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Minerals of Moscow

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Abstract—By the example of the territory of Moscow, possibilities of studying large cities as independent topomineralogical objects are shown. A cadastre of minerals, their varieties, and mineral formations, consisting of more than 100 names, has been collected for Moscow for the first time on the basis of different sources (publications, geological funds, and museums). Distribution of important discoveries of minerals on the territory of the city is demonstrated in detail and their characteristics are given.

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On the territory of Moscow, however strange it may seem at first glance, there are minerals as well, and not only in museums and industrial institutions [1]. The significance of these natural chemical compounds will become quite evident if we mention the fact that a great number of geological experts and enthusiasts, including such well-known scientists as V.I. Vernadskii and A.E. Fersman, have in one way or another passed through the school of Moscow mineralogy.

At the same time, the degree of mineralogical knowledge regarding the Moscow city area is still considered unsatisfactory [2], and no topomineralogical generalizations as such are available. Some pieces of information can be found in works on mineralogy of the Moscow Oblast [3–6], in occasional case studies in mineralogy and petrography [7–13], and in numerous publications in geology and mineral resources [14–30]. This type of materials can be also found in records of geological foundations and in collections of geological and mineralogical museums of A.E. Fersman, of V.I. Vernadskii, of P.A. Gerasimov, and of V.V. Ershov, as well as in Moscow State Geological Prospecting University.

The objective of this work is to compile the first generalizing list of minerals and mineral formations of Moscow and to raise an issue of mineralogy of large cities in general (no examples of works in this field are available as yet).

According to museum registries and individual works by various authors, the list of Moscow minerals usually consists of from 5–8 to 17–20 mineral species, varieties and mineral formations. The largest lists contain some records of foundations, which include up to 48 mineral names. Among the published works, the longest list (41 names) can be found in the first edition of “Geology of USSR,” [19], a number of other publications contain lists of approximately 30 names of minerals [11, 18, 22, 28, 29]. It is noteworthy that mineral samples from the territory of the city can be found in many private collections (author’s collection embraces more than 30 names).

In general, a historical and cadastral analysis for the last 100 years demonstrates a general increase in the list of Moscow minerals from 10–20 names at the beginning of XX to 40–48 names at the end of XX. For obvious reasons quantitative “outbursts” in the list are connected with the 800th and 850th anniversaries of the capital.

As a result of mineralogical “hunting sessions,” the total list of mineral names now includes from 78 to more than 150 names depending on the applied approach. The cadastre given below, consisting of more than a hundred names, has been complied as a result of desk calculations and sorting of local lists covering the territory of the city within the Moscow Ring Road.

The key symbols used below are as follows: (!) collection material (including museum collections); (xl) mineral is found in the form of visually distinguishable precipitates, interesting for the regional mineralogical collection; (+) first record for the Moscow region; (?) presence of minerals in Moscow needs further confirmation (questionable definitions or assumptions); ("vad") mineral varieties, minerals or mineral formations which have not been sufficiently studied.

List of Moscow Minerals and Mineral Formations

Native elements – graphite and gold.

Sulphides – "fahlore" (+), bravoite (+), galena (+), marcasite (! xl), "melnikovite" and other metastable ferric sulphides (? xl), pyrite (! xl), and sphalerite (+).

Chlorides – halite (?), sylvite (?), and carnallite (?).

Fluorides – fluorite.

Simple oxides – anatase, hematite (?), quartz (! xl) (including "aventurine," "agate," "amethyst," "rock crystal," "volcanic glass," "smoky quartz," "quartzine" (? xl), "quartzite," "chert" (! xl), "silicate," "chalcedony" (! xl), "jasper" (?), corundum, and opal (! xl), including "hyalite," pyrolusite (?), and rutile.

Complex oxides – ilmenite (including "pseudo-rutile"), "ore mineral" (?), "leucoxene," magnetite (! xl) (including "titanomagnetite"), psilomelane (! xl) (including "vad"), and spinel [including "chromites" (?)].

Hydroxides – goethite ("onegite") (! xl), hydro-hematite, hydrogoethite ("limonite") (! xl), "Fe and Mn hydroxides" (xl), lepidocrocite (xl), and manganite (! xl).

Carbonates – aragonite (! xl), dolomite (xl), calcite (! xl) (including varieties "lublinite," "stalactite," "travertine," "limestone," and "calcitite"), and siderite (! xl).

Sulphates – anhydrite (xl), barite, basanite (?), gypsum (! xl), melanterite (?), mirabilite (?), natrojarosite (?), sulphuric acid, celestine (+), epsomite (?), and jarosite (! xl).

Phosphates – apatite [including fluorcarbonapatite, carbonate-fluorapatite, and "phosphorite" (! xl)], beraunite (?), vivianite (! xl), delvauxite (+ xl), xenotime, and monazite.

Nesosilicates – andalusite; garnets: almandine (! xl); kyanite (xl), clinozoisite, staurolite (! xl), titanite, topaz; olivine group, zircon, zoisite (including "saussurite"), and epidote.

Cyclosilicates – cordierite; tourmaline group: dravite.

Inosilicates (single-chain) – pyroxenes: clino-hypersthene, aegirine, clino- and orthopyroxene.

Inosilicates (double-chain) – amphiboles: glaucophane, hornblende, cummingtonite; tremolite, and sillimanite.

Phyllosilicates – kaolinite-serpentine group: kaolinite and halloysite; micas: muscovite (including "sericite," "hydromuscovite," "micaceous ore" or "hydromicas" (? xl)), illite, biotite, and glauconite (! xl); smectites: montmorillonite (? xl) and nontronite; chlorites: ortho- and leptochlorites, (? xl), and chamosite (?); mixed-layer minerals, palygorskite (! xl), sepiolite, and allophane (? xl); "clay minerals" (! xl).

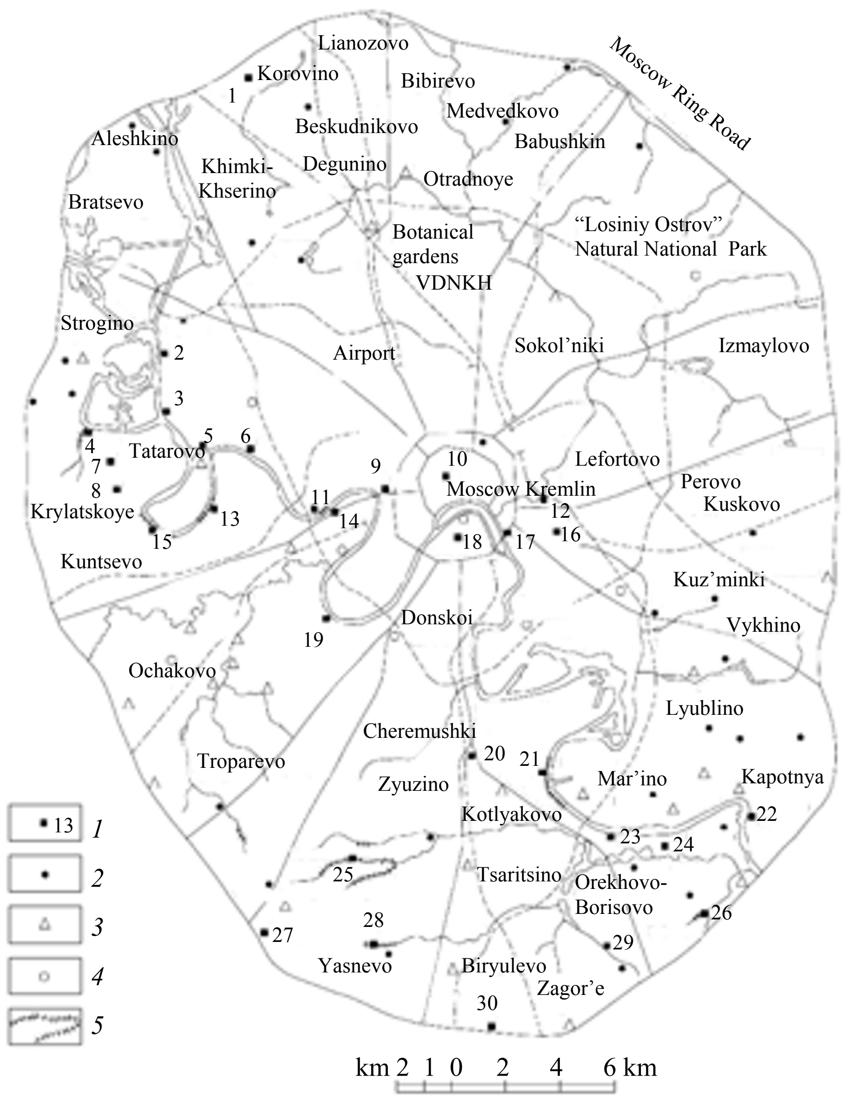
Tectosilicates – feldspars (! xl): potassium feldspars (orthoclase and microcline (! xl)), plagioclase feldspars (albite, oligoclase, "acidic" and "basic" plagioclases), and "antiperthite"; zeolites: heudroicite (?), heulandite, and clinoptilolite (?).

Organic compounds – "asphaltenes," "bitumens," "brown coal" (xl), "oil shale" (! xl), "lignite" (xl), "fossilized wood" (! xl), "organic matter" (including "kerogen"), "X-ray amorphous material," "resins" (xl), "peat" (xl), "hydrocarbons" (including "oil" and "gas"), and amber (?).

Overview of Mineral Locations in Moscow

As an annex to this list, below we provide an overview of almost all major locations of minerals in Moscow. In generalization of topomineralogical data, the following aspects have been taken into account: popularity of the area (frequency of references), collection potential (discovery of macroscopic precipitates), and the scale of mineralization (deposits, occurrences). Attention has also been paid to the locations of the mineral first record and detection in the Moscow region. The identified locations include 30 places where minerals were found in bedrocks and 4 multiple, complicated objects, characterized by special accessibility of minerals. The locations are given in alphabetical order; their numbering corresponds to the numbering on the schematic map (see figure).

Alekseevskaya Quarry (12) was located on the left bank of the lower reaches of the Yauza River, along the Andronievskaya embankment, upstream from Kostomarovskiy Bridge. Old limestone mines, used for production of building stones and lime are overlapped with Jurassic clays and sands [31]. Calcite forms distinctive sinter crusts on the walls of limestone cracks, and in individual cavities even needle-like



Map of Moscow mineral locations. (*1*) Discoveries of minerals and the corresponding numbers (in compliance with the text); (*2*) bore wells with mineralogical data; (*3*) stone piles from metro shafts with interesting mineralization; (*4*) extraction of brines from deep wells; and (*5*) accumulations of heavy mineral concentrates.

formations can be found. Discovery of phosphorites and glauconite are associated with Jurassic rocks.

Bitsevskaya well (30) was drilled in 1992 on the territory of CHPP-26, at the end of Bulatnikovskaya street [26–29]. It is the deepest well on the territory of the city (1998 m), reaching sedimentary rocks of the Vendian. Vendian dark clays and argillites are composed predominantly of kaolinite and hydromicas and are quite similar to the so-called "black shale." Quartz occurs in the form of gray sandstone interlayers and pebbles; there are also unusual light-colored interlayers of decrystallized volcanic glass, represented by irregularly-fragmented, spindle-shaped and sickle-shaped quartz grains seen in the microscope. Thorough studies of the organic matter at this location make it possible to speak of hydrocarbons.

Boenskaya well (16) was drilled before 1940 on the territory of TSFTB, at the end of Tallikhina street [19]. The well 1683 meters deep went through almost all formations of the Devonian, Vendian, and reached, for the first time in the region, the Archean-Paleoproterozoic crystalline basement. An anhydrite formation of the Middle Devonian is found at a depth of approximately 1150 m. It consists of three productive benches separated by dolomites; the total thickness of the formation reaches 15 m. Sections of sillimanite-cordierite, graphite, and feldspar mineralization, occurring within enclosing gneisses and migmatites (identified through the microscope) are confined to the crystalline basement (from a depth of 1641 m). In thin sections cordierite forms elongated isometric microcrystals and sillimanite – needle-like prismatic microcrystals. Graphite is represented by curved flakes with farinaceous edges. Feldspars (microcline, less frequently oligoclase) form pinkish-red and gray crystal grains, reaching 1–2 mm in size.

Brateevo (24), a former village between the Moskva River and the lower reaches of the Gorodnya River (starting from Borisovskiy pond); at present a city district of the same name. During the built-up process formations of the Jurrasic and the Early Cretaceous were found in groundworks and trenches. An occurrence of phosphorites, consisting of 2 layers of grayish-black argillaceous concretions (up to 10–15 cm) and brownish-black arenaceous concretions (up to 3–5 cm) was found. Sand interlayers (0.3–0.5 m) are enriched with glauconite, which gives the sand an intensive bright green color (best samples). There are also pyrite nodules, partially oxidized to jarosite and limonite. Lower Cretaceous sands are significantly enriched with thin sheets of hydromicas. In peaty dark-gray sand and clay loams of the Gorodnya River there are accumulations of rounded earthy concretions of blue vivianite, reaching 0.5 cm in size.

Shallow bore wells (below 150–200 m) also provide some materials for the city mineralogy. In different geographical locations (see figure) it has been detected that formations of the Middle Carboniferous contain gray (with shades of purple and red) and brown cherts (0.1–0.4 m), sometimes with a jasper-like laminated pattern. There are small yellowish crystals of calcite and pink quartz, as well as bluish paly-gorskite precipitates; gypsum and celestine can be seen in the microscope. Rocks of the Middle Jurrasic contain sections of conglomerate and sandstone, cemented together with pyrite; large (up to 10 cm) pyrite concretions can be found in brown lignites. The basal layer contains gravel, pebbles of milky vein quartz and reniform formations; sharp calcite rhombohedra (4 mm) are found in marlaceous phosphorites. Formations of the Late Jurrasic contain worm-like and rounded pyrite nodules (up to 8 cm). In several wells, at depths varying from 8 to 30 meters, stratified accumulations of phosphorites reaching 0.1–0.3 m in thickness (ore occurrences) are detected.

Vorobyovy Gory (19), area of a former village on the high right landslide bank of the Moskva River, from the mouth of the Setun’ River to Krymsky Bridge. Outcrops of Jurassic and Cretaceous rocks were observed [3, 21, 28, 32]. The Jurrasic association includes phosphorite (small arenacaous-type nodules along the water edge of the Moskva River), glauconite (sand interlayers of bright and gray-green), and pyrite (nodules were collected for sulphuric acid production along the river tow path); the Cretaceous association includes quartz (Vorobyovskiye white fine-grained sands used for glass production), micaceous ore (enriching Cretaceous sands), and limonite (brown ferruginous sandstones). Calcite appears on the surface in the form of significant accumulations of gray travertine.

Gnilusha (4), ravines of Bol’shaya and Malaya Gnilusha, between former villages of Troitse-Lykovo and Tatarovo, the right bank of the Moskva River opposite the “Serebryaniy Bor” Park; excavation pits of Krasnopresnenskaya main road and Stroginskaya metro line. Natural and man-caused outcrops of Mesozoic sandstones, sands, siltstones, and clays were observed. A phosphorite-containing ore occurrence consists of five productive levels of concentration of nodules and pebbles in formations of the the Early Cretaceous and the Late Jurassic. There are pseudomorphs and cements of microscopic carbonate-fluorapatite identified in the fauna and rocks, reaching 30–40 cm in size and 5–7 kg in weight: forming arenaceous, argillaceous, and marlaceous types of concretions. Phosphorites are found in close association with greenish glauconite – a component of sands and silts. Pyrite occurs in the form of tubular (25 cm in length, 3 cm in diameter) and irregularly-rounded (10–15 cm in size) fine-grained concretions, sometimes with millimeter-sized crystals on the surface. There are biogenic carbonates, represented by iridescent colorful aragonite in the mother-of-pearl coatings of ammonites and radial fibrous calcite in the brown rostra of belemnites. Micaceous ore forms sheets varying from 0.05 to 3–5 mm in size, its concentration in individual interlayers reaches 30%. Mica concentrate washed from Aptian sands has proved very effective for demonstrations: this monomineral shiny silvery aggregate consists of relatively large sheets. Psilomelane is found in the form of small (0.5 cm) gray dendrites in the subsurface layer of white quartz sandstones of Aptian formations. Limonite is quite diverse in terms of morphology. In Neocomian sands it is represented by small (below 5 cm) brown irregular-shaped nodules, prettily powdered with fine spangles of hydromica. Dark-brown secondary veinlets (1–3 cm thick) are found in cracks of Hauterivian ferruginous sandstones. There are records of large (reaching 30 cm) "fossilized" Liesegang rings: concentrically-zoned yellow-brown "cabbage-like" limonite aggregate. As a result of their partial destruction a kind of "rattle-boxes" is formed, i.e. closed spheres and ellipses (reaching 5–7 cm in length) with loose sand inside.

Gorodnya (28), the right bank of the upper reaches of the Moskva River within the boundaries of Bitsevskiy Park. There are outcrops of Lower Cretaceous sands, silts, and clays in the steep slopes along the river. From terrigenous rocks differentiated by size, it is possible to extract white powdery quartz, fine-grained dark-colored heavy minerals and hydromica flakes, lilac-gray clays, colored by manganese oxides and hydroxides, and small (3–5 cm) loose gray-yellow limonite nodules.

Dorogomilovo (14), a former village on the right bank of the Moskva River near Kutuzovskaya pier, along the embankment of Taras Shevchenko. Old quarries produced limestones for cement production, the overburden was formed with Jurrasic rocks; the location was used by students of Moscow Higher Education Institutions to perform practical studies in geology before the 1930s [3, 4, 14, 33]. Chert is found in the form of elliptical and pancake-shaped nodules reaching 0.1–0.3 m in size, the chipped surfaces of the nodules are yellow-brown with concentrically-banded patterns. It can be seen in the microscope that they are formed by fine-grained chalcedony-quartz aggregate with nonuniform inclusions of hydrogoethite or less frequently – hydrohematite (red-colored rocks) [9]. In these limestones calcite forms fibers and druses of yellowish well-faceted rhombohedral-scalenohedral crystals, reaching 2–3 cm in size. Quartz is found inside cherts in the form of fibers and druses of cloudy-white and watery-transparent short-prismatic crystals, reaching 1 cm in size. Aggregates of Fe hydroxides (goethite (onegite) and hydrogoethite) and Mn hydroxides (psilomelane and manganite) are also common for this location. Jurassic rocks, recently opened with a construction excavation pit, contain occurrences of phosphorites of arenaceous, argillaceous, and marlaceous types at several levels, with concretions reaching 0.1 m in size. The location is characterized by the presence of gray-green glauconite, biogenic calcite, and aragonite (shell material). Pyrite forms well-pronounced small (below 5–7 cm) recrystallized nodules, consisting of many crumbling shiny brass-yellow crystal grains of 1–2 mm. There are also pyrite pseudomorphs after wood, reaching up to 1 m is size and 5–7 kg in weight. During pyrite oxidation, tiny gypsum crystals and powdery melanterite, jarosite, and limonite precipitates are formed.

Zyablikovo (26), a former village in the upper reaches of the Shmelevka creek (a right tributary of the Moskva River); at present a city district near Krasnogvardeyskaya metro station. In the river slopes there are outcrops of Mesozoic formations, in which argillaceous-type phosphorites (15–30 cm in size) are known to be found. The formations also contain glauconite and pyrite, oxidized to gypsum (crystals of 5 mm), as well as limonite and jarosite in the form of powdery brown and yellow efflorescences.

Kamushki (11), the neighborhood of a former village, the left bank of the Moskva River along Shelepikhinskaya and Krasnopresnenskaya embankments. The location covers the territory of the old quarries of Mindovskiy and Khorvat (XIX–XX), Kamushki quarry which was producing cement limestones in 1933–1954, and the Moscow-City Center construction site with its extremely deep (reaching 35 m) excavation pits, penetrating Jurrasic and Upper Carboniferous formations. In these limestones chert forms a wide variety of nodules (cups, clubs, cakes etc.), ranging from 0.03 to 1.50 m in size, and stratal bodies up to 0.3 m thick. They are found at certain levels and are apparently associated with transformations of the opal skeletons of fossilized calcareous sponges. Cherts are brown, gray or reddish in color, with spotted and concentric-banded patterns. Apart from usual calcite accumulations (limestones and marlstones), calcite is found in the form of a stratal vein (0.03–0.30 m in thickness), containing white saccharoidal solid and framework aggregates. Granular calcite grows further to become columnar and radial fibrous; at the same time, in loose crystallization areas well-pronounced "hedgehogs" (up to 3 cm in diameter), consisting of small needle-like crystals, are formed. Karst caverns contain rare large (reaching 3–5 cm in size) yellowish blocks which are often split, as well as druses and fibers formed by smaller (1–2 cm) but better faceted and more transparent crystals. The facets include rhombohedra, scalenohedra, and a hexagonal prism.

Quartz is found in the form of radial fibrous "hedgehogs" and "rosettes," reaching 3–5 cm in diameter and consisting of zonal gray-white crystals with induction facets at the sides and a rhombohedra-faceted vertex (sometimes covered with pyrite). Large-size (0.2–0.3 m) nodules of grayish-white quartz are well-faceted with shiny translucent crystals (0.5–1.0 cm) and in some places are covered with orange-brown limonite. Pieces (0.5–3.0 cm) of light-purple crystal-grained quartz look beautiful on the white calcite substrate; druses and fibers of rock crystal and pale amethyst (rare) with crystals, reaching 0.5–1.0 cm in size, look very impressive inside cherts. There are also quartzine-chalcedony orange and gray-green agate "buds" (up to 0.5 cm). Apparently, quartzine produces fine-crystalline porous light white-colored patina aggregates (nodules reaching 15 cm in size) in cherts. Psilomelane forms black, gray, and brown dendrites (0.3–1.5 cm) in metacherts and some cherts (resembling moss agate) and black sooty adhesions in the limestone cracks (vad).

A lenslike stratal body of sedimentary oolitic iron ores, reaching 3.5 m in thickness is found in rocks of the Middle Jurrasic. The ores are formed by dark-brown dull-glistening ferruginous oolites (20%), quartz and chert pieces (10%), and fragments of ferruginous carbonate rocks (70%). The oolites reach about 1 mm in size and are, probably, represented by chamosite or leptochlorite, oxidized to hydrogoethite. Gray clays found at this location are close to montmorillonite in properties.

Kolomenskoye (21), a former village on the right high landslide bank of the Moskva River, between the mouth of the Zhuzha River and Moskvorechye railroad bridge; composed of Jurassic and Cretaceous terrigenous bedrocks [21, 34]. An occurrence of phosphorites is known in Tsaritsynskiy mine adit [16]; phosphorites are found in the form of conglomerate-like gray-black nodules (up to 0.1 m), black shiny pebbles (up to 0.05 m), small dark-gray arenaceous nodules, and light brownish marlaceous concretions (up to 0.3 m). Oil shale is represented by black, relatively light, fine slabby bituminous clays [19]. Pyrite nodules are characterized by micro-inclusions (below 0.2 mm) of galena, sphalerite, bravoite, and "fahlore." It is the location of the first record of Zn, Pb, Sb, As, Cu, Cd, and Ni sulphides in Jurrasic rocks of the Moscow region [8]. Clusters of small gypsum crystals (5–7 mm) in association with limonite and jarosite are formed as a result of weathering of Jurrasic rocks. High concentrations of hydromica and glauconite are associated with sands of Dyakovskaya series of the Early Cretaceous. Large pieces of Aptian grayish-white and light-gray quartz sandstones are also of interest. Hard sandstone varieties are used as pavement stones, and a dozen of large irregular-shaped blocks (reaching 2,5–3,0 m in size) cause adoration of the ignorant. In some cases at the outlets of underground waters it is possible to find orange-brown hydrogoethite sandstones (up to 0.3–0.5 m) with dark-gray veins (probably, goethite).

Korovinskaya well (1) was drilled in 1992 on the territory of CHPP-21, at the end of Korovinskoye highway [26–28]. The well, 1615 meters deep penetrates Vendian formations and the Archean-Paleoproterozoic crystalline basement (the second record in the city). Vendian argillaceous rocks are mostly composed of kaolinite and hydromica, although organic matter is also found. The crystalline basement contains granulites; rock-forming basic plagioclases, clino- and orthopyroxene are found in the form of crystal grains, reaching 1 mm in size.

Krasnokholmskiy bridge (17), on the left bank of the Moskva River and the approach to the Taganskaya Square. During the reconstruction of the bridge, delvauxite was discovered at the border of the moraine and Jurrasic sands with phosphorites, which was the first record for the Moscow Region [7]. The mineral is found in the form of brown-black dense fragile gelatinous masses, characterized by resinous luster and dehydration cracks.

Krylatskoye (Krylatskiye Hills) (8), a former village, the southern part of the Olympic cycling track, indented by deep ravines and gullies. In certain interlayers (3–5 cm thick) of outcropping Aptian sands, it is possible to select demonstration materials – white "pure" fine-grained quartz and light-gray coarse-, and medium-grained quartz, as well as materials for refining natural heavy mineral concentrates (of tourmaline-staurolite-rutile-kyanite composition) and light mineral concentrates (silvery hydromica sheets of 3–5 mm). There are yellowish-white small (5–15 cm) well-shaped quartz sandstones, and in eluvium there are dark-brown shiny limonite crusts up to 5–7 mm thick. At the bottom of dry valleys it is possible to find outwashed moraine fragments: jasper-like and banded chert, sometimes with chalcedony incrustations (0.2–5.0 mm) or quartz veins (0.5–1.0 cm).

Kuntsevo (15), the northern edge of a former village, the right bank of the Moskva River between Krylatskiy Bridge and Kuntsevo pier, and Fili-

Kuntsevskiy Park. Outcrops of Jurassic and Cretaceous rocks can be seen in gullies along the creeks. Phosphorites occur in the form of a stratum (0.5 m), consisting of dark-gray and black loose arenacaous-type concretions (up to 3–5 cm), often containing fauna remnants (biogenic aragonite and calcite), in association with glauconite sands and rare pyrite nodules (forming gypsum crystals as a result of oxidation). Limonite is found in Cretaceous orange-brown sands in the form of rounded nodules (up to 5 cm) and ferruginous conglomerate [21].

Manezhnaya Square (10), located not far from the Moscow Kremlin; during construction works of an underground trade centre, excavation pits penetrated Jurrasic and Upper Carboniferous formations [28]. This location is known for the discovery of vivianite and minor quartz precipitates (oral information by V.M. Kozlovskii). Calcite and dolomite are found at this location as components of Upper Carboniferous rocks. Stone piles (apparently from Manezhnaya Square) contain calcite fibers and grayish-white crystalline levels, forming unusual banded veins reaching 0.2 m in thickness.

Metro shafts and the corresponding stone piles have been known since the beginning of the Moscow Metro construction (in 1932), as a reliable supplier of paleontological and mineralogical materials [5, 24, 25, 35]. They are figuratively called "Moscow murzinka" to emphasize their significance for the city. [36]. Dozens of locations with accumulations of Middle and Upper Carboniferous bedrocks (Figure) are known on the territory of Moscow. Cherts greatly vary in shape (ellipses, spheres, tubes, and plates), in size (0.05–1.50 m), in color (purple, gray, brown, rarely white, red, and mottled), and in pattern (concentric, banded, spotted, and landscape). Minor (1–2 mm) precipitates of chalcedony (including gray-white agate crusts), melnikovite (sooty-black spots and films), and pyrite (octahedral fibers and radial fibrous spherulites) are usually found in association with cherts. Quartz forms rather indistinctly-faceted glass-shiny white, transparent, and pale-purple crystals (up to 1–2 cm), sometimes with pyrite and goethite inclusions. Quartz geodes inside cherts look very decorative. Fluorite is apparently represented by ratovkite, which gives a characteristic gray-purple color to some marlstones. Palygorskite is found in the form of small grayish-white filamentous formations in limestone cracks and in shell cavities. Calcite forms yellowish or grayish-white, cloudy or almost transparent shiny crystals (up to 1–2 cm), with facets of rhombohedra, scalenohedra, and a hexagonal prism. Calcite is almost entirely associated with Upper Carboniferous rocks.

Mnevniki (5), former villages of Verkhniye and Nizhniye Mnevniki on the left bank of the Moskva River, at present river piers, including Karamyshevskoye river cutoff, the corresponding bridge, dam, and sluice no. 9. There are outcrops of Jurrasic rocks, containing pseudomorphs of pyrite after ammonites (0.3–2.5 cm), fossilized wood (reaching 7–10 cm in section), and burrows (tubular forms reaching 10 cm in length and 0.5–3.0 cm in diameter); sometimes small (up to 1–3 mm) cubooctahedral fibers are found. Phosphorites form arenaceous- and argillaceous-type nodules; sometimes pseudomorphs after Jurrasic fauna representatives are found. Calcite forms small scalenhedral fibers in cavities of phosphorites [3]. There are also rock-forming glauconite and secondary gypsum.

Orekhovo (29), a former village, the right effluent of Verkhniy Tsaritsynskiy Pond (Tsaritsynskiy gully). In ravines, gullies, and long-unused sand pits of the right bank there are outcrops of rocks belonging to the Hauterivian Stage of the Early Cretaceous. Glauconite is found in pseudopebbles (up to 5–7 cm) of gray-green inequigranular glauconite-quartz sand. There also "nests" of white quartz sand, micaceous ore, and heavy minerals.

Ordynskaya (Moskovskaya) well (18) was drilled in 1930 near Bolshaya Ordynka street, on the territory of the Russian Scientific and Research Institute of Mineral Resources [19, 35, 37]. The well, 732 meters deep, was the first in Moscow to penetrate with certainty formations of the Middle and Early Carboniferous and the Late Devonian. The Middle Carboniferous layer contain macroscopic precipitates of brown and gray chert with reddish blurs, quartz in caverns, and veinlets of palygorskite with silky luster. There are two generations of palygorskite in thin rock sections; as well as calcite, dolomite, chalcedony, and fluorite (the first detection of palygorskite and fluorite on the territory of the city). Lower Carboniferous rocks contain areas of local recrystallization of limestones in the form of medium-grained calcite nests (0.5 cm); pyrite forms tiny concretions (1–5 mm) in clays. Strontium mineralization – the first record of celestine in the region – is associated with Upper Devonian formations. Enclosing dolomites have bunches and interlayers of bluish-gray anhydrite, gradually replaced with gypsum. Secondary calcites are black and brown, irregularly-crystalline and sandstone-shaped; metasomatites accompany interlayers (1–2 mm) of bituminous material, microscopic scattered pyrite (0.05–1.00 mm), modified quartz-chalcedony concretions of dark-gray chert, and individual scattered chalcedony spherulites (found also inside celestine grains). Celestine in thin rock sections is characterized with long-prismatic crystals (up to 1.5 mm). The mineral content reaches 35%.

Presnenskaya well (9) was drilled in 1940 on the territory of the Central Institute of Spa Treatment, at the beginning of Novinskiy boulevard [10. 19]. The well, 500 m deep, penetrated Lower Carboniferous and Upper Devonian formations. Lower Carboniferous clays contain kaolinite. Interesting discoveries at this location include a "pyrite plate" and Lower Carboniferous brown coal interlayers (up to 5–25 cm), for the first time detected on the territory of the city at a depth of approximately 300 m. An accumulation of gypsum, confined to Upper Devonian formations, is found at a depth of 350 m and reaches 20 m in thickness. Gypsum is found in the form of solid fine-grained, fibrous, and spherulitic formations; it fills erratic cracks and cavities in Carboniferous interbeds. Anhydrite forms relict interlayers, lenses, and nests (up to 3 cm), often with gypsum margins. Sulphate rocks are accompanied by aureoles of gray irregularly-crystalline calcitites with black interlayers of bituminous material. Metasomatites are characterized with fluorite and celestine mineralization: it is possible to detect their individual fine-shaped crystals and veinlets with the use of the microscope.

Brines, actually, a preserved pool of untapped minerals in the form of aqueous solutions found at depths exceeding 800 m in Devonian, Proterozoic, and Archean formations. There is a dozen of specially-designated deep (1050–1400 m) brine wells on the territory of city, producing brines for CHHP technological needs [28, 29] (see figure). Concentration of soluble salts varies from 50 to 287 g/l depending on the depth. Brines are used for production of halite (operation of Boenskaya well in 1942–44 [38]), carnallite, sylvite, epsomite, mirabilite (possible minerals), $CaCl_2$, and Br; brines also contain Li, Cs, Rb, Sr, and J [24, 25], and sometimes – combustible gases (H_2 and CH_4). In the core of some wells faceted cavities were discovered, which are presumably associated with secondary halite. In the city neighborhood there have been cases of gypsum crystallization in brines, impeding brine extraction from wells [39].

Saburovo (23), a former village on the right bank of the Moskva River, including the territory of a former village of Borisovskiye Vyselki. There are outcrops of Jurrasic bedrocks, including pyrite in small (up to 3–7 cm) concretions of a wide variety of shapes (tubular, elliptical, and irregular). Phosphorite is found in the form of small (up to 3–5 cm) arenaceous- and marlaceous-type nodules. Aragonite is represented by shells of contemporary freshwater bivalves, reaching 10 cm in size.

Savkin gully (20), the upper and middle reaches of the Zhuzha River, near the crossing of Varshavskoye and Kashirskoye highways; outcrops of light-gray fine-grained sands of Ikshinskaya series; a placer (titanium-zirconium) occurrence of Lipetsk-type formation. Ore-bearing coastal-marine monomineral sands, consisting of quartz with an admixture of mica, contain relatively rich interlayers of heavy mineral concentrates (heavy fraction varying from 0.5 to 5.4%), reaching 0.5 m in thickness. The mineral composition of the heavy fraction is as follows: zircon, rutile (and anatase), ilmenite, kyanite, leucoxene, staurolite, tourmaline, garnet, sillimanite, epidote, monazite, and limonite. As a result of a proper washing, it is possible to obtain a complex concentrate (kyanite-ilmenite-rutile-zircon) with admixtures of leucoxene, staurolite, tourmaline, and garnet, and signs of the other components.

Studyoniy gully (Chyornaya Gora) (6), the left high bank of the Moskva River, near the mouth of Khodynka River, between former villages of Shelepikha and Nizhniye Mnevniki. It is an old location of geological studies of Jurassic formations, which is completely built up at present. Small rounded pyrite nodules were found [15]. Museums and publications refer to discoveries of phosphorites, glauconite, and limonite in this area [3, 14, 18, 19].

Tatarovo (7), the southern part of a former village, Tatarovskiy gully, and old quarries; at present, the northern part of the Olympic cycling track. Deltaic sandstones of the Aptian age were extracted for production of building stones (in operation from 1787 to the 1930s [14, 18]). There are about half a hundred sandstone blocks, reaching 3–4 m in size, left on the surface since the production time. It is possible to select standard-size sandstone pieces of various yellow and gray shades (including white), different in strength, which are suitable for collections. The sandstones are solid, almost monomineral, quartz or fine-grained quartz-cemented; in open cracks it is possible to find sparking rock crystal fibers. In Tatarovskiy gully there is an occurrence of brown iron ore in the eluvium – a short lenslike body, reaching 0.15–0.30 m in thickness and 20–50 m in length. It is formed by collapsible ferruginous conglomerate with fragments of 0.5–20 cm. The ores are of low quality; nevertheless, even being significantly impoverished with sand aggregates, the ores contain good samples of black-brown goethite and hydrogoethite, resembling Uralian porous nodules from the oxidation zone.

Tyopliy Stan (27), surroundings of a former village, a village of Golubino, Teplostanskaya elevation, and an old quarry (currently buried) to the east of Profsoyuznaya street, near the Moscow Ring Road. The quarry was used for production of Upper Cretaceous sands and sandstones for road construction works. Quartz is found in the form of light-gray monomineral inequigranular quartzitic sandstone (including tubular pseudomorphs after siliceous sponges, reaching 3–5 cm in size) with smoky gravel grains and veinlets. Opal is found in the form of light-gray and yellowish-white aphanitic uneven basal cement (accounting for 40–45%) in quartz sandstones. These rocks are also characterized with admixtures of microscopic chalcedony and glauconite, in some places oxidized to limonite, and sooty formations of manganese hydroxides. Teplostanskaya ilmenite-rutile-zircon placer deposit is confined to the Cenomanian stage of the Late Cretaceous; the content of ore minerals in the greenish and yellowish-gray inequigranular sands amounts to 34 kg m^{-3}, the thickness of the placer reaches 1.3 m [24, 25].

Fili (13), a former village on the right bank of the Moskva River, between Kuntsevo and Fili piers, and Filevskiy Park. Phosphorite is found along the creeks and the Moskva River as debris of small arenaceous-type nodules. Pyrite (and/or marcasite) was found on the tow path along the Moskva River in the form of triradial stars [22], small “sticks” (oral information by E.M. Spiridonov), and pseudomorphs after ammonites (2–3 cm) [5, 28]. Microscopic sulphides of Pb, Zn, Sb, As, Cd, and Ni, and in case of oxidation: jarosite and gypsum, are closely associated with pyrite [8]. Aragonite is represented by shells of contemporary freshwater bivalves.

Khoroshevo (3), a former village near a bridge of the same name, the left bank of the Moskva River, along Khoroshevskoye river cutoff. There are outcrops of Jurrasic and Cretaceous rocks in the steep slopes and along the waterline. The location is known for discoveries of arenaceous- and argillaceous-type phosphorites and pyrite nodules (since 1773 [18]), glauconite, melanterite, jarosite, and limonite [3, 4]. Contemporary aragonite (mother-of-pearl) shells are found along the river.

Chagino (22), a former village on the left bank of the Moskva River; at present, the southern edge of Kapotnya district. There are outcrops of Jurrasic rocks on the banks of the Moskva River. There were three mine adits of Tsaritsynskiy phosphorite mine in this area [16]. It is known that there are three-four horizons of phosphorite accumulations of arenaceous, argillaceous, and marlaceous types, different in morphology: irregular, elongated, and almost isometric. There is an occurrence of oil shale (stratum 0.2–0.4 m thick), consisting of black bituminous claystone [19]. Pyrite forms accumulations of nodules found on the tow path, varying in shape and size (reaching 10–15 cm in size and 0.5–1.0 kg in weight). Gypsum alongside with jarosite and limonite is formed in cases of long-lasting exposures of pyrite-containing rocks, thus creating a kind of sub-surface “gypsum armor” 0.1–0.2 m thick; there are large (up to 1–2 cm) elongated crystals of the mineral. Calcite is found in the form of fine-grained travertine aggregate and needle-like formations of belemnite rostra.

Chertanovka (25), a right tributary of the Moskva River, its upper reaches on the territory of Bitsevskiy Park. There are bedrock outcrops of terrigenous formations of the Early Cretaceous in the slopes. White fine-grained quartz sands contain rare coarse-grained interlayers, consisting of rounded translucent dull-glistening grains of the mineral. In pieces of almost indigenous moraine sandstones of the Late Cretaceous it is possible to find millimeter-sized veinlets of gray quartz, white isolated opal formations in the cement, and black psilomelane efflorescences.

Heavy mineral concentrates, apparently, due to their usually small size and difficulties in their extraction from alluvial deposits are poorly studied on the territory of the city. Nevertheless, some test washings were performed in this area even at the turn of XX, detecting gold, magnetite, and garnet [3]. Signs of gold on the city territory were also found during practical washing studies (oral information by A.V. Surkov). The same can be said about individual discoveries of pebbles of colored chert, chalcedony, and agate [5]. The author’s prospecting and assessment investigation of the Moscow water network (90 washings) has shown the presence of water flows, containing high concentrations of heavy minerals. As a result a number of placer occurrences have been detected (see Figure). In terms of collecting, grains (0.5–5.0 mm) of the following minerals are of interest: garnet (rhombododecahedra), magnetite (octahedra), staurolite (prisms and twin crystals), limonite (oolites), kyanite (flat pieces), and pyrite (cubes). They can be selectively extracted from heavy mineral concentrates in the form of monomineral fractions and individual crystals.

Shchukino (2), a former village on the left bank of the Moskva River, downstream from Stroginskiy Bridge. There are outcrops of Upper Jurrasic rocks near the water edge. According to the published sources, phosphorites (ore occurrence), pyrite, glauconite, limonite, micaceous ore, and fossilized wood were discovered at this location [3, 18, 19].

Therefore, the map demonstrates where it is possible to look for minerals on the territory of the city, and what their characteristics and application opportunities are.

We would like to conclude this survey with the words of A.E. Fersman, “Get to know your country, your region, your kolkhoz, your hill or your small river! Do not be afraid that these hills and streams are small – as little streams make great rivers!”

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