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SÜLFÜR THROUGHOUT GEOLOGİCAL TIME IN BALKAN PENINSULA**

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ABSTRACT.- During investigations for a long time it has been remarked that the oldest metallogenic epochs in Balkan Peninsula include a limited number of, occurrences with sülfür as one of the chief chemical elements. Thus it could be said that in these epochs the deposits with sulphur compounds either have not been formed or in some cases there were only rare showings. So, for instance with the Grenvilian epoch, according to date knowledge, only one occurrence in Pelagonids (Nezilovo) could be associated. In the Baikalian metallogenic epoch, characterized by formation of greenschists in western Macedonian only traces of sulfide mineralizations, then one deposit of lead, zinc and copper sulfides, as well as one pyrite impregnation in the larger Popcevo - Dojran area (eastern Macedonia), exhibiting sülfür content less than 0,11% are present. In contrast to Pelagonian-Rhodopean massif, in the Green complex (Vlasina) of eastern Serbia numerous deposits and occurrences of pyrite and lead, zinc and copper sulfides are present, indicating a more remarkable sülfür yield in this district during Baikalian metallogenic epoch. Thanks to this fact it could be estimated this epoch to be much more enriched in sülfür in Balkan Peninsula, compared with the Grenvilian epoch. In the next epochs (Caledonian and Hercynian) the sülfür yield had become more and more intensive. This is especially related to the phytlitic volcanogenic-sedimentary origin formation of western Macedonian. in which fifteen deposits and occurrences of lead. zinc, copper and molybdenum sulfides have been registered, indicating numerous richer and poorer, certainly irregular pyrite impregnations. Compared with all previous epochs, the Alpine (early and late) time is characterized by great number of deposits of lead, zinc, copper, iron, arsenic, mercury sulfides and other metals, then by sulphates in sedimentary complexes, thus geochemically very sharply differing Alpine time from all previous epochs. On the basis of these facts, one could ascertain that the Cretaceous-Tertiary period could geochemically be characterized as the Sulphur Epoch. Judging by all these facts this is only the feature of Balkan Peninsula, but is probably of Global importance (phenomena).

Key words: Sülfür, epoch, sulfates, green complex, phyllitic formation, Cretaceous - Tertiary, intrusive-volcanogenic complex, Balkan Peninsula.

İNTRODUCTİON

During geological investigations lasting several years in the territories of Macedonian, Serbia, Bosnia-and-Herzegoniva, Montenegro and Turkey, as well as the visits to other regions in Balkan Peninsula, it was noticed that sulfide deposits are very rare in the oldest formations of these regions, and going throughout time they are more and more freguent so that in the Cretaceous and Tertiary time there. occur numerous smaller or larger suifide deposits of iron, copper, lead, zinc, antimony, arsenic and other metals, as well as sulphate deposits. This appearance has induced certain curiosity, resulting in some attempts this phenomenon to be deciphered. In that sense some investigations were undertaken, but these couldn't be studious and more universal because of limited financial support and other circumstances. In that way, ideas presented in this paper are based upon incomplete evidences, although sufficient, according to our opinion, the problem to be opened and some distinct observations to be presented.

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SHORT REVIEW OF GEOLOGİCAL EVO LUTİON OF BALKAN PENINSULA

In aim the phenomenon of geochemical evolution of sülfür to be perceived in the best way, it is necessary to present in brief some newer comprehensions on geotectonical evolution and some magmatic events related to certain geochemical processes.

According to knowledges to date the oldest formations in the Balkans occur in the eastern part of the Pelagonian-Rhodopean massif or in Rhodopeans, including highly metamorphosed rocks constituting the geotectonical block, which is confined, according to all features, to continental type of the earth crust. Numerous characteristics of Pelagonian-Rhodopean massif have indicated that its origin and evolution during longer span of geologic time cannot coincide with formation and evolution of the Morava massif* and other crystalline complexes in Balkan Peninsula. Just during the younger Paleozoic and in Mesozoic time the Pelagonian-Rhodopean block entered along with other geotectonical blocks, a part of the unique assemblages of Balkan Peninsula.

According to available data the Pelagonian-Rhodopean massif originated 2.5 billion years ago, being in that time a part of the Gondwana supercontinent. From the other side, it is considered (Popovic, 1991, 1995, 1998) that the Morava massif (crystalline complexes in the Juzna Morava and Velika Morava valleys) is composed of two complexes formed in various geotectonical settings. It is under discussion, accordingly, the Gneiss complex and the Green-or Vlasina complex respectively. The Gneiss complex exhibits properties of continental type of the earth crust and initially it was a part of Bohemian or Middle European massif (Popovic, 1988), being formed 700 million or more years ago (Balogh et al., 1994), and the other, Green or Vlasina complex respectively, according to all its features is restricted to the ocean type of the earth crust. This part had originated in the area Paleoasiatic ocean (as named by Zonensain et. al., 1976), nearly in the same time as the Gneiss complex. The Vrvi Kobila structure, şeparating these two complexes, as far as concerned all facts represents a rudiment of a Collision structure, one part of it being originated between Paleoasiatic ocean and Middle European continent.

By separation of Mediterranean subcontinent from the Gondwana, and Morava massif from the Middle European continent (Popovic, 1998), and their motion in later times, they were included into the contemporaneous geotectonical mosaic of Balkan Peninsula.

Such a dynamic evolution of geotectonical blocks of the Balkans, as well as geotectonic processes, which have been developed during the younger Paleozoic, Mesozoic and Cenozoic (including the modern time as well) or after creation of the contemporaneous Balkan Peninsula respectively, have been accompanied by corresponding magmatism, which played an impressive role in geochemistry of individual elements in the same area, one of these being sulphur.

GEOCHEMİCAL EVOLUTİON OF SÜLFÜR IN BALKAN PENINSULA

Taking into consideration the independent pre-Mesozoic evolution of individual geotectonical settings of their origin, being specific for each of individual blocks in a

The Serbo-Macedonian mass is divided into Pelagonian-Rhodopean and Morava massifs (Popovic. 1991) corresponding way, one of the features, beside other individualities, is the sülfür as a chemical element, exhibiting his own geochemical and metallogenic evolution. In the same time this is a common feature of all unified geotectonical blocks in frames of Balkan Peninsula during Mesozoic and especially Cenozoic time.

These Studies are based first of all on relatively limited and non-systematic investigations of sülfür contents, in conditions of deficiency of detailed Studies on distribution of this element throughout metallogenic epochs in Balkan Peninsula, concerning the Proterozoic complexes of Pelagonian-Rhodopean massif (Macedonia), then Drina, Ivanjica and Jadar metamorphics (western Serbia), area of southern Serbia, the Vlasina or Green complex of eastern Serbia. These facts are supported by presence of numerous sulfide and sulfate deposits originated during Mesozoic and Cenozoic epochs, in which the sülfür percentage varies mostly from 1 % to 20%.

In the oldest petrogenetic complexes in Balkan Peninsula (Pelagonian-Rhodopean massif) are not known some more important occurrences of sulfides and other sülfür compounds, thus the pre-Grenvilian epochs could be considered as depleted in this element. Just in the Grenvilian epoch in Pelagonides (Nezilovo at Mt. Babuna) some smaller sulfide occurrences are preserit, which could be assumed as the first traces of increased sülfür concentrations in the area of Balkan Peninsula. The Origin of this sülfür cannot be discussed since these investigations have not been . completed, and from the other side the occurrence itself had several times undergone the hydrothermal, tectonical and all other geological transformations, which affected this part of Pelagonides throughout the geological time.

In the next, Baikalian epoch the green schists had been formed, whose protoliths are confined to the rocks originated in the area of oceanic type of the earth crust. Formations of this complex occur in the Pelagonian-Rhodopean and Morava massifs, then in western Serbia, Zagrebacka Gora and elsewhere.

In greenschists of western Macedonia, as a part of Pelagonian-Rhodopean massif, trending form Sar Planina, across Kicevo, Demir Hisar and Pelister, Continuing further to Greece, some low order, until recently not investigated sulfide mineralization have been registered. In contrast to them, in the district occurring between Strumica and Dorjan in eastern Macedonia occur much larger concentrations of iron, lead, zinc and copper sulfides. This has particularly been manifested by the lead-zinc deposits near Dojran, with indicated ore reserves of about 25 million tons averaging 3.8% lead-and-zinc and 0.1% copper. The chief minerals in this deposit are pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, marcasite, enargite, pyrrhotite and others. Although the lead-zinc and copper contents are low, it is stili to be ascertained, according to frequency of all sulfides, including the pyrite impregnations in concentrations of 0.3% covering a large area of greenschists, that in the mean sülfür content in these schists is higher than the mean value in basic magmatic rocks (0.03% after Vinograd ov, 1962). The investigations in the district between Strumica and Dojran (Popovic, 1993) exhibited the sülfür content (according to 100 analyzed samples) in greenschist from 0.042% to 0.11%, evidently speaking about sülfür increase from about 1.5 to 4 times (averaging about 2 times) compared with basic magmatic rocks.

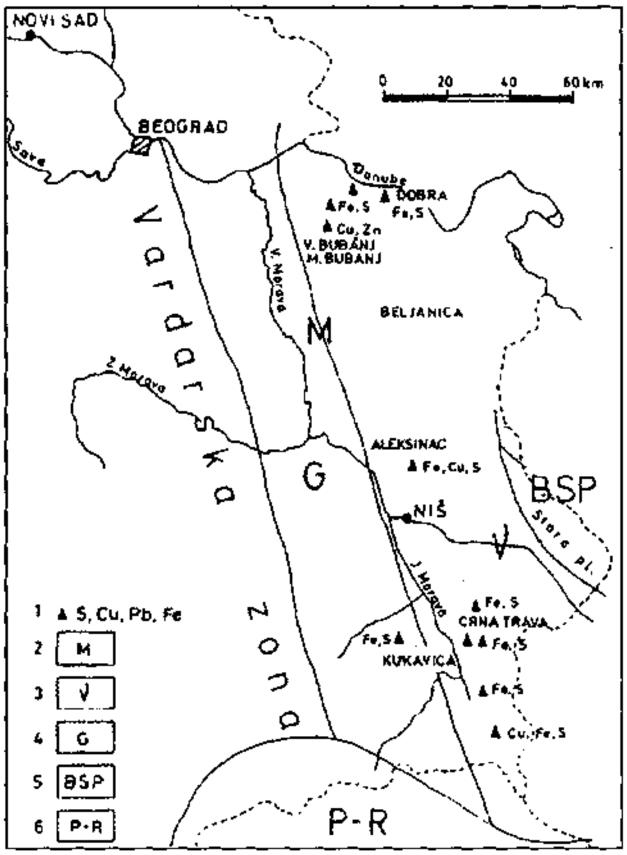

Fig. 1- Distribution of sulfide occurrences in Green complex (Baikalian) of the east Serbia.
1. Sulfides of Cu, Pb, Zn occurrences, 2. Morava massif, 3. Green complex, 4. gneiss complex, 5. block Stara Planina, 6. Pelagonian-Rhodopian massif.

In contrast to Pelgonian-Rhodopean massif, where in greenschists took place relatively limited concentrations of sülfür compounds in the same rocks of the Vlasina complex or the Morava massif respectively, which extends from Carpathians in Romania. Continuing across eastern and SE Serbia, to NE Macedonia and further throughout Bulgaria. The sulfide mineralizations are widespread in the whole area. They were formed during Baikalian tectono-magmatic cycle in the area of oceanic type of the earth crust. These are most commonly poor or rich sulfide impregnations as well as smaller or iarger suifide ore deposits in which the pyrite is predominant, accompanied by chalcopyrite. sphalerite, galena and others. The most important sulfide occurrences and deposits appear near Golubac, at Veliki Bubanj and Mali Bubanj nearby Petrovac na Mlavi, then occurrences near Aleksinac and at Bukovik and Rozanj, in the iarger area of the Crna Trava and Blagodat (Ljubata) district, near Trgoviste etc. (Fig. 1). Considering the length and width of the greenschist zone with sulfide impregnations and higher concentrations in form of deposits, and according to investigations to date (drilling), extending more than 200 m depth, the sülfür mean content in greenschist could be estimated at about 0.08%, which is about 3 times higher than the average (clarke) content in basic magmatic rocks after Vinogradov (1962). Taking this information into consideration, including also the mentioned sulfide deposits only in the area of eastern Serbia, it could be concluded that this tract of land is very promising for discovery of lead, zinc, copper and most probably gold deposits, the last ones otherwise coinciding with the Green complex of this region.

The Caledonian and Hercynian metallogenic epochs in Macedonia or in Pelagonian-Rhodopean massif respectively are characterized by relatively higher sulfide concentrations, most commonly represented by pyrite, galena, sphalerite, chalcopyrite, molybdenite, and lesser arsenopyrite, pyrrhotite, marcasite, antimonite and others, bearing in mind that higher concentrations could be consıdered as ore deposits and occurrences. In western Macedonia following occurrences and deposits of sulfide mineralizations are known: molybdenurn - Strelci (near Kicevo) and Vrutok (near Gostivar), copper, zinc and iron at Berikovo, copper at Padaliste, lead and zinc near Kolari, copper near Judovo, lead and zinc at Openica, as well as numerous pyrite concentrations in the Phyllite compiex of volcanic-sedimentary Origin. On the basis of distribution and local sampling, it could be estimated that the average sülfür content varies in the pyhllitic formation complex from 0.014% to 0.37% (according to only 50 analyses of rocks of this formation), thus evidentfy indicating the increased content of this element, denoting that both Caledonian and Hercynian epochs are markedly enriched in sülfür, compared with previous epochs. especially in amount of sulfide deposits and occurrences (about 15). Similar features as in mentioned two epochs are in other parts of Balkan Peninsula. aithough in some districts the sulfide concentrations in the Phyllitoid complex are lower than in western Macedonia (as for instance in the Drina river region, Polimlje, SE Bosnia, eastern Serbia ete.), but essentially not changing the impression on the sülfür content in general.

The Alpine (early and later) time has been defined, after Haq and Eysinga (1987), as early, middle and Late one, including the whole Mesozoic and Cenozoic era. When considered the distribution of intrusive-volcanic complex accompanied by sulfide ore deposits and occurrences, in such cases in the Balkans have existed vast areas occupied by these complexes (Fig. 2). In addition of widespread anhydrite and gypsum sedimentary deposits in Dinarids and in other areas of the Balkans it could be comprised that during the Mesozoic and Cenozoic took place remarkable sülfür enrichment. Considering only sulfide ore deposits one could say that 90% of Pb, Zn, Cu, Mo etc. deposits in Balkan Peninsula originated in that period. In lack of other investigations (on sülfür contents and distribution) this is the most important criterion for estimation of the sulfur yield throughout Mesozoic and Cenozoic time in the Balkan Peninsula. If compared with older epochs an evident difference is remarkable, not only in freguency of deposits, but in the total reserves of Pb, Zn, Cu and other sulfides as well. If the pyrite impregnations in rocks are added, locally being the genuine pyrite ore deposits with reserves of several million tons, considering gypsum and anhydrite in Sediments, relatively simple and real estimations are achievable, but it should be noticed that during Alpine time the sülfür yield was not Uniform. Namely, in the Mesozoic the largest sülfür concentrations are related to anhydrite and gypsum, lesser to sulfide deposite. From the other side. at the end of Mesozoic and Cenozoic epochs extremely great number of the Fe. Pb, Zn, Cu and other metals took place. Taking into account the roughly calculated ore reserves of all sulfides in the area of the former SFR Yugoslavia, quantities are greater than 2 billion tons. The calculated sulfur grade has exhibited more than 5%, from that amount minimum 0.5% sulfur is restricted to disseminations in dacite-andesitic rocks, thus indicating the huge sülfür quantities. Similar situation is in the other Balkan areas, particularly in Rumania and Bulgaria. However, it should not be neglected that during these times the active subaerial volcanoes had emitted also great amounts of sulfur, as it could be compared with contemporaneous volcanoes. Some of these volcanoes have extruded, for extample, 50 tons of sülfür per year or more, and the others extruded during a single day 100 tons of sulfur or more, as emanations. The best illustration for it is the Mount St. Helena volcano, which emitted from June, 6-22, 1980 between 950 and 1300 tons SO_2, including periodical 15 minutes paroxysms emitting 40 tons SO_2 or recalculated at 3800 tons SO_2 per 24 hours (Lipman, Donald, 1980).

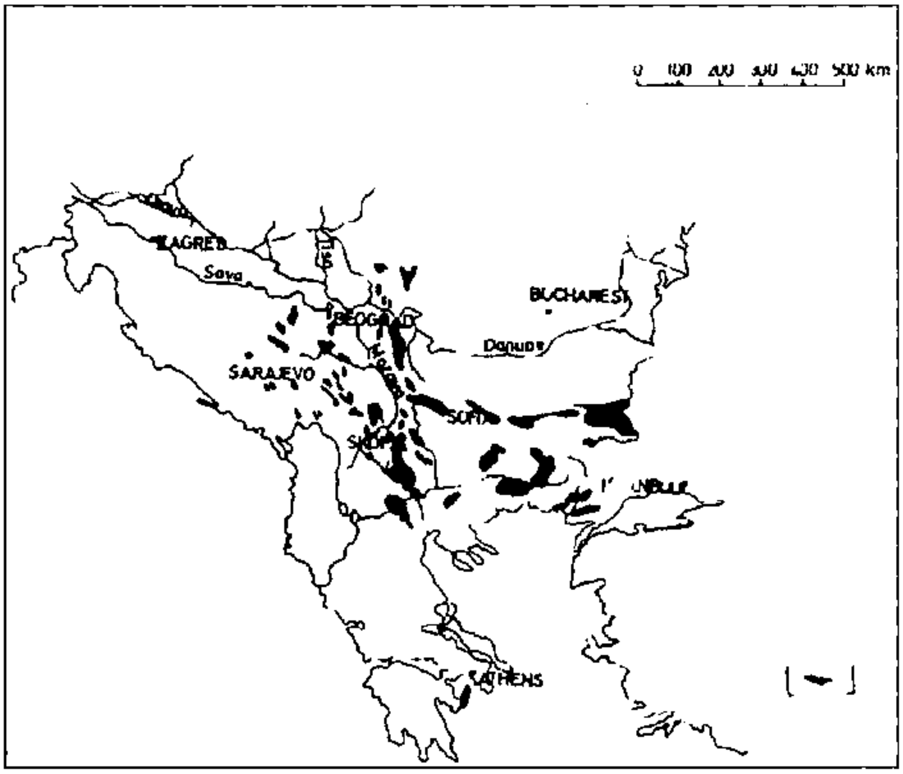

Fig. 2- Simplified map of distribution Mesozoic-Cenozoic volcanites on the Balkan Peninsula. 1. Mesozoic-Cenozoic volcanites.

All the presented data are in favour of the fact that in the intrusive-volcanic complex of Balkan Peninsula during Alpine epoch intensive enrichment in sulfur took place. According to roughly estimated sulfur amounts in rocks (complexes) it has averaged about 1 %. Such a content of this element is 30 times higher, compared with the mean (clarke) values in similar or same magmatic rocks (Vinogradov, 1962), and 10-15 times higher in relation to the older metallogenic epochs. These are features distinguishing the Mesozoic-Cenozoic time as an extraordinary geochemical appearance.

ORİGİN OF SULFUR IN THE BALKAN PENINSULA DURING THE ALPİNE TIME

If compared number of sulfide ore deposits and disseminated sulfides of iron, copper, lead, zinc, arsenic, and others, as well as various sulfates originated in sedimentary complexes in the Balkans during Mesozoic and Cenozoic periods with the same or similar complexes of Paleozoic or older time, enormous differences are evident. This is particularly characteristically for the period of the latest Mesozoic and Tertiary or better to say the whole Cenozoic time. In that way the Upper Cretaceous, Paleogene, Neogene, and Quaternary times should be defined as the Sülfür Epoch in the Balkan Peninsula. But this phenomenon has opened numerous probems, among them the most important being origin of sülfür. This is not all an Uniform and unilateral problem, especially bearing in mind limited amounts of direct geochemical and other informations and that this phenomenon was not to date in focus of corresponding Studies.

If this complicated problem would be open to be solved, especially in frames of actual knowledge, it is necessary to start from Alpine geotectonical events in Balkan Peninsula. In that regard the most important problem to be analyzed is the so called Tertiary tectonomagmatic activation. The authors of this concept (Grubic, 1974b; Jankovic and Petrovic, 1974), although being seriously occupied by problem of geotectonical events and related metallogenic manifestations characterising the mentioned activation, have not been occupied neither by the problem of sul-fur origin nor by its enormous yield and deposition in the intrusive-volcanic complexes of that period. However, the concept of origin-of. large intrusive-volcanic complexes in the process of tectonic-magmatic activation in the Balkans has indirectly suggested the assumption that this process resulted from subduction of the ophiolitic belt and Inner Dinarids below the continent (in this case these are the Morava and Pelagonian-Rhodopean massifs or Serbo-Macedonian mass, after Grubic (1974b), Jankovic and Petkovic (1974). Such an unilateral explanation is hard to be accepted if considered only one segment (Inner Dinarids and ophiolites of the Vardar zone), because a simple explanation is that the tract of subduction is not remarkable compared with the span of time of its activity.

In fact, the numerous sulfur emanations and pyritizations (Vranje Spa, Sijarina Spa etc.) speak that ophiolites and Inner Dinarids, sometimes being active segments of subduction of the earth crust, ended this activity, but that the sülfür yield has continued. This fact is of primordial importance for these tracts. If to these considerations is added the fact that sülfür in the area Carpatho-Balcanids is also abundant, but not being related to the same geological processes of tectono-magrnatic activation, an-other problem has been opened: of what kind and which mechanisms were producing sulfur in that area; And then appears a common problem of the total sulfur yield. This problem or huge guantity of the sülfür introduced during Alpine time is not restricted only to Balkan Peninsula but has continued from one side to the Aegea, Asia Minör and further to the east and, and from the other side, across the Carpathians to middle Europe as well.

The conception of the authors for the Tertiary tectono-magmatic activation unclearly has defined the causes and direct factors of the tectono-magmatic activation. Only Karamata (1983), Grubic (1974) and partly Auboin, Blanchet (1981) have been more concrete in that sense, especially Karamata

(Fig. 3), who has analyzed, throughout geochemical features, the direct relation of ophiolitic complexes with Tertiary dacite-andesitic volcanites in the tract of Tertiary tectono-magmatic activation. Namely, he has observed, from one side, the Inner Dinarids including so called Drina-lvanjica block and ophiolites of the Vardar zone, being subducted as a whole, and from the other side, the Outer Dinarids, which also had parallel entered into the process, leading to distinct magmatic processes, being reflected to the earth surface: either at the border of Morava massif or inside the Pelagonian-Rhodopean massive or the Serbo-Macedonian mass respectively, and in frames of the Drina-lvanjica block and Vardar zone or the ophiolitic zone respectively. This model is acceptable if it would be taken into consideration that subduction of the mentioned blocks is a conseguence of another subduction, much more widespread, being stili active in the present days. Thsi is subduction of the Mediterranean bottom or African continent respectively, which also contains high sulfates concentrations, beneath the Europe, i.e. Balkan Peninsula in our case.

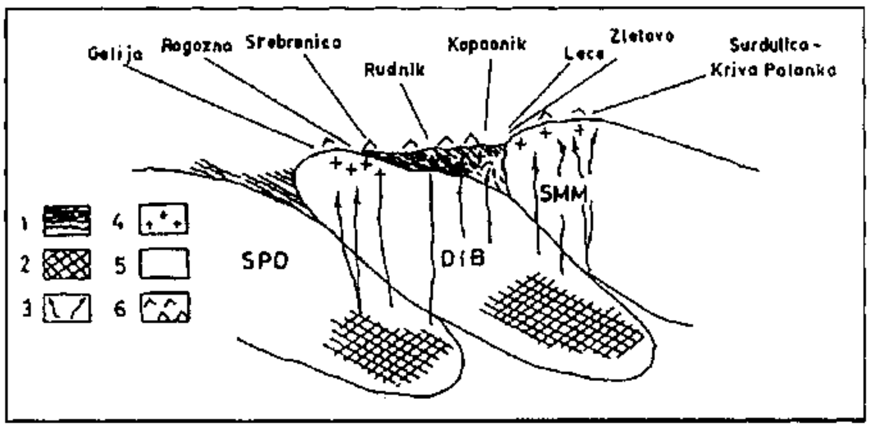

Fig. 3- Geotectonic setting of Tertiary magmatic rocks and distribution of ore deposits (Karamata, 1983).
SPD - Outer Dinarides, DIB - Drina-Ivanjica block, SMM - Serbo-Macedonian mass.
1. Ophiolitic melange, 2. zone of origin of Tertiary magmas, 3. rise direction of Tertiary magmas, 4. intruzive rocks, 5. continental crust, 6. volcanic rocks.

In such circumstances one could suppose that formerly deposited sulfur (in form of gypsum and anhydrite) in Dinarids could be the chief source of sulfur that area. So called tectonomagmatic activation is not autochtonous in this case, but had resulted from a complex spacious and longtherm process having lasted from jurassic time (Auboin, Blanchet, 1981, Fig. 4).

The subducting evidently commenced with ophiolites of the Vardar zone and metamorphites of Inner Dinarids below the Morava massif (in the southern part of the Balkans, beneath the eastern segment of the Pelagonian-Rhodopeans or Rhodopean massive in this case), accompanied by another subduction related to the western ophiolitic zone and Outer Dinarids beneath Inner Dinarids (as reported by Karamata, 1983), and further in the district of Hellenic trench initiated by subduction of the Tethyan ocean bottom or remains of the oceanic crust and African continent beneath the Europe or Balkan Peninsula in such a case (Underhill, 1989). All these very intricated processes had initiated a vigorous magmatism, partly reflected as so called Tertiary tectono-magmatic activation (Grubic, 1974b; Jankovic and Petkovic, 1974), accompanied by corresponding geochemical masifestations. One could say, neglecting other phenomena, which otherwise follow all geodynamic processes of such complexity, and retaining only at so called Tertiary tectono-magmatic activation or at the magmatism introducing large sulfur amounts into Balkan Peninsula, that the zone of Tertiary intrusive-volcanic complex stretches across the Balkans in the northwest-southeast direction, cutting all older structures and the Vardar zone as well, as formerly reported by numerous authors. This zone strikes in length of several hundred kilometres and probably across the Aegean sea continues to Asia Minor, thus measuring more than 2000 km in total length.

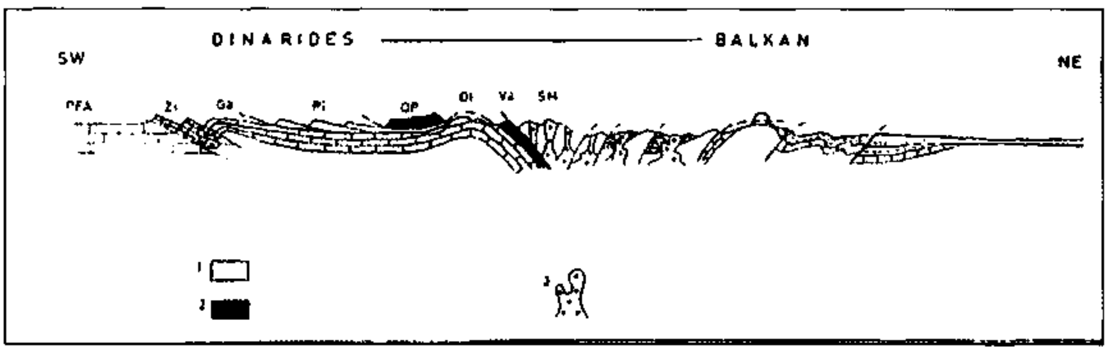

Fig. 4- Cross section of the Dinarides and Balkan Alpine chains (Aubouin, Blanchet, 1981).
1. Prealpine continental basement, 2. Alpine oceanic crust (ophiolites), 3. Alpine granodiorites (Jurassic-Cretaceous-Tertiary).

Differing from the zone of tectono-magmatic activation, in Rumania, eastern Serbia and Bulgaria the Carpatho-Balkanids are present, also characterized by abundant intruzive-volcanic complexes with the outstanding sülfür enrichment. We don't enter now in their origin since various opinions have existed. Some authors such as Grubic (1974a) have proceeded from rifting, the others, Bogdanov (1977) for instance, have taken into account the subdictioh of Moesian plate bellow the Balkans, the third ones - Vukasinovic, Antonovic (1989) have considered impacts as a cause etc. The fact is that in this belt also occur extremely spacious intrusive-volcanic complexes, with high concentrations of (iron, copper, lead, zinc etc.) sulfides, lesser sulfates. This region evidently has similar, not only petrogenic but also geochemical characteristics of sulfur, as the trans-Balkan intrusive-volcanic complexes (the zone of Tertiary tectono-magmatic activation).

For geochemical Studies of the sülfür excess during the Cretaceous-Tertiary period, a partial assistance may offer the tests of the sülfür isotopic composition, as reported by Putnik (1981) in the zone of Diabase-Chert Formation in western Serbia, then by Aleksandrov (1992), Efremov (1993) and Serafimovski (1993) for districts of the Lece massif and in deposits of NE Macedonia, as well as former Studies by Drovenik et al. (1975) in sulfide deposits of N.E Serbia. Their interpretations of the sülfür isotopic composition are rather Uniform, although with some reserves. Certainly, numerous measurements of ^{34}S have varied around values linked to magmatogenic sulfur, which most of authors have related to the upper mantle. However, when the cited results presented by them are observed, it is to be noticed that most of these could not be connected with the mentioned concept. They actually have not an obvious explanation for the isotope values higher than +7 $‰_0$ and lesser than -7$‰_0$. So for example for the Markov Karnen in NE Serbia Drovenik et al. (1974/75) have cited the ^{34}S values starting from -20$‰_0$., which is evidently characterized for enrichment in the light sülfür isotope. Similar results have been obtained for the ore deposits of NE Macedonia as well. Such appearances would be rather interpreted as a consequence of various Origin of the primitive sülfür. One could, namely, suppose that one part of sülfür has originated from the upper mantle, but for the other part would be rather assumed to originate from the former Sediments entering during subduction in the zone of magma generation, as well as from lovver parts of the continental crust, affected by partial melting. Such a ^{34}S fractionation from the melt created in the mentioned manner depended on physical-chemical conditions, pH value, transport length, thermodynamical and other terms.

it has been considered that such factors would improve the fractionation of heavy isotopes, but in the case of light isotopes the ımproving would be partial. But results reported by the mentioned authors could not be simplified as they did. Intricated processes, which took place in the tract of formation of the magma melt and the yield of sülfür from sedimentary rocks during subduction, introducjng it into the magmatic melt, show much more complicated processes of the sülfür isotope fractionation. In that manner, sülfür from the upper mantle, then from the subducted Sediments and from lovver parts of the earth crust represent the reaj primitive sources of sülfür. All these processes have together conditioned the high heterogenity of the sülfür isotopic composition in individual sulfide ore deposits in Balkan Peninsula. This phenomenon has especially been focused by Drovenik et al. (1974/75) in an attempt to find out a satisfactory solution considering the horizontal zonality around the magmatic body, while other authors have mostly neglected this phenomenon. It is possible that Sediments in Dinarids or from another geotectonic block, then the bottom of Mediterranean sea, and African plate would not be the primary source at least of one part of sülfür in sulfide deposits and impregnations occurring in the zone of tectono-magmatic activation? Wen the Carpatho-Balkan arc in question, it is hard to favour either the subduction process, although Bogdanov (1977) postulated this way, or other planetary geotectonical process, as reported by Grubic (1974a) and Vukasinovic, Antonovic (1989). In all such cases the Sediments or continental crust in this district respectively occur as primordial source of one part of sülfür, entering into composition of sulfide deposits in Carpatho-Balkanids.

If duration of the subduction process, then the phase of magmatic melt, introduction of sülfür into Cretaceous-Tertiary intrusive-volcanic complexes, and certainly continuation of its yield till the present days would be taken into consideration, it is evident that this is included in a relatively longterm process, having lasted for about 140 million years.

If this period would be better focused one should get to the judgement that this geochemical feature of the Balkan Peninsula is not of a local importance. Contrary, it could be said that in guestion is a global phenomenon, which in the best way reflects distribution of the Cretaceous-Tertiary sulfide deposits around the Pacific, in Mediterranean regions and ın districts with contemporaneous active volcanoes. This is related to the so called circumpacific fire belt, then to the middle- southern and SW Pacific, middle America, Mediterranean, southern and SE Asia, Malaya archipelago, middle oceanic rifts (in Atlantic, Indian ocean etc.). All together it has led to an unigue conclusion that the Cretaceous-Tertiary period could be announced as the Epoch of Sülfür from the geochemical point of view, not only for Balkan Peninsula but in larger sense as well, representing a global geochemical epoch.

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GEOLOGY AND ORİGİN OF THE PYROPHYLLITE - DEPOSİTS IN THE PÜTÜRGE MASSIF (MALATYA - EASTERN TURKEY)

Ali UYGUN* and Enis SOLAKOĞLU*

ABSTRACT.- The pyrophyllite deposits of Pütürge massif (Malatya - Eastern Turkey) have been increasingly used in last years for white cement Production because of their low iron and chromium content. Around 25 pyrophyllite occurrences are explored along a nearly 15 km's long belt south of Pütürge, where 10 guarries are opened. The co-existence of high-Al pyrophyllite and kyanite indicate that the pyrophyllites were formed during a retrograde greenschist metamorphic phase, which the massif had experienced. Five different types of pyrophyllite are identified; pyrophyllite with high Al content. pyrophyllite with sericite, pyrophyllite with high silica modüle, pyrophyllite with low silica modüle and pyrophyllite with low alkaline content respectively. In this study, mineralogical and geochemical properties of these pyrophyllites are described.

Key Words: Pyrophyllite, Pütürge massif, mineralogy, genesis, geochemistry.

İNTRODUCTİON

The first Identification of pyrophyllite ($Al_2O_3.4SiO2.H_2O$) in Turkey rests up to beginning of 1970's. As it resembles talc, pyrophyllites were mined for a while as talc in limited amounts. In 1976, pyrophyllite was mentioned in the Turkish Mining Law. Up to 1990's the annual Production was around 2-3000 typ (tones per year) and used in refractory industry. Starting with this date it has become an important row material since ÇİMSA Cement industry Comp., has started to use pyrophyllite instead of kaolin in white cement Production. Recently, it has been consumed in the rate of 100-120.000 tpy.

By using the Pütürge pyrophyllite with its low iron and chromium content, the whiteness of the cement produced by ÇİMSA has reached to 90, termed as "Süper white". Today, it takes place within the best guality cements in Europe. By the capacity of 1 Mt per year, the factory of ÇİMSA-Mersin has reached to the position of world's largest white cement producer.

According to the US Geological Survey statistics (Harben, 1999), undifferentiated world talc and pyrophyllite Production is about 2.2 Mt's per year, China's Production excluded. Turkey is one of the 10 pyrophyllite producing countries and is at the fifth rank after Japan, South Korea, Brazil and India. In Far East, rocks with mixed composition of pyrophyllite, sericite, kaolinite and quartz are termed as "roseki". However, in Brazil, the blend of pyrophyllite, sericite, diasporite, kyanite and quartz is termed as "agalmatolite". In South Africa, the mixture of pyrophyllite, chloritoid, rutile and epidote is termed as "wonderstone" (Harben, 1999).

In this study, the authors present their own data and observations on the genesis, properties and geological setting of pyrophyllite occurences, gained during their study within last 10 years in Malatya - Pütürge region.

Evaluations are based on a Series of geochemical and mineralogical investigations in the laboratories, besides the photogeology, geological mapping and drilling with coring or by reverse circulation.

GEOLOGY AND DISTRIBUTION OF PÜTÜRGE PYROPHYLLITES

Within the first investigations in the region, Danış (1978) mentioned that the pyrophyllite-bearing schists were located between quartz-sericite-schists and tourmaline-schists. Cornish (1983) reported the presence of 3 types of pyrophyllites, which were formed as a result of hydrothermal alteration of dacitic tuffs. Presence of pyrophyllite in Pütürge massif was reported by in Yazgan (1984) and in the explanations of the Malatya İ-27 sheet of 1/100.000 scaled geological map Series of Turkey (MTA, 1986) as "the pyrophyllite, kyanite. diaspore assemblage is tormed within the shear-zones in tourmaline-rich orthogneısses. According to Erdem and Bingöl (1977), pyrophyllite developed along a main shear-zone between the Lovver and Upper units of Pütürge massif.

The Pütürge massif, composed of augen gneisses, amphibolite - prasnite, mica schists with pelitic origin, orthogneisses and marbles, radiometric ages of 70 - 85 Ma (MTA, 1986) were obtained from the metamorphic rocks. Widespread amphibolites and augen gneisses forming the core of the massif outcrop in the area between Babik stream and Tepehan at the southern of the massif (Fig. 1). At the southern part of Pütürge where pyrophyllites are frequently observed, orthogenesises and mica schists dominate, however meta-carbonates take place mostly at the northern part of Pütürge (MTA, 1986).

The pyrophyllite occurrences ın Pütürge massif are aligned along a 10 km long belt, trending about N 60° W starting from around Karataş hill at 6 Km's SE of Pütürge at the eastern tip through south of Yıldırım hill, Keşan hill, north of Babik, Ümik hill, Şahantaşı hill, Sınık hill, Aytez hill, and Vaktık hill. To the west of Vaktık hill the belt is branched, with a southern arm following the Keşen hill, Kösemustafa hill, Hopan ridge, Cünütü hill. The northern one follows the line of Kütüreş hill, Güreş hill, west of Tümbelek hill and east of " Şiro stream. The position of the pyrophyllite occurrences and main fault systems around Pütürge are presented in figüre 1. The quarries opened on these occurrences within last 10 years are as follows:

1-) Karataş hill - İmrün quarry

2-) Keşen hill

3-) Ümik hill

4-) Aytez hill

5-) 1407 m. hill

6-) West Vaktık hill

7-) East Vaktık hill

8-) Kösemustafa hill

9-) Güreş hill

10-) Mukul hill

Pyrophyllite occurrences are of lensoidal from with different sizes. At the bottom of the lenses, 2-mica orthogneisses or schists are usually observed. Schists with muscovites or sericites are observed as wall rocks. Ouartzites observed together with pyrophyllites are mostly quartz-dykes. No stratigraphic relationship between these quartzites and rare tourmaline-schists with pyrophyllite could be encountered.

Although the pyrophyllite occurrences in Vaktık hill and Keşen hill are related to shear zones, there are also pyrophyllite occurrences without any relationship with tectonic zones (e.g. Ümik hill and Sınık hill). This situation relates pyrophyllite-formation with retrograde metarmorphism rather than to a structural control, as it will be explained in the next chapter.

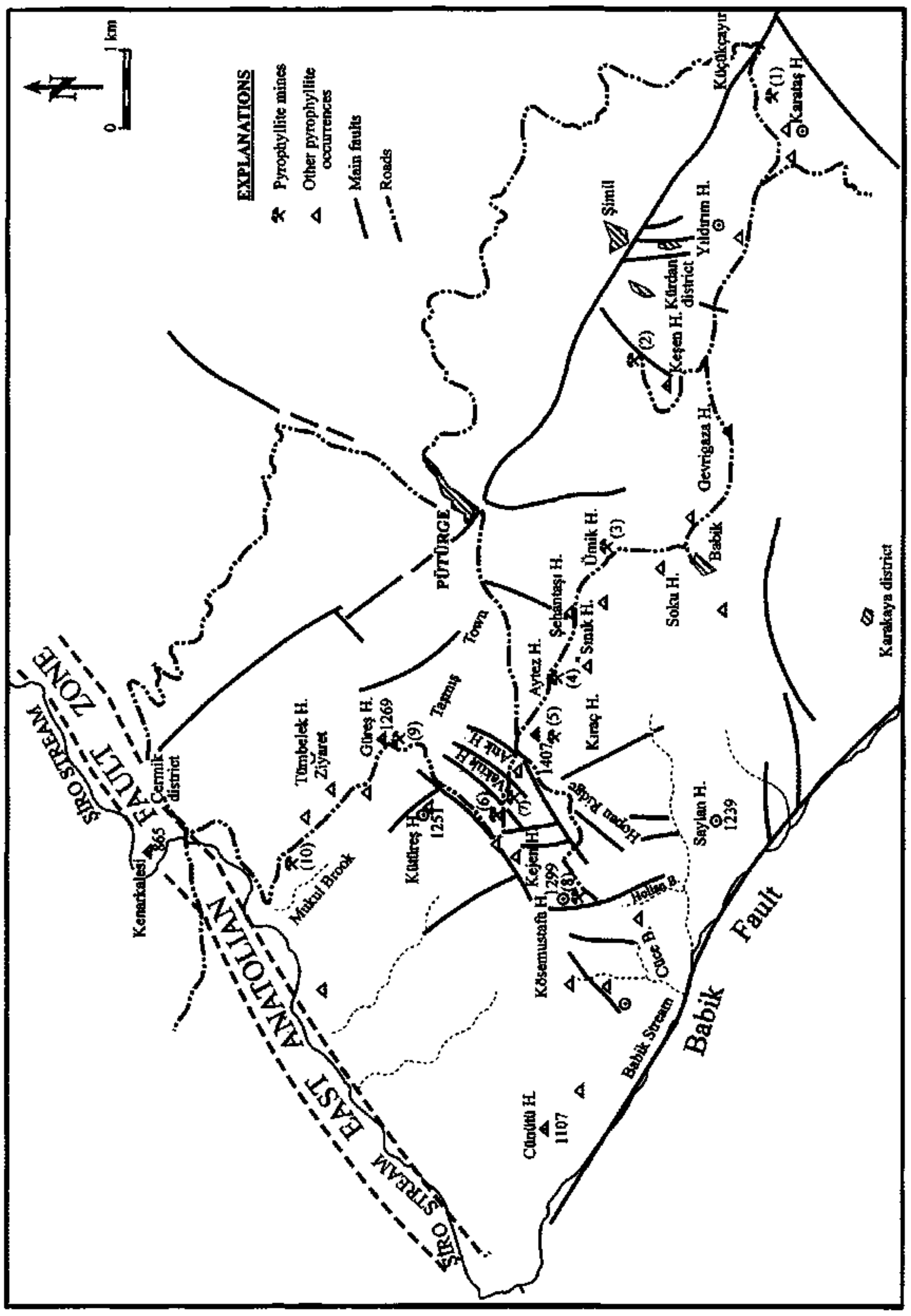

Fig. 1- Location map of the main pyrophyllite mines and occurrences in Pütürge area (Eastern Turkey).

Length of the pyrophyllite lenses reach up to 600m in Vaktık hill, and 400m's in Keşen hill and widths of the lenses range between 20 - 50 m's. Depths are around 20 - 30 m's maximum. The maximum thickness of pyrophyllites cut in bore-holes is 39 m's in Ümik hill section.

MINERALOGY AND GEOCHEMISTRY OF PYROPHYLLITE OCCURRENCES

In the pyrophyllite occurrences in Pütürge, pyrophyllite and quartz are main observed minerals. Kyanite, muscovite, sericite, illite, kaolinite, dickite and alunite are the accompanying minerals at some places. Pyrophyllite is mainly gray or greenish gray or greenish white in color and oily and dull in appearance. Its association with fine-grained quartz gives a resistant appearence to the rock.

Theoretically the Al_2O_3 content in pure pyrophyllite, is about 28.3%. Al_2O_3 contents around 30.52% from trenches of western Vaktık hill, are found out to be due to the presence o kyanite determined by microscope and XRD studies. The electron microprobe analyses have shown that the kyanites contain 60 - 62 % Al_2O_3 (Uygun, 1995). Our suggestion that pyrophyllites were formed by retrograde metamorphism is evidenced by the replacement of the kyanite porphyroblasts by pyrophyllite observed on the microphotograph (Fig. 2).

Pyrophyllite occurences are usually divided in to two groups (Carnish, 1983).

a- By loss of alkalies and iron of acidic volcanic rocks by the effect of hydrothermal fluids along the fault zones. The main examples to this first group are the pyrophyllites derived from porphyries and liparites in Japan, from quartz porphyry and trachyandesite in South Korea, from rhyolitic volcanics in North Carolina in USA, and from rhyolitic pyroclastics in Australia.

b- Podiform pyrophyllites of metamorphic origin where metamorphosed volcanic tuff and ashes are associated with schists, as those in Brazil.

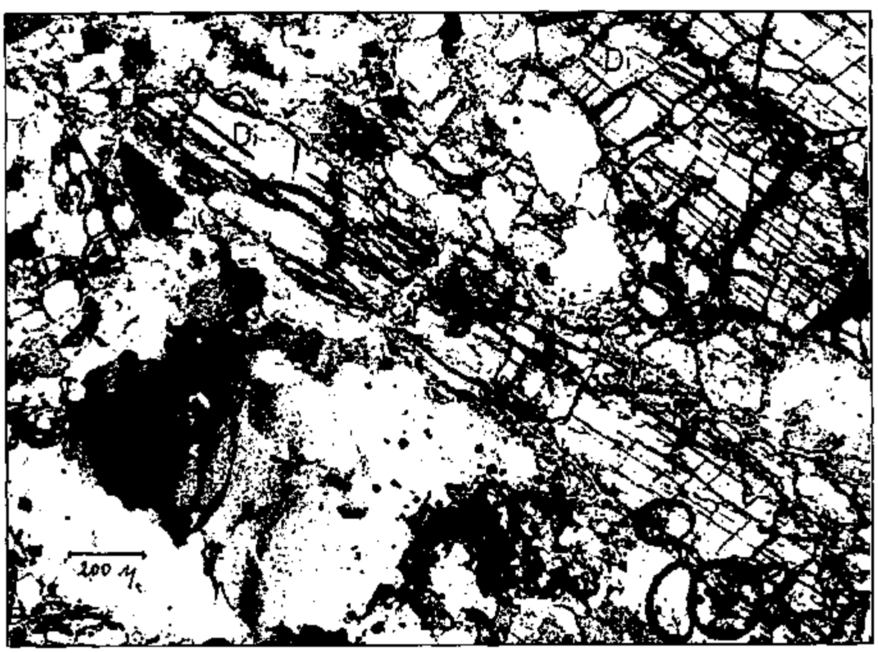

Fig. 2- Micrograph showing the replacement of kyanite (Di) by pyrophyllite in the sample from Vaktık hill.

Especially, the presence of kyanite together with pyrophyllites is critical for the metamorphic origin of Pütürge pyrophyllites. The presence of two successive metamorphic phases in Pütürge massif, one in prograding amphibolite facies and the other one in retrograding green schist facies were reported by Yazgan (1984) and MTA (1986). So, it is interpreted that kyanite was developed from tuffs with high Al content or kaolinites in granites or their volcanic equivalents in the progressive stage and replaced by pyrophyllites in the retrograde stage.

Bucher and Frey (1994) reported that kaolinite in the temperatures above 300˚C and kyanite+quartz at temperatures of 400˚C and <4 Kbar P_{water} reacts to form pyrophyllites. Association of quartz either with pyrophyllites or with kyanite, and even presence of silicarich rocks together with pyrophyllites implies that transformations in this stage were below 400˚C.

On the other hand, the distribution of pyrophyllite occurrences in the massif indicate that their formation can not be simply explained by their association with shear zones, but supports our suggestion for retrograde metamorphism. Besides, pyrophyllites do not show any oriented fabrics nor foliation, which could have been the case if formed in a shear zone. Moreover, their distribution in the massif also seem not, to be restricted to the contact between the lower and upper units as proposed by Erdem and Bingöl (1997).

Muscovite and sericite as other accessory minerals observed form more prominent zones in different outcrops. For example, marginal zones with muscovite (Keşen hill quarry), and with sericite have developed (Ümik hill and 1407m. hill). In these areas, they also include illite as determined by XRD studies.

Kaolinite and dickite are comparably rare and they are most probably mineralisations developed along hyrothermally activity zones or in secondary shear zones. This kind of kaolinite alterations with small dimensions are observed within very young shear systems associated with the east Anatolian Fault passing through Şiro stream at 10 Km's west of Puturge.

Main characteristics of the Pütürge pyrophyllites is the whiteness of their firing colour due to their iron content below % 0.2 in average. Moreover, for the importance of white cement production, chromium with values less then 100 ppm, and Mn with less 10 ppm are far below the critical limits. Measured SO_3 values, which are secondary in origin, reach to maximum % 4.8 in alunitisations observed in east Vaktık hill and Sınık hill quarries. TiO_2 present in average of % 0.5 ratio in pyrophyllites is related with minerals like rutile of sphene.

5 types of ores have been identified (Table 1) in Pütürge massif according to XRD, microscopy and XRF analysis in based on samples obtained from field work, drilling and production:

Table-1: Typical chemical compositions of the 5 types of pyrophyllites of Pütürge massif: Type-A: Ümik hill (Drilling Nr 9), Type-B: Şahantaşı hill (Drilling Nr 5), Type-C: Keşen hill quarry production, Type-D: production of the 1407 m. hill quarry, Type-E: Eastern Vaktık hill quarry production

	TYPE-A (high Al)	TYPE-B (low silica)	TYPE-C (high silica)	TYPE-D (with sericite)	TYPE-E (low alkaline)
SiO_2	54.5	64.4	74.9	77.7	75.8
Al_2O_3	37.9	25.6	17.4	15.6	16.2
Fe_2O_3	0.4	0.3	0.2	0.2	0.2
K_2O	0.5	0.9	1,1	2.8	0.3
Na_2O	0.1	0.3	0.6	0.1	0.1
SO_3	0.1	0.1	0.1	0.1	0.6
TiO_2	0.4	0.5	0.5	0.6	0.6
Cr (ppm)	100	120	58	55	69
Mn (ppm)	7	4	1	10	9
AK	2.6	4.7	2.7	3.2	5.0
SM	1.4	2.5	4.2	4.9	4.6

A) High Al-Pyrophyllites.- Al_2O_3 content in this type are above 28%. They are rich in kyanite. Al_2O_3 content in these ores in west Vaktık hill and in Ümik hill reaches up to 38% at some samples. Here 40% of the rock is made up of kyanite. Al_2O_3 contents even reaching up to 40.1% are found in core samples of Aytez hill.

B) Low silica Pyrophyllites.- Al_2O_3 content of this type changes between 20 - 35%. The silica module reaches to about 2.5 - 3. In these pyrophyllites, cut in limited amounts in the borings of Ümik hill, Şahantaşı hill, and 1407 m. hill, kyanite is nearly not recorded.

C) High silica Pyrophyilites.- These types are pyrophyllites are originally with quartz and have Al_2O_3 with values ranging between 15 - 18%. In these types of ores observed in some places such as Karataş hill-imrün quarry, Keşen hill and 1407 m. hill, silica module (SM) is observed to be around 4-5. They are ores that can be directly used in white cement production.

D) Pyrophyllites with sericites.- Pyrophyllites with sericite including some alkalies (in average 2 - 4% K_2O) are observed in Keşen hill quarry, Ümik hill and in 1407 m. hill. They have schistose appearance and include primary feldspars.

E) Low alkali Pyrophyllites.- This type of ores observed in eastern Vaktık hill can be differentiated from high silica pyrophyllites with their very low alkaline content (max. 0.5%).

The melting point of pyrophyllite, which is actually a refractory mineral, is given as 1200°C. In mixtures such as "algaimatolite" and "wonderstone", it is given as 1530°C and even as 1630°C. However, easy participation of Puturge pyrophyllites in reactions, in kiln temperatures are reasoned by presence of either low temperature quartz or fluxes such as F and B. The F content of pyrophyllites used for fiberglass production is found to be around 1500 ppm, which might be controlled by coexisting apatite.

Abundance of boron in pyrophyllites associated with granitic gneisses depends on presence of tourmaline and even dumortierite ($Al_7 [O_3/BO3/(SiO_4)_3]$). This paragenesis is observed in misroscopic investigations (Cemal Göncüoğlu. personal communications) of some Pütürge samples. Especially, in the Hollan dere occurrences, pyrophyllites with tourmaline are observed.

CONCLUSIONS

Around 25 pyrophyllite occurrences have been detected in a 15 km long, E-W trending belt in the Pütürge massif. The massif was subjected to two successive phases of metamorphism; an earlier progressive one within the amphibolite facies and a retrogressive one in green schist facies, respectively. Mineralogical and geochemical data indicate that originally high-alumina tuffs, clays or kaolinites gave way in the first phase to the formation of kyanite and in retrograde conditions, kyanite - pyrophyllite transformations were realized.

The Pütürge pyrophyllites are increasingiy used in white cement production because of their low iron and chromium content. Due to these properties it is used for the production of the best quality European white cement in ÇİMSA-Mersin, termed as "Super White" that has "whiteness" around 90.

The 5 different groups of Pütürge pyrophyllites with their outstanding mineralogical and geochemical properties, if elaborated in to economically more valuable products in ceramics, refractory, fiberglass, fillings, paper, and plastic industry will have high importance for economy of the country in the future.

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A PELAGIC PALAEOCENE SEOUENCE IN THE BİGA PENINSULA NORTHWEST TURKEY

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ABSTRACT.- A sequence of pelagic limestone, calciturbidite, debris flow, greywacke, basalt and limestone blocks. up to several hundred metres across, occur west of the town of Biga in northwest Turkey. The pelagic limestones in this seguence, named as the Ballıkaya formation, comprise pelagic foraminifera of Palaeocene age. Neritic limestone of Mid-Eocene age lies unconformably over the Ballıkaya formation. The age and the sedimentary environment of the Ballıkaya formation indicate the presence of a tectonically active deep sea environment in northwest Turkey during the Palaeocene, and constrain the main Alpide deformation in northwest Turkey to the Late Palaeocene - Early Eocene interval.

İNTRODUCTİON

Late Cretaceous and Palaeocene are critical tectonic periods in Anatolia. Subduction, ophiolite obduction, regional metamorphism and Aipide deformation occurred or started during this time span. Upper Cretaceous-Palaeocene stratigraphy has, therefore, a special importance in Turkey. However, Upper Cretaceous-Palaeocene outcrops have not been described over a very large region extending from Bursa westwards to the Aegean Sea, and information of the palaeogeographic and tectonic evolution of northwest Turkey during the Late Cretaceous and Palaeocene is very limited. In this context the discovery of a Palaeocene seguence in the Biga peninsula in the immediate vicinity of the town of Biga is of special importance for the tectonics of northwest Turkey. This paper describes the Palaeocene sequence in Biga and discusses its significance for the tectonics of western Anatolia.

GEOLOGİCAL SETTING

The eastern part of the peninsula belongs to the Sakarya zone of the Pondides. The Sakarya zone consists of Late Triassic subduction-accretion units, collectively named as the Karakaya complex, unconformably overlain by a Jurassic-Cretaceous sedimentary sequence. Rocks of the Karakaya complex crop out widely in the eastern part of the Biga peninsula (Bingöl et al., 1975; Okay et al., 1991). These rocks are unconformably overlain by the Liassic Bayırköy formation and the Middle-Upper Jurassic Bilecek limestone. Cretaceous rocks generally do not crop out in the Biga peninsula and farther east, probably due to erosional removal during the Tertiary. In the Biga peninsula the Jurassic Bileck limestone is unconformably overlain by the Upper Oligocene-Miocene Volcanic and volcanoclastic rocks. An exception to this situation is observed west of Balya, where a sequence of Bilecik limestone, 800 m thick, is overlain unconformably by thinly to medium bedded pelagic shaley limestones. The pelagic limestones are only 30 m thick, and are in turn unconformably overlain by the Neogene Volcanic rocks. They contain the foraminifera *Bonetocardiella conoidea,* characteristic for the Albian to Cenomanian period (Okay et aI,

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1991). Similar pink pelagic limestone seguences with *Hedbergella* sp. form small outcrops west of Gönen, around the margins of the Hamdibey-Kalkım Neogene basin and north of Balya. In these regions the stratigraphic position of these Cretaceous limestones is not clear. Upper Cretaceous ophiolitic melanges crop out in the centre of the Biga peninsula along a zone extending from Küçükkuyu to Karabiga (Fig. 1). Upper Cretaceous pelagic limestone blocks have been described in these ophiolitic melanges, which mark the western boundary of the Sakarya zone (Brinkmann et al., 1977; Okay et al., 1991).

The Palaeocene seguence described in this paper occurs immediately west of the town of Biga and forms an outcrop, two kilometres wide, surrounded by the Neogene volcanic rocks and Eocene sandstones.

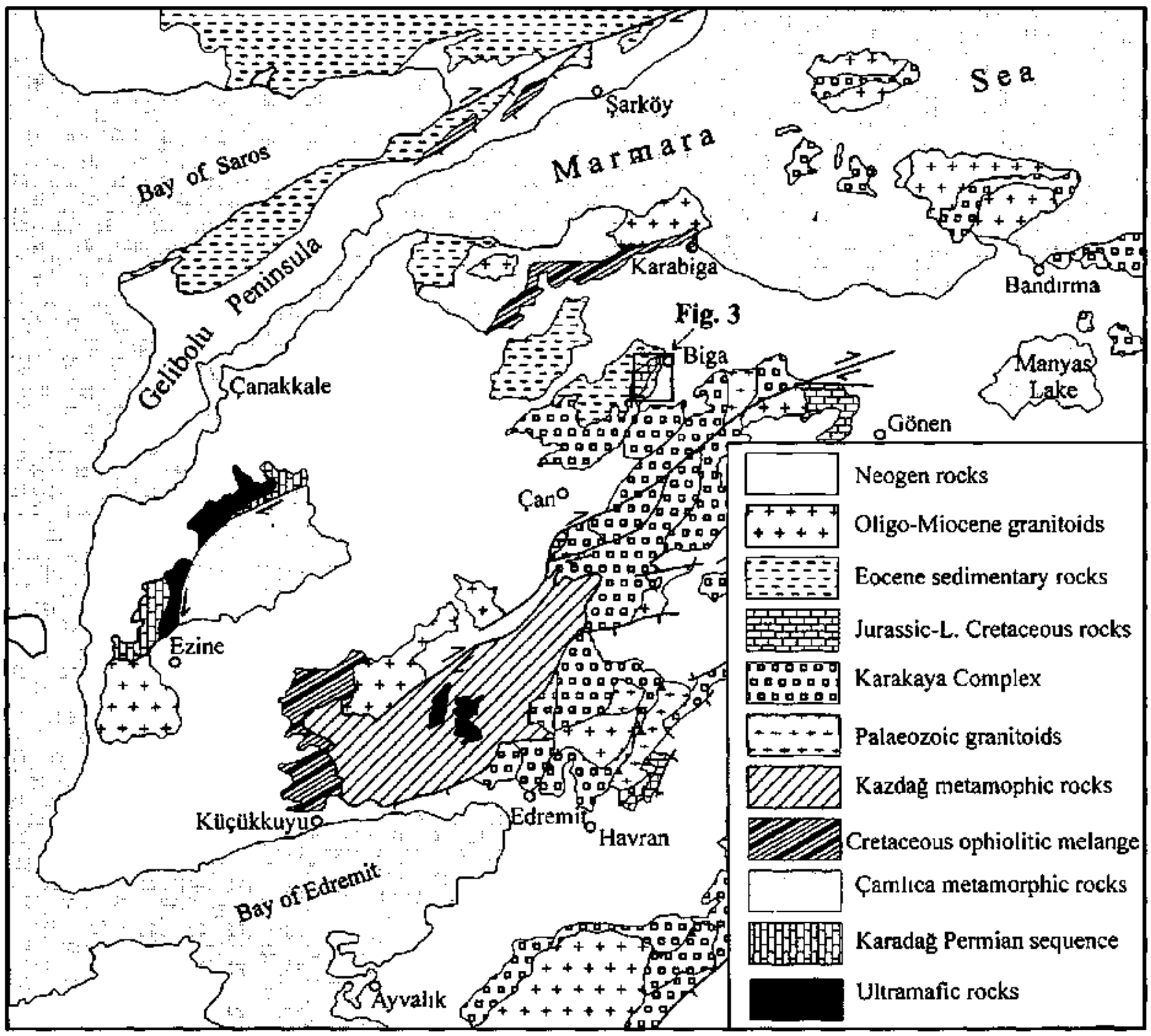

Fig. 1- Simplified geological map of the Biga peninsula and the surroundings (Okay et al., 1991). The area of study southwest of Biga is outlined.

GEOLOGY OF THE WEST BİGA REGİON

In the area studied, southwest of the town of Biga, the Palaeocene Ballıkaya formation is the lowest exposed unit (Fig. 2). It is overlain unconformably by the Eocene limestone, sandstone and shale. The Palaeocene and Eocene seguence is cut by a Neogene microgranodiorite and is overlain unconformably by the Neogene acidic tuffs.

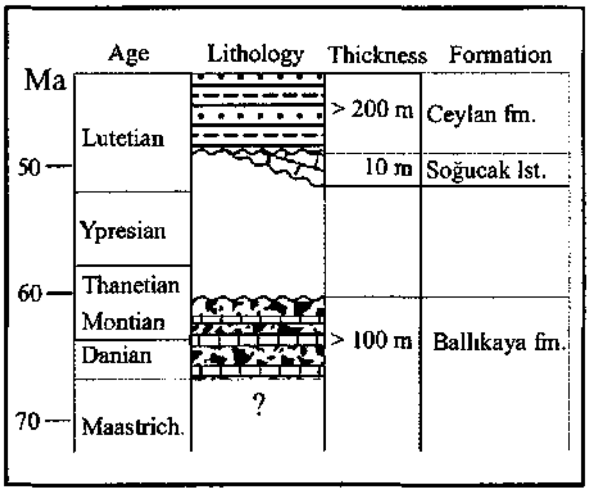

Fig. 2- Stratigraphic section west of Biga

Ballıkaya formation

The Ballıkaya formation, first described in this study, consists of pelagic limestone, calciturbidite, debris an grain flows, greywacke and basalt and large number of neritic limestone blocks of various sizes. The name of the formation comes from the Ballıkaya hill, 500 m west of the town of Biga, where the best and most representative outcrops are located (Fig. 3). The geographic coordinates of the type section are north 40°13'25" and east 27° 14'15".

Most of the Ballıkaya formation consists of grey, pale grey, thickly bedded to massive limestone blocks up to several hundred metres across. Lithologically these limestone blocks resemble the Jurassic Bilecik limestone, which outcrops around Balya and Gönen. The limestone blocks in the Ballıkaya formation constitute the hills west of Biga. The matrix to the blocks, which crops out in the valleys, consists of pelagic limestone, calciturbidite, debris and grain flows, greywacke and basalt. In the previous Studies, the matrix was not recognized and the region was ascribed to the Bilecik limestone (Okay et al., 1991).

Pelagic limestones and the intercalated calciturbidites are best observed on the Ballıkaya hill west of Biga. Similar outcrops of pelagic limestone also occur southwest of the village of Havdan (Fig. 3). The pelagic limestones are red, violet, thinly to medium bedded micrites with radiolaria and foraminifera (Plate 1 - fig. 2). The micrites are intercalated with pink, red and white calciturbidites and calcirudites. The limestone clasts in the calciturbidites and calcirudites are poorly sorted (0.5-25 cm) and medium to poorly rounded (Plate 1 - fig. 1). Red, brown debris flows with a volcanogenic matrix are observed on the Ahlatlı hill southwest of Biga. The debris flows comprise poorly sorted (1-75 cm) limestone and mudstone clasts and are intercalated with, grey, laminated mudstones and silstones. Greyish green greywacke and spilitic basalt forms rare outcrops in the Ballıkaya formation east of Havdan.

The Ballıkaya formation is dated through the abundant pelagic foraminifera in the red pelagic limestones. Three samples of micritic limestone around the Ballıkaya hill (sample numbers 146A, B, 163A) contain radiolaria and the foilowing foraminifera characteristic for the Early Palaeocene (Danian) *Morozovella pseudobulloides* (Plummer), *M. uncinata* (Bolli), *M.* cf. *trinidadensis* (Bolli), *Morozovella* sp., *Planorotalites compressa* (Plummer), *Planorotalites* sp., *Globigerina triloculinoides*

Plummer, *Globigerina* sp., *Racemiquembelina* sp., *Bolivina* sp. (Plate 1 - fig. 3). Another specimen of micrite from the same region (number 160) contains *Morozovella velascoensis* (Bolli), *Planorotalites* sp. and Radiolaria indicative for the Late Palaeocene (Thanetian) (Plate 1 - figs. 4 and 5). Another micrite sample collected from southwest of the village of Havdan (sample number 93) contains *Planorotalites compresssa* (Plummer), *Planorotalites sp., P. Morozovella sp., Globoconusa* sp., *Globotruncanita* cf. *stuarti* (d'Lapparent), *Globotruncanita* sp., *Abathomphalus* sp. (Plate 1 - fig. 6). These foraminifera indicate latest Maastrichtian and earliest Palaeocene. The Globotruncana forms in the sample are probably reworked from the Upper Cretaceous limestones. The foraminifera in the pelagic limestones indicate a Palaeocene age (Danian-Thanetian) for the Ballıkaya formation.

The presence of large number of limestone blocks in the Ballıkaya formation, as well as the scarcity of bedding, make the estimation of its thickness difficult. However, a minimum thickness of two hundred metres can be estimated for the Ballıkaya formation. In the area of study the base of the Ballıkaya formation is not observed, it is overlain unconformably by the Soğucak limestone of Middle Eocene age.

Soğucak limestone

The neritic limestones, that lie unconformably over the Ballıkaya formation, are called Soğucak limestone following the stratigraphic nomenclature in the Thrace basin and in the Biga peninsula. (Siyako et al., 1989). The Soğucak limestone is made up of yellowish, thickly bedded to massive reefal limestones with abundant nummulites, corals and algae. In the study are the Soğucak limestone is only observed on the Ballıkaya hill west of Biga (Fig. 3). In this locality limestones with abundant nummulites lie unconformably over the limestone blocks of the Ballıkaya formation. In other regions Eocene sandstones and shales lie directly over the Ballıkaya formation without the intervening Soğucak limestone (Fig. 3). West of Biga the Soğucak limestone has a thickness of about ten meters and is overlain by the sandstones and shales of the Ceylan formation. The contact between the Soğucak limestone and the Ceylan formation could not be observed in the field.

The Soğucak limestone west of Biga contains abundant nummulites and other benthic foraminifera. Samples of the Soğucak limestone from this region contain *Nummulites beaumonti* d'Archiac and Haime, *Nummulites* spp., *Discocyclina* sp., *Asterocyclina* sp., *Operculina* sp., *Quinqeuloculina* sp., Rotaliidae, Rupertidae, *Anomalina* sp., and indicate a Middle Eocene (Lutetian) for the Soğucak limestone.

Ceylan formation

Eocene sandstone, siltstone, mudstone and microconglomerate form a belt around the Ballıkaya formation west of Biga (Fig. 3). This Clastic sedimentary unit has been named as the Ceylan formation following the stratigraphic nomenclature in the Thrace basin and the Biga peninsula (Siyako et al., 1989). The dominant lithology of the Ceylan formation in the area of study is medium bedded, fine-grained yollowish brown sandstones. Locally siltstone, mudstone and microconglomerate beds are intercalated with the sandstones. Outcrops of the Ceylan sandstones are very rare in the area studied. In Thrace, the Ceylan formation is known to consist of siliciclastic turbidites.

No fossils have been found in the Ceylan formation in the area studied. However, its stratigraphic position above the Lutetian Soğucak Limestone, as well as palaeontological data from other parts of the Biga peninsula (Siyako et al., 1989) indicate a Mid-to Late Eocene age for the Ceylan formation west of Biga.

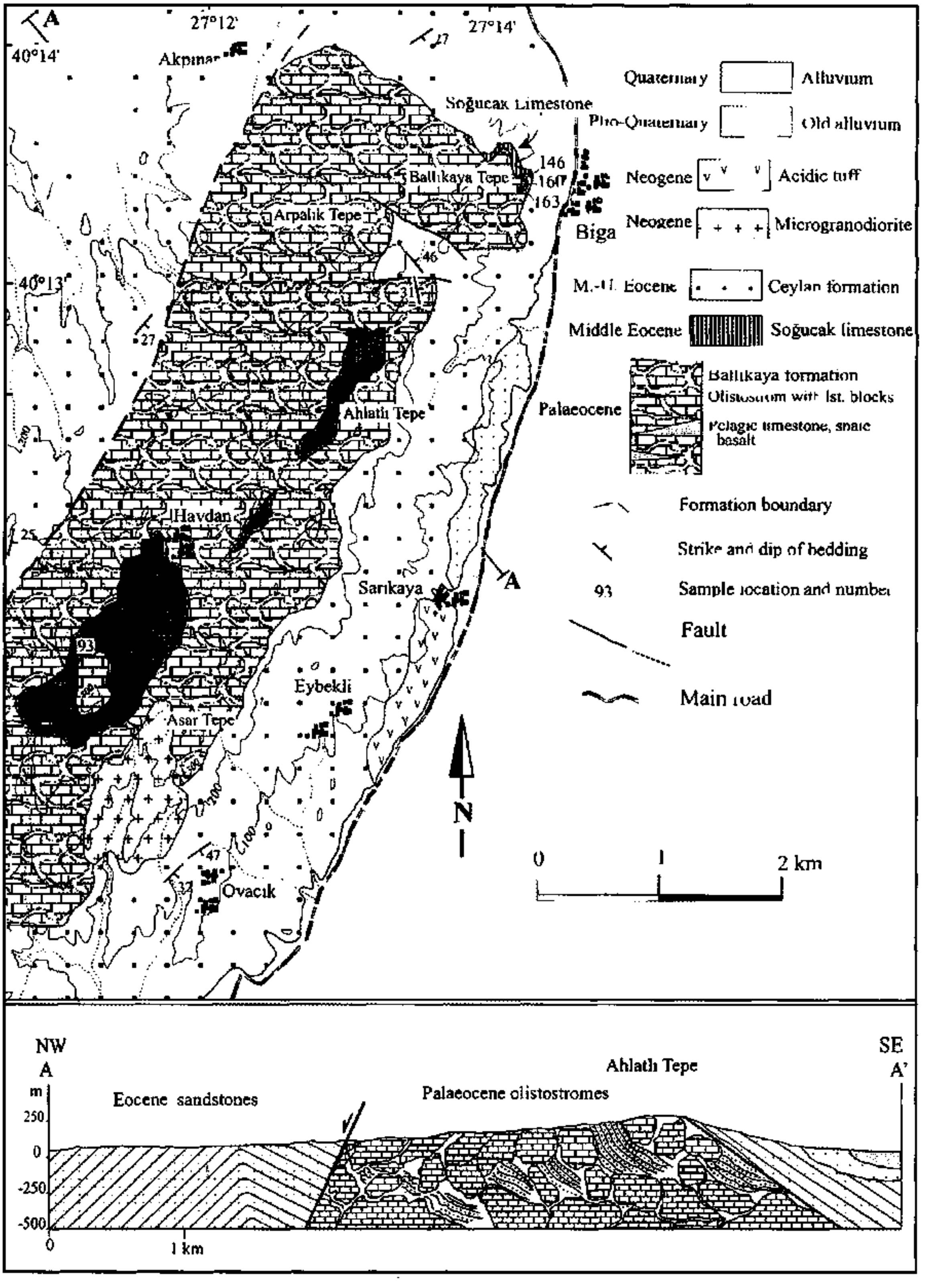

Fig. 3- Geological map and cross-section west of Biga. For location see Fig. 1

Neogene rocks

A small microgranodiorite cuts the Ballıkava and Ceylan formations in the southwest. The microgranodiorite consists mainly ot quartz and plagioclase with minor amounts of bioiite and amphibole. Extensive zoning in the plagioclase crystals in microgranodiorite indicates a shallow intrusion.

On the main road between Biga and Çan, white acitic tuffs lie unconformably over the Ceylan formation. The microgranodiorite and the acidic tuff are products of the extensive late Oligocene-Early Miocene calc-alkaline magmatism in northwest Turkey.

DISCUSSIONS AND CONCLUSIONS

A Palaeocene sequence of pelagic limestone, calciturbidite, debris and grain flows, greywacke, basalt and large number of limestone blocks crops out west of the town of Biga. This sequence is unconformably overlam by the Soğucak Limestone of Middle Eocene age.

Palaeocene outcrops in the northwestern Turkey are scarce. Upper Cretaceous-Palaeocene limestones have been described form the northern margin of the Gelibolu peninsula under the name of Lört formation (Önal, 1986). Blocks of Upper Cretaceous (Maastrichtian) and Lower to mid-Palaeocene (Danian and Montian) pelagic limestone, together with blocks of serpentinite, metadiabase, reefal Upper Eocene limestone blocks have been described as olistoliths in an Upper Eocene Clastic seguence north of Şarköy (Okay and Tansel, 1994). The Lört limestone could also be a large block in the Eocene seguence.

The Palaeocene rocks in Biga, Gelibolu and Şarköy indicate the presence of a tectonically active, deep sea to oceanic environment in northwestern Turkey during this period. This deep marine environment could be related to the Intra-Pontide ocean. The Alpide deformation and uplift in trtis region, probably related to the closure of the Intra-Pontide ocean, in constrained in northwest Turkey to the late Palaeocene-Early Eocene.

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PLATE

PLATE-I

Fig. 1- Field photograph of the calcirudites in the Palaeocene Ballıkaya formation, Ballıkaya hill, west of Biga.

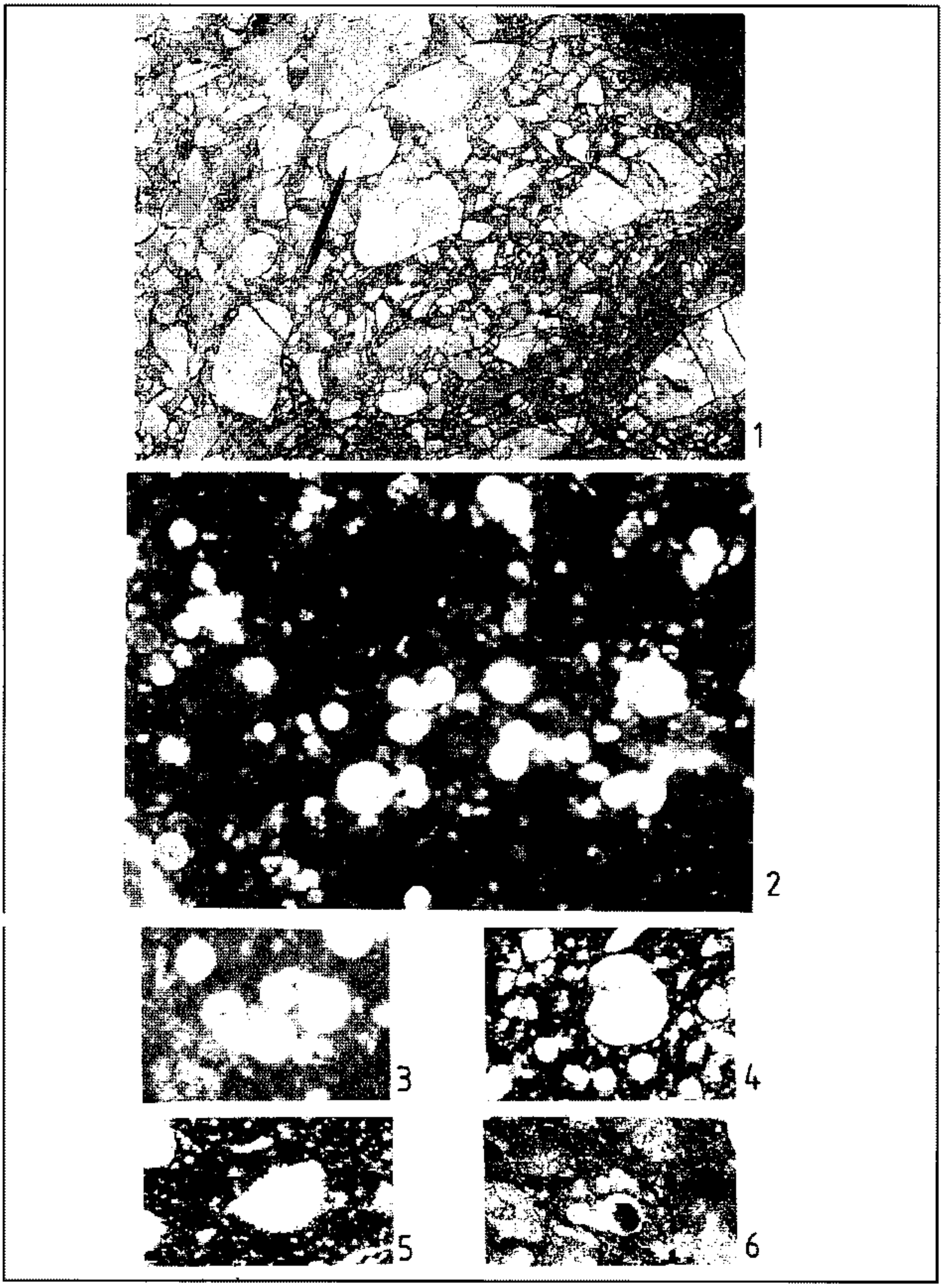
Fig. 2- Microphoto of a typical pelagic micrite in the Palaeocene Ballıkaya formation with radiolaria and foraminifera (*Morozovella pseudobulloides* (Plummer)), sample number 163A, the long edge of the photo is 2 mm,

Fig. 3- *Morozovella pseudobulloides* (Plummer), sample 163A, Ballıkaya formation, Danian, long edge 0.41 mm.

Fig. 4- *Morozovella* sp., sample 160, Ballıkaya formation, Palaeocene, long edge 0.82 mm.

Fig. 5- *Morozovella velascoensis* (Bolli), sample 160, Ballıkaya formasyonu, Thanetian, long edge 0.41 mm.

Fig. 6- *Planorotalites compresssa* (Plummer), sample 93 Ballıkaya formation, Danian; long edge 0.41 mm.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Mineral Res. Expl. Bul.. 123-124, 27-58. 2002

THE MOLLUSCAN FAUNA AND STRATIGRAPHY OF ANTALYA MIOCENE BASIN (WEST-CENTRAL TAURIDS, SW TURKEY)

Yeşim İSLAMOGĞU*

ABSTRACT.- This study has been carried out in Miocene units containing molluscan fauna, deposited in Antalya Miocene basin located at Western and Central Taurids. In the circumstances of this study, the eight stratigraphic sections were measured and the stratigraphy of the basin has been re-evaluated, based on the examination of the chronostratigraphic ranges of the collected samples belonging to the molluscan fauna. In this respect, the Lower Miocene Kepez travertine is the lowermost unit and unconformable with the basement, at the southeast of the basin. Succeded up, the Burdigalian Seving conglomerate of alluvial fan - fan delta character overlies this unit. The Upper Burdigalian - Langhian (Karpatian - Lower Badenian) Oymapınar limestone is composed of reefal - massive limestones and conformably overlies the Seving conglomerate. The Sevinc conglomerate and Oymapınar limestone are also unconformably overlying the basement rocks. The Oymapınar limestone is overlain by Çakallar formation (Upper Burdigalian - Lower Langhian) and Geceleme formation (Langhian). Geceleme formation is overlain by Serravalian - Tortonian levels of the Karpuzçay formation. It is the first in this study, that the units exposed in central and northern parts of the basin have been differentiated from the Aksu formation and defined as the Altınkaya formation. The Altınkaya formation is characterized by brackish water - marinal properties and contains Upper Burdigalian - Langhian (Ottnangian - Karpatian - Lower Burdigalian) molluscan fauna. It unconformably overlies the basement rock units and is overlain by Aksu formation. The Altınkaya formation is also laterally transitional with Upper Burdigalian - Langhian levels of the Karpuzçay formation. The Aksu formation widely cropped out widely at western and central parts of Antalya Miocene basin was dated as Lower Tortonian due to its molluscan fauna. However, the overall age of the formation was accepted as Serravalian - Tortonian.

INTRODUCTION

The Antalya Miocene basin is located at east of Western Taurids and west of Central Taurids in the area among Antalya, Alanya and Isparta provinces (Fig. 1). In this study, the Miocene units in the basin have been investigated and eight stratigraphic sections have been measured with compilation of samples collected from levels rich in molluscan fauna. The paleogeographic properties and taxonomies of molluscan fauna in measured sections were studied in detail (İslamoğlu, 2001).

The Miocene sediment fill in the region has been the subject of many studies since 1940's from the sedimentologic, paleontologic, stratigraphic and tectonic point of view and different ideas have been suggested (Altmli, 1945; Blumenthal, 1951; Özer at al., 1974; Öztümer, 1974; Dumont and Kerey, 1975a and *b;* Monod, 1977; Akbulut, 1980; Akoz, 1981; Akay and Uysal, 1984; Akay et al., 1985; Şenel et al., 1992, 1996 and 1998; Naz et al., 1991 and 1992; Tuzcu et al., 1994; Flecker et al., 1995; Erk et al., 1995; Karabıyıkoğlu et al., 1996 and 1997; Atabey, 1998; Karabıyıkoğlu et al., 2000).

Such a paleontological and stratigraphic study based on the molluscan fauna in the Antalya Miocene basin was firstly carried out and by using the obtained data, it is tried to make a contribution to the basin stratigraphy.

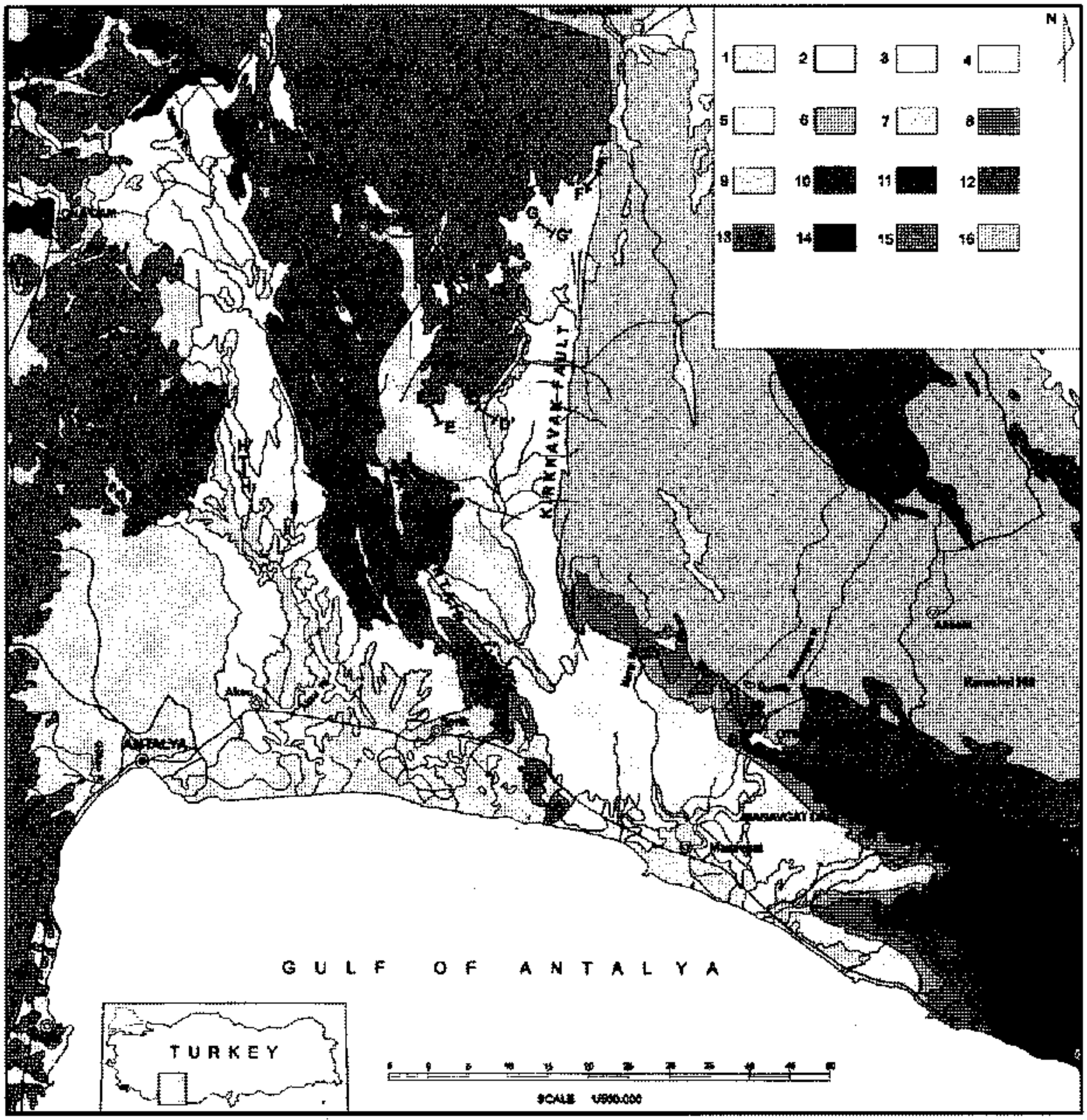


fig. 1- Geological map of the Antalya Miocene basin and surrounding area (modified by Şenel, 1997 *a,b,c*). 1- Quaternary, 2- Pliocene, 3- Taşlık formation, 4- Aksu formation, 5- Karpuzçay formation, 6- Oymapınar limestone, 7- Altınkaya formation, 8- Sevinç conglomerate, 9- Karabayır formation, + Karakuştepe formation, 10- Yeşilbarak nappe, 11- Lycian nappes, 12- Beyşehir-Hoyran-Hadim nappes, 13- Antalya nappes, 14- Alanya nappe, 15- Beydağları autochthone, 16- Anamas-Akseki autochthone. AA' Alarahan section, BB' Oymapınar section, CC' Radioring section, DD' Ballıbucak section, EE' Altınkaya section, FF' Aşağıyaylabel section, GG' Hocalarsırtı section, HH' Kargı section.

GEOLOGY OF THE BASEMENT ROCKS

The Neogene marinal deposits cover wide area in the region where the autochthonous and allocthonous rock units of Precambrian - Quaternary time interval are exposed.

In the region, the autochthonous rock units are Beydağları and Anamas - Akseki autochthone whereas the allocthonous were defined as Antalya nappe and Beysehir-Hoyran-Hadim nappes (Brunn et al., 1971, 1973; Dumont and Kerey, 1975a; Dumont, 1976; Monod, 1977; Poisson, 1977; Akbulut, 1977 and 1980; Waldron, 1982; Akay and Uysal, 1984; Akay et al., 1985; Şenel et al., 1992, 1996; Şenel, 1997a, *b).*

The Beydağları autochthone is located at west of Antalya Miocene basin and generally represented by Moesozoic platform carbonates. The Anamas-Akseki autochthone is observed at east and north of Antalya basin and consists of Mesozoic - Lower Tertiary carbonates with minor amount of clastic rocks. The Beydağları and Anamas-Akseki autochthones were combined and defined as Geyikdağ unit by Özgül (1976).

In the region, the Antalya nappes emplaced from the south, during Early Paleocene (Danian) and they include Upper Triassic platform, Jurassic - Cretaceous slope-basin type deposits of Çataltepe nappe, Permian-Lower Triassic platform, Middle Triassic-Upper Cretaceous basin type deposits with dominant basic volcanism of Alakırçay nappe-Tekirova ophiolite nappe and Tahtalıdağ nappe composed of Cambrian-Upper Cretaceous . platform type deposits (Brunn et al., 1971; Monod, 1977; Şenel et al., 1992; 1996). The Antalya nappes were also defined as "Antalya Unit" and "Antalya complex" by Özgül (1976) and Woodcock and Robertson (1977) respectively.

The Alanya nappe, overlying the Antalya nappes, includes Mahmutlar and Yumrudağ and Sugozu units undergone greenschist and blueschist facies metamorphism respectively (Özgül, 1984). Özgül (1976) defined the Alanya nappe as "Antalya unit".

Özgül (1976) distinguished three tectonic units namely; Aladağ unit, Bozkır unit and Bolkar unit based upon sequential between Lycian nappes and Beyşehir-Hoyran-Hadim nappes, Şenel (1997 *a,b,c)* classified the Lycian nappes into many structural units as Tavas nappe, Bodrum nappe, Marmaris ophiolite nappe, Domuzdağ nappe and Gülbahar nappe.

The Neogene deposits in the Antalya basin have been investigated by many researchers (Monod, 1977; Poisson, 1977; Dumont and Kerey, 1975a and *b;* Akay and Uysal, 1984; Akay et al., 1985; Şenel et al., 1991, 1992, 1996; Naz et al., 1991 and 1992; Flecker et al., 1995; Şenel and Bölükbaşı, 1997; Karabıyıkoğlu et al., 2000). The region has undergone the effect of Kırkkavak fault (Dumont and Kerey, 1975a) and Aksu thrust (Poisson, 1977) which are coeval with the sedimentation. For this reason, some of the researchers preferred to investigate the region under the three subbasin areas namely; N-S trending Aksu and Köprüçay subbasins and

NW-SE trending Manavgat subbasin (Flecker et al., 1995; Robertson et al., 1996).

Generally, at east and southeast of the basin, the Kepez travertine (Lower Miocene), the Seving conglomerate (Burdigalian), the Oymapınar limestone (Upper Burdigalian-Langhian), the Çakallar formation (Upper Burdigalian-Lower Langhian) and the Geceleme formation (Langhian) are cropped out. The Altınkaya formation (Upper Burdigalian-Lower Langhian) is exposed at central, northern and southern parts of the basin. The Karpuzçay formation (Upper Burdigalian-Tortonian) is observed in the whole basin, whereas the Aksu formation (Serravalian-Tortonian) is cropped out at central and western parts of it.

The other units in the region are the Lower Pliocene the Gebiz, the Eskiköy and the Yenimahalle formations, the Upper Pliocene Alakilise formation, the Pleistocene Belkıs conglomerate and the Quaternary Antalya travertine and alluvions (Poisson, 1977; Akay and Uysal, 1984; Akay et al., 1985).

There has been a compression - extention type tectonic regime prevailed since Miocene in the region. The products of the compressional regime are the empiacement of Lycian nappes from northwest to southeast, NE-SW trending Aksu thrust and Kırkkavak fault which is right-lateral strikeslip fault with reverse slip component (Dumont and Kerey, 1975a; Poisson, 1977; Akay and Uysal, 1988; Şenel et al., 1992). Antalya graben has developed by the E-W and later N-S trending compressions since Late Pliocene (Akay and Uysal, 1988).

LOCATIONS OF MEASURED STRATIGRAPHIC SECTIONS

In the region, the Miocene units containing molluscan fauna (Seving conglomerate, Oymapınar limestone, Altınkaya formation and Aksu formation) have been investigated in detail, and eight section were measured (Fig. 1). Measured sections and their locations are as follows.

The Alarahan measured stratigraphic section (Fig. 1, AA')

This section was measured in NE-SW direction at southeast of Antalya Miocene basin (Alanya 027d2 quadrangle) at eastern slope of the Alara stream. It has a 190 m total thickness, starting at X1 86400, Y1 62600 and finishing at X2 86350, Y2 62400 coordinates. Lower part of the section (170 m.) is represented by the Seving conglomerate, whereas the rest 20 m is the Oymapınar limestone (Fig. 2).

The Oymapınar measured section (Fig. 1, BB')

This section is located at O27a1 quadrangle and was measured along Manavgat stream toward southwest, at Oymapınar Dam and is situated approximately 3 km to the north of Oymapınar village. It is about 95 m thick and starting at X1 69150, Y1 85450 and finishing at X2 68950, Y2 85975 coordinates. Throughout the section, the basal 55 m part is belonging to Oymapınar limestone and the overlying 40 m thick upper part is represented by the Geceleme formation (Fig. 3).

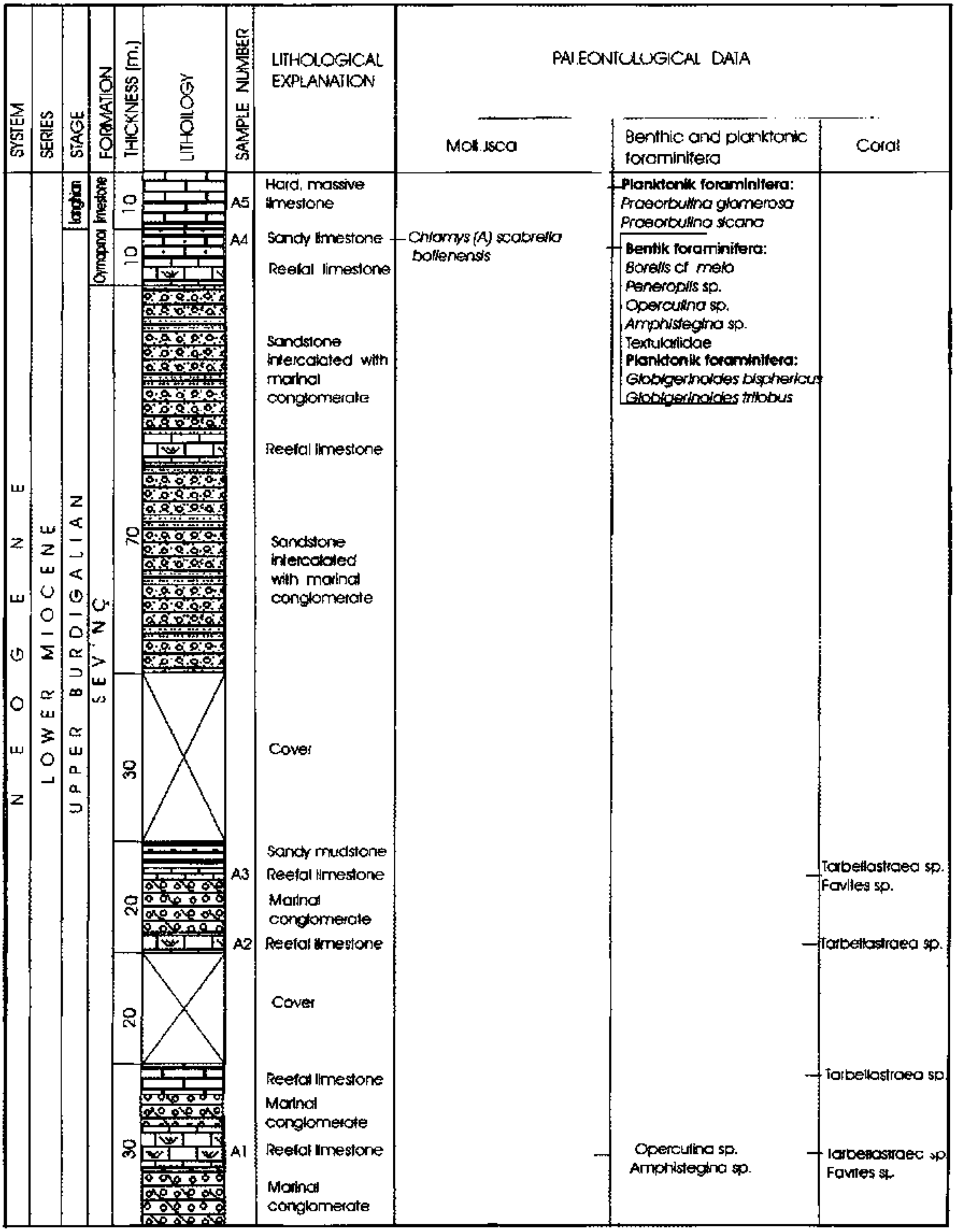


Fig. 2- The Alarahan stratigraphic section measured in the Seving conglomerate and the Oymapınar limestone (AA')

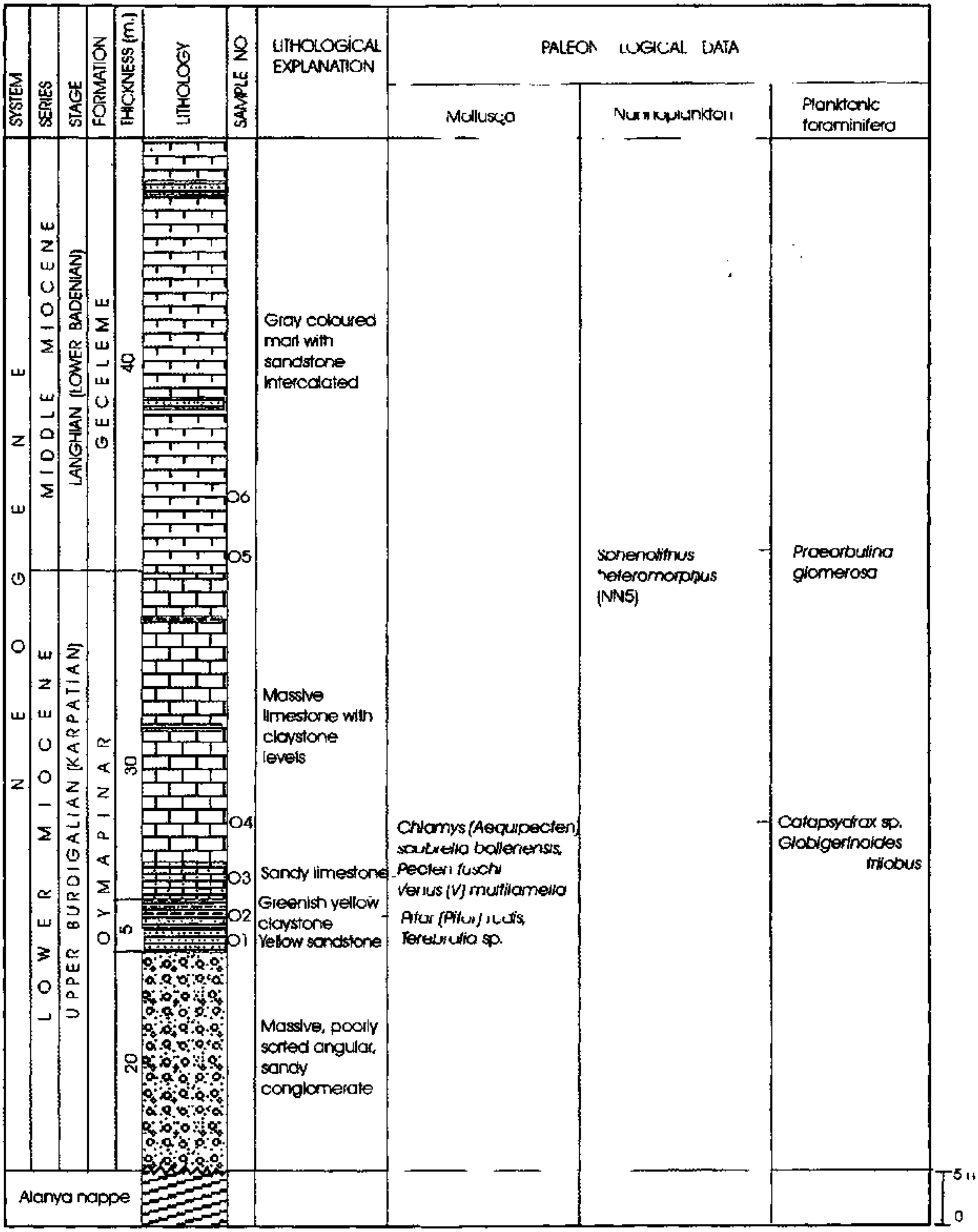


Fig. 3- The Oymapınar stratigraphic section measured in the teh Oymapınar limestone (BB')

The Radioring measured stratigraphic section (Fig. 1, CC')

This section is located at Antalya O26a2 quadrangle, 4.5 km northwest of Tasagil and 1 km south of Radioring station ancl was measured from southeast to northwest. The coordinates are starting at X1 40020, Y1 90020 and finishing at X2 40125, Y2 90000. It is only represented by 40 thick the Oymapınar limestone (Fig. 4)

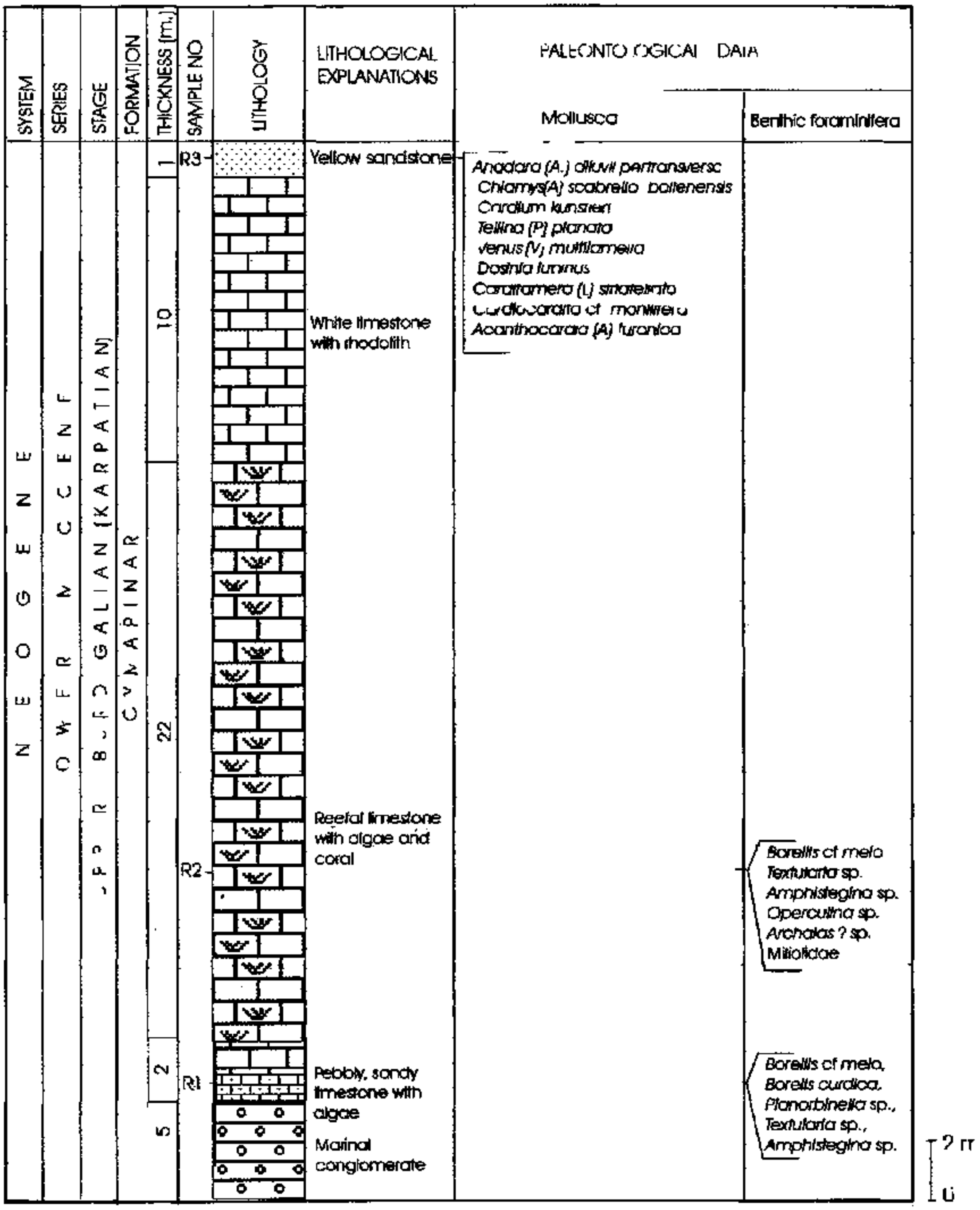


Fig. 4- The Radioring stratigraphic section measured in the Oymapınar limestone (CC')

The Ballıbucak measured stratigraphic section (Fig. 1, DD')

The section is located at Isparta N26a4 quadrangle, approximately 700 m to the southeast of Ballıbucak village and was measured in NW-SE direction. It starts at X1 33165, Y1 29425 and finishes at X2 33800, Y2 29000 coordinates. The basal 86 m part of 101m total thickness is characterized by the Oymapınar limestone. Unconformably overlying this is the 15 m thick conglomerates, probably belonging to Aksu formation (Fig. 5).

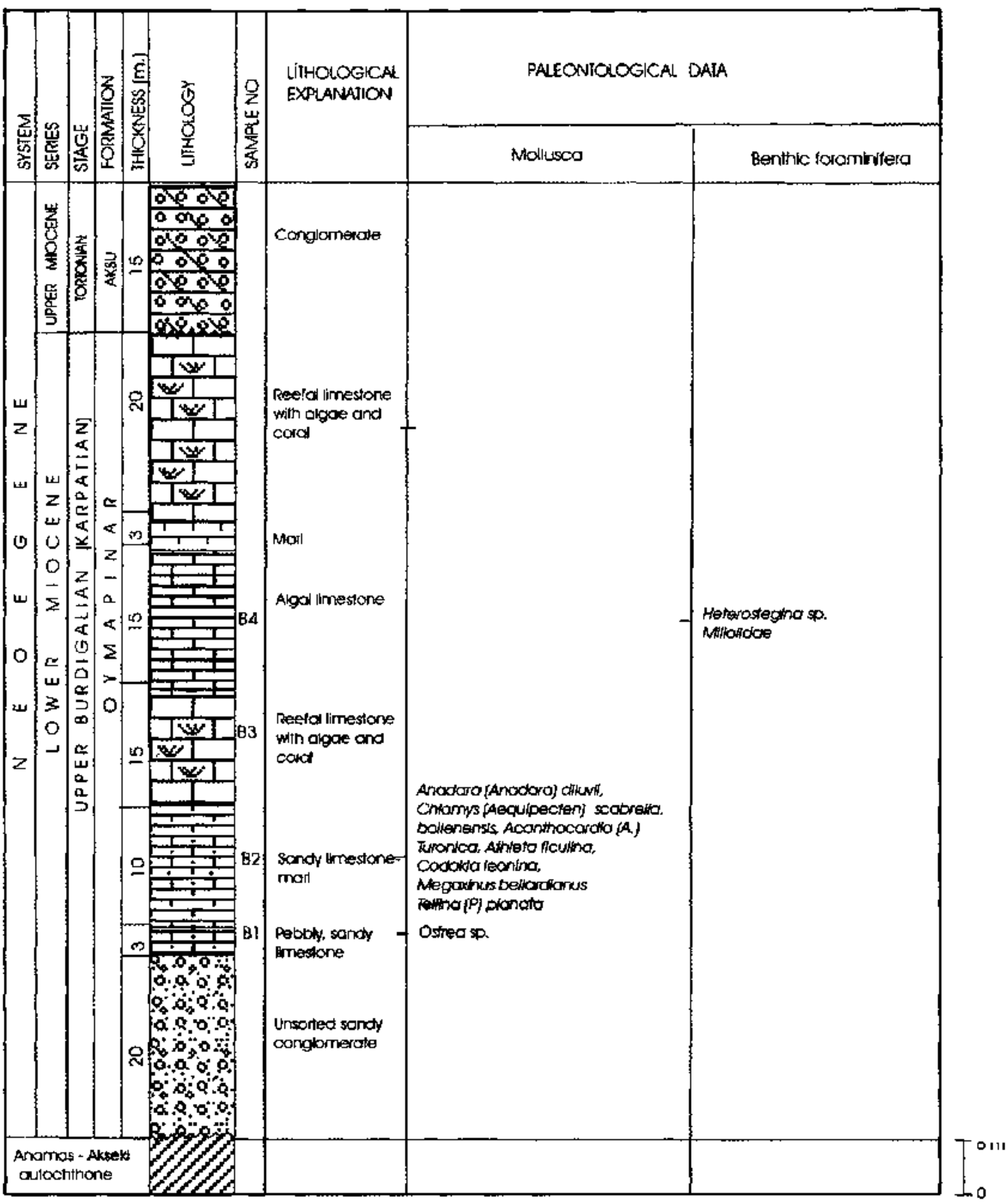


Fig. 5- The Ballıbucak stratigraphic section measured in the Oymapınar limestone and the Aksu formation (DD')

The Altınkaya measured stratigraphic section (Fig. 1, EE')

The Altınkaya measured section is located at Isparta N26d2 quadrangle. The section is 750 m in total thickness and was measured 2.5 km from north of Beşkonak village in northwest direction to the antique Zelga theatre (Altınkaya village). The section starts at X1 39250, Y1 15400 and finishes at X2 33825, Y2 22200 and it is completely represented by the Altınkaya formation (Fig. 6).

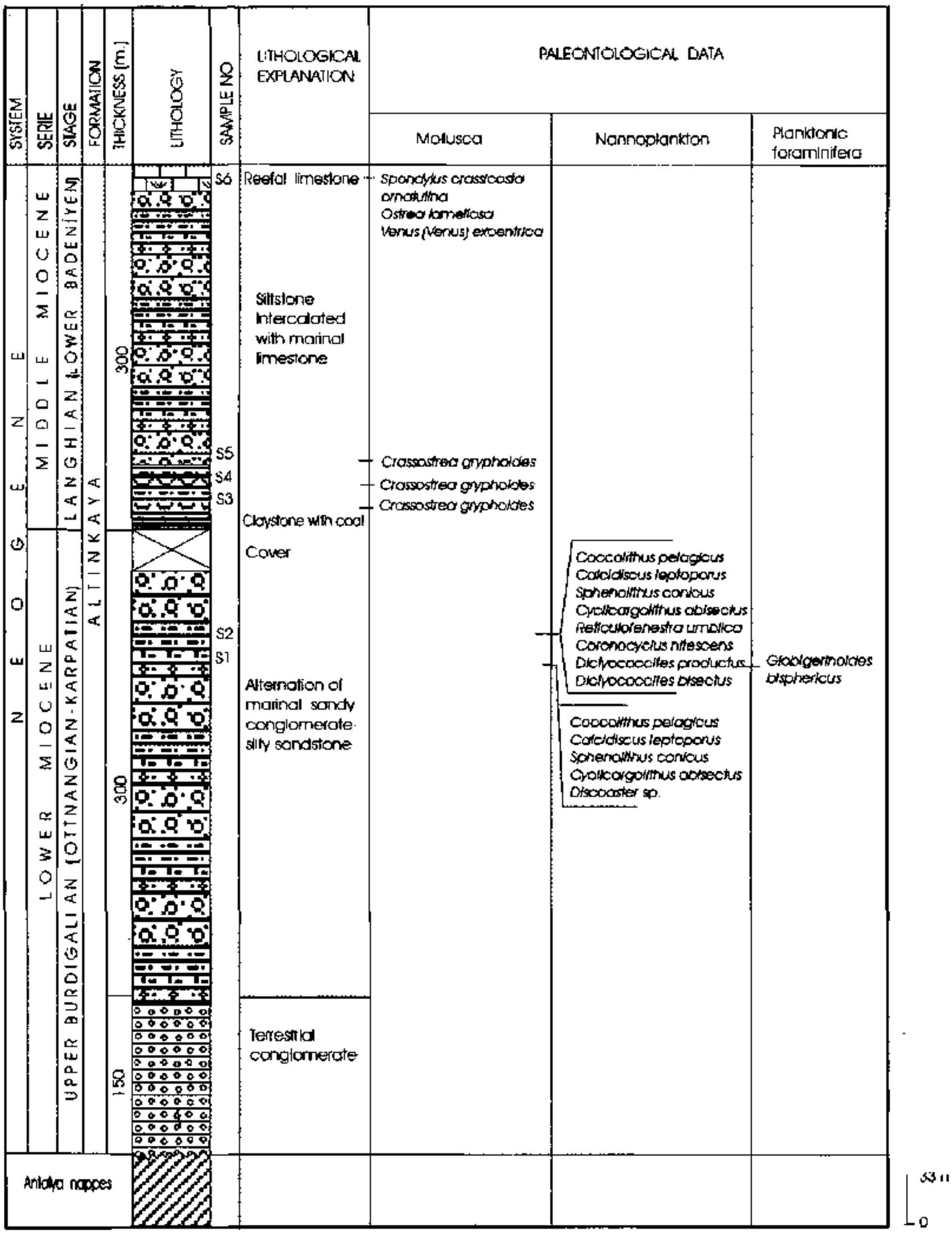


Fig. 6- The Altınkaya stratigraphic section measured in the Altınkaya formation (EE')

The Asağıyaylabel measured stratigraphic section (Fig. 1, FF')

This section is located at M26c4 quadrangle and was measured in northeast direction 1.5 km to the southwest Aşağıyaylabel province. It is approximately 54 m in thickness and starts at X1 49400, Y1 57175 and finishes at X2 49875, Y2 57275 coordinates. The whole section is characterized by the Altınkaya formation (Fig. 7).

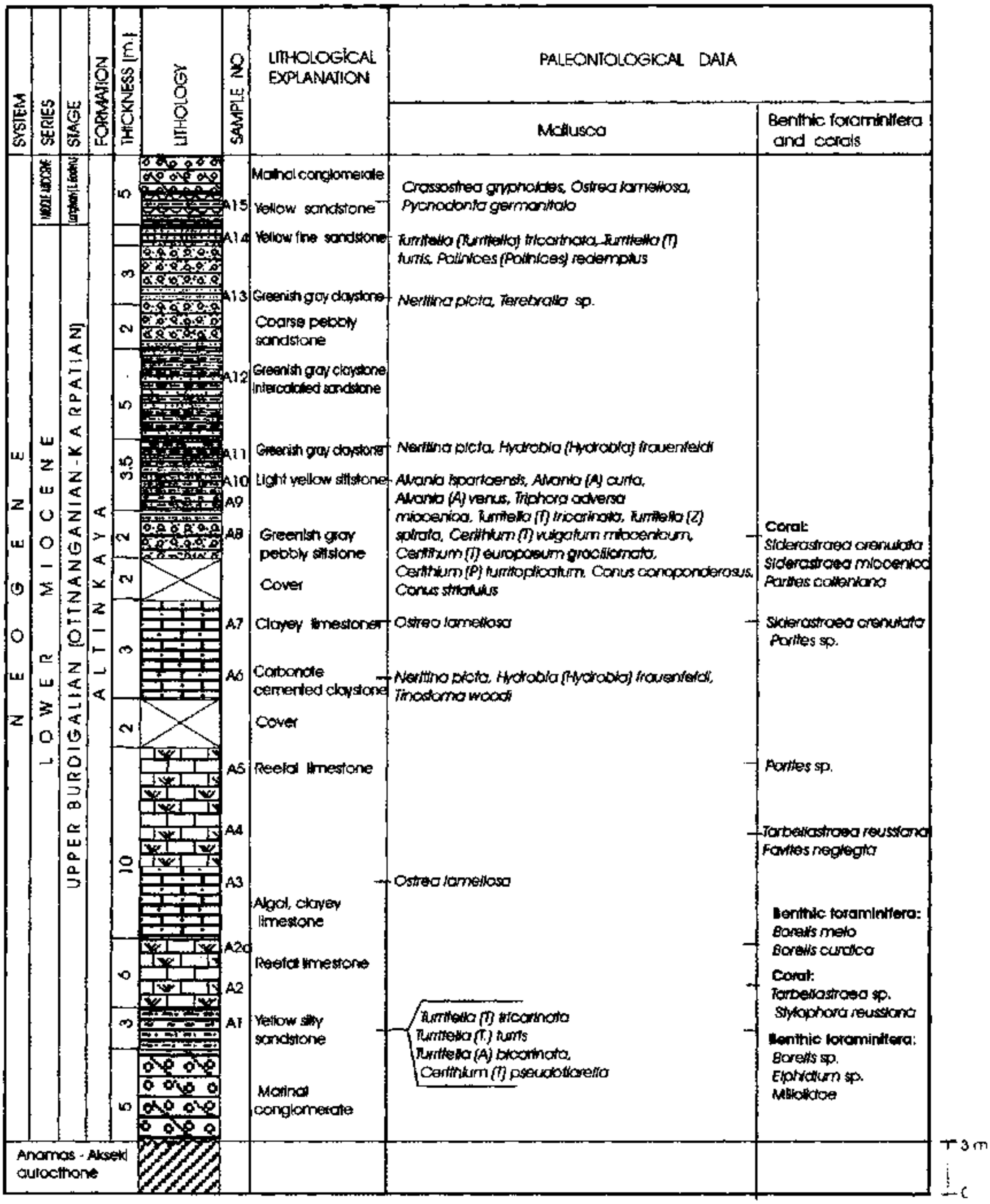


Fig. 7- The Aşağıyaylabel stratigraphic section measured in the Altınkaya formation (FF')

The Hocalarsırtı measured stratigraphic section (Fig. 1, GG')

This section is located at Isparta N26b2 quadrangle, approximately 1 km northwest of Hocalarsırtı and 1 km south of Karakaya province. The starting and finishing coordinates are X1 49250, Y1 45800 and X2 49750, Y2 45550 respectively. The thickness of the section is about 36 m and it belongs completely to the Altınkaya formation (Fig. 8).

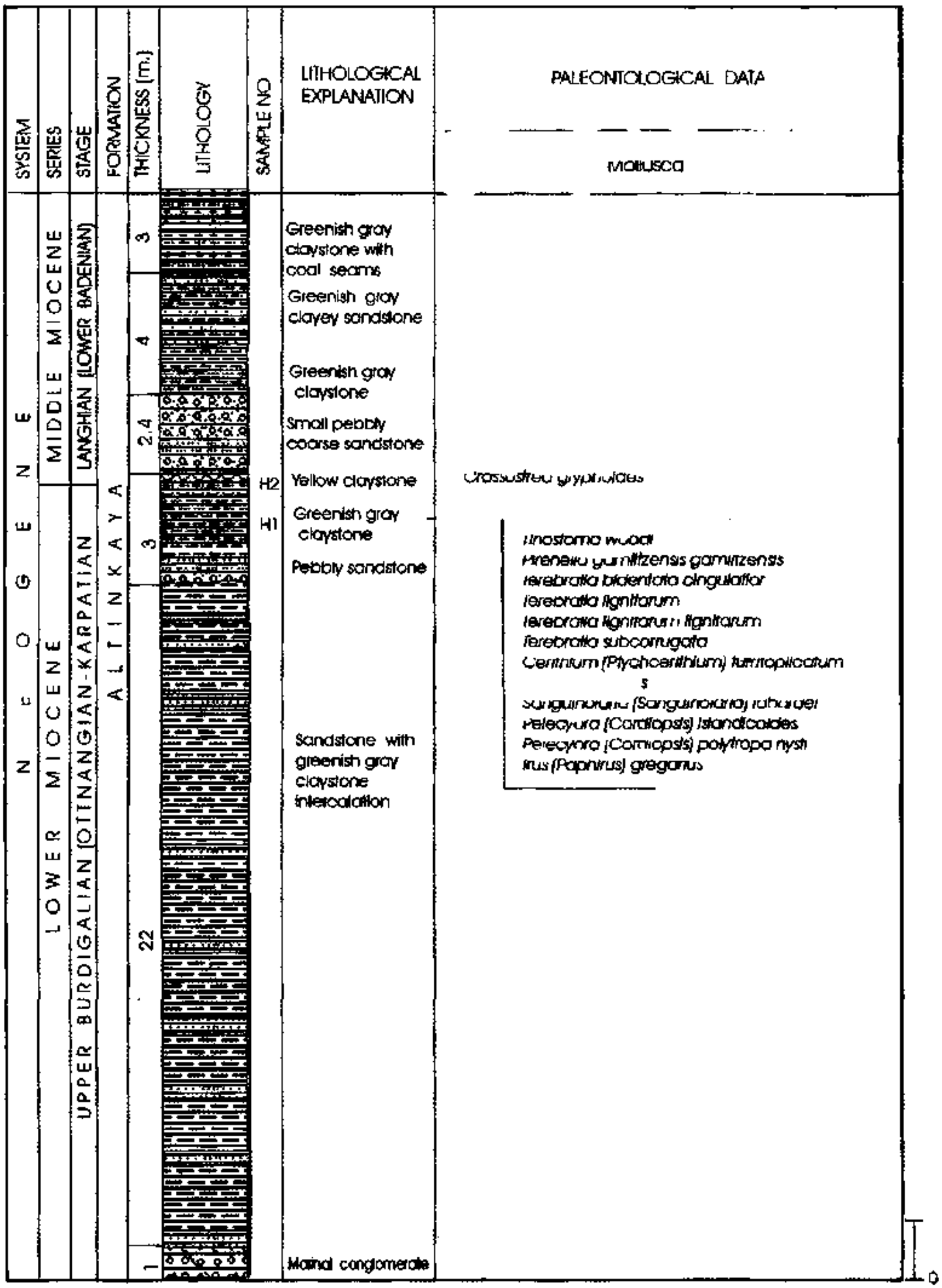


Fig. 8- The Hocalarsırtı stratigraphic section measured in the Altınkaya formation (GG')

The Kargı measured stratigraphic section (Fig. 1,HH')

This section is located at Isparta N25b4 quadrangle, 12 km to the south of Kargı and was measured from southwest to northeast around Kargı Tunnel. It is 56.5 m in total thickness and starting at X1 06150, Y1 27350 and finishing with X2 06275, Y2 27850 coordinates. The section was completely measured within Aksu formation (Fig. 9).

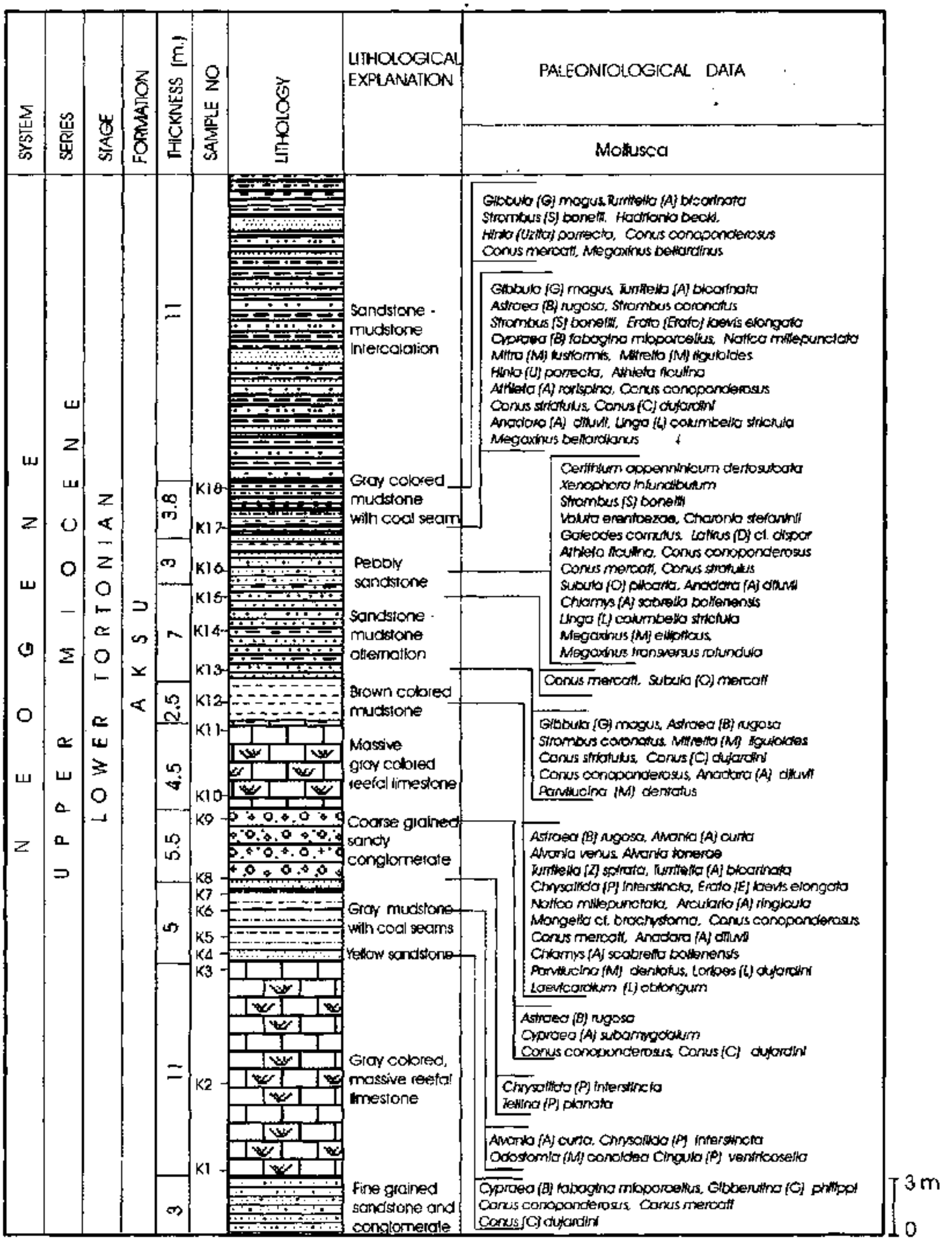


Fig. 9- The Kargı stratigraphic section measured in the Aksu formation (HH')

THE STRATIGRAPHY OF THE ANTALYA MIOCENE BASIN

For the better understanding the stratigraphic relationships in the basin, the other Miocene units in the region have been also investigated together with the studied formations. These units are Kepez Travertine, Seving conglomerate, Altınkaya formation, Oymapınar limestone, Çakallar formation, Geceleme formation, Karpuzçay formation and Aksu formation.

The Kepez travertine

Definition and nomenclature- It was firstly named by Monod (1977).

Type section locality.- It was defined at 300 m east of Kepez village (Antalya O27a1).

Lower-Upper boundary relations.- It unconformably overlies Alanya massif and is overlain by Upper Burdigalian deposits.

Lithology.- It is compposed of brown colored, massive calcium carbonate with solution cavity and plant fragments.

Thickness and distribution.- The unit is appoximately 20 m thick and pinches out laterally.

Fossil content and age.- It contains leave and plant fragments and rare green algae *(Charophyte)* (Monod, 1977). No age assignment was estimated these fossils. It is thought to be Lower Miocene based on stratigraphic relations.

Depositional environment.- It reflects a brackish water environment.

The Sevinç conglomerate

Definition and nomenclature.- Monod (1977) assigned the unit as Tepekli detritics. Later, Gutnic et al., (1979) defined it as Sevinç conglomerate in their geological map. Şenel et al., (1992, 1998) also adopted the name Sevinç conglomerate for the unit. Akay and Uysal (1984) and Akay et al., (1985) considered the unit together with Aksu formation.

Type section locality.- The type section is located around Sevinç village (Antalya O27a quadrangle).

Lower-Upper boundary relations.- The formation is observed at south and southeastern parts of the basin. It unconformably overlies the basement rock units and is conformably overlain by the Oymapınar limestone.

Lithology.- The formation is dominantly represented by unbedded or cross-lenticular stratified, continental and marinal conglomerates of different size. In some levels, it includes yellow, reddish brown colored sandstone and mudstone on small reefal limestone lenses. Sandstone and mudstone levels pinch out laterally. The marinal conglomerate is intercalated with reefal limestone in Alarahan section representing marine level of the formation.

Thickness and Distribution.- It is about 600 m thick (Şenel et al., 1992) and it pinches out laterally.

Fossil Content and age.- No fossil record was encountered to give an age data within terrestrial level of the formation. Late Burdigalian age has been suggested from the Alarahan section representing marine levels. It is concluded that due to unsuitable environmental conditions, the molluscan fauna could not find opportunity to develope in diversity. For this reason, only the *Chlamys (Aequipecten) scabrella bollenensis* (Mayer) and.Osfrea *lamellosa* Brocchi characterizing the Late Burdigalian were found and for this part of the formation this age has been accepted. Also in the same level, the presence of the benthic foraminfera such as *Borelis* cf. *melo* Fichtel and Moll, *Amphistegina* sp., *Peneroplis* sp., *Operculina* sp., Textulariidae (identified by

E. Sirel) and planktonic foraminifera *Globigerinoides trilobus* (Reuss) and *Globigerinoides Dsphericus Todd* (identified by A. Hakyemez) confirm this ageassigment. The age of the formation has been accepted as Burdigalian.

Depositional Environment.- The continental parts of the formation indicate alluvial fan (Şenel et al., 1992, 1996), whereas the marinal levels reflect shallow marine environment. Karabıyıkoğlu et al., (1996, 1997, 2000) pointed out that, the deposits indicate facies characteristics of alluvial fan-fan delta environment.

Altınkaya formation

Definition an nomenclature.- The all basal conglomerates developed during different stages of Miocene in Antalya Miocene basin were considered under the name of Aksu formation and have been dated as Oligocene-Tortonian by Akay and Uysal (1984) and Akay et al., (1985). Şenel et al., (1992, 1997b, 1998) considered the continental conglomerates, developed at the base of Upper Burdigalian - Langhian units, as the Sevinç conglomerates and Tortonian conglomerates as the Aksu formation. They also named the conglomerates deposited during Late Burdigalian-Langhian time interval at northeastern part of the basin as Aksu formation. Dumont (1976) considered the same unit as the Kesme conglomerates. In this study, this unit not differentiated from Aksu formation will be considered as Altınkaya formation.

Type section locality.- It is not possible to observe the whole formation in one locality. The type section locality has been chosen along the road continues towards Altınkaya village (historical Selge city and theatre) located at northwest of Beşkonak.

Reference section localities.- These are Ute Asağıyaylabel section (Isparta M26c4) located 2.5 km to the northwest of Yaka village and Hocalarsırtı section (Isparta N26b1) situated at Hocalarsırtı ridge 1 km to the south of . Karakaya. The formation is also observed along the road continued from Ballıbucak village towards east (Köprüçay) (Isparta N26a4) and along the road between Kesme and Yeşilbağ village and north of Yeşilbağ village (Isparta M26c4).

Lower-Upper boundary relations.- The formation unconformably overlies the Antalya nappes, Beydağları-Karacahisar autochthone and Anamas-Akseki autochthone at northeastern parts of the basin. At central parts of the basin, it is laterally interfingering with turbiditic deposits of the Karpuzçay formation. This boundary relationship is best observed in Köprülü Canyon. The Aksu formation unconformably overlies the Altınkaya formation (Brunn etal, 1971).

Lithology.- The dominant lithology in the formation is the marinal conglomerates. In some levels, the sandstone, shale, claystone and sometimes reefal limestones are also present. The conglomerates are generally sandy conglomerate and pebbly sandstone in types and they are dark gray colored, welllithified, carbonate cemented and the pebbles are radiolarite, chert and limestone in origine. In Aşağıyaylabel section, the formation transgressively overlies the Anamas-Akseki autochthone and starts with marinal conglomerates at the base and succeded up by yellow colored silty fine-grained sandstones, transitional to reefs. Upwards, the marinal units with brackish water levels intercalate once more and the sequence ends regressively. The sequential development like Aşağıyaylabel section was also observed in Hocalarsırtı section. In this case, the thickness of coral reefs and intercalated underlying conglomerates can not be measured due to unsuitable topographic conditions. Also their boundary relation with basement rocks were not observed. The observable lowermost part of the section starts with 1 m thick marinal conglomerates, overlain by the 22 m thick sandstone, greenish gray colored claystone. The sandstone beds are 10-30 cm in thickness and become more thicker at upper part. The 80 cm thick, small pebbly fine-grained sandstone bed with scored base, overlies overlying this level. The sequence continues with 2 m thick greenish gray colored claystone. As it is explained below, the section is rich in molluscan fauna representing brackish water-marine conditions with nearly the same salinity of marine water.

The H1 sample is rich in molluscan fauna representing brackish water - marine environment in this unit. It yields *Tinostoma woodi* (Homes), *Pirenella gamlitzensis gamlitzensis* (Hilber), *Terebralia bidentata cingulatior* Sacco, *Terebralia lignitarum* (Eichwald), *Terebralia lignitarum lignitarum* (Eichwald), *Terebralia subcorrugata* d'Orbigny and *Cerithium (Ptychocerithium) turhtoplicatum* Sacco of class Gastropoda; *Gastrana fragilis* (Linne), *Sanguinolaria (Soletellina) labordei* (Basterot), *Pelecyora (Cordiopsis) islandicoides* Lamarck, *Pelecyora (Cordiopsis) polytropa suborbicularis* (Goldfuss) and *Irus (Paphirus) gregarius* Partsch from class Bivalvia. Based on these molluscan fauna, this part of the section represents the stage of Upper Burdigalian (Karpation) (Table 1a, 1c). The accumulation of thick and coarse shell fragments (20-35 cm) of *Crassostrea gryphoides* (Schlotheim) bearing fine-grained siltstones conformably overly this unit. With this level, the Langhian (Early Badenian) starts and it can be also correlated with A14 sample numoer of Aşağıyaylabel and S3-S4-S5 sample numbers of Altınkaya measured sections. This level is succeded up by 2-4 m thick fine-grained pebbly coarse sandstones. It continues upward with 80 cm thick greenish gray claystone, 40 cm thick matrix-supported conglomerates, 70 cm thick fine-grained sandstone with clay intercalation, 2.2 m thick green-blue colored fine grained clayey sandstone and 3 m thick green-blue colored claystones with thin coal seams. At uppermost part, the 2 m thick matrix-supported conglomerates were observed.

The thin coal seams developed within the formation are similar to the levels in the Altınkaya and Hocalarsırtı sections.

Thickness and distribution.- It is about 600 m, although the thickness changes laterally.

Fossil content and age.- The moluscan fauna, found within sections measured from different localities of Altınkaya formation, indicate generally Upper Burdigalian - Langhian (Ottnangian-Karpatian-Lower Badenian) age also supported by the other faunas.

The molluscan fauna hasn't been found at lowermost part of Altınkaya section. However, in the sandstone-marl intercalations of this level, the nannoplankton flora such as *Coccolithus pelagicus* (Wallich), *Sphenolithus conicus* Bukry, *Cyclicargolithus abisectus* (Muller), *Calcidiscus leptoporus* (Murray-Blackman), *Dictyococcites productus* (Kamptner), *Dictyococcites bisectus* (Hay-Mohler-Wade), *Reticuloenestra umblica* (Levin) and *Coronocyclus nitescens* (Kamptner) were detected. This flora indicate and give the Lower Miocene age (identified by H. Karakullukçu). In the same unit, rare planktonic foraminifera was found such as *Globigerinoides bisphericus* Todd which is known to be appeared in Early Burdigalian (identified by A. Hakyemez). For this part of the section mentioned above, althought there is no presence of the molluscan fauna, considering its stratigraphic position and the presence of nannoplankton assemblage and planktonic foraminifer fauna, its age was accepted as Upper Burdigalian (Ottnangian-Karpatian). After a 5 m thick covered interval, 50 cm thick ctaystones with thin coal seams were observed. Upward, yellow colored, silty fine grained sandstone (S3) containing 70-80 cm thick accumulations of the Crassostrea gryphoides (Schlotheim) of class Bivalvia are present. For this level, the age of the sequence was accepted as Langnian (Lower Badenian) based on the presence of the *Crassostrea gryphoides* (Schlotheim). Overlying this level, the section continues with nearly 280 m thick marine conglomerates and ends with 6 m thick coral reefs observed around antique theatre. Within the S6 sample number of coral reefs as *Ostrea lamellosa* Brocchi, *Spondylus crassicosta ornatulina* Sacco and *Venus (Venus) excentrica* Agassız were identified. This fauna also indicate the Langhian (Lower Badenian) age. At the lowermost part of the Aşağıyaylabel section, the identified Gastropods are *Turritella (Turhtella) rricarinata* (Brocchi), *Turritella (Archimediella) bicarinata* Eichwald, *Chrysallida (Parthenina) mterstincta* (Montagu) and *Cerithium (Tiaracerithium) pseudotiarella* D'Orbigny which the last one became extinct at the end of Burdigalian. This unit also includes benthic foraminifera as *Borelis* sp., *Elphidium* sp., Miliolidae (identified by E. Sirel) and ostracoda as *Aurila) cicatricosa* (Reuss) survived in neritic environment and widely distributed in Middle-Upper Miocene (identified by M. Duru). The yellow colored silty sandstones are transitional to 6 m thick and 40 m wide reefal limestones. Sample A2 collected from this level contains *Heliastraea* sp., *Stylophora reussina* (Montarano-Galitelli) like coral fauna (identified by S. Babayiğit). Also in sample A2a, the benthic foraminifera (A3) as *Borelis melo* (Fichtel and Moll) and *Borelis curdica* (Reichel) (identified by E. Sirel), indicate the Upper Burdigalian-Tortonian age and marine environment with low salinity. In the overlying reefal limestones (sample A4), the *Tarbellastraea reussiana* (Milne Edwards and J. Haime) and *Favites neglegta* (Michelotti) corals were found (identified by S. Babayiğit). The sequence continues with 60 cm thick clayey limestone and 5 m thick limestone including Porites sp fragments. In this level a sample as A6 many Gastropoda representing low-salinity marine environment as *Neritine picta* (Ferussac), *Hydrobia (Hydrobia) frauenfeldi frauenfeldi* (Hoernes) and *Tinostoma woodi* (Hoernes) were found. In the sample A7 taken from 3 m thick clayey limestone, Bivalvia as *Ostrea lamellosa* Brocchi, corals as *Siderastraea crenulata* (Goldfuss) *Porites* sp. (identified by S. Babayiğit) and ostracoda as *Bairdia* sp. (identified by M. Duru) were found.

After 2 m thick cover, light greenish gray colored, 2 m thick fine grained pebbly, silty clay overlies the unferlying levels. In the sample A8, the corals as *Siderastraea crenulata* (Goldfuss), *Sedirastraea miocenica* (Osasco) and *Porites collegniana* (Michelin) were found (identified by S. Babayiğit). The level of sample A9 taken for nannoplankton is 70 cm thic and is composed of greenish gray colored, parallel laminated clay stone containing no nannoplanktons. The section continues with light yellow colored, 60 cm thick clayey siltstone. Sample A10 taken from this level yielded following marine Gastropod fauna are *Alvania ispartaensis* n.sp., *Alvania (Alvania) curta* (Dujardin), *Alvania (Alvania) venus* d'Orbigny), *Triphora adversa miocenica* Cossmann ve Peyrot, *Turritella (Turritella) tricarinata* (Brocchi), *Turritella (Zaria) spirata* (Brocchi), *Cerithium (Thericium) vulgatum miocenicum* (Vignal), *Cerithium (Thericium) europaeum graciliornata* (Sacco), *Cerithium (Ptychocerithium) turritoplicatum* Sacco, *Conus conoponderosus* (Sacco) and *Conus striatulus* Brocchi. The sample A11 taken from greenish gray colored 1.6 m thick clays with thin clayey limestone intercalation also yielded Gastropoda as *Neritina picta* (Ferussac), *Hydrobia (Hydrobia) frauenfeldi frauenfeldi* (Hoernes) characterizing brackish water-marine environment. No fauna was found in yellowish colored 10 cm thick carbonate cemented sandstone (A12 sample).

Towards the upper part of the section is represented by greenish gray colored, 1.1 m thick, thin laminated claystones and continues with yellow colored, 10 cm thick, carbonate cemented sandstone. The greenish gray colored 4 m thick claystones with increasing sandstone intercalations are succeded up by yellow colored, parallel lamimated 2.5 m thick coarse-grained pebbly sandstones with scored bases. Within the 1 m thick greenish gray claystone the identified Gastropods are *Neritina picta* (Ferussac), *Terebralia* sp. and *Valvata* sp. (sample A13) which also characterizing the low salinity marine conditions. The section continues with yellow colored, carbonated, sandy siltstone. In thp 1 m interval of yellow colored silty sandstone, the Gastropoda fauna as *Turritella (Turritella) thcarinata tricarinata* (Brocchi), *Turritella (Turritella) turris* Basterot and *Polinices (Polinices) redemptus* (Michelotti) indicating the marinal conditions were found (A14). This part of the section was dated as Upper Burdigalian (Ottnangian-Karpatian) based on this fauna (Table 1).

From this level upward, the sequence includes Bivalvia as *Crassostrea giyphoides* (Schlotheim) which can survive in very low salinity environments. The other species are the *Ostrea lamellosa* Brocchi and *Pycnodonte germanitala* (De Gregoria) which their shell fragments accumulated in 70 cm thick siltstone and adopted themselves to salinity changes in environment. Uppermost part of the sequence is characterized by 5 m thick marinal conglomerates. The age of this part of the section has been accepted as Langhian (Lower Badenian) based on the molluscan fauna.

The sample H1 in Hocalarsırtı section is rich in moluscan fauna which represents the low salinity marine environment. The identified Gastropods are *Tinostoma woodi* (Hornes), *Pirenella gamlitzensis gamlitzensis* (Hilber), *Terebralia bidentata cingulatior* Sacco, *Terebralia lignitarum* (Eichwald), *Terebralia lignitarum lignutarum* (Eichwald), *Terebralia subcorrugata* d'Orbigny and *Cerithium (Ptychocerithium) turritoplicatum* Sacco. The Bivalves are *Gastrana fragilis* (Linne), *Sanguinolaria (Soletellina) labordei* (Basterot), *Pelecyora (Cordiopsis) islandicoides* Lamarck, *Pelecyora (Cordiopsis) polytropa suborbicularis* (Goldfuss) and *Irus (Paphirus) gregahus* Partsch. Based on the mentioned molluscan fauna, the age of the section at this level was assigned as Upper Burdigalian (Karpatian) (Table 1a-b-c). The Langhian (Lower Badenian) starts with the *Crassostrea giyphoides* (Schlotheim) found as accumulation of thick and coarse shell fragments (20-35 cm) overlying the basal level. This level can be correlated with other measured sections in the basin, such as, sample A14 of Aşağıyaylabel and sample S3, S4 and S5 of Altınkaya measured stratigraphic sections.

Depositional environment.- The Altınkaya formation contains molluscan fauna which generally indicates the low salinity brackish water-marine environments. Especially, in Hocalarsırtı and Aşağıyaylabel sections the euryhaline mollusc species survive in low salinity environment were detected in greenish gray colored claystones. In this sections, also in the Altınkaya section, the accumulation of shell fragments of the *Crassostrea giyphoides* (Schlotheim) were detected which developed in much lower salinity environments (Cox et al., 1969). These levels are intercalated with marinal units. The intercalations of molluscan fauna representing low salinity marine environment and small-scale coral reefs indicate tidal changes in sea level throughout the time. This change is especially well-observed in Aşağıyaylabel section. The benthic foraminifera encountered within sandy limestones of this section are *Borelis melo* Fichtel and Moll and Miliofidae representing back reef-lagoon environmental conditions (identified by E. Sirel).

In the formation, similar to the Altınkaya section, the nannoplanktons and planktonic foraminifera implying the deeper and more saline environmental conditions were found. As it is seen from the Altınkaya and Aşağıyaylabel sections the presences of algae and small patchy reefs indicates the marine environment.

The geochemical analyses were carried out on shell fragments of molluscs found in Hocalarsırtı, Aşağıyaylabel and Altınkaya sections to interprete the paleoecological conditons. These analyses also imply the presence of cold and low saline marine water conditions (İslamoğlu, 2001). The faunal data from the formation also support this idea. Although the euryhaline molluscs are abundant, the stenohaline nannoplanktons and planktonic foraminifera are not abundant and diverse in the section (Flecker et al. 1995 and Hakyemez, 2001, personal communication). It is observed that, the types and number of diversity are less and the wall structures of the planktonic foraminifera were destroyed (Hakyemez, personal communication). This is interpreted that, the environmental salinity and temperature conditions were not suitable for the surviving of planktonic foraminifera.

The Oymapınar limestone

Definition and nomenclature.- Oymapınar limestone as a formation was first given by Monod (1977). It was previously named as Burdigalian limestone by Altınlı (1943) and Miocene limestone facies by Blumenthal (1951). Later, Derman (1977) and Aköz (1981) used the name as Sakseydi limestone and Naz et al., (1992) considered it under the name of Oymapınar formation. Akay and Uysal (1984), Akay et al. (1985) and Şenel et al., (1992, 1996) adopted and used the same name as Oymapınar limestone.

Type-section locality.- It is located at slope of Manavgat stream, 3 km north of Oymapınar.

Reference sections.- Two reference sections sections are observed; one is located at 4.5 km northwest of Taşağıl, the Radioring and the other is situated about 700 m southeast of Ballıbucak village, the Ballıbucak section.

Lower-Upper boundary relations.- This unit unconformably overlies the Alanya nappe, Antalya nappes and Anamas-Akseki autochthone and conformable over the Sevinç conglomerate. The Oymapınar limestone is conformably overlain by the Çakallar formation at southeast of the basin and Geceleme formation in Oymapınar section. It is unconformably overlain by the Aksu formation in Ballıbucak section.

Lithology.- The Oymapınar limestone is composed of medium-thick bedded, polygenic base conglomerate, sandstone, white-gray colored hard, sandy limestone, algal limestone, massive limestone, coral-algae reefal limestone and mudstone. It sometimes starts with conglomerate or sandstones and continues with reefal limestone and with massive limestones. The sequence in Oymapınar section transgressively overlies the Alanya nappes and it starts at the base with 20 m thick, red colored poorly sorted and angular conglomerates (Fig. 3). The limestone breccias are exposed following the conglomerates at the slope face to measured section locality. These breccias indicate the tectonic activity which is known to be developed at the beginning of the Miocene in the region (Akay et al., 1985; Şenel et al., 1992, 1996). The terrestrial conglomerates are followed by greenish yellow colored, small pebbly 1.55 m thick sandstones. These are succeded up by green colored, 60 cm thick claystones and greenish yellow, 1.8 m thick, semi-lithified siltstones.

In Alarahan section, the topmost 10 m is represented by white-gray colored very hard, massive, algae limestones which are the Oymapınar limestone (Fig. 2).

In Radioring section, the Oymapınar limestone overlies conformably the 5 m thick marinal conglomerates and continues with 2 m thick, algae, distributed pebbly, sandy limestone (Fig. 4).

In Ballıbucak section, the sequence again starts transgressively and at the base it contains thick, massive, sandy, poorly sorted, grain-supported conglomerates. It continues with 3 m thick, small pebbly, bioclastic limestone containing coral and mollusc fragments. In sample B1 of this level, the *Ostrea* sp. was found. Upward, the sequence continues with 10 m thick sandy limestone and marl alternation.

Thickness and distribution.- Although the thickness is changeable, it reaches up to 100 m.

Fossil content and age.- The molluscan fauna identified in the Oymapınar limestone indicate generally Upper Burdigalian-Langhian (Karpatian-Lower Badenian) age (Table 1). The Bivalve as *Pitar (Pitar) rudis* (Poli) and Gastropod as *Terebralia* sp. found in sample O2 reveal the shallow marine environment. The sequence continuing with green colored, 50 cm thick clays with coal seams, is later transitional to light colored, 3 m thick massive sandy limestones. The sample O3 from this level contains *Pecten fuschi* Fontannes, *Chlamys (Aequipecten) scabrella bollenensis* (Mayer). *Venus (Ventricoloidea) multilamella* (Lamarck) characterizing also marine environment. Overlying this level, is the 27 m thick, sometimes claystone intercalated with hard, massive algal limestones. Sample O4 in this unit includes planktonic foraminifera *Catapsydrax* sp., *Globigerinoides trilobus* (Reuss) representing Burdigalian age (identified by A. Hakyemez). Based on these data, it is accepted that this part of the sequence represents the Upper Burdigalian (Karpatian) stage (Table 1).

At the locality of Oymapınar section, the olistoliths derived from coral reefs of the Oymapınar limestone are found in Geceleme formation. The thin sections prepared from the samples of this olistolits indicate Upper Burdigalian - Tortonian age based on the benthic foraminifera suchs as *Borelis melo* (Fichtel and Moll), *Borelis* cf. *curdica* (Reichel), *Amphisteginasp., Planorbulinella* sp., *Lepidocyclina* sp., *Operculina* sp., Miliolidae, Rotaliidae, Victoriellidae (identified by E. Sirel). The fauna also confirms the Upper Burdigalian (Karpatian-Lower Badenian) age formation the Oymapınar limestone in this section.

In Alarahan section, the uppermost parts of the formation were dated as Langhian based on planktonic foraminifera. These levels indicate that the environment was deeper Gastropod and Bivalve fauna were not detected there. However, there was abundance of planktonic foraminifera, the sample A5 includes *Praeorbulina glomerosa glomerosa* (Blow), *Praeorbulina glomerosa curva* (Blow) and *Praeorbulina sicana* de Stefani which characterizing the transition to Langhian (identified A. Hakyemez). The *Praeorbulina* sp. appeared at the beginning of the Middle Miocene and indicates a great distribution both Mediterranean Tethys Langhian and Central Paratethys Lower Badenian (Steininger and Rogl, 1984; Rogl, 1998). Although it was not found in Alarahan section, the presence of turbiditic deposits of Serravalian and Tortonian in the region has been determined in the other studies (Öztümer, 1974; Akay ve Uysal, 1984; Akay ve dig., 1985; Naz ve diğerleri, 1991, 1992; Şenel, 1996). The sample R1 in Radioring section is taken from 2 m thick algae pebbly, sandy limestone and benthie foraminifera assigning to Upper Burdigalian-Tortonian age were found in this level. These are *Borelis* cf. *melo* (Fichtel and Moll). *Borelis curdica* (Reichel), *Planorbulinella* sp., *Textularia* sp., *Amphistegina* sp. (identified by E. Sirel). 22 m Thick coral and algae reefal limestone overlies this level. The sample R2 also includes benthic foraminfera as *Borelis* cf. *melo* (Fichtel and Moll), *Amphistegina* sp., *Textularia* sp., *Operculina* sp., *Archaias* ? sp., Miliolidae (identified by E. Sirel) Later, it is 10 m thick, white colored limestone with rodolithes (identified by. N. Atabey) and the section ends with 1 m thick yellow colored sandstone. In sample R3 of this level, the following molluscan fauna were found; *Anadara (Anadara) diluvii pertransversa* Sacco, *Chlamys (Aequipecten) scabrella bollenensis* (Mayer), *Tellina (Peronaea) planata* Linne, *Venus (Ventricoloidea) multilamella* (Lamarck), *Carditamera (Lazariella) striatellata* (Sacco), *Cardiocardita* cf. *monilifera* (Dujardin), *Acanthocardia (Acarthocardia) turonica* (Mayer), *Cardium kunstleri* Cossmann ve Peyrot, *Tellina (Peronidia) planata* Linne, *Venus (Ventricoloidea) multilamella* (Lamarck), *Dosinia lupinus* (Linne). These fauna represent marine environment and indicate Upper Burdigalian (Karpatian) age. They include both Mediteranean Tethys and Central Paratethys species. For this reason, the age of the section was estimated as Upper Burdigalian (Karpatian) based on the molluscan fauna (Table 1).

In Ballıbucak section, within sample B2, the Bivalves and Gastropods characterizing marine environment were found. The Bivalves are *Anadara (Anadara) diluvii* (Lamarck), *Chlamys (Aequipecten) scabrella bollenensis* (Mayer), *Codakia leonina* (Basterot), *Acanthocardia (Acanthocardia) turonica* (Mayer), *Tellina (Peronaea) planata* Linne, *Megaxinus bellardianus* (Mayer) whereas the Gastropod is-*Athleta ficulina* (Lamarck). At the basal part of the 15 m thick massive algae-coral reefal limestone Miliolidae was obtained (Sample B3). After this level, again at the lower part of the 15m thick limestones, the *Heterostegina* sp., Miliolidae type benthic foraminifera were obtained and algal abundance increase towards up the section. The sequence foraminifera were obtained and algal abundance increase towards up the section. The sequence continues with 3 m thick marls and 20 m thick reefal limestone where the algae and corals become abundant. The age of the this part of the section was accepted as Upper Burdigalian (Karpatian) based on the molluscan fauna (Table 1). The 15 m thick conglomerates unconformably overlie the limestone levels. These conglomerates are conglomerate could be suggested as Tortonian due to its stratigraphical position. It can be assumed that this formation formed in transgressive and reefal conditions.

Depositional environment.- The formation is generally reflecting transgressive and reefal characteristics.

Table 1 a- Ranges of the molluscan fauna determined in the Antalya Miocene basin

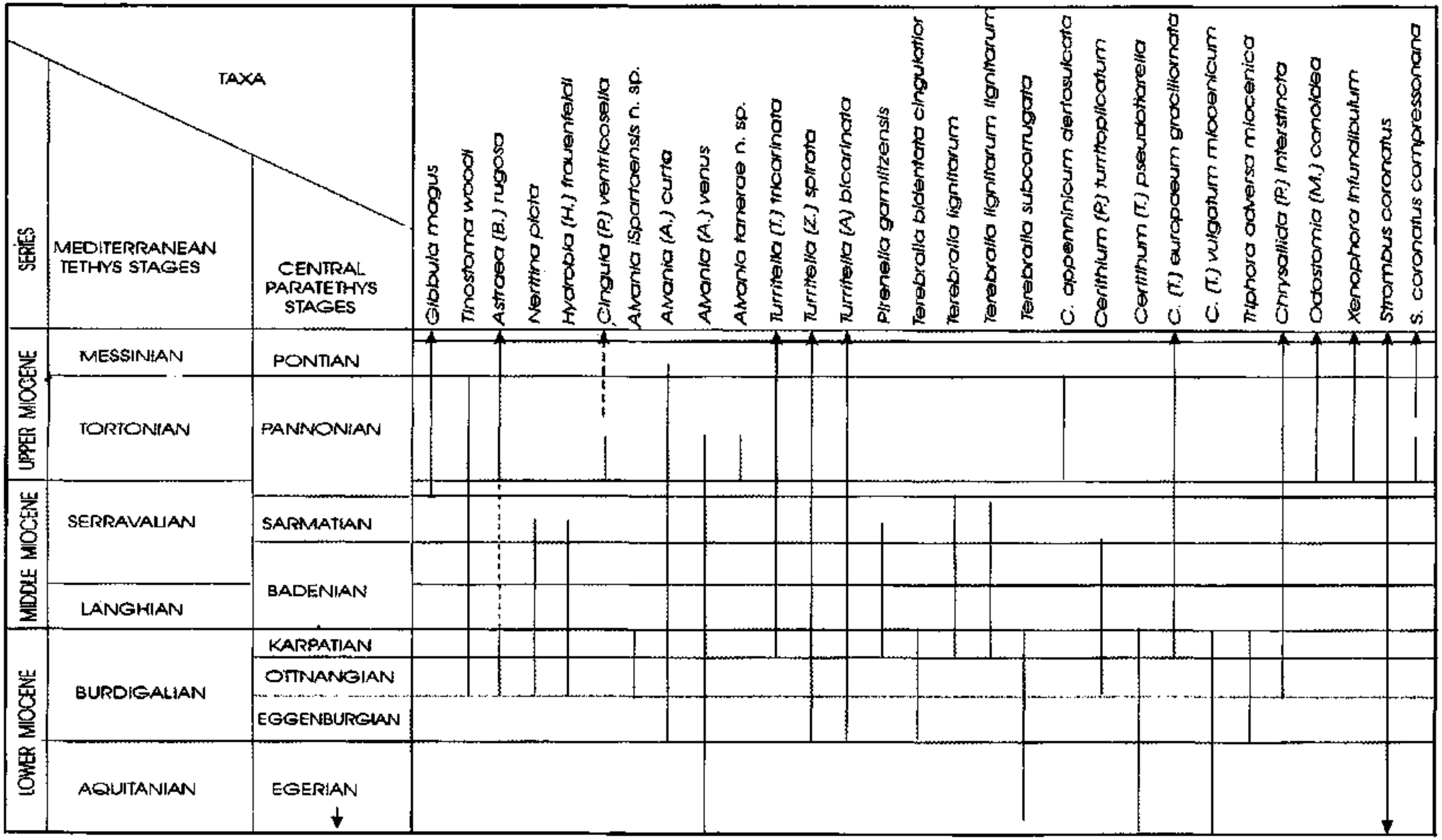
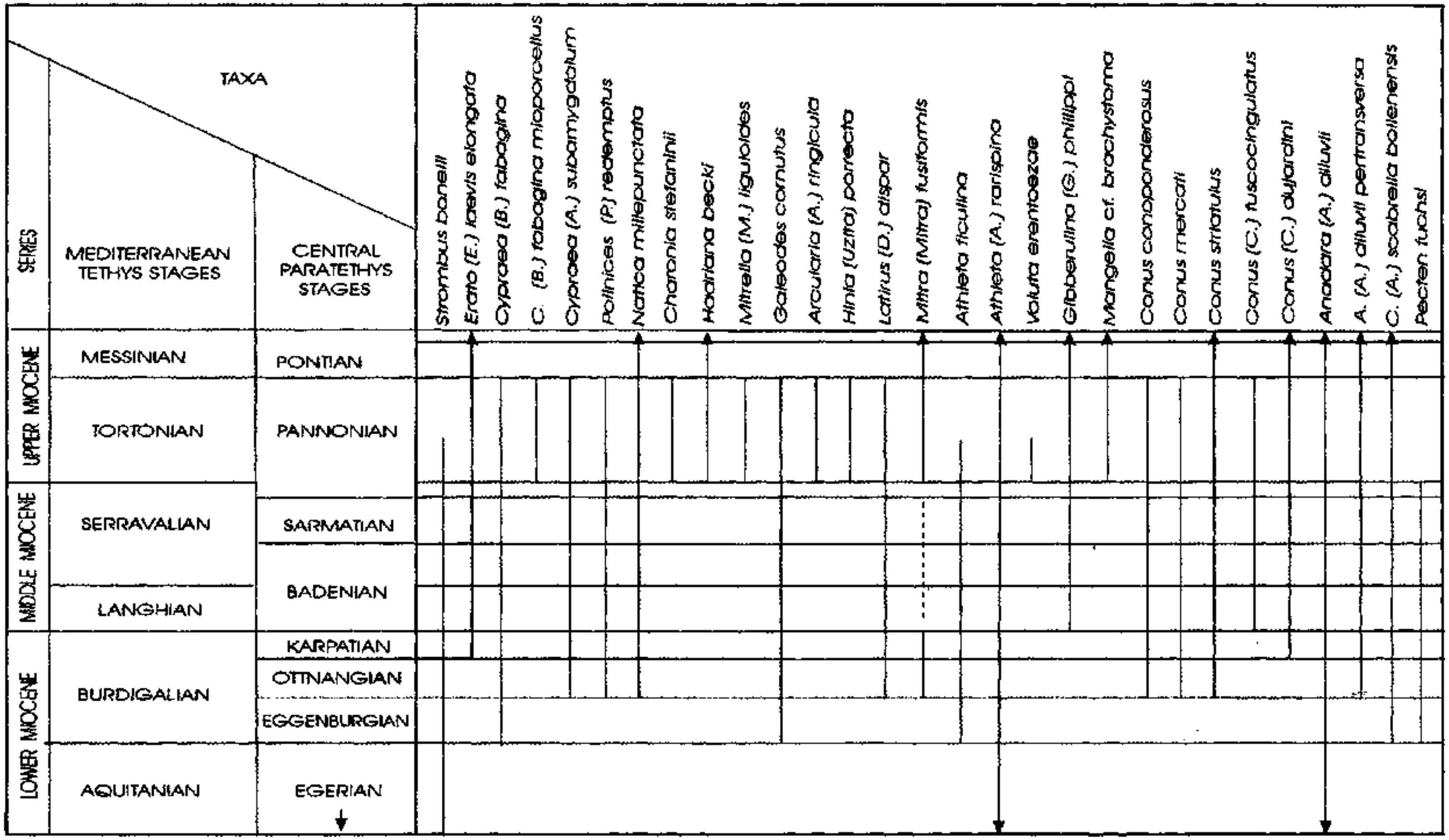


Table 1 b-


TAXA
SERIES
MEDITERRANEAN TETHYS STAGES
CENTRAL PARATETHYS STAGES
UPPER MIOCENE
MIDDLE MIOCENE
LOWER MIOCENE
MESSINIAN
TORTONIAN
SERRAVALIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
PONTIAN
PANNONIAN
SARMATIAN
BADENIAN
KARPATIAN
OTTNANGIAN
EGGENBURGIAN
EGERIAN
Strombus bonelli
Erato (E.) laevis elongata
Cypraea (B.) fabagina
C. (B.) fabagina mioporcellus
Cypraea (A.) subamygdalum
Polinices (P.) redemptus
Natica millepunctata
Charonia stefaninii
Hadriana becki
Mitrella (M.) liguloides
Galeodes cornutus
Arcularia (A.) ringicula
Hinia (Uzita) porrecta
Latirus (D.) dispar
Mitra (Mitra) fusiformis
Athleta ficulina
Athleta (A.) rarispina
Voluta erentoezae
Gibberulina (G.) phillippi
Mangelia cf. brachystoma
Conus conoponderosus
Conus mercati
Conus striatulus
Conus (C.) fuscocingulatus
Conus (C.) dujardini
Anadara (A.) diluvii
A. (A.) diluvii pertransversa
C. (A.) scabrella bollenensis
Pecten fuchsi

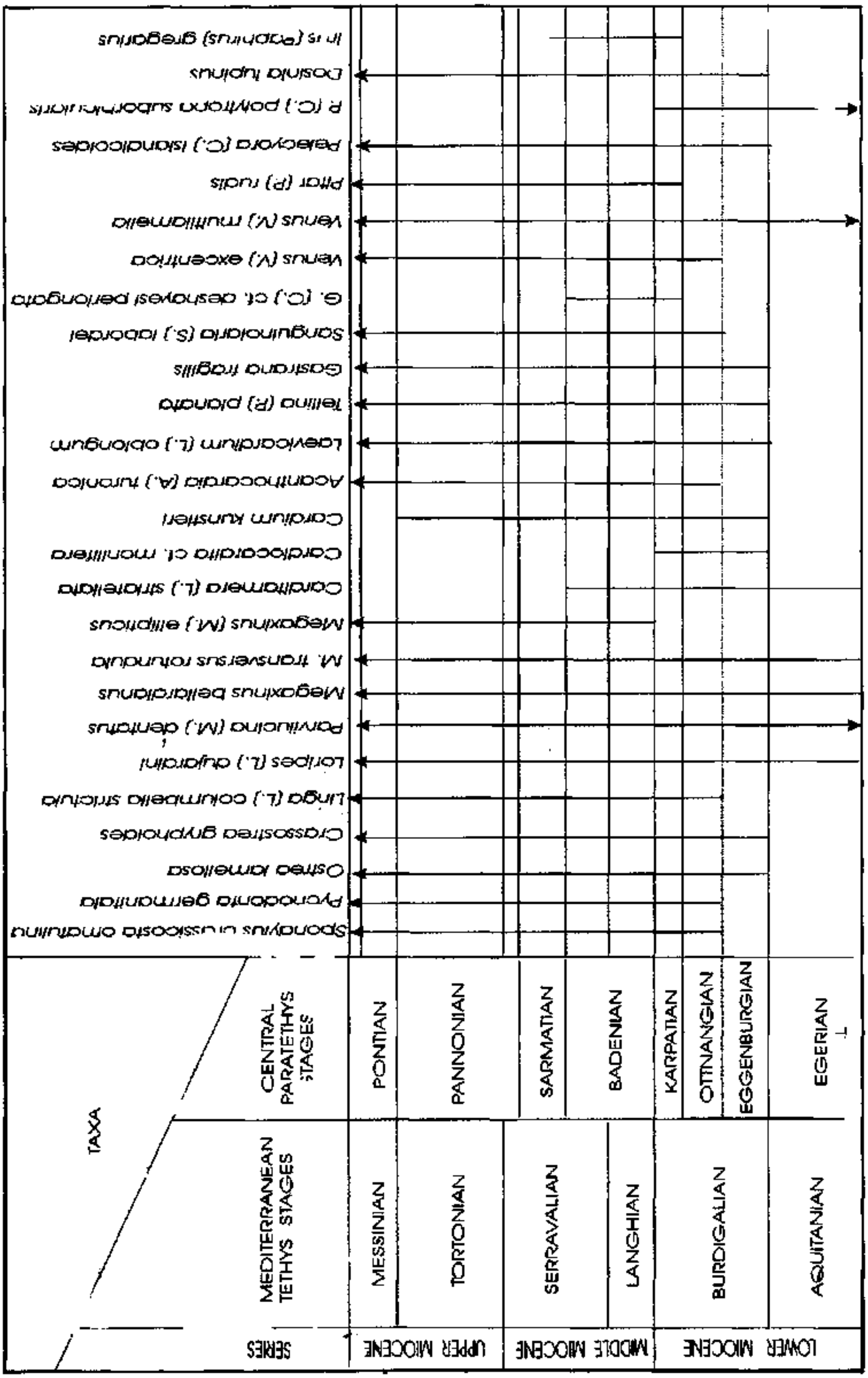

Irus (Paphirus) gregarius
Dosinia lupinus
R (C.) polytropa suborbicularis
Pelecyora (C.) islandicoides
Pitar (P.) rudis
Venus (V.) multilamella
Venus (V.) excentrica
G. (C.) cf. deshayesi perlongata
Sanguinolaria (S.) labordei
Gastrana fragilis
Tellina (P.) planata
Laevicardium (L.) oblongum
Acanthocardia (A.) turonica
Cardium kunstleri
Cardiocardita cf. monilifera
Cardilamera (L.) striatellata
Megaxinus (M.) ellipticus
M. transversus rotundula
Megaxinus bellardianus
Parvilucina (M.) dentatus
Loripes (L.) dujardini
Linga (L.) columbella stricta
Crassostrea gryphoides
Ostrea lamellosa
Pycnodonta germanitala
Spondylus crassicosta ornatum
TAXA
CENTRAL PARATETHYS STAGES
MEDITERRANEAN TETHYS STAGES
SERIES
PONTIAN
PANNONIAN
SARMATIAN
BADENIAN
KARPATIAN
OTTNANGIAN
EGGENBURGIAN
EGERIAN
MESSINIAN
TORTONIAN
SERRAVALIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
UPPER MIOCENE
MIDDLE MIOCENE
LOWER MIOCENE

Table 1 c-

The Çakallar formation

Definition and nomenclature.- Akay and Uysal (1984) and Akay et al., (1985) defined this unit which is composed of breccia limestone. It is onlyobserved at southeast part of Antalya Miocene basin.

Type section locality.- This unit is cropped out at eastern part of the basin and its type locality is at the eastern slope of Alara stream to the west of Çakallar.

Lower-Upper boundary relations.- It conformably overlies Oymapınar limestone with a sharp contact relation.

Lithology.- It is brecciated and represented by beige-dirty yellow colored, clayey limestone-limestone alternations.

Thickness and distribution.- The unit is about 80 m thick and displays a lenticular geometry.

Fossil content and age.- No age data has been found in the unit. Since it is overlying the Upper Burdigalian Oymapınar limestone and underlying the Geceleme formation, its age was accepted as Upper Burdigalian-Lower Langhian.

Depositional environment.- It reflects the slope environmental conditions.

The Geceleme formation

Definition and nomenclature.- The unit was firstly named as Geceleme marls by Blumenthal (1951), Monod (1977), Akay and Uysal, (1984); Akay et al., (1985); Şenel et al., (1992); Naz et al., (1992) adopted the same name.

Type section locality.- The type locality of the unit is located at 1 km north of Gençler village.

Reference section.- It is partly observed in Oymapınar section.

Lower-Upper boundary relations.- Geceleme formation crops out only in the southeast part of the basin and it lies conformably between Oymapınar limestone and çarpuzcay formation. At southeast of the basin, it is transitionally overlying the Çakallar formation.

Lithology.- The formation is generally composed of marls and clayey limestones. The thinmedium bedded, light gray, greenish gray, green, dark colored clayey - sandy limestone, claystone and siltstone levels are also observed. In the Oymapınar section, the Geceleme formation is represented by 1.3 m thick, light gray colored marls and continues with 30 m thick, sandstone intercalated marl. It also contains limestone blocks derived from Oymapınar limestone.

Thickness and distribution.- The thickness of the unit was measured as 410 m by Akay etal., (1985).

Fossil content and age.- The identified fossils are the Bivalves and Gastropods. The age of the formation was accepted as Langhian based on the microfossil assemblage. In Oymapınar section, the sample O5 yields *Helicosphaera kamptneri* Hay-Mohler, *Cyclicargolithus abisectus* (Muller), *Calcidiscus leptoporus* (Murray-Blackman), *Dictyococites productus* (Kamptner), *Dictyococites bisectus* (Hay-Mohler-Wade), *Sphenolithus heteromorphus* Deflandre, *Coccolithus pelagicus* (Wallich) and *Pontosphaera* sp. like nannoplanktons of biozones NN5 (Langhian-Lower Serravalian) (identified by H. Karakullukçu and E. Erkan) and planktonic foraminifera *Praeorbulina glomerosa glomerosa* (Blow) characterizing Langhian age (identified by A. Hakyemez). After 1.2 m thick sandstone level, the 2 m thick marls are observed. In this level, again *Helicosphaera kamptneri* Hay-Mohler, *Sphenolithus heteromorphus* Deflandre, *Sphenolithus conicus* Bukry, *Sphenolithus compactus* Backman, *Dictyococites produc-*

tus (Kamptner), *Dictyococcites antarcticus* Haq, *Coccolithus pelagicus* (Wallich7, *Braarudosphaera bigelowi* (Gran-Braarud). *Discoasfer*sp. corresponding to NN5 biozone of nannoplankton flora are present (Langhian-Lower Serravalian) (identified by H. Karakullukçu, E. Erkan). Based on these data of the age was accepted as Langhian.

Depositional environment.- The presence of abundant planktonic foraminifera and nannoplankton flora, reveals relatively deep marine environment.

The Karpuzçay formation

Definition and nomenclature.- Previously defined units such as flysch and conglomerate (Altınlı, 1943), partly Beşkonak formation (Eroskay, 1968), Manavgat molasse (Monod, 1977) Kargı molasse (Poisson, 1977) have been combined under the name Karpuzçay formation by Akay and Uysal (1984), Akay et al., (1985) which is best observed along the Karpuzçay stream.

Type section locality.- The type section of the formation strats at 2 km west of Gençler village and continues along the ridge located between two branches of Karpuzçay stream.

Lower-Upper boundary relations.- The unit is widely cropped out in all parts, of the basin. It conformably overlies Oymapınar limestone and Geceleme formation at central and southeastern part of the basin respectively. At the west of the basin, it is overlain by Aksu formation, in other parts it is, either unconfortnably overlain by Pliocene rock units or exposed as recent erosional surface.

Lithology.- It is cdmposed of gray, green greenish gray, beige, dirty yellow colored, thinmedium-thick-bedded sandstone, conglomerate, siltstone, claystone and detritic limestones.

Thickness and distribution.- It has a variable thickness throughout the basin. It was measured as 2050 m between Kızıldağ-Karabekir.

Fossil content and age.- It was not studied in detail because of absence of molluscan fauna. Based on its planktonic foraminifera and nannoplankton contents, its age was accepted as Upper Burdigalian-Tortonian.

Depositional environment.- The presence of synsedimentary fold and slump structures implies turbiditic characteristics.

The Aksu formation

Definition and nomenclature.- In the region, the Tortonian molassic conglomerates has been considered as Aksu conglomerate by Poisson (1977) and Aksuçayı formation by Akbulut (1977). Akay and Uysal (1984) and Akay et al. (1985) defined the unit as Aksu formation, since they mapped the conglomerates over and under the unconformity plane below Langhian age. However, they were unable to separate these conglomerates. Naz et al., (1992) defined this unit as the Aksu member of Karpuzçay formation. Şenel et al., (1992, 19976, 1997c) mapped and defined the Tortonian rock units as Aksu formation. In this study based on the Poisson (1977) and Akbulut (1977) definitions, the name Aksu formation is adopted, since the type section of molassic deposits is located along Aksu stream. Due to stratigraphic and faunal environmental differences of the unit, the "Aksu formation" definition applied for whole basin by Akay and Uysal (1984) and Akay et al., (1985) should be separated and the "Aksu formation" definition must be used for Serravalian-Tortonian molassic deposits which are exposed at west of the basin.

Type section locality.- The type section of the formation is best observed at junction of Sinne stream with Aksu stream in Eskiköy village (Akay et al., 1985).

Reference section.- It is also observed in Kargı section.

Lower-Upper boundary relations.- The Aksu formation unconformably overlies the basement at the locality 5 km to the southwest of Kargı tunnel. It is conformably overlying the Karpuzçay formation. Its relation with Altınkaya formation has not been differentiated yet. In the region, the presence of a unconformity is known between Lower-Middle Miocene and Tortonian (Brunn et al., 1971).

Lithology.- It is generally composed of alternations of red, reddish brown, yellowish green colored, thick bedded, molassic sandstone and conglomerates. At some levels, the dark gray, brown colored marls and sandstones, gray colored limestones, algae and coral reef limestones and locally very thin coal seams are also present.

The reddish brown colored conglomerate-sandstone alternation forming the lower part of the formation is considerably thick and observed along the road arrived Kargı. It was not measured as no fossil record was obtained in this unit.

The Kargı section starts at the base with 3 m thick altenations of conglomerate, sandstone and mudstone. No fossils was observed from this level (sample K1). Over this level, me 11 m thick, massive, gray colored, algae and coral reefal limestone succeds. The sample K2 taken from this unit yields Tortonian age based on the Molluscan fauna as *Pontes lobatosepta* (Chevalier), *Tarbellastraea siciliae* (Chevalier), *Tarbellastraea reussiana* (Milne-Edwards and J. Haime), *Siderastraea crenulata* (Goldfuss), *Tarbellastraea* sp., *Aquitanastraea* sp. and in the K3 sample taken from uppermost of reefal limestone, continues with 30 cm thick yellow colored sandstone. In the sample K4 of this level, the Gastropods are represented by *Cypraea (Bernaya) fabagina* (Lamarck), *Gibberulina (Gibberulina)* , *philippi* (Monterosato), *Conus conoponderoSus* (Sacco), *Conus mercati* Brocchi, *Conus (Conolithus) dujardini* Deshayes and *Terebralia* sp., *Cerithium* sp. The following level is the 64 cm thick gray colored mudstone in which *Cerithium* sp. was obtained (K5).

Overlying this level is the gray colored. 17 cm thick mudstone with, laminated coal seam. In this level (sample K6), Gastropods as *Alvania (Alvania) curta* (Dujardin), *Chrysallida (Parthenina) interstincta* (Montagu), *Odostomia (Megastomia) conoidea* (Brocchi), *Valvata* sp., *Cerithium* sp. *Alvania (Alvania) curta* (Dujardin), *Chrysallida (Parthenina) interstincta* (Montagu), *Odostomia (Megastomia) conoidea* (Brocchi), *Valvata* sp., and *Cerithium* sp. were determined.

After 7 cm thick, white colored clay level, the *Cerithium* sp.was found (K7) within 60 cm thick, gray colored mudstones with coal seam. In the overlying 30 cm thick fine-grained sandstone, the *Chrysallida (Parthenina) interstincta* (Montagu), *Cerithium* sp. of class Gastropoda and *Tellina (Peronaea) planata* Linne of class Bivalvia were identified (K8).

The sample K9 was taken from the level which is represented by 4 cm thick, white colored lenticular claystone followed by 5.5 m thick, coarse grained pebbly sandstones. The (K9) sample yields *Astraea (Bolma) rugosa* (Linne), *Cypraea (Adusta) subamygdalum* d'Orbigny, *Conus conoponderosus* (Sacco), *Conus (Conolithus) dujardini* Deshayes of class Gastropoda and *Tellina (Peronaea) planata* Linne of class Bivalvia. The gray colored, massive, algae and coral reefal limestones 4.5 m thickness overly the conglomerates. The sample K10 and K11 were collected from this level and they contain the corals, as *Porites lobatosepta* (Chevalier), *Tarbellastraea siciliae* (Chevalier), *Favites neglegta* (Michelotti), *Aquinastraea* sp., *Porites* sp. implying Tortonian age (determined by S. Babayiğit).

The brown-colored, 2.5 m thick mudstone overlies the reefal limestone. Many gastropods and bivalvia were obtained from sample K12 taken from mud stone level. Gastropods are *Astraea (Bolma) rugosa* (Linne). *Tinostoma woodi* (Homes), *Alvania (Alvania) curia* (Dujardin), *Alvania (Alvania) venus* (d'Orbigny), *Alvania tanerae* n. sp., *Turritella (Zaria) spirata* (Brocchi), *Turritella (Archimedielrdi bicarinata* (Eichwald), *Chrysallida (Parthenina) interstincta* (Montagu), *Erato (Erato) laevis elongata* Sacco, *Natica millepunctata* Lamarck, *Arcularia (Arcularia) ringicula* (Bellardi), *Mangelia brachystoma* (Philippi), *Conus conoponderosus* (Sacco), *Conus mercati* Brocchi and *Cerithium appenninicum dertosulcata* Sacco whereas. The Bivalves are *Anadara (Anadara) diluvii* (Lamarck), *Cniamys (Aequipecten) scabrella bollenensis* (Mayer), *Parvilucina (Microloripes) dentatus* (Defrance), *Loripes (Lonpes) dujardini* (Deshayes) and *Laevicardium (Laevicardium) oblongum* (Chemnitz) (Table 1),. Also in the same level (K12), the Rotaliidae type benchic foraminifera (determined by. E. Sirel) and Ostracoda as *Bairdia* sp. were determined (identified by M. Duru).

Above this level, the brown-colored, 2.5 m thick, fine sadstone intercalated mudstone is present. In the 12 cm thick mudstone level, the sample K13 includes Gastropoda as *Gibbula (Gibbula) magus* (Linne), *Astraea (Bolma) rugosa* (Linne), *Cerithium appenninicum dertosulcata* Sacco. *Strombus (Strombus) bone//ii*Brongniart *Strombus cononatus* Defrance, *Mitiella (Mitrella) liguloides* (Doderlein), *Conus conoponderosus* (Sacco), *Conus striatulus* Brocchi. *Conus striatulus* Brocchi. *Conus (Conolithus) dujardini* Deshayes and Bivaivia as *Anadara (Anadara) diluvii* (Lamarck)-- and *Parvilucina (Microlonpes) dentaius* (Defrance).

The section upward with increasing bed thickness of 2 m thick sandstone - mudstone intercalations. This level is overlain by yellow colored 15 cm thick, pebbly coarse-grained sandstone, gray colored 15 cm thick, fine-grained sandstone and 8 cm claystone. The sample K 15 from the mudstone of 7 m thick sandstone-mudstone alternation includes Gastropoda as *Conus mercati* Brocchi ve *Subula (Oxymeris) plicaria* (Basterot). The 20 cm thick sandstone and 2 m thick pebbly coarse-grained thick sandstone overlies the former level. The sample K16 collected from pebbly sandstone contains *Xenophora infundibulum* Brocchi, *Strombus (Strombus) bonel/ii* Brongniart, *Strombus coronatus* Defrance, *Galeodes cornutus* (Agassız), *Latirus (Dolicholatirus) dispar (Peyrot), Mitra (Mitra) fusiformis* (Brocchi), *Athleta ficulina* (Limarcks), *Conus conoponderosus* (Sacco), *Conus striatulus* Brocchi and *Cerithium appenninicum dertosulcata* Sacco of class Gastropoda and *Anadara (Anadara) diluvii* (Lamarck), *Linga (Linga) columbella* (Lamarck), *Megaxinus bellardianus* (Mayer), *Megaxinus (Megaxinus) ellipticus* (Borson), *Megaxinus (Megaxinus) transversus* (Bronn) and *Nemocardium spondyloides* (Hauer) of class Bivalvia.

The level of sample K 17 is represented by the 50 cm thick gray colored mudstone and rich in molluscan fauna. In this sample, gastropods ane *Gibbula (Gibbula) magus* (Linne), *Astraea (Bolma) rugosa* (Linne), *Turritella (Archimediella) bicarinata* (Eichwald), *Cerithium appenninicum dertosulcata* Sacco, *Strombus coronatus* Defrance, *Strombus coronatus compressonana* Sacco, *Strombus (Strombus) bonelli* Brongniart, *Erato (Erato) laevis elongata* Sacco, *Cypraea (Bernaya) fabagina mioporcellus* Sacco, *Natica millepunctata* Lamarck, *Charonia stefaninii* (Montarano), *Mitrella (Mitrella) liguloides* (Doderlein), *Hinia*

(Uzita) porrecta (Bellardi), *Athleta ficulina* (Lamarck), *Voluta erentoezae* n. sp., *Conus conoponderosus* (Sacco), *Conus (Chelyconus) fuscocingulatus* Bronn, *Conus mercati turricula* Brocchi, *Conus striatulus* Brocchi, *Conus (Conolithus) dujardini* Deshayes. Within this sample some Bivalvia as *Anadara (Anadara) diluvii* (Lamarck), *Linga (Linga) columbella* (Lamarck), *Parvilucina (Microloripes) dentatus* (Defrance), *Megaxinus bellardianus* (Mayer) and *Megaxinus (Megaxinus) ellipticus* (Borson) were also determined.

The sequence continues upward whith gray colored, 30 cm thick sandstone and dark gray colored, 3.8 m mudstone with coal seam. In the sample K18 taken from this level, the *Strombus coronatus* Defrance, *Strombus (Strombus) bonellii* Brongniart, *Murex (Pseudomurex) becki* Michelotti, *Hinia (Uzita) porrecta* (Bellardi), *Conus conoponderosus* (Sacco), *Conus mercati* Brocchi belonging to class Gastropoda were identified. At the uppermost part, the section is represented by 75 cm thick conglomerate, gray colored, mudstone intercalated, thick bedded. 4 m thick sandstone, brown colored 3 m thick mudstone. 30 cm thick sandstone and 4 m thick mudstone. The section is laterally transitional to sandstones and conglomerates towards the northwest part.

Thickness and distribution.- The total thickness of the formation was not measured. However, it is known to be reached up to 450 m in thickness (Akay et al., 1985).

Fossil content and age.- In the formation, the molluscan fauna reveals Lower Tortonian age and implies marine suptropic environment. The previously identified nannoplankton flora submitted by Akay et al., (1985) is also confirmed this age assignment.

In this unit, the molluscan fauna *Gibberuhna (Gibberulina) philippi* (Monterosato), *Odostomia (Megastomia) conoidea* (Brocchi), Arcularia *(Arcularia) ringicula* (Bellardi), *Mangelia brachystoma* (Philippi), *Cerithium appenninicum dertosulcata* Sacco, *Gibbula (Gibbula) magus* (Linne) and *Charonia stefaninii* (Montarano) indicate the Tortonian age. However, the typical molluscan fauna representing Upper Tortonian (Robba, 1970) which are *Parvamussium (Parvamussium) duodecimlamellatum* (Bronn), *Polinices (Lunatia) catena helicina* (Brocchi), *Amycyclina semistriata dertonensis* (Bellardi), *Hinia (Hinia) turbinella turbinella* (Brocchi), *Turricula (Knefastia) bellardii bellardi* (Desmoulins), *Gemmusa (Gemmula) rotata rotata* (Brocchi) and *Gemmula (Gemmula) rotata coronata* (Münster in Goldfus) have not been found in this unit. For this reason, the levels containing mollusc fauna in Kargı section of the Aksu formation was accepted as Lower Tortonian.

Corals as *Porites lobatosepta* (Chevalier), *Favites neglegta* (Michelotti), *Tarbellastraea siciliae* (Chevalier) *Tarbellastraea reussiana* (Milne-Edwards ve J. Haime) and *Siderastraea crenulata* (Goldfuss) (determined by by S. Babayiğit) obtained from Kargı section also confirm the Tortonian age.

Based on this idea, the age of the hundred meter thick conglomerates underlying conformably the Kargı section of the Aksu formation should be stratigraphically Serrevalian in age. For this reason, overall age of the formation was accepted as Serravalian - Tortonian.

Depositional environment.- The formation represents the continental and shallow marine environments. The marine environment indicates shallow shelf-deep shelf repetition and the great abundance of molluscan fauna was present in shallow shelf implying warm and normal salinity marine environment (suptropic climate). Coral reefs were developed during deepening of environment. This environmental change can be observed in Kargı section (Fig. 9).

CONCLUSION AND DISCUSSION

The stratigraphical study related to the molluscan fauna in the Antalya Miocene basin was firstly established in this study. The stratigraphy of the basin has re-evaluated by using all fossil records.

The oldest unit in the basin is the Kepez travertine. It stratigraphically underlies the Upper Burdigalian rock units (the Sevinç conglomerate and the Oymapınar limestone). Since the unit is terrestrial in origine and has no reliable age data, the stage name was not used and its age was fixed as Lower Miocene.

Another unit in the basin is the Sevinç conglomerate cropping out at south and southeastern parts of the basin. This unit was considered as Tepekli conglomerates by Monod (1977). later it was mapped and defined as Sevinç conglomerate by Gutnic et al. (1979). As it is pointed out by Şenel et al. (1992, 1998), this unit is not only in continental characteristics, but also includes marine levels. This evidence is also confirmed by other researchers such as Monod (1977), Akay and Uysal (1984), Akay et al. (1985), Karabıyıkoğlu et al. (1996, 1997. 2000). The marine levels of the Sevinç conglomerate was dated as Upper Burdigalian. By considering the continental levels of the formation, as a whole, its age was accepted as Burdigalian.

The Aksu formation was previously generallized to the whole basin by Akay and Uysal (1984) and Akay et al. (1985). In this case, clue to stratigraphic, faunal and environmental differences, it has been thought that, it should oe differentiated. For this reason, the units exposed at central and northern parts of the basin and Upper Burdigalian-Langhian (Ottnangıan-Karpatian-Lower Badenian) and containing brackish water-marine molluscan fauna-was firstly named as the Altınkaya formation in this study. The Altınkaya formation unconformably overlies the basement units. It is also interfingering with turbiditic deposits of Karpuzçay formation outcropping at central parts. It is unconformably overlain by Aksu formation. This unit was previously investigated under the name Aksu formation. The previous researchers assigned Upper Burdigalian - Langhian age which also support the age data obtained during this study (Akay and Uysal, 1984; Akay et al., 1985 and Tuzcu et al., 1994).

The other investigated unit in the basin is the Oymapınar limestone. Its age was previously claimed to be Lower Langhian (Akay and Uysal, 1984; Akay et al., 1985; Şenel et al., 1992. 1996). This age has been modified as Upper Burdigalian - Langhian (Karpatian-Lower Badenian). The identified benthic and planktonic foraminifera and corals also confirm this age assignment.

The planktonic foraminifera and nannoplankton obtained from the Geceleme formation which conformably overlies the Upper Burdigalian levels of the Oymapınar limestone, also confirmed with age evidences of Öztümer (1974), Akay and Uysal (1984), Akay et al. (1985), Nazetal. (1991, 1992), Seneletal. (1991, 1992, 1996, 1998) and Karabıyıkoğlu et al. (2000).

The Çakallar formation conformably overlies the Oymapınar limestone and underlies the Geceleme formation and is observed only at southeastern part of the basin. Althought it is brecciated and has no fossil record, its age was accepted as Upper Burdigalian-Lower Langhian.

In this study, no detailed study was carried out in widely exposed at west of the basin and the previously suggested Aksu formation for the whole basin by Akay et Uysal (1984) and Akay et al. (1985) has been modified. The levels of the formation containing molluscan fauna was dated as Lower Tortonian. The lower parts composed of alternations of thick conglomerate and sandstone levels are thought to be Serravalian in age. Based on this data, the age of the Aksu formation was accepted as Serravalian- Tortonian but not Tortonian as the previous investigators suggested (Akbulut, 1977: 1980; Şenel et al., 1997 *a,b,c; Ş*enel et al.. 1991, 1992, 1996. 1998).

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THE FORMATION OF FISSURE RIDGE TYPE LAMINATED TRAVERTINE-TUFA DEPOSITS MICROSCOPICAL CHARACTERISTICS AND DIAGENESIS, KIRŞEHİR CENTRAL ANATOLIA

Eşref ATABEY*

ABSTRACT.- At Kırşehir center, in Kuşdili and Kayabaşı, along NE-SW directed extensional fracture, there is a fissure ridge type-travertine-tufa deposits. Travertine-tufa ridge is appoximately 800 m in length and 10-30 m in width. The hot-water saturated with calcium bicarbonate and minerals are enhensed from fissures and have caused to deposit yellow orange, brown and cream colored travertine in the walls of fissures as well as along the both sides. On the walls of the fissure, parallel to the fissure, compact and hard, laminated and thin bedded travertine crusts were deposited. However, in the both sides of the ridge, consistent with the slopes, the bedded crusts being porous, spongy tufas were deposites as well. Milimeter and Centimeter sized microscopic structures, similar to shrubs, are commonly found in this hot water originated travertine-tufas. These are; 1-Dendritic structures and, 2-Crystal bunches. Dendritic structures own micritic aggregate, shrub bunch, reed bunch and small twig shapes. There are calcite crystallisations among the twigs. But the crystal bunches are knife-shaped, large crystals and fibrous ray crystal structures. Dendritic structures have developed in the laminated crust and microterrace pools, located on both slopes of the fissure. On the other hand, the crystal bunches are common on the parallel-laminated crusts deposited an developed chemically. Super crystals were developed on the prismatic crystals, that were also developed along c-axes of the fibrous crystals.

INTRODUCTION

Travertines are calcium carbonate precipitations developed from organic and inorganic processes in karstic, hydrothermal springs, small rivers and swamps. They are spongy, compact and indicate crystal structures in different colors. They are named as calcitic tufa, calc tufa, sinter crust and plant tufa. However, there are characteristic features which make differency between tufa and travertine. Pedley (1990) used to define the tufa as high porous, spongy, paper-leaved and woody texture cool-fresh water carbonate deposits. In contrast, He defined the travertine as extremely well-lithified, spari calcite textured, diagenetic old calcerous tufa deposit.

The research works have been carried out about the classification formational environment, origin and diagenesis of the travertine and tufas (Julia, 1983; Chafetz and Folk, 1984; Pedley, 1990; Ford and Pedley, 1996; Pentecost, 1990; Evams, 1999; Chafetz and Guidry, 1999; Guo and Riding, 1994, 1998). In Türkiye, such a study like occurrence, age, microorganism effects and depositional kinetics of travertines have been concentrated on Pamukkale (Denizli) travertines (Pentecost et al., 1997; Altunel and Hancock, 1993; Ekmekçi et al., 1995; Altunel, 1996). Moreover, the characteristics of within-travertine pisolites in Mut (İçel) and petrography of travertines in Sıcakçermik (Sivas) areas were conducted by Atabey (2002) and Tekin et al., (2000) respectively. The tufa deposits are subdivided into two classes, namely, autochthonous-and clastic-originated by Pedley (1990). Chafetz and Folk (1984) distinguished five classes of travertine accumulations. These are, 1-Lake deposits, 2-Mounds and cones, 3-Terraced mounds, 4-Fissure ridges, 5-Waterfall deposits.

The fissure ridge-type travertine of this classification is found in Kırşehir (Fig. 1 and Plate-I, fig. 1). The formation of fissure ridge-type travertine has previously been investiga-

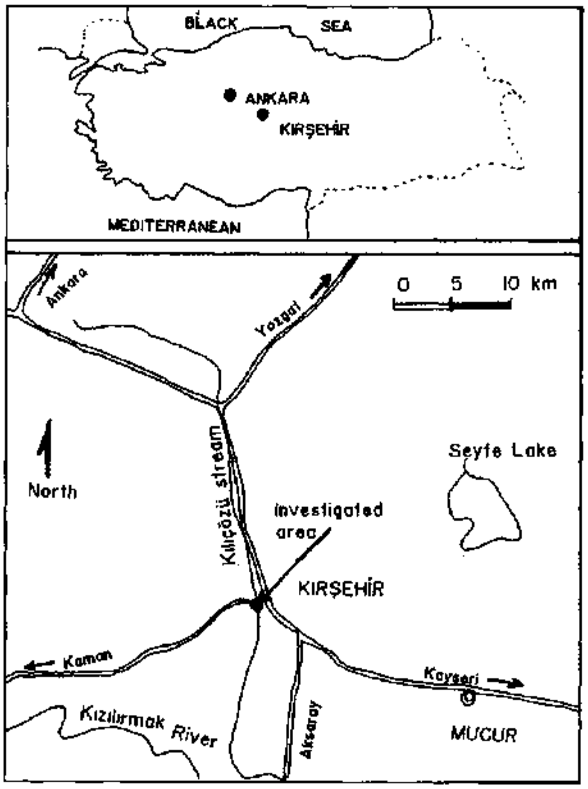


Fig. 1- Location map.

ted at Pamukkale (Altunel, 1996). In Kırşehir, at Kuşdili and Kayabaşı localities, fissure ridge-type travertine deposits formed along a N-S directed fracture (Fig. 2). For the purpose of hot water supply, the drilling facilities by MTA have been carried out and the characteristics of the hot water were given (Özmutaf and Didik, 1992; Didik and Tekin, 1995).

Based upon the microscopic characteristics of the samples taken from the travertines, it is observed that the structures are of two types, dendritic shape and crystal bunches. The purpose of this study is to present the properties, formation and diagenesis of these structures and their role in the formation of travertihe-tufa deposition.

In consistency with the purpose of study, systematic samples were collected from different parts of travertine-tufa mass, in the order from fissure ridge outward. These samples have been examined under Polarization Microscope and Scanning Electron Microscope (SEM), including x-ray analysis. The drilling locations have been correlated to establish the relationship between spring water and travertine deposit.

GENERAL GEOLOGY

Fissure ridge-type travertine accumulated at intersection points of the northeast-southwest and eastwest trending faults in southern part of Kırşehir massif. The Kırşehir metamorphic rock units consisting of Paleozoic age marble and schists are exposed at north, east and southwest of Kırşehir (Fig. 3). At southwest of Kırşehir, the Late Cretaceous Baranadağ granodiorite and Early Eocene conglomerate, sandstone and limestone of Baraklı formation are exposed (Kara, 1991) in the

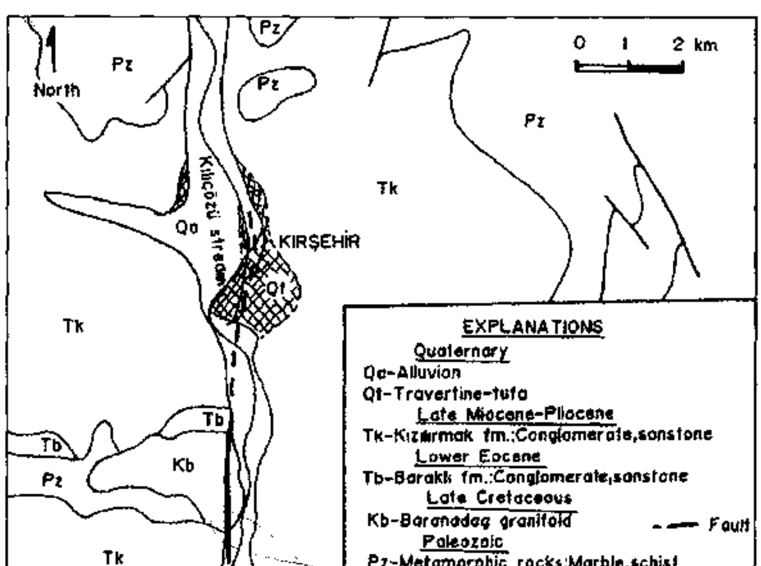


Fig. 2- Map indicating the setting of travertine-tufa mass. (Modified from Kara, 1991).

area to the west of Kılıçözü stream. These units are overlain by Late Miocene-Pliocene Kızılırmak formation, composed of conglomerate, sandstone, mudstone and tuffite (Fig. 2 and 3) (Kara, 1991). The alluvium sediments are present along Kılıçözü stream. Travertine is Quaternary ?-Recent in age, overlying the Kızılırmak formation and it is formed around the fault located along Kılıçözü stream. As it is shown on the drillings facilitied by MTA (inturn 1, 6, 7, 5, 4, 3 and 8 numbered drillings), the thickness of travertine and late Miocene-Pliocene unit, consequently depth to the metamorphic unit as source rock are changed. At number 1, the travertine is 46 m and late Miocene-Pliocene unit is 175 m in thickness. These thickness values are 28 m and 20 m at number 6, 22 m and 26 m at number 7, 38 m and 15 m at number 5, 18 m and 55 m at number 4, 10 m and 118 m at 3, and 10 m and 87 m at drilling number 8, respectively. Consequently, it is deduced that, a downthrown block side is present between 1 and 6, and 4 and 3, whereas at 6, 7, 5 and 4, the metamorphic basement was uplifted.

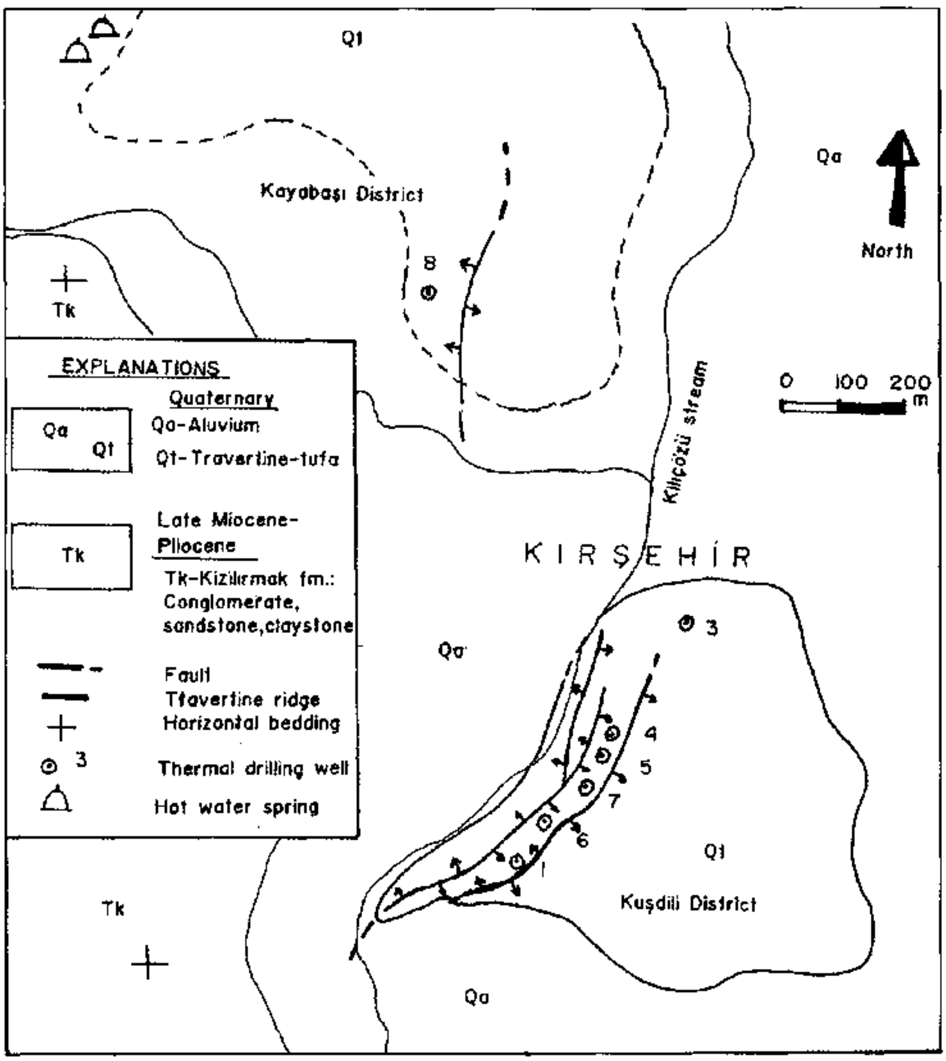


Fig. 3- Geological map

CHARACTERISTICS OF TRAVERTINE-TUFA DEPOSITS

The ridge-type travertine-tufa deposits are located in Kuşdili and Kayabaşı districts at Kırşehir center along a northeast-southwest trending fissure fracture. The ridge is approximately 800 m in length, 10-30 m in width and 2-4 m in height. The travertine-tufa rocks due to the effect of mineral-saturated hot groundwater are reddish, brown, yellow, blue, green, orange, beige, white and blackish in color (Plate-I, fig. 1). There is a fissure at the center of travertine ridge and parallel to this fissure, laminated, thin-bedded, hard and compact crystalline crusts are present (Plate-I, figs. 2, 3). At both slopes of fissure microterrace pools tufas are deposited. Within the tufas, round, ellipsoidal and composite tube-shaped, calcite-filled gas cavities are present (Plate-II, fig. 1).

MICROSCOPICAL CHARACTERISTICS OF DENDRITIC STRUCTURES AND CRYSTAL BUNCHES

Based on the samples collected from hot water originated Kırşehir travertine-tufa deposits, there are shrub-like structures changing from milimeter to centimeter in scale. These are 1-Dendritic structures and 2-Crystal bunches. The widely occurrence of these dendritic structures in hot water travertines has been assigned in studies by Chafetz and Folk (1984), Chafetz and Guidry (1999) in Italy. As a result of x-ray analyses of samples, together with aragonite and calcite crystal structure, iodine, phosphate, iron, chlorine, borax and sodium carbonate has been detected.

Dendritic structures

The dendritic structures are extensively developed within the yellow, brown, green, blue, reddish, beige colored, laminated and thin-bedded travertine crusts and microterrace pools at both slopes of the ridge, and within the porous, spongy tufa. They are changing from 3 mm to 3-4 cm and characterized 6y dark color, mottled and micritic aggregate-shaped (Plate-II, fig. 2), herbage-shaped (Plate-II, fig. 3), asicular redd-shaped (Plate-II, fig. 4), woody plant overgrowth on crust surface and small twig-shaped (Plate-II, fig. 5). The dendrites similar to reed, feather shaped ones have been interpreted by Weijermers et al. (1986) that were originated from *Bryum* cf. (algae) in Spain travertines. In interareas of dendrites there is light-colored spari-calcite, in other areas, they are yellow and brown-colored due to limonitization, iron and phosphate content. In the dendrites of short herbage bunch, the micritic aggregate-shaped ones are in medium-coarse grained calcite crystall, whereas the woody, tree twig-shaped ones are overgrowth on laminated crust surface and within bed calcite crystalls (Plate-II, fig. 6). Jones and Renaut (1995) is their study in Kenya, defined the dendrite structures as non-crystal asicular dendrites.

Crystal bunches

Crystal bunches are mostly found in fissure-parallel laminated travertine crusts and in thin-bedded, laminated crusts at both slopes of the ridge. The crystal bunches, unlike the dendrites, similar to reed bunches are fan, ray-shaped and longer in length. The reed bunch-like ones are in 5-8 cm in length and fan in shape (Plate-III, fig. 1). The area among twigs is spari-calcite. The ray, fibrous crystal bunches (Plate-III, fig. 2) and fan-shaped crystal bunches are also present (Plate-III, fig. 3). Jones and Renaut (1995) defined the similar crystal bunches as scandulitic dentrites in Kenya.

FORMATION AND DIAGENESIS

A close relationship is present between the thickness of basement marble mass and thickness or depositional rate of travertine-tufa. Based on the drilling data, the thickness of travertine and depth to the marble is different.

The bicarbonate-saturated hot-water originated from massive and thick marble basement rock has caused the thick travertine deposition.

The fissures-parallel hard and compact, laminated and thin-bedded travertine crusts have developed with the lower hydrostatic pressure and decreasing water content. In contrast, the porous tufa has been deposited at higher hydrostatic pressure, much water content, turbulant and during sudden CO_2 loss. Dentdritic structures have been formed in microterrace pools at suitable environment. As it is seen from the scanning electron microscopic view, they are the calcitized algae filaments (Plate-IV, figs. 1, 2, 3). These filaments, formed from carbonate crystalls, are a green type of algae which are *Schzotrix* cf. and *Bryum* cf. (Nevbahar Atabey, personal communication). The algae survive by feeding with CO_2 present in the calcium bicarbonate-rich hot groundwater. Later the calcite crystalls increased at periphery of algae filaments and carbonate deposition occurred. The filament has a tube at its center and knife-shaped calcite crystalls are formed at inner and outer part of this tube. At a later diagenetic stage, this type formations are caused the development of dentritic and crystal bunch shape structures. After completion of each calcium carbonate structure, suitable to the second, third and there after laminated crust structures, the bedded shape dendritic and crystal bunch structure layers formed (Fig. 4)

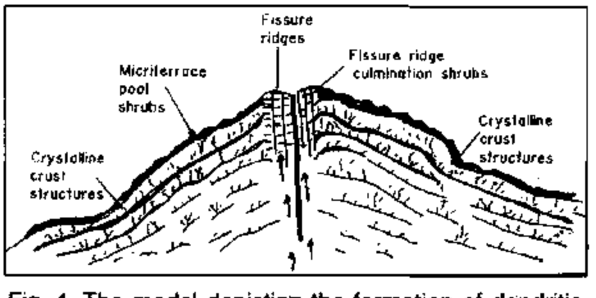
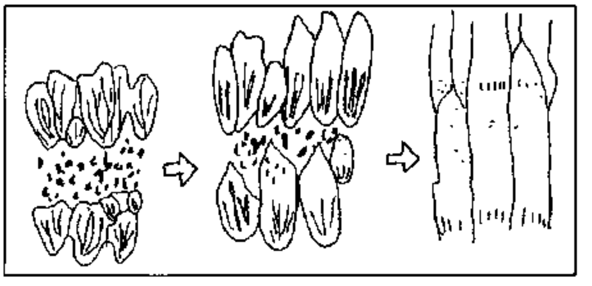


Fig. 4- The model depicting the formation of dendritic and crystal bunch-structured crusts.

(Plate-IV, figs. 4, 5). This layered structure has formed as a result of neomorphism according to Love and Chafetz (1988). The neomorphism takes place in such processes; first overgrowth of crystalls on dendrites, later along their c-axes the overgrowing of these crystalls in the form of columnar crystalls (Figs. 5, 6). There after, as it is seen from Plate-IV, figs. 5 and 6, the bedded and inclusion-type crystal structures are formed at progressive stage of diagenesis. Jones and Kahle



Şek. 5- Asicular, fibrous, coarse prismatic and uneven crystal formation (From (Braithwaite, 1979).

(1986, 1993), examined the crystal shrub structures formed by the calcitization of algae filaments. Furthermore, they pointed out that; the secondary twigs orthogonally cutting the first asicular crystalls and the third-order twigs cutting the secondary asicular crystalls were developed. Pentecost (1990) interpreted the formation of hot water originated dendritic structures, as the overgrowth of preferred crystalls on sharpened top part of mounds of microstructures. The calcitized bunches are arranged in a pattern parallel to laminated crusts. When viewed under the microscope, on the early formed coarse crystalls, fibrous, small, ray crystalls, that also developed along c-axes of the fibrous crystalls (Fig. 6). The deposits precipitated from mineral-rich hot water at slope of travertine ridge are in different colors (Plate-IV, fig. 6). This is due to oxidation and evaporation processes.

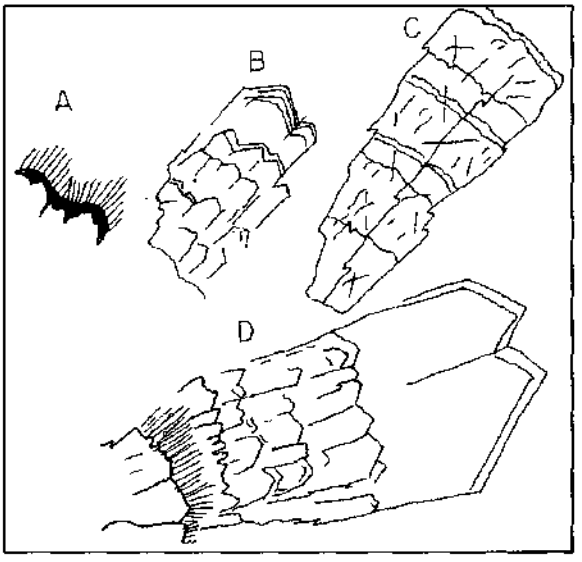


Fig. 6- The formation of coarse, columnar crystalls by neomorphism (From Love and Chafetz, 1988)

DISCUSSION AND CONCLUSION

The Kırşehir travertine-tufa has been deposited by the precipitation of calcium carbonate developed due to mineral-rich and calcium bicarbonate-saturated hot groundwater, reached at ground surface and loss of its CO_2 content. However, green algae species *Schrotrixsp.,* has played an active role during formation of Kırşehir travertine-tufa deposits. Especially, the slow rate of decreasing amount of CO_2 dissolved in microterrace pools has caused algae to use and deposite the carbonates. This also has made suitable conditions for feeding green algae to form the dendritic structures developed at both slopes of the ridge. Dendrites have relatively formed in horizontal areas and microterrace pools. Guo and Riding (1992, 1998), in their studies, assigned the neccessity of low-slope surfaces for microorganism activity. The crystal bunches have developed in fissure-parallel laminated crusts and those at both slopes of the ridge. The algae activity in Kırşehir travertine-tufa deposits led to the formation of dendrites. Guo and Riding (1994), in their study about hot-water travertines in Italy, considered these structures as microbial originated. Pentecost (1990) pointed out a cyanobacteria origin for the hot-water travertine shrubs in Wyoming. USA, also Chafetz and Folk (1984) agreed with the bacterial origin. Based on the x-ray analyses, phosphate, iodine, chlorine, borax and sodium carbonate in Kırşehir travertine-tufa deposits might have been developed from basement and surrounding rocks. The dominant tufa deposits formed at both slopes of travertine-tufa mass indicate high hydrostatic pressure, great groundwater discharge and sudden CO_2 loss. The bedded crusts within the fissure of the ridge, depict the low hydrostatic pressure, less groundwater dischange and slow loss of CO_2. The lower content of water caused the slow rate of deposition and the complete depleted water with time made carbonate deposition within the fissure at the center of the travertine-tufa mass.

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PLATES

PLATE-I

Fig. 1- View to the eastern flank of travertine-tufa mass. Kuşdili district.

Fig. 1-2- The ridge of travertine-tufa mass and central fissure (y), ridge slope (Y) and fissure-parallel laminated and thin-bedded travertine crust structures (Tk).

Fig. 4- The microterrace pools developed at travertine ridge slope

Fig. 1

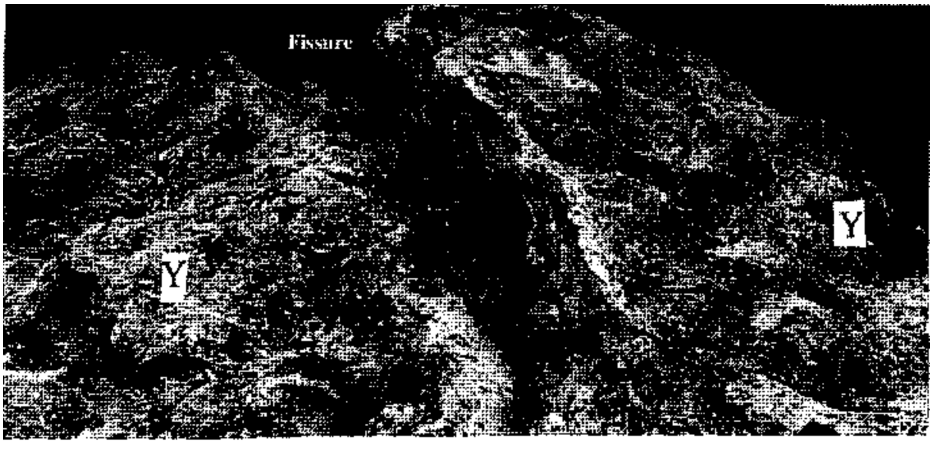
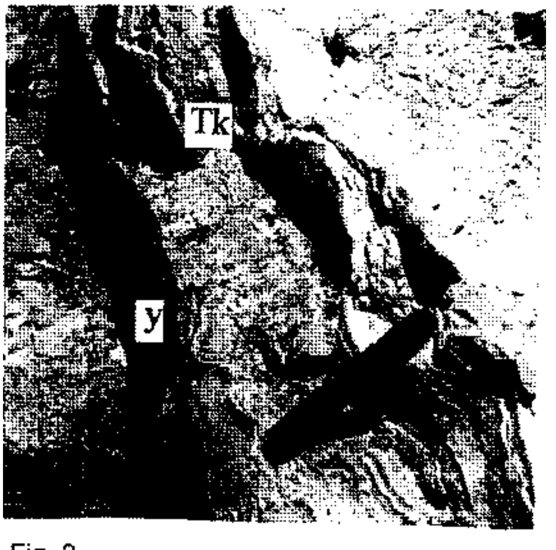


Fig. 2



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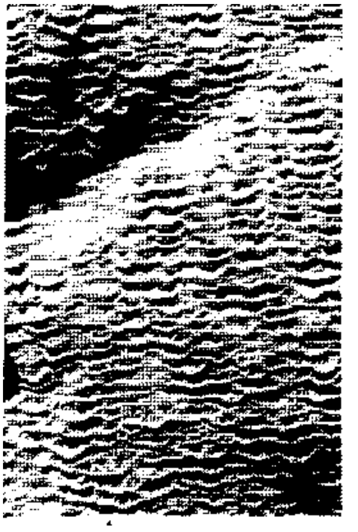


Fig. 4

PLATE-II

Fig. 1- The composite tube (Bt) and laminated crust (Lk) developed in tufa deposit formed at slope of travertine-tufa mass.

Fig. 2- Microscopic view of the mottled (B) and micritic aggregate (Ma) dendritic structures (6X).

Fig. 3- Microscopic view of the herbage-shaped dendritic structures (09) (6X).

Fig. 4- Microscopic view of the feather-shaped dendritic structures (6X)

Fig. 5- Small tree twig-shaped (aç) dendritic structures overgrown on laminated crust surface (6X)

Fig. 6- Microscopic view of small tree twig (Ad) and micritic aggregate (Ma) dendritic structures (6X)

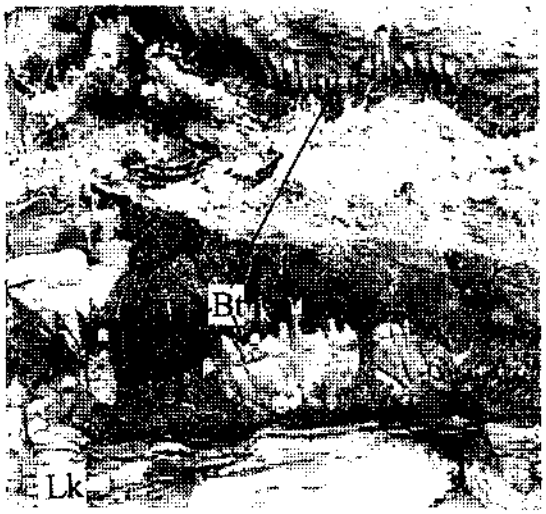


Fig. 1

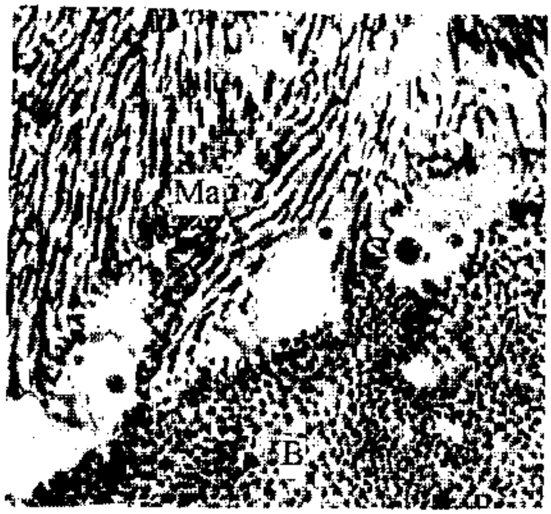
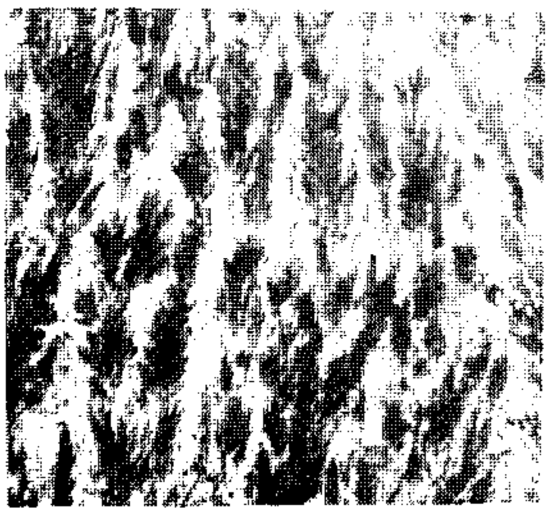


Fig. 2

Fig. 3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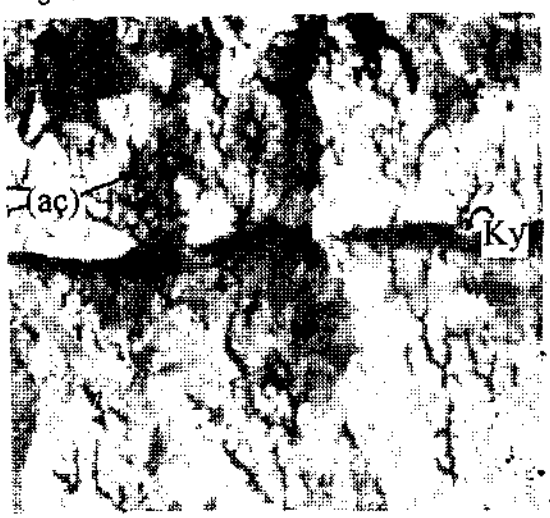

Fig. 5

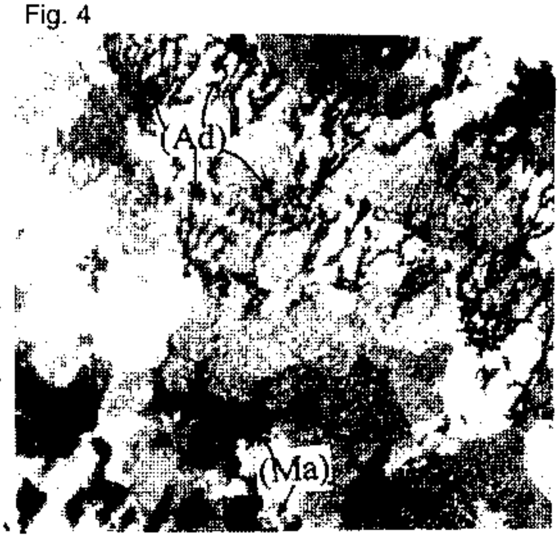

Fig. 6

PLATE-III

Fig. 1- Microscopic view of the fan-shaped crystal bunch (6X)

Fig. 2- Microscopic view of the ray, fibrous crystal bunch (6X)

Şek. 3- Microscopic view of the fan-shaped, ray crystal bunch (6X)

Fig. 1

Fig. 2

Fig. 3

PLATE-IV

Figs. 1-2-3- SEM view of the calcitized algae filaments (Af).

Fig. 4- Prismatic crystalls (Pk) overgrown fibrous crystalls (K) that overgrown laminated crust (Lk)

Fig. 5- Microscopic view of the fibrous (L), prismatic (P) crystalls (6X)

Fig. 6- Different coloration developed due to • different mineral content in hot groundwater

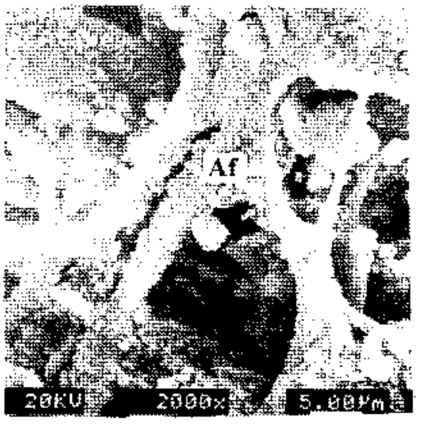

Fig. 1

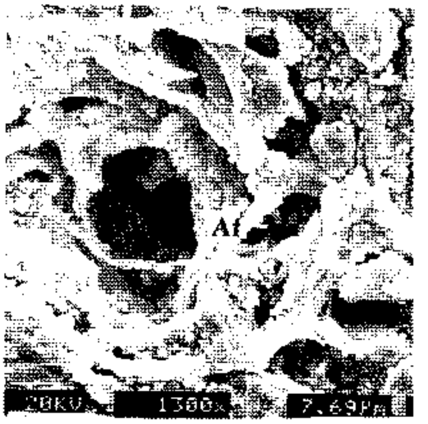

Fig. 2

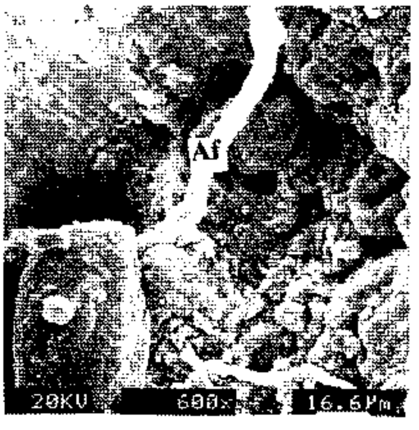

Fig. 3

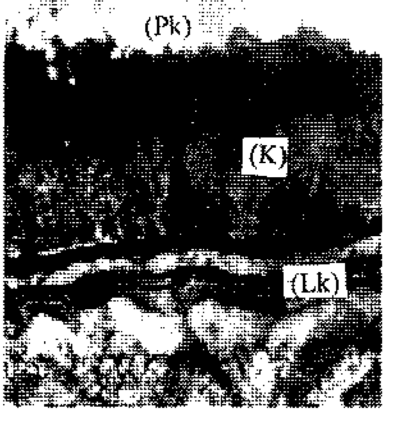

Fig. 4

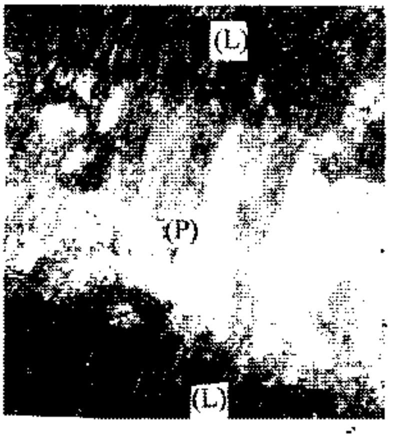

Fig. 5

Fig. 6

GEOCHEMICAL CHARACTERISTICS AND ORIGIN OF BARITE DEPOSITS BETWEEN ŞARKİKARAAĞAÇ (ISPARTA) AND HÜYÜK (KONYA)

Oya CENGİZ* and Mustafa KUŞÇU*

ABSTRACT.- Barite deposits in the region of Şarkikaraağaç and Hüyük which are generally located in the form of veins, lenses and layers along the contacts of these units and the schists showing an extensive distribution within the same formation found within recrystallized Çaltepe limestone and dolomite, Çavuştepe calcschists of the Cambrian-Devonian age Sultandede formation are epigenetic in character. According to the results of chemical analysis of barite mineralization in the region, the presence of trace elements such as Pb, Zn, Cu, Cd, Ni, Co, Ag, Sb are locally identified in low values within barites of the region. Especially, in some trace elements such as Pb, Zn, Cu, Cd, Ag and As show an increase towards from Hüyük region to Çarıksaraylar area. When the results of chemical analysis of barite samples evaluated statistically, the presence of high correlation between Ba-Pb, Ba-Ag. Pb-Ag, and Al_2O_3-K_2O element pairs and mediumgrade correlation between Ba-Sr, Pb-Cu, Zn-Cd, CaO-Fe_2O_3, CaO-SiO_2, SiO_2-Al_2O_3, CO- MgO, Fe_2O_3-Al_2O_3, Fe_2O_3, Fe_2O_3-Na_2O, MgO-K_2O element pairs of barite ores have been determined. The deposition forms of the barites in the investigated area, paragenesis, wall rock alteration, the high amount of trace elements, high Ba/Sr ratio, SrO values over 1.5 %, 180°-360°C homogenisation temperatures of the two-phase (liquid+gas) fluid inclusions, +30.15 ‰ and +13.9 ‰ ^{34}S isotope ratio in galena and barites, and 434°C high formation temperature indicate a hydrothermal origin of barite deposits in the region.

SEDIMENTOLOGY OF OYLAT CAVE SEDIMENTARY ROCKS İNEGÖL (BURSA)

Eşref ATABEY**; Lütfi NAZİK** and Koray TÖRK**

ABSTRACT.- Oylat cave is located at 17 km southeast of the İnegöl (Bursa) in the exit of Oylat River canyon. Oylat cave has been developed at the intersection of two fault zones striking along WNW-ESE and NE-SW directions in recrystalized limestone unit of Permian-Triassic age. Clastics and carbonate sediments are in the Oylat cave developet due to karstification. The cave, presenting multi-stage development character can be divided into three sections. In the third section karst breccias, siltstone and mudstone, in the second section the great rimstone pools and flowstones had grown. In the first division at the end of the cave huge rock fragments due to the collapsing of roof, karst breccia, stalactite, stalacmite, soda straws, flowstones and cave pearls (pisolites) had grown. Moreever, in this part, a sedimentary sequence formed by a alteration of conglomerate, sandstone, siltstone and mudstone crops out. The clastic sediments in the Oylat cave is deposited from the sediments carried by surficial water entering the cave system, and flowstones, rimstones, cave pearls have been formed by the dripping from the cave roof, whereas rimstones pools were formed by the steadly flowing intra cave river.

POST STACK SEISMIC ATTRIBUTE ANALYSIS

Zafer ÖZER* and Turan KAYIRAN**

ABSTRACT.- Hydrocarbon accumulations sometimes have effects on seismic data which can be used to indicate suitable worthy accumulations of hydrocarbon areas. The most prominent of these effects in increase in amplitude. Hydrocarbon accumulations may produce sufficent changes in amplitude however changes in acoustic impedance can be caused by various reasons. To get more information possible from the seismic data, impedance comparison and examination of all the properties constitutes the basic idea of seismic attribute analysis. From the analysis of seismic data by the amplitude information which has a primordial importance and other factors to be taken into cosideration are called seicmic attributes which are used to get contribution to interpretation and to make detailed analysis. The most useful attributes are amplitude, phase, frequency, polarity and velocity. Depending on the problem to be solved, seismic attributes can be obtained from instantaneous analysis, lateral continuity relationship and large variety of seismic data. In this work, several post stack seismic attributes is defined and how they can be used to get opportunities for interpretation is examined. After the application of migration, seismic attribute analysis is applied to two dimensional seismic data in Trakya region and provide the opportunity for comparison between seismic subsurface characteristics. With the comparison of conventional sections by the information of seismic attributes, it is observed that attributes can be used to enhance the interpretation.