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Stuttgart, August 2017 **Article**

Ammonite assemblages in the Lower to Upper Kimmeridgian boundary interval (Cymodoce to Mutabilis zones) of Tatarstan (central European Russia) and their correlation importance

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With 13 figures

Abstract: For the first time upper part of the Cymodoce Zone sensu lato (mostly Askepta Subzone) of the Lower Kimmeridgian and the Mutabilis Zone of the Upper Kimmeridgian are described in detail from the Russian Platform. The most fully developed ammonite succession, which includes Boreal, Subboreal and Submediterranean faunal elements, is recognized in southern Tatarstan (Tarkhanovskaya Pristan and Memei sections). The lowermost assemblage, consisting of late representatives of *Rasenia* and *Zonovia* was found in the Memei section only (cf. Hantzpergue et al. 1998). Well above, numerous Submediterranean *Crussoliceras* occurrences were discovered in the upper part of the Cymodoce Zone of the whole area, whereas younger assemblages yielded Boreal *Amoebites* and/or Subboreal *Rasenioides* followed by *Aulacostephanoides* with some addition of *Aspidoceras* and *Orthaspidoceras* above. The aulacostephanid genus *Zenostephanus* is recorded in the studied region for the first time. Significant lateral variability of the deposits of the Cymodoce and Mutabilis zones in thickness and completeness through a small distance in South Tatarstan along with other evidence suggests the strong influence of synsedimentary tectonics on sedimentation at the Early to Late Kimmeridgian transition of this region. Mass immigration of the Submediterranean ammonites *Crussoliceras* into the Subboreal Russian Sea resulted in their short-time dominance over a wide area. The *Crussoliceras* ammonites are recognized also in the condensed sections of the Moscow and Kaluga areas in the north, and their re-deposited records are known (along with uncommon *Zenostephanus*, *Aulacostephanoides* and *Amoebites*) from the basal phosphorite band of the Middle Volgian of the Unzha river (Kostroma area). This "*Crussoliceras* event", which is well-recognized in Submediterranean areas, as well as the subsequent expansion of *Zenostephanus*, both correspond to a sea-level high-stand, which resulted in faunal mixing of ammonites indicative of different bioprovinces. They provide key correlative levels which can be recognized around the Lower/Upper Kimmeridgian boundary, especially in the ecotone area of the Russian Sea. These levels include also occurrences of *Crussoliceras*, *Rasenoiodes* and rare *Amoebites* of the *kitchini* group in the Askepta Subzone, of *Aulacostephanoides* spp. along with *Amoebites peregrinator* and *Zenostephanus sachsi* in the lower part of the Mutabilis Subzone as well as of Aspidoceratidae and *Aulacostephanoides* in higher parts of this subzone, followed by *Orthaspidoceras*. At least six successive ammonite assemblages can be recognized through the studied part of the Kimmeridgian, providing interregional correlation with Submediterranean and Boreal sections.

Key words: Kimmeridgian, Askepta Subzone, Mutabilis Zone, Russian Platform, biostratigraphy, palaeobiogeography, *Crussoliceras* migration event, *Zenostephanus*.

1. Introduction

Changes in ammonite assemblages during the latest Early Kimmeridgian and the beginning of the Late Kimmeridgian in the northern shelf of the Tethys in Western and Central Europe have been the subject of several studies. They indicated an abrupt appearance of Subboreal ammonites of the family Aulacostepha-

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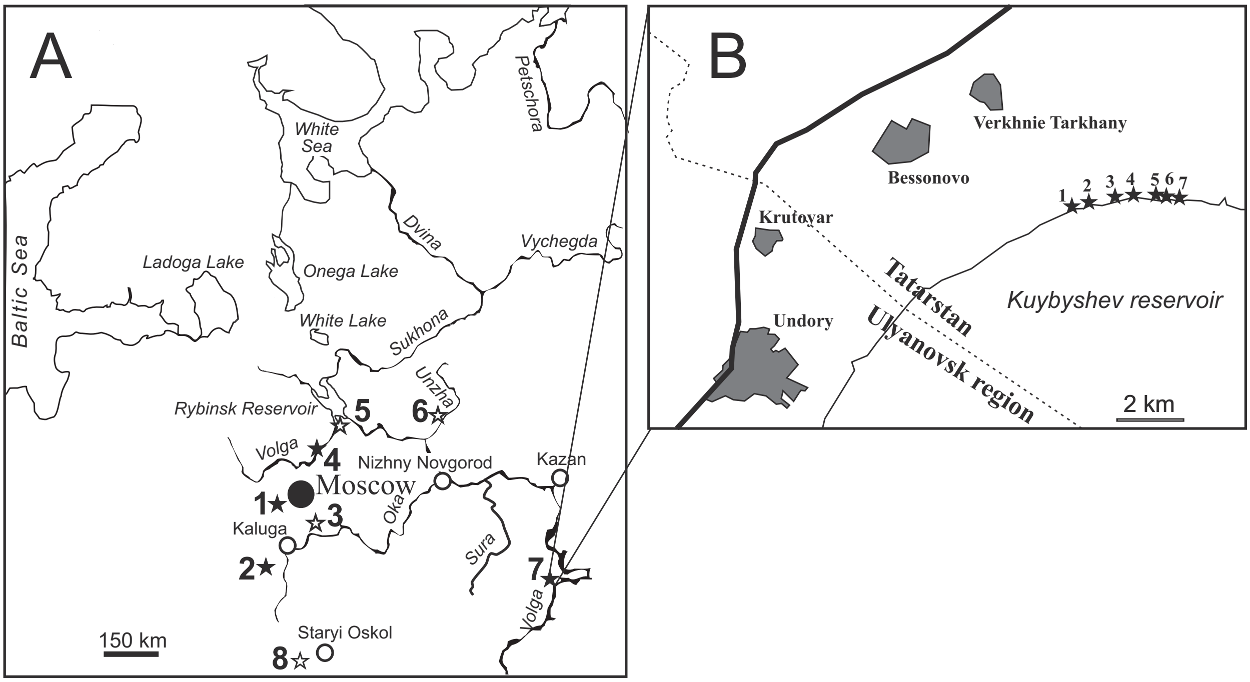

Fig. 1. Locality map. **A** – Distribution of localities with ammonites of the Lower/Upper Kimmeridgian transitional strata in European Russia. Open stars: sections in which re-deposited ammonites of the Mutabilis Zone were found; filled stars: sections yielding in situ ammonite records. Numbers refer to the following sections: 1 – Ignatievo, 55º36'56" N, 36º29'20" E; 2 – Serensk, 54º18'36" N, 35º33'11" E; 3 – Voskresensk, mine no.9, 55º21'24" N, 38º51'21" E; 4 – Kimry, 56º53'20" N, 37º27'07" E; 5 – Koprino, 58º03'50" N, 38º20'16" E; 6 – Unzha river, few sections; 7 – southern Tatarstan, few sections (see Fig. 1B for details); 8 – Stoilensk open mine, 51º15'45" N; 37º43'40" E. **B** – Details of the localities in the Southern Tatarstan, studied in detail. 1 – Memei 1; 2 – Memei 2; 3 – T5; 4 – locality with loose *Crussoliceras* (TP); 5 – T3, 4; 6 – T1; 7 – T2.

nidae – mostly of the genus *Rasenioides* in the north, and the time-corresponding appearance of new Tethyan representatives of the family Ataxioceratidae – such as *Crussoliceras* and *Garnierisphinctes* in the south, during the latest Early Kimmeridgian. These changes which have a fundamental significance for stratigraphy and palaeogeography were also related to marked facies transformations – mostly the appearance of the "facies virgulien", and similar siliciclastic and lumachelle deposits over wide areas of Europe (e.g., Birkelund et al. 1983; Hantzpergue 1989, 1995; Matyja & Wierzbowski 2000; Enay et al. 2014, and earlier papers cited therein). The succeeding changes in ammonite assemblages during the early Late Kimmeridgian showed, on the other hand, a marked northward distribution of Tethyan ammonites – mostly Aspidoceratidae – which ranged so far north as eastern England (see Geyssant 1994) and the Middle Volga area (Pavlow 1886). These episodes of maximum distribution of Submediterranean and/or Subboreal ammonites at the Early/Late Kimmeridgian transition are commonly interpreted as a consequence of transgressive impulses related to sea-level rises (e.g., Marques & Olóriz 1992; Hantzpergue 1995).

This study presents the results of field-investigations at Memei and Tarkhanovskaya Pristan on the right bank of the Volga river of the Kuybyshev reservoir in southern Tatarstan (central European Russia) conducted by the authors in August, 2010 and 2011. The study revealed the presence of an uppermost Lower Kimmeridgian to lowermost Upper Kimmeridgian succession with abundant ammonites. The succession may be correlated also with that described previously by Hantzpergue et al. (1998) from Mimei (Memei herein, as this is more correct transliteration of Russian «Memeй», nearby village), which also yielded some late Early Kimmeridgian ammonites, unfortunately non-illustrated. Because the stratigraphical interval in question has been so far generally poorly known in European Russia being mostly referred to the occurrence of the *Aspidoceras* – fauna in the Ulyanovsk (formerly

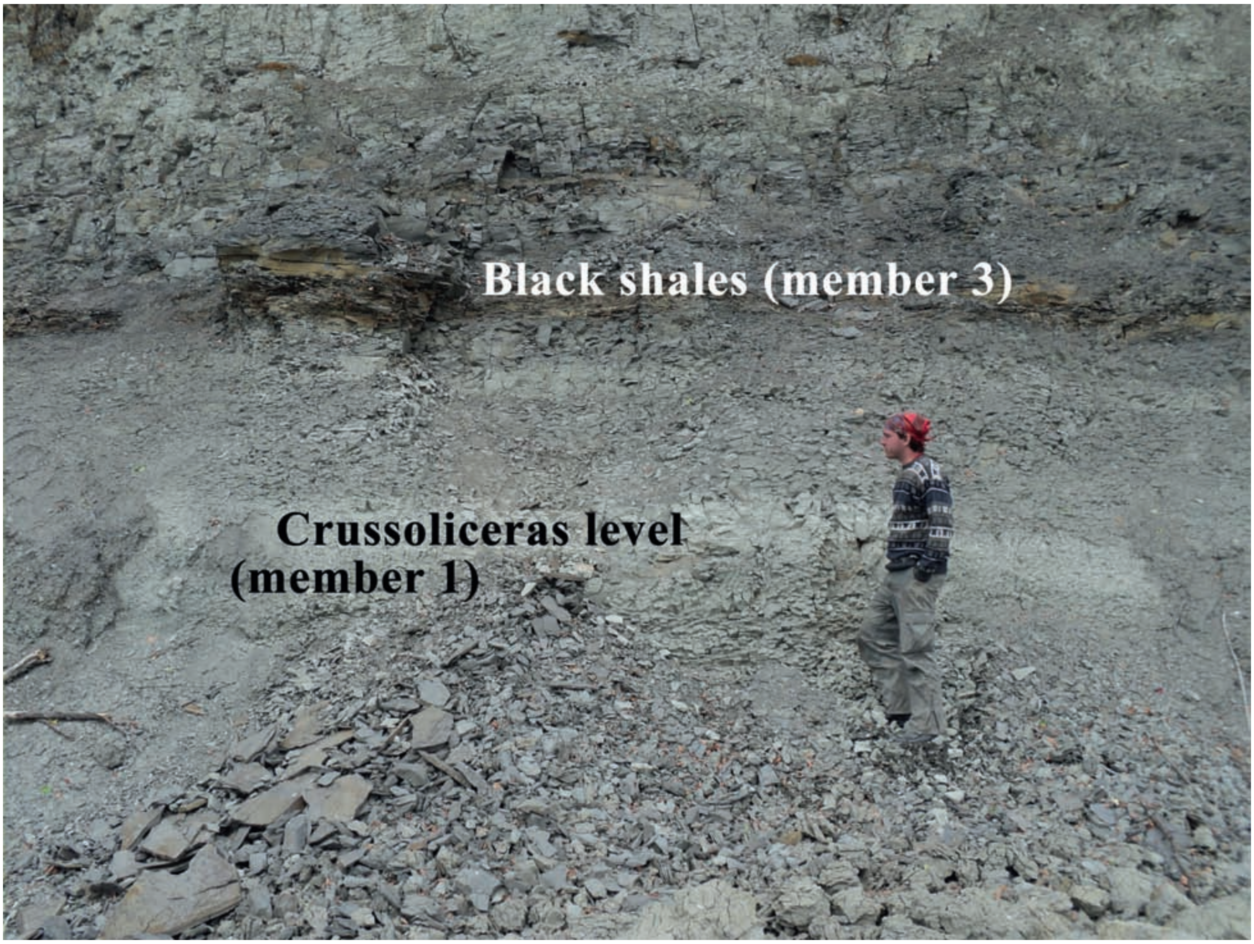

Fig. 2. Memei 2 locality – general view.

Simbirsk) area by Pavlow (1886), and poorly known occurrences from abandoned sites in the Yaroslavl region (Nikitin 1881, 1884), the new material offers the possibility of wider recognition of the ammonite assemblages and their palaeogeographical interpretation in relation to those of Western and Central European areas (Fig. 1A). The preliminary results of the study were presented by the authors during the 9th Jurassic Congress in Jaipur, India in 2014 (Rogov et al. 2014).

Besides the ammonites from Tatarstan discussed here (collected by the authors), and including those collected by Vladimir Efimov (Undory), some additional material was considered in this study – such as that collected in the Moscow area (1990-1993, 2011) and the Kaluga region (1999, 2007) by the first author (M.R), and donated by Denis Gulyaev (Yaroslavl), as well as Andrey Shkolin (Moscow). Figured specimens are stored in State Vernadsky Geological Museum, Moscow (SGM) and Museum of Geological Faculty, University of Warsaw (MWG UW ZI/80). Specimens described by S.N. Nikitin (1881, 1884) are kept in the Central Geological-Prospecting Museum, Saint-Petersburg (CNIGR).

Analyses determining the $CaCO_3$ and C_{org} content were performed by Elena Shchepetova (Geological Institute of RAS); she also improved the descriptions of the rocks occurring in the sections T1, T3 and T4 as based on investigation of thin sections.

2. Stratigraphy

2.1. Description of the sections

The sections showing particular parts of the succession studied were easily accessible in the steep slopes on the right hand side of the Volga valley east of Tarkhanovskaya Pristan during the summer season of 2011. They were, however, only temporary in character, as shown by observations in 2015, when almost all the sections described herein appeared completely destroyed by landslides. Five sections described as T1, T2, T3, T4 and T5 (see Figs. 1B, 2, 5) show the succeeding parts of the succession studied.

Section T1 begins at the water-table and shows Upper Jurassic deposits about 3.20 m in thickness. These deposits rest on Middle Jurassic non-calcareous silty dark grayish-green clay (0.68% $CaCO_3$), with thin laminations of yellowish-grey silty to sandy laminae (1-5 mm); the lamination is not observed in the uppermost part of the deposits which is heavily bioturbated. The following members have been distinguished above (from the base):

Member 1 – 1.4-1.5 m thick – calcareous, light greenish-grey clay and marl (26.90-45.29% $CaCO_3$), with glauconite, semi-rounded quartz grains and fragments of ferruginous oolites. In the lower part of the member the clays are characterized by their darker colour and the presence of numerous *Chondrites* burrows. The base of the bed is characterized by the presence of phosphorite conglomerate (0.05-0.07 m), which consists of angular fragments of phosphorites, some of them containing ammonite fragments (identified as *Cadoceras*). Such pieces of phosphorite are also relatively abundant some 10-15 cm above the phosphorite layer; moreover there occur ferruginous concretions, and fragments of various fossils (fragments of large bivalves, belemnite rostra, fragments of large ammonites including that of *Crussoliceras*); the following ammonites have been identified in the overlying part of the member 1: *Crussoliceras atavum* (Schneid) (at 0.35 m above the base) (Fig. 6A), *C.* cf. *atavum* (0.85 m above the base), *C. lacertosum* (Fontannes)/cf. *lacertosum* (Fontannes) (0.15 and 0.55 m above the base, Fig. 10G), and several fragments of inner whorls possibly representing the genus *Crussoliceras*;

Member 2 – about 1.8 m thick – is composed of calcareous greenish-grey silty clay (22.59-26.67% $CaCO_3$), with numerous thin pyritized ichnofossil tubes with glauconite grains. At the base of the member a thin (up to 0.1 m) band of greenish-grey dark clay (1.04-2.00% C_{org}; 8.29-24.51% $CaCO_3$) with numerous yellowish bodies of gypsum and iron hydroxides could be recognized. Pyritized ammonites occurring in the lower part of this member are generally of small size, but some larger specimens in the clays were encountered as well; the findings include: *Crussoliceras* cf. *atavum* (Schneid) (0.3 m above the base), *Crussoliceras lacertosum* (Fontannes) (0.45 m above the base) (Fig. 6B), *C.* cf. *lacertosum* (base of member 2), and several fragments of inner whorls possibly representing the genus *Crussoliceras* in the whole member; also present were *Amoebites kitchini* (Salfeld) (0.25 m above the base) and *A.* cf. *kitchini* (0.55 m above the base) (Fig. 13B, C).

Section T2 was situated about 500 m east of section T1. The deposits are dark clays and marls about 2 meters in thickness. These are of the ‘Fleckenmergel’-type calcareous marls in their upper part and show the presence of numerous burrows. Here, a several centimeters thick level with common ammonites (partly pyritized) and rare phosphorites occurs. The identified ammonites are mostly small-sized representatives of the genus *Aulacostephanoides* such as *Aulacostephanoides eulepidus* (Schneid) and *A.* cf. *desmonotus* (Oppel) (Fig. 12I, R); a single specimen of *Eurasenia* or heavily ornamented *Involuticeras* (Fig. 12P) and two specimens of *Amoebites kitchini* (Salfeld) (Fig. 13L) were also found here.

Sections T3 and T4 (Fig. 3) located at about one hundred meters west of section T1 included deposits about 14-15 m in thickness – from the base: calcareous greenish-grey platy clay (7.95-15.78% $CaCO_3$), showing an alteration of light highly bioturbated clay and darker clay with abundant subhorizontal ichnofossil tubes (member 3, nearly 5 m thick). Small (1-2 cm) phosphorite concretions occur in some levels. These deposits could represent at their base the uppermost part of member 2 from locality T1, but because there is no direct correlation possible between sections T1 and T3, they are distinguished as belonging to a separate rock-unit – member 3. The deposits of member 3 resemble those of member 5, but are characterized by a bigger size of silt particles and the constant presence of glauconite. Calcareous bluish-grey clays and silty marls (16.57-23.27 % $CaCO_3$), highly bioturbated and massive, with occasional pyrite and phosphorite concretions, represent member 4, about 5-5.5 m thick. The lower part of the member, which has been sampled in the T3 section, is characterized by its higher $CaCO_3$ content (28.03-31.21 %); a similar lithological character is also present in the upper part of the member. These deposits are overlain by calcareous greenish-grey well-bedded silty clay (9.19-13.05 % $CaCO_3$), belonging to member 5 (1.5-1.6 m thick). Small (2-3 cm) pyrite and phosphorite concretions occur on some levels. At the top of section T4, calcareous finely-laminated black shales (member 6, up to 1.2 m thick) occur which are dark-grey to brownish in colour (9.3%-12.4% C_{org};

11.92%-14.87% $CaCO_3$). Flattened pyrite concretions up to 10-15 cm in diameter occur in the upper part of the shale bed. Fossils are mainly represented by the bivalve *Aulacomyella* and gastropods; ammonites (*Aspidoceras* sp. indet., *Aulacostephanoides* sp. ind. (Fig. 12C-E) are very rare and were collected from loose blocks only. The sections T4 and T5 were described in detail by Shchepetova & Rogov (2013, fig. 1 – where the succession of their locality 1 corresponds to the deposits of sections T1, T3 and T4 as shown herein), who also provided results of Rock-Eval analysis of organic matter derived from black shales at the top of the succession.

The identified ammonites from sections T3 and T4 include: an assemblage composed of *Crussoliceras* spp. from the lower part of the light-gray marls (section T3) of member 3 (partly found in the rubble; Fig. 9A, C-F), followed by an assemblage of *Rasenioides* spp. The partially preserved imprints of a finely ribbed cardioceratid ammonite, strongly resembling *Amoebites* (?) *kapffi* (Oppel) (Fig. 13A) and *Amoebites* sp. were collected at the level with *Rasenioides*, 1.9 m above the base of the section T3. Ammonites of the genus *Aulacostephanoides* (Fig. 12F, G) and small-sized *Amoebites peregrinator* Rogov (Fig. 13D, E; see description in Rogov 2016) occur in the upper part of the light-grey marls of member 3, and the lower part of member 4 (section T3). The characteristic species *Zenostephanus sachsi* (Mesezhnikov), the index-species of the horizon, well-recognized through the different parts of the Arctic (i.e. Franz-Josef Land, Spitsbergen, Khatanga depression, Western Siberia and possibly British Columbia – see Rogov 2014, 2016; Rogov & Poulton 2015) was found in the upper part of the marly unit of member 4 and in the rubble (section T4; Fig. 13G-I, K). A still younger assemblage of ammonites composed of *Aulacostephanoides* and *Aspidoceras* sp. indet. (Fig. 12A, B) is known from marls in a higher part of section T4 and it occurs up to the black shale unit at the top of the succession studied (see Rogov et al. 2014).

Section Memei-2 (Figs. 2, 5) is located slightly eastwards from the Memei section (distinguished herein as Memei-1) as described by Hantzpergue et al. (1998); it was studied during the field season of the year 2010, when it was easily accessible due to the very low water level in the Kuybyshev reservoir. The succession given below is exposed here (from the base).

Member 1 – calcareous light-grey to white if weathered clay (1 m thick), strongly bioturbated (especially at the top of the bed and in its middle part), with phosphorite concretions 0.7 m below the top; numerous *Crussoliceras lacertosum* (Fontannes) (Figs. 9B, 10C, F) were found between 0.25 and 0.55 m below the top; in addition one indeterminable *Amoebites* sp. ind. has been collected 0.3 m below the top of this member. This member correspondings to the upper part of bed Ta 1, bed Ta 2, and bed Ta 3 of Hantzpergue et al.(1998) where only the presence of indeterminate "perisphinctids" in bed Ta 2 has been mentioned. A few bands of grey and light grey clays without macrofossils with a total thickness 1.65 m could be recognized above (member 2). These beds are overlain by member 3 - dark-grey to brown black shales (0.4 m), with numerous *Aulacomyella* bivalves on the bedding planes, while ammonites (indeterminable juvenile cardioceratid and *Aspidoceras* sp. indet.) are very uncommon.

Between the Tarkhanovskaya Pristan and Memei sections the *Crussoliceras*-bearing beds are not exposed but a few big-sized *Crussoliceras atavum* (Schneid) were found loose in rubble (locality TP; Figs. 7A, 8A).

Fig. 3. Tarkhanovskaya pristan T3-T4 localities – general view.

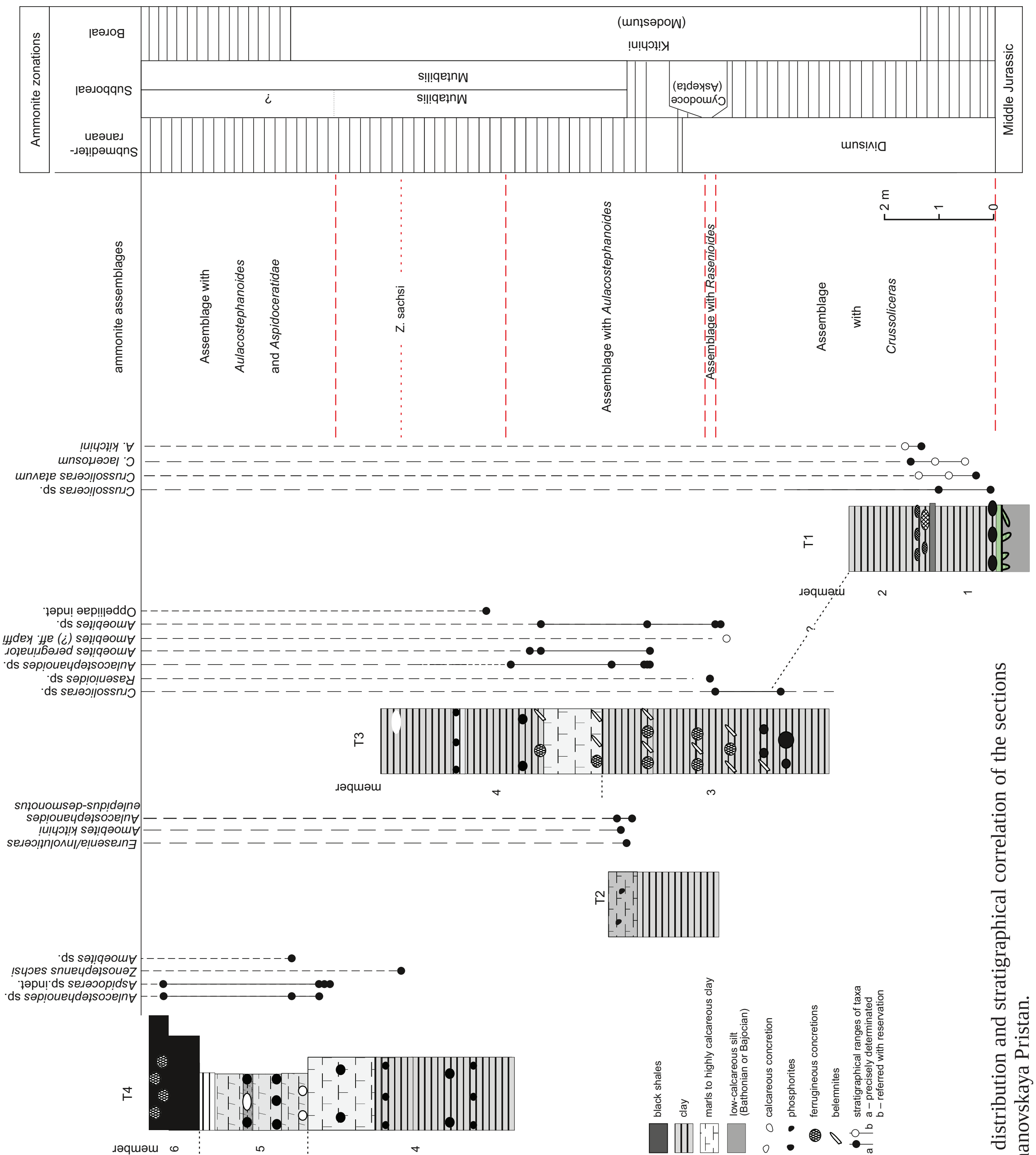

Fig. 4. Ammonite distribution and stratigraphical correlation of the sections T1-T4 at the Tarkhanovskaya Pristan.

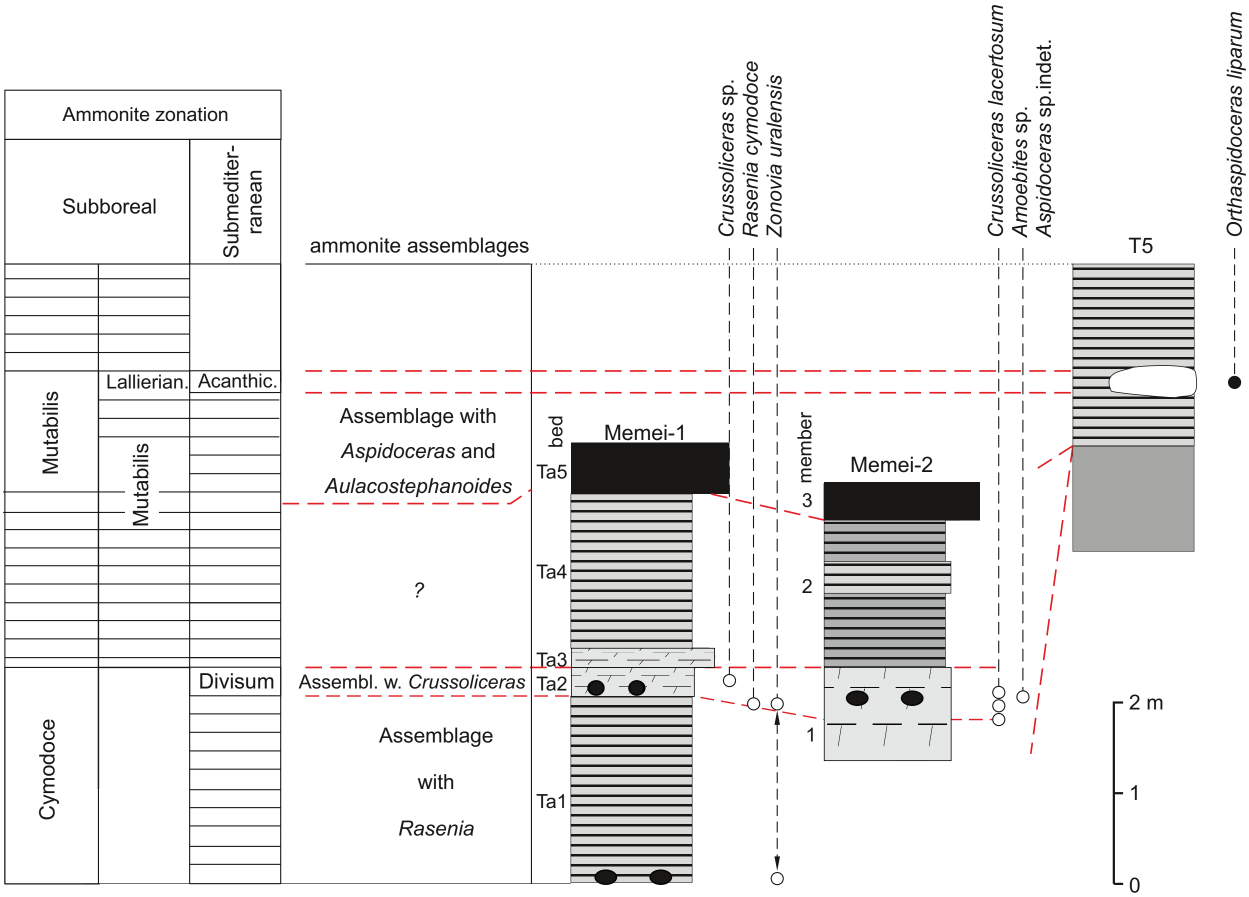

Fig. 5. Ammonite distribution and stratigraphical correlation of the sections between Memei and Tarkhanovskaya Pristan (section T5).

An additional small section (T5) is located between this locality with *Crussoliceras* found loose and the Memei sections discussed above. Here, above the Middle Jurassic cliff of Bathonian silts (~ 4-5 m high), calcareous greenish-grey clays (2 m thick) appear. The clays yield septarian limestone concretions occurring at 0.7 m above the base of the unit. Such concretions are unknown from units exposed at localities T1-T4 of Tarkhanovskaya Pristan and Memei-1 and 2. The septarian concretions yielded *Orthaspidoceras liparum* (Oppel) (Fig. 11B).

Some 1.5 km northwards of the T2 section at Tarkhanovskaya Pristan, Bathonian silts covered by Callovian marls and Lower Oxfordian clays, and overlain by Kimmeridgian deposits, were exposed in the sections described by Mitta et al. (2014).

Very quick changes in the completeness and thickness of the Lower/Upper Kimmeridgian boundary beds in a distance of a few kilometers as well as the same variability in structure of the underlying Middle Jurassic deposits as shown in descriptions of the sections given above (see also Mitta et al. 2014) in the area of study suggest a significant role of synsedimentary tectonics in the development of sedimentation in this part of basin. The tectonic phenomena were especially active during the late Cymodoce Chron, and especially during the formation of the beds with *Crussoliceras* which show large differences in thickness and sedimentological character between the Tarkhanovskaya Pristan and the Memei localities (Figs. 4-5; see also chapter on ammonite stratigraphy). An active tectonic setting during the Jurassic in this area was also assumed by Korolev et al. (2012) to explain the occurrence of the barite-rich concretions in the Kimmeridgian deposits. As suggested by Korolev et al. (2012), the origin of barite in these concretions occurred through fault-controlling underwater hydrothermal vents. Barite concretions from Southern Tatarstan were also reported previously in the Callovian deposits (Korchagin 1962), which suggest repeated tectonic activity during the Middle and Late Jurassic.

2.2. Ammonite stratigraphy

The oldest ammonites have been discovered in a lag-deposit, in reworked, mostly crushed, phosphorite nodules, at the base of the Upper Jurassic succession in section T1. Some phosphorites yielded imprints of ammonites of the subfamily Cadoceratinae – of the genus *Cadoceras* and its close allies. These findings indicate the original presence of deposits (mostly of Lower Callovian age) which have been completely washed out during the Late Jurassic. However, a few kilometers eastwards, Lower and Upper Callovian deposits, which overlie the poorly fossiliferous Bajocian (?) to Bathonian strata, are well developed (Mitta et al. 2014).

The Upper Jurassic succession is composed of six main ammonite assemblages (Figs. 4-5). The oldest Kimmeridgian assemblage was discovered by Hantzpergue et al. (1998) in the the Memei-1 section, where unfigured *Rasenia* cf. *cymodoce* (d'Orbigny) and *Zonovia* cf. *uralensis* (d'Orbigny) together with the Boreal bivalve *Buchia concentrica* (v. Buch) have been mentioned. The Subboreal ammonite assemblage with *Rasenia* is replaced upwards by a new assemblage dominated by drastically different ammonites of Submediterranean affinity. This assemblage occurring in sections Memei 1-2, and at Tarkhanovskaya Pristan (section T1 and a lower part of section T3) in deposits strongly contrasted in their thickness (from about 0,3 m to 3.5 m thick), consists mostly of the Submediterranean representatives of the genus *Crussoliceras* – *C. atavum* (Schneid) [M] and *C. lacertosum* (Fontannes) [m], representing possibly a dimorphic pair. The occurrence of these forms in the described ammonite succession is indicative of the Divisum Zone of the Submediterranean zonal scheme; and the occurrence of *C. atavum* suggests additionally the upper part of this zone (e.g., Schick 2004) although the species shows a wide stratigraphical range from the upper part of the Divisum Zone up to the Acanthicum Zone and the Eudoxus Zone (see Enay et al. 2014, and earlier papers cited therein). The Boreal ammonites of the genus *Amoebites* – such as *Amoebites kitchini* (Salfeld) and *Amoebites* sp. – occur additionally in the middle-upper parts of the stratigraphical interval discussed. These ammonites are indicative of the upper part of the Kitchini Zone – the Modestum Subzone (see Wierzbowski & Smelror 1993; Wierzbowski et al. 2002).

A younger ammonite assemblage is composed of *Rasenioides* sp. found in deposits about 0.1 m thick in section T3 (member 3 – middle part). This assemblage could nearly correspond to the *Rasenioides*-bearing beds of the Tver (Buev 2012) and Kaluga (Fig. 12N) areas. These ammonites are indicative of the upper part of the Subboreal Cymodoce Zone, an upper part of the Chatelaillonensis Subzone of the "Biome Franco-Germanique" (after presence of *Rasenioides*, see e.g., Hantzpergue 1989; Matyja & Wierzbowski, 2000; Comment et al. 2015).

The ammonite assemblage composed of numerous representatives of the genus *Aulacostephanoides* occurs in a narrow interval about 1 m in thickness in section T2 (upper part) and in section T3 (member 3 – upper part, and member 4 – lower part). The fauna with *Aulacostephanoides* is indicative of the Subboreal Mutabilis Zone in its traditional (and accepted herein) interpretation. It should be remembered that the deposits of this interval in section T2 are possibly stratigraphically condensed as shown by their small thickness, common occurrence of ammonites, as well as the presence of numerous burrows and phosphorites. The section T2 has yielded additionally a single specimen of a rasenoid – *Eurasenia* or strongly ribbed *Involuticeras* which range up at least into higher part of the Lower Kimmeridgian (cf. Matyja & Wierzbowski 1998, 2000; see also Comment et al. 2015), being thus a link with the underlying ammonite assemblage described herein. Additionally, a few specimens of the Boreal genus *Amoebites* including *Amoebites kitchini* (Salfeld) as well as the recently described small-sized species *A. peregrinator* Rogov have been found in the assemblage in question. They are indicative of the uppermost part of the Boreal Kitchini Zone – the Modestum Subzone. *Amoeboceras peregrinator* is also typical of this assemblage.

The Boreal aulacostephanid *Zenostephanus sachsi* (Mesezhnikov) was found above the discussed ammonite assemblage. This species is indicative of the *sachsi* horizon, which is widely distributed in the Arctic (cf. Rogov 2016).

The ammonite assemblage occurring in section T4 from the marl unit of the topmost part of member 4 up to the black-shale member 6 is composed of numerous *Aulacostephanoides* still indicating the presence of the Subboreal Mutabilis Zone, but with a marked admixture of the ammonites of Tethyan origin (mainly badly preserved aspidoceratids and oppeliids).

A single record of *Orthaspidoceras liparum* (Oppel), indicative of the Lallierianum Subzone of the Mutabilis Zone, was made in section T5 in a bed of clay with septarian concretions, difficult to correlate lithologically with other sections at Tarkhanovskaya Pristan and Memei. The ammonite *Orthaspidoceras lallierianum* (d'Orbigny) originally described as *Aspidoceras liparum* by Pavlow (1886, pl. 9, fig. 3; see Hantzpergue 1989: 305) coming from the neighbouring outcrops on the Volga river near Goridischi (now covered by water of the Kuybyshev reservoir) possibly belongs to the same ammonite assemblage. The assemblage of the Lallierianum Subzone is characterized by dominance of "an endemic and monotaxic *Orthaspidoceras* fauna originating from the Submediterranean stock" (Hantzpergue 1995), although *Aulacostephanoides* records are also known from this subzone (e.g., Samson et al. 1996). Because the group of *O. lallierianum* is strictly related to the Mediterranean *Aspidoceras* of the *A. acanthicum* group (Hantzpergue 1989, fig. 136), the discussed assemblage of ammonites may be also compared with the Submediterranean Acanthicum Zone (although the detailed correlation between the Mutabilis Zone and the Acanthicum Zone is still an open question); an occurrence of *Orthaspidoceras* is known also from one of the famous Crussol sections being the typical locality of the Acanthicum fauna (Baudouin et al. 2011). It should be noted that *Aulacostephanoides* ranges up into the Acanthicum Zone (Ziegler 1962; Borrelli 2014). Thus, the occurrence of *O.lallierianum* may be treated as indicative of the uppermost ammonite assemblage of those distinguished herein in the succession studied.

3. Discussion

The changes in the character of the ammonite faunas in the succession studied are of biogeographical nature. They are the result of migrations of the ammonite groups which occupied various areas from the oceanic Tethyan basins to shallow epicontinental seas during the Late Jurassic. The distribution of special ammonite groups in Eurasia was strictly confined to particular areas, each of them related to environmental – palaeoclimatic conditions. These areas (bioprovinces) were characterized during the Kimmeridgian by the development of different ammonite groups: the families Ataxioceratidae, Aspidoceratidae and Oppeliidae for the Submediterranean Province, the Aulacostephanidae for the Subboreal Province and the Cardioceratidae for the Boreal Province. In the Subboreal Province all these groups co-occurred during the Kimmeridgian in some levels, whereas their joint records were also known in the Submediterranean Province, while aulacostephanids were widely distributed in the Boreal Province except some high-latitude sites.

Above the *Rasenia* cf. *cymodoce* – *Zonovia* cf. *uralensis* assemblage of Hantzpergue et al. (1998), represented by Subboreal ammonites, the oldest assemblage in the succession studied is characterized by the occurrence of Submediterranean Ataxioceratidae of the genus *Crussoliceras*. The appearance of the ammonite group of *Crussoliceras* and the closely related *Garnierisphinctes* at the end of Early Kimmeridgian over wide areas of the Submediterranean Province had most possibly the character of migration from the Mediterranean Province. During this time an older assemblage of Ataxioceratinae (from *Orthosphinctes* to *Ataxioceras*) was replaced by a new wave of Ataxioceratidae, representing possibly a new subfamily, and having their roots in forms related to Passendorferiinae in the Mediterranean basins (see Pavia et al. 1987). Such an interpretation seems to be in full agreement with the character of the inner whorls of *Crussoliceras* specimens from Tatarstan, which reveal typical passendorferiid very evolute coiling showing the common occurrence of simple ribs. The suggestion postulating the origin of the *Crussoliceras* group directly from Passendorferiinae seems thus more plausible for the present authors than an alternative assumption according to which the roots of the *Crussoliceras* group have been in the *Lithacosphinctes* – *Orthosphinctes* group of strictly Submediterranean origin (see also Enay et al 2014, where both these interpretations are discussed).

It should be noted that *Crussoliceras* occurs in other Subboreal areas such as Northern Poland (Wierzbowski et al. 2015), and is widely distributed in the European part of Russia. This genus is known from the historical sections of the Yaroslavl region (*Perisphinctes pralairei* in Nikitin, 1884, pl. 3, fig. 17, refigured here at Fig. 10A), as well as from pebbles of the re-worked deposits at the base of the Middle Volgian of the Unzha river, Kostroma area (Figs. 9G, 10D). Specimens of *Crussoliceras* associated with *Rasenioides* have been reported from the Kaluga region, where they are known from highly condensed glauconitic sand with whitish phosphorite concretions. *Crussoliceras* records are also known from the Moscow region (Fig. 10B). They are mainly noted in reworked phosphorites at the base of the Middle Volgian, but there is at least one section near to Ignatievo village, in which clays with

Crussoliceras-bearing phosphorites occur below the Autissiodorensis Zone (the latter is characterized by *Sarmatisphinctes subborealis* Kutek & Zeiss and *Aulacostephanus* spp.). Additional *Crussoliceras* records were made recently by the amateur palaeontologist Dmitry Buev at the Volga river coast near to Kimry town, ca 150 km north of Moscow (Buev 2012). These ammonites were found in a thin band (0.1-0.2 m) of black clay with occasional phosphorite nodules. The assemblage described is mainly dominated by *Crussoliceras* cf./aff. *lacertosum* (Buev 2012, pl. 1, figs. 1-10; pl. 2, figs. 3-8) with uncommon *Amoebites kitchini* (Buev 2012, pl. 2, fig. 1) and *Aspidoceras binodum* (Buev 2012, pl. 2, fig. 2). One additional ammonite record, figured under the name *Vineta* cf. *jaeckeli* (Buev 2012, pl. 2, fig. 9) is of a special interest, as it could represent *Rasenioides (Semirasenia) discoides*, the index species of the uppermost horizon of the Askepta Subzone in France (Hantzpergue 1989).

The sudden appearance of the new ataxioceratid ammonites (*Crussoliceras* – *Granierisphinctes*) during the late Early Kimmeridgian (at the boundary of the Hypselocyclum and Divisum chrons) over wide areas of the Submediterranean Province in the south has its time equivalent in the sudden appearance of a new group of aulacostephanids (*Rasenioides*) at the *Askepta* horizon of the Chatelaillonensis Subchron in the Subboreal Province in the north (as well as some transitional areas called “Biome franco-germanique”) (Matyja & Wierzbowski 2000; see also Hantzpergue 1989, 1995). This phenomenon is often interpreted in sequence stratigraphic terms as corresponding to the beginning of the transgressive phase of the eustatic cycle (Hantzpergue 1995), but possibly it may be better interpreted as a consequence of tectonically enhanced changes over wide areas of the northern Tethyan shelf. The synsedimentary tectonic activity recognized at the stratigraphical interval with *Crussoliceras* ammonites in the Tatarstan (central European Russia) section seems to confirm such an interpretation.

Study of the Tatarstan succession indicates that after an initial dominance of Submediterranean ammonites of the *Crussoliceras* group of the oldest ammonite assemblage, a new assemblage of ammonites composed of Aulacostephanidae of Subboreal character has appeared. It marks the replacement of the Submediterranean ammonites by Subboreal ones. These Subboreal ammonites are late *Rasenioides*, and co-occur with finely ribbed cardioceratids showing a transitional character between *A. modestum* and *Amoebites* (or *Euprionoceras*) *kapffi* (Oppel). Additionally, a single specimen of *Eurasenia* or heavily ribbed *Involuticeras* indicative of the areas transitional between the Subboreal and Submediterranean provinces (Matyja & Wierzbowski 2000) is known also from the Tatarstan succession at the transition into a younger assemblage with *Aulacostephanoides*. A “mixed character” of rasenioid ammonites, representing different lineages of the Aulacostephanidae (genera *Rasenia*, *Eurasenia* and *Rasenioides*), with some Submediterranean ammonites like *Crussoliceras* and *Progeronia*, was recognized in a similar stratigraphical position at the end of the Cymodoce Zone in northern areas of the Jura Mts. in Switzerland (Comment et al. 2015). The occurrence of such an assemblage composed of various rasenoids in the Tatarstan succession, indicates a high gradient of diversity of the local environmental factors and/or the opening of the migration pathways during the sea-level highstand which resulted in the existence of a highly diversified ammonite fauna.

The subsequent *Aulacostephanoides* ammonite assemblage had a fairly uniform character over wide areas of the Subboreal, and partly Submediterranean areas. It indicates generally similar environmental conditions which favoured the strong development of a single aulacostephanid stock having its roots in older *Rasenioides*. The only other ammonites were representatives of the Boreal genus *Amoebites* which occurred nearly continuously from the upper part of the *Crussoliceras* assemblage at the base of the succession studied in Tatarstan, although always in subordinate numbers, but nevertheless indicating an open sea connection with the Boreal Province. Among the cardioceratids the presence of small-sized coarsely ribbed *Amoebites* (*A. peregrinator* Rogov) being the late representative of the genus has a special interest, as this species as recently recognized is characterized by wide geographic and narrow stratigraphic ranges

Fig. 6. Ammonites from the Lower-Upper Kimmeridgian transitional beds. **A** – *Crussoliceras atavum* (Schneid), Tarkhanovskaya Pristan, locality T1, member 1, 0.35 m above the base, specimen SGM MK4047. **B** – *Crussoliceras lacertosum* (Fontannes): Tarkhanovskaya Pristan, locality T1, member 2, 0.45 m above the base, specimen MWG UW ZI/80/03. All specimens depicted in Figs. 6-13 are coated with ammonium chloride except indicated otherwise.

Fig. 6.

(Rogov 2016). Slightly above these cardioceratids and within the *Aulacostephanoides* range a remarkable record of *Zenostephanus* is especially important for correlation with Boreal succession. Although the first *Zenostephanus* originated during the late Cymodoce Chron (Mesezhnikov 1984; Wierzbowski & Rogov 2013), *Z. (Z.) sachsi* (Mesezhnikov) – typical of the so-called *sachsi* horizon of the Mutabilis Zone – was characterized by wide geographic distribution in high-latitude sites (Rogov 2016), and a closely related *Zenostephanus* penetrated that time to British Columbia (Rogov & Poulton 2015). It is very possible that the historical record of *Zenostephanus (Xenostephanoides) fraasiformis* (Nikitin) in the Yaroslavl region (=*Perisphinctes fraasiformis* Nikitin, 1881, pl. V, figs. 42-43, refigured here at Fig. 13J) should be assigned to the *sachsi* horizon. This species was found at the same site as *"Perisphinctes pralairei"* mentioned above (and interpreted herein as *Crussoliceras*), which came from the phosphorite nodules at the top of the "Oxfordian clay" below the Middle Volgian Nikitini Zone of Koprino village. These ammonites were mentioned among the other Oxfordian and Lower Kimmeridgian taxa from the 10-m thick clayey succession, which is now unavailable through flooding by Rybinsk reservoir. Re-worked *Zenostephanus* are also known from the phosphorite pebbles of the basal Middle Volgian of Unzha river (collection by A. Stupachenko, Moscow).

In contrast to multiple occurrences of *Crussoliceras* and *Zenostephanus* in the European part of Russia, *Aulacostephanoides* are virtually missing outside Southern Tatarstan, except for the single record of *A. mutabilis* (Sowerby) from the Valanginian phosphorite conglomerate of the Belgorod region (Rogov 2015, pl. 2, fig. 1).

The decline of the *Aulacostephanoides* group at the end of the Mutabilis Chron was proceeded by the appearance of a new Submediterranean group of ammonites (especially Aspidoceratidae with development of the special group of *Orthaspidoceras*), indicating the beginning of a new "transgressive phase" (Hantzpergue 1995).

4. Systematic palaeontology

The following abbreviations are used in description of the ammonites: D – diameter of specimen in mm; Wh – whorl height as a percentage of D; Ud – umbilical diameter as a percentage of D; Wb – whorl breadth as a percentage of D; PR – number of primary ribs per whorl (PR/2 on a half a whorl); SR/PR – number of secondary ribs per one umbilical ribs (usually counted on 5 neighbouring primary ribs at diameter given).

Family Ataxioceratidae

Several large macroconch specimens are referred to the genus *Crussoliceras* (according to the original definition of Enay 1959; see also Enay et al. 2014). These specimens attaining about 200-300 mm in diameter are preserved in clays which makes their extraction from the rock difficult. Some of the better preserved of them were photographed in the field and their larger fragments were collected. The most carefully studied was a specimen from locality T1 – member 1 (0.35 m above the base; Fig. 6A). It attains about 270 mm in diameter; the coiling is evolute (at D = 210 mm, Wh = 28; Ud = 54); the ribbing is fairly dense on the inner whorls and consists of numerous, prominent, almost rectiradiate primary ribs which are regularly bifurcated; PR equals 40 at D = 90 mm, and 43 at D between 120-160 mm, and markedly decreases thereafter, attaining about 35 at D = 200 mm. The ribs on the outer whorl are swollen, initially branched high on the whorl side into three secondaries, then becoming simple. The specimen shows marked similarities to the type specimens of *Crussoliceras atavum* (Schneid) as illustrated and described by Schneid (1915: 94-95, pl. 2, fig. 2; pl. 9, fig. 1) which corresponds strictly to *Ammonites divisum coronatus* of Quenstedt (1888, pl. 106, figs. 6-8), a very characteristic species showing the dense biplicate ribs on the inner whorls, and the polygyrate and single ribs on the outer whorl with a coronate whorl section (see Geyer 1961; Schick 2004). An allied form is *Crussoliceras petitclerci* Enay, Gallois & Etches whose variability is unknown because the species is based on a single specimen (see Enay et al. 2014: 319-320, pl. 7, fig. 1); thus the name may even appear a younger synonym of *C. atavum*.

Another specimen from member 1 (0.85 m above the base) although not so well preserved is of similar size (up to about 300 mm in diameters), shows fairly densely ribbed inner whorls (PR/2 is about 25 at 150 mm diameter) and swollen simple ribs on the outer whorl (PR/2 is about 10 at about 300 mm diameter). It seems generally similar to that described below and may be referred to as *Crussoliceras* cf. *atavum*. Another specimen from member 2 (0.3 m above the base) was photographed in the field, and only fragments of its inner whorls were collected. The specimen is about 190 mm in diameter and shows only biplicate ribbing very close to that of the specimens described above (PR equals: 32 at D = 80 mm, 35 at D = 95 mm, 37 at

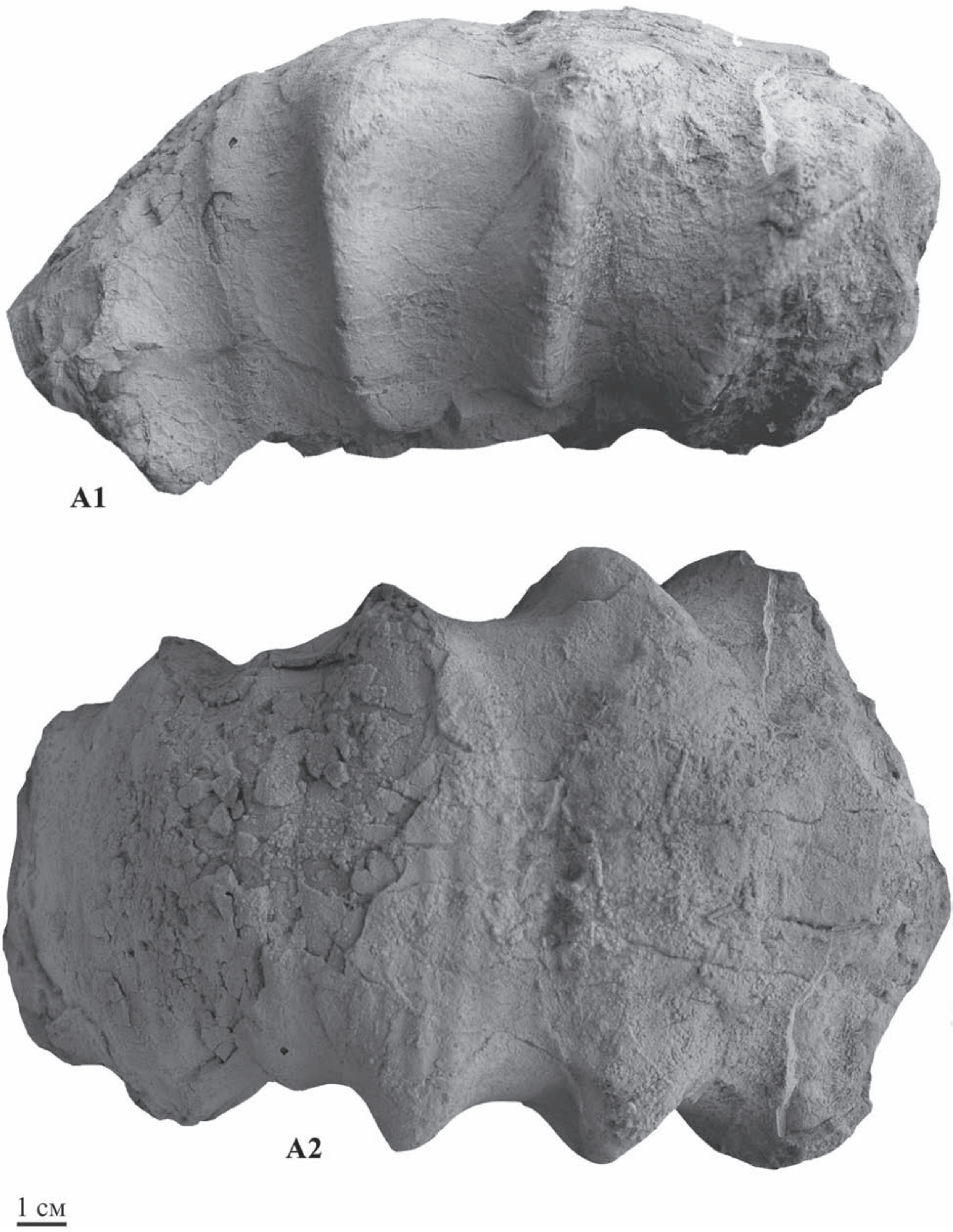

Fig. 7. *Crussoliceras atavum* (Schneid), Tarkhanovskaya Pristan, locality TP, loose, specimen SGM MK2905. A1 – lateral view; A2 – ventral view.

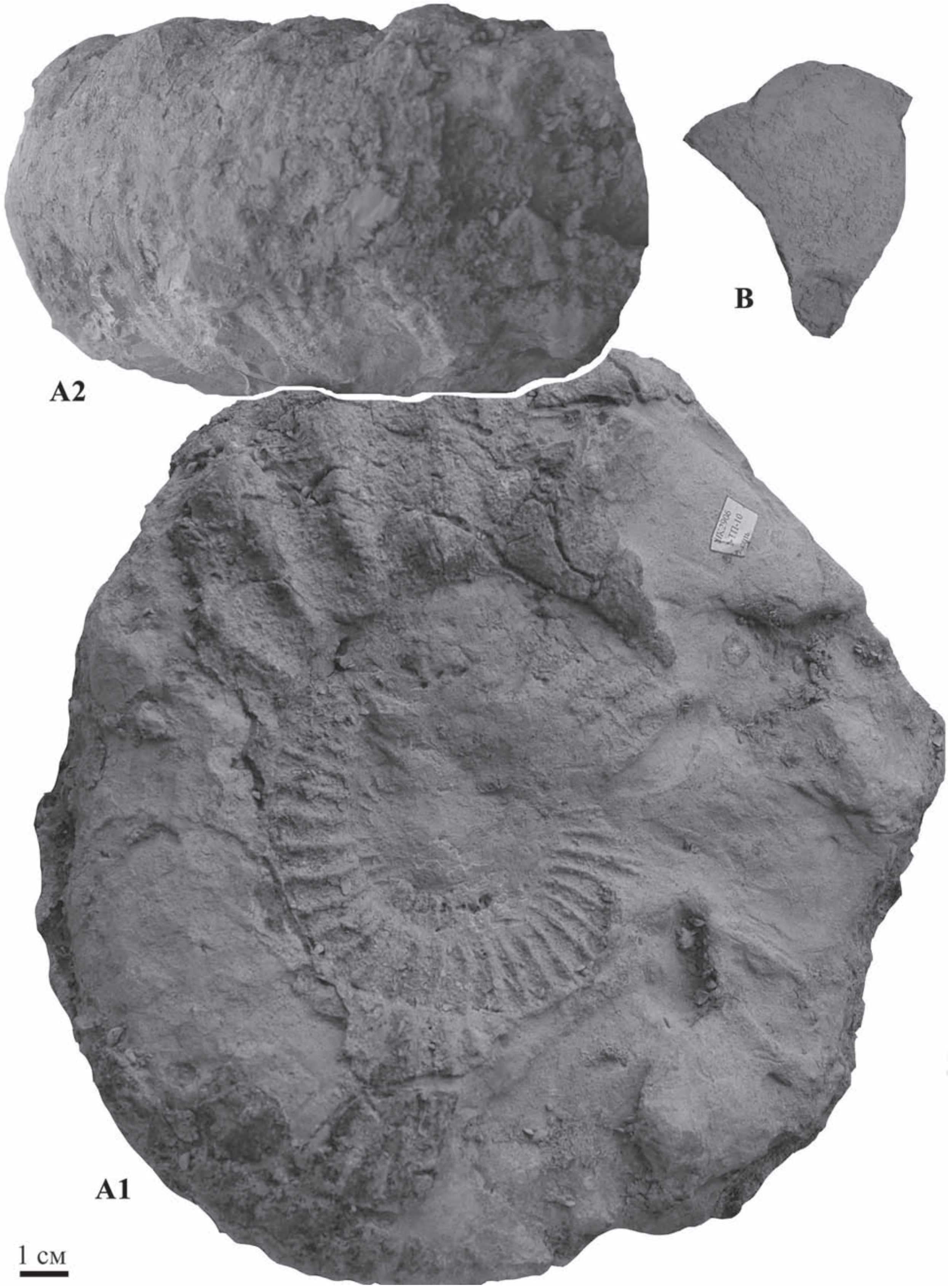

Fig. 8.

D = 120 mm, 38 at D = 140 mm, and about 42 at D = 190 mm). It represents possibly the same form as the above, although the specimen is not fully grown (or not completely preserved) because of the absence of single swollen ribs typical of the outer whorl of *Crussoliceras* macroconchs. Similar big-sized macroconchs of *Crussoliceras* were found loose some 500 m westwards from the T4 section (Figs. 7A, 8A).

Smaller-sized, fairly densely ribbed specimens represent either *Crussoliceras* microconchs, or the innermost whorls of the macroconch of the genus and are difficult for closer identification. The better preserved specimen (Fig. 6B) found in locality T1 – member 2 (0.45 m above the base) is the phragmocone about 95 mm in diameter. The whorl section is trapezoidal (Wh = Wb = about 30 at D = 90 mm) with a larger whorl breadth directly above the umbilical wall, and a wide ventral side; the coiling is evolute (Ud = 49.5 at D = 90 mm). The ribs are distinct, somewhat prorsiradiate, splitting high into two secondary ribs showing a weak forward sweep, and regularly joining the secondary ribs of the corresponding rib on the opposite side of whorl. PR equals 36 at D = 70 mm, and 42 at D = 95 mm. The specimen may be compared with the type specimen of *Crussoliceras lacertosum* (Fontannes), differing only in its somewhat more dense ribbing (Dumortier & Fontannes 1886: 100, pl. 15, fig. 1; cf. Geyer 1961: 49). Smaller-sized specimens found in members 1 and 2 of locality T1 represent the phragmocone or phragmocone with initial part of the body chamber. The specimens show evolute coiling, low oval to trapezoidal whorl sections (at D = 40 mm, Wb = 36-42), and moderately dense ribbing (at D = 20-40 mm, PR = 28-31). They may be referred to as *C.* cf. *lacertosum* (Fontannes). The species *C. lacertosum* is akin to *Crussoliceras lotharingicum* Enay, Gallois & Etches (Enay et al. 2014: 324-325, pl. 7, fig. 2) but it differs in its less evolute coiling and smaller number of primary ribs in the early whorls. Because the forms *Crussoliceras petitclerci* and *C. lotharingicum* have been interpreted by Enay et al. (2014: 325) as dimorphic counterparts, a similar relation between closely related forms referred to herein as *C. atavum* and *C. lacertosum* seems also plausible. Additional *C. lacertosum* were found also in member 1 of the Memei 2 section (Figs. 9B, 10C, F). Among these ammonites a few specimens are especially interesting: a piece of the body chamber, showing a few single ribs, and two well preserved specimens, in which the cross-section is clearly visible. One juvenile specimen (D = 50 mm) is characterized by a very low cross section with Wb/Wh ratio 1.42, while a bigger specimen with body chamber (D~92 mm) is characterized by nearly equal Wb and Wh. Well-preserved macroconchs of *Crussoliceras* (*C. atavum*) found loose at locality TP, between sections T5 and T3-4 (Figs. 7A, 8A) show additional features not seen clearly in crushed specimens from Tarkhanovskaya Pristan. One of these ammonites is represented by part of the terminal body chamber (Wh = 81 mm), covered by thick primaries, which branch into 4-5 thin secondaries at the ventrolateral margin; it is characterized by a very thick cross-section (Wb/Wh = 1.51). Another ammonite (D = 200 mm) has the same pattern of ribbing on the body chamber and a similar cross-section. It should be noted, that in at least some cases significant changes of ribbing from dense biplicate to distant ribs with a higher rib ratio and lowering of the cross-section occur in *C. atavum* before the terminal body chamber. Such a specimen from the Unzha river shows a similar "adult" morphology on the fully septate part of the whorl (Fig. 9G).

Family Aspidoceratidae

Aspidoceratid ammonites from the clayey deposits of the Mutabilis Zone in the Tarkhanovskaya Pristan are generally very badly preserved and cannot be determined at the species level. For example, *Aspidoceras* sp. indet. from the black shale member (Fig. 12C, D) and numerous *Aspidoceras* sp. indet. collected at 2.6-2.8 m below the black shales (Fig. 12A, B) of the T4 section are recognized by the presence of spines on the midflanks and their general shell outline, but other shell features are unclear. The only exception is a well-preserved *Orthaspidoceras* collected from a big septarian concretion from section T5. This specimen (D = 192 mm), ascribed to *O. liparum* (Oppel) shows the periumbilical spines, which were well vis-

Fig. 8. A – *Crussoliceras atavum* (Schneid), Tarkhanovskaya Pristan, locality TP, loose, specimen SGM MK2906. A1 – lateral view; A2 – ventral view. **B** – Oppeliidae sp. indet: Tarkhanovskaya Pristan, locality T3, member 4, 6.5 m above the base of the section, specimen SGM MK4206.

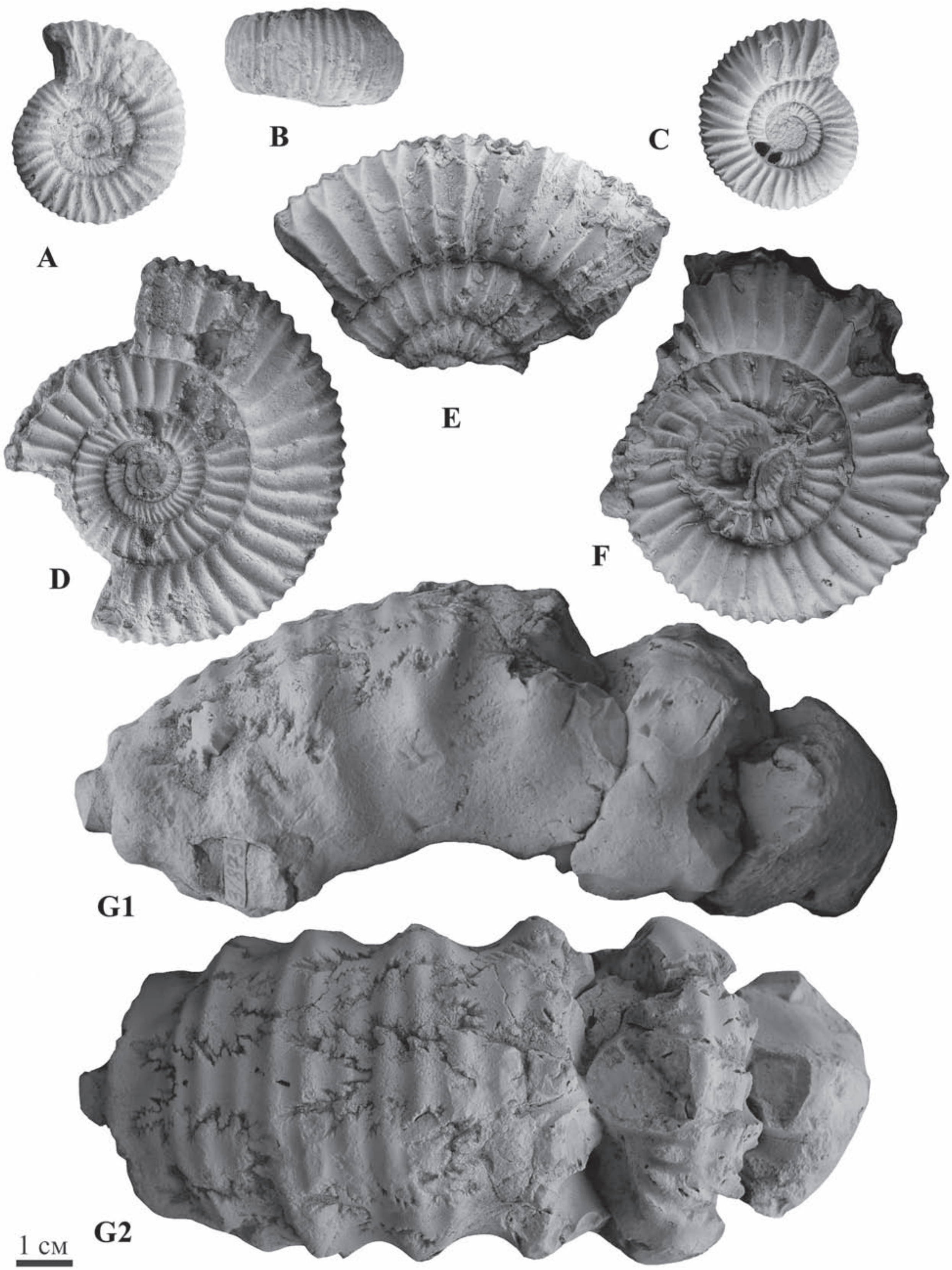

Fig. 9.

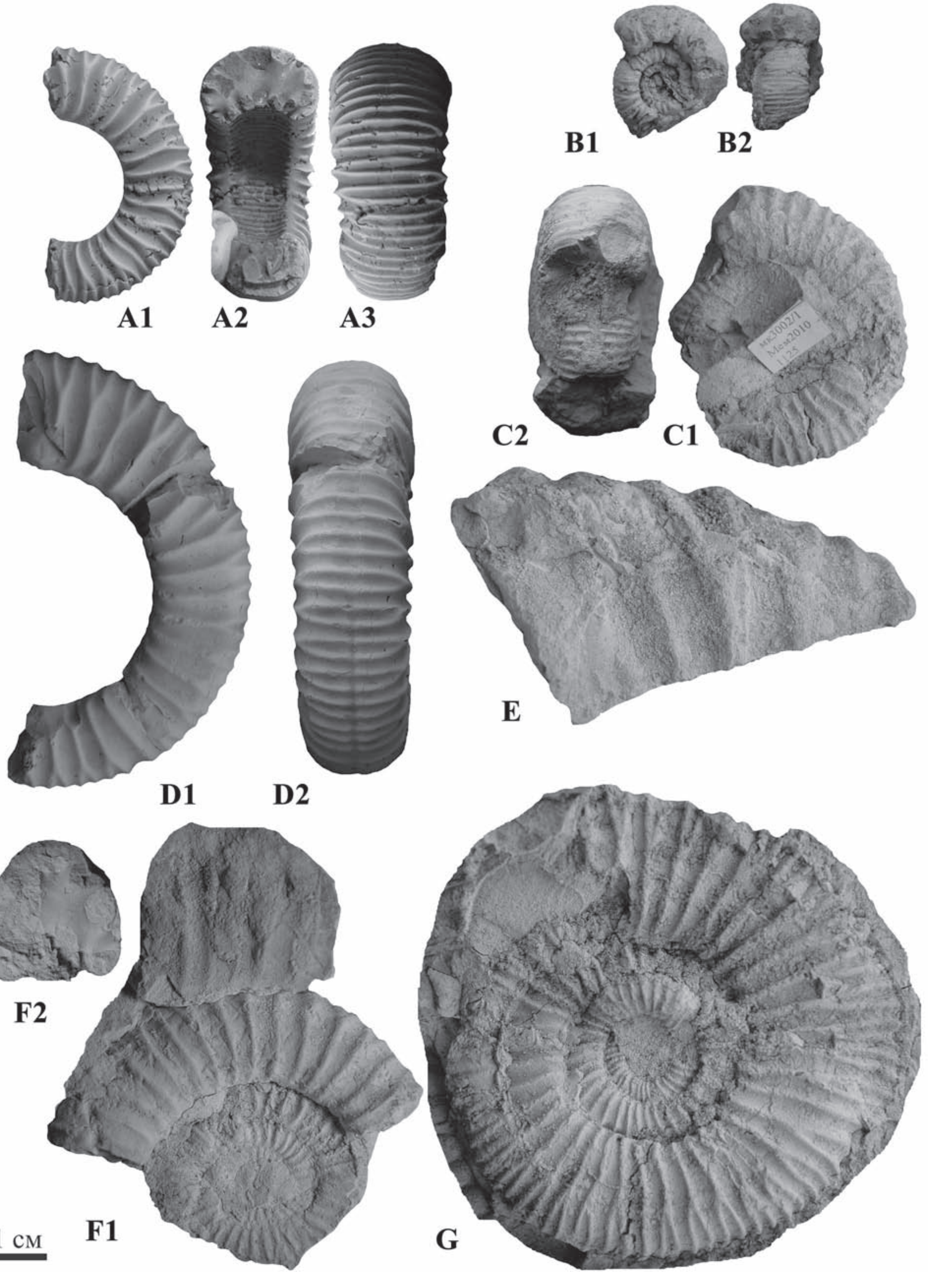

Fig. 10.

ible when specimen was fractured during the preparation (Fig. 11B). An historical record of *O. lallierianum* (d'Orbigny) was given by Pavlow (1886) possibly from the same level near Gorodischi (north of Ulianovsk region), but now these deposits are flooded by the Kuybyshev reservoir. The ammonite from Pavlow's collection (refigured herein, Fig. 11A) belongs to a small-sized morphotype of *Orthaspidoceras* (described as 'microconchs' by Hantzpergue 1989). This specimen shows clearly visible periumbilical nodes (4 node per quarter of whorl), which split into very fine and poorly developed secondaries on the body chamber.

Family Oppeliidae

A single oppeliid ammonite with a narrow umbilicus and completely smooth whorls was recorded from the uppermost part of the T3 succession (Fig. 8B).

Family Aulacostephanidae

Several specimens from locality T2 may be attributed to the genus *Aulacostephanoides* Schindewolf, 1925. The specimens are generally of small-size, from about 25 mm to 45 mm in diameter, having short swollen umbilical ribs, and numerous secondary ribs and all of them reveal a well developed ventral smooth band. Some of them are more evolute (although the specimens are often badly deformed which precludes very detailed measurements), including one with the final peristome preserved with lappets. They can be safely attributed to *Aulacostephanoides eulepidus* (Schneid) (Fig. 12H) – well characterized by Ziegler (1962: 44-48, pl. 1, figs. 1-16) and recognized as the type of the new microconch subgenus *Aulacostephanites.* It is highly probable that the pyritized nuclei showing weakly evolute coiling, and the presence of thick short umbilical ribs (PR = 16-18, SR = 3.4-4 at D = 15 mm) represent the inner whorls of *A. eulepidus.* Two larger specimens attaining 34 mm, and 45 mm in diameter, respectively (Fig. 12I, R), show more involute coiling (Wh = 44-47, Ud = 20-22) with a higher number of secondary ribs at a larger diameter (at D = 45 mm, SR is about 7-8), and may be referred to as *Aulacostephanoides* cf. *desmonotus* (Oppel) (see Ziegler: 50-52, pl. 2, figs. 13-15). It should be remembered that the occurrence of specimens showing a similar variability in a single bed and referred to as *Aulacostephanoides eulepidus* (Schneid) and *A.* cf. *desmonotus* (Oppel), but representing possibly the "end-members in the variability of the same species", has been described by Birkelund et al. (1983, fig. 5F-H) in the English sections.

Members of the genus *Aulacostephanoides* from sections T3 and T4 are mainly represented by small badly preserved incomplete specimens, showing clearly visible rib interruption at the ventral side. One speci-

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Fig. 9. A-C – *Crussoliceras* cf. *lacertosum* (Fontannes), A, C – Tarkhanovskaya Pristan, loose; B – Memei-2, 0.25-0.3 m below the top of member 1. A – specimen SGM MK4; B – specimen SGM MK3001; C – specimen SGM MK 3000. **D-F** – *Crussoliceras lacertosum* (Fontannes), Tarkhanovskaya Pristan, loose; D – specimen SGM MK7; E – specimen SGM MK12; F – specimen SGM MK 10. **G** – *Crussoliceras atavum* (Schneid): right bank of the Unzha river near to Burdovo village, specimen SGM 3-873. G1 – lateral view; G2 – ventral view.

Fig. 10. A-D, F, G – *Crussoliceras lacertosum* (Fontannes), A – Koprino section, Yaroslavl region (refigured from Nikitin 1884, pl. 3, figs. 17-18), specimen CNIGR 36-373, A1 – lateral view; A2 – apertural view, A3 – ventral view; B – Ignatievo section, Moscow area, bed 2; specimen GIN MK4615, B1 – lateral view, B2 – apertural view; C – Memei-2 section, 0.25 m below the top of member 1, specimen SGM MK3002, C1 – apertural view, C2 – lateral view; D – Unzha river, 2 km below Yakovlevo village, specimen SGM 3-941, D1 – lateral view, D2 – ventral view; F – Memei 2 section, member 1, 2.2 m below base of member 3; specimen SGM MK 2935; G – Tarkhanovskaya Pristan, locality T 1, 0.15 m above the base of the Kimmeridgian. **E** – *Crussoliceras* sp., Memei 2 section, 0.25-0.3 m below the top of member 1; specimen SGM MK3003.

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Fig. 11. A. *Orthaspidoceras lallieranum* (d'Orbigny), Gorodischi near Undory, Ulyanovsk region; specimen CNIGR 11/312 (Pavlow 1886, pl. 9, fig. 3), not coated with ammonium chloride; A1– lateral view, A2 – cross-section of the body chamber; **B** – *Orthaspidoceras liparum* (Oppel), Tarkhanovskaya Pristan, locality T 5, 0.7 m above the base of the Kimmeridgian; specimen SGM MK 4519.

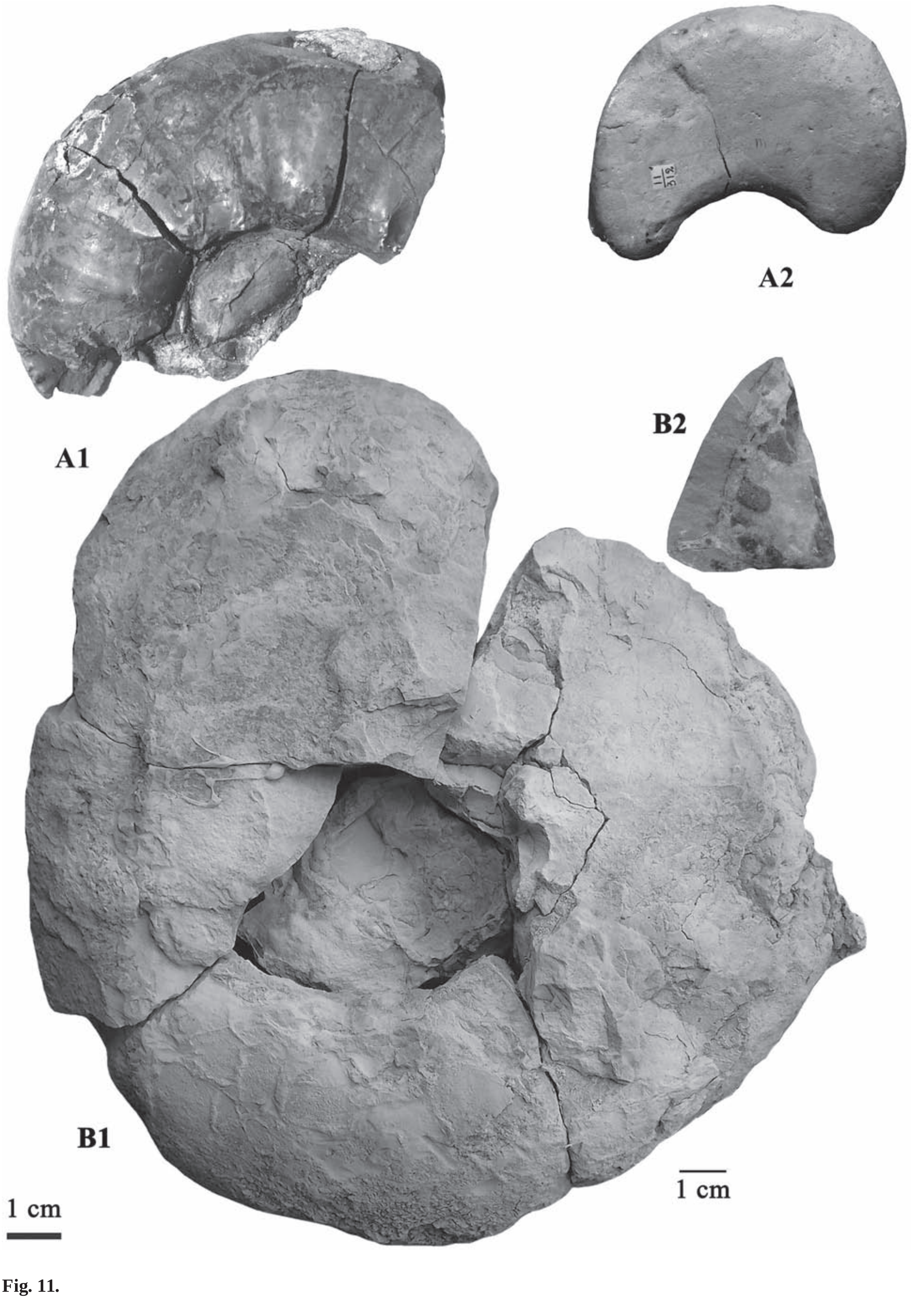

Fig. 11.

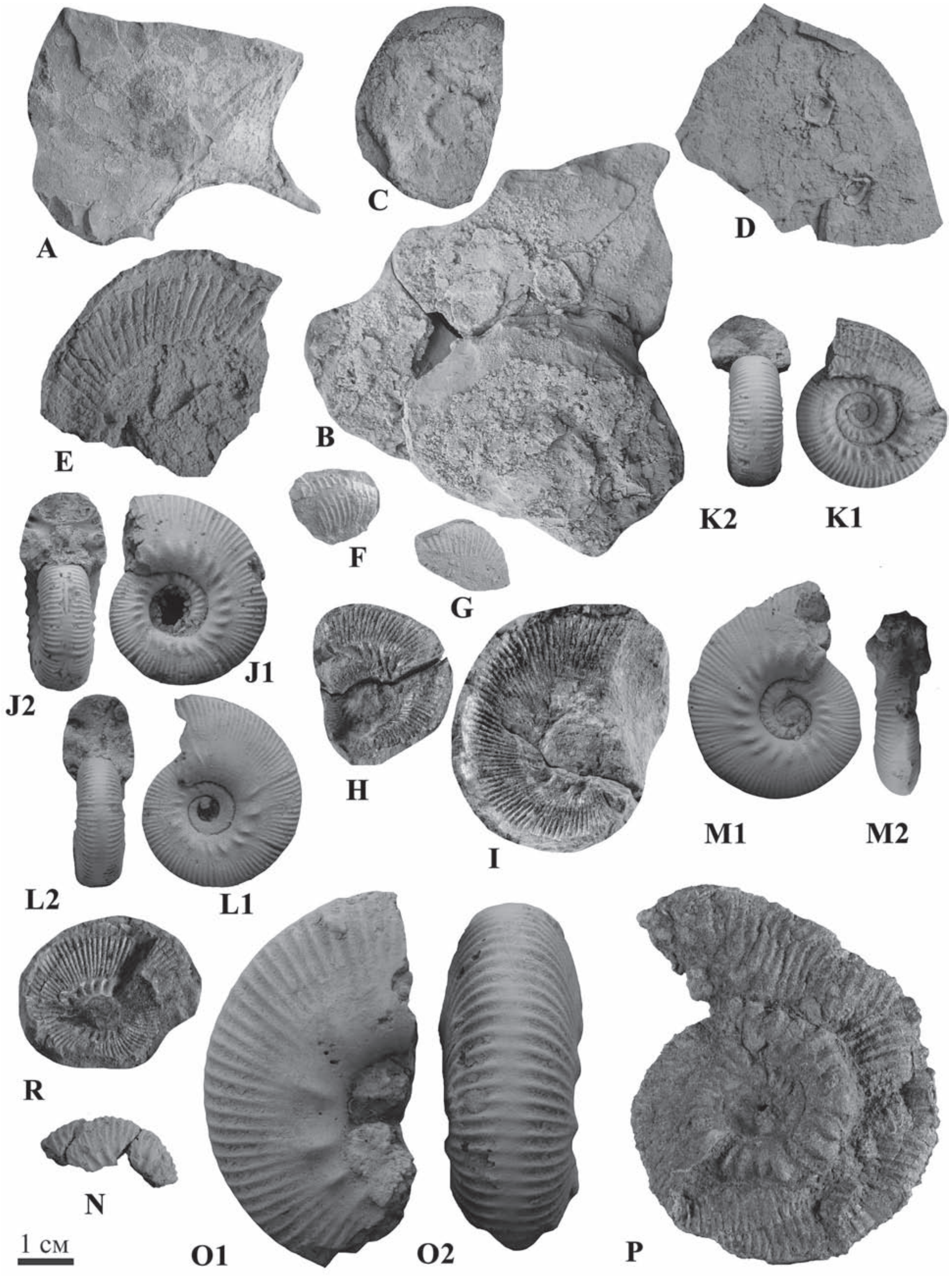

Fig. 12.

men from the black shales can be tentatively assigned to as *A.* aff. *mutabilis* (SOWERBY). Additional well-preserved pyritized moulds of *Aulacostephanoides* were collected loose near T3 section by Dr. VLADIMIR EFIMOV (Undory). Among these specimens *A. mutabilis* is represented by the relatively big-sized septate whorls (Fig. 12O) (D~69 mm), with PR = 7 and SR/PR = 5.6, whorl section with flattened ventral side, Wb/Wh = 0.86. The inner septate whorls of *Aulacostephanus* cf. *desmonotus* (Fig. 12L-M) (D = 38 mm) are characterized by short primaries (PR = 10), which split into numerous secondaries (slightly rursiradiate to rectiradiate) below the midflanks (SR/PR = 4.9). Other specimens collected in the rubble include: *A.* cf. *eulepidus* (OPPEL) (Fig. 12J) and *A.* cf. *peregrinus* (ZIEGLER) (Fig. 12K).

A single strongly compressed specimen from locality T2, attaining about 80 mm in diameter (Fig. 12P) shows strongly involute coiling (at D = 54 mm, Wh = 44.4, Ud = 25.9). The ribbing is stout and consists of short well developed primary ribs and markedly thinner secondary ribs which appear low on the whorl side and cross the ventral side without any weakening: PR = 21 at D = 80 mm, and 23 at D = 50 mm; number of secondary ribs is fairly high (SR/PR = 4.0 at D = 55-80 mm). The presence of strongly developed primary ribs is often recognized in the genus *Eurasenia* GEYER, 1961, whereas the involute coiling and the presence of fairly numerous, markedly thinner, secondary ribs is a feature of the genus *Involuticeras* SALFELD, 1917, and the specimen in question may be informally referred to as *Eurasenia/Involuticeras* sp.

A single crushed specimen of *Zenostephanus (Z.) sachsi* (MESEZHNIKOV) was found in section T4 (Fig. 13K). It is characterized by strongly evolute coiling (at D = 129 mm, Ud = 48.5), thus both primaries and secondaries are easily visible in the umbilicus, including the innermost whorls. The ribbing is typical of *Zenostephanus* and consists of short node-like primaries, clearly separated from numerous thin secondaries. Due to poor preservation of the primary ribs on the outer whorls they cannot be precisely counted. In the inner whorls PR/2 = 10, SR/PR = 4 (at D = 40 mm). Additional moulds of pyritized *Zenostephanus (Z.) sachsi* were found loose near Tarkhanovskaya Pristan by the authors as well as similar derived specimens from the Dr. VLADIMIR EFIMOV (Undory) collection (Fig. 13G-I). These well-preserved ammonites show the well-developed interruption of ribs at the ventral side, which along with the mode of coiling, cross-section and type of ribbing are typical of *Zenostephanus*. The specimens are characterized by a gradual increase of the SR/PR ratio through ontogeny, from 2.5-3 (at D = 20-30 mm) to 4 in full-grown specimens.

One badly preserved and crushed aulacostephanid ammonite, which has been found at 2.4 m below the black shales of the T4 section, is characterized by relatively distant and coarse ribs with prominent ventrolateral nodes. Although imperfectly preserved, in can be tentatively ascribed to the poorly-known genus *Sarygulia*. This name is here accepted for the ammonite group usually referred to the genus *Pararasenia*. The type species of *Pararasenia* (*Aulacostephanus zacatacanus* BURCKHARDT) is known from a single record from the *Idoceras* Beds of Mexico, and differs from *Aulacostephanus* in its smaller size and septal suture. The generic name *Sarygylia* (nomen nudum) has been published by KHUDYAEV (1932) in the figure caption only for *S. pischmae* KHUDYAEV, while in his text this species

Fig. 12. A-D – *Aspidoceras* sp. indet., Tarkhanovskaya Pristan, locality T4. A – member 4, 2.8 m below the black shales, specimen SGM MK4216; B – member 4, 2.8 m below the black shales, specimen SGM MK7634; C, D – member 6 (black shales), C – specimen SGM MK4235, D – specimen SGM MK 4233. **E-G** – *Aulacostephanoides* sp. indet. E – Tarkhanovskaya Pristan, locality T4, member 6 (black shales), specimen SGM MK 4234; F, G – Tarkhanovskaya Pristan, locality T3, member 3; F – 3.4 m above the base of the section, specimen SGM MK4227; G – 2.1 m above the base of the section, specimen SGM MK4224. **H** – *Aulacostephanoides eulepidus* (OPPEL), Tarkhanovskaya Pristan, locality T2, top of the section, specimen MWG UW ZI/80/13, with lappet preserved. **I, L, M, R** – *Aulacostephanoides* cf. *desmonotus* (OPPEL): I, R – Tarkhanovskaya Pristan, locality T2, top of the section: I – specimen MWG UW ZI/80/08; R – specimen MWG UW ZI/80/02; L, M – Tarkhanovskaya Pristan, loose; L – specimen SGM TP 5, L1 – apertural view, L2 – lateral view; M – specimen SGM TP 6, M1 – lateral view, M2 – apertural view. **J** – *Aulacostephanoides* cf. *eulepidus* (OPPEL): Tarkhanovskaya Pristan, loose, specimen SGM TP6/2, J1 – apertural view, J2 – lateral view. **K** – *Aulacostephanoides* cf. *peregrinus* (ZIEGLER), Tarkhanovskaya Pristan, loose, specimen SGM TP3, K1 – apertural view, K2 – lateral view. **N** – *Rasenioides* sp. indet., Lipitsy, Kaluga region, base of the bed 5; specimen GIN MK 4756. **O** – *Aulacostephanoides mutabilis* (J. SOWERBY), Tarkhanovskaya Pristan, loose, specimen SGM TP2, O1 – lateral view, O2 – ventral view. **P** – *Eurasenia* or *Involuticeras* sp., Tarkhanovskaya Pristan, locality T2, top of the section, specimen MWG UW ZI/80/01.

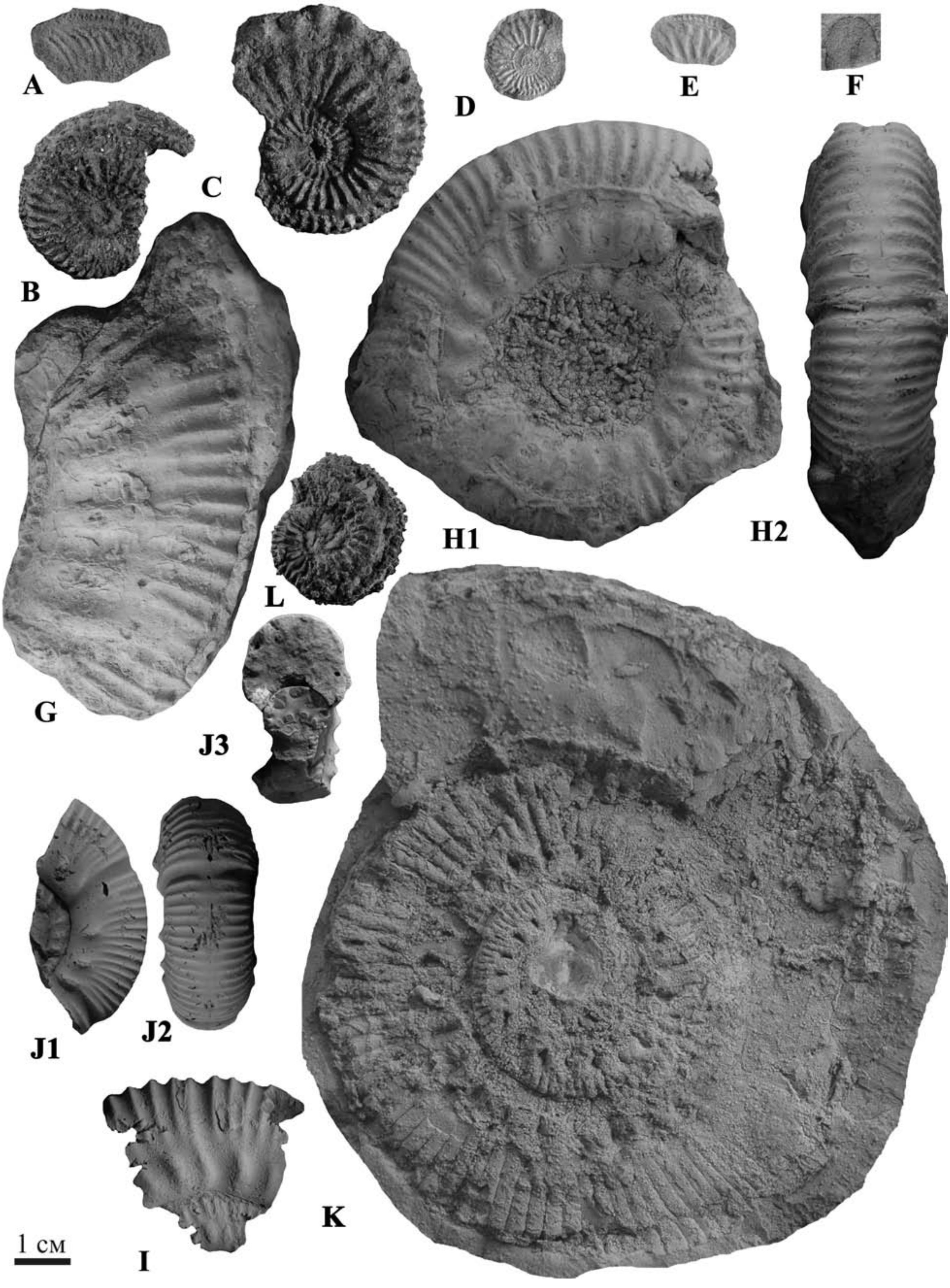

Fig. 13.

was assigned to the genus *Aulacostephanus*. Later N.T. Sasonov (1960) provided a full diagnosis of the genus *Sarygulia*, and he should be considered as the author of this genus.

Family Cardioceratidae

Four specimens coming from locality T1 – member 2 (0.25 m, and 0.55 m, above the base, Fig. 13B, C), and locality T2 (Fig. 13L) show fairly uniform features, indicating affiliation to the genus *Amoebites* Buckman, 1925. The specimens are very coarsely ribbed with short primaries (PR = 23-27 at D = 25-45 mm), strongly accentuated at two/thirds of the whorl height, and separated on the outer whorl by a smooth spiral band from heavy ventrolateral nodes which become fused into clavi with growing diameter; the strongly crenulated keel is bordered by well developed ventral sulci. The small-size of the specimens and their involute coiling (at D = 28-44 mm, Wh = 43-44.6, Ud = 27-33) indicate their close relation to *Amoebites kitchini* (Salfeld) (see Salfeld 1915; see also Birkelund & Callomon 1985: 20-22, fig. 6 – where the lectotype of the species has been designated).

Still another specimen found loose in the rubble but in the stratigraphical interval of locality T3 is a fragmentarily preserved specimen showing markedly prorsiradiate and simple ribbing, and a well developed keel bordered by distinct ventral sulci. This finely-ribbed cardioceratid ammonite, co-occurring with *Rasenioides* in the lower portion of T3 section, is closely related to *A. kapffi* (Oppel) but it differs in the presence of well developed ventral sulci along the keel (Fig. 13A).

Aptychi

In addition to the ammonites a few aptychi were collected from a level 2.55 m below the black shales in section T4. These includes a few partially preserved pyritized *Laevaptychus* and small elongated *Praestriaptychis* sp. (Fig. 13F). The latter could belong to an aulacostephanid ammonite.

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Fig. 13. A – *Amoebites* (?) or *Euprionoceras* cf. *kapffi* (Oppel), Tarkhanovskaya Pristan, locality T3, member 3, 1.9 m above the base of the section, specimen SGM MK 4212. **B, C, L** – *Amoeboceras* (*Amoebites*) *kitchini* (Salfeld), Tarkhanovskaya Pristan, 2, 3 – locality T1, member 2: B – 0.55 m above the base, specimen MWG UW ZI/80/15, C – 0.25 m above the base, specimen MWG UW ZI/80/14; L – locality T2, uppermost part of the section, specimen MWG UW ZI/80/16. **D, E** – *Amoebites peregrinator* Rogov, Tarkhanovskaya Pristan, locality T3, D – member 4, 5.1 m above the base of the section, holotype, specimen SGM MK 4223; E – member 3, 3.2–3.4 m above the base of the section, specimen SGM MK 4212. **F** – *Praestriaptychus* sp., Tarkhanovskaya Pristan, locality T4, member 4, 2.55 m below black shales, specimen SGM MK 7635. **G-I, K** – *Zenostephanus sachsi* (Mesezhnikov), Tarkhanovskaya Pristan, G-I – loose, G – specimen SGM MK 7636; H – specimen SGM TP 1, H1 – lateral vies, H2 – ventral view; I – specimen SGM MK 2938, K – locality T4, member 4 , 4.1 m below black shales, specimen SGM MK4232. **J** – *Zenostephanus fraasiformis* (Nikitin), Koprino, Yaroslavl region (holotype of *Perisphinctes fraasiformis* Nikitin, 1881, pl. V, fig. 42), specimen CNIGR 101-102/1363, J1 – lateral view, J2 – ventral view, J3 – apertural view.

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