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Jurassic palynoevents in the circum-Arctic region
Palynophénomènes jurassiques dans la région circumarctique

Jonathan Bujak, Manuel Bringué, Anna A. Goryacheva, Natalia K. Lebedeva, Ekaterina B. Pestchevitskaya, James B. Riding et Morten Smelror

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Résumé de l'article

Les successions de strates jurassiques dans la région de l'Arctique recèlent normalement de riches assemblages de palynomorphes d'origine terrestre et marins reflétant les températures relativement chaudes de l'air et à la surface de la mer. Les flores de plantes terrestres étaient susceptibles de favoriser l'épanouissement de communautés locales et d'un provincialisme régional, alors que les biotes marins se développaient sur de vastes secteurs marins ouverts à un rythme de productivité élevé, ce qui a entraîné l'évolution rapide de kystes de dinoflagellés (dinokystes) d'après leur plus récents enregistrements fossiles au cours du Trias. Les dinokystes affichent une faible richesse taxonomique et produisent une faible résolution biostratigraphique dans toutes les sections du Jurassique inférieur. Par contre, ils se diversifient dans les strates du Jurassique moyen et supérieur, où ils représentent d'excellents repères biostratigraphiques pour la corrélation et la datation de sections de surface et de subsurface. Plus d'une vingtaine de biozonations officielles et officieuses basées sur les premières et dernières manifestations de dinokystes ont été établies en Alaska, dans l'Arctique canadien, dans la région de la mer de Barents, au Groenland et dans le nord de la Russie, lesquelles sont dans de nombreux cas corrélées avec des macrofossiles, notamment des ammonites, présents dans les mêmes sections. Le présent article présente une compilation de 214 phénomènes palynostratigraphiques du Jurassique (118 premières manifestations et 96 dernières manifestations) ayant une valeur chronostratigraphique régionale dans la région circumarctique, d'après les documents pertinents publiés. Chaque phénomène est corrélé avec la base d'une unité chronostratigraphique (notamment les stades et les zones d'ammonites subboréales officielles), ou sous forme d'un pourcentage estimatif au-dessus de la base de l'unité chronostratigraphique par rapport à l'ensemble de l'unité. Les liens entre chaque phénomène et les stades et principaux mécanismes zonaux fossiles sont illustrés dans les schémas chronostratigrapiques des figures 1 à 9 au moyen de la version de 2020 de TimeScale Creator®.

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Jurassic palynoevents in the circum-Arctic region

Jonathan Bujak[1*], Manuel Bringué[2], Anna A. Goryacheva[3, 4], Natalia K. Lebedeva[3], Ekaterina B. Pestchevitskaya[3], James B. Riding[5] and Morten Smelror[6]

1. Bujak Research International, Burbage Lodge, 200 Queens Promenade, Blackpool, Lancashire FY2 9JS, UK
2. Geological Survey of Canada, 3303–3333 Street NW, Calgary, Alberta T2L 2A7, Canada
3. Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, pr. Akademika Koptyuga 3, 630090 Novosibirsk, Russia
4. Novosibirsk State University, ul. Pirogova 2, 630090 Novosibirsk, Russia
5. British Geological Survey, Keyworth, Nottingham NG12 5GG, UK
6. Geological Survey of Norway, Leiv Eirikssons vei 39, 7040 Trondheim, Norway
*corresponding author: jonathanbujak@outlook.com

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ABSTRACT

Successions of Jurassic strata located in the Arctic region normally yield rich assemblages of terrestrially-derived and marine palynomorphs, reflecting relatively warm air and sea-surface temperatures. The land plant floras were prone to the development of local communities and regional provincialism, whereas the marine biotas thrived across extensive open marine areas with high productivity, resulting in the rapid evolution of dinoflagellate cysts (dinocysts) following their earliest fossil record in the Triassic. Dinocysts exhibit low taxonomic richness and provide low biostratigraphic resolution throughout the Lower Jurassic sections. By contrast, they are diverse in Middle and Upper Jurassic strata where they provide excellent biostratigraphic markers for correlating and dating both surface and subsurface sections. Over twenty formal and informal biozonations based on the first and last occurrences of dinocysts have been erected in Alaska, Arctic Canada, the Barents Sea region, Greenland and northern Russia, many of which are correlated with macrofossils, including ammonites, that occur in the same sections. This paper presents a compilation of 214 Jurassic palynostratigraphic events (118 first occurrences and 96 last occurrences) that have regional chronostratigraphic value in the Circum-Arctic, based on their published records. Each event is correlated with the base of a chronostratigraphical unit (including formal stages and sub-Boreal ammonite zones), or as an estimated percentage above the base of the chronostratigraphical unit relative to the entire unit. The relationships of each event to stages and key fossil zonal schemes is shown on chronostratigraphic plots using the 2020 version of TimeScale Creator®.

RÉSUMÉ

Les successions de strates jurassiques dans la région de l'Arctique recèlent normalement de riches assemblages de palynomorphes d'origine terrestre et marins reflétant les températures relativement chaudes de l'air et à la surface de la mer. Les flores de plantes terrestres étaient susceptibles de favoriser l'épanouissement de communautés locales et d'un provincialisme régional, alors que les biotes marins se développaient sur de vastes secteurs marins ouverts à un rythme de productivité élevé, ce qui a entraîné l'évolution rapide de kystes de dinoflagellés (dinokystes) d'après leur plus récents enregistrements fossiles au cours du Trias. Les dinokystes affichent une faible richesse taxonomique et produisent une faible résolution biostratigraphique dans toutes les sections du Jurassique inférieur. Par contre, ils se diversifient dans les strates du Jurassique moyen et supérieur, où ils représentent d'excellents repères biostratigraphiques pour la corrélation et la datation de sections de surface et de subsurface. Plus d'une vingtaine de biozonations officielles et officieuses basées sur les premières et dernières manifestations de dinokystes ont été établies en Alaska, dans l'Arctique canadien, dans la région de la mer de Barents, au Groenland et dans le nord de la Russie, lesquelles sont dans de nombreux cas corrélées avec des macrofossiles, notamment des ammonites, présents dans les mêmes sections. Le présent article présente une compilation de 214 phénomènes palynostratigraphiques du Jurassique (118 premières manifestations et 96 dernières manifestations) ayant une valeur chronostratigraphique régionale dans la région circumarctique, d'après les documents pertinents publiés. Chaque phénomène est corrélé avec la base d'une unité chronostratigraphique (notamment les stades et les zones d'ammonites subboréales officielles), ou sous forme d'un pourcentage estimatif au-dessus de la base de l'unité chronostratigraphique par rapport à l'ensemble de l'unité. Les liens entre chaque phénomène et les stades et principaux mécanismes zonaux fossiles sont illustrés dans les schémas chronostratigrapiques au moyen de la version de 2020 de TimeScale Creator®.

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INTRODUCTION

This article is a contribution to the Circum-Arctic Palynological Events (CAPE) project, providing a scheme of selected bioevents for the Jurassic Period. The Jurassic extended from 201.36 to 143.10 Ma according to the timescale of Gradstein *et al.* (2021). The Jurassic Period is divided into three epochs, Early Jurassic, Middle Jurassic (with a base at 174.70 Ma) and Late Jurassic (with a base at 161.53 Ma).

The present Jurassic compilation will be added to others from the CAPE series of articles in *Atlantic Geology* (now *Atantic Geoscience*), which will contribute ultimately (when all articles in the series are complete) to the "CAPE datapack" in TimeScale Creator® (TSC; https://timescalecreator.org/index/index.php) and thus can be used with other data in TSC to make plots such as that shown in Figures 1–9. The latter diagrams include age calibrations in millions of years ago (Ma) according to the 2020 version of TSC and in Gradstein *et al.* (2021). Similar compilations for the Early, Middle and Late Jurassic are provided in the Supplementary Data. The main Jurassic locations discussed in this paper are shown in Figure 10.

The events compiled herein include last occurrences (LOs), first occurrences (FOs), and some abundance events. Their relationship to other fossil zonal schemes is shown in Figures 1–9. Where possible, each event is correlated with the base of a chronostratigraphic unit, for example a Sub-Boreal ammonite zone or a formal stage. If the event is not equivalent to the base of such a unit, then an estimation is given as a percentage above the base of the chronostratigraphic unit relative to the entire unit. Details of how a biostratigraphic datapack is constructed in TSC from such information are given in Bringué *et al.* (in press).

PALYNOSTRATIGRAPHY

Background

The transition from the Triassic to the Jurassic at 201.36 Ma was followed over time by major changes in the continental configuration, seaway connections and climate. Pangaea fragmented and North America drifted away from Africa, the North Atlantic Ocean opened, and major tectonic changes led to transgressions over extensive shelf and land areas in the circum-Arctic region (Blakey 2021). These profound changes brought about the development of various phytogeographic marine and terrestrial provinces, with diachronous originations and extinctions, and the evolution of endemic taxa. During the Jurassic, significant radiations of marine taxa occurred, principally dinoflagellate cysts (dinocysts) which became more diverse and abundant. As a consequence, biostratigraphic ranges and biozonations established in the formal or proposed stage type areas in the Tethyan and Sub-Boreal realms may be based on species not found in the Boreal/Arctic Realm or defined by species that may have diachronous stratigraphic ranges within different biogeographic provinces. Equally, palynostratigraphic zonations defined in the Boreal Realm may not be readily applicable farther south.

There have been several Jurassic palynostratigraphic zonations established which are based on records from different areas in the Arctic region. Several of them are calibrated to established Boreal and Sub-Boreal ammonite zonations, but some discrepancies and uncertaincies still exist with respect to correlation to the latest Geological Time Scale (Gradstein *et al.* 2021). In the present study, the first and last occurrences of the listed species calibrated to the 2020 Geological Time Scale are shown in Figures 1–9.

Jurassic dinocysts of the Canadian Arctic and Alaska

In the Canadian Arctic, the first biostratigraphic zonation for the Jurassic based on dinocysts was from the Sverdrup Basin (Johnson and Hills 1973). This landmark study comprised four range-zones, four range-subzones, one concurrent range-zone and one peak-zone, and was established on three sections of the Savik and Awingak formations on Axel Heiberg, Bjarnason and Ellesmere islands (Fig. 10). In general, these sections were characterized by poor preservation and low species richness. This material was also described by Johnson (1974). Subsequently, Pocock (1976) presented a preliminary zonation for the uppermost Jurassic to Lower Cretaceous of the Canadian Arctic based on material from the Awingak and Deer Bay formations on Amund Ringnes Island (Fig. 10), and Tan and Hills (1978) documented the dinocyst succession of the Ringnes Formation (Oxfordian–Kimmeridgian), calibrated with ammonite faunas.

A more comprehensive dinocyst zonation of the Jurassic and Lower Cretaceous successions in the Sverdrup Basin was defined by Davies (1983), who erected 17 Oppel zones. Twelve of these Oppel-zones (A–L) cover the Jurassic part of the succession. Comparisons of the zonations of Johnson and Hills (1973) and Davies (1983) were made by Davies (1983) and Smelror and Below (1992). The latest contribution on the dinocyst zonation of the Canadian Arctic was by Ingrams *et al.* (2021). These authors studied the Upper Jurassic and Lower Cretaceous (Oxfordian–lower Valanginian) succession of the Rollrock section, northern Ellesmere Island, a largely complete and expanded section for which they established seven dinocyst biozones. Their zones H to L/M cover the Oxfordian to Tithonian interval and have substantial calibration to macrofossil biostratigraphy.

Several other publications have recorded Jurassic dinocysts from Arctic Canada, but no additional formal zonations have been proposed. These works include Brideaux (1975, 1976), Brideaux and Myhr (1976), van Helden (1977), Pocock (1980), Poulton *et al.* (1982), Poulton (1989),and Pimpirev and Pavlishina (2005a, b)..

By contrast with the Canadian Arctic, the literature on Jurassic dinocysts from Alaska is relatively sparse. The most detailed publication, by Wiggins (1973), is a comprehensive systematic treatment of the family Pareodiniaceae from the Middle Jurassic to Early Cretaceous of northern and south-

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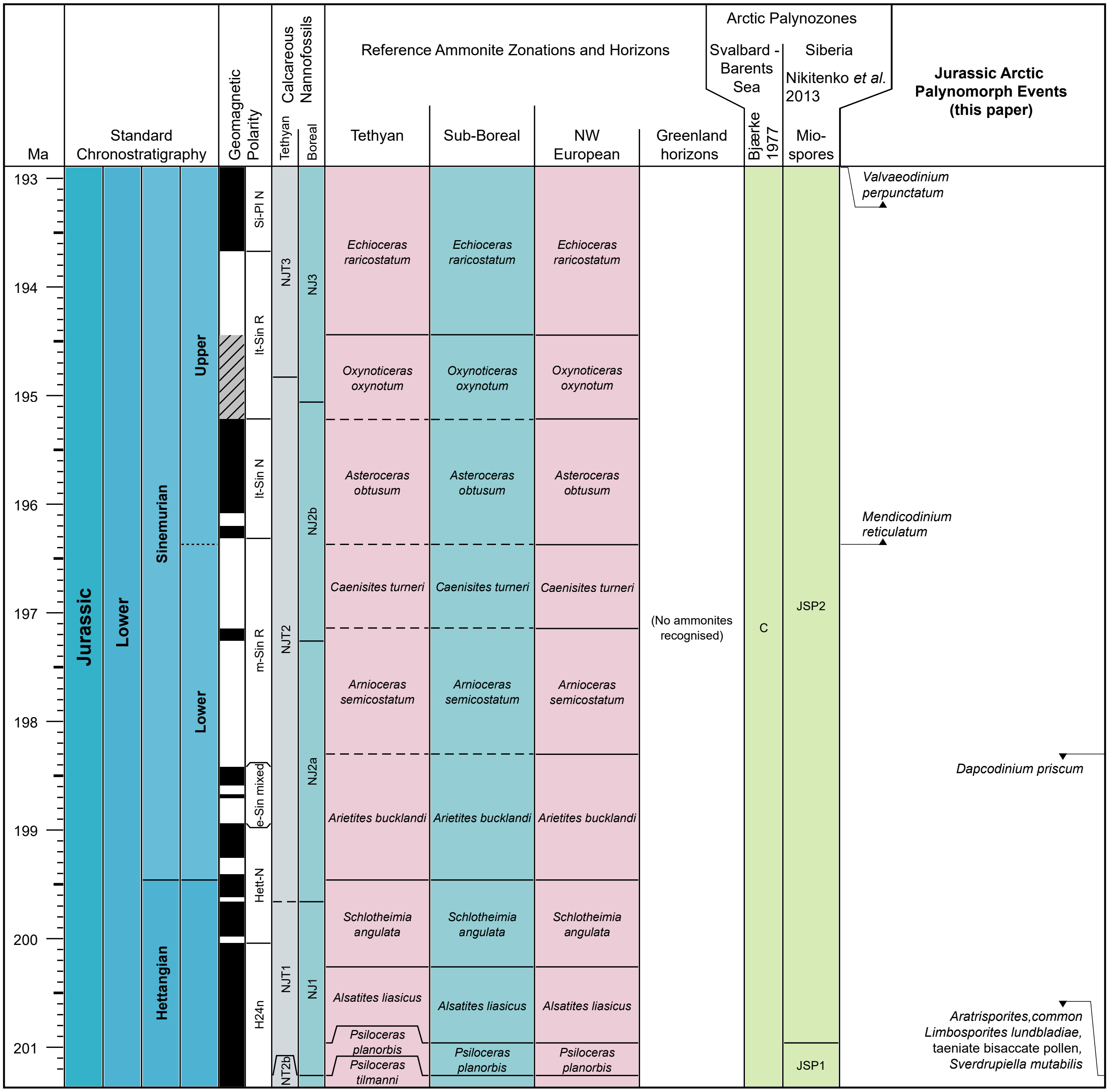

Figure 1. Stratigraphic chart for the Hettangian–Sinemurian showing palynomorph bioevents compiled in this paper, in the context of geomagnetic polarity, standard calcareous nannofossil zones, reference ammonite zonations and horizons and published Arctic palynomorph zonations. The chart was generated using TimeScale Creator®. Standard chronostratigraphy and reference data from Gradstein *et al.* (2021).

ern Alaska. Albert *et al.* (1986) made a later taxonomic contribution, but other records in the public domain are abstracts (e.g., Wharton 1988), doctoral dissertations (e.g., Albert 1988), and unpublished reports (e.g., Bjærke 1993; Witmer *et al.* 1981).

Jurassic dinocysts of northern Russia

In Russia, a Boreal Lower–Middle Jurassic dinocyst biostratigraphy was published by Ilyina *et al.* (1994) and subsequently presented in Zakharov *et al.* (1997). This dinocyst zonation was later refined by Riding *et al.* (1999) and Shurygin *et al.* (2000), and the ages of some of the biostratigraphic

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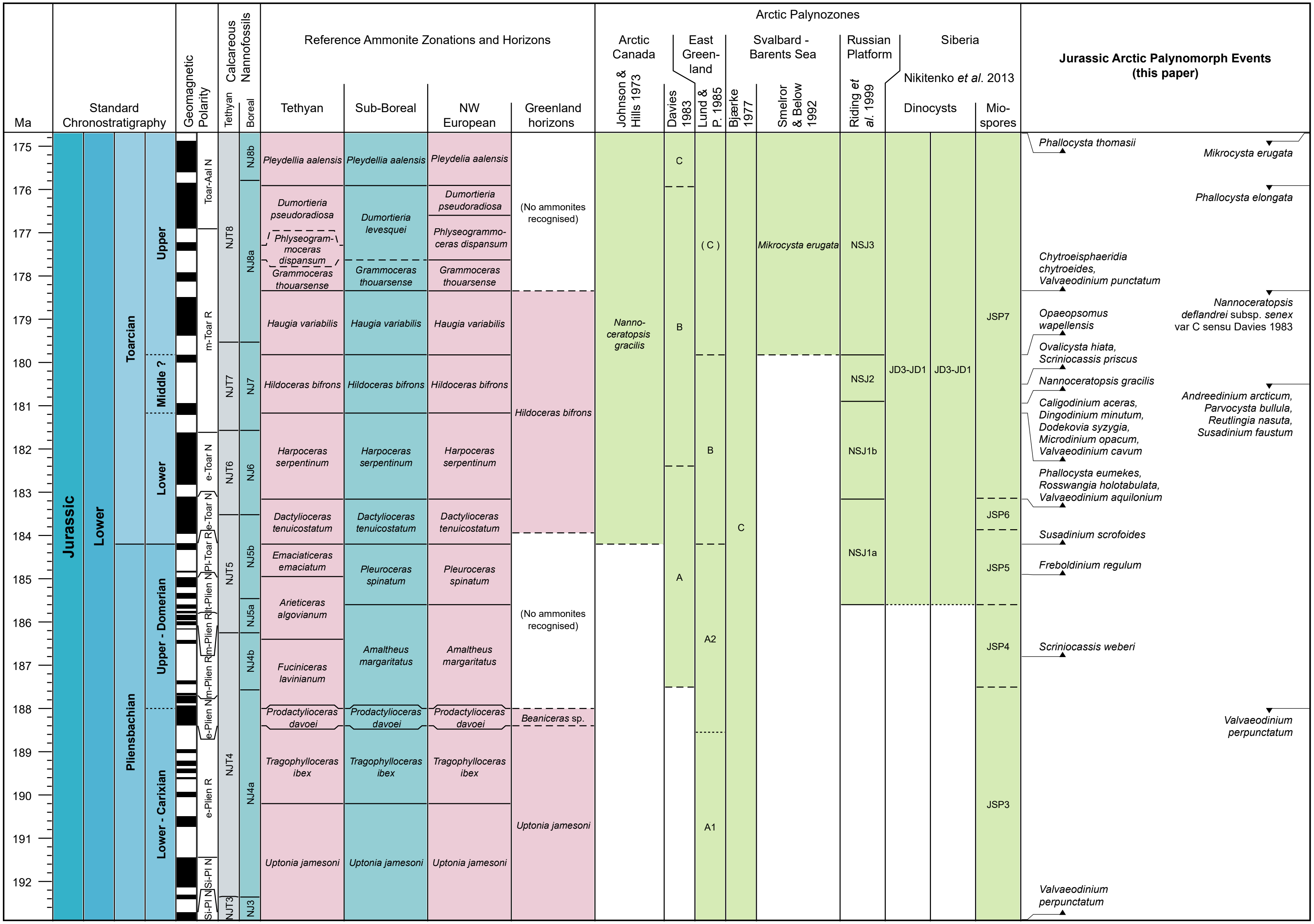

Figure 2. Stratigraphic chart for the Pliensbachian–Toarcian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

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units have been revised in light of new data on index species from sections in northern East Siberia (Nikitenko *et al.* 2011; Goryacheva 2017).

The uppermost Pliensbachian to upper Toarcian of northern East Siberia was studied by Riding *et al.* (1999), who subdivided the interval into three dinocyst biozones, of which one is subdivided into two interval subbiozones. Later Ilyina *et al.* (2005) presented a Middle and Upper Jurassic dinocyst zonation comprising 11 interval zones for the Boreal zonal standard scheme in Zakharov *et al.* (1997), with new data on the dinocyst stratigraphic distributions for the Callovian to Volgian strata of West Siberia. The material for these studies was obtained from a study of the Tyumenskaya superdeep well (SDW-6; Ilyina *et al.* 2005). This zonation was correlated to time-equivalent Callovian to Volgian dino cyst zonations of West Siberia, the Russian Platform and northwestern Europe by Ilyina *et al.* (2005).

Riding *et al.* (1999) also included a comprehensive record from the Jurassic and lowermost Cretaceous of the Russian Platform. In parts of the Jurassic, the dinocyst assemblages from northeast Siberia exhibit significant provincial differences from those of the Pechora Basin (Meledina *et al.* 1998; Riding *et al.* 1999); consequently, the assemblages from, and the zonation of, the Russian Platform are not further discussed herein. References to additional publications on Jurassic dinocysts from Siberia can be found in Riding *et al.* (1999), Ilyina *et al.* (2005) and Riding (2019).

Pestchevitskaya *et al.* (2011) identified a series of Volgian to Berriasian palynostratigraphic events based on a substantial database. The data comprises material from Nordvik on the Laptev Sea coast (Nikitenko *et al.* 2008; Nikitenko *et al.* 2011); the Severo-Vologochanskaya-18 well at the mouth of the Yenisei River and the Zapadno-Purpeiskaya-710 well in northwestern Siberia (Beisel *et al.* 2002); the River Yatriya in the Subarctic Urals (Lebedeva and Nikitenko 1998, 1999); and Kashpir located in the middle reaches of the River Volga (Riding *et al.* 1999; Harding *et al.* 2011). Of particular relevance herein are the data from the several outcrops on the Nordvik Peninsula (Nikitenko *et al.* 2008; Nikitenko *et al.* 2011; Pestchevitskaya *et al.* 2011). Pestchevitskaya *et al.* (2011) compared their results to existing palynological data from America, Antarctica, Australia and Europe using first and last appearances of selected key species and evolutionary trends of dinocyst floras. They defined four correlative horizons in the Volgian and Berriasian, thus providing interregional correlation of the dinocyst successions.

In an integrated study of the Jurassic and Cretaceous of the Anabar Bay area on the Laptev Sea coast, Nikitenko *et al.* (2013) provided a comprehensive review of the Jurassic and Cretaceous dinocyst zones of pan-northern Siberia correlated to the Boreal ammonite standard and to coeval belemnite, bivalve, ostracod and spore–pollen (miospore) zones. Due to lack of data, these authors defined no dinocyst zones for the Hettangian to Pliensbachian and Aalenian to Bathonian intervals. Later, Nikitenko *et al.* (2017, 2018a) made comprehensive studies of the Jurassic–Cretaceous paralic successions of the New Siberian Islands based on dinocysts, foraminifera, ostracods, and miospores.

Nikitenko *et al.* (2015a, b) described the dinocyst biostratigraphy and paleoecology of the upper Oxfordian to middle Volgian interval of the Paksa section in Nordvik. These studies provided comprehensive information on the Upper Jurassic marine microfloras of the Laptev Sea region compared to previous works such as Ilyina (1986, 1988). Nikitenko *et al.* (2018b) also studied rich dinocyst assemblages from the Volgian–Hauterivian of the River Olenek region of northern Siberia. The investigations of Nikitenko *et al.* (2015a, b; 2018b) included detailed biozonations based on the dinocyst assemblages, specifically FOs and LOs of key geographically widespread species that are also recorded from North America, northwest Europe and the Russian Platform. The dinocyst zones were all calibrated against biostratigraphic scales based on ammonites and foraminifera.

Jurassic dinocysts of the Barents Sea and Svalbard

In the Barents Sea area and Svalbard, dinocyst zonations covering the whole or parts of the Jurassic include Bjærke (1977), Smelror and Below (1992), Dalseg *et al.* (2016) and Rismyhr *et al.* (2019). Bjærke (1977) introduced an informal palynomorph zonation scheme comprising associations A–F for the uppermost Triassic (Rhaetian) to Lower Cretaceous of Kong Karls Land. Smelror and Below (1992) proposed a dinocyst zonation for the Toarcian to lower Oxfordian of the Barents Sea region. This zonation comprises seven dinocyst zones and is based on the stratigraphic distribution of ninety Toarcian to early Oxfordian dinocyst species from outcrops from Svalbard and Franz Josef Land, as well as from boreholes in the Nordkapp and Hammerfest basins. Dalseg *et al.* (2016) introduced a scheme of informal dinocyst zones for the Upper Jurassic and Lower Cretaceous of central Spitsbergen. Rismyhr *et al.* (2019), a major work on the palynology and sedimentology of the Late Triassic (Carnian) to Middle Jurassic (Callovian) of west-central Spitsbergen, established ten composite assemblage zones based on palynomorphs, six of which are based on dinocysts (Rismyhr *et al.* 2019, fig. 3).

In addition to the works cited above, several other studies treat the dinocyst biostratigraphy of the Barents Sea region, most of which have ranges calibrated to ammonite zones, but lack formal palynological zonation schemes. These include Bjærke *et al.* (1976), Thusu (1978), Bjærke and Dypvik (1977), Bjærke (1980a, b), Dypvik *et al.* (1985), Smelror (1988a, 1991, 1994), Wierzbowski and Århus (1990), Smelror *et al.* (1998, 2018), Wierzbowski *et al.* (2002), Smelror and Dypvik (2005), Koevoets *et al.* (2018), Olaussen *et al.* (2018) and Turner *et al.* (2019).

Jurassic dinocysts of Greenland

Jurassic marine faunas (e.g., ammonites and bivalves) and microfloras of Greenland are more similar in overall character to Boreal faunas, than to, for example, those of Sub-Boreal northern Europe. Several comprehensive palynological

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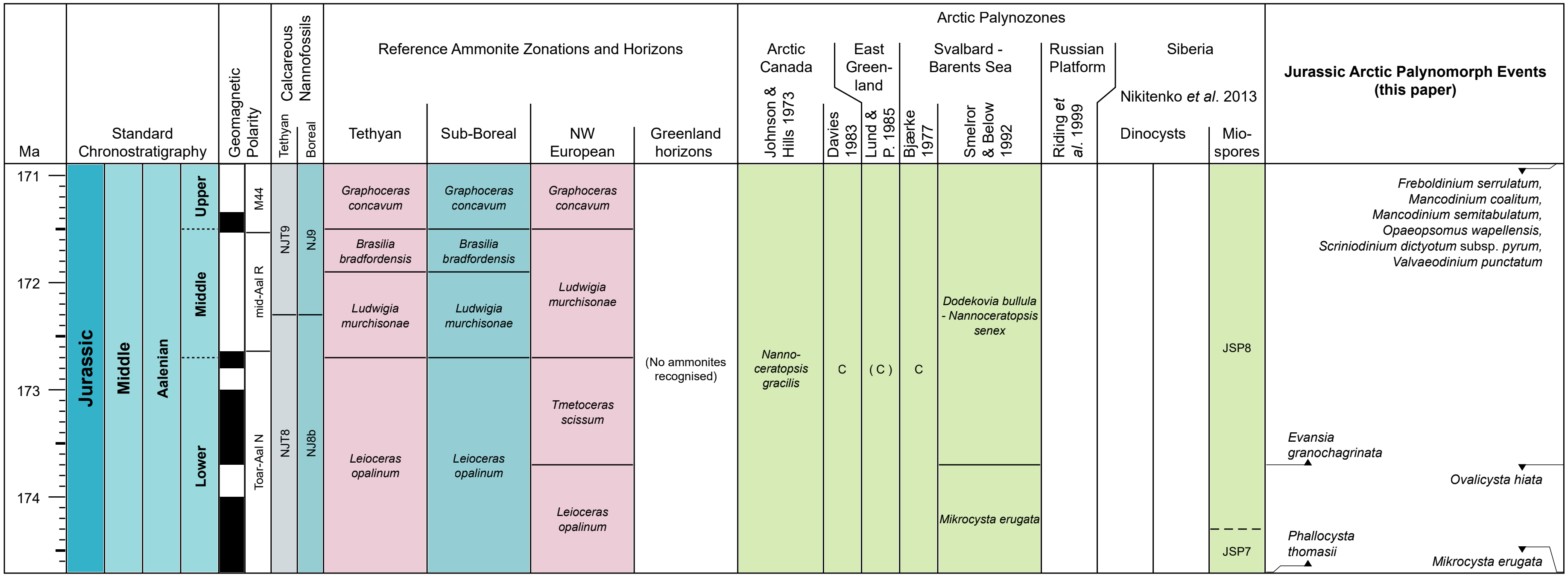

Figure 3. Stratigraphic chart for the Aalenian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

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contributions from Greenland have been published (e.g., Sarjeant 1972; Fensome 1979), although not all of them include zonation schemes. Studies with biozonations include the unpublished doctoral thesis by Piasecki (1980) on Milne Land and his subsequent publication (Piasecki 1996). Other publications on Jameson Land include those by Poulsen (1985), Smelror (1988b) and Milner and Piasecki (1996). Smelror (1988b) defined six dinocyst zones and five subzones for the upper Bathonian to lower Oxfordian successions of East Greenland. The proposed dinocyst zones were all correlated to the ammonite zonation for this region (Callomon and Birkelund 1980). Contributions on Jurassic dinocysts from northeast Greenland include Piasecki *et al.* (2004a) on Hold with Hope, Piasecki and Stemmerik (2004) on Hochstetter Foreland, and Piasecki *et al.* (2004b) on Store Koldewey. These papers document the dinocyst distributions calibrated with relatively few Bathonian to Kimmeridgian ammonite records, but lack a unifying palynological zonation scheme. Other relevant papers on the Jurassic dinocysts of Greenland include Pocock and Sarjeant (1972), Håkansson *et al.* (1981), Lund and Pedersen (1985), Poulsen (1991), Piasecki (2001), Koppelhus and Dam (2003), Koppelhus and Hansen (2003), Kelly *et al.* (2015).

Jurassic miospores of northern Russia

Whereas dinocysts have proved to be reliable biostratigraphic markers for the marine Middle and Upper Jurassic throughout the Circum-Arctic, correlations and relative age assessments based on miospores are frequently used for Lower and Middle Jurassic non-marine strata. The Boreal standard presented by Zakharov *et al.* (1997) incorporated the Lower and Middle Jurassic (excluding Callovian) miospore palynostratigraphic scheme for Siberia published by Ilyina (1985). This Boreal standard does not contain data on terrestrially derived palynomorphs for the Upper Jurassic (Zakharov *et al.* 1997). Subsequently, a palynozonation for the Lower and Middle Jurassic (excluding the Callovian) for Western Siberia was published by Gurari and Mogucheva (2004). A succession of palynostratigraphic units for the uppermost Middle Jurassic (Callovian) and Upper Jurassic of northeastern Siberia based on the studies of key sections of Jurassic marine sediments was established by Shurygin *et al.* (2000). The study areas for that major work were the coast of Anabar Bay, the banks of the River Anabar, Bol'shoi Begichev Island, the lower reaches of the River Lena, and the Nordvik Peninsula.

Miospore palynostratigraphic units are well defined for the Callovian–Oxfordian and middle–upper Volgian, whereas assemblages from the Kimmeridgian, lower Volgian, and part of the middle Volgian in northeastern Siberia have been barely studied. The Callovian to Volgian miospore units have been calibrated against local ammonite faunas. The proposed zonation by Ilyina (1985, 1988) and Shurygin *et al.* (2000) covers a virtually continuous succession of six palynostratigraphic units.

In their comprehensive review of the Jurassic and Cretaceous stratigraphy of the Anabar Bay area on the Laptev Sea coast, Nikitenko *et al.* (2013) presented a review of the Jurassic and Cretaceous miospore zones of Arctic Siberia correlated to the Boreal ammonite standard and to coeval belemnite, bivalve, ostracod and dinocyst zones. Twenty-one zones were defined covering the Early and Middle Jurassic, and five zones were established for the Late Jurassic. No mio spore zones were erected for the middle Oxfordian and Kimmeridgian to middle Volgian (Nikitenko *et al.* 2013).

Further investigations have contributed to the miospore zonation of the Jurassic of northern Russia. Four miospore zones were proposed for the upper Oxfordian to middle Volgian of Arctic Siberia based on analysis of terrestrially derived palynomorphs from the Nordvik (Paksa) section by Nikitenko *et al.* (2015a, b). Two miospore zones were later defined for the Volgian to lowermost Berriasian of the Olenek River section (Nikitenko *et al.* 2018b). The bioevents used for the definition of the boundaries of Siberian miospore zones are mainly applicable to local to sub-regional correlations.

Dzyuba *et al.* (2018) proposed the first formal biostratigraphy for the upper Volgian to lower Ryazanian of the Northern Urals, defining two miospore zones. In addition to regional correlations, the key taxa from the upper Volgian interval enabled these authors to make a biostratigraphic comparison with coeval successions of terrestrially derived palynomorphs from Australia.

Jurassic miospores of the Arctic excluding Russia

No miospore zonations have been established for the Jurassic of the Barents Sea. Lund and Pedersen (1985), Koppelhus and Dam (2003) and Koppelhus and Hansen (2003) used pollen, spores and dinocysts, to subdivide the Lower and Middle Jurassic successions of northeast Greenland. In the most detailed of these studies, Koppelhus and Dam (2003) identified four assemblage zones (AZ1–4) for the Pliensbachian of Jameson Land.

There are several records, including some relatively comprehensive accounts, of Jurassic miospores from the Canadian Arctic (e.g., Davies 1983 and references therein). Detailed descriptions of various assemblages have been reported, but formal zonations are lacking. Galloway *et al.* (2013) applied a multivariate statistical approach to long-ranging miospore taxa from the Aalenian to the Albian, and defined four palynomorph assemblages in the Hoodoo Dome H-37 well drilled on southern Ellef Ringnes Island, near the centre of the Sverdrup Basin. They also characterized their as-semblages in terms of Middle Jurassic to Early Cretaceous pan-hemispherical paleoclimate events.

ARCTIC JURASSIC PALYNOEVENTS

A summary of the following events in spreadsheet format is provided as Appendix B. All taxon names with authors are

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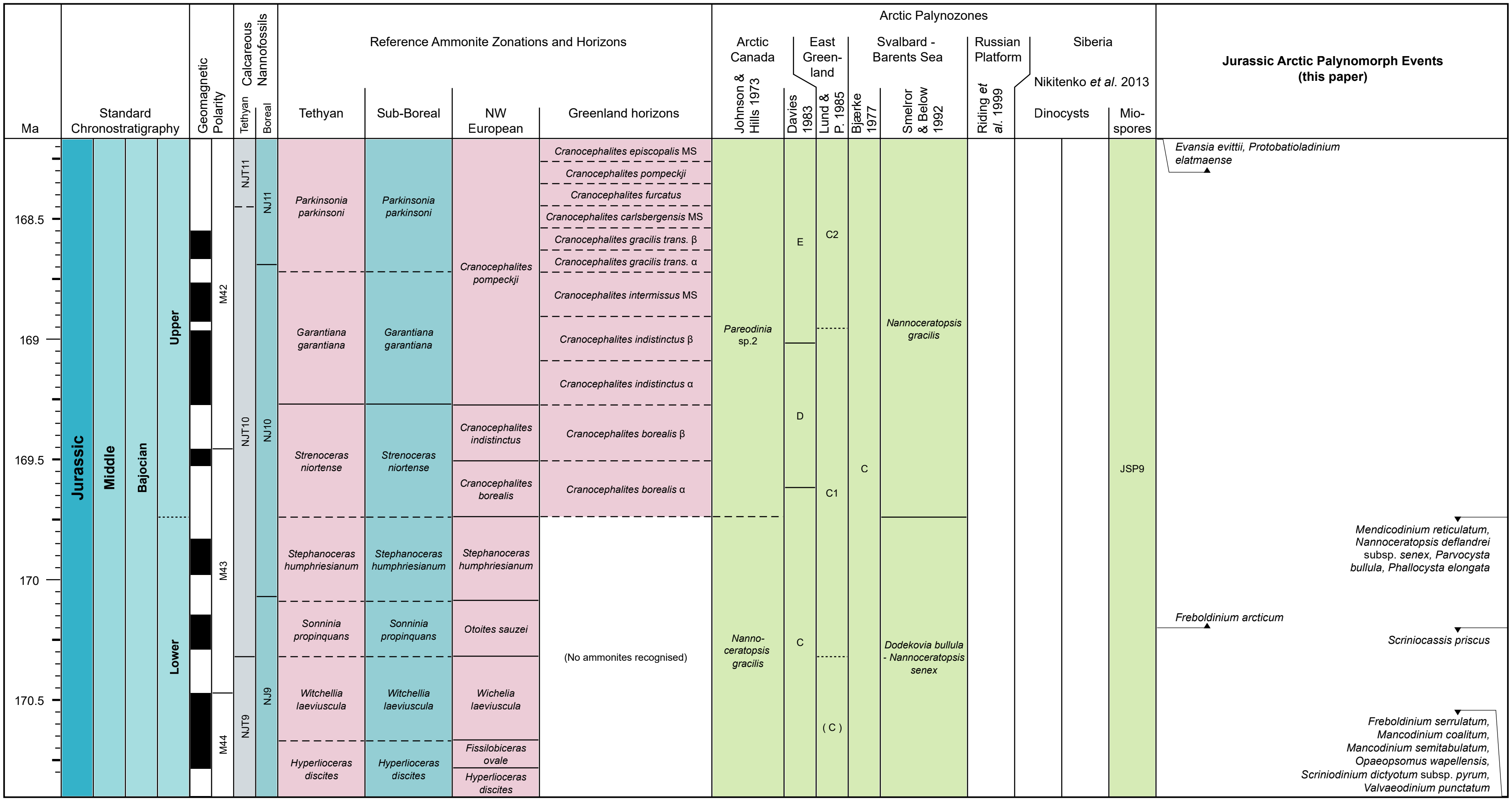

Figure 4. Stratigraphic chart for the Bajocian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

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listed in Appendix A. Events that occur at the Triassic/Jurassic boundary were defined in Mangerud *et al.* (2021) and are grouped below in the LO of *Sverdrupiella mutabilis*. Appendix C includes the Beechey Point State 1 reference well plus three other reference wells reproduced from Mangerud *et al.* (2021): Fireweed 1 (offshore northern Alaska), Klondike OCS-Y-1482 (Chukchi Sea) and Romulus C-67 (Sverdrup Basin) as they include the Triassic/Jurassic boundary. All palynoevents are shown in Figures 1–9.

LO of *Sverdrupiella mutabilis* and other taxa listed below

Sverdrupiella mutabilis has a longer stratigraphic range than other species of *Sverdrupiella*. The LO is based on its occurrence relative to miospore LOs in the Fireweed 1 well, offshore northern Alaska, the Klondike OCS-Y-1482 well in the Chukchi Sea and the Romulus C-67 well in the Sverdrup Basin, plus outcrops and wells documented by Mangerud *et al.* (2021).

The LO of the spore genus *Aratrisporites* occurs at the Triassic/Jurassic transition, within the Heiberg Formation, in the Sverdrup Basin (Felix 1975; Suneby and Hills 1988) Vigran *et al.* (2014) also listed several species of *Aratrisporites* with LOs at the top of the Triassic. Paterson and Mangerud (2015) recorded several *Aratrisporites* species in their uppermost samples from the Svenskøya Formation on Hopen, including *Aratrisporites scabratus, Aratrisporites laevigatus*, *Aratrisporites macrocavatus* and *Aratrisporites tenuispinosus*. Mangerud *et al.* (2021) commented that no records of *Aratrisporites* occur younger than Triassic in the circum-Arctic region.

Suneby and Hills (1988) reported the LO of common *Limbosporites lundbladiae* at the top of their *Limbosporites lundbladiae–Ricciisporites tuberculatus* Zone and tentatively suggested its age as latest Norian or early Rhaetian. Vigran *et al.* (2014) reported the LO of common *Limbosporites lundbladiae* as an intra-Rhaetian event. Paterson and Mangerud (2015) defined their *Limbosporites lundbladiae–Quadraeculina anellaeformis* Assemblage from the Svenskøya Formation and recorded common *Limbosporites lundbladiae* in the uppermost part of this unit. Since *Limbosporites lundbladiae* has not been reported from the Jurassic, this LO is inferred to coincide with the base of the Jurassic.

The LO of taeniate bisaccate pollen has been reported from multiple localities in the Arctic. Vigran *et al.* (2014) used the LO of taeniate bisaccate pollen as a top Triassic event. Suneby and Hills (1988) stated that *Lunatisporites rhaeticus* (as *Taeniasporites rhaeticus*) extends to the top of the Triassic in the Sverdrup Basin. *Lunatisporites rhaeticus* was also recorded by Felix (1975) and Paterson and Mangerud (2015), the latter authors recording it as a single specimen in their uppermost sample from the Norian–Rhaetian Svenskøya Formation on Hopen.

The LOs of *Sverdrupiella mutabilis, Aratrisporites*, common *Limbosporites lundbladiae,* and taeniate bisaccate pollen are taken as the base of the ammonite *Psiloceras planorbis* Zone (i.e., at the base of the Hettangian).

LO of *Dapcodinium priscum*

The LO of *Dapcodinium priscum* occurs within the ammonite *Arnioceras semicostatum* Zone in the Barents Sea and on Svalbard (Feist-Burkhardt 1994, based on Below 1987a, 1990).

The LO of *Dapcodinium priscum* is taken as the base of the ammonite *Arnioceras semicostatum* Zone (i.e., earliest Sinemurian).

FO of *Mendicodinium reticulatum*

The FO of *Mendicodinium reticulatum* occurs at the base of beds with *Mendicodinium* spp. in the Middle-Nakynskaya 360 Borehole, northeastern Siberia, at the base of the ammonite *Asteroceras obtusum* Zone and the foraminiferal *Trochammina inusitata–Turritellella volubilis* Zone (Nikitenko 2009; Goryacheva and Nikitenko 2016).

The FO of *Mendicodinium reticulatum* is taken as the base of the ammonite *Asteroceras obtusum* Zone (i.e., the base of the upper Sinemurian).

FO of *Valvaeodinium perpunctatum*

The FO of *Valvaeodinium perpunctatum* occurs at the base of the early Pliensbachian as extrapolated from a compilation of Pliensbachian to early Toarcian dinocysts from the Tethyan and Boreal realms by Bucefalo Palliani and Riding (2003). These authors concluded that *Valvaeodinium perpunctatum* is confined to the early Pliensbachian in the Boreal Realm.

The FO of *Valvaeodinium perpunctatum* is taken as the base of the ammonite *Uptonia jamesoni* Zone (i.e., the base of the early Pliensbachian).

LO of *Valvaeodinium perpunctatum*

The LO of *Valvaeodinium perpunctatum* occurs at the base of the late Pliensbachian as extrapolated from a compilation of Pliensbachian to early Toarcian dinocysts from the Tethyan and Boreal realms by Bucefalo Palliani and Riding (2003), who concluded that *Valvaeodinium perpunctatum* is confined to the early Pliensbachian in the Boreal Realm.

The LO of *Valvaeodinium perpunctatum* is taken as the base of the ammonite *Almaltheus margaritatus* Zone (i.e., the base of the late Pliensbachian).

FO of *Scriniocassis weberi*

The FO of *Scriniocassis weberi* occurs at the base of the Toarcian in the Barents Sea area and on Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, b, 1990). However, this range base is of late Pliensbachian (ammonite *Amaltheus margaritatus* Zone) age throughout the Sub-Boreal and Boreal relams according to, for example,

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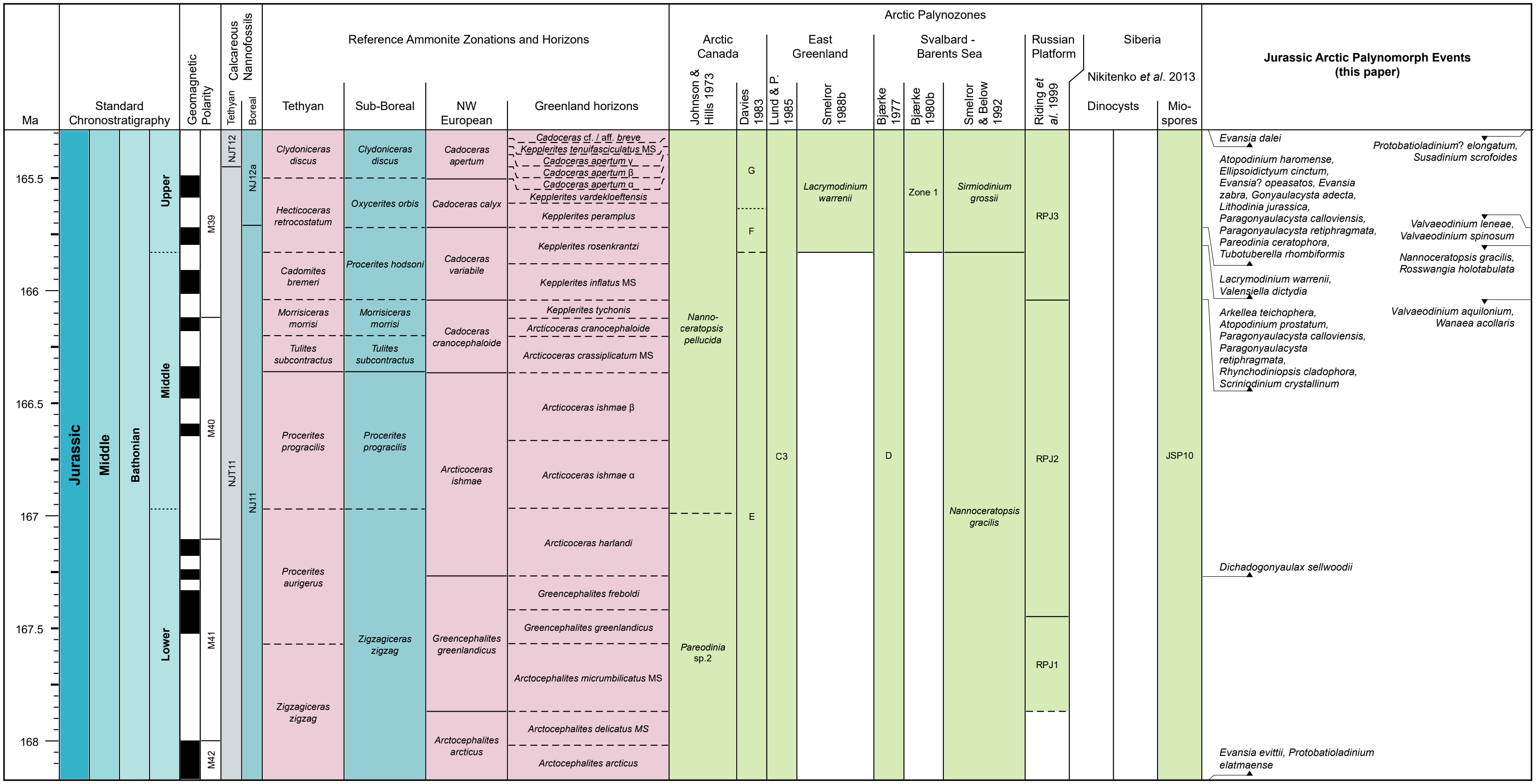

Figure 5. Stratigraphic chart for the Bathonian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

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Morgenroth (1970) and Riding and Thomas (1992).

The FO of *Scriniocassis weberi* is taken as 50% up from the base of the ammonite *Amaltheus margaritatus* Zone (i.e., late Pliensbachian).

FO of *Freboldinium regulum*

The FO of *Freboldinium regulum* occurs in the latest Pliensbachian ammonite *Pleuroceras spinatum* Zone on Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, b, 1990).

The FO of *Freboldinium regulum* is taken as 50% up from the base of the ammonite *Pleuroceras spinatum* Zone (i.e., latest Pliensbachian).

FO of *Susadinium scrofoides*

The FO of *Susadinium scrofoides* occurs at the base of dinocyst Oppel Zone B of Davies (1983), which was assigned to the early Toarcian based on the presence of the marker ammonites *Dactylioceras commune, Peronoceras spinatum*, *Peronoceras polare* and *Pseudoleoceras* aff. *compactile* in the Sverdrup Basin (Davies 1983). The FO of *Mancodinium semitabulatum* also occurs within the Pliensbachian–Toarcian dinocyst *Nannoceratopsis deflandrei* Zone and the Pliensbachian–Toarcian dinocyst *Nannoceratopsis deflandrei* subsp. *anabarensis* Subzone defined in northern East Siberia by Riding *et al.* (1999), equivalent to the base of the ammonite *Dactylioceras tenuicostatum* Zone. However, van de Schootbrugge *et al.* (2020) reported *Mancodinium semitabulatum* from the upper Pliensbachian of northeast Russia.

The FO of *Susadinium scrofoides* is taken as the base of the ammonite *Dactylioceras tenuicostatum* Zone (i.e., the base of the early Toarcian).

FOs of *Phallocysta eumekes* and other taxa listed below

The FOs of *Phallocysta eumekes* and *Valvaeodinium aquilonium* occur at the base of the ammonite *Harpoceras falciferum* Zone at the Kelimyar River, northeastern Siberia. These biovents are within the foraminiferal *Ammobaculites lobus–Trochammina kisselmani* Zone (Nikitenko *et al.* 2013). The FO of *Rosswangia holotabulata* is also placed, albeit tentatively, at the base of the ammonite *Harpoceras falciferum* Zone based on regional synthesis of Tethyan to Boreal dinocyst events by Goryacheva (2017, fig. 14). The latter work incorporated data from Davies (1983, 1985) from Arctic Canada.

The FOs of *Phallocysta eumekes, Rosswangia holotabulata* and *Valvaeodinium aquilonium* are taken as the base of the ammonite *Harpoceras serpentinum* Zone (i.e., early Toarcian).

FOs of *Caligodinium aceras* and other taxa listed below

The FOs of *Caligodinium aceras*, *Dingodinium minutum*, *Dodekovia syzygia*, *Microdinium opacum* and *Valvaeodinium cavum* occur at base of Zone B of Davies (1983), which was assigned to the Toarcian of the Sverdrup Basin, interpreted here as the base of the ammonite *Hildoceras bifrons* Zone.

The FOs of *Caligodinium aceras*, *Dingodinium minutum*, *Dodekovia syzygia*, *Microdinium opacum* and *Valvaeodinium cavum* are taken as the base of the ammonite *Hildoceras bifrons* Zone (i.e., the base of the middle Toarcian).

FO of *Nannoceratopsis gracilis*

The FO of *Nannoceratopsis gracilis* occurs in the lower parts of the ammonite *Hildoceras bifrons* Zone and the foraminiferal *Ammobaculites lobus–Trochammina kisselmani* Zone in the Kelimyar River area, northeastern Siberia (Nikitenko *et al.* 2013).

The FO of *Nannoceratopsis gracilis* is taken as 17% up from the base of the ammonite *Hildoceras bifrons* Zone (i.e., middle Toarcian).

LOs of *Andreedinium arcticum* and other taxa listed below

The LOs of *Andreedinium arcticum*, *Parvocysta bullula*, *Reutlingia nasuta* and *Susadinium faustum* occur in the Toarcian ammonite *Porpoceras polare–Pseudolioceras rosenkrantzi* Zone on Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, 1990).

The LOs of *Andreedinium arcticum*, *Parvocysta bullula*, *Reutlingia nasuta* and *Susadinium faustum* are taken as 50% up from the base of the ammonite *Hildoceras bifrons* Zone (i.e., middle Toarcian).

FOs of *Ovalicysta hiata* and *Scriniocassis priscus*

The FOs of *Ovalicysta hiata* and *Scriniocassis priscus* occur in the Toarcian ammonite *Porpoceras polare–Pseudolioceras rosenkrantzi* Zone in the Barents Sea region (Feist-Burkhardt 1994, based on data from Below 1987a, 1990).

The FOs of *Ovalicysta hiata* and *Scriniocassis priscus* are taken as 50% up from the base of the ammonite *Hildoceras bifrons* Zone (i.e., middle Toarcian).

FO of *Opaeopsomus wapellensis*

The FO of *Opaeopsomus wapellensis* occurs within dinocyst Oppel-Zone B of Davies (1983), which was assigned to the Toarcian to early Bajocian in the Sverdrup Basin, interpreted here as the base of the ammonite *Haugia variabilis* Zone.

The FO of *Opaeopsomus wapellensis* is taken as the base of the ammonite *Haugia variabilis* Zone (i.e., the base of the late Toarcian).

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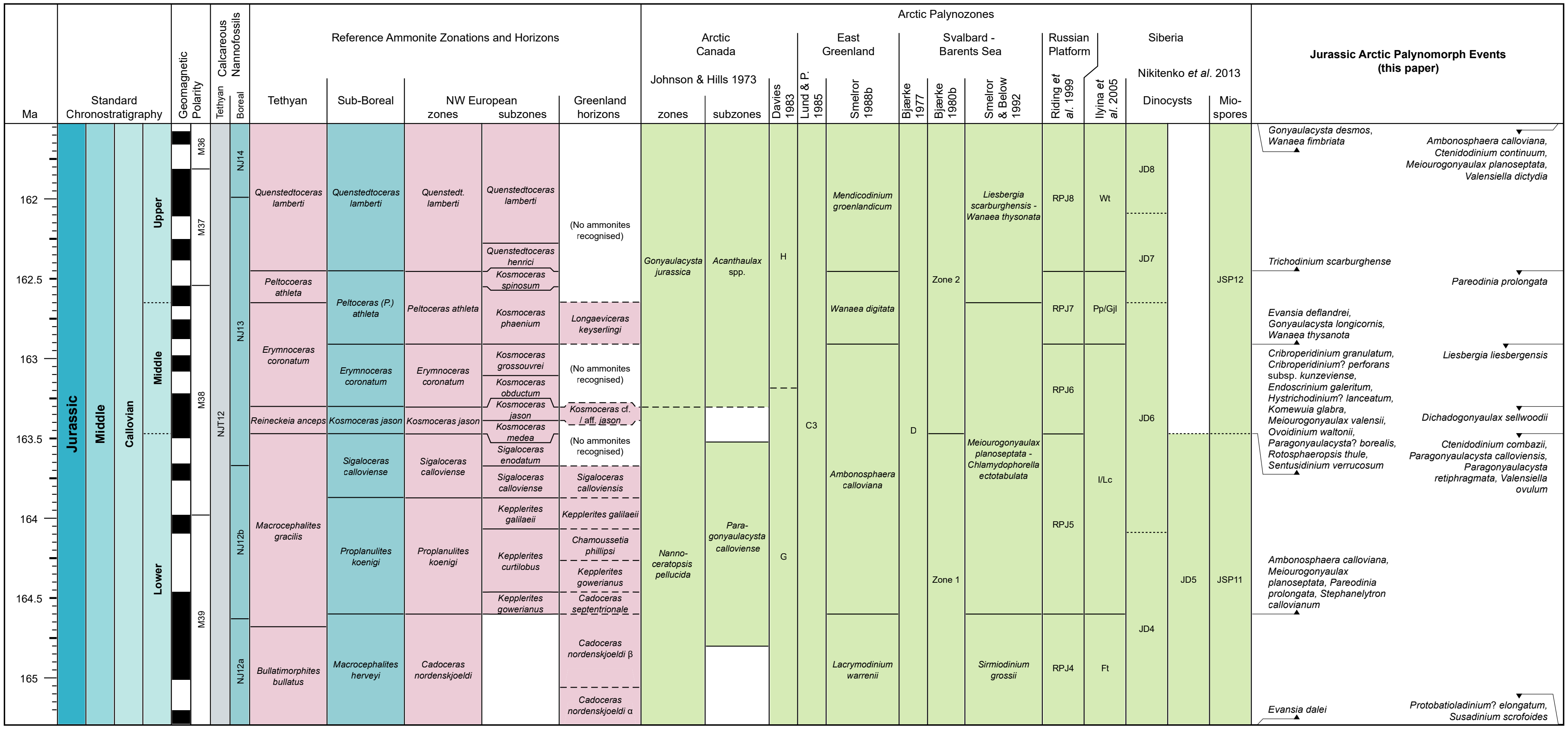

Figure 6. **Stratigraphic chart for the Callovian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).**

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LO of *Nannoceratopsis deflandrei* subsp. *senex* var. C sensu Davies 1983

The LO of *Nannoceratopsis deflandrei* subsp. *senex* var. C sensu Davies 1983 occurs at base of dinocyst Oppel-Zone C of Davies (1983) which was assigned to the Toarcian to Early Bajocian in the Sverdrup Basin.

The LO of *Nannoceratopsis deflandrei* subsp. *senex* var. C sensu Davies 1983 is taken as the base of the ammonite *Grammoceras thouarsense* Zone (i.e., late Toarcian).

FOs of *Chytroeisphaeridia chytroeides* and *Valvaeodinium punctatum*

The FOs of *Chytroeisphaeridia chytroeides* and *Valvaeodinium punctatum* occur at base of dinocyst Oppel-Zone C of Davies (1983) which was assigned to the Toarcian to early Bajocian in the Sverdrup Basin.

The FOs of *Chytroeisphaeridia chytroeides* and *Valvaeodinium punctatum* are taken as the base of the ammonite *Grammoceras thouarsense* Zone (i.e., late Toarcian).

LO of *Phallocysta elongata*

The LO of *Phallocysta elongata* occurs at the top of the Toarcian dinocyst *Phallocysta eumekes* Zone defined in northern East Siberia by Riding *et al.* (1999); this horizon is coeval with the top of the ammonite *Dumortieria levesquei* Zone and is overlain by an Aalenian to Bajocian interval in northern East Siberian sections devoid of dinocysts (Riding *et al.* 1999).

The LO of *Phallocysta elongata* is taken as the base of the ammonite *Pleydellia aalensis* Zone (i.e., latest Toarcian).

LO of *Mikrocysta erugata*

The LO of *Mikrocysta erugata* occurs close to the base of the Aalenian, based on its occurrence near the top of the dinocyst *Mikrocysta erugata* Zone of Smelror and Below (1992, fig. 4). This zone was assigned to the Toarcian in the Arctic Norway/Barents Sea region.

The LO of *Mikrocysta erugata* is taken as the base of the ammonite *Leioceras opalinum* Zone (i.e., the base of the Aalenian).

FO of *Phallocysta thomasii*

The FO of *Phallocysta thomasii* occurs at the base of the Aalenian, based on its occurrence close to the top of the dinocyst *Mikrocysta erugata* Zone of Smelror and Below (1992, fig. 4), which these authors assigned to the Toarcian in the Arctic Norway–Barents Sea region.

The FO of *Phallocysta thomasii* is taken as the the base of the ammonite *Leioceras opalinum* Zone (i.e., the base of the Aalenian).

LO of *Ovalicysta hiata*

The LO of *Ovalicysta hiata* occurs in the Toarcian ammonite *Porpoceras polare–Pseudolioceras rosenkrantzi* Zone in the Barents Sea and on Svalbard (Bjærke 1980a).

The LO of *Ovalicysta hiata* is taken as at 50% up from the base of the ammonite *Leioceras opalinum* Zone (i.e., earliest Aalenian).

FO of *Evansia granochagrinata*

The FO of *Evansia granochagrinata* occurs in the latest Pliensbachian ammonite *Pleuroceras spinatum* Zone on Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, 1990).

The FO of *Evansia granochagrinata* is taken as 50% up from the base of the ammonite *Leioceras opalinum* Zone (i.e., earliest Aalenian).

LOs of *Freboldinium serrulatum* and other taxa listed below

The LOs of *Freboldinium serrulatum, Mancodinium coalitum*, *Mancodinium semitabulatum*, *Opaeopsomus wapellensis*, *Scriniodinium dictyotum* subsp. *pyrum* and *Valvaeodinium punctatum* occur at the base of dinocyst Oppel-Zone D of Davies (1983), which was assigned to the early Bajocian. The age of this zone was calibrated to the early Bajocian by Davies (1983) due to the presence of the ammonite *Leioceras opalinum* near its base on Ellef Ringnes Island (Fig. 10). This distinctive mollusk is the only age-diagnostic macrofossil in this zone. Strata immediately above this zone at Vantage Point, Axel Heiberg Island, have yielded the middle Bajocian ammonite *Arkelloceras mclearni* (Davies 1983).

The LOs of *Freboldinium serrulatum, Mancodinium coalitum*, *Mancodinium semitabulatum*, *Opaeopsomus wapellensis*, *Scriniodinium dictyotum* subsp. *pyrum* and *Valvaeodinium punctatum* are taken as the base of the ammonite *Hyperlioceras discites* Zone (i.e., the base of the Bajocian).

LO of *Scriniocassis priscus*

The LO of *Scriniocassis priscus* occurs in the Aalenian to early Bajocian ammonite *Leioceras opalinum–Hyperlioceras discites* Zone in the Barents Sea and on Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, 1990).

The LO of *Scriniocassis priscus* is taken as 50% up from the base of the ammonite *Sonninia propinquans* Zone (i.e., early Bajocian).

FO of *Freboldinium arcticum*

The FO of *Freboldinium arcticum* occurs in the Toarcian ammonite *Porpoceras polare–Pseudolioceras rosenkrantzi* Zone in the Barents Sea region and Svalbard (Feist-Burkhardt 1994, based on data from Below 1987a, 1990).

The FO of *Freboldinium arcticum* is taken as 50% up from

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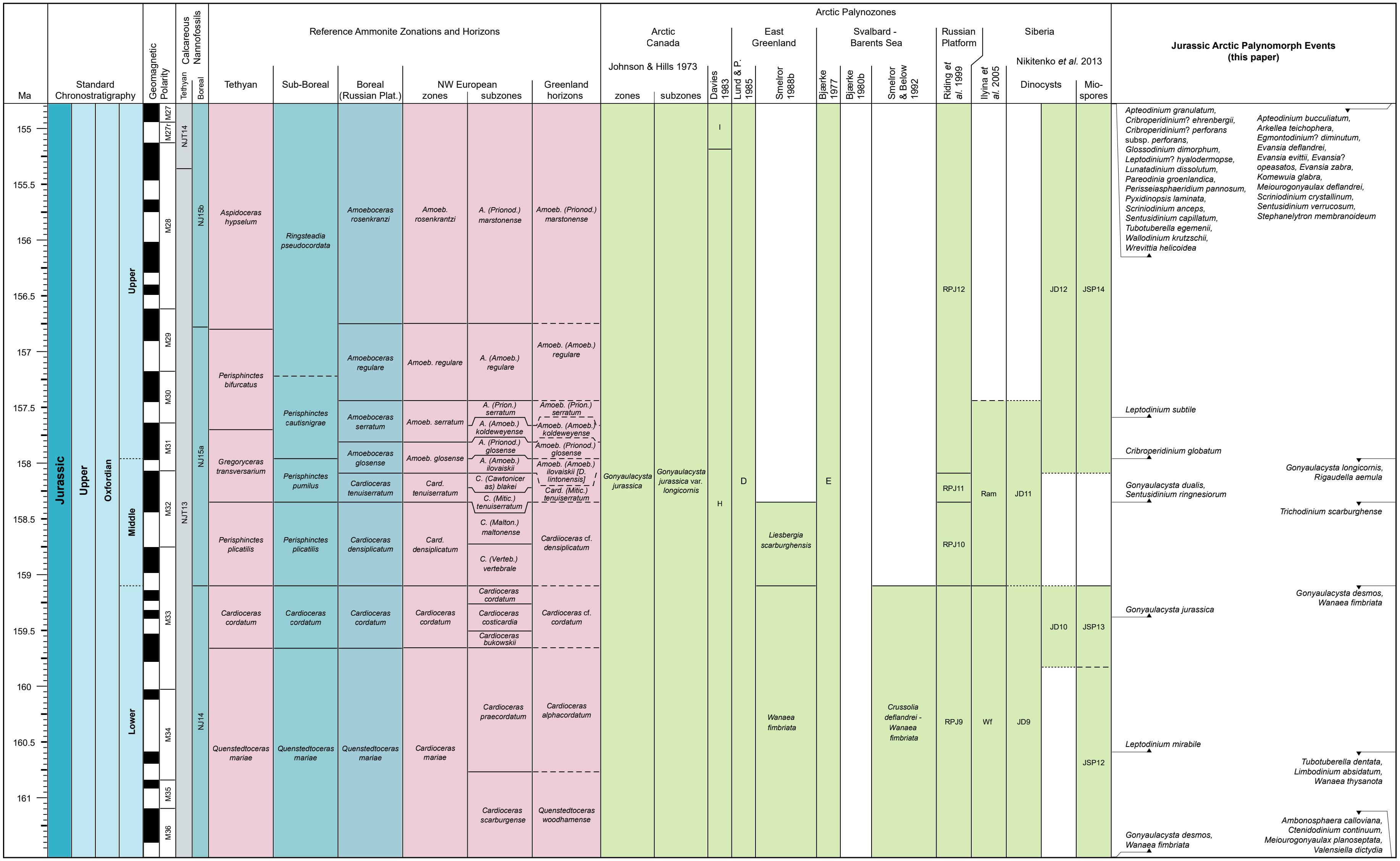

Figure 7. Stratigraphic chart for the Oxfordian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

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the base of the ammonite *Sonninia propinquans* Zone (i.e., early Bajocian).

LOs of *Mendicodinium reticulatum* and other taxa listed below

The LOs of *Mendicodinium reticulatum* and *Phallocysta elongata* occur at the base of dinocyst Oppel-Zone E of Davies (1983), which was dated as late Bajocian to middle Bathonian in the Sverdrup Basin. The presence of the ammonite *Arkelloceras mclearni* at the base of Oppel-Zone E at Vantage Point, Axel Heiberg Island, indicates a middle Bajocian age (Frebold in Tozer 1963; Frebold 1964; Frebold *et al.* 1967; Davies 1983). Stratigraphically higher in Oppel-Zone E the ammonite *Arctocephalites elegans* is present and indicates a middle Bathonian age (Davies 1983). The LOs of *Nannoceratopsis deflandrei* subsp. *senex* and *Parvocysta bullula* are correlated with the base of the late Bajocian based on its occurrence near the top of the dinocyst *Dodekovia bullula–Nannoceratopsis senex* Zone of Smelror and Below (1992, fig. 4), which they assigned to the Aalenian and early Bajocian in the Barents Sea region.

The LOs of *Mendicodinium reticulatum*, *Nannoceratopsis deflandrei* subsp. *senex*, *Parvocysta bullula* and *Phallocysta elongata* are taken as the base of the late Bajocian.

FOs of *Evansia evittii* and *Protobatioladinium elatmaense*

The FOs of *Evansia evittii* and *Protobatioladinium elatmaense* occur at the base of the Bathonian dinocyst *Evansia evittii* Zone defined in the Russian Platform by Riding *et al.* (1999). This is equivalent to the top of the ammonite *Parkinsonia parkinsoni* Zone which is at the Bajocian–Bathonian transition. This interval is underlain by an Aalenian–Bajocian interval in northeastern Siberia, which is devoid of dinocysts (Riding *et al.* 1999).

The FOs of *Evansia evittii* and *Protobatioladinium elatmaense* are taken as the base of the ammonite *Zigzagiceras zigzag* Zone (i.e., the base of the Bathonian).

FO of *Dichadogonyaulax sellwoodii*

The FO of *Dichadogonyaulax sellwoodii* occurs at the top of the Bathonian dinocyst *Evansia evittii* Zone defined in the Russian Platform by Riding *et al.* (1999), and thus within the earliest Bathonian ammonite *Zigzagiceras zigzag* Zone.

The FO of *Dichadogonyaulax sellwoodii* is taken as 75% above the base of the ammonite *Zigzagiceras zigzag* Zone (i.e., earliest Bathonian).

FOs of *Arkellea teichophera* and other taxa listed below

The FOs of *Arkellea teichophera*, *Atopodinium prostatum*, *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata*, *Rhynchodiniopsis cladophora* and *Scriniodinium crystallinum* occur at the base of dinocyst Oppel-Zone F of Davies (1983), which was assigned to the late Bathonian in the Sverdrup Basin. No index macrofossils occur in strata correlative with Oppel-Zone F. This Oppel-Zone, however, is bracketed by the middle Bathonian ammonite *Arctocephalites elegans* in Oppel-Zone E and the early Callovian ammonite *Cadoceras bodylevski* in Oppel-Zone G. The age of Oppel-Zone F is probably late Bathonian based on the ammonites *Arcticoceras ishmae* and *Arcticoceras kochi* (Davies 1983). The FOs occuring at this horizon are interpreted to occur at the base of the middle Bathonian ammonite *Procerites hodsoni* Zone.

The FOs of *Arkellea teichophera*, *Atopodinium prostatum*, *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata*, *Rhynchodiniopsis cladophora* and *Scriniodinium crystallinum* are taken as the base of the ammonite *Procerites hodsoni* Zone (i.e., middle Bathonian).

LOs of *Valvaeodinium aquilonium* and *Wanaea acollaris*

The LO of *Valvaeodinium aquilonium* occurs at base of dinocyst Oppel-Zone F of Davies (1983) which was assigned to the late Bathonian in the Sverdrup Basin. The LO of *Wanaea acollaris* is coeval with the LO of *Valvaeodinium aquilonium* based on the co-occurrence of these species in northern Alaska and the Sverdrup Basin (see the Beechey Point State 1 reference well in Appendix C).

The LOs of *Valvaeodinium aquilonium* and *Wanaea acollaris* are taken as the base of the ammonite *Procerites hodsoni* Zone (i.e., middle Bathonian).

LOs of *Nannoceratopsis gracilis* and *Rosswangia holotabulata*

The LOs of *Nannoceratopsis gracilis* and *Rosswangia holotabulata* are correlated with the boundary between the dinocyst *Nannoceratopsis gracilis* and *Sirmiodinium grossii* zones of Smelror and Below (1992), at the base of the late Bathonian in the Barents Sea area. These two LOs are coeval based on data from northern Alaska and the Sverdrup Basin, including the Beechey Point State 1 reference well (Appendix C).

The LOs of *Nannoceratopsis gracilis* and *Rosswangia holotabulata* are taken as 75% up from the base of the ammonite *Procerites hodsoni* Zone (i.e., close to the middle/late Bathonian transition).

FOs of *Lacrymodinium warrenii* and *Valensiella dictydia*

The FOs of *Lacrymodinium warrenii* and *Valensiella dictydia* are assigned to the late Bathonian based on their occurrence at the boundary between the dinocyst *Nannoceratopsis gracilis* and *Sirmiodinium grossii* zones of Smelror and Below (1992) in the Barents Sea region.

The FOs of *Lacrymodinium warrenii* and *Valensiella*

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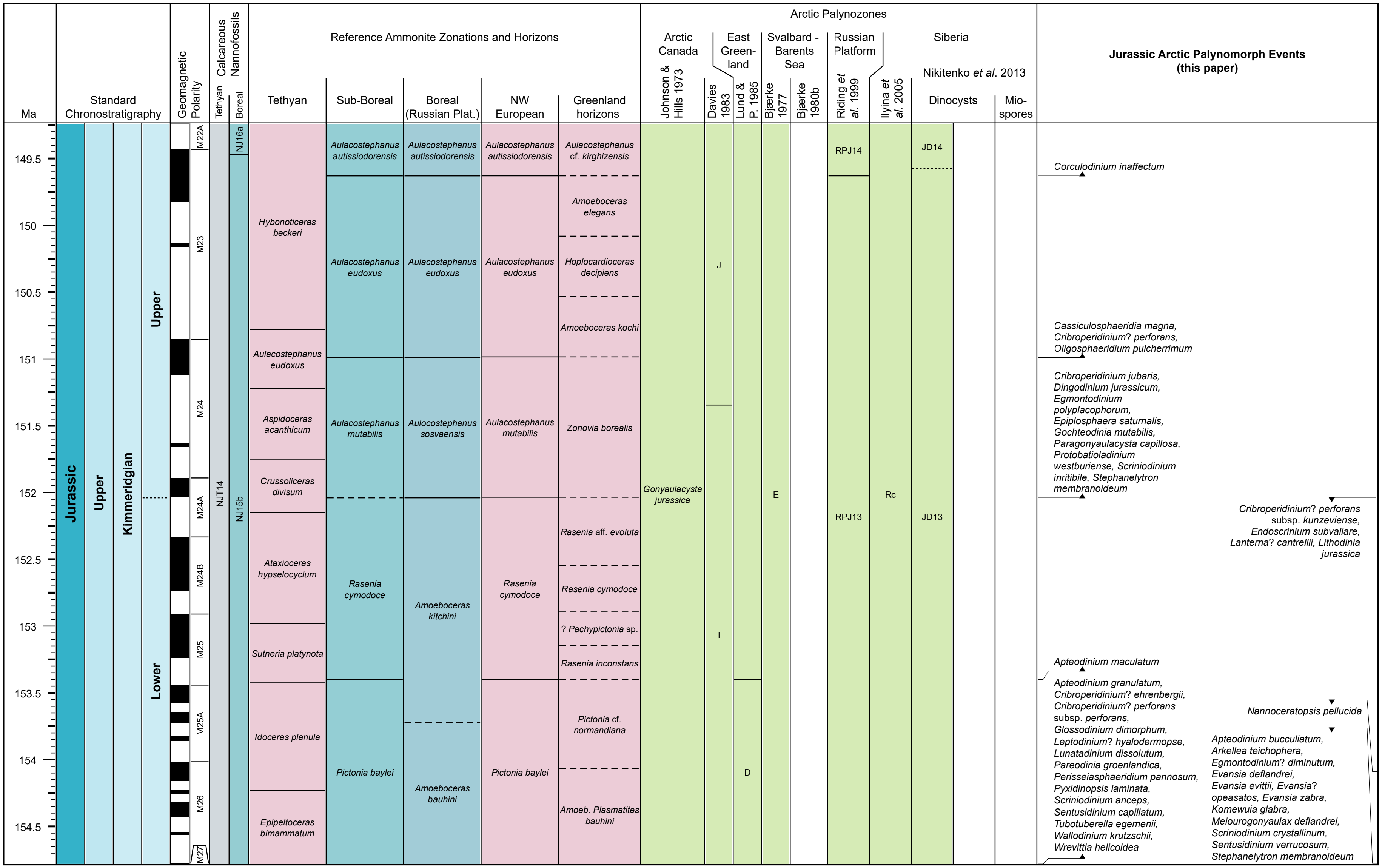

Figure 8. Stratigraphic chart for the Kimmeridgian; details as for Figure 1. Lund & P. 1985 - Lund and Pedersen (1985).

dictydia are taken as 75% up from the base of the ammonite *Procerites hodsoni* Zone (i.e., close to the middle/late Bathonian transition).

LOs of *Valvaeodinium leneae* and *Valvaeodinium spinosum*

The LO of *Valvaeodinium leneae* occurs in the latest Bath-onian ammonite *Cadoceras apertum* Zone in East Green-land (Piasecki 2001). However, the LO of *Valvaeodinium spinosum* is present in the late Bathonian ammonite *Cadoceras calyx* Zone in central Spitsbergen, Svalbard (Koevoets *et al.* 2018), which is coeval with the ammonite *Oxycerites orbis* Zone (Fig. 5).

The LOs of *Valvaeodinium leneae* and *Valvaeodinium spinosum* are taken as the base of the ammonite *Oxycerites orbis* Zone (i.e., late Bathonian).

FOs of *Atopodinium haromense* and other taxa listed below

The FO of *Atopodinium haromense* occurs in the late Bathonian ammonite *Cadoceras calyx* Zone in central Spitsbergen, Svalbard (Koevoets *et al.* 2018) and is interpreted to occur at the base of the ammonite *Oxycerites orbis* Zone. The FOs of *Ellipsoidictyum cinctum*, *Evansia*? *opeasatos*, *Evansia zabra*, *Gonyaulacysta adecta, Lithodinia jurassica*, *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata*, *Pareodinia ceratophora* and *Tubotuberella rhombiformis* also occur within dinocyst Zone F of Davies (1983), in the late Bathonian of the Sverdrup Basin.

The FOs of *Atopodinium haromense, Ellipsoidictyum cinctum*, *Evansia*? *opeasatos*, *Evansia zabra*, *Gonyaulacysta adecta, Lithodinia jurassica*, *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata*, *Pareodinia ceratophora* and *Tubotuberella rhombiformis* are taken as the base of the ammonite *Oxycerites orbis* Zone (i.e., late Bathonian).

LOs of *Protobatioladinium*? *elongatum* and *Susadinium scrofoides*

The LO of *Protobatioladinium*? *elongatum* occurs at the top of the latest Bathonian dinocyst *Protobatioladinium*? *elongatum* Zone defined in the Russian Platform by Riding *et al.* (1999). Likewise, the LO of *Susadinium scrofoides* occurs at the top of dinocyst Oppel-Zone F of Davies (1983), which was assigned to the late Bathonian. Evidence for the age of Oppel-Zone F is provided by the middle Bathonian ammonite *Arctocephalites elegans* in Oppel-Zone E below, and the early Callovian ammonite *Cadoceras bodylevski* in Oppel-Zone G.

The LOs of *Protobatioladinium*? *elongatum* and *Susadinium scrofoides* are taken as the base of the ammonite *Macrocephalites herveyi* Zone (i.e., at the base of the Callovian).

FO of *Evansia dalei*

The FO of *Evansia dalei* occurs at the base of the early Callovian *Fromea tornatilis* Zone defined by Ilyina *et al.* (2005) in the Tyumenskaya superdeep well-6, West Siberia. This bioevent lies at the base of the ammonite *Macrocephalites herveyi* Zone and the foraminiferal *Kutsevella memorabilis–Guttulina tatarensis* Zone. *Evansia dalei* was also reported from the lowermost Callovian of the Russian Platform by Riding *et al.* (1999).

The FO of *Evansia dalei* is taken as the base of the ammonite *Macrocephalites herveyi* Zone (i.e., at the base of the Callovian).

FOs of *Ambonosphaera calloviana* and other taxa listed below

The FOs of *Ambonosphaera calloviana* and *Meiourogonyaulax planoseptata* occur in the Barents Sea at the boundary of the dinocyst *Sirmiodinium grossii* Zone, and the dinocyst *Meiourogonyaulax planoseptata–Chlamydophorella ectotabulata* Zone of Smelror and Below (1992). These events were assigned to the earliest Callovian. The FOs of *Pareodinia prolongata* and *Stephanelytron callovianum* occur in the Tyumenskaya superdeep well-6, West Siberia at the base of the Callovian dinocyst *Impletosphaeridium* spp.–*Stephanelytron* Zone; this horizon is equivalent to the bases of the earliest Callovian ammonite *Proplanulites koenigi* Zone and the foraminiferal *Dorothia insperata–Trochammina rostovzevi* Zone (Ilyina *et al.* 2005).

The FOs of *Ambonosphaera calloviana*, *Meiourogonyaulax planoseptata*, *Pareodinia prolongata* and *Stephanelytron callovianum* are taken as the base of the ammonite *Proplanulites koenigi* Zone (i.e., earliest Callovian).

LOs of *Ctenidodinium combazii* and other taxa listed below

The LO of *Ctenidodinium combazii* occurs at the top of the early Callovian dinocyst *Lagenadinium callovianum* (now *Stephanelytron callovianum*) zone defined on the Russian Platform by Riding *et al.* (1999). The LOs of *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata* and *Valensiella ovulum* are coeval with the LO of *Ctenidodinium combazii* based on their occurrences in northern Alaska and the Sverdrup Basin, for example the Beechey Point State 1 reference well (Appendix C).

The LOs of *Ctenidodinium combazii*, *Paragonyaulacysta calloviensis*, *Paragonyaulacysta retiphragmata* and *Valensiella ovulum* are taken as the base of the ammonite *Kosmoceras jason* Zone (i.e., the base of the middle Callovian).

FOs of *Cribroperidinium granulatum* and the other taxa listed below

The FOs of *Cribroperidinium granulatum*, *Cribroperidinium*? *perforans* subsp. *kunzeviense*, *Endoscrinium galeritum*,

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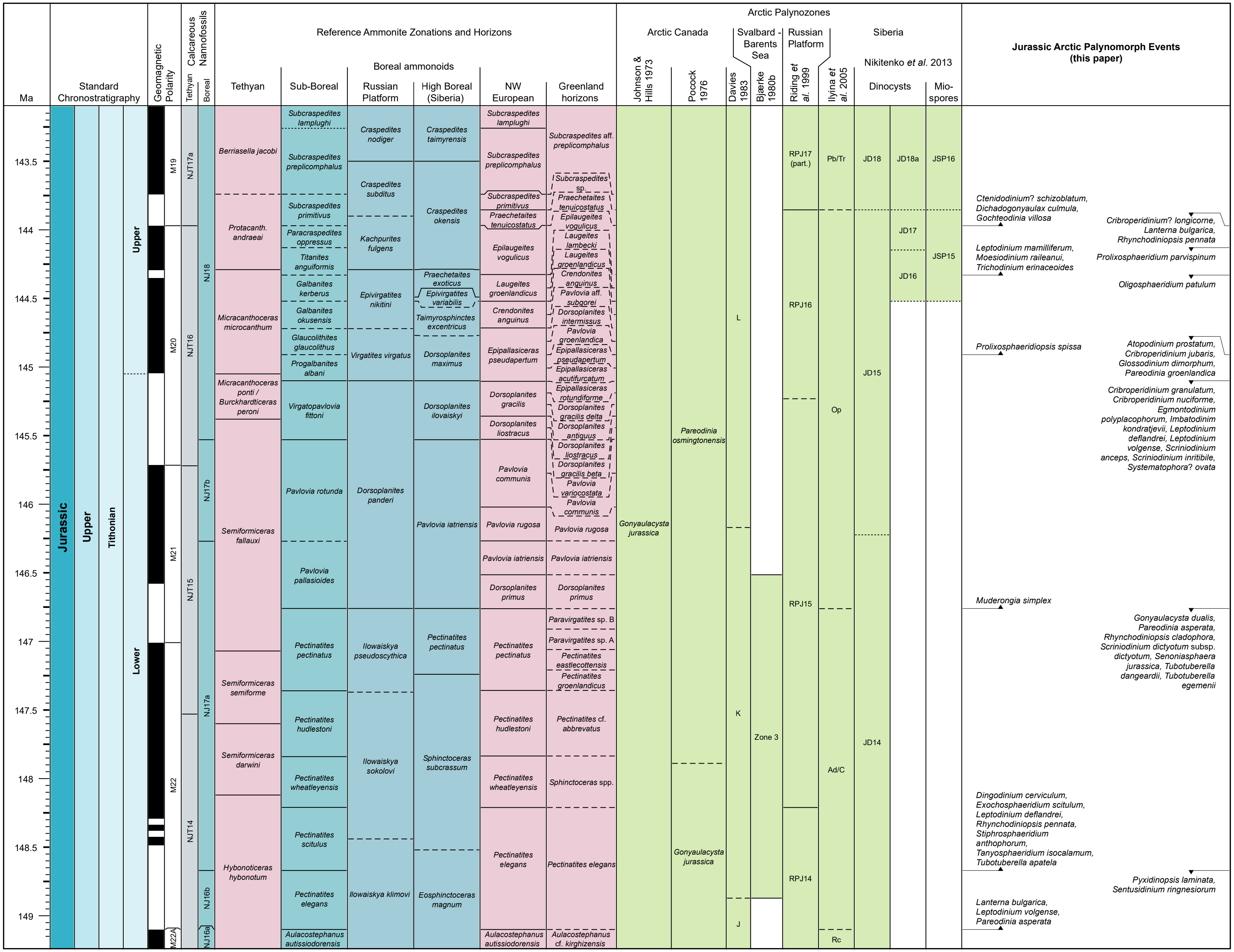

Figure 9. Stratigraphic chart for the Tithonian; details as for Figure 1.

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Hystrichodinium? *lanceatum*, *Komewuia glabra*, *Meiourogonyaulax valensii*, *Ovoidinium waltonii, Paragonyaulacysta*? *borealis*, *Rotosphaeropsis thule* and *Sentusidinium verrucosum* occur at base of dinocyst Oppel-Zone H of Davies (1983). This zone was assigned to the middle Callovian–Oxfordian in the Sverdrup Basin and the base of it is interpreted here to represent the base of the ammonite *Kosmoceras jason* Zone.

The FOs of *Cribroperidinium granulatum*, *Cribroperidinium*? *perforans* subsp. *kunzeviense*, *Endoscrinium galeritum*, *Hystrichodinium*? *lanceatum*, *Komewuia glabra*, *Meiourogonyaulax valensii*, *Ovoidinium waltonii, Paragonyaulacysta*? *borealis*, *Rotosphaeropsis thule* and *Sentusidinium verrucosum* are taken as the base of the ammonite *Kosmoceras jason* Zone (i.e., the base of the middle Callovian).

LO of *Dichadogonyaulax sellwoodii*

The LO of *Dichadogonyaulax sellwoodii* occurs within the middle Callovian dinocyst *Kalyptea stegasta* Zone defined in the Russian Platform by Riding *et al.* (1999) at the base of the ammonite *Erymnoceras coronatum* Zone.

The LO of *Dichadogonyaulax sellwoodii* is taken as the base of the ammonite *Erymnoceras coronatum* Zone (i.e., middle Callovian).

LO of *Liesbergia liesbergensis*

The LO of *Liesbergia liesbergensis* occurs in Tyumenskaya superdeep well-6, West Siberia, at the base of the Callovian dinocyst *Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis* Zone (Ilyina *et al.* 2005). The datum corresponds to the base of the ammonite *Peltoceras athleta* Zone on the Russian Platform (Riding *et al.* 1999).

The LO of *Liesbergia liesbergensis* is taken as the base of the ammonite *Peltoceras athleta* Zone (i.e., close to the middle/late Callovian transition).

FOs of *Evansia deflandrei* and the other taxa listed below

The FO of *Gonyaulacysta longicornis* occurs at the base of the late Callovian dinocyst *Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis* Zone defined in the Tyumenskaya SDW-6 borehole of West Siberia by Ilyina *et al.* (2005) and calibrated by ammonites indicative of the ammonite *Peltoceras athleta* Zone. The base of the dinocyst *Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis* Zone of Ilyina *et al.* (2005) is equivalent to the base of the late Callovian dinocyst *Pareodinia prolongata* Zone of Riding *et al.* (1999) of the Russian Platform. Similarly, this bioevent is coeval with the base of the dinocyst *Liesbergia scarburghensis–Wanaea thysanota* Zone of Smelror and Below (1992) in the Barents Sea. The FO of *Evansia deflandrei* occurs at top of the dinocyst *Meiourogonyaulax planoseptata–Chlamydophorella ectotabulata* Zone (= base of the dinocyst *Liesbergia scarburghensis – Wanaea thysanota* Zone) of Smelror and Below (1992), which was assigned by the latter authors to the later early and middle Callovian in the Norwegian Barents Sea region.

The FOs of *Evansia deflandrei, Gonyaulacysta longicornis* and *Wanaea thysanota* are taken as the base of the ammonite *Peltoceras athleta* Zone (i.e., close to the middle/late Callovian transition).

LO of *Pareodinia prolongata*

The LO of *Pareodinia prolongata* occurs at the top of the Callovian dinocyst *Pareodinia prolongata* Zone defined in the Russian Platform by Riding *et al.* (1999), equivalent to the top of the ammonite *Peltoceras athleta* Zone and the base of the ammonite *Quenstedtoceras lamberti* Zone.

The LO of *Pareodinia prolongata* is taken as the base of the ammonite *Quenstedtoceras lamberti* Zone (i.e., late Callovian).

FO of *Trichodinium scarburghense*

The FO of *Trichodinium scarburghense* occurs at the base of latest Callovian dinocyst *Trichodinium scarburghense* Zone of Riding *et al.* (1999) on the Russian Platform, equating with the base of the ammonite *Quenstedtoceras lamberti* Zone.

The FO of *Trichodinium scarburghense* is taken as the base of the ammonite *Quenstedtoceras lamberti* Zone (i.e., late Callovian).

LOs of *Ambonosphaera calloviana* and other taxa listed below

The LOs of *Ambonosphaera calloviana*, *Ctenidodinium continuum*, *Meiourogonyaulax planoseptata* and *Valensiella dictydia* occur at the base of the early Oxfordian. This is based on their occurrences at the base of the dinocyst *Crussolia deflandrei–Wanaea fimbriata* Zone of Smelror and Below (1992) in the Barents Sea, and the base of the dinocyst *Wanaea fimbriata* Zone on the Russian Platform (Riding *et al.* 1999).

The LOs of *Ambonosphaera calloviana*, *Ctenidodinium continuum*, *Meiourogonyaulax planoseptata* and *Valensiella dictydia* are taken as the base of the ammonite *Quenstedtoceras mariae* Zone (i.e., the base of the Oxfordian).

FOs of *Gonyaulacysta desmos* and *Wanaea fimbriata*

Gonyaulacysta desmos is a characteristically Arctic form which is confined to the early Oxfordian (Poulsen 1991; Riding *et al.* 2022). The FO of *Wanaea fimbriata* occurs in the Tyumenskaya superdeep well-6, West Siberia, is close to the base of the early Oxfordian dinocyst *Wanaea fimbriata* Zone in West Siberia (Ilyina *et al.* 2005). This event is also observed in the Barents Sea and the Russian Platform (Smelror and Below 1992; Riding *et al.* 1999).

The FOs of *Gonyaulacysta desmos* and *Wanaea fimbriata*

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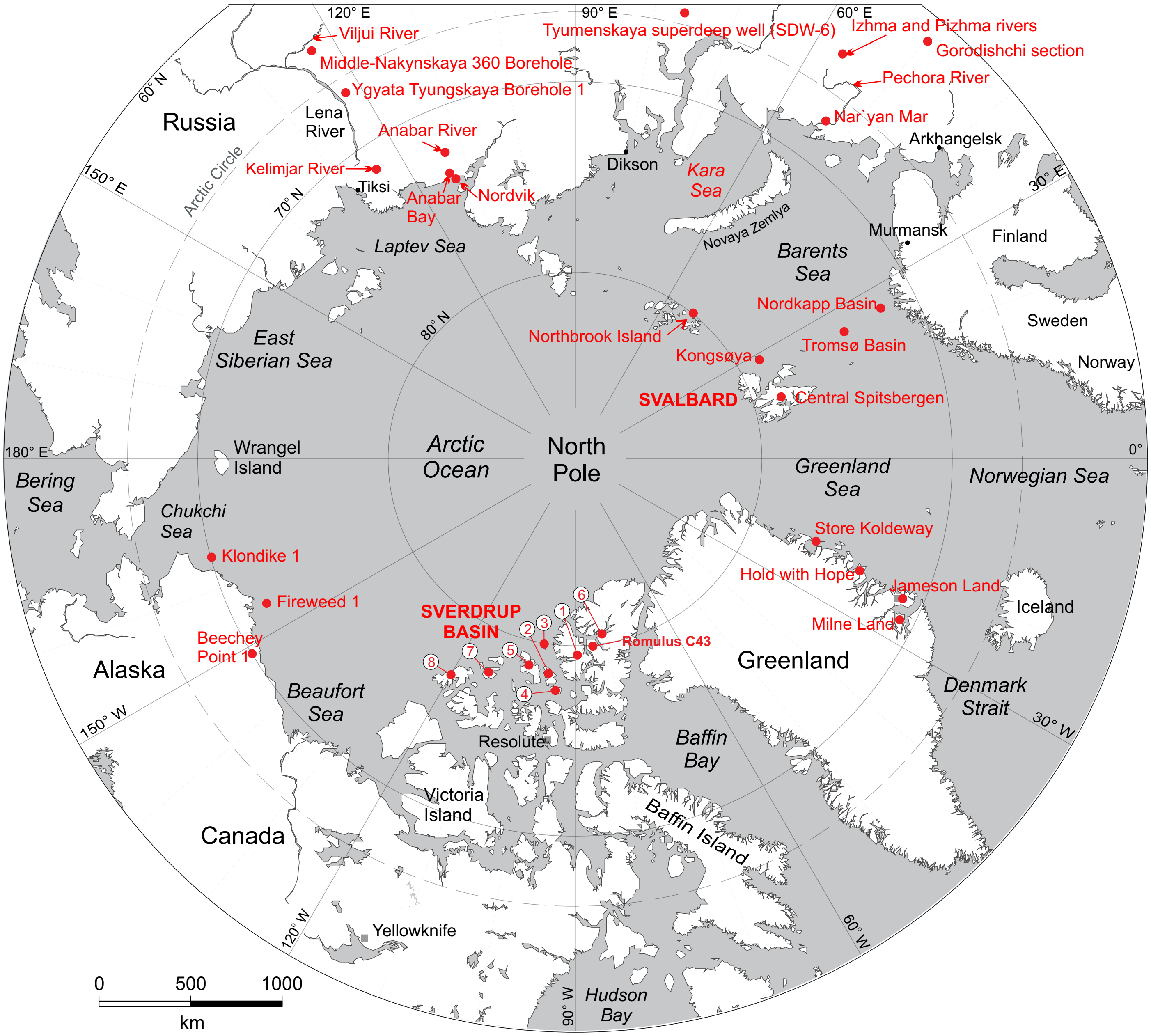

Figure 10. Circumpolar projection map showing the main Jurassic localities discussed in the text. Key to islands in the Sverdrup Basin is as follows: 1= Axel Heiberg; 2 = Amund Ringnes; 3 = Bjarnason; 4 = Cornwall; 5 = Ellef Ringnes; 6 = Ellesmere; 7 = Mackenzie King; 8 = Prince Patrick.

are taken as the base of the ammonite *Quenstedtoceras mariae* Zone (i.e., the base of the Oxfordian).

LOs of *Limbodinium absidatum* and other taxa listed below

The LO of the typically Arctic species *Tubotuberella dentata* occurs within the ammonite *Quenstedtoceras mariae* Zone (Riding 2012a). The LOs of *Limbodinium absidatum* and *Wanaea thysanota* occur in the lower part of the Oxfordian dinocyst *Wanaea fimbriata* Zone defined in the Russian Platform by Riding *et al.* (1999), an interval also within the ammonite *Quenstedtoceras mariae* Zone.

The LOs of *Limbodinium absidatum*, *Tubotuberella dentata* and *Wanaea thysanota* are taken as 50% up from the base of the ammonite *Quenstedtoceras mariae* Zone (i.e., earliest Oxfordian).

FO of *Leptodinium mirabile*

The FO of *Leptodinium mirabile* occurs in the lower part of the Oxfordian dinocyst *Wanaea fimbriata* Zone defined in the Russian Platform by Riding *et al.* (1999), within the ammonite *Quenstedtoceras mariae* Zone.

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The FO of *Leptodinium mirabile* is taken as 50% above the base of the ammonite *Quenstedtoceras mariae* Zone (i.e., earliest Oxfordian).

FO of *Gonyaulacysta jurassica*

The FO of *Gonyaulacysta jurassica* occurs within the upper part of the dinocyst *Wanaea fimbriata* Zone established for the Russian Platform (Riding *et al.* 1999). This event is therefore within the ammonite *Cardioceras cordatum* Zone.

The FO of *Gonyaulacysta jurassica* is taken as 50% above the base of the ammonite *Cardioceras cordatum* Zone (i.e., early Oxfordian).

LOs of *Gonyaulacysta desmos* and *Wanaea fimbriata*

The extinction of *Gonyaulacysta desmos* occurs at the top of the early Oxfordian and has been reported from East Greenland (Poulsen 1991). The LO of *Wanaea fimbriata* occurs at the top of the early Oxfordian dinocyst *Wanaea fimbriata* Zone defined from the Russian Platform by Riding *et al.* (1999), equivalent to the top of the ammonite *Cardioceras cordatum* Zone. This event also occurs at the top of the dinocyst *Wanaea fimbriata* Zone of West Siberia (Ilyina *et al.* 2005), and at the top of the dinocyst *Crussolia deflandrei–Wanaea fimbriata* Zone in the Barents Sea (Smelror and Below 1992). The latter dinocyst zones are of early Oxfordian age.

The LOs of *Gonyaulacysta desmos* and *Wanaea fimbriata* are taken as the base of the ammonite *Perisphinctes plicatilis* Zone (i.e., the base of the middle Oxfordian).

LO of *Trichodinium scarburghense*

The LO of *Trichodinium scarburghense* occurs at the top of the middle Oxfordian dinocyst *Endoscrinium galeritum* subsp. *reticulatum* Zone defined in the Russian Platform by Riding *et al.* (1999). This zone is equivalent to the ammonite *Perisphinctes plicatilis* and *Cardioceras densiplicatum* zones.

The LO of *Trichodinium scarburghense* is taken as the base of the ammonite *Cardioceras tenuiserratum* Zone (i.e., middle Oxfordian).

FOs of *Gonyaulacysta dualis* and *Sentusidinium ringnesiorum*

Sentusidinium ringnesiorum was recorded by Davies (1983) as *Chytroeisphaeridia*? *mantellii* (subsequently *Escharisphaeridia mantellii*), *Escharisphaeridia pocockii* and *Escharisphaeridia rudis*, all of which were considered to be taxonomic junior synonyms of *Sentusidinium ringnesiorum* by Wood *et al.* (2016). The FOs of *Sentusidinium ringnesiorum* and *Gonyaulacysta dualis* occur within dinocyst zone H of Davies (1983) established in the Sverdrup Basin. Both events are interpreted here as representing the top of the ammonite *Perisphinctes plicatilis* Zone.

The FOs of *Gonyaulacysta dualis* and *Sentusidinium ringnesiorum* are taken as the base of the ammonite *Perisphinctites pumilis* Zone (i.e., middle Oxfordian).

LOs of *Gonyaulacysta longicornis* and *Rigaudella aemula*

The LOs of *Gonyaulacysta longicornis* and *Rigaudella aemula* occur at the top of the Oxfordian dinocyst *Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis* Zone defined in the Russian Platform by Riding *et al.* (1999). These events are broadly coeval with the boundary between the ammonite *Perisphinctites pumilis* and *Perisphinctes cautisnigrae* zones.

The LOs of *Gonyaulacysta longicornis* and *Rigaudella aemula* are taken as the base of the ammonite *Perisphinctites cautisnigrae* Zone (i.e., at the base of the late Oxfordian).

FO of *Cribroperidinium globatum*

The FO of *Cribroperidinium globatum* occurs at the top of the Oxfordian dinocyst *Gonyaulacysta jurassica* subsp. *adecta* var. *longicornis* Zone defined in the Russian Platform by Riding *et al.* (1999). This datum is approximately equivalent to the top of the ammonite ammonite *Perisphinctites pumilis* Zone.

The FO of *Cribroperidinium globatum* is taken as the base of the ammonite *Perisphinctites cautisnigrae* Zone (i.e., at the base of the late Oxfordian transition).

FO of *Leptodinium subtile*

The FO of *Leptodinium subtile* occurs in the late Oxfordian ammonite *Amoeboceras serratum* Zone in Jameson Land, East Greenland (Alsen and Pasecki 2018).

The FO of *Leptodinium subtile* is taken as 50% up from the base of the ammonite *Perisphinctites cautisnigrae* Zone (i.e., late Oxfordian).

LOs of *Apteodinium bucculiatum* and other taxa listed below

The LOs of *Evansia deflandrei* and *Scriniodinium crystallinum* occur close to the top of the late Oxfordian dinocyst *Cribroperidinium globatum* Zone defined in the Russian Platform by Riding *et al.* (1999), equivalent to the top of the ammonite *Amoeboceras rosenkrantzi* Zone. LOs of the other species mentioned below occur at base of the early Kimmeridgian dinocyst Oppel-Zone I of Davies (1983) for the Sverdrup Basin. These datums are interpreted herein as representing the Oxfordian/Kimmeridgian transition.

The LOs of *Apteodinium bucculiatum*, *Arkellea teichophera*, *Sentusidinium verrucosum, Egmontodinium*? *diminutum*, *Evansia deflandrei*, *Evansia evittii*, *Evansia*? *opeasatos*, *Evansia zabra, Komewuia glabra*, *Meiourogonyaulax deflandrei*, *Scriniodinium crystallinum* and *Stephanelytron membranoideum* are taken as the base of the ammonite *Pictonia baylei* Zone (i.e., at the base of the Kimmeridgian).

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FOs of *Apteodinium granulatum* and other taxa listed below

The FOs of *Apteodinium granulatum*, *Cribroperidinium*? *ehrenbergii*, *Cribroperidinium*? *perforans* subsp. *perforans, Leptodinium*? *hyalodermopse*, *Lunatadinium dissolutum*, *Pareodinia groenlandica*, *Pyxidinopsis laminata*, *Sentusidinium capillatum* (including *Pilosidinium filiatum*, a taxonomic junior synonym according to Wood *et al.* 2016), *Tubotuberella egemenii*, *Wallodinium krutzschii* and *Wrevittia helicoidea* occur at the base of dinocyst Oppel-Zone I of Davies (1983). This horizon is considered here to be coeval with the boundary between the Oxfordian and Kimmeridgian. The FOs of *Glossodinium dimorphum*, *Perisseiasphaeridium pannosum* and *Scriniodinium anceps* occur at the top of the late Oxfordian dinocyst *Cribroperidinium globatum* Zone defined in the Russian Platform by Riding *et al.* (1999), again equivalent to the Oxfordian/Kimmeridgian transition.

The FOs of *Apteodinium granulatum*, *Cribroperidinium*? *ehrenbergii*, *Cribroperidinium*? *perforans* subsp. *perforans*, *Glossodinium dimorphum, Leptodinium*? *hyalodermopse*, *Lunatadinium dissolutum*, *Pareodinia groenlandica*, *Perisseiasphaeridium pannosum*, *Pyxidinopsis laminata*, *Scriniodinium anceps*, *Sentusidinium capillatum*, *Tubotuberella egemenii*, *Wallodinium krutzschii* and *Wrevittia helicoidea* are taken as the base of the ammonite *Pictonia baylei* Zone (i.e., at the base of the Kimmeridgian).

LO of *Nannoceratopsis pellucida*

The LO of *Nannoceratopsis pellucida* was reported by Ilyina *et al.* (2005) in the earliest Kimmeridgian of West Siberia, specifically within the Boreal ammonite *Amoeboceras kitchini* Zone. By contrast, this event occurs in the strata assigned to the upper Oxfordian ammonite *Amoeboceras regulare* Zone in the Barents Sea (MS personal observations).

The LO of *Nannoceratopsis pellucida* is taken as at 50% up from the base of the ammonite *Pictonia baylei* Zone (i.e., earliest Kimmeridgian).

FO of *Apteodinium maculatum*

The FO of *Apteodinium maculatum* occurs within dinocyst Oppel-Zone I of Davies (1983) in the Sverdrup Basin. This zone was dated using evidence from ammonites and bivalves; Davies (1983) interpreted Oppel-Zone I as including the transition of the ammonite *Pictonia baylei* and *Rasenia cymodoce* zones.

The FO of *Apteodinium maculatum* is taken as the base of the ammonite *Rasenia cymodoce* Zone (i.e., early Kimmeridgian).

LOs of *Cribroperidinium*? *perforans* subsp. *kunzeviense* and other taxa listed below

The LOs of *Cribroperidinium*? *perforans* subsp. *kunzeviense*, *Endoscrinium subvallare*, *Lanterna*? *cantrellii* and *Lithodinia jurassica* occur at base of dinocyst Oppel-Zone J of Davies (1983) in the Sverdrup Basin. This intra-Kimmeridgian age is consistent with the presence of the bivalve species *Buchia mosquensis* in the central Amund Ringnes Dome. Furthermore, due to the occurrence of *Buchia jischeriana* in the lowermost part of Oppel-Zone K, (Davies 1983) interpreted his J/K zonal boundary as "middle" Kimmeridgian (top of the ammonite *Rasenia cymodoce* Zone).

The LOs of *Cribroperidinium*? *perforans* subsp. *kunzeviense*, *Endoscrinium subvallare*, *Lanterna*? *cantrellii* and *Lithodinia jurassica* are taken as the base of the ammonite *Aulacostephanus mutabilis* Zone (i.e., the base of the late Kimmeridgian).

FOs of *Cribroperidinium jubaris* and other taxa listed below

The FOs of *Cribroperidinium jubaris*, *Epiplosphaera saturnalis* and *Paragonyaulacysta capillosa* occur at the base of dinocyst Oppel-Zone J of Davies (1983) in the Sverdrup Basin. The Kimmeridgian age of this biozone is based on evidence from the bivalve genus *Buchia*. The FOs of *Dingodinium jurassicum, Gochteodinia mutabilis*, *Protobatioladinium westburiense* and *Stephanelytron membranoideum* occur in the Tyumenskaya superdeep well-6, West Siberia, at the base of the Kimmeridgian dinocyst *Rhynchodiniopsis cladophora* Zone defined by Ilyina *et al.* (2005). Lastly, the FOs of *Egmontodinium polyplacophorum* and *Scriniodinium inritibile* occur in the dinocyst *Pareodinia nuda* (= *Pareodinia ceratophora*) Subzone of Fisher and Riley (1980), equivalent to the boundary between the ammonite *Rasenia cymodoce* and *Aulacostephanus mutabilis* zones.

The FOs of *Cribroperidinium jubaris*, *Dingodinium jurassicum*, *Egmontodinium polyplacophorum*, *Epiplosphaera saturnalis, Gochteodinia mutabilis*, *Paragonyaulacysta capillosa*, *Protobatioladinium westburiense, Scriniodinium inritibile* and *Stephanelytron membranoideum* are taken as the base of the ammonite *Aulacostephanus mutabilis* Zone (i.e., the base of the late Kimmeridgian).

FOs of *Cassiculosphaeridia magna* and other taxa listed below

The FOs of *Cassiculosphaeridia magna*, *Cribroperidinium*? *perforans* and *Oligosphaeridium pulcherrimum* occur at the base of the Boreal dinocyst *Pareodinia nuda* Subzone of Fisher and Riley (1980).

The FOs of *Cassiculosphaeridia magna*, *Cribroperidinium*? *perforans* and *Oligosphaeridium pulcherrimum* are taken as the base of the ammonite *Aulacostephanus eudoxus* Zone (i.e., late Kimmeridgian).

FO of *Corculodinium inaffectum*

The FO of *Corculodinium inaffectum* occurs at the top of the Kimmeridgian dinocyst *Gonyaulacysta jurassica* subsp. *jurassica* Zone defined in the Russian Platform by Riding *et*

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al. (1999). This is equivalent to the boundary between the ammonite *Aulacostephanus eudoxus* and *Aulacostephanus autissiodorensis* zones.

The FO of *Corculodinium inaffectum* is taken as the base of the ammonite *Aulacostephanus autissiodorensis* Zone (i.e., latest Kimmeridgian).

FOs of *Lanterna bulgarica* and other taxa listed below

The FOs of *Lanterna bulgarica*, *Leptodinium volgense* and *Pareodinia asperata* occur at the base of the Boreal dinocyst *Gonyaulacysta jurassica* Subzone of Fisher and Riley (1980). The datum approximately correlates with the boundary between the ammonite *Aulacostephanus autissiodorensis* and *Pectinatites elegans* zones.

The LOs of *Lanterna bulgarica*, *Leptodinium volgense* and *Pareodinia asperata* are taken as the base of the ammonite *Pectinatites elegans* Zone (i.e., the base of the Tithonian).

LOs of *Pyxidinopsis laminata* and *Sentusidinium ringnesiorum*

The LOs of *Pyxidinopsis laminata* and *Sentusidinium ringnesiorum* occur at the base of dinocyst zone K of Davies (1983) which was assigned to the earliest Tithonian in the Sverdrup Basin. (*Sentusidinium ringnesiorum* was recorded by Davies as *Chytroeisphaeridia*? *mantellii*, *Escharisphaeridia pocockii* and *Escharisphaeridia rudis*, all of which were considered taxonomic junior synonyms of *Sentusidinium ringnesiorum* by Wood *et al.* 2016.) These events are interpreted herein as being at the transition of the ammonite *Pectinatites elegans* and *Pectinatites scitulus* zones.

The LOs of *Pyxidinopsis laminata* and *Sentusidinium ringnesiorum* are taken as the base of the ammonite *Pectinatites scitulus* Zone (i.e., earliest Tithonian).

FOs of *Dingodinium cerviculum* and the other taxa listed below

The FOs of *Dingodinium cerviculum*, *Exochosphaeridium scitulum*, *Leptodinium deflandrei, Rhynchodiniopsis pennata*, *Stiphrosphaeridium anthophorum*, *Tanyosphaeridium isocalamum* and *Tubotuberella apatela* occur at the base of the dinocyst *Gonyaulacysta pennata* Subzone of Fisher and Riley (1980). These datums correlate roughly with the top of the ammonite *Pectinatites elegans* Zone and the base of the ammonite *Pectinatites scitulus* Zone in the Boreal Realm.

The FOs of *Dingodinium cerviculum*, *Exochosphaeridium scitulum*, *Leptodinium deflandrei*, *Rhynchodiniopsis pennata*, *Stiphrosphaeridium anthophorum*, *Tanyosphaeridium isocalamum* and *Tubotuberella apatela* are taken as the base of the ammonite *Pectinatites scitulus* Zone (i.e., earliest Tithonian).

LOs of *Gonyaulacysta dualis* and other taxa listed below

The LOs of *Gonyaulacysta dualis* and *Pareodinia asperata* occur at the base of the dinocyst *Muderongia simplex* zone defined by Fisher and Riley (1980). These events correlate approximately with the transition between the ammonite *Pectinatites pectinatus* and *Pavlovia pallasioides* zones. Furthermore, the LOs of *Rhynchodiniopsis cladophora*, *Scriniodinium dictyotum* subsp. *dictyotum*, *Senoniasphaera jurassica, Tubotuberella dangeardii* and *Tubotuberella egemenii* are coeval with the range tops of *Gonyaulacysta dualis* and *Pareodinia asperata* based on their occurrences in northern Alaska and the Sverdrup Basin, including the Beechey Point State 1 reference well (Appendix C).

The LOs of *Gonyaulacysta dualis*, *Pareodinia asperata*, *Rhynchodiniopsis cladophora*, *Scriniodinium dictyotum* subsp. *dictyotum, Senoniasphaera jurassica, Tubotuberella dangeardii* and *Tubotuberella egemenii* are taken as the base of the ammonite *Pavlovia pallasioides* Zone (i.e., early Tithonian).

FO of *Muderongia simplex*

The FO of *Muderongia simplex* occurs in the Boreal Realm at the base of the dinocyst *Muderongia simplex* Zone of Fisher and Riley (1980). This horizon approximately correlates with the base of the ammonite *Pavlovia pallasioides* Zone.

The FO of *Muderongia simplex* is taken as the base of the ammonite *Pavlovia pallasioides* Zone (i.e., early Tithonian).

LOs of *Cribroperidinium granulatum* and other taxa listed below

The LOs of *Cribroperidinium granulatum*, *Cribroperidinium nuciforme*, *Egmontodinium polyplacophorum*, *Imbatodinim kondratjevii*, *Leptodinium deflandrei*, *Leptodinium volgense*, *Scriniodinium anceps*, *Scriniodinium inritibile* and *Systematophora*? *ovata* occur at the base of the palynomorph *Pterospermopsis aureolata* Subzone defined in Canada, Greenland and northwestern Europe by Fisher and Riley (1980).

The LOs of *Cribroperidinium granulatum, Cribroperidinium nuciforme*, *Egmontodinium polyplacophorum*, *Imbatodinim kondratjevii*, *Leptodinium deflandrei*, *Leptodinium volgense*, *Scriniodinium anceps, Scriniodinium inritibile* and *Systematophora*? *ovata* are taken as the base of the ammonite *Progalbanites albani* Zone (i.e., the base of the late Tithonian).

LOs of *Atopodinium prostatum* and other taxa listed below

The LOs of *Atopodinium prostatum*, *Cribroperidinium jubaris*, *Glossodinium dimorphum* and *Pareodinia groenlandica* occur at the base of dinocyst Oppel-Zone L of Davies (1983) in the late Tithonian in the Sverdrup Basin. This

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horizon is interpreted here as equating with the top of the ammonite *Progalbanites albani* Zone. The LO of *Glossodinium dimorphum* also occurs at the top of the dinocyst *Glossodinium dimorphum* Zone defined in the Russian Platform by Riding *et al.* (1999). This event is coeval with the transition between the ammonite *Progalbanites albani* and *Glaucolithites glaucolithus* zones.

The LOs of *Atopodinium prostatum*, *Cribroperidinium jubaris*, *Glossodinium dimorphum* and *Pareodinia groenlandica* are taken as the base of the ammonite *Glaucolithites glaucolithus* Zone (i.e., late Tithonian).

FO of *Prolixosphaeridiopsis spissa*

The FO of the acritarch species *Prolixosphaeridiopsis spissa* occurs at base of dinocyst Oppel-Zone L of Davies (1983), within the late Tithonian in the Sverdrup Basin, interpreted here as equating with the base of the ammonite *Glaucolithites glaucolithus* Zone.

The FO of *Prolixosphaeridiopsis spissa* is taken as the base of the ammonite *Glaucolithites glaucolithus* Zone (i.e., late Tithonian).

LO of *Oligosphaeridium patulum*

The LO of *Oligosphaeridium patulum* occurs in the late Tithonian, close to the base of the Boreal ammonite *Craspidites okensis* Zone in Andøya, Arctic Norway (MS, personal observations). Ilyina *et al.* (2005) also recorded this event at the base of the ammonite *Craspedites okensis* Zone in West Siberia, approximately coeval with the base of the ammonite *Titanites anguiformis* Zone (Fig. 9).

The LO of *Oligosphaeridium patulum* is taken as the base of the ammonite *Titanites anguiformis* Zone (i.e., late Tithonian).

FOs of *Leptodinium mamilliferum* and other taxa listed below

The FOs of *Leptodinium mamilliferum*, *Moesiodinium raileanui* and *Trichodinium erinaceoides* occur at the base of dinocyst Oppel-Zone M of Davies (1983) in the late Tithonian of the Sverdrup Basin. This horizon is interpreted here as equating with the base of the ammonite *Titanites anguiformis* Zone. The stratigraphic range of *Moesiodinium raileanui* is early Toarcian to earliest Bajocian, i.e., substantially older in northwestern Europe (e.g., Riding and Thomas 1992) than in northern Canada. The occurrences of *Moesiodinium raileanui* reported by Davies (1983) may be either misidentified or reworked. The characteristic hexagonal archaeopyle with geniculate top and base is not visible in the single specimen illustrated by Davies (1983, pl. 6, fig. 23).

The FOs of *Leptodinium mamilliferum*, *Moesiodinium raileanui* and *Trichodinium erinaceoides* are taken as the base of the ammonite *Titanites anguiformis* Zone (i.e., late Tithonian).

LO of *Prolixosphaeridium parvispinum*

The LO of *Prolixosphaeridium parvispinum* occurs in the upper part of the dinocyst *Senoniasphaera jurassica* Zone defined in the Russian Platform by Riding *et al.* (1999). This event is coeval with the transition between the ammonite *Titanites anguiformis* and *Paracraspedites oppressus* zones.

The LO of *Prolixosphaeridium parvispinum* is taken as the base of the ammonite *Paracraspedites oppressus* Zone (i.e., late Tithonian).

LOs of *Cribroperidinium*? *longicorne* and other taxa listed below

The LOs of *Cribroperidinium*? *longicorne*, *Lanterna bulgarica* and *Rhynchodiniopsis pennata* occur at the base of the dinocyst *Dichadogonyaulax culmula* Subzone of Fisher and Riley (1980), which approximately correlates to the top of the ammonite *Paracraspedites oppressus* Zone.

The LOs of *Cribroperidinium*? *longicorne*, *Lanterna bulgarica* and *Rhynchodiniopsis pennata* are taken as the base of the ammonite *Subcraspedites primitivus* Zone (i.e., late Tithonian).

FOs of *Ctenidodinium*? *schizoblatum* and other taxa listed below

The FOs of *Ctenidodinium*? *schizoblatum* and *Dichadogonyaulax culmula* occur in the late Tithonian, at the base of the dinocyst *Dichadogonyaulax culmula* Subzone of Fisher and Riley (1980), which is broadly coeval with the top of the ammonite *Paracraspedites oppressus* Zone. Furthermore, the FO of *Gochteodinia villosa* occurs at the top of the late Tithonian dinocyst *Senoniasphaera jurassica* Zone defined in the Russian Platform by Riding *et al.* (1999). This event also equates to the boundary between the ammonite *Paracraspedites oppressus* and *Subcraspedites primitivus* zones.

The FOs of *Ctenidodinium*? *schizoblatum*, *Dichadogonyaulax culmula* and *Gochteodinia villosa* are taken as the base of the ammonite *Subcraspedites primitivus* Zone (i.e., late Tithonian).

DISCUSSION AND CONCLUSIONS

In this contribution we summarize the Jurassic palynostratigraphy of the circum-Arctic region (i.e., northern North America and Greenland in the west, and arctic Norway, the Barents Sea and northern Russia in the east) with the principal emphasis on dinocyst bioevents. The literature on the marine palynology of the Arctic is mainly centred on the eastern Arctic (Svalbard and northern Russia), with substantially fewer papers on the western Arctic (Canadian Arctic and Greenland). There is relatively little relevant information in the public domain on Alaska. In terms of stratigraphic coverage, most data are from the Upper Jurassic with markedly fewer contributons on Middle Jurassic

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successions. The palynology of the Arctic Lower Jurassic has not been extensively researched, and this overall pattern closely follows the global trend in terms of the research effort on Jurassic dinocysts (Riding 2012b).

We document herein a succession of 214 bioevents (FOs and LOs), calibrated to ammonite zones, from the Hettangian to the Tithonian. These biohorizons have been selected to provide a practical succession of datums based on common and easy to recognize taxa that give a high resolution biostratigraphic coverage of the entire Jurassic System in the Arctic. This reflects the typically highly diverse floras during the Jurassic at high northern latitudes, which appear to have been an evolutionary "hotspot" (Mantle *et al.* 2020; van de Schootbrugge *et al.* 2020; Correia *et al.* 2021). The main Arctic Jurassic palynozonations such as those by Johnson and Hills (1973), Fisher and Riley (1980), Davies (1983), Smelror and Below (1992), Riding *et al.* (1999) and Ilyina *et al.* (2005) are referenced extensively.

The parent cells of dinocysts are largely motile and planktonic, and therefore they typically have extensive geographical distributions (Riding and Lucas-Clark 2016). Substantial numbers of cosmopolitan Jurassic taxa occur generally, and many were present in the Boreal, sub-Boreal and Tethyan realms in the northern hemisphere (Riding *et al.* 2010; Mantle and Riding 2012). However, some provincialism did occur and the intensity of this endemism fluctuated during the Jurassic. The diversity of Early Jurassic dinocysts is relatively low compared to the post-Bajocian interval (e.g., Riding and Thomas 1992). Bucefalo Palliani and Riding (2003) demonstrated that Boreal Pliensbachian and Toarcian dinocysts were markedly more species-rich than their Tethyan counterparts. The Bathonian during the Middle Jurassic was a time of relatively high levels of eustatic-driven endemism, prior to substantially more cosmopolitan and diverse floras in the Callovian and onwards (Riding *et al.* 1985, 1991). The latest Jurassic was characterized by very high levels of provincialism largely due to land barriers and low sea levels (e.g., Abbink *et al.* 2001). The provincialism of Lower, Middle and Late Jurassic floras was discussed by, for example, Riding (1984), Smelror (1993), Riding and Ioannides (1996), Riding and Hubbard (1999), Riding *et al.* (1999) and Harding *et al.* (2011). These studies confirm that genera such as *Evansia* and *Paragonyaulacysta* and species such as *Gonyaulacysta dualis* are typically Arctic (Riding *et al.* 1999; Riding and Lucas-Clark 2016; Riding *et al.* 2022). More specifically, Riding and Michoux (2013) discussed the migration southward of Boreal forms such as *Evansia deflandrei, Mendicodinium groenlandicum, Rigaudella aemula, Trichodinium scarburghensis, Tubotuberella dentata* and *Wanaea fimbriata* at the Callovian–Oxfordian transition. These taxa are envisaged as being cold water forms, however it should be borne in mind that seasonality and thermal latitudinal gradients during the Mesozoic greenhouse were generally considerably less than those in today's Quaternary Icehouse (Valdes and Sellwood 1992; Alberti *et al.* 2017).

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REFERENCES

Abbink, O.A., Callomon, J.H., Riding, J.B., Williams, P.D.B., and Wolfard, A. 2001. Biostratigraphy of Jurassic–Cretaceous boundary strata in the Terschelling Basin, The Netherlands. Proceedings of the Yorkshire Geological Society, 53, pp. 275–302. https://doi.org/10.1144/pygs.53.4.275

Albert, N.R. 1988. Dinoflagellate cysts from the Early Cretaceous of the Yukon–Koyukuk Basin and from the Upper Jurassic Naknek Formation, Alaska. University Microfilms International (U.M.I.) Dissertation Information Service, Ann Arbor, Michigan, USA, 481 pp.

Albert, N.R., Evitt, W.R., and Stein, J.A. 1986. *Lacrymodinium,* n. gen., a gonyaulacoid dinoflagellate with intercalary archeopyle from the Jurassic and Early Cretaceous of California and Alaska. Micropaleontology, 32, pp. 303–315. https://doi.org/10.2307/1485724

Alberti, M., Fürsich, F.T., Abdelhady, A.A., and Andersen, N. 2017. Middle to Late Jurassic equatorial seawater temperatures and latitudinal temperature gradients based on stable isotopes of brachiopods and oysters from Gebel Maghara, Egypt. Palaeogeography, Palaeoclimatology, Palaeoecology, 468, pp. 301–313. https://doi.org/10.1016/j.palaeo.2016.11.052

Alsen, P. and Piasecki, S. 2018. Biostratigraphy of the Hareelv Formation (Upper Jurassic) in the Blokelv-1 core, Jameson Land, East Greenland. Geological Survey of Denmark and Greenland Bulletin, 42, pp. 15–37. https://doi.org/10.34194/geusb.v42.4308

Beisel, A.L., Zanin, Y.N., Zamirailova, A.G., Ilyina, V.I., Lebedeva, N.K., Levchuk, L.K., Levchuk, M.A., Meledina, S.V., Nikitenko, B.L., Shurygin, B.N., and Yan, P.A. 2002. Reference section for the Upper Jurassic and Callovian in northern West Siberia. Russian Geology and Geophysics, 43, pp. 811–825.

Below, R. 1987a. Evolution und Systematik von Dinoflagellaten-Zysten aus der Ordnung Peridiniales. I. Allgemeine

 Copyright © Atlantic Geoscience, 2022

Grundlagen und Subfamilie Rhaetogonyaulacoideae (Familie Peridiniaceae). Palaeontographica Abteilung B, 205, pp. 1–164.

Below, R. 1987b. Evolution und Systematik von Dinoflagellaten-Zysten aus der Ordnung Peridiniales. II. Cladopyxiaceae und Valvaeodiniaceae. Palaeontographica Abteilung B, 206, pp. 1–115.

Below, R. 1990: Evolution und Systematik von Dinoflagellaten-Zysten aus der Ordnung Peridiniales. III. Familie Pareodiniaceae. Palaeontographica Abteilung B, 220, pp. 1–96.

Bjærke, T. 1977. Mesozoic palynology of Svalbard II. Palynomorphs from the Mesozoic sequence of Kong Karls Land. Norsk Polarinstituttt, Årbok 1976, pp. 83–120.

Bjærke, T. 1980a. Mesozoic palynology of Svalbard IV. Toarcian dinoflagellates from Spitsbergen. Palynology, 4, pp. 57–77. https://doi.org/10.1080/01916122.1980.9989202

Bjærke, T. 1980b. Mesozoic palynology of Svalbard V. Dinoflagellates from the Agardhfjellet Member (Middle and Upper Jurassic) in Spitsbergen. Norsk Polarinstitutt, Skrifter, 172, pp.145–167.

Bjærke, T. 1993. Palynological examination of samples from Alaska. Alaska Geologic Materials Center Data Report, 210, pp. 1–18.

Bjærke, T. and Dypvik, H. 1977. Sedimentological and palynological studies of Upper Triassic–Lower Jurassic sediments in Sassenfjorden, Spitsbergen. Norsk Polarinstitutt Årbok, 1976, pp. 131–150.

Bjærke, T. and Manum, S.B. 1977. Mesozoic palynology of Svalbard I. The Rhaetian of Hopen, with a preliminary report on the Rhaetian and Jurassic of Kong Karls Land. Norsk Polarinstitutt, Skrifter, Nr. 165, 48 pp.

Bjærke, T., Edwards, M.B., and Thusu, B. 1976. Microplankton from the Janusfjellet Subgroup (Jurassic–Lower Cretaceous) at Agardhfjellet Spitsbergen. A preliminary report. Norsk Polarinstitutt Årbok, 1974, pp. 63–68.

Blakey, R. 2021. Paleotectonic and paleogeographic history of the Arctic region. Atlantic Geology, 57, pp. 7–39. https://doi.org/10.4138/atlgeol.2021.002

Brideaux, W.W. 1975. Status of Mesozoic and Tertiary dinoflagellate studies in the Canadian Arctic. American Association of Stratigraphic Palynologists Contributions Series, 4, pp. 15–28.

Brideaux, W.W. 1976. Taxonomic notes and illustrations of selected dinoflagellate cyst species from the Gulf Mobil Parsons N–10 well. Geological Survey of Canada Paper 76–1B, pp. 251–257. https://doi.org/10.4095/104107

Brideaux, W.W. and Myhr, D.W. 1976. Lithostratigraphy and dinoflagellate cyst succession in the Gulf Mobil Parsons N–10 well, District of Mackenzie. Geological Survey of Canada Paper, 76–1B, pp. 235–249. https://doi.org/10.4095/104106

Bringué, M., Fensome, R.A., Poulton, T.P., Galloway, J.M., Bujak, J.P., Golding, M.L., Orchard, M.J., and Williams, G.L. in press. The 2020 Canada datapack for TimeScale Creator: a new tool for Mesozoic–Cenozoic stratigraphy of the Canadian North. Geological Survey of Canada, Bulletin 609. https://doi.org/10.1130/abs/2020AM-353274

Bucefalo Palliani, R. and Riding, J.B. 2003. Biostratigraphy, provincialism and evolution of European early Jurassic (Pliensbachian to early Toarcian) dinoflagellate cysts. Palynology, 27, pp.179–214. https://doi.org/10.2113/27.1.179

Callomon, J.H. and Birkelund, T. 1980. The Jurassic transgression and the mid–late Jurassic succession in Milne Land, central East Greenland. Geological Magazine, 117, pp. 211–226. https://doi.org/10.1017/S0016756800030442

Cookson, I.C. and Eisenack, A. 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. Proceedings of the Royal Society of Victoria, 70, pp. 19–79.

Correia, V.F., Riding, J.B., Duarte, L.V., Fernandes, P., and Pereira, Z. 2021. The effects of the Jenkyns Event on the radiation of Early Jurassic dinoflagellate cysts. *In* Carbon cycle and ecosystem response to the Jenkyns Event in the early Toarcian (Jurassic). *Edited by* M. Reolid, L.V. Duarte, E. Mattioli, and W Ruebsam. Geological Society, London Special Publications, 514, pp. 13–30. https://doi.org/10.1144/SP514-2020-255

Dalseg, T.S., Nakrem, H.A., and Smelror, M. 2016. Dinoflagellate biostratigraphy, palynofacies, depositional environment and sequence stratigraphy of the Agardhfjellet Formation (Upper Jurassic–Lower Cretaceous) in central Spitsbergen (Arctic Norway). Norwegian Journal of Geology, 96, pp. 119–133. https://doi.org/10.17850/njg96-2-04

Davies, E.H. 1983. The dinoflagellate Oppel zonation of the Jurassic-lower Cretaceous sequence in the Sverdrup Basin, Arctic Canada. Geological Survey of Canada, Bulletin, 359, 59 pp. https://doi.org/10.4095/119736

Davies, E.H. 1985. Dinoflagellate cyst occurrences of the Jurassic–Lower Cretaceous sequence in the Sverdrup Basin, arctic Canada. Geological Survey of Canada, Open File Report, 1153, 28 pp. https://doi.org/10.4095/129945

Drugg, W.S. 1978. Some Jurassic dinoflagellate cysts from England, France and Germany. Palaeontographica Abteilung B, 168, pp. 61–79.

Dypvik, H., Hvoslef, S., Bjærke, T., and Finnerud, E. 1985. The Wilhelmøya Formation (Upper Triassic–Lower Jurassic) at Bohemanflya, Spitsbergen. Polar Research, 3, pp. 155–165. https://doi.org/10.3402/polar.v3i2.6949

Dzyuba O.S., Pestchevitskaya E.B., Urman O.S., Shurygin B.N., Alifirov A.S., Igolnikov A.E., and Kosenko I.N. 2018. The Maurynya section, western Siberia: a key section of the Jurassic-Cretaceous boundary deposits of shallow marine origin. Russian Geology and Geophysics, 59, pp. 1072–1102. https://doi.org/10.1016/j.rgg.2018.07.010

Eisenack, A. 1972. Kritische Bemerkung zur Gattung *Pterospermopsis* (Chlorophyta, Prasinophyceae). [Critical remarks about *Pterospermopsis*]. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 10, pp. 596–601.

Feist-Burkhardt, S. 1994. Stratigaphic compilation of Below's data (1987A, 1987B and 1990) on Early and Middle Jurassic dinoflagellate cysts. Revue de Paleobiologie, 13, pp. 313–318.

 Copyright © Atlantic Geoscience, 2022

Felix, C.J. 1975. Palynological zonation of the Heiberg Formation (Triassic–Jurassic) eastern Sverdrup Basin, Arctic Canada. Bulletin of Canadian Petroleum Geology, 36, pp. 347–361.

Fensome, R.A. 1979. Dinoflagellate cysts and acritarchs from the Middle and Upper Jurassic of Jameson Land, East Greenland. Grønlands Geologiske Undersøgelse Bulletin, 132, 98 pp. https://doi.org/10.34194/bullggu.v132.6674

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, 50, 1173 pp.

Fisher, M.J. and Riley, L.A. 1980. The stratigraphic distribution of dinoflagellate cysts at the Boreal Jurassic–Cretaceous boundary. Fourth International Palynology Conference, Lucknow, 1976–77, Proceedings, 2, pp. 313–329.

Frebold, F.H. 1964. The Jurassic faunas of the Canadian Arctic. Cadoceratinae. Geological Survey of Canada Bulletin, 119, 27 pp. https://doi.org/10.4095/100627

Frebold, H., Mountjoy, E.W., and Tempelman-Kluit, D.J. 1967. New occurrences of Jurassic rocks and fossils in central and northern Yukon Territory. Geological Survey of Canada Paper 67–12, 35 pp. https://doi.org/10.4095/100917

Galloway, J.M., Sweet, A.R., Swindles, G.T., Dewing, K., Hadlari, T., Embry, A.F., and Sanei, H. 2013. Middle Jurassic to Lower Cretaceous paleoclimate of Sverdrup Basin, Canadian Arctic Archipelago inferred from the palynostratigraphy. Marine and Petroleum Geology, 44, pp. 240–255. https://doi.org/10.1016/j.marpetgeo.2013.01.001

Goryacheva, A.A. 2017. Lower Jurassic palynostratigraphy of eastern Siberia. Stratigraphy and Geological Correlation, 25, pp. 265–295. https://doi.org/10.1134/S0869593817030042

Goryacheva, A.A. and Nikitenko, B.L. 2016. Biostratigraphy of Lower Jurassic in Borehole Middle-Nakyn 360 (East Siberia). *In* Algae in biosphere evolution. *Edited by* N.K. Lebedeva and A.A. Goryacheva. Proceedings of the Second Palaeoalgological Conference, Institute of Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, Doklady Akademii Nauk, Novosibirsk, pp. 33–35 (in Russian).

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., and Ogg, G. (editors). 2021. The geologic time scale 2020. Second edition. Elsevier, The Netherlands, 1176 pp.

Gurari, F.G. and Mogucheva, N.K. (editors.). 2004. Resolution of the sixth interdepartmental stratigraphic meeting on the consideration and acceptance of refined stratigraphic charts of the Mesozoic sediments of West Siberia (Novosibirsk, 2003). SNIIGGiMS, Novosibirsk.

Håkansson, E., Birkelund, T., Piasecki, S., and Zakharov, V. 1981. Jurassic–Cretaceous boundary strata of the extreme Arctic (Peary Land, North Greenland). Bulletin of the Geological Society of Denmark, 30, pp. 11–42. https://doi.org/10.37570/bgsd-1981-30-02

Harding, I.C., Smith, G.A., Riding, J.B., and Wimbledon, W.A.P. 2011. Inter-regional correlation of Jurassic/Cretaceous boundary strata based on the Tithonian–Valanginian dinoflagellate cyst biostratigraphy of the Volga Basin, western Russia. Review of Palaeobotany and Palynology, 167, pp. 82–116. https://doi.org/10.1016/j.revpalbo.2011.07.002

Hogg, N.M. and Bailey, D.A. 1997. *Prolixosphaeridiopsis spissus* gen. et comb. nov. for the dinoflagellate cyst *Cleistosphaeridium spissum* McIntyre and Brideaux 1980. Journal of Micropalaeontology, 16, p. 50. https://doi.org/10.1144/jm.16.1.50

Ilyina, V.I. 1986. Subdivision and correlation of the marine and non-marine Jurassic sediments in Siberia based on palynological evidence. Review of Palaeobotany and Palynology, 46, 357–364. https://doi.org/10.1016/0034-6667(86)90073-4

Ilyina, V.I. 1988. Microphytoplankton of the Jurassic–Cretaceous boundary deposits of Urduk-Chaya Cape (Paksa Peninsula). *In* Palynology in the USSR. *Edited by* A.E. Khlonova. Novosibirsk: Nauka, 103–107.

Ilyina, V.I., Kulkova, I.A., and Lebedeva, N.K. 1994. Microphytofossils and detail stratigraphy of marine Mesozoic and Cenozoic of Siberia. Russian Academy of Sciences, Siberian Branch, United Institute of Geology, Geophysics and Mineralogy, Transactions, 818, 192 pp. (in Russian).

Ilyina, V.I., Nikitenko, B.L., and Glinskikh, L.A. 2005. Foraminifera and dinoflagellate cyst zonation and stratigraphy of the Callovian to Volgian reference section in the Tyumenskya superdeep well (West Siberia, Russia). *In* Recent developments in applied biostratigraphy. *Edited by* A.J. Powell and J.B. Riding. The Micropalaeontological Society, Special Publication, pp. 109–144. https://doi.org/10.1144/TMS001.8

Ingrams, S., Jolley, D.W., and Schneider, S. 2021. High latitude stratigraphical palynology of the Jurassic–Cretaceous boundary interval, Sverdrup Basin, Arctic Canada. Cretaceous Research, 126, 104922, 15 pp. https://doi.org/10.1016/j.cretres.2021.104922

Johnson, C.D. 1974. Microplankton palynostratigraphy of the Savik Formation (Jurassic), Axel Heiberg and Ellesmere Islands. Geological Association of Canada and the Canadian Society of Petroleum Geologists, Proceedings of the Canadian Arctic Geological Symposium, pp. 259–275.

Johnson, C.D. and Hills, L.V. 1973. Microplankton from the Savik Formation (Jurassic), Axel Heiberg and Ellesmere Island, District of Franklin. Bulletin of Canadian Petroleum Geology, 21, pp. 178–218.

Kelly, S.R.A., Gregory, F.J., Braham, W., Strogen, D.P., and Whitham, A.G. 2015. Towards an integrated Jurassic biostratigraphy for eastern Greenland. Volumina Jurassica, 13, pp. 43–64.

Klaus, W. 1960. Sporen der karnischen Stufe der ostalpinen Trias. Jahrbuch der Geologischen Bundesanstalt, 5, pp. 107–184.

Koevoets, M.J., Hammer, Ø., Olaussen, S., Senger, K., and Smelror, M. 2018. Integrating subsurface and outcrop

 Copyright © Atlantic Geoscience, 2022

data of the Middle Jurassic to Lower Cretaceous Agardhfjellet Formation in central Spitsbergen. Norwegian Journal of Geology, 98, pp. 1–34. https://doi.org/10.17850/njg98-4-01

Koppelhus, E.B. and Dam, G. 2003. Palynostratigraphy and palaeoenvironments of the Rævekøft, Gule Horn and Ostreaelv formations (Lower–Middle Jurassic), Neill Klinter Group, Jameson Land East Greenland. *In* The Jurassic of Denmark and Greenland. *Edited by* J.R. Ineson and F. Surlyk. Geological Survey of Denmark and Greenland Bulletin, 1, pp. 723–775. https://doi.org/10.34194/geusb.v1.4688

Koppelhus, E.B. and Hansen, C.F. 2003. Palynostratigraphy and palaeoenvironment of the Middle Jurassic Sortehat Formation (Neill Klinter Group), Jameson Land East Greenland. *In* The Jurassic of Denmark and Greenland. *Edited by* J.R. Ineson and F. Surlyk. Geological Survey of Denmark and Greenland Bulletin, 1, pp. 777–811. https://doi.org/10.34194/geusb.v1.4689

Lebedeva, N.K. and Nikitenko, B.L. 1998. Microphytoplankton and microforaminifera in the Lower Cretaceous reference section in Subarctic Ural (West Siberia). Russian Geology and Geophysics, 39, pp. 810–832.

Lebedeva N.K. and Nikitenko B.L. 1999. Dinoflagellate cysts and microforaminifera of the Lower Cretaceous Yatria River section, Subarctic Ural, NW Siberia (Russia). Palaeogeographic and palaeoenvironmental discussion. Grana, 38, pp. 134–143. https://doi.org/10.1080/713786920

Lentin, J.K. and Willliams, G.L. 1981. Fossil dinoflagellates: index to genera and species, 1981 edition. Bedford Institute of Oceanography, Report Series, BI–R-81–12, 345 pp.Leschik, G. 1956. Die Keuperflora von Neuewelt bei Basel: II. Die iso-und mikrosporen. Schweiz. Paläontologisches Abhandlung, 72, pp. 1–70.

Leschik, G. 1956. Die Keuperflora yon Neuwelt bei Basel. II. Die Iso- und Mikrosporen. Schweizerische Paläontologische Abhandlungen, 71, pp. 1–70.

Lund, J.J. and Pedersen, K.R. 1985. Palynology of the marine Jurassic formations in the Vardekløft Ravine, Jameson Land, East Greenland. Bulletin of the Geological Society of Denmark, 33, pp. 371–399. https://doi.org/10.37570/bgsd-1984-33-30

Lundblad, B. 1954. Contributions to the geological history of the Hepaticae. Fossil Marchantiales from the Rhaetic-Liassic coal mines of Skrombergea (Prov. of Scania), Sweden. Svensk Botanisk Tidskrift, 48, pp. 381–417

Malyavkina, V.S. 1949. Index of spores and pollen; Jurassic-Cretaceous. Vsesoyuznyi Neftyanoi Nauchno Issledovatelskii Geologorazvedochnyi Institut, Leningrad (VNIGRI), Trudy, 33, pp.1–137, 51 pl. (in Russian).

Mangerud, G., Paterson, N.W., and Bujak, J. 2021. Triassic palynoevents in the circum-Arctic region. Atlantic Geology, 57, pp. 71–101. https://doi.org/10.4138/atlgeol.2021.005

Mantle, D.J. and Riding, J.B. 2012. Palynology of the Middle Jurassic (Bajocian–Bathonian) *Wanaea verrucosa* dinoflagellate cyst zone of the North West Shelf of Australia. Review of Palaeobotany and Palynology, 180, pp. 41–78. https://doi.org/10.1016/j.revpalbo.2012.03.005

Mantle, D.J., Riding, J.B., and Hannaford, C. 2020. Late Triassic dinoflagellate cysts from the Northern Carnarvon Basin, Western Australia. Review of Palaeobotany and Palynology, 281, 104254, 53 pp. https://doi.org/10.1016/j.revpalbo.2020.104254

McIntyre, D.J. and Brideaux, W.W. 1980. Valanginian miospore and microplankton assemblages from the northern Richardson Mountains, District of Mackenzie, Canada. Geological Survey of Canada, Bulletin, 320, 57 pp.

Meledina, S.V., Ilyina, V.I., and Nalnjaeva, T.I. 1998. Parallel biostratigraphic scales of the Boreal Bathonian and Callovian in the North Pechora region as a tool for interregional correlation. Stratigraphy and Geological Correlation, 6, pp. 29–42.

Milner, P.S. and Piasecki, S. 1996. Boreal Middle Jurassic dinoflagellate cyst stratigraphy of Jameson Land, East Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport, 1996/30, Appendix 12, 32 pp.

Morgenroth, P. 1970. Dinoflagellate cysts from the Lias Delta of Lühnde/Germany. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 136, pp. 345–359.

Nikitenko, B.L. 2009. Jurassic stratigraphy, palaeobiogeography and biofacies of Siberia on microfauna (foraminifers and ostracodes). Parallel, Novosibirsk (in Russian with extended English summary).

Nikitenko, B.L., Pestchevitskaya, E.B., Lebedeva, N.K., and Ilyina, V.I. 2008. Micropalaeontological and palynological analyses across the Jurassic–Cretaceous boundary on Nordvik Peninsula, northeast Siberia. Newsletters on Stratigraphy, 42, pp. 181–222. https://doi.org/10.1127/0078-0421/2008/0042-0181

Nikitenko, B.L., Lebedeva, N.K., Peshchevitskaya, E.B., Knyazev, V.G., and Kutygin, R.V. 2011. Problems of Oxfordian and Kimmeridgian stratigraphy in northern Central Siberia (Nordvik Peninsula section). Russian Geology and Geophysics, 52, pp. 963–978. https://doi.org/10.1016/j.rgg.2011.08.003

Nikitenko, B.L., Shurygin, B.N., Knyazev, V.G., Meledina, S.V., Dzyuba, O.S., Lebedeva, N.K., Peshchevitskaya, E.B., Glinskikh, L.A., Goryacheva, A.A., and Khafaeva, S.N. 2013. Jurassic and Cretaceous stratigraphy of the Anabar area (Arctic Siberia, Laptev Sea coast) and the Boreal zonal standard. Russian Geology and Geophysics, 54, pp. 808–837. https://doi.org/10.1016/j.rgg.2013.07.005

Nikitenko, B.L., Knyazev, V.G., Peshchevitskaya, E.B., Glinskikh, L.A., Kutygin, R.V., and Alifirov, A.S. 2015a. High-resolution stratigraphy of the Upper Jurassic section (Laptev Sea coast). Russian Geology and Geophysics, 56, pp. 663–685. https://doi.org/10.1016/j.rgg.2015.03.014

Nikitenko, B.L., Knyazev, V.G., Peshchevitskaya, E.B., and Glinskikh L.A. 2015b. The Upper Jurassic of the Laptev Sea: interregional correlations and paleoenvironments. Russian Geology and Geophysics, 56, pp. 1173–1193. https://doi.org/10.1016/j.rgg.2015.07.008

Nikitenko B.L., Devyatov V.PP., Lebedeva N.K., Basov V.A.,

 Copyright © Atlantic Geoscience, 2022

Goryacheva A.A., Pestchevitskaya E.B., and Glinskikh L.A. 2017. Jurassic and Cretaceous stratigraphy of the New Siberian Archipelago (Laptev and East Siberian Seas): facies zoning and lithostratigraphy. Russian Geology and Geophysics, 58, pp. 1478–1493. https://doi.org/10.1016/j.rgg.2017.11.012

Nikitenko, B.L., Devyatov, V.PP., Lebedeva, N.K., Basov, V.A., Fursenko, E.A., Goryacheva, A.A., Peshchevitskaya, E.B., Glinskikh, L.A., and Khafaeva, S.N. 2018a. Jurassic and Cretaceous biostratigraphy and organic matter geochemistry of the New Siberian Islands (Russian Arctic). Russian Geology and Geophysics, 59, pp. 168–185. https://doi.org/10.1016/j.rgg.2018.01.014

Nikitenko, B.L., Pestchevitskaya, E.B., and Khafaeva, S.N. 2018b. High-resolution stratigraphy and palaeoenvironments of the Volgian–Valanginian in the Olenek section (Anabar–Lena region, Arctic Eastern Siberia). Revue de Micropalaeontology, 61, pp. 271–312. https://doi.org/10.1016/j.revmic.2018.07.001

Nilsson, T. 1958. Uber das Vorkommen eines mesozoischen Sapropelgesteins in Schonen. Lunds Universitets Arsskrift, Ny Följd, Avd. 2, 54 (10), pp. 1–112.

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, pp. 1–69. https://doi.org/10.17850/njg98-4-06

Paterson, N.W. and Mangerud G. 2015. Late Triassic (Carnian–Rhaetian) palynology of Hopen, Svalbard. Review of Palaeobotany and Palynology, 220, pp. 98–119. https://doi.org/10.1016/j.revpalbo.2015.05.001

Pestchevitskaya, E., Lebedeva, N., and Ryabokon, A. 2011. Uppermost Jurassic and lowermost Cretaceous dinocyst successions of Siberia, the Subarctic Urals and Russian Platform and their interregional correlation. Geologicia Carpathica, 62, pp. 189–202. https://doi.org/10.2478/v10096-011-0016-9

Piasecki, S. 1980. Mid to Late Jurassic dinoflagellate cyst stratigraphy from Milne Land (East Greenland). Ph.D. thesis, University of Copenhagen (unpublished), 167 pp. https://doi.org/10.37570/bgsd-1979-28-06

Piasecki, S. 1996. Boreal dinoflagellate cyst stratigaphy of Middle to Upper Jurassic sediments of Milne Land, East Greenland. *In* Formation of source and reservoir rocks in a sequence stratigraphic framework, Jameson Land, East Greenland. *Edited by* S. Piasecki *et al.* Energy research programme EFP-93, projects 1313/93-0010 and 0017. Danmarks og Grønlands Geologiske Undersøgelse Rapport 1996/30, v 1–2, 100 pp.

Piasecki, S. 2001. Three new Middle Jurassic dinoflagellate cysts from East Greenland. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 219, pp. 15–31. https://doi.org/10.1127/njgpa/219/2001/15

Piasecki, S. and Stemmerik, L. 2004. Jurassic dinoflagellate cysts from Hochstetter Forland, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin, 5, pp. 89–97. https://doi.org/10.34194/geusb.v5.4809

Piasecki, S., Larsen, M., Therkelsen, J., and Vosgerau, H. 2004a. Jurassic dinoflagellate cyst stratigraphy of Hold with Hope, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin, 5, pp. 73–88. https://doi.org/10.34194/geusb.v5.4808

Piasecki, S., Callomon, J.H., and Stemmerik, L. 2004b. Jurassic dinoflagellate cyst stratigraphy of Store Koldewey, North-East Greenland. Geological Survey of Denmark and Greenland Bulletin, 5, pp. 99–112. https://doi.org/10.34194/geusb.v5.4810

Pimpirev, C. and Pavlishina, P. 2005a. New data on the stratigraphy and palynological asessments of the Upper Jurassic–Lower Cretaceous sediments in the area of Lake Hazen, Ellesmere Island, Canadian Arctic. Comptes rendus de l'Académie bulgare des Sciences, 58, pp. 783–788.

Pimpirev, C. and Pavlishina, P. 2005b. Stratigraphy, age constraints and paleoenvironmental interpretations of the Upper Jurassic–Lower Cretaceous sediments in the area of Lake Hazen, Ellesmere Island, Canadian Arctic. Proceedings of Anniversary International Scientific Conference, Bulgarian Geological Society 80th Anniversary, pp. 14–17.

Playford, G. 1965. Plant microfossils from Triassic sediments near Poatina, Tasmania. Journal of the Geological Society of Australia, 12, pp. 173–210. https://doi.org/10.1080/00167616508728592

Pocock, S.A.J. 1976. A preliminary dinoflagellate zonation of the uppermost Jurassic and lower part of the Cretaceous, Canadian Arctic, and possible correlation in the Western Canadian basin. Geoscience and Man, 16, pp. 101–114. https://doi.org/10.1080/00721395.1976.9989778

Pocock, S.A.J. 1980. Palynology at the Jurassic–Cretaceous boundary in North America. Proceedings of the Fourth International Palynological Conference, Lucknow (1976–1977), 2, pp. 377–385 (cover date 1978).

Pocock, S.A.J. and Sarjeant, W.A.S. 1972. Partitomorphitae, a new subgroup of Triassic and Jurassic acritarchs. Bulletin of the Geological Society of Denmark, 21, pp. 346–357.

Poulsen, N.E. 1985. Dinocystestratigrafien i den nedre del af Hareelv Formation (Øvre Jura), Jameson Land, Østgrønland. Dansk Geologisk Forening Årsskrift, 1984, pp. 133–137.

Poulsen, N.E. 1991. *Gonyaulacysta jurassica desmos*, a new subspecies of dinoflagellate cyst from the early Oxfordian (Late Jurassic) of northwestern Europe and East Greenland. Palynology, 15, pp. 211–217. https://doi.org/10.1080/01916122.1991.9989396

Poulton, T.P. 1989. Current status of Jurassic biostratigraphy and stratigraphy, northern Yukon and adjacent Mackenzie Delta. *In* Current Research, Part G. Geological Survey of Canada Paper, 89-1G, pp. 25–30. https://doi.org/10.4095/127560

Poulton, T.P., Leskiw, K., and Audretsch, A. 1982. Stratigraphy and microfossils of the Jurassic Bug Creek Group of northern Richardson Mountains, northern Yukon and

 Copyright © Atlantic Geoscience, 2022

adjacent Northwest Territories. Geological Survey of Canada Bulletin, 325, 137 pp. https://doi.org/10.4095/111358

Riding, J.B. 1984. A palynological investigation of Toarcian to early Aalenian strata from the Blea Wyke area, Ravenscar, North Yorkshire. Proceedings of the Yorkshire Geological Society, 45, pp. 109–122. https://doi.org/10.1144/pygs.45.1-2.109

Riding, J.B. 2012a. The Jurassic dinoflagellate cyst *Gonyaulacysta dentata* (Raynaud 1978) Lentin and Vozzhennikova 1990 emend. nov.: an index species for the late Callovian to earliest Oxfordian of the northern hemisphere. Review of Palaeobotany and Palynology, 176–177, pp. 68–81. https://doi.org/10.1016/j.revpalbo.2012.02.008

Riding, J.B. 2012b. A compilation and review of the literature on Triassic, Jurassic, and earliest Cretaceous dinoflagellate cysts. American Association of Stratigraphic Palynologists Contributions Series, 46, 119 pp.

Riding, J.B. 2019. Vera Ivanovna Ilyina (1930–2018). Palynology, 43, pp. 349–354. https://doi.org/10.1080/01916122.2019.1586090

Riding, J.B. and Hubbard, R.N.L.B. 1999. Jurassic (Toarcian to Kimmeridgian) dinoflagellate cysts and paleoclimates. Palynology, 23, pp. 15–30. https://doi.org/10.1080/01916122.1999.9989516

Riding, J.B., and Ioannides, N.S. 1996. A review of Jurassic dinoflagellate cyst biostratigraphy and global provincialism. Bulletin de la Société Géologique de France, 167, pp. 3–14.

Riding, J.B. and Lucas-Clark, J. 2016. The life and scientific work of William R. Evitt (1923–2009). Palynology, 40, Supplement 1, 130 pp. https://doi.org/10.1080/01916122.2016.1147792

Riding, J.B. and Michoux, D. 2013. Further observations on the Jurassic dinoflagellate cyst *Gonyaulacysta dentata* (Raynaud 1978) Lentin and Vozzhennikova 1990 emended Riding 2012. Review of Palaeobotany and Palynology, 196, pp. 51–56. https://doi.org/10.1016/j.revpalbo.2013.01.010

Riding, J.B. and Thomas, J.E. 1992. Dinoflagellate cysts of the Jurassic System. *In* A stratigraphic index of dinoflagellate cysts. *Edited by* A.J. Powell. British Micropalaeontological Society Publication Series, Chapman and Hall, London, pp. 7–97. https://doi.org/10.1007/978-94-011-2386-0_2

Riding, J.B., Penn, I.E., and Woollam, R. 1985. Dinoflagellate cysts from the type area of the Bathonian Stage (Middle Jurassic; southwest England). Review of Palaeobotany and Palynology, 45, pp. 149–169. https://doi.org/10.1016/0034-6667(85)90068-5

Riding, J.B., Walton, W., and Shaw, D. 1991. Toarcian to Bathonian (Jurassic) palynology of the Inner Hebrides, northwest Scotland. Palynology, 15, pp. 115–179. https://doi.org/10.1080/01916122.1991.9989393

Riding, J.B., Fedorova, V.A., and Ilyina, V.I. 1999. Jurassic and lowermost Cretaceous dinoflagellate cyst biostratigarphy of the Russian Platform and northern Siberia. American Association of Stratigraphic Palynologists Contribution Series, 36, 179 pp.

Riding, J.B., Mantle, D.J., and Backhouse, J. 2010. A review of the chronostratigraphical ages of Middle Triassic to Late Jurassic dinoflagellate cyst biozones of the North West Shelf of Australia. Review of Palaeobotany and Palynology, 162, pp. 543–575. https://doi.org/10.1016/j.revpalbo.2010.07.008

Riding, J.B., Mariani, E., and Fensome, R.A. 2022. A review of the Jurassic dinoflagellate cyst genus *Gonyaulacysta* Deflandre 1964 emend. nov. Review of Palaeobotany and Palynology, 299, 104605. https://doi.org/10.1016/j.revpalbo.2022.104605

Rismyhr, B., Bjærke, T., Olaussen, S., Mulrooney, M.J., and Senger, K. 2019. Facies, palynostratigraphy and sequence stratigraphy of the Wilhelmøya Subgroup (Upper Triassic–Middle Jurassic) in western central Spitsbergen, Svalbard. Norwegian Journal of Geology, 99, pp. 189–218. https://doi.org/10.17850/njg001

Sarjeant, W.A.S. 1972. Dinoflagellate cysts and acritarchs from the Upper Vardekløft Formation (Jurassic) of Jameson Land, East Greenland. Medelelser Grønland, 195, pp. 1–65.

Schulz, E. 1967. Sporenpaläontologische Untersuchungen rätoliassischer Schichten im Zentralteil des Germanischen Beckens. Paläontologische Abhandlungen, Paläobotanik B2, pp. 427–633.

Shurygin, B.N., Nikitenko, B.L., Devyatov, V.PP., Ilyina, V.I., Meledina, S.V., Gaideburova, E.A., Dzyuba, O.S., Kazakov, A.M., and Mogucheva, N.K. 2000. Stratigraphy of oil and gas basins of Siberia: The Jurassic System Izd. SO RAN, Filial "Geo," Novosibirsk. (in Russian).

Smelror, M. 1988a. Bathonian to early Oxfordian dinoflagellate cysts and acritarchs from Kong Karls Land, Svalbard. Review of Palaeobotany and Palynology, 56, pp. 275–304. https://doi.org/10.1016/0034-6667(88)90061-9

Smelror, M. 1988b. Late Bathonian to early Oxfordian dinoflagellate cyst stratigraphy of Jameson Land, East Greenland. Grønlands Geologiske Undersøgelse Rapport, 137, pp. 135–159. https://doi.org/10.34194/rapggu.v137.8019

Smelror, M. 1991. Two new dinoflagellate cysts from the Middle Jurassic of the Barents Sea region. Journal of Micropalaeontology, 10, pp. 175–180. https://doi.org/10.1144/jm.10.2.175

Smelror, M. 1993. Biogeography of Bathonian to Oxfordian (Jurassic) dinoflagellates: Arctic, NW Europe and circum-Mediterranean regions. Palaeogeography, Palaeoclimatology, Palaeoecology, 102, pp. 121–160. https://doi.org/10.1016/0031-0182(93)90009-8

Smelror, M. 1994. Jurassic stratigraphy of the western Barents Sea region: a review. Geobios, 17, pp. 441–451. https://doi.org/10.1016/S0016-6995(94)80165-7

Smelror, M., and Below, R. 1992. Dinoflagellate biostratigraphy of the Toarcian to lower Oxfordian (Jurassic) of the Barents Sea region. *In* Arctic Geology and Petroleum Potential. *Edited by* T.O. Vorren, E. Bergsager, Ø.A. Dahl-Stammes, E. Holter, B. Johansen, E. Lie, and T.B. Lund. Norwegian Petroleum Society (NPF), Special Publication, 2, pp. 495–513. https://doi.org/10.1016/B978-0-444-

 Copyright © Atlantic Geoscience, 2022

88943-0.50035-6
Smelror, M., and Dypvik, H. 2005. Marine microplankton biostratigraphy of the Volgian–Ryazanian boundary strata, western Barents Shelf. Norges Geologiske Undersøkelse Bulletin, 443, pp. 61–69.
Smelror, M., Mørk, A., Monteil, E., Rutledge, D., and Leereveld, H. 1998. The Klippfisk Formation — a new lithostratigraphic unit of lower Cretaceous platform carbonates on the western Barents Shelf. Polar Research, 17, pp. 181–202. https://doi.org/10.1111/j.1751-8369.1998.tb00271.x
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, pp. 1–31. https://doi.org/10.17850/njg004
Suneby L.B. and Hills L.V. 1988. Palynological zonation of the Heiberg Formation (Triassic–Jurassic) eastern Sverdrup Basin, Arctic Canada. Bulletin of Canadian Petroleum Geology, 36 (4), pp. 347–361.
Tan, J.T. and Hills, L.V. 1978. Oxfordian–Kimmeridgian dinoflagellate assemblage, Ringnes Formation, Arctic Canada. Current Research, Part C, Geological Survey of Canada, Paper 78-1C, pp. 63–73. https://doi.org/10.4095/104592
Thusu, B. 1978. Aptian to Toarcian dinoflagellate cysts from Arctic Norway. *In* Distribution of biostratigraphically diagnostic dinoflagellate cysts and miospores from the northwest European continental shelf and adjacent areas. *Edited by* B. Thusu. Continental Shelf Institute Publication, 100, pp. 61–95.
Tozer, E.T.1963. Mesozoic and Tertiary stratigraphy, western Ellesmere Island and Axel Heiberg Island, District of Franklin. Geological Survey of Canada, Paper 63-60, 38 pp. https://doi.org/10.4095/101061
Turner, H.E., Batenburg, S.J., Gale, A.S., and Gradstein, F.M. 2019. The Kimmeridge Clay Formation (Upper Jurassic–Lower Cretaceous) of the Norwegian Continental Shelf and Dorset, UK: a chemostratigraphic correlation. Newsletters on Stratigraphy, 52, pp. 1–32. https://doi.org/10.1127/nos/2018/0436
Valdes, P.J. and Sellwood, B.W. 1992. A palaeoclimate model for the Kimmeridgian. Palaeogeography, Palaeoclimatology, Palaeoecology, 95, pp. 47–72. https://doi.org/10.1016/0031-0182(92)90165-2
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. 2020. Enhanced Arctic–Tethys connectivity ended the Toarcian Oceanic Anoxic Event in NW Europe. Geological Magazine, 157, pp. 1593–1611. https://doi.org/10.1017/S0016756819001262
van Helden, B.G.T. 1977. Correlation of microplankton assemblages with ammonite faunas from the Jurassic Wilkie Point Formation, Prince Patrick Island, District of Franklin. Geological Survey of Canada Paper, 77–1B, pp. 163–171. https://doi.org/10.4095/102776
Vigran, J.O., Mangerud G., Mørk A., Worsley D., and Hochuli P.A. 2014. Palynology and geology of the Triassic succession of Svalbard and the Barents Sea. Geological Survey of Norway Special Publication 14, pp. 1–247.
Warrington, G. 1974. Studies in the palynological biostratigraphy of the British Trias. I. Reference sections in West Lancashire and North Somerset. Review of Palaeobotany and Palynology, 17, pp. 133–147. https://doi.org/10.1016/0034-6667(74)90095-5
Wharton, D.I. 1988. Dinoflagellates from Middle Jurassic sediments of Alaska. Palynology, 12, p. 248.
Wierzbowski, A. and Århus, N. 1990. Ammonite and dinoflagellate cyst succesion of an upper Oxfordian–Kimmeridgian black shale core from the Nordkapp Basin, southern Barents Sea. Newsletter on Stratigraphy, 22, pp. 7–19. https://doi.org/10.1127/nos/22/1990/7
Wierzbowski, A., Smelror, M., and Mørk, A. 2002. Ammonites and dinoflagellates in the upper Oxfordian and Kimmeridgian of the northeastern Norwegian Sea (Nordland VII offshore area): biostratigraphical and biogeograhical signicifance. Neues Jahrbuch für Geologie und Palaeontolgie, Abhandlungen, 226, pp. 145–164. https://doi.org/10.1127/njgpa/226/2002/145
Wiggins, V.D. 1973. The dinoflagellate family Pareodiniaceae: a discussion. Geoscience and Man, 11, pp. 95–115. https://doi.org/10.1080/00721395.1975.9989759
Witmer, R.J., Mickey, M.B., and Haga, H. 1981. Biostratigraphic correlations of selected test wells of National Petroleum Reserve in Alaska. United States Geological Survey Open-File Report, 81-1165, 89 pp. https://doi.org/10.3133/ofr811165
Wood, S.E.L., Riding, J.B., Fensome, R.A., and Williams, G.L. 2016: A review of the *Sentusidinium* complex of dinoflagellate cysts. Review of Palaeobotany and Palynology, 234, pp. 61–93. https://doi.org/10.1016/j.revpalbo.2016.08.008
Zakharov, V.A., Bogomolov, Yu.I., Ilyina, V.I., Konstantinov, A.G., Kurushin, N.I., Lebedeva, N.K., Meledina, S.V., Nikitenko, B.L., Sobolev, E.S., and Shurygin, B.N. 1997. Boreal zonal standard and biostratigraphy of the Siberian Mesozoic. Geologiya i Geofizika, 38, pp. 927–956.

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APPENDIX A: TAXON NAMES WITH AUTHOR CITATIONS

Note that the references for the dinocyst author citations may be found in Fensome *et al.* (2019).

Acritarchs and Algae

Fromea tornatilis (Drugg 1978) Lentin and Williams 1981
Prolixosphaeridiopsis spissa (McIntyre and Brideaux 1980) Hogg and Bailey 1997
Pterospermopsis aureolata (Cookson and Eisenack 1958) Eisenack 1972

Dinocysts

Ambonosphaera calloviana Fensome 1979
Andreedinium arcticum Below 1987a (now *Phallocysta arctica*)
Apteodinium bucculiatum Davies 1983
Apteodinium granulatum Eisenack 1958
Apteodinium maculatum Eisenack and Cookson 1960
Arkellea teichophera (Sarjeant 1961) Below 1990
Atopodinium haromense Thomas and Cox 1988
Atopodinium prostatum Drugg 1978
Caligodinium aceras (Manum and Cookson 1964) Lentin and Williams 1973
Cassiculosphaeridia magna Davey 1974
Chlamydophorella ectotabulata Smelror 1989
Chytroeisphaeridia chytroeides (Sarjeant 1962) Downie and Sarjeant 1965
Chytroeisphaeridia? *mantellii* Gitmez and Sarjeant 1972 (now considered a taxonomic junior synonym of *Sentusidinium ringnesiorum)*
Corculodinium inaffectum (Drugg 1978) Courtinat 2000
Cribroperidinium? *ehrenbergii* (Gitmez 1970) Helenes 1984
Cribroperidinium globatum (Gitmez and Sarjeant 1972) Helenes 1984
Cribroperidinium granulatum (Klement 1960) Stover and Evitt 1978
Cribroperidinium? *longicorne* (Downie 1957) Lentin and Williams 1985
Cribroperidinium jubaris (Davies 1983) Lentin and Williams 1985
Cribroperidinium nuciforme (Deflandre 1962) Courtinat 1989
Cribroperidinium? *perforans* (Cookson and Eisenack 1958) Morgan 1980
Cribroperidinium? *perforans* subsp. *kunzeviense* (Vozzhennikova 1967) Lentin and Williams 1989
Cribroperidinium ? *perforans* subsp. *perforans (Cookson and Eisenack 1958) Morgan 1980*
Crussolia deflandrei Wolfard and Van Erve 1981 (now *Evansia deflandrei*)
Ctenidodinium combazii Dupin 1968
Ctenidodinium continuum Gocht 1970
Ctenidodinium? *schizoblatum* (Norris 1965) Lentin and Williams 1973
Dapcodinium priscum Evitt 1961
Dichadogonyaulax culmula (Norris 1965) Loeblich Jr. and Loeblich III 1968
Dichadogonyaulax sellwoodii Sarjeant 1975
Dingodinium cerviculum Cookson and Eisenack 1958
Dingodinium jurassicum Cookson and Eisenack 1958
Dingodinium minutum Dodekova 1975
Dodekovia bullula (Bjærke 1980) Below 1987a (now *Parvocysta bullula*)
Dodekovia syzygia Dörhöfer and Davies 1980
Egmontodinium? *diminutum* Davies 1983
Egmontodinium polyplacophorum Gitmez and Sarjeant 1972
Ellipsoidictyum cinctum Klement 1960
Endoscrinium galeritum (Deflandre 1939) Vozzhennikova 1967
Endoscrinium galeritum subsp. *reticulatum* (Klement 1960) Górka 1970
Endoscrinium subvallare (Sarjeant 1962) Lentin and Williams 1973
Epiplosphaera saturnalis (Brideaux and Fisher 1976) Dodekova 1994
Escharisphaeridia mantellii (Gitmez and Sarjeant 1972) Courtinat 1989 (now considered a taxonomic junior *synonym of Sentusidinium ringnesiorum)*

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APPENDIX A: continued.

Escharisphaeridia pocockii (Sarjeant 1968) Erkmen and Sarjeant 1980 (now considered a taxonomic junior synonym of *Sentusidinium ringnesiorum)*
Escharisphaeridia rudis Davies 1983 (now considered a taxonomic junior synonym of *Sentusidinium ringnesiorum*)
Evansia Pocock 1972
Evansia dalei Smelror and Århus 1989
Evansia deflandrei (Wolfard and Van Erve 1981) Below 1990
Evansia evittii (Pocock 1972) Jansonius 1986
Evansia granochagrinata Below 1990
Evansia? *opeasatos* (Davies 1983) Jansonius 1986
Evansia zabra (Davies 1983) Jansonius 1986
Exochosphaeridium scitulum Singh 1971
Freboldinium arcticum Below 1990
Freboldinium regulum Below 1990
Freboldinium serrulatum (Davies 1983) Below 1990
Glossodinium dimorphum Ioannides *et al*. 1977
Gochteodinia mutabilis (Riley in Fisher and Riley 1980) Fisher and Riley 1982
Gochteodinia villosa (Vozzhennikova 1967) Norris1978
Gonyaulacysta adecta (Sarjeant 1982) Riding*et al*. 2022
Gonyaulacysta desmos (Poulsen 1991) Riding *et al*. 2022
Gonyaulacysta dualis (Brideaux and Fisher 1976) Stover and Evitt 1978
Gonyaulacysta jurassica (Deflandre 1939) Norris and Sarjeant 1965
Gonyaulacysta jurassica subsp. *adecta* var. *longicornis* (Deflandre 1938) Downie and Sarjeant 1965 *(now Gonyaulacysta longicornis)*
Gonyaulacysta jurassica subsp. *jurassica* (autonym, now redundant)
Gonyaulacysta longicornis (Deflandre 1939) Riding *et al*. 2022
Hystrichodinium? *lanceatum* Davies 1983
Imbatodinim kondratjevii Vozzhennikova 1967
Impletosphaeridium Morgenroth 1966a
Kalyptea stegasta (Sarjeant 1961a) Wiggins 1975
Komewuia glabra Cookson and Eisenack 1960
Lacrymodinium warrenii Albert *et al*. 1986
Lagenadinium callovianum Piel 1985 (now *Stephanelytron callovianum*)
Lanterna bulgarica Dodekova 1969
Lanterna? *cantrellii* (Sarjeant 1972) Williams *et al*. 1993
Leptodinium deflandrei (Riley in Fisher and Riley 1980) Lentin and Williams 1981
Leptodinium? *hyalodermopse* (Cookson and Eisenack 1958) Stover and Evitt 1978
Leptodinium mamilliferum (Deflandre 1939) Helenes 1984
Leptodinium mirabile Klement 1960
Leptodinium subtile Klement 1960
Leptodinium volgense Lentin and Williams 1981
Liesbergia liesbergensis Berger 1986 *Liesbergia scarburghensis* (Sarjeant 1964b) Berger 1986 (now *Trichodinium scarburghense*)
Limbodinium absidatum (Drugg 1978) Riding 1987
Lithodinia jurassica Eisenack 1935
Lunatadinium dissolutum Brideaux and McIntyre 1973
Mancodinium coalitum Morgenroth 1970
Mancodinium semitabulatum Morgenroth 1970
Meiourogonyaulax deflandrei Sarjeant 1968
Meiourogonyaulax planoseptata Riding 1987
Meiourogonyaulax valensii Sarjeant 1966
Mendicodinium Morgenroth 1970
Mendicodinium groenlandicum (Pocock and Sarjeant 1972) Davey 1979
Mendicodinium reticulatum Morgenroth 1970

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APPENDIX A: continued.

Microdinium opacum Brideaux 1971
Mikrocysta erugata Bjærke 1980
Moesiodinium raileanui Antonesçu 1974
Muderongia simplex Alberti 1961
Nannoceratopsis deflandrei Evitt 1961b
Nannoceratopsis deflandrei subsp. *anabarensis* Ilyina in Ilyina *et al*. 1994
Nannoceratopsis deflandrei subsp. *senex* (van Helden 1977) Ilyina in Ilyina *et al*. 1994
Nannoceratopsis deflandrei subsp. *senex* var. C sensu Davies 1983
Nannoceratopsis gracilis Alberti 1961
Nannoceratopsis pellucida Deflandre 1939
Nannoceratopsis senex van Helden, 1977 (now *Nannoceratopsis deflandrei* subsp. *senex*)
Oligosphaeridium patulum Riding and Thomas 1988
Oligosphaeridium pulcherrimum (Deflandre and Cookson 1955) Davey and Williams 1966
Opaeopsomus wapellensis Pocock 1972
Ovalicysta hiata Bjærke 1980
Ovoidinium waltonii (Pocock 1972) Lentin and Williams 1976
Paragonyaulacysta Johnson and Hills 1973
Paragonyaulacysta? *borealis* (Brideaux and Fisher 1976) Stover and Evitt 1978
Paragonyaulacysta calloviensis Johnson and Hills 1973
Paragonyaulacysta capillosa (Brideaux and Fisher 1976) Stover and Evitt 1978
Paragonyaulacysta retiphragmata Dörhöfer and Davies 1980
Pareodinia asperata Riley in Fisher and Riley 1980
Pareodinia ceratophora Deflandre 1947
Pareodinia groenlandica Sarjeant 1972
Pareodinia prolongata Sarjeant 1959
Parvocysta bullula Bjærke 1980
Perisseiasphaeridium pannosum Davey and Williams 1966
Phallocysta arctica (Below 1987a) Riding 1994
Phallocysta elongata (Beju 1971) Riding 1994
Phallocysta eumekes Dörhöfer and Davies 1980
Phallocysta thomasii Smelror 1991
Pilosidinium filiatum (Davies, 1983) Courtinat 1989 (now considered a taxonomic junior synonym of *Sentusidinium capillatum*)
Prolixosphaeridium parvispinum (Deflandre 1937) Davey *et al*. 1969
Protobatioladinium elatmaense Riding and Ilyina 1996
Protobatioladinium? *elongatum* Riding and Ilyina 1998
Protobatioladinium westburiense Nøhr-Hansen 1986
Pyxidinopsis laminata (Davies 1983) Lentin and Williams 1985
Reutlingia cracens (Bjærke 1980) Prauss 1989
Rhynchodiniopsis cladophora (Deflandre 1939) Below 1981
Rhynchodiniopsis pennata (Riley in Fisher and Riley 1980) Jan du Chêne *et al*. 1985
Rigaudella aemula (Deflandre 1939) Below 1982
Rosswangia holotabulata (Davies 1983) Below 1987b
Rotosphaeropsis thule (Davey 1982) Riding and Davey 1989
Scriniocassis priscus (Gocht 1979) Below 1990
Scriniocassis weberi Gocht 1964
Scriniodinium anceps (Raynaud 1978) Jan du Chêne *et al*. 1986
Scriniodinium crystallinum (Deflandre 1939) Klement 1960
Scriniodinium dictyotum subsp. *dictyotum* Cookson and Eisenack 1960
Scriniodinium dictyotum subsp. *pyrum* Gitmez 1970
Scriniodinium inritibile Fisher and Riley 1980
Senoniasphaera jurassica (Gitmez and Sarjeant 1972) Lentin and Williams 1976

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APPENDIX A: continued.

Sentusidinium capillatum (Davies 1983) Courtinat 1989
Sentusidinium ringnesiorum (Manum and Cookson 1964) Wood *et al*. 2016
Sentusidinium verrucosum (Sarjeant 1968) Sarjeant and Stover 1978
Sirmiodinium grossii Alberti 1961
Stephanelytron Sarjeant 1961a
Stephanelytron callovianum (Piel 1985) Courtinat 1999
Stephanelytron membranoideum (Vozzhennikova 1967) Courtinat 1999
Stiphrosphaeridium anthophorum (Cookson and Eisenack 1958) Lentin and Williams
1985 *Susadinium faustum* (Bjærke 1980) Lentin and Williams 1985
Susadinium scrofoides Dörhöfer and Davies 1980
Sverdrupiella Bujak and Fisher 1976
Sverdrupiella mutabilis Bujak and Fisher 1976
Systematophora? *ovata* Gitmez and Sarjeant 1972
Tanyosphaeridium isocalamum (Deflandre and Cookson 1955) Davey and Williams 1969
Trichodinium erinaceoides Davies 1983
Trichodinium scarburghense (Sarjeant 1964) Williams *et al* . 1993
Tubotuberella apatela (Cookson andEisenack 1960) Ioannides *et al* . 1977 *Tubotuberella*
dangeardii (Sarjeant 1968) Stover and Evitt 1978
Tubotuberella dentata Raynaud 1978
Tubotuberella egemenii (Gitmez 1970) Stover and Evitt 1978
Tubotuberella rhombiformis Vozzhennikova 1967
Valensiella dictydia (Sarjeant 1972) Lentin and Williams 1993
Valensiella ovulum (Deflandre 1947) Eisenack 1963
Valvaeodinium aquilonium (Dörhöfer and Davies 1980) Below 1987b
Valvaeodinium cavum (Davies 1983) Below 1987b
Valvaeodinium leneae Piasecki 2001
Valvaeodinium perpunctatum (Wille and Gocht 1979) Below 1987b
Valvaeodinium punctatum (Wille and Gocht 1979) Below 1987b
Valvaeodinium spinosum (Fenton *et al*. 1980) Below 1987b
Wallodinium krutzschii (Alberti 1961) Habib 1972
Wanaea acollaris Dodekova 1975
Wanaea fimbriata Sarjeant 1961
Wanaea thysanota Woollam 1982
Wrevittia helicoidea (Eisenack andCookson 1960) Helenes and Lucas-Clark 1997

Miospores

Aratrisporites Leschik 1956
Aratrisporites laevigatus Bjærke and Manum 1977
Aratrisporites macrocavatus Bjærke and Manum 1977
Aratrisporites scabratus Klaus 1960
Aratrisporites tenuispinosus Playford 1965
Limbosporites lundbladiae Nilsson 1958
Lunatisporites rhaeticus (Schulz 1967) Warrington 1974
Quadraeculina anellaeformis Malyavkina 1949
Ricciisporites tuberculatus Lundblad 1954
Taeniasporites rhaeticus (Schulz 1967) Warrington 1974

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APPENDIX B: SPREADSHEET SUMMARIZING PALYNOEVENTS

All mentions of ammonite zones refer to the Sub-Boreal ammonite zonation.

Event	Calibration
LO of *Aratrisporites*	Base of the ammonite *Psiloceras planorbis* Zone
LO of Common *Limbosporites lundbladiae*	Base of the ammonite *Psiloceras planorbis* Zone
LO of *Sverdrupiella mutabilis*	Base of the ammonite *Psiloceras planorbis* Zone
LO of Taeniate bisaccate pollen	Base of the ammonite *Psiloceras planorbis* Zone
LO of *Dapcodinium priscum*	Base of the ammonite *Arnioceras semicostatum* Zone
FO of *Mendicodinium reticulatum*	Base of the ammonite *Asteroceras obtusum* Zone
FO of *Valvaeodinium perpunctatum*	Base of the ammonite *Uptonia jamesoni* Zone
LO of *Valvaeodinium perpunctatum*	Base of the ammonite *Almaltheus margaritatus* Zone
FO of *Scriniocassis weberi*	50% up the ammonite *Amaltheus margaritatus* Zone
FO of *Freboldinium regulum*	50% up the ammonite *Pleuroceras spinatum* Zone
FO of *Susadinium scrofoides*	Base of the ammonite *Dactylioceras tenuicostatum* Zone
FO of *Phallocysta eumekes*	Base of the ammonite *Harpoceras serpentinum* Zone
FO of *Rosswangia holotabulata*	Base of the ammonite *Harpoceras serpentinum* Zone
FO of *Valvaeodinium aquilonium*	Base of the ammonite *Harpoceras serpentinum* Zone
FO of *Caligodinium aceras*	Base of the ammonite *Hildoceras bifrons* Zone
FO of *Dingodinium minutum*	Base of the ammonite *Hildoceras bifrons* Zone
FO of *Dodekovia syzygia*	Base of the ammonite *Hildoceras bifrons* Zone
FO of *Microdinium opacum*	Base of the ammonite *Hildoceras bifrons* Zone
FO of *Valvaeodinium cavum*	Base of the ammonite *Hildoceras bifrons* Zone
FO of *Nannoceratopsis gracilis*	17% up the ammonite *Hildoceras bifrons* Zone
FO of *Ovalicysta hiata*	50% up the ammonite *Hildoceras bifrons* Zone
FO of *Scriniocassis priscus*	50% up the ammonite *Hildoceras bifrons* Zone
LO of *Andreedinium arcticum*	50% up the ammonite *Hildoceras bifrons* Zone
LO of *Parvocysta bullula*	50% up the ammonite *Hildoceras bifrons* Zone
LO of *Reutlingia nasuta*	50% up the ammonite *Hildoceras bifrons* Zone
LO of *Susadinium faustum*	50% up the ammonite *Hildoceras bifrons* Zone
FO of *Opaeopsomus wapellensis*	Base of the ammonite *Haugia variabilis* Zone
FO of *Susadinium scrofoides*	Base of the ammonite *Haugia variabilis* Zone
FO of *Chytroeisphaeridia chytroeides*	Base of the ammonite *Grammoceras thouarsense* Zone
FO of *Valvaeodinium punctatum*	Base of the ammonite *Grammoceras thouarsense* Zone
LO of *Nannoceratopsis deflandrei* subsp. *senex* var C sensu Davies 1983	Base of the ammonite *Grammoceras thouarsense* Zone
LO of *Phallocysta elongata*	Base of the ammonite *Pleydellia aalensis* Zone
FO of *Phallocysta thomasii*	Base of the ammonite *Leioceras opalinum* Zone
LO of *Mikrocysta erugata*	Base of the ammonite *Leioceras opalinum* Zone
FO of *Evansia granochagrinata*	50% up the ammonite *Leioceras opalinum* Zone
LO of *Ovalicysta hiata*	50% up the ammonite *Leioceras opalinum* Zone
LO of *Freboldinium serrulatum*	Base of the ammonite *Hyperlioceras discites* Zone
LO of *Mancodinium coalitum*	Base of the ammonite *Hyperlioceras discites* Zone
LO of *Mancodinium semitabulatum*	Base of the ammonite *Hyperlioceras discites* Zone
LO of *Opaeopsomus wapellensis*	Base of the ammonite *Hyperlioceras discites* Zone
LO of *Scriniodinium dictyotum* subsp. *pyrum*	Base of the ammonite *Hyperlioceras discites* Zone
LO of *Valvaeodinium punctatum*	Base of the ammonite *Hyperlioceras discites* Zone
FO of *Freboldinium arcticum*	50% up the ammonite *Sonninia propinquans* Zone
LO of *Scriniocassis priscus*	50% up the ammonite *Sonninia propinquans* Zone
LO of *Mendicodinium reticulatum*	Base of the late Bajocian
LO of *Nannoceratopsis deflandrei* subsp. *senex*	Base of the late Bajocian
LO of *Parvocysta bullula*	Base of the late Bajocian
LO of *Phallocysta elongata*	Base of the late Bajocian
FO of *Evansia evittii*	Base of the ammonite *Zigzagiceras zigzag* Zone

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APPENDIX B: Continued.

FO of *Protobatioladinium elatmaense*	Base of the ammonite *Zigzagiceras zigzag* Zone
FO of *Dichadogonyaulax sellwoodii*	75% up the ammonite *Zigzagiceras zigzag* Zone
FO of *Arkellea teichophera*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Atopodinium prostatum*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Paragonyaulacysta calloviensis*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Paragonyaulacysta retiphragmata*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Rhynchodiniopsis cladophora*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Scriniodinium crystallinum*	Base of the ammonite *Procerites hodsoni* Zone
LO of *Valvaeodinium aquilonium*	Base of the ammonite *Procerites hodsoni* Zone
LO of *Wanaea acollaris*	Base of the ammonite *Procerites hodsoni* Zone
FO of *Lacrymodinium warrenii*	75% up the ammonite *Procerites hodsoni* Zone
FO of *Valensiella dictydia*	75% up the ammonite *Procerites hodsoni* Zone
LO of *Nannoceratopsis gracilis*	75% up the ammonite *Procerites hodsoni* Zone
LO of *Rosswangia holotabulata*	75% up the ammonite *Procerites hodsoni* Zone
FO of *Atopodinium haromense*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Ellipsoidictyum cinctum*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Evansia zabra*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Evansia*? *opeasatos*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Gonyaulacysta jurassica*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Lithodinia jurassica*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Paragonyaulacysta calloviensis*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Paragonyaulacysta retiphragmata*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Pareodinia ceratophora*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Tubotuberella rhombiformis*	Base of the ammonite *Oxycerites orbis* Zone
LO of *Valvaeodinium leneae*	Base of the ammonite *Oxycerites orbis* Zone
LO of *Valvaeodinium spinosum*	Base of the ammonite *Oxycerites orbis* Zone
FO of *Evansia dalei*	Base of the ammonite *Macrocephalites herveyi* Zone
LO of *Protobatioladinium*? *elongatum*	Base of the ammonite *Macrocephalites herveyi* Zone
LO of *Susadinium scrofoides*	Base of the ammonite *Macrocephalites herveyi* Zone
FO of *Ambonosphaera calloviana*	Base of the ammonite *Proplanulites koenigi* Zone
FO of *Meiourogonyaulax planoseptata*	Base of the ammonite *Proplanulites koenigi* Zone
FO of *Pareodinia prolongata*	Base of the ammonite *Proplanulites koenigi* Zone
FO of *Stephanelytron callovianum*	Base of the ammonite *Proplanulites koenigi* Zone
FO of *Cribroperidinium granulatum*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Cribroperidinium*? *perforans* subsp. *kunzeviense*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Endoscrinium galeritum*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Hystrichodinium*? *lanceatum*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Komewuia glabra*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Meiourogonyaulax valensii*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Ovoidinium waltonii*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Paragonyaulacysta*? *borealis*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Rotosphaeropsis thule*	Base of the ammonite *Kosmoceras jason* Zone
FO of *Sentusidinium verrucosum*	Base of the ammonite *Kosmoceras jason* Zone
LO of *Ctenidodinium combazii*	Base of the ammonite *Kosmoceras jason* Zone
LO of *Paragonyaulacysta calloviensis*	Base of the ammonite *Kosmoceras jason* Zone
LO of *Paragonyaulacysta retiphragmata*	Base of the ammonite *Kosmoceras jason* Zone
LO of *Valensiella ovulum*	Base of the ammonite *Kosmoceras jason* Zone
LO of *Dichadogonyaulax sellwoodii*	Base of the ammonite *Erymnoceras coronatum* Zone
FO of *Evansia deflandrei*	Base of the ammonite *Peltoceras athleta* Zone
FO of *Gonyaulacysta jurassica* var. *longicornis*	Base of the ammonite *Peltoceras athleta* Zone
FO of *Wanaea thysanota*	Base of the ammonite *Peltoceras athleta* Zone

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APPENDIX B: Continued.

LO of *Liesbergia liesbergensis*	Base of the ammonite *Peltoceras athleta* Zone
FO of *Trichodinium scarburghense*	Base of the ammonite *Quenstedtoceras lamberti* Zone
LO of *Pareodinia prolongata*	Base of the ammonite *Quenstedtoceras lamberti* Zone
FO of *Gonyaulacysta jurassica* subsp. *desmos*	Base of the ammonite *Quenstedtoceras mariae* Zone
FO of *Wanaea fimbriata*	Base of the ammonite *Quenstedtoceras mariae* Zone
LO of *Ambonosphaera calloviana*	Base of the ammonite *Quenstedtoceras mariae* Zone
LO of *Ctenidodinium continuum*	Base of the ammonite *Quenstedtoceras mariae* Zone
LO of *Meiourogonyaulax planoseptata*	Base of the ammonite *Quenstedtoceras mariae* Zone
LO of *Valensiella dictydia*	Base of the ammonite *Quenstedtoceras mariae* Zone
FO of *Leptodinium mirabile*	50% up the ammonite *Quenstedtoceras mariae* Zone
LO of *Gonyaulacysta dentata*	50% up the ammonite *Quenstedtoceras mariae* Zone
LO of *Limbodinium absidatum*	50% up the ammonite *Quenstedtoceras mariae* Zone
LO of *Wanaea thysanota*	50% up the ammonite *Quenstedtoceras mariae* Zone
FO of *Gonyaulacysta jurassica* subsp. *jurassica*	50% up the ammonite *Cardioceras cordatum* Zone
LO of *Gonyaulacysta jurassica* subsp. *desmos*	Base of the ammonite *Perisphinctes plicatilis* Zone
LO of *Wanaea fimbriata*	Base of the ammonite *Perisphinctes plicatilis* Zone
FO of *Gonyaulacysta dualis*	Base of the ammonite *Perisphinctes pumilus* Zone
FO of *Sentusidinium ringnesiorum*	Base of the ammonite *Perisphinctes pumilus* Zone
LO of *Trichodinium scarburghense*	Base of the ammonite *Perisphinctes pumilus* Zone
FO of *Cribroperidinium globatum*	Base of the ammonite *Perisphinctes cautisnigrae* Zone
LO of *Gonyaulacysta jurassica* var. *longicornis*	Base of the ammonite *Perisphinctes cautisnigrae* Zone
LO of *Rigaudella aemula*	Base of the ammonite *Perisphinctes cautisnigrae* Zone
FO of *Leptodinium subtile*	50% up the ammonite *Perisphinctites cautisnigrae* Zone
FO of *Apteodinium granulatum*	Base of the ammonite *Pictonia baylei* Zone
FO of *Cribroperidinium*? *ehrenbergii*	Base of the ammonite *Pictonia baylei* Zone
FO of *Cribroperidinium*? *perforans* subsp. *perforans*	Base of the ammonite *Pictonia baylei* Zone
FO of *Glossodinium dimorphum*	Base of the ammonite *Pictonia baylei* Zone
FO of *Leptodinium*? *hyalodermopse*	Base of the ammonite *Pictonia baylei* Zone
FO of *Lunatadinium dissolutum*	Base of the ammonite *Pictonia baylei* Zone
FO of *Pareodinia groenlandica*	Base of the ammonite *Pictonia baylei* Zone
FO of *Perisseiasphaeridium pannosum*	Base of the ammonite *Pictonia baylei* Zone
FO of *Pyxidinopsis laminata*	Base of the ammonite *Pictonia baylei* Zone
FO of *Scriniodinium anceps*	Base of the ammonite *Pictonia baylei* Zone
FO of *Sentusidinium capillatum*	Base of the ammonite *Pictonia baylei* Zone
FO of *Tubotuberella egemenii*	Base of the ammonite *Pictonia baylei* Zone
FO of *Wallodinium krutzschii*	Base of the ammonite *Pictonia baylei* Zone
FO of *Wrevittia helicoidea*	Base of the ammonite *Pictonia baylei* Zone
LO of *Apteodinium bucculiatum*	Base of the ammonite *Pictonia baylei* Zone
LO of *Arkellea teichophera*	Base of the ammonite *Pictonia baylei* Zone
LO of *Egmontodinium*? *diminutum*	Base of the ammonite *Pictonia baylei* Zone
LO of *Evansia deflandrei*	Base of the ammonite *Pictonia baylei* Zone
LO of *Evansia evittii*	Base of the ammonite *Pictonia baylei* Zone
LO of *Evansia zabra*	Base of the ammonite *Pictonia baylei* Zone
LO of *Evansia*? *opeasatos*	Base of the ammonite *Pictonia baylei* Zone
LO of *Komewuia glabra*	Base of the ammonite *Pictonia baylei* Zone
LO of *Meiourogonyaulax deflandrei*	Base of the ammonite *Pictonia baylei* Zone
LO of *Scriniodinium crystallinum*	Base of the ammonite *Pictonia baylei* Zone
LO of *Sentusidinium verrucosum*	Base of the ammonite *Pictonia baylei* Zone
LO of *Stephanelytron membranoideum*	Base of the ammonite *Pictonia baylei* Zone
LO of *Nannoceratopsis pellucida*	50% up the ammonite *Pictonia baylei* Zone
FO of *Apteodinium maculatum*	Base of the ammonite *Rasenia cymodoce* Zone

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APPENDIX B: Continued.

FO of *Cribroperidinium jubaris*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Dingodinium jurassicum*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Egmontodinium polyplacophorum*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Epiplosphaera saturnalis*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Gochteodinia mutabilis*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Paragonyaulacysta capillosa*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Protobatioladinium westburiense*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Scriniodinium inritibile*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Stephanelytron membranoideum*	Base of the ammonite *Aulacostephanus mutabilis* Zone
LO of *Cribroperidinium*? *perforans* subsp. *kunzeviense*	Base of the ammonite *Aulacostephanus mutabilis* Zone
LO of *Endoscrinium subvallare*	Base of the ammonite *Aulacostephanus mutabilis* Zone
LO of *Lanterna*? *cantrellii*	Base of the ammonite *Aulacostephanus mutabilis* Zone
LO of *Lithodinia jurassica*	Base of the ammonite *Aulacostephanus mutabilis* Zone
FO of *Cassiculosphaeridia magna*	Base of the ammonite *Aulacostephanus eudoxus* Zone
FO of *Cribroperidinium*? *perforans*	Base of the ammonite *Aulacostephanus eudoxus* Zone
FO of *Oligosphaeridium pulcherrimum*	Base of the ammonite *Aulacostephanus eudoxus* Zone
FO of *Corculodinium inaffectum*	Base of the ammonite *Aulacostephanus autissiodorensis* Zone
FO of *Lanterna bulgarica*	Base of the ammonite *Pectinatites elegans* Zone
FO of *Leptodinium volgense*	Base of the ammonite *Pectinatites elegans* Zone
FO of *Pareodinia asperata*	Base of the ammonite *Pectinatites elegans* Zone
FO of *Dingodinium cerviculum*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Exochosphaeridium scitulum*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Leptodinium deflandrei*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Rhynchodiniopsis pennata*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Stiphrosphaeridium anthophorum*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Tanyosphaeridium isocalamum*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Tubotuberella apatela*	Base of the ammonite *Pectinatites scitulus* Zone
LO of *Pyxidinopsis laminata*	Base of the ammonite *Pectinatites scitulus* Zone
LO of *Sentusidinium ringnesiorum*	Base of the ammonite *Pectinatites scitulus* Zone
FO of *Muderongia simplex*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Gonyaulacysta dualis*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Pareodinia asperata*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Rhynchodiniopsis cladophora*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Scriniodinium dictyotum* subsp. *dictyotum*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Senoniasphaera jurassica*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Tubotuberella dangeardii*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Tubotuberella egemenii*	Base of the ammonite *Pavlovia pallasioides* Zone
LO of *Cribroperidinium granulatum*	Base of the ammonite *Progalbanites albani* Zone
LO of *Cribroperidinium nuciforme*	Base of the ammonite *Progalbanites albani* Zone
LO of *Egmontodinium polyplacophorum*	Base of the ammonite *Progalbanites albani* Zone
LO of *Imbatodinim kondratjevii*	Base of the ammonite *Progalbanites albani* Zone
LO of *Leptodinium deflandrei*	Base of the ammonite *Progalbanites albani* Zone
LO of *Leptodinium volgense*	Base of the ammonite *Progalbanites albani* Zone
LO of *Scriniodinium anceps*	Base of the ammonite *Progalbanites albani* Zone
LO of *Scriniodinium inritibile*	Base of the ammonite *Progalbanites albani* Zone
LO of *Systematophora*? *ovata*	Base of the ammonite *Progalbanites albani* Zone
FO of *Prolixosphaeridiopsis spissa*	Base of the ammonite *Glaucolithites glaucolithus* Zone
LO of *Atopodinium prostatum*	Base of the ammonite *Glaucolithites glaucolithus* Zone
LO of *Cribroperidinium jubaris*	Base of the ammonite *Glaucolithites glaucolithus* Zone
LO of *Glossodinium dimorphum*	Base of the ammonite *Glaucolithites glaucolithus* Zone
LO of *Pareodinia groenlandica*	Base of the ammonite *Glaucolithites glaucolithus* Zone

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APPENDIX B: Continued.

FO of *Leptodinium mamilliferum*	Base of the ammonite *Titanites anguiformis* Zone
FO of *Moesiodinium raileanui*	Base of the ammonite *Titanites anguiformis* Zone
FO of *Trichodinium erinaceoides*	Base of the ammonite *Titanites anguiformis* Zone
LO of *Oligosphaeridium patulum*	Base of the ammonite *Titanites anguiformis* Zone
LO of *Prolixosphaeridium parvispinum*	Base of the ammonite *Paracraspedites oppressus* Zone
FO of *Ctenidodinium*? *schizoblatum*	Base of the ammonite *Subcraspedites primitivus* Zone
FO of *Dichadogonyaulax culmula*	Base of the ammonite *Subcraspedites primitivus* Zone
FO of *Gochteodinia villosa*	Base of the ammonite *Subcraspedites primitivus* Zone
LO of *Cribroperidinium*? *longicorne* LO	Base of the ammonite *Subcraspedites primitivus* Zone
of *Lanterna bulgarica*	Base of the ammonite *Subcraspedites primitivus* Zone
LO of *Rhynchodiniopsis pennata*	Base of the ammonite *Subcraspedites primitivus* Zone

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APPENDIX C: REFERENCE WELLS.

Charts showing palynological analyses of Beechey Point State 1 reference well (onshore northern Alaska) which provides supporting evidence for palynoevent events. The following pages includes three relevant wells that are reproduced from Mangerud *et al.* (2021) which also provide supporting evidence for palynoevent events: Fireweed 1 (offshore northern Alaska), Klondike OCS-Y-1482 (Chukchi Sea), and Romulus C-67 (Sverdrup Basin).

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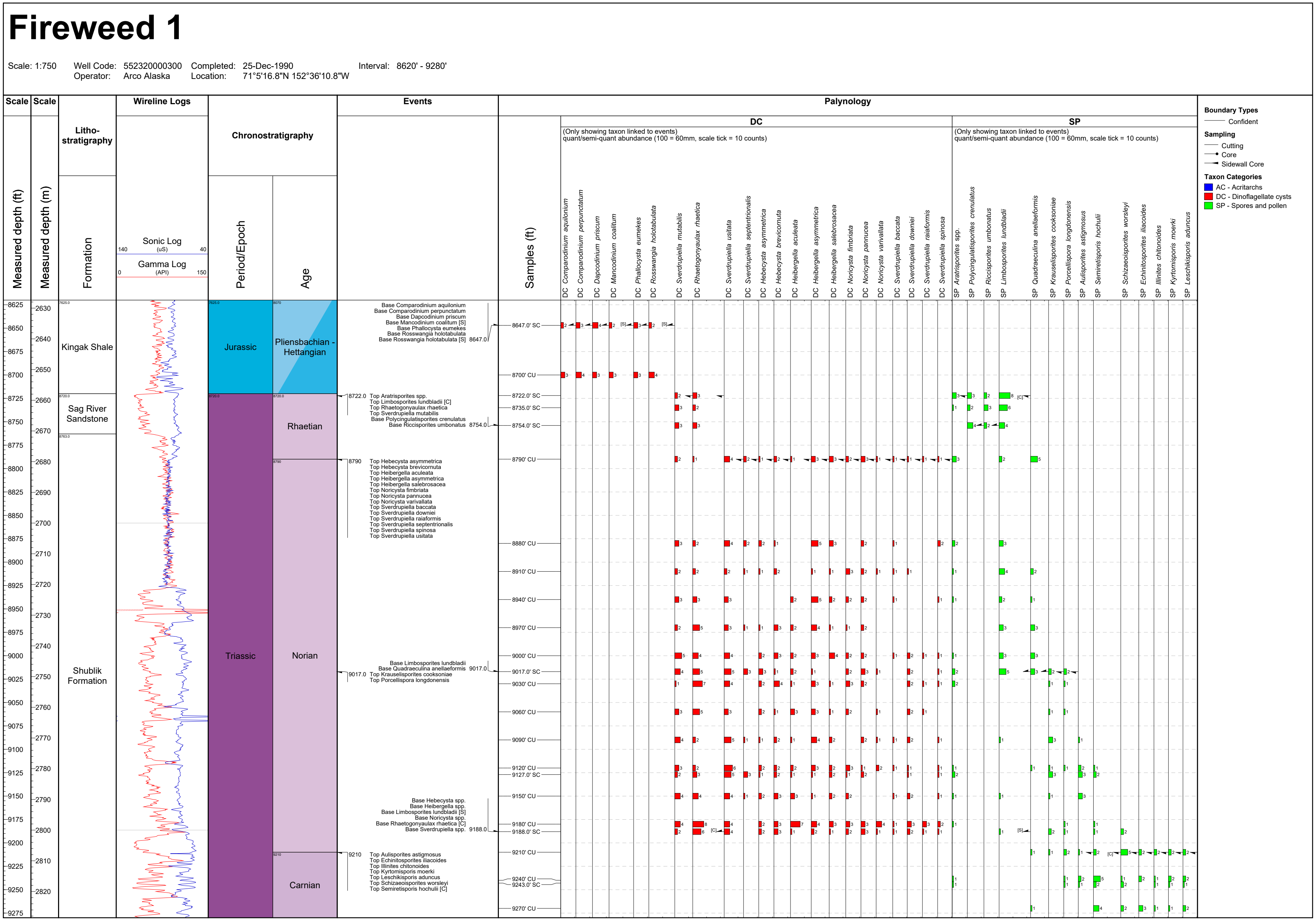
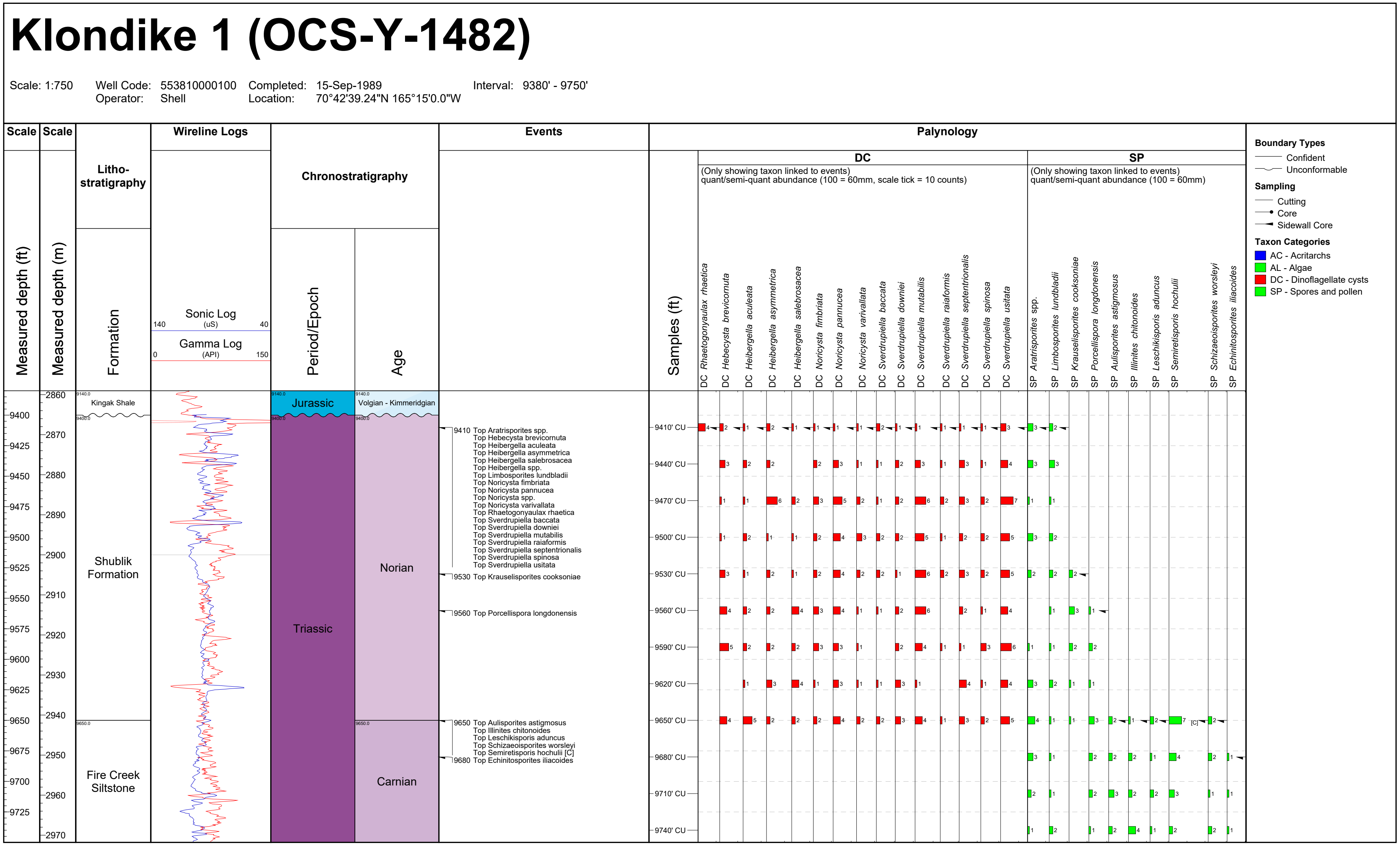


Fireweed 1
Scale: 1:750 Well Code: 552320000300 Completed: 25-Dec-1990 Interval: 8620' - 9280'
Operator: Arco Alaska Location: 71°5'16.8"N 152°36'10.8"W
Scale
Measured depth (ft)
Measured depth (m)
Litho-stratigraphy
Formation
Wireline Logs
Sonic Log 140 (uS) 40
Gamma Log 0 (API) 150
Chronostratigraphy
Period/Epoch
Age
Events
Palynology
Samples (ft)
DC
(Only showing taxon linked to events) quant/semi-quant abundance (100 = 60mm, scale tick = 10 counts)
SP
(Only showing taxon linked to events) quant/semi-quant abundance (100 = 60mm, scale tick = 10 counts)
Kingak Shale
Sag River Sandstone
Shublik Formation
Jurassic
Triassic
Pliensbachian - Hettangian
Rhaetian
Norian
Carnian
Base Comparodinium aquilonium
Base Comparodinium perpunctatum
Base Dapcodinium priscum
Base Mancodinium coalitum [S]
Base Phallocysta eumekes
Base Rosswangia holotabulata
Base Rosswangia holotabulata [S] 8647.0
8722.0 Top Aratrisporites spp.
Top Limbosporites lundbladii [C]
Top Rhaetogonyaulax rhaetica
Top Sverdrupiella mutabilis
Base Polycingulatisporites crenulatus
Base Riccisporites umbonatus 8754.0
8790 Top Hebecysta asymmetrica
Top Hebecysta brevicornuta
Top Heibergella aculeata
Top Heibergella asymmetrica
Top Heibergella salebrosacea
Top Noricysta fimbriata
Top Noricysta pannucea
Top Noricysta varivallata
Top Sverdrupiella baccata
Top Sverdrupiella downiei
Top Sverdrupiella raiaformis
Top Sverdrupiella septentrionalis
Top Sverdrupiella spinosa
Top Sverdrupiella usitata
Base Limbosporites lundbladii
Base Quadraeculina anellaeformis 9017.0
9017.0 Top Krauselisporites cooksoniae
Top Porcellispora longdonensis
Base Hebecysta spp.
Base Heibergella spp.
Base Limbosporites lundbladii [C]
Base Noricysta spp.
Base Rhaetogonyaulax rhaetica [C]
Base Sverdrupiella spp. 9188.0
9210 Top Aulisporites astigmosus
Top Echinitosporites iliacoides
Top Illinites chitonoides
Top Kyrtomisporis moerki
Top Leschikisporis aduncus
Top Schizaeoisporites worsleyi
Top Semiretisporis hochulii [C]
8647.0' SC
8700' CU
8722.0' SC
8735.0' SC
8754.0' SC
8790' CU
8880' CU
8910' CU
8940' CU
8970' CU
9000' CU
9017.0' SC
9030' CU
9060' CU
9090' CU
9120' CU
9127.0' SC
9150' CU
9180' CU
9188.0' SC
9210' CU
9240' CU
9243.0' SC
9270' CU
DC Comparodinium aquilonium
DC Comparodinium perpunctatum
DC Dapcodinium priscum
DC Mancodinium coalitum
DC Phallocysta eumekes
DC Rosswangia holotabulata
DC Sverdrupiella mutabilis
DC Rhaetogonyaulax rhaetica
DC Sverdrupiella usitata
DC Sverdrupiella septentrionalis
DC Hebecysta asymmetrica
DC Hebecysta brevicornuta
DC Heibergella aculeata
DC Heibergella asymmetrica
DC Heibergella salebrosacea
DC Noricysta fimbriata
DC Noricysta pannucea
DC Noricysta varivallata
DC Sverdrupiella baccata
DC Sverdrupiella downiei
DC Sverdrupiella raiaformis
DC Sverdrupiella spinosa
SP Aratrisporites spp.
SP Polycingulatisporites crenulatus
SP Riccisporites umbonatus
SP Limbosporites lundbladii
SP Quadraeculina anellaeformis
SP Krauselisporites cooksoniae
SP Porcellispora longdonensis
SP Aulisporites astigmosus
SP Semiretisporis hochulii
SP Schizaeoisporites worsleyi
SP Echinitosporites iliacoides
SP Illinites chitonoides
SP Kyrtomisporis moerki
SP Leschikisporis aduncus
Boundary Types
Confident
Sampling
Cutting
Core
Sidewall Core
Taxon Categories
AC - Acritarchs
DC - Dinoflagellate cysts
SP - Spores and pollen



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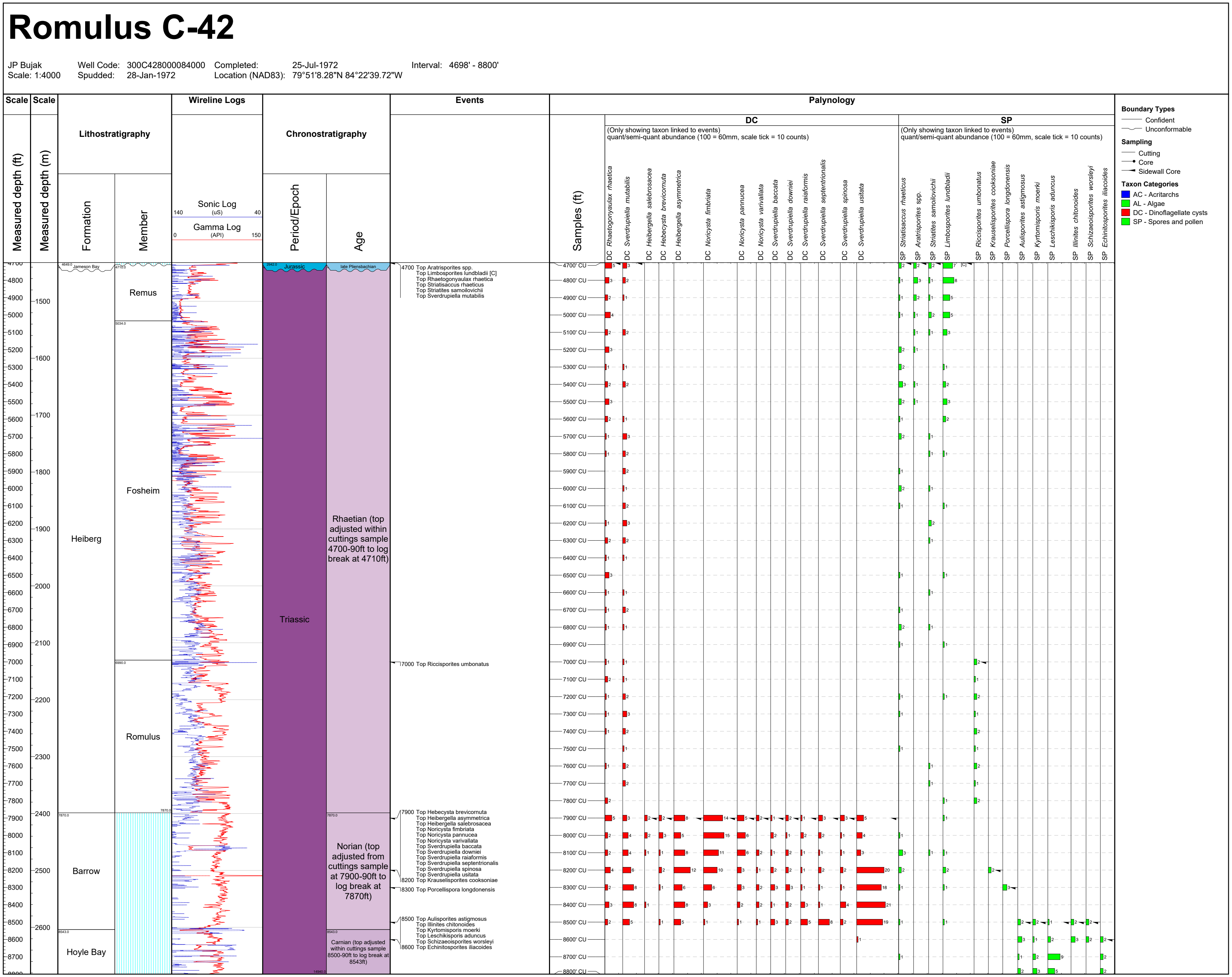

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