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STRATIGRAPHY OF KARABURUN PENINSULA

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ABSTRACT. — In the Karaburun peninsula, a tectonic bell with a thick Mesozoic succession is located bordering the Izmir-Ankara zone on its western side. In the stratigrapnic column of the Karaburun belt, the oldest unit is the Lower and Middle Carboniferous Alandere forma tion consisting dominantly of fossiliferous limestones. Lower Triassic rocks rest directly above this unit and Upper Carboniferous and Permian sections are missing. The Lower Triassic is represented by rock units showing facies changes in short distances along vertical and horizontal directions. In this part of the section, the Karareis and Gerence formations are differentiated which are collectively named as the Denizgiren group. The Karareis formation is composed of intercalations of sandstones, bedded-black cherts, pelagic limestones and mafic volcanics, whereas the Gerence formation composed dominantly of ammonitic red limestones, thinly-bedded gray limestones and chcrty limestones. The Karareis and Gerence formations grade laterally into each other and range in age from Scythian to Late Anisian. The Camiboğazı formation resting with a gradational contact on each of these units, consists of massive limestones with reefal facies in places and yields an age of Ladinian-Camian. The Güvercinlik formation lies conformably above the Camiboğazı formation, and consists of algal stromatolites, megalodon-bearing limestones and quartzitic sandstone intervals. This unit ranges in age from Norian-Rheatian. The Nohutalan formation which is dominantly represented by thick-bedded ncritic limestones, overlies the Güvercinlik formation gradationally and yields an age ranging from Liassic to Albian. This unit appears to be lithologically continuous in the field without any indications of a break in the stratigraphic or structural record, however the Dogger age has not been determined which may probably indicate a presence of a hia tus. Above this Mesozoic comprehensive succession with an age spanning from Early Triassic to Early Cretaceous, The Balıklıova formation of Campanian-Maastrichtian age rests unconformably, which consists of carbonate rocks and sandstones of flysch facies. The Karaburun belt with the stratigraphy outlined above, is surrounded from all sides by a blocky unit which is called the Bomova melange. This blocky unit with highly sheared flysch matrix, was formed in the Izmir-Ankara zone during a Maastrichtian-Danian interval. The boundary relations between the Karaburun belt and the Bomova melange indicate that the Karaburun platform was transported tectonically as a nap into the İzmir-Ankara zone during its opening. In this study we have also found that, the stratigraphy of the Karaburun belt is completely different from that of the so-called Sakarya continent, and they can not be correlated with each other as suggested by the earlier workers.

INTRODUCTION

Three tectonic belts are located in the western Anatolia, that have taken their present position during the Middle to Late Eocene thrusting (Fig. 1). The easternmost of these is the Menderes massif, the middle one İzmir-Ankara zone and the western one is the Karaburun belt. During an extensional tectonics since Middle Miocene, grabens cutting obliquely the strike of these older belts have been formed and, in which lacustrine and continental sediments have been deposited.

The Menderes massif consists of very thick mica schists and quartz mica schists in the lower and marbles in the upper parts. The marbles give an age of Devonian-Permian in the lower horizons and Triassic to Late Cretaceous in the upper continuous sections. In recent studies, the youngest age from the metamorphic massif, has been reported as Early Eo*cene,* indicating that the main metamorphism took place after this period (Boray and others, 1973; Çağlayan and others, 1980; Konak and others, 1987).

The İzmir-Ankara zone, that forms general NW-SE trending outcrops in the west of the Menderes massif, is represented by a rock unit called the Bornova melange in the western Anatolia (Erdoğan, 1985). The Bornova melange with strongly deformed internal fabric, is composed of a matrix of flysch and mafic volcanic rocks of Campanian-Danian age and blocks of neritic limestones up to 20 km in length. Partial sections measured from these blocks indicate that they the broken parts of a platform-type succession with an age range from Triassic to Late Cretaceous and this succession was similar on lithological, paleontological and stratigraphic aspects to the Karaburun carbonate association (Erdoğan, 1990). The İzmir Ankara zone represented by the Bornova melange, thrustcd in the Late Eocene on top of the Menderes massif along low angle faults.

The Karaburun belt lies in the westernmost side.of the paleotectonic belts of Anatolia and in which a thick and continuous carbonate succession with an age spaning from Triassic to Albian crops out. It constituted the platform of the İzmir-Ankara zone and moved first as blocks and later as a large nappe into the Bomova melange in the Late Cretaceous (Erdoğan, 1990). Later on, together with the rock units of the İzmir-Ankara zone, the Karaburun nappe thrusted over the Menderes massif in the Late Eocene. This compressional tectonics, which started with the dislocation of the Karaburun platform in

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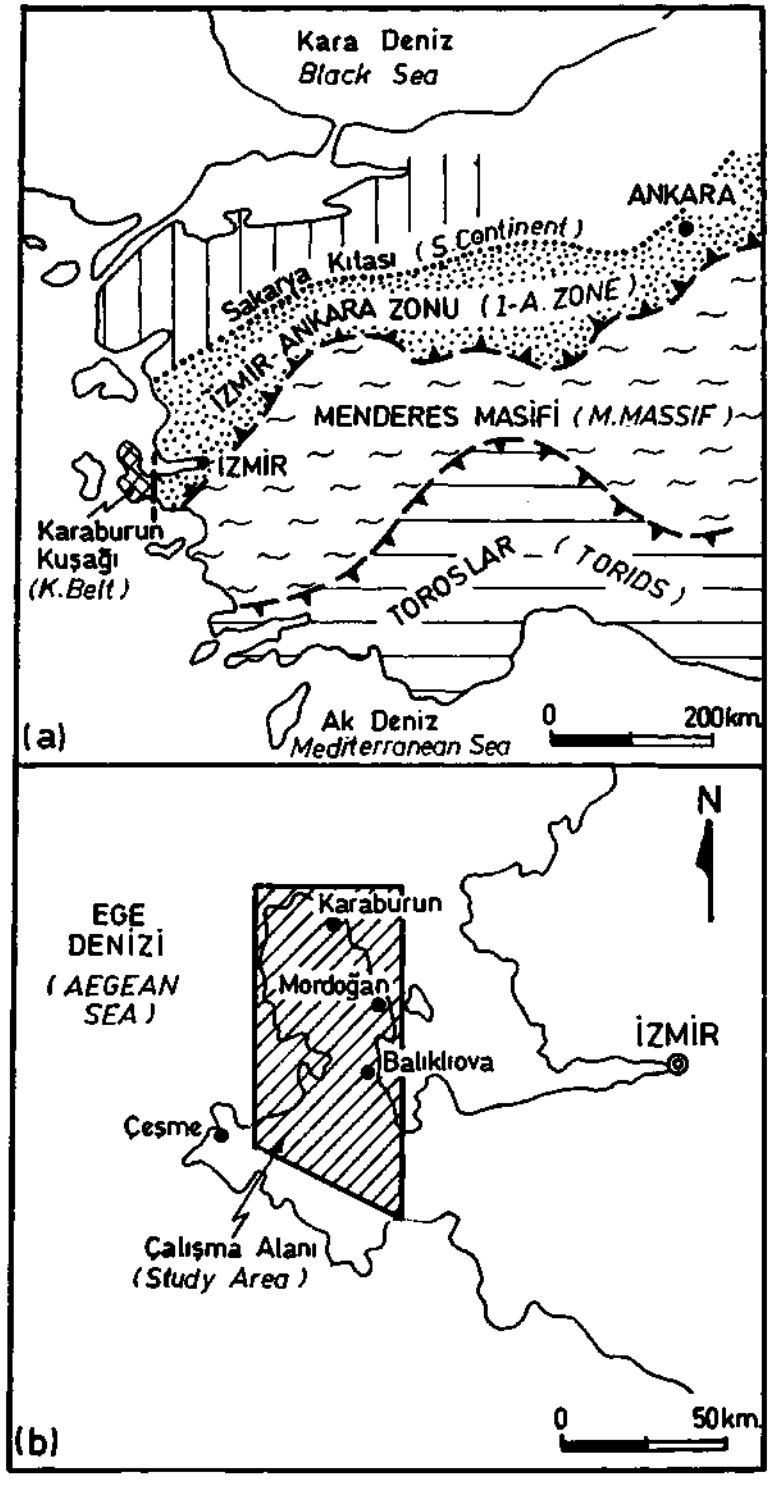

Fig. 1 – Paleotectonic belts of the western Anatolia; In the east Menderes massif, in the middle İzmir-Ankara zone and in the west Karaburun belt are located. The İzmir-Ankara zone thrust over the Menderes massif along low angle thrust faults.

the Maasirichtian and ended in the Late Eocene, strongly erased tracts of the early history of the tectonic evolution of the region. Detailed examination of the stratigraphy of the Karaburun carbonate succession will probably disclose the pre-Maastrichtian evolution of the western Anatolia. The stratigraphy of this succession was constructed on the basis of geological mappings of small areas, in the previous studies. However, the rock units of the area show facies changes in short distances and thus too many units were differentiated in each small areas studied, and mistakes were made in their stratigraphic correlations.

In this study, the geological map of the entire peninsula is prepared on 1:25 000 scale (Fig.2) and by measuring sections, stratigraphic relations of the differentiated units are determined. In namming the formations, earlier recommended

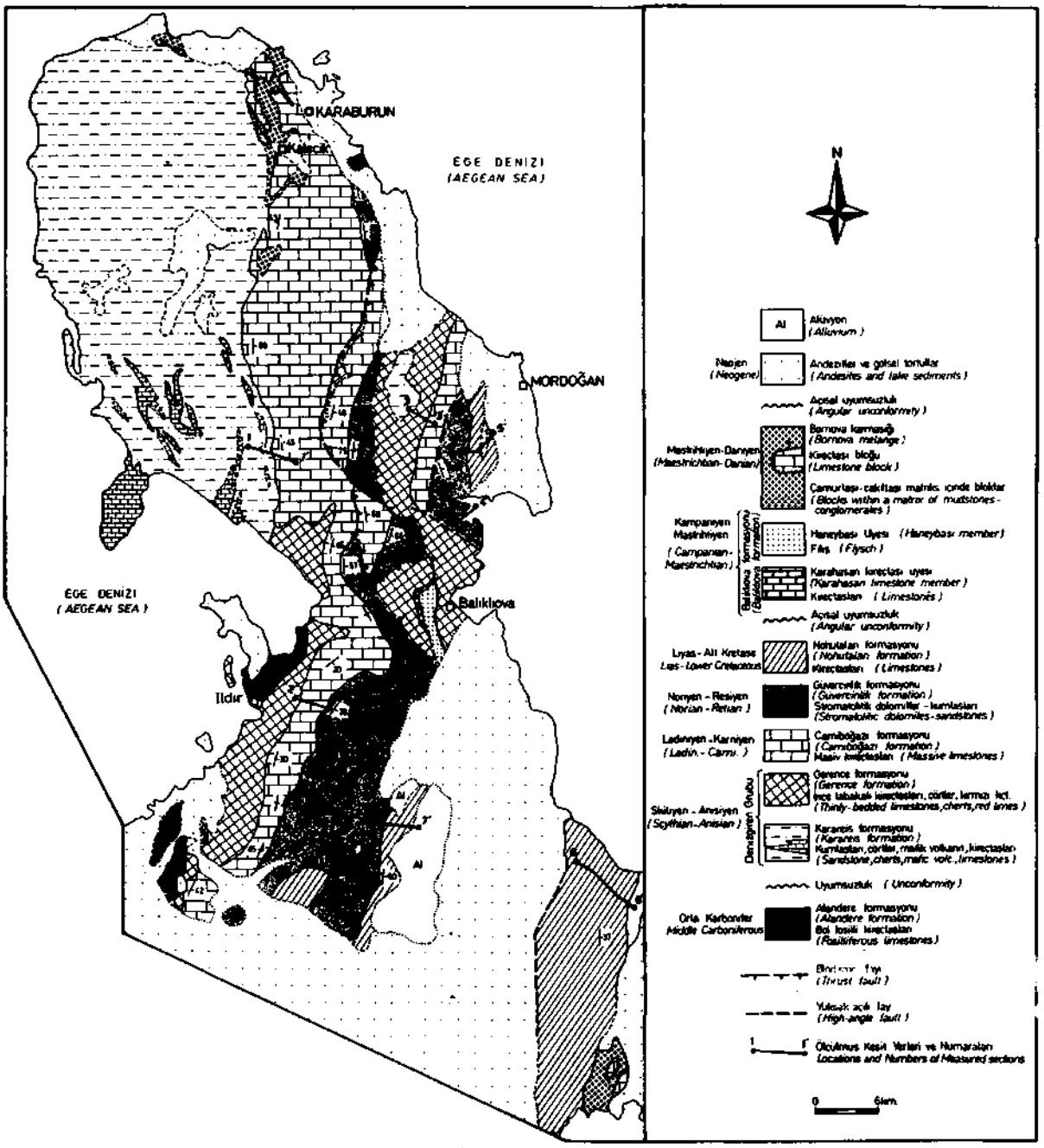

Fig. 2 - Simplified geological map of the Karaburun peninsula; locations of the measured sections discussed in the text are identified with numbers

names have been conserved as much as possible, but their boundaries arc redefined. Some new names arc given and number of units is reduced based on their map ability.

The geological mapping and writing of this paper were made by Burhan Erdoğan. Talip Güngör has joined to the first author in the geological mapping of the Balıklıova-Ildır area. The palconlological determinations were made by Demir Altıner and the stratigraphic sections were measured by Burhan Erdoğan and Sacit Özer.

PREVIOUS STUDIES

The first study on the stratigraphy of the Karaburun peninsula is that of Phillipson who prepared in 1911 a 1:300 000 scale map of the region. He called the Paleozoic basement to the unit forming large outcrops in the northwestern part of the peninsula, that is composed of sandstones, black cherts (lidites) and mafic volcanic rocks, and he suggested its age as Carboniferous on the basis of *Fusulinella* sp. found in the limestones around Ildır. He noted that above this detrital Paleozoic laid along an unconformity a thick Mesozoic carbonate succession.

Ktenas (1925) examined Chios Island and Karaburun together and stated that the oldest part of the succession is located in Oinoussai Island (Koyun adası) to the east of Chios and it consists of low-grade mctamorphic rocks, slates and sandstones with a probable age of Ordovician. He proposed the name Denizgiren group to the intercalations of black cherts and sandstones forming extensive outcrops in the northwest of the Karaburun peninsula, and assigned their age as the Early Devonian. The limestones and detrital rocks around Kalecik village were called by him as the Kalecik beds and they were thought to be the Devonian-Carboniferous. Above the Kalecik beds, he distinguished the Ildır and Yayla groups which were described as consisting of black cherts, graywackes, mafic volcanics and conglomerates with assigned age of the Middle Carboniferous. Above these various detrital Paleozoic he differentiated a thick Mesozoic carbonate succession.

Kalafalçıoğlu (1961) prepared a 1:100 000 scale geological map of the peninsula in the later period. He defined the detrital rocks of the northwestern part of Karaburun as the Devonian graywackes, and recognized on top of these units a continuous carbonate succession of Jurassic to Cretaceous age.

Höll (1966) and Lehnert-Thiel (1968) examined the mercury deposits in the detrital rocks which were considered Paleozoic in the previous studies. Correlating with the similar units in Chios they assigned their age as ranging from Gothlandian to Carboniferous.

In a relatively recent work, the stratigraphy of Karaburun has been examined by Brinkmann and his students between Ildır and Balıklıova regions (Brinkmann and others, 1972, 1977; Gümüş., 1971). In these works, the detrital rocks covering extensive areas in the northwestern part of the peninsula have been omitted all together and not been shown in their stratigraphic column. In their stratigraphic sequence, the oldest units are the Alandere and Tınaztepe formations of Early Carboniferous age. Above this old basement as stated so, they have differentiated a continuous series from Lower Triassic to Lower Cretaceous. Their defined stratigraphy consists of the following units from the bottom to the top: the Domuzçukuru, Koyutepe and the Laleköy formations of Scythian-Anisian; the Camiboğazı formation of Ladinian; the Hanaylı and Güvercinlik formalions of Camian; the Nohutalan formation of Rhaetian-Liassic; the Cladocoropsis limestones of Malm and the Aktepe formation of Early Cretaceous.

The northwestern part of the peninsula has been examined by Konuk (1979). He has determined the age of the detrital units which are composed of graywackes, cherts, olistostromal intervals and limestone lenses as Triassic, and considered as a separate tectonic belt from the Mesozoic carbonate succession of the Karaburun peninsula. He has given the name of the Karareis belt for these detrital and pelagic Triassic and the Karaburun bell for the Mesozoic carbonate succession. He has interpreted the Karaburun belt as a nappe overlaying the Karareis belt along a low-angle thrust fault.

STRATIGRAPHY

PALEOZOIC

The lowermost part of the Karaburun succession is made up of Lower to Middle Carboniferous limestones and above this there is a continuous section with an age range from Early Triassic to Early Cretaceous. On top of this continuous section, a Campanian-Maastrichtian unit lays along an unconformity.

Alundere formation

The oldest unit of the Karaburun succession is the Lower-Middle Carboniferous Alandere formation. This unit, which crops out in a region between Ildır and Reisdere, is composed of dark brown and dark gray limestones with abundant fossils and crinoid stalks. This unit is equivalent of both the Tınaztepe and Alandere formations of Gümüş (1971). Brinkmann and others (1972), however, have called the stratigraphic equivalent of this unit as the Lower Carboniferous massive limestones in their stratigraphic column.

The Alandere formation, besides in the close vicinity of Ildır, forms small outcrops in the northeast of Ildır and near the Balıklıova village. Around Reisdere, this unit is represented by massive limestones with gray and buff color. The most pronounced feature of these limestones is their abundance in coral fossils and in crinoid stalks. In the north of Ildır, this unit consists of dark-gray fossilliferous limestones, limestone conglomerates and green sandstone intervals. The detrital facies of the Alandere formation resembles lithologically to the Lower Triassic rocks and for this reason these different units have been confused by Gümüş. (1971) and Brinkmann and others (1972) in their geological mappings. The marked difference of the Alandere formation from the Lower Triassic rocks is their limestones being dark-gray in color and rich in fossils relative to the Triassic counterparts. In addition, the red and green cherts and red limestones which characterize the Lower Triassic units arc lacking in the Alandere formation.

The lower contact of the Alandere formation is not seen in the Karaburun peninsula and the total thickness of the outcropping part is more than 300 m. This unit forms the lowest part of the Karaburun succession and as contrary to the opinions of earlier workers (Ktenas, 1925; Höll, 1966; Lehnert-Thiel, 1968) there is no older unit than the Alandere formation in the peninsula. The upper contact is observed along the road connecting Ildır to the Gerence bay and, dark-gray fossilliferous limestones of this unit is directly overlain by light-gray limestones of the Lower Triassic. Along the contact zone, there is a karstic and oxidized horizon suggesting a subaerial exposure. To the east of Reisdere village, this contact can again be seen but 3-4 m wide area along the boundary is covered. At this last location, massive limestones of the Alandere formation are covered by thinly-bedded limestones and red-green chert intercalations of the Lower Triassic Gercnce formation. Close to the boundary, a conglomerate horizon, that can be traced laterally 15 to 20 m, is present but its clasts consist entirely of Triassic material suggesting its being an intraformational breccia rather than a basal conglomerate. In the north of Ildır, close to the Alantepe location, thinly-bedded cherty limestones and pelecypoda-rich limestones of the Gerence formation rest directly above the Alandere formation. This contact is also seen to the west of Eski Balıklıova village where the limestones of the Lower Triassic overlay the Carboniferous; at this last location lithologically there is no distinction between the two different units and only by palcontologic determinations they can be distinguished from each other.

As summarized above, observations from different areas suggest that, the Lower Triassic rocks directly rest upon the Lower-Middle Carboniferous Alandere formation and, in between. Upper Carboniferous and Permian are missing. The presence of a zone of karstic solutions along the boundary may suggest a period of subaerial exposure between the two units.

Point samples collected from different levels of this formations and, series of samples from the upper parts, have yielded the following list of fossils that give the early Middle carboniferous (Baskhirian) age for the formation.

Eostafella postmosquensis, E. postmosquensis acutiformis, E. pseudostruvei, E. varvariensis, E. ex gr. *ikensis, Pseudoslafella antiqua, P. compressa, Eostqfellina protvae, Eos. paraprotvae, Plectostaffella inconstans, Globivalvulina moderala, G. scaphoidea, G. bulloides, Bradyina cribrostomata, Earlandia elegans, Endothyra baschkirica, E. spirilliniformis, Pscudoendothyra* aff. *struvei. Planoendothyra* sp., *Eotuberitina reitlingerae, Glomospira subquadrata, Pseudoglomospira* sp., *Palaeonubecularia fluxa, Asteroarchaediscus gregorii, A. postrugosus, Monotaxinoides donbassicus, Diplosphaerina Inacqualis. Tetraxis conica." Endotexis "* sp., *Milerella* sp., *Trepeilopsis* sp., *Haplophragmina* sp., *Clymacammina* sp., *Turrispiroides* sp., *Deckerelta* sp., *Mediocris* sp.

Brinkmann and others (1972) have described the Alandere formation of this paper as the Paleozoic massive limestones and given their age as Early Carboniferous. Gümüş, (1971) suggested the age of the equivalent units as Early Carboniferous including Viscan. In these two papers below the Carboniferous units, Devonian black cherts and graywakes have been mentioned. We have found that, their Devonian, partly belongs to the detrital facies of the Lower Triassic and partly to the Carboniferous Alandere formation.

This formation is rich in coral and crinoid fossils, and in places the limestones of reefal facies contain intraformational conglomerate intervals. It was formed in a shallow marine environment with moderate climatic conditions.

MESOZOIC

In the Karaburun peninsula the Mesozoic is represented by a continuous succession from Lower Triassic to Albian. The lower part of this succession, which is Scythian-Anisian in age, shows facies changes even in short distances. These different facies have been named as formations in the earlier studies (Brinkmann and others, 1972; Konuk, 1979), and thus their stratigraphic relations have created problems.

In our study, in the *Lower*-Middle Triassic, the Denizgiren group has been differentiated as it was first suggested by Ktenas (1925). In this group, the Karareis and the Gerence formations have been recognized. The Karareis formation forms extensive outcrops in the northwestern corner of the peninsula and consists of bedded black cherts, sandstones, mudstones, mafic volcanics and pelagic limestones. The Gerence formation is the lateral equivalent of the Karareis formation and consists dominantly of thinly-bedded gray limestones, marls, ammonitic red limestones and red-green cherts. This unit is found in the southwest and east of the peninsula.

The Camiboğazı formation rests with a gradational contact on both of the formations of the Denizgiren group. Upward in the sequence above the Camiboğazı formation, first the Güvercinlik and second the Nohutalan formations arc present. The Upper Cretaceous Balıklıova formation unconformably overlies the Mesozoic sequence.

Denizgiren group

The Denizgiren group includes the detrital-rich Karareis and the carbonate-rich Gerence formations.

Karareis formation . _ This unit is composed of buff sandstones, mudstones, thinly-bedded black cherts and lenses of pelagic limestones. In the upper part of the unit, there are intervals of mafic tuffs and mafic volcanics.

This unit first has been examined by Konuk (1979) and interpreted as a separate tectonic belt in the peninsula and named as the Karareis tectonic belt. In our study, the Karareis formation is equivalent of 6 out of the total 7 formations of the Karareis tectonic belt of Konuk, excluding only his Tuzluk formation. This unit is heterogeneous in lithology and various lithologics grade laterally into each other. These various lithologies are named together as one formation, rather than distinct units as proposed by Konuk. Besides that, in our study, the Karareis formation is not considered as a separate tectonic belt but only a unit in the Karaburun succession.

The lower parts of the Karareis formation, as seen in the northwestern corner of the peninsula near Sarpıncık village, consist of a thick succession of mudstones. Upward in the sequence buff sandstones and thinly-bedded black cherts become dominant. In the middle and upper parts, yellow and red coloured thinly-bedded limestone lenses with micritic facies are abundant. These lenses include thin-shelled pelecypods and rarely ammonites and reach up to 300 m in thickness. They can be faced laterally one or two kilometers. These pelagic limestone lenses grade laterally into black chert intervals and mudstones.

In the Karareis formation, there are intervals of olistostromes with limestone blocks of various sizes and ages set in a matrix of mudstones. In rare cases, these blocks reach up to 500 m in length and contain abundant crinoid stalks. In some of these blocks Carboniferous age has been determined and they are found to be similar in lithology to the limestones of the Alandere formation.

In the uppermost parts of the Karareis formation, there arc hyaloclastites and mafic lavas interbedded with mudstones. The mafic lavas are composed of albite and augite fenocrysts of up to 0.5 cm set in an aphanitic matrix. They have affected by strong alteration and amgydules and veins are filled with chlorite, calcite and epidote minerals.

Although the Karareis formation shows heterogeneous lilhology, the internal structure is rather regular. For example, the black chert and pelagic limestone lenses thin and thicken along the strike but still show lateral continuity, so that their map patterns discern very tightly folded internal structure of the Karareis formation.

Because of the tightly folded internal structure, the true thickness of the unit can not be predicted definitely but from geological cross sections it is estimated to be more than 2000 m.

The lower contact of the formation is now here seen in the peninsula but its equivalent Gerence formation rests on the Carboniferous Alandere formation. The upper contact is gradational with the Camiboğazı formation and as seen along the İdecik Çeşmesi section on Figure 3, there is a 19 m thick gradational zone between these two units characterized with thinly-bedded yellow limestones. The gradational nature of these two formations can also be followed in the paleontological determinations as there is a continuous range of an age from Anisian to Ladinian.

The Karareis formation is very poor in fossil content and, because of strong secondary dolomitization, only radiolaria remains and sponge spines arc found in few places. In only a few of the samples collected from various levels of the formation, *Spirorbis phlyctaena* and, pelecypoda and echinodermata remains have been recognized which have yielded a probable Early Triassic age (Scythian).

In the upper part of the formation, in the vicinity of the İdecik Çeşmesi section (Fig. 3), a badly-preserved ammonite has been found, which docs not give a precise age. The samples collected for conodont determinations (Fig. 3), however have yielded Late Schythian-Early Anisian age. The foraminifera contents, on the other hand, indicate a range of age from Late Anisian to Early Ladinian between the Karareis and overlaying Camiboğazı formation. Along this transitional zone, about 3 km far from the İdecik Çeşmesi. in thinly-bedded limestones and cherty limestones *Daonella elongata, D. semicordiformis* and D. *moussori* have been determined suggesting Late Anisian to Early Ladinian age.

Konuk (1979) has found *Naticella acuticostata* in the lower parts of this formation, which indicates Late Scythian age. The paleontologic determinations from various parts as summarized above, indicate that the age of the Karareis formation ranges from Scythian to Late Anisian.

The Karareis formation has been deposited in a marine environment in which detrital input was very high. From time to time, pelagic limestones and bedded black cherts were formed in this basin. As olistostromal intervals and old limestone blocks of up to 500 m in length suggest, the depositional site was technically active and in this opening and foundering Early Triassic basin, mafic volcanism took place during the Anisian period. In Ladinian, the opening had stopped and a platform condition, in which a thick neritic carbonate succession builded up, had prevailed.

Gerence formation . _ If the Karareis formation is followed from the northwestern part of the peninsula, where it forms large outcrops, southward to the Gerence bay, it gradually changes into a unit composed dominantly of thinly-bedded limestones, marls, ammonilic red limestones, green-red cherts and sandstones. This carbonate-rich equivalent of the Karareis formation is called, in this study, the Gerence formation.

This formation is lithologically heterogeneous and its various facies have been named as formations by Brinkmann and others (1972) and the Domuzçukuru, Koyutepe and the Laleköy units have been differentiated in upward sequence. In our study, the Gerence formation encompases their three formations. The ammonitic red limestones, for example, which have been named as the Laleköy formation by Brinkmann and others (1972) are found repeatedly in different levels of the Gerence formation and thus can not be considered a separate unit but rather a change in lithology.

The Gerence formation forms large outcrops in two regions, one in the western side of the peninsula between Ildır and Gerence bay and the other as a belt starting from Balıklıova village extending northward from the western side of Küre mountain and ending near to Eylenhoca village.

This unit is composed of light-gray cherty limestones and light-gray marls. In the lower parts of the unit, there are sandstone intervals with plant fragments and red to green cherts. In the detrital facies of the Gerence formation, there are fossil-rich bioclastic limestone lenses. The detrital facies of this unit is confused in places with the Carboniferous Alandere formation. In the upper parts of the formation, ammonitic red limestone intervals are present. In the middle and upper parts of the unit, conglomerate horizons with limestone and chert particles are abundant These horizons laterally and vertically grade into massive limestones which are lithologically similar to the clasts of the conglomeratic intervals. They seem to be intraformational breccias 'inside the massive limestone. Around the Sıcakbük location, 4-5 km to the north of Balıklıova, interbeddcd with the conglomerate intervals there are massive reefal limestones up to 50 m in thickness composed entirely of coral, bryozoa and algae colonies. These reef and fore reef facies of the Gerence formation gradually pass upward to the massive limestones of the overlaying Camiboğazı formation as observed around Küre mountain.

The minimum thickness of the Gerence formation is about 150-200 m but it measures more than 500 m in the north of Balıklıova.

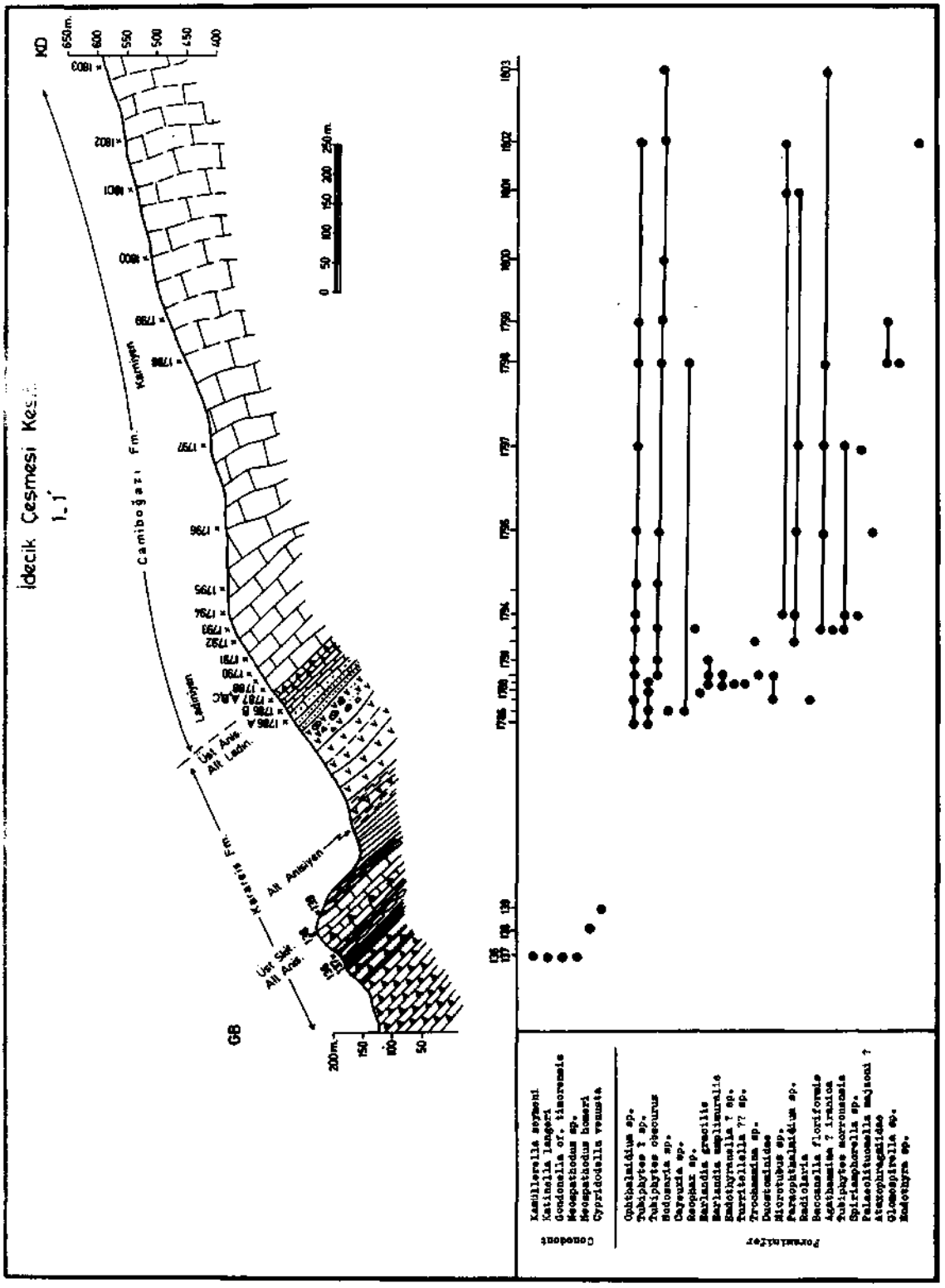

Fig. 3 – İdecik Çeşmesi section; Karaisalı formation lays below the Camiboğazı formation and the boundary between them is gradational. Sample numbers and fossil contents are given below the section. See Figure 2 for the location of the section.

This unit is laterally gradational with the Karareis formation and this relation can be observed along the road between Gerence bay and Küçük Bahçe village. At this location thinly-to moderately-bedded gray limestones of the Gerence formation change gradually along the strike to the red pelagic limestones with volcanic intercalations, bedded-black cherts and, the sandstones of the Karareis formation.

The Gerence formation overlies the Lower-Middle Carboniferous Alandere formation and this relation is described in that section. Along the boundary, although there is no angular unconformity, Upper Carboniferous and Permian are not present and in the contact zone karstic cavities are abundant.

On top of the Gerence formation, rests with a gradational relation, the Camiboğazı formation (Fig. 4). In between the two units, there is a zone characterized by thinly-bedded yellow limestones which gradually passes upward into the massive limestones of the overlaying unit. Similar gradational boundary is seen to the west of Küre mountain and the transition zone is 15-20 m in thickness.

The uppermost parts of the Gerence formation arc determined to be Late Anisian in age (Fig. 4). Below these parts, there are ammonite-bearing red pelagic limestones which have been determined by Brinkmann and others (1972) as Late Anisian by ammonite faunas.

The middle and upper parts of the unit arc observed in the Küre mountain section (Fig. 5) and their age arc probably Scythian. Near Ildır, close to the lower contact, samples have yielded thin-shelled pelecypods, echinid particles and *Ophihalmidium* sp., which may only suggest a range of Triassic.

The Domuzçukuru and Koyutepe units of Brinkmann and others (1972), which arc interpreted as different facies within the Gerence formation of our study, have been reported as Scythian and Late Anisian.

In summary, the age of the Gerence formation probably starts from the Scythian and continuous to the Late Anisian. Above this unit, along a transitional zone, that yields Late Anisian-Early Ladinian age, the Camiboğazı formation is present.

This unit was formed in a relatively deep marine environment in which cherts and ammonitic pelagic limestones were formed. Sporadic submarine volcanic activities had produced thin mafic tuff intervals. Upward in the unit, reefal massive limestones and intraformational conglomerate horizons arc present, that suggest a gradual shallowing of the dcpositional site. As the lateral interfingering relations with the Karareis formation suggest, from the southern carbonate-forming marine environment of the Gerence formation, it was passed northwestward into the tectonically active deep trench of the Karareis formation.

Camiboğazı formation

The Camiboğazı formation consists dominantly of light-gray massive limestones that form relatively sharp topography comparing to the surrounding units. It overlies both the Gerence and Karareis formations of the Denizgiren group. This unit was first named and described by Brinkmann and others (1972) and Gümüş (1971).

The most open outcrops of this formation arc seen to the cast of Ildır, near the Camiboğazı location (Fig. 4). From this area, the thickness of the unit increases to the north and it forms the Akdağ Range which is topographically highest parts of the peninsula (Fig. 2).

The lower parts of the unit arc veined with pink color and these parts were excavated for marbles in historic times. The Camiboğazı limestones appear to be lack of fossils with naked eyes but in thin sections, abundant algae colonies arc seen, and bioclasts of foraminifers, ostracods, crinoids and gastropods arc common.

At the type location, along the Camiboğazı section, the formation measures 400 to 500 m in thickness, but along the Akdağ Range to the north, it is more than 1000 m.

The lower, contact of this unit is gradational with the Gerence and the Kararcis formations (Fig. 2, 4 ,5) and the upper contact is conformable with the Güvercinlik formation (Fig. 4).

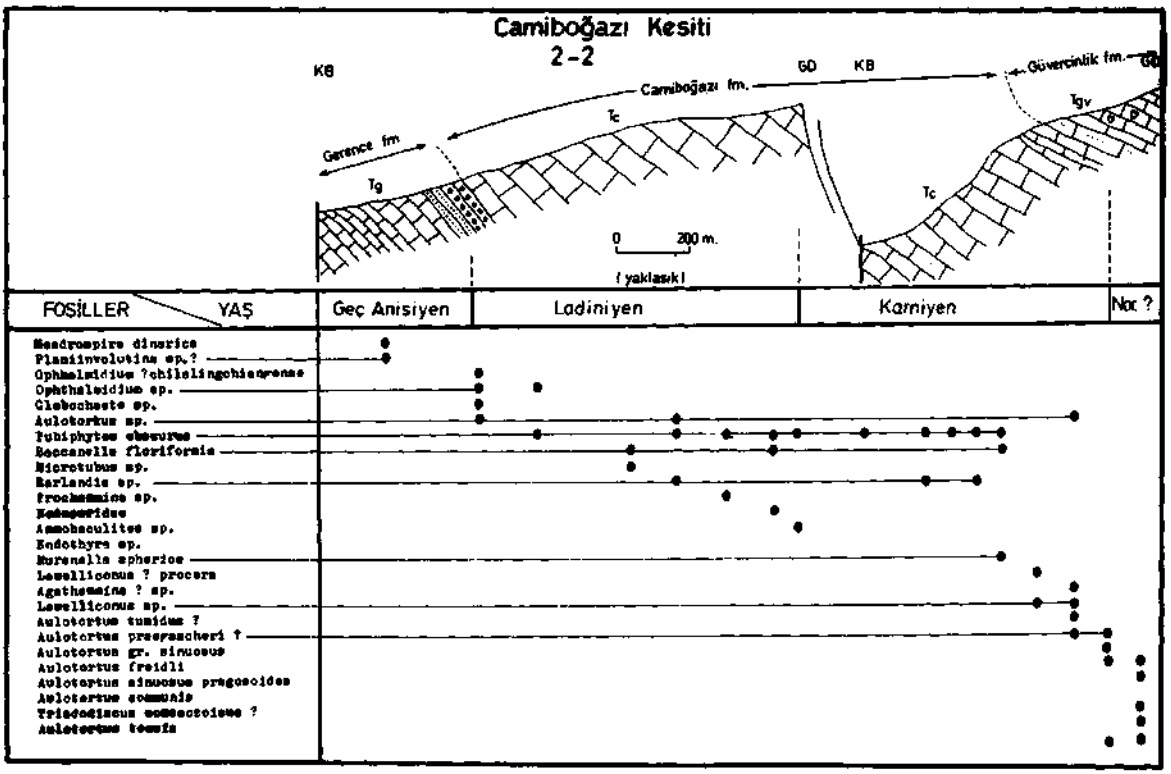

Fig. 4 - Camiboğazı section; Stratigraphic relations of the Camiboğazı formation with the Gerence formation below and the Güvercinlik formation above are seen. See Figure 2 for the location of the section.

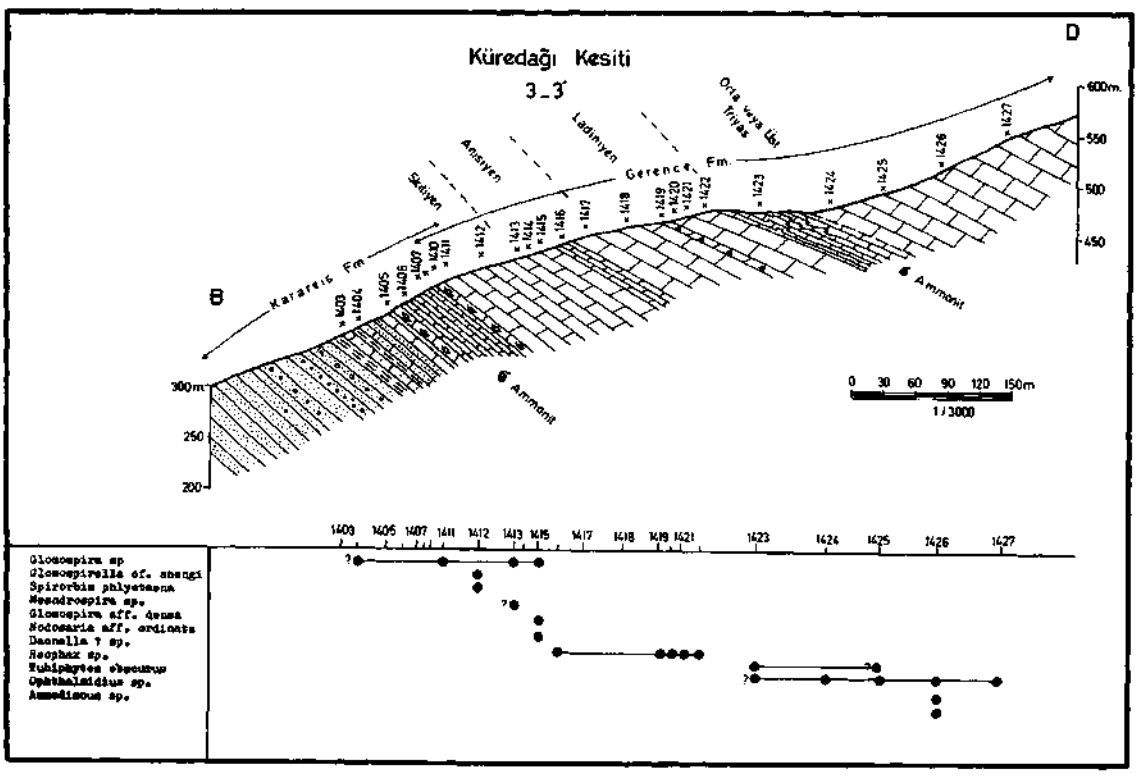

Fig. 5 - Küre mountain section; Stratigraphic relations between Gerence and Karareis formations are observed. See Figure 2 for the location of the section.

The age of this unit ranges from Ladinian to Carnian, as observed in the Camiboğazı and İdecik Çeşmesi sections in Figure 3 and 4.

The limestones of the unit arc light gray in color and generally massive-bedded with abundant bioclasts and algae colonies which suggest a shallow marine depositional environment with sporadic patch reefs.

Güvercinlik formation

The Güvercinlik formation consists of intercalations of dolomitized algal stromatolites, megalodon-bearing limestones and quartzitic red sandstones.

In this study, this formation comprizes both of the Hanaylı and Güvercinlik formations of Brinkmann and others (1972). In their definitions, these workers have put dolomites under the Hanaylı unit and sandstone with dolomite intervals under the Güvercinlik unit. These different lithologies interdigitate along lateral and vertical directions and so that it is considered to be better to put them into one formation.

The open outcrops of this unit are seen along the road-cuts between Ildır and Barbaros villages and near the Tahtaiskele location, which is in the north of Balıklıova (Fig. 4,6).

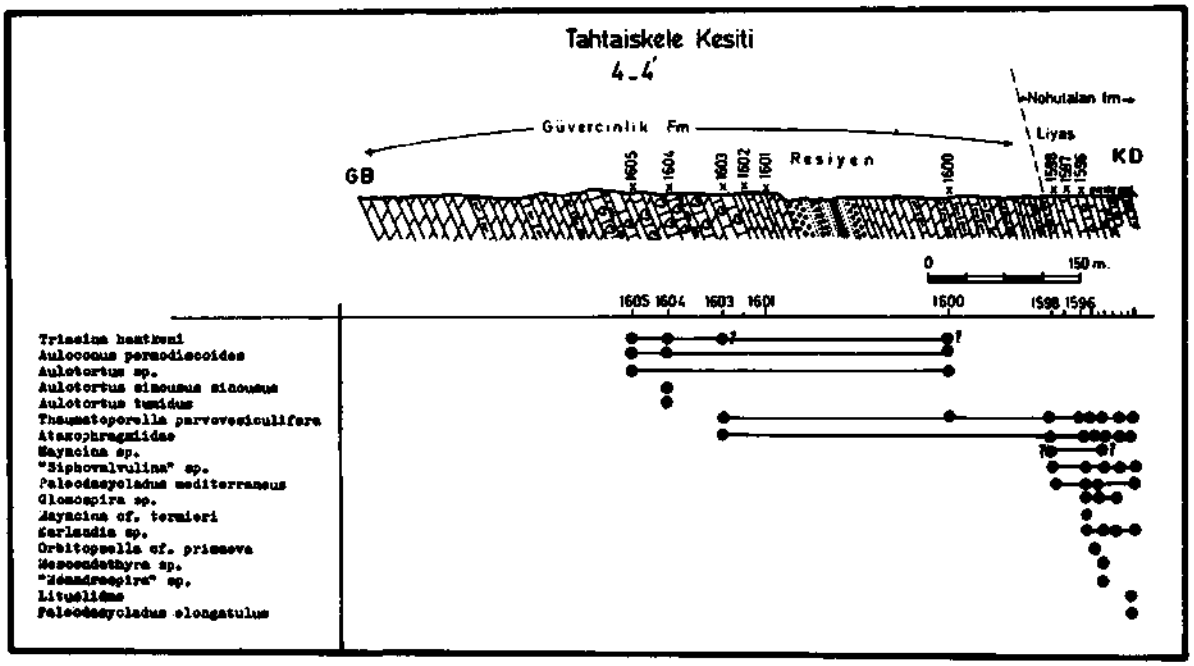

Fig. 6 - Tahtaiskele section; Stratigraphic relations between the Güvercinlik and the Nohutalan formations are observed. See Figure 2 for the location of the section.

In the lower section, the unit consists of thinly bedded, megalodon-rich yellow limestones. Upward in the sequence, laminated dolomites and algal stromatolites become dominant. Interbedded with laminated dolomites, there are 1-5 m thick massive limestone intervals which contain big megalodons up to 30 cm in diameter. Associated with algal stromatolites, lithoclastic conglomerate horizons are present, and the particles of these intervals arc cemented by red carbonate and sandy materials. In the algal stromatolites, birds-eye structures are abundant and their voids are filled with calcite.

In the Güvercinlik formation, claystone intervals with red and green colors and quartzitic red sandstone lenses are seen and, they laterally interfinger with laminated dolomite horizons. In the claystone beds, loferite structures are present in places, that can be recognized with skeletal calcite vugs and with high porosity.

The lower contact of the Güvercinlik formation, as seen in Figure 4, is gradational with the Camiboğazı limestones. The upper contact is also gradational and at the Tahtaiskele location (Fig. 6) the Nohutalan formation rests conformably above this unit. Samples collected along two sections (Fig. 4,6) indicate the age of this formation as Norian and Rhaetian.

This unit was deposited in a shallow carbonate-depositing basin. The laminated dolomite intervals suggest a tidal-flat environment in which algal stromatolites deposited as primary dolomites. Intercalation of the algal stromatolites and massive megalodon-rich limestone intervals indicate sporadic change in the depth so that patch-reefs formed when the sea-level rised and the environment become suitable for prolification of the big megalodons. The loferite horizons in the green claystone beds suggest dominance of a evaporitic conditions from time to time and, lithoclastic conglomerates were formed from the disintegration of subaerially exposed dolomites.

Into the carbonate depositing sedimentary environment of the Güvercinlik formation, detrital materials were carried sporadically and the cross-bedded sandstone lenses were formed.

Nohutalan formation

The Nohutalan formation consists of well-bedded gray limestones and dolomitic limestones. This unit is equivalent of both the Nohutalan unit and "the Cladocoropsis limestones" of Brinkmann and others (1972).

In five different areas, sections have been measured and samples have been collected from this unit; three of the measured sections will be discussed in this paper. Mapping of the entire Karaburun peninsula has shown us that there is nolithological variation to divide this unit into two different formations as done by Brinkmann and others (1972).

This unit can be examined in open outcrops in an area to the north of Balıklıova, in the vicinity of Barbaros village and around the Urla İçmeler region (Fig. 2).

Along the Tahlaiskele section (Fig. 6), the lower part of the unit is seen, which is composed of thick-bedded gray limestones with abundant small megalodon fossils. Upward in the sequence, dolomitic limestones and well-bedded limestones become predominant. In the middle and upper parts of the formation, as seen along the Çatalkaya sections (Fig. 7,8),

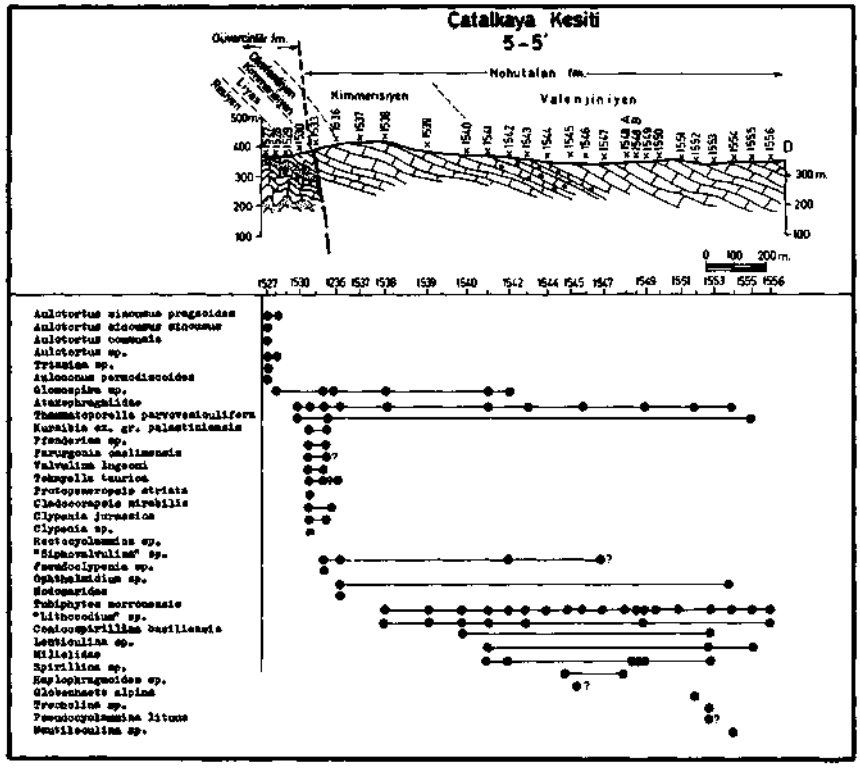

Fig. 7 - Çatalkaya section; Age of the middle and upper parts of the Nohutalan formation is observed. See Figure 2 for the location of the section.

there are chert nodules and beds within gray limestones. Along the İçmeler section in Figure 8, pelecypoda-rich horizons arc found that can be followed as key beds along their strikes. In the upper parts of this last section bryozoa, coral and algae-rich

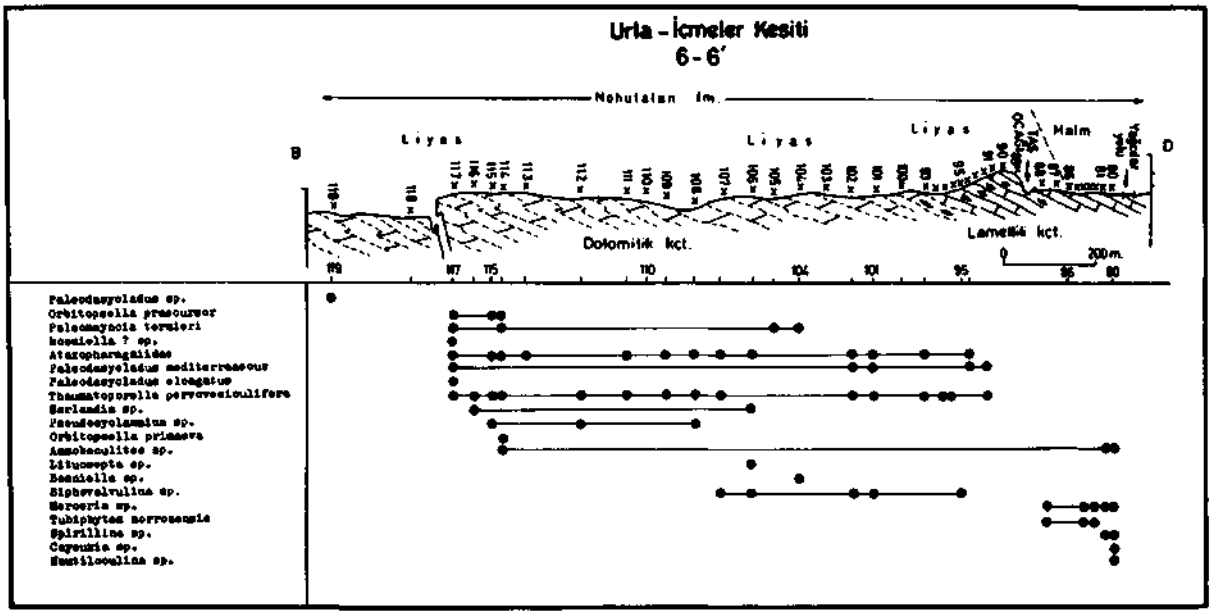

Fig. 8 - Urla İçmeler section; Lower and middle parts of the Nohutalan formation arc observed. See Figure 2 for the location of the section.

reefal limestones predominate. Along the Barbaros section in Figure 9, nearly the complete thickness of the Nohutalan formation can be seen. In the lower parts at this location dolomites arc common, in the middle parts buff limestones with abundant miliolids and gastropodas are found and in the upper part of the section there are laterally discontinuous bauxite pockets which are only a few meter in length.

The thickness of this formation is estimated to be more than 500 m. The lower contact is gradalional and can be seen along the Tahtaiskele section (Fig. 6). The Balıklıova formation of Campanian-Maastrichtian age rests unconformably above the Nohutalan formation.

The lower part of the Nohutalan formation yields the Liassic age as observed in Figure 6. Along the Çatalkaya, Barbaros and the Urla sections (Fig. 7,8,9) without any lilhological changes, the unit is represented by neritic shallow-marine limestones. In these three sections, Liassic Malm and Early Cretaceous ages have been determined, but Dogger is absent. In addition to these three sections, along two more which arc not shown in this paper, it has been observed a continuous carbonate succession from Liassic to Albian but still no characteristic fossils suggesting the Dogger age has been found. It is probable that there is a Dogger hiatus in the Nohutalan formation.

Our study shows that the age of the Nohutalan formation ranges from Liassic to Albian. However, in an earlier paper, Brinkmann and others (1972) have separated a Liassic Nohutalan formation and a Malm "Cladocoropsis limestone unit" although they have not mentioned any lithological distinction.

The Nohutalan formation deposited in a shallow marine platform environment. The lower part of the unit, similar to the underlaying Güvercinlik formation, was formed in a tidal-flat and a sublidal environment. In the middle part of the unit abundant bryozoa, coral and pelecypoda fossils arc found which form reefs in places. The uppermost parts of the unit, as the presence of bauxite lenses suggest, were formed in a very shallow carbonate-depositing platform area which was subacrially exposed from time to time. The subacrial conditions were probably short-lived and not extensive laterally, so that above the laterally discontinuous bauxite lenses, carbonate rocto with similar lithology to the underlaying part of the unit, were deposited. The bauxite lenses are located within the Nohutafan formation, not at the base of a overlaying Upper Cretaceous unit as proposed by Brinkmann and others (1972). Thus, they do not indicate a well-marked unconformity, but rather sporadic sea level changes during the Albian time.

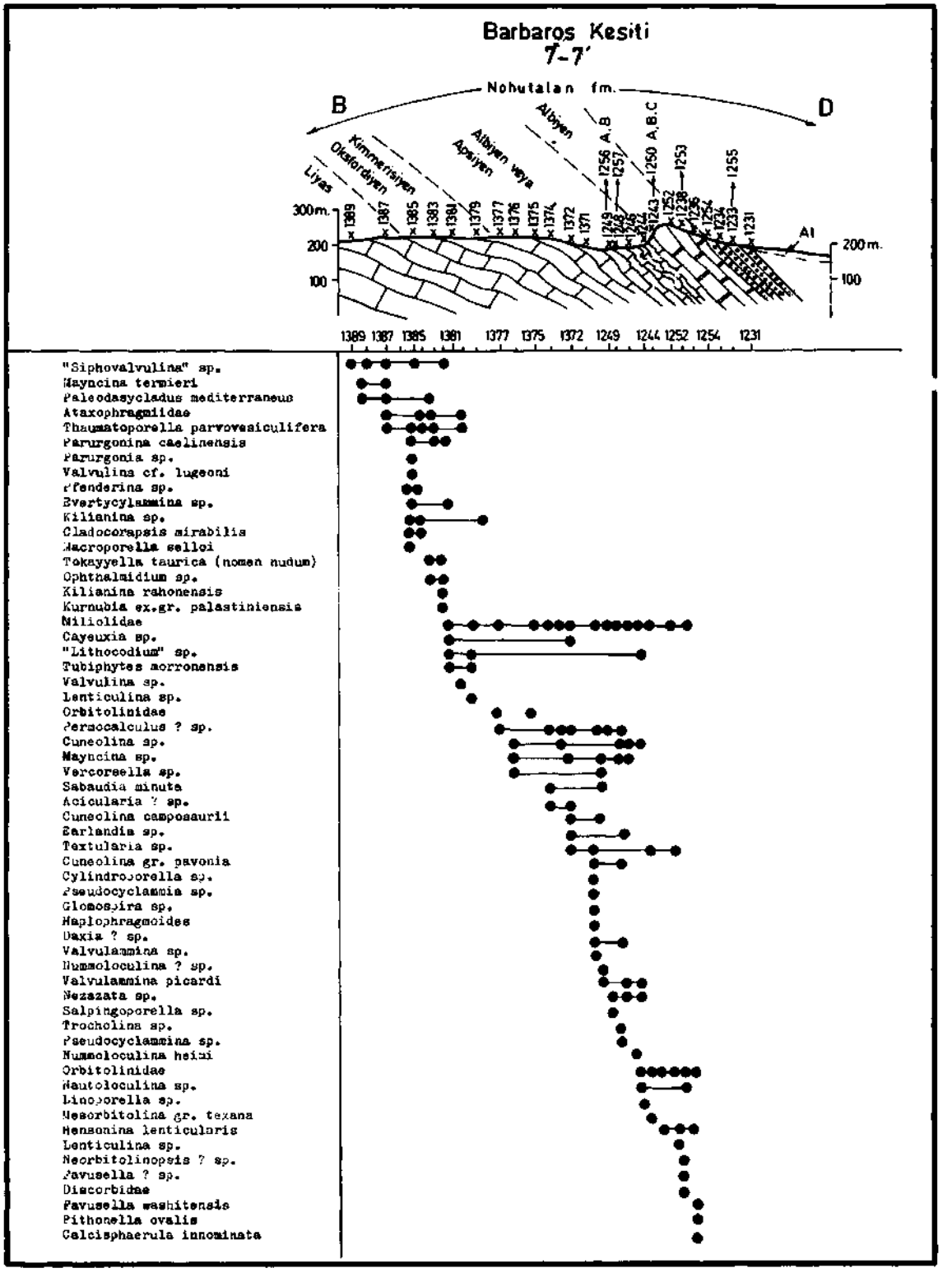

Fig. 9 - Barbaros section; Nohutalan formation is observed. See Figure 2 for the location of the section.

Balıklıova formation

In the Karaburun peninsula, above the continuous Mesozoic carbonate succession, lays along an unconformity the Balıklıova formation of the Campanian-Maastrichtian age. The stratigraphy of the Upper Cretaceous in the area was described by the first author in a separate paper (Erdoğan, 1990) and the tectonic relations between the Karaburun belt and the İzmir-Ankara zone was discussed. In this paper only a short summary of this formation will be given.

The Balıklıova formation consists of two members, which are named the Karahasan limestone and Haneybaşı member in ascending order. The Karahasan limestone is composed of thick-bedded gray limestones at the lower parts and pelagic cherty and thinly-bedded limestones in the upper sections, which together range from 5 to 100 m in thickness. The pelagic red-to pink-coloured uppermost part of the member gradually passes to the flysch-type detrital rocks of the Haneybaşı member above.

The Balıklıova formation overlays various parts of the Karaburun succession; in places directly resting over the Lower Triassic unit and in others over the Nohutalan formation of Liassic to Albian age. There is a marked angular unconformity at the base of this formation.

The Karahasan limestone is fossilifcrous and yields an age of Campanian-Maastrichlian, whereas the Haneybaşı member is Maastrichtian as determined from a rare thin carbonate lenses in the flysch-type sandstone and mudstone intercalations. The detrital rocks of this upper member of the Balıklıova formation measure at least 300 m in thickness, but the upper contact is a thrust fault.

The Balıklı3ova formation was formed in a shallow-marine carbonate-depositing environment at its lowermost part but as the lithological changes in the middle and upper part of the unit indicate, the shallow environment suddenly changed into a deep basin, in which first the pelagic limestones and later the flysch-type detrital rocks were formed. This sudden and fast subsidence of the basin might be related to the openning of the İzmir-Ankara zone that was probably reached on an oceanic extend from place to place in the western Anatolia.

The Karaburun succession formed the platform of the İzmir-Ankara zone and when it was openning, small and large slices of this platform were technically transported into this nearby basin, so that the blocky unit called the Bornova melange was formed. The Bornova melange includes large and small limestone blocks derived from the Karaburun succession, and it was formed during the Campanian-Danian interval, as determined from the age of the matrix of this chaotic unit.

This blocky unit crops out both in the northern and eastern parts of the peninsula, and the contact relations with the Karaburun succession indicate that, this belt is a large nappe in the chaotic unit and the tectonic transport occurred during the opening of the İzmir-Ankara zone (Erdoğan, 1990).

STRATIGRAPHIC AND STRUCTURAL EVOLUTION OF THE KARABURUN PLATFORM

The generalized stratigraphic section of the Karaburun succession, and the ages and lateral relations of the outlined rock units arc shown in Figure 10. The Alandere formation of the Early-Middle Carboniferous represents the oldest unit in the succession. After the deposition of the reefal limestones of this unit and before Scythian, the platform was uplifted and as the absence of the Upper Carboniferous and Permian suggests, these scries were either not deposited or erroded in the peninsula.

The Gerence formation deposited over the Carboniferous unit with the Scythian transgression and there is a hiatus at the base of this unit.

The basin, in which the Gerence formation was formed, continued as a deeper trench to the north of the peninsula and in this teclonically active tantional furrow, the pelagic limestones, bedded cherts, mafic volcanics of the Karareis formation were formed. In this relatively deeper basin, which was spreading and producing the mafic volcanic intervals, very thick mudstone and sandstone deposition took place that arc found nowinterdigitatingwith the pelagic sediments.

Due to this tantional spreading and opening in the northward direction, the Karareis formation had reached more than 2000 m in thickness while the equivalent Gerence formation measuring only 200 m in the south. Besides that, the presence of more than 100 m thick interval of the mafic volcanic rocks, olistostromal horizons with older limestone particles, and lime-

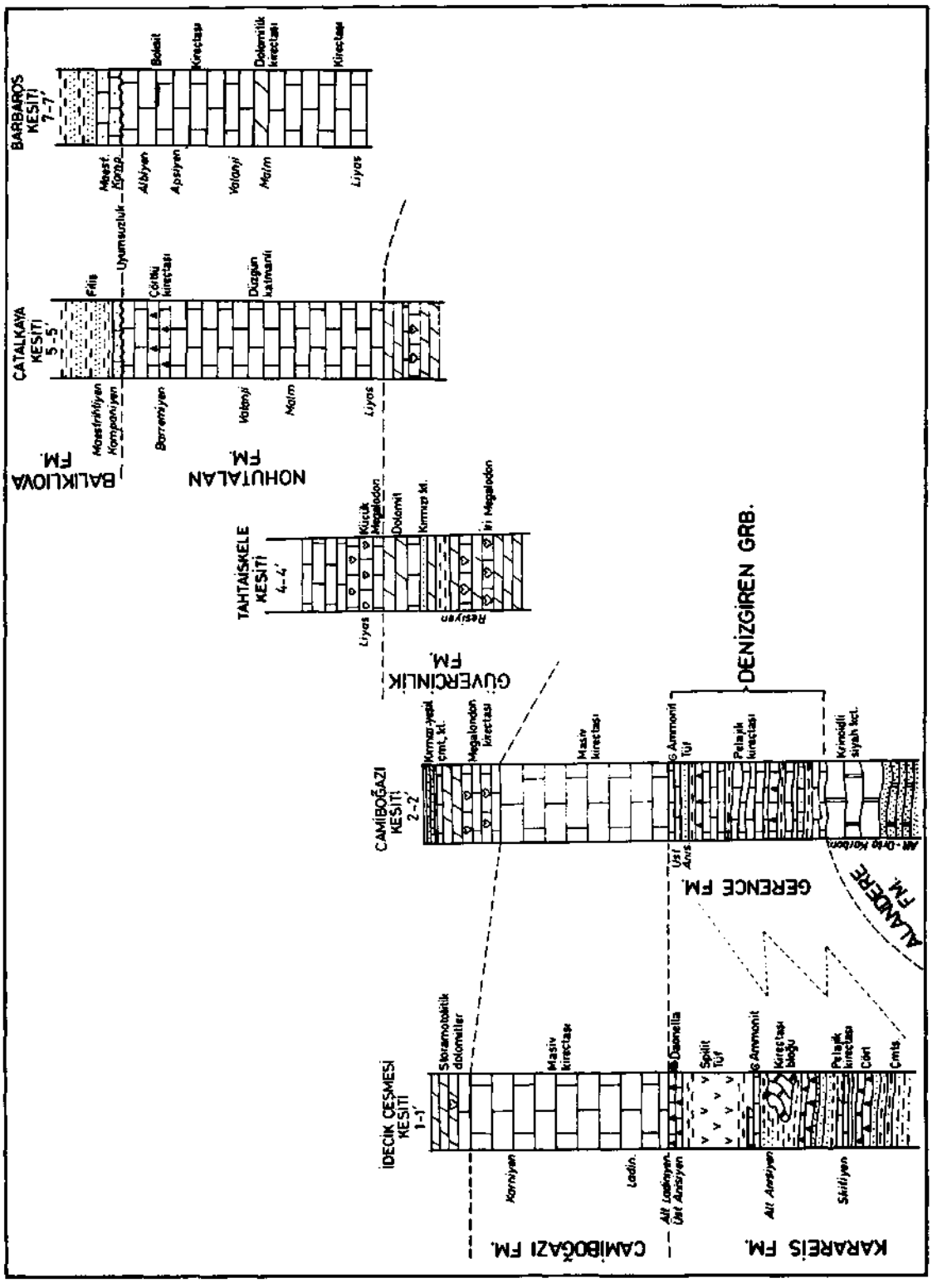

Fig. 10 – Stratigraphy of the Karaburun succession and correlation of the measured sections.

stone blocks of up to 500 m in length, are all indicative of continuous tectonic activities in the basin. Due to this synsedimantary tectonic activities, the chert intervals in the Karareis formation become brecciated and in places, formed chert olistostromes bound with mudstone matrix.

In the Gerence formation, short-distance facies changes are common and especially in its upper parts, the unit is represented by carbonate rocks of reefal facies that gradually pass upward into the Camiboğazı formation, that was deposited in a neritic environment.

During the Late Anisian and Early Ladinian, the spreading in the Karareis trench had seized and a platform condition had prevailed up to the Albian time. It is discemable that, the Early Triassic opening in the Karaburun platform took place on a limited extend and a relatively narrow aulacogen was only formed.

The Camiboğazı formation, which is Ladinian-Carnian in age, is represented by shallow marine limestones with abundant reef colonies. Overlaying this unit, the Güvercinlik formation, which consists of dolomitic algal stromatolites and megalodon-bearing limestones, were deposited. The lithological characteristics of this unit indicate a tidal-flat environment that turned to a evaporitic condition from time to time. Into this very shallow carbonate sedimentary environment, fluxes of detrital materials occurred and the sandstone intervals with cross-stratification were formed as discontinious lenses. In the region, this sedimentary condition was dominant from the Norian to the end of Rhactian. From the Liassic to Albian, in a shallow and sporadically reefal marine environment, the Nohutalan formation which consists of well-bedded limestones and dolomites, were formed. This unit contains horizons rich in algae, corals, bryozoa and pelecypoda colonies. The measured sections from this unit have yielded Liassic, Malm and Early Cretaceous (Valanginian to Albian) ages, but Dogger has not been determined, which may suggest a short-lived nondeposition during this interval.

During the Albian time, the Karaburun platform became very shallow and in a sporadic subaerial conditions the bauxite pockets were formed.

A tectonic activity took place in the region some time after the Albian and before the Campanian time and the angular unconformity at the base of the Balıklıova formation was formed. This tectonic activity was probably related to the initiation of the opening of the İzmir-Ankara zone which become pronounced during the Maastrichtian time. With this rapid subsidance, the Balıklıova formation that consists of a shallow marine limestones at the base and pelagic limestones and flysch-type sediments in the upper sections, was formed. This unit overlaid the various formations of the Karaburun succession.

Following this rapid subsidance in the Campanian-Maastrichtian interval, the Karaburun platform broke into large and small slices and was transported into the Izmir-Ankara zone. Some of these large slices measure up to 20 km in length in the sedimentary units of the Izmir-Ankara zone. In the final period of this tectonic deformation, the platform thrusted as a huge nappe into the nearby basin and surrounded by the blocky unit of the Maastrichtian-Danian age, which was called the Bomova melange.

The Bornova melange thrusted above the Menderes massif during the Late Eocene and it was carried on its back the already transported Karaburun nappe, and with this last episode, the paleotectonic evolution of the western Anatolia has ended.

Şengör and Yılmaz (1983) explained the tectonic evolution of Anatolia by opening and closing of the Tethyan ocean and delineated continents which controlled the large-scale deformational history of the region. They named the Sakarya continent to a small one located in the northwestern part of the Anatolia and stated that its southern boundary was first defined by Brinkmann (1966). In their map, they showed this continent to narrow toward Sakarya in the east and to continue southwestward enclosing the Karaburun Peninsula.

In the correlation of different tectonic belts, the most reliable attribute appear to be unconformity surfaces in the related stratigraphic colurhns. In the Karaburun succession, there is an unconformity between the Carboniferous and the Scythian units and above this horizon there is a continuous section including the Albian rocks on the top. In the stratigraphic column of the Sakarya continent, however, there is a marked angular unconformity at the base of the Liassic and with a basal conglomerate it overlies the deformed Triassic Karakaya formation or older units. Şengör and Yılmaz (1983) interpreted this Liassic unconformity with the closing of the Karakaya marginal basin.

The Karaburun stratigraphy can not be correlated with that of the Sakarya continent. There is no unconformity between the Triassic and Liassic sections and also no equivalence of tectonic deformation is noted which may suggest closing

of a Karakaya-type ocean, in the same time-span. For this reason. It would not be correct to extend the boundary of the so-called Sakarya continent southwestward to include the Karaburun peninsula into the same micro continent.

The correlation of the Karaburun stratigraphy with the Menderes massif and with the Lycian nappes in the south is subject of a different paper in preparation.

CORRELATION OF KARABURUN STRATIGRAPHY OF THIS PAPER WITH THOSE OF EARLIER STUDIES

The stratigraphy of the Karaburun Peninsula was studied for the first time in detail by Brinkmann and others (1972). In examining Figure 10 and 11, their stratigraphic column can be correlated with this study. The Devonian-Carboniferous limestones of these workers are equivalent of the Alandere formation of our study which is found to be Early to Middle Carboniferous in age. The Domuzçukuru, Koyutepe and the Laleköy formations of them with an age range from Scythian to Anisian, are put together under the Gerence formation in this study and they are found to be laterally and vertically digitating facies changes in our formation. The Karareis formation, which is the lateral extention of the Gerence formation in the northeastern part of the peninsula is not present in their stratigraphic column.

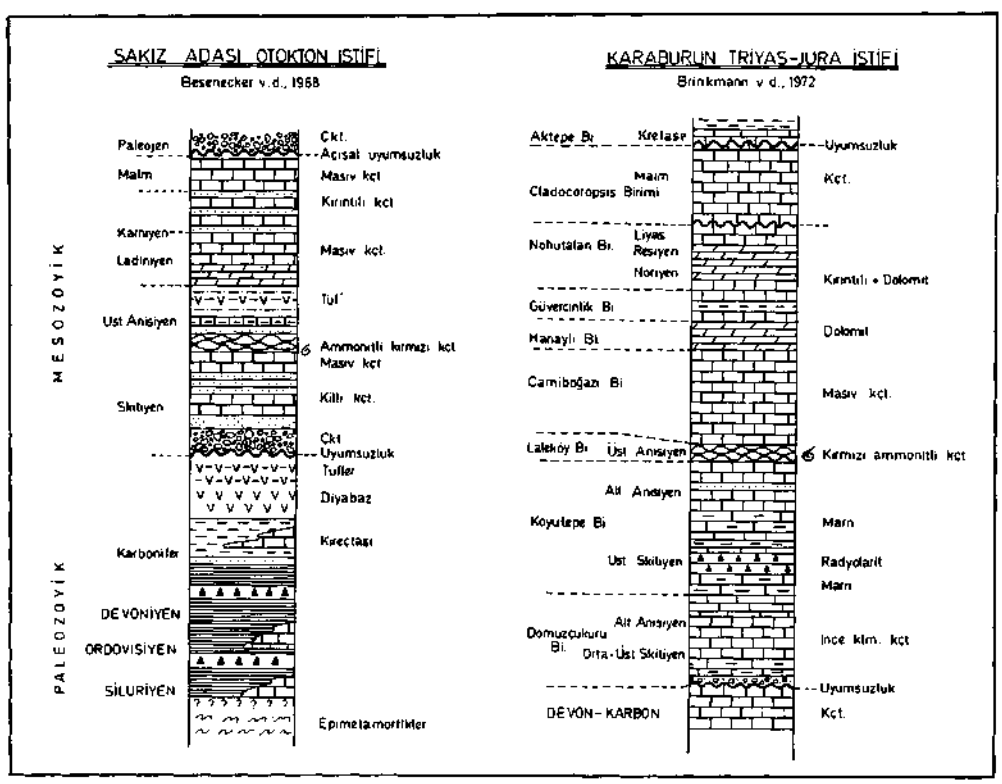

Fig. 11 – Stratigraphy of the Karaburun peninsula according to Brinkmann and others (1972), and stratigraphy of Chios autockthonous section accordng to Besenecker and others (1968).

The Camiboğazı formation of Brinkmann and others is the same in our study. The Hanaylı and Güvercinlik formations in their column are grouped under one unit in our study and called the Güvercinlik formation. We have also determined the age of this newly defined unit as Norian-Rhaetian. Similarly, the Nohutalan formation of our work is represented in their paper by two units named as Nohutalan unit and "Cladocoropsis unit". We have found that there is only one formation with an age range from Liassic to Albian. In this continuous section, we have not determined Dogger but still no lithological interruption or change have been noted.

In our study, the uppermost unit in the Karaburun succession is called the Balıklıova formation, which is separated into two members.

The Karareis formation in our column, which crops out in the northwestern part of the peninsula, is equivalent of the Karareis tectonic belt of Konuk (1979). We have found that it is only a stratigraphic unit below the Camiboğazı formation rather than a separate tectonic slice as proposed by this worker. We have mapped N-S trending reverse faults that cause rcpetaiion of the same stratigraphy from one compartment to another in the peninsula, but they are not found to be large-scale thrust faults juxtaposing completely different tectonic belts.

In our work, the Gerence and Karareis formations grade laterally into each other and are collectively called the Denizgircn group. Further detailed studies in the future may necessitate separation of members in these two formations.

In the Chios Island (Fig. 11) a similar stratigraphy with the Karaburun succession has been described in the autochthonous association by Besenecker and others (1968). The heterogeneous unit in the lower part of their stratigraphic column with lithologies of cherts, mudstones diabases and limestones, resemble closely to our Karareis formation of the Scythian Anisian age. However, they have indicated the age of this unit as ranging from Silurian to Carboniferous, which are probably given the ages of the included blocks. The similarity between these rocks in Chios with the Karareis formation has been first noted by Konuk (1979).

Likewise, the carbonate-rich unit of Besenecker and others (1968) with tuff intervals and red ammonitic limestones, that yielded the age of Scythian-Anisian, is similar to our Gerence formation.

In the same paper, the massive limestones of the Ladinian age, are similar to the Camiboğazı formation and the formation designated as the dethtal unit appears to be the equivalent of the Güvercinlik formation. The massive limestones with the Malm age in their column match with the Nohutalan formation of the Karaburun succession.

The correlation of the Chios Island and the Karaburun peninsula requires a field checking.

As discussed in the earlier sections, the stratigraphy of the Karaburun peninsula does not match with that of the Sakarya continent, so that in delineating tectonic belts of the western Anatolia this dissimilarity should be taken into account.

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