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Facies Characteristics of the Cenomanian–Maastrichtian Sequence of the Beydaglari Carbonate Platform, Korkuteli Area, Western Taurides, Turkey[1]

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Abstract

In the Korkuteli area of the western Taurides, Upper Cretaceous sequences consist of the neritic and hemipelagic Beydaglari Formation and the pelagic Akdag Formation. These formations show important facies variations and stratigraphic gaps. The Beydaglari Formation, ranging in age from Cenomanian to Santonian, is approximately 600 m thick, and is composed mainly of platform-type neritic carbonates. Five microfacies indicating tidal-flat, subtidal (lagoonal), reef, and forereef sub-environments are distinguished in the neritic carbonates of the formation. Benthic foraminifera and rudists are the main biological components that provide information about the environment and age of the unit. In addition, cryptalgal lamination also is recognized as an important tool in determining environment. The uppermost part of the Beydaglari Formation is composed of hemipelagic carbonates (a sixth microfacies), which were deposited under basinal conditions. The Akdag Formation consists of planktonic foraminifera-bearing pelagic carbonates, suggesting a Campanian–Maastrichtian age and deposition as a basinal facies. The formation disconformably overlies the Beydaglari Formation along an erosional surface.

Eocene transgressive pelagic clayey carbonates of the Ulucak Formation unconformably overlie the Upper Cretaceous carbonate sequences. Detailed investigations have shown that, at least in the studied part of the autochthonous unit, the platform began to drown during the Santonian and that a true basinal environment persisted from the Campanian to the Maastrichtian. Two erosional phases are recorded; one occurred after the Santonian and is characterized by a prominent erosional surface, and the other is responsible for the post-Cretaceous regression.

Introduction

THE SEQUENCES of the Beydaglari autochthonous unit were deposited on the northern paleomargin of the Arabian-African plate, and are equivalent to the rest of the Taurides and Zagrides to the east and the Hellenides and Dinarides to the west. This unit is bordered on the west by the Lycian nappes and on the east by the Antalya nappes (Fig. 1); it is mainly composed of Triassic to Tertiary platform-type carbonates. Many studies focused on the Beydaglari carbonate platform have shown that the sequences are characterized by breaks in deposition and important facies variations in both the neritic and pelagic carbonates (Özgül, 1976; Farinacci and Köylüoglu, 1982; Özyegin et al., 1985; Farinacci and Yeniay, 1986; Gültekin, 1986; Özkan and Köylüoglu, 1988).

These facies variations are readily observable in the Korkuteli area. In order to elucidate lateral and vertical variations in the Upper Cretaceous carbonates and the evolution of the platform, a detailed microfacies and biostratigraphic study was carried out. Six measured stratigraphic sections are presented herein (Fig. 2). In this study, the limestone classification of Folk (1959) is followed.

Stratigraphy and Facies Characteristics

Three formations belonging to the Beydaglari autochthonous unit have been distinguished. Two of these and their facies characteristics have been studied in detail.

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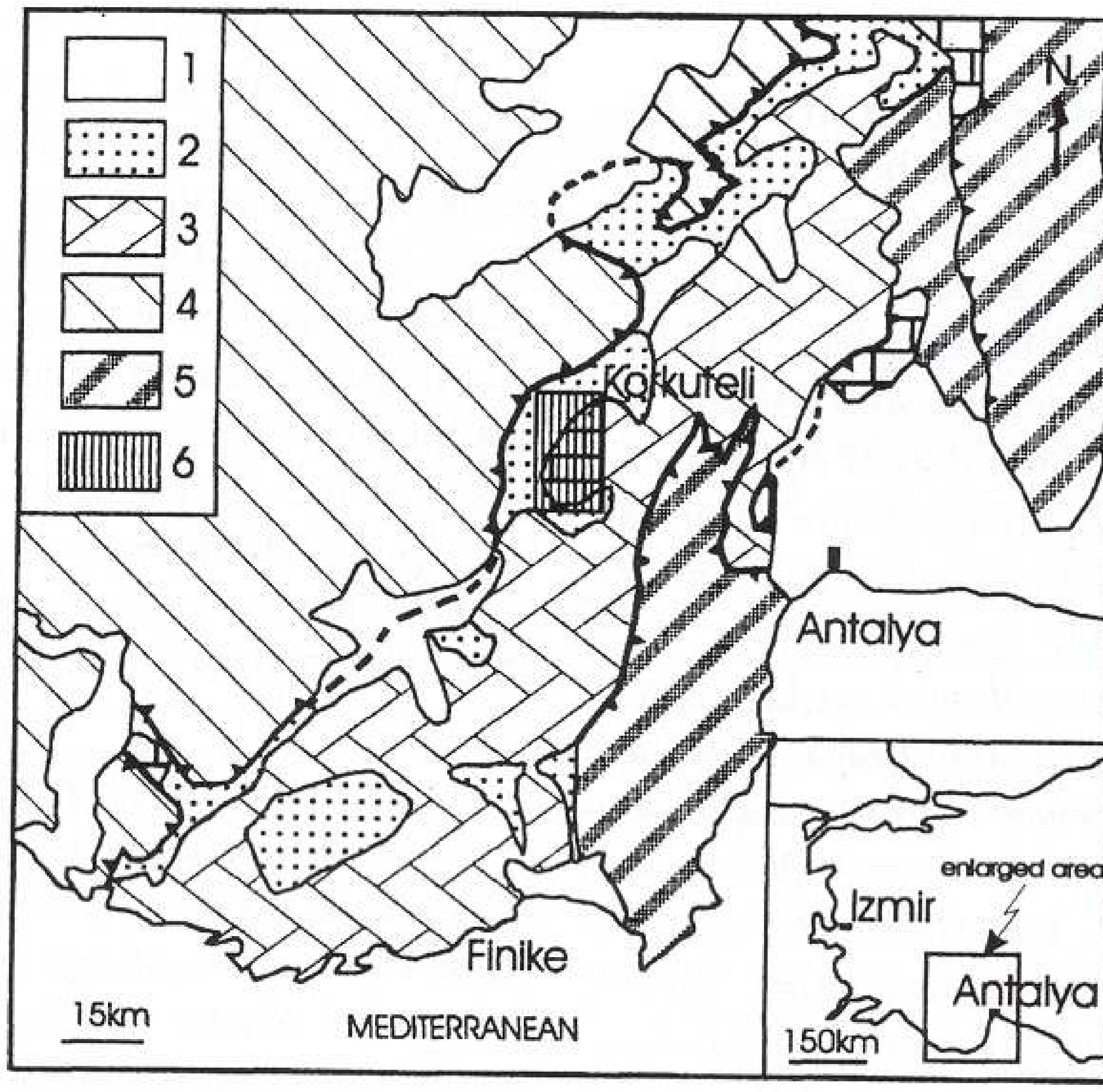

FIG. 1. Simplified geological map of the Western Taurides (from Poisson, 1977). Legend: 1 = Quaternary; 2 = Tertiary; 3 = Beydaglari autochthonous unit; 4 = Lycian nappes; 5 = Antalya nappes; 6 = study area.

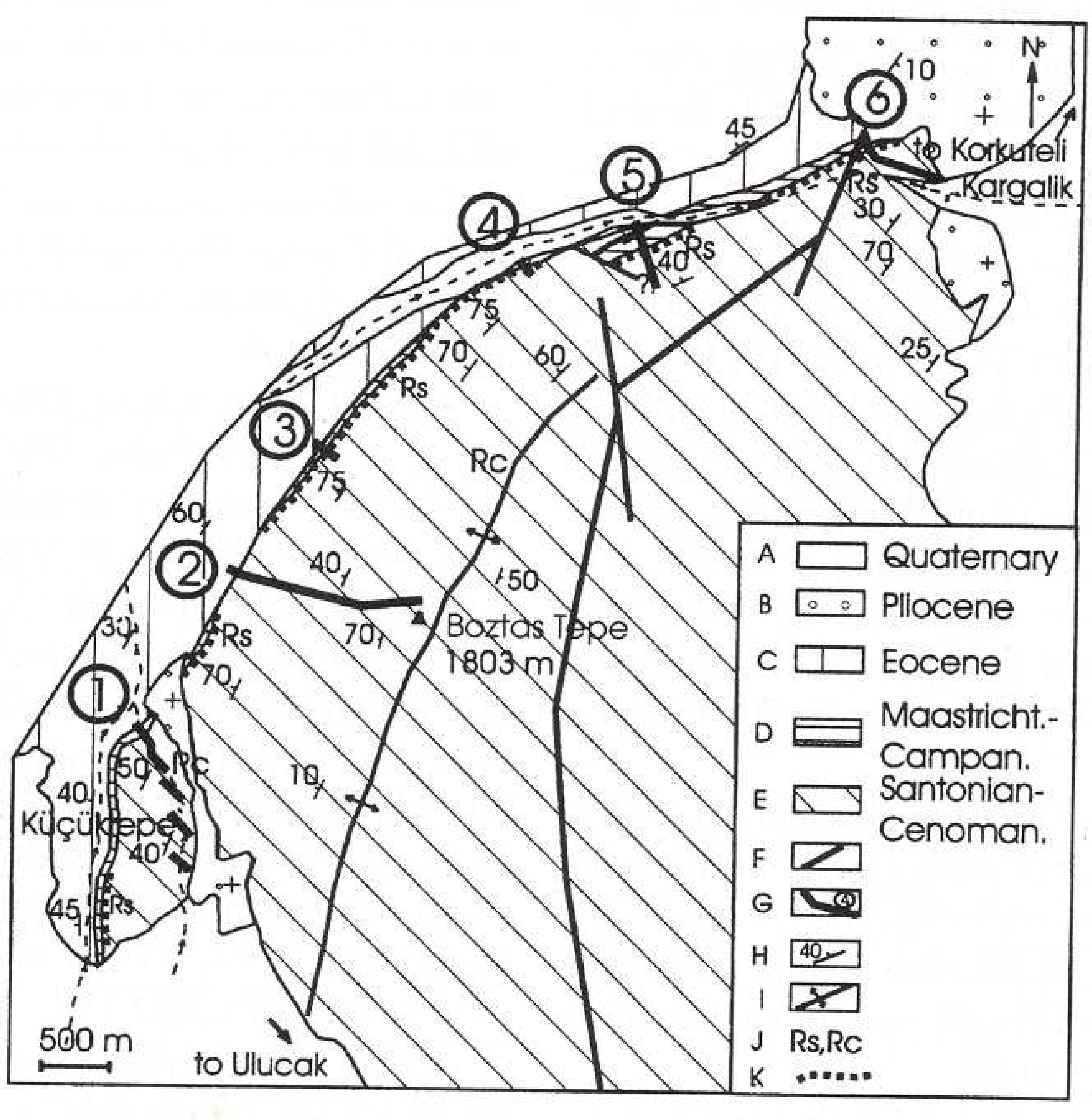

FIG. 2. Geological map of the Korkuteli region. Legend: A = alluvium; B = Pliocene conglomerate; C = Ulucak Formation; D = Akdag Formation; E = Beydaglari Formation; F = fault; G = section line and section number; H = strike and dip; I = axis of anticline; J = rudist reef of Santonian (Rs) and Cenomanian (Rc) age; K = pelagic carbonates of Santonian age.

Beydaglari Formation

The formation can be divided into two main levels; at the bottom, medium- to thick-bedded, cream-colored peritidal carbonates form the main part of the formation and cream-colored, massive pelagic carbonates occur at the top. Our microfacies studies have mainly focused on the neritic carbonates.

Some levels, especially those deposited in a subtidal environment, contain rich benthic foraminifera. Because of the restriction of the environment, they are rich in number but low in diversity. The fauna—consisting of *Pseudodomia viallii* (Colalongo), *Chrysalidina gradata* d'Orbigny, *Pseudolituonella reicheli* Marie, *Pseudorhapydionina dubia* (de Castro), *P.* cf. *laurinensis* (de Castro), *Nummoloculina* sp., *Nezzazata* sp., and *Cuneolina* sp.—is recorded in the lower part of the formation. Bignot and Poisson (1974) found a similar foraminifer association around Katran Dag, northeast of the study area. *P. laurinensis*, associated with *C. gradata* and *Cisalveolina fallax* Reichel, is accepted as an indicator of the late Cenomanian in Italy (de Castro, 1965, 1966), in Portugal (Berthou and Philip, 1972), in Greece (Guernet, 1971), and probably in Iran (Sampo, 1969). *P. viallii* was found in the level beneath *P. laurinensis* and *C. fallax* in Italy (Sartoni and Crescenti, 1962; Colalongo, 1963; Devoto, 1964; Farinacci and Radoicic, 1965; de Castro, 1966; Angelucci and Devoto, 1966), in Yugoslavia (Radoicic, 1960), in Greece (Fleury, 1972), in Lebanon (Saint-Marc, 1969, 1970), and in Tunisia (Bismuth et al., 1967; Bignot and Poisson, 1974).

P. viallii had been regarded as a perfect guide to determine the middle Cenomanian. Although Bignot and Poisson (1974) also found *P. viallii* beneath the level with *P. laurinensis*, they found no evidence to support the previously suggested idea; thus, they were content to accept that *P. viallii* indicated a level beneath the late Cenomanian with *P. laurinensis.*

Farinacci and Yeniay (1986) also found a similar foraminiferal fauna in the Beydaglari autochthonous unit and used it to propose a Cenomanian age. In the present study, *P.* cf. *laurinensis* is found together with *P. viallii,* and carbonates containing this fauna are accepted as Cenomanian.

The rudist fauna associated with benthic foraminifera consists especially of caprinids and radiolitids, which indicate a Cenomanian age. Özer (1988) described a rudist fauna from the Cenomanian of the Katran Dag (Sam Dag) (30 km east of the study area). The present forms are similar to Özer's (1988) fauna, which consists of *Neocaprina gigantea* Plenicar, *Caprina schiosensis* Boehm, *Caprina* cf. *carinata* (Boehm), and *Ichthyosarcolites bicarinatus* (Gemmellaro). The thickness of these levels is about 300 m. These levels grade into the carbonates that have the same lithologic and microscopic features as the underlying ones, but they do not include diagnostic foraminifera and rudist fossils. The age of these levels is controversial. Toward the top, rudistid limestones indicating a Santonian–Campanian age appear (see Fig. 4, section 6). The thickness of the carbonates above the Cenomanian is ~300 m.

Toward the top, neritic carbonates pass into cream-colored, massive, hemipelagic carbonates with chert nodules. The planktonic foraminifera suggest a Santonian age (Sari, 1999). Macroscopic features of neritic and hemipelagic carbonates are nearly the same. In some sections, these hemipelagic levels are not observable because of erosion (Figs. 3 and 4, section 1). The thickness of the hemipelagic carbonates is ~15 m in Kargalik (Fig. 4, section 6), 10 m in section 4, and ~3 m in section 3.

Carbonates of the Beydaglari Formation mainly accumulated in a platform environment that existed from the Cenomanian to the Santonian. Microscopic studies have indicated peritidal, lagoonal, reef, fore-reef, and hemipelagic subenvironments (Fig. 4).

The following microfacies (MF) have been distinguished for the aforementioned subenvironments. These are the main microfacies and they are mutually transitional.

MF-1: Laminated pelsparite/pelmicrite and fenestral micrite microfacies (Figs. 5A and 5B). This microfacies consists of alternating pelsparite/pelmicrite and fenestral micrite. The matrix is profoundly mud-supported. The most characteristic feature of this microfacies is a fenestral fabric that is indicative of deposition in intertidal and especially in supratidal subenvironments. Ostracods are generally widespread, but benthic foraminifera scattered in micrite are present locally. This microfacies in places grades into the cryptalgal laminated pelsparite/pelmicrite, similar to Wilson's (1975) standard microfacies (SMF) 19.

MF-2: Alternating cryptalgal and pelsparite/pelmicrite lamina microfacies (Fig. 5C). This microfacies consists of cryptalgal laminates alternating with pelsparite and more typically with pelmicrite. Benthic foraminifera occur sparsely. Peloids are present locally in the cryptalgal lamination. Laminates formed by blue-green algae are especially

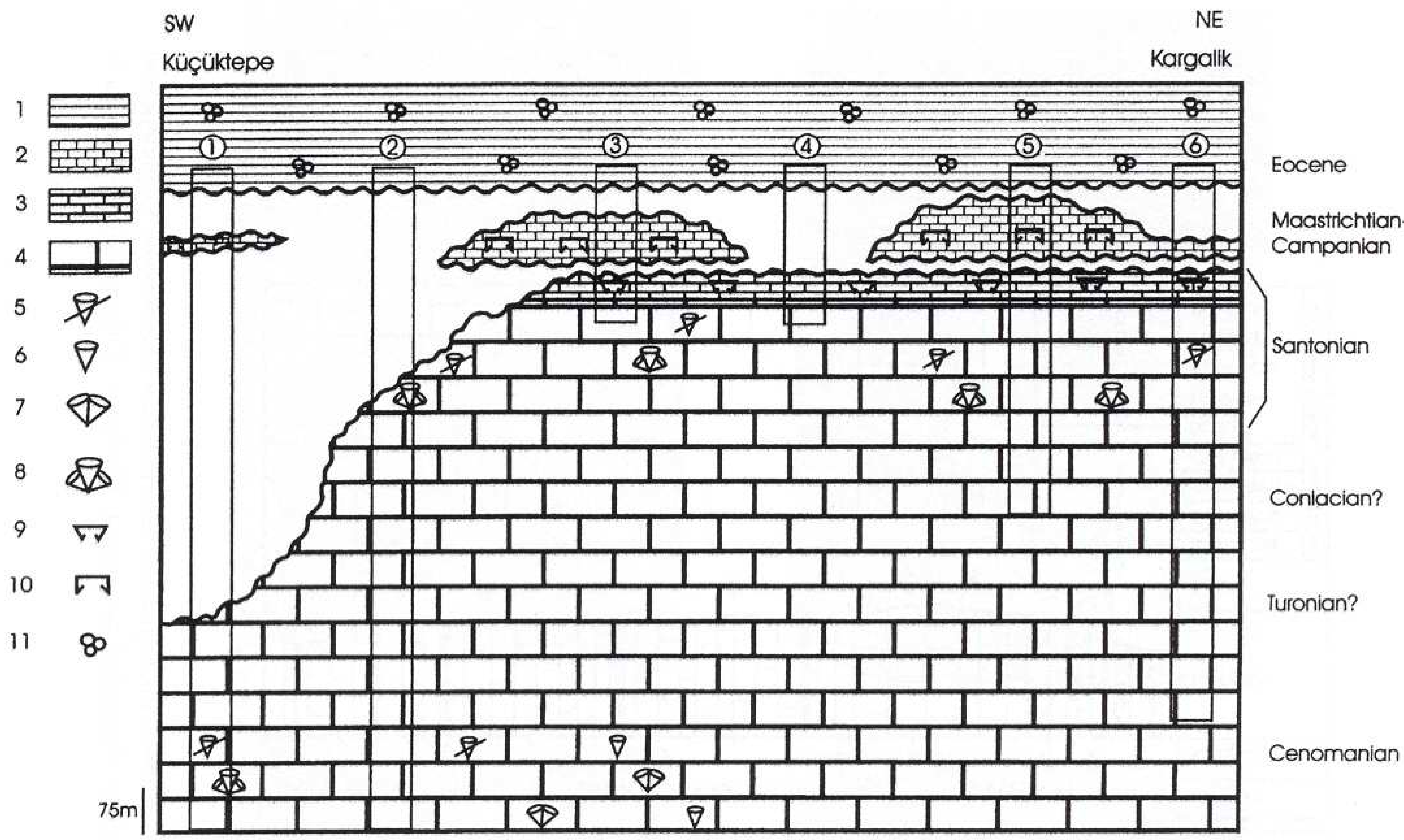

FIG. 3. Facies distribution of the study area between Küçüktepe and Kargalik. Locations of the measured stratigraphic sections: 1 = pelagic clayey carbonates of the Ulucak Formation; 2 = thin-bedded cherty pelagic carbonates of the Akdag Formation; 3 = massive hemipelagic carbonates of the Beydaglari Formation; 4 = neritic carbonates of the Beydaglari Formation; 5 = rudist fragments; 6 = individual rudists; 7 = small rudist biostrome; 8 = rudist reef; 9 = Santonian planktonic foraminifera; 10 = Campanian–Maastrichtian planktonic foraminifera; 11= Eocene planktonic foraminifera (thickness of the pelagic levels is exaggerated).

lamellar but, in some levels, they cut each other; this fabric is referred to as anastomosing laminae, and this is the most characteristic fabric of this microfacies. Some cryptalgal-laminated limestones include sparse, small rudist biostromes.

Cryptalgal lamination is the characteristic structure of tidal ponds (Wilson, 1975), and also can be seen in various bathymetric situations, from tidal-flat to very shallow but unagitated subtidal. This microfacies corresponds to Wilson's SMF-21.

MF-3: Sparse benthic foraminifera-bearing pelsparite/pelmicrite microfacies (Fig. 5D). Pelmicrite is a more common fabric than pelsparite, and these fabrics rarely alternate. Dispersed, small benthic foraminifera occur throughout this facies. Pure micrite with rare stromatolitic algae and scattered foraminifera is associated locally with this microfacies. Pelsparites consisting of well-sorted, dark peloids are indicative of tidal-channel deposition, and pelmicrites are especially deposited in intertidal-flat environments (Gültekin, 1986). This microfacies has characteristics similar to Wilson's SMF-16.

MF-4: Rich benthic foraminifera-bearing biomicrite microfacies (Fig. 6A). This facies ranges from pure micrite with rare benthic foraminifera to sparse peloid biomicrite with abundant benthic foraminifera. Locally, rudist fragments and dismicrite are observed in this facies. The majority of the benthic foraminifera in this facies are typically wide-ranging and eurytopic forms, but in places, diagnostic forms accompany this assemblage.

Pseudodomia viallii was found only in one sample (thin section no. [tsn] 23), and is associated with *Crysalidina gradata*, *Pseudolituonella reicheli*, *Pseudorhapydionina dubia*, *P.* cf. *laurinensis*, *Nummoloculina* sp., *Nezzazata* sp., and *Cuneolina* sp. Toward the top of the sequence, *Bolivinopsis capitata* Yakovlev occurs (tsn:12) in this facies.

In the upper part of the formation, the same microfacies contains wide-ranging forms such as *Dicyclina schlumbergeri* Munier-Chalmas, *Moncharmontia apenninica* (de Castro), and miliolids, appearing as a special microfacies. *D. schlumbergeri* embedded in micrite is the main biologic content of the facies (Fig. 6A). The diversity of the benthic

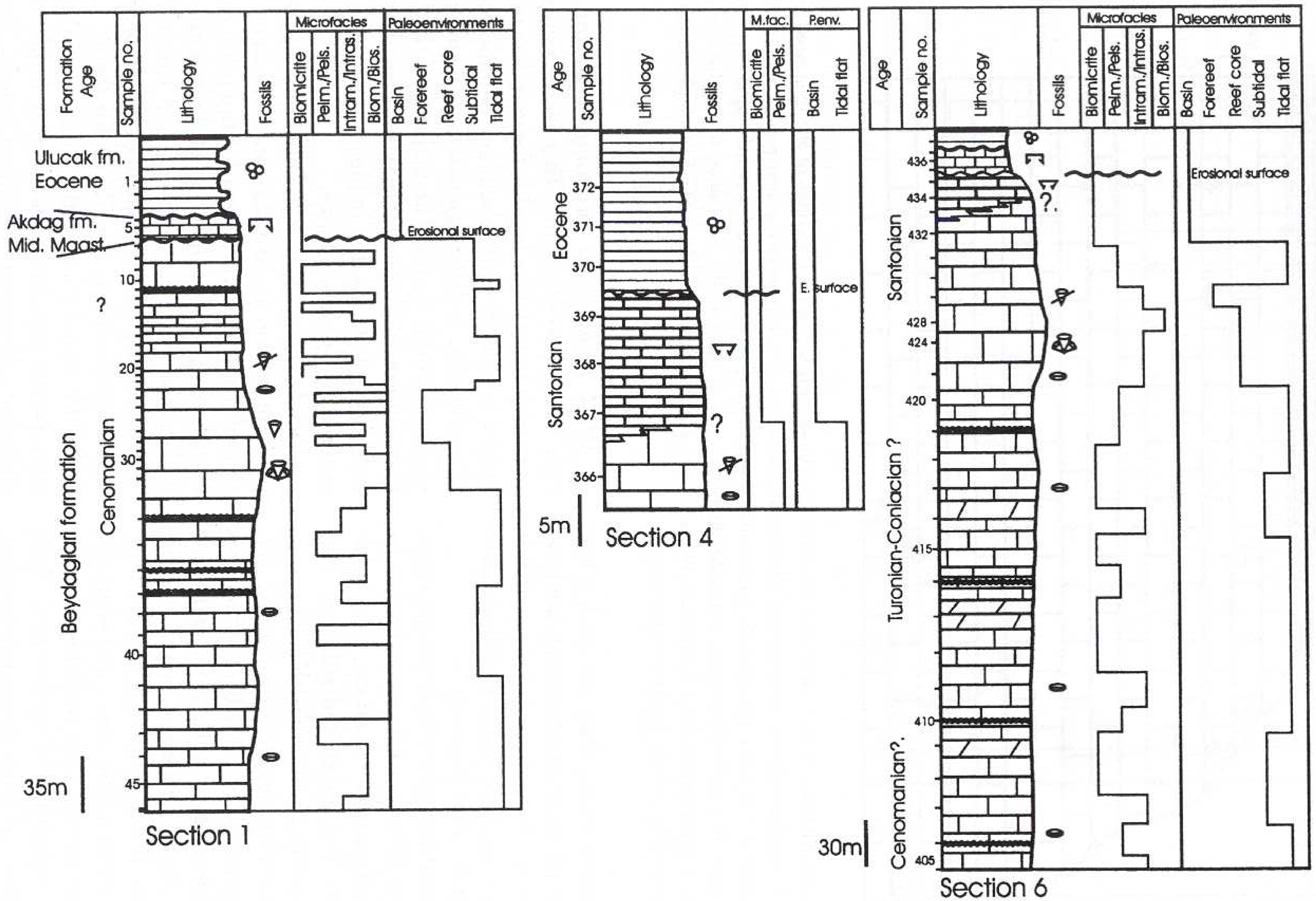

FIG. 4. Measured stratigraphic sections showing the microfacies and depositional environments of the carbonates of the Beydaglari autochthonous unit between Küçüktepe and Kargalik. See Figures 2 and 3 for the locations of the sections, and Figure 3 for explanations of the symbols. Cryptalgal lamination. Thickness of the pelagic carbonates is exaggerated.

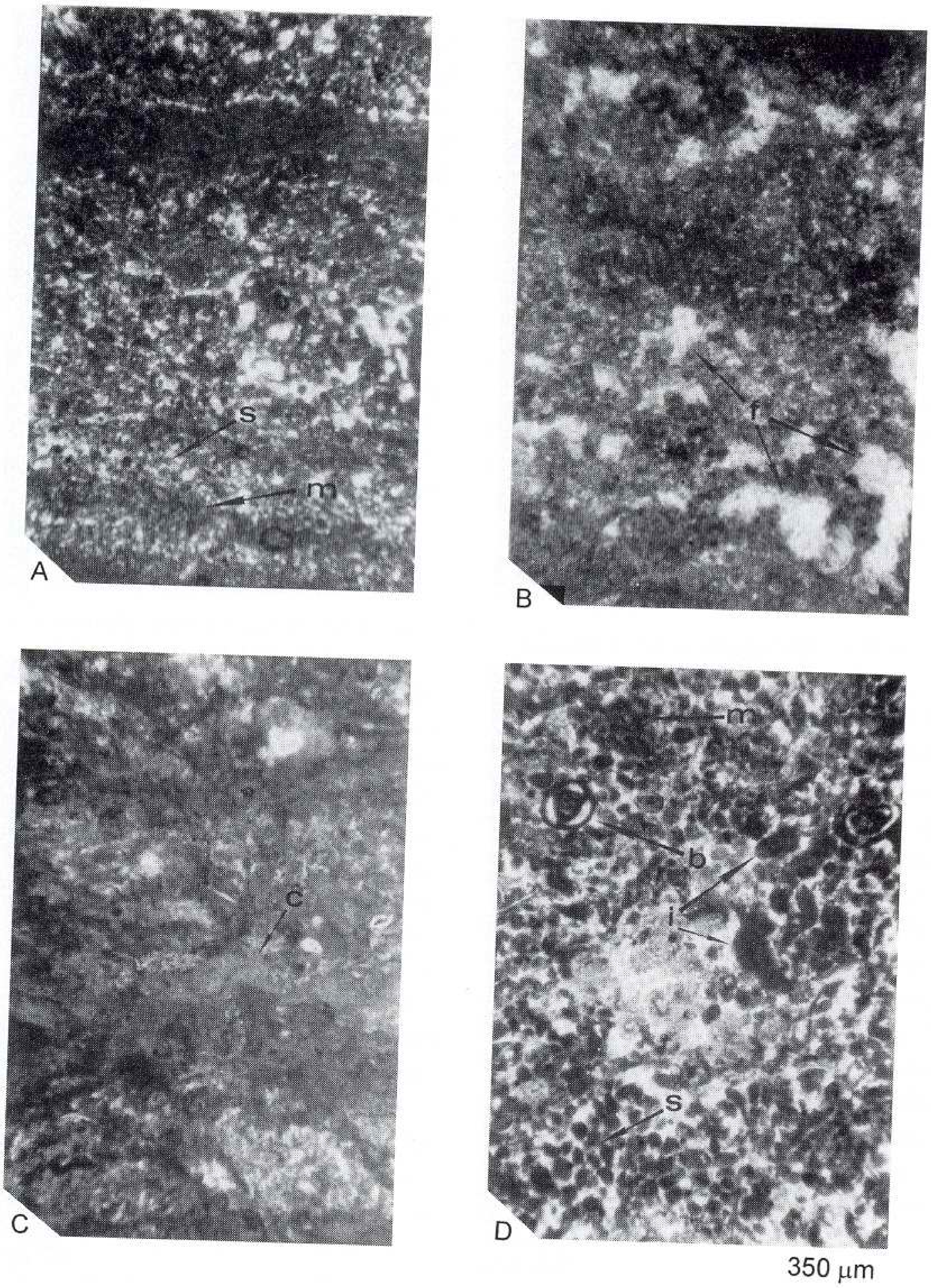

FIG. 5. A. Alternation of laminated pelsparite (s) and pelmicrite (m). Lime-mud matrix locally rather dominant (Microfacies 1). B. Fenestral micrite (f = fenestrae) indicative of deposition in intertidal and especially in supratidal subenvironments, locally accompanied by laminated pelsparite and pelmicrite (Microfacies 1). C. Cryptalgal lamination (c) is a characteristic structure of tidal ponds and shallow but not agitated subtidal subenvironments. Lime mud rather dominant with dispersed peloids (Microfacies 2). D. Pelsparite (s) and pelmicrite (m) with intraclasts (i) and scattered benthic foraminifera (b) (mainly miliolids) (Microfacies-3). Scale bar is 350 μm for all figures.

foraminifera is quite low; although they are poor in a number of species, they are abundant in terms of the number of individuals.

The microfacies must have formed in a subtidal (lagoonal) environment where small rudistid buildups grew. This microfacies may be equivalent to Wilson's SMF-8.

MF-5: Rudist fragment–bearing biosparite/biomicrite microfacies (Fig. 6B). Rudistid limestones constitute two main levels in the Beydaglari Formation. The lower level is mainly composed of caprinids and radiolitids (*Sauvagesia* sp., *Durania* sp.) of Cenomanian age. Only one true rudist reef has been observed (Fig. 4, section 1). In addition, many small

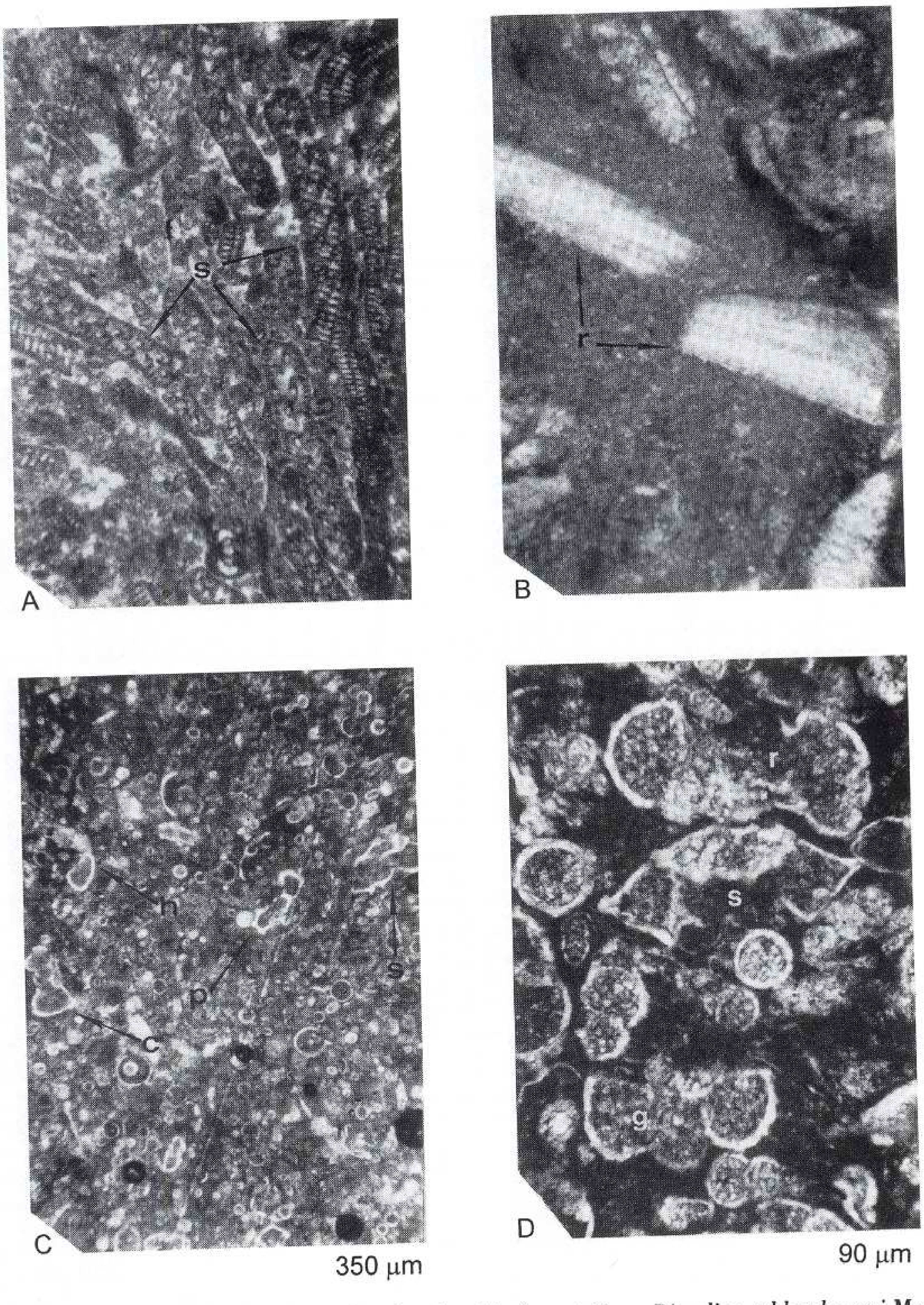

FIG. 6. A. Biosparite and biomicrite with abundant benthic foraminifera. *Dicyclina schlumbergeri* Munier-Chalmas (s) is the dominant species of this special microfacies (Microfacies 4). B. Biomicrite with rudist fragments (r) (Microfacies 5). C. Biomicrite with planktonic foraminifera. *Dicarinella concavata* (Brotzen) (c), characteristic form for Coniacian and Santonian; *Marginotruncana pseudolinneiana* Pessagno (p); *M.* cf. *sigali* (Reichel) (s); and *Hedbergella* sp. (h) (Microfacies 6). D. Biomicrite with diverse planktonic foraminifera from the pelagic carbonates of the Akdag Formation. *Gansserina gansseri* (Bolli) (g), *Globotruncanita subspinosa* (Pessagno) (s), and *Rugoglobigerina* sp. (r) indicate the lower part of the middle Maastrichtian. Scale bar is 350 μm for Figures 1, 2, and 3 and 90 μm for Figure 4.

biostromes, especially consisting of radiolitids, are present in this level. They are thought to be distributed intermittently within the restricted platform (Fig. 3). The upper level is chiefly composed of *Hippurites nabresinensis* Futterer, *H. colliciatus* Woodward, and *Vaccinites taburni* (Guiscardi). The rudist fauna indicates a Santonian–Campanian age (Fig. 4, sections 5 and 6). These forms always build a reef of variable thickness and can be followed from southwest to northeast of the study area. This reef is not observable in section 1 (Figs. 3 and 4) because of post-Santonian erosion. This microfacies is always observed around and in the reefs and rudistid biostromes. Biologic components are mostly rudist fragments and benthic foraminifera. Upper levels of the Santonian reefs are rich in rudist fragments, and carbonate cement is dominant as a result of the removal of lime mud by winnowing. Carbonates at this level may have accumulated in a forereef environment. This microfacies is very similar to Wilson's SMF-12.

MF-6: Planktonic foraminifera–bearing biomicrite facies (Fig. 6C). Limestones (especially pelsparite, pelmicrite, and biomicrite) with *Cuneolina* sp., rotalids, bryozoans, and spheroidal forms overlie the rudist fragment–bearing limestones. Toward the top, the benthic foraminifera ratio decreases, the spheroidal form ratio increases, and planktonic foraminifera begin to appear. This microfacies forms the uppermost part of the Beydaglari Formation (Figs. 3 and 4) and is composed of mainly pure micrite with planktonic foraminifera, spheroidal forms, rare echinid, rudist, and lamellibranchiata fragments. The planktonic foraminifera generally show low diversity (Fig. 6C). *Dicarinella asymetrica* (Sigal), *D. concavata* (Brotzen), *Marginotruncana pseudolinneiana* Pessagno, *M. coronata* (Bolli), *M.* cf. *sigali* (Reichel), *Marginotruncana* sp., *Contusotruncana fornicata* (Plummer), *Heterohelix* sp., *Rotalina* sp., *Goupillaudina* sp., and *Hedbergella* sp. are the main components of this facies and suggest a Santonian age (Sari, 1999). The disappearance of *D. asymetrica* and *D. concavata* has been used by many authors to draw the Santonian–Campanian boundary (Robaszynski et al., 1984; Caron, 1985; Almogi-Labin et al., 1986; Sliter, 1989).

Planktonic foraminifera scattered throughout the micrite are generally small and thin tested. It should be remembered that the pelagic facies do not necessarily indicate great depth. The carbonates in which the planktonic foraminifera first appear are considered to represent the transitional zone between the neritic and hemipelagic facies. This microfacies may correspond to Wilson's SMF-3.

Akdag Formation

The Akdag Formation consists mainly of thin-bedded (2 to 10 cm), cherty, clayey, pelagic limestones ("scaglia" limestones) that disconformably overlie the Beydaglari Formation along an erosional surface (Figs. 3 and 4) that shows iron oxidation, silicification, and bioturbation indicative of a later period with low rates of sedimentation due to relative starvation (Rosales et al., 1994). This formation contains diverse planktonic foraminifera indicating a Campanian–Maastrichtian age (Fig. 6D). The maximum thickness of the formation is about 75 m in Kargalik (section 5), and thins to about 1.5 m around Küçüktepe (section 1).

Globotruncana arca (Cushman), *G. bulloides* Vogler, *G.*(?) *insignis* Gandolfi, *G. linneiana* (d'Orbigny), *G. mariei* Banner & Blow, *G. orientalis* El Naggar, *G. rosetta* (Carsey), *G. ventricosa* White, *Globotruncanita atlantica* (Caron), *Gt. calcarata* (Cushman), *Gt. elevata* (Brotzen), *Gt. stuartiformis* (Dalbiez), *Gt. subspinosa* (Pessagno), *Contusotruncana fornicata*, *Archaeglobigerina* sp., *Rugoglobigerina* sp., and *Heterohelix* sp. make up the Campanian assemblage (Sari, 1999). The Campanian–Maastrichtian boundary is marked by the disappearance of *Gt. calcarata* (Robaszynski et al., 1984; Caron, 1985; Almogi-Labin et al., 1986; Sliter, 1989).

Globotruncana aegyptiaca Nakkady, *G. arca*, *G. bulloides*, *G. dupeublei* Caron et al., *G. esnehensis* Nakkady, *G. falsostuarti* Sigal, *G. linneiana*, *G. mariei*, *G. orientalis*, *G. rosetta*, *G. ventricosa*, *Globotruncanita angulata* (Tilev), *Gt. conica* White, *Gt. pettersi* (Gandolfi), *Gt. stuarti* (de Lapparent), *Gt. stuartiformis*, *Gt. subspinosa* , *Contusotruncana contusa* (Cushman), *C. fornicata*, *Gasserina gansseri* (Bolli), *G. wiedenmayeri* (Gandolfi), *Abathomphalus mayaroensis* (Bolli), *Archaeglobigerina* sp., *Rugoglobigerina rugosa* (Plummer), *Heterohelix* sp., and *Racemiguembelina* sp. make up the Maastrichtian assemblage (Sari, 1999). The appearance of *G. gansseri* is used by many researchers to draw the early–middle Maastrichtian boundary (Robaszynski et al., 1984; Caron, 1985; Almogi-Labin et al., 1986; Sliter, 1989). *A. mayaroensis* is scarce in the study area and is the characteristic form for the late Maastrichtian.

The microfacies of this formation is very characteristic and comprises pure micrite with rich and highly diversified planktonic foraminifera and spheroidal forms (Fig. 6D). The planktonic foraminifera of the formation are especially thick tested, well developed large forms indicative of K-selection, and great depth indicates a true basinal facies (Wilson's SMF-3).

Ulucak Formation

The Ulucak Formation, which unconformably overlies the Beydaglari and Akdag formations, was not studied in detail. The formation mainly comprises thin-bedded, cherty-layered, clayey carbonates with alternating mudstone, and contains planktonic foraminifera indicating an Eocene age (Poisson, 1977).

The microfacies of the formation is typical of a basinal environment. Planktonic foraminifera are embedded in lime-mud matrix (Wilson's SMF-3).

Conclusions and Events on the Platform during the Late Cretaceous

Two formations of the Beydaglari autochthonous unit have been studied in detail and the following conclusions have been drawn. The microfacies and microenvironments of the neritic carbonates of the Beydaglari Formation have been established. The five main microfacies (MF-1 to MF-5) were deposited in tidal-flat, subtidal (lagoonal), reef, and fore-reef subenvironments. These conditions persisted from Cenomanian to Santonian time, leading to the deposition of an almost 600 m thick carbonate sequence where small rudistid build-ups and reefs developed.

Slight drowning of the platform during the Santonian resulted in a hemipelagic environment (MF-6) (shelf sea with open circulation) on the platform that gave rise to the appearance of planktonic foraminifera and spheroidal forms. This level is the uppermost part of the Beydaglari Formation.

The Akdag Formation, deposited in a true basinal environment, disconformably overlies the Beydaglari Formation along an erosional surface. Planktonic foraminifera suggest a Campanian–Maastrichtian age. This prominent erosional surface can be traced throughout the study area.

The Ulucak Formation unconformably overlies different levels of the two formations. Two breaks in deposition have been clearly observed. The first break occurred after Santonian regression. Transgressive sediments of the Akdag Formation disconformably overlie the different levels of the Beydaglari Formation. Evidence of that relationship includes the erosional surface that cuts the late Cenomanian (?) carbonates at Küçüktepe, and the first deposition on that surface in middle Maastrichtian time (Fig. 4, section 1). This surface separates the Santonian and Campanian pelagic carbonates in the northeastern part of the study area (Fig. 3, sections 3, 5, and 6).

The second break occurred during the post-Cretaceous regression. Eocene transgressive sediments unconformably overlie the different levels of the pelagic sediments of the Akdag formation (Fig. 3, sections 1, 3, 5, and 6), and pelagic carbonates (Fig. 3, section 4) and/or neritic carbonates (Fig. 3, section 2) of the Beydaglari Formation.

These data demonstrate that either some parts of the platform were exposed subaerially or a great amount of sediments belonging to the Beydaglari and Akdag formations were eroded during the post-Santonian and post-Cretaceous regressions. Both of these alternatives may be possible. It is clear that conditions were rather changeable on the platform during the Late Cretaceous.

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