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Stratigraphic organisation, spatial distribution, palaeoenvironmental reconstruction, and demise of Lower Cretaceous (Barremian-lower Aptian) carbonate platforms of the Western Pontides (Black Sea region, Turkey)

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ABSTRACT

Barremian-Lower Aptian platform carbonates ("Urgonian limestones") of the northern margin of the Istanbul zone extend from Zonguldak to the Kurucasile area along the Black Sea coast. New stratigraphic data on the "Inpiri" Formation of the Inpiri-Kurucasile area are based on the identification of calcareous algae, foraminifera, and rudists. They show that this lithostratigraphic unit is stratigraphically and lithologically equivalent to the Öküşmedere Formation from Zonguldak. Some of the biostratigraphic markers are reported for the first time in Anatolia. Foraminifera are represented by several forms with a significant biostratigraphic potential used to distinguish the Barremian from the lower Aptian. Lower Aptian beds also yield relatively advanced caprinid rudists.

The Öküşmedere Formation is relatively thin, terrigeneous-rich, and rudist-free or rudist-poor in the Kurucasile sector, and thick, terrigeneous-poor, and rudist-rich from Amasra to Zonguldak, with a set of marker beds including either charophytes or *Palorbitolina* and capped by a coral unit underlying ammonite bearing marls. Terrigeneous-rich carbonates from the eastern sector are interpreted as marginal marine coastal, infralittoral environments and grade distally, northward, to marly basinal sediments. By contrast "Urgonian type" limestones from the Zonguldak-Amasra region possess a wide extent and no transition to coastal or basinal sediments has been observed. A transition from a typical platform westward to a mixed siliciclastic-carbonate ramp eastward was controlled by both the nature of the adjacent exposed area and tectonic factors affecting the overall continental margin that is a northward downwarping. The exposed area was flanked southward by a belt of coastal siliciclastics grading southward and eastward to deep water sediments of the Ulus basin. In mid-Bedoulian time, carbonate platform demise from the western region was drowned below deeper marly sediments whereas the eastern siliciclastic-carbonate ramp was buried below coastal clastics.

1. Introduction

In the Western Pontides (Istanbul zone sensu Okay, 1989) shallow water carbonates are represented by two main stratigraphic entities, the lower one corresponds to the Inalti Formation, ascribed to the Kimmeridgian-Valanginian, the upper one corresponds to the Öküşmedere Formation, ascribed to the Barremian-lower Aptian (Derman, 1990; Derman and Sayılı, 1995; Tüysüz et al., 1997; Masse et al., 2002, 2004). Outcrops of the Öküşmedere Formation, the type locality of which is close to Kozlu, near Zonguldak, extend eastward from this locality to the Kurucasile area, over nearly 80 km (Fig. 1).

The so-called Inpiri Formation in the sense of Tüysüz (1999), the type locality of which is close to Amasra, which includes both siliciclastic and carbonate sediments, is in part equivalent to the Öküşmedere Formation. Stratigraphical and palaeontological data on the Öküşmedere Formation of the Kozlu-Zonguldak and Amasra areas, and its relationships with the underlying and overlying rocks have been described by Charles and Flandrin (1929), Astre and Charles (1931), Tokay (1952), Derman (1990), Derman and Sayılı (1995), Tüysüz (1999) and Masse et al. (2002, 2004). The lithostratigraphic framework and nomenclature of the Lower Cretaceous of the study region are summarized on Table 1.

Stratigraphic data on the Inpiri-Kurucasile area were hitherto relatively poor and or limited to unpublished technical reports, precluding the establishment of precise stratigraphic relationships

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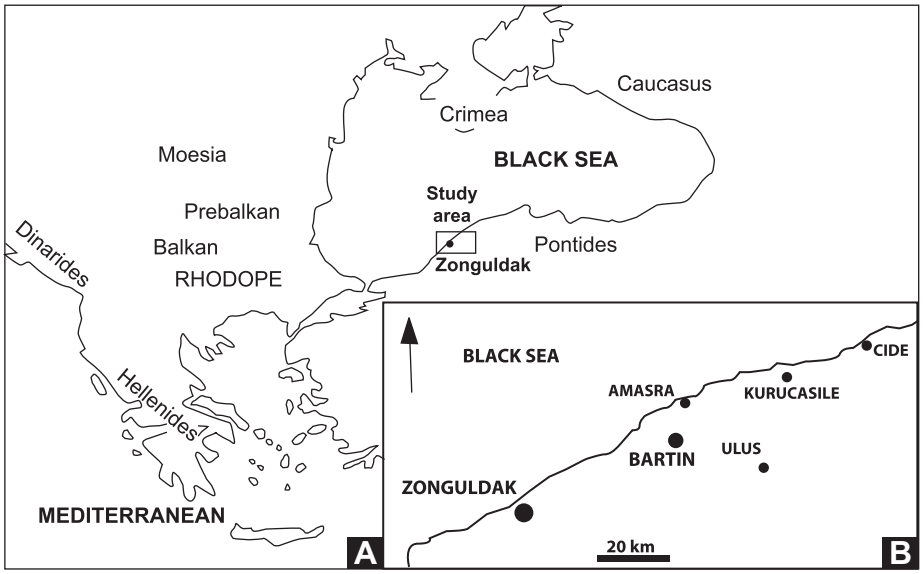

Fig. 1. Geographic setting of the study region (A), and location of the investigated localities (B).

with the western region. For the entire region palaeoenvironmental investigations concerning the shallow-water carbonates and demise of carbonate system were also very limited.

The present paper focuses on the Öküşmedere Formation, namely the "Urgonian limestones" in the sense of Charles and Flandrin (1929), and deals with the following objectives:

(1) providing new stratigraphic data on sections studied during a field work survey performed in the Inpiri-Kurucaşile area, and establishing a regional stratigraphic correlation in combining the new data with those previously obtained from the Zonguldak-Amasra area (Masse et al., 2002, 2004);
(2) defining the main depositional environments based on biological and sedimentological characters, in order to reconstruct the configuration of the Barremian-Aptian platform carbonates, their terrigeneous cover, and the controlling factors of their organisation in space and time;
(3) analysing the patterns and origin of platform demise, and acknowledging their regional and possibly global causes.

2. Geographical and geological framework of the study region

The study area belongs to the Istanbul zone also known as the Western Pontides, limited eastward from the Central Pontides by a regional fault infered to be the onshore prolongation of Western Black Sea Fault, to the east by the Arac-Daday-Inebolu shear zone and to the south by the Intra-Pontide suture (Okay et al., 1994; Tüysüz, 1999) (Fig. 2). The so-called Zonguldak and Ulus Lower Cretaceous sedimentary basins, presently separated by the late Cretaceous–Eocene Devrek basin, are considered a single basin prior to the development of the Tertiary Cide uplift, the former consists essentially of neritic deposits whereas the latter is made of relatively deep,

Table 1
Lithostratigraphic framework of the Lower Cretaceous of the Zonguldak-Kurucasile region

		ZONGULDAK BASIN	DEVREK BASIN	ULUS BASIN
ALBIAN		SAPCA FM.		ULUS FM.
APTIAN	Clansayesian	VELIBEY FM.		
	Gargasian	CENGELLIDERE FM.		
	Bedoulian	"PURPLEMARL" FM.	KILIMLI FM.	
		OKUSMEDERE FM.	INPIRI FM.	
BARREMIAN				
HAUTERIVIAN				
VALANGINIAN		INALTI FM.		
BERRIASIAN				

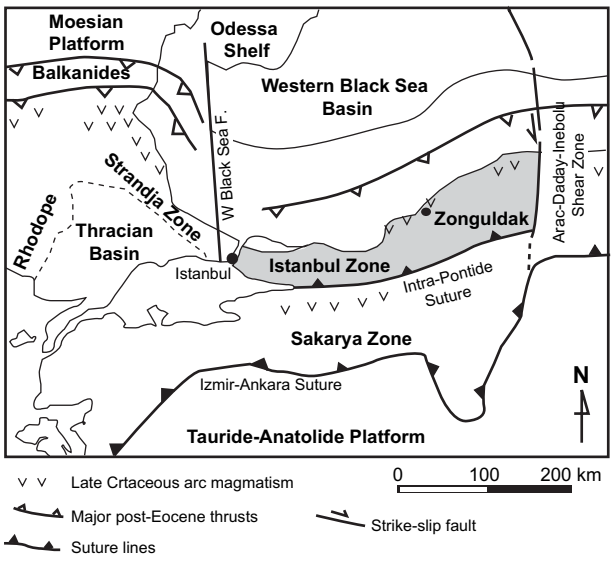

Fig. 2. Structural setting of the western Pontides, showing the complex tectonic relationships of the Istanbul zone with the adjacent structural elements.

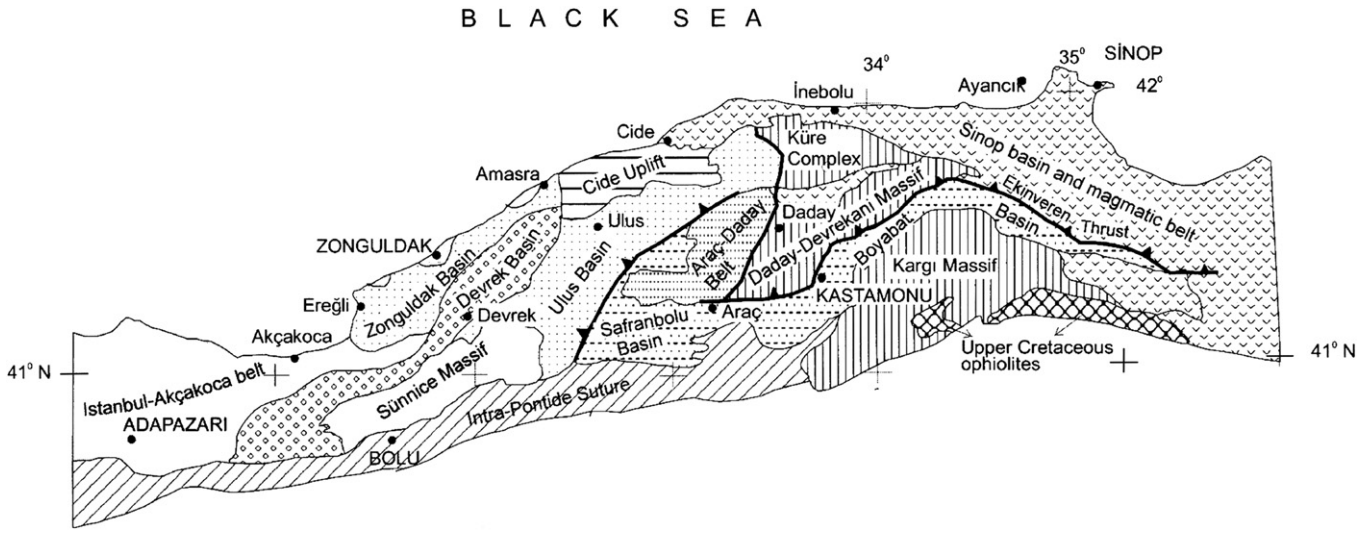

Fig. 3. Main tectonic elements of the Western Pontides (from Tüysüz, 1999).

basinal deposits, corresponding with the Ulus Formation (Tüysüz, 1999) (Fig. 3). The study area corresponds with the Zonguldak basin to the west and the western edge of the Ulus basin to the east.

3. New stratigraphic data on the Öküşmedere formation from the Inpiri-Kurucasile area

At Paşalilar the Öküşmedere Formation is represented by a 20–30 m thick carbonate succession, overlying the Inalti Formation, and capped by a drowning surface overlaid by marly limestones containing sponge spicules and glauconite, interbedded with marls (Fig.4). The corresponding packstones-wackestones contain sponge elements including spicules (globular type) and calcareous forms (*Corynella*), associated with fragments of echinoids, brachiopods, bryozoans, *Lithocodium*, and quartz grains. Foraminifera include *Lenticulina*, *Praedorothia*, *Meandrospira*, and *Spririllina*; this assemblage has only a broad Lower Cretaceous stratigraphic significance. Of special biostratigraphic interest is the presence of the red algae *Sporolithon phylloideum* (Bucur and Dragastan), only known from the Hauterivian- Aptian (Bucur and Dragastan, 1986; Moussavian, 1987; Bucur, 1994; Tomás et al., 2007). Northward (Tasça) the Öküşmedere Formation grades to basinal sediments, representatives of the Ulus Formation, overlying calcareous submarine breccias the elements of which contain *Andersenolina sp*., *Clypeina solkani* Conrad and Radoicic, *Montsalevia salevensis* (Charollais et al.), and *Danubiella gracilima* Neagu, of early Valanginian age. These talus carbonate deposits are a time equivalent to the Inalti Formation.

At Çukurköy the Öküşmedere carbonates are much thicker (50–60 m). The underlying rocks, attributed to the Inalti Formation, consist of coral-rich packstones-wackestones with early dissolution features on top, which document subaerial exposure prior to the deposition of the succeeding Öküşmedere carbonates. These carbonates are overlaid by sands and sandstones, with some gravelly intercalations, ascribed to the Velibey Formation in the sense of Derman (1990). The Öküşmedere carbonates are essentially quartz-rich grainstones with oblique bedding, detrital quartz increases upward, therefore the contact with the Velibey sands is transitional. The skeletal fraction consists of coral, rudist, echinoid and bryozoan fragments, foraminifera being represented by *Coscinophragma cribrosum* (Reuss), ?*Reophax giganteus* Arnaud-Vanneau, *Charentia* gr. *cuvillieri* Neumann, and "*Textularia*" *bernardii* Chevalier, associated with representatives of *Lenticulina*, *Melathrokerion*, and *Triplasia*, with a broad Lower Cretaceous biostratigraphic significance. Of special interest is the occurence of "*Trocholina*" *odukpaniensis* Dessauvagie and Iovcheva (Fig. 6B) with an upper Barremian?–lower Aptian (Bedoulian) significance (see discussion below).

In the Dağköy area the Öküşmedere carbonates are distributed in scattered outcrops precluding reliable estimates of their thickness that might be in the range of 30 to 50 m. The formation overlies sandstones and conglomerates and contains cobbles derived from Paleozoic rocks. Depositional textures vary from grainstones to wackestones with quartz. The skeletal fraction of grainstones is dominated by coral and rudist fragments, by contrast, in wackestones and packstones small foraminifera and peloids tend to play the major role, requieniid rudists being locally present. The assemblage of foraminifera consists of representatives of *Lenticulina*, *Melathrokerion*, and *Praedorothia* associated with *Arenobulimina cochleata* Arnaud-Vanneau, *Sabaudia minuta* (Hofker), *Vercorsella scarcellai* (De Castro), *Montseciella arabica* (Henson), "*Trocholina*" *scythica* Neagu, and "*Neotrocholina*" *aptiensis*, which are the key biostratigraphic markers indicative of the upper Barremian-lower Aptian. The sedimentary cover of the carbonates is hardly visible in outcrop, ammonite bearing black marly limestones (of late Aptian—Albian p.p. age) are nevertheless present in the area but their stratigraphic relationships with the Öküşmedere carbonates are unclear.

The Gürcüoluk plateau shows the contact between the underlying conglomerates and the Öküşmedere carbonates the overall thickness of which exceeds 30 m, the stratigraphic cover of the succession is missing and the succession itself incomplete. Muddy, quartz-free limestones are dominant, rudists are well represented and include *Requienia cf. zlatarskii* Paquier, *Requienia migliorinii* Tavani, and *Lovetchenia* sp.; that is the assemblage found in the type locality of the Öküşmedere Formation of Zonguldak and Amasra (Masse et al., 2004). The late Barremian-Bedoulian? age of Gürcüoluk carbonates is in agreement with the micropaleontological association of dasycladales *Salpingoporella melitae* Radoicic and *Cylindroporella ivanovici* Sokac, and foraminifera *Sabaudia minuta* and *Vercorsella scarcellai*. The lithological and biological characters of the Gürcüoluk limestones are similar to those of the Öküşmedere Formation of Amasra (Boztepe) (Masse et al., 2004), nevertheless, as suggested above, the part of the Gürcüoluk section at outcrop represents only the lower part of the Amasra (Boztepe) succession.

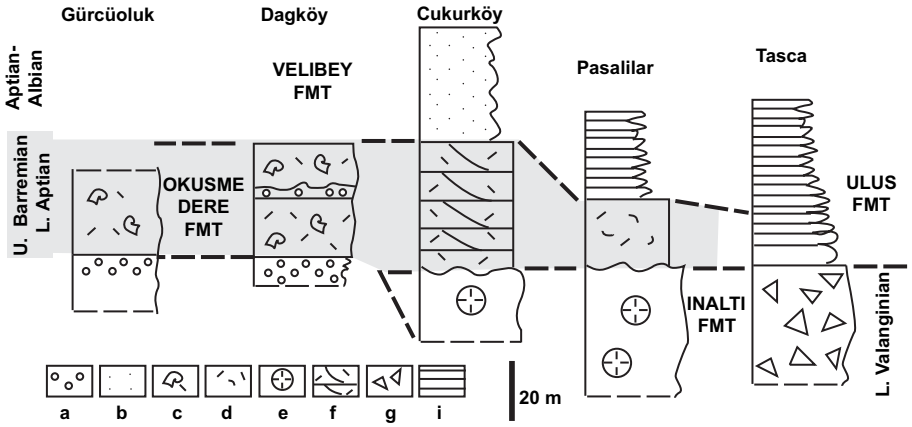

Fig. 4. Stratigraphic sections of the Oküsmedere Formation of the Inpiri-Kurucasile area, their correlations and relationships with the Velibey, Inalti and Ulus Formations. Facies legend: a, conglomerates; b, sandstones; c, rudist bearing platform carbonates; d, skeletal bioclastics; e, coral facies; f, cross-bedded bioclastics; g, calcareous breccias; h, outer shelf carbonates.

4. The Inpiri stratigraphic section: an equivalent of the Amasra-Boztepe and Zonguldak Öküşmedere type section

The core of the Inpiri hill anticline exhibits a well exposed section of the Öküşmedere carbonates and their overlying sediments whereas the underlying rocks do not outcrop (Fig. 5). The stratigraphic succession consists of three segments bounded by faults. The lower segment, about 20 m thick, is dominated by grainstones.The middle segment is 40 m thick and consists of skeletal grainstones with corals and large rudist fragments with interbedded muddy, sandy, black muddy intercalations with charophytes in its middle. Early exposure surfaces punctuate the entire succession. Microfossils and rudists are the same, the latter being represented by problematic Caprinidae and poorly defined requieniids. The associated micropalaeontological assemblage is composed of *Cylindroporella lyrata* Luperto-Sinni and Masse, *Acroporella radoiciciae* Praturlon (Fig. 6C), *Suppiluliumaella cf. praebalkanica* Bakalova, *Pseudoactinoporella fragilis* Conrad (Fig. 6D), *Salpingoporella muelhbergii* (Lorenz), *Actinoporella nigra* (Conrad and Peybernès), *Montseciella arabica*, *Palorbitolina lenticularis* (Blumenbach) (Fig. 6F), *Falsurgonina cf. pileola* Arnaud-Vanneau and Angot, and "*Neotrocholina*" *aptiensis*, ascribed to the upper Barremian- lower Aptian, whereas the presence of Caprinidae is more diagnostic and suggests an early Aptian age (Masse et al., 2004). The upper segment is 54 m thick and dominated by grainstones with coral and rudist fragments interbedded with wackestones which contain either charophytes or miliolids (*Istriloculina*) and gastropods, the upper part is

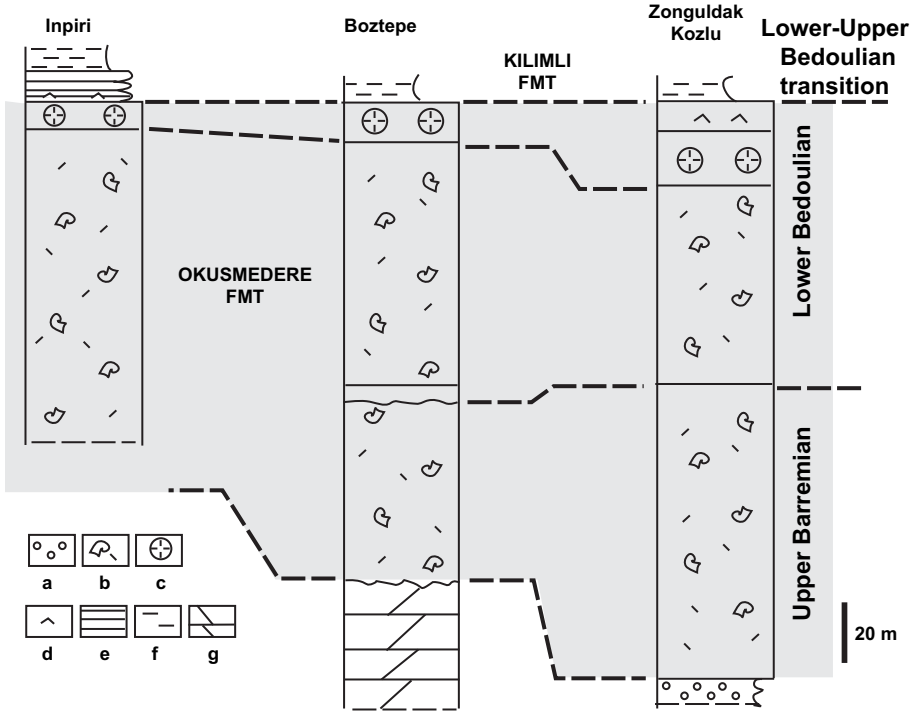

Fig. 5. East-west stratigraphic correlations of the Öküşmedere Formation showing the lateral continuity of the upper Barremian-lower Bedoulian limestones from Inpiri to Zonguldak. Facies legend: a, conglomerates; b, rudist bearing platform carbonates; c, coral facies; d, orbitolinids; e, outer shelf carbonates; f, marls; g, dolomites.

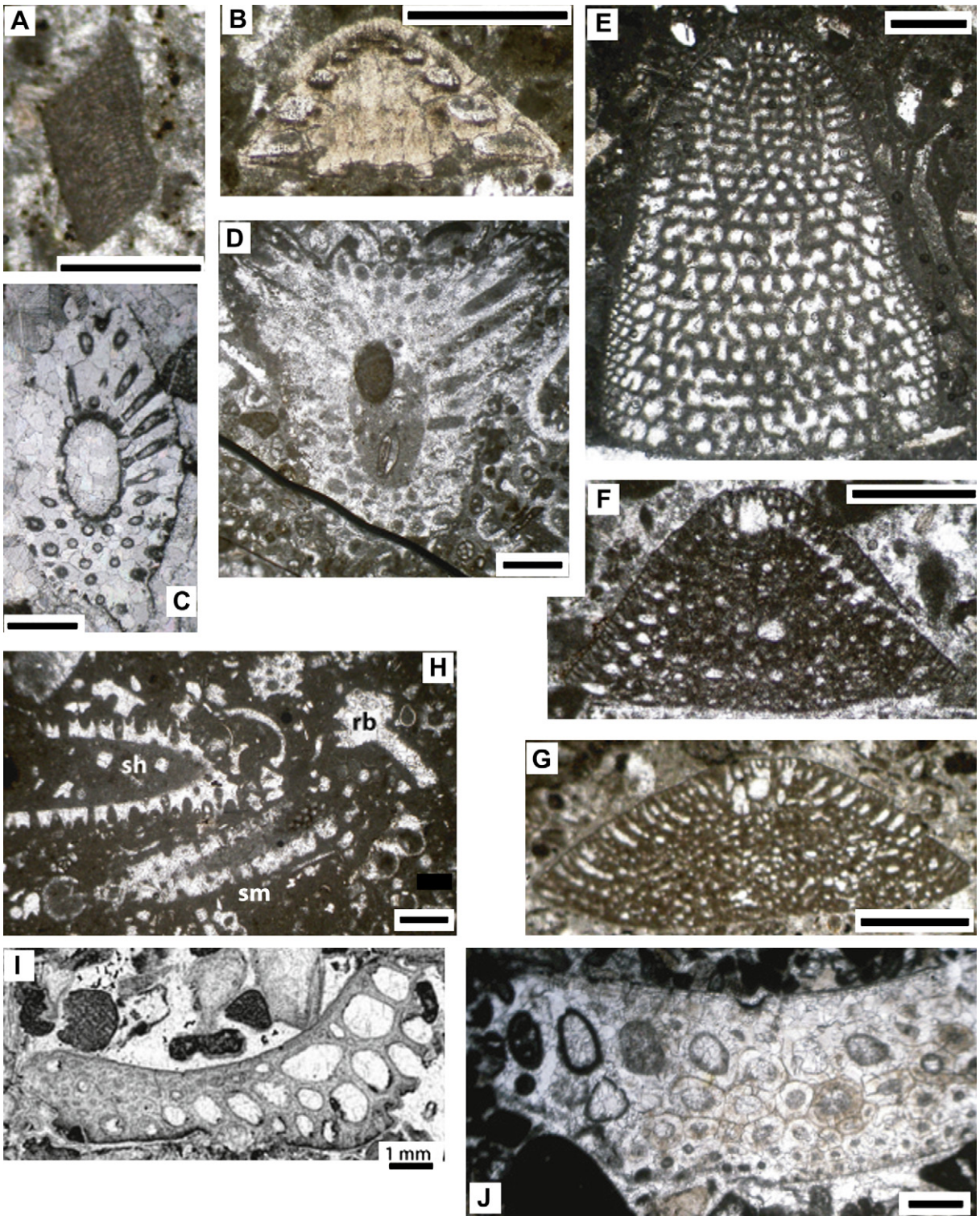

Fig. 6. Biostratigraphic markers of the Öküşmedere limestones. A, *Sporolithon phylloideum;* B,*"Neotrocholina"aptiensis;* C, *Acroporella radoiciciae;* D,*Pseudoactinoporella fragilis,* E, *Rectodictyoconus giganteus*; F, *Palorbitolina lenticularis*; G, *Mesorbitolina parva*; H, *Salpingoporella muelberghii* (sm), *Salpingoporella cf. hasi* (sh) , and *"Rajkaella" cf. banatica* (rb); I-J, caprinid rudists.

grainy and rich in corals and rudists fragments whereas the topmost part (5 m) is a coral-*Lithocodium* bafflestone. Caprinidae are still present in this segment and are associated with *Rectodictyoconus giganteus* Schroeder (Fig. 6E) and *Palorbitolina lenticularis* (Blumenbach).The transition to the overlying ammonite bearing marls corresponds with an *Palorbitolina*-rich, glauconitic, marly limestone (2 m). Ammonites found in the marly beds belong to the *Deshayesites weissi* zone, these beds are tentatively placed at the transition between the lower and upper Bedoulian (work in progress).

The following data regarding the Amasra and Zonguldak areas are summarized from Masse et al. (2004). In the Boztepe section the

overall thickness of the Ökuşmedere Formation is 170 m, the upper Barremian part, with *Actinoporella nigra,* is 70 m thick, and the Bedoulian part, with *"Rajkaella" banatica* Dragastan and Bucur, *Salpingoporella hasi* Radoicic et al. *Montseciella arabica* (base), *Caprinidae* and *Rectodictyoconus giganteus* (top) is 100 m thick, which is in the same thickness range of the corresponding Bedoulian beds of Inpiri. In the Zonguldak-Kozlu area the index biostratigraphic markers *Actinoporella nigra*, *Montseciella arabica,* Caprinidae, and *Rectodictyoconus giganteus* have been identified; the upper Barremian beds are relatively thick, about 100 m, the lower Aptian being in the same thickness range as for the Amasra region, 110 m.

A common feature to the lower Aptian portion of the Inpiri, Boztepe, and Zonguldak stratigraphic successions is the presence of coral-rich beds in their uppermost part and the existence of overlying marl-bearing ammonites first reported by Charles and Flandrin (1929). At Kozlu the coral beds are capped by *Mesorbitolina parva* (Douglass) (Fig. 6G) beds, an orbitolinid which has its FO (First Occurence) at the transition between the lower and upper Bedoulian (Peybernès, 1976).

5. Discussion on biostratigraphic markers

Upper Barremian and lower Aptian carbonates tend to be restricted to the outer Western Pontides; in the eastern Pontides platform carbonates are usually older, Berriasian to Barremian p. p., e. g. the Berdiga limestone from the Kale-Gumushane region (Bucur et al., 2000). They are limited to the Berriasian–lower Valanginian in the Inner Pontides (Altiner, 1991; Farinacci and Radoicic, 1991). This contrasting stratigraphic distribution of Lower Cretaceous platform carbonates in the Pontides explains why the paleontological assemblages (Fig. 6) found in the study region contain many species, mainly calcareous algae, still poorly documented and reported for the first time in the European part (North Tethyan margin) of Anatolia. The following tends to focus on those forms.

5.1. Calcareous algae

Sporolithon phylloideum (Fig. 6A) was hitherto poorly known outside Eastern Europe and is described herein for the time in Turkey. *Salpingoporella melitae*, *S. muehlbergii* (Fig. 6Hsm), *Acroporella radoiciciae* (Fig. 6C), *Pseudoactinoporella fragilis* (Fig. 6D), *"Rajkaella" banatica* (a form with a problematic generic status) (Fig. 6 Hrb), and *Cylindroporella lyrata*, with contrasting stratigraphic distributions ranging from upper Hauterivian to lower Aptian, are also reported for the first time in Turkey, whereas *Cylindroporella ivanovici* and *Salpingoporella hasi* (Fig. 6 Hsh) were only documented from the Taurus.

5.2. Foraminifera

The trocholinid group includes two sets of genera which differ by the original mineralogy of the test. *Neotrocholina* Reichel, type species *Neotrocholina valdensis* (Reichel, 1955) was originally fibrous calcitic, is typically pale brown, fibrous in thin sections, and the whorls do not overlap, i.e., the spiral convex side is monolamellar; this genus is known to appear probably in the Kimmeridgian (Altiner, 1991). *Trocholina* Paalzov was originally aragonitic and is usually preserved as neomorphic clear, sparry calcite in thin sections (Reichel, 1955; Masse, 1976). The shell organisation of *Neotrocholina* and *Trocholina* are homeomorphic whereas owing to their contrasting original mineralogy they belong to distinct families or suborders. Some forms usually ascribed to *Neotrocholina* or *Trocholina*, frequent in the Barremian–Aptian, do not conform to the definition of the corresponding genus. This is the case for «*Neotrocholina*» *friburgensis* Guillaume and Reichel (Guillaume and Reichel, 1957) «*Neotrocholina*» *aptiensis* (Iovcheva), with a multilamellar arrangement of the spiral convex side (Fig. 6B), and "*Trocholina*" *scythica* Neagu , with a fibrous microstructure (Neagu, 1995). Notwithstanding their questionable generic position "*Neotrocholina*"*aptiensis* and "*Trocholina*" *scythica* are well defined species and their stratigraphic range is the upper Barremian-lower Aptian (Iovcheva, 1962; Arnaud-Vanneau, 1980; Neagu, 1995).

Montseciella arabica, formerly placed in the genus *Dictyoconus* by Henson (1948), or *Paleodictyoconus* (e.g., Masse et al., 2004), has been transfered into *Montseciella* defined by Cherchi and Schroeder (1999). This species is known from the uppermost Barremian and lower Bedoulian where it is commonly associated with *Palorbitolina lenticularis* (Baud et al., 1994; Granier et al., 2003), its descendant *Rectodictyoconus giganteus* (Fig. 6E) being a species found essentially in the middle part of the Bedoulian.

5.3. Rudist bivalves

Distinctive faunas including Requieniidae and Monopleuridae have been reported by Masse et al. (2004) from the Barremian and the lower Aptian of the study region, but Caprinidae appear the most reliable stratigraphical markers notwithstanding their poorly defined systematic status due to their occurrence as fragments. Actually the larger fragments show relatively large polygonal canals arranged in 3 rows, passing laterally to minute rounded canals in 5 to 6 rows, with size decreasing outward (Fig. 6I, J). Isolated fragments with numerous rounded canals (Fig. 6J) mimics the organisation of *Ichthyosarcolites*. A canaliculate shell structure of this type, having two types of canals is unknown in European caprinids. This arrangement is somewhat similar to that of *Offneria nicolinae* (Mainelli) whose canals possess transverse concave partitions (Masse, 1992), lacking in the Pontides specimens, moreover the canaliculate structure of *O. nicolinae* is much coarser and the number of canals far more limited. Whatever its generic position the Pontides material has a relatively advanced evolutionary status regarding its canal system and somewhat comparable to that of the lower Aptian *Offneria* species (Chartrousse, 1998).

6. Upper Barremian—Bedoulian regional stratigraphic organisation

The foregoing stratigraphic description shows that the Öküşmedere Formation is represented by two types of successions having strong dissimilarities regarding thickness, facies associations, terrigeneous content, and the nature of underlying and overlying rocks. These two types of successions show a specific geographic distribution: relatively thin, terrigeneous-rich, rudist-free or rudist-poor successions are restricted to the eastern sector, east to Amasra, whereas thick (>100 m) rudist-bearing, terrigeneous-poor carbonate successions with a marly cover, run from Amasra to the Zonguldak area. Due to this dual typology, stratigraphic correlations will be presented first for the eastern sector then for the western region.

6.1. Eastern sector (Fig. 4)

Bioclastic grainstones with reworked rudists and coarse grained intercalations from Dağköy and Cukurköy are usually quartz-rich and contain significant amounts of coral fragments. A typical feature is the presence of siliciclastic pebbles reworked from the Paleozoic basement of the Cretaceous rocks. The stratigraphic successions tend to be relatively thin, i.e., less than 60 m, and overly the Inalti carbonates, moreover when the overlying beds are preserved, they are represented by sandstones. At Pasalilar the siliciclastic content of the carbonate decreases whereas rudist and

coral elements are replaced by sponges and red algae; the platform carbonates grades northward to basinal sediments which represent the eastern edge of the Ulus basin. One must notice that:

(1) to the south (Gürcüoluk, Dagköy) the Öküşmedere carbonates overly conglomerates with Paleozoic pebbles, and
(2) to the north (Cukurköy, Pasalilar) the Öküşmedere carbonates overly the Inalti limestones and are overlaid either by sandstones or deep water marly limestones.

6.2. Western region (Fig. 5)

In the area of Zonguldak the Barremian part of the Öküşmedere Formation overlies the Incigez beds in which *Silesites seranonis* Kilian, an index of the upper Barremian, has been reported (Charles and Flandrin, 1929). This species is known to have its FO in the *Sartousiana* zone and is documented up to the *Sarasini* zone (Delanoy, 1994). Common characters to the Zonguldak, Boztepe and Inpiri sections are the presence of a set of "marker beds" regarded as guide levels, including:

(1) *Palorbitolina* and Charophyte bearing -well bedded- limestones and marls, at /or close to the Barremian-Bedoulian boundary, a feature closely resembling the "lower *Palorbitolina* beds" of the subalpine part of southeastern France (Arnaud-Vanneau, 1980; Clavel et al., 2002), Switzerland (Funk et al., 1993), which possess equivalents in Spain (Vilas et al., 1995) and the Middle-East (Masse et al., 1998); and represent as other "*Orbitolina* episodes", major breaks in the temporal and spatial evolution of Mid-Cretaceous carbonate platforms (Vilas et al., 1995);
(2) a quartz-rich and charophyte-bearing bed within the *Montseciella arabica* stratigraphic interval;
(3) coral-rich beds in the uppermost part of the sections, within the *Rectodictyoconus giganteus* stratigraphic interval, capped by *Palorbitolina*-rich marls and marl-bearing ammonites, first reported by Charles and Flandrin (1929). The marly cover of the carbonates corespond with the "Purple marls" of Charles and Flandrin (1929) equivalent of the Kilimli Formation (in Tüysüz, 1999). At Kozlu the coral beds are capped by *Mesorbitolina parva* (Douglass).

In the three above mentioned localities, the dominant lithology consists of quartz-free, bioclastic or peloidal packstones or grainstones with orbitolinids, coral or rudist fagments, interbedded with rudist-rich beds; muddy sediments being usually subordinate. From a macroscopic point of view rudists are the most significant fossils whereas "rudist beds" are not prominent and represent usually only 2 to 10% of the cumulative thickness. The overall relative proportion of muddy and grainy facies varies, e.g., in the Inpiri section the *M. arabica* stratigraphic interval is dominated by grainy sediments whereas muddy sediments dominate at Boztepe. Evidence for intertidal or supratidal sediments are rare but early exposure surfaces are not uncommon, especially in the uppermost Barremian and Bedoulian successions. By contrast the lower part of the upper Barremian shows typical loferitic sequences bounded by early exposure surfaces, this may be regarded as the expression of the "incipient transgression" which characterises this time interval marked by the gradual replacement of marginal marine terrigeneous sediments by platform carbonates.

7. Palaeoenvironmental reconstruction of shallow carbonates

The two main types of stratigraphic successions with specific: thickness, facies associations, terrigeneous content, and the nature of underlying and overlying rocks, which characterize the eastern sector and the western region, may be ascribed to distinct carbonate settings, that is a mixed carbonate-siliciclastic ramp to the east and a carbonate platform s.s. to the west (Figs. 7, and 8).

Terrigeneous-rich carbonates with reworked calcareous macrobiotas represent marginal marine or coastal environments, adjacent to a terrestrial region with Paleozoic rocks. Depositional textures and sedimentary structures reflect a relatively high hydrodynamic regime in infralittoral settings. Sponge-rich and quartz-poor muddy limestones with red coralline algae, *Praedorothia* and *Lenticulina*, with a circa-littoral significance, represent the distal equivalents of the foregoing terrigeneous carbonates. The corresponding margin is located at less than 5 km from basinal settings observed at Tasla, this close vicinity suggest that the ramp/basin transition may be an escarpement possibly controlled by a palaeofault. The overall depositional system is interpreted as a ramp dipping northward, with a relatively short radial dimension (perpendicular to the palaeoshoreline) in the range of 10 to 15 km from the palaeoshoreline to the basin.

By contrast pure carbonates of "Urgonian type" represent very shallow environments with a wide lateral extent. For instance small and large requienid communities found at Zonguldak and Amasra (Masse et al., 2004), which are the prominent facies of the classical "Urgonian limestones" from southeastern France, tended to thrive in water depth in the range of 0.5 to 2–3 m (Masse et al., 2003), and the corresponding beds may spread over more than 40 km (Masse and Fenerci-Masse, 2006). Coral dominated facies, a classical facies type from Urgonian platforms (Masse and Philip, 1981), are interpreted as outer platform facies, nevertheless their muddy matrix suggest quiet water settings, which means that notwithstanding their palaeogeographic location on the margin of the platform, facing the ocean, they were associated with low energy conditions expected to reflect a significant water depth, probably exceeding 10 to 15 m. The strong encrustation of corals by microbial communities, especially those of *Lithocodium-Bacinella*, shows that this kind of biological association observed here in the Weissi zone (see discussion above) is not necessarily linked to strong anomalous oceanic conditions, e. g., deep water anoxia which characterizes the uppermost Deshayesi zone (Kuhnt et al., 1998; Moullade et al., 1998), as suggested by Immenhauser et al. (2006). *Palorbitolina*-rich sediments are found in two different facies associations. First they are interbedded with charophyte bearing beds in relatively shallow marine, highly unstable settings, in correspondence with a phase of destabilisation of the platform evolving temporarily in a ramp. Second they are observed with glauconite in circa-littoral settings generated during a deepening phase and associated with platform

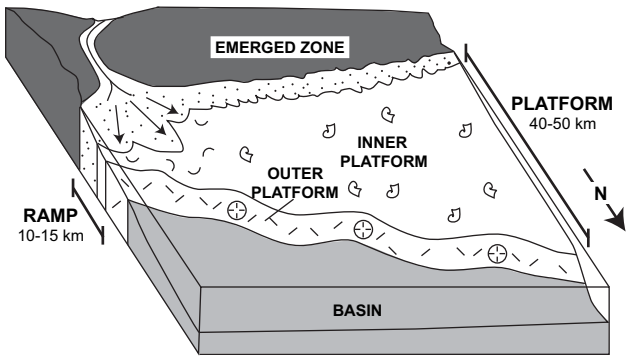

Fig. 7. Palaeogeographic regional reconstruction of the Zonguldak-Amasra area showing the spatial reduction of the western carbonate platform grading to the eastern ramp flanking an emerged zone, and the inferred location of the adjacent basin.

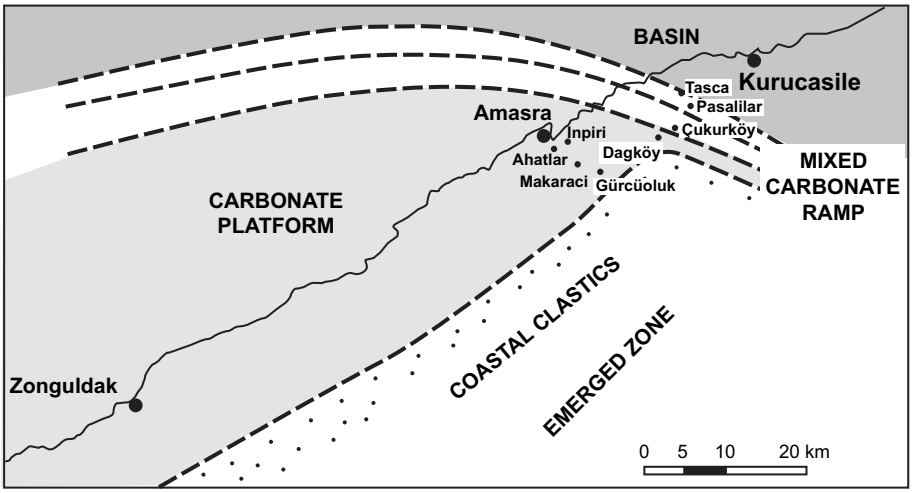

Fig. 8. Palaeoenvironmental sketch of the Zonguldak-Amasra region (referred to Fig. 7) showing the transition from a western carbonate platform to an eastern mixed carbonate-siliciclastic ramp adjacent to a fluviatile system.

demise. This apparent dual pattern may be just the end members of a ramp facies suite established between coastal, shallow and relatively deep water environments. Similar "Orbitolina bearing beds" represent major breaks in the temporal and spatial evolution of Mid-Cretaceous carbonate platforms (see Vilas et al., 1995), usually indicative of turning from a platform type s.s. to a ramp type organisation.

The platform/basin transition which does not presently outcrop is thought to be in the offshore of the Black Sea coast. The position of the platform/continent transition is tentatively located at 10 km south to Zonguldak where the Velibey sandstones overly the Paleozoic basement (Tüysüz, 1999). This correlation is true if we assume that the Velibey sandstones are in part time equivalent to the Öküşmedere carbonates, an assumption suggested by the lateral transition between the Cengelidere carbonates and sandstones, late Aptian in age (Masse et al., 2002), with the upper part of Kilimli marls p.p., which means a southward trend towards coastal terrigeneous settings, as reported from the eastern sector. This reconstruction suggests that the minimum radial dimensions of the platform were in the range of 20 to 30 km.

The foregoing paleogeographic and environmental reconstruction documents an east-west trending spatial variation of a carbonate system including: westward an Urgonian type platform 20 to 30 km wide, passing eastward to ramp type mixed siliciclastic and carbonate settings, 10 to 15 km wide, with an abrupt transition to deep water settings (Figs. 7, and 8). Several factors may account for these lateral changes:

(1) spatial climatic changes, that is relatively arid conditions westward and humid conditions eastward promoting increasing siliciclastic output from the continent, as known for instance in the Modern, on the southern part of the Yucatan shelf of Belize (Purdy et al., 1975), but the short distance between the two investigated areas precludes the existence of significant climatic modifications;
(2) antecedent palaeotopography may explain distinctive palaeobathymetric profiles between the western region, nearly flat, and the eastern sector, with a gentle slope from the shoreline to the platform-to-basin transition zone; because modern carbonate platform settings show that shallow water carbonates tend to build sedimentary bodies parallel to sea-level (Schlager, 1992), whatever the initial topography, the role of antecedent topography looks therefore unlikely;
(3) tectonic instability and/or differential subsidence between the two investigated areas may be responsible for their dimensional and topographic differences, basement mobility was probably stronger eastward than westward, due to a more active flexural downwarpping;
(4) the existence in the eastern sector of a fluviatile system responsible for high siliciclastic input into the coastal domain may be postulated; this may account for high clastic coastal sedimentation rates decreasing offshore, coupled with a reduced growth potential of carbonates in the outer shelf, due to the detrimental effect of the siliciclastics and the limited production of relatively deep water biotas (Friedman, 1988), as illustrated by modern mixed carbonate and terrigeneous settings such as the North Queensland shelf (Belperio, 1983). Another modern reference is the Nicaragua shelf (Murray et al., 1988) where river derived clastics are confined to the coastal zone due to longshore currents, whereas carbonates spread over the outer shelf; the overall resulting shelf morphology being a distally flattened ramp.

To conclude, in terms of submarine morphology, the presence of an active fuviatile system eastward in concurrence with structural aspects, having both a strong influence on the balance between carbonate and terrigeneous sedimentation, may explain why the eastern sector has a relatively narrow ramp type morphology whereas the western region shows a wide, nearly flat platform organisation. At a broader scale (Fig. 9), the southern flank of the exposed area was lined by coastal clastics grading southward to deep water sediments of the Ulus Formation (Tüysüz, 1999) without interposition of shallow water carbonates. This sedimentary organisation which contrasts with that of the northern side may reflect positive uplifting of the emerged area, due to significant tectonic movements of the corresponding margin controlled by ENE-WSW trending active faults associated with tilted blocks (Tüysüz, 1999).

8. Platform demise

In the eastern sector (Fig. 10) close to the Ulus basin, platform demise is linked to a replacement of carbonates by siliciclastic sands, owing to the fluvio-deltaic character of these sediments platform demise is therefore associated with shallowing. The transitional character of this replacement suggests an increase of

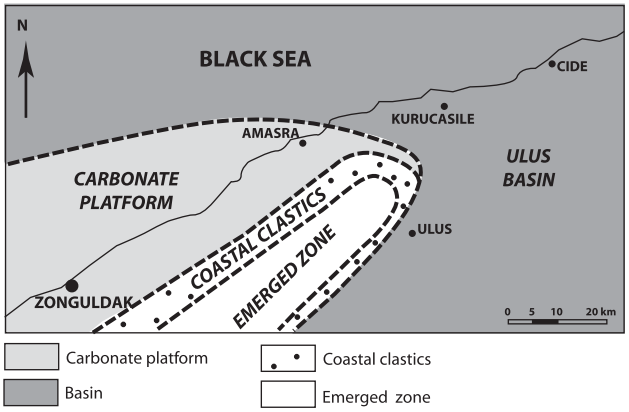

Fig. 9. Regional palaeogeographic reconstruction of the Western Black Sea region (Zonguldak to Cide) showing the contrasting patterns between the northern and southern margins of the emerged zone: with a relatively wide shallow carbonate platform to the north and a narrow siliclastic ribbon to the south surrounded by the Ulus Basin.

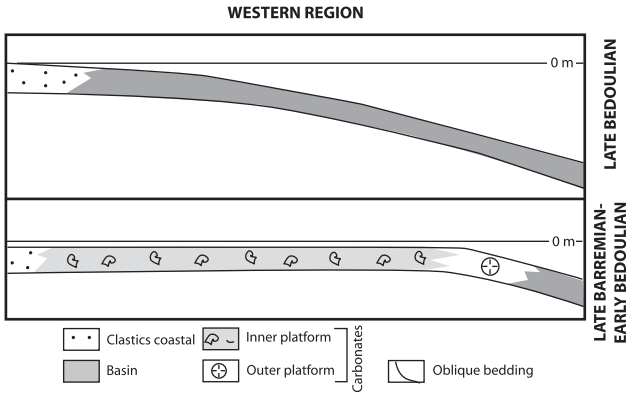

Fig. 11. Cross section of the western region (Zonguldak area) showing the distribution of the main palaeoenvironments and their evolution from a late Barremian-early Bedoulian carbonate platform to a late Bedoulian siliciclastic downwarpped system.

terrigeneous fluxes in this area during the late Bedoulian. The timing of this event is assumed to be contemporaneous with the drowning recorded in the western region. Burial of lower Aptian platform carbonates by deep-water marly sediments is a common feature in Western Europe, e.g., northeastern Spain, southwestern France, but also in the Caribbean region (Masse et al., 1993). Shallow water sandy siliciclastics are less common and mainly documented from the margins of Paleozoic-bearing shields, for instance the Arabian shield in Iraq (Radoicic, 1981), Iran (James and Wynd, 1965) and Levant (Bachmann and Hirsch, 2006), but also from the South America Maracaibo platform from Venezuela (Vahrenkamp et al., 1993), all in marginal coastal settings. In the case of the Outer Pontides one can assume the presence of a southern Palaeozoic bearing emerged area, with a limited spatial extent (see Figs. 7, and 8 and discussion above).

In the western region (Fig. 11) that is the "Zonguldak basin", platform demise is characterized by the replacement of shallow water carbonates by *Palorbitolina* then ammonite bearing marly sediments associated with glauconite, that is correlated with an abrupt deepening or drowning event. The drowning surface marks to top of coral-*Lithocodium* beds.

The age of the underlying carbonates and the chronologic significance of the ammonite fauna found on top of the drowning surface observed in the western region suggests that the corresponding event is coeval with the demise of Urgonian platforms from southeastern France and Switzerland, that is at the transition between the Weissi and Deshayesi ammonite zones. This event, the so-called intra-Urgonian discontinuity (Masse et al., 1999; Renard et al., 2005) in correspondance with the end of rudist dominated environments, is usually marked by an emersion followed by a rapid deepening locally associated with *Palorbitolina* facies, e.g., the "upper *Palorbitolina* beds" from the subalpine region (Arnaud-Vanneau, 1980), it predates the Selli/Goguel anoxic event OAE1a. Tectonics appear the prominent controlling factor for this intra-Urgonian discontinuity, whereas some geochemical evidence for a coincident methane hydrate dissociation event has also been proposed, including a δ^{13} C depletion and a peak in Mn which started in the Weissi zone and peaked in the Deshayesi zone (Renard et al., 2005). A northward downwarping of tectonic origin, a possible expression of tilted blocks rotated southward, is also suggested for the demise of the Öküşmedere platform. This interpretation is based on the temporal correspondance between the shallowing of the eastern sector and the deepening of the western region.

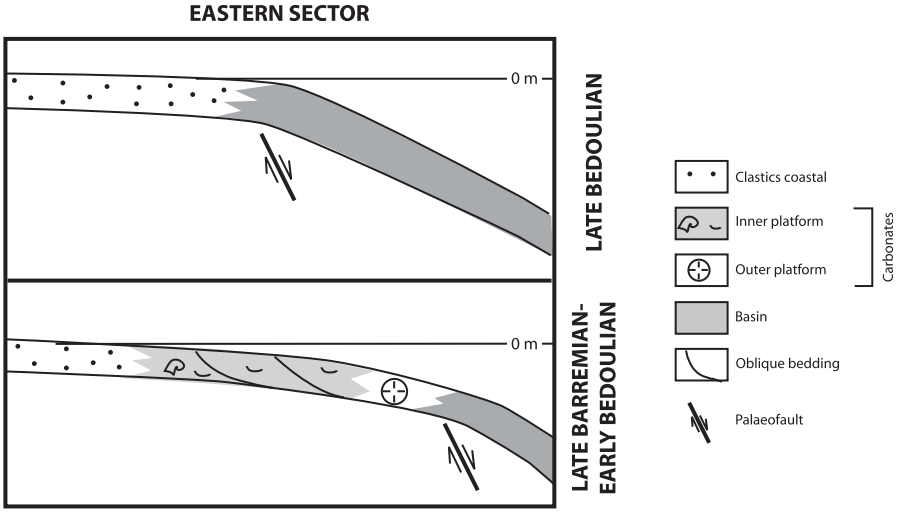

Fig. 10. Cross section of the eastern sector (Amasra area) showing the distribution of the main palaeoenvironments and their evolution from a late Barremian-early Bedoulian mixed carbonate-siliciclastic ramp to a late Bedoulian siliciclastic downwarped system.

9. Conclusions

Barremian-lower Aptian platform carbonates (“Urgonian limestones”) of the northern margin of the Istanbul zone extend over nearly 80 km from Zonguldak to the Kurucasile area along the Black Sea coast. New stratigraphic data on the “Inpiri” Formation of the Inpiri-Kurucasile area, based on the identification of calcareous algae, foraminifera and rudists show that this lithostratigraphic unit is stratigraphically and lithologically equivalent to the Öküşmedere Formation. Some of the biostratigraphic markers are reported for the first time in Anatolia, for instance the calcareous algae: *Sporolithon phylloideum*, *Salpingoporella melitae*, *Acroporella radoiciciae*, and *Pseudoactinoporella fragilis*. Foraminifera are represented by several forms belonging to the “*Neotrocholina*” group with a significant biostratigraphic potential; of special interest is the *Montseciella arabica-Rectodictyoconus giganteus* lineage, the stratigraphic distribution of which is used to distinguish the Barremian from the lower Aptian. Lower Aptian beds also yield relatively advanced caprinid rudists, with a problematic systematic position.

The Öküşmedere Formation is relatively thin, terrigeneous-rich, and rudist-free or rudist-poor in the Kurucasile sector and thick, terrigeneous-poor, and rudist-rich from Amasra to Zonguldak, with a set of marker beds including either charophytes or *Palorbitolina*, and a coral unit underlying ammonite bearing marls. Terrigeneous-rich carbonates from the eastern sector are interpreted as marginal marine coastal, infralittoral environments and grade distally, northward, to sponge-rich, circa-littoral, nearly pure limestones, then to marly basinal sediments, in a distance of 5 km. By contrast “Urgonian type” limestones from the Zonguldak-Amasra region possess a wide extent and no transitional outcrop to coastal or basinal sediments have been observed. As in many parts of the Tethys *Palorbitolina* facies marks a break in platform evolution. The foregoing dual lithological and palaeoenvironmental system documents a transition from a typical platform westward, to a mixed siliciclastic-carbonate ramp eastward, in correspondence with the existence of a terrigeneous source (fluviatile complex) eastward, controlled by both the nature of the adjacent exposed area and tectonic factors affecting the overall continental margin, that is a northward downwarping possibly due to the southward rotation of tilted blocks. Structural controls are also invoked to explain the absence of shallow water carbonates on the southern flank of the exposed area, which is lined by coastal clastics graded to deep water sediments. The mode of platform demise in mid-Bedoulian times between the two regions of the Black Sea coast also reflects the role of tectonic factors coupled with the dynamics of the adjacent terrestrial domain: platforms from the western region were drowned below deeper marly sediments whereas the eastern ramp was buried below coastal clastics.

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