Mynerageny of Jurassic deposits of the northeastern side of the Ulyanovsk-Saratov depression

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Abstract. The Jurassic terrigenous-clayey complex on the territory of the northeastern side of the Ulyanovsk-Saratov depression contains numerous groups of solid minerals. Some of them are at the stages of industrial development, some have not found application due to local distribution. Analysis of the composition and conditions of formation of solid mineral raw materials showed that the main factor influencing the formation of minerals was the marginal position of the territory in the Middle-Upper Jurassic time. The relatively high bioproductivity of the epicontinental Central Russian paleosea contributed to the accumulation of layers of calcareous marls, oil shale and phosphate raw materials. All these rocks were formed in the Mesozoic basin of sedimentation with the active participation of organic matter, the producers of which were zoo- and phytoplankton. The accumulation of coccolithophora in clayey silts led to the formation of calcareous marls, the accumulation of dying algae in bottom sediments led to the formation of oil shale. Nodular phosphorites are also biochemogenic raw materials. During periods of regressive development of the Central Russian paleosea along the coast, conditions were created for the accumulation of oolitic siderites together with leguminous goethite-hydrogethite aggregates of iron ores. Periodically, regional faults were activated on the northeastern edge of the Ulnovsko-Saratov depression. At this time, there was an upward migration of deep mineralized fluids through weakened zones. Unloading in the bottom part of the Central Russian paleosea, they contributed to the formation of fields of pyrite and barite mineralization in sedimentary rocks.

1 Introduction

The Ulyanovsk-Saratov depression is one of the first-order tectonic structures of the Volga-Ural anteclise, located within the East European Platform. It became isolated as an independent structure in the Mesozoic era, when there was an intensive tectonic restructuring of the structural plan of the territory under consideration. In the Jurassic period, the Ulyanovsk-Saratov depression was an integral part of the Central Russian paleosea, wich connecting the Arctic basin and the Tethys Ocean [1-2]. At this time,

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predominantly terrigenous sedimentation took place within the depression, and carbonate accumulation was practically absent. The main sources of clastic material in the northeastern part of the paleosea were the denudation plain of the Cis-Urals. Previously, numerous meandering rivers originating from the collapsing Ural Mountains carried fragments of rocks, minerals and clays here. In the Middle and Late Jurassic period, all the terrigenous material accumulated in the Urzhumian Age was transported by temporary water flows to the swampy coast of the shallow Central Russian paleosea. According to a number of authors [3, 4] part of the terrigenous component came from the Voronezh anteclise and the emerging Caucasus Mountains. At the end of the Jurassic period, in the shallow sea basin-strait there was a surge in the vital activity of planktonic organisms and microalgae. This time period coincides with the Late Jurassic transgressive stage of development of the sea basin [5]. Probably, the advance of the Central Russian paleosea onto land contributed to the removal of a large amount of organic matter from the swampy northeastern coast into the sedimentation basin. This served to activate the vital activity of microorganisms. In areas along the northeastern coast of the paleosea, regional faults became active, along which the blocks of the crystalline basement were subsiding. Along the vertical disjunctive zones of decompaction there was an upward migration of deep fluids enriched in ore and non-ore chemical elements. Reaching the bottom layer of the Central Russian paleosea, the fluids were unloaded, forming linear zones with mineralization uncharacteristic of marine sedimentation. As part of this work, mineral resources of solid minerals localized within sedimentary rocks of Upper Jurassic age were considered.

2 Methods

The method for identifying mineral deposits consisted of route observations from the city of Tetyushi to the city of Ulyanovsk. The main route passed along the right bank of the Volga River, where Middle-Upper Jurassic deposits are exposed. Some of the routes passed through quarries established in terrigenous rocks for the extraction of construction raw materials. The routes included a description of natural outcrops, identifying areas of localization and conditions of occurrence of solid minerals. If it was difficult to diagnose a mineral substance, samples were taken for subsequent laboratory tests. Laboratory studies included X-ray, thermal, X-ray fluorescence and optical-microscopic analyses.

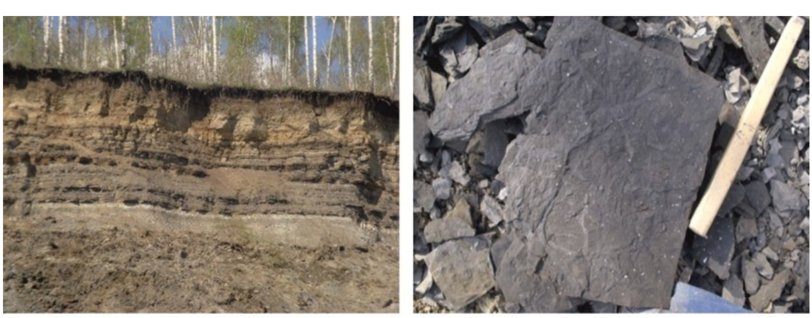
3 Research results

Analysis of geological sections of the Middle-Upper Jurassic age showed that downstream the Volga River there is a constant increase in the thickness of the terrigenous clayey strata. The first Jurassic deposits appear near the town of Tetyushi. Here, along the strike, the red-colored rocks of the Urzhum stage of the Middle Permian system gradually transform into greenish-gray rocks of Jurassic age. There is an erosional boundary between the Permian and Jurassic deposits, marking a stratigraphic unconformity. Below the Volga River, near the village of Bolshie Tarkhany, Permian deposits are completely immersed deep into the earth, and Middle and Upper Jurassic rocks, up to 20-30 m thick, are exposed in outcrops. Lower along the Volga River, near the village Undory, on the right bank only rocks of Upper Jurassic age come to the surface, the Middle Jurassic terrigenous complex plunges into the depths of the earth. Further, to the city of Ulyanovsk, the sections are represented by Upper Jurassic deposits. This nature of the occurrence of the Jurassic terrigenous-clayey complex along strike is due to the gradual transition of the coastal part of the Central Russian paleosea into a deeper basin.

The most complete sections of Jurassic age contain deposits of the following stratigraphic units, identified by V.V. Mitta [6]. At the base of the section, rocks of the Bajocian stage are exposed, lying on an eroded surface of Middle Permian age. In the lower part they are represented by quartz sandstones (up to 2.5 m), which higher up the section are replaced by greenish-gray clays with inclusions of plant detritus and small-thick interlayers of siltstones and sandstones. The thickness of the layer is 19.0-22.0 m. Above them lie sediments of the Bathonian stage with stratigraphic unconformity. They are dominated by feldspathic-quartz siltstones with goethite segregations. The thickness of the stage is 0.8-4.0 m. Higher in the section there are rocks of the Callovian stage, unconformably overlying rocks of the Bathonian stage. They are represented by greenish-gray calcareous marls up to 1.7 m thick. Then they are replaced by Upper Jurassic calcareous clays of the Oxfordian stage up to 1.8 m thick and dense clays of the Kimmeridgian stage with a thickness of 4.5 m. Near the village of Undory, the sections reveal deposits of the Tithonian stage up to 8.0 m thick, represented by a thickness of oil shale with interlayers of black clays.

The main mineral resources of the terrigenous-clayey Middle-Upper Jurassic age of the northeastern margin of the Ulyanovsk-Saratov depression, which is currently being developed on an industrial scale, are calcareous marls. They are widely used for the production of Portland cement and light-burning ceramic bricks. The average thickness of the productive strata is 20.0-25.0 m. Development is carried out by open pit mining. The clay composition is dominated by illite, kaolinite and mixed-layer illite-montmorillonite phase. In addition to clay minerals, it contains 25-35% calcareous remains of colithophores and 10-15% fragments of rocks and minerals of silt size [7]. The presence of calcareous microfossils determines the quality properties of clays as cement and ceramic raw materials. The potential resources of calcareous marls occurring in the near-surface areas, according to preliminary estimates, amount to more than 100 million m^3.

The next most important are oil shale [8]. They form extended layers in the Tithonian stage with a thickness of up to 8.0 m (Figure 1). The rocks are composed predominantly of mixed-layer clay minerals of illite-montmorillonite composition; chlorite and muscovite flakes, as well as allotigenic grains of quartz, albite and microcline up to 0.1 mm in size are present as impurities. The shales are enriched with calcareous fragments of marine animals and pyrite aggregates. The organic matter content ranges from 9 to 47%. Part of the organic component belongs to marine phytoplankton, part to processed remains of terrestrial vegetation [9]. In terms of the composition of organic matter, the rocks are sapropelic, pyrobitumen oil shale with a relatively high content of volatile components [10]. Their calorific effect is 1118-3779 kcal. The area of distribution of oil shale reaches 350 thousand km^2. Potential reserves are likely to be 500 billion tons with average TOC content. 20% [11]. Mining is carried out by open and closed methods.



Oil shale in outcrop **Oil shale in a piece**

Fig. 1. Photo of oil shale in a natural outcrop and in a piece of rock.

The third most important solid mineral resource of the Ulyanovsk-Saratov depression is phosphorites. In the Ulyanovsk region, three deposits of phosphate raw materials are currently being developed: Vasilyevskoye, Gorodishchenskoye, Undorovskoye. In all cases, phosphate raw materials are confined to the deposits of the lower part of the Tithonian stage of the Upper Jurassic. The phosphorite layer is located under the oil shale, can be traced over long distances, and is known as the "phosphate slab". The thickness of the layer varies from 1.0 to 2.0 m. The phosphate plate is represented by light grey calcareous fine-grained sandstone with a large number of black and dark brown inclusions of concretionary phosphorite nodules ranging in size from 1.0 to 4.0 cm (Figure 2). Phosphatizied organic residues are often present. The P_2O_5 content varies throughout the layer from 9.0 to 15.0% in areas reaching 30.0% [12].

In addition to industrially significant solid minerals, local manifestations of siderite, pyrite and barite mineralization were noted on the territory of the northeastern margin of the Ulyanovsk-Saratov depression. Currently, they are not of interest for development due to small reserves. However, they are nevertheless an indicator of the potential prospects of the region for searching for ferrous, barite and sulfur raw materials.

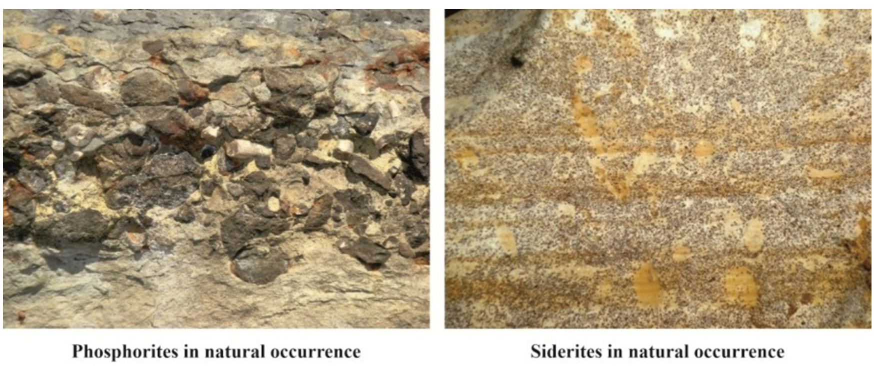


Fig. 2. Photo of phosphorites and siderites in natural occurrence.

Siderite mineralization is confined to the middle and upper parts of the Upper Bajosian section and the base of the Callovian stage. Their host rocks are marls, characterized by a greenish-gray color, predominantly pelitic structure, and thin-layered texture. The clayey component (55-60%) is represented by a mixed-layer mineral phase of illite-montmorillonite composition, chlorite and illite. The clastic part is represented by rock fragments (15-20%) and calcareous fragments of coccolithophoras (25-30%). From bottom to top along the section, a certain zonality in the location of siderite aggregates is noted, differing from each other in structural and morphological characteristics. In the lower part of the Upper Bajosian section, siderite occurs in the form of small-sized sheet stromatolites layers, and higher up – in the form of columnar stromatolites. In the Callovian section, siderite forms extended lenses up to 2.5 m thick, composed of oolites. It is the latter that are of certain geological interest. Siderite lens-shaped bodies are composed of concentrically zonal oolites about 1.0 mm in size. The oolite core is represented by iron hydroxides, giving it a dark brown color (Figure 2). Along the periphery of the cores, zones of lighter, yellowish, pelitomorphic siderite are developed. Isometric-rounded oolites predominate; elliptical oolites are present in smaller quantities. Oolitic aggregates have a dense structural packing, with edges touching. The cement is micro-fine-grained siderite with inclusions of quartz and feldspar fragments. Basal-pore type cement, filling. Among other ferruginous minerals, glauconite aggregates are found sporadically.

Pyrite mineralization was noted in the lower parts of sections of the clayey-terrigenous complex of Middle Jurassic age. It manifested itself most intensively in the sediments of the

Bajocian stage. Here, in clays and sandstones, extended ore bodies (up to 5.0 km) are noted, the main mineral in which is pyrite. Pyrite occurs in the form of nodules of various shapes ranging in size from 1.0 to 10.0 cm (Figure 3). Some of the pyrite nodules develop from organic remains, some from fragments of carbonized wood, and some are pyritized cyanobacterial colonies [13]. Within the ore field, there is a tendency for pyrite aggregates to decrease from the center, where the number of nodules is 40-60 pieces/m^2, to the periphery, where the number of nodules is 10-15 pieces/m^2. In the central parts of the pyrite field, cone-shaped formations up to 30.0 cm high are recorded in clay deposits, which in the form of outliers protrude above the abrasion terraces eroded by waves. The cone-shaped remains are composed of particles of clay minerals of the original rock, held together by numerous pyrite aggregates. The latter, obviously, give strength to structures, preserving them from erosion. In the sandstones, less pronounced paleo-seepage zones are observed in the form of small pyrite cones, around which traces of the spreading of hydrogen sulfide-containing solutions are recorded. The limited pyrite mineralization laterally and traces of seeps indicate that ore mineral matter entered the bottom layer of the Central Russian paleosea from underlying sediments through systems of vertical deep solutions.

Barite mineralization in significant quantities is noted in the deposits of calcareous marls of the Kimmeridgian stage. Barites form laterally sustained interlayers at distances of up to 0.5 km. The interlayers are composed of nodules, secretions and septaria of barite ranging in size from 5.0 to 60.0 cm (Fig. 3). Within the interlayers, as in the case of pyrite mineralization, lateral (areal) variability in the concentration and size of barite aggregates is recorded. In the conventionally central part of the barite field, the sizes of aggregates range from 30.0 to 60.0 cm with a concentration of 25-30 pieces/m2, closer to the edges - 5.0-10.0 cm with a concentration of 5-10 pieces/m^2. Barite nodules and secretions have an ellipsoidal shape, light grey color, dense build, and often have gypsum, pyrite and goethite rims on the periphery. Inside the nodules there are large organic remains captured during the growth process, which are the centre of crystallization. Some of the nodules in the central part contain previously formed dark brown phosphorite aggregates. Considering the low clarke values of barium in the host calcareous marls, one should assume the presence of an external source for the mineralization. The location of the barite field in the regional fault zone suggests that barite mineralization in the Kimmeridgian stage deposits is caused by the unloading of deep fluids enriched with migratory barium compounds in the bottom layer of the Central Russian paleosea. The presence of oxidized oil in some barite secretions, captured during the growth of aggregates, speaks in favor of a deep source of fluids.

Fig. 3. Photos of pyrite and barite nodules.

4 Discussion

As follows from the above, the northeastern side of the Ulyanovsk-Saratov depression contains a fairly diverse complex of solid minerals. Rocks necessary for the construction industry (lime marls), rocks that represent an energy and chemical resource (oil shale), as well as agrochemical raw materials for agriculture (phosphorites) are concentrated here. No less significant are the manifestations of siderite, pyrite and barite mineralization. Although currently their identified deposits are insignificant, nevertheless, these finds allow us to make optimistic forecasts for the development of the solid mineral resource base of the region. The main factors of high prospects of the northeast of the Ulyanovsk-Saratov depression for identifying a number of deposits and manifestations of the types of raw materials discussed above are the marginal position of the studied territory and the generally relatively high productivity of the Mesozoic sedimentary basin. Shallow sedimentation conditions, warming of sea waters to a temperature of about 20°C and the proximity of a swampy coastline from which nutrients were supplied together were ideal conditions for the development of zoo- and phytoplankton in the Central Russian paleosea. Due to this, over long periods of time, the joint accumulation of clayey-terrigenous and biogenic material took place in the marine paleobasin. In relatively deep areas of the coastal region, calcareous marls accumulated, in which the carbonate part was represented by the remains of coccolithophoras. In shallow areas of the seabed, where seaweed flourished, decaying remains of phytoplankton created anoxic environmental conditions in the bottom layer. This contributed to the accumulation of oil shale layers. The biochemical processes of the formation of nodular phosphorites in the sand layer were at the regressive stage of development of the marine epicontinental basin on the gently sloping coast. When a sufficient amount of migratory iron was removed from the swampy shore of the denudation plain of the Cis-Urals, siderite ores were deposited along the coast together with goethite-hydrogoethite oolites. Apparently, the formation of siderite-goethite solid minerals did not occur along the entire coastal strip, but only on relatively elevated areas of the seabed with active wave hydrodynamics. In the Middle-Upper Jurassic, tectonic processes took place on the northeastern edge of the Ulyanovsk-Saratov depression. Along vertical regional faults, individual blocks of the crystalline basement sank, while others rose. These movements were accompanied by the opening of vertical migration paths for underground fluids located lower in the sedimentary cover. It should be said that the period under consideration coincided in time with the lateral movements of oil-water solutions from the central part of the Ulyanovsk-Saratov depression along the rise of reservoir layers towards the eastern margin. It is possible that echoes of this global migration of mineralized fluids are recorded in sedimentary rocks in the form of superimposed barite and pyrite mineralization. Indeed, long-distance migration of barium ions could only occur in sodium chloride solutions. Their rise to the surface of the earth and unloading in the bottom layer of the marine paleobasin could well have formed a field of barite mineralization in the sedimentary rocks. This is supported by the local areal distribution of barite mineralization, its association with a regional fault, and the form of barite release in the form of nodules, secretions, and septaria. The formation of the pyrite ore field is apparently associated with the upward migration of deep fluids saturated with hydrogen sulfide. By creating anoxic conditions in the bottom layer of the Central Russian paleosea, fluids contributed to the development of anaerobic sulfate-reducing microbial communities in clayey silts, which, in the presence of free iron ions, formed pyrite aggregates. Thus, the features of the minerageny of the northeastern margin of the Ulyanovsk-Saratov depression are determined both by sedimentation processes that occurred on the margin of the Central Russian paleosea and by ascending inflows of deep mineralized fluids along regional fault systems.

5 Conclusion

Considering the above, the following conclusions can be drawn:

- The uniqueness of the minerageny of the northeastern margin of the Ulyanovsk-Saratov depression is determined by the combination of solid mineral deposits formed in the process of combined terrigenous and biogenic sedimentation, as well as due to superimposed processes of fluid lithogenesis.
- The spatial location of solid minerals in the sedimentary terrigenous-clayey complex of the Middle and Upper Jurassic to the eastern margin of the Central Russian paleosea is determined by several factors. Frequent progressive-regressive cycles of fluctuations in the level of sea water in the shallow sedimentation basin, which, with good heating of the reservoir, ensured the biological activity of zoo- and phytoplankton. Tectonic activation at this time of the Ulyanovsk-Saratov depression, which caused the lateral migration of water-oil and mineralized underground fluids from the center to the marginal zones and contributed to the opening of regional faults. The latter ensured the rise of deep mineralized solutions to the surface of the earth with the formation of fields of pyrite and barite mineralization.
- The northeastern margin of the Ulyanovsk-Saratov depression has high potential for increasing the range of mineral raw materials by identifying new mineral deposits associated with the unloading of deep mineralized fluids onto the earth's surface.

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