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Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics

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Abstract

The Adriatic Carbonate Platform (AdCP) is one of the largest Mesozoic carbonate platforms of the Perimediterranean region. Its deposits comprise a major part of the entire carbonate succession of the Croatian Karst (External or Outer) Dinarides, which is very thick (in places more than 8000 m), and ranges in age from the Middle Permian (or even Upper Carboniferous) to the Eocene.

However, only deposits ranging from the top of the Lower Jurassic (Toarcian) to the top of the Cretaceous can be attributed to the AdCP (defined as an isolated palaeogeographical entity). Although the entire carbonate succession of the Karst Dinarides was deposited within carbonate platform environments, there were different types of carbonate platforms located in different palaeogeographical settings. Carboniferous to Middle Triassic mixed siliciclastic–carbonate deposits were accumulated along the Gondwanian margin, on a spacious epeiric carbonate platform. After tectonic activity, culminating by regional Middle Triassic volcanism recorded throughout Adria (the African promontory), a huge isolated carbonate Southern Tethyan Megaplatform (abbreviated as STM) was formed, with the area of the future AdCP located in its inner part.

Tectonic disintegration of the Megaplatform during the middle to late Early Jurassic resulted in the establishment of several carbonate platforms (including the Adriatic, Apenninic and Apulian) separated by newly drowned deeper marine areas (including the Adriatic Basin as a connection between the Ionian and Belluno basins, Lagonero Basin, and the area of the Slovenian and Bosnian troughs). The AdCP was characterised by predominantly shallow-marine deposition, although short or long periods of emergence were numerous, as a consequence of the interaction of synsedimentary tectonics and eustatic changes. Also, several events of temporary platform drowning were recorded, especially in the Late Cretaceous, when synsedimentary tectonics became stronger, leading up to the final disintegration of the AdCP. The thickness of deposits formed during the 125 My of the AdCP's existence is variable (between 3500 and 5000 m).

The end of AdCP deposition was marked by regional emergence between the Cretaceous and the Palaeogene. Deposition during the Palaeogene was mainly controlled by intense synsedimentary tectonic deformation of the former platform area—some carbonates (mostly Eocene in age) were deposited on irregular ramp type carbonate platforms surrounding newly formed flysch basins, and the final uplift of the Dinarides reached its maximum in the Oligocene/Miocene.

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The Adriatic Carbonate Platform represents a part (although a relatively large and well-preserved one) of the broader shallow-water carbonate platform that extended from NE Italy to Turkey (although its continuity is somewhat debatable in the area near Albanian/Greece boundary). This large carbonate body, which was deformed mostly in the Cenozoic (including a significant reduction of its width), needs a specific name, and the Central Mediterranean Carbonate Platform is proposed (abbreviated to CMCP), although the local names (such as AdCP for its NW part) should be kept to enable easier communication, and to facilitate description of local differences in platform evolution.

Keywords: Adriatic Carbonate Platform (AdCP); Palaeogeography; Jurassic; Cretaceous; Karst Dinarides

1. Introduction

The Adriatic Carbonate Platform (AdCP) is one of the largest Mesozoic carbonate platforms of the Perimediterranean region, as can be seen on palaeogeographical maps presented in Dercourt et al. (1993, 2000). However, its geological and palaeogeographical evolution, as well as postsedimentary tectonic deformation are complex, and in large-scale palaeogeographical interpretations, this area is either too simplified, erroneously interpreted or even omitted. This paper aims to contribute to better understanding of this part of the Perimediterranean region.

AdCP deposits crop out in Italy, Slovenia, Croatia, Bosnia and Herzegovina, Serbia and Montenegro, and Albania (Fig. 1). These deposits comprise a major part of the entire carbonate succession of the Croatian part of the Karst (External or Outer) Dinarides, which is very thick (in places more than 8000 m—Tišljar et al., 2002; Velić et al., 2002a), with a stratigraphic range from the Middle Permian (or even Upper Carboniferous, i.e. Moscovian) to the Eocene (Velić et al., 2002a).

Only deposits ranging from the top Lower Jurassic (Toarcian) to the top of the Cretaceous can be attributed to the AdCP, defined as a palaeogeographical entity isolated from other parts of the former huge carbonate platform based on the Adria, as discussed later. The thickness of these deposits formed during 125 My of the platform's existence is variable (between 3500 and 5000 m). In other words, the Karst Dinarides are composed of carbonate deposits representing relics of several vertically stacked carbonate platforms of different ages, type and palaeogeographical setting.

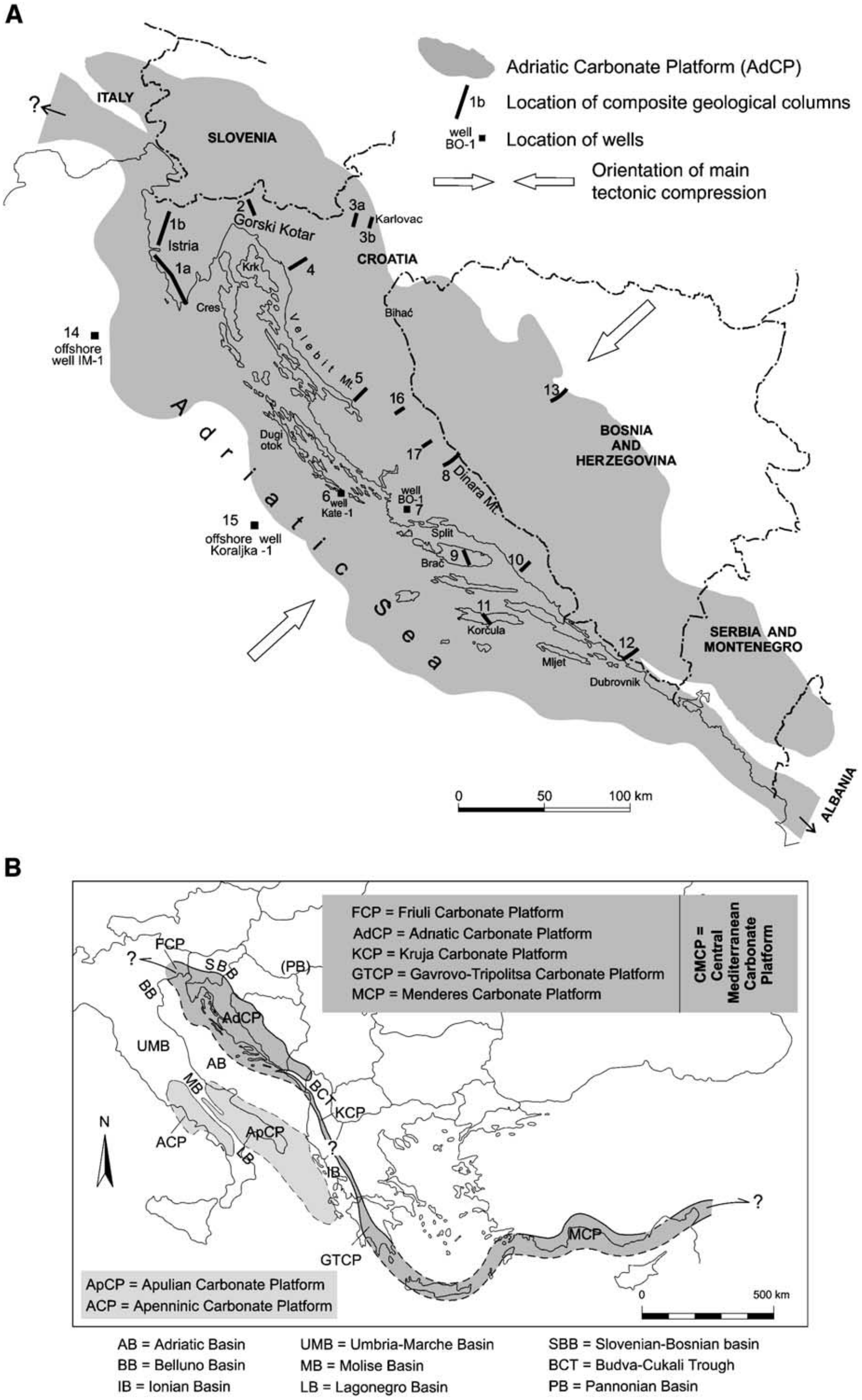
There are two major problems regarding the reconstruction of the platform architecture:

(1) only the inner platform facies crop out on the mainland and the islands along the NE Adriatic coast, as the platform margins are covered. The NE platform margin is covered by Cretaceous/Palaeogene flysch deposits, Palaeozoic–Triassic nappes and Neogene deposits (Jelaska, 1987; Dragičević and Velić, 1994, 2002; Pamić et al., 1998), while the SW margin is covered by Neogene and Quaternary deposits under the recent Adriatic Sea (Grandić et al., 1999; Veseli, 1999).
(2) the entire area was intensely tectonized, especially during the Cenozoic tectonic deformation.

2. The Adriatic Carbonate Platform basement

The platform basement can be divided into three major sequences.

Fig. 1. (A) Location map showing the recent distribution of Adriatic Carbonate Platform (AdCP) deposits on the basis of outcrops and off-shore well data (SW platform boundary after Grandić et al., 1999, NE after Dragičević and Velić, 2002), and location of studied composite geological columns: 1a—W and S Istria; 1b—W and N Istria; 2—Gorski Kotar (Platak area); 3a—Karlovac (Dubravčani area); 3b—Karlovac (Duga Resa area); 4—Velika Kapela Mt.; 5—S Velebit Mt.; 6—off-shore well Kate-1 (Kornati area); 7—well Boraja-1; 8—Dinara Mt.; 9—island of Brač; 10—Biokovo Mt.; 11—island of Korčula; 12—Dubrovnik area; 13—Jajce area (Donji Bešpelj); 14—off-shore well Istra more IM—1; 15—off-shore well Koraljka-1; 16—Poštak Mt.; 17—Knin area. (B) Recent distribution of carbonate platform deposits in the central Mediterranean region.


A
Adriatic Carbonate Platform (AdCP)
1b Location of composite geological columns
well BO-1 Location of wells
Orientation of main tectonic compression
ITALY
SLOVENIA
CROATIA
BOSNIA AND HERZEGOVINA
SERBIA AND MONTENEGRO
ALBANIA
Adriatic Sea
Gorski Kotar
Istria
Krk
Cres
Velebit Mt.
Karlovac
Bihać
Dugi otok
Dinara Mt.
Split
Brač
Korčula
Mljet
Dubrovnik
14 offshore well IM-1
15 offshore well Koraljka -1
6 well Kate -1
well BO-1 7
0 50 100 km
B
FCP = Friuli Carbonate Platform
AdCP = Adriatic Carbonate Platform
KCP = Kruja Carbonate Platform
GTCP = Gavrovo-Tripolitsa Carbonate Platform
MCP = Menderes Carbonate Platform
CMCP = Central Mediterranean Carbonate Platform
ApCP = Apulian Carbonate Platform
ACP = Apenninic Carbonate Platform
0 500 km
AB = Adriatic Basin
BB = Belluno Basin
IB = Ionian Basin
UMB = Umbria-Marche Basin
MB = Molise Basin
LB = Lagonegro Basin
SBB = Slovenian-Bosnian basin
BCT = Budva-Cukali Trough
PB = Pannonian Basin

The oldest one (Upper Carboniferous to Middle Permian) represents part of the Variscan basement (Tišljar et al., 1991; Pamić et al., 1998; Velić et al., 2002a). In the Carboniferous period, siliciclastic deposition prevailed, with rare lenses of limestone. The Lower Permian is characterised by mixed clastic–carbonate deposits and Lower/Middle Permian transition by continental clastic deposits (occurring below *Neoschwagerina craticulifera* zone—J. Sremac, personal communication; i.e. these deposits are older than Upper Permian Val Gardena deposits of the Southern Calcareous Alps).

The second sequence (Middle Permian to Middle Triassic) is characterised by carbonate and mixed siliciclastic–carbonate deposits, because the study area during this period was still an epeiric platform along the northern Gondwana margin (1 in Fig. 2). The upper part of the Middle Permian and the Upper Permian is characterised by carbonates, mostly dolostones (including common early-diagenetic dolostones—Tišljar et al., 1991; Velić et al., 2002a) and some sabkha evaporites (Šušnjara et al., 1992; Tišljar, 1992). The Lower Triassic is characterised by mixed clastic–carbonate deposits. During the Middle Triassic, a thick sequence of shallow-water limestones was deposited, with numerous occurrences of volcanic and volcaniclastic rocks predominantly in the Ladinian (Bahun, 1963; Pamić, 1984).

The Middle/Upper Triassic boundary is mostly characterised by a relatively long emersion phase, including common bauxite occurrences in S Slovenia, NE Velebit Mt. (Croatia) and Montenegro. The

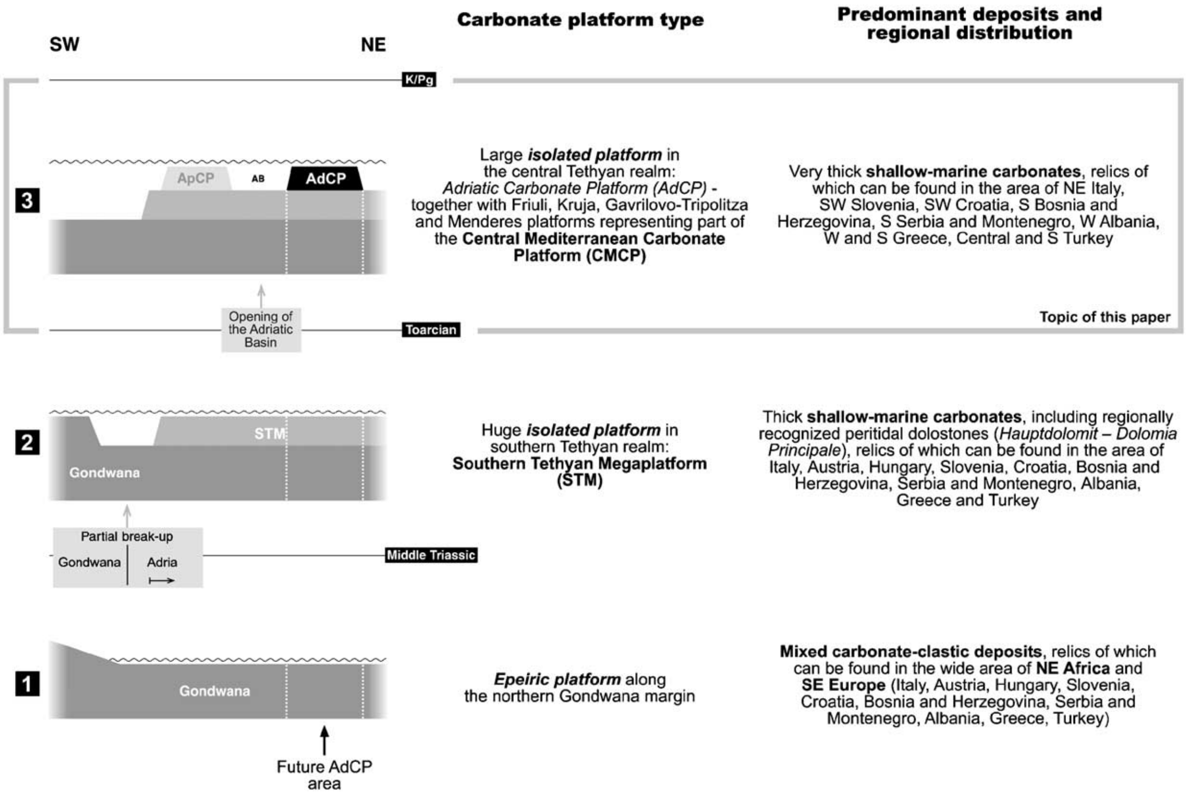


Fig. 2. Schematic illustration showing the main events before the separation of the AdCP (slightly modified after Vlahović et al., 2002a): (1) prior to Middle Triassic rifting, the study area represented part of the epeiric platform located along the northern Gondwana margin; during this event Adria broke-up, and a huge isolated Southern Tethyan Megaplatform (STM) was formed (2), which partly disintegrated during the Toarcian, resulting in formation of the Adriatic Basin (AB) and the Molise–Lagonegro Basin (not shown), and the final separation and isolation (3) of the Central Mediterranean Carbonate Platform (including the Adriatic Carbonate Platform—AdCP), the Apulian Carbonate Platform (ApCP) and the Apenninic Carbonate Platform (not shown).

Middle Triassic volcanism within the huge, still epeiric carbonate platform and regional Middle/Late Triassic emersion were a consequence of regional events connected with Middle Triassic continental rifting (Channell et al., 1979)—break-up of Adria (Pamić et al., 1998). This basement represented an ideal basis for the formation of a huge isolated intraoceanic carbonate platform, for which we propose the term *Southern Tethyan Megaplatform* (STM—2 in Fig. 2). Break-up of the Adria was accompanied by extension of the entire area, resulting in the formation of deep normal faults (half-graben structures—Lawrence et al., 1995) of wide regional extent. These faults, as lineaments in the basement of the future platform, were very important during later deformation within the platform and subsequent tectogenesis of the Dinarides.

This event marked the beginning of the third sequence of the AdCP basement, although in some places in the Dinaric part of the STM, the Middle/Upper Triassic transition is practically continuous within shallow-marine environments (e.g. in W Slovenia, vicinity of Karlovac in Central Croatia, W and Central Bosnia and Herzegovina, or N and S Montenegro). The huge isolated intraoceanic platform (STM), relics of which can be found throughout the wider region (e.g. in central and northern Italy, Austria, Slovenia, Hungary, Bosnia, etc...), was characterised by very thick carbonate deposits, including Upper Triassic *Hauptdolomit* (*Dolomia Principale*) and lower and middle Lower Jurassic limestones (with characteristic Lithiotid limestones in the Pliensbachian—Fig. 3).

For more information and different opinions on the wider palaeogeographic relationships, which are beyond the scope of this paper, see, e.g. Dercourt et al. (1993, 2000), Stampfli and Mosar (1999) and Bosellini (2002).

3. The Adriatic Carbonate Platform

3.1. The name and stratigraphic range of the platform

Due to the complex geological history of the platform area, especially the significant post-depositional tectonics, there are different opinions among geologists concerning two important issues: its name and stratigraphic range. In this review of the Adriatic Carbonate Platform, we will briefly discuss the opinion presented in more detail in a paper by Vlahović et al. (2002a), in a keynote lecture of the 22nd IAS Meeting of Sedimentology (Vlahović et al., 2003a), and in the introduction to the A1 field trip guidebook of the same meeting (Velić et al., 2003).

It is very important to discuss these questions separately to avoid the confusion of previous discussions, i.e.:

(1) to try to find the best designation for the platform, and
(2) to determine its stratigraphic range.

The most important issue for designation of the Adriatic Carbonate Platform (AdCP) is enabling a clear differentiation between palaeogeographic relationships during the platform's existence in the Mesozoic and the present structural pattern of the Dinaric mountain belt uplifted during the Cenozoic. The Dinarides are composed of two genetically different parts: the Outer (Karst or External) Dinarides along the Adriatic Sea, composed mostly of relics of the carbonate platform and its basement, and the Inner (or Internal) Dinarides, situated between the Outer Dinarides and the Pannonian Basin, composed of passive and active continental margin rocks including ophiolites (e.g. Pamić et al., 1998).

Among numerous designations used for the studied carbonate platform deposits cropping out in the area of the Karst Dinarides over the last decades, the most frequent in the recent geological literature are the Dinaric Carbonate Platform (e.g., Ogorelec, 1987; Velić et al., 1989; Buser, 1989, etc.), Adriatic–Dinaric Carbonate Platform (or Adriatic–Dinaridic Carbonate Platform; e.g. Velić et al., 1987; Gušić and Jelaska, 1993; Pamić et al., 1998, etc.) and Adriatic Carbonate Platform (e.g. Gušić and Jelaska, 1990; Tišljar et al., 1991; Velić et al., 2002a, etc.).

Probably the best term is the Adriatic Carbonate Platform (see discussion in Vlahović et al., 2002a), since the term 'Adriatic':

– fits well geographically, since the remains of the platform are situated in the belt stretching along the NE Adriatic coast, and a significant part of the former platform is covered by the present Adriatic

Sea; moreover, the name 'Adriatic' is "free" for use, because the platforms located along the SW Adriatic coast have their own names—Apulian and Apenninic Carbonate Platforms.

- its temporal dimensions fit perfectly: disintegration of the Adria in the middle to late Early Jurassic caused formation of the precursor of the present Adriatic Sea, the Adriatic Basin, and in this way separation of the newly formed carbonate platforms—Adriatic, Apulian and Apenninic.
- it cannot cause confusion between the carbonate platform and the result of its disintegration: the Mesozoic Adriatic Carbonate Platform finally disintegrated in the Cenozoic, and was incorporated into the SW part of the Dinaric mountain belt.

Considering the abbreviation of the platform name, Vlahović et al. (2002a) proposed 'AdCP' instead of the usually used 'ACP', to avoid confusion with the same abbreviation commonly used for the Apenninic Carbonate Platform.

Concerning the second issue, the stratigraphic range of the Adriatic Carbonate Platform (AdCP) as an autonomous entity, the most important point is to define this huge carbonate body to be palaeogeographically recognisable. Although the Karst Dinarides comprise carbonate deposits of a wider stratigraphic range (from the Upper Carboniferous to the Eocene), only part of this succession belongs to the AdCP, i.e. to the spatially defined isolated shallow-water platform (3 in Fig. 2).

In the wider sense, the entire sequence of Upper Palaeozoic, Mesozoic and Palaeogene carbonates of the Karst Dinarides has, in some papers, been included into the Adriatic Carbonate Platform (e.g. Tišljar et al., 1991; Velić, 2000) or Adriatic–Dinaridic Carbonate Platform (e.g. Pamić et al., 1998). These opinions were based on the general depositional environments, i.e. a practically continuous sequence of inner carbonate platform deposits. However, the entire carbonate sequence was deposited on different types of carbonate platforms—an epeiric carbonate platform from the Permian to the Middle Triassic, predominantly isolated carbonate platforms from the Late Triassic to the end of the Cretaceous, and carbonate ramps during the Palaeogene. Therefore, if we define the Adriatic Carbonate Platform sensu stricto as a specific palaeogeographical entity representing a completely isolated, intraoceanic carbonate platform, surrounded by other separate carbonate platforms formed on the same basement (already having specific names—e.g. Apenninic Carbonate Platform and Apulian Carbonate Platform), its stratigraphic range should be significantly reduced to include only a part of the Mesozoic deposits. Thus defined, the AdCP would nevertheless include the major part of the carbonate succession of the Karst Dinarides.

Until the Middle Triassic, the area of the future AdCP represented a part of the northern Gondwana margin, characterised by deposition of siliciclastics and carbonates on a vast carbonate platform of the epeiric type. During the Late Permian to Middle Triassic, intense tectonic activity took place, culminating by regional Middle Triassic volcanism recorded throughout Adria (e.g. Channell et al., 1979; Pamić et al., 1998). This led to the formation of a huge shallow-marine isolated carbonate platform within the southern Tethyan realm, and we propose the name *Southern Tethyan Megaplatform* (which could be abbreviated as *STM*) for this palaeogeographical entity (Fig. 2). Consequently, although the thick Upper Triassic alternation of early- and late-diagenetic dolostones (regionally known as the *Hauptdolomit* or *Dolomia Principale*), found at numerous localities throughout the Dinarides, represent typical deposits of the isolated carbonate platform, they should not be ascribed to the AdCP. Namely, during that period the entire area was still united, as a huge *Southern Tethyan Megaplatform* (2 in Fig. 2).

Disintegration of the huge platform (STM), i.e. separation of the AdCP from the Apenninic and Apulian platforms, took place in the Toarcian (although it started in the Pliensbachian), by formation of a trough connecting the Ionian Basin with the Umbria-Marche and Belluno pelagic basins (Bernoulli, 1971; Jelaska, 1973; Zappaterra, 1990, 1994; Grandić et al., 1999). In this way, the Adriatic Basin characterised by deep-marine deposition was formed as the first precursor of the present Adriatic Sea, and this event should define the lower stratigraphical boundary of the AdCP. During the same period, as a result of an extensional regime, some areas along the NE margin were also drowned (Šikić and Basch, 1975; Babić, 1976; Dragičević and Velić, 2002), resulting in a further reduction of the former platform area.

The Middle and Late Jurassic and Cretaceous periods were characterised by gradual subsidence of the platform basement enabling deposition of a several km-thick succession of almost pure shallow-water deposits on the AdCP (e.g. Tišljar et al., 2002; Velić et al., 2002a). Although this succession in general may be defined as deposits of the isolated carbonate platform, it should be mentioned that during some periods other types of carbonate platforms existed in this area: during some events small platforms of a rimmed type were established (around emerged parts when the depositional area was significantly reduced, e.g. around emerged areas in the Kimmeridgian or the uplifted blocks in the Late Cretaceous), drowned platform environments existed (e.g. near Cenomanian–Turonian boundary—Gušić and Jelaska, 1993) or carbonate ramps were formed (e.g. in the Cenomanian—Tišljar et al., 1998; Korbar et al., 2001).

The question of the upper stratigraphical boundary of the AdCP is arguable. In the Late Cretaceous, the platform was characterised by gradual disintegration as a result of collisional processes, causing significant differentiation of sedimentary environments, culminating in the latest Cretaceous and Palaeogene with the formation of flysch troughs within the former platform area. Since the Early Cenomanian the platform was characterised by the existence of different blocks, i.e. a subsequently more and more complex palaeogeographical pattern including emerged areas, shallow-water environments, carbonate ramps and deeper intraplatform troughs (Gušić and Jelaska, 1990; Vlahović et al., 1994; Tišljar et al., 1998; Korbar et al., 2001). By the end of the Cretaceous, large areas of the platform emerged, and the depositional area of the platform gradually became smaller and smaller. At the very end of the Cretaceous, a general emersion took place, and the Palaeogene transgression over an intense palaeorelief occurred mostly in the Eocene (Palaeocene rocks have only been documented in some places, e.g. in the area of W Slovenia and in restricted areas of S Croatia, where the hiatus was shortest—Ćosović et al., 1994). However, deposition of the so-called Liburnian deposits and Foraminiferal Limestones in the Palaeogene was primarily influenced by intense tectonics, i.e. formation of the foreland basin(s) within the former carbonate platform–carbonate depositional environments represented irregular carbonate ramps characterised by narrow belts retreating contemporaneously with tectonic deformation. The resulting carbonate successions of a foramol type, mostly only several to 200 m thick, represented merely the prelude to flysch deposition and the subsequent infilling of the basins with clastic–carbonate deposits (Promina deposits—marls, calcarenites and conglomerates, and the Jelar breccia). Therefore, considering (1) the restricted depositional area, (2) the principal role of synsedimentary tectonics and the subordinate role of primary carbonate production, and (3) the resulting fairly thin sequence of carbonate deposits, the Palaeogene deposits did not represent a massive shallow-water carbonate factory covering a vast area. Consequently, these deposits, which are mostly separated from the Cretaceous succession by a relatively long hiatus, should not be considered as part of the AdCP.

In conclusion, we would like to emphasize once again the importance of making a clear terminological distinction between the carbonate platform and the product of its disintegration. Therefore, disintegration of the AdCP (including its basement with predominant carbonate deposits, and thin overlying carbonate deposits) and its neighbouring areas, which culminated in the Oligocene–Miocene, resulted in the formation of the Dinaric mountain belt. The stratigraphical range of the AdCP, i.e. a completely isolated carbonate platform, might be defined as being from the late Early Jurassic to the end of the Cretaceous.

3.2. Shape of the platform

Even after the important transversal (SW–NE) Cenozoic tectonic reduction, relics of the Adriatic Carbonate Platform (AdCP) still cover an area 80–200 km wide, which is nearly 700 km long (Fig. 1A). However, the estimated length represents only a part of the wider shallow-marine area. Although this carbonate body seems quite narrow in the area of SE Croatia, Montenegro and Albania, relics of the Mesozoic carbonate platform can be more or less continuously traced further SE towards Greece and Turkey (Fig. 1B), as shown on both palaeogeographical maps presented in Dercourt et al. (1993, 2000), and on reconstructions in other publications (e.g. Zappaterra, 1994; Bosellini, 2002). Nevertheless, continuity is to some extent questionable in the border area between Albania and Greece, where supposed relics of the carbonate platform consisting only of the Upper Cretaceous and Eocene deposits exposed in a narrow zone (e.g. Beccaluva et al., 1997) are covered by the Pind nappe (e.g. see map in Diamanti, 2002). However, if we assume continuity for this Mesozoic carbonate platform, the complete length may be estimated at more than 3000 km (Fig. 1B).

Practically, this means that the AdCP represents merely a part, although a relatively large and well-preserved one, of a huge Mesozoic platform (Fig. 1B; 3 in Fig. 2) which is known by different names from Italy (Friuli platform), Slovenia (Dinaric platform), Croatia (Adriatic or Adriatic–Dinaric platform), Serbia and Montenegro (Adriatic and Dinaric carbonate platforms), Albania (Kruja platform) and Greece (Gavrovo and Tripolitza platforms) to Turkey (Menderes platform). Therefore, we consider that this huge carbonate body, which was more or less continuous (except for the aforementioned problematic zone near the Albanian–Greece boundary) and isolated during the Mesozoic and deformed mostly in the Cenozoic, should have a specific name. Probably the best term would be the Central Mediterranean Carbonate Platform (CMCP), although we think that the local names (such as the AdCP for its NW part) should be kept to enable easier communication, and to facilitate descriptions of local differences in platform evolution.

AdCP margins are almost completely covered. The SW margin of the platform is today covered by the recent Adriatic Sea deposits, and can only be studied by geophysical methods and analysis of offshore wells (Grandić et al., 1999; Veseli, 1999). In contrast, the NE platform margin is exposed in the area of Žumberak Mt. and Samoborska Gora Mt. north of Karlovac (Fig. 1A), although it is for the major part, covered by overthrusted Palaeozoic–Triassic deposits, Late Cretaceous–Palaeogene flysch or Neogene and Quaternary deposits (Jelaska, 1973, 1987; Šparica, 1981; Dragičević and Velić, 1994, 2002; Pamić et al., 1998).

3.3. Main events

During its lengthy history, the Adriatic Carbonate Platform was a very dynamic entity, as a consequence of the numerous events which influenced the sensitive shallow-marine platform depositional system (Table 1), of which only the most important are mentioned below.

3.3.1. Jurassic

The inception of the Central Mediterranean Carbonate Platform (CMCP, 3 in Fig. 2), including the AdCP as an integral part (i.e. disintegration of the former Southern Tethyan Megaplatform-STM, 2 in Fig. 2) was caused by Toarcian extensional tectonics. This event resulted in the formation of the Adriatic Basin which connected the Belluno and Umbria-Marche basins with the Ionian Basin (e.g. Bernoulli, 1971; Jelaska, 1973; Zappaterra, 1990, 1994; Grandić et al., 1999). At the same time future NE margin of the platform emerged, and areas NE of the margin subsided (Gušić and Babić, 1970; Šikić and Basch, 1975; Dragičević and Velić, 2002). This event coincided with the well-documented Toarcian oceanic anoxic event (OAE—e.g. Jenkyns and Clayton, 1986; Jenkyns, 1988; Pálfy and Smith, 2000; Jones and Jenkyns, 2001), i.e. the influence of the anoxic event probably slowed down deposition and facilitated the drowning of tectonically subsided parts of the former platform.

However, this event, which is clearly recorded in off-shore wells (Grandić et al., 1999), was, in the inner part of the platform, i.e. in the mainland outcrops (on Adriatic islands there are no outcrops of Lower Jurassic deposits), registered only indirectly by deposition of two different lithotypes. The so-called “spotty limestones”, dark heavily bioturbated limestones, were deposited in the NW part of the platform (Slovenia, central and W Croatia and W Bosnia—see columns 2, 4, 5 and 8 in Fig. 3), while the rest of the platform was characterised by high-energy oolitic limestones (columns 10 and 12 in Fig. 3). “Spotty limestones” were characterised by low sedimentation rates, i.e. during almost 8 My less than 150 m of these limestones were deposited in restricted lagoon settings. Contemporaneously, the northeastern margin (from SE Slovenia to central Bosnia) became emerged (probably in the latest Pliensbachian—Bukovac et al., 1974; Dragičević and Velić, 2002; column 3a in Figs. 5 and 6).

The palaeogeography of the platform during the Middle Jurassic was characterised by the general inheritance of Toarcian palaeogeography: the NW part was mostly characterised by massive mudstones with lenses of late-diagenetic dolostones, while in the SE part, high-energy environments with common ooid grainstones and rudstones prevailed (Fig. 3). Along the NE margin of the platform, Middle Jurassic deposits are missing within a long-lasting hiatus (column 3a in Fig. 6), and between the emerged areas and inner platform lagoons, narrow belts of high-energy ooid grainstones can be found. In SE Slovenia, Middle Jurassic and Oxfordian ooid limestones reach thicknesses of nearly 500 m (Dozet, 2000). Tectonic activity in the Middle Jurassic caused local uplifts with short-lasting emersions and deposition of thin carbonate breccia beds in the area of Istria (Marinčić and Matičec, 1991; column 1a in Figs. 5 and 6), but short-lasting emersions were also recorded in different levels of the Middle Jurassic in Gorski Kotar, Velika Kapela Mt., S Velebit Mt., Dinara Mt. and Biokovo (columns 2, 4, 5, 8 and 10 in Figs. 3 and 4).

Oxfordian deposits are mostly of lagoonal origin, except for marginal parts where high-energy grainstone facies prevailed. In the latest Oxfordian, some parts of the platform emerged (e.g. Istria—column 1a on Figs. 5 and 6; S Velebit Mt. and Biokovo Mt.—columns 5 and 10 in Figs. 3 and 4) as a prelude to the facies differentiation in the Kimmeridgian.

The major influence on the complex palaeogeographical and depositional relationships in the Kimmeridgian and Tithonian may be attributed to synsedimentary tectonics (Matičec, 1989; Tišljar et al., 1994, 2002; Velić et al., 1994, 2002a,b). A major part of the platform remained within restricted lagoonal settings, but some areas of the platform were uplifted, emerged and karstified, characterised by local deposition of bauxites (e.g. in W Croatia, W Bosnia, E Herzegovina and W Montenegro—column 1a in Figs. 5, 6 and 7). However, the NE margin of the platform, which had been emergent since the Pliensbachian, was contemporaneously partially drowned after more than 35 My (column 3a in Fig. 6). In the central part of the platform, as a consequence of these tectonic movements, somewhat deeper depositional areas were formed as relatively shallow intraplatform troughs, as in the area of the Gorski Kotar (e.g. in Velika Kapela Mt.—column 4 in Figs. 3, 4 and 8) or from Bihać towards the SSE (Croatia and W Bosnia; e.g. Poštak Mt. and Knin area—columns 16–17 in Fig. 8). The latter trough was connected with the open Tethyan realm, and therefore comprises deposits with more pelagic influences (limestones with chert, including radiolarians and ammonites, i.e. so-called Lemeš Beds—Furlani, 1910; Chorowicz and Geyssant, 1972). The margins of both intraplatform troughs represented ideal environments for the development of hydrozoan–coral reefs. Gradual progradation of reefal and peri-reefal facies followed by oolithic facies resulted in the final infilling of the intraplatform troughs and re-establishment of peritidal algal facies (Velić et al., 1994). The general palaeogeographical pattern during the Tithonian was also characterised by different facies relationships along the platform margins. Toward the "Open Tethys" the NE margin was characterised by a more or less continuous belt of hydrozoan–coral barrier reefs and bioclastic–ooid shoals along the entire margin from Slovenia to Montenegro (Dragičević and Velić, 1994, 2002; Turnšek, 1997; column 3a in Figs. 5 and 7). Along the SW edge there were no barrier reefs, patch reefs were relatively infrequent, and carbonate sand bars were the most important feature (Tišljar and Velić, 1987).

Kimmeridgian facies variability was the consequence of a new tectonic regime, representing the beginning of the period characterised by inverse tectonics, since existing lineaments began to reactivate in order to adjust to the new conditions of compression/transpression. This resulted in the formation of small pull-apart basins, local emersions and facies differentiation. Younger tectonic movements have largely masked traces of these events.

In contrast to the extension in the Toarcian, this event represents the first record of compressional tectonics in the platform area, probably connected with the beginning of subduction in the area NE of the platform.

During the Tithonian, former depressions were completely filled by progradation from the surrounding reefs and a shallow-water depositional system was re-established over almost the entire platform (Figs. 3–6), including formerly emerged areas (e.g. column 10 in Figs. 3 and 4, and column 1a in Figs. 5 and 6), resulting in regionally important deposition of peritidal–lagoonal algal wackestones—so-called *Clypeina–Campbelliella* limestones. Only in some areas were Tithonian carbonates deposited within high-

Table 1
Main events recorded in the geological history of the Adriatic Carbonate Platform

Time	Main events	Area	Consequences	Deposits
Late Maastrichtian	intense synsedimentary tectonics	entire platform	complete emergence, final disintegration of the platform, intense karstification	stratigraphic hiatus throughout the platform; continuous transition Cretaceous/Palaeogene only in basinal environments surrounding the platform
Late Campanian – Early Maastrichtian	synsedimentary tectonics	central Bosnia and Herzegovina, S Croatia	continuation of the Budva – Cukali trough towards the W to Central Dalmatia, dinosaur and crocodile bones in SW Slovenia	debrites, calclithites, distal flysch, laterally pelagic limestones ("Scaglia")
Late Santonian – Early Campanian	synsedimentary tectonics	entire platform	transgression of formerly emerged area along the NE platform margin, formation of small elongated troughs in the inner part of the platform, dinosaur bones in NE Italy	carbonate debrites, pelagic and allodapic limestones in deeper parts, rudist limestones in platform shallows
Turonian – Early Santonian	synsedimentary tectonics	inner platform and area along the NE platform margin	local emergences, local continuation of pelagic deposition, ?dinosaur trackways	locally karstified rudist limestones and bauxite deposits, locally pelagic limestones
Late Cenomanian – Early Turonian	synsedimentary tectonics, eustatic sea-level rise (OAE−2)	entire platform	drowning of the major part of the platform, restricted shallow-marine environments with rare dinosaur trackways, final uplift of the W part of the platform	pelagic limestones (locally with ammonites and fish remains), less frequent peritidal deposits, karstified Upper Cenomanian deposits in the W part of the platform (locally bauxite)
latest Albian – Early Cenomanian	synsedimentary tectonics	entire platform	very significant facies variability, from emergences to platform drowning	early- and late-diagenetic dolostones, tectogenic-diagenetic breccia, locally bauxite, pelagic limestones and bioclastic clinoforms
Late Albian	volcanic activity in neighbouring areeas, synsedimentary tectonics	W and S Croatia	diagenetic alterations in carbonates, general shallowing, several levels with dinosaur trackways	diagenetic quartz deposits within shallow-marine carbonates
Late Aptian	synsedimentary tectonics	entire platform	emergences of variable duration	emersion breccia-conglomerates, palaeosoil
Early Aptian	eustatic sea-level rise (OAE−1a)	major part of the inner platform	partial platform drowning	massive lagoonal mudstones and oncoid floatstones, sporadically with pelagic influence
		locally in W Slovenia, SE Slovenia, central Croatia, S Croatia, central Bosnia	local formation of patch reefs	reefal and peri-reefal limestones
Hauterivian – Barremian	local synsedimentary tectonics	W Istria	frequent local emergences, dinoturbations and trackways within Hauterivian deposits, dinosaur bones in uppermost Hauterivian marginal swamp deposits, several levels with dinosaur trackways in Upper Barremian deposits	peritidal limestones with frequent emersion and black-pebble breccia-conglomerates
Berriasian	synsedimentary tectonics ?dinoturbation	W Istria, ?Gorski Kotar, ?Mljet island, ?Korčula island, ?E Herzegovina	intertidal/supratidal deposition	early-diagenetic/late-diagenetic dolostones alternation, seizmites, ?dinoturbation
Early Berriasian – latest Tithonian	local uplift	W and S Croatia, W Bosnia, locally central Bosnia and Montenegro	local emergence	karstification breccia
Late Tithonian	first occurrence of dinosaurs	W Istria		
Tithonian Kimmeridgian	compressional tectonics subduction and volcanism in neighbouring areas	Istria, SE Slovenia, NW Bosnia, SE Croatia, E Herzegovina, central Montenegro	emergence	bauxite occurrences and deposits
		SE Gorski Kotar, Bihać-Dinara Mt. area	formation of intraplatform troughs	succession from lagoonal limestones to pelagic limestones with chert, ammonites and tuffitic interbeds, and gradual infilling of troughs with peri-reefal carbonates
		margins of intraplatform troughs	formation of massive reefs	coral-hydrozoan carbonate buildups
		NE platform margin	drowning after long-lasting emergence and formation of barrier reefs	palaeorelief covered by pelagic limestones with, chert, ammonites and tuffitic interbeds, and gradual infilling of troughs with peri-reefal carbonates and coral-hydrozoan reefs
		inner platform	continuous shallow-marine deposition	peritidal limestones
Toarcian (latest Pliensbachian)	extensional tectonics OAE	entire platform, especially margins	establishment of AdCP: formation of the Adriatic Basin, emergence of the NE platform margin, drowning of the area NE of platform	pelagic carbonates within newly formed deeper-marine areas (Adriatic Basin, area NE of platform), high-energy ooid shoals (central and SE part)
		W part of the platform	partial drowning	"spotty limestones"

energy environments (e.g. columns 8 and 12 in Figs. 3 and 4). The oldest dinosaur footprints of the AdCP have been found within Upper Tithonian deposits of Istria (Mezga et al., 2003).

3.3.2. Early Cretaceous

The Jurassic/Cretaceous transition in the central parts of the platform was marked by a short emergence, e.g. in W and S Croatia, W Bosnia, and some parts of Montenegro, in some places accompanied by bauxite occurrences (e.g. in Dinara Mt.; Velić et al., 2002a). In other areas, the transition is commonly found within thick late-diagenetic dolostones, including relics of early-diagenetic dolostones (e.g. in Istria—column 1a in Figs. 5 and 6, island of Mljet).

Berriasian and Valanginian deposits accumulated in shallow-water environments with numerous shallowing-upward cycles, including local short-lasting emersions (Figs. 9 and 10). From the Early Hauterivian to the Albian, the interaction of tectonics and eustatic changes resulted in more frequent emersions, and in some areas long-lasting emergences (Matičec et al., 1996), accompanied by dinosaur footprints in the Berriasian(?), Hauterivian, Barremian and Albian of Istria (e.g., Bachofen-Echt, 1925a,b; Dalla Vecchia and Tarlao, 1995 Dalla Vecchia et al., 2000, 2002), as well as dinosaur bones in uppermost Hauterivian deposits (Dalla Vecchia, 1998; Dini et al., 1998). Barremian deposits are characterised by the alternation of stromatolites and grainy lithotypes. Lower Aptian deposits represent a regionally recognisable event connected with the partial drowning of the platform, recorded either within massive mudstones and oncolites (e.g. in Istria, Biokovo Mt., Korčula island), or well-bedded orbitolinid limestones with *Hedbergella* and *Saccoccoma* (e.g. in Velika Kapela Mt.—Velić and Sokač, 1978). This event correlates well with the Early Aptian oceanic anoxic event (OAE-1a—e.g. Jenkyns, 1980; Jones and Jenkyns, 2001).

The most important Early Cretaceous event was the regional Aptian emersion (Figs. 9 and 10), which in the major part of the platform occurred close to the transition between the Aptian and Albian, although in some parts, e.g. Istria, it lasted much longer (columns 1a and 1b in Fig. 10; Velić et al., 1989). Penecontemporaneous deposits in basin environments include debrites composed of platform-derived material (column 14 in Figs. 9 and 10).

Albian deposits are usually relatively thin-bedded and are characterised by typical marginal features, including desiccation cracks, ripple marks and dinosaur tracks. In the Upper Albian of Istria and the island of Vis there are economic occurrences of diagenetic quartz, although occurrences of diagenetic quartz can also be found elsewhere within Upper Albian deposits (Ćićarija Mt. in NE Istria, Velika Kapela Mt., Dinara Mt., etc.).

During the Barremian, Aptian and Albian, the major part of the platform was dominated by shallow subtidal environments (Figs. 9 and 10) rich in foraminiferal, especially orbitolinid assemblages, as well as with the gradual rise and importance of rudist bivalves. In some places in the inner part of the platform, conditions favoured the growth of rudist communities. Barrier coral–hydrozoan reefs were developed in some parts of the NE margin of the platform (Turnšek and Buser, 1974; Buser, 1987; Turnšek, 1997), but they were mostly destroyed and covered by younger deposits (Dragičević and Velić, 1994, 2002). Deposits representing the SW margin of the platform were discovered deep below the Adriatic Sea. However, data from the wells are still insufficient for reliable interpretation of the depositional relationships.

3.3.3. Late Cretaceous

The transition from Lower to Upper Cretaceous deposits is, in the major part of the platform, characterised by thick late-diagenetic dolostones and heavily recrystallized limestones (columns 4, 7, 8 and 11 in Fig. 9), including some relics of early-diagenetic dolostones and tectogenic–diagenetic breccias (Vlahović et al., 2002b). Exceptions are S Istria, Biokovo Mt. and the Dubrovnik area (columns 1a, 10 and 12 in Fig. 9), characterised by a continuous transition within a succession of mostly shallow-water limestones, and local bauxite deposits (in Montenegro—Vujisić, 1975).

The Late Cretaceous period was the most complex in the history of the platform, when the platform attained its full maturity and began to disintegrate (Velić et al., 2002a). Important palaeogeographical events that influenced the entire area of the platform were controlled by the variable effect of three factors:

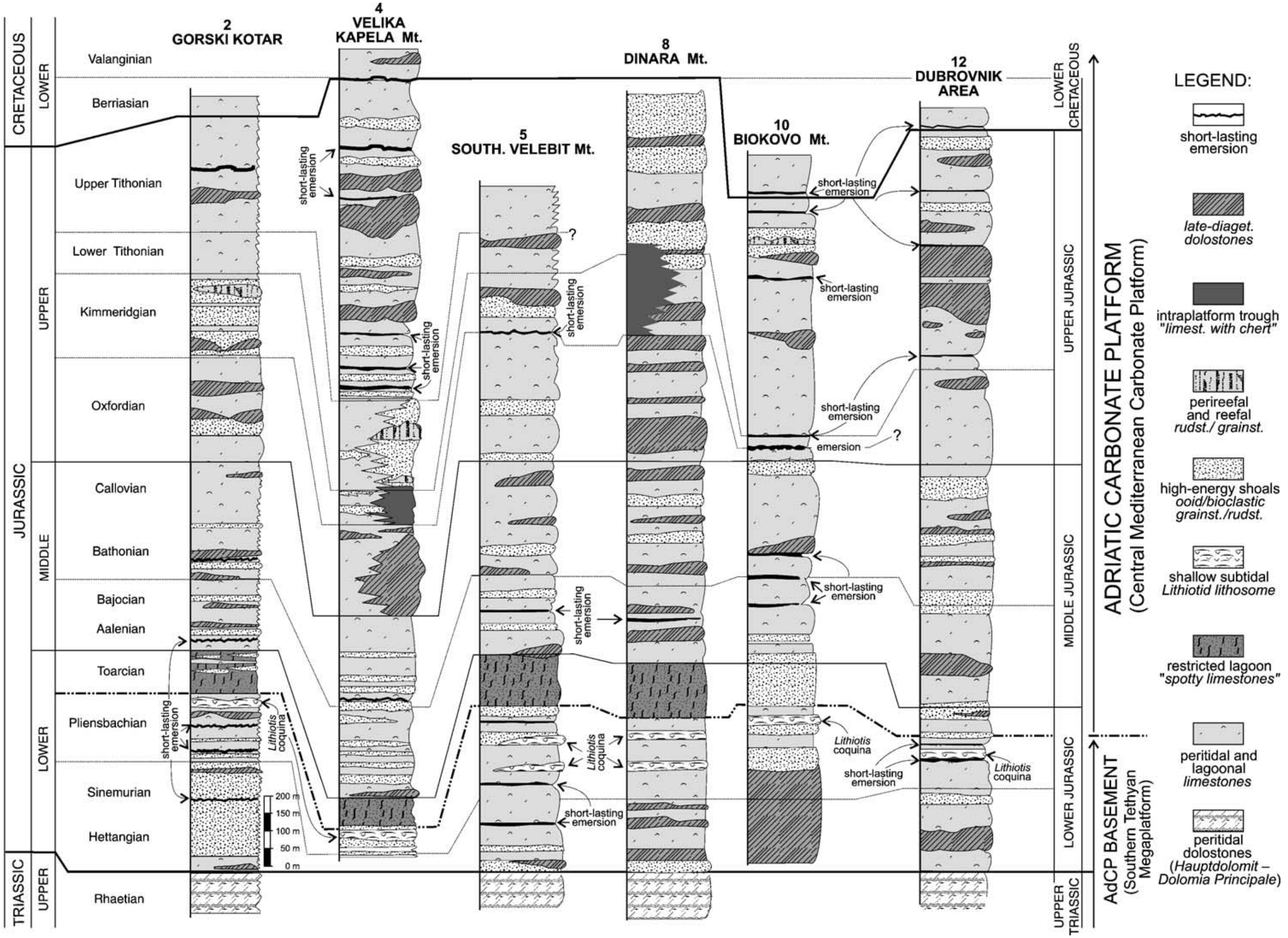


Fig. 3. Correlation chart of the main facies types of Jurassic deposits in the Croatian part of the AdCP along the Adriatic coast from NW (Gorski Kotar) to SE (Dubrovnik area).

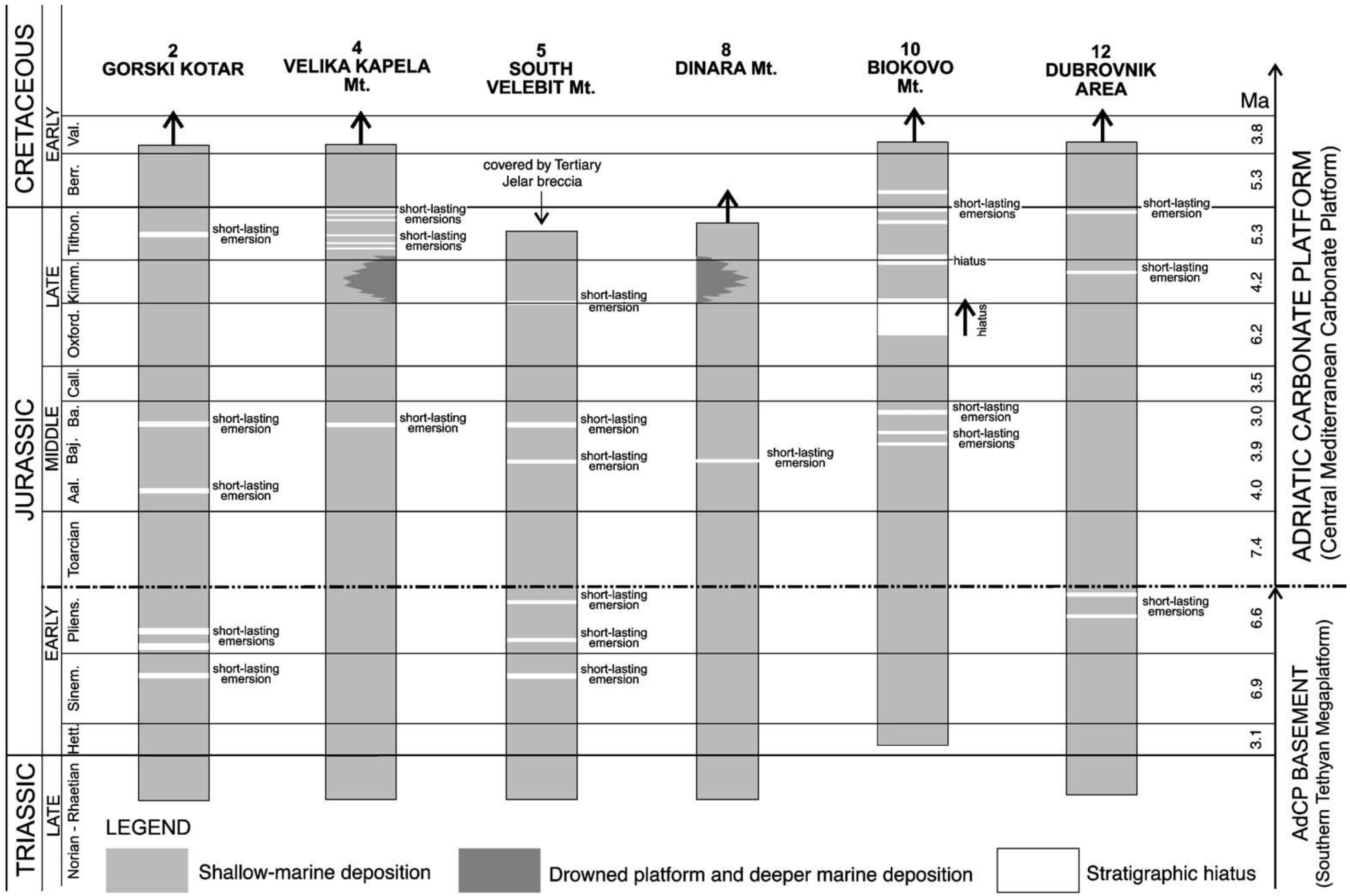


Fig. 4. Temporal correlation chart of the main facies types of the Jurassic deposits of the AdCP along the Adriatic coast from NW (Gorski Kotar) to SE (Dubrovnik area). Time scale after Gradstein et al. (2004).

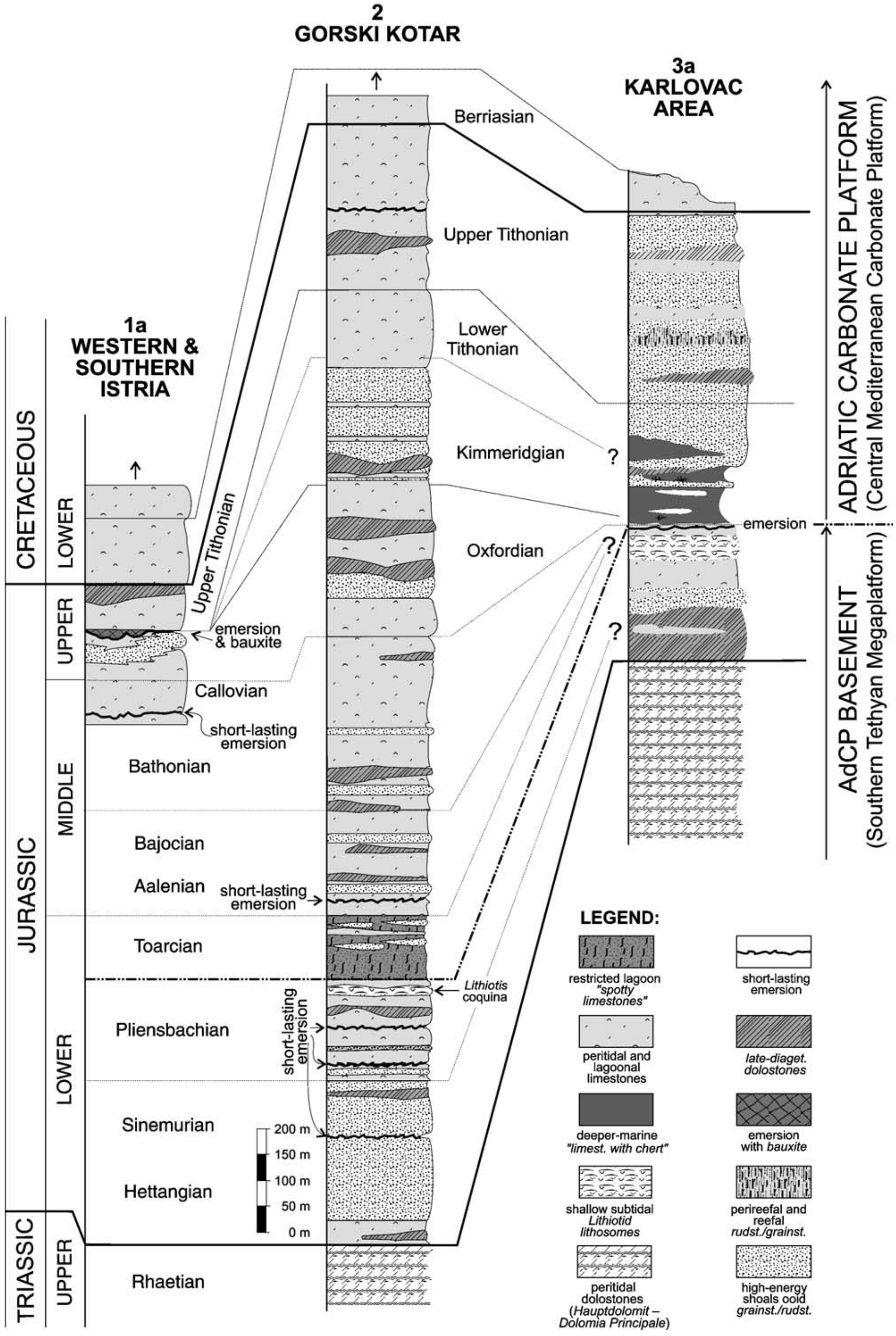


Fig. 5. Correlation chart of the main facies types of Jurassic deposits of the AdCP in W Croatia from SW (Istria) to NE (Karlovac area).

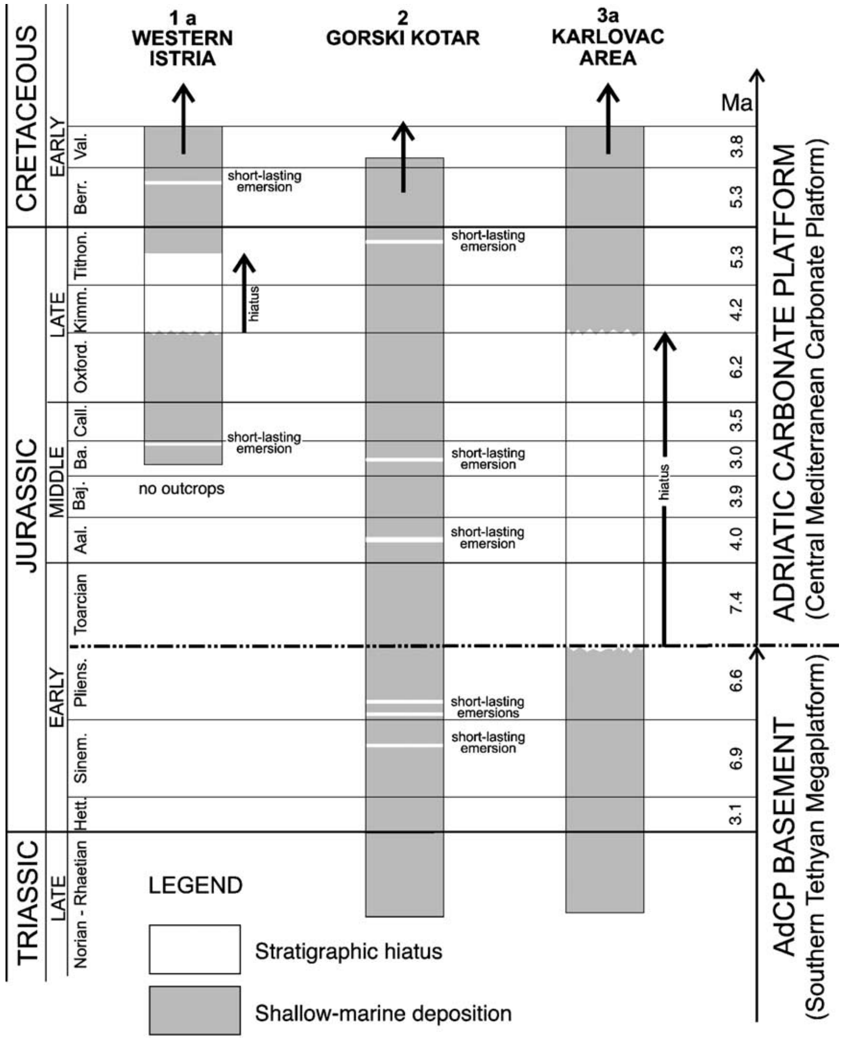


Fig. 6. Temporal chart correlation of the main facies types of the Jurassic deposits of the AdCP in W Croatia from SW (Istria) to NE (Karlovac area). Time scale after Gradstein et al. (2004).

almost continuous synsedimentary tectonic activity with a specific influence in different areas, eustatic changes, and extensive development of rudist communities producing vast amounts of carbonate material. Interaction of these factors resulted in numerous local responses, so only the most important trends will be highlighted.

Lower Cenomanian deposits are characterised by very important facies variability caused by the synsedimentary tectonic deformation of a formerly more or less uniform platform area. Clear examples have been studied in the NW part of the platform (Vlahović et al., 1994, 2003b; Tišljar et al., 1998; Korbar et al., 2001), including areas with continuous shallow-water deposition and areas with temporary deepening and partial drowning of the platform. After the Middle Cenomanian, gradual re-unification occurred characterised by the establishment of environments with more or less stable shallow-marine deposition (including dinosaur footprints within the Upper Cenomanian deposits of Istria—Gogala, 1975; Tišljar et al., 1983; Dalla Vecchia and Tarlao, 1995).

During the latest Cenomanian, new facies differentiation took place. One of the most important events

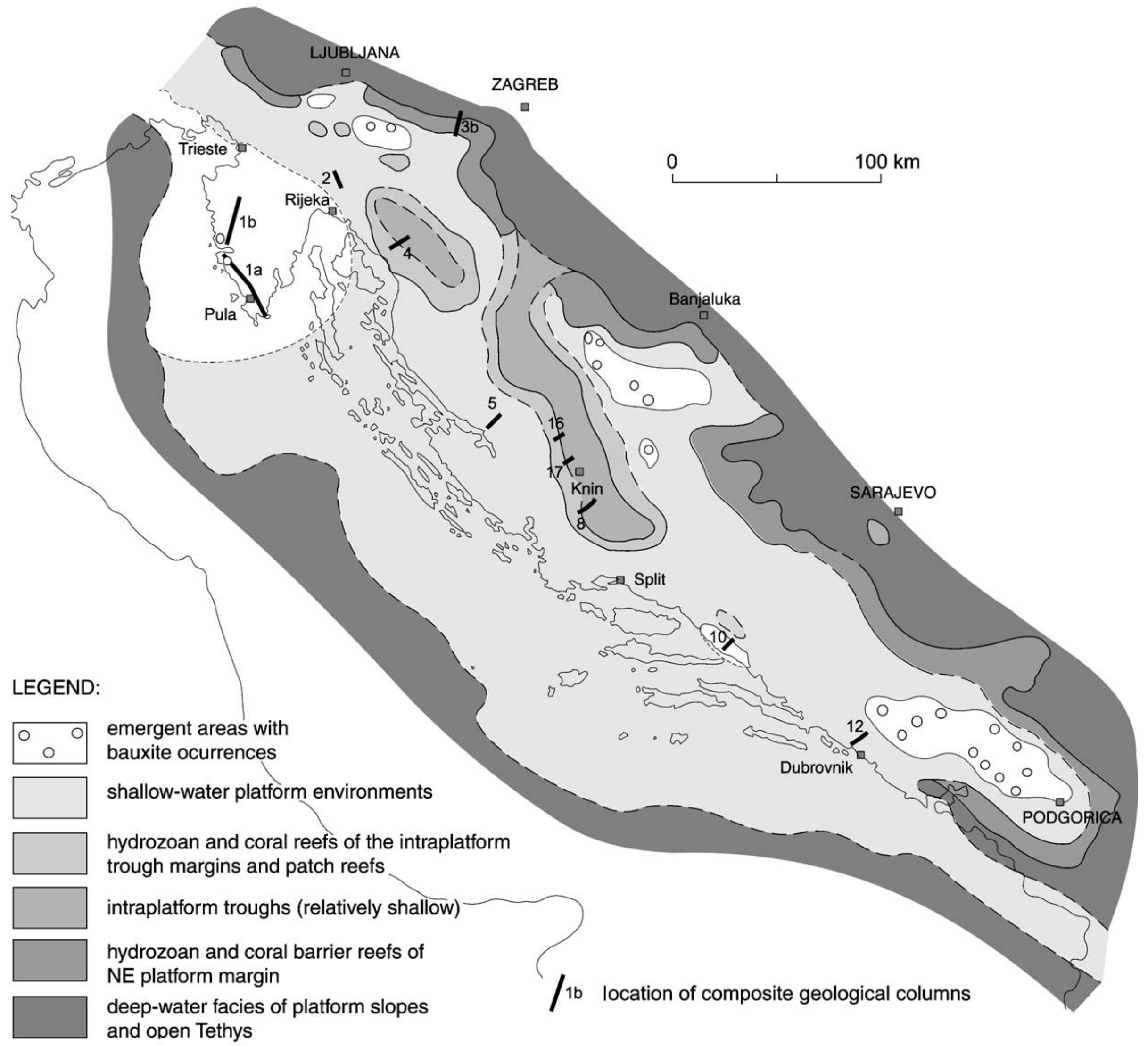


Fig. 7. Schematic palaeogeographical map showing the main environments on the AdCP during the Kimmeridgian (after Velić et al., 2002a).

in the evolution of the AdCP took place around the Cenomanian/Turonian transition as temporary platform drowning recorded over a major part of the platform (Gušić and Jelaska, 1990, 1993; Fuček et al., 1991; Jelaska et al., 1994; Tišljar et al., 2002; Vlahović et al., 2003b; Figs. 9 and 10). However, although this regional eustatic event was recorded throughout the Perimediterranean realm, a regional emersion commenced simultaneously in N Istria (column 1b in Figs. 9 and 10) and the northern part of Cres Island (this area was emergent until the Eocene), i.e. synsedimentary deformation was able to overtake even this significant eustatic sea-level rise. Similarly, the area of the NE platform margin was emergent from the Late Cenomanian (in places even earliest Cenomanian) until the Late Santonian, with local bauxite deposits forming in Slovenia, Croatia and Bosnia and Herzegovina (column 13 in Fig. 11; Šparica, 1981; Buser, 1987; Dragičević and Velić, 2002). This event correlates well with the Cenoma-

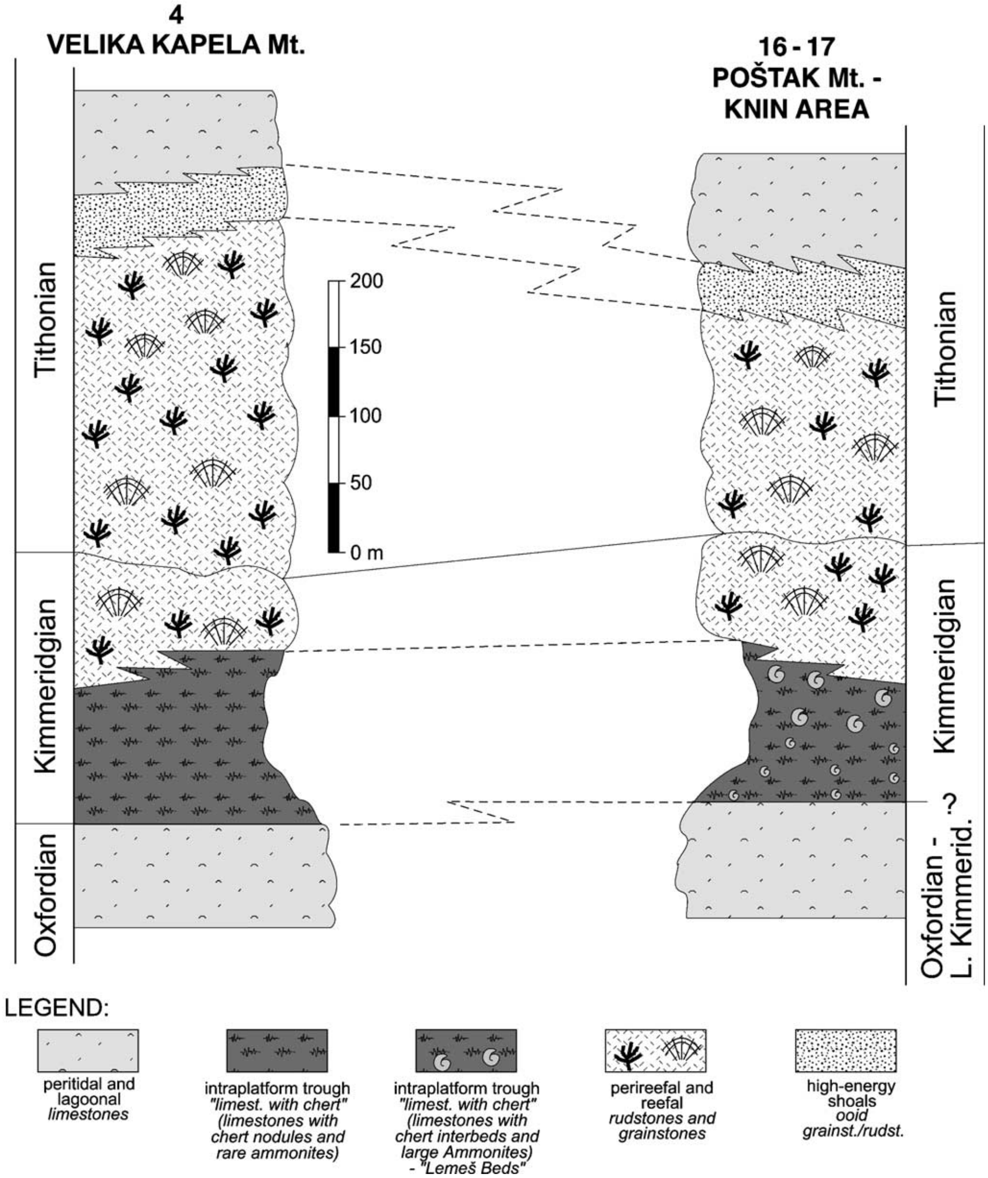


Fig. 8. Correlation of Upper Jurassic deposits in the inner part of the AdCP.

nian/Turonian oceanic anoxic event (OAE-2—e.g. Schlanger et al., 1987; Jenkyns, 1991; Jones and Jenkyns, 2001).

Although at some localities deep-marine deposition continued (e.g. until earliest Santonian at Dugi otok island—Fuček et al., 1991), Turonian, Coniacian and Lower Santonian deposits typically accumulated in shallow-water environments (Figs. 9 and 10). During the Late Santonian, transgression of the formerly emerged areas along the NE platform was recorded, and shallow-water deposition continued until the Late Campanian. This event was also recorded in the inner part of the platform, e.g. with gradual drowning of the platform in southernmost Croatia from the Late Santonian to the Middle Campanian (Gušić and Jelaska, 1990; Jelaska et al.,

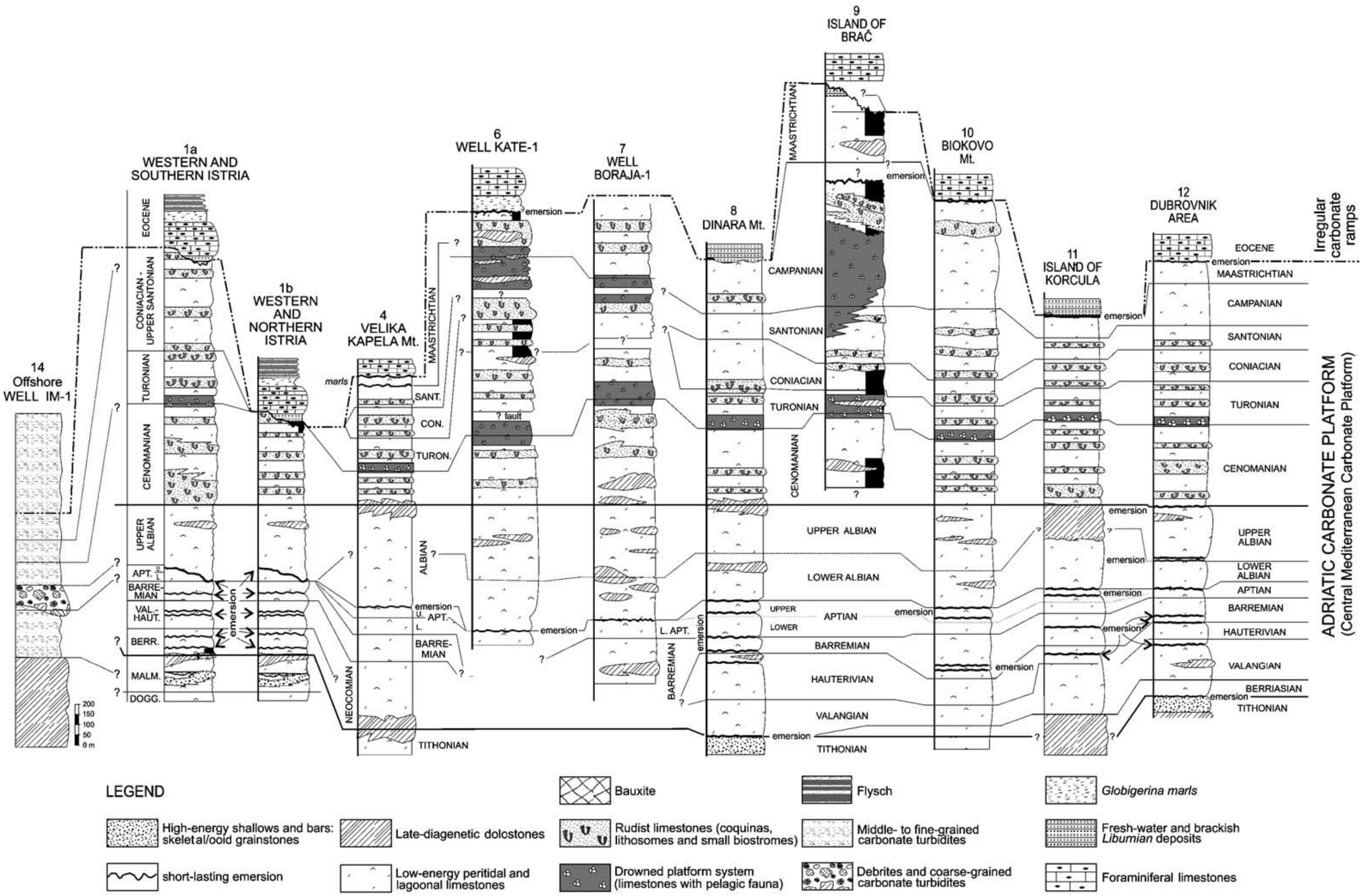


Fig. 9. Correlation chart of the main facies types of the Cretaceous deposits in the Croatian part of the AdCP from NW (Istria) to SE (Dubrovnik area).

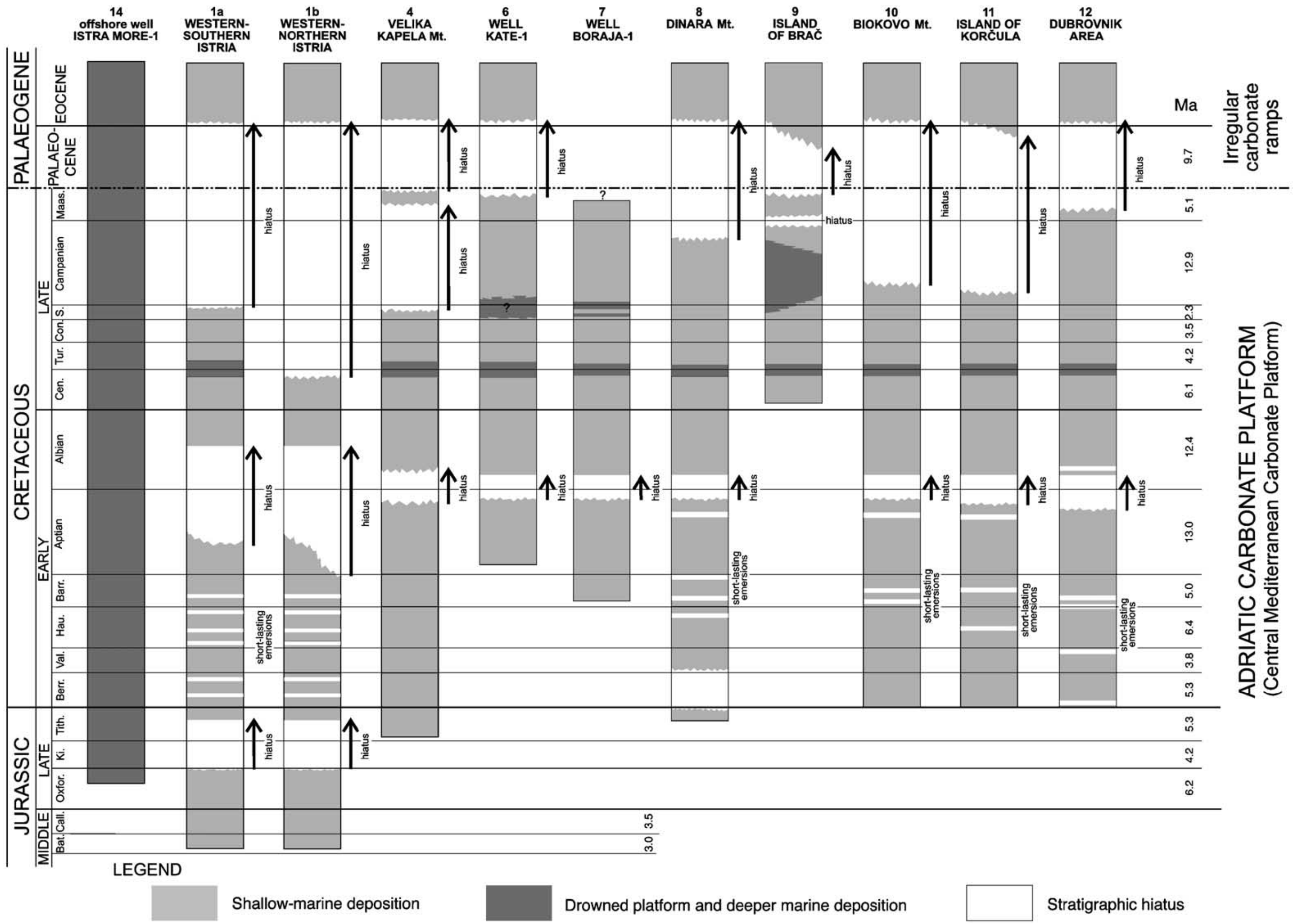


Fig. 10. Temporal correlation chart of the main facies types of the Cretaceous deposits of the AdCP from NW (Istria) to SE (Dubrovnik area). Time scale after Gradstein et al. (2004).

1994; columns 6, 7 and 9 in Figs. 9 and 10). These events, caused by the interaction of eustatic sea-level changes and local tectonic controls represent the final disintegration of the platform in the Late Cretaceous, when compression (with increasing intensity from the late Santonian/early Campanian), resulted in the formation of several small elongated troughs separated by shallower areas, which were either completely emergent or covered by a shallow sea (Fig. 12; Dragičević, 1987; Velić et al., 2002a). Troughs were filled by carbonate–clastic material with pelagic characteristics, while contemporaneous shallow-water environments were characterised by flourishing developments of rudists which contributed large amounts of bioclastic detritus to neighbouring slope deposits and troughs.

The Late Cretaceous emergence, recorded over the platform, did not cause important changes in these troughs. Troughs located near the NE platform margin are characterised by continuous carbonate–clastic, flysch-type deposition from the Maastrichtian to the Palaeocene (Dragičević and Velić, 2002; Velić et al., 2002a). Deeper-marine deposition with pelagic influences from the neighbouring Budva–Cukali trough was recorded in the Split–Dubrovnik intraplatform trough during the Campanian, Maastrichtian and Early Palaeogene (Jelaska et al., 2000).

The Late Cretaceous emersion phase was recorded throughout the shallow-marine platform environments, with significantly variable duration (Fig. 10). For example, some localities in Istria were already emergent from the Valanginian to the Albian, some in the Cenomanian, Campanian, and Santonian (Matičec et al., 1996). Similarly, the youngest Cretaceous deposits in the area of Cres and Krk islands in the northern Adriatic are of Late Cenomanian, Turonian or Coniacian/Santonian age, and the largest part of S Croatia and Herzegovina was emergent from the Santonian. However, in some parts of the platform, sedimentation was more or less continuous up to the Maastrichtian, as in the areas of western Slovenia (Drobne et al., 1989; Jurkovšek et al., 1996; including Late Campanian/Early Maastrichtian dinosaur bones—Debeljak et al., 1999, 2002) and southernmost Croatia (Ćosović et al., 1994). Depressions of the karstified Cretaceous are filled by bauxite deposits in many places.

Practically throughout the entire period of the existence of the AdCP land conditions prevailed somewhere on it (Tišljar et al., 2002). Occurrences of dinosaur bones and footprints in Istria, NE Italy and SW Slovenia from the Upper Tithonian (Mezga et al., 2003) to the Upper Campanian/Lower Maastrichtian (Debeljak et al., 1999, 2002) document the existence of long-lasting continental environments (Dalla Vecchia and Tarlao, 1995; Matičec et al., 1996) in the NW part of the platform. The fact that dinosaurs inhabited this part of the AdCP over a period of almost 80 My indicates the continuous existence of specific conditions—first of all enough food (vegetation and/or prey) and fresh water. Therefore, this area should have represented a continuous habitat for their existence, even during the highest relative sea-levels, probably as a spacious island in the central and western part of present Istria (Matičec et al., 1996). Given additional data indicating an even longer hiatus in the neighbouring offshore area (from Late Tithonian to Pliocene—Veseli, 1999), a relatively large emerged area can be inferred. However, numerous and varied occurrences of dinosaur footprints and fossil remains in the NW part of the platform definitely indicate the possibility of the existence of palaeogeographic "bridges" during the Cretaceous towards Gondwana and Eurasia (Dalla Vecchia, 2002), at least during the lowest relative sea-levels.

Dalla Vecchia (2002) proposed that dinosaurs at the AdCP could be separated into three different groups: (1) "Early Cretaceous" large theropods and sauropods indicating African affinity; (2) "Middle Cretaceous" small sauropods indicating insular isolation, and (3) "Late Cretaceous" primitive small hadrosaurids indicating (Eur)Asian affinity. This hypothesis indicating temporary connections with different neighbouring areas needs further confirmation but fits well into the obviously dynamic history of the investigated area. In any case, changes between different groups of dinosaurs fit perfectly with the major events recorded in the stratigraphic succession of the platform—partial drowning in the Early Aptian, as a possible trigger for the subsequent isolation of the platform during the "Middle Cretaceous", and significant platform drowning near the Cenomanian/Turonian boundary, both recorded on several Perimediterranean platforms.

This interpretation would favour palaeogeographical maps in which the area of the huge Mesozoic carbonate platform (Central Mediterranean Carbonate

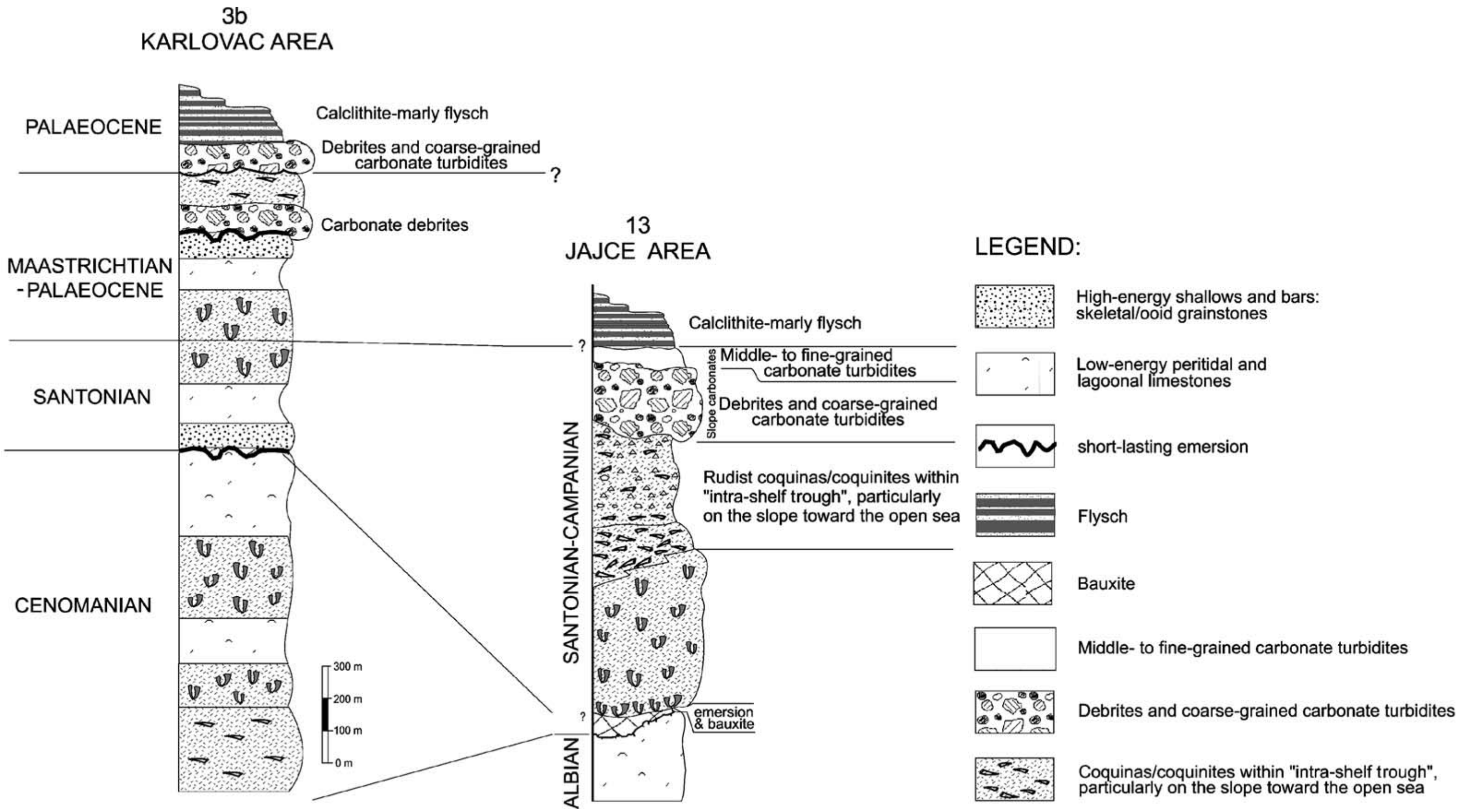


Fig. 11. Correlation chart of the main facies types of the Upper Cretaceous deposits along the NE margin of the AdCP (after Dragičević and Velić, 2002).

Platform in this paper) is proposed as being located relatively close to Gondwana, e.g. the map proposed by Stampfli and Mosar (1999). Their location of the palaeogeographic "bridges" in the northern part of the huge platform can be supported by the fact that, at present, there are no published reports on dinosaur activity on the Adriatic Carbonate Platform south of NE Italy, SW Slovenia and Istria (Croatia). Even if some isolated occurrences of dinosaur activity could be found in the southern area (e.g. some recent indications of dinosaur footprints within Upper Cretaceous deposits in S Croatia–island of Hvar, Radovčić, personal communication, and hinterland of Biokovo Mt.–personal observations) they could be interpreted as consequences of common temporary emergences in the wider platform areas, which would enable migration of some individuals. However, dinosaur occurrences on the neighbouring Apulian platform are interpreted as being the result of also possible southward connection to Gondwana (Bosellini, 2002).

On the basis of the occurrence of different groups of dinosaurs (Dalla Vecchia, 2002), the maps presented by Stampfli and Mosar (1999) could be refined, suggesting that until the Barremian there was probably a "bridge" between Gondwana and the Adriatic Carbonate Platform. From the Aptian to the Turonian, the

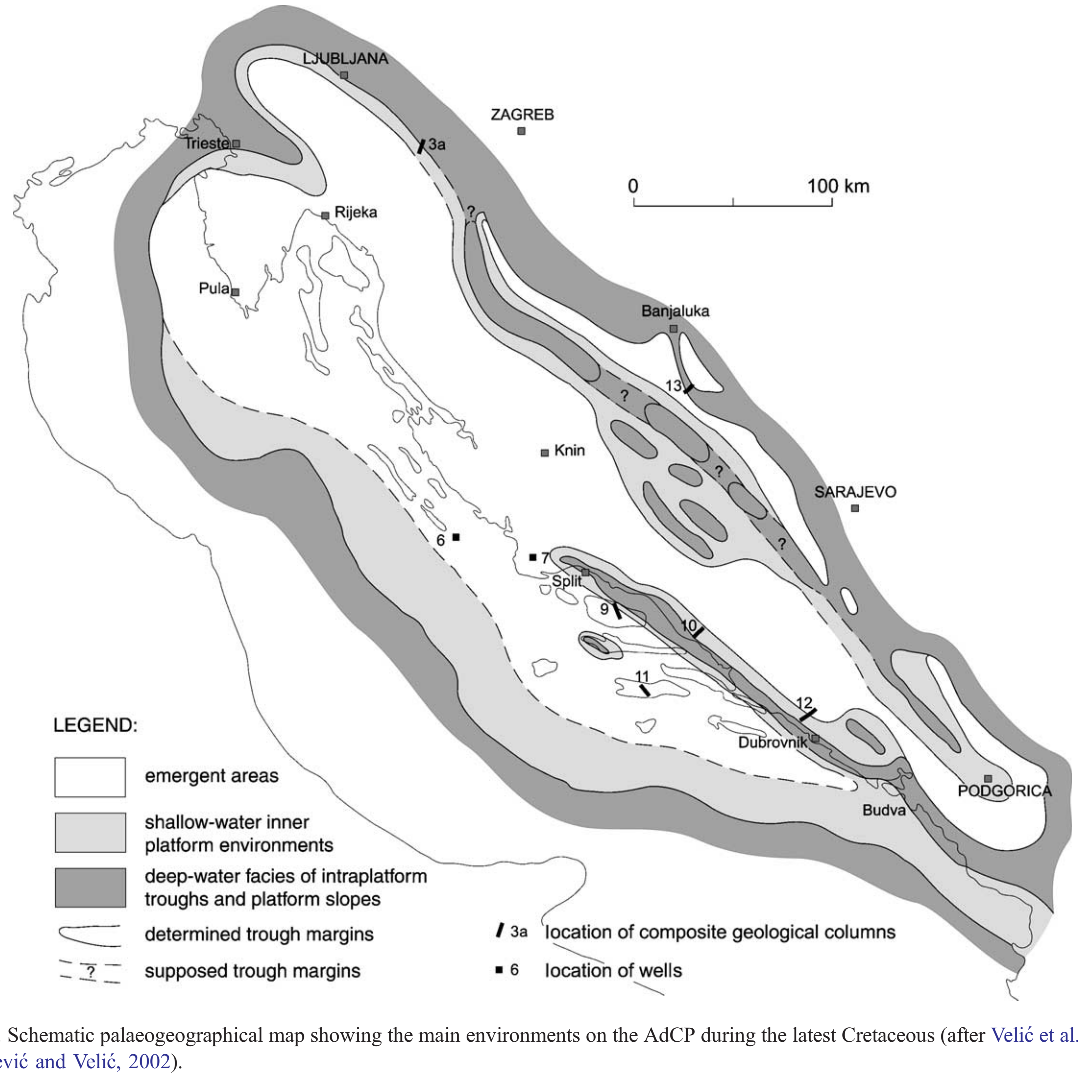


Fig. 12. Schematic palaeogeographical map showing the main environments on the AdCP during the latest Cretaceous (after Velić et al., 2002a; Dragičević and Velić, 2002).

platform was probably completely isolated, while during the latest Cretaceous at least a temporary connection with Eurasia was established.

Consequently, the term "isolated" when referring to the Adriatic Carbonate Platform as part of the huge Central Mediterranean Carbonate Platform should be used carefully: it does indicate practically a complete lack of terrigenous influence from distant continental masses, and generally, the platform was surrounded by deeper marine environments. However, in the geological history of the AdCP there were obviously some events caused by the interaction of tectonic movements and eustatic sea-level fall when migration of large animals from different neighbouring continental areas was enabled across some temporary palaeogeographic "bridges".

4. Platform disintegration and overlying deposits

The transition from the Cretaceous to the Palaeogene was marked everywhere on the AdCP by a period of emersion (of variable duration), commonly with bauxites. In most places the oldest Palaeogene deposits are of Eocene age, although in some localities in SW Slovenia (Drobne et al., 1989; Jurkovšek et al., 1996) and southern Croatia (Gušić and Jelaska, 1990) both Maastrichtian and Palaeocene strata have been documented, i.e. the hiatus was much shorter.

Palaeogene deposition was predominantly controlled by tectonics, and primary carbonate production played a subordinate role—a huge contrast to the Mesozoic situation. Deposits of the AdCP became tectonically dissected during the Palaeogene into several small sedimentary basins (with flysch deposition in their mature stage), characterised by ramp-type carbonate deposition along their margins. Continuation of compressional tectonics with maximal stress oriented SW–NE resulted in the final uplift of the Dinarides during the Oligocene–Miocene, which therefore attained their NW–SE orientation—the "Dinaric strike" (Fig. 1A). During this compression, inherited lineaments from the platform basement, oriented normal to the stress direction, were reactivated as major reverse faults with a vertical component of up to 1500 m and steep fault planes (mostly 60–80° at the surface). Their regional character has significantly affected the orography of the Dinarides.

During the Palaeogene, carbonate depositional environments only temporarily occurred in suitable areas, since carbonate production was insufficient to cope with intense subsidence. Therefore, different carbonate zones gradually migrated towards the margins of tectonically formed basins, resulting in a typical vertical and lateral trend of deposits representing more or less continuous deepening.

In general Tertiary deposits can be divided into several units:

(1) Liburnian deposits—Palaeocene to Eocene fresh water to brackish limestones, present only locally;
(2) Foraminiferal limestones—mainly Lower to Middle Eocene *foramol*-type limestones representing a succession of different environments, from the restricted inner part of the carbonate platform (*Miliolid* limestones), through shallower and deeper parts of shoreface environments (*Alveolina* and *Nummulite* limestones), to the deeper parts of relatively open carbonate ramps (*Discocyclina* limestones);
(3) Transitional beds—deeper marine clayey mudstones and "*Globigerina* marls" of Middle Eocene age, and
(4) Flysch—mainly Middle Eocene to Lower Oligocene, in places up to the Lower Miocene deposits.

Some parts of the foreland basins (in S Croatia and Herzegovina) were finally infilled by the Promina clastic deposits, a regressive succession from marine, brackish, coastal and alluvial deposits interfingering with the rockfall Jelar breccia. Flysch, Promina and Jelar deposits represent a consequence of the main tectonic events, achieving their maximum extent during the Eocene formation of the flysch basins and the final uplift of the Dinarides in the Oligocene–Miocene.

Although the major tectonic and depositional events in the Neogene and Quaternary took place in the neighbouring Pannonian Basin, the area of the former carbonate platform was also affected by Neotectonic deformation with a new, N–S orientation of the regional stress. Besides the changed character of movement along the inherited brittle structures, some new, Neotectonic structures have been formed.

5. Conclusions

The Adriatic Carbonate Platform (AdCP) is one of the largest Mesozoic carbonate platforms of the Perimediterranean region, and its deposits crop out in Italy, Slovenia, Croatia, Bosnia and Herzegovina, Serbia and Montenegro, and Albania. These deposits comprise a major part of the entire carbonate succession cropping out in the Croatian part of the Karst Dinarides, and are very thick (in places more than 8000 m), with a stratigraphic range from the Middle Permian (or even Upper Carboniferous) to the Eocene.

However, only deposits ranging from the top of the Lower Jurassic (Toarcian) to the top of the Cretaceous can be attributed to the AdCP, and the thickness of deposits formed during 125 My of the platform's existence is variable (between 3500 and 5000 m). AdCP margins are practically completely covered: the SW margin of the platform is presently covered by modern Adriatic Sea deposits, and can only be studied by geophysical methods and analysis of offshore wells. In contrast, the NE platform margin is partly exposed, although it is in its major part covered by overthrusted Palaeozoic–Triassic deposits, Late Cretaceous–Palaeogene flysch or Neogene and Quaternary deposits.

The following conclusions on the platform dynamics may be drawn:

- The basement of the AdCP is composed of
  (1) mixed siliciclastic–carbonate deposits formed in epeiric seas along the northern Gondwana margin from the Carboniferous to the Middle Triassic, and
  (2) pure carbonates formed on a huge isolated carbonate platform from the Middle Triassic to the Pliensbachian (Southern Tethyan Megaplatform—STM).
- The AdCP became a separate entity during the middle/late Early Jurassic by formation of a deeper area connecting the Ionian Basin with the Belluno Basin, and subsidence of the NE part of the former huge platform (STM). This event may be correlated with the widely recognised Toarcian oceanic anoxic event (OAE). However, the AdCP represents only a well-preserved part of the large Central Mediterranean Carbonate Platform (CMCP), relics of which occur from NE Italy through Slovenia, Croatia, Bosnia and Herzegovina, Serbia and Montenegro, Albania and Greece to Turkey (continuity of this shallow-marine carbonate platform is questionable only in the border area between Albania and Greece, where supposed relics of the carbonate platform are today covered by Pind nappe). According to Dalla Vecchia (2002) different groups of dinosaurs found on the AdCP might indicate that until Barremian there was probably a "bridge" between Gondwana and the platform, from Aptian to Turonian the platform was probably completely isolated, while during the latest Cretaceous at least temporal connection with Eurasia was established.
- The AdCP was characterised by predominantly shallow-marine deposition, although periods of emergence of variable duration were numerous, as a consequence of the interaction of synsedimentary tectonics (especially significant during the Kimmeridgian, Aptian and Late Cretaceous) and eustatic changes. Also, several events of temporary platform drowning were recorded, especially in the Late Cretaceous. Influences of global oceanic anoxic events can be recognised within Toarcian, Lower Aptian (OAE-1a) and Cenomanian/Turonian transition deposits (OAE-2).
- Synsedimentary tectonics became stronger in the Late Cretaceous, as a prelude to the final platform disintegration.
- The end of the AdCP deposition was marked by regional emergence between the Cretaceous and the Palaeogene.
- Deposition during the Palaeogene was mainly controlled by intense synsedimentary tectonics—carbonates were deposited on irregular ramps surrounding flysch basins formed mainly during the Eocene.
- Continuation of the compression resulted with the final uplift of the Dinarides in the Oligocene/Miocene.
- A clear terminological distinction between the carbonate platform and the product of its disintegration should be made. Therefore, disintegration of the AdCP (including its basement with predominant carbonate deposits, and thin overlying deposits) and its neighbouring areas, which culminated in the Oligocene–Miocene, resulted in the formation of the Dinaric mountain belt.

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