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Middle Jurassic Stratigraphy in the Southwestern Part of the Republic of Tatarstan

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Abstract—Data on the structure of the Middle Jurassic marine deposits in the vicinity of Ulyanovsk (sections of the Tarkhanovskaya Pristan–Dolinovka profile) are generalized with due regard for ammonites, bivalves, and microfossils occurring in sediments. Outcrops of the Tarkhanovskaya Pristan site represent the northernmost Bajocian section of the Russian Platform, where ammonites of Tethyan origin are identified. As is established, the pre-Callovian sand-clay sequence formerly attributed to the Bathonian includes the Garantiana beds of the upper Bajocian in its middle part. The multidisciplinary biostratigraphic-sedimentological research showed that downwarping of the Ulyanovsk–Saratov basin and origin of the Simbirsk Bay of the Tethyan marginal sea commenced in the Bajocian Age. The identified fossils of the upper Bajocian and lower and upper Callovian are cited in paleontological plates of this work.

Keywords: Ulyanovsk area of the Volga region, ammonites, bivalves, foraminifers, ostracodes, Bajocian, Callovian, stratigraphy, sedimentology

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INTRODUCTION

The investigative history of Mesozoic deposits exposed along the right bank of the Volga River upstream of Ulyanovsk (Simbirsk) is long. The Upper Jurassic and Lower Cretaceous sediments exposed 25 km upstream of Ulyanovsk in Ulyanovsk oblast (lectostratotype of the Volgian Stage) were of primary interest to researchers. The Middle Jurassic rocks are exposed further upstream at the same riverbank, flanking at present the Kuybyshev Reservoir (Republic of Tatarstan). Their outcrops extending from the Tarkhanovskaya Pristan site to the abandoned settlement of Dolinovka (Fig. 1) and being a continuation of the above set of outcrops have been studied to a lesser extent, although the respective area appears to be unique in the Middle Volga region. Natural outcrops of this area exhibit the succession of Middle Jurassic marine sediments overlying the erosion surface of the Permian variegated clays and limestones and yielding diverse fossils of the upper Bajocian and lower–upper Callovian.

Original paleontological remains listed and depicted in this work are stored in two depositories: ammonites and bivalves at the Borisyak Paleontological Institute (PIN); foraminifers and ostracodes at the Trofimuk Institute of Petroleum Geology and Geophysics (IPGG).

INVESTIGATIVE HISTORY

First data on Jurassic deposits that rest on the "variegated marl stage" (the Permian in current understanding) near the village of Tetyushi, on the right bank of the Volga River, appeared in publications by Golovkinskii (1869), Laguzen (1874), Sintsov (1872), and Shtukenberg (1882). These researchers described deposits southward of the village of Dolinovka in very general terms, however. Actually, we should honor A.P. Pavlov for the discovery and first comprehensive description of Middle Jurassic deposits in the Ulyanovsk area of the Volga region (Pavlov, 1883, 1884). Later, Rosanov (1919), who also studied outcrops near that village, confirmed the observations of Pavlov. The subsequent work by Zonov (1939) described outcrops of the Middle Jurassic rocks exposed along the Kilna River and its tributaries.

After a long break in investigations, the upper Callovian marls containing ferruginous ooliths and ammonites *Quenstedtoceras, Euaspidoceras, Kosmoceras*, and others were described for the first time at the Tarkhanovskaya Pristan site (Mitta, 2001, 2003). In

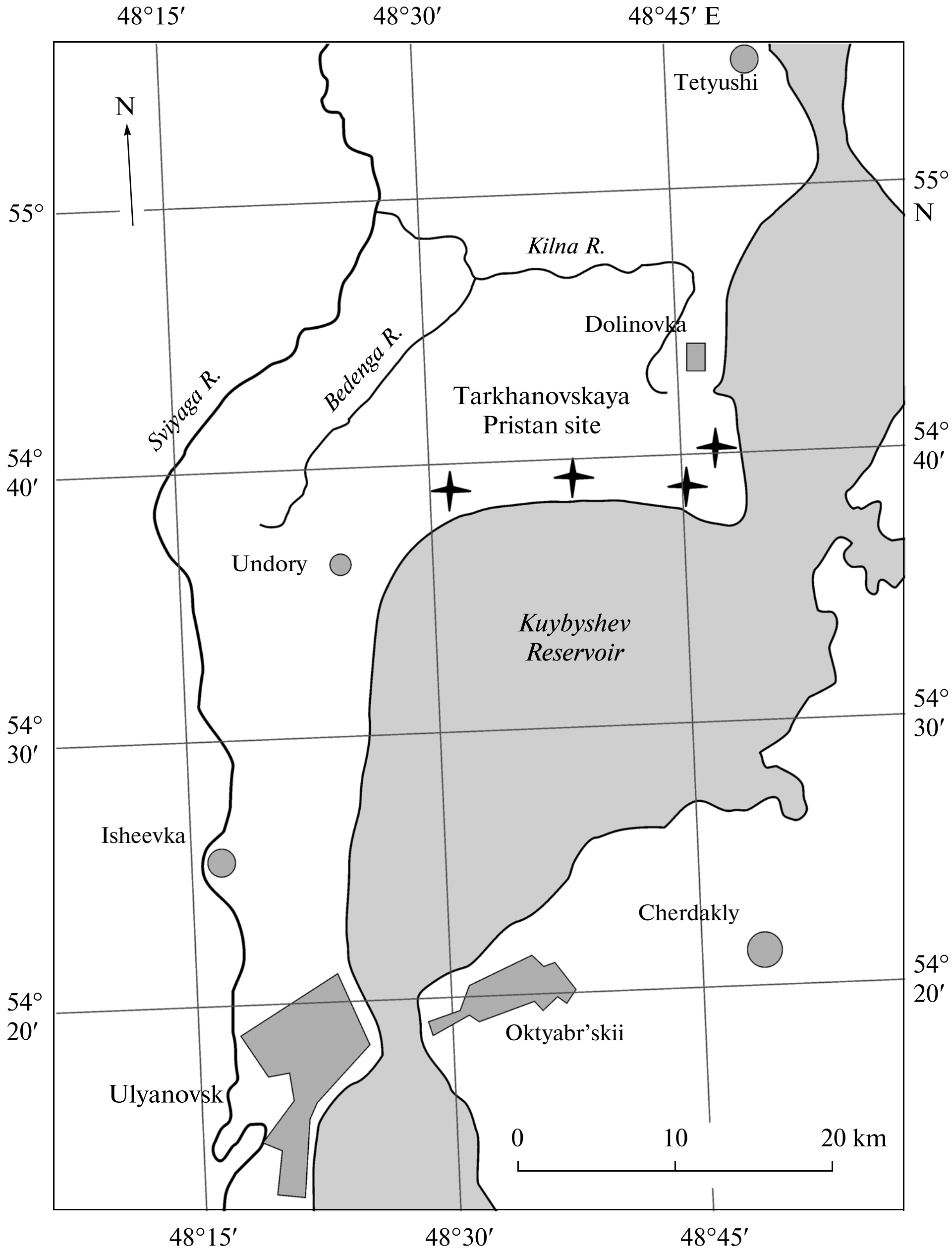


Fig. 1. Geographic localities of the studied sections.

southwestern Tatarstan, the pre-Callovian part of the Jurassic sedimentary succession (Laishevo Sequence) was attributed to the Bathonian on the basis of examination of palynological assemblages macerated from the rocks (Didenko and Zorina, 2003; Zorina, 2007).

In 2010 and 2011, Mitta, Kostyleva, and Starodubtseva resumed their field examinations of Middle Jurassic deposits within the Dolinovka–Tarkhanovskaya Pristan area and presented preliminary results at several scientific conferences (Mitta, 2010; Kostyleva and Mitta, 2011; Kostyleva, 2011; Mitta et al., 2011; Mitta and Ditl', 2012). In this work, all the results obtained and additional data on found bivalves (determinations by B.N. Shurygin), foraminifers, and ostracodes (determinations by L.A. Glinskikh) are summarized and interpreted.

DESCRIPTION OF SECTIONS

The Middle Jurassic deposits are exposed on the coastal slope almost everywhere beginning from a ravine mouth near the abandoned village of Dolinovka to the Tarkhanovskaya Pristan site. Their beds dip southwestward (toward the village of Memei) under the Upper Jurassic clays. In places, the rocks are concealed under taluses and this is an obstacle for correlating the beds and measuring their thickness. The variegated sequence of the Upper Permian is composed of alternating clay beds pale green to crimson red in coloration, intercalated with interlayers of pale yellow marl and interbeds of calcareous conglomerates and graywacke sandstones. The erosion surface of these rocks is overlain with a stratigraphic hiatus by a sand-silt-clay sequence of the Middle Jurassic that is divided into four members. The three lower members of siliciclastic sediments correspond to the pre-Callovian part of the sequence. The fourth member of the upper Callovian marls is separated from underlying sediments by a hiatus of eluvial erosion type. Along the sloped bank, the succession of outcrops is divided into the eastern (sections 1–6), central (sections 7–9), and western (sections 10, 11) parts, differing from each other in structure and completeness of the sections. Description of the Middle Jurassic beds is presented below (Figs. 2, 3).

? Lower Bajocian

Member I (beds 1–3): rocks of the member are exposed in eastern sections of the Tarkhanovskaya Pristan site and near Dolinovka (sections 1, 3). Its presumable age is determined on the basis of the position of the rocks in the succession. The apparent thickness of the member is not greater than 6.5 m. The beds described below are numbered from the base upward:

1. Quartz graywacke sands, coarse- to medium-grained and medium-grained, grayish olive green ("snuff-colored"), variably compact, slightly argillaceous, displaying cross or wedge-shaped gentle bedding that is variably oriented and grades upward into vague trough-shaped bedding. Sediments comprise rounded ferruginous concretions of diagenetic origin. Thickness of the bed persistently ranges from 1.6 to 2.2 m.

2. Smectite-chlorite-kaolinite-hydromica clays, noncalcareous, containing rare and small coaly detritus, horizontally intercalated with quartz graywacke and oligomictic sands; occasional intercalations of weakly lithified gravel are tawny to olive green in coloration. Thickness of sandy and gravely intercalations ranges from 0.01 to 0.1 m. Clays are partially bioturbated. Bed is 1.0 to 2.0 m thick.

3. Chlorite-smectite-kaolinite-hydromica clays, noncalcareous, lumpy, bioturbated, with insignificant admixture of coaly detritus and nests of pale grayish olive green quartz sand, which are surrounded by iron hydroxides. Clays grade upward into irregularly undulating lenticular alternation of pale grayish olive green fine-grained quartz sands and gray silty clays. Apparent thickness is up to 2.5 m.

Upper Bajocian

Member II (Beds 4, 4^a, 4^b) is recognizable in all parts of the coastal slope, being though of variable completeness. Its apparent thickness ranges from 9 to 14 m. Contact with Member I was not observed.

4. Chlorite-smectite-kaolinite-hydromica clays, gray, silty, noncalcareous, with fine cross-lamination and horizontal and lenticular undulating bedding that is underlined by accumulations of yellowish gray silty material and diagenetic marcasite segregations. Higher in the bed, clays comprise intercalations of pale gray, slightly clayey quartz silt. Silt intercalations include admixture of goethite, jarosite, and rare marcasite. The intercalations range in thickness from 0.1 to 2.0 m. Large (up to 2 m across) loaf-shaped concretions of well-lithified calcareous feldspar-quartz siltstone observable in Section 4 as associated in places with the above intercalations slide downslope, when weathered, to the bank edge. Ripple marks, predominantly cellular ones, which were produced by waves of variably oriented water flows, are observable on the upper surface of these concretions. Apparent thickness of the bed is 3 to 10 m.

4^{a-b}. Smectite-kaolinite-hydromica clays, dark brownish gray, silty, noncalcareous, with minor admixture of fine coaly detritus and chlorite sometimes; in places, the rocks reveal fine horizontal or horizontally undulating lamination that is detectable owing to yellowish gray coloration of silt laminae and occurrence of gypsum crystals on bedding planes. In the lower third of the unit, there are thin (not thicker than 0.04 m) interlayers of yellowish gray silt. Clays seemingly form the lens-shaped bodies 2 to 6 m thick inside the clay-silt matrix of Bed 4, which wedge out in all directions (Fig. 2, sections 2, 7–9, and beds 4^a, 4^b).

In central section 8, an interlayer interruptive along the strike and confined to the top of Bed 4^b comprises segregations of yellowish brown limonite up to 0.15 m thick, which are dark brown to black on the weathered surface. Within the interval from 0.9 to 1.5 m below the top, we found fairly frequent bivalve shells, less abundant molds and casts of small crushed ammonites (*Garantiana* sp., *Othogarantiana* cf. *baculata* (Quenstedt)), and very rare cavities after belemnite rostra leached out. Total thickness of the bed is 4 m. In Section 7, clays are not thicker than 2 m (Fig. 4a).

? Bathonian (Observable above the Erosion Surface)

Member III (Bed 5) is exposed in its most complete volume within the western (sections 10, 11) and eastern (sections 2, 4–6) parts of the studied exposure. Member III overlies Member II with scouring marks in between.

5. Feldspar-quartz silt loams, pale gray to grayish yellow, with horizontal wavy bedding and insignificant content of pelitic fraction; mineral composition of the latter is dominated by smectite. Goethite and some-

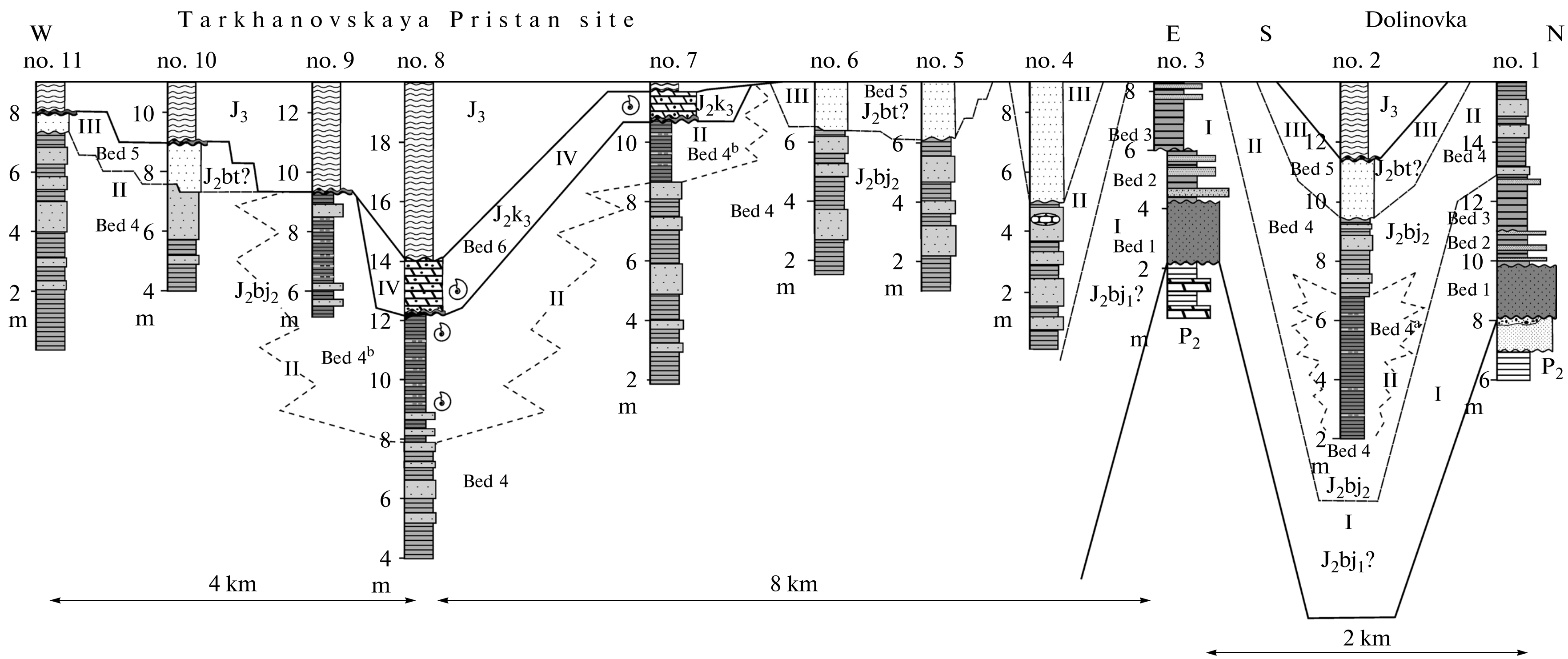


Fig. 2. Correlation scheme of sections studied between the Dolinovka and Tarkhanovskaya Pristan sites (symbols for lithology as in Fig. 3). Abbreviated designation of stratigraphic units: P_2—Permian System, Upper Series; J_2bj_1—Jurassic System, Middle Series, Bajocian Stage, lower substage; J_2bj_2—Jurassic System, Middle Series, Bajocian Stage, upper substage; J_2bt—Jurassic System, Middle Series, Bathonian Stage; J_2k_3—Jurassic System, Middle Series, Callovian Stage; J_3—Jurassic System, Upper Series.

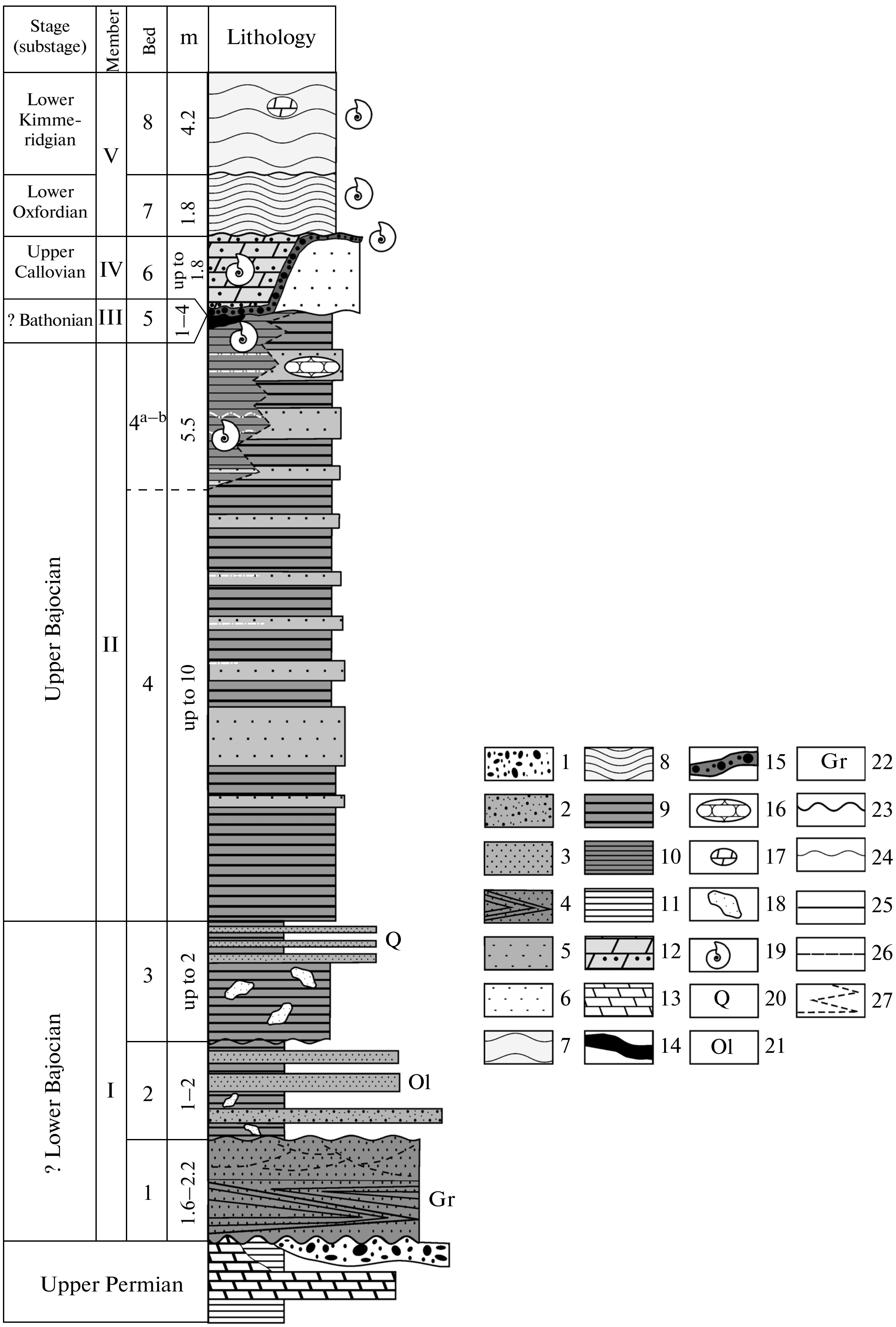


Fig. 3. Composite section of the Middle–Upper Jurassic deposits, Tarkhanovskaya Pristan site, Tatarstan: (1) conglomerate, (2) gravelstone, (3) sands, (4) cross-bedded sands, (5) clayey silt, (6) slightly clayey loess-like silt, (7) compact limy clay, (8) flaky limy clay, (9) silt clay, (10) silty clay, (11) clay, (12) marl with ferruginous ooliths, (13) marl, (14) limonite concretions, (15) condensed horizon, (16) silty-limy concretions, (17) clayey-limy concretions, (18) sand nests, (19) fossils, (20) quartz sand, (21) oligomictic sand, (22) graywacke-like sand, (23) stratigraphic hiatus, (24) erosion boundary, (25) reliable correlation lines, (26) presumable correlation lines, (27) facies boundary.

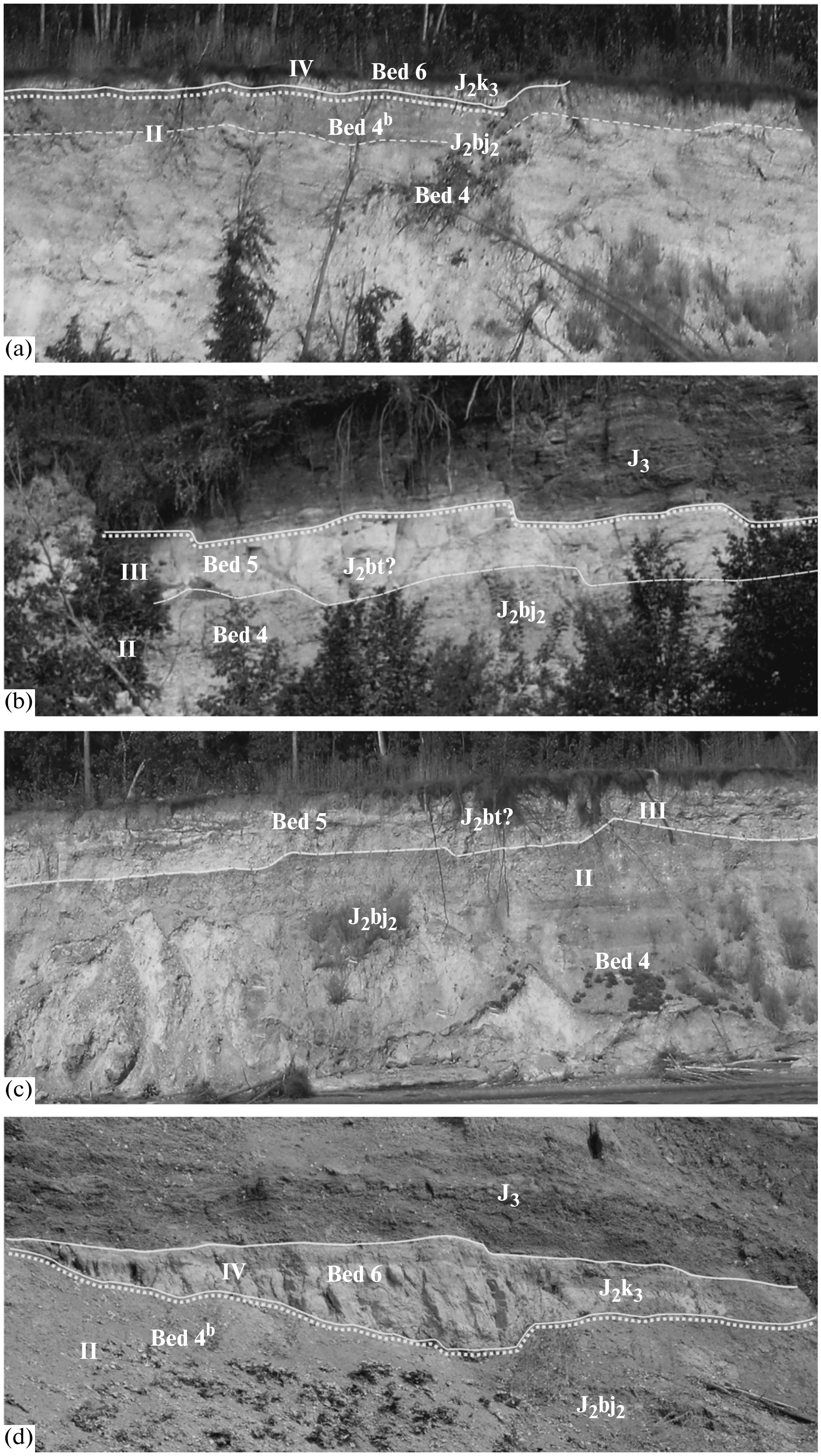


Fig. 4. Structure of Middle Jurassic deposits in sections between the Dolinovka and Tarkhanovskaya Pristan sites: (a) pinch-out of the upper Bajocian clay, Bed 4^b, Section 7; (b, c) contact between the upper Bajocian silty clay and Bathonian (?) silt, Sections 10 and 5, respectively; (d) contact between the upper Bajocian clay and upper Callovian marl, Section 8. Abbreviated designation of stratigraphic units in profiles: J_2bj_1—Jurassic System, Middle Series, Bajocian Stage, lower substage; J_2bj_2—Jurassic System, Middle Series, Bajocian Stage, upper substage; J_2bt—Jurassic System, Middle Series, Bathonian Stage; J_2k_3—Jurassic System, Middle Series, Callovian Stage; J_3—Jurassic System, Upper Series.

times jarosite grains occur in its composition as well. Apparent thickness of the bed ranges from 0.8 to 4 m.

The bed is overlain by a thin condensation horizon spanning the stratigraphic interval of the lower, middle, and basal upper Callovian (sections 2, 10, 11) or by the recent soil (sections 4–6; see Figs. 4b, 4c).

Upper Callovian

Member IV consists of one marl bed (Bed 6) is observable only in the central part of the exposure (sections 7, 8). Bed 6 rests on the uneven erosion surface of the upper Bajocian clays (Bed 4^b), which is indicative of scouring. Lens-shaped bodies of marl about 100 m long along the strike pinch out in the western and eastern directions (Fig. 4d).

6. Marl, yellowish gray to yellow in the upper third, contains redeposited ferruginous ooliths that are irregularly distributed. At the base, there is a thin (0.02–0.12 m) condensation horizon persistent along the strike, which is composed of ferruginous ooliths, phosphatized and limonitized casts (of living chambers predominantly) and molds of ammonites (*Chamoussetia* cf. *buckmani* Callomon et Wright, *Kepplerites* cf. *galilaeii* (Buckman), *Proplanulites* sp., and others), fragments of belemnite rostra, and semi-rounded limonite pebbles cemented in places by gypsum and calcite. In the marl proper, we found abundant ammonites (*Quenstedtoceras pseudolamberti* Sintzov, *Q. paucicostatum* (Lange), *Euaspidoceras subbabeanum* (Sintzov), *Klematosphinctes perisphinctoides* (Sintzov), and others (Mitta, 2003)), belemnite rostra, and bivalve shells. The maximum thickness of the bed is up to 1.7 m.

The Upper Jurassic clays unconformably overlying the bed are up to 6.0 m thick (Member V, beds 7, 8).

CHARACTERIZATION OF FOSSILS

According to A.P. Pavlov, Jurassic fossils already occur in Member I, where he detected unidentifiable bivalves and cavities after dissolved belemnite rostra "with alveoli casts" (Pavlov, 1883, p. 57), and this forced him to argue for the Jurassic age of the rocks. We found determinable fossils (remains of ammonites, bivalves, and single belemnite rostra) in the central part of the exposure, namely, in the upper part (0.9–1.5 m below the top) of Bed 4^b (Member II, sections 7–9).

Ammonites are largely represented by small (15–20 mm in diameter, sometimes up to 35 mm) completely crushed shells or their fragments and molds, which are poorly preserved (Mitta and Ditl', 2012, Plate I, figs. 1–6; this work, Plate I, figs. 1–11). Morphological peculiarities of shells and their sculpturing suggest that these remains belong to genera *Garantiana* Masce, 1907 and *Orthogarantiana* Bentz, 1928, which are characteristic of the baculata Subzone in the Strenoceras niortense Zone in northern peripheral sections of the Tethys (Western Europe, Northern Caucasus, Donbas, Middle Asia) and of the Garantiana garantiana Zone of the Submediterranean scale. Peculiarities of occurrence and preservation of ammonites indicate for sure the autochthonous type of their burial.

A single ammonite found in the lower silt interlayers of Bed 4^b (3.2 m below the top), Section 8 (Mitta and Ditl', 2012, Plate I, fig. 6; this work, Plate I, fig. 11), differs from the above taxa, as bifurcation points of ribs are located on its shell closer to the umbilical area. In addition, tubercles at bifurcation points are more embossed. This specimen can be determined as representative of the family Stephanoceratidae but not at the generic or species rank.

The bivalve assemblage found in the lower parts of sections 7 and 8 (Plate I, figs. 12–17) includes specimens of heterodont mollusks and ctenodontids whose stratigraphic ranges are known insufficiently well. *Phaenodesmia* forms from the same assemblage are most similar to species *P. sobetskii* Romanov described from the upper Bajocian–Bathonian interval of sections in the Dniester–Prut interfluve (Romanov, 1973). In Eastern Europe, bivalves *Protocardia borissjaki* Pčelincev are known from the Bajocian–Callovian stratigraphic interval, and species *Camptonectes laminatus* (Sowerby) are widespread in the Bajocian–Callovian of Western and Eastern Europe. Forms comparable with *Tancredia* ex gr. *zakharovi* Yazikova used to be described from the Upper Jurassic of Eurasia. However, taxonomic composition of the genus *Tancredia* and stratigraphic distribution of its species have not been estimated precisely as yet. In the Asian part of Russia, *Tancredia* shells of similar morphology in their rear parts are known from the Lower Jurassic, Bajocian, and Upper Jurassic. Hence, the described bivalve assemblage does not contradict the Bajocian age estimated for the bed based on ammonites.

Bivalves identified in the assemblage are characteristic of shallow-water habitats with weak hydrodynamics near the bottom. They are typical of assemblages of the middle sublittoral zone, although the main factor controlling their population is the weak near-bottom hydrodynamics rather than the depth. These hydrodynamic conditions can also be inherent in flat shoals of the upper sublittoral zone.

In basal phosphorite and limonite pebbles of Bed 6 (sections 7–10), we found numerous fragments and molds of *Cadoceras?* sp. juv., *Chamoussetia* cf. *buckmani* Callomon et Wright, *Kepplerites* sp. juv., *Parapatoceras* cf. *distans* (Baugier et Sauzé), *Kepplerites galilaeii* (Oppel), *K.* cf. *curtilobus* Buckman, *K.* (*Toricellites*) *curticornutus* (Buckman), and *Sigaloceras?* sp. juv. (Mitta, 2003, Plate III, figs. 2–6). All these ammonites characterize different intervals of the lower Callovian, and their host sediments were washed away after deposition.

Abundant casts of ammonites *Quenstedtoceras pseudolamberti* Sintzov, *Q. paucicostatum* (Lange),

Plate I

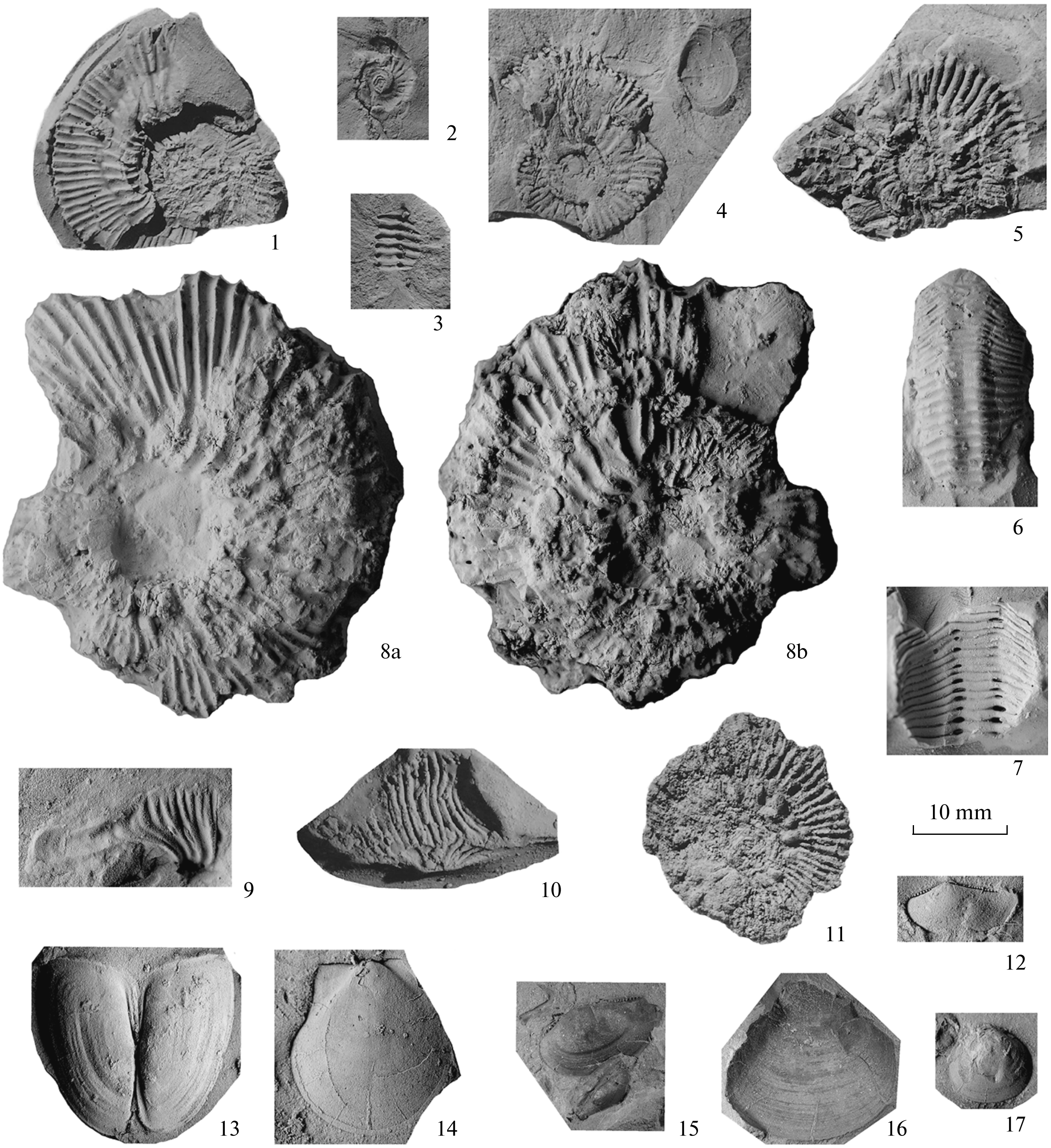
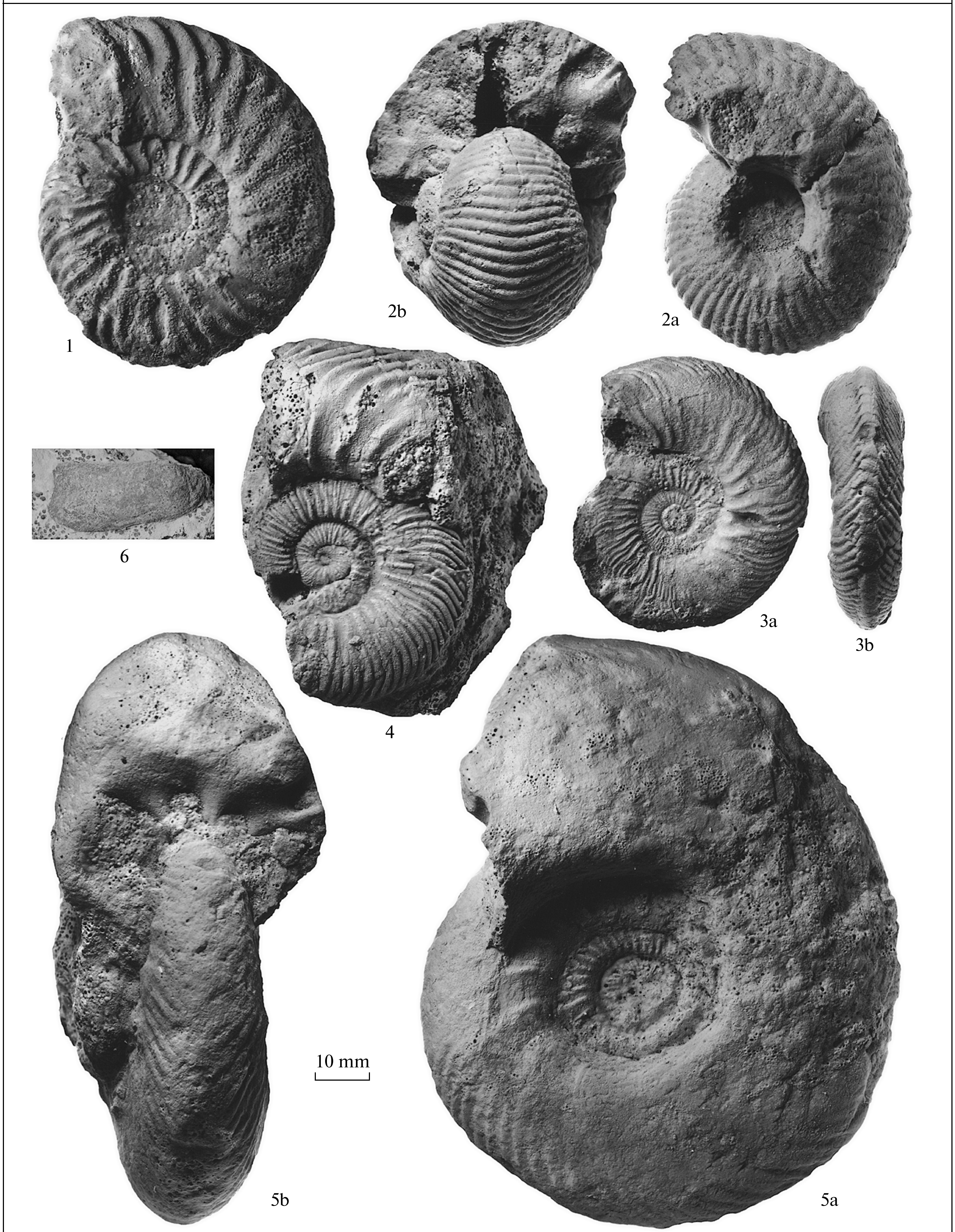


Plate I. Ammonites and bivalves from Bed 5, Section 7, Ulyanovsk area of the Volga region, Tarkhanovskaya Pristan site; upper Bajocian, Garantiana beds; Originals are stored at the Paleontological Institute, Russian Academy of Sciences.

(1, 4, 6) *Garantiana* sp.: (1) specimen no. 5029/098, mold with part of a crushed living chamber, lateral view; (4) specimen no. 5029/100, lateral view of crushed living chamber; (6) specimen no. 5029/099, ventral view of slightly deformed shell; (2, 3) *Garantiana?* sp. juv.: (2) specimen no. 5029/104, lateral view of juvenile shell; (3) specimen no. 5029/105, fragment of juvenile shell ventral side; (5) *Garantiana?* sp., specimen no. 5029/106, lateral view; (7) *Orthogarantiana* cf. *baculata* (Quenstedt), specimen no. 5029/101, mold of shell fragment, ventral view; (8) *Orthogarantiana* cf. *densicostata* (Quenstedt), specimen no. 5029/107, (8a) lateral view, (8b) view from aperture side; (9) *Garantiana (Pseudogarantiana)* sp., specimen no. 5029/102, apertural part of living chamber with a lappet; (10) specimen no. 5029/108, apertural part of living chamber; (11) Stephanoceratidae gen. et sp. indet., specimen no. 5029/103; (12, 15) *Phaenodesmia sobetskii* Romanov: (12) specimen no. 5029/109, view from side of the left valve; (15) specimen no. 5029/110, view of intact shell from hinge-line side, above there is the left valve and *Onychites* sp. nearby; (13) *Tancredia* ex gr. *zakharovi* Yazikova, specimen no. 5029/111, shell with open valves; (14) *Camptonectes laminatus* (Sowerby), specimen no. 5029/112, left valve; (16, 17) *Protocardia* cf. *borissjaki* Pčelincev, 1927: (16) specimen no. 5029/113, mold of left valve; (17) specimen no. 5029/114, left valve.

Plate II



Q. mologae Nikitin, *Euaspidoceras subbabeanum* (Sintzov), *Klematosphinctes perisphinctoides* (Sintzov), and others were found in marl of Bed 6, Section 8 (Mitta, 2003, Plate I, figs. 1–4; Plate II, figs. 3, 4, 7). In Section 7, situated 1.5 km upstream, ammonites from analogous marl are represented by partially preserved casts and their fragments. Taxa identified among these remains are *Quenstedtoceras* cf./aff. *henrici* Douvillé, *Q. mologae* Nikitin, *Longaeviceras?* sp. nov., *Kosmoceras* cf. *transitionis* Nikitin, *K.* cf. *mojarowskii* (Nikolaeva et Rozhdestvenskaya), and *Peltoceras?* sp. (Mitta, 2003, Plate II, figs. 1, 2, 5, 6; this work, Plate II, figs. 1–5; Plate III, figs. 1–4). Ammonite shells are of variable dimensions, from 25 to 250 mm in diameter. According to degree of preservation, these ammonites were certainly redeposited. According to taxonomic composition, their assemblage is somewhat older than the ammonite assemblage from the same bed of Section 8.

In addition, Bed 6 yielded one specimen of nautilids and numerous belemnite rostra, including *Holcobeloides beamontianus* (d'Orbigny) identified by O.S. Dzyuba. The bivalve assemblage of the bed (Plate II, fig. 6; Plate III, figs. 5, 6) includes species characteristic of the Callovian–Oxfordian strata in Eurasia. For instance, *Pinna lanceolata* Sowerby is known from the Callovian of the Russian platform. Comparable *Pinna* forms occur also in the Oxfordian of the European and Asian parts of Russia. In the Russian Platform, *Gryphaea lucerna* (Trautschold) has been described from the Callovian, while *Cosmetodon keyserlingii* d'Orbigny, 1850 is known from the lower Oxfordian. Similar *Cosmetodon* morphotypes are also known from the upper Callovian and Kimmeridgian. Hence, similar sets of bivalve species can be found within the Callovian–Kimmeridgian stratigraphic interval. All the bivalve taxa identified in the assemblage are dwellers of comparatively shallow sea zones with a well-aerated water layer near the bottom.

For micropaleontological analysis, we collected three marl samples from Bed 6 of Section 8, namely, from the base and top of the bed and at the level of 1 m below its top. Foraminifers and ostracodes were found in each sample.

Foraminifers (Plate IV, figs. 1–10). Foraminiferal assemblages macerated from the collected samples are fairly diverse, represented by agglutinated and calcareous species whose abundance and taxonomic diversity increase upward in the bed section. At the base and in the middle of the bed, the dominant species of foraminifers is *Ophthalmidium areniforme* (E. Bykova). At the top, the foraminiferal assemblage is of somewhat different structure and composition. It is more diverse in taxonomic aspect and deprived of obvious dominant taxa. In total, we identified over 30 species: *Trochammina baltica* Grigelis, *Paleogaudryina terra* (E. Bykova et Azbel), *Verneuilinoides minimus* (Kosyreva), *Verneuilinoides* sp., *Marssonella doneziana* Dain, *Nubeculinella* ex gr. *parasitica* Dain, *Ophthalmidium areniforme* (E. Bykova), *Nodosaria mutabilis* Terquem, *Pseudonodosaria lahuseni* (Uhlig), *Ichtyolaria suprajurensis* (Mjatliuk), *Dentalina brueckmanni* Mjatliuk, *Dentalina* sp., *Lenticulina tumida* Mjatliuk, *L. uhligi* (Wisniowski), *L. polonica* (Wisniowski), *L. hoplites* (Wisniowski), *L. involvens* (Wisniowski), *L. simplex* (Kuebler et Zwingli), *Astacolus colligatum* (Brueckmann), *A. calloviensis* (Mjatliuk), *A. batrakiensis* (Mjatliuk), *Planularia deeckei* (Wisniowski), *P. guttus* (Mitjanina), *Vaginulina dimidia* Grigelis, *Citharinella moelleri* (Uhlig), *Citharina* cf. *chanika* (Mjatliuk), *Saracenaria engelsensis* Kosyreva, *S. graciliis* Kosyreva, *Globulina* ex gr. *oolithica* (Terquem), *Eoguttulina* sp., *Spirillina kuebleri* Mjatliuk, *Miliospirella lithuanica* Grigelis, and others.

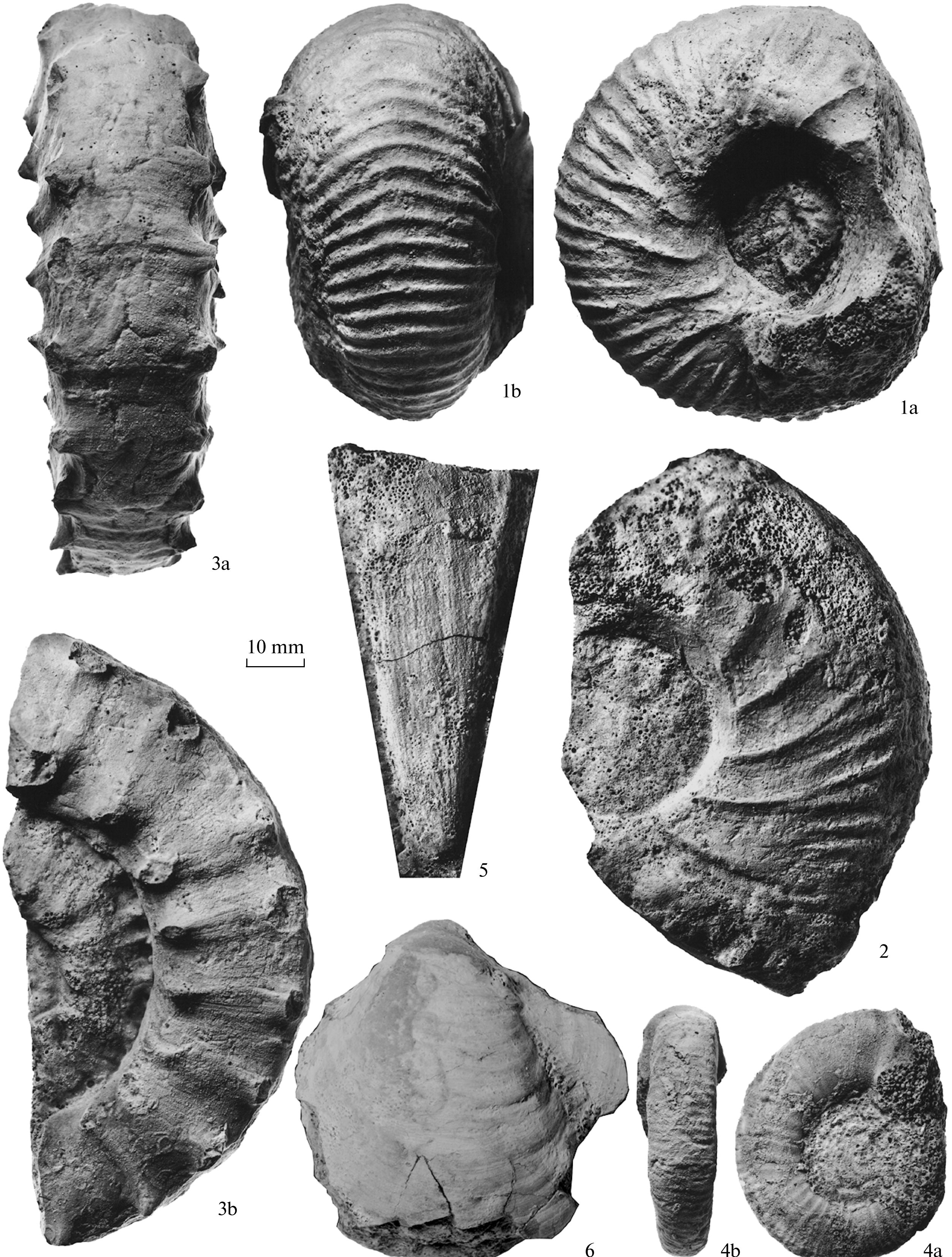
The taxonomic composition of foraminifers, among which there are zonal index species *Lenticulina tumida* and other species of biostratigraphic significance, suggests that their host deposits correspond in range to the Lenticulina tumida–Epistomina elschankaensis Zone of the foraminiferal zonation and to the athleta and lamberti zones of the ammonite scale. The complete absence of foraminifers belonging to the genus *Epistomina* and commonly dominating within the designated foraminiferal zone over the other groups of foraminifers (*Biostratigrafiya*..., 1982; *Prakticheskoe*..., 1991) is a distinctive feature of the described assemblage.

Ostracodes (Plate IV, figs. 11–18). At the base of Bed 6, ostracodes are not abundant, represented by single specimens of *Polycope* sp. and *Vesticytherura* sp. Their abundance and taxonomic diversity are higher in the middle and at the top of the bed. We identified the following taxa of these fossils: *Pontocyprella aureola* Lyubimova, *Paracipris* cf. *lubrica* Lyubimova, *Paracipris* sp., *Vesticytherura paula* (Lyubimova), *Cytheropteron* sp., *Galliaecytheridea legitima* (Lyubimova), *Fuhrbergiella archangelskyi* (Mandelstam), *Neurocythere catephracta* (Mandelstam), *N. oxfordiana* (Lutze), *Infacythere dulcis* (Lyubimova), and *Polycope* sp.

Plate II. Ammonites and bivalves from Bed 7, Section 5, Ulyanovsk area of the Volga region, Tarkhanovskaya Pristan site; upper Callovian, Quenstedtoceras lamberti zone. Originals are stored at the Paleontological Institute, Russian Academy of Sciences.

(1) *Quenstedtoceras* aff. *henrici* Douvillé, specimen no. 5475/1, lateral view; (2) *Quenstedtoceras mologae* Nikitin, specimen no. 5475/2, (2a) lateral view, (2b) view from aperture side; (3, 4) *Quenstedtoceras flexicostatum* (Phillips): (3) specimen no. 5475/3, (3a) lateral view, (3b) ventral view; (4) specimen no. 5475/4, lateral view; (5) *Quenstedtoceras* aff. *henrici* Douvillé, specimen no. 5475/5, (5a) lateral view, (5b) view from aperture side; (6) *Cosmetodon keyserlingi* (d'Orbigny, 1850), specimen no. 5475/6, right valve.

Plate III



The assemblage of listed species is characteristic of the Infacythere dulcis ostracode beds of the upper Callovian, which are correlated with the athleta and lamberti ammonite zones (Tesakova, 2003).

CONDITIONS OF SEDIMENTATION

In the study area, the Middle Jurassic sequence is composed predominantly of terrigenous and terrigenous-carbonate sedimentary complexes deposited in shallow sea settings.

Members I and II exemplify one transgressive cycle of sedimentation complicated by synsedimentary breaks. The paragenesis of sandy coastal-accumulative and calm-water clayey bioturbated deposits of Member I evidences sediment accumulation on an open shoal with periodic pauses in sedimentation. The degree of maturity of sandy grains increasing upward in the section apparently characterizes maturation of clastic material inside the basin under the influence of intense hydrodynamics. Silt-clay sediments of the overlying Member II also accumulated in the shallow-water zone under intense hydrodynamic conditions, which is evident from structural patterns of sediments, e.g., from the ripple marks on bedding planes. In this case, we suspect a sag-and-swell topography of the seafloor, as in places silt-clayey sediments reveal facies transitions into substantially clayey sediments typical of calm-water shelf pits and containing paleontological remains (ammonites and bivalves). The latter sediments presumably form lens-shaped bodies approximately a hundred meters long along the strike. Sagged shelf areas were of submeridional orientation in present-day coordinates, as we think, and entered the shelf zone as comparatively narrow inlets. Formation of the inlets was likely controlled by differentiated downwarping associated with development of the Ulyanovsk–Saratov submeridional basin.

Member I is conventionally assigned to the lower Bajocian, because beds of this member and overlying sediments of Member II bearing paleontological remains of the upper Bajocian belong to one cycle of sedimentation.

In different part of the exposure, the upper Bajocian sediments are overlain by either the Bathonian (?) silt loams or the upper Callovian marl and even the Upper Jurassic clays. These stratigraphic relations evidence recurrent breaks in sedimentation during the post-Bajocian time. Silts of Member III rest on the erosion, sometimes stepped surface of the Bajocian deposits. Distinctive peculiarities of these silts are their granulometric uniformity, silt-sized clastic material, practical absence of coalified organic substance, and prevalence of smectite in the clay fraction. Judging from their structures, the silts accumulated for certain under water, most likely in shallow marine settings of semi-isolated shelf parts near the coast.

The thin (2–10 cm) interlayer overlying the Bajocian and Bathonian deposits includes ferruginous ooliths and rounded fragments of belemnite rostra and casts of the lower Callovian ammonites. The interlayer exemplifies coupling of the erosion surface and thin condensation horizon corresponding in range to the lower and probably middle–basal upper Callovian. The condensation horizon was formed after a break in sedimentation followed by partial erosion of the Bathonian and upper Bajocian deposits with subsequent resumption of marine sedimentation.

It is difficult to speak about composition and environments of formation of the lower–middle Callovian deposits. Perhaps, they are similar in composition to concurrent deposits in the adjacent area (marine silt-clay sediments frequently containing ferruginous ooliths). It is possible to assume as well the discrete character of sedimentation in the study area during the early and probably middle Callovian, when periods of accumulation of sediments gave way to their erosion and removal of fine-grained material by bottom currents. As a result, the erosion surface of the Bathonian and Bajocian rocks became buried under coarse-grained components of sediments (ferruginous ooliths, fragments of ammonite shells and belemnite rostra), which were recurrently redeposited without meaningful transportation from the sites of their original deposition. Differentiated tectonic movements that accompanied further development of the Ulyanovsk–Saratov submeridional basin could also be regarded as one more factor responsible for the absence of lower–middle Callovian deposits in the study area.

The condensation horizon is overlain with scouring by the upper Callovian marl of Member IV comprising abundant paleontological remains and accumulations of ferruginous ooliths that are irregularly distributed. Carbonate sediments accumulated in a calm-water shelf zone fairly remote from the coast, where carbonate-clayey ooze periodically roiled under influence of wave activity mixed with components of the underlying condensation horizon. It should be noted as well that the lens-shaped marl bodies of insignificant extension (up to 100 m) are intercalated everywhere with the upper Bajocian clays characteristic of sagged

Plate III. Ammonites and bivalves from Bed 7, Section 5, Ulyanovsk area of the Volga region, Tarkhanovskaya Pristan site; upper Callovian, Quenstedtoceras lamberti Zone. Originals are stored at the Paleontological Institute, Russian Academy of Sciences. (1, 2) *Longaeviceras* sp. nov.: (1) specimen no. 5475/7, (1a) lateral view, (1b) ventral side; (2) specimen no. 5475/8, lateral view; (3) *Euaspidoceras subbabeanum* (Sintzov), specimen no. 5475/9, (3a) lateral view, (3b) ventral side; (4) *Klematosphinctes perisphinctoides* (Sintzov), specimen no. 5475/10, (4a) lateral view, (4b) ventral side; (5) *Pinna lanceolata* Sowerby, specimen no. 5475/11, view from side of the left valve; (6) *Gryphaea lucerna* Trautschold, specimen no. 5475/12.

shelf areas. Accordingly, the late Callovian marine sedimentation in the study area seems to have also been controlled by tectonic movements along submeridional fault zones of the Ulyanovsk–Saratov basin. These tectonic events were likely triggered by the general eustatic subsidence of the southeastern part of the East European Platform.

DISCUSSION AND CONCLUSIONS

The Bajocian ammonites are reliably known in the Volga region only from the upper part of the stage corresponding here and on the Russian Platform to the Pseudocosmoceras michalskii Zone more or less correlative with the Parkinsonia parkinsoni Zone of the Submediterranean scale. Ammonites of the latter zone have been found in southerly sections situated at the latitude of Saratov and Volgograd. In addition, single *Parkinsonia* forms are described from the Samara Bend area of the region (Sazonova and Sazonov, 1967). Ammonites of the genus *Garantiana* typical of the underlying Garantiana garantiana Zone have been mentioned as characteristic of the Russian Platform in a series of works dedicated to examination of borehole sections drilled in the surroundings of Saratov and Volgograd (unpublished reports; Saltykov, 2008; etc.). This information has been regarded as sufficient for discriminating the Garantiana Zone in the middle part of the upper Bajocian (*Unifitsirovannya...*, 1993). On the other hand, identifications of ammonite taxa listed in the works have never been confirmed by reproduction of their figures, descriptions, and references to museum collections. Consequently, discrimination of the biostratigraphic unit ranked as the Garantiana Zone (and considering it as a regional biostratigraphic subdivision) cannot be regarded as substantiated in the Volga region. Considering our and other available data on the distribution range of the genus *Garantiana*, the lower and upper boundaries of which are imprecisely defined within the Russian Platform, we propose to rank the biostratigraphic unit in question as the Garantiana beds (Mitta and Ditl', 2012). In the regional zonation, these beds should be placed immediately below the michalskii Zone and tentatively correlated with the Orthogarantiana baculata Subzone of the Strenoceras niortense Zone and with the Garantiana garantiana Zone in the Bajocian zonation established in the Submediterranean region (Fig. 5). As far as we know, the unit under consideration corresponds to the oldest Jurassic beds of the Russian Platform, which reliably yield ammonites described in this work. It is remarkable as well that outcrops studied at the Tarkhanovskaya Pristan site are the northernmost ones yielding the Bajocian ammonites of Tethyan origin. Accordingly, our data prove that a sea basin at the northern margin of the Tethys reached in the Bajocian time the latitude of Kazan and Ulyanovsk (this basin can be termed the Simbirsk Bay). At the same time, the southernmost occurrence of *Arctocephalites arcticus* (Newton et Till), the Bajocian ammonite of boreal origin, is known in the Pechora River basin north of Ukhta (Mitta, 2006, 2009). Consequently, eustatic and tectonic movements that commenced in the Bajocian resulted during the middle Bajocian time in formation of the Izhma (in the north) and Simbirsk (in the south) bays of the Boreal and Tethys oceans, respectively. In the next epoch, i.e., in the early Bathonian, coalescence of the bays formed the meridional seaway, which is evident from the occurrence of early Bathonian ammonites, belemnites, and bivalves in the surroundings of Saratov immediately above the Bajocian and Bathonian strata with Tethyan parkinsoniids (Mitta and Sel'tser, 2002).

The pre-Callovian clay-sand deposits (Laishevo sequence) were formerly regarded on the basis of composition of palynological spectra as the Bathonian in age. K.V. Nikolaeva and O.V. Makarova consider the respective palynological assemblages as comparable with the Bathonian assemblages from the Lower Volga region, as "pollen of the genus *Brachyphyllum* occurring as a subordinate component in the rocks appears only in the Bathonian Stage" (Didenko and Zorina, 2003, p. 199; Zorina, 2007, p. 33). In the opinion of N.K. Mogucheva and A.A. Goryacheva, however (oral

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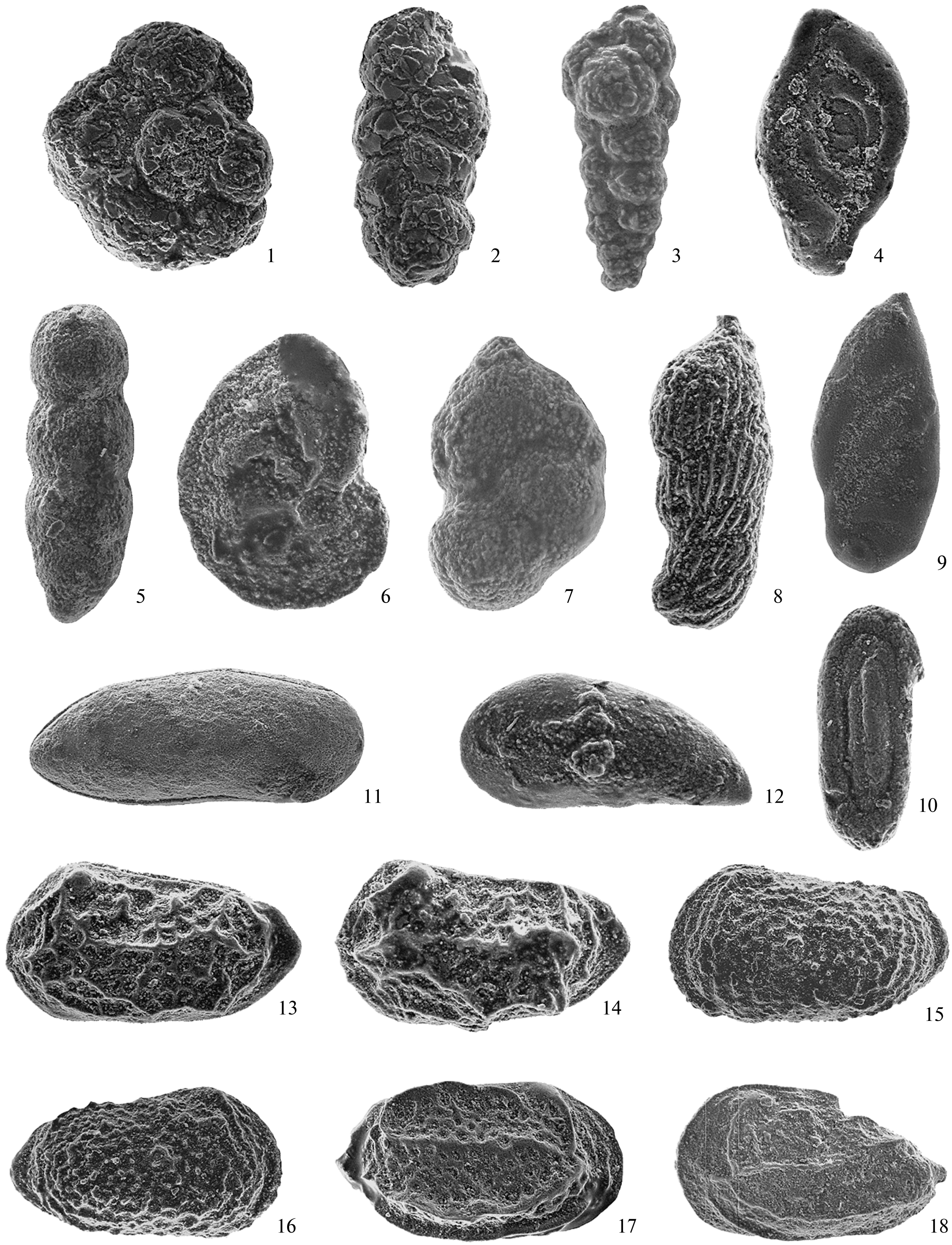
Plate IV. Foraminifers and ostracodes from Bed 7, Section 7, Ulyanovsk area of the Volga region, Tarkhanovskaya Pristan site; upper Callovian, Lenticulina tumida–Epistomina elshankaensis Zone of foraminiferal scale, Infacythere dulcis ostracode beds. Collection of microfauna is stored at the Laboratory of Micropaleontology, Trofimuk Institute of Petroleum Geology and Geophysics.
(1) *Trochammina baltica* Grigelis, ×105, occurrence level 1 m below top of Bed 7; (2) *Paleogaudryina terra* (E. Bykova et Azbel), ×130, top of Bed 7; (3) *Verneuilinoides minimus* (Kosyreva), ×215, top of Bed 7; (4) *Ophthalmidium areniforme* (E. Bykova), ×125, occurrence level 1 m below top of Bed 7; (5) *Pseudonodosaria lahuseni* (Uhlig), ×120, top of Bed 7; (6) *Lenticulina polonica* (Wisniowski), ×140, top of Bed 7; (7) *Lenticulina hoplites* (Wisniowski), ×220, top of Bed 7; (8) *Astacolus batrakiensis* (Mjatliuk), ×190, top of Bed 7; (9) *Planularia guttus* (Mitjanina), ×110, top of Bed 7; (10) *Miliospirella lithuanica* Grigelis, ×125, top of Bed 7; (11) *Pontocyprella aureola* Lyubimova, closed shell on the right, ×70, top of Bed 7; (12) *Paracipris* sp., closed shell on the left, ×170, top of Bed 7; (13, 14) *Vesticytherura paula* (Lyubimova), ×145: (13) external view of the left valve, top of Bed 7; (14) closed shell on the left, occurrence level 1 m below top of Bed 7; (15, 16) *Fuhrbergiella archangelskyi* (Mandelstam), ×80, top of Bed 7: (15) external view of the left valve, (16) external view of the right valve; (17) *Neurocythere catephracta* (Mandelstam), external view of the right valve, ×85, top of Bed 7; (18) *Neurocythere oxfordiana* (Lutze), external view of the left valve, ×90, top of Bed 7.

Plate IV



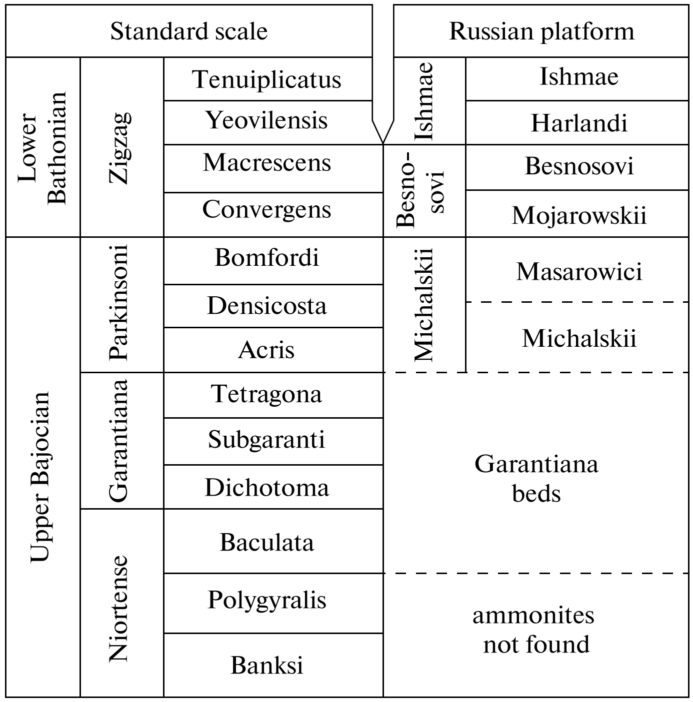


Fig. 5. Correlation of biostratigraphic units established in the Bajocian–Bathonian transition of the Russian platform with the West European standard scale.

communication with reference to works by Il'ina, 1985, and Shurygin et al., 2000), palynological spectra reproduced in the works cited above can also be the Bajocian in age. Consequently, the age of the aforementioned sequence cannot be restricted to just the Bathonian.

On the basis of structural peculiarities of the Middle Jurassic deposits studied in the Middle Volga region, we can assume that shallow-water marine sedimentation commenced here, as we think, prior to accumulation of the upper Bajocian silt-clay sequence. The Late Bajocian–Late Callovian sedimentation progressed against a background of eustatic fluctuations of sea level, being largely controlled by differentiated tectonic movements of submeridional orientation responsible in general for formation of the Ulyanovsk–Saratov basin. Precisely these movements determined the peculiarities of sedimentogenesis in the study area during the Middle Jurassic time.

The reliably established occurrence in the Ulyanovsk area of the Volga region of marine deposits correlative with the lamberti Zone of the upper Callovian (Mitta, 2003) and subsequent recognition of the upper Bajocian strata bearing ammonites of Tethyan origin place sections of the Tarkhanovskaya Pristan site into a set of middle Jurassic sections that are of prime importance for stratigraphy of the Russian Platform.

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