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STRATIGRAPHY AND TECTONICS OF THE PULUR (BAYBURT) REGION IN THE EASTERN PONTIDES

Aral i. OKAY*, Ömer ŞAHİNTüRK** and Hüseyin YAKAR***

ABSTRACT.- The Pulur (Bayburt) region in the Eastern Pontides is a typical Alpide fold and thrust belt. In the region a relative autochthon and three north-vergent thrust sheets are differentiated, which are the Cebre relative autochthon, and the Hamurkesen, Aşutka and İmalıdağ thrusts sheets. When the thrust stack is palinspastically restored, the Jurassic-Lower Cretaceous sequences in the thrust sheets represent depositional settings that range from shelf in the north to oceanic crust in the south. The Cebre relative autochthon consists of Upper Carboniferous sedimentary rocks, neritic Jurassic limestones and Upper Cretaceous hemipelagic clastic and carbonate rocks. The Cebre relative autochthon is tectonically overlain by the Hamurkesen thrust sheet, which consists of Jurassic volcanoclastic rocks, uppermost Jurassic oolitic limestones, and a thick sequence of Lower Cretaceous pelagic micrites. The next overlying thrust sheet, the Aşutka sheet, comprises a crystalline basement of cordierite-sillimanite-schist, gneiss and amphibolite, which is unconformably overlain by Jurassic volcanoclastic rocks and Lower Cretaceous pelagic micrites. The Lower Cretaceous limestones are tectonically overlain by an ophiolitic melange, which is unconformably overlain by the Maastrichtian neritic limestones and a Paleocene-Lower Eocene flysch. The imalidag thrust sheet of Jurassic-Cretaceous pelagic micrites, lies tectonically over the Paleocene-Lower Eocene flysch. It forms a pop-up structure and rests in the south over the ultramafic rocks of the Ankara-Erzincan Neo-Tethyan suture.

During the Cenomanian-Turonian the ophiolitic melange was obducted northward over the south-facing passive continental margin of the Eastern Pontides. This obduction event was probably caused by the attempted subduction of the Eastern Pontide continental margin in a south-dipping intra-oceanic subduction zone. The polarity of the subduction changed after this event and the Tethyan ocean floor started to subduct northward under the Eastern Pontides. This led to the development of a major Senonian volcanic arc in the outer Eastern Pontides, while the inner Eastern Pontides including the area studied were in fore-arc position. The thrust and fold tectonics developed during the collision between the Eastern Pontides and the Anatolide-Tauride microplate, which took place in the Late Paleocene-Early Eocene. Post-collisional Middle Eocene marine limestones and sandstones overlie unconformably the various thrust sheets.

INTRODUCTION

The Pulur region contains the only autochthonous Carboniferous outcrops in the Eastern Pontides (Fig. 1). The Carboniferous outcrops, discovered by Ketin (1951), comprise coal and bituminous exploration (Akdeniz, 1988). Other important geological problems in this region are the relations of the Carboniferous sequence to the pre-Jurassic Pulur metamorphic rocks and to the Permo-Triassic Karakaya Complex. This paper comprises the results of the field work in the Pulur region during the summer months of 1992 with the aim of solving some of the above problems.

Because of the presence of the Carboniferous rocks, the Pulur region has attracted the attention of several geologists. After the initial study by Ketin (1951), the region was investigated by Ağar (1977), Akdeniz (1988), Tanyolu (1988) and Keskin et al., (1989).

TECTONIC FRAMEWORK OF THE PULUR REGION

The Pulur region lines in the internal part of the Eastern Pontides (Ketin, 1966). Tectonically this regions forms the easternmost part of the Sakarya Zone of the Pontides. The characteristic features of the Sakarya Zone are a Hercynian metamorphic basement of Carboniferous age, Permo- Triassic subduction-accretion units (Karakaya Complex), a widespread Liassic transgression and ubiquitous Upper Jurassic-Lower Cretaceous limestones (Okay, 1989; Okay et al., 1996). The region studied shows these typical features.

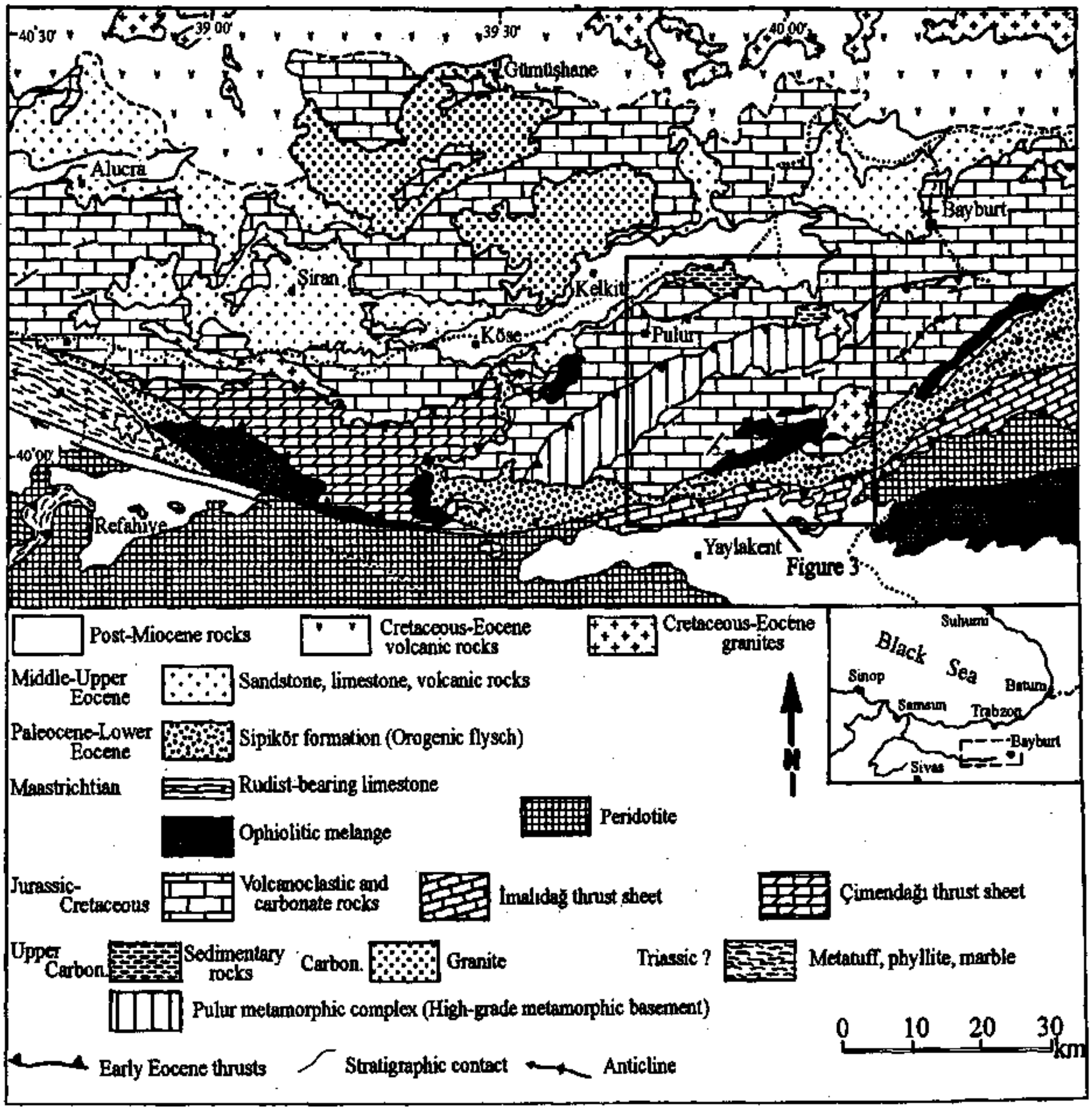

Fig. 1- Tectonic map of the southern part of the Eastern Pontides (modified from Yılmaz (1985) and Bergougnan (1987). The area studied and shown in Fig. 3 is outlined.

The internal parts of the Eastern Pontides formed a north-vergent thrust stack during the Early Tertiary continent-continent collison. In the Pulur region such thrusts were first recognised by Ketin (1951) and later shown on a geological cross-section by Akdeniz (1988). We have mapped a relative autochthon and three major thrusts sheets in the Pulur region, which were emplaced northward during the Late Paleocene - Early Eocene. These are named as the Cebre relative autochthon and going up and southward in the thrust stack the Hamurkesen, Aşutka and İmalidağ thrust sheets (Fig. 2). The pre-Jurassic basement is observed in the Cebre relative autochthon and in the Hamurkesen and Aşutka thrusts sheets, while the İmalidağ thrusts sheet is made up of Jurassic and

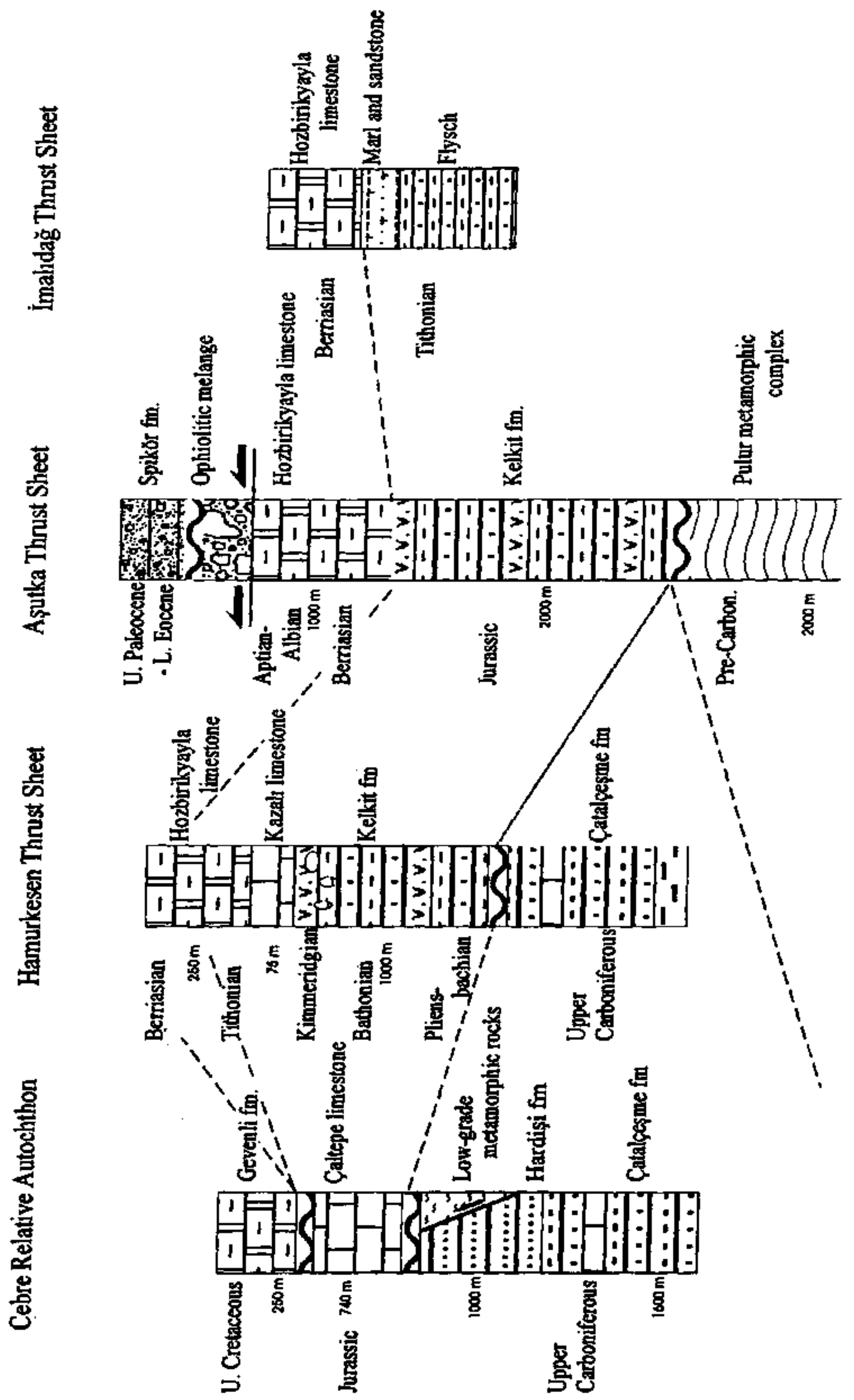

Fig. 2- Stratigraphy of the thrust sheets in the Pulur region

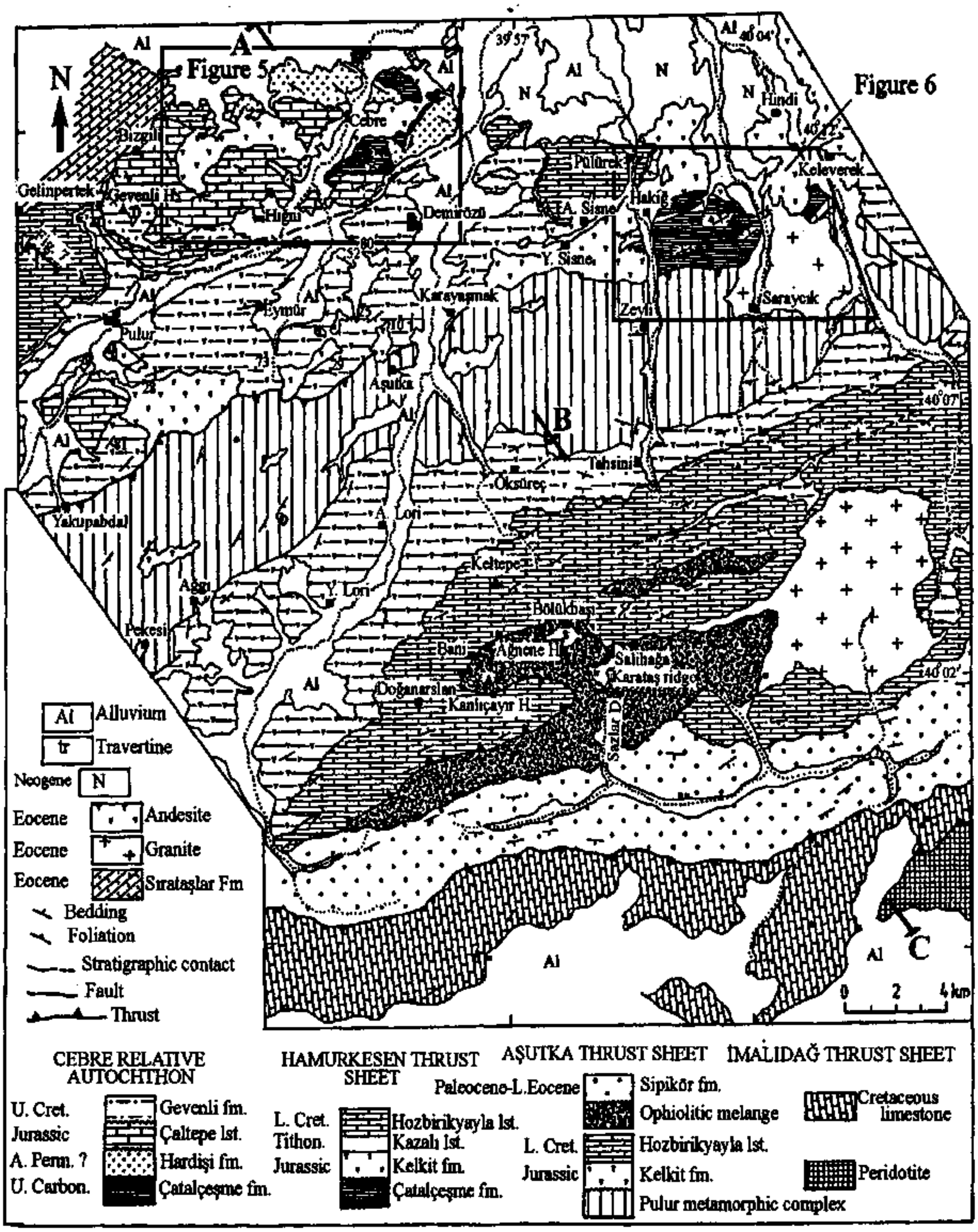

Fig. 3- Geological map of the Pulur region. For location see Figure 1.

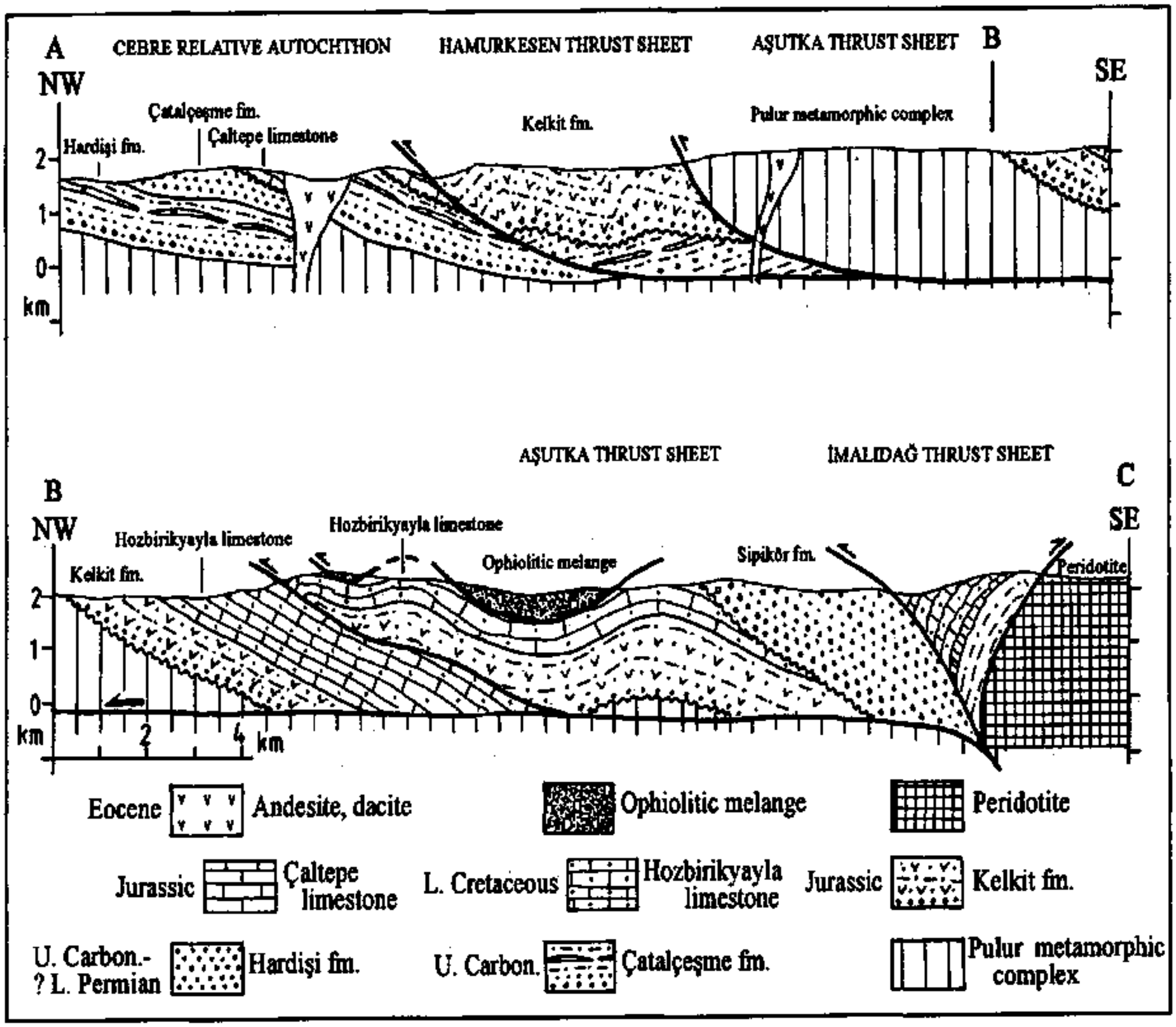

Fig. 4- Geological cross-section of the Pulur region. The section is along a single NW-SE trending line, the lower section continues from the upper one with some overlap around "B". For location see Fig. 3.

younger rocks. The bulk of the thrust sheets are constituted of Jurassic-Lower Cretaceous sedimentary rocks, which exhibit facies differences among the thrust sheets (Fig. 2). The Jurassic-Lower Cretaceous sequence of the Cebre relative autochthon was deposited in a shallow carbonate" platform in the north whereas the Lower cretaceous pelagic micrites of the İmalıdağ thrust sheet were deposited in the south-facing Tethyan continental margin. The ophiolitic melange in the Aşutka thrust sheet represents, the Mesozoic sedimentary and volcanic rocks of the Tethyan ocean floor. •

STRATIGRAPHY

Cebre relative autochthon

The relative autochthon was subdivided into four formations (Figs. 3 and 4). These are from bottom to top, Çatalçeşme formation, Hardişi formation, Çaltepe limestone and Gevenli formation (Fig. 2). Apart from these formations, low-grade metamorphic rocks of uncertain stratigraphic position outcrop in two small areas.

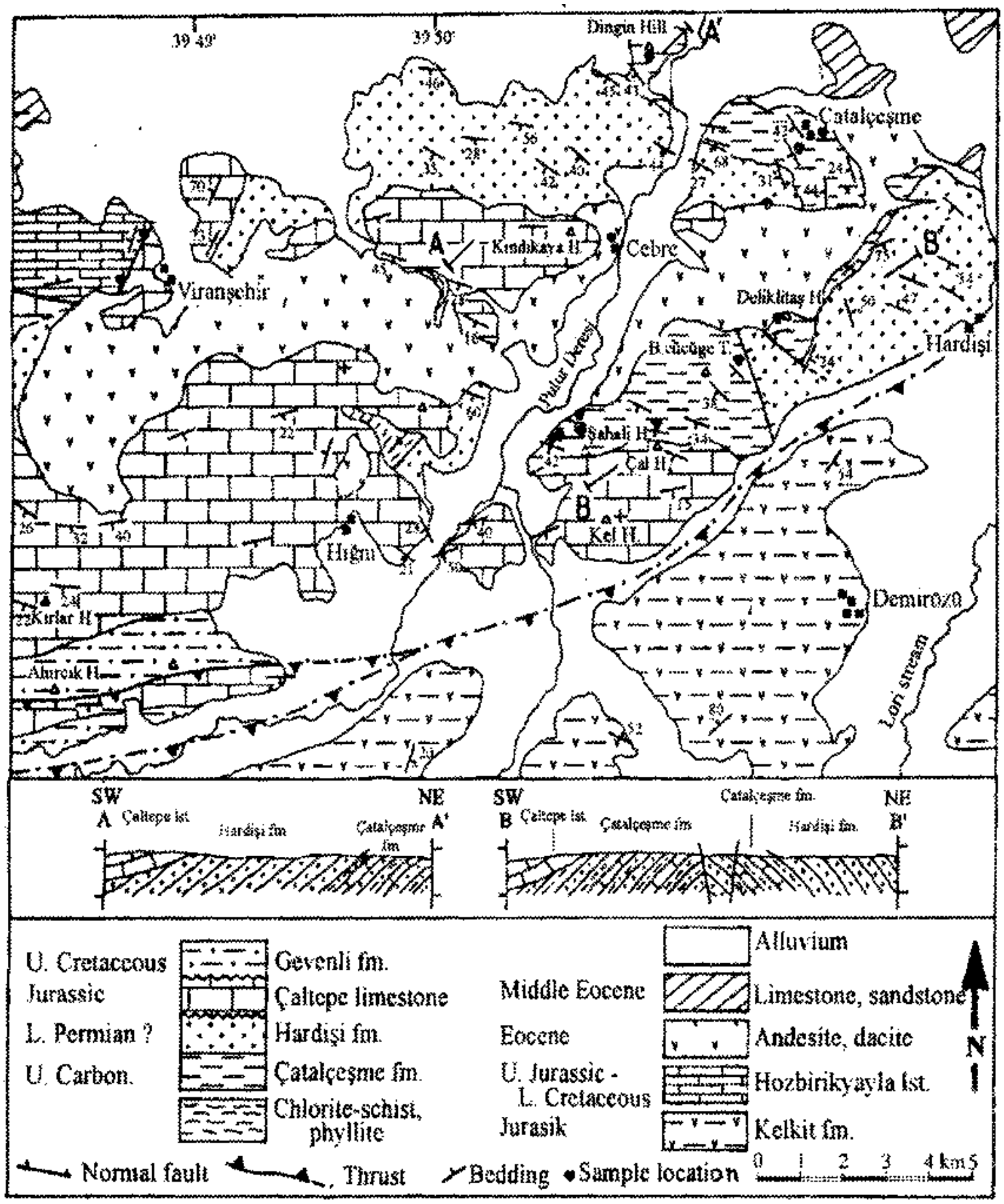

Fig. 5- Detailed geological map and cross-section of the Cebre-Demirözü region showing the Carboniferous outcrops (from Akdeniz (1988) and our own mapping). For location see Fig. 3.

Low-Grade Metamorphic Rocks.- These metamorphic rocks are represented by very fine-grained, greyish green, quartz-chlorite-schists and grey phyllites with a mylonitic foliation. They are cut by Tertiary andesites, and give poor outcrops north of the village of Hığnı and west of the Kındıkkaya hill (Fig. 5). North of the village of Hığnı, these rock are unconformably overlain by the Jurassic Çaltepe limestone. Akdeniz (1988), who first described these metamorphic rocks, places a probable angular unconformity between the metamorphic rock north of Hığnı, and the Hardişi Formation of Carboniferous age. The contact between these two units is covered in this region. However, the sub-vertical foliation in the metamorpihc rocks, and the attitude of the strike in the Hardişi formation, which is at right angles to the rock is much lower than that in the Pulur metamorphic complex, and resembles that in the Ağvanis Massif northwest of Refahiye (Okay, 1984; Fig. 1). The probable relation of the low-grade metamorpic rocks, which also outcrop in the Hamurkesen thrust sheet, to be Carboniferous sedimentary sequence and to the Pulur metamorphic rocks will be discussed in the final section of the paper.

The Permo-Carboniferous sequence of the Pulur region.- Ketin (1951), who first described the Permo-Carboniferous series in the Pulur region, divided the sequence into two lithostratigraphic units: At the base there were a monotonous series of thick, red sandstones, which were overlain by a heterogeneous series of intercalated fusulinid-bearing dark limestone, shale, quartzite and pebbly sandstone. Later Ağar (1977) stated, in our view correctly, that the red terrigeneous sandstones lay not below but above the heterogeneous series. Ağar (1977) placed an angular unconformity between the heterogeneous series, which he named the Çatalçeşme Formation, and the overlying terrigeneous sandstones, and suggested without any paleontological evidence, a Triassic age for the monotonous red sandstones. A third change in the Permo-Carboniferous stratigraphy of the region was introduced by Akdeniz (1988). Akdeniz (1988). who made a detailed geological map of the region, subdivided the Permo-Carboniferous sequence into three formations. At the base there was the Upper Carboniferous Çatalçeşme formation, overlain conformably-by the terrigeneous red sandstones, which in turn passed up into the Lower Permian Büyükcücüğe formation, which was lithologically very similar to the Çatalçeşme formation. In contrast to this, our study has shown that the Büyükcücüğe ad Çatalçeşme formations represent the same formation, which is repeated by faulting (Fig. 5), and both lie below the red sandstones. Moreover, our paleontological samples from "both formations" gave the same age range. Akdeniz (1988) correctly identified that the andesites, which were regarded by Ketin (1951) as part of the Permo-Carboniferous sequence, were in fact part of the Eocene volcanism, and were intrusive into the Permo-Carboniferous sequence. The British Petroleum geologists, who last studied the Pulur region (Robinson et al., 1995), suggested an Upper Paleozoic stratigraphy, which is not compatible with the field data and in fact with the lithologies in the Paleozoic sequence.

In our study, the Permo-Carboniferous sequence in the Pulur region is subdivided into two formations. At the base three is the Çatalçeşme formation of indercalated limestone, sandstone and shale, which is overlain by the red sandstones of the Hardişi formation. Although the Hardişi formation is referred to as Karakaya formation in previous studies (Ağar, 1977; Akdeniz, 1988), this name is not used as "Karakaya" is an already well-known lithostratigraphic name in the Pontides.

Çatalçeşme formation (Upper Carboniferous).- The Upper Carboniferous sequence of intercalated pebbly sandstone, limestone, conglomerate, quartzite and black shale with thin coal seams is named as the Çatalçeşme formation (Ağar, 1977). The Çatalçeşme formation used in this study encompasses the Çatalçeşme and Büyükcücüğe formations of Akdeniz (1988). Its type section, where its upper contact with the Hardişi formation is observed, is the unnamed valley, which runs parallel to the Demirözü-Cebre road, and climbs up to the Deliktaş hill (Fig. 5). Additional good section exist along the ridge from the Büyükcücüğe hill southwestard towards the Çal hill, and southeast of the Çatalçeşme village (Fig. 5).

The siratigcaphic base of the Çatalçeşme formation is not observed. The Çatalçeşme formation is overlain conformable by the Hardişi formation and unconformably by the Çaltepe limestone of Jurassic age. Ağar (1977) and Robinson et al. (1995) place an unconformity between the Çatalçeşme and Hardişi formations. However, as observed south of the Deliklitaş hill, an intercalation of limestofte, shale and pebbly sandstone of the Çatalçeşme formation passes upwards to the pebbly sandstones of the Hardişi formation with the gradual disappearance of limestones and shales in the sequence. The maximum observed thickness of the Çatalçeşme formation is about 1100 between the Büyükcücüğe and Şahali hills.

The Çatalçeşme formation has two main outcrop areas, one around the Çatalçeşme village and the other around the Büyükcücüğe hill (Fig. 5). In both of these outcrop areas the Çatalçeşme formation consists of sandstone, pebbly sandstone, dark limestone, siltstone, dark shale with coal seams, which are intercalated on a few to ten metre scale. The sandstones are medium to coarsa grained, beige, grey, yellowish pink and pink arkosic arenites with well-rounded pebbles. They are intercalated with dark grey, black, medium to thickly bedded limestones locally rich in brachiopods, corals, gastropods, algs and fusulinids. The thickness of the limestone horizons ranges from a few ten centimetres to few ten metres, and there are more than 20 limestone horizons ranges from a few ten centimetres to few ten metres, and there are more than 20 limestone horizons in the Çatalçeşme formation. Black, grey shales with thin, discontinuous coal seams, and yellowish brown, thinly bedded, strongly bioturbudited siltstones with plant fossils occur between the limestone beds and horizons. In the first outcrop area, around the village of Çatalçeşme, the Çatalçeşme formation passes up to the red sandstones of the Hardişi formation, as observed by Akdeniz (1988) (Fig. 5). Six limestones samples collected from around the village of Çatalçeşme contain the following fossils characteristic for Kasimovian-Gzelian (Upper Carboniferous): Syzran/a sp., *Eotuberiting* sp., *Palaeonubecularia* sp., *Palaonubecularia uniserialis* REITLINGER, *Palaeonubecularia fluxa* REITLINGER, *Tetrataxis* sp., *Tetrataxis linea* OZAWA, *Globivalvulina* sp., *Bradyinasp., Ozawainella sp., Staffellasp., Schubertella* sp., *Triticitessp., Pseudoenothyrasp., Hemigordius* sp., *Tubiphytes obscurus* MASLOW.

The sequence of sandstone, fusulinid limestones and shale in the second outcrop area, around the Büyükcücüğe hill was assigned by Akdeniz (1988) to the Büyükcücüğe formation, to which he gave an " early Permian age and placed above,he Hardişi formation. However, the contact of the Çatalçeşme and Hardişi formations to the east of the Büyükcücüğe hill is not stratigraphic but is consituted by a NNW trending normal fault (Fig. 5). Furthermore, fossils from eight limestone samples collected from around the Büyükcücüğe hill also give a Kasimovian-Gzelian (Late Carboniferous) age: Syzran/a sp., *Eotuberitina sp:, Palaeonubecularia* sp., Paleonubecularia uniserialis REITLINGER, *Deckeralla sp., Tetrataxis* sp., *Globivalvulina* sp., *Monotaxinoides* sp., *Ozawainella sp., Ozawainella angulata* (COLANI), *Staffella* sp., *Schubertella* sp., *Quasifusulina* sp., *Triticites sp., Tubiphytes sp., Girvanella* sp., *Beresella sp.*

Hardişi formation (Upper Carboniferous- ? Lower Permian).- The sequence of red, terrigeneous sandstones, which lies conformably over the Çatalçeşme formation is named after the Hardişi (Çiftetaş) village, around which it gives good exposures. The Hardişi formation is unconformably overlain by the Çaltepe limestones of Jurassic age (Figs, and 5). The type section of the Hardişi formation, where its lower and upper contacts are observed, is between the Kındıkkaya and Dingin hills (Fig. 5). In this section it has a thickness of about 1000 metres.

Hardişi formation consists of thickly bedded, pale pink, white, red feldspathic arkosic arenites and pebbly arenites. The poorly sorted and well rounded pebbles, generally 2 to 5 cm in diamater, are constituted of quartz and magmatic rocks, such as microgranite, microdiorite, rhyolite. These pebbles are most probably derived from Köse or Gümüşhane granodiorites of similar late Hercynian plutons, which outcrop north of the Pulur basin, and have given a 360±2 Ma (earliest Carboniferous) Rb/Sr whole rock isochron age (Bergoughan, 1987). No fossil has been found in the terrigeneous sandstones of the Hardişi formation. However, considering that it lies conformable on the Çatalçeşme formation of Kasimovian-Gzelian age, the Hardişi formation can be said to be of latest Carboniferous age and may possibly reach into the earliest Permian.

Çaltepe limestone (Jurassic).- The neritic carbonate sequence of Jurassic age, which lies unconformably over the Çatalçeşme and Hardişi formations, was named by Ağar (1977) as the Çaltepe limestone. It is striking that the Jurassic system in the Cebre relative authochthon is represented by neritic limestones and not the by widespread and typical volcanoclastic facies (Kelkit formation) of the Eastern Pontides. The best sections of the Çaltepe limestone is overlain unconformably by the Gevenli formation, as can be seen in the Kurtkoyağı Creek north of the Demirözü-Pulur road. The Çaltepe limestone has a thickness of 740 metres in the Kırlar hill section.

The Çaltepe limestone starts with sandstones with a carbonate matrix; these sandstones, which form a thin horizon at the base, pass up to medium to thickly bedded, dark grey, black, oolitic limestones. Above this oolitic limestones horizon there are thickly bedded, massive, grey and beige micrites with irregular black chert nodules and bands, which form the bulk of the Sequence. The lower part of the Çaltepe formation was assigned a Liassic (Pliensbachian) age by Akdeniz (1988) through microfossils and by Robinson et al. (1995) through Sr isotopic analyses. In contrast, our samples from the Çaltepe limestone have yielded microfossils with a wider age range of Jurassic-Early Cretaceous of Late Jurassic-Early Cretaceous: *Glomospira* sp., *Reophax* sp., *Textularia* sp., *Opthalmidium* sp., *Protopeneroplis?* Sp., *Trocholina* sp., *Lithocodium aggregatum* ELLIOT, *Bacinella irregularis* RADOICIC, *Saccocoma* sp., *Globochaete* sp. However, samples collected from the top of the sequence just below the Gevenli formation have yielded microfossils characteristic of Tithonian-Valanginian: *Pseudocylammina* spp., *Pseudocylammina lituus* YOKOYAMA, *Patellina* sp., *Neotrocholina* sp., *Cladocoropsis mirabilis* FELIX, *Tubiphytes morronen*s/sCRESCENTI, *Opthalmidium sp.* Akdeniz (1988) also describes foraminifera of Late Jurassic-Berriasian age from the upper parts of the Çaltepe limestone. The available data indicate that the age range of the Çaltepe limestone includes the whole of the Jurassic and possibly passes into the earliest Cretaceous.

Gevenli formation (Upper Cretaceous).- The sequence of siltstone.-sandstone, shale, marl and pelagic limestones, which lies unconformably over the Çaltepe limestones has been named as the Gevenli formation. The name of the formation comes from the Gevenli hill between the Pulur and Bizgili villages. Gevenli formation corresponds to the upper part of the Çaltepe formation of Akdeniz (1988). The Gevenli formation is overlain with a low-angle thrust contact by the Jurassic Kelkit formation. It is also repeated by thrusting south of the Ahırcık hill (Fig. 5). The Gevenli formation has a minimum thickness of 250 metres.

The Gevenli formation outcrops widely to the south of the village of Pulur. Although its type section is along the road between the Pulur and Bizgili villages, the base of the Gevenli formation is best observed in the Kurtkoyağı creek. Here, the Gevenli formation starts above the Çaltepe limestone with a half a metre thick conglomerate with limestone clasts. The conglomerate is overlain by fine-grained, yellowish grey, yellow sandstone with bluish green tuff clasts; fine to medium bedded, yellowish silstone showing graded bedding; bluish grey marl and rare sandy limestone, the upper parts of the sequence is made up of brown, regularly and thinly bedded siltstone, shale and mudstone intercalation. It comprises limestone olistoliths derived from the Çaltepe limestone. The Gevenli formation is poorly fossiliferous. Only a single sample from the lowermost parts of the Gevenli formation has yielded *Hedbergella* sp. and undeterminable planktic foraminifera of the Globotruncanidae family indicating a Turoniyen-Maastrihtiyen age range. Akdeniz (1988) assignes a Valanginian age to the topmost part of the Çaltepe limestone, which in our scheme corresponds to the Gevenli formation. However, this age probably comes from the blocks of the Çaltepe limestone in the Gevenli elastics, and does not reflect the age of the Gevenli formation. Robinson et al. (1995) has obtained Late Cretaceous ages from the basal parts of the Gevenli formation and Santonian- ? Turonian ages from its middle parts. These data indicate a Senonian age range for the Gevenli formation.

Hamurkesen thrust sheet

The Cebre relative authochthon is technically overlain by the Hamurkesen thrust sheet. The Hamurkesen thrust, which forms the contact between the two units, can be followed for five kilometres north of the Pulur village between the Gevenli formation or the Çaltepe limestone below and Jurassic volcanoclastic rocks (Kelkit formation) above (Fig. 3). The thrust fault is represented by a few metres thick, sheared shale horizon and dips to the south at 50 degrees. Eastward the Hamurkesen thrust is covered by alluvium and follows the Pulur stream for 14 km. The non-recognition of the Hamurkesen thrust in the older studies has resulted in confusion. For example, in the map and section of Ağar (1977) the Gevenli formation of Cretaceous age is shown to lie strarigraphically below the Jurassic Kelkit formation. The Hamurkesen thrust corresponds to an important paleogeographic and sedimentological threshhold. In the Cebre relative authochthon below the thrust, the Jurassic system is represented by a carbonate facies, whereas above the thrust in the Hamurkesen and Aşutka thrust sheets the Jurassic is represented by volcanoclastic rock probably deposited in a depeer marine environment.

The Hamurkesen thrust sheet consists mainly of three formations (Fig. 2). At the base there is the Kelkit formation, a thick volcanoclastic sequence of Jurassic age, this is succeded by oolitic limestones of Kazalı limestone, and at the top there is the Hozbirikyayla limestone of thick radiolarian biomicrites of Lower Cretaceous age (Fig. 3). Apart from these formations, low-grade metamorphic rocks and Carboniferous sedimentary rocks outcrop in a restricted area.

Low-Grade metamorphic rocks.- These metamorphic rocks, which outcrop around the village of Hakiğ as a small tectonic slice, are made up of well foliated, grey phyllite and fine-grained green metatuffs (Fig. 6). Like in the Cebre relative autochthon, these rocks may be correlated with the Ağvanis metamorphic rocks or with a more metamorphic part of the Carboniferous sequence.

Çatalçeşme formation (Carboniferous).- The Çatalçeşme formation in the Hamurkesen thrust sheet (Keskin, 1987) is more recrystallised and more strongly deformed compared to that of the Cebre relative autochthon. It has undergone a very low-grade metamorphism, and the fine-grained clastic rocks, especially the shales, are well foliated and have been transformed into slates. The lower part of the Çatalçeşme formation outcrops north of the Sarigüney hill (Fig. 6). In this region slightly recrystallised black slates and siltstones form a sequence of over 500 m in thickness. These fine-grained clastic rocks, which are not observed in the Çatalçeşme formation of the Cebre relative authochthon, also contain rare beds of sandstone, metatuff and recrystallised limestone. These black slate series are conformabje overlain by a sequence of closely interclated sandstone, pebbly sandstone, dark limestone, siltstone and dark shale, very similar to that observed in the Çatalçeşme formation of the Cebre relative authochthon. Five limestone samples from the limestones of this sequence comprise foraminifera of Kasimovian-Gzelian age: *Syzrania* sp., *Eotuberitina* sp., *Paleonubecularia* sp., *Climacammina* sp. *Tetrataxis* sp., *Endothyranella* sp., *Bradyina* sp., *Monotaxinoides* sp., *Ozawainella* sp., *Schubertella* sp., Keskin (1987), who described However, the contact between the Çatalçeşme formation and the Pulur metamorphics in this region is not stratigraphic as claimed by Keskin (1987), but is a steep thrust fault (Fig. 6).

Kelkit formation (Jurassic).- It is made up of volcanogenic sandstone, siliceous shale, andesitic and basaltic tuff, agglomerate and rare sandy limestone, limestone, and grain and debris flows with volcanic material and up to a few kilometres largo block of Upper Jurassic limestone. This typical Jurassic formation of the Eastern Pontides is named by Bergougnan (1987). The Kelkit formation lies over the Gevenli formation of Upper Cretaceous age along the Hamurkesen thrust, and it is stratigraphically overlain by the oolitic limestones of the Kazalı formation and technically by the Pulur metamorphic complex (Figs. 3 and 4).

Reference section for the Kelkit formation in the region studied is the Hamurkesen valey north of the Pulur village. Kelkit formation has a thickness of over 1000 metres. No in situ fossils have been found in the Kelkit formation; however, the limestone olistoliths in the formation contain fossils of Kimmeridgian-Valanginian age: *Cladocoropsis mirabilis* FELIX, *Tubiphytes morronensis* CRESCENTI, *Protopeneroplis striata* WEYNSCHENCK, *Protopeneroplis trochoangulata* SEPTFONTAINE, *Bacinella irregularis* RADOICIC, *Koskinobullina*

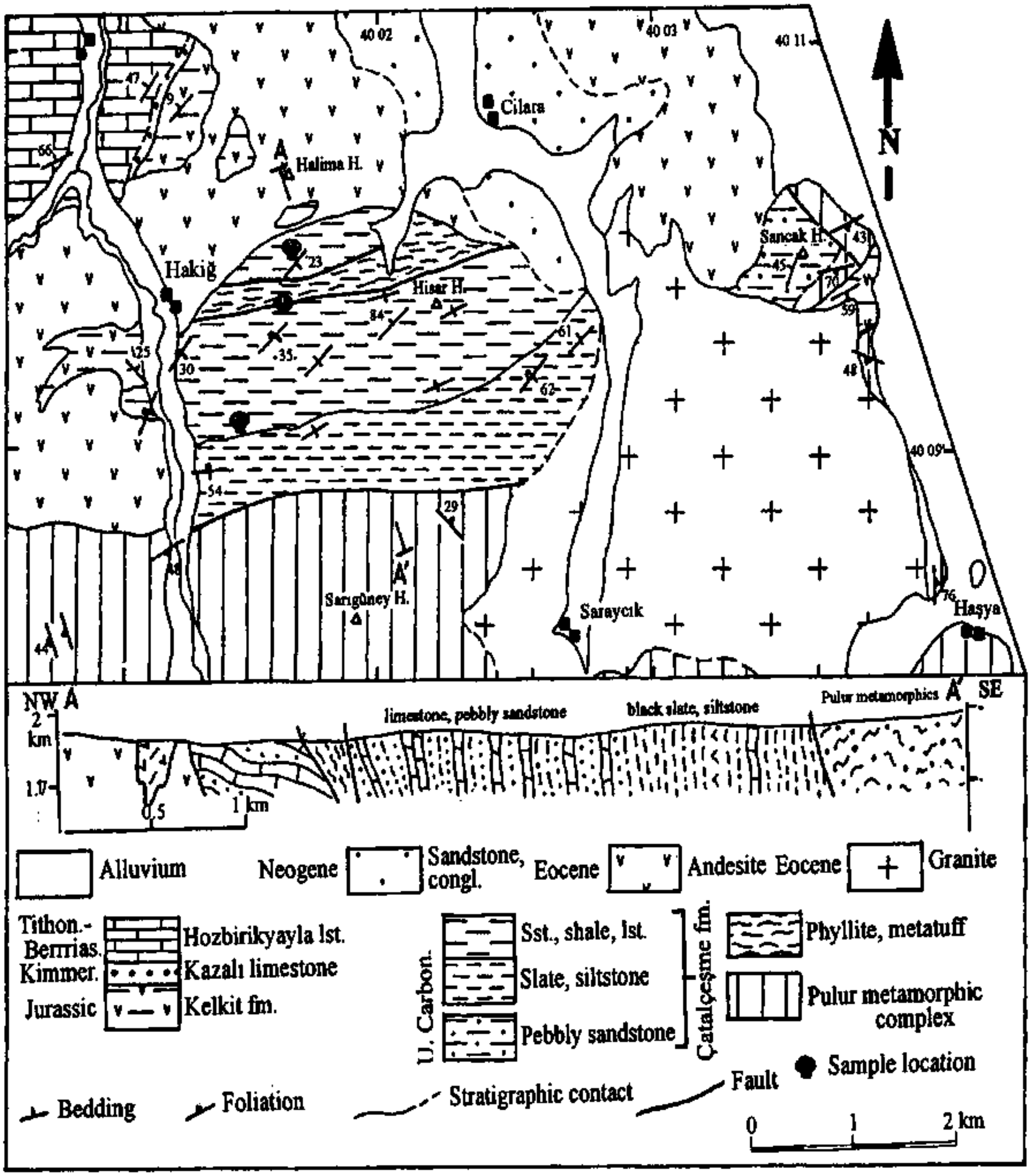

Fig. 6- Detalied geological map and cross-section of the Hakiğ (Çamdere) region showing the relation between the Carboniferous rocks and the Pulur memamorphic complex. For location see Fig. 3.

socialis CHERCI & SCHROEDER, *Reophax* sp., *Lenticulina* sp., *Patellina* sp., *Spirillina* sp: *Trocholina* sp. These age data and the age of the overlying Kazalı formation constrain the upper age limit of the Kelkit formation as Kimmeridgian. Data on the lower age limit of the Kelkit formation is provided by other workers. Robinson et al. (1995) have obtained dinoflagellates of Bathonian age from the middle parts of the Kelkit formation in the region studied. Özer (1984), who studied the eastward extension of the Kelkit formation to the south of Bayburt, describes a rich Lower Pliensbachian-Upper Toarcian ammonite fauna from the ammonitico rosso limestones rich Lower Pliensbachian-Upper Toarcian ammonite fauna from the ammonitico rosso limestones horizons in the Kelkit formation. Akdeniz (1988) describes Liassic fossils from the limestones blocks in the Kelkit formation. These data indicate that the age range of the Kelkit formation is from Late Pliensbachian to Kimmeridgian.

Kazalı limestone (Kimmeridgian). - The neritic limestones, which form a thin but laterally continuOUS stratigraphic horizon, above the Kelkit formation, is named as the Kazalı limestone. The Kazalı limestone corresponds to the lower parts of the Hozbirikyayla limestone of Ağar (1977) and Akdeniz (1988). The type section of the Kazalı limestone is the Kazalı valley west of the Pulur-Gelinpertek road, 2.5 km north of Pulur. The Kazalı limestone consists of thickly bedded, oolitic black limestones, and has a thickness of 50 to 100 metres (Fig. 2). Samples from the Kazalı limestone collected from north of the Pulur and Sisne villages contain a Kimmeridgian-Berriasian microfauna: *Nautiloculina* sp., *Protopeneroplis* sp., *Protopeneroplis trochoangulata* SEPTFONTAINE, *Conicospirillina basiliensis* MOHLER, *Trocholina alpina* (LEUPOLD), *Cayeuxina* sp., *Tubiphytes morronensis* CRESCENTI, *Bacinella irregularis* RADOICIC, *Siphovalvulina* sp., *Lenticulina* sp. Considering that the lower parts of the overlying Hozbirikyayla limestone is of Tithonian age, a Kimmeridgian age can be assigned to the Kazalı limestone.

Hozbirikyayla limestone (Tithonian-Berriasian) The Upper Jurassic-Lower Cretaceous radiolarian biomicrites, which overlie the Kazalı limestone, have been named as the Hozbirikyayla limestone (Ağar, 1977; Akdeniz, 1988). In the region studied the Hozbirikyayla limestone is intruded by magmatic rocks of probable Eocene age, and is unconformably overlain by Eocene and younger sedimentary rocks (Fig. 3). The Hozbirikyayla limestone is well exposed on the Pulur-Gelinpertek, road, and in the Karseçenin stream to the west of this road. The minimum thickness of the formation is 250 metres. The Hozbirikyayla limestone consists mainly of thinly to medium bedded, pink, grey, yellowish grey radiolarian micrite and marly micrite with intercalations of medium to thickly bedded calciturbidites with tuff clasts, reddish marly siltstones and pale green, fine-grained volcanogenic sandstones. A 280 metres thick section has been measured in the Kazalı limestone and Hozbirikyayla limestone in the Karseçenin stream (Fig. 7). In this section a sample from the top of the Kazalı limestone (sample no. 817) and a sample from the base of the Hozbirikyayla limestone (sample no. 816) contain Kimmeridgian faunas: *Trocholina* s., *Lenticulina* sp., *Spirillina* sp., *Tubiphytes morronensis* CRESCENTI (sample 817), and *Charantia* sp., *Nautiloculina* sp., *Mesoendothyra* cf. *izjumiana* DAIN (sample 816). Samples collected upwards in the sequence contain fauna of Kimmeridgian-Early Tithonian and Early Tithonian ages respectively: *Tubiphytes morronensis* CRESCENTI, *Charantia* sp., *Koskinobullina socialis* CHERCI & SCHROEDER (sample 815) and *Saccocoma* sp., *Cadosina* sp. (sampel 813). About 140 metres above the base of the Hozbirikyayla limestone, the rocks begin to comprise *Calpionella-bearing* faunas. Samples collected above 140 meters from the base contain faunas of Late Tithonian-Early Berriasian, Berriasian and Late Berriasian ages upwards in the sequence (Fig. 7): *Calpionella alpina* LORENZ, *Tintinopsella carpathica* (MURGEANU & FILIPESCU), *Crassirollaria parvula* REMANE (sample 812), *Calpionella alpina* LORENZ; *Tubiphytes* sp. (sample 811), and *Tintinopsella longa* (COLOM), *Cadosina* sp., *Calpinellopsis simplex* (COLOM) (sample 809). Apart from this section, samples of the Hozbirikyayla limestones collected from around the Pülürek villages, north of the Pulur village and north of the Sisne villages also contain fossils of Tithonian-Berriasian ages: *Calpionella alpina* LORENZ, *Calpionella elliptica* CADISH, *Calpionellopsis oblanga* (CADISH), *Calpionellopsis simplex* (COLOM), *Tintinopsella carpathica* (MURGEANU & PILIPESCU), *Tintinopsella longa* (COLOM), *Conicospirillina basiliensis* MOHLER, *Bacinella irregularis* RADOICIC, *Siphovalvulina* sp., *Sphaerostylus lanceola* (PARONA). All these data indicate a Tithonian-Berriasian age range for the Hozbirikyayla limestone. Similarly, Ağar (1977) indicates a Kimmeridgian-Berriasian, Akdeniz (1988) a Late Jurassic-Berriasian and Özer (1984) a Late Tithonian-Early Cretaceous age range for the Hozbirikyayla limestone.

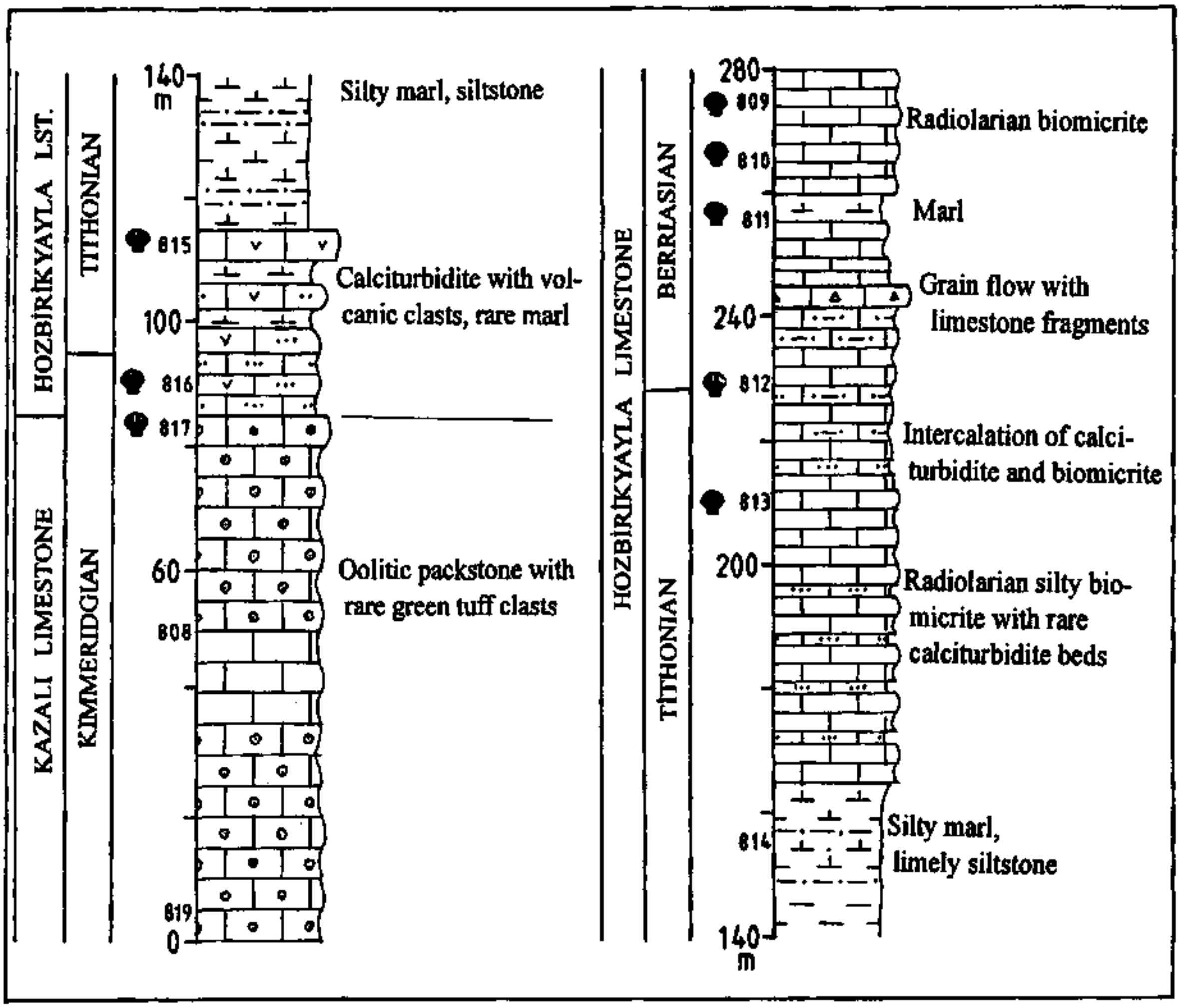

Fig. 7: Measured stratigraphic section of the Kazalı limestone and Hozbirikyayla limestone along the Karseçenin stream west of the Pulur-Gelinpertek road. For location see Fig. 3. Numbers starting with 8 to west of the columns indicate sample locations and numbers. For the microfossils in these samples see the text.

Aşutka thrust sheet

Hamurkesen sheet is tectonically overlain by the Aşutka thrust sheet along the Pulur thrust. The Pulur thrust, known since Ketin (1951) work, places the Pulur metamorphic complex over the Kelkit formation of Jurassic age. Due to the extensive andesite intrusions, it is difficult to determine the precise location and attitude of the Pulur thrust in the field. Nevertheless, a 20 m thick serpentinite lens outcrops along the Pulur thrust north of the village of Aşutka, in this region the thrust plane appears to be steep (>70°). East of the Karayaşmak village the Pulur thrust plane has also steep dips of 60-70°, in this area garnet-cordierite-micaschists lie over the Kelkit formation.

The Aşutka thrust sheet consists of a metamorphic basement (Pulur metamorphic complex), which is unconformably overlain by Jurassic-Cretaceous sedimentary and volcanic rocks (Kelkit formation and Hozbirikyayla limestones). Silices of ophiolitic melange lie with a thrust contact over the Cretaceous limestones, both are unconformably overlain by Maastrichtian rudist-bearing limestones outsidethearPaleocene-Lowereastudied,andby

Eocene flysch (Sipikör formation) in the region studied.

Pulur metamorphic complex (Pre~ Carboniferous) The basement of the Aşutka thrust sheet is made up of strongly tectonised micaschist, cordierite-sillimanite-garnet schist, amphibolite, gneiss, metagranite and very rare marble, which are intruded by Eocene or younger volcanic and subvolcanic rocks (Topuz and Sadıklar, 1994; Okay, 1996). The Pulur metamorphic complex lies tectonically over the Kelkit formation of the Hamurkesen thrust sheet along the Pulur thrust, and is also unconformably overlain by the Jurassic Kelkit formation (Figs. 3 and 4). The Pulur metamorphic complex has generally bad and discontinuous exposures, the best section is along the road between the Yakupaddal and Pekesi villages. Because of strong shearing and extensive magmatic intrusions, it has an irregular and disharmonious internal structure. The foliation in metamorphic rocks, although generally dipping to the south, changes over short distances.

Kelkit formation (Jurassic).-The Kelkit formation in the Aşutka thrust sheet consists of siltstone, tuff, shale and andesitic volcanic rocks, and has a thickness of between 1200 and 2500 metres. It lies unconformably over the Pulur metamorphic complex. This unconformity can be seen south of the Ağği village and west of the Öksüreç village (Fig. 3). The Kelkit formation passes upwards conformably to the Hozbirikyayla limestone. The Kelkit fomation starts on the metamorphic rocks with pebbly sandstones and microconglomerates. In this few ten metres thick basal horizon, there are thin and discontinuous coal horizons, for example to the south of the Aggi village. The bulk of the Kelkit formation consists of dark greenish brown, bluish grey shale, medium bedded dark greenish brown siltstone, bright bluish green, very fine grained, rare tuff beds, rare red soft shale and 1-2 m hick yellowish brown andesitic lavas with plagioclase phenocrysts. In comparison with the Kelkit formation in the Hamurkesen thrust sheet, the Kelkit formation in the Aşutka thrust sheet is on the whole finer grained and contains no large limestone olistoliths, suggesting a deeper and/or more pelagic depositional environment.

No age diagnostic fossils have been found in the Kelkit formation of the Aşutka thrust sheet. However, correlation with, the formation of the same name in the Hamurkesen thrust sheet, and the Berriasian age from the base of the overlying Hozbirikyayla limestone indicate a Jurassic age for the Kelkit formatio in the Aşutka thrust sheet.

Hozbirikyayla limestone (Lower Cretaceous) The pelagic biomicrites which lie conformably over the Kelkit formation are assigned to the Hozbirikyayla limestone. The conformable stratigraphic contact between the Kelkit formation and the Hozbirikyayla limestone can be clearly seen on the road continuing south from the Tahsini village (Fig. 3). Here, the fine-grained elastics of the Kelkit formation pass upwards to pelagic micrites through an interval of intercalated dark grey carbonate-rich mudstone, shale and black cherty limestone. In the Aşutka thrust sheet the Hozbirikyayla formation has a folded stucture and is stratigraphically overlain by the Sipikör formation and tectonically by the dphiolitic melange. It has a minimum thickness of 1000 metres.

The bulk of the Hozbirikyayla limestone in the Aşutka thrust sheet is made up of thinly to medium bedded, light beige, locally pink, radiolarian biomicrites. There are also rare intercalations of medium bedded calciturbidites within the biomicrites. Samples collected from the middle parts of the Hozbirikyayla limestone south of the Kel hill, contain a Beriasian fauna: *Calpionella alpine* LORENZ, *Calpionella elliptica* CADISCH, *Tintinopsella carpathica* (MURGEANU & FILIPESCU), *Trocholina sagittaria, Neotrocholina* sp., *Protopeneroplis trochoangulata* SEPTFONTAINE, Radiolaria. A sample from the topmost part of the section, just below the ophiolitic melange, contains Aptian-Albian fossils: *Hedbergella* cf. *gorbachikae* LONGARA, *Hedbergella planispira* (TAPPAN), *Planamalina?* sp. These data indicate a Berriasian to Aptian/Albian age range for the Hozbirikyayla limestone in the Aşutka thrust sheet.

Ophiolitic melange.- The ophiolitic melange is made up mainly of radiolarian chert, pelagic and neritic limestone, spilitised basalt, serpentinite, sandstone, shale and siltstone blocks and slices. The ophiolitic melange is thrust over the Hozbirikyayla limestone; a tear fault divide the thrust fault into two sections (Fig. 3). To the east of the tear fault, rocks of the ophiolitic melange lie with a low-angle thrust contact over the Hozbirikyayla limestone; in this region a long but narrow klip of ophiolitic melange also occurs above the limestones (Fig. 3). To the west of the tear fault, the thrust fault is overturned and the Hozbirikyayla limestone lies with a medium angle contact over the ophiolitic melange.

The ophiolitic melange is unconformably overlain by the Kapıkaya limestone or by the Sipikör formation (Figs. 2 and 3). The best outcrops of the ophiolitic melange are along the road following the Sazlar valley and continuing southward from the Bölükbaşı hamlet. Thinly to medium bedded red radiolarian chert, which forms an important part of the ophiolitic melange, make up the Büyük Karataş ridge south of the Salihağa hamlet. To the south of this large radiolarite outcrop, there are blocks of pillowed spilitised basalts intercalated with red pelagic limestones. Serpentinite is a rare lithology in the melange. Serpentinite bodies, 20-30 m large, occur 2.5 km southwest of the Bölükbaşı hamlet, in the Ağnene hill and in the Kanlıçayır hill, 3 km east of the Doğanarslan village. Blocks of radiolarian biomicrite, ilthologically similar to the Hozbirikyayla limestone, and neritic limestone blocks outcrop along the Otlukbeli stream.

A sample collected from a three metres large neritic limestone block in the Ovacık valley contains fossils of Oxfordian-Albian age: *Lithocodium aggregatum* ELLIOT, *Tubiphytes* sp. Blocks of red biomicrite in the thickly bedded, laminated, brownish grey sandstones along the road between the Bain and Bölükbaşı hamlets comprise *Hedbergella* species of Aptian-Albian age: *Hedbergella* spp., *Hedbergella trochoidea* (GANDOLFI), *Hedbergella gorbachikae* LONGARIA, *Hedbergella delrioensis* (CARSEY), *Hedbergella sigali* MOULLADE, *Hedbergella planispira* (TAPPAN). Another limestones sample collected again from this region has yielded a microfauna indicating an Aptian age: *Hedbergella* sp., *Hedbergella planispira* (TAPPAN), *Globigerinelloides blowi* (BOLLI), *Ticinella bejaouensis* SIGAL. These data indicates that the melange must have formed after the Aptian. The Upper Campanian-Maastrichtian age of the unconformably overlying Kapıkaya formation contrains the age of melange formation and emplacement to the Aptian-Upper Campanian interval. This indicates that the thrust fault between the ophiolitic melange and the underlying Lower Cretaceous Hozbirikyayla limestone is older than the Early Eocene Hamurkesen and Pulur thrusts.

Kapıkaya limestone (Maastrichtian).- This sequence of neritic limestone, which unconformably overlies the ophiolitic melange, outcrops outside and to the east of the area studied, along the main Bayburt-Erzurum road, and gives good outcrops two kilometres north of Maden. It was first described and mapped by Ketin (1951) and later named by Keskin et al. (1989). The Kapıkaya limestone continues westward from the main Bayburt-Erzurum road for 13 km forming a limestone cover of gradually decreasing thickness over the ophiolitic melange (Fig. 1). Farther west, the Kapıkaya limestone is totally eroded and, as in the area studied, the Sipikör formation lies unconformably over the ophiolitic melange.

The Kapıkaya limestone is made up of thickly bedded neritic limestones with abundant rudist. Bergougnan (1987) assigns a Late Campanian-Maastrichtian age, while Fenerci (1994) and Elmas (1994) give Maastrichtian ages to the rudists in the Kapıkaya limestone.

Sipikör formation (Upper Paleocene.- Lower Eocene)- The flysch-type clastic sequence of sandstone, conglomerate and shale, which lies unconformably over the ophiolitic melange and the Hozbirikyayla limestone in the southern part of the area studied, is assigned to the Sipikör formation of Bergougnan (1987). The sipikör formation also lies unconformably over the Maastrichtian Kapıkaya limestone in the east towards the Bayburt-Erzurum main road, and is tectonically overlain by the imalidag thrust sheet. It starts with a few hundred metres thick conglomerate with clasts of Jurassic-Lower Cretaceous limestone, spilitised basalt, serpentinite, metamorphic rock and sandstone, and passes upwards to siltstones and a turbidite sequence of sandstone and shale of over 1000m in thickness. The Spikör formation locally contains large olistoliths. Norman (1976) studied the sedimentary structures in the turbidites over a large region, and showed that the paleo-currents were largely parallel to the axis of the basin and were flowing from the southwest towards the northeast. The Sipikor formation, which has a thickness of about 1500 metres, represents a clastic wedge deposited in a foreland basin in front of the northward advancing İmalidağ thrust sheet. Paleontological data of Ketin (1951), Bergougnan (1976) and Norman (1975) indicate a Late Paleocene-Early Eocene age for the Sipikor formation.

İmalıdağ thrust sheet

To the north of the ultramafic rocks in the Ankara-Erzincan Neo-Tethyan suture zone, allochthonous Mesozoic carbonates outcrop along a 200 km long region between Ağvanis and Erzurum (Fig. 1). These allochthonous rocks were named by A. Yılmaz (1985) and Bergougnan (1987) as the Çimendağı nappe in the west and İmalıdağı nappe in the east. The main feature differentiating these two nappes is that the Jurassic-Lower Cretaceous sequence in the İmalıdağ thrust sheet has developed in a more pelagic facies that in the Çimendağı thrust sheet. Both thrust sheets lie tectonically over the Sipikör formation in the north and over the ultramafic rocks in the south. In the southern part of the region pelagic limestone of the İmalıdağı thrust sheet outcrop in a small area. In the section along the Kop stream the İmalıdağ thrust sheet consists of a sandstone-shale series at the base stratigraphically overlain by pelagic micrites of Tithonian-Berriasian age (Bergougnan, 1987). In the section in the Yeşirçöl Dağı there is a volcanoclastic sequence of Tithonian age with limestone intercalations at the base and a stratigraphically overlying Upper Tithonian-Hauterivian cherty biomictires (Bergougnan, 1987).

Post-collisionalsequences

In the region studied rocks deposited after the Early Eocene tectonics can be subdivided into three formations: the Sirataslar formation of Eocene age made up of limestone, sandstone and conglomerate; Eocene of younger, intermediate magmatic rocks; and a Neogene sequence of terrigeneous, poorly consolidated, poorly sorted conglomerates with limestone pebbles, semi-consolidated sandstone and pinkish white tuffs. The first two formations will be described in more detail below.

Sırataşlar formation (Eocene).- The Sırataşlar formation (Ağar, 1977), which unconformably covers the thrust sheet in the region studied, and forms the base of the Bayburt-Pulur basin. It is made up mainly of limestone, conglomerate and sandstone. North of the village of Bizgili, the Sırataşlar formation starts above the Çaltepe limestone with thickly bedded conglomerates with 1 to 10 cm large, well rounded limestone clasts. The conglomerate beds are succeeded by pinkish white, thickly bedded, pebbly, nummulitic limestone, which pass up to terrgeneous red conglomerates and red sandstones. This outcrop of the Sırataşlar formation continues westward and covers the thrust contact between the Cebre relative authochthon and the Hamurkesen thrust sheet (Fig. 3). Around the village of Gelinpertek the nummulitic limestones of the Sırataşlar formation has a thickness of over 50 metres. The bedding in the Sırataşlar formation is subhorizontal.

Two limestone samples from the Sırataşlar formation collected from north of the Bizgili village contain the following Middle up Upper Eocene fossils. *Nummulites* sp., *Orbitolites* sp., *Turboratalia* sp., *Turboratalia cerroazulensis* COLE, *Globigerinatheka* sp. Apart from these Eocene fossils, the samples also contain *Calpionellid type* pelagic microfossils derived from the Mesozoic limestones. Samples taken from the thickly bedded nummulitic and sandy limestones from around the village of Gelinpertek and north of the Hardişi village also contain Eocene fossils: *Nummulites* sp., *Discocyclina* sp., *Rotalia* sp., *Sphaerogypsina* sp. These data indicates a Mid to Late Eocene age for the Sırataşlar formation. This age also provides an upper age limit for the main compressional tectonics in the region. Ağar (1977) assigns a Ypresian-Early Lutetian age to the Sırataşlar formation based on the foraminifera and echinodermata. In the Eastern Pontides the Middle Eocene rocks have generally a post-tectonic character and unconformably cover the older rocks. For example, in the Berdiga mountains in the Alucra region Middle Eocene limestone and volcanic rocks lie with an angular unconfomity over Jurassic clastic rocks (Nebert, 1961; Pelin, 1977).

Magmatic rocks.- In the region studied all pre-Eocene units are cut by intermediate subvolcanic rocks of andesite, dacite, diorite and diabase composition. These strongly altered magmatic rocks cover large areas in the region and with their irregular boundaries make geological mapping and determination of contract relation difficult. The contacts of the subvolcanic rocks rarely observed. However, rare andesite dykes are seen to cross-cut the Pulur metamorphic rocks. Apart from these subvolcanic rocks, a granitoid with a diameter of 3-4 km, occurs around the Saraycık village (Figs. 3 and 6). This pluton, which forms part of the same magmatic cycle as the subvolcanic rocks, has a granodiorite composition and intrudes the Pulur metamorphic complex, the Çatalçeşme and Kelkit formations. Another similar pluton occurs farther south (Fig. 3). The subvolcanic rocks cross-cut the thrust contact between the Hamurkesen and Aşutka thrust sheets, indicating a post-Early Eocene age for these shallow intrusions. Correlations with intermediate tuffs in the Middle Eocene sequence suggest a similar age for the subvolcanic rocks.

GEOLOGICAL EVOLUTION OF THE REGION

Pre-Jurassic evolution

The geological evolution of the region can be constructed by palinspastically restoring the thrust stack in the Pulur region. When this palinspastic restoration is done, the pre-Jurassic basement is represented by the Pulur metamorphic rocks in the south, and by the Upper Carboniferous- ? Lower Permian sedimentary rocks in the north. Although the surface contact between these two units is represented by a fault, it is probable that the Upper Paleozoic sequence was initially deposited unconformably over the Pulur metamorphic rocks. Outside the area studied, the pre-Jurassic basement of the Eastern Pontides is constituted by the earliest Carboniferous Köse and Gümüşhane granodiorites (360 ± 2 My; Yılmaz, 1976, Bergougnan, 1987) in the Gümüşhane region, and by the dacites and rhyolites in the Olur region (H. Yılmaz, 1985; Bozkuş, 1992).

The presence of minerals like cordierite and sillimanite in the Pulur metamorphic rocks indicates a high temperature and low pressure (HT/LP) regional metamorphism. It is probable that this HT/LP regional metamorphism was gnetically related to the magmatism producing the earliest Carboniferous granodiorites, and both may have formed at the basal levels of a Devonian-Carboniferous Andean-type magmatic arc. This implies a Devonian or earliest Carboniferous age for the regional metamorphism of the Pulur metamorphic complex. Following the regional metamorphism. the metamorphic and associated magmatic rocks were exhumed and were unconformably overlain during the Late Carboniferous by shallow marine and terrigeneous molasse-type sedimentary rocks (Fig. 8). Late Hercynian HT/LP metamorphic rocks and granodiorites, similar to the Pulur metamorphic complex and Köse-Gümüşhane granodiorites, have been described from the Greater and Lesser Caucasus (Khain, 1975; Adamia et al., 1982). As in the Pulur region, in the Caucasus these rocks are unconformably overlain by Upper Carboniferous molasse-type sedimentary rocks (Khain, 1975; Yılmaz, 1989). This remarkable similarity of the pre-Jurassic basements of the Eastern Pontides and the Caucasus (Yılmaz, 1989) indicates that the Eastern Pontides were situated during the Late Paleozoic along the southern margin of Laurasia.

In the region studied, and in the whole of the Eastern Pontides no Triassic sedimentary rocks are known. However, the metabasite-marble-phyllite association, which forms the Ağvanis Massif, 90 km west of the region studied, is lithologically very similar to the Permo-Triassic Nilüfer unit of the Karakaya Complex described from northwest Anatolia (Okay, 1984; Okay et al., 1991). Nilüfer unit is believed to have been deposited in a Permo-Triassic ensimatic fore-arc or intra-arc basin, and in the late Tnassic was thrust over a continental basement represented by the Kazdağ Group (Okay et al., 1991, 1996). The Pulur metamorphic complex, which is lithologically and metamorphically different from the Ağvanis Massif, can possibly be correlated with the Kazdağ Group of gneiss, marble and amphibolite. The latest geochronological studies in the gneisses of the Kazdağ Complex yielded zircon ages of 308 ±16 my (Okay et al., 1996). A similar tectonic relation can be envisaged for the Eastern Pontide basement (Fig. 8). In this context the low-grade metamorphic rocks in the region

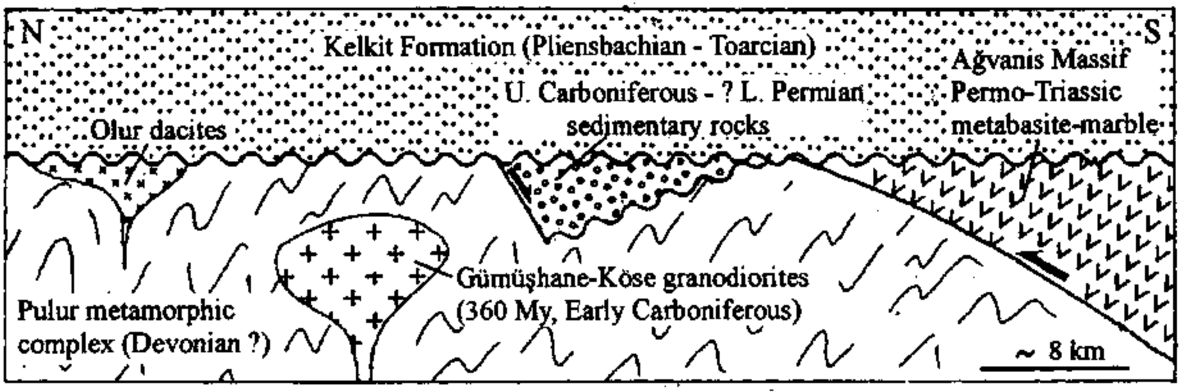

Fig. 8- Speculative section showing possible relations between the various pre-Jurassic units of the basement of the Eastern Pontides.

studied may represent relics of a thrust sheet over the Pulur metamorphic complex and over the Upper Paleozoic sedimentary sequence.

Jurassic - Early Cretaceous: Development of a passive continental margin

During the Lias (Pliensbachian) there was a major marine transgression from the south along the whole of the Sakarya Zone, and a large region including the Eastern Pontides were covered by the sea (Akın, 1978). In this newly formed basin, neritic carbonate rocks, represented by the Çaltepe limestone, were formed in high-standing areas possibly bounded by faults, while in the rest of the basin clastic rocks were deposited accompained by volcanic rocks related to rifting, represented by the Kelkit formation. Large limestone blocks slid into the basin from the high-standing areas. This sedimentation pattern in the Jurassic signifies rifting possibly related to the opening of the Neo-Tethys, as first claimed by Görür et al. (1983).

In the latest Jurassic and Early Cretaceous a transition from volcanoclastic to carbonate deposition took place in the whole of the basin. Carbonate deposition continued throughout the Early Cretaceous in the region studied and throughout the Eastern Pontides. However, a facies difference is noticable during the Early Cretaceous in the Eastern Pontides with neritic carbonate deposition in the north, an pelagic limestone and calciturbidite deposition in the south nearer to the Tethyan ocean. For example, in the Berdiga mountains the Upper Jurassic to Barremian sequence is represented by the shelf-type carbonates (Pelin, 1977), whereas in the Bayburt region and in the area studied pelagic limestones and calciturbidites (the Hozbirikyayla limestone) were deposited during this time interval (Burşuk, 1975; Özer, 1984). This situation indicates the development of a passive continental margin facing the Tethyan ocean in the Eastern Pontides during the early Cretaceous (Fig. 9).

Cenomanian-Turonian: Uplift and erosion related to the obduction of ophiolitic melange

In several regions in the Eastern Pontides, all the Lower Cretaceous sequence is eroded and the Senonian rocks rest with an angular unconformity over the Jurassic or over the Kelkit formation (Nebert, 1961; Pelin, 1977; Özsayar et al., 1981). In the Gümüşhane region the Senonian sequence rests directly over the Carboniferous Gümüşhane granodiorite (Yılmaz, 1976). This major phase of uplift and erosion affecting the whole of the Eastern Pontides is caused by the obduction of an ophiolitic melange over the Eastern Pontide passive continental margin during the Cenomanian-Turonian. During this period ophiolite and ophiolitic melange were also emplaced from the south in the Lesser Caucasus (Knipper, 1980). Thus, during the Cenomanian-Turonian oceanic crust and/or oceanic accretionary complexes were thrust northward over the 100/ km long Eastern Pontides-Lesser Caucasus passive continental margin. Although the ophiolitic melange thrust slice in the Eastern

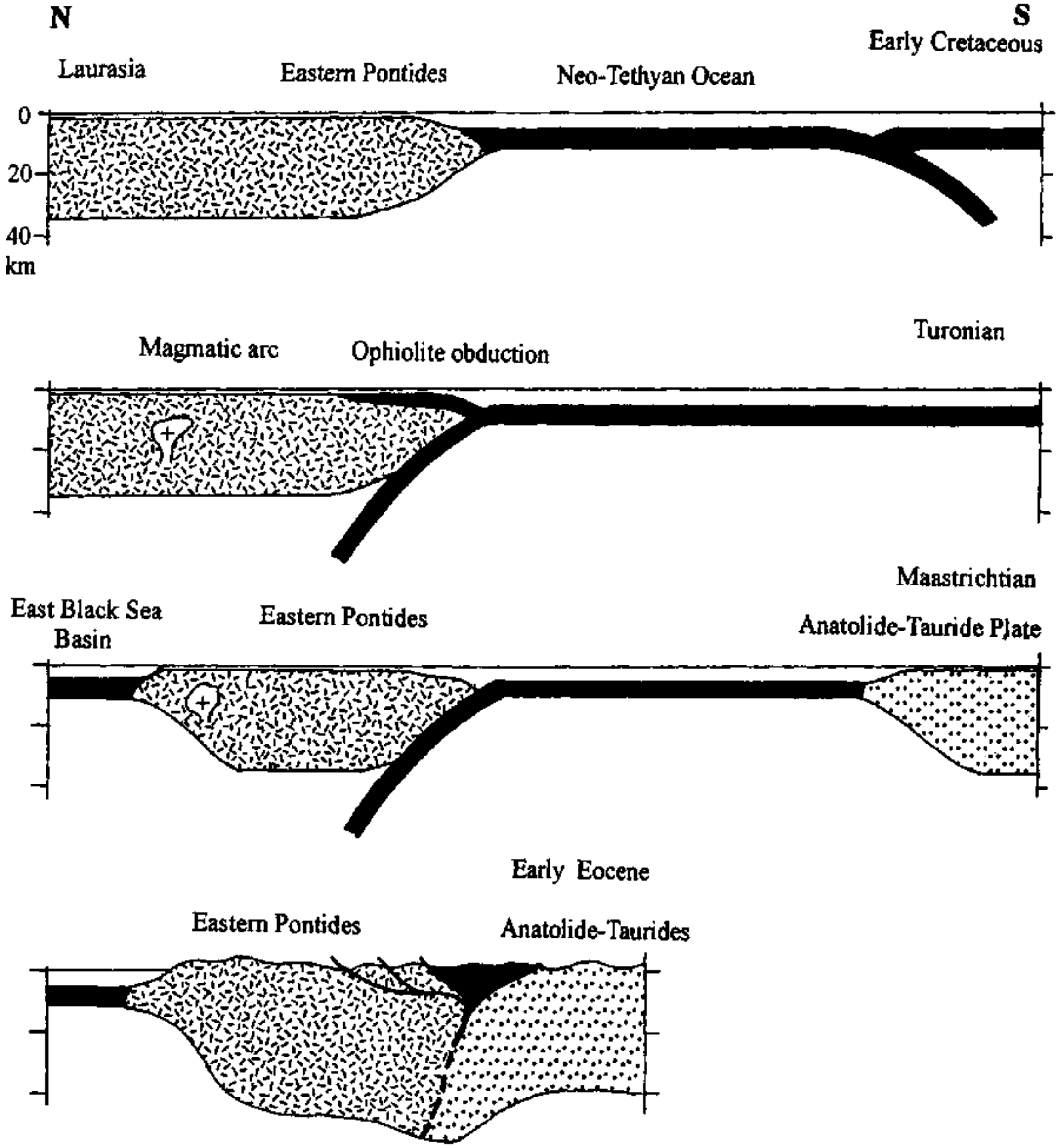

Fig. 9- Schematic and speculative sections illustrating Cretaceous-Early Tertiary plate tectonic evolution of the Eastern Pontides. In the Early Cretaceous the Eastern Pontides formed part of the south-facing passive continental margin of Laurasia. During the Cenomanian-Turoniah the southern part of the Eastern Pontides were partly subducted in an intra-oceanic subduction zone resulting in the obduction of the ophiolite and ophiolitic melange. Following this attempted subduction of the continental margin, the subduction zone changed its polarity and the Neo-Tethys ocean started to subduct northward under the Eastern Pontides. As a result of this northward subduction a major magmatic arc started to develop in the Turanian in the outer part of the Eastern Pontides. During the Maastrichtian this magmatic arc split and thereby creating in the north the East Black Sea basin as an oceanic back-arc basin. In the Late Paleocene-Early Eocene the Eastern Pontide magmatic arc collided with the Anatolide-Tauride plate resulting in the northward imbrication of the Eastern Pontide continental margin.

Pontides did not reach farther north than the Bayburt-Köse-Şiran line, this major obduction event showed itself farher north as a period of uplift and erosion.

It is not clear, why the ophiolitic melange was emplaced over the Eastern Pontide continental margin during the Cenomanian-Turonian. The subduction-related, extensive Senonian magmatism in the outer Eastern Pontides (e.g., Akın, 1978) shows that the Tethyan ocean was extant at the beginning of the Senonian, and thus no continent-continent collision could have occurred during the Cenomanian-Turonian. Elmas (1994) explains the obduction of the ophiolitic melange through the back-thrusting of an over-thickened Tethyan oceanic accretionary complex, developed above a northward-dipping subduction zone. However, there is no evidence for any, let alone a thick, accretionary complex during the Cenomanian-Turonian to the south of the Eastern Pontides. The ubiquitous Upper Jurassic-Lower Cretaceous carbonates show that subduction magmatism, and hence subduction, had not started by the Early Cretaceous under the Eastern Pontides. In the outer Eastern Pontides the first widespread by the Early Cretaceous under the Eastern Pontides. In the outer Eastern Pontides the fist widespread subduction-related magmatism starts in the Turanian (Özsayar, 1971; Taner and Zaninetti, 1978). A possible mechanism to explain the emplacement of the ophiolitic melange during the Cenomanian-Turonian is the partial subduction of the Eastern Pontide continental margin in an intra-oceanic subduction zone (Fig. 9). As it difficult to subduct the continental lithosphere because of its low density, the subduction polarity changed during the Turonian, and the Tethyan ocean started to subduct northward under the Eastern Pontides (Fig. 9). It is well known from the tectonics of the present day southeast Asia, that the intra-oceanic subduction zones can change their polarity (Hamilton, 1979). This model presented here, also explains why immediately following the obduction of the ophiolitic melange in the Turonian, the subduction-related magmatism started in the outer Eastern Pontides.

Senonian: development of the Eastern Porttide island-arc

A volcanic arc sequence mainly of andesitic and dacitic rocks, over 2000 metres thick, developed in the outer Eastern Pontides as a result of the Senonian subduction (Boccaletti et al., 1974; Akın, 1978; Eğin and Hirst, 1979; Gedikoğlu et al., 1979; Terlemez and Yılmaz, 1980, Şengör and Yılmaz, 1981). The East Black Sea basin started to form probably during the Maastrichtian as an oceanic back-arc basin a result of the splitting of this volcanic arc axis (Boccaletti et al., 1974, Robertson and Dixon, 1984; Zonenshain and Le Pichon, 1986; Görür, 1988; Okay et al. 1994, Robertson et al., 1996). As a result of the opening of the East Black Sea basin, the Eastern Pontides were transformed into an island arc, similar to the present day Japanase islands. During the Senonian the southern part of the Eastern Pontides, including the region studied, was in a fore-arc position. The volcanogenic sandstones, siltstones and marls in the Gevenli formation were deposited in a fore-arc environment. Subduction-related magmatism in the Eastern Pontides continued up to the end Maastrichtian and beginning of Paleocene (Korkmaz and Gedik, 1988; Korkmaz, 1993), and later the whole region was sliced, folded and uplifted as a result of the collision between the Anatolide-Tauride plate and the Eastern island arc.

Late Paleocene-Early Eocene: continent - island-arc collision

In the Late Paleocene - Early Eocene the continental margin of the Eastern Pontides were imbricated and formed a north-vergent thrust stack. The age of the thrusting is given by the age of the Sipikör formation, which was deposited in a foreland basin in front of the north-vergent İmalidağ thrust sheet. The north-vergent thrusting most probably did not reach farther north than the Bayburt-Pulur basin, although it was felt farther north as a phase of folding, uplift and erosion. For example, in the Berdiga mountains Middle Eocene nummulite and older formations (Pelin, 1977). The north-vergent imbrication of the Eastern Pontide continental margin is caused by the collision of the Eastern Pontide island arc with the Anatolide-

Tauride plate following the complete consummation of the Neo-Tethyan ocean in the region. The deformation ended by the Mid-Eocene, and nummulite-bearing limestones were deposited over a wide region in the Eastern Pontides over a folded and thrust-faulted basement. The ubiquitous Mid-Eocene magmatism observed in the region stutied and thoughout the Eastern Pontides is probably related to a post-collisional regional extension.

CONCLUSIONS

The main conclusions of the study are:

1/In a region of 1200 km^2 in the southern internal part of the Eastern Pontides a north-vergent Alpide thrust stack has been differentiated an mapped. There are important stratigraphic differences among the thrust sheets. When the thrust stack is palinspastically restored, the Jurassic-Lower Cretaceous sequences in the thrust sheets represent facies ranging from shelf in the north to continental margin and ocean floor in the south.

2/ The basement of the Cebre relative authochthon is constituted by an Upper Carboniferous sedimentary sequence. This Upper Carboniferous sequence consists of a lower formation of pebbly sandstone, limestone, quartzite and shale of Kasimovian-Gzelian age, which is conformably overlain by terrigeneous red sandstones and pebbly sandstones.

3/In the Cebre relative authochthon the Carboniferous is unconformably overlain by Jurassic carbonates. Upper Cretaceous siltstone, sandstone, shale, marl and pelagic limestone lie unconformably over the Jurassic carbonates.

4/ In the Hamurkesen thrust sheet, which lies tectonically over the Cebre relative authochthon, the Jurassic sequence consists dominantly of volcan--oclastic rocks and comprises Jurassic limestone blocks derived from the Cebre relative authochthon.

5/ The Asuka thrust sheet, which forms the next higher up thrust sheet, consist of fine-grained Jurassic clastic and volcanoclastic rocks, and-Lower Cretaceous pelagic carbonates. The Jurassic-Lower Cretaceous sequence was deposited in a deeper marine environment than the corresponding sequence in the Hamurkesen thrust sheet. In the Aşutka thrust sheet the Lower Cretaceous pelagic limestones are tectonically overlain by an ophiolitic melange. The ophiolitic melange was emplaced northward over the south-facing passive continental margin of the Eastern Pontides during the Cenomanian-Turonian. The absence of Upper Cretaceous rocks in the Hamurkesen andn Aşutka thrust sheet can be explained by uplift and erosion related to the tectonic emplacement of the ophiolitic melange.

6/An Upper Paleocene-Lower Eocene flysch lies uncorformably over the ophiolitic melange. This flysch was deposited in a foreland basin during the northward imbrication of the Eastern Pontide continental margin. This deformation event was caused by the collision of the Eastern Pontides with the Anatolide-Tauride plate. The Flysch is tectonically overlain by a rootless limestone nappe, which has provided detritus to the flysch. Middle Eocene rocks of post-collisional character lie unconformably over the various thrustsheets and cover the thrusts separating these sheets.

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