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The International Scientific Conference on the Jurassic/Cretaceous boundary

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The International Scientific Conference on the Jurassic/Cretaceous boundary. September 7-13, 2015, Samara (Russia). – Togliatti: Kassandra, 2015. – 102 p.

The present volume compiles short papers with new data on the Jurassic-Cretaceous boundary strata and their fauna of different regions of Russia (Volga region, Siberia, Crimea, Primorye) and of North America. Most papers are devoted to problems of biostratigraphy and paleontology of marine animals and their trace fossils. Besides this, some data on magnetostratigraphy, interregional correlations, history of defining J/K boundary in the Decisions of ISC, and eoomic value of the interval.

For geologists, paleontologists, stratigraphers, students of geological and geographical profiles.

Международная научная конференция по проблеме границы юрской и меловой систем. 7-13 сентября 2015 г., г.Самара (Россия): Материалы совещания. – Тольятти: Издательство «Кассандра», 2015. – 102 с.

В сборнике опубликованы новые данные о пограничных отложениях юры и мела различных регионов России (Поволжье, Сибирь, Крым, Приморье) и Северной Америки. Большинство работ посвящено биостратиграфии и палеонтологии морских животных и следов их жизнедеятельности. Кроме того, приводятся сведения о магнитостратиграфии, межрегиональной корреляции, истории проведения границы юры и мела в постановлениях МСК, и экономической важности этого интервала.

Сборник представляет интерес для геологов, палеонтологов, стратиграфов, студентов геологического и географического факультетов.

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PREFACE

The Jurassic/Cretaceous is the only system boundary within the Phanerozoic, which still has debatable position. Moreover, according to different paleobiogeographical ground, International and national stratigraphic scales use different units for the boundary interval. Numerous conferences, symposiums and working group meetings has not brought the stratigraphers to any consensus on opinions yet.In addition, much new data has been accumulated, and is still being acumulating, making us taking some decision. Papers providing such data are put together in the present volume.

Important data are provided in the papers, presenting new interpretations on the Boreal-Tethyan correlation in the Pacific region. They are based on a complex magneto- and biostratigraphic (ammonites, foraminifera, palynology, ichnofossils) study of the sections located in Primorye (A.Yu. Guzhikov et al.; E.Yu. Baraboshkin, E.E. Baraboshkin) and revision of the buchiid succession in Northern California (V.A. Zakharov).

Many papers are devoted to the re-study of classic sections in the Volga area, including Kashpir and Gorodischi sections, which are planned to be visited during the field excursions. For these sections, new data on bio- and magnetostratigraphy (E.Yu. Baraboshkin et al.; V.P. Morov), and on new finds of fossil vertebrates (V.M. Efimov; I.A. Meleshin) are provided. For Kashpir section, data on belemnites and bivalves are presented (O.S. Dzyuba, O.S. Urman, B.N. Shurygin). There is some interesting information on the stratigraphy of Jurassic-Cretaceous boundary strata in the sections along the Menya river (A.Y. Berezin), and on finds of marine reptiles from the Kirov region (M.S. Arkhangelsky, N.G. Zverkov).

A number of papers is based on materials from Crimea. The boundary interval of Berriasian and Valanginian in section near Feodosya is studied using integrative approach (ammonites, foraminifera, ostracods, palynology, magnetostratigraphy; V.V. Arkadiev et al.). Unusual find of a belemnite of South American origin is described from the Berriasian of Central Crimea (A.P. Ippolitov, B. Desai, V.V. Arkadiev), and of Jurassic-like *Pliosaurus* – from the Valanginian of south-west Crimea (N.G. Zverkov).

Finally, one paper is devoted to a revision of high-Boreal Late Volgian ammonites from the Nordvik section (M.A. Rogov, A.S. Alifirov, A.E.Igolnikov).

One cannot forget that any scientific research, held over the Jurassic-Cretaceous boundary interval, will be reflected on different aspects of geological practice – mapping, based on unit boundaries, validated by the Interdepartmental Stratigraphic Commitee, mineral resources exploration, qualification of young geologists. These problems are discussed by N.L. Erofeeva & V.V. Gusev and by E.L. Vasileva.

The present volume probably will not solve the problem of the Jurassic-Cretaceous boundary, but let us make a new step in this direction.

E.Yu. Baraboshkin

THE ROLE OF GEOLOGY IN SOCIAL AND ECONOMIC DEVELOPMENT OF THE SAMARA REGION

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This meeting is dedicated to the Jurassic and Cretaceous boundary stages and their equivalents in the Boreal paleogeographic Realm - the Volgian and the Rhyazanian Stages. These seemingly purely scientific issues directly affect the development of the mineral resource base of the region. Their decision is related to the accuracy of geological maps, using for the evaluation of mineral resources. The state of the mineral resource base, in turn, influences the economic development of any region.

The well-known Kashpir oil shale field is developed in the Volgian deposits of the Samara Region, and Volgian, Ryazanian and Valanginian deposits contain phosphorites. The most famous is Kashpir oil shale field, which is under development since 1920. Its reserves are estimated at 11.5 billion tons; it is one of the largest deposits of oil shale. Initially these shales were used as fuel for power stations and boilers, and later as raw material for the chemical industry - getting medical ihtiola, phenol, benzene, toluene, thiophene, and other substances, many of which can not be obtained from any other raw materials. The phosphorites were mined in past in Kashpir during the 50th - 60th. Their reserves are 7 million tons here, although now their production is not economically effective.

Other natural resources which have significant economic value are subsurface water of drinking quality and mineral waters, building and silicate sands, clays (aggloporite, high-melting, brick and tegular, ceramsite), gypsum, carbonates (building stone, glass materials), native sulfur, bitumen and bituminous material. One of the major mineral resources of the region is hydrocarbon crude, which includes oil, gas (dissolved and free), condensate, natural bitumens. condensation product and solid bitumen. Currently, Samara region has considerable reserves and is among the main oil producing and refining regions of the country. The ratio of oil reserves of the Samara region corresponds to about 1.5%, while the ratio of oil-extracting overland Russia of the Samara region equals 3.0%.

A purposeful examination of oil and gas content of the earth depths of Samara region started in 1929. The first oil fields were discovered in 1936 (Syzranskoe) and in 1937 (Yablonevyi Ovrag). In 1940 on the results of Craelius core drilling geologists began to develop Kalinovskoe gas-and-oil field. During the World War II Zaborovskoe, Gubinskoe, Strelnikovskoe, Karlovo-Sytovskoe, Zolnenskoe and some other fields were discovered. The landmark event of that time was the discovery of Devonian oil in 1944 on the Yablonebskoye field. This discovery happened to be the biggest event in the petroleum branch of our country and it justified the extension of exploration works of oil finding in the Devonian sediments in other regions of Ural and Volga region. Later some fields with large reserves were discovered, such as Muhanovskoe, Dmitrievskoe, Radaevskoe, Pokrovskoe, Kuleshovskoe, Novo-Zaprudnenskoe and others. Commencement of these fields ensured a rapid growth of oil extraction and in 1957 their daily production rate exceeded that of the oldest oil field in Baku. Thus, the Samara region ranked third in the country according to the level of oil extraction.

By the present time 334 oil-and-gas fields have been discovered within the Samara region and most of them are being developed at the moment. Only 10 % of hydrocarbon reserves are not subject to development as they are located in undeveloped reserves, suspended reserves, in reserves which are being prepared for development or in places which are under exploration. Besides, the Samara region possesses long-range resources of oil of the category C3 (to the number of 215 million tons) and inferred resources of oil by the category D1 (to the number of 735 million tons). For the short-term the average annual volume is anticipated to reach 15-16 million tons. Thus, oil extraction in the samara region will continue for the next 34-40 years upon condition of a full examination and exploration of oil resources.

The main oil production enterprise of the region is still JSCo “Samaraneftegaz”. As far as the majority of oil fields have been developed for several decades, the medium reserves depletion of the enterprise is 78.3% and the medium water cut is 84.5%. It is reasonable, that the level of extraction of exploited for a long time fields has to decrease gradually. But due to active implementation of innovative technologies and bringing into service overlooked fields, “Samaraneftegaz” continues to ramp up oil production (2005 – 9.5 mil tons, 2014 –11.2 mil tons).

As the analysis of materials from the develop reserves has shown, oil reserves growth continues even after 40 and 50 years from discovery of the fields. For example, on Syzranskoye field during the 55th year of development the growth of 60 000 tons was achieved (1,77% of the initial reserves as on 01.01.1998). On Yablonevoye field during the 52nd year of exploitation the growth was 20.8% higher than the initial estimate. All in all, the analysis of 60 fields has shown the growth of: 6 fields with more than 50 years run life, 22 fields with 40-50 years run life, 54 fields with 30-40 years run life, 74 fields with 20-30 years run life. So, owing to their natural features as well as methodological and physical capabilities of reserve calculation, even very old fields can provide the reserves growth. Let us hope that the fields which were discovered at a later time will also come into the category of “old” fields and will serve as a source of the reserve growth but with a less volume.

There are twenty-two oil production enterprises in the Samara region besides “Samaraneftegaz”. Over a period of 2005-2014 the volume of produced oil increased from 10.7 mil. tons to 15.7 mil. tons. What is more, natural rate of growth is observed among small companies. In 2005 the extent of production of small companies was 1.0 mil. tons (7.7 %), while in 2014 it was 4.52 mil. tons or 28.8% of the whole extent of production within the region.

The increase of oil production enterprises and improvement of tax system have enabled a systematic growth of earnings into both federal and regional budgets in the form of mineral replacement tax. The federal tax increased from 36.0 mil. roubles in 2010 to 68.2 mil. roubles in 2014. The regional tax reached 70.6 mil. roubles in 2014.

Because of the increase of the reserves-to-resources ratio in the region as well as the exploration maturity, the level of supply is decreasing naturally from 18.9 mil. tons in 1946-1960 to 0.1 mil. tons in 1999-2015 per each field. Previously these fields (mainly, with reserves difficult to recover) have not been brought into development for costs reasons. The emergence of new special space planning solutions and operation practices, as well as the stable growth of prices for hydrocarbon made it possible to develop these fields in the present. According to the specialists' research, the reserves of some small and smallest fields are regarded as active and can practically be involved into development.

It is noteworthy that on the territory of our region even the deposits with the reserves of 100 000 tons are commercially viable. This is because of the high density of resources within a tight territory, high quality of the oils and relatively small cover thickness (75% of reserves occur at a depth of less than 3000 m), well-developed infrastructure, closeness to the consumer market and the objects of refining and convenient transfer system with regard to Europe.

The geological exploration of the recent years has shown the following: from 6 to 13 new fields are discovered every year, there is an annual reserves growth which 2-4 times exceeds the extraction (25-50 mil. tons), there is an annual increase of oil extraction (2005г. – 10.7 mil. tons, 2014г. – 15.7 mil. tons). All of the above proves that the system licensing of mineral resource use stimulates the development of the oil branch. This task is successfully performed by the surface management department called "Samaranedra". This body coordinates the activities of all the geological and mineral extracting enterprises, works out a strategy and tactics of the geological study of subsurface resources, provides the state licensing system of mineral resource use, invites a tender for the right of mineral resource use.

In 1980s there was a school of thought that oil and gas reserves had been worked out for 80% and later the production of hydrocarbons would decrease. Especially as the production level was 8.8 mil. tons in 1996 and 7.7 mil. tons in 1999. But those prognoses did not prove to be right. Due to the implementation of new technologies, the production level has increased to 15 mil. tons per year.

Apart from the regular on spec oil the resources of which have not been explored to a fully extent yet, our region possesses non-conventional resources of hydrocarbon such as high-viscosity oil, native bitumen, bituminous shale, light tight oil which are to be explored in the future. Search and prospecting of new fields (including nonconventional ones) require skilled workforce.

The value of fresh ground water remains to be high. Moreover, in the context of a growing deficiency of the fresh water of drinking quality its value is increasing. The general demand of the Samara region in drinking quality water for the short-term is 2984,41 thousand cubic meters per day. Search and prospecting of new groundwater deposits require professional geological organizations.

By common commercial minerals are meant subsurface rock and minerals which are mainly used as building materials in their native state or with inessential processing and clearing aimed mostly at local need-satisfaction. Their exploration also requires geologists.

Nowadays for successful prospecting and effective development of identified fields we need to have qualified personnel.

Degree program 130304 "Oil and Gas Geology" was established at Federal State Budgetary Educational Institution of Higher Vocational Education "Samara State Technical University" (one of the oldest university of the Povolzhie region with its own developed traditions and a huge history) in 2007 under order of the users of subsurface resources of the Samara region. In 2012 the first mining engineers got their diplomas of this degree program. The graduates – mining engineers having a degree in 130304 “Oil and Gas Geology” – master the high-effective up-to-date methods of information processing and they are able to create a geological model of a field. There is a demand for such specialists at geological departments of huge oil and gas companies, design and research institutions, Oil/Gas Production Division, Management of Drilling Work and other geological and oil enterprises.

Because of the change in the nomenclature of degree programmes and the implementation of a new educational standard FSES-3, since 2011 students have been enrolled to study the degree program 130101 “Applied Geology” (specialization “Oil and Gas Geology”) and they graduate with a qualification “specialist”.

Now it can be seen that the economy of the Samara region largely depends on the effectiveness of usage of the mineral resources base, replacement of which requires highly qualified specialists in geology.

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NEW DATA ON BIO- AND MAGNETOSTRATIGRAPHY OF THE UPPER BERRIASIAN SECTION "ZAVODSKAYA BALKA" (EASTERN CRIMEA, FEODOSIYA)

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***Abstract**: The results of bio- and magnetostratigraphic investigations of the uppermost Upper Berriasian in Zavodskaya Balka section (Feodosiya, Crimea) are presented. The ammonites of the genus Riasanites (Ammonoidea) were found in this section for the first time. The studied section corresponds to Boissieri Zone (Crassicostatum Subzone) of standard Tethyan scale by ammmonites. Data on foraminifera and dinocysts indicate Late Berriasian – Early Valanginian age. Magnetostratigraphic data shows that the section resembles the uppermost Berriasian - lowermost Valanginian interval (Otopeta Subzone and Pertransiens Zone).*

***Key words**: Biostratigraphy, Berriasian, Valanginian, ammonites, foraminifers, ostracods, dinocysts, magnetostratigraphy, geomagnetic polarity, magnetic Chrons, correlation, Mountainous Crimea.*

The well known section of Sultanovka Formation is located in the clay quarry «Zavodskaya Balka» at the northern outskirt of Feodosiya (Eastern Crimea). By ammonites, the age of formation is considered to be Berriasian [3] (**Fig. 1, 2**). Bio- and magnetostratigraphic studies for this section were carried out by V.V. Arkadiev, A.Yu. Guzhikov, A.G. Manikin and V.A. Perminov in 2009. Among results of these studies, there was a discovery of ammonites *Neocosmoceras euthymi* (Pictet), *Fauriella* cf. *boissieri* (Pictet), *Malbosiceras malbosi* (Pictet) in the upper part of the succession. This assemblage is characteristic for Neocosmoceras euthymi Subzone of the Mountainous Crimea [2] corresponding to standard Tethyan Malbosiceras paramimounum Subzone of Boissieri Zone [12].

The main result of the fieldwork in 2010 was the paleomagnetic characteristic of the succession. On this base the existence of reversed polarity epoch during Chron M16n (the M16n.1r Subchron or "Feodosiya") was stated and trans-regional correlations of the Upper Berriasian were carried out [2, 6].

New stratigraphic units - beds with ostracods *Robsoniella obovata* and the beds with dinocyst *Phoberocysta neocomica* [3] - were established as a result of micropaleontological investigation.

Ammonites classified as *Riasanites* by shell shape and distinctive ribbing (**Plate**

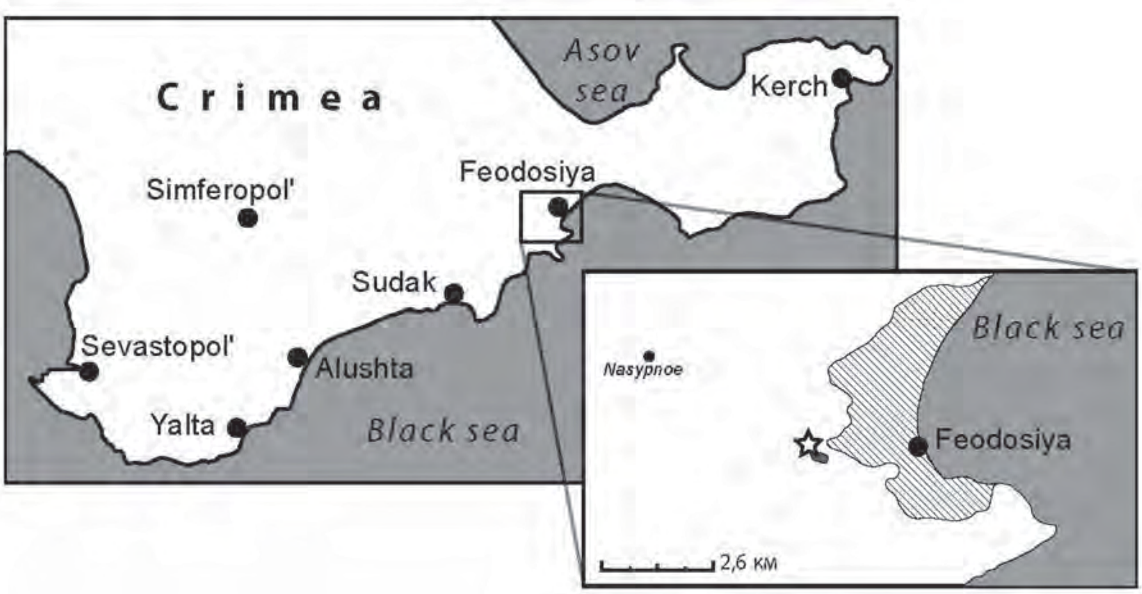


Fig. 1. Location of the Upper Berriasian “Zavodskaya Balka” section

Fig. 2. Quarry “Zavodskaya Balka” showing the Upper Berriasian – Lower Valanginian strata.

I), were discovered in 2014 in the upper part of the section, 40 m above the *Neocosmoceras euthymi* (Pictet) finds. These ammonites were not determined up to the species level because of poor preservation. In addition, a fragment of a large ammonite *Neocosmoceras* sp. was found. These two ammonites are the first finds of *Riasanites* in the Eastern Crimea. Previous records were made in the sucessions of Central Crimea only [3], where Riasanites crassicostatum Subzone can be distinguished above Neocosmoceras euthymi Subzone.

Paleontological (ammonites) and paleomagnetic data obtained from «Zavodskaya Balka» section are ambiguous (**Fig. 3**). *Riasanites* is unknown from Otopeta Subzone (Zone), but is known from three stratigraphic levels within Boissieri Zone [14] on the North Caucasus (Uruch River Basin), moreover, the uppermost level corresponds to Berriasella picteti Subzone on the South-East France. *Riasanites* was not recorded from the overlying beds with *Berriasella callisto* and *Jabronella paquieri* at the Caucasus. Formerly Riasanites crassicostatum Subzone of Central Crimea was correlated to the lower part of Berriasella picteti Subzone of Boissieri Zone [3]. On the Russian Plate species belonging to *Riasanites* characterize Riasanites rjasanensis Zone [8], which is correlated to Occitanica and Boissieri Zones [9], or only to Boissieri Zone [3]. On the other hand, obtained paleomagnetic data indicate that the uppermost part of Zavodskaya Balka section is equivalent of the Otopeta Zone in Western Europe by age [1]. Consequently, wider stratigraphic range for the genus *Riasanites* should be recognized. The question is still open until the species of this genus will be found along with the characteristic ammonites of the Otopeta Subzone. Foraminiferal assemblage with *Lingulina trilobitomorpha, Haplophragmoides vocontianus* established in the upper part of the section is correlated by A. Fedorova to the Valanginian of standard Tethyan scale (**Fig. 4**). It points on the presence of intermediate from Berriasian to Valanginian deposits.

The ostracod assemblages show some similarities with the Middle Berriasian – Valanginian complexes. Upper part of the studied section is well correlated to Boissieri Zone of the Berriasian and Pertransiens Zone of the Lower Valanginian of Tethyan standard on the base of dinoflagellate data and this assumption corresponds well with paleomagnetic data.

This study was supported by RFBR grant no. 14-05-31152 and the RF Ministry of Education and Sciences in the scientific field (project 1757).

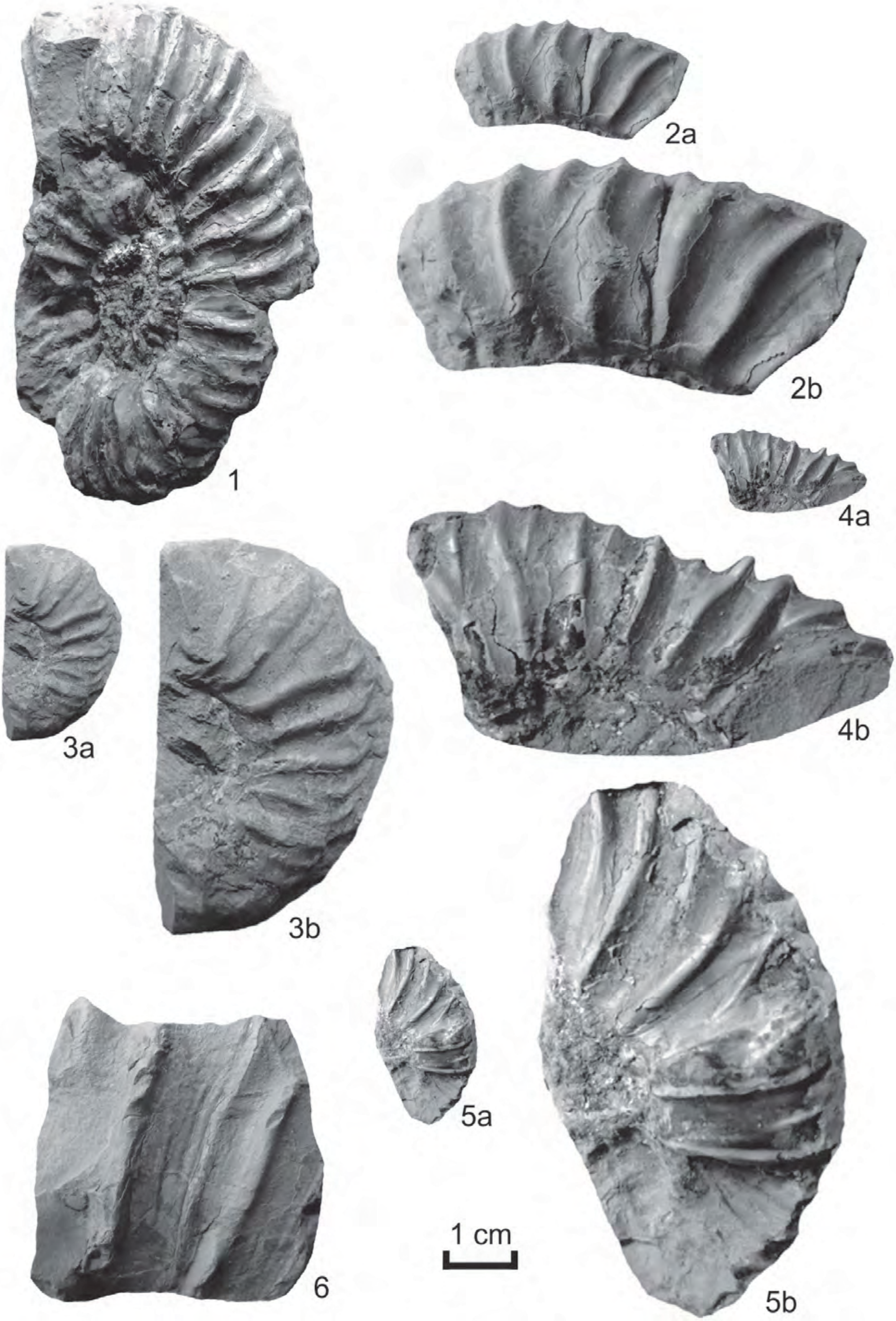
Plate I

Ammonites from the Upper Berriasian Boissieri zone of the “Zavodskaya Balka” section

Fig. 1-5 – *Riasanites* sp., 1 – no 1/409, side view, 2 – no 2/409, side view, 2a, 2b, 3 – no 3/409, side view, 3a, 3b, 4 – no 4/409, side view, 4a, 4b, 5 – no 5/409, side view, 5a, 5b.

Fig. 6 – *Neocosmoceras* sp., no 7/409, side view.

Plate I



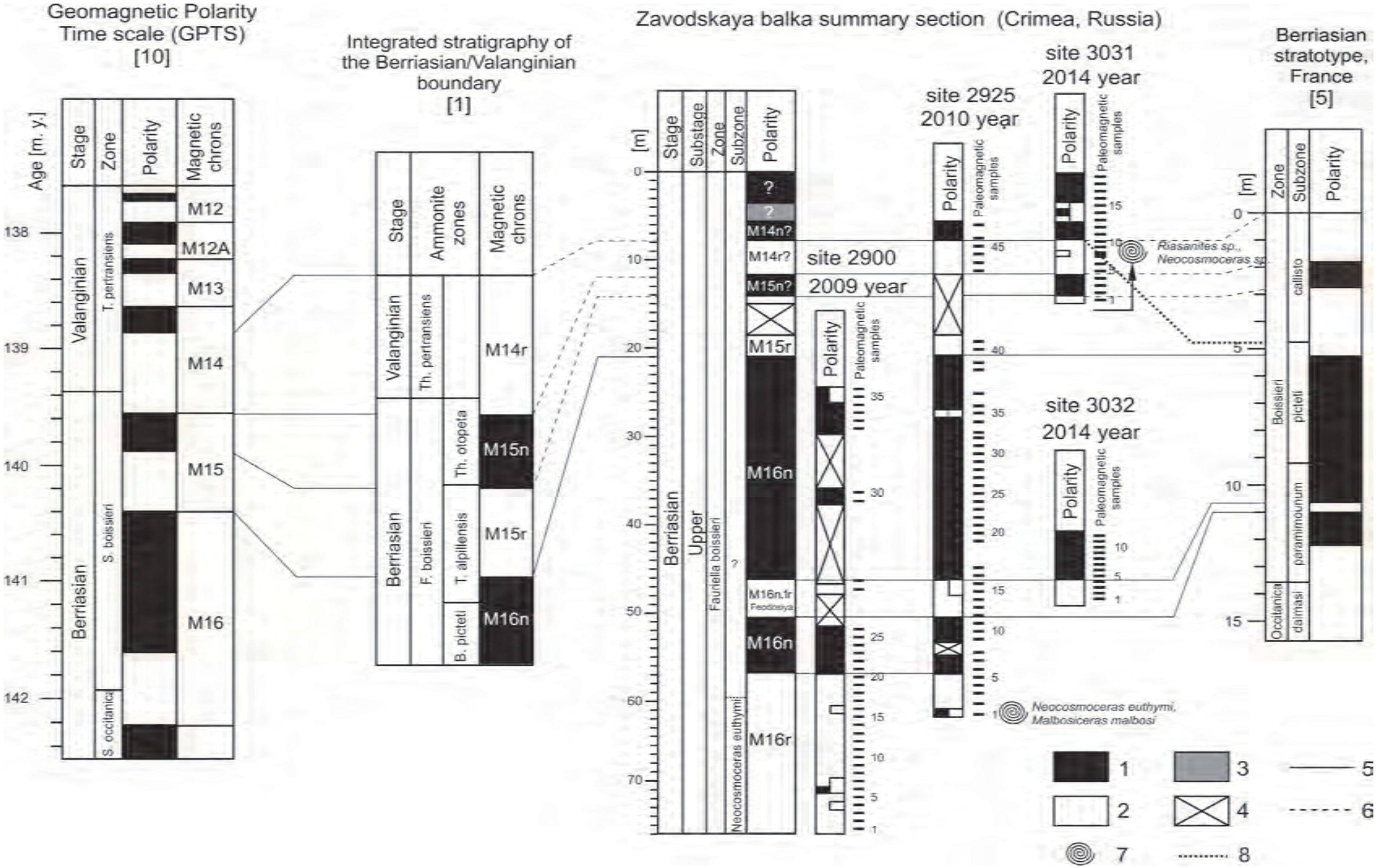


Fig. 3. Correlation of the "Zavodskaya Balka" section with the magnetochronologic scale of the Berriasian-Valanginian boundary interval and with Berriasian stratotype. Captions: 1 – normal polarity, 2 – reverse polarity, 3 – anomaly polarity, 4 – missing polarity data, paleomagnetic correlation: 5 – reliable, 6 – assumed, 7 – finds of ammonites, 8 – correlation based on ammonites.

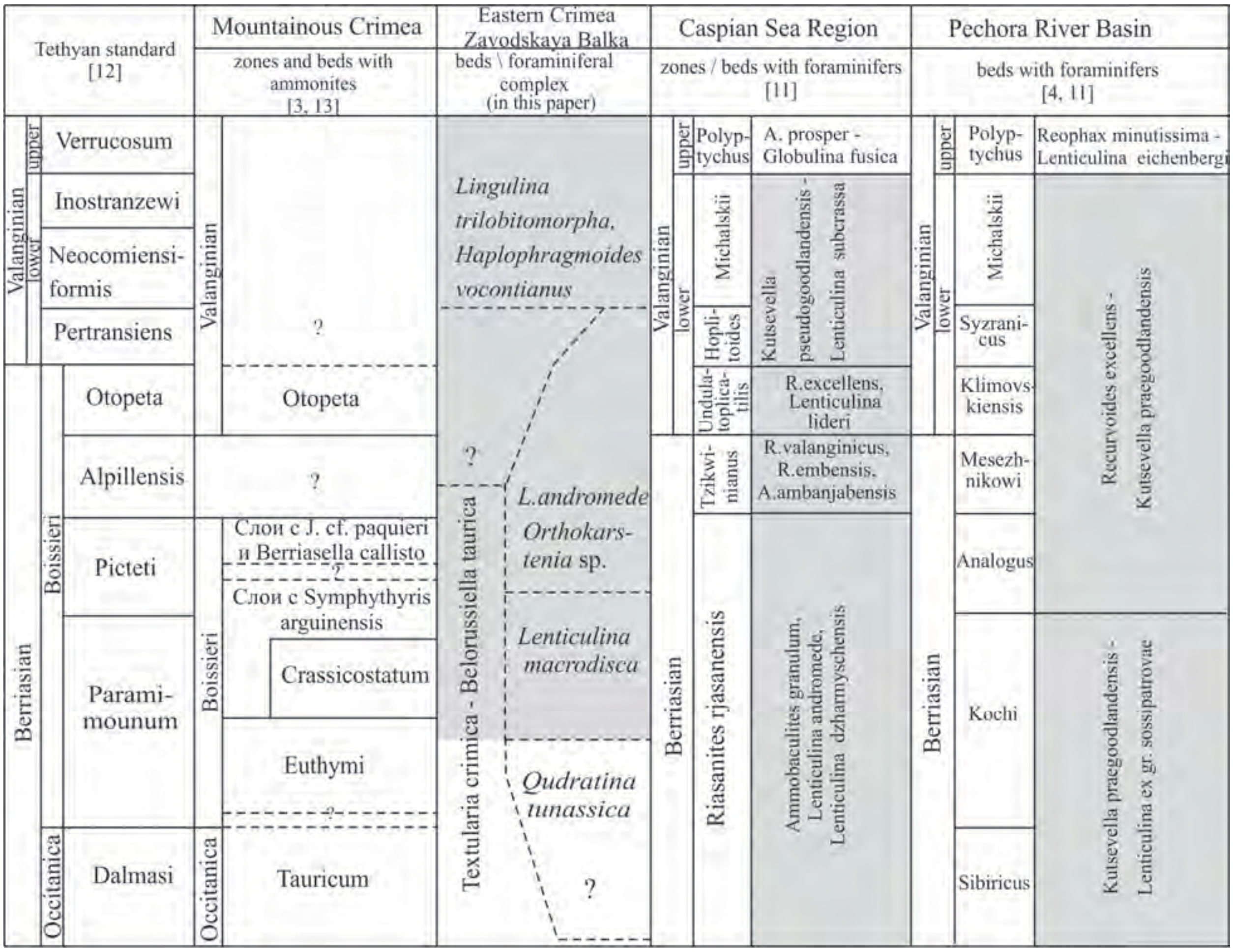


Fig. 4. Correlation of the beds with foraminifers of Eastern Crimea and Berriasian-Valanginian zones and beds of the Caspian Sea Region and the Pechora River Basin.

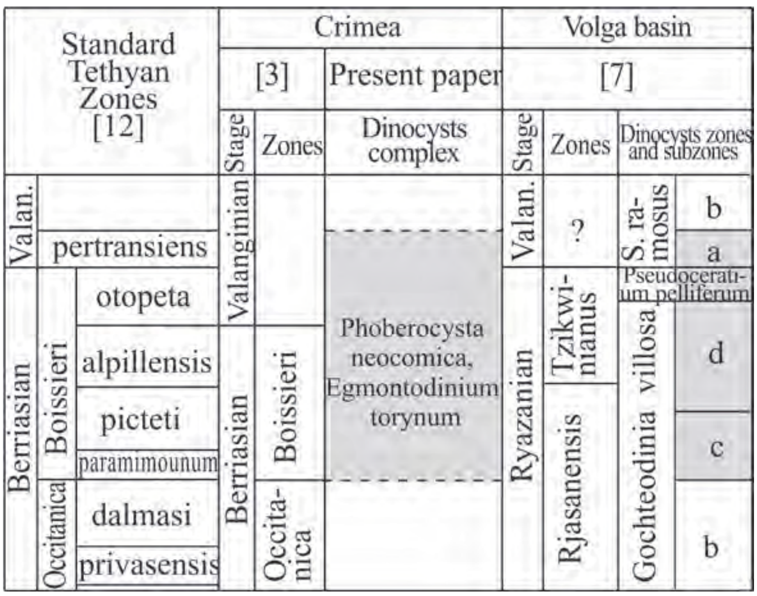


Fig. 5. Correlation of the beds with dinocysts with standard scale and zones of the Volga Basin. Gray filling shows the stratigraphic ranges of similar dinocyst assemblages.

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A VALANGINIAN ICHTHYOSAUR FROM KIROV REGION (RUSSIA) SUPPORTING THE JURASSIC-CRETACEOUS BOUNDARY CROSSING FOR ICHTHYOSAURS

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***Abstract**: Here we gave a brief description of an ichthyosaurian remains from the Lower Valanginian of the European Russia (Kirov region) referable to the family Ophthalmosauridae Baur, 1887. The record of ichthyosaurs from the Berriasian–Barremian interval is extremely limited so even fragmental remains are of great interest. This finding confirms the assumption that the Jurassic–Cretaceous boundary extinction event had a negligible effect on ichthyosaurs [9].*

***Key words:** Ichthyosauria, Ophthalmosauridae, Cretaceous, Valanginian, Russia.*

Introduction. Berriasian-Valanginian marine reptiles, inter alia ichthyosaurs, are quite rare all over the world, as repeatedly pointed out by many authors [2, 9, 13]. Considerable part of the ichthyosaurian remains from this stratigraphic interval for a long time was defined only as Ichthyosauria indet., Thunnosauria indet., Ophthalmosauridae indet. and Platypterygiinae indet. [1, 5, 12, 18]. Only a few platyperygiines from the Berriasian-Valanginian were identified at genus and species level: *Aegirosaurus* sp. (Valanginian, southeastern France) [8], *'Platypterygius' hauthali* (Huene, 1922) (Valanginian–Hauterivian, Chile) [15, 19] and *Caypullisaurus bonapartei* Fernandez, 1997 (Tithonian–Berriasian, Argentina) [6, 19]. It was previously believed that the representatives of the subfamily Ophthalmosaurinae Baur, 1887 became extinct at the Jurassic–Cretaceous boundary. In recent years, it has been found that ophthalmosaurines did not disappear in the Late Jurassic and continued to exist in the Early Cretaceous [8-10]. This was evidenced by the recently described remains of *Acamptonectes densus* Fischer et al., 2012 (upper Hauterivian, Germany) [9], *Leninia stellans* Fischer et al., 2013 (Lower Aptian, Western Russia) [10], cf. *Ophthalmosaurus* (Uppermost Tithonian to Berriasian, England) [9] and indeterminate ophthalmosaurines in Cambridge Greensand (Uppermost Albian, England) [11].

As such, a partial ichthyosaur skull and two associated vertebrae from the Valanginian are of considerable interest. The material is deposited at the Vernadsky State Geological Museum of Russian Academy of Sciences, Moscow (specimen SGM 1574-02, 1574-03). Remains belong to a medium-sized ichthyosaur. The scarcity of the material does not permit to unambiguously identify it and conduct a detailed comparative analysis. The presence of a relatively large orbit and a narrow postorbital bar demonstrates similarity with several ophthalmosaurines - *Ophthalmosaurus* Seeley, 1874, *Paraophthalmosaurus* Arkhangelsky, 1997, as well as the peculiar platypterygiines *Aegirosaurus* Bardet et Fernandez, 2000 and *Sveltonectes* Fischer et al., 2011. Thus, we conservatively identify the remains as a small form belonging to the family Ophthalmosauridae.

The history of discovery and geological settings. The bones were found in Vyatka phosphorite mine, located in Verkhnekamsk district of Kirov region. Mine was organized in 1915, but the mechanized mining operations were started here only in 1930. The find was made in August, 1926, obviously due to the manual artisanal mining process of phosphorite recovery. Currently the mine is not functional.

According to the label, the remains were found in Pyankovka branch that was situated near the village Pyankovka, now a part of Rudnichny township (**Fig. 1**).

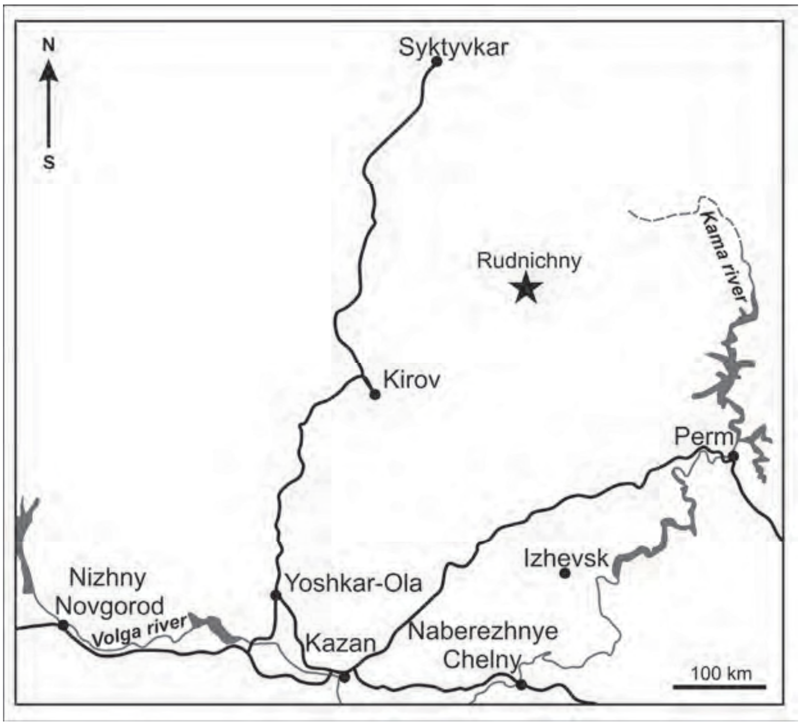

Fig. 1. Map showing the discovery site of SGM SGM 1574-02 Ophthalmosauridae indet. Locality is marked with an asterisk.

The bones were removed from the main phosphorite seam by I. Galin in August, 1926 and later (25.03.1927) they were delivered to Geological Cabinet of Moscow State University. Now the bones are deposited at V.M. Vernadsky State Geological Museum of RAS. According to the literature, the mine was a part of the Vyatka-Kama phosphorite deposits. It is located 150-200 km north-east from Kirov. It stretches from south-west to north-east between the rivers Vyatka and Kama for 120 km and was 30-50 km in width. The phosphorite deposit is confined to a broad trough formed by the Jurassic, Cretaceous and Quaternary sediments. The main phosphorite layer refers to the lower Valanginian Nikitinoceras hoplitoides Zone [3, 14]. The mined seam lies almost horizontally, folded by black and dark brown phosphorite nodules up to 10 cm, at the top - up to 20-30 cm, are firmly concentrated in the quartz-glauconite sands. The overburden is represented by the Hauterivian dense, micaceous, sandy clays interbedded with thin layers of quartz-glauconite sands and phosphorite gravel. In the clays, eluvial-diluvial and alluvial loams and sands commonly occur. Thickness of phosphorite horizon is 0.5-1.7 m. The depth of the reservoir is from 1-2 m to 60-80 m [16, 17].

SYSTEMATIC PALAEONTOLOGY

Ichthyosauria Blainville, 1835
Neoichthyosauria Sander, 2000
Thunnosauria Motani, 1999
Ophthalmosauridae Baur, 1887
Ophthalmosauridae indet.
Fig. 2

Description. Preservation of bones is poor. The orbit is large, oval in shape, slightly constricting posteriorly. It is incompletely preserved, its ventral and front edges are missing (**Fig. 2A-C**). Dorsally it is formed by the postfrontal, posteriorly by the postorbital. The postorbital is thin and gracile, slightly extended downward. The suture between the postfrontal and the supratemporal is undistinguishable. A small fragment of the quadratojugal is preserved.

The sclerotic ring is preserved in three dimensions, but partially broken. The diameter of the external area is 130 mm, the diameter of the aperture is 50 mm, as in the must larger taxon *Caypullisaurus* [10], suggesting a relatively large eye size for SGM 1574-02. Nine sclerotic plates are preserved, eight of them are in natural articulation. The sclerotic ring occupies the entire area of the orbit, which probably suggests SGM 1574-02 was a juvenile [7].

Two anterior caudal vertebrae are preserved (**Fig. 2D-F**). They are relatively elongated (length to height ratio - 0.43).

Material. State Geological Museum of RAS, SGM 1574-02, fragment of right half of skull related to the orbital area, sclerotic ring, SGM 1574-03, two anterior caudal vertebrae; Kirov region, Verkhnekamsk district, near the township Rudnichny, Vyatka phosphorite mine, Pyankovka branch; Lower Cretaceous, Lower Valanginian, Nikitinoceras hoplitoides Zone.

Conclusion. The studied remains may be identyfined as a representative of the family Ophthalmosauridae. Ichthyosaurian remains previously described from the Valanginian of Crimea [4] are also could be defined only as Ophthalmosauridae indet. Thus, in the Valanginian the Russian Sea and adjacent water basins were inhabited by medium-sized ophthalmosaurids, most likely specialized on hunting for small soft-bodies nekton – fish and cephalopods. This finding confirms that ichthyosaurs successfully crossed the Jurassic-Cretaceous boundary and thereby further search for the Lower Cretaceous ichthyosaurs in Central Russia should yield positive results. View of the fact that ichthyosaurs were not affected by the Jurassic-Cretaceous boundary extinction event [9], and their taxonomic composition appears to be the same in both the Upper Jurassic and early Early Cretaceous, they can not be regarded as stratigraphic indicators for the Jurassic-Cretaceous boundary at the current level of knowledge.

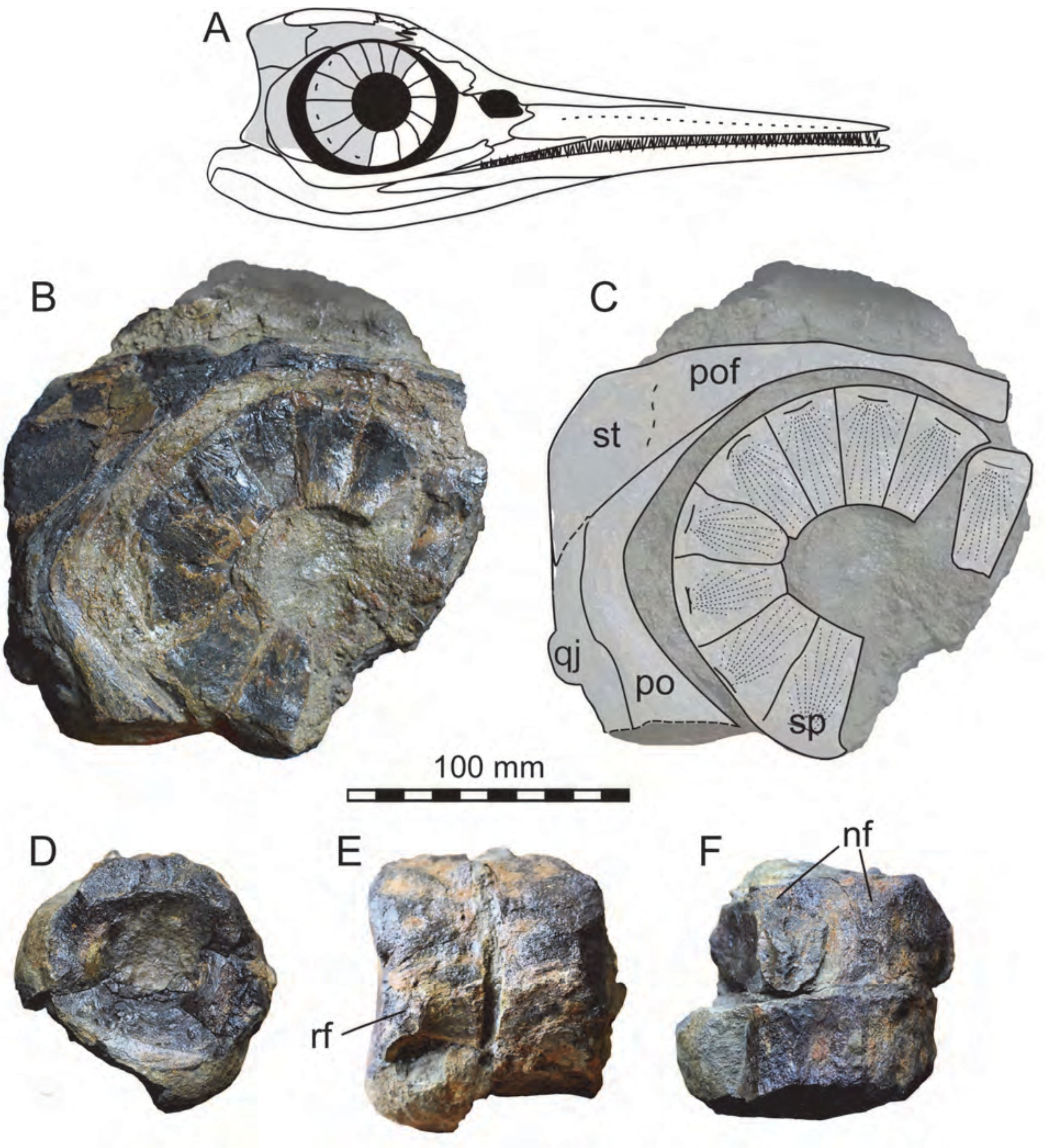

Fig. 2. Ophthalmosauridae indet. (SGM 1574-02, 1574-03): A – a position of the described fragment in the skull; B – fragment of the skull; C – interpretive outline; D-F – anterior caudal vertebrae (SGM 1574-03) in anterior (D), lateral (E) and dorsal (F) views. Abbreviations: nf – neural arch facet, po – postorbitale, pof – postfrontale, qj – qadratojugale, rf – rib facet, sp – sclerotic plate, st – supratemporale.

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ICHNOLOGY OF THE JURASSIC-CRETACEOUS BOUNDARY INTERVAL OF THE CHIGAN CAPE (VLADIVOSTOK REGION, RUSSIA)

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Abstract: *The results of the ichnological study of the Jurassic / Cretaceous boundary section of Chigan Cape are discussed.*

Key words: *Cretaceous, Jurassic, ichnology, trace fossils, Russian Far East.*

We have studied the well-known Jurassic–Cretaceous Chigan section (Chigan Cape, Podiapolsky Town area, Vladivostok Region) with the group of geologists from Saratov and Saint Petersburg State Universities, and Far East Geological Institute FEB RAS in September 2014. The location, stratigraphy and sedimentology of this section are discussed in the paper of Guzhikov and others, this volume. The succession is represented by intensively bioturbated (bioturbation index of Droser and Bottjer = 5-6) lower shoreface muddy sandstones (Members 1-3 and 5: [3]) and non-bioturbated middle-upper shoreface sandstones (Member 4: [3]).

The variability of trace fossils is rather high within *Schaubcylindrichnus* - dominated ichnofabric. It contains *Schaubcylindrichnus coronus* Frey et Howard, 1981, *Teichichnus* isp., *Thalassinoides* isp., *Ophiomorpha irregulaire* Frey, Howard et Pryor, 1978, *Phycosiphon incertum* Fischer-Ooster, 1858, *Rhizocorallium commune* Schmid, 1876, *Asterichnus lawrencensis* Bandel, 1967, *Bichordites monastiriensis* Plaziat and Mahmoudi, 1988, *Neonereites uniserialis* Seilacher, 1960, *N. biserialis* Seilacher, 1960 and some non-identified taxa.

Ichnogenus ***Schaubcylindrichnus*** is the most common ichnofossil in the section. It is typical of lower shoreface to offshore-transition zone [6] and has been interpreted as a funnel feeder such as enteropneust polychaetes [7] or passive carnivore trace [6]. The number of tubes per sheaf varies at the same stratigraphic level, so our data do not confirm conclusions of Löwemark and Nara [8] on the relation of their number to the wave energy in shoreface settings.

Ichnogenus ***Bichordites*** has different preservation styles: *Laminites, Scolicia* and *Bichordites*, which could be observed in the same sample. We use the only name *Bichordites*, because in all cases both meniscate laminae and central cord are visible. *Bichordites* is produced by irregular spatangoid echinoids with a single drainage tube, which belong to the *Echinocardium* group [2].

Ichnogenus ***Rhizocorallium*** is distributed in the shoreface to deep-water environments, being typical for Cruziana ichnofacies. *Rhizocorallium* is a rare trace fossil in the studied succession. Producers of the ichnogenus could be mobile carnivore crustaceans (amphipods of the genus *Corophium*), or deposit-feeding annelids (eunicid polychaete *Marphysa sanguinea* or Spionidae, Capitellidae, Terebellidae), or even burrowing mayflies (Ephemeridae) [5]. However, for the *Rhizocorallium commune* Schmid, 1876 the polychaete producer is a more likely case [5]. It seems that our samples belong to *Rhizocorallium commune irregulare* - type, which usually occurs in the intertidal or littoral zone, but was also reported from the deep-water environments [5].

Ichnogenus ***Ophiomorpha*** often accompanies *Schaubcylindrichnus, Cylindichnus,* etc. being a typical shoreface to shallow-marine trace fossil [1]. *Ophiomorpha irregulaire* differs from other ophiomorphs by curved irregular shape in subhorizontal plane, poorly visible in vertical outcrops. These traces belong to suspension-feeder crustacean producers.

Ichnogenus ***Phycosiphon*** is normally distributed in the lower shoreface to offshore conditions, often in poorly oxygenated sediments. *Phycosiphon incertum* has been regarded as a trace made by a subsurface opportunistic deposit feeder, who ingested finer grains and sorted out coarser grains during deposit-feeding activity like in modern marine holothurians or some opheliid polychaetes like *Euzonus* and *Travisia* [4].

Ichnogenus ***Neonereites*** is probably a junior synonym to *Nereites* [9]. It ranges from the lower shoreface to deep-marine environments and restricted to oxygenated sedimentary environments [11]. It is considered to be a grazing trace, which represents combined locomotion and feeding activities. *Neonereites* is most likely produced by enteropneust or polychaete worm or even anthozoan.

Ichnogenus ***Asterichnus*** was originally described by L.D. Miroshnikov [10] from Chigan Cape as "false impressions of jellyfishes", belonging to unknown star-shaped trace-makers. It is still poorly known trace fossil, which was found in a large spectrum of environments: from near-shore to deep-water. *Asterichnus* is a combination of dwelling and feeding trace that could be produced by a large number of different animals: bivalves (*Macoma, Scrobicularia*), amphipods (*Corophium*), fishes (*Gobius*), annelid worms (*Glycera, Gonidia, and Nereis*).

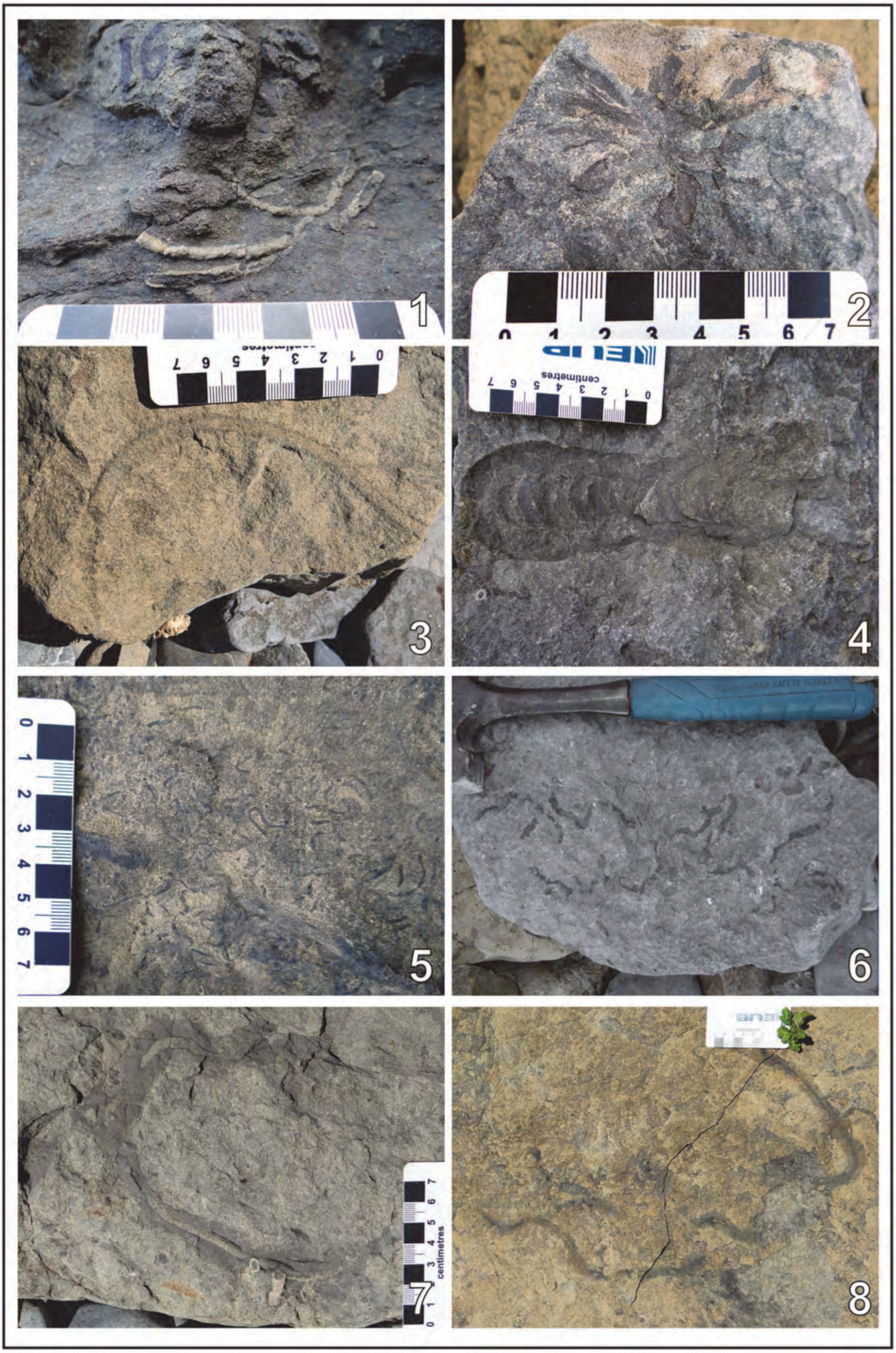
Ichnogenus ***Thalassinoides*** is widely distributed in the near-shore to deep-marine environments and even in the continental conditions [12]. The most of *Thalassinoides* belong to dwelling burrows of callianassid crustaceans, which feed by small organisms and organic detritus, extracting particles from suspension.

Ichnogenus ***Teichichnus*** is rather rare in the succession. It is typical representative of Cruziana ichnofacies, but distributed in near-shore to deep-marine

Fig. 1. Selected ichnofossils from the Chigan section.

1. *Schaubcylindrichnus coronus* Frey et Howard, 1981;
2. *Asterichnus lawrencensis* Bandel, 1967;
3. *Ophiomorpha irregulaire* Frey, Howard et Pryor, 1978;
4. *Rhizocorallium commune* Schmid, 1876;
5. *Phycosiphon incertum* Fischer-Ooster, 1858;
6. *Neonereites* uniserialis Seilacher, 1960;

7-8. *Bichordites monastiriensis* Plaziat and Mahmoudi, 1988.



successions [6]. *Teichichnus* is a deposit-feeding trace produced by crustaceans or polychaetes.

The ichnoassemblage is related to different groups of marine worms, echinoids and arthropods, which body-fossils were not preserved. Its interpretation indicates lower shoreface to offshore-transition zone conditions, Cruziana ichnofacies, normally oxygenated, but rich in organic debris. The studied sections [3] demonstrate almost uniform ichnoassemblages through the whole succession except the single level of middle-upper shoreface Member 4 [3], indicating presence of potential sequence boundary.

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BIO- AND MAGNETOSTRATIGRAPHIC DATA ON THE JURASSIC-CRETACEOUS BOUNDARY OF THE KASHPIR AND GORODISHCHI SECTIONS (VOLGA REGION, RUSSIA)

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***Abstract**: The results of the integrated study of Gorodischi and Kashpir sections (Volga River region), the type sections of the Volgian Stage, provide possibility to speculate on the interregional correlation of the Jurassic/Cretaceous boundary interval.*

***Key words**: magnetostratigraphy, Jurassic-Cretaceous boundary, Russian Platform.*

The Jurassic-Cretaceous boundary interval on Russian Platform (RP) is represented by condensed deposits, which have traditionally been considered not available for magnetostratigraphy, because of numerous gaps, a multi-phase oxidation of ferromagnetic minerals, extremely weak natural residual magnetization (J_n), etc. However, the Volgian Stage reference sections (Fig. 1) at Kashpir township (Samara region) and Gorodischi Village (Ulyanovsk region), contain nearly complete Middle Volgian - Ryazanian ammonite zonal sequence. Therefore they are the key sections for getting magnetic polarity data to solve a number of important problems of the detailed Boreal-Tethyan correlation of the Jurassic-Cretaceous boundary interval. Sections Kashpir and Gorodischi were studied by numerous geologists (S.N. Nikitin, A.P. Pavlow, E.V. Milanovsky, P.A. Gerasimov, N.P. Mikhailov, I.G. Sazonova, N.T. Sazonov, etc.). We also have studied these sections in 1995-2000, and new data on the sedimentology, biostratigraphy, mineralogy, and paleomagnetic structure were obtained.

The succession and sedimentology. Our understanding of the Gorodischi section subdivision have been published in [5, 12, 13], and the Kashpir section was published very briefly [2], so we characterize it below (**Fig. 1**). The section is located near the boat station of Novokashpirsky Village, at the right bank of the Volga River (N 53°02'42.9'', E 48°26'86.7''), where outcropped (base to the top):

1. The rhythmic alternation of bioturbated clays and planar-laminated shales of Dorsoplanites panderi Zone. The apparent thickness is 2.5 m.

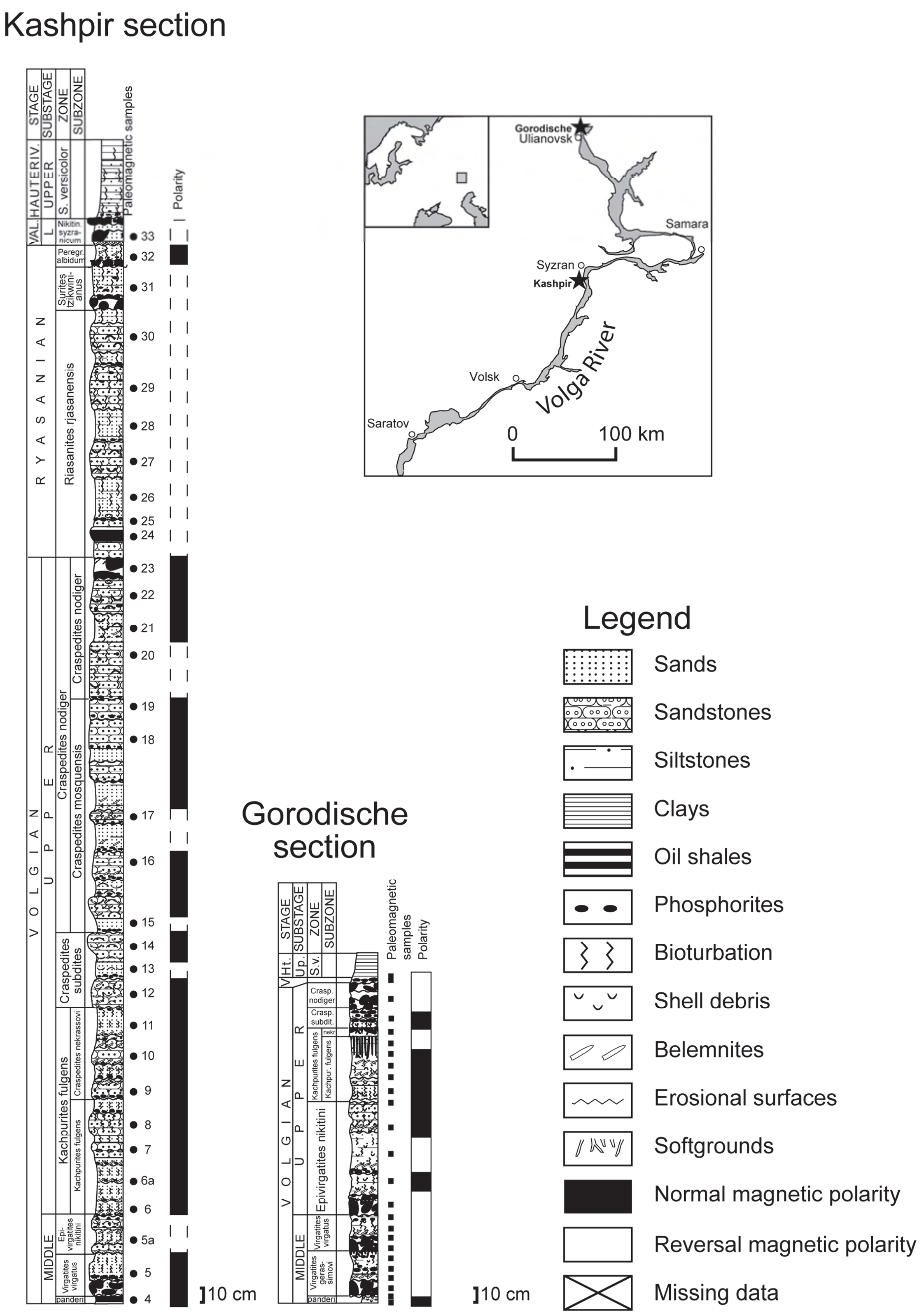

Fig. 1. Location, stratigraphy and paleomagnetic sampling in Gorodischi and Kashpir sections

2. The rhythmic alternation of soft and cemented greenish-gray bioturbated glauconitic sandstones of Virgatites virgatus and Epivirgatites nikitini Zone with phosphorite conglomerate at the base. Numerous erosional surfaces are marked by belemnite rostra and phosphatic pebbles. The top is eroded and colored in red. The thickness is 0.5-0.55 m.
3. The rhythmic alternation of soft and cemented greenish-gray bioturbated glauconitic opoka-like sandstones. Numerous erosional surfaces are marked by belemnite rostra and phosphatic pebbles. Completeness of rhythms is different as well as the thickness of phosphorite horizons. The member contains all Upper Volgian ammonite Zones [2]. The thickness is 3.85 m.
4. The rhythmic alternation of yellowish-gray soft and cemented bioturbated opoka-like sandstones. The member consists of five rhythms, separated by erosional surfaces. The upper element of the lower rhythm is represented by characteristic brownish black shale. The thickness is 1.7 m. The Member begins the Ryazanian Stage (Riasanites rjasanensis Zone).
5. The yellowish-gray bioturbated sandstones, uged, opoka-like, muddy, with scattered phosphorites, phosphorite conglomerates, and mature phosphatic hardground. The thickness is 0.6 m. The Member refers to the Surites tzikwinianus and Peregrinoceras albidum Zones.

The Valanginian succession erosionally overlies the Ryazanian.

The Lower-Middle Volgian sequence is better represented in the Gorodischi section, while the Upper Volgian is better represented in the Kashpir section. Ryazanian and Valanginian are almost missing in the Gorodischi outcrop. It should, however, be noted that the completeness of the condensed Middle Volgian - Valanginian strata is changing rapidly, so individual sections are different in details.

The black shales of the Dorsoplanites panderi Zone were formed in the transition to offshore zones of the basin with changing sediment anoxia during the eustatic sea-level rise. Similar conditions periodically repeated in the beginning of the Ryazanian to Valanginian as evidenced by the presence of black shales in the Kashpir section. The overlying succession of Virgatites gerassimovi Zone and higher strata accumulated in the lower shoreface environment. This is evidenced by the sandy composition, absence of primary textures and intensive bioturbation by *Thalassinoides, Skolithos, Macaronichnus, Phycosiphon, Bichordites, Chondrites, Asterosoma*, etc., indicating Skolithos - Cruziana ichnofacies.

Mineralogy. Major sedimentological characteristics of the studied sections are confirmed by the granulometric data (upwards mudstones are replaced by sandstones) and mineralogical composition. The magmatic mineral assemblage dominates in the Middle Volgian detritic sediments and metamorphic mineral assemblage dominates the Late Volgian to Early Cretaceous detritic sediments [9].

Magnetostratigraphy. The earlier paleomagnetic data by E.A. Molostovsky and V.N. Eremin [10] is not based on the quantitative component analysis because of some external reasons (natural remanent magnetization (J_n) is below the sensitivity of the measuring equipment). Recent study of the Middle Volgian – Lower Valanginian deposits of Kashpir and Gorodischi sections included a magnetic cleaning by

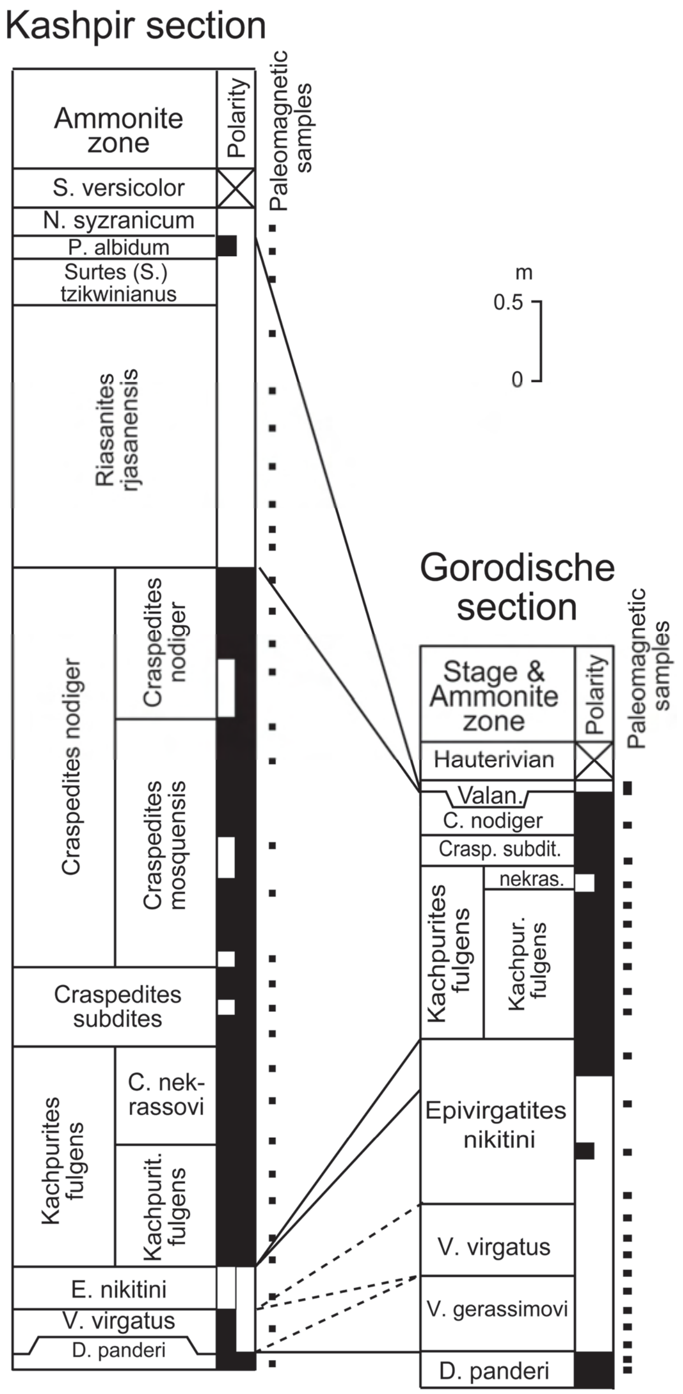

Fig. 2. Magnetostratigraphic correlation of Middle Volgian – Ryazanian in the studied sections (dashed line - estimated). For the legend see Fig. 1.

alternating field up to 50 mT with demagnetizer LDA-3A and subsequent measurements on spin-magnetometers JR-6. Measured samples demonstrate characteristic components (ChRM), despite J_n values are small (around hundredths of 10^{-3}A/m). The paleomagnetic statistics is poor (for the ChRM projected onto the upper hemisphere, the maximum deviation angle is 15-25°, interlayer paleomagnetic precision parameter <5), but the presence of ChRM of both normal and reversal polarity is is beyond all questions. Totally 23 samples were studied from the interval of ~2.5 m in Goodischi section and 30 samples from the interval of ~7 m in Kashpir section (**Fig. 1, 2**).

Discussion. The polarity reasonably groups into the magnetozones (**Fig. 1, 2**) despite numerous gaps. The paleomagnetic structure of the two sections is consistent (**Fig. 2**): the interval of K. fulgens[1] - C. nodiger Zones both in Kashpir and Gorodischi corresponds to the dominant normal polarity (N). The reversal polarity (R) in V. virgatus Zone of Gorodischi does not contradict the Kashpir data because of very small thickness of V. virgatus Zone, characterized by the only sample (**Fig. 2**). Magnetostratigraphic interpretation of these data and paleomagnetic interregional correlations should be made extremely cautiously because of very low sedimentation rates and numerous hiatuses in the condensed succession. However, it

[1] D.N. Kiselev and M.A.Rogov [8] refer this part of the section to the Middle Volgian, at the same time, noting the presence of a new species of *Kachpurites*. According to our opinion, the Upper Volgian at the Russian Platform should be defined by the appearance of the genus *Kachpurites*.

cannot be a coincidence that K. fulgens - C. nodiger Zones are marked mostly by normal polarity and the Riasanites rjasanensis Zone by reversal polarity.

It was justified earlier [11] that D. panderi Zone should be compared with the magnetic Chron M21n, and V. virgatus Zone - with Chron M20r. Thus, N-Magnetic Zone of E. nikitini Zone - Upper Volgian of the composite section, corresponds to the combination of Chrons M20-M18 (**Fig. 3**). It is not a surprise that short-term Chrons M19r and M18r (and, especially, R-Subchron "Brodno" and "Kysuca") could not be preserved in such condensed sections. On the contrary, during the long-term period of Chrons M17r and M16r sediments are most likely having the reversal polarity. From this point, R-magnetozone covering the whole Ryazanian, should be identified as the superposition of Chrons M17r-M16r. However, existing biostratigraphic comparisons ([3] and others) and the fact that *Riasanites* in Tethyan sections is distributed within Chron M16r or above [1], Ryazanian R-magnetozone should be correlated with only M16r (**Fig. 2**). In the last case one should consider that there is a large hiatus in Kashpir corresponding to the Chron M17 or even larger.

However, a more detailed correlation of the Upper Volgian - Ryazanian of Volga River region should be avoided, since the magnetostratigraphic interpretation allows various conclusions. At the moment we have demonstrated the basic possibility to get paleomagnetic information from the condensed sections. There is a hope that more detailed sampling of these sections will bring more valid data for interregional correlations of the Jurassic-Cretaceous boundary interval. In the meantime, the most confident conclusion is that the base of R. rjasanensis Zone of the RP is not younger than M17r Chron and is likely to be close to the base of the Boreal Sibiricus Zone and Tethyan Occitanica Zone (**Fig. 3**).

Acknowledgements. The study has been supported by RFBR grants № 14-05-31152, 13-05-00745a, 12-05-00196a, 14-05-31152-мол_а and the RF Ministry of Education and Sciences in the scientific field (project 1757).

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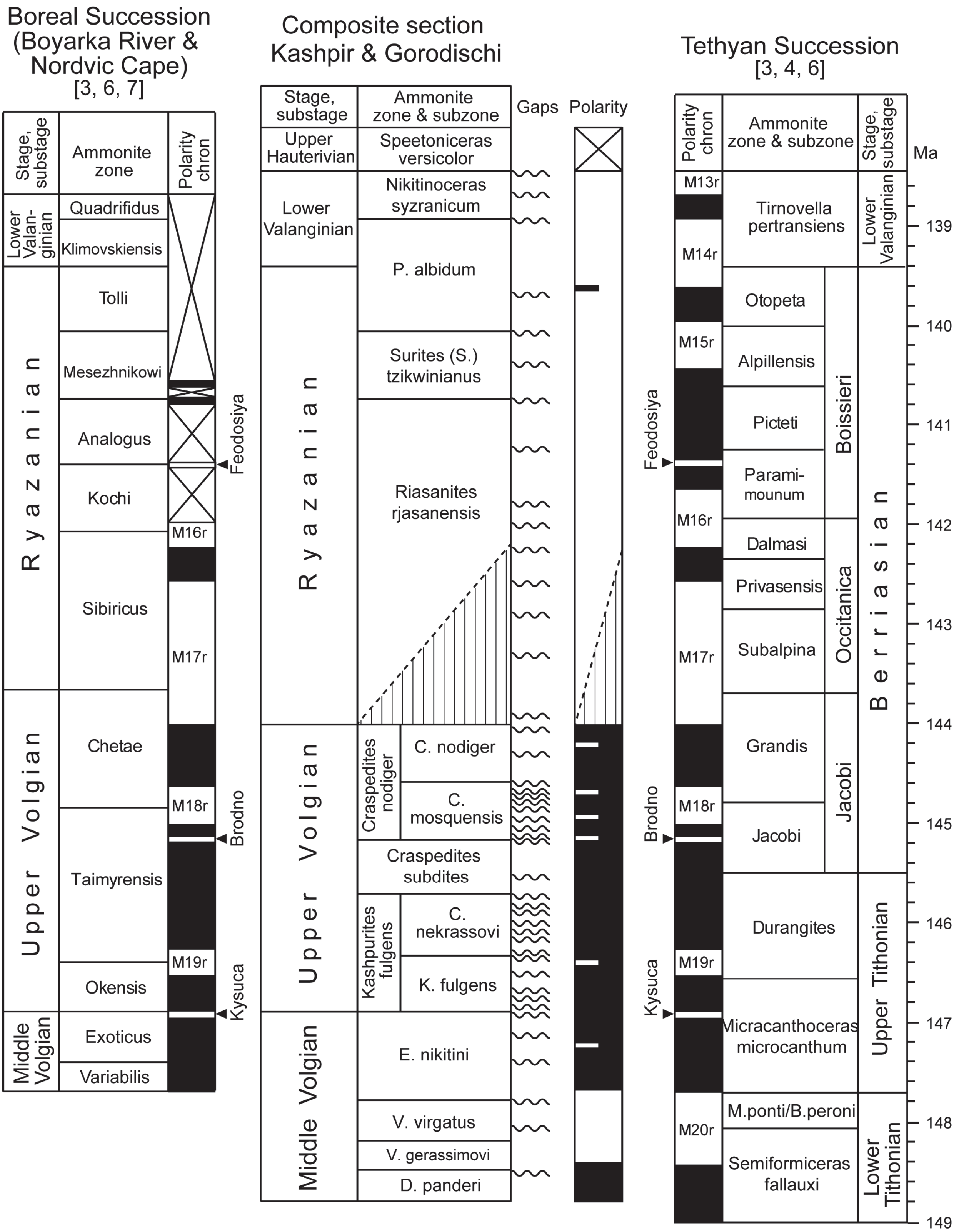

Fig. 3. Magnetostratigraphic correlation of the Jurassic-Cretaceous boundary composite succession of the Middle Volga region with other regions. For the legend see Fig. 1.

data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia)" by V. Yu. Bragin, OS Dzyuba, A. Yu. Kazansky, and BN Shurygin). *Russian Geology and Geophysics*, 54(3), 349-354.

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JURASSIC-CRETACEOUS BOUNDARY BEDS AT MENYA RIVER, CENTER OF THE RUSSIAN PLATFORM

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***Abstract**: This article presents a short description of the J/K boundary deposits at Menya River, Center of the Russian Platform, as well as the results of the long-term research of the author, describing the Upper Volgian deposits with the ammonites Chuvaschites.*

Key words: *ammonites, Jurassic/Cretaceous boundary, Menya River, Russia*

Outcrops of the Jurassic-Cretaceous boundary beds located at Menya River in Poretskoe district, Chuvashia republic has been studied for more than 100 years. For the first time they were mentioned by I.I. Lahusen, who noted presence of glauconitic sandstone unit, rich in *Aucella mosquensis (*von Buch), between Jurassic and Cretaceous clays in Kurmysh county [6]. In 1893 W.A. Stchirowcky pointed out that the outcrop near Pekhorka village, located within 91th sheet of the topographic map of Russia, was found and studied by professor A.P. Pavlow, who also took note on occurrence of ammonites in this area, further described by W.A. Stchirowsky [15]. Several years earlier A.P. Pavlow described a new species of Neocomian ammonite, founded near Poretskoe at the Sura River - *Olcostephanus stenomphalus* Pavlow [8]. Since 1891, W.A. Stchirowsky visited the outcrop at the Menya River near Pekhorka village several times. He recognized here a thick layer (0,5 m) of oolithic grey marl of the Early Neocomian age underlying the dark blue clays with *Astarte porrecta* Buch and *Simbirskites (Speetoniceras) versicolor* (Tr.) and overlying Middle Volgian black shales. Stchirowsky described the following ammonites from the grey marl: *Oxynoticeras gevrili* (d'Orb.), *Oxynoticeras marcoui* (d'Orb.), and some new species: *Oxynoticeras tuberculiferus* Stchirowsky, *Hoplites menensis* Stchirowsky, *Hoplites kurmyschensis* Stchirowsky [15]. He also performed an extended geological research over Kurmysh County and its vicinities, including Menya River and left-bank tributaries of the Sura River. He mentions the Jurassic deposits with the Early and Middle Callovian fauna near Semenovskoe village, Kimmeridgian and Volgian strata near Poretskoe, Ryapino and Ustinovka villages. V.A. Stchirowsky referred to the Neocomian the glauconitic black phosphorite conglomerates, marls and sandstones with *Aucella* fauna underlying Hauterivian clays near Ryapino, Tikhomirovo and Ustinovka villages [7, 14].

Jurassic-Cretaceous boundary beds of the Menya River became intensively studied since the middle of XX century, when N.T. Sazonov described two ammonites from Poretskoe ascribed to a new genus *Surites* [10]. Slightly later the outcrop near Pekhorka village at the Menya River was studied by I.G. Sazonova. In the core of a small elevation, known as “Abal”, she describes the succession, consisting of 5

Berriasian layers and 2-3 Valanginian layers, rich in cephalopods and buchiid bivalves [11, 12]. I.G. Sazonova also performed the comparison of this section with the coeval deposits on the right shore of the Oka River near Chevkino village, later chosen as lectostratotype of the Ryazan horizon and Berriasian reference section for the Central Russian province of the Boreal Realm. During the study of the outcrop "Abal", I.G. Sazonova described nearly 30 new ammonite species and 10 new genera, as well as a new family Suritidae with two new subfamilies Suritinae and Menjaitinae [11, 12]. However, most of the researchers had not supported her new taxa, considering all these ammonites belonging to the family Craspeditidae.

After 1992 biostratigraphic studies in Alatyr and Kurmysh region were performed by V.V. Mitta [7]. He points out, that at the present time there is no outcrop near Pekhorka village. However, 1 km downstream, near the margin of Mishukovo village, yellowish-grey calcareous sandstones with rare oolites and numerous *Surites*, *Menjaites* and other ammonites, as well as bivalves *Buchia* are exposed. V.V. Mitta determined *Tollia* aff. *tolli* Pavlow from the Valanginian Undulatoplicatilis zone of the Menya River in his own collection and in the old collection of A.P. Pavlow [4].

Our investigations at the Jurassic-Cretaceous boundary interval in Chuvashia, performed in 1996–2015, enabled the author to study several new outcrops and to collect ammonites resembling Arctic *Taimyroceras* [1, 2]. The outcrops of the Sura bank near Kozlovka village and in the body of the Menya River near Ryapino village in the Poretskoe region were described. The Upper Volgian was recognized in these outcrops for the first time (beds with *Garniericeras subclypeiforme, Craspedites* (*C.*) *okensis* var. *crassa*) and some new Craspeditidae were described: *Chuvaschites sasonovi* Berezin, *Chuv. perspectivus* Berezin, *Chuv. latus* Berezin. These beds are underlied by phosphorites with the Middle Volgian fossils. Upper Volgian is overlied by hard calcareous oolitic grey sandstone with rusty brown spots and with the filling of cracks, holes and belemnite moulds by green and pink marl. *Chandomirovia pechorkensis* I. Sasonova and *Ch. ilekensis* Sasonov were found on the contact with the underlying layers. There are no ammonites in the layer, but it contains belemnites, numerous *Buchia*, among which there are large *Buchia surensis* (Pavlow) and a lot of shingled large clasts of *Craticularias* sp. sponges. It is possible, that sponge layer protected the layers below from being eroded.

Ammonite genus *Chuvaschites* differs from *Craspedites* in poorly developed primaries and by diminishing of ribbing on the ventral side [1, 2]. These ammonites are closely related to the Arctic ammonites *Craspedites (C.) bodylevski* Erschova, *C. (Taimyroceras) agardensis* Erschova from West Spitsbergen, *C. (C. s. str.) cf. okensis* d'Orb. from Greenland, *C. (T.) canadensis* Jeletzky from Arctic Canada, *C. (T.) taimyrense* (Bodylevsky), *C. (C.) pseudonodiger* Schulg. from Taymyr, as it is evident from the common feature – flattened ventral side of the shell [3]. Beds with ammonites *Ch. sasonovi* are probably the terminal part of the Jurassic Upper Volgian succession within the discussed territory.

The general idea is that «it is rather difficult to trace stratigraphic confinement of several ammonites in the sections of the Upper Jurassic and Lower Cretaceous along the Menya River near Pekhorka village, because of lithological similarity of all the beds in this area (Volgian Craspedites nodiger zone(?), Berriasian Surites tzikwinianus zone, Early Valanginian), which are condensed and lie with erosion (marked by pebbles) over the previous one» [5]. Our longstanding studies show that though there is condensation of many layers at the Jurassic-Cretaceous boundary interval, careful investigation over the described area can reveal the same succession which once was described in the “Abal” section.

In the outcrops at the Menya River the Upper Volgian phosphate sandstone with *Chuv. sasonovi* is overlied by ?Valanginian sponge calcareous sandstone with *Ch. ilekensis*. Ammonites of the genus *Surites* from the Spasskensis zone occur only in the upper part of the preceeding layer. Lower Berriasian layers are blurred, and Upper Berriasian can be subdivided into Spasskensis and Simplex zones. Ryazanian and Valaninian beds differ in lithology and associated faunas, especially in the presence of *Tollia* and *Delphinites* typical for Undulatoplicatilis zone, in the Valaginian. Large ammonite *Luppoviceras validum* Sasonova occurs in the lowest part of the Valanginian, *Tollia* occurs just above, and the latter unit is overlied by *Delphinites* –bearing strata.

At the present time “Abal” section is not available for study. Outcrops at the Menya River change annually, new lens and beds, allowing obtaining new data on fauna and stratigraphy of the Jurassic and Cretaceous boundary beds, become exposed.

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BELEMNITES AND BIVALVES FROM THE JURASSIC-CRETACEOUS BOUNDARY INTERVAL OF THE KASHPIR SECTION, MIDDLE VOLGA BASIN, RUSSIA: IMPLICATIONS FOR BIOSTRATIGRAPHY AND PANBOREAL CORRELATION

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***Abstract**: Abundant belemnites and bivalves from the Middle Volgian–Ryazanian of the Kashpir section (Middle Volga Basin, Russia) were studied. Belemnite assemblages are typically Subboreal. Here, from the base upwards, the following biostratigraphic units based on belemnites were recognized: Lagonibelus magnificus Beds, Eulagonibelus rosanovi Beds, E. volgensis Beds, Liobelus russiensis & Acroteuthis mosquensis Beds, Liobelus lateralis Beds, and Acroteuthis explanatoides Beds. The studied bivalve assemblages are mainly represented by both typically Boreal and Subboreal forms. The following beds and zones based on Buchia are established in the Kashpir section: B. russiensis-mosquensis Beds, B. terebratuloides Zone, B. obliqua Zone, B. unschensis Zone, B. volgensis Zone, B. okensis Zone, B. jasikovi Zone, and B. tolmatschowi Zone. In general, the above-mentioned buchiid succession repeats that of the Boreal standard. A brief review is presented of belemnite and buchiid zonations in the Kashpir section and their application to successions in other Boreal regions.*

***Key words:** belemnites; bivalves; Volgian; Ryazanian; Central Russia; biostratigraphy*

In the late XIX century, the Volgian to Valanginian succession at Kashpir (nearby Syzran town) has already attracted the attention of paleontologists. The first description of the section was provided by R. Pakht in 1856. The description was specified subsequently by G.A. Trautschold, I.I. Lahusen, N.P. Vishnyakov and A.P. Pavlow. The Kashpir section was studied in a series of exposures at the right bank of the Volga River as well as along the walls of gullies. Detailed lithological and paleontological characteristics of this section were provided by I.G. Sasonova & N.T. Sasonov [15] and P.A. Gerasimov [6]. In a subsequent period, lithology and paleontology (ammonites, belemnites, bivalves, etc.) were subjected to repeated revisions [1, 2, 8, 16], and special attention was paid to palynological studies [9, 12, 13]. K. Kessels et al. [10] have reported calcareous nannofossils from the Volgian of the Kashpir section, whereas D.V. Efimov [5] has studied Volgian ichthyosaurs. E.A. Molostovsky & V.N. Eremin [11] have proposed a magnetostratigraphic column for the Upper Volgian, but detailed paleomagnetic and rock magnetic data are not presented in the work. O- and C-isotope data have been collected mainly from the Ryazanian of the Kashpir section [7].

In 2013, the 10 m thick Jurassic–Cretaceous boundary section (Middle Volgian to Ryazanian) was studied by the authors at several points: a) Volga River bank, to the south of the Novokashpirskii Boat Station (NK-1); b) Novokashpirskii oil shale mine (NK-2); c) Kashpirovka gully, right bank near Kashpir village (K-1); d) Volga River bank, near the mouth of the Kashpirovka Brook (K-2) (**Fig. 1**). Preliminary results from this study were published in 2014 [18]. The most representative section of the Volgian and Ryazanian stages (NK-1) is exposed along the bank slopes of the Volga River near Novokashpirskii village; the outcrop was identified here along a ~900 m stretch of the river with almost no interruption.

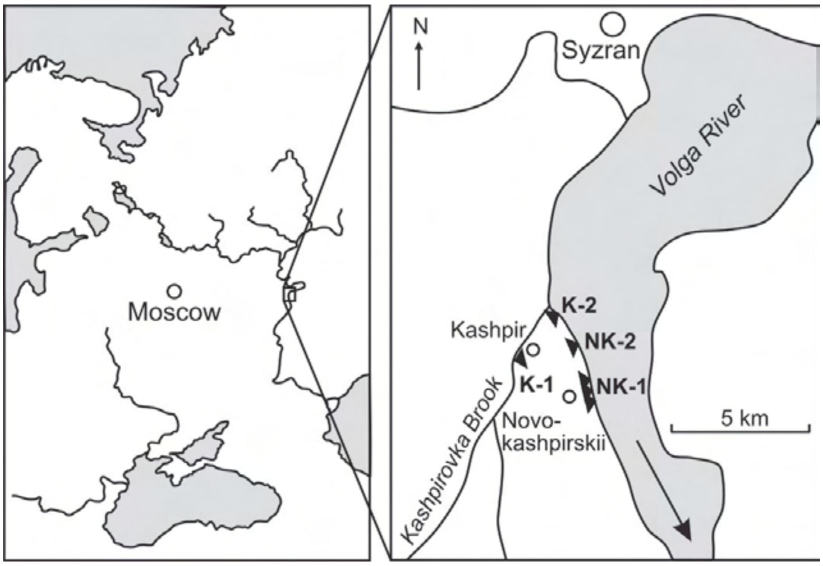
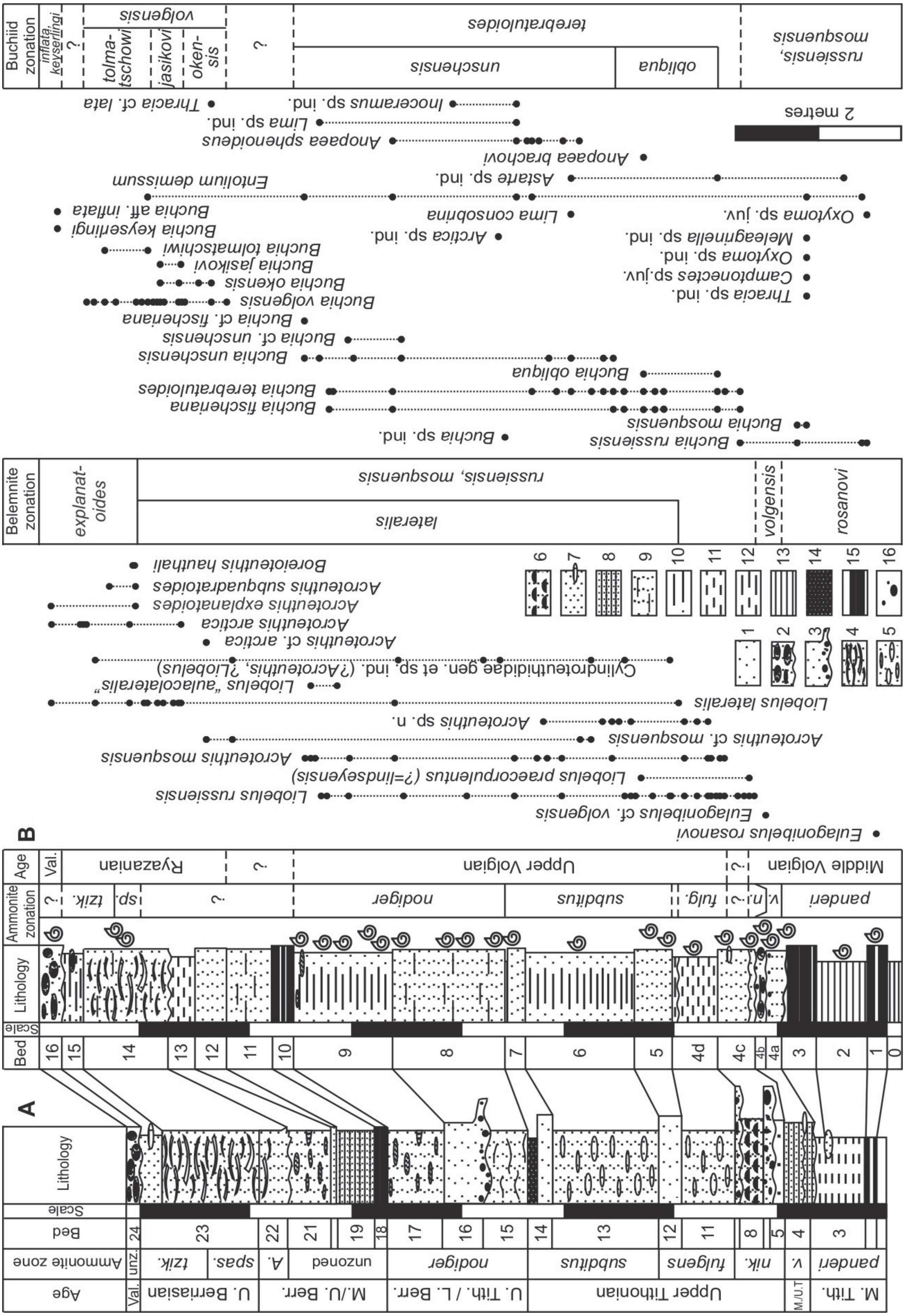


Fig. 1. Location of studied sections: NK-1 – Volga River bank, to the south of the Novokashpirskii Boat Station; NK-2 – Novokashpirskii oil shale mine; K-1 – Kashpirovka gully, right bank near Kashpir village; K-2 – Volga River bank, near the mouth of the Kashpirovka Brook.

In the outcrop NK-1, the Volgian–Ryazanian succession is subdivided by us into 16 beds, which have a good correlation with lithological column constructed by Harding et al. [9] (**Fig. 2**). The section is extremely rich in fossils, including ammonites, belemnites and bivalves. However, the Volgian–Ryazanian boundary interval (beds 10 and 11) is not characterised by macrofossils with the exception of poorly preserved belemnites at the top of the bed 11. Hence, the definition of precise position of the Volgian–Ryazanian boundary in the Kashpir section is rather problematic.

The Volgian Stage in the outcrop NK-1 is well characterised by ammonites of the Dorsoplanites panderi Zone to the Craspedites nodiger Zone. The investigation of ammonites revealed that FADs (first appearance datum) of two zonal index species, *Kachpurites fulgens* and *Craspedites subditus*, are lower than it was supposed earlier [9]. The FAD of *K. fulgens* has been fixed by us at the top of the bed 4c (=bed 9 in [9]), and the FAD of *C. subditus* has been fixed in the bed 5 (=bed 12 in [9]), exactly at its base. Two ammonite zones are commonly recognised in the Ryazanian of the Kashpir section: Surites spasskensis Zone (or the uppermost part of the Riasanites rjasanensis Zone in some publications) and S. tzikwinianus Zone [1, 2, 9]. We found *S. spasskensis* (bed 14, 40 cm above the bottom) and *S*. cf. *subtzikwinianus* (bed 14, 50 cm above the bottom).

Belemnites (Cylindroteuthididae) in the Kashpir section are of great abundance but generally poorly diversified. Their assemblages consist mainly of Subboreal representatives of the genera *Lagonibelus, Eulagonibelus, Liobelus,* and *Acroteuthis*.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subditus
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nodiger
sp.
tzik.
Eulagonibelus rosanovi
Eulagonibelus cf. volgensis
Liobelus russiensis
Liobelus praecorpulentus (?=lindseyensis)
Acroteuthis mosquensis
Acroteuthis cf. mosquensis
Acroteuthis sp. n.
Liobelus lateralis
Liobelus "aulacolateralis"
Cylindroteuthididae gen. et sp. ind. (?Acroteuthis, ?Liobelus)
Acroteuthis cf. arctica
Acroteuthis arctica
Acroteuthis explanatoides
Acroteuthis subquadratoides
Boreioteuthis hauthali
Belemnite zonation
rosanovi
volgensis
lateralis
russiensis, mosquensis
explanatoides
Buchia russiensis
Buchia mosquensis
Buchia sp. ind.
Buchia fischeriana
Buchia terebratuloides
Buchia obliqua
Buchia unschensis
Buchia cf. unschensis
Buchia cf. fischeriana
Buchia volgensis
Buchia okensis
Buchia jasikovi
Buchia tolmatschiwi
Buchia keyserlingi
Buchia aff. inflata
Thracia sp. ind.
Camptonectes sp.juv.
Oxytoma sp. ind.
Meleagrinella sp. ind.
Arctica sp. ind.
Oxytoma sp. juv.
Lima consobrina
Entolium demissum
Astarte sp. ind.
Anopaea brachovi
Anopaea sphenoideus
Lima sp. ind.
Inoceramus sp. ind.
Thracia cf. lata
2 metres
Buchiid zonation
russiensis, mosquensis
obliqua
unschensis
terebratuloides
okensis
jasikovi
tolmatschowi
volgensis
inflata, keyserlingi

The study of new collection from the Kashpir section has allowed to obtain accurate information about stratigraphic range of belemnite species and for the first time to establish here the following regional biostratigraphic units: *Eulagonibelus volgensis* Beds (4a–4b beds transition), *Liobelus russiensis* & *Acroteuthis mosquensis* Beds (bed 4c – lower part of the bed 14), *Liobelus lateralis* Beds (top of the bed 4d – lower part of the bed 14), and *Acroteuthis explanatoides* Beds (upper part of the bed 14 and above). In addition, the allocation of the *Eulagonibelus rosanovi* Beds is suggested for the topmost Dorsoplanites panderi ammonite Zone (beds 1–3). The lowermost layers of the Middle Volgian D. panderi Zone were established by excavation on the Kashpirovka Brook where the index species of the regional *Lagonibelus magnificus* belemnite Beds was found. The topmost Middle Volgian (Epivirgatites nikitini ammonite Zone), Upper Volgian and Ryazanian are characterised almost entirely by representatives of the genera *Acroteuthis* and *Liobelus*. Only rare *Boreioteuthis* have been found in the upper part of the Ryazanian. In the Ryazanian, the remarkable change in belemnite assemblages is observed in the middle part of the bed 13 and especially in the bed 14: several species make their first appearance in the section (*Acroteuthis arctica, A. explanatoides, A. subquadratoides, Boreioteuthis hauthali*).

Almost all belemnite units determined in the Kashpir section can be traced in NW Europe, namely *Lagonibelus magnificus* Beds, *Eulagonibelus volgensis* Beds, *Liobelus russiensis* & *Acroteuthis mosquensis* Beds, *Liobelus lateralis* Beds, and *Acroteuthis explanatoides* Beds [3, 4]. West and East European belemnite scales considerably differ from Siberian ones in the interval from the upper half of Volgian to the Ryazanian that is directly connected with peculiarities of development of Boreal-Atlantic and Arctic biogeographic realms [3].

The study of bivalves collected in the Kashpir section showed that *Buchia russiensis* and *B. mosquensis* are numerous in the lower part of the section (bed 1 – middle part of the bed 4c). These two species are characteristic of the Middle Volgian Buchia mosquensis Zone. Representatives of the genera *Oxytoma, Astarte, Entolium, Thracia, Camptonectes* and *Meleagrinella* have been found here together with buchiids. A change in the *Buchia* assemblages is fixed in the middle part of the bed 4c, where *B. terebratuloides* and *B. fischeriana*, characteristic of the Upper Volgian B. obliqua Zone, appear in the section. However, *B. obliqua* occurs only in the bed 4d. The bivalve assemblage also contains *Astarte* and *Anopaea*. In the beds 6–9, the *Buchia* assemblage typical for the B. unschensis Zone is found. Here, *B. terebratuloides, B. fischeriana* and the index species are accompanied by *Entolium, Lima, Arctica, Anopaea*, etc.

Numerous buchiids, which assemblage is characteristic for the Buchia okensis Zone, are found within the bed 12. Only few *B. volgensis* are recorded from the bottom of this bed (see **Fig. 2**), whereas numerous *B. okensis* and *B. volgensis* are found a

Fig. 2. Jurassic-Cretaceous boundary strata of the Kashpir section: A, according to Harding et al. [9]; B, present paper. Lithology: 1 – sandstone; 2 – sandstone with phosphatic concretions; 3 – sandstone with conglomerate base; 4 – sandstone with shelly hash; 5 – lenticular-bedded sandstone; 6 – phosphoritic sandstone; 7 – sandstone with carbonate concretions; 8 – laminated sandstone; 9 – silty sandstone; 10 – sandy siltstone; 11 – siltstone; 12 – clayey siltstone; 13 – mudstone; 14 – dark grey calcareous mudstone; 15 – bituminous shale; 16 – pebble.

little above. Therefore, the bed 12 undoubtedly belongs to the Ryazanian. Respectively the beds 10 and 11 (i.e., the beds lacking macrofossils) can belong to the top part of the B. unschensis Zone. In overlying part of the section (beds 13 and 14), the index species of the B. jasikovi and B. tolmatschowi zones are found. The bivalve assemblage of the bed 15 is not identified. Typical Valanginian bivalves, *B. keyserlingi* and *B.* aff. *inflata*, are found in the bed 16.

Thus, a buchiid zonation, characteristic of the Jurassic–Cretaceous boundary interval of Boreal sections, is observed at the Kashpir section. It is noteworthy that the FAD of *Buchia terebratuloides* is commonly fixed at the base of the Upper Volgian in Siberian sections, together with the FAD of *B. obliqua*. However, in the Kashpir section, the first representatives of *B. terebratuloides* appear slightly earlier than *B. obliqua*. The similar case was previously described by V.A. Zakharov [19] for the Boyarka River section (Eastern Siberia), where the FAD of *B. terebratuloides* was also recorded below than the FAD of *B. obliqua*, i.e. below the base of the Craspedites okensis ammonite Zone. The lower boundary of the Buchia unschensis Zone in the Kashpir section also does not correspond to that in the Boreal standard [17, 20]. Representatives of *B. unschensis* appear in the middle part of the Craspedites subditus ammonite Zone. The similar situation was described from the East Siberian sections (Boyarka and Lena rivers), where the FAD of *B. unschensis* has been fixed at the top part of Craspedites okensis ammonite Zone [14, 19].

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A FIRST FIND OF VERTEBRATE REMAINS IN THE BERRIASIAN OF THE SAMARA REGION

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***Abstract**. Berriasian deposits are very poor in any vertebrate remains. The longtanding monitoring of the Kashpir section brought no finds. For this reason the first finding of vertebrate remains in this section is of special interest.*

***Key words**: Berriasian, first finding, Kashpir, vertebrates, marine reptiles*

The Berriasian of Samara region is exposed at the surface over the relatively small area in the southwestern part of the region [3]. They make outcrops along the Volga river bank in Syzran' district nearby Novokahpirsky settlement, and along the valley of river Kashpirka. The most representative succession can be observed nearby the boat station, where the following beds are exposed (from the bottom up):

Jurassic system
Volgian Stage
Middle Volgian Substage
Dorsoplanites panderi Zone

Bed 1. Intercalation of bituminous clays and shales with imprints of Zaraiskites, Dorsoplanites, Buchia. Apparent thickness 4,5 m.

Virgatites virgatus Zone

Bed 2. Dark-brown glauconitic sandstone, with phosphorite nodules. Thickness 0,15 m.

Epivirgatites nikitini Zone

Bed 3. Grayish-green glauconitic sandstone. Thickness 0,35 m.

Upper Volgian Substage
Kashpurites fulgens Zone

Bed 4. Gray clayey siltstone, thin-bedded, with clay seams. Thickness 0,5 m.

Craspedites subditus Zone

Bed 5. Light-gray calcareous sandstone with glauconite clusters. Thickness 1,2 m

Craspedites nodiger Zone

Bed 6. Light-gray calcareous slabby siltstone, with lenses of ferrugineous limestone. Thickness 2,5 m.

Cretaceous system
Berriasian Stage
Riasanites rjasanensis Zone

Bed. 7. Compact-grained glauconitic sand, micaceous, with rare phosphorite pebbles. Thickness 0,2 m.

Bed 8. Bituminous shale, clayey, calcareous. No fossils found. Fractured surfaces demonstrate ichnofossils - burrows of crustaceans and other organisms. Thickness is highly variable, from 0,4 to 0,01 m.

Bed 9. Calcareous glauconitic sandstone, with large amout of *Buchia* shells and *Acroteuthis* rostra. Thickness 1,2 m.

Surites spasskensis Zone

Bed 10. Glauconitic micaceous sandstone, with rare phosphorite nodules, with agglomeration of *Buchia* shells in the upper part and with ammonite *Surites peckorensis* (Sason.). Thickness 0,5 m.

Valanginian Stage
Temnoptychites hoplitoides Zone

Bed 11. Conglomerate of dark-brown phosphorite pebbles, embedded into greenish-gray calciferous sandstone, containing ammonites *Temnoptychites* sp. and *Craspedites* sp., replaced by calcite. Thickness 0,2-0,4 m.

Monitoring of this locality since 1987 brought over 30 fragments of skeletons of marine reptiles [1]. However, Berriasian part of the succession brought no finds so far. So much the surprise was a message by M.A. Rogov in the summer of 2013 about a bone accumulation of unknown animal nearby township Kahspir. This finding was made by the staff of LLC “Sterkh” while preparing the data for the Field Trip Guide for the present meeting. The company collaborates with Undory Paleontological Museum in the popularization of paleontology and development of geological tourism. Vladimir Morov, an employee of the Scientific Research Institute of Ecology of Volga basin of RAS, guided us to the location of finding, situated nearby the boat station at the Volga river bank. The specimen was numbered as 1503.

Taphonomy. The specimen is embedded into dense light-gray calcareous glauconitic sandstone, located in the base of bed 9. Framents of skeleton (**Fig. 1**) are impressed into the underlying bed 8, represented by bituminous shale. The preservation of bones is average to poor. The skeleton was insignificantly transported, but the completeness was disturbed by the scavengers, locally the skeleton is heavily damaged. Bones are phosphatized, but poorly mineralized and their thinnest part are fragile. No traces of pyritization were observed. The total amout of rock taken with the skeleton was about $1m^2$, and stripping around revealed no futher bones. At the present moment, attribtion of the skeleton to any certain animal is difficult, as the preparation process is not finished yet. Preliminary determination, based on the fragment, available

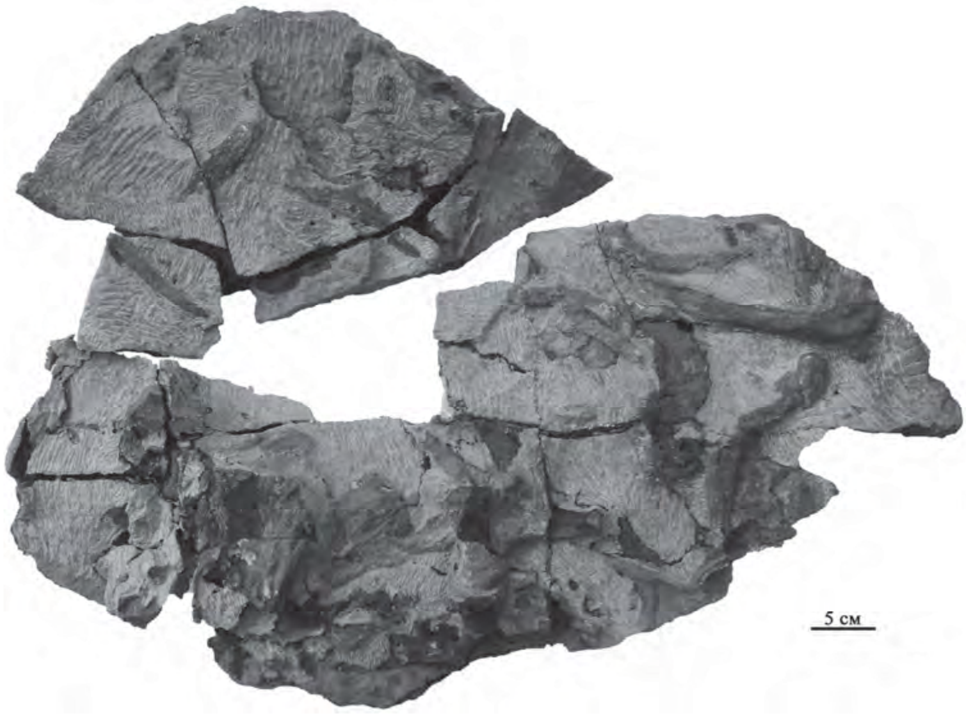

Fig. 1. Disarticulated bones of marine crocodile on a sandstone slab

to the moment, let us presuppose the attribution to marine crocodile *Metriorhynchus*. If further preparation will support this assumption, the specimen from Kashpir will be the second find of the mentioned genus in Russia and the first one made in Samara region. A similar find was made in the 90^{th} of XX century in the Volgian lectostratotype at the locality Gorodischi [2]. In the Berriasian no vertebrate remains were known up to now.

Metriorhynchus is a crocodile, well-adapted to the offshore environments, having flapper-like limbs and a rudder-like tail, and which lost the horny coat of the body. It was a competitor of ichtyosaurs and plesiosaurs in shallow-water environments, having a size of 2-3 meters long. Metriorhynchids flourished in the Middle and Upper Jurassic, and are reported from England, France and South America.

The significance of the find. The study of fossil invertebrates of the Berriasian of Russian platform has a 200-year history, however, as it was mentioned before, no reports of vertebrates were made so far. Possibly, the new skeleton described herein will allow to paint over this “white spot” in Russian paleontology.

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NEW BIO- AND MAGNETOSTRATIGRAPHIC DATA ON THE JURASSIC-CRETACEOUS BOUNDARY OF THE CHIGAN CAPE (VLADIVOSTOK AREA, RUSSIA)

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***Abstract**: The results of the integrated study of the section located at the cape of Chigan (Primorsky Krai) bring a possibility to specify the position of the Jurassic / Cretaceous boundary. Paleomagnetic, palynological and micropaleontological (foraminiferal) data combined with ammonite characteristics were received for the Chigan Formation for the first time.*

***Key words**: magnetostratigraphy, ammonites, foraminifers, dinocysts, Russian Far East.*

In September 2014 we have studied the well-known Chigan section (Chigan Cape, Pod'yapolsky Town district: **Fig. 1**) previously referred to Berriasella jacobi ammonite zone [5, 15] based on the following ammonite finds: *Pseudosubplanites* cf. *grandis*, *P.* aff. *combesi*, *Berriasella* ex gr. *jacobi*, *Dalmasiceras* and others. Some geologists [5] supposed that the section contains Jurassic–Cretaceous (J/K) boundary interval. Stratigraphic description of the section was accomplished by the search of macrofossils and samples collected for the paleomagnetic and micropaleontological analyses.

The succession. Outcrops 3046 (42°57'37.8"N, 123°17'47.0"E) and 3047 consist of five Members (**Figs. 1, 2**) of gray sandstones, poorly sorted and muddy. Most of the sandstones are intensively burrowed by *Schaubcylindrichnus*, as a dominate ichnogenus. The ichnogenus and lithology are typical for the lower shoreface zone (Members 1-3 and 5). A specific 1.5-m level of middle-upper shoreface massive sandstones (Member 4) was recognized in the middle part of the section. It is limited by the erosional surfaces at the base and at the top. The upper surface has transgressive nature, and is overlaid by 10-cm cross-bedded sandstone, replaced

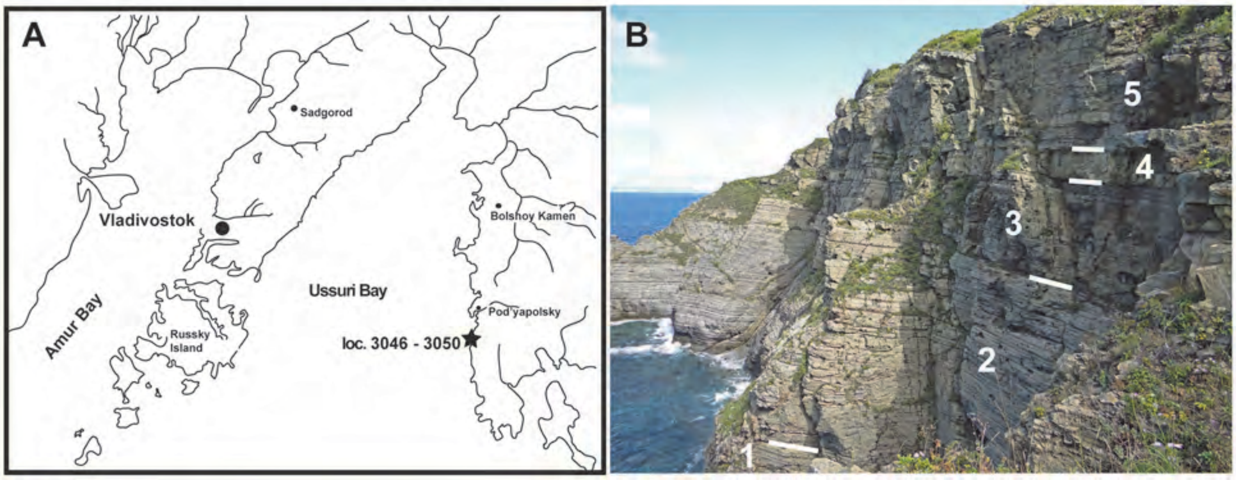


Fig. 1. The locality (A) and the section (B) 3046 in the Chigan Cape. The Member numbers and their boundaries are marked at the photo.

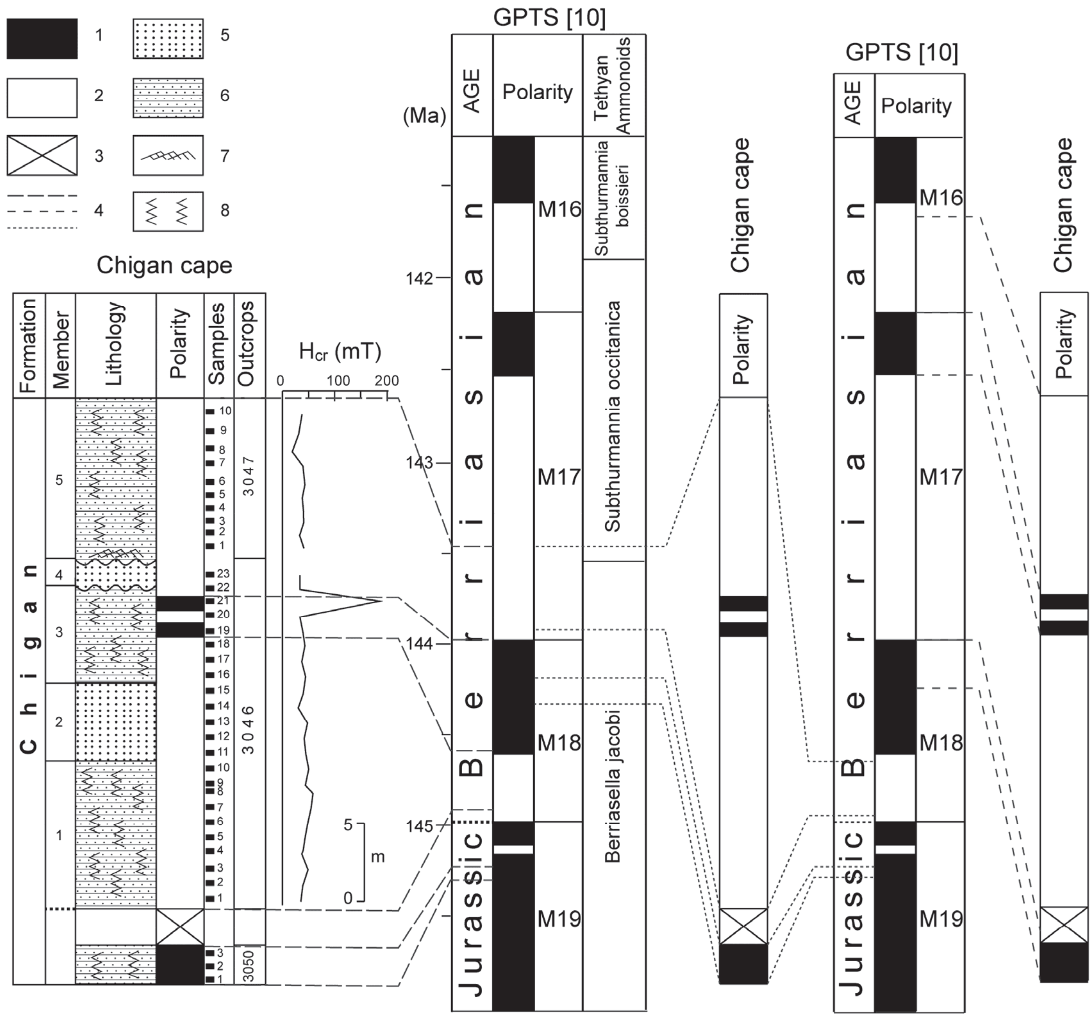


Fig. 2. Different variants of paleomagnetic correlations of the Chigan cape section with the Geomagnetic Polarity Time Scale (GPTS). Legend: polarity: 1 – normal, 2 – reverse, 3 – no data; 4 – correlation lines of different possible correlations; lithology: 5 – sandstones, 6 – muddy sandstones, 7 – cross-bedding, 8 – bioturbations.

laterally by bioclastic rudstones. The visible thickness of the section is 33 m. These layers crop out in steep cliffs at a distance of 500 meters to the north from the section 3046. The bedding is nearly horizontal (inclining angles are fewer than first degrees) and they are crossed by a number of Late Cretaceous gabbro dikes. For the comparison we have studied section 3050 to the south (~1.1 km), which continues the Chigan Formation [15] and has the same stratigraphic age [5].

Macrofauna. In the rockfall at the base of the section we found the remains of ammonites: an imprint of *Pseudosubplanites* cf. *combesi* Le Hégarat and body chamber fragment of *Pseudosubplanites* sp. In addition, in the collection of I.V. Konovalova (1993), courtesy of the "Primorgeologiya" Company, we have determined *Berriasella* cf. *jacobi* Mazenot and *Pseudosubplanites* sp., also found in the debris at the base of the same sections. All these findings characterize the Lower Berriasian Jacobi Zone. It should be noted that *P*. cf. *combesi* differs from other *Pseudosubplanites* by evolute shell and prevalence of bifurcate ribs, also being very similar to some Upper Tithonian forms (*Oloriziceras* type).

Palynology. The plant detritus, poorly preserved gymnosperms pollen and spores, rare indeterminate proximochorate–proximate cysts and dinocysts *Sirmiodinium grossii* Alberti, *Systematophora areolata* Klement и *Tubotuberella rhombiformis* Vozzhen. were found in one sample only (3046/3) out of 14. This assemblage ranges from Oxfordian to Early Valanginian. Dark brown organic residues indicates the mesocatagenetic stage [14] with paleotemperature about 200°.

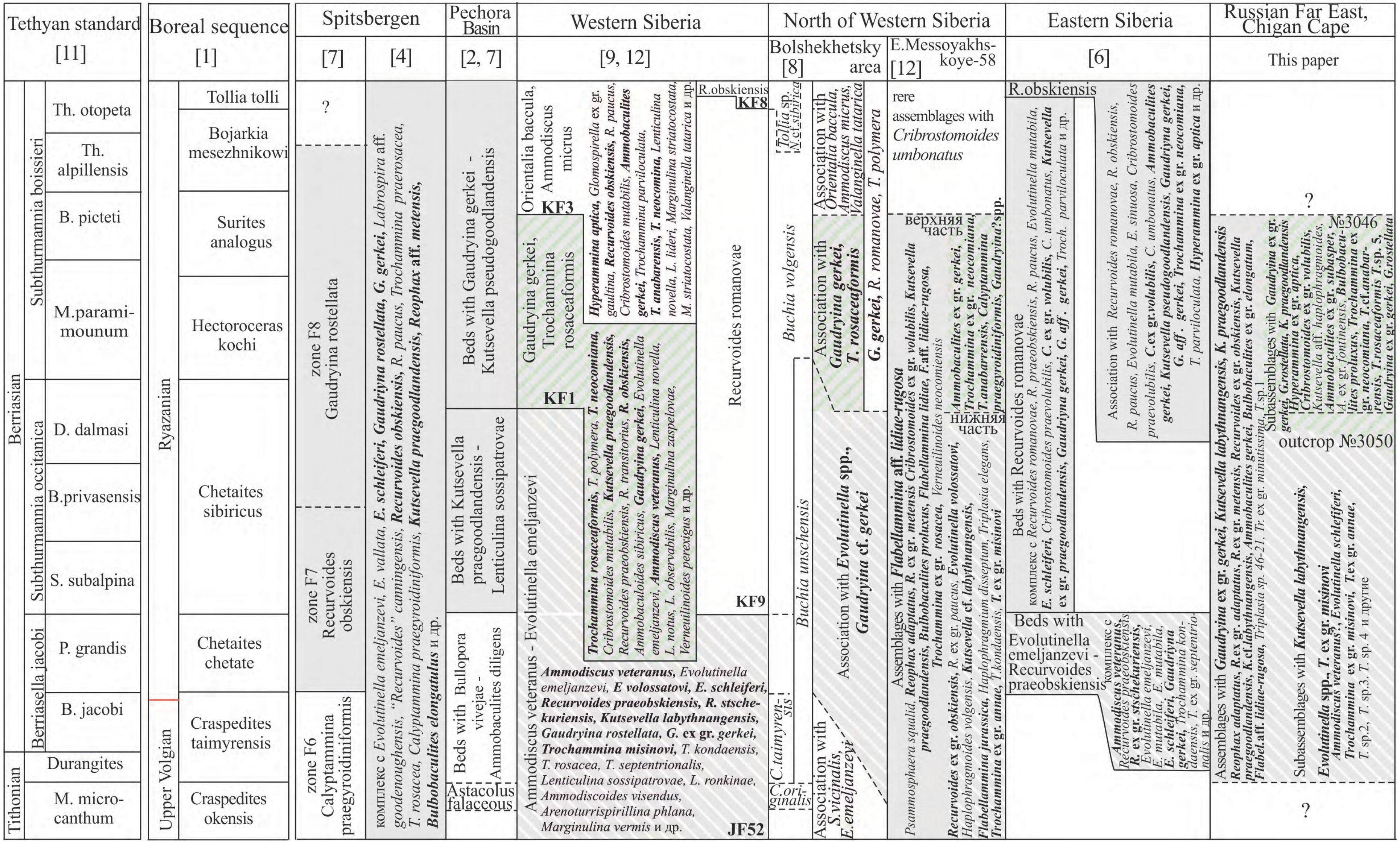
Foraminifers. It was studied 11 powders and 3 thin sections for the definition of microfossils. The thin sections (№№3046-3, 3a, 10) contain hardly distinguishable sections of *Reophax, Bulbobaculites, Ammobaculites, Kutsevella, Flabellammina, Triplasia*?, *Gaudryina*?, *Trochammina.* Sandstones near the contact with the gabbro dike contain fully recrystallized unrecognizable fossils. The assemblage of agglutinated foraminifers was found in the samples from the outcrops 3046, 3047, 3050. It consists of primitive forms (~ 30%), *Reophax* (40%), Haplophragmiidae (50%), *Trochammina* (10%) and rare Ataxophragmiid species (3%). The complex contains a large number of huge forms with coarse-, medium- to fine-grained agglutinant of poorly rounded quartz. A number of species were determined (**Tabl. 1**).

The comparison of the assemblages with *Gaudryina* ex gr. *gerkei, Kutsevella labythnangensis, K. praegoodlandensis* from Chigan Cape with foraminiferal zones (f-zones) and beds of Spitsbergen, Pechora Basin, Siberia (**Tabl. 1**) is difficult, as they were formed under different conditions. They are more similar to the shallow-water assemblages of the north of Western Siberia.

In Bolshekhetsky area (**Tabl. 1**) the assemblage with *Evolutinella* spp., *Gaudryina* cf. *gerkei* was found together with ammonites from the Taimyrensis Zone. It has 16 species common with f-assemblage of Chigan Cape. The assemblage with *Gaudryina gerkei, Trochammina rosaceaformis*, which was found together with *Buchia* cf. *volgensis* (Lahusen) has 13 common species [8].

Table 1

Comparison of the f-assemblages from Chigun Cape with f-zones and beds of Spitsbergen, Pechora Basin, Siberia



The coarse-grained shoreface sandstones of East Messoyakhskaya-58 well are characterized by the *Flabellammina* aff. *lidiae-rugosa* assemblage, which is similar to Chigan Formation assemblage in taxonomic composition. The lower part of the assemblage with *F.* aff. *lidiae-rugosa* contains “Volga-type” *Trochammina* and *Evolutinella* close to that from the Upper Volgian - the lower part of Ryazanian. However, the upper part of the assemblage with “the Neocomian type" *Gaudryina* and *Trochammina* tends to be close to the "Boreal Berriasian" [13].

A similar pattern is observed in the Chigan Formation sandstones with *Gaudryina* ex gr. *gerkei, Kutsevella labythnangensis, K. praegoodlandensis.* The section 3050 contains “Volgian-type” *Trochammina* and *Evolutinella*, but the section 3046 contains "the Neocomian-type" *Gaudryina* ex gr. *gerkei* and a lot of *Trochammina*.

Rare *Gaudryina*? sp., however, appears in the upper part of the section 3050. Nevertheless, we can separate the succession in two parts: the subassemblage with *Kutsevella labythnangensis, Evolutinella* spp., *Trochammina* ex gr. *misinovi* in the lower part and the subassemblage with *Gaudryina* ex gr. *gerkei, G.rostellata, K. praegoodlandensis* in the upper part.

Magnetostratigraphy. Samples from 34 stratigraphic levels were studied in the sections 3046, 3047 and from three stratigraphic levels – in section 3050 (**Fig. 2**). The sandstones have a magnetic susceptibility (*K*) $6\text{-}12 * 10^{-5}$ SI units and a natural remnant magnetization ($\mathbf{J_n}$) $0.02\text{-}2.15 * 10^{-3}$ A/m. The samples from the gabbro dikes were also studied ($K = 60\text{-}140 * 10^{-5}$ SI units, $\mathbf{J_n} = 100\text{-}1000 * 10^{-3}$A/m). The differential thermomagnetic analysis and magnetic saturation demonstrate that magnetite or related titanomagnetite are principal magnetic minerals in the sandstones and in the gabbro. The hematite was fixed at one level only (sample 3046/21 near the base of member 4) (**Fig. 2**). Usually such levels fix hiatuses, related to active oxidation of magnetite particles [3]. Thermomagnetic and alternating field cleaning showed reproducible results, which substantially increase the reliability of paleomagnetic measurements relative to the results based only on one of magnetic cleaning procedures. The gabbro samples have one component of the $\mathbf{J_n}$ – characteristic magnetization component (**ChRM**). The $\mathbf{J_n}$ components in the paleomagnetically less stable sandstones are not distinguished completely.

The paleomagnetic column of sections 3046-3047 consists of the reverse polarity zone (R). In the middle part of the R-zone, two narrow intervals of normal polarity (N) were recorded (**Fig. 2**). The baked contact test is positive (the sandstones from unbaked zone have a reverse magnetization; the baked zone and the gabbro have normal $\mathbf{J_n}$). Normal polarity fixes in the outcrop 3050 (**Fig. 2**). These facts demonstrate the ancient nature of the magnetization. The test of reversal is negative, but this fact does not reject the hypothesis of the ancient nature of the $\mathbf{J_n}$, because gabbro is tens of millions years younger than the sandstone, and outcrops 3050 and 3046-3047 are located in different tectonic blocks.

Discussion. Ammonite findings correspond to the well-known data [5, 15] on presence of the Jacobi Zone in the studied section. The previous ammonite findings from the uppermost Chigan Formation characterize the Jacobi zone, therefore the R-magnetozone can be analogue either of polarity Chron M18r or M17r. This R-zone may be equivalent to M18+M17r, because small N-polarity interval (samples 3046/19-21) corresponds to the break in sedimentation and the significant part of M18n may be absent in the succession (**Fig. 2**). All variants are not compatible with the version of the presence of the J/K boundary in sections 3046 and 3047, no matter to determine it either at the base of Jacobi zone or at the base of M18r [10]. In any case, the J/K boundary in the area is below the sea level. N-magnetozone located below in the section 3050 corresponds or Chron M19n, or M18n (**Fig. 2**). The foraminiferal data from the section 3046 confirm the correlation with the middle part of the Berriasian (Kochi and Analogus Zones) and allow to identify R-zone of Chron M17r or M17 + M16r (**Fig. 2**). The main result of this study is the possibility of correlation of paleomagnetic, micropaleontological data and ammonite stratigraphy, which brings a hope for the solution of the J/K boundary problem in the Chigan Formation in future.

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FIRST FIND OF *PARABELEMNOPSIS*, THE ALIEN BELEMNITE FROM THE SOUTHERN HEMISPHERE, IN THE UPPER BERRIASIAN OF CENTRAL CRIMEA

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Abstract*. In the present paper we report about the find of belemnite of the Gondwanian origin, determined as Parabelemnopsis* cf. *patagoniensis, in the Late Berriasian of Central Crimea. This is the first find of such type over Northern Hemisphere known so far. Its appearance is correlated with probable ammonite invasions from South America to Europe and thus indicates an episode of invasion of Austral biota to the Northern Tethyan margin.*

Key words*: belemnites, Upper Berriasian, invasion, Gondwana, Crimea*

Introduction. After breakage of Gondwana and Laurasia during the Middle-Late Jurassic belemnite assemblages at southern margin of Tethys ocean (Northern Hemisphere: Southern Europe) and at epicontinental seas of Gondwana located south to the equator (Southern Africa, Madagaskar, India, South America, Antarctica, Australia) evolved relatively independently [17, 18, 33]. Some common species for Europe and Gondwanian basins still were common around the Middle/Upper Jurassic boundary (e.g. see the review in [18]: 173), while the Lower Cretaceous has no well-established common species, except for those in some old publications which are in need of revision both systematically and stratigraphically (cf. [32]). No certain belemnite invasion and/or immigration events with precise stratigraphic position were discussed so far. However, such invasion episodes may indicate important paleoceanographic and paleoclimatic events, providing keys for the far-distance correlation levels, and thus need high attention.

Geological setting. The locality is situated 1.3 km south from the southern margin of the village Petrovo (coordinates: N 44°58'10.50"; E 34°18'39.29", altitude 480 m), in Fundukly ravine (**Fig. 1A,B**). The sequence of Upper Berriasian is represented by thick sandstones members with bands of sandy limestones and their ammonite assemblages were described by V.V.Arkadiev (in [4,5]) and is figured in more details herein (**Fig. 1C**). It is also known as the topotypic locality for a single ammonite species (*Pomeliceras* (?) *funduklense* Lysenko et Arkadiev, 2007 in Arkadiev, Bogdanova et Lysenko, 2007).

The part of the sequence containing described belemnite represents Bechku suite

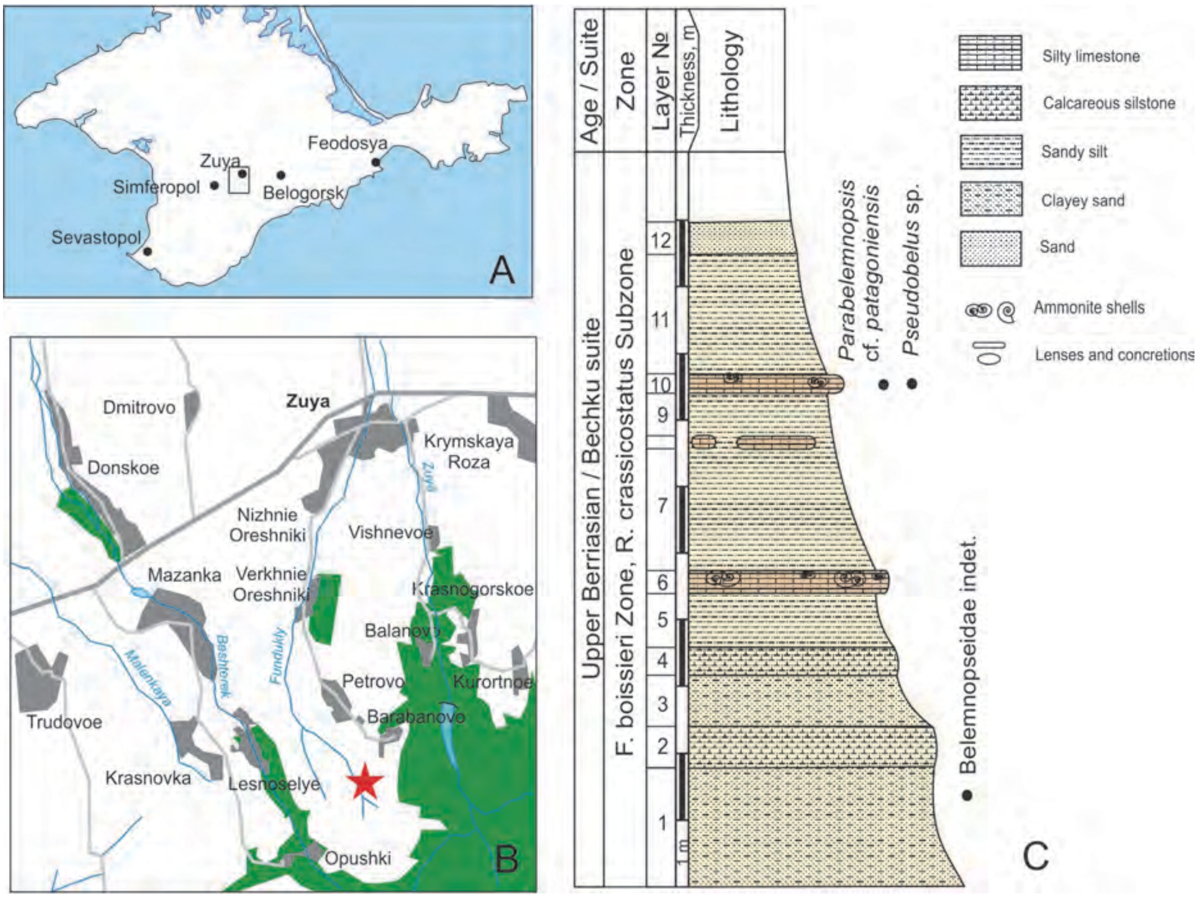

Fig. 1. Map showing the locality (A, B), which is marked with asterisk, and schematic drawing of the section (C).

and dated by the Late Berriassian Fauriella boissieri Zone, Riasanites crassicostatus Subzone [4]. *Parabelemnopsis* cf. *patagoniensis* originates from the bed 10, represented by the limestone, which is characterized by numerous ammonites *Riasanites,* solitary corals, abundant bivalve shells etc.; all the shelly fauna is overgrown by epibionts (serpulids and small oysters).

SYSTEMATIC PALEONTOLOGY

Family BELEMNOPSEIDAE Naef, 1922

The classic name *Belemnopsis* Bayle, 1878 in most publications during last 15 years was replaced by its junior synonym *Pachybelemnopsis* Riegraf, 1980 due to some formal taxonomical assumptions (see [30]). This also led to annihilation of associated family name BELEMNOPSEIDAE Naef, 1922 and replacement by its oldest junior synonym MESOHIBOLITIDAE Nerodenko, 1983. Recently Mitchell [24] has shown that taxonomical justifications for such replacement were not fully consistent and re-established the validity of both classic generic and family names. Herein we follow his suggestion.

Parabelemnopsis Howlett, 1989

1989 *Belemnopsis (Parabelemnopsis)* Howlett: p. 43.

Type species. *Belemnites madagascariensis* Besairie, 1930; Tithonian-Valanginian of Madagascar.

Species included. *P. madagascariensis* (Besairie, 1930); *P. patagoniensis* (Favre, 1908), *P. casterasi* (= ? "*Belemnopsis elongata*" Yin, 1975; "*Belemnopsis muricatus*" Chen, 1982), *P. regularis* (Yin, 1975), and one yet unnamed species from the Oxfordian of India and Indonesia.

Remarks. A cluster of large-sized elongated conical to subconical rostra with shallow ventral groove of common Madagascarian-South American origin was first recognized among *Belemnopsis* by Stevens ([34]: 160). Later this concept was used by Howlett [22], who established *Parabelemnopsis* as a new subgenus of *Belemnopsis*, however, this new taxon was not accepted by most belemnite taxonomists and synonymyzed with its parent taxon, *Belemnopsis* ([30] etc.). If one supports such "wide" concept of *Belemnopsis*, the genus will totally count ~100 species [30, 32] with huge morphological variety and spread all over the world in range from Middle Jurassic to Lower Cretaceous. From methodological point of view, splitting such "large genera" into smaller units is more productive ground for further research. Even if the demarcation between smaller genera is not completely distinct, applying different generic names tied to certain type species of different morphological types provide "growth points" for further elaboration of classification. For this reason, we support both subgeneric taxa, introduced by Howlett [22] – *Parabelemnopsis* and *Telobelemnopsis* --– as valid separate genera.

Howlett [22], who established *Belemnites madagascariensis* Besairie, 1930 as type species of his new subgenus *Belemnopsis (Parabelemnopsis),* included two more species into the subgenus – *P. casterasi* Besairie, 1936 from the Lower Kimmeridgian of Madagaskar and and *P. patagoniensis* Favre, 1908 from the Hauterivian of Argentina.

Type specimen of *P. casterasi* differ markedly by elongation from *P. madagascariensis*, but further revision by Combémorel [15] postulated very wide intraspecific variety for both species and much extended stratigraphic ranges (Oxfordian/Kimmeridgian to Valanginian/Hauterivian for the former and Kimmeridgian–Upper Valanginian for the latter). *P. casterasi* was even expected to be a possible sexual dimorph of *P. madagascariensis* [15]. To our opinion, these two names may hide even a bush of closely related biological species waiting for their researcher.

One more poorly known species, *Belemnopsis muricatus* Chen, 1982 is definitely a member of *Parabelemnopsis* and probably a synonym of *P. casterasi* Besairie, 1936; but it is reported from Gyabula Formation in Tibet, which could mean Berriasian or younger age [23], while *P. casterasi* type material is Kimmeridgian, therefore, confirmation of synonymy needs new data on both species.

There is at least one find from the Oxfordian of Misool Island (Indonesia), described as "*Hibolithes longiscissus* Stolley, 1935" (see [11]: pl. 16, fig. 3,4, later re-figured in [12, 13], which belongs to the same group of species and should be described as a new species. It is also known from the Indian Oxfordian (Ippolitov & Desai, unpublished data).

All this extends the distribution of the genus *Parabelemnopsis* to the Indo-Pacific region and stratigraphic range to the Oxfordian.

Parabelemnopsis cf. *patagoniensis* (F. Favre, 1908)
Fig. 2a-d

cf. *1908 *Belemnopsis patagoniensis* sp. nov. Favre, s. 640, taf. XXXVII, fig. 6,7 [=lectotype, designated by Riccardi, 1977].

(?) cf. 1921 *Belemnites (Belemnopsis) patagonensis* [sic!] (Favre): Bonarelli & Nágera, p. 16-17, fig. 2.

non 1937 *Belemnites (Belemnopsis) patagoniensis* Favre: Feruglio, pp. 81-83, tav. X, fig. 1-4.

cf. 1977 *Belemnopsis patagoniensis* (Favre): Riccardi, p. 243-344, fig. 6a-i, g-i.

cf. 1977 *Belemnopsis* cf. *madagascariensis* (Besairie): Riccardi, p. 244-245, fig. 6d-f, j-l.

(?) cf. 1985 *Belemnopsis madagascariensis* (Besairie): Aguirre Urreta & Suarez, p. 1.9-1.12, pl. 1, figs. a-y.

cf. 1988 *Belemnopsis patagoniensis* Favre: Riccardi, pl. 9, figs. 5-6.

cf. 1988 *Belemnopsis madagascariensis* (Besairie): Riccardi, pl. 8, fig. 5.

cf. 1988 *Belemnopsis* cf. *madagascariensis* (Besairie): Crame & Howlett, Fig. 8e,f.

cf. 1989 *Belemnopsis* cf. *madagascariensis* (Besairie): Doyle & Howlett, text-fig. 1c [the same specimen as in Crame & Howlett, 1988].

cf. 1989 *Belemnopsis (Parabelemnopsis)* cf. *madagascariensis* (Besairie, 1930): Howlett, p. 43-44, pl. 9, fig. 3-4 [the same specimen as in Crame & Howlett, 1988].

Material. 1 fully preserved rostrum; № 01-ФУН; Petrovo, Late Berriasian, bed 10.

Description. The only fully preserved rostrum is medium-sized and strongly elongated, with conical outline and profile in the posterior half, transforming to subconical in anterior part. Apical part is not clearly defined, apex is pointed. Cross-section is laterally compressed anteriorly, becoming rounded and even slightly depressed posteriorly. In alveolar region ventral side is wider, than dorsal and cross-section is egg-like. Ventral furrow is narrow. It runs adorally over a half of postalveolar part, then shallowing away posteriorly. No lateral lines can be observed. Apical line is ortholineate, as this can be judged from the central position of the protoconch.

Dimensions (mm), abbreviations after [19]. R=858; PA=61.6 (689%); DV=8.94 (100%); LL=8.47(95%); dv=5.70(100%); ll=5.75(101%).

Distribution. Tithonian (?), Berriasian-Barremian of Argentina and Antarctic peninsula.

Remarks. Among all known species of *Parabelemnopsis* the strongest affinity is observed to the South American Lower Cretaceous material. Unfortunately, the type series of *P. patagoniensis*, including the only figured specimen designated as lectotype by Riccardi ([27]: 243) is represented by fragments only. The type material is reported from the Lower Hauterivian of Argentina and associated with specimens determined as *"madagascariensis"* (see [28]), but having evidently more conical shape and more acute apex, than any topotypic specimens. However, in the same interval there are specimens which are much closer to Madagaskarian material and characterized by blunt apex. Riccardi [27] discussed the difference between two species – according to his opinion, *P. madagascariensis* is characterized by shorter rostrum with deeper and broader ventral groove. The second criteria is not fully reliable, as large ventrally grooved belemnites often show significant variety in this feature, but the first one looks true. Following this criteria, the only fully preserved rostrum of "*B. madagascariensis*" (figured in [28]) coming from type horizon should be re-determined as *P. patagoniensis.* To conclude, to the moment there are no evident specimens of typical *P. madagascariensis* known from Antarctica and Argentina so far. Some of

Fig. 2. *Parabelemnopsis* cf. *patagoniensis* (F. Favre, 1908): a—outline, ventral; b—left profile; c—cross-section in the apical part; d—cross-section in the alveolar part near protoconch. Black cross denotes the position of the protoconch.

described *P. madagascariensis* specimens belong not to *P. patagonensis*, but to other species and even genera.

All Feruglio's [21] specimens from the Tithonian, referred as *P. patagoniensis* do not belong to this species. The specimen on his fig.1 has too wide furrow, running over the whole rostrum and should be definitely reclassified. Specimens on fig. 2-4 have much shorter rostra and partly were reclassified into other species [22]. However, Bonarelli & Nagera's [10] fragment from the Tithonian and especially Riccardi's [27] fragments from the Berriasian may really belong to the species.

The only Crimean find is a rostrum of a young specimen, and is smaller than any known mature *Parabelemnopsis* species. This makes some restrictions for comparison and together with poorly studied intraspecific variability of all the species, make us leave the determination in open nomenclature.

Discussion. Members of the genus *Parabelemnopsis* are probably not subtropical warm-water Tethyan elements, but true Austral species more or less analogous by biogeographic position to Boreal biota in Northern Hemisphere ([34]: 160). They are unknown along the northern margin of Tethys (Africa, Arabia), but are common at Madagaskar, in South America and Antarctic peninsula; some few are known from Indo-Pacific region, along southern Tethyan margin (see above) and were never reported from Europe, including Crimea. The collection of the first author (A.I.), covering several hundreds of belemnites from the Berriasian, has no other finds of the genus, indicating that the find is more or less occasional. All this indicates that the find of *Parabelemnopsis* in Crimea is more likely a result of some short invasion episode rather than large total distribution over some time period.

Faunal exchange with Gondwanian biota for the Berriasian of Crimea is reflected not only in belemnites, but ammonites as well. First, there is a number of cross-Tethyan taxa known along both southern (Northern Africa, Arabia, Pakistan, Himalaya) and northern Tethyan margins, which are relatively common for Crimea (*Malbosiceras, Pomeliceras, Himalayites, Negreliceras, Spiticeras*: see [5] for the full review), among them some species are not yet recorded from Southern Europe, but well-known from Indo-Himalayan region (like *Negreliceras mirum*, *Spiticeras subspitiense, S. obliquelobatum*). Second, there are several records of ammonite *Substeueroceras* [3] in Central Crimea, a genus widely spread in South and North Americas and only rarely met in Europe and along northern and Southern and Northern Tethyan margins. Despite stratigraphic position of *Substeueroceras* finds is not estimated, most probably they originate from the Tirnovella occitanica Zone, and therefore are a little bit more ancient than our *Parabelemnopsis* find.

To conclude, two main routes for Gondwana-Crimean faunal exchange were possible this time: one along Sothern Tethyan margin from Indo-Himalaya region and another from South America via Caribbean region. At Late Jurassic – Earliest Cretaceous *Parabelemnopsis* existed both in South America (*P. patagoniensis*) and at Southern Tethyan margin (Tibet: "*Belemnopsis elongata*" Yin, 1975 and *P. regularis* (Yin, 1975)). The exchange between these two areas was easy because of exisiting trans-Gondwanian seaway this time [18]. However, belemnite complexes from Tibet (e.g. see [14]) definitely do not contain rostra similar in morphology to our find, therefore most probably *Parabelemnopsis* cf. *patagoniensis* came to Crimea by the second route. This assumption is supported by close morphological similarity with South American and Antarctic specimens rather than with Madagascarian-Tibetian ones (see above). However, relatively poor state of knowledge on belemnite biotas in all studied regions leaves some points for further discussion.

Conclusions. The belemnite invasion from Gondwana recorded from the Upper Berriasian of Crimea is the first record of such type all around Europe. The appearance of *Parabelemnopsis* cf. *patagoniensis* is roughly coeval with finds of ammonites of American origin (*Substeueroceras*) in the same geographic district, indicating that time cephalopod migrations from South America to European region were relatively common. Episode of appearance of biogeographically alien belemnite in Fauriella boissieri Zone still needs a comprehensive explanation from the point of paleoceanography and paleoclimatology. Potentially, further attention to the Berriasian belemnites provides opportunities for establishing interregional "datum planes". Unfortunately, wide stratigraphic interval postulated for *P.* cf. *patagoniensis* in its home region (Tithonian? Berriassian-Barremian), the scarcity of its records and unstudied morphological variation in time do not allow to use Crimean find for any stratigraphical interpretations at the moment.

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CROCODILES OF THE FAMILY *METRIORHYNCHIDAE* IN THE MESOZOIC OF THE VOLGA REGION

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***Abstract**: A review of fossil crocodiles belonging to the family Metriorhynchidae from the Mesozoic of the Volga region is provided. A special attention is paid to a new find of metriorhynchid from the Berriasian of Kashpir section (Samara region).*

***Key words**: marine crocodiles, Thalattosuchia, Metriorhynchidae, Berriasian, Mesozoic, Volga area.*

Marine crocodiles (Thalattosuchia) is a unique group of Mesozoic reptiles, closely connected to marine habitats. Despite sharing the environment with formidable monsters, namely ichtyosaurs and plesiosaurs, marine crocodyles were successful enough to withstand the severe competition - in fact they even could hunt on other marine reptiles [2]. The most speciealized among marine crocodiles are the members of the family Metriorhynchidae. As they completely shifted from the nearshore environments to the open sea, their skin lost the osteoderms, forming the defensive horny coat of the body, their appendiculars were transformed into paddles, and the tail became reversed heterocercal (turning down in the last quarter), like it is in ichtyosaurs, forming a sinewed rudder (**Fig. 1a**; [5]). Metriorhynchids are known starting from the Middle Jurassic up to the Early Cretaceous. Most finds originate from the Western Europe, but from time to time they are recorded from North and South Americas and from Southeast Asia. In Russia finds of fossil marine crocodiles are extremely rare and represented mainly by scattered bone fragments, cranial fragments and isolated teeth [1]. The precise determination of such material is problematic (except some teeth) but usually possible at least up to the family level. To the moment, there are only 4 metriorhynchid records from the Volga region.

The first unequivocal metriorhynchid find originates from Saratov region, where was once discovered nearby Hvalynsk town, on the Khoroshevsky island (now sunk). At this locality, the local lore experts O.K. Gross and V.N. Orekhov gathered the extensive collection of fossil vertebrates, and the materials from their collection were partially studied and exposed in the Hvalynsk local lore museum. Later, in 1981 the professor of Saratov State University V.G. Otchev, while studying this collection, marked two relatively large bones, which he treated as marine crocodiles belonging to the genus *Dakosaurus*. Material is represented by partly destroyed posterior truncle spondylus with preserved diapophyses and by a wide tarsus [4]. Unfortunately, the age of fossils was not established precisely, as they were obtained from the towpath. Conventionally this find is considered to be of Late Jurassic age.

Another find, represented by an isolated tooth, presumably also belonging to the *Dakosaurus*, comes from the Oxfordian deposits of Staroe Shaigovo district of

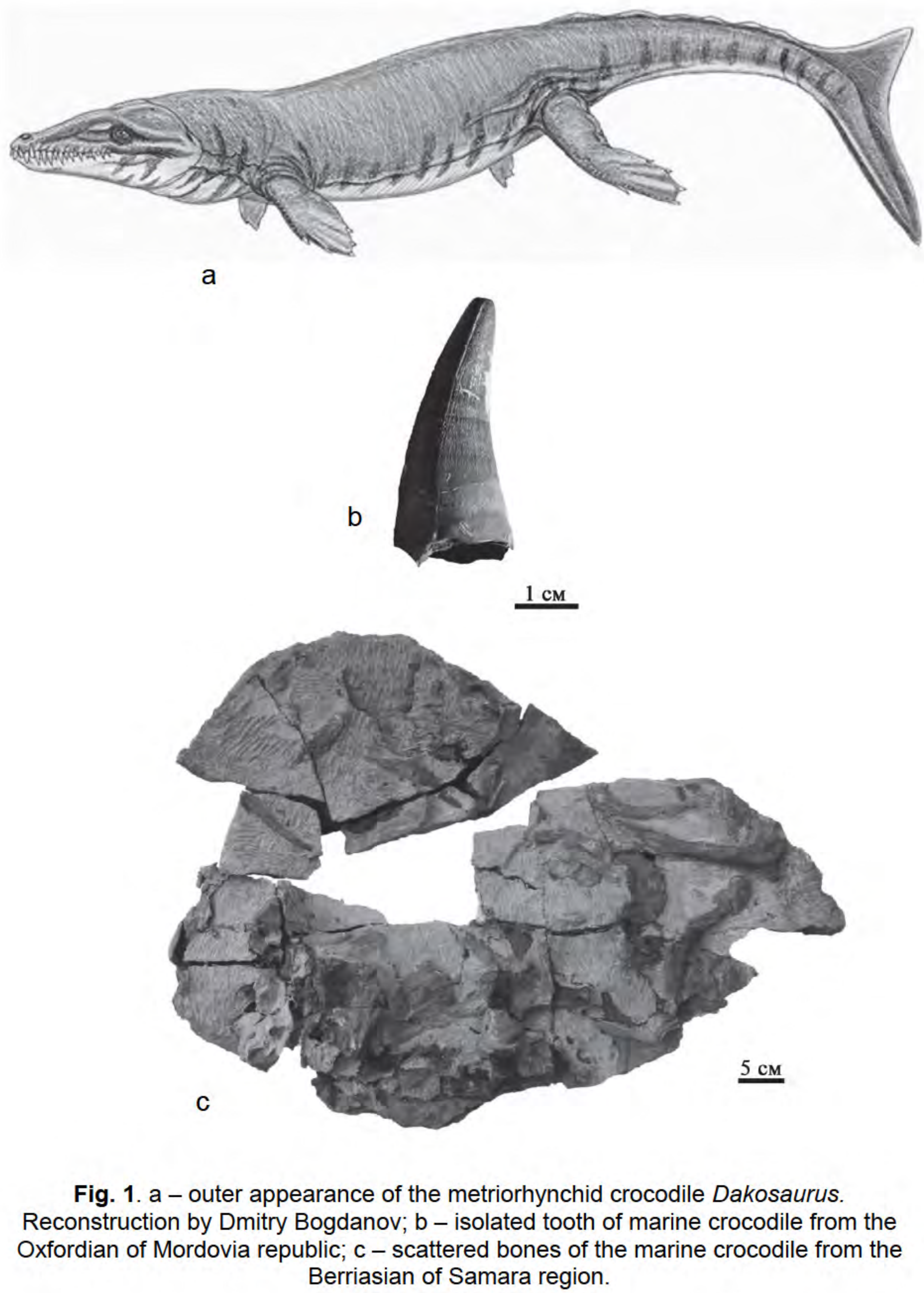

Fig. 1. a – outer appearance of the metriorhynchid crocodile *Dakosaurus.* Reconstruction by Dmitry Bogdanov; b – isolated tooth of marine crocodile from the Oxfordian of Mordovia republic; c – scattered bones of the marine crocodile from the Berriasian of Samara region.

Republic of Mordovia. The tooth demonstrates preserved crown and partly the root, its the total length is about 3 cm (**Fig. 1b**). The tooth is massive and have distinct cutting edges, characteristic for large predators, agreeing with the postulated lifestyle of the genus.

In the Middle Volgian bituminous shales of the Gorodischi locality (Ulyanovsk region), V.M. Efimov discovered an uncomplete skeleton of metriorhynchid, represented by the fragmented cranium, a fragment of the right half of mandible, one neck spondylus, four well-preserved truncle spondyli, one sacral spondylus with adjoining costal bones and right tibiotarsus with preserved proximal epiphysis [3]. The systematic position of this find was determined only up to the family level because of insufficient number of diagnostic characters.

Separately I would like to mention the metriorhynchid rests from the Berriasian strata of the locality Kashpir (Samara region), found by M.A. Rogov in 2013. This is the first find of fossil vertebrate from the Berriasian of the Volga region known so far, and the unicity of this find is appended by the fact that the animal was represented by the marine crocodile, which are extremely rare in the fossil record of Russia. The specimen is represented by disconnected cranial and postcranial skeletal fragments on the exposed surface of gray calciferous sandstone. The specimen is now under preparation process held in the laboratory of Undory Paleontological museum, and the skeleton has beed opened up from the ventral side only partly up to now (**Fig. 1c**). Currenly two truncle spondyli with preserved neural spines, fragments of anterior and middle costae and gastralium are well-discernible. Cranial bones are strongly fragmented and macerated, and can not be determined now. There was also a small teeth fragment, but unfortunately, while extracting the skeleton from the layer, its middle part was destroyed by a crack, which progradated across it. Judging from all available characters, the specimen can be classified within Thalattosuchia. A characteristic appearance of transverse processes in the truncle vertebra clearly shows the Metriorhynchidae affinity. Further preparation potentially can help to obtain new data, which will help to determine this crocodile more precisely.

The scarcity of marine crocodiles in the fossil record, comparing with other marine reptiles, is due to several external reasons. The main one is the temperature. As all the crocodiles are poikilotherms, temperature of the water mass directly influences on the distribution area of Recent species, not allowing them to penetrate into habitats with the yearly average temperature below 24,2 C^o [5]. It seems that the same factor could restrict the distribution of fossil marine crocodiles as well. Another reason was the availability of shallow water environments nearby: despite thalattosuchii successively adapted for the life in open sea, they had not lost the connection with the land completely, like ichtyosaurs and late plesiosaurs did. There are no indications that crocodiles could have ovoviviparity, consequently, they had to went onshore for the oviposition, and this tied them up to the coastal areas. The third factor is that in the open sea it was more difficult to compete with other, highly specialized marine reptiles.

The presence of marine crocodiles in the fossil assemblages can be used as a paleoecological indicator for the reconstruction of the Mesozoic environments. Further study of geographic distribution and adaptive radiation of metriorhynchids will allow to estimate their migration routes and the diversity of this group in the mid-Russian sea, providing important information for understanding the evolution of the order Crocodilia.

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THE PALEONTOLOGICAL CHARACTERISTICS OF THE VALANGINIAN DEPOSITS OF THE AREA NEARBY SYZRAN

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***Abstract**: A comprehensive lists of cephalopods of the Valanginian age (Lower Cretaceous) from the Kashpir and Mar'evka reference sections are provided.*

***Key words**: cephalopods, ammonites, Valanginian, Kashpir*

The Valanginian strata of the Lower Cretaceous within the Middle Volga region have been known for ages, and the age of beds treated as Valanginian does not provide much doubts. The main factors here are both high saturation by fossil cephalopods and clear lithological boundaries with the strata above and below, marked by discontinuities.

Low interest of stratigraphers to the Valanginian strata, lying slightly above the Jurassic–Cretaceous boundary, which remains a subject of the continuous discussion for the Russian plate, may be somewhat compensated by the fact that the Ryazanian Regional Stage in the Middle Volga region is highly condensed and sometimes missing, and in such cases the Valanginian lies directly upon the Volgian.

At most reference sections of the Jurassic–Cretaceous boundary strata on the territory of the Middle Volga region – for example, in the areas nearby Ulyanovsk and Orlovka – Valanginian is not or almost not represented. At the same time, in the sections of Kashpir and Mar'evka the Valanginian strata are well characterized and their stratigraphic position was established starting from the paper by A.P. Pavlow [10].

Paradoxically, the Valanginian fossil fauna from the long-known and well-studied localities of Middle Volga region has never been thoroughly studied. There are very few data in the literature: in addition to originals figured by A.P. Pavlow, there are several images of a single ammonite species in the article [6]. The explanation of such a situation is the fact that because of the lower stratigraphic value of Valanginian fauna, extracted from the strongly condensated succession in Central Russia, the main focus of studying Valanginian in Russia shifted to the north of the European part and Siberia.

At both Kashpir and Maryevka sections the beds corresponding to Valanginian age lie horizontally at relatively thin Ryazanian regional stage. The upper part of the Ryazanian is composed of finely-grained weakly cemented sandstone, strongly calcareous, with shell detritus and phosphorite concretions, and characterized with numerous fossils. The only unit dated by the Valanginian in the Middle Volga region is Mar'evka member, corresponding to the upper (larger) part of the Lower Valanginian and, apparently, lower part of the Upper Valanginian substage. At the bottom this unit is represented by the phosphorite broadstone, having thickness 0,2 m stable over a large area nearby Syzran Town. In Kashpir this plate is composed of a conglomerate made of black phosphorite pebbles and (especially in its lower part) belemnite rostra. The cement is represented by phosphate of later generations and calcite; a strong ferrugination often occurs. In Mar’evka the phosphorite layer has dark gray color and is significantly more stable by its thickness, as well as more sandy.

The zonal scale of the Valanginian is represented in a simplified form in the **Tab.1**.

Table 1

The zonal scale of the Valanginian

Substage	Zones of the Biostratigrafic Scheme for the North of the Russian Plate [2]	Approximate Location of Obsolete Units (boundary matching is imperfect)
Upper	Prodichotomites ivanovi	
	Dichotomites bidichotomus	
Lower	Polyptychites polyptychus	(Nikitinoceras hoplitoides)
	Polyptychites michalskii	
	Nikitinoceras syzranicum	(Polyptychites keyserlingi)
	Pseudogarnieria undulatoplicatilis	(Tollia stenomphala) (Surites simplex)

It was A.P. Pavlow who had described and figured in his works the ammonite fauna of Kashpir phosphorite conglomerates. Basing on it, he established the stratigraphic correlation of the phosphorite broadstone with the Lower Cretaceous ("Lower Neocomian") beds [10]. This fauna consists of *Tollia stenomphala* (Pavl.) [9], *Nikitinoceras syzranicum* (Pavl.), *Polyptychites* (*Euryptychites*) *gravesiformis* (Pavl.), *P. keyserlingi* Neum. et Uhl. [10]; the first three listed species were first described just from Kashpir. In subsequent studies the extended list of the Valanginian ammonite fauna from Kashpir included *N. hoplitoides* (Nik.), *P. michalskii* Bogosl. [1], *P. polyptychus* (Keys.) [3], *“Subpolyptychites” orbicularis* Sazonova, *“Surites” simplex* (Bogosl.) [12]. The new, preliminary defined species are: *N. cf. diptychum* (Keys.) [M. Rogov, pers. comm.], *Menjaites cf. elegans* (Bod.), *N. cf. rudis* (Bod.) [8]. The shells of ammonites are very unevenly distributed along the layer. All ammonite species represent the family Polyptychitidae (including Craspeditinae), which, in general, is widely spread in the East European province of the Boreal-Atlantic subrealm, to which the Russian sea belongs as well [13].

Concerning the Valanginian conglomerate in Maryevka, there is a mention of a find of *P. keyserlingi*, and in the top (i.e., at the base of clay formation) *Dichotomites bidichotomus* Leym. was recorded (from "*glauconite in unconsolidated sandstones above the main phosphorite Valanginian conglomerate*" – [11]). Both species were not figured anyhow. In phosphorite layer of Maryevka we found a single specimen of *N. hoplitoides* characterized by good preservation.

The Valanginian phosphorite broadstone, in addition to ammonite moulds of good preservation and associated bivalve fauna, is abundant in belemnite rostra (full or fragmented) and phragmocones, but stratigraphic range of the species stretches outside the Valanginian stage. Here are recorded: *Pachyteuthis subquadratus* (Roem.), *Simobelus lateralis* (Phil.), *Acroteuthis arctica* (Bluth.) [4, 5, 7].

In spite of the correlation of Mar'evka member to several ammonite zones of the Valanginian, more detailed subdivision of it is apparently unlikely because of the stong discontinuity and rewashing preceeding the cementation of phosphorite pebbles into a broadstone. This resulted in the co-occurrence of species indexing different zones. At the same time one must pay attention to some lithological difference in upper and lower zones of the plate: ammonite finds are confined mainly to the upper zone. This may indicate the presence of several discontinuities.

The phosphorite broadstone is overlapped with the light-gray shales containing jarosite, having full thickness of up to 4.0-4.5 m (in Mar'evka this is erosionally reduced up to 1.5-2.0 m). In Kashpir near the top they change into the sandy clay, with smears of limonite and gypsum crystals. Fossils in these clays are represents only by gipsym and badly deformed belemnite rostra, which are not determinable generally. According to our own observations, the lower 0.8 m layer of shales in Mar'evka does not contain any belemnites; however, they are not rare above. *P. subquadratus* is known from Kashpir, thus claming that the age of clays is presumably Upper Valanginian [14].

Discussion and conclusion. The discoveries of Valanginian ammonite species, previously unknown in the Middle Volga region, made over the recent years by the author, lead to the conclusion that the state of knowledge on the Valanginian strata is still far from being complete. Despite the weak stratigraphic interest, reference sections of the Jurassic/Cretaceous boundary stages located nearby Syzran can enrich the scientific knowledge in terms of both paleobiogeography and paleontology.

The author thanks M.A. Rogov (GIN RAS, Moscow) for the important comments and remarks.

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PLATE CAPTIONS

Plate I

All the specimens are from Novokashpirsky township, bank of the Volga river, Mar'evka member, collected 2013.

Fig. 1. *Menjaites* cf. *elegans* (Bodylevsky, 1949). The mould with remnants of the shell; no. 3629.

Fig. 2. *Menjaites* cf. *elegans* (Bodylevsky, 1949). no. 3630; (figured in mirror position).

Fig. 3. *Nikitinoceras* cf. *rudis* (Bodylevsky, 1949). Mould; no. 3628.

Fig. 4. *Polyptychites michalskii* Bogoslowsky, 1902. a-b – mould having preserved umbilicus, remnants of the shell on ventral side and poorly kept sculpture of lateral side; no. 3633; c – mould after the removal of the outer part of the shell; no. 3634.

Plate II

Fig. 1. *Nikitinoceras hoplitoides* (Nikitin, 1888). Novokashpirsky township, bank of the Volga river, Mar'evka member, 2013. Mould; no. 3632.

Fig. 2. *Nikitinoceras hoplitoides* (Nikitin, 1888). Kashpir, Kashpirka river, Mar'evka member, 2012. Mould; no. 3489.

Fig. 3. *Nikitinoceras hoplitoides* (Nikitin, 1888). Mar'evka, Kamenny gully, Mar'evka member, 2015. Mould with remnants of the shell; no. 3589.

Fig. 4. *Nikitinoceras syzranicum* (Pavlow, 1899). Novokashpirsky township, bank of the Volga river, Mar'evka member, 2013. Mould; no. 3627.

Plate I

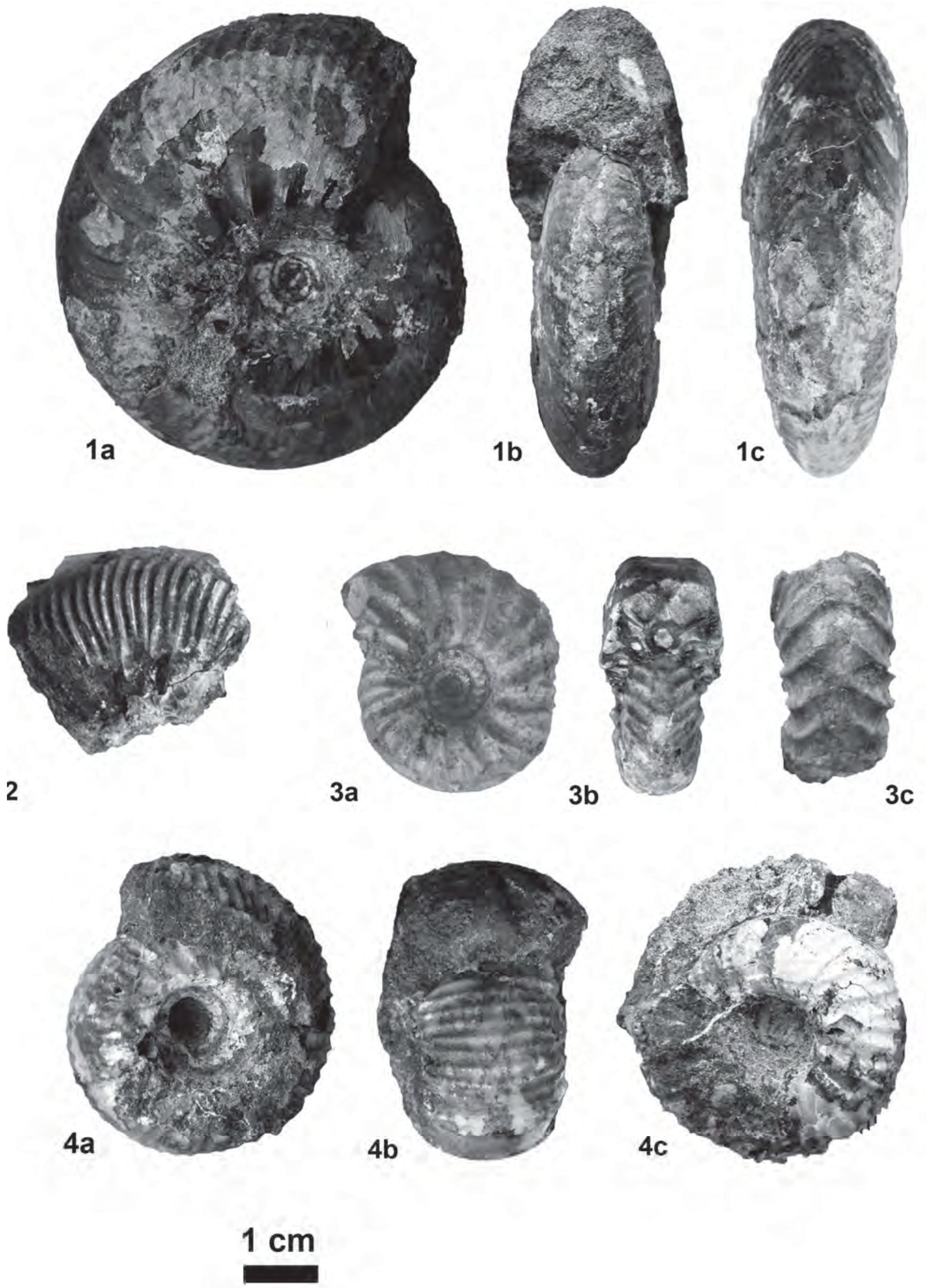
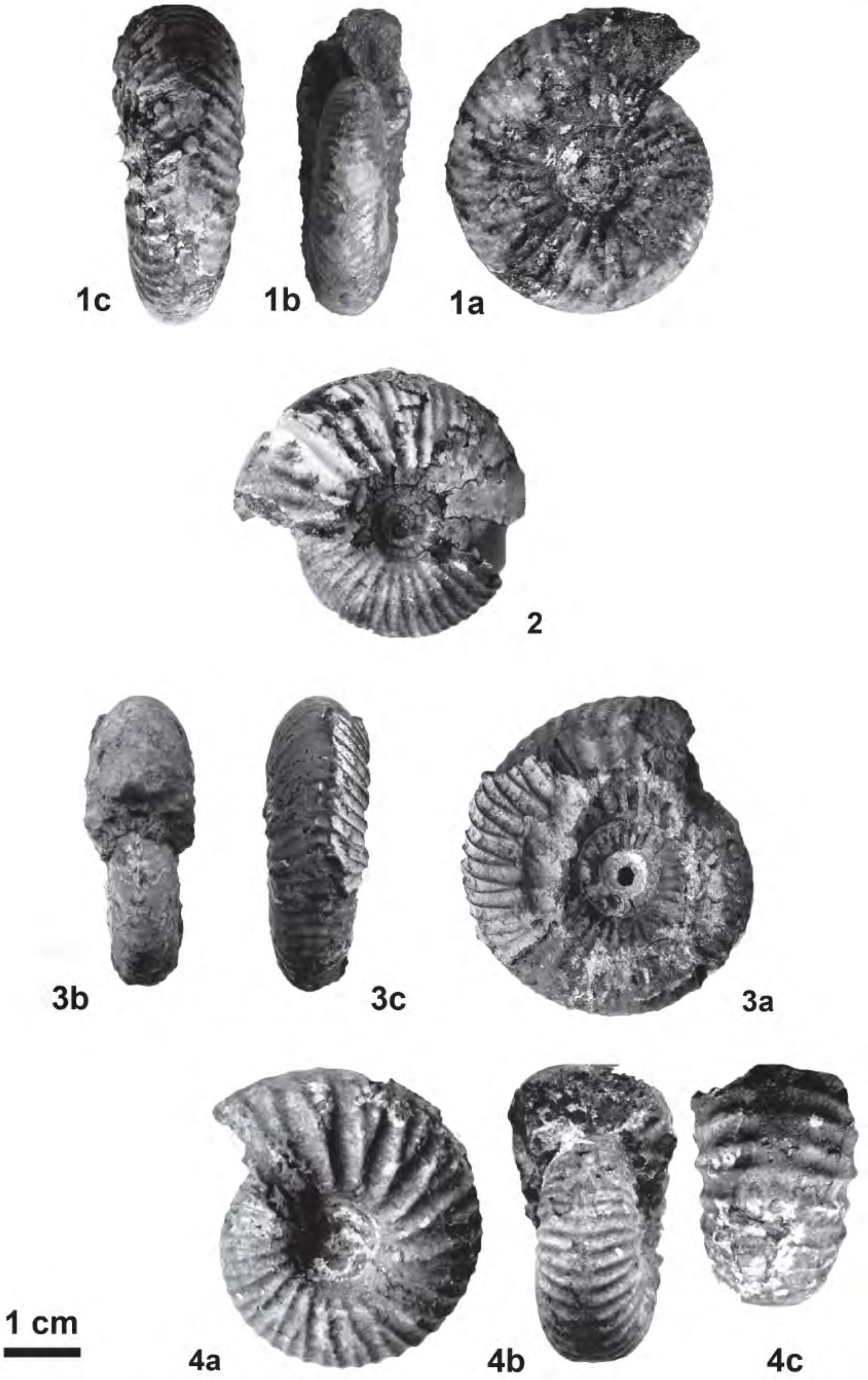


Plate II



REVISED AMMONITE SUCCESSION OF THE UPPER VOLGIAN OF NORDVIK SECTION: ZONAL BOUNDARIES AND UNCERTAINTIES

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***Abstract**: Revision of all ammonite records from the Upper Volgian Substage of the Nordvik section leads to the improvement of its zonal subdivision. For the first time presence of the Originalis Zone is proven for this section. However, due to rarity of ammonite occurrences in the upper part of the succession the position of the boundary between Okensis and Taimyrensis Zones remains unclear, and position of the Tithonian-Berriasian boundary (i.e. base of the Jacobi Zone) could be corresponding either to the uppermost part of the Originalis Subzone of the Okensis Zone or to the lower part of the Taimyrensis Zone.*

***Key words**: ammonites, Upper Volgian, zonal boundaries, Nordvik*

The Nordvik section, located at the Laptev Sea coast near Urdyuck-Khaya Cape (**Fig. 1**), is one of the most well-studied sections of the Jurassic/Cretaceous boundary interval over the whole Panboreal Superrealm [14], but its ammonite fauna are insufficiently investigated, and position of zonal boundaries should be revised. Since the publication of article by Basov et al. [2] this section has been subdivided into beds and members, and nearly all ammonite records were tied to members not to certain defined levels. As a result, zonal boundaries coincide with the base of members characterized by key ammonite taxa. Additional problems appear due to unclear characteristics of ammonite zones and their boundaries. Such uncertainties led to discussion on the possible problems and errors in correlation of Upper Volgian ammonite zones with paleomagnetic reversals [3,6] and thus with Submediterranean succession [9].

Here we are reviewing all the available data on precisely collected Upper Volgian ammonites from the discussed section as well as the positions of zonal boundaries and their correlation with palaeomagnetic reversals.

Upper Volgian ammonites of the Nordvik section

Ammonites from the Upper Volgian part of the Nordvik section are preserved as crushed clayey moulds, which sometimes cannot be successfully collected, and as 3D moulds in concretions. In early papers describing the Nordvik succession [2, 13] the precise stratigraphic position of figured specimens was not clearly indicated, but some of key records were lately shown on the log, published by Zakharov [12]. Additional

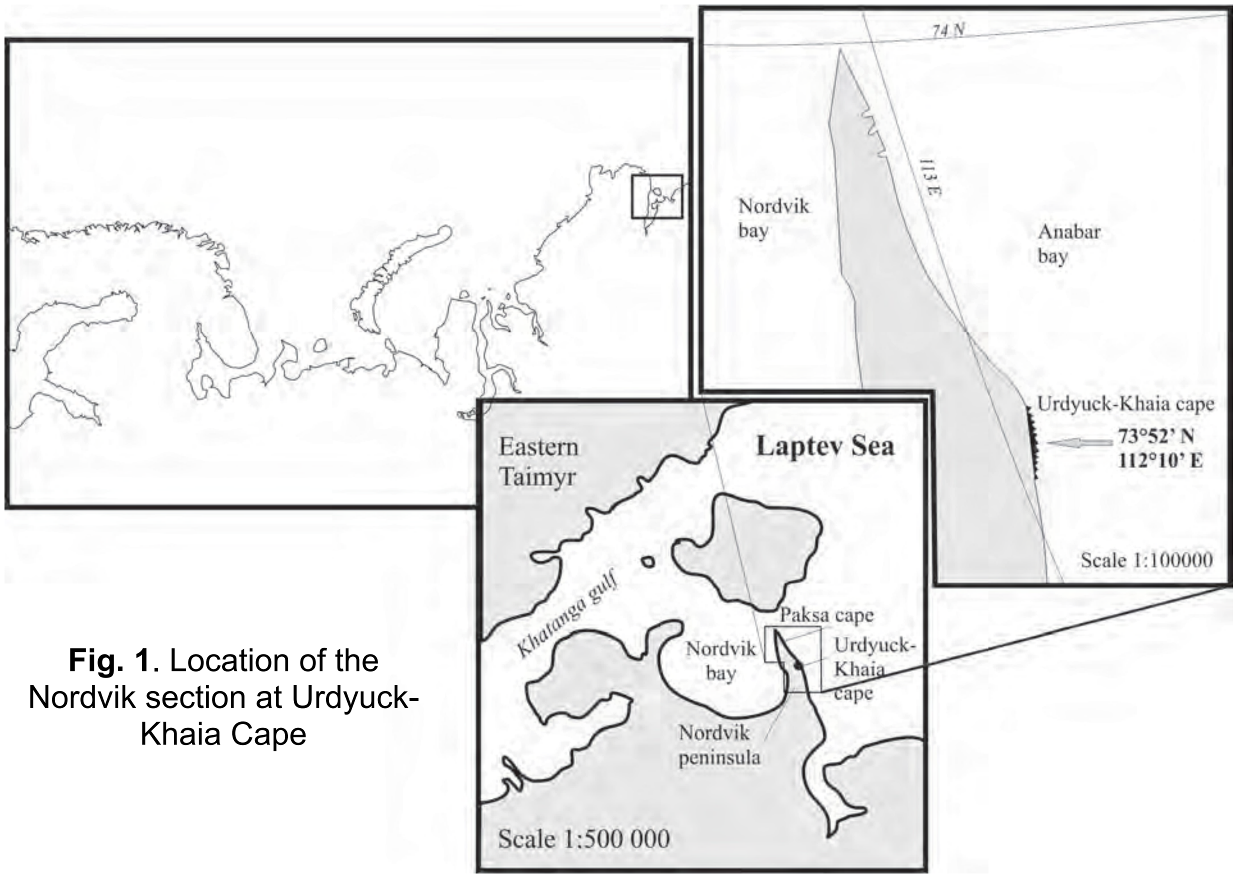


Fig. 1. Location of the Nordvik section at Urdyuck-Khaia Cape

specimens (mainly from the lower part of the Upper Volgian) were also collected by the authors during the field works held in 2003 and 2011.

All *in situ* ammonite occurrences from the Upper Volgian of the Nordvik section are shown on the **Fig. 2**. Some of these specimens were not collected (due to their fragility) or became crushed during the transportation. Such finds are marked by open circles at the figure.

Zones and zonal boundaries of the Upper Volgian Substage of Nordvik

Boundaries of ammonite zones of the Upper Volgian of Siberia were not characterized when they were described at the first time [5]. Later updated definitions of zones, their boundaries and type sections were proposed by Casey et al. [4] and Baraboshkin [1]. Nevertheless, these new definitions also should be corrected.

Lower boundary of the Okensis Zone (and the Upper Volgian Substage, respectively) is marked by the changes in *Laugeites – Craspedites* lineage and established by FAD of typical *Craspedites* [M] [9]. As a marker of the upper boundary of the Okensis Zone, Casey et al. [4] proposed to use disappearance of *C. (C.). okensis* (d'Orb.) and *C. (Taimyroceras) originalis* Schulg. (the latter species is the index for the Originalis Subzone, determined by full range of its index). However, a contact of this zone with the overlying Taimyrensis Zone in the type section was missing, as in the section of Boyarka river above the Okensis Zone significant part of the succession was obscured by the landslides, glacial boulders and quaternary cover, and the next available units are of Ryazanian age. For the lower boundary of the Originalis Subzone the level of first appearance of *C. (Taimyroceras)* in the upper part

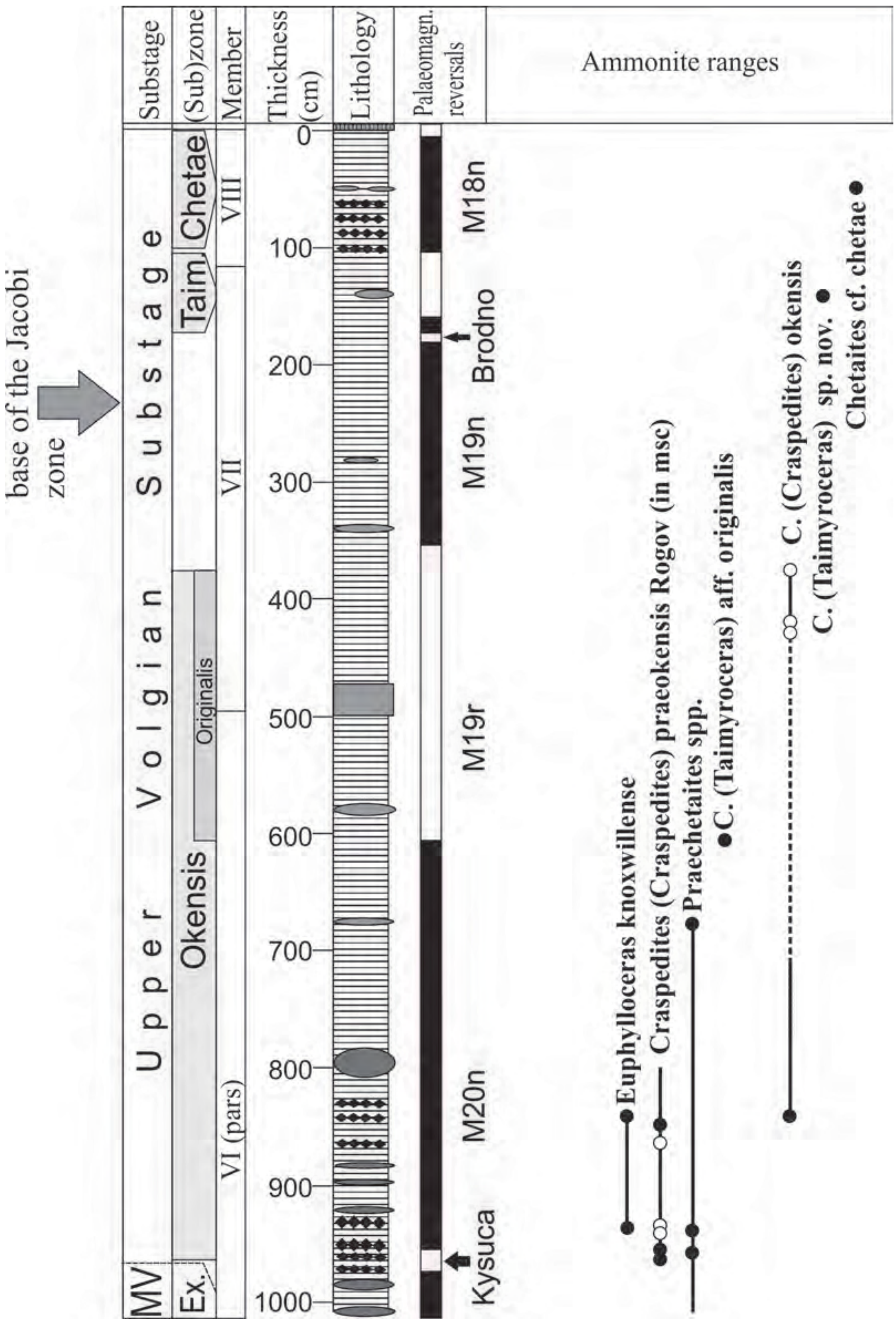


Fig. 2. Ammonite distribution in the Upper Volgian substage of the Nordvik section. Ammonites determined in the field but missing in collections are marked by open circles; specimens present in collections are marked by solid circles.

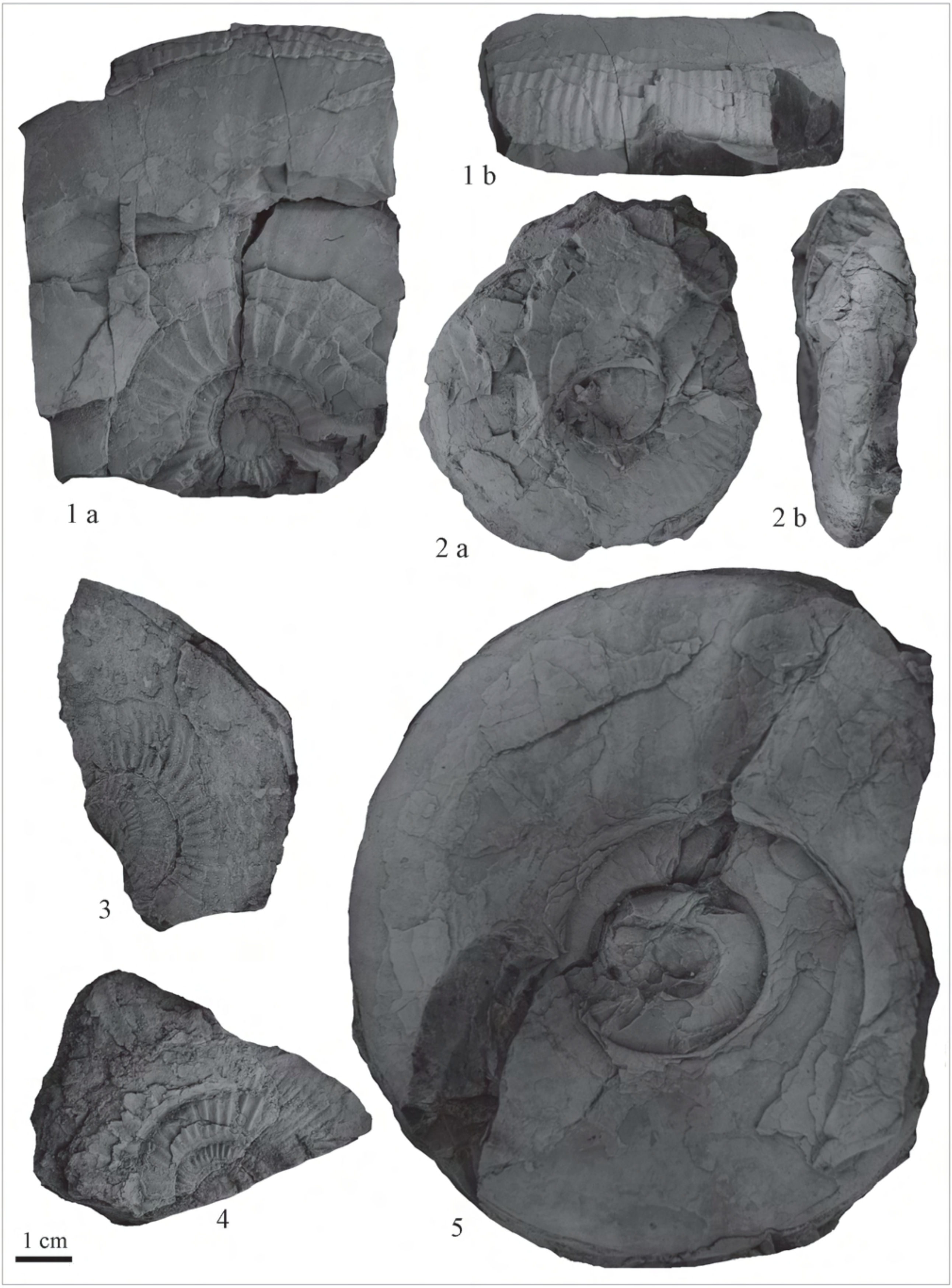
of the Okensis Zone could be used for more accurate determination. In the Nordvik section Okensis Subzone is well-recognized by numerous occurrences of *Craspedites (C.) praeokensis* Rogov (in msc) (**Fig. 3.5**), *C. (C.) okensis* (d'Orb.) [M], and *Praechetaites* sp. Lowermost part of the subzone is also characterized by the presence of phylloceratid ammonites *Euphylloceras knoxvillensis* (Stant.) ([15], **Fig. 4e**). Originalis Subzone is recognized here for the first time by the record of the *C. (Taimyroceras)* aff. *originalis* Schulg., resembling macroconchs recently figured from this subzone of Svalbard ([11], **Fig. 5.2**).

In the Kheta section, where the stratotype section of the Taimyrensis Zone is located, *C. (C.) okensis* (d'Orb.) was not found *in situ* and rocks considered as belonging to the Originalis Subzone of the Okensis Zone were characterized by occurrence of *C. (Taimyroceras)* sp. only [5]. Thus, the position of the lower boundary of the Taimyrensis Zone in its type section is unclear. Moreover, Sachs et al. [5] suggested that in the Kheta river section this zone corresponds with members 4-6, while the index species has been recorded from the uppermost only. Later Casey et al. [4] have proposed to use first appearance of *C. (T.) taimyrensis* (Bodyl.) for the recognition of the lower boundary of the cognomial zone. However, usage of disappearance of *Craspedites (Craspedites)* as a marker for the Okensis/Taimyrensis zonal boundary makes this boundary well-traceable throughout the whole Arctic and permits to recognize the Taimyrensis Zone in those section where *C. (T.) taimyrensis* (Bodyl.) is missing. In the Nordvik section N.I. Shulgina (in [13]) on the base of records of "*C. (Taimyroceras) canadensis* Jeletz." ([13], pl. III, fig. 1-2) considered the member VII (4,2 m) as belonging to the Taimyrensis Zone. But lower part of this member contains *C. (C.) okensis* (d'Orb.) [14], while *C. (Taimyroceras)* were collected from the concretions located in the topmost part of the member [12]. Therefore, the position of the Okensis – Taimyrensis zonal boundary in this section should be drawn somewhere within the Member VII. It should be noted that all known specimens from Nordvik are referred to as *C. (Taimyroceras) canadensis* Jeletz. by Shulgina and are characterized by very narrow cross-section and poorly developed ribbing, being easily distinguishable from any topotypic specimens [7]. In our opinion, these ammonites (as well as "*C. (Taimyroceras)* cf. *canadensis*" from Svalbard, figured in [8], pl. VII, fig. 8) should be ascribed to a new species of the subgenus *Taimyroceras* (**Fig. 3.2**).

The Chetae Zone is determined by the full range of its index species *Chetaites chetae* Schulg. [1, 4]. In the Nordvik section crushed small-sized *Chetaites* cf. *chetae* Schulg. were found within the Member VIII ([13], pl. III, fig. 3-4; see also **Fig. 3.3-4**), along with unfigured phylloceratids and *Praechetaites*. One more ammonite, referred to as *Chetaites* cf. *chetae* Schulg. by Shulgina ([13], pl. IV, fig. 1, refigured herein, **Fig. 3.1**), by its relatively distant and coarse ribbing of the inner whorls and smoothening of the ribbing in the middle part of the outer whorls should be re-determined as *Praechetaites*. After Zakharov [12], all *Chetaites* cf. *chetae* Schulg. from the Nordvik section were collected from the middle part of the Member VIII, and the position of the Taimyrensis – Chetae zonal boundary in this section still cannot be precisely determined.

Discussion and conclusion

Subdivision of the Upper Volgian Substage of the Nordvik section by ammonites, even including data about the newly recorded specimens, remains unclear in the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Okensis – Taimyrensis transitional interval, which is lacking ammonite finds. Thus the position of the Jacobi Zone lower boundary in terms of Boreal ammonite zones is also indefinite, as this level could be either in the uppermost part of the Originalis Subzone of the Okensis Zone or in the lower part of the Taimyrensis Zone. Additional palaeomagnetic studies of ammonites-rich Boreal sections are strongly required, and the sections of the Subpolar Urals, Spitsbergen and the central part of the Russian Platform are among the most awaiting aims for further investigations.

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Fig. 3. Selected Upper Volgian ammonites from the Nordvik section (re-figured from [13]). All the specimens are kept in CNIGR Museum, Saint-Petersburg. 1. *Praechetaites* sp., a – lateral view, b – ventral view. Loose from beds 14-17 (loc. 33), no. 12/9843; 2. *Craspedites (Taimyroceras)* sp. nov., a – lateral view, b – ventral view, bed 9 (loc. 32), no. 9/9843; 3-4. *Chetaites* cf. *chetae* Schulg., lateral view, middle part of the bed 17 (loc. 32), 3 - no. 11/9843; 4 - no. 10/9843; 5. Craspedites *(Craspedites) praeokensis* Rogov, in litt., bed 5 (loc. 32), no. 6/9843.

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ON THE JURASSIC/CRETACEOUS BOUNDARY IN THE DECISIONS OF THE INTERDEPARTMENTAL STRATIGRAPHIC COMMITTEE

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***Abstract**: Defining the boundary between the Jurassic and Cretaceous systems is one of the most important issues of the Mesozoic stratigraphy. This problem is reflected in the decisions of the Interdepartmental Stratigraphic Committee.*

***Key words**: Jurassic, Cretaceous, Tithonian, Volgian, Berriasian.*

The decisions of the Interdepartmental Stratigraphic Committee (ISC), issued from 1958, reflect the problem of definition of the boundary between the Jurassic and Cretaceous system first over the territory of USSR, and later Russia.

“The first meeting of the Standing Comission on the Jurassic system was held on January 30-31, 1959 in Leningrad” [1]. The Bulletin №2 (1960) provides information on the work of the Commission on Jurassic system (chairman G.Ya. Krymgolts), which recommended to use the following Stages for the forthcoming reference book "Stratigraphy of the USSR" in the Upper Jurassic: Callovian, Oxfordian, Kimmeridgian and Tithonian (and parallel to the latter - the Lower and Upper Volgian Stages). [1]

"In the Luxembourg the First International Colloquium on the Jurassic system was held from 1 to 4 of August 1962" [2]. The recommendations of the Colloquium are related to the development of the unified (global) timescale of the Jurassic. "Consiering the subdivision of the upper part of the Jurassic system the Colloquium has not accepted the final recommendation"[2]. Plenary Session of the Commission on the Jurassic System ISC discussed the recommendations of the Colloquium and took a number of decisions (approved by the ISC Bureau on 21 February 1963), including those touching the upper part of the Jurassic system. "As an upper stage of the Jurassic of the unified stratigraphic scale the Comission proposes the Tithonian Stage, widely represented by marine facies and covering the whole interval from the Kimmeridgian up to the Lower Cretaceous, and widely distributed.geographically. The Commission considers it necessary to raise a question over the Permanent International Commission on Stratigraphic Nomenclature on the approval, as exceptional case, the name of this stage (which was named not on the geographical basis) and the question about the definition of its stratotype (within the Alpine bow area). The Commission considers that for the Boreal region the Lower and Upper Volgian Stages should be maintained, together being an equivalent of the Tithonian". "To fix the upper boundary of the Jurassic system in the base of the Subthurmannia boissieri Zone (Mediterranean area) and Riasanites rjasanensis Zone (Boreal region)" [2]. The stratigraphic scheme of Jurassic subdivision was accepted as well.

The issue no.7 of ISC Desisions (1965) contains materials of Comission on the Cretaceous system of the USSR (chairman. N.P. Luppov), prepared for the Volume VIII ("Cretaceous System") of the International stratigraphic dictionary. Explanatory articles highlight the usage of the names of the main stratigraphic units of the Cretaceous system in USSR. “Cretaceous system is subdivided in the USSR, as in most other countries, into two series - Upper and Lower". "Lower Cretaceous is divided into five stages: Valanginian, Hauterivian, Barremian, Aptian and Albian." "Berriasian is accepted in the USSR as the substage of the Valanginian" [2]. The common opinion was the correlation of the Ryazanian horizon, distinguished in the Lower Cretaceous succession of the Russian Platform, with the Lower Valanginian (Berriasian). Riasanites rjasanensis Zone is the lowermost zone of the Ryazanian horizon.

An extended meeting of the Bureau of the Jurassic Commission of ISC, held in Moscow in October 28-29, 1964 discussed the usage of the Volgian Stage. "It was decided on all hands to consider the deposits previously treated as Lower Volgian Stage and Upper Volgian Stage, as a single united Volgian Stage" [2]. Due to the fact that the author of the Volgian Stage "S.N.Nikitin did not selected the stratotype", Jurassic Commission of ISC "decided to accept as lectostratotype of the Volgian a section located on the right bank of the Volga river about 25 km north of Ulyanovsk and 1 km south of the village Gorodische. Here the Volgian immediately overlies the Upper Kimmeridgian and is covered by the Lower Cretaceous"[2].

At the plenary session of the ISC (chairman acad. D.V.Nalivkin), held on April 14, 1965, a decision was taken on *the assignment of the Volgian stage in the General Stratigraphic Scale of the Jurassic* [2].

At the same time the work on the stratigraphy of the Lower Cretaceous was carried out. At the Colloquium on the Stratigraphy of the Lower Cretaceous of France, held in Lyon on September 20 to October 1, 1963 the refined stratigraphic scale of the Lower Cretaceous of France, having the meaning as a global stratotype, was accepted [2]. According to the recommendations of the Permanent Bureau of the Colloquium, Commission on Cretaceous system of the ISC of the USSR accepted a number of decisions on the stratigraphy of the Lower Cretaceous, including the Berriasian. "Fauna of the Berriasian is very specific, clearly different from the younger Valanginian fauna and have features similar to the fauna of the Tithonian, allowing to separate Berriasian deposits from the overlying Valanginian (from the Kilianella roubaudiana Zone)» [2].

At the third plenary meeting of the Commission on the Cretaceous system of ISC, held from 25 to 28 April, 1964 in Leningrad, controversial questions of the stratigraphy of the Lower Cretaceous, including the status of the Berriasian. "The separation of faunisitc complexes from Berriasian strata provides the basis to join the recommendations of the Lyon Colloquium and consider the Berriassian as a separate stage of the Lower Cretaceous Series" [2].

From January 30 to February 4, 1967 a joint Plenum of the Commissions on the Jurassic and Cretaceous systems of the ISC of USSR was held. The question on the position of the boundary between the Jurassic and Cretaceous systems was discussed, and it was decided to fix this boundary in the top of the Volgian stage. “1. The boundary between the Jurassic and Cretaceous systems can be established quite clearly by ammonites ... 2. This boundary should be fixed in the top of the Volgian Stage ... 4. In the Boreal Realm the boundary between the Craspedites nodiger Zone of the Volgian Stage and the Riasanites rjasanensis Zone (or its corrrelatives) of the Berriasian Stage. 5. In the Mediterranean region, this boundary is located between Virgatosphinctes transitorius Zone of the Volgian (Tithonian) and Berriasella grandis Zone of the Berriasian ... 8. On the Russian platform the Berriasian is subdivided into two zones: lower Riasanites rjasanensis Zone and upper– Surites spasskensis Zone ... »[3].

At the plenary session of the ISC (chairman Acad. D.V. Nalivkin), held on January 18, 1968, the Berriasian stage was decided to be *assigned in the united Stratigraphic Scale of the Cretaceous system* [5]. To the Berriasian Stage were referred the strata, previously considered in USSR as the ”lower substage of the Valanginian” [4].

The Decisions of ISC for 1970 provide information on the Second International Colloquium on the Stratigraphy of the Jurassic system, held from 17 to 28 July 1967 in Luxembourg. "The aim of the Colloquium was to discuss the questions of stratigraphy of the Jurassic system, in particular, those which were not considered at the First Colloquium (1962), the question on the upper stage of the Jurassic system and on the boundary of the Jurassic and Cretaceous systems" [4]. "At present, many agree to hold the base of the Cretaceous at the base of Berriasella grandis Zone (or B. boissieri s.1. Zone) in the Mediterranean region, and the base of Riasanites rjasanensis Zone in Eastern Europe and the base of Chetaites sibiricus Zone in Siberia" [4]. The resolution claimed the need of additional research.

The Decisions of ISC for 1972 provide information on the Joint extended Session of the Standing Bureau of the two Stratigraphic Commissions - on the Jurassic and Cretaceous systems (February 2-3, 1970). "The main issue … was the discussion of the necessary research in the Soviet Union to solve the problem of the Jurassic/ Cretaceous boundary... Attention was drawn to the need of appropriate work in southern areas, referring to the Mediterranean paleogeographic realm and in the northern areas referred to the Boreal paleogeographic realm" [5].

On January 29-31, 1973 in Leningrad a meeting on the Jurassic/Cretaceous boundary was held in connection with the preparation for the International Colloquium of the Jurassic/Cretaceous boundary, planned for 1973 [6]. It was noted that "the position of the boundary between the Jurassic and Cretaceous systems is one of the most important controversial questions under discussion of the Mesozoic stratigraphy." "Before a forthcoming decision on the position of the boundary according to the established international procedure it should be placed in traditional position, between the Tithonian (Volgian) and Berriasian Stages, as recorded in the Decisions of the Joint Plenum of the Comissions on the Jurassic and Cretaceous systems of ISC, held on January 30 - February 4, 1967" [6].

In September 1973 Lyon, Grenoble and Neuchatel hosted the International Colloquium on the Jurassic/Cretaceous boundary, details of which can be found in the 15^{th} issue of ISC Decisions (1975). "The aim of the colloquium was a comprehensive discussion of the problem of the Jurassic/Cretaceous boundary". which "revealed significantly different views on the position of the boundary between the Jurassic and the Cretaceous." "However, no decisions on the position of the boundary between these systems has not yet been taken". [7]

At an Extended meeting of the Bureau of Commissions on the Jurassic and Cretaceous Systems (February 9, 1974) the results of the International Colloquium of 1973 were analyzed. "Currently, the position of the boundary between the Jurassic and

Cretaceous systems should be based on the Decision of the Commissions on the Jurassic and Cretaceous systems, accepted on 30/I - 4/II.1967, i.e. to place it in the base of the Berriasian Stage" [7].

In the16th issue of ISC Decisions (1976; [8]) there is information on the results of the Commissions on the Systems provided, including the Jurassic and Cretaceous ones, over the past twenty years of existence of the ISC. While elaboration process of the "global (standard) scale, carried out through the International Subcomission on the Jurassic stratigraphy", "the question about the upper stage of the Jurassic, locate above the Kimmeridgian, remained unresolved, despite its lower boundary is defined (in the base of beds with *Gravesia*). In 1967, soviet scientists proposed to introduce the Volgian Stage into the International Scale, but the majority of foreign experts met this proposal negatively ... The reason for the discussion of this problem is clear. The problem is the essential biogeographic differentiation of the Boreal and Mediterranean (Tethyan) faunas, which increased strongly after the Kimmeridgian "[8].

The International Colloquium on the Upper Jurassic and the Jurassic-Cretaceous boundary was held on 12 - 24 July 1977 in the USSR (Novosibirsk, Tyumen, Ulyanovsk and Leningrad). Field excursions were arranged to the Severnaya Sos'va river basin and along the Volga river. "On the Volga river there was examined the Volgian lectostratotype nearby the village Gorodische (district of Ulyanovsk) and an additional section of the upper part of the Volgian Stage neaby Kashpir township (Syzran district)" [9]. The following conclusions were made: 1. In the Boreal belt currently the topmost stage of the Jurassic should be the Volgian, parallel to the Tithonian. ... 4. The boundary between the Jurassic and Cretaceous systems in the Boreal Realm at the present level of knowledge should be preserved in the traditional position between layers with Craspedites nodiger and layers with Riasanites at the Russian plate, and between the layers with Chetaites chetae and layers with Ch. sibiricus and Praetollia in the Arctic region, and between the layers with Volgidiscus and the layers Runctonia in East England... " [9].

From 25 to 28 January 1978 in Leningrad "the Commission on the Jurassic system held a plenary session devoted to the refinement of the zonal subdivision." The "general approved Jurassic zonal scale was maintained" [9].

From 7 to 9 February 1979 in Leningrad a Plenary meeting of the Commission on the Cretaceous system of ISC was held, which discussed the General Stratigraphic Scale of the Cretaceous of USSR. ." The "general approved Cretaceous zonal scale was maintained" [10].

With the release of the 27th issue of ISC Desicions (1994), the Commission on the Cretaceous system (chairman. V.A. Prozorovsky) published the results of its work for the improvement of the General zonal scale of the Lower Cretaceous and zonal standards for the Berriasian, Valanginian, Hauterivian and Albian [11].

At an extended meeting of the ISC Bureau (chairman A.I. Zhamoyda), held on February 2, 1996, a *resolution considering the General Zonal Scale of the Lower Cretaceous was accepted* [12]. The succession, presented by the Commission on the Cretaceous system, included three zones within the Berriasian (bottom-up): Berriasella jacobi - Pseudosubplanites grandis; Tirnovella occitanica; Fauriella boissieri.

"Commission on the Jurassic and Cretaceous systems over the last three years worked to improve the correlation of the Tithonian, Volgian and Berriasian and to specify the position of the Jurassic/Cretaceous boundary in the Boreal Realm" [12]. In the 29th issue of ISC Decisions (1997) there was a *resolution published to specify the position of the Jurassic-Cretaceous boundary in the Boreal Realm and the status of the Volgian Stage*, accepted at the Extended Meeting of the ISC Bureau (chairman A.I. Zhamoyda), on February 2, 1996. The accepted position of the Jurassic/Cretaceous boundary in the Boreal Realm was between the Middle and Upper Volgian Substages. It was accepted to "re-classify the Volgian stage in the same volume from the category of general units into the category of regional stratigraphic units as a horizon (regional stage), leaving in a General Stratigraphic Scale of Russia only Tithonian and Berriassian stages in the boundary interval" [12].

In the 38th issue of ISC Desisions (2008) the state of knowledge on the stratigraphy of the Precambrian and Phanerozoic of Russia is represented, including the data on the Jurassic and Cretaceous systems. Chairman of the Comission of the Jurassic system of ISC, V.A. Zakharov, considers the ISC resolution from February 2, 1996 unjustified, as both previous and new data do not confirm such an interpretation. "Essentially new data suggest that almost the entire Upper Volgian Substage must be included into the Jurassic, not into the Cretaceous system" [15].

"The Commission on the Jurassic system is working on the restoration of the inclusion of the volgian stage into the Jurassic system, based on the new magnetostratigraphic and biostratigraphic data" [13]. The Extended Meeting of the Commission on the Jurassic System (3 April 2012) decided to "... recommend ISC to replace the Tithonian stage by the Volgian in the General Stratigraphic Scale of Russia, preserving the latter in the volume, accepted before 1996 (from the base of Ilowaiskya klimovi Zone to the top of Craspedites nodiger Zone" and to discuss this issue at a Joint meeting of the Comissions on the Jurassic and Cretaceous systems of ISC [13].

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UPPER TITHONIAN - HAUTERIVIAN BIOSTRATIGRAPHY OF THE PASKENTA AREA (NORTHERN CALIFORNIA) AS A KEY FOR BOREAL-TETHYAN CORRELATION

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***Abstract**: Buchiid biostratigraphy of the Paskenta area (California) is reviewed on the base of newly collected material from Grindstone Creek and McCarthy Creek sections. Three new biostratigraphical units have been proposed: Buchia sublaevis Zone - Upper Valanginian – Lower Hauterivian (above Buchia keyserlingi Zone) and Buchia inflata Beds (between B.uncitoides and B.pacifica Zones) in the McCarty Creek section; Buchia aff. volgensis-B unschensis Beds (between Buchia piochii Zone at the top of Tithonian and B.okensis Zone at the bottom of Berriasian, Grindstone Creek). The position of zonal boundaries was determined more precisely. The stratoecotones - the stratigraphical intervals with the mixing of buchiid species determining successive zones - have been established in the both sections (Grindstone Creek and McCarty Creek) between Piochii and Okensis Zones; Okensis - Uncitoides Zones (at the Grindstone Creek section); Uncitoides - Inflata Zones; Inflata - Pacifica Zones; Keyserlingi - Sublaevis Zones (at the McCarty Creek section).*

***Key words**: Buchia, Jurassic-Cretaceous boundary, California, Northern Siberia, correlation*

The succession of the Buchia-zones of the Paskenta area has been established by D. Jones, E. Bailey and R. Imlay [8]. The geological age of the Buchia-zones has been indicated by ammonites, which were found sporadically throughout the sections (Imlay, Jones, 1970). As a result of this work the following zonation has been proposed: Buchia elderensis Zone (Lower Tithonian), B. piochii Zone (Middle - Upper Tithonian), B. aff. okensis Zone (Upper Tithonian), B. uncitoides Zone (Berriasian), B. pacifica Zone (Lower Valanginian), B. keyserlingi Zone (Middle Valanginian), B.crassicollis solida Zone (Upper Valanginian).

The nomenclature and geological age of the several North American Pacific Buchia-zones do not coincide, in most cases, with those of the Arctic region [11-13]. The author at the base of data on ammonites and *Buchia* as well as circum-Boreal and Boreal - Tethyan zonal correlation, proposed to accept the age of the B. aff. okensis and B. tolmatschowi Zones as Berriasian, and the age of B. keyserlingi Zone as Lower Valanginian [12, 13, 15, 16].

In the year 1990 the Upper Tithonian - Hauterivian sections of the Grindstone Creek and McCarty Creek area have been visited by P.Roth and V.Zakharov. The mollusks and nannofossils were collected very carefully throughout the both sections mentioned above. The Buchias have been identified by V.Zakharov and ammonites-by V.Zakharov, Yu.Bogomolov and M. Rogov. Unfortunately nannofossils have not been studied since P.Roth stopped his research. P. Roth proposed to finish the work without him, giving me the opportunity to use the field data. Incentive for continued research was the participation in the International Working Group on Berriasian and Jurassic - Cretaceous systems boundary.

Results

The following results have been obtained:

1) Representative mollusc (buchiids and ammonites) collection has been sampled and identified;

2) The Buchia-zones succession proposed by D.Jones and co-authors was corrected;

3) Three new biostratigraphical units have been established: Buchia sublaevis Zone - Upper Valanginian (above Buchia keyserlingi Zone) and Buchia inflata Beds (between B. uncitoides and B. pacifica Zones) in the McCarty Creek section; Buchia aff. volgensis-B. unschensis Beds (between Buchia piochii Zone at the top of Tithonian and B. okensis Zone (formerly B. aff. okensis Zone) at the base of the Berriasian of Grindstone Creek (**Table 1**);

4) The positions of zonal boundaries were determined more precisely;

5) The stratoecotones - the stratigraphical intervals with the mixing occurrences of Buchia index-species of the successive zones have been established in the both (Grindstone Creek and McCarty Creek) sections between Piochii and Okensis Zones; Okensis - Uncitoides Zones (at the Grindstone Creek section); Uncitoides - Inflata Zones; Inflata - Pacifica Zones; Keyserlingi - Sublaevis Zones (at the McCarty Creek section).

6) The zonal correlation of the Upper Tithonian - Berriasian – Valanginian and lowermost Hauterivian sections of Paskenta area with the Upper Volgian - Boreal Berriasian - Boreal Valanginian and Lower Hauterivian sections of Northern Siberia has been proposed (**Table 1**).

Discussion

Paleontology. Many buchias from Paskenta area are very similar to those from Northern Siberia. However, some Upper Tithonian - Valanginian Northern California Buchias, such as *Buchia terebratuloides, B. uncitoides, B. inflata, B. keyserlingi, B. sublaevis* are more convex comparing to the same species from Northern Siberia. The other Northern California buchias, such as *B. okensis* (= *B.* aff. *okensis*) and *B. volgensis* are some smaller than Northern Siberian members of these species. Basing on these morphological features, it seems possible to create some new Northern American species like *B. pacifica* Jeletzky. In my opinion, this approach is not productive. It is necessary to search for the similarities of the *Buchia*'s characteristics, rather than for differences.

Biostratigraphy. There is a very similar succession of the Buchia Zones both in the Paskenta area sections and in the Northern Siberia sections in the Valanginian but not in the Upper Tithonian and partly Berriasian. The most unreliable correlation is

Table 1

Correlation of buchiid successions of Northern Siberia and Northern California

Stage, Substage	Northern Siberia: Ammonite zones	Northern Siberia: Buchiazones	Northern California: Buchiazones and beds	Northern California: Ammonite records	Stage
Hauter.	Bojarkensis	Crassicollis	Sublaevis	*Jeannoticeras*	
Valanginian	Bidichotomoides	Sublaevis	Keyserlingi	*Thurmanniceras*	Valanginian
	Ramulicosta	Keyserlingi		*Neocomites*	
	Astieryptychus				
	Quadrifidus				
	Klimovskiensis	Inflata	Pacifica	*Neotollia* *Paskentites*	
Ryazanian	Tolli		Inflata		Berriasian
	Mesezhnikowi	Tolmatschowi	Tolmatschowi	*Neocosmoceras* *Negreliceras*	
	Analogus	Jasikovi	Uncitoides		
	Kochi	Okensis	Okensis		
	Sibiricus	Unschensis	*B. aff. volgensis* *B. terebratuloides*		
Volgian (pars)	Chetae				
	Taimyrense				Tithonian (pars)
	Okensis	Obliqua	Piochii	*"Groebericeras"*	
	Exoticus	Taimyrensis	Elderensis		
	Variabilis				
	Excentricus				
	Maximus	Russiensis			
	Ilovaiskii				
	Iatriensis				

around the Jurassic-Cretaceous boundary interval. The B. piochii Zone is the uppermost Jurassic unit in the Paskenta area sections. The B. unschensis Zone comprises the top of Jurassic and the base of Boreal Berriasian in the Northern Siberia. Both index species are strongly different. *B. piochii* have a narrow and high shell (the curved ontogenetic type). *B. unschensis* are characterized by rounded and convex shell (the ortoid ontogenetic type) [8, 11, 12]. *B. unschensis* is very rare in the B. piochii Zone, while *B. piochii* is almost missing in all the Siberian sections, however recently it was found at Stolbovoi Island [9], while previously this species was reported only from the Subpolar Urals [13]. The age of the B. piochii Zone has been determined by the presence of ammonites *Kossmatia* and *Durangites*(?) (both dubious) at the lower part of the zone, and *Spiticeras*, *Parodontoceras*, *Groebericeras* (not older than the Late Tithonian) at the upper part of the zone. We accept the age of Piochii Zone, at least taken as sensu stricto, as Upper Tithonian. This fact supports the assumption of Imlay and Jones ([5], p.B11) that "the specimen from California illustrated by Anderson

([1], pl.2, figs. 4a, b) as *Durangites* is now lost, and a positive generic identification cannot be made from the illustrations....*Kossmatia*, in southern Europe and Northern Africa, is reported to have an age interval through the entire Tithonian". The age of the *B. piochii* -like species at the uppermost part of the Jurassic sections of Russian platform is Late Volgian [4]. The age of B. piochii Beds at the Russian Far East is determined as Upper Tithonian - Lower Berriasian [10]. In the North-East of Russia (Magadan area) the stratigraphic range of *B. piochii* coincides with that of B. unschensis Zone in the interval from the Upper Volgian to the lower part of Boreal Berriasian [16]. The B. unschensis Zone characterizes the Jurassic/Cretaceous boundary in the Northern Siberia. This Buchia-zone corresponds to several ammonite zones, and can not be correlated with upper part of Craspedites okensis and C. taimyrensis Zones (Upper Volgian), Praetollia maynci Zone and lower part of Hectoroceras kochi Zone (the lower part of the Boreal Berriasian). There is a good correlation of all these ammonite zones over Boreal realm, but not over Tethys. The direct correlation is possible by using *Buchia* zonation. Taking into account the same range of both *B. piochii* and *B. unschensis* species at some sections it seems possible to correlate the Piochii Zone at least within Jurassic portion of the Unschensis Zone. Most likely, that the Cretaceous part of Unschensis Zone corresponds to the B. aff. volgensis – B. unschensis Beds of the Paskenta area sections (**Table 1**). Basing on the occurrence of ammonites *Substeuroceras*, *Parodontoceras*, *Blanfordiceras*, *Proniceras*, and *Spiticeras (Spiticeras)* R. Imlay and D. Jones [5] accepted Upper Tithonian age of the B. aff. okensis Zone. Unfortunately, we did not find any ammonites above the B. okensis Zone during the 1990 field season. In their list of Grindstone Creek ammonites Imlay and Jones ([5], table 2) mentioned only *Phylloceras*, *Lytoceras*, *Spiticeras* sp. ind. and *Parodontoceras reedi* (Anderson). First two genera are not important for chronostratigraphy. Both *Spiticeras* and *Parodontoceras* occur within the Uncitoides Zone. Based on the similarity of the main morphological features of both *B.* aff. *okensis* and *B. okensis* (Pavl.), I considered these taxa as synonymous [12]. At the same time I propose to accept the base of the B. okensis Zone (former B. aff. okensis Zone) as a Jurassic/Cretaceous boundary in the Paskenta area [11-15]. Later T. Bralower [3] came to the same conclusion. The Berriasian B. uncitoides Zone is correlated with the B. jasikovi and B. tolmatschowi Zones of the Northern Siberia (**Table 1**). There is no equivalent of the Siberian Tolmatschowi Zone in the Paskenta area sections, but few B. tolmatschowi -like forms have been found at the top of B. uncitoides Zone in the McCarty Creek section. The Berriasian age of Tolmatschowi Zone at the Pacific coast sections [6, 7] has been presumed before ([12]; see also later papers). According to our previous idea ([12] and following publications), the Berriasian/Valanginian boundary should be placed at the boundary between Uncitoides / Inflata-Pacifica Buchia-zones in the Paskenta area sections. T. Bralower [3] had a similar opinion on the base of nannofossils data.

Mainly Valanginian age of the B. inflata-pacifica Zone do not excite any doubt. There is some problem with the lower boundary of this zone in Northern Siberia, because Neotollia klimovskiesis Zone and Buchia inflata Zone lower boundaries do not coincide a little (**Table 1**). The precise correlation of the Berriasian / Valanginian boundary is a future problem. The best correlational level in the Valanginian is the lower boundary of the B. keyserlingi Zone. This boundary most probably lies near to the base of Astieriptychites astieriptychus ammonite zone, which is well-correlated with Placenticeras heteropleurum Zone of Saxony and Pertransiense Zone of the stratotype [2, 15].

Another reliable correlational level within the Valanginian is a lower boundary of the B. sublaevis Zone, which is roughly corresponding to the Lower/Upper Valanginian boundary (**Table 1**). In my opinion, *Buchia crassicollis solida* [5] is in reality *B. sublaevis* (Keyserling), which is abundant in the lower part of the Upper Valanginian at the Northern Siberia [12]. We have collected this species at the McCarty Creek section. In the both areas (Northern Siberia and Paskenta) the Sublaevis Buchia-zone overlies the Keyserlingi Buchia-zone. There is the same situation in the McCarty Creek section, although one specimen of this species was found in the Keyserlingi Buchia-Zone. Jones [8] assigned the portion of McCarty section lying above Keyserlingy Zone to Hauterivian. Such a conclusion is well corresponding to co-occurrence of B. sublaevis and Hauterivian ammonite *Jeannoticeras* in the uppermost fossiliferous level of the McCarthy Creek section.

Conclusion

The revision of the Tithonian-Hauterivian Buchia zonation of Paskenta area provides a chance to improve the stratigraphy of the sections which are very important for the Boreal-Tethyan correlation. The new biostratigraphical units have been established, including the Upper Valanginian – Lower Hauterivian Buchia sublaevis Zone. The zonal boundaries have been defined more precisely. The *Buchia* zonal correlation of the Subtethyan and Boreal successions has been proposed. On the other hand, many problems have been revealed. There are no correlational levels established throughout the Tithonian and around the Jurassic/Cretaceous boundary beds so far. There are no precise correlational levels within the Boreal and Subtethyan Berriasian. Many stratigraphical problems can be solved by collaboration of the specialists on the biostratigraphy and paleomagnetology (magnetostratigraphy). It is necessary also to sample a representative collections of buchias and ammonites together with microfossils in several parallel sections at the Paskenta area, Oregon, Washington states, Southern Alaska and in the Northern Siberia. I believe that the joint analysis of new data will make it possible to solve many problems of the Boreal-Tethyan correlation of the Jurassic/Cretaceous boundary interval.

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ON A TYPICALLY LATE JURASSIC PLIOSAUR FROM THE LOWER CRETACEOUS OF CRIMEA

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***Abstract**: For the first time a specimen referred to Pliosaurus is described from the Lower Cretaceous (Lower Valanginian), represented by a single tooth from Mount Sheludivaya in Crimea. This specimen demonstrates that two pliosaurian lineages crossed the Jurassic – Cretaceous boundary: the typically Cretaceous subfamily Brachaucheninae Benson et Druckenmiller, 2013 and typically Late Jurassic genus Pliosaurus Owen, 1841.*

***Key words**: Crimea, Lower Cretaceous, Pliosaurus*

Introduction

Pliosaurids were a long-lived and cosmopolitan group of marine top predators that spanned from the Middle Jurassic until the early Late Cretaceous (110 million years). Middle Jurassic and younger pliosaurids belong to a clade Thalassophonea [5]. Pliosaurid diversity declined in the Late Jurassic, with only macropredaceous forms remaining [5]. The latest pliosaurids are well known from the early Late Cretaceous [26]. However hitherto there were no authentic finds of pliosaurs in the early Early Cretaceous forming a gap in pliosaurian history.

In the collection of the Museum at the academic base named after Professor A.A. Bogdanov of Geological Faculty of Lomonosov Moscow State University there are several plesiosaurian teeth. One of them is diagnostic of the thalassophonean *Pliosaurus*: it is triangular in cross-section and possesses a broad flat

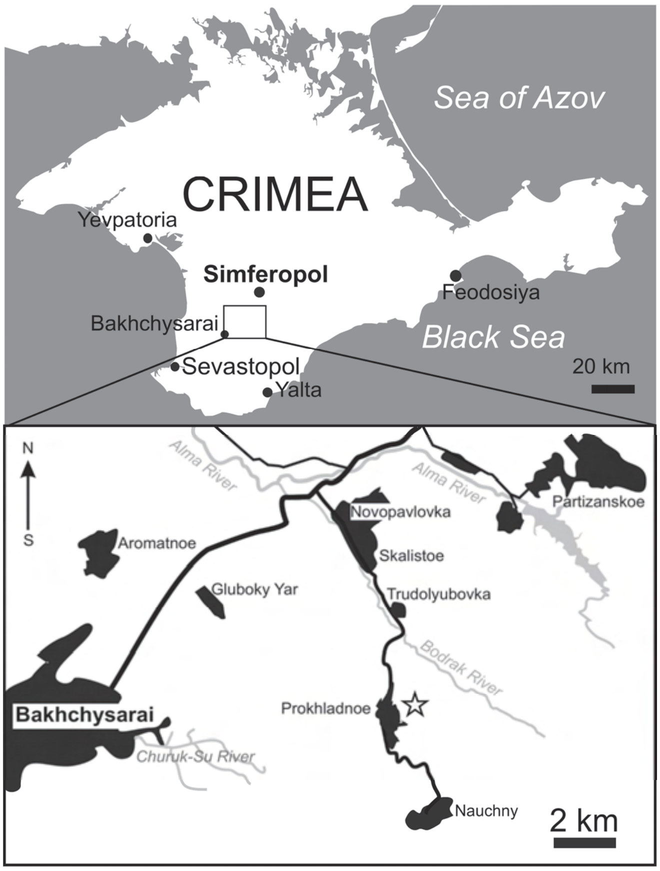

Fig. 1. Map showing the discovery site of h-216, *Pliosaurus* sp. indet. Locality is marked with an asterisk

labial surface [6, 27].

According to museum data this specimen was collected at the top of Mt. Sheludivaya (near Prokhladnoe village, Bakhchisaray district, Crimea) (**Fig. 1**). The top of the mountain is represented by Lower Valanginian sediments (conglomerates; sandstones and sandy limestones of nearshore facies), which lie transgressively over a Triassic – Middle Jurassic folded structure of terrigenous flysch deposits [3].

SYSTEMATIC PALEONTOLOGY

Sauropterygia Owen, 1860
Plesiosauria de Blainville, 1835
Pliosauridae Seeley, 1874
Thalassophonea Benson et Druckenmiller, 2013
Pliosaurus Owen, 1841
Pliosaurus sp. indet.
Fig. 2

Referred specimen**.** h-216, a partial tooth crown of *Pliosaurus* sp. indet; Museum at the academic base named after Professor A.A. Bogdanov of Geological Faculty of Lomonosov Moscow State University.

Locality and horizon**.** Lower Valanginian; Mt. Sheludivaya, Prokhladnoe village, Bakhchisaray district, Crimea.

Description**.** The preserved part of a tooth is a central fragment of the crown with broken base and apex. It is 22 mm long apicobasally and 15 mm wide in the broadest part of the labial surface.

The crown is pyramidal, slightly curved, and trihedral in cross section with a flattened labial surface (**Fig. 2D**). The apicobasally convex labial surface is flattened. It is the broadest surface of the tooth and bounded by two finely scalloped carinae. The lingual surface is weakly divided into three additional surfaces and the cross section becomes approximately trapezoidal to the base. The enamel of the flat surface lacks enamel ridges. The enamel of the lingual surface bears numerous coarse, apicobasally oriented dental enamel ridges. Ridges are widely spaced on the lingual surface, most enamel ridges extend half way up the crown. One ridge runs all along the apicobasal axis at the centre of the convex surface (**Fig. 2A**). The ridges are semicircular in cross-section, the longest ridge bears a fine groove in its center (**Fig. 2A**).

Discussion

Triangular cross-sectioned tooth crowns with flattened labial surface are common among Late Jurassic pliosaurids [6, 12, 17–20, 21–25, 27, 28], and this morphology is a unique synapomorphy of the genus *Pliosaurus* [6, 27]. By contrast, Middle Jurassic and all hitherto known Cretaceous pliosaurids possess subcircular cross-sectioned crowns with longitudinal ridges around the entire circumference of the crown [1, 2, 7, 10, 11, 14–16; 26, 27, 29].

Given that, the presence of trihedral crowns with flattened labial surface is a synapomorphy of *Pliosaurus* [6, 17], the described specimen can be defined as *Pliosaurus* sp. indet. However the described tooth lacks ‘classic’ trihedral moprhology

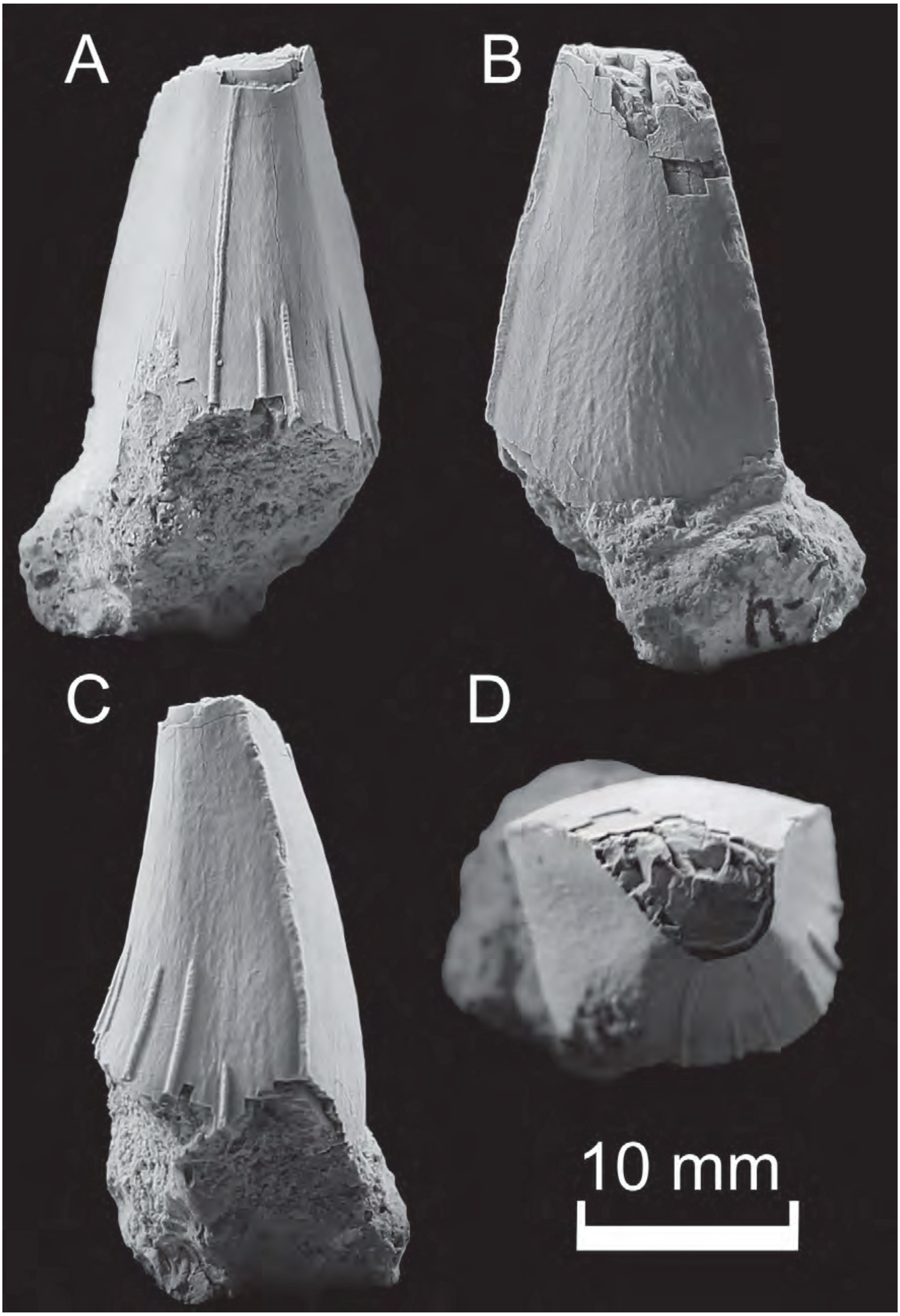

Fig. 2. The tooth of *Pliosaurus* sp. (h-216) in lingual (A), labial (B), 'axial' (C) and apical (D) views. Specimen was coated in ammonium chloride prior to being photographed.

and becomes trapezoidal to the base. So it seems different to both the 'classic' trihedral morphology and the subtrihedral morphology of some English Late Jurassic specimens [6, 27]. The trapezoidal and even squared cross-sectioned teeth occurred in some Russian Volgian (Tithonian) specimens ([9] Tab. II, figs. 4,5 and the author's pers. obs.), indicating a relationship of h-216 with a Volgian pliosaurids of the Russian Sea.

The oldest Early Cretaceous pliosaur hitherto known occured in the Late Barremian of Columbia and represents Brachaucheninae (referred to *Brachauchenius* by Hampe [13]). Until now, available fossil evidence indicated that that Brachaucheninae was the only pliosaurid clade to occur in the Cretaceous [5]. However unlike the specimen reported here, brachauchenines possesses circular cross-sectioned teeth [1, 26].

The new finding shows, that *Pliosaurus* also crossed the Jurassic – Cretaceous boundary, surviving into the earliest Cretaceous, in a similar manner to the cryptoclidid plesiosaurians, which are represented in the earliest Cretaceous by *Abyssosaurus nataliae* from the Hauterivian of Russia [4,8]. Both *Pliosaurus* and Cryptoclididae are more typical for Late Jurassic marine reptile assemblages, giving a reason to suggest that poorly known Early Cretaceous marine herpetofauna was transitional, and included both 'Jurassic' and 'Cretaceous' forms.

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PATTERNS OF SEDIMENTATION AT THE JURASSIC-CRETACEOUS BOUNDARY INTERVAL AT THE SOUTH OF PRICASPIAN DEPRESSION

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Abstract: *Characteristics of sediments characterizing the Jurassic-Cretaceous boundary interval of southern part of Pricaspian depression are provided. The most prospective objects for oil and gas exploration are the Valanginian rocks of the Lower Cretaceous. Spatial distribution of reservoirs within the Valanginian complex was controlled by paleo-elevation zones.*

Key words: *fluctuations of the sea level, paleo-elevations, downdip zones.*

Due to the active oil and gas exploration at the south of Pricaspian depression, both onshore and offshore, the study of Jurassic-Cretaceous boundary sediments, which are scarcely studied and poorly developed, but still perspective for oil exploration, become especially actual.

Upper Jurassic at the south of Pricaspian depression is represented by the Volgian (boreal analogue of the Tithonian stage) which is uniform in many wells and is represented mainly by limestones of mudstone type, gray, light-gray or dark-gray, fine-grained, composed by micro- to fine-grained dark-gray micrite (grain size less than 0,01 mm), with occasional debris of brachiopod shells. Locally the mudstone has an admixture of angular quartz grains (up to 5%) of 0,01-0,05 mm size. Infrequent packstones, composed of unbroken ostracod shells of 0,5 mm size, cemented by dark-gray micro-grained micrite (grain size less than 0,01 mm), are also met. Foraminiferal complex includes typical Volgian species: *Lenticulina infravolgaensis* Furss., *Lenticulina ponderossa* Mjatl., *Marginulina striatocostata* Furss., *Tristix temirica* Dain., *Saracenaria kasanzevi* Furss. Total thickness of the Volgian is 60-81 m. At the south of Pricaspian depression sediments of Volgian age are missing locally, in the areas of active saline domes. Larger areas with missing Volgian are known from the territory of Buzachi peninsula as well as to the south of it, in the sections of Mountain Mangyshlak.

It is assumed that on the Jurassic-Cretaceous boundary there is a non-sequence, i.e. the Berriasian stage is missing due to the terrestrial environment over the whole territory of Pricaspian depression, which is as a result of drastic fall of the sea level. Volgian sediments are mainly covered by the Valanginian, lying with unconformity. The only well at the south of Pricaspian depression with the Berriasian present, characterized by pelecypoda and foraminifera, is West Kusanbai P-58 [2]. The presence of the Berriasian sediments in the area nearby this well is explained by the downwarping of the local swally. Beyond the southern margin of Pricaspian depression the Berriasian is represented by shallow-water facies, well studied at Mangyshlak [3].

Due to their complicated geological structure, Valanginian sediments are currently out of the focus of oil and gas exploration, despite several commercial oil reservoirs were discovered both in terrigenous (Sazankurak oilfield) and carbonate (Kisimbai oilfield) reservoirs. However, further exploration surveys around known reservoirs in the Valanginian can significantly expand the prospects for the production and provide new lease of life to reservoirs, which are now considered depleted.

Valanginian sediments at south of Pricaspian depression are represented by various types of sequences reflecting fluctuations of the sea level and influenced by the paleo-elevations located to the south. One of such major paleo-elevations coincides with recent North Caspian elevation, where Valanginian sediments are missing, thus coinciding with certain area of missing Volgian. At Kurmangazy elevation the succession of the Valanginian, exposed by drilling in G-1 well section, is represented by 39 m thick clay-sandstone intercalation, with occasional beds of limestones and dolomites. Clay is dark-gray to gray, soft, pliable, subcalcareous and silty. Sandstone is fine to close-grained, gray, polymict, with grains of angular shape, with carbonate and locally sulphide cement. Limestone is fine-grained, with admixture of quartz and feldspar grains (up to 30%) of 0,1-0,2 mm size, of angular shapes, also with admixture of 1-2% to 10-15% rounded grains of brown colour with concentrical structure, 0,5-1 mm size, supposedly of siderite or leptochlorite nature. Also occasional glauconite grains of 0,1-0,2 mm size and rounded quartz grains of 1-2 mm size are encountered in the limestones. Also dolomite, fine-grained, brown-gray, composed of aggregates of fine-grained dolomite (size of grains less than 0,01 mm) locally with occasional grains of glauconite of 0,1 mm size and limestone of grainstone type, consisting of oolites cemented by sparite, is encountered. The presence of ferrigenous oolite in the Valanginian sediments was discovered in the section of South-Emba OP-2 well [1], and chamosite grains are mentioned by T. E. Ulanovskaya [6] in Shirotnaya 1 well. The Valanginian sediments in Kurmangazy G-2 well, having thickness 85 m, are characterized by higher concentration of sandstones and dolomites in comparison with G-1 well [6]. In the lower part of the succession of G-2 well there are sandstones, close-grained, with dolomitic cement (locally with high porosity) and dolomites, fined-grained with admixture of sandy material, mainly quartz grains, with interlayers of clays and limestones (mainly of grainstone type), silicified and dolomitized to the varying degree. At the top of the succession the rocks are represented by dolomites, fine-grained, with admixture of sandy material, mainly quartz grains and rarer glauconite grains, with interlayers of clays and limestones (mainly of grainstone type), dolomitized. At the topmost part of the succession there is the intercalation of clays, dolomites and limestones, dolomitized to the varying degree, where limestones are fine-grained and have the admixture (1-2% to 10-15%) of brown grains of 0,5-1 mm size with concentrical structure, supposedly of sideritic composition. By their lithological characteristics, these sediments are confidently correlated with the Valanginian sediments of G-1 well [5]. Thus, Valanginian sediments, uncovered by Kurmangazy G-2 well, had been accumulating with intensive income of clastic material from a local source.

Other type of Valanginian succession at the North Caspian paleo-elevation, having thickness up to 40 m, is exposed by Khazar 1 and Kalamkas-more 1 wells. The Valanginian in Khazar 1 well is represented by the intercalation of clay and limestone beds, with occasional interlayers of sandstones and dolomites. Clays are dark-gray to gray, soft, flexible, non-calcareous, silty. Limestones (of packstone-grainstone type) are light-grey, composed of grains, among which oolites are well-recognizable; also non-porous oolitic grainstones fully consisting of oolitic grains with sparite cement, are met. Sandstones are close-grained, gray to light-gray, of quartz-feldspar composition, with calcareous cement, non-porous. Dolomites are grey to grey with yellowish shade, close-grained, locally fine-grained, porous, cavernous (nariform). Detailed petrographic study has revealed that the dolomite has relict structure and wasformed over the oolitic limestone of grainstone type. Also occasional inclusions of light-grey, almost white anhydrite, fine-crystalline and saccharoid, are encountered. A similar oolitic limestone is found in the Kalamkas-sea 1 well, however, dolomite is not present there.

At the south of Pricaspian depression beyond the North Caspian paleo-elevation the accumulation of the Valanginian rock complex is controlled by the growing saline domes, which are distributed locally and occupy just small areas. Saline domes can be subdivided into two types by their tectonic activity: 1) passive domes – produce an elevation, but without erosion of overlying sediments; 2) active domes, which change the relief of basin floor, and their growth is accompanied by the erosion of overlying rocks and appearance of local subaqueous source of clastic material.

Paleo-elevation, produced by the passive domes, is exposed by Kashagan West 1 well. The Valanginian section here is represented by the alternation of clay, dolomite and limestone beds, with total thickness of 18 m. Clay is dark-gray to gray, soft, flexible, non-calcareous, silty. Dolomite is fine- to close-grained, gray, porous, locally cavernous, locally with the admixture of 1-5% to 10-30% quartz grains and occasional glauconite grains. Rarer dolomite is fine-grained, gray, poor-porous. Limestone (of grainstone type) consists of carbonate oolites, locally with the admixture of bioclasts, cemented by sparite. Foraminiferal complex includes typical Valanginian species: *Lenticulina infravolgaensis* Furss., *Lenticulina ponderossa* Mjatl., *Marginulina striatocostata* Furss., *Tristix temirica* Dain., *Saracenaria kasanzevi* Furss. The porosity observed in dolomite is secondary, caused by the processes of secondary dolomitization over the limestone of grainstone type, consisting mainly of bioclasts and oolites. The following sequence of pore space formation can be deduced: after accumulation of carbonate sediments, dolomitization of cement and partly of skeletal grains occured, followed by the processes of dissolution that affected still untouched bioclasts and oolites.

Similar successions of the Valanginian having 15-20 m thickness and also associated with paleo-elevations produced by passive domes, are exposed by Kisimbai 34 and Elemes North 806 wells. They are represented by limestone and dolomite, and the best reservoirs are associated with secondary dolomites formed over grainstones with large number of bioclasts as well as oolitic grains.

Valanginian sediments in the downdip zones (located between paleo-elevations of passive domes) are exposed by Kashagan East 1 well, where they have thickness 50 m. Clay is dark-gray to gray, soft, flexible, non-calcareous, silty, dolomite is fine- to close-grained, gray, poor-porous to porous, locally cavernous, locally with admixture of up to 10-30% quartz and occasional glauconite grains. Sandstone is gray fine- to close-grained, polymict,, with grains of angular shapes, with calcite cement having block structure. Also rare anhydrites of fine- to close-crystalline structure and gray colour are encountered.

Similar sections of Valanginian, developed between the paleo-elevations of passive saline domes, are exposed by S. Nurzhanov 652 and Matken South 1 wells, having thickness 70-80 m. According to the core from S. Nurzhanov 652 well, the Valanginian is dominated by close-grained sandstone, with varying content of clayish material, and also core samples characterized by high porosity and permeability are met, but mainly the sandstone is poor-porous. This can be explained by the intensive bioturbation of the sediments, which disrupted the connectivity of pore space. Locally lithoclasts of limestone with oolitic grains are encountered. Rarer interlayers of clay, dolomite and anhydrite of 0,1-1 thickness and frequent inclusions of anhydrite both in sandstone and dolomite are met.

The paleo-elevation, associated with formation of active saline dome, is exposed by wells at Sazankurak oilfield. Here the Valanginian complex has thickness from 26 to 79 m and is developed at the flanks of the dome, overlying the eroded top of the Middle Jurassic. Productive beds of the Valanginian are represented by sandstones, locally sands, gray, fine- to medium-grained, polymict, with argillaceous-calcareous cement. The thickness of sandy rocks is mainly 10-15 m, locally increasing up to 20-45 m. Zone of enhanced thickness of reservoirs has the form of band (along the paleo-coastline) running parallel to the flank of the dome.

The following scenario of sea level changes near the Jurassic-Cretaceous boundary can be supposed with high confidence: in the Volgian the sea level of shallow-water marine basin remained relatively low comparing with the Kimmeridgian, and in the Berriassian the whole territory of Pricaspian depression was elevated and exposed above the sea-level. In the Valanginian there was a small sea level rise, which resulted in mosaic facies distribution (shallow-water at paleo-elevations, and deepwater facies in the depressions). Also from time to time sea-level falls occurred, resulting in the formation of mini-basins. In the Hauterivian there was even a bigger sea level rise which resulted in the equation and reduction of facies diversity, i.e. the sediments were accumulated throughout in the deep sea environments and paleo-elevations did not have significant influence at the distribution of sediments anymore.

Thus, during the Valanginian the southern part of Pricaspian depression was a marine basin, and three zones can be emphasized (**Fig. 1**):

1. Zone of missing sediments (islands) including the North Caspian elevation as well as areas of active saline domes which possibly were islands at that time and acted as source areas of terrigenous material.

2. Shallow-water zone with active hydrodynamics, which includes areas of passive saline domes and coastline around islands, with sandy and carbonate sedimentation (oolitic grainstones), free of argillaceous material. Thickness of sediments here varies from 10 up to 30-50 m, rarely up to 90-100 m. A similar zone is typical for Mountain Mangyshlak, where the Valanginian sediments overlie with major stratigraphic unconformity sediments of different age [2].

The base of the Neocomian is characterized by the presence of thin basal conglomerate, which includes pebbles of the Upper Jurassic carbonate rocks. Valanginian sediments of Mountain Mangyshlak are represented by sandstones with the traces of cross-bedding, ripplemarks and by clastic limestones characterized by oolites, numerous oyster banks, bryozoan colonies and corals.

3. Relatively deep-water zone with quiet hydrodynamics, where mainly

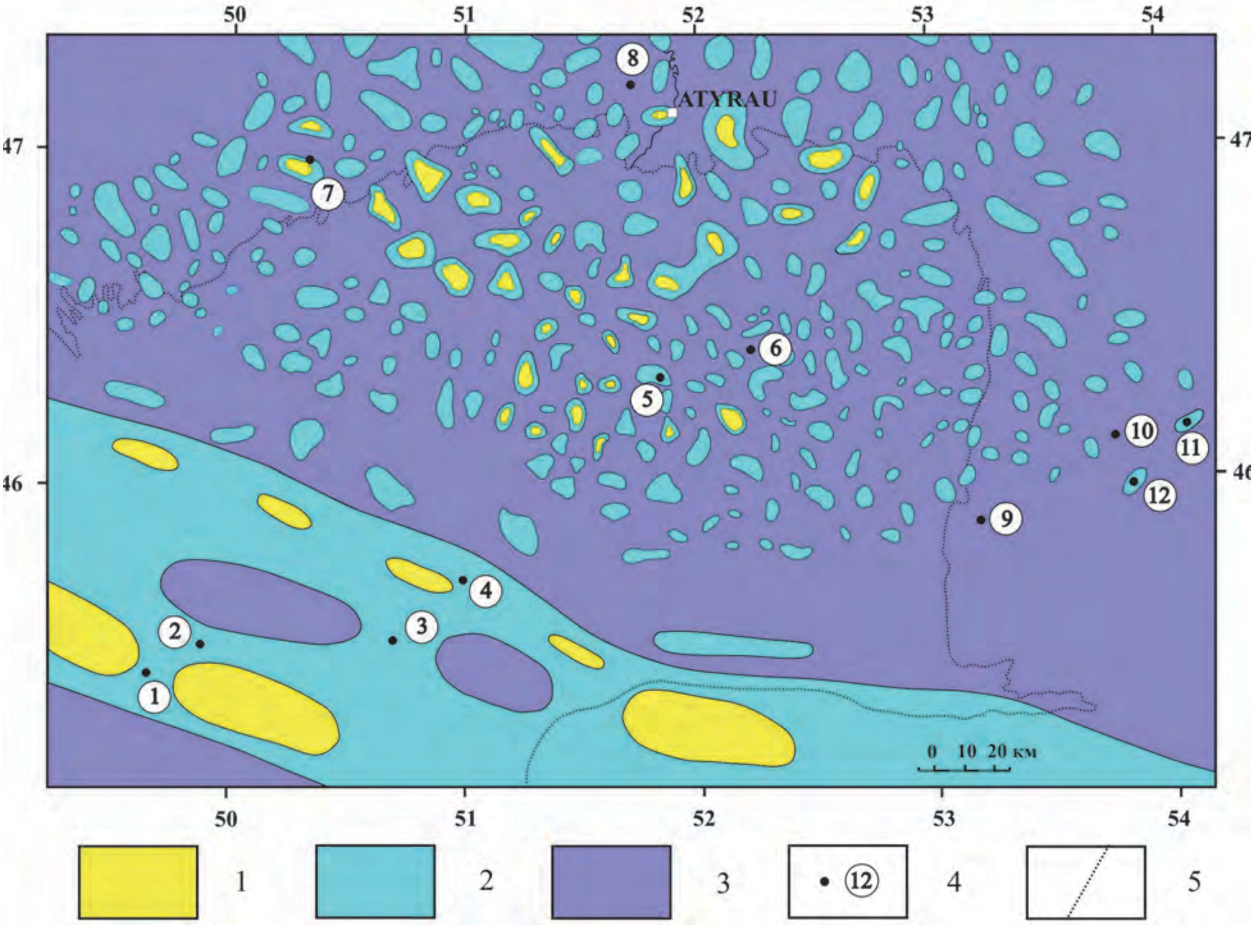

Fig. 1. Distribution of facial zones of the Valanginian sediments at the south of Pricaspian basin.

Legend: Sedimentation types: 1. Zone of missing sediments (islands), 2. Shallow-water zone with active hydrodynamics, 3. Relatively deep-water zone, 4. Wells: 1. Kurmangazy G-1. 2. Kurmangazy G-2. 3. Khazar 1. 4. Kalamkas-sea 1. 5. Kashagan West 1. 6. Kashagan East 1. 7. Sazankurak G-2. 8. West Kusanbai P-58. 9. S. Nurzhanov 652. 10. Matken South 1. 11. Kisimbai 34. 12. Elemes North 806, 5. an outline of modern Caspian Sea.

argillaceous sediments were accumulated. Not only argillaceous, but also sandy material and limestone lithoclasts were washed into this zone from the paleo-elevation (section of S. Nurzhanov 652 well). Sedimentation of anhydrite, supposedly, occurred locally (in the mini-basins) accordingly with the periodical sea-level falls. Thickness of such sediments is 60-100 m, rarely up to 150 m. Similar characteristics are observed for zones with inherited sags (eg. South-Bozachi sag).

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