BioOne COMPLETE

Ammonite Faunal Dynamics Across Bio-Events During the Mid-and Late Cretaceous Along the Russian Pacific Coast

Author: Jagt-Yazykova, Elena A.

Source: Acta Palaeontologica Polonica, 57(4) : 737-748

Published By: Institute of Paleobiology, Polish Academy of Sciences

URL: https://doi.org/10.4202/app.2011.0076

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Ammonite faunal dynamics across bio-events during the mid- and Late Cretaceous along the Russian Pacific coast

ELENA A. JAGT-YAZYKOVA



Jagt-Yazykova, E.A. 2012. Ammonite faunal dynamics across bio-events during the mid- and Late Cretaceous along the Russian Pacific coast. *Acta Palaeontologica Polonica* 57 (4): 737–748.

The present paper focuses on the evolutionary dynamics of ammonites from sections along the Russian Pacific coast during the mid- and Late Cretaceous. Changes in ammonite diversity (i.e., disappearance [extinction or emigration], appearance [origination or immigration], and total number of species present) constitute the basis for the identification of the main bio-events. The regional diversity curve reflects all global mass extinctions, faunal turnovers, and radiations. In the case of the Pacific coastal regions, such bio-events (which are comparatively easily recognised and have been described in detail), rather than first or last appearance datums of index species, should be used for global correlation. This is because of the high degree of endemism and provinciality of Cretaceous macrofaunas from the Pacific region in general and of ammonites in particular.

Key words: Ammonoidea, evolution, bio-events, Cretaceous, Far East Russia, Pacific.

Elena A. Jagt-Yazykova [eyazykova@uni.opole.pl], Zakład Paleobiologii, Katedra Biosystematyki, Uniwersytet Opolski, ul. Oleska 22, PL-45-052 Opole, Poland.

Received 9 July 2011, accepted 6 March 2012, available online 8 March 2012.

Copyright © 2012 E.A. Jagt-Yazykova. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Cretaceous marine strata are widely distributed along the Russian Pacific coast (Fig. 1), reaching a total thickness of circa 10 km and yielding comparatively diverse macrofaunal assemblages. The emphasis in the present paper is on bio-events and a few notes on palaeoecological and palaeogeographical aspects of ammonite evolution are added for the upper Albian to uppermost Maastrichtian interval, the average thickness of which varies between 4000 and 7000 m (Vereschagin et al. 1965; Poyarkova 1987; Yazykova 2004; Zonova 2004).

A major obstacle encountered in correlations with the type areas (most of them in western Europe) of the various mid- and Late Cretaceous stages is the high degree of faunal endemicity, which characterises Pacific Cretaceous faunas in general and Late Cretaceous ones in particular (Yazykova 2004; Jagt-Yazykova 2011). This explains why most of the recently proposed criteria for the recognition of stage boundaries in the type localities cannot be applied in the study area. However, it has been demonstrated that general trends of ammonite evolution in the boreal Pacific are the same as elsewhere (Yazykova 1996, 2002, 2004; Jagt-Yazykova 2011). From bio-event to bio-event, and/or from zone to zone, overall changes in ammonite morphotypes and ecosystems are comparable to those observed in other regions, and this can be assumed to be so because the organic world is largely dependent of the global rules, which govern local environments. I support the general view that unrelated taxa with similar life habits and occurrences tend to be of a comparable morphotype, while species with a wide range of intraspecific variation, either throughout ontogeny or in the adult stage, have shell features, which reflect diverse modes of life or environments inhabited. Recently, Paul and Lamolda (2009) have argued that bio-events based on first or last appearance datums (FADs, LADs) occasionally may not be recognisable in all sections, not even within the same area, particularly when these events are based on a single taxon. In addition, whenever recognisable, they may turn out to be diachronous. Thus, morphotypes, rather than taxonomic designation, should be used for correlations because relationships between shell shapes and environments appear to be species independent (Batt 1989, 1993). Certainly, all results presented here are based on the study of adult individuals; larvae or juvenile forms were nektoplanktonic and lived elsewhere in the photic and neritic shallow zones (50–250 m; see Westermann 1989, 1996). Changes in ammonite diversity, viz. disappearance (extinction or emigration), appearance (origination or immigration) and total number of species (see Fig. 2), constitute the basis for the identification of the main bio-events.

All published data on ammonite taxa from the Albian to

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use



Fig. 1. Distribution of Cretaceous deposits in Far East Russia.

Maastrichtian of areas along the Russian Pacific coast (Sakhalin, Shikotan Island, Chukotka and Kamchatka peninsulas, the Koryak Upland, Sikhote Alin and Primorye; see Fig. 1), have recently been critically re-evaluated (Jagt-Yazykova 2011). In total, 200 species, inclusive of specifically indeterminate taxa, denoted with "sp.", "cf.", "aff.", have been accepted for this area, distributed over ninety genera, twenty-two families and twenty-seven subfamilies (Jagt-Yazykova 2011). A revised biostratigraphical framework, based on ammonites, inoceramid bivalves and radiolarians, has also been proposed previously for Far East Russia (mainly Sakhalin, Shikotan, and Sikhote Alin; Yazykova 2004; Jagt-Yazykova 2011), using data supplied by Russian and Japanese colleagues. In addition, the interrelationship between ammonite evolution and environmental changes in palaeobasins along the Russian Pacific coast, local bio-events, links with lithofacies types, hypothetical phylogenetic links, plus selected examples of homoeomorphy have lately been discussed in detail (Jagt-Yazykova 2011). The present paper focuses on the evolutionary dynamics of ammonites from sections along the Russian Pacific coast during the mid- and Late Cretaceous.

Abbreviations.—OAE, Oxygen Anoxic Event.

Discussion

The late Albian migration bio-event.—Strata of late Albian age are comparatively widely distributed in all regions of the Russian Pacific, i.e., Sakhalin Island, the Sikhote Alin Mountains and in the Amur River valley, as well as in the northeasterly areas such as the Chukotka Peninsula, the Koryak Upland, and Penzhyna Gulf coast of the Kamchatka Peninsula (Fig. 1), the average thickness being between 700 and 1000 m. The general diversity amongst Russian Pacific Cretaceous ammonites is highest during the late Albian (Fig. 2), the greatest taxonomic diversity being noted amongst desmoceratids and kossmaticeratids (compare Jagt-Yazykova 2011: fig. 7). In consideration of palaeobiogeographical aspects and the taxonomically mixed composition of macrofaunal assemblages recorded, this might be interpreted as a migration bio-event, possibly correlative with similar levels elsewhere, e.g., northern California (Amédro and Robaszynski 2005), where successions yielded both Tethyan ammonites (for example, *Oxytropidoceras* and *Lyelliceras*) and Boreal taxa such as *Gastroplites* and *Pseudopulchellia*. Those authors discussed possible ammonite-based correlations between Albian sequences of northern California and the European and Arctic provinces and concluded that the stratigraphic distribution of non-endemic Albian ammonites in northern California and Europe was controlled largely by global eustatic events. In addition, they showed some possible ways of migration for endemic forms.

Macrofaunal complexes from the Russian Pacific area are characterised by similar patterns. The comparatively shallow Lower Cretaceous basins of central-northeast Russia were inhabited by numerous representatives of different bivalve groups (mainly Aucellidae, Inoceramidae, and Pectinidae) and some brachiopods (Vereschagin et al. 1965). In contrast to the numerous bivalves, ammonites are rather uncommon but represented by taxa originating from different palaeobiogeographic realms. The southern end of the vast Russian Pacific area (Amur River valley and Sikhote Alin Mountains) was also inhabited by numerous non-inoceramid bivalves and the first genuine *Inoceramus* (see Krymholz 1938; Zonova 1982; Sey et al. 2004), which were commoner than ammonites. Recently, a European cirripede, *Pycnolepas* aff. *rigida* (Sowerby, 1836), has been recorded from Primorye (Jagt et al. 2007). The Albian ammonite assemblage also has a mixed taxonomic composition, in showing both Tethyan and Boreal genera and endemic species. For example, finds of the European (Boreal) *Anahoplites* sp. and *Sonneratia* sp. can only be explained by immigration of these taxa via the Arctic. The former is confined to Sakhalin (Zhuravlev 1969), while the latter has been noted in Sakhalin, Primorye, and northeast Russia (Vereschagin et al. 1965). Members of the genus *Sonneratia* have also been described from Arctic Canada (Jeletzky 1964), as well as from California and Oregon (Anderson 1938; Jones et al. 1965), but comprise exclusively endemic species, which supports the notion of larvae and/or juveniles being taken across the Arctic by favourable cur-

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

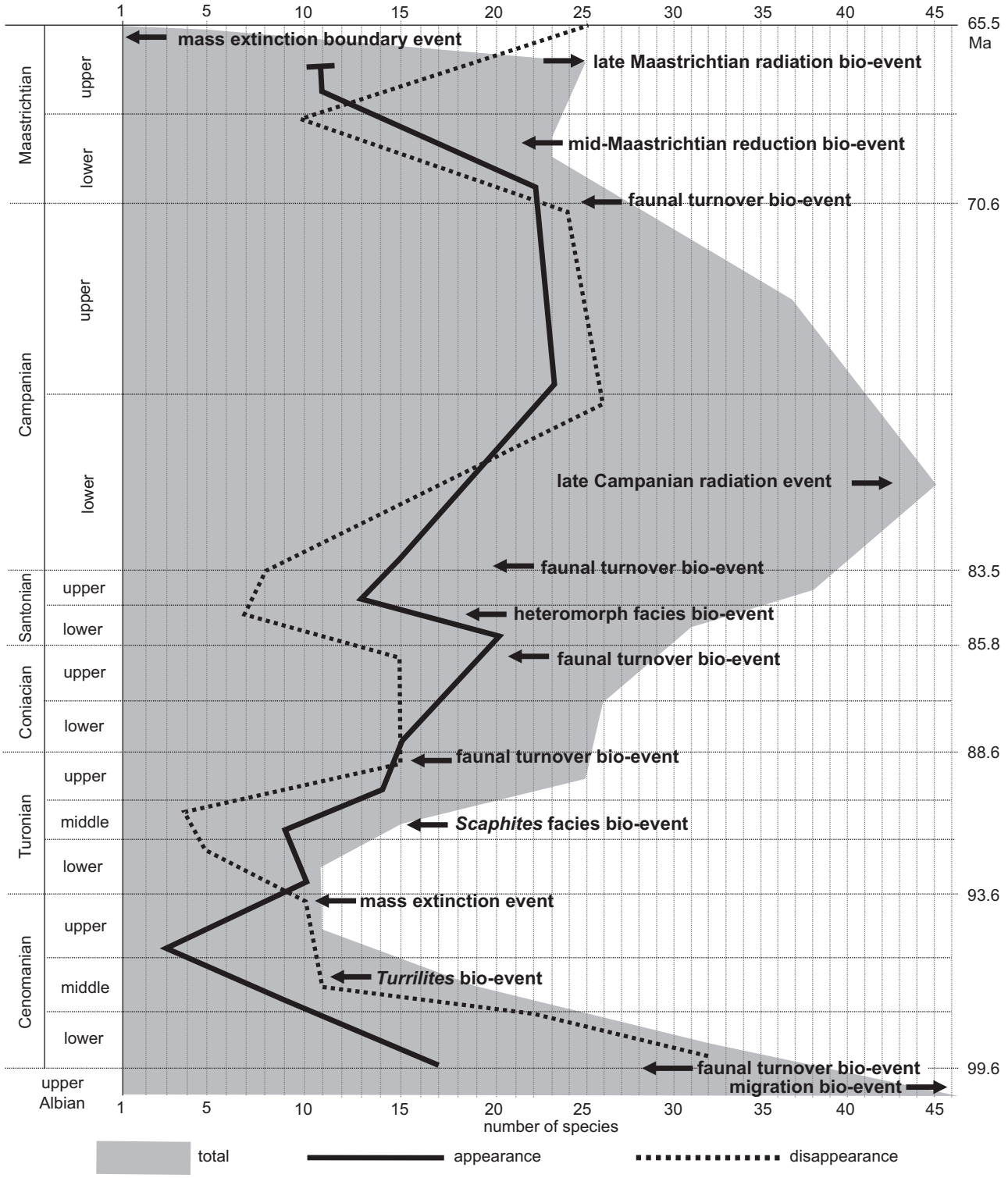


Fig. 2. Changes in Cretaceous ammonite diversity in Far East Russia: disappearance, appearance, and total number of species recorded.

rents which ultimately led to the establishment of a convergent lineage of this European genus. Representatives of *Anahoplites* and *Sonneratia* from the Russian Pacific may either belong to some new endemic species or are conspecific with those described from Arctic Canada, California, or Oregon. Similar patterns are represented by desmoceratids. Out of the ten desmoceratid taxa recorded from here only a single, truly cosmopolitan taxon is known from Albian levels, namely *Puzosia* cf. *lata* (Seitz, 1931) found in Sikhote Alin (Yazykova 2001). All remaining taxa are true endemics.

The mixed character of ammonite assemblages is a feature that characterises the late Albian time slice in the Pacific realm in general. Some typically Boreal taxa such as *Arcthoplites* (*Subarcthoplites*), *Phyllopachyceras*, *Parasilesites*, *Marshal-*

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

lites, and *Eogunnarites* from the Koryak-Kamchatka palaeobasin migrated to the south using favourable currents and later were widely distributed in Sakhalin and Japan (Matsumoto 1991). Some isolated representatives of *Marshallites* probably migrated during the Turonian–Coniacian even to the African-Indian province and later possibly continued southeasterly, towards New Zealand (compare Kennedy and Klinger 1985).

Amongst others, an interesting case is the appearance of the cosmopolitan *Eogaudryceras* (*Eotetragonites*) *duvalianus* (d'Orbigny, 1840) and a single lytoceratoid, *Protetragonites* cf. *aeolus aeolus* d'Orbigny, 1850. Both can be considered to have been good swimmers, because the occurrence in the Pacific of these European taxa cannot be explained otherwise. The former is known also from the Aptian–lower Albian of the northern Caucasus (Dagestan) (Kasansky 1914; Druschic and Mikhailova 1963). *Protetragonites aeolus aeliformis* Fallot, 1885, recorded from the Aptian of Spain (López Garrido and Orozco 1970), is similar to *P. aeolus aeolus* and *P.* ex gr. *aeolus* was recorded from the lower Albian of the western Carpathians in Slovakia (Potfaj et al. 2008). Thus, during the Cretaceous the territory of Far East Russia belonged to a marginal shelf continental sea, and during the Albian maximum flooding occurred as a result of global transgression. The deepest basin is likely to be found in Sakhalin. Here, probably poorly oxygenated, yet not completely anoxic, conditions prevailed, while northeasterly regions were characterised by warm, well-oxygenated waters. The Sikhote Alin palaeobasin appears to have been comparatively shallow and well-oxygenated. This could explain the mixed character of taxonomic composition and the absence or very low numbers of juvenile forms, because most forms probably appeared here after long-distance transport with favourable currents via the Arctic and/or via Tethys, that is, successful dispersal, but without subsequent speciation.

In conclusion, the late Albian migration event recorded in the sections of Russian Pacific coast could be linked to the middle–late Albian bio-event (Fig. 4) that has been recorded from North America, Europe, India, and North Africa, and which is characterised by short-term extinctions among ammonite genera and species, especially in northern temperate faunas (e.g., *Gastroplites*, *Pseudopulchellia*) and warm-temperate subtropical taxa (e.g., *Oxytropidoceras* and *Lyelliceras*) connected with OAE1b and OAE1c (Barnes et al. 1995). Thus, those ammonites which disappeared in the regions mentioned could have migrated into more marginal areas such as California, northeast Russia, Sakhalin, and Sikhote Alin during the late Albian.

Albian–Cenomanian faunal turnover bio-event.—The late Albian anoxic-event OAE1d has been recorded in many sections of the Pacific realm (Hirano and Takagi 1995; Hasegawa 1997; Hirano and Fukuju 1997; and others). This was followed by global regression, as a result of global tectonic reconstruction and environmental changes. In turn, this again triggered changes in biodiversity at the Lower–Upper Cretaceous boundary. Some families and subfamilies disappeared altogether (i.e., Cleoniceratidae, Silesitoidinae, Beudanticeratinae, Sonneratiinae; see Wright et al. 1996). Almost all Albian ammonite taxa known from northwest Pacific provinces became extinct, except for a few species, which survived these crises but did not persist longer than the early Cenomanian. These survival taxa are best seen as failed crisis progenitor species (Kauffman and Erwin 1995; Harries and Little 1999), which did not appear until the latest Albian, and already were better adapted to changing environmental conditions. In short, changes which took place during the latest Albian to the earliest Cenomanian are best considered to illustrate a global faunal turnover bio-event.

The most drastic changes occurred in Sikhote Alin and Amur River basin. During the early Cenomanian, this basin became shallower and gradually disappeared as a result of plate tectonic movements and high volcanic activity which started in the mid-Albian (Kirillova et al. 2000). This explains why ammonite assemblages of early Cenomanian age here comprise only few survival forms, such as *Puzosia* and *Desmoceras* (*Pseudouhligella*) and the heteromorph *Mariella*. This was a small, shallow-water basin which existed only until the end of the Cenomanian, when it disappeared altogether.

However, the new early Cenomanian transgression allowed the entry of immigrant species into the Pacific region, such as *Phylloceras* (*Neophylloceras*) *seresitense* Pervinquière, 1907; *Anagaudryceras buddha* (Forbes, 1846); *Parapuzosia* (*Austiniceras*) *austeni* (Sharpe, 1855); *Mantelliceras* sp.; and *Acanthoceras* sp. These taxa probably originated from the Tethys and migrated into Sakhalin and northeast Russia. In those areas diverse micro- and macrofaunal complexes existed, in which endemics predominated. The Cenomanian shelf sea of southern Sakhalin was inhabited by representatives of sixteen genera, some of which appeared here for the first time. Cenomanian deposits of northeast Russia have yielded ammonite associations comprising thirteen genera. In taxonomic composition these are similar to those in Sakhalin, and involve mostly new taxa.

Two remarkable global bio-events can be recognised in the early Cenomanian: the taxonomic bloom of the Kossmaticeratidae (seven new genera appearing) and the entry of the family Acanthoceratidae (Wright et al. 1996). In Far East Russia, the former family was represented by ten species of two genera, *Marshallites* and *Mikasaites*, while the latter comprised four genera/subgenera, *Mantelliceras*, *Calycoceras* (*Calycoceras*), *C.* (*Newboldiceras*), and *Acanthoceras*. However, in view of the fact that all of these acanthoceratids are represented only by few examples, they probably were poorly adapted to the Pacific setting, which was likely cooler than the Tethyan realm. Only few of these taxa have been found along the Russian Pacific coast and some are known from Japan (Jimbô 1894; Matsumoto 1943; Shigeta 2001; Matsumoto and Toshimitsu 2005). Meanwhile, the Cenomanian of Western Interior of North America, as well as the European, Mediterranean, and African-Indian provinces is characterised by high diversity levels of the family Acanthoceratidae (e.g., Wright

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

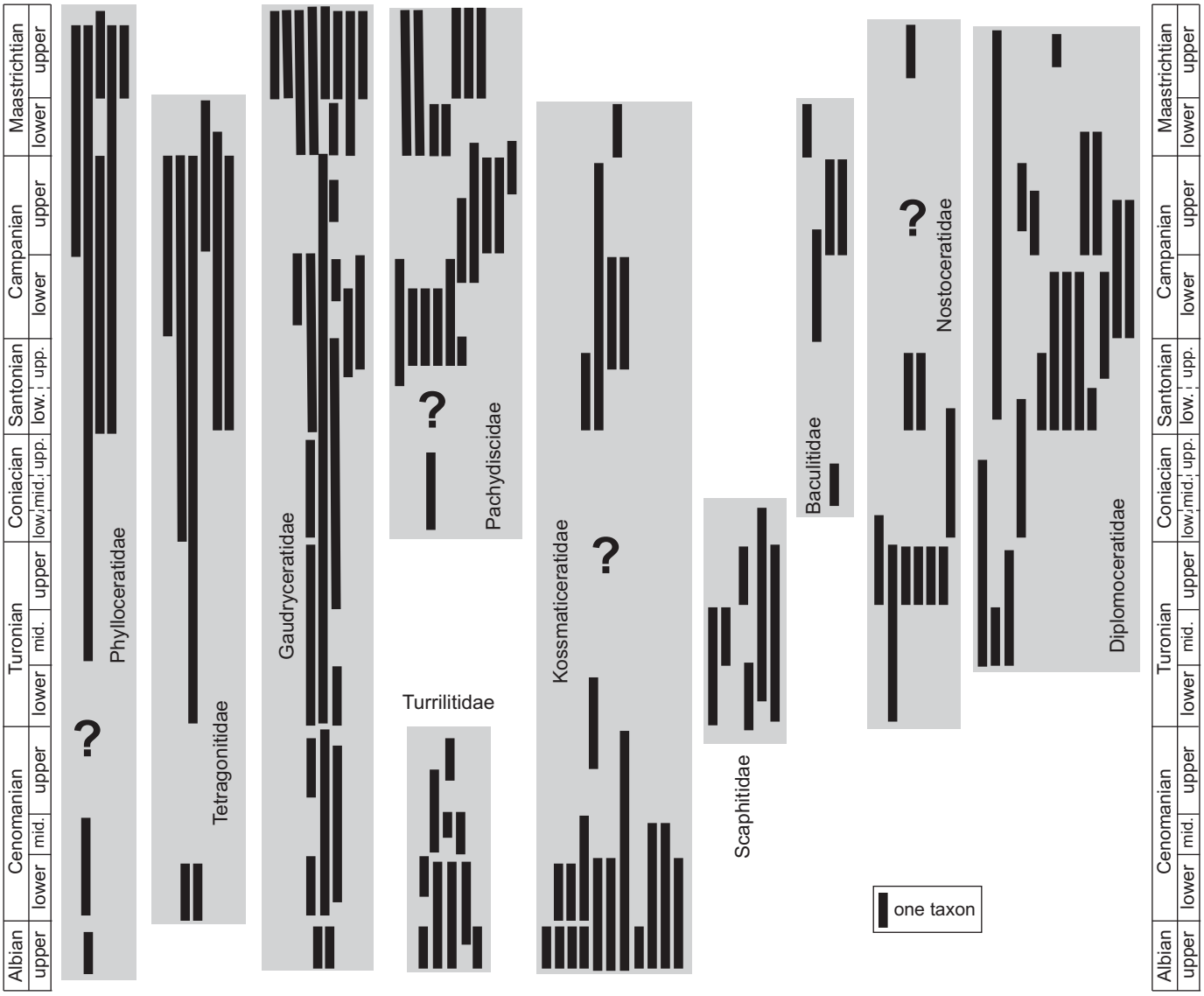


Fig. 3. Changes in the number of Cretaceous ammonite species from Far East Russia, arranged in the ten most speciose families: non-heteromorphs (Phylloceratidae, Tetragonitidae, Gaudryceratidae, Pachydiscidae, Kossmaticeratidae) and heteromorphs (Scaphitidae, Baculitidae, Turrilitidae, Nostoceratidae, Diplomoceratidae). Abbreviations: low., lower; mid., middle; up., upper.

and Kennedy 1990; Kennedy 1994; Kennedy et al. 1996; Arkadiev et al. 2000).

In summary, all but two Albian taxa disappeared at the Albian–Cenomanian boundary interval in the Russian Pacific. A short-term, global turnover in marine biota following OAE1d (Barnes et al. 1995) is characteristic of this level in many regions of the world (Fig. 3), inclusive of the Pacific as outlined above. The disappearance of Albian forms and the first occurrence of new species and even genera, as well as of new morphotypes amongst ammonites and inoceramids, is also typical of this boundary in the Pacific Realm.

Mid-Cenomanian *Turrilites* bio-event.—Representatives of *Turrilites costatus* and *T. acutus* are known from middle and upper middle Cenomanian deposits (Fig. 2) of Sakhalin Island and the Penzhyna Gulf coast, respectively, as well as from the Koryak Upland (Vereschagin et al. 1965; Terekhova and Mikhajlova 1977) and Japan (Hayakawa and Nishino 1999; Shigeta 2001; Matsumoto and Takahashi 2001). These two levels could possibly be correlated (Fig. 3) with the so-called mid-Cenomanian Regressive Trough (*Turrilites costatus* event) and the mid-Cenomanian eustatic low (*T. acutus* records), respectively (Hancock 2003). This eustatic lowstand has been recorded from northwest Europe, western Kazakhstan, Texas, Colorado, and South Dakota. Monnet and Bucher (2007) proposed the last occurrence of *T. acutus* as a marker for the middle–late Cenomanian boundary since that species was abundant and widely distributed. This marker is useful in Sakhalin as well as in northeasterly regions of Russia.

Cenomanian–Turonian mass extinction event.—The Cenomanian–Turonian boundary mass extinction is reflected in drop of diversity curves for all biotic groups, both at the generic and specific level. Some ammonite families and subfamilies

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

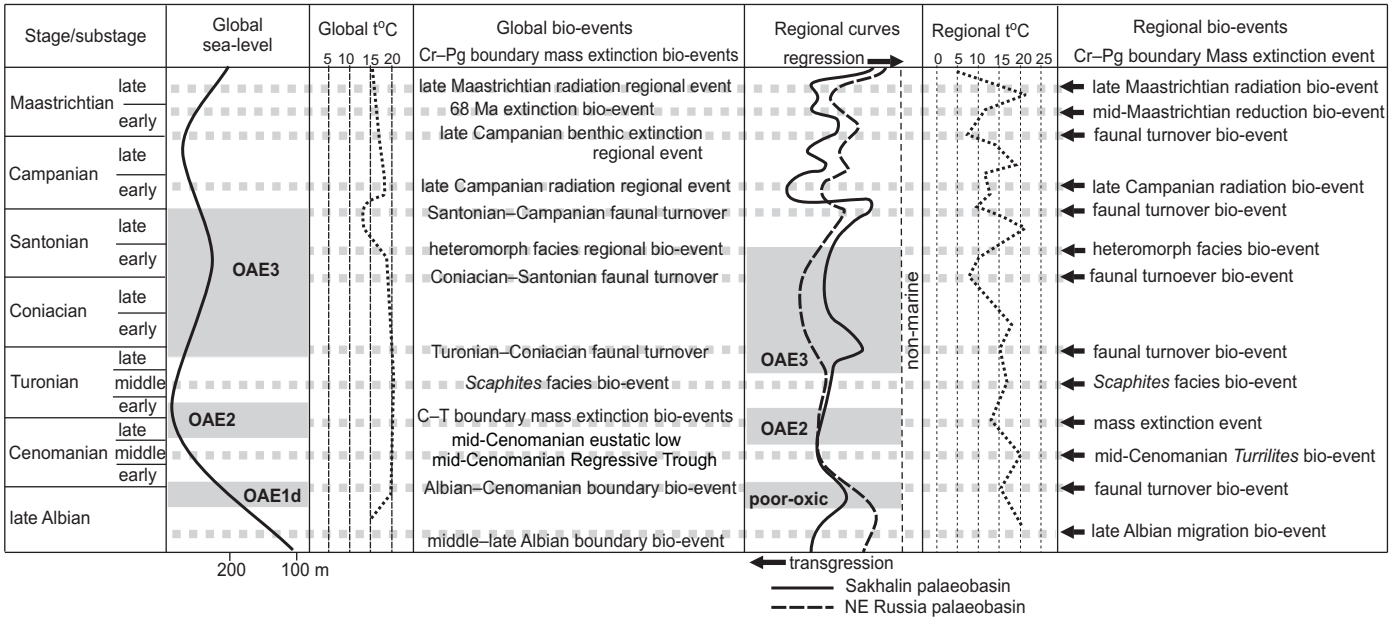


Fig. 4. Regional bio-events recorded in ammonite assemblages from Far East Russian regions (present paper); regional palaeotemperature curves modified after Zakharov et al. (1998, 1999, 2005); generalised scheme of records of transgression and regression from Sakhalin and northeast Russia; global bio-events (Kauffmann and Hart 1995); global sea level curves by Haq et al. (1987); global palaeotemperature curves by Skelton (2003). Stages are shown without calibration to absolute time. Abbreviations: C–T, Cenomanian–Turonian boundary; Cr–Pg, Cretaceous Paleogene boundary; OAE, Oxygen Anoxic Event.

disappeared altogether, for example, the Turrilitidae, Acanthoceratinae, and Lyelliceratidae (Wright et al. 1996). The late Cenomanian OAE2 event (Barnes et al. 1995; Hirano and Takagi 1995; Hasegawa 1997) was possibly the main trigger to the extirpation of many Cenomanian faunal elements near globally. In the Russian Pacific not a single Cenomanian taxon survived this crisis. Global correlation is based on OAE2 and the appearance of the ammonite genera *Fagesia* and *Jimboiceras*, as well as the inoceramid *Mytiloides*, and the appearance of new ammonite morphotypes in general. The global mid-Cenomanian–Turonian transgression has also been recorded in the entire Far East Russia and is reflected in relatively deep-water sedimentation. Anoxic conditions connected with strong active volcanism are reflected in the presence of mudstone interbedded with black, grey and green tuffaceous sandstone and siltstone as well as bentonitic clay. This "coloured" interval is barren of fossils (probably as a result of dysoxic conditions, as well as volcanic fallout) and generally reaches a thickness of some 40-50 m in Sakhalin (see also Yazykova et al. 2004) as well as in northeast Russia (EAJ-Y unpublished data).

The early Turonian survival interval is characterised by the gradual appearance of new ammonite genera. Later, following a radiation event recorded in the mid-Turonian, the general diversity of ammonites reached a maximum during the late Turonian. Moreover, because of a highstand, some taxonomic unification appeared in the Pacific and, apart from a few taxa, ammonite compositions in northeast Russia and Sakhalin are almost identical and still predominantly endemic to the western Pacific.

The mid-Turonian *Scaphites* facies bio-event.—A wide distribution of heteromorph ammonites (e.g., the *Scaphites* facies) during the late early–middle Turonian has been recorded from numerous regions in the world, occurring at the same level (Tanabe 1979; Kaplan et al. 1987; Hirano et al. 2000). In Far East Russia, numerous representatives of the family Scaphitidae co-occur with endemic species of the genera *Scalarites* and *Hyphantoceras* (Vereschagin et al. 1965; Mirolubov in Poyarkova 1987; Zonova and Yazykova 1998; Yazykova et al. 2004). The *Scaphites* facies is one of the best correlative levels across the globe. However, all scaphitids are represented in Far East Russia by exclusively endemic species of two genera, *Yezoites* and *Scaphites*, similar to California (Matsumoto 1959). It seems that the appearance of heteromorph genus *Scalarites* would be a good marker for the early–middle Turonian boundary, coupled with *Scaphites* facies in spite of the endemic character of this assemblage.

The middle–late Turonian boundary bio-event.—The regression which began at the middle–late Turonian boundary in Russian Pacific basins is marked by the appearance of coarsely ornamented ammonites and heteromorphs (Vereschagin et al. 1965; Mirolubov in Poyarkova 1987; Zonova and Yazykova 1998; Yazykova et al. 2004), indicative of relatively shallow waters (Tanabe 1979; Westermann 1996). Heteromorphs are numerous (the new western north Pacific endemic genus *Nipponites*), alongside gaudryceratids, tetragonitids, phylloceratids, and acanthoceratids (*R.* [*Romaniceras*], *R.* [*Yubariceras*], *Kamerunoceras*, and *Pseudaspidoceras*). Desmoceratids such as *Puzosia* (*Mesopuzosia* and *Pachydesmoceras*), the cosmopolitan vascoceratid genus *Fagesia* and *Tragodesmoceroides subcostatus* predominated the entire sublittoral basin of the West Sakhalin Mountains, which was warm (15.8–17.5°C according to Zakharov et al. 1999),

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

and about 150–200 m deep. This interpretation is supported also by single representatives of hexacorals and thin carbonate layers (Poyarkova 1987), which is absolutely atypical for this area. New ammonite taxa gradually appeared in the late Turonian: heteromorphs (*Nostoceras* [*Eubostrychoceras*] and *Hyphantoceras*), as well as *Damesites* and *Hourcquia*, and rare *Subprionocyclus*. There were diversity and abundance peaks in the late Turonian (Fig. 2) illustrating favourable conditions in these areas.

The Turonian–Coniacian faunal turnover bio-event.—The Turonian–Coniacian boundary faunal turnover bio-event in Far East Russia was marked by the entry of new ammonite and inoceramid morphotypes with a slight reduction in taxonomic diversity (Zonova and Yazykova 1998). This was a comparatively stable period, interrupted only by local sea level changes and a minimum of volcanic activity.

However, some sections display a huge thickness of Turonian strata, in excess of 1000 m, but in northeast Russia, the basin was shallower than in Sakhalin as evidenced by prevalent deposition of sandstone there. The base of the Coniacian has been defined by the last appearance of *Jimboiceras planulatiforme* (Jimbô, 1894) with thin ribs and an evolute shell shape, and the entry of *J. mihoense* Matsumoto, 1954 with coarse ribs, as well as by the first occurrence of *Anagaudryceras politissimum* (Kossmat, 1895) and *Gaudryceras denseplicatum* Jimbô, 1894. *Jimboiceras mihoense*, *A. politissimum*, and *G. denseplicatum* demonstrate the appearance of new morphotypes as a result of adaptation within their phylogenetic lineages to new ecological conditions, demanding thicker shells and coarse ornament characteristic of higher-energy environments. The appearance of small-sized inoceramids (*Inoceramus uwajimensis* Yehara, 1924; see Zonova and Yazykova 1998) supports this interpretation because later representatives of the *Inoceramus uwajimensis* group reach larger sizes and co-occur with numerous *Inoceramus mihoensis* Matsumoto, 1957 and *Jimboiceras mihoensis.* The ammonite *Forresteria* (*F.*) *alluaudi* (Boule, Lemoine, and Thevenin, 1907) was found at the same level which marks the onset of a new transgression, which is supported by other immigrant species in the latest Coniacian, namely *Peroniceras* sp. and *Binneyites* (?) sp. Thus, the appearance of coarser ornament and the abundance of heteromorphs (*Yezoites*, *Scalarites*, and *P.* (*Pseudoxybeloceras*)), as well as the first pachydiscid here, *Menuites* (*Anapachydiscus*), might be indicative of a relatively shallow-water basin with high energy, which would correspond to a lowstand period.

Approximately at the early–late Coniacian boundary, another radiation of new species of the heteromorph ammonite genera *Scaphites*, *Scalarites*, and *Nipponites* is noted, and, in total, the taxonomic diversity increased (Fig. 2). Probably this bio-event could be put forward to characterise the early–late Coniacian boundary, after it has been properly documented from other regions.

The Coniacian–Santonian faunal turnover bio-event.—Zakharov et al. (2005) assumed the occurrence of short-lived, subfreezing conditions periodically in the Northern Hemisphere during the late Coniacian–early Santonian, most probably in polar winter months. Moreover, basins in the Russian Pacific region became deeper and, perhaps, as a result of deepening and/or cooling, all of the Coniacian taxa above noted disappeared, although new supplements appeared comparatively rapidly. Zakharov et al. (2005) noted that the cold periods were probably never sufficiently long enough to form permanent sea ice, because of the absence of a continent in the North Pole region and a significant ameliorating effect of oceanic heat-transport towards the pole, mainly via the Strait of Turgai and the Western Interior of North America. That also could be the explanation of the appearance at this time of the widespread ammonites *Polyptychoceras quadrinodosum* Jimbô, 1894, *Desmophyllites diphylloides* (Forbes, 1846) and *Phyllopachyceras forbesianum* (d'Orbigny, 1850), which co-occurred with local indexes for this boundary such as *Texanites* (*Plesiotexanites*) *kawasakii* Kawada, 1929 and *Inoceramus amakusensis* (Yazykova 1996, 2002; Yazykova and Zonova 2002). In spite of the fact that the placement of the Coniacian–Santonian boundary is still very problematic in the Russian Far East, we can recognise the principal elements of general ammonite evolution, namely the disappearance of typical Coniacian ammonites, such as *Peroniceras* sp., *Jimboiceras mihoense*, *Forresteria* (*F.*) *alluaudi* and of inoceramids of the *Inoceramus mihoensis/I. uwajimensis* group (Zonova and Yazykova 1998), as well as the common occurrence of new taxa, representing new morphotypes, plus the abundance of new heteromorph (sub)genera such as *Glyptoxoceras*, *Didymoceras*, *Pseudoxybeloceras*, *Polyptychoceras*, *Neocrioceras*, *Subptychoceras*, *Eubostrychoceras*, and *Baculites* (Poyarkova 1987; Alabushev and Wiedmann 1997; Yazykova 2004). Generally, the Santonian interval is typified by a continuous increase of taxonomic diversity amongst ammonites (Fig. 2). New migration routes which appeared during the latest Coniacian transgression were gradually widening during the Santonian and the percentage of cosmopolitan species during this time is much higher (see Yazykova 2002). This boundary is characterised also by new taxa amongst two of the most conservative families, namely the Phylloceratidae and Tetragonitidae, and by the recovery of the Kossmaticeratidae along the Russian Pacific coast (Fig. 3), where after a long period of absence two new species appeared. The tetragonitid *Pseudophyllites* could be an immigrant from the European Boreal province into the northern Pacific, via the Arctic, because *P. indra* (Forbes, 1846) first appeared in Europe and subsequently spread to the Tethys and Pacific. This species was, probably, very well adapted to a range of environments and typically occurs worldwide in abundance.

The Coniacian–Santonian boundary was very important also for the development of the Diplomoceratidae (Fig. 3). Six new species appeared in the earliest Santonian, which marked the onset of the future bloom which this family experienced during the Campanian in Far East Russian regions as well as in many other regions of the world (Wright et al. 1996).

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

The late Santonian heteromorph facies bio-event.—Near the early–late Santonian boundary, macrofaunal taxonomic diversity increased again, linked to a global sea level rise and an increase in temperature. New taxa, representing new morphotypes, appeared. Heteromorphs present a special case. They are represented by eight species, in six genera/subgenera such as *Hyphantoceras*, *Neocrioceras*, *Diplomoceras*, *Pseudoxybeloceras*, *P.* (*Polyptychoceras*), and *P.* (*Subptychoceras*). This bio-event could be proposed for the early–late Santonian boundary, awaiting detailed documentation elsewhere. The following examples appear to support the distinctiveness of this event: representatives of *Hyphantoceras* appeared at the same level in Japan (Matsumoto 1977), southeast France (Thomel 1988), Westfalen, Germany (Kennedy and Kaplan 2000), Zululand and Pondoland (Kennedy et al. 1995) and members of *Necrioceras* are known from this level in Japan and British Columbia (Haggart and Higgs 1989; Shigeta 2001). This list will undoubtedly be longer after detailed study of this interval in different regions across the world. Interestingly, at the same level new representatives of the family Pachydiscidae make their appearance in the Pacific region. For that basin, this particular moment marks the start in the development and wide distribution of this family (Fig. 3).

The Santonian–Campanian faunal turnover bio-event.—In Far East Russia, the Santonian–Campanian boundary is characterised by an abrupt regressive pulse which interrupted deep-water sedimentation and triggered notable environmental changes, causing a regional biotic event which is evident in different regions across the world. Zakharov et al. (1998) recorded some increase in temperature during the early late Santonian which could have had an impact on the disappearance of many Santonian taxa (Fig. 4). However, the total number of ammonite taxa increased and reached its maximum in the early Campanian (Fig. 2). Thus, this is another example of rapid recovery amongst ammonites (Yazykova et al. 2002).

In general, the early Campanian in the Russian Pacific region was characterised by a high diversity of diplomoceratids, pachydiscids, gaudryceratids, and tetragonitids (Fig. 3). The two last-named families are not only diverse but also greatly abundant. This was a fairly warm-water basin with normal salinity. Meanwhile, nearly seventy taxa of foraminifera, most of them benthic and stenobiontic, indicate a well-oxygenated basin, which also hosted new species of gastropod, inoceramid and non-inoceramid bivalves (Poyarkova 1987; Yazykova et al. 2002). Thus, during the early Campanian this basin was very conducive to the development of numerous marine biotic groups.

The end of the early Campanian was characterised by a relative fall in ammonite diversity, reflected in the disappearance of some heteromorphs and the last representatives of *Menuites*, and also a rise in inoceramid diversity, i.e., the appearance of the first radially ribbed *Pennatoceramus* providing evidence of higher energy in the basin, coupled with a rise in the abundance of foraminifera and a decrease in radiolarian abundance (Yazykova et al. 2002).

The late Campanian radiation bio-event.—The faunal impoverishment at the end of early Campanian was followed by a radiation at the start of the late Campanian (Figs. 2–4), which is well traceable from northeast Russia, through Sakhalin and Japan, and into Europe, for example, in southern Poland (EAJ-Y unpublished data). In the Russian Far East this level is marked by the onset of shallow-water facies with abundant ammonites, new morphotypes of inoceramids and new taxa of gastropods and non-inoceramid bivalves. Vishnevskaya (2009) noted remarkable taxonomic changes in early and late Campanian radiolarian associations, which may reflect environmental changes within the palaeobasins of Sakhalin, the Koryak Upland and Kamchatka; the highest diversity is found amongst benthic groups and some associated planktonic forms. Representatives of several macrofauna groups form coquina-like beds. In southern Poland, in sections in the Miechów area, the early–late Campanian interval is marked by a regressive hardground surface and the early Campanian is characterised by an abundance of fossils (Jagt et al. 2004). The biotic event(s) at the early–late Campanian level in different regions of the world may constitute a good correlative marker level, but is (are) in need of further study. Similar features can be seen at this level in British Columbia (Canada) and Alaska (Ward 1978; Haggart et al. 2009). On the other hand, the late Campanian time slice was a period of general reduction in taxonomic diversity amongst heteromorphs in Russian Pacific regions (Fig. 3).

The latest Campanian regression and temperature drop (Fig. 4) caused the gradual disappearance of all taxa amongst inoceramids and ammonites typical of this interval, with the exception of a few rare occurrences at the base of the Maastrichtian. Kirillova (2003) noted the onset of tectonic activity near the end of the late Campanian which resulted in an overall uplift of the whole region with the new regression-transgression pulse. Moreover, some cooling effect at this time, which has been documented in the North Atlantic (Linnert and Mutterlose 2009) and also in the Pacific (Zakharov et al. 1999, 2005), led to changes in oceanic circulation and caused climatic oscillations. A reduction of diversity and a slow recovery in the early Maastrichtian have also been recorded for benthic foraminiferal assemblages (Kalishevich et al. 1981; Turenko in Poyarkova 1987); this bio-event could be correlated with the late Campanian benthic extinction regional event (Fig. 4) described by Kauffmann and Hart (1995).

The Campanian–Maastrichtian faunal turnover.—The Russian Pacific coast is characterised by a relatively widespread distribution of Maastrichtian sedimentary rocks. They have been studied not only in Sakhalin and northeast Russia, but also in Shikotan Island, the smallest island of the southern Kuril Ridge. The disappearance of most Campanian ammonites and inoceramids, noted above, and the first occurrence of *Pachydiscus* (*P.*) *subcompressus* Matsumoto, 1959 and *P.* (*Neodesmoceras*) *japonicus* (Matsumoto,

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

1947), both widely distributed Pacific species (Yazykova 2004) are the criteria for placement of this boundary. This is supported by data on inoceramids and radiolarians (Palechek et al. 2008), this level being matched by a similar horizon in Japan (Toshimitsu et al. 1995). In total, twenty-two new taxa appeared in the early Maastrichtian, mainly pachydiscids and gaudryceratids (Fig. 3). General ammonite diversity is lower even than during the late Campanian but still comparatively high (Fig. 2).

The mid-Maastrichtian reduction bio-event.—Around 50% of ammonite taxa became extinct at this time, and this holds true for almost all inoceramids as well. The last representatives of the Tetragonitidae and Kossmaticeratidae, and, probably, also the Baculitidae have been found in the latest early Maastrichtian. A slight increase in temperature was recorded by Zakharov et al. (1999). This bio-event can be correlated (Fig. 4) with the 68 Ma extinction bio-event of Kauffmann and Hart (1995).

The late Maastrichtian radiation bio-event.—The global late Maastrichtian transgression triggered maximum diversity in the families Pachydiscidae, Phylloceratidae, and Gaudryceratidae (Fig. 3 here; Hirano et al. 2000; Yazykova 2004), and during the same time, the northern Pacific ammonites again witnessed a "surge" of new taxa. In contrast, inoceramids did not recover after the decimation noted above. Some Russian Pacific ammonite species are immigrants from the European and Mediterranean realms, e.g., *Pseudophyllites indra* (Forbes, 1846) and *Zelandites varuna* (Forbes, 1846). The subgenus *Hypophylloceras* (*Neophylloceras*) is represented by the new *H*. (*N*.) *hetonaiense* Matsumoto, 1942 and *H*. (*N*.) *victriense* Shigeta and Maeda, 2005, alongside the long-lived *H.* (*N*.) *ramosum* (Meek, 1857). The gaudryceratids comprised nine endemic species: *Anagaudryceras matsumotoi* Morozumi, 1985; *A. seymouriense* Macellari, 1986; *Gaudryceras venustum* Matsumoto, 1984; *G. denmanense* (Whiteaves, 1901); *G. tombetsense* Matsumoto, 1984; *G*. cf. *tombetsense* Matsumoto, 1984; *G. hamanakense* Matsumoto and Yoshida, 1979; *G. makarovense* Shigeta and Maeda, 2005; and *Zelandites japonicus* Matsumoto, 1938. The last kossmaticeratid, *Brahmaites* (*Subbrahmaites*) *sachalinensis* Yabe and Shimizu, 1924, probably was a demersal taxon. The family Pachydiscidae is highly diverse, with four new species of *P.* (*Pachydiscus*) and two new species of a new subgenus, *P*. (*Neodesmoceras*), plus new species of *Patagiosites* and *Pseudomenuites*. Heteromorphs are represented by species of *Diplomoceras*, *Neancyloceras*, *Nostoceras* (*Didymoceras*), and *Glyptoxoceras*.

The Cretaceous–Paleogene mass extinction event.—The Cretaceous–Paleogene boundary in the Russian Pacific region was characterised by a global regression and strong volcanic activity with drastic environmental changes; these are here reflected in the total extinction of ammonites and inoceramid bivalves, and by some remarkable changes in other groups of organisms (Kalishevich et al. 1981; Turenko in Poyarkova 1987; Zonova et al. 1993; Yazikova 1994; Yazykova 2004; Jagt-Yazykova 2011).

In Sakhalin the youngest ammonites were found almost 2 m below the Maastrichtian–Paleogene boundary along the River Krasnoyarka (Naiba River Valley). These are numerous representatives of small-sized *Zelandites* (Zonova et al. 1993; Yazikova 1994) and one poorly preserved *Gaudryceras*. Wiedmann and Kullmann (1996: 807) suggested that, "just eight genera are recorded 15 meters (~150 000 years) below the boundary" at the "two most complete boundary sections, Zumaya and Hendaye", that is, *Neophylloceras*, *Gaudryceras*, *Saghalinites*, *Pseudophyllites*, *Vertebrites*, *Anapachydiscus*, *Pachydiscus*, and *Diplomoceras*. To these records I here add the Naiba section in Sakhalin, because, with the exception of *Vertebrites* and *Anapachydiscus*, all genera listed above have also been recorded here from the latest Maastrichtian. In addition, numerous individuals of *Zelandites japonicus* Matsumoto, 1938 and a single specimen of *Gaudryceras hamanakense* (Matsumoto and Yoshida, 1979) have been collected by myself about 2 m (~20 000 years) below the Cretaceous–Paleogene boundary.

Conclusions

Ammonite evolution dynamics during the mid- and Late Cretaceous along the Russian Pacific coast reflected periods of crisis and bloom (radiation and recovery) as well as other bio-events. The majority of these probably have a global character and could possibly be used for correlation. In the Far East Russian sections the following bio-events have been recorded: the late Albian migration bio-event; Albian–Cenomanian faunal turnover bio-event; mid-Cenomanian *Turrilites* event; Cenomanian–Turonian boundary extinction bio-event; mid-Turonian *Scaphites* facies bio-event; mid–late Turonian boundary bio-event; Turonian–Coniacian faunal turnover bio-event; Coniacian–Santonian faunal turnover bio-event; late Santonian heteromorph facies bio-event; Santonian–Campanian faunal turnover bio-event; late Campanian radiation bio-event; Campanian–Maastrichtian faunal turnover bio-event; mid-Maastrichtian reduction bio-event and late Maastrichtian radiation event; Cretaceous–Paleogene mass extinction bio-event (Figs. 2, 4).

Moreover, studies of ammonite evolution and phylogeny in the Russian Pacific region show that recovery after environmental stress usually was rapid enough within this faunal group and a subsequent radiation event invariably followed. It seems that ammonites were characterised by rapid evolutionary rates and a wide range of morphologies which reflect a marked degree of environmental adaptation. This group existed for over 300 million years and likely would not be driven to extinction merely by cooling, anoxia or volcanic eruptive phases. Such kind of "drawbacks" were successfully dealt with. Stress suffered across the Cretaceous–Paleogene boundary had to be really strong and relatively sudden, and probably comprised all detrimental factors taken together, including

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

high concentrations of toxic gases in the atmosphere and dissolved in ocean water. Such an event could only have been triggered by an impact or even multiple impacts, followed by hypercanes and giant tsunamis, widespread wildfires, plus intensified tectonic and volcanic activity, probably across the globe.

Acknowledgements

The present paper constitutes a small portion of my PhD thesis, which was successfully defended at the Free University Amsterdam in May 2010. One of the committee members was Professor William J. Kennedy (formerly at the Oxford University Museum of Natural History, Oxford, UK; now retired). I have taken his extremely detailed comments into consideration and, once again, wish to acknowledge his help. I also would like to thank the journal reviewers, Seiichi Toshimitsu (Geological Survey of Japan, Tokyo, Japan), James W. Haggart (Geological Survey of Canada, Vancouver, Canada), and Christina Ifrim (Institut für Geowissenschaften, Ruprecht-Karls-Universität, Heidelberg, Germany), for useful comments. My warm thanks are also going to John W.M. Jagt (Natuurhistorisch Museum Maastricht, the Netherlands), for linguistic correction and permanent support. Lastly, I wish to thank my aunt, and first teacher of palaeontology, Tatjana D. Zonova (VNIGRI, Sankt Peterburg, Russia), who has co-authored numerous papers and who has permanently supported me in my research endeavours.

References

Alabushev, A. and Wiedmann, J. 1997. Upper Cretaceous ammonites from southern Sakhalin and northwestern Kamchatka (north-east Russia). *Palaeontographica A* 244: 1–36.

Amédro, F. and Robaszynski, F. 2005. Corrélation des successions de l'Albien par les ammonites entre la Province Nord-Pacifique et les provinces européenne et arctique du Domaine boréal: zonation, eustatisme et paléobiogéographie. *Geobios* 38: 585–607.

Anderson, F.M. 1938. Lower Cretaceous deposits in California and Oregon. *Geological Society of America, Special Papers* 16: 1–244.

Arkadiev, V.V., Atabekyan, A.A., Baraboshkin, E.Yu., and Bogdanova, T.N. 2000. Stratigraphy and ammonites of Cretaceous deposits of south-west Crimea. *Palaeontographica* A 255: 85–128.

Barnes, C., Hallam, A., Kaljo, D., Kauffman, E.G., and Walliser O.H. 1995. Global event stratigraphy. *In*: O.H. Walliser (ed.), *Global Events and Event Stratigraphy in the Phanerozoic*, 319–333. Springer, Berlin.

Batt, R. 1989. Ammonite shell distributions in the Western Interior Greenhorn Sea and some paleoecological implications. *Palaios* 4: 32–42.

Batt, R. 1993. Ammonite morphotypes as indicators of oxygination in a Cretaceous epicontinental sea. *Lethaia* 26: 49–63.

Boule, M., Lemoine, P., and Thevenin, A. 1907. Céphalopodes Crétacés des environs de Diego-Suarez (Madagascar). *Annales de Paléontologie* 2(1): 1–56.

Druschic, V.V. [Drušic. V.V] and Mikhailova, I.A. [Mihajlova, I.A.] 1963. On the border between Aptian and Albian stages [in Russian]. *Bûlleten' Moskovskogo Obŝestva Ispytatelej Prirody* 38: 84–93.

Fallot, E. 1885. Étude géologique sur les étages moyens et supérieurs du terrain Crétacé dans le sud-est de la France. *Annales de Sciences géologiques* 18: 1–263.

Forbes, E. 1846. Report on the fossil Invertebrata from southern India, collected by Mr Kaye and Mr Cunliffe. *Transactions of the Geological Society of London* 7: 97–174.

Haggart, J.W. and Higgs, R. 1989. A new Late Cretaceous mollusc fauna from the Queen Charlotte Islands, British Columbia. *Geological Survey of Canada Paper* 89-1H: 59–64.

Haggart, J.W., Ward, P.D., Raub, T.D., Carter, E.S., and Kirschvink, J.L. 2009. Molluscan biostratigraphy and paleomagnetism of Campanian strata, Queen Charlotte Islands, British Columbia: implications for Pacific coast North America biochronology. *Cretaceous Research* 30: 939–951.

Hancock, J.M. 2003. Lower sea levels in the Middle Cenomanian. *Notebooks on Geology—Letter* 2003/02: 16.

Haq, B.U., Hardenbol, J., and Vail, P.R. 1987. Chronology of fluctuating sea levels since Triassic. *Science* 235: 1156–1167.

Harries, P.J. and Little, C.T.S. 1999. The early Toarcian (Early Jurassic) and the Cenomanian–Turonian (Late Cretaceous) mass extinctions: similarities and contrasts. *Palaeogeography, Palaeoclimatology, Palaeoecology* 154: 39–66.

Hasegawa, T. 1997. Cenomanian–Turonian carbon isotope events recorded in terrestrial organic matter from northern Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 130: 251–273.

Hayakawa, H. and Nishino, T. 1999. Cenomanian ammonite fauna from Nakagawa, Hokkaido, Japan [in Japanese, with English abstract]. *Bulletin of the Nakagawa Museum of Natural History* 2: 1–40.

Hirano, H. and Fukuju, T. 1997. Lower Cretaceous oceanic anoxic event in the lower Yezo Group, Hokkaido, Japan. *Journal of the Geological Society of the Philippines* 52: 173–182.

Hirano, H. and Takagi, K. 1995. Cretaceous oceanic anoxias in northwestern Pacific—current conditions and prospect of research. *Proceedings of 14th International Symposium of Kyungpook National University*, 343–355. Kyungpook National University, Daegu.

Hirano, H., Toshimitsu, S., Matsumoto, T., and Takahashi, K. 2000. Changes in Cretaceous ammonoid diversity and marine environments of the Japanese Islands. *In*: H. Okada and N.J. Mateer (eds.), *Cretaceous environments of Asia*, 145–154. Elsevier, Amsterdam.

Jagt, J.W.M., Walaszczyk, I., Yazykova, E.A., and Zatoń, M. 2004. Linking southern Poland and northern Germany: Campanian cephalopods, inoceramid bivalves and echinoids. *Acta Geologica Polonica* 54: 573–586.

Jagt, J.W.M., Zonova T.D., and Jagt-Yazykova, E.A. 2007. A review of the brachylepadomorph cirripede genus *Pycnolepas*, including the first record of an Early Cretaceous species from the Russian Far East. *Zootaxa* 1545: 33–47.

Jagt-Yazykova, E.A. 2011. Palaeobiogeographical and palaeobiological aspects of mid- and Late Cretaceous ammonite evolution and bio-events in the Russian Pacific. *Scripta Geologica* 143: 15–122.

Jeletzky, J.A. 1964. Illustrations of Canadian fossils. Lower Cretaceous marine index fossils of the sedimentary basins of western and Arctic Canada. *Geological Survey of Canada, Department of Mines and Technical Surveys* 64-11: 1–101.

Jimbô, K. 1894. Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido. *Palaeontologische Abhandlungen* 2: 149–194.

Jones, D.L., Murphy, M.A., and Packard, E.L. 1965. The Lower Cretaceous (Albian) ammonite genera *Leconteites* and *Brewericeras*. *United States Geological Survey, Professional Paper* 503-F: 1–21.

Kalishevich, T.G. [Kališevič, T.G.], Zaklinskaya, E.D. [Zaklinskaâ, E.D.], and Serova, M.Ya. [Serova, M.Â.] 1981. *Razvitie organičeskogo mira Tihookeanskogo poâsa na rubeže mezozoâ i kajnozoâ: foraminifery,molluski i palinoflora Severo-Zapadnogo sektora*. 164 pp. Nauka, Moskva.

Kaplan, U., Kennedy, W.J., and Wright, C.W. 1987. Turonian and Coniacian Scaphitidae from England and north-western Germany. *Geologisches Jahrbuch A* 103: 5–39.

Kasansky, P. 1914. Description d'une collection des céphalopodes des terrains crétacés du Daghestan. *Izvestiâ Tomskogo Tehnologičeskogo Instituta Imperatora Nikolaâ II* 32: 1–127.

Kauffman, E.G. and Erwin, D.H. 1995. Surviving mass extinctions. *Geotimes* 14: 14–17.

Kauffman, E.G. and Hart, M.B. 1995. Cretaceous bio-events. *In*: O.H. Walliser (ed.), *Global Events and Event Stratigraphy in the Phanerozoic*: 285–312. Springer, Berlin.

Kawada, M. 1929. On some new species of ammonites from Naibuchi dis-

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

trict, south Saghalien. *Journal of the Geological Society of Tokyo* 36: 1–6.

Kennedy, W.J. 1994. Cenomanian ammonites from Cassis, Bouches-du-Rhône, France. *Palaeopelagos, Special Publication* 1: 209–254.

Kennedy, W.J., Bilotte, M., and Melchior, P. 1995. Ammonite faunas, biostratigraphy and sequence stratigraphy of the Coniacian–Santonian of the Corbières (NE Pyrénées). *Bulletin des Centres de Recherches d'Exploration-Production Elf-Aquitaine* 19: 377–499.

Kennedy, W.J., Cobban, W.A., and Landman, N.H. 1996. New records of acanthoceratid ammonoids from the Upper Cenomanian of South Dakota. *American Museum Novitates* 3161: 1–18.

Kennedy, W.J. and Kaplan, U. 2000. Ammonitenfaunen des hohen Coniac und Santon in Westfalen. *Geologie und Paläontologie in Westfalen* 57: 1–126.

Kennedy, W.J. and Klinger, H.C. 1985. Cretaceous faunas from Zululand and Natal, South Africa. The ammonite family Kossmaticeratidae Spath, 1922. *Annals of the South African Museum* 95: 165–231.

Kirillova, G.L. 2003. Cretaceous tectonics and geological environments in East Russia. *Journal of Asian Earth Sciences* 21: 967–977.

Kirillova, G.L., Markievitch, V.S., and Belyi, V.F. 2000. Cretaceous environmental changes of East Russia. *In*: H. Okada and N.J. Mateer (eds.), *Cretaceous Environments of Asia*: 1–47. Elsevier, Amsterdam.

Kossmat, F. 1895. Untersuchungen über die Südindische Kreideformation. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients* 9: 1–107.

Krymholz, G.Ya. [Krymgolc, G.Â.] 1938. About new distribution of Cretaceous fauna from the lower part of Amur river [in Russian]. *Učenyje zapiski LGU* 26: 155–163.

Linnert, C. and Mutterlose, J. 2009. Evidence of increasing of surface water oligotrophy during the Campanian–Maastrichtian boundary interval: calcareous nannofossils from DSDP Hole 390A (Blake Nose). *Marine Micropaleontology* 73: 26–36.

López Garrido, A.C. and Orozco, M. 1970. Estudio estratigráfico del sector centro-oriental de Sierra Arana (Cordilleras Béticas). *Acta Geológica Hispánica* 5: 4–7.

Matsumoto, T. 1938. *Zelandites*, a genus of Cretaceous ammonites [Contribution to the Cretaceous Palaeontology of Japan, IV]. *Japanese Journal of Geology and Geography* 15: 137–148.

Matsumoto, T. 1942. Fundamentals in the Cretaceous stratigraphy of Japan, Part I. *Memoirs of the Faculty of Sciences, Kyushu University, D. Geology* 1: 129–280.

Matsumoto, T. 1943. Fundamentals in the Cretaceous stratigraphy of Japan, Part I. *Memoirs of the Faculty of Sciences, Kyushu University, D. Geology* 1: 129–280.

Matsumoto, T. 1947. A note on the Japanese Pachydiscidae [in Japanese]. *The Science Reports of the Faculty of Science, Kyushu University. Geology* 2: 34–46.

Matsumoto, T. 1954. Family Puzosiidae from Hokkaido and Saghalien. *Memoirs of the Faculty of Sciences, Kyushu University, D. Geology* 5: 69–118.

Matsumoto, T. 1957. *Inoceramus mihoensis* n. sp. and its significance. *Memoirs of the Faculty of Science, Kyushu University, Series D, Geology* 6: 65–68.

Matsumoto, T. 1959. Upper Cretaceous ammonites from California, Part 2. *Memoirs of the Faculty of Sciences, Kyushu University, D. Geology, Special Volume* 1: 1–172.

Matsumoto, T. 1977. Zonal correlation of the Upper Cretaceous in Japan. *Journal of the Paleontological Society of Japan*, *Special Paper* 21: 63–74.

Matsumoto, T. 1991. The mid-Cretaceous ammonites of the family Kossmaticeratidae from Japan. *Palaeontological Society of Japan*, *Special Papers* 33: 1–143.

Matsumoto, T. and Takahashi, T. 2001. Further notes on the turrilitid ammonoids from Hokkaido—Part 2. [Studies of the Cretaceous ammonites from Hokkaido and Sakhalin – XC]. *Paleontological Research* 5: 163–176.

Matsumoto, T. and Toshimitsu, S. 2005. Additional notes on some species of Mantelliceras (Ammonoidea) from central Hokkaido, North Japan [Studies of the Cretaceous ammonites from Hokkaido – XCVIII]. *The Bulletin of the Geological Society of Japan* 56: 31–36.

Matsumoto, T. and Yoshida, S. 1979. A new gaudryceratid ammonite from eastern Hokkaido. *Transactions and Proceedings of The Palaeontological Society of Japan* 114: 65–76.

Meek, F.B. 1857. Descriptions of new organic remains from the Cretaceous rocks of Vancouver Island. *Transactions of the Albany Institute* 4: 37–49.

Monnet, C. and Bucher, H. 2007. Ammonite-based correlations in the Cenomanian–lower Turonian of north-west Europe, central Tunisia and the Western Interior (North America). *Cretaceous Research* 28: 1017–1032.

Orbigny, A. d' 1840–1842. Paléontologie française: Terrains crétacés 1, Céphalopodes: 1–120 (1840); 121–430 (1841); 431–662 (1842). Masson, Paris.

Orbigny, A. d' 1850. *Prodrome de Paléontologie stratigraphique universelle des animaux mollusques et rayonnés, 2*. 248 pp. Masson, Paris.

Palechek, T.N., Terekhov, E.P., and Mozherovskii, A.V. 2008. Campanian–Maastrichtian radiolarians from the Malokuril'skaya Formation, the Shikotan Island. *Stratigraphy and Geological Correlation* 16: 76–89.

Paul, C.R.C. and Lamolda, M.A. 2009. Testing the precision of bioevents. *Geological Magazine* 146: 1–13.

Pervinquière, L. 1907. Études de Paléontologie tunisienne. I. Céphalopodes des terrains secondaires. *Carte géologique de la Tunisie*, v+438 pp. F.R. de Rudeval, Paris.

Potfaj, M., Boorová, D., Vašiček, Z., and Žeková, K. 2008. New fossiliferous locality in the Pieniny Klippen Belt in Myjava vicinity (Western Carpathians, Slovakia). *In*: A. Pisera, M.A. Bitner, and A.T. Halamski (eds.), *9th Paleontological Conference, Warszawa, 10–11 October 2008. Abstract Conference Volume*, 71–73. Instytut Paleobiologii PAN, Warszawa.

Poyarkova, Z.N. [Poârkova, Z.N.] (ed.) 1987. Reference section of Cretaceous deposits in Sakhalin (Naiba section) [in Russian]. *Izvestiâ Akademii Nauk SSSR* 16: 1–197.

Seitz, 0. 1931. Zur Morphologie der Ammoniten aus dem Albien. II. *Jahrbuch der Preussischen geologischen Landesanstalt* 52: 391–415.

Sey, I.I. [Sej, I.I.], Okuneva, T.M., Zonova, T.D., Kalacheva, E. D. [Kalačeva, E.D.], and Yazykova, E.A. [Âzykova, E.A.] 2004. *Atlas morskoj fauny mezozoâ Dalnego Vostoka Rossii*. 234 pp. Vserosyjskij Naučno-Issledovatelskij Geologičeskij Institut Press, Sankt Peterburg.

Sharpe, D. 1855. Description of the fossil remains of Mollusca found in the chalk of England. Part II. Cephalopoda. *Monograph of the Palaeontological society London* 1855: 27–36.

Shigeta, Y. 2001. *Ammonitology*. 155 pp. National Science Museum Tokai University Press, Tokyo.

Shigeta, Y. and Maeda, H. (eds.) 2005. The Cretaceous system in the Makarov area, southern Sakhalin, Russian Far East. *National Science Museum Monographs* 31: 1–136.

Skelton, P.W. 2003. *The Cretaceous world.* 360 pp. Cambridge University Press, Cambridge.

Sowerby, J. de C. 1836. Descriptive notes respecting the shells figured in plates xi–xxiii (pp. 335–348), Appendix A. *In*: W.H. Fitton (ed.), Observations on Some of the Strata Between the Chalk and the Oxford Oolite in the South-east of England. *Transactions of the Geological Society of London* 2 (4): 103–389.

Tanabe, K. 1979. Paleontological analysis of ammonoid assemblages in the Turonian *Scaphites* facies of Hokkaido, Japan. *Palaeontology* 22: 609–630.

Terekhova, G.P. [Terehova, G.P.] and Mikhajlova, I.A. [Mihajlova, I.A.] 1977. Stratigraphy of Cenomanian sediments of Anadyr-Koriak region and finds here the ammonites of genera *Turrilites* and *Hypoturrilites* [in Russian]. *Izvestiâ Akademii Nauk SSSR, Seriâ Geologičeskajâ* 1: 50–60.

Thomel, G. 1988. Les ammonites néocrétacées (Coniacien–Santonien–Campanien) des chaînes subalpines méridionales (Alpes-Maritimes et Alpes de Haute-Provence). *Mémoires de la Société géologique de France, n.s.* 153: 1–79.

Toshimitsu, S., Matsumoto, T., Noda, M., Nishida, T., and Maiya, S. 1995.

http://dx.doi.org/10.4202/app.2011.0076

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Towards an integrated of mega-, micro- and magneto-stratigraphy of the Upper Cretaceous in Japan. *Journal of the Geological Society of Japan* 101: 19–29.

Vereschagin, V.N. [Vereŝagin, V.N.], Kinasov, V.P., Paraketsov, K.V. [Parakecov, K.V.], and Terekhova, G.P. [Terehova, G.P.] 1965. *Polevoj atlas Melovoj fauny severovostoka SSSR*. 215 pp. Magadanskoe Knižnoe Izdatel'stvo, Magadan.

Vishnevskaya, V.S. 2009. Evolution of taxonomical diversity of Cretaceous radiolarian from high-latitude palaeobiochores. *Stratigraphia. Geologicheskaya Korrelacja* 17: 112–123.

Ward, P.D. 1978. Revision to the stratigraphy and biochronology of the Upper Cretaceous Nanaimo Group, British Columbia and Washington State. *Canadian Journal of Earth Sciences* 15: 405–423.

Westermann, G.E.G. 1989. New developments in ecology of Jurassic–Cretaceous ammonoids. *In*: G. Pallini, F. Cecca, S. Cresta, and M. Santantonio (eds.), *Proceedings of II Pergola Symposium 1987, Atti del secondo convegno internazionale Fossili, Evoluzione, Ambiente Pergola 25–30 ottobre 1987 estratto*, 1–21.

Westermann, G.E.G. 1996. Ammonoid life and habitat. *In*: N.H. Landman, K. Tanabe, and R.A. Davis (eds.), *Ammonite Paleobiology*, 607–707. Plenum Press, New York.

Wiedmann, J. and Kullmann, J. 1996. Crises in ammonoid evolution. *In*: N.H. Landman, K. Tanabe, and R.A. Davis (eds.), *Ammonite Paleobiology*, 795–813. Plenum Press, New York.

Wright, C.W., Calloman, J.H., and Howarth, M.K. 1996. Rangers of taxa. Part L. Mollusca 4 (revised), Cretaceous Ammonoidea. *In*: R.L. Kaesler (ed.), *Treatise on Invertebrate Paleontology*, L1–L362. The Geological Society of America, Boulder.

Wright, C.W. and Kennedy, W.J. 1990. The Ammonoidea of the Lower Chalk. Part 3. *Monograph of the Palaeontographical Society London* 144 (585): 219–294.

Yabe, H. and Shimizu, S. 1924. A new species of *Brahmaites* from the Upper Cretaceous of S. Saghalin. With a remark on the genus *Brahmaites*. *Japanese Journal of Geology and Geography* 3: 77–80.

Yazikova [= Yazykova], E.A. 1994. Maastrichtian ammonites and biostratigraphy of the Sakhalin and the Shikotan Islands, Far Eastern Russia. *Acta Geologica Polonica* 44: 277–303.

Yazykova, E.A. 1996. Post-crisis recovery of Campanian desmoceratacean ammonites from Sakhalin, Far East Russia. *In*: M.B. Hart (ed.), Biotic Recovery from Mass Extinction Events. *Geological Society, Special Publication* 102: 299–307.

Yazykova, E.A. [Âzykova. E.A.] 2001. Some Early Cretaceous ammonites from Sikhote Alin [in Russian, with English abstract]. *Tihookeanskaâ Geologiâ* 20: 100–106.

Yazykova, E.A. 2002. Ammonite and inoceramid radiations after the Santonian–Campanian bioevent in Sakhalin, Far East Russia. *Lethaia* 35: 51–60.

Yazykova, E.A. 2004. Ammonite biozonation and litho-/chronostratigraphy of the Cretaceous in Sakhalin and adjacent territories of Far East Russia. *Acta Geologica Polonica* 54: 273–312.

Yazykova, E.A. and Zonova, T.D. 2002. The problem of the Coniacian–Santonian boundary in far eastern regions of Russia. *In*: M. Lamolda (ed.), *Meeting on the Coniacian–Santonian Boundary, Abstracts. Santonian Working Group, Subcommission on Cretaceous Stratigraphy. International Commission on Stratigraphy and Instituto Geológico y Minero de España*, 30–31. Instituto Geológico y Minero de España, Bilbao.

Yazykova, E.A., Peryt, D., Zonova, T.D., and Kasintzova, L.I. 2004. The Cenomanian/Turonian boundary in Sakhalin, Far East Russia: ammonites, inoceramids, foraminifera, and radiolarians. *New Zealand Journal of Geology and Geophysics* 47: 291–320.

Yazykova, E.A., Zonova, T.D., and Kazintsova, L.T. 2002. Campanian Integrated Biostratigraphy and Palaeocommunities of Sakhalin Island (Far East Russia). *In*: M. Wagreich (ed.), Aspects of Cretaceous stratigraphy and palaeobiogeography. *Proceedings of the 6th International Cretaceous Symposium, Vienna 2000*, 269–292. Werlag der Österreichischen Akademie der Wissenschaften, Wien.

Yehara, S. 1924. On the Izumi-sandstone group in the Onogawa basin, Prov. Bungo, and the same group in Uwajima, Prov. Iyo. *Japanese Journal of Geology and Geography* 3: 27–40.

Zakharov, Yu.D., Smyshlaeva, O.P., Tanabe, K., Shigeta, Y., Maeda, H., Ignatjev, A.V. ,Veliveckaya, T.G., Afanaseva, T.B., Popov, A. M., Golozubov, V.V., Kolyada, A.A., Cherbadzhi, A.K., and Moriya, K. 2005. Seasonal temperature fluctuations in the high northern latitudes during the Cretaceous Period: isotopic evidence from Albian and Coniacian shallow-water invertebrates of the Talovka River Basin, Koryak Upland, Russian Far East. *Cretaceous Research* 26: 113–132.

Zakharov, Yu.D., Ukhaneva, N.G., Ignatyev, A.V., Tanabe, K., Shigeta, Y., Afanaseva, T.B., and Popov, A.M. 1998. Palaeotemperature curve for Late Cretaceous of the north-western circum-Pacific. *In*: L.F. Kopaevich and A. Dondt (eds.), Bio-events at the K/T Boundary on the Southern Margin of the White Chalk Sea—Palaeobiology, Palaeobiogeography, Sequence Stratigraphy, Geochemistry and Geochronology. *Final Meeting, Moscow, March 23–25, 1998. Abstract Volume*, 31–32. Moscow State University press, Moscow.

Zakharov, Yu.D., Ukhaneva, N.G., Ignatyev, A.V., Tanabe, K., Shigeta, Y., Afanaseva, T.B., and Popov, A.M. 1999. Palaeotemperature curve for Late Cretaceous of the north-western circum-Pacific. *Cretaceous Research* 20: 685–697.

Zhuravlev, Yu.G. [Žuravlev, Û.G.] 1969. About finds of *Anachoplites* in Cretaceous of south Sakhalin [in Russian]. *Izvestiâ Akademii Nauk SSSR, Seriâ Geologičeskajâ* 187: 397–398.

Zonova, T.D. 1982. Cretaceous inoceramids of Sikhote Alin and lower part of the River Amur [in Russian]. *In*: A.G. Ablaev (ed.), *Nowye dannye po stratigrafii i paleogeografii Dal'nego Vostoka*, 42–52. DVNC AN SSSR, Vladivostok.

Zonova, T.D. 2004. Albian–Cenomanian inoceramids from the Penzhyna Gulf coast (North-East Russia) [in Russian]. *Bûlleten' Paleontologičeskoj i Lithologičeskoj Kollekcjonnoj Fundacii VNIGRI* 1: 1–142.

Zonova, T.D. and Yazykova, E.A. 1998. Biostratigraphy and correlation of the Turonian–Coniacian succession and the Turonian–Coniacian boundary problem in the Far East Russia based on ammonites and inoceramids. *Acta Geologica Polonica* 48: 483–494.

Zonova, T.D., Kasintsova, L.I. [Kazincova, L.I.], and Yazykova, E.A. 1993. *Atlas rukovodiaŝih grup melovoj fauny Sahalina*. 327 pp. Nedra, Sankt Peterburg.

Downloaded From: https://bioone.org/journals/Acta-Palaeontologica-Polonica on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use