VOLUMINA JURASSICA, 2010, VIII: 103–130

A precise ammonite biostratigraphy through the Kimmeridgian--Volgian boundary beds in the Gorodischi section (Middle Volga area, Russia), and the base of the Volgian Stage in its type area

Mikhail ROGOV [1]

Key words: Kimmeridgian/Volgian boundary, Volgian SSSP, ammonite faunal horizons, Boreal-Tethyan correlation.

Abstract. A detailed study of the ammonite faunal horizons of the uppermost Kimmeridgian–Lower Volgian of the Middle Volga area (Russia) was undertaken at the most complete and well-known Gorodischi section. This section shows a complete transition from the Kimmeridgian to the Volgian and is a possible SSSP candidate for the Volgian Stage. Sixteen faunal horizons have been established between the top of the Eudoxus Zone and the top of the Lower Volgian. Revised descriptions of existing horizons (especially in the Kimmeridgian) are given and description of new horizons: cf. *anglicum*, aff. *rebholzi*, *zeissi*, *ilowaiskii*, cf. *praecursor*, *sokolovi*, *pavida*, "*Franconites*". Oscillations in the ratios of ammonites with different affinities from horizon to horizon reflect short-term changes in the climate and/or palaeogeography. The presence of ammonites with Submediterranean affinities throughout the studied interval enables correlations to be made with the Tethyan ammonite succession. The evolution of the eudemic Subboreal lineage of *Sarmatisphinctes* has been analysed, and a succession of species through the complete Autissiodorensis Zone has been recognised. This comprises, in ascending order, *S.* cf./aff. *subborealis*, *S. subborealis*, *S. zeissi*, *S. fallax* and *S. ilowaiskii*. Two of the species described, *Sarmatisphinctes zeissi* and *S. ilowaiskii*, are new.

GEOLOGICAL SETTING

The Gorodischi section is one of the most famous and best-studied sections in the Russian Jurassic. It is located high on the right bank of the River Volga, *c.* 25 km north of Ul'anovsk (Figs 1, 2). It was chosen as the lectostratotype for the Volgian Stage by Gerasimov and Mikhailov (1966). Following a suggestion by Cope (1996) that secondary standards should be accepted, Zakharov (2003) proposed the Gorodischi section as the Secondary Stratotype Section and Point (SSSP) for the Volgian Stage. Although the Volgian succession there is thin and condensed, recent studies have shown that it contains no biostratigraphically significant gaps (Kiselev, Rogov, 2005). The ammonite infrazonal biostratigraphy of several additional sections in the Kimmeridgian--Volgian (Ki/Vo) transition beds were also studied. These are mostly located in the Middle Volga area and, farther south, on the borders of the Peri-Caspian Lowland (Fig. 1).

A recent study of the Ki/Vo boundary beds at Gorodischi (Rogov *et al.*, 2006) included the collection of magnetostratigraphic, geochemical and microfossil data that is currently being analysed. A detailed description of the section has been published (Rogov, Kiselev, 2007): a log of the section together with the ammonite data is given here (Fig. 3).

[1] Geological Institute, Russian Academy of Sciences, Pyzhevskii Lane 7, Moscow 119017, Russia; e-mail: russianjurassic@gmail.com

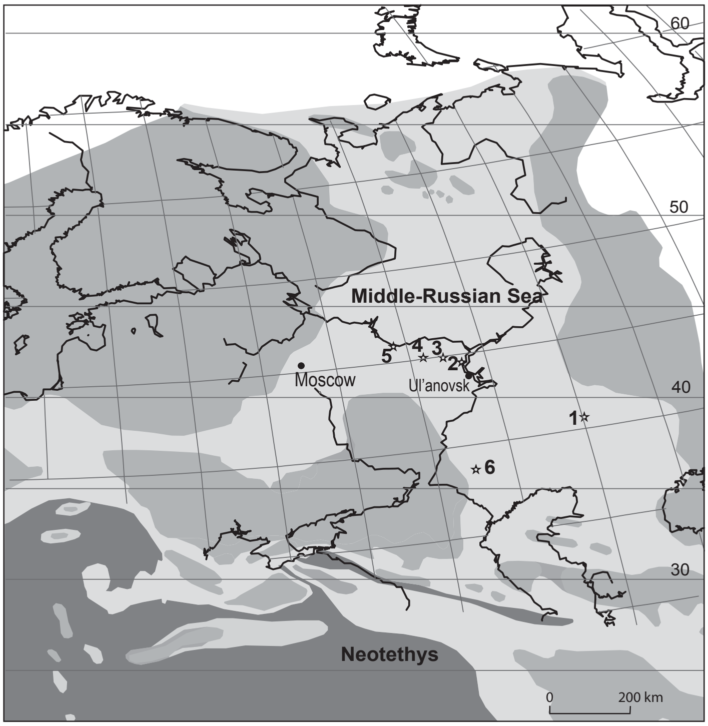


Fig. 1. Palaeogeography of the Middle-Russian Sea during the Kimmeridgian-Volgian transition (modified after Thierry, 2000)

Kimmeridgian-Volgian sections of the European Russia mentioned in article: **1** – Berd'yanka (51°25'55" N; 55°25'07" E), **2** – Gorodischi (54°34'55" N; 48°24'56" E), **3** – Polevye-Bikishiki (55°05'40" N; 47°29'21" E), **4** – Murzicy (55°18'15" N; 46°11'40" E), **5** – Isady (56°04'40" N; 45°07'13" E), **6** – Elton (49°8'56" N; 46°50'49" E)

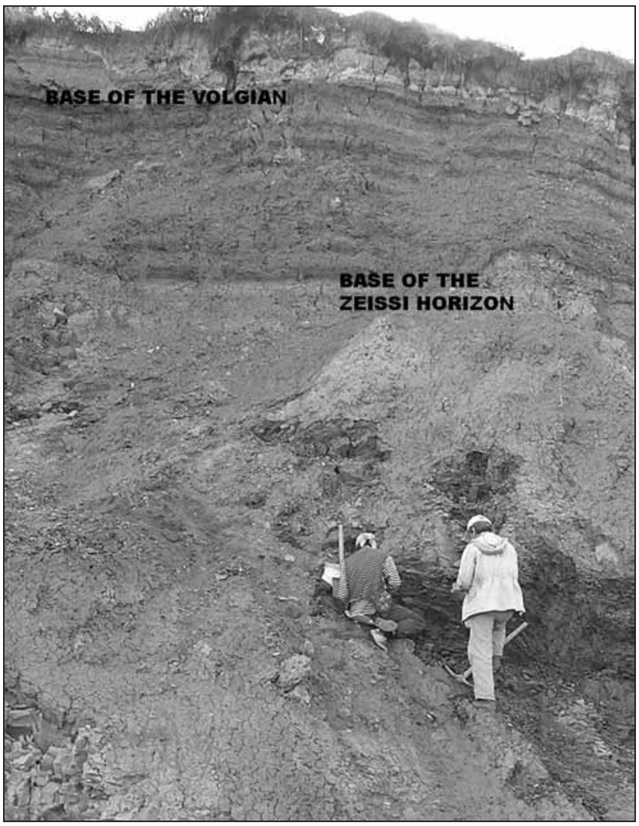


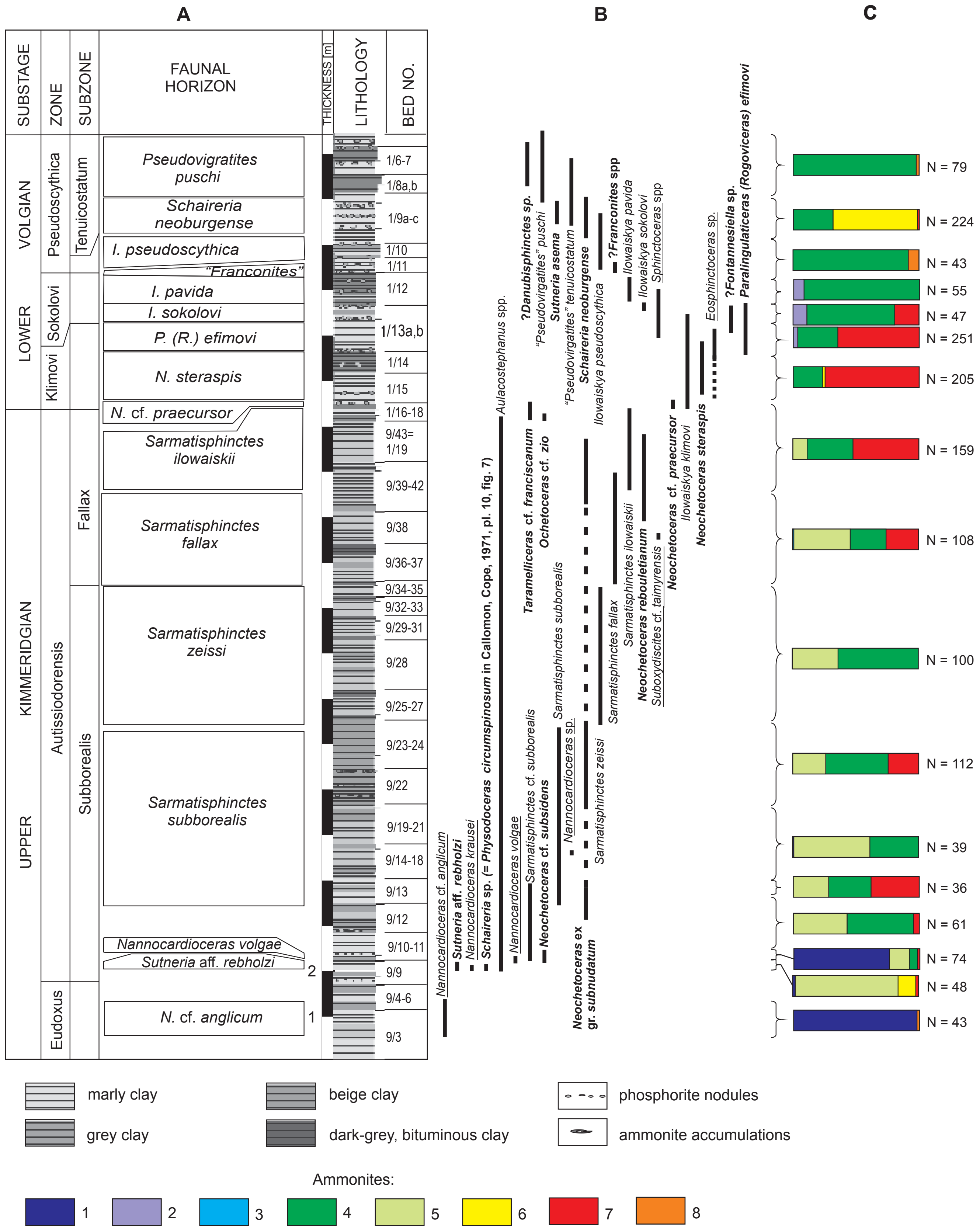
Fig. 2. Uppermost Kimmeridgian of the Gorodischi section (*photo by A. Manikin, 2005*)

Fig. 3. Ammonite succession through the Kimmeridgian--Volgian transition of the Gorodischi section

A – stratigraphical log (bed numbers after Rogov, Kiselev, 2007); **B** – ammonite ranges; **C** – ammonite assemblages.

Boreal ammonites (1–2): 1 – Cardioceratidae (*Nannocardioceras*, *Hoplocardioceras*, *Euprionoceras*); 2 – Dorsoplanitidae (*Eosphinctoceras*, *Subdichotomoceras*); 3 – Boreal Ochetoceratinae (*Suboxydiscites*); **Subboreal ammonites** (4–5): 4 – Virgatitidae (*Sarmatisphinctes*, *Ilowaiskya*, "*Pseudovirgatites*"); 5 – Aulacostephanidae (*Aulacostephanus*); **Submediterranean ammonites** (6–8): 6 – Aspidoceratidae (*Aspidoceras*, *Schaireria*, *Sutneria*); 7 – Oppeliidae (*Neochetoceras*, *Taramelliceras*, *Ochetoceras*, *Paralingulaticeras* (*Rogoviceras*)); 8 – Lithacoceratinae (*Discosphinctoides*, ?*Franconites*).

Ammonites with Subtethyan affinities marked by bold; Boreal ammonoids are underlined; N – number of specimens


A
B
C
SUBSTAGE
ZONE
SUBZONE
FAUNAL HORIZON
THICKNESS [m]
LITHOLOGY
BED NO.
UPPER
KIMMERIDGIAN
LOWER
VOLGIAN
Eudoxus
Autissiodorensis
Klimovi
Sokolovi
Pseudoscythica
Subborealis
Fallax
Tenuicostatum
Pseudovigratites puschi
Schaireria neoburgense
I. pseudoscythica
"Franconites"
I. pavida
I. sokolovi
P. (R.) efimovi
N. steraspis
N. cf. praecursor
Sarmatisphinctes ilowaiskii
Sarmatisphinctes fallax
Sarmatisphinctes zeissi
Sarmatisphinctes subborealis
Nannocardioceras volgae
Sutneria aff. rebholzi
N. cf. anglicum
1/6-7
1/8a,b
1/9a-c
1/10
1/11
1/12
1/13a,b
1/14
1/15
1/16-18
9/43= 1/19
9/39-42
9/38
9/36-37
9/34-35
9/32-33
9/29-31
9/28
9/25-27
9/23-24
9/22
9/19-21
9/14-18
9/13
9/12
9/10-11
9/9
9/4-6
9/3
N = 79
N = 224
N = 43
N = 55
N = 47
N = 251
N = 205
N = 159
N = 108
N = 100
N = 112
N = 39
N = 36
N = 61
N = 74
N = 48
N = 43
marly clay
grey clay
beige clay
dark-grey, bituminous clay
phosphorite nodules
ammonite accumulations
Ammonites:
1
2
3
4
5
6
7
8

INFRAZONAL AMMONITE BIOSTRATIGRAPHY

The ammonite successions in all the sections studied show mixtures of Suboreal, Boreal and Submediterranean taxa which enable detailed long-range correlations within the Kimmeridgian, as well as between the Lower Volgian, the Arctic Volgian and the Tithonian Stage. The ammonite biostratigraphy of the Lower Volgian has been described in detail (Rogov, 2004a); some additional remarks are included here. In contrast, the ammonite biostratigraphy of the Upper Kimmeridgian has been little studied in the area under consideration. The ammonite succession has been summarized in a field guide (Rogov, Kiselev, 2007), but without descriptions of the biostratigraphical units or fossils. The same bed numbers are used here as in the field guide.

UPPER KIMMERIDGIAN

Eudoxus Zone Neumayr, 1873

The uppermost part of the Eudoxus Zone in the Gorodischi section is characterized by an ammonite succession that is close to those of other Subboreal regions such as England and Extra-Carpathian Poland. The highest ammonite faunal horizon of this zone is marked by an absence of aulacostephanids and a strong Boreal influence. Ammonites at this level are represented chiefly by the small-sized *Nannocardioceras* cf. *anglicum* (Salfeld) (Pl. 1: 1) and are assigned to the cf. *anglicum* faunal horizon (Rogov, Kiselev, 2007) which corresponds to the Nannocardioceras Beds of Callomon and Cope (1971). On the Dorset coast the Nannocardioceras Beds lie a little below the Flats Stone Band which marks the base of the Autissiodorensis Zone (Cox, Gallois, 1981).

Autissiodorensis Zone Ziegler, 1962

Scherzinger and Mitta (2006) assumed that the Fallax Zone should replace the Autissiodorensis Zone in the Russian succession on the grounds of priority, and because of the differences in interpretation of the Autissiodorensis Zone by the different authors. The Fallax Zone was proposed more than 20 years before the Autissiodorensis Zone, but the replacement of the one zone by the other is not convincing because the two zones have different stratigraphical ranges. If the Autissiodorensis Zone is defined as the interval between the FAD of *Aulacostephanus autissiodorensis* and the LAD of *Aulacostephanus*, this zone can be recognizable over a large area. The Fallax Subzone corresponds to the upper part of the Autissiodorensis Zone in East Europe (Russian Platform and Extra-Carpathian Poland).

Subborealis Subzone Zeiss, 2003 emend. Rogov, herein

This subzone is marked by the occurrences in large numbers of the Subboreal ammonite genus *Sarmatisphinctes*, possibly derived from *Discosphinctoides*, throughout the southeast part of the Russian Platform and as far as central Poland. The base of the subzone in the area studied is characterized by sudden changes in the ammonite assemblages. The rarity of *A. autissiodorensis* records in the higher parts of subzone and the absence of aulacostephanids in some areas (*e.g.* the Elton section) makes the Subborealis Subzone easier to recognise in the area investigated. Scherzinger and Mitta (2006) have introduced the Volgae Subzone for the same stratigraphical interval on the grounds that “at the present time it is unclear if the species ‘*Divisosphinctes sublacertosus*’ and ‘*Discosphinctoides subborealis’* are conspecific” (*loc. cit*., p. 233). However, “*D. sublacertosus*”, as noted by Ilovaisky (*in*: Ilovaisky, Florensky, 1941), occurs below *Aulacostephanus*. Moreover, *S. subborealis* offers additional advantages as an index-species for the following reasons:

– it has a wide stratigraphical range within the subzone;
– it belongs to the lineage that is used as the basis for subzonal and zonal subdivision of the Upper Kimmeridgian and a major part of the Volgian;
– as index species it has priority over the Volgae Subzone proposal.

Both subzones – the Subborealis and Volgae subzones – were erected (*cf*. Zeiss, 2003; Scherzinger, Mitta, 2006) without their boundaries being defined. The Subborealis Subzone is here defined as follows: the lower boundary is marked by the FADs of *Aulacostephanus autissiodorensis*, *Sarmatisphinctes* aff. *subborealis*, *Aspidoceras* ex gr. *catalaunicum* and *Sutneria* aff. *rebholzi*. The upper boundary is marked by the FAD of *Sarmatisphinctes fallax*.

aff. rebholzi horizon Rogov, nov.

Stratotype. — Gorodischi section, bed 9/9, light beige to gray calcareous clays.

Index species. — *Sutneria* aff. *rebholzi* Berckhemer [m] (Pls 1: 7–9; 5: 7); the neotype of *S. rebholzi* designated and figured by Berckhemer and Hölder (1959, pl. 12: 61) was stated to have come from the ?Subeumela Subzone (after Berckhemer, Hölder, 1959), but the preservation of the specimen suggests that it came from the Ulmensis Subzone, *zio-wepferi* β horizon (Schweigert, 1998). Specimens from Russia differ from the neotype of *S. rebholzi*, and are almost identical to those from the basal Autissiodorensis Zone of England referred to as *S. rebholzi* (Callomon, Cope, 1971, pl. 9: 2–4) and from northern Poland (Krause, 1908, pl. 3: 8, 9).

Characteristic ammonites. — *Nannocardioceras krausei* (Salfeld) [m] (Pl. 1: 2, 3); *N.* cf. *ewae* (Malinowska) [m] (in the uppermost part only, uncommon); *Aulacostephanus autissiodorensis* (Cotteau) [M]; *A. undorae* (Pavlov) [m]; *A.* cf./aff. *eudoxus* (d'Orbigny) [m]; *A. kirghisensis* (d'Orbigny) [m] (Pl. 5: 5); *A. volgensis* (Pavlov) [?m]; *Aspidoceras* aff./cf. *catalaunicum* (Loriol) [M] (Pl. 2: 8); ?*Anaspidoceras* sp. [M]; *Neochetoceras* cf. *subsidens* (Fontannes)[1] [M] (Pl. 1: 10); *Lingulaticeras* sp. [m]; rare *Sarmatisphinctes* cf./aff. *subborealis* (Kutek and Zeiss)[2], which is usually characterized by a lower rib ratio compared to typical *S. subborealis*.

Comments. — In spite of doubts about the identification of some of the English and Russian specimens referred to as *S. rebholzi* Berckhemer (see below), this is possibly the best index-form for the horizon. Macroconchiate aspidoceratids are usually poorly preserved in that horizon, and *Nannocardioceras krausei* (Salfeld), which occurs at this level on the Russian Platform, may have a longer range in England, extending down into the uppermost Eudoxus Zone. In the Orenburg area this level is characterized by *Aspidoceras catalaunicum*, but the lacks aspidoceratid microconchs. Uncommon records of *A. catalaunicum* in the Pechora area and Subpolar Urals may be dated to the same horizon. However, these cannot be considered as indicative of a *catalaunicum* horizon because this lies at a different stratigraphical level in the French succession (Hantzpergue, 1989). *Anaspidoceras* sp. from this horizon in Russia is characterized by the presence of periumbilical tubercles only. Crushed shells of such ammonites resemble *A. fluegeli* (Zeiss, 1994, figs 1, 2; pl. 1: 1, 2) and other early species of *Anaspidoceras*, but poor preservation prevents their precise identification.

Correlation. — The occurrence of the index form (microconchs) and accompanying macroconchs in the English succession provides a good correlation with the basal beds of the Autissiodorensis Zone; the presence of comparable rare *Sutneria* in the basal part of the Autissiodorensis Zone in the J. Kutek collection (Stobnica 36 see Kutek, 1961; *cf.* Kutek, Zeiss, 1997) and those figured by Krause (1908), provide a correlation with the Polish succession. Records of *Neochetoceras* cf. *subsidens* in the Russian sections suggests a correlation with the Late Kimmeridgian in Germany as proposed by Schweigert *et al*. (1996), but the known range of the species of *Sutneria* in Germany does not support such a correlation. In Germany *Neochetoceras subsidens* is accompanied by numerous *S. subeumela* (*op. cit.*), and *S. rebholzi* is only known from the *zio-wepferi* α-β horizons (*i.e.* 5 horizons higher), The Setatum Subzone – especially the *ornatum* horizon (Tab. 1), is characterized in Germany by *S. casimiriana* (Font.). The stratigraphical range of forms referred to herein as *S.* aff. *rebholzi* in the Subboreal Realm may thus be lower than the Swabian records of typical *S. rebholzi*. The presence of rare *S. subeumela* (Schneid) in bed 9/10 at Gorodischi attributed to the *volgae* horizon (see below), and the presence of *S. subeumela* above *S.* aff. *rebholzi* (Krause, 1908, pl. 3: 6) additionally suggest that *S.* aff. *rebholzi* represents a new species independent of true *S. rebholzi.*

Geographical range. — Middle Volga area (Gorodischi, Murzicy sections), England (from Dorset to Wash area), northern and central Poland.

volgae horizon Scherzinger and Mitta (2006) (as subzone) emend. Rogov, herein

Stratotype. — Gorodischi section. This horizon was not defined in the stratigraphical log of Scherzinger and Mitta (2006): the highly bioturbated dark-gray clays of bed 9/10 are proposed here as the stratotype.

Index species. — *Nannocardioceras volgae* (Pavlov) [m] (Pl. 1: 4–6); type (SD by Malinowska, 2001), CNIGR Museum, Saint-Petersburg no. 37/312 (re-figured by Malinowska, 2001 and herein – Pl. 1: 4); Kimmeridgian ("Acanthicum Zone" of Pavlov, 1886) of the Gorodischi section, perhaps bed 9/10 (based on lithology and mode of preservation).

Characteristic ammonites. — *Nannocardioceras volgae* (Salfeld) [m] (very common); *Aulacostephanus undorae* (Pavlov) [m] (Scherzinger, Mitta, 2006, fig. 6: 2); *N. krausei* (Salfeld) [m] (very rare); *Aulacostephanus* sp. (= "*volongensis*"[3] Khudyaev *sensu* Scherzinger and Mitta – Scherzinger, Mitta, 2006, fig. 6: 3); *Aulacostephanus autissiodorensis* (Cotteau) [M]; *Sarmatisphinctes* aff./cf. *subborealis* (Kutek et Zeiss) [m], *Sutneria subeumela* Schneid [m] (*cf*. Geyer,

[1] The precise identification of the *Neochetoceras* is difficult due to their mode of preservation, usually as crushed clayey moulds. *Neochetoceras* from the uppermost Eudoxus Zone of Gorodischi, sampled during the recent fieldwork, can be assigned to *N. acallopistum* by comparison with specimens from the basal Autissiodorensis Zone, which are assigned to *N.* cf. *subsidens*.

[2] This species was referred to the genus *Sarmatisphinctes* by Scherzinger and Mitta (2006). This interpretation is supported here: the species cf./aff. *subborealis–subborealis–zeissi–fallax–ilowaiskii* represent a continuous lineage of true Subboreal derivates of *Discosphinctoides*.

[3] The type specimens of *A. volongensis*, stored at CNIGR Museum (Saint-Petersburg), were considered by M.S. Mesezhnikov (1984) as Upper Cretaceous ammonites. Reevaluation of these specimens (refigured here at Pl. 2: 1a–c), has shown that they could be the microconchiate *Aulacostephanus* resembling *A. undorae* (Pavlov). The ammonite figured by Scherzinger and Mitta (2006) under the name *A. volongensis* could be either microconch or small-sized macroconch resembling *A. undorae* (Pavlov) or *A. autissiodorensis* (Cottreau), respectively. Typical *A. autissiodorensis* (Cottreau) were also found in this horizon.

Table 1

Correlation of the Kimmeridgian-Volgian boundary beds of European Russia and Southern Germany

Kimmeridgian-Tithonian boundary beds of SW Germany (Scherzinger, Schweigert 2003; Schweigert *et al*., 1996; Schweigert, 2000)					Kimmeridgian-Volgian boundary beds of Russian Platform			
sub-stage	zone	subzone	faunal horizon		faunal horizon	sub-zone	zone	sub-stage
LOWER TITHONIAN	VIMINEUS		*vimineus*	→	"*Franconites*"			LOWER VOLGIAN (partially)
					pavida		SOKOLOVI	
	MUCRONATUM		*levicostatum*					
			franconicum					
					sokolovi			
	HYBONOTUM	Moernsheimensis	*laisackerensis*		*efimovi*		KLIMOVI	
		Ruepellianum	cf. *eystettense*					
			riedlingense	→				
			rueppellianum	→	*steraspis*			
		Riedense	*eigeltingense*	→	cf. *praecursor*			
UPPER KIMMERIDGIAN	BECKERI	Ulmense	*rebouletianum*	→	*ilowaiskii*	Fallax	AUTISSIODORENSIS	UPPER KIMMERIDGIAN
			hoelderi		*fallax*			
			zio-wepferi α	→				
			zio-wepferi β					
		Setatum	*siliceus*		*zeissi*	Subborealis		
			uracensis					
			ornatum		*subborealis*			
			supinum					
			minutum					
		Subeumela	*subsidens*	→	*volgae*			
				→	aff. *rebholzi*			

Black arrows indicates levels of occurrence of ammonites of the Submediterranean origin in the Ul'anovsk Volga area suggesting possibilities of direct Subboreal/Submediterranean correlation

1969, fig. 4; Scherzinger, Mitta, 2006, fig. 6: 1; the matrix shows that it came from the bed 9/10 – Mitta, 2007, person. commun).

Comments. — In England, a faunal marker bed identified in the lowermost Autissiodorensis Zone by Cox and Gallois (1981) was characterised by a distinctive form of *N.* aff. *anglicum* (Salfeld) with fine rectiradiate ribbing identified by Van de Vyver (1986) as *N. volgae*, and named the Volgae Band by Gallois (2000). A similar bed has been recorded in Poland (Kutek, Zeiss, 1997).

In both countries mentioned above, and in Russia, *N. volgae* has a very restricted stratigraphical range and has the potential to be the index fossil of a faunal horizon that can be used for correlation over much of the Boreal Province despite the fact that its range in Poland is still imprecisely known. The FAD of *N. volgae* has been proposed as a marker for the base of the Fallax Zone and the Volgae Subzone (Scherzinger, Mitta, 2006) but such an interpretation differs from that accepted herein. Among the pecularities of this level in Russia should be noted: a rarity of macroconch records (similarly in Poland; Kutek, Zeiss, 1997), its development in a particular lithology, and its narrow stratigraphical range. In the Middle Volga area, between Gorodischi and the eastern part of the Nizhny Novgorod region (Murzicy section), the *volgae* horizon consists of a thin, highly bioturbated bed of dark gray clay that is easily distinguished from the other beds in the section except for the uppermost beds of the Kimmeridgian which are lithologically similar but have other fossil contents. The *volgae* horizon marks the youngest mass occurrence of *Nannocardioceras*. Above this horizon, a single crushed specimen of *Nannocardioceras* was recorded in the Gorodischi section (in the *subborealis* horizon). *Sarmatisphinctes* is very rare and poorly preserved in the *volgae* horizon, mostly as inner whorls. Rogov (*in*: Pimenov *et al*., 2005) provisionally identified the earliest *Sarmatisphinctes* of the Autissiodorensis Zone as *S. magistri* and suggested that a possible *magistri* faunal horizon was present in the Gorodischi section. More detailed collecting at this level has not yielded any well-preserved specimens of *Sarmatisphinctes* below the appearance of true *S. subborealis*. Perisphinctids from the Eudoxus Zone that were tentatively determined as *Discosphinctoides* ex gr. *roubyanus* (Fontannes) (Rogov, Kiselev, 2007) may belong to the ancestral lineage of *Sarmatisphinctes*.

Correlation. — *Nannocardioceras volgae* (Pavlov) has a narrow range in the basal Autiossiodorensis Zone throughout the Subboreal Province. In Poland, Malinowska (2001) identified a wider stratigraphical range for this species ranging into the Eudoxus Zone. However, re-evaluation of her collection has shown that the stratigraphical position of at least some of the specimens was misinterpreted. For example, a borehole core with *N. volgae* and *N. ewae* on one side of the sample (Malinowska, 2001, pl. 3: 1) shows a crushed *Sarmatisphinctes* cf./aff. *subborealis* (Kutek and Zeiss) on the opposite side and should be dated as belonging to the Subborealis Subzone. The presence of rare *Sutneria subeumela* Schneid indicates that this horizon should be correlated with part of the Subeumela Subzone of the Submediterranean Kimmeridgian.

Geographical range. — Middle Volga area (Gorodischi, Murzicy sections), England (from Dorset to Wash area), northern Poland (but precise information concerning range of *N. volgae* in Poland is still absent).

subborealis horizon Zeiss, 2003 (as subzone), emend. Rogov, herein

Stratotype. — Gorodischi section, beds 9/13–9/24 (with the exception of the uppermost *c*. 0.13 m of bed 9/24) alternating light beige and dark gray clays with phosphorite nodules.

Index species. — *Sarmatisphinctes subborealis* (Kutek et Zeiss, 1997) (Pls 1: 11, 12; 5: 1); holotype IGP UW/A/32/305 (Kutek, Zeiss, 1997, pl. 15: 5)

Characteristic ammonites. — *Aulacostephanus autissiodorensis* (Cotteau) [M] (Pl. 6: 2); *Aulacostephanus* sp. [m]; *A. kirghisensis* (d'Orbigny) [m]; *A. volgensis* (Vischniakoff) [m] (Pl. 5: 9); *A. subundorae* (Pavlov) [m] (Pl. 5: 4, 10); *Neochetoceras* cf./aff. *subnudatum* (Fontannes) [M] (Pl. 2: 6); *Lingulaticeras modestum* (Ziegler) [m]; *Suboxydiscites* sp. [M]; *Sarmatisphinctes* sp. [M]; ?*Tolvericeras* sp. [M] (uncommon).

Comments. — *S. subborealis* was chosen as subzonal index by Zeiss (2003): it is applicable to most of the Russian sections. The *subborealis* horizon has been referred to in publications (Rogov, 2005; Pimenov *et al*., 2005), but has not been described. In Russia and Poland (Kutek, Zeiss, 1997), *S. subborealis* ranges through the bulk of the former Autissiodorensis Subzone without marked change in morphology. In the higher part of the horizon in the Volga area and in Poland there is a thin bed rich in *Neochetoceras* cf./aff. *subnudatum* (Fontannes) (Subnudatum level of Kutek, Zeiss, 1997). This marks a short-lived event of northeastward mass immigration of Subtethyan ammonites to East Europe that can be regarded as a "migrational" faunal horizon (Rogov, 2005). This level is well-represented in the upper portion of the *subborealis* horizon in the Murzicy section. A second level rich in Submediterranean ammonites (oppeliids) occurs in both these sections in the lower part of the *subborealis* horizon. The *subborealis* horizon could be subdivided into at least three separate informal units on the basis of the relative frequency of occurrence of oppeliid ammonites: lower and upper beds enriched in oppeliids separated by an interval characterized by Subboreal perisphinctids and aulacostephanids.

The perisphinctid infrazonal scale, beginning in the Upper Kimmeridgian in the *subborealis* horizon, can be considered as primary for the Subboreal East-European Kimmeridgian-Volgian as based on good phylogenetic evidence. Kimmeridgian records of macroconchiate perisphinctids are uncommon and poorly preserved, and the scale is therefore based on the microconchiate succession.

Correlation. — This horizon can be correlated with the Boreal and Submediterranean successions using aulacostephanid and *Neochetoceras* occurrences, respectively. However, its precise position in the Submediterranean succession is determined mainly by correlation with the adjacent Subboreal horizons, not with the *subborealis* horizon itself. An increase in the number of records of *Neochetoceras* near to the top of the horizon reflects climatic or/and biogeographic causes. The range of *N. subnudatum* is poorly known in France; in Swabia this species has been recorded in the *hoelderi* horizon of the Nusplingen Plattenkalk

(Schweigert, 1998). Probable correlations with the *subborealis* horizon are shown in Figure 3 and Table 1.

Geographical range. — Middle Volga area (Gorodischi, Murzicy sections), Peri-Caspian area (Elton), Orenburg area (Berd'anka); central Poland.

zeissi horizon Rogov, nov. (= *Discosphinctoides* sp. nov. horizon in Pimenov *et al*., 2005; Rogov, 2005)

Stratotype. — Gorodischi section, from the uppermost *c*. 0.13 m of bed 9/24 to bed 9/34, alternating light beige and dark gray clays with uncommon phosphorite nodules and pyritized ammonoids.

Index species. — *Sarmatisphintes zeissi* Rogov, sp. nov. [m] (Pl. 2: 4, 5); holotype VH-17/1 (Pl. 2: 4), Gorodischi, 5 cm above the bottom of bed 9/25.

Characteristic ammonites. — *Aulacostephanus* aff. *autissiodorensis* (Cotteau) [M]; *A. mammatus* Ziegler [m]; *A. volgensis* (Pavlov) [m]; *A*. cf. *kirghisensis* (d'Orbigny) (Pl. 5: 6).

Comments. — This is the only faunal horizon of the Upper Kimmeridgian in Russia that does not contain Submediterranean and Boreal ammonoids.

Correlation. — Tentative, based on its position within the whole succession (Fig. 3, Tab. 1).

Geographical range. — Middle Volga area (Gorodischi, Murzicy sections), Orenburg area (Berd'anka); ?Peri-Caspian area (Elton).

Fallax Subzone Ilovaisky, 1941 in: Ilovaisky and Florensky (1941)

fallax horizon Ilovaisky emend. Rogov, herein

Stratotype. — Gorodischi section, beds 9/35 to the lower part of bed 9/40, alternating light beige and dark gray clays with phosphorite nodules.

Index species. — *Sarmatisphinctes fallax* (Ilovaisky) [m]; holotype not designated, the type succession includes micro- and macroconchs. Two microconchs figured by Ilovaisky and Florensky (1941) were recently found in the collection of the Paleontological Institute, Moscow (person. commun. by V.V. Mitta, June 2009).

Characteristic ammonites. — *Aulacostephanus* sp. nov. [M]; *A. mammatus* Ziegler [m] (Pl. 2: 2, 3); *A. subundorae* (Pavlov) [m] (rare); *Neochetoceras* ex gr. *subnudatum* (Fontannes), *Lingulaticeras* sp., *Suboxydiscites* cf. *taimyrensis* (Mesezhnikov) (extremely rare; Pl. 2: 7); an ammonite assemblage from the *fallax* horizon collected from the Elton section (Rogov, 2005) includes, in addition to the above, *Taramelliceras* cf. *wepferi* (Berckhemer) [M] and *Glochiceras lens* Berckhemer [m].

Comments. — The horizon was proposed by Rogov (2004c) and has been referred to by Rogov (2005) and by Pimenov *et al*. (2005), but has not been formally described. It is present in the type area of the Fallax Subzone, but the succession at Gorodischi is more complete and contains a richer ammonite assemblage, and is here chosen as the stratotype.

Correlation. — The records of the Submediterranean ammonite assemblage in the Elton section, combined with a preliminary correlation using oppeliids (Rogov, 2002a), suggest that the horizon in question corresponds to the upper part of the Ulmense Subzone from the *zio-wepferi β* to, probably, the *hoelderi* horizon (Tab. 1). This suggestion is supported by the record of *Sarmatisphinctes* cf. *fallax* (Ilovaisky) in the *zio-wepferi* β horizon of Swabia (Schweigert, 2000, pl. 2: 2), although the determination has been questioned by Scherzinger (2007): the inner whorls of *S. fallax* are so variable (*e.g*. Pl. 5: 2, 3) that the Swabian specimen might in fact belong to *S. fallax*. A unique record of *Suboxydiscites* allows correlation with some part of the Taimyrensis Zone of Northern Siberia, but the full range of the species *S. taimyrensis* in the Subboreal succession is still unknown.

Geographical range. — Middle Volga area (Gorodischi, Murzicy sections), Orenburg area (Berd'anka), Peri-Caspian area (Elton); Poland.

ilowaiskii horizon Rogov, nov. (= unnamed horizon *in*: Rogov, 2005; *Sarmatisphinctes* sp. nov. horizon *in*: Pimenov *et al*., 2005)

Stratotype. — Gorodischi section, upper part of bed 9/40 to bed 1/16, alternating light beige and dark gray clays, in part highly bioturbated, with phosphorite nodules.

Index species. — *Sarmatisphinctes ilowaiskii* Rogov, sp. nov. [m] (Pl. 3: 1, 2); holotype VH-17/13 (Pl. 3: 1), Gorodischi, 10 cm above the base of bed 1/19.

Characteristic ammonites. — *Aulacostephanus* sp. nov. [M] (Pl. 6: 1); *A. mammatus* Ziegler [m]; *A. jasonoides* (Pavlov) [m]; *Neochetoceras* ex gr. *subnudatum* (Fontannes) [M]; *N. rebouletianum* (Fontannes) [M]; *Lingulaticeras solenoides* (Quenstedt) [m]. The uppermost part of this horizon in the type section contains oppeliid ammonites (*Ochetoceras* cf. *zio* (Oppel) [M], *Taramelliceras* cf. *franciscanum* (Fontannes) [M]) (Rogov, 2004c).

Comments. — The possibility of the dividing the Fallax Subzone into two horizons was first recognised by Rogov (2004c).

Correlation. — Records of Submediterranean ammonites indicate correlation with the *rebouletianum* horizon (Tab. 1).

Geographical range. — Middle Volga area (Gorodischi, Murzicy, Isady sections), Orenburg area (Berd'anka), Peri-Caspian area (Elton).

LOWER VOLGIAN

The detailed ammonite biostratigraphy of the Lower Volgian has been updated by Rogov (2002b, 2004a) and Rogov *et al.* (2006). A few new faunal horizons, including the *sokolovi* and *pavida* horizons that were proposed by Kutek and Zeiss (1997) and Rogov (2004c), are described in this paper.

Klimovi Zone Mikhailov, 1962

The lowermost part of the Klimovi Zone should be assigned to the separate faunal horizon, but its most characteristic ammonite, *Neochetoceras*, is usually poorly preserved. Some of the small specimens resemble *N. praecursor*, but the precise determination of this species is a matter of controversy.

Characteristic ammonites. — *Neochetoceras* cf. *nodulosum* (Berckhemer, Hölder)/*N.* cf. *praecursor* Zeiss (rare); *Ilowaiskya/Sarmatisphinctes* transiens [M, m]; *Taramelliceras* cf. *franciscanum* (Fontannes) [M].

Comments. — The possible presence of the horizon in question (cf. *praecursor*) in the Russian sections was noted by Rogov (2004c). Its correlation is tentative because of the poor preservation of the ammonites. Oppeliids from this level resemble the uppermost Kimmeridgian (*N. nodulosum*, *T. franciscanum*) and lowermost Tithonian (*N. praecursor*) taxa.

Correlation. — The Lower Tithonian *eigeltingense* horizon (Tab. 1).

Geographical range. — Middle Volga area (Gorodischi, ?Murzicy, Polevye-Bikshiki sections), Orenburg area (Berd'anka); ?central Poland.

For two overlying units, which were recognized initially as "beds with ammonites" and afterwards as faunal horizons, new names are proposed. There are: the *steraspis* horizon below and the *efimovi* horizon above, which are characterized by acme-levels of their index species (for *Paralingulaticeras* (*Rogoviceras*)[4] *efimovi* see Pl. 5: 8).

Sokolovi Zone Ilovaisky, 1941 in: Ilovaisky and Florensky (1941)

sokolovi horizon Ilovaisky emend. Rogov, herein

Stratotype. — Gorodischi section, bed 1/13a, light grey clay with numerous phosphorite nodules.

Index species. — *Ilowaiskya sokolovi* (Ilovaisky) [m] (Pl. 3: 3); holotype (SD Mikhailov, 1964): *Ilowaiskya sokolovi* var. *typica* (Ilowaisky, Florenski, 1941, p. 76, pl. 8: 18); Sokolovi Zone of the Sukhaya Peschanka section, Orenburg area.

Characteristic ammonites. — *Paralingulaticeras* (*Rogoviceras*) cf. *efimovi* (Rogov) [m] (Pl. 3: 4, 5); *Subdichotomoceras* sp.

Comments. — *Ilowaiskya sokolovi* and *I. pavida* have been shown by Kutek and Zeiss (1997) to have different ranges; a possible presence of this horizon in Russia was noted by Rogov (2004 c).

Correlation. — Probably with the upper part of the Hybonotum Zone (Rogov, 2004a, c) and by the occurrence of *Neochetoceras mucronatum* Berckhemer et Hölder in Poland (Kutek, Zeiss, 1997), with ?part of the Mucronatum Zone (Tab. 1). The presence of *Subdichotomoceras* (*Sphinctoceras*) suggests at least the partial correlation of this horizon with the Subcrassum Zone of the Subpolar Urals and the Scitulus-Wheatleyensis Zones of the British succession.

Geographical range. — Middle Volga area (Gorodischi, Polevye-Bikshiki sections), Orenburg area; central Poland.

pavida horizon Rogov, nov.

Stratotype. — Gorodischi section, bulk of the bed 1/12, dark grey clays, sometimes with grey interbeds.

Index species. — *Ilowaiskya pavida* (Ilovaisky) [m]; lectotype (SD Mikhailov, 1964): *Ilowaiskya sokolovi* var. *pavida* (Ilowaisky, Florenski, 1941, p. 76, pl. 12: 25); Sokolovi Zone of the Sukhaya Peschanka section, Orenburg area.

Characteristic ammonites. — *Subdichotomoceras* sp.; "*Franconites*" sp. (?) (upper part of horizon in the type section).

Correlation. — Based on the correlation of adjacent horizons (Tab. 1).

Geographical range. — Middle Volga area (Gorodischi, Polevye-Bikshiki sections), Orenburg area (Berd'anka); central Poland.

[4] *Rogoviceras* considered here as a subgenus of *Paralingulaticeras* because the species *P.* (*R.*) *efimovi* in author's opinion directly derived from true Submediterranean *Paralingulaticeras*, but inhabited Subboreal Middle-Russian Sea and represented here by dwarf neotenic species showing features typical for non-mature *Paralingulaticeras* s.s. Perhaps such morphological shift appeared in response to unusual environments (compare with occurrence of dwarf *Amoeboceras* in the *Amoeboceras* layers of Poland, described by Matyja, Wierzbowski, 2000).

?Pseudoscythica Zone Ilovaisky, 1941 in: Ilovaisky and Florensky (1941)

"Franconites" horizon Rogov, nov.
(proposed by Rogov, 2005; Pimenov *et al*., 2005)

Stratotype. — Gorodischi section, uppermost part of bed 1/12 and lowermost part of bed 1/11, highly bioturbated dark grey clays and light beige clays.

Index species. — Horizon determined by the presence of ammonites resembling the Submediterranean *Franconites*.

Characteristic ammonites. — ?*Franconites* cf. *vimineus* (Schneid) (Mikhailov, 1964, pl. 9: 1; Rogov, 2005, fig. 4, refigured at Pl. 4: 1 herein) [M]; ?*Franconites* sp.

Comments. — The ?*Franconites* figured from the Russian Platform by Mikhailov (1964) and Mitta (2004) were re-determined as *Ilowaiskya* by Scherzinger and Mitta (2006). Additional sampling of this stratigraphical level is necessary before further progress can be made.

Geographical range. — Middle Volga area (Gorodischi, Polevye-Bikshiki sections), Orenburg area (Berd'anka).

BRIEF REVIEW OF OSCILLATIONS IN THE AMMONITE ASSEMBLAGES THROUGH THE KIMMERIDGIAN-VOLGIAN TRANSITION OF THE MIDDLE VOLGA AREA

The ammonite assemblages in the Kimmerdigian-Volgian transition beds consist of mixtures of Subboreal, Boreal and Submediterranean taxa. The Lower Volgian assemblages were shown by the present author (Rogov, 2004c) to contain oscillating compositions, but the Upper Kimmeridgian part of the Gorodischi section has only been intensively excavated since 2005. The Upper Kimmeridgian ammonite assemblages have now been shown to be characterized also by changes in the relative abundances of ammonites of Submediterranean, Subboreal and Boreal affinities (Fig. 3C).

The highest part of the Eudoxus Zone (cf. *anglicum* horizon) is characterized by the mass occurrence of the Boreal ammonite *Nannocardioceras*. A similar event has been recorded in England (Nannocardioceras Beds) and Poland where it correspond in part to the Amoeboceras Beds of Malinowska (2001). Beds with *Nannocardioceras* in the upper part of the Eudoxus Zone of the Subpolar Urals (Zakharov *et al*., 2005) and Northern Siberia (Mesezhnikov, 1984) represent correlatives of this faunal event.

The beginning of the Autissiodorensis Zone (aff. *rebholzi* horizon) is marked by a conspicuous change in the ammonite assemblage. Aulacostephanids (including two morphotypes of *A. autissiodorensis* with smooth and ribbed terminal body chambers) become numerous, and aspidoceratids (macroconchiate *Aspidoceras* cf. *catalaunicum* (Loriol) and *Anaspidoceras* sp. accompanied by microconchs – *Sutneria*) make up 37% of the assemblage (Murzicy section).

There are a few records of aspidoceratids at the same stratigraphical level in Poland and in England. Geyssant (1994) described two influxes of "*Sutneria rebholzi*" at the beginning of the Autissiodorensis Zone in Yorkshire. In addition, rare records of *A.* cf. *catalaunicum* (Loriol) from the Pechora area (Mesezhnikov, 1984, pl. 32: 1) and the Subpolar Urals (referred to as *A. longispinum* by Zakharov *et al*., 2005) show how extensive spread of these ammonites was, possibly as the result of a short-lived warmer climate. Cardioceratids are represented at this stratigraphical level by the wide-ranging species *N. krausei* (Salfeld) and possibly by *N.* cf. *ewae* (Malinowska), although records of the latter species are not numerous.

The *volgae* horizon represents the last mass occurrence of cardioceratids throughout the Middle Volga area and westwards from there as far as England. It is the youngest level in the Kimmeridgian of European Russia in which Boreal ammonoids predominate. The next mass immigration of Boreal ammonites occurred at the beginning of the Middle Volgian. Interestingly, the lithology, thickness and ammonite assemblages of the *volgae* horizon are closely similar throughout the Middle Volga area.

Most of the Upper Kimmeridgian ammonite assemblages above the *volgae* horizon are characterized by a predominance of the Subboreal *Sarmatisphinctes* and *Aulacostephanus*. The abundance of the Submediterranean taramelliceratid *Neochetoceras* shows remarkable oscillations. The lower and upper parts of the *subborealis* horizon are characterized in Russia by a high *Neochetoceras* contents: the upper level has a well-documented distribution as far as central Poland (the Subnudatum level of Kutek, Zeiss, 1997) which may reflect a climatic change.

The Fallax Subzone is characterized by a steady upward increase in Submediterranean influence that has been well documented throughout the Middle Volga area and up into the Lower Volgian (see Rogov, 2004c). Boreal ammonites, including very rare *Suboxydiscites* cf. *taimyrensis* (Mesezhnikov), suggest that the Taimyrensis Zone of Northern Siberia is the correlative of the whole Autissiodorensis Zone.

The beginning of the Lower Volgian is marked by the maximum proportion of Submediterranean ammonites in the assemblages of the Middle Volga area. This proportion then gradually decreases as the Boreal *Eosphinctoceras* and *Subdichotomoceras* become increasingly abundant. The *pavida* horizon contains a poor assemblage that includes a mixture of Boreal (*Subdichotomoceras*) and Subboreal (*Ilowaiskya*) ammonites, Boreal belemnites, and Boreal bivalves including *Buchia* and oysters (Rogov, 2005).

The "*Franconites*" horizon contains a few *Franconites*--like ammonites accompanied by badly preserved *Ilowaiskya* of the *pseudoscythica* group. Another mass immigration of Submediterranean ammonites occurred in the *neoburgense* hemera (Rogov, 2004a, 2005) when *Anaspidoceras neoburgense* became the most numerous ammonite in the Gorodischi area. This horizon has been recognized in other regions of European Russia, including the Belgorod and Moscow areas, where that ammonite occurs re-deposited in phosphorite moulds, and in the Orenburg area (Berd'yanka section). In the Middle Volga area these ammonites are accompanied by numerous belemnites of Submediterranean origin (*Hibolithes*, see Ippolitov, 2006; Rogov *et al*., 2006), which are smaller in size than their counterparts in Tethys.

Another marked change in the ammonite assemblages occurs at the beginning of the *puschi* horizon where the ammonites are mainly Subboreal ("*Pseudovirgatites*" derived from *Ilowaiskya*: possibly homoeomorphs of the true Submediterranean *Pseudovirgatites*). Possible Submediterranean perisphinctids are uncommon at this stratigraphical level where they are represented by *Danubisphinctes* sp. (Rogov, 2004c).

DESCRIPTIONS OF NEW AMMONITE SPECIES

Sarmatisphinctes zeissi Rogov, sp. nov. [m]

(Pl. 2: 4, 5)

1963 *Subplanites pseudoscythicus* (Ilovaisky et Florensky); Pachucki p. 9, pl. 3: 4.
1997 *Discosphinctoides subborealis* sp. nov; Kutek and Zeiss, p. 139, pl. 18: 3.

Holotype: Specimen VH-17/1, Vernadsky State Geological Museum of RAS (Pl. 2: 4).
Type locality: Gorodischi section, Ulianovsk Volga area, 5 cm above the bottom of bed 9/25.
Type horizon: Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *zeissi* horizon.
Derivation of name: In honor of Dr. Arnold Zeiss (Erlangen, Germany), whose research greatly improved our understanding of the ammonite assemblages and biostratigraphy of the Kimmeridgian-Volgian boundary beds.
Diagnosis: Microconchs showing features intermediate between *S. subborealis* and *S. fallax*. *S. zeissi* has some triplicate ribs, but these are not connected to constrictions; constrictions are usually bounded by simple and dichotomitic ribs. Aperture with small lappets.

Material. — Gorodischi section: VH-17/1, VH-17/2, VH-17/3, VH-17/4, VH-17/5, VH-17/6, VH-17/7, VH-17/8, VH-17/51, VH-17/55; Murzicy section: VH-17/9, VH-17/10; Berd'yanka section: VH-17/12.

Description. — *S. zeissi* has dense biplicate ribbing with a few triplicate ribs in the mature stages of ontogenic development not connected directly to constrictions. Innermost whorls usually covered by bifurcate ribs. Prorsiradiate constrictions are not numerous and are usually weakly developed. They are mostly followed by a simple rib, and preceded by a compound bidichotome (or sometimes triplicate) rib. The ribs are rusiradiate at the umbilical edge, becoming rectiradiate to prorsiradiate near the whorl-flanks. The ribs furcate relatively higher than in *S. subborealis*, in the upper half to upper third of the whorl side. Ribs may furcate in a symmetrical or asymmetrical fashion. In the latter case the anterior secondary rib approximately follows the course of the primary rib and the anterior rib diverges backwards from this direction. An unstable, irregular mode of furcation (a typical feature of *Sarmatisphinctes*) is represented in *S. zeissi* by the difference in the neighbouring rib furcation. In addition, the rib density, furcation point and character of the constrictions are highly variable in this species in comparison with other forms of *Sarmatisphinctes*. The sizes of adults in this genus shows significant variation, up to at least two diameters.

Discussion. — *Sarmatisphinctes zeissi* is distinguished from the closely similar form *S. subborealis* by the presence of triplicate ribs which are not connected to constrictions. In addition, the rib density (estimated from the number of primary ribs per quarter whorl) is usually significantly higher in *S. zeissi* than in *S. subborealis*. Interestingly, in the Gorodischi and Murzicy sections (*c*. 200 km apart) the first representatives of *S. zeissi* appear at the same level which is developed in the same lithology in the lithostratigraphical succession. The first appearance of *S. subborealis* is in the uppermost part of a light grey bed at the base of alternating dense dark grey and grey clays. *S. zeissi* also resembles *S. fallax* of the ancient morphotype, but in the latter species tripartite ribs (sometimes with virgatotome ribs) are much more numerous and the rib density is lower in the outer whorls. *S. fallax*, *S. zeissi* and *S. subborealis* appear to be closely related forms that belong to the same lineage.

Geographical and stratigraphical range. — *Zeissi* horizon of the Middle Volga area (Gorodischi, Murzicy sections), Orenburg area (Berd'anka); Peri-Caspian area (Elton) and Polish Lowland.

Sarmatisphinctes ilowaiskii Rogov, sp. nov. [m]

(Pl. 3: 1, 2)

1963 *Zaraiskites pilicensis* (Michalsky); Pachucki, p. 8, pl. 3: 5, 6.
1963 *Zaraiskites scythicus* (Michalsky); Pachucki, p. 8, pl. 4: 2 (only).

1973 *Subplanites klimovi* (Ilovayski et Florenski); Dembowska, p. 99, pl. 1: 5, 6.
1973 *Subplanites kokeni* (Behrendsen); Dembowska, p. 99, pl. 2: 1.
1973 *Subplanites* cf. *kokeni* (Behrendsen); Dembowska, p. 99, pl. 2: 2, 5.
1973 *Subplanites* sp.; Dembowska, p. 100, pl. 2: 3.
1997 *Sarmatisphinctes fallax* (Ilovaisky); Kutek and Zeiss, p. 145, pl. 20: 1; pl. 21: 1, 3, 4; pl. 22: 1–6.
2002a *Sarmatisphinctes fallax* (Ilovaisky); Rogov, pl. 1: 6.
2004b *Sarmatisphinctes* sp. nov.; Rogov, pl. 1: 2, 3.

Holotype: Specimen VH-17/13 (Pl. 3: 1), Vernadsky State Geological Museum of RAS.
Type locality: Gorodischi section, Ulianovsk Volga area, bed 1/19, 10 cm above the base.
Type horizon: Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *ilowaiskii* horizon.
Derivation of name: In honor of David Ilowaisky, distinguished Russian paleontologist who carried out detailed studies of the Kimmeridgian-Volgian boundary beds of the Orenburg area.

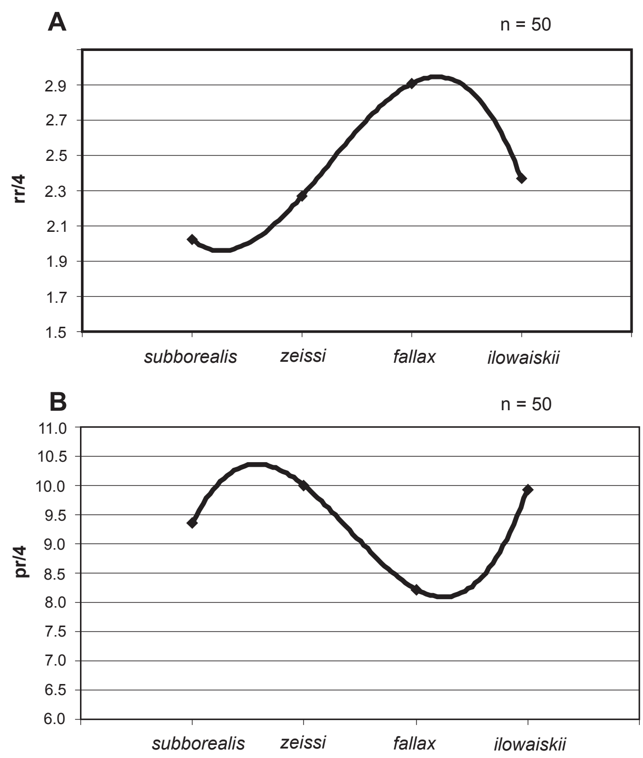


Fig. 4. Change of primary rib density and secondary/primary rib ratio in the evolution of the *Sarmatisphinctes subborealis – S. zeissi – S. fallax – S. ilowaiskii* lineage

A – variations in the average rib ratio per $^1/_4$ whorl (rr/4); **B** – variations in the average rib density per $^1/_4$ whorl (pr/4); n – number of specimens

Diagnosis: Microconchs having closely similar ornamentation to that of the earliest *Ilowaiskya* from which they are distinguished by more unstable ribbing. *Sarmatisphinctes* usually has biplicate and triplicate ribs in more or less equal proportion, with virgatotome ribs in some specimens. Triplicate ribs mostly appear at the diameters of 3 to 5 cm. Aperture with small lappets.

Material. — Gorodischi section: VH-17/13, VH-17/15, VH-17/16, VH-17/17; Berd'yanka section: VH-17/19, VH-17/20, VH-17/21; Elton section: VH-17/22, VH-17/23; Isady section: VH-17/24, VH-17/25, VH-17/26, VH-17/27, VH-17/28; Murzicy section: VH-17/14, VH-17/29, VH-17/30, VH-17/31.

Description. — The ribbing pattern consists of dense biplicate and triplicate ribs in different ratios. In the outer whorls it varies from ~equal to a prevalence of either biplicate or triplicate ribs with additional virgataxioceratid ribs and simple ribs. The ribbing in the innermost whorls is predominantly bifurcate, but tripartite ribs appear early in the shell ontogeny in some specimens. Prorsiradiate constrictions are not common and are sometimes absent. They are usually followed by a simple rib, and preceded by a compound bidichotome (or sometimes triplicate) rib. The ribs are rusiradiate at the umbilical edge, becoming rectiradiate to prorsiradiate on the whorl-flank. The ribs furcate approximately at the middle of the flanks, but the furcation point is variable and can be located in the lower or upper half of the whorl. Ribs may furcate in a symmetrical or asymmetrical fashion; in the latter case the anterior secondary rib follows approximately the course of the primary rib and the anterior rib diverges backwards. An irregular mode of furcation frequently appears in the rib succession: biplicate, triplicate, simple and virgatotome ribs alternate in the different modes. The evolution of the *Sarmatisphinctes* lineage shows major alternations in the principal ornamentation features such as secondary/primary rib ratio and density of primary ribs (Figs 4, 5). The same phenomenon is present in the evolutionary successions of the Keppleritinae (Callomon, 2004; Kiselev, Rogov, 2007) and the Cadoceratinae (Kiselev, Rogov, 2007). In consequence it is easy to confuse ammonites of different ages with one another. When collected from loose blocks, the specimens of *Sarmatisphinctes zeissi* and *S. ilowaiskii* could be misidentified as belonging to a single species. Both, however, can be separated from *S. fallax* without difficulty.

Discussion. — It is difficult to distinguish *S. ilowaiskii* from progressive and ancestral morphotypes of *S. fallax*. The principal distinction of the species is a rarity of virgatotome ribs and the prevalence of biplicate and triplicate ribs in *S. ilowaiskii*. This species is also closely related to the earliest *Ilowaiskya* (*I. klimovi*) from which it differs in having

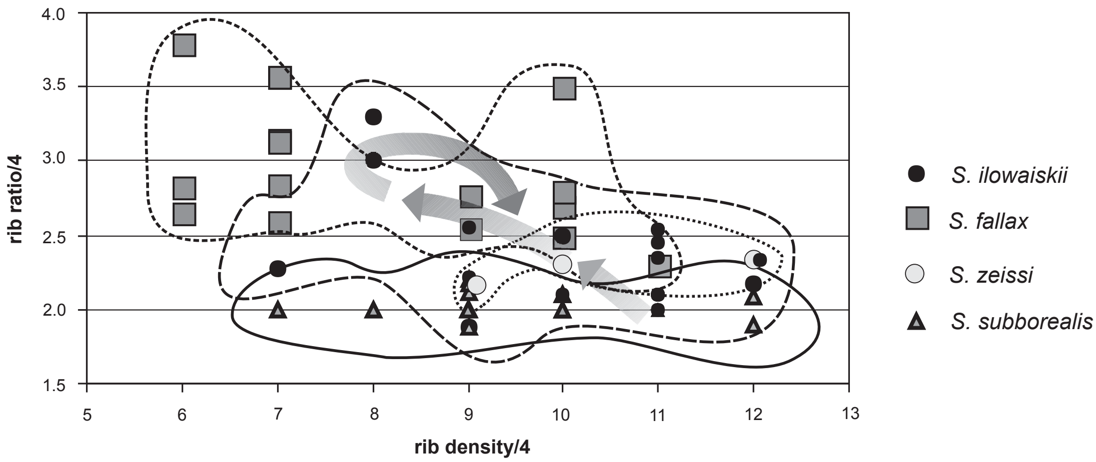


Fig. 5. Evolutionary changes in the *Sarmatisphinctes subborealis – S. zeissi – S. fallax – S. iloiwaiskii* lineage

Transparent arrows show the trend of the changes (cf. Fig. 4) in the principal features

more irregular ribbing and an earlier appearance of triplicate ribs. The latter usually appear at half of the diameter at which they occur in *Ilowaiskya*.

Geographical and stratigraphical range. — *Ilowaiskii* horizon of the Middle Volga area (Gorodischi, Murzicy, Isady sections); Orenburg area (Berd'anka); Peri-Caspian area (Elton); central Poland.

Acknowledgements. This study has been supported by RFBR grants 06-05-64284, 05-05-65262, 09-05-00456 Russian Science Support Foundation and by grant of the President of the Russian Federation MK-856.2008.5. I also warmly thank V.V. Mitta (Moscow), F. Atrops (Lyon) and A. Scherzinger (Hattingen) for their valuable comments and discussions, and to my colleagues who helped me in the fieldwork in the Middle Volga area during the last few years: A. Guzhov, A. Manikin, M. Pimenov (Saratov), A. Guzhov, L. Ermakova, A. Ippolitov, A. Orlova, V. Piskunov, E. Schepetova, E. Terekhova (Moscow), A. Sapozhenkov (Kostroma), O. Dzyuba (Novosibirsk) and D. Kiselev (Yaroslavl). Additional valuable suggestions were made by two reviewers, G. Schweigert (Stuttgart) and J. Kutek (Warsaw), who also introduced the author to the collections of Kimmeridgian, Tithonian and Volgian ammonites from Swabia and Poland. The collections of L. Malinowska, stored in the Polish Geological Institute, were made available through the friendly help of T. Woroncowa-Marcinowska, W. Mizerski and H. Wierzbowski (Warsaw); while access to collections of Kimmeridgian ammonites from southern England stored in the British Museum (Natural History) was organized through the help of W. Wimbledon (Bristol), A. McGowan and S. Nikolaeva (London). Valuable remarks concerning English uppermost Kimmeridgian were made by R. Gallois (Exeter), who also checked spelling of the text.

Studied ammonites are stored in the Vernadsky Geological Museum of RAS, Moscow (VH), and CNIGR Museum, Saint-Petersburg (CNIGR).

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PLATES

PLATE 1

Fig. 1. *Nannocardioceras* cf. *anglicum* (Salfeld, 1915) [m]
VH-17/32; Gorodischi, 2.25 m above the base of the bed 9/2; Upper Kimmeridgian, Eudoxus Zone, cf. *anglicum* horizon; × 2

Figs 2–3. *Nannocardioceras krausei* (Salfeld, 1915) [m]
2 – specimen lost. Murzicy, bed 2; 3 – VH-17/33; Gorodischi, bed 9/9; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon; × 2

Figs 4–6. *Nannocardioceras volgae* (Pavlov, 1886) [m]
4 – lectotype, CNIGR 37/312 (= Pavlov, 1886, pl. 8: 5); 5 – VH-17/34; 6 – VH-17/11; bed 9/10; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *volgae* horizon; × 2

Figs 7–9. *Sutneria* aff. *rebholzi* Berckhemer, 1922 [m]
7 – VH-17/35, 8 – VH-17/36, 9 – VH-17/37; Murzicy, bed 1/2; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon; 7, 8 – × 2; 9 – natural size

Figs 10. *Neochetoceras* cf. *subsidens* (Fontannes, 1879) [M]
specimen lost; Gorodischi, bed 9/9; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon; natural size

Figs 11–12. *Sarmatisphinctes subborealis* (Kutek et Zeiss, 1997) [m]
11 – VH-17/38, 12 – VH-17/39; Gorodischi, 1 m below the top of the bed 9/24; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *subborealis* horizon; natural size

All ammonites are coated with ammonium chloride

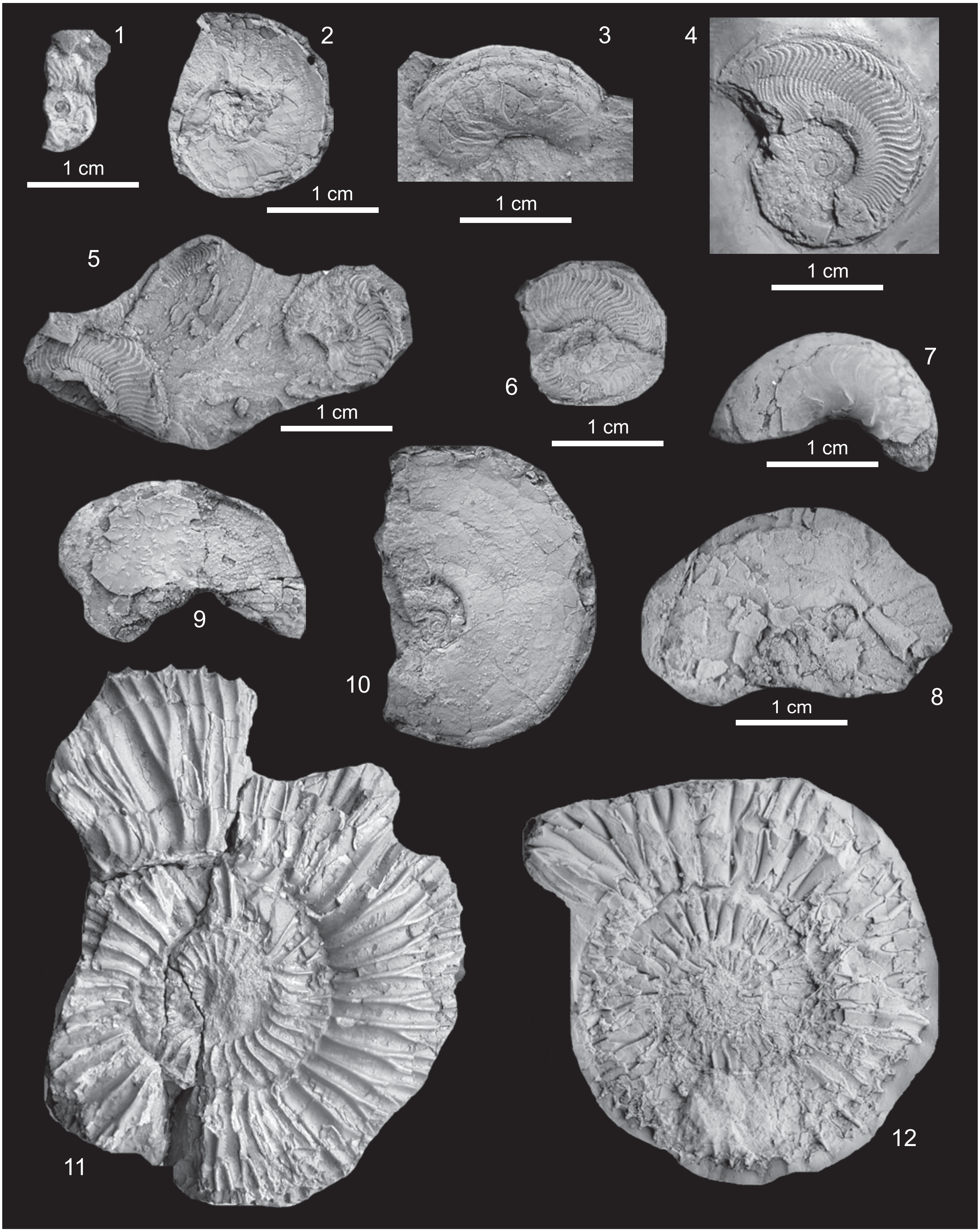
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PLATE 2

Fig. 1a–c. *Aulacostephanus volongensis* Khudyaev 1932 [m]
holotype CNIGR 2/3434 (= Khudyaev, 1932, pl. 1: 3); glauconitic clay of Volonga river; Upper Kimmeridgian

Figs 2–3. *Aulacostephanus* sp. nov. aff. *mammatus* Ziegler, 1962 [m]
2 – VH-17/40; Murzicy, 2.3 m above the base of bed 14; 3 – VH-17/41, Gorodischi, bed 9/37; Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *fallax* horizon

Figs 4–5. *Sarmatisphinctes zeissi* Rogov sp. nov. [m]
4 – holotype VH-17/1, 5 – VH-17/8; Gorodischi, bed 9/25; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *zeissi* horizon

Fig. 6. *Neochetoceras* cf. *subnudatum* (Fontannes, 1879) [M]
VH-17/42; Gorodischi, 6.95 m above the base of bed 9/2; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *subborealis* horizon

Fig. 7. *Suboxydiscites* cf. *taimyrensis* (Mesezhnikov, 1976) [M]
VH-17/43; Gorodischi, 1.65 m below the top of the bed 9/41; Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *fallax* horizon

Fig. 8. *Aspidoceras* cf. *catalaunicum* (Loriol, 1872) [M]
VH-17/44; Murzicy, beds 1–2; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon

All ammonites are coated with ammonium chloride, figured in natural size


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PLATE 3

Figs 1–2. *Sarmatisphinctes ilowaiskii* Rogov sp. nov. [m]
1 – holotype VH-17/13, Gorodischi, 0.1 m above the base of bed 1/19; 2 – VH-17/17, Gorodischi, bed 1/16; Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *ilowaiskii* horizon

Fig. 3. *Ilowaiskya sokolovi* (Ilovaisky, 1941) [m]
VH-17/45; Gorodischi, bed 1/13a; Lower Volgian, Sokolovi Zone, *sokolovi* horizon

Figs 4–5. *Paralingulaticeras* (*Rogoviceras*) cf. *efimovi* (Rogov, 2002) [m]
4 – VH-17/46, 5 – VH-17/47; Gorodischi, bed 1/13a; Lower Volgian, Sokolovi Zone, *sokolovi* horizon; × 2

All ammonites are coated with ammonium chloride, figured in natural size (with exception of Figs 4, 5)

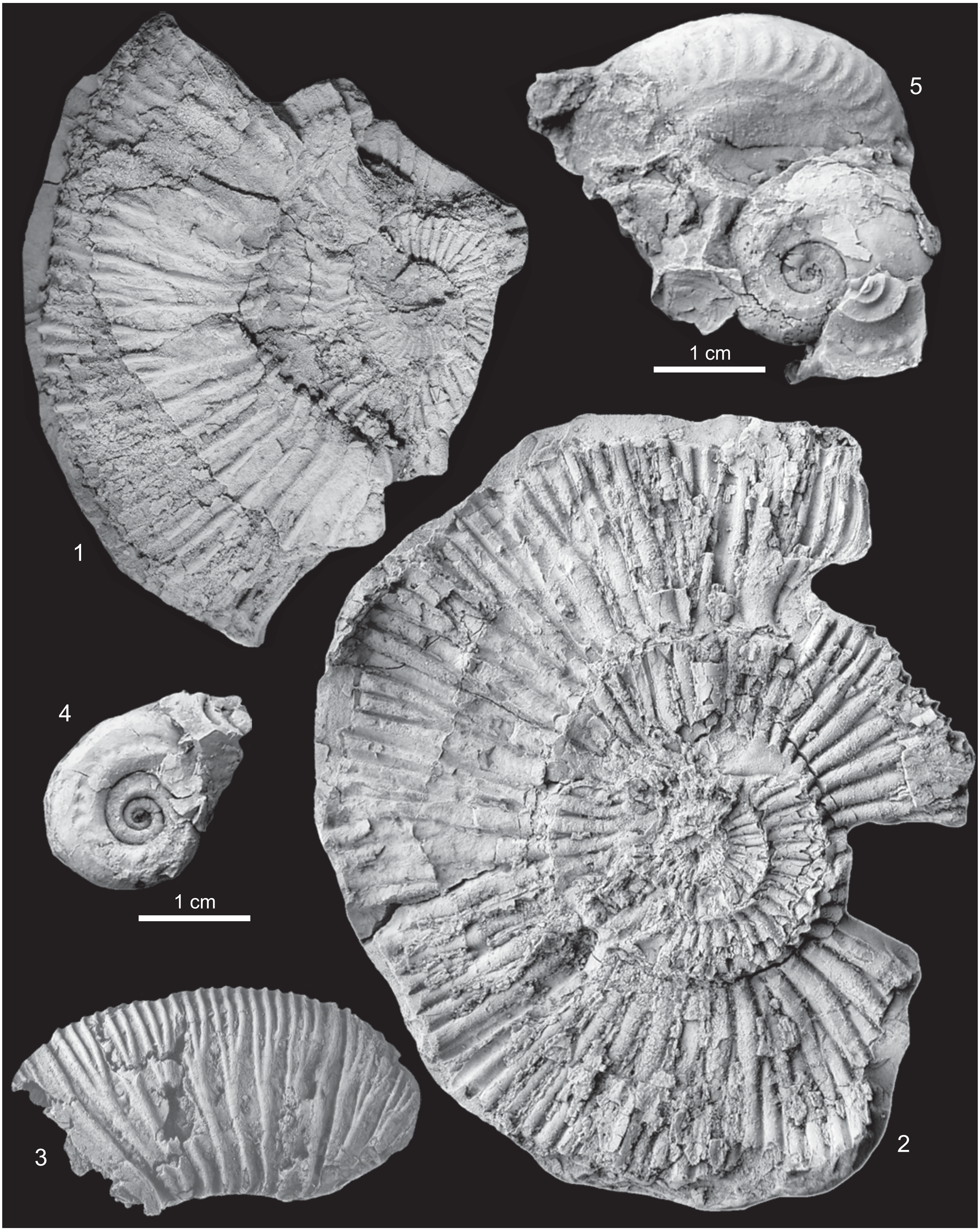
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PLATE 4

Fig. 1. ?*Franconites* sp.
Photographed *in situ* in the field at Gorodischi, bed 1/10; Lower Volgian, ?Pseudoscythica Zone, "*Franconites*" horizon; × 0.5

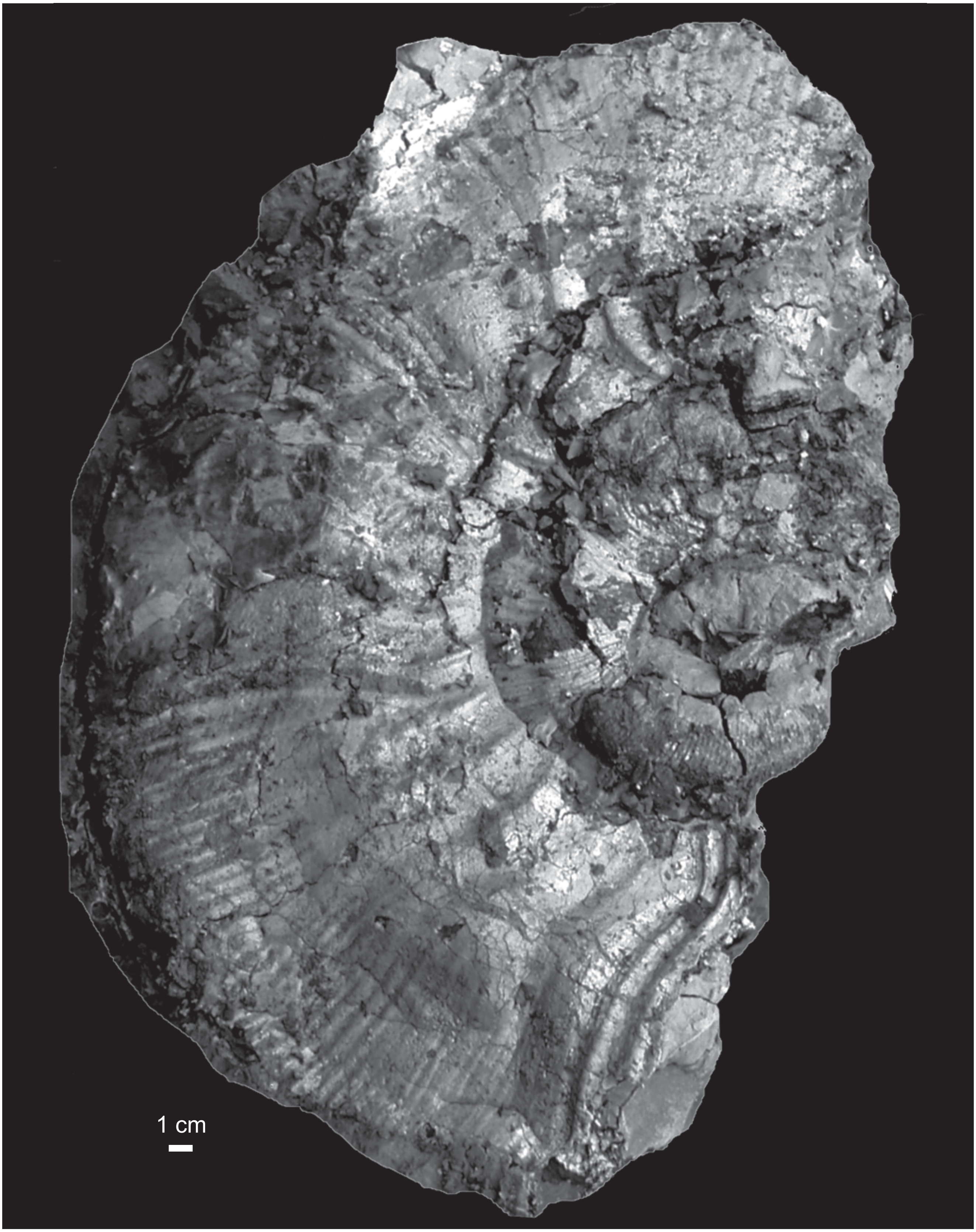
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PLATE 5

Fig. 1. *Sarmatispinctes subborealis* (Kutek et Zeiss, 1997)
VH-17/48; Murzicy, 0.1 m below the top of the bed 13; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *subborealis* horizon

Figs 2–3. *Sarmatisphinctes fallax* (Ilovaisky)
2 – VH-17/49, Murzicy, 2 m above the base of the bed 14; 3 – VH-17/50, Murzicy, 2.1 m above the base of the bed 14; Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *fallax* horizon

Figs 4, 10. *Aulacostephanus subundorae* (Pavlov) [m]
4 – specimen lost, Gorodischi, 7.45 m above the base of the bed 9/2; 10 – BX-17/52, Gorodischi, 1 m below the top of the bed 9/24; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *subborealis* horizon ("*Taramelliceras* level")

Fig. 5. *Aulacostephanus kirghisensis* (d'Orbigny) [m]
VH-17/53; Murzicy, bed 2; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon

Fig. 6. *A.* cf. *kirghisensis* (d'Orbigny) [m]
VH-17/54; base of the bed 9/25; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *zeissi* horizon

Fig. 7. *Sutneria* aff. *rebholzi* Berckhemer [m]
specimen lost; Gorodischi, 0.1 m above the base of the bed 9/9; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, aff. *rebholzi* horizon; × 2

Fig. 8. *Paralingulaticeras* (*Rogoviceras*) *efimovi* (Rogov) [m]
VH-17/18; Lower Volgian, Klimovi Zone; × 2

Fig. 9. *Aulacostephanus* cf. *volgensis* (Vischniakoff)
VH-17/52; Gorodschi, 1 m below the top of the bed 9/24; Subborealis Subzone, *subborealis* horizon ("Taramelliceras level")

All ammonites are coated with ammonium chloride, figured in natural size except Fig. 7, 8, which are enlarged two times

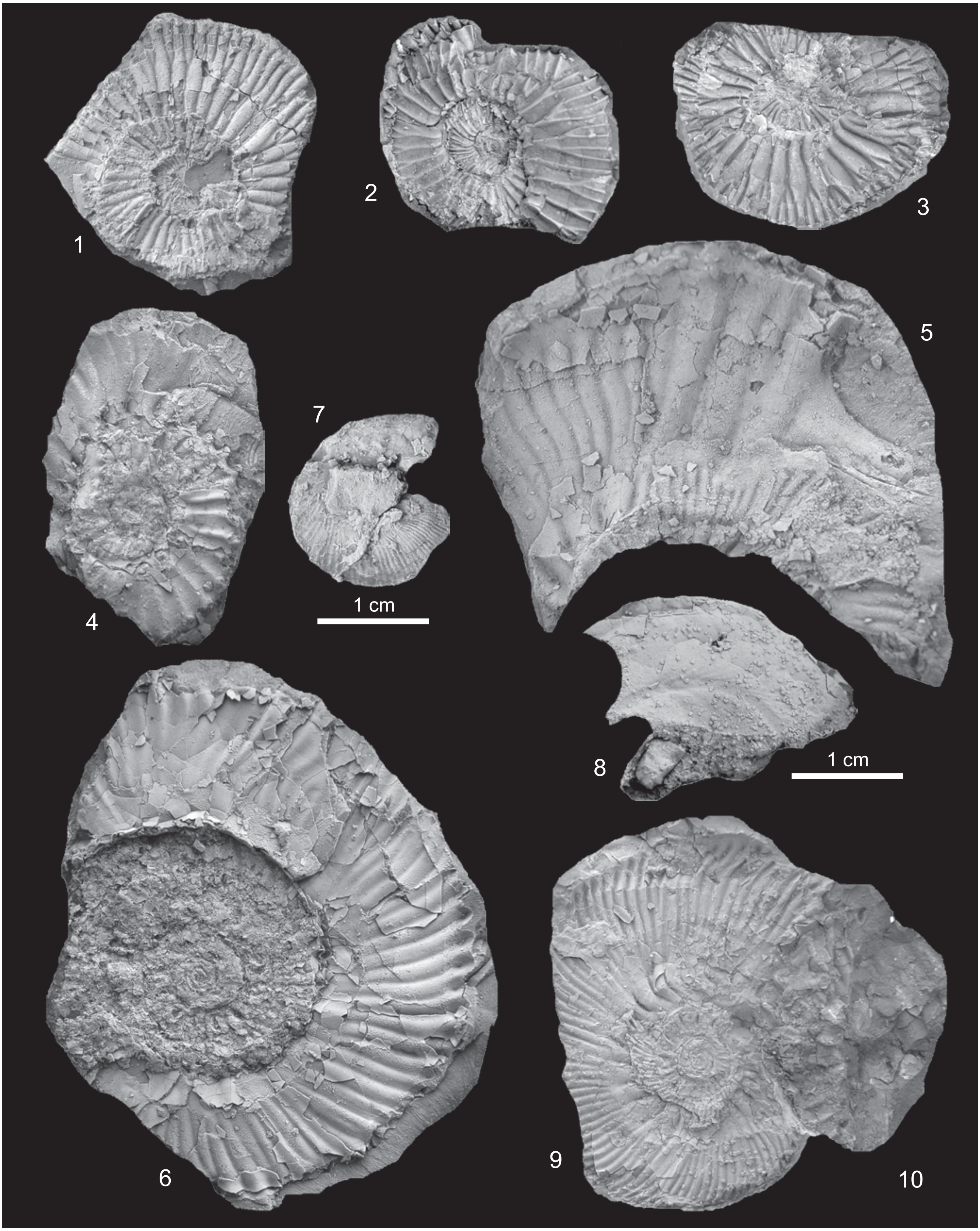
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PLATE 6

Fig. 1. *Aulacostephanus* sp. nov. [M]
Gorodischi, photographed in the field (2005), 1 m below the top of the bed 1/19; Upper Kimmeridgian, Autissiodorensis Zone, Fallax Subzone, *ilowaiskii* horizon; × 0.4

Fig. 2. *Aulacostephanus autissiodorensis* (Cotteau) [M]
Murzicy, photographed in the field (2006), 0.1 m above the base of the bed 5; Upper Kimmeridgian, Autissiodorensis Zone, Subborealis Subzone, *subborealis* horizon; × 0.4


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