Geologia Croatica	55/2	185–232	33 Figs.			ZAGREB 2002

The Northeastern Margin of the Adriatic Carbonate Platform

Ivan **DRAGIČEVIĆ**[1] and Ivo **VELIĆ**[2]

Key words: Adriatic Carbonate Platform (AdCP), External Dinarides, Northeastern margin, Depositional systems, Palaeogeography, Geodynamic evolution, Jurassic, Cretaceous, Croatia, Bosnia and Herzegovina, Slovenia, Montenegro.

Abstract

At the end of Pliensbachian or during the Toarcian, several carbonate platforms were individualised by extensional tectonics in southern Tethys, of which the Adriatic Carbonate Platform is one. As a unique and isolated shallow marine depositional system it existed until the end of the Cretaceous. In the Late Lias, the platform margins and slopes were formed by the individualisation processes. Due to the presence of younger sedimentary cover and tectonic disruption from the Early Jurassic until the present, only small parts of the north-eastern margin and its slope are exposed at the surface.

During the entire "life-span" of the platform, its NE margin and slope retained more or less the same palaeogeographic position – from western to south-eastern Slovenia, through the central part of Croatia, western and central Bosnia, northern Herzegovina and Montenegro all the way to northern Albania. The region between Žumberak in Croatia and central Bosnia was the most dynamic part of the platform margin during the Jurassic and Cretaceous. Shifts of the marginal and slope facies were recorded in Žumberak, where the platform area was progressively reduced during the period from the Lias to the Malm. At the same time, the platform was extended in central Bosnia and Montenegro. A more pronounced reduction of the platform in Cenomanian times marked the beginning of the process of disintegration. The end of the Cretaceous was also the end of the "life" of the Adriatic Carbonate Platform. It mostly became emergent, and the renewed shallow marine carbonate depositional environments in the Eocene were short-lived and lacked the previous platform characteristics, as well as the regional distribution and integrity.

1. INTRODUCTION

The evolution of the northern margin of the Adriatic Carbonate Platform (AdCP) can be reconstructed for the period between the Early Jurassic and the Early Palaeogene. Its recent strike is NW–SE (DRAGIČEVIĆ & VELIĆ, 1994) and can be followed from the Slovenian basin (near Tolmin in Slovenia) extending all the way to the Krasta–Cukali–Budva trough in northern Albania and southern Montenegro (Fig. 1). This zone extends in a NW–SE direction through central Slovenia (BUSER, 1987; TURNŠEK, 1997; DOZET & ŠRIBAR, 1998a) in the direction of the Žumberak region and the surroundings of Karlovac in Croatia (BUKOVAC et al., 1974, 1984; ŠPARICA, 1981; JELASKA, 1987). From Karlovac, it extends in a southerly direction, through the Kordun area, towards Slunj and then towards the south-east in NW Bosnia, in the environs of Bihać, Bosanska Krupa and Sanski Most, and towards Banjaluka (ŠPARICA, 1981; JELASKA, 1987). From there, the margin extends in a south-eastern direction, through central Bosnia towards Jajce and Kupres (DRAGIČEVIĆ, 1987; DRAGIČEVIĆ & VELIĆ, 1994), and passes close to Prozor into northern Herzegovina, where it can be followed north and east of Mt. Prenj, or south of the upstream part of the river Neretva (SOFILJ & ŽIVANOVIĆ, 1979; MOJIČEVIĆ & TOMIĆ, 1982a), and finally east of Nevesinje all the way to Gacko (MOJIČEVIĆ & LAUŠEVIĆ, 1969; MIRKOVIĆ, 1980). In Montenegro, the margin strikes between Mt. Golija and Mt. Durmitor (MIRKOVIĆ & VUJISIĆ, 1989) and in a SE direction towards the Maglić and Prokletije Mts. (KALEZIĆ et al., 1973; ĐOKIĆ et al., 1973) where it passes into the Albanian Alps in northern Albania, approximately along the Skadar–Peć line, i.e. to the Krasta–Cukali–Budva trough in the SE. The total length of the northern or north-eastern margin of the platform is over 700 km (VELIĆ et al., 2002a), but it should be stressed in the beginning, that the palaeogeographic continuity of both the Adriatic Carbonate Platform and its northern margin can also be recognised over a broader region than described above. It is just a part of the large shallow marine platform system of Tethys (DERCOURT et al., 1993) that extends from the region of Furlania in the Southern Calcareous Alps (in the NW) towards the SE through the karst Dinarides, Albanides and Helenides all the way to the Eastern Taurides.

The recent position of the margin is marked at the surface by the maximal extension of Mesozoic shallow-marine carbonate rocks of platform characteristics in a direction NE of the contact with the slope and/or deep-marine, basinal sediments, mostly represented by clastics, that are usually called the "flysch". In the present, complex geological structure, the northern margin of AdCP is best observed along the strike from the Žumberak region in Croatia to central Bosnia (Fig. 1). Data acquired by field study of the platform margin in

[1] University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, HR-10000 Zagreb, Croatia; e-mail: idragic@rgn.hr

[2] Institute of Geology, Sachsova 2, HR-10000 Zagreb, Croatia.

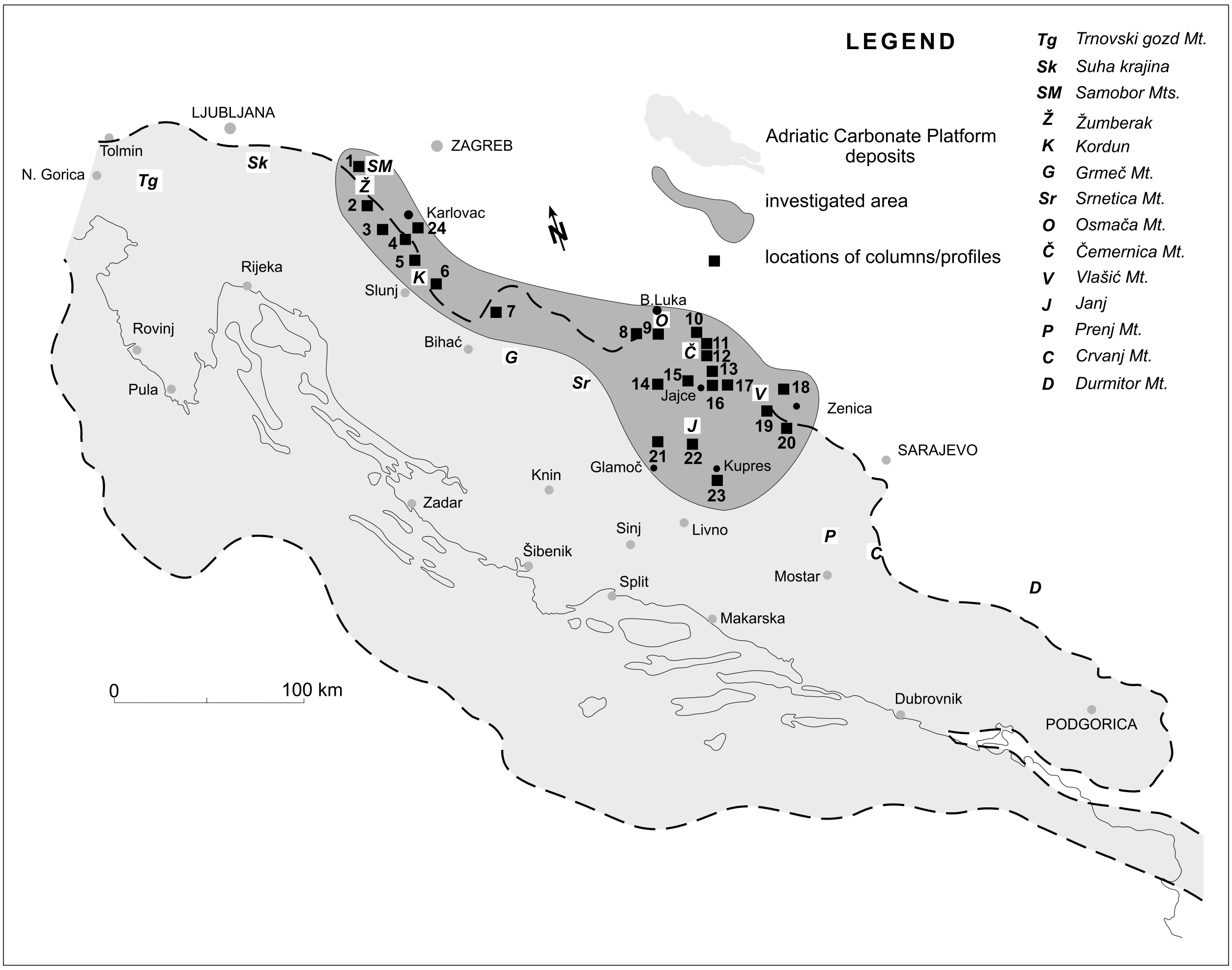


Fig. 1 Recent boundaries of the Adriatic Carbonate Platform deposits and geographic position of the geological columns, profiles and outcrops within the investigated area of the northeastern platform margin: 1) Žumberak–Samobor Mts.; 2) Ozalj; 3) Dubravčani; 4) Martinšćak–Barilović; 5) Budački Gornji; 6) Cetingrad; 7) Otoka (Bosanska Krupa); 8) Subotica (Bronzani Majdan); 9) Jagare (Banja-luka); 10) Kotor Varoš; 11) Kotor Varoš–Skender Vakuf; 12) Paunovići (Skender Vakuf); 13) Vidovo vrelo; 14) Trijebovo (Mrkonjić Grad); 15) Liskovica–Bešpelj; 16) Seoci (Jajce); 17) Ravanac; 18) Bila; 19) Guča Gora; 20) Kaonik; 21) Čardak livade; 22) Strojice (Janj); 23) Kupres; 24) Karlovac.

this region offers a reliable starting point for interpretation of the Jurassic and Cretaceous evolution of the margin. The available published sources will also be fully utilised to reconstruct the general palaeogeographic relations in the other parts of the platform margin, both in Slovenia, south-eastern Bosnia and Herzegovina and in Montenegro. Since there are not so many new papers on this subject, several sheets of the Basic Geological Map (scale 1:100,000) and their accompanying notes of explanation were used as fundamental references.

Through geodynamic evolution during the Jurassic and Cretaceous the AdCP and its NE margin changed in (palaeo)geographical orientation from nearly meridional, i.e. NNE–SSW strike (DERCOURT, 1993; STAMPFLI & MOSAR, 1999) in the Early Jurassic, to a NNW–SSE orientation in the Late Cretaceous. Recently it mostly corresponds to the Dinaric strike (NW–SE) in Croatia, Bosnia and Herzegovina and Montenegro, but in Slovenia it is oriented W–E. Since the results presented in this paper were mostly obtained from investigation in Croatia and Bosnia and Herzegovina its recent position as the NE platform margin has been preferred and accepted.

2. RECENT GEOLOGICAL SETTING

The complex recent geological structure is a consequence of the post-platform structural-tectonic changes that had already started at the end of Cretaceous and intensified through the Early Tertiary. They culminated in the Neogene and Quaternary and the original geological relationships from the time when the carbonate platform existed are now partly overprinted and masked by fault tectonics. The Late Cretaceous–Tertiary deposition of the carbonate–clastic sediments covered a substantial part of older carbonate sequences of the platform margin and slope which are, therefore, both in a stratigraphical and geographical sense, only partially available for field investigations. Besides, it is necessary to take into consideration the geodynamics of the platform margin i.e. its migration, uplift, erosion, and drowning mostly as consequences of permanent tectonic activity during the Jurassic and Cretaceous. These are the reasons why there are no localities or sections where the sedimentary stratigraphic sequences from the Early Jurassic to the end of Cretaceous could be followed continuously and in their entirety. Also, there is no continuity of the described units or stratigraphic sequences along the strike of the recent geographic position of the platform margin.

Facies of the platform margin were not uniform throughout the entire time span of its existence (Early Jurassic to the end of Cretaceous). They are very rarely recognisable in the Early and Middle Jurassic successions and most extensively distributed and best determined in the Late Jurassic strata. The Early Cretaceous sections are also seldom preserved – there are only traces from the Barremian, Early Aptian and Cenomanian and relatively frequent occurrences of Santonian, Campanian and Maastrichtian deposits (Fig. 3).

Generally, Jurassic and Cretaceous shallow water carbonates of the platform margin are to a large extent covered by clastic sediments, i.e. by Campanian–Maastrichtian–Palaeocene flysch. This reduces the investigation of the NE platform margin mostly to the deposits cropping out beneath this flysch, and to the area of contact between the stratigraphically older carbonate platform sequences and slope-to-basin sequences in localities where they are not covered with the aforementioned flysch deposits.

2.1. Geological columns and cross-sections

At locations through the investigated area with comparatively well exposed sections along the margin of the Adriatic Carbonate Platform, several geological columns were measured and analysed in detail. Generalised geological cross-sections were surveyed in areas where sequences are weakly exposed. Some interesting locations were regretfully unreachable for field investigation. These parts are complemented by the results of work of previous researchers. Descriptions are grouped geographically, from NW to SE (i.e. from Žumberak to central Bosnia).

2.1.1. Žumberak–Samobor Mts.

Jurassic deposits in Žumberak and in the Samobor Mts. were described by RADOIČIĆ (1966), GUŠIĆ & BABIĆ (1970), BABIĆ (1973, 1976), ŠIKIĆ & BASCH (1975), PLENIČAR et al. (1976), ŠIKIĆ et al. (1978, 1979), BUKOVAC & SOKAČ (1989) and BUCKOVIĆ et al. (2001). Based on the investigations of these authors and our own results, facies characteristics and interpretation of depositional environments are shown in geological column (Fig. 1, location 1; Fig. 2).

Shallow marine Lower Lias and lowermost Middle Lias at the very margin of the platform, are represented by an alternation of mudstones, fossiliferous wackestones and pelletal packstones with bioclastic and ooid grainstones and late diagenetic dolomites, containing calcareous algae *Palaeodasycladus mediterraneus* (PIA), *Sestrosphaera liasina* PIA and benthic foraminifera *Lituosepta recoarensis* (CATI). They are overlain by slope limestones of the Late Lias: mud-supported mostly fossiliferous wackestones with lithoclasts of platform limestones, rarely containing ooids, *Involutina liassica* (JONES), lagenids, nodosarids and other organisms of the slope biotope.

Lias slope deposits are followed by limestones with filaments, spicules, globigerinids, saccocomas and other pelagic organisms, which also occasionally contain platform benthic foraminifera (trocholinas). Laterally, there are bodies of slope breccias (?debrites) wherein the fragments of all the previously mentioned limestone types were found. In this way the described sequence of slope sediments would correspond to the time span from the Middle Jurassic to the pre-Tithonian part of the Late Jurassic.

The final part of the Jurassic sequence of Žumberak and the Samobor Mts. is mostly composed of basinal "calpionella limestones" of Tithonian, Berriasian and Valanginian age that were thoroughly investigated by BABIĆ (1973). On the platform margin a coral–hydrozoan barrier reef existed throughout the uppermost Oxfordian to the lowermost Berriasian.

2.1.2. Ozalj

The platform margin and slope-to-basin facies ranging from Early Jurassic to uppermost Cretaceous age were investigated in the Karlovac area (Fig. 1, locations 2 to 5).

In the Ozalj locality (Fig 1, location 2; Fig. 3) oolithic grainstones prograde over Upper Jurassic barrier coral–hydrozoan reefs and they are mostly covered by Berriasian mudstones. Laterally, the slope breccias, calpionellid and fossiliferous mudstones (with *Calpionella alpina* LORENZ and other tintinnids) of Late Tithonian and Berriasian age were deposited. Together with remains of pelagic organisms, they contain carbonate grains (bioclasts and ooids) derived from the platform margin and shallows. These deposits are unconformably overlain by Santonian–Campanian breccias and conglomerates – basal part of the Campanian–Maastrichtian flysch. To the north and northeast (in Žumberak), BABIĆ (1974) described slope and basinal sediments of Hauterivian–Cenomanian age overlying older deposits of different ages ranging from the Late Triassic to Valanginian. The author interpreted their position as displacements of the platform margin including the broadening of the basin from the Late Lias to Tithonian–Valanginian, broadening of the platform from the Hauterivian to the Aptian and then again basinal broadening from the Albian onwards.

2.1.3. Dubravčani

GRANDIĆ & VUKSANOVIĆ (1973) and ŠPARICA (1981) investigated the Upper Cretaceous to Palae-

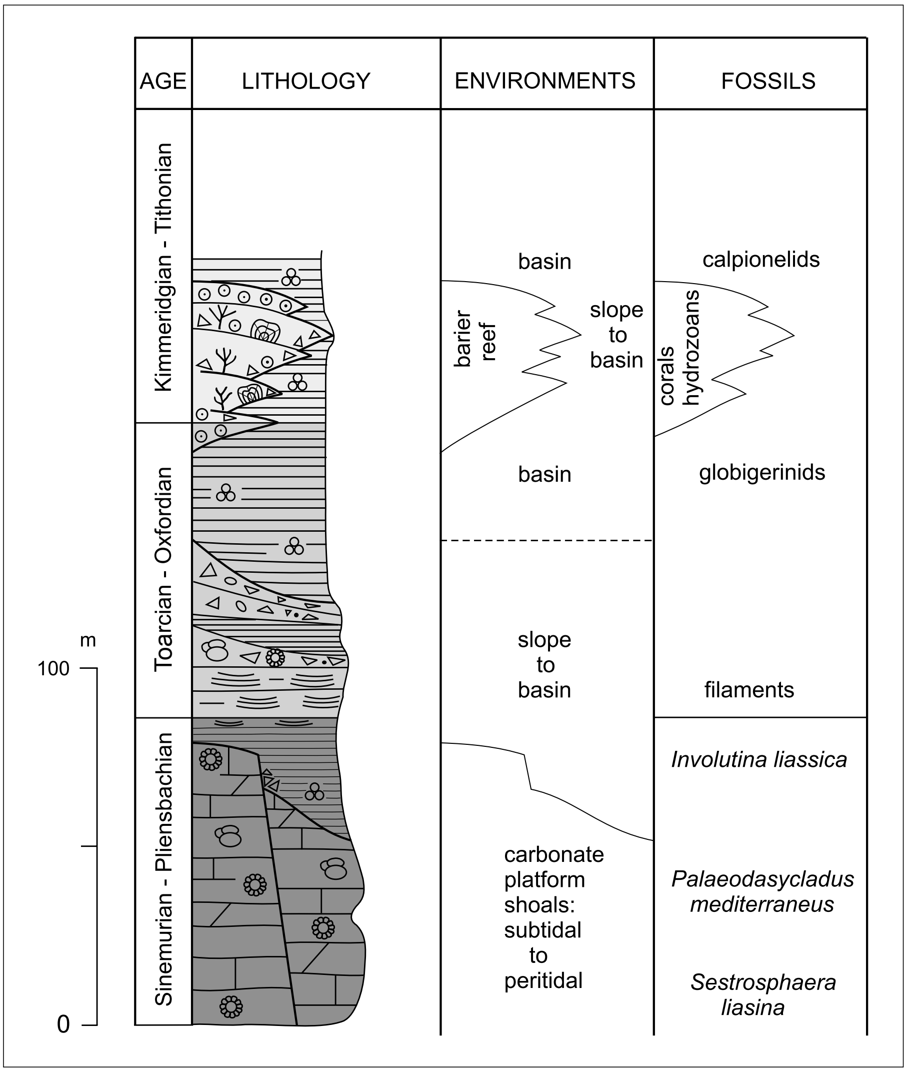
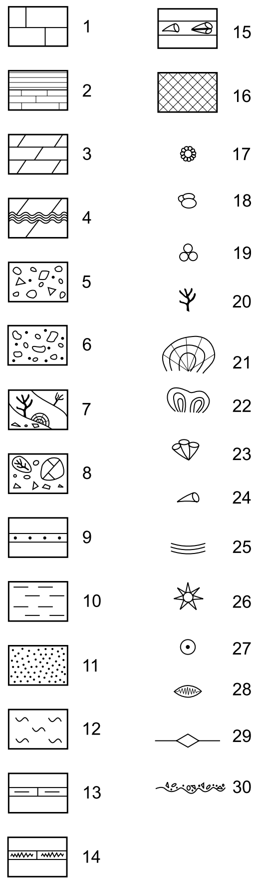


Fig. 2 The Žumberak–Samobor Mts. column and lithological legend for all figures: 1) platform limestone; 2) slope to basin limestone; 3) late-diagenetic dolomite; 4) stromatolite and early-diagenetic dolomite; 5) calcareous breccia; 6) slope breccia; 7) reef limestones; 8) debrite; 9) calcarenite; 10) marl; 11) sandy matrix; 12) clayey matrix; 13) clayey limestone; 14) limestone with chert; 15) bivalve coquina; 16) bauxite; 17) calcareous algae; 18) benthic foraminifera; 19) planktonic foraminifera; 20) corals; 21) hydrozoans and stromatoporoids; 22) bryozoans and sponges; 23) bivalves in living position; 24) resedimented bivalves; 25) pelagic bivalves (“filaments”); 26) echinoderms; 27) ooids; 28) chert nodules; 29) fenestrae; 30) emersions.



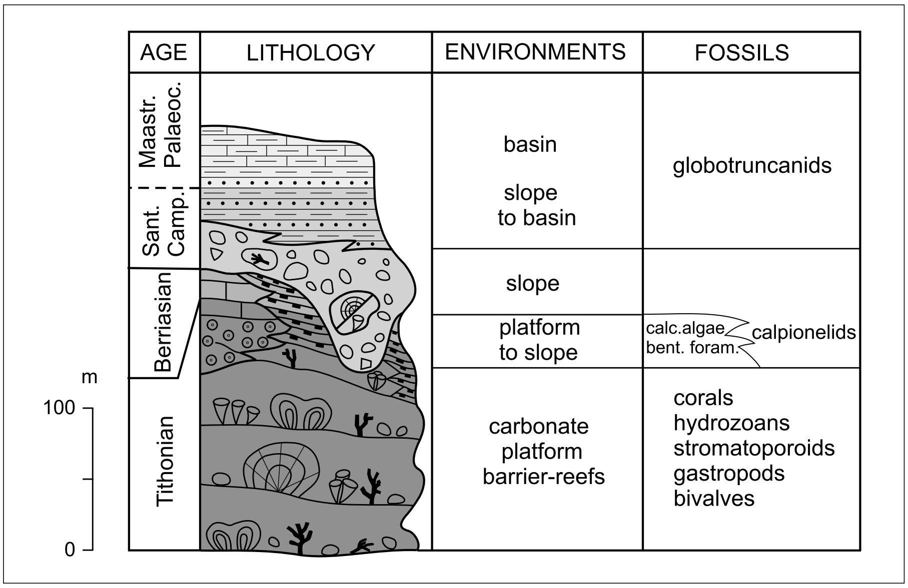


Fig. 3 The Ozalj column.

ocene platform carbonate succession in Dubravčani (W of Karlovac – Fig. 1, location 3; Fig. 4). A karstified palaeorelief of Middle to Upper Cenomanian rudist bioclastic floatstones to rudstones with bauxite occurrences is covered by the “Senonian” rudist limestones. The microfossil association quoted therein indicates an Upper Santonian–Campanian age. The Cretaceous–Palaeocene continuity of deposition was highlighted by

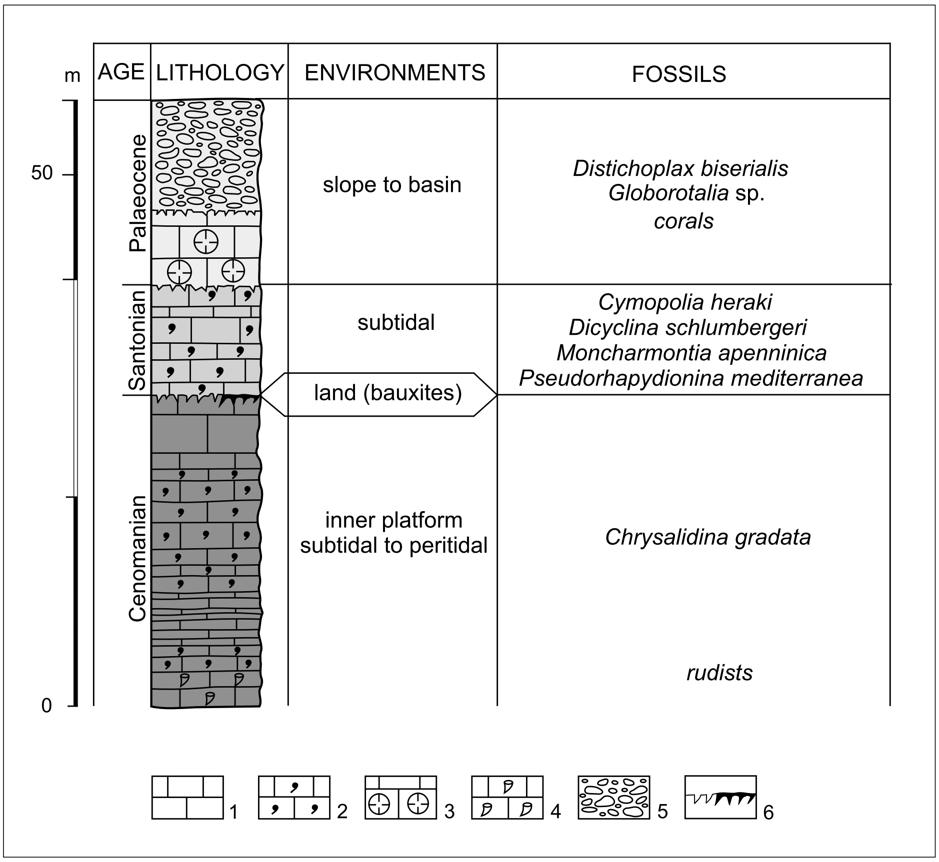


Fig. 4 The Dubravčani column (after ŠPARICA, 1981, partly modified). Legend: 1) mudstones/wackestones; 2) packstones/grainstones; 3) coral limestones; 4) rudist limestones; 5) conglomerates; 6) karstified surfaces with bauxite occurrences.

ŠPARICA (1981), while GRANDIĆ & VUKSANOVIĆ (1973) and BUKOVAC et al. (1984) elaborated on the unconformable/transgressive relationship of the Palaeocene limestones. The latter interpretation is more likely, because the thickness of Upper Santonian–Campanian platform limestones is enormously reduced to less than 40 m.

2.1.4. Martinšćak – Barilović

Several local columns were measured through the Jurassic marginal platform sequences W and SW of Karlovac, in the area between Dugaresa and Skradska gora. The central part of the area is best studied at Martinšćak hill and in Barilović (Fig. 1, location 4; Fig. 5).

The subtidal and peritidal Middle Lias limestones are covered by oolitic to fine-grained bioclastic grainstones formed in the tidal-bar environments of the platform margin. These sediments contain interbeds of the tempestite bioclastic grainstones to rudstones mostly composed of lithiotid bivalve shells and fragmented *Orbitopsella praecursor* (GÜMBEL). They are overlain by bioturbated mudstones which mark the end of the Lower Jurassic part of the platform carbonate sequence: this area was emergent until the Late Oxfordian. Laterally, at the platform slope mud-supported limestones with clasts from the platform shallows and a pelagic fauna were deposited. Oolitic limestones of the platform margin prograded over the slope facies.

These Lower Jurassic carbonates are overlain by the Upper Oxfordian–Kimmeridgian limestone which is characterised by a brecciated lower part that is gradually replaced by the oolitic–oncolitic wackestone–packstone. The next 20 m thick interval composed of well-bedded, mostly oolitic grainstones and packstones, was gradually covered by fossiliferous mudstones containing chert nodules and a mixture of the platform litho- and bioclasts with pelagic fauna. This facies indicates the Kimmeridgian restoration of platform slope environments. On the platform margin the coral–hydrozoan reef had been formed, which gradually became the barrier-reef and prograded over the slope-forming fossiliferous mudstones with nodules and interbeds of chert. Clasts which originated from the barrier-reef are very frequent within slope mudstones.

2.1.5. Budački Gornji

The Budački Gornji section (Fig. 1, location 5; Fig. 6) was analysed by ŠPARICA (1981). Tithonian–Berriasian limestones are mostly fossiliferous mudstones with calpionellids, among which *Calpionella alpina* LORENZ was determined. They are overlain by the Upper Santonian to Maastrichtian carbonate–clastic sediments. The transgressive contact is marked by the karstified Malmian limestones covered by limestone breccias with marly matrix. These breccias are in turn overlain firstly by clayey limestone with interbeds of tuffaceous material and marl, and then by "Scaglia"

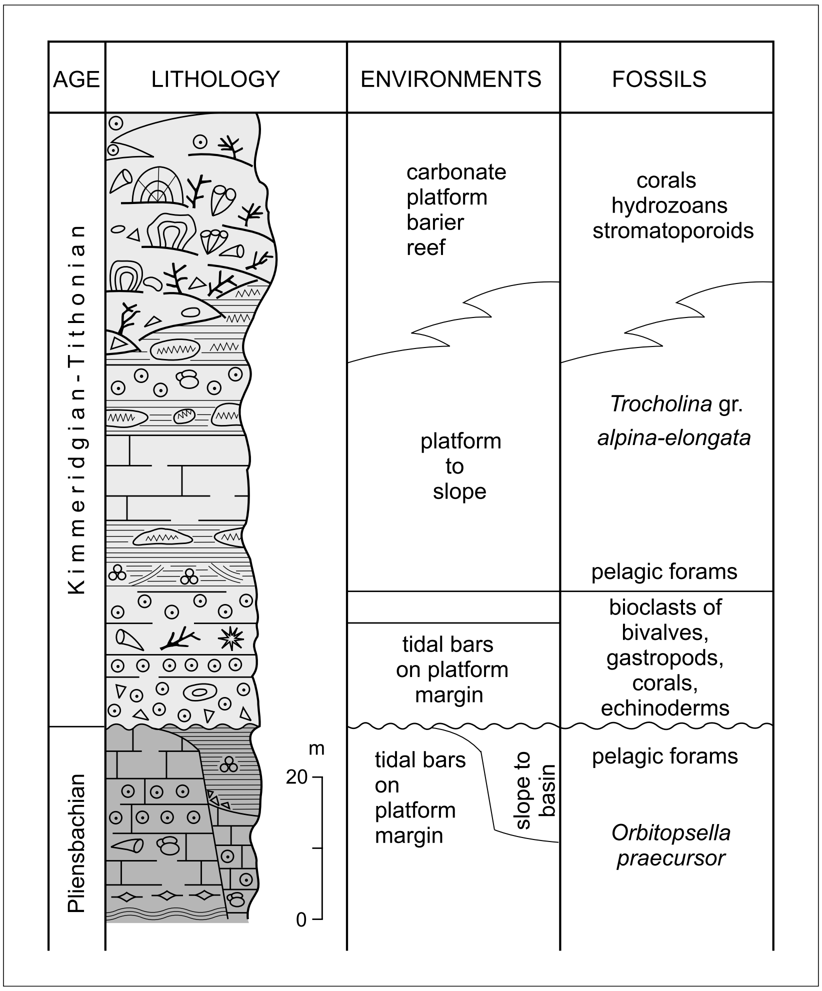


Fig. 5 The Martinšćak–Barilović column.

type limestone containing calcisphaeras and globotruncanids.

2.1.6. Cetingrad

According to SOKAČ (1964), ŠPARICA (1981) and MRINJEK (1988a, b) in the wider area of Cetingrad there are two horizons of Cretaceous carbonate–clastic sediments (flysch): the older one of Late Cenomanian–Turonian (possibly Early Coniacian) age, which is supposed to be transgressive, and a younger one of Late Santonian/Early Campanian to Palaeocene age (Fig. 1, location 6; Fig. 7).

In the base of the Cenomanian–Turonian flysch there are platform carbonates of different ages: Middle to Upper Triassic dolomites, and Upper Jurassic and Lower Cretaceous fossiliferous limestones. Marls predominate in the flysch, shales are subordinate and they contain interbeds of chert, calcarenites and calcirudites. The coarse-grained units frequently contain a redeposited platform benthos, of mostly Upper Jurassic, Lower Cretaceous and Cenomanian foraminifera. Especially frequent are redeposited Cenomanian orbitolinids (the "Orbitolinid Cretaceous").

Younger flysch deposits of Senonian–Palaeocene age unconformably overlie different units – the Middle–Upper Triassic dolomites, Upper Jurassic and Lower Cretaceous limestones and dolomites and Cenomanian–Turonian flysch. In the broader area they also cover the Norian–Rhaetian "Hauptdolomit" and platform carbonates of the Middle and Upper Jurassic, Lower Cretaceous and Cenomanian (KOROLIJA et al., 1980). A coarse conglomeratic breccia with fragments and smaller blocks of Cretaceous and Jurassic limestones represents the base of the Cenomanian–Turonian flysch (after SOKAČ, 1964). The breccia is followed by the typical flysch alternation of calcarenites, rarely calcirudites and marls in Bouma turbidite sequences. All intervals are present, including the pelagic ones represented by the globotruncanid, platy "Scaglia" limestones that also locally form thicker lenses within the flysch (Fig. 7 – $bK_2^{4\text{-}6}$).

In the Slunj area (Tatar Varoš) MRINJEK (1988a) described Cenomanian fine-grained turbidites deposited on the upper part of the slope. On the geological map of the area, the author subdivided the younger succession of Upper Cretaceous flysch deposits into the Upper Campanian and Maastrichtian stratigraphic units.

2.1.7. Otoka (Bosanska Krupa)

The stratigraphic sequence of the basinal Upper Cretaceous sediments described by JELASKA (1987) is

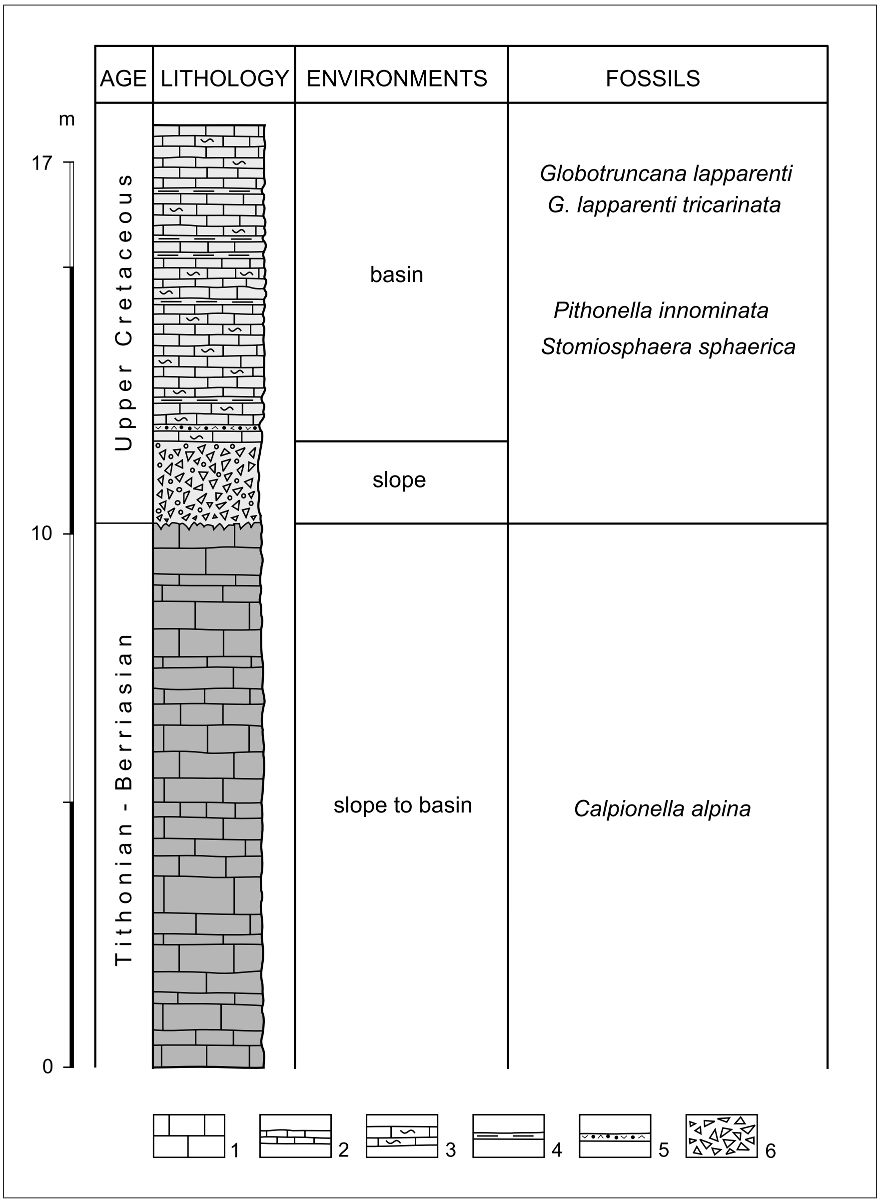


Fig. 6 The Budački Gornji column (after ŠPARICA, 1981). Legend: 1) calpionella limestones; 2) thin-bedded limestones with globotruncanids ("Scaglia" type); 3) clayey limestone; 4) marl; 5) tuff; 6) breccia.

shown in Fig. 8. Due to the faulted terrain, the cross-section is constructed on the basis of a survey of several smaller columns and cross-sections between Otoka and Bosanska Krupa (Fig. 1, location 7). The total thickness of explored sediments exceeds 1100 m.

Karstified Kimmeridgian–Tithonian platform carbonates are overlain by Cenomanian clastic–carbonate pelagic deposits composed of thin-bedded and platy marls, clayey limestones, limestones (mudstones and wackestones) and cherts (in the form of laminae and nodules). It is supposed that pelagic sedimentation through the entire Upper Cretaceous was continuous, only occasionally interrupted by deposition of detrital carbonates, which appear as variously thick intercalations of bioclastic limestones – calcarenites and calcirudites containing clasts of different age, (e.g. of the Upper Jurassic, Lower Cretaceous and most frequently of the Upper Cretaceous carbonates), with remains of calcareous algae, foraminifera and macrofossils, especially rudists, derived from the area of the platform margin. Pelagic sequences are rich in an autochthonous microfauna, globotruncanids in particular, that define the stratigraphy of these sediments through the Cenomanian–Maastrichtian. A sequence of graded bioclastic limestones – carbonate turbidites, occurs approximately in the middle of this part of the column and thus separates the sequence of pelagic sediments into two. The younger unit is more markedly pelagic and corresponds to the "Scaglia"-type sediments.

2.1.8. Subotica (Bronzani Majdan)

Lower Jurassic carbonates of the platform margin and slope along the Subotica creek near the village of Bronzani Majdan (W of Banjaluka – Fig. 1, location 8; Fig. 9) were described by JELASKA (1987). The investigated succession is approximately 200 m thick.

Continuity of sedimentation is recorded from the Upper Triassic "Hauptdolomit" into the Lower Lias plat-

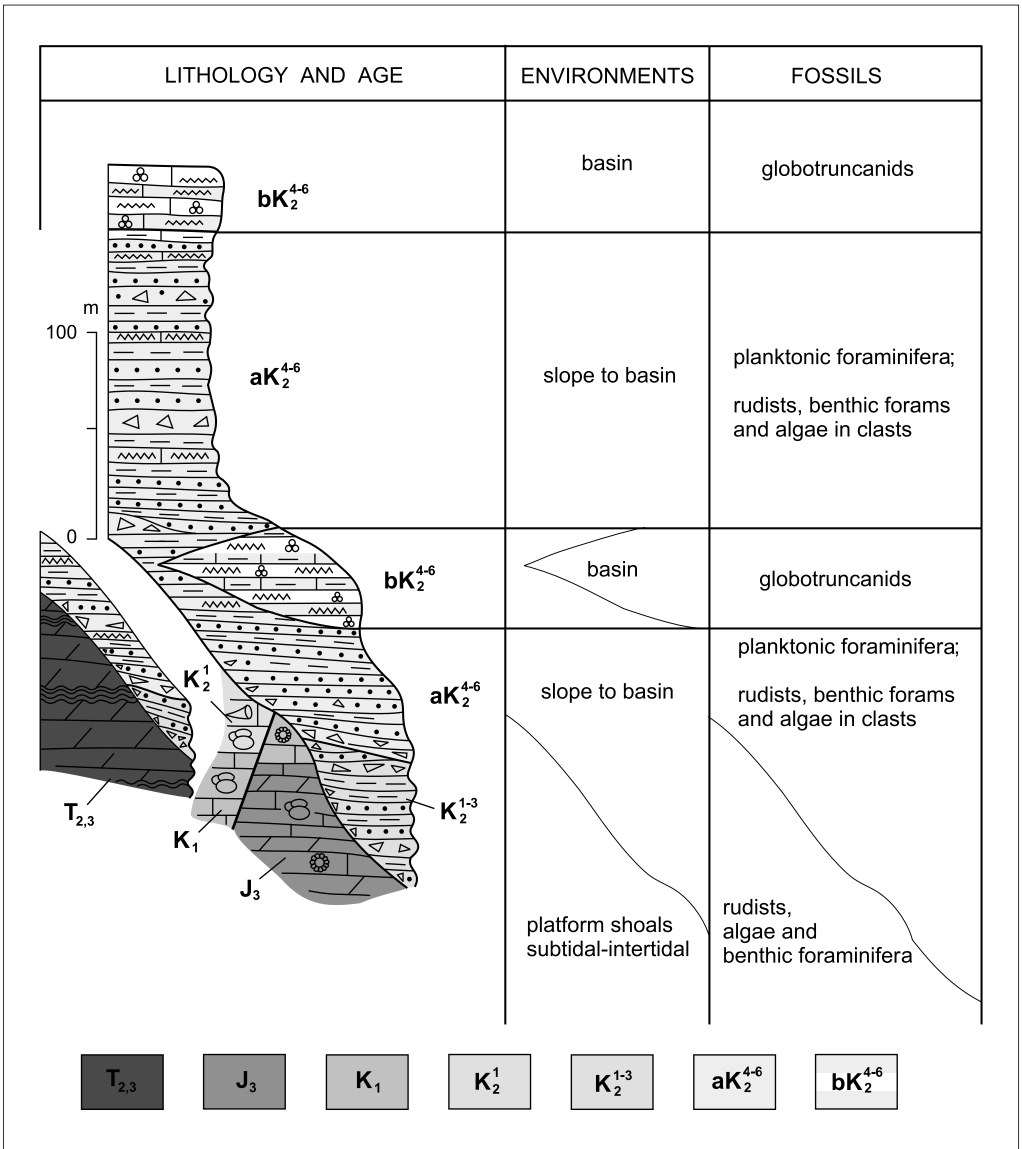


Fig. 7 The Cetingrad column.

form mud-supported limestones containing the index alga *Palaeodasycladus mediterraneus* (PIA). These limestones are overlain by the Middle Lias grain-supported limestones, predominantly oolitic packstones and grainstones (with sporadic occurrences of mudstones) and the index lituolid foraminifera *Orbitopsella praecursor* (GÜMBEL) and *Lituosepta recoarensis* CATI (according to JURIĆ, 1977). This sequence is unconformably overlain by slope breccias with slump structures recording the movement of unconsolidated sediment, brecciation, chaotic orientation of angular lithoclasts in the muddy matrix etc. Such intervals are up to 10 m thick and contain up to 3 m thick packages of massive mudstones. The only autochthonous fossils that were discovered are the Liassic involutinas, including the index species *Involutina liassica* (JONES) and "vidalinas". The sequence of these Lower Jurassic deposits is overlain by the remains of Upper Jurassic coral–hydrozoan barrier reefs. This relationship suggests a significant hiatus – land conditions most probably existed in this area through the Middle and early Late Jurassic.

2.1.9. Jagare (Banjaluka)

This column was investigated in the village of Jagare on the southern outskirts of Banjaluka. Around 80 m of sediments are exposed here, on the contact between the Upper Triassic carbonates and carbonate clastics of Late Santonian to Maastrichtian age (Fig. 1, location 9; Fig 10).

The basal part of the Upper Cretaceous clastic–carbonate sequence is represented by breccias and calcarenites 6 m thick containing clasts of older carbonates, that unconformably overlie the Upper Triassic dolomites. Within the sandy and carbonate matrix there are orbitoids and siderolitids with fractured tests. The following 67 m are composed of an alternation of calcirudites, calcarenites and marls. Clasts are variable – Lower Cretaceous orbitolinid limestones, Upper Cretaceous rudist and calcisphaera limestones, fragments

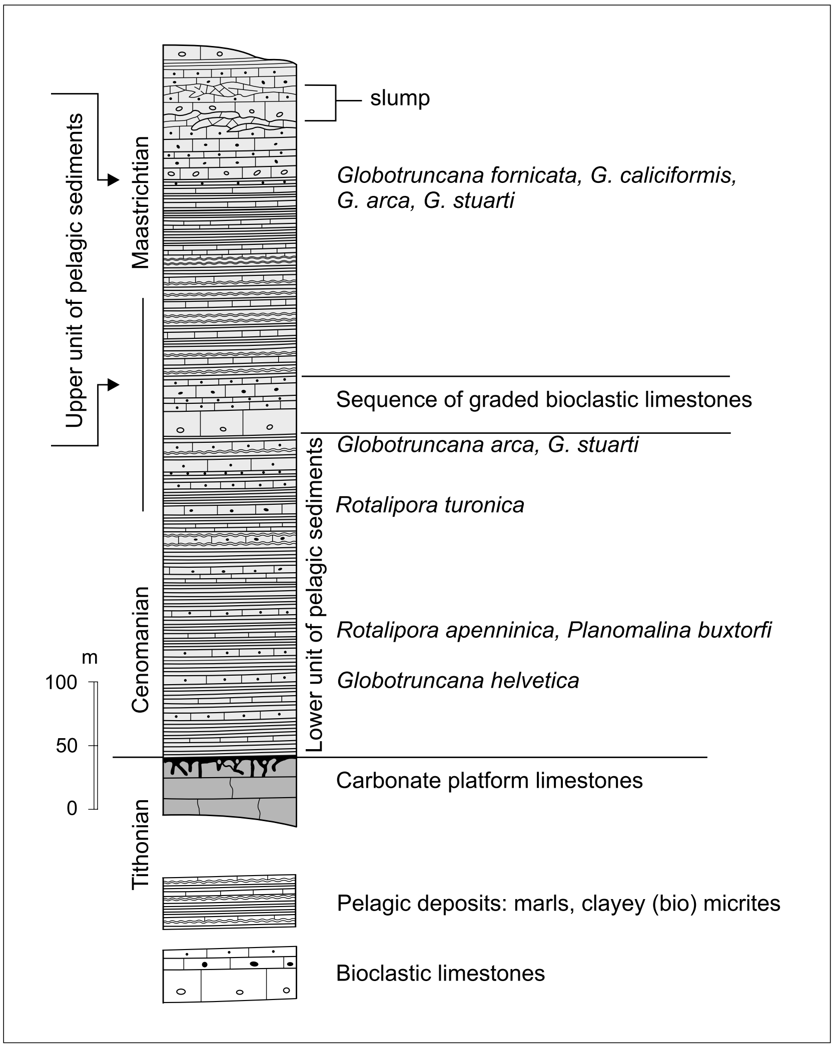


Fig. 8 The Otoka (Bosanska Krupa) column (after JELASKA, 1987).

of orbitoids and siderolitids, also sporadic grains of chert or igneous rocks. Marls are the most subordinate component. In the calcarenite beds the foraminifera *Pseudonummoloculina heimi* (BONET) and *Omphalocyclus macroporus* (LAMARCK) were determined, but in the marls only unidentifiable globotruncanids and other pelagic organisms were observed.

With the exception of the chaotic package of basal breccia, the lithological composition and sedimentary textures indicate a turbiditic mechanism of deposition. Triassic dolomites were deposited mostly in intertidal environments, while Cretaceous clastics were deposited on the slope of the carbonate platform and in the corresponding part of the basin. The source area was represented by faulted carbonate land, rudist bioherms and shallows of the platform margin. Some fragments of chert and igneous rocks originated from the Ladinian volcanic–sedimentary complex.

2.1.10. Kotor Varoš

The sequence of clastic–carbonate sediments deposited in the slope-to-basin environments was investigated to define the autochthonous basinal "Scaglia"-type limestones. Around 50 m of sediments were studied in a profile cropping out SE of Banjaluka (Fig. 1, location 10; Fig. 11).

The basal part of the column is characterised by a relatively regular alternation of calcarenites, marls and clayey "Scaglia" limestones. Both the clasts in the calcarenites and the finer grains of the marls originated from crushed mollusc shells (mostly of rudists) and echinoderms. Fragments of Aptian, Albian and Cenomanian limestones have also been determined, predominantly of the orbitolinid wackestone type. The matrix is carbonate mud with globotruncanids, hedbergellas and heterohelicids. Pelagic foraminifera have also been found in the marls, but they are particularly frequent in the "Scaglia" limestones with a rich association of globotruncanids. Calcirudites and calcarenites prevail in the third quarter of the column and "Scaglia" limestones in the uppermost part.

The stratigraphic range of these sediments was determined on the basis of globotruncanids, since the association contains nearly 20 species, which mostly have a broad Upper Cretaceous span. Some of the species found – *Globotruncanita calcarata* (CUSHMAN) and

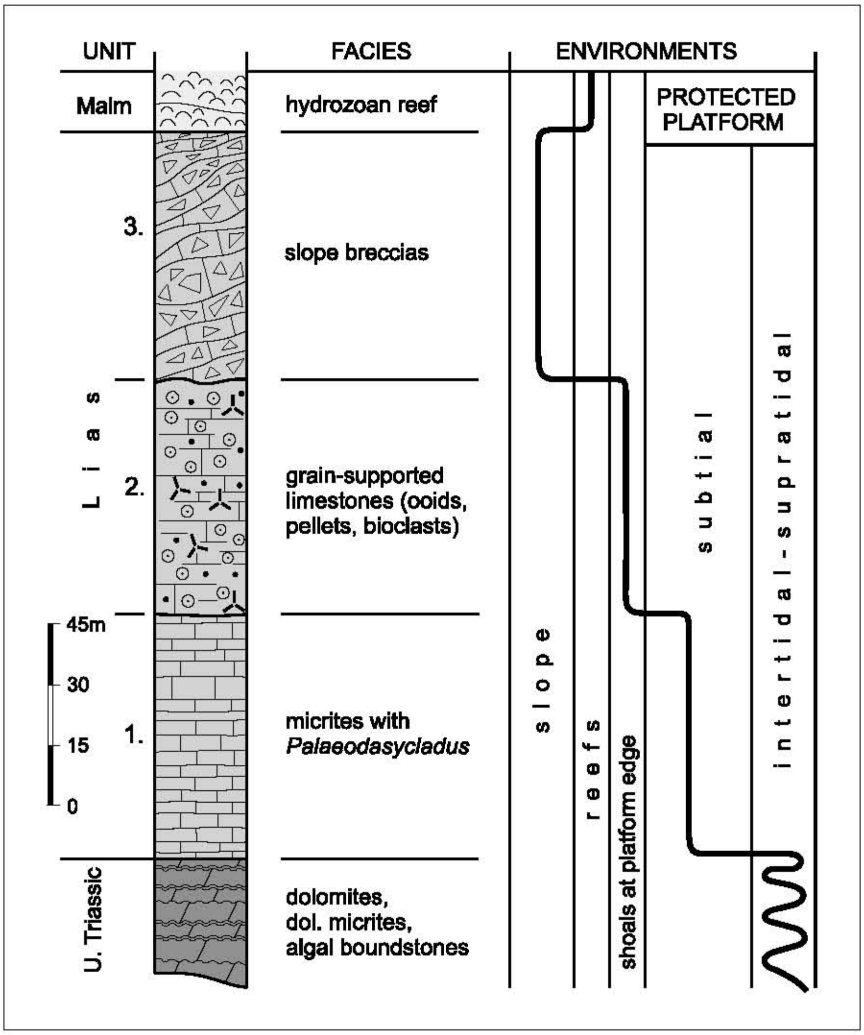


Fig. 9 The Subotica (Bronzani Majdan) column (after JELASKA, 1987).

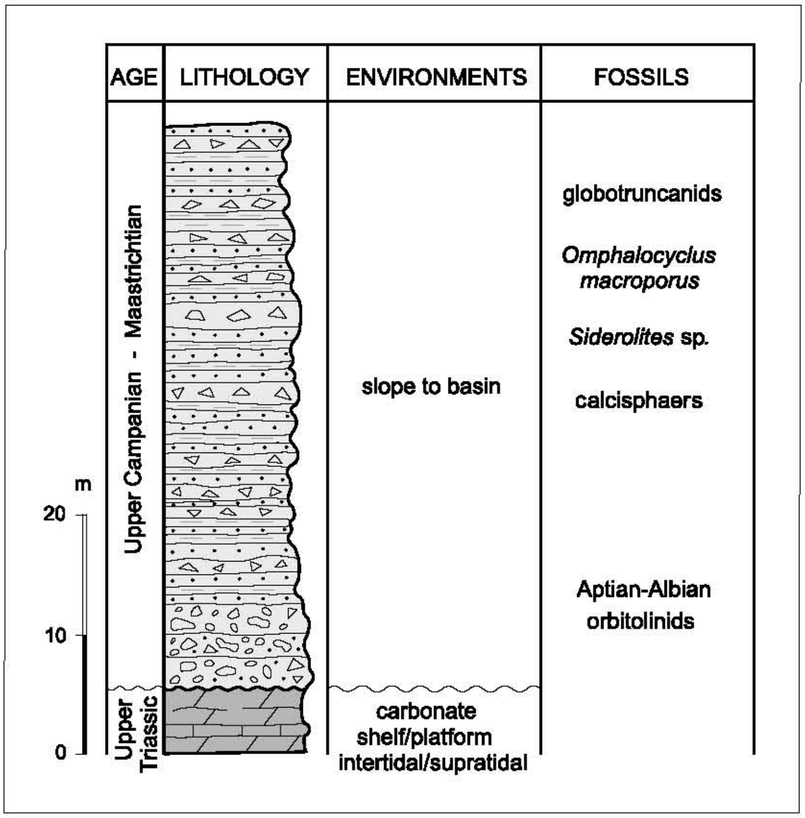


Fig. 10 The Jagare (Banjaluka) column.

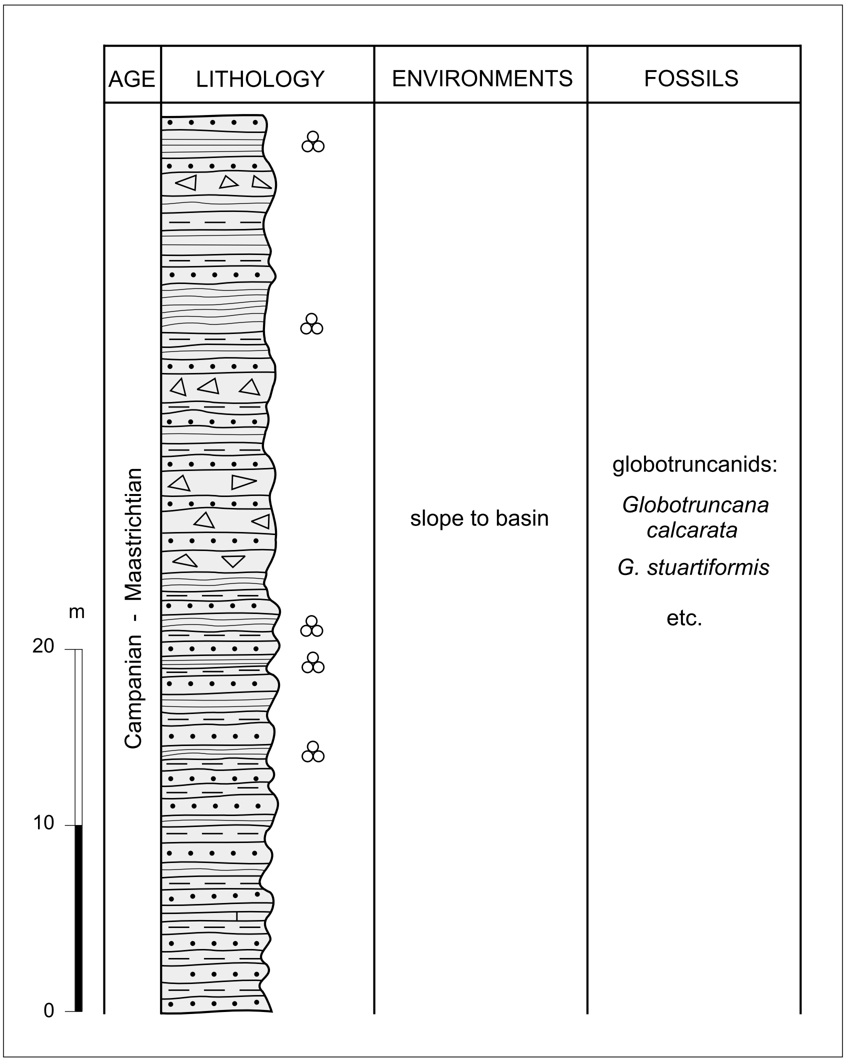


Fig. 11 The Kotor Varoš column.

G. stuartiformis (DALBIEZ) are index fossils for the Upper Campanian and Maastrichtian.

2.1.11. Kotor Varoš – Skender Vakuf

In order to study the slope and basinal facies, a geological cross-section was measured in the Upper Cretaceous carbonate clastics and limestones which are approximately 700 m thick, along the Kotor Varoš–Skender Vakuf road, (Fig. 1, location 11; Fig. 12).

The first 350 m of the column is characterised by regularly stacked sequences of thicker calcirudite/calcarenite beds with terminal members composed of thinner marl beds, sporadically by clayey "Scaglia" limestones. In the next 150 m of the middle part of the column there are mostly marls with occasional interbeds of calcirudites and calcarenites, while the uppermost 200 m is composed almost entirely of thin-bedded marly "Scaglia" limestones containing only two thicker calcirudite interbeds.

The basal part of the column can be interpreted as turbidites of the lower slope or proximal part of the basin. The upper half with marls and predominating "Scaglia" limestones consists of autochthonous basinal sediments. The sporadic thick calcirudite beds represent debrites.

2.1.12. Paunovići (Skender Vakuf)

This column was measured in Paunovići village SE of Banjaluka (Fig. 1, location 12). The horizons near the contact between the Lower Aptian limestones and the Maastrichtian to Palaeocene carbonate clastics were studied. The thickness of the explored sediments is 26 m (Fig. 13).

Lower Aptian platform carbonates are represented by well-bedded fossiliferous mudstones and wackestones and rudist coquinas. A microfossil assemblage with numerous foraminifera of extensive Early Cretaceous range contains Early Aptian *Sabaudia briacensis* ARNAUD-VANNEAU, fragments of palorbitolinids and bacinellas. Karstified Aptian limestones are overlain by a 30 cm thick sequence of basal conglomerate, with pebbles of limestones, carbonate sand and mud matrix. They are followed by intraclastic–fossiliferous wackestones and then predominantly biocalcarenite that mostly contains clasts of abraded rudists, bryozoans and corallinaceans. Probable source rocks were rud-

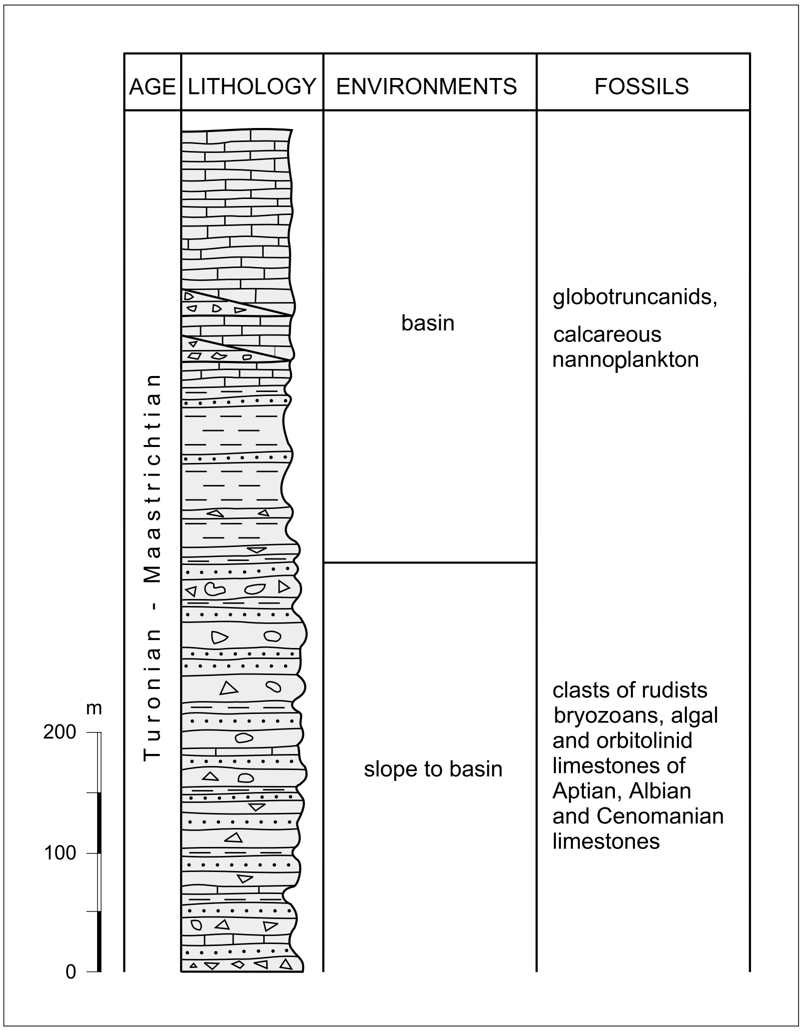


Fig. 12 The Kotor Varoš–Skender Vakuf profile.

ist assemblages near the platform margin. The central part of the carbonate clastic sequence is composed of an alternation of biocalcirudites and biocalcarenites containing orbitoids, siderolitids and omphalocycles of Campanian and Maastrichtian age. Biocalcarenites containing *Ethelia alba* (PFENDER) in the topmost part of column determine the Palaeocene age.

Depositional environments of the Maastrichtian sediments are defined as the back-reef shallows–fore-reef–upper part of the platform slope.

2.1.13. Vidovo vrelo

Near the Vidovo vrelo spring there is a road-cut in Maastrichtian–Palaeocene clastics 8 m wide and 2.5 m high (Fig. 1, location 13; Fig. 14). The exposed rocks are heterogeneous and of complex composition.

Within the sandy–clayey matrix there are irregularly spaced fragments and thinner bedded fragments and blocks of various types of platform shallow marine limestones ranging in age from Barremian to Maastrichtian. The clasts are usually subrounded and measure from 5 to 80 cm. There are also disintegrated and folded beds, parts of beds or lithoclasts of clayey mudstones and marls of Campanian–Maastrichtian age that together form subaqeous slump structures.

Palaeontological analyses of clasts revealed their age as either Albian or Turonian–Early Campanian on the basis of numerous foraminifera species such as *Mesorbitolina texana* (ROEMER), *M. subconcava* LEYMERIE, *M. pervia* DOUGLAS, *Pseudonummoloculina heimi* (BONET), *Moncharmontia apenninica* (DE CASTRO), *M. compressa* (DE CASTRO), *Dicyclina schlumbergeri* MUNIER-CHALMAS, *Scandonea samnitica* DE CASTRO, *Murgella lata* LUPERTO-SINNI, *Keramosphaerina tergestina* STACHE etc. A rich association of the Campanian and Maastrichtian calcareous nanoplankton was found both in clasts and in the slumped marl beds. The youngest clasts are either redeposited bioclasts or complete specimens of Maastrichtian rudists. Notably, there are no clasts of Cenomanian age, suggesting that the stratigraphic base of the Maastrichtian transgressive clastic deposits on the platform margin and slope were Early Albian and Turonian to Early Campanian limestones.

The described clastic deposits of the Vidovo vrelo outcrop can be defined as slump structures incorpo-

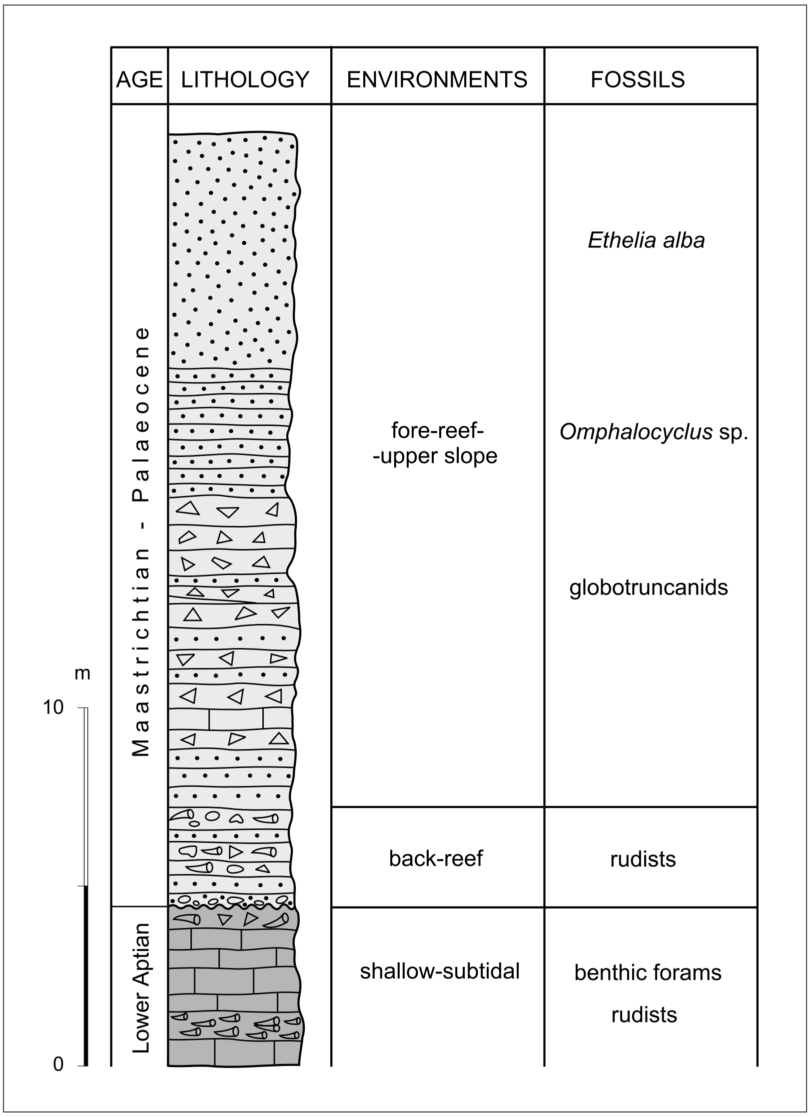


Fig. 13 The Paunovići (Skender Vakuf) column.

rated in the debris flow breccia. Due to the fact that no autochthonous fossils were found in the sandy–clayey matrix of these sediments, the age is estimated according to the age of the clasts, which are youngest Maastrichtian and oldest Palaeocene.

2.1.14. Trijebovo (Mrkonjić grad)

Near the village of Trijebovo, W of Jajce (Fig. 1, location 14) a geological column of approximately 40 m was analysed at the contact between Upper Albian limestones and carbonate clastics of Maastrichtian–Palaeocene age. The lithological composition of Maastrichtian clastics is very interesting because this unit is mostly represented by conglomerate–breccia (Fig. 15).

These karstified Upper Albian platform limestones have identical facies characteristics to those in the Liskovica and Bešpelj areas (see section 2.1.15.), and are transgressively and unconformably overlain by the Maastrichtian coarse carbonate clastics, mostly calcirudites (breccia) with subordinate calcarenites. Basal biocalcarenites consist mostly of rudist fragments and benthic foraminifera of the platform margin and slope provenance (genera *Orbitoides*, *Siderolites*, *Omphalocyclus*), with sporadic Albian to Upper Cretaceous limestone lithoclasts containing pithonellid calcisphaeres. The predominating breccia member consists of lithoclasts of the same composition and age as the calcarenites, only of larger dimensions. These are most frequently subrounded to angular clasts of Upper Cretaceous rudist and calcisphaere limestones, together with less frequent clasts of the Albian orbitolinid and ostracod limestones. There are also rudist and bryozoan bioclasts. The matrix of carbonate sand has the same petrographic composition as the lithoclasts. The only internal structure in the breccia is a general gradation (fining-upwards).

The stratigraphic range of these clastics is estimated from the age of the fragments – as the youngest bioclasts contain Maastrichtian foraminifera it can be interpreted as being of Late Maastrichtian to Palaeocene age.

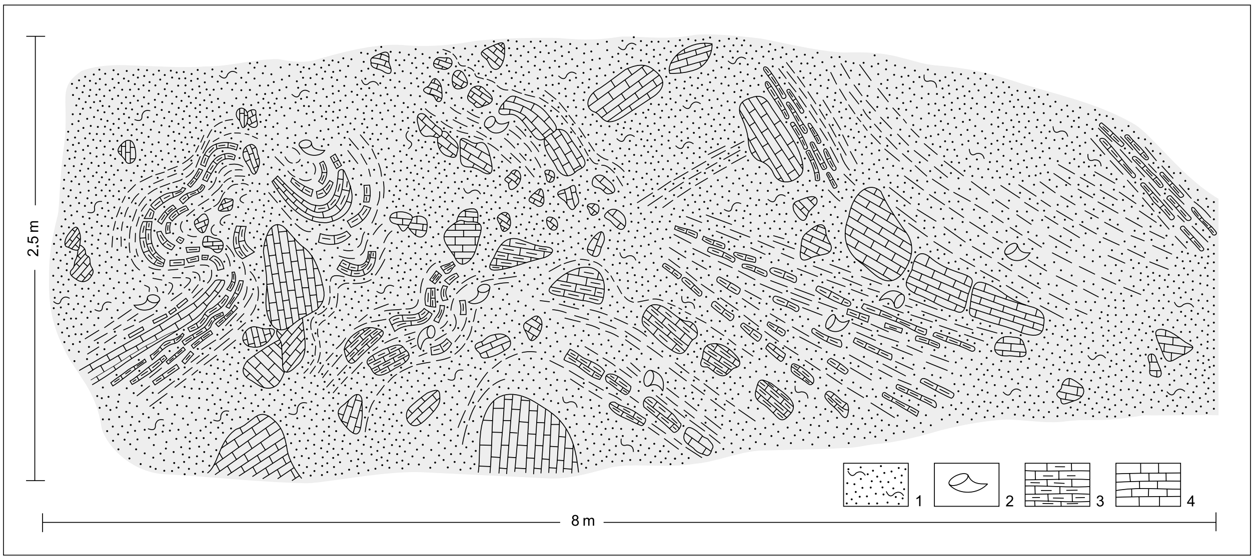


Fig. 14 The Vidovo vrelo outcrop. Legend: 1) sandy–clayey matrix; 2) resedimented Maastrichtian rudists; 3) Santonian–Campanian clayey mudstone; 4) Barremian to Santonian limestones.

2.1.15. Liskovica – Bešpelj

Several detailed columns were measured N of Jajce, along the contact of the younger Lower Cretaceous platform carbonates with the clastic–carbonate sediments of the younger Upper Cretaceous deposited in slope to basin environments. The locations include Brenica (in the canyon of the Vrbas river), Liskovica, Donji Bešpelj, Kober, Crvene stijene, Poljane and Brnjići. In the base of the Upper Cretaceous clastic sediments there are karstified Albian limestones, the palaeo-depressions (*dolinas*) of which are filled with large and economically very important bauxite deposits. The best known are those at the Liskovica and Bešpelj localities (Fig. 1, location 15) which have similar stratigraphic–sedimentological characteristics and will be illustrated with a single stratigraphic column (Fig. 16).

The basal platform limestones are mostly represented by muddy varieties with a marked shallowing-upward tendency (stacking of mudstone–fenestral mudstone small-scale cycles), occasionally with emersions that resulted in interbeds of emersion mud-pebble conglomerates. There are also sparse interbeds of rudist coquinas. An Upper Albian age was determined on the basis of the microfossil assemblage containing orbitolinids *Neoiraquia insolita* (DECROUEZ & MOULLADE) and *Valdanchella dercourti* DECROUEZ & MOULLADE.

The karstified palaeorelief of the Albian limestones with sporadic bauxite deposits in palaeodolinas and depressions was transgressively overlain by either the Upper Santonian and Campanian platform margin carbonates or by the Upper Santonian to Maastrichtian flysch deposits. Contacts are marked by a very low angular unconformity. When traced along the strike at Liskovica, the base of the sequence is variable – e.g. there are either conglomerates with pebbles of basal limestones, or shallow-marine grain-supported limestones, or even rudist biolithites. Biolithites are most frequently found at Bešpelj, where they directly overlie bauxite deposits. Rudists are in the growth position, intraformational space being filled up with carbonate sand consisting of rudist fragments, benthic foraminifera and fragments of echinoids, bryozoans, etc. The biolithites are covered by rudist coquinas passing both vertically and laterally into alternations of biocalcirudites and biocalcarenites. The continuation of the column is marked with an increasing proportion of marl in alternation with calcarenites and calcirudites, and deposits gradually acquire a turbiditic character. Carbonate clasts originated exclusively from the destruction of rudist lithosomes and their redeposition in the reef and fore-reef shallows and on the platform slope.

The facies characteristics of these deposits clearly reflect changes of depositional environments in the following sequence: carbonate shallows–reef–fore-reef–platform slope. A depositional age of Upper Santonian to Maastrichtian is documented by numerous index fossils – benthic foraminifera such as *Murgella lata* LUPERTO-SINNI, *Keramosphaerina tergestina* STACHE, *Pseudorhapydionina mediterranea* (DE CASTRO), *Orbitoides media* (d'ARCHIAC), *Siderolites calcitrapoides* LAMARCK, *Omphalocyclus macroporus* (LAMARCK), and numerous pelagic microorganisms – foraminifera (most frequently globotruncanids), pithonellid calcisphaeras and calcareous nannoplankton.

2.1.16. Seoci (Jajce)

In the Seoci village on the Jajce–Bešpelj road there is a 20 m long and 4–6 m high road-cut opened in debrites (Fig. 1, location 16; Fig. 17).

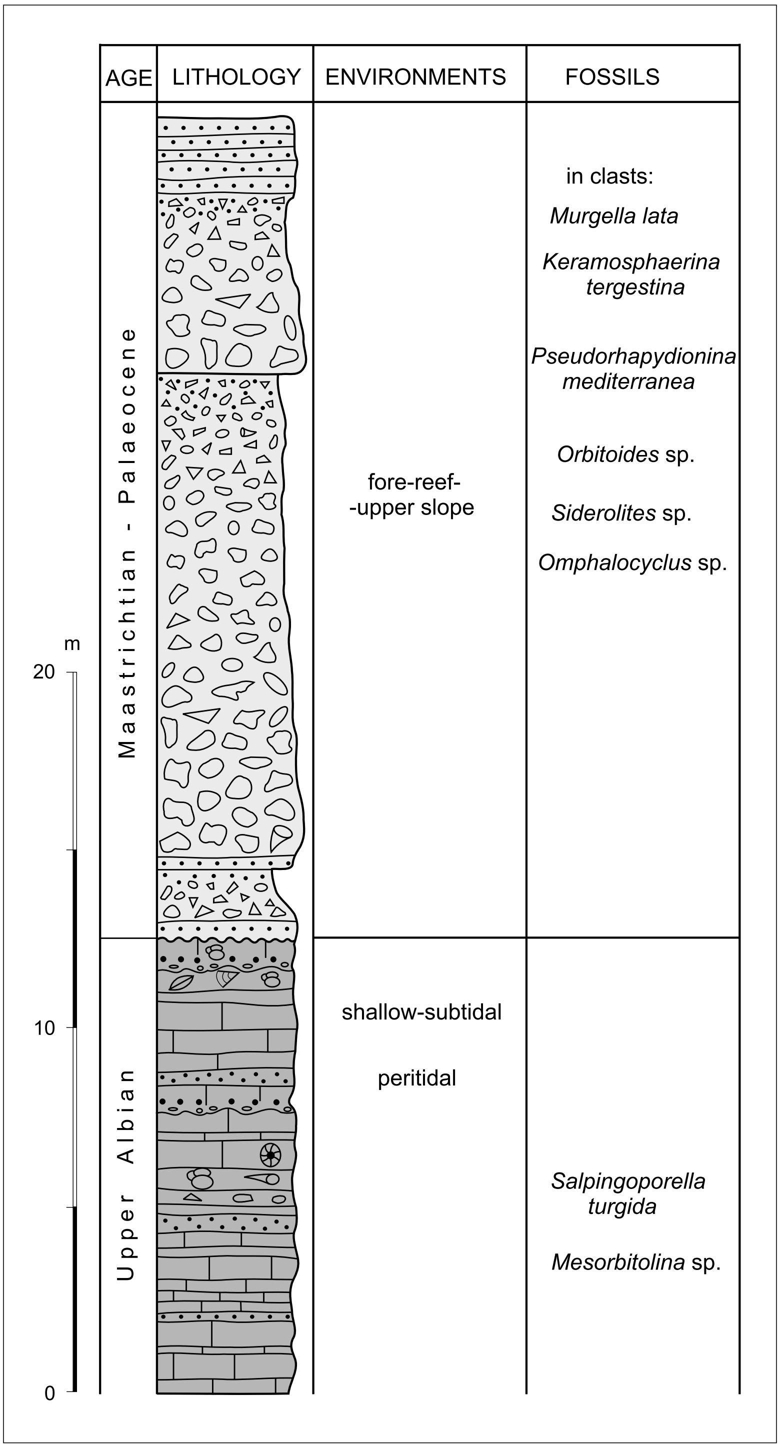


Fig. 15 The Trijebovo (Mrkonjić Grad) column.

These coarse-grained sediments consist of variously sized lithoclasts in a sandy–clayey matrix: larger clasts measure 5–200 cm, and smaller ones, which are the most frequent, less than 5 cm. Clasts originated from various types of limestones of Barremian to Albian age, and also from sequences of Upper Cretaceous clastic–carbonate sediments. They are mostly angular or weakly rounded. Marl clasts are, in addition, deformed.

The sediment is completely unsorted and chaotic. Since the terrain is covered it is impossible to study lateral and vertical relationships. Nevertheless, this is interpreted as a channel sedimentary body because the largest clasts were mostly found in the central part of the outcrop and their size gradually diminishes towards both flanks. It is also concluded that such sediments were probably formed from massive rock-falls which occurred at the platform margin as a consequence of synsedimentary seismo-tectonic activity. The accumulated material was transported down the platform slope in the form of grain flows which incorporated increasing amounts of muddy material and were thus changed into debris flows.

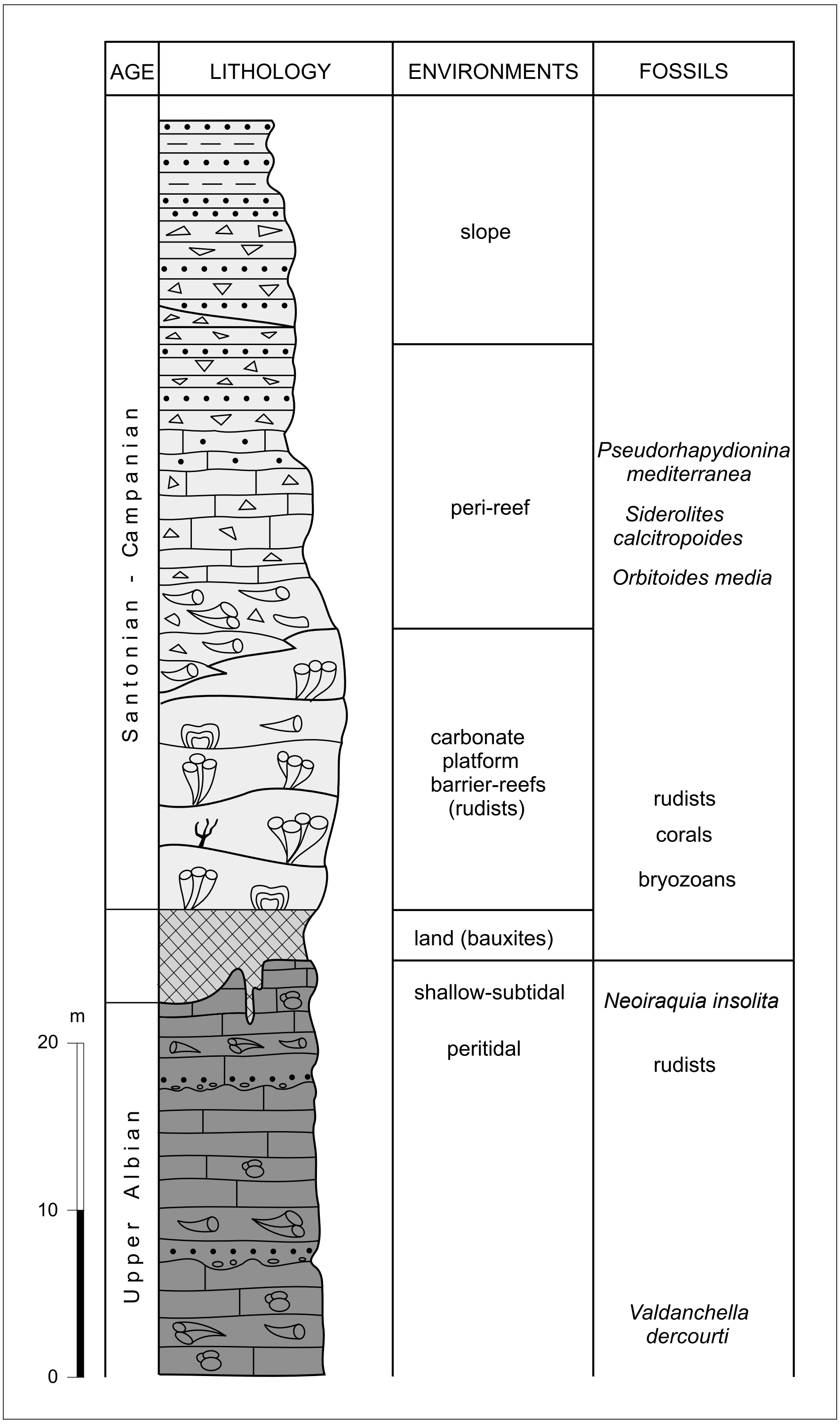


Fig. 16 The Liskovica–Bešpelj column.

According to the stratigraphic age of the clasts and matrix these debrite deposits are of Maastrichtian age.

2.1.17. Ravanac

This column was measured NE of Jajce (Fig. 1, location 17), and the sequence of deposits is approximately 45 m thick, composed of Cenomanian and Santonian limestones and Maastrichtian–Palaeocene carbonate clastics (Fig. 18).

The Cenomanian part of the column (15 m thick) starts with a coquina of small current-oriented rudists. It is covered by the alternation of mostly fossiliferous varieties of platform carbonates – mudstones, pelletal mudstones, wackestones and packstone–grainstones within which a stromatolite interbed >1 m thick was observed. These limestones are of Middle Cenomanian age, since they contain a benthic foraminifera association where the most important species are *Conicor-*

Fig. 17 The Seoci (Jajce) outcrop.

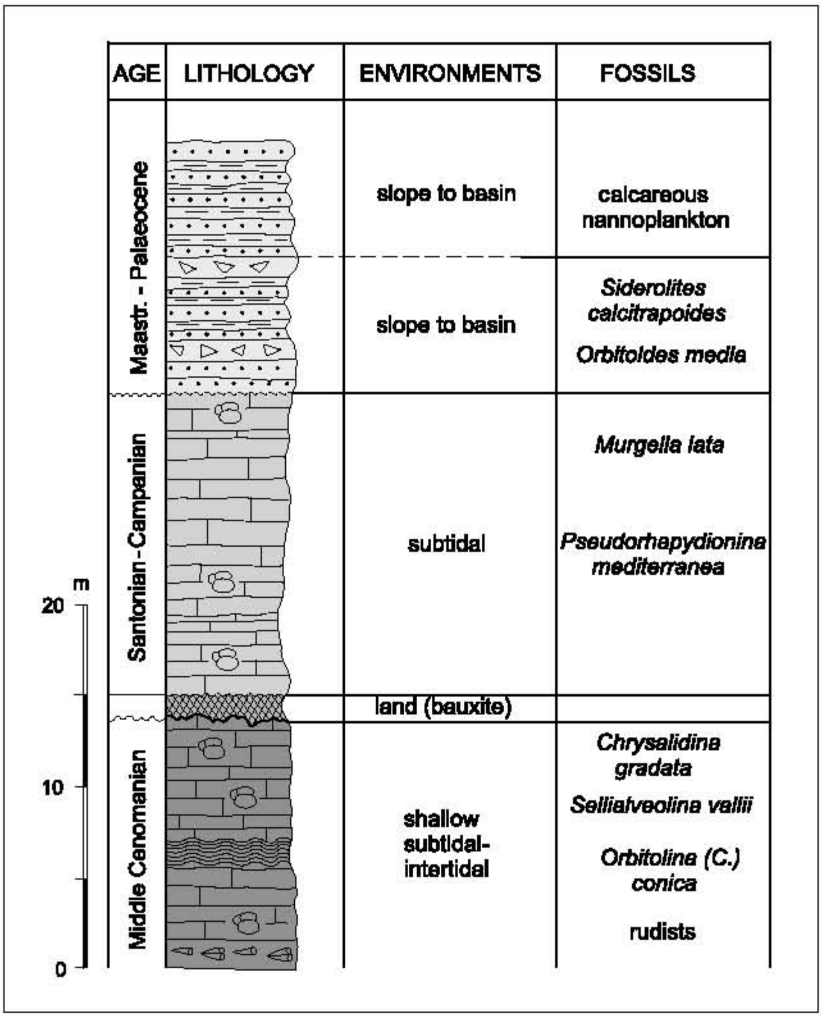


Fig. 18 The Ravanac column.

bitolina conica (d'ARCHIAC), *Sellialveolina viallii* COLALONGO, *Chrysalidina gradata* d'ORBIGNY and *Pseudolituonella reicheli* MARIE.

Karstified Cenomanian limestones are overlain by a 70–150 cm thick "layer" of bauxite, which is in turn, gently unconformably, covered by a 17 m thick package of Santonian rudist platform limestones consisting of an alternation of fossiliferous fenestral mudstones and wackestones. Their Upper Santonian age is confirmed by the presence of *Murgella lata* LUPERTO-SINNI.

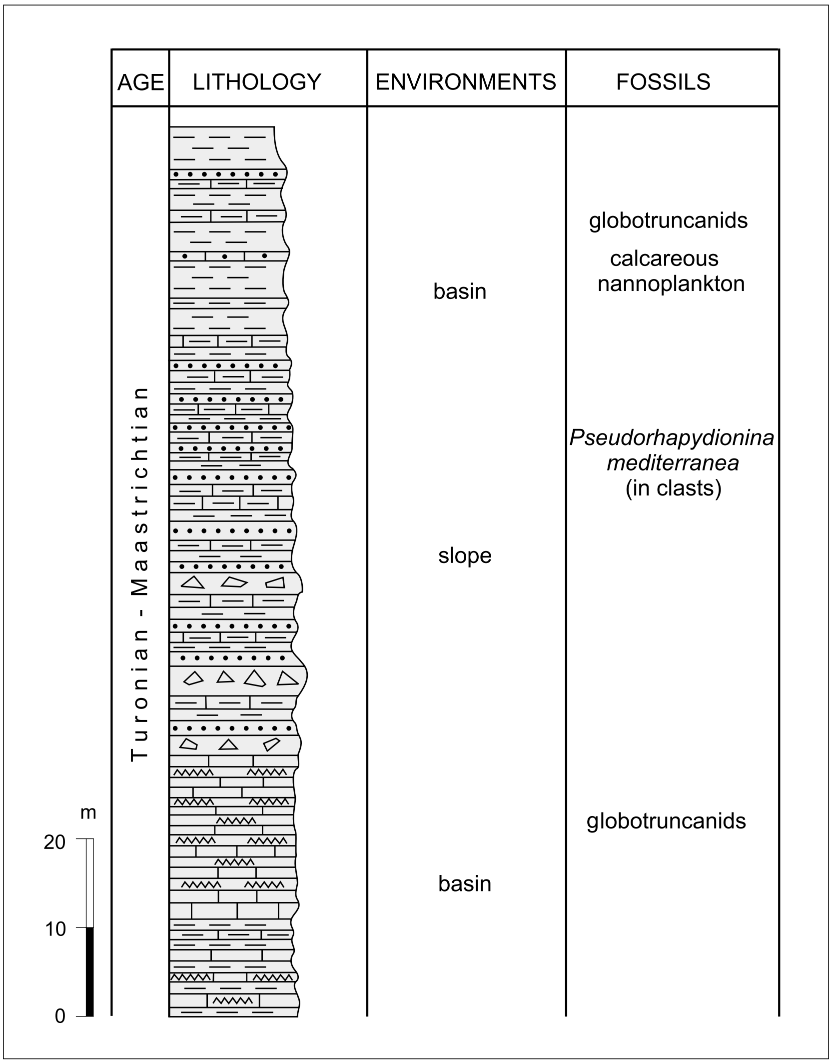


Fig. 19 The Bila column.

Santonian limestones are transgressively and unconformably overlain by Maastrichtian–Palaeocene carbonate clastics. They are represented by the alternation of biocalcirudites, biocalcarenites, marls and clayey micrites. The first three members are typical for the turbidite sequences of the platform slope environment, while the inserts of clayey limestones pertain to the basinal environment with autochthonous pelagic sedimentation. In the coarse-grained intervals, lithoclasts are of Albian to Campanian age, including slope benthic foraminifera of Campanian and Maastrichtian age (orbitoids, siderolitids). Pelagic organisms – calcareous nannoplankton and globigerinids define the Palaeocene age of the clayey limestones.

2.1.18. Bila

The Bila column is approximately 100 m thick (Fig. 19) and was measured in order to investigate sediments of completely basinal characteristics. It is located in the canyon of the small river Bila, NW of Zenica (Fig. 1, location 18). The lowest 30 m consist of an alternation of globotruncanid mudstones, cherts, silicified mudstones, mudstones with chert lenses, clayey mudstones and marls. Mudstones are autochthonous pelagic sediment and include frequent globotruncanids, calcisphaerulids and heterohelicids.

Marls with parallel lamination in the lower parts of beds, represent distal turbidites, while numerous fragmented planktonic forms in the topmost parts of beds indicate hemipelagic sedimentation. The brown-reddish to greenish-grey cherts represent radiolarites.

The middle part of the column, (40 m thick), consists of an alternation of calcirudites, calcarenites, marls and clayey micrites. The coarse-grained members are composed of rudists, bryozoans, lithothamnion and benthic foraminiferal bioclasts, as well as clasts of the Upper Cretaceous limestones, clasts of orbitolinid limestones and other types of younger Lower Cretaceous limestones. All these clasts originated from carbonate units of the platform margin and upper slope.

Marls prevail in the third, terminal part of the column, within a 30 m thick sequence. The lower part of this interval consists of complete turbidite sequences deposited in the middle of a depositional fan. Undercut

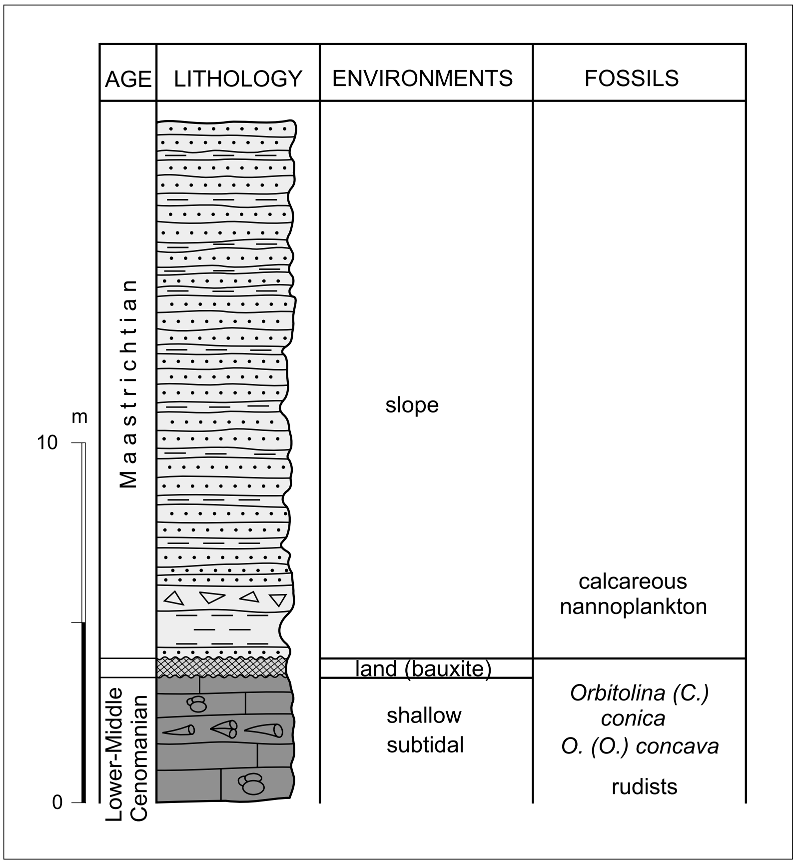


Fig. 20 The Guča Gora column.

sequences (mostly Tb–e) in the upper part indicate distal turbidites.

The described deposits are composed of material originating from the destruction of rudist lithosomes and of shallow marine carbonates of the platform margin and platform slope, as well as from the autochthonous basinal pelagic deposits. A Campanian–Maastrichtian age is determined on the basis of the globotruncanid association.

2.1.19. Guča Gora

This column was surveyed on the SE slopes of Vlašić Mt., W of Zenica (Fig. 1, location 19). A sequence of sediments 25 m thick comprises Cenomanian carbonates in contact with the youngest Upper Cretaceous carbonate clastics (Fig. 20).

Cenomanian limestones are represented by the irregular alternation of mudstones, fossiliferous wackestones to grainstones, intraclastic grainstones and rudist coquinas deposited in the platform shallows, mostly under the influence of stronger currents. Several index species of Cenomanian orbitolinids were identified from the fossiliferous grainstones.

Karstified Cenomanian grainstones are covered by an approximately 10 cm thick interbed of bauxite. Above the bauxite there is a thinner bed of bauxitic clay, covered by a thinner bed of calcarenite, and then by approximately 150 cm of marl. The marl is overlain by a thicker biocalcirudite bed followed by the relatively regular alternation of well-bedded biocalcarenites and marls. The depositional environment was the carbonate platform slope.

Clasts in calcirudites and calcarenites include Lower Aptian limestones with orbitolinids, Upper Albian algal limestones, Cenomanian limestones, calcisphaera limestones, rudist bioclasts and fragmented Campanian–Maastrichtian foraminifera (siderolitids, orbitoids and globotruncanids). In the marls there are numerous tiny unidentifiable globotruncanids that belong to the autochthonous pelagic sediment, as well as calcareous nannoplankton in the topmost parts of the marl beds. According to the fossil content, the described deposits are of Campanian and Maastrichtian age.

2.1.20. Kaonik

The column was measured SW of Zenica (Fig. 1, location 20), and the geology of this locality is comparable to that at the Jagare (Banjaluka) area. Upper Triassic late-diagenetic dolomites in the base are unconformably overlain by Late Cretaceous carbonate clastics (Fig. 21) composed of the regular alternation of calcirudites, calcarenites, marls and clayey mudstones. Two bodies of breccio–conglomerates are especially marked in the upper part of the column.

Calcirudites and calcarenites are composed of rudists and large foraminiferal bioclasts of Campanian and Maastrichtian age (orbitoids and siderolitids), as well as

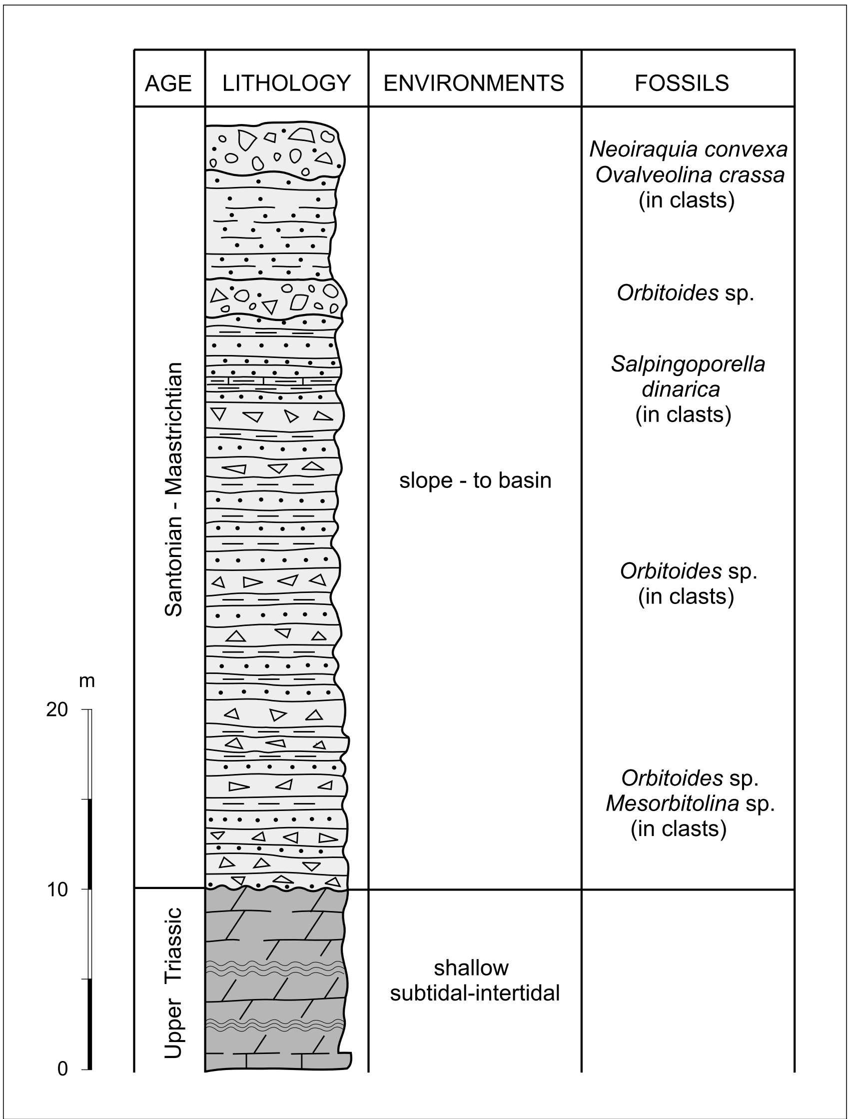


Fig. 21 The Kaonik column.

lithoclasts of Cenomanian and Turonian calcisphaera limestones and Aptian and Albian limestones. The mud matrix contains frequent fragmented globotruncanids. The marls and clayey limestones contain undeterminable pelagic foraminifera.

The structure and composition of the breccias is very interesting. They comprise limestone clasts and pebbles from a few to 40 cm in size. The sparse matrix consists of clayey carbonate sand. Clasts originate from the platform limestones of various stratigraphic ages, determined mostly on the basis of microfossils.

According to their sedimentological characteristics, the described deposits represent typical turbidites which most frequently contain complete Bouma sequences. Both chaotic sequences of breccia within the turbidites have erosive lower surfaces, and are interpreted as debris flows. The depositional environment of these clastics was the toe-of-the-slope and transition to the basin. The source area was the faulted and locally emerged platform margin, where material was provided by the rudist biolithites and erosion of older rocks.

2.1.21. Čardak livade

This location is N of Glamoč (Fig. 1, location 21) where, during the Late Cretaceous, there was an intraplatform trough (one of several) that existed in the broader area of the NE margin of the Adriatic Carbonate Platform. A sequence of sediments was studied from the Middle Cenomanian limestones in the base through the carbonate clastics and limestones of Coniacian–Campanian age to the Maastrichtian carbonate clastics (Fig. 22).

Basal Middle Cenomanian limestones are represented by the alternation of fossiliferous varieties – from wackestone to grainstone, formed in subtidal environments. This is confirmed by very rich associations of benthic foraminifera including *Chrysalidina gradata* d'ORBIGNY, *Broeckina* (*Pastrikella*) *balcanica* CHERCHI et al., *Pseudorhapydionina dubia* DE CASTRO and *P. laurinensis* DE CASTRO. The karstified palaeorelief of these limestones is covered by a 1–3 m thick bauxite body which is transgressively (with low angle unconformity) overlain by three thick calcirudite beds

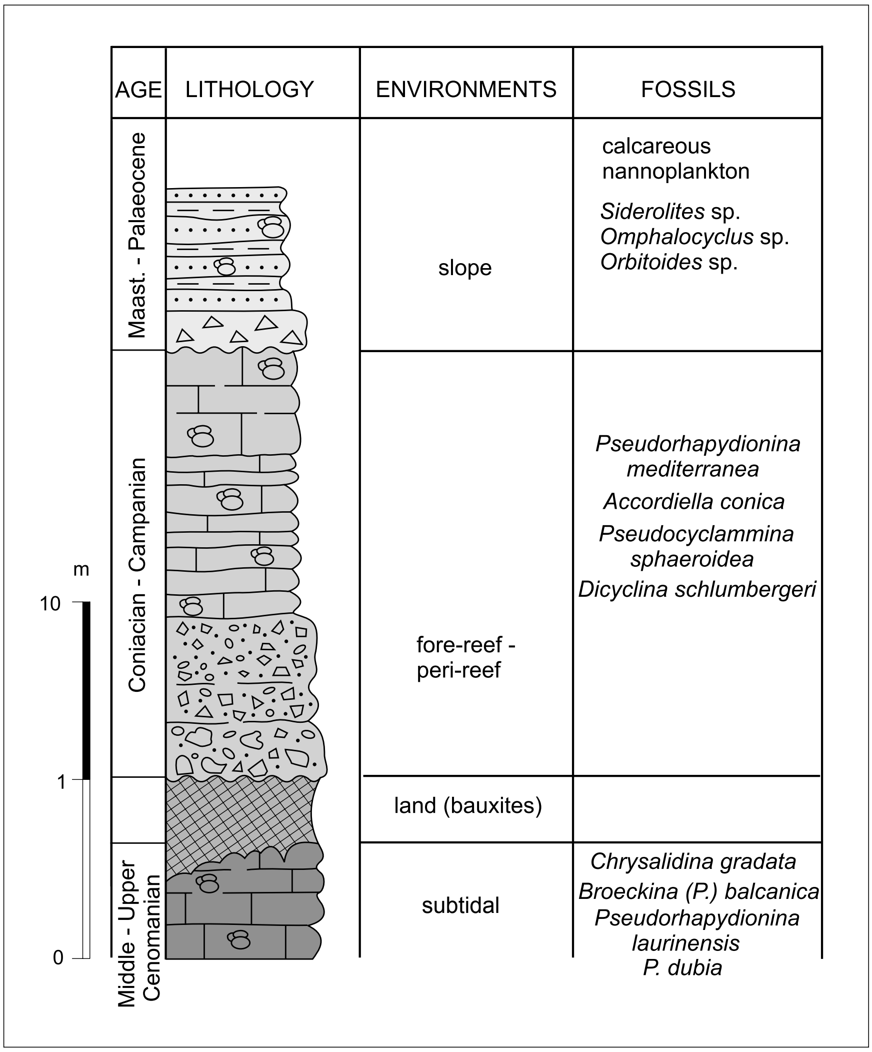


Fig. 22 The Čardak livade column.

of carbonate breccia, composed of fragments of basal Cenomanian limestones that measure 5–40 cm. They are calcite-cemented. The breccia is covered by fenestral mudstones followed by thick-bedded wackestones. These rocks contain a microfossil foraminiferal association *Pseudorhapydionina mediterranea* (DE CASTRO), *Accordiella conica* FARINACCI, *Dicyclina schlumbergeri* MUNIER-CHALMAS and *Pseudocyclammina sphaeroidea* GENDROT of Coniacian to Santonian age, and were deposited in the platform shallows. Contact with transgressive Maastrichtian–Palaeocene carbonate clastics shows no angular unconformity and lacks signs of karstification. This sequence starts with biocalcirudites followed by the alternation of biocalcarenites and marls. Campanian–Maastrichtian benthic foraminifera (orbitoids, siderolitids and omphalocycles) were found in the calcarenites, and some associations of calcareous nannoplankton determined in marls indicate the Maastrichtian–Danian contact horizon. Detritus originated from destroyed rudist bioherms and from carbonate sand and mud of the platform shallows. The poorly developed gradation and parallel lamination depict local transport in fore-reef environments.

2.1.22. Strojice

The column was measured NW of Kupres (Fig. 1, location 22), where an exposed sequence (85 m thick) consists of carbonates of platform margin and carbonate clastic slope deposits occurs towards one of the intra-platform troughs in the general area of the NE margin of the AdCP (Fig. 23).

The platform margin carbonates are represented by a 12 m thick alternation of fore-reef bioclastic grainstones and fossiliferous wackestones, and contain rare mudstones of more restricted environments. There are relics of biolithite bodies in the grainstones that contain corals, stromatoporoids, bryozoans, echinoids, algae, foraminifera, gastropods and bivalves (including rudists). The rudists are mostly redeposited, but there are also some in growth position, representing the reef environment at the margin of one of the intra-platform troughs. The Upper Barremian age was determined by discovery of the orbitolinids *Rectodictyoconus giganteus* SCHROEDER and *Palorbitolina lenticularis* (BLUMENBACH).

The karstified Barremian limestones are transgressively and unconformably overlain by a 12 m thick

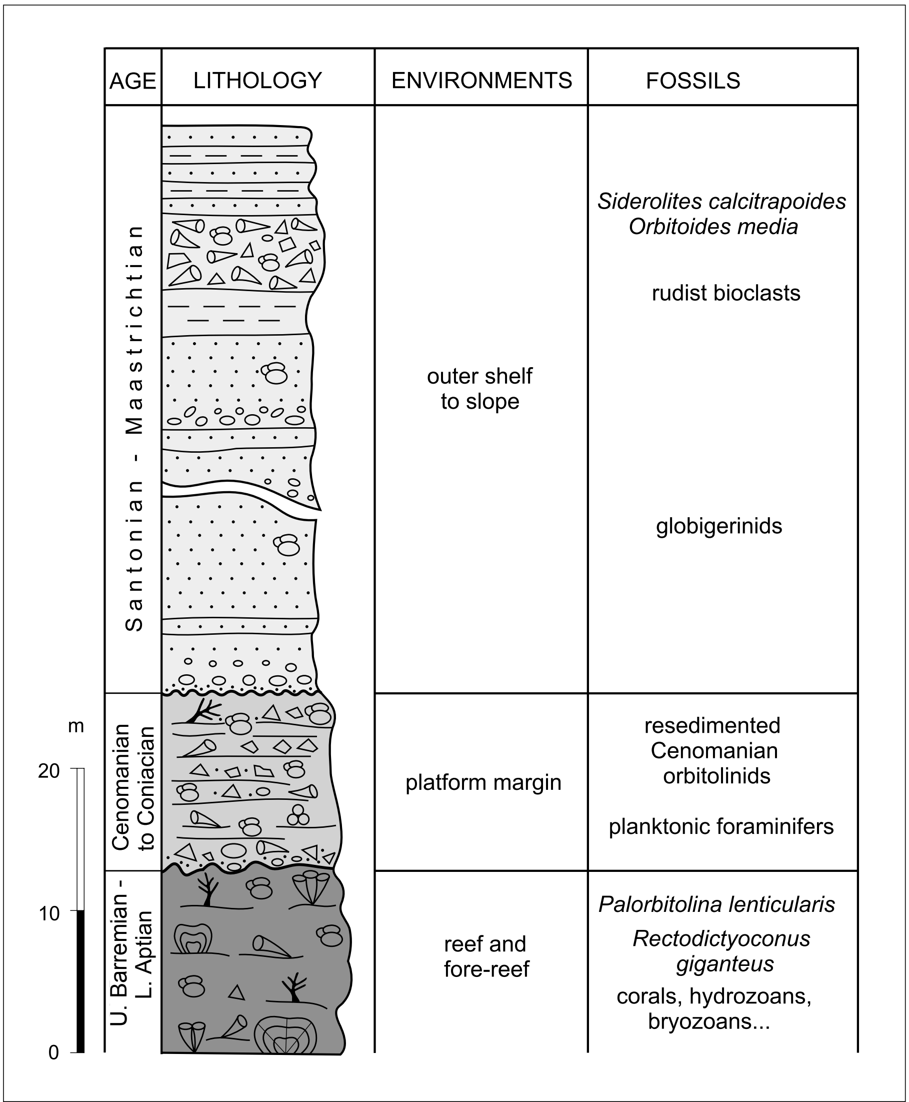


Fig. 23 The Strojice (Janj) column.

sequence of calcareous basal breccia–conglomerate with pebbles and fragments of Barremian to Cenomanian limestones. Fine-grained carbonate mud matrix contains unidentifiable planktonic foraminifera. Lithoclasts are orbitolinid limestones of Lower Aptian, Albian and Cenomanian age, while bioclasts are composed of Albian and Cenomanian orbitolinids, gastropods, and a lot of bivalves, mostly rudists. The breccia–conglomerate is covered by a 55 m thick transgressive sequence of massive fine-grained clayey arenite, which only sporadically exhibits weak bedding. The particles are limestone–dolomite sand-sized grains, rarely chert and igneous rocks grains, with clayey mudstone matrix with tiny globigerinids. Gradation and parallel lamination are rarely observed in this interval. These rocks were deposited in shallow marine environments with a low coastline and flattened lowlands behind it. The arenites are overlain by 3 m of marl and a final, 5 m thick massive bed composed of unsorted biocalcirudite with up to 5 cm sized particles of Lower Cretaceous limestone lithoclasts and rudists, orbitoids, siderolitids and heterohelicids. The matrix is fine-grained carbonate sand. The described biocalcirudite is followed by flysch deposits with the characteristic alternation of calcarenites and marls.

This depositional environment is interpreted as a carbonate slope where the source material was derived from both older carbonate rocks of the platform margin and Campanian–Maastrichtian rudist bioherms and carbonates from the platform shallows.

2.1.23. Kupres

At the southern margin of the Kupres polje, 75 m of Upper Tithonian and Berriasian carbonates in contact with the Upper Cretaceous carbonate clastics were studied. These were deposited in fore-reef to platform slope environments (Fig. 1, location 23; Fig. 24). Due to the complex recent tectonic relationships in the area, it is difficult to define whether this is the NE margin, the "main" slope of the AdCP, or just the margin and slope of one of the intraplatform troughs in the broader area of the platform margin.

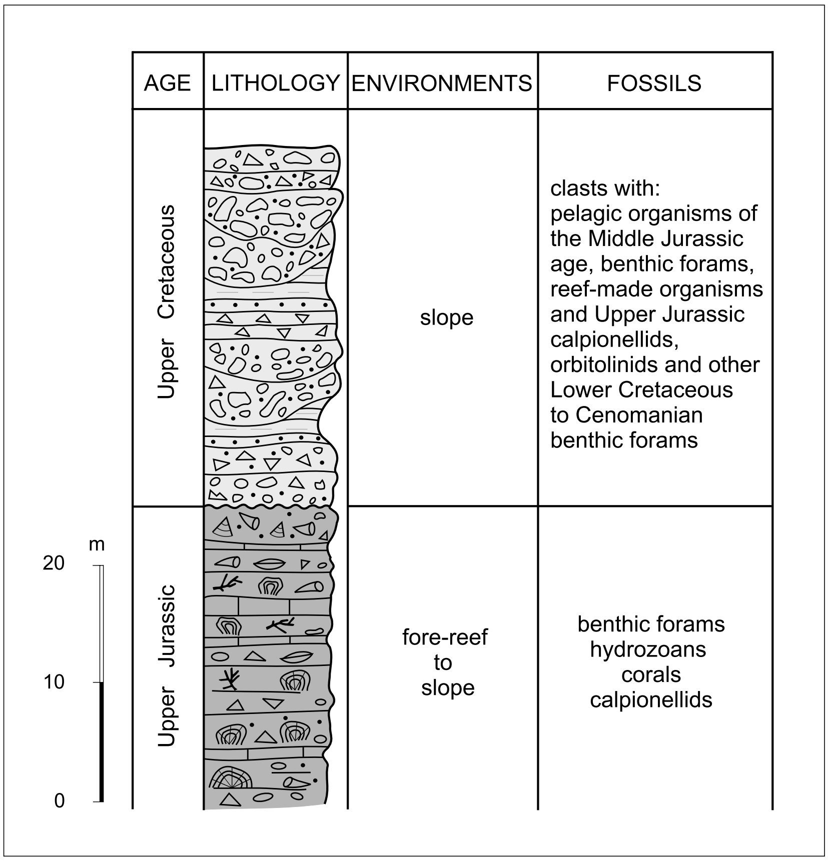


Fig. 24 The Kupres column.

Interestingly, the basal Tithonian–Berriasian sediments and transgressive Upper Cretaceous carbonate clastics in part of this column both represent slope facies characterised by the processes of destruction and redeposition of the Tithonian–Berriasian reef-forming organisms and of lithoclasts derived from platform margin deposits of units older than Upper Cretaceous.

The basal, thick-layered limestones are mostly composed of clasts of reef-building organisms – corals, hydrozoans, stromatoporoids, bryozoans, sponges, echinoids, gastropods, bivalves and algae. In the grain-supported varieties they are the only component of the rock, while in the mud-supported carbonates they represent isolated clasts in a matrix containing autochthonous pelagic microorganisms – calpionellids, radiolarians and small foraminifera. These limestones are transgressively overlain by thick-bedded breccias composed of both rounded and angular clasts which originate from the platform and slope carbonates of a wide stratigraphic time span, ranging from Middle Jurassic limestones with filaments, Upper Jurassic fore-reef and reef limestones, Tithonian–Berriasian fossiliferous calpionella mudstones, Valanginian–Hauterivian fossiliferous packstone–grainstones, Barremian–Aptian orbitolinid limestones, and bioclasts of hydrozoans, corals, molluscs, rudists etc. The matrix is represented by carbonate mud that contains tiny Upper Cretaceous planktonic foraminifera. Gradation is observed in some of the breccia beds. The base of each layer is frequently irregular, due to erosion of the underlying layer. Lateral relationships in the field cannot be explored because of the Quaternary cover, and it can only be assumed that these breccias are debrites deposited on the platform slope. The large stratigraphic range and variety of clasts suggest fast and intense mechanical weathering of the faulted and partly also emerged steep platform margins. Large masses of coarse-grained material were accumulated along a broad front and transported down the slope by gravitational currents.

2.2. Correlation of studied geological columns

On the basis of analysis of the relationships of the investigated facies along the NE margin of the Adriatic Carbonate Platform only partial correlations are possible, although rarely within Jurassic and Lower Cretaceous deposits and more frequently within Upper Cretaceous sequences.

The Jurassic palaeogeography of the investigated area was characterised by the predominant deposition of oolithic limestones during the Early and Middle Jurassic, but also a long-lasting hiatus along the very platform margin, lasting from the Middle Lias to the Kimmeridgian (Figs. 25–27). In the Kimmeridgian and the Tithonian the area was characterised by barrier coral–hydrozoan reefs (Fig. 28). Such relationships have been noticed on the Martinšćak–Barilović (Fig. 5) and Subotica (Fig. 9) geological columns, which can be well correlated.

On the platform slope, predominantly mud-supported limestones comprising pelagic organisms and litho- and bioclasts originating from shallow-marine marginal platform environments were deposited contemporaneously from the Middle Lias. In some levels clasts are so frequent that they form breccia deposits, which in places represent part of the debris flows, e.g. in the Žumberak–Samobor Mts. (Fig. 2), Subotica (Fig. 9) and Kupres (Fig. 24) columns.

Data on the Lower Cretaceous marginal facies are very scarce. In the recent geological framework Lower Cretaceous deposits are common, but are mostly of inner platform facies, e.g. subtidal, lagoonal or peritidal algal–foraminiferal limestones with frequent salpingoporellas, orbitolinids and other microfossils. Some temporary emersions have been documented within the Lower Cretaceous deposits, the most important of which were those in the Albian, including a lengthy hiatus in the Jajce area, which lasted until the Late Santonian (Liskovica–Bešpelj column, Fig. 16), or even the Maastrichtian (Trijebovo column, Fig. 15), and included development of significant bauxite deposits. In the area of Janj (south of Jajce) an important emersion was recorded from the Late Barremian/Early Aptian to the Late Cenomanian (Strojice column, Fig. 23), which also resulted in frequent clayey mudstone interbeds within the Albian deposits of the neighbouring shallow-marine areas.

These long-lasting emersion phases represent the consequence of tectonic activity in the marginal part of the platform. The very variable successions of the Cenomanian deposits are especially interesting, indicating differential tectonic influences in the studied area. Along the platform margin, Cenomanian deposits have been documented in the vicinity of Karlovac (Dubravčani, Fig. 4), in the Kordun area (Cetingrad, Fig. 7), east of Jajce (Ravanac, Fig. 18), in Vlašić Mt. (Guča Gora, Fig. 20), north of Glamoč (Čardak livade, Fig. 22) and in the Janj area (Strojice, Fig. 23). Among these columns, Dubravčani, Ravanac and Čardak livade are very similar, since karstified Cenomanian limestones are overlain by bauxite occurrences and deposits, followed by Coniacian–Campanian limestones. In the Guča Gora column bauxites are covered by Maastrichtian flysch.

Upper Cretaceous slope and basin deposits are determined in most of the columns, with the most common stratigraphic range being from the Campanian to the Maastrichtian. In the Cetingrad column (Fig. 7) older deposits (Cenomanian to Campanian) are also present, while in the Otoka column (Fig. 8) sedimentary continuity from the Cenomanian to the Maastrichtian was supposed.

In the investigated marginal area of the AdCP, from Žumberak to Kupres, stratigraphically different deposits, ranging from Upper Triassic to the Upper Santonian/lowermost Campanian age, are overlain by youngest Upper Cretaceous clastic–carbonate deposits, indicating significant pre-Santonian synsedimentary tectonics. Upper Triassic shallow-marine carbonates are overlain by Upper Cretaceous flysch deposits in Cetingrad (Fig. 7), Jagare (Fig. 10) and the Kaonik columns (Fig. 21). Upper Jurassic limestones and dolomites or Tithonian–Berriasian slope–basin "calpionella limestones" represent the underlying deposits of flysch in the Ozalj (Fig. 3), Budački Gornji (Fig. 6), Cetingrad (Fig. 7), Otoka (Fig. 8) and Kupres columns (Fig. 24). Lower Aptian deposits are overlain by Upper Cretaceous flysch deposits in the Paunovići column (Fig. 13), and Upper Albian in the Trijebovo column (Fig. 15). An Upper Cretaceous age for deposits of underlying flysch has been determined in the Cetingrad column (Cenomanian; Fig. 7), Liskovica–Bešpelj and Ravanac (Upper Santonian/Lower Campanian; Figs. 16 and 18), Guča Gora (Lower to Middle Cenomanian; Fig. 20), Čardak livade (Coniacian to Lower Campanian; Fig. 22) and Strojice (Middle Cenomanian to Coniacian; Fig. 23).

According to the results obtained by investigation at the aforementioned localities it is obvious that palaeogeographic relationships were variable during the geological history of the northeastern margin of the AdCP. By correlation of events recorded in different columns, geodynamic changes may be reconstructed, facilitating the evolution of the NE platform margin to be deciphered.

2.3. Carbonate sequences of the northeastern margin of the Adriatic Carbonate Platform

In spite of the fact that the Adriatic Carbonate Platform was isolated as a separate shallow marine depositional system on the Adria plate during the Early Jurassic, description of the carbonate sediments of the platform margin will start with the Upper Triassic deposits. Upper Triassic carbonates ("Hauptdolomit") and Lower Jurassic platform carbonates are both in sedimentological and stratigraphic continuity, in spite of the fact that AdCP started as an isolated carbonate platform system from the latest Sinemurian or earlier Pliensbachian. For the purpose of this review, the two characteristic groups of sediments will be described separately – the shallow marine carbonate facies of the platform margin (1) and the facies of the platform slope together with the basinal facies (2). It should be pointed out that "Hauptdolomit" was the palaeoenvironmental precursor on the entire shallow marine area of the Adria Microplate which split into several isolated carbonate platforms. Within the carbonate sequences of all those Periadriatic platforms there are "Hauptdolomit" deposits.

2.3.1. Platform shallow marine facies along the NE margin of the AdCP

In the NE marginal part of the AdCP, carbonate platform sediments ranging from the Early Jurassic to the end of the Cretaceous were determined. Numerous geological columns and sections were investigated between the Žumberak area in Croatia to the Kupres polje and river Bosna in Bosnia and Herzegovina (Fig. 1). In addition, the available published data were used, although they are mostly older because field work in this area was impossible for almost 15 years.

2.3.1.1. Upper Triassic

Shallow marine carbonate sediments of Upper Triassic age are found in almost continuous strike along the entire NE margin of the AdCP, from western Slovenia to southern Montenegro and northern Albania. Due to the fact that individualisation of the AdCP happened in the Early Jurassic, Upper Triassic carbonates cannot be considered as AdCP deposits but as their older foundation.

Two characteristic formations of different lithological composition are discerned – (1) the limestone–dolomite formation, partly comparable with the well known "Dachstein limestones" of the Southern Alps, and (2) the dolomite formation with prevalence of the so-called "Hauptdolomit" or the "Dolomia principale" ("Main dolomite"), distributed throughout the Perimediterranean region, also with a holotype in the Southern Alps. The platform margin between the Žumberak region and central Bosnia has a base of "Hauptdolomit", composed of light-coloured layered stromatolitic and laminated early-diagenetic dolomites, alternating with darker medium to coarse-crystalline late-diagenetic dolomites. Occasionally, there are also thin layers or lenses of grey limestones, mostly fossiliferous wackestones to grainstones.

In the limestones, the following association of foraminifera of Upper Triassic involutinides was determined: *Aulotortus friedli* (KRISTIAN-TOLMANN), *A. sinuosus* (WEYNSCHENK), *Auloconus permodiscoides* (OBERHAUSER) and *Triasina hantkeni* MAJZON, with occasional occurrences of macrofossil megalodon shells.

In the marginal parts of the platform in Herzegovina, Montenegro and in northern Albania, the Upper Triassic is developed into two formations (as in the Southern Alps) – the limestone formation consisting of the megalodon ("Dachstein") limestones and the dolomite formation ("Hauptdolomit"). Similar conditions are also found at the platform margin in western Slovenia where the lower part of the Upper Triassic is represented by dolomites in a facies corresponding to the "Hauptdolomit" and the upper part by Dachstein limestones.

2.3.1.2. Lower Jurassic

In Croatia, Lower Jurassic carbonates of the platform margin crop out at numerous localities in Žumberak – NE and E of Sošice, and in the Samobor Mts. (ŠIKIĆ & BASCH, 1975; PLENIČAR et al., 1976; BABIĆ, 1976; ŠIKIĆ et al., 1978; BUKOVAC & SOKAČ, 1989; BUCKOVIĆ et al., 2001), in the surroundings of Karlovac, along the downstream parts of the Mrežnica and Korana river valleys (BUKOVAC et al., 1974, 1984), and in the Kordun area at several localities near Slunj (SOKAČ, 1964; KOROLIJA et al., 1980; ŠPARICA, 1981). The shallow marine middle Lower Jurassic platform fossiliferous mudstones with benthic microfossils were described by ŠPARICA (1981) at a single location in the Banovina region (Prosinja west of Žirovac), where they are found "surrounded" by deep marine Jurassic facies. Similar sediments are found in NW Bosnia – N and NE of Bihać (POLŠAK et al., 1977), in the vicinity of Bosanska Krupa (MOJIČEVIĆ et al., 1978), W of Banjaluka (ĐERKOVIĆ et al., 1976; MOJIČEVIĆ et al., 1977; JELASKA, 1987), in the surroundings of Ključ (VRHOVČIĆ et al., 1983), in the region between the upstream part of the Sana river valley and the river Vrbas (near Manjača), and also S of Banjaluka (MARINKOVIĆ & AHAC, 1980). In central Bosnia, Lower Jurassic limestones and dolomites are found not only at several locations in the vicinity of Jajce (MARINKOVIĆ & AHAC, 1980), south-west of Šipovo and in the northern part of the Kupres polje (VUJNOVIĆ, 1980), but also along the western and southern margin of the same polje (PAPEŠ, 1972, 1985) as well as near Prozor and Jablanica lake in the Neretva river canyon (SOFILJ & ŽIVANOVIĆ, 1979).

Lower Jurassic carbonates are represented by fossiliferous limestones, partly wackestones to packstones that were mostly deposited in the restricted inner platform shallows and/or lagoons, and partly packstone–grainstones from the platform shallows close to the very margin of the platform where the oolitic limestones also frequently occur (Figs. 25, 26). They were found in the vicinity of Karlovac in Croatia (BUKOVAC et al., 1974), and especially in western (JELASKA, 1987; MOJIČEVIĆ et al., 1979) and central Bosnia (PAPEŠ, 1975, 1985; SOFILJ et al., 1980; VUJNOVIĆ, 1981; VRHOVČIĆ & MOJIČEVIĆ, 1983). Dolomites are almost entirely of late-diagenetic origin occurring as thin layers or lenses in the limestones, or occasionally as an equal part of the limestone–dolomite sequence.

These sediments are relatively rich in fossils, mostly molluscs – gastropods, bivalves, brachiopods, as well as calcareous algae and benthic foraminifera. The Early Jurassic age of these carbonates is determined from a benthic microfossil assemblage containing the early and middle Lower Jurassic (Hettangian to Pliensbachian) index species – algae *Palaeodasycladus mediterraneus* (PIA), *Sestrosphera liasina* PIA, *Solenopora liasica* LE MAITRE, and foraminifera *Lituosepta recoarensis* CATI and *Orbitopsella praecursor* (GUEMBEL). Uppermost Lower Jurassic (Toarcian) carbonates at this margin, but also on the entire platform are markedly barren with no significant or index fossils.

The Lower Jurassic of the NE margin of the AdCP in Slovenia, from Tolmin (BUSER, 1987) towards Vrhnika and Novo Mesto (BUSER, 1968, 1969; BUSER

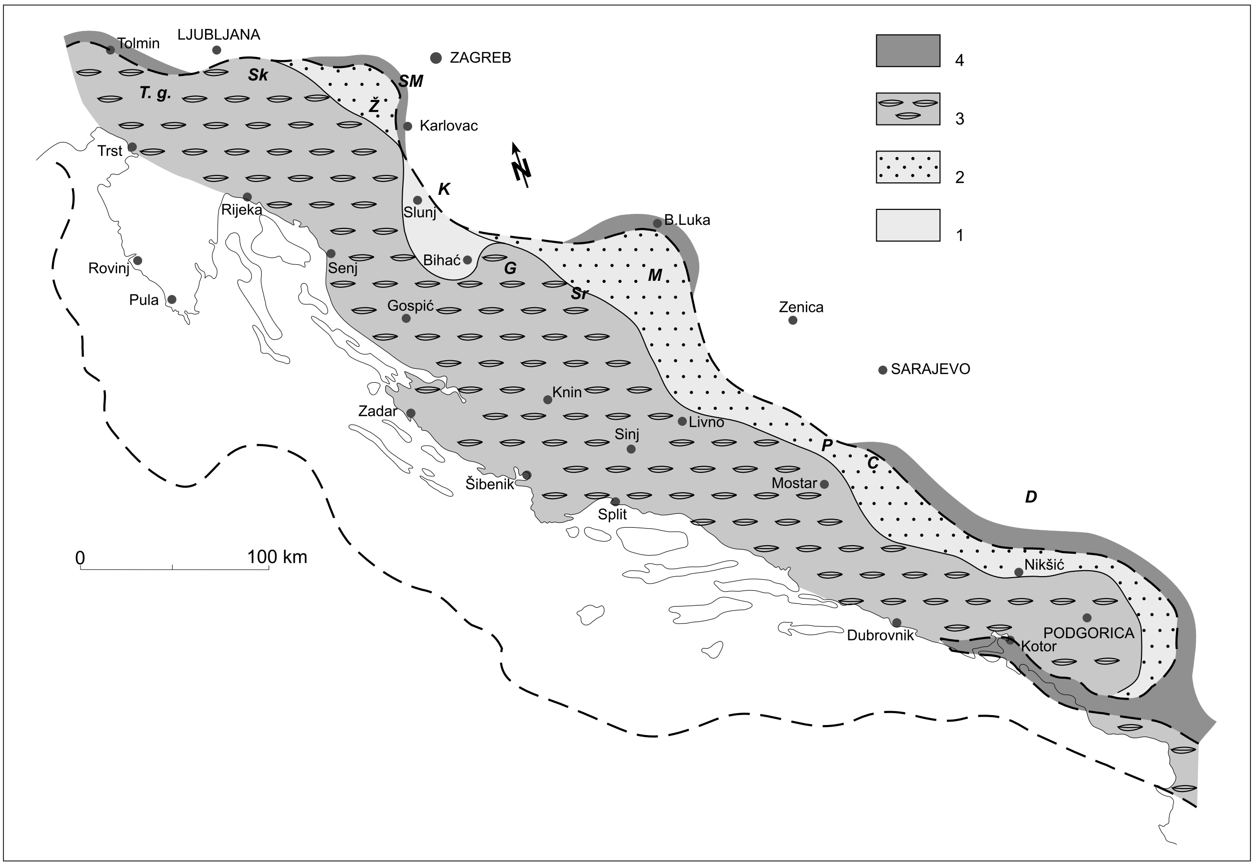


Fig. 25 Recent position of the Pliensbachian NE platform margin deposits. Legend: 1) inner platform carbonate deposits; 2) ooid grainstones; 3) "Lithiotis" limestones; 4) slope to basin deposits.

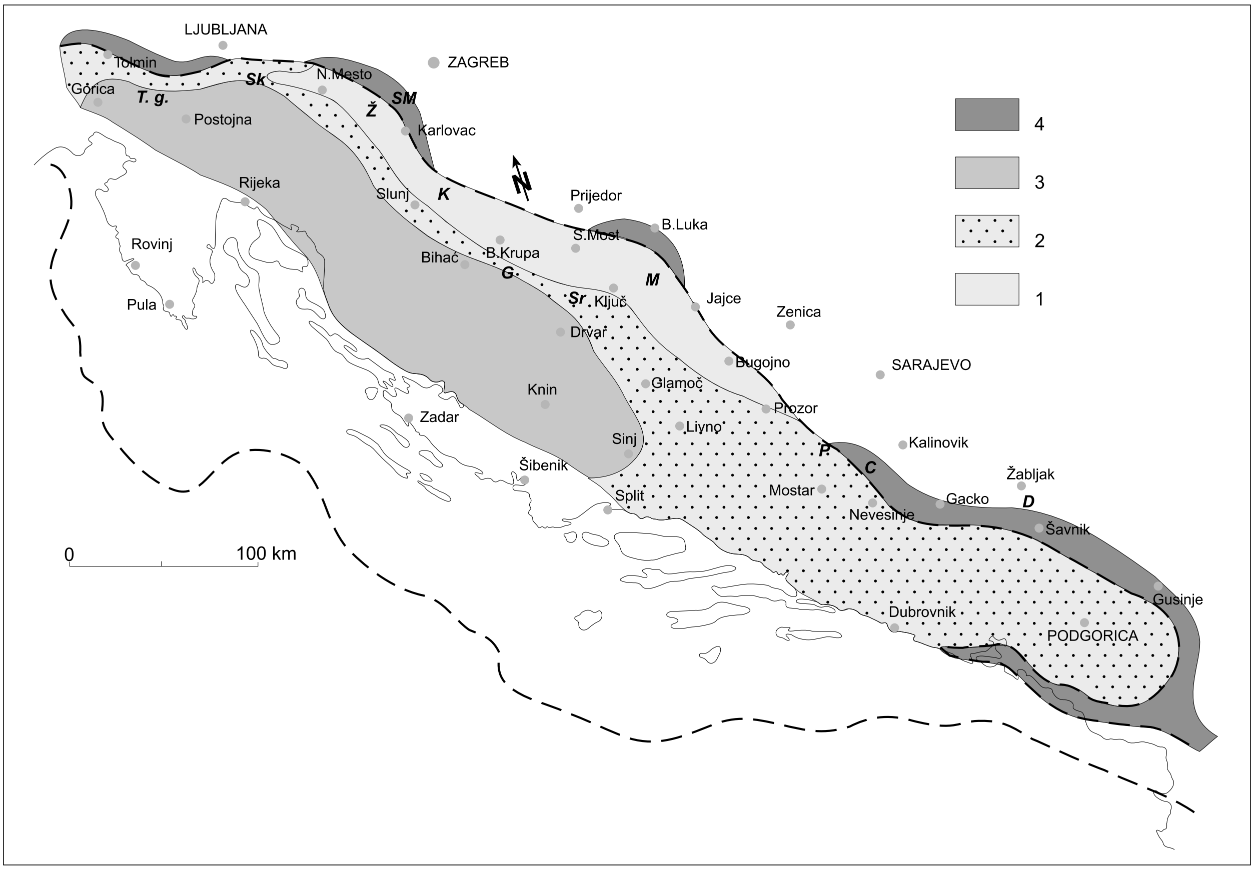


Fig. 26 Recent position of the Toarcian NE platform margin deposits. Legend: 1) emerged area; 2) ooid grainstones; 3) "spotty limestones"; 4) slope to basin deposits.

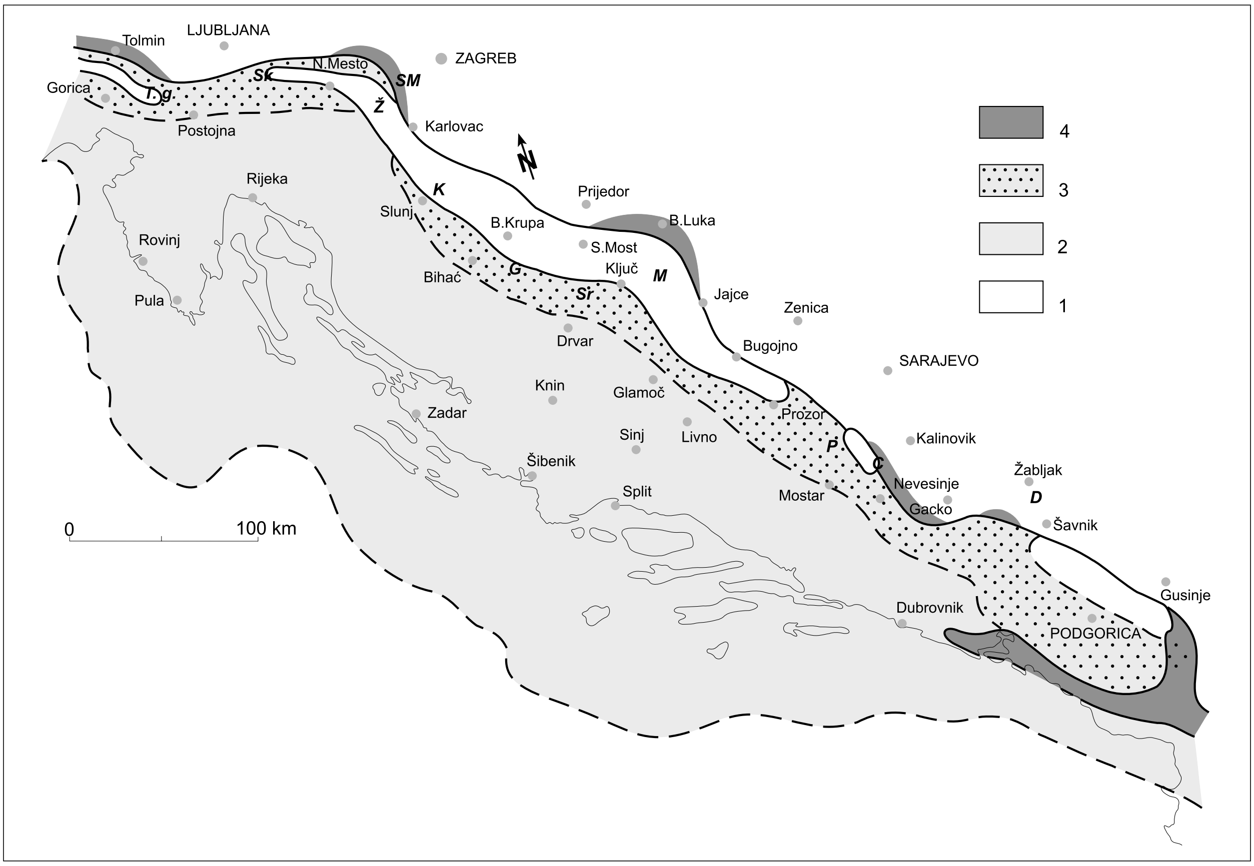


Fig. 27 Recent position of the Middle Jurassic NE platform margin deposits. Legend: 1) emerged areas; 2) inner platform deposits; 3) ooid grainstones; 4) slope to basin deposits.

et al., 1967; DOZET & ŠRIBAR, 1998a), Krško and Gorjanci (i.e. Žumberak) area (PLENIČAR et al., 1976) consists of well layered dark-coloured platform carbonates – interlayered mudstones, fossiliferous wackestones, oolitic grainstones and late-diagenetic dolomites. This carbonate sequence frequently contain interbeds of the lithiotid bivalve (*Lithiotis*, *Cohlaerites*; Fig. 25), gastropod and brachiopod coquinas.

The Lower Jurassic carbonates of the NE platform margin in Herzegovina and all the way through Montenegro to northern Albania (to the Cukali–Budva trough) are mostly covered by younger sediments. The sparse exposed sections are also marked by oolitic limestones (Figs. 25, 26) containing intercalations of late-diagenetic dolomite, only in the Lower Jurassic limestones which can be attributed to environments close to the marginal part of the platform found W of Nikšić, NE of Podgorica and in the Rumija Mt. (VUJISIĆ, 1972; ŽIVALJEVIĆ et al., 1971; MIRKOVIĆ et al., 1977; RADOIČIĆ, 1966).

2.3.1.3. Middle Jurassic

Within the study area of the platform margin there are not many data of the Middle Jurassic sediments. They were mentioned at several locations, but they are only supposed as being associated with the Lower Jurassic carbonates and they have not so far been palaeontologically determined. In this way the Middle Jurassic was interpreted in Žumberak and in the Samobor Mts., as being composed of both the micrite varieties and oolitic limestones (RADOIČIĆ, 1966; PLENIČAR et al., 1976; ŠIKIĆ et al., 1978). Similar carbonate facies crop out along the platform margin in the vicinity of Bosanska Krupa, Ključ, W and S of Banjaluka, and also in the area of the Kupres polje and Prozor (PAPEŠ, 1975, 1985; MOJIČEVIĆ et al., 1979; MARINKOVIĆ & AHAC, 1980; SOFILJ et al., 1980; VRHOVČIĆ & MOJIČEVIĆ, 1983).

Middle Jurassic carbonates – thick-layered mudstones with interbeds of fossiliferous wackestones–packstones, have been found in the Kordun region N of Slunj with continuation in a SW direction towards Bihać and in the surroundings of Ključ. They contain characteristic microfossil benthic foraminiferal taxa: *Mesoendothyra croatica* GUŠIĆ, *Gutnicella cayeuxi* (LUCAS) in Alenian and Bajocian, *Paleopfenderina salernitana* (SARTONI & CRESCENTI) and *Satorina apuliensis* FOURCADE & CHOROWICZ in Bathonian, as well as algae *Selliporella donzellii* SARTONI & CRESCENTI in Bajocian and Bathonian.

The shallow marine Middle Jurassic deposits in the back-reef environments of the platform margin in Slovenia are generally marked by two types of carbonates: mud-supported limestones and oolitic limestones, and some significant occurrences of late-diagenetic dolomites (BUSER, 1969, 1987; BUSER et al., 1967; OREHEK & OGORELEC, 1981; DOZET & ŠRIBAR, 1998a; DOZET, 2000a, b). Of special importance are the occurrences of oolitic limestones of the Middle Jurassic and the lower part of the Late Jurassic of the platform margin. According to DOZET (2000a, b) they locally reach the thickness of approximately 450 to 500 m. These limestones have characteristics of the carbonate platform margin. Their long-lasting deposition and duration were the result of relative stability of palaeoenvironments in this part of the platform margin through the Jurassic period.

At the platform margin SE of the study area, the platform carbonate facies of Middle Jurassic age are known in Mt. Prenj (MOJIČEVIĆ & LAUŠEVIĆ, 1971) and east of Nevesinje in Herzegovina (MOJIČEVIĆ & LAUŠEVIĆ, 1969; MOJIČEVIĆ & TOMIĆ, 1982a), also in the Piva area and in the vicinity of Nikšić and Žabljak in Montenegro (VUJISIĆ, 1972; MIRKOVIĆ et al., 1979; MIRKOVIĆ & MIRKOVIĆ, 1987). This SE part of the platform margin in the Dogger was also marked by the predominance of two types of limestone – different mudstone varieties and oolitic grainstones with subordinate late-diagenetic dolomites. In conclusion, it can be stated that, the platform margin in the Middle Jurassic was dominated by oolitic limestones in the similar manner to that in the Early Jurassic.

2.3.1.4. Upper Jurassic

In the geological history of the AdCP, i.e. through the Jurassic and Cretaceous, its NE margin was the most prominent margin and most clearly marked during the Late Jurassic, especially in the Kimmeridgian and Tithonian. Generally, two facies groups were differentiated. The first one is composed of carbonates formed in back-reef environments close to the platform margin, in high energy shallows and in restricted shallows and lagoons, while the second group belongs to the platform barrier reefs (Fig. 28).

In the first group there is the alternation of fossiliferous algal–foraminiferal (sporadically also oncolitic) mudstones, wackestones and packstones, and more rarely occurring oolitic, intraclastic and tempestitic fossiliferous packstones–grainstones. They were deposited in restricted subtidal shallows, lagoons and fore-reef environments with clear characteristics of shallowing upward cycles. These limestones contain late-diagenetic dolomites, usually in the form of thin interbeds and in alternation with limestones, but there are also lenses and massive dolomite bodies of tens of km-sized bands. Limestones contain rich microfossil assemblages which determine the stratigraphic range of the entire Late Jurassic. The most important are algal species *Salpingoporella sellii* (CRESCENTI), *Clypeina jurassica* FAVRE and *Campbelliella striata* (CAROZZI), and foraminifera *Kurnubia palastiniensis* HENSON, *Labyrinthina mirabilis* WEYNSCHENK, *Parurgonina caelinensis* CUVILLIER et al. and *Neokilianina rahonensis* FOURY & VINCENT. In the study area this facies can be traced from the surroundings of Slunj in Croatia (KOROLIJA et al., 1980; ŠPARICA, 1981), through the area of Bihać in NW Bosnia (POLŠAK et al., 1977) and also Bosanska Krupa (MOJIČEVIĆ et al., 1978), Sanski Most (ĐERKOVIĆ et al., 1976), from Banjaluka (MOJIČEVIĆ et al., 1977) to Jajce (MARINKOVIĆ & AHAC, 1980) and to the Kupres polje in the central Bosnia (VUJNOVIĆ, 1980).

In the marginal part of the AdCP in Slovenia, Malm carbonate facies with these characteristics are not widely distributed. In the SE parts of the study area, they were determined at Mts. Prenj and Velež in Herzegovina (MOJIČEVIĆ & LAUŠEVIĆ, 1971; MOJIČEVIĆ & TOMIĆ, 1982b), while mostly younger Malm was found in Montenegro in the vicinity of Nikšić (VUJISIĆ, 1972) and Žabljak (MIRKOVIĆ & MIRKOVIĆ, 1987).

The second group of Upper Jurassic facies is represented by the coral–hydrozoan barrier reefs. These markedly marginal platform facies are the most prominent organic build-ups on the AdCP in its entire geological history. They remain relatively well preserved and extend from western Slovenia, south of the Slovenian trough along the northern, north-eastern and eastern margin of the platform all the way to southern Montenegro and northern Albania, to the Krasta–Cukali–Budva trough (Fig. 28).

These biolithite build-ups are composed both of the complete skeletons and fragments of reef-building organisms including hydrozoans, especially stromatoporoids, bryozoans, sponges, corals, calcareous algae, gastropods, bivalves, echinoids, foraminifera, etc. (Fig. 3). The complete palaeontological study of these fossils was not performed, except for the corals (TURNŠEK, 1997; TURNŠEK et al., 1981). In the literature, most papers dealing with stratigraphy usually contain quotations of the fossils from the mentioned macrofossil groups, e.g. the stromatoporoids such as *Ellipsactinia*, *Sphaeractinia*, *Actinostromina*, *Parastromatopora*, chaetetids *Bauneia*, *Chaetetopsis*, corals *Amphistraea*, *Stylosmilia*, *Montlivaltia*, *Thecosmilia*, gastropods *Ptygmatis*, *Nerinea*, *Phaneroptyxis*, *Cryptoplocus*, and bivalves *Diceras*, etc.

Within the reef facies, microfossils occur sporadically, including benthic foraminifera *Kurnubia palastiniensis* HENSON, *Labyrinthina mirabilis* WEYNSCHENK, *Parurgonina caelinensis* CUVILLIER, FOURY & PIGNATTI-MORANO, *Neokilianina rahonensis* FOURY & VINCENT and algae *Clypeina jurassica* FAVRE, *Campbelliella striata* (CAROZZI) and *C. milesi* (RADOIČIĆ).

Upper Jurassic barrier reefs were found in the broader surroundings of Karlovac in Croatia (BUKOVAC et al., 1974, 1984). Significant extension of these reefs has been known along the platform margin from Bosanska Krupa in NW Bosnia (ĐERKOVIĆ et al., 1976; MOJI-

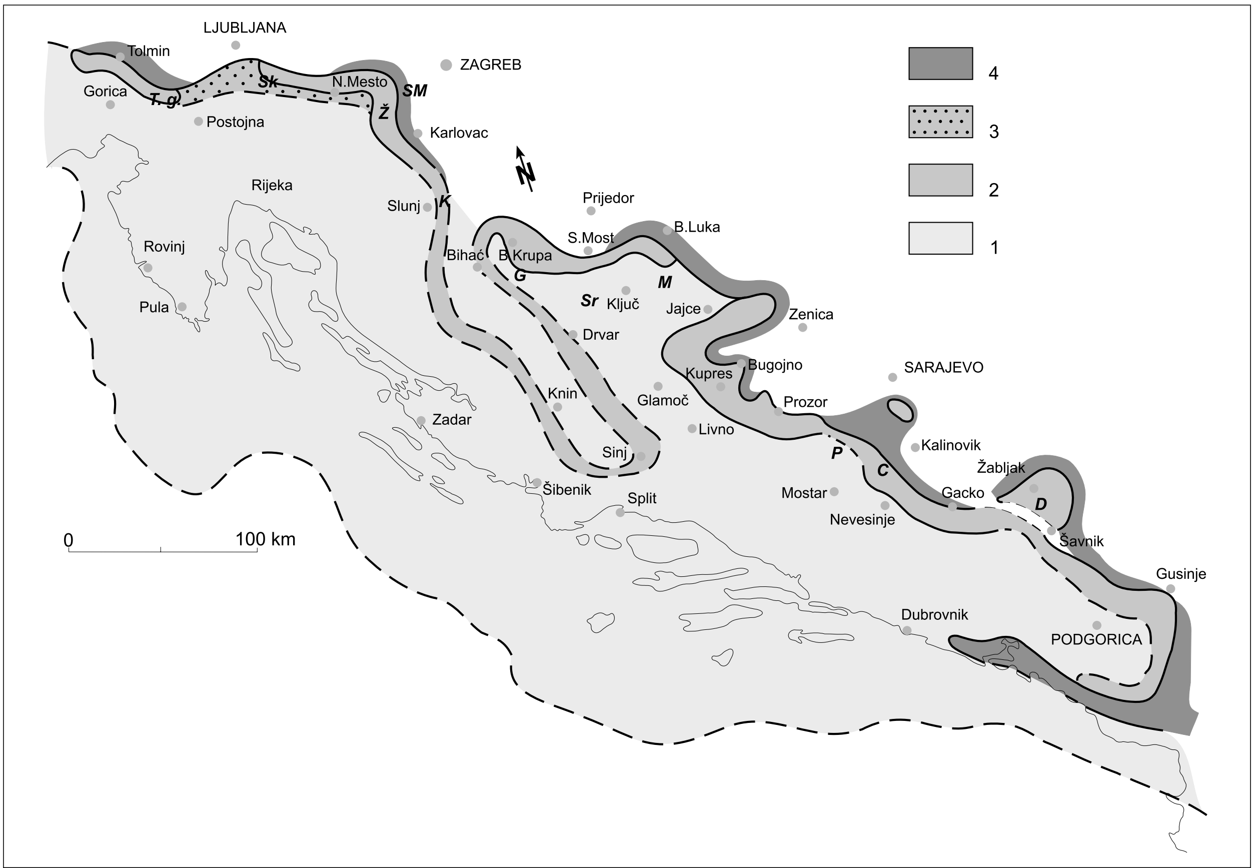


Fig. 28 Recent position of the Kimmeridgian and Tithonian NE platform margin deposits. Legend: 1) inner platform deposits; 2) coral–hydrozoan barrier reefs; 3) ooid grainstones; 4) slope to basin deposits.

ČEVIĆ et al., 1977, 1978; JELASKA, 1987) southeastward through central Bosnia (MARINKOVIĆ & AHAC, 1980; VUJNOVIĆ, 1980; ŽIVANOVIĆ et al., 1971; PAPEŠ, 1972) to northern Herzegovina (SOFILJ & ŽIVANOVIĆ, 1979) and south of Sarajevo (JOVANOVIĆ et al., 1977).

The continuation of reef facies of the platform margin is traced through Herzegovina, east of Velež (MOJIČEVIĆ & TOMIĆ, 1982a) and Nevesinje (MOJIČEVIĆ & LAUŠEVIĆ, 1969) to the Piva area in Montenegro (MIRKOVIĆ et al., 1979). They have been preserved in northern Montenegro – in the vicinity of Žabljak (MIRKOVIĆ & MIRKOVIĆ, 1987; MIRKOVIĆ & VUJISIĆ, 1989) and on Rumija Mt. (MIRKOVIĆ et al., 1977). Between these two regions, in northern Albania, there are no reliable data. Nevertheless, from the available literature (PEZA & PEZA, 1994) the existence of reef facies, either in the form of barrier reefs or patch reefs, can also be supposed for that marginal part of the platform N and NW of the Cukali–Krasta–Budva trough.

The Malmian coral–hydrozoan barrier reefs also extended along the NW margin of the AdCP in Slovenia, where they were most carefully palaeontologically investigated (e.g. TURNŠEK, 1966, 1997; TURNŠEK & BUSER, 1974; TURNŠEK et al., 1981). They strike from Novo Mesto (PLENIČAR et al., 1976) west towards Trnovski gozd Mt. and the Tolmin environs (BUSER, 1968, 1969, 1987; BUSER et al., 1967; TURNŠEK, 1997; TURNŠEK et al., 1981; DOZET & ŠRIBAR, 1998a).

These barrier reefs were rapidly subjected to abrasion and fragmentation while extant, due to the action of oceanic waves and currents, and also due to the influence of synsedimentary tectonics and earthquakes. This is the most important reason for the discontinuous appearance of this unit that strikes along the NE margin of the AdCP. These destructive processes provided the sources of different materials – blocks and clasts that were further crushed and redeposited in the back-reef shallows towards the inner part of the platform, but mostly at the platform slope, so they are found as fragments within the slope sediments and/or in the proximal basin sediments.

2.3.1.5. Lower Cretaceous

Lower Cretaceous platform carbonates crop out in the platform marginal area from Žumberak to the Kupres polje. They are known in the vicinity of Karlovac (BUKOVAC et al., 1974), in the Kordun area (KOROLIJA et al., 1980; ŠPARICA, 1981) and in the surroundings of Bihać (POLŠAK et al., 1977). They were also documented in NW Bosnia, in the area of Bosanska Krupa (MOJIČEVIĆ et al., 1978), Sanski

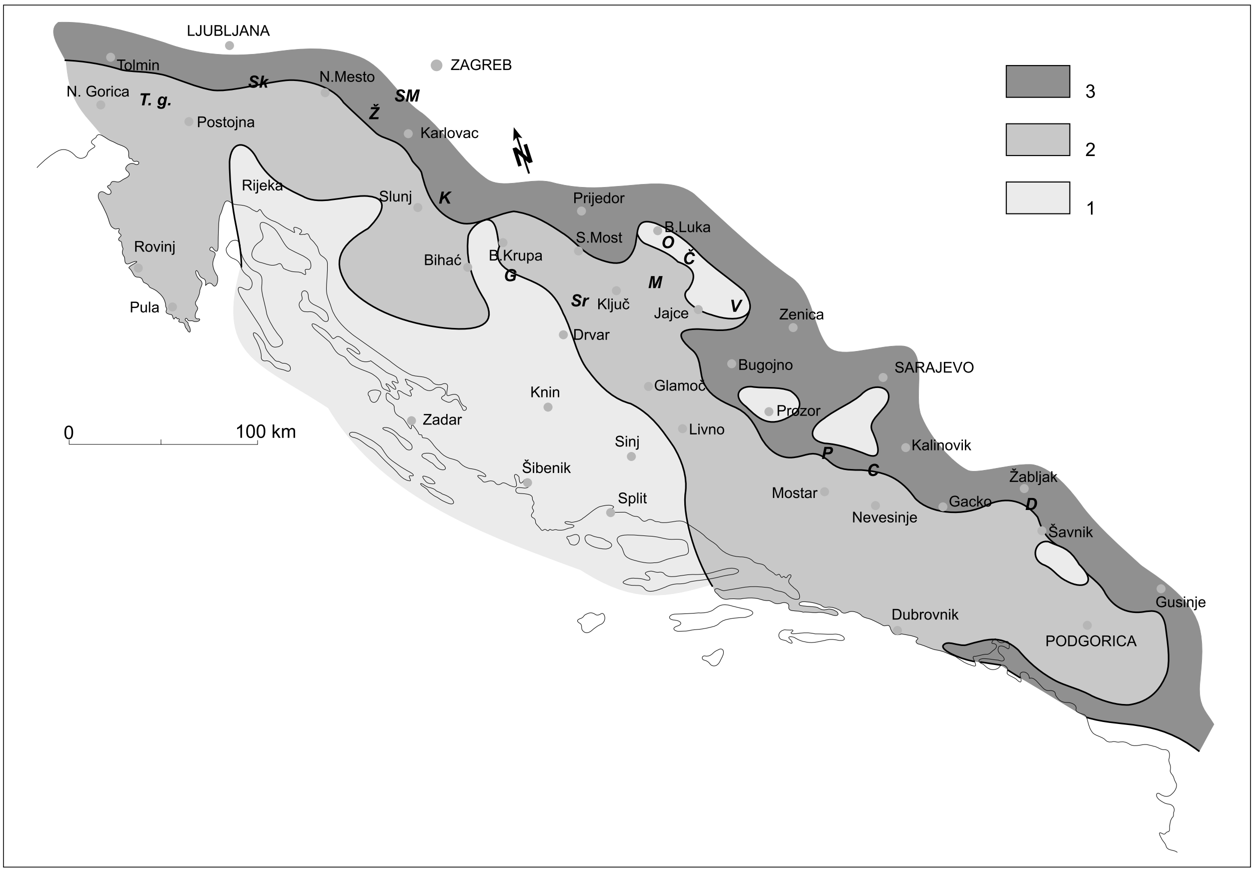


Fig. 29 Recent position of the Jurassic–Cretaceous transition NE platform margin deposits. Legend: 1) emerged areas; 2) inner platform carbonate deposits; 3) slope to basin deposits.

Most (ĐERKOVIĆ et al., 1976) and in the vicinity of Ključ to the SE (VRHOVČIĆ et al., 1983), in Manjača and on both slopes of the Vrbas river canyon (Fig. 5), in the broader region of Jajce (MARINKOVIĆ & AHAC, 1980), on Vlašić Mt., in the canyon of the Janj river and north west and south-east of the Kupres polje (PAPEŠ, 1972, 1985; VUJNOVIĆ, 1980). Some parts of the platform were occasionally emerged (Fig. 29).

The Lower Cretaceous carbonates are mostly represented by different varieties of limestones, mostly mudstones, fossiliferous wackestones and packstones. In the Neocomian and older Barremian, the thick-layered to massive mudstones and fossiliferous mudstones prevail. Younger Barremian and Aptian deposits are characterised by orbitolinid and *Salpingoporella* wackestones, as well as interbeds of rudist coquinas. Sporadically there are coral–hydrozoan–rudist biolithite build-ups which originated from patch-reefs (Fig. 30). In the Albian, orbitolinid wackestones, locally also grainstones (tempestites) are prominent, together with miliolid wackestones/packstones as well as bivalves and gastropod coquinas and floatstones. Apart from the limestones, throughout the entire column of Lower Cretaceous sediments there are interbeds and lenses of late-diagenetic dolomites.

Lower Cretaceous deposits are rich in fossils, especially calcareous algae and foraminifera (particularly orbitolinids). Frequently entire beds of wackestones, packstones or tempestite grainstones are composed of orbitolinid shells. Because of the rich fossil assemblages in which orbitolinids form the framework of biostratigraphic zonation, the Lower Cretaceous of the study area has been stratigraphically subdivided relatively well. Only the most important index fossils will be mentioned here: *Protopeneroplis ultragranulata* (GORBATCHIK) in Berriasian, *Vercorsella camposaurii* (SARTONI & CRESCENTI), *V. tenuis* (VELIĆ & GUŠIĆ), C*ampanellulla capuensis* DE CASTRO and *Clypeina solkani* CONRAD & RADOIČIĆ in Valanginian and Hauterivian, *Salpingoporella muehlbergii* LORENZ, *Rectodictyoconus giganteus* SCHROEDER and *Palorbitolina lenticularis* (BLUMENBACH) in Barremian, *P. lenticularis*, *Praeorbitolina cormyi* SCHROEDER, *P. wienandsi* SCHROEDER and *Mesorbitolina lotzei* SCHROEDER, *Archalveolina reicheli* (DE CASTRO) and very abundant *Salpingoporella dinarica* RADOIČIĆ in Aptian, *Mesorbitolina parva* DOUGLASS and *M. texana* (ROEMER) in Late Aptian and Early Albian, *Mesorbitolina subconcava* LEYMERIE and *M. pervia* DOUGLASS in Early Albian and *Salpingoporella turgida* (RADOIČIĆ), *Valdanchella dercourti* (DECROUEZ & MOULLADE), *Neoiraquia insolita (*DECROUEZ & MOULLADE) and *N. convexa* DANILOVA in Late Albian. Barremian and Lower Aptian floatstones, coquinas and occasion-

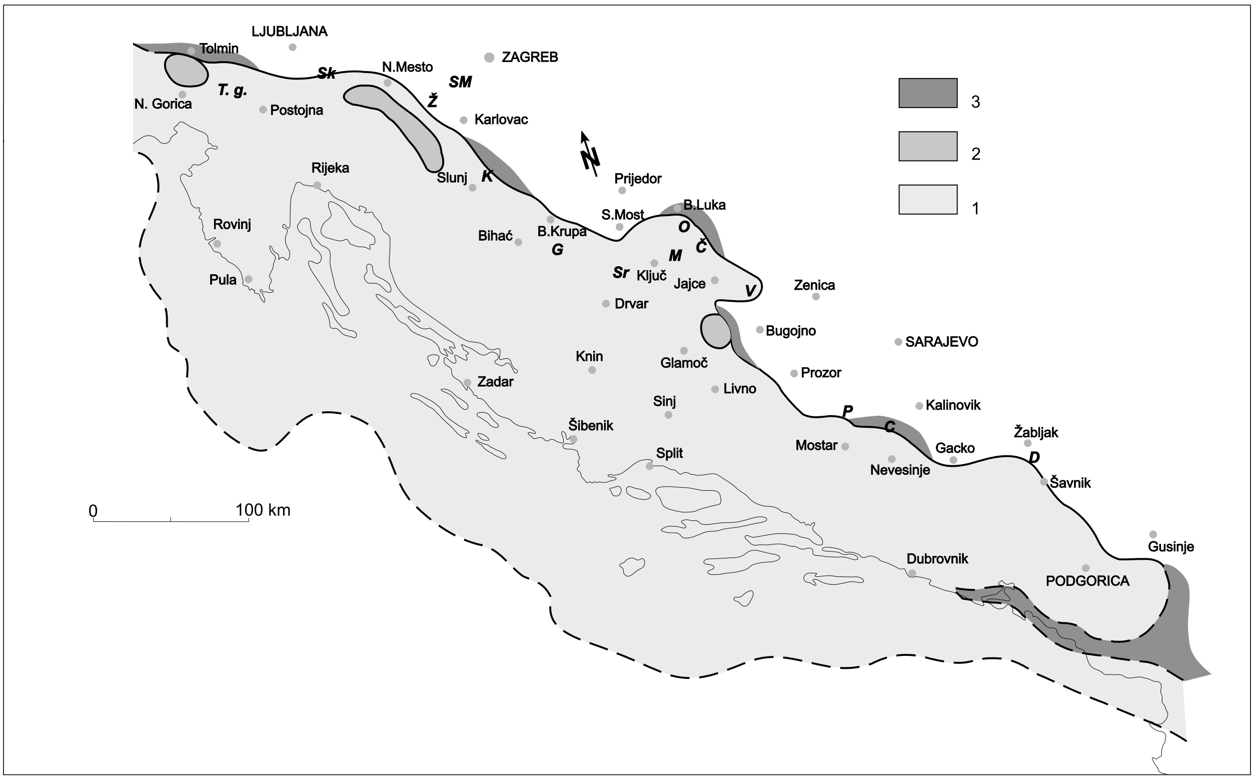


Fig. 30 Recent position of the Aptian to Cenomanian NE platform margin deposits. Legend: 1) inner platform carbonate deposits; 2) biolitiths (patch-reefs); 3) slope to basin deposits.

ally biolithites contain numerous rudists of the genera *Requienia*, *Toucasia*, *Caprina* and *Praeradiolites*, together with remains of bryozoans, hydrozoans, corals and molluscs.

The platform margin could be traced in a SE direction through Herzegovina and Montenegro with the same facies characteristics as in Croatia and Bosnia. A similar situation occurs in southeastern Slovenia, where, surrounded by subtidal, lagoonal restricted environments, Barremian–Aptian biolithites and patch-reefs with rudists, corals, hetetids, bryozoans etc. were discovered (BUKOVAC et al., 1984; DOZET & ŠRIBAR, 1998b). In western Slovenia the reef build-ups of Valanginian and Barremian–Aptian age (TURNŠEK & BUSER, 1974; BUSER, 1987; TURNŠEK, 1997), could be the remains of platform margin barrier reefs (Fig. 30).

2.3.1.6. Upper Cretaceous

There are sparse outcrops of the older Upper Cretaceous sediments at the very margin of the platform. Most of the marginal area from Žumberak in Croatia to the Bosna river valley and to the Kupres polje in Bosnia and Herzegovina was mostly emergent at that time. That is why these sediments in the study area are displaced in a S–SW direction, from the margin towards the inner parts of the platform. Their basic facies characteristics are more or less the same as in other parts of the AdCP. In the explored area they were determined in the surroundings of Karlovac (BUKOVAC et al., 1984), N and SE of Slunj (KOROLIJA et al., 1980; ŠPARICA, 1981), in the vicinity of Bihać (POLŠAK et al., 1977), in Manjača, in the Jajce area, on Vlašić Mt. (MARINKOVIĆ & AHAC, 1980; ŽIVANOVIĆ et al., 1971; DRAGIČEVIĆ, 1987) and north of the Kupres polje (VUJNOVIĆ, 1980).

In the Cenomanian, shallower subtidal and peritidal environments dominated with numerous communities and colonies of rudists. There were pelagic influences from time to time, and sequences composed of alternations of rudist floatstones, coquinas, rudstones and foraminiferal wackestones to grainstones frequently containing interbeds of platy limestones, mudstones to fossiliferous wackestones with calcisphaeras, globotruncanids and globigerinids, and occasionally with nodules and lenses of chert. They were found in the Kordun area, on Lička Plješevica Mt. and in the surroundings of Bihać (POLŠAK et al., 1978), but they also most probably extend in a SE direction. This is the consequence of the Upper Cenomanian/Lower Turonian platform drowning that was determined more or less over the entire platform area (e.g. GUŠIĆ & JELASKA, 1990, 1993; JELASKA et al., 1994; JURKOVŠEK et al., 1996; KORBAR et al., 2001).

There are only scarce data on the development of Turonian deposits. The rudist limestones above the calcisphaera limestones in Kordun, Lička Plješevica Mt. and in the area of Bihać (POLŠAK et al., 1977, 1978; ŠPARICA, 1981) are of Turonian age. This pertains to the inner parts of the platform SW of its margin. The platform margin was, in most of the study area, from

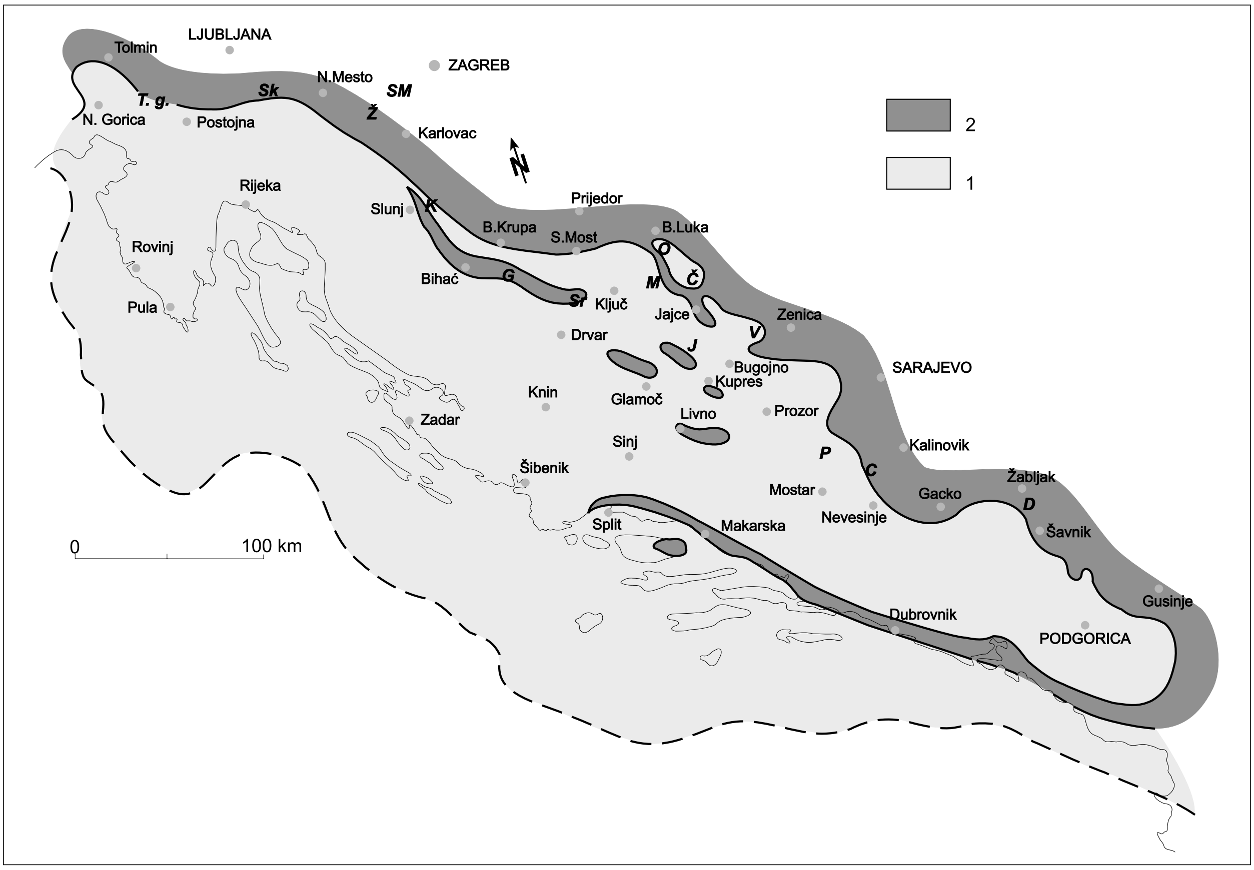


Fig. 31 Recent position of the Santonian and Maastrichtian NE platform margin deposits. Legend: 1) inner platform carbonate deposits; 2) carbonate–clastic deposits of intraplatform troughs, platform slope and basin.

Žumberak to Kupres polje and to the Bosna river valley, emerged from the Late Albian or Early Cenomanian to the Early Santonian. Exceptions are only found at some localities in the vicinity of Karlovac (Fig. 4; ŠPARICA, 1981), in Manjača (MARINKOVIĆ & AHAC, 1980; MOJIČEVIĆ et al., 1977), east of Jajce (Fig. 18) and in the Vlašić Mt. (Fig. 20), where Middle and Upper Cenomanian limestones were determined.

The karstified Lower Cretaceous limestones south of Banjaluka and in the surroundings of Jajce are directly covered by the youngest Cretaceous rudist limestones of Upper Santonian to Campanian age. These are biohermal biolithites, frequently of the barrier reef type (Fig. 16), but also rudist rudstones, coquinas, foraminiferal calcarenites, and sporadically rudist floatstones and foraminiferal wackestones. Towards the younger levels, the ratio of rudist fragments and carbonate clasts in general diminishes, grains become smaller and the ratio of the clastic components gradually rises all the way to the typical flysch facies of the Campanian–Maastrichtian age. In Žumberak, the Slunj area, in Grmeč Mt., N of Jajce and in Vlašić Mt., rudist biolithite complexes of the platform margin of the Santonian, Campanian and Maastrichtian age are mentioned by POLŠAK (1981), while ŠPARICA (1981) describes them at several localities in Kordun as being generally of Senonian age.

Upper Cretaceous carbonates are markedly fossiliferous. The rudists predominate, and other important macrofossils are chondrodonts, gastropods, and in the biolithites corals, corallinaceans, bryozoans, echinoids, etc. But foraminifera are the most important for stratigraphic subdivision. Only several of the index species and some more important rudist genera will be mentioned. The following foraminifera were determined in the Cenomanian deposits: *Orbitolina* (*Conicorbitolina*) *conica* (d'ARCHIAC), *Chrysalidina gradata* d'ORBIGNY, *Broeckina* (*Pastrikella*) *balcanica* CHERCHI et al., *Pseudolituonella reicheli* MARIE, *Pseudorhapydionina dubia* DE CASTRO and *P. laurinensis* DE CASTRO etc., together with rudists of the genera *Radiolites*, *Caprina, Neocaprina*, *Sauvagesia*, *Ichthyosarcolites*, *Gyropleura*, *Monopleura*, *Preradiolites*, chondrodonts *Chondrodonta joannae* (CHOFFAT), *Ch. joannae angusta* (SCHUBERT) and *Ch. munsoni* HILL, gastropods (mostly of genus *Nerinea*) etc. There are no foraminifera that are exactly the index species for the Turonian, but important ones are *Moncharmontia apenninica* (DE CASTRO) and *Pseudocyclammina sphaeroidea* GENDROT, together with rudists – tiny radiolitides and those of the genera *Biradiolites*, *Distefanella*, *Sauvagesia*, *Durania* etc. (POLŠAK et al., 1978). Foraminiferal assemblages containing the species *Scandonea samnitica* DE CASTRO, *Pseudorha-*

pydionina mediterranea (DE CASTRO), *Accordiella conica* FARINACCI, *Dicyclina schlumbergeri* MUNIER-CHALMAS, *Keramosphaerina tergestina* STACHE and *Murgella lata* LUPERTO-SINNI define the Santonian–Campanian age of the rudist limestones above the Albian/Cenomanian–Early Santonian emersion. They contain a mass of rudist shells of different genera – *Radiolites*, *Gorjanovicia*, *Biradiolites*, *Bournonia*, *Hippurites* etc. In Maastrichtian–Palaeocene debrites SE of Banjaluka DRAGIČEVIĆ (1987) has also determined Maastrichtian species *Vaccinites vesiculosus* (WOODWARD) and *V. conicus adriaticus* SLADIĆ-TRIFUNOVIĆ.

Upper Cretaceous carbonates close to the platform margin SE of central Bosnia, including local occurrences of biolithite build-ups, were found in the Prenj and Velež Mts. (MOJIČEVIĆ & TOMIĆ, 1982a), in the vicinity of Nevesinje (MOJIČEVIĆ & LAUŠEVIĆ, 1969) and southeastward, in Herzegovina, as well as west of the Piva area (MIRKOVIĆ et al., 1979), in the vicinity of Nikšić (VUJISIĆ, 1972) and on Maganik Mt. (KALEZIĆ & MIRKOVIĆ, 1970). There are no available detailed data of lithofacies and stratigraphy but, according to the publications, similar facies development as in the described terrains of Croatia and Bosnia with a stratigraphic range from younger Cenomanian to the Campanian can be supposed.

Along the platform margin in Slovenia, Upper Cretaceous carbonates are exposed between Gorica and Tolmin (BUSER, 1987). There was an emersion phase with bauxite occurrences between the Cenomanian and Senonian limestones, at the same level as near Karlovac (Dubravčani, Fig. 4) and Jajce (Ravanac, Fig. 18). In Trnovski gozd Mt. (BUSER, 1968), Nanos Mt., and areas of Notranjska (BUSER et al., 1967), Suha krajina (BUSER, 1969) and Novo Mesto (PLENIČAR et al., 1976), rudist limestones, most likely not younger than Cenomanian or Early Turonian, were closest to the platform margin.

2.3.2. Slope and basin facies of the NE margin of the platform

In the investigated region from Žumberak to central Bosnia, slope facies on the NE slopes of the platform, as well as basinal facies extending in the direction of the open-marine Tethys are fragmentary and only crop out sporadically. In the region to the south-east, in Herzegovina, Montenegro and northern Albania, and also in the north-west, in Slovenia, they crop out over larger areas and with regional strikes.

2.3.2.1. Lower and Middle Jurassic

Slope to basinal limestones in direct contact with platform limestones of the uppermost Lower Jurassic and Middle Jurassic age have been known near Sošice in Žumberak (RADOIČIĆ, 1966; GUŠIĆ & BABIĆ, 1970; PLENIČAR et al., 1976; BUCKOVIĆ et al., 2001) and also in the Samobor Mts. (ŠIKIĆ & BASCH, 1975; ŠIKIĆ et al., 1978; Fig. 2). Their basal parts are composed of oolitic limestones with radiolarian chert interbeds, followed by a sequence of alternating mudstones, fossiliferous mudstones/wackestones and cherts (ŠIKIĆ et al., 1979). Locally, e.g. south of Karlovac (in Barilović and Sića), dark and well-bedded mostly fossiliferous Lower Jurassic wackestones were determined. They were deposited in the platform slope environments wherein the slope benthos and pelagic microorganisms are mixed with the fossils, lithoclasts and bioclasts originating from the platform margin (GUŠIĆ, 1969).

In Kordun and in western and central Bosnia, data on slope deposits of the Early and Middle Jurassic are very poor. The clastic–carbonate sediments (marls and shales with limestone lenses and thicker tuff intercalations) near Veljun in Kordun were interpreted by ŠPARICA (1981) as basinal deposits of the Early Jurassic. The same author also describes olistoliths of basinal limestones (limestones with “filaments” and radiolarians) of Early and Middle Jurassic age within shales of the “magmatic–sedimentary complex” in the Banija area. In the Subotica creek profile W of Banjaluka (Fig. 9) JELASKA (1987) described the slope breccias with “packages” of massive mudstones that unconformably overlie Middle Liassic oolitic limestones, characterised by slumping and the chaotic arrangement of angular lithofragments in the micrite matrix. These rocks are mostly of Upper Lias age and contain typical “slope” foraminifera (involutinids and “vidalinas”). The breccia is overlain by Upper Jurassic hydrozoan reef limestones. This breccia unit can be compared with similar breccias containing fragments of slope limestones deposited in deeper environments that were found near Sošice in Žumberak and explained by GUŠIĆ & BABIĆ (1970) as being connected to tectonics on the Early–Middle Jurassic boundary.

Early Jurassic basinal deposits closest to the platform in Šehitluci (Banjaluka) were mentioned by BLANCHET (1975). MOJIČEVIĆ et al. (1977) and ŽIVANOVIĆ et al. (1971) described clastic–carbonate basinal sequences of generally Jurassic or Late Jurassic age in the area of Banjaluka and Zenica.

The fossil content and therefore the palaeontological documentation of these sediments is poor. Only *Involutina liassica* (JONES) is an index species of Early Jurassic age, while *Ophthalmidium martanum* (FARINACCI), *Globochaete alpina* LOMBARD, *Frondicularia* sp., *Lenticulina* sp., *Cristellaria* sp., *Saccocoma* sp., globigerinids, radiolarians and “filaments” are of environmental significance.

There is significantly more data regarding the slope, and especially the basinal sequences of the SE marginal parts of the platform (Figs. 25–27). The platy limestones of the Lower and Middle Jurassic are found north and south of Prozor (SOFILJ & ŽIVANOVIĆ, 1979), platy and clayey limestones with ammonites in Crvanj Mt. in NE Herzegovina (MOJIČEVIĆ & TOMIĆ, 1982a, b), grey and red platy clayey limestones with cherts and ammonites east of Nevesinje, in the surroundings of Gacko (MOJIČEVIĆ & LAUŠEVIĆ, 1969, 1973; MIRKOVIĆ, 1980; MIRKOVIĆ et al., 1979). In Montenegro, in the Piva area, the red and grey clayey limestones with cherts, containing ammonites and pelagic microfauna, were described by MIRKOVIĆ (1980) and MIRKOVIĆ et al. (1979). Lower Jurassic red platy clayey limestones with ammonites and Middle Jurassic limestones with filaments and globigerinids in the Dogger were described from the Vojnik and Durmitor Mts., as well as in the broader surroundings of Žabljak (VUJISIĆ, 1972, 1975; MIRKOVIĆ & MIRKOVIĆ, 1987; MIRKOVIĆ & VUJISIĆ, 1989; ŽIVALJEVIĆ et al., 1989). Finally, deep marine facies of the Early and Middle Jurassic are known from the Cukali–Budva trough, occasionally represented by reddish limestones with ammonites (MIRKOVIĆ et al., 1978).

The deep marine Lower and Middle Jurassic sequences are also known in western Slovenia (Figs. 25–27), north of the AdCP margin – in the Slovenian trough (KUŠČER et al., 1974; BUSER, 1986, 1987; JURKOVŠEK et al., 1988/89; OGORELEC & DOZET, 1997). The Lower Jurassic is represented by platy mudstones with lenses and nodules of chert, locally containing shale and marl, and the Middle Jurassic sequence is composed of the alternation of shale and chert. To the east, close to the northern margin of the platform in Žumberak there are no outcrops of slope and/or basinal sequences of the Lower and Middle Jurassic. Originally they probably existed but were affected by later events – either being eroded or tectonically reduced or covered with younger sediments.

2.3.2.2. Upper Jurassic

Slope facies of the Upper Jurassic are represented by carbonate sequences, and basinal facies by both carbonate and clastic–carbonate ("flysch") sequences. Fine-grained muddy limestones, among which are the "calpionella limestones" (mudstones, fossiliferous mudstones to wackestones) alternating with calcarenites and cherts are known from Sošice in Žumberak (RADOIČIĆ, 1966; PLENIČAR et al., 1976; BUCKOVIĆ et al., 2001) and from the Samobor Mts. (BABIĆ, 1973; ŠIKIĆ & BASCH, 1975; ŠIKIĆ et al., 1979). "Calpionella limestones" have also been found in the vicinity of Ozalj (BUKOVAC et al., 1984). These are typical basinal sediments that can be traced in a SE direction through Kordun and Banovina (KOROLIJA et al., 1981; ŠPARICA, 1981).

In the vicinity of Karlovac (Dugaresa, Martinšćak hill, Barilović), slope facies of the Late Jurassic were also determined (BUKOVAC et al., 1974; ŠPARICA, 1981), mostly consisting of fine-grained mud-supported limestones with nodules and occasionally with interbeds of chert. These limestones contain litho- and bioclasts that originated from the platform shallows, together with slope benthic and pelagic microfauna. There are also sporadic occurrences of detrital limestones (calcarenite) composed of particles from the platform carbonates transported down the slope by occasional turbidity currents. Interbeds and lenses of such calcarenites with clasts from the shallow marine facies are also found in the basinal facies.

In NW Bosnia, in the surroundings of Bihać, the "Lemeš deposits" are known. These are platy limestones with chert and sporadic ammonites, containing interbeds of black kerogeneous schisty laminites of Kimmeridgian and Early Tithonian age (POLŠAK et al., 1978). These are deposits of a shallower marine trough which extended from the NE margin into the central parts of the AdCP (Fig. 28; see discussion in VELIĆ et al., 2002b). This trough was not deep enough for deep marine, basinal sedimentation to develop. Further in an E and SE direction, close to the platform margin in the Banjaluka and Zenica area, deep marine, basinal sediments ("flyschs") of the Bosnian trough were proven biostratigraphically by calpionellids of Tithonian to Valanginian age (ŽIVANOVIĆ et al., 1971; BLANCHET, 1975; MOJIČEVIĆ et al., 1977).

South of Kupres, DRAGIČEVIĆ (1987) described limestones, mostly mudstones and floatstones, deposited in fore-reef shallows, as the products of destruction of hydrozoan reefs. Apart from clasts of the reef-building organisms, they contain benthic foraminifera and numerous calpionellids. More detailed study was prevented by the terrain being covered, but it can be assumed that this is the slope facies of Tithonian to Valangian age.

This autochthonous fossil content is exclusively composed of calpionellids, radiolarians, calcisphaers and ammonites. Within the "Lemeš deposits" POLŠAK et al. (1978) mentioned the ammonite genera *Perisphinctes* and *Virgatosphinctes*. Among the calpionellids, those specifically determined were *Calpionella alpina* LORENZ and *C. elliptica* CADISH. In the Samobor Mts. BABIĆ (1973) performed a detailed biostratigraphic zonation and described a significant calpionellid assemblage with taxa of Tithonian to Valanginian age. Apart from the ones mentioned above, he also quotes the following more important species: *Crasicollaria intermedia* (DURAN-DELGA), *C. parvula* REMANE, *Remaniella cadischiana* (COLOM), *Tintinnopsella carpathica* (MURGEANU & FILIPESCU), *T. longa* (COLOM), *Calpionellopsis simplex* (COLOM), *C. oblonga* (CADISH), *Cadosina lapidosa* VOGLER and *Calpionellites darderi* (COLOM).

In Herzegovina and Montenegro, in the basinal clastic–carbonate sediments – the "flyschs" and the "diabase–chert formation" a Tithonian–Berriasian–Valanginian age was determined by calpionellids (MOJIČEVIĆ & LAUŠEVIĆ, 1973; KALEZIĆ et al., 1973; ANTONIJEVIĆ et al., 1973; MIRKOVIĆ, 1980; MIRKOVIĆ & MIRKOVIĆ, 1987; ŽIVALJEVIĆ et al., 1989; RADOIČIĆ, 1989). This was also done in the north-west, in the Slovenian trough (BABIĆ, 1980; BUSER, 1986; JURKOVŠEK et al., 1988/89).

2.3.2.3. Lower Cretaceous

Outcrops of slope or basinal facies of Lower Cretaceous age close to the NE margin of the AdCP were only locally determined. It is clear that part of the "calpionella limestones" at every location mentioned above also belong to the oldest Cretaceous – Berriasian and Valanginian. In this way, the "calpionella limestones" in Žumberak are followed by younger slope-to-basin sediments of Hauterivian, Albian and Cenomanian age (BABIĆ, 1974). Close to the Žumberak area, near Krško in SE Slovenia, MARJANAC & MARJANAC (1987) determined Aptian and Albian slope deposits represented by shales with intercalations of thin mudstones, tuffitic limestones and debrites. Upper Albian flysch comprises sandstones, mudstones, marls and mud supported debrites. In the Banovina area, ŠPARICA (1981) described the basinal carbonate–clastic sediments of turbidite characteristics containing a shallow marine Lower Cretaceous benthos (foraminifera and calcareous algae) in clasts of the calcarenite intervals and pelagic microfossils including calpionellids, calcisphaeres and hedbergellas in the limestones, marls and shales. Parts of the Jurassic–Cretaceous flysch of the Bosnian trough in the vicinity of Banjaluka and Zenica (BLANCHET, 1975; MOJIČEVIĆ et al., 1977; ŽIVANOVIĆ et al., 1971) are also most likely to belong to the Early Cretaceous.

In the area S of Sarajevo, the clastic–carbonate sediments of the basinal Lower Cretaceous are exposed on the slopes of the Igman, Bjelašnica and Visočica Mts. They were also determined in the region all the way to the upstream part of the Neretva river valley (JOVANOVIĆ et al., 1977; MOJIČEVIĆ & TOMIĆ, 1982a). In Montenegro, they were found E of Žabljak (MIRKOVIĆ & VUJISIĆ, 1989). The Cukali–Budva trough is mostly filled with siliceous sediments – cherts and radiolarites in general (ANTONIJEVIĆ et al., 1973), containing lenses and interbeds of detrital limestones and breccias with clasts of platform carbonates and fossils, which is usual in the turbidite facies. In the NW part of the platform, on the slope towards the Slovenian trough, Lower Cretaceous flysch deposits are characterised by an alternation of shales, cherts, platy limestones, calcarenites and breccias (BUSER, 1986, 1989; JURKOVŠEK et al., 1988/89).

2.3.2.4. Upper Cretaceous

The recent regional distribution of the Upper Cretaceous slope and basin sediments enables good contouring of the border with the platform shallow marine environments during the time of deposition. It also enables the reliable palaeogeographic description of the final disintegration of the AdCP which happened during the Late Cretaceous. These slope-to-basin sediments are mostly defined as flysch, and there was an almost continuous zone extending either at or close to the NE margin of the platform from the Slovenian trough to the Cukali–Budva trough (Fig. 31). Moreover, in a general transgressive trend, the youngest horizons of these sediments had not only covered significant parts of the older marginal platform sequences, but were also deposited in several smaller troughs which were formed SW of the platform margin by strong tectonic compression during the Late Cretaceous (DRAGIČEVIĆ, 1987). This is discussed in more detail below in section 3.

The slope and basin sediments of the Upper Cretaceous are developed almost continuously along the strike of the NE platform margin. They are known from Žumberak, the Karlovac area, Kordun, areas of Bihać, Bosanska Krupa, Ključ, Banjaluka, Jajce and Vlašić Mt. to the areas both N and S of the Kupres polje.

Within the Upper Cretaceous slope-to-basin carbonate–clastic or flysch sediments there are two stratigraphic sequences – an older one of Cenomanian–Turonian age and a younger one of Santonian–Campanian–Maastrichtian age (SOKAČ, 1964; KOROLIJA et al., 1980, 1981; ŠPARICA, 1981; MARJANAC & MARJANAC, 1987; MRINJEK, 1988a, b). JELASKA et al. (1969) and JELASKA (1987) described these sediments, including basinal limestones of the "Scaglia" type, at various Late Cretaceous horizons.

In Kordun (Cetingrad area) Cenomanian–Turonian flysch deposits that are closest to the NE platform margin are composed of turbidite sequences, mostly of marls alternating with fine-grained sandstones, rarely with calcarenites and breccias (SOKAČ, 1964; KOROLIJA et al., 1980, 1981; ŠPARICA, 1981; MRINJEK, 1988a, b). Apart from these lithologic members, SOKAČ (1964) also mentioned lenses of thin-layered limestones. The main constituents of the calcarenites and breccias are lithoclasts and macrofossil bioclasts, as well as a lot of fragmented and abraded Cenomanian orbitolinids. Due to the mass occurrences of redeposited orbitolinids, these sediments were frequently named the "orbitolinid Cretaceous". As there are no records of autochthonous fossils, a Late Albian to Early Turonian time span has been proposed.

There are numerous data on composition, age, mechanisms and environments of deposition of younger, Santonian–Campanian–Maastrichtian carbonate–clastic sediments at the NE margin of the platform. The regional setting of this unit was analysed in the works of JELASKA et al. (1969), POLŠAK (1981), ŠPARICA (1981) and JELASKA (1987).

Basinal sediments of the Late Cretaceous are represented by mostly platy limestones with globotruncanids (the "Scaglia" type limestones) that are found interbedded within the distal parts of the flysch sequences or alternating with flysch. These are thin-layered and platy, grey and reddish, frequently clayey mudstones and fossiliferous mudstones with nodules and interbeds of chert, containing lots of pelagic organisms, primarily globotruncanids followed by globigerinids, heterohelicids, radiolarians etc. Although these sediments are mostly covered by Tertiary and Quaternary deposits, they were identified at numerous locations from

Žumberak all the way to the valley of the River Bosna (Fig. 31). Only the areas closest to the platform margin will be described from NW to SE. These deposits were investigated in central Croatia – Žumberak, Karlovac area, Banovina and Kordun (SOKAČ, 1964; ZUPANIČ, 1976; BABIĆ & ZUPANIČ, 1976; ŠPARICA, 1981; MRINJEK, 1988a, b), in western Bosnia (JELASKA et al., 1969; ŠPARICA, 1981; JELASKA, 1987) and in central Bosnia (TOMIĆ, 1985; DRAGIČEVIĆ, 1987).

Further in a southeastern direction, Upper Cretaceous slope and basinal sediments are found alongside the recent position of the platform margin in Bosnia – on the southern slopes of. Visočica Mt and in the upstream part of the Neretva river valley, with a continuation through NE Herzegovina and Montenegro (the "Durmitor flysch") to northern Albania (Fig. 31). In the northwest, in the Slovenian trough, flysch sedimentation continued from the Albian into the Cenomanian, platy reddish limestones with interbeds of red marls were deposited in the Turonian, during the Coniacian–Maastrichtian time span, platy "Volča" limestones with chert were deposited, and then flysch again in the Maastrichtian (PLENIČAR, 1958; ŠRIBAR, 1965; OGORELEC et al., 1976; PAVŠIČ, 1977; BUSER et al., 1982; MARJANAC & MARJANAC, 1987; BUSER, 1989).

3. GEODYNAMIC EVOLUTION AND PALAEOGEOGRAPHY OF THE NORTHEASTERN MARGIN OF THE ADRIATIC CARBONATE PLATFORM DURING THE JURASSIC AND CRETACEOUS

The geological history of the platform margin area during the Permian–Palaeogene time span can be interpreted through six evolutionary phases. Each was characterised by specific palaeogeographic relationships and is a continuation of the preceding phase. The phases are: (1) Permian to the Lower Jurassic as the pre-individualisation period, (2) Pliensbachian to Toarcian – time of individualisation of the platform during the Lower Jurassic, (3) Toarcian to the Late Albian – a relatively stable period of the platform shallow water regime, (4) Late Albian/Early Cenomanian to Santonian – the phase of significant tectonic events which caused regression, emersion and transgression, i.e. the beginning of platform disintegration, (5) Santonian transgression and continuation of platform disintegration, (6) Campanian gradual flooding of the platform margin area with the peak of the transgression during the Maastrichtian and Palaeocene.

3.1. Pre-individualisation relationships from Permian to Lias

During the Late Permian and Early to Middle Triassic, the study area was part of the shallow marine carbonate shelf, i.e. epeiric carbonate platform of the Gondwana. Both within the investigated area and further afield (Jajce–Šipovo, Kupres, Eastern Bosnia) several smaller carbonate platforms already existed within this shelf in the **Late Permian**, and they were later "incorporated" in the thick sequence of carbonate rocks which continuously overlaid them through the Triassic. The **Early Triassic** was characterised by an alternation of shallow water carbonate and siliciclastic deposition. Through the **Middle Triassic** significant masses of shallow water sediments, mostly algal limestones were deposited. From the Anisian to the Carnian (culminating in the Ladinian) there were complex rifting processes with submarine volcanic activity. Dominant rock types were diabase and spilite accompanied by clastics, pyroclastics and limestones. Due to the constant tectonic activity there was pronounced diversification of depositional environments and lithofacies. At the Ladinian–Carnian transition some morphologically elevated areas were emerged and covered by laterite bauxites (e.g. Ljuša locality south of Jajce).

During the **Late Triassic,** extensive and relatively stable carbonate sedimentation of a markedly platform character was established, but without a clearly defined margin towards the opened oceanic, basinal domains. Prevailing facies were of the shallow marine, intertidal and supratidal environments wherein two regionally well known formations were deposited – the Dachstein limestones and the "Hauptdolomit" ("Main dolomite") which are widely distributed in the Perimediterranean region. There were no signs of more important events in the area of the future platform margin. In fact, these Upper Triassic facies/formations are widely distributed over the wider area, i.e. also outside the area of the future AdCP during the Jurassic and Cretaceous.

The "Hauptdolomit" is conformably overlain by the Lower Jurassic carbonates, the facies differentiation of which allows interpretation of various depositional environments. This is most likely the beginning of tectonic movements that caused significant changes in the palaeogeography during the Early Jurassic, since in the Early Lias the platform margin was still not pronounced. In areas where it was going to be formed (during the Late Pliensbachian and Toarcian) grain-supported and oolitic limestones were deposited within sand bar environments. In more restricted environments, the subtidal algal–foraminiferal wackestones, brachiopod and lithiotid floatstones and tempestite coquinas were deposited (Fig. 25).

3.2. Individualisation of the platform in the Early Jurassic

Significant palaeogeographic changes that took place in the Periadriatic area during the Early Jurassic were the direct consequence of regional extensional movements with rifting connected with the beginning of the opening of the Atlantic Ocean. This was the time of separation of the previously united shallow marine carbonate area of the Adria Microplate into several isolated carbonate platforms. The Adriatic Carbonate Platform was separated from the Apulian and Apenninic platforms by the connection of the Ionian and Belluno pelagic basins (e.g. BERNOULLI, 1971; JELASKA, 1973; ZAPPATERRA, 1990, 1994; GAMBINI & TOZZI, 1996; GRANDIĆ et al., 1999). The most important consequence of this tectonic activity and palaeogeographic changes was the individualization of the Adriatic Carbonate Platform and formation of its SW and NE margins and slopes.

These events were reflected in the NE margin as identified in the Žumberak area (GUŠIĆ & BABIĆ, 1970; ŠIKIĆ & BASCH, 1975; ŠIKIĆ et al., 1979). Extensional faulting along an approximately NW–SE line, resulted in the gradual subsidence and drowning of the NE part of the former shallow water environments. This was a process which led to the formation of the platform slope. Areas where platform carbonates were previously deposited became the sites of slope to basin deep water carbonate sedimentation. In the Samobor Mts. Lower Liassic shallow marine carbonates were covered by Middle to Upper Liassic and Middle Jurassic deep marine slope to basinal carbonates with pelagic microfossils. The lack of shallow marine fossil assemblages, both macrofossils (e.g. lithiotids or brachiopods) and large lituolid foraminifera, especially orbitopsellas, indicate that formation of the NE slope of the AdCP started even earlier, in the Late Sinemurian (latest Early Lias).

Southwestward on the carbonate platform area, shallow water sedimentation continued. At the same time the very platform margin was emerged, so that the shallow marine platform area SW of the margin was separated by the land from the basinal deep marine area to the NE. The emergence lasted from the latest Pliensbachian to the Kimmeridgian, and a hiatus was determined in the surroundings of Karlovac (BUKOVAC et al., 1974), in the Kordun area, and in NW Bosnia (ŠPARICA, 1981). This was either a linear archipelago or a united larger land area extending from Trnovski gozd Mt. (NIKLER, 1978), through the Suha krajina area in Slovenija (BUSER, 1969; PLENIČAR, et al., 1976; DOZET, 1994), and through Žumberak, the Karlovac area (BUKOVAC et al., 1974, 1984; ŠPARICA, 1981; DRAGIČEVIĆ & VELIĆ, 1994) and Kordun in Croatia all the way to NW Bosnia (ŠPARICA, 1981). In the direction of the south-east, in Bosnia, there was a larger island or several islands in the region from Bosanska Krupa to Banjaluka (JELASKA, 1987), in Manjača and towards Jajce (MARINKOVIĆ & AHAC, 1980). The existence of land or islands exactly along the margin in central Bosnia is confirmed by the hiatus from the Late Triassic/Early Jurassic to the Late Jurassic which was determined north of the Kupres polje (VUJNOVIĆ, 1980).

Tectonic reductions and coverage of the marginal area with younger sediments make continuous tracing of the Early Jurassic palaeogeographic events and changes along the platform margin impossible. Mostly oolitic, intraclastic and bioclastic limestones were deposited in the shallows around island(s). They were formed from the large accumulations of carbonate sands of the platform marginal area. In the external marginal parts which were exposed to mechanical disintegration, there was accumulation of significant masses of carbonate detritus that was transported by repeated gravitational currents downslope and into the basin. Examples of such events during the Early Jurassic have been found within the slope sediments in the vicinity of Karlovac and Banjaluka (GUŠIĆ, 1969; MOJIČEVIĆ et al., 1977; JELASKA, 1987), but they also occur in Upper Jurassic and Upper Cretaceous deposits.

It may be concluded that according to the results and data obtained, tectonic events in which the AdCP was individualised, i.e. the events that marked the beginning of formation of its margins were not momentary, but rather the tectonic activity that lasted from the Late Sinemurian to the end of the Toarcian. This interpretation correspond to the results from the study of the Early Jurassic extensional tectonic activity in the Periadriatic region published by different authors (e.g. BERNOULLI, 1971; JELASKA, 1973; ZAPPATERRA, 1990, 1994; BASSOULLET et al., 1993; GAMBINI & TOZZI, 1996; GRANDIĆ et al., 1999).

3.3. Stable period of the platform regime

Palaeogeographic relationships in the marginal part of the carbonate platform – on the carbonate slope and nearby basin – were relatively straightforward from the earliest Middle Jurassic to the Late Albian/Early Cenomanian. On the platform, a thick sequence of shallow marine carbonates of mostly biogenic origin was deposited.

However, as already described, during the **Middle Jurassic** the very margin of the platform was mostly emerged (Fig. 27). During this period the emerged area was similar to that in the Toarcian, spreading continuously from the Slovenian Suha Krajina area to southern Bosnia in the Kupres polje. In the platform shallows around land areas and between islands, predominantly oolitic carbonates were deposited. As already pointed out in southern Slovenia according to DOZET (2000a, b), such carbonate sedimentation lasted from the Aalenian to the Kimmeridgian, resulting in 450 to 500 m thick ooid limestones.

The main characteristic of the **Late Jurassic** events was the fast growth of reef-building organisms along the platform margin. Their large biologic potential produced significant masses of reef limestones and biodetritus, and they built the most significant and most characteristic palaeogeomorphological buildups during the whole history of the AdCP – the coral–hydrozoan barrier-type reefs (Fig. 28). In the study area between the rivers Kupa, Bosna and Neretva such buildups were found in the broader surroundings of Karlovac in

Croatia (BUKOVAC et al., 1974, 1984). To the south, in the region of Kordun and further SE in NW Bosnia all the way to Bosanska Krupa they were not preserved in the form of a continuous biolithite belt. Locally, there are remains of patch-reefs within the "*Clypeina–Campbelliella* limestones", e.g. west of Cetingrad and near Cazin (ŠPARICA, 1981). There are three main reasons for their non-existence or non-preservation. The first one was the fact that during the Kimmeridgian and Tithonian a "tongue" of the Lemeš trough existed in the broader area of Bihać, extending into the open and deep marine Tethys. This means that it was a deeper water area (Fig. 28) where reefs could not exist. An unknown part of the platform marginal area, covered by transgressive successions of younger deposits (of Upper Cretaceous, Neogene and Quaternary age) is the second reason and the third one was a consequence of the Tertiary tectonics, since the platform margin is recently covered by overthrust Permian and Triassic deposits.

The Lemeš trough extended in a southerly direction into the platform interior, all the way to Sinj (VELIĆ et al., 2002a, b). If any reefs did exist at all at the platform margin in the area of the Lemeš trough "tongue", they were destroyed by the synsedimentary activity of waves and currents, as well as by younger tectonics. Additionally, a significant part of the older marginal platform facies and sequences was tectonically disrupted and reduced during the Cretaceous, and during the Late Cretaceous covered by younger transgressive Upper Cretaceous–Palaeogene carbonate–clastic sediments. Southeastward in the study area, the Upper Jurassic barrier reefs appear on the platform margin near Bosanska Krupa and extend in a SE direction through NW and central Bosnia to the region S of Sarajevo and then to northern Herzegovina.

Continuation of the reef facies along the platform margin in a SE direction can be traced through Herzegovina and Montenegro all the way to the Cukali–Budva trough in northern Albania and southern Montenegro. Barrier reefs have also been found at the NW margin of the AdCP in Slovenia, in the area of Novo Mesto extending in a western direction to Trnovski gozd and S of Tolmin (e.g. BUSER, 1973, 1986; BUSER et al., 1967; TURNŠEK et al., 1981; TURNŠEK, 1997).

Due to the fact that reef-building organisms have lived within specific environments they are not reliable index fossils. To some extent, this has resulted in differences in the interpretation of the age of this marginal biolithite belt. In Slovenia and Croatia, where its stratigraphic position was mostly explored, the reef facies of the platform margin is covered with prograding oolithic–bioclastic grainstones and peritidal "*Clypeina–Campbelliella* limestones". The stratigraphic position of the reef facies in the Slovenian literature was denoted within the Oxfordian and Kimmeridgian (e.g. BUSER, 1973, 1986; BUSER et al., 1967; TURNŠEK et al., 1981; TURNŠEK, 1997). Alternatively, NIKLER (1978) has determined Upper Malm, most likely Tithonian reef facies in the Slovenian Trnovski Gozd Mt. The reef limestones in Croatia are of Kimmeridgian–Tithonian age, not exclusively at the platform margin near Karlovac (BUKOVAC et al., 1974, 1984) but also in the inner parts of the platform, e.g. in Velika Kapela Mt. (MILAN, 1969; VELIĆ, 1977; NIKLER, 1978). These limestones are the lateral time-equivalent of the "*Clypeina–Campbeliella* limestones" which were deposited in the back-reef platform shallows. According to the aforementioned references, the barrier reef limestones in Bosnia and Herzegovina and in northern Montenegro were attributed to the Late Jurassic, and this cannot be revised without more detailed stratigraphic determination.

The Jurassic/Cretaceous transition is marked by the emersion of the central parts of the platform (Fig. 29; VELIĆ et al., 2002a). Some emerged areas (islands) were determined along the NE platform margin between Bihać and Bosanska Krupa, Banjaluka and Jajce, Bugojno and Prozor, and also SW of Sarajevo in Bosnia and SE of Šavnik in Montenegro.

Facies characteristics of **Lower Cretaceous** carbonates of the marginal area do not differ from contemporaneous deposits in other parts of the platform. They have no specific characteristics which would indicate platform margin environments. Contrary to the Upper Jurassic carbonates close to or at the platform margin, the Lower Cretaceous carbonate sequences are significantly more uniform in terms of facies. They were mostly deposited in restricted environments, from lagoonal to shallow subtidal areas (orbitolinid and salpingoporella limestones), but occasionally also to supratidal ones, with emersions. No significant occurrences of marginal platform facies, e.g. oolithic or biolithite limestones were determined, especially of the barrier type (Fig. 30). Even if they existed, they were most probably penecontemporaneously destroyed by waves, and the material was redeposited. This is proven by the very frequent rudist and other bioclasts (including other bivalves, gastropods, corals, hydrozoans etc.), that are found in limestones deposited in the restricted back-reef shallows. Fragments, boulders and blocks formed during the Late Cretaceous destruction of the Lower Cretaceous shallow marine carbonates on the platform margin have been found in the clastic–carbonate debrites in the vicinity of Banjaluka and Jajce (DRAGIČEVIĆ, 1987). There is only one location, N of the Kupres polje (Fig. 30), where the Upper Barremian–Lower Aptian reef limestones were determined. They probably belong to the marginal platform reef with remains of corals, bryozoans, hydrozoans, corallinaceans, large gastropods and rudists (DRAGIČEVIĆ & VELIĆ, 1994).

Similar relationships were determined for the Early Cretaceous in other marginal parts – extending in both SE and NW directions. It is interesting to mention that in western Slovenia, S of Tolmin (Banjška planota and Trnovski Gozd Mts.) the coral–hydrozoan reef lime-

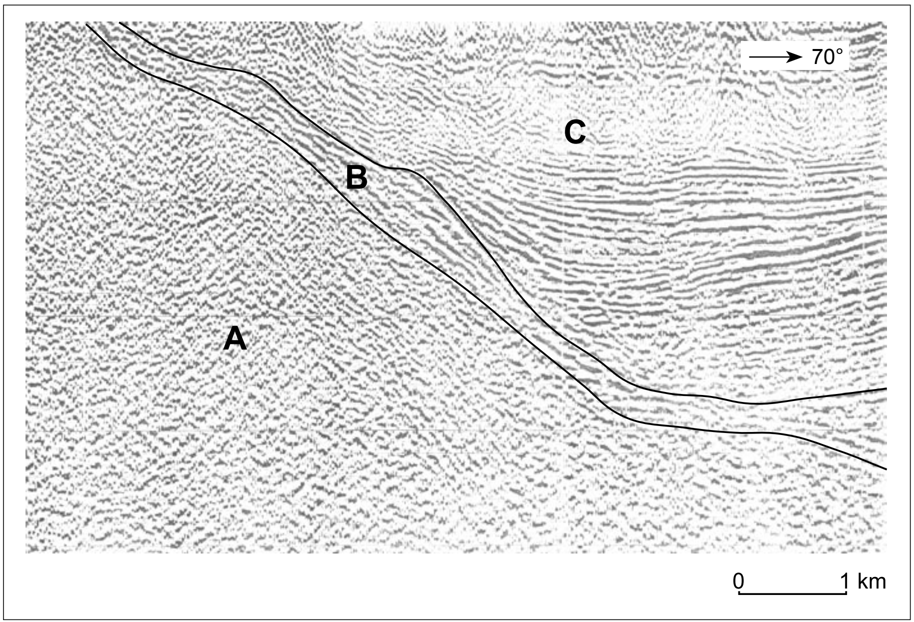


Fig. 32 Seismic profile of the Adriatic Carbonate Platform margin S of Karlovac (Fig. 1, locality 24). Legend: A) Mesozoic platform carbonates; B) Upper Cretaceous debrites and turbidites; C) Tertiary and Quaternary carbonate-clastic deposits

stones of Aptian and Albian age were developed (Fig. 30), containing numerous remains of corals, hydrozoans, chaetids, gastropods (nerineids) etc. (BUSER, 1986; TURNŠEK, 1997).

The end of the Early and beginning of the Late Cretaceous was, in the study area of the platform margin, marked by significant tectonics and emersion. During this period bauxite deposits were deposited in the vicinity of Jajce on the palaeorelief of the extensively eroded and karstified Albian limestones (DRAGIČEVIĆ, 1987). Similar conditions were also determined in the surroundings of Bihać in NW Bosnia and on Grmeč Mt. (POLŠAK et al., 1978; ŠINKOVEC & BABIĆ, 1973). This was the end of the long-lasting period of the relatively stable shallow marine platform regime, which lasted from the younger Early Jurassic to the end of the Early Cretaceous/Early Cenomanian.

3.4. The beginning of platform disintegration in the Cenomanian–Santonian

The **Late Cretaceous** was the time of the most significant events and biggest changes along the NE margin of the AdCP and the beginning of platform disintegration. These events and changes were mostly and most complexelly reflected exactly in the area investigated from Žumberak in central Croatia to the valley of the Bosna river and Kupres polje in Bosnia and Herzegovina. As already mentioned, the older Upper Cretaceous deposits were sporadically deposited and they can be found in rare localities along the platform margin (e.g. Dubravčani, Cetingrad, Ravanac, Guča Gora, Čardak livade, Strojice – Figs. 4, 7, 18, 20, 22, 23). Most of the platform marginal area was emergent during this period (DRAGIČEVIĆ & VELIĆ, 1994).

The Late Albian or Early Cenomanian was a period of significant tectonic movements when the process of disintegration and changes in physiography of the NE platform margin was initiated. The sequence of events started with differential faulting and folding parallel to the previous platform margin, followed by uplift, emersion and karstification. During the emersion phase, which at the platform margin lasted during the Cenomanian, Turonian and Coniacian (probably even during the Early Santonian), bauxite deposits were formed on land in areas of favourable relief. With continuing tectonics, the previously morphologically flattened area of the platform margin was fragmented and reshaped into several chains of longitudinal, more or less parallel morphological uplifts – the uplifted parts separated by elongated depressions. These events played a decisive role in the palaeogeography of the platform margin in the final phase of its disintegration during the Late Cretaceous.

3.5. Santonian transgression

A **Late Santonian** transgression gradually flooded the aforementioned emergent areas, so that in some places there were pronounced changes in palaeogeography and architecture of the marginal area. The most markedly developed changes were documented in the area SE of Banjaluka and in some places in the vicinity of Karlovac. Due to the gradual transgression, the sea flooded depressions in the relief where clastic–carbonate sedimentation of slope-to-basin facies developed. Recently their remains are found in several, isolated narrow elongated troughs in the area between Livno, Kupres, Jajce, Banjaluka, Bihać, Slunj and Ozalj (Fig. 31). Uplifted parts of the terrain became islands with a continuation of the erosion and karstification processes. Several "island chains" existed that were parallel to the platform margin. The largest islands, and also those with the longest terrestrial regime were located exactly at the platform margin ("outer island chain"), while both the dimensions of the islands and their duration diminished towards the central parts of the platform ("inner island chains"). Due to mechanical weathering in the coastal areas, large masses of lithoclasts were formed (predominantly of Lower Cretaceous limestones) that were transported to the basin by gravitational currents. In the islands interior there was mostly chemical weathering and modelling of the karst relief so that the source material (most likely volcanic ash and volcanic dust) for the bauxite occurrences and deposits was accumulated in the relief depressions – *dolinas*. These occurrences are of broad regional extent, and were found in many places along the platform margin: in Sabotin (Gorica) in Slovenia, in Kordun and Karlovac areas in Croatia, in the surroundings of Jajce, Bosanska Krupa and Grmeč Mt. in western Bosnia, and near Klina (Kosovo – Serbia and Montenegro).

With the advancement of the transgression, depositional environments changed: islands became small isolated carbonate platforms and depressions were transformed into troughs with basinal sedimentation. On the small platforms there was explosive renovation and fast growth of rudist communities. Biolithite bodies and bioherms up to a km in length are frequently encountered, especially at the platforms' margins. Basinal sedimentation in troughs under constant tectonic influence produced unstable environmental conditions, especially marked by the redeposition of large masses of both litho- and bioclasts derived from destruction of the rudist biolithites at the margins of small platforms. Blocks, boulders and lithoclasts within debrites originate from the platform carbonates of various ages. Those of Early and Late Cretaceous age prevail, but there are also some of Triassic and Late Jurassic age. Such relationships lasted from the Late Santonian, through the Campanian and most of the Maastrichtian.

3.6. The end of the platform regime: Maastrichtian and Palaeocene flooding of the marginal area

At the Maastrichtian/Palaeocene transition, fragmented carbonate complexes – small platforms of the AdCP margin area – were finally drowned. Deeper water to basinal environments were formed, resulting in the Cretaceous/Palaeocene continuity of basinal deposition. All of this indicates migration of the platform margin and deep marine environments in the direction of the south and south-west, and also the gradual diminishing of platform "stability" and at the same time intensified tectonic mobility.

Tectonic activity at the NE margin of the AdCP was the most important factor during its entire evolution. It directly or indirectly controlled the intensity of erosion, inclination of slopes, bathymetric relationships, reef growth and formation of other environments. Tectonics also initiated the sedimentary gravitational flows that deposited large masses of turbidites and debrites. In the basinal areas, significant masses of autochthonous sediments ("scaglia" type limestones and chert) accumulated.

The almost constant tectonic activity in the studied part of the platform margin can be interpreted from the given descriptions of palaeogeographic changes and registered hiatuses, including the unconformable and transgressive position of the Santonian–Maastrichtian carbonate–clastic sediments over various older stratigraphic units. This allows the conclusion that pre-Santonian tectonics resulted in the formation of fault contacts between various units of the Lower Triassic to Upper Cretaceous time span.

In this way carbonate–clastic sediments of the Santonian to Maastrichtian/Palaeocene age in the Žumberak area overlie various stratigraphic units of Triassic, basinal Jurassic and Upper Jurassic barrier-reef carbonates (PLENIČAR et al., 1976; BUKOVAC et al., 1984). In the Kordun area they overlie the Middle and Upper Triassic, Upper Jurassic, Barremian to Turonian platform carbonates (KOROLIJA et al., 1981; ŠPARICA, 1981), and in the surroundings of Bihać Upper Jurassic "Clypeina limestones" and Barremian to Albian salpingoporella and orbitolinid carbonates (POLŠAK et al., 1977). Between the Una and Vrbas rivers they cover the Triassic (mostly Upper Triassic) carbonates and Upper Jurassic coral–hydrozoan barrier-reefs (MOJIČEVIĆ et al., 1978; MARINKOVIĆ & AHAC, 1980; JELASKA, 1987). In the vicinity of Jajce, they transgressively cover platform carbonates of Aptian, Albian and Cenomanian age, and also Cenomanian limestones in Vlašić Mt. (DRAGIČEVIĆ, 1987). They also overlie Upper Jurassic platform barrier-reef to slope deposits and various platform carbonate sequences of the Early Cretaceous in the Kupres polje and Tomislavgrad area in SW Bosnia (PAPEŠ, 1972, 1985; VUJNOVIĆ, 1980; DRAGIČEVIĆ, 1987).

Tectogenesis of the NE AdCP margin and formation of the recent tectonic relationships evolved in the framework of regional changes and events of the wider Mediterranean region. Complex tectonic relationships were formed in the period from the Upper Cretaceous to the Recent. Their recent manifestation is the existence of large masses of Mesozoic platform carbonate rocks, which originally represented integral parts of the Adriatic Carbonate Platform, overthrust toward the NE and E and recently located NE of the main body of clastic deposits – flysch that was deposited on the slope and in the basin along the NE platform margin. This is especially obvious in some areas in Bosnia, such as Vlašić, Čemernica and the Osmača Mts., and probably also the Igman and Bjelašnica Mts. The present setting of the shallow marine Mesozoic carbonate complex in Žumberak and the Samobor Mts. in Croatia is almost identical to the one described above – it is located NE of the main zone of Upper Cretaceous flysch, which means that their allochthonous position can not be excluded.

4. PALAEOGEOGRAPHIC MIGRATION OF THE NORTHEASTERN MARGIN OF THE ADRIATIC CARBONATE PLATFORM

The recent geological relationships along the entire margin of the AdCP are very complex and frequently unclear. Nevertheless, they enable at least a partial reconstruction of its variable (palaeo)geographic position during the platform's existence (Fig. 33). By analysis of the spatial distribution and interrelationships between the relevant facies of the platform margin, slope and basin, margin migrations probably occurred during the Jurassic and Cretaceous. Although recently identifiable only in some areas, changes of the platform margin position were more frequent due to the tectonic–eustatic factors which consequently determined its extent and size.

The best explored and determined (both in a stratigraphic and palaeogeographic sense) is the example of the migration of the platform margin in the Jurassic of Žumberak and Samobor Mts. in Croatia. Its different positions in the Early and Late Jurassic were described by BABIĆ (1976). Compared to the Early Jurassic the platform margin during the Late Jurassic was located approximately 25 km southwestward (BABIĆ, 1976; BUKOVAC et al., 1984). This means that, by the end of Jurassic and in the beginning of Cretaceous, the platform was "narrowed" by the size of this displacement. The development and cause of these changes were explained by ŠIKIĆ & BASCH (1975) and ŠIKIĆ et al. (1979), as being due to regional tectonic activity during the Middle and beginning of the Late Lias. The NE parts of the Triassic–Lias carbonate platform were fragmented by faults of NW–SE strike and submerged, and platform sedimentation was gradually replaced by basinal types.

These Jurassic changes of the platform margin were consequences of the determined Early Jurassic extensional tectonics in the Periadriatic area which caused significant palaeogeographical events – isolation of the Adriatic Carbonate Platform and its separation from the Apulian and Apenninic platforms (BERNOULLI, 1971; JELASKA, 1973; ZAPATERRA, 1990, 1994; BASSOULLET et al., 1993; GRANDIĆ et al., 1999). Reflection of the extensional tectonics on the Adriatic platform resulted in regional faulting and sea-level fall and emersion of the NE marginal area. From Trnovski Gozd Mt. in Slovenia at the western part of the platform margin all the way to northern Montenegro and NW Albania, the emerged areas existed as smaller or larger islands between the inner platform shallows towards the SW and slope to basinal environments in the NE (Figs. 26, 27). The biggest land area, more likely an elongated island than a linear archipelago, extended from the Suha krajina region in SE Slovenia to the central part of the Neretva river-course in Bosnia and Herzegovina. In the shallows of the platform margin area that had not been emerged, ooid carbonates were mostly deposited.

There are no reliable data on the position of the platform margin during the Middle Jurasic. The platform was reduced in respect to the size of the shallow water area in Early Lias time in Slovenia and the Žumberak area, but its margin and slope lay NE of the island(s) belt and extended from Žumberak to central Bosnia, supposedly being shifted in a NE direction i.e. towards the basinal area. According to recent relationships, the Middle Jurassic position of the platform margin in Herzegovina is supposed somewhat northeastward and in Montenegro southwestward of the location of the Early Jurassic one. In Slovenia it was slightly shifted toward the inner platform area.

The barrier coral–hydrozoan reefs marked the platform margin during the Late Jurassic. These biolithite complexes were environmentally connected with the very margin of the platform and the platform area slowly expanded with their progradation over the slope facies towards the basinal area. The Recent position of the platform margin in the Jajce–Zenica area where, compared with its position during the Early and Middle Jurassic, the platform is approximately 70 km shifted eastward, is probably a consequence of the Tertiary overthrust tectonics.

Outwith the study area, the Late Jurassic extension of the platform margin by progradation of the reef facies was not very important, except at some localities in Montenegro.

According to the recent distribution of platform facies pertaining to the Early Cretaceous and the Early Late Cretaceous (Fig. 33) the platform margin retreated in a SW direction with respect to its Jurassic position. However, as in the Upper Jurassic, precise data can not be obtained due to masking of the marginal area either by overthrust older or transgressive younger deposits.

The shift of the margin towards the SW during the latest Cretaceous (from the Santonian to the end of the Maastrichtian) in a constant transgressive trend marked the final phase of platform disintegration by its continuous narrowing, i.e. extension of the slope and basinal facies and reduction of the platform facies area. As described in the previous section, this was mostly reflected in the area from Žumberak to central Bosnia from the Santonian to the end of the Cretaceous. Together with the previously quoted authors, some interesting data regarding the Late Jurassic–Maastrichtian shifts of the platform margin were provided by JELASKA (1987).

Late Cretaceous tectonics disrupted the transgressive tendencies and the process of narrowing of the shallow marine depositional area by the uplift and emersion of the largest part of the platform. This degraded an integral and long lasting shallow marine depositional area and marked the end of the existence of the Adriatic Carbonate Platform as a unique shallow marine depositional system. The NE platform margin area composed of Jurassic and Cretaceous carbonate platform sequences was, during the Maastrichtian progressive transgres-

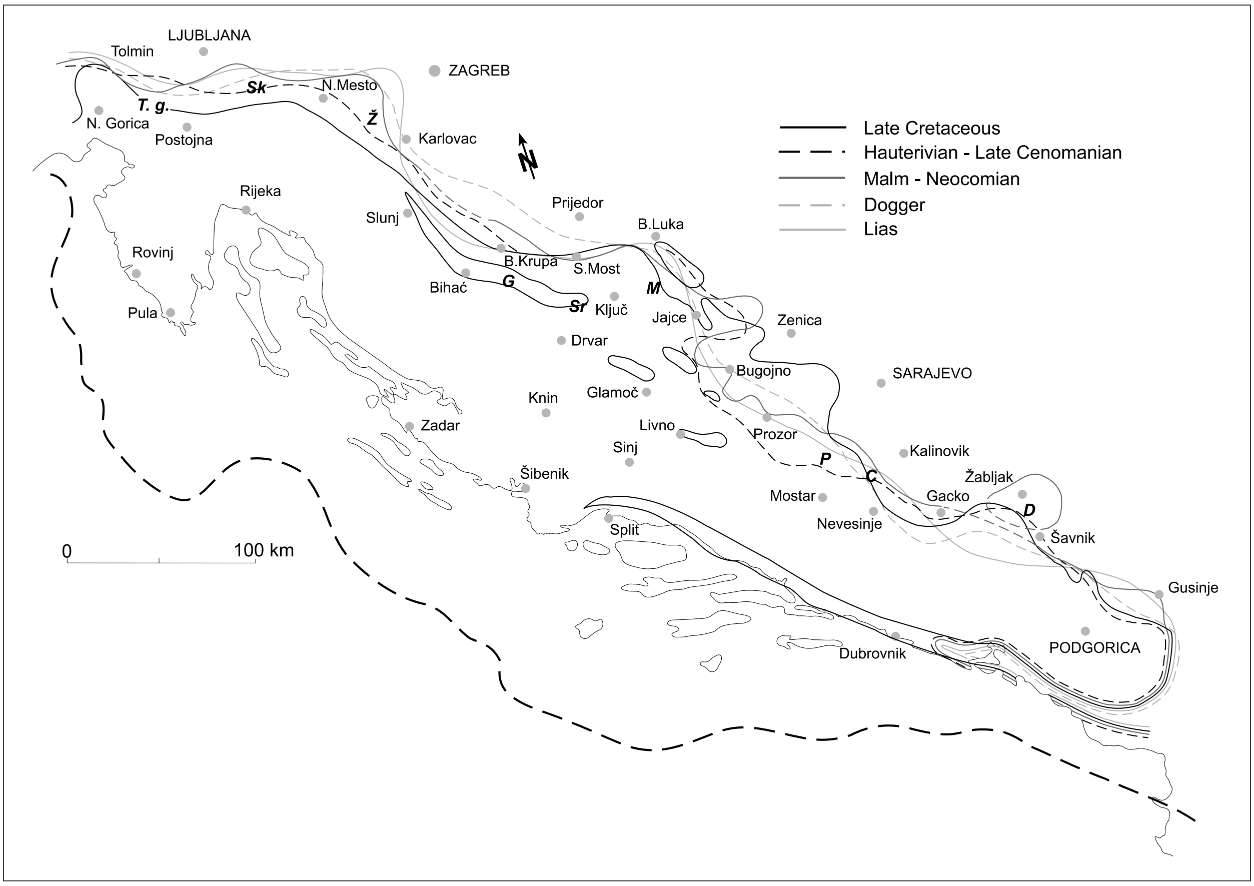


Fig. 33 Sketch of the NE Adriatic Carbonate Platform margin migrations from the Toarcian to the Maastrichtian.

sion, mostly "flooded" and covered with Maastrichtian–Palaeogene basinal, mostly flysch deposits. In spite of these changes, the NE margin of the AdCP, has kept its relatively stable position and orientation during the "life" of the platform and its geodynamic development that lasted from the Early Jurassic to the end of Cretaceous. Smaller differences and migrations of the margin were caused by its geodynamic evolution, reflecting the influences of eustatic and tectonic events, most frequently on a local scale. These events caused either the regressive or transgressive movements which resulted in progradational or retrogradational processes and deposition of their corresponding sequences on the very margin of the platform.

The platform margin migrations on Fig. 33 show that there is clear disharmony in the position of the margin through time from the Early Jurassic to the end of the Cretaceous in the area from Žumberak to central Bosnia (Bugojno–Zenica area). In contrast, in Slovenia, Herzegovina and Montenegro, the margin position was more or less constant. Disharmony could be interpreted by different palaeogeographic positions in various Jurassic and Cretaceous ages, and by the consequences of post-platform tectonics.

In the Kordun and NW Bosnia the platform marginal parts were overthrust by the Permian and Triassic deposits. Southeastward, in the area between Ključ and Sarajevo, uplift of the Central Bosnian Palaeozoic complex of the platform basement caused faulting of the platform margin carbonate successions and their partial overthrusting over the slope and basinal flysch deposits of Upper Cretaceous and Palaeogene age. As a result of this tectonic activity the Osmača, Čemernica and Vlašić Mts., between Banjaluka and Zenica, were torn away from the AdCP margin and overthrust on the aforementioned younger deposits (DRAGIČEVIĆ, 1987). It seems that similar events took place in Žumberak and the Samobor Mts. where allochthonous Triassic and earliest Jurassic shallow marine carbonates were overthrust over Upper Cretaceous–Palaeocene basinal deposits, mostly flysch (ŠIKIĆ et al., 1978; PLENIČAR et al., 1976).

5. CONCLUSION

Due to extensional tectonics in the Periadriatic region that occurred from the end of the Sinemurian through the Pliensbachian and Toarcian, the previously unified shallow marine area on the Adria Microplate was split into several smaller entities. In this way, in the southern part of Tethys, several isolated carbonate platforms were formed, of which the Adriatic Carbonate Platform (AdCP) was one. As a shallow marine carbonate depositional system it lasted until the end of the Cretaceous. When this platform was individualised, its margins and slopes were formed, which are recently mostly unavailable for investigation, partly because of the tectonic complexity and partly due to coverage by younger deposits. The SW margin and slope lie beneath the Adriatic Sea completely covered by Tertiary and Quaternary sediments, and only data regarding their shape and position have been acquired by geophysical measurements and results from deep oil and gas exploration wells. On the opposite side of the platform, in spite of the significant tectonic disruption and partial coverage with Cretaceous–Palaeogene flysch and Neogene–Quaternary deposits, the NE marginal area with the characteristic facies of the platform margin and slope is locally exposed and can be recognized.

The initial tectonic–palaeogeographic changes connected with the processes of individualisation of the AdCP in the Early Jurassic were reflected at its NE margin. Part of the previous shallow marine area was flooded and the border between the basinal and platform sedimentation during the Middle and Late Jurassic was shifted in a SW direction. This is most clearly marked in the Žumberak and Karlovac area, in the Middle Lias to Valanginian depositional sequences, in spite of the fact that most of the platform margin along the strike was emerged during the Middle Lias–Kimmeridgian period. Contemporaneously, mostly ooid–bioclastic carbonates were deposited in the marginal platform shallows, and the platform margin mostly retains its (palaeo)geographic position.

In the Late Jurassic (Kimmeridgian and Tithonian) the platform margin was marked by the coral–hydrozoan barrier reefs. The platform margin locally migrated towards the north-east by reef progradation in the basinal direction, over the slope facies.

The smallest amount of data is available on the events at the platform margin during the Early Cretaceous and the Cenomanian. There are sporadic occurrences of the coral–hydrozoan–rudist biolithite buildups such as in western Slovenia (Banjška planota) and in central Bosnia (between Jajce and Kupres polje). Facies characteristics of the recently discovered carbonate sediments of the platform margin indicate more restricted environments. It is supposed that during the Early Cretaceous, the platform margin was located somewhat further SW of its Late Jurassic position.

The Late Cretaceous period was the most dynamic period in the history of the platform. The fact that rudist limestones, which are very important for the inner platform area, were found only in a few localities along the platform margin, indicate that the platform margin was emerged from the Late Albian to Early Santonian. This is a consequence of the Late Cretaceous tectonics that started in the Upper Albian and were continuously active until it finally destroyed the platform at the end of the Cretaceous. In the vicinity of Jajce (Liskovica, Bešpelj etc.), the karstified palaeorelief of Albian limestones was partially infilled by bauxite deposits. There are some localities with continuity of depositon of rudist limestones until the emersion in the Middle and Late Cenomanian. On the karstified palaeorelief of these limestones there are also bauxite occurrences, e.g. in the vicinity of Karlovac in Croatia (Dubravčani), and in Bosnia – in the Grmeč Mt., N of Glamoč (Čardak livade), E of Jajce (Ravanac) and in Vlašić Mt. (Guča Gora locality).

Deposition of platform rudist limestones was renewed during the Santonian transgression. At the very margin of the platform towards the open Tethys, there were numerous rudist colonies building biolithite bodies. Apart from rudists, there are the remains of reef-building organisms – corals, hydrozoans, stromatoporoids, bryozoans, sponges, algae, echinoids, gastropods and bivalves. Due to the penecontemporaneous mechanical destruction of these buildups, large masses of bioclasts and lithoclasts were formed and together with the mud deposited on the fore-reef and upper slope, were transported down the slope by turbidity currents and debris flows. These coarse-grained clastic sediments represent the proximal facies of the more fine-grained Campanian–Maastrichtian carbonate–clastic sediments (flysch) deposited during the peak of the transgression. The area of carbonate–clastic sedimentation gradually retreated from the former marginal area in a SW direction, covering the platform carbonates. This relatively fast flooding also represented the end of the platform margin and final disintegration of the platform. In this way the end of the Cretaceous marked the end of the existence of the dynamic shallow marine carbonate depositional system – the Adriatic Carbonate Platform which, in this final act, changed from being extant into extinct.

Acknowledgement

The authors are sincerely grateful to the reviewers, Professor Vladimir JELASKA (Faculty of Sciences, University of Zagreb), Dr. Bojan OGORELEC (Geological Survey of Slovenia), Dr. Igor VLAHOVIĆ (Institute of Geology Zagreb) and Dr. Julie ROBSON (Open University Milton Keynes) for their comments and useful suggestions, as well as to Mr. Ivan KRATKOVIĆ and Mr. Željko MARKULIN (INA-Naftaplin Zagreb) for seismic profile presented in this paper.

6. REFERENCES

ANTONIJEVIĆ, R., PAVIĆ, A., KAROVIĆ, J., DIMITRIJEVIĆ, M., RADOIČIĆ, R., PEJOVIĆ, D., PANTIĆ, S. & ROKSANDIĆ, M. (1973): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Kotor L34–50 (Basic geological map of SFRY 1:100,000. Geology of the Kotor sheet).– Zavod za geološka i geofizička istraživanja Beograd (1964), Savezni geološki zavod Beograd, 64 p.

BABIĆ, Lj. (1973): Bazenski sedimenti gornjeg titona, berijasa i valendisa zapadno od Bregane (Upper Tithonian to Valanginian basinal sediments west of Bregana).– Geol. vjesnik, 26, 11–27.

BABIĆ, Lj. (1974): Razdoblje otriv–cenoman u Žumberku: stratigrafija, postanak sedimenata i razvoj prostora (Hauterivian to Cenomanian time in the region of Žumberak, northwestern Croatia).– Geol. vjesnik, 27, 11–33.

BABIĆ, Lj. (1976): Pomak granice između unutrašnje i vanjske Dinarske regije, primjer šireg područja Žumberka (Migration of the boundary between "inner" and "outer" Dinaric zones).– Zbornik radova 8 jugosl. geol. kongresa Bled (1974), Ljubljana (Proceedings of the 8th Yugosl. geol. congress), 2, 45–51.

BABIĆ, Lj. (1980): Pojave vapnenanca s kalpionelidama na Rudnici (Posavske bore, istočna Slovenija) (Limestone with Calpionellids on Mt. Rudnica, eastern Slovenia) – Geol. vjesnik, 31, 13–20.

BABIĆ, Lj. & ZUPANIČ, J. (1976): Sedimenti i paleogeografija zone *Globotruncana calcarata* (gornja kreda) u Baniji i Kordunu (središnja Hrvatska) (Sediments and paleogeography of the *Globotruncana calcarata* (Upper Cretaceous) in Banija and Kordun, central Croatia).– Geol. vjesnik, 29, 49–73.

BASSOULLET, J.P., ELMI, S., POISSON, A., CECCA, F., BELLION, Y., GUIRAUD, R. & BAUDIN, F. (1993): Middle Toarcian (184 to 182 Ma).– In: DERCOURT, J., RICOU, L.E. & VRIELYNCK, B. (eds.): Atlas Tethys Palaeoenvinronmental Maps. Explanatory notes. Gauthier-Villars, Paris, 63–80.

BERNOULLI, D. (1971): Redeposited pelagic sediments in the Jurassic of the central Mediterranean area.– Annales Instituti Geologici Publici Hungarici, 54/2, 71–90.

BLANCHET, R. (1975): De l'Adriatique au bassin Pannonique – essai d'un modèle de chaîne alpine.– Mém. Soc. géol. France, 53 (120), 1–172.

BUCKOVIĆ, D., JELASKA, V. & CVETKO, B. (2001): Facies variability in Lower Liassic carbonate successions of the western Dinarides (Croatia).– Facies, 44, 151–162.

BUKOVAC, J. & SOKAČ, B. (1989): Upper Triassic–Lower Liassic limestones on the northern slopes of Mt. Gorjanci and south of Kostanjevica (southeast Slovenia) and their significance for the geotectonics of the larger area.– Geol. vjesnik, 42, 7–13.

BUKOVAC, J., VELIĆ, I. & SOKAČ, B. (1974): Stratigrafski, tektonski i paleogeografski odnosi u području Dugarese, Barilovića i Skradske gore (Stratigraphy, tectonics and paleogeography of the region between Dugaresa, Barilović and Skradska gora).– Geol. vjesnik, 27, 59–77.

BUKOVAC, J., ŠUŠNJAR, M., POLJAK, M. & ČAKALO, M. (1984): Osnovna geološka karta SFRJ 1:100.000. List Črnomelj L33–91 (Basic geological map of SFRY 1: 100,000. The Črnomelj sheet).– Geološki zavod Zagreb, Geološki zavod Ljubljana (1972–1983), Savezni geološki zavod Beograd.

BUSER, S. (1968): Osnovna geološka karta SFRJ 1:100.000. List Gorica L33–76 (Basic geological map of SFRY 1: 100,000. The Gorica sheet).– Geološki zavod Ljubljana (1958–1963), Savezni geološki zavod Beograd.

BUSER, S. (1969): Osnovna geološka karta SFRJ 1:100.000. List Ribnica L33–78 (Basic geological map of SFRY 1: 100,000. The Ribnica sheet).– Geološki zavod Ljubljana (1961–1965), Savezni geološki zavod Beograd.

BUSER, S. (1973): Osnovna geološka karta SFRJ 1:100.000. Tolmač lista Gorica L33–76 (Basic geological map of SFRY 1:100,000. Geology of the Gorica sheet).– Geološki zavod Ljubljana (1964), Savezni geološki zavod Beograd, 50 p.

BUSER, S. (1986): Osnovna geološka karta SFRJ 1:100.000. Tolmač listov Tolmin in Videm L33–64, L33–63 (Basic geological map of SFRY 1:100,000. Geology of the Tolmin and Videm sheet).– Geološki zavod Ljubljana (1985), Savezni geološki zavod Beograd, 1–103.

BUSER, S. (1987): Osnovna geološka karta SFRJ 1:100.000. List Tolmin in Videm L33–64 (Basic geological map of SFRY 1:100,000. The Tolmin and Videm sheet).– Geološki zavod Ljubljana (1969–1984), Savezni geološki zavod Beograd.

BUSER, S. (1989): Development of the Dinaric and the Julian Carbonate platforms and of the intermediate Slovenian basin (NW Yugoslavia).– Mem. Soc. Geol. Ital., 40, 313–320.

BUSER, S., GRAD, K. & PLENIČAR, M. (1967): Osnovna geološka karta SFRJ 1:100.000. List Postojna L33–77 (Basic geological map of SFRY 1:100,000. The Postojna sheet).– Geološki zavod Ljubljana (1963), Savezni geološki zavod Beograd.

BUSER, S., PAVŠIČ, J. & ANIČIĆ, B. (1982): Globokomorske kredne plasti v vzhodni Sloveniji (Deep sea Cretaceous beds of eastern Slovenia).– Zbornik radova 10. jub. kongr. geol. Juslavije – Budva, 1, 11–23.

DERCOURT, J., RICOU, L.E. & VRIELYNCK, B. (eds.) (1993): Atlas Tethys palaeoenvinronmental maps.– Gauthier-Villars, Paris, 307 p.

DOZET, S. (1994): Stratigraphy of the Suha Krajina area (Slovenia) and stratigraphic gap Middle Liassic–Lower Malm.– Rudarsko–metalurški zbornik, 41, 231–238, Ljubljana.

DOZET, S. (2000a): Hočevje oolitic group, central Slovenia.– Acta Carsologica, 29/1,185–189, Postojna.

DOZET, S. (2000b): Stratigraphy of the Verd oolitic limestone complex.– Rudarsko–metalurški zbornik, 47, 245–254, Ljubljana.

DOZET, S. & ŠRIBAR, Lj. (1998a): Biostratigraphy of shallow marine Jurassic beds in southeastern Slovenia.– Geologija, 40, 187–221.

DOZET, S. & ŠRIBAR, Lj. (1998b): Lower Cretaceous shallow-marine sedimentation and biota on Dinaric carbonate platform between Logatec, Krka and Kolpa (southeastern Slovenia).– Geologija, 40, 153–185, Ljubljana.

DRAGIČEVIĆ, I. (1987): Paleogeografska evolucija rubnog dijela mezozojske karbonatne platforme Dinarida između Vrbasa i Bosne (Palaeogeographical evolution of the marginal zone of the Mesozoic carbonate platform of Dinarides in the area between Vrbas and Bosna rivers – in Croatian with English summary).– Unpubl. PhD Thesis, University of Zagreb, 90 p.

DRAGIČEVIĆ, I. & VELIĆ, I. (1994): Stratigraphical position and significance of reef facies at the northern margin of the Dinaric carbonate platform during the Late Jurassic and Cretaceous in Croatia and Bosnia.– Géologie Méditerranéenne, 21/3–4, 59–63

ĐERKOVIĆ, B., MAKSIMČEV, S., VILOVSKI, S., KUJUNDŽIĆ, S., SUNARIĆ, O., HOHRAJN, J., KOVAČEVIĆ, R., KAČAR, B., VELJOVIĆ, R., JOJIĆ, D., MARIĆ, Lj., LOŽAJIĆ, M., PAMIĆ, J., KAPELER, I., ĐORĐEVIĆ, D. & JURIĆ, M. (1976): Osnovna geološka karta SFRJ 1:100.000. List Prijedor L33–118 (Basic geological map of SFRY 1:100,000. The Prijedor sheet).– Institut za geološka istraživanja Sarajevo (1961–1967), Savezni geološki zavod Beograd.

ĐOKIĆ, V., ŽIVALJEVIĆ, M. & PEROVIĆ, Z. (1973): Osnovna geološka karta SFRJ 1:100.000. List Gusinje K34–52 (Basic geological map of SFRY 1:100,000. The Gusinje sheet).– Zavod za geološka istraživanja Titograd (1958–1968), Savezni geološki zavod Beograd.

GAMBINI, R. & TOZZI, M. (1996): Tertiary geodynamic evolution of the Southern Adria microplate.– Terra Nova, 8, 593–602.

GRANDIĆ, S. & VUKSANOVIĆ, B. (1973): Kordun kao novo boksitonosno područje na teritoriji SR Hrvatske (Kordun als neues Bauxit-gebiet auf dem Terrain der SR Kroatien).– 2. jugosl. simp. istraž. ekspl. boksita, Tuzla, 5.

GRANDIĆ, S., BOROMISA-BALAŠ, E., ŠUŠTERČIĆ, M. & KOLBAH, S. (1999): Hydrocarbon possibilities in the eastern Adriatic slope zone of Croatian offshore area.– Nafta, 50/2, 51–73, Zagreb.

GUŠIĆ, I. (1969): Biostratigrafske i mikropaleontološke karakteristike nekih jurskih profila iz područja centralne Hrvatske (Biostratigraphic and micropaleontologic characteristics of some Jurassic cross-sections in central Croatia).– Geol. vjesnik, 22, 89–97.

GUŠIĆ, I. & BABIĆ, Lj. (1970): Neke biostratigrafske i litogenetske osobine jure Žumberka (Some biostratigraphic and lithogenetic characteristic of the Jurassic in Žumberak, northwest Croatia).– Geol. vjesnik, 23, 39–54.

GUŠIĆ, I. & JELASKA, V. (1990): Stratigrafija gornjokrednih naslaga otoka Brača u okviru geodinamske evolucije Jadranske karbonatne platforme (Upper Cretaceous stratigraphy of the Island of Brač within the geodynamic evolution of the Adriatic Carbonate Platform).– JAZU and Inst. geol. istraživanja, Zagreb, 160 p.

GUŠIĆ, I. & JELASKA, V. (1993): Upper Cenomanian–Lower Turonian sea-level rise and consequences on the Adriatic–Dinaric carbonate platform.– Geol. Rundschau, 82/4, 676–686.

JELASKA, V. (1973): Paleogeografska i naftnogeološka razmatranja zapadnog dijela karbonatnog šelfa Dinarida (Paleogeographic and oil-geologic considerations of the west part of the Dinaride carbonate shelf).– Geol. vjesnik, 25, 57–64.

JELASKA, V. (1987): Paleoambijentalna dinamika sjeveroistočnog rubnog prostora Vanjskih Dinarida u juri i kredi (Jurassic and Cretaceous paleoenvironmental dynamic of the northeastern margin of the Outer Dinarides).– Geol. vjesnik, 40, 195–216.

JELASKA, V., AMŠEL, V., KAPOVIĆ, B. & VUKSANOVIĆ, B. (1969): Sedimentološke karakteristike klastične gornje krede zapadnog dijela Bosanske Krajine (Sedimentologic characteristics of the clastic Upper Cretaceous of the western part of Bosanska Krajina).– Nafta, 10, 487–495, Zagreb.

JELASKA, V., GUŠIĆ, I., JURKOVŠEK, B., OGORELEC, B., ĆOSOVIĆ, V., ŠRIBAR, L. & TOMAN, M. (1994): The Upper Cretaceous geodynamic evolution of the Adriatic–Dinaric carbonate platform(s).– Géol. Méditerranéenne, 21/3–4, 89–91.

JOVANOVIĆ, R., MOJIČEVIĆ, M., TOKIĆ, S. & ROKIĆ, Lj. (1977): Osnovna geološka karta SFRJ 1:100.000. List Sarajevo K34–1 (Basic geological map of SFRY 1: 100,000. The Sarajevo sheet).– Zavod za inženjersku geologiju i hidrogeologiju Građevinskog fakulteta u Sarajevu (1962–1967), Savezni geološki zavod Beograd.

JURIĆ, M. (1977): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Prijedor L33–118 (Basic geological map of SFRY 1:100,000. Geology of the Prijedor sheet).– Geoinženjering Sarajevo (1975), Savezni geološki zavod Beograd, 55 p.

JURKOVŠEK, B., ŠRIBAR, L., OGORELEC, B. & KOLAR-JURKOVŠEK, T. (1988/89): Pelagične jurske in kredne plasti v vzhodnem delu Julijskih Alp (Pelagic Jurassic and Cretaceous beds in the western part of the Julian Alps).– Geologija, 31–32, 285–328.

JURKOVŠEK, B., TOMAN, M., OGORELEC, B., ŠRIBAR, L., DROBNE, K., POLJAK, M. & ŠRIBAR, Lj. (1996): Formacijska geološka karta južnega dela Tržaško–Komenske planote. Kredne in paleogenske karbonatne kamnine, 1:50.000 (Geological map of the southern part of the Trieste–Komen plateau. Cretaceous and Paleogene carbonate rocks).– Inst. geol., geoteh., geofiz. Ljubljana, 143 p.

KALEZIĆ, M. & MIRKOVIĆ, M. (1970): Osnovna geološka karta SFRJ 1:100.000. List Šavnik K34–39 (Basic geological map of SFRY 1:100,000, The Šavnik sheet).– Zavod za geološka istraživanja Titograd (1962–1966), Savezni geološki zavod Beograd.

KALEZIĆ, M., MIRKOVIĆ, M. & ŠKULETIĆ, D. (1973): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Šavnik K34–39 (Basic geological map of SFRY 1: 100,000. Geology of the Šavnik sheet).– Zavod za geološka istraživanja Titograd (1966), Savezni geološki zavod Beograd, 65 p.

KORBAR, T., FUČEK, L., HUSINEC, A., VLAHOVIĆ, I., OŠTRIĆ, N., MATIČEC, D. & JELASKA, V. (2001): Cenomanian carbonate facies and rudists along shallow intraplatform basin margin – the island of Cres (Adriatic Sea, Croatia).– Facies, 45, 39–58.

KOROLIJA, B., ŽIVALJEVIĆ, T. & ŠIMUNIĆ, A. (1980): Osnovna geološka karta SFRJ 1:100.000. List Slunj L33–104 (Basic geological map of SFRY 1:100,000. The Slunj sheet).– Institut za geološka istraživanja Zagreb, Geološki zavod Sarajevo (1968–1972), Savezni geološki zavod Beograd.

KOROLIJA, B., ŽIVALJEVIĆ, T. & ŠIMUNIĆ, A. (1981): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Slunj L33–104 (Basic geological map of SFRY 1:100,000. Geology of the Slunj sheet).– Institut za geološka istraživanja Zagreb (1972) and Geološki zavod Sarajevo (1968), Savezni geološki zavod Beograd, 47 p.

KUŠČER, D., GRAD, K., NOSAN, A. & OGORELEC, B. (1974): Geološke raziskave soške doline med Bovcem in Kobaridom (Geology of the Soča valley between Bovec and Kobarid).– Geologija, 17, 425–476, Ljubljana.

MARINKOVIĆ, R. & AHAC, A. (1980): Osnovna geološka karta SFRJ 1:100.000. List Jajce L33–131 (Basic geological map of SFRY 1:100,000, The Jajce sheet).– Geoinženjering Sarajevo (1975), Savezni geološki zavod Beograd.

MARJANAC, Lj. & MARJANAC, T. (1987): Continental slope and its sediments during Cretaceous in Krško Hribovje (SE Slovenia, Yugoslavia).– Intern. Symp. on the Evolut. of Karstic Carbonate Platform: Relation with Other Periadriatic Carb. Platforms. Univ. degli studi di Trieste, Abstracts, 43.

MILAN, A. (1969): Facijelni odnosi i hidrozojska fauna malma primorskog dijela sjevernog Velebita i Velike Kapele (Faziesverhältnisse und Hydrozoenfauna des Malms im Küstenland des Nördlichen Velebit und Velika Kapela).– Geol. vjesnik, 22, 135–217.

MIRKOVIĆ, M. (1980): Osnovna geološka karta SFRJ 1: 100.000. Tumač za list Gacko K34–26 (Basic geological map of SFRY 1:100,000. Geology of the Gacko sheet).– Zavod za geološka istraživanja Titograd (1974), Savezni geološki zavod Beograd, 67 p.

MIRKOVIĆ, M. & MIRKOVIĆ, B. (1987): Novi podaci o rasprostranjenju jurskih sedimenata u području Sinjavine, Durmitora i Ljubišnje (New data about distribution of Jurassic sediments in the area of Sinjavina, Durmitor and Ljubišnja).– Geološki glasnik, 12, 61–87, Titograd.

MIRKOVIĆ, M. & VUJISIĆ, P. (1989): Osnovna geološka karta SFRJ 1:100.000. List Žabljak K34–27 (Basic geological map of SFRY 1:100,000. The Žabljak sheet).– Zavod za geološka istraživanja Titograd (1980–1986), Savezni geološki zavod Beograd.

MIRKOVIĆ, M., KALEZIĆ, M. & PAJOVIĆ, M. (1977): Osnovna geološka karta SFRJ 1:100.000. List Bar K34–63 (Basic geological map of SFRY 1:100,000. The Bar sheet).– Zavod za geološka istraživanja Titograd (1968), Savezni geološki zavod Beograd.

MIRKOVIĆ, M., KALEZIĆ, M., PAJOVIĆ, M., ŽIVALJEVIĆ, M. & ŠKULETIĆ, D. (1978): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Bar K34–63 (Basic geological map of SFRY 1:100,000. Geology of the Bar sheet).– Zavod za geološka istraživanja Titograd (1968), Savezni geološki zavod Beograd, 67 p.

MIRKOVIĆ, M., PAJOVIĆ, M. & KALEZIĆ, M. (1979): Osnovna geološka karta SFRJ 1:100.000. List Gacko K34–26 (Basic geological map of SFRY 1:100,000. The Gacko sheet).– Zavod za geološka istraživanja Titograd (1967–1974), Savezni geološki zavod Beograd.

MOJIČEVIĆ, M. & LAUŠEVIĆ, M. (1969): Osnovna geološka karta SFRJ 1:100.000. List Nevesinje K34–25 (Basic geological map of SFRY 1:100,000. The Nevesinje sheet).– Geološki zavod Sarajevo (1958–1964), Savezni geološki zavod Beograd.

MOJIČEVIĆ, M. & LAUŠEVIĆ, M. (1971): Osnovna geološka karta SFRJ 1:100.000. List Mostar K33–24 (Basic geological map of SFRY 1:100,000. The Mostar sheet).– Geološki zavod Sarajevo (1958–1969), Savezni geološki zavod Beograd.

MOJIČEVIĆ, M. & LAUŠEVIĆ, M. (1973): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Nevesinje K34–25 (Basic geological map of SFRY 1:100,000. Geology of the Nevesinje sheet).– Institut za geološka istraživanja Sarajevo (1965), Savezni geološki zavod Beograd, 53 p.

MOJIČEVIĆ, M. & TOMIĆ, B. (1982a): Osnovna geološka karta SFRJ 1:100.000. List Kalinovik K34–13 (Basic geological map of SFRY 1:100,000. The Kalinovik sheet).– Geoinženjering Sarajevo (1969–1977), Savezni geološki zavod Beograd.

MOJIČEVIĆ & TOMIĆ (1982b): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Kalinovik K34–13 (Basic geological map of SFRY 1:100,000. Geology of the Kalinovik sheet).– Geoinženjering Sarajevo (1981), Savezni geološki zavod Beograd, 60 p.

MOJIČEVIĆ, M., VILOVSKI, S. & TOMIĆ, B. (1977): Osnovna geološka karta SFRJ 1:100.000. List Banjaluka L33–119 (Basic geological map of SFRY 1:100,000. The Banjaluka sheet).– Institut za geološka istraživanja Sarajevo (1964–1969), Savezni geološki zavod Beograd.

MOJIČEVIĆ, M., MAKSIMČEV, S. & VRHOVČIĆ, J. (1978): Osnovna geološka karta SFRJ 1:100.000. List Bosanska Krupa L33–117 (Basic geological map of SFRY 1:100,000. The Bosanska Krupa sheet).– Institut za geološka istraživanja Sarajevo (1964–1971), Savezni geološki zavod Beograd.

MOJIČEVIĆ, M., PAMIĆ, J., MAKSIMČEV, S. & PAPEŠ, J. (1979): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Bosanska Krupa L33–117 (Basic geological map of SFRY 1:100,000. Geology of the Bosanska Krupa sheet).– Geoinženjering Sarajevo (1971), Savezni geološki zavod Beograd, 50 p.

MRINJEK, E. (1988a): Sitnozrnati turbiditi cenomana u prelaznom pojasu Unutrašnjih i Vanjskih Dinarida sjeveroistočno od Slunja (Fine-grained turbidites in the Cenomanian of the transitional zone between Inner and Outer Dinarides, NE of Slunj).– Geol. vjesnik, 41, 181–196.

MRINJEK, E. (1988b): Sitnozrnati turbiditi i konturiti u dubokovodnim sedimentima gornje krede kod Slunja i u Žumberku (Fine grained turbidites and conturites in the deep-water sediments of the Upper Cretaceous age near Slunj and in Žumberak).– Zbornik radova 6. skup sediment. Jugosl. Titograd (Proc. of the 6th meeting of sedimentologists of Yugoslavia, Titograd), Geol. glasnik, Posebna izd., 6, 135–149, Titograd.

NIKLER, L. (1978): Stratigrafski položaj grebenskoga facijesa malma u sjevero-zapadnim dijelovima Dinarida (Stratigraphic position of the Malmian reef facies in northwestern Dinarids).– Geol. vjesnik, 30/1, 137–150.

OGORELEC, B. & DOZET, S. (1997): Upper Triassic, Jurassic and Lower Cretaceous beds in eastern Sava folds – Section Laze at Boštanj (Slovenia).– Rud. metal. zbornik, 44/3–4, 223–235, Ljubljana.

OGORELEC, B., ŠRIBAR, L. & BUSER, S. (1976): O litologiji in biostratigrafiji volčanskega apnenca (On lithology and biostratigraphy of Volče limestone).– Geologija, 19, 125–151, Ljubljana.

OREHEK, S. & OGORELEC, B. (1981): Korelacija mikrofacialnih i geohemijskih osobina jurskih i krednih stena južne karbonatne platforme Slovenije (Correlation of microfacial and geochemical characteristics of Jurassic and Cretaceous rocks of the Southern carbonate platform in Slovenia).– Glas. republ. zav. zašt. prirode – Prirodnjačkog muzeja, 14, 161–181, Titograd.

PAPEŠ, J. (1972): Osnovna geološka karta SFRJ 1:100.000. List Livno K33–11 (Basic geological map of SFRY 1: 100,000. The Livno sheet).– Geološki zavod Sarajevo (1962–1967), Savezni geološki zavod Beograd.

PAPEŠ, J. (1975): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Livno K33–11 (Basic geological map of SFRY 1:100,000. Geology of the Livno sheet).– Institut za geološka istraživanja Sarajevo (1967), Savezni geološki zavod Beograd, 64 p.

PAPEŠ, J. (1985): Geologija jugozapadne Bosne (Geology of the southwestern Bosnia).– Geol. glasnik, Pos. izd. (Spec. Publ.), 19, 197 p., Sarajevo.

PAVŠIČ, J. (1977): Nanoplankton v zgornjekrednih in paleocenskih plasteh na Goriškem (Nannoplankton from the Upper Cretaceous and Paleocene beds in the Gorica region).– Geologija, 20, 33–83.

PEZA, L.H. & PEZA, E. (1994): The Mesozoic development of the Albanian Alps carbonate systems and its relatioships with the Cukali and Kelmendi troughs.– Géologie Méditerranéenne, 21/3–4, 145–148.

PLENIČAR, M. (1958): Poročilo o globokomorskem razvoju krednih plasti pri Kostanjevici (Report on the deep-sea development of the Cretaceous beds at Kostanjevica).– Geologija, 4, 152–156, Ljubljana.

PLENIČAR, M., PREMRU, U. & HERAK, M. (1976): Osnovna geološka karta SFRJ 1:100.000. List Novo Mesto L33–79 (Basic geological map of SFRY 1:100,000. The Novo Mesto sheet).– Geološki zavod Ljubljana (1963–1969), Savezni geološki zavod Beograd.

POLŠAK, A. (1981): Upper Cretaceous biolithitic complexes in a subduction zone: examples from the Inner Dinarids, Yugoslavia.– In: TOOMEY, D.F. (ed.): European Fossil Reef Models. Soc. Econ. Pal. Mineral., Spec. Publ., 30, 447–472.

POLŠAK, A., JURIŠA, M., ŠPARICA, M. & ŠIMUNIĆ, An. (1977): Osnovna geološka karta SFRJ 1:100.000. List Bihać L33–116 (Basic geological map of SFRY 1: 100,000. The Bihać sheet).– Institut za geološka istraživanja Zagreb (1962–1967), Savezni geološki zavod Beograd.

POLŠAK, A., CRNKO, J., ŠIMUNIĆ, An., ŠIMUNIĆ, Al., ŠPARICA, M. & JURIŠA, M. (1978): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Bihać L33–116 (Basic geological map of SFRY 1:100,000. Geology of the Bihać sheet).– Institut za geološka istraživanja Zagreb (1967), Savezni geološki zavod Beograd, 51 p.

RADOIČIĆ, R. (1966): Microfaciès du Jurasique des Dinarides externes de la Yougoslavie.– Geologija, 9, 5–378, Ljubljana.

RADOIČIĆ, R. (1989): The Dinaric carbonate platform: adjacent basins and depressions.– Mem. Soc. Geol. It., 40, 309–311.

SOFILJ, J. & ŽIVANOVIĆ, M. (1979): Osnovna geološka karta SFRJ 1:100.000. List Prozor K33–12 (Basic geological map of SFRY 1:100,000. The Prozor sheet).– Institut za geološka istraživanja Sarajevo (1965–1971), Savezni geološki zavod Beograd.

SOFILJ, J., ŽIVANOVIĆ, M. & PAMIĆ, J. (1980): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Prozor K33–12 (Basic geological map of SFRY 1:100,000. Geology of the Prozor sheet).– Institut za geološka istraživanja Sarajevo (1971), Savezni geološki zavod Beograd, 49 p.

SOKAČ, B. (1964): Geološki odnosi u području Krstinja–Cetingrad (Geology of the Krstinja–Cetingrad area).– Unpubl. MSc. Thesis, University of Zagreb, 37 p.

STAMPFLI, G.M. & MOSAR, J. (1999): The making and becoming of Apulia.– In: GOSSO, G., JADOUL, F., SELLA, M. & SPALLA, M.I. (eds.): 3rd Workshop on Alpine Geological Studies. Memorie di scienze geologiche, 51/1, 141–154, Padova.

ŠIKIĆ, K. & BASCH, O. (1975): Geološka zbivanja od paleozoika do kvartara u zapadnom dijelu zagrebačke regije (Geological events from Paleozoic to Quaternary in the western part of Zagreb area).– 2. godišnji znanstveni skup sekcije za primjenu geol., geofiz., geokem., Znanstveni savjet za naftu JAZU Zagreb (A), 5, 69–86.

ŠIKIĆ, K., BASCH, O. & ŠIMUNIĆ, A. (1978): Osnovna geološka karta SFRJ 1:100.000. List Zagreb L33–80 (Basic geological map of SFRY 1:100,000. The Zagreb sheet).– Institut za geološka istraživanja Zagreb (1972), Savezni geološki zavod Beograd.

ŠIKIĆ, K., BASCH, O. & ŠIMUNIĆ, A. (1979): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Zagreb L33–80 (Basic geological map of SFRY 1:100,000. Geology of the Zagreb sheet).– Institut za geološka istraživanja Zagreb (1972), Savezni geološki zavod Beograd, 81 p.

ŠINKOVEC, B. & BABIĆ, V. (1973): Kemijski i mineralni sastav donjokrednih glinovitih boksita u planini Grmeč (Chemical and mineralogical composition of the Lower Cretaceous clayey bauxites of the Grmeč Mountain).– Geol. vjesnik, 25, 245–253.

ŠPARICA, M. (1981): Mezozoik Banije, Korduna i dodirnog područja Bosne (Geology of the Mesozoic areas of Kordun, Banija and NW Bosnia, Yugoslavia).– Nafta, Zagreb, Spec. Publ., XII+245 p.

ŠRIBAR, Lj. (1965): Meja med krednimi in terciarnimi skladi v Goriških Brdih (The boundary between Cretaceous and Tertiary in Goriška brda).– Geologija, 8, 121–129, Ljubljana.

TOMIĆ, V. (1985): Prigrebenske i bazenske naslage senona u području Donjeg Bešpelja, sjeverno od Jajca (Peri-reefal and basin deposits of the Senonian in the area of Donji Bešpelj, in the north of Jajce).– Geol. vjesnik, 38, 81–86.

TURNŠEK, D. (1966): Zgornjejurska hidrozojska favna iz južne Slovenije (Upper Jurasic hydrozoan fauna from southern Slovenia).– Razprave SAZU, 9, 335–428, Ljubljana.

TURNŠEK, D. (1997): Mesozoic Corals of Slovenia.– ZRC SAZU, Ljubljana, 513 p.

TURNŠEK, D. & BUSER, S. (1974): Spodnjekredne korale, hidrozoji in hetetide z Banjške planote in Trnovskega gozda (The Lower Cretaceous corals, hydrozoans and chaetetids of Banjška planota and Trnovski gozd).– Razprave SAZU, 17, 81–124, Ljubljana.

TURNŠEK, D., BUSER, S. & OGORELEC, B. (1981): An Upper Jurassic reef complex from Slovenia, Yugoslavia.– In: TOOMEY, D.F. (ed.): European Fossil Reef Models. Soc. Econ. Pal. Mineral. Spec. Publ., 30, 361–369.

VELIĆ, I. (1977): Jurassic and Lower Cretaceous assemblage-zones in Mt. Velika Kapela, central Croatia.– Acta geologica, 9/2, 15–37, Zagreb.

VELIĆ, I., VLAHOVIĆ, I. & MATIČEC, D. (2002a): Depositional sequences and palaeogeography of the Adriatic carbonate platform.– Mem. Soc. Geol. It., 57, 141–151.

VELIĆ, I., TIŠLJAR, J., VLAHOVIĆ, I., VELIĆ, J., KOCH, G. & MATIČEC, D. (2002b): Palaeogeographic variability and depositional environments of the Upper Jurassic carbonate rocks of Velika Kapela Mt. (Gorski Kotar area, Adriatic Carbonate Platform, Croatia).– Geol. Croatica, 55/2, 121–138.

VRHOVČIĆ, J. & MOJIČEVIĆ, M. (1983): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Ključ L33–130 (Basic geological map of SFRJ 1:100,000. Geology of the Ključ sheet).– Geoinženjering Sarajevo (1976), Savezni geološki zavod Beograd, 40 p.

VRHOVČIĆ, J., VUJNOVIĆ, L. & MOJIČEVIĆ, M. (1983): Osnovna geološka karta SFRJ 1:100.000. List Ključ L33–130 (Basic geological map of SFRJ 1:100,000. The Ključ sheet).– Geoinženjering Sarajevo (1969–1978), Savezni geološki zavod Beograd.

VUJISIĆ, T. (1972): Osnovna geološka karta SFRJ 1: 100.000. List Nikšić K34–38 (Basic geological map of SFRJ 1:100,000. The Nikšić sheet).– Zavod za geološka i geofizička istraživanja Beograd (1962–1967), Savezni geološki zavod Beograd.

VUJISIĆ, T. (1975): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Nikšić K34–38 (Basic geological map of SFRJ 1:100,000. Geology of the Nikšić sheet).– Zavod za geološka i geofizička istraživanja Beograd (1967), Savezni geološki zavod Beograd, 53 p.

VUJNOVIĆ, L. (1980): Osnovna geološka karta SFRJ 1: 100.000. List Bugojno L33–143 (Basic geological map of SFRJ 1:100,000. The Bugojno sheet).– Geoinženjering Sarajevo (1967–1975), Savezni geološki zavod Beograd.

VUJNOVIĆ, L. (1981): Osnovna geološka karta SFRJ 1: 100.000. Tumač za list Bugojno L33–140 (Basic geological map of SFRJ 1:100,000. Geology of the Bugojno sheet).– Geoinženjering Sarajevo (1975), Savezni geološki zavod Beograd, 58 p.

ZAPPATERRA, E. (1990): Carbonate paleogeographic sequences of the Periadriatic region.– Boll. Soc. Geol. Ital., 109, 5–20.

ZAPPATERRA, E. (1994): Source rock distribution model of the Periadriatic region.– Am. Ass. Petrol. Geol. Bull., 78/3, 333–354.

ZUPANIČ, J. (1976): Senonske naslage tipa Scaglia u zapadnim Dinaridima: postanak sedimenata, lateralne promjene i varijabilnost paleogeografskog značenja (Genesis and lateral variability of Senonian "Scaglia type" sediments in western part of Dinarids).– 8. jugosl. geol. kongr. Bled (1974), 2, 335–341, Ljubljana.

ŽIVALJEVIĆ, M., ĐOKIĆ, V. & PAJOVIĆ, M. (1971): Osnovna geološka karta SFRJ 1:100.000. List Titograd K34–51 (Basic geological map of SFRJ 1:100,000. The Titograd sheet).– Zavod za geološka istraživanja Titograd (1962–1967), Savezni geološki zavod Beograd.

ŽIVALJEVIĆ, M., VUJISIĆ, P. & STIJOVIĆ, V. (1989): Osnovna geološka karta SFRJ 1:100.000. Tumač za list Žabljak K34–27 (Basic geological map of SFRJ 1: 100,000. Geology of the Žabljak sheet).– Zavod za geološka istraživanja Titograd (1987), Savezni geološki zavod Beograd, 62 p.

ŽIVANOVIĆ, M., SOFILJ, J. & MILOJEVIĆ, R. (1971): Osnovna geološka karta SFRJ 1:100.000. List Zenica L33–144 (Basic geological map of SFRJ 1:100,000. The Zenica sheet).– Institut za geološka istraživanja Sarajevo (1962–1967), Savezni geološki zavod Beograd.