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## Stratigraphy and Palaeobiogeography of Mesozoic Benthic Foraminifera of the Karst Dinarides (SE Europe)

Ivo VELIĆ

**Key words:** Benthic foraminifera, Chronostratigraphy, Biostratigraphy, Palaeobiogeography, Mesozoic, Karst Dinarides, Adriatic Carbonate Platform, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro.

### Abstract

The Adriatic Carbonate Platform (AdCP), was a separate shallow-marine depositional system characterized by a lack of terrigenous input and was connected to Gondwana towards the South via Gavrovo–Tripolitza or Apulia. It existed for approximately 120 MY, from the Early Jurassic (Pliensbachian/Toarcian) to the end of the Cretaceous, resulting in a 4000–6500 m thick succession of almost pure carbonates. However, this is part of a thicker (>8000 m) sequence of predominantly carbonate rocks which forms the Karst Dinarides, and was deposited during more than 270 MY – at least from the Carboniferous (Moscovian) to the Late Eocene.

Among many different groups of fossil organisms, benthic foraminifera are especially abundant and well preserved, so they, along with calcareous algae (Dasycladales), are the most important fossils used for age determination and stratigraphic subdivision of shallow-marine carbonate deposits.

Within the 257 determined taxa belonging to different foraminiferal families which lived through the Mesozoic, numerous different index fossils occur in assemblages indicating various ages: Early Triassic, Anisian, Carnian, Norian–Rhaetian, Late Sinemurian, Early and Late Pliensbachian (Carixian and Domerian), Early and Late Aalenian, Early and Late Bajocian, Early and Late Bathonian, Callovian, Early and Late Oxfordian, Kimmeridgian, Tithonian, Berriasian, Valanginian, Late Hauterivian, Late Barremian, Early and Late Aptian (Bedulian and Gargasian), Early and Late Albian, Early, Middle and Late Cenomanian, Turonian, Coniacian, Santonian, Early and Late Campanian and Early and Late Maastrichtian.

A total of 64 biostratigraphic units – biozones of different categories, from subzone to superzone, were defined within the stratigraphic interval from the Carnian to the Late Maastrichtian. This enabled very detailed biostratigraphic subdivision of the carbonate deposits within the Karst Dinarides. This is one of the most precise sequences, not only in this area, but also among former shallow marine deposits of the entire Neotethyan realm in the present Mediterranean region.

The palaeobiogeographic characteristics of biotopes and the composition of foraminiferal assemblages during the Mesozoic were controlled by the position of the study area within the Neotethyan bioprovinces. Until the Albian, this area represented part of the Southern Neotethyan bioprovince, while from the Cenomanian to its final disintegration at the end of the Cretaceous it belonged to a separate, Central Mediterranean Neotethyan bioprovince.

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*Ovaj rad posvećujem članovima Velebitsko–kapelske ekipe (1962–1980) – kolegama Anti Ivanoviću, Leonu Nikleru, Branku Sokaču, Ivanu Galoviću i Stjepanu Markoviću s kojima sam zajedno sudjelovao u izradbi Osnovne geološke karte 1:100.000 u Velebitu, Lici, Velikoj i Maloj Kapeli i Ogulinskome kraju. Tada su se, prvenstveno prema mikrofosilima, a među njima i bentičkim foraminiferama, provele prve detaljnije stratigrafske raščlambe jurskih i krednih naslaga u Krškim Dinaridima. To je bilo polazište za kasnija paleontološko–stratigrafska istraživanja koja su rezultirala mnogobrojnim znanstvenim radovima, pa tako i ovim radom.*

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*This paper is dedicated to the members of the Velebit–Kapela team (1962–1980) – my colleagues Ante Ivanović, Leon Nikler, Branko Sokač, Ivan Galović and Stjepan Marković. Together we produced a Basic Geological Map at 1:100,000 scale, and performed detailed stratigraphical subdivision of the Jurassic and Cretaceous rocks of Velebit Mt., Lika, Velika and Mala Kapela Mts. and the Ogulin area. Based on benthic microfossils – foraminifera and dasyclad algae, this was the first such subdivision in the Dinarides. That work represented a foundation for subsequent palaeontological–stratigraphic investigations which resulted in numerous scientific papers, of which the present paper is included.*

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### 1. INTRODUCTION

Benthic foraminifera are among the most important fossil organisms for age determination and stratigraphic subdivision of shallow-marine carbonate deposits of the Mesozoic Karst Dinarides. Some taxa (or even entire assemblages) enable chronostratigraphic determination, because their stratigraphic ranges were evaluated by correlation with ammonite zones, mostly in the Western Mediterranean realm, e.g. Moroccan Atlas, Spanish Betic Cordillera, and especially in France: Pyrenees, Aquitaine and Paris Basins, Provence, Western Alps, etc. The Jurassic litiolids can be highlighted, as an example of

stratigraphically well determined forms; especially the *Orbitopsella* spp. of the Lower Jurassic of Morocco (SEPTFONTAINE, 1984), hauranids and pfenderinids in the Middle Jurassic and kurnubiinids in the Upper Jurassic of the Western Mediterranean in Europe and Northern Africa (BASSOULLET, 1997), orbitolinids in the Hauterivian–Aptian (‘Urgonian’) deposits of SE France (e.g. CLAVEL et al., 1995; ARNAUD et al., 1998; SCHROEDER et al., 2002), or within Upper Barremian–Middle Cenomanian stratigraphic range in the Prebetian Platform of SE Spain (CASTRO et al., 2001). Other examples include the orbitolinids and alveolinids of Vraconian and Cenomanian deposits of the Eastern Pyrenees (BILOTTE, 1985), etc.

During the last couple of decades, new and sophisticated methods have been introduced into stratigraphic and palaeontologic investigations, e.g. dating on the basis of isotopic or palaeomagnetic analyses, or determination of DNA within fossil organisms, and many papers were published. Recently, when the term palaeontology has become increasingly substituted by the term palaeobiology, the purpose of a paper such as this, i.e. the stratigraphy of benthic foraminifera within the shallow-marine Mesozoic carbonates of the Adriatic Carbonate Platform, may be questioned. This is especially true since papers on similar topics in the neighbouring carbonate platforms were published more than 10 years ago (e.g. CHIOCCHINI et al., 1994: Apenninic Platform). However, this is the first synthesis of the results of stratigraphic investigation of benthic foraminifera of the AdCP in the last fifty years, especially on Upper Triassic to Uppermost Cretaceous deposits.

The Adriatic Carbonate Platform (AdCP, Fig. 1) is a term for a palaeogeographic entity which existed from the Early Jurassic to the end of the Cretaceous, and which forms an important part of the Karst Dinarides. However, shallow-marine environments mostly characterised by carbonate deposition existed for much longer in the study area. The oldest carbonate rocks cropping out in the Karst Dinarides are Carboniferous in age, while almost continuous carbonate deposition lasted for some 220 MY, from the Middle Permian to the Eocene (VELIĆ et al., 2002).

Before the individualization, i.e. during the Late Palaeozoic and Early Triassic, the area of the future Karst Dinarides represented part of the Gondwanian epicontinental shelf (see discussion in VLAHOVIĆ et al., 2005).

From the Middle Triassic to the middle Early Jurassic, the area of the present Karst Dinarides was part of the huge, more or less isolated carbonate platform (free from continental influences), which covered a large part of present Southern and Central Europe. This was called the *Southern Tethyan Megaplatform* by VLAHOVIĆ et al. (2005), and it disintegrated into several smaller, relatively isolated carbonate platforms during Late Sinemurian to Late Toarcian times. These smaller platforms included, among others, the Adriatic, Apulian and Apenninic platforms (VLAHOVIĆ et al., 2002, 2005; DRAGIČEVIĆ & VELIĆ, 2002).

The Adriatic Carbonate Platform *s.str.* existed from the late Early Jurassic (Pliensbachian/Toarcian) to near the end of the Cretaceous, when it was finally destroyed. It represented an almost completely isolated shallow-marine depositional system, which was probably connected towards the S and SE to the Kruja and Gavrovo–Tripolitza platforms (VLAHOVIĆ et al., 2005). During the Mesozoic period the platform continuously migrated from the Southern Tethyan realm, where it was placed during the Early Jurassic, towards the N and NE, to the Northern areas of this palaeo-ocean in the Late Maastrichtian. It was surrounded by deep-marine basins: the

Bosnian to the N and NE, Krasta–Budva–Cukali to the SE, Ionian–Adriatic–Belluno to the S and SW and the Slovenian Basin to the NW.

During the late Maastrichtian and Palaeogene, the platform significantly disintegrated, and carbonate depositional environments were established only within restricted areas, particularly several narrow carbonate ramps along flysch–molasse basins surrounding uplifted areas of the former AdCP (VLAHOVIĆ et al., 2002).

Despite significant tectonic disintegration, which had already begun in the Mesozoic and lasted practically throughout the Cenozoic, the Adriatic Carbonate Platform is one of the best preserved fossil carbonate platforms in the World (except for its marginal parts).

Unlike the aforementioned areas of the Western Mediterranean, which were characterized by interfingering of shallow-marine and open-marine/basinal facies, allowing chronostratigraphic determination of many foraminiferal taxa, no such possibilities occurred on the AdCP. This platform was geotectonically relatively stable throughout its existence, without significant palaeogeographic and palaeoenvironmental changes. Therefore, intra-platform shallow-marine deposits were only sporadically accompanied by temporary drowned-platform environments containing ammonites or other pelagic organisms enabling stratigraphic correlation. However, platform margin and slope facies, which interfingered with basinal deposits, were overlain by younger, Tertiary and Quaternary clastic rocks, or by nappes composed of Palaeozoic and older Triassic rocks. Therefore, numerous taxa of benthic foraminifera, the chronostratigraphic range of which were already determined in other Peri-Mediterranean platforms, represent a very important, and sometimes even the only tool for the stratigraphic subdivision of the Karst Dinarides.

This paper considers benthic foraminiferal taxa and assemblages from the stratigraphic viewpoint, as well as examining their importance for the stratigraphic determination of shallow-marine carbonate sequences, especially for geological mapping. In addition, the palaeobiogeography of the most important (mostly index fossils), is presented. Major attention was given to the so-called larger foraminifera, while smaller forms were discussed only if they represent index fossils.

## 2. FORAMINIFERAL TAXA AND ASSEMBLAGES IN THE CHRONO-STRATIGRAPHIC SUCCESSION

Some periods in the geological history of the Adriatic Carbonate Platform and its basement were characterized by the predominance of certain groups of benthic foraminifera. For example, the Early and Middle Triassic were characterized by amoniscids, Late Triassic by involutinids, and the Jurassic by lituolids. During the Cretaceous, diversification was significant. Several groups of smaller foraminifera characterized the Neo-

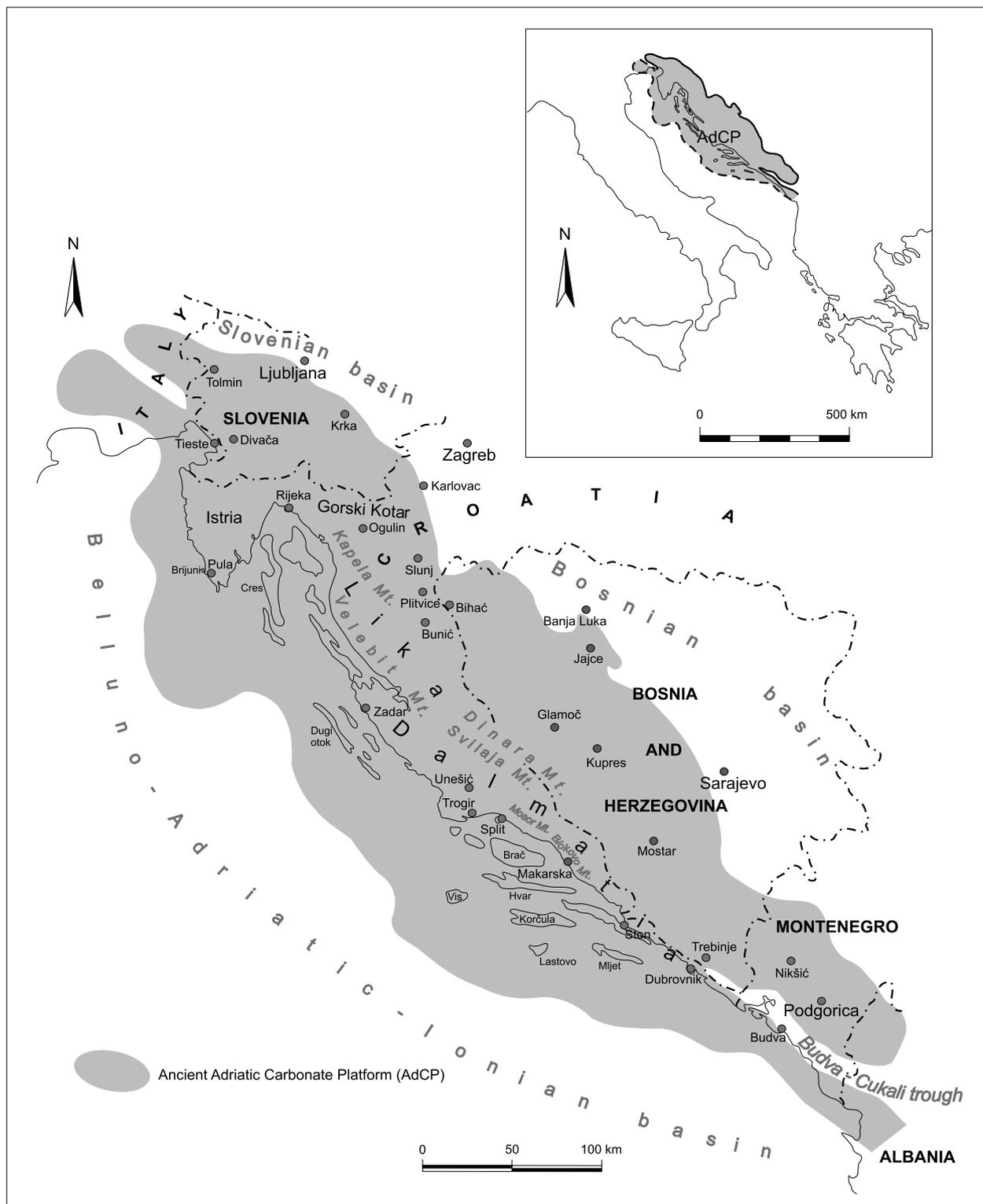


Fig. 1 Recent area covered by the Adriatic Carbonate Platform deposits.

comian. From the Barremian to the Middle Cenomanian the most important foraminifera were orbitolinids accompanied by ataxophragmiids, lituolids, cyclamminids as well as frequent miliolids, cuneolinids, etc. The evolution of soritids and alveolinids can be traced from the Aptian, while orbitoids and siderolitids were important during the Campanian and Maastrichtian.

Genera and species, either individually or within foraminiferal assemblages, are mostly presented in their order of occurrence.

## 2.1. Triassic

As the shallow-marine deposits accumulated during the Triassic belong to the basement of the Adriatic Carbon-

ate Platform, only their general foraminiferal taxa and assemblages are presented. After the Late Permian global biological crisis, when most of the Late Palaeozoic foraminifera (including the most important group, the fusulinids) became extinct, there was a gradual restoration of shallow-marine environments, which were ecologically suitable for the existence of benthic foraminifera.

During the Early Triassic, carbonate deposition was characterized by an important terrigenous influence, and mixed carbonate–siliciclastic environments were not favourable as niches allowing the larger foraminifera to thrive. Therefore, the Early Triassic represented a period during which smaller foraminifera (mostly ammodiscids) predominated. In the Middle Triassic, shallow-marine environments characterized by ‘pure’ carbonate deposition were restored, but in some areas temporary lateral replacement by deeper-marine carbonate–volcanoclastic deposits occurred. From a palaeontological point of view, an abundant flora of calcareous algae, including in particular the Diploporacean family of the Dasycladales, characterized these environments. Reefal–perireefal environments favourable for the development of corals, hydrozoans, molluscs, etc. were also very common. Benthic foraminifera were not very important, but the most frequent were still ammodiscids, meandrospirids, endotriadids, duostominids etc. During the Late Triassic involutinids were the most important foraminifera.

### 2.1.1. Early Triassic – Scythian (Induan and Olenekian)

**General characteristics:** Early Triassic foraminifera were not systematically investigated in the Karst Dinarides, although they are very abundant at some localities. Their occurrence is of great stratigraphic value, because they frequently represent the only palaeontological evidence for the determination of Lower Triassic deposits. Therefore, the most frequent genera and index species are mentioned here.

**Foraminiferal assemblage:** *Cyclogyra mahayeri*, *Meandrospira pusila*, *Ammodiscus parapriscus*, *Arenovidalina chialingchiangensis*, *Glomospirella triphonensis* and numerous other undeterminable smaller foraminifera, mostly ammodiscids.

**Discussion:** This assemblage is characteristic of the Early Triassic of the Karst Dinarides in the Induan–Olenekian stratigraphic range. In his comprehensive and detailed treatise of Croatian Triassic stratigraphy, which also included the NE parts of the AdCP basement in the vicinity of Karlovac GRGASOVIĆ (2003) separated two foraminiferal zones: the older *Cyclogyra mahayeri* zone and younger *Meandrospira pusila* zone, and he cited most of the species listed above. Some of these forms were also listed in some older papers discussing the platform area, e.g. KOCHANSKY-DEVIDÉ & PANTIĆ (1966) and PANTIĆ-PRODANOVIĆ (1975).

### 2.1.2. Middle Triassic

**General characteristics:** Anisian and Ladinian foraminiferal assemblages show great differences, both in their composition and stratigraphic value. While Anisian deposits contain several index species, none have so far been discovered in the Ladinian sediments, where smaller foraminifera predominate.

#### 2.1.2.1. Anisian

**Foraminiferal assemblage:** *Meandrospira dinarica*, *Pilamina densa*, *Pilaminella semiplana*, *Hoyenella* gr. *sinensis*, *Duostomina alta*, *Neoendothyra reicheli*, *Turriplomina mesotriassica*, *Arenovidalina chialingchiangensis*, *Endotriadella wirtzi*, *Froncdularia woodwardi*, *Ammobaculites radstadtensis*, *Aulotortus* sp., *Haplophragmium* sp., *Glomospira* sp., *Glomospirella* sp. and other smaller foraminifera.

**Discussion:** Anisian index species, *Meandrospira dinarica*, *Pilamina densa* and *Pilaminella semiplana*, are widely distributed, and have been described in the area of the Karst Dinarides (PANTIĆ, 1965; KOCHANSKY-DEVIDÉ & PANTIĆ, 1966). They were also cited in later papers (PANTIĆ-PRODANOVIĆ, 1975; GRGASOVIĆ et al., 2000; GRGASOVIĆ, 2003). Other taxa have a wider stratigraphic range, and most of them also occur in Ladinian deposits.

#### 2.1.2.2. Ladinian

**Foraminiferal assemblage:** Most taxa cited in the Anisian assemblage also occur in Ladinian deposits, except for Anisian index forms. However, the most frequent are specifically undeterminable forms of *Diplotremina* and *Duostomina*.

**Discussion:** Ladinian foraminifera have not been previously systematically determined because of their scarcity and the lack of index forms. Therefore, stratigraphic determination and distinction between Anisian and Ladinian deposits has been based on calcareous algal assemblages. On the basis of detailed analysis by GRGASOVIĆ (2003) it may be concluded that there are rare occurrences of *Aulotortus* species in the Ladinian (e.g. *A. praegaschei* and *A. sinuosus*). In the present area of the Karst Dinarides these also occur in Anisian deposits, reaching maximum frequency during the Norian and Rhaetian.

### 2.1.3. Late Triassic

**General characteristics:** Late Triassic foraminiferal assemblages are not especially rich in genera and species. This is the result of palaeogeographic relationships, since the area of the present Karst Dinarides was emergent from the Late Ladinian to the Early Norian (VELIĆ et al., 2002; VLAHOVIĆ et al., 2005). Therefore, older Upper Triassic deposits (Carnian and Lower Norian), can only be observed

along the marginal parts of the platform area, e.g. in the vicinity of Karlovac, from where GRGASOVIĆ (2003) listed rich foraminiferal assemblages. During the Norian and Rhaetian, limestones and early-diagenetic dolomites were deposited within peritidal environments. Limestones mostly suffered late-diagenetic dolomitization, so rocks of this age, usually known as the Main Dolomite (*Hauptdolomit* or *Dolomia principale*), only sporadically contain undolomitized lenses and thinner packages of limestones with Late Triassic fossil assemblages, including frequent foraminifera. The most important group are involutinids, including some index species of the Late Triassic.

#### 2.1.3.1. Carnian

**Foraminiferal assemblage:** *Lamelliconus multispirus*, *L. procerus*, *Aulotortus friedli*, *A. praegaschei*, *A. sinuosus*, *A. tenuis* and numerous smaller foraminifera of greater, Middle and Upper Triassic stratigraphic range.

**Discussion:** Due to emergence, Carnian deposits are either missing, or are represented by terrigenous clastic sediments over much of the Karst Dinarides. Shallow-marine carbonates were only deposited in some places which were not emergent, e.g. central Slovenia, or the vicinity of Karlovac in Croatia along the NE margin, as well as Komiža on the island of Vis, the vicinity of Trebinje in Herzegovina or in Montenegro along the SW and SE margins. Within these rocks a Carnian algal–foraminiferal assemblage has been discovered, including index forms foraminifera *Lamelliconus multispirus* and *L. procerus*. In addition to these two forms, GRGASOVIĆ (2003) also cited numerous other species of smaller foraminifera.

#### 2.1.3.2. Norian

**Foraminiferal assemblage:** *Aulotortus friedli*, *A. praegaschei*, *A. sinuosus*, *A. tenuis*, *A. tumidus*, *Aulococcus permodisoides*, *Trocholina crassa*, *T. acuta* and *Turrispirillina minima*.

**Discussion:** The aforementioned species of *Aulotortus* reached their maximum development in the Late Norian and Rhaetian. They were documented in the regionally very well known Periadriatic and Central European formations of the Main Dolomite (*Hauptdolomit* or *Dolomia principale*) and Dachstein limestones of Upper Triassic age. In the Karst Dinarides, the Main Dolomite is of Late Norian and Rhaetian age. In older papers (PANTIĆ, 1966/67; PANTIĆ-PRODANOVIĆ, 1975) *Turrispirillina minima* was described as a Norian species.

#### 2.1.3.3. Rhaetian

**Foraminiferal assemblage:** *Triasina hantkeni*, *Aulococcus permodisoides*, *Aulotortus friedli*, *A. sinuosus*, *A. tenuis*, *A. tumidus*, *A. pokorny*, *Trocholina crassa* and *T. acuta*.

**Discussion:** *Triasina hantkeni* is the index fossil of the Rhaetian. The maximum frequency of the cited species of *Aulotortus* which appeared in the Late Norian continued into the Early Rhaetian.

## 2.2. Jurassic

During the Jurassic in the area of the present Karst Dinarides, litoiids represented the major foraminiferal group. They occurred in the Sinemurian and had already reached their maximum in the Pliensbachian. They were very frequent in the Middle Jurassic, when together with cyclamminids, valvulinids (especially pfinderinids), as well as other groups they represent the major fossils used for stratigraphic division. The largest number of index fossil taxa occurred in Bathonian deposits. During the Late Jurassic, the number of taxa, as well as individual specimens decreased.

### 2.2.1. Early Jurassic

**General characteristics:** In several very important papers, SEPTFONTAINE (1980, 1984, 1988; SEPTFONTAINE et al., 1991) presented the best evolution, classification/taxonomy, biostratigraphy and palaeobiogeography of the Jurassic litoiids. Subsequently BASSOULET (1997), in his revision of the stratigraphic ranges of larger Jurassic foraminifera, mostly litoiids, confirmed Septfontaine's thoughts on the Early Jurassic litoiids. This is especially important for the discussion of Early Jurassic foraminiferal assemblages, because almost all genera and species that Septfontaine cited from the Moroccan High Atlas (Fig. 2b), and Bassoulet in Northern Africa and Western Europe (Fig. 2c) occur in the Adriatic Carbonate Platform (Fig. 2a). However, their occurrence did not commence at the Triassic–Jurassic boundary but later in the Sinemurian.

#### 2.2.1.1. Hettangian

**Foraminiferal assemblage:** *Involutina liassica*, *Duotaxis metula*, *Amijiella amiji*, *Siphovalvulina variabilis* and *Everticyclammina* sp. – ?*E. praevirguliana*.

**Discussion:** There are no very important foraminiferal taxa in the Hettangian deposits. Therefore, the stratigraphy of this stage on the AdCP is based on Dasycladacean calcareous algae, mostly on species of *Palaeodasycladus* (SOKAČ, 2001), among which *P. mediteraneus* is the most frequent and ranges from the Hettangian to the end of the Pliensbachian. *Involutina liassica* occurs throughout the Lower Jurassic deposits, but only in the rocks originating at the platform margins and slopes. *Duotaxis metula* is characterized by a stratigraphic range throughout the Early Jurassic, while *Amijiella amiji* has an even wider range, from the Early to Middle Jurassic.

#### 2.2.1.2. Sinemurian

**Foraminiferal assemblage:**

(a) **Early Sinemurian:** *Mesoendothyra* sp., *Siphovalvulina gibraltarensis*, *S. colomi*, *S. variabilis*, *Duotaxis*

STAGES	Hett.	Sinemurian	Pliensbachian	Toarcian
Geological time (duration) in My	3.1	6.9	6.6	7.4
<i>Involutina liassica</i>				
<i>Duotaxis metula</i>				
<i>Everticyclammina praevirguliana</i>				
<i>Amijiella amiji</i>				
<i>Siphovulvulina variabilis</i>				
<i>Siphovulvulina gibraltarensis</i>				
<i>Siphovulvulina colomi</i>				
<i>Meandrovoluta asiagoensis</i>				
<i>Mesoendothyra</i> sp.				
<i>Lituolipora termieri</i>				
<i>Lituosepta recoarensis</i>				
<i>Planisepta compressa</i>				
<i>Orbitopsella primaeva</i>				
<i>Haurania deserta</i>				
<i>Agerina martana</i>				
<i>Orbitopsella praecursor</i>				
<i>Biokovina gradacensis</i>				
<i>Bosniella oenensis</i>				
<i>Orbitopsella ?dubari</i>				
<i>Pseudocyclammina liassica</i>				
<i>Mesoendothyra croatica</i>				

**A**

	Hett.	Sinemurian	Pliensbachian				Toarcian
			Carixian	Domerian			
" <i>Siphovulvulina</i> "		?					
<i>Mesoendothyra</i> sp.		?					
<i>Haurania</i> spp.							
<i>Lituosepta recoarensis</i>							
<i>Orbitopsella primaeva</i>							
<i>Pseudopfender. butterlini</i>							
<i>Paleomayncina termieri</i>							
<i>Planisepta compressa</i>							
<i>Orbitopsella praecursor</i> s. l.							
<i>Pseudocyclam. liassica emend.</i>							
		A	B	C <sub>1</sub>	C <sub>2</sub>	D	E
		<i>Siphovulvulina</i> sp. and <i>Mesoendothyra</i> sp. interval zone	<i>Lituosepta recoarensis</i> lineage zone	<i>Orbitopsella primaeva</i> lineage zone	<i>Orbitopsella praecursor</i> lineage zone	<i>Paleomayncina termieri</i> and <i>Planisepta compressa</i> interval zone	<i>Pseudocyclammina liassica</i> taxon-range zone

**B**

STAGES	Hettangian	Sinemurian		Pliensbachian		Toarcian
SUBSTAGES		Early	Late	Carixian	Domerian	
<i>Involutina liassica</i>						
" <i>Everticyclammina</i> " sp. A						
" <i>Mesoendothyra</i> " sp.						
<i>Haurania deserta</i>						
<i>Amijiella amiji</i>						
<i>Lituosepta recoarensis</i>						
<i>Orbitopsella primaeva</i>						
<i>Pseudopfenderina butterlini</i>						
<i>Paleomayncina termieri</i>						
<i>Planisepta compressa</i>						
<i>Orbitopsella praecursor</i>						
<i>Orbitopsella dubari</i>						
<i>Bosniella oenensis</i>						
<i>Biokovina gradacensis</i>						
<i>Pseudocyclammina liassica</i>						

**C**

Fig. 2 Stratigraphic ranges of the Early Jurassic benthic foraminifera on the AdCP (A) and comparison with stratigraphic ranges in High Atlas (B – after SEPTFONTAINE, 1984) and Western Europe and Northern Africa (C – after BASSOULLET, 1997). Stratigraphic ranges are shown according to their duration in MY (time scale after GRADSTEIN et al., 2004).

*metula*, *Amijiella amiji*, *Everticyclammina praevirguliana*, *Meandrovoluta asiagoensis*, *Pseudocyclammina* sp. and *Involutina liassica*.

- (b) Late Sinemurian:** *Mesoendothyra* sp., *A. amiji*, *D. metula*, *S. variabilis*, *S. gibraltarensis*, *S. colomi*, *E. praevirguliana*, *M. asiagoensis*, *Lituosepta recoarensis*, *Orbitopsella primaeva*, *Haurania deserta*, *Lituolipora termieri*, *Planisepta compressa*, *Agerina martana* and *I. liassica*.

**Discussion:** The Early Sinemurian is characterized by the appearance of more abundant foraminiferal assemblage, but without very good index forms. The most important is *Mesoendothyra* sp., which according to SEPTFONTAINE (1984, 1988) is the source form of the most important Early Jurassic litoiids in the Southern Tethyan Bioprovince. This foraminifera has been found in many localities on the AdCP, and is especially abundant in Velebit Mt. (TIŠLJAR et al., 1991), where it occurs in the Early Sinemurian. According to SEPTFONTAINE (1984, 1988), two lines of Early Jurassic litoiids evolved from this form in the Late Sinemurian and Pliensbachian: (1) *Mesoendothyra* sp. – *Lituosepta? recoarensis* – *O.? primaeva* – *O. praecursor* – *O. dubari*, and (2) *Mesoendothyra* sp. – *Lituolipora termieri* – *Planisepta compressa*, which has also been confirmed on the AdCP. KABAL & TASLI (2003) described *Lituolipora termieri* as a synonym of both *Paleomayncina termieri* (HOTTINGER, 1967; SEPTFONTAINE, 1988) and *Lituolipora polymorpha* (GUŠIĆ & VELIĆ, 1978). The only index forms for the Late Sinemurian are *L. recoarensis* (its entire stratigraphic range is within this part of the stage), accompanied by *O. primaeva* occurring in Late Sinemurian and Early Pliensbachian. During the Sinemurian *H. deserta* occurs which is similar to *A. amiji*, and is observed in the later stages (Pliensbachian, Aalenian and Bajocian).

#### 2.2.1.3. Pliensbachian

##### Foraminiferal assemblage:

- (a) Early Pliensbachian – Carixian:** *Mesoendothyra* sp., *L. recoarensis*, *Orbitopsella praecursor*, *O. primaeva*, *H. deserta*, *A. amiji*, *P. compressa*, *L. termieri*, *Biokovina gradacensis*, *Bosniella oenensis*, *A. martana*, *D. metula*, *S. variabilis*, *S. gibraltarensis*, *S. colomi*, *E. praevirguliana*, *M. asiagoensis* and *I. liassica*.
- (b) Late Pliensbachian – Domerian:** *Mesoendothyra* sp., *O. praecursor*, *O. ?dubari*, *H. deserta*, *A. amiji*, *L. termieri*, *P. compressa*, *B. gradacensis*, *B. oenensis*, *D. metula*, *Pseudocyclammina liassica*, *S. variabilis*, *S. gibraltarensis*, *S. colomi*, *E. praevirguliana*, *M. asiagoensis*, *A. martana*, in places calcisphaerulids and *I. liassica*.

**Discussion:** Within the Carixian foraminiferal assemblage, the occurrence of *Orbitopsella* species are very important. *O. primaeva* reached its maximum

in the Early Carixian, *O. praecursor* in the Late Carixian, and the occurrence of the Early Domerian index fossil *O. dubari* is assumed. *P. liassica* is an index form of the Late Domerian. Observations of biokovinids – *Biokovina gradacensis* and *Bosniella oenensis* – are rare and mostly occur in the tectonized parts of the southern Karst Dinarides, so their stratigraphy may be approximated to within the Pliensbachian. *P. compressa* reaches its maximum frequency in the Domerian. *L. termieri* is an index form for the Late Sinemurian and Carixian. SEPTFONTAINE (1980, 1988) considered the genus *Bosniella* as a synonym of the genus *Mesoendothyra*.

*L. recoarensis* has been discovered within the earliest Pliensbachian (Early Carixian) in the Karst Dinarides, although occurrences are rare. This confirms the partial overlap of its stratigraphic range with that of *O. primaeva* in detailed profiles investigated in the Velebit Mt. area. In Western Tethys it is exclusively a Sinemurian species, as illustrated by SEPTFONTAINE (1984) and BASSOULLET (1997). Towards the East, in Italy, on the Apenninic Carbonate Platform CHIOCCHINI et al. (1994) found this form within (or even after) the stratigraphic range of *O. praecursor*, in the Monte Sorgenza and Monte della Selva columns, indicating that in the Apennines *L. recoarensis* was definitely of Carixian, and possibly even Early Domerian age.

#### 2.2.1.4. Toarcian

**Foraminiferal assemblage:** *E. praevirguliana*, *Mesoendothyra croatica*, *I. liassica*, *A. martana*, *S. variabilis*, *S. gibraltarensis*, *S. colomi* and *M. asiagoensis*.

**Discussion:** Due to palaeoenvironmental and sedimentological circumstances, larger foraminifera have never been observed in the youngest Lower Jurassic deposits of the Adriatic Carbonate Platform, nor on neighbouring platforms in the Southern Tethyan realm. As a consequence of the intense regional extensional tectonic movements described in the introduction, the Adriatic Carbonate Platform separated from the neighbouring Apulian and Apenninic ones during the Toarcian (VLAHOVIĆ et al., 2002, 2005; DRAGIČEVIĆ & VELIĆ, 2002). Western areas of the Adriatic Carbonate Platform were temporarily drowned, resulting in deposition of bioturbated mudstones and subordinate peletal-oid wackestone/packstones, the so-called ‘spotty limestones’. This event correlates with a Toarcian Oceanic Anoxic Event (JENKYN, 1988, 1991; VLAHOVIĆ et al., 2005). Penecontemporaneously, the NE margin emerged, while in the SE, high-energy shallows were locally formed, characterized by deposition of beach and bar ooid grainstones. Generally, depositional environments throughout the platform area were unfavourable for the growth of benthic organisms of all kinds, not only for foraminifera, which are very scarce. Interesting first

STAGES	Aalenian	Bajocian	Bathonian	Callovian
Geological time (duration) in My	4.0	3.9	3.0	3.5
<i>Siphovalvulina variabilis</i>				
<i>Mesoendothyra croatica</i>				
<i>Redmondoides lugeoni</i>				
<i>Everticyclammina</i> sp.				
<i>Amijiella amiji</i>				
<i>Haurania deserta</i>				
<i>Gutnicella cayeuxi</i>				
<i>Pseudocyclammina maynci</i>				
<i>Spiraloconus perconigi</i>				
<i>Timidonella sarda</i>				
<i>Spiraloconus giganteus</i>				
<i>Nautiloculina</i> gr. <i>oolithica</i>				
<i>Pseudodictyopsella jurassica</i>				
<i>Marzoella ficcarellii</i>				
<i>Protopenneroplis striata</i>				
<i>Trocholina</i> sp.				
<i>Trocholina</i> gr. <i>alpina-elongata</i>				
<i>Pfenderella arabica</i>				
<i>Paravalvulina complicata</i>				
<i>Pseudoeggerella elongata</i>				
<i>Praekurmubia crusei</i>				
<i>Paleopfenderina salernitana</i>				
<i>Paleopfenderina trochoidea</i>				
<i>Satorina apuliensis</i>				
<i>Alzonella cuvillieri</i>				
<i>Kilianina blancheti</i>				
<i>Orbitamina elliptica</i>				
<i>Satorina mesojurassica</i>				
<i>Chablaisia chablaisensis</i>				
<i>Mohlerina basiliensis</i>				
<i>Kurmubia jurassica</i>				
<i>Selliporella donzellii</i>				

Fig. 3 Stratigraphic ranges of the Middle Jurassic benthic foraminifera on the AdCP and dasycladalean alga *Selliporella donzellii* for comparison with foraminiferal ranges.

occurrences of rare forms close to *M. croatica* were recorded in the 'spotty limestones', representing an age probably from the beginning of the Toarcian to the beginning of the Aalenian. This species had the major part of its range in the Middle Jurassic (to the Early Bathonian), and its maximum in the Bajocian. The Toarcian represents the end of the stratigraphic range of *I. liassica*, which has never been found in the inner part of the platform.

### 2.2.2. Middle Jurassic

**General characteristics:** Before late 1980's, Middle Jurassic platform carbonates were considered to be quite unfossiliferous, except for the part belonging to the Bathonian. However, new investigations proved that they are relatively rich in a number of fossils. According to the number of determined fossil taxa, they represent the most fossiliferous Jurassic deposits (Fig. 3). Among the larger foraminifera, lituolids, hauraniids, cyclamminids and pfenderinids were determined. Most of these taxa represent index fossils, most frequently in the Upper Aalenian, Lower Bajocian and Bathonian deposits.

#### 2.2.2.1. Aalenian

##### Foraminiferal assemblage:

- (a) **Early Aalenian:** *Mesoendothyra croatica*, *Gutnicella cayeuxi*, *Pseudocyclammina maynci*, *Amijiella amiji*, *Haurania deserta*, *Redmondoides lugeoni*, *Siphovalvulina variabilis* and *Everticyclammina* sp.
- (b) **Late Aalenian:** *M. croatica*, *G. cayeuxi*, *P. maynci*, *A. amiji*, *H. deserta*, *R. lugeoni*, *S. variabilis*, *Timidonella sarda*, *Spiraloconus perconigi* and *Everticyclammina* sp.

**Discussion:** All cited taxa were determined in the S and SE parts of the AdCP, and locally in the NE, marginal parts of the platform. In these areas Middle Jurassic carbonates are mostly represented by ooid, bioclastic and intraclastic limestones deposited in the higher water energy environments of the platform shallows. They are relatively rich in their foraminiferal assemblages. However, in the central, relatively deeper and more restricted areas, predominantly thick-bedded mudstones were deposited, characterized by relatively rare findings of the cited taxa, with the exception of *M. croatica* which is relatively frequent. Among the stratigraphically more important species, *G. cayeuxi* has a stratigraphic

range through most of the Aalenian, and is accompanied by *S. perconigi* and *T. sarda* in the Upper Aalenian deposits. These two latter species have not been previously determined within the Middle Jurassic carbonates of the AdCP.

#### 2.2.2.2. Bajocian

##### Foraminiferal assemblage:

- (a) **Early Bajocian:** *M. croatica*, *P. maynci*, *G. cayeuxi*, *T. sarda*, *A. amiji*, *H. deserta*, *R. lugeoni*, *S. variabilis*, *Spiraloconulus giganteus*, *S. perconigi*, *Pseudodictyopsella jurassica*, *Marzoella ficcarellii*, *Protopenneroplis striata*, *Nautiloculina* sp. – probably *N. gr. oolithica*, *Trocholina* sp. and *Everticyclammina* sp.
- (b) **Late Bajocian:** *M. croatica*, *S. giganteus*, *A. amiji*, *H. deserta*, *R. lugeoni*, *S. variabilis*, *P. striata*, *Paravalvulina complicata*, *Pseudoeggerella elongata*, *Pfenderella arabica*, *Praekurnubia crusei*, *N. gr. ?oolithica*, *Trocholina gr. alpina*, *Trocholina* sp. and *Everticyclammina* sp.

**Discussion:** Forms typical of Aalenian deposits also occur in the earliest Bajocian, including *G. cayeuxi*, *S. perconigi* and *T. sarda*. Above these, during the end of the Early and the beginning of the Late Bajocian, *P. jurassica* and *M. ficcarellii* (index species) occur with *N. gr. ?oolithica*. Although BASSOULET (1997) indicated a stratigraphic range for *S. giganteus* from the Early Bajocian to the Early Callovian, with the most definite occurrences in the Bathonian, this form only occurs in the Bajocian on the AdCP. *M. croatica* reaches its maximum in the Early Bajocian, while *P. striata* is at the beginning of its stratigraphic range, which extends until the end of the Jurassic in the AdCP. In the topmost levels of Bajocian carbonates, *P. arabica* and *T. gr. alpina* were determined, and these also occur in the younger stages. The index form of younger Upper Bajocian deposits is *P. complicata*. *P. elongata* occurs in the continuous succession from topmost Upper Bajocian beds and are more common in the Bathonian. *Trocholina* species of the *T. alpina–elongata* group were reported within the genus *Andersenolina* (NEAGU, 1994). This view has been followed by some, e.g. BUCUR et al. (2004), but not by all authors, e.g. CHIOCCHINI et al. (1994), RADOIČIĆ (2005), etc. Until recently *S. giganteus*, *P. jurassica*, *M. ficcarellii*, *P. complicata* and *P. elongata* were not known within the Bathonian, or generally in the Middle Jurassic in the area of the AdCP. They have very recently been reported by VELIĆ (2005). The first occurrences of *P. crusei* occur in transitional beds at the base of the Bathonian. By the end of the Early Bajocian *Selliporella donzellii* appears, and its stratigraphic range includes the earliest Late Bathonian. This dasyclad alga is very important for the stratigraphy of the Middle Jurassic shallow-marine carbonate succession of the Karst Dinarides.

#### 2.2.2.3. Bathonian

##### Foraminiferal assemblage:

- (a) **Early Bathonian:** *M. croatica*, *S. variabilis*, *R. lugeoni*, *P. striata*, *P. arabica*, *T. gr. alpina*, *P. elongata*, *P. crusei*, *Paleopfenderina salernitana*, *P. trochoidea*, *Nautiloculina gr. oolithica* and *Everticyclammina* sp.
- (b) **Late Bathonian:** *S. variabilis*, *R. lugeoni*, *P. striata*, *P. arabica*, *T. gr. alpina–elongata*, *P. elongata*, *P. crusei*, *P. salernitana*, *P. trochoidea*, *Alzonella cuvillieri*, *Satorina apuliensis*, *Satorina mesojurassica*, *Kilianina blancheti*, *Orbitamina elliptica*, *N. gr. oolithica* and *Everticyclammina* sp.

**Discussion:** The Bathonian is the richest stage within Middle Jurassic deposits of the AdCP with regard to the abundance of larger foraminifera. Within this assemblage index fossils of the Early Bathonian are absent, but the age is reliably indicated between the beginning of the stratigraphic range of *P. salernitana* and the first occurrence of the following index fossils of the Late Bathonian: *A. cuvillieri*, *S. apuliensis*, *S. mesojurassica*, *K. blancheti* and *O. elliptica*. *P. elongata*, *S. mesojurassica* and *A. cuvillieri* have only a single record in the AdCP area (VELIĆ et al., 1995), but have not been previously illustrated. *O. elliptica* has been observed here for the first time.

*P. salernitana* is the most frequent and most widely distributed Bathonian species on the AdCP. *S. apuliensis*, and other Bathonian species are less common.

#### 2.2.2.4. Callovian

**Foraminiferal assemblage:** *P. salernitana*, *S. variabilis*, *R. lugeoni*, *P. striata*, *P. arabica*, *T. gr. alpina–elongata*, *P. crusei*, *N. gr. oolithica*, *Mohlerina basiliensis*, *Kurnubia jurassica*, probably *Chablaisia chablaisensis* and *Everticyclammina* sp.

**Discussion:** There are no specific index forms in the Callovian sediments: this assemblage has a 'transitional' character with taxa that can be traced from older Middle Jurassic to Late Jurassic stages: *R. lugeoni*, *P. crusei*, *P. arabica*, *P. striata* and *T. gr. alpina–elongata*. This assemblage also comprises the beginning of the *M. basiliensis* range (TASLI, 1993 and CHIOCCHINI et al., 1994, this form being attributed to *Archaeosepta*). By the end of the Callovian the first kurnubias occur, e.g. *K. jurassica*.

*Ch. chablaisensis* has only been observed at one locality in Biokovo Mt., within tectonically very disturbed deposits also containing *P. crusei*. Other index forms are absent, but neighbouring older outcrops are of Bathonian age. *Ch. chablaisensis* is only previously known from Oxfordian deposits in the AdCP area (VELIĆ & TIŠLJAR, 1988; TIŠLJAR & VELIĆ, 1993; VELIĆ et al., 1995). At the aforementioned localities other Oxfordian forms are also absent. Therefore, it could be concluded that this occurrence probably indicates somewhat older,

STAGES	Oxfordian	Kimmeridgian	Tithonian
Geological time (duration) in My	6.2	4.2	5.3
<i>Siphovavulina variabilis</i>			
<i>Everticyclammina virguliana</i>			
<i>Redmondoides lugeoni</i>			
<i>Protopeneroplis striata</i>			
<i>Trocholina alpina</i>			
<i>Trocholina elongata</i>			
<i>Mohlerina basiliensis</i>			
<i>Kurnubia jurassica</i>			
<i>Kurnubia palastiniensis</i>			
<i>Pfenderella arabica</i>			
<i>Praekurnubia crusei</i>			
<i>Nautiloculina oolithica</i>			
<i>Karaisella uzbekistanica</i>			
<i>Chablaisia chablaisensis</i>			
<i>Trocholina gigantea</i>			
<i>Nautiloculina circularis</i>			
<i>Labyrinthina mirabilis</i>			
<i>Kurnubia wellingsi</i>			
<i>Pseudocyclammina lituus</i>			
<i>Coniocurnubia orbitoliniformis</i>			
<i>Alveosepta jaccardi</i>			
<i>Kilianina? rahonensis</i>			
<i>Parurgonina caelinensis</i>			
<i>Anchispirocyclina lusitanica</i>			
<i>Protopeneroplis ultragranulata</i>			
<i>Pseudoclypeina cirici</i>			
<i>Clypeina jurassica</i>			

Fig. 4 Stratigraphic ranges of the Late Jurassic benthic foraminifera on the AdCP.

probably Callovian or even Bathonian deposits (see Fig. 3).

### 2.2.3. Late Jurassic

**General characteristics:** Among the foraminifera in the Upper Jurassic carbonates of the AdCP, those belonging to the genus *Kurnubia* are the most important. In spite of the occurrence of either other index species or those species that are very abundant in certain levels, the stratigraphic range of different species from Late Callovian to the Middle Tithonian designates this genus as typically indicating a Late Jurassic age (Fig. 4). Several species of the genus *Kurnubia* have been described in the Perimediterranean area, while on the AdCP the following species have been documented: *K. palastiniensis*, *K. wellingsi* (e.g. RADOIČIĆ, 1966; GUŠIĆ, 1969a, b; VELIĆ, 1977, etc.) and *K. jurassica* (GUŠIĆ, 1969a, b).

#### 2.2.3.1. Oxfordian

##### Foraminiferal assemblage:

**(a) Early Oxfordian:** *Pseudocyclammina lituus*, *Siphovavulina variabilis*, *Redmondoides lugeoni*, *Pfenderella arabica*, *Praekurnubia crusei*, *Mohlerina basiliensis*, *Protopeneroplis striata*, *Kurnubia palastiniensis*, *K. jurassica*, *Karaisella uzbekistanica*, *Trocholina alpina*, *T. elongata*, *T. gigantea*, *Chablaisia chablaisensis*, *Nautiloculina oolithica*, *N. circularis* and *Everticyclammina virguliana*.

**(b) Late Oxfordian:** *Labyrinthina mirabilis*, *Kurnubia wellingsi*, *K. jurassica*, *K. palastiniensis*, *K. uzbekistanica*, *Ch. chablaisensis*, *N. oolithica*, *N. circularis*, *T. alpina*, *T. elongata*, *T. gigantea*, *P. lituus*, *S. variabilis*, *R. lugeoni*, *P. arabica*, *P. crusei*, *M. basiliensis*, *P. striata* and *E. virguliana*.

**Discussion:** In the assemblage cited above, the only form which represents an index fossil for the Oxfordian is *K. uzbekistanica* (occurring in quiet subtidal and/or lagoonal facies). *T. gigantea*, determined in Middle Oxfordian deposits is significant, but is very rare (mostly in higher energy and tempestite facies). *Kurnubia* forms predominate, and *K. palastiniensis* is the most frequent species, while maximum frequency was also achieved by *T. alpina*, *T. elongata* and *C. chablaisensis*. The latter form disappeared in the late Oxfordian, and it frequently occurs in the tempestitic grainstones. The beginning of the stratigraphic range of *L. mirabilis* and *K. wellingsi* is considered to represent the approximate boundary between the Early and Late Oxfordian. *N. circularis* appeared by the end of the Early Oxfordian, and reached its maximum in the Late Oxfordian.

#### 2.2.3.2. Kimmeridgian

##### Foraminiferal assemblage:

**(a) Early Kimmeridgian:** *S. variabilis*, *E. virguliana*, *R. lugeoni*, *P. arabica*, *P. crusei*, *P. striata*, *K. jurassica*, *K. palastiniensis*, *K. wellingsi*, *L. mirabilis*, *T. alpina*, *T. elongata*, *M. basiliensis*, *P. lituus*, *Coni-*

*cocurnubia orbitoliniformis*, *Alveosepta jaccardi*, *Kilianina? rahonensis* and *Parurgonina caelinensis*.

- (b) Late Kimmeridgian:** *S. variabilis*, *E. virguliana*, *R. lugeoni*, *P. striata*, *T. alpina*, *T. elongata*, *M. basilienensis*, *K. palastiniensis*, *K. wellingsi*, *P. lituus*, *C. orbitoliniformis*, *A. jaccardi*, *K.? rahonensis* and *P. caelinensis*.

**Discussion:** Index forms for the Kimmeridgian deposits of the AdCP are *C. orbitoliniformis* and *A. jaccardi*, and partially *K.? rahonensis*, which has a stratigraphic range through the major part of the Kimmeridgian, and *P. caelinensis* in the terminal Early and Late Kimmeridgian. However, the latter two species can also be observed in Lower Tithonian deposits. *L. mirabilis*, *P. crusei*, *P. arabica* and *K. jurassica* disappeared in the Early Kimmeridgian. For stratigraphic correlation, the important dasyclad algae are *Pseudoclypeina cirici* (index fossil of the Early Kimmeridgian), as well as the first occurrence of the Late Jurassic species *Clypeina jurassica*. Dasyclad algae are distributed throughout the AdCP area from the Middle Kimmeridgian to the transitional level between the Tithonian and Berriasian.

#### 2.2.3.3. Tithonian

##### Foraminiferal assemblage:

- (a) Early Tithonian:** *S. variabilis*, *E. virguliana*, *R. lugeoni*, *P. striata*, *T. alpina*, *T. elongata*, *M. basilienensis*, *K. palastiniensis*, *P. lituus*, *K.? rahonensis* and *P. caelinensis*.
- (b) Late Tithonian:** *E. virguliana*, *R. lugeoni*, *P. striata*, *T. alpina*, *T. elongata*, *M. basilienensis*, *K. palastiniensis*, *P. lituus*, *Protopenneroplis ultragranulata*, *Anchispirocyclina lusitanica* and/or *A. neumannae*.

**Discussion:** In the youngest Upper Jurassic carbonates of the AdCP there are almost no typical index forms of foraminifera. Very rarely, specimens of *Anchispirocyclina* occur, which are specifically almost impossible to determine because of significant micritization, probably belong to index Tithonian forms including *A. lusitanica* and/or *A. neumannae*. All the cited species except the trocholinids, *R. lugeoni*, *P. lituus* and *P. ultragranulata* disappeared in Tithonian: first *P. caelinensis* then *K.? rahonensis* in the Early Tithonian, *K. palastiniensis* at the beginning of the Late Tithonian, and *A. lusitanica/neumannae* at the end of Tithonian. According to BUCUR (1993), *P. ultragranulata* has a wider stratigraphic range from the Middle Tithonian to the Early Barremian, but on the AdCP it has only been found in the Late Tithonian and Early Berriasian.

## 2.3. Cretaceous

The orbitolinids are the most important Cretaceous larger foraminifera. On the AdCP they appear in the Late Barremian, and inhabited the platform, with temporary breaks, until the end of the Cretaceous. Almost all orbitolinid species have stratigraphic importance. However,

if orbitolinids are the most important, cuneolinids and miliolids were the most abundant Cretaceous foraminifera. Besides these groups, Early Cretaceous foraminiferal assemblages include numerous smaller forms – involutinids, ataxophragmiids, novalesinids, and cyclamminids. From the Aptian to the Late Cretaceous, alveolinids and nezzatatids became more and more frequent, while during the Late Cretaceous soritids, fischerinids, pavonitids, dicyclinids, rhapsydioninids and rotaliids increased noticeably. Orbitoidids and siderolitids were important on the platform slopes and in the deeper intra-platform troughs formed in the Late Cretaceous.

### 2.3.1. Early Cretaceous

**General characteristics:** The end of the Jurassic and the beginning of the Cretaceous are characterized by the emergence of a large part of the central AdCP (VELIĆ et al., 2002). Deposits from areas with continuous deposition were late-diagenetically dolomitized, while in the shallowest areas early-diagenetic dolomites were formed. Therefore, within these unfavourable conditions foraminiferal assemblages were reduced, especially those of the larger foraminifera. Until the first occurrence of orbitolinids in the Late Barremian, smaller foraminifera were predominant. The richest foraminiferal assemblages were determined from Early Aptian and Albian deposits (Fig. 5). During the Late Aptian, there was a decrease in the number of foraminiferal taxa, as a result of the regional relative sea-level fall and frequent short periods of emergence (e.g. VLAHOVIĆ et al., 2005), as well as longer local emergent phases, e.g. in Western Istria (VELIĆ et al., 1989).

The most important studies of palaeontology, biostratigraphy and modern systematics of orbitolinids are those of Schroeder (particularly SCHROEDER, 1975, 1979). These two papers on the general evolutionary trends, definitions and origin of orbitolinids from the Early Aptian to Middle Cenomanian resulted from his earlier studies (e.g. SCHROEDER, 1962, 1964a, b, c). The evolutionary line, which commenced in the Early Aptian, with *Praeorbitolina cormyi* – *P. wienandsii* – *Mesorbitolina lotzei* has also been documented on the Adriatic Carbonate Platform (VELIĆ & SOKAČ, 1978a, b; VELIĆ, 1988).

#### 2.3.1.1. Berriasian

##### Foraminiferal assemblage:

- (a) Early Berriasian:** *Mohlerina basilienensis*, *Trocholina alpina*, *T. elongata*, *Pseudocyclammina lituus*, *Protopenneroplis ultragranulata*, *Mayncina bulgarica* and *Charentia cuvillieri*.
- (b) Late Berriasian:** *M. basilienensis*, *T. alpina*, *T. elongata*, *P. lituus*, *M. bulgarica*, *C. cuvillieri*, *Montsalevia salevensis*, *Meandrospira favrei*, *Haplophragmoides joukowskyi*, *Vercorsella tenuis*, *V. camposaurii* and *Praechrysalidina* sp.

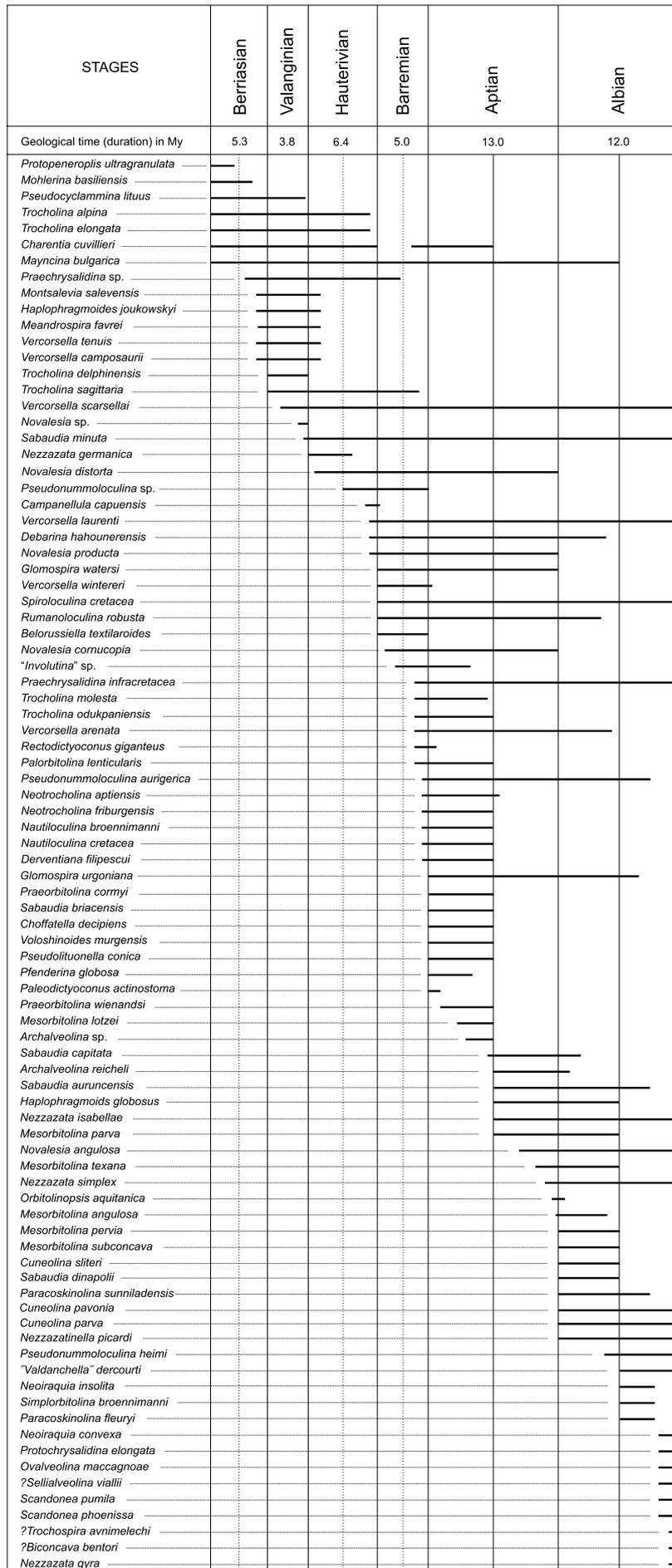


Fig. 5 Stratigraphic ranges of the Early Cretaceous benthic foraminifera on the AdCP.

**Discussion:** In the transitional level between the Tithonian and Berriasian, and for the Early Berriasian, the index form is *P. ultragranulata*. The Berriasian represents the end of the stratigraphic range of *M. basiliensis*. The beginning of this stage is characterized by the first occurrences of *M. bulgarica* (with a stratigraphic range throughout the Early Cretaceous) and infrequent observations of *C. cuvillieri* (the stratigraphic range of which continued into the Late Cretaceous). First occurrences of small *Praechrysalidina* sp. (which may be ancestors of *Praechrysalidina infracretacea* that ranges from the Late Barremian until the Late Albian), were documented from Upper Berriasian to Lower Barremian deposits. Near the end of the Berriasian, important species of smaller foraminifera occur, including *M. salevensis*, *M. favrei*, *H. joukowskyi*, *V. tenuis* and *V. camposaurii*, which reached their maximum in the Valanginian.

#### 2.3.1.2. Valanginian

**Foraminiferal assemblage:** *Trocholina sagittaria*, *T. delphinensis*, *T. alpina-elongata*, *P. lituus*, *M. bulgarica*, *C. cuvillieri*, *M. salevensis*, *M. favrei*, *H. joukowskyi*, *Vercorsella scarsellai*, *V. camposaurii*, *V. tenuis*, *Saubaudia minuta*, as well as *Novalesia* sp. and *Praechrysalidina* sp.

**Discussion:** Index fossils for the Valanginian of the AdCP are *M. salevensis*, *H. joukowskyi*, *M. favrei*, *V. tenuis*, and *V. camposaurii*, which is particularly common. All these forms appear near the end of the Berriasian, and disappear in the Early Hauterivian. There are additional forms that first occur in the Valanginian, and others that are also present in younger intervals of the Early Cretaceous, including *T. sagittaria*, *V. scarsellai*, and very rarely *S. minuta*. Throughout the Valanginian, trocholinids of the *T. alpina-elongata* group, *P. lituus* and *Praechrysalidina* sp. are still present. *T. delphinensis* was determined exclusively in Valanginian deposits. Although Valanginian deposits contain the largest number of index fossils of all the Neocomian units, more detailed stratigraphic subdivision of Valanginian deposits is not presently possible since all these index forms, together with numerous calcareous algae (*Dasycladales*), have stratigraphic ranges spanning the whole of the Valanginian.

#### 2.3.1.3. Hauterivian

**Foraminiferal assemblage:**

(a) **Early Hauterivian:** *T. gr. alpina-elongata*, *T. sagittaria*, *M. bulgarica*, *C. cuvillieri*, *S. minuta*, *M. salevensis*, *H. joukowskyi*, *M. favrei*, *V. tenuis*, *V. camposaurii*, *V. scarsellai*, *Novalesia distorta*, *Nezzazata germanica* and *Praechrysalidina* sp.

(b) **Late Hauterivian:** *T. gr. alpina-elongata*, *T. sagittaria*, *M. bulgarica*, *C. cuvillieri*, *S. minuta*, *N. germanica*, *Vercorsella laurentii*, *V. scarsellai*, *Debarina hahounerensis*, *Novalesia producta*, *N. distorta*,

*Campanellula capuensis*, *Pseudonummoloculina* sp. and *Praechrysalidina* sp.

**Discussion:** *N. distorta* occurs in the Early Hauterivian. The Late Hauterivian is characterized by the disappearance of *T. gr. alpina-elongata*. The entire stage is characterised by several species which continued from the Valanginian, e.g. *T. sagittaria*, *V. scarsellai*, *M. bulgarica*, *C. cuvillieri* and *S. minuta*. Species appearing for the first time in the latest Hauterivian, and occurring throughout the younger stages of the Early Cretaceous are *D. hahounerensis*, *N. producta* and *V. laurentii*. This group also contains species of *Pseudonummoloculina*, similar to *P. aurigerica*. *Nezzazata germanica* represents an index species, but is very rare, while in the latest Hauterivian and transitional beds to the Barremian *C. capuensis* is very common.

#### 2.3.1.4. Barremian

**Foraminiferal assemblage:**

(a) **Early Barremian:** *N. distorta*, *N. cornucopia*, *N. producta*, *Vercorsella wintereri*, *V. scarsellai*, *V. laurentii*, *M. bulgarica*, *T. sagittaria*, *D. hahounerensis*, *S. minuta*, *Spiroloculina cretacea*, *Rumanoloculina robusta*, *Belorussiella textilarioides*, *Glomospira watersi*, *Pseudonummoloculina* sp., *Praechrysalidina* sp. and involutinids – ‘*Involutina*’ sp.

(b) **Late Barremian:** all taxa from the Early Barremian are present but are also accompanied by *Rectodictyoconus giganteus*, *Palorbitolina lenticularis*, *Trocholina molesta*, *T. odukpaniensis*, *Vercorsella arenata*, *Derventina filipescui*, *Neotrocholina friburgensis*, *N. aptiensis*, *Nautiloculina broennimanni*, *N. cretacea*, *Charentia cuvillieri*, *Praechrysalidina infracretacea*, *Pseudonummoloculina aurigerica* and ‘*Involutina*’ sp.

**Discussion:** During the earliest Barremian, there were no significant changes in the foraminiferal assemblage compared to the Late Hauterivian. This marks the beginning of the stratigraphic range of some species which are typical of the Early Cretaceous, as well as *S. cretacea*, *R. robusta*, *B. textilarioides* and *V. wintereri*, which were documented in the Barremian of the Western part of the AdCP by CVETKO TEŠOVIĆ (2000). *C. cuvillieri* also occurs in these deposits, although it has not been observed in the Lower Barremian deposits.

Near the end of the Barremian, orbitolinids occur as the first genuine larger foraminifera on the AdCP. The oldest forms belong to *R. giganteus* observed along the northern platform margin between Banja Luka and Kupres, and *P. lenticularis* which is widely distributed across the platform. VELIĆ & SOKAČ (1978a) proposed that the stratigraphic range of *P. lenticularis* began, before the occurrence of the Early Aptian praeorbitolinids, indicating the Late Barremian. This approach was later confirmed by GUŠIĆ (1981), who compared the dimensions of

the proloculus and embrional apparatuses of this species, and documented the gradual increase in these dimensions from older, Barremian, to younger, Aptian palorbitolinids. Furthermore, in the absence of other criteria within the palorbitolinid limestones of the AdCP, the size of the proloculus can even be used to determine the boundary between the Barremian and the Aptian (GUŠIĆ, 1981).

In addition, several other foraminifera of a wider stratigraphic range have been determined – *Trocholina sagittaria*, *T. molesta*, *T. odukpaniensis*, *Vercorsella arenata*, *Pseudonummolucina aurigerica* and *P. infracretacea*, as well as all the taxa found in the Lower Barremian deposits. At the very end of the Barremian *Derventina filipescui*, *Neotrocholina friburgensis*, *N. aptiensis*, *Nautiloculina broennimanni* and *N. cretacea* occur before the first appearance of the praorbitolinids indicating the beginning of the Aptian.

#### 2.3.1.5. Aptian

##### Foraminiferal assemblage:

- (a) **Early Aptian:** *P. lenticularis*, *R. giganteus*, *Paleodictyoconus actinostoma*, *Praeorbitolina cormyi*, *P. wienandsi*, *Mesorbitolina lotzei*, *Voloshinoides murgensis*, *Sabaudia briacensis*, *S. minuta*, *Choffatella decipiens*, *D. filipescui*, *N. friburgensis*, *N. aptiensis*, *T. molesta*, *T. odukpaniensis*, *Pfenderina globosa*, *Pseudolituonella conica*, *D. hahounerensis*, *M. bulgarica*, *P. infracretacea*, *V. laurentii*, *V. scarsellai*, *V. arenata*, *N. producta*, *N. distorta*, *N. cornucopia*, *N. broennimanni*, *N. cretacea*, *C. cuvillieri*, *P. aurigerica*, *Glomospira urgoniana*, *G. watersi*, *S. cretacea*, *R. robusta*, *Archaealveolina* sp. and ‘*Involutina*’ sp.
- (b) **Late Aptian:** *Mesorbitolina parva*, *M. texana*, *N. aptiensis*, *D. hahounerensis*, *M. bulgarica*, *P. infracretacea*, *Sabaudia auruncensis*, *S. capitata*, *S. minuta*, *V. laurentii*, *V. scarsellai*, *V. arenata*, *Novallesia angulosa*, *N. producta*, *N. distorta*, *N. cornucopia*, *Haplophragmoides globosus*, *Archalveolina reicheli*, *P. aurigerica*, *Nezzazata isabellae*, *N. simplex*, *G. urgoniana*, *G. watersi*, *S. cretacea*, *R. robusta* and *Orbitolinopsis aquitanica*.

**Discussion:** Occurrence of the first orbitolinids near the end of the Barremian marks the beginning of the dominance of these larger foraminifera on the AdCP which lasted until the Middle Cenomanian. One of the most frequent and widely distributed species is *P. lenticularis*, which reaches its maximum during the Early Aptian. In some localities it is so abundant that it has lithogenetic value as some tempestite layers are composed almost exclusively of tests of this foraminifera (see cover page of this issue). In the undisturbed succession of Lower Aptian deposits, the first part of the evolutionary trend of orbitolinids can be traced, which, according to SCHROEDER (1962, 1964a, b, c, 1975, 1979), commences in the

Early Aptian and ends in the Middle Cenomanian. This was confirmed on the AdCP by VELIĆ & SOKAČ (1978a) and VELIĆ (1988), where the Aptian forms occur in the stratigraphic succession of *P. cormyi* – *P. wienandsi* – *M. lotzei* (Early Aptian) – *M. parva* – *M. texana* (Late Aptian).

The Early Aptian foraminiferal assemblage also contains other index fossils, including *V. murgensis*, *S. briacensis*, *C. decipiens*, *D. filipescui*, *N. friburgensis*, *N. aptiensis*, *P. globosa* and *P. conica*. Others, characterized by a wider stratigraphic range throughout the Early Cretaceous include *P. aurigerica*, *N. broennimanni* and *N. cretacea*, as well as an alveolinid form very close to *A. reicheli*, which has a stratigraphic range through the Late Aptian and Early Albian. Furthermore, numerous specimens of involutinids also occur, but due to intense recrystallization, can only be determined as ‘*Involutina*’ sp.

The evolutionary trend of genuine orbitolinids is continued in the Late Aptian by the new species *M. parva* and *M. texana*. Among other orbitolinids in the youngest Aptian deposits *O. aquitanica* was also determined.

The most abundant foraminifera are of somewhat wider stratigraphic ranges, e.g. *D. hahounerensis*, *M. bulgarica*, *P. infracretacea*, *S. minuta*, *S. capitata*, *S. auruncensis*, *V. laurentii*, *V. scarsellai* and *V. arenata*, including the first occurrences of *H. globosus* (or *Trochaminoides coronus* according to CHIOCCINI et al., 1994) and *N. simplex*. *A. reicheli*, which can also be observed locally in mesorbitolinid tempestites, reaches its maximum in the Aptian. Smaller forms, together with some still not completely determined forms, cited by CVETKO TEŠOVIĆ (2000) include *G. urgoniana*, *G. watersi*, *N. isabellae*, *S. cretacea* and *R. robusta*. In the Late Aptian, species of *Novallesia* disappeared except for *N. angulosa*.

#### 2.3.1.6. Albian

##### Foraminiferal assemblage:

- (a) **Early Albian:** *Mesorbitolina pervia*, *M. subconca-va*, *M. parva*, *M. texana*, *Paracoskinolina sunniladensis*, *Cuneolina pavonia*, *C. parva*, *C. sliteri*, *Sabaudia dinapolii*, *S. minuta*, *S. auruncensis*, *S. capitata*, *Nezzazinella picardi*, *Pseudonummolucina heimi*, *P. aurigerica*, *S. cretacea*, *R. robusta*, *G. urgoniana*, *N. isabellae*, *N. simplex*, *D. hahounerensis*, *H. globosus*, *M. bulgarica*, *P. infracretacea*, *A. reicheli*, *V. laurentii*, *V. scarsellai*, *V. arenata*, *N. angulosa* and *Orbitolinopsis* sp. cf. *O. aquitanica*.
- (b) **Late Albian:** ‘*Valdanchella*’ *dercourtii*, *Neoiraquia insolita*, *N. convexa*, *Simplorbitolina broennimanni*, *Paracoskinolina fleuryi*, *P. sunniladensis*, *C. pavonia*, *C. parva*, *Scandonea pumila*, *S. phoenissa*, *N. simplex*, *N. isabellae*, *N. gyra*, ?*Trochospira avni-melechi*, ?*Biconcava bentori*, *N. picardi*, *P. heimi*, *P. aurigerica*, *S. cretacea*, *S. minuta*, *S. auruncen-*

*sis*, *V. laurentii*, *V. scarsellai*, *N. angulosa*, *G. urgoniana*, *P. infracretacea*, *Protochrysalidina elongata*, *Ovalveolina maccagnoae* and ?*Sellialveolina viallii*.

**Discussion:** Albian deposits on the AdCP contain rich foraminiferal assemblages dominated by different miliolids. Among other larger foraminifera, the most important are the orbitolinids because of both their stratigraphic value and abundance in certain levels.

The most important event for determination of the boundary between Upper Aptian and Lower Albian deposits is the first occurrence of species of cuneolina, including *C. pavonia*, *C. parva* and *C. sliteri* which are certain indicators of the beginning of the Albian. Albian deposits also contain numerous foraminifera known from Barremian (or even earlier) and Aptian sediments: *P. aurigerica*, *D. hahounerensis*, *M. bulgarica*, *P. infracretacea*, *A. reicheli* as well as all previously mentioned species of *Sabaudia* and *Vercorsella*. During the Early Albian, the widely distributed species *P. heimi* and *N. picardi*, occur for the first time. These, together with the cuneolinids, continue to the Late Cretaceous in the area of the AdCP. Of these, *P. aurigerica* is the most common. According to CVETKO TEŠOVIĆ (2000), Lower Albian carbonates also contain smaller foraminifera, including *G. urgoniana*, *N. isabellae*, *S. cretacea* and *R. robusta*. Within the orbitolinid assemblage, the mesorbitolinids *M. parva* and especially *M. texana* are important. These, together with *P. lenticularis*, constitute the most abundant Early Cretaceous larger foraminifera on the AdCP. *M. texana* is also frequently lithogenic, especially along the NE platform margin from Banja Luka towards Jajce and Kupres. The largest, most advanced mesorbitolinids are *M. pervia* and *M. subconca*, and these are also index fossils for the Albian. In the area of the AdCP, the latter species represents the final member of the mesorbitolinid part of the evolutionary trend of the 'genuine' orbitolinids (after SCHROEDER, 1975). These deposits rarely contain specifically undeterminable (mostly micritized) specimens of *Orbitolinopsis* sp., as well as *P. sunilandensis*.

Upper Albian deposits are characterized by two zones with orbitolinids: the first one in the older part, and the second one in uppermost part of the Vraconian, below the Cenomanian. In the first orbitolinid-rich zone, '*V.*' *dercourtii*, *N. insolita*, *S. broenimanni* and *P. fleuryi* were determined, while the second one contains only '*V.*' *dercourtii* and *N. convexa*. During the Late Albian *S. pumila* and *S. phoenissa* occur together with other foraminifera, and in the youngest part there is also *P. elongata* and *O. maccagnoae*. From the Early Albian some forms with wider stratigraphic ranges continued, of which the most important include the pseudonummolucinids, cuneolinids and sabaudias cited above. In the terminal part of the Late Albian, and the transi-

tional level to the Cenomanian, *N. simplex* occurs together with the first appearance of other nezzazatinids including *N. gyra*, *Trochospira avnimelechi* and *Biconcava bentori*, which reached their maximum in the Cenomanian.

### 2.3.2. Late Cretaceous

**General characteristics:** Foraminiferal assemblages in the AdCP Upper Cretaceous deposits are not regularly distributed (Fig. 6). If the frequency and abundance of all taxa within specific stages were analysed statistically, Cenomanian foraminiferal assemblages would probably be the richest in the entire succession of shallow-marine carbonates. In contrast, the Turonian is characterized by an evident decrease in the diversity and abundance of foraminiferal assemblages, as a consequence of the prominent global sea-level rise in the youngest Cenomanian and oldest Turonian, first recognised in the AdCP by GUŠIĆ & JELASKA (1990, 1993). This sea-level rise resulted in the temporary drowning of a major part of the AdCP (see JELASKA et al., 1994; VLAHOVIĆ et al., 1994, 2003, 2005; TIŠLJAR et al., 2002; VELIĆ et al., 2002). Another earlier regionally important sea-level rise was determined within the youngest Albian and oldest Cenomanian deposits on the island of Cres (HUSINEC et al., 2000; KORBAR et al., 2001) and some neighbouring areas. After restoration of the shallow marine environments and ecosystems in the Late Turonian, a gradual recolonization of benthic foraminifera took place, but this was not characterized by such a richness of taxa and specimens as during the Cenomanian. However, the next resurgence in the foraminiferal assemblages took place in the Late Santonian and, especially, the Campanian. Maastrichtian assemblages were characterized by a relative decrease in the number of taxa, which is not surprising considering that by this time the platform had already largely disintegrated and most of it was emergent, resulting in a significant decrease of the shallow-marine areas.

#### 2.3.2.1. Cenomanian

**Foraminiferal assemblage:** Foraminifera determined within the Cenomanian deposits of the AdCP can generally be divided into two groups.

The first group comprises forms which originated in the Early Cretaceous or the Cenomanian, and some of them continue into younger periods. Forms from the Early Cretaceous include *Cuneolina pavonia*, *C. parva*, *Pseudonummoloculina heimi*, *Spiroloculina cretacea*, *Nezzazatinella picardi*, *Nezzazata simplex*, *N. gyra*, *Trochospira avnimelechi*, *Biconcava bentori*, *Charentia cuvillieri* and *Scandonea pumila*. Since Cenomanian they were accompanied by *Biplanata peneropliformis*, *Nezzazata conica* and *Rotalia mesogeensis*, as well as *Cuneolina conica*, *Murgeina apula* and *Spiroloculina robusta*, which

STAGES	Cenomanian	Turonian	Coniacian	Santonian	Campanian	Maastrichtian
Geological time (duration) in My	6.1	4.2	3.5	2.3	12.9	5.1
<i>Cuneolina pavonia</i>						
<i>Nezzazinella picardi</i>						
<i>Nezzazata simplex</i>						
<i>Trochospira avnimelechi</i>						
<i>Nezzazata gyra</i>						
<i>Cuneolina parva</i>						
<i>Pseudonummoloculina heimi</i>						
<i>Cuneolina conica</i>						
<i>Biconcava bentori</i>						
<i>Nezzazata conica</i>						
<i>Spiroloculina cretacea</i>						
<i>Spiroloculina robusta</i>						
<i>Biplanata peneropliformis</i>						
<i>Rotalia mesogensis</i>						
<i>Charentia cuvillieri</i>						
<i>Scandonea pumila</i>						
<i>Ovalveolina maccagnoae</i>						
<i>?Sellialveolina viallii</i>						
<i>Orbitolina concava</i>						
<i>Conicorbitolina cuvillieri</i>						
<i>Conicorbitolina conica</i>						
<i>Conicorbitolina corbarica</i>						
<i>Orbitolina sefini</i>						
<i>Praealveolina simplex</i>						
<i>Trocholina arabica</i>						
<i>Pseudocyclammina rugosa</i>						
<i>Ovalveolina crassa</i>						
<i>Praealveolina iberica</i>						
<i>Cisalveolina lechneri</i>						
<i>Pastrikella biplana</i>						
<i>Chrysalidina gradata</i>						
<i>Nummuloculina? regularis</i>						
<i>Pseudolituonella reicheli</i>						
<i>Pseudorhapydionina dubia</i>						
<i>Merlingina cretacea</i>						
<i>Peneroplis turonicus</i>						
<i>Pastrikella balcanica</i>						
<i>Cisalveolina fraasi</i>						
<i>Vidalina radoicicae</i>						
<i>Vidalina hispanica</i>						
<i>Pseudorhapydionina laurinsensis</i>						
<i>Pseudorhapydionina casertana</i>						
<i>Pseudorhapydionina murgiana</i>						
<i>Peneroplis parvus</i>						
<i>Murgeina cenomana</i>						
<i>Murgeina apula</i>						
<i>Pseudocyclammina sphaeroidea</i>						
<i>Moncharmontia apenninica</i>						
<i>Moncharmontia compressa</i>						
<i>Cuneolina compressa</i>						
<i>Scandonea samnitica</i>						
<i>Dicyclina schlumbergeri</i>						
<i>Accordiella conica</i>						
<i>Idalina antiqua</i>						
<i>Pseudorhapydionina mediterranea</i>						
<i>Murgella lata</i>						
<i>Keramosphaerina ?sarda</i>						
<i>Keramosphaerina tergestina</i>						
<i>Reticulinella fleuryi</i>						
<i>Rotorbinaella scarsellai</i>						
<i>Pseudocyclammina massiliensis</i>						
<i>Dictyopsella kiliani</i>						
<i>Dictyopselloides cuvillieri</i>						
<i>Raadshovenia salentina</i>						
<i>Spirolina cretacea</i>						
<i>Minouxia lobata</i>						
<i>Broekinella neumannae</i>						
<i>Archiacina munieri</i>						
<i>Pseudolituonella mariae</i>						
<i>Orbitoides gr. hottingeri</i>						
<i>Stensjöina surrentina</i>						
<i>Reticulinella reicheli</i>						
<i>Calveziconus lecalveziae</i>						
<i>Praesiderolites douvillei</i>						
<i>Orbitoides douvillei</i>						
<i>Orbitoides tissoti</i>						
<i>Nummofallotia cretacea</i>						
<i>Pseudosiderolites vidali</i>						
<i>Orbitoides media</i>						
<i>Murciella cuvillieri</i>						
<i>Murciella renzi</i>						
<i>Rhapydionina liburnica</i>						
<i>Siderolites calcitrapoides</i>						
<i>Omphalocyclus macroporus</i>						
<i>Hellenocyclina beotica</i>						
<i>Lepidorbitoides minor</i>						
<i>Cuneolina ketini</i>						
<i>Fleuryana adriatica</i>						
<i>Laffitteina mengaudi</i>						

Fig. 6 Stratigraphic ranges of the Late Cretaceous benthic foraminifera on the AdCP.

can be found also in younger Upper Cretaceous deposits.

The second group comprises foraminifera that are either index fossils for some parts of the Cenomanian, or were found only in some levels of the Cenomanian of the AdCP although they are of a wider stratigraphic range in the Cretaceous. In this group, the following forms are characteristic:

- (a) **Early Cenomanian:** *Ovalveolina maccagnoae*, *O. crassa*, ?*Selliaveolina viallii*, *Praealveolina iberica*, *P. simplex*, *Cisalveolina lehneri*, *Orbitolina* gr. *sefini-concava*, *Conicorbitolina conica*, *C. cuvillieri*, *C.* gr. *corbarica-conica*, *Pseudocyclammina rugosa*, *Trocholina arabica* and *Pastrikella biplana*.
- (b) **Middle Cenomanian:** *Conicorbitolina conica*, *C.* gr. *corbarica-conica*, *C. cuvillieri*, *O. gr. sefini-concava*, *P. iberica*, *C. lehneri*, *O. crassa*, *Chrysalidina gradata*, *Nummuloculina?* *regularis*, *Pseudolituonella reicheli*, *Pseudorhapydionina dubia*, *Merlingina cretacea*, *Peneroplis turonicus*, *Pastrikella balcanica* and *P. biplana*.
- (c) **Late Cenomanian:** *C. gradata*, *N.?* *regularis*, *P. reicheli*, *P. balcanica*, *P. dubia*, *Cisalveolina fraasi*, *Vidalina radoicae*, *V. hispanica*, *Murgeina cenomana*, *Pseudorhapydionina laurinensis*, *Pseudorhapydionina casertana*, *P. murgiana*, *M. cretacea*, *Peneroplis parvus* and *P. turonicus*.

**Discussion:** The maximum abundances of *P. heimi*, *C. pavonia*, *C. parva* and nezzatids, some of which previously occur in the Late Albian (VELIĆ & SOKAČ, 1979), and some in the Early Cenomanian, are particularly important in the first group. Among the second group, the alveolinids *O. maccagnoae*, *O. crassa*, *S. viallii*, *C. lehneri*, *P. simplex* and *P. iberica* are stratigraphically very important for the Early Cenomanian. Index fossils for the Middle Cenomanian alone are absent, except for *P. biplana* which is known as the Early to Middle Cenomanian form (CHERCHI & SCHROEDER, 1980, 1985), and is frequent in Middle Cenomanian beds with *P. balcanica* on the AdCP. Reliable definition of this part of the Cenomanian is based on the overlapping stratigraphic ranges of the cited orbitolinids, which ended their stratigraphic range near the end of the Middle Cenomanian, together with foraminifera of characteristic Middle to Late Cenomanian stratigraphic range, including *C. gradata*, *N.?* *regularis*, *P. reicheli*, *P. balcanica* and *P. dubia*. Index fossils of the Late Cenomanian are *C. fraasi*, *V. radoicae*, *V. hispanica*, *P. laurinensis*, *P. casertana*, *P. murgiana* and *P. parvus*.

POLŠAK et al. (1982) cited *S. minuta* as being of Early Cenomanian age, although they commented that their Early Cenomanian foraminiferal assemblage does not differ from that of the Late Albian. Therefore, the question of the position of the exact boundary between the Albian and the Cenomanian,

as well as the exact stratigraphic range of this form, remains open.

#### 2.3.2.2. Turonian

##### Foraminiferal assemblage:

- (a) **Early Turonian:** *P. heimi*, *C. pavonia*, *C. parva*, *S. cretacea*, *N. simplex*, *N. gyra*, *N. conica*, *T. avnimelechi*, *B. bentori*, *N. picardi* and *M. apula*.
- (b) **Late Turonian:** *P. heimi*, *Cuneolina compressa*, *C. pavonia*, *C. parva*, *S. cretacea*, *N. simplex*, *N. gyra*, *N. conica*, *T. avnimelechi*, *B. bentori*, *N. picardi*, *M. apula*, *Pseudocyclammina sphaeroidea*, *Moncharmontia apenninica* and *M. compressa*.

**Discussion:** The Early Turonian is characterized by platform drowning, resulting in impoverishment of the shallow-marine benthic foraminifera assemblages, which are mostly composed of taxa with broad stratigraphic ranges. Restoration of assemblages in subtidal, lagoonal and peritidal environments took place at the end of the Early and during the Late Turonian. The most frequent forms were those with their maximum abundance in the Cenomanian, including *C. pavonia*, *C. parva*, *C. conica*, *P. heimi*, *S. cretacea*, *N. simplex*, *N. gyra*, *N. conica*, *T. avnimelechi*, *B. bentori*, *N. picardi* and *M. apula*. New species like *P. sphaeroidea*, *M. compressa* and *C. compressa* occurred in the Late Turonian.

#### 2.3.2.3. Coniacian

**Foraminiferal assemblage:** *C. pavonia*, *C. parva*, *C. conica*, *C. compressa*, *Dicyclina schlumbergeri*, *P. heimi*, *N. picardi*, *N. simplex*, *N. gyra*, *N. conica*, *B. bentori*, *T. avnimelechi*, *M. apula*, *M. compressa*, *M. apenninica*, *P. sphaeroidea*, *Scandonea samnitica*, *Accordiella conica* and *Idalina antiqua*.

**Discussion:** The Coniacian foraminiferal assemblage also does not contain index forms, since most of the determined taxa first appeared in Turonian or older deposits. The Coniacian is characterized by the first occurrence of *D. schlumbergeri*, *S. samnitica*, *A. conica* and *I. antiqua*, the stratigraphic range of which extends into younger Cretaceous stages.

#### 2.3.2.4. Santonian

##### Foraminiferal assemblage:

- (a) **Early Santonian:** *C. pavonia*, *C. parva*, *C. conica*, *P. heimi*, *S. samnitica*, *P. sphaeroidea*, *M. compressa*, *M. apenninica*, *N. simplex*, *N. gyra*, *B. bentori*, *T. avnimelechi*, *N. picardi*, *D. schlumbergeri*, *M. apula*, *A. conica*, *I. antiqua*, *Keramosphaerina ?sarda*, *K. tergestina*, *Pseudorhapydionina mediterranea* and *Murgella lata*.

(b) **Late Santonian:** all species from the Early Santonian and new forms: *Reticulinella fleuryi*, *Dictyopsella kiliani*, *Dictyopselloides cuvillieri*, *Spirolina cretacea*, *Minouxia lobata*, *Broekinella neumannae*, *Archiacina munieri*, *Pseudolituonella marie*, *Pseudocyclammina massiliensis*, *Rotorbinella scarsellai*,

*Stensiöina surrentina*, *Raadshovenia salentina* and *Orbitoides* gr. *hottingeri*.

**Discussion:** In the Early Santonian, some species first appear that continue into the Early Campanian including, for example, *K. tergestina* and *M. lata*, or into the Maastrichtian for example *P. mediterranea*. The first occurrence of the index species *M. lata* in the Santonian is very important (after GUŠIĆ & JELASKA, 1990), together with *P. mediterranea*, *K. tergestina*, *R. fleuryi*, *S. cretacea*, *D. kiliani*, *D. cuvillieri*, *R. scarsellai*, *S. surrentina* and *O.* gr. *hottingeri*, which are also index fossils for the Early Campanian. The beginning of the stratigraphic range of *K. tergestina* in the Early Santonian is characterized by small specimens, among which forms indicating *K. sarda* were observed. The largest specimens of *K. tergestina* occur exclusively in uppermost Santonian and lowermost Campanian deposits. *B. neumannae* and *A. munieri* occur for the first time in the Late Santonian–Early Campanian foraminiferal assemblage of the AdCP. POLŠAK et al. (1982) and VENTURINI (2005) also cited *R. salentina* from the Santonian–Campanian assemblages.

Due to the pronounced similarity of Late Santonian and Early Campanian assemblages it is not easy to reliably establish the boundary between these two stages. Another, relatively new problem, is connected to the general division of younger Upper Cretaceous deposits of the AdCP. Strontium isotope analysis performed by STEUBER et al. (2005) resulted in revision of the stratigraphic ranges of the majority of larger benthic foraminifera index forms, and consequently the stratigraphy of the Coniacian–Maastrichtian deposits of the island of Brač as determined by GUŠIĆ & JELASKA (1990). According to this investigation *M. lata* occurred in the Late Coniacian, *P. mediterranea* and *A. conica* had a stratigraphic range from the Late Coniacian to the Early Campanian, and *K. tergestina* and *Calveziconus lecalvezae* occur in the Early Campanian (their first occurrence would mark the beginning of the Campanian). However, VENTURINI (2005) published results of the strontium isotope analysis from Santonian–Campanian deposits of the Slovenian–Trieste Karst region, according to which *K. tergestina* and *M. lata* occur in Upper Santonian, and *C. lecalvezae* in Lower Campanian limestones. On the basis of Sr isotopes MARITAN et al. (2003) proposed Santonian age for *K. tergestina* and Santonian–Lower Campanian age for *M. lata* in the Trieste Karst area. Furthermore, FRIJIA & PARENTE (2007) suggest on the basis of strontium and carbon isotope stratigraphy in the southern Apennines, that the first occurrence of *M. lata* occurs in the Early Coniacian and *K. tergestina* in the Early Campanian.

Here, on the AdCP, the stratigraphic ranges of *M. lata* and *K. tergestina* are proposed as extending from the Early Santonian to the Early Campanian,

which is in close agreement with the opinion of GUŠIĆ & JELASKA (1990).

### 2.3.2.5. Campanian

#### Foraminiferal assemblage:

**(a) Early Campanian:** *C. pavonia*, *C. parva*, *C. conica*, *P. heimi*, *D. schlumbergeri*, *N. simplex*, *N. gyra*, *T. avnimelechi*, *B. bentori*, *N. picardi*, *P. sphaeroidea*, *P. massiliensis*, *M. apula*, *M. apenninica*, *M. compressa*, *A. conica*, *P. mediterranea*, *S. samnitica*, *K. tergestina*, *M. lata*, *S. cretacea*, *I. antiqua*, *M. lobata*, *Calveziconus lecalvezae*, *B. neumannae*, *A. munieri*, *P. marie*, *Reticulinella reicheli*, *R. fleuryi*, *D. kiliani*, *D. cuvillieri*, *R. scarsellai*, *S. surrentina*, *Orbitoides* gr. *hottingeri*, *O. douvillei*, *O. tissoti* and *Praesiderolites douvillei*.

**(b) Late Campanian:** *C. pavonia*, *C. parva*, *N. simplex*, *N. gyra*, *T. avnimelechi*, *N. picardi*, *M. apula*, *M. apenninica*, *M. compressa*, *D. schlumbergeri*, *A. conica*, *R. scarsellai*, *P. mediterranea*, *S. samnitica*, *P. sphaeroidea*, *P. massiliensis*, *R. reicheli*, *R. fleuryi*, *D. kiliani*, *D. cuvillieri*, *I. antiqua*, *C. lecalvezae*, *Nummofallotia cretacea*, *Praesiderolites douvillei*, *Orbitoides douvillei*, *O. tissoti*, *O. media* and *Pseudosiderolites vidali*.

**Discussion:** There is little difference between the foraminiferal assemblages of the Late Santonian and the Early Campanian, when new forms *Orbitoides douvillei*, *O. tissoti* and *Praesiderolites douvillei* appeared. Most of the taxa continued to the Late Campanian, where they are accompanied by new forms – *R. reicheli*, *N. cretacea* and *Pseudosiderolites vidali* and *Orbitoides media*, which is also an index fossil for the Maastrichtian.

### 2.3.2.6. Maastrichtian

**Foraminiferal assemblage:** *D. schlumbergeri*, *Cuneolina ketini*, *C. pavonia*, *N. picardi*, *M. apula*, *R. scarsellai*, *Murciella cuvillieri*, *M. renzi*, *Rhapydionina liburnica*, *Laffitteina mengaudi*, *Fleuryana adriatica*, *O. media*, *Siderolites calcitrapoides*, *Omphalocyclus macroporus*, *Lepidorbitoides minor* and *Hellenocyclina beotica*.

**Discussion:** The foraminiferal assemblage of the Maastrichtian comprises several species which continued from earlier stages, e.g. *C. pavonia*, *D. schlumbergeri*, *N. picardi* and *O. media*. Exclusively Maastrichtian index fossils are *M. cuvillieri*, *M. renzi*, *R. liburnica*, *C. ketini*, *F. adriatica*, *L. mengaudi*, *S. calcitrapoides*, *O. macroporus*, *L. minor* and *H. beotica*.

Upper Campanian and Maastrichtian deposits are not very common on the AdCP. They occur only in its SW marginal areas – in Divača area (SW Slovenia), near Trogir and Dubrovnik, and on the islands of Brač and Hvar (S, SE Croatia) (MARKOVIĆ, 1975; GUŠIĆ & JELASKA, 1990; JURKOVŠEK et al., 1996; MARINČIĆ, 1997). Such a restricted

distribution is the consequence of a decreased depositional area due to the intense disintegration of the platform that began in the Cenomanian, gradual emergence of its central parts and the culmination of uplift in the Maastrichtian. Depositional environments favourable for the development of shallow-marine benthic communities were also frequently influenced by open marine conditions. At the NE margin of the AdCP (DRAGIČEVIĆ & VELIĆ, 2002), and in the intraplatform troughs formed within the central part of the platform (W Bosnia and Herzegovina, S Croatia – VELIĆ et al., 2002), clastic-carbonate deposits accumulated with predominantly planktonic foraminiferal assemblages, but also rich assemblages of benthic foraminifera, especially orbitoids and siderolitids. The SW platform margin is presently located beneath the Adriatic Sea, mostly covered by Tertiary and Quaternary deposits. However, slope deposits of Maastrichtian age were determined in off-shore exploratory wells, e.g. W and SW of Istria, containing orbitoid and siderolite assemblages (VESELI, 1999).

### 3. BIOSTRATIGRAPHY

Mesozoic carbonate deposits of the Adriatic Carbonate Platform are, although partially, relatively well biostratigraphically investigated. Most of the studies were restricted to relatively small areas. However, the work of RADOIČIĆ (1966) is more of an attempt at the regional biostratigraphic analysis of a major part of the platform. An integrated biostratigraphic subdivision of the entire platform is presented here from the Upper Triassic to the end of the Cretaceous, based also on results of all available former investigations.

Lower and Middle Triassic deposits have not been systematically stratigraphically investigated, so there are no reliable recent data that are needed for their stratigraphic zonation.

It should be noted that benthic foraminifera on the AdCP were most frequently biostratigraphically analyzed together with calcareous algae. Therefore, this paper represents the first zonation based exclusively on benthic foraminifera that can be used platformwide. It will be a reliable starting point not only for more detailed biozonation, but also for stratigraphic analysis and determination.

#### 3.1. Previous investigations

Triassic deposits of the Karst Dinarides have been relatively poorly investigated, and there are no data on detailed recent studies. Palaeontological papers on Early and Middle Triassic foraminiferal assemblages are scarce, and several decades old. Furthermore, they usually refer to specific localities dealing with narrow stratigraphic ranges, specific taxa, etc., generally lacking reliable data based on the studies of continuous

stratigraphic sequences and regional correlation and synthesis. Recent data can only be found in relation to Upper Triassic deposits, and therefore biostratigraphic zonation can be attempted from this level onwards. The previously acknowledged subdivision of the Upper Triassic deposits of Karlovac area (Central Croatia) is that published by GRGASOVIĆ (1997). However, results of older investigations from different parts of the platform are also used for biostratigraphic zonation presented in this paper.

Jurassic deposits have interested biostratigraphers for a long time, as witnessed by a long list of papers published since the 1960's. Authors usually followed a scheme proposed for the Apennines by SARTONI & CRESCENTI (1962). For the AdCP, the first such subdivision was published by FARINACCI & RADOIČIĆ (1964), followed by RADOIČIĆ (1966), NIKLER & SOKAČ (1968), GUŠIĆ (1969b), GUŠIĆ et al. (1971), VELIĆ & SOKAČ (1974 – only for Late Jurassic), VELIĆ (1977), VELIĆ & SOKAČ (1978a) and SOKAČ & VELIĆ (1979a). SEPTFONTAINE et al. (1991) presented a general biostratigraphic zonation of Jurassic imperforate foraminifera on Tethyan carbonate platforms of the Mediterranean, which included the area of the AdCP. VELIĆ et al. (1995) biostratigraphically subdivided younger Middle and Upper Jurassic deposits of Western Istria.

Papers dealing with Cretaceous microfossil assemblages are very numerous. One of the first papers illustrating Cretaceous assemblages is that by RADOIČIĆ (1960). Besides stratigraphic relationships more and more attention was gradually given to biostratigraphic subdivision. Some of the aforementioned papers dealing with Jurassic biostratigraphy also included, either partly or completely, Cretaceous deposits, e.g. FARINACCI & RADOIČIĆ (1964), VELIĆ (1977), VELIĆ & SOKAČ (1978a, b) and SOKAČ & VELIĆ (1979a). Lower Cretaceous microfossil assemblages and/or biozonations were also investigated, including those by VELIĆ (1973), SOKAČ & VELIĆ (1978, 1979a, b), SOKAČ et al. (1978), VELIĆ & SOKAČ (1978a, b, 1979, 1980, 1983), VELIĆ et al. (1979) and FUČEK et al. (1995). The most detailed study of foraminiferal biostratigraphy of Lower Cretaceous deposits is that by VELIĆ (1988). CVETKO TEŠOVIĆ (2000) analyzed foraminiferal assemblages of the Barremian, Aptian and Albian, while the orbitolinid biostratigraphy of the so-called Mid-Cretaceous (stratigraphic range Early Aptian–Middle Cenomanian), was presented by HUSINEC et al. (2000). ARNAUD-VANNEAU et al. (1991) presented stratigraphic ranges of Early Cretaceous benthic foraminifera of the AdCP and neighbouring platforms, particularly the Apenninic, Apulian and Hellenic. VELIĆ et al. (1995) presented microfossil assemblages and determined biozones within a major part of the Lower Cretaceous deposits of Western Istria.

Upper Cretaceous deposits of the AdCP are not so well biostratigraphically subdivided as Jurassic and

Lower Cretaceous deposits. Foraminiferal assemblages, mostly from the Adriatic coastal area and islands, were studied by MAMUŽIĆ & GRIMANI (1970), MAMUŽIĆ et al. (1976, 1980, 1981a, b, 1982, 1983, 1984), POLŠAK et al. (1982), GUŠIĆ et al. (1988), FUČEK et al. (1990) and others. VELJIĆ & VLAHOVIĆ (1994) published detailed biostratigraphic zonation of the Cenomanian deposits. Regionally important results on the biostratigraphy of benthic foraminifera on the AdCP are presented in monographs published by GUŠIĆ & JELASKA (1990) and JURKOVŠEK et al. (1996), as well as in papers by CVETKO TEŠOVIĆ et al. (2001) and KORBAR et al. (2001), using biozonation after FLEURY (1980).

### 3.2. Biostratigraphic zonation and subdivision

From the introduction above it is clear that the distribution of biostratigraphic investigations of benthic foraminifera over the entire AdCP area is uneven. There is more or less continuous coverage over the Croatian part of the platform, but papers dealing with neighbouring areas are infrequent. The least investigated areas are Bosnia and Herzegovina and Montenegro, so mostly older papers were relied on here.

Since Lower and Middle Triassic rocks were relatively poorly investigated, biostratigraphic zonation cannot be based exclusively on benthic foraminifera. Detailed investigation of Early Triassic and Anisian foraminiferal assemblages reveals the presence of index taxa of narrow stratigraphic range. However, Ladinian carbonate deposits do not contain index forms of foraminifera, and biostratigraphic zonations of Middle Triassic deposits are based mainly on dasyclad algae. The first such zonation was published by GRGASOVIĆ (2003). Therefore, in this paper biozonation of the shallow-marine carbonate deposits of the AdCP will be limited to the stratigraphic range Late Triassic–end Cretaceous.

The biozones and accompanying tables only list index fossils and the more important taxa for the foraminiferal assemblages in order to avoid repetition of all determined taxa previously cited in the description of assemblages. There are several cases when one biozone was determined as e.g. lineage zone or interval zone or partial-range zone. These zones were defined as being between the first occurrences of two index or more important foraminiferal taxa. Priority was given to lineage zones, followed by partial-range zones named after species with narrow chrono- and biostratigraphical range, and interval zones if the older taxa is of a wider stratigraphic range. For each biozone, the chronostratigraphic range is presented, to enable correlation of the studied deposits. However, there are cases when new investigations significantly changed the chronostratigraphic ranges of some important foraminiferal taxa, for example the strontium isotope analysis of the Upper Cretaceous deposits of the island of Brač by STEUBER et al. (2005). Such changes are important, but not essen-

tial for biostratigraphic subdivision, because it is based mostly on the order of occurrence, i.e. stratigraphic succession of individual taxa and assemblages.

#### 3.2.1. Late Triassic

GRGASOVIĆ (1997) established three biozones within the Upper Triassic deposits of Žumberak (NW Croatia): (1) *Clypeina besici* taxon-range zone in the Carnian, (2) *Aulotortus sinuosus* interval zone of approximately Norian age, and (3) *Triasina hantkeni* taxon-range zone in the Rhaetian. This subdivision is acceptable and usable throughout the AdCP area. However, zonation based exclusively on benthic foraminifera will produce zones which are not completely correlatable with those based on dasyclad algae. According to the stratigraphic ranges of Late Triassic foraminifera the following superimposed Upper Triassic foraminiferal biozones could be established: (1) *Lamelliconus procerus* taxon-range zone, (2) *Lamelliconus procerus*–*Triasina hantkeni* interval zone, and (3) *Triasina hantkeni* taxon-range zone.

##### 3.2.1.1. *Lamelliconus procerus* taxon-range zone

**Boundaries:** stratigraphic range of *L. procerus*.

**Index and important taxa:** *L. procerus*, *L. multispinus*, *Aulotortus friedli*, *A. sinuosus*, *A. praegaschei* and *A. tenuis*.

**Stratigraphic range:** Carnian.

**Discussion:** Within the cited assemblage only *L. procerus* and *L. multispinus* are index fossils, while species of *Aulotortus* have wider stratigraphic ranges through the Late Triassic.

##### 3.2.1.2. *Lamelliconus procerus*–*Triasina hantkeni* interval zone

**Boundaries:** from the last occurrence of *L. procerus* to the first occurrence of *T. hantkeni*.

**Important taxa:** *Aulotortus friedli*, *A. sinuosus*, *A. praegaschei*, *A. tenuis*, *A. tumidus*, *Trocholina crassa* and *T. acuta*.

**Stratigraphic range:** Late Carnian–Early Rhaetian.

**Discussion:** Within well studied Upper Triassic deposits of Karlovac area, GRGASOVIĆ (1997) separated the *A. sinuosus* interval zone of Norian stratigraphic range (from the last occurrence of Carnian algae *Clypeina besici* to the first occurrence of the Rhaetian foraminifera *T. hantkeni*). If only benthic foraminifera are considered the zone would be somewhat wider, but would not contain any index forms, since the stratigraphic ranges of cited species of *Aulotortus* commenced in the Anisian. Separation of this, as well as the previous zone in the area of the AdCP can only be made in areas where Upper Triassic deposits are not dolomitized, as discussed in section 2.1.3.

STAGES	Hett.	Sinemurian			Pliensbachian			Toarcian
Geological time (duration) in My	3.1	6.9			6.6			7.4
BIOZONES	1	2	3	4	5	6	7	8
				4.1	4.2	5.1	5.2	
<i>Mesoendothyra</i> sp.								
<i>Lituolipora termieri</i>								
<i>Lituosepta recoarensis</i>								
<i>Planisepta compressa</i>								
<i>Orbitopsella primaeva</i>								
<i>Orbitopsella praecursor</i>								
<i>Biokovina gradacensis</i>								
<i>Bosniella oenensis</i>								
? <i>Orbitopsella dubari</i>								
<i>Pseudocyclammina liassica</i>								
<i>Mesoendothyra croatica</i>								

Fig. 7 Biostratigraphic subdivision of the Lower Jurassic deposits of the AdCP. Legend: 1) *Triasina hantkeni*–*Mesoendothyra* sp. interval zone; 2) *Mesoendothyra* sp. lineage zone; 3) *Lituosepta recoarensis* lineage zone; 4) *Orbitopsella primaeva* lineage zone: 4.1) *Orbitopsella primaeva*–*Lituosepta recoarensis* concurrent-range subzone, 4.2) *Lituosepta recoarensis*–*Orbitopsella praecursor* interval subzone; 5) *Orbitopsella praecursor* taxon-range zone: 5.1) *Orbitopsella praecursor*–*O. primaeva* concurrent-range subzone, 5.2) *Orbitopsella praecursor* abundance subzone; 6) *Orbitopsella praecursor*–*Pseudocyclammina liassica* interval zone; 7) *Pseudocyclammina liassica* taxon-range zone; 8) *Pseudocyclammina liassica*–*Gutnicella cayeuxi* interval zone.

### 3.2.1.3. *Triasina hantkeni* taxon-range zone, GRGASOVIĆ (1997)

**Boundaries:** stratigraphic range of *T. hantkeni*.

**Index and important taxa:** *T. hantkeni*, *Auloconus permodisoides*, *Aulotortus friedli*, *A. sinuosus*, *A. tenuis*, *A. tumidus*, *A. pokorny*, *Trocholina crassa* and *T. acuta*.

**Stratigraphic range:** Rhaetian.

**Discussion:** Foraminiferal assemblages of this zone cannot be traced through the entire sequence of Rhaetian deposits, due to extensive late-diagenetic dolomites, while non-dolomitized limestones can be found in alternation with dolomites in certain levels or as lenses and interbeds within dolomites. Index fossils for this zone are *T. hantkeni* and *A. permodisoides*.

### 3.2.2. Early Jurassic

Due to the evident decrease of fossils during the earliest Jurassic, biostratigraphic studies and subdivisions based exclusively on benthic foraminifera have not previously been attempted. Authors dealing with Jurassic biostratigraphy only defined the subzone *Orbitopsella praecursor* in the middle part of the Early Jurassic within the *Palaeodasycladus mediterraneus* zone (NIKLER & SOKAČ, 1968; GUŠIĆ, 1969b; GUŠIĆ et al., 1971; VELIĆ, 1977; VELIĆ & SOKAČ, 1978a).

Biozonation within the Lower Jurassic deposits is presented here (Fig. 7). It is based upon results of biostratigraphic investigations of Early Jurassic lito-lids made by SEPTFONTAINE (1984) in shallow-marine, mostly carbonate sequences of Western Mediterranean, especially in the Lower Jurassic of the High Atlas in Morocco, from where HOTTINGER (1967), described most of the Early Jurassic lito-lid species. This subdivision not only correlates well with the biostratigraphy of lito-lids in Velebit Mt., but also in the wider area of

the AdCP, where more than 90% of genera and species are common and occur in the same stratigraphic ranges. Therefore, the relationships between different taxa are also the same as in the Lower Jurassic of the High Atlas (compare Fig. 2 with Figs. 3 & 7).

#### 3.2.2.1. *Triasina hantkeni*–*Mesoendothyra* sp. interval zone

**Boundaries:** from the last occurrence of *T. hantkeni* to the first occurrence of *Mesoendothyra* sp.

**Index and important taxa:** not applicable, only small valvulinids and lito-lids without significant stratigraphic value, e.g. *Duotaxis metula*, *Amijiella amiji*, *Siphovalvulina variabilis* and *Everticyclammina* sp. – ?*E. praevirguliana*.

**Stratigraphic range:** Late Rhaetian–Early Sinemurian.

**Discussion:** During the Late Rhaetian and Hettangian, environmental conditions were very unfavourable for foraminifera, due to extensive coverage of the platform by tidal flats or very shallow subtidal seas. Rhaetian carbonate deposits are represented by the alternation of early- and late-diagenetic stromatolitic dolomites (*Hauptdolomite* – Main Dolomite Formation). The Hettangian deposits consist of the alternation of limestones and late-diagenetic dolomites with rare intercalations of early-diagenetic dolomites. In Hettangian environments dasyclad algae sporadically flourished. Although all the studied sections contain benthic foraminifera there are no index species, which only occur later in the Early Sinemurian. Therefore, this part of the sequence is marked as an interval zone.

#### 3.2.2.2. *Mesoendothyra* sp. lineage zone or *Mesoendothyra* sp. interval zone, SEPTFONTAINE (1984) or *Mesoendothyra* sp. partial-range zone

**Boundaries:** from the first occurrence of *Mesoendothyra* sp. sensu SEPTFONTAINE (1988) to the first

occurrence of *Lituosepta recoarensis*.

**Important taxa:** *Mesoendothyra* sp. and *Lituolipora termieri*.

**Stratigraphic range:** transitional beds between Lower and Upper Sinemurian.

**Discussion:** Within the previously established Lower Jurassic, Hettangian, Sinemurian and Pliensbachian united zone, a dasyclad algal – Palaeodasycladus mediterraneus zone was separated on the AdCP (e.g. FARINACCI & RADOIČIĆ, 1964; NIKLER & SOKAČ, 1968; GUŠIĆ et al., 1971; VELIĆ, 1977). Co-occurring foraminifera have no stratigraphic value. Foraminiferal biozones were established, as subzones of the aforementioned algal zone only in the Upper Sinemurian and Pliensbachian deposits, as a result of the significant development of orbitopsellinids. In the biostratigraphic investigations of solely foraminiferal assemblages, this is the first time that a *Mesoendothyra* sp. lineage zone has been determined in the Lower Jurassic deposits of the AdCP. SEPTFONTAINE (1984) marked it as an interval-zone. However, according to the International Stratigraphic Guide (SALVADOR, 1994) it corresponds to a lineage zone, since this form represents an ancestor of *L. recoarensis* within the evolutionary line of Early Jurassic litiolids.

3.2.2.3. *Lituosepta recoarensis* lineage zone, SEPTFONTAINE (1984) or *Lituosepta recoarensis* partial-range zone

**Boundaries:** from the first occurrence of *L. recoarensis* to the first occurrence of *Orbitopsella primaeva*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *L. recoarensis* and *Planisepta compressa*.

**Stratigraphic range:** older Late Sinemurian (Early Lotharingian).

**Discussion:** This zone is determined as a lineage zone, and not interval or range or taxon-range zone, because *L. recoarensis* within the evolutionary line of Early Jurassic litiolids has a place between the ancestor *Mesoendothyra* sp. and *O. primaeva*. The stratigraphic range of *L. recoarensis* on the AdCP continues from this to the next zone.

3.2.2.4. *Orbitopsella primaeva* lineage zone, SEPTFONTAINE (1984) or *Orbitopsella primaeva* partial-range zone

**Boundaries:** from the first occurrence of *O. primaeva* to the first occurrence of *Orbitopsella praecursor*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *L. recoarensis*, *P. compressa* and *O. primaeva*.

**Stratigraphic range:** Late Sinemurian–Early Carixian.

**Discussion:** Within the evolutionary line of the Early Jurassic litiolids, *O. primaeva* is a ‘transitional’ form between *L. recoarensis* and *O. praecursor*. Therefore, this zone is referred to as a lineage zone in the manner proposed by SEPTFONTAINE

(1984). In Velebit Mt. and Lika the index fossil *O. primaeva* also reaches maximum abundance within this zone, so it may also be defined as an abundance zone. However, if one analyzes the ranges of the three most important index fossils found within Lower Jurassic deposits – *L. recoarensis*, *O. primaeva* and *O. praecursor* – this zone can be further subdivided into two subzones: *Orbitopsella primaeva* – *Lituosepta recoarensis* concurrent-range subzone and *Lituosepta recoarensis* – *Orbitopsella praecursor* interval subzone.

3.2.2.4.1. *Orbitopsella primaeva*–*Lituosepta recoarensis* concurrent-range subzone

**Boundaries:** from the first occurrence of *O. primaeva* to the last occurrence of *L. recoarensis*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *L. recoarensis*, *P. compressa* and *O. primaeva*.

**Stratigraphic range:** Late Sinemurian–earliest Carixian.

**Discussion:** This biozone comprises part of the Lower Jurassic deposits with *Orbitopsella* spp. in which the index species *L. recoarensis* and *O. primaeva* occur together.

3.2.2.4.2. *Lituosepta recoarensis*–*Orbitopsella praecursor* interval subzone

**Boundaries:** from the last occurrence of *L. recoarensis* to the first occurrence of *O. praecursor*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *P. compressa* and *O. primaeva*.

**Stratigraphic range:** Early Carixian.

**Discussion:** This subzone comprises a part of the Lower Jurassic orbitopsella-bearing deposits containing only *O. primaeva*. Other forms continue from zones older than this to the younger biozones.

3.2.2.5. *Orbitopsella praecursor* taxon-range zone (SARTONI & CRESCENTI, 1962)

**Boundaries:** stratigraphic range of *O. praecursor*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *P. compressa*, *O. primaeva*, *O. praecursor* and *O. ?dubari*.

**Stratigraphic range:** Early Pliensbachian (Late Carixian).

**Discussion:** The *Orbitopsella praecursor* biozone was first established by SARTONI & CRESCENTI (1962) in the Apennines, as a subzone of the Palaeodasycladus mediterraneus cenozoone (assemblage zone), with a stratigraphic position in the middle part of the Early Jurassic. This was also accepted in all investigations within the Karst Dinarides. Within this zone, all three cited orbitopsellas occur, but the occurrence of *O. dubari* is dubious, although this is not critical either for chronostratigraphical or for biostratigraphical subdivision. Theoretically, this

zone might be subdivided as in the *Orbitopsella primaeva* lineage zone into two subzones: *Orbitopsella primaeva*–*Orbitopsella praecursor* concurrent-range subzone and *Orbitopsella praecursor* abundance subzone.

#### 3.2.2.5.1. *Orbitopsella praecursor*–*Orbitopsella primaeva* concurrent-range subzone

**Boundaries:** from the first occurrence of *O. praecursor* to the last occurrence of *O. primaeva*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *P. compressa*, *O. primaeva*, *O. praecursor*, *Biokovina gradacensis* and *Bosniella oenensis*.

**Stratigraphic range:** Late Carixian.

**Discussion:** This zone covers part of the Lower Jurassic deposits in which the stratigraphic ranges of two orbitopsella index forms overlap: the first part of the *O. praecursor* stratigraphic range and the last part of the *O. primaeva* range. These forms are followed by a standard assemblage of Early Jurassic lituolids, the stratigraphic ranges of which continued from earlier biozones. *B. gradacensis* occurs in this zone for the first time.

#### 3.2.2.5.2. *Orbitopsella praecursor* abundance subzone

**Boundaries:** maximum abundance of the species *O. praecursor*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri*, *P. compressa*, *Orbitopsella ?dubari*, *O. praecursor*, *B. gradacensis* and *B. oenensis*.

**Stratigraphic range:** Late Carixian–earliest Domerian.

**Discussion:** The index form *O. praecursor* is the most frequent and this zone reflects its maximum abundance in the younger part of its stratigraphic range. Along with *O. praecursor* and other typical Early Jurassic lituolids the occurrence of *O. dubari* is supposed.

#### 3.2.2.6. *Orbitopsella praecursor*–*Pseudocyclammina liassica* interval zone

**Boundaries:** from the last occurrence of *O. praecursor* to the first occurrence of *P. liassica*.

**Index and important taxa:** *Mesoendothyra* sp., *L. termieri* and *P. compressa*.

**Stratigraphic range:** Late Pliensbachian (Domerian); probably also the beginning of Toarcian.

**Discussion:** Although this zone contains frequent specimens of *L. termieri* and *P. compressa* (general index fossils of the middle part of the Early Jurassic – Sinemurian and Pliensbachian), they cannot be used for naming this zone, since they also occur in younger and older biozones. Therefore, due to the lack of index taxa this zone is defined as an interval zone.

#### 3.2.2.7. *Pseudocyclammina liassica* taxon-range zone, SEPTFONTAINE (1984)

**Boundaries:** stratigraphic range of *P. liassica*.

**Index and important taxa:** *L. termieri*, *P. compressa* and *P. liassica*.

**Stratigraphic range:** Late Pliensbachian (Late Domerian).

**Discussion:** Investigation of detailed undisturbed sections of Lower Jurassic deposits highlighted layers where *P. liassica* was determined, which had not previously been recorded in the area of the Karst Dinarides. Investigations in the Western Mediterranean realm (HOTTINGER, 1967; SEPTFONTAINE, 1984) showed the exact position of this species in the Late Domerian, and SEPTFONTAINE (1984) founded a biozone of the same name. Comparison of the stratigraphic ranges of index species of Early Jurassic foraminifera of these areas with the Karst Dinarides (Fig. 2) shows perfect correlation, and further supports the establishment of this zone.

#### 3.2.2.8. *Pseudocyclammina liassica*–*Gutnicella cayeuxi* interval zone

**Boundaries:** from the last occurrence of *P. liassica* to the first occurrence of *Gutnicella cayeuxi*.

**Important taxa:** *Involutina liassica*, *Agerina martana* and *Mesoendothyra croatica*.

**Stratigraphic range:** Toarcian–Early Aalenian.

**Discussion:** Cited taxa have a wider stratigraphic range within Lower and Middle Jurassic deposits, so this zone contains no index taxa or even a large number of foraminiferal taxa as in previous biozones. This is a consequence of altered depositional environments, from mostly subtidal and lagoonal to either deeper or shallower water regions. In the NW part of the platform, regional deepening was recorded, with local terrigenous influences, while in the SE part of the platform shallowing occurred, marked by deposition of mostly oolitic limestones. Such environments were probably not very favourable for benthic organisms, so only small, undeterminable foraminifera and *A. martana*, which has a wider stratigraphic range within Lower Jurassic, have been found in this zone. *I. liassica* has been determined only in deposits indicating an open marine influence, such as platform margins and slopes. *M. croatica* rarely appears in Toarcian beds, but is frequent in Middle Jurassic deposits.

### 3.2.3. Middle Jurassic

Similar to the Lower Jurassic, the Middle Jurassic deposits of the Karst Dinarides were not biostratigraphically subdivided in detail. Previously, one zone with three subzones had been proposed: (1) Trochamniidae, Verneuilinidae and Textulariidae, (2) Selliporella donzellii, and (3) Pfenderinidae (FARINACCI & RADOIČIĆ, 1964), or one zone – Pfenderina salerni-

STAGES	Aalenian			Bajocian				Bathonian		Callovian	
Geological time (duration) in My	4.0			3.9				3.0		3.5	
BIOZONES	1	2	3	4	5	6	7	8	8.1	9	10
<i>Mesoendothyra croatica</i>	[Stratigraphic range bar]										
<i>Gutnicella cayeuxi</i>	[Stratigraphic range bar]										
<i>Pseudocyclammina maynci</i>	[Stratigraphic range bar]										
<i>Timidonella sarda</i>	[Stratigraphic range bar]										
<i>Spiraloconulus perconigi</i>	[Stratigraphic range bar]										
<i>Spiraloconulus giganteus</i>	[Stratigraphic range bar]										
<i>Pseudodictyopsella jurassica</i>	[Stratigraphic range bar]										
<i>Marzoella ficcarellii</i>	[Stratigraphic range bar]										
<i>Paravalvulina complicata</i>	[Stratigraphic range bar]										
<i>Pseudoeggerella elongata</i>	[Stratigraphic range bar]										
<i>Paleopfenderina salernitana</i>	[Stratigraphic range bar]										
<i>Paleopfenderina trochoidea</i>	[Stratigraphic range bar]										
<i>Alzonella cuvillieri</i>	[Stratigraphic range bar]										
<i>Satorina apulensis</i>	[Stratigraphic range bar]										
<i>Kilianina blancheti</i>	[Stratigraphic range bar]										
<i>Orbitamina elliptica</i>	[Stratigraphic range bar]										
<i>Satorina mesojurassica</i>	[Stratigraphic range bar]										
<i>Kurnubia jurassica</i>	[Stratigraphic range bar]										
<i>Selliporella donzellii</i>	[Stratigraphic range bar]										

Fig. 8 Biostratigraphic subdivision of the Middle Jurassic deposits of the AdCP. Legend: 1) *Pseudocyclammina liassica*–*Gutnicella cayeuxi* interval zone; 2) *Gutnicella cayeuxi* partial range zone; 3) *Timidonella sarda* taxon-range zone; 4) *Timidonella sarda*–*Pseudodictyopsella jurassica* interval zone; 5) *Pseudodictyopsella jurassica* and *Marzoella ficcarellii* assemblage zone; 6) *Pseudodictyopsella jurassica*–*Paravalvulina complicata* interval zone; 7) *Paravalvulina complicata* taxon-range zone; 8) *Paleopfenderina salernitana* taxon-range zone; 8.1) *Satorina apulensis* taxon range subzone; 9) *Paleopfenderina salernitana*–*Kurnubia jurassica* interval zone; 10) *Kurnubia jurassica* lineage zone.

tana in younger part of the Middle Jurassic (NIKLER & SOKAČ, 1968; GUŠIĆ, 1969b; GUŠIĆ et al., 1971), or two zones: (1) *Mesoendothyra croatica*, and (2) *Selliporella donzellii* (VELIĆ, 1977; VELIĆ & SOKAČ, 1978a).

Biozonation of the Middle Jurassic deposits presented here (Fig. 8) is based upon recent investigations, during which numerous index species have been determined. Among them are taxa which were previously relatively unknown in the area of the AdCP or have been discovered for the first time.

3.2.2.8. and 3.2.3.1. *Pseudocyclammina liassica*–*Gutnicella cayeuxi* interval zone or *Mesoendothyra croatica* partial range zone

**Boundaries:** from the first occurrence of *Mesoendothyra croatica* to the first occurrence of *G. cayeuxi*.

**Important taxa:** *M. croatica*.

**Stratigraphic range:** Toarcian and Early Aalenian.

**Discussion:** This interval-zone comprises Jurassic deposits between the first occurrence of *M. croatica* to the first occurrence of *G. cayeuxi*, but it can also be defined as the *M. croatica* partial range zone, since it comprises the lowermost part of the stratigraphic range of this taxon. *M. croatica* is the most important of the index species in this zone. Within this weakly fossiliferous interval, a chronostratigraphic boundary between the Lower and Middle Jurassic occurs, since the first occurrence of *M. croatica* probably took place in the early Toarcian deposits.

3.2.3.2. *Gutnicella cayeuxi* partial range zone or *Gutnicella cayeuxi*–*Timidonella sarda* interval zone

**Boundaries:** from the first occurrence of *G. cayeuxi* to the first occurrence of *T. sarda*.

**Index and important taxa:** *G. cayeuxi*, *Mesoendothyra croatica* and *Pseudocyclammina maynci*.

**Stratigraphic range:** Middle to Late Aalenian.

**Discussion:** Deposits of this zone and the next one could also be defined as an assemblage zone within the stratigraphic range of both *G. cayeuxi* and *T. sarda*, as proposed by SEPTFONTAINE et al. (1991). Given the fact that the first occurrences of the cited taxa represent important biohorizons, deposits between them were defined as an interval zone. Besides *G. cayeuxi*, *P. maynci* is another index form for these deposits.

3.2.3.3. *Timidonella sarda* taxon-range zone, SEPTFONTAINE (1980)

**Boundaries:** stratigraphic range of *T. sarda*.

**Index and important taxa:** *T. sarda*, *M. croatica*, *G. cayeuxi*, *P. maynci*, *Spiraloconulus perconigi* and *S. giganteus*.

**Stratigraphic range:** Late Aalenian–Early Bajocian.

**Discussion:** *T. sarda* was discovered on the AdCP some 20 years ago, but this fact was never published. The beginning of its stratigraphic range coincides with the last occurrence of *G. cayeuxi*. In the younger part of its stratigraphic range *S. perconigi* and *S. giganteus* also occur. Given these relationships, this

zone was defined as being of latest Aalenian and earliest Bajocian age, according to the results of the investigations on the AdCP, and comparison with well established chronostratigraphic positions of these taxa in the Western Mediterranean realm (e.g. BASSOULLET et al., 1976; SEPTFONTAINE, 1980; SEPTFONTAINE et al., 1991; BASSOULLET, 1997).

#### 3.2.3.4. *Timidonella sarda*–*Pseudodictyopsella jurassica* interval zone

**Boundaries:** from the last occurrence of *T. sarda* to the first occurrence of *P. jurassica*.

**Important taxa:** *M. croatica*, *P. maynci* and *S. giganteus*.

**Stratigraphic range:** younger part of the Early Bajocian.

**Discussion:** There are no index taxa, and only two other important taxa – *P. maynci* and *S. giganteus* continuing from the earlier biozone, as well as *M. croatica*, which has a wider Middle Jurassic range. Generally, from the biostratigraphic point of the view it is important to note that this zone marks the beginning of the stratigraphic range of the important Bajocian–early Bathonian dasyclad species *Selliporella donzelli*.

#### 3.2.3.5. *Pseudodictyopsella jurassica* and *Marzoella ficcarellii* assemblage zone

**Boundaries:** stratigraphic ranges of *P. jurassica* and *M. ficcarellii*.

**Index and important taxa:** *P. jurassica*, *M. ficcarellii*, *M. croatica* and *S. giganteus*.

**Stratigraphic range:** middle part of the Bajocian.

**Discussion:** This foraminiferal assemblage is characteristically of high abundance but low species diversity, where the only index forms are *P. jurassica* and *M. ficcarellii* found in the central part of the Bajocian succession (Fig. 3), probably in transitional deposits between the early and late Bajocian of Biokovo Mt., together with *S. giganteus*. Despite this narrow stratigraphic range, and their occurrence in only one locality, a separate biostratigraphic unit was defined. However, the occurrence of these species in one level, could also allow these biohorizons to be termed the *P. jurassica* and *M. ficcarellii* FADs (First Appearance Datums). Since investigation of the Middle Jurassic deposits of the AdCP represents a work in progress, new data which would confirm the establishment of this zone are expected.

#### 3.2.3.6. *Pseudodictyopsella jurassica*–*Paravalvulina complicata* interval zone

**Boundaries:** from the last occurrence of *P. jurassica* to the first occurrence of *P. complicata*.

**Important taxa:** *M. croatica* and *S. giganteus*.

**Stratigraphic range:** approximately Middle Bajocian.

**Discussion:** Deposits of this biozone contain a rich assemblage of small foraminifera, most of which belong to taxa of wider stratigraphic ranges. The maximum frequency of *M. croatica* was determined, so this zone could also be defined as an abundance zone. This zone comprises a major part of the stratigraphic range of the important dasyclad species *Selliporella donzelli*, which is less frequent in deposits of the succeeding zone.

#### 3.2.3.7. *Paravalvulina complicata* taxon-range zone

**Boundaries:** stratigraphic range of the species *P. complicata*.

**Index and important taxa:** *P. complicata*, *Pseudoeggerella elongata* and *M. croatica*.

**Stratigraphic range:** latest Bajocian.

**Discussion:** The stratigraphic positions of *P. complicata* and *P. elongata*, which were recently unknown in Jurassic deposits of the AdCP (VELIĆ, 2005), are the same as those defined by SEPTFONTAINE (1988) for the Western Mediterranean. *P. complicata* occurs somewhat earlier (probably at the very end of Bajocian) than *P. elongata*, which occurs at the Bajocian–Bathonian transition and through Bathonian. Therefore this zone occurs in part of the Middle Jurassic deposits directly underlying the horizon characterized by the first occurrence of *Paleopfenderina salernitana*, the Bathonian index form which is widespread over the Mediterranean.

#### 3.2.3.8. *Paleopfenderina salernitana* taxon-range zone SARTONI & CRESCENTI (1962)

**Boundaries:** stratigraphic range of *P. salernitana*.

**Index and important taxa:** *P. salernitana*, *P. trochoidea*, *M. croatica*, *P. elongata*, *Alzonella cuvillieri*, *Kilianina blancheti*, *Satorina apuliensis*, *S. mesojurassica* and *Orbitamina elliptica*.

**Stratigraphic range:** Bathonian–?earliest Callovian.

**Discussion:** *P. salernitana* is connected with the beginning of the Bathonian on the AdCP, so the lower boundary of this biozone coincides with the Bajocian–Bathonian chronostratigraphic boundary. In the younger part of this zone the *S. apuliensis* subzone was defined within the stratigraphic range of the Late Bathonian.

##### 3.2.3.8.1. *Satorina apuliensis* taxon range subzone

**Boundaries:** stratigraphic range of *S. apuliensis*.

**Index and important taxa:** *Satorina apuliensis*, *S. mesojurassica*, *P. salernitana*, *P. trochoidea*, *A. cuvillieri*, *K. blancheti*, *O. elliptica* and *P. elongata*.

**Stratigraphic range:** Late Bathonian.

**Discussion:** This subzone comprises the younger part of the *P. salernitana* taxon-range zone. The stratigraphic range of *S. apuliensis* on the AdCP is longer than that of the other cited late Bathonian species, so it is probable that it occurred until the end of the Batho-

nian, or even to the earliest Callovian. However, the stratigraphic range of *P. salernitana* exceeds even the range of *S. apuliensis*, so it is almost certain that it also occurs in the early Callovian.

#### 3.2.3.9. *Paleopfenderina salernitana*–*Kurnubia jurassica* interval zone

**Boundaries:** from the last occurrence of *P. salernitana* to the first occurrence of *Kurnubia jurassica*.

**Important taxa:** *P. arabica*, *P. crusei* and *Trocholina* gr. *alpina*–*elongata*.

**Stratigraphic range:** Callovian.

**Discussion:** Within the interval from the last occurrence of *P. salernitana* to the first occurrence of *K. jurassica* the foraminiferal assemblage contains no index taxa. However, the stratigraphic range of this zone is unambiguous, since the last occurrence of *P. salernitana* at the AdCP was in the early Callovian, and the first occurrence of *K. jurassica* took place in the late Callovian. Therefore, the range of this zone is Callovian.

#### 3.2.3.10. *Kurnubia jurassica* lineage zone or *Kurnubia jurassica* partial-range zone or *Kurnubia jurassica*–*Kurnubia palastiniensis* interval zone

**Boundaries:** from the first occurrence of *K. jurassica* to the first occurrence of *K. palastiniensis*.

**Important taxa:** *P. arabica*, *P. crusei*, *Trocholina* gr. *alpina*–*elongata* and *K. jurassica*.

**Stratigraphic range:** latest Callovian–earliest Oxfordian.

**Discussion:** This interval zone comprises the youngest part of the Middle Jurassic and the oldest part of the Upper Jurassic deposits with clearly defined boundaries between two biohorizons, the first occurrences of two cited species of *Kurnubia*. Therefore, this zone includes the chronostratigraphic boundary between the Middle and Late Jurassic.

Alternatively, this zone can also be defined as a lineage zone because of the taxonomic position of *K. jurassica* as the first form in the evolutionary trend of kurnubians. GUŠIĆ (1969a, b) discussed and illustrated *K. jurassica* in Upper Jurassic deposits of Central Croatia from inner platform environments of the NW parts of the former AdCP. Since then, this species has not been cited again in publications dealing with the AdCP. However, recent investigations of a series of detailed columns dispersed around the AdCP, suggest that this form occurs before *K. palastiniensis*, indicating the youngest Callovian. Among kurnubians, *K. jurassica* represents a transitional form between *P. crusei* and *K. palastiniensis*. Therefore the definition of this zone as a lineage zone is also approved within the evolutionary line of kurnubians: *Praekurnubia crusei* – *K. jurassica* – *Kurnubia palastiniensis* – *K. wellingsi* – *Conicokurnubia orbitoliniformis*.

### 3.2.4. Late Jurassic

Hitherto biostratigraphic subdivisions of the Upper Jurassic deposits of the AdCP were mostly based on calcareous algae (NIKLER & SOKAČ, 1968; GUŠIĆ, 1969b; GUŠIĆ et al., 1971; VELIĆ, 1977; VELIĆ & SOKAČ, 1974, 1978a). Although benthic foraminifera were cited in these papers they were not discussed in detail. Only GUŠIĆ (1969b) and GUŠIĆ et al. (1971), following subdivision by SARTONI & CRESCENTI (1962), separated the *Kurnubia palastiniensis* assemblage zone in the older part of the Late Jurassic.

*K. palastiniensis* has a stratigraphic range in the AdCP from the earliest Oxfordian to the Late Tithonian, so it has an important role in biostratigraphy of the Late Jurassic. Therefore the major part of the Upper Jurassic deposits can be defined as a *K. palastiniensis* superzone (Fig. 9).

#### 3.2.4.1–3.2.4.6. *Kurnubia palastiniensis* superzone

**Boundaries:** Stratigraphic range of *K. palastiniensis*.

**Index and important taxa:** Includes all taxa cited in the next four biozones.

**Stratigraphic range:** Oxfordian–Late Tithonian.

**Discussion:** This superzone comprises the following biozones:

- *Kurnubia palastiniensis* lineage zone,
- *Kurnubia wellingsi* lineage zone,
- *Chablaisia chablaisensis*–*Alveosepta jaccardi* interval zone,
- *Alveosepta jaccardi* partial-range zone,
- *Parurgonina caelinensis*–*Conicokurnubia orbitoliniformis* concurrent range-zone, and
- *C. orbitoliniformis*–*K. palastiniensis* interval zone (highest-occurrence zone).

#### 3.2.4.1. *Kurnubia palastiniensis* lineage zone or *Kurnubia palastiniensis* partial-range zone or *Kurnubia palastiniensis*–*Kurnubia wellingsi* interval zone

**Boundaries:** From the first occurrence of *K. palastiniensis* to the first occurrence of *K. wellingsi*.

**Important taxa:** *K. palastiniensis*, *K. jurassica*, *Chablaisia chablaisensis* and *Karaisella uzbekistanica*.

**Stratigraphic range:** Early Oxfordian.

**Discussion:** Separation of this part of the Upper Jurassic deposits as a lineage zone is based on the position of *K. palastiniensis* within the evolutionary trend of kurnubians *P. crusei* – *K. jurassica*, *K. palastiniensis* – *K. wellingsi* – *C. orbitoliniformis*. Due to the lack of foraminiferal species with a stratigraphic range confined to this interval, this unit could also be defined as an interval zone, or as the *K. palastiniensis* partial-range zone, since it comprises the first part of the stratigraphic range of this species. Within tempestites of the younger part of this zone and the older part of the next zone, *Ch. chablaisensis*, *Trocholina alpina* and *T. elongata* (*chablaisia*–

STAGES	Oxfordian			Kimmeridgian		Tithonian	
Geological time (duration) in My	6.2			4.2		5.3	
BIOZONES	1–6						
	1	2	3	4	5	6	7
<i>Kurnubia palastiniensis</i>							
<i>Kurnubia jurassica</i>							
<i>Karaisella uzbekistanica</i>							
<i>Chablaisia chablaisensis</i>							
<i>Labyrinthina mirabilis</i>							
<i>Kurnubia wellingsi</i>							
<i>Conicokurnubia orbitoliniformis</i>							
<i>Alveosepta jaccardi</i>							
<i>Kilianina? rahonensis</i>							
<i>Parurgonina caelinensis</i>							
<i>Anchispirocyclina lusitanica</i>							
<i>Protopeneroplis ultragranulata</i>							

Fig. 9 Biostratigraphic subdivision of the Upper Jurassic deposits of the AdCP. Legend: 1–6) *Kurnubia palastiniensis* superzone: 1) *Kurnubia palastiniensis* lineage zone; 2) *Kurnubia wellingsi* lineage zone; 3) *Chablaisia chablaisensis*–*Alveosepta jaccardi* interval zone; 4) *Alveosepta jaccardi* partial-range zone; 5) *Parurgonina caelinensis*–*Conicokurnubia orbitoliniformis* concurrent range zone; 6) *Conicokurnubia orbitoliniformis*–*Kurnubia palastiniensis* interval zone (highest-occurrence zone); 7) *Kurnubia palastiniensis*–*Protopeneroplis ultragranulata* interval zone.

trocholina tempestites) are abundant in the western part of the AdCP – Velebit Mt., Gorski Kotar and Istria. So in this area, this part of the unit could be defined as an abundance zone.

#### 3.2.4.2. *Kurnubia wellingsi* lineage zone or *Labyrinthina mirabilis*–*Karaisella uzbekistanica* concurrent-range zone or *Kurnubia wellingsi* partial-range zone

**Boundaries:** From the first occurrence of *K. wellingsi* to the first occurrence of *Conicokurnubia orbitoliniformis* for the lineage and partial-range zones. From the first occurrence of *L. mirabilis* to the last occurrence of *K. uzbekistanica* for the concurrent-range zone.

**Stratigraphic range:** older part of Late Oxfordian.

**Important taxa:** *K. wellingsi*, *K. palastiniensis*, *K. jurassica*, *Ch. chablaisensis*, *K. uzbekistanica* and *L. mirabilis*.

**Discussion:** In the aforementioned evolution of Jurassic kurnubians, *K. wellingsi* represents a transitional form between *K. palastiniensis* and *C. orbitoliniformis*, for the Late Oxfordian and the beginning of the Kimmeridgian. Therefore, this zone is defined as a lineage-zone. Alternatively, it may be defined as a concurrent-range zone from the first occurrence of *L. mirabilis* to the last occurrence of *K. uzbekistanica*, the stratigraphic ranges of which overlap, or as the *K. wellingsi* and *L. mirabilis* partial-range zone. *K. wellingsi* is common, which supports and enables the definition of this zone. Its first occurrence coincides with the first occurrence of *L. mirabilis*, and they both continue into the next zone.

#### 3.2.4.3. *Chablaisia chablaisensis*–*Alveosepta jaccardi* interval zone

**Boundaries:** from the last occurrence of *Ch. chablaisensis* to the first occurrence of *A. jaccardi*.

**Important taxa:** *L. mirabilis*, *K. palastiniensis*, *K. wellingsi* and *K. jurassica*.

**Stratigraphic range:** younger part of the Late Oxfordian.

**Discussion:** There are no foraminiferal index-taxa in the uppermost Oxfordian deposits. However, they could be separated as an interval zone between two biostratigraphic boundaries: the last occurrence of *Ch. chablaisensis* and *K. uzbekistanica* and the first occurrence of *A. jaccardi*, *C. orbitoliniformis* and *Kilianina? rahonensis*.

#### 3.2.4.4. *Alveosepta jaccardi* partial-range zone or *Alveosepta jaccardi*–*Parurgonina caelinensis* interval zone

**Boundaries:** from the first occurrence of *A. jaccardi* to the first occurrence of *P. caelinensis*.

**Important taxa:** *L. mirabilis*, *K. palastiniensis*, *K. wellingsi*, *K. jurassica*, *A. jaccardi*, *C. orbitoliniformis* and *K.? rahonensis*.

**Stratigraphic range:** Early Kimmeridgian.

**Discussion:** This foraminiferal assemblage is currently the richest known in the Kimmeridgian of the AdCP. Most of the taxa have a wide stratigraphic range, both those occurring for the first time in younger zones of the Middle Jurassic, and those first occurring in the oldest Late Jurassic zones. *A. jaccardi*, *C. orbitoliniformis* and *K.? rahonensis* occur here for the first time, but they are not index forms, since their stratigraphic ranges continue into younger zones. Since former biostratigraphic zonations of the AdCP deposits were mostly based on rich calcareous algal assemblages it should be noted that this zone covers the stratigraphic range of *Pseudoclypeina cirici*.

3.2.4.5. *Parurgonina caelinensis*–*Conicokurnubia orbitoliniformis* concurrent range zone or *Parurgonina caelinensis* partial–range zone

**Boundaries:** from the first occurrence of *P. caelinensis* to the last occurrence of *C. orbitoliniformis*.

**Important taxa:** *K. palastiniensis*, *K. wellingsi*, *C. orbitoliniformis*, *A. jaccardi*, *L. mirabilis*, *K.?* *rahonensis* and *Parurgonina caelinensis*.

**Stratigraphic range:** Middle and Late Kimmeridgian.

**Discussion:** There are no index forms in this foraminiferal assemblage. The upper boundary is marked by the last occurrence of *A. jaccardi* and *C. orbitoliniformis*, and this approximately corresponds to the Kimmeridgian–Tithonian chronostratigraphic boundary, and the beginning of the stratigraphic range of dasyclad alga *Clypeina jurassica*.

3.2.4.6. *Conicokurnubia orbitoliniformis*–*Kurnubia palastiniensis* interval zone (highest-occurrence zone)

**Boundaries:** from the last occurrence of *C. orbitoliniformis* to the last occurrence of *K. palastiniensis*.

**Important taxa:** *K. palastiniensis*, *P. caelinensis* and *K.?* *rahonensis*.

**Stratigraphic range:** Early Tithonian.

**Discussion:** In addition to *K. palastiniensis*, *P. caelinensis* and *K.?* *rahonensis*, which have their last occurrences near the end of this zone, this assemblage contains other forms of much wider stratigraphic range (Fig. 4). In the continuous succession of the Upper Jurassic, carbonate deposits of this zone can exceed 400 m thickness, and contain the middle part of the stratigraphic range of the dasyclad index fossil *Clypeina jurassica*.

3.2.4.7. *Kurnubia palastiniensis*–*Protopenneroplis ultragranulata* interval zone

**Boundaries:** from the last occurrence of *K. palastiniensis* to the first occurrence of *P. ultragranulata*.

**Important taxa:** *Anchispirocyclina lusitanica*, probably also *A. neumannae*.

**Stratigraphic range:** Late Tithonian.

**Discussion:** In the youngermost part of the Upper Jurassic deposits of the AdCP a significant decrease in frequency and diversity of the foraminiferal assemblage is observed. This is largely because the peritidal environments were more favourable for abundant calcareous algae. This level is famous throughout the platform for rich assemblages and the maximum development of dasyclad species including *Clypeina jurassica* and *Campbelliella striata*. *A. lusitanica* and/or *A.?* *neumannae* are index foraminifera but only for the youngermost part of this zone. They have only been discovered at two localities: Biokovo Mt., and around Dubrovnik. Separation of a specific zone for the entire AdCP is not possible because of such very scarce and restricted observations, although theoretically it might be pro-

posed, since SEPTFONTAINE et al. (1991) defined *Anchispirocyclina lusitanica* taxon-range zone in the Late Tithonian (Portlandian).

### 3.2.5. Early Cretaceous

Relatively rich foraminiferal assemblages in the Lower Cretaceous platform carbonate deposits of the Adriatic Carbonate Platform have previously enabled the most detailed biostratigraphic zonation (Fig. 10). Zonations proposed in former studies, e.g. those by VELIĆ & SOKAČ (1978b) and VELIĆ (1988), will represent the basis for biozonation proposed here.

3.2.5.1. *Protopenneroplis ultragranulata* taxon-range zone (VELIĆ, 1988)

**Boundaries:** stratigraphic range of *P. ultragranulata*.

**Index and important taxa:** *P. ultragranulata* is the only index fossil, and other forms have a wider stratigraphic range, either from the Jurassic into the Early Cretaceous or through the Cretaceous, e.g. *Mohlerina basiliensis*, *Trocholina alpina*, *T. elongata*, *Mayncina bulgarica* and *Charentia cuvillieri*.

**Stratigraphic range:** Late Tithonian–Early Berriasian.

**Discussion:** Central parts of the AdCP in present Croatia and W Bosnia were emergent during the Late Tithonian and Early Berriasian, while in other parts peritidal environments predominated, which were very unfavourable for benthic foraminifera. This is the main reason why the foraminiferal assemblage is very poor.

3.2.5.2. *Protopenneroplis ultragranulata*–*Vercorsella camposaurii* interval zone

**Boundaries:** from the last occurrence of *P. ultragranulata* to the first occurrence of *V. camposaurii*.

**Important taxa:** there are no important taxa, since only forms of wider stratigraphic range were determined, such as *Trocholina alpina*, *T. elongata*, *Mayncina bulgarica* and *Charentia cuvillieri*.

**Stratigraphic range:** Middle and Late Berriasian.

**Discussion:** As for the previous zone, carbonate deposits of this zone were deposited in peritidal environments, and temporary subtidal environments. Therefore the foraminiferal assemblage is also poor and without index fossils.

3.2.5.3. *Vercorsella camposaurii* taxon-range zone (SARTONI & CRESCENTI, 1962)

**Boundaries:** stratigraphic range of *V. camposaurii*.

**Index and important taxa:** *Vercorsella tenuis*, *V. camposaurii*, *Montsalevia salevensis*, *Meandrospira favrei*, *Haplophragmoides joukowskyi*, *Trocholina delphinensis* and *T. sagittaria*.

**Stratigraphic range:** latest Berriasian, Valanginian and earliest Hauterivian.

**Discussion:** SARTONI & CRESCENTI (1962) defined the *Cuneolina camposaurii* assemblage zone with

STAGES	Berriasian		Valanginian	Hauterivian		Barremian		Aptian				Albian			
	Geological time (duration) in My		5.3	3.8	6.4	5.0	13.0				12.0				
BIOZONES	1	2	3	4	5	6	7-10				11	12	13	14	15
							7	8	9	10					
<i>Protopenneroplis ultragranulata</i>	1														
<i>Vercorsella tenuis</i>															
<i>Vercorsella camposaurii</i>															
<i>Montsalevia salevensis</i>															
<i>Haplophragmoides joukowskyi</i>															
<i>Meandrospira favrei</i>															
<i>Trocholina delphinensis</i>															
<i>Trocholina sagittaria</i>															
<i>Campanellula capuensis</i>															
<i>Rectodictyoconus giganteus</i>															
<i>Palorbitolina lenticularis</i>															
<i>Trocholina molesta</i>															
<i>Trocholina odukpaniensis</i>															
<i>Derventina filipesculi</i>															
<i>Neotrocholina friburgensis</i>															
<i>Nautiloculina broennimanni</i>															
<i>Nautiloculina cretacea</i>															
<i>Neotrocholina aptiensis</i>															
<i>Voloshinoides murgensis</i>															
<i>Sabaudia briacensis</i>															
<i>Choffatella decipiens</i>															
<i>Pseudolituonella conica</i>															
<i>Praeorbitolina cormyi</i>															
<i>Pfenderina globosa</i>															
<i>Paleodictyoconus actinostoma</i>															
<i>Praeorbitolina wienandsi</i>															
<i>Mesorbitolina lotzei</i>															
<i>Archalveolina</i> sp.															
<i>Sabaudia capitata</i>															
<i>Sabaudia auruncensis</i>															
<i>Haplophragmoides globosus</i>															
<i>Mesorbitolina parva</i>															
<i>Archalveolina reicheli</i>															
<i>Mesorbitolina texana</i>															
<i>Orbitolinopsis aquitanica</i>															
<i>Mesorbitolina angulosa</i>															
<i>Sabaudia dinapolii</i>															
<i>Cuneolina sliteri</i>															
<i>Mesorbitolina pervia</i>															
<i>Mesorbitolina subconcava</i>															
<i>Paracoskinolina sunniladensis</i>															
" <i>Valdanchella</i> " <i>dercourti</i>															
<i>Neoiraquia insolita</i>															
<i>Simplorbitolina broennimanni</i>															
<i>Paracoskinolina fleuryi</i>															
<i>Protochrysalidina elongata</i>															
<i>Neoiraquia convexa</i>															
<i>Scandonea pumila</i>															
<i>Scandonea phoenissa</i>															
<i>Ovalveolina maccagnoeae</i>															
? <i>Sellialveolina viallii</i>															

Fig. 10 Biostratigraphic subdivision of the Lower Cretaceous deposits of the AdCP. Legend: 1) *Protopenneroplis ultragranulata* taxon-range zone; 2) *Protopenneroplis ultragranulata*–*Vercorsella camposaurii* interval zone; 3) *Vercorsella camposaurii* taxon-range zone; 4) *Vercorsella camposaurii*–*Campanellula capuensis* interval zone; 5) *Campanellula capuensis* taxon-range zone; 6) *Campanellula capuensis*–*Palorbitolina lenticularis* interval zone; 7–10) *Palorbitolina lenticularis* superzone: 7) *Rectodictyoconus giganteus* and *Palorbitolina lenticularis* assemblage zone, 8) *Praeorbitolina cormyi* lineage zone, 9) *Praeorbitolina wienandsi* lineage zone, 10) *Mesorbitolina lotzei* lineage zone; 11) *Mesorbitolina parva* lineage zone; 12) *Mesorbitolina texana* lineage zone; 13) *Mesorbitolina subconcava* taxon-range zone; 14) "*Valdanchella*" *dercourti* partial-range zone; 15) *Neoiraquia convexa* taxon-range zone.

the stratigraphic range of Valanginian–Aptian. The stratigraphic range of *V. camposaurii* is also stated as being Valanginian–Aptian, but they noted that elsewhere this species is of Valanginian age (Provence, according to PFENDER, 1938) or Barremian age (Montenegro, according to RADOIČIĆ, 1960). Detailed investigations on the AdCP have proven that forms which correspond to the original description of *V. camposaurii* (SARTONI & CRESCENTI, 1962) are of exclusively Neocomian age, with a stratigraphic range of latest Berriasian–earliest Hauterivian. So this form can be considered as an index form of the Valanginian. This species has latterly been included into the genus *Vercorsella*

(ARNAUD-VANNEAU et al., 1991). Almost all forms defined as *C. camposaurii* by VELIĆ (1973, 1977) correspond to other species of *Vercorsella*.

Other additional index forms in this assemblage include *V. tenuis*, *M. salevensis*, *M. favrei*, *H. joukowskyi*, *T. delphinensis* and *T. sagittaria*. Other taxa have different, but wider stratigraphic ranges through the Early Cretaceous (Fig. 5).

#### 3.2.5.4. *Vercorsella camposaurii*–*Campanellula capuensis* interval zone

**Boundaries:** from the last occurrence of *V. camposaurii* or other index taxa of the previous zone to the first occurrence of *C. capuensis*.

**Important taxa:** No important taxa, only forms of wider stratigraphic range, e.g. *T. alpina*, *T. elongata* and *T. sagittaria*.

**Stratigraphic range:** Within the Hauterivian.

**Discussion:** This is an interval within the Hauterivian with a poor foraminiferal assemblage and no index forms. All taxa have wider stratigraphic ranges through the Early Cretaceous, and the cited trocholinids do not occur after the Hauterivian.

#### 3.2.5.5. *Campanellula capuensis* taxon-range zone, VELIĆ (1988)

**Boundaries:** stratigraphic range of *C. capuensis*.

**Index and important taxa:** *C. capuensis*, *T. sagittaria*.

**Stratigraphic range:** latest Hauterivian and transition into the Barremian.

**Discussion:** *C. capuensis* is very frequent and important in this assemblage. Within the relatively poor assemblages in Lower Cretaceous deposits from the early Hauterivian to the late Barremian, its stratigraphic position is very important, as it represents an essential biofacies. Other forms have wider, but variable stratigraphic ranges through the Early Cretaceous. This zone is also characterized by end of the stratigraphic ranges of *T. alpina* and *T. elongata*.

#### 3.2.5.6. *Campanellula capuensis*–*Palorbitolina lenticularis* interval zone

**Boundaries:** Between two important biohorizons last occurrence of *C. capuensis* and first occurrence of *P. lenticularis*.

**Important taxa:** No important taxa, only forms of wider stratigraphic range, e.g. *Vercorsella laurentii*, *Novallesia distorta*, *N. cornucopia*, *N. producta*, *Sabaudia minuta*, *Debarina hahounerensis* and *T. sagittaria*.

**Stratigraphic range:** Early and Middle Barremian.

**Discussion:** In this relatively rich foraminiferal assemblage there are no index forms. This zone marks the beginning of the stratigraphic ranges of species that are relatively abundant in younger Lower Cretaceous deposits of the AdCP – *S. minuta* and *D. hahounerensis*, as well as species of *Vercorsella* and *Novallesia*.

#### 3.2.5.7–3.2.5.10. *Palorbitolina lenticularis* superzone (taxon-range zone, HUSINEC et al., 2000)

**Boundaries:** the stratigraphic range of *P. lenticularis*.

**Index and important taxa:** Comprises all taxa included in the next four biozones. It is important to note that the most important species in all of these zones is *P. lenticularis*.

**Stratigraphic range:** Late Barremian and Early Aptian.

**Discussion:** Carbonate deposits within the stratigraphic range of *P. lenticularis* on the AdCP represent the regionally most important biofacies level of the Early Cretaceous, known as the ‘Lower Orbitolina

Limestones’ (VELIĆ, 1988). Within this superzone, which could also be defined as the *P. lenticularis* taxon-range zone (HUSINEC et al., 2000), four zones have been determined (Fig. 12):

- *Rectodictyoconus giganteus* and *Palorbitolina lenticularis* assemblage zone,
- *Praeorbitolina cormyi* lineage zone,
- *Praeorbitolina wienandsi* lineage zone, and
- *Mesorbitolina lotzei* lineage zone.

Within deposits of the *P. lenticularis* superzone on the AdCP, VELIĆ & SOKAČ (1978a) and VELIĆ (1988) discovered all of the first (Aptian) part of the evolutionary trend of orbitolinids according to SCHROEDER (1975, 1979). Therefore, these zones were defined as lineage zones, and were named after the first three species within the evolutionary line.

#### 3.2.5.7. *Rectodictyoconus giganteus* and *Palorbitolina lenticularis* assemblage zone (VELIĆ, 1988) or *Palorbitolina lenticularis* partial-range zone

**Boundaries:** from the first occurrence of *R. giganteus* and *P. lenticularis* to the first occurrence of *Praeorbitolina cormyi*.

**Index and important taxa:** *R. giganteus*, *P. lenticularis*, *Derventina filipescui*, *Trocholina molesta*, *T. odukpaniensis*, *Neotrocholina aptiensis*, *N. friburgensis*, *Nautiloculina broennimanni* and *N. cretacea*.

**Stratigraphic range:** Late Barremian and beginning of the Early Aptian (Bedoulian).

**Discussion:** *R. giganteus* is the index form for this zone. However, this orbitolinid was only discovered in the NE marginal area of the AdCP in the vicinity of Banja Luka and Jajce. Elsewhere, over the major part of the platform, deposits of this zone are recognized as belonging to the lowermost part of the ‘Lower Orbitolina Limestones’, where the predominant foraminifera is *P. lenticularis*, and praeorbitolinids are absent (VELIĆ & SOKAČ, 1978a). All other forms in the foraminiferal assemblage have a wider stratigraphic range, except partially *N. aptiensis* and *N. friburgensis*, which can also be found in the next three zones of the Early Aptian.

#### 3.2.5.8. *Praeorbitolina cormyi* lineage zone (VELIĆ, 1988) or *Praeorbitolina cormyi* partial-range zone

**Boundaries:** from the first occurrence of *P. cormyi* to the first occurrence of *Praeorbitolina wienandsi*.

**Index and important taxa:** *P. lenticularis*, *R. giganteus*, *P. cormyi*, *Paleodictyoconus actinostoma*, *Sabaudia briacensis*, *Pfenderina globosa*, *D. filipescui*, *N. aptiensis*, *N. friburgensis*, *T. molesta*, *T. odukpaniensis*, *N. broennimanni*, *N. cretacea*, *Choffatella decipiens*, *Voloshinoides murgensis* and *Pseudolituonella conica*.

**Stratigraphic range:** Early Aptian (Early Bedoulian).

**Discussion:** *P. cormyi* is the only index form of this zone. *P. lenticularis*, predominates the assemblage

together with forms of variable stratigraphic range through the Early Cretaceous, including index species for the Late Barremian and Early Aptian – *N. aptiensis* and *N. friburgensis*, as well as species determined only from the Early Aptian – *S. briacensis*, *C. decipiens*, *V. murgensis* and *P. conica*. At the NE margin of the AdCP (Mt. Vlašić in Central Bosnia), the orbitolinid *P. actinostoma* was discovered, which is unknown in other areas of the platform, although there are data on the discovery of the genus *Paleodictyoconus* (e.g. VELIĆ & SOKAČ, 1978a).

#### 3.2.5.9. *Praeorbitolina wienandsi* lineage zone or *Praeorbitolina wienandsi* partial-range zone

**Boundaries:** from the first occurrence of *P. wienandsi* to the first occurrence of *Mesorbitolina lotzei*.

**Index and important taxa:** *P. wienandsi* and most of taxa cited in the previous zone.

**Stratigraphic range:** middle part of the Early Aptian (Middle Bedoulian).

**Discussion:** Foraminiferal frequencies in this assemblage are almost identical to the assemblage of the *P. cormyi* zone. It is however enriched by the index form *P. wienandsi*, small trocholinas, and in places specifically undeterminable involutinids. *P. lenticularis* remains a predominant form.

#### 3.2.5.10. *Mesorbitolina lotzei* lineage zone or *Mesorbitolina lotzei* taxon-range zone (VELIĆ, 1988)

**Boundaries:** from the first occurrence of *M. lotzei* to the first occurrence of *Mesorbitolina parva* or within the stratigraphic range of *M. lotzei*.

**Index and important taxa:** As for the *P. cormyi* and *P. wienandsi* zones, enriched in *M. lotzei* and *Sabaudia capitata*, *S. auruncensis* and *Archaealveolina* sp.

**Stratigraphic range:** Late Early Aptian (Late Bedoulian).

**Discussion:** The foraminiferal assemblage of this zone remains mostly unchanged from the composition of the previous two zones, characterized by a predominance of *P. lenticularis*, and enrichment in *M. lotzei*. Poorly preserved, very micritized sections determined as *Archaealveolina* sp. could represent *A. reicheli*, described from Late Aptian deposits (DE CASTRO, 1966, 1980, 1988). If this specific determination is proven to be correct then the occurrence of *A. reicheli* in the Early Aptian of the AdCP would be the first occurrence of this form (VELIĆ & SOKAČ, 1978a). The end of this zone is characterized by disappearance of index forms for the Late Barremian and Early Aptian: *P. lenticularis*, *P. cormyi*, *P. wienandsi*, *M. lotzei*, *P. globosa*, *D. filipescui*, *N. friburgensis*, as well as other trocholins and *N. broennimanni*, *N. cretacea*, *C. decipiens*, *S. briacensis*, *V. murgensis* and *P. conica*. Other forms have continuous stratigraphic ranges into the Late Aptian, and this zone represents the beginning of the stratigraphic ranges of *S. capitata* and *S. auruncensis*.

#### 3.2.5.11. *Mesorbitolina parva* lineage zone or *Mesorbitolina parva* partial-range zone

**Boundaries:** from the first occurrence of *M. parva* to the first occurrence of *Mesorbitolina texana*.

**Index and important taxa:** *M. parva*, *N. aptiensis*, *Archalveolina reicheli*, *S. auruncensis*, *S. capitata* and *Haplophragmoides globosus*.

**Stratigraphic range:** transitional level Early–Late Aptian and Late Aptian (Gargasian).

**Discussion:** The first occurrence of *M. parva* was noted immediately after the last occurrence of *M. lotzei* in the vicinity of Ogulin (Central Croatia). This assemblage contains numerous specimens of *N. aptiensis*, which on the AdCP is regarded as an index form of the Early Aptian (e.g. VELIĆ & SOKAČ, 1978a; VELIĆ, 1988; HUSINEC et al., 2000). It is therefore probable that the first appearance of *M. parva* occurred in the final part of the Early Aptian and/or transition into the Late Aptian. *H. globosus* was recorded in this zone, but is illustrated as *Trochamminoides coronus* by CHIOCCHINI et al. (1994). Other taxa of wider stratigraphic range through the early Cretaceous were cited in the rich Late Aptian fossil assemblage in the previous section. Among them, *Praechrysalidina infracretacea* reached its maximum in this zone.

Deposits of this zone belong to the lowermost part of the biofacies known as the ‘Upper Orbitolina Limestones’ (VELIĆ & SOKAČ, 1978a; VELIĆ, 1988), that are regionally distributed over the AdCP. It encompasses the stratigraphic range of Aptian and Albian mesorbitolinids, i.e. Late Aptian and Early Albian, and, from the biostratigraphic point of view, deposits of this and the two following zones. In comparison with the evolution of important calcareous algae, this and the following zone represent the maximum of the dasyclad alga *Salpingoporella dinarica* RADOIČIĆ (VELIĆ & SOKAČ, 1978a).

#### 3.2.5.12. *Mesorbitolina texana* lineage zone (VELIĆ, 1988) or *Mesorbitolina texana* partial-range zone

**Boundaries:** from the first occurrence of *M. texana* to the first occurrence of *Mesorbitolina subconca*.

**Index and important taxa:** *M. texana*, *M. parva*, *A. reicheli*, *S. auruncensis*, *S. capitata*, *H. globosus* and *Orbitolinopsis aquitanica*.

**Stratigraphic range:** Late Aptian.

**Discussion:** *M. texana* is the most widespread mesorbitolinid form on the AdCP, with a stratigraphic range from the middle of the Late Aptian to the Middle Albian. It can be found in limestones originating in different environments, and is very abundant in lagoonal–subtidal environments and tempestites. However, there are areas with very rare occurrences (e.g. SE Croatia and islands) or where it is absent (e.g. W Istria; Fig. 18), due to regional shallowing and emergence (VELIĆ et al., 1989, 2002).

*M. parva* spreads through the entire zone, and this zone represents the maximum of *H. globosus* and *A. reicheli*. *O. aquitanica* occurs infrequently, and is restricted to the latest Aptian and earliest Albian.

### 3.2.5.13. *Mesorbitolina subconcava* taxon-range zone (VELIĆ, 1988)

**Boundaries:** stratigraphic range of *M. subconcava*.

**Index and important taxa:** *M. subconcava*, *M. pervia*, *M. texana*, *M. parva*, *Paracoskinolina sunnilandensis*, *O. aquitanica*, *A. reicheli*, *Sabaudia dinapolii*, *S. auruncensis*, *S. capitata*, *Cuneolina sliteri* and *H. globosus*.

**Stratigraphic range:** Transitional level between the Aptian and Albian and/or the Early Albian.

**Discussion:** This zone forms the major part of the 'Upper Orbitolina Limestones', a typical facies of the AdCP (VELIĆ & SOKAČ, 1978a; VELIĆ, 1988). The foraminiferal assemblage is dominated by mesorbitolinids, among which *M. parva* occurs, while other species of this genus – *M. texana*, *M. subconcava* and *M. pervia* – reached their maximum, but disappeared at the end of this zone. Within this zone the maximum of many other taxa which range through several Early Cretaceous zones occurred, e.g. *A. reicheli*, *Vercorsella scarsellai*, *V. laurentii*, *V. arenata*, *S. minuta*, *S. auruncensis*, *S. capitata*, *S. dinapolii* and *M. bulgarica*. *A. reicheli*, *V. arenata*, *S. auruncensis*, *S. capitata*, *S. dinapolii*, *Rumanolocolina robusta* and *Glomospira urgoniana* disappear within this zone. In contrast, there is the first occurrence of important Cretaceous foraminifera, which reached their maximum in the Late Cretaceous – *Cuneolina pavonia*, *C. parva*, *Nezzazatinella picardi* and *Pseudonummolocolina heimi*. The lower boundary is, besides the first occurrence of *M. subconcava*, marked by the occurrence of the cited cuneolinids, including *C. sliteri*, and approximates the Aptian–Albian chronostratigraphic boundary.

### 3.2.5.14. "*Valdanchella*" *dercourtii* partial-range zone or "*Valdanchella*" *dercourtii*–*Neoiraquia convexa* interval zone (VELIĆ & SOKAČ, 1978b)

**Boundaries:** from the first occurrence of '*V.*' *dercourtii* to the first occurrence of *N. convexa*.

**Index and important taxa:** '*V.*' *dercourtii*, *Simplorbitolina broennimanni*, *Neoiraquia insolita*, *Paracoskinolina fleuryi*, *P. sunnilandensis* and *S. auruncensis*.

**Stratigraphic range:** Older part of the Late Albian.

**Discussion:** This foraminiferal assemblage has a mixed character, since it is composed of taxa of wider stratigraphic range through the Early Cretaceous, together with index fossils and taxa which first appeared in the Albian and continued into the Late Cretaceous. Index fossils for this zone are orbitolinid species '*V.*' *dercourtii*, *N. insolita*, *S. broen-*

*nimanni* and *P. fleuryi*. Taxa of wider stratigraphic range through several Early Cretaceous zones are *V. scarsellai*, *V. laurentii*, *S. minuta*, *S. auruncensis*, *M. bulgarica*, and *P. infracretacea*, which disappeared by the end of the Albian, while *P. aurigerica*, *P. heimi*, *S. cretacea*, *S. pumila*, *S. phoenissa*, *N. picardi* and *N. simplex* continued into the Late Cretaceous (GUŠIĆ & JELASKA, 1990; VELIĆ & VLAHOVIĆ, 1994). Dasyclad alga *Salpingoporella turgida* is, among other microfossils, very important for this zone, and it frequently accompanies the cited orbitolinids (VELIĆ & SOKAČ, 1978a, 1979, 1983; VELIĆ et al., 1995; HUSINEC et al., 2000; CVETKO TEŠOVIĆ, 2000).

### 3.2.5.15. *Neoiraquia convexa* taxon-range zone or *Neoiraquia convexa*–*Conicorbitolina conica* interval zone

**Boundaries:** stratigraphic range of *N. convexa*.

**Index and important taxa:** *N. convexa*, '*V.*' *dercourtii*, *Ovalveolina maccagnoae*, ?*Sellialveolina viallii*, *Scandonea pumila*, *S. phoenissa* and *Protochrysalidina elongata*.

**Stratigraphic range:** latest Albian (Vraconian)–earliest Cenomanian.

**Discussion:** Index fossils are *N. convexa*, '*V.*' *dercourtii* and *P. elongata* which did not survive into the Cenomanian, as well as *O. maccagnoae* and *S. viallii*, the stratigraphic range of which is Late Albian and Early Cenomanian. Therefore, this zone would comprise the boundary between the Albian and the Cenomanian. *Sabaudia minuta* ends in this zone, while all other taxa continue into the Late Cretaceous. POLŠAK et al. (1982) also mentioned *S. minuta* in Lower Cenomanian deposits. The beginning of the stratigraphic range of the nezzazatids *N. gyra* and *N. conica* occurs within this zone, and their maximum was during the Cenomanian.

## 3.2.6. Late Cretaceous

In spite of the numerous published papers with cited taxa and assemblages of benthic foraminifera from Upper Cretaceous deposits of the AdCP, there are relatively little data on the biostratigraphical zonation. As previously mentioned, GUŠIĆ & JELASKA (1990) correlated lithostratigraphic units of the island of Brač with the biozonation after FLEURY (1980), and VELIĆ & VLAHOVIĆ (1994) determined five biozones in the Cenomanian deposits of N Istria. Zones defined here (Fig. 11) represent the first attempt to biostratigraphically subdivide the Upper Cretaceous deposits of the AdCP on the basis of foraminiferal assemblages.

### 3.2.6.1. *Conicorbitolina conica*/*Conicorbitolina cuvillieri* partial-range zone or *Conicorbitolina conica*/*Conicorbitolina cuvillieri*–*Chrysalidina gradata* interval zone

**Boundaries:** from the first occurrence of *C. conica* and/or *C. cuvillieri* to the first occurrence of *C. gradata*.

STAGES	Cenomanian				Turonian		Coniacian		Santonian	Campanian			Maastrichtian	
Geological time (duration) in My	6.1				4.2		3.5		2.3	12.9			5.1	
BIOZONES	1	2-4			5	6	7	8	9	9.1	10	11	12	12.1
<i>Ovalveolina maccagnoae</i>														
<i>Sellialveolina viallii</i>														
<i>Praealveolina simplex</i>														
<i>Trocholina arabica</i>														
<i>Pseudocyclammina rugosa</i>														
<i>Ovalveolina crassa</i>														
<i>Conicorbitolina cuvillieri</i>														
<i>Orbitolina concava</i>														
<i>Praealveolina iberica</i>														
<i>Conicorbitolina conica</i>														
<i>Conicorbitolina corbarica</i>														
<i>Orbitolina sefini</i>														
<i>Cisalveolina lechneri</i>														
<i>Pastrikella biplana</i>														
<i>Chrysalidina gradata</i>														
<i>Nummoloculina? regularis</i>														
<i>Pseudolituonella reicheli</i>														
<i>Pseudorhapydionina dubia</i>														
<i>Merlingina cretacea</i>														
<i>Peneroplis turonicus</i>														
<i>Pastrikella balcanica</i>														
<i>Cisalveolina fraasi</i>														
<i>Vidalina radoicicae</i>														
<i>Pseudorhapydionina laurinensis</i>														
<i>Pseudorhapydionina casertana</i>														
<i>Pseudorhapydionina murgiana</i>														
<i>Peneroplis parvus</i>														
<i>Pseudocyclammina sphaeroidea</i>														
<i>Monchamontia apenninica</i>														
<i>Monchamontia compressa</i>														
<i>Scandonea samnitica</i>														
<i>Dicyclina schlumbergeri</i>														
<i>Accordiella conica</i>														
<i>Idalina antiqua</i>														
<i>Pseudorhapydionina mediterranea</i>														
<i>Murgella lata</i>														
<i>Keramosphaerina ?sarda</i>														
<i>Keramosphaerina tergestina</i>														
<i>Reticulinella fleuryi</i>														
<i>Broekinella neumannae</i>														
<i>Archiacina munieri</i>														
<i>Pseudolituonella mariae</i>														
<i>Orbitoides gr. hottingeri</i>														
<i>Dictyopsella kiliani</i>														
<i>Dictyopselloides cuvillieri</i>														
<i>Pseudocyclammina massiliensis</i>														
<i>Reticulinella reicheli</i>														
<i>Calveziconus lecalvezae</i>														
<i>Orbitoides douvillei</i>														
<i>Praesiderolites douvillei</i>														
<i>Orbitoides tissoti</i>														
<i>Pseudosiderolites vidali</i>														
<i>Nummofalotia cretacea</i>														
<i>Orbitoides media</i>														
<i>Murciella cuvillieri</i>														
<i>Murciella renzi</i>														
<i>Rhapydionina liburnica</i>														
<i>Siderolites calcitrapoides</i>														
<i>Omphalocyclus macroporus</i>														
<i>Hellenocyclina beotica</i>														
<i>Cuneolina ketini</i>														
<i>Fleuryana adriatica</i>														
<i>Laffitteina mengaudi</i>														

Fig. 11 Biostratigraphic subdivision of the Upper Cretaceous deposits of the AdCP. Legend: 1) *Conicorbitolina conica*/*Conicorbitolina cuvillieri* partial-range zone; 2–4) *Chrysalidina gradata* superzone: 2) *Chrysalidina gradata* partial-range zone; 3) *Pastrikella balcanica*–*Conicorbitolina conica* concurrent-range zone; 4) *Vidalina radoicicae*–*C. gradata* concurrent-range zone; 5) *Chrysalidina gradata*–*Pseudocyclammina sphaeroidea* interval zone; 6) *Pseudocyclammina sphaeroidea*–*Scandonea samnitica* interval zone; 7) *Scandonea samnitica*–*Dicyclina schlumbergeri* interval zone; 8) *Dicyclina schlumbergeri*–*Murgella lata* interval zone; 9) *Murgella lata* partial-range zone; 9.1) *Keramosphaerina tergestina* abundance subzone; 10) *Calveziconus lecalvezae* taxon-range zone; 11) *Calveziconus lecalvezae*–*Murciella cuvillieri* interval zone; 12) *Murciella cuvillieri* and *Rhapydionina liburnica* assemblage zone; 12.1) *Fleuryana adriatica* taxon-range subzone.

**Index and important taxa:** *C. conica*, *C. cuvillieri*, *C. gr. corbarica–conica*, *Orbitolina gr. concava*, *O. gr. sefini–concava*, ?*Sellialveolina viallii*, *Ovalveolina maccagnoae*, *O. crassa*, *Praealveolina simplex*, *P. iberica*, *Cisalveolina lehneri*, *Pseudocyclamina rugosa*, *Pastrikella biplana* and *Trocholina arabica*.

**Stratigraphic range:** Early Cenomanian.

**Discussion:** The orbitolinids *C. conica*, *C. cuvillieri*, *C. gr. corbarica–conica*, *O. gr. concava* and *O. gr. sefini–concava* were determined in the assemblage, together with index forms of Cenomanian alveolinids, *O. crassa*, *P. simplex* and *P. iberica*. The stratigraphic ranges of these taxa were according to SCHROEDER & NEUMANN (1985), undoubtedly defined as Early Cenomanian.

### 3.2.6.2–3.2.6.4. *Chrysalidina gradata* superzone

**Boundaries:** stratigraphic range of *Chrysalidina gradata*.

**Index and important taxa:** Cited in descriptions of the following three zones.

**Stratigraphic range:** Middle and Late Cenomanian.

**Discussion:** *C. gradata* is probably the most widespread foraminiferal species within Middle and Upper Cenomanian deposits of the AdCP. The chronostratigraphic value of this species has been confirmed in numerous publications in the last two decades (e.g. GUŠIĆ et al., 1988; FUČEK et al., 1990; GUŠIĆ & JELASKA, 1990; VELIĆ & VLAHOVIĆ, 1994; HUSINEC et al., 2000; KORBAR et al., 2001). Therefore, within these deposits, i.e. within its stratigraphic range, one superzone, and at least three clearly differentiated zones can be defined:

- *Chrysalidina gradata* partial-range zone,
- *Pastrikella balcanica–Conicorbitolina conica* concurrent-range zone, and
- *Vidalina radoicicae–C. gradata* concurrent-range zone.

### 3.2.6.2. *Chrysalidina gradata* partial-range zone or *Chrysalidina gradata–Pastrikella balcanica* interval zone

**Boundaries:** From the first occurrence of *C. gradata* to the first occurrence of *P. balcanica*.

**Index and important taxa:** *C. gradata*, *C. cuvillieri*, *C. conica*, *C. gr. corbarica–conica*, *O. gr. concava*, *O. gr. sefini–concava*, *P. iberica*, *O. crassa*, *C. lehneri*, *Nummoloculina? regularis*, *Pseudolituonella reicheli*, *Pseudorhapydionina dubia*, *Merlingina cretacea*, *P. biplana* and *Peneroplis turonicus*.

**Stratigraphic range:** Early Middle Cenomanian.

**Discussion:** Most of the Cenomanian orbitolinids still occurred in the first part of the stratigraphic range of *C. gradata* together with other index fossils of the Middle–Late Cenomanian, including *N.? regularis*, *P. turonicus* and *P. reicheli*, continuing up to the first occurrence of *P. balcanica*. By analysis and

correlation of the stratigraphic ranges, and comparison with other Cenomanian foraminifera, it is possible to conclude a very precise chronostratigraphic definition for this zone in the early Middle Cenomanian.

Within older Middle Cenomanian deposits of N Istria, VELIĆ & VLAHOVIĆ (1994) proposed an earlier *Chrysalidina gradata* partial-range zone and younger *Chrysalidina gradata* and *Pastrikella balcanica* assemblage zone. They divided the earlier zone into two subzones: an older, *C. gradata* with orbitolinids, and younger, *C. gradata* without orbitolinids. During later investigations in other parts of the AdCP, partly published in a paper by HUSINEC et al. (2000), as well as during detailed investigations for this study, Cenomanian orbitolinids were discovered in deposits of ages up to the end of the Middle Cenomanian in different parts of the platform: it seems that their absence in some places is locally restricted. Therefore, it seems that definition of three zones within the Middle and Late Cenomanian, as proposed here, would be best.

### 3.2.6.3. *Pastrikella balcanica–Conicorbitolina conica* concurrent-range zone (older part of the zone *Broeckina balcanica* FLEURY, 1980).

**Boundaries:** From the first occurrence of *P. balcanica* to the last occurrence of *C. conica*.

**Index and important taxa:** Most of the species as in the previous zone (Fig. 13), accompanied by *P. balcanica*.

**Stratigraphic range:** Late Middle Cenomanian.

**Discussion:** *P. balcanica* is, together with *C. gradata*, the most common, and widely distributed index fossil within the Middle and Upper Cenomanian deposits of the AdCP. Its first occurrence represents an important biohorizon at the beginning of the younger part of Middle Cenomanian deposits. This provides a basis for the definition of this biozone, which is, according to its foraminiferal assemblage and stratigraphic position in the late Middle Cenomanian, equivalent to the *C. gradata* and *P. balcanica* assemblage zone of VELIĆ & VLAHOVIĆ (1994). HUSINEC et al. (2000) have defined a maximum of the development (and abundance) of *Conicorbitolina conica* in the Middle Cenomanian limestones of the island of Cres, which are stratigraphically equivalent to the top part of this zone.

### 3.2.6.4. *Vidalina radoicicae–Chrysalidina gradata* concurrent-range zone (younger part of the *P. balcanica* zone after FLEURY, 1980; *C. gradata* and *V. radoicicae* assemblage zone or *P. balcanica* and *N.? regularis* abundance zone after VELIĆ & VLAHOVIĆ, 1994).

**Boundaries:** From the first occurrence of *V. radoicicae* to the last occurrence of *C. gradata* or range of the maximum abundance of *P. balcanica* and *N.? regularis*.

**Index and important taxa:** *C. gradata*, *V. radoicicae*, *Nummoloculina? regularis*, *Pseudolituonella reicheli*, *Pseudorhapydionina dubia*, *P. laurinen-sis*, *Merlingina cretacea*, *Cisalveolina fraasi*, *Pseudorhapydionina casertana*, *P. murgiana*, *Peneroplis turonicus* and *Peneroplis parvus*.

**Stratigraphic range:** Late Cenomanian.

**Discussion:** The *C. gradata*, *P. balcanica* and *V. radoicicae* assemblage zone was defined within the Upper Cenomanian carbonates of N Istria by VELIĆ & VLAHOVIĆ (1994). They noted that this zone could also have been defined as the *P. balcanica* and *N. regularis* abundance or acme-zone, because these species had their maximum frequency within this biozone, although their stratigraphic range is wider than the Late Cenomanian. Within the foraminiferal assemblage, cited index forms have variable stratigraphic ranges, and only *V. radoicicae* has a stratigraphic range throughout the zone. However, on the basis of the former investigation it seems that this fossil had a relatively poor distribution over the platform, and so was not used to define this zone as a taxon-range zone. A similar situation occurs for the other index fossils, including *C. fraasi*, *P. laurinen-sis*, *P. casertana*, *P. murgiana* and *P. parvus*.

### 3.2.6.5. *Chrysalidina gradata*–*Pseudocyclammina sphaeroidea* interval zone

**Boundaries:** from the last occurrence of *C. gradata* to the first occurrence of *P. sphaeroidea*.

**Important taxa:** The foraminiferal assemblage is significantly reduced due to temporary drowning of the platform, so there are no index fossils. Only taxa of wider stratigraphic range occurred, cited in the previous section (and shown on Fig. 6), as well as planktonic foraminifera in pelagic deposits.

**Stratigraphic range:** Latest Cenomanian–Early Turonian.

**Discussion:** Drowning of the platform also interrupted the evolution of the platform benthic foraminifera. Consequently, this zone comprises only forms of a wider stratigraphic range. However, its boundaries are clearly defined by two important biohorizons, the last occurrence of *C. gradata* and the first occurrence of *P. sphaeroidea* and *Moncharmontia apenninica*.

### 3.2.6.6. *Pseudocyclammina sphaeroidea*–*Scandonea samnitica* interval zone or *Pseudocyclammina sphaeroidea* partial-range zone

**Boundaries:** From the first occurrence of *P. sphaeroidea* to the first occurrence of *S. samnitica*.

**Important taxa:** *P. sphaeroidea* and *M. apenninica*.

**Stratigraphic range:** Late Turonian–earliest Coniacian

**Discussion:** There are no index fossils; *P. sphaeroidea* occurs from the beginning of the zone, while *M. apenninica* and *M. compressa* appear in younger levels.

### 3.2.6.7. *Scandonea samnitica*–*Dicyclina schlumbergeri* interval zone or *Scandonea samnitica* partial-range zone

**Boundaries:** From the first occurrence of *S. samnitica* to the first occurrence of *D. schlumbergeri*.

**Important taxa:** *S. samnitica*, *P. sphaeroidea*, *M. compressa* and *M. apenninica*.

**Stratigraphic range:** Early Coniacian.

**Discussion:** This zone has no index fossils: it contains forms determined in the previous zone as well as some without biostratigraphic significance.

### 3.2.6.8. *Dicyclina schlumbergeri*–*Murgella lata* interval zone or *Dicyclina schlumbergeri* partial-range zone

**Boundaries:** From the first occurrence of *D. schlumbergeri* to the first occurrence of *M. lata*.

**Important taxa:** *S. samnitica*, *P. sphaeroidea*, *M. apenninica*, *M. compressa*, *D. schlumbergeri*, *Accordiel-la conica* and *Idalina antiqua*.

**Stratigraphic range:** Coniacian.

**Discussion:** This zone represents the most of Coniacian deposits without forms of narrow stratigraphic range, but which lies between two important biohorizons, between the first occurrences of *D. schlumbergeri* and *M. lata*, two frequent larger benthic foraminifera on the AdCP.

### 3.2.6.9. *Murgella lata* partial-range zone or *Murgella lata*–*Calveziconus lecalvezae* interval zone

**Boundaries:** From the first occurrence of *M. lata* to the first occurrence of *C. lecalvezae*.

**Index and important taxa:** *Murgella lata*, *Pseudorhapydionina mediterranea*, *Keramosphaerina tergestina*, *K. ?sarda*, *S. samnitica*, *Reticulinella fleuryi*, *R. reicheli*, *D. schlumbergeri*, *A. conica*, *Broekinella neumannae*, *M. apenninica*, *M. compressa*, *Pseudocyclammina massiliensis*, *P. sphaeroidea*, *Pseudolituonella mariae*, *Archiacina munieri*, *Dictyopsella kiliani*, *Dictyopselloides cuvillieri*, *I. antiqua* and *Orbitoides* gr. *hottingeri*.

**Stratigraphic range:** Early Santonian–Early Campanian.

**Discussion:** Deposits within this zone contain one of the richest, and biostratigraphically and palaeogeographically most important Upper Cretaceous foraminiferal assemblages. The most important species is *M. lata*, accompanied by almost all the forms cited in the previous two zones, together with newly occurring index forms – *P. mediterranea*, *K. tergestina*, *P. massiliensis*, *P. mariae*, *R. fleuryi*, *R. reicheli*, *D. kiliani*, *D. cuvillieri*, *A. munieri*, *B. neumannae* and *O. gr. hottingeri*.

The palaeogeographic significance of this zone is that it represents the youngest Cretaceous deposits covered by Eocene deposits over the major part of the Adriatic Carbonate Platform in NE Istria, S and E Lika, Dalmatia and Herzegovina.

### 3.2.6.9.1. *Keramosphaerina tergestina* abundance subzone

**Boundaries:** stratigraphic range of the maximum abundance of *K. tergestina*.

**Index and important taxa:** Most of the taxa cited in the previous zone (Fig. 11).

**Stratigraphic range:** Late Santonian–Early Campanian.

**Discussion:** In the younger part of this zone the level with frequent and/or abundant occurrences of larger *K. tergestina* is especially important, enabling separation of these deposits in the subzone.

### 3.2.6.10. *Calveziconus lecalvezae* taxon-range zone

**Boundaries:** Stratigraphic range of *C. lecalvezae*.

**Index and important taxa:** *C. lecalvezae*, most of the taxa cited in the previous zone (Fig. 11) and *Nummofallotia cretacea*, *Orbitoides tissoti*, *O. douvillei*, *O. media*, *P. douvillei* and *Pseudosiderolites vidali*.

**Stratigraphic range:** Campanian.

**Discussion:** Index fossils are *C. lecalvezae* and *O. tissoti*. Within this zone, many of the important Late Santonian–Campanian species disappeared: *K. tergestina*, *M. lata*, *A. munieri*, *P. mariae*, *B. neumannae*, and *O. gr. hottingeri* (Fig. 13). Most of the orbitoids continued into the next zone, and *O. media* occurs near the end of this zone.

There are only a few areas on the AdCP with continuous depositional sequences and foraminiferal assemblages which could enable detailed biostratigraphic zonation within these youngest Cretaceous deposits. Different environments existed within these spatially restricted depositional areas, representing an additional difficulty for biostratigraphic zonation and correlation. Therefore this zone contains foraminifera from different biotopes, e.g. *O. tissoti*, *O. douvillei*, *O. media*, *P. douvillei* and *P. vidali* from platform margin and slopes and *R. liburnica*, *P. mediterranea*, *S. samnitica*, *P. massiliensis* and *P. sphaeroidea* from subtidal environments. It is difficult to precisely correlate the stratigraphic ranges of taxa from both groups. GUŠIĆ & JELASKA (1990) discussed in detail the difficulties with facies interpretation with a simultaneous occurrence of hyaline and imperforate foraminifera. This was based on the relationship between the Campanian Pučišća formation and the Maastrichtian Sumartin formation on the island of Brač. Each attempt to produce a more detailed biozonation in cases like this would be uncertain and speculative, and would only increase possible mistakes. Therefore, the best or the least erroneous choice would be to unite taxa in assemblages within assemblage zones.

### 3.2.6.11. *Calveziconus lecalvezae*–*Murciella cuvillieri* interval zone

**Boundaries:** from the last occurrence of *C. lecalvezae* to the first occurrence of *M. cuvillieri*.

**Important taxa:** *M. apenninica*, *M. compressa*, *D. schlumbergeri*, *P. sphaeroidea*, *P. douvillei*, *P. vidali*, *O. douvillei*, *O. media* and *N. cretacea*.

**Stratigraphic range:** Latest Campanian–Early Maastrichtian.

**Discussion:** Deposits of this zone have been found near the platform margins and slopes of the AdCP, while the major part of it was emergent. These deposits crop out e.g. in S Croatia, on the island of Brač, where GUŠIĆ & JELASKA (1990) determined foraminiferal assemblages with predominant orbitoids from detailed studied sections. There are no index fossils specific for this zone.

### 3.2.6.12. *Murciella cuvillieri* and *Rhapydionina liburnica* assemblage zone

**Boundaries:** from the first occurrence of *M. cuvillieri* to the last occurrence of *R. liburnica*.

**Index and important taxa:** *Murciella cuvillieri*, *M. renzi*, *Rhapydionina liburnica*, *Cuneolina ketini*, *Fleuryana adriatica*, *Orbitoides media*, *Siderolites calcitrapoides*, *Omphalocyclus macroporus* and *Hellenocyclina beotica*.

**Stratigraphic range:** Maastrichtian.

**Discussion:** Deposits of this zone were studied on the island of Brač (GUŠIĆ & JELASKA, 1990), where in the studied sections *Murciella* gr. *cuvillieri* occurs before *Rhapydionina liburnica*. An orbitoidid and siderolite assemblage was determined in slope facies of the platform margins, and also locally in the area of intraplatform troughs (e.g. VELIĆ, 1973; VELIĆ et al., 1982; GUŠIĆ & JELASKA, 1990; VESELI, 1999; DRAGIČEVIĆ & VELIĆ, 2002).

#### 3.2.6.12.1. *Fleuryana adriatica* taxon-range subzone

**Boundaries:** Stratigraphic range of *F. adriatica*.

**Index and important taxa:** *F. adriatica*, *R. liburnica*, *D. schlumbergeri* and *Laffitteina? mengaudi*.

**Stratigraphic range:** Late Maastrichtian.

**Discussion:** Deposits of this subzone were observed in S Croatia (island of Brač), in the central Adriatic in the Kate-1 well, as well as in the NW part of the platform in SW Slovenia, and in the vicinity of Trieste in Italy (DE CASTRO et al., 1994). Within the deposits with abundant *F. adriatica*, DROBNE et al. (1989) discovered two very important species of larger foraminifera, *R. liburnica* and *D. schlumbergeri*, while JURKOVŠEK et al. (1996) only cited *R. liburnica*. At the type locality of *F. adriatica* within the Upper Maastrichtian deposits on the island of Brač, DE CASTRO et al. (1994) mentioned only *Laffitteina* sp. and *Bolivinopsis* sp. *R. liburnica* and *Laffitteina mengaudi* were discovered earlier in the same deposits (GUŠIĆ & JELASKA, 1990).

#### 4. PALAEOBIOGEOGRAPHY OF MESOZOIC BENTHIC FORAMINIFERA OF THE KARST DINARIDES

The limited platform area and incomplete micropalaeontological investigation are two important factors that hinder construction of a complete and detailed palaeobiogeography of benthic foraminifera on the AdCP. Taking into account that the AdCP was about 700 km long and probably 300–400 km wide, it is clear that it represented a relatively small part of large shallow-marine areas of Tethys. Within the continuous dynamic succession of events, the Adriatic Carbonate Platform evolved from a position in the southern, marginal area of Tethys during the Early Jurassic, through an individualized oceanic platform in the Central Tethyan area with a probable connection to the Albanian and Hellenic platforms, to its disintegration in the Northern Tethyan area during the Late Cretaceous. Its palaeogeographic position controlled climatic changes, sedimentary environments and ecological conditions, which directed the palaeobiogeography of the foraminiferal taxa, groups or complete assemblages. Given the aforementioned limited extent and moderate knowledge, the distribution of mostly larger foraminifera, especially index forms, will be discussed and presented here. This review will cover Mesozoic assemblages, becoming more detailed after the Early and Middle Triassic, through the Late Triassic and Early Jurassic (when the AdCP became separated from the Apulian and Apenninic platforms), to the end of Cretaceous. The process of platform separation probably started in the Late Triassic, and was completed during the Pliensbachian and Toarcian. Since then, the AdCP represented a specific palaeogeographic entity until its final disintegration by the end of Cretaceous.

##### 4.1. Triassic

Among **Early Triassic** foraminifera, *Meandrospira pusila* was the most widespread and the most frequent, together with abundant, though often poorly studied specimens of other smaller foraminifera, including *Glomospira sygmoidalis*, *Glomospirella triphonensis*, *Ammodiscus paraprisus*, *Arenovidalina* sp., etc. These forms were discovered in all areas with outcrops of Lower Triassic rocks, e.g. SW Slovenia, around Karlovac and Slunj, in Velebit Mt., Lika, and Dalmatia in Croatia, SW Bosnia and Herzegovina and S Montenegro.

**Middle Triassic** index forms were only observed within Anisian deposits. These are smaller foraminifera *Meandrospira dinarica*, *Pilamina densa* and *Pilaminella semiplana*. These forms were widespread throughout the Dinarides, including areas that represented the basement of the future AdCP. As in other Periadriatic regions (e.g. the Alps and the Carpathians), there are no index foraminifera for the Ladinian in the Dinarides, since all forms (mostly the smaller foraminifera) had wider stratigraphic ranges. Within Middle Tri-

assic deposits GRGASOVIĆ (2003) mentioned the beginning of the stratigraphic ranges of some species of involutinids – *Aulotortus sinuosus* from the Late Anisian and *A. praegaschei* from the Late Ladinian.

During a considerable part of the **Late Triassic**, i.e. during the Carnian and Early Norian, the major part of the investigated area was emergent. Therefore, deposits containing shallow-marine benthos occurred only within marginal areas, e.g. around Karlovac specimens of *Lamelliconus* – *L. multispirus* and *L. procerus* occurred (GRGASOVIĆ, 1997), as well as *L. procerus* in the area of Komiža on the island of Vis (BELAK et al., 2005).

Assemblages within Upper Norian deposits contain the following involutinids: *Aulotortus friedli*, *A. tenuis*, *A. sinuosus*, *A. praegaschei* and *A. tumidus*. These were accompanied in the Rhaetian by *Triasina hantkeni* and *Auloconus permodiscoides*. Localities in the Croatian part of the Karst Dinarides where these are observed include the area of Karlovac (BUKOVAC et al., 1974, 1984; GRGASOVIĆ, 1997, 2003), the Gorski Kotar (SAVIĆ & DOZET, 1985), Ogulin (VELIĆ et al., 1982), vicinity of Slunj (KOROLIJA et al., 1981), S Velebit Mt. and Lika, Svilaja Mt. (BUCKOVIĆ et al., 2003) and the vicinity of Ston (RAIĆ & PAPEŠ, 1982). In Slovenia they have been found in the vicinity of Tolmin (BUSER, 1986). In Bosnia and Herzegovina and Montenegro the aforementioned assemblages were found along NE and SE margin of the AdCP (MOJIČEVIĆ et al., 1977, 1979; MARINKOVIĆ & ĐORĐEVIĆ, 1981; VRHOVIĆ & MOJIČEVIĆ, 1983; VUJNOVIĆ, 1981; PAPEŠ, 1975; SOFILJ et al., 1980; MIRKOVIĆ, 1980; VUJISIĆ, 1975; ŽIVALJEVIĆ et al., 1971, 1989; KALEZIĆ et al., 1973; ĐOKIĆ et al., 1976; MIRKOVIĆ et al., 1978). Therefore, it may be concluded that this assemblage was very widespread in the Karst Dinarides deposits in the immediate basement of the Adriatic Carbonate Platform.

##### 4.2. Jurassic

There are no specific issues with the palaeobiogeography of the **Early Jurassic** foraminifera (Fig. 12). Assemblages of the Early Jurassic litiolids are known from all areas where lower and middle Lower Jurassic deposits crop out, so it may be concluded that these foraminifera were spread throughout the area of the Karst Dinarides. The most widespread were renowned assemblages of Early Jurassic litiolids with *Mesoendothyra* sp. and *Orbitopsella praecursor*, *O. primaeva*, *Lituosepta recoarensis*, *Haurania deserta* and *Amijiella amiji*. Representatives of the biokovinids in the Karst Dinarides (GUŠIĆ, 1977) were restricted to local occurrences, e.g. *Bosniella oenensis* in W Bosnia and the vicinity of Dubrovnik, *Biokovina gradacensis* in Biokovo Mt. and Dubrovnik area. *Pseudocyclamina liasica* was found at several localities in Croatia (W Gorski Kotar, Velika Kapela, Velebit, Biokovo and vicinity of Dubrovnik), but it may be proposed that it has been

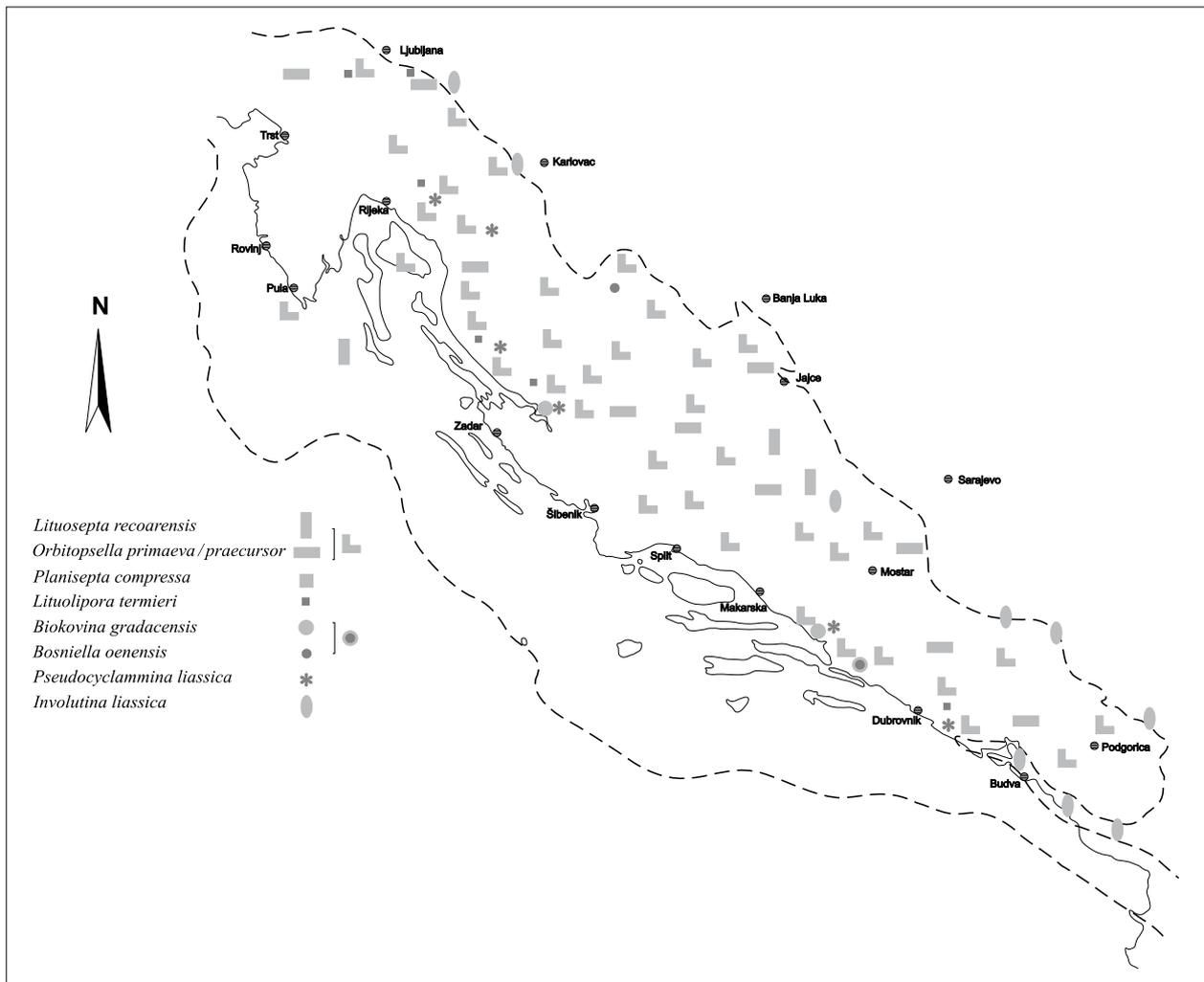


Fig. 12 Distribution of important foraminiferal taxa within the Lower Jurassic deposits of the AdCP.

more widespread, since sampling of this level was very restricted. Distribution of *Lituolipora termieri*, shows a similar pattern as it is common in the middle part of the Lower Jurassic deposits of Velika Kapela Mt. (W Croatia).

Toarcian and Early Aalenian deposits of the Karst Dinarides contain no larger foraminifera, as a consequence of unfavourable ecological conditions, since the very shallow marginal parts of the platform were covered by ooid–intraclastic bars, and the inner parts had lagoonal environments with low sedimentation rates of fine-grained deposits. *Involutina liassica* seems restricted to the NE marginal areas of the platform towards the Slovenian and Bosnian basin, in Karlovac area (RADOIČIĆ, 1966; GUŠIĆ & BABIĆ, 1970; DRAGIČEVIĆ & VELIĆ, 2002), northern Herzegovina (SOFILJ et al., 1980), Montenegro (RADOIČIĆ, 1966; MIRKOVIĆ, 1980; VUJISIĆ, 1975; ŽIVALJEVIĆ et al., 1989), and on the slopes towards the Budva–Čukali trough (MIRKOVIĆ et al., 1978; ANTONIJEVIĆ et al., 1973).

The palaeobiogeography of the **Middle Jurassic** foraminifera is much more interesting. Their occurrence

and frequency was controlled by palaeogeography. More variable and rich assemblages were found in the marginal, mostly peritidal parts of the platform, less in the slightly deeper subtidal inner platform environments (Fig. 13).

*Mesoendothyra croatica* was the most widespread Middle Jurassic foraminifera, with a stratigraphic range from the Late Toarcian to the Early Bathonian. It spread all over the AdCP, and in places is very abundant (e.g. in the vicinity of Dubrovnik). For years this foraminifera was the only index fossil in Middle Jurassic rocks older than the Bathonian, especially in the central and western parts of the platform. *Gutnicella cayeuxi* had been described (ANIĆ, 1962; RADOIČIĆ, 1966) prior to the description of *M. croatica* (GUŠIĆ, 1969a). This foraminifera is much rarer than *M. croatica*, being common only in the SE part of the platform (S Croatia and Montenegro; Fig. 13). Aalenian–Bajocian foraminifera, including *Timidonella sarda*, *Spiraloconus giganteus* and *S. perconigi* are new discoveries on the AdCP. They were observed in two areas: the NW part of the platform, SE of Ljubljana (Krka, Slovenia), and in the SE part in Biokovo Mt., and the vicinity of Dubrovnik

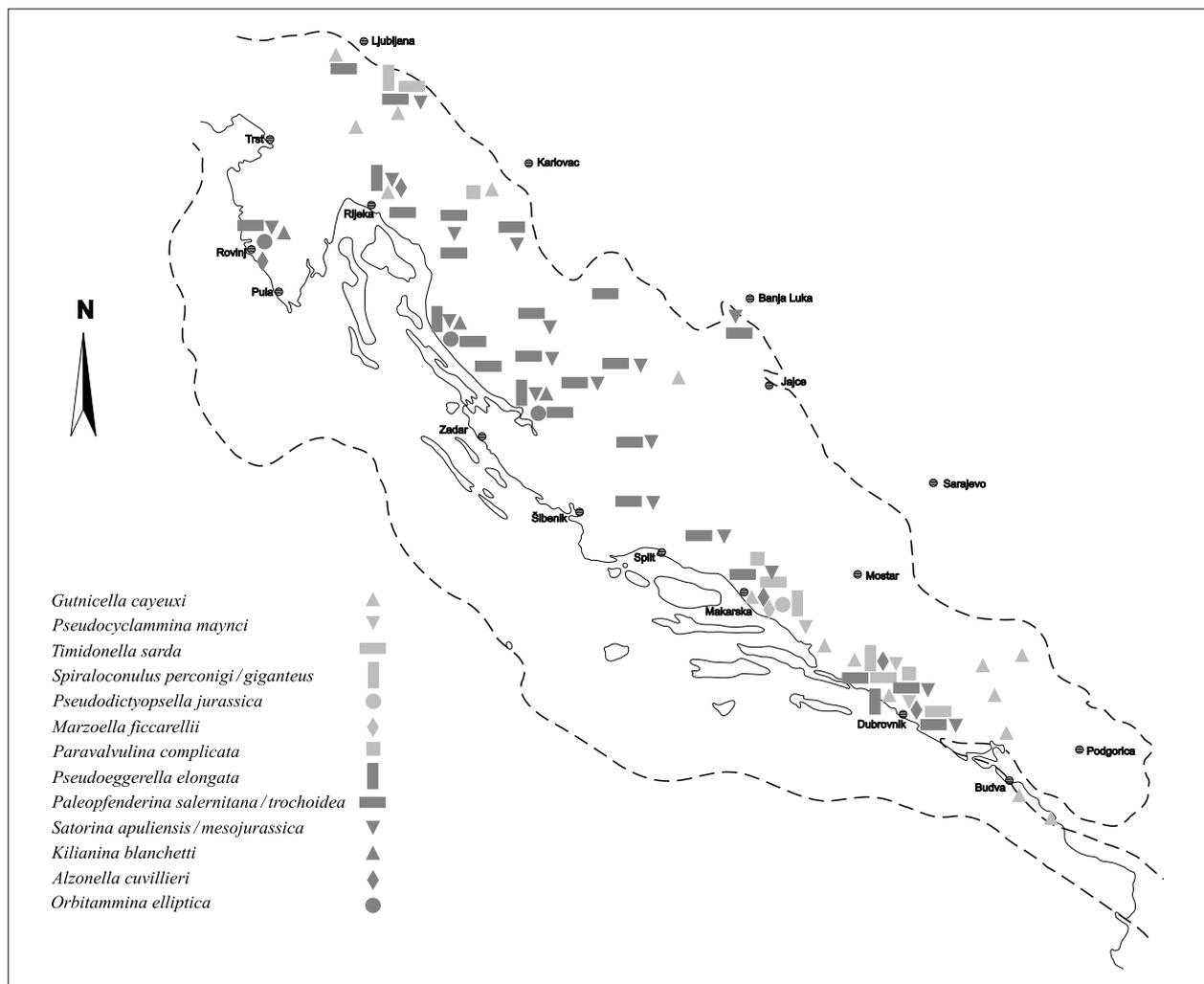


Fig. 13 Distribution of important foraminiferal taxa within the Middle Jurassic deposits of the AdCP.

in Croatia (Fig. 13), together with *G. cayeuxi* and *M. croatica*. Isolated occurrences of *G. cayeuxi* were also observed in Gorski Kotar and SW of Karlovac in Croatia, the vicinity of Jajce in Bosnia, as well as in Montenegro – in the vicinity of Nikšić and the coastal area. Within Middle Jurassic deposits, *Haurania desertata* and *Amijiella amiji* occur in places. These were once considered to be index fossils of the middle part of the Early Jurassic. *Pseudodictyopsella jurassica* and *Marzoella ficcarellii* are first documented here for the AdCP in the area of the Biokovo Mt. This represents the second occurrence of these forms in the World, after initial discovery of *P. jurassica* in Oman (SEPTFONTAINE & DE MATOS, 1998), and *M. ficcarellii* in Italy (CHIOCCHINI & MANCINELLI, 2000). *P. maynci* has previously only been observed at the Aalenian–Bajocian transition on the AdCP, while in other parts of both major Neotethyan provinces it was described as being of Bathonian and Callovian age (BASSOULLET et al., 1985; BASSOULLET, 1997).

*Orbitamina elliptica* occurs in an assemblage with other Bathonian species, previously unknown on the AdCP, including *Alzonella cuvillieri*, *Satorina*

*mesojurassica* and *Pseudoeggerella elongata* in Istria and Velebit Mt. (Fig. 13). These occur together with the somewhat more frequent *Kilianina blanchetti* and *Pfenderella arabica*. However, within this assemblage the most important and most widespread forms on the AdCP are those that are also very frequent in the Mediterranean area – *Paleopfenderina salernitana*, *P. trochoidea* and *Satorina apuliensis*.

Forms having wider stratigraphic ranges through either the entire or a larger part of the Middle Jurassic frequently occur. These include *Redmondoides lugeoni*, *Siphovalvulina variabilis*, *Pfenderella arabica* and *Protopenneroplis striata*, and *Praekurnubia crusei* from the Bathonian, and *Mohlerina basiliensis* and *Kurnubia jurassica* from the Callovian.

Discovery of species previously unknown on the AdCP are especially important for the palaeobiogeography of the Middle Jurassic foraminifera. Of these, *Spiraloconulus giganteus* and *Orbitamina elliptica*, are particularly interesting, as they had been considered as forms inhabiting the Western Mediterranean palaeobiogeographic province (W Alps, Jura Mt., N Sardinia, Aquitaine and Paris basins), as well as some

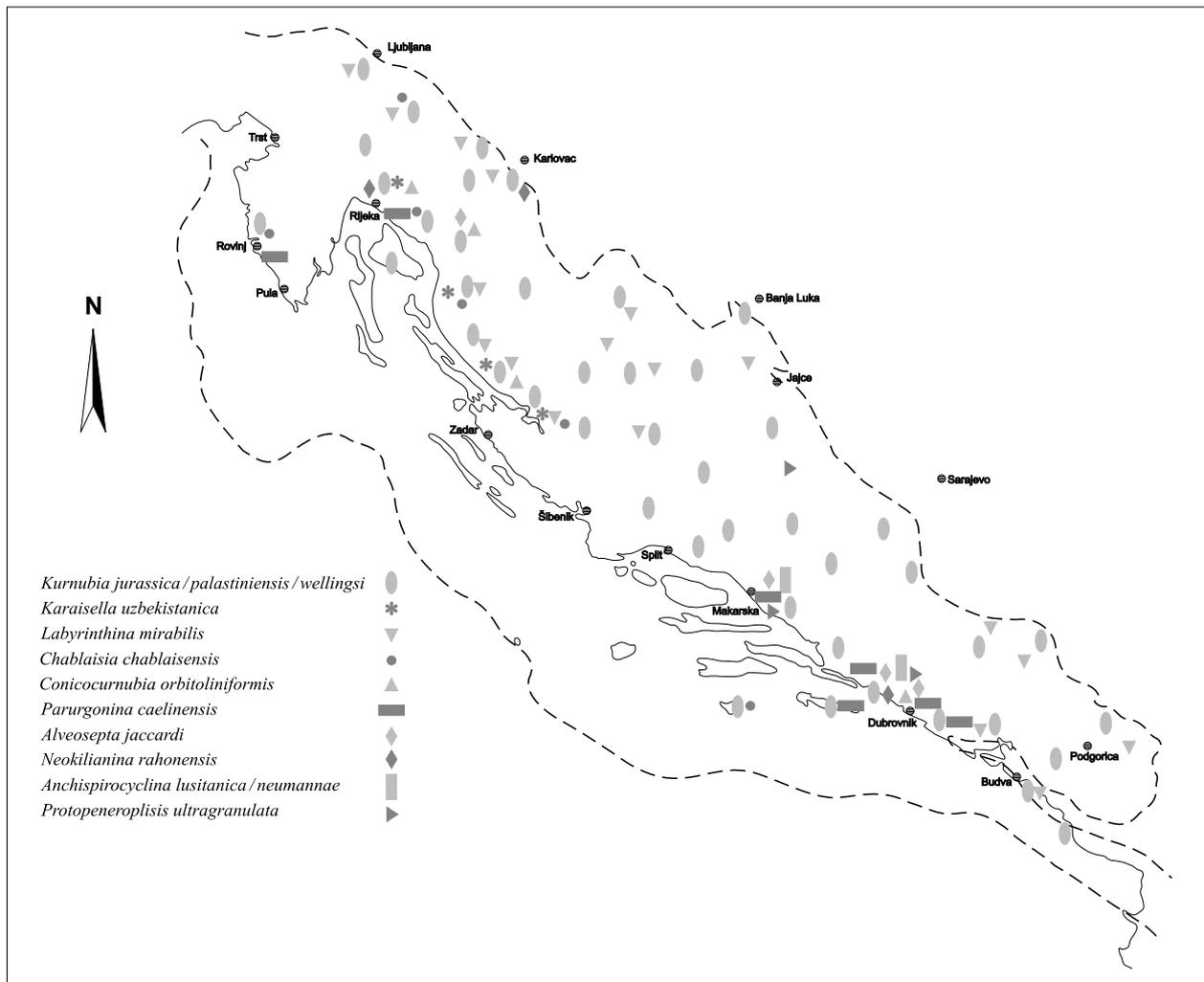


Fig. 14. Distribution of important foraminiferal taxa within the Upper Jurassic deposits of the AdCP.

Eastern provinces (Caucasus and Turkmenistan). These western and eastern provinces represented parts of the northern Neotethyan margin (BASSOULET et al., 1985). Occurrences of *S. giganteus* (Fig. 13) in Krka area (Slovenia), Biokovo Mt. and Dubrovnik, together with observations of *O. elliptica* (Fig. 13) in Istria and Velebit Mt. extend their distribution to the southern marginal areas of Neotethys, indicating the necessary reinterpretation of traditional Middle Jurassic palaeobiogeography. *K. blancheti*, *S. mesojurassica* and *P. elongata* also occur in smaller areas of the western part of the platform, between W Istria and S Velebit Mt., while *Paravalvulina complicata* was found for the first time on the AdCP in the vicinity of Dubrovnik, and later in Biokovo Mt. and vicinity of Karlovac.

The most widespread **Late Jurassic** foraminifera was *Kurnubia palastiniensis*, occurring in all parts of the platform. Two other forms of *Kurnubia* were frequently cited under this name: *K. wellingsi* and *K. jurassica*. There is no consensus among micropalaeontologists as to the validity of these citations. All three species are widespread on the AdCP. In addition to kurnubias, the most frequent species were *Mohlerina basil-*

*ensis*, *Nautiloculina oolithica*, *Praekurnubia crusei* and *Protopenneroplitis striata*, while *Labyrinthina mirabilis* and *Parurgonina caelinensis* are somewhat rarer (Fig. 14).

*Trocholina* species are frequent, especially *T. alpina*, with a stratigraphic range from the Bajocian to the Late Hauterivian, and *T. elongata* from the Oxfordian. They were the most abundant in the Oxfordian tempestites and carbonate beach sands of W Istria, Gorski Kotar and Velebit Mt., in an assemblage with *Chablaisia chablaisensis*. In the central parts of the platform *Ch. chablaisensis* had only been reported at one locality in Biokovo Mt. (but was probably of Bathonian/Callovian age), and in the Oxfordian of Lastovo island. *Trocholina gigantea* was only found in the Oxfordian of Istria and Gorski Kotar (W Croatia).

*Alveosepta jaccardi* and *Conicokurnubia orbitoliniformis* were discovered in the Kimmeridgian of the Velika Kapela, Velebit and Biokovo Mts. in Croatia, so, at this point they can be considered as index fossils of that stage in the area of the AdCP. Three additional infrequent foraminifera, previously unknown in the AdCP area, are *Kilianina? rahonensis* from the Late

Kimmeridgian and Tithonian of W Croatia, and the Late Tithonian *Anchispirocyclus lusitanica* and/or *A. neumannae*, found only in S Croatia (Fig. 14). This list could be completed by *Everticyclammina virguliana*, usually found within Upper Jurassic peri-reefal deposits of marginal parts of the platform.

### 4.3. Cretaceous

The Adriatic Carbonate Platform and neighbouring more or less isolated Central Mediterranean carbonate platforms (e.g. Apenninic, Apulian, Gavrovo–Tripolitza, etc.) were all located within Southern Tethyan bioprovinces. They were characterized by the reduced occurrence of larger foraminifera from the Berriasian to the Late Barremian. In contrast, in the Western Mediterranean, carbonate platforms belonging to the Northern Tethyan bioprovinces (Cantabria, Pyreneans, Sardinia, Vercors, Chartreuse, Jura Mt., etc.) larger foraminifera were present in the Berriasian, Valanginian and Hauterivian. Species include *Keramosphaera allobrogensis* STEINHAUSER, BRÖNNIMANN & KOEHN-ZANNETTI, *Eclusia moutyi* SEPTFONTAINE, *E. decastroi* CHERCHI & SCHROEDER and *Valdanchella miliani* (SCHROEDER), as well as other orbitolinids which were completely missing in the contemporaneous deposits in the AdCP area.

In the Neocomian and Early Barremian deposits of the AdCP foraminiferal assemblage including *Trocholina* gr. *alpina*–*elongata*, *Charentia cuvillieri*, *Mayncina bulgarica* and *Praechrysalidina infracretacea* is characterized by a modest stratigraphic value, and the first index fossils occur in the orbitolinid assemblages of the Late Barremian. However, many small foraminifera represent index fossils, e.g. for the Valanginian *Vercorsella camposaurii*, *V. tenuis*, *Montsalevia salevensis*, *Haplophragmoides joukowskyi*, or Late Hauterivian *Campanellula capuensis*. All these taxa were distributed throughout the AdCP.

*Protopenneroplis ultragranulata* is the index species of transitional Tithonian–Berriasian and Berriasian deposits, and was previously only known from the coastal part of Southern Croatia (Biokovo Mt., vicinity of Dubrovnik). Representatives of the genus *Trocholina*, for example, *T. gr. alpina*–*elongata*, as well as *T. sagittaria*, *T. delphinensis*, and probably also *T. molesta* occur throughout the platform area. In the Barremian and Early Aptian of the Western parts of the platform, *T. lenticularis* was locally found, and mostly undetermined small involutinids are also frequent.

The entire platform area is also characterized by the occurrence of representatives of *Vercorsella*, *Saubaudia* and *Novallesia* with *V. camposaurii*, *V. tenuis* (the index fossil of the Valanginian and Early Hauterivian), *V. scarsellai*, *V. laurentii*, *V. arenata* and *V. wintereri*, *N. cornucopia*, *N. distorta*, *N. producta* and *S. minuta*. All of these have a wider stratigraphic range through the Early Cretaceous. *S. briacensis* is always found together with palorbitolinids (and is the index fossil of the Early

Aptian), *S. auruncensis*, *S. capitata* and *S. dinapolii* range from the Late Aptian–Early Albian.

During the Late Barremian an orbitolinid assemblage occurred on the AdCP. *Rectodictyoconus giganteus* is the oldest orbitolinid genera on the AdCP, previously known only in the vicinity of Jajce and Banja Luka near the northern margin of the platform.

Comparison with the palaeogeography of orbitolinids found on Perimediterranean platforms indicates differences between the AdCP and Western Mediterranean platforms. Orbitolinid assemblages in the Western Mediterranean, i.e. Northern Tethyan provinces, developed in the earliest Cretaceous. Examples include the Valanginian of the Pyrenees (*Valdanchella*, *Paracoskinolina* etc., according to PEYBERNES, 1976), Hauterivian of SE France (e.g. evolutionary lines *Praedictyoorbitolina*–*Dictyoorbitolina* and *Valserina*–*Palorbitolina* (according to CLAVEL et al., 1995 and ARNAUD et al., 1998) and the Barremian of the aforementioned areas (*Eopalorbitolina*–*Palorbitolina* after SCHROEDER et al., 2002 or *Paracoskinolina*, *Urgonina*, *Alpillina*, *Cribellopsis* and diverse species of genus *Orbitolinopsis* according to, e.g. ARNAUD et al., 1998).

A rich and explosive development of orbitolinids on the Adriatic Carbonate Platform started in the latest Barremian/earliest Aptian, when varied assemblages of taxa especially abundant in the Northern Tethyan provinces (like palorbitolinids and praeorbitolinids, as well as mesorbitolinids in the Late Aptian and Albian), became distributed throughout the platform. In contrast to *R. giganteus*, only discovered in the central part of the NE AdCP margin in Upper Barremian deposits (Fig. 16), *Palorbitolina lenticularis* was found all over the AdCP. Some authors (VELIĆ & SOKAČ, 1978a) indicate that this species occurred on the AdCP at the very end of the Barremian, i.e. somewhat later than in the Western Mediterranean, where it occurred in the Middle Barremian (e.g. SCHROEDER, 1964c; SCHROEDER et al., 1974; PEYBERNES, 1976; ARNAUD-VANNEAU, 1980; JAFFREZO, 1980; CLAVEL et al., 1995; ARNAUD et al., 1998). On the Apenninic Carbonate Platform (which should have been, according to the palaeogeographic interpretations, located between the Western Mediterranean platforms and the AdCP during the Aptian), deposits with palorbitolinids are either of Upper Barremian–Lower Aptian age (CHIOCCHINI et al., 1994) or Lower Aptian age (CHERCHI et al., 1978).

The palaeobiogeography of Early Aptian foraminifera on the AdCP was very controlled by the palaeoenvironments. Generally, in this area, this period was characterized by sea-level rise and pelagic influences, represented by common findings of *Hedbergella* sp., *Saccocoma* sp. etc. (VELIĆ & SOKAČ, 1978a). These forms only occur in very restricted subtidal facies and lagoons together with *Choffatella decipiens*, in the central and western parts of the platform.

Dominant Early Aptian foraminifera are orbitoli-

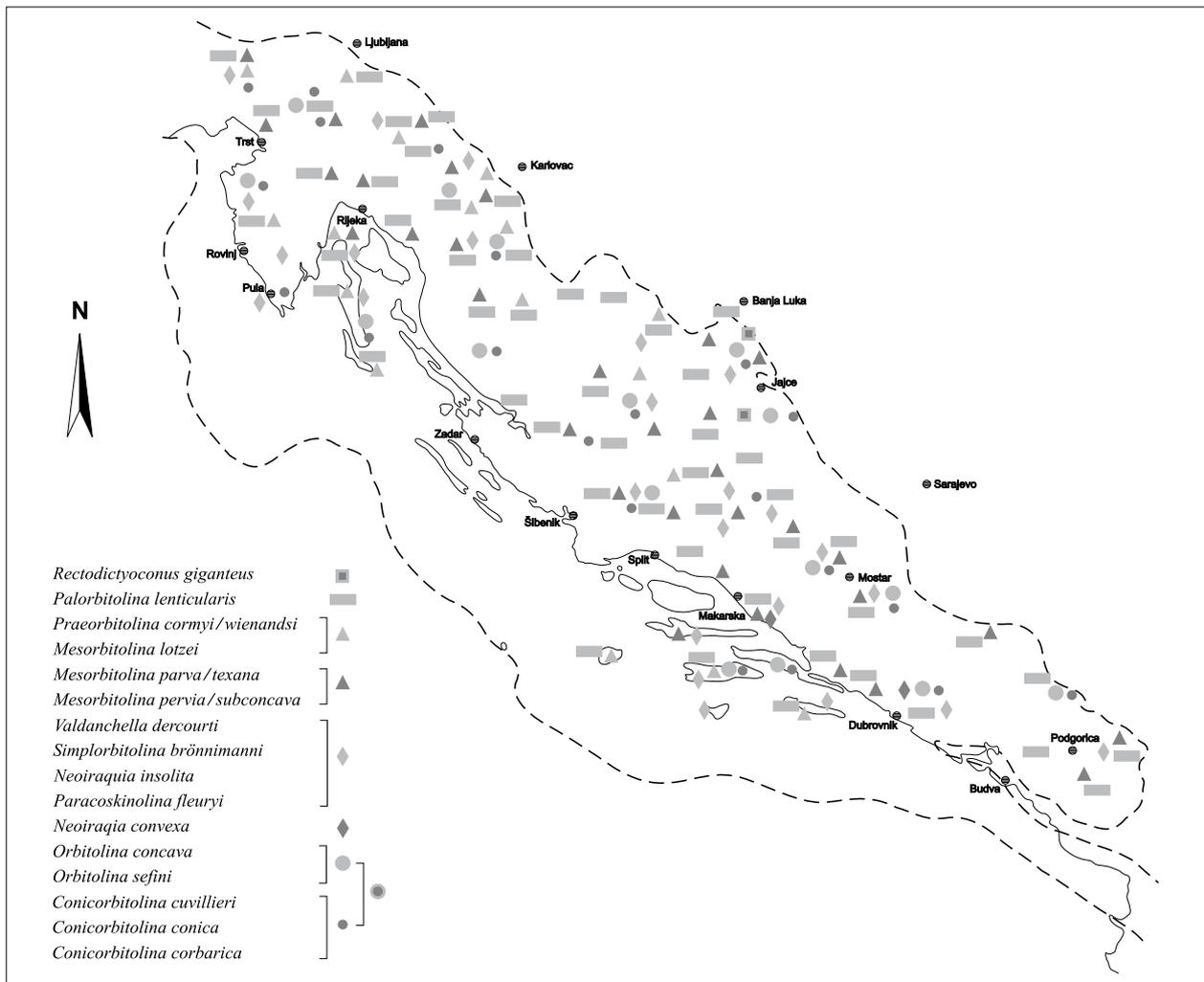


Fig. 15 Distribution of orbitolinids within the Cretaceous deposits of the AdCP.

nids from the evolutionary line *Praeorbitolina cormyi* – *P. wienandsi* – *Mesorbitolina lotzei*. They occur in the W, central and SE parts of the platform (VELIĆ & SOKAČ, 1978b; VELIĆ et al., 1979; HUSINEC et al., 2000) (Fig. 15). Accompanying forms are Early Aptian index fossils found throughout the platform area: *Voloshinoides murgensis* (the most frequent), *Sabaudia briacensis*, *Derwentina filipescui*, *Pseudolituonella conica*, *Neotrocholina aptiensis* and *N. friburgensis*, as well as rare *Pfenderina globosa*. Earliest representatives of the *Archalveolina* genus (VELIĆ & SOKAČ, 1978a), *Pseudonummoloculina aurigerica*, as well as all the aforementioned species of *Sabaudia*, *Vercorsella*, *Novallesia*, *Nautiloculina*, etc. occur.

In the Late Aptian, orbitolinid evolutionary trends continued with *Mesorbitolina parva* and *Mesorbitolina texana*, found in all parts of the platform. These forms were accompanied by *Archalveolina reicheli*, locally very abundant *Haplophragmoides globosus* (or *Trochamminoides coronus* according to CHIOCCHINI et al., 1994), and, close to the end of Aptian, *Orbitolinopsis aquitanica*. All these forms were, previously only known from the coastal, Adriatic part of Croatia.

Mesorbitolinid assemblages continued into the Early Albian. They were widespread, and known from all parts of the platform. Therefore, with the Early Aptian palorbitolinids, they represent not only the most frequent orbitolinids, but also some of the most extensive foraminifera on the entire AdCP. In addition, in the Late Aptian, *M. parva* and *M. texana* occur, continuing into the Early Albian, where they are accompanied by *Mesorbitolina subconcava* and *Mesorbitolina pervia*.

In addition to the Early Albian mesorbitolinids, specifically undeterminable forms of the genera *Orbitolinopsis* and *Paracoskinolina*, as well as other, previously cited species of *Vercorsella*, *Sabaudia*, *Novallesia* etc. were also widespread throughout the platform. However, the predominant species in foraminiferal assemblages of the youngest Lower Cretaceous deposits were *Cuneolina pavonia*, *C. parva*, *Pseudonummoloculina heimi* and *Nezzazatinella picardi*, with stratigraphic ranges through the entire Albian and a larger part of the Late Cretaceous.

In the Late Albian orbitolinid assemblages with ‘*Valdanchella dercourti*’, *Simplorbitolina broennimanni*, *Neoraiquia insolita*, *Paracoskinolina fleuryi*,

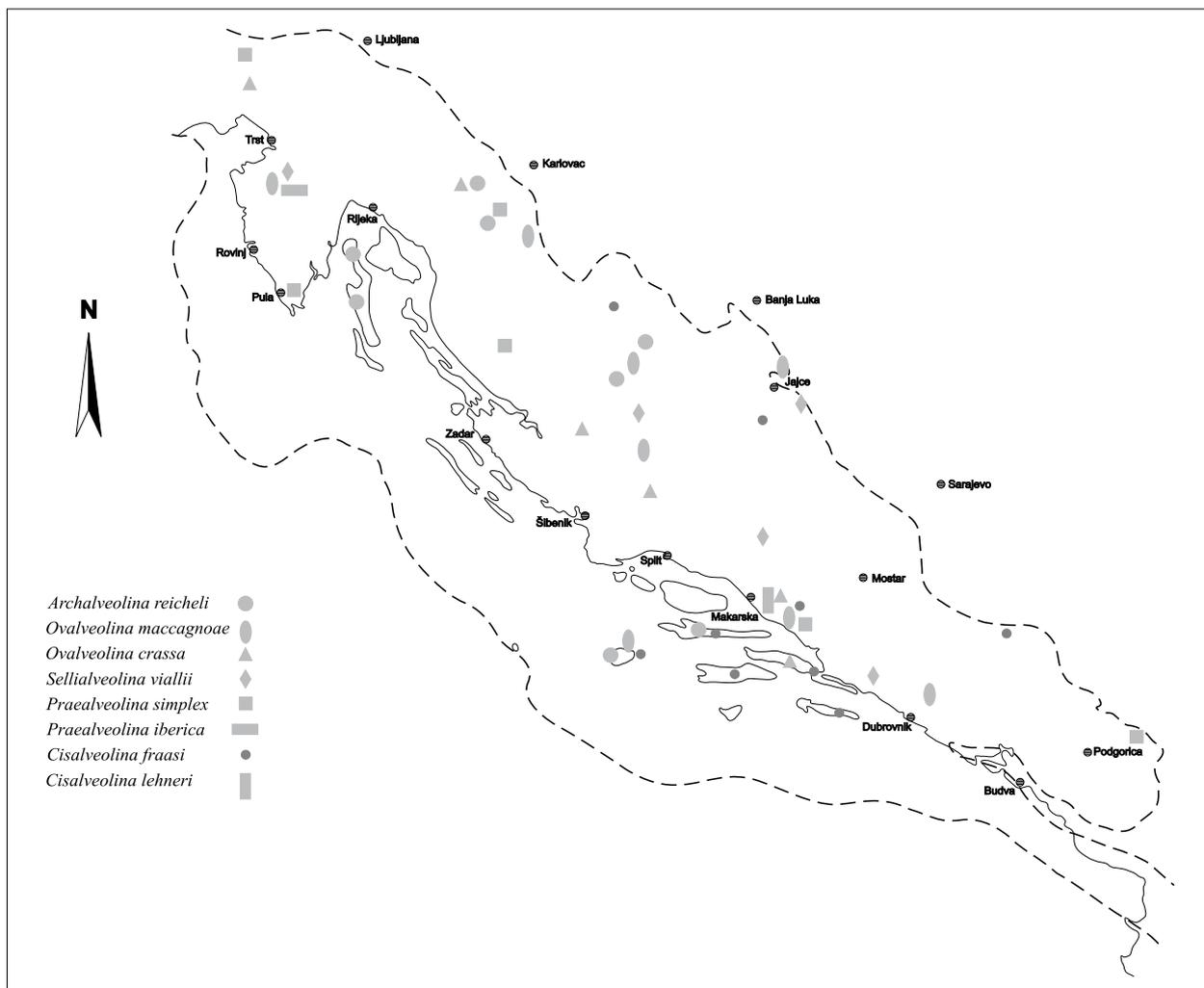


Fig. 16 Distribution of alveolinids within the Cretaceous deposits of the AdCP.

and *Paracoskinolina sunnilandensis* were frequent. Among other rare foraminifera were *Scandonea phoenixa* and *S. pumila* (e.g. at Biokovo Mt. and the island of Korčula). For the very end of the Albian, Vraconian or the base of Cenomanian, occurrences of *Neoiraquia convexa* (in the vicinity of Dubrovnik and Biokovo Mt.) and *Protochrysalidina elongata* (island of Cres), as well as the more frequent *Ovalveolina maccagnoae* are typical, though relatively rarely observed.

During the Cenomanian, there was a successive occurrence of alveolinids from *Ovalveolina maccagnoae* and ?*Sellialveolina viallii*, through *O. crassa*, *Cisalveolina lehneri* and *Praealveolina iberica* in the Early Cenomanian, *P. simplex* in the Middle, to *Cisalveolina fraasi* in the Late Cenomanian. These forms were found, although not frequently, in different parts of the AdCP (Fig. 16). The situation with the orbitolinids *Orbitolina* gr. *concava*, *Conicorbitolina cuvillieri*, *C. conica*, *C. gr. corbarica-conica* and *Orbitolina* gr. *sefini-concava* was similar. These however, were extinct before the late Cenomanian, but were widespread all over the platform (Fig. 15). *Pastrikella biplana* occurs in younger Lower Cenomanian beds and in older Mid-

dle Cenomanian deposits, where it is accompanied by *P. balcanica* and other Middle Cenomanian species. A group of index fossils of the Middle and Late Cenomanian, comprising *Chrysalidina gradata*, *Nummoloculina? regularis*, *Pseudolituonella reicheli*, *Pastrikella balcanica* and *Pseudorhapydionina dubia*, was very abundant in all parts of the platform (Fig. 17), as well as other taxa of a wider stratigraphic range cited within the Cenomanian assemblages (cuneolinas, nezzazatids, pseudonumoloculinas, soritids, peneroplids). The Late Cenomanian *Pseudorhapydionina laurinensis* and *Pseudorhipidionina casertana* (POLŠAK et al., 1982; VELIĆ & VLAHOVIĆ, 1994) (Fig. 17), found in Istria, Lika, and Dalmatia are rare.

The Early Turonian was characterised by restricted foraminiferal assemblages due to platform drowning, so in a palaeobiogeographic sense it is not very interesting. During the Late Turonian, the entire platform (except for minor parts emergent since at least the Late Cenomanian), was again covered by shallow-marine environments with assemblages of cuneolinas, nezzazatids, miliolids and other groups of foraminifera known since the Albian and through the Cenomanian. New forms

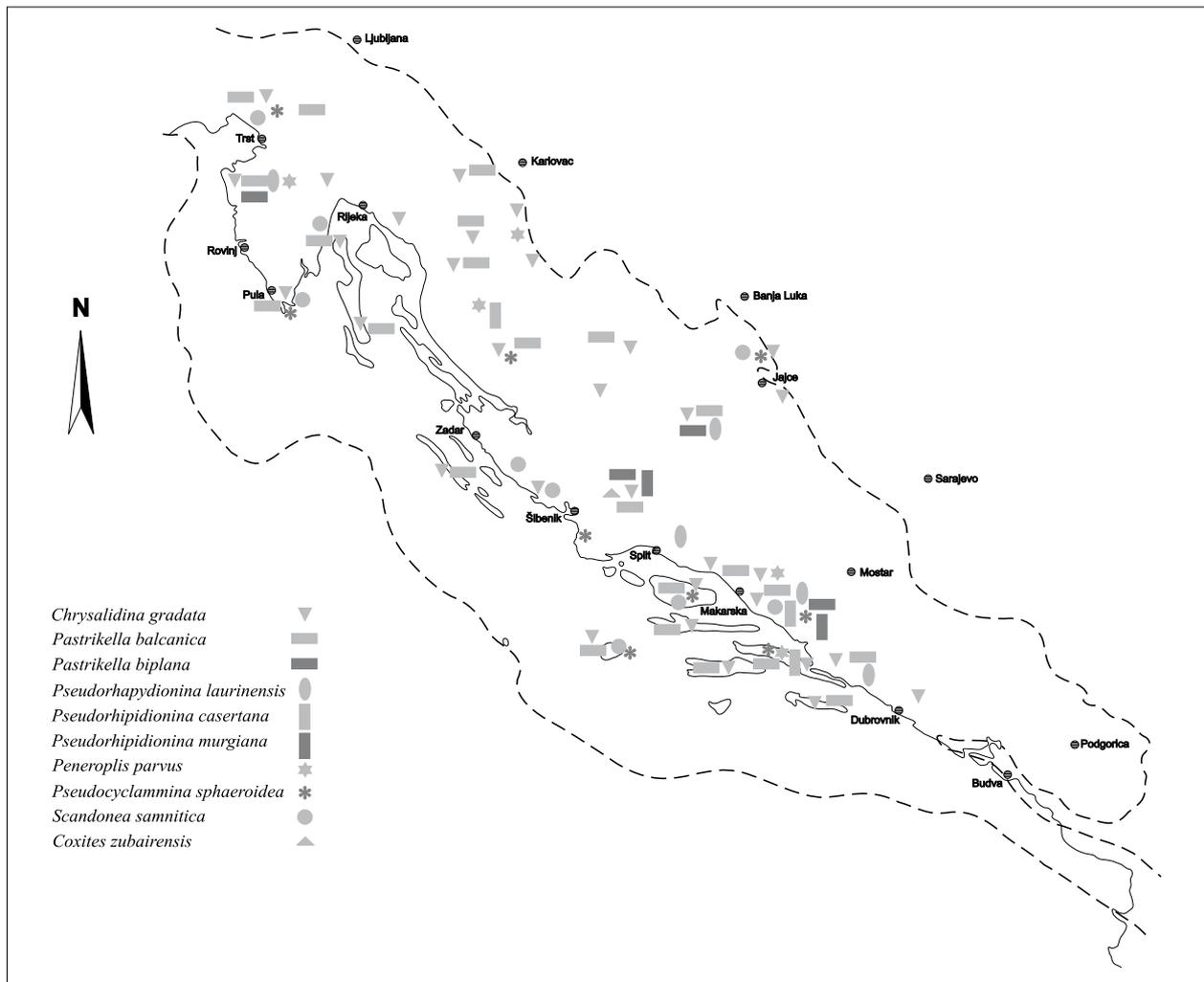


Fig. 17 Distribution of several index and the more important foraminiferal species within the older Upper Cretaceous deposits (Cenomanian–Lower Santonian) of the AdCP.

which were widespread include *Moncharmontia apenninica* and *Pseudocyclammina sphaeroidea*. *Cuneolina compressa* was only found in the deep off-shore well near the island of Palagruža.

The composition of Coniacian and Early Santonian assemblages was very similar to those from the Late Turonian, with the exception of newly occurring forms: *Scandonea samnitica*, *Dicyclina schlumbergeri* and *Moncharmontia compressa*. Important changes took place in the Late Santonian with the occurrence of new species of larger foraminifera – *Murgella lata*, *Pseudorhapydionina mediterranea*, *Idalina antiqua*, *Keramospharina tergestina* and *Pseudocyclammina massiliensis*, as well as several species of smaller foraminifera – *Accordiella conica*, *Murgeina apula*, *Reticulinella fleuryi*, *Dictyopsella kiliani*, *Dictyopselloides cuvillieri*, *Spirolina cretacea*, *Minouxia lobata*, *Pseudolituonella marie*, *Rotorbinella scarsellai* and *Stensiöina surrentina*. All these forms were widespread over the AdCP (Fig. 18). *Raadshovenia salentina* occurs in the Santonian deposits of the NW part of the platform (S Istria – POLŠAK et al., 1982, and in the area of Trieste Karst – VENTURINI, 2005), while *Broekinella neu-*

*manae*, *Nummofallotia cretacea*, *Archiacina munieri* and *Abrardia mosae* were discovered in central Bosnia (near Jajce). Along the platform slopes, as well as in the deeper parts of the inner platform, the previously mentioned forms were accompanied by the orbitoid species *Orbitoides gr. hottingeri*.

Late Santonian species also continued into the Early Campanian, when they were accompanied by new ones. *Calveziconus lecalvezae* and *Reticulinella reicheli* were found over the major part of the platform. However, they are most abundant along the Adriatic coast and on the islands. Along the platform margins and on the slopes or in deeper areas within the inner parts of the platform, the aforementioned assemblage was accompanied by *Praesiderolites douvillei*, *Orbitoides douvillei*, *O. tissoti*, *O. media* and *Pseudosiderolites vidali* (GUŠIĆ & JELASKA, 1990; Fig. 18).

During the Maastrichtian margins, slopes and inner platform deeper areas were inhabited by abundant *Orbitoides media*, *Siderolites calcitrapoides* and *Omphalocyclus macroporus*. *Murciella cuvillieri*, *M. renzi*, *Fleuryana adriatica* and *Laffitteina mengaudi* occur on the island of Brač (GUŠIĆ & JELASKA,

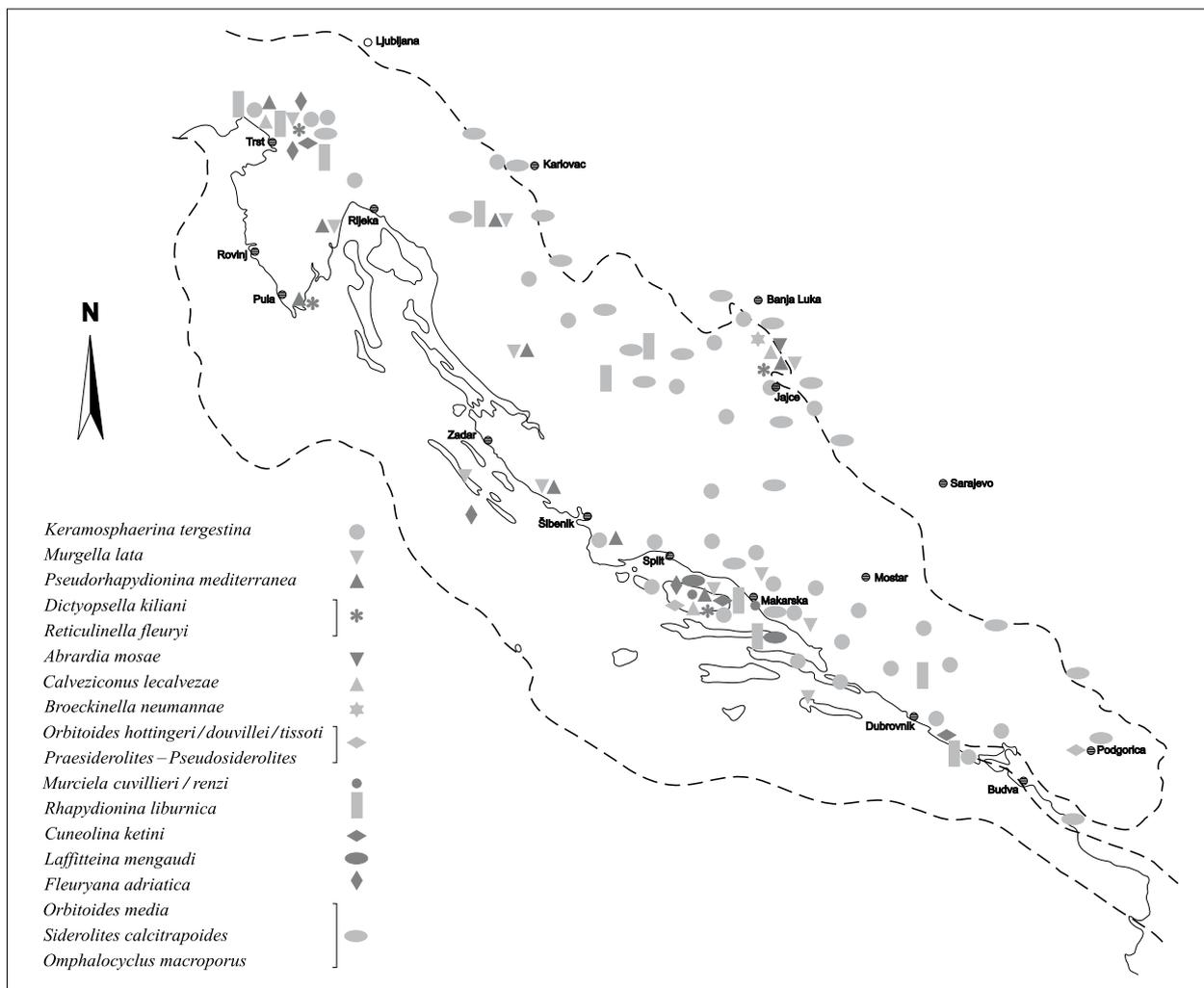


Fig. 18 Distribution of several index and the more important foraminiferal species within the younger Upper Cretaceous deposits (Upper Santonian–Upper Maastrichtian) of the AdCP.

1990; DE CASTRO et al., 1994) and vicinity of Makarska. *Rhapydionina liburnica* was found in areas containing Maastrichtian deposits across the AdCP, accompanied by species with wider stratigraphic ranges through the Late Cretaceous, like *C. pavonia*, *N. picardi*, *D. schlumbergeri*, *M. apula*, *M. apenninica*, *A. conica* and *R. scarsellai*.

#### 4.4. Correlation

This palaeogeographic data on the AdCP can be correlated with data from other Periadriatic carbonate platforms, as well as with previous knowledge on palaeobiogeographic provinces in Neotethys during the Jurassic and the Cretaceous. Results of these comparisons show important similarities, but also certain specificities of the AdCP, which will not change the general concept of the position of the AdCP in the Tethyan realm during the younger Mesozoic.

The composition of foraminiferal assemblages definitely indicates the location of the AdCP within the southern marginal part of this palaeocean during the Early and Middle Jurassic (BASSOULLET et al.,

1985). This can be shown by comparison of the stratigraphic ranges of foraminifera and biozones within Lower Jurassic deposits of the High Atlas in Morocco and Velebit Mt. in Croatia (SEPTFONTAINE, 1984; TIŠLJAR et al., 1991; SEPTFONTAINE et al., 1991), which are almost identical. The other Perimediterranean platforms in Italy, Greece and Turkey also belonged to South-Tethyan bioprovince during the Early and Middle Jurassic.

A significant new result is the co-occurrence of *Orbitamina elliptica* and *Satorina apuliensis* in the Bathonian deposits of Istria and Velebit. Namely, these two forms are typical for two major Neotethyan provinces, *O. elliptica* for the Northern province, and *S. apuliensis* for the Southern one (BASSOULLET et al., 1985). The discovery of *O. elliptica* within the foraminiferal assemblage of the Southern Neotethyan province (VELIĆ, 2005), as well as the very serious indications of its presence in the Bathonian deposits of the Apenninic Carbonate Platform (LUPERTO-SINNI, 1968, pl./fig.: 7/1, 8/3, 9/2,3, 10/2, 11, 12), indicate that its area of distribution included the northernmost parts

of the Southern Neotethyan bioprovince during the Bathonian. During the Late Cretaceous both provinces had more or less similar foraminiferal assemblages. Abundant occurrences of *Chablaisia chablaisensis* in the Oxfordian of the AdCP, but only in its NW part are interesting, because S of Velebit Mt. it has only been found at one locality in the Bathonian of Biokovo Mt. (VELIĆ, 2005) and the island of Lastovo. Present data also indicate the location of the AdCP within Southern Neotethys during the Late Jurassic.

From the beginning of the Cretaceous to the Late Barremian, shallow-marine environments of the Northern Neotethyan bioprovince were gradually inhabited by orbitolinids and other larger foraminifera (genera *Valdanchella*, *Praedictyorbitolina*, *Dictyorbitolina*, *Valserina*, *Eygallerina*, *Eopalarbitolina*, *Montseciella*, *Eclusia*, *Keramosphaera*, *Pfenderina* etc. – see e.g. BASSOULLET et al., 1985; CLAVEL et al., 1995; SCHROEDER et al., 2002). Contemporaneous deposits of the AdCP contain no foraminifera. This indicates that at that time, the AdCP was still a part of the Southern bioprovince, and that there was still no connection between the two major Neotethyan bioprovinces. In contrast, assemblages of small foraminifera found on the AdCP containing index forms for the Valanginian and Early Hauterivian, including *Montsalevia salevensis*, *Haplophragmoides joukowskyi*, *Meandrospira favrei*, *Vercorsella tenuis* and *V. camposaurii*, are also known from the areas along the northern Neotethyan margin (where the first three cited species were originally described by CHAROLLAIS et al., 1966).

In the Late Barremian and Early Aptian, orbitolinid assemblages rapidly spread over the Southern Neotethyan bioprovince, led by *Palorbitolina lenticularis*, which was accompanied by praeorbitolinids – *Praeorbitolina cormyi* and *P. wienandsi*, as well as *Mesorbitolina lotzei* during the Early Aptian. Therefore, since the Late Barremian through the Aptian, Albian and Early Cenomanian, biofacies and biotopes of the larger foraminifera on the AdCP gradually became more and more similar to those from the Northern Neotethyan bioprovince. BASSOULLET et al. (1985) acknowledged that during the Late Aptian and Albian it was still possible to clearly differentiate two bioprovinces within Neotethys: a northern one with *Simplorbitolina manasi* and *Neorbitolinopsis conulus*, and a southern one with *Archaealveolina* and *Simplorbitolina ?brönnimanni*.

During the Cenomanian, composition of orbitolinid and alveolinid assemblages on the AdCP (e.g. VELIĆ & VLAHOVIĆ, 1994; HUSINEC et al., 2000; TIŠLJAR et al., 2002) was similar, but not identical, to contemporaneous assemblages in SW Europe, i.e. areas belonging to the Northern Neotethyan province (e.g. SCHROEDER, 1962, 1964a, 1975; BILOTTE, 1985; CASTRO et al., 2001). In the area of the AdCP, there are presently no known occurrences of *Mesorbitolina aperta* (ERMAN) and *Orbitolina durandelgai* SCHROEDER among the orbitolinids, while among the

alveolinids *Praealveolina cretacea* (D'ARCHIAC), *P. brevis* REICHEL, *Ovalveolina ovum* (D'ORBIGNY) and *Pseudedomia drorimensis* REISS, HAMAOUÏ & ECKER are also absent. However, it cannot be affirmed that the AdCP was still part of the Southern Neotethys bioprovince during the Cenomanian, in spite of the significant similarity of foraminiferal assemblages. For this province, typical Near East species of larger foraminifera, including *Cycledomia iranica* HENSON, *Taberina bingistani* HENSON, *P. drorimensis* and *Thomasinella punica* SCHLUMBERGER (e.g. SAINT-MARC, 1974, 1977; HAMAOUÏ, 1979) have never been found on the AdCP. On the basis of the presented data, it may be concluded that during the Cenomanian and the Turonian, the AdCP was probably biogeographically isolated, i.e. that it was not part of either of the two major biogeographical provinces. This is indicated by the composition of the foraminiferal assemblage, which is similar to assemblages of both bioprovinces, but lacking forms characteristic of either. A similar view was proposed by FLEURY et al. (1985) for the Periadriatic–Aegean provinces during the Late Cretaceous, i.e. the Adriatic Carbonate Platform, South Apenninic platforms (most likely Apulian and Apenninic), Hellenic platforms (Gavrovo–Tripolitza) and Tauridic platforms (probably Menderes).

A Late Cenomanian–Early Turonian sea-level rise caused temporary drowning of the AdCP (GUŠIĆ & JELASKA, 1990, 1993; JENKYNS, 1991; JELASKA et al., 1994; TIŠLJAR et al., 2002; VLAHOVIĆ et al., 2003, 2005), resulting in the temporary disappearance of shallow-marine environments favourable for biotopes of benthic foraminifera. They were later re-established due to shallowing in the Late Turonian, and lasted until the end of the Cretaceous in parts of the platform covered by the sea.

On the basis of foraminiferal assemblage composition in Upper Cretaceous deposits of Western Neotethys (Upper Turonian to Maastrichtian), two bioprovinces can be clearly distinguished: *Central Mediterranean*, composed of the Periadriatic carbonate platforms – Adriatic, Apenninic, Apulian and Gavrovo–Tripolitza, and *Western Mediterranean*, comprising carbonate platforms and shallow-marine areas of the present Pyrenees, Aquitaine, Provence and Sardinia. Within foraminiferal assemblages of the Central Mediterranean bioprovince, on the AdCP and neighbouring platforms (e.g. LUPERTO-SINNI, 1976; LUPERTO-SINNI & RICCHETTI, 1978; FLEURY, 1980; FLEURY et al., 1985; GUŠIĆ & JELASKA, 1990; CHIOCCHINI et al., 1994; CVETKO TEŠOVIĆ et al., 2001, and Section 2 of this paper), there are no presently known occurrences of taxa typical for the Western Mediterranean bioprovince. Such absent species include *Orbitolinopsis senonicus* GENDROT, *Peneroplis giganteus* GENDROT, *Lacazina elongata* SCHLUMBERGER, *L. compressa* MUNIER-CHALMAS, *Pseudolacazina cantabrica* HOTTINGER, DROBNE & CAUS, *Ilerdorbis decussatus* HOTTINGER & CAUS, *Broeckina dufrenoyi* (D'ARCHIAC),

*Cyclopsinella steinmanni* (MUNIER-CHALMAS), *Paleodictyoconus senonicus* MOULLADE & VIAL-LARD, *Abrardia catalunica* BILOTTE, *Lamarmorella sarda* CHERCHI & SCHROEDER, *Periloculina zitelii* MUNIER-CHALMAS & SCHLUMBERGER, etc. (GENDROT, 1968, CHERCHI & SCHROEDER, 1977; BILOTTE, 1985; HOTTINGER et al., 1989). Likewise, species typical for the Central Mediterranean bioprovince, e.g. *Pseudorhapydionina mediterranea*, *Murgella lata*, *Keramosphaerina tergestina*, *Murciella cuvillieri*, *M. renzi*, *Rhapydionina liburnica* and *Fleuryana adriatica*, have never been observed in the Western Mediterranean bioprovince. Therefore, it is clear that these two provinces were, according to the larger foraminifera, 'isolated' from each other. Each had their typical species and assemblages, in places with even endemic characteristics (e.g. Catalonian subprovince, after HOTTINGER et al., 1989). The palaeogeographic position of these provinces was from the Turonian to the end of Cretaceous in Central Neotethys, because both provinces were placed between 23° and 35° N of equator after DERCOURT et al. (2000). During this period, the Gondwanian coast of Neotethys (from Ethiopia/Erithrea to Morocco), was placed between 5° S and 18° N in the Cenomanian, and from the equator to the 20° N in the Maastrichtian. The European coastline was more stable, and during the Late Cretaceous its position was between 35° and 45° N (after DERCOURT et al., 2000). The position of the AdCP, as the northernmost Periadriatic platform in the Central Mediterranean bioprovince and in the Late Cretaceous Neotethys, was between 23° and 30° N. In such a palaeogeographic constellation, when Neotethys was at its widest and most complex, including the beginning of its closure, it was characterized by the occurrence of more biogeographical provinces than at any other time. Therefore, it may be concluded that in the Late Cretaceous, the area of the Adriatic Carbonate Platform represented part of the Central Mediterranean bioprovince in the Central Neotethyan area.

## 5. REVIEW OF THE RESULTS

The most important results of the investigation presented in this paper can be summarised in the following conclusions:

- this is the first paper synthesizing and summarizing the results of Mesozoic benthic foraminiferal study in the Karst Dinarides undertaken by the author during almost 50 years of research,
- numerous new results regarding foraminiferal assemblages were achieved, including discovery of many taxa previously unknown in the Karst Dinarides,
- a chronostratigraphic position is provided for foraminiferal assemblages,
- a completely new biostratigraphic zonation was produced, respecting the results of previous investigations,

- for the first time the palaeobiogeography of larger foraminifera of the AdCP is proposed, which is especially important for regional Mediterranean correlation, in which the AdCP was previously inadequately represented or was completely excluded.

The **chronostratigraphic succession** comprises foraminiferal assemblages from the Early Triassic to the end of the Cretaceous. Previous knowledge on the assemblages within Lower and Middle Triassic deposits of the Adriatic Carbonate Platform indicate a probably rich assemblage of genera and species, but reliable data could only be provided after detailed investigations which have not yet been performed. At this moment it can be stated that smaller foraminifera prevailed within these deposits, mostly ammodiscids and endothyrids. Index forms are: *Cyclogyra mahayeri*, *Ammodiscus parapriscus*, *Meandrospira pusilla*, *Glomospira sygmoïdalis* and *Glomospirella triphonensis* for the Scythian, and *Meandrospira dinarica*, *Pilamina densa* and *Pilaminella semiplana* for the Anisian. Within Ladinian deposits there are no index species of foraminifera, but the beginning of the stratigraphic ranges of some species of *Aulotortus* (*A. praegaschei* and *A. sinuosus*) can be presumed, as stated by GRGASOVIĆ (2003). The maximum abundance of these was in the Norian and Rhaetian. An assemblage of involutinids, with *Aulotortus friedli*, *A. praegaschei*, *A. sinuosus*, *A. tenuis*, *A. tumidus*, was generally predominant in Upper Triassic deposits, and *Aulotortus pokornyi*, *Trocholina crassa* and *T. acuta* in the Norian and Rhaetian. Besides the cited species, discovery of the index forms *Lamelliconus multispirus* and *L. procerus* in Carnian, *Turrispirillina minima* in the Norian, and *Triasina hantkeni* in the Rhaetian are very important.

Within the Jurassic deposits, litoolid foraminifera predominate, which were not equally distributed in time. During the Early Jurassic, mesoendothyrids were predominant with index forms including *Mesoendothyra* sp., *Lituosepta recoarensis*, *Orbitopsella primaeva* and *Paleomayncina termieri* in the Sinemurian, *Mesoendothyra* sp., *L. recoarensis*, *O. primaeva*, *O. praecursor*, *P. termieri*, *Planisepta compressa*, *Lituolipora polymorpha*, *Biokovina gradacensi* and *Bosniella oenensis* in the Early Pliensbachian (Carixian), and *O. praecursor*, *O. ?dubari*, *Pseudocyclammmina liassica*, *P. termieri*, *P. compressa*, *B. gradacensis* and *B. oenensis* in the Late Pliensbachian (Domerian). As a consequence of unfavourable palaeoecological conditions during the Toarcian, a significant decline took place in the foraminiferal assemblage, and there were no index forms. Middle Jurassic deposits contain the richest foraminiferal assemblages with numerous taxa, including well known index species – *Gutnicella cayeuxi*, *Pseudocyclammmina maynci*, *Spiraloconulus perconigi*, *S. giganteus*, *Timidonella sarda* in the Aalenian and Early Bajocian, *S. giganteus*, *Pseudodictyopsella jurassica* and *Marzoella ficcarellii* in the Bajocian, *Paravalvulina complicata* at the end of Bajocian and beginning of the Bathonian,

as well as *Pseudoeggerella elongata*, *Paleopfenderina salernitana*, *P. trochoidea*, *Alzonella cuvillieri*, *Orbitamina elliptica*, *Kilianina blancheti*, *Satorina apulensis* and *S. mesojurassica* in the Bathonian. Among the cited species *P. maynci*, *S. perconigi*, *S. giganteus*, *T. sarda*, *P. complicata*, *P. elongata*, *A. cuvillieri* and *O. elliptica* had not been previously observed on the AdCP. Occurrences of *P. jurassica* and *M. ficcarellii* are not only the first on the AdCP, but probably the first observations outside the type localities. Upper Jurassic deposits are characterized by numerous specimens of some taxa, but diversification was less pronounced, as well as there being a low number of index species. The most frequent are kurnubias – *Kurnubia jurassica*, *K. palastiniensis* and *K. wellingsi*, and index fossils were *Labyrinthis mirabilis*, *Alveosepta jaccardi*, *Parurgonina caelinensis* and *Kilianina? rahonensis*. *Conicocurnubia orbitoliniformis*, *Anchispirocyclina lusitanica* and/or *A. neumannae* are documented for the first time on the AdCP.

Cretaceous assemblages are much richer than Triassic and Jurassic ones. Taxa of wider stratigraphic ranges through the Cretaceous are predominant. From the beginning of the Early Cretaceous to the Late Barremian the most important index forms were *Protopenneroplis ultragramulata* in the Early Berriasian, *Montsalevia salevensis*, *Haplophragmoides joukowskyi*, *Meandrospira favrei*, *Vercorsella tenuis* and *V. camposaurii* in the Valanginian and Early Hauterivian, and *Campanellula capuensis* in the Late Hauterivian. From the Late Barremian and Early Aptian to the Middle and Late Cenomanian, the most important species were orbitolinids and alveolinids, accompanied by taxa from different foraminiferal groups. Index forms include *Rectodictyoconus giganteus* and *Palorbitolina lenticularis* in the Late Barremian, *P. lenticularis*, *Paleodictyoconus actinostoma*, *Praeorbitolina cormyi*, *P. wienandsi*, *Mesorbitolina lotzei*, *Voloshinoides murgensis*, *Sabaudia briacensis*, *Choffatella decipiens*, *Derventina filipescui*, *Neotrocholina friburgensis*, *N. aptiensis*, *Trocholina lenticularis*, *Pfenderina globosa* and *Pseudolituonella conica* in the Early Aptian, *Mesorbitolina parva*, *M. texana*, *Archalveolina reicheli*, *Sabaudia capitata* and *Orbitolinopsis aquitanica* in the Late Aptian, *M. parva*, *M. texana*, *M. pervia*, *M. subconcava*, *Paracoskinolina sunnilandensis*, *A. reicheli* and *S. capitata* in the Early Albian, as well as ‘*Valdanchella*’ *dercourtii*, *Neiraquia insolita*, *N. convexa*, *Simplorbitolina broennimanni*, *Paracoskinolina fleuryi*, *Protochrysalidina elongata* and *Ovalveolina maccagnoae* in the Late Albian. In addition to orbitolinids and alveolinids, Upper Cretaceous deposits also contain nezzazatids, chrysalinids, miliolids and soritids. However, despite relatively rich fossil assemblages within certain sequences, which comprise all or part of some epochs, e.g. a stratigraphic range of Turonian–Early Santonian, there are no index forms of short stratigraphic range. The most important index forms are: *Ovalveolina maccagnoae*, *O. crassa*, *Sellialveolina viallii*, *Orbitolina gr. concava*, *Conicor-*

*bitolina conica*, *C. cuvillieri*, *Praealveolina iberica* and *P. simplex* in Early Cenomanian, *Chrysalidina gradata*, *Nummoloculina? regularis*, *Pseudolituonella reicheli*, *Pastrickella balcanica*, *Conicorbitolina conica*, *C. gr. corbarica–conica*, *Orbitolina gr. sefini–concava*, *Pseudorhapydionina dubia* and *Peneroplis turonicus* in the Middle Cenomanian, *C. gradata*, *N.? regularis*, *P. reicheli*, *P. balcanica*, *P. dubia*, *Cisalveolina fraasi*, *Vidalina radoicicae*, *V. hispanica*, *Pseudorhapydionina laurinensis*, *Pseudorhipidionina casertana* and *Peneroplis parvus* in the Late Cenomanian, *Pseudorhapydionina mediterranea*, *Murgella lata*, *Keramosphaerina tergestina*, *Pseudocyclammina massiliensis*, *Pseudolituonella marie*, *Spirolina cretacea*, *Minouxia lobata*, *Broekinella neumannae*, *Reticulinella fleuryi*, *Dictyopsella kiliani*, *Dictyopselloides cuvillieri* and *Orbitoides gr. hottingeri* in the Late Santonian and Early Campanian, *P. mediterranea*, *K. tergestina*, *P. massiliensis*, *Reticulinella reicheli*, *R. fleuryi*, *D. kiliani*, *D. cuvillieri*, *Calveziconus lecalvezae*, *Nummofallotia cretacea*, *Praesiderolites douvillei*, *Orbitoides douvillei*, *O. tissoti*, *O. media* and *Pseudosiderolites vidali* in the Late Campanian, and *Murciella cuvillieri*, *M. renzi*, *Rhapydionina liburnica*, *Fleuryana adriatica*, *Laffitteina mengaudi*, *O. media*, *Siderolites calcitrapoides* and *Omphalocyclus macroporus* in the Maastrichtian.

**Biostratigraphic zonation** was performed on deposits ranging from the Carnian to the Maastrichtian. Lower and Middle Triassic rocks have not been investigated sufficiently in order to propose a reliable subdivision. With respect to previous knowledge on the biostratigraphy of shallow-marine, platform carbonate deposits of the Mediterranean area, a new, more detailed biostratigraphic subdivision is proposed. The following biozones were defined:

– **within Upper Triassic deposits:**

- Lamelliconus procerus taxon-range zone,
- Lamelliconus procerus–Triasina hantkeni interval zone,
- Triasina hantkeni taxon-range zone, and
- Triasina hantkeni–Mesoendothyra sp. interval zone;

– **within Lower Jurassic deposits:**

- Triasina hantkeni–Mesoendothyra sp. interval zone,
- Mesoendothyra sp. lineage zone,
- Lituosepta recoarensis lineage zone,
- Orbitopsella primaeva lineage zone,
- Orbitopsella primaeva–Lituosepta recoarensis concurrent-range subzone,
- Lituosepta recoarensis–Orbitopsella praecursor interval subzone,
- Orbitopsella praecursor taxon-range zone,
- Orbitopsella praecursor–Orbitopsella primaeva concurrent-range subzone,
- Orbitopsella praecursor abundance subzone,

- Orbitopsella praecursor–Pseudocyclammina liassica interval zone,  
 Pseudocyclammina liassica taxon-range zone, and  
 Pseudocyclammina liassica–Gutnicella cayeuxi interval zone;
- **within Middle Jurassic deposits:**  
 Pseudocyclammina liassica–Gutnicella cayeuxi interval zone  
 Gutnicella cayeuxi partial-range zone,  
 Timidonella sarda taxon-range zone,  
 Timidonella sarda–Pseudodictyopsella jurassica interval zone,  
 Pseudodictyopsella jurassica and Marzoella ficcarelli assemblage zone,  
 Pseudodictyopsella jurassica–Paravalvulina complicata interval zone,  
 Paravalvulina complicata taxon-range zone,  
 Paleopfenderina salernitana taxon-range zone,  
 Satorina apuliensis taxon range subzone,  
 Paleopfenderina salernitana–Kurnubia jurassica interval zone, and  
 Kurnubia jurassica lineage zone;
- **within Upper Jurassic deposits:**  
 Kurnubia palastiniensis superzone,  
 Kurnubia palastiniensis lineage zone,  
 Kurnubia wellingsi lineage zone,  
 Chablaisia chablaisensis–Alveosepta jaccardi interval zone,  
 Alveosepta jaccardi partial-range zone,  
 Parurgonina caelinensis–Conicokurnubia orbitoliniformis concurrent range-zone,  
 Conicokurnubia orbitoliniformis–Kurnubia palastiniensis interval zone (highest occurrence zone),  
 Kurnubia palastiniensis–Protopeneroplis ultragranulata interval zone, and  
 Protopeneroplis ultragranulata taxon-range zone;
- **within Lower Cretaceous deposits:**  
 Protopeneroplis ultragranulata taxon-range zone,  
 Protopeneroplis ultragranulata–Vercorsella camposaurii interval zone,  
 Vercorsella camposaurii taxon-range zone,  
 Vercorsella camposaurii–Campanellula capuensis interval zone,  
 Campanellula capuensis taxon-range zone,  
 Campanellula capuensis–Palorbitolina lenticularis interval zone  
 Palorbitolina lenticularis superzone,  
 Rectodictyoconus giganteus and Palorbitolina lenticularis assemblage zone,  
 Praeorbitolina cormyi lineage zone,  
 Praeorbitolina wienandsi lineage zone,  
 Mesorbitolina lotzei lineage zone,  
 Mesorbitolina parva lineage zone,  
 Mesorbitolina texana lineage zone,  
 Mesorbitolina subconcava taxon-range zone,  
 ‘Valdanchella dercourtii’ partial-range zone, and  
 Neoiraquia convexa taxon-range zone;
- **within Upper Cretaceous deposits:**  
 Conicorbitolina conica/Conicorbitolina cuvillieri partial-range zone,  
 Chrysalidina gradata superzone,  
 Chrysalidina gradata partial-range zone,  
 Pastrokella balcanica–Conicorbitolina conica concurrent-range zone,  
 Vidalina radoicicae–Chrysalidina gradata concurrent-range zone,  
 Chrysalidina gradata–Pseudocyclammina sphaeroidea interval zone,  
 Pseudocyclammina sphaeroidea–Scandonea samnitica interval zone,  
 Scandonea samnitica–Dicyclina schlumbergeri interval zone,  
 Dicyclina schlumbergeri–Murgella lata interval zone,  
 Murgella lata partial-range zone,  
 Keramosphaerina tergestina abundance subzone,  
 Calveziconus lecalvezae taxon-range zone,  
 Calveziconus lecalvezae–Murciella cuvillieri interval zone,  
 Murciella cuvillieri and Rhapydionina liburnica assemblage zone, and  
 Fleuryana adriatica taxon-range subzone.
- With a total of 64 biozones in the stratigraphic range from the Carnian to Maastrichtian this is up to now not only the most detailed subdivision of the shallow-marine carbonate deposits of the Karst Dinarides, but also in the wider Tethyan/Mediterranean area.
- Palaeobiogeographic analysis** of the Adriatic Carbonate Platform deposits indicated similarities and differences of biotopes and foraminiferal assemblage compositions between the AdCP and other Tethyan shallow-marine areas. Close similarities with neighbouring Peri-adriatic platforms are especially important, as well as changes in the platform position within the Neotethyan realm, from individualization in the Triassic and Early Jurassic to disintegration in the Late Cretaceous. It may be concluded, that from its individualization to the Late Albian the AdCP represented part of the Southern Neotethyan palaeobiogeographic province, while during the Cenomanian it was probably palaeobiogeographically isolated from both main Neotethyan bioprovinces, and together with the neighbouring Periadriatic carbon-

ate platforms represented part of the Central Mediterranean province until its final disintegration in the Latest Cretaceous.

During a span of almost 280 MY, i.e. from the Moscovian to the end of the Eocene in the area of the present Karst Dinarides, approximately 8000 m of almost pure carbonates was deposited, most of them Mesozoic in age. Deposits of the Adriatic Carbonate Platform, representing a succession from the Toarcian to the end of the Cretaceous, are up to 6500 m thick, and they had only been partially adequately investigated. They were mostly relatively poorly subdivided, and some sequences were almost completely undivided. Therefore, this paper will contribute to the more detailed stratigraphic subdivision of the Late Triassic, Jurassic and Cretaceous. The results presented here may represent a sound foundation for future investigation of these deposits in the Karst Dinarides, especially those dealing with chronostratigraphy.

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## APPENDIX

### LIST OF TAXA

#### 1. Foraminifera

- Accordiella conica* FARINACCI, 1962  
*Agerina martana* (FARINACCI, 1959)  
*Alveosepta jaccardi* (SCHRODT, 1894)  
*Alzonella cuvillieri* BERNIER & NEUMANN, 1970  
*Amijiella amiji* (HENSON), 1948  
*Ammobaculites radstadtensis* KRISTAN-TOLLMANN, 1964  
*Ammodiscus parapriscus* (HO, 1959)  
*Anchispirocyclina lusitanica* (EGGER, 1902)  
*Anchispirocyclina neumannae* BERNIER, FLEURY & RAMALHO, 1979  
*Archaealveolina* sp.  
*Archaealveolina reicheli* (DE CASTRO, 1966)  
*Archiacina munieri* (MARIE, 1958)  
*Arenovidalina chialingchiangensis* HO, 1959  
*Auloconus permoldiscoides* (OBERHAUSER, 1964)  
*Aulotortus* sp.  
*Aulotortus friedli* (KRISTAN-TOLLMANN, 1962)  
*Aulotortus pokorny* (SALAJ, 1967)  
*Aulotortus praegaschei* (KOEHN-ZANINETTI, 1968)  
*Aulotortus sinuosus* (WEYNSCHENK, 1956)  
*Aulotortus tenuis* (KRISTAN, 1957)  
*Aulotortus tumidus* (KRISTAN-TOLLMANN, 1964)  
*Belorussiella textilarioides* (REUSS, 1863)  
*Biconcava bentori* HAMAOU & SAINT-MARC, 1970  
*Biokovina gradacensis* GUŠIĆ, 1977  
*Biplanata peneropliformis* HAMAOU & SAINT-MARC, 1970  
*Bosniella oenensis* GUŠIĆ, 1977  
*Broekinella neumannae* GENDROT, 1968  
*Calveziconus lecalvezae* CAUS & CORNELLA, 1981  
*Campanellula captensis* DE CASTRO, 1964  
*Chablaista chablaisensis* (SEPTFONTAINE, 1977)  
*Charentia cuvillieri* NEUMANN, 1965  
*Choffatella decipiens* SCHLUMBERGER, 1904  
*Chrysalidina gradata* D'ORBIGNY, 1839  
*Cisalveolina fraasi* (GÜMBEL, 1872)  
*Cisalveolina lehneri* REICHEL, 1941  
*Conicokurnubia orbitoliniformis* SEPTFONTAINE, 1988  
*Conicorbitolina conica* (D'ARCHIAC, 1837)  
*Conicorbitolina corbarica* SCHROEDER, 1985  
*Conicorbitolina cuvillieri* (MOULLADE, 1972)  
*Cuneolina compressa* SCHLAGINTWEIT, 1988  
*Cuneolina conica* D'ORBIGNY, 1846  
*Cuneolina ketini* INAN, 1988  
*Cuneolina parva* HENSON, 1948  
*Cuneolina pavonia* D'ORBIGNY, 1846  
*Cuneolina sliteri* ARNAUD-VANNEAU & PREMOLI SILVA, 1995  
*Cyclogyra mahayeri* (BRÖNNIMANN, ZANINETTI & BOZORGNIA, 1972)  
*Debarina hahounerensis* FOURCADE, RAOULT & VILA, 1972  
*Derventina filipescai* NEAGU, 1968  
*Dictyopsella kiliani* MUNIER-CHALMAS, 1900  
*Dictyopselloides cuvillieri* (GENDROT, 1968)  
*Dicyclina schlumbergeri* MUNIER-CHALMAS, 1887  
*Duostomina alta* KRISTAN-TOLLMANN, 1960  
*Duotaxis metula* KRISTAN, 1957  
*Endotriadella wirtzi* (KOEHN-ZANINETTI, 1968)  
*Everticyclammina praevirguliana* FUGAGNOLI, 2000  
*Everticyclammina virguliana* (KOEHLIN, 1942)  
*Fleuryana adriatica* DE CASTRO, DROBNE & GUŠIĆ, 1994  
*Frondicularia woodwardi* HOWCHIN, 1895  
*Glomospira* sp.  
*Glomospira urgoniana* ARNAUD-VANNEAU, 1980  
*Glomospira watersi* LOEBLICH, 1946  
*Glomospirella* sp.  
*Glomospirella triphonensis* BAUD, ZANINETTI & BRÖNNIMANN, 1971  
*Gutnicella cayeuxi* (LUCAS, 1935)  
*Haplophragmium* sp.  
*Haplophragmoides joukowskyi* CHAROLLAIS, BRÖNNIMANN & ZANINETTI, 1966  
*Haplophragmoides globosus* LOZO, 1944  
*Haurania deserta* HENSON, 1948  
*Hellenocyclina beotica* REICHEL, 1949  
*Hoyenella sinensis* (HO, 1959)  
*Idalina antiqua* MUNIER-CHALMAS & SCHLUMBERGER, 1885  
*'Involutina'* sp.  
*Involutina liasica* (JONES, 1853)  
*Karaisella uzbekistanica* KURBATOV, 1971  
*Keramosphaerina tergestina* STACHE, 1913  
*Keramosphaerina sarda* CHERCHI & SCHROEDER, 1990  
*Kilianina blancheti* PFENDER, 1933  
*Kilianina? rahonensis* (FOURY & VINCENT, 1967)  
*Kurnubia jurassica* (HENSON, 1948)  
*Kurnubia palastiniensis* HENSON, 1948  
*Kurnubia wellingsi* (HENSON, 1948)  
*Labyrinthina mirabilis* WEYNSCHENK, 1951  
*Laffiteina mengaudi* (ASTRE, 1923)  
*Lamelliconus multispirus* (OBERHAUSER, 1957)  
*Lamelliconus procerus* (LIEBUS, 1942)  
*Lepidorbitoides minor* (SCHLUMBERGER, 1901)  
*Lituolipora termieri* (HOTTINGER, 1967)  
*Litiosepta recoarensis* CATI, 1959  
*Marzoella ficcarellii* CHIOCCHINI & MANCINELLI, 2000  
*Mayncina bulgarica* LAUG, PEYBERNÈS & REY, 1980  
*Meandrospira dinarica* KOCHANSKY-DEVIDÉ & PANTIĆ, 1966  
*Meandrospira favrei* (CHAROLLAIS, BRÖNNIMANN & ZANINETTI, 1966)  
*Meandrospira pusila* (HO, 1959)  
*Meandrovoluta asiagoensis* FUGAGNOLI, GIANNETTI & RETTORI, 2003  
*Merlingina cretacea* HAMAOU & SAINT-MARC, 1970  
*Mesoendothyra croatica* GUŠIĆ, 1969  
*Mesoendothyra* sp.  
*Mesorbitolina lotzei* SCHROEDER, 1964  
*Mesorbitolina oculata* DOUGLASS, 1960  
*Mesorbitolina parva* DOUGLASS, 1960  
*Mesorbitolina pervia* DOUGLASS, 1960  
*Mesorbitolina subconcava* LEYMERIE, 1878  
*Mesorbitolina texana* (ROEMER), 1849  
*Minouxia lobata* GENDROT, 1963  
*Mohlerina basiliensis* (MOHLER, 1938)  
*Moncharmontia apenninica* (DE CASTRO, 1966)  
*Moncharmontia compressa* (DE CASTRO, 1966)  
*Montsalevia salevensis* (CHAROLLAIS, BRÖNNIMANN & ZANINETTI, 1966)  
*Murciella cuvillieri* FOURCADE, 1966  
*Murciella renzi* FLEURY, 1979  
*Murgeina apula* (LUPERTO SINNI, 1968)  
*Murgeina cenomana* (LUPERTO SINNI, 1998)  
*Murgella lata* LUPERTO SINNI, 1966  
*Nautiloculina* sp.  
*Nautiloculina broennimanni* ARNAUD-VANNEAU & PEYBERNÈS, 1978  
*Nautiloculina circularis* (SAID & BARAKAT, 1959)  
*Nautiloculina cretacea* PEYBERNÈS, 1976  
*Nautiloculina oolithica* MOHLER, 1938

- Neoendothyra reicheli* REITLINGER, 1965  
*Neoiraquia convexa* DANILOVA, 1963  
*Neoiraquia insolita* (DECROUEZ & MOULLADE, 1974)  
*Neotrocholina aptiensis* (IOVCHEVA, 1969)  
*Neotrocholina friburgensis* GUILLAUME & REICHEL, 1957  
*Nezzazata conica* (SMOUT, 1956)  
*Nezzazata germanica* OMARA & STRAUCH, 1965  
*Nezzazata gyra* (SMOUT, 1956)  
*Nezzazata isabellae* ARNAUD-VANNEAU & SLITER, 1995  
*Nezzazata simplex* OMARA, 1956  
*Nezzazatinella picardi* (HENSON, 1948)  
*Novalesia* sp.  
*Novalesia angulosa* (MAGNIEZ, 1972)  
*Novalesia cornucopia* ARNAUD-VANNEAU, 1980  
*Novalesia distorta* ARNAUD-VANNEAU, 1980  
*Novalesia producta* (MAGNIEZ, 1972)  
*Nummofallotia cretacea* (SCHLUMBERGER, 1900)  
*Nummoloculina? regularis* PHILIPPSON, 1887  
*Omphalocyclus macroporus* (LAMARCK, 1816)  
*Orbitamina elliptica* (D'ARCHIAC, 1843)  
*Orbitoides douvillei* (SILVESTRI, 1910)  
*Orbitoides hottingeri* VAN HINTE, 1966  
*Orbitoides media* (D'ARCHIAC, 1837)  
*Orbitoides tissoti* (SCHLUMBERGER, 1902)  
*Orbitolina concava* (LAMARCK, 1816)  
*Orbitolina sefini* HENSON, 1948  
*Orbitolinopsis* sp.  
*Orbitolinopsis aquitanica* SCHROEDER & POIGNANT, 1964  
*Orbitopsella ?dubari* HOTTINGER, 1967  
*Orbitopsella praecursor* (GÜMBEL, 1872)  
*Orbitopsella primaeva* (HENSON, 1948)  
*Ovalveolina crassa* DE CASTRO, 1966  
*Ovalveolina maccagnoae* DE CASTRO, 1966  
*Paleodictyoconus actinostoma* ARNAUD-VANNEAU & SCHROEDER, 1976  
*Paleopfenderina salernitana* (SARTONI & CRESCENTI, 1962)  
*Paleopfenderina trochoidea* (SMOUT & SUGDEN, 1962)  
*Palorbitolina lenticularis* (BLUMENBACH, 1805)  
*Paracoskinolina fleuryi* DECROUEZ & MOULLADE, 1974  
*Paracoskinolina sunniladensis* (MAYNC, 1955)  
*Paravalvulina complicata* SEPTFONTAINE, 1988  
*Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI-MORANO, 1968  
*Pastrikella balcanica* CHERCHI, RADOIČIĆ & SCHROEDER, 1976  
*Pastrikella biplana* CHERCHI & SCHROEDER, 1980  
*Peneroplis parvus* DE CASTRO, 1965  
*Peneroplis turonicus* SAID & KENAWY, 1957  
*Pfenderella arabica* REDMOND, 1964  
*Pfenderina globosa* FOURY, 1968  
*Pilamina densa* PANTIĆ, 1965  
*Pilaminella semiplana* (KOCHANSKY-DEVIDÉ & PANTIĆ, 1966)  
*Planisepta compressa* (HOTTINGER, 1967)  
*Praealveolina iberica* REICHEL, 1936  
*Praealveolina simplex* REICHEL, 1936  
*Praechrysalidina* sp.  
*Praechrysalidina infracretacea* LUPERTO SINNI, 1979  
*Praekurnubia crusei* REDMOND, 1964  
*Praeorbitolina cormyi* SCHROEDER, 1964  
*Praeorbitolina wienandsi* SCHROEDER, 1964  
*Praesiderolites douvillei* WANNIER, 1983  
*Protochrysalidina elongata* LUPERTO-SINNI, 1999  
*Protopeneroplis striata* WEYNSCHENK, 1950  
*Protopeneroplis ultragranulata* (GORBATCHIK, 1971)  
*Pseudocyclammina liassica* HOTTINGER, 1967  
*Pseudocyclammina lituus* (YOKOYAMA, 1890)  
*Pseudocyclammina massiliensis* MAYNC, 1959  
*Pseudocyclammina maynci* HOTTINGER, 1967  
*Pseudocyclammina rugosa* (D'ORBIGNY, 1850)  
*Pseudocyclammina sphaeroidea* GENDROT, 1968  
*Pseudodictyopsella jurassica* SEPTFONTAINE & DE MATOS, 1998  
*Pseudoeggerella elongata* SEPTFONTAINE, 1988  
*Pseudolituonella conica* LUPERTO SINNI & MASSE, 1993  
*Pseudolituonella marie* GENDROT, 1968  
*Pseudolituonella reicheli* MARIE, 1955  
*Pseudonummoloculina* sp.  
*Pseudonummoloculina aurigerica* CALVEZ, 1988  
*Pseudonummoloculina heimi* (BONET, 1956)  
*Pseudorhapydionina dubia* (DE CASTRO, 1965)  
*Pseudorhapydionina laurinensis* (DE CASTRO, 1965)  
*Pseudorhapydionina mediterranea* (DE CASTRO, 1974)  
*Pseudorhipidionina casertana* (DE CASTRO, 1965)  
*Pseudorhipidionina murgeana* (CRESCENTI, 1964)  
*Pseudosiderolites vidali* (DOUVILLE, 1907)  
*Raadshovenia salentina* (PAPETTI & TEDESCHI, 1965)  
*Rectodictyoconus giganteus* SCHROEDER, 1964  
*Redmondoides lugeoni* (SEPTFONTAINE, 1977)  
*Reticulinella fleuryi* CVETKO, GUŠIĆ & SCHROEDER, 1997  
*Reticulinella reicheli* CUVILLIER, BONNEFOUS, HAMAOU & TIXIER, 1969  
*Rhapydionina liburnica* (STACHE, 1889)  
*Rotalia mesogeensis* TRONCHETTI, 1993  
*Rotorbinella scarsellai* TORRE, 1966  
*Rumanoloculina robusta* (NEAGU, 1968)  
*Sabaudia auruncensis* (CHIOCCHINI & DI NAPOLI ALLIATA, 1966)  
*Sabaudia briacensis* ARNAUD-VANNEAU, 1980  
*Sabaudia capitata* ARNAUD-VANNEAU, 1980  
*Sabaudia dinapolii* CHIOCCHINI, 1984  
*Sabaudia minuta* (HOFKER, 1965)  
*Satorina apuliensis* FUORCADE & CHOROWICZ, 1980  
*Satorina mesojurassica* (MAYNC, 1972)  
*Scandonea phoenissa* SAINT-MARC, 1974  
*Scandonea pumila* SAINT-MARC, 1974  
*Scandonea samnitica* DE CASTRO, 1971  
*Sellialveolina viallii* COLALONGO, 1963  
*Siderolites calcitrapoides* LAMARCK, 1801  
*Simplorbitolina brönnimanni* (DECROUEZ & MOULLADE, 1974)  
*Siphovalvulina colomi* BOU DAGHER-FADEL, ROSE, BOSENCE & LORD, 2001  
*Siphovalvulina gibraltarensis* BOU DAGHER-FADEL, ROSE, BOSENCE & LORD, 2001  
*Siphovalvulina variabilis* SEPTFONTAINE, 1988  
*Spiraloconus giganteus* CHERCHI & SCHROEDER, 1982  
*Spiraloconus perconigi* (ALLEMANN & SCHROEDER, 1972)  
*Spirolina cretacea* TRONCHETTI & GROSHENY, 1993  
*Spiroloculina cretacea* REUSS, 1854  
*Spiroloculina robusta* BRADY, 1884  
*Stensiöina surrentina* TORRE, 1966  
*Timidonella sarda* BASSOULLET, CHABRIER & FOURCADE, 1974  
*Triasina hantkeni* MAJZON, 1954  
*Trochaminoides coronus* LOEBLICH & TAPPAN, 1946  
*Trocholina* sp.  
*Trocholina acuta* OBERHAUSER, 1964  
*Trocholina alpina* (LEUPOLD, 1935)  
*Trocholina arabica* HENSON, 1949  
*Trocholina crassa* KRISTAN, 1957  
*Trocholina delphinensis* ARNAUD-VANNEAU, BOISSEAU & DARSAC, 1988  
*Trocholina elongata* (LEUPOLD, 1935)  
*Trocholina molesta* GORBATCHIK, 1959  
*Trocholina gigantea* PELISSIE & PEYBERNÈS, 1983  
*Trocholina odukpaniensis* DESSAUVAGIE, 1968  
*Trocholina sagittaria* ARNAUD-VANNEAU, BOISSEAU & DARSAC, 1988  
*Trochospira avnimelechi* HAMAOU & SAINT-MARC, 1970  
*Turrispirillina minima* PANTIĆ, 1967  
*Turrioglomina mesotriassica* (KOEHN-ZANINETTI, 1968)  
*'Valdanchella' decourtii* DECROUEZ & MOULLADE, 1974  
*Vercorsella arenata* ARNAUD-VANNEAU, 1980