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Eocene Limestones Overlying Lower Cretaceous Deposits of Western Istria (Croatia): Did Some Parts of Present Istria Form Land During the Cretaceous?

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Ključne riječi: kredni tektonski ciklus, kredno kopno, zapadnoistarska antiklinalna struktura, transgresivni eocenski vapnenci, Jadranska karbonatna platforma, Istra, Hrvatska.

Abstract

In the region of the western Istrian anticline, erosional remains of the transgressive Eocene Foraminiferal limestones overly shallow-water deposits of Early Cretaceous age (Valanginian, Hauterivian and Barremian). This evidence, together with the ocurrence of bauxite deposits and Palaeogene beds overlying Albian, Cenomanian and Senonian limestones indicate the very high relief of the land transgressed by the Palaeogene sea. Contrary to the traditional connection between the formation of the western Istrian anticline and the Laramian tectonic phase at the end of the Cretaceous (Maastrichtian), new investigations suggest sporadic tectonic movements (with constant tectonic coordinate orientation) from the Hauterivian to the end of the Cretaceous. With these movements, formation of the anticline structure began in the Early Cretaceous, with the emerged apical parts representing land areas throughout most of the Cretaceous.

Sažetak

U području zapadnoistarske antiklinale utvrđene su pojave erozijskih ostataka transgresivnih eocenskih foraminiferskih vapnenaca na plitkovodnim naslagama donje krede (valendisu, otrivu i baremu). Ti nalazi zajedno s pojavama boksita i paleogenskih naslaga na albskim, cenomanskim i senonskim vapnencima, ukazuju na izrazit reljef kopna na koje je transgrediralo paleogensko more. Nasuprot dosadašnjem vezivanju nastanka zapadnoistarske antiklinale za laramijsku tektonsku fazu krajem krede (u mastrihtu), rezultati novijih istraživanja ukazuju da su povremeni tektonski pokreti djelovali od otriva do kraja krede s istom orijentacijom tektonskih koordinata. Tim je pokretima već u starijoj kredi započelo formiranje antiklinalne strukture, čiji je emergirani središnji dio predstavljao kopno tijekom gotovo cijele krede. Dakle, područje zapadnoistarske antiklinale je u mlađemu dijelu starije krede i mlađoj kredi bilo kopno!

1. INTRODUCTION

Recent systematic geological investigations in western Istria (Fig. 1), especially during research for the 1:50,000 scale Geological Map of the Republic of Croatia indicate a need for a new interpretation of the geological evolution of the Istrian peninsula during the Cretaceous and older Tertiary. Previous interpretations were based on the results of investigations for the Basic Geological Map (POLŠAK & ŠIKIĆ, 1969), as represented in the explanatory notes of the Rovinj sheet (POLŠAK & ŠIKIĆ, 1973).

The authors of subsequent papers on the geology of central and western Istria accepted the tectonic scheme from this work, where the dominant structure, the NNE-SSW oriented western Istrian anticline, is interpreted as being formed by the end of the Late Cretaceous during the Laramian tectonic phase. As the influence of the Laramian tectonic phase declined by the end of the Cretaceous and beginning of the Palaeogene, the new, Pyrrenean tectonic phase began. This was characterised by a change in the orientation of the compression of the carbonate platform, i.e. the greatest principal stress was oriented NE-SW. As orogenic movements occurred in the NE hinterland of the newly formed basin, as evidenced by the sedimentary succession from the Foraminiferal limestones to flysch, incomplete successions are not unusual. In some places different units of the Foraminiferal limestones are missing, and elsewhere flysch was deposited directly over Cretaceous beds (POLŠAK & ŠIKIĆ, 1969; MARINČIĆ, 1986). The flysch deposits in central Istria (from Brtonigla to Labin) represent the SW part of the former flysch basin with a Dinaric orientation (NW-SE). Through further compression the NE part of the basin was partially consumed by underthrusting beneath the Ćićarija mountain range, and became partially involved in its nappe structure.

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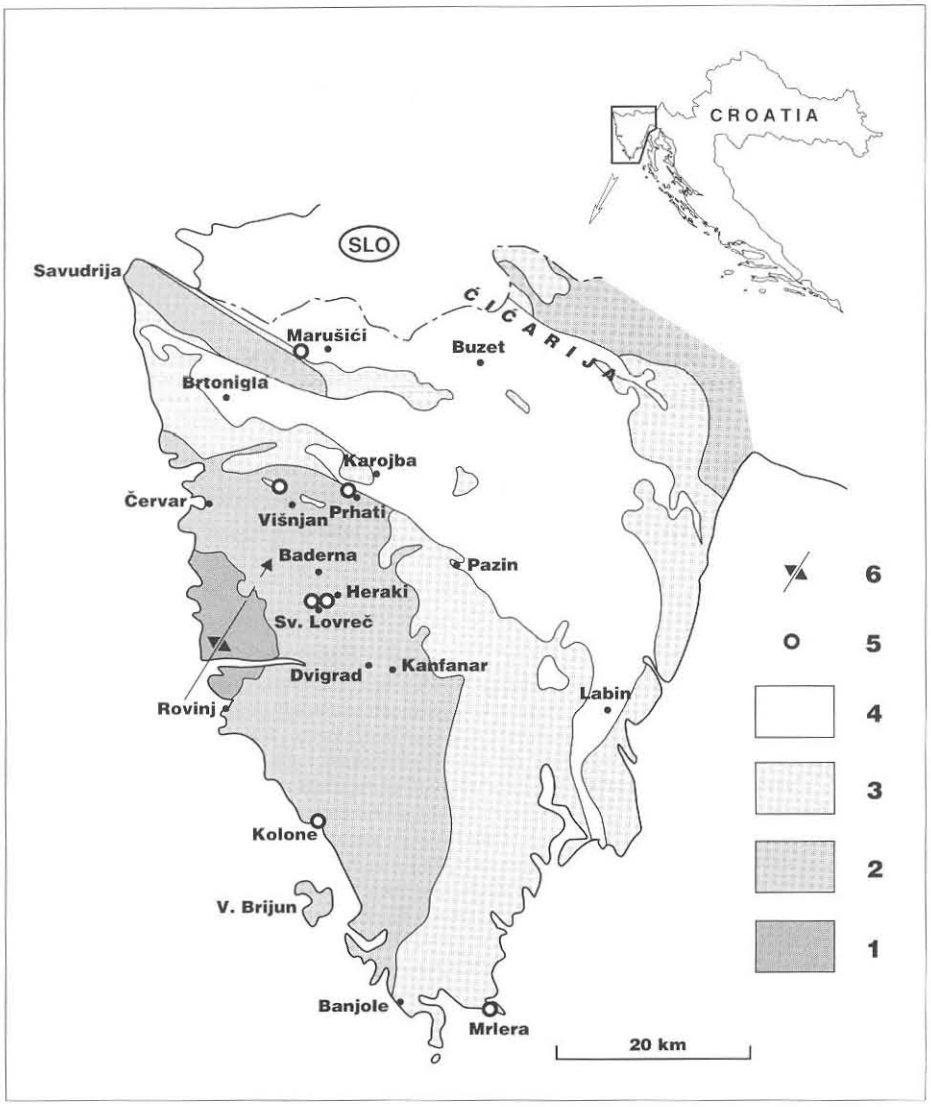

Fig. 1 Geological sketch map of Istria (modified after the Geological Map of SFRY 1:500.000, published by the Federal Geological Institute, Belgrade, 1970) with the localities mentioned in the text. Legend: 1) Jurassic; 2) Lower Cretaceous; 3) Upper Cretaceous; 4) Palaeogene Foraminiferal limestones and flysch deposits; 5) Investigated occurrences of the Eocene Foraminiferal limestones; 6) Axis of the western Istrian anticline.

Despite the intense regional tectonics which resulted in the uplift of the Dinarides, the area of western Istria suffered no intense structural-tectonical deformation. This is probably the consequence of deformation of the flysch basin which resulted with the early formation of the regional underthrusting zone. In this way the resistence against the movement of the SW part of the platform decreased significantly, and it started to underthrust towards the NE. While the basic structure of the peninsula, i.e. SW part of the basin, remained rather undisturbed, the obducted part was strongly contracted and tectonically deformed. Younger, Post-Miocene movements are characterised by a regional stress oriented approximately S-N (MATIČEC, 1994), and resulted in the formation of new structures with the characteristic E-W orientation of the b-axis.

MARINČIĆ & MATIČEC (1989, 1991) have confirmed the aforementioned orientation of the western Istrian structure (b-axis oriented 35/8) by detailed field investigations, and determined the basic orientation of the tectonic coordinates of the Laramian phase in the region of Istria. Therefore the present structural fabric and orientation, as well as the timing of the final formation of the western Istrian anticline are well known. However, traditional view of a structurally stable Istria, characterised by the continuous deposition of carbonate platform deposits over the entire area through the Cretaceous and subsequent gentle folding with important erosion during the Laramian tectonic phase, cannot explain some new discoveries in stratigraphy and tectonics of western Istria.

2. STRATIGRAPHIC POSITION AND CHARACTERISTICS OF FORAMINIFERAL LIMESTONES IN THE VICINITY OF SV. LOVREČ AND VIŠNJAN

Figure 2 represents a geological sketch-map of the area near Sv. Lovreč showing the outcrops of the Eocene Foraminiferal limestones, which transgressively overlie Valanginian (Fig. 2, A) and Barremian limestones (Fig. 2, B), in the form of a small erosional relics. The Valanginian deposits are characterised by

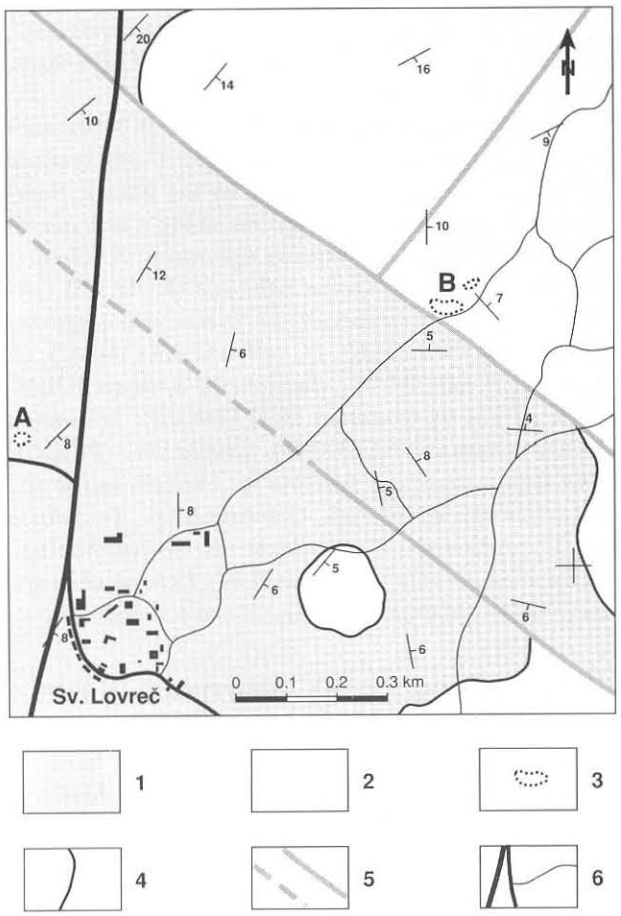

Fig. 2 Lithostratigraphic sketch map of the Sv. Lovreč area. Legend: 1) Valanginian and Hauterivian deposits; 2) Barremian deposits; 3) Erosional relics of the Eocene Foraminiferal limestone - A) overlying Valanginian, B) overlying Barremian; 4) Normal geological boundary; 5) Faults; 6) Roads.

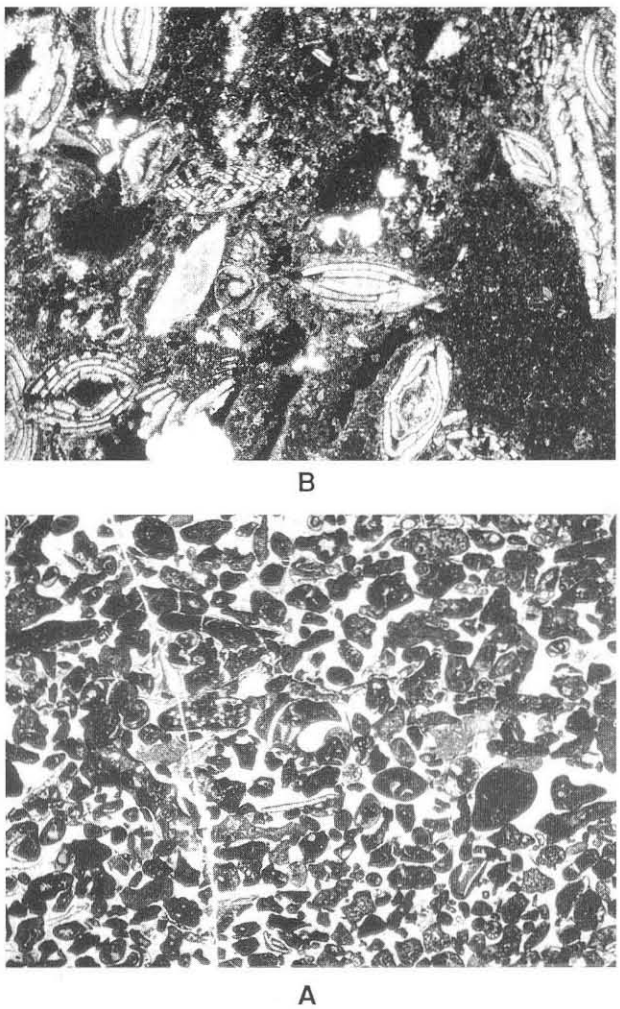

Fig. 3 Sv. Lovreč B locality: A) A photomicrograph of skeletal-peloid-intraclast grainstone of Barremian age, x6.5; B) A photomicrograph of the Eocene Foraminiferal limestone, x4.5.

the rhythmical alternation of light-coloured mudstones with pelletal packstones, and favreina-intraclastic grainstones containing the following microfossil assemblage: *Epimastopora cekici* RADOIČIĆ, *Salpingoporella istriana* GUŠIĆ, *S. praturloni* DRAGASTAN, *Heteroporella paucicalcarea* CONRAD & RADOIČIĆ, *Falsolikanella campanensis* (AZEMA & JAFREZZO), *Dissocladella hauteriviana* MASSE, *Vercorsella tenuis* (VELIĆ & GUŠIĆ), *V. camposaurii* (SARTONI & CRESCENTI), *Pseudotextulariella salevensis* CHAROLLAIS et al., *Citaella? favrei* CHAROLLAIS et al., *Trocholina sagittaria* ARNAUD-VANNEAU, *T. delphinensis* ARNAUD-VANNEAU, *Favreina njegosensis* BRÖNNIMANN, etc. Barremian deposits are represented by the alternation of miliolid wackestones, ostracod mudstones, skeletal-peloid-intraclast grainstones and gastropod-mollusc grainstones/floatstones (Fig. 3A). Their age is detemined by the frequent occurrence of fossil algae and benthic foraminifera: *Salpingoporella melitae* RADOIČIĆ, *S. muehlbergii* (LORENZ), *S. genevensis* CONRAD, *Praturlonella danilovae* (RADOIČIĆ), *Cylindroporella ivanovici* (SOKAČ), *Humiella pupnatensis* SOKAČ, *Clypeina solkani* CONRAD & RADOIČIĆ, *C. somalica* CONRAD et al., *Sabaudia minuta* (HOFKER), *Novalesia distorta* ARNAUD-VANNEAU, *N. cornucopia* ARNAUD-VANNEAU, *Debarina hahounerensis* FOURCADE et al., *Pseudonummoloculina* sp., etc.

In the samples of the Palaeogene limestones the following microfossil assemblage has been determined: *Nummulites* sp., *Assilina* sp., *Discocyclina* sp., *Lenticularia* sp., *Rotalia* sp., ?*Fabiania* sp., ?corallinaceae or ?*Acervulina* (i.e. red algae or incrusting foraminifera, indeterminable because of the recrystallisation and partial dolomitization of the sediment), as well as crinoid plates and relics of bryozoans, molluscs and corals. Such an assemblage indicates a Lutetian age, and can be compared with the uppermost part of the Nummulite Beds elsewhere in the Adriatic Carbonate Platform. It should be mentioned that foraminifera are specifically indeterminable because of the intense weathering and recrystallisation - they are mostly dissolved, and only skeletal voids are preserved. The limestones are intensely recrystallised with late diagenetic dolomitisa-

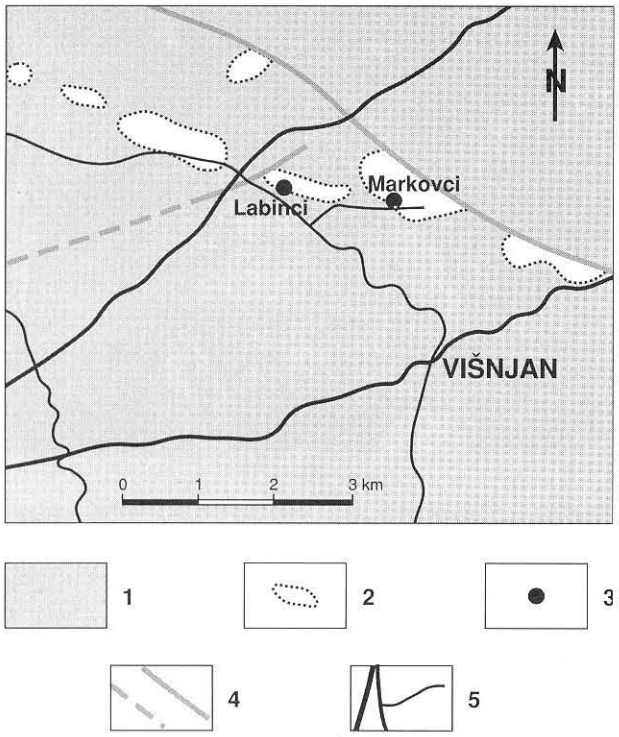

Fig. 4 Geological sketch map of the area near Višnjan (simplified after POLŠAK & ŠIKIĆ, 1969). Legend: 1) Lower Cretaceous limestones; 2) Eocene Foraminiferal limestones; 3) Studied localities; 4) Faults; 5) Roads.

tion of skeletal-peloid wackestone/packstones to floatstones, composed of mechanically destroyed bioclasts and more or less recrystallised fine-grained pelmicritic matrix (Fig. 3B). Grains range in size from peloids and bioclasts smaller than 1 mm to foraminifera tests larger than 15 mm.

According to the Basic geological map of the Rovinj sheet (POLŠAK & ŠIKIĆ, 1969) outcrops of the Eocene Foraminiferal limestones closest to Sv. Lovreč were found near Višnjan (Fig. 4). Among several outcrops presented on this map two localities, Labinci and Markovci, were investigated in detail for the present study. At both localities it has been determined that the Eocene beds are overlying Hauterivian deposits.

In a detailed measured column near Labinci (Fig. 5) peritidal mudstones, skeletal wackestones and packstones contain the following microfossil assemblage: green algae *Clypeina solkani* CONRAD & RADOIČIĆ and *Salpingoporella annulata* CAROZZI, and foraminifera *Campanellula capuensis* DE CASTRO, indicating an Upper Hauterivian age (Fig. 5A). In the Palaeogene foraminiferal packstone/grainstones (Fig. 5B), the following assemblage indicating a Lower to Middle Eocene age has been determined: *Acervulina ogormani* (DOUVILLEI), *Sphaerogypsina globula* REISS, *Nummulites* sp., *Dermatolithon* sp., *Alveolina* sp., *Lenticularia* sp., *Rotalia* sp., *Gyroidina* sp., *Asterigerina* sp., *Cibicides* sp., as well as skeletal remains of bryozoans, molluscs and corals.

Near Markovci village the Hauterivian limestones with *Salpingoporella annulata* and *Campanellula capuensis* (Fig. 6A) are overlain by the Eocene Foraminiferal limestones (Fig. 6B) containing a rich microfossil assemblage: *Acervulina ogormani*, *A. linearis* (HANZAWA), *Cuvillerina vallensis* (RUIZ DE GAONA), *Sphaerogypsina globula*, *Discocyclina agustae* (VAN DER WEIJDEN), *D. sella* (D'ARCHIAC), *D. radians* (D'ARCHIAC), *Peysonelia antiqua* JOHNSON, *Alveolina levantina* HOTTINGER, *Miniacina multicamerata* (SCHEIBNER), *Ethelia alba* (PFENDER), *Nummulites* sp., *Assilina* sp., *Asterocyclina* sp., *Cibicides* sp., *Rotalia* sp., *Orbitolites* sp., *Textularia* sp., *Gyroidina* sp., *Lenticularia* sp., *Spirolithon* sp., *Lithotamnium melobesium* (FOSLIE), *Lithophyllum* sp., and bioclasts of crinoids, molluscs and echinoderms.

3. SYNSEDIMENTARY TECTONICS IN THE CRETACEOUS DEPOSITS OF ISTRIA

Cretaceous orogenic movements in the Mediterranean region affected the Adriatic Carbonate Platform. To define these compressive movements it is necessary to explain the relationship between the *continuous* regional tectonism and the sporadically discernible consequences of the synsedimentary deformation.

The period of deformation caused by the regional stress of the same orientation represents a *tectonic cycle*. Cessation of the stress results in cessation of the deformation, and the change of its orientation results in new deformation, i.e. a new tectonic cycle. The process of deformation is usually gradual, being composed of the individual episodes of increased tectonic activity (i.e. parts of the tectonic cycle - *tectonic phases*), and relatively calm periods between them. A tectonic cycle is defined by its duration, the orientation of its tectonic coordinates (the greatest principal stress and position of the B-axis), and direction of the tectonic transport. Hence, it is recognisable in time and space. Its cessation is marked by the maximum deformation. Therefore the deformation represents a cumulative process - during each phase in a cycle deformation being added to the former phase. Consequently, in consideration of the tectonic activity in the Cretaceous of Istria we have to start from its youngest records working backwards towards the older ones with the same tectonic coordinates, as follows:

a) Bauxite deposits in Istria are most commonly situated above the Cenomanian deposits. Bauxitic material had filled depressions in the relief formed by the erosion of junctions of the youngest, Post-Cenomanian joint systems (MARINČIĆ & MATIČEC, 1989) with orientations corresponding to h00 and 0k0 joint systems of the western Istrian anticline (i.e. NNE-SSW and ESE-WNW).

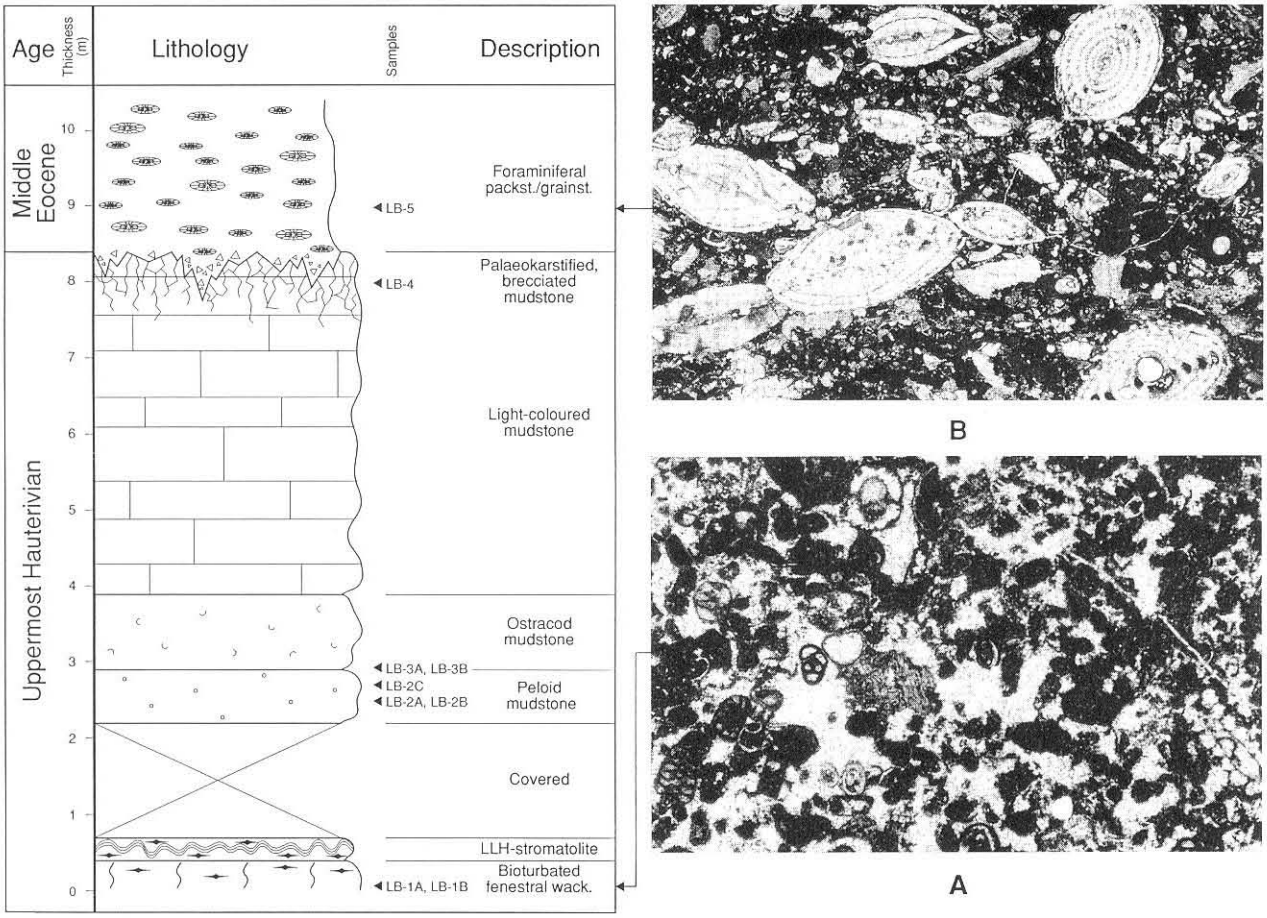

Fig. 5 Detailed geological column at the Labinci locality; A) A photomicrograph of the Upper Hauterivian limestone with *Salpingoporella annulata* CAROZZI and *Campanellula capuensis* DE CASTRO, x20; B) A photomicrograph of the Eocene Foraminiferal limestones (bioclastic packstone) containing nummulitids and alveolinids, x5.5.

b) Facies differentiation that has been recorded at the beginning of the Cenomanian in the area of Istria is a consequence of the synsedimentary, compressive tectonic activity (VLAHOVIĆ et al., 1994; TIŠLJAR et al., 1995). In southern Istria near Banjole, a tilting of the platform towards the ESE has been determined. The distribution of the contemporaneous different facies in northern Istria, near Savudrija, is also characterised by the same orientation. The lateral extent of the facies belts, as well as the orientation of ripple-axes in the Cenomanian (NNE-SSW), corresponds to the orientation of the western Istrian anticline. The highest parts of the structure probably remained emerged until the transgression in the Palaeogene: in central Istria bauxite deposits overlie either Albian deposits (Prhat) or Mid-

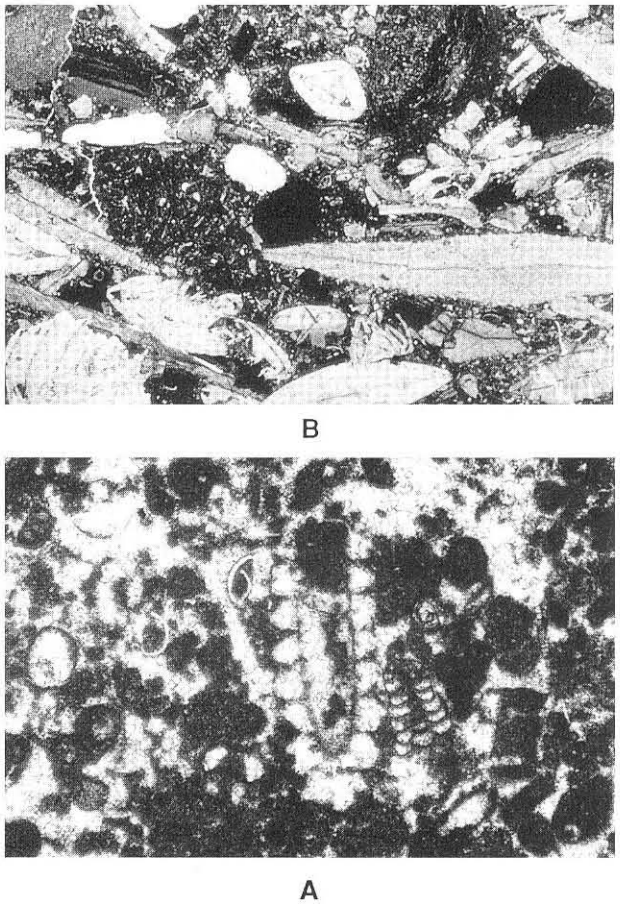

Fig. 6 Markovci locality: A) A photomicrograph of the Upper Hauterivian limestone containing *Salpingoporella annulata* CAROZZI and *Campanellula capuensis* DE CASTRO, x35; B) A photomicrograph of the Eocene Foraminiferal limestones (bioclastic packstone) with nummulitids, discocyclinids, etc., x5.5.

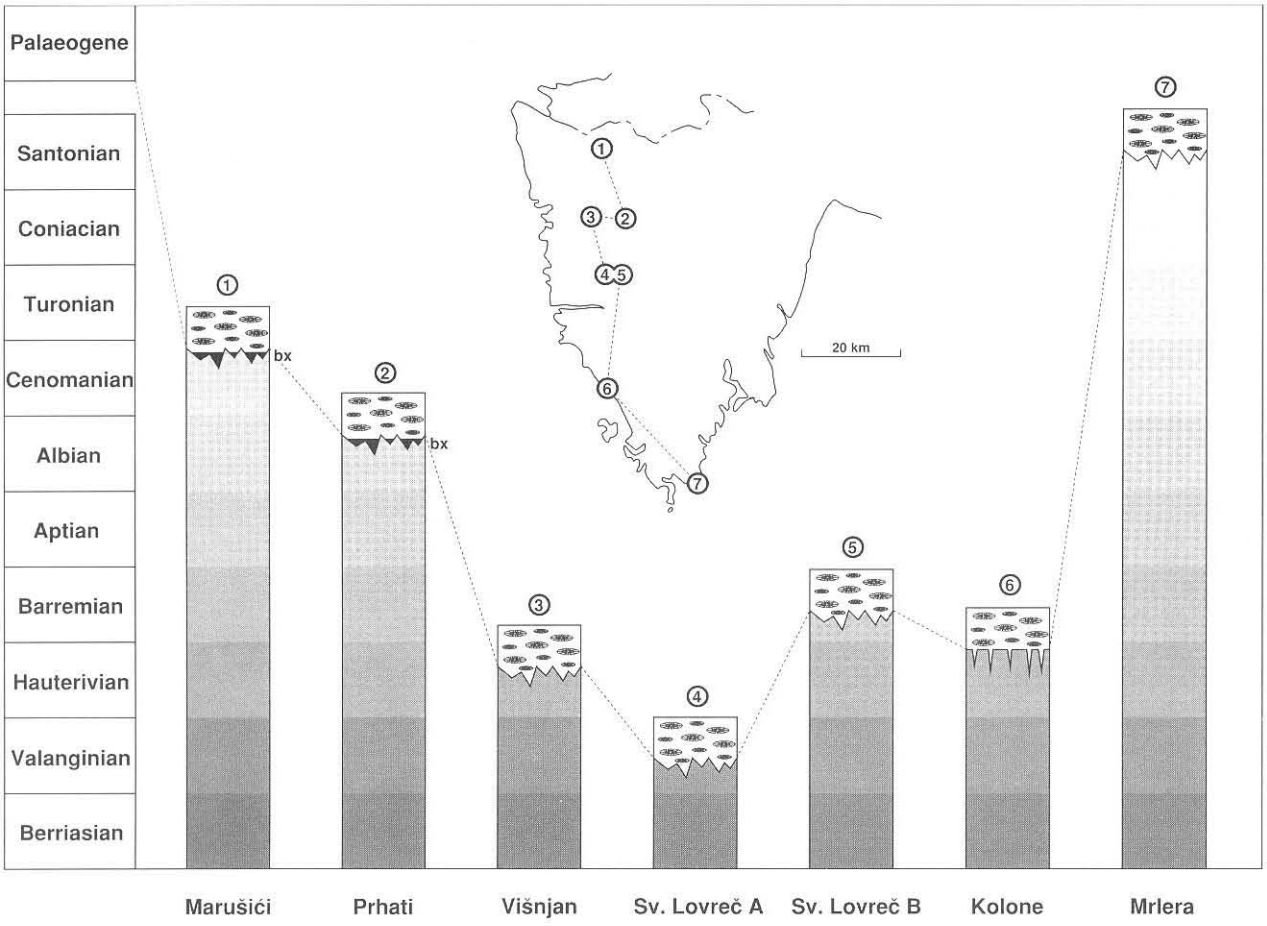

Fig. 7 A schematic correlation showing the position of Eocene Foraminifera limestones overlying different stratigraphic levels of the Cretaceous (Valanginian to Santonian).

dle to Upper Cenomanian deposits (Pazin area - POLŠAK & ŠIKIĆ, 1969), while in northern Istria (Buzet and Karojba - DROBNE, 1977; Marušići - VELIĆ & VLAHOVIĆ, 1994) Palaeogene Foraminiferal limestones lie on the Upper Cenomanian beds.

c) The complete area of western Istria was emergent during the major part of the Aptian, and during the Lower Albian. There are no clear structural indications as to the coordinates and character of the tectonics, but the influence of the synsedimentary tectonics is evidenced by the palaeogeographical situation in this period of the Lower Cretaceous in the Istrian part of the platform. In the central part of the Western Istrian structure (Baderna - Heraki area) the emersion started during the Late Barremian, and lasted until the Late Albian. On the limbs of the structure deposition continued in the Early Aptian, but with laterally distinct different facies: in the SE part (Dvigrad - Kanfanar - Veli Brijun area) massive lagoonal oncolite micrites were deposited, while in the NW part (Heraki - Červar area) there are limestones originating from the shallow-water, higher energy environments. Over the major part of the structure emersion started during the Early Aptian, but in the Dvigrad - Kanfanar area deposition was prolonged even to the basal part of the Late Aptian. All these areas were flooded by the transgression in the Late Albian (VELIĆ et al., 1989; TIŠLJAR et al., 1995).

d) Our recent investigations in the Kolone Cove (SE of Rovinj) indicate synsedimentary tectonics in the Hauterivian, with the orientation of the greatest principal stress corresponding to the aforementioned episodes (c. 308°).

The constant orientation of the tectonic coordinates of the aforementioned movements during different periods of the *Cretaceous* indicate that they belong to a single *tectonic cycle*, with activity evidenced sporadically from the Hauterivian to the end of the Cretaceous.

4. PALAEOGEOGRAPHICAL CONSIDERATIONS

Eocene Foraminiferal limestones transgressively overlie deposits of different stratigraphical levels (Fig. 7). In addition to the described Valanginian and Barremian examples near Sv. Lovreč and those of the Hau-

terivian near Višnjan, TUNIS et al. (1994) reported on Nummulite limestones and breccias in contact with the Hauterivian limestones in the Kolone Cove (SE of Rovinj). From previous studies there are data on Palaeogene deposits overlying Albian carbonates North of Višnjan and Cenomanian sediments in central and northern Istria (POLŠAK & ŠIKIĆ, 1969; DROBNE, 1977), as well as the Senonian of southern Istria and in the vicinity of Labin (POLŠAK, 1967; ŠIKIĆ et al., 1969).

Besides three very important long-lasting emersions influencing Istria (Kimmeridgian - Late Tithonian, Barremian/Early Aptian - Late Albian, and Cretaceous - Palaeogene) short emersions were so frequent during some periods (e.g. Hauterivian, Barremian) that they represent a specific characteristic of the facies. Parasequences, i.e. shallowing-upward cycles, usually ended by emersion, are commonly composed of clayey material and frequent black-pebble breccias. Considering the fact that during these periods there are traces of dinosaur activity, the palaeoenvironment would probably represent a wide coastal zone surrounding the land, with peritidal deposits and numerous coastal swamps. During periodic relative sea-level oscillations black, reductive swamp deposits were reworked and redeposited by tidal channels in neighbouring intertidal and shallow subtidal environments.

In western Istria there are several localities with dinosaur footprints which span a broad stratigraphic range (Late Barremian, Late Albian and Late Cenomanian) and bone remains (Late Hauterivian/basal Barremian). DALLA VECCHIA & TARLAO (1995) made some very interesting palaeogeographic interpretations: on the basis of the available data they concluded that most of the animals were carnivorous, i.e. they needed a land area large enough to enable their survival by supporting herbivorous animals, which need huge amounts of plant material, as well as fresh water. It should be emphasised that the environments where the footprints were found, with conditions favourable for their preservation, were not a habitat of the dinosaurs. They lived on the land, and probably only transgressed across the coastal areas. With regard to the repeated occurrence of footprints which span a lengthy stratigraphic range, it may be concluded that Istria represented a suitable area for their colonisation and existence during the Cretaceous. Since the apical parts of the western Istrian anticline represented the land area with a changing surface due to the interaction of tectonic and eustatic factors, it is possible to suppose at least occasional connection with neighbouring larger continental areas.

In the area of Istria there are two levels of bauxite deposits: between the Oxfordian and Upper Tithonian, and Cretaceous and Palaeogene. While the footwall of the Jurassic bauxites is of the same age in all localities, the footwall of the younger bauxites belongs to the different levels of the Cretaceous - mostly to the Cenomanian, but in the area of Prhat to the Albian. This indicates that the bauxitic material was accumulated in the depressions of subaerially exposed rocks of different age.

Aforementioned findings of the bauxite deposits on the Albian and Cenomanian, as well as Palaeogene Foraminiferal limestones on the Lower Cretaceous considerably alters the probability of the intense erosion of the Cretaceous deposits, which was proposed in the former interpretations. Lack of the younger Cretaceous deposits was interpreted as a consequence of significant erosion after the Santonian. However, discovery of Palaeogene deposits overlying the Valanginian, Hauterivian and Barremian beds indicate the absence of the upper part of the Lower Cretaceous and complete Upper Cretaceous beds prior to the Palaeogene transgression, which would correspond to more than a 2.000 m thick sequence of carbonates deposited in the neighbouring areas of southern Istria. This fact indicates on a very low possibility that during the Cretaceous/Palaeogene transition huge amount of deposits, of laterally variable age (the footwall of the Palaeogene deposits ranges from the Valanginian to the Santonian/Campanian) were eroded without any relics, and without any evidence of intense tectonics. Without excluding some subaerial erosion, or possibly somewhat condensed deposition, we consider that in the discussed areas of Istria, the major part of the Cretaceous deposits was not deposited, as a consequence of the relatively mild, but during the Cretaceous continuously present synsedimentary tectonics. Consequently, these facts indicate that the lack of the Upper Cretaceous and, partly Lower Cretaceous deposits in western Istria is probably the consequence of a long-lasting phase of terrestrial exposure in Istria rather than the subsequent intense erosion of a completely deposited sequence.

5. PALAEOGEOLOGICAL EVOLUTION OF WESTERN ISTRIA THROUGH THE CRETACEOUS AND PALAEOGENE

Occurrences of the erosional relics of the Palaeogene limestones on the different stratigraphical members of the Lower Cretaceous deposits of Istria, as well as the other facts presented in this paper enable modification of the traditional interpretations of the tectogenesis of Istria. Contrary to the former opinion that the anticline structure of the peninsula is a consequence of a single tectonic act at the end of the Cretaceous, it may be concluded that Istria was subjected to gentle, but distinct tectonic movements during the major part of the Early and the complete Late Cretaceous. These movements led to important palaeogeographic changes, since in the shallow-water environments of the carbonate platform even small elevations result in an entirely different facies distribution, and the establishment of rather spacious land areas (Fig. 8A, B). The extent of the land was changing during the Cretaceous, depending upon the relation between the synsedimentary tectonics and the eustatic changes; therefore the position of the shoreline was variable (Fig. 8C). The land represented a good habitat for dinosaurs, since in the border-

ing areas probably large swamps with flourishing vegetation existed. Sporadically these animals, (most likely during their search for food) went to the marginal marine environments, where they left their traces in a soft sediment.

During the sporadic episodes of sea-level rise there was probably a partial flooding of the inland area of the western Istrian anticline, e.g. in the Dinarides there is a regionally recorded drowning of the platform in the Late Cenomanian and Early Turonian (GUŠIĆ & JELASKA, 1993). As the apical parts of the structure represented the emerged area, during the sea-level rise a probably relatively thin succession of sediments was deposited in the marginal parts, which was eroded during subsequent sea-level fall (Fig. 8C).

On the basis of current knowledge, the only evidence of flooding of the inner part of the uplifted, inner part of the platform, are outcrops of the Palaeogene Foraminiferal limestones mentioned in this paper. Their existence should be analysed in the light of the palaeogeographic situation in the Istrian part of the Adriatic Carbonate Platform during the Palaeogene. Due to the change of the regional stress orientation, i.e. the beginning of the new, *Tertiary tectonic cycle*, a sedimentary basin of Dinaric strike (NW-SE) was formed. Foraminiferal limestones were deposited in its marginal parts, while in the deeper, central parts flysch deposition took place (Fig. 8D). During the episodes of relative sea-level rise the inner parts of the western Istrian anticline were flooded, as evidenced by the deposition of the Foraminiferal limestones. This, SW slope of the basin represented the source area for part of the calcareous material in the flysch deposits, and BABIĆ et al. (1995) have determined palaeotransport directions towards the N-NE. It should be emphasised that the preservation of the Foraminiferal limestones on the older Cretaceous deposits after prolonged subaerial exposure represents an exception, not a rule. Anyway, it is to be assumed that additional similar findings will be recorded during further detailed work.

It is very important to bear in mind that Istria represents (due to the relatively weak disturbance by the younger tectonics), a very suitable area for the study of the geological history of the Adriatic Carbonate Platform during the Mesozoic. The described dynamics of the Cretaceous events could also be expected therefore in the neighbouring areas, since there is a common absence of at least part of the Upper Cretaceous deposits (e.g. the islands of Cres, Krk, Sv. Grgur, Prvić and Goli Otok, as well as on part of the Ćićarija Mt.). Therefore, during further investigations special attention should be given to the palaeogeographic aspect.

6. CONCLUSIONS

On the basis of the presented data and their discussion the following results important for the interpretation of the geological events which occured during the Cretaceous and Tertiary in western Istria should be emphasised:

1) Near Sv. Lovreč previously unknown erosional relics of the Eocene Foraminiferal limestone were discovered overlying Valanginian and Barremian limestones.
2) The footwall of the relics of the Eocene Foraminiferal limestone near Višnjan is composed of the peritidal mudstones and wackestone/packstones of Hauterivian age. A similar situation occurs in the Kolone Cove SE of Rovinj, where the Eocene Foraminiferal limestone is in contact with the Hauterivian limestone.
3) Tectonic activity (i.e. relative uplift caused by the gentle folding and/or faulting) and eustatic changes (i.e. the sea-level fall) has produced frequent emersions of variable duration during the Late Jurassic and Cretaceous: in the Kimmeridgian/Tithonian, Hauterivian, Barremian and Aptian/Albian.
4) The emerged areas were inhabited by dinosaurs, during the stratigraphic range from the Late Hauterivian to the Upper Cenomanian (at least), as evidenced by relics of their footprints and bones.
5) Facts stated in 1-4 were determined in the wider area of the western Istrian anticline, and are closely related to the timing of its formation and later related geological events.
6) The beginning of the formation of the structure took place earlier than in the Maastrichtian: it is determined by the palaeotectonical parameters determined in the Hauterivian and Cenomanian, and registered in the Aptian and Albian.
7) The orientation of the above mentioned palaeostructural elements formed by synsedimentary tectonical activity during the Early and Late Cretaceous of Istria is in agreement with the elements whose formation was formerly attributed exclusively to the Maastrichtian age in Istria, as well as in the other regions of the Adriatic Carbonate Platform.
8) Bauxites from the footwall of the Palaeogene limestones were deposited in the palaeorelief of the Cenomanian and Albian limestones. This fact together with the transgressive nature of the Eocene Foraminiferal limestones on the Valanginian, Hauterivian, Barremian, Albian and Cenomanian deposits exclude the possibility of the continuous deposition of a complete Upper Cretaceous sequence, and its subsequent erosion prior to deposition of the Foraminiferal limestones, especially as there should have been eroded laterally different amounts of material (from 1.000 to 2.000 m) without any trace, and without any evidence of intense tectonics.

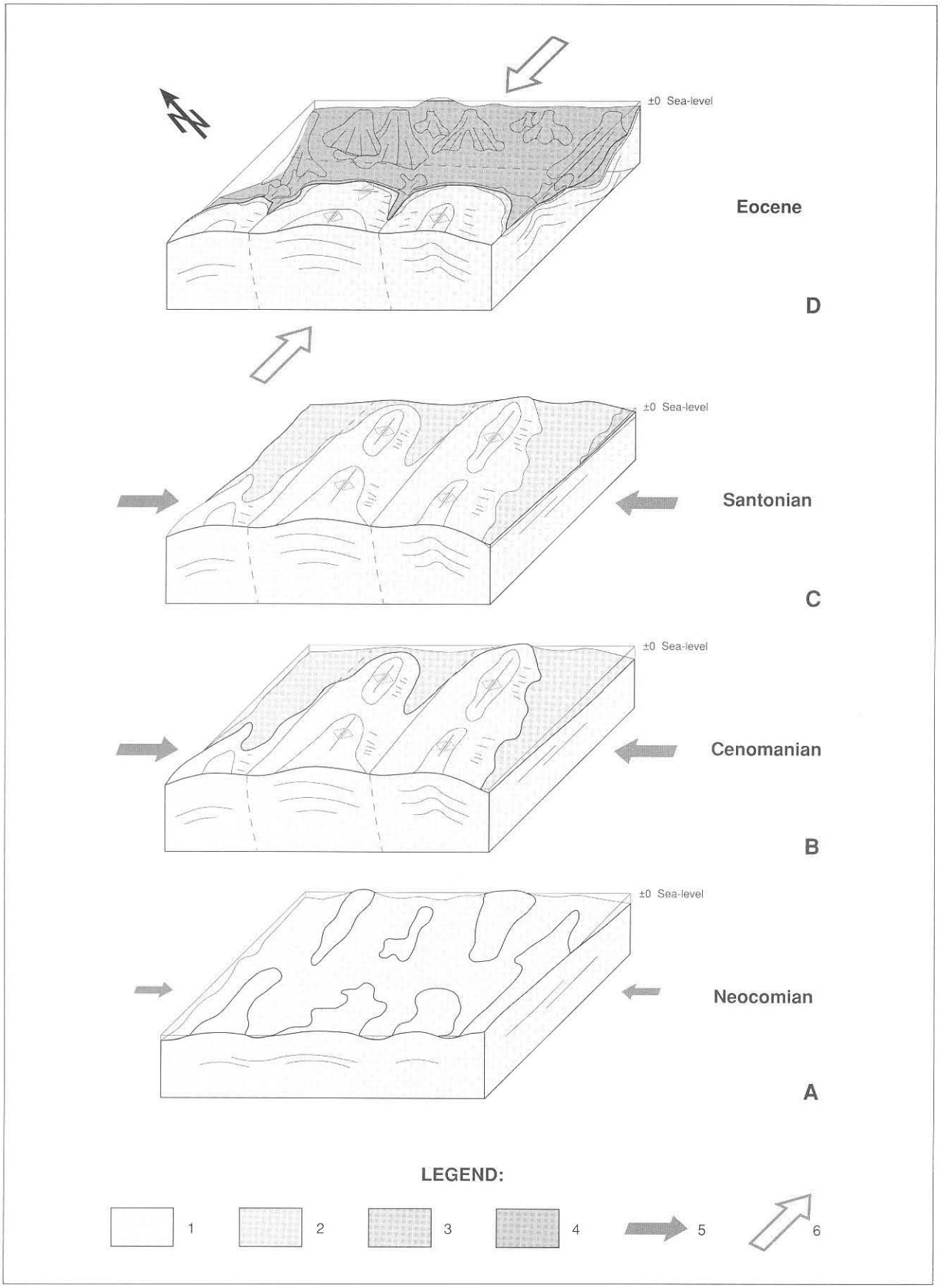

Fig. 8 A schematic drawing representing the palaeogeological dynamics of western Istria during the Cretaceous and Palaeogene. A) The initial stage of formation of the western Istrian structure; B) Relation between the shallow-water environments and the land areas in the complex geomorphology of the structure caused by tectonic uplift; C) Decrease of marine deposition during the extensive emersion; D) Formation of the flysch basin by the refolding of the Cretaceous anticline; Legend: 1) Lower Cretaceous deposits; 2) Cenomanian deposits; 3) Turonian-Santonian deposits; 4) Palaeogene Foraminiferal limestones and flysch deposits; 5) Orientation of the regional stress during the *Cretaceous tectonic cycle*; 6) Orientation of the regional stress during the *Tertiary tectonic cycle*.

Analysis and interpretation of the presented results facilitate the following conclusions on the palaeogeological evolution of the western Istria:

- *The mutual relations of the Cretaceous and Palaeogene stratigraphic units, as well as the other mentioned data indicate that in the central part of the structure younger Early Cretaceous and Late Cretaceous units were not deposited as a consequence of the prolonged subaerial exposure.*
- *The Laramian tectonic phase, which is in the Dinarides attributed to be of the youngest Cretaceous (Maastrichtian) and oldest Palaeogene age, at least in the area of the western Istrian anticline represents only one of the tectonic phases within the* ***Cretaceous tectonic cycle****, characterised by the same tectonic coordinates since the Neocomian.*

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