GEODIVERSITY OF KHIBINY MOUNTAINS IN KOLA PENINSULA, NORTH-EASTERN FENNOSCANDIA AS A BASIS FOR GEOPARK DEVELOPMENT

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ABSTRACT. Geodiversity of the Khibini Mountains has two main aspects: petrographic/mineralogical and geomorphological. The first aspect makes this low mountain massif situated in the central part of the Kola Peninsula, in the northwestern part of the Russian Federation, world famous for its enormous mineral diversity and the richest apatite-nepheline ore deposits in the world. As a part of the Baltic shield, it is built mainly of Lower Palaeozoic crystalline rocks and represents an intrusive alkaline massif in the contact of granulite-gneiss complexes of the Archaen Kola Series (Central Kola megablock, including the oldest rocks in Europe) and Proterozoic Imandra-Varzuga volcanogenic-sedimentary belt. More than 1000 mineral species are found in Khibiny Mountains and 115 of them are described for the first time in the world. The second aspect, the geomorphological diversity of Khibiny Mountains with high aesthetic value, reflects their complex glaciation history including various glacial formations such as cirques, glacier valleys, different types of moraines, fluvioglacial deposits, relict and contemporary cryogenic formations. For a long time Khibiny Mountains have been a very popular place among geotourists. Several popular geotrails transecting Khibiny allow to visit also old abandoned mining sites of rare-elements. There are two geological museums in the local towns of Kirovsk and Apatity with great collections representing the unique Khibiny minerals and rocks.

Keywords: Kola Peninsula, Khibini Massif, geodiversity

ГЕОРАЗНООБРАЗИЕТО НА ХИБИНСКИТЕ ПЛАНИНИ В КОЛСКИЯ ПОЛУОСТРОВ, СЕВЕРОИЗТОЧНА ФЕНОСКАНДИЯ, КАТО ОСНОВА ЗА РАЗРАБОТВАНЕ НА ГЕОПАРК

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РЕЗЮМЕ. Георазнообразието на Хибинските планини има два главни аспекта: петрографско/минераложки и геоморфоложки. Първият аспект прави този нископланински масив, разположен в централната част на Колския полуостров в северозападната част на Руската федерация, световно известен с огромното си минерално разнообразие и най-богатите апатит-нефелинови руди в света. Като част от Балтийския щит, той е изграден главно от палеозойски нискометаморфни кристалинни скали и представлява интрузивен алкален масив на контакта на гранулито-гнайсовите комплекси от архайската Колска серия (Централен Колски мегаблок, включващ най-старите скали в Европа) и протерозойския вулканогенно-седиментния пояс Имандра-Варзуга. В Хибинските планини са открити над 1000 вида минерали, 115 от които са описани тук за пръв път в света. Вторият аспект, геоморфоложото разнообразие на Хибинските планини с висока естетическа стойност, отразява сложната им ледникова история, включваща ледникови релефни форми като циркуси, различни видове морени, флувиоглациални отложения, реликтови и съвременни криогенни образувания. От доста време Хибинските планини са много популярно място сред геотуристите. Няколко популярни геопътеки, пресичащи Хибините, позволяват да се посетят стари изоставени рудници за редки елементи. В местните градове Кировск и Апатити има два геоложки музея с богати колекции, представящи уникалните хибински минерали и скали.

Ключови думи: Колски полуостров, Хибински масив, георазнообразие

Introduction

The Khibiny Mountain massif (Fig. 1) is within the Polar circle in the central part of the Kola Peninsula between Imandra and Umbozero Lakes. The morphology of the massif is low mountainous with the highest peak Yudichvumchor (1200 m) which is rounded and flat, as most of the peaks in the mountain. Their slopes are steep with numerous firn fields, cirques and small glaciers. There are many remnants of the Quaternary glacial history in the area. During glaciation, the mountain valleys are widened, deepened and smoothed to form a U-shaped glacial troughs, as it is sometimes. At the end of the glacial valleys, where the glaciers left the mountain and flowed into the polar ice shield, triangular-shaped cliffs, called truncated spurs, were formed.

From geological point of view this massif is a part of the Baltic (Fennoscandian) Shield belonging to the East European Craton, representing a large part of Fennoscandia, northwestern Russia and the northern Baltic Sea. It is composed mostly of Archean and Proterozoic gneisses,

greenstones and other high-grade metamorphic rocks including the oldest rocks of the European continent.

The Baltic Shield yields important industrial minerals and ores, such as those of iron, nickel, copper and rare metals. The development of rich apatite deposits in the Khibiny Mountains begins after the geological study of the famous Russian mineralogist A. E. Fersman during the 20–30th years of the twentieth century. Fersman is the founder and chairman of the Khibiny research mountain station of the USSR Academy of Sciences "Tietta" (1930–1938), later transformed into the Kola branch of the USSR Academy of Sciences (now Kola Scientific Centre of the Russian Academy of Sciences). Fersman's expeditions discovered the Khibiny apatite deposits, the world's largest apatite deposits.

Fig. 1. The Khibiny Mountain is a low mountainous massif in the centre of the Kola Peninsula with rounded peaks, glacier valleys and cirques

Geological setting

The Kola Peninsula is the north-eastern suburb of the Baltic shield. It is built mainly of lower Paleozoic, Proterozoic and Archean crystalline rocks, among which are the oldest rocks in Europe. Structurally it is divided into 4 parts: the Murmansk Block (along the Barents Sea), built of Archean and lower Proterozoic rocks; Belomorian Block (southwestern and southern parts of the peninsula), built of Archean Belomirian rocks; Granulite belt (northwest) and Karelitic geosyncline folded zone (in the central part) formed through the early and middle Proterozoic.

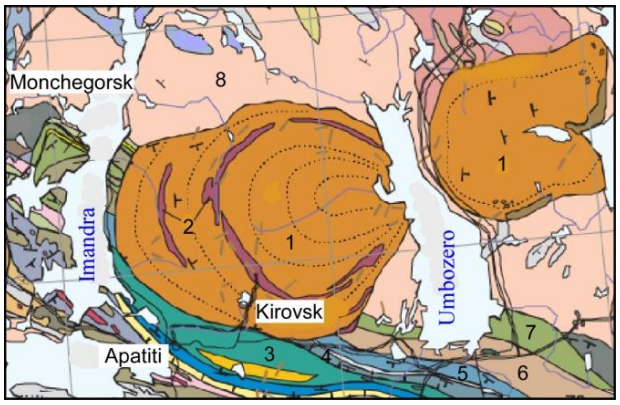

Fig. 2. Geological map of the Khibini Mountain (after Mitrofanov, 2001): *1*, nepheline syenite (Devonian); *2*, alkaline dykes, pikrit, kimberlite, carbonatite (Devonian); *3–7*, Lower Proterozoic (Kalevian-Sumian): *3*, basalt-porphyry, diabase (Kalevian); *4*, diabase, basalt-andesite-porphyry (Yatulian), *5*, pikrit-diabase porphyry (Sariolian), *6*, riolite-dacite, dacite, andesite-dacite (Sumian), *7*, basalt-porphyry, mandelsteine, diabase (Sumian); *8*, Upper Archean (Lopian) – granodiorites, tonalities, enderbites

The Khibini Mountains represent an intrusive massif composed of nepheline syenites, to which rich apatite-nepheline deposits, such as Kukisvumchor, Yukspor, Radvumchor, etc., are attached. It is an approximately 350 Ma-old multiphase intrusive with the total area of 1327 km^2 intruded in late Archean (Lopian) granodiorites, plagiogranites, harzburgites and gabbro as well as various early Proterozoic volcanic rocks – Kalevian-Yatulian basalt porphyry and diabase, Sariolian pikrit-diabase porphyry and Sumian riolite-dacite, dacite, andesite-dacite, basalt porphyry, mandelsteine and diabase (Fig. 2). This unique intrusive massif is formed of compositionally and structurally varied nepheline syenites crystallised from magmas intruded along conic faults (Voyteckhovsky, 2014). The magmatism ended with dykes of phonolites and tinguaites having intruded along faults.

Geodiversity

Geodiversity of the Khibini Mountains can be considered in two main aspects: petrographic/mineralogical and geomorphological. The first aspect is the basis of the idea for geopark development. Due to the multiphase magmatic activity during Paleozoic a huge variety of minerals have been formed that made the Khibini Mountain massif world famous mineralogical deposit, often called the Mecca of minerals. More than 1000 types of minerals are found here, 115 of which are described for the first time in the world. Another outstanding feature of the Khibiny minerals is that they occur in the form of big crystals and aggregates. Among the most frequently encountered giant forms are the crystals of eudialyte, aegirine, astrophillyte, apatite, titanite, nephelline, lamprophyllite, granate, as well rare minerals such as cancrinite, villiaumite, lomonosovite, mosandrite, fersmanite, murmanite, natrolite, narsarsukite, annite, etc. (Plate I, 1–19).

Along with the unique minerals, many unique petrographic varieties are encountered in Khibiny Mountains, such as khibinites, lujavrites, foyaites, tinguaites, urtites, etc. (Plate II, 1–16). Many of these rock varieties are of great decorative value and can be promoted as a raw material for the production of rare decorative stones. All this mineralogical treasure is stored in two professionally arranged museums: the Mineralogical museum of the Kola Science Centre of Russian Academy of Sciences in the town of Apatity (Fig. 3) and Mineralogical museum in the town of Kirovsk (Fig. 4).

Fig. 3. Mineralogical museum of the Kola Science Centre of Russian Academy of Sciences in the town of Apatity, Kola Peninsula

Fig. 4. Mineralogical Museum in the town of Kirovsk, Kola Peninsula

The second aspect, the geomorphological diversity of Khibiny Mountains with high aesthetic value, reflects their complex glaciation history including various glacial formations such as cirques, glacier valleys, different types of moraines, fluvioglacial deposits, relict and contemporary cryogenic formations. During the Quaternary glaciations the ice of several short mountain glaciers flowed into the great continental glacier (ice sheet), forming typical U-shaped glacier valleys of Belaya River, Malaya Belaya River, Golcovka, Kuniyok, Kaskasnewyok, Tuliyok, and Vuonemyok. Glacial lakes are very characteristic feature of this polar landscape. While the big lakes surrounding Khibini Massif – Imandra and Umbozero are of tectonic-glacial origin, the small lakes such as Bolshoy and Maliy Vudyavr near Kirovsk, Golcovoe, Verhniy and Nizhniy Newyavr, are of glacial origin. There are also several tarns formed in the deep cirques mainly in the western part of the mountains. The largest tarn is Ozero Academicheskoe, which is the source of Yuzhnoy Kaskasnewyok River. On the western slope of the Belaya glacier valley near Kirovsk glacially plucked bedrock of trachytoid khibinites can be observed (Fig. 5).

Fig. 5. Western slope of Belaya glacier valley SW of the town of Kirovsk is a glacially plucked bedrock of trachytoid khibinites

It was at the exit of the glacier valley where the small mountain glacier was flowing into the large sheet glacier. Tens of cirques in the feeding area of the mountain glaciers are carved during the Quaternary glaciations. Only in the vicinity of the town of Kirovsk more than 10 circuses can be counted, which give the alpine appearance of the otherwise low mountain.

One of the largest cirques Snezhniy (Fig. 6) is developed in the feeding area of Belaya glacier valley east of the famous Fersman's Rock that rises on the western slope of the valley (Fig. 7). Different kinds of moraines are developed here. Lateral and bottom moraines predominate in the glacier valleys (Fig. 8) while outside the mountain, ground moraines are developed, formed by the continental sheet glacier that covered the surrounding terrain where erratic boulders are frequently encountered in the lesotundra (Fig. 9).

Fig. 6. Snezhniy cirque in the feeding area of Belaya River Glacier

Fig. 7. Fersman's Rock in rischorites of the Polchvumchor Ridge

Fig. 8. Moraines with tundra vegetation represented by dwarf shrubs, grasses, mosses, and lichens

Fig. 9. Erratic boulders in lesotundra south of Knibini Massif

Geotourism

Most of the geological landmarks in the area are related to the activities of the Finnish geologist W. Ramsay and the Russian academician A. E. Fersman. Due to Fersman's expeditions in the 1920's and 1930's the mineral deposits in the area are systematically studied and industrially developed. A good basis for geotourism development in the Khibini Mountains are the routs described by Voytekhovsky (2014) in the form of a guidebook application to the geological map of the Khibini Mountain at a scale 1:50000, published by the Geological Survey of Finland and the Geological Institute of the Kola Science Centre of the Russian Academy of Sciences.

Within 16 routes the most famous geological and geographic sights associated with the history of geological/geographic studies of the Khibines are described. Among the most famous routes are the Fersman's Trail, along which A. E. Fersman passed for the first time in the Khibiny on August 25, 1920, the Molybdenite Mine and Geographers' Pass with mount Vudyavrchorr, Lake Maly Vudyavr with the first mountain station "Tietta", Ramsay Gorge with Malaya Belaya River valley, Western and Eastern Petrelius Passes, Aku-Aku Gorge, Eveslogchorr mount astrophyllites, and so on.

All these merits of the Khibini Mountains make this polar mountain very attractive in terms of geoconservation and geopark establishment. The recent development of its status in the context of its proclamation as a national park under the management of the Lapland Reserve, is a step in the right direction. However, the development of a Geopark is related to the activation of the local initiative and the provision of own funding. Despite the difficulties, the Khibini Mountain, representing an invaluable mineralogical treasure of global importance, deserves to take its place among the most attractive UNESCO geosparks.

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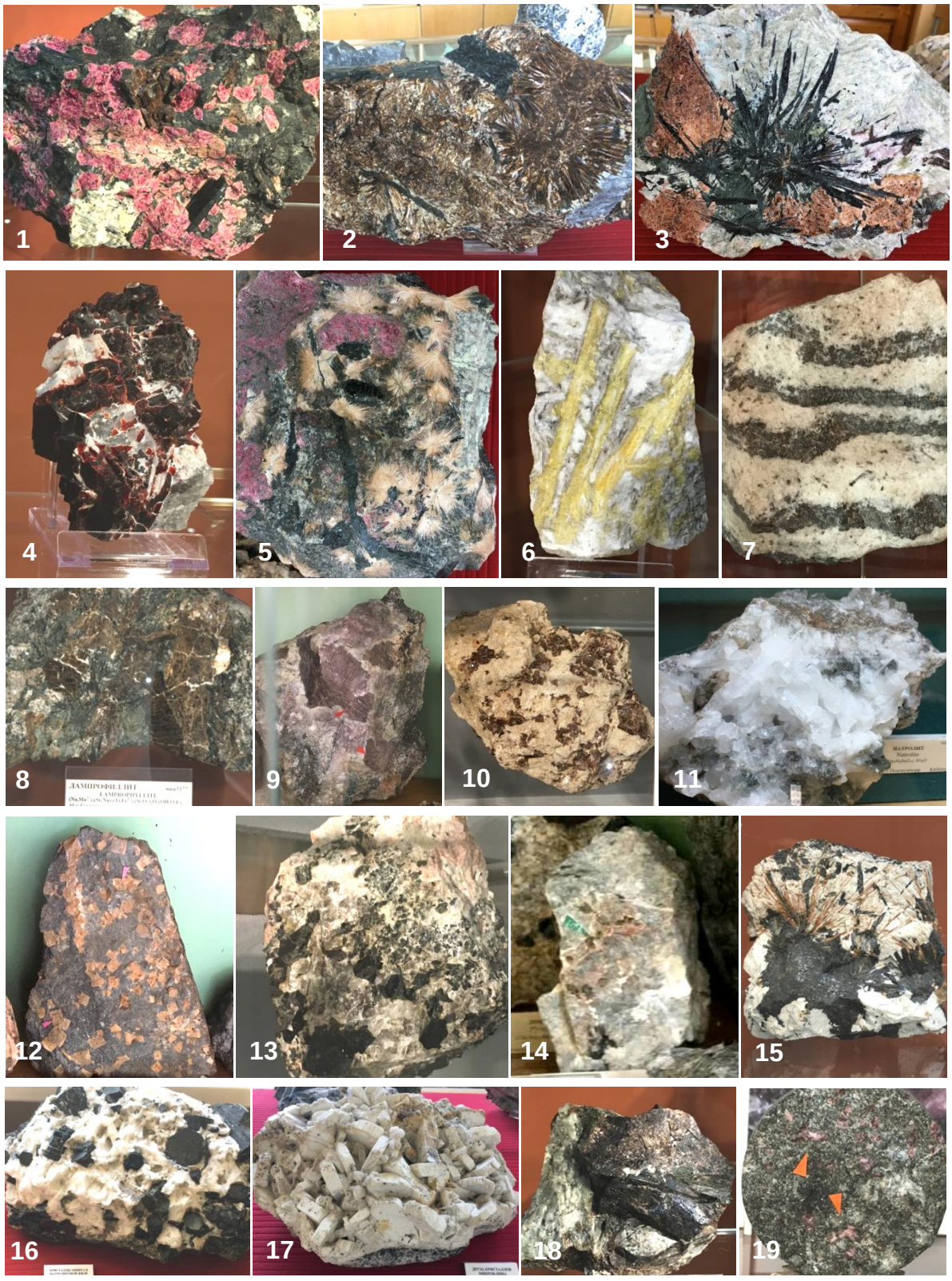

Plate I: ***1***, Eudialyte, Kukisvumchorr, Apatiti Museum; ***2***, Astrophillyte, Eveslogchorr, Apatiti Museum; ***3***, Radiate-fibrose aegirine with eudialyte, Lovozero, Apatiti Museum; ***4***, Villiaumite, Koashva, Kirovsk Museum; ***5***, Radiate-fibrose pink titanite, Kukisvumchorr, Apatiti Museum; ***6***, Cancrinite, Nyorkpakhk, Kirovsk Museum; ***7***, Widely-banded apatite-nepheline ore, Rasvumchorr, Kirovsk Museum; ***8***, Lamprophyllite, Kukisvumchorr, Kirovsk Museum; ***9***, Murmanite, Lovozero, Apatiti Museum; ***10***, Giant zircon crystals, Lovozero, Kirovsk Museum; ***11***, Natrolite, Poachvumchorr, Apatiti Museum; ***12***, Narsarsukite, Lovozero, Apatiti Museum, ***13***, Annite, Kejvy, Kirovsk Museum; ***14***, Fersmanite, Kukisvumchorr, Apatiti Museum; ***15***, Mosandrite, Kukisvumchorr, Kirovsk Museum; ***16***, Annite crystals in natrolite vein, Khibini, Apatiti Museum; ***17***, Microcline, Khibini, Apatiti Museum; ***18***, Lomonosovite, Jukspor, Kirovsk Museum; ***19***, Khibinskite, Hackman valley, Kirovsk Museum

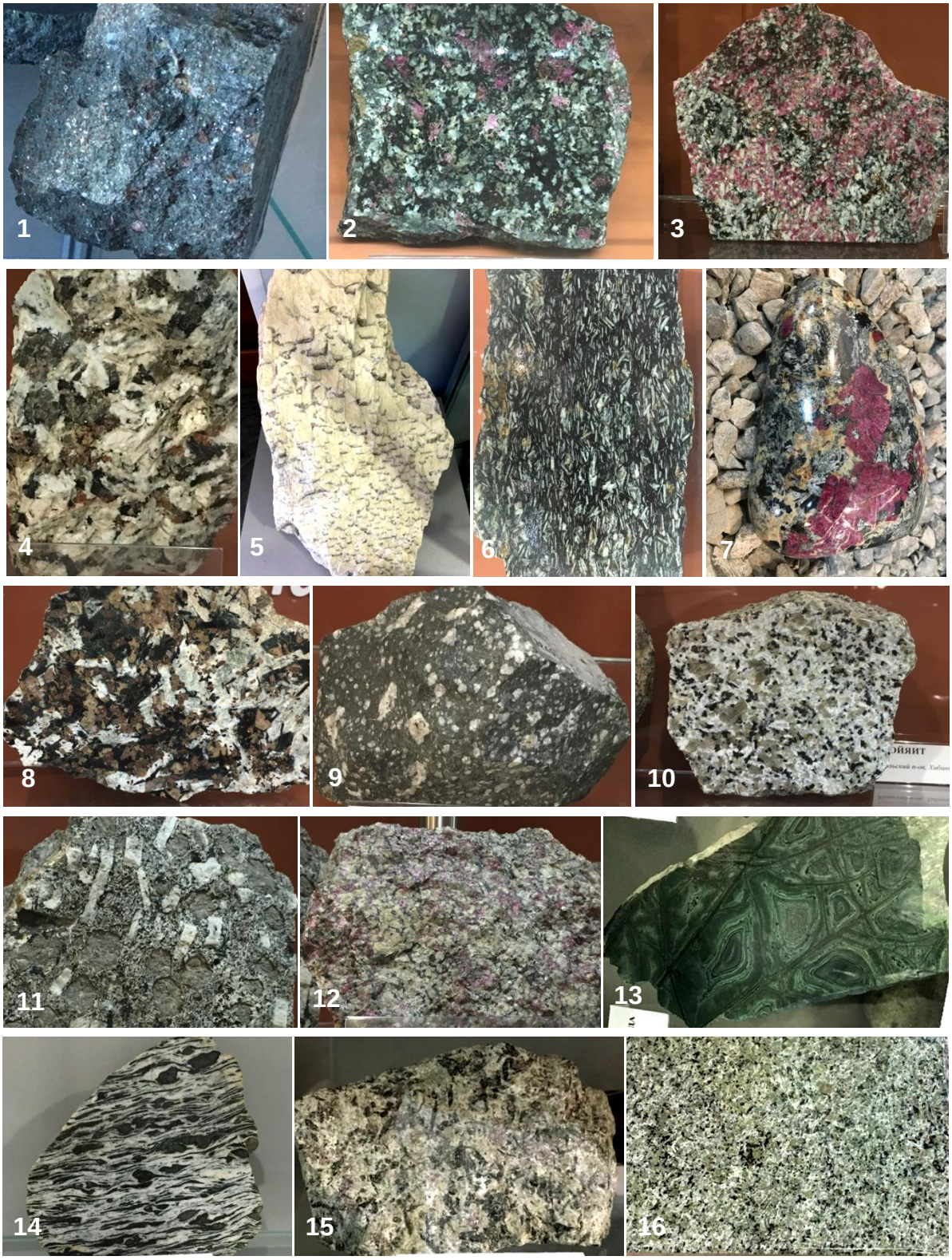

Plate II: *1*, Explosive kimberlite pype "Ermakovskaya", Apatiti Museum; *2*, Eudialite urtite, Khibini, Kirovsk Museum; *3*, Eudialyte luyavrite, Khibini, Kirovsk Museum; *4*, Foyaite, Eveslogchorr, Kirovsk Museum; *5*, Graphic pegmatite, Rikolatva, Kirovsk Museum; *6*, Luyavrite, Lovozero, Kirovsk Museum; *7*, Polished eudialyte pegmatite, Art Arctic creative centre, Apatiti; *8*, Khibinite, Khibini, Kirovsk Museum; *9*, Mandelstone, Khibini, Kirovsk Museum; *10*, Foyaite, Khibini, Kirovsk Museum; *11*, Nepheline syenite porphyry, Yudichvumchorr, Kirovsk Museum; *12*, Nepheline syenite with eudialite, Khibini, Kirovsk Museum; *13*, Dactyloscopic tinguaite, Partomchor, Apatiti museum; *14*, Milonitised gabbro, Monche tundra, Apatiti museum; *15*, Murmanite jolite-urtite, Lovozero, Kirovsk Museum; *16*, Khibinite as decorative stone, Khibini, Kirovsk Museum