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New palynological data for Toarcian (Lower Jurassic) deep-marine sandstones of the Western Caucasus, southwestern Russia

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Abstract

Information on Jurassic palynomorphs from the Greater Caucasus is potentially of great importance, but its availability to the international research community is severely limited. New palynological data for Toarcian deposits of the Western Caucasus are recorded in the present paper. Particularly, dinoflagellate cysts are described for the first time from the Bagovskaja Formation; palynomorphs are found in sandstone levels within this unit. The most representative assemblage includes pollen (with predominant bisaccate pollen), spores (*Cyathidites* being commonest), and dinoflagellate cysts amongst which the predominant taxon is *Nannoceratopsis spiculata*. The dinocyst assemblage implies a late Toarcian age for the upper part of the Bagovskaja Formation. On the basis of these new palynostratigraphical results, the range of the formation is extended; previously, only the lower part had been dated on ammonite evidence.

Key words: dinoflagellate cysts, pollen and spores, sandstones, Jurassic, Greater Caucasus

1. Introduction

Jurassic sedimentary sequences of the Greater Caucasus, a large region between the Black Sea and the Caspian Sea (Fig. 1), have the potential of supplying globally important data on the development of back-arc sedimentary basins and the evolution of life across some critical boundaries (Saintot et al., 2006; Ruban, 2007, 2008, 2012, 2018; Adamia et al., 2011; Varsimashvili & Meparishvili, 2017). However, much of our current knowledge of these sequences is incomplete and generally inaccessible to the international research community. An additional problem is the mode of exposure of the Jurassic rocks in this region. Continuous, well-dated sections are few and far between, while more or less small outcrops prevail. These outcrops often do not yield macrofossils and strong tectonic deformation of the rocks does not permit to determine the stratigraphical relationships amongst these outcrops. As

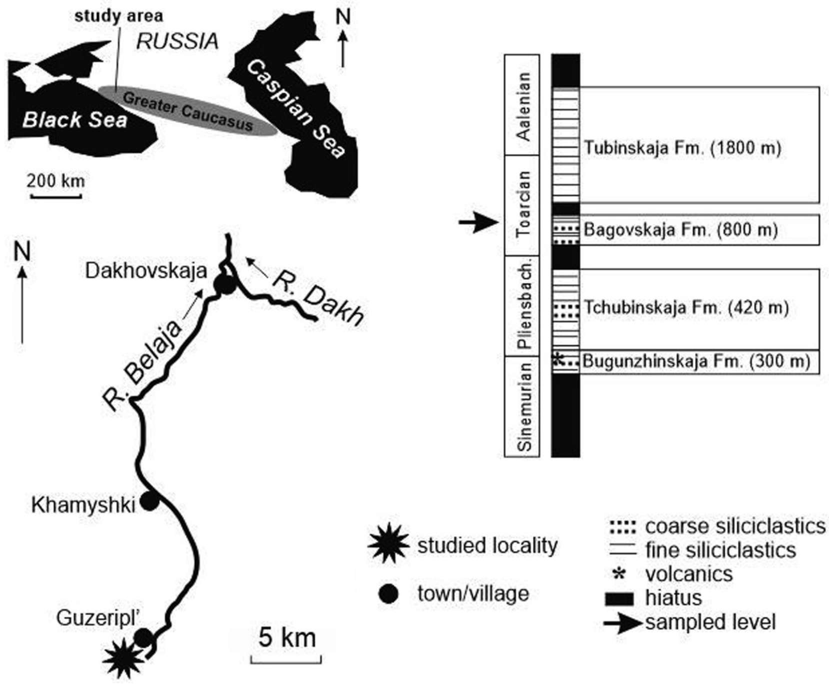

Fig. 1. Geographical location of the study area and composite Lower-Middle Jurassic section of the Northern Arkhyz-Guzerepl'skaja area (based on Ruban, 2007; adapted from Rostovtsev et al., 1992).

a result, knowledge of regional Jurassic sedimentary sequences still is very meagre.

Micropalaeontological studies would be conducive to solving those problems, but these have only rarely been undertaken. A significant portion of promising outcrops have yet to be studied. For instance, palynological studies in the Greater Caucasus appear very promising; the outcome of previous studies of spores and pollen from Jurassic deposits in this region was summarised by Jaroshenko (1965), Beznosov et al. (1973) and Rostovtsev et al. (1992). However, their data are very general in nature and often do not refer to particular sections and outcrops. In addition, those data were not published in English and thus cannot be used in interregional comparisons and correlations. Moreover, there are no data on dinoflagellate cysts (dinocysts), although these microfossils might be very useful for regional biostratigraphical schemes. New field work in the western part of the Greater Caucasus (commonly referred to as the 'Western Caucasus') has considered extensive, albeit fragmented, sections of Lower-Middle Jurassic deposits that are potentially interesting for palynological investigations. The most widely distributed rocks are shales, but samples taken from various horizons have not yielded any palynomorphs. Fortunately, sandstones of the Bagovskaja Formation (Toarcian, Lower Jurassic) are more promising having yielded some palynomorphs. The first results from these studies are summarised below.

2. Geological setting

The Greater Caucasus is a large Cenozoic orogen and a constituent of the Alpine tectonic belt of Eurasia. Its Phanerozoic evolution was highly complex with multiple terrane re-organisations and several phases of deformation (Saintot et al., 2006; Adamia et al., 2011; Ruban, 2013a; Rolland, 2017). Jurassic deposits are distributed widely in the Western Caucasus and, in particular, crop out in the Northern Arkhyz-Guzeripl' area (Rostovtsev et al., 1992). These deposits are subdivided into lower siliciclastic (Lower-Middle Jurassic) and upper carbonate (Upper Jurassic) packages with thicknesses of ~10,000 m and ~3,000 m, respectively. The lower package comprises several formations (Fig. 1), the age of which was established mainly on the basis of rare ammonites (Rostovtsev et al., 1992). These strata accumulated in a marine, back-arc basin that existed between the islands (i.e., the axial part of the present-day Greater Caucasus) in the south and the land of the Scythian Platform, the southern and youngest part of the stable Russian Platform, in the north (Saintot et al., 2006; Ruban, 2007, 2013b). According to palaeogeographical reconstructions by Golonka (2004), this basin was located along the northern periphery of the Neo-Tethys Ocean.

The general characteristis of the Bagovskaja Formation of the Northern Arkhyz-Guzeripl' area can be found in the papers by Teodorovitch & Pokhvisneva (1964) and Rostovtsev et al. (1992). The formation is a relatively thick (up to 800 m), siliciclastic

Fig. 2. A typical outcrop of sandstone beds in the Toarcian siliciclastic sequence at the locality of Guzeripl′ South.

sequence that is dominated by alternating dark-grey or even black shales and yellowish sandstones. The thickness of individual layers varies between centimetres and dozens of centimetres (Fig. 2). In this sequence, shales are more common than sandstones. The age of the formation has been determined on the basis of rare ammonites as early-middle Toarcian, i.e., the interval of the *Harpoceras falciferum*–*Hildoceras bifrons* zones (Rostovtsev et al., 1992; Ruban, 2013b). The depositional environments have generally been interpreted as deep-marine and oxygen depleted (Ruban, 2013b), although shallow-marine facies do occur at the very base of the formation. The results of ichnological studies (Ruban et al., 2017) confirm this interpretation.

3. Material and methods

The Bagovskaja Formation of the Northern Arkhyz-Guzeripl′ area in the Western Caucasus is represented in an extended section that stretches over several kilometres along both banks of the River Belaja near the town of Guzeripl′ (Fig. 1). Unfortunately, this section consists of isolated, often small fragments, the mutual relationship of which is very difficult to determine because of the fact that the entire sedimentary sequence is strongly deformed through intense folding and faulting. The locality of Guzeripl′ South, situated on the left bank of this river south of the town of Guzeripl′, is especially interesting because the relevant section fragments exhibit a sufficient number of sandstone beds.

The single sandstone layer of the Bagovskaja Formation yields a more or less rich assemblage of palynomorphs (Fig. 1). In other layers, palynomorphs are rare or absent, most probably because of the poor preservation potential in such tectonically distorted sedimentary packages. In addition to examination in the field and under the microscope, laboratory investigations of sandstones were conducted using X-ray powder diffraction (XRD) analysis. This is a basic method for identifying mineral types in multicomponent sedimentary rocks such as the sandstones of the Bagovskaja Formation. Mineral types are determined by comparing experimentally obtained values of interplanar distance (d, Å) and relative intensity (I_{rel}) of reflections to the standard XRD data from the International Database PDF-2 ICDD. When specifying species of clay minerals by XRD analysis, both natural and glycerin-saturated specimens are used. XRD analysis is performed using a hardware-software package based on an investigation of the powders in Bragg-Brentano geometry by the D2 Phaser X-ray diffractometer (Bruker). Conditions of diffraction spectra recording with the monochromatised Cu–Kα radiation (λ=1,54178 Å) are as follows: voltage 30 kV, current 30 mA; scanning step 0.02°2Θ; and exposure time 3 sec. The range of scanning angles in Bragg-Brentano geometry is 3–40°.

For the purpose of palynological studies, samples were first treated using hydrofluoric acid and then potassium pyrophosphate, with subsequent separation of organic and mineral components in heavy liquid (cadmium; specific gravity of 2.25) by centrifuging. After initial preparation, the palynological objects were examined using a Zeiss Primo Star microscope; images were obtained with a Zeiss Axioskop 40 and a Canon PowerShot G10. During analysis, diverse palynomorphs were recovered, including marine microphytoplankton and pollen and spores of terrestrial plants. All samples studied are now stored in the Laboratory of Paleontology and Stratigraphy of the Mesozoic and Cenozoic, Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of Russian Academy of Sciences (Novosibirsk).

4. Results

The sandstones of the Bagovskaja Formation sampled at the locality of Guzeripl′ South include several components, namely quartz (45%), albite (28%), chlorite (16%), muscovite (6%) and calcite (5%). This composition is confirmed by results of XRD analysis (Fig. 3). Most likely, these sandstones formed from material derived from nearby islands (island arc) that stretched along the axial part of the Greater Caucasus and supplied to the deep part of the marine basin; for the present interpretation, Ruban's (2013b) reconstructions are adopted.

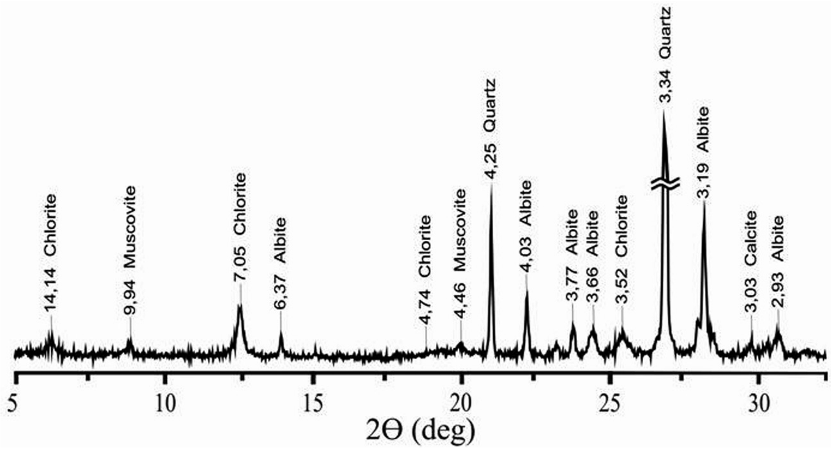

Fig. 3. XRD diagram of Toarcian sandstone of the locality of Guzeripl' South (sample PS1).

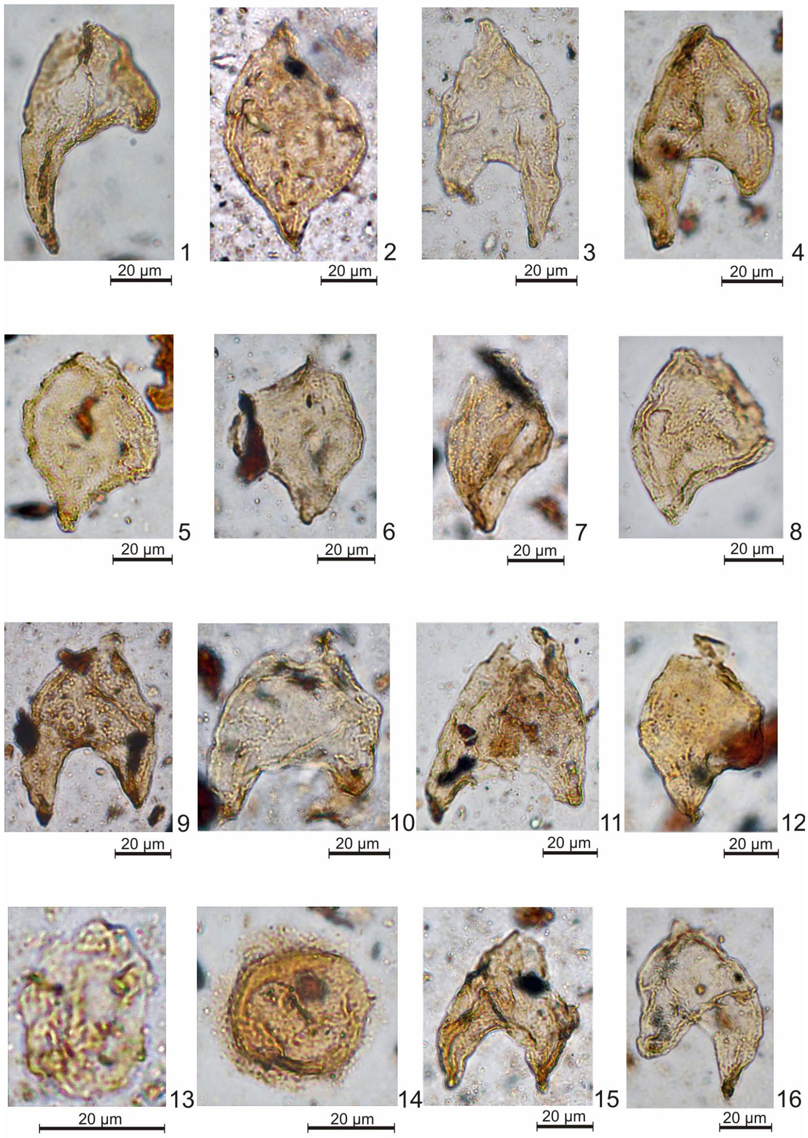

Fig. 4. Dinoflagellate cysts from the Toarcian sandstone (sample PS1) of the locality of Guzeripl' South (part 1). **1 –** *Nannoceratopsis plegas* Drugg, 1978; **2 –** *Nannoceratopsis senex* van Helden, 1977; **3, 4, 9–11, 15, 16 –** *Nannoceratopsis spiculata* Stover, 1966; **5 –** *Nannoceratopsis ?gracilis* Alberti, 1961; **6–8, 12 –** *Nannoceratopsis deflandrei* Evitt, 1962; **13 –** *Susadinium faustum* (Bjaerke, 1980) Lentin and Williams, 1985; **14 –** *Pareodinia halosa* (Filatoff, 1975) Prauss, 1989. All specimens are from sample PS1.

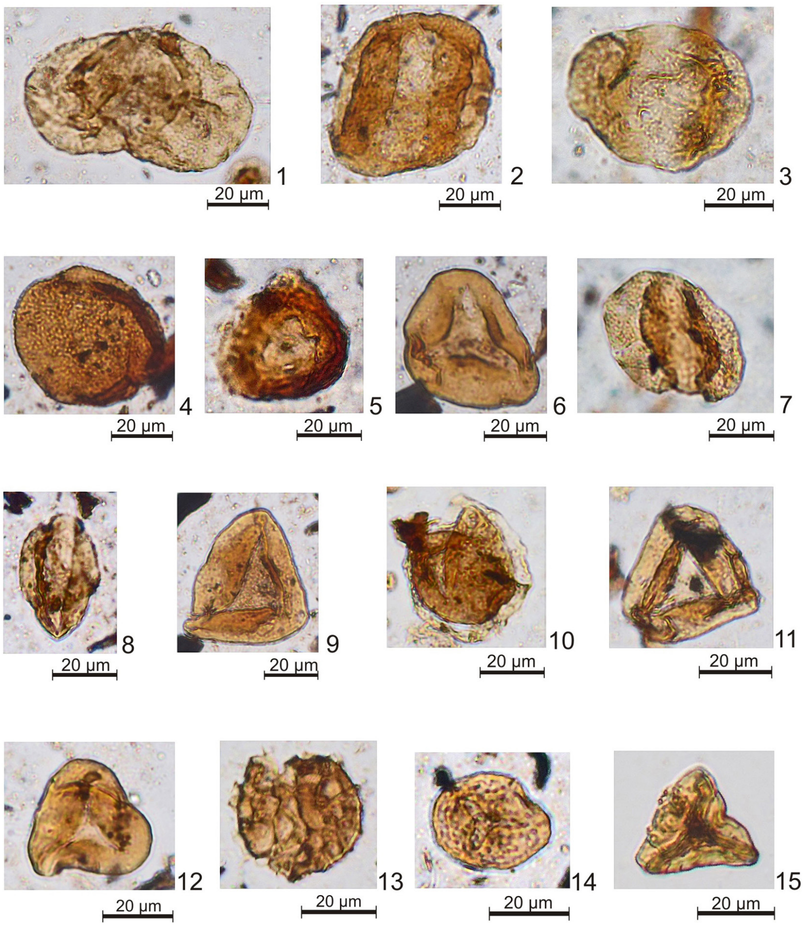

Fig. 5. Palynomorphs (pollen and spores) from the Toarcian sandstone (sample PS1) of the locality of Guzeripl' South (part 2). **1 –** *Alisporites* sp.; **2 –** *Quadraeculina limbata* Maljavkina, 1949; **3 –** Coniferales gen. indet.; **4 –** *Osmundacidites* sp.; **5 –** *Hymenozonotriletes bicycla* (Maljavkina, 1949) Sachanova ex Fradkina, 1967; **6, 9, 11, 12 –** *Cyathidites minor* Couper, 1953; **7 –** Coniferales gen. indet.; **8 –** *Ginkgocycadophytus* sp.; **10 –** *Perinopollenites elatoides* Couper, 1958; **13 –** *Lycopodiumsporites* sp.; **14 –** *Stereisporites* sp.; **15 –** *Dictyophyllidites harrisii* Couper, 1958.

The palynological investigation has revealed the presence of a representative palynomorph assemblage in a single sample, PS1. It includes spores (31%) and pollen (43%) of land plants and microphytoplankton (26%). Dinoflagellate cysts are recorded from the Bagovskaja Formation, and probably from the entire Lower Jurassic of the Western Caucasus, for the first time. Some palynomorph taxa are illustrated in Figures 4 and 5; the Appendix comprises a taxonomic synopsis.

In sample PS1, pollen grains are represented mainly by poorly preserved bisaccate pollen of Coniferales gen. indet. (>20% in total), *Ginkgocycadophytus* spp. (4%), *Classopollis* sp. (2%) and rare (up to 2%) *Quadraeculina limbata*, *Vitreisporites pallidus*, *Perinopollenites elatoides*, *Sciadopityspollenites macroverrucosus* and *Callialasporites* sp. are also known. Spores in this assemblage account for a smaller proportion than pollen, but the former are more diverse. Fern spores, *Cyathidites* (11 %), predominate. *Dictyophyllidites harrisii* (4%), *Dictyophyllidites* spp. (3%), *Osmundacidites* spp. (2%) and rare (up to 2%) *Cadargasporites robustus*, *Duplexisporites anagrammensis*, *Klukisporites variegatus*, *Obtusisporis junctus*, *Hymenozonotriletes bicycla*, *Lycopodiumsporites* spp., *Camptotriletes* sp., *Pilasporites marcidus*, *Densoisporites* sp., *Neoraistrickia rotundiformis*, *Neoraistrickia* sp., *Marattisporites scabratus*, *Lophotriletes* sp., *Matonisporites* sp., *Gleicheniidites* sp. and *Stereisporites* sp. have been noted.

Microphytoplankton is represented by dinocysts, prasinophytes and green algae. Amongst dinoflagellate cysts, the most common taxa are *Nannoceratopsis spiculata* (9%), *Nannoceratopsis deflandrei* (4%), *Nannoceratopsis plegas* (2%), *Nannoceratopsis gracilis* (1%), *Nannoceratopsis senex* (1%), *Nannoceratopsis* spp., *Susadinium faustum* (1%), while *Pareodinia halosa*, *Phallocysta eumekes* and *Susadinium* sp. are rare. Prasinophytes are represented by two taxa, namely *Pterospermella* sp. and *Leios-*

phaeridia sp. Green algae (*Schizocystia* sp.) have also been recorded.

Some other sandstone layers at the same locality contain rare palynomorphs of a very poor preservation. These include pollen (*Ginkgocycadophytus* sp. and Coniferales gen. indet.), spores (*Cyathidites* sp., *Marattisporites* sp., *Osmundacidites* sp.), and microphytoplankton taxa such as *Micrhystridium* sp. and *Leiosphaeridia* sp. These data are worthy of consideration since they are novel; however, they are in general of limited importance in the interpretations presented herein.

5. Discussion

The new data on palynomorphs from Toarcian deep-marine sandstones at the locality of Guzeripl' South have important stratigraphical implications. Pollen and spores are less informative, although these can be compared to those recorded earlier from the Caucasus and some other regions (Table 1). However, microphytoplankton, and dinocysts in particular, allow a more detailed discussion of the age of these sandstones. Generally, the assemblage recorded corresponds to typical Toarcian associations that are on record from the entire Northern Caucasus (Jaroshenko, 1965; Beznosov, 1973; Rostovtsev et al., 1992), which is in agreement with the previously established age of the Bagovskaja Formation (Rostovtsev et al., 1992; Ruban, 2013b).

The earliest appearance of *Nannoceratopsis spiculata* in northwest Europe is in the upper Pliensbachian (Palliani & Riding, 2003), but the regular presence of this taxon is typical of the upper part of the lower Toarcian (Riding & Thomas, 1992; Palliani & Riding, 2000). The assemblage of *Nannoceratopsis spiculata*, *Nannoceratopsis gracilis* and *Phallocysta eumekes* characterises the middle Toarcian (*Hildoceras bifrons-Grammoceras thouarsense* ammonite zones; Riding & Thomas, 1992; Poulsen & Riding, 2003). The upper Toarcian of southwestern France contains abundant *Nannoceratopsis spiculata* and also *Nannoceratopsis gracilis*, *Pareodinia halosa* and *Nannoceratopsis plegas*. *Pareodinia halosa* appears earlier in Europe, in the upper Toarcian (*Grammoceras thouarsense-Pleydellia aalensis* ammonite zones; Palliani & Riding, 1997; Feist-Burkhardt & Pross, 2010). *Susadinium faustum* has been described from Toarcian deposits of Svalbard, together with *Phallocysta eumekes* and *Susadinium* spp. (Bjaerke, 1980). In Europe, the first-named taxon first appears in the upper lower Toarcian (*Hildoceras bifrons* ammonite zone; Palliani & Raiding, 2003). In Europe, as well as in Siberia, *Nannoceratopsis plegas* appears in the lower Toarcian (Palliani & Riding, 2003; Grinenko et al., 2015) and its co-occurrence with *Nannoceratopsis gracilis*, *Nannoceratopsis senex*, *Nannoceratopsis* spp., *Susadinium* spp. and *Phallocysta eumekes* is characteristic of the Toarcian of eastern Siberia (Riding et al., 1999; Goryacheva, 2017).

The stratigraphical ranges of the above-listed taxa are long (i.e., upper Pliensbachian–upper Bajocian), but their co-occurrence in the sandstones studied and the predominance of *Nannoceratopsis spiculata* implies the late Toarcian age, i.e., within the interval of the *Grammoceras thouarsense-Pleydellia aalensis* ammonite zones. The implications of such an age assessment are twofold. Firstly, the uppermost horizons of the Bagovskaja Formation in the Northern Arkhyz-Guzeripl' area are of late Toarcian age. Previous studies of ammonites had suggested a greater age of this formation, i.e., early-middle Toarcian (*Harpoceras falciferum-Hildoceras bifrons* ammonite zones; see Rostovtsev et al., 1992; Ruban, 2013b). The ammonite-based dating cannot be disputed, but it should be noted that this refers to the lower and middle parts of the formation (Rostovtsev et al., 1992). Therefore, most probably, accumulation of the Bagovskaja Formation continued longer than assumed earlier. It is a matter for future studies to investigate whether the upper part of the Bagovskaja Formation is of late Toarcian age in other areas of the Western Caucasus. If the boundary between the Bagovskaja Formation and the overlying Tubinskaja Formation is located in a higher stratigraphical position within the succession, this requires certain corrections of regional models of oxygen depletion in the Caucasian Sea (e.g., Ruban, 2007). Secondly, the established age implies that the locality of Guzeripl' South represents the upper part of the Bagovskaja Formation, which is important for future correlation of this section fragment.

Results of studies (microscope examination and XRD analysis) of the composition of the sandstones from the locality of Guzeripl' South stress their provenance related to the island arc that was located to the south of the study area (see above). Therefore, the origin of terrestrial palynomorphs recovered from these sandstones can also be linked to these islands. If this interpretation is correct, conifer and fern vegetation dominated in these places.

6. Conclusions

The study of a palynomorph assemblage from a Toarcian deep-marine sequence in the Western Caucasus allows three general conclusions to be drawn.

Table 1. Comparison of spores and pollen assemblage documented in the present study with those recorded previously from the Caucasus and some other regions.

This work	Toarcian of the Northern Caucasus (Jaroshenko, 1965; Beznosov et al., 1973; Rostovtsev et al., 1992)	Pliensbachian–Toarcian of the East European Platform (Mitta et al., 2012)	Upper Toarcian of Spain (Barrón et al., 2010)	Lower Toarcian of Italy (Palliani, 1997)
Pollen: Bisaccate pollen of Gymnospermae (dominants), *Piceapollenites* spp., *Pinuspollenites* spp., *Alisporites* spp., *Ginkgocycadophytus* spp., *Classopollis* sp., *Quadraeculina limbata, Vitreisporites pallidus, Perinopollenites elatoides, Sciadopityspollenites macroverrucosus, Callialasporites* sp. **Spores:** *Cyathidites* spp. (dominants), *Dictyophyllidites harrisii, Dictyophyllidites* spp., *Osmundacidites* spp., *Cadargasporites robustus, Duplexisporites anagrammensis, Klukisporites variegatus, Obtusisporis junctus, Hymenozonotriletes bicycla, Lycopodiumsporites* spp., *Camptotriletes* sp., *Pilasporites marcidus, Densoisporites* sp., *Neoraistrickia rotundiformis, Neoraistrickia* sp., *Marattisporites scabratus, Lophotriletes* sp., *Matonisporites* sp., *Gleicheniidites* sp., *Stereisporites* sp.	**Pollen:** *Ginkgocycadophytus* spp.+ *Cycadopites* spp. or *Classopollis* sp. (dominants), *Chasmatosporites* spp., *Vitreisporites pallidus, Araucariacites* spp., bisaccate pollen of Gymnospermae **Spores**: *Cyathidites* spp. or *Marattisporites scabratus+Klukisporites variegatus+Matonosporites* spp. (dominants), *Tripartina variabilis, Duplexisporites anagrammensis, Dictyophyllidites harrisii, Camptotriletes* sp., *Lophotriletes* sp., *Converrucosisporites* sp.	**Pollen:** *Dipterella oblatinoides, Chasmatosporites apertus, Alisporites* sp. **Spores:** *Concavisporites* spp., *Auritulinasporites scanicus, Levisporites decorus, Tripartina variabilis, Cadargasporites robustus, Contignisporites problematicus, Klukisporites variegatus, Marattisporites scabratus, Taurocusporites verrucatus, Polycingulatisporites liassicus, Densoisporites velatus, Uvaesporites argenteaeformis*	**Pollen**: *Spheripollenites psilatus* and *Classopollis* spp. (dominants), Circumpolles gen. et. sp. indet., *Alisporites* sp., bisaccate pollen of Gymnospermae, *Cycadopites* sp., *Perinopollenites elatoides, Araucariacites australis, Callialasporites minus, C. turbatus, Vitreisporites pallidus, Podocarpidites* sp. **Spores**: *Cyathidites minor, C. australis, Leptolepidites* sp., *Lycopodiacidites rugulatus, Ischyosporites variegatus (=Klukisporites variegatus), Leptolepidites macroverrucosus, Dictyophyllidites harrisii, Uvaesporites argenteaeformis, Tuberositriletes* sp., *Trachysporites fuscus, Anapiculatisporites* sp., *Cibotiumspora juriensis, Krausellisporites reissingeri, Todisporites minor, Cardioangulina* sp., *Densoisporites velatus, Converrucosisporites* sp., *Cingutriletes* sp., *Baculatisporites* sp., *Ischyosporites pseudoreticulatus*	**Pollen**: *Classopollis* spp. (dominants), *Gliscopollis meyeriana, Vitreisporites pallidus, Vitreisporites* sp., *Pinuspollenites* sp., *Monosulcites minimus, Callialasporites* spp., *Araucariacites australis, Cycadopites* sp., *Eucommiidites troedssonii* **Spores**: *Cyathidites minor, Concavisporites* sp., *Annulispora folliculosa, Cicatricosisporites mohrioides, Deltoidospora minor, D. toralis, Densoisporites fissus, Densoisporites* sp., *Leptolepidites* sp., *Uvaesporites argenteaeformis, Cingulatisporites* sp., *Cingulatisporites marginatus, Dictyophyllidites equiexinus, D.* sp., *Ischyosporites variegatus (=Klukisporites variegatus), Ischyosporites* sp., *Klukisporites pseudoreticulatus, Contignisporites problematicus, Neoraistrickia taylorii, Lycopodiacidites* sp., *Osmundacidites* sp., *Foveosporites canalis, Densoisporites velatus, Leptolepidites major, Lycopodiumsporites clavatoides, Gleicheniidites senonicus*

1. A rich and fairly diverse palynomorph assemblage is recorded from one of the rare sandstone layers within the Bagovskaja Formation.
2. The palynomorph assemblage studied includes spores (representatives of *Cyathidites* predominating), pollen (fern pollen, Coniferales gen. indet. predominating), and dinocysts (representatives of *Nannoceratopsis* preominating), the last-named of which are here recorded from this unit and, probably, from the entire Western Caucasus for the first time.
3. Dinocysts are valuable for regional stratigraphical assessments, and these indicate a late Toarcian age for the upper part of the Bagovskaja Formation.

The methodological significance of the present study is determined by demonstration of the value of a palynological approach in studies of fragmented sections of Jurassic strata in the Greater Caucasus.

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Appendix. List of palynomorph species considered in the present work

Palynomorphs, in three groups, are listed alphabetically. Detailed references to dinoflagellate cyst taxa can be found in Williams et al. (2017). Taxa in open nomenclature are not listed.

1. Pollen

Araucariacites australis Cookson, 1947
Callialasporites minus (Tralau, 1968) Guy, 1971
Callialasporites turbatus (Balme, 1957) Schulz, 1967
Chasmatosporites apertus (Rogalska, 1954) Nilsson, 1958
Classopollis classoides (Pflug, 1953) Pocock & Jansonius, 1961
Classopollis torosus (Reissinger, 1950) Couper, 1958
Dipterella oblatinoides Maljavkina, 1953
Eucommiidites troedssonii Erdtman, 1948
Monosulcites minimus Couper, 1953
Perinopollenites elatoides Couper, 1958
Quadraeculina limbata Maljavkina, 1949
Sciadopityspollenites macroverrucosus (Thiergart, 1949) Iljina, 1985
Spheripollenites psilatus Couper, 1958
Vitreisporites pallidus (Reissinger, 1939) Nilsson, 1958

2. Spores

Annulispora folliculosa (Rogalska, 1954) de Jersey, 1959
Auritulinasporites scanicus Nilsson, 1958
Cadargasporites robustus Menshikova, 1980
Cibotiumspora juriensis (Balme, 1957) Filatoff, 1975
Cicatricosisporites mohrioides Delcourt & Sprumont, 1955
Cingulatisporites marginatus Mädler, 1963
Contignisporites problematicus (Couper, 1958) Döring, 1965
Cyathidites australis Couper, 1953
Cyathidites minor Couper, 1953
Deltoidospora minor (Couper, 1953) Pocock, 1970
Deltoidospora toralis (Leschik, 1955) Lund, 1977
Densoisporites fissus (Reinhardt, 1964) Schulz, 1967
Densoisporites velatus Weyland & Krieger, 1953 emend. Dettmann, 1963
Dictyophyllidites equiexinus (Couper, 1958) Dettmann, 1963
Dictyophyllidites harrisii Couper, 1958
Duplexisporites anagrammensis (Kara-Murza & Bolchovitina, 1956) Schugaevskaja, 1969
Foveosporites canalis Balme, 1957
Gleicheniidites senonicus Ross, 1949
Hymenozonotriletes bicycla (Maljavkina, 1949) Sachanova ex Fradkina, 1967
Ischyosporites pseudoreticulatus (Couper, 1958) Döring, 1965
Ischyosporites variegatus (Couper, 1958) Schulz, 1967
Klukisporites pseudoreticulatus Couper, 1958
Klukisporites variegatus Couper, 1958

Krausellisporites reissingeri (Harris, 1957) Morbey, 1975
Leptolepidites macroverrucosus Schulz, 1967
Leptolepidites major Couper, 1958
Levisporites decorus Iljina, 1968
Lycopodiacidites rugulatus (Couper, 1958) Schulz, 1967
Lycopodiumsporites clavatoides (Couper, 1958) Tralau, 1968
Marattisporites scabratus Couper, 1958
Neoraistrickia rotundiformis (Kara-Mursa, 1951) Tarasova, 1971
Neoraistrickia taylorii Playford & Dettmann, 1965
Obtusisporis junctus (Kara-Murza, 1956) Pocock, 1970
Pilasporites marcidus Balme, 1957
Polycingulatisporites liassicus Schulz, 1967
Taurocusporites verrucatus Schulz, 1967
Todisporites minor Couper, 1958
Trachysporites fuscus Nilsson, 1958
Tripartina variabilis Maljavkina, 1949
Uvaesporites argenteaeformis (Bolchovitina, 1953) Schulz, 1967

3. Dinoflagellate cysts
Nannoceratopsis spiculata Stover, 1966
Nannoceratopsis deflandrei Evitt, 1962
Nannoceratopsis plegas Drugg, 1978
Nannoceratopsis gracilis Alberti, 1961
Nannoceratopsis senex van Helden, 1977
Susadinium faustum (Bjaerke, 1980) Lentin and Williams, 1985
Pareodinia halosa (Filatoff, 1975) Prauss, 1989
Phallocysta eumekes Dörhöfer and Davies, 1980

References

Adamia, S., Alania, V., Chabukiani, A., Kutelia, Z. & Sadradze, N., 2011. Great Caucasus (Cavcasioni): A Long-lived North-Tethyan Back-Arc Basin. *Turkish Journal of Earth Sciences* 20, 611–628.

Barrón, E., Ureta S., Goy A., Lassaletta L. 2010. Palynology of the Toarcian-Aalenian Global Boundary Stratotype Section and Point (GSSP) at Fuentelsaz (Lower-Middle Jurassic, Iberian Range, Spain). *Review of Palaeobotany and Palynology* 162, 11–28.

Beznosov, N.V., Burshtar, M.S., Vakhrameev, V.A., Krymgol'ts, G.Ya., Kutuzova, V.V., Rostovtsev, K.O., Snegireva, O.V. (Eds.), 1973. *Ob'jasnitel'naja zapiska k stratigrafitcheskoj skheme jurskikh otlozhenij Severnogo Kavkaza (Explanatory note to the stratigraphical scheme of the Jurassic deposits of the Northern Caucasus)*. Moskva (Nedra), 194 pp. (in Russian)

Bjaerke, T., 1980. Mesozoic palynology of Svalbard IV. Toarcian dinoflagellates from Spitsbergen. *Palynology* 4, 57–77.

Feist-Burkhardt, S. & Pross, J., 2010. Dinoflagellate cyst biostratigraphy of the Opalinuston Formation (Middle Jurassic) in the Aalenian type area in southwest Germany and north Switzerland. *Lethaia* 43, 10–31.

Golonka, J., 2004. Plate tectonic evolution of the southern margin of Eurasia in the Mesozoic and Cenozoic. *Tectonophysics* 381, 235–273.

Goryacheva, A.A., 2017. Lower Jurassic palynostratigraphy of Eastern Siberia. *Stratigraphy and Geological Correlation* 25, 265–295.

Grinenko, V.S., Goryacheva, A.A., Devyatov, V.P., Knyazev, V.G. & Mikhailova, T.E., 2015. Novyj tip razreza nizhnej jury Viljujskoj sineklizy i ego paleontologitcheskaja kharakteristika [A new type of succession of the Lower Jurassic of the Viljuj Syneclise and its palaeontological characteristics]. [In:] *Jurskaja sistema Rossii: problemy stratigrafii i paleogeografii*. Makhatchkala (ALEF), pp. 72–77. (in Russian)

Jaroshenko, O.P., 1965. *Sporovo-pyl'tsevye kompleksy jurskikh i nizhnemelovykh otlozhenij Severnogo Kavkaza i ikh stratigrafitcheskoe znatchenie (Spore-pollen assemblages of the Jurassic and Lower Cretaceous deposits of the Northern Caucasus and their stratigraphical importance)*. Moskva (Nauka), 131 pp. (in Russian)

Mitta, V.V., Alekseev, A.S., Shik, S.M. (eds.), 2012. *Unificirovannaya regional`naya stratigraficheskaya sxema jurskikh otlogeniy Bostochno-Evropeiskoi platformy* (*Unified regional stratigraphic scheme of the Jurassic of East European Platform. Explanatory note*). Moscow (PIN RAS – VNIGNI). 64 pp. (in Russian)

Palliani, B. 1997. Toarcian sporomorph assemblages from the Umbria-Marche Basin, central Italy. *Palynology* 21, 105–123.

Palliani, B. & Riding, J.B., 1997. The influence of palaeoenvironmental change on dinoflagellate cyst distribution. An example from the Lower and Middle Jurassic of Quercy, southwest France. *Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine* 21, 107–123.

Palliani, B. & Riding, J.B., 2000. A palynological investigation of the Lower and lowermost Middle Jurassic strata (Sinemurian to Aalenian) from North Yorkshire, UK. *Proceedings of the Yorkshire Geological Society* 53, 1–16.

Palliani, B. & Riding, J.B., 2003. The effects of global oceanographic changes on early dinoflagellate evolution. *The Annals of the Marie Curie Fellowships* 2, 39–44.

Poulsen, N.E. & Riding, J.B., 2003. The Jurassic dinoflagellate cyst zonation of Subboreal Northwest Europe. *Geological Survey of Denmark and Greenland Bulletin* 1, 115–144.

Riding, J.B., Fedorova, V.A. & Ilyina, V.I., 1999. Jurassic and lowermost Cretaceous dinoflagellate cyst biostratigraphy of the Russian Platform and northern Siberia, Russia. *American Association of Stratigraphic Palynologists Contributions Series* 36, 1–179 .

Riding, J.B. & Thomas, J.E., 1992. Dinoflagellate cysts of the Jurassic System. [In]: Powell A.J. (Ed.). *A stratigraphic index of dinoflagellate cysts. British Micropalaeontological Society Publications Series*. London (Chapman and Hall), pp. 7–97.

Rostovtsev, K.O., Agaev, V.B., Azarian, N.R., Babaev, R.G., Besnosov, N.V., Hassanov, N.A., Zesashvili, V.I., Lomize, M.G., Paitschadze, T.A., Panov, D.I., Prosorovskaya, E.L., Sakharov, A.S., Thodria, V.A., Topchishvili, M.V., Abdulkasumzade, M.R., Avanesian, A.S., Belenkova, V.S., Bendukidze, N.S., Vuks, V.Ya., Doludenko, M.P., Kiritchkova, A.I., Klikushin, V.G., Krimholz, G.Ya., Romanovskaya, G.M. & Schevchenko, T.V., 1992. *Yura Kavkaza (Jurassic of the Caucasus)*. St. Petersburg (Nauka), 192 pp. (in Russian)

Rolland, Y., 2017. Caucasus collisional history: Review of data from East Anatolia to West Iran. *Gondwana Research* 49, 130–136.

Ruban, D.A., 2007. Jurassic transgressions and regressions in the Caucasus (northern Neotethys Ocean) and their influences on the marine biodiversity. *Palaeogeography, Palaeoclimatology, Palaeoecology* 251, 422–436.

Ruban, D.A., 2008. The Jurassic events in the Greater Caucasus basin (central Northern Neotethys) and the Neuquén basin (West Gondwana): A comparison. *Revista de Asociaciöón Geológica Argentina* 63, 766–775.

Ruban, D.A., 2012. Diversity dynamics of Toarcian-Aalenian (Jurassic) ammonites and transgressions/regressions in the Greater Caucasus Basin (Caucasian Sea, northern Neo-Tethys Ocean): an evidence of partial dependence. *Palaeogeography, Palaeoclimatology, Palaeoecology* 315–316, 124–133.

Ruban, D.A., 2013a. The Greater Caucasus – A Galatian or Hanseatic terrane? Comment on "The formation of Pangea" by G.M. Stampfli, C. Hochard, C. Vérard, C. Wilhem and J. von Raumer [Tectonophysics 593 (2013) 1–19]. *Tectonophysics* 608, 1442–1444.

Ruban, D.A., 2013b. Spatial heterogeneity of the Early-Middle Toarcian (Jurassic) ammonite diversity and basin geometry in the Northwestern Caucasus (southwestern Russia; northern Neo-Tethys). *Palaeogeography, Palaeoclimatology, Palaeoecology* 386, 225–232.

Ruban, D.A., 2018. Episodic events in long-term geological processes: A new classification and its applications. *Geoscience Frontiers* 9, 377–389.

Ruban, D.A., Nielsen, J.K., Mikhailenko, A.V., Nazarenko, O.V. & Zayats, P.P., 2017. Ichnogeneric diversity in the Jurassic deposits of the Western Caucasus: A brief summary. *Stratigraphy and sedimentology of oil-gas basins* no. 1, 3–10.

Saintot, A., Brunet, M.-F., Yakovlev, F., Sébrier, M., Stephenson, R., Ershov, A., Chalot-Prat, F. & McCann, T., 2006. The Mesozoic-Cenozoic tectonic evolution of the Greater Caucasus. [In:] Gee, D.G. & Stephenson, R.A. (Eds): *European Lithosphere Dynamics. Geological Society, London, Memoirs* 32, 277–289.

Teodorovitch, G.I. & Pokhvisneva, E.A., 1964. *Litologija i diagenez jurskikh otlozhenij Severo-Zapadnogo Kavkaza (Lithology and diagenesis of the Jurassic deposits of the North-Western Caucasus)*. Moskva (Nauka), 104 pp. (in Russian)

Varsimashvili, E. & Meparishvili, S., 2017. Flysch character of the upper Jurassic-Cretaceous formation of the Caucasus marginal sea eastern basin and some issues of its origin. *Bulletin of the Georgian National Academy of Sciences* 11, 90–95.

Williams, G.L., Fensome, R.A. & MacRae, R.A., 2017. The Lentin and Williams index of fossil dinoflagellates. *American Association of Stratigraphic palynologists Contributions Series* 48, 1–1097.

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