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Cretaceous red pelagic carbonates of northern Turkey: Their place in the opening history of the Black Sea

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To the memory of Lev Pavlovich Zonenshain from his Turkish colleagues who work on the Black Sea.

ABSTRACT

Northern Turkey forms a part of the Rhodope-Pontide Fragment, one of Turkey's main tectono-stratigraphic units. Cretaceous geology of this region is characterized by the presence of a series of horsts, grabens and tilted and rotated fault blocks buried beneath the Upper Cretaceous to Lower Tertiary volcanic material-bearing turbiditic sediments. These structures and sedimentary and igneous rocks represent the most complete record of the opening of the oceanic Black Sea back-arc basin which began forming in the Aptian-Albian behind a continental extensional margin magmatic arc. This was followed by a fault-controlled syn-rift sedimentation and subsidence until the late Cenomanain when sea-floor spreading in the basin and thermally-induced subsidence of the basin margins started.

Rift-drift transition in the formation of the Black Sea was marked by a drastic change in sedimentation from the deposition of dark-coloured and organic-rich shales with limestone interbeds to the accumulation of red pelagic carbonates and marls. Facies analyses of these sediments reveal that the Black Sea was restricted during its advanced rift stage from free interchange with the Neo-Tethys to the south and received a large amount of organic debris. Immediately after the onset of spreading in the late Cenomanian, the euxinic conditions disappeared and the water column above the southern margin of this juvenile ocean became well stirred as a gentle basinward tilting of this margin took place. This tilting caused a wide transgression accross the margin which eliminated most of the terrigenous sediment sources, thus providing a suitable location for the deposition of the red pelagic carbonates.

Such syn-breakup sequences in migratory island arcs may be important guides to establishing the onset of sea-floor spreading in back-arc basins, whose magnetic record is commonly poor and basin floor basements are hidden under thick sedimentary blankets.

ZUSAMMENFASSUNG

Die nördliche Türkei stellt einen Teil des Rhodope-Pontid-Fragments dar, eine der tektonischen Einheiten des Landes. Die Kreidegeologie dieser Region wird durch die Existenz der Horste und Gräben und rotierten Blöcke charakterisiert, die unter einer Decke von Kreide und Tertiärer, Vulkanitführender turbiditischer Sedimente begraben sind. Diese Strukturen und die Sediment- und Erstarrungsgesteine stellen die umfassendsten Belege der Öffnungsgeschichte des Schwarzen Meeres dar. Diese Öffnung begann während des Apt-Alb-Intervalls hinter einem sich aktiv dehnenden magmatischen Kontinentalrandbogen. Rifting ist bis zum Cenomanian von einer durch Abschiebungen kontrollierten Sedimentation und Senkung gefolgt, erst dann begann die Ausbreitung des Ozeanbodens gleichzeitig mit der thermalbedingten Senkung des Beckenrandes.

Der Rift-Drift-Übergang während der Entstehung des Schwarzen Meeres wurde durch einen drastischen Wechsel in der Sedimentation gekennzeichnet, z. B. von der Ablagerung der dunkelfarbigen, an organischem

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Material reichen Schiefer mit Kalksteineinlagerungen zur Akkumulation der roten pelagischen Karbonate und Mergel. Die Faziesanalyse der Sedimente zeigt, dass das Schwarze Meer während seinem fortgeschrittenen Riftstadium von der im Süden gelegenen Neo-Tethys abgeschnitten war und sich in ihm Schutt reich an organischen Material sammelte. Gleich nach dem Beginn des Sea-Floor-Spreading verschwanden die euxinischen Absatzbedingungen und die Wassermassen über dem Kontinentalrand dieses juvenilen Beckens wurden gut gemischt. Zugleich kippte der Kontinentalrand nach Norden. Diese Kippung verursachte eine weitgehende Transgression des Meeres, die zur Überschwemmung der damals vorhandenen terrigenen Sedimentliefergebieten und zur Ablagerung von pelagischen Sedimenten führte.

Solche syn-breakup-Sequenzen in migrierenden Inselbögen können wichtige Wegweiser sein für die Feststellung des Beginns des Sea-Floor-Spreading in den Randbecken deren magnetischer Nachweis oft mangelhaft ist und deren Beckenboden unter mächtigen Sedimentfüllungen verborgen ist.

1. Introduction

This paper deals with Cretaceous red pelagic carbonates and associated clastic sediments on the Rhodope-Pontide Fragment between Zonguldak and Sinop, Northern Turkey (Fig. 1). Here, these rocks are well exposed with characteristic fossils to allow dating, stratigraphic correlation and environmental interpretation. They constitute a part of the southern continental margin sequence of the present Black Sea (Görür 1988, 1989; Manetti et al. 1988; Tüysüz 1990) which accumulated during the rift-drift extensional stage of this basin, a mini ocean (Neprochnov 1966; Neprochnov et al. 1975; Bulandje 1976; Sidorenko 1978; see also Zonenshain and Le Pichon 1986). They record, therefore, both depositional and tectonic conditions that prevailed during such a critical phase in the development of a passive margin in a back-arc setting (Görür 1988, 1989). Especially the red pelagic carbonates (the Kapanboğazi Formation) appear to be sensitive indicators of tectono-sedimentary conditions (Berger 1970; Berger & Winterer 1974; Zeitschel 1978; Scholle et al. 1983) and provide important clues to those drastic changes that took place during the onset of spreading in water circulation, sea-level, water chemistry, fertility and temperature.

The purpose of this study is (1) to discuss the depositional conditions of red pelagic carbonates and the rocks immediately above and below, in order to show what sort of sedimentological and tectonic changes occurred during the transition from a back-arc rift to a juvenile ocean. Detailed discussions on mechanism of these changes are deliberately avoided, because the exclusively sedimentary data presented in this paper are clearly not sufficient for such a purpose.

(2) To contribute new data to improve the understanding of the evolution of the Black Sea and thus back-arc basins in general. Despite its critical importance for the Mesozoic-Cainozoic palaeotectonics of the central Tethyan area, the timing and mechanism of formation of the Black Sea ocean have been debated and still there is no concensus of opinion about either of these questions (e.g., Brinkmann 1974; Adamia et al. 1974; Hsü et al. 1977; Letouzey et al. 1977; Dercourt et al. 1985; Zonenshain & Le Pichon 1986; Manetti et al. 1988; Görür 1988, 1989).

(3) To evaluate criteria based on facies analysis of the red pelagic limestones and marls that may prove useful in interpreting the depositional and tectonic settings of similar but less well-known carbonate deposits along the Tethyan belt. Such sediments occur, not only in the Cretaceous, but also in the Jurassic, in the Alps, Appennines, Carpathians, Balkans, Western Greece, Cyprus, Himalaya, Indonesia and Western North Atlantic (Aubouin 1964; Farinacci 1964; Hallam 1967; Garrison 1967; Garrison

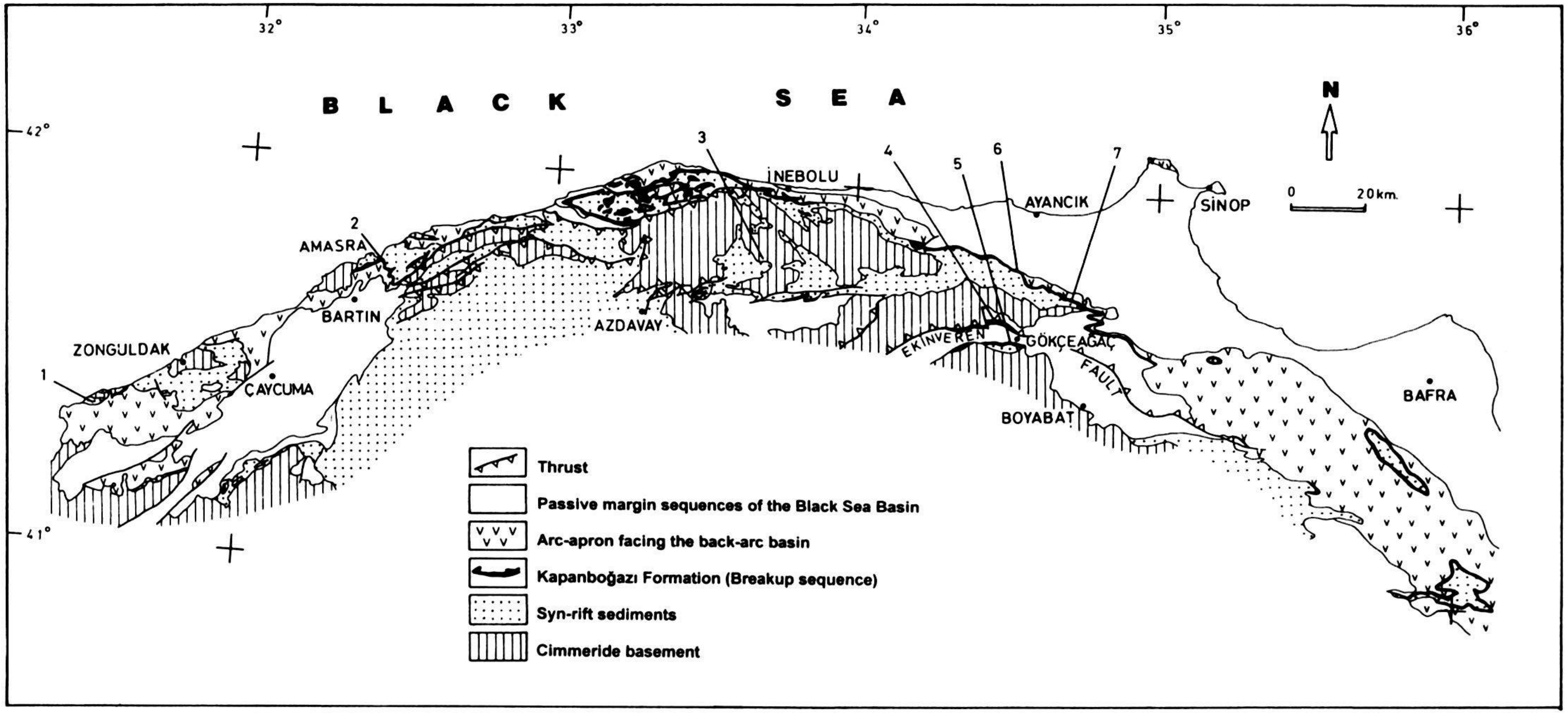


Fig. 1. Distribution of Cretaceous red pelagic carbonates (Kapanboğazi Formation) and associated clastic sediments of the Rhodope-Pontide Fragment. Numbers show the locations of sections studied. 1-Ereğli-Alapli-Alacaağzi (Tokay 1952); 2-Inpiri village (10 km west of Amasra); 3–15 km southeast of Küre (Kastamonu); 4-Payamca village (10 km north of Gökçeağaç); 5-Vakif village (3 km west of Gökçeağaç); 6-Yemişliçay creek (South of Ayancik); 7-Kayadibi village (South of Sinop).

& Fischer 1969; Bernoulli & Jenkyns 1970; Bernoulli 1971, 1972; Renz & Jung 1978; Kalin et al. 1979; Weissert 1981; Bichse & Häring 1981). Although they reflect a similar sedimentary and bathymetric evolution, their tectonic and depositional settings seem to vary throughout these regions.

2. Stratigraphic and tectonic setting

The stratigraphic sequence of the Rhodope-Pontide Fragment (Fig. 1), ranges in age from Middle Cambrian to Recent (e.g. Ketin 1983). It may be divided into two major sequences separated by a distinct angular unconformity: pre-Middle Jurassic basement sequence and overlying Middle Jurassic to Middle Eocene cover sequence (Fig. 2). The basement sequence consists mainly of metamorphic, magmatic, and sedimentary rocks with complicated stratigraphic and structural relations (i.e., see Şengör & Yilmaz 1981; Şengör 1984; Şengör et al. 1984; Yilmaz & Tüysüz 1988, 1991; Tüysüz 1990; Tüysüz et al. 1990a, 1990b; Ustaömer & Robertson 1992). Their detailed description is beyond the scope of this paper and therefore they are called hereinafter "basement rocks" regardless of their ages and lithologies. The cover sequence consist mainly of a large variety of sedimentary and associated volcanic and volcaniclastic rocks, constituting the continental margin sequence of both Neo-Tethys ocean and its back-arc basin, the Black Sea. Following is a brief generalized stratigraphic and tectonic evolution of the cover sequence as a whole (Fig. 1 and 2). Those rocks related to the rift-drift transition of the Black Sea basin form the main subject of this paper.

At the base of the cover sequence are red and coarse conglomerates of Middle Jurassic age (Bürnük Formation). The conglomerates pass upward through a platform carbonate (Inalti Formation) into a deepening-upward clastic unit of the Aptian to Cenomanian age (Çağlayan Formation) (Tokay 1952; Ketin & Gümüş 1963; Gedik & Korkmaz 1984; Tüysüz 1990; Tüysüz et al. 1990b). This unit is unconformably overlain by red pelagic limestones and marls (Kapanboğazi Formation) ranging in age from the Cenomanian to the Campanian (Ketin & Gümüş 1963; Yiğitbaş et al. 1990). Towards the top of the carbonate sequence, thin volcanic and volcaniclastic horizons appear and they increase in abundance and eventually pass into an entirely volcaniclastic flysch of Coniacian to Campanian age (Yemişliçay Formation) (Aydin et al. 1986; Gedik & Korkmaz 1984; Tüysüz 1990). They are followed by a non-volcanogenic Campanian to Lower Maastrichtian turbiditic sandstone-marl-shale-limestone alternation (Gürsökü Formation) (Gedik & Korkmaz 1984; Aydin et al. 1986; Tüysüz 1990). With the upward increase in abundance of bioclastic limestone beds, these turbidites grade into a calciturbidite of Maastrichtian to Palaeocene age (Akveren Formation) (Aydin et al. 1986). Farther up the section, above the calciturbidites, a fairly uniform sequence of Upper Palaeocene to Lower Eocene red marls and shales with thin layers of limestone and volcaniclastic conglomerate occur (Atbaşi Formation) (Aydin et al. 1986). These are in turn succeeded by siliciclastic turbidites of Eocene age, consisting of a thick series of sandstones, marls, tuffs, agglomerates, and lavas (Kusuri Formation) (Aydin et al. 1986). Then, the sequence continues across an angular unconformity with shallow water sediments and volcanic rocks of Lutetian age (Yenikonak Formation) (Gedik & Korkmaz 1984). The tectonic evolution of the Rhodope-Pontide Fragment during the development of this cover sequence is as follows (Fig. 3):

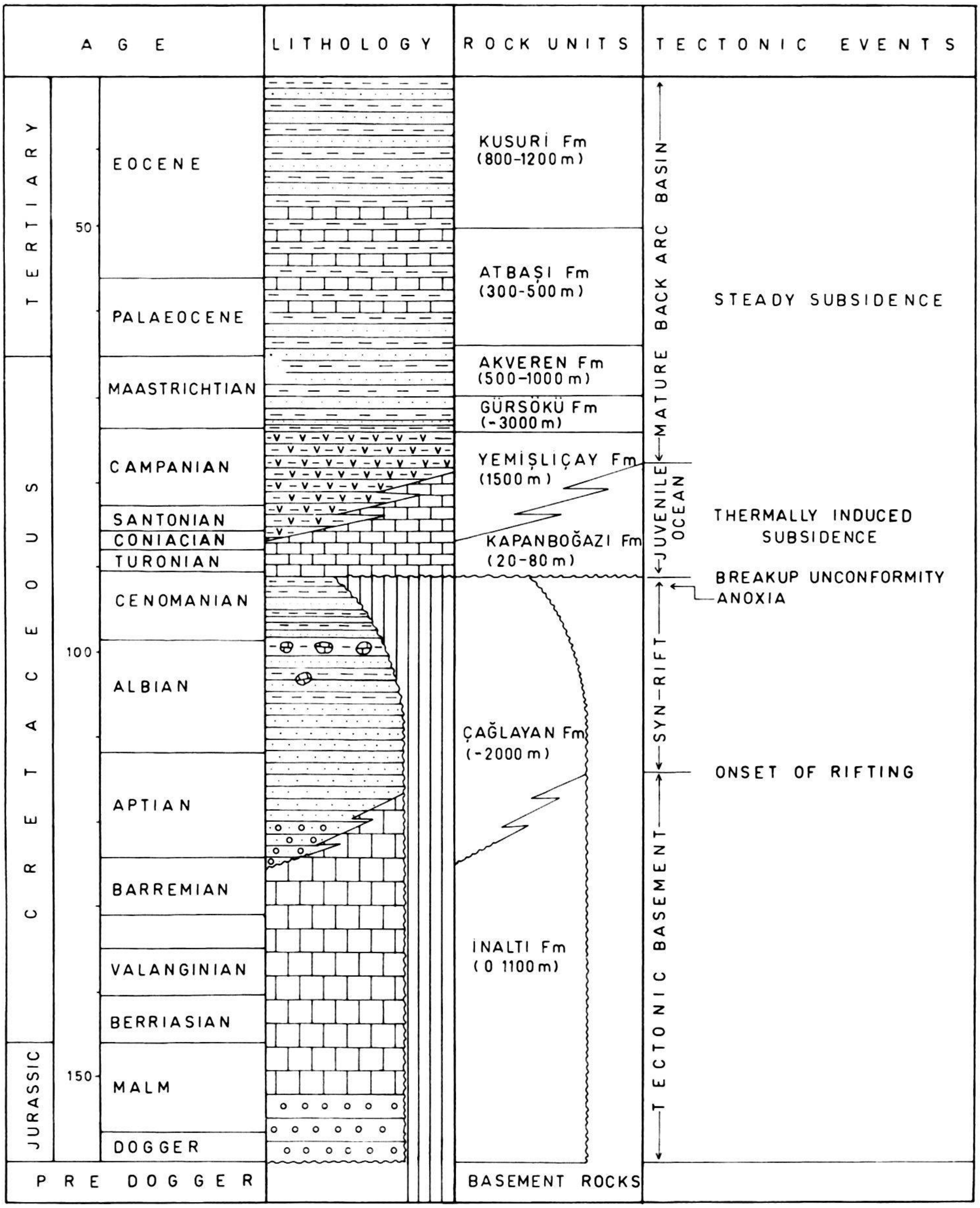
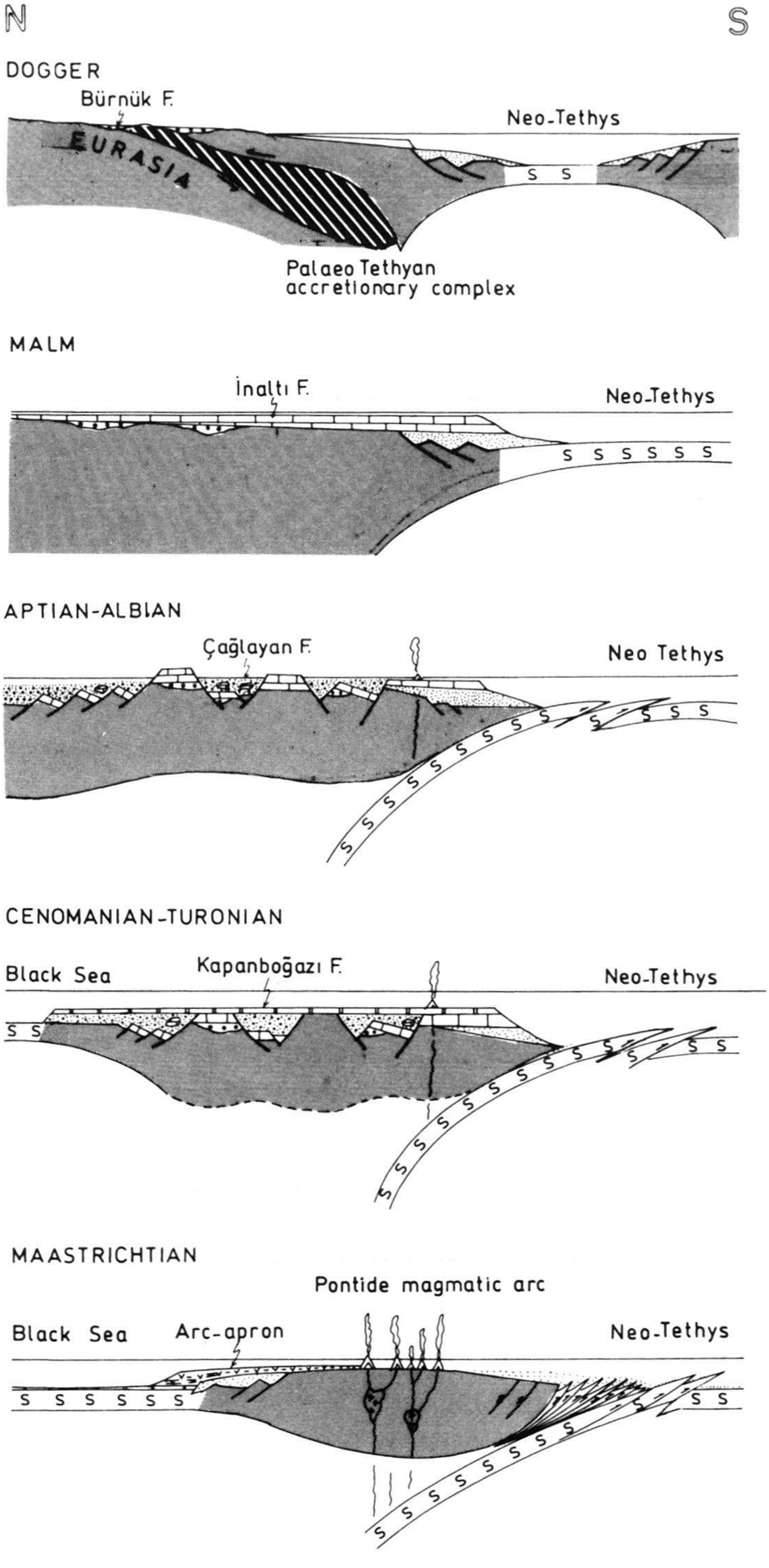


Fig. 2. Generalized stratigraphy and major tectonic events of the Rhodope-Pontide Fragment from Dogger to Eocene.

When Palaeo-Tethys closed in the mid-Jurassic, palaeotectonic units of both continental (Cimmerian Continent) and oceanic origin were welded onto the southern margin of Eurasia to the south of which a new ocean basin, called Neo-Tethys, had already formed (Şengör & Yilmaz 1981; Şengör 1984, Şengör et al. 1984; Şengör 1987; Görür


N
S
DOGGER
Bürnük F.
EURASIA
Neo-Tethys
S S
Palaeo Tethyan accretionary complex
MALM
İnaltı F.
Neo-Tethys
S S S S S S
APTIAN-ALBIAN
Çağlayan F.
Neo Tethys
CENOMANIAN-TURONIAN
Black Sea
Kapanboğazı F.
Neo-Tethys
MAASTRICHTIAN
Pontide magmatic arc
Black Sea
Arc-apron
Neo-Tethys
S S S S S S S

et al. 1983; Görür 1988). By this time, the Rhodope-Pontide Fragment was not yet separated from Eurasia but was forming the southernmost part of its south-facing continental margin. It gained its individuality after the opening of the Black Sea in the Late Cenomanian (Görür 1988). Between the mid-Jurassic and Aptian-Albian, the Eurasian continental margin was of Atlantic type and was receiving the sediments now constituting the cover sequence of the Rhodope-Pontide Fragment. The red conglomerates of the Bürnük Formation accumulated as continental molasse deposits with a pronounced unconformity on the deformed and newly amalgamated Cimmeride basement rocks. As the margin was transgressed from the south by the Neo-Tethys Ocean, it became a shelf depositing the carbonates of the Inalti Formation. When a major north-dipping subduction zone was established during the Aptian-Albian along its southern periphery (Görür 1988, 1991), this margin was converted into an active margin (Aydin et al. 1986; Şengör 1987; Şengör et al. 1988; Yiğitbaş et al. 1990; Görür 1991). Subsequently during the late Cretaceous and the early Cainozoic a large magmatic arc with back-arc extension in its early stages developed in the region of the present Black Sea. The former carbonate shelf broke up during the Aptian-Albian mainly by block-faulting along the axis of the newly developing magmatic arc (Yilmaz & Tüysüz 1988; Tüysüz et al. 1990b, see also Hsü et al. 1977). In the deeper troughs, the deepening-upward syn-rift sediments of the Çağlayan Formation accumulated. This rift basin turned into a proto-oceanic basin in the late Cenomanian probably just before the deposition of the Kapanboğazi Formation on the southern continental margin of the juvenile Black Sea Ocean. Following this pelagic carbonate accumulation, the sedimentation on this margin became dominated mainly by both volcanogenic siliciclastics and calciturbidites. Their deposition may have been triggered by repeated tectonic activity contemporaneous with magmatism in the Rhodope-Pontide magmatic arc developing since Aptian-Albian time to the immediate south. Clastic grains of the siliciclastic turbidites were derived mostly from this contemporaneous violent nearby volcanism, although a small percentage was supplied by the erosion of the basement rocks in the Rhodope-Pontide Fragment. The bioclasts of the calciturbidites were derived from shallow marine carbonate platforms that existed in part throughout the late Cretaceous on the southern margin of the progressively growing oceanic basin of the Black Sea (Görür 1988).

The Kapanboğazi Formation represents the first post-breakup sediments laid down on the southern margin of the juvenile Black Sea basin during a more uniform and thermally-induced subsidence associated with possible oceanic crust formation in the basin. Examination of this formation, as well as of those stratigraphically above and below may therefore provide valuable insight into the understanding of tectonic and sedimentological processes acting in and around this back-arc basin during the change from the rifting to the sea-floor spreading. The detailed descriptions of these formations with a special emphasis on the red pelagic carbonates of the Kapanboğazi Formation are given below; they are represented schematically in Fig. 4.

Fig. 3. Tectonic evolution of the Rhodope-Pontide Fragment during the development of the cover sequence between the Middle Jurassic and the Maastrichtian.

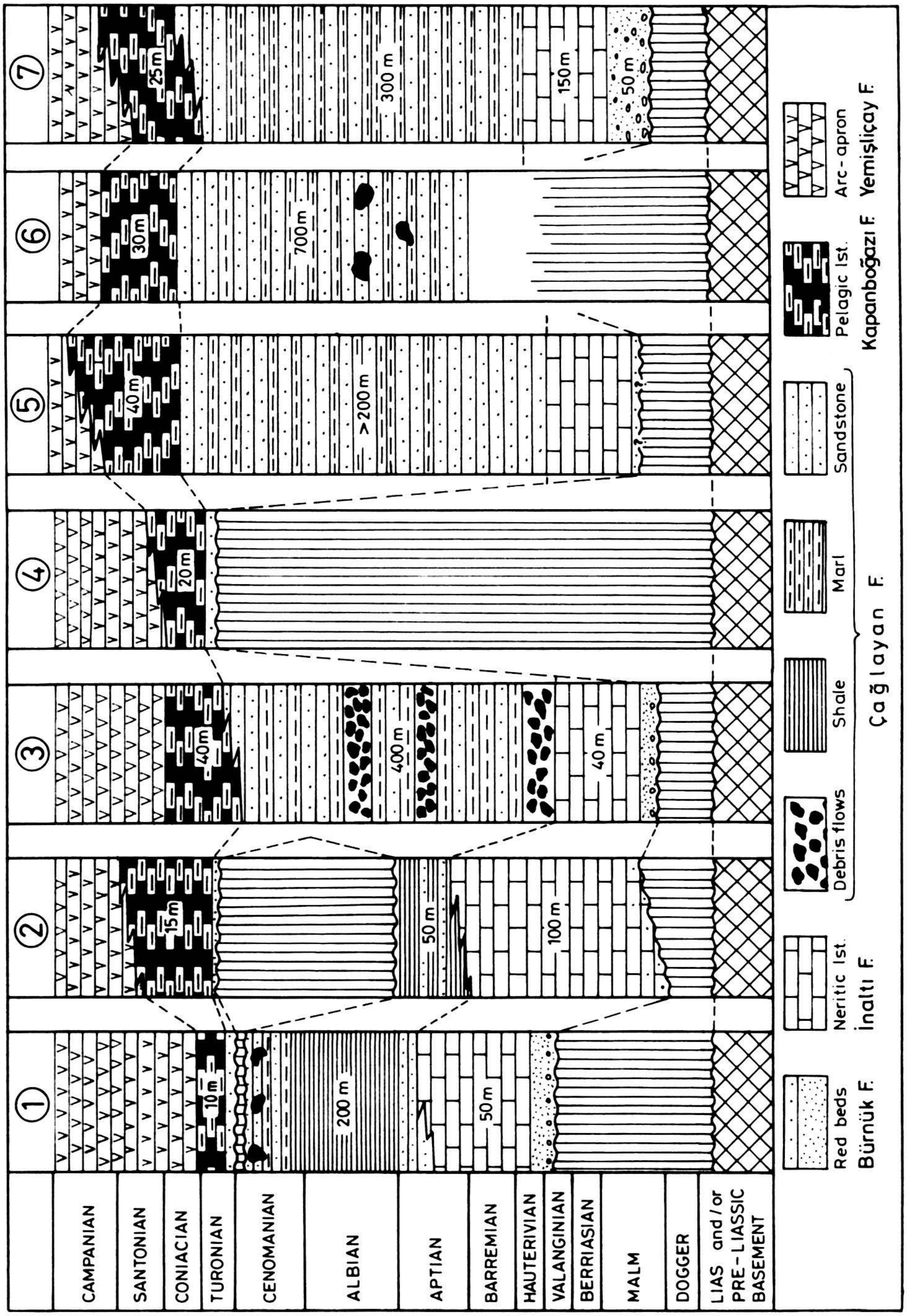


Fig. 4. Correlation of the sections studied. See Fig. 1 for their locations.

3. Lithofacies

3.1 Çağlayan Formation

This formation consists, at the base, mainly of yellowish grey, medium to thickly-bedded, and also planar cross-bedded quartzites (the Velibey Member) locally with a black and organic-rich shale horizon below the quartzites (the Kilimli Shales). The quartzites are medium- to coarse-grained and well-sorted orthoquartzites with more than 95% subrounded quartz grains. Other minor grain constituents include feldspars, micas, magmatic rock fragments derived from the crystalline basement and clay minerals. Toward the top of the member, lithic grains (including sedimentary, magmatic and metamorphic rock fragments) increase in abundance and consequently the quartzites become quartzose litharenites with some glauconites (Saner 1981). In the Zonguldak region (Fig. 1), rudist- and Orbitolina-bearing limestone interbeds are also locally observed in these upper horizons (Tokay 1952; Ketin 1955; Özer 1986; Derman 1990).

The quartzites pass laterally and upward into a succession of grey to black shales alternating with thinly- to thickly-bedded turbiditic sandstones and sandy limestones with common glauconites in the fine-grained clastics and carbonates (the Sapça Member). The sandstones are dominantly fine- to medium-grained feldspathic litharenite or arkose and consist of angular to subrounded rock fragments and feldspars with a considerable amount of quartz. They have a wide lateral continuity and show T a–c Bouma sequences with well-developed sole marks, including flute, groove and load casts and tool marks. The sandstone/shale ratio in the sequence is about 5:1 which seems to decrease northward (Akarsu & Aydin 1979). The sandstone-shale intercalation is sporadically interrupted by conglomerates, slumps and debris flows [1]. Clasts of diverse sizes in these coarse sediments are mostly derived from the underlying Inalti carbonates, although those of older rocks are also common in these horizons. Clasts interpreted as gravity slide blocks (olistoliths) show a great variation in size, ranging from a few centimetres to hundreds of metres in diameter. These exotic components seem to be abundant in the south where the Çağlayan Formation unconformably overlies the Inalti Formation. When the latter is absent, the Çağlayan Formation oversteps the Palaeozoic rocks.

In the upper parts, the Çağlayan Formation is represented mainly by a uniform sequence of black shales and clayey limestones (the Tasmaca Member). The shales are poorly-bedded, locally laminated, organic-rich and in part sandy and micaceous with a distinct nannoplankton and ammonite fauna (Tokay 1952; Gedik & Korkmaz 1984). The limestone interbeds are generally acyclically arranged and consist of thinly- to medium-bedded clayey and in places sandy micrites.

This division of the Çağlayan Formation into four members was established in the Zonguldak region, whereas in the Sinop area, the distinction between the Sapça and Tasmaca Members seems difficult to maintain.

The thickness of the Çağlayan Formation as a whole is variable, ranging from 235 m to 1325 m in the Sinop (Gedik & Korkmaz 1984) and from 160 m to 1100 m in the Zonguldak regions. The average thickness of the members in the latter region are as

[1] These debris flows have been described previously as "olistostromes". We avoid this term, following Hsü's well-justified recommendation (Hsü 1988).

follows: Velibey 250 m, Sapça 450 m and Tasmaca 100 to 400 m. The thickness of the Kilimli shales has not been accurately measured.

On the basis of the following fossils, a Barremian to Cenomanain age is attributed to the Çağlayan Formation (Gedik & Korkmaz 1984; Aydin et al. 1986; Derman 1990; Tüysüz 1990): *Rotalipora subticinensis* (Gandolfi), *Rotalipora ticinensis* (Gandolfi)., *Lenticulina münsteri* (Roemer), *Epistomina*, sp. (gr. catenula), *Praeglobotruncana* sp., *Nannoconus colomii* Lap., *Coccolithus* cf. *cuvillieri* Manivit, *Coccolithus bernase* (Black), *Cribrosphaeralla ehrenbergi* (Arkh)., *Calcisphaerula* sp., *Dictiyomictra* sp., *Euhoplites* sp.

3.2 Kapanboğazi Formation

The Kapanboğazi Formation is easily distinguished by its typical red colour in the cover sequence of the Rhodope-Pontide Fragment. It crops out among the Cretaceous sediments as thin interlayers with an average thickness of 40 m (Fig. 2) despite the existence of few local variations that are considerable (i.e. Gedik & Korkmaz 1984). Its thickness appears to be generally uniform from west to east along the strike and to diminish from north to south. The formation consists mainly of thinly-to medium-bedded limestones in part with marl and volcanic interbeds. The marl interbeds occur in lower, middle or upper parts of the formation and alternate with the limestones with or without a regular interval. The thickness of each marl unit ranges from a few cm to 1 m. Volcanic interbeds usually occur at the top of the formation and consists of andesitic and basaltic volcanic and volcanogenic sedimentary material. Both the limestones and marls commonly show horizontal laminae in part with burrows and mottling. In places the laminae in the limestones are marked by alternation of red and white layers; the latter seems more calcareous. Beside the laminae, white- and grey-coloured patches, bands, and beds also occur locally in these red sediments.

The limestones in the Kapanboğazi Formation are represented mostly by biomicrites, rich in planktonic foraminifera with subordinate radiolaria and echinoderm fragments. Planktonic foraminifera include various species of Globotruncanidae and Herteroheli-cidae, such as *Praeglobotruncana delrioensis* (Plummer), *Globotruncana imbricata* (Mornod), *Globotruncana lapparenti* (Brotzen), *Globotruncana linneiana* (D'Orbigny), *Globotruncana bulloides* (Vogler), *Globotruncana ventricosa* (White), *Globotruncana helvetica* (Bolli), *Globotruncana calcarata* (Cushman), *Marginotruncana coronata* (Bolli), *Marginotruncana pseudolinneiana*, *Heterohelix globulosa* (Ehrenberg), *Rugoglobigerina* sp., *Globigerinelloides* sp. and, *Radiolaria* indicating an age span from Cenomanian to Campanian for these carbonates. In most of the thin-sections studied, these microfossils, ranging in size from 200 to 500 microns, are usually well-preserved, although few of them are partially or completely altered by recrystallization and consequently replaced by neomorphic sparry calcite (Folk 1965). The cells of these organisms are filled with micrite, sparry calcite, and rarely haematite. In places, the microfossils are rather tightly packed, but commonly they occur scattered through a micritic matrix. The matrix appears to be red to light brown in reflected light and consists mostly of micrite intimately mixed with fine fossil debris and some finely crystalline microspars (less than 10 microns). The latter probably resulted from neomorphic alteration of the matrix as suggested by the presence of altered pelagic foraminiferal tests and patchy clouds of micrite left behind floating in this calcite after the replacement.

A series of analyses, including microprobe, trace element, and X-Ray diffractometer, were made on few samples of both limestones and marls, in order to determine their precise composition. The results of the analyses are shown in Table 1.

The mineral assemblage of these sediments is represented mainly by carbonates, clay minerals, quartz, and haematite with traces of feldspars, heavy minerals, sulphides and hydroxides. Following are the brief descriptions of these minerals:

Carbonate minerals include both calcite and dolomite; the former predominates over the latter and constitutes the bulk of both the allochems and the orthochems in the limestones, whereas the dolomite is rarely found replacing the micritic matrix in part. The total calcium carbonate content of the Kapanboğazi Formation is variable and ranges from 40 to 70% in the marls and from 80 to 95% in the limestones.

Few clay samples were analyzed. Illite with subordinate montmorillonite appears to be the common clay minerals in the limestones and marls (Yilmaz 1980). Usually, they amount to less than 10 per cent in the limestones and may reach appreciable quantities in the marls.

Quartz is often recognized under the microscope, varying in amount from 5 to 15% with an average of about 10%. Microcrystalline chalcedonic quartz in the form of cherts is also common in some thin sections. These are of course post-depositional and occur as thin layers and lenses on the outcrops.

Haematite is found disseminated in both limestones and marls. It is most probably responsible for the red colour of these rocks. Redness in the sediments is usually attributed to high concentrations of ferric iron in conjunction with deficiency of organic carbon and pyrite (Fabricius 1960; Hallam 1967; Lancelot et al. 1972).

Sample	Red limestone		Red marl	
Sample No	1	2	3	4
SiO2	07.80	03.89	16.90	29.00
Al2O3	01.30	00.79	05.60	06.00
Fe2O3	00.70	00.44	02.40	06.00
MgO	00.25	00.30	00.60	02.00
K2O	00.00	00.00	00.00	01.00
MnO	00.00	00.00	00.00	01.10
CaO	50.70	50.70	41.01	28.00
CO2	40.00	40.00	33.00	24.00
Ti	1000			
Sr	250			
Cr	140			
Ni	120			
Cu	30			
Zn	20			
Co	20			

Table 1. Chemical analysis of red pelagic sediments of the Kapanboğazi Formation. (Oxides in wt%, trace elements in ppm).

Feldspars, heavy minerals, sulphides and hydroxides are present in minor concentrations in the Kapanboğazi sediments. Feldspars appear to be fresh and devoid of sericitization. They are mostly found in the marls and their species unfortunately cannot be recognized. Major heavy minerals are rutile, anatase, sphene, chromite, chrome spinel and psilomelane. They are commonly very fine-grained, ranging in size from 20 to 100 microns. Rutile seems to be associated with haematite and chromite is idiomorphic. Sulphides are represented mainly by extremely small (commonly, less than 15 microns) mineral compounds, such as chalcopyrite, pyrite and sphalerite. Hydroxides include limonite and goethite, common secondary minerals formed by weathering of iron or iron-bearing minerals.

3.3 Yemişliçay Formation

This formation is represented by a series of pyroclastic flows, lithic tuffs, tuffites, andesites and basalts alternating with shales, marls and volcaniclastic sandstones and conglomerates. Thin interbeds of red and pelagic limestones, similar to those of the Kapanboğazi Formation are also found in the lower part of this formation. Many volcaniclastic beds have flute and load casts on their lower surfaces and are in places well-graded and channellized. They commonly display T b–c Bouma sequences with a wide lateral continuity. The shale horizons contain abundant pelagic foraminifera and nannoplankton, including *Globotruncana concavata* (Brotzen), *Globotruncana coronata* (Bolli), *Globotruncana arca* (Cushman), *Globotruncana renzi* (Gandolfi), *Globotruncana lapparenti* (Brotzen), *Arkhongelskiella cymbiformis* (Vekshina), *Litraphidites quadratus* (Bram.-Mart.), *Watznauneria barnasae* (Black), *Zygolithus consinnus* (Martini), *Predicosphaera cretacea* (Arkhangelsky) and *Discolithus numerosus* (Gorka). On the basis of these fossils a Coniacian to Campanian age is assigned to the Yemişliçay Formation (Gedik & Korkmaz 1984; Aydin et al. 1986; Tüysüz 1990).

The tickness of the Yemişliçay Formation is variable in the area studied; it is thickly developed (up to 2000 m) in the vicinity of the areas where a mid-Cretaceous to early Cainozoic magmatic arc developed and away from such areas it becomes thinner (Aydin et al. 1986).

4. Discussion

The carbonate platform sloping in the middle Jurassic to early Cretaceous almost imperceptibly from the East European Platform onto its sourthernmost edge, the future Rhodope-Pontide Fragment, continued to be present during the Aptian with a very similar geographical setting. Beginning with the Aptian, carbonate deposition on its southern fringe was largely masked by the arrival of abundant terrigeneous material, constituting the Velibey Member of the Çağlayan Formation. The appearance of such a change, introducing abundant clastics into the previously quiet carbonate platform regime probably marked the initial local disintegration and overall subsidence of this platform. When these processes accelerated during the Albian to Cenomanian (Görür 1988), the shallow-water platform broke apart by pervasive normal faulting and subsided, in part, rapidly to considerable depths along with the deposition of the Sapça Member. The existence of syn-sedimentary normal faults is indicated both by the rapid changes in facies as well as in thickness of this member and of the Çağlayan Formation as a whole. The presence of gravity slide blocks in the Sapça Member may also suggest penecontemporaneous fault activity. Such blocks were probably deposited, together with the proximal turbidites of this unit, in the areas bordering the carbonate platforms, by either submarine slumping and sliding on steep slopes adjoining actively rising fault blocks or by the catastrophic collapse of the newly formed fault escarpments. Off the platforms or the horsts, relatively finer-grained turbiditic sandstones, shales, marls and sandy limestones of the Sapça Member were deposited. The abundance of glauconites in the fine-grained clastics, marls and limestones of this member may indicate a small rate of detritial sedimentation in the rift basin during non-turbiditic depositional intervals. Glauconites occur in greatest abundance in water depths, ranging from 30 to 80 m (Heckel 1972). Considering both the depositional features and the setting of the Sapça Member, water depths close to the upper limit of this range may be suggested for the depositional site of the member.

As the Rhodope-Pontide Fragment was further attenuated and subsided further, the black, organic-rich and nannoplankton-bearing shales and limestone interbeds of the Tasmaca Member accumulated probably in bathyal depths (500–1000 m) in an ev-erdeepening receptacle enclosed by horsts that temporarily sealed it off from the world-ocean. The general lack of coarse detritius in these sediments, however, may indicate that the southern margin source for the course detritius supply had disappeared and the submarine topography created by the rifting had been levelled by the turbiditic sediments of the Sapça member. The fine clastics in the Tasmaca Member were perhaps introduced into the basin from a distant source and deposited from dilute suspension. The limestone interbeds in this member accumulated probably during temporary pauses in the supply of these fine clastics. Also, the scarcity of volcanic material both in these sediments and in the underlying Sapça Member suggests that the magmatic arc which was initiated during the Aptian-Albian on the Rhodope-Pontide Fragment was not yet a prominent submarine feature to supply this material to the basin behind it or alternatively the depositional site for these sediments was somehow beyond their reach.

The black and organic-rich sediments of the Tasmaca Member record basin-wide anoxic events in the deep waters of the rift basin whose enlargement led eventually to the formation of the Black Sea Ocean in the late Cenomanian. Although recent research (i.e. Pederson & Calvert 1990) suggests that high primary organic production and not water-column anoxia provides the first-order control on the accumulation of organic-rich sediments in modern oceans, the deposition of the Tasmaca sediments took place in the restricted Black Sea rift, indicating that anoxic conditions also played an important role in their accumulation. During the deposition of these sediments, the Black Sea Ocean was only beginning to form from a back-arc rift and the water circulation in the rift basin seems to have been restricted leading to the development of anoxic conditions in the water column (Dickinson 1974; Schlanger & Jenkyns 1976; Dow 1977; Ryan & Cita 1977; Montadert et al. 1979; Jenkyns 1980; Demaison & Moore 1980; Parrish & Curtis 1982; Tucker & Wright 1990; Blatt et al. 1991; Görür 1991). Productivity in such a basin is not expected to be high because of limited water circulation and lack of upwelling; organic production in today's oceans is usually high where relatively deep and cold oceanic waters, rich in nutrients, well up along continental margins into surface waters (Fleming 1957; Koblenz-Miskhe 1965; Berger 1970; Parrish & Curtis 1982; Scholle et al.

1983). Organic matter in the Tasmaca Member was perhaps derived mostly from deltaic areas and coastal plains which were flooded during the Aptian-Albian, owing to the world-wide transgression in this period (Schlanger & Jenkyns 1976; Montadert et al. 1979; Haq et al. 1987) as argued by Görür (1991).

The drastic change in the sedimentation during the late Cenomanian from the deposition of the dark-coloured and organic-rich siliciclastic sediments of the Tasmaca Member to the accumulation of the red and pelagic carbonates of the Kapanboğazi Formation indicates the following: (1) Cessation of normal faulting, (2) possible rapid widening of the Black Sea rift to end the anoxia, and (3) a widespread subsidence on the southern continental margin to allow a wide transgression, eliminating most of the terrigeneous sediment sources on this margin and thus providing a suitable location for the deposition of the red and pelagic fossil-bearing sediments of the Kapanboğazi Formation. All these events are interpreted to imply that the formation of oceanic crust in the axis of the Black Sea rift started during the deposition of these carbonates. Pelagic carbonate deposition during the post-breakup subsidence on the juvenile ocean margins is generally dominant, because these areas are not aggressive in this stage in carbonate dissolution and stood above the CCD (Berger 1970; Jenkyns 1978). The Kapanboğazi Formation represents the first post-breakup sediments which buried the syn-rift deposits of the Çağlayan Formation with a slight angular unconformity. This break-up unconformity formed probably as a result of the gentle and oceanward tilt of the continental margin during the post-breakup subsidence (Pitman 1978; Curray 1980).

The main criteria indicating a pelagic origin for the Kapanboğazi sediments include (1) the presence of abundant pelagic organisms, such as Globotruncanidae and Heterohelicidae, (2) their great lateral extent with remarkably uniform lithology and thickness, (3) the association of these well-bedded and finely laminated sediments with the deep water turbidites, and (4) their great similarities in facies and composition to those deposits described as pelagic facies in other areas of Tethys (Garrison & Fischer 1969). The presence and composition of pelagic sediments are controlled by a variety of interrelated primary factors, such as biogenic productivity, water circulation, CCD, climate, latitude, proximity to continental land masses and regional volcanism (Tappan & Loeblich 1971; Scholle et al. 1983). Influences of these factors on the deposition of the Kapanboğazi Formation in the juvenile Black Sea basin are briefly discussed below:

The depositional environment of the Kapanboğazi Formation was characterized by a high rate of pelagic biogenic supply as indicated by the abundance of pelagic fossils in these carbonates. Planktonic foraminiferal oozes on today's ocean are found in warm low lattitude areas, mostly within 60° of the equator where productivity is high (Fleming 1957; Schwarzbach 1961; Koblenz-Mishke 1965; Berger 1970, 1974; Parrish & Curtis 1982; Scholle et al. 1983; Pedersen & Calvert 1990). Probably, similar conditions existed during the deposition of the Kapanboğazi Formation. Recent studies (i.e. Parrish & Curtis 1982; Barron 1983; Manabe & Bryan 1985; Pedersen & Calvert 1990) indicate that a warm climate characterized the Cretaceous Period and the oceans of this time were more nutrient-rich and had higher rates of upwelling and were thus more productive. An increasing exchange of water during the rapid widening of the Black Sea juvenile ocean with the Neo-Tethys may have also enhanced the bloom of the Globotruncanidae and the Heterohelicidae in the surface waters above the southern continental margin. Water depths attained during the deposition of the Kapanboğazi sediments were probably in the range of 500 to 1000 metres, characterizing a bathyal zone. The environment of deposition was evidently an oxidizing one as indicated by the red colour and significant haematite content of these sediments.

Two sources may have contributed to the haematite concentration in the Kapanboğazi Formation: a continental detrital source and a submarine volcanic source (H. & G. Termier 1962; Bostrom & Peterson 1966; Hallam 1967; Bostrom et al. 1969; Von der Borch & Rex 1970; Von der Borch et al. 1971). The continental source would provide the ferric iron by the weathering of various sediments on the neighbouring landmass and transportation of the end product to the site of deposition (Pelin et al. 1982). The volcanic source would be the nearby submarine volcanic activity associated either with the arc-magmatism on the Rhodope-Pontide Fragment or the sea-floor spreading in the Black Sea Ocean. The predominance of illites both in the marls and limestones of the Kapanboğazi Formation may indicate that the continental source played a major role in the supply of the ferric iron to the depositional site. This source was probably located in the western Pontides where a land mass existed throughout the early Cretaceous and Cenomanian time (Görür 1988). The presence of the volcanic interbeds, montmorillonites and some trace elements, including Ti, Sr, Ni, Cu, and Co in the sediments of the Kapanboğazi Formation may provide evidence for volcanic and hydrothermal activities during the deposition of this formation in the area studied (Taylor & McLennan 1985). The main center of these activities were most likely the young magmatic arc of the Rhodope-Pontide Fragment developing since Aptian-Albian time to the south of the juvenile Black Sea (Görür 1988). The volcanic activity increased in intensity soon after the deposition of the Kapanboğazi Formation as indicated by the overlying volcanogenic turbidites of the Coniacian to Campanian Yemişliçay Formation.

5. Summary and conclusions

The conclusions of this study may be itemized as follows:

1) Following the establishment in the Aptian-Albian of a major north-dipping subduction zone along its sourthern periphery, the northern part of the Rhodope-Pontide Fragment, the region of the present Black Sea, apparently underwent back-arc extensional deformation between the Aptian-Albian and Cenomanian. These areas contain series of horsts, grabens and tilted and rotated fault blocks buried beneath the Upper Cretaceous to Recent sediments. Regional studies indicate that an early phase of the rifting of the Black Sea basin initiated in Aptian-Albian time and this was followed by fault-controlled syn-rift sedimentation and subsidence until the late Cenomanian when ocean-floor spreading and thermally-induced subsidence started in this basin (Görür 1988).

2) The syn-rift facies in the Black Sea basin is represented by a deepening-upward sedimentary sequence deposited mainly by gravity- and slope-dependent processes (Çağlayan Formation). Constituents of these sediments were derived rather from a land source than from a volcanic arc which indicates that during the rifting stage, the magmatic arc on the Rhodope-Pontide Fragment was not yet a prominent feature to provide detritus to the basin opening behind it.

3) During the most advanced stage of the Black Sea rift, i.e. just before the major breakup, the sedimentation in this basin switched from the deposition of the siliciclastic turbidites to the accumulation of the dark-coloured, organic-rich, and fine-grained clastics and limestones (Tasmaca Member). The cessation of the turbidite deposition and the absence of coarse detritus in these sediments imply that source terrains during this stage were characterized by minimal rates of tectonic uplift.

The dark colour and organic content of the Tasmaca sediments suggest that the rift basin was restricted from free interchange with the Neo-Tethys Ocean to the south and probably had either a high primary organic production or received a large amount of organic debris or both.

4) Immediately after the major breakup in the late Cenomanian, a body of fairly deep water bounded the Rhodope-Pontide Fragment to the north and a gentle basinward tilt of this southern margin developed as the oceanic crust of the juvenile Black Sea cooled and subsided, pulling the margin down. This subsidence caused a wide transgression of the margin with the development of a major post-breakup unconformity separating the faulted syn-rift sequence from the unfaulted post-rift sequence.

5) Following the onset of spreading in the juvenile Black Sea, the euxinic conditions of the rift stage disappeared and the detrital sedimentation gave way to that of the red pelagic carbonates and marls (Kapanboğazi Formation). These carbonates were probably deposited on the newly developed southern continental margin during the post-breakup subsidence as most of the terrigeneous sediment sources on this margin were eliminated by flooding. Water exchange with the Neo-Tethys Ocean was perhaps also increased during this period and the water column above the southern margin therefore became well stirred and characterized by high fertility, contributing, together with the generally warm climate of the Cenomanian time, to both the blooming of pelagic foraminifera in surface waters and their supply to the sea-floor of the margin.

6) The presence of the andesitic and basaltic interbeds in the upper part of the red pelagic sediments suggest that arc magmatism initiated on the Rhodope-Pontide Fragment in Aptian-Albian times intensified from the time of deposition of these sediments onward.

7) Red pelagic carbonates having a similar tectono-stratigraphic condition to that of the Kapanboğazi Formation may prove useful in the establishment of the onset of sea-floor spreading in the basins they filled.

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REFERENCES

Adamia, S. H. A., Gamkrelidze, I. P., Zakariadze, G. S. & Lordkipanidze, M. B. 1974: Adjaro-Trialetsky progib i problema formirovaniya glubokovodnoi vpadiny chernogo morya. Geotektonika 1, 78–94.

Akarsu, I. & Aydin, M. 1979: Sinop-Inebolu-Küre-Kastamonu-Taşköprü-Boyabat-Durağan yerleşme merkezleri ile çevrili sahanin genel jeoloji raporu. Turkish Pet. Co. Arşiv no. 1323, (Unpublished internal report).

AUBOUIN, J. 1964: Reflexions sur le facies "Ammonitico Rosso". Bull. Soc. geol. Fr. 6, 475–501.

AYDIN, M., ŞAHINTÜRK, Ö., SERDAR, H. S., ÖZÇELIK, Y., AKARSU, I., ÜNGÖR, A., ÇOKUĞRAŞ, R. & KASAR, S. 1986: Ballidağ-Çangaldağ (Kastamonu) arasindaki bölgenin jeolojisi. Türkiye Jeol. Kur. Bült. 29, 2, 1–16.

BARRON, E. J. 1983: A warm equable Cretaceous: the nature of the problem. Earth Science Rewiews 19, 305–338.

BERGER, W. H. 1970: Biogenous deep sea sediments; fractionation by deep-sea circulation. Geol. Soc. Am. Bull. 81, 1385–1402.

BERGER, W. H. 1974: Deep-sea sedimentation. In: The geology of continental margins (Ed. by BURKE, C. A. & DRAKE, C. L.) 213–241, Springer-Verlag.

BERGER, W. H. & WINTERER, E. L. 1974: Plate stratigraphy and the fluctuating carbonate line. In: Pelagic sediments on land and under the sea (Ed. by HSÜ, K. J. & JENKYNS, H.) 11–48, Internat. Assoc. Sedimentol. Spec. Publ. 1.

BERNOULLI, D. 1971: Redeposited pelagic sediments in the Jurassic of the Central Mediterranean area. Ann. Inst. Geol. Pub. Hung. 54, 71–87.

– 1972: North Atlantic and Mediterranean Mesozoic facies: a comparison. In: Initial reports of the Deep Sea Drilling Project, VXI (Ed. by HOLLISTER, C. D., EWING, J. I. et al.), 801–871, U.S. Government Printing Office, Washington DC.

BERNOULLI, D. & JENKYNS, H. C. 1970: A Jurassic basin: the Glasenbach Gorge, Salzburg, Austria. Verhandl. Geol. Bundesanstalt Wien. 504–525.

BICHSEL, M. & HÄRING, M. O. 1981: Facies evolution of late Cretaceous flysch in Lombardy (northern Italy). Eclogae geol. Helv. 74, 383–420.

BLATT, H., BERRY, W. B. N. & BRANDE, S. 1991: Principles of stratigraphic analysis. Blackwell Sci. Pub., Oxford.

BOSTROM, K. & Peterson, M. N. A. 1966: Precipitates from hydrothermal exhalations on the East Pasific Rise. Econ. Geol. 6, 1258–1266.

BOSTROM, K., PETERSON, M. N. A., JOENSUU, O. & FISCHER, D. E. 1969: Aluminiumpoor ferromanganoan sediments on active oceanic ridges. J. Geophys. Res. 74, 3261–3270.

BRINKMANN, R. 1974: Geologic relations between Black Sea and Anatolia. In: The Black Sea-Geology, Chemistry, and Biology (Ed. by DEGENS, E. T. & ROSS, D. A.), 63–76, Am. Assoc. Pet. Geol. Mem. 20.

BULANDJE, Y. D., (Editor) 1976: Kompleksnoye Issledovaniye Chernomorksky Vpadini. Akad. Nauk SSR. Moscow.

CURRAY, J. R. 1980: The IPOD programme on passive continental margins. Phil. Trans. R. Soc. London. A 294, 17–33.

DEMAISON, G. J. & Moore, G. E. 1980: Anoxic environments and oil source bed genesis. Bull. Am. Assoc. Pet. Geol. 64, 1179–1209.

DERCOURT, J., ZONENSHAIN, L. P., RICOU, L. E., KAZMIN, V. G., LE PICHON, X., KNIPPER, A. L., GRANDJACQUET, C., SBORSHCHIKOV, I. M., BOULIN, J., SOROKHTIN, O., GEYSSANT, J., LEPVRIER, C., BIJU-DUVAL, B., SIBUET, J. C., SAVOSTIN, L. A., WESTPHAL, M. & LAUER, J. P. 1985: Presentation de 9 cartes paléogéographiques au 1/20000000 s'étendant de l'Atlantique au Pamir pour la periode du Lias a l'Actuel. Bull. Soc. Geol. Fr. 1, 637–652.

DERMAN, S. 1990: Bati Karadeniz bölgesinin geç Jura ve erken Kretase'deki jeolojik evrimi. Türkiye 8. Petrol Kongresi, Bildiriler, Jeoloji, Türkiye Petrol Jeologlari Derneği TMMOB Petrol Mühendisleri Odasi, 328–339.

DICKINSON, W. R. 1974: Plate tectonics and sedimentation. In: Tectonics and sedimention (Ed. by DICKINSON, W. R.), Soc. Econ. Paleont. Mint. Spec. Pub. 22, 1–27.

DOW, W. G. 1977: Petroleum source beds on continental slopes and rises. In: Geology of continental margins. Am. Assoc. Pet. Geol., Education course note series #5, D1–D37.

FABRICIUS, F. H. 1960: Sedimentation und Fazies des Rät und der Lias-Überdeckung in den Bayerisch-Tirolischen Kalkalpen. Dissertation, Techn. Hochschule München.

FARINACCI, A. 1964: Microorganismi dei calcari "maiolica" e "scaglia" osservati al microscopio elettronica (Nannoconi e Coccolithoporidi). Bull. Soc. Paleont. Ital. 3, 172–181.

FLEMING, R. H. 1957: General features of the oceans. In: "Trestise on marine ecology and paleoecology" 1: Ecology (Ed. by HEDGEPTH, J. W.), Geol. Soc. Am. Mem. 67, 87–108.

FOLK, R. L. 1965: Some aspects of recrystallization in ancient limestones. In: Dolomitization and limestone diagenesis: A symposium (Ed. by PRAY, L. C. & MURRAY, R. C.), Soc. Econ. Paleont. Min. Spec. Pub. 13, 14–48.

GARRISON, R. E. 1967: Pelagic limestones of the Oberalm Beds (Upper Jurassic-Lower Cretaceous), Austrian Alps. Bull. Canadian Petrol. Geol. 15, 21–49.

GARRISON, R. E. & FISCHER, A. G. 1969: Deep-water limestones and radiolarites of the Alpine Jurassic. In: Depositional environments in carbonate rocks (Ed. by FRIEDMAN, G. M.), Soc. Econ. Paleont. Min. Spes. Pub. 14, 20–56.

GEDIK, A. & KORKMAZ, S. 1984: Sinop havzasinin jeolojisi ve petrol olanaklari. Jeol. Müh. Dergisi 19, 53–79.

GÖRÜR, N. 1988: Timing of opening of the Black Sea basin. Tectonophysics 147, 247–262.

– 1989: Timing of opening of the Black Sea: Sedimentological evidence from the Rhodope-Pontide Fragment. In: Tectonic evolution of the Tethyan region (Ed. by ŞENGÖR, A. M. C.) 131–137, Nato ASI Ser. C.

– 1991: Aptian-Albian palaeogeography of Neo-Tethyan domain. Palaeogeography, Palaeoclimatology, Palaeoecology 87, 267–288.

GÖRÜR, N., ŞENGÖR, A. M. C., AKKÖK, R. & YILMAZ, Y. 1983: Pontidlerde Neotetisin kuzey kolunun açilmasina ilişkin sedimentolojik veriler. Türkiye Jeol. Kur. Bült. 26, 11–20.

HALLAM, A. 1967: Sedimentology and palaeogeographic significance of certain red limestones and associated beds in the Lias of Alpine region. J. Geol. 3, 195–220.

HAQ, B. U., HARDENBOL, J. & VAIL, P. R. 1987: Chronology of fluctuating sea levels since the Triassic. Science 235, 1156–1167.

HECKEL, P. H. 1972: Recognition of ancient shallow marine environments. In: Recognition of ancient sedimentary environments (Ed. by RIGBY, J. K. & HAMBLIN, WM. K.), 226–286, Soc. Econ. Paleont. Min. Spec. Pub. 16.

HSÜ, K. J. 1988: Melange and the melange tectonics of Taiwan. Proceedings of the Geol. Soc. of China 3, 2, 87–92.

HSÜ, K. J., NACEV, I. K. & VUCHEV, V. T. 1977: Geologic evolution of Bulgaria in the light of plate tectonics. Tectonophysics 40, 245, 256.

JENKYNS, H. C. 1978: Pelagic environments. In: Sedimentary environments and facies (Ed. by READING, G.), Elsevier, 314–371.

– 1980: Cretaceous anoxic events: from continents to oceans. J. Geol. Soc. Lond. 137, 171–188.

KÄLIN, O., PATACCA, E. & RENZ, O. 1979: Jurassic pelagic deposits from southeastern Tuscany, aspects of sedimentation and new biostratigraphic data. Eclogae geol. Helv. 72, 716–762.

KETIN, I. 1955: Über die Geologie der Gegend von Ovacuma östlich Zonguldak. Rev. Fac. Sci. Univ. Istanbul B-20, 147–154.

– 1983: Türkiye jeolojisine genel bir bakiş. Istanbul Teknik Üniversitesi Vakfi, Kitap Yayin No: 32.

KETIN, I. & GÜMÜŞ, Ö. 1963: Sinop-Ayancik arasindaki III. bölgeye dahil sahalarin jeolojisi hakkinda rapor. 2. kisim. Jura ve Kretase formasyonlarinin etüdü. Turkish Pet. Co. Arşiv no. 213, Ankara (Unpublished internal report).

KOBLENZ-MISKHE, O. I. 1965: The value of primary productivity in the Pacific Ocean. Okeanologiia 5, 325–337.

LANCELOT, Y., HATHAWAY, J. C. & HOLLISTER, C. D. 1972: Lithology of sediments from the western North Atlantic Leg 11 Deep Sea Drilling Project. In: Initial reports of the Deep Sea Drilling Project, V. XI (Ed. by HOLLISTER, C. D., EWING, J. I. et al.), 910–949, U.S. Government Printing Office, Washington DC.

LETOUZEY, J., BIJU-DUVAL, B., DORKEL, A., GONNARD, R. KRISTCHEV, K., MONTADERT, L. & SUNGURLU, O. 1977: The Black Sea: A marginal basin. Geophysical and geological data. In: Structural history of the Mediterranean basins (Ed. by BIJUDUVAL, B. & MONTADERT, L.), Technip, 363–379.

MANABE, S. & BRYAN, K. 1985: CO_2-induced change in a coupled ocean-atmosphere model and its paleoclimatic implications. Journal of Geophysical Research 90, 11689–11707.

MANETTI, P., BOCCALETTI, M. & PECERILLO, A. 1988: The Black Sea: Remnant of a marginal basin behind the Srednogorie-Pontides island-arc system during the Upper Cretaceous-Eocene times. Bull. Geofis. theor. ed appl. XXX, 39–51.

MONTADERT, L., ROBERTS, D. G., DE CHARPAL, O. & GUENNOL, P. 1979: Rifting and subsidence of the northern continental margin of the Bay of Biscay. In: Initial reports of the Deep Sea Drilling Project, V. XLIII (Ed. by MONTADERT, L., ROBERTS D. G. et al.), U.S. Government Printing Office, Washington DC, 1025–1060.

NEPROCHNOV, YU. P. 1966: Glubinnoye stroyeniye zemnoi korypod Chernym Morem po seismicheskim dannym. Byull. Mosk. Ova Ispyt. Prir., Otd. Geol. 4, 15–29.

NEPROCHNOV, YU. P., MALOVITSKY, Y. P., BELOKUROV, V. S. & GARKALENKO, I. A. 1975: Profilnie sechénia kori po dannim gze. In: Zemnaya Kora i istoriya razvitiya Chernomor skoy Vpadiny. (Ed. by Y. D. BULANDJE, M. V. MURATOV, S. I. SUBBOTIN & B. K. BALAVADZE). Nauka, Moscow, 284–288.

ÖZER, S. 1986: Bati Karadeniz Alt Kretase Rudist faunasi ve paleoekoloji, ön rapor. Turkish Pet. Co. Arşivi, Ankara. (Unpublished internal report).

PARRISH, J. T. & CURTIS, R. L. 1982: Atmospheric circulation, upwelling, and organic-rich rocks in the Mesozoic and Cenozoic eras. Palaeogeogr., Palaeoclimatol., Palaeoecol. 40, 31–66.

PEDERSEN, T. F. & CALVERT, S. E. 1990: Anoxia vs. productivity: what controls the formation of organic-rich sediments and sedimentary rocks? Am. Assoc. Pet. Geol. 74, 454–466.

PELIN, S., ÖZSAYAR, T., GEDIKOĞLU, A. & TÜLÜMEN, E. 1982: Doğu Pontid'lerde Üst Kretase yaşli kirmizi biyomikritlerin oluşumu. Karadeniz Üniversitesi Yer Bilimleri Dergisi, 2, 69–79.

PITMAN, III, W. C. 1978: Relationship between eustasy and stratigraphic sequences of passive margins. Geol. Soc. Am. Bull. 89, 1389–1403.

RENZ, O. & JUNG, P. 1978: Aptian to Maastrichtian in the Swiss Jura Mountains. Eclogae geol. Helv. 71, 1–18.

RYAN, W. B. F. & CITA, M. B. 1977: Ignorance concerning episodes of ocean-wide stagnation. Mar. Geol. 23, 197–215.

SANER, S. 1981. Zonguldak dolaylarinin jeolojisi ve hidrokarbon olanaklari. Turkish Pet. Co. Arşiv no. 1536, Ankara (Unpublished internal report).

SCHLANGER, S. O. & JENKYNS, H. C. 1976: Cretaceous oceanic anoxic events: causes and consequences. Geol. Mijnbouw 55, 179–184.

SCHOLLE, P. A., ARTHUR, M. A. & EKDALE, A. A. 1983: Pelagic environment. In: Carbonate depositional environments (Ed. by SCHOLLE, P. A., BEBOUT, D. G. & MORE, C. H.) Am. Assoc. Pet. Geol. Mem. 33, 620–691.

SCHWARZBACH, M. 1961: Das Klima der Vorzeit. Ferdinand Enke, Stuttgart.

ŞENGÖR, A. M. C. 1984: The Cimmeride orogenic system and the tectonics of Eurasia. Geol. Soc. Am. Spec. Pap. 195.

– 1987: Tectonics of the Tethysides: Orogenic collage development in a collisional setting. Ann. Rev. Earth Planet Sci. 15, 213–244.

ŞENGÖR, A. M. C., ALTINER, D., CIN, A., USTAÖMER, T. & HSÜ, K. J. 1988: Origin and assembly of the Tethyside orogenic collage at the expense of Gondwana-Land. In: Gondwana and Tethys (Ed. by AUDLEY-CHARLS, M. G & HALLAM, A.), Geol. Soc. London Spec. Pub. 37, 119–181.

ŞENGÖR, A. M. C. & YILMAZ, Y. 1981: Tethyan evolution of Turkey: A plate tectonic approach. Tectonophysics 75, 181–241.

ŞENGÖR, A. M. C., YILMAZ, Y. & SUNGURLU, O. 1985: Tectonics of the Mediterranean Cimmerides: Nature and evolution of the western termination of Palaeo-Tethys. In: The geological evolution of the eastern Mediterranean (Edts. DIXON, J. H. & ROBERTSON, A. H. F.), Geol. Soc. London Spec. Pub. 17, Blackwell Sci. Publ., Oxford 77–112.

SIDORENKO, A. V. 1978: Karta razlomov territorii SSSR i sopredelnich stran, 1/2500000 Akad. Nauka. SSSR, Moscow.

TAPPAN, H. & LOEBLICH, A. R. 1971: Geobiologic implications of fossil phytoplankton evolution and time-space distribution. In: Symposium on palynology of the late Cretaceous and early Tertiary (Ed. by KOSANKE, R. & CROSS, A. T.), Geol. Soc. Am. Spec. Pap. 127, 247–339.

TAYLOR, S. R. & MCLENNAN, S. M. 1985: The continental crust: its composition and evolution. Blackwell Scientific Publ., Oxford.

TERMIER, H. & TERMIER, G. 1962: Une hypotese sur le role des courants marins dans le depot de certains calcaires jurassiques et cretaces. In: Livre Mém. P. Fallot (Ed. by DURAND-DELGA, M.) Soc. géol. France 97–102.

TOKAY, M. 1952: Contribution a l'étude geologique de la région comprise entre Ereğli, Alapli, Kiziltepe et Alacaağzi. Mineral Res. and Explor. Inst. Bull. 42/43, 37–38.

TUCKER, M. E. & WRIGHT, V. P. 1990: Carbonate sedimentology. Blackwell Sci. Pub., Oxford.

TÜYSÜZ, O. 1990: Tectonic evolution of a part of the Tethyside orogenic collage: The Kargi massif, Northern Turkey. Tectonics 9, 141–160.

TÜYSÜZ, O., YIĞITBAŞ, E. & SENDAR, H. S. 1990a: Orta Pontidlerin erken Mesozoyik evrimine bir yaklaşim: Paleo-Tetis/Karakaya kenar denizi problemi. Türkiye 8. Petrol Kongresi, Bildiriler, Jeoloji, Türkiye Petrol Jeologlari Derneği/TMMOB Petrol Mühendisleri Odasi, 351–362.

TÜYSÜZ, O., YILMAZ, Y., YIĞITBAŞ, E. & SERDAR, H. S. 1990b: Orta Pontidlerde Üst Jura-Alt Kretase stratigrafisi ve tektonik anlami. Türkiye 8. Petrol Kongresi, Bildiriler, Jeoloji, Türkiye Petrol Jeologlari Derneği/TMMOB Petrol Mühendisleri Odasi, 340–350.

USTAÖMER, T. & ROBERTSON, A. H. F. 1992: Pre-late Jurassic tectonic evolution of the Central Pontides. Int. Symp. on the Geology of the Black Sea Region, MTA Generl Directorate, Ankara, Abstracts, 13.

VON DER BORCH, C. C. & REX, R. W. 1970: Amorphous iron oxide precipitates in sediments cored during Leg 5, Deep Sea Drilling Project. In: Initial reports of the Deep Sea Drilling Project, V. V (Ed. by MCMANUS, D. A. et al.), U.S. Government Printing Ofice, Washington DC, 541.

Von der Borch, C. C., Nesteroff, W. D. & Galehouse, J. S. 1971: Iron rich sediments cored during Leg 8 of the Deep Sea Drilling Project. In: Initial reports of the Deep Sea Drilling Project, V. VII (Ed. by Tracey, J. et al.), U.S. Government Printing Ofice, Washington DC, 541.

Weissert, H. 1981: Depositional processes in an ancient pelagic environment: the Lower Cretaceous Majolica of the Southern Alps. Eclogae geol. Helv. 74, 339–352.

Yilmaz, O. 1980: Daday-Devrekani masifi kuzeydoğu kesimi litostratigrafi birimleri ve tektoniği. Yerbilimleri, Hacettepe Universitesi Yerbilimleri Enstitüsü Yayin Organi, 5–6, 101–135.

Yilmaz, Y. & Tüysüz, O. 1988: Kargi masifi ve dolaylarinda Mesozoyik tektonik birliklerin düzenlenmeleri sorununa bir yaklaşim. Turkish Assoc. Pet. Geol. Bull. 1, 73–86.

– 1991: Anatomy of an imbricated zone: Geology of the Kargi massif, Central Pontides. Bulletin of the Technical University of Istanbul, 44, 279–299.

Yiğitbaş, E., Tüysüz, O. & Serdar, H. S. 1990: Orta Pontidlerde Üst Kretase yaşli aktif kita kenarinin jeolojik özellikleri Türkiye 8. Petrol Kongresi, Bildiriler, Jeoloji, Türkiye Petrol Jeologlari Derneği/TMMOB Petrol Mühendisleri Odasi, 141–151.

Zeitschel, B. 1978: Oceanographic factors influencing the distribution of plankton in space and time. Micropaleontology 24, 139–159.

Zonenshain, L. P. & Le Pichon, X. 1986: Deep basins of the Black Sea and Caspian Sea as remnants of Mesozoic back-arc basins. Tectonophysics 123, 181–211.

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