Ammonites and palynomorphs from the Lower–Middle Jurassic transition of the North Caucasus, southwest Russia

Ammonites et palynomorphes de la transition du Jurassique inférieur–moyen du Caucase du Nord, sud-ouest de la Russie

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Abstract: Palynomorphs from the Toarcian and Aalenian Djigiat Formation of Karachay-Cherkessia in the Kuban River Basin of the North Caucasus, southwest Russia are reported for the first time. Five horizons were studied which were all collected from key index ammonite samples. Three of these samples yielded relatively abundant and diverse marine and terrestrial palynomorphs; the remaining two samples were less productive. The dinoflagellate cysts allow two characteristic assemblages to be defined. These are the uppermost Toarcian *Nannoceratopsis* Assemblage and the uppermost Toarcian to lowermost Aalenian *Parvocysta* suite Assemblage. The former is overwhelmingly dominated by *Nannoceratopsis* with sparse numbers of the *Parvocysta* suite, and the latter yielded more diverse and common specimens of *Parvocysta* and its relatives. This is consistent with the hypothesis that the *Parvocysta* suite migrated from the Boreal Realm further south into Laurasia during the Toarcian. Certain dinoflagellate cysts such as *Mancodinium semitabulatum* and *Scriniocassis* spp., which are typical of Europe and much of Greater Laurasia are absent. The pollen and spores proved relatively stratigraphically conservative throughout, and cannot be subdivided.

Résumé: Les palynomorphes de la formation de Djigiat Toarcian et Aalenian de Karachay-Cherkessia dans le bassin de la rivière Kuban dans le Caucase du Nord, au sud-ouest de la Russie, sont signalés pour la première fois. Cinq échantillons ont été étudiés, qui ont tous été prélevés sur des ammonites d'indice clé. Trois de ces échantillons ont donné des palynomorphes marins et terrestres relativement abondants et diversifiés ; les deux autres échantillons étaient moins productifs. Les kystes de dinoflagellés permettent de définir deux assemblages caractéristiques. Il s'agit de l'assemblage supérieur de *Nannoceratopsis* du Toarcien et de l'assemblage supérieur de la suite de *Parvocysta* du Toarcien à l'Aalénien inférieur. Le Caucase du Nord était situé vers le nord de la ceinture tempérée pendant la transition entre l'Aalénien et le Toarcien, c'est pourquoi l'apparition de la suite de *Parvocysta* typiquement boréale dans cette région n'est pas surprenante. Le pollen et les spores se sont avérés relativement conservateurs d'un point de vue stratigraphique et ne peuvent être subdivisés.

Keywords: biostratigraphy, palynomorphs, ammonites, Lower–Middle Jurassic transition, North Caucasus, southwest Russia.

Mots-clés: biostratigraphie, ammonites, palynomorphes, transition Jurassique inférieur – moyen, Caucase du Nord, sud-ouest de la Russie.

1. Introduction

Palynological studies of the Jurassic strata of the North Caucasus region in southwest Russia began in the mid-1960s. Results based on pollen and spores were included in major studies on the Jurassic stratigraphy of the North Caucasus and adjacent regions such as Yaroshenko (1965), Besnosov et al. (1973), Rostovtsev et al. (1992), Yakovleva (1993) and Mitta et al. (2012). However, there are very few published data on the Lower and Middle Jurassic dinoflagellate cysts of the Caucasus (Mitta et al., 2017, 2018a; Goryacheva et al., 2018; Goryacheva and Ruban, 2018). Dinoflagellate cysts are used extensively for the correlation and subdivision of marine sediments, because these palynomorphs exhibit relatively rapid evolution, are relatively facies independent and have wide geographical distributions. Biozonal schemes based on dinoflagellate cysts are normally of substantially higher resolution than those based on pollen and spores. Hence, the new data presented herein on ammonites and palynomorphs from the Lower and Middle Jurassic (Toarcian–Aalenian) strata of the North Caucasus are strategically highly relevant. Vasily V. Mitta was responsible for the ammonites and the geological background; Anna A. Goryacheva and James B. Riding undertook the palynological analysis and interpretation.

2. Material and methods

In 2014 and 2015, one of us (V.V. Mitta) undertook fieldwork in the Bolshoi Zelenchuk River Basin in the Zelenchuksky district of the Karachay-Cherkess Republic located in the North Caucasus region, southwest Russia. The main purpose of this was to study sections of the Djangura Formation (Middle Jurassic), which is well developed in this area in the extensive intermontane basin between the Peredovoy and Skalistyi mountain ranges (Besnosov, 1967; Mitta and Sherstyukov, 2014). However, there are many roadside exposures of the underlying Djigiat Formation of Toarcian–Aalenian age in the foothills of the Peredovoy Mountains, and this topic is the subject of this contribution. These outcrops of the Djigiat Formation are especially prevalent around the villages of Khussa-Kardonikskaya and Nizhnaya Ermolovka (Fig. 1; Besnosov et al., 1960). The Djigiat Formation of this area has previously been studied by Zhivago (1960), Migacheva (1962), Rostovtsev (1965), Kazakova (1984, 1987) and Rostovtsev et al. (1992).

Several ammonite specimens were collected from the Djigiat Formation by V.V. Mitta; these are both *in situ* forms and from weathered debris (Plate 1). Samples of sedimentary rock matrix from five of these Toarcian and Aalenian ammonites were prepared for palynological analysis. The sample horizons span the Levesquei, Aalensis and Opalinum zones (Plate 1). Samples 1 to 4 are from rock extracted from ammonite shells; the remaining sample 5 is from a concretion. The material was treated with hydrofluoric acid, then potassium pyrophosphate, followed by centrifugation in a heavy liquid with a specific gravity of 2.25.

The palynomorphs were studied using a Zeiss Primo Star biological light microscope, and the images were obtained using a Zeiss Axioskop 40 and a Canon PowerShot G10. At least 200 grains were counted for samples 4, 2 and 1. By contrast, samples 3 and 5 were relatively sparse and only yielded 47 and 42 specimens, respectively. All the sample residues and the palynology slides studied are curated in the Laboratory of Mesozoic and Cenozoic Palaeontology and Stratigraphy, Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russia. The ammonites are curated in the Borissiak Paleontological Institute of the Russian Academy of Sciences, Moscow, Russia.

3. The sample locations and ammonites

The ammonites were collected from two localities, 6 and 7, in the foothills of the Peredovoy Range (Fig. 1). Locality 6 is ~5 km west of locality 7, at the side of a road between the villages of Leso-Kyafar and Niznyaya Ermolovka; samples 2, 3 and 4 were collected here. This outcrop comprises the Toarcian part of Djigiat Formation; it is largely represented by sandstones, with lenses of conglomerate lenses overlain by mudstones and siltstones (Kazakova 1984, 1987; Rostovtsev et al., 1992). Sample 3 is grey-yellow sandstone from weathered debris derived from the lower part of the section. It yielded a well-preserved specimen of *Dumortieria radiosa* (v. Seebach) (Plate 1, fig.4; Fig. 2). This species is known from the North Caucasus, and is characteristic of the Late Toarcian Levesquei Zone (Rostovtsev, 1965; Schulbert, 2001). Sample 4 is part of a large carbonate concretion from the middle part of the section, and includes *Pleydellia costula* (Zieten) (Plate 1, fig. 2; Fig. 2). This species is characteristic of the Late Toarcian Aalensis Zone (Schulbert, 2001). Sample No. 2 is *in situ*, from a mudstone in the upper part of the section. Numerous poorly preserved inner whorls of ammonites, transitional from the predominantly Toarcian genus *Pleydellia* to the Aalenian genus *Leioceras* are present here. One of these ammonites, *Pleydellia* cf. *leura*

(Buckman) [M], interpreted as being from the Toarcian–Aalenian transition, is illustrated (Plate 1, fig.3; Fig. 2).

Locality 7 is ~5 km east-south-east of locality 6, in Khussa Kardonikskaya village, specifically a gully on the left bank of the Khussa Kardonikskaya River. The lowermost beds are ca. ~25 m thick, and represent the upper part of Djigiat Formation. They are largely fossiliferous massive grey and yellow-brown sandstones with concretions, overlain by clayey sandstones and sandy mudstones. The Djigiat Formation is overlain by ~30 m of dark grey mudstone with concretions. This is the lowermost part of the Lower Bajocian Djangura Formation. Previous studies on these strata include Migacheva (1962), Rostovtsev (1965) and Kazakova (1984). Samples 1 and 5 were collected from section 7. Sample 1 is the matrix produced during the preparation of *Rhodaniceras* ex gr. *rhodanicum* Renz found in talus near the lowermost part of the section. (Plate 1, fig.1; Fig. 2). This form is characteristic of the earliest Aalenian Opalinum Subzone (Rulleau et al., 2001). Sample 5 is from a concretion which yields *Leioceras opalinum* (Reinecke), the index species of the Opalinum Subzone. Images of ammonites and their aptychi from a similar concretion were given by Mitta et al. (2018b).

4. Palynostratigraphy

Relatively abundant and diverse palynomorph associations were recovered from the five samples examined (Fig. 2; Plate 2-4; Appendices 1, 2). These comprise marine forms (36.8–62.0%), cryptogam spores (25.5–42.1%) and gymnosperm pollen (12.5–21.1%). The more abundant samples, numbers 4, 2 and 1 are analysed, with the emphasis on biostratigraphy, in the subsections below.

4.1. Microplankton

Dinoflagellate cysts, and other aquatic microplankton (acritarchs, prasinophytes and zygnematalean algae), were found in all the five samples examined (Plate 3, 4; Appendix 2). Two assemblages of dinoflagellate cysts were identified, based on samples 4, 2 and 1. These are assemblages characterised by *Nannoceratopsis* (sample 4), and the *Parvocysta* suite (samples 2 and 1).

The *Nannoceratopsis* Assemblage (sample 4, uppermost Toarcian)

The dinoflagellate cysts in sample 4, from the uppermost Toarcian, are dominated by *Nannoceratopsis* and this genus accounts for 55.8% of the entire palynoflora. *Nannoceratopsis deflandrei* and *Nannoceratopsis magnicornis* are especially common with the latter being confined to this assemblage (Appendix 2). Other forms present comprise *Parvocysta* sp., *Susadinium faustum*, *Susadinium scrofoides* and *Susadinium* sp. The latter four forms are all representatives of the *Parvocysta* suite of Riding (1984) and, amalgamated, represent 4.1% of the total palynomorphs. Other marine microplankton is also present in sample 4; this comprises acritarchs (*Micrhystridium* spp.) and prasinophytes (*Cymatiosphaera* sp. and *Tasmanites* sp.). The lower boundary of this assemblage cannot be established herein, as the underlying sample (number 3), yielded only sparse dinoflagellate cysts. Seventeen specimens of *Nannoceratopsis* and 18 specimens of the *Parvocysta* suite were recorded from this horizon (Appendix 2). The marine microplankton recorded here compares well with other records from the late Toarcian from elsewhere in the northern hemisphere (e.g. Bjaerke, 1980; Riding, 1984; Prauss, 1989; Feist-Burkhardt, 1990, 1994; Riding et al., 1991, 1999; Smelror and Below, 1992; Koppelhus and Nielsen, 1994; Poulsen, 1996; Bucefalo Palliani and

Riding, 1997; 1998; Butler et al., 2005; Feist-Burkhardt and Pross, 2010; Goryacheva, 2017).

The *Parvocysta* suite Assemblage (samples 2 and 1, uppermost Toarcian–lowermost Aalenian)

Sample 2 yielded substantially more diverse dinoflagellate cyst associations than the underlying sample 4. Despite this, several species are common to both assemblages. The genus *Nannoceratopsis* is present, but represents only 4.3% of the assemblage, i.e. in far lower proportions than in sample 4. *Nannoceratopsis magnicornis* is absent, but *Nannoceratopsis deflandrei, Nannoceratopsis gracilis, Nannoceratopsis senex* and *Nannoceratopsis* spp. were recognised. By contrast, the *Parvocysta* suite is both relatively common and diverse. In sample 2, this comprises *Parvocysta ampulla*, *Parvocysta bullula*, *Parvocysta* sp., *Phallocysta elongata*, *Phallocysta eumekes*, *Susadinium faustum*, *Susadinium scrofoides* and *Susadinium* sp. This association accounts for 15.4% of the entire palynoflora. *Kallosphaeridium* sp., ?*Luehndea* sp. and *Maturodinium* sp. were also encountered in very low numbers.

Sample 1 produced lower proportions of dinoflagellate cysts in comparison to sample 2. *Nannoceratopsis deflandrei*, *Nannoceratopsis gracilis*, *Nannoceratopsis* senex and *Nannoceratopsis* spp. were encountered, and account for 6.7% of the entire palynoflora. The only representative of the the *Parvocysta* suite was *Phallocysta eumekes* (0.4%), and it is this record that places sample 1 into this assemblage. Furthermore, *Kallosphaeridium* sp. and ?*Luehndea* sp. were also recognised in sample 1. The latter form may be reworked from the Upper Pliensbachian or earliest Toarcian (Morgenroth, 1970, Riding, 1987). Other marine microplankton were also recorded in samples 2 and 1. These comprise acritarchs (*Leiofusa jurassica*, *Leiofusa* spp., *Micrhystridium* spp., *Polygonium* spp. and *Veryhachium* spp.), prasinophytes (*Cymatiosphaera* sp., *Leiosphaeridia* sp., *Pterospermella* sp. and *Tasmanites* sp.) and zygnematalean algae (*Schizosporis* sp.) (Appendix 2).

In summary therefore, the *Parvocysta* suite Assemblage is distinguished from the underlying *Nannoceratopsis* Assemblage by a significant reduction in the proportions of the genus *Nannoceratopsis*, the absence of *Nannoceratopsis magnicornis*, and by a marked increase in the diversity and numbers of representatives of the *Parvocysta* suite, principally the genera *Parvocysta* and *Susadinium*. The aquatic palynomorphs encountered in samples 2 and 1 are generally consistent with other relevant records from Eurasia. The range top of the overwhelming majority of the *Parvocysta* suite is in the earliest Aalenian (Opalinum Zone) according to, for example, Riding (1984) and Butler et al. (2005).

4.2. Pollen and spores

The pollen and spores are relatively stratigraphically conservative throughout, and consequently only a single assemblage can be recognised (Fig. 2, Plate 2; Appendix 2). In the gymnosperm pollen associations, bisaccate pollen (*Alisporites*, *Piceapollenites*, *Pinuspollenites* and *Podocarpidites*) and monosulcate pollen such as *Ginkgocycadophytus* were prominent elements. *Classopollis*, *Perinopollenites elatoides*, *Quadraeculina limbata* and *Vitreisporites pallidus* were also encountered. Cryptogam spores, from ferns and lycophytes, are generally more abundant than gymnosperm pollen, and were consistently more diverse. The genus *Cyathidites* is the most prominent in addition to, for example, *Concavisporites* spp., *Dictyophyllidites* spp., *Duplexisporites* spp., *Gleicheniidites* spp., *Hymenozonotriletes bicycla*, *Lycopodiumsporites* spp., *Marattisporites scabratus*, *Matonisporites* spp., *Obtusisporis juncta*, *Osmundacidites* spp., *Pilasporites marcidus* and *Stereisporites* spp. The pollen and spores are entirely consistent with the Toarcian–Aalenian transition; notably the typically Middle Jurassic saccate araucariacean pollen genus *Callialasporites* is absent. Similar miospore assemblages have been described from the Toarcian of the North Caucasus by Yaroshenko (1965), Besnosov et al. (1973), Rostovtsev et al. (1992) and Goryacheva et al. (2018).

The mixed microplankton and pollen/spore assemblages are consistent with shelfal marine deposition. This epicontinental setting was adjacent to damp, low-lying land with abundant stands of relatively diverse cryptogams (ferns and lycophytes). Occasional gymnosperms, largely conifers, grew nearby, however most of these were most probably growing upstream of the drainage systems in this area. The palaeoclimate was likely to have been cold temperate because the pollen genus *Classopollis* is not especially common (Appendix 2) (Vakhrameyev, 1982).

5. Conclusions and Discussion

This study documents the first report of palynomorphs from the Toarcian and Aalenian Djigiat Formation of Karachay-Cherkessia in the North Caucasus, southwest Russia. As such, it is the first report on the palynology of the Lower–Middle Jurassic transition of the Caucasus (Riding, 2021). Five ammonite-calibrated samples were examined, allowing two assemblages based on dinoflagellate cysts to be identified based on three abundant associations. These are the *Nannoceratopsis* Assemblage (sample 4, uppermost Toarcian) and the *Parvocysta* suite Assemblage (samples 2 and 1, uppermost

Toarcian–lowermost Aalenian). The terrestrial palynomorphs are relatively stratigraphically conservative throughout, and cannot be realistically subdivided. The dinoflagellate cyst associations offer more biostratigraphical potential and are highly significant palaeogeographically. Unlike further to the north in Laurasia, taxa such as *Mancodinium semitabulatum* and the partiform genus *Scriniocassis* are absent in the North Caucasus. The *Nannoceratopsis* Assemblage is overwhelmingly dominated by the nominative genus, with relatively low proportions of the *Parvocysta* suite. The latter plexus is much more diverse and prominent in sample 2. This situation suggests that, representatives of this association, which emerged in the East Arctic region according to van der Schootbrugge et al. (2020), migrated south during the Toarcian and earliest Aalenian, probably through the Viking Corridor. The *Parvocysta* suite is demonstrably more diverse and abundant in the high palaeolatitudes of the northern hemisphere, but was also present further south in the temperate regions (e.g. Bjaerke, 1980; Riding, 1984; Riding et al., 1991; Riding et al., 1999; van der Schootbrugge et al., 2020). The North Caucasus lay well within the temperate belt at the Toarcian–Aalenian transition (Golonka, 2007), so the presence of genera such as *Parvocysta* and *Susadinium* in this area is perhaps unsurprising in a regional sense. However, these small dinoflagellate cysts are, by contrast, either extremely rare or entirely absent in southern Europe (Bucefalo Palliani and Riding, 2003; Correia, 2021).This is the first report of these important forms from central southern Laurasia (Riding, 2021). It seems clear that the dinoflagellates in the North Caucasus had fully recovered from the Toarcian Oceanic Anoxic Event (T-OAE at ca. 183 Ma) by the late Toarcian. In the far west of Tethys in the temperate zone, this recovery was extremely protracted (Correia, 2018; 2021). The presence of *Kallosphaeridium* close to the Toarcian–Aalenian transition helps prove that the family Gonyaulacaceae evolved during the latest Early Jurassic (van der Schootbrugge et al., 2020; Correia, 2021).

Despite this pilot study, there remains a paucity of data on Jurassic palynology in the North Caucasus and this work illustrates that more research is required.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix 1

List of palynomorph species

The palynomorphs species recognised, in four groups, are listed alphabetically here with author citations. The taxa in open nomenclature are not listed. References to the dinoflagellate cyst taxa can be found in Fensome et al. (2019).

Acritarch:

Leiofusa jurassica Cookson & Eisenack 1958

Dinoflagellate cysts:

Nannoceratopsis deflandrei Evitt 1961

Nannoceratopsis gracilis Alberti 1961

Nannoceratopsis magnicornis Bucefalo Palliani & Riding 1997

Nannoceratopsis senex van Helden 1977

Parvocysta ampulla Riding & Shaw in Riding et al. 1991

Parvocysta bullula Bjaerke 1980

Phallocysta elongata (Beju 1971) Riding 1994

Phallocysta eumekes Dörhöfer & Davies 1980

Susadinium faustum (Bjaerke 1980) Lentin & Williams 1985

Susadinium scrofoides Dörhöfer & Davies 1980

Cryptogam spores:

Hymenozonotriletes bicycla (Maljavkina 1949) Sachanova & Fradkina 1967

Marattisporites scabratus Couper 1958

Matonisporites phlebopteroides Couper 1958

Monolites couperi Tralau 1968

Obtusisporis juncta (Kara-Murza 1956) Pocock 1970

Pilasporites marcidus Balme 1957

Stereisporites brandenburghensis Schulz 1970

Stereisporites bujargiensis (Bolchovitina 1956) Schulz 1966

Stereisporites compactus (Bolchovitina 1956) Ilyina 1985

Stereisporites incertus (Bolchovitina 1956) Semenova 1970

Stereisporites infragranulatus Schulz 1970

Stereisporites psilatus (Ross 1949) Pflug 1953

Tripartina variabilis Maljavkina 1949

Gymnosperm pollen:

Perinopollenites elatoides Couper 1958

Quadraeculina limbata Maljavkina 1949

Sciadopityspollenites macroverrucosus (Thiergart 1949) Ilyina 1985

Vitreisporites pallidus (Reissinger 1939) Nilsson 1958

Appendix 2

The distribution of palynomorphs in the five samples

Sample number	**3**	**4**	**2**	**1**	**5**
	Number of specimens	%age	%age	%age	Number of specimens
Cryptogam spores					
Marattisporites scabratus	…	0.8	0.3	1.8	…
Pilasporites marcidus	…	…	…	2.1	…
Lycopodiumsporites sp.	2	1.6	1.0	0.9	1
Camptotriletes sp.	…	…	…	0.9	…
Monolites couperi	…	…	…	0.4	…
Osmundacidites sp.	…	1.1	8.3	3.5	…
Densoisporites spp.	…	…	0.3	0.4	…
Tripartina variabilis	…	…	0.3	1.3	…
Matonisporites phlebobteroides	…	…	…	0.4	…
Matonisporites sp.	…	0.4	0.3	0.4	1
Stereisporites compactus	…	…	…	0.9	…
Stereisporites sp.	…	0.8	1.7	3.5	3
Cyathidites sp.	5	14.1	13.9	17.4	9
Acanthotriletes sp.	…	…	…	0.4	…
Gleicheniidites sp.	…	0.8	0.3	1.8	1
Obtusisporis juncta	…	1.2	…	0.4	…

Dictyophyllidites sp.	…	1.2	1.0	1.8	1
Concavisporites sp.	…	2.7	0.3	2.1	…
Stereisporites infragranulatus	…	…	0.3	0.4	…
Stereisporites bujargiensis	…	…	1.0	0.9	…
Stereisporites brandenburgensis	…	…	…	0.4	…
Stereisporites psilatus	…	…	1.3	…	1
Duplexisporites sp.	…	…	0.7	…	…
Stereisporites incertus	…	…	0.3	…	…
Hymenozonotriletes bicycla	…	0.8	…	…	…
Indeterminate spores	…	…	1.3	…	2
Total cryptogam spores	**7**	**25.5**	**32.6**	**42.1**	**19**
Gymnosperm pollen					
Pinuspollenites sp.	3	2.7	0.6	2.3	3
Ginkgocycadophytus sp.	…	…	4.3	6.3	2
Piceapollenites sp.	1	1.6	0.6	1.9	3
Eucommiidites sp.	…	…	…	1.3	…
Classopollis sp.	…	…	0.3	0.9	…
Vitreisporites pallidus	…	…	0.3	2.3	…
Alisporites sp.	…	1.6	0.6	0.9	…
Podocarpidites sp.	1	1.5	0.3	0.4	2
Perinopollenites elatoides	…	…	2.3	0.9	…
Quadraeculina limbata	…	…	…	0.4	…
Pseudopicea sp.	…	0.4	…	…	…
Sciadopityspollenites macroverrucosus	…	…	…	…	1
Coniferales genus indeterminate	1	4.7	3.6	3.5	8
Total gymnosperm pollen	**6**	**12.5**	**12.9**	**21.1**	**19**
Dinoflagellate cysts					
Nannoceratopsis gracilis	1	3.5	0.9	1.8	…
Nannoceratopsis senex	4	1.9	1.3	1.8	…
Nannoceratopsis deflandrei	2	8.2	0.6	0.9	…
Nannoceratopsis magnicornis	7	29.1	…	…	…
Nannoceratopsis spp.	3	13.1	1.5	2.2	2
Parvocysta bullula	1	…	0.6	…	…
Susadinium faustum	1	0.4	1.5	…	…
Susadinium scrofoides	1	0.4	1.0	…	…
Parvocysta sp.	8	2.3	8.9	…	…
Susadinium sp.	7	1.0	1.6	…	…
Kallosphaeridium sp.	…	…	0.6	0.4	…
?*Luehndea* sp.	…	…	0.3	0.4	…
Phallocysta eumekes	…	…	0.3	0.4	…
Parvocysta ampulla	…	…	1.2	…	…

Maturodinium sp.	…	…	0.3	…	…
Phallocysta elongata	…	…	0.3	…	1
Acritarchs					
Leiofusa spp.	…	…	…	1.3	…
Leiofusa jurassica	…	…	4.3	8.2	…
Micrhystridium sp.	…	1.3	7.6	7.6	2
Veryhachium sp.	…	…	10.8	2.7	…
Polygonium sp.	…	…	2.1	3.7	…
Prasinophytes					
Pterospermella sp.	…	…	…	0.4	…
Leiosphaeridia sp.	…	…	7.6	3.8	…
Tasmanites sp.	…	0.4	0.6	0.4	2
Cymatiosphaera sp.	…	0.4	0.6	…	…
Zygnematalean algae					
Schizosporis sp.	…	…	…	0.8	…
Total microplankton	**35**	**62.0**	**54.5**	**36.8**	**7**

Captions for figures 1–2 and Plate 1-4:

Fig. 1. The sample localities. Maps of Russia illustrating the geographical context of the region studied (above and A). The Djigiat Formation sample localities (6 and 7) in the Kuban River Basin are illustrated in B.

Plate 1. Ammonites from the Toarcian–Aalenian transition of localities 6 and 7 in the Kuban River Basin, Zelenchuk District, Karachai-Cherkessia Republic. The asterisks (*) mark the start of the body chamber.

1. *Rhodaniceras* ex gr. *rhodanicum* Renz [m], specimen no. 5611/11, 1a – lateral view, 1b – ventral view; locality 7; Lower Aalenian, Opalinum zone, *ex situ*.

2. *Pleydellia costula* (Zieten), specimen no. 5611/14, 2a – lateral view, 2b – apertural view, locality 6; Upper Toarcian, Aalensis Zone, *in situ*.

3. *Pleydellia* cf. *leura* (Buckman) [M], specimen no. 5611/12, 3a – lateral view, 3b –

ventral view; locality 6; Toarcian–Aalenian boundary beds, *in situ*.

4. *Dumortieria radiosa* (v. Seebach), specimen no. 5611/13: 4a – lateral view, 4b – ventral view; locality 6; Upper Toarcian, Levesquei Zone, *ex situ*.

Fig. 2. The ranges of the ammonites studied herein, the stratigraphical positions of palynology samples 1 to 5 and a summary of the palynomorphs encountered herein from the Djigiat Formation. The ammonite zones are after Schulbert (2001).

Plate 2. Gymnosperm pollen (1–4, 6, 8, 9, 13, 16, 21) and cryptogam spores (5, 7, 10–12, 14, 15, 17–20, 22) from the Djigiat Formation (Upper Toarcian–Lower Aalenian) of locations 6 and 7, Karachay-Cherkessia, North Caucasus, southwest Russia.

1. *Piceapollenites* sp., sample 2.

2. *Alisporites* sp., sample 1.

3. *Podocarpidites* sp., sample 4.

4. *Ginkgocycadophytus* sp., sample 1.

5. *Matonisporites phlebopteroides* Couper 1958, sample 1.

6, 8, 9. *Perinopollenites elatoides* Couper 1958, sample 2.

7, 12. *Hymenozonotriletes bicycla* (Maljavkina 1949) Sachanova & Fradkina 1967, sample 4.

10, 11. *Cyathidites* sp., samples 2 and 4 respectively.

13. *Monolites couperi* Tralau 1968, sample 1.

14. *Densoisporites* sp., sample 1.

15. *Gleicheniidites* sp., sample 1.

16. *Classopollis* sp., sample 1.

17, 19. *Stereisporites bujargiensis* (Bolchovitina 1956) Schulz 1966, samples 2 and 1 respectively.

18. *Acanthotriletes* sp., sample 1.

20. *Stereisporites brandenburghensis* Schulz 1970, sample 1.

21. *Vitreisporites pallidus* (Reissinger 1939) Nilsson 1958, sample 1.

22. *Marattisporites scabratus* Couper 1958, sample 1.

Plate 3. Dinoflagellate cysts (1–12 and 14–23) and a prasinophyte (13) from the Djigiat Formation (Upper Toarcian–Lower Aalenian) of locations 6 and 7, Karachay-Cherkessia, North Caucasus, southwest Russia.

1, 8. *Nannoceratopsis gracilis* Alberti 1961, samples 1 and 2 respectively.

2, 5. *Nannoceratopsis magnicornis* Bucefalo Palliani & Riding 1997, sample 3.

3. *Nannoceratopsis* sp. cf. *N. magnicornis* Bucefalo Palliani and Riding 1997, sample 3.

4. *Nannoceratopsis senex* van Helden 1977, samples 1.

6, 9, 10, 11. *Nannoceratopsis* spp., samples 2 (specimens 9, 10 and 11) and 3 (specimen 6).

7, 14. *Nannoceratopsis senex* van Helden 1977, samples 1 and 2 respectively.

12, 18. ?*Parvocysta* sp., sample 2.

13. *Tasmanites* sp., sample 2.

15. *Phallocysta elongata* (Beju 1971) Riding 1994, sample 2.

16. *Sentusidinium* sp., sample 2.

17, 20. *Susadinium faustum* (Bjaerke 1980) Lentin & Williams 1985, samples 3 and 2 respectively.

19. *Parvocysta ampulla* Riding & Shaw in Riding et al. 1991, sample 2.

21, 22. *Parvocysta bullula* Bjaerke 1980, sample 2.

23. *Susadinium scrofoides* Dörhöfer & Davies 1980, sample 3.

Plate 4. Acritarchs (18, 23–27), dinoflagellate cysts (1–16, 19, 20–22) and a prasinophyte (17 and 27) from the Djigiat Formation (Upper Toarcian–Lower Aalenian) of locations 6 and 7, Karachay-Cherkessia, North Caucasus, southwest Russia.

1, 2, 4, 5. *Nannoceratopsis* sp., sample 4.

3, 12. ?*Nannoceratopsis magnicornis* Bucefalo Palliani & Riding 1997, sample 4. 6. 6.

6, 7. *Nannoceratopsis gracilis* Alberti 1961, sample 4.

8. *Nannoceratopsis senex* van Helden 1977, sample 4.

9–11, 13, 15, 16. *Nannoceratopsis magnicornis* Bucefalo Palliani and Riding 1997, sample 4.

14. *Nannoceratopsis* sp., sample 5.

17. *Tasmanites* sp., sample 1.

18, 26. *Veryhachium* spp., samples 2 and 1 respectively.

19. *Susadinium scrofoides* Dörhöfer & Davies 1980, sample 4.

20. ?*Phallocysta elongata* (Beju 1971) Riding 1994, sample 5.

21, 22. ?*Luehndea* sp., samples 2 and 1 respectively.

23, 24. *Leiofusa jurassica* Cookson & Eisenack 1958, samples 2 and 1 respectively.

25. *Polygonium* sp., sample 1.

27. *Leiosphaeridia* sp., sample 1.