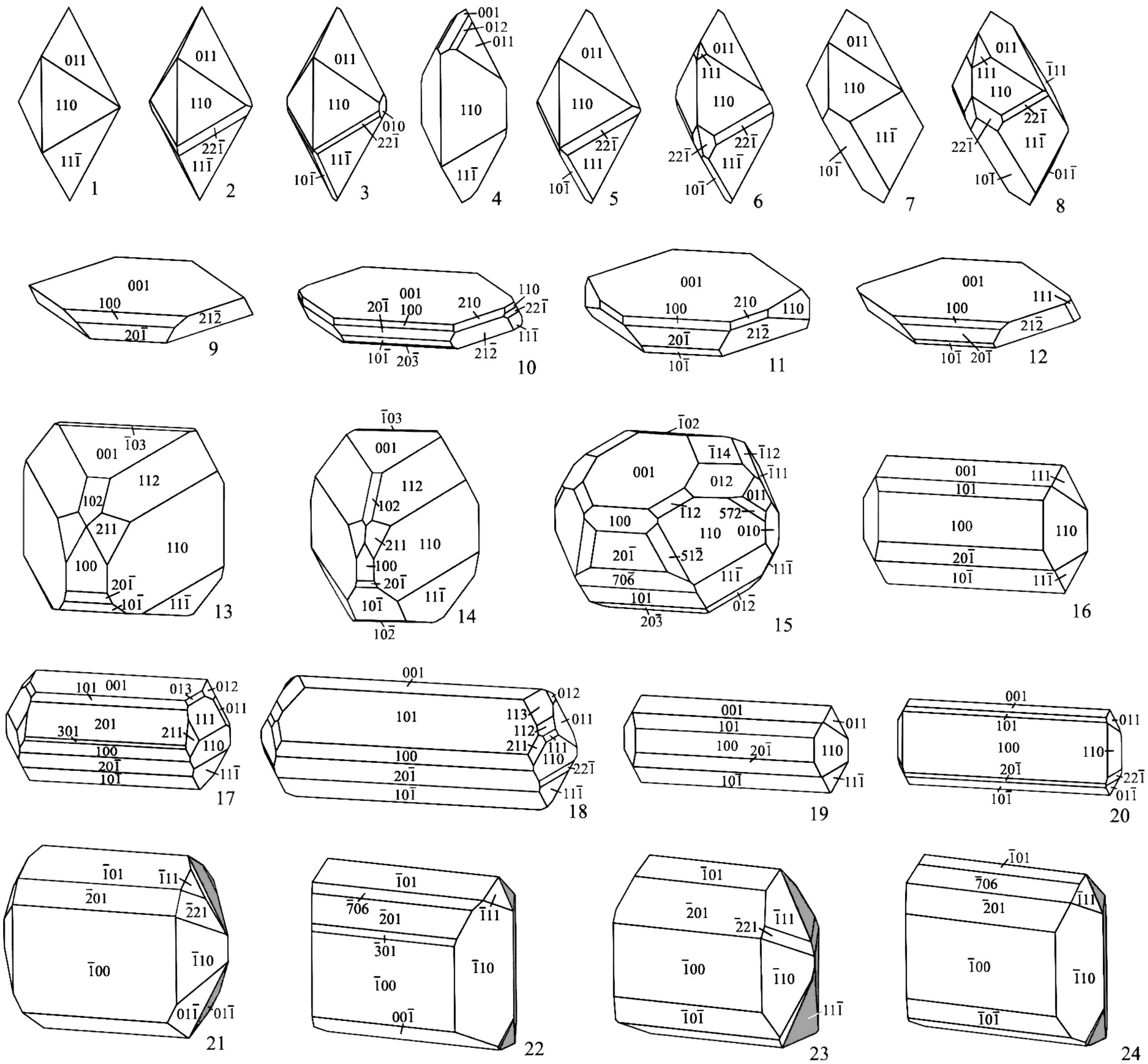


Fig. 53. Crystals and twins of **epidote** from the Akhmatov mine. The habits from Goldschmidt atlas are redrawn in the setting corresponding to the unit cells; all symbols of crystal forms are changed to the Miller indices; crystal No 15 after V.A. Popov.

have a lot of faces: for example, 22 crystal forms were found in crystal no. 15 (not all faces are plotted). The twins of studied epidote are intergrown on {100}.

Perovskite, as a new mineral, was found for the first time in the Akhmatov mine by A.B. Kemmerer and studied by Rose (Rose, 1839). The crystal shape of this mineral is cubic (*Fig. 54*). It was found later, that many crystals of perovskite are in fact to be usually paramorphs. As a result of cooling, the high-temperature isometric structure transforms into an orthorhombic modification with necessary twining that relieves stress arising from the change in volume accompanying this polymorphic transition. Perovskite from the Akhmatov mine shows great morphological diversity. In the modern A.A. Tsyplenkov collection, the author observed the

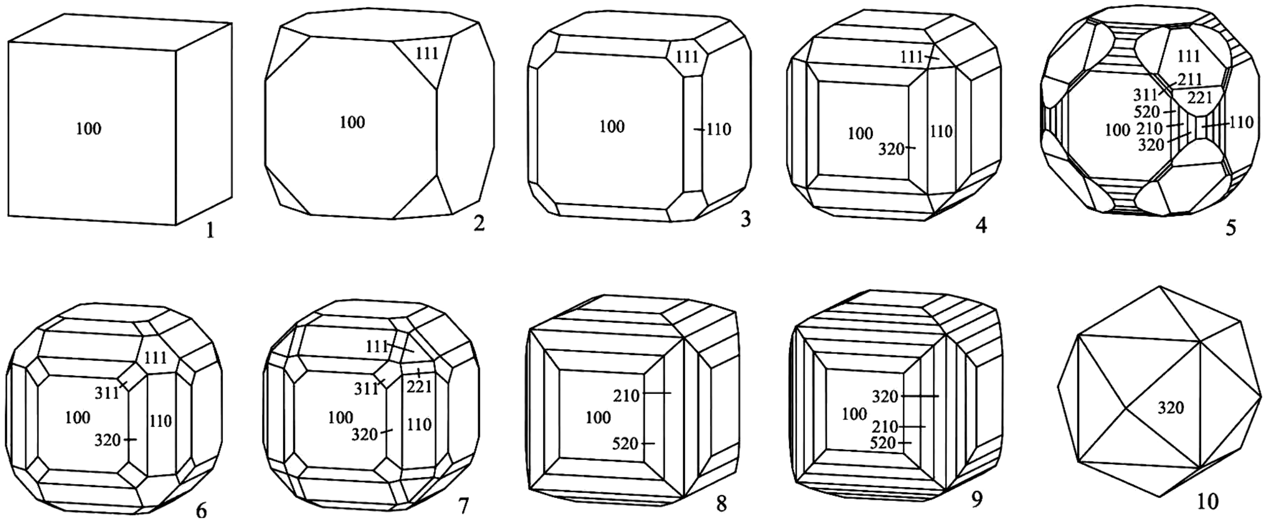


Fig. 54. Crystals of **perovskite** (cubic symmetry) from the Akhmatov mine.

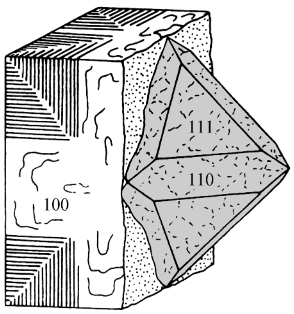
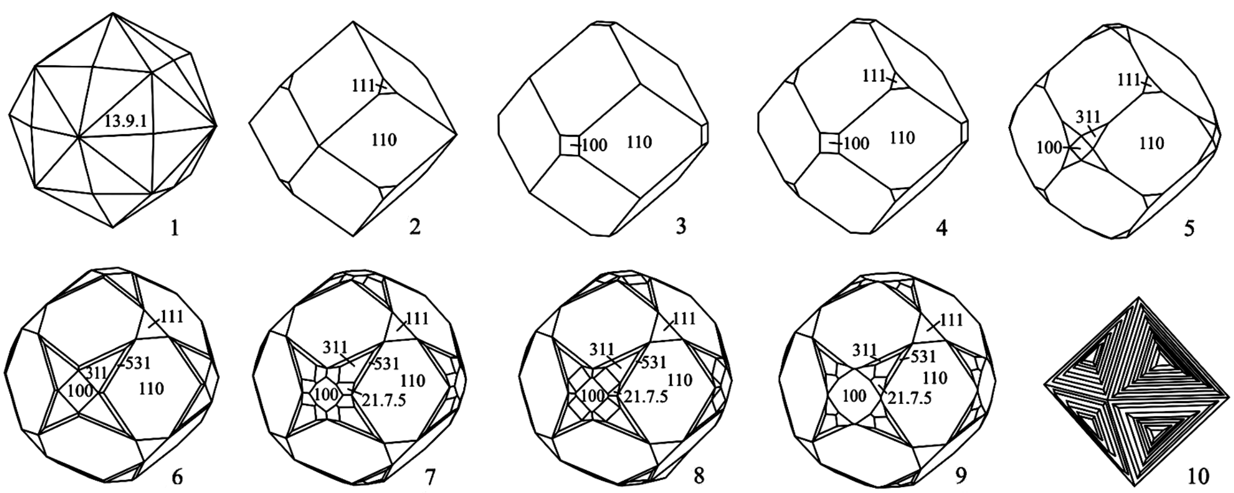


Fig. 55. Evolution of habit of **perovskite** crystal: {111+110}⇨{100}.

evolution of form from the inner part of crystal (a combination of the octahedron and the dodecahedron) toward an outer zone (cube) (*Fig. 55*). There are interference growth surfaces with chlorite and calcite on the crystals of perovskite. The early fine-grained calcite is embedded in perovskite, whereas later calcite was growing much more rapidly than perovskite to form interference growth surfaces with perovskite as very flat "plates" with meandering growth layers. According to Gekimyants (2000), the composition of the Akhmatov brownish perovskite is nearly stoichiometric corresponding to the formula $CaTiO_3$; an admixture of FeO up to 0.14 wt.% and MgO up to 0.2 wt.% (our data) was measured only in pinkish violet perovskite from the veinlet with melanite.

Magnetite occurs commonly as octahedra and less frequently dodecahedra. In the Akhmatov mine, Koksharov and other researchers have revealed a lot of various shapes of magnetite crystals (*Fig. 56*). For example, the cube form (with the growth sculpture and corresponding growth pyramid) considered by some scientists as

Fig. 56. Crystals of **magnetite** from the Akhmatov mine.



Acknowledgements

The author thanks Alexey N. Trushkin, N.Yu. Prikhod'ko, and Sergei Yu. Stepanov for assistance in selection of specimens and study of archival data, Eugene I. Churin for analyses of minerals, Valentina I. Popova for technical and editorial assistance, and Igor V. Pekov for constructive remarks.

Editorial convey our special thanks to Dr. John S. White for reviewing the manuscript and improoving English.

Editorial express our gratitude to the directors and curators of museums for their help and kind permission to illustrate this article with photos of mineral specimens from their collections: *Fersman Mineralogical Museum, Moscow* – Victor K. Garanin (Director), Elena N. Matvienko (Head of Department of Science); *Vernadsky State Geological Museum, Moscow* – Mikhail N. Kandinov (Senior Curator); *St-Petersburg State University* – Vladimir G. Krivovichev (Head of Mineralogy Department), and Galina F. Anastasenko (Curator of the Mineralogical Museum); *The Natural Science Museum at Ilmeny State Reserve, Miass* – Sergey N. Nikandrov (Head of Geology Department)

References

Belkovsky, A.I., Loktina, I.N., and Nesterov, A.R. (**1998**): Mineral mines of the Shishim-Nazyam Mountains: pre-carbonatite skarn and early (barren) carbonatites. In: Problems of petrogenesis and ore formation. IGG Ural Branch Russian Academy of Sciences, Ekaterinburg. P. 12–14 (in Russian).

Dolgov, V.S., Sereda, M.S., and Kozlov, A.V. (**2007**): Minerals of the Zlatoust Urals. PhotoMir Ltd, Zlatoust (in Russian).

Gekimyants, V.M. (**2000**): Mineralogy of titanium and zirconium in skarn, rodingite, and rodinigite-type rocks of the western Urals. Unpub. Candidate dissertation. Moscow State University, Moscow (in Russian).

Goldschmidt, V. (**1913, 1916, 1918, 1920, 1922, 1923**): Atlas der Kristallformen. Winter, Heidelberg. Bd 1, 2; Bd 3; Bd 4, 5; Bd 6; Bd 7, 8; Bd 9.

Mushketov, I.V. (**1877**): Materials for the study of geognostical structure and ores of the Zlatoust mining district in the South Urals. Imperial Academy of Science Press, St.-Petersburg (in Russian).

Myasnikov, V.S. (**1954**): Minerla minas of the Shishim and Nazyam Mountains. In: Minerals of the Urals. Vol. 1. AN SSSR, Moscow. P. 250–268 (in Russian).

Nikandrov, S.N. & Suzdal'tsev, L.A. (**1982**): Finding of zircom crystals in skarn of the Akhmatov mine in the South Urals. Mineral. J., no. 2. P. 77–78 (in Russian).

Popov, V.A. & Makagonov, E.P. (**1998**): New occurrences of carbonatites in the Urals. In: Ural mineralogical review, no. 8. Institute of Mineralogy, Ural Branch, Russian Academy of sciences, Miass. P. 240–248 (in Russian).

Popov, V.A. (**1976**): The model of hydrothermal process based on ontogenetic observation. In: Mineralogical problems of the Urals. Ural Scientific Center, AN SSSR, Sverdlovsk. P. 3–17 (in Russian).

Popov, V.A. (**2009**): The history of geological and mineralogical study of the Akhmatov mine in the South Urals. In: Ural mineralogical review, no. 16. Ural Branch, Russian Academy of sciences, Miass-Ekaterinburg. P. 25–33 (in Russian).

Popov, V.A. (**2009**): Various habits of mineral crystals in skarn and carbonatitic pegmatite from the Akhmatov mine in the South Urals. In: Ural mineralogical review, no. 16. Ural Branch, Russian Academy of sciences, Miass-Ekaterinburg. P. 34–41 (in Russian).

Rose, G. (**1839**): De novis quibusdam fossilibus, quae in montibus uraliis inveniuntur, scripsit. Ann. Phys. Berlin, Bd 48. S. 558.

Shteinberg, D.D., Varlakov, A.S. & Kravtsova, L.I. (**1965**): Estimation of the Kusa iron district. Sverdlovsk Mining Institute, Sverdlovsk (in Russian).

Spiridonov, E.M., Gekimyants, V.M. & Kulikova, I.M. (**1998**): A new metamorphic type of calcirtite. Zap. VMO, no. 6. P. 36–39 (in Russian).

Toporkov, D.D. (**1935**): Study of contact between gabbroic rocks of the Kusa dyke and limestone. Geological report. Uralgeomin, Sverdlovsk (in Russian).

Varlakov, A.S. (**1959**): Monticellite rock from the Akhmatov mine. // Zap. VMO, no. 5. P. 594–597 (in Russian).

Voitekhovsky, Yu.L. (**2002**): Russian minerals in "*Atlas der Kristallformen*" by V. Goldschmidt. Satis, St. Petersburg (in Russian).

Zlatoust encyclopedia. Vol. 1. Zlatoust rabochy, Zlatoust (**1994**) (in Russian).

Table. **Minerals of consequently formed rocks on the Akhmatov mine**

	Minerals of gabbro-amphibolite		
Albite	Labradorite	Titanite	
Andesine	Magnesiohornblende	Ti-bearing magnetite	
Apatite	Pyrite	Chalcopyrite	
Ilmenite	Pyrrhotite	Epidote	
	Minerals of diabase dyke		
Augite	Cr-bearing magnetite	Labradorite	Pyrite
	Minerals of skarn		
Andradite	Diopside	Titanite	Apatite
Clinochlore	Chondrodite	Vesuvianite	Magnetite
Spinel	Grossular	Monticellite	Epidote
	Minerals of carbonate rocks		
Antigorite	Calcite	Tremolite	Brucite
Clinochlore	Forsterite	Valleriite	Ludwigite
Phlogopite	Gibbsite	Mg-bearing magnetite	Chrysotile
Hydroxylclinohumite	Perovskite	Zircon	Dolomite
Pyrite	*REE*-bearing epidote		
	Supergene minerals		
Azurite	Calcite	Montmorillonite	Goethite
	Malachite	Opal	

Mineral Index

Numbers denote pages of this publication, where these minerals are reported.
Numbers of pages with photos of these minerals are **bolded**.