The literature on Triassic, Jurassic and earliest Cretaceous dinoflagellate cysts: supplement five

James B. Riding

British Geological Survey, Keyworth, Nottingham NG12 5GG, United Kingdom

CONTACT James B. Riding email jbri@bgs.ac.uk

ABSTRACT

Since the publication of five literature compilations issued between 2012 and 2020, 63 further published contributions on Triassic, Jurassic and earliest Cretaceous (Berriasian) dinoflagellate cysts have been discovered, or were issued in the last 14 months (i.e. between February 2019 and March 2020). These studies are on North Africa, Southern Africa, East Arctic, West Arctic, east and west sub-Arctic Canada, China and Japan, East Europe, West Europe, the Middle East, and sub-Arctic Russia west of the Ural Mountains, plus multi-region studies and items with no geographical focus. The single-region studies are mostly focused on Africa, the Arctic, Europe and the Middle East. All the 63 publications are listed herein with doi numbers where applicable, and a description of each item as a string of keywords.

KEYWORDS dinoflagellate cysts; earliest Cretaceous (Berriasian); Jurassic; literature compilation and analysis; Triassic; worldwide

1. Introduction

The literature on Triassic to earliest Cretaceous (Berriasian) dinoflagellate cysts is relatively extensive, and it has been compiled and reviewed by Riding (2012, 2013, 2014, 2019a, 2020). These five items listed 1347, 94, 89, 266 and 93 publications respectively on this topic, with each citation followed by a string of keywords detailing the scope of these 1889 studies. Unfortunately 11 publications were mentioned twice, hence the true culmulative total of published items is 1878 (Riding 2019b). The works of Riding (2014, 2019a, 2020) were substantially more interpretive than Riding (2012, 2013); the former three papers reviewed and summarised the major items of literature which were listed. During the 14 months since the finalisation of Riding (2020), the author has compiled 63 relevant items which were either previously inadvertently overlooked or have been recently published (i.e. issued between February 2019 and March 2020). The 63 contributions listed herein makes the current cumulative total 1941 (Table 1).

These 63 articles are largely on the Jurassic of Africa, the Arctic, Europe and the Middle East (Table 2), and are listed in Appendix 1 of the Supplementary data. Papers on West Europe are most numerous (17), and comprise 27% of the overall total (Table 2). This continues the substantial Euro-centric bias noted by Riding (2012, 2013, 2014, 2019a, 2020). No single stratigraphical interval is dominant, but 19 papers are focused on, or include data from, the Early Jurassic (Table 3).

In this compilation, more selected catalogues, contributions on suprageneric classification, indexes and major taxonomic reviews are included where considered stratigraphically appropriate. Examples of these are Stover and Evitt (1978), Wilson and Clowes (1981) and Fensome et al. (2019a, 2019b).

2. Regional review and synthesis

In this section, brief commentaries/reviews of selected articles from the 63 publications listed in Appendix 1 of the Supplemental data are presented. These items are deemed particularly worthy of mention, and are from nine of the 11 geographical regions relevant to this contribution (Table 2). These 11 territories are North Africa, Southern Africa, East Arctic, West Arctic, east and west sub-Arctic Canada, China and Japan, East Europe, West Europe, the Middle East, and sub-Arctic Russia west of the Ural Mountains. Forty-nine of the 63 contributions in Appendix 1 of the Supplemental data is referred to one of these 11 regions; the remaining 14 are assigned as either ‘multi-region’ or ‘no geographical focus’ (Tables 1, 2). Van de Schootbrugge et al. (2019) and Stover and Evitt (1978) are good examples of ‘multi-region’ and ‘no geographical focus’ respectively. In this compilation, there are no relevant single-region publications from East Africa, Central America, South America, Antarctica, Southeast Asia, Australasia, the Indian subcontinent, sub-Arctic Russia east of the Ural Mountains, and the U.S.A. east and west of the Rocky Mountains (Tables 1, 2). All the dinoflagellate cysts, at and below species level, mentioned throughout this paper are listed in Appendix 2 of the Supplemental data with full author citations. All the biozones referred to herein are deemed to be have chronostratigraphical significance and the terminology used reflects this.

2.1. North Africa

Four contributions on material from the continent of Africa are included in this review. Three of these are on Egypt and Morocco in North Africa, and are summarised below.

Omran et al. (1990) is largely focussed on the palynology of the Lower Cretaceous (Hauterivian/Barremian to Albian) successions penetrated by three boreholes in the northern Western Desert of Egypt. However, eight dinoflagellate cyst taxa were reported from the Middle and Upper Jurassic, below a substantial hiatus in the Alam el Bueib Formation (Omran et al. 1990, figs 2, 9). These include the genera *Ctenidodinium, Escharisphaeridia* and *Sentusidinium*. The presence of *Apteodinium* spp., *Cribroperidinium* spp., *Hystrichosphaerina* spp. and *Systematophora areolata* means that the Jurassic samples studied are all Late Jurassic in age (e.g. Klement 1960, Riding and Thomas 1992).

El Atfy et al. (2019) is a detailed study of the palynology of the Alam El Bueib and Alamein members within the Burg El Arab Formation from the Obaiyed Oilfield in the northwest Matruh Basin, northern Western Desert, northwest Egypt. Sixty-two cuttings samples were examined from two boreholes. This succession is of Early Cretaceous age and ranges from Berriasian to Aptian, and the entire palynomorph spectra were thoroughly documented, and these include 24 dinoflagellate cyst species. These authors recognised a single dinoflagellate cyst 'phase', of Berriasian to Barremian age. Dinoflagellate cysts proved subordinate to pollen and spores, however dinoflagellate cyst phase DI of Berriasian to Barremian age was identified. This was defined as the base of the two successions studied to the range top of *Tenua anaphrissa* (as *Pseudoceratium anaphrissum*) (see Costa and Davey 1992, fig. 3.5). Also present were *Cribroperidinium* spp., *Coronifera oceanica*, *Cyclonephelium* spp., *Oligosphaeridium* spp., *Sentusidinium* spp., *Subtilisphaera* sp. and *Trichodinium castanea*. The age of phase DI was discussed by El Atfy et al. (2019, p. 114); the Berriasian–Barremian age was determined largely due to a correlation with a nearby successions studied by El Beialy (1994) and Mahmoud and Deaf (2007).

The geochemistry and palynofacies of the Pliensbachian–Toarcian Event from Ait Moussa and Issouka, northeast of Boulemane, in the Fès-Meknès region, Middle Atlas Basin, northeast Morocco was studied by Rodrigues et al. (2020) in order to investigate palaeoclimate, sea level fluctuations, sedimentology and tectonic history. The succession investigated exhibits strong terrestrial affinity, and was deposited in nearshore settings. The dinoflagellate cysts *Luehndea spinosa* and *Nannoceratopsis gracilis* were recorded from the Pliensbachian–Toarcian transition at Ait Moussa, and were attributed to post Late Pliensbachian cooling by Rodrigues et al. (2020). *Luehndea spinosa* was also encountered at Issouka.

2.2. Southern Africa

Steeman et al. (2020), is a study on material from on Angola and it represents the first relevant record from Southern Africa. These authors undertook a study of Paleogene dinoflagellate cysts of the Landana section on the coast of Cabinda Province in Angola, western Southern Africa. They noted some reworking from the underlying Mesozoic, including the characteristically Middle Jurassic species *Aldorfia aldorfensis* (see, for example, Gocht 1970; Wiggan et al. 2017). As mentioned above, this represents the first record of Jurassic dinoflagellate cysts from the region of Southern Africa.

2.3. East Arctic

Eight contributions listed in Appendix 1 of the Supplemental data are on the East Arctic region; four of these are deemed to be substantially impactful. One of them, van de Schootbrugge et al. (2019), is a multi-region study. Five of the eight items are on the Svalbard Archipelago in the Arctic Ocean, and four of these are described in subsection 2.3.1. below. The following subsection, 2.3.2, concerns two major investigations of important Lower and Upper Jurassic successions from northern Russia.

2.3.1. The Svalbard region

Koevoets et al. (2018) is a major multidisciplinary study of the Agardhfjellet Formation of borehole material from central Spitsbergen, Svalbard that was drilled for the Longyearbyen carbon dioxide storage project. These authors obtained two dinoflagellate cyst associations, one from the uppermost Bathonian Oppdalen Member and the other from the uppermost Kimmeridgian to Ryazanian (Berriasian) Oppdalssåta and Slottsmøya members (Koevoets et al. 2018, figs 8, 16). Samples from the Oppdalen Member yielded *Atopodinium haromense, Chytroeisphaeridia hyalina, Gonyaulacysta jurassica, Sirmiodinium grossii, Valensiella ovulum* and *Valvaeodinium spinosum* amongst others. This succession was assigned to the *Cadoceras calyx* boreal ammonite zone of late Bathonian age and Koevoets et al. (2018) concluded that the dinoflagellate cysts are consistent with this assessment based on the presence of *Sirmiodinium grossii* and *Valvaeodinium spinosum* (see Woollam and Riding

1983, Riding et al. 1985). The identification of *Atopodinium haromense* may be questionable as this species is typical of the Oxfordian–Kimmeridgian transition in the Late Jurassic (Thomas and Cox 1988). The Oppdalssåta and Slottsmøya members produced apparently more diverse associations including *Leptodinium subtile, Rhynchodiniopsis cladophora, Senoniasphaera jurassica* and *Tubotuberella apatela,* and typical of the Upper Jurassic. The upper, palynologically productive, part of the Oppdalssåta Member was interpreted as being late Kimmeridgian to Tithonian (early Volgian) in age. The overlying Slottsmøya Member spans the lower Volgian to Berriasian (Ryazanian), which is consistent with the boreal ammonites recovered. However, some reworking of dinoflagellate cysts from the Kimmeridgian was noted (Koevoets et al. 2018, p. 12).

The occurrence of the late Pliensbachian to early Toarcian marker dinoflagellate cyst *Mancodinium semitabulatum* in the Mohnhøgda Member (Svenskøya Formation) was mentioned in Olaussen et al. (2018, p. 48). This occurrence is coeval with a global flooding event (Smelror et al. 2018). Paterson and Mangerud (2019) produced an extensively illustrated revised palynomorph zonation for the Middle and Upper Triassic (Anisian–Rhaetian) of the Barents Sea between Svalbard in the north, and Arctic Norway in the south. Most of the biozones considered are based on spores and pollen, but the *Rhaetogonyaulax arctica* and *Rhaetogonyaulax rhaetica* dinoflagellate cyst zones of late Carnian-early Norian and early Norian age respectively were also established (Paterson and Mangerud 2019, p. 18–19, fig. 3).

Smelror et al. (2018) is a comprehensive illustrated account of the Upper Triassic to Lower Cretaceous (Norian–Aptian) palynostratigraphy of Kong Karls Land in the eastern part of the Svalbard Archipelago, north of the Barents Sea in the Arctic Ocean. The material comprises samples collected from seven formations in the Kapp Toscana and Adventdalen groups (Smelror et al. 2018, fig. 3). The oldest material are three samples from the Flatsalen Formation of Kapp Koburg, Kongsøya. The two uppermost samples yielded *Rhaetogonyaulax* sp., thereby placing the Flatsalen Formation in the *Rhaetogonyaulax rhaetica* Assemblage Zone of Paterson and Mangerud (2015) of early Norian age. This is consistent with several other studies in the Barents Sea area.

The Svenskøya Formation (Norian–?Rhaetian to Toarcian) comprises two members and is thought to include several hiatuses. The lower unit, the Sjøgrenfjellet Member, is devoid of dinoflagellate cysts and is of Norian–?Rhaetian to Hettangian–early Pliensbachian age based on pollen and spores. The overlying Moenhøgda Member yielded abundant palynomorphs including the dinoflagellate cysts *Luehndea spinosa, Mancodinium* *semitabulatum, Nannoceratopsis gracilis, Pareodinia halosa* (as *Caddasphaera halosa*) and *Phallocysta* sp. This association indicates a late Pliensbachian to early Toarcian age, correlating with the DSJ6 and DSJ7 dinoflagellate cyst zones of Poulsen and Riding (2003).

The Kongsøya Formation was interpreted as being of late Toarcian to Aalenian in age by Smelror et al. (2018). This unit produced *Nannoceratopsis gracilis*, *Nannoceratopsis* spp., *Ovalicysta hiata*, *Parvocysta* spp., *Phallocysta eumekes*, *Scriniocassis priscus* (as *Eyachia prisca*), *Scriniocassis weberi* and *Susadinium scrofoides*. The co-occurrences of *Ovalicysta hiata*, *Phallocysta eumekes* and *Susadinium scrofoides* allows a correlation to the latest Toarcian to earliest Aalenian DSJ10 dinoflagellate cyst zone of Poulsen and Riding (2003). The Flatsalen, Svenskøya and Kongsøya formations are largely conformable. However there is a major hiatus above the Kongsøya Formation and these are no Bajocian strata preserved on Kong Karls Land (Smelror et al. 2018, fig. 17).

The lowermost unit of the Agardhfjellet Formation, the Oppdalen Member has a transgressive base. The latter unit generally yielded common dinoflagellate cysts. These include *Arkellea teichophera* (as *Heslertonia teichophera), Chytroeisphaeridia cerastes, Chytroeisphaeridia hyalina, Ctenidodinium continuum, Ctenidodinium ornatum, Endoscrinium galeritum, Nannoceratopsis pellucida*, the *Paragonyaulacysta* group, *Rhynchodiniopsis cladophora* and *Sirmiodinium grossii*. On the basis of the aforementioned taxa, together with key ammonites, the Oppdalen Member was assigned to the upper Bathonian to middle Callovian (Smelror et al. 2018, fig. 13). The overlying Lardyfjellet Member of the Agardhfjellet Formation produced relatively diverse dinoflagellate cyst associations. These include the marker species *Evansia deflandrei* (as *Crussolia deflandrei*), *Gonyaulacysta eisenackii, Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis, Kalyptea diceras, Scriniodinium crystallinum, Stephanelytron redcliffense, Trichodinium scarburghense, Wanaea fimbriata* and *Wanaea thysanota*. This association is indicative of the late Callovian to early Oxfordian interval (Poulsen and Riding 2003). However, evidence from ammonites and foraminifera indicates that the upper part of the Lardyfjellet Member is early Kimmeridgian in age. There is a substantial hiatus above the Agardhfjellet Formation (Smelror et al. 2018, fig. 17).

The overlying strata, the Klippfisk, Kolje and Helvetiafjellet formations are Early Cretaceous (Valanginian–Aptian) in age. This study has allowed reliable correlations to Triassic to Cretaceous successions in Franz Josef Land, Arctic Russia (Smelror et al. 2018, fig. 17).

2.3.2. Northern Russia

The foraminifera and palynomorphs from samples collected from two sections of the Upper Jurassic (Oxfordian–Tithonian [Volgian]) on the banks of the Lopsiya River immediately east of the northern Ural Mountains in north-central Russia were studied by Lebedeva et al. (2019). This is an extremely important reference section largely due to its stratigraphical completeness, and the presence throughout of zonal ammonites and other molluscs. Lebedeva et al. (2019, figs 4, 5) reported relatively diverse marine and terrestrial palynomorphs. The dinoflagellate cyst associations are dominated by non-tabulate, proximate forms with apical archaeopyles referred to the *Sentusidinium-Batiacasphaera-Kallosphaeridium* group (Wood et al. 2016), and chorate taxa are relatively rare. The latter phenomenon is typical of the Boreal Realm (Wierzbowski et al. 2002). However, the assemblages also include typically Late Jurassic dinoflagellate cysts including *Ambonosphaera*? *staffinensis, Cribroperidinium globatum, Cribroperidinium*? *longicorne, Dingodinium* spp., *Endoscrinium luridum, Glossodinium dimorphum, Leptodinium* spp., *Scriniodinium crystallinum, Senoniasphaera jurassica, Systematophora areolata* and *Tubotuberella apatela*.

Two dinoflagellate cyst biozones were described by Lebedeva et al. (2019). These are the *Gonyaulacysta jurassica* subsp. *jurassica* and *Corculodinium inaffectum* assemblage zones of early Kimmeridgian, and latest early Kimmeridgian to earliest Tithonian (Volgian) age respectively. The *Gonyaulacysta jurassica* subsp. *jurassica* assemblage zone is equivalent to the early Kimmeridgian *Eurorasenia pseudoouralensis* ammonite subzone of the *Rasenia evoluta* ammonite zone. Lebedeva et al. (2019, p. 9) stated that the Lopsiya River material is closely comparable with the dinoflagellate cysts from around the Oxfordian–Kimmeridgian transition of northwest Europe and adjacent areas and the central Russian Platform (e.g. Riding and Thomas 1988, 1997; Riding et al. 1999). By contrast, it is markedly different from coeval material from central northern Siberia (e.g. Ilyina et al. 2005). Lebedeva et al. (2019) deemed the dinoflagellate cyst assemblages from Lopsiya River to be intermediate in floral character between coeval material from Subboreal northwestern Europe and the Boreal Realm. The overlying *Corculodinium inaffectum* assemblage zone ranges from the *Zonovia ulalensis* ammonite subzone of the *Rasenia evoluta* ammonite zone to the *Eosphinctoceras magnum* ammonite zone, and is latest early Kimmeridgian to earliest Tithonian (Volgian) in age (Lebedeva et al. 2019, fig. 4). The base of this biozone was formally identified as the range base of *Corculodinium inaffectum.*

The same succession of dinoflagellate cyst biozones were established in western Russia by Riding et al. (1999). A major difference in Lebedeva et al. (2019) is that the inception of *Corculodinium inaffectum* is substantially older than documented by Riding et al. (1999), i.e. immediately below the *Aulacostephanus mutabilis* ammonite zone. Riding et al. (1999) placed the range base of *Corculodinium inaffectum* (as *Subtilisphaera*? *inaffecta*) at the base of the *Aulacostephanus autissiodorensis* ammonite zone. As Lebedeva et al. (2019) pointed out, there is substantial congruence between their data with dinoflagellate cyst ranges established in northern Europe and adjacent regions. For example, the range bases of *Corculodinium inaffectum* and *Cribroperidinium*? *longicorne*, and the apparent extinctions of *Endoscrinium luridum* and *Gonyaulacysta jurassica* subsp. *jurassica* are extremely similar in both areas in terms of their calibration with the ammonite zonations.

Two successions spanning the Kyra and Kelimyar formations of late Pliensbachian and Toarcian age from two exposures near the Kelimyar River in northern Siberia were studied by van de Schootbrugge et al. (2019) as part of a major multi-region study comparing the Arctic with sub-Arctic West Europe. These were sections S16 and S5-D1, and the former comprises Upper Pliensbachian to Upper Toarcian strata. Most of the Upper Pliensbachian Kyra Formation yielded sparse dinoflagellate cyst associations dominated by the genus *Nannoceratopsis*. By contrast, the uppermost Kyra Formation, and the overlying Kelimyar Formation of Toarcian age produced much more species-rich dinoflagellate cyst palynofloras. *Batiacasphaera* sp., *Dissiliodinium* sp., *Maturodinium inornatum*, *Pareodinia*? *pseudochytroeides* (as *Dodekovia pseudochytroeides*), *Parvocysta* spp., *Phallocysta eumekes*, *Scriniocassis weberi*, *Susadinium scrofoides*, *Valvaeodinium koessenium* (as *Comparodinium koessenium*), *Valvaeodinium* spp. and *Wallodinium cylindricum* were recorded from this succession, together with the acritarch *Limbicysta bjaerkei* (see van de Schootbrugge et al. 2019, fig. 7). Biostratigrapically, the most notable aspect of this succession is that the *Parvocysta-Phallocysta* suite has a substantially younger inception, i.e. earliest Toarcian, than further south in western Europe (e.g. Riding 1984, Riding et al. 1991).

The transition between the Kyra and Kelimyar formations (uppermost Pliensbachian–Lower Toarcian) was sampled in the Kelimyar River S5-D1 section by van de Schootbrugge et al. (2019). At the onset of the Early Toarcian negative Carbon Isotope Excursion, there is a dramatic increase in dinoflagellate cyst diversity. *Mancodinium semitabulatum, Moesiodinium raileanui, Nannoceratopsis* spp., *Parvocysta* spp., *Phallocysta* spp., *Susadinium scrofoides* and *Valvaeodinium* spp. all appeared at this time (van de Schootbrugge et al. 2019, fig. 9). This succession proves that the range base of the *Parvocysta-Phallocysta* suite is early Toarcian in age in the high palaeolatitudes.

The data from the two Kelimyar River sections examined by van de Schootbrugge et al. (2019) disproves the contention of, for example Riding et al. (1999, fig. 11) that the *Parvocysta-Phallocysta* suite emerged in the high northerly palaeolatitudes during the Late Toarcian. By contrast, this group emerged during the early Toarcian, and thrived during the Toarcian Oceanic Anoxic Event (T-OAE) in northern Siberia. As the *Parvocysta-Phallocysta* suite co-occurred with early representatives of the Gonyaulacales during the Early Toarcian, the high northerly latidudes appear to represent the cradle of dinoflagellate evolution at this critical interval in plankton evolution (Wiggan et al. 2018). The abundance of dinoflagellate cysts in northern Siberia during the T-OAE is believed to be as a result of only sporadic benthic anoxia due to seasonally-driven marine mixing. Further south, there was a virtual blackout of dinoflagellate cysts during the early Toarcian (Correia et al. 2017). Furthermore, the *Parvocysta-Phallocysta* suite migrated into Europe in southerly-moving currents through the Viking Corridor after oceanic deepening during the middle part of the early Toarcian (van de Schootbrugge et al. 2019, fig. 11). These authors suggested that this enhanced Arctic-Tethys marine connectivity, specifically the influx of cold, low-salinity, nutrient-rich waters from the Arctic region helped to end the T-OAE. These conclusions are supported by the fact that the late Pliensbachian and Toarcian ammonite zonal schemes are substantially different in the Arctic, Suboreal and Tethyan regons, indicating intense provincialism at this time (van de Schootbrugge et al. 2019, fig. 1).

2.4. West Arctic

In this review there are three items relevant to the West Arctic region. These are one on Arctic Canada, one on northeast Greenland and there is one multi-region contribution (Appendix 1 of the Supplemental data). An abstract on the dinoflagellate cysts from the Upper Jurassic to Lower Cretaceous (Oxfordian–Valanginian) succession of the Rollrock section on northern Ellesmere Island in the Sverdrup Basin of Arctic Canada was issued by Ingrams (2019). This successon is an important high latiutude reference section for the Jurassic–Cretacous transition. Seven biozones were distinguished, defined by the range bases and tops of marker taxa such as *Muderongia simplex* and *Oligosphaeridium complex*. Glacioeustacy is thought to influence spine-bearing dinoflagellate cyst morphology with major fluctuations in proximochorate forms reflecting relative sea level fall.

A major paper on the Cretaceous palynostratigraphy of northeast Greenland between Traill Ø in the south and Store Koldeway in the north was published by Nøhr-Hansen et al. (2019). The interval considered was latest Jurassic to Late Cretaceous

(Tithonian–Maastrichtian) in age and the biozonation, which comprises 15 zones, was calibrated to an updated ammonite zonation and based on three boreholes and over 100 outcrop sections. It is the first palynozonation for the entire Cretaceous of East Greenland, and can be correlated to other areas in the Arctic region. The *Gochteodinia villosa villosa* (NEG Cr 1) and *Oligosphaeridium complex* (NEG Cr 2) zones cover the late Tithonian to earliest Hauterivian interval. The base of the former was defined as the inceptions of *Gochteodinia villosa villosa* and *Isthmocystis distincta* in the upper Tithonian. Bioevents in the *Gochteodinia villosa villosa* zone include the range base of *Scriniodinium pharo*, the ranges of *Lagenorhytis delicatula* and *Rotosphaeropsis thule* and the range top of *Paragonyaulacysta*? *borealis* in the Berriasian of the Rødryggen-1 core 517001. The base of the succeeding *Oligosphaeridium complex* zone was drawn in the uppermost Berriasian at the range base of the index species (Nøhr-Hansen et al. 2019, fig. 7).

Krencker et al. (2019) is a contribution based largely on geochemistry and sedimentology which posited a temporally short, high amplitude global forced regression, due to polar ice sheet dynamics, which immediately preceded the major marine transgression associated with the Toarcian Oceanic Anoxic Event (T-OAE). It suggests that this, and other, hyperthermal events may have had their origins in short-lived 'cold snaps'. This study was based on data and material from the Central High Atlas Basin in Morocco and Jameson Land, East Greenland. The palynology data in Krencker et al. (2019) is entirely from the uppermost Pliensbachian, Toarcian and lowermost Aalenian strata within the Neill Klinter Group of Jameson Land Basin in East Greenland. The samples used were originally collected from the Gule Horn to Sortehat formations for the study of Koppelhus and Dam (2003). The material yielded the dinoflagellate cysts *Luehndea spinosa, Mancodinium semitabulatum, Nannoceratopsis gracilis, Phallocysta elongata* (as *Parvocysta elongata*), *Parvocysta* sp., *Phallocysta eumekes* and *Valvaeodinium armatum* (see Krencker et al. 2019, p. 6, 7; fig. 5).

2.5. China and Japan

Two contributions on the marine palynology of the Jurassic of China and Japan were issued during the period of this review. Lin and Li (2019, fig. 4E) illustrated '?Dinoflagellate cyst' from the Lower Cretaceous Duoni Formation of Wadga coal mine, near Baxoi, Qinghai-Xizang Plateau, western China. This highly thermally mature specimen has a substantial opening that may be an archaeopyle. However the lack of other microplankton, the resemblance to certain Mesozoic gymnospermous pollen such as *Perinopollenites* and the poor preservation strongly suggests it is not of dinoflagellate affinity.

Kemp et al. (2019) is the first report of Jurassic dinoflagellate cysts from Japan. This paper is an integrated study on the isotope geochemistry, palynofacies and palynology of a highly expanded succession through the Toarcian Oceanic Anoxic Event (T-OAE) in southwest Japan. Palynomorphs were extracted from 32 samples of the Nishinakayama Formation collected from the Sakuraguchi-dani stream section near Toyota Town. The palynoflora is of relatively low diversity and two samples apparently yielded the dinoflagellate cyst *Luehndea spinosa* (see Kemp et al. 2019, fig. 4). The two samples precede the T-OAE, and this scenario is consistent with the results of Correia et al. (2017, fig. 3). The latter study found that *Luehndea spinosa* is highly characteristic of the pre T-OAE succession in the Lusitanian Basin in Portugal. Due to the intense tectonism which has affected Japan, the Nishinakayama Formation is highly thermally altered and substantially overmature. This is confirmed by the extremely poor preservation of the palynomorphs extracted by Kemp et al. (2019, fig. 3). They are intensely blackened and degraded such that identification to species level is highly problematical. This includes the photograph of *Luehndea spinosa* (see Kemp et al. 2019, fig. 3T). This specimen is a poorly-preserved subangular polygonal body approximately 40 µm in diameter and bearing irregular spines. The epicystal archaeopyle, gonal spines and gonyaulacacean tabulation characteristic of *Luehndea spinosa* are not evident (Morgenroth 1970), and the validity of the identification of this specimen is therefore not considered to be secure.

2.6. East Europe

In this compilation, eight items concerning East Europe were listed in Appendix 1 of the Supplemental data; these are studies from the Czech Republic, Poland and Ukraine. Four of these items, Birkenmajer and Gedl (2019), Skupien and Doupovcova (2019), Svobodová et al. (2019) and Kowal-Kasprzyk et al. (2020), have substantial contributions on dinoflagellate cysts.

The study of Birkenmajer and Gedl (2019) investigated the Jurassic to Paleogene dinoflagellate cyst biostratigraphy of borehole PD-9 drilled at Szczawnica in central southern Poland. This well was drilled in the intensely tectonised northern boundary fault zone of the Pieniny Klippen Belt in the West Carpathians. Specifically, this borehole indicates that the Grajcarek Main Dislocation is virtually vertical and separates the Magura Nappe of the Outer Carpathians to the north, and the Pieniny Klippen Belt to the south. The authors reported dinoflagellate cyst assemblages from the Lower–Middle Jurassic, Upper Cretaceous and Eocene.

A steeply-dipping thrust sheet of the Szlachtowa Formation of Jurassic age was identified. This is the oldest unit of the Grajcarek Unit and two samples were collected at 716.4–710.4 m and 710.4–707.1 m (Birkenmajer and Gedl 2019, fig. 4, table 1). The lowermost sample at 716.4–710.4 m yielded a low diversity dinoflagellate cyst association. It is dominated by *Nannoceratopsis gracilis* and *Phallocysta elongata*, and some Eocene contaminants are also present. The occurrence of the latter species, together with the absence of *Dissiliodinium*, is indicative of a latest Toarcian to Aalenian age (Feist-Burkhardt 1990, Riding 1994). By contrast, the uppermost sample at 710.4–707.1 m produced a relatively abundant assemblage, which lacks contamination, and is overwhelmingly dominated by *Nannoceratopsis dictyambonis*. Also present, but in lower proportions, are *Batiacasphaera* sp., *Dissiliodinium* sp., *Kallosphaeridium*? sp., *Nannoceratopsis gracilis, Nannoceratopsis raunsgaardii, Nannoceratopsis spiculata, Nannoceratopsis* sp. and *Sentusidinium explanatum* (as *Kallosphaeridium praussii*) (Birkenmajer and Gedl 2019, table 1). The authors used *Dissiliodinium* and *Nannoceratopsis dictyambonis* to interpret a latest Aalenian age for the sample at 710.4–707.1 m. The overlapping ranges of this species and genus is indicative of the latest Aalenian interval (Birkenmajer and Gedl 2019, p. 247). Furthermore, the absence of *Dissiliodinium giganteum* provides substantial negative evidence that this sample is not Bajocian in age (e.g. Gedl 2008; Segit et al. 2015).

Skupien and Doupovcova (2019) is of substantial regional significance because the succession examined is one of the few localites in the Tethyan Realm where the Jurassic–Cretaceous transition is suitable for palynological study. These authors undertook biostratigraphical research on the calcareous and organic dinoflagellate cysts, and calpionellids of the Vendryně Formation and Těšín Limestone (Tithonian and Beriasian respectively) at Bruzovice, Outer Western Carpathians in the eastern Czech Republic. These lower Tithonian and Beriasian strata were sampled and several biostratigraphically significant dinoflagellate cyst taxa recovered. These include *Amphorulacysta metaelliptica* (as *Amphorula metaelliptica*), *Diacanthum hollisteri, Dichadogonyaulax bensonii, Glossodinum dimorphum, Muderongia longicorna, Phoberocysta tabulata* (as *Muderongia tabulata*), *Prolixosphaeridium anasillum, Spiculodinium neptuni* (as *Achomosphaera neptuni*) and *Spiniferites* sp. *S.* cf. *ramosus* (see Skupien and Doupovcova 2019, fig. 6). The biostratigraphy was discussed in detail, and a very extensive set of photographs was presented (Skupien and Doupovcova 2019, p. 221, 226 and figs 7–13 respectively). The

Jurassic–Cretaceous transition was established to occur between samples Br 12 and Br 10 (Skupien and Doupovcova 2019, fig. 6). Some reworking from the Pliensbachian to Bajocian was noted; *Nannoceratopsis gracilis* and *Nannoceratopsis raunsgaardii* were encountered in the lowermost Cretaceous Těšín Limestone (Skupien and Doupovcova 2019, figs 11F, G).

Svobodová et al. (2019) examined the micropalaeontological biostratigraphy and palaeocological analysis of the Kurovice Limestone from Kurovice Quarry in southeast Czech Republic as part of a larger project the determine a Global Stratotype Section and Point (GSSP) for the Berriasian. This study includes analysis of the entire palynoflora and integrated all results with magnetostratigraphy. A total of 24 samples were examined for palynomorphs, and seven of these produced relatively rare and often poorly-preserved material due largely to the organic-lean nature of the succession (Svobodová et al. 2019, p. 166, 168, figs 13–16). Because of this, the majority of the biostratigraphical conclusions are based on the calcareous microfossils. However, bioevents such as the range tops of *Amphorulacysta*? *dodekovae* (as *Amphorula dodekovae*) and *Glossodinium dimorphum*, and the range bases of, for example, *Amphorulacysta metaelliptica* (as *Amphorula metaelliptica*), *Dichadogonyaulax bensonii, Dingodinium tuberosum* (as *Dingodinium 'tuberculosum'*), *Scriniodinium campanula, Spiculodinium neptuni* (as *Achomosphaera neptuni*) and *Tehamadinium evittii* proved to be stratigraphically useful. Some reworking was discerned.

Kowal-Kasprzyk et al. (2020) studied the dinoflagellate cysts (calcareous and organic) and foraminifera of exotic clasts of Upper Jurassic (Oxfordian–Kimmeridgian) strata from southern Poland which have been reworked into an extensive Lower Cretaceous to Eocene succession. These allochthonous fragments of sedimentary rocks deposited in shelfal settings are proxies for the understanding of the palaeogeography of this region prior to the development of the Outer Carpathian flysch basins. The clasts are from three carbonate facies types. Key marker organic dinoflagellate cyst species recognised include *Endoscrinium luridum, Glossodinium dimorphum, Gonyaulacysta jurassica, Leptodinium subtile* and *Rhynchodiniopsis cladophora* (see Kowal-Kasprzyk et al. 2020, figs 8, 9).

2.7. Sub-Arctic West Europe

Seventeen contributions solely on the Triassic, Jurassic and lowermost Cretaceous successions of sub-Arctic West Europe are covered in this review, one of which is deemed especially significant (Appendix 1 of the Supplementary data). Of these 17 single-region items, seven are briefly outlined below, and one highly impactful multi-region publication is described.

Adloff and Doubinger (1982) recorded *Dapcodinium priscum* and *Rhaetogonyaulax rhaetica* from the Rhaetian and lowermost Hettangian strata of Mersch, central Luxembourg. Similarly, Hillebrandt et al. (2013) recorded *Dapcodinium priscum* and *Rhaetogonyaulax rhaetica* from the Rhaetian of the Kuhjoch Pass in the Karwendel Mountains, western Austria, although abundance, sample and range data are lacking.

The palaeontology of the lowermost Cretaceous (Berriasian and Valanginian) strata of central Austria was studied by Boorová et al. (2015). This study is centered on the Schrambach Formation at its type locality and was multidisciplinary, encompassing ammonites, calpionellids and calcareous dinoflagellate cysts. The Oberalm, Schrambach and Rossfeld formations yielded organic-walled dinoflagellte cysts (Boorová et al. 2015, p. 106–107, figs 3A–3F, 7–8, table 1). Biostratigraphically significant taxa recorded by these authors include *Amphorulacysta metaelliptica* (as *Amphorula metaelliptica*), *Ctenidodinium elegantulum, Cribroperidinium*? *edwardsii, Dichadogonyaulax bensonii, Kleithriasphaeridium corrugatum, Kleithriasphaeridium fasciatum, Phoberocysta neocomica, Pseudoceratium pelliferum, Scriniodinium campanula, Spiculodinium neptuni* (as *Achomosphaera neptuni*), *Spiniferites ramosus* and *Stanfordella*? *cretacea*. Some reworking of specimens of *Nannoceratopsis*, including *Nannoceratopsis gracilis*, from the underlying Lower–Middle Jurassic (Pliensbachian–Bajocian) was observed in the Oberalm and Schrambach formations (Boorová et al. 2015, figs 7P, 7Q).

The palynology and sedimentology of the Rannoch Formation (Brent Group) in the northern North Sea was studied by Slater et al. (2017). These authors reported the presence of the dinoflagellate cyst genera *Evansia, Kallosphaeridium, Mancodinium, Nannoceratopsis, Pareodinia* and *Phallocysta* in bioturbated sandy facies of three wells in block 211/14. This association, together with rare *Botryococcus*, is indicative of shallow marine conditions within the Rannoch Formation which is late Aalenian–early Bajocian in age (Richards et al. 1993).

Schobben et al. (2019) undertook a multidisciplinary study of the uppermost Triassic and lowermost Jurassic (Rhaetian–Hettangian) strata of central Europe in order to beeter understand the end-Triassic mass extinction. These authors recorded *Dapcodinium priscum*, *Rhaetogonyaulax rhaetica* and *Suessia swabiana* from the Rhaetian and Hettangian succession at a quarry northwest of Bonenburg in central Germany. *Suessia swabiana* was confined to the Rhaetian, but *Dapcodinium priscum* and *Rhaetogonyaulax rhaetica* were recorded throughout (Schobben et al. 2019, fig. 2).

The vegetational response to the Toarcian Oceanic Anoxic Event (T-OAE) in northern England was investigated by Slater et al. (2019). Despite the focus on the terrestrial realm, these authors discussed the dynamics of marine phytoplankton and illustrated the dominance of sphaeromorphs, together with abundant amorphous organic material with much reduced numbers of dinoflagellate cysts during the T-OAE, which is characterised by a marked negative carbon isotope excursion (Slater et al. 2019, fig. 2).

A major multi-region study on the Lower Jurassic (Pliensbachian and Toarcian) of the East Arctic and West Europe was published recently by van de Schootbrugge et al. (2019). These authors worked on the Cleveland Basin in northern England and the Norwegian North Sea. In the Cleveland Basin, van de Schootbrugge et al. (2019, fig. 5) examined productive samples from the Cleveland Ironstone and Whitby Mudstone formations (Upper Pliensbachian to Upper Toarcian). In broad terms, the floras recorded by van de Schootbrugge et al. (2019) are complementary to, and consistent with, the assemblages documented by Riding (1984) and Bucefalo Palliani and Riding (2000) from this depocentre. The oldest dinoflagellate cyst species recorded by van de Schootbrugge et al. (2019) was *Luehndea spinosa* in the *Amaltheus margaritatus* ammonite zone of the Upper Pliensbachian and this was followed by a substantial influx of taxa at the Pliensbachian–Toarcian transition. These include the inceptions of *Mancodinium semitabulatum, Maturodinium inornatum, Nannoceratopsis gracilis, Nannoceratopsis senex* and *Scriniocassis weberi*. There is a marked decrease in dinoflagellate cysts, but not a total blackout, during the Carbon Isotope Excursion (CIE) interval at the base of the *Harpoceras falciferum* ammonite zone in the T-OAE. The *Parvocysta-Phallocysta* suite are first observed in the *Harpoceras falciferum–Hildoceras bifrons* ammonite zone transition, after the T-OAE. Of this major plexus of forms, *Parvocysta bullula, Phallocysta eumekes* and *Susadinium scrofoides* were recorded by van de Schootbrugge et al. (2019, figs 5, 12). The subsequent diversity only increased marginally up-section, with *Scriniocassis priscus* appearing in the middle part of the *Hildoceras bifrons* ammonite zone (van de Schootbrugge et al. (2019, fig. 5). Taken together, Riding (1984), Bucefalo Palliani and Riding (2000) and van de Schootbrugge et al. (2019) provide an excellent composite palynologcal reference section for the Sinemurian to the Aalenian of the Cleveland Basin.

The uppermost Pliensbachian and Toarcian succession from the Norwegian North Sea, specifically well 34/10-35 in the Gulfaks South oilfield, was studied by van de Schootbrugge et al. (2019, fig. 6) as part of an investigation of the Arctic and Europe. This is the only succession in this study that is not calibrated to the ammonite zonation. It appears that, in general terms, this North Sea record is similar to coeval floras from northern England, but nonetheless and intermediate between northern Siberia and northwest Europe. *Luehndea spinosa* ranges slightly stratigraphically higher (to the end of the CIE in the T-OAE) than in southern Europe and Tethys, i.e. into the *Harpoceras falciferum* ammonite zone equivalent based on chemostratigraphy (van de Schootbrugge et al. 2019, fig. 12). There is no virtual blackout of dinoflagellate cysts in the T-OAE, as is the case further south in Europe, in the Norwegian North Sea (e.g. Correia et al. 2017). Early representatives of the Gonyaulacales such as the genera *Batiacasphaera* and *Dissiliodinium* are present in the upper Pliensbachian, and throughout the T-OAE of well 34/10-35. This is similar to the records from northern Siberia (van de Schootbrugge et al. 2019, figs 7, 9). Potentially most significantly, in well 34/10-35 is the range bases of *Parvocysta bullula* and *Parvocysta nasuta* within the T-OAE, i.e. within the negative CIE (lowermost Toarcian). These species are typical of the *Parvocysta-Phallocysta* suite, and this inception is similar to the situation in northern Siberia (see section 2.2; van de Schootbrugge et al. 2019, figs 6, 7, 9, 12).

Hesselbo et al. (2020) is a follow-up paper to Riding et al. (2013). The latter is an account of acmes of the dinoflagellate cyst *Liasidium variabile* and the pollen species *Classopollis classoides*, together with a marked negative CIE of 2–3‰ in the upper Sinemurian strata of Lincolnshire, eastern England. These phenomena were collectively termed the S-CIE and interpreted as a hyperthermal event of global extent. Hesselbo et al. (2020) sampled the shallow marine Sinemurian succession at Robin Hood's Bay in the Cleveland Basin, North Yorkshire, northern England at a high resolution. These authors confirmed the presence of the S-CIE (and renamed it the Liasidium Event), which corresponds very closely to the *Oxynoticeras oxynotum* ammonite zone. The Liasidium Event at Robin Hood's Bay also is coeval with a negative CIE that exhibits a distinctive double spike in the middle part of the *Oxynoticeras oxynotum* ammonite zone (Hesselbo et al. 2020, fig. 3). The peak occurrences of *Liasidium variabile* correspond to deep water and maximum flooding. Analysis of parasequences in this succession allow an age assessment of at least one million years for the Liasidium Event. The intensity of this relatively minor hyperthermal is far less than the subsequent T-OAE, and no evidence of significant bottom water deoxygenation was developed. This study established a chronostratigraphical range for *Liasidium variabile* at Robin Hood's Bay as middle late Sinemurian. Specifically this is the base of the *Eparietites denotatus* ammonite subzone of the *Asteroceras obtusum* ammonite zone, to close to the top of the *Oxynoticeras oxynotum* ammonite subzone of the *Oxynoticeras oxynotum* ammonite zone. However, *Liasidium variabile* is only consistent and common (i.e. >5 %) in the *Oxynoticeras oxynotum* ammonite zone, from the middle of the *Oxynoticeras simpsoni* ammonite subzone to the base of the *Oxynoticeras oxynotum* ammonite subzone (Hesselbo et al. 2020, fig. 3).

2.8. The Middle East

In this review, there are six contributions which are focused exclusively on the Middle East, two of which are considered especially impactful (Appendix 1 of the Supplementary data). Five of these six items are on the Lower and Middle Jurassic (Pliensbachian to Callovian) successions of northern Iran. The material documented in these five articles is dominated by pollen and spores, and all the palynomorphs are blackened and poorly-preserved due to substantial levels of thermal alteration.

Four of the items on Iran were authored or co-authored by Fatemeh Vaez-Javadi, and three of these are centered on northeast Iran. The first of these was Vaez-Javadi et al. (2003), a study of the marine palynomorphs in six samples collected from the Shemshak Formation of Jajarm County, northeast Iran. The material is highly blackened, and includes nine species of dinoflagellate cysts and two acritarchs. Two zones, the *Nannoceratopsis spiculata* and *Valensiella ovulum* biozones were established, and are of Pliensbachian–Toarcian and Bajocian age respectively (Vaez-Javadi et al. 2003, fig. 2, pl. 1, 2). The *Nannoceratopsis spiculata* biozone yielded four taxa; these are *Kalyptea diceras*, *Liesbergia liesbergensis*, *Nannoceratopsis spiculata* and *Scriniodinium*? *dictyophorum* (as '*Aldorfia dictyophora'*) (see Vaez-Javadi et al. 2003, fig. 2). *Nannoceratopsis spiculata* does not normally occur in the Pliensbachian–Toarcian interval with younger gonyaulacacean taxa such as *Liesbergia liesbergensis* (see Berger 1986). In the succeeding *Valensiella ovulum* biozone (Bajocian), a more diverse flora was recorded. However, as in the *Nannoceratopsis spiculata* biozone, some species such as *Gonyaulacysta centriconnata* appear to be stratigraphically anomalous (Riding 1983).

Vaez-Javadi (2018, 2019) are both on the palynology of the Middle Jurassic (Aalenian–Bajocian) Hojedk Formation of the Tabas Block in northeast Iran. In a substantial paper, Vaez-Javadi (2018, fig. 2) reported a moderately diverse dinoflagellate cyst association dominated by the genera *Kalyptea, Nannoceratopsis* and *Pareodinia*. This assemblage was assigned to the *Nannoceratopsis triceras-Pareodinia ceratophora* assemblage zone. The presence of species such as *Nannoceratopsis gracilis, Nannoceratopsis symmetrica, Nannoceratopsis triceras* and *Pareodinia ceratophora* is consistent with an Aalenian–Bajocian age (Bucefalo Palliani and Riding 2000, 2003). Vaez-Javadi (2019) is a report on 38 samples from the Hojedk Formation of the Chahrekhneh borehole, southwest of Tabas, in South Khorasan Province, northeast Iran. A less diverse dinoflagellate cyst assemblage was recovered than in Vaez-Javadi (2018), but it also comprised the genera *Kalyptea, Nannoceratopsis* and *Pareodinia*. The *Nannoceratopsis* sp. cf. *N. gracilis* interval zone was established, and was assigned an Aalenian–Bajocian age. Miospore evidence also contributed to this age assignment, which is consistent with other studies on marine microplankton (Riding and Thomas 1992, Poulsen and Riding 2003).

An integrated study on the palaeobotany and palynology of the Dansirit Formation (Middle Jurassic) from the Soltanieh Mountains of Zanjan Province, northwest Iran was undertaken by Vaez-Javadi and Abbassi (2018). The dinoflagellate cysts recorded were *Nannoceratopsis triceras*, *Pareodinia ceratophora* and *Pareodinia* sp. cf. *P. prolongata*. The specimens figured are not in an optimal preservational state (Vaez-Javadi and Abbassi 2018, pl. 1/16–19). The *Pareodinia ceratophora-Nannoceratopsis triceras* assemblage zone, of Aalenian–Bajocian age, was erected on the basis of this material.

Badihagh et al. (2019) is a detailed study of the palynomorphs and plant macrofossils from the Hojedk Formation of Well 233, southwest of Tabas city, northeast Iran. This part of the Hojedk Formation of the Tabas Block is interpreted as being Middle Jurassic (?Bajocian–Bathonian) in age based on the pollen and spores which dominate the 48 samples studied. The entire succession studied was assigned to the *Klukisporites variegatus* acme zone by Badihagh et al. (2019). This interpretation was based on the consistent and abundant occurrence of the pteridophytic spore *Klukisporites variegatus*. However rare unidentified dinoflagellate cysts were recorded in samples 42 and 41, in the uppermost part of the Hojedk Formation, by Badihagh et al. (2019, fig. 2, tables 1, 2). It is clear that all the palynomorphs recovered from the Hojedk Formation of the South Khorasan Province are very dark and relatively poorly-preserved (Badihagh et al. 2019, fig. 4). This is indicative that this unit had been subjected to high levels of thermal alteration. These authors illustrated one indeterminate dinoflagellate cyst (Badihagh et al. 2019, fig. 4r). It is a poorly-preserved subpentagonal specimen which is circumcavate/epicavate, and has a cingulum and a precingular archaeopyle. The overall morphology, plus the relatively small hypocyst and the apparently broken/damaged apical horn strongly suggests that this specimen is referable to *Gonyaulacysta jurassica* subsp. *adecta*. The total range of this subspecies is Bathonian to Oxfordian, but it is only common and consistent between the Callovian and middle Oxfordian (Riding et al. 1985, Riding and Thomas 1992, 1997, Wiggan et al. 2017). If the specimen illustrated by Badihagh et al. (2019, fig. 4r) is *Gonyaulacysta jurassica* subsp. *adecta*, this is substantially more suggestive that the uppermost Hojedk Formation is Callovian as opposed to Bathonian; it cannot be of Bajocian age.

The five contributions reviewed herein on the Lower and Middle Jurassic (Pliensbachian–Callovian) successions of northern Iran indicate clearly that the entire region has been subjected to significant levels of sub-metamorphic thermal alteration over a substantial interval. This is because, following faulting during the early part of the Cimmerian orogeny, Middle Jurassic siliciclastic successons were deposited in northern Iran and these were affected by the Mid Cimmerian orogenic event throughout the Iran Plate (Zanchi et al., 2009). Unsurprisingly, this intense tectonism has badly affected palynomorph preservation. The four contributions authored or co-authored by Fatemeh Vaez-Javadi clearly prove that there was a low diversity dinoflagellate cyst association, dominated by the genera *Nannoceratopsis* and *Pareodinia,* in Aalenian and Bajocian successions throughout northern Iran. The units examined were the Dansirit Formation of northwest Iran and the Hojedk and Shemshak formations of northeast Iran. Badihagh et al. (2019) also studied the Hojedk Formation of northeast Iran. These authors found evidence that part of this unit appears to be somewhat younger, i.e. Callovian in age.

The remaining contribution on the Middle East is Issautier et al. (2019). This is a major work on the depositional environments, palynostratigraphy, sedimentology and sequence stratigraphy of the Minjur Formation in central Saudi Arabia. This unit was studied in detail via examination of 112 cuttings and 12 core samples collected from five exploration wells in central and eastern Saudi Arabia (Issautier et al. 2019, figs 1, 11, 12). The palynology of this material was documented in detail, and six palynomorph zones (‘palynozones’) established which span the late Carnian to Pliensbachian interval. These authors reported the occurrences of the dinoflagellate cyst species *Dapcodinium priscum,* ?*Hebecysta* spp., *Nannoceratopsis gracilis, Rhaetogonyaulax dilatata, Rhaetogonyaulax rhaetica* and *Rhaetogonyaulax wigginsii*, together with acritarchs, foraminiferal test linings, freshwater algae, pollen and spores, and prasinophytes (Issautier et al. 2019, p. 155–158; 170–179). It is clear that the cuttings samples are badly affected by uphole contamination or caving of substantially younger Jurassic dinoflagellate cysts such as *Ctenidodinium sellwoodii*, *Korystocysta* spp. and *Systematophora penicillata* (see Issautier et al. 2019, fig. 16, enclosures 1–4). Significantly, one of these allochthonous forms is *Wanaea verrucosa* which is a marker for the late Bajocian to early Bathonian interval of Australasia (Mantle and Riding 2012). These occurrences indicate that *Wanaea verrucosa* has a wider palaeogeographical extent than was initially envisaged.

2.9. *Sub-Arctic Russia west of the Ural Mountains*

Holm-Alwmark et al. (2019) is the only item solely on sub-Arctic western Russia that is relevant to this review (Appendix 1 of the Supplementary data). These authors analysed samples from a basal breccia and the overlying Kovernino Formation, both from above the Puchezh-Katunki impact structure east of Moscow in western Russia. Abundant pollen and spores, together with *Mendicodinium* spp. and unidentified dinoflagellate cysts were reported, and interpreted to be Pliensbachian to early Toarcian in age.

3. Conclusions

From February 2019 to March 2020, 63 publications pertaining to Triassic to earliest Cretaceous dinoflagellate cysts were discovered which are further to the 1878 already compiled by Riding (2012, 2013, 2014, 2019a, 2020). This makes a culmulative total of 1941 relevant items (Table 1). These 63 contributions are listed in Appendix 1 of the Supplemental data, and are mostly on the Jurassic of Africa, the Arctic, Europe and the Middle East (Table 2). Items on East and West Europe are most numerous (eight and 17 respectively), and overall comprise 39.7% of the total (Table 2). This marked bias towards Europe was previously recorded by by Riding (2012, 2013, 2014, 2019a, 2020). Nine and six items are on the Arctic and the Middle East, and this represents 14.2% and 9.5% respectively. Africa is also well-represented with 4 papers (6.4%). The other regions represented, sub-Arctic Canada, China and Japan and sub-Arctic Russia, together make up 8% of the total. Multi-region studies and publications with no geographical focus comprise 6.3% and 16% respectively (Table 2). In terms of the stratigraphical intervals investigated, the spread is relatively equable. The Early Jurassic has most studies with 19 papers either entirely focused on, or including data from, this interval (Table 3).

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Disclosure statement

The author has no potential conflict of interest.

Notes on contributor

JAMES B. RIDING is a geologist/palynologist working at the British Geological Survey (BGS) in Nottingham, UK. He undertook the MSc in palynology at the University of Sheffield and, several years later, Jim was awarded a PhD by the same institution. During 2004, Jim gained a DSc from the University of Leicester, where he did his Bachelor's degree in geology. His interests include the Mesozoic–Cenozoic palynology of the world, palaeoenvironmental palynology, palynomorph floral provinces, forensic palynology, palynomorph preparation techniques, the history of palynology, and the morphology, systematics and taxonomy of dinoflagellate cysts. Jim is a past Director-at-Large and President of AASP – The Palynological Society, and became Managing Editor in 2004.

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Display material captions:

Table 1. A breakdown of the 1941 publications on Triassic to earliest Cretaceous dinoflagellate cysts compiled by Riding (2012, 2013, 2014, 2019a, 2020) and herein based on the 23 relevant specified geographical region(s), plus multi-region studies and those with no

geographical focus, and the initial letter of the family name of the first author. The number in the geographical region cell refers to the number of relevant published items on that area alone. An ellipsis (…) indicates a zero return for that particular parameter.

Table 2. A breakdown of the 63 publications on Triassic to earliest Cretaceous dinoflagellate cysts compiled herein, based on 11 specified relevant geographical region(s) plus multi-region studies and those with no geographical focus, and the initial letter of the family name of the first author. The number in the geographical region cell refers to the number of relevant published items on that area alone. An ellipsis (…) indicates a zero return for that particular parameter.

Table 3. A breakdown of the 63 publications on Triassic to earliest Cretaceous dinoflagellate cysts compiled herein, subdivided chronostratigraphically. The intervals are Triassic, Early Jurassic, Middle Jurassic, Late Jurassic, Jurassic-Cretaceous transition, investigations comprising three or more of the previous intervals and studies with no stratigraphical focus, and reworking. Some latitude and pragmatism are used in this compilation. For example if a publication is on the Berriasian and Valanginian it is classified as covering the Jurassic-Cretaceous transition. One item may be counted twice if, for example, it spans the Toarcian to Bathonian i.e. Early and Middle Jurassic) but not three times. An ellipsis (…) indicates a zero return for that particular parameter.

SUPPLEMENTARY DATA I

Appendix 1. List of Literature

Sixty-three contributions on Triassic to earliest Cretaceous dinoflagellate cysts issued after the publication of Riding (2012, 2013, 2014, 2019a, 2020), and older papers discovered after these compilations were made, are listed in alphabetical/chronological order below. The reference format used is much the same as in Riding (2013), which was slightly modified from Riding (2012). Digital Object Identifier (doi) numbers are included where these are available. The nine papers which are deemed to be of major significance are asterisked. The language in which a paper was written in is indicated if it is not in English. A synthesis of the scope of each item is given as a string of keywords in parentheses after each citation. These keywords attempt to comprehensively summarise the principal subject matter, age range, major geographical region(s) and country/countries. A distinction is made between publications which present new data ('primary data'), and those which compile, review or summarise existing data ('compilation' etc.). Two abstracts are listed here, and these are denoted by the word 'summary' in the keyword string. If the author(s) have included photographs, occurrence charts and a zonal breakdown, these are indicated respectively in the keywords. For the purpose of this work, the world is subdivided into 23 major geographical regions. These are East Africa, North Africa, Southern Africa, Central America, northern South America, southern South America, Greater Antarctica, the Antarctic Peninsula, East Arctic, West Arctic, Southeast Asia, Australasia, sub-Arctic East Canada, sub-Arctic West Canada, China and Japan, East Europe, sub-Arctic West Europe, the Indian subcontinent, the Middle East, sub-Arctic Russia east of the Ural Mountains, sub-Arctic Russia west of the Ural Mountains, U.S.A. east of the Rocky Mountains and U.S.A. west of the Rocky Mountains (Table 1).

A

ADLOFF, M.-C., and DOUBINGER, J. 1982. Étude palynologique du Rhétien et de l'Hettangien de cinq sondages situés dans les environs de Mersch (Luxembourg). *Bulletin*

d'information des géologues du bassin de Paris, 19(2): 9–20 (in French with an English abstract).
(acritarchs; biostratigraphy; biozonation; boreholes; *Dapcodinium priscum*; diversity; pollen and spores; prasinophytes; *Rhaetogonyaulax rhaetica*; primary data; quantitative occurrence charts; photographs; latest Triassic–earliest Jurassic [Rhaetian–Hettangian]; sub-Arctic West Europe [Mersch, central Luxembourg])

B

BADIHAGH, M.T., SAJJADI, F., FARMANI, T., and UHL, D. 2019. Middle Jurassic palaeoenvironment and palaeobiogeography of the Tabas Block, Central Iran: palynological and palaeobotanical investigations. *Palaeobiodiversity and Palaeoenvironments*, 99: 379–399 (doi: 10.1007/s12549-018-0361-0).
(biostratigraphy; biozonation; correlation; floral affinities; kerogen; *Klukisporites variegatus* acme zone; lithostratigraphy [Hojedk Formation]; Mid Asian part of the Indo-European floral province; palaeobiogeography; palaeobotany; palaeoclimate; palaeoecology; palynofacies; plant macrofossils; pollen and spores; primary data; occurrence charts; photographs; Middle Jurassic [?Bajocian–Bathonian]; Middle East [Well 233, South Kuchak-Ali area, South Khorasan Province, southwest of Tabas city, Tabas Block, central Iran])

BAILEY, D.A. 2020. BioStrat Limited Early Jurassic Zonation. Available online at: http://www.biostrat.org.uk/EJ%202011%20postcon.pdf (accessed 30 January 2020).
(ammonite zones; bioevents; biostratigraphy; biozonation; chronostratigraphy; informal taxa; pollen and spores; prasinophytes; compilation; Early Jurassic [Hettangian–Toarcian]; sub-Arctic West Europe [no specific geographical focus])

BAILEY, D.A. 2020. BioStrat Limited Mid Jurassic Zonation. Available online at: http://www.biostrat.org.uk/MJ%202011%20eventspostcon.pdf (accessed 30 January 2020).
(ammonite zones; bioevents; biostratigraphy; biozonation; *Botryococcus*; chronostratigraphy; informal taxa; pollen and spores; compilation; Middle Jurassic [Aalenian–Callovian]; sub-Arctic West Europe [no specific geographical focus])

BAILEY, D.A. 2020. BioStrat Limited Late Jurassic Zonation. Available online at: http://www.biostrat.org.uk/LJ%202011%20events%20postcon.pdf (accessed 30 January 2020).
(acritarchs; ammonite zones; bioevents; biostratigraphy; biozonation; chronostratigraphy; informal taxa; compilation; Late Jurassic–earliest Cretaceous [Oxfordian–Berriasian]; sub-Arctic West Europe [no specific geographical focus])

BAILEY, D.A. 2020. BioStrat Limited Early Cretaceous Zonation. Available online at: http://www.biostrat.org.uk/EK%20Zones%202011postcon.pdf (accessed 30 January 2020).
(bioevents; biostratigraphy; biozonation; chronostratigraphy; informal taxa; compilation; Early Cretaceous [Berriasian–Albian]; sub-Arctic West Europe [no specific geographical focus])

BIRKENMAJER, K., and GEDL, P. 2019. The Jurassic to Palaeogene strata in the northern boundary fault zone in deep borehole PD-9 at Szczawnica, Pieniny Klippen Belt, West Carpathians, Poland: biostratigraphy and tectonic implications. *Annales Societatis Geologorum Poloniae*, 89(3): 233–257 (doi: 10.14241/asgp.2019.18).
(biostratigraphy; geological background; Grajcarek Unit; lithostratigraphy [the Bryjarka Member and the Hałuszowa, Jarmuta, Malinowa Shale, Szczawnica and Szlachtowa formations]; Magura Nappe; Pieniny Klippen Belt; structural geology; tectonic thrust sheet; tectonics; West Carpathian Mountains; primary data; quantitative occurrence chart; photographs; Early–Middle Jurassic to Eocene [Toarcian–Aalenian to Ypresian]; East Europe [Szczawnica, central southern Poland])

BOOROVÁ, D., SKUPIEN, P., VAŠÍČEK, Z., and LOBITZER, H. 2015. Biostratigraphy of the Lower Cretaceous Schrambach Formation on the classical locality of Schrambachgraben (Northern Calcareous Alps, Salzburg Area). *Bulletin of Geosciences,* 90(1), 89–131 (doi: 10.3140/bull.geosci).
(ammonites; aptychi, biostratigraphy; calpionellids; calcareous dinoflagellate cysts; geological background; palynofacies; lithostratigraphy [Oberalm, Schrambach and Rossfeld formations], reworking; taxonomy; tectonic slices; primary data; non-quantitative occurrence charts; photographs; Early Cretaceous [Berriasian–Valanginian]; sub-Arctic West Europe [Schrambachgraben, Salzachtal, near Hallein and Kuchl, south of Salzburg, central Austria])

D

DOWNIE, C., and SARJEANT, W.A.S. 1965. Bibliography and index of fossil dinoflagellates and acritarchs. *Geological Society of America, Memoir*, No. 94, 180 p.
(acritarchs; bibliography; index; compilation; no geographical or stratigraphical focus)

E

EL ATFY, H., MOSTAFA, A., MAHER, A., MAHFOUZ, K., and HOSNY, A. 2019. Early Cretaceous biostratigraphy and palaeoenvironment of the northern Western Desert, Egypt: an integrated palynological and micropalaeontological approach. *Palaeontographica Abteilung B: Palaeobotany – Palaeophytology*, 299 (1–6): 103–132 (doi: 10.1127/palb/2019/0064).
(biostratigraphy; biozonation; correlation; floral dynamics; foraminifera; foraminiferal test linings; freshwater algae; fungal remains; geological background; lithostratigraphy [Alam El Bueib and Alamein members of the Burg El Arab Formation]; palaeoclimate; palaeoecology; palynofacies; pollen and spores; prasinophytes; primary data; photographs; non-quantitative and quantitative occurrence charts; Early Cretacous [Berriasian–Aptian]; North Africa [Obaiyed Oilfield, northwest Matruh Basin, northern Western Desert, northwest Egypt])

F

FENSOME, R.A., WILLIAMS, G.L., and MACRAE, R.A. 2019. The Lentin and Williams index of fossil dinoflagellates 2019 edition. *American Association of Stratigraphic Palynologists Contributions Series*, No. 50, 1173 p.
(acritarchs; age of type material; alphabetical index; calcareous dinoflagellate cysts; coccolithophorids; cyanobacteria; dictyophycea; desmids; foraminifera; freshwater algae; fungi; glossary; *incertae sedis*; mineral grains; pollen; prasinophytes; radiolaria; rules of nomenclature; schizosporous algae; silicoflagellates; sponges; spores; taxonomy; compilation; no geographical or stratigraphical focus)

FENSOME, R.A., WILLIAMS, G.L., WOOD, S.E.L., and RIDING, J.B. 2019. A review of the areoligeracean and ceratiacean dinoflagellate cyst *Cyclonephelium* and morphologically similar genera. *Palynology,* 43, Supplement No. 1, 71 p. (doi: 10.1080/01916122.2019.1596391).

(areoligeracean dinoflagellate cysts; ceratiacean dinoflagellate cysts; *Cyclonephelium* group (11 genera); evolution; generic definitions; history; morphology (acavate/cavate; horn and ornamentation distribution; intergradation; sulcus offset to the left); palaeoecology; palaeogeography; stratigraphical occurrences; tabulation; taxonomy; type material; taxonomic review; photographs; Late Jurassic–Cretaceous–Paleogene/Neogene [Kimmeridgian–Holocene]; no geographical focus)

Note that the online Supplemental data to this paper comprises primary data on the Early Cretaceous (?Barremian) and younger successions of Arctic Canada and offshore eastern Canada (https://doi.org/110.1080/01916122.2019.1596391).

H

HABIB, D. 1979. Sedimentary origin of North Atlantic Cretaceous palynomorphs. *In*: Talwani, M., Hay, W., and Ryan, W.B.F. (editors). *Deep drilling results in the Atlantic Ocean: continental margins and paleoenvironment*, 3: 420–437 (doi: 10.1029/ME003p0420) American Geophysical Union, Maurice Ewing Series.

(biostratigraphy; biozonation; Deep Sea Drilling Project [DSDP]; deltaic deposition; palaeoecology; palaeogeography; palynofacies; pollen and spores; sedimentology; primary data; quantitative occurrence charts; photographs; earliest–Late Cretaceous [Berriasian–Cenomanian]; multi-region: sub-Arctic West Europe [Spain]; U.S.A. east of the Rocky Mountains [offshore East U.S.A., western North Atlantic Ocean])

HESSELBO, S.P., and PIEŃKOWSKI, G. 2011. Stepwise atmospheric carbon-isotope excursion during the Toarcian Oceanic Anoxic Event (Early Jurassic, Polish Basin). *Earth and Planetary Science Letters*, 301(1–2): 365–372 (doi: 10.1016/j.epsl.2010.11.021).

(ammonites; carbon cycle; chemostratigraphy; clay minerals; correlation; eccentricity forcing; eustacy; flooding surfaces; gas hydrate (methane) release; glacioeustacy; lithostratigraphy [Komorowo, Drzewica and Ciechocinek formations]; *Luehndea spinosa*; megaspores; palaeoclimate; Polish Basin; sedimentology; sediment supply; sequence stratigraphy; stepwise carbon isotope excursions; terrestrial organic matter; Toarcian Oceanic Anoxic Event [T-OAE]; weathering; primary data; Early Jurassic [Pliensbachian–Toarcian]; East Europe [Brody-Lubienia, Gorzów Wielkopolski, Kozłowice, Mechowo, Parkoszowice and Suliszowice, central Poland])

*HESSELBO, S.P., HUDSON, A.J.L., HUGGETT, J.M., LENG, M.J., RIDING, J.B., and ULLMANN, C.V. 2020. Palynological, geochemical, and mineralogical characteristics of the Early Jurassic Liasidium Event in the Cleveland Basin, Yorkshire, UK. *Newsletters on Stratigraphy,* 53(2): 191–211 (doi: 10.1127/nos/2019/0536). (acritarchs; *Asteroceras obtusum* and *Oxynoticeras oxynotum* ammonite zones; authigenic processes; biostratigraphy; *Botryococcus braunii*; carbonate minerals; Carboniferous reworking; chemostratigraphy; *Classopollis classoides*; clay mineralogy; Cleveland Basin; diagenesis; geochemistry [carbon isotope analysis; carbon:nitrogen ratios, elemental analyses; total nitrogen; total organic carbon]; hand-held X-ray fluorescence analyses; hyperthermal event; kerogen; Liasidium Event; *Liasidium variabile*; lithostratigraphy [Silicious Shale Member of the Redcar Mudstone Formation]; organic matter; palaeoclimatology; palaeoecology; paragenesis; petrography; pollen and spores; prasinophytes; scanning electron microscopy; sea level changes and sequence stratigraphy [lithological cycles/parasequences, maximum flooding, regressive-transgressive facies trends; short eccentricity cycles]; X-ray diffraction; primary data; quantitative occurrence chart; photographs; Early Jurassic [Sinemurian]; sub-Arctic West Europe [Boggle Hole, Robin Hood's Bay, North Yorkshire, northern England])

HILLEBRANDT, A.V., KRYSTYN, L., KÜRSCHNER, W.M., BONIS, N.R., RUHL, M., RICHOZ, S., SCHOBBEN, M.A.N., URLICHS, M., BOWN, P.R., KMENT, K., McROBERTS, C.A., SIMMS, M., and TOMÃSOVÝCH, A. 2013. The Global Stratotype Sections and Point (GSSP) for the base of the Jurassic System at Kuhjoch (Karwendel Mountains, Northern Calcareous Alps, Tyrol, Austria). *Episodes*, 36(3): 162–198. (acritarchs; ammonites; biostratigraphy; bivalves; brachiopods; calcareous nannofossils; carbon isotope data; correlation; cyclo- and isotope stratigraphy; diagenesis; conodonts; crinoids; crustaceans; *Dapcodinium priscum*; echinoids; foraminifera; gastropods; geochemistry; geological setting; Global Stratotype Section and Point (GSSP); kerogen analysis; lithostratigraphy (the Eiberg Member of the Kössen Formation and the Tiefengraben Member of the Kendlbach Formation); ostracods; palaeobiogeography;

palaeomagnetism; pollen and spores; radiometric geochronology; *Rhaetogonyaulax rhaetica*; Triassic-Jurassic (T-J) boundary; scaphopods; primary data; latest Triassic and earliest Jurassic [Rhaetian–Hettangian]; sub-Arctic West Europe [the Kuhjoch Pass, Karwendel Mountains, Northern Calcareous Alps, Tyrol, western Austria])

HOLM-ALWMARK, S., ALWMARK, C., FERRIÈRE, L., LINDSTRÖM, S., MEIER, M.M.M., SCHERSTÉN, A., HERRMANN, M., MASAITIS, V.L., MASHCHAK, M.S., NAUMOV, M.V., and JOURDAN, F. 2019. An Early Jurassic age for the Puchezh-Katunki impact structure (Russia) based on ^{40}Ar/^{39}Ar data and palynology. *Meteoritics and Planetary Science*, 54(8): 1764–1780 (doi: 10.1111/maps.13309).
(acritarchs; biostratigraphy; biozonation; *Botryococcus braunii*; geochronology (^{40}Ar/^{39}Ar dating); geological setting; history of study; impactites; lithostratigraphy (Kovernino Formation); *Mendicodinium* spp.; Permian reworking; petrography; pollen and spores; post-impact crater lake sediments; prasinophytes; radiometric dating; thin sections; Early Jurassic [Pliensbachian–Toarcian]; sub-Arctic Russia west of the Ural Mountains [Puchezh-Katunki impact structure, Privolzhsky Fereral District, east of Moscow])

I

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(biostratigraphy; biozonation; chorate and proximochorate dinoflagellate cysts; dropstones; eustacy; glaciations; glendonites; morphology; palaeoclimate; palaeoecology; summary; Late Jurassic–Early Cretaceous [Oxfordian–Valanginian]; West Arctic [Rollrock section, northern Ellesmere Island, Sverdrup Basin, Arctic Canada])

*ISSAUTIER, B., LE NINDRE, Y.-M., HOOKER, N., REID, C., MEMESH, A., and DINI, S. 2019. Chapter 5. Depositional environments, age, and sequence stratigraphy of the Minjur Formation in outcrop and near subsurface–Central Saudi Arabia. *In*: Al Anzi, H.R., Rahmani, R.A., Steel, R.J., and Soliman, O.M. (editors). Siliciclastic Reservoirs of the Arabian Plate. *AAPG Memoir*, No. 116: 141–183 (doi: 10.1306/13642172M1183803).

(acritarchs; biostratigraphy; biozonation; caving; conodonts; correlation; depositional environments; facies analysis; foraminiferal test linings; freshwater algae; geological background; isopach map; lithostratigraphy [Minjur Formation]; palaeoclimate; palaeoecology; palaeogeography; pollen and spores; prasinophytes; reworking; sedimentology; sequence stratigraphy; primary data; semi-quantitative occurrence charts; Late Triassic–Early Jurassic [Carnian–Pliensbachian]; Middle East [central Saudi Arabia])

J

JAIN, S. 2020. Dinoflagellates. In: *Fundamentals of Invertebrate Palaeontology*. Springer Geology. Springer, New Delhi, 67–92 (doi: 10.1007/978-81-322-3962-8_4).
(archaeopyle; biostratigraphy; geological record; living dinoflagellates; morphology; phytoplankton; tabulation; zooplankton; review article; bioevent charts; line drawings; Late Triassic–Quaternary [Rhaetian–Holocene]; no geographical focus)

K

KEMP, D.B., BARANYI, V., IZUMI, K., and BURGESS, R.D. 2019. Organic matter variations and links to climate across the early Toarcian oceanic anoxic event (T-OAE) in Toyora area, southwest Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 530: 90–102 (doi: 10.1016/j.palaeo.2019.05.040).
(acritarchs; ammonite zones; carbon and nitrogen isotopes; carbon cycle; climate change/global warming; fluvial flood events; global carbon release; hydrological cycling; lithostratigraphy [Nishinakayama Formation, Toyora Group]; *Luehndea spinosa*; palaeoecology; palynofacies; pollen and spores; Tabe Basin; thermal maturity; thin sections; Toarcian Oceanic Anoxic Event (T-OAE); primary data; semi-quantitative occurrence chart; photographs; Early Jurassic [Toarcian]; China and Japan [Sakuraguchi-dani stream section, Toyota Town area, Yamaguchi Prefecture, southwest Japan])

*KOEVOETS, M.J., HAMMER, O., OLAUSSEN, S., SENGER, K., and SMELROR, M. 2018. Integrating subsurface and outcrop data of the Middle Jurassic to Lower Cretaceous

Agardhfjellet Formation in central Spitsbergen. *Norwegian Journal of Geology,* 98(4): 1–34 (doi: 10.17850/njg98-4-01).
(ammonites; biostratigraphy; *Botryococcus*; brachiopods; carbon isotopes; chemostratigraphy; correlation; downhole logging; facies analysis; fish teeth; frost weathering; geological setting; lithostratigraphy [Agardhfjellet Formation]; Longyearbyen carbon dioxide storage project; palaeoecology; marine reptiles; molluscs; reworking; sea floor oxygenation levels; sedimentology; sequence stratigraphy; structural geology; this sections; total organic carbon [TOC]; trace fossils; X-ray flourescence geochemistry; primary data; semi-quantitative occurrence chart; Middle Jurassic–earliest Cretaceous [Bathonian–Berriasian (Ryazanian)]; East Arctic [central Spitsbergen, Svalbard Archipelago, Arctic Ocean])

KOWAL-KASPRZYK, J., KRAJEWSKI, M., and GEDL, P. 2020. The oldest stage of the Outer Carpathian evolution in the light of Oxfordian–Kimmeridgian exotic clast studies (southern Poland). *Facies*, 66, 11, doi: 10.1007/s10347-020-0595-y.
(biostratigraphy; calcareous dinoflagellate cysts; exotic clasts; facies analysis; foraminifera; foraminiferal test linings; geological background; limestones; lithostratigraphy; microfacies; palaeobathymmetry; palaeoecology; palaeogeography; provenance analysis; reworking; primary data; occurrence chart; photographs; Late Jurassic [Oxfordian–Kimmeridgian]; East Europe [Outer Carpathians, south of Kraków, southern Poland])

KRENCKER, F.-N., LINDSTRÖM, S., and BODIN, S. 2019. A major sea-level drop briefly precedes the Toarcian oceanic anoxic event: implication for Early Jurassic climate and carbon cycle. *Nature Scientific Reports*, 9: 12518, 12 p. (doi: 10.1038/s41598-019-48956-x).
(biozonation; carbon cycle; correlation; eustacy; geochemistry; glaciation; global warming; lithostratigraphy; macrofossils; palaeoclimate; polar ice sheet; pollen and spores; reworking; sedimentology; sequence stratigraphy; Toarcian Oceanic Anoxic Event [T-OAE]; trace fossils; primary data; Early–Middle Jurassic [Pliensbachian–Aalenian]; multi-region: North Africa [Central High Atlas Basin, Morocco]; West Arctic (Jameson Land Basin, East Greenland)

L

*LEBEDEVA, N.K., NIKITENKO, B.L., and COLPAERT, C. 2019. Dinoflagellate cysts and foraminifera of the Upper Jurassic Lopsiya River sections, Nether-Polar Urals, NW Western Siberia (Russia). *Revue de Micropaléontologie*, 64: 100361 (doi: 10.1016/j.revmic.2019.07.001).
(acritarchs; ammonite zones; biostratigraphy; biozonation; correlation; foraminifera; freshwater algae; geological setting; molluscs; pollen and spores; prasinophytes; *Sentusidinium-Batiacasphaera-Kallosphaeridium* group; primary data; photographs; Late Jurassic [Oxfordian–Tithonian (Volgian)]; East Arctic [Lopsiya River, sub-Polar Ural Mountains, northwest Siberia, northern Russia])

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(biostratigraphy; lithostratigraphy [Duoni, Duodigou, Linbuzong and Chumulong formations]; palaeoclimates; palaeoecology; palaeogeography; palaeovegetation; pollen and spores; primary data; photographs; Late Jurassic–Early Cretaceous [undifferentiated–Barremian]; China and Japan [Doilongdegqin County, Lhasa Block, central Qinghai-Xizang Plateau, western central China]

M

MUDIE, P.J., FENSOME, R.A., ROCHON, A., and BAKRAČ, K. 2020. The dinoflagellate cysts *Thalassiphora subreticulata* n.sp. and *Thalassiphora balcanica*: their taxonomy, ontogenetic variation and evolution. *Palynology*, 44(2), 237–269 (doi: 10.1080/01916122.2019.1567614).
(evolution; global compilation; morphology; ontogenetic variation; oxygen gradients; palaeosalinity; Paratethyan basins; size variation; tabulation; taxonomy; *Thalassiphora robusta*; *Thalassiphora* species complex; primary data and review article; occurrence chart; photographs; Late Jurassic–Late Miocene [Tithonian (Volgian)–undifferentiated]; multi-region: sub-Arctic East Canada [Shubenacadie H-100 well, Scotian margin, offshore Nova Scotia]; East Europe [Medvednica, Slavonija, Zagorje and Žumberak, Croatia and unknown locations in southwestern Romania])

N

*NØHR-HANSEN, H., PIASECKI, S., and ALSEN, P. 2019. A Cretaceous dinoflagellate cyst zonation for NE Greenland. *Geological Magazine*, doi: 10.1017/ S0016756819001043. (ammonite zones; bioevents; biostratigraphy; biozonation; correlation; lithostratigraphy; pollen; compilation/primary data; photographs; bioevent charts; latest Jurassic–Late Cretaceous [Tithonian–Maastrichtian]; West Arctic [Traill Ø to Store Koldeway, northeast Greenland])

O

OLAUSSEN, S., LARSSEN, G.B., HELLAND-HANSEN, W., JOHANNESSEN, E.P., NOTTVEDT, A., RIIS, F., RISMYHR, B., SMELROR, M., and WORSLEY, D. 2018. Mesozoic strata of Kong Karls Land, Svalbard, Norway; a link to the northern Barents Sea basins and platforms. *Norwegian Journal of Geology*, 98(4): 1–69 (doi: 10.17850/njg98-4-06).
(basin and tectonic history; biostratigraphy; *Botryococcus*; correlation; facies analysis; geological setting; lithostratigraphy [Kapp Toscana and Adventdalen groups]; macrofossils; *Mancodinium semitabulatum*; palaeogeography; plant fossils; sedimentology; seismic interpretation; sequence stratigraphy; structural geology; trace fossils; volcanism; primary data and compilation; Late Triassic–Early Cretaceous [Norian–Aptian]; East Arctic [Kong Karls Land, eastern Svalbard Archipelago, Arctic Ocean])

OMRAN, A.M., SOLIMAN, H.A., and MAHMOUD, M.S. 1990. Early Cretaceous palynology of three boreholes from northern Western Desert (Egypt). *Review of Palaeobotany and Palynology*, 66(3/4): 293–312 (doi: 10.1016/0034-6667(90)90044-J). (biostratigraphy; biozonation; boreholes; correlation; ditch cuttings; geological setting; palaeoecology; pollen and spores; primary data; non-quantitative occurrence charts; photographs; Middle Jurassic to Early Cretaceous [?Bajocian–Tithonian to Albian]; North Africa (northern Western Desert, northern Egypt)

P

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(acritarchs; ammonoids; biostratigraphy; biozonation; foraminiferal test linings; geological background; lithostratigraphy; palaeoclimate; palaeoecology; pollen and spores; prasinophytes; *Rhaetogonyaulax arctica*; *Rhaetogonyaulax rhaetica*; sequence stratigraphy; taxonomy; primary data/compilation; bioevent charts; photographs; Middle–Late Triassic [Anisian–Rhaetian]; East Arctic [Arctic Norway, Barents Sea, Svalbard Archipelago])

PATERSON, N.W., MORRIS, P.H., and MANGERUD, G. 2019. Lycopsid megaspores from the Upper Triassic of Svalbard and their relationship to the floras and palaeoenvironments of northern Pangaea. *Papers in Palaeontology*, 5(4): 577–599 (doi: 10.1002/spp2.1251).
(agglutinated foraminifera; biostratigraphy; biozonation; eustacy; foraminiferal test linings; freshwater algae; geological setting; kerogen; lithostratigraphy [Kapp Toscana Group]; megaspores from heterosporous lycopsids; micro-biofacies; ostracods; palaeoecology; preservation potential; pollen and spores; radiolaria; *Rhaetogonyaulax rhaetica*; sedimentology; primary data; Late Triassic [Carnian–Rhaetian]; East Arctic [Hopen Island, southeast Svalbard archipelago, Arctic Ocean])

POCOCK, S.A.J. 1962. Jurassic palynology in the Western Canada Basin. *Oil in Canada*, February 8th, 1962: 36–40.
(acritarchs; biostratigraphy; correlation [with Europe]; foraminiferal test linings; *Gonyaulacysta jurassica*; Jurassic–Cretaceous transition; lithostratigraphy [Fernie Shale and Manneville groups]; palaeoecology; pollen and spores; West Canada Basin; review article; histograms; photographs; Late Jurassic–Early Cretaceous [Kimmeridgian–Hauterivian]; sub-Arctic West Canada [British Columbia, Alberta and Saskatchewan])

R

REOLID, M., DUARTE, L.V., and RITA, P. 2019. Changes in foraminiferal assemblages and environmental conditions during the T-OAE (Early Jurassic) in the northern Lusitanian

Basin, Portugal. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 520: 30–43 (doi: 10.1016/j.palaeo.2019.01.022).
(ammonite zones; biotic crisis and recovery; brachiopods; calcareous nannofossils; diversity; echinoderms; foraminifera; geological setting; Iberian palaeomargin; lithostratigraphy [Sao Giao Formation]; mass extinction; opportunistic taxa; organic geochemistry; ostracods; oxygen depletion; palaeoecology; palaeoproductivity; phosphorus; redox-sensitive elements; tempestite-turbidite facies; Toarcian Oceanic Anoxic Event [T-OAE]; trace fossils; data compilation; Early Jurassic [Toarcian]; sub-Arctic West Europe [Maria Pares section, Rabaçal, northern Lusitanian Basin, western Portugal])

RIDING, J.B., LEBEDEVA, N.K., and GORYACHEVA, A.A. 2019. Obituary. Vera Ivanovna Ilyina (1930–2018). *Palynology*, 43(3): 349–354 (doi: 10.1080/01916122.2019.1586090).
(acritarchs; biography; biostratigraphy; biozonation; history; Institute of Geology and Geophysics, Academgorodok, Novosibirsk, Siberia; International Association for the Promotion of Co-operation with Scientists from the New Independent States of the former Soviet Union [INTAS]; obituary, pollen and spores; prasinophytes; Third International Conference on Palynology [1971]; Vera I. Ilyina; review article; Early Jurassic–Early Cretaceous [Hettangian–Valanginian]; multi-region: East Arctic [northern Russia]; sub-Arctic Russia east of the Ural Mountains [undifferentiated], sub-Arctic Russia west of the Ural Mountains [undifferentiated] including Kazakhstan])

RODRIGUES, B., SILVA, R.L., FILHO, J.G.M., SADKI, D., MENDONÇA, J.O., and DUARTE, L.V. 2020. Late Pliensbachian–Early Toarcian palaeoenvironmental dynamics and the Pliensbachian–Toarcian Event in the Middle Atlas Basin (Morocco). *International Journal of Coal Geology*, 217, 103339 (doi: 10.1016/j.coal.2019.103339).
(acritarchs; ammonite zones; *Botryococcus*; carbon cycle; continental weathering; eustacy; foraminiferal test linings; fungal spores; geological background; *Luehndea spinosa*; *Nannoceratopsis gracilis*; organic geochemistry; palaeoclimate; palaeoecology; palaeoenvironments; palynofacies; Pliensbachian–Toarcian event; pollen and spores; prasinophytes; sedimentology; sequence stratigraphy; tectonics; thermal maturity; total organic carbon [TOC]; vitrinite reflectance; zygospores; primary data; photographs; Early Jurassic [Pliensbachian–Toarcian]; North Africa [Ait Moussa and Issouka sections, northeast of Boulemane, Fès-Meknès region, Middle Atlas Basin, northeast Morocco])

ROGALSKA, M. 1962. Analiza sporowo-pyłkowa osadów jurajskich północnej części Pasma Krakowsko-Wieluńskiego. [Spore and pollen grain analysis of Jurassic sediments in the northern part of the Cracow – Wieluń Cuesta] *Instytut Geologi Czny Odbitka z Prac*, 30(3): 495–524 (in Polish with English and Russian summaries).
(biostratigraphy; correlation; lithostratigraphy; *Pareodinia*; pollen and spores; prasinophytes; taxonomy; primary data; quantitative occurrence chart and non-quantitative occurrence chart; photographs; Triassic–Middle Jurassic [Rhaetian–?Bathonian]; East Europe [northern Kraków–Wieluń Cuesta/Scarp, southern Poland])

S

SARJEANT, W.A.S., and DOWNIE, C. 1966. The classification of dinoflagellate cysts above generic level. *Grana Palynologica*, 6(3): 503–527 (doi: 10.1080/00173136609430038).
(history of study; morphological basis of dinoflagellate ctst classification; problems of the previous classification; suprageneric classification; taxonomy; compilation/review; no geographical or stratigraphical focus)

SARJEANT, W.A.S., and DOWNIE, C. 1974. The classification of dinoflagellate cysts above generic level: a discussion and revisions. *Symposium on Stratigraphical Palynology. Birbal Sahni Instiutute of Palaeobotany Special Publication*, No. 3: 9–32.
(familial groupings; living dinoflagellates and their cysts; principles of classification; suprageneric classification; taxonomy; compilation/review; no geographical or stratigraphical focus)

SCHOBBEN, M., GRAVENDYCK, J., MANGELS, F., STRUCK, U., BUSSERT, R., KÜRSCHNER, W.M., KORN, D., SANDER, P.M., and ABERHAN, M. 2019. A comparative study of total organic carbon-δ13C signatures in the Triassic–Jurassic transitional beds of the Central European Basin and western Tethys shelf seas. *Newsletters on Stratigraphy*, 52(4): 461–486 (doi: 10.1127/nos/2019/0499).
(ammonites; biostratigraphy; biozonation; bivalves; carbon cycle; carbon isotope analysis; chemostratigraphy; clay mineralogy; conchostracans; correlation; *Dapcodinium priscum*;

end-Triassic mass extinction; geological setting; Global Stratotype Section and Point [GSSP]; lithostratigraphy [Postera Beds to the Psilonotenton Formation]; palaeoclimate; pollen and spores; *Rhaetogonyaulax rhaetica*; *Suessia swabiana*; total nitrogen (TN); total organic carbon (TOC); weathering; primary data; semiquantitative occurrence chart; latest Triassic–earliest Jurassic [Rhaetian–Hettangian]; sub-Arctic West Europe [clay quarry northwest of Bonenburg village, near Warburg, North Rhine-Westphalia, west central Germany; Kuhjoch, near Hinteriss, central Austria])

SCHÖLLHORN, I., ADATTE, T., VAN DE SCHOOTBRUGGE, B., HOUBEN, A., CHARBONNIER, G., JANSSEN, N., and FÖLLMI, K.B. 2020. Climate and environmental response to the break-up of Pangea during the Early Jurassic (Hettangian–Pliensbachian); the Dorset coast (UK) revisited. *Global and Planetary Change*, 185, 103096 (doi: 10.1016/j.gloplacha.2019.103096).
(anoxia; bioproductivity; carbon and oxygen isotopes; chemical index of alteration; clay mineralogy; continenrtal breakup; correlation; eustacy; geochemistry; mineralogy; palaeoclimatology; palaeogeography; palaeoceanography; Pangea; sediment deposition rates; compilation; Early Jurassic (Hettangian–Pliensbachian); sub-Arctic West Europe [Pinhay Bay to Eype Mouth, Dorset, and St Audries Bay, Somerset, southern England])

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(acritarchs; *Botryococcus*; biostratigraphy; biozonation; correlation; foraminiferal test linings; fungal spores; megaspores; palynofacies; *Pediastrum*; pollen and spores; prasinophytes; thesis summary; quantitative range charts; Middle Jurassic–Cretaceous [Aalenian–Maastrichtian]; East Europe [Teteic and Boreal-Atlantic belt, Ukraine])

SHEVCHUK, O., SLATER, S.M., and VAJDA, V. 2018. Palynology of Jurassic (Bathonian) sediments from Donbas, northeast Ukraine. *Palaeobiodiversity and Palaeoenvironments*, 98(1): 153–164 (doi: 10.1007/s12549-017-0310-3).
(biostratigraphy; *Botryococcus*; Dnieper–Donets Basin; Donbas fold belt; insect remains; lithostratigraphy [Kamyanska suite]; parent plants; petroleum geology; pollen and spores;

provincialism; regional geology; sedimentology; thermal alteration index [TAI]; vegetation dynamics; primary data; quantitative occurrence charts; photographs; Middle Jurassic [Bathonian]; East Europe [Kamyanka village, Kharkiv region, northeast Ukraine])

*SKUPIEN, P., and DOUPOVCOVÁ, P. 2019. Dinoflagellates and calpionellids of the Jurassic–Cretaceous boundary, Outer Western Carpathians (Czech Republic). *Cretaceous Research*, 99: 209–228 (doi: 10.1016/j.cretres.2019.02.017).
(biostratigraphy; calcareous dinoflagellate cysts; calpionellids; Jurassic–Cretaceous boundary; lithostratigraphy [Vendryně Formation and Těšín Limestone]; *Nannoceratopsis*; reworking; primary data; non-quantitative occurrence chart; photographs; latest Jurassic–earliest Cretaceous [Tithonian–Berriasian]; East Europe [Bruzovice River locality, Bruzovice, Outer Western Carpathians, eastern Czech Republic])

SLATER, S.M., McKIE, T., VIEIRA, M., WELLMAN, C.H., and VAJDA, V. 2017. Episodic river flooding events revealed by palynological assemblages in Jurassic deposits of the Brent Group, North Sea. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 485: 389–400 (doi: 10.1016/j.palaeo.2017.06.028).
(acritarchs; *Botryococcus*; correlation; facies analysis; foraminiferal test linings; geological setting; hyperpycnites; lithostratigraphy [Rannoch Formation of the Brent Group]; megaspores; non-metric multidimensional scaling; palaeoecology; palaeogeography; palynofacies; pollen and spores; prasinophytes; sedimentology; vegetational dynamics; primary data; photographs; Middle Jurassic [Aalenian–Bajocian]; sub-Arctic West Europe [Don North East and Penguins Cluster oilfields, Viking Graben, northern North Sea, UK sector])

SLATER, S.M., TWITCHETT, R.J., DANISE, S., and VAJDA, V. 2019. Substantial vegetation response to Early Jurassic global warming with impacts on oceanic anoxia. *Nature Geoscience*, 12: 462–467 (doi: 10.1038/s41561-019-0349-z).
(acritarchs; global warming; lithostratigraphy [Cleveland Ironstone and Whitby Mudstone formations]; palynofacies; pollen and spores; prasinophytes; Toarcian Oceanic Anoxic Event; vegetation dynamics; primary data; photographs; Early Jurassic [Pliensbachian–Toarcian]; sub-Arctic West Europe [Kettleness, Port Mulgrave, Runswick Bay, Saltwick Bay and Staithes, North Yorkshire, northern England])

*SMELROR, M., LARSSEN, G.B., OLAUSSEN, S., RØMULD, A., and WILLIAMS, R. 2018. Late Triassic to Early Cretaceous palynostratigraphy of Kong Karls Land, Svalbard, Arctic Norway, with correlations to Franz Josef Land, Arctic Russia. *Norwegian Journal of Geology,* 98(4): 1–31 (doi: 10.17850/njg004).
(acritarchs; ammonites; biostratigraphy; biozonation; correlation; freshwater algae; hiatuses; lithostratigraphy [Kapp Toscana and Adventdalen groups]; pollen and spores; prasinophytes; reworking; sedimentology; sequence stratigraphy; primary data; non-quantitative occurrence charts; photographs; Late Triassic–Early Cretaceous [Norian–Aptian]; East Arctic [Kong Karls Land, eastern Svalbard Archipelago, Arctic Ocean])

SMITH, D.G. 1982. Stratigraphic significance of a palynoflora from ammonoid-bearing Early Norian strata in Svalbard. *Newsletters on Stratigraphy*, 11(3): 154–161 (doi: 10.1127/nos/11/1982/154).
(ammonoids; ammonoid zones; biostratigraphy; biozonation; chronostratigraphy; correlation; lithostratigraphy [Flatsalen Formation]; pollen and spores; *Rhaetipollis germanicus* assemblage; *Rhaetogonyaulax rhaetica*; primary data and review; Late Triassic [Norian]; East Arctic [Hopen Island, Svalbard archipelago])

STEEMAN, T., DE WEIRDT, J., SMITH, T., DE PUTTER, T., MEES, F., and LOUWYE, S. 2020. Dinoflagellate cyst biostratigraphy and palaeoecology of the early Paleogene Landana reference section, Cabinda Province, Angola. *Palynology*, 44(2), 280–309 (doi: 10.1080/01916122.2019.1575091).
(*Aldorfia aldorfensis*; biostratigraphy; biozonation; correlation; Darteville collection; foraminifera; organic geochemistry [total organic carbon - TOC]; palaeoecology; reworking; primary data; quantitative and semi-quantitative occurrence charts; photographs; Middle Jurassic reworking into Palaeocene–Eocene/Oligocene [Bathonian reworking into Danian/Selandian–?Priabonian/Rupelian]; Southern Africa [Landana coastal section, Cabinda Province, Congo Basin, Angola])

STORM, M.S., HESSELBO, S.P., JENKYNS, H.C., RUHL, M., ULLMANN, C.V., XU, W., LENG, M.J., RIDING, J.B., and GORBANENKO, O. 2020. Orbital pacing and secular evolution of the Early Jurassic carbon cycle. *PNAS (Proceedings of the National Academy of Sciences of the United States of America)*, 117(8): 3974–3982 (doi: 10.1073/pnas.1912094117).

(ammonite zones and subzones; astrochronology; carbon isotopes [$\delta^{13}C_{TOC}$] and their excursions; chemostratigraphy; chronostratigraphy; geochemistry; geological background; global carbon cycle; magmatic events; orbital forcing; organic geochemistry; palaeoenvironment; palaeogeography; palaeotemperature; sedimentary organic matter; Toarcian Oceanic Anoxic Event [T-OAE]; Triassic–Jurassic transition; compilation/data review; latest Triassic–Early Jurassic [Rhaetian–Toarcian]; sub-Arctic West Europe [Bristol Channel Basin, southwest England, UK; Mochras Borehole, Cardigan Bay Basin, West Wales, UK; Sancerre-Couy Borehole, Paris Basin, northern France])

STOVER, L.E., and EVITT, W.R. 1978. Analyses of pre-Pleistocene organic-walled dinoflagellates. *Stanford University Publications, Geological Sciences*, 15, 300 p. (appendices; archaeopyle types and variability; catalogue/index; classification; *Gonyaulacysta* complex [e.g. *Gonyaulacysta, Impagidinium, Leptodinium* and *Rhynchodiniopsis*]; *Herendeenia-Omatia*; *Kiokansium unituberculatum*; *Lanternosphaeridium* complex; line drawings; lists of species; morphology; opercula; peridiniacean genera; *Spiniferites* complex; synopsis of genera; taxonomy; compilation; no specific geographical and stratigraphical focus)

SVOBODOVÁ, A., ŠVÁBENICKÁ, L., REHÁKOVÁ, D., SVOBODOVÁ, M., SKUPIEN, P., ELBRA, T., and SCHNABL, P. 2019. The Jurassic/Cretaceous boundary and high resolution biostratigraphy of the pelagic sequences of the Kurovice section (Outer Western Carpathians, the northern Tethyan margin). *Geologica Carpathica*, 70(2): 153–182 (doi: 10.2478/geoca-2019-0009).
(acritarchs; biostratigraphy; calcareous dinoflagellate cysts; calcareous nannofossils; calpionellids; foraminiferal test linings; geological setting; Jurassic–Cretaceous boundary; Kurovice Limestone; limestones; magnetostratigaphy; microfacies; palaeobathymetry; palaeoecology; pollen and spores; prasinophytes; radiolarians; reworking; sponge spicules; Tethys; primary data; non-quantitative occurrence chart; photographs; latest Jurassic–earliest Cretaceous [Tithonian–Berriasian]); East Europe [Kurovice Quarry, near Zlín, Outer Western Carpathians, southeast Czech Republic])

T

TAUGOURDEAU LANTZ, J., and DONZE, P. 1971. Un aperçu de l'environnement végétal pendant l'épisode régressif du Berriasien terminal dans le Jura méridional (France). *Revue de Micropaléontologie*, 14(5): 102–120 (in French).
(acritarchs; *Botryococcus*; eustacy; foraminiferal text linings; geological background; megaspores; palaeoecology; pollen and spores; prasinophytes; taxonomy; vegetational reconstructions; primary data; occurrence chart [percentages]; photographs; earliest Cretaceous [Berriasian]; sub-Arctic West Europe [France])

V

*VAEZ-JAVADI, F. 2018. Dinoflagellate palynostratigraphy of Middle Jurassic of the Hojedk Formation, Tabas, central-east Iran and its correlation to the other palynomorph zones in Iran and elsewhere. *Quarterly Journal of Geosciences*, 127: 265–276 (in Persian).
(acritarchs; biostratigraphy; biozonation [*Nannoceratopsis gracilis* total range subzone and *Nannoceratopsis triceras-Pareodinia ceratophora* assemblage zone]; correlation; lithostratigraphy [Hojedk Formation]; palaeoclimate; pollen and spores; prasinophytes; Tabas Block; primary data; occurrence chart; photographs; Middle Jurassic [Aalenian–Bajocian]; Middle East [Tabas County, South Khorasan Province, northeast Iran])

VAEZ JAVADI, F. 2019. Middle Jurassic palynology of the southwest Tabas Block, Central-East Iran. *Palynology*, doi: 10.1080/01916122.2019.1637954.
(acritarchs; biostratigraphy; biozonation [*Nannoceratopsis* sp. cf. *N. gracilis* interval zone]; botanical affinity; Chahrekhneh borehole; correlation; Iran Plate; lithostratigraphy [Hojedk Formation]; palaeoclimate; palaeoecology; palaeogeography; pollen and spores; Tabas Block; Tethys Ocean; primary data; occurrence chart; photographs; Middle Jurassic [Aalenian–Bajocian]; Middle East [southwest of Tabas, Tabas County, South Khorasan Province, northeast Iran])

VAEZ-JAVADI, F., and ABBASSI, N. 2018. Middle Jurassic biostratigraphy of plant macro and microfossils in Soltanieh Mountains, south of Zanjan, NW Iran. *Geosciences*, 106: 91–102.
(biostratigraphy; biozonation [*Pareodinia ceratophora-Nannoceratopsis triceras* assemblage zone]; correlation; lithostratigraphy [Dansirit Formation, Shemshak Group]; palaeoecology;

palaeogeography; plant macrofossils; pollen and spores; Tethys Ocean; primary data; occurrence chart; photographs; Middle Jurassic [Aalenian–Bajocian]; Middle East [Soltanieh Mountains, south of Zanjan city, Zanjan Province, northwest Iran])

VAEZ-JAVADI, F., GHAVIDEL-SYOOKI, M., and GHASEMI-NEJAD, I. 2003. Biostratigraphy of Shemshak Formation in Ozon Mountain, Jajarm based on dinoflagellata. *Journal of Science, University of Tehran*, 29(1): 141–160 (in Persian with an English abstract).
(acritarchs; biostratigraphy; biozonation [*Nannoceratopsis spiculata* and *Valensiella ovulum* biozones]; lithostratigraphy [Shemshak Formation]; primary data; occurrence chart; photographs; Early–Middle Jurassic [Pliensbachian–Bajocian]; Middle East [Ozon Mountain, Jajarm County, North Khorasan Province, northeast Iran])

*VAN DE SCHOOTBRUGGE, B., HOUBEN, A.J.P., ERCAN, F.E.Z., VERREUSSEL, R., KERSTHOLT, S., JANSSEN, N.M.M., NIKITENKO, B., and SUAN, G. 2019. Enhanced Arctic-Tethys connectivity ended the Toarcian Oceanic Anoxic Event in NW Europe. *Geological Magazine*, doi: 10.1017/S0016756819001262.
(ammonite zones; anoxia; bioproductivity; biostratigraphy; black shale; carbon cycle; carbon isotopes; chemostratigraphy; correlation; diversity; eustacy; geochemistry; geological background; global warming; heterochroneity; lithostratigraphy; marine stratification; migrations; ocean circulation; palaeoenvironmental recovery; palaeoceanography; palaeosalinity; Toarcian Oceanic Anoxic Event [T-OAE]; total organic carbon; primary data; occurrence charts; photographs; Early Jurassic [Pliensbachian–Toarcian]; multi-region: East Arctic [Kelimyar River, Siberia, northeast Russia]; sub-Arctic West Europe [coastal outcrops between Staithes and Ravenscar, North Yorkshire, northern England and well 34/10-35, Tjalve Terrace, Gulfaks South oilfield, Norwegian sector of the northern North Sea])

W

WARRINGTON, G. 1976. British Triassic palaeontology. *Proceedings of the Ussher Society*, 3(3): 341–353.

(acritarchs; biostratigraphy; correlation; lithostratigraphy; macrofossils; microfossils; pollen and spores; prasinophytes; scolecodonts; compilation/review paper; Triassic [Induan–Rhaetian]; sub-Arctic West Europe [pan-United Kingdom])

WARRINGTON, G. 1980. Palynological studies of Triassic rocks in central Somerset (Abstract). *Proceedings of the Ussher Society*, 5(1): 90.
(biostratigraphy; correlation; diversity; foraminiferal test linings; lithostratigraphy [Mercia Mudstone and Penarth groups]; pollen and spores; scolecodonts; summary; Late Triassic [Carnian and Rhaetian]; sub-Arctic West Europe [Burton Row and Puriton boreholes, near Bridgwater, central Somerset, southwest England])

WILLIAMS, G.L. 1965. Organic-walled microfossils aid oil search. *The Oil and Gas Journal*, November 22 1965: 108–112.
(acritarchs; biostratigraphy; correlation; *Gonyaulacysta jurassica*; history of study; hystrichospheres; life cycle; modern dinoflagellates; morphology; oil/gas exploration; palaeoecology; review article; photographs; no geographical or stratigraphical focus)

WILLIAMS, G.L. 1974. 57. Biostratigraphy and paleoecology of the Mesozoic and Cenozoic rocks of the Atlantic Shelf. Project 710062. *Geological Survey of Canada Paper* 74–1, Part B: 150–152.
(biostratigraphy; biozonation; correlation; lithostratigraphy [Western Bank, Nova Scotia and Gully groups]; offshore boreholes; oil/gas exploration; palaeoecology; pollen and spores; unconformity; review article; Middle Jurassic to Pliocene/Pleistocene [Bathonian/Callovian – undifferentiated]; sub-Arctic East Canada [Grand Banks and Scotian Shelf, offshore eastern Canada])

WILSON, G.J., and CLOWES, C.D. 1981. A concise catalogue of organic-walled fossil dinoflagellate genera. *New Zealand Geological Survey Report*, No. 92, 199 p.
(archaeopyle type; catalogue; descriptions of genera; line drawings; morphology; range charts; compilation; Late Triassic [undifferentiated] to Holocene; no geographical or stratigraphical focus)

SUPPLEMENTARY DATA II

Appendix 2. List of palynomorph species, subspecies and varieties

This Appendix alphabetically lists all valid palynomorph taxa below generic level which are mentioned in this contribution with full author citations. References to the author citations for the dinoflagellate cysts can be found in Williams et al. (2019 - *American Asssociation of Stratigraphic Palynologists Contribution Series* 50, available at: https://palynology.org/contribution-series-number-50-the-new-lentin-and-williams-index-2019/). The recommendations of Williams et al. (2019) are followed with the following two exceptions. The proposals of Correia et al. (2017 - *Review of Palaeobotany and Palynology* 237, p. 93) on the species *Nannoceratopsis senex* are followed herein. With regard to this species, Williams et al. (2019) adopted the taxonomic proposals of Ilyina et al. (1994 - *Russian Academy of Sciences, Siberian Branch, United Institute of Geology, Geophysics and Mineralogy, Transactions* 818), who proposed that *Nannoceratopsis senex* is a subspecies of *Nannoceratopsis deflandrei* Evitt 1961. Furthermore, the Linnaean binomial *Ctenidodinium sellwoodii* (Sarjeant 1975) Stover & Evitt 1978 is preferred herein to *Dichadogonyaulax sellwoodii* Sarjeant 1975. Most of the Jurassic tabulate gonyaulacoid species with epicystal archaeopyles are placed in *Ctenidodinium*. The species *sellwoodii* is clearly closely related to two contemporary species which are accommodated in *Ctenidodinium* according to Williams et al. (2019). These are *Ctenidodinium combazii* Dupin 1968 and *Ctenidodinium cornigerum* (Valensi 1953) Jan du Chêne et al. 1985. That said, there are substantial taxonomic issues with the two apparently very similar genera *Ctenidodinium* and *Dichadogonyaulax*. These genera require a thorough taxonomic review. It is eminently possible that *Dichadogonyaulax* is a junior synonym of *Ctenidodinium* as previously suggested by Lentin and Williams (1973 - *Geological Survey of Canada Paper* 73–42, p. 46).

Acritarch:

Limbicysta bjaerkei (Smelror, 1987) MacRae et al. 1996

Dinoflagellate cysts:

Aldorfia aldorfensis (Gocht 1970) Stover & Evitt 1978

Ambonosphaera? *staffinensis* (Gitmez 1970) Poulsen & Riding 1992

Amphorulacysta? *dodekovae* (Zotto et al. 1987) Williams & Fensome 2016

Amphorulacysta metaelliptica (Dodekova 1969) Williams & Fensome 2016

Arkellea teichophera (Sarjeant 1961) Below 1990

Atopodinium haromense Thomas & Cox 1988

Chytroeisphaeridia cerastes Davey 1979

Chytroeisphaeridia hyalina (Raynaud 1978) Lentin & Williams 1981

Corculodinium inaffectum (Drugg 1978) Courtinat 2000

Coronifera oceanica Cookson & Eisenack 1958

Cribroperidinium? edwardsii (Cookson & Eisenack 1958) Davey 1969

Cribroperidinium globatum (Gitmez & Sarjeant 1972) Helenes 1984

Cribroperidinium? longicorne (Downie 1957) Lentin & Williams 1985

Ctenidodinium continuum Gocht 1970

Ctenidodinium elegantulum Millioud 1969

Ctenidodinium ornatum (Eisenack 1935) Deflandre 1938

Ctenidodinium sellwoodii (Sarjeant 1975) Stover & Evitt 1978

Dapcodinium priscum Evitt 1961

Diacanthum hollisteri Habib 1972

Dichadogonyaulax bensonii Monteil 1992

Dingodinium tuberosum (Gitmez 1970) Fisher & Riley 1980

Dissiliodinium giganteum Feist-Burkhardt 1990

Endoscrinium galeritum (Deflandre 1938) Vozzhennikova 1967

Endoscrinium luridum (Deflandre 1938) Gocht 1970

Evansia deflandrei (Wolfard & Van Erve 1981) Below 1990

Glossodinium dimorphum Ioannides et al. 1977

Gochteodinia villosa (Vozzhennikova 1967) Norris 1978 subsp. *villosa* autonym

Gonyaulacysta centriconnata Riding 1983

Gonyaulacysta eisenackii (Deflandre 1938) Górka 1965

Gonyaulacysta jurassica (Deflandre 1938) Norris & Sarjeant 1965

Gonyaulacysta jurassica (Deflandre 1938) Norris & Sarjeant 1965 subsp. *adecta* Sarjeant 1982

Gonyaulacysta jurassica (Deflandre 1938) Norris & Sarjeant 1965 subsp. *adecta* Sarjeant 1982 var. *longicornis* (Deflandre 1938) Downie & Sarjeant 1965

Gonyaulacysta jurassica (Deflandre 1938) Norris & Sarjeant 1965 subsp. *jurassica* autonym

Heibergella asymmetrica Bujak & Fisher 1976

Isthmocystis distincta Duxbury 1979

Kalyptea diceras Cookson & Eisenack 1960

1812 *Kleithriasphaeridium corrugatum* Davey 1974

1813 *Kleithriasphaeridium fasciatum* (Davey & Williams 1966) Davey 1974

1814 *Lagenorhytis delicatula* (Duxbury 1977) Duxbury 1979

1815 *Leptodinium subtile* Klement 1960

1816 *Liasidium variabile* Drugg 1978

1817 *Liesbergia liesbergensis* Berger 1986

1818 *Luehndea spinosa* Morgenroth 1970

1819 *Mancodinium semitabulatum* Morgenroth 1970

1820 *Maturodinium inornatum* Morgenroth 1970

1821 *Moesiodinium raileanui* Antonesçu 1974

1822 *Muderongia longicorna* Monteil 1991

1823 *Muderongia simplex* Alberti 1961

1824 *Nannoceratopsis dictyambonis* Riding 1984

1825 *Nannoceratopsis gracilis* Alberti 1961

1826 *Nannoceratopsis pellucida* Deflandre 1938

1827 *Nannoceratopsis plegas* Drugg 1978

1828 *Nannoceratopsis raunsgaardii* Poulsen 1996

1829 *Nannoceratopsis senex* van Helden 1977

1830 *Nannoceratopsis spiculata* Stover 1966

1831 *Nannoceratopsis symmetrica* Bucefalo Palliani & Riding 2000

1832 *Nannoceratopsis triceras* Drugg 1978

1833 *Noricysta fimbriata* Bujak & Fisher 1976

1834 *Oligosphaeridium complex* (White 1842) Davey & Williams 1966

1835 *Ovalicysta hiata* Bjaerke 1980

1836 *Paragonyaulacysta*? *borealis* (Brideaux & Fisher 1976) Stover & Evitt 1978

1837 *Pareodinia ceratophora* Deflandre 1947

1838 *Pareodinia halosa* (Filatoff 1975) Prauss 1989

1839 *Pareodinia prolongata* Sarjeant 1959

1840 *Pareodinia*? *pseudochytroeides* (Below 1987) Lentin & Williams 1989

1841 *Parvocysta bullula* Bjaerke 1980

1842 *Parvocysta nasuta* Bjaerke 1980

1843 *Phallocysta elongata* (Beju 1971) Riding 1994

1844 *Phallocysta eumekes* Dörhöfer & Davies 1980

1845 *Phoberocysta neocomica* (Gocht 1957) Millioud 1969

Phoberocysta tabulata Raynaud 1978

Prolixosphaeridium anasillum Erkmen & Sarjeant 1980

Pseudoceratium pelliferum Gocht 1957

Rhaetogonyaulax arctica (Wiggins 1973) Stover & Evitt 1978

Rhaetogonyaulax dilatata (Wiggins 1973) Stover & Evitt 1978

Rhaetogonyaulax rhaetica (Sarjeant 1963) Loeblich Jr. & Loeblich III 1968

Rhaetogonyaulax wigginsii (Stover & Helby 1987) Lentin & Williams 1989

Rhynchodiniopsis cladophora (Deflandre 1938) Below 1981

Rotosphaeropsis thule (Davey 1982) Riding & Davey 1989

Sahulidinium ottii Stover & Helby 1987

Scriniocassis priscus (Gocht 1979) Below 1990

Scriniocassis weberi Gocht 1964

Scriniodinium campanula Gocht 1959

Scriniodinium crystallinum (Deflandre 1938) Klement 1960

Scriniodinium? *dictyophorum* (Deflandre 1938 ex Sarjeant 1967) Brenner 1988

Scriniodinium pharo (Duxbury 1977) Davey 1982

Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976

Sentusidinium explanatum (Bujak in Bujak et al. 1980) Wood et al. 2016

Sirmiodinium grossii Alberti 1961

Spiculodinium neptuni (Eisenack 1958) Duxbury 2018

Spiniferites ramosus (Ehrenberg 1837) Mantell 1854

Stanfordella? *cretacea* (Neale & Sarjeant 1962) Helenes & Lucas-Clark 1997

Stephanelytron redcliffense Sarjeant 1961

Suessia swabiana Morbey 1975

Susadinium faustum (Bjaerke 1980) Lentin & Williams 1985

Susadinium scrofoides Dörhöfer & Davies 1980

Systematophora areolata Klement 1960

Systematophora penicillata (Ehrenberg 1843 ex Ehrenberg 1854) Sarjeant 1980

Tehamadinium evittii (Dodekova 1969) Jan du Chêne et al. 1986

Tenua anaphrissa (Sarjeant 1966) Benedek 1972

Trichodinium castanea Deflandre 1935 ex Clarke & Verdier 1967

Trichodinium scarburghense (Sarjeant 1964) Williams et al. 1993

Tubotuberella apatela (Cookson & Eisenack 1960) Ioannides et al. 1977

Valensiella ovulum (Deflandre 1947) Eisenack 1963

Valvaeodinium armatum Morgenroth 1970

Valvaeodinium koessenium (Morbey 1975) Below 1987

Valvaeodinium spinosum (Fenton et al. 1980) Below 1987

Wallodinium cylindricum (Habib 1970) Duxbury 1983

Wanaea fimbriata Sarjeant 1961

Wanaea thysanota Woollam 1982

Wanaea verrucosa Riding & Helby 2001

Pollen and Spores:

Classopollis classoides Pflug 1953

Klukisporites variegatus Couper 1958