Some Calcareous Nannofossils from the Upper Jurassic-Lower Cretaceous Bazhenov Formation of the West Siberian Marine Basin, Russia

Yuri N. Zanin*, Albina G. Zamirailova and Vika G. Eder

Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences Acad Koptyug pr. 3, Novosibirsk, 630090, Russia

Abstract: Six species of four calcareous nannofossil genera (*Ellipsagelosphaera* Noël,1965, *Watznaueria* Reinhardt, 1964, *Cyclagelosphaera* Noël, 1965 and *Tetralithus* Gardet, 1955) from the black shale Bazhenov Formation of the West Siberian marine basin are described in layers, transitional from the Upper Jurassic (the Volgian-Tithonian Stage) to the Lower Cretaceous (the Berriasian Stage). Stratigraphically, the presence of the species of all genera in the Bazhenov Formation corresponds to the world data. Three new species (*Ellipsagelosphaera bazhenovi* Zanin sp.n., *Watznaueria* sp. and *Tetralithus isopelxiros* Zanin sp.n. have been determined.

Keywords: Calcareous nannofossils, upper Jurassic-lower cretaceous, Siberia, Russia.

1. INTRODUCTION

The black shale Bazhenov Formation (Upper Jurassic-Lower Cretaceous) is regarded as a source for the rich oil fields of West Siberia, which attracted the attention of many researchers in the last fifty years (1-6). It is distributed in West Siberia in an extensive (more than 1 million sq. km.) area between the Yenisei River region in the east and Urals in the west (Fig. **1**). Its thickness in most cases does not exceed 25-35 m, occasionally reaching 60 m. The main feature of the formation is the high content of organic carbon, which amount reaches in private samples 20% in the central part of the basin, decreasing to the margins. The leading rock-forming inorganic components of the formation are autogenous silica, which is believed to form due to the dissolution of radiolarian shells, clay minerals (mixed-layer illite-montmorillonite, chlorite, kaolinite, less commonly montmorillonite proper), pyrite, and carbonate minerals [1-6].

The authors [4, 6] have divided the entire set of rocks of the formation into two groups: clayey-siliceous rocks (including silicites), which are dominant, and mudstones. The rocks of the first group have a higher average content of total organic carbon (11% for the central part of the basin), pyrite (7.8%), quartz (42.6%) and a lower content of clay (20.3%), whereas for the mudstone these parameters are 3.0%, 3.72%, 23.8%, 50.4%, respectively. By combination of features, mudstones are considered as products of rapid turbidite sedimentation, and clay-siliceous rocks the result of slow hemipelagic sedimentation [4, 6]. Stratigraphic position of the Bazhenov Formation is defined from the lower part of the Volgian (Tithonian) to the Berriasian, inclusive of some rejuvenation of the Formation upper boundary in a westerly direction [3].

*Address correspondence to this author at the Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences Acad Koptyug pr. 3, Novosibirsk, 630090, Russia;
Tel: +7 (383) 333 23 03; E-mail: zaninyn@ipgg.nsc.ru

The study of Mesozoic calcareous nannofossils of the region was firstly conducted by Vekshina [7], who investigated the calcareous nannofossil of Maastrichtian rocks of the West Siberian marine basin. Later, this author [8, 9] described calcareous nannofloras from a part of the Maryanovsk Formation, later formalized as Bazhenov Formation [10], identifing the following species: *Micula exile* Vekshina cent. n., *Micula culp* Vekshina cent. n., *Rhabdolithus sp.*, *Zigolithus sp.* [8]; *Discolithus sp.sp., Sphenolithus sp.sp., Tremalithus sp.sp., Calcidiscus sp.sp., Rhabdolithus sp.sp.*, and *Caliptrolithus sp.sp.* [9]. It was also noted that these nannofloral assemblages were characterized by very poor preservation. Kontorovich *et al.* [11] noted indeterminate specimens in thin sections from the same deposits. Gurari *et al.* [10] interpreted the pelletal limestone of the Bazhenov Formation as calcareous nannofossil oozes, but actually none were identified by the authors.

In recent decades, the Jurassic calcareous nannofossils taxonomy and biostratigraphy were deeply studied in several worldwide regions and oceans: Cuba [12], North Africa [13], Ukraine [14, 15], Britain and France [16-26], Swizerland and Germany [27, 28], Eastern Trans-Ural region [29], Moscow region [30], Volgian River basin [31, 32], Mediterranean region [33-40], as well as from Altantic and Pacific Oceans through the Deep Sea Drilling Project (DSDP) [41-43 and references therein]. However, limited attention [7-9] has focused on the Jurassic deposits of the West Siberian marine basin. The materials presented in this study may help to some extent to fill this gap.

2. METHODOLOGY

The study of calcareous nannofossils was performed using a scanning electron microscope GEO 1430VP. Studied samples were rock chips sprayed with gold. The clay-siliceous samples analyzed are characterized by higher content of calcite compared with the mudstone [4, 6], suggesting also higher content of calcareous nannoplankton. Nannofossils identified in the Bazhenov Formation come from borehole No. 8155 of the North Nivagalskaya area

Fig. (1). Some Calcareous Nannofossils from the Upper Jurassic-Lower Cretaceous Bazhenov Formation of the West Siberian Marine Basin, Russia. 1 – position of the borehole No 8155 of the North-Nivagalskaya area.

(Fig. **1**), core sample of clay-siliceous rock No. 8155-CH-23 taken at a depth of 2770 meters, from layers dated as upper substages of the Upper Jurassic and Lower Berriasian (V.A. Zakharov and Yu.I. Bogomolov, written communication). The mineralogical composition of this rock sample is pyrite (11.5%), organic matter (13.7%), calcite (21%), clay and silica (54%). Abundance of calcareous nannoplankton is high and six species have been identified. It has to be noted that none of the identified species are identical to those previously described by the precedent author [7-9].

3. SYSTEMATIC DESCRIPTION

Class **HAPTOPHYCEAE** Christensen, 1962

Suborder **COCCOLITHOPHORALES** Schiller, 1936

Family **Ellipsagelosphaeraceae** Noël, 1965

Genus ***Ellipsagelosphaera*** Noël, 1965

Ellipsagelosphaera keftalrempti Grün, 1975

Fig. (**2a**)

1964 *Watznaueria communis* Reinhardt: Reinhardt [28, p.19, plate 4, fig.1].

1975 *Ellipsagelosphaera keftalrempti* Grün: Grün, Allemann **[**44, p. 161, text-fig. 7, pl. II, figs. 5-6].

1979 *Ellipsagelosphaera keftalrempti* Grün: Hamilton [45, p.10-11, pl., fig. 3,4].

1980 *Watznaueria communis* Reinhardt: Lyulieva and Permyakov [15, p. 21, table. 20, fig. 2].

1982 *Ellipsagelosphaera keftalrempti* Grün: Lyulieva, Zmur [29, p. 1197, pl. 1, fig. 2].

1991 *Ellipsagelosphaera keftalrempti* Grün: Fiorentino [46, p. 121, pl. I, figs.13,14, pl. II, figs. 6,7].

Derivation of name: After the terrain Kef Alrempt, North Africa.

Holotype: SEM 71,159. Department of scanning electron microscopy of the Institute of Geology, University of Berne. Berriasian, Miravetes section in the area of Murtsipa, Spain [25, table. II, fig. 6, SEM micrograph of 216/1].

Material: Seven well-preserved forms.

Diagnosis: The species is composed of three concentric rings of plate elements which are not deformed, with a small change in the width of the plates from the periphery to the center, a very substantial reduction in the length of the

elements from the first (external) ring to the second and from the second – to the third. The slopes of the first ring elements in the plan are oriented in the opposite direction clockwise. The number of elements in the first concentric ring is 24. All these features are characteristic of the species *Ellipsagelosphaera keftalrempti* Grün: from Berriasian sediments of southern Spain [44, table II, fig. 5].

Description: Forms are slightly or substantially elliptical, 4-4.8 μ in width and 4.9-5.2 μ in length with a central hole of 1.2-1.5 μ in diameter. Plate elements form three concentric rings, either of which is individual and with sharp boundaries between them. In all rings, plate elements do not overlap each other. The external ring, the first concentric layer, is composed of elongated plate elements l.2-1.5 μ in length, with slightly reduced width in the direction from the margin to the central part of coccolith. Edges of these external plate members on the outer side are smooth and straight. The secondary, intermediate ring is composed of the elongated members of 0.3-0.5 μ in length, slightly narrowing towards the inner part of coccoliths. These elements are closely adjacent to the inherent limitations of plate elements in the outer zone, but are not continuations. The third inner layer is composed square "cubes" that are not connected with the elements of the intermediate layer. Their width is 1/3 of the value of the latter. On the distal side the elements of the first (external) ring are tilted to the outer side and are oriented in plan a counter-clockwise direction. The elements of the second and third rings are tilted toward the center of coccolith and are oriented radially in plane-view.

Comparison and remarks: The form considered is completely identical to those described in the literature [44]. Sometimes the family *Ellipsagelosphaeraceae* is identified with family *Watznaueriaceae* [16] and based on the rule of priority, the preference is given to the last of these terms, but such a combination of these two families is not accepted by all [17,18]. This concept is shared by the authors, who accepted the indication [44, p. 80] that plate elements of coccoliths *Watznueria* are crescent-shaped, which does not correspond to the described forms.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), Storage No. 2024, (Fig. **1**), SEM micrograph 07.13. 2009/9.

Ellipsagelosphaera bazhenovi Zanin sp.nov.

Fig. (**2b**)

Derivation of name: After the Bazhenov Formation.

Holotype: SEM 2024 CSGM MS. West Siberia, North-Nivagalskaya area, well 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage, sample 8155-CH-23, (Fig. **2c**, **d**) SEM micrograph.

Material: Six incomplete forms, well preserved.

Diagnosis: Coccolite composed of three weak elliptical rings, the external of which is tilted to the outside, intermediate and internal - to the internal side. Characterized by rounded inner and outer ends of the plate elements of the external ring.

Description: The complete forms of coccoliths of this type are not encountered, but even incomplete forms allow us to give their qualitative description. Coccoliths are slightly elliptical, 3-4 μ in size, composed of three concentric layers, the dimensions of the external elements are drastically reduce towards the inside. The elements of the outer layer of the distal part are inclined outwards, the intermediate and internal - to the center of coccoliths. The elements of the external ring have rounded exterior and interior ends. The elements of the intermediate ring are square in plane-view.

Comparison and remarks: This species differs from the species *Ellipsagelosphaera keftalrempti* Grün, 1975, similar in morphology, in rounded but not straight external and internal ends of the plates of the exterior ring and square in plan, rather than elongated, like in the indicated species, elements of the intermediate ring.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), Storage No. 2024, (Fig. **2b**) SEM micrograph 15/02/2008/4.

Ellipsagelosphaera ovata (Bukry, 1969) Black,1973

Fig. (**2c**)

1969 *Watznaueriaceae ovata* Bukry: Bukry [47, p. 33, pl.11, fig. 11].

1973 *Ellipsagelosphaera ovata* Black:Black [48, p.71, pl.26, figs. 10-12].

1975 *Ellipsagelosphaera ovata* Black: Grün, Allemann [44 p.160-161, text-fig. 6, pl. II, figs. 7-9].

1980 *Ellipsagelosphaera ovata* Black: Grün, Zweili [27, 233-234, pl. 3, figs. 2-4].

1991 *Ellipsagelosphaera ovata* Black:Fiorentino [46, p. 121, pl.III, fig. 3].

2008 *Watznaueria ovata* Bukry: Gavrilov *et al.*, [49, p. 402, pl. 6, fig. "r"].

Holotype: Gault Clay Formation, Lower Cretaceous, England

Material: Nine forms, well preserved.

Diagnosis: The oblong oval form, the large internal opening, the bend of plates composing distal shield in their middle parts.

Description: Coccoliths substantially elliptical shape, with single distal shield, 4 - 5 μ in length and 3-4 μ wide. The size of the inner hole 2-2.5 μ long and 1-1.3 μ in width. Plates of elements of proximal shields are bent and their external parts are oriented clockwise.

Comparison and remarks: The species differs from the close to it *E. britanica* by significant lengthening and the lack of a bridge or other filling in the central area what is often observed for *Ellipsagelosphaera britanica*.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), Storage No. 2024, (Fig. **2c**), SEM micrograph 15/02/2008/4.

Genus ***Cyclagelosphaera*** Noël 1965

Cyclagelosphaera margereli Noël, 1965

Fig. (**2d**)

1965 *Cyclagelosphaera margereli* Noël: Noël [50, p. 8, figs. 45,46, 48].

1971 *Cyclagelosphaera margereli* Noël: Rood, Hay, Barnard [17, p. 220, pl. 5, figs. 8, 9].

1975 *Cyclagelosphaera margereli* Noël: Grün, Allemann [44, p. 165,166, text-fig.10, pl. III, figs. 1-3].

1979 *Cyclagelosphaera margereli* Noël: Medd [19, p. 73, pl. 8, fig. 5].

1991 *Cyclagelosphaera margereli* Noël: Fiorentino [46, p. 121, pl. III, fig.1].

2008 *Cyclagelosphaera margereli* Noël: Casellato [51, p. 85, pl. VIII, figs. 5-7].

2008 *Cyclagelosphaera margereli* Noël: Gavrilov *et al*., [49, p. 403, pl. 6, fig. "z"].

2009 *Cyclagelosphaera margereli* Noël: Matveev [52, p. 105, pl.1, fig. 3].

Holotype: Number is not indicated. Original specimen is kept at the Scripps Institution of Oceanography, La Jolla, California.

Material: Five well-preserved forms.

Diagnosis: Proximal single-layer forms formed by radial or close to radial plate elements, closely adjoined to each other without overlapping, and with serrated external borders.

Description: Rounded or very weakly pronounced elliptical shapes of 3.4 to 4.6 μ in size, composed of straight single-layer plate elements, which are located radially or close to radially, slightly inclined in the latter case counterclockwise tight to each other without overlapping or with very weak overlapping, sharply tapering from the edge of the form to the center, with a relatively small inclination of the elements in this direction, with serrated external borders. The length of the plates is 1.1 μ, their width at external boundary part is 0.45 μ, in the central part - 0.11 μ. The central area is small (0.5-0.75 μ).

Comparison and remarks: The general structure, similar to the morphology of the plate elements (significant restriction to the center of the form, serrated external borders), their number, the radial orientation and interrelations (tight fit without overlapping each other) are considered to correspond to species *Discoaster multiradiatus* Bramlette, Riedel, 1954. However, in contrast to this form the described one is characterized by its smaller dimension and its shield morphology.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), Storage No. 2024, (Fig. **2d**), SEM micrograph 13.07.09/16.

Family **Watznaueriaceae nom. subst.** Rood *et al*., 197

Genus ***Watznaueria*** Reinhardt, 1964

Watznaueria sp.

Fig. (**2e**)

Holotype: SEM 2024 CSGM MS North-Nivagalskaya area, well 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage, sample 8155-CH-23, (Fig. **2c**). SEM micrograph 14.05.07/2-1.

Material: Two well-preserved forms.

Diagnosis: Single-layer elliptical coccoliths, with plate elements that have a kink in their middle part. The outer parts of the elements have a steep slope and are oriented in a counter-clockwise pattern and the internal ones are essentially flattened.

Description: Coccoliths slightly elliptical, single-layer, 4 and 6 μ in size, formed by the deformed plate elements, which do not overlap each other. There is a twofold deformation of plate elements. On one hand, they are bent in their middle (in length) at an angle close to 90 degrees, forming a funnel with a wide edge. In the outer parts of the elements, crescent-shaped curves are observed, oriented on the distal side counterclockwise, as well as the orientation of elements themselves in this direction at an angle of 45^{o}. The width of the plate elements towards the central hole is narrowed considerably. The total number of plate elements is defined as 26. Judging from the inflection in the middle part of the layers, the form is assigned to zigolith.

Comparison and remarks: A close bend of the plate elements is observed in the form *Birkelundia arenosa* Perch-Nielsen, 1971 [53, pl. VI, fig. 8], but in this species the angle of bend in the middle of the plate is sharp, but not slightly rounded, as in our case. The observed crescent-shaped bend is very weak and corresponds to the marginal outer parts of the plate, but not to the middle ones.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), № Storage 2024, (Fig. **2e**), SEM micrograph 14.05.07/2-1.

Family **Braarudosphaeraceae** Deflandre, 1947

Genus ***Tetralithus*** Gardet, 1955

Tetralithus isoplexiros Zanin, 2012 n.sp.

Fig. (**2f**)

Derivation of name: From tetra (four) and isoplexiros (equilateral) - in Greek. It was impossible to give to this form the name "pyramidal" as it was used early for the form of other habit.

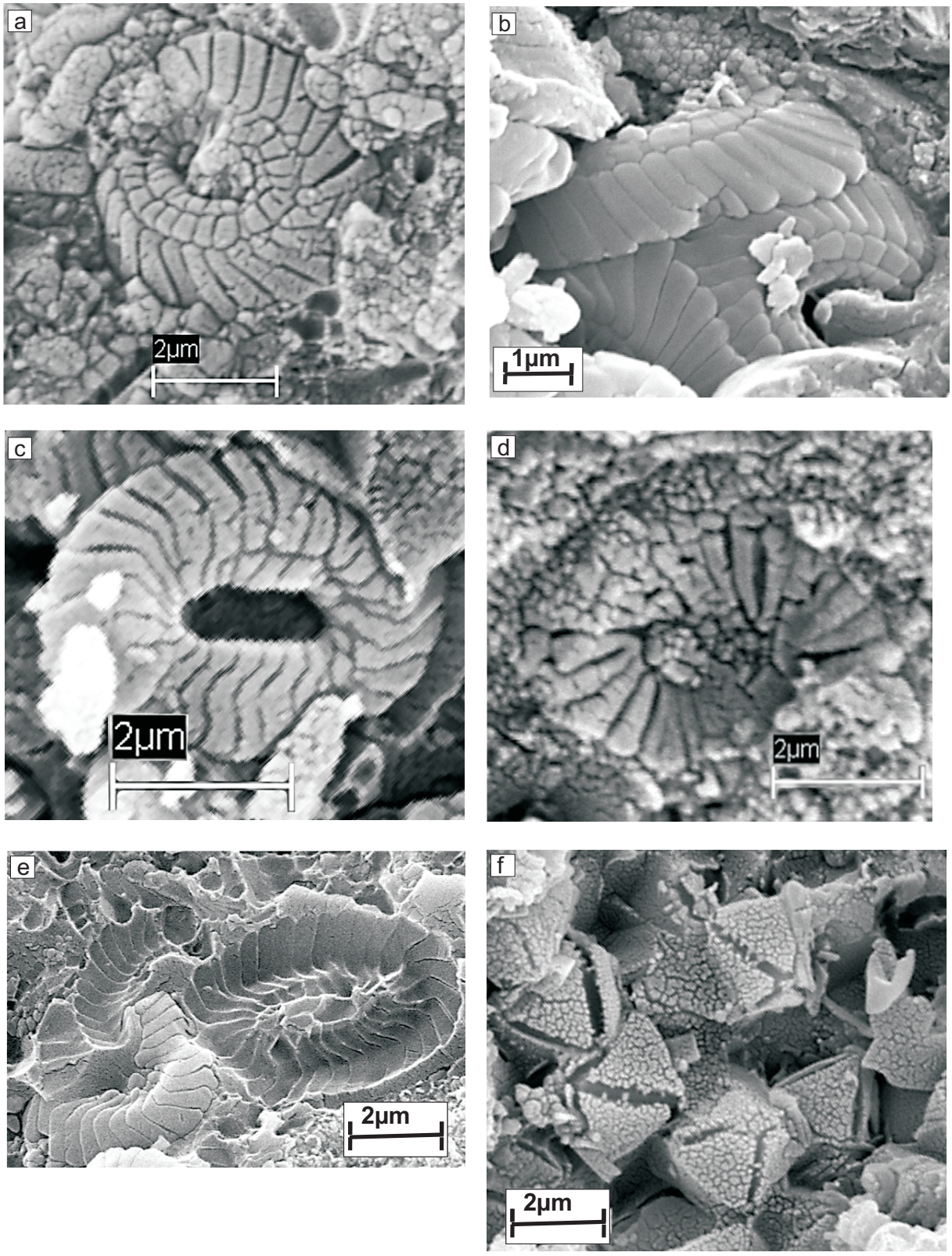

Fig. (2). **(a)**. *Ellipsagelosphaera keftalrempti* Grün, 1975. Distal sides.
(b). *Ellipsagelosphaera bazhenovi* Zanin sp.nov. Distal sides.
(c). *Ellipsagelosphaera ovata* (Bukry, 1969) Black, 1973. Distal sides.
(d). *Cyclagelosphaera margere*li Noël, 1965. Distal sides.
(e). *Watznaueria sp.* Distal sides.
(f). *Tetralithus isoplexiros* Zanin, 2012 n.sp. Distal sides.

Holotype: SEM 2024 CSGM MS. West Siberia, North-Nivagalskaya area, well 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage, sample 8155-CH-23, (Fig. **2f**), SEM micrograph.

Material: Five complete well-preserved forms.

Diagnosis: Forms are of true pyramids, with gaps between the joints of edges.

Description: The forms are composed of four triangular equilateral elements forming pyramides. The width of these elements at their base is 2 μ, the height along the diagonal is 1.8 μ. Along the edges of the pyramid, at the junctions of the elements 0.2-0.3 μ-wide gaps are observed, framed on both sides by needle-like outgrowths on the adjacent sides (edges) of the elements whose length is half the width of the gap. We do not exclude that some of these forms constitute bipyramids (octahedrons).

Comparison and remarks: Such species of coccoliths have not been described previously. Coccoliths of the *Tetralithus obscurus* Deflandre 1959 are composed of four triangular elements too, sometimes with gaps along the edges of these elements [15], but forms of these triangular elements are incorrect and they do not form pyramids.

Locality: West Siberia, North-Nivagalskaya area, borehole No 8155, depth 2770 m, Bazhenov Formation, transitional layers from the Volgian (Tithonian) stage of the Upper Jurassic to the Berriasian stage.

Depository: sample 8155-CH-23, Central Siberian Geological Museum, Monograph Section (CSGM MS), Storage No. 2024, (Fig. **2f**), SEM micrograph 15.02.08/10.

4. DISCUSSION AND CONCLUSION

Calcareous nannofossils are of important stratigraphic significance. We consider from this point of view the forms described above. It concerns genera *Watznaueria* Reinhardt, 1964, *Ellipsagelosphaera* Noël, 1965, *Cyclagelosphaera* Noël, 1965. Authors observed in the Bazhenov Formation the above-stated, coccoliths *Ellipsagelosphaera keftalrempti* Grün (Fig. **2a**), *Ellipsagelosphaera bazhenovi Zanin sp.n.* (Fig. **2b**). *Ellipsagelosphaera ovata* Black (Fig. **2c**). *Cyclagelosphaera margereli* Noël (Fig. **2d**), *Watznaueria bazhenovi Zanin sp.n.* (Fig. **2e**), *Tetralithus isoplexiros* Zanin (Fig. **2f**). In accordance with the publications of various authors the age distribution of *Ellipsagelosphaera keftalrempti* Grün was specified as the Middle Callovian-Upper Hauterivian [44], Bathonian-Bajocian [45], Oxfordian (*Watznaueria communis* Reinhardt [15]), Tithonian [29], Valanginian [46], the age intervals distribution of *Ellipsagelosphaera ovata* Black was determined as Upper Tithonian-Santonian [44], Upper Cretaceous [47] Lower Cretaceous [48], Dogger-Malm [27], Valanginian [46], Kimmeridgian-Tithonian [49], the age intervals distribution of *Cyclagelosphaera margereli* Noël, 1965 was determined as Oxfordian-Maastrichtian [44], Tithonian [29], Bathonian-Callovian and Oxfordian-Danian [53], Tithonian [52], Early Tithonian [54], Kimmeridgian-Tithonian [49] Valanginian [46], Lower Tithonian to Berriasian [51], Oxfordian-Albian [55]. Apparently *Ellipsagelosphaera keftalrempti* Grün characterizes an age interval from the middle of the Middle Jurassic to the middle of the Lower Cretaceous, *Ellipsagelosphaera ovata* Black – an age interval from the middle of the Lower Jurassic to the middle of the Upper Cretaceous, *Cyclagelosphaera margereli* Noël – from the upper part of the Middle Jurassic to the upper part of the Upper Cretaceous inclusive. Thus the majority of authors attribute the last form to the Tithonian, and the age interval of existence of other described forms, almost in all cases, except the most rare exceptions, includes this stage. As for the new forms that are discussed in the article (*Ellipsagelosphaera Bazhenovi* Zanin 2012*, Watznaueria sp., Tetralithus isoplexiros* Zanin, 2012) they by definition in the Bazhenov Formation should be referred to the Tithonian - Berriasian boundary.

ACKNOWLEDGEMENTS

We are grateful to A.T. Titov and I.V. Aborneva for help in obtaining electron microscope pictures of the described forms of the calcareous nannofossils, Yu.I. Tesakov for the contributing to the preparation of the manuscript and reviewers of the article for many helpful recommendations.

CONFLICT OF INTEREST

Declared none.

REFERENCES

[1] Kontorovich AE, Nesterov II, Salmanov FK, Surkov VS, Trofimuk AA, Erv'e JG. Oil and gas geology of Western Siberia. Moscow: Nedra 1975.

[2] Braduchan Y, Golbert AV, Gurari FG, *et al*. Bazhenov horizon of Western Siberia. Novosibirsk: Nauka1986.

[3] Shurygin BN, Nikitenko BL, Devyatov VP, *et al*. Stratigraphy of the oil and gas basins in Siberia. Jurassic system. Novosibirsk: Publishing House SB RAS Branch "GEO" 2000.

[4] Zanin YuN, Zamirailova AG, Eder VG. Some aspects of the formation of the Bazhenov Formation in the central areas of the Western Siberian sedimentary basin. Lithosphere 2005; 4:118-35.

[5] Zakharov VA Conditions of the formation of the high carbonaceous Bazhenov Formation of the Volgian-Berriasian stages of Western Siberia according to paleoecology. In: Rozhnov SV, Ed-in-Chief. Evolution of the biosphere and biodiversity. 5. Problems of stratigraphy and paleobiogeography. Moscow: KMK Scientific Press Association 2006; pp. 552-68.

[6] Zanin, YuN, Eder VG, Zamirailova AG. Composition and formation environments of the Upper Jurassic-Lower Cretaceous black shale Bazhenov Formation (the central part of the Western Siberian Basin). Mar Pet Geol 2008; 25: 289-06.

[7] Vekshina VN. Coccolithophorids of Maastrichtian Stage deposits of the Western Siberian Plain: Proceedings of paleontology and stratigraphy of Western Siberia. In: Proceedings of the SNIIGIMS. Leningrad: Gostoptekhizdat 1959; vol. 2: pp. 56-82.

[8] Vekshina VN. Coccolithophorids of the Maryanovsk Formation of the Western Siberian Plain. In: Proceedings of paleontology and stratigraphy of Western Siberia. Proceedings of the SNIIGIMS. Leningrad: Gostoptekhizdat 1962; vol. 23: pp. 101-3.

[9] Vekshina VN. Elements of the paleogeography of the Mesozoic and Paleogene deposits of the Western Siberian lowlands by the data of diatoms and coccolithophorids. In: Proceedings of the SNIIGIMS. Leningrad: Gostoptekhizdat 1962; vol. 26: pp. 48-61.

[10] Gurari FG, Weitz EY, Melenevsky VN, *et al*. Conditions of the formation and methods of searching for oil fields in the Bazhenov Formation mudstones. Moscow: Nedra 1988.

[11] Kontorovich AE, Berman EL, Bogorodskaya LI, *et al*. Geochemistry of the Jurassic and Lower Cretaceous Western Siberian Plain. Moscow: Nedra 1971.

[12] Bronnimann P. Microfossils incertae sedis from the Upper Jurassic and Lower Cretaceous of Cuba. Micropaleontology 1955; 1: 28-51.

[13] Noël D. Sur les du Jurassique Européen et d'Afrique du Nord. Essai de classification des coccolithes fossiles. Paris: CNRS 1965.

[14] Shumenko SI, Sotnikov OV, Sterlina NB. The first discovery of coccoliths in the Jurassic deposits of Ukraine. Rep Ukr Acad Sci B 1971; 12: 1095-6.

[15] Lyulieva SA, Permyakov VV. Coccolithophorids and corals of the Mesozoic of Ukraine. Paleontological directory. Kiev: Naukova Dumka 1980.

[16] Black M, Barnes B. The structure of coccoliths from the English Chalk. Geol Mag 1959; 96: 321-8.

[17] Rood AP, Hay WW, Barnard T. Electron microscope studies of Oxford Clay. Eclogae Geol Helv 1971; 64: 245-72.

[18] Medd AW. Some Middle and Upper Jurassic coccolithophoridae from England and France. In: Farinacci A, Ed. Proceedings of the II planktonic conference. Roma : Edizioni Tecnoscienza 1970; vol. 2: pp. 821-45.

[19] Medd AW. The Upper Jurassic coccoliths from the Haddenham and Gamlngay boreholes (Cambridgeshire, England). Eclogae Geol Helv 1979; 72: 19-110.

[20] Medd AW. Nannofossils zonation of the English Middle and Upper Jurassic. Mar Micropaleontol 1982; 7: 73-95

[21] Barnard T, Hay WW. On Jurassic coccolithes: A tentative zonation of the Jurassic of Southern England and North France. Eclogae Geol Helv 1974; 67: 563-85.

[22] Thierstein HR. Mesozoic calcareous nannoplankton biostratigraphy of marine sediments. Mar Micropaleotol 1976, 1: 325-62.

[23] Bown PR. Taxonomy, biostratigraphy, and evolution of late Triassic-early Jurassic calcareous nannofossils. Spec Pap Palaeontol 1987; 38: 1-118.

[24] Bown PR, Cooper MKE. Conical calcareous nannofossils in the Mesozoic. In: Crux JA, van Heck SE, Eds. Nannofossils and their Applications. Chichester: Ellis Harwood Ltd. 1989; pp. 98-106.

[25] Bown PR, Cooper MKE, Lord AR. A Calcareous nannofossil biozonation scheme for early to mid Mesozoic. Newsl Stratigr 1988; 20(2): 91-114.

[26] Bown PR, Baldanza A, Bergen J, *et al*. Recent advantages in Jurassic Calcareous Nannofossil Research. GeoResearch Forum 1996; 1-2: 55-66.

[27] Grün W, Zweili F. Das kalkige Nannoplankton der Dogger-Malm-Grenze im Berner Jura bei Liesberg (Schweiz). Jahrb Geol Bundesanst 1980; 123(1): 231-341.

[28] Reinhardt P. Einige Kalkflagellaten-gattungen (Coccolitho- phoriden, Coccolithineen) aus dem Mesozoikum Deutschlands. Deutsche Akad Wiss 1964; 6: 749-59.

[29] Lyulieva SA, Zhmur SI. Nannoplankton of the Upper Jurassic of the Eastern Trans-Urals region. Rep USSR Ac Sc 1982; 283: 1197-200.

[30] Ustinova MA, Radugin SV. Dismemberment of the Callovian and Oxfordian deposits of Moscow on the basis of calcareous nannoplankton and foraminifers. Bull Moscow Soc Nat Res Geol Sect 2004; 79; 3: 20-5.

[31] Matveev AV. Calcareous nannoplankton of the Oxfordian section of the Ioda River (Yaroslavl region). In: Zakharov VA, Ed. Jurassic System of Russia: problems of stratigraphy and paleogeography: Third All-Russian meeting: scientific papers. Saratov: Publishing House Science 2009; pp. 142-3.

[32] Kessels K, Mutterlose J, Rufell A. Calcareous nannofossils from late Jurassic sediments of the Volgian Basin (Russian Platform): evidence for productivity-controlled black shale deposition. Int J Earth Sci 2003; 92: 743-57.

[33] Perch-Nielsen K. Mesozoic calcareous nannofossils. In: Bolli HM, Sounders JB, Perch-Nielsen K, Eds. Plankton stratpgraphy. Cambridge: Cambridge University Press 1985; pp. 329-426.

[34] Bralower TJ, Monechi S, Thierstein HR. Calcareous nannofossils zonation of the Jurassic/Cretaceous boundary interval and correlation with the geomagnetic polarity timescales. Mar Micropaleontol 1989; 14: 153-235.

[35] Baldanza A, Mattioli E. Biostratigraphical synthesis of nannofossils in the Early Middle Jurassic of Southern Tethys. Knihovnicka ZPN 1992; 14: 111-41.

[36] Cobianchi M. Sinemurian-Early Bajocian calcareous nannofossil biostratigraphy of the Lombardy Basin (Southern Calcareous Alps; Northern Italy*)*. Atti Ticinensi di Scienze della Terra 1992; 35: 61-106.

[37] Cobianchi M, Picotti V. Sedimentary and biological response to sea-level paleoceanographic changes of a Lower-Middle Jurassic Tethian platform margin (Southern Alps, Iyaly). Palaeogeogr Palaeoclimatol Palaeoecol 2001; 169: 219-44.

[38] Mattioli E, Erba E. Biostratigraphic syntesis of calcareous nannofossil events in the Tethyan Jurassic. Rivista Italiana Paleontologia e Stratigrafia 1999; 105, 3: 343-76.

[39] Casellato CE. Calcareous nannofossil biostratigraphy of Upper Callovian–Lower Berriasian successions from the Southern Alps, North Italy. Rivista Italiana di Paleontologia e Stratigrafia 2010; 116: 357-404.

[40] De Kaenel E*,* Villa G. Oligocene-Miocene calcareous nannofossils biostratigraphy and paleoecology from the Iberia abyssal plain*.* Sci Res Ocean Drill Prog 1996; 149: 79-145.

[41] Roth PH. Cretaceous nannoplankton biostratigraphy and oceanography of the north-western Atlantic Ocean. Initial Reports of the Deep Sea Drilling Project. Washington DC: US Government Printing Office 1978; vol. 44: pp. 731-59.

[42] Wind FH. Western North Atlantic Upper Jurassic calcareous nannofossil biostratigraphy. Initial Reports of the Deep Sea Drilling Project. Washington DC: US Government Printing Office 1978; vol. 44: pp. 761-71.

[43] Roth PH. Jurassic and Lower Cretaceous nannofossils in the western North Atlantic (Site 534): biostratigraphy, preservation and some observations on biogeography and paleoceanography. Initial Reports of the Deep Sea Drilling Project. Washington DC: US Government Printing Office 1983; vol. 76: pp. 573-79.

[44] Grün W, Allemann F. The Lower Cretaceous of Caravaca (Spain). Berriasian calcareous nannoplankton of the Miravetes section (Subbetic Zone, Prov. of Murcia). Eclogae Geol Helv 11975; 68: 147-12.

[45] Hamilton G. Lower and Middle Jurassic calcareous nannofossils from Portugal. Eclogae Geol Helv 1979; 72: 1-18.

[46] Fiorentino A. Nannofossil stratigraphy of the Late Jurassic Early Cretaceous Cay sequence, Western Pontides, Turkey. Geologica Rom 1991; 27: 113-33.

[47] Bukry D. Upper Cretaceous coccoliths from Texas and Europe. Univ Kansas Paleont Contr 1969; 51 (Protista 2): 1-79.

[48] Black M. British Lower Cretaceous coccoliths I Gault clay. Monogr Palaeontogr Soc Lond 1973; 127(537): 49-112.

[49] Gavrilov YuO, Shchepetova EV, Rogov MA, Shcherbinina EA. Sedimentology, Geochronology and biota of Volgian carbonaceous sequences in the northern part of the Central Russia (Kostroma region). Lithol Miner Resour 2008; 4: 396-424.

[50] Noël D. Note préliminaire sur des coccolithes juassiques. Centre National de la recherche Scientifique, Cahiers de Micropaléontol 1965; 1: 1-12.

[51] Casellato CE. Calcareous nannofossil and calpionellid calcification events across: Tithonian – Berriasian time interval and low latitudes paleoceanographic implications. PhD Thesis. Milano: Università degli Studi di Milano 2008.

[52] Matveev AV. Calcareous nannoplankton of the Tithonian of the Eastern Crimea. Collection of Scientific Papers of the Institute of Geological Sciences. Kiev: National Academy of Sciences of Ukraine 2009; pp. 104-7.

[53] Practical guide on the microfauna of the USSR. Volume 1, Calcareois nannoplancton. (Compiled by SI Shumenko). Leningrad: Nrdra 1987.

[54] Barthel KW. Solnhofen: A study in Mesozoic Palaeontology. Cambridge: University Press 1990; p. 245.

[55] Thierstain HR. Lower Cretaceous calcareous nannoplankton biostratigraphy. Abhandlungen der Geologischen Bundesanstalt 1973; 29: 52.

Received: April 27, 2012 Revised: May 4, 2012 Accepted: May 7, 2012