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Lithofacies Features and Formational Conditions of Paleogene Zeolite-Bearing Complexes in the Southern Russian Platform

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Abstract—Zeolites are represented by clinoptilolite (from 15–20 to 30–32%) in Paleogene rocks of the southern Russian Platform. Zeolite-bearing complexes formed under coastal-marine conditions of the platform type. Clinoptilolite, originated at the diagenetic stage from mud solutions predominantly at the expense of biogenic silica, belongs to the sedimentary genetic type.

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Zeolite-bearing rocks are found at different stratigraphic intervals in the southern and southeastern Russian Platform. Concentrations of zeolites are significant in Upper Cretaceous and Paleogene sediments of the Volgograd district (Volga region), Don–Medveditsa Ridge, Donskaya Luka area, lower reaches of the Severskii Donets River basin, and other areas. In the 1970s, the East European zeolite-bearing province with Cretaceous and Paleogene productive units was outlined in the southern Russian Platform. Subsequently, the Cretaceous–Paleogene clinoptilolite formation was recognized within this province. The siliceous–chalk domain occupies a vast area (lower course of the Volga River, periphery of the eastern Donbass, and lower course of the Don River) and extends to the west and east to the Dnepr River basin and Transural region, respectively (Shamrai et al., 1972; Kossovskaya et al., 1980). In the Cretaceous and Paleogene sediments of the southern Russian Platform, zeolite deposits of various scales were discovered in different years. Reserves and resources in these deposits were also estimated (Terentenko, 1975; Khardikov et al., 1997, 1999, 2000). The highest zeolite concentrations (up to 32%) are typical of sediments of the Upper Tatsinskaya layers of the Upper Paleocene, as well as the Buchakovo, Kiev, Kharkov, and Solonka formations of the Eocene. The zeolite-bearing rocks are valuable mineral deposits that can be used as land reclamation material, sorbents, mineral dust, as well as raw material for the production of light fillers and facing tiles.

The method of geological prospecting for zeolites in order to create their raw mineral base in the European part of Russia is mainly based on elucidation of lithofacies features of the formation of zeolite-bearing sediments.

LITHOFACIES FEATURES OF PALEOGENE ROCKS

The study region embraces the southern part of the Russian Platform (the southern limb of the Voronezh anteclise and Rostov swell) and the northern part of the Scythian Plate (eastern Donbass, Karpinskii Ridge, and Manych trough zone). Boundary between the platforms is traced along the Donetsk-Astrakhan tectonic suture. Paleogene sediments are widespread in this region. They make up a significant portion of the sedimentary cover in both platforms. The schematic stratigraphic subdivision of Paleogene rocks in the study region is shown in the table based on (*Geologiya SSSR…*, 1970; *Stratigraficheskii…*, 1992).

The Paleogene rocks were studied in natural exposures of the Don River basin and cores. In order to reflect the complex pattern of facies replacements in the rocks, we use here the term "lithofacies complex," that designates a group of rocks with characteristic features indicating certain formation conditions of these rocks. The complexes can be divided into subcomplexes. The Paleocene and Lower Eocene sediments essentially differ from the Middle–Upper Eocene ones by lithological composition, thickness, and distribution.

Paleocene and Lower Eocene Sediments

Paleocene and Lower Eocene sediments are grouped into three lithofacies complexes: coastal-marine sediments; lagoon and liman sediments, and shallow shelf sediments (Fig. 1).

Lithofacies complex of coastal-marine sediments embraces the southwestern slope of the Voronezh anteclise, northern slope of the eastern Donbass, and northwestern part of the Karpinskii Ridge. The complex is divided into three subcomplexes that differ in the struc-

Scheme of stratigraphic subdivision of Paleogene rocks

Division	Subdivision	Stage	Rostov Swell, Karpinskii Ridge, Manych trough zone	Voronezh anteclise, Eastern Donbass	
Oligocene	upper	Chattian	Nugra Formation	Poltava Group	
	lower	Rupelian	Listovataya Formation		
			Ostracod Bed		
Eocene	upper	Priabonian	Solonka Formation	Luchinka layers	
				Kharkov Formation	
			Kerestinka Formation	Kiev Formation	
	middle	Bartonian	Cherkessk Formation	Chir layers	Buchak Formation
		Lutetian		Osinovka layers	
	lower	Ypresian		Surovikino layers	
				Veshenskaya layers	
Paleocene	upper	Thanetian	Nal'chik Group	Buzinovka layers	
		Zelandian		Upper Tatsinskaya layers	
	lower	Danian	Eya Formation	Lower Tatsinskaya layers	Agglomerate member

ture of sections: (a) sands (A_1); (b) clastic breccias (A_2), and (c) sands and bioclastic limestones (A_3).

The sand subcomplex (A_1), distinguished on the southwestern limb of the Voronezh anteclise (upper reaches of the Kalitva and Glubokaya rivers), is composed of sandy rocks. In the Setraki Farm area (Kalitva River), the lower section of the Paleocene sandy subcomplex overlies the uneven surface of Upper Cretaceous limestones (from bottom to top):

(1) Medium- to fine-grained silty glauconite–quartz sand with inclusions of phosphorite nodules, phosphatized nuclei of bivalves, and coral fragments. The layer base contains chert and quartz pebbles and nodular phosphorite clasts (thickness 4.6 m).

(2) Coarse- to medium-grained gravelly poorly sorted glauconite–quartz sand (10 m).

Total thickness 14.6 m.

The Paleocene sequence is overlain by the Early Eocene fine-grained sand bed with subrounded phosphorite nodules and interlayers of siliceous sandstones with numerous imprints of Turitella and bivalves.

The clastic breccia subcomplex (A_2) is developed on the northern slope of the eastern Donbass (lower reaches of the Kalitva, Glubokaya, and Severskii Donets rivers). The lower sequence (400–500 m) includes boulder breccia (Carboniferous and Upper Cretaceous rocks fragments cemented by the clayey–calcareous matrix) known in the Russian geological literature as the “agglomerate bed” (*Geologiya SSSR*…, 1970). Upward the sequence, the size of fragments decreases, and the sequence is dominated by calcareous–clayey sands and poorly cemented sandstones with rare siliceous rock clasts. The agglomerate bed is overlain by glauconite–quartz sands (Buzinovka layers) at lower reaches of the Kalitva River and by gravel-bearing glauconite–quartz sands (Veshenskaya layers) in the Glubokaya River basin.

The subcomplex of sands and bioclastic limestones (A_3) is encountered at the Voronezh anteclise/Karpinskii Ridge junction. In borehole Tatsinskaya drilled 10 km northeast of the Settlement of Tatsinskaya, Upper Cretaceous rocks are overlain by the following sequence (from bottom to top) (Shamrai, 1964):

(1) Bioclastic fine-grained limestone with quartz–glauconite material and hard coal fragments. The base of the sequence contains phosphorite and chert pebbles and rounded nuclei of mollusks (thickness 34 m).

(2) Dark gray (almost black) argillaceous massive clay with lenses and nests of quartz–glauconite sand (6 m).

(3) Conglomerate consisting of chert pebbles (2 cm in size) and abundant inclusions of green clay (0.3 m).

(4) Fine-grained clayey carbonate-free glauconite–quartz sand with interlayers of massive siliceous sandstones (23 m).

(5) Gray (with brownish tint) laminated sandy opoka with small fragments of macrofauna (8 m).

Total thickness 71.3 m.

Lihofacies complex of lagoons and limans (B) is distinguished in the Rostov Swell. The lower sequence

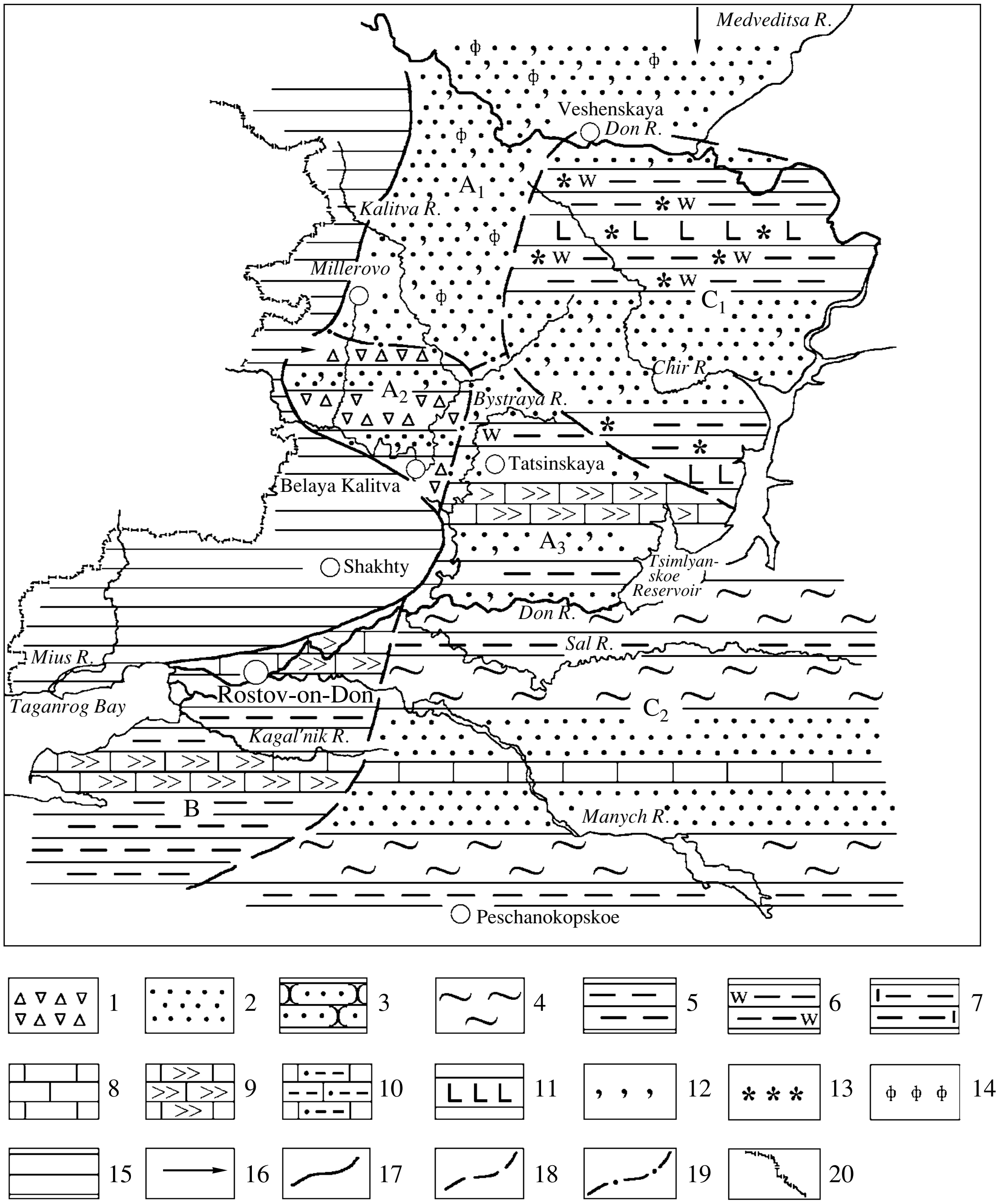

Fig. 1. Lithological-paleogeographic scheme for Paleocene–Early Eocene time. (1) Breccia; (2) sand; (3) sandstone; (4) siltstone; (5) clay; (6) siliceous clay; (7) calcareous clay; (8) limestone; (9) bioclastic limestone; (10) sandy–clayey limestone; (11) opoka; (12) glauconite; (13) zeolite; (14) nodular phosphorite; (15) area of ancient land washout; (16) direction of sedimentary material transport; (17) shoreline; (18) boundaries of lithofacies complexes; (19) boundaries of subcomplexes; (20) state boundary. Lithofacies complexes: (A) coastal-marine sediments; (B) sediments of lagoons and limans; (C) sediments of shallow shelf. Subcomplexes: (A_1) sand, (A_2) breccia, (A_3) sand and bioclastic limestones, (C_1) zeolite sands and siliceous clays with opoka interlayers, (C_2) sands and siltstones.

(Eya Formation) is composed of bioclastic limestones (up to 40 m). The middle (Upper Paleocene) sequence consists of black coaly clays, which successively grade upsection into glauconitic gravelly sands and clays with pyrite and siderite concretions. The upper (Lower Eocene) sequence is mainly composed of fine-grained quartz–glauconite sands and siltstones (200–300 m). The base of the sequence includes clays (12–30 m).

Lithofacies complex of shallow shelf sediments is subdivided into two subcomplexes: (a) zeolite sands and siliceous clays with interlayers of opoka (C_1) and (b) sands and siltstones (C_2).

The first subcomplex (C_1) is developed on the southeastern slope of the Voronezh anteclise (middle reaches of the Don River, Chir River basin, and upper course of the Berezovaya River). This subcomplex overlies the eroded surface of Upper Cretaceous clayey–carbonate rocks. Its composition is dominated by silty and clayey rocks. In the Bol'shenapolovskii Farm area (Chir River), the Lower Paleocene part of the subcomplex includes the following sequences (from bottom to top):

(1) Clayey–sandy–silty chlidolite with discontinuous interlayers of siliceous zeolite-bearing green clay (0.02–0.03 m) and poorly cemented fine-grained sandstone (0.2–0.3 m). Total thickness of the sequence 4.6 m.

(2) Sandy siltstone with horizontal bedding (4.6 m).

Total thickness of the section 9.2 m.

The overlying zeolite-bearing sequence (up to 12 m) is composed of siliceous clays with opoka interlayers (Upper Tatsinskaya layers). In the Settlement of Bazkovskaya area, they overlie the eroded surface of Upper Cretaceous rocks. Here, the clay sequence decreases to 6–8 m. It contains gritstone interlayers (0.1–1.1 m), fucoids and remnants of phosphatized fauna. The clays are replaced by quartz–glauconite sandstones (Buzinovka layers). In the upper course of the Chir River, the sequence is as follows (from bottom to top):

(1) Ash-gray glauconite–quartz sandstone with inclusions of hard siliceous sandstones and two units of nodular sandy phosphorites (10 m).

(2) Glauconite–quartz opoka-like sandstone (with siliceous cement) grading into sandy glauconitic opoka (up to 0.5 m).

Total thickness 10.5 m.

This sequence is crowned by sandy–siliceous clays (up to 15 m) with opoka interlayers (Veshenskaya layers) and fine-grained glauconite–quartz sands up to 15–20 m thick (Surovikino layers).

The subcomplex of sands and siltstones (C_2) is found in the Manych trough zone and adjacent Karpinskii Ridge. The subcomplex is composed of two units. Based on drilling data, the lower (Paleocene) unit is 360 m thick in the Manych trough zone (borehole Peschanokopskaya). The sequence is composed of calcareous sandstones with interlayers of hard sandstones and nodular phosphorites. The upper (Early Eocene) unit, 360 m thick, consists of sandstones and siltstones with interlayers of argillaceous clays. In the Karpinskii Ridge (Elista sequence), the lower unit (135–260 m) is composed of calcareous sandstones with limestone interlayers, whereas the upper unit (350 m) consists of siltstones and clays with turbid structures.

Middle–Upper Eocene Sediments

Middle–Upper Eocene sediments are grouped into two lithofacies complexes: coastal-marine sediments and shallow shelf sediments (Fig. 2).

Lithofacies complex of coastal-marine sediments (A) is developed on the southern slope of the Voronezh anteclise—upper reaches of the Kalitva River, middle reaches of the Don River, and the Chir River basin. The base of the complex is represented by gritstones (4–5 m) with an admixture of siliceous quartz pebbles and shark teeth. At upper reaches of the Kalitva and Bystraya rivers, the overlying sequence includes fine-grained cross-bedded glauconite–quartz sands (Buchak Formation) with a thickness of 25–30 m. Fragments of silicified trunks and plant leaves, as well as fucoids, are observed in the upper part of the complex. In the Setraki Farm area (upper reaches of the Kalitva River), one can see the following sequences (from bottom to top):

(1) Alternation of (a) fine-grained sand (2 m), (b) coarse-grained sandstone with gravel (0.5 m), (c) hard fine-grained sandstone with zeolite cement (0.5 m), and (d) hard coarse-grained sandstone with gravel and interlayers of very hard siliceous sandstones (0.5 m). Total thickness of the sequence 7–8 m.

(2) Coarse-grained sand with gravel admixture (2 m).

(3) Coarse-grained sand with interlayers of very hard fine-grained sandstone penetrated by fucoids (10 m).

Total thickness of the section 19–20 m.

In the eastern (Chir River) area, sands become enriched in silt and grade into siliceous siltstones in the upper part of the sequence. Their thickness increases to 30–35 m. Upper Eocene sediments are absent in the glauconite–quartz sand field.

Lithofacies complex of shallow shelf sediments is subdivided into two subcomplexes: (a) zeolite sandstones, limestones, and clays with interlayers of opoka (C_1); and (b) coccolithic zeolite limestones, siltstones, and clays with interlayers of diatomites and radiolarites (C_2).

The subcomplex of zeolite sandstones, limestones, and clays with opoka interlayers (C_1) is developed at the junction of the Voronezh anteclise, eastern Donbass, and Karpinskii Ridge, i.e., at lower courses of the Glubokaya, Kalitva, Bystraya, and Severskii Donets rivers. The subcomplex includes two sequences. The lower sequence (Buchak Formation), developed in the neighborhood of the Dolotinka Farm (upper reaches of Glubokaya River), represents an alternation (10–12 m) of (a) poorly cemented cross-bedded fine- to medium-grained glauconite–quartz sandstone with siderite concretions (up to 2 cm across) and interlayers (1–20 cm) of sand (0.5–0.7 m); (b) lenslike interlayers of hard sandstone (0.5–1.5 m); and (c) poorly cemented cross-bedded glauconite–quartz sandstone with interlayers (up to 10 cm) of opoka (0.5–1 m).

The sandstones include zeolites as microaggregates and cryptocrystalline mass (15–20%) and opal as a cement. The sandy rocks with zeolite cement occur in the neighborhood of Volgograd (Volga River) in the Middle Eocene sections (Shamrai et al., 1972).

The upper sequence is mainly composed of carbonates and clays. A layer (0.5–2 m) of sand with pebbles

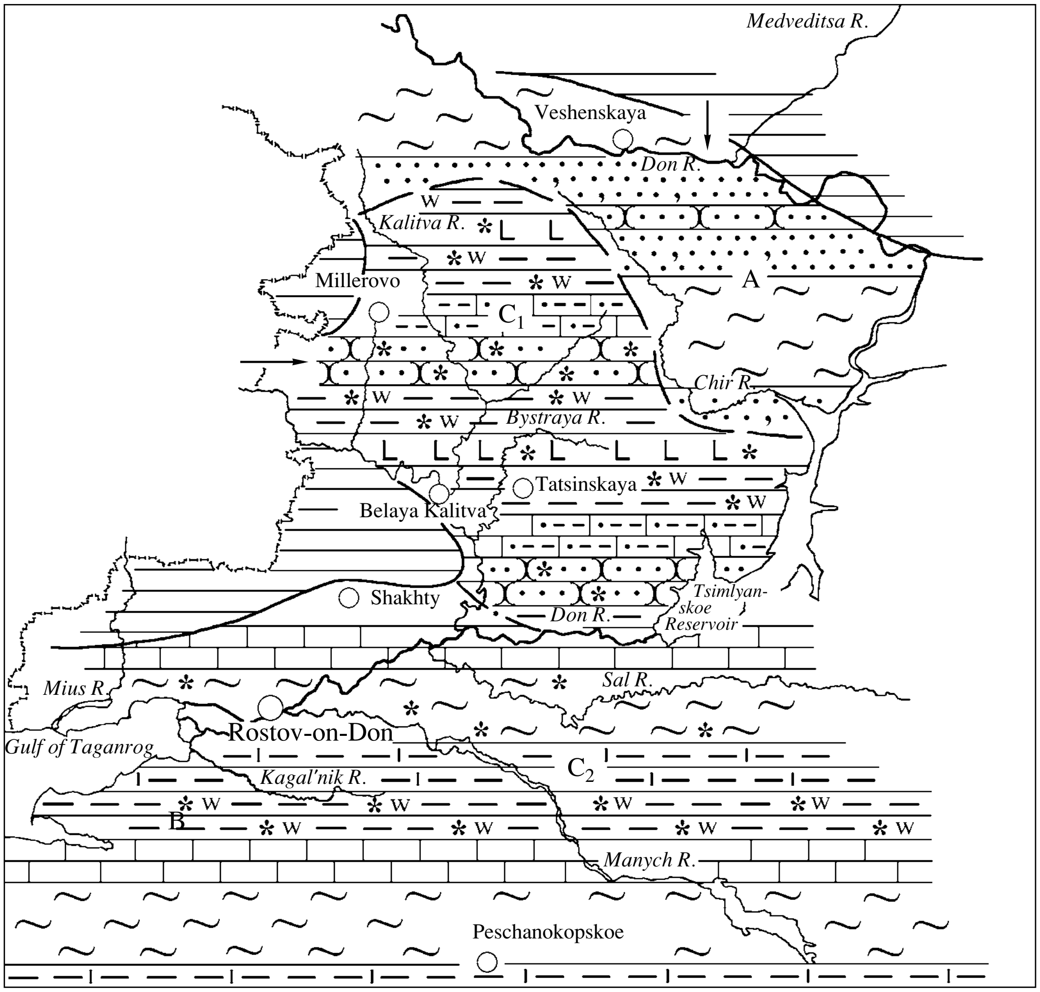

Fig. 2. Lithological–paleogeographic scheme for Middle–Late Eocene time. Lithofacies complexes: (A) coastal-marine sediments; (C) sediments of shallow shelf. Subcomplexes: (C_1) zeolite sandstones, limestones, and clays with opoka interlayers; (C_2) coccolithic zeolite limestones, siltstones, and clays with diatomite and radiolarite interlayers. See Fig. 1 for the legend.

of black cherts and nodular phosphorites lies at its base. This layer is successively overlain by sandy–clayey limestones (5–10 m) and siliceous clays with opoka interlayers (Kiev Formation). At the Settlement of Tarasovskii (Glubokaya River), the Kiev Formation (up to 10 m thick) is composed of fine-pelitic smectite–zeolite clays. Thin exposures of the Kharkov Formation are observed in some places. In the Bol'shenapolovskii Farm area, this formation is composed of sandy rocks with chert pebbles and nodular phosphorites. In the Settlement of Mal'chevskaya area, the Kharkov Formation includes zeolite-bearing clays with diatomite interlayers.

The zeolite subcomplex of coccolithic limestones, siltstones, and clays with interlayers of diatomites and radiolarites (C_2) is defined in the Rostov ledge, northwestern Manych trough zone, and Karpinskii Ridge. This subcomplex also consists of two sequences. The lower sequence is composed of zeolite- and glauconite-bearing siltstones (2–15 m). In the Rostov ledge, the siltstones include interlayers and lenses of sandstones. The upper sequence is mainly composed of carbonate–siliceous–clayey sediments with chalklike coccolithic limestones at the base (7–10 m) and carbonaceous–siliceous zeolite-bearing clays with interlayers of diatomites, radiolarites, and opoka at the top (100–150 m). In the lower course of the Don River, the upper sequence is dominated by weakly cemented carbonaceous quartz–glauconite sandstones and siltstones (70 m) with the basal unit of mud rolls. According to (Shamrai, 1952), sediments of the Kiev and Kharkov formations are exposed on the left bank of the lower Don River (from bottom to top):

(1) Green fine-grained silty glauconite-bearing sand with abundant admixture of fine zeolitic, opaline–calcareous, and clayey material.

(2) Chalklike coccolithic white (with greenish tint) limestone with a minor admixture of glauconite, clay minerals, opal, and silty detritus (8–10 m).

(3) Calcareous–siliceous zeolite-bearing light gray clays with greenish tint. In addition to clay minerals, calcareous spherulites and opal are present as slime (8 m).

(4) Alternation of (a) light (with abundant calcareous material in some places) diatomites in the form of coccolithophorids and (b) quartz–glauconite sands and siltstones with zeolites and opal (35–37 m).

These rocks are overlain by the Maikop Group.

Thus, the zeolite-bearing rocks are represented by sandstones, siltstones, clays, siliceous rocks, and zeolitites in the study region. The identification and quantitative determination of zeolites were carried out with the X-ray analysis, infrared spectroscopy, thermochemical analysis, and optical and electron microscopy (Khardikov et al., 1997, 1999, 2000; Shamrai, 1952; Shamrai et al., 1972). The results show that zeolites are represented by clinoptilolite.

The study region incorporates several petrographic types of weakly cemented sandstones and siltstones: (a) zeolite-bearing glauconite–quartz; (b) zeolite- and opal-bearing glauconite–quartz; (c) zeolite-bearing calcareous glauconite–quartz; and (d) zeolite-bearing clayey glauconite–quartz. The first two types compose thick beds of the Buchak Formation. Calcareous zeolite-bearing clastic rocks are developed in the Kiev and Kharkov formations, while the clayey sediments occur as thin interlayers throughout the whole Paleogene sequence. In addition, hard siliceous (quartzitelike) sandstones are present in this sequence. The sandstones are also found here in the form of interlayers and lenses, but they are absent in rocks of the Rostov ledge and Karpinskii Ridge.

The content of clinoptilolite in the clastic rocks is 15–20 vol %. It plays the role of cement and occurs as cryptocrystalline material and intergrowths of crystals (7–20 μm).

The zeolite-bearing clayey rocks are subordinate in the Paleocene–Lower Eocene rocks. They are predominantly confined to the Upper Tatsinskaya layers. In the Middle–Upper Eocene rocks, these rocks make up rather thick units in the Kiev and Kharkov formations. Light gray (with greenish tint) opal-bearing (sometimes calcareous) clays are most widespread. The major clay minerals are represented by monothermite and smectite. Clinoptilolite, the constant component, forms intricate lamellar and branching intergrowths and associates with opal–cristobalite framework-forming spheres that are products of the secondary redistribution and crystallization of biogenic silica. The content of clinoptilolite in clays of the Kiev Formation reaches 30–32%.

The zeolite-bearing siliceous rocks are represented by diatomites, spongolites, radiolarites, and opokas. Diatomites, spongolites, and radiolarites are most abundant in rocks of the Kharkov Formation. They have biomorphic and relict-biomorphic textures. The slime of siliceous organisms amounts to 40–50% or more. Sheeted opoka and opokalike rocks occur in the Upper Tatsinskaya layers. They also make up lenslike interlayers of cryptocrystalline and globular aggregates in the Kiev, Kharkov, and Solonka formations. In the siliceous rocks, the content of clinoptilolite is 20–24%. However, the content of clinoptilolite in diatomites, spongolites, and radiolarites is significantly higher. They are gradually replaced by zeolitites in some interlayers.

Zeolitites were first distinguished in the study region by Shamrai (1952). They make up interlayers in rocks of the Kiev and Kharkov formations. The zeolitites are macroscopically similar to diatomites and tripolis. They are found as greenish gray or white, relatively dense rocks, in which zeolites are associated with numerous opaline skeleton fragments of diatomaceous algae, sponges and radiolarians. Frequently, opal is replaced by zeolite developed as pseudomorphs after siliceous organisms. The zeolitites also contain glauconite and remnants of coccolithophorids and foraminifers. Zeolitites are only found in deep beds recovered by boreholes. In natural exposures, the content of zeolite sharply decreases due to its replacement by opal.

FORMATION CONDITIONS OF THE PALEOGENE ZEOLITE-BEARING SEDIMENTS

The relatively deep Cretaceous marine basin significantly reduced as result of the general uplift of the Russian Platform, leading to the emergence of a vast dry land within the framework of the Voronezh anteclise, eastern Donbass, and Rostov swell by the end of the Danian. By the mid-Paleocene time, almost the entire study region (except the eastern Donbass) was transformed into a shallow epicontinental marine basin owing to transgression (Fig. 1). Coastal-marine environments existed at the junction of the Voronezh anteclise, eastern Donbass, and Karpinskii Ridge. The shoreline was characterized by sinuous pattern and constant changes of its position. Here, gravelly–sandy sediments with washout units marked by nodular phosphorites accumulated during the Paleocene and Early Eocene (subcomplex A_1). On the northern slope of the eastern Donbass, the prolonged abrasion of rocky shores and strong near-shore currents produced a thick sequence of clastic breccias. Its cement contains foraminifers *Cibicides lectus* (subcomplex A_2). The structure of subcomplex A_3 indicates that the northwestern Karpinskii Ridge of the Paleocene time was characterized by an active hydrodynamic regime that gave way to a more quite shallow shelf-type environment in the Early Eocene.

The Rostov ledge area represented lowland periodically flooded by the sea. Here, lagoons with reductive environments existed in the Paleocene and Early Eocene.

On the southeastern slope of the Voronezh anteclise and the northern Scythian Plate, the shallow shelf of a wide marine basin occupied the southern Russian Platform and freely communicated with the external (larger) water areas. Its waters were of normal (oceanic) salinity. Sediments of this area contain numerous benthic forms of foraminifers *Cibicides lectus, Cibicides incognitue* and gastropods *Natica*, indicating the shallowness of the basin. The waterdepth was 50–70 m. In the Manych trough zone and Karpinskii Ridge, the Paleocene–Early Eocene period was marked by intense roiling of coastal-marine sediments due to the high hydrodynamic activity and irregular relief of this area of the basin (subcomplex C_1). Siliceous–clayey sediments with a minor quantity of terrigenous material were deposited on the southeastern slope of the Voronezh anteclise (subcomplex C_2).

The transgression started in the Paleocene and continued to expand in the Eocene. At that time, the southern Russian Platform and the entire Scythian Plate were covered by a single marine basin that extended far beyond the region (Fig. 2). The open Middle–Late Eocene basin had free communication with vast marine areas of West Europe. The Eocene fauna type testifies to this conclusion. Bivalve mollusks include forms, such as *Cyprina* and *Arca*. They have many common features with representatives of fossil fauna of West Europe. The presence of representatives of genus *Pecten* also suggests the open oceanic nature of the basin. The Eocene sea had warm waters of normal salinity. The existence of warm waters is indicated by remnants of thermophilic forms of bivalve mollusks, such as *Lucina, Cyprina*, and *Natica*. The normal oceanic salinity is confirmed by the presence of pelecypods of genera *Cardita* and *Nucula*, articulate brachiopods, and radiolarians in Eocene rocks.

Coastal-marine conditions existed in the southern Voronezh anteclise. Rocks of this area have clear cross-bedding, because they formed under the influence of strong marine currents. Their formation was governed by the northern or northwestern delta of a large river that transported large stems and remnants of higher vegetation to the littoral zone.

Sedimentation conditions in the southern area corresponded to a shallow shelf, which also extended to the modern Volga River region. The basin was up to 50–70 m deep. This is indicated by findings of gastropods of genera *Turitella* and *Natica*, Mediterranean genera *Natica* and *Pteurotoma*, and remnants of spongy spicules and diatom shells. The transgressive pattern of subcomplexes C_1 and C_2 suggests the gradual deepening of basin in the Eocene. At the junction of the eastern Donbass and Voronezh anteclise, the coastal-marine conditions existing in the Middle Eocene gave way to a deeper-water environment. This is reflected in the decrease of clastic material content in the sediments. In the Rostov ledge, Karpinskii Ridge, and Manych trough zone, sediments accumulated in an open sea (distal zone). This is indicated by the presence of interlayers of coccolithic limestones and diatomites in subcomplex C_2.

In the Middle–Later Eocene time, the eastern Donbass retained a provenance that delivered terrigenous material to the southern and southwestern shallow shelf.

At the end of the Late Eocene time, the Voronezh anteclise and eastern Donbass experienced uplift and the marine basin became shallower, resulting in terrigenous sedimentation instead of the accumulation of carbonate–siliceous–clayey sediments and termination of the process of zeolite formation.

Paleogene zeolite-bearing complexes of the southern Russian Platform are sedimentary accumulations, because the initial material for zeolite formation is represented by skeleton remnants of siliceous organisms, amorphous silica, and aluminosilicate gels delivered by river discharge (*Fanerozoiskie* ..., 2000). According to (Shamrai, 1964; Shamrai et al., 1972), the western or northwestern area of the eastern Donbass incorporated the estuary of a large river that transported terrigenous products from the Russian Platform. In addition, erosion of Lower Cretaceous sandy–silty sediments of the Don–Medveditsa Uplift and Donskaya Luka area played a significant part in the zeolite formation. Cations were derived from marine waters. Zeolites formed in pore spaces due to the concentration of free silica, alumina, and alkalis. Mud solutions contained excess silica (as indicated by the presence of opal) and alumina and alkalis (as indicated by the findings of glauconite in the zeolite-bearing rocks). Geochemical conditions of zeolite formation were characterized by Eh ~ 0 and pH ~ 8. Only clinoptilolite could be formed if volcanic glass was absent in the sediment.

CONCLUSIONS

The Paleogene zeolite-bearing complexes are shallow-marine, predominantly shelf accumulations. They formed in an epicontinental basin during the transgression in the southern part of the Russian Platform. Sediments accumulated under stable tectonic conditions characterized by low-amplitude epeirogenic movements. The presence of weathering crusts of aluminosilicate rocks and the abundance of siliceous organisms in the sedimentation basin favored the accumulation of material needed for zeolite synthesis. The decrease of zeolite content in the coastal-marine sediments is related to terrigenous sedimentation and active hydrodynamic regime.

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