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MIDDLE JURASSIC-EARLY CRETACEOUS FORAMINIFERAL ZONATION AND PALEOECOLOGY OF OFFSHORE EASTERN CANADA AND THE EAST EUROPEAN PLATFORM

by

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ABSTRACT

This study consists of detailed biostratigraphic analysis based on comparisons of foraminiferal microfossil assemblages and zones of the Middle Jurassic-Early Cretaceous deposits on both sides of the North Atlantic Ocean: Canadian Atlantic Shelf and the East European Platform. This analysis shows that many foraminiferal species from the Canadian Atlantic Shelf range higher than in the East European Platform. This is probably due to a westward migration of species within the Boreal Atlantic Basin as the North Atlantic progressively opened. In the Early Kimmeridgian, the Tethyan influence became stronger on the Canadian Atlantic Shelf than in the East European Platform.

Key words: Jurassic, Early Cretaceous, Foraminifera, biostratigraphy, paleoecology, paleobiogeography.

INTRODUCTION

This study aims to compare the stratigraphic ranges of foraminiferal species from the Jurassic and Early Cretaceous deposits of the Canadian Atlantic Shelf with those from corresponding strata of the East European Platform. A Russian version of this paper was published by the same authors on the Journal of the Russian Academy of Sciences (Ascoli and Grigelis (1993). In recent years, many new data on the Jurassic and Early Cretaceous Foraminifera and on the stratigraphy of different regions of the Northern Hemisphere have been published. This information has provided the base for a zonation using foraminiferal assemblages from the Jurassic and Early Cretaceous deposits of the Canadian Atlantic Shelf, eastern and western Europe, Crimea, and Caucasus (Ascoli, 1976, 1988, 1990; Grigelis and Kuznetsova, 1987; Kuznetsova and Gorbachik, 1985; Foraminiferal stratigraphy .... 1985; Williams *et al.*, 1990).

The analysis of the stratigraphic ranges of Jurassic-Early Cretaceous Foraminifera common to both sides of the Atlantic Ocean was, however, previously based only on material from the Scotian Shelf of Canada and western Europe (Ascoli, 1976). It was pointed out at that time that most of the Middle-Late Jurassic and all the Early Cretaceous diagnostic species from western Europe have also been recorded from the Scotian Shelf of Canada. It was also noted that, in many cases, the highest stratigraphic occurrences (extinction points) of diagnostic species from the Middle Jurassic (Bathonian) to the latest Cretaceous (Maastrichtian) on the Scotian Shelf are the same as those recorded from Germany and other regions of western Europe.

The compilation of data presented in this study is based on previously published papers, as well as on the present authors' own collections and data banks.

MATERIALS AND METHODS

The foraminiferal material used for this research comes from deep oil exploratory wells drilled on the Canadian Atlantic Shelf and from outcrops and boreholes in the East European Platform (the Baltic, Pechora, Moscow and Saratov regions). Foraminifera from Polish and German basins are also included in our study. As to the European foraminiferal material, correlation with the ammonite zonation has been made. For the Canadian Atlantic Shelf Foraminifera, correlation has been made with the calpionellid stratigraphic zonation (Late Tithonian-Middle Valanginian interval). Planktonic Foraminifera are also used for stratigraphic correlation.

The foraminiferal biozonation of the Jurassic and Early Cretaceous in the regions studied is based on several criteria. On the Canadian Atlantic Shelf, where the material available consists mostly of borehole cuttings samples, the foraminiferal and ostracod zones are based on the last or highest stratigraphic occurrences of species, which define the top of all zones. Such species are termed "zonal diagnostic species", one or two of which are, for each zone, called "zonal marker" or "index species" and give their name(s) to the zone. These zones are all considered "informal assemblage zones".

The studied Jurassic and Early Cretaceous surface material, collected in the East European Platform and Crimea respectively, is controlled by ammonite zonation. The investigation of Foraminifera from these sections thus makes it possible to establish with precision both lower and upper boundaries of each zone. These zones are classified as assemblage zones or concurrent-range zones (Azbel and Grigelis (eds.), 1991; Grigelis, 1985).

STRATIGRAPHIC RANGE OF SPECIES

Thus far, no analysis has been made of the ranges of the Jurassic and Early Cretaceous

foraminiferal species from the Canadian Atlantic Shelf and the East European Platform. Nevertheless, in Jurassic-Early Cretaceous times these areas were located in the same paleobiogeographic region because the North Atlantic Basin had not yet opened. It is the existence of the same paleobiogeographic environment and the development of terrigenous-carbonate marine sedimentation, that account for the similarity in the taxonomic composition of the fauna (genera and families of Foraminifera).

Middle Jurassic

Figure 1 shows the stratigraphic range of the Middle Jurassic species on the Canadian Atlantic Shelf and the East European Platform. In the interval between the Bajocian and the Callovian, there are 53 common species, with a maximum of 11 species in the Early Bathonian.

One common species in the Bajocian deposits is *Garantella rudia* Kaptarenko. Few wells on the Canadian Atlantic Shelf have penetrated Bajocian sediments. Nevertheless, the discovery of *Garantella rudia* there makes it possible to recognize a new zone of the same name (Eider M-75 well, Grand Banks). On the East European Platform, the *Garantella rudia* zone has been recognized in the Dnepr-Donets Basin in association with the *Garantiana garantiana* ammonite zone of the Late Bajocian (Pyatkova and Permyakova, 1978). On the Canadian Atlantic Shelf the geologic age of the *Garantella rudia* zone is Bajocian. Foraminiferal assemblages are poor; *Garantella ampasindavaensis* Espitalié and Sigal, *Garantella semiornata* (Schwager), *Epistomina praecursor* Ohm are the most common species found in these assemblages.

The Bathonian contains seven common species. Among the planktonic Foraminifera,

Conoglobigerina bathoniana (Pazdro) has been identified. On the East European Platform this species occurs in the Bathonian deposits of the Polish Lowlands (Pazdro, 1969). A comparison of the topotypes of *Conoglobigerina bathoniana* from Ogrodzieniec (Poland: collection of A. Grigelis) with specimens on the Canadian Atlantic Shelf revealed that they are identical. This species marks a common zonal level in both regions.

Of the benthic Foraminifera of Bathonian age common to both regions, but having slight different stratigraphic ranges, the following have been recorded: *Epistomina bireticulata* Pazdro, *Garantella ornata* (Hofker), *Reinholdella crebra* Pazdro, *Lenticulina daphne* Bielecka and Styk, *Trocholina conica* (Schlumberger). On the East European Platform these species are known in the Bathonian of the Polish Lowlands (western part of the platform), but some of them first appear in the Late Bajocian (Bielecka and Styk, 1981). *Reinholdella media* (Kaptarenko) occurs not only in the Bajocian-Bathonian of Poland, but in the Late Bajocian of Ukraine as well (zones of *Strenoceras subfurcatum* and *Garantiana garantiana*).

On the basis of its zonal diagnostic species, the Bathonian *Epistomina bireticulata-Garantella ornata* Zone of the Canadian Atlantic Shelf correlates with the Bathonian deposits of the Polish Lowlands, where the *Epistomina bireticulata-Reinholdella crebra* Zone was first recognized. In the easternmost part of the East European Platform, Bathonian deposits (except for the Late Bathonian) occur in the Ryazan-Saratov Trough and in the Dnepr-Donets Basin, but the foraminiferal assemblages at these two locations are different (Azbel and Grigelis (eds.), 1991; Pyatkova and Permyakova, 1978).

The Callovian has five species common to both areas. On the Canadian Atlantic Shelf, the planktonic species *Globuligerina calloviensis* Kuznetsova can be used for recognizing a zone of the same name (well Acadia K-62, Scotian Shelf). This species is

unknown in the Callovian of the East European Platform. The *Globuliderina calloviensis* zone has been recognized in the lower part of the Callovian of Crimea, and it also occurs in the eastern Mediterranean (Syria). Reported occurrences of this important species are very rare to date.

Among the common benthic species, the stratigraphic range of *Epistomina porcellanea* Brückmann is restricted to the Callovian. Other species, such as *Epistomina coronata* Terquem and *Epistomina regularis* Terquem, both on the Canadian Atlantic Shelf and on the East European Platform appear earlier, i.e. in the Late Bajocian or Bathonian. On the other hand, *Epistomina nuda* Terquem and *Ophthalmidium carinatum* Kübler and Zwingli are known since the Late Bajocian in the Polish Lowlands. None of these species occur above the top of the Callovian, except *Epistomina mosquensis* Uhlig, which appears in the Bathonian worldwide, ranges throughout the Middle Oxfordian in the East European Platform (Polish Lowlands) and is found throughout the Oxfordian and in the Kimmeridgian on the Canadian Atlantic Shelf.

In the Callovian of the Canadian Atlantic Shelf, epistominids became dominant, being often the most important components of the foraminiferal fauna throughout the Late Jurassic and Early Cretaceous. In the Callovian of the East European Platform, the epistominids were accompanied by numerous species of lenticulinids; in the Early Callovian the lenticulinids are associated with increased number of polymorphinids.

The Callovian zones of the Canadian Atlantic Shelf and the East European Platform are based on different diagnostic assemblages. Some zonal diagnostic species of benthic calcareous Foraminifera from the *Epistomina coronata-Epistomina regularis-Epistomina omninoreticulata* Callovian zone on the Canadian Atlantic Shelf are also found in the Early

Callovian of the Polish Lowlands. These are *Ophthalmidium carinatum* Kübler and Zwingli, *Epistomina nuda* Terquem and *Epistomina coronata* Terquem (Bielecka and Styk, 1981; Malinowska (ed.), 1980), whereas in the Middle and Late Callovian of the easternmost parts of the East European Platform the only diagnostic species is *Epistomina porcellanea* Brückmann (Azbel and Grigelis (eds.), 1991). In the interval of the benthic agglutinated foraminifera *Trocholina conica* Zone (Bathonian-Callovian age on the Canadian Atlantic Shelf), several species of the genus *Trocholina* occur in the East European Platform: *Trocholina nana* Kaptarenko in the Bathonian and Early Callovian, *Trocholina conica* (Schlumberger) in the Bathonian, and *Trocholina klaipedica* Grigelis in the Middle and Late Callovian (Grigelis, 1985).

Late Jurassic

Figure 2 illustrates the stratigraphic ranges of Late Jurassic species; 33 common species were discovered in the Oxfordian-Tithonian interval. Their maximum of 13-16 species in common falls within the Oxfordian and Early Kimmeridgian, their minimum co-occurence of four species is seen in the Late Tithonian.

In the Oxfordian, nine common species have been identified. The presence of the planktonic species *Globuligerina oxfordiana* (Grigelis) in both regions justifies recognizing a coeval zone of the same name (Grigelis and Kuznetsova, 1987; Ascoli, 1988.).

The benthic species in common include *Saracenaria triquetra* (Gümbel) and *Conorboides paraspis* (Schwager), restricted in both regions to the Oxfordian. First appearing in the Callovian, and more characteristic of the Oxfordian, are *Conorboides scutuliformis* (Seibold and Seibold) and *Saracenaria cornucopiae* (Schwager); the latter species ranges into

the Early Kimmeridgian on the East European Platform (Lithuania). *Ophthalmidium strumosum* (Gümbel), the zonal marker species for the Middle Oxfordian of the East European Platform, has also been recorded in the Callovian of the Canadian Atlantic Shelf. Characteristic of the Oxfordian of both regions are *Astacolus irretitus* (Schwager) and *Trocholina transversarii* Paalzow, which are also known in the Early Kimmeridgian.

On the Canadian Atlantic Shelf, the Oxfordian is recognized by the calcareous benthic Foraminifera assemblages of the *Epistomina soldanii-Conorboides paraspis* Zone, and by the agglutinated benthic Foraminifera assemblages of the *Alveosepta jaccardi* Zone (upper part of the Oxfordian). On the East European Platform the zonation of the Oxfordian is more detailed, and is based on the study of reference sections dated by ammonites (Mesezhnikov (ed.), 1989). In this region, the *Ophthalmidium sagittum-Epistomina volgensis* Zone of the Early and early-Middle Oxfordian has no "zonal marker species" in common with the Canadian Atlantic Shelf, but it does contain *Epistomina nemunensis* Grigelis and *Trocholina transversarii* Paalzow which appear in the Oxfordian of the latter area. *Lenticulina brueckmanni* Mjatliuk and *Epistomina volgensis* Mjatliuk, which are zonal marker species for the Early Oxfordian of the East European Platform, appear only in the Kimmeridgian on the Canadian Atlantic Shelf. The species observed in common in the fossil assemblage of the *Ophthalmidium strumosum-Lenticulina brestica* Zone of the Middle Oxfordian of the East European Platform are the zonal marker *Ophthalmidium strumosum* (Gümbel), plus *Epistomina volgensis* Mjatliuk, *Epistomina nemunensis* Grigelis and *Trocholina transversii* Paalzow. The species in common in the zonal diagnostic assemblage of the *Lenticulina russiensis-Epistomina uhligi* Zone of the Late Oxfordian of the East European Platform is *Ophthalmidium strumosum*; *Astacolus irretitus* (Schwager), *Lenticulina quenstedti* (Gümbel)

and *Epistomina nemunensis* Grigelis have also been recorded.

The agglutinated benthic zone of *Alveosepta jaccardi* is recognized as an acme-zone for the Late Oxfordian both on the Canadian Atlantic Shelf and in the Crimea-Caucasus region (southern rim of the East European Platform) (Azbel and Grigelis (eds.), 1991; Ascoli, 1988).

In the Kimmeridgian, 14 common species, all benthic, have been found. The Kimmeridgian age designation has been assigned with confidence on the basis of the occurrence of the benthic calcareous Foraminifera *Epistomina cognita* Yakovleva, *Epistomina arkelli* Bielecka and Kuznetsova and *Paulina marginata* (Lloyd), which are unknown above the Kimmeridgian. *Epistomina nemunensis* Grigelis, *Planularia tricarinella* (Reuss), *Planularia feifeli* Paalzow and *Lenticulina brueckmanni* Mjatliuk range throughout the Oxfordian and the Kimmeridgian. In the Kimmeridgian of the Canadian Atlantic Shelf, *Epistomina mosquensis* Uhlig and *Epistomina volgensis* Mjatliuk, occur later than on the East European Platform, where they are not known above the Early-Middle Oxfordian. In both regions *Epistomina praereticulata* Mjatliuk and *Eoguttulina inovroclaviensis* Bielecka and Pozaryski appear in the Kimmeridgian. The characteristic Polish Kimmeridgian species *Lenticulina vistulae* Bielecka and Pozaryski appears in the Oxfordian on the Canadian Atlantic Shelf, whereas *Trocholina solecensis* Bielecka and Pozaryski in Poland appears in the Late Oxfordian.

Among benthic agglutinated Foraminifera, *Alveosepta jaccardi* (Schrodt) survives in the Kimmeridgian of both regions. This species ranges as high as Early Kimmeridgian on the Canadian Atlantic Shelf and in Poland, and extends into the Late Kimmeridgian in Crimea. *Mesoendothyra izjumiana* Dain (*Everticyclammina* sp.1 sensu Ascoli, 1988), which is known

in the Oxfordian of both regions, is also present in the Kimmeridgian of the Canadian Atlantic Shelf.

The zonation of the Kimmeridgian of the Canadian Atlantic Shelf and the East European Platform can be compared on the basis of common species among the zonal diagnostic assemblages. The calcareous benthic zone of *Planularia tricarinella-Epistomina mosquensis* of Kimmeridgian age on the Canadian Atlantic Shelf has some species in common with the *Lenticulina kuznetsovae-Epistomina praetatariensis* Zone in the Early Kimmeridgian of the East European Platform, i.e. *Epistomina cognita, Epistomina arkelli* and *Paulina marginata.* In the latter region, the *Haplophragmium monstratum-Pseudolamarckina pseudorjasanensis* Zone of Late Kimmeridgian age has two species (*Epistomina praereticulata* and *Epistomina stellicostata*) in common with the Canadian Atlantic Shelf.

The agglutinated benthic zones of *Alveosepta jaccardi* in the Early Kimmeridgian and of *Trocholina solecensis* in the Late Kimmeridgian of the Canadian Atlantic Shelf correlate with the Kimmeridgian of the East European Platform on the basis of common zonal index species. In the Late Kimmeridgian, *Mesoendothyra izjumiana* Dain and *Paleogaudryina varsoviensis* (Bielecka and Pozaryski) are also present in both regions.

In the Tithonian stage, corresponding to the Early and Middle Volgian, eleven common species have been identified. No planktonic Foraminifera have been found.

Characteristic of the Tithonian of the southern part of the Canadian Atlantic Shelf is the Tethyan endemic species *Anchispirocyclina lusitanica* (Egger), which originates in the Kimmeridgian. This species is also known from the Tithonian deposits of Crimea, where it ranges into the Berriasian (Kuznetsova and Gorbachik, 1985). Many species originating from older deposits become extinct in the Tithonian of the Canadian Atlantic Shelf. These include

Epistomina ex gr. *parastelligera* (Hofker)-*Epistomina ventriosa* Espitalié and Sigal, *Epistomina stellicostata* Bielecka and Pozaryski, *Epistomina madagascariensis* Espitalié and Sigal, *Trocholina elongata* (Leupold), *Ammobaculites coprolithiformis* (Schwager), *Paleogaudryina varsoviensis* (Bielecka and Pozaryski) and *Planularia dofleini* Kasantsev. *Lenticulina quenstedti* (Gümbel) and *Lenticulina polonica* (Wisniowski) become extinct in the Early Tithonian, whereas *Planularia beierana* (Gümbel) persists into the Berriasian. In the East European Platform the range intervals of some of these species are often one or two stages lower than on the Canadian Atlantic Shelf, and the top of their range corresponds to the Oxfordian or Kimmeridgian (see Figure 2).

On the basis of calcareous benthic Foraminifera, the *Epistomina stellicostata-Epistomina* ex gr. *Epistomina parastelligera-Epistomina ventriosa* Zone has been recognized in the Tithonian of the Canadian Atlantic Shelf (Ascoli, 1990). This interval corresponds to three zones of Early and Middle Volgian age in the East European Platform: *Lenticulina undorica-Pseudolamarckina bieleckae* Zone (Early Volgian), *Lenticulina ponderosa-Saracenaria pravoslavlevi* Zone (Middle Volgian) and *Spirofrondicularia rhabdogonioides-Lenticulina oligostegia* Zone (Middle Volgian). On the basis of its zonal diagnostic species, the Tithonian zone of the Canadian Atlantic Shelf correlates with the Early Volgian zone delimited by the top of *Ilovayskya pseudoscythica*, in which the common species *Planularia dofleini* Kasantsev, *Epistomina stellicostata* (Bielecka and Pozaryski) and *Epistomina praereticulata* Mjatliuk have been identified. Judging by the zonal diagnostic assemblages, the zones of the Middle and Late Volgian (on the Canadian Atlantic Shelf the latter corresponds to the Early Berriasian) do not have any species in common.

The agglutinated benthic zone of *Anchispirocyclina lusitanica-Ammobaculites*

coprolithiformis of Tithonian age on the Canadian Atlantic Shelf is correlatable with the East European Platform on the basis of the species *Anchispirocyclina lusitanica* (Egger) (known from the Tithonian of Crimea) and *Trocholina elongata* (Leupold), known from the Tithonian of the Ukrainian Carpathians (Azbel and Grigelis (eds.), 1991; Kuznetsova and Gorbachik, 1985).

Early Cretaceous

An analysis was made of the interval from the Berriasian to the Barremian. The presence in the Berriasian of some Tithonian species such as *Epistomina volgensis* Mjatliuk, *Verneuilinoides neocomiensis* (Mjatliuk) and *Planularia beierana* (Gümbel), justifies the establishment of separate foraminiferal zones for the Tithonian and the Berriasian. On the whole, the Tithonian-Berriasian boundary is clearly defined; seven out of the nine species constituting the zonal diagnostic assemblage of the Late Tithonian on the Canadian Atlantic Shelf (Figure 3) disappear at this boundary. The zonation of the latter area was analyzed using data from the northern part of the East European Platform (Pechora Basin) and from the southern rim of the Platform (Crimean-Caucasus Basin) (Bystrova, 1991; Gorbachik, 1991; Kuznetsova and Gorbachik, 1985).

In the Berriasian-Valanginian, seven species common to both regions have been identified. The planktonic species *Favusella hoterivica* (*Subbotina*) is presumed to appear for the first time in the Berriasian of the Canadian Atlantic Shelf and in the Hauterivian of the East European Platform, where only *Favusella caucasica* (Gorbachik and Poroschina) and *Favusella gulekhensis* (Gorbachik and Poroschina) are known to be present in the Berriasian and Valanginian deposits (Grigelis and Gorbachik, 1980). Since specimens of *Favusella*

hoterivica from the Valanginian beds of the Scotian Shelf have been examined by Dr. T. Gorbachik and identified by her as *Favusella gulekhensis* (Gorbachik, personal communication to P. Ascoli), the latter species is considered by Wernli, Ascoli and Williams (in press) to be an Early Berriasian-Valanginian variant of the typical *Favusella hoterivica*, which on the Scotian Shelf ranges as high as Barremian. Consequently, in the Crimea-Caucasus region the Berriasian-Valanginian beds are characterized by the presence of *Favusella gulekhensis* (= early *Favusella hoterivica*), whereas the Hauterivian beds are characterized by the typical *Favusella hoterivica.* In contrast, on the Canadian Atlantic Shelf, *Favusella gulekhensis* has not been separated by *Favusella hoterivica*, and a unique *Favusella hoterivica* Zone of comprehensive Berriasian-Barremian age has been established (Ascoli, 1988, 1990).

Among the benthic species, there are no common ones in the Early Berriasian of the Pechora Basin, whereas *Verneuilinoides neocomiensis* (Mjatliuk) is common to both regions in the Late Berriasian-Valanginian. In the Late Valanginian (*Polyptychites polyptychus* Zone) of the Pechora Basin, the species shared with the Canadian Atlantic Shelf, apart from the already-mentioned *Verneuilinoides neocomiensis*, are *Lenticulina eichenbergi* Bartenstein and Brand, *Lenticulina schreiteri* Bartenstein and Brand, *Planularia crepidularis* (Reuss), *Epistomina caracolla caracolla* Roemer, *Epistomina tenuicostata* Bartenstein and Brand, and *Epistomina ornata* Roemer. Of these, *Planularia crepidularis*, *Epistomina caracolla* and *Epistomina ornata* make their first appearance on the Canadian Atlantic Shelf in the Berriasian, while *Lenticulina eichenbergi, Lenticulina schreiteri* and *Epistomina tenuicostata* are known from the Valanginian.

In the Berriasian and Valanginian of the southern rim of the East European Platform,

the benthic species in common include *Trocholina elongata* (Leupold), which disappears in the Late Berriasian, *Conoroides hofkeri* (Bartenstein and Brand) and *Saracenaria valanginiana* Bartenstein and Brand which appear in the Late Berriasian, and *Lenticulina busnardoi* Moullade, *Lenticulina guttata* (Ten Dam) and *Epistomina ornata* (Roemer) which appear in the Valanginian.

Within the Berriasian-Valanginian interval, the calcareous benthic Foraminifera zones of the Canadian Atlantic Shelf can be correlated with those of the Pechora Basin in the Late Valanginian, where *Lenticulina eichenbergi* Bartenstein and Brand is the index species of the *Reophax minutissima-Lenticulina eichenbergi* Zone (Bystrova, 1991). The common species *Epistomina caracolla* (Roemer), *Epistomina ornata* (Roemer) and *Epistomina tenuicostata* Bartenstein and Brand are used on the Canadian Atlantic Shelf as zonal index species marking the top of the Hauterivian and Barremian stages on the basis of their highest stratigraphic occurrence.

Among the calcareous benthic zones in the Berriasian and Valanginian, the *Epistomina* aff. *Epistomina minutereticulata-Epitomina volgensis* Zone of Berriasian age on the Canadian Atlantic Shelf is not correlatable on the basis of common species. The *Conorboides hofkeri-Conorbina heteromorpha* Zone of the Late Berriasian of Crimea can be correlated owing to the presence of *Conorboides hofkeri* (Bartenstein and Brand) in the Berriasian of the Canadian Atlantic Shelf. The *Lenticulina busnardoi-Lenticulina guttata guttata* Zone in the Early Valanginian of Crimea and the *Lenticulina busnardoi-Lenticulina saxonica bifurcilla* Zone in the Valanginian of the Canadian Atlantic Shelf can be correlated on the basis of the presence of *Lenticulina busnardoi.*

The agglutinated benthic "*Everticyclamina virguliana*" *plexus-Haplophragmoides*

concavus Zone has no species in common with the East European Platform and its southern rim.

In the Hauterivian there are eleven species in common between the Canadian Atlantic Shelf and the East European Platform. Of these, *Conorboides valendisensis* (Bartenstein and Brand) and *Epistomina caracolla caracolla* (Roemer) have been identified both on the Canadian Atlantic Shelf and in the Pechora and Crimean-Caucasus basins. The species *Haplophragmoides concavus* (Chapman) from the Valanginian-Early Hauterivian of the Canadian Atlantic Shelf and *Haplophragmoides* ex gr. *Haplophragmoides concavus* from the Hauterivian of the Pechora Basin may be identical. Except the above-mentioned *Favusella hoterivica, Epistomina caracolla* and *Conorboides valendisensis* in the Hauterivian of the Canadian Atlantic Shelf and the Crimean-Caucasus region, *Dorothia kummi* Zedler, *Lenticulina saxconica bifurcilla* Bartenstein and Brand, *Lenticulina saxonica saxonica* Bartenstein and Brand, *Lenticulina eichenbergi* Bartenstein and Brand, *Lenticulina nodosa* (Reuss) and *Lenticulina collignoni* Espitalié and Sigal have been identified.

The zonation of the Hauterivian on the Canadian Atlantic Shelf includes the calcareous benthic *Planularia crepidularis-Epistomina tenuicostata* Zone. This zone can be correlated with the Hauterivian of the East European Platform and Crimea on the basis of the common species listed above. On the basis of the agglutinated benthics, the *Verneuilinoides neocomiensis-Dorothia kummi* Zone has been recognized in the Hauterivian-Barremian of the Canadian Atlantic Shelf. The Early Hauterivian part of this zone is correlatable on the basis of its index species with the *Marginulinopsis sigali-Dorothia kummi* Zone of the Early Hauterivian of the Crimean-Caucasus region (Kuznetsova and Gorbachik, 1985; Ascoli, 1990).

In the Barremian there are seven species common to both the Canadian Atlantic Shelf

and the southern rim of the East European Platform. The Early Barremian has not been identified in the Pechora Basin, and there are no common species in the Late Barremian. In the Crimean-Caucasus Basin, *Marginulinopsis sigali* Bartenstein, Bettenstedt and Bolli is restricted to the Barremian, whereas the characteristic species *Gavellina barremiana* (Bettenstedt) ranges into the Aptian. *Lenticulina nodosa* (Reuss) occurs as high as Early Barremian and *Lenticulina collignoni* Espitalié and Sigal disappears in the Late Barremian. The Early Barremian is characterized only by *Lenticulina ouachensis* Sigal. *Planularia crepidularis* (Reuss) and *Lenticulina kugleri* Bartenstein, Bettenstedt and Bolli persist in the Aptian. In the Barremian of the Canadian Atlantic Shelf, the highest stratigraphic occurrences of some of these species coincide whereas those of others differ by half a stage (Figure 3).

Zonation of the Barremian on the basis of calcareous benthic Foraminifera utilizes different zonal marker species for the Canadian Atlantic Shelf and the Crimean-Caucasus region. However, if foraminiferal species common to both regions are considered, the *Epistomina ornata-Epistomina hechti-Epistomina caracolla* Barremian zone of the Canadian Atlantic Shelf correlates with the *Gavelinella barremiana-Conorotalites bartensteini* Zone in the Crimean-Caucasus. The planktonic foraminiferal zonation of the Barremian of the latter region is more detailed and appears to encompass the upper part of the *Favusella hoterivica* zone of the Canadian Atlantic Shelf.

CONCLUDING REMARKS ON ZONATION

Analysis of the stratigraphic ranges of species shows a common succession of foraminiferal faunal assemblages throughout the entire Bajocian-Barremian interval of the Canadian Atlantic Shelf and the East European Platform, including the Crimean-Caucasus

area.

Foraminiferal zones are correlated on the basis of three different kinds of species in common to both regions: 1) common zonal marker species; 2) common zonal diagnostic species; and 3) common species l.s. (i.e. neither "marker species" nor "diagnostic species").

The recognized foraminiferal zones have been calibrated chronologically with the standard ammonite zones, established in the East European Platform. On the Canadian Atlantic Shelf, where the nature of samples (mostly well cuttings) has prevented any ammonite study, foraminiferal zones have been calibrated chronologically with the standard calpionellid zones that have been established for the calpionellid assemblages in the Tithonian-Valanginian interval.

The differences in the methods used to establish the zones and to select the index species (on the basis of their highest or lowest stratigraphic occurrence) did not cause any significant contradiction when validating the adopted zonation of the Middle Jurassic-Early Cretaceous of the two regions. The assessment seems objective because the authors worked out the zonation of the two regions independently. Differences in the stratigraphic ranges of the species from the two continents clearly show that many species from the Canadian Atlantic Shelf range higher than in the East European Platform. This is probably due to a westward migration of species within the Boreal-Atlantic Basin as the North Atlantic progressively opened (e.g. genus *Epistomina*; Ascoli, 1976).

PALEOECOLOGY

The zonation of the Jurassic-Early Cretaceous deposits is based on different ecological groups of Foraminifera, namely planktonic, calcareous benthic and agglutinated benthic. It takes into account the relationship between the distribution of foraminiferal zones and

sedimentation zones within the basin, i.e. the relatively exposed argillaceous-carbonate shelf facies (plankton), the slope carbonate-argillaceous and reef facies (calcareous benthic), and the shallow-water arenaceous-argillaceous facies (agglutinated benthic). One of the most interesting tasks of future research may be to analyze the distribution of these ecozones in relationship to specific sections of offshore wells drilled on the Canadian Atlantic Shelf, for the purpose of basin analysis and reconstruction of facies zonation.

The features of the taxonomic composition of the Jurassic and Early Cretaceous foraminiferal assemblages were determined not only by facies characteristics, but also by the paleobiogeographic (climatic) zonation as well. The Jurassic and Early Cretaceous basin of the East European Platform was inhabited by a "Boreal-Atlantic" (nodosariid-epistominid) type of foraminiferal fauna (Basov, 1991; Grigelis, 1985). A similar kind of microfauna was living at the same time on the Canadian Atlantic Shelf, being characterized by abundant epistominids and lenticulinids and by very scarce nodosariids. This kind of foraminiferal assemblage, neither typically Boreal nor typically Tethyan, could perhaps be named "sub-Boreal-Atlantic". Both the "Boreal-Atlantic" and the "sub-Boreal-Atlantic" kinds of microfauna are characterized by considerable taxonomic diversity, heterogeneity of the population and a rapid rate of evolution of lenticulinids and epistominids. Characteristic of the carbonate and arenaceous-argillaceous shallow-water facies of the East European Platform was the facies-related explosive development of the genera *Ammobaculites*, *Ophthalmidium*, *Trocholina* and *Spirillina*. In the deeper water of the Canadian Atlantic Shelf, with continuous sedimentation taking place from the beginning of the Middle Jurassic, epistominids became dominant.

The boundary of the two largest paleobiogeographic zones of the Jurassic and Cretaceous, namely the Boreal and Tethyan realms, extended along the southern margin of the

two studied regions. In the Late Jurassic, this boundary - which stretches along the present northern latitude of 44°-45° - was clearly defined by the appearance in both regions of the Tethyan species *Alveosepta jaccardi* in the Oxfordian, *Trocholina elongata* in the Kimmeridgian, and *Anchispirocyclina lusitanica* in the Tithonian (Ascoli, 1976, 1988). On the Canadian Atlantic Shelf, the latter species was recorded in wells on the Scotian Shelf (Oneida O-25, Migrant N-20), the Scotian Basin (Citnalta I-59, South Griffin J-13) and Jeanne d'Arc Basin (Bonnition H-32).

Chronologically, the point in time when the Tethyan influence became stronger on the Canadian Atlantic Shelf than in the East European Platform has been established as Early Kimmeridgian, when the typical Tethyan faunal complex known as "*Everticyclammina virguliana* plexus" first appears in the former region, reaching its peak near the Jurassic-Cretaceous boundary and disappearing in the Late Valanginian-Early Hauterivian. Another typical representative of the Tethyan realm is *Choffatella decipiens* (Schlumberger), which on the Canadian Atlantic Shelf, as well as in the Mediterranean area, appears in the Late Berriasian-Early Valanginian and peaks in the Hauterivian-Barremian; it becomes extinct in the Early Aptian. Neither *Everticyclammina virguliana*, nor *Choffatella decipiens* have thus fas been found in the Kimmeridgian-Aptian beds of the East European Platform. These beds were deposited in a more typical boreal environment.

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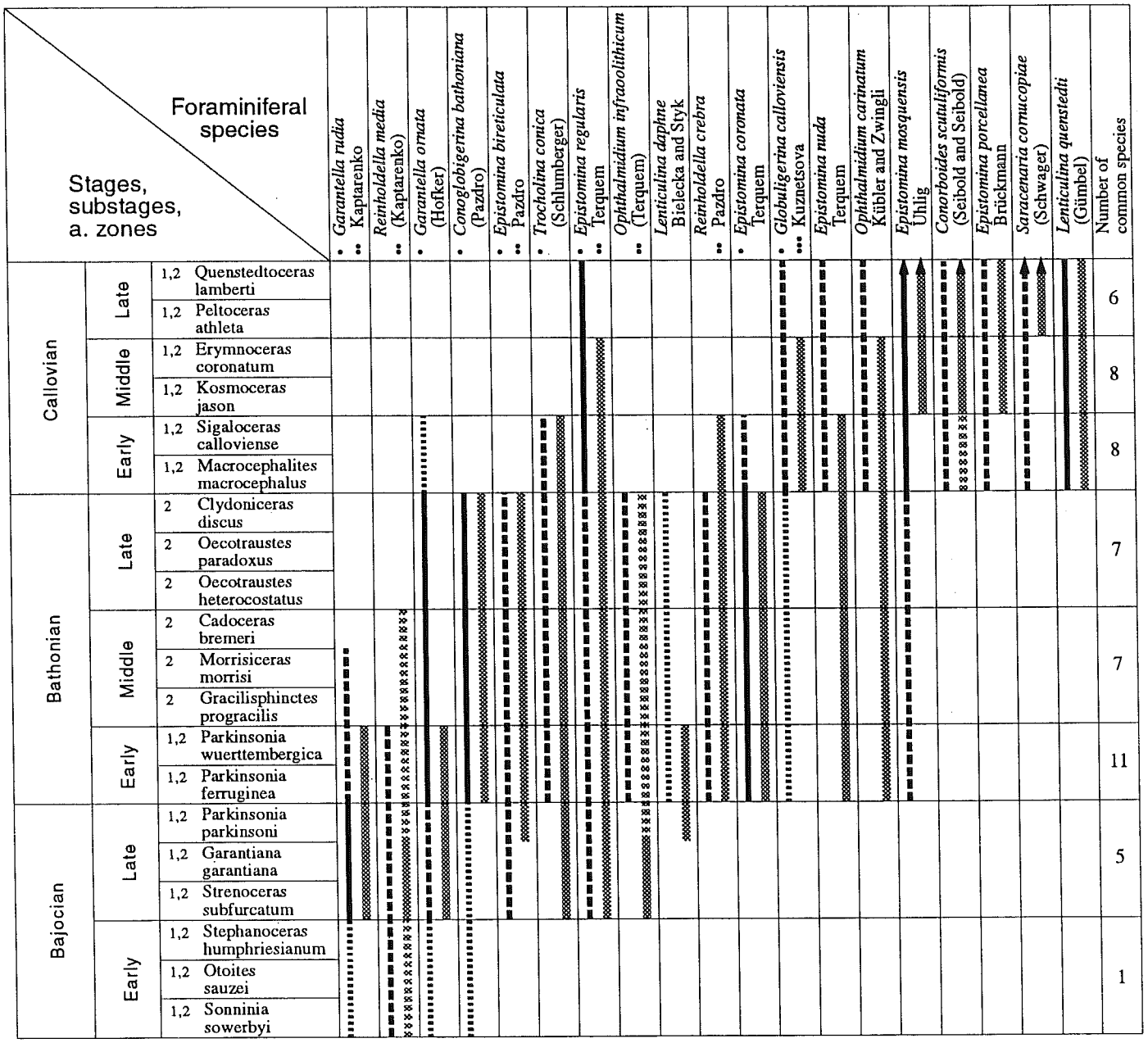

Ammonite zonation: 1 data for the East European Platform; 2 data for the Polish Lowlands

Ranges of selected foraminiferal species

Canadian Atlantic Shelf
- > 5 wells
- < 5 wells
- possible presence

East European Platform
- confirmed presence
- possible presence

southern rim of East European Platform
- confirmed presence
- possible presence

Zonal index species
- Canadian Atlantic Shelf
- East European Platform
- southern rim of East European Platform

Fig. 1 Stratigraphic ranges of Middle Jurassic Foraminifera on the Canadian Atlantic Shelf and the East European Platform.

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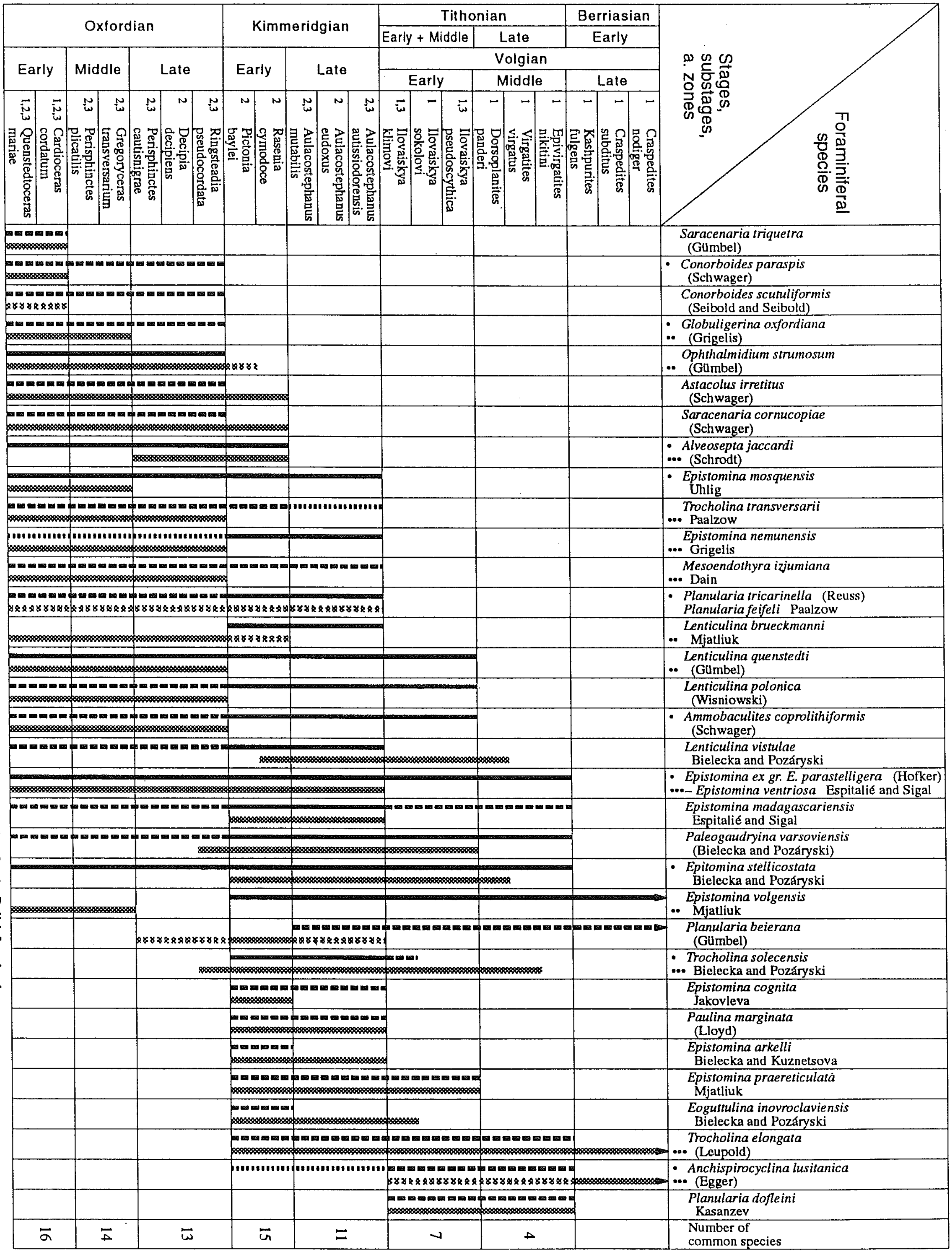

Ammonite zonation: 1 data for the East European Platform; 2 data for the southern rim of the East European Platform; 3 data for the Polish Lowlands

Fig. 2 Stratigraphic ranges of Late Jurassic Foraminifera on the Canadian Atlantic Shelf and the East European Platform (symbols as in Fig.1).

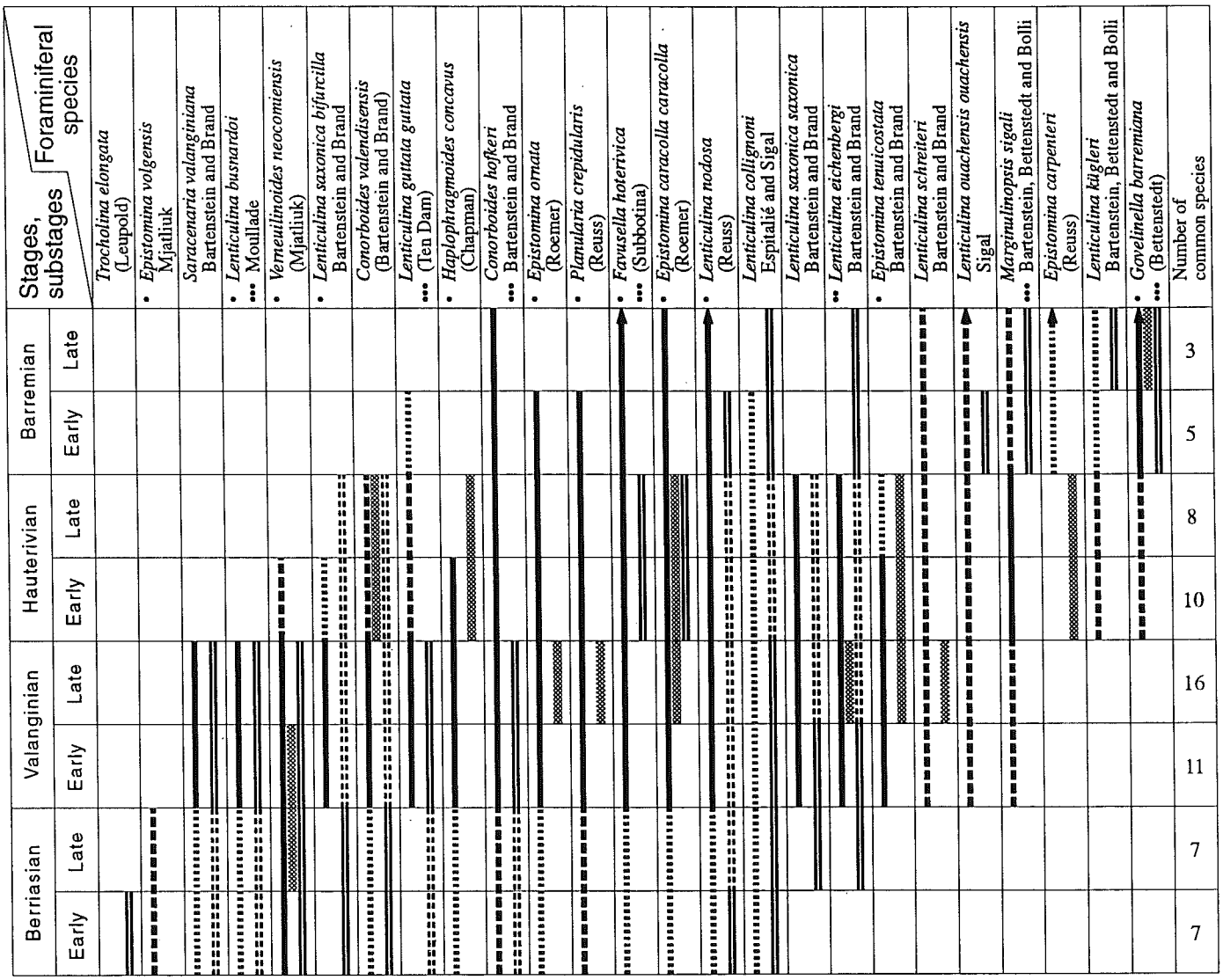

Fig. 3 Stratigraphic ranges of Early Cretaceous (Berriasian-Barremian) Foraminifera on the Canadian Atlantic Shelf, the East European Platform and its southern rim (symbols as in Fig. 1).

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