Cenomanian Carbonate Facies and Rudists along Shallow Intraplatform Basin Margin - the Island of Cres (Adriatic Sea, Croatia)

Tvrto Kobar, Ladislav Fuček, Antun Husinec, Igor Vlahović, Nenad Oštrić, Dubravko Matičec and Vladimir Jelaska, Zagreb


Summary

The island of Cres is located in the northern part of the Adriatic Sea. The island is built up of predominantly Cretaceous carbonates deposited in north-western part of extensive and long-lasting Adriatic Carbonate Platform. Owing to the influence of synsedimentary tectonics supported by eustatic changes during the latest Albian/Early Cenomanian, different sedimentary environments were established: from shallow intraplatform basin and related slope, across basin margin to protected shallow-platform. During the Early to Middle Cenomanian rudist communities (fichthysarcolid/caprinid/radiolitid) flourished along a relatively high-energy intraplatform basin margin. Fair amounts of coarse-grained bioclasts, derived almost exclusively from broken rudist shells, were deposited over a marginal depocenter. Contemporaneously, pithonellid wackestones-packstones containing microbioclasts and planktonic foraminifera were deposited basinward while marginal bioclastic sediments and limestone blocks of the basin margin origin were sporadically deposited within the basin. The opening of the Cren intraplatform basin was aborted and the basin was finally filled up during the Late Cenomanian. Since the Cren intraplatform basin was establised at the beginning of the Cenomanian it probably represented the initiation phase in the north-western extension of the later Adriatic Trough development.

1 INTRODUCTION

The island of Cres is situated in the northern part of the Adriatic Sea, Croatia (Fig. 1), representing the western part of the Dinarides, which resulted from disintegration of large and long-lasting Adriatic Carbonate Platform (Gušić and Jelaska, 1990; Tišljar and Velić, 1991). Several reverse faults, striking NW-SSE, almost parallel to the island's orientation, represent its major geological structure (Polšak, 1967a; Majaš, 1968; Mamuzić, 1968; Šikić et al., 1969). Most of the outcrops are of the Cretaceous age, but there are some Palaeogene deposits, too. The approximately 800 m thick succession of Lower Cretaceous carbonates, ranging from Valanginian (?)Berriasian) to Uppermost Albian, is characterised by a predominantly shallow-marine deposition sporadically interrupted by minor emersions (Fuček et al., 1995).

By the end of the Albian, or at the beginning of the Cenomanian, different sedimentary environments were established, similar to the events registered in the neighbouring area of Istria (Vlahović et al., 1994; Tišljar et al., 1998). Lateral changes from peritidal protected facies with radiolitids, marginal coarse-grained bioclastic facies with recumbent rudists to deeper-water pithonellid facies across and along the island are evident. The observed thickness of the Cenomanian deposits varies. Mamuzić et al. (1982) reported an approximately 370 m thick sequence of Cenomanian carbonates. According to new measurements and observations, the thickness is somewhat smaller: approximately 150 m in the north-eastern part to c. 300 m in the southern part of the island. Consequently, in the NE part of the island of Cres the foraminiferal Palaeogene lithstones directly overly Cenomanian carbonates, while in the SW part deposition continued until the Coniacian–Early Santonian.

Three sections (Balardin, Sveti Damjan and Osor) composed of penecontemporaneous deposits from different environments, located in the southern part of the island (Fig. 1), have been analysed in order to define their different depositional conditions.

Rudist determinations were made according to descriptions of rudist fauna collected in the neighbouring southern Istria (Polšak, 1967b). Terminology concerning rudist morphotypes was applied according to Skelton and Gili (1991). The strata were biostratigraphically zoned according to already established biozones in the Karst Dinarides (Velić and Sokac, 1978; Velić, 1988; Velić and Vlahović, 1994; Husinec et al., 2000) and the planktonic foraminifera zonal scheme in the Mediterranean area (after Robaszyński and Caron, 1995).

The objectives of the present paper are: (1) to describe and analyse different sedimentary environments that existed on the present day island of Cres during the Cenomanian; (2) to improve the sedimentologic and stratigraphic knowledge of the breccias exposed at Balardin section, probably a key-area of the debated Cretaceous geology; (3) to discuss and

Addresses: M.Sc T. Kobar, Dipl. Geol. L. Fuček, M.Sc. A. Husinec, Dr. I. Vlahović, Dipl. Geol. N. Oštrić and Dr. D. Matičec, Institute of Geology, Sachsova 2, P.O. Box 268, HR-1000 Zagreb, Croatia (e-mail: kobar@igi.hr). Prof. Dr. V. Jelaska, University of Zagreb, Faculty of Science, Department of Geology and Palaeontology, Zvonimirova 8/II, HR-1000 Zagreb, Croatia.
interpret the initial phase of deep-water sedimentation and
(4) to provide some stratigraphical and palaeoenvironmental
elements linking the dynamics of the western part of the
Dinarides to the regional evolutionary trend of the Periadriatic
domain.

2 FACIES, FOSSILS
AND DEPOSITIONAL ENVIRONMENTS

Six facies associations have been distinguished (Fig. 2,
table 1):
A) ostracod wackestone-packstones alternating with finely
laminated mudstones;
B) pithonellid wackestone-packstones containing microbio-
clasts and planktonic foraminifera;
C) rudist floatstone-rudstones composed mainly of recum-
bent rudist morphotypes;
D) lithoclastic/bioclastic breccia;
E) bioclastic wackestone-grainstones alternating with rudist
floatstones and fenestral mudstones;
F) mudstone-wackestones with intercalations of fine-grained
bioclastic wackestone-packstones and floatstones con-
taining pithonellid calcispheres in the matrix.

2.1 Facies association “A”:
Ostracod wackestone-packstones alternating with
finely laminated mudstones (Pl. 9/1-2)
2.1.1 Description
An about 13 m thick sequence of the Facies association
“A” was measured on the Baldarin section (Fig. 3),
while on the Osor section this sequence is only a few meters
thick. No similar deposits exist in the Sveti Damjan sec-
tion, but they may have been reduced by a fault tectonics.
The sequence consists mainly of thin-bedded to laminated
(mm to dm) alternation of ostracod wackestone-pack-
stones, mudstones, ostracod-peloidal packstones and finely
laminated mudstones (Pl. 9/1-2), and rare peloidal pack-
stone-grainstones with a sporadic occurrence of small
benthic foraminifera (miliolids). Laminites consist of a
finely laminated cryptomictic matrix alternating with
ostracod microbioclasts that form laminae. Bituminous
matter is concentrated between laminae and along dissolu-
tion contacts between the different lithotypes mentioned.
All lithotypes are slightly recrystallized. Rare micritic
intraclasts are masked by recrystallization. Intraskeletal
and shelter (“umbrella effect”) pores are filled by sparite.
The lower part of this unit in the Baldarin section is
characterised by decimeter-scale slides and slumps.

2.1.2 Biostratigraphy and age

An Early Cenomanian age of the sediments can only be
assumed according to their position in the profile. These
deposits are underlain by the uppermost Albian-lower-
most Cenomanian dolomite (the age according to Fuček et
al., 1995) and directly overlain by deposits of the Facies
association “B” comprising Favusella washiensis (Carsey),
(Fig. 3).

2.1.3 Interpretation

Because ostracods can tolerate a wide range of environ-
ments (concerning salinity, temperature and water depth),
including deep-water (epi- and mesobathyal) environments
(Neale, 1986) and because other fossils are lacking, it is not
easy to interpret the environment of deposition of the Facies
association “A”.

Depositional setting of the Facies association “A” was
probably a low-energy dysoxic to anaerobic environ-
ment. No evidence of subaerial exposures exists within these deposits. Decimeter-scale slides and slumps indicate synsedimentary tectonics. Moreover, the influence of synsedimentary tectonics on the formation of environments of variable bathymetry is demonstrated by the lateral thickness variations of this facies association. Especially in the northern part of the island, which is characterized by continuous shallow water sediments from Albian to Cenomanian age, i.e. without deposits indicating open-marine influence (Facies association "A"), no deposits of the Facies association "A" were encountered. Their first occurrence is recorded in the central part of the island in the form of an only 0.5 m thick bed, which gradually becomes thicker towards the south where it is accompanied by an successively thicker package of the Facies association "B" deposits.

A restricted intraplatform basin or lagoon was probably formed by synsedimentary tectonics near the Albian/Cenomanian boundary. Furthermore, the deposition of such sediments could have been enhanced by the relative sea-level rise resulting in an influence of dysoxic/anoxic water onto these parts of the former shallow-water platform.

2.2 Facies association "B":

Pithonellid wackestone-packstones containing microbioclasst and planktonic foraminifera (PL. 9/3-4)

Deposits of the Facies association "B" are specific for the southern part of the island of Cres and can be divided in two stratigraphical levels (Fig. 2):

"B1" - Lower to Middle Cenomanian sequence with Favasella washitensis (Carsey);

"B2" - Upper Cenomanian to Lower Turonian sequence corresponding to the Sveti Duh Formation in the Dinarides (Gusić and Jelaska, 1990, 1993).

The "B1" sequence is present in two of the analysed sections (Osor and Baldrin), while in the Sveti Damjan section it may have been reduced by faulting at the contact with the underlying dolomites (Fig. 4). The "B2" sequence is present only in the uppermost part of the Osor section. Especially in the other two sections overlying deposits are reduced either by a major fault or are now covered by the sea.

2.2.1 Description

This Facies association is characterised by 20-100 cm thick beds of brownish biomicrites. Transition from the Facies association "A" to the Facies association "B" is sharp (Fig. 3). The initial part of the succession is characterised by an alternation of mudstones, pithonellid wackestones and packstones with sporadically visible hummocky cross-stratification (HCS). Pithonellid calcioplates are represented by *Favasella* and *Bonetocardiella*. Subsequent pithonellid wackestones, subordinate packstones, also contain microbioclasst and non-keeled planktonic foraminifera. Fragments of rudists, gastropods, echinoid spines, benthic foraminifera (miliolids, textulariids, rotaliids, lagenids) and rare ostracods can be recognized among the bioclasts. Undistinct peloids are visible within the micritic matrix. Voids are filled with sparry calcite. Some beds contain bioturbations in their lower parts. Unclear lamination is commonly present within some beds of the sequence. Minor amounts of bituminous matter are either dispersed within these limestones or concentrated along microfractures. A few analysed samples were partially late-diagenetically dolomitized.

2.2.2 Biostratigraphy and age

*Favasella washitensis* (Carsey) (PL. 9/4) together with orbitoriids (Husin et al., 2000) defines an Early to Middle Cenomanian age of the level "B1". On the other hand, pithonellids are known from Albian to Maastrichtian car-

Fig. 2. Schematic relationship between investigated Cenomanian facies associations (A-F) on southern part of the island of Cres and legend of the facies associations.
<table>
<thead>
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<th>Facies association</th>
<th>Lithology</th>
<th>Biota</th>
<th>Environmental interpretation</th>
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| A                 | Thin-bedded to laminated alternation of ostracod wackestone-packstones, mudstones, ostracod-peloidal packstones and finely laminated mudstones. Bituminous matter is concentrated between laminae. Rare micritic intraslits are masked by recrystallization. Small-scale slides and slumps indicating synsedimentary tectonics. | Ostracods and sporadic occurrence of small benthic foraminifera (miliolids). | Low-energy dysoxic to anaerobic environment.  
Restricted intraplatform basin/lagoon. |
| B                 | Well-bedded (20-100 cm thick) brownish biomicrites. Alternation of mudstones, pithonellid wackestones and packstones containing microbioclasts and planktonic foraminifera. Initial beds exhibit hummocky cross-stratification. | Fragments of rudists, gastropods, echinoid spines, benthic foraminifera (miliolids, textularids, reticulids, lagenids, etc.) and rare ostracods. Pithonellid calcispheres (Pithonella and Bonetocaradina) and some non-isometric planktonic foraminifera (favaellids, hofbergellids). | Low-energy deeper water environment below storm-wave base.  
Shallow intraplatform basin connected to open sea and related slope. |
| C                 | Massive to thick-bedded rudist floatstones and rudstones. Rudists form loosely packed communities associated with large quantities of angular/subangular and poorly-sorted skeletal debris. | Caprinidae, Icthyosarcoididae and Radiolitidae as well as small amount of gastropods. Icthyosarcoidites tricornatus PORAT, Neocaprina sp., Orthopychus striatus PUTTERER, Caprina carinata (BOEHM), Schloenbacarinaaformis POLSAK and Sannenaggeria sp. | Relatively high-energy marginal environment.  
Margin and related upper slope. |
| D                 | Massive breccia. Subangular lithoclasts of variable size (including boulders up to 70 cm in diameter). Angular, unsorted rudist debris (rudstone) and rudist shells. Rounded intraslits of the same type as matrix. Matrix is composed of microbioclastic wackestone-packstones with pithonellid calcispheres. | Caprinidae, Icthyosarcoididae and Radiolitidae as well as rare gastropods. Icthyosarcoidites tricornatus PORAT. | Low-energy deeper water environment with sporadic sedimentation from rock-falls/debris flows.  
Base-of-slope or lower slope. |
| E                 | Thick-bedded bioclastic wackestone-packstones, bioclastic peloidal packstone-grainstones, rarely floatstones and fenestral mudstones. Rare radiolitid bouquets. Bioclasts show traces of bioturbation and micronitized rims. Well-rounded rudist-shell fragments and foraminifera are the most abundant. Other bivalve, hydrozoan and echinoid fragments are rarely present. | Foraminifera (orbitolinids, miliolids etc.), slender radiolitids, chondrodonts. Broeckina (Paratubella) balcanica SERGI et al., Chrysalina gradata D’ORBIGNY, Psepholyptidina dubia (DE CASTRO) and Orbitolina (Conicorbitolina) conica (D’ARCHIA). | Transition from agitated environment situated probably around fair-weather wave base to quiet-water shallow subtidal environment with intermittent excursions to intertidal.  
Prograding subtidal dissected-barrier bank-margin and back-margin lagoon or protected platform (banktop). |
| F                 | Well-bedded (30-100 cm) bioclastic mudstone-wackestones and mudstones with intercalations of single beds of bioclastic wackestone-packstones and subordinately floatstones. Pithonellid calcispheres in matrix sparcidomethy. Bioclasts, rare peloids and sporadic micritic intraslits are poorly sorted. | Benthic foraminifera, pithonellid calcispheres, ostracods, small gastropods, calcareous algae and echinoids. Micritized radiolitid shell fragments. Chondrodonts. Broeckina (Paratubella) balcanica SERGI et al., Chrysalina gradata D’ORBIGNY, Psepholyptidina dubia (DE CASTRO) and Vidalina radiocasia SCHERCH & SCHROEDER. | Low-energy environment probably around storm-wave base.  
Deeper subtidal/shallow basin or slope. |

Table 1. Facies associations, lithology, characteristic biota and palaeoenvironmental interpretation of the Cenomanian carbonates on the island of Cres, Croatia.
bonate rocks occupying a broad Tethyan realm and therefore have no specific value as a stratigraphic markers.

The level “B2” is directly underlain by the Upper Cenomanian Facies association “F” deposits (Osor section, Fig. 6) and therefore corresponds to the Late Cenomanian/Early Turonian world-wide eustatic sea-level rise (Jenkins, 1991; Gasic and Jelaska, 1993; Davey and Jenkins, 1999).

Fig. 3. Baldarin section and legend for all sections.

2.2.3 Interpretation

Pithonellids were opportunistic Tethyan organisms that flourished in warm, saline and CaCO₃-rich surface waters of epicontinental and marginal seas (Dias-Brito, 2000). Accordingly, they have flourished under variable water conditions caused by the influence of relative sea-level variations. Pithonellids reached their acme during the mid Cretaceous, when Earth was under warm, equable climate, and experiencing the most thessalassic episode of the Mesozoic-Cenozoic interval (Barron, 1983; Ronov, 1994). Such conditions were favourable to the opportunistic r-selected pithonellids in association with some non-keeled foraminifera including favusellids, globigerinellids and hedbergellids (Dias-Brito, 2000). According to the same author B. conoidea and P. ovalis bloomed in surface waters of the outer neritic-oceanic transitional zone (approximately 80-300 m deep), while P. spheraica occurred also in shallower parts of the neritic environment.
The planktonic biota and the scarce benthic remains in these deposits indicate a relatively open marine environment with water depths below the storm wave-base (SWB). The initial beds of the sequence of the Baldarin section were probably deposited around the SWB as indicated by HCS, and the rest of the sequence was probably deposited below the SWB (according to criteria of Tucker and Wright, 1990; Wright and Burchette, 1996). Water energy, water depth, slope gradient and proximity of bioclastic debris sources were the main factors that influenced the facies. Rather light rock colours indicate relatively well oxygenated water. The most probable mechanism for transportation of microbioclasts were storm-currents that mobilized the finest bioclastic material and removed it basinward (Wright and Burchette, 1996). That material was sedimented from suspension together with the autochthonous planktonic biota. Scott (1990) interpreted the source area for similar bioclasts (thin-walled miliolids, calcispheres, ostracodes) as forereef, while basinal laminated mudstone-packstones were interpreted as distal forereef slope or possibly even basin deposits.

Gusić and Jelaska (1990, 1993) argued for an eustatic sea-level rise around Ce/Tu boundary that caused drowning of the Adriatic/Dinaric platform and discussed sedimentation in water depths of up to 200 m, where pithonellid deposits were accumulated overlying shallow-platform carbonates. However, the lower level of pithonellid limestones on the island of Cres (Facies association “B1”) was deposited during Early to Middle Cenomanian and cannot therefore be correlated with the Cenomanian/Turonian sea-level rise. Abrupt changes in sediment type (transition between Facies association “A” to Facies association “B” in the Baldarin section, Fig. 3) can be a consequence of inflow of higher oxygenated water from the open sea. Because synsedimentary tectonics contributed to the formation of new accommodation space during the Early to Middle Cenomanian, this event cannot be correlated to an eustatic sea-level rise, because result would be regional, rather than local drowning effects. The upper level of the association (“B2”) can be correlated to the Ce/Tu sea-level rise (Gusić and Jelaska, 1990, 1993) that re-established deposition of pithonellid limestones, as recorded in the Osor section (Fig. 6).

The depositional environment can be interpreted as an at least 100 m deep intraplatform basin connected with the open sea or an embayment of a larger basin. Open questions concerning the palaeogeography of the wider area are discussed in section 4.

2.3 Facies association “C”:
Rudist floatstone-rudstones composed mainly of recumbent rudist morphotypes (Pl. 10)

2.3.1 Description

An approximately 250 m thick sequence of these massive deposits has been observed in the Sveti Damjan section (Fig. 4). A minor fault at the contact with underlying uppermost Albian – lowermost Cenomanian dolomites probably did not severely affect the general succession. A few meters of recrystallized Facies association “B” exist at the contact with the underlyng dolomites. Transition to the overlying sequence of the Facies association “C” is covered by recent coastal deposits.

Within the generally massive deposits of the Facies association “C” bedding is clearly visible only in a few meter-thick levels where fine-grained and coarse-grained
bioclasts alternate (Pl. 10/2). Whitish rudist floatstones and rudstones (Pl. 10/1) are common within the sequence, though no rudist “reefal” constructions very found. Rudist shells are most frequent and well preserved, while bioclasts are slightly abraded and poorly sorted. Rudists commonly form loosely packed communities associated with large quantities of skeletal debris. The taxa belong to the Caprinidae, Ichthyosarcolitidae and Radiolitidae. Caprinids and ichthyosarcolitids (recumbent-rudists) prevail over radiolitids (elevator-rudists). The matrix is variable and strongly recrystallized and contains in addition to rudist bioclasts sporadically small gastropods and specimens of different types of miliolids that cannot be identified due to recrystallization and dissolution. The vertical succession seems to be completely irregular, and lateral relationships are not observable due to restricted outcrops.

2.3.2 Biostratigraphy and age

The deposits are underlain by uppermost Albian - lowermost Cenomanian dolomites as in all the Cenomanian successions in the area. A few rudists of the Cenomanian age have been found: Ichthyosarcolitidae tricarinatus Parona, Neocaprina sp. (Pl. 10/5), Orthoptichus straitus Futterer (Pl 10/4), Caprina carinata (Bochm) (Pl. 10/3), Schizosia cariniformis Polak and Sautagesia sp. This rudist association was attributed to the Cenomanian in general (Polak, 1965, 1967b; Polak et al., 1982; Mamuzic et al., 1982). Cestari and Santorino (1999) narrowed the stratigraphic range of this association in the Periodicam realm to the Lower to Middle Cenomanian. Tisjar et al. (1998) confirmed this age of the rudist association in the neighbour Istria by well-defined biostratigraphy of benthic foraminifera.

2.3.3 Interpretation

Scott (1990) discussed a “reef core facies” characterised by lenticular rudist bioherms elongated parallel to the shelf edge and interbedded with skeletal grainstone beds. According to the same author the upper forshore facies is characterised by rudist grainstone-packstones containing angular and poorly sorted bioclasts intercalated with lens-shaped caprinid bioherms. Collins (1988) mentioned that caprinid rudist individuals are not commonly found in point contact or with intergrowth, and that paleocommunities defined by dominant caprinid taxa exhibit no successional pattern of diversification and domination, which is a common characteristic of the Facies association “C” on the island of Cres. Di Stefano and Ruberti (2000) described Cenomanian rudist-dominated shelf-margin limestones from Sicily. They interpreted a coarse-grained bioclastic caprinid-rich lithofacies (similar to the Facies association “C” in this paper) as platform margin rudist patches and/or knolls.

Importance of synsedimentary tectonics on changes in depositional system near the Albian/Cenomanian transition in neighbouring southern Istria was described by Tisjar et al. (1998). The authors described the geometry of clinostratified bioclastic bodies (composed mostly of rudist bioclasts and infrequent complete shells) in a prograding system on ramp setting. In comparison with their facies unit 5 (Lower to Middle Cenomanian prograding rudist bioclastic clinostratified bodies), the Sveti Danjan section is characterised by a thicker and more massive sequence of deposits, probably because of a more aggradational sequence deposited in deeper water (below fairweather wave-base) enabled by interaction of sea-level changes and synsedimentary tectonics.

The term “reef” used by Scott (1990) for platform margin rudist formations implies a coherent organic wave-resistant framework similar to modern coral reefs. However, Ross and Skelton (1993) suggested the most appropriate terminology. They used terms “rounded-shouldered carbonate bank complexes” developing along (intra)shelf or (intra)platform breaks and inhabited by rudists frequently shedding large quantities of grainy bioclastic sediment downslope. It seems that this type of rudist community and associated bioclastic lithofacies inhabited areas with favourable water-energy conditions related to specific type of platform margin physiography (Ross and Skelton, 1993). The absence of corals in the Facies association “C” suggests fluctuating water chemistry in a probably more or less enclosed basin (cf. Ross and Skelton, 1993).

The deposits of the Facies association “C” are interpreted as products of a relatively high-energy marginal environment similar to the “reef core facies” and “foreslope facies” of the Late Albian–Early Cenomanian El Abra Formation (Scott, 1990). Because no evidence of a basinal area in the vicinity of the island of Cres exists, the facies most probably represents a smaller-scale complex of rudist knolls and lenticular bodies situated at a margin of a more or less enclosed shallow basin and its upper slope.

2.4 Facies association “D”:
Lithoclastic/bioclastic breccia (Pl. 11/1-3)

2.4.1 Description

An approximately 5 m thick package of a massive lithoclastic breccia is intercalated within the Facies association “B1” on the Baldaarin section (Fig. 3). The transition between Facies associations “B” and “D” (“Baldaarin” section, Fig. 3) is sharp. These limestone breccia deposits are characterised by numerous subangular lithoclasts of redeposited shallow-water limestones of the Facies association “C” and commonly smaller slightly rounded intraclasts of semi-consolidated microbioclastic wackestone-packstones with pithonellid calcispheres. Lithoclasts include boulders up to 70 cm in diameter (Pl. 11/2), they are composed of recrystallized rudstones and floatstones with coarse-grained caprinid, ichthyosarcolitid and radiolitoid shell fragments as well as complete shells. Benthic foraminifera (including orbitolinids) are present, but are highly recrystallized. Small gastropods are rare. Intraskeletal cavities are almost completely reduced by secondary drusy calcite crystals. The matrix of the breccia is composed of the same lithotype as the one of the rounded semi-consolidated intraclasts, but the intraclasts are of lighter colour. A meter-scale folded surface exists within this massive package.
A subsequent massive intercalation of a lithoclastic/bio-
lithoclastic breccia is almost entirely composed of ichthy-
osarcolitid, caprinid and radiolitid shell fragments (rudist
rudstone), rarely complete shells and in the lower part of
the sediment package sporadical lithoclasts (blocks) of the
same lithotype. Small gastropods and orbitolinids occur
within these recrystallized rudstones. Bio­clasts are angu-
lar, unsorted and completely disorganized. Transition to
the overlying deposits of the Facies association “B1” is
characterised by slightly rounded intraclasts of the same
lithotype as the Facies association “B1” but of lighter
colour. Lower contact of the package with the Facies
association “B1” is faulted (Fig. 3). However, this package
is stratigraphically overlain by the Facies association “B1”
indicating that the package is an intercalation within the
Facies association “B1”.

2.4.2 Biostratigraphy and age

The precise stratigraphical position of the package is
problematic owing to the faults observed within the Facies
association “B” in the Baldarin section (Fig. 3). However,
Lower to Middle Cenomanian rudists Ichthyosarcolithes
triarcanus Parona (Pl. 11/2), I. bicarinatus (Gemmellaro)
and Neocaprina sp. have been found within these deposits,
and orbitolinids in lithoclasts indicate a Lower to Middle
Cenomanian age according to Husinec et al. (2000). In
addition, this unit is more or less distinctly intercalated
within the deposits of the Facies association “B1”, that is
Lower to Middle Cenomanian in age.

2.4.3 Interpretation

Deposits very similar to the Facies association “D”
(skeletal-fragment grainstone-packstone and limestone breccia)
were interpreted by Scott (1990) as deeper slope
elastic rocks (Tamabra Limestone). Clasts in breccia in-
clude rudist-fragment yielding grainstone and a wacke-
estone with pelagic-microfossils in a micritic matrix. Nu-
merous smaller-scale steep intraplatform margins in other
areas are characterised by lithified blocks containing
rudists transported downslope (Ross and Skelton, 1993).

We have not found blocks larger than 1 m required to
call a breccia a megabreccia (according to criteria dis-
cussed by Tucker and Wright, 1990). However, we think
that their origin can be similar to the below discussed
megabreccia. Blocks of lithified platform margin limes-
tones (boulders up to 70 cm in diameter) and their trans-
port in somewhat deeper environments imply a relatively
high-gradient slope or marginal escarpment, although
metastable oversteepened slopes are not necessary for
megabreccia genesis (Spence and Tucker, 1997). Two
particularly important mechanisms in generating mega-
breccias are endogenic processes causing overpressure at
discrete hydrologically confined horizons beneath the sea-
floor during relative sea-level falls, and increases in stress
as pore-fluid drains from the sediment when the platform-
top becomes subaerially exposed, also during relative
lowstands of sea-level.

Late Albian-Cenomanian platform-margins that pro-
duced huge accumulations of megabreccia on the Apulian
platform margin (Boselli et al., 1999) can be used to
explain also important processes present on the adjacent
Adriatic (intra)platform margins during the same time.
One of the main causes for the origin of the Gargano
megabreccias can be the seismic shocks associated with
regional tectonism, although the ultimate cause of their
origin is still problematic (Boselli et al., 1999).

The breccia unit described in this paper can be com-
pared with the breccias discussed above, but at a much
smaller scale. The main cause responsible for the origin of
the Facies association “D” remains unknown. Slope insta-
Bility is suggested by presence of some obviously semi-
consolidated intraclasts within the breccia deposits. An
interaction of tectonics (that directly induced the collapse
by seismic shocks or caused relative sea-level fall), eustatic
sea-level fall and slope oversteepening (caused by sedi-
ment overloading) seems to be most probably.

In conclusion, we propose a base-of-slope (probably
with a marginal small-scale escarpment) depositional en-
vIRONMENT for the Facies association “D” (according to
criteria in models of Wright and Burchette, 1996).

Plate 9 Cenomanian carbonate facies and rudists along shallow intraplatform basin margin - the island of Cres
(Adriatic sea, Croatia). Facies associations “A” and “B”.

Fig. 1. Thin-beded to laminated ostracod wackestone-packstones alternating with finely laminated mudstones.
Facies association “A”, Baldarin section, Early Cenomanian. Lens-cap is 6 cm in diameter.

Fig. 2. Microphotograph of laminated ostracod wackestone-packstones alternating with finely laminated
mudstones (x8). Facies association “A”, Baldarin section, Early Cenomanian.

Fig. 3. Microphotograph of pithonellid wackestone containing microbioclasts and non-keeled planktonic foraminifera (x32). Facies association “B”, Baldarin section, Early to Middle Cenomanian.

Fig. 4. Microphotography of Favissella washitensis (Carsey) within facies association “B” (x80), Baldarin section, Early to Middle Cenomanian.
Plate 10 Cenomanian carbonate facies and rudists along shallow intraplatform basin margin - the island of Cres (Adriatic sea, Croatia). Facies association “C”.

Fig. 1. Rudist floatstone-rudstone with abundant elongated (Ichthyosarcolithid) rudist shells. Facies association “C”, Sveti Damjan section, Early to Middle Cenomanian. Lens-cap is 6 cm in diameter.

Fig. 2. Alternation of fine-grained and coarse-grained rudist bioclasts. Facies association “C”, Sveti Damjan section, Early to Middle Cenomanian. Lens-cap is 6 cm in diameter.

Fig. 3. Transverse section of Caprina carinata (Boehm). Facies association “C”, Sveti Damjan section, Early to Middle Cenomanian. Lens-cap is 6 cm in diameter.

Fig. 4. Transverse section of Orthoptychus striatus Futterer. Facies association “C”, Sveti Damjan section, Early to Middle Cenomanian. Scale bar in centimeters.

Fig. 5. Transverse section of Neocaprina sp. Facies association “C”, Sveti Damjan section, Early to Middle Cenomanian. Lens-cap is 6 cm in diameter.
2.5 Facies association “E”:
Bioclastic wackestone-grainstones alternating with
rudist floatstones and fenestral mudstones

2.5.1 Description

These thick-bedded to massive limestones are found only within the Balardin section (Figs. 3 and 5), and are underlain by pithonellid wackestone-packstones (Facies association “B”). Transition between these two associations is characterised by an approximately 14 m thick dolomitized sequence probably belonging to the Facies association “B”. At the top of the dolomite a bed of recrystallized and partially dolomitized pithonellid wackestone exists.

The base of Facies association “E” is characterised by the prevalence of bioclasts and a complete absence of pithonellid calcispheres. The lower part of the association is characterised by approximately 7 m thick interval of recrystallized bioclastic-intraclastic wackestone-packstones followed by an approximately 25 m thick succession of recrystallized bioclastic-peloidal packstone-grainstones (Fig. 5). Orbitolinites and miliolids are the most abundant foraminifera. Radiolitid and other mollusc fragments are also very frequent, while hydrozoan and echinoid fragments, as well as gastropods are scarce. Both bioclasts and intraclasts are well-rounded, and bioclasts show traces of bioerosion and micritized rims. The overlying interval (27 m thick) of well-bedded brownish to grey-brownish mudstones and bioclastic wackestone-packstones also contains abundant benthic foraminifera. Rudist-shelf fragments are abundant within floatstones, representing the uppermost parts of some of the beds. Radiolitid fragments prevail among the coarse-grained bioclastic particles, but groups of slender radiolitids are rarely preserved within bioclastic wackestone-packstones. A few caprinid and chondroodont shell fragments were recognized. Fenestral mudstones (frequently with laminoid fenestrae) become more frequent towards the upper part of the sequence, which is characterised by small-scale shallowing-upward cycles. Unfortunately, overlying deposits are covered by the sea.

2.5.2 Biostratigraphy and age

The association of benthic foraminifera, and particularly samples of Broeckina (Pasirikella) balcanica Cherchi et al., Chrysalidina gradata d’Orbigny, Pseudohapydino-
nina dubia (De Castro) and Orbitolina (Conicorbitolina) conica (d’Archiac) (Pl. 11/4) indicate a Middle Cenomanian age (probably the upper part of the Middle Cenomanian - cf. Velić and Vlahović, 1994 and Husinec et al., 2000).

2.5.3 Interpretation

The facies succession within the Facies association “E” in the Balardin section (Fig. 5) represents a prograding agitated subtidal environment in the lower part of the sequence, as indicated by the prevalence of packstone-grainstones over wackestone-packstones. The absence of complete shells and the abundance of well-rounded micritized bioclasts and intraclasts indicate relatively long-lasting reworking (prolonged relatively high-energy conditions) and bioerosion in an environment situated probably around the fairweather wave-base. Groups of slender radiolitids and chondroodonts in the central part of the sequence may indicate a decrease of water energy in transitional, more protected environments (cf. Scott, 1990). Gradual increase of mudstones towards the upper part of the sequence, as well as fenestral fabrics in the upper part of the association, suggest a general shallowing-upward trend in more protected, probably open-lagoonal environments. The upper part of the sequence was related to low-energy shallow subtidal conditions with intermittent excursions into intertidal areas, as indicated by laminoid fenestrae (cf. Wright and Burchette, 1996).

A very similar grainy crest facies have been documented for the inner-shelf basin prograding Mishrif Formation (Albian to Cenomanian) of the Arabian Peninsula (Burchette, 1993) and the intraplatform basin prograding Pučica Formation (Campanian) of Brac Island, Croatia (Gusić and Jelaska, 1990).

The succession probably represents a prograding subtidal dissected barrier bank-margin and back-margin open

Plate 11 Cenomanian carbonate facies and rudists along shallow intraplatform basin margin - the island of Cres (Adriatic sea, Croatia). Facies associations “D”, “E” and “F”.

Fig. 1. Lithoclastic breccia of the Facies association “D”, Lithoclasts are mainly composed of rudist rudstones (originated from Facies association “C”) and pithonellid wackestone-packstones containing microbioclasts (originated from Facies association “B”), Balardin section, Middle Cenomanian.

Fig. 2. Boulder of rudist floatstone-rudstone (originated from Facies association “C”) as part of lithoclastic/bioclastic breccia containing abundant ichthyosauridid (Ichthyosarcollites tricarinatus Parona), Facies association “D”, Balardin section, Middle Cenomanian.

Fig. 3. Boulder of rudist rudstone (originated from Facies association “C”) extracted from lithoclastic/bioclastic breccia, Coarse bioclasts originated from caprinid, ichthyosauridid and radiolitid shells are recognizable, Facies association “D”, Balardin section, Middle Cenomanian.

Fig. 4. Microphotography of Orbitolina (Conicorbitolina) conica (d’Archiac) (x32), Facies association “E”, Balardin section, upper part of Middle Cenomanian.

Fig. 5. Microphotography of Broeckina (Pasirikella) balcanica Cherchi (x32), Facies association “F”, Osor section, Late Cenomanian.
lagoon or protected platform (banktop). The lack of specific styles of bedding and sedimentary structures expected at barrier shoal environments implies that this submarine dissected barrier bank-margin was continuously submerged probably because of high rate of relative sea-level rise. This led to a progradation of the bank probably in form of gently dipping clinoforms (similar as the Lower to Middle Cenomanian prograding clinostratified bodies in neighboring southern Istria-Tišljarić et al., 1998).

2.6 Facies association “F”:
Mudstone-wackestones with intercalations of fine-grained bioclastic wackestone-packstones and floatstones containing pithonellid calcispheres in the matrix

2.6.1 Description

The Facies association “F” is characterised by well-bedded (30-100 cm) mudstones and bioclastic mudstone-wackestones with intercalations and single beds of bioclastic wackestone-packstones and subordinately floatstones containing pithonellid calcispheres in the matrix. The approximately 37 m thick sequence is underlain and overlain by pithonellid wackestone-packstones (Facies association “B, lower and upper level”) in the area represented by the Osor section (Fig. 6). Transitions between these facies associations are characterised by a difference in the fine-grained bioclastic components, typically overwhelming calcispherulids. Bioclasts, rare peloids and sporadic micritic intraclasts are poorly sorted. Fine-grained skeletal detritus and benthic foraminifera are the most abundant particles within the wackestone-packstones. Pithonellid calcispheres and planktonic foraminifera are common too, but subordinate. Ostracods, small gastropods, calcareous algae and echinoid fragments are present. Micritized radiolitid shell fragments are common, and chondroodont bivalves as well as thin-shell bivalves are rare within floatstones. Bioturbation associated with pellets occurs sporadically in the upper part of the sequence. Intraskeletal pores are filled by sparite.

2.6.2 Biostratigraphy and age

The foraminiferal association, especially Broeckina (Pastrikiella) balcanica Cherchi et al. (Pl. 11/5), Chrysallina gradata d’Orbigny, Pseudoraphidonina dubia (De Castro) and Vidalina radioelaece Cherchi and Schroeder implies latest Middle to earliest Late Cenomanian age (cf. Velić and Vlahović, 1994).

2.6.3 Interpretation

The position of the Facies association “F” between two thick intervals of the Facies association “B” deposits (originating in deeper environments, as discussed in section 2.2.3), suggests a depositional environment situated around the storm wave-base and an interfingering of these two facies associations. The absence of any distinct microfacies features indicating shallow-water regimes, as well as field observations, support this interpretation. However, the dynamics of sediment movement during storms can be complex and is poorly understood (Wright and Burchette, 1996). Similar muddy bioclastic sediments were accumulated downslope within inner-shelf/platform basin margin prograding complexes (e.g., Campanian of
the island of Brač - Gušić and Jelaska, 1990; Albain to Cenomanian Mishrif platform of the Arabian Peninsula - Burchette, 1995). Bioclastic material was probably increasingly redeposited into deeper-water environment due to the progradation of adjacent shallow-water environments caused by high primary biogenic carbonate production. The progradation could also have been enhanced by a relative sea-level fall. Subsequent retrogradation and/or reduction of adjacent shallow-water environments, probably caused by a sea-level rise during the latest Cenomanian (Gušić and Jelaska, 1993; Davey and Jenkyns, 1999), allowed predominance of planktonic biota.

The Facies association “F” probably represents a slightly younger (see section 2.5.2) progradational counterpart of Facies association “E” found in the Baldarin section (Figs. 3 and 5).

The association was probably deposited in a deeper subtidal/shallow basin or slope environment with influence of the open sea.

3 DEPOSITIONAL SYSTEM

Lateral relationships between described facies associations are poorly traceable in the field due to a relatively complex tectonic pattern and scarce outcrops. However, data-analysis, field observations and comparison with similar Middle Cretaceous rudist-bearing facies described by other authors (e.g. Carbone and Sirna, 1981; Scott, 1990; Burchette, 1993; Caus et al., 1997; Laviano et al., 1998; Tišlar et al., 1998; Di Stefano and Ruberti, 2000; Drzewiecki and Simo, 2000), as well as similar lithofacies characteristics in some Lower Cretaceous (e.g. Hughes, 1998) and Upper Cretaceous examples (e.g. Borgomano and Phillip, 1987; Gušić and Jelaska, 1990; Ruberti, 1993), allow comparison, and consequently enable interpretation of the depositional system (Fig. 7).

Slide and small slump occurrences in the Lower Cenomanian thin-bedded to laminated ostracod wackestone-packstones alternating with finely laminated mudstones (the facies association “A”) announce changes that affected formerly almost intact parts of the shallow protected platform. Rapid changes occurred in platform bathymetry and a relatively small intraplatform basin was formed, resulting in establishment of high-energy environments in the eastern part of the study area. Massive bioclastic floatstone-rudstones, containing numerous, mostly recumbent-rudist shells (Facies association “C”), indicate probably rapid sedimentation. This aggradational or slightly progradational sequence was deposited during the Early to Middle Cenomanian within depocenter situated along the basin margin (see right part of the lowermost cross-section on Fig. 7). Simultaneously, pithonellid wackestone-packstones containing microbioclasts and non-planktonic foraminifera (Facies association “B” lower level “B1”) were deposited within more open deeper-water environments in the western part of the area (Baldarin and Osor sections, Fig. 7).

Penecontemporaneous Lower to Middle Cenomanian carbonates in southern Istria (Tišlar et al., 1998) are geographically the nearest example, and are characterised by generally similar characteristics as those described in our paper. However, there some important differences exist. The Istrian example is characterised by an approximately 50 meters thick sequence of prograding clinostratified bodies, each of them representing a fining-upward paraquence. No pithonellid facies exists in this area. The example is interpreted as an ESE inclined ramp with 4-6° gradient representing the ESE limb of the large West Istran anticlinal structure (i.e., anticlinorium - Š-tičev et al., 1996). The example described in our paper is characterised by a different paleogeographic setting and a tectonic pattern, which resulted in a thicker package of massive and structureless floatstone-rudstones as well as an occurrence of resedimented limestones from this facies within a deeper-water pithonellid facies.

The resedimented limestones, lithoclastic/bioclastic breccia (Facies association “D”), are the most interesting sedimentological feature in the study area. Boulders of these bioclastic rudist floatstone-rudstones within deeper-water pithonellid wackestone-packstones (Facies association “B”) imply slope instability and provide important evidence of an early cementation of marginal bioclastic limestones comparable to massive rudist floatstone-rudstones (Facies association “C”) from the Sveti Damjan section. All observations support the idea of a steep slope configuration and/or possible escarpment of the margin (cf. Ross and Skelton, 1993; Sanders, 1998). Furthermore, metastable steepened slopes or synsedimentary tectonic activity could have been supported by a relative sea-level fall, i.e. emergence of the areas adjacent to the basin.

Therefore, this redeposited unit can be very important for sequence stratigraphical correlation. There are many authors who reported on mid-Cenomanian unconformities corresponding to major regional event (e.g. in the Eastern Atlantic and Tethys: Philip, 1978; Benezio e Fornaciari, 1987; Sartorio, 1987; Robaszyński et al., 1993; Jenkins et al., 1994; Paul et al., 1994; Caus et al., 1997; Fouquet, 1998; Philip, 1998; Rodríguez-Lázaro et al., 1998; Altiner et al., 1999). Robaszyński et al. (1998) discussed an important sea-level fall and faunal changes at the Lower-Middle Cenomanian boundary, represented at the basin margins by a marked break. Unfortunately, complex tectonic patterns and scarce outcrops in heavily vegetated area, as well as reduced lateral extension of the “Baldarin breccia”, hinder us to reconstruct a detailed sequence stratigraphic framework. Higher biostratigraphical resolution within Cenomanian deposits on the island of Cres is not possible due to scarcity of planktonic foraminifera and the lack of ammonites. Therefore, the “Baldarin breccia” is not precisely correlative to one of the well-defined mid-Cenomanian sequence boundaries established by Hardenbol et al. (1998).

However, it is important to note that the late Albain to Cenomanian is a period that well corresponds to some Mid-Cretaceous large-scale collapses and consequent retreats of isolated carbonate platform margins (Mullins et al., 1991; Bosellini et al., 1999). These authors discuss such processes as a reaction to distant plate collisions and lithospheric plate bending. The same tectonics can be responsible for tectonic processes within the previously more or less intact Adriatic
Carbonate Platform and can represent an initiation of its final disintegration during the Late Cretaceous.

The “Baldrin breccia”, together with slumps in the Early Cenomanian thin-bedded and laminated limestones (Facies association “A”), and contemporary facies differentiation throughout the studied Cenomanian localities in the neighbouring areas (Vlahović et al., 1994; Tílljar et al., 1998), indicate an important influence of synsedimentary tectonics during the Late Albian and Early to Middle Cenomanian.

During the Middle Cenomanian the lower depositional system was gradually changed into a low-gradient slope or ramp-like topography (second cross-section on Fig. 7). An approximately 25 meters thick sequence of orbitolinid packstone-grainstones (lower part of Facies association “E” in the Baldrin section, Figs. 3 and 5) probably represents the prograding submarine dissected barrier bank-margin. Subsequent deposits of this facies association exhibit shallowing-upwards parasequences with radiolitid assemblages in more protected shallow-water environments (upper part of Facies association “E” on the Baldrin section, Figs. 3 and 5). The absence of shelly rudstone-floatstones with recumbent rudists suggests lower water-energy environments (at least in the area of the Baldrin section, Fig. 3), i.e. high-energy environments with recumbent rudists were either displaced or reduced.

Biolastic wackestone-packstones and floatstones containing pithonellid calcispheres in the matrix (Facies association “F”), intercalated within deeper-water pithonellid wackestone-packstones (Facies association “B”) in the Orso section (see Fig. 6 and left-hand part of the uppermost cross-section in Fig. 7), probably represent younger progradational counterparts of the prograding submarine dissected barrier bank-margin (Facies association “E”).

The Late Cenomanian/Early Turonian world-wide platform drowning event (Jenkyns, 1991) terminated the progradation and re-established deposition of deeper-water pithonellid wackestone-packstones (Facies association “B” – upper level “B2”), at least in the area of the Orso section. Unfortunately, the other two sections are either
tectonically reduced or covered by the sea, except in the lower stratigraphical levels. However, in a wider area this is a regionally recognizable unit, usually referred to as the Sveti Duh Formation (Gusić and Jelaska, 1990, 1993).

Terminology concerning the nature of rudist formations in relation to the platform setting and physiography was suggested by Ross and Skelton (1993). Relatively small thickness of the marginal facies, as well as the absence of indubitable deep-water basin facies in the wider area, suggest an intraplatform setting (as discussed in section 4). Consequently, according to the terminology of Ross and Skelton (1993), the most probable setting of the southerna Cres area during the Early to Middle Cenomanian was a small-scale steep intraplatform margin as transition to the shallow intraplatform basin. Similar physiography (including marginal escarpment) was proposed by Sanders (1998) for peri-Adriatic carbonate platform margins. During the Middle Cenomanian, the setting probably changed and an intraplatform basin prograding margin complex was formed (cf. Ross and Skelton, 1993).

4 LATE CRETACEOUS PALAEOGEOGRAPHY OF THE NORTH-WESTERN PART OF THE ADRIATIC CARBONATE PLATFORM

During the Albiano peritidal carbonates of the western part of the Adriatic Carbonate Platform were more or less similar (Fuček et al., 1995; Tilšjar et al., 1995). Environmental changes during the Late Albanian/Early Cenomanian, that affected neighboring area of the present day Istria (Vlahović et al., 1994; Tilšjar et al., 1998), have been observed within the Cenomanian carbonates of the island of Cres, too (Fig. 8). However, it seems that synsedimentary tectonics had different and an even more important influence on the southern part of the present day island of Cres than on Istria. It should be noticed that these two examples were palaeogeographically separated by the regionally important Kvarner fault (Waagen, 1906; Štikić, 1951-1953; Aljnović and Błašković, 1981; Matić, 1998).

Different facies of the Late Cretaceous were found in several other localities from the north-western part of the Adriatic Carbonate Platform (Fig. 8), this is an obvious evidence for an important differentiation of formerly more or less united depositional area.

Peritidal carbonates were deposited in protected shallow-platform environments on the south-eastern part of the island of Dugi otok (Fuček et al., 1990) and on the islands of Olib and Ist (Moro and Jelaska, 1994) during the Middle Cenomanian to Santonian (Fig. 8). Furthermore, Moro (1997) reported on the Turonian to Santonian inner to outer shelf carbonates following the Cenomanian/Turonian pelagic limestones in the southern Istria (Fig. 8).

Kapović and Bauer (1970) reported on the Turonian to Santonian carbonate turbidites observed on the island of Premuda and on the north-western part of the island of Dugi otok. Carbonate slope deposits in the central part of the island of Dugi otok (Fuček et al., 1991) indicate major environmental changes in that part of the platform during the latest Cenomanian. It is fairly logical that the locations surrounding the island of Dugi otok (7 and 8 on Fig. 8) were connected during the Late Cretaceous, forming some kind of basin or trough. Gusić and Jelaska (1993) proposed the name for this area characterised by slope or basinale facies: the Adriatic Trough. According to our preliminary field observations and correlation with data from the geological map of the area (Mamusić, 1968), we can conclude that the south-western part of the island of Lošinj was characterised by similar deeper-water sedimentation during the Turonian to Coniacian (?Santonian).

As discussed by Gusić and Jelaska (1993), one cannot discuss about the dimensions of the Adriatic Trough and its possible connection with the Marche-Umbrian Basin without detailed data from the Adriatic subsurface (Fig. 8). However, the Late Cretaceous position of the boundary of facies domains delineating the Adriatic Carbonate Platform and Marche-Umbrian Basin in the central part of the Adriatic Sea (Cati et al., 1987; Jenkyns, 1991), corresponds to the Eastern Adriatic Slope zone documented by Grandić et al. (1999). Consequently, it seems that the Adriatic Trough was an elongated intraplatform basin, but its connection with the open marine Marche-Umbrian Basin is still controversial. Concerning the NW extension, and the role of transverse Kvarner fault (Waagen, 1906; Štikić, 1951-1953; Aljnović and Błašković, 1981; Matić, 1998), there is a question about possible underthrust south-eastern part of the Friuli Basin beneath the Čičarija structures (Cati et al., 1987 – 1 on Fig. 8).

The Adriatic Trough more probably represented an equivalent of a closed seaway comparable to the Bahamian closed seaways (Wright and Burchette, 1996). In our opinion, the trough had a dead-end somewhere in the area of the present day Kvarner bay (Fig. 8).

5 CONCLUSIONS

(1) Due to the influence of synsedimentary tectonics supported by eustatic changes and local anoxia during the latest Albanian/Early Cenomanian, different sedimentary environments were established in the area of the present day island of Cres: from shallow intraplatform basin and related slope, across basin margin to protected shallow-platform.

(2) The differences in thickness and lateral variability among facies associations recognized within the studied successions are mostly a consequence of variable amounts of accommodation space and complex palaeo-relief of the depositional area during the Cenomanian.

(3) Primary relationships between laterally different Cenomanian successions have been tectonically masked during intense Tertiary deformations.

(4) Recumbent-rudist (caprinids and ichthyosarcolithids) prevail over elevator-rudists (radiolitids) within bioclastic rudist floatstone-rudstones deposited at relatively high-energy intraplatform basin margin during the Early to Middle Cenomanian.

(5) Boulders of bioclastic rudist floatstone-rudstones within deeper-water pithonellid wackestone-packstones
Fig. 8. A) Simplified Late Cretaceous facies domains within the wider area (after Cati et al., 1987; Jenkys, 1991; Gusić and Jelaska, 1993; Grandić et al., 1999). B) Position of localities described in papers discussed in the text and, consequently, schematically reconstructed facies domains:
1: Cati et al. (1987) - supposed extension of the Friuli basin, Early Senonian;
2: Vlahovic et al. (1994) - lagoon to offshore, Cenomanian;
3: Tiljar et al. (1998) - prograding clinostratified bodies over 4-6° dipping ramp, Early to Middle Cenomanian;
4: Moro (1997) - inner to outer shelf, Turonian to Santonian;
5: This paper - shallow intraplatform basin and basin margin, Cenomanian;
6: Moro and Jelaska (1994) - peritidal, Middle Cenomanian to Lower Santonian;
7: Kapovic and Bauer (1970); Gusić and Jelaska (1993) - carbonate turbidites, slope deposits, Late Cenomanian to Santonian;
8: Fuček et al. (1991) - slope deposits, latest Cenomanian to Coniacian;
9: Fuček et al. (1990) - peritidal, Cenomanian to Santonian.

imply slope instability and provide important evidence of the early cementation of marginal bioclastic limestones. Slope instability could have been triggered by seismic shocks and supported by a relative sea-level fall. The observations discussed support the idea of a steep slope configuration and/or a possible escarpment physiography of the margin.

6) The opening of the intraplatform basin in the area of the island of Cres was aborted and the basin was filled up with sediments during the Late Cenomanian.

7) The Adriatic Trough was an elongated intraplatform basin established during the Late Cenomanian and situated within the north-western part of the Adriatic Carbonate Platform.

8) The deeper-water sedimentation in the area of the present day island of Cres was initiated at the beginning of the Cenomanian, while available data suggest opening of the Adriatic Trough at the end of the Cenomanian. Therefore, Cenomanian deeper-water environments recognized in the area of the island of Cres can be interpreted as an intraplatform basin, representing the initiation phase in the north-western extension of the later Adriatic Trough development.

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