EXHIBITION OF BAUXITES AT THE FERSMAN MINERALOGICAL MUSEUM, RUSSIAN ACADEMY OF SCIENCES

Oksana L. Sveshnikova
Fersman Mineralogical Museum, Russian Academy of Sciences, Moscow, olsveshnikova@mail.ru
Anatoly D. Slukin
Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (IGEM), Russian Academy of Sciences, Moscow
Elena L. Sokolova
Fersman Mineralogical Museum, Russian Academy of Sciences, Moscow, sokolova.e_59@mail.ru

The Fersman Mineralogical Museum exhibits a genetic collection of bauxites, which is the first exhibition of the type ever on display at such museums. According to their genesis, bauxites are classified into two major types: residual and sedimentary. The former are produced by in-situ weathering of aluminosilicate rocks and compose a portion of the laterite weathering crust that is preserved where it has been generated. The exhibition displays composite profiles of laterite weathering crusts on granites, gabbro, gabbro-amphibolites, and phyllites, with the uppermost zones of the profiles made up of bauxite. Sedimentary bauxite is formed when a laterite weathering crust suffers destruction, and its clastic material is then redeposited. Depending on the environment in which this material is redeposited, sedimentary bauxite is further classified into lagoonal, lacustrine, paludal, riverine, slope, and karst types. Almost all of these are on display at the exhibition, which demonstrates the diversity of bauxite textures. Some of them provide unambiguous evidence of the bauxite type.
9 figures, 6 references.
Keywords: bauxite, laterite, weathering crust.

Bauxite is produced by a diversity of complicated processes at the Earth's surface. These processes are very closely related to weathering (physical, chemical, and biochemical) of aluminosilicate bedrocks. The destruction of the latter and their deep transformation under certain circumstances gives rise to bauxite, which is a rock consisting mostly of such hardly soluble Fe and Al compounds as Al and/or Fe hydroxides and/or oxides: gibbsite – $Al(OH)_3$, boehmite – $\gamma AlO(OH)$, diaspore – $\alpha AlO(OH)$, hematite – αFe_2O_3, maghemite – γFe_2O_3, goethite – $\alpha FeO(OH)$ and hydrogoethite – $\alpha FeO(OH) \cdot nH_2O$. Bauxite sometimes additionally contains Ti oxides (anatase and rutile), kaolinite, Fe-rich chlorites, quartz, and some other minerals. The quantitative proportions of major minerals of bauxite broadly vary, up to the development of almost monomineralic bauxite varieties: gibbsite, boehmite, and diaspore bauxite.

Because bauxite is a fine-grained rock, its minerals are usually unidentifiable and indiscernible with the naked eye. Even in bauxite domains enriched in certain Al hydroxide (these rocks contain up to 70–80% aluminum hydroxide) (Fig. 1), it is very hard to identify these minerals. Visually indiscernible Al hydroxides reveal crystalline structures and specific morphologies of mineral crystals at high magnifications under an scanning electron microscope (Fig. 2).

If the content of Al_2O_3 (alumina) in a rock is not lower than 28% and the Al_2O_3/SiO_2 ratio is higher than 2.6, the bauxite can be utilized as an Al ore, and if bauxite is dominated by Fe, it can be viewed as a Fe ore.

The exhibition of bauxites is housed in a showcase consisting of two parts. The genetic collection of bauxites is displayed in the horizontal part. The genetic types are presented in compliance with the systematics developed at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (IGEM), Russian Academy of Sciences, by a research team headed by Dr. D.G. Sapozhnikov (Sapozhnikov *et al*., 1974). The specimens are arranged corresponding to their affiliation with certain genetic types (Fig. 3). The vertical part of the showcase exhibits the most illustrative and representative bauxite specimens, and these specimens are not arranged according to their types.

In terms of their genesis, bauxites are classified into residual (lateritic) and sedimentary.

Residual (lateritic) bauxites are eluvial lateritic rocks that are formed *in situ* in bedrocks of various composition because of the accumulation of difficulty soluble products of their decomposition. Bauxites of this type are formed in a warm and humid climate. Alternating dry and rainy seasons is optimal to form bauxite. An important factor is thereby the topography of the terrain, with residual bauxite most commonly produced on plateaus raising not very high above nearby lowlands. The core meaning of the chemistry of the processes of laterite weathering is decomposition of silicates and aluminosilicates of the bedrock,

Fig. 1. Aggregates of porcelaneous gibbsite in hematite and residual bauxite (developing after basalt), central India, 14.5 x 9.5 cm. FMM # 92368. Photo: M.B. Leybov.

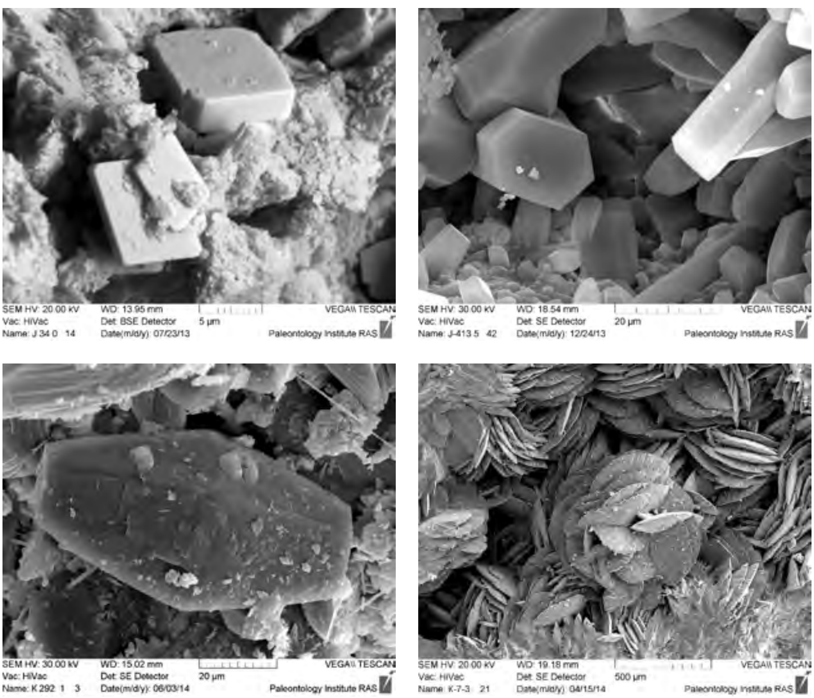


Fig. 2. SEM images of bauxite minerals: (a) Diaspore, Jammu and Kashmir, India; (b) gibbsite, Poços de Caldas, Brazil; (c, d) bohmite, Vislovskoe deposit, Kursk Magnetic Anomaly (KMA) area, Russia.

gradual leaching of silica and alkali-earth elements, and hydrolysis of aluminum and iron oxides, which enrich the rock.

Deposits of residual bauxites can be produced in stages or continuously. In the former instance, bauxite is formed by moderately fast tropical weathering that gradually destructs and decomposes the bedrock to form a zoned weathering crust (laterite profile), in which the decomposition intensity of the bedrock varies over the vertical section, and the zones of the profile differ in composition. For example, such a type of weathering of feldspar, one of the dominant rock-forming minerals, proceeds as follows: feldspar → hydromica → kaolinite → gibbsite. The general trend of the process largely controls the mineralogy of the zones and the general course of transformation of the pristine bedrock into bauxite. This trend is always discernible, but the compositions of zones and their numbers in

Fig. 3. Horizontal part of the showcase. Photo: M.B. Leybov.

Fig. 4. Various crusts of weathering.
Left: gabbro-amphibolite, Novo-Burakovskoe deposit, Kazakhstan; from bottom to top: banded gabbro-amphibolite, kaolinizated gabbro-amphibolite, banded gibbsite-goethite bauxite.
Right: phyllite schist, Vislovskoe deposit, KMA, Russia; from bottom to top: banded phyllite schist, kaolinizated banded schist, banded hematite-bohmite bauxite, chamosite bauxite. Photo: M.B. Leybov.

individual profiles replacing various rocks may somewhat differ.

The profiles can be either complete or incomplete. The exhibition presents composite profiles, which are prepared of specimens of naturally occurring rocks, that develop after basalt, granite, gabbro-amphibolite, and phyllite schist (Fig. 4). The profiles are generally similar and reflect the aforementioned sequence of transformations of the pristine bedrock into bauxite. The only exception is the somewhat different profile on phyllite schist at the Vislovskoe deposit, which is the only one whose uppermost horizons include a zone of chamosite bauxite. This deposit deserves closer consideration because it is economic. The deposit affiliates with the Voronezh bauxite-bearing province in the iron-ore basin of the Kursk Magnetic Anomaly (KMA) and is spatially constrained to an ancient weathering crust. The bauxite deposits occur in close spatial and genetic relations with high-grade iron ores, alternate with them, and/or sometimes surround their orebodies. The very fine-grained fabrics of the schists were favorable for their replacement with bauxite because made it easier to dissolve quartz and leach silica from the weathering crust before the replacement of the rocks by kaolinite. The bauxite thus absolutely free of quartz. Because of the high alumina content of the schists, the hematite-boehmite bauxite produced by their weathering is also high in alumina and has a high quality. This crust displays iron behavior that is anomalous in the classic laterite profile. Iron ions are contained in the bauxite both trivalent and bivalent modes, the latter in chamosite $(Fe^{2+},Mg,Fe^{3+})_5Al(Si_3Al)O_{10}(OH,O)_8$, siderite, and pyrite. Such iron reduction can proceed in an reducing environment, which is ensured in this situation by bogging-up of the weathered profile during its late evolution (Nikitina, 1968).

The exhibition displays one more specimen (from the Kutch Peninsula, India) (Fig. 5) for which a change in the environment (land subsidence below the sea level and subsequent uplift) and related changes in the redox conditions resulted in berthierine $(Fe_4^{2+}Fe_2^{3+})(Al_2Si_2O_{10})(OH)_8$ bauxite in submarine environments and redeposition of Fe oxides and hydroxides on land.

Capillary water ascent through the weathering crust during the dry season is associated with the ascent of elements dissolved in this water, including Fe^{2+}, which is oxidized and precipitates on the surface in the form of goethite and hematite. As a consequence, bauxite in the upper portion of the profile is enriched in iron compounds and forms compact rust-brown rocks of pisolitic texture. This rock is referred to as cuirasse (the word means armor in French). The aforementioned profiles do not contain this zone, but one specimen of cuirasse is on display.

Bauxite deposits that are formed continuously occur in incomplete weathering crusts. In these instances, the bauxite layer rests immediately on fresh unaltered bedrock. An example of such a single-zone weathered profiles is relatively thin goethite-gibbsite crusts (referred to as pain d'épice in the French geological literature) that develop on fresh rocks (nepheline syenite and dolerite in Guinea, diabase in British Guiana, diabase in Cuba, etc.). Such crusts usually occur locally and make up merely a small percentage of the material of the bauxite profile. The exhibition displays a specimen of such a crust from Cuba, where it was produced via gabbro weathering (Fig. 6). Bauxite of this type can be formed only by very fast and intense weathering, when feldspar is immediately replaced by gibbsite without any intermediate products.

Sedimentary bauxites are formed by surface water that destructs and decomposes laterite weathering crusts and then redeposits their clastic material in topographic lows, often in water bodies of various type. These bauxites can be of the littoral-lagoonal type, which usually occur as layers resting on the eroded surface of reef limestone, and continental type, which comprises a large group of genetic varieties. Depending on the environment in which the terrigenous material of continental bauxites is deposited, these are classified into diluvial (accumulated on slopes), valley, riverine, lacustrine-palidal, and karst. Relations between bauxite deposits and certain landforms are schematically portrayed in Fig. 7.

The exhibition displays practically all types of sedimentary bauxites (Fig. 3), among which karst bauxite seems to be of particular interest. Bauxite of this type is formed when karst cavities and caves are filled with clayey and bauxite material. The karst cavities can be of various shape (sinkholes, karst funnels, valleys, etc.) and not only function as natural depressions able to accumulate clastic material but may also affect the latter and sometimes control its in-situ replacement by bauxite. These facts led some researchers to view these deposits as laterite-karst and distinguish them in the group of sedimentary bauxite deposits as an individual group of karst deposits. Bauxite deposits on Jamaica are interpreted by some geologists as formed on volcanic material redeposited in karst depressions and replaced there by bauxite. Also, bauxite deposits in the Northern Ural Bauxite District are also sometimes thought (Gutkin, 1978) to have been produced by redeposition of both bauxite material and the aluminosilicate material of volcanic-sedimentary rocks in karst funnels,

Fig. 5. Residual pisolitic bauxite whose composition has been twice modified in response to variations in the sea level, Kach Peninsula, India. 14 x 10 cm. FMM #VF264. Photo: M.B. Leybov.
Fig. 6. Crust of residual bauxite on fresh gabbro. Quesigua, Cuba. 9 x 7 cm. FMM #VF266. Photo: M.B. Leybov.

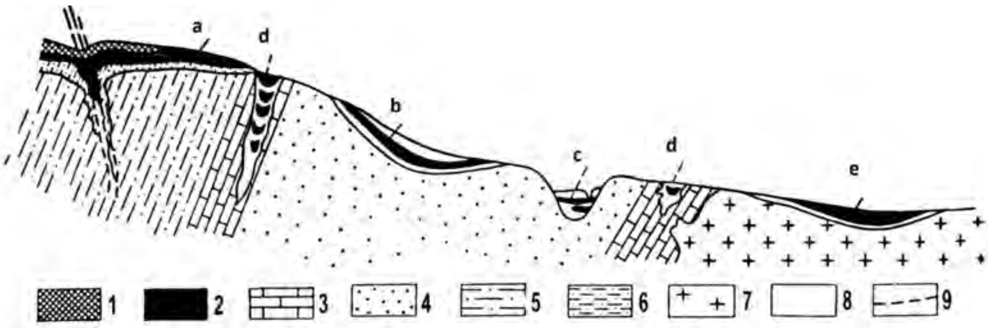


Fig. 7. Setting of bauxite deposits in relation to various landforms.
1 — duricrust; 2 — bauxites (a — residual, b — diluvial-slope, c — alluvial-fluvial and others, d — karst, e — lacustrine-paludal); 3 — limestone; 4 — sandstone; 5 — schist; 6 — weathering crust on schist; 7 — granite; 8 — (b, c, d, e) host rocks of sedimentary bauxite; 9 — faults.

with the latter type of material replaced with bauxite when in the funnels.

The principal source of alumina for sedimentary bauxites was definitely terrigenous material: residual bauxites and rocks of laterite weathering crusts. However, aluminum could also be partly transported as soluble compounds with naturally occurring organic acids, first and foremost when bauxites were formed in aquatic environments. When decomposed, these compounds precipitated aluminum in the form of hydroxides, which are then accommodated in sedimentary bauxite as its fine-grained (pelitic) constituent.

A bauxite sphere approximately 30 cm in diameter is on display on the stand near the showcase housing the exhibition (Fig. 8). This bauxite specimen was found in the Moscow area. The genesis of bauxite spatially related to a coal-bearing unit in the area is disputable, but all researchers admit that this bauxite is of chemogenic nature. According to this viewpoint, the bauxite was formed via alumina deposition from aqueous sulfate solutions, which have been generated by oxidation of pyrite, which abounds in the coal-bearing unit (Zakharova, 1974).

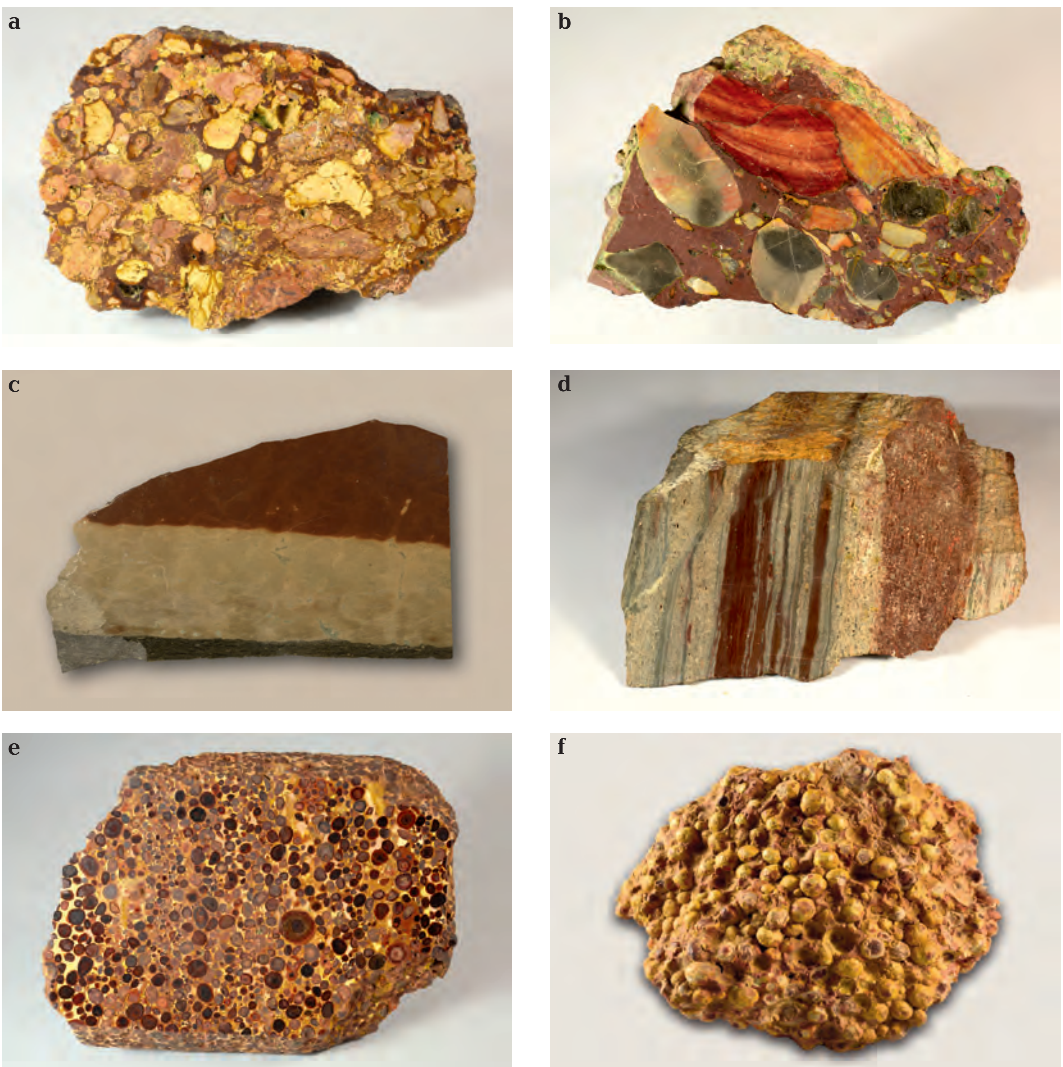
Contrary to what is usually thought, the bauxite collection displayed at the exhibition demonstrates that not all bauxites are alike. Although naturally occurring bauxites are dominated by brownish red types, more rare varieties (which are also exhibited) may be whitish, grayish green, gray, and even black. The fabrics of bauxites are also extremely diverse. Residual bauxites typically show relict textures and structures inherited from the bedrocks, for example, their banding (Fig. 4). Pisolite and pisolitic-clastic structures are typical of diluvial (Fig. 9a) and karst bauxites. The latter may be not only rudaceous up to breccia-like (Fig. 9b) but also massive fine-grained and resemble jasper (Fig. 9c). When deposited in aquatic environments, bauxite material forms laminated silty and pelitic varieties of lacustrine and lagoonal genesis (Fig. 9d). Some of them may contain floral and faunal remnants replaced by bauxite material. Such specimens are also displayed at the exhibition. Pisolitic textures are known to occur in both sedimentary (including karst) (Fig. 9e) and lateritic bauxites. The original color and fabric of bauxite, as well as its mineralogy, may be modified during various episodes of bauxite lithogenesis and metamorphism after the bauxite was buried beneath sediments.

Deposits of lateritic (sedimentary) bauxite are typical of countries with a tropical climate (Guinea, Brazil, Venezuela, and India). Bauxite deposits of this type were found in Russia in the Voronezh bauxite province and in the Central Timan. Some deposits of the Chadobetsk group in the Krasnoyarsk territory also belong to this type (Slukin, 1973). For Russia, the most important bauxite deposits are of sedimentary genesis (of various types). In the broadly known Ural province, the largest deposits are concentrated in the North Ural Group (NUG) and South Ural Group. Numerous deposits are also constrained to the northern part of the Russian Platform and are combined into the North Onega, Tikhvin, and South Timan groups (Ore deposits of the USSR, 1974). Promising bauxite deposits were also discovered in the Krasnoyarsk territory (Chadobetskoe and Tatarskoe).

Bauxites are produced by complicated supergene processes that are controlled by a large number of diverse factors, so that no exhibition is able comprehensively enough reflect the complicatedness of bauxite genesis. The exhibition at the Fersman Museum is the first in museum practice to represent a genetic collection of bauxites and display the diversity of their genetic types and their distinguishing features.

Fig. 8. Gibbsite pisolitic bauxite, Myachkovo, Moscow territory, Russia, 30 x 25 cm. FMM #88779. Photo: M.B. Leybov.

Fig. 9. Bauxite textures.
a — Clastic texture of diluvial-slope bauxite with clasts of residual bauxite. Ishkininskoe deposit, Orenburg region, Russia. 12.5 x 8 cm. FMM #VF250.
b — Brecciated texture of karst bauxite with bauxite cement of the breccia, Northern Urals bauxite region, Russia. 10 x 6.5 cm. FMM #VF271.
c — Jaspidean karst bauxite, Northern Ural bauxite region, Russia. 9.5 x 5.5 cm. FMM #VF270.
d — Laminated pelitic texture of lagoonal bauxite, Cheremukhovskoe deposit, Urals, Russia. 11.5 x 11.5 cm. FMM #VF268.
e — Pisolitic texture of sedimentary bauxite, Central deposit, Krasnoyarsk district, Russia. 15 x 10 cm. FMM #M32133.
f — Pisolitic texture of residual bauxite, Madhya Pradesh, India. 11 x 9.5 cm. FMM #VF265.
Photo: M.B. Leybov.



The exhibition was made possible thanks to help of scientists studying bauxites at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (IGEM), Russian Academy of Sciences, A.D. Slukin, V.M. Novikov, B.A. Bogatyrev, and Yu.Yu. Bugelsky, who provided bauxite specimens for the genetic part of the exhibition. The staff of the museum thanks these researchers for furnishing bauxite specimens for the exhibition and for valuable consultations and constructive criticism in the course of installing this exhibition.

References

Gutkin E.S. Geology and geochemistry of Devonian bauxites in the Northern Urals. Moscow: Nedra. **1978**. 238 p. (in Russian).

Nikitina A.P. Ancient weathering crusts on the crystalline basement of the Voronezh anteclise and its bauxite potential. Moscow: Nauka. **1968**. 160 p. (in Russian).

Ore deposits of the USSR / Ed. V.I. Smirnov. Moscow: Nedra. **1974**. Vol. 1. 328 p. (in Russian).

Sapozhnikov D.G. Genetic classification of bauxite deposits // Genetic classification and types of bauxite deposits in the USSR. Moscow: Nauka. **1974**. P. 5–20 (in Russian).

Slukin A.D. Weathering crusts and bauxites at the Chadobetskoe Uplift. Moscow: Nauka. **1973**. 126 p. (in Russian).

Zakharova L.N. Shenurovskoe deposit, Moscow Basin, of afacies type // Genetic classification and types of bauxite deposits in the USSR. Moscow: Nauka. **1974**. P. 284–286 (in Russian).