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Stratigraphy of Lower Volgian Deposits in the Russian Plate and Correlation between Volgian and Tithonian Stages

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Abstract—A detailed biostratigraphic scale is suggested for the Lower Volgian Substage of the Russian Plate. The *Ilowaiskya klimovi* Zone is subdivided (from the base upward) into the *Glochiceras (Lingitlaticeras) solenoides* and *Neochetoceras steraspis* beds underlying the *Glochiceras (Paralingulaticeras) lithographicum efimovi* horizon, and *Anaspidoceras neoburgense* and *Pseudovirgatites puschi* horizons are discriminated within the *Ilowaiskya pseudoscythica* Zone. Data on distribution of Submediterranean ammonites (species of *Glochiceras* s.l., *Neochetoceras, Pseudolissoceras, Anaspidoceras,* and *Pseudolissoceras* genera) in the Russian Plate are used to correlate the Lower Volgian Substage with the Tithonian in accord with the following scheme: (1) the Klimovi Zone corresponds to the lower half of the Hybonotum Zone; (2) the Sokolovi Zone is an equivalent of the upper portion of Hybonotum Zone coupled with a basal interval of the Darwini Zone; (3) the Pseudoscythica Zone ranges from the upper portion of the Darwini Zone to the top of Semiforme Zone and even through the basal part of the Fallauxi Zone so that the entire *neoburgense* horizon falls into the *Semiforme Zone.* Migration paths of thermophilic ammonites into the Central Russian Sea are depicted. Ammonites of Poland actively migrated eastward during the Klimovi Chron, in the early Sokolovi Chron, and at the moment corresponding to the *puschi* horizon. The diverse Submediterranean ammonites present in the *neoburgense* horizon point to progressing connections with the North Caucasian Basin. Species *Neochetoceras steraspis* (Oppel, 1863), *Glochiceras (Lingulaticeras) solenoides* (Quenstedt. 1849), *Pseudolissoceras* sp. ind., and new subspecies *Glochiceras (Paralingulaticeras) lithographicum efimovi* Rogov, subsp. nov., which have been found in the Russian Platform, are described for the first time. Figures of some other ammonite species important for correlation are presented as well.

Key words: lower Volgian Substage, biostratigraphy, Boreal/Tethyan correlation, ammonites, paleobiogeography.

INTRODUCTION

The problem of correlation between Volgian and Tithonian stages attracted attention of many researches, but it still remains unsolved with respect to stages as such and to their subdivisions of lower rank—substages, zones, etc. Stratigraphy of the Tithonian Stage is well elaborated now. The greater part of the stage is divided into subzones, and characteristic faunal horizons are distinguished in the lower and middle Tithonian substages of Germany. At the same time, the Volgian Stage and its lower substage, in particular, are inadequately investigated. It seems reasonable therefore to study in detail the lower Volgian deposits, which bear diverse ammonites comparable with the West European species, in order to elucidate many debatable aspects of correlation between the Volgian and Tithonian stages.

INVESTIGATION HISTORY OF LOWER VOLGIAN DEPOSITS IN THE RUSSIAN PLATE

When Nikitin (1881) originally distinguished the "Volgian Formation" (ranked as a stage later on), he placed its lower boundary between the lower Volgian and Kimmeridgian strata in their current understanding. This follows from his opinion that beds with *Amaltheus alternans* correspond to an upper part of the Oxfordian Stage and *Tenuilobatus Zone* that was considered at that time as an equivalent of the entire Kimmeridgian Stage.

Pavlow (1884, 1886) who was first to discriminate the lower Volgian deposits in the Gorodishche section (beds with *Perisphinctes bleicheri* according to Pavlow, 1896) considered them as correlative with the lower Portlandian deposits of England and France.

Close to the end of 19th century, Semenov (1896) described exposures of Kimmeridgian and lower Volgian deposits in the Orenburg region. Among many ammonites from these deposits (mostly attributed to taxa known from the Kimmeridgian of southeastern France), the early Volgian *Aspidoceras* sp. is most remarkable one (Semenov, 1896, p. 182). This ammonite from his collection stored at the Department of Historical geology, St. Petersburg State University, represents species *Anaspidoceras neoburgense* widespread in Tithonian deposits of western Europe.

Five years later, Sokolov (1901) published first work of his series devoted to the same deposits, in which he

suggested to attribute them to the "Vetlyanka Horizon." He also revised determination of ammonites described by Semenov (1896) and concluded that the Vetlyanka Horizon is transitional between the Kimmeridgian and Volgian strata. He wrote: "... my collection of fossils from the Vetlyanka Sandstone undoubtedly implies that they represent mixture of the Lower Volgian and Kimmeridgian forms" (Sokolov, 1901, p. 55).

Later on, Ilovaiskii and Florenskii (194!) distinguished the lower Ilowaiskya sokolovi and upper I. pseudoscythica Zones of the Vetlyanka Horizon and suggested to rank it as a stage in contrast to opinion of Sokolov (1921) who considered the horizon as a subdivision of the Lower Volgian Substage. Sazonov (1953, 1957) also regarded this unit as the stage, but he was against its zonal subdivisions (he pointed out that Ilovaiskii did not observe both zones in a single section). For a while, the Vetlyanka Horizon was accepted as a one-zone unit, but later on (Michailov, 1964a, 1964b, 1966, Gerasimov and Michailov, 1966) it was proved that the Lower Volgian Substage is divisible into three zones (originally, the Klimovi, Sokolovi, and Pseudoscythica Subzones). Sazonov (1961) finally joined this opinion, but he designated the lowermost subdivision of the Volgian Stage as the *Gravesia gravesiana* Zone based on this species find in the Gorodishche section, though the species have not been figured in his publication. A more detailed subdivision scheme of Lower Volgian has never been suggested despite the recurrent reexamination of the section. The only exception is the Ilowaiskya tenuicostata Zone assumed to be present, by analogy with Poland, in the Russian plate as well (Zeiss, 1983; Kutek and Zeiss, 1997). However, this viewpoint has not been properly substantiated. The sole argument in favor is presence of zonal species in sections of the Russian plate, but Mesezhnikov (1982) showed earlier that this form occurs at all levels of the Pseudoscythica Zone.

The most complete sequence of deposits under consideration is exposed in the Gorodishche section (Ul'yanovsk district of the Ul'yanovsk region) located at the right-hand bank of the Volga River (Fig. 1), where both boundaries and all three zones of the Lower Volgian Substage are established.

DESCRIPTION OF THE GORODISHCHE SECTION

The Gorodishche section is one of well known and perfectly studied Jurassic sections in the Russian plate. On the one hand, it has been under examination for more than 150 years and is one of few others accessible now. On the other hand, exactly this section is the lectostratotype of the Volgian Stage, the only Jurassic stage having the type section located in Russia.

The section was discovered in 1801 by expedition under leadership of P. Pallas, and many researchers kept it in view since the end of 19th century, at least. As the

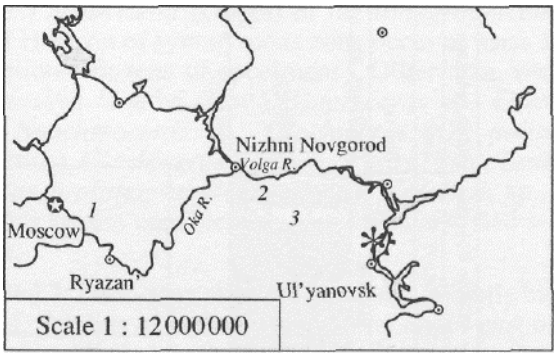


Fig. 1. Localities of studied sections; asterisk denotes the Gorodishche lectostratotype. Other sections: (/) Lopatinskii phosphorite pit 7-2'; (2) Isady; *(3)* Poretskoe.

section is sketched and described in dozens of articles and monographs, I mention below only most important works devoted to the issue.

Murchison *et al.* (1845) presented the first description of the Gorodishche section. Pavlow (1884, 1886) was first to note that it includes strata attributed now to the lower Volgian Substage. Zonov (1937, 1939) reported that deposits under consideration yield *Glochiceras fialar,* though he presumably meant *G. (Paralingulaticeras)* form. Michailov (1964a, 1964b) distinguished all three zones of the lower Volgian Substage and reported on occurrence of *Neochetoceras* and *Glochiceras* forms in the *klimovi* Zone. Soon afterward, Gerasimov and Michailov (1966) suggested to consider the Gorodishche section as the lectostratotype of the Volgian Stage.

Later on, Mesezhnikov and his colleagues (Mesezhnikov *et al.,* 1977; Mesezhnikov, 1982; Blom *et al.,* 1984) demonstrated that Haploceratidae and some other Submediterranea ammonites (e.g., *Sutneria)* occur throughout the Lower Volgian Substage. Their data have been recently confirmed, to some extent at least, in a joint publication of French and Russian researchers (Hantzpergue *et al.,* 1998).

Deposits in question are exposed over a distance of 15 km along the right steep bank of the Volga River in the Ul'yanovsk district of the Ul'yanovsk region and southern Tatarstan (area of the Ul'yanovsk water storage basin). The section part exposed near the village of Gorodishche and described below (Fig. 2) is about 3 km long.

The Upper Kimmeridgian Eudoxus Zone is composed here of gray and dense calcareous clay that locally grades into marl and yields *Aspidoceras* spp., *Aulacostephanus* ex gr. *undorae* (Pavlow), *A. yo* (Orb.), *Sutneria* aff. *cyclodorsata* (Moesch), *S.* ex gr. *eumela* (Orb.), Ochetoceratinae gen. ind. *[Ochetoceras canaliferum (Oppel)/Streblites levipictum* (Fontannes) group], *Amoeboceras* spp., *Tolvericeras sevogodense* (Contini et Hantzpergue), *Laevaptychus* spp., and *Lamellaptychus* sp. (with pyritized aptychi). The over-

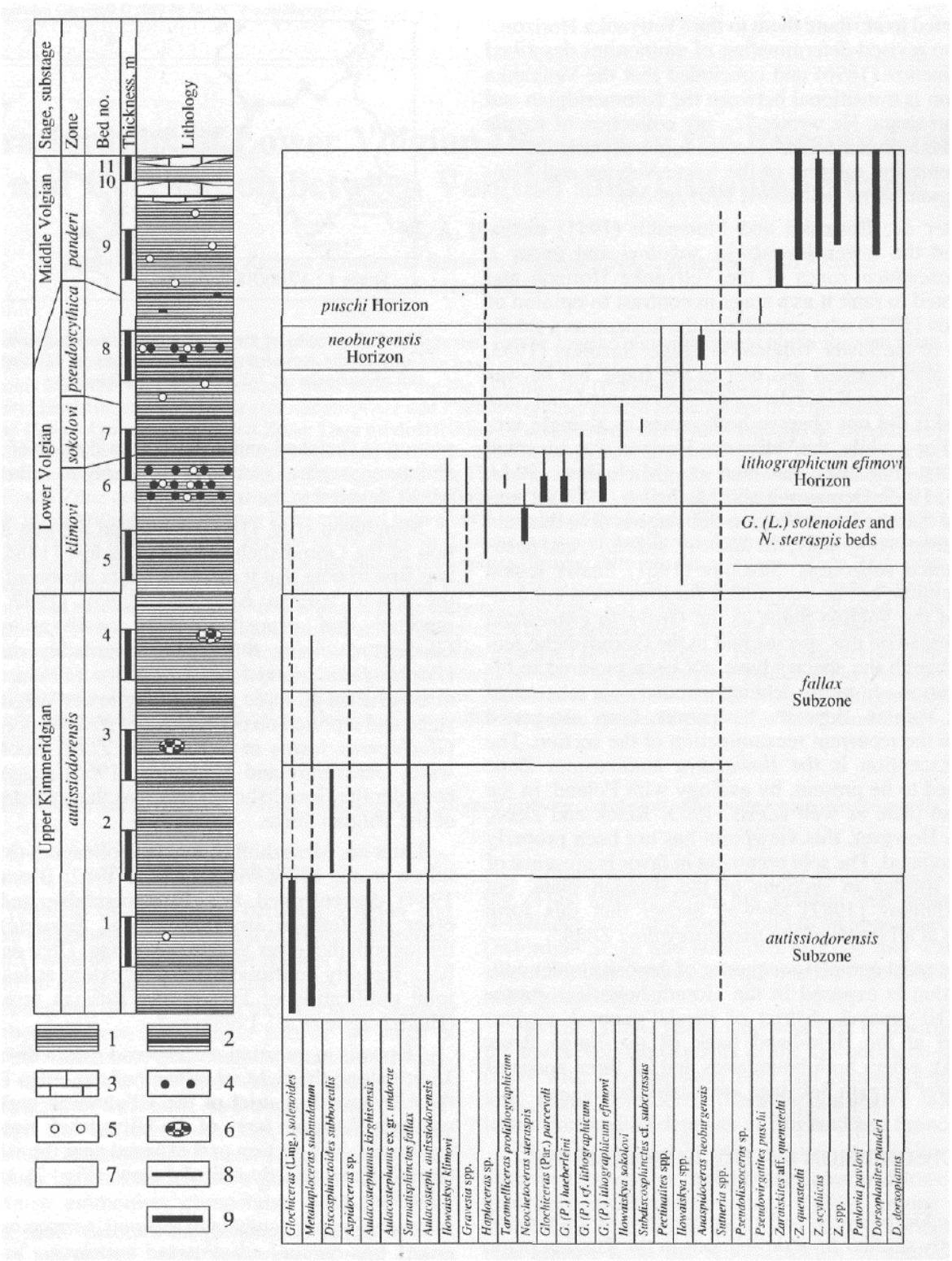


Fig. 2. Stratigraphic ranges of ammonites in the Gorodishche section; (1) clay; *(2)* alternating light-and dark-colored clay laminae; (3) marl; (4) phosphorite nodules; (5) marl nodules; (6) marcasite segregations; (7) one to five, (8) six to ten, and (9) more than ten ammonite specimens.

lying rock sequence (Fig. 2), contact with which is concealed under grassy interval about 3 m wide, is composed of the following beds (from the base upward):

Bed 1. Gray to light-gray clay; the rock is slightly bioturbated, calcareous, dense, bearing rare marl concretions. Clay yields bivalves and gastropods, *Rhab-*

docidaris spp. (spines), *Liostrea* sp., *Astarte* sp., *Buchia* sp., *Grammatodon* sp., *Eucyclus* sp., and *Laevidentalium* sp. which are frequently grouped and coexist with ammonites *Glochiceras (Glochiceras)* sp., *Glochiceras (Lingulaticeras) solenoides* (Quenst.), *Metahaploceras* ex gr. *subnudatum* (Font.), *Aspidoceras* sp., *Discosphinctoides subborealis* (Kutek et Zeiss), *D.* cf. *sublatertosus* (Ilov.), *Aulacostephanus* cf. *kirghisensis* (Orb.), *A.* ex gr. *undorae* (Pavlow), *A.* aff. *yo* (Orb.), and *Lamellaptychus* sp. of the Upper Kimmeridgian Autissiodorensis Zone and Subzone. The apparent thickness is about 1.5-2.0 m.

Bed 2. Gray clay (darker than in Bed 1); clay is calcareous, dense, slightly bioturbated, bearing abundant (especially near the base) pyritized and crushed ammonites *Aspidoceras* sp., *Aulacostephanus* ex gr. *autissiodorensis* (Cotteau), *A.* cf. *undorae* (Pavlow), *Sarmatisphinctes* cf. *fallax* (Ilov.), and *? Discosphinctoides* sp. (in the lowermost part) of the Autissiodorensis Zone (lower part of *the* Fallax Subzone). Bed is 2 m thick.

Bed 3. Alternating dark- and light-gray highly bioturbated clays bearing marcasite segregations; light-colored laminae are thicker, some up to 0.3-0.5 m thick. Mass accumulations of *Sarmatisphinctes fallax* (Ilov.) are observed in the lower part of bed. *Aulacostephanus* cf. *undorae* (Pavlow), *A.* sp., *Metahaploceras* ex gr. *subnudatum* (Font.), *Astarte* sp., and *Laevidentalium* sp. are also rather abundant. Bed is 2 m thick.

Bed 4. Gray calcareous clay; the rock is slightly bioturbated, bearing rare marcasite nodules. Bed yields abundant bivalves, gastropods, ammonites, and echinoid spines, identified among which are *Grammatodon* sp., *Astarte* sp., *Buchia* spp., *Eucyclus* sp., *Rhabdocidaris* sp., *Aulacostephanus* cf. *undorae* (Pavlow), *A.* sp., *Metahaploceras* cf. *subnudatum* (Font.), *Glochiceras (Lingulaticeras)* sp., *Aspidoceras* sp., and *Sarmatisphinctes* sp. Bed is 1.5 m thick.

Bed 5. Alternating laminae of gray dense and dark-gray bioturbated calcareous clays; some laminae are 0.1-0.2 m thick. Ammonites are usually pyritized. Occurring *Rhabdocidaris* sp., *Dicraloma* sp., and *Buchia* sp. coexist with ammonites, of the Klimovi Zone [*Glochiceras (Lingulaticeras) solenoides* and *Neochetoceras steraspis* Beds] of the lower Volgian Substage: *llowaiskya* cf. *klimovi* (Ilov.), *Gravesia* sp. ind., *Haploceras* sp., *Glochiceras (Lingulaticeras) solenoides* (Quenst.), *Neochetoceras steraspis* (Oppel) (in the upper 1-m-thick interval of the bed, *Neochetoceras* forms represent about 75% of found specimens), and *?Lamellaptychus* sp. Bed is 2.9 m thick.

Bed 6. Gray calcareous clay; bed encloses phosphorite and marl interlayers near the base and at the levels of 0.15 and 0.5 m above the base. Marcasite pseudo-morphs after ammonites can be observed sometimes. Ammonites *Glochiceras (Paralingulaticeras) parcevali* (Font.), *G. (P.)* cf. *lithographicum* (Oppel), *G.(P.) lithographicum efimovi* Rogov, subsp. nov., and *G. (P.) haeberleini* (Oppel) of the *lithographicum efimovi* horizon of synonymous zone occur as mass accumulations (dozens of specimens). Other taxa, such as *llowaiskya klimovi* (Ilov.), *Haploceras* sp., *Gravesia* sp., *Neochetoceras* sp., *Glochiceras (G.) politulum* (Quenst.), *Glochiceras (Lingulaticeras ?)* sp., *Taramelliceras prolithographicum* (Font.), *Entolium* sp., and *Buchia* sp. are considerably less abundant. Bed is 1 m thick.

Bed 7. Dark-gray clay; rock is dense, slightly bioturbated. Patches of lighter color in the upper part of the bed are still darker than the underlying clay. Ammonites *llowaiskya* cf. *sokolovi* (Ilov.) and *Subdichotomoceras* cf. *subcrassum* Mesezhn. occurring in the bed are characteristic of the Sokolovi Zone and coexist with *Buchia* sp. and *Grammatodon,* sp. Bed is 0.7 m thick.

Bed 8. Clay laminae alternating as in Bed 2; marl and less frequent marcasite nodules are dispersed throughout the bed. At the level of about 1.2 m above the base, there is an interlayer of phosphorite and marl nodules. Rare *Buchia* and *Liostrea* specimens are characteristic of the whole bed that is attributed to the Pseudoscythica Zone. Three intervals with different associations of fossils are distinguishable in the bed: (1) *llowaiskya* sp. and *? Pectinatites* sp. characterize the lower 0.5-0.7 m of the bed; (2) abundant (dozens of specimens) *Anaspidoceras neoburgense* (Oppel), *Laevaptychus (Obliquus-laevaptychus)* sp., and *llowaiskya* sp. associate with rare *Haploceras* sp., *Sutneria (S.)* ex gr. *asema* (Oppel), and *Pseudolissoceras* sp. ind. in the interval of 0.7-1.3 m above the base (the *neoburgense* horizon); (3) rare *Pseudovirgatites puschi* (Kutek et Zeiss) are typical of the upper bed portion (the *puschi* horizon). Bed is 2.2 m thick.

Bed 9. Gray calcareous clay; rock is dense, bearing abundant and small marl nodules. The bed is crowned with a lenticular marl interlayer (0.2 m thick). Remains of *Buchia* sp., *Liostrea* sp., *Entolium* sp., *Grammatodon* sp., *Oxytoma* sp., *Myophorella* sp., and *Rhabdocidaris* sp. are characteristic of the entire bed. Two ammonite assemblages are distinguished: (1) *Pavlovia* sp., *Zaraiskites quenstedti* (Rouill. et Fahrekohl) whose large forms with unmodified sculpture frequently are up to 150 mm in diameter and resemble *Pseudovirgatites puschi* (Kutek et Zeiss) from underlying bed, *Z. scythicus* (Vischn.), and *Pavlovia pavlovi* (Michalsky) are confined to the basal interval 1 m thick; (2) *Pavlovia* sp., *Acuticostites* sp., *Dorsoplanites panderi* (Orb.), *D. dorsoplanus* (Vischn.), *Zaraiskites scythicus* (Vischn.), Z. *quenstedti* (Rouill. et Fahrekohl), and *Praestriaptychus* sp. nov.[1] are typical of the upper bed portion and occur in beds 10, 11, and (?) 12. Bed is 2.4 m thick.

Bed 10. Dark-gray calcareous bioturbated clay; clay is rich in small marl nodules. *Buchia* sp., *Liostrea* sp., *"Terebratula"* sp., *Astarte* sp., *Dicraloma* sp. (abundant), *Oxytoma* sp., and *Rhabdocidaris* sp. represent

[1]The aptychi likely belong to Virgatitinae or Dorsoplanitinae.

taxa associated with ammonites characterizing the upper part of Bed 9. Bed is 0.35 m thick.

Bed 11. Light-gray calcareous clay; rock is dense, locally grading into porcelaneous marl. *Buchia* sp., *Astarte* sp., *Entolium* sp., *Serpula* sp., and *Rhabdocidaris* sp. associate in the bed with ammonites of Bed 10, except for representatives of *Pavlovia* and *Acuticostites* genera, which have not been detected (maybe it is a new assemblage). Bed is 0.3 m thick.

Bituminous shales above Bed 11 are intercalated with gray dense calcareous clay of the *panderi* Zone.

BIOSTRATIGRAPHIC SUBDIVISIONS AND CORRELATION

Ilowaiskya klimovi Zone

Index species: Ilowaiskya klimovi (Ilovaisky, 1941). Lectotype was selected by Michailov (1964) and figured by Ilovaiskii and Florenskii (1941, Pl. XXI, fig. 40).

Nomenclature: zone is distinguished and termed by Michailov (1964).

Stratotype: section of opoka-like, sometimes calcareous sandstones exposed along the Berdyanka River (Orenburg region); thickness up to 3 m.

Subdivisions: in Ul'yanovsk, Nizhni Novgorod, and southern Tatarstan areas, the unit is divisible in two parts, the upper of which can be regarded as a faunal horizon. In other regions, these subdivisions have not been recognized so far.

Glochiceras (Lingulaticeras) solenoides and *Neochetoceras steraspis* Beds

Index species: Glochiceras (Lingulaticeras) soleoides (Quenstedt, 1849); holotype was originally figured by Quenstedt (1849, Pl. 9, fig. 10) and then reproduced by Quenstedt (1887-1888, Pl. 126, fig. 8) and Ziegler (1958, Pl. 15, fig. I). *Neochetoceras steraspis* (Oppel, 1863) was selected for lectotype by Spath (1925, p. 115) and once again by Arkell (1956); original image is presented in work by Oppel (1863, Pl. 69, fig. 1) and reproduced by Arkeil (1956, Pl. 43, fig. 2), Barthel and Schairer (1977, Pl. 10, fig. 1), Schlampp (1991, Pl. 31, fig. 6), and Schlegelmilch (1994, Pl. 13, fig. 3).

Nomenclature: Beds are distinguished for the first time.

Stratotype: Gorodishche section, Bed 5 of alternating gray dense and dark-gray bioturbated calcareous clay laminae (some up to 0.1-0.2 m thick); bed is 2.9 m thick.

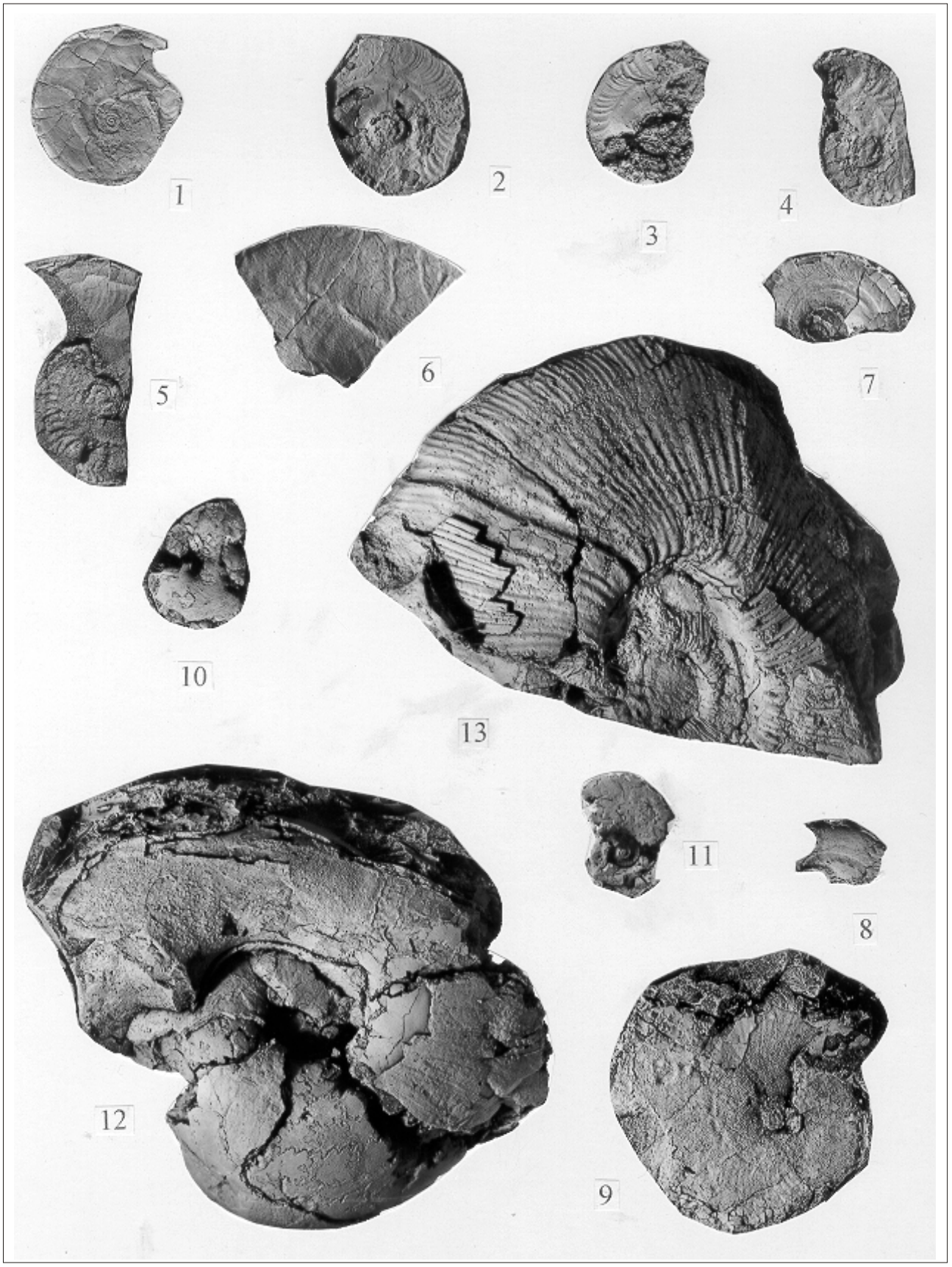
Locality: Volga River, village of Gorodishche (Bed 5).

Ammonites: Ilowaiskya klimovi (Ilov.), *Gravesia* sp., *Neochetoceras steraspis* (Oppel) abundant close to the beds top, and *Glochiceras (Lingulaticeras) solenoides* (Quenstedt). Occurrence of *Haploceras* sp. has been also mentioned (Mesezhnikov *et al,* 1977; Blom *et al.,* 1984;Olfer'ev, 1997; Hantzpergue *et al,* 1998), but images of these forms have never been published.

Boundaries: The lower one corresponds to the first occurrence level *of Ilowaiskya* and *Neochetoceras* species, where *Sarmatisphinctes* forms and *Metahaploceras rebouletianum* (Font.) disappear. The upper boundary marks appearance of *Glochiceras (Paralingulaticeras)* spp. and extinction of *G. (Lingulaticeras) solenoides* (Quenst.). A considerable decrease in abundance of *Neochetoceras* spp. takes place at the same level.

Lower Volgian ammonites from Ihe Russian plate:

(1) *Glochiceras (Lingulaticeras) solenoides* (Quenstedt, 1849), specimen SGM-572-2, Isady site (Lyskovo district, Novgorod region), upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone: (2) *G. (Paralingulaticeras) lithographicum efimovi* Rogov, subsp. nov., holotype SGM-572-11. right side of the Volga River, Gorodishche site (Ul'yanovsk district. Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (3) *G. (P.)* cf. *lithographicum* (Oppel, 1863), specimen SGM-572-21, right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (4) *G. (P.) haeberleini(Oppel,* 1863), specimen SGM-572-3, right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (5) *Taramelliceras prolithographicum* (Fontannes, 1879); specimen SGM-572-6; right side of the Volga River, Gorodishche site (Ul'yanovsk district. Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (6) *G. (P.)* cf. *nodosum* (Berckhemcr in Ziegler, 1958), specimen SGM-572-5, left side of the Sura River. Poretskoe site (Poretskoe district of Chuvashia), Lower Volgian Substage, Klimovi Zone, (?) *lithographicum efimovi* horizon; (7) *G. (P.)* cf. *parcevali* (Fontannes, 1879). specimen SGM-572-1, right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (8) *G. (G.)* cf. *politulum* (Quenstedl, 1858). specimen SGM-572-4, right side of the Volga River. Gorodishche site (Ul'yanovsk district. Ul'yanovsk region), Lower Volgian Substage. Klimovi Zone, *lithographicum efimovi* horizon; (9) *Neochetoceras steraspis* (Oppel, 1863), specimen SGM-572-22. right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *Glochiceras (Lingulaticeras) solenoides and Neochetoceras steraspis* Beds: (10) *Pseudolissoceras* sp. ind., specimen SGM-572-10; right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage. Pseudoscythica Zone, *neoburgense* horizon; (11) *Haploceras* sp. ind., specimen SGM-572-7 (x2), right side of the Volga River, Gorodishche site (Ul'yanovsk district. Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon; (12) *Anaspidoceras neoburgense* (Oppel, 1863), specimen SGM-572-25, right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Pseudoscythica Zone, *neoburgense* horizon; (13) *Pseudovirgatites puschi* (Kutek et Zeiss, 1974). specimen SGM-572-24, right side of the Volga River, Gorodishche site (Ul'yanovsk district, Ul'yanovsk region); Lower Volgian Substage, Pseudoscythica Zone, *puschi* horizon.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Remarks: In the Russian Plate, the beds are distinguishable in the Gorodishche section, because occurrence of *Neochetoceras* forms is established only here. In distinction from the overlying *Glochiceras (Paralingulaticeras) lithographicum efimovi* horizon, the ammonite assemblage of the beds shows the other *Neochetoceras/Glochiceras* ratio and absence of reliably identified *Glochiceras (Paralingitiaticeras)* species. Succession of Haploceratidae forms occurring in the beds and overlying *Glochiceras (Paralingulaticeras) lithographicum efimovi* horizon is very similar to that established in many West European sections. In Ardéche (France) and Franconian Alb (southwestern Germany), Haploceratidae usually appear in sections in the same succession: first *Neochetoceras steraspis* (Oppel) and higher (or concurrently sometimes) *Glochiceras (Paralingulaticeras) lithographicum* (Oppel) (Hölder and Ziegler, 1959; Zeiss, 1977).[2] It is also remarkable that *Neochetoceras* species coexist with *Glochiceras (Paralingulaticeras)* forms, unknown above the top of the Hybonotum Zone, at higher stratigraphic levels of West European sections and represent noticeable components of ammonite assemblages up to the terminal Middle Tithonian. In the Russian plate, only rare *Neochetoceras* specimens are recorded above the beds under discussion.

The *Glochiceras (Lingulaticeras) solenoides* and *Neochetoceras steraspis* Beds do not correspond to range charts of both species. These beds do not correspond as well to the range of the N. steraspis Zone distinguished in some sections of Germany (Hahn, 1963) and East Africa (Spath, 1925).

Correlation. The beds are correlative with the lower part of the Hybonotum Zone. Since all species occurring in the beds of the Russian plate are also known in western and eastern Europe, they offer a possibility to precisely correlate the beds with the Submediterranean subdivisions. In the Swabian Alb (Germany), the *Neochetoceras steraspis-Glochiceras (Lingulaticeras) solenoides* assemblage appears, together with single G. *(Paralingulaticeras) lithographicum,* in the *riedlingensis* horizon of the Lower Tithonian Hybonotum Zone. At the same time, species *Neochetoceras praecursor* is characteristic of the basal *eigeltingense* horizon of the Tithonian (Schweigert, 1996). It likely therefore that analogues of the *eigeltingense* horizon can be found in the lower part of Bed 5 of the Gorodishche section, where ammonites are rare.

Glochiceras (Paralingulaticeras) lithographicum efimovi Horizon

Index subspecies: Glochiceras (Paralingulaticeras) lithographicum efimovi Rogov, subsp. nov.; holotype is figured in this work (Plate, fig. 2).

Nomenclature: horizon is distinguished for the first time.

Stratotype: Gorodishche section, Bed 6 of gray calcareous clay with interlayers of phosphorite and marl nodules near the base and at the levels of 0.15 and 0.5 m above the base; local marcasite segregations (pseudomorphs after ammonites) are also present in the bed.

Localities: Volga River, village of Gorodishche (Bed 6); Sura River, village of Poretskoe.

Ammonites: llowaiskya klimovi (Ilov.), *Neochetoceras* cf. *steraspis* (Oppel), very rare *Taramelliceras prolithographicun* (Font.), *Glochiceras (Paralingulaticeras) haeberleini* (Oppel), G. *(P.)* cf. *nodosum* Berckhemer in Ziegler, *G. (P.) parcevali* (Font.), G. *(P.) lithographicum efimovi* Rogov, subsp. nov. [all representatives of the subgenus *Glochiceras (Paralingulaticeras)* occur in abundance], *Glochiceras (G.) politulitm* (Quenst.), *G. (Lingulaticeras?)* sp., *Gravesia* sp., and *Haploceras* sp.

Boundaries. The lower one corresponds to the disappearance level of *G. (Lingulaticeras) solenoides* (Quenst.), where *Glochiceras (Paralingulaticeras)* forms become very abundant in contrast to rare occurrence of *Neochetoceras* sp. The upper boundary marks appearance *of Ilowaiskya sokolovi* (Ilov.) in association with *I. pavida* (Ilov.) and disappearance of *Neochetoceras* species; *Glochiceras (Paralingulaticeras)* forms are rare at this level.

Remarks. As is already noted, diagnostic features of the horizon are the abundance of *Glochiceras (Paralingulaticeras)* forms, absence of *G. (Lingulaticeras) solenoides,* and sporadic *Neochetoceras* species. Presence of indicative subspecies is unnecessary for the horizon recognition in particular sections. For instance, the horizon was distinguished in outcrops of lower Volgian deposits near the village of Poretskoe (synonymous district of Chuvashia) based on association of *llowaiskya klimovi* (Ilov.) with abundant *Glochiceras (Paralingulaticeras) haeberleini* (Oppel), G. *(P.) lithographicum* (Oppel) and G. *(P.)* cf. *nodosum* Berckhemer in Ziegler.

Correlation. The horizon corresponds to the greater upper part of the Moernsheimensis Subzone of the Hybonotum Zone except for the uppermost interval of the former. The horizon base is likely corresponding to the base of the Franconian Lithographicum Subzone (Barthel, Schairer, 1978) that marks the appearance of the *Taramelliceras prolithographicum-Glochiceras lithographicum* assemblage. The *Glochiceras (Paralingulaticeras)* species abundant in the unit imply that it is correlative to some extent with the Mörnsheimer Schichten of the Franconian Alb. These species are known, however, from the Sokolovi Zone as well, and it is possible to assume that terminal parts of the Hybonotum Zone and Mornsheimensis Subzone correspond to

[2] In Franconian Alb (southwestern Germany), stratigraphic ranges *of Glochiceras (Paralingulaticeras) lithographicum* and *Neochetoceras steraspis* are almost identical, but the first form is rare in the lower part and abundant in the upper one of the Malm ζ2 section (Zeiss, 1964. 1968).

the lower part of the Sokolovi Zone. Accordingly, the Klimovi Zone is lesser in range than the Hybonotum Zone. Despite the common opinion that they are equivalent in this aspect, the coincidence of their upper boundaries has never been substantiated. For instance, Kutek and Zeiss (1997) who studied the Volgian Stage of Poland argued for the identical ranges of both zones. They based their opinion on range chart of *Neochetoceras* in sections of Poland and Germany. In Germany, the greater part of the Hybonotum Zone yields *N. steraspis* (Oppel), which coexists in its upper interval with the newly appearing *N. mucronatum* Berckhemer et Hölder, the species that survived almost till the end of the Early Tithonian. In contrast, *N. steraspis* has never been found above the Hybonotum Zone. In Poland, *N. steraspis* is known from the Klimovi Zone only, the upper interval of which yields first specimens of *N. mucronatum* known as well from the Sokolovi Zone. Accordingly, Kutek and Zeiss based their correlation on the disappearance, but not on appearance of the indicative taxon, and their results seem insufficiently credible, especially if we take into account that they predominantly analyzed the core sections.

The considered version is incompatible with occurrence of *Glochiceras (Parolingulaticeras)* in the Sokolovi Zone that is established in the Gorodishche section (Mesezhnikov *et al,* 1977; Blom *et al.,* 1984) and in Poland *(Ochetoceras* or *Taramelliceras* in Kutek and Zeiss, 1997, Plate 31, fig. 6). Representatives of subgenus *Glochiceras (Paralingulaticeras)* have never been detected above the top of the Hybonotum Zone, which does not correspond therefore to the top of the *lithographicum efimovi* horizon.

Ilowaiskya sokolovi Zone

Index species: Ilowaiskya sokolovi (Ilovaisky, 1941); lectotype was selected by Michailov (1964) and figured by Ilovaiskii and Florenskii (1941, Plate VIII, fig. 18).

Nomenclature: a zone corresponding to summary range of the Klimovi and Sokolovi Zones was distinguished and termed by Ilovaiskii and Florenskii (1941); in its current range, it was first considered by Michailov (1964a).

Stratotype: section up to 3 m thick of opoka-like, sometimes calcareous gray sandstones exposed along the Sukhaya Peschanka River (Orenburg region).

Localities: Volga River, village of Gorodishche (Bed 7), and sections in the Orenburg region and Poland.

Ammonites: Ilowaiskya cf. *sokolovi* (Ilov.), *Subdichotomoceras* cf. *subcrassum* Mesezhn., and *Ilowaiskya pavida* (Ilov.), *Glochiceras (Paralingulaticeras)* cf. *parcevali* (Font.), *G. (P.)* cf. *lithographicum* (Oppel), *Haploceras (Haploceras)* cf. *elimatum* (Oppel), and *Sutneria* sp. known from publications (Mesezhnikov *et al.,* 1977; Blom *et al,* 1984; Gerasimov *et al,* 1995; Olfer'ev, 1997). In collection of Mesezhnikov that is not included in the VNIGRI catalog, I found samples with labels indicating their origin from the Sokolovi Zone of the Gorodishche section. Several samples (Exposure 12, field nos. 148, 150,154, and 155) enclose abundant *Glochiceras (Paralingulaticeras)* ex gr. *lithographicum* and small poorly sculptured ammonites, which have been considered by Mesezhnikov, I guess, as representatives *of Haploceras* and *Glochiceras* genera. In their sculpturing, the latter resemble the juvenile *Neochetoceras*. Lithological peculiarities of samples suggest that they were collected from the lower part of the Sokolovi Zone. If range chart of *Glochiceras (Paralingulaticeras* will be known more precisely, the Sokolovi Zone can be divided into subunits.

Boundaries. The lower one marks appearance of *Ilowaiskya sokolovi* (Ilov.) and disappearance of *Ilowaiskya klimovi* (Ilov.) and *Gravesia* spp. The upper boundary corresponds to first occurrence level of *Ilowaiskya pseudoscythica* and *Pectinatites* spp. and marks simultaneously the disappearance of *Ilowaiskya sokolovi* (Ilov.) and *I. pavida* (Ilov.)

Correlation. The zone corresponds to an upper part of the Hybonotum Zone coupled with a lower portion of the Darwini Zone. The partial overlapping of Hybonotum and Sokolovi zones was demonstrated above. I place its upper boundary in the Darwini Zone with due regard for the known fact that *Ilowaiskya* cf. *pseudoscythica* (Ilov.) (index species of the overlying zone) coexists with *Virgatosimoceras albertinum* (Cat.) that is the index species of the Darwini/Albertinum Zone in Bed 22 of the Neuburg section of Germany (bed number after Jeletzky, 1989). A form close in morphology to *I. pseudoscythica* is also known from the upper part of the Lower Tithonian (Zeiss, 1968, p. 116).

I should mention that many researchers consider the Sokolovi Zone as an equivalent of the Darwini Zone so that its upper boundary simultaneously separates the Lower and Middle Tithonian. The only argument in favor of this viewpoint is a comparison of distribution ranges of *Neochetoceras mucronatum* Berckhemer et Hölder in sections of Franconian Alb (Germany) and Poland. According to Kutek and Zeiss (1994, 1997), this species is known above the Sokolovi Zone in Poland and within the interval from the upper part of Hybonotum Zone to the top of the Lower Tithonian in Germany. Accordingly, they correlate the Sokolovi and Darwini Zones assuming that stratigraphic ranges of *Neochetoceras mucronatum* Berckhemer et Hölder and its disappearance levels are concurrent in both regions. At the same time, it is well known that a given species may occur at various stratigraphic levels in different regions, and the considered correlation scheme based on distribution of sole species seem to be insufficiently correct. The zone under consideration is well correlative with the Subcrassum Zone of the Subpolar Urals. On the one hand, the Subcrassum Zone yields here

Ilowaiskya cf. *sokolovi* (Ilov.) (Michailov, 1964a), and on the other hand, species *Subdichotomoceras* cf. *subcrassum* Mesezhn. are known from the Sokolovi Zone of the Ulyanovsk region.

Ilowaiskya pseudoscythica Zone

Index species: Ilowaiskya pseudoscythica (Ilovaisky, 1941); lectotype was selected by Michailov (I964a) and figured by Ilovaiskii and Florenskii (1941, Pl. XVI, fig. 31).

Nomenclature: zone was distinguished by Ilovaiskii and Florenskii (1941).

Stratotype has not been indicated. In the stratotype area, the Vetlyanka River section is composed of gray to yellowish gray sandstones up to 4.5 m thick.

Subdivisions. Two faunal horizons appear to be distinct in the upper part of the zone. List of ammonites known from publications and absent in my collection includes the following forms: *Ilowaiskya schaschkovae* (Ilov.)[3] *"Pseudovirgatites" arkelli* (Michailov), *Glochiceras* sp., and *Neochetoceras* sp. (Mesezhnikov *et al.,* 1977; Blom *et a*/., 1984; *Urufttsirovannaya...,* 1993).

Anaspidoceras neoburgense Horizon

Index species: Anaspidoceras neoburgense (Oppel, 1863); lectotype (erroneously attributed to holotype in Zeiss, 1968) is figured in Oppel, 1863 (Pl. 58, fig. 5) and in Schlampp, 1991 (Pl. 26, fig. 3), and neotype is figured by Schlegelmilch (1994, Plate 72, fig. 4).

Nomenclature: horizon is distinguished for the first time.

Stratotype: Gorodishche section, middle part of Bed 8 (interval of 0.7-1.3 m above the base) that is composed of gray and dark-gray laminae of calcareous clay. Marl nodules and less frequent marcasite segregations are dispersed throughout the bed. The remarkable interlayer of small (up to 10 cm in diameter) phosphorite and marl nodules is located at the level of 1.2 m above the base of Bed 8.

Localities: Gorodishche site, middle part of Bed 8; Orenburg region; and rare redeposited specimens of *Anaspidoceras neoburgense* (Oppel) in the abandoned Lopatinskii phosphorite pit of the Moscow region. Sazonov (1962) mentioned occurrence of these species in the Zvenigorod district but did not present their images in his publication.

[3] Kutek and Zeiss (1997) suggested to attribute this species to the genus *Isterites.* The *Ilowaiskya schaschkovae* lectotype selected by Michailov (see in Ilovaiskii and Florenskii. 1941, Pl. XIX. figs. 37 and 37a) has, however, the following features untypical of *Isterites*: distinct constrictions and frequent bipartite ribs in the upper part of whorl, when shell is about 100 mm in diameter. These features and occurrence of taxa in different regions *(Isterites* in Germany and Poland, *Ilov. schaschkovae* in Orenburg region and Komi Republic of Russia) allow me to think that species in question belongs to *Ilowaiskya,* but not to *Isterites.*

Ammonites: abundant *Anaspidoceras neoburgense* (Oppel), *Laevaptychus {Obliquuslaevaptychus)* sp., *Ilowaiskya* sp., rare *Sutneria (S.)* ex gr. *asema* (Oppel), and *Pseudolissoceras* sp. ind.

Boundaries. The lower boundary marks appearance of *Anaspidoceras neoburgense* (Oppel) and *Laevaptychus (Obliqiiuslaevaptychus)* sp. The upper one corresponds to appearance level of *Pseudovirgatites puschi* (Kutek et Zeiss) and marks disappearance of *Anaspidoceras neoburgense* (Oppel) and *Laevaptychus (Obliquuslaevaptychus)* sp.

Remarks. In the Russian plate, the horizon defines stratigraphic range of *Anaspidoceras neoburgense* (Oppel). Gerasimov *et al.* (1995) considered this species as characteristic of the entire *pseitdoscythica* Zone. My reexamination of the Gorodishche section in 1999 and 2000 showed, however, that these ammonites and specimens of *Laevaptyctins* occur in the middle part of the zone only. Single finds of *Anaspidoceras neoburgensis* (Oppel) have been also reported from other sites of Moscow and Orenburg regions, though their exact position in sections is unknown (Semenov, 1896; Sokolov, 1903; Ilovaiskii and Florenskii, 1941; Sazonov, 1953). It seems reasonable to think that these thermophilic ammonites appeared in the Russian plate (like *Neochetoceras, Sutneria,* and *Glochiceras*) during the relatively short phase of warming. Actually, ammonite assemblages of Klimovi, Sokolovi, and Pseudoscythica (lower part) Zones are very similar in European Russia and platform part of Poland, but analogues of *neoburgense* horizon have never been detected in Poland, where warm-water ammonites, except for *Pseudovirgatites* and *Isterites*, do not occur above the Sokolovi Zone. Consequently, it is possible to assume that Submediterranean ammonites migrated in the Russian plate from the Caucasus, where representatives of *Glochiceras* and *Neochetoceras* genera ("*Oppelia strambergensis*" in Khudyaev, 1932, and in Khimshiashvili, 1957) are known, in association with *Aspidoceras* (Khimshiashvili, 1989) and *Sutneria* species (Khalilov and Abdulkasumzade, 1969), from the Middle Tithonian.

Correlation. In western Europe (Germany, Poland, Spain) and northern Africa, first *Anaspidoceras neoburgense* (Oppel) appear in the Hybonotum Zone and become abundant in Darwini and Semiforme Zones (Barthel, 1975; Kutek and Wierzbowski, 1986; Jeletzky, 1989; Checa and Olóriz, 1984; Benzaggagh, 2000). Only in Spain (Enay and Geyssant, 1975), this species was detected in the basal Berriasian Jacobi/Grandis (=Euxinus*)* Zone. In addition, the species is abundant in the Semiforme Zone of Hungary (Fözy, 1988). Checa *et al* (1986) established that there is a noticeable hiatus in the distribution range of *Anaspidoceras neoburgense* (Oppel): above the Middle Tithonian Burckhardiceras Zone, the species appears again in the Berriasian strata only. *Anaspidoceras* abundant in the Semiforme Zone of western Europe

suggest that the *neoburgense* horizon of the Russian Plate can be correlative, at least partially, with that zone, although its correlation with the Darwini Zone is also possible. In the Franconian Alb (Germany), it likely corresponds to a part of the Ciliata Zone, the lower *penicillatum* and *ciliata* horizons of which yield *A. neoburgense* (Oppel) (Scherzinger and Schweigert, 1999). It is impossible to correlate the *neoburgense* horizon with younger Middle Tithonian subdivisions above the Semiforme Zone, although rare specimens of this species occur even here. The fact is that the Panderi Zone of the Russian plate yields representatives of *Glochiceras, Pseudolissoceras,* and *Sutneria* genera, which are unknown above the Fallauxi Zone of western Europe.

Pseudovirgatites puschi Horizon

Index species: Pseudovirgatites puschi (Kutek et Zeiss, 1974); holotype is figured in Kutek and Zeiss (1974, Pl. 11, figs. 1 and 4), and refigured by Malinowska *et al*. (1980, Pl. CUV, fig. 1; 1988, Pl. CLIV,fig. 1).

Nomenclature: In the Russian plate, the horizon is distinguished for the first time. Kutek and Zeiss (1974) established the Puschi Subzone in the Brzostówka clay quarry near Tomaszów Mazowiecki (Poland), but later on the unit index species was changed for *llowaiskya tenuikostata.*

Stratotype: Gorodishche section, the upper 0.9-m-thick part of Bed 8 that is composed of alternating gray and dark-gray laminae of calcareous clay bearing rare marl and marcasite nodules. Stratotype of the Puschi Zone corresponds to beds "a-1" (marl 0.4 m thick) and "a-2" (calcareous clay 6 m thick) in Brzostówka clay quarry near Tomaszów Mazowiecki (Poland).

Localities: Gorodishche site, upper part of Bed 8, and presumably some sections in Orenburg region.

Ammonites: Pseudovirgatites puschi (Kutek et Zeiss).

Boundaries. The lower boundary marks appearance of *Pseudovirgatites puschi* (Kutek et Zeiss) and disappearance of *Anaspidoceras neoburgense* (Oppel) and *llowaiskya* spp. The upper one, above which *Pseudovirgatites* forms disappear, corresponds to the first occurrence level of *Pavlovia pavlovi, Zaraiskites* ex gr. *quenstedti* (Rouill. et Fahrekohl), and *Z. scythicus* (Vischn.)

Remarks. Representatives of the genus *Pseudovirgatites,* the descendants of genus *llowaiskya* (Kutek and Zeiss, 1974, 1975, 1997; Kutek, 1994), appear in the Tenuicostata Zone of Poland. In distinction from *llowaiskya* and *Zaraiskites* forms, they show the low position of rib bifurcation points in their inner whorls and smoothened sculpturing in the middle of lateral sides of some large shells (more than 150 mm in diameter). Kutek (1994) and Kutek and Zeiss (1997) attributed to the genus *Pseudovirgatites* the ammonites originally described as *Pectinatites (Wheatleyites) arkelli* Michailov (Michailov, 1964). Under this name, Michailov described fragments of large (about 200 mm in diameter) ammonites, position of rib bifurcation points in which has not been established because of a poor preservation of fossils. Nevertheless, smooth sculpturing in the middle of lateral sides indicates that these ammonites are similar to some *Pseudovirgatites*. In Poland, representatives of this genus appear in the Tenuicostata Zone approximately correlative with the *puschi* horizon, and their occurrence in the Vetlyanka River section implies that this horizon can be established in Orenburg region. *Pseudovirgatites puschi* (Kutek et Zeiss) is distributed throughout the Tenuicostata Zone, but nothing proves the same stratigraphic range for this species in Russia.

Correlation. None of ammonites from the *puschi* horizon can be used to correlate this with the Tithonian, because *Pseudovirgatites* representatives are known from the Middle-Upper Tithonian interval of western Europe, and species *P. puschi* (Kutek et Zeiss) is unknown outside Poland and Russia. Any conclusion about possible relationships between the *puschi* horizon and Tithonian subdivisions can be inferred only from correlation of underlying and overlying beds. As stated above, the Panderi Zone yields representatives of Tethyan ammonite genera, which do not occur above the Fallauxi Zone, and the *puschi* horizon should be correlated consequently with the boundary beds between the Semiforme and Fallauxi Zones. The more precise correlation could be based on distribution of Haploceratidaes, if they will be found at this level that is quite possible, because they are known from underlying and overlying deposits.

EARLY VOLGIAN PALEOGEOGRAPHY OF THE RUSSIAN PLATE, AMMONITE MIGRATION PATHS, AND DYNAMICS OF CHANGES IN AMMONITE ASSEMBLAGES

A considerable similarity between Lower Volgian ammonite assemblages of Poland and Russia implies that ammonites migrated at that time between these two regions. Conclusions on paleogeography and migration paths of ammonites, whish are presented below, are based on their distribution in sections of the Russian Plate and adjacent territories only.

[4] Bed indices after Kutek and Zeiss (1974, 1975) and Kutek (1994).

[5] Kutek and Zeiss (1974) described three subspecies of these ammonites. Specimen from the Gorodishche section corresponds to nominal subspecies most similar to an early form from Bed a-1 of the Brzostówka section in Poland that was figured by Kutek and Zeiss (Pl. 13. fig. 2).

[6] Ammonite *llowaiskya* sp. nov. aff. *sokolovi* f. D (Pl. XIV, fig. 29 in Ilovaiskii and Florenskii, 1941) that was included by Michailov in the species synonymy shows a high position of rib bifurcation points that is untypical of *Pseudovirgarites* forms.

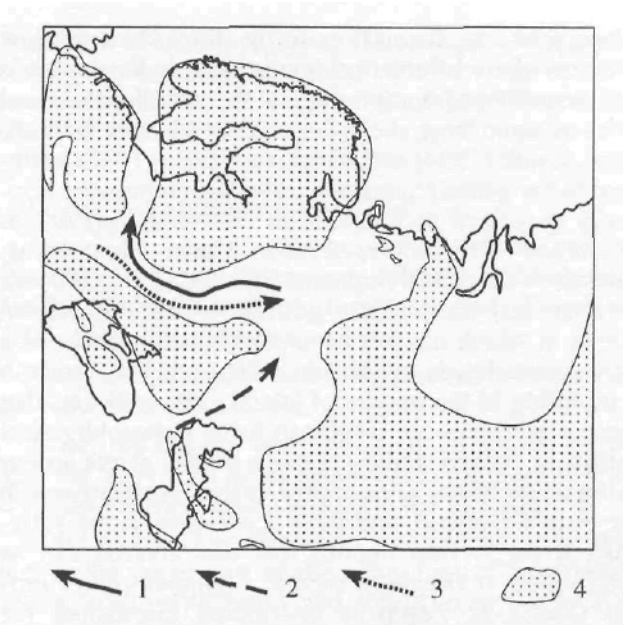


Fig. 3. Paleogeography of the Russian plate and inferable migration paths of ammonites during the early Volgian time (land and sea areas after Thierry. 2001, simplified). Migration palhs: (I) Boreal ammonites: (21 Tethyan ammonites at the *lithographicum eftmovi* and *neoburgensis* times: (3) Tethyan ammonites at the *ktimovi-sokolovi* and *puschi* times; (4) land.

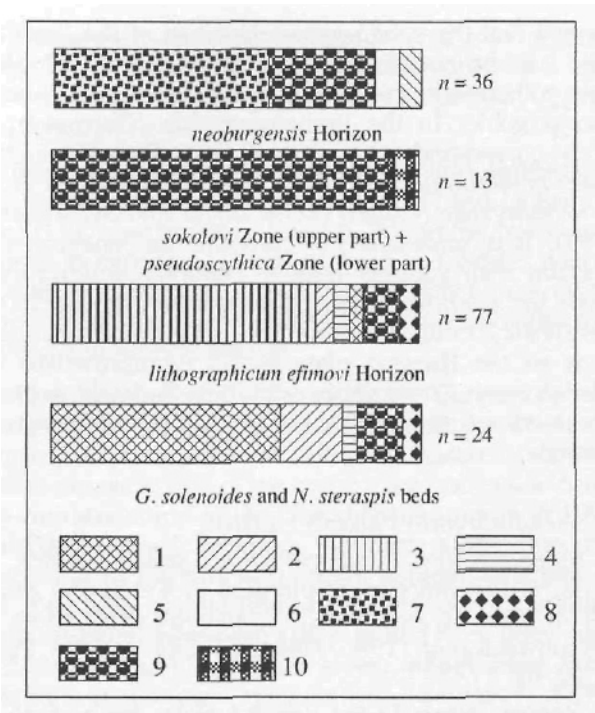


Fig. 4. Dynamics of changes in the Early Volgian ammonite assemblages of the Gorodishche section (original observations of 1999 and 2000. data of Mesezhnikov for the lower part of the Sokolovi Zones are excluded from calculations): (I) *Neochetoceras;* (2) *Glochiceras* (s. str. + *Lingulaticeras):* (3) *Glochiceras (Paralingulaticeras)* + *Taramelliceras;* (4) *Haploceras;* (5) *? Pseudolissoceras;* (6) *Sutneria;* (7) *Anaspidoceras;* (8) *Gravesia;* (9) *Ilowaiskya* + *Pectinatites;* (1O) *Subdichatomoceras.*

Distribution patterns of ammonites in the Russian Plate and Platformal part of Poland suggest that the Central Russian Sea influenced the Polish Basins throughout the Early Volgian period and at the beginning of the Middle Volgian time, whereas ammonites from Poland were able to migrate eastward in particular Chrons only. Ammonite assemblages of the Klimovi and Sokolovi Zones (Fig. 3) are very similar in Poland and Russia, and this implies existence at that time of the Pripyat' strait (term from Sazonova and Sazonov, 1967) that favored migration of thermophilic ammonites to the east and opposite migration of *Ilowaiskya*. For the episode corresponding to the *lithographicum eftmovi* horizon, we should admit the additional influence of the North Caucasian Basin, the cradle of migrants representing genera *Glochiceras (Paralingilaticeras)* and *Taramelliceras* absent in Poland. At the end of the Sokolovi Chron, the cold-water Central Russian Sea was more influential than Polish Sea, because *Ilowaiskya* still migrated to the west, but *Neochetoceras* species were unable to penetrate eastward. This situation lasted till the period of *puschi* horizon. It is reasonable to expect that abundant Tethyan ammonites penetrated in the Russian sea at the *neoburgense* hemera from the North Caucasian Basin, because Polish Sea was lacking at that time the thermophilic ammonite taxa other than perisphinctids.

The last event suggesting influence of Polish sea is penetration of *Pseudovirgantes* species in the Central Russian Sea at the end of the Pseudoscythica Chron (*puschi* horizon). Afterward, till the end of the Middle Volgian Panderi Chron, abundance of thermophilic ammonites was gradually decreasing here, and Tethyan forms penetrated once again in the Central Russian sea only at the terminal Berriasian time.

Dynamics of changes in ammonite assemblages from the Gorodishche section (Fig. 4) illustrates fluctuating abundance of Tethyan taxa (Haploceratacea, Aspidoceratidae, and Pseudovirgatites forms) in ammonite assemblages of the Early Volgian time. One can easily see that these taxa are abundant at two stratigraphic levels: in the Klimovi Zone and *neoburgense* horizon (Pseudoscythica Zone). Sharp changes in abundance of thermophilic ammonites likely reflect changes in the general paleogeographic situation over the Russian Plate (changes in thermal regime, first of all), because lithology and composition of benthic fossils change insignificantly throughout the substage.

Description of Ammonites

The Lower Volgian representatives of superfamily Haploceratacea, which are described below, are mentioned in various publications on stratigraphy, but they have never been pictured and properly characterized. In

addition, the described species are extremely important for the Boreal-Tethyan correlation.

Used abbreviations: (D) shell diameter; (DU) diameter of umbilicus; (H) lateral height of whorl; (T) thickness of whorl.

Size groups of shells: small (40 mm and less in diameter); medium-sized (40-80 mm in diameter); large (more than 80 mm in diameter).

Morphological groups of shells: discoid (T/D less than 20%); flattened (T/D 20-30%); medium-thick (T/D 30-40%).

Character of umbilicus: wide (DU/D more than 50%); moderately wide (DU/D 25-50%); moderately narrow (DU/D 17-25%); narrow (DU/D less than 17%).

Abbreviated names of institutions where the type material is stored: (SGM) Vernadsky State Geological Museum, Moscow, author's collection; (BSM) Bayerische Staatssammlung für Paläontologie und historische Geologie, München, Germany; (GPIT) Geologisch-Paläontologisches Institut der Universität Tübingen, Germany.

Superfamily HaploceratacceaeZittel, 1884

Family Oppeliidae Bonarelli, 1894 Genus

Neochetoceras Spath, 1925

Neochetoceras steraspis (Oppel, 1863)

Plate, fig. 8

Ammonites steraspis: Oppel, 1863, p. 251, Plate 69, figs. 1-3 and 5-7.

Ammonites bous: Oppel, 1863, p. 252, Plate 70, fig. 1-

Neochetoceras steraspis: Basse, 1952, Plate VIII, fig. 4; Arkell, 1956, Plate 43, fig. 2; Berckhemer and Holder, 1959, p. 103; Holder and Ziegler, 1959, p. 203, Plate 22, fig. 5; Arkell, 1961, Plate XLIII, fig. 2; Barthel and Schairer, 1977, p. 107, Plate 9, figs. 5-7, Plate 10, figs. 1-7; Barthel and Schairer, 1978, p. 15, Plate 2, fig. 3; Ohmert and Zeiss, 1980, p. 41, Plate 13, figs. 4 and 5; Schlampp, 1991, Plate 31, fig. 6; Schlegelmilch, 1994, p. 44, Plate 13, fig. 3; Schweigert, 1996, Plate 3, fig. 5; Kutek and Zeiss, 1997, Plate 29, figs. 2-8.

Neochetoceras sp. aff. *steraspis:* Myczynski, 1989, Plate 1, figs. 6, 8-10.

Lectotype: specimen BSM As VI 5b figured by Oppel (1863, Plate 69, fig. 1), Germany, Solnhofen; Lower Tithonian, Solnhofener Schichten, Hybonotum Zone; selected by Spath (1925, p. 115) and once again by Arkell (1956); reproduced by Arkell (1956, Plate 43, fig. 2), Arkell, 1961, Plate XLIII, fig. 2; Barthel and Schairer (1977, Plate 10, fig. 1), Schlampp (1991, Plate 31, fig. 6), and Schlegelmilch (1994, Plate 13, fig. 3).

Morphology: small to medium-sized discoid shell with narrow umbilicus and gentle umbilical shoulder.

Dimensional parameters (mm) and ratios (%)

Specimen no.	T	H	D	DU	T/H	T/D	H/D	DU/D
SGM-572-25	26.2	46.2	6.7		57	14		

Upper parts of lateral side are decorated with falculate ribs. Inner indistinct ribs are inclined toward aperture.

Comparison. Species differs from *N.mucronatum* (Berckhemer and Hölder, 1959, Plate 27, figs. 145, 146) and *N. usselense* (Zeiss, 1968, Plate 26, figs. 1, 2) because of indistinct ventrolateral inflection. In distinction from younger species, e.g., from *N. griesbachiformis* (Donze and Enay, 1961, Plate IV, fig. 5), it has less developed external ribs.

Remarks. Species has been reported as found in the Middle Tithonian deposits (Fözy *et al,,* 1994; Benzaggagh, 2000), but judging from published images, these finds exemplify the middle Tithonian species *N. paternoi* (Di Stefano).

Distribution: Lower Tithonian (Hybonotum/Lithographicitm Zone) in Germany, France, and Cuba; Lower Volgian Substage (Klimovi Zone) in Poland and the Russian Plate.

Material: one specimen SGM-572-25 (seven other specimens in my collection are poorly preserved and cannot be identified at the species level); Gorodishche section (Ul'yanovsk district, Ul'yanovsk region); Lower Volgian Substage, Klimovi Zone, *Glochiceras (Lingulaticeras) solenoides* and *Neochetoceras steraspis* Beds.

Family Haploceratidae Zittel, 1884

Subfamily Glochiceratinae Hyatt, 1900

Genus *Glochiceras* Hyatt, 1900

Subgenus *Lingulaticeras* Ziegler, 1958

Glochiceras (Lingulaticeras) solenoides (Quenstedt, 1849)

Plate, fig. 1

Ammonites lingulatus solenoides: Quenstedt, 1849 (p. 131, Plate 9, fig. 10); Quenstedt, 1887-1888 (p. 1092, Plate 126, fig. 8).

Ammonites lingulatus: Quenstedt, 1887-1888 (p. 848, Plate 92, fig. 35).

Glochiceras (Lingulaticeras) solenoides: Ziegler (1958, p. 145, Plate 15, figs. 1-5), Berckhemer and Holder (1959, p. 110, Plate 26, fig. 141), Barthel and Schairer (1977, p. 104, Plate 9, figs. 1 and 2), Schlegelmilch (1994, p. 55, Plate 16, fig. 16).

Glochiceras solenoides: Kutek and Zeiss (1997, Plate 31, fig. 8).

Holotype (monotype): specimen GPIT Ce 5/126/8 figured by Quenstedt (1849, Plate 9, fig. 10); Germany, Solnhofen; Lower Tithonian, Weißjura Zeta; reproduced in Quenstedt (! 887-1888, Plate l26, fig. 8) and Ziegler (1958, Plate 15, fig. 1).

Morphology. Discoid shell with semi-involute whorls has a moderately narrow umbilicus. Its lateral groove is well developed. Lappets are large, bending toward the previous whorl (Plate, fig. 1).

Dimensional parameters (mm) and ratios (%)

Specimen no.	T	H	D	DU	T/H	T/D	H/D	DU/D
SGM-372-2		12.7	27.4	5.1		-	0.46	0.186

Thin growth lines are the only sculptural elements. The septal suture has not been observed.

Comparison. Species differs from G. *(L.) contracfum* (Ziegler, 1958, Plate 14, fig. 14) because of a wider umbilicus and greater whorls, the latter slowly growing in height. In distinction from *G. (L.) crenosum* (Ziegler, 1958, Plate 13, figs. I i-16), it has no ribs on the ventral side.

Variability. Specimens from my collection show some variability of the relative umbilicus width. Because of the deformed core area, it is impossible to establish how this variability is connected with the relative whorl width.

Distribution: Upper Kimmeridgian (Beckeri Zone) and LowerTithonian (Hybonotiim/Lithographicum Zone) in Germany and France; Upper Kimmeridgian (Autissiodorensis Zone) and Lower Volgian (Klimovi Zone, *G. solenoides* and *N. steraspis* Beds) in the Russian Plate; Upper Kimmeridgian (Autissiodorensis Zone) in Poland.

Material: four specimens; samples SGM-572-12 and SGM-572-2 from the Isady site (Lyskovo district, Nizhegorod region), Upper Kimmeridgian Substage, Autissiodorensis Zone, Fallax Subzone; samples SGM-572-18 and SGM-572-23 from the Gorodishche section (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *G. solenoides* and *N. steraspis* Beds.

Subgenus *Paralingulaticeras* Ziegler, 1958

Glochiceras (Paralingulaticeras) lithographicum (Oppel, 1863)

Glochiceras (Paralingulaticeras) lithographicum efimovi Rogov, subsp. nov.

Plate, fig. 2

Subspecies is named in honor of paleontologist V.M. Efimov.

Holotype: specimen SGM-572-11, Ul'yanovsk region, right-hand bank of the Volga River near the village of Gorodishche; Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon 0.35 m above the base of Bed 6.

Morphology. Shell seems to be flattened (all specimens available are deformed so that the original shape cannot be established). Umbilicus is moderately wide.

Dimensional parameters (mm) and ratios (%)

Specimen no.	T	H	D	DU	T/H	T/D	H/D	DU/D
Holotype SGM-572-11	-	-	29.1	5.7	-	-	-	20
SGM-572-17	-	13.2	28.0	5.2		-	47	18

Abundant falculate ribs define sculpturing of the upper whorl part. Closer to aperture, rib frequency is 2-3 times higher, and their width proportionally decreases. Because of the imperfect preservation state (impressions in clay), ventrolateral tubercles are distinguishable in some specimens only. The septal suture has not been observed.

Comparison. From the nominal subspecies, the new one differs by changeable frequency and thickness of ribs decorating the living chamber.[7] In distinction from *G. (P.) parcevali* (Fontannes, 1879; see fig. 7 in the Plate) that has abundant thin ribs at all stages of ontogeny, ribs in inner whorls of new subspecies are noticeably coarser.

Remarks. Variability of rib frequency seems to be dependent on the species distribution areas. For instance, the nominal subspecies is known from all distribution areas mentioned above, but G. *(P.) lithographicum efimovi* occurs in the Russian plate only. Apparently, the nominal subspecies is ancestor of the described form.

Material: three specimens SGM-572-11, SGM-572-20, and SGM-572-17 from the Gorodishche section (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Klimovi Zone, *lithographicum efimovi* horizon. Several other specimens of G. *(P.)* cf. *lithographicum* (Plate, fig. 3) are so poorly preserved that cannot be attributed to a definite subspecies.

Subfamily Haploceratinae Zittel, 1884

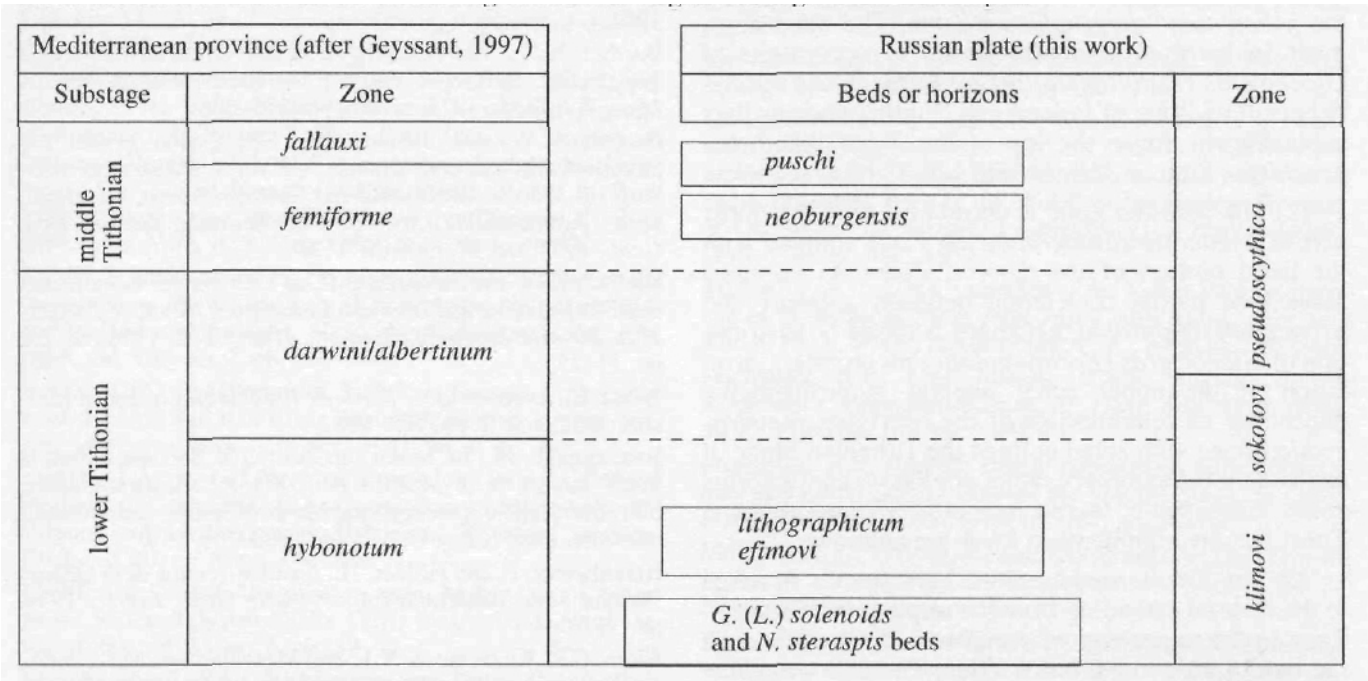
Genus *Pseudolissoceras* Spath, 1925

Pseudolissoceras sp. ind. Plate, fig. 9

Morphology. Discoid shell with a moderately narrow umbilicus; it is likely high-oval in section (ammonites are deformed). Umbilical shoulder is gently sloping. Shell is lacking sculptural elements other than growth lines. The lobe line has three slightly dissected lobes on outer side.

Comparison. Owing to a narrow umbilicus and gently sloping umbilical shoulder, the studied specimens are most close in morphology to *Pseudolissoceras zitteli* only. Unfortunately, they are of poor preservation and cannot be identified at the species level.

[7] Some specimens of *G. (P.) lithographicum lithographicum.* e.g., that figured by Ziegler (1958. Plate 16. fig. I), also show more frequent ribs in the last whorl, which almost disappear near aperture. These changes in ornamentation are however less distinct than in G. *(P.) lithographicum efimovi* subsp. nov.



DEPOSITS Correlated biozonation of the Tithonian Stage and lower Volgian

Substage of the Russian plate

Remarks. The described ammonites occur together with abundant *Anaspidoceras neoburgense,* which also have narrow umbilicus and no sculptural elements. Accordingly, a simple septal suture is the only criterion allowing the specimens in question to be classed with *Pseudolissoceras*. *Anaspidoceras* species similar in dimensions (undamaged specimens in my collection) have one or two more lobes in the lobe line, which are dissected to a greater extent as compared with these characters of *Pseudolissoceras*.

Material: specimens SGM-572-9 and SGM-572-10 from the Gorodishche section (Ul'yanovsk district, Ul'yanovsk region), Lower Volgian Substage, Pseudoscythica Zone, *neoburgensis* horizon.

BOREAL-TETHYAN CORRELATION OF THE LOWER VOLGIAN SUBSTAGE

The suggested biozonation of the Lower Volgian Substage is based on stratigraphic distribution of Tethyan ammonites in sections of the Russian Plate. To a considerable extent, it depicts events of taxa migration, which have been connected somehow with the climatic and paleogeographic reorganizations and enable the direct correlation between some levels of the Tithonian and Volgian Stages.

Species of the genus *Ilowaiskya* (Pseudovirgatitinae) representing endemics of the Central Russian Sea are basic taxa of the Lower Volgian biozonation. It was difficult to use representatives of the Tethyan ammonite genera to designate subdivisions of subzonal ranks, because boundaries of zones and subzones may turn out to be incompatible owing to the suspected difference in evolution rates of various ammonite groups.

For instance, Haploceratidae are rather abundant in the Klimovi Zone, and it possible in principle to discriminate subzones of the latter, but I used another approach taking into account the doubt mentioned above. The lower subdivisions of the zone were ranked as *G. (L.) solenoides* and *N. steraspis* Beds, and the upper one was designated as the biohorizon. The different ranks of subdivisions resulted from the fact that none of specific ammonite taxa has been detected in the *G. (L.) solenoides* and *N. steraspis* Beds. The beds actually represent the acme zone of *Neochetoceras steraspis,* and as is known, the acme zones of sole species can be essentially different even in closely spaced sections. However, the succession of ammonite assemblages has been established in the sequence of monofacial sediments and coincides with that observable in West Europe. Therefore, the distinguished subdivisions can be regarded as quite reliable.

Despite the fact that Submediterranean ammonites and some their successions recognizable in the Volgian Stage of the Russian Plate are similar to West European ones, it is impossible to speak about the complete coincidence of their stratigraphic ranges. Nevertheless, the distinguished biostratigraphic units are more useful for correlation of Tithonian and Volgian stages than data on distribution of Pseudovirgatitinae, the evolution of which is used as a basis for zonal scheme of the lower Volgian Substage.

CONCLUSION

The following main points characterize the suggested scheme of correlation between the Lower Volgian Substage and Tithonian Stage (table):

(1) The Klimovi Zone corresponds to a greater part of the Hybonotum/Lithographicum Zone. The main argument in favor of this assumption is occurrence of *Glochiceras (Paralingulaticeras)* forms in the overlying Sokolovi Zone of Poland and Russia, whereas they are unknown above the top of the Hybonotum/Lithographicum Zone in Tethyan and Submediterranean sections.

(2) The Sokolovi Zone is correlative with the upper part of Hybonotum/Lithographicum Zone coupled with the basal portion of the Darwini Zone. As is stated above, the partial correlation between Sokolovi and Hybonotum/Lithographicum Zones is based on distribution of *Glochiceras (Paralingulaticeras)* forms. Correlation of the upper zonal interval is problematic, depending on relationships of the overlying Pseudoscythica Zone with zonal units of the Tithonian Stage. It can be that the summary range of Klimovi and Sokolovi Zones corresponds to the Hybonotum/Lilhographicum Zone, but any arguments in favor are unknown.

(3) The Pseudoscythica Zone corresponds in range to the interval extending from the upper part of Darwini Zone to the upper part of Semiforme Zone or through the basal part of Fallauxi Zone. The entire *neoburgense* horizon falls therewith in the Semiforme Zone. The partial overlapping of Pseudoscythica and Darwini zones is defined by coexistence of *Ilowaiskya* cf. *pseudoscythica* with *Vtrgatosimoceras albertinum* in the Neuburg section of Germany. The fact that the Middle Volgian Panderi Zone of Russian plate yields *Glochiceras (Lingulaticeras) blaschkei* Cecca et Enay in association with *Sutneria* and *Pseüdolissoceras* implies that the top of Pseudoscythica Zone cannot be located higher than the Fallauxi Zone of the Middle Tithonian, because the mentioned forms are unknown above the latter subdivision in Western Europe. The partial correlation between the *neoburgense* horizon and Semiforme Zone of the Middle Tithonian is inferable from their positions in the sections. In addition, exactly the Semiforme Zone represents the acme zone of *A. neoburgense* in most sections of Western and Eastern Europe, and it seems reasonable to suggest that distribution areas of this species extended at the time of its mass abundance.

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Reviewer V.A. Zakharov

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