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Biostratigraphy and paleoenvironmental interpretation of the Middle Miocene submarine fan in the Adana Basin (southern Turkey)

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Abstract: The turbiditic Cingöz Formation of the Karaisah-Çatalan-Eğner region, Adana Basin, southern Turkey was studied in detail in two sections based on planktonic foraminifers, calcareous nannofossils and trace fossils. The Middle Miocene (Langhian–Serravalian) age of the sediments is supported by the *Praeorbulina glomerosa curva* and *Orbulina suturalis* planktonic foraminiferal Zones and by standard nannoplankton Zones NN5 *Sphenolithus heteromorphus* and NN6 *Discoaster exilis*. Moreover, 24 ichnotaxa were identified and attributed to the *Skolithos-Cruziana*, mixed (*Skolithos-Cruziana* and *Nereites*), and *Nereites* ichnofacies. Fossil assemblages indicate eutrophic and oligotrophic conditions. In the Langhian, the distribution and percentage abundances of temperature sensitive planktonic taxa including *Globigerina falconensis* reflect temperate to cold surface waters in the depositional area of the western and eastern fans of Cingöz Formation. In Serravalian, higher numbers of warm-water prefering taxa indicate the rise in temperature in the western fan.

Key words: Middle Miocene, southern Turkey, biostratigraphy, paleoenvironmental interpretation, calcareous nannoplankton, planktonic foraminifers, trace fossils, ichnofacies.

Introduction

The Cingöz submarine fan system is located approximately fifty km north of Adana in 1:100,000 Kozan N34 Sheet in the northern part of the Adana Basin (Fig. 1). The following studies on the studied region and closed areas have been published: Schmidt (1961), Özgül et al. (1972, 1973), Yetiş & Demirkol (1984) studies about the stratigraphic properties of the area; Görür (1980), Erten (1983), Yalçın & Görür (1984), Yetiş et al. (1986), Gökçen et al. (1987), Naz & Çuhadar (1988), Ünlügenç et al. (1993), Gürbüz (1998) studies about the sedimen-

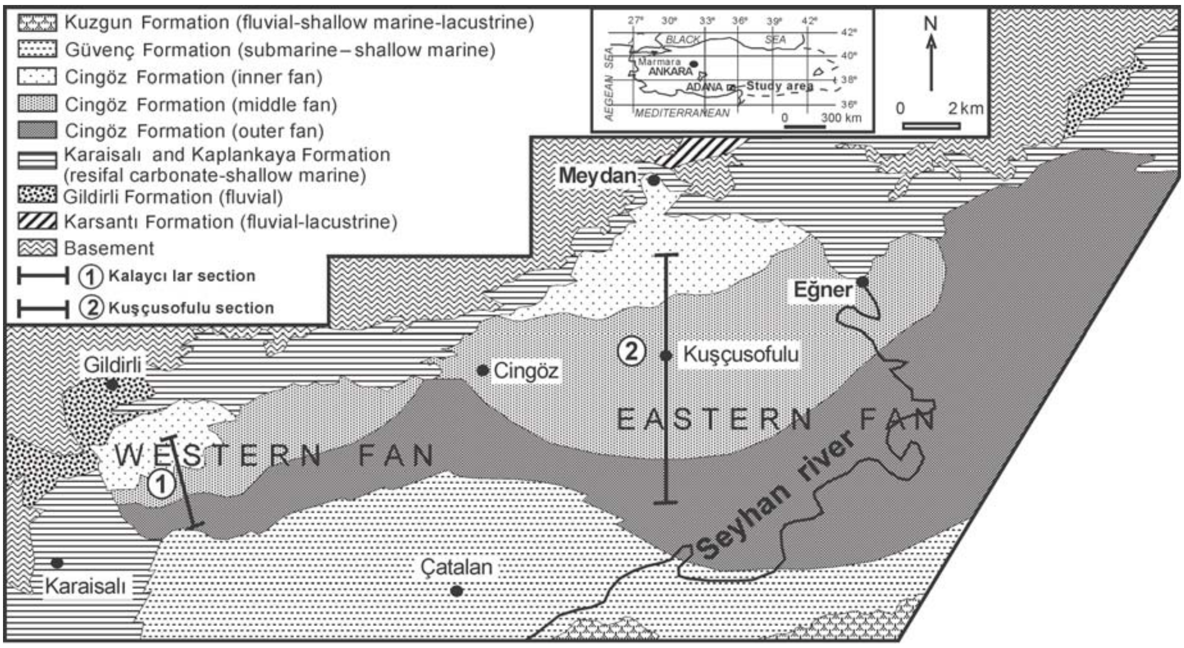

Fig. 1. Geological sketch map and the position of the investigated sections (after Gürbüz 1993 modified).

tology of the area; Nazik & Toker (1986), Toker & Yıldız (1991), Ünlügenç & Şafak (1992), Nazik & Gürbüz (1992), Toker et al. (1996), Akça et al. (1998), Yıldız et al. (2003) studies about the paleontology; Uchman & Demircan (1999a,b), Uchman et al. (2002), Demircan & Toker (2003, 2004) dealt with trace fossils; Özgül (1976), Şengör et al. (1985), Gökçen et al. (1988) studies concentrated on the plate tectonic evolution of the area and vicinity while Ketin (1966) and Ayhan (1978) studies concentrated on the general geology.

The purpose of this study is to present the planktonic foraminiferal and calcareous nannoplankton biostratigraphy of the Cingöz Formation, to evaluate depositional environments on the basis of trace fossil assemblages, and to determine changes in paleotemperature of the sea-surface water in the region during the Middle Miocene based on abundance and distribution of temperature-sensitive planktonic foraminiferal and calcareous nannoplankton species.

Material and method

The material for this study comprised 30 samples collected from two sections — Kalaycılar (western fan) and Kuşçusofulu (eastern fan) (Fig. 1). The numbers of specimens of different species of planktonic foraminifers in 100 g of washed sample were recorded as abundant, 60–100 specimens; common, 30–60 specimens; few, 10–30 specimens; and rare 1–10 specimens. For the analysis of calcareous nannoplankton, smear slides were prepared from raw (untreated) samples. No specific techniques were applied to clean or concentrate the biogenic fraction, the aim being to maintain the original composition of the nannofossil assemblages. Smear slides were examined under an Ortholux polarizing microscope using an oil-immersion objective of ×100. Nannofossil abundances were estimated using the scheme of Wei (1988). Based on this method, one or more specimens of a taxon in each field of view was abundant, one specimen of a taxon in 2–10 fields of view was common, one specimen of a taxon in 11–50 fields of view was nominated as a few, and one specimen of a taxon per 51–200 fields of view was accepted as rare.

In this paper the planktonic foraminiferal zonations of Jenkins (1985) (Southern mid-latitude), Iaccarino (1985) (Mediterranean), Krasheninnikov & Kaleda (1994) (Southern Cyprus), and Berggren et al. (1995) (Subtropical) and the calcareous nannoplankton zones of Martini (1971) and Perch-Nielsen (1985) were used for biostratigraphic interpretations. In addition, the abundance (%) and distribution of temperature-sensitive planktonic foraminiferal and calcareous nannoplankton species in each sample were determined for the next paleoenvironmental interpretations.

Trace fossil studies were concentrated on the various lithologies represented in the two sections. Trace fossils investigations were carried out both on bedding and parting surfaces of sections and photographed when necessary. Ichnofacies interpretation was done by Seilacher (1967).

Geological setting and sedimentology of the Cingöz Formation

Two major sedimentary basins (Antalya and Çukurova) existed in the Late Cenozoic epoch in the southern Turkey (Kelling et al. 1987). The Çukurova Basin Complex comprises the Adana and Iskenderun Sub-Basins separated by the Misis Structural High Complex, which is bounded by the Ecemiş fault in the west, the Tauride Orogenic Belt in the north and the Amanos Mountains in the east. In the study area, Yetiş & Demirkol (1986), and Gürbüz & Kelling (1991), have undertaken sedimentological investigation of the Cingöz Formation. These authors concluded that the formation was deposited in a basin plain and built by distal and proximal portions of submarine fans. The deep marine turbiditic sandstone systems of Middle Miocene age were formed in the northern part of the Adana Basin as two (western and eastern) deep-sea fans. The western fan derived from the northwest, whereas the eastern fan was supplied from the north (Fig. 1). These are small, 'classical', sand-rich submarine fans as defined by Mutti (1985) and Mutti & Normak (1987).

Western fan

The western fan consists of two megacycles: lower sequence and upper lobe-dominated succession dominated by coarse- to fine-grained sandstone, upwards gradually passing into the outer fan/basin plain sediment. The lobe and channel deposits are attached physically, both laterally and vertically. No clear distinction between the lower, middle and upper fan elements are observed in the field because of the attached geometry. The maximum thickness of the fan is around 1500 m and corresponds well to the low efficiency or type II turbidite system sensu Mutti (1985) (Gürbüz 1993).

Eastern fan

The eastern submarine fan system was initiated by the incision of individual proximal fan channels that were probably physically linked to major channels cut into shallow marine sediments to the north, permitting the 'by passing' of coarse sediments through the mixed carbonate-siliciclastic marginal facies belt. The lower part of this body starts with isolated channels and is less conglomeratic than the western body, with maximum clast sizes around 60 cm. The thickness of this basal sequence is around 500 m. The second phase of this eastern submarine fan starts with a sequence of small isolated channels. These are followed by a succession of prograding lobe-dominated mid-fan cycles with thick, coarsening and thickening upward cycles of sandstone beds. Thin-bedded sandstone beds characterize the upper part of the eastern fan sequence and shale intercalations belong to the lower fan/basin environment. The channels and the lobes in the lower part of phase 2 sequences are detached physically, but the overlying lobes are generally mutually attached. The eastern fan is more complex, laterally extensive and thicker (approximately 3000 m maximum) than the western body (Gürbüz 1993).

Results

Sediments of the Kalaycılar and Kuşçusofulu sections (see Fig. 1), provided rare but well preserved tests of planktonic foraminifers and medium well preserved calcareous nannofossils. The foraminiferal assemblages are composed of 11 species of 6 genera, and the nannofossil associations are composed of 27 species of 10 genera. Some taxa and abundance differences were recorded in both sections.

Kalaycılar section, western fan of the Cingöz Formation

Foraminifers (Fig. 3)

The lower part of the section (samples 1–5, Fig. 2) is characterized by abundances of species *Praeorbulina glomerosa curva*, *Globigerinoides bisphericus*, *G. trilobus*, and *Globoquadrina dehiscens*. Tests of *Globigerina falconensis* form 2–6 % of the assemblage. In the upper part of the section (samples 6–14) specimens of *Orbulina suturalis* and *O. bilobata* were recorded accompanied by higher numbers of *Globigerinoides trilobus*, *Globoquadrina altispira conica*, and *G. dehiscens*. The abundance of *Globigerina falconensis* falls, forming about 1–2 % of assemblage. Specimens of *P. glomerosa curva* have not been already recorded (see Fig. 2).

Calcareous nannoplankton (Fig. 4)

Samples 1–7 (see Fig. 2) contain rare *Sphenolithus heteromorphus* and higher numbers of *Coccolithus miopelagicus* and *Sphenolithus abies*. The upper part of the section (samples 8–14) is characterized by abundance of *Reticulofenestra pseudoumbilica* (recorded first in sample No. 8) and by higher numbers of *Discoaster aulakos*, *D. variabilis* and *Coccolithus miopelagicus* (Fig. 2). Concerning sphenoliths, *S. abies* occurs up to the sample No. 9 and *S. heteromorphus* is already absent in this interval. Rare specimens of *Braarudosphaera bigelowii* were observed through the whole profile.

Kuşçusofulu section, eastern fan of the Cingöz Formation

Foraminifers (Fig. 3)

Lower part of section (samples 1–7, Fig. 5) contained abundant specimens of *Praeorbulina glome-*

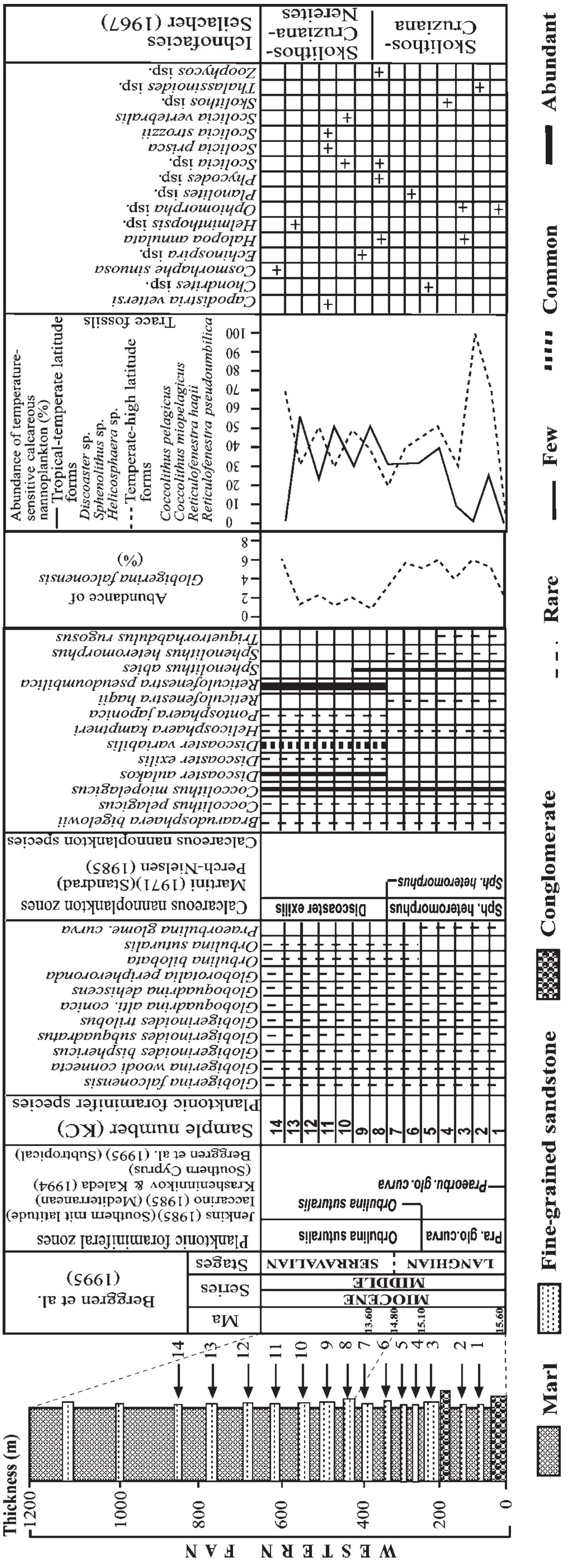

Fig. 2. Kalaycılar section, western fan of the Cingöz Formation. Distribution of planktonic foraminifers, calcareous nannofossils and trace fossils and their biostratigraphic interpretation including percentage of *Globigerina falconensis* and temperature sensitive nannoplankton taxa.

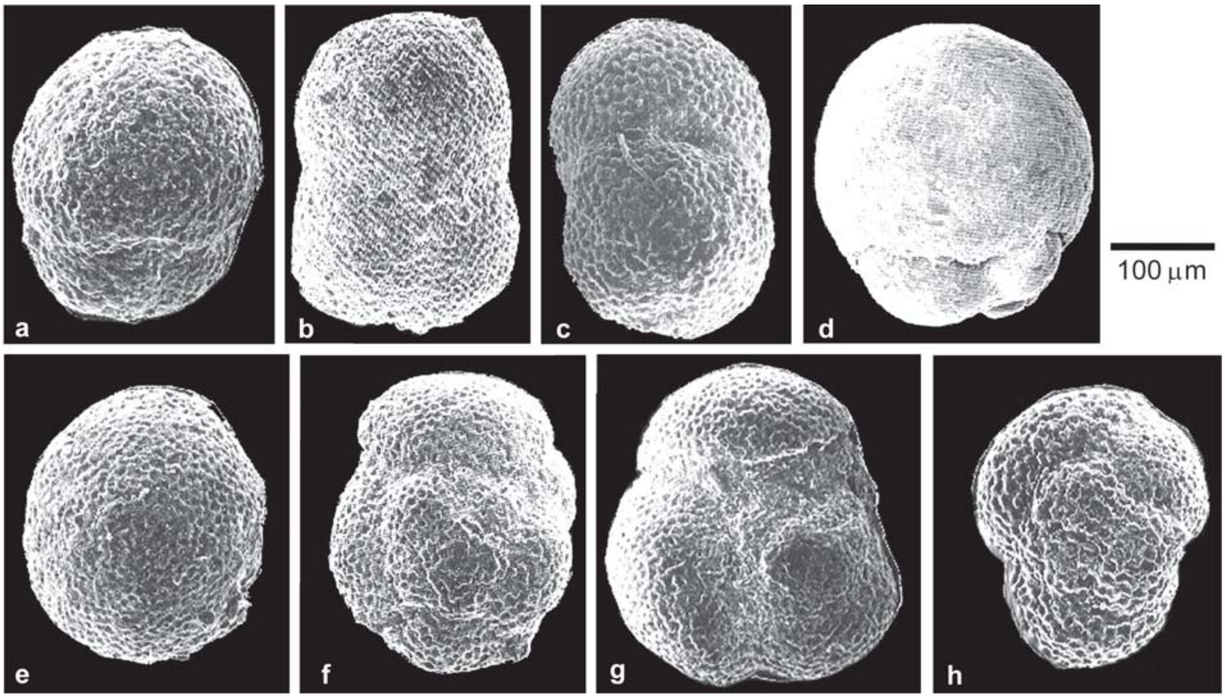

Fig. 3. a — *Globigerinoides bisphericus*, Kalaycılar section, Sample KC-2; **b** — *Globigerinoides trilobus*, Kuşçusofulu section, Sample KS-4; **c** — *Globigerinoides trilobus*, Kuşçusofulu section, Sample KS-16; **d** — *Praeorbulina glomerosa curva*, Kuşçusofulu section, Sample KS-3; **e** — *Orbulina suturalis*, Kuşçusofulu section, Sample KS-10; **f** — *Globoquadrina dehiscens*, Kalaycılar section, Sample KC-5; **g** — *Globoquadrina dehiscens*, Kalaycılar section, Sample KC-3; **h** — *Globigerina woodi connecta*, Kalaycılar section, Sample KC-5.

rosa curva, *Globigerinoides bisphericus*, *G. trilobus*, and *Globoquadrina dehiscens*. The upper part of the section (samples 8–16) is characterized by the occurrence of *Orbulina suturalis* and *O. bilobata* and by higher numbers of *Globigerinoides trilobus*, *Globoquadrina altispira conica*, and *G. dehiscens*. Species *P. glomerosa curva* has not been found here. Abundance of *Globigerina falconensis* varies between 2–6 % during the whole section (see Fig. 5).

Calcareous nannoplankton (Fig. 4)

The lower part of the fan (samples 1–10) is characterized by the presence of *Sphenolithus heteromorphus* and *S. abies* and by high numbers of *Coccolithus miopelagicus*, *Reticulofenestra pseudoumbilica* and *Helicosphaera philippinensis*. In the overlying strata (samples No. 11–16) the occurrence of other taxa was recorded, such as *Dictyococcites productus*, *Coronocylus nitescens*, *Helicosphaera orientalis*, and others (see Fig. 5). The assemblages contain abundant specimens of *Coccolithus miopelagicus* and *Reticulofenestra pseudoumbilica*. The stratigraphically important species *Sphenolithus heteromorphus* and *S. abies* have not been recorded. Rare specimens of *Braarudosphaera bigelowii* were observed through the whole profile.

Trace fossils

Twenty-four ichnotaxa have been recognized in the investigated area. Trace fossils have been observed on bedding and on parting surfaces and in vertical sections. The following trace fossil assemblages were determined in the Cingöz Formation western fan — from the lower part of the section to the top: *Ophiomorpha* isp., *Thalassinoides* isp., *Skolithos* isp., *Chondrites* isp., *Scolicia* isp., *Planolites* isp., *Scolicia vertebralis*, *Phycodes* isp., *Zoophycos* isp., *Capodistria vettersi*, *Halopoa annulata*, *Helminthopsis* isp., and *Cosmorhaphe sinuosa*. In the lower part of the eastern fan to the top: *Ophiomorpha* isp., *Ophiomorpha annulata*, *Thalassinoides* isp., *Halopoa annulata*, *Lophoctenium* isp., *Phymatoderma* isp., *Nereites* isp., *Nereites irregularis*, *Paleodictyon* isp., *Paleodictyon delicatulum*, and *Paleodictyon majus*. Distribution of most of the described trace fossils does not show any distinct rules. Only, *Scolicia vertebralis* and *Echinospira* isp., display a tendency to occur in the thicker beds. *Ophiomorpha* and *Thalassinoides* isp. only occur in thicker beds. The remaining ichnotaxa are separated more or less in thinner beds. The described trace fossil assemblage is dominated by ichnotaxa of the *Nereites* ichnofacies, represented by meandering pascichnia (*Nereites*, *Scolicia)* and different graphoglyptids (e.g. *Paleodictyon* isp., *Desmograpton* isp., *Cosmorhaphe* isp., *Helminthorhaphe* isp.). Stationary fodichnia (*Echinospira* isp.) and ?chemichnia/fodichnia (*Chondrites* isp.) also occur there. 'Shallow-water' vertical forms (horn-like form and *Ophiomorpha* isp.) typical of the *Skolithos* ichnofacies, and *Thalassinoides*, which is the most characteristic of the *Cruziana* ichnofacies, are present there (Figs. 2, 5, 8, 9).

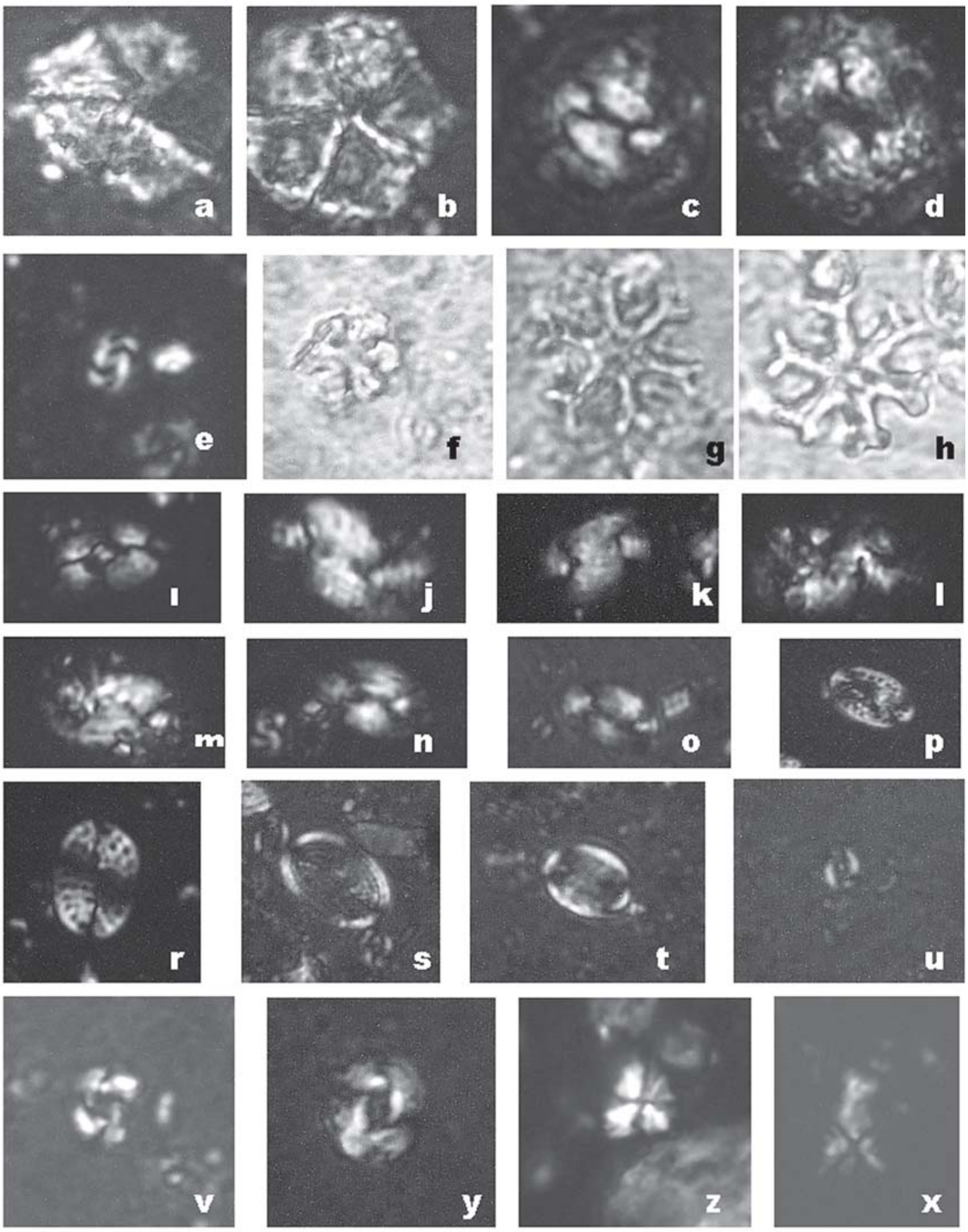

Fig. 4. **a** — *Braarudosphaera bigelowii*, Kuşçusofulu section, Sample no. KS.4 ×4000; **b** — *Braarudosphaera bigelowii*, Kuşçusofulu section, Sample no. KS.2 ×4000; **c** — *Coccolithus miopelagicus*, Kuşçusofulu section, Sample no. KS.2 ×2000; **d** — *Coccolithus pelagicus*, Kuşçusofulu section, Sample no. KS.4 ×2000; **e** — *Dictyococcites productus*, Kuşçusofulu section, Sample no. KS.12 ×2000; **f** — *Discoaster aulakos*, Kalaycılar section, Sample no. KC.12 ×1350; **g** — *Discoaster variabilis*, Kalaycılar section, Sample no. KC.12 ×2000; **h** — *Discoaster variabilis*, Kalaycılar section, Sample no. KC.14 ×2000; **i** — *Helicosphaera intermedia*, Kuşçusofulu section, Sample no. KS.13 ×1500; **j** — *Helicosphaera kamptneri*, Kalaycılar section, Sample no. KC.10 ×3000; **k** — *Helicosphaera kamptneri*, Kalaycılar section, Sample no. KC.9 ×2250; **l** — *Helicosphaera orientalis*, Kuşçusofulu section, Sample no. KS.13 ×2500; **m** — *Helicosphaera orientalis*, Kuşçusofulu section, Sample no. KS.12 ×2500; **n** — *Helicosphaera sellii*, Kuşçusofulu section, Sample no. KS.4 ×1500; **o** — *Helicosphaera sellii*, Kuşçusofulu section, Sample no. KS.12 ×1500; **p** — *Pontosphaera* sp., Kuşçusofulu section, Sample no. KS.13 ×1500; **r** — *Pontosphaera* sp., Kuşçusofulu section, Sample no. KS.11 ×1500; **s** — *Pontosphaera japonica*, Kalaycılar section, Sample no. KC.11 ×1150; **t** — *Pontosphaera multipora*, Kuşçusofulu section, Sample no. KS.12 ×1750; **u** — *Reticulofenestra minutula*, Kuşçusofulu section, Sample no. KS.12 ×2000; **v** — *Reticulofenestra pseudoumbilica*, Kuşçusofulu section, Sample no. KS.11 ×2500; **y** — *Reticulofenestra pseudoumbilica*, Kuşçusofulu section, Sample no. KS.13 ×3000; **z** — *Sphenolithus conicus*, Kuşçusofulu section, Sample no. KS.12 ×1600; **x** — *Sphenolithus heteromorphus*, Kuşçusofulu section, Sample no. KS.3 ×1700.

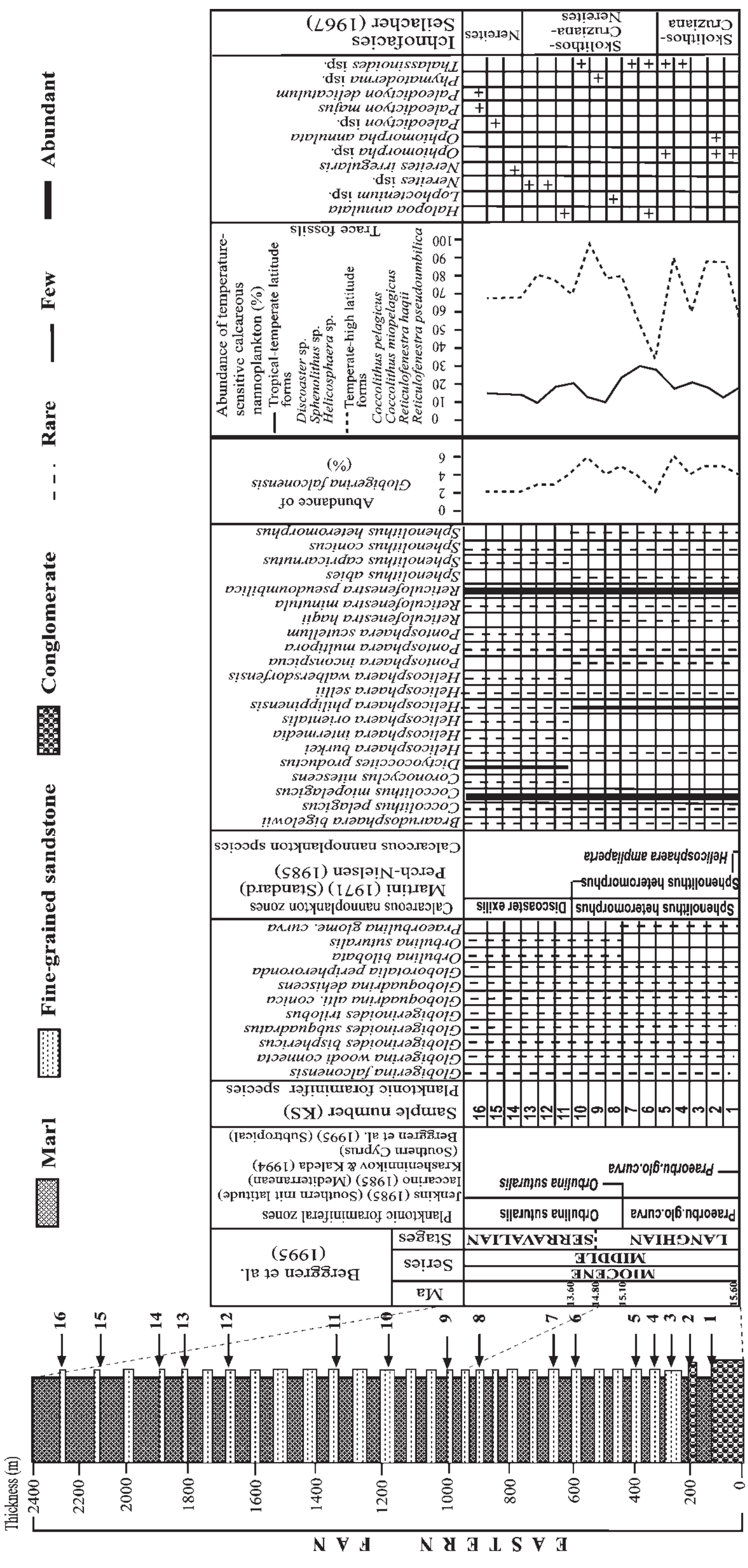

Fig. 5 Kuşçusofulu section, eastern fan of the Cingöz Formation. Distribution of planktonic foraminifers, calcareous nannofossils and trace fossils and their biostratigraphic interpretation including percentage of *Globigerina falconensis* and temperature sensitive nannoplankton taxa.

Biostratigraphy

According to the presence of the foraminiferal species *Praeorbulina glomerosa curva*, the sediments from the localities Kalaycılar, western fan (samples 1–5, Fig. 2) and Kuşçusofulu, eastern fan (samples 1–7, Fig. 5) are correlated with Zone *Praeorbulina glomerosa curva* (sensu Jenkins 1985; Iaccarino 1985; Krasheninnikov & Kaleda 1994; Berggren et al. 1995) (Fig. 6). This interval is also defined as the *Praeorbulina glomerosa* s.s. Zone in subtropical areas (Berggren et al. 1995), Mediterranean (Iaccarino 1985) and Southern Cyprus (Krasheninnikov & Kaleda 1994) and as the *Praeorbulina glomerosa curva* Zone in southern mid-latitudes (Jenkins 1985). Zone *Praeorbulina glomerosa curva* is attributed to the Langhian Stage (16.1–15.1 Ma) (Berggren et al. 1995). In the studied material, this interval is correlated with nannoplankton Zone NN5 (Martini 1971; Perch-Nielsen 1985) (Fig. 7) according to the presence of the species *Sphenolithus heteromorphus* and absence of *Helicosphaera ampliaperta* (see Figs. 2 and 5).

The foraminiferal species *Orbulina suturalis* and *O. bilobata* (Kalaycılar, samples 6–14, Fig. 2 and Kuşçusofulu, samples 8–16, Fig. 5) indicate Zone *Orbulina suturalis* (Jenkins 1985; Iaccarino 1985) that is correlated with the upper part of Langhian Stage and with the Serravalian (15.1–12.7 Ma). The presence of *Sphenolithus heteromorphus* in the sections of Kalaycılar (samples 6, 7, Fig. 2) and Kuşçusofulu (samples 8–10, Fig. 5) gives evidence for the standard nannoplankton Zone NN5 and its absence in the overlying strata may indicate Zone NN6.

Paleoenvironmental interpretations

The foraminiferal species *Globigerina falconensis* is a temperature sensitive taxon and its presence reflects cold to subtropical water conditions (water temperature 2–20 °C) (Parker & Berger 1971; Thunell 1977; Cullen & Prell 1984). Distribution and percentage abundances of *G. falconensis* in the western and eastern fans of Cingöz For-

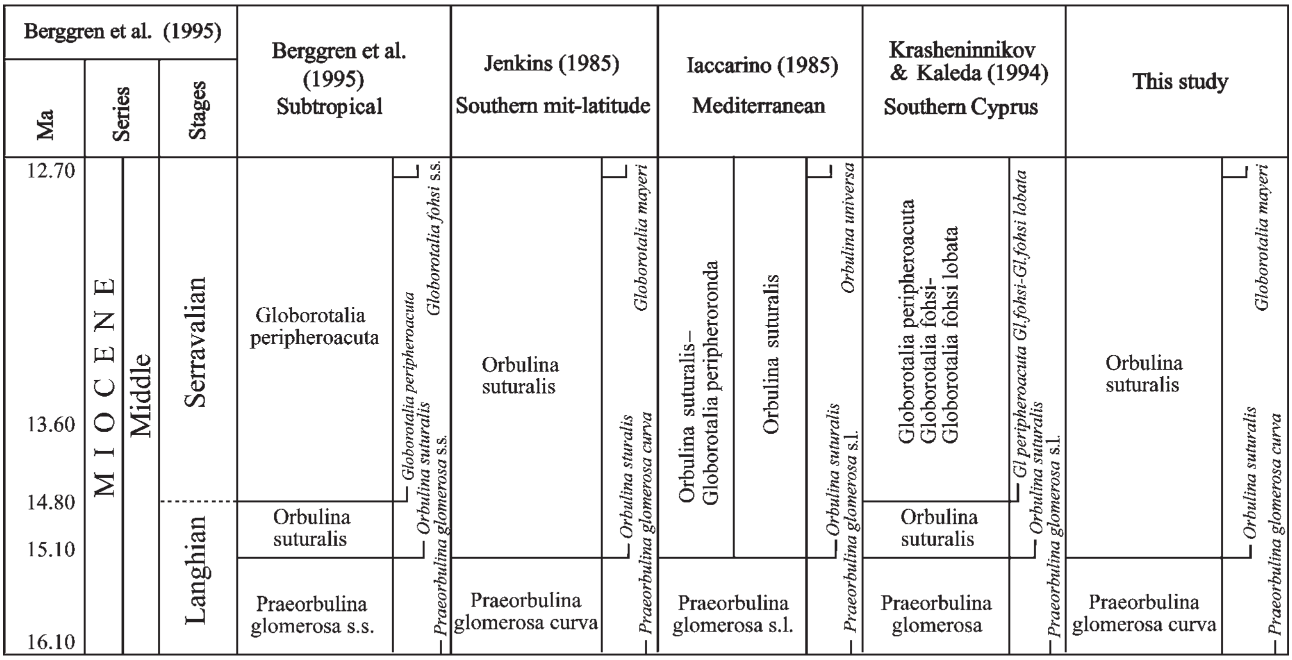

Fig. 6. Correlation schema of the planktonic foraminiferal zones with results of this study.

mation varies between 1–6 % (see Figs. 2 and 5), so, presence of this species indicates temperate to cold sea surface waters. The locality Kalaycılar, western fan of the Cingöz Formation in an exception. The numbers of *G. falconensis* fall to about 1–2 % of assemblage during Serravalian (see Figs. 2 and 5). This phenomenon may indicate input of warm waters.

Concerning calcareous nannoflora, higher numbers (22–95 %) of *Coccolithus miopelagicus*, *C. pelagicus*, *Reticulofenestra pseudoumbilica* and *R. haqii* support temperate to cold water conditions (McIntyre et al. 1970; Bukry 1973; Siesser & Haq 1987; Wei & Wise 1989) whereas species that are mentioned as tropical to temperate latitude taxa, such as genera *Discoaster*, *Sphenolithus* and *Helicosphaera* form ca. 5–55 % of assemblage. The exception is the Serravalian deposits at the locality of Kalaycılar, western fan that provided higher numbers of tropical to temperate latitude nannofossils with increasing percentages from 30 to 50–55 % and decreasing numbers of temperate to high-latitude taxa (25–30 %). These observations support the theory that the sea-surface waters were relatively cold in the depositional area of the Cingöz Formation in the Langhian but during the Serravalian the sea-surface waters were getting warm especially in the area of the western fan. It was caused rather by warm water currents than by the change of environmental conditions (Figs. 2, 5). Nevertheless, the different character of the nannofossil assemblages in the western and eastern fans may also indicate different ecological conditions. Moreover, discoasters appear during Zone NN6, Serravalian in the western fan, but in the eastern fan were not recorded. According to Young (1999) discoasters reflect oligotrophic environments.

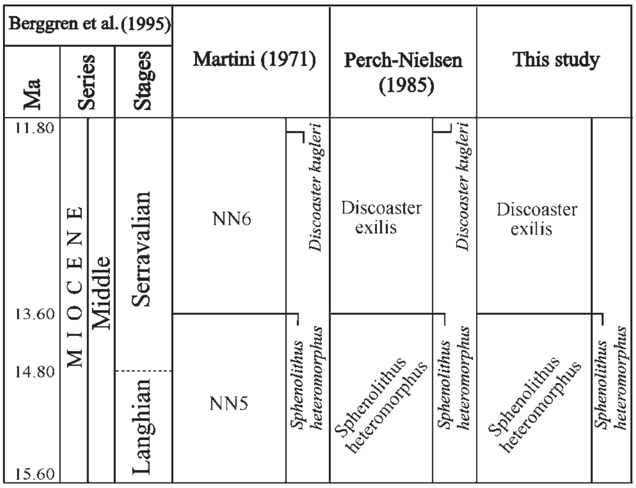

Fig. 7. Correlation schema of the standard nannoplankton zones with results of this study.

According to the distribution of trace fossil content, the inner part of both fans represent *Skolithos-Cruziana* ichnofacies and eutrophic condition. However, the middle part of both fans have mixed ichnoassemblages (*Skolithos-Cruziana* ichnofacies and *Nereites* ichnofacies) that show eutrophic-oligotrophic conditions while the outer fans indicate *Nereites* ichnofacies, and oligotrophic conditions. The distributions of the trace fossil assemblages show that the eastern fan has more mixed assemblages than the western (in the middle of the fan). On the other hand, the fan fringe environment has *Ophiomorpha* isp. It can be explained by the import of its trace marker within stronger turbidity currents from the inner part of a deep-sea fan, or by normal 'planned' colonization (Uchman & Demircan 1999a,b) (Figs. 2, 5).

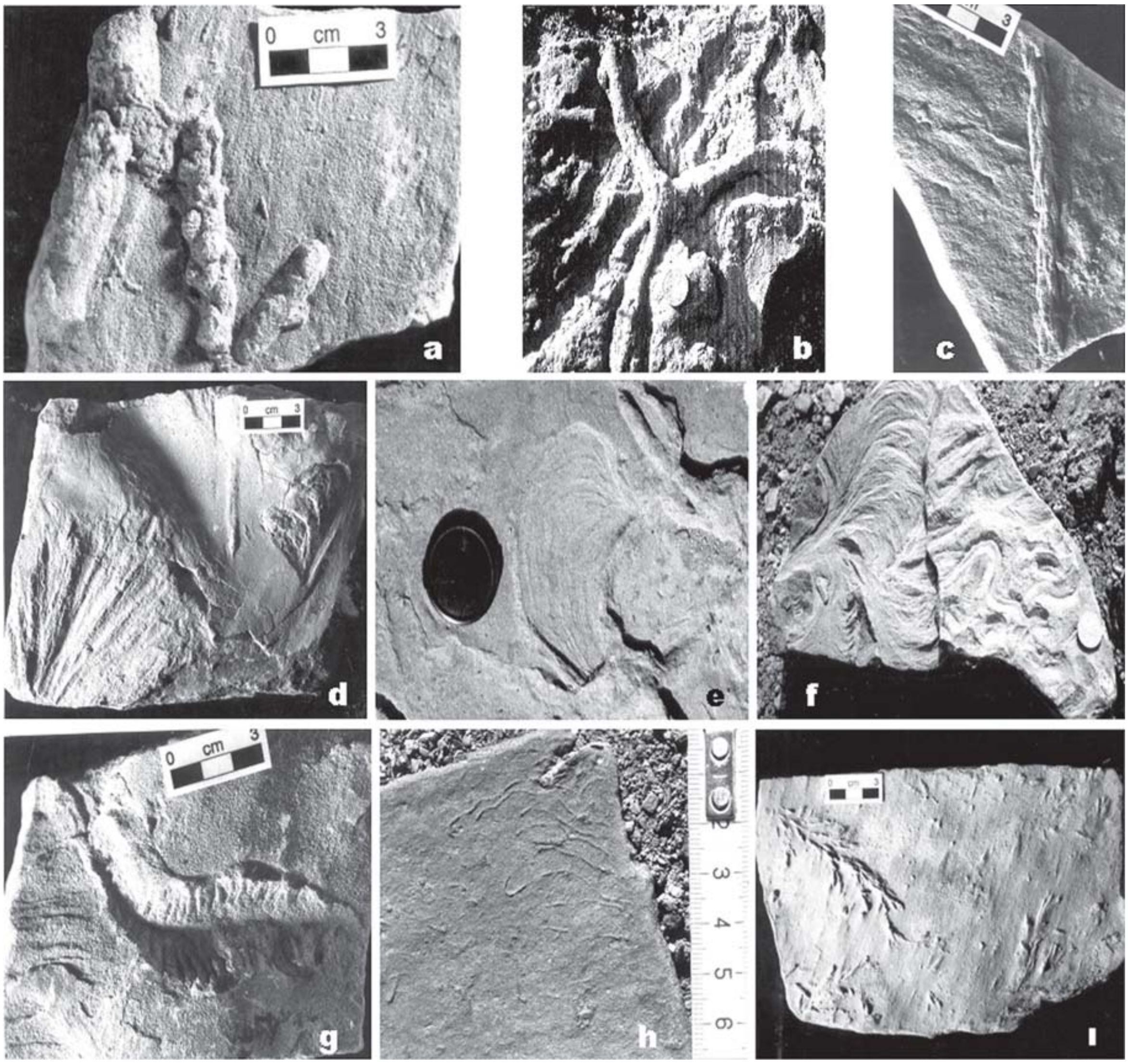

Fig. 8. a — *Ophiomorpha* isp., endichnial full-relief in coarse–medium-grained sandstone, inner fan; **b** — *Thallassinoides* isp., endichnial full-relief in medium-grained sandstone, middle fan; **c** — *Halopoa annulata* (Uchman), hypichnial full-relief in fine-grained sandstone, levee and inter channel; **d** — *Zoophycos* isp., and *Phycodes* isp., endichnial semi-relief in medium–fine-grained sandstone, fan fringe/middle fan; **e** — *Zoophycos* isp., endichnial semi-relief in medium–fine-grained sandstone, slope/middle fan; **f** — *Echinospira* isp., endichnial semi-relief in fine-grained sandstone, middle fan; **g** — *Scolicia vertebralis* Ksiazkiewicz, epichnial full-relief in fine-grained sandstone, middle fan; **h** — *Helminthorhaphe flexuosa* Uchman, hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe; **i** — *Lophoctenium* isp., hypichnial full-relief in fine-grained sandstone, outer fan.

Conclusions

The sediments of the western fan (Kalaycılar section) and eastern fan (Kuşçusofulu section) of the Cingöz Formation, southern Turkey contained well preserved planktonic foraminifers and calcareouss nannofossils.

The assemblages of planktonic foraminifers comprise 11 species of 6 genera and are correlated with the *Praeorbulina glomerosa curva* and *Orbulina suturalis* Zones. The calcareous nannofossil associations are composed of 27 species of 10 genera and give evidence for the standard nannoplankton Zones NN5 *Sphenolithus heteromorphus* and NN6 *Discoaster exilis*. According to the biostratigraphic data, sediments of the Cingöz Formation are attributed to the Langhian and Serravalian Stages of the Middle Miocene.

In the depositional area of the Cingöz Formation, the distribution and percentage abundances of temperature sensitive planktonic foraminifers and calcareous nannofossils indicate temperate to cold sea waters in the Langhian–Serravalian interval. A different situation is found in the Serravalian sediments of the western fan where calcareous nannofossils give evidence for the rise in temperature caused probably by warm water currents and the occurrence of discoasters reflects oligotrophic conditions.

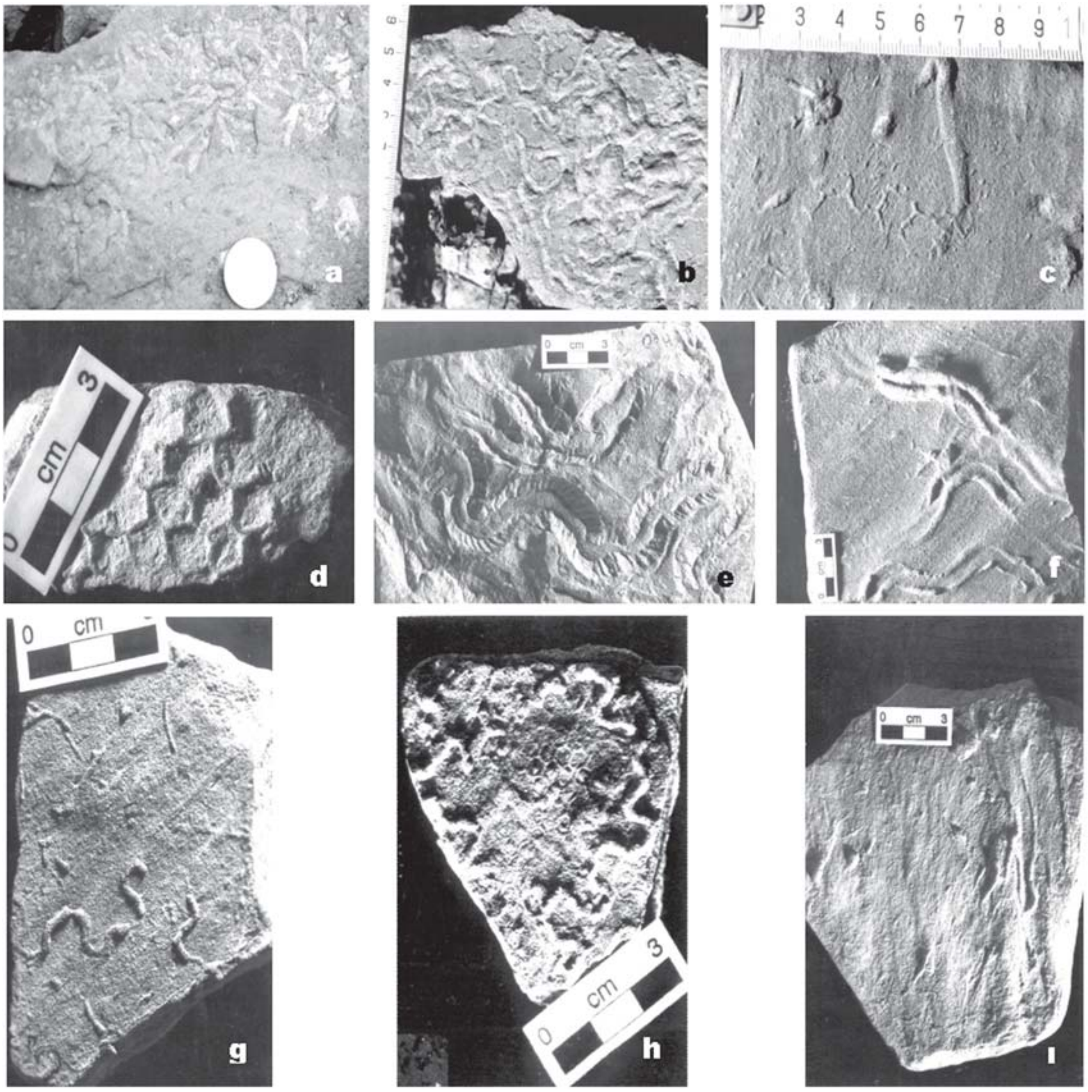

Fig. 9. a — *Phymatoderma* isp., hypichnial full-relief in fine-grained sandstone, middle fan/outer fan; **b** — *Nereites irregularis* (Schafhäutl), endichnial/endichnial full-relief in fine-grained sandstone, outer fan lobes/fan fringe; **c** — *Paleodictyon majus* Meneghini and *Planolites* isp., hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe; **d** — *Paleodictyon delicatum* Uchman, hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe; **e** — *Scolicia prisca* De Quatrafages, endichnial semi-relief in fine-grained sandstone, middle fan; **f** — *Scolicia strozzii* (Savi et Meneghini), hypichnial semi-relief in fine-grained sandstone, middle fan/outer fan; **g** — *Cosmorhaphe* isp., hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe; **h** — *Cosmorhaphe sinuosa* (Azpeita), hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe; **i** — *Helminthorhaphe flexuosa* Uchman, hypichnial semi-relief in fine-grained sandstone, outer fan lobes/fan fringe.

The Cingöz Formation consists of 24 ichnotaxa and the inner part of both fans representing *Skolithos-Cruziana* ichnofacies and eutrophic conditions. The middle part of both fans have mixed ichnoassemblages (*Skolithos-Cruziana* ichnofacies and *Nereites* ichnofacies) that show eutrophic-oligotrophic conditions. *Nereites* ichnofacies and oligotrophic conditions are indicated in the outer part of the eastern fan. According to these data the upper level of the eastern fan characterized a deeper environment than the western fan. The fan fringe environment has *Ophiomorpha* isp. It can be explained by import of its trace marker within stronger turbidity currents from the inner part of the deep-sea fan, or by normal ‘planned’ colonization.

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Appendix

List of planktonic foraminiferal species mentioned in this study

Globigerina falconensis Blow, 1959
Globigerina woodi connecta Jenkins, 1964
Globigerinoides bisphericus Todd, 1954
Globigerinoides subquadratus Brönnimann, 1951
Globigerinoides trilobus (Reuss, 1850) Grimsdale, 1951
Globoquadrina altispira conica Brönnimann et Resig, 1971
Globoquadrina dehiscens (Chapman, Par et Collins, 1934) Blow, 1959
Globorotalia peripheroronda Blow et Banner, 1966
Praeorbulina glomerosa curva Blow, 1956
Orbulina bilobata (d'Orbigny, 1846) Palmer, 1941
Orbulina suturalis Brönnimann, 1951

List of calcareous nannoplankton species mentioned in this study

Braarudosphaera bigelowii (Gran et Braarud, 1935) Deflandre, 1947
Coccolithus miopelagicus Bukry, 1971
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Coronocyclus nitescens (Kamptner, 1963) Bramlette et Wilcoxon, 1967
Dictyococcites productus (Kamptner, 1963) Backman, 1980
Discoaster aulakos Gartner, 1967
Discoaster exilis Martini et Bramlette, 1963
Discoaster variabilis Martini et Bramlette, 1963
Helicosphaera burkei Black, 1971
Helicosphaera intermedia Martini, 1965
Helicosphaera kamptneri Hay et Mohler in Hay et al., 1967
Helicosphaera sellii Bukry et Bramlette, 1969
Helicosphaera orientalis Black, 1971
Helicosphaera philippinensis Müller, 1981
Helicosphaera walbersdorfensis Müller, 1974
Pontosphaera inconspicua (Sullivan, 1964) Perch-Nielsen, 1984
Pontosphaera japonica (Takayama, 1967) Nishida, 1971
Pontosphaera multipora Roth (Kamptner, 1948) Roth, 1970
Pontosphaera scutellum Kamptner, 1952
Reticulofenestra haqii Backman, 1978
Reticulofenestra minutula (Gartner, 1967) Haq et Berggren, 1978
Reticulofenestra pseudoumbilica (Gartner, 1967) Gartner, 1969
Sphenolithus abies Deflandre in Deflandre et Fert, 1954
Sphenolithus capricornutus Bukry et Percival, 1971
Sphenolithus conicus Bukry, 1971
Sphenolithus heteromorphus Deflandre, 1953
Triquetrorhabdulus rugosus Bramlette et Wilcoxon, 1967