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NEOGENE - QUATERNARY STRATIGRAPHY OF KİRAZ - BEYDAĞ VICINITY, KÜÇÜK MENDERES GRABEN, WEST ANATOLIA

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ABSTRACT.- The study area constitutes the eastern end of the Küçük Menderes Graben and is underlain by the Ödemiş-Kiraz Submassif of the Menderes Masif. The Middle Miocene Başova andezite, cut the metamorphic basement and they are calc-alkaline in nature. Basalts and andesites are considered to be the products of the common igneous activity because their trace element compositions. During the Late Middle Miocene time the Kiraz basin way stated to form. In this extensional basin small lakes were formed with algae and ostracoda populations. At the beginning the basin was connected to an open sea but later it was controlled by rivers with alluvial fan deposits. The Suludere formation consist of lacustrine and fluvial sedimentary rocks and yield ostracoda fossils of the Middle to Late Miocene. This formation overlaps the metamorphic basement and the volcanic rocks and unconformably covered by the Aydoğdu formation. This unit consists of alluvial fan deposits which were formed along high angle faults. The Aydoğdu formation includes semiconsolidated poorly sorted and laterally digitated sedimentary rocks. The alluvium covers the youngest depresion. The faults controlled the extensional basin and the geometry of the sediment in fill. These faults are a few kilometers in length and bring the various Neogene units in contact with the older units. The high angle active faults control the present morphology of the area.

Key words: West Anatolia, Küçük Menderes Graben, Neogene- Quaternary continental sedimentary rocks, Neogene volcanism.

INTRODUCTION

There are several studies on the structure of the Küçük Menderes graben (Philippson 1910-1915, 1918, Erinç 1955, Ketin 1968, McKenzie 1978, Dewey and Şengör 1979, Dumont et al. 1979, Angelier et al. 1981, Şengör 1982, 1987, Jackson and McKenzie 1984, Şengör et al. 1984, 1985, Rojay et al. 2001, Emre et al. 2003, Bozkurt and Rojay 2005, Rojay et al. 2005, Emre and Sözbilir 2006 *b*) and Neogene rocks of the region (Ozansoy 1960, Nakoman 1971, United Nations 1974, Kaya 1987, Gemici et al. 1992, Ercan et al. 1996, Emre et al. 2005, Emre and Sözbilir 2006 *a*) which the geological studies have been started many years ago in Western Anatolia (Hamilton and Strickland 1840, Tchihatcheff 1869, Phillipson 1911-1918).

There are different models on the origin and age of extensional tectonic regime dominated Western Anatolia and related graben formation. a- Some investigators suggest that a N-S tension forces originated from westward escape ("tectonic escape") of the Anatolian platelet between the North and East Anatolian Faults during Late Serravallian initiated the formation of the grabens (Dewey and Şengör 1979, Şengör 1979, 1982, 1987, Şengör et al. 1985, Görür et al. 1995). b- Another model suggests that the extensional regime in Western Anatolia started in Early Miocene (McKenzie 1978, Le Pichon and Angelier 1979, 1981, Jackson and McKenzie 1988, Okay and Satır 2000). The "Back arc spreading model" explains that the formation of the grabens are due to back arc spreading of the region caused by the southward N-S tension forces formed as migration of the Aegean Arc. c- According to the "orogenic collapse" model, N-S trended extension dominated Western Anatolia commenced by Late Oligocene-Early Miocene (Seyitoğlu and Scott 1992, Seyitoğlu et al. 1992). d- In the fourth

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model, it is proposed that the extension affected Western Anatolia by two different mechanisms. This model claims that orogenic collapse controlled by low-angle normal faults in Early Miocene is followed by a rifting stage formed under the effect of high-angle faults. The second stage also maintains its development under the effect of North Anatolian fault (Sözbilir and Emre 1996 *b*, Koçyiğit et al. 1999, Bozkurt 2000, 2001 *a*-*b*, 2003, Bozkurt and Sözbilir 2004). Similarly, the relationship between geochemical features of Late Cenozoic volcanism in Western Anatolia controlled by regional tectonic evolution and time is controversial. Geochemical character of the volcanism being active from Late Eocene period (Ercan et al., 1995) up to the recent times (Richardson-Bunbury, 1996) in Western Anatolia, varies from acidic to basic (Ercan et al., 1985, Yılmaz, 1990). This volcanism is considered to be a product of thickened continental crust in the region due to the orogenic activities (Şengör 1980, Şengör and Dewey 1980, Şengör and Yılmaz 1981, Şengör et al. 1984, Fytikas et al. 1984, Pe-Piper and Piper 1989, Gülen 1990, Aldanmaz et al. 2000). According to some researchers, Western Anatolia was under the effect of N-S trend compression during Late Oligocene-Middle Miocene and magmatism commenced when thickened upper continental crust fractionally melted (anatexis) at depths, compressional tectonic regime ended in the presence of WNW-ESE trended extensional regime and NE-SW trended weakness zones, there were generally calcalkaline, continental crust volcanics and some hybrid intracontinental volcanics in these zones. Lithospheric thickness decreases owing to the fact that N-S trend extensional regime commenced in Middle-Late Miocene, and alkaline magmatism of mantle together with E-W trend graben structures existed from the latest Late Miocene-Pliocene to recent (Keller 1969, Borsi et al. 1972, Keller and Villari 1972, Dewey and Şengör 1979, Sunder 1979, Ercan 1981, 1982, 1987, Şengör and Yılmaz 1981, Ercan and Öztunalı 1982, Ercan et al. 1984, Ercan et al. 1985, 1996, Yılmaz 1989, 1990, 1997, 2000, Savaşçın 1990, Savaşçın and Güleç 1990, Güleç 1991, Yılmaz et al. 1994, 2000, 2001). According to some researchers, N-S trending extensional regime has been active since Late Oligocene in West Anatolia and compositional change in associated volcanism is due to the asthenospheric contribution (Seyitoğlu and Scott 1991, 1992, Seyitoğlu et al. 1992, 1997).

It is considered that E-W trending Küçük Menderes valley is one of numerous E-W and WNW-ESE trending grabens like Gediz and Büyük Menderes developed under the effect of approximately N-S tension forces based on the conducted studies (Philipson 1910-1915, 1918, Ketin 1968, McKenzie 1978, Jackson and Mc Kenzie 1984, Şengör 1987, Şengör et al. 1984). It is reported that a significant, northward dipping fault is traced at western half of the south rim on Küçük Menderes valley (Erinç 1955, Şengör et al. 1985) and through just southeast of Ephesus ancient city (Dumont et al. 1979, Angelier et al. 1981) to Aegean Sea. Rojay et al. (2001 and 2005) state that Küçük Menderes Graben develops on an E-W trended syncline among Beydağ-Gökçen-Tire-Belevi. There are three stages of the deformation and a counterclockwise rotation movement in the region after Miocene period. Strike-slip regime in the first stage, caused by N-S compression, is followed by WSW-ENE trending extensional regime with a strike slip component, and in the last stage seismically active at the present in which NW-SE and NE-SW extensional regime is dominant. To Bozkurt and Rojay (2005), a short-ranged N-S trending compressional stage is present between the extensional phases forming low- and high-angled normal faults in the region, respectively.

Only few of the previous studies are related with the Neogene rocks at the eastern part of Küçük Menderes Graben which is a subject of this article (United Nations 1974, Ercan et al. 1996, Rojay et al. 2001, Emre et al. 2003, Bozkurt and Rojay 2005, Emre et al. 2005, Rojay et al. 2005, Emre and Sözbilir 2006 *a*).

Rojay et al. 2001 and 2005 suggest that secondary basins, on which Neogene-Quaternary clastics deposited and developed at various directions, exist on the Küçük Menderes Graben. Of these, Miocene-Quaternary aged sediments have deposited in Kiraz, Dağkızılca-Torbalı and Selçuk regions and Quaternary sediments have deposited in Ödemiş and Bayındır areas. Bozkurt and Rojay (2005) and Rojay et al. (2005) have no paleontological and radiometric evidences for the age determination of the sedimentary and volcanic rock units in Kiraz basin.

In this study, with using paleontological and radiometric age determinations Neogene-Quaternary rock units were discerned (Figure 1). Firstly determined micropaleontological evidences and the radiometric age data of the volcanics in the region confirm eachother. In this article, stratigraphy of the sediment filling, the facies properties and findings related the age of Kiraz basin will be given in details (Emre ve Sözbilir 2006 *a*), and the Neogene aged volcanics which is a subject to another paperwill be shortly discussed.

STRATIGRAPHY

Precambrian-Mesozoic aged schists, marbles, orthogneisses, paragneisses and metagabbros of Ödemiş-Kiraz Submassif in Menderes Masif constitute the basement rocks (Candan et

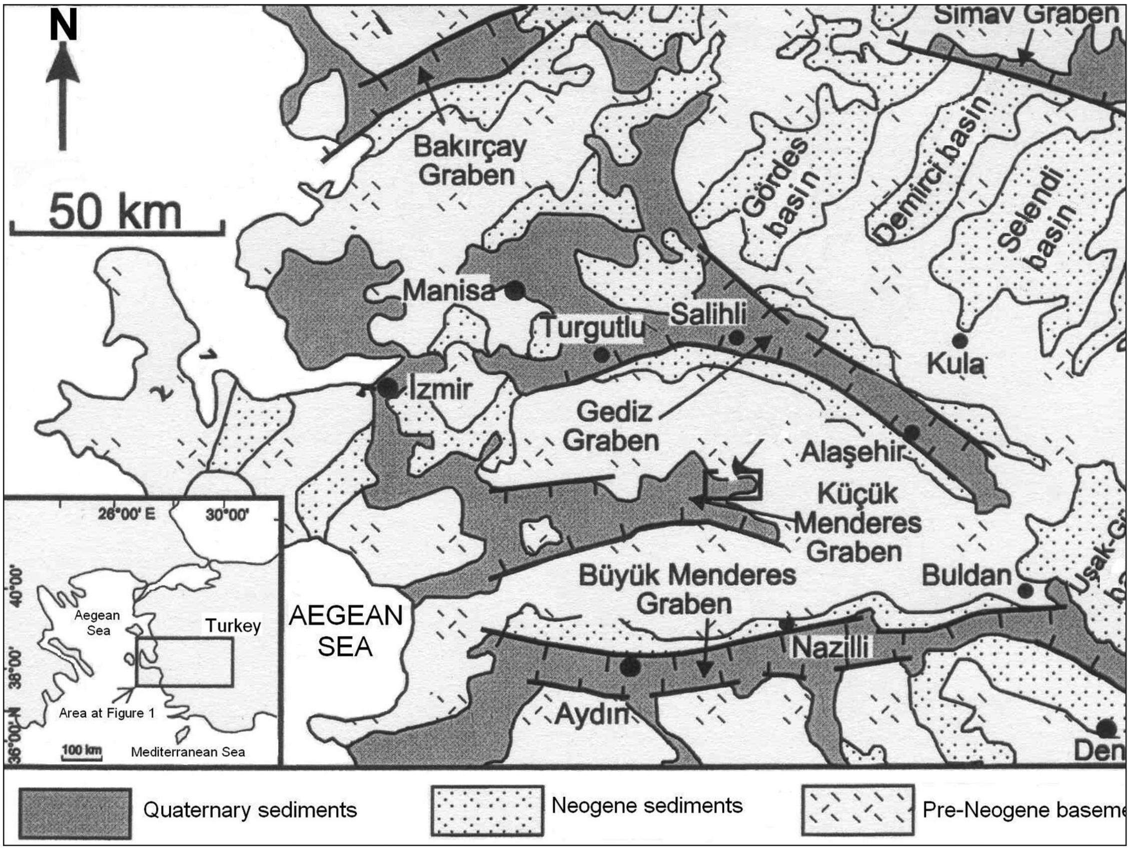

Figure 1- Location of the Study Area (modified from Bozkurt, 2000).

al., 2001). Başova andesites, Suludere formation, Aydoğdu formation and alluvium overlay this basement unconformably (Figure 2).

BAŞOVA ANDESITES

Başova andesites which exposed at three localities (Figure 3) are composed of dykes,

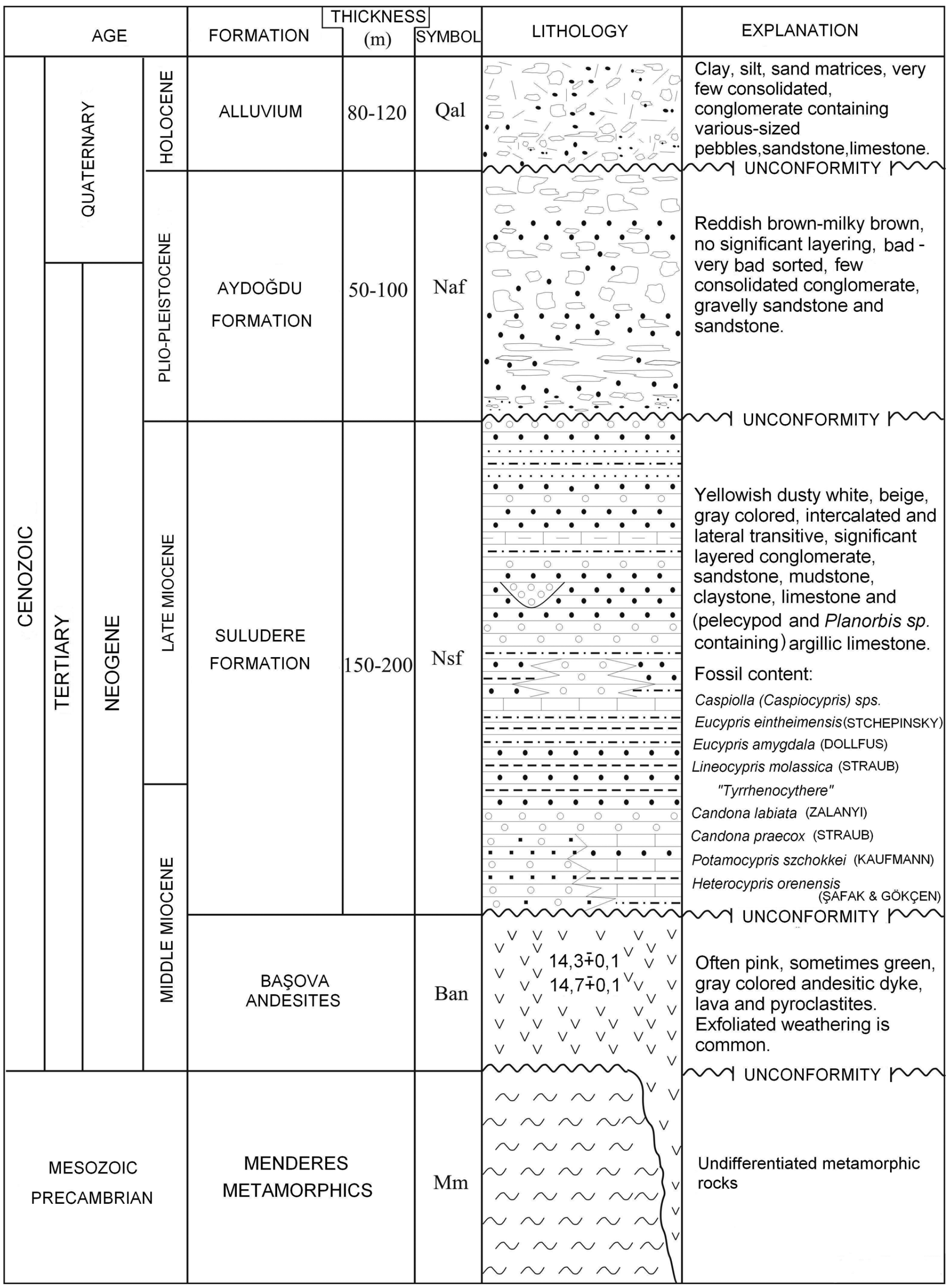

Figure 2- Generalized Stratigraphic Column of the Study Area.

lavas, volcanic breccias and pyroclastites. Volcanics mainly composed of andesites and basaltic andesites, are generally pink, gray and greenish gray in color. These volcanic rocks owning hypocrystalline porphyritic and some hyalopilitic textures contain phenocrysts of plagioclase, biotite, amphibole and pyroxene minerals. The matrix is composed of glass-microlites. Microlites have no obvious orientation, but some are observed as to circle some of the phenocrysts. The various-sized xenoliths of schist and gneiss including andesites, where intrude metamorphic rocks, commonly tend to display limonitisation and kaolinitisation. Radiometric age ($^{40}Ar/^{39}Ar$) of the weathered parts of which are yellowish, orange and red colored, of the volcanic rocks is among 14,3±0,1 and 14,7±0,1 million years (Emre and Sözbilir 2006 *a*). Trace element distributions of these calcalkaline andesitic rocks which there is a small difference of age between them, point out that those are derived from probably a similar source. Trace element and rare earth element variation diagrams of volcanic rocks generally resemble the pattern of calc-alkaline arc volcanic rocks or orogenic volcanic rocks (Emre and Sözbilir 2006 *a*).

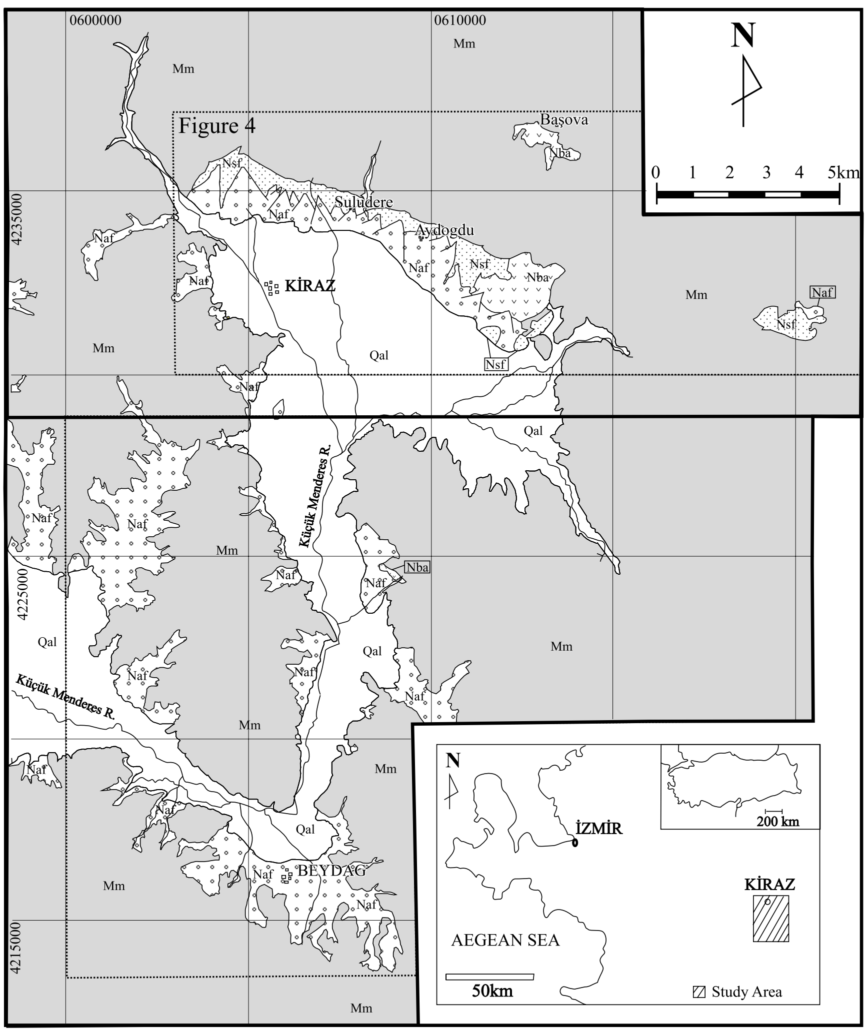

Figure 3- Simplified Geological Map of Kiraz - Beydağ Vicinity.

SULUDERE FORMATION

Definition

The unit exposed around Kürlüorman Hill, 8 km east of Taşlı Hill in the north and northeast of Kiraz covers a total area of 7 km², in addition, it is exposed in small areas on N and S rims of the Küçük Menderes River valley in the North of Beydağ and around Avunduruk area, 8 km southeast of Kiraz (Figure 4 and 5). Because the best observed outcrops are around Suludere, the formation is called as "Suludere formation". Generally yellowish, dusty white, beige and some gray and greenish gray colored unit consists of lacustrine and fluvial sediments.

Lithology

The unit presents a succession including varies in composition, color, texture and thickness of conglomerates, gravelly sandstones, sandstones, mudstones, clayey limestones and limestones displaying vertical and horizontal transitions, intercalations, interfingering and interlayerings. Thickness of lacustrine carbonate deposits, often found at bottom levels of the sequence, is less than 12 meters.

Conglomerates are of yellow-orange, milky white, gray-dusty white colored, bad-medium (some well) consolidated, and medium-thick-very thick layered. These sediments, generally half-matured and some unmatured or matured, have a range of very bad to well sortings. Sometimes normal or reverse gradings are seen from bottom to the top. Conglomerate occasionally pass to gravelly sandstones and the latters also pass to sandstones. Often angular, jagged edged, round or platy gravels have a low sphericity. Gravels have a ratio of between 20 % - 80 %, and a varying sizes between few millimeters to large boul-

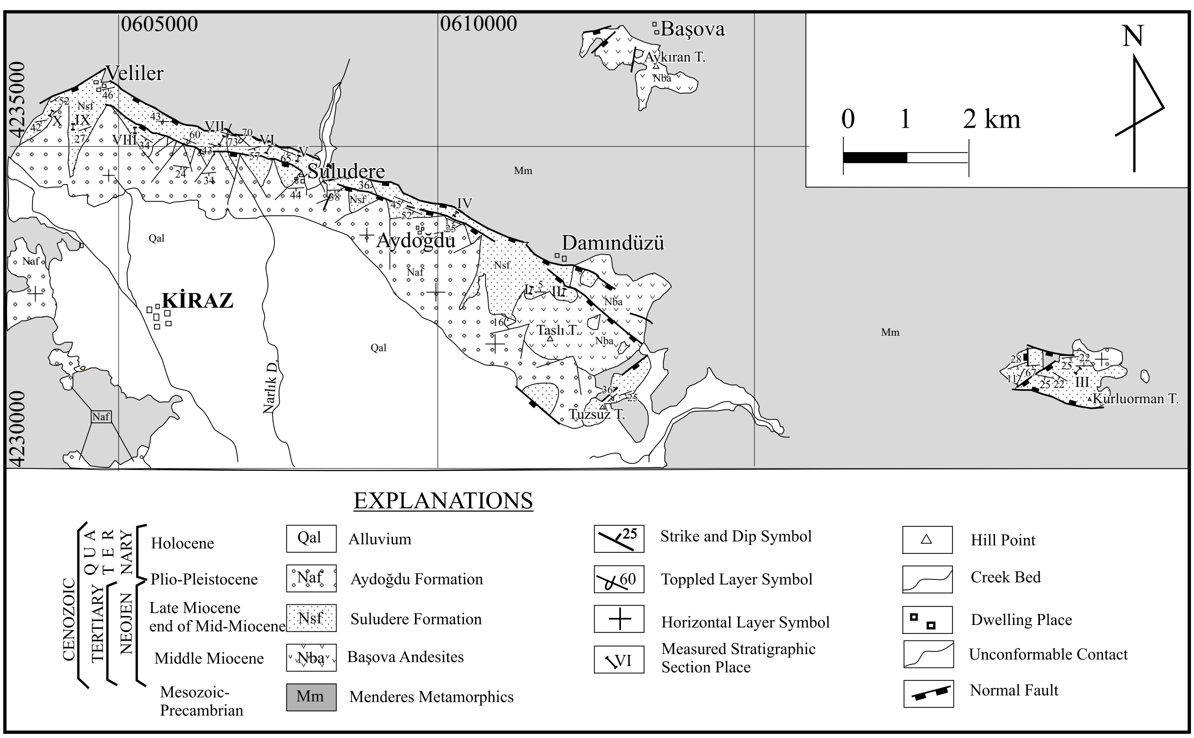

Figure 4- Geological Map of Kiraz Region.

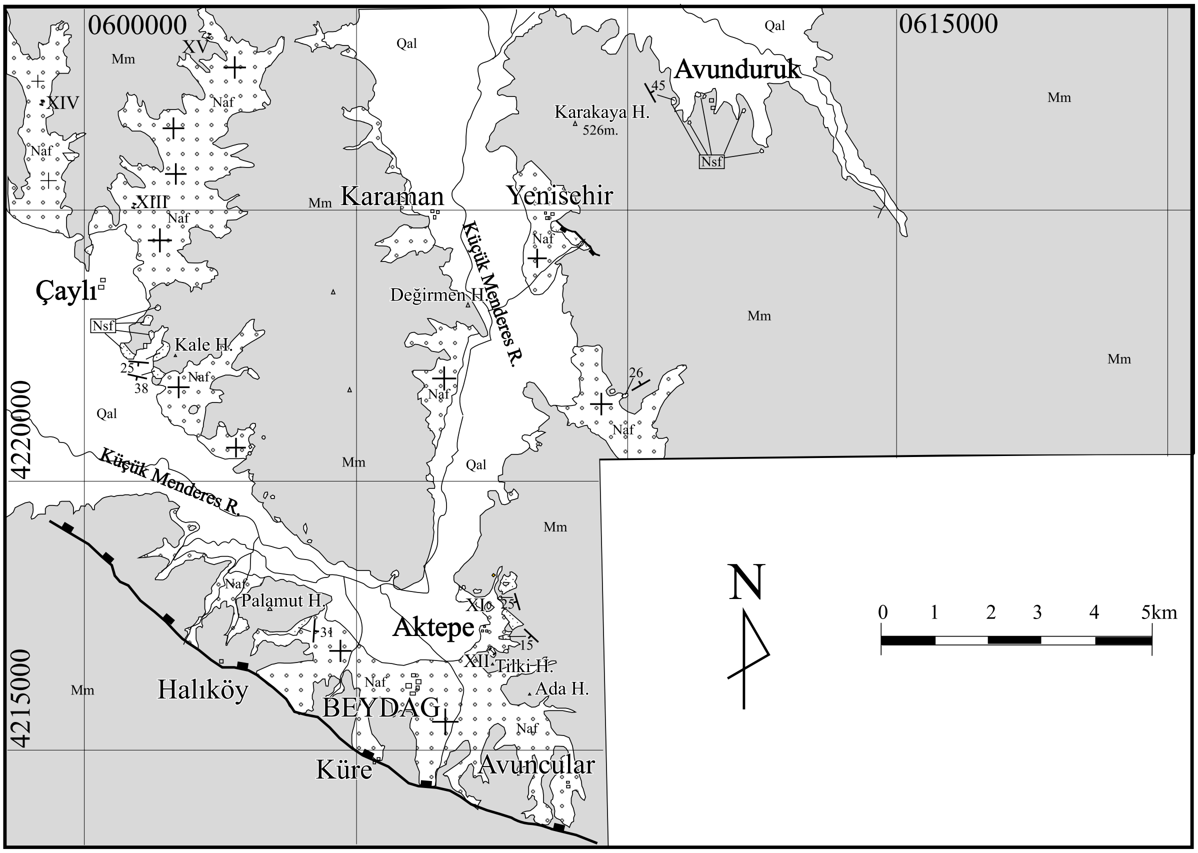

Figure 5- Geological Map of Beydağ Region (see Figure 4 for the Explanation).

ders (rarely 80-90 x 60 cm). Nearly all grains were derived from metamorphics. The ratio of andesitic pebbles seen occassionally seems to be up to 1 %. The ratio of metamorphic derived gravels changes: Dominant grain type depends on the supply area. In some parts, they may contain 60 % of marble, 20 - 30 % of schist and of minor quartzite or 60 % of schist, 20 - 30 % of marble, in some places 60 - 90 % of gneiss and remaining schist and metaquartzite, sometimes 45 % of schist and 50 % of gneiss. Conglomerates with matrix- or grain-supported texture have generally fine-coarse sand, fine gravel-coarse sand and some clay-sand matrices. At the lower parts of the succession, the cement is composed of algal limestone or of clayey-silty-sandy carbonates. Conglomerates have some interfingers and lenses of sandstone and gravelly sandstone with varying thicknesses. Conglomerate levels, displaying different packing and sorting properties are intercalated or well sorted conglomerates include badly sorted conglomerate lenses. Long axis of gravels or large surfaces of platey gravels are generally parallel to stratification.

Sandstones are dusty white, gray, milky white-beige, greenish, yellowish, milky brown colored, often few-medium, some well and some very few consolidated, and generally fine, some very fine or medium-coarse grained, and often medium-thick, rarely laminated, thin or very thick layered. They rarely display cross-stratification. The regular layers generally have some fining upward. Occasionally gravelly, coarse grained sandstones at the base change upward to fine grained sandstones and some claystones or clayey-sandy limestones. Sandstones contain bird's eye voids, fine angular andesitic gravels and oval carbonate nodules in some parts, and have a black-gray dotted appearance thanks to abundant mica flakes. Sandstones are sometimes intercalated with conglomerates or mudstones, and they have some lenses or interfingers of gravelly sandstone and conglomerate, rarely claystone, milky white clayey limestone or limestone.

Gravely sandstones are greenish-light gray, light brick red, light brown colored, and medium-well consolidated, and well-medium sorted, and medium-thick layered. These levels changing to conglomerate and sandstone or display succession with them may include some interfingers of mudstones. Grain size of scattered gravels within medium-coarse grained sandstones range from 3 mm to 5-10 cm, but dominant grain size is between 2-3 cm and 5-6 cm. They also include scarce small andesite gravels smaller than 5 cm or 8-10 cm long platy schist gravels. Long axis of the gravels or wide surfaces of platy gravels seem to be parallel to the stratification in general.

Claystones and mudstones are gray, beige, reddish, light brown, light gray, greenish gray colored, and generally bad-medium packed, some well packed, poorly compacted, and medium-thick, some fine layered or laminated. These levels, which are intercalated with each other, may be lenses or interfingers of another level. Mudstones intercalated with clayey limestones or sandstones sometime, may include some lenses or interfingers of sandstones, conglomerates, gravelly sandstones, gravelly mudstones, clayey limestone and limestones. Claystones and mudstones have rare *Planorbis* sp. fossils, calcareous nodules or scattered pebbles.

Limestones are dusty white, beige, milky white, light gray, milky brown colored, and fine-medium and thick layered, and compacted (Plate 1-a). Limestones contain algal-wrapped reed spikes, intraformational gravels, small oval limestone nodules, spherical algal bioherms with varying diameter between 3-5 cm and 25 cm (Figure 6), oncoidal stromatolites, and pelecypod and Planorbis sp. fossils (Plate 1-d). Some of the voids caused by rotting algal-wrapped reeds or other plant fragments have calcite-crystalled walls. Limestones, which are of a spotted appearance, silicified and manganous dendrites in some parts, are considerably tough. Algal limestones comprising superposed algal bioherms or semi-spherical stromatolites (Plate 1-b) laterally pass to sandy or clayey limestones. Sandy limestone levels are less observed than clayey limestone levels.

Algal limestones are intercalated with sandy and clayey limestones (Plate 1-c), laterally and

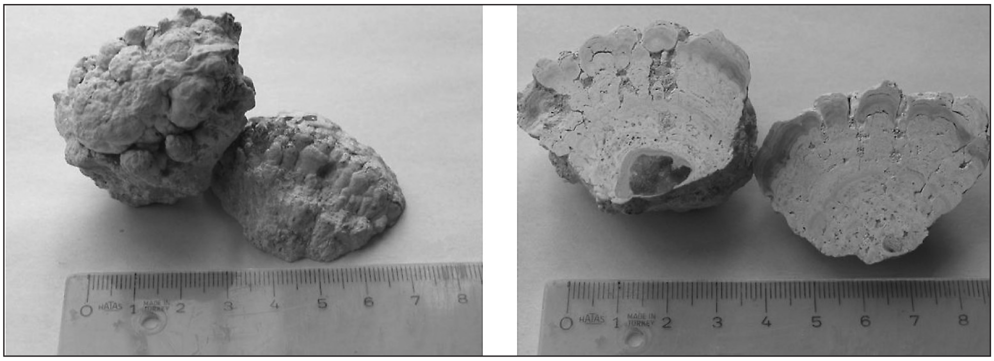

Figure 6- (a) Exterior and (b) Polished Surface Views of Spherical-Subspherical Algal Bioherms.

vertically passing to sandstones and mudstones in some places, and mudstones in some places. Light gray-beige clayey limestones are composed of layers between 2 and 30 cm thick, and include some 1-2 mm wide bird's eye voids, plant spikes or angular-jagged schist or andesite gravels with varying size between 2 mm and 3-4 cm.

The sequence I, seen at 700 m north-northwest of Taşlı Hill, has a thin basal conglomerate level at the top followed by limestone-mudstone intercalation. Sandstones are dominant. There are limestone (Plate I-e), claystone and mudstone levels between sandstones (Figure 7, see Table 1a- for fossil content of the samples).

The sequence II observed at 600 m north of Taşlı Hill, is composed of sandstones with thin clayey limestone and conglomerate levels, underlain by andesites and conglomerates (Figure 8, see table 1b- for fossil content of the samples). Clayey limestones, which have varying thickness between 3 and 8 cm (Plate I-f), contain plant spikes and small angular-sub-angular andesite gravels.

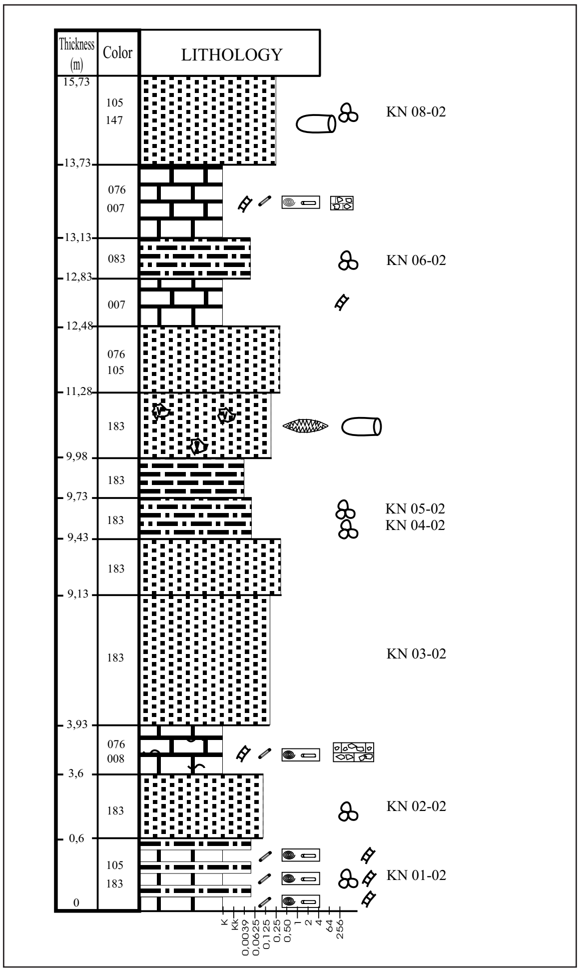

Figure 7- Part of Measured Stratigraphic Section from Suludere formation (11555/32670) Section I (N of Taşlı Hill). (see Figure 30 for the Explanation).

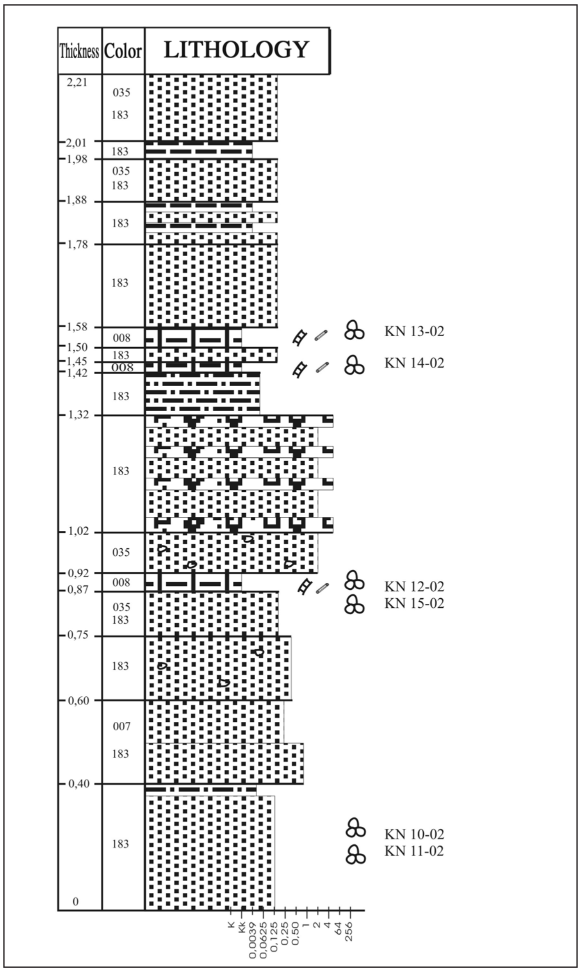

Figure 8- Part of Measured Stratigraphic Section from Suludere formation (11860/32890) Section II (N of Taşlı Hill). (see Figure 30 for the Explanation).

Table 1- Fossil Content of Measured Section Localites

Sample No	Fossil content (SECTION I)
KN 01-02	*Globigerinoides trilobus* (REUSS) *Globoquadrina dehiscens* (CHAPMAN PARR COLLİNS) *Globorotalia obesa* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY)
KN 02-02	*Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI
KN 03-02	*Orbulina universa* d'ORBIGNY *Globoquadrina dehiscens* (CHAPMAN PARR COLLINS) *Globigerinoides trilobus* (REUSS) *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI *Hastigerina* cf. *siphonifera* (d'ORBIGNY)
KN 04-02	*Globorotalia* cf *obesa BOLLI* *Orbulina universa* d'ORBIGNY *Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Globoquadrina* cf *altispira* (CUSHMAN ve JARVIS) *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globigerinoides trilobus* (REUSS) *Globigerinoides obliquus* BOLLI
KN 05-02	*Globorotalia* cf *obesa* BOLLI *Globigerinoides obliquus* BOLLI *Globigerinoides trilobus* (REUSS)
KN 06-02	*Globigerinoides trilobus* (REUSS) *Globigerinoides* cf. *obliquus* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI
KN 08-02	*Globorotalia obesa* BOLLI Undetermined, badly preserved Foraminifera like *Globigerina, Globigerinoides.*

a

Sample No	Fossil Content (SECTION II)
KN 10-02	*Globigerinoides trilobus* (REUSS) *Orbulina universa* d'ORBIGNY *Globoquadrina dehiscens* (CHAPMAN PARR COLLINS) *Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Globorotalia* cf. *menardii* (d'ORBIGNY)
KN 11-02	*Globorotalia obesa* BOLLI *Globigerinoides* cf. *obliquus* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY)
KN 12-02	*Globorotalia* cf. *menardii* (d'ORBIGNY) *Globigerinoides* cf. *obliquus* BOLLI *Globigerinoides trilobus* (REUSS) *Globorotalia obesa* BOLLI *Orbulina universa* d'ORBIGNY
KN 13-02	*Globorotalia obesa* BOLLI Undetermined Foraminifera like *Globigerina, Globigerinoides*.
KN 14-02	*Globorotalia obesa* BOLLI *Globigerinoides trilobus* (REUSS) *Globigerinoides* cf. *obliquus* BOLLI
KN 15-02	*Globorotalia* cf. *obesa* BOLLI *Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Globorotalia* cf. *mayeri* CUSHMAN ve ELLISOR *Globigerinoides* cf. *obliquus* BOLLI *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS) *Orbulina universa* d'ORBIGNY

b

The sequence III, seen in the north of Kürlüorman Hill starting with a mudstone-claystone intercalation has sandstones as dominant unit (Figure 9, see table 2 for fossil content of the samples). Lenses and interfingers of gravelly sandstone, conglomerate and mudstone within the sandstones are less than 15 cm thickness. Lateral extention of mudstone and claystone lenses is about 1-2 m. Lenses and interfingers of clayey-sandy limestone have thicknesses up to 25 cm. Conglomerates have carbonate and sandy cements with lateral and vertical transitions. At algal limestone-clayey limestone cemented levels, various-sized grains between 4-5 mm and 50-60 cm are wrapped and encrusted by algal limestones. Dusty white-beige colored limestones are composed of superposed algal bioherms and few gravels (Plate 2-a). Gravels, often marble, are less than 15 cm size with medium-coarse grained sand matrix.

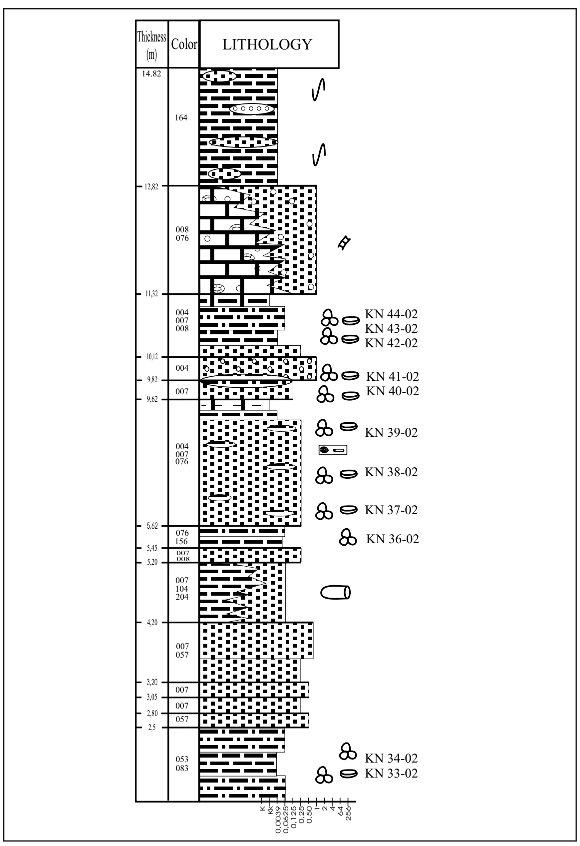

Figure 9- Part of Measured Stratigraphic Section from Suludere formation (19935/31540) Section III (N of Kürlüorman Hill). (see Figure 30 for the Explanation).

The sequence IV, seen at Çömlekçi vicinity, contains sandstone mudstone intercalations, limestone-clayey limestones, clayey limestones with mudstone interfingers and sandstone-mudstone levels, all underlain by conglomerates with thin sandstone levels (Figure 10, see table 3a for fossil content of the samples). Various-sized constituents between 3 mm and 20 cm are often 2-6 cm. Rarely observed lime cemented levels of the conglomerates pass laterally to gravelly-clayey limestones.

The sequence V observed at 250 m north of Suludere Village, is mainly composed of sandstones, mudstones and conglomerates. The sequence begins by sandstones and mudstones, and lasts by conglomerates, gravelly sandstones and sandstones, and ends by conglomerates (Figure 11). Lens-shaped interfingers are between 15 and 28 cm thick. Gravels have various sized between 2-3 mm and 50cm. Dominant grain size is between 2-3 cm and 5-6 cm in conglomerates, and between 2-3 cm and 5-6 cm in gravelly sandstones.

The sequence VI seen at NW of Suludere Village, begins by conglomerates and sandstones, lasts by mudstones, gravelly sandstones and sandstones, and ends by conglomerates (Figure 12, see table 3b for fossil content of the samples). Gravelly sandstones have gravel sizes between 4 and 5 cm, conglomerates have between 1 and 15 cm, but dominant grain size is between 3 and 8 cm.

The sequence VII observed at 150 m northwest of Suludere Village, is mainly composed of conglomerates, sandstones and mudstones. The sequence begins by gravelly sandstone-conglomerate and lasts by conglomerates, gravelly sandstones, sandstones and mudstones. Rarely

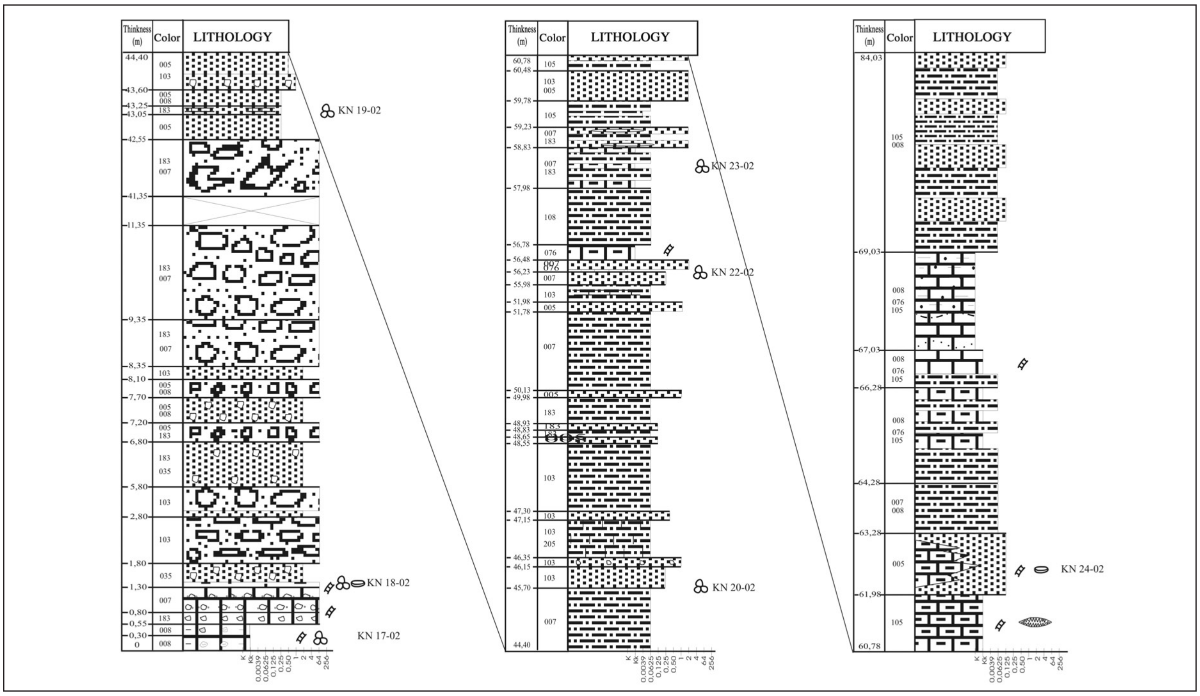

Figure 10- Part of Measured Stratigraphic Section from Suludere formation (10390/33970) Section IV (NW of Aydoğdu Village). (see Figure 30 for the Explanation).

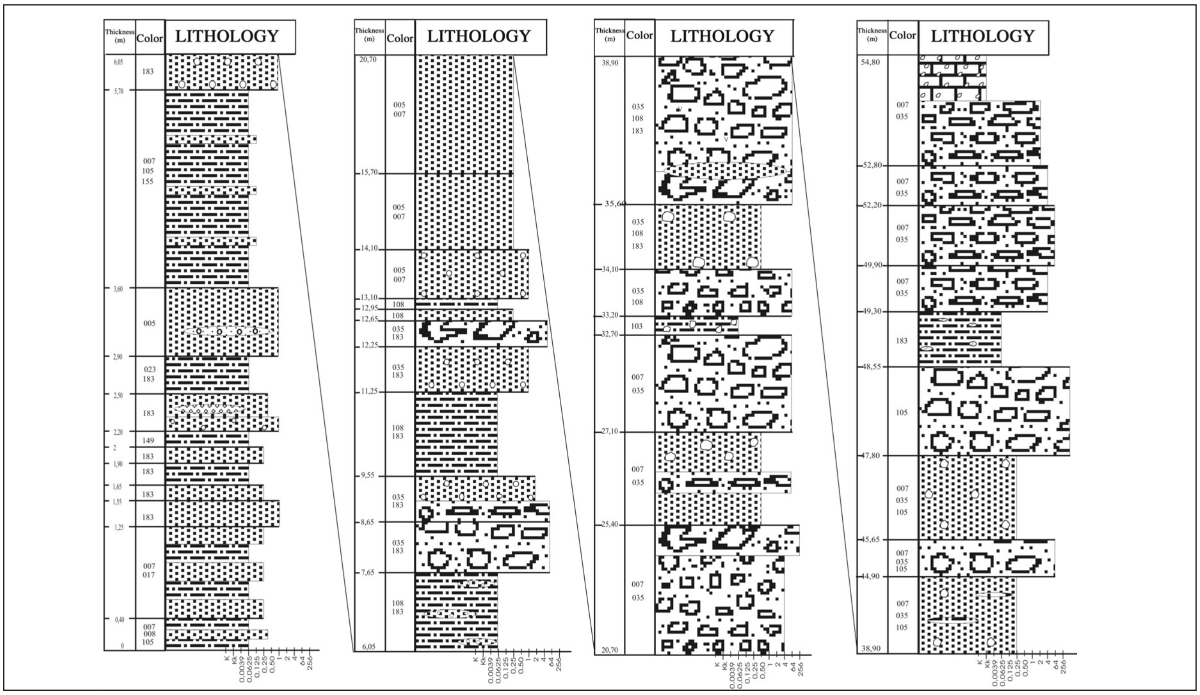

Figure 11-Part of Measured Stratigraphic Section from Suludere formation (07695/34985) Section V (N of Suludere Village). (see Figure 30 for the Explanation).

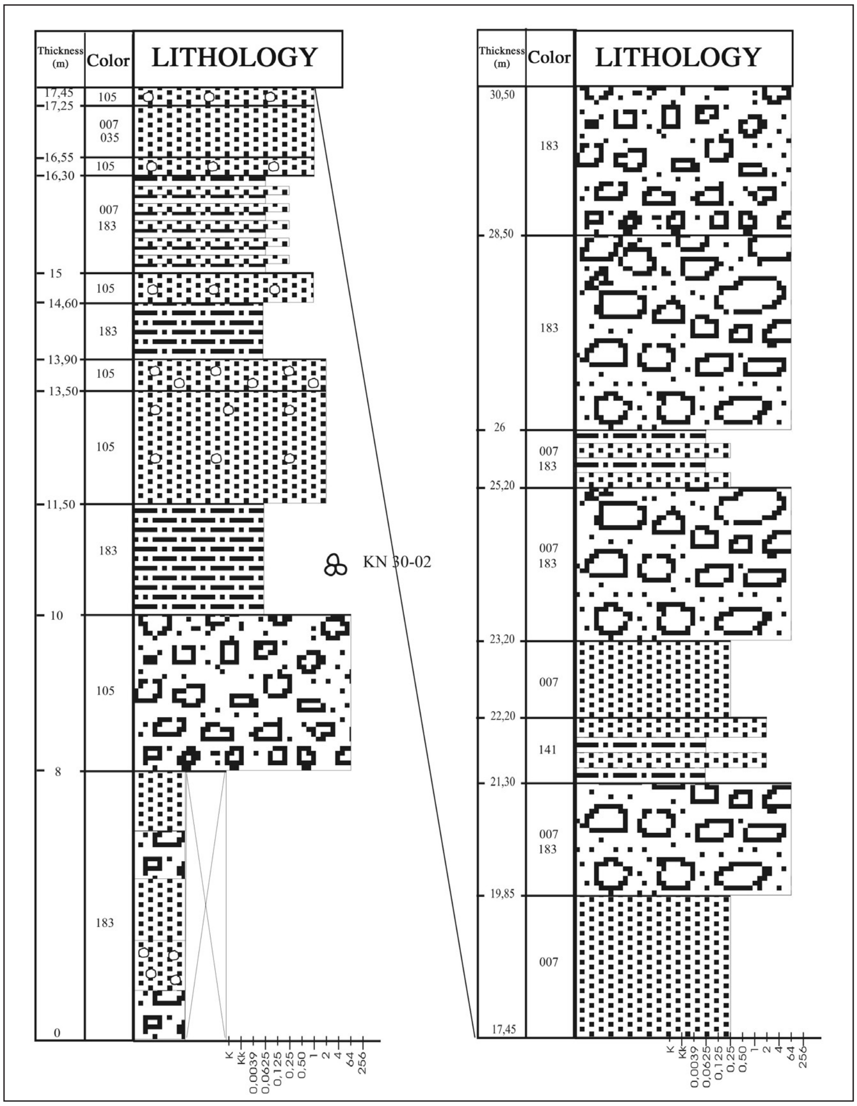

Figure 12- Part of Measured Stratigraphic Section from Suludere formation (07300/35050) Section VI (NW of Suludere Village). (see Figure 30 for the Explanation).

including claystone and clayey limestone interfingers, the sequence ends by mudstones (Figure 13, see table 2c for fossil content of the samples). Various-sized constituents between 3 mm and 40 cm are often between 3 mm and 5 cm.

The sequence VIII, seen at 650 m. to the southeast of Veliler village, is mainly composed of conglomerates, sandstones and gravelly sandstones. The sequence begins with sandstones containing of scattered gravels and conglomerates, and lasts by intercalated and interfingered successions of conglomerates, gravelly sandstones and sandstones with passing laterally and vertically each other (Figure 14). Various-sized constituents between 3-4 mm and 15 cm are often between 2 and 5 cm. 60 - 70 % of the constituents are derived from gneiss.

Table 2- Fossil Content of Measured Section Localites

Sample No	Fossil Content (SECTION III)
KN 33-02	**Ostracod:** *Candona sps.* **Foraminiferid**:*Globigerinoides* cf. *obliquus* BOLLI
KN 34-02	*Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Globigerinoides* cf. *obliquus* BOLLI
KN 36-02	*Globigerinoides* cf. *obliquus* BOLLI *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS)
KN 37-02	**Ostracod (Freshwater):***Eucypris amygdala* (DOLLFUS) *Candona (Caspiocypris) labiata* (ZALANYI) *Candona (Candona) kirchbergensis* (STRAUB) *Paracypris bouldnorensis* KEEN *Ilyocypris* sp. *Orbulina universa* d'ORBIGNY *Globigerinoides* cf. *obliquus* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY)
KN 38-02	*Globigerinoides* cf. *obliquus* BOLLI *Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Orbulina universa* d'ORBIGNY *Candona labiata* (ZALANYI) (Freshwater ostracod)
KN 39-02	*Globigerinoides* cf. *obliquus* BOLLI *Hastigerina* cf. *siphonifera* (d'ORBIGNY) *Globorotalia obesa* BOLLI *Globorotalia* cf. *scitula scitula* (BRADY) *Candona labiata* (ZALANYI) (Freshwater ostracod)
KN 40-02	*Orbulina universa* d'ORBIGNY *Candona labiata* (ZALANYI)
KN 41-02	*Orbulina universa* d'ORBIGNY *Globigerinoides trilobus* (REUSS) **Ostracod:***Candona labiata* (ZALANYI) *Candona praecox* (STRAUB) *Potamocypris szchokkei* (KAUFMANN) *Heterocypris orenensis* ŞAFAK&GÖKÇEN *Eucypris eintheimensis* STCHEPINSKY
KN 42-02	*Globorotalia* cf. *mayeri* CUSHMAN ve ELLISOR *Orbulina universa* d'ORBIGNY *Globigerinoides trilobus* (REUSS) *Globigerinoides* cf. *obliquus* BOLLI *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS) *Globorotalia obesa* BOLLI *Hastigerina* cf. *siphonifera* (d'ORBIGNY) **Ostracod:***Candona praecox* (STRAUB) *Eucypris eintheimensis* STCHEPINSKY
KN 43-02	*Globoquadrina* cf *altispira* (CUSHMAN ve JARVIS) *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI *Globigerinoides trilobus* (REUSS) *Globigerinoides* cf. *obliquus* BOLLI **Ostracod:***Caspiolla (Caspiocypris) sps.* *Candona praecox* (STRAUB) *Eucypris eintheimensis* STCHEPINSKY *Eucypris amygdala* (DOLLFUS) *Lineocypris molassica* (STRAUB) *"Tyrrhenocythere"*
KN 44-02	*Globigerinoides obliquus* BOLLI *Globigerinoides* cf. *trilobus* (REUSS) *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS) *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI *Lineocypris* cf. *molassica* (STRAUB) *Eucpris* sp. *Candona lycica* FREELS

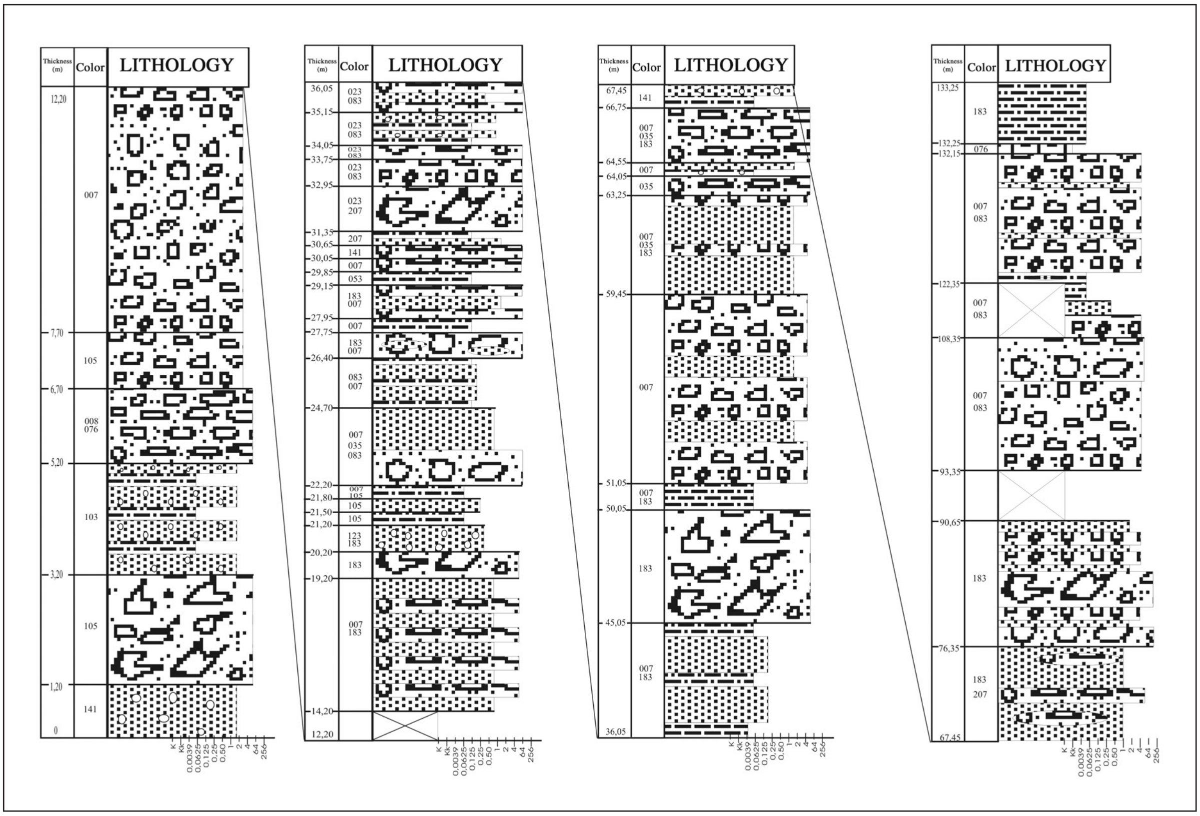

Figure13- Part of Measured Stratigraphic Section from Suludere formation (06760/35165)Section VII (NW of Suludere Village). (see Figure 30 for the Explanation).

The sequence IX located in southwest of Veliler is mainly composed of conglomerates and sandstones. The sequence begins by well-sorted conglomerates and lasts by gravelly sandstones and sandstones. Dominant lithology is conglomerate (Figure 15). Various-sized clastics between 2-3 mm and 45 cm are abundant between 3-4 mm and 8-10 cm. There are very rare blocks up to 90x60x35 cm in size.

The sequence X located in southwest of Veliler Village, is composed of poor-medium consolidated conglomerates and sandstones. The sequence begins with conglomerates containing of sandstone and gravelly sandstone levels, and lasts by sandstone-conglomerate intercalations, conglomerates and sandstone-gravelly sandstone-mudstone levels, and ends up with sandstone-conglomerate intercalation (Figure 16). Various-sized constituents between 3-4 mm and 60 cm are abundant between 3-4 mm and 2 cm. The constituents are often derived from gneisses.

The sequence XI, located at 1,5 km to northeast of Beydağ, is composed of medium-consolidated mudstones and sandstones. The sequence begins with mudstones, and lasts by conglomerates, conglomerate-sandstone and sandstone-conglomerate intercalations. At some places conglomerates change upwardly to sandstones and sandstones to conglomerates (Figure 17). Often few rounded - subangular and less than 1 cm size, gravels have a low sphericity.

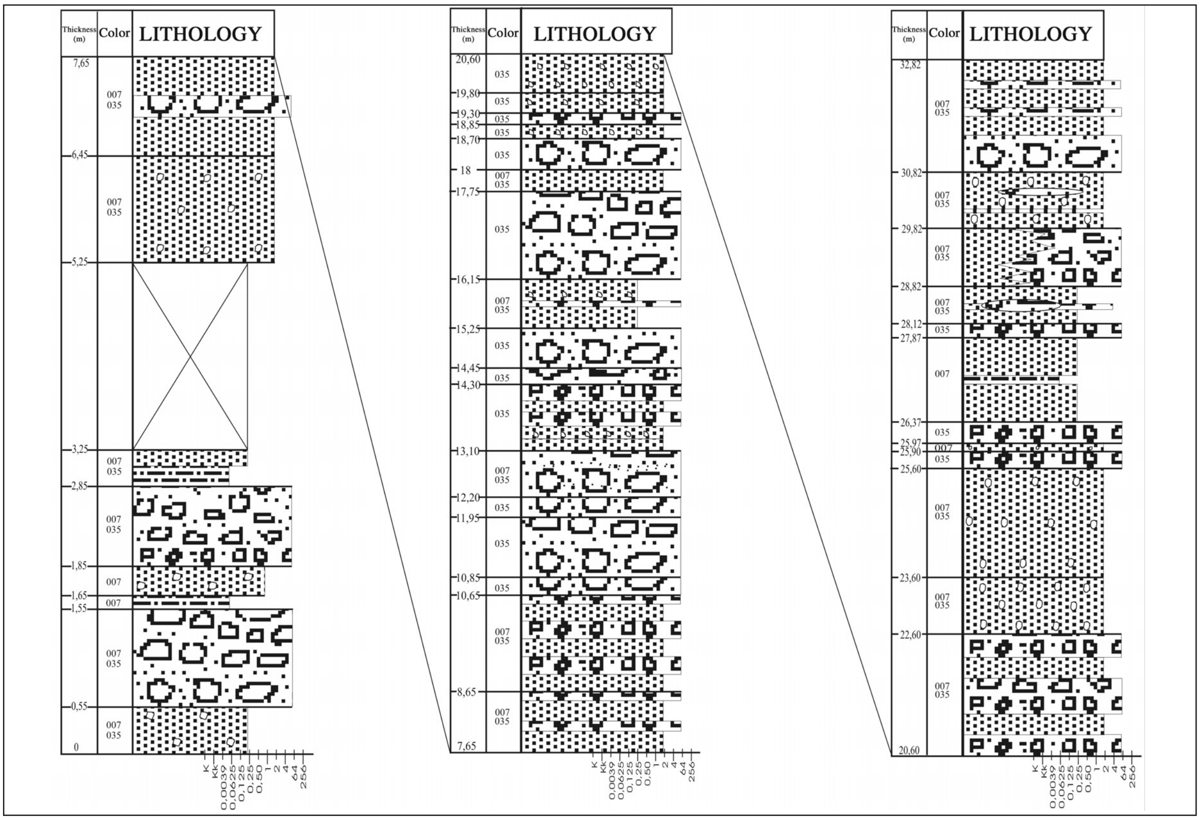

Figure 14- Part of Measured Stratigraphic Section from Suludere formation (05207/35207) Section VIII (SE of Veliler Village). (see Figure 30 for the Explanation).

The sequence XII observed at south of Beydağ-Aktepe Village, is mainly composed of sandstones and conglomerates. The sequence, beginning with conglomerates, continues with sandstones, interfingered with mudstone and limestone, conglomerates containing of sandstone lenses, sandstones and conglomerates (Figure 18). Various-sized gravels, changing between 2-3 mm and 20 cm, but mostly between 5 mm-2 cm and 6-7 cm, are generally derived from gneisses.

The Contact

Suludere formation, unconformably underlain by Menderes Massif Metamorphics and Başova andesites, begins with basal conglomerates including some badly sorted, clay-sand matrices and some carbonate cements (Figures 19 and 20). These conglomerates have no significant stratification and has bad sortings. At 600 m north of Taşlı Hill, conglomerate constituents underlain by andesites are generally angular, various-sized andesite gravels between 2-3 mm and 50 cm (Figure 20). The contact between Suludere formation and metamorphic rocks on Damındüzü-Veliler is faulted along a NW-SE trended line. Suludere formation is overlain by Aydoğdu formation and alluvium with an angular unconformity.

Age

Palynological samples from clayey levels of Suludere formation have not yielded an age. Freshwater ostracods at clayey - carbonate lev-

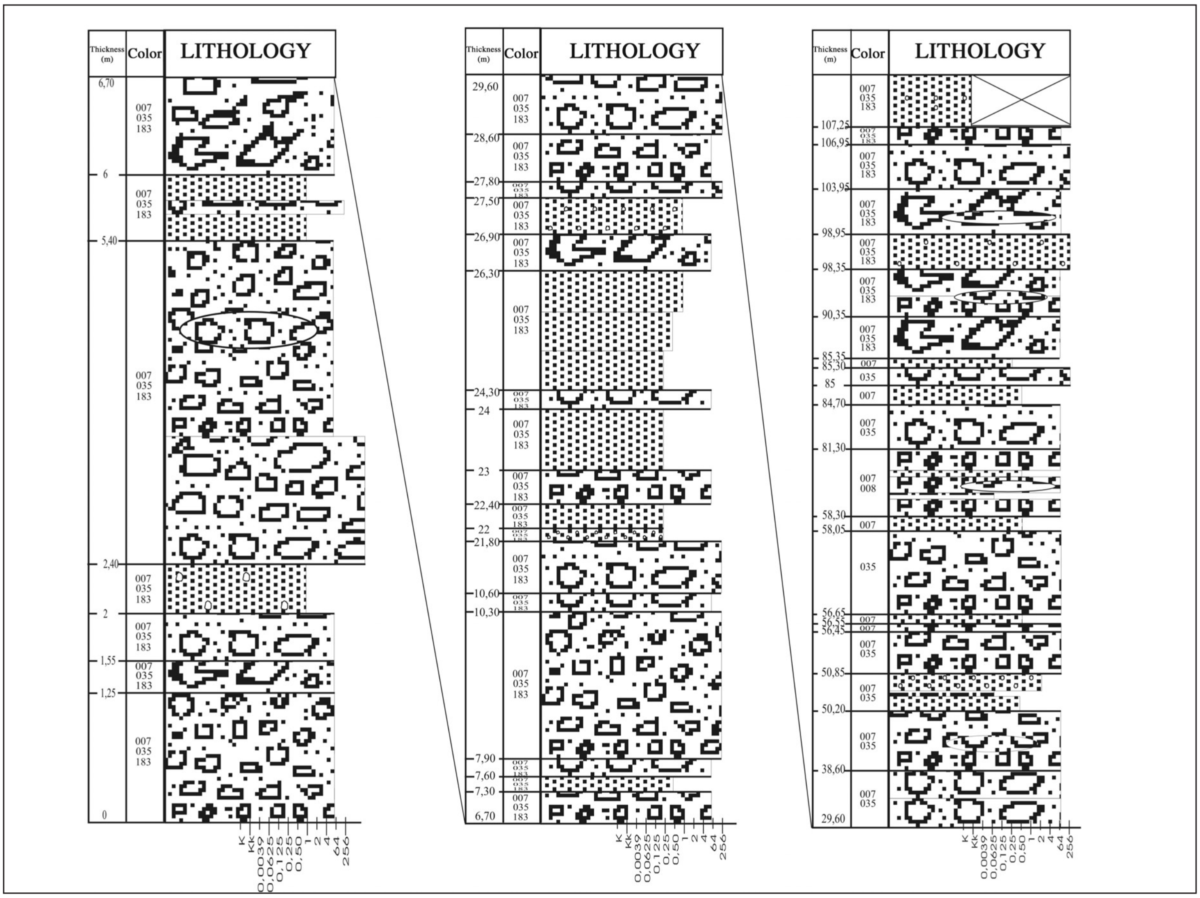

Figure 15- Part of Measured Stratigraphic Section from Suludere formation (04370/35295) Section IX (SW of Veliler Village). (see Figure 30 for the Explanation).

els of the formation (Table 3-2a) give an age of the latest Middle Miocene-Late Miocene. Taking into consideration of Suludere formation overlying Başova andesites (14,7±1- 14,3±1 My) with an unconformity, the radiometric and paleontological age data seem to be consistent.

Comment

Beginning of the Suludere formation with a basal conglomerate, having a limestone and clayey limestone cement and continuing with limestone-clayey limestone and mudstone levels with planktonic and benthonic foraminifers and freshwater fossils on the basement at many places, indicate the formation to start to deposit on a low energy, shallow lacustrine environment connected to an open sea. The lithological composition in the lakes depends on input of clay and silt amounts.

Very bad preserved foraminifers might have been washed in by surface currents which have connections to open sea and probably carried to the depositional environments by them. That lacustrine ostracods increase at upper levels of the formation and only freshwater ostracods are found which attributed to open sea contribution to these coastal lakes ended when basin floor uplifted/filled as clastic supply increased due to tectonic activity and/or climatic conditions.

Table 3- Fossil Content of Measured Section Localites

Sample No	Fossil Content (SECTION IV)
KN 17-02	*Orbulina universa* d'ORBIGNY *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI
KN 18-02	**Ostracod:***Ilyocypris bradyi* SARS *Candona paralela pannonica* (ZALANYI) **Foraminiferid:***Globigerinoides trilobus* (REUSS) *Globorotalia* cf. *menardii* (d'ORBIGNY)
KN 19-02	*Globigerinoides* cf. *obliquus* BOLLI *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS)
KN 20-02	*Globigerinoides trilobus* (REUSS) *Globigerinoides* cf. *obliquus* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globorotalia obesa* BOLLI
KN 22-02	*Globigerinoides* cf. *obliquus* BOLLI
KN 23-02	*Globorotalia obesa* BOLLI
KN 24-02	**Ostracod:***Candona(Candona)* cf. *devexa* (KAUFMANN) *Potamocypris szchokkei* (KAUFMANN)

a

Sample No	Fossil Content (SECTION VI)
KN 30-02	*Globigerinoides* cf. *obliquus* BOLLI *Globigerinoides trilobus* (REUSS) *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS)

b

Sample No	Fossil Content (SECTION VII)
KN 31-02	*Globorotalia obesa* BOLLI *Globigerinoides obliquus* BOLLI *Globorotalia scitula scitula* (BRADY) *Globigerinoides trilobus* (REUSS)
KN 32-02	*Globorotalia obesa* BOLLI *Globorotalia* cf. *menardii* (d'ORBIGNY) *Globiquadrina dehiscens* (CHAPMAN PARR COLLINS)

c

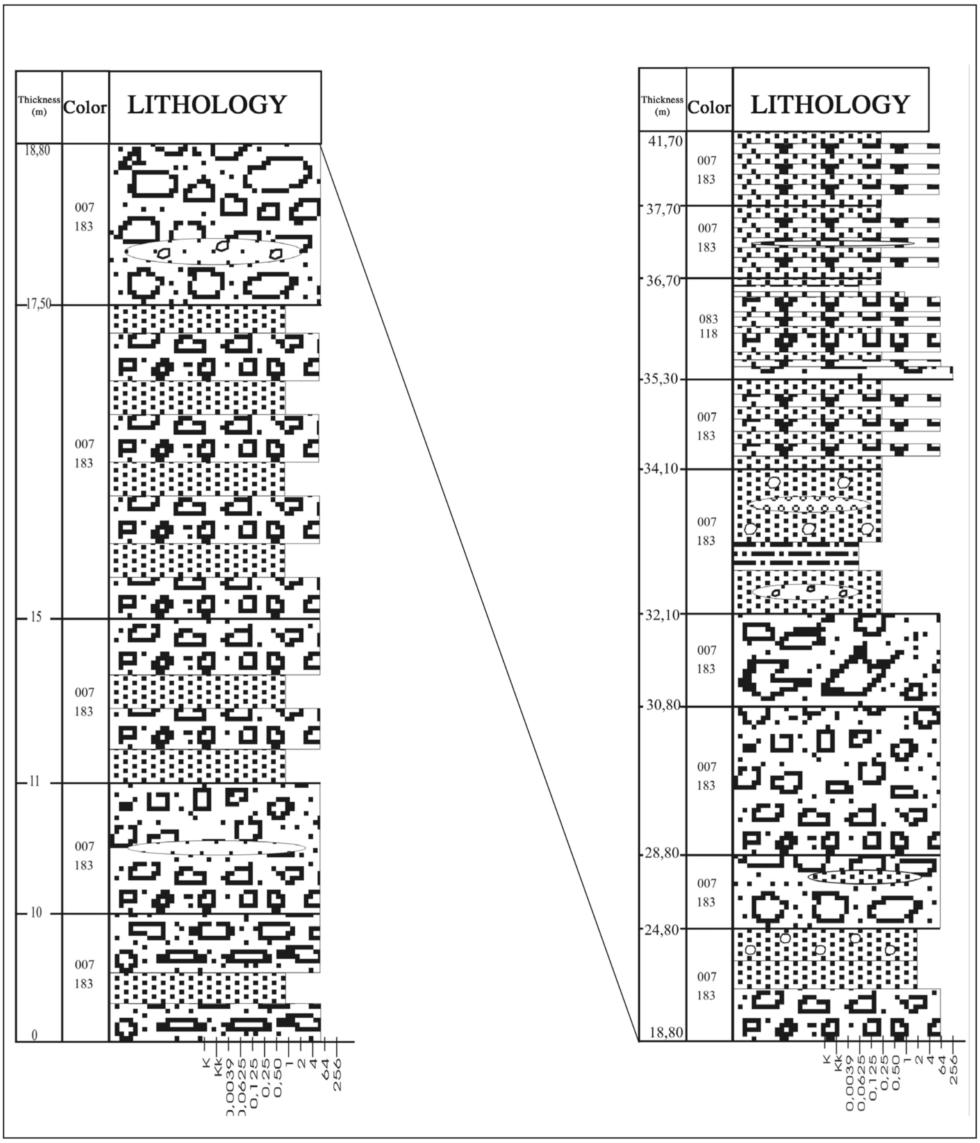

Figure 16- Part of Measured Stratigraphic Section from Suludere formation (03980/35435) Section X (SW of Veliler Village). (see Figure 30 for the Explanation).

It is considered that sediments on the limestones are composed of superposed channel and flood plain sediments of low curved rivers on a gentle topography in a humid climate. In this period, topographic gradient is favorable to develop flood plains, and water energy flowed on this low inclined topography is suitable to lay down the suspended material.

Mudstones overlying sandstones and conglomerates overlap channel fills owing to lateral migration and bed displacement.

Limestone and clayey limestone levels among clastic materials indicate the flood plains to be stagnent for limestone deposition but clastic inputs to alleviate in this process.

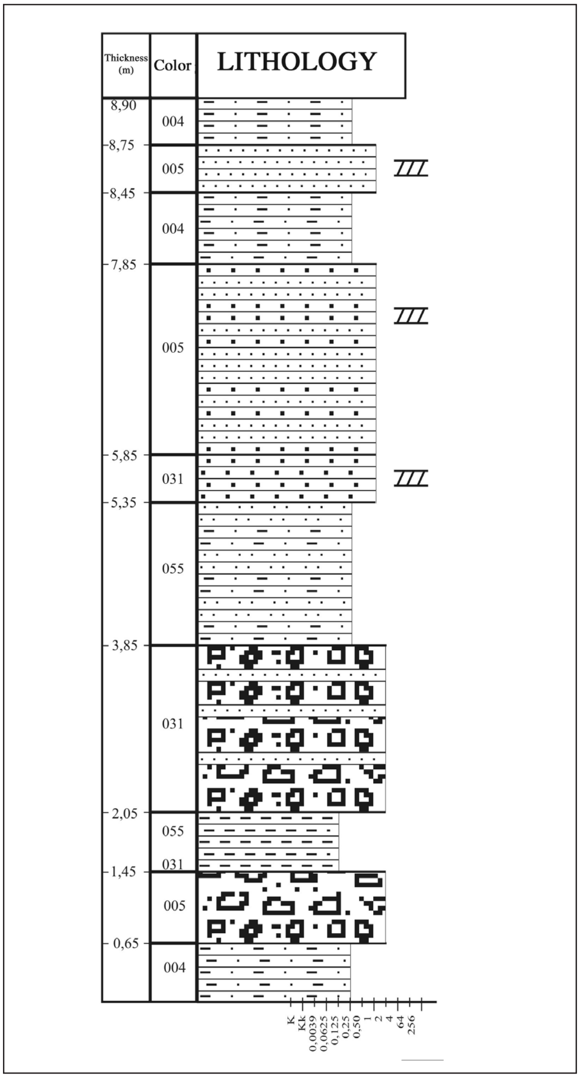

Figure 17- Part of Measured Stratigraphic Section from Suludere formation (07500/ 17650) Section XI (N of Aktepe Village). (see Figure 30 for the Explanation).

Decrease of mudtones and claystones, and increase of conglomerates and gravelly sandstones imply the increase of topographic gradient and strong river energy. These sediments were deposited on a high inclined topography in more humid climate by controlling high energy waters. Succession of the well- and bad-sorted conglomerates emphasize the stream energy to have sudden changes.

Based on textural and geometrical features of conglomerates, we can say that sediment transport was not by debris flow, developed on a river-dominated alluvial fan environment.

Sandstone overlying conglomerate reflect the current energy decreased to be in time. Sand-

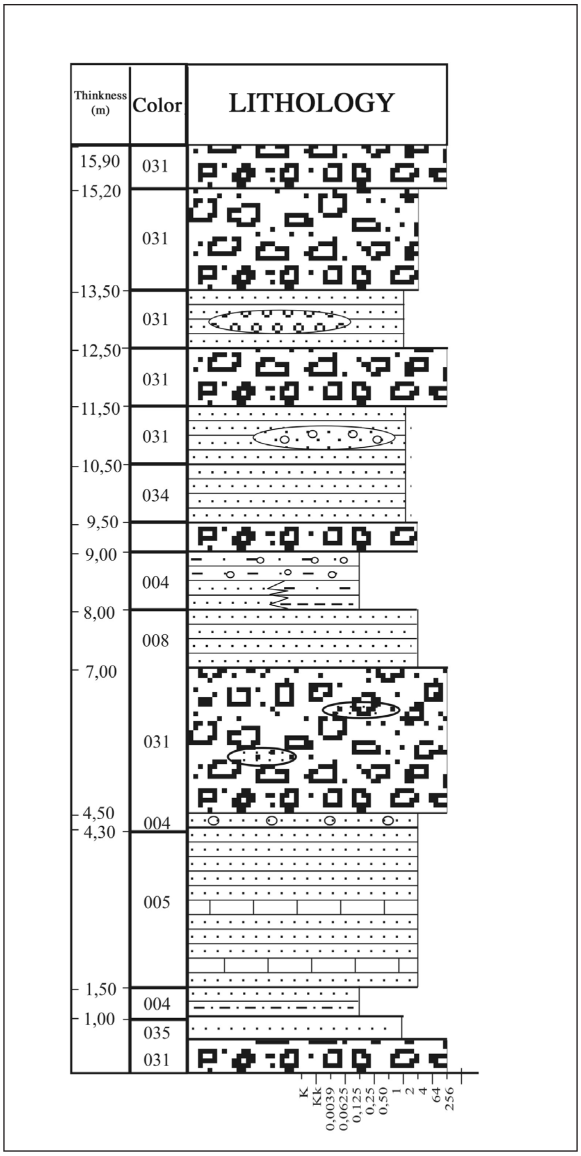

Figure 18- Part of Measured Stratigraphic Section from Suludere formation (07495/16930) Section XII (S of Aktepe Village). (see Figure 30 for the Explanation).

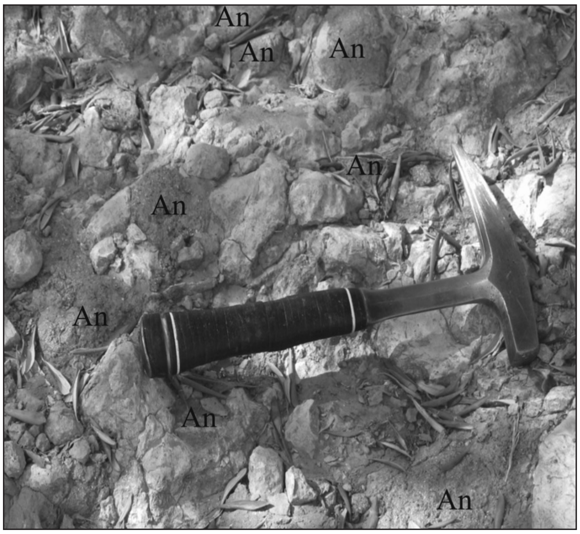

Figure 19- Carbonate-cemented basal conglomerates of Suludere Formation (An: Gravels derived from andesite).

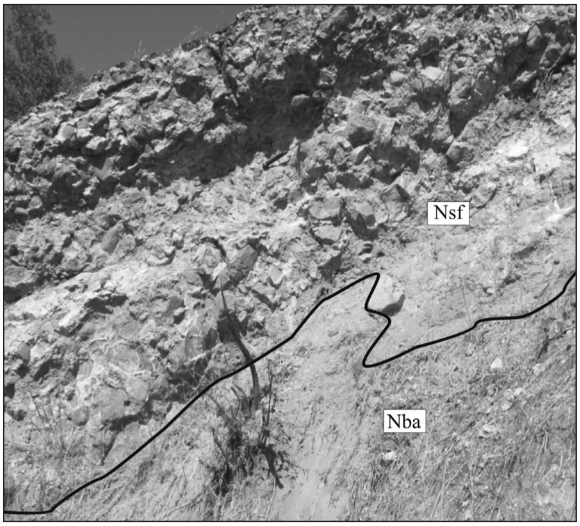

Figure 20- Conglomerates overlaying andesites unconformably.

stones with lenses of mudstone or coarse-grained conglomerate may be explained by development of barriers and/or by local energy change in the channel. Variously observed reverse/normal gradings on sandstones and conglomerates imply the water energy gradually to rise/fall.

The clayey levels having no spores and pollens are consistent with the implied depositional environments.

AYDOĞDU FORMASYONU

Definition

The formation observed around Beydağı, Uzundere, Çaylı, Aydoğdu, Gedik and Ceritler covers a total area of 35 km² (Figures 4 and 5), and outcrops best at around Aydoğdu. It is generally of reddish brown-milky brown, rarely yellowish brown-gray colored, and few consolidated, and composed of conglomerates, gravelly sandstones as well as sandstones, changing laterally and vertically to each other. These levels may be lenses, wedgings or interfingerings of eachother. Conglomerates are more abundant than sandstones. The formation with unmatured-half matured texture displays sharp slopes and fairy chimneylike morphologies due to rapid erosions (Figure 21).

Figure 21- Views from Aydoğdu Formation.

Lithology

Ranging from light brown to red dark brown colors, conglomerates are medium-bad consolidated, and medium-thick and very thick layered. Layer thickness varies from 20 cm to 500 cm, but often among 25-50 cm, 100-170 cm and 300-500 cm. These sediments, usually unmatured-half mature textured and very bad-badly sorted, some matured and medium-well sorted, have angular, sub-angular and some bladed or platy constituents with a low sphericity. Majority of the constituents are derived from metamorphic rocks (70 % schist, 20 % gneiss and 5 % marble) and the remains are andesite gravels. Occasionally gneiss gravels may compose of it, up to 80 - 95 % amount, and schist derived gravels may be up to 90 %. Andesite derived gravels may be up to 5 % and 30x20 cm in size. Various-sized constituents are between 3-4 mm and 60 cm. Gravels rarely reaches 1-3 m. Conglomerates with matrix-supported, matrix or grain-supported textures and a generally irregular internal structure have clay-sand or coarse sand-fine gravel matrices. Coarsening upward is common. Longitudinal axis of gravels with a bricklike arrangement at some places are sometimes parallel to the stratification. Conglomerates including some coarse sand grained, medium-thick sandstone lenses have rare cross stratifications (Figure 22), channel fill, erosional surfaces (Figure 23) and faults coeval with sedimentation (Figure 24).

Sandstones, are often light brown, some red brown, and medium consolidated, and usually coarse grained, and medium-thick layered. They tend to exhibit regular stratifications. Layer thickness varies from 20 cm to 200 cm, but often between 30-60 cm and 80-100 cm. At lower parts, sometimes, scattered gravelly rough sandstones tend to display fining upwards.

Gravelly sandstones are light brown-reddish brown, and medium consolidated, and thick-very thick layered. Scattered gravels within coarse

Figure 22- Cross-stratified conglomerate-sandstone observed on Aydoğdu Formation.

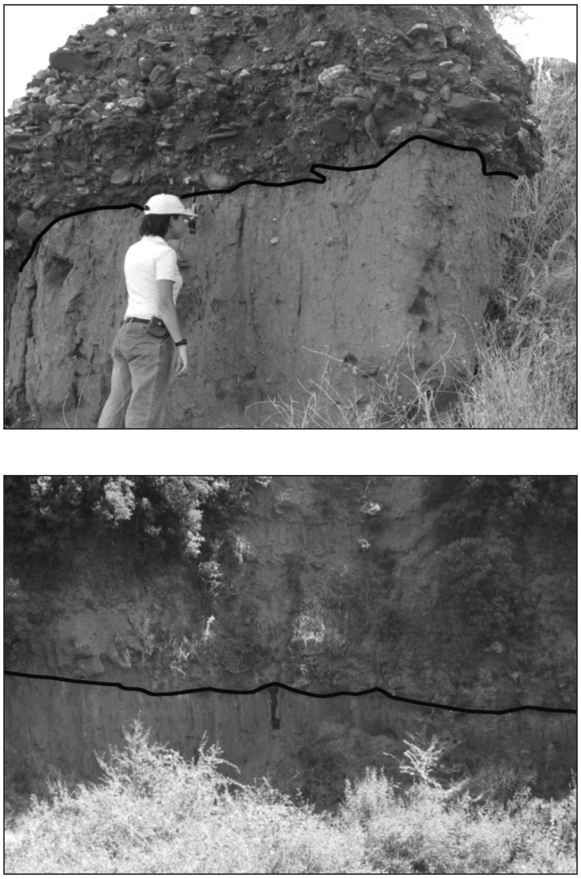

Figure 23- Conglomerates deposited to form an erosional surface within Aydoğdu Formation.

grained sands are less than 5 %. At some levels grain size do not exceed 3-5 cm, some are between 30 and 40 cm.

Aydoğdu formation is often horizontal layered (Figure 25).

At northwest of Eselli, the sequence is mainly composed of sandstones and conglomerates. The sequence begins with conglomerates, and lasts with medium-thick layered sandstone levels and finally thick-very thick layered gravelly sand stones. Conglomerates usually have grain sizes varied between 5 and 20 cm (Figure 26).

Figure 24- Fault coeval with sedimentation observed on Aydoğdu Formation (Fault slip: 130 cm).

Figure 25- Horizontal layered conglomerate-sandstone included in Aydoğdu Formation.

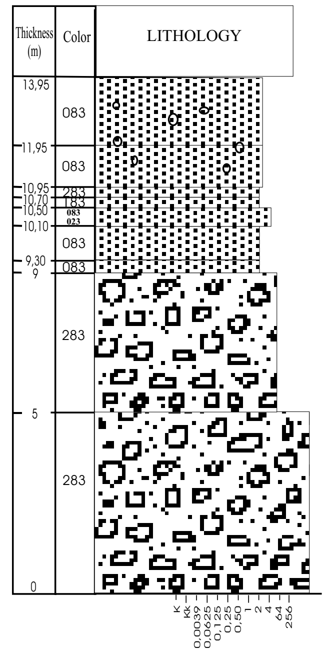

Figure 26- Part of Measured Stratigraphic Section from Aydoğdu Formation (99125/27300) Section XIV (NW of Eselli). (see Figure 30 for the Explanation).

The sequence, measured at Köfündere, is composed of conglomerates, gravelly sandstones and sandstones. It begins with conglomerates at the base and continues with an intercalation of 1-2 m thick sandstones and 40 cm thick gravelly sandstone (Figure 27).

The sequence, measured at Çaylı, is composed of conglomerates and sandstones in general: It begins with coarse grained sandstones containing rare gravels, and continues with a conglomerate-sandstone intercalation (Figure 28).

The Contact

Menderes Massif metamorphics constituting the basement rocks and Aydoğdu formation, which underlain Başova andesites cutting these units, and Suludere formation with an angular unconformity, are all covered by an alluvium with an angular disconformity (Figure 29). Basal conglomerates on lower contact of Aydoğdu formation are badly sorted. These conglomerates, owning no significant layering and owning coarse sand-fine gravel matrices, seem to contain generally angular, variously sized constituents changing from several cm to 2-3 m.

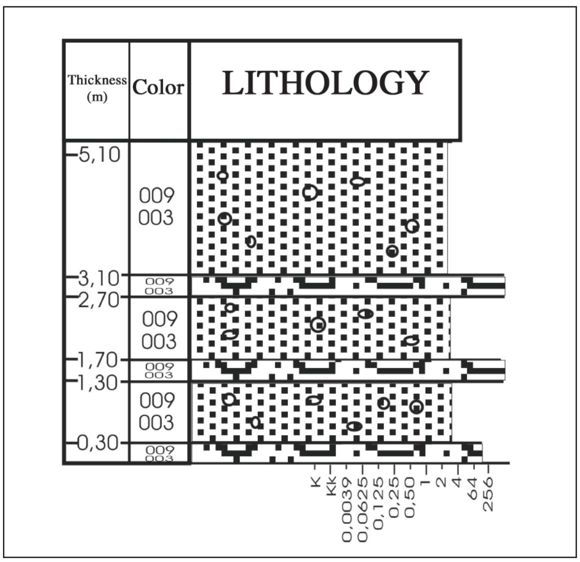

Figure 27- Part of Measured Stratigraphic Section from Aydoğdu Formation (02025/28850) Section XV (Köfündere). (see Figure 30 for the Explanation).

Age

Since Aydoğdu formation displays no paleontological evidences except for overlying Suludere formation of the latest Middle Miocene-Late Miocene, the age of Aydoğdu formation is assumed to be Plio-Pleistocene.

Comment

Conglomerates' containing both of sand-sized clastics and of very large boulders, as well as

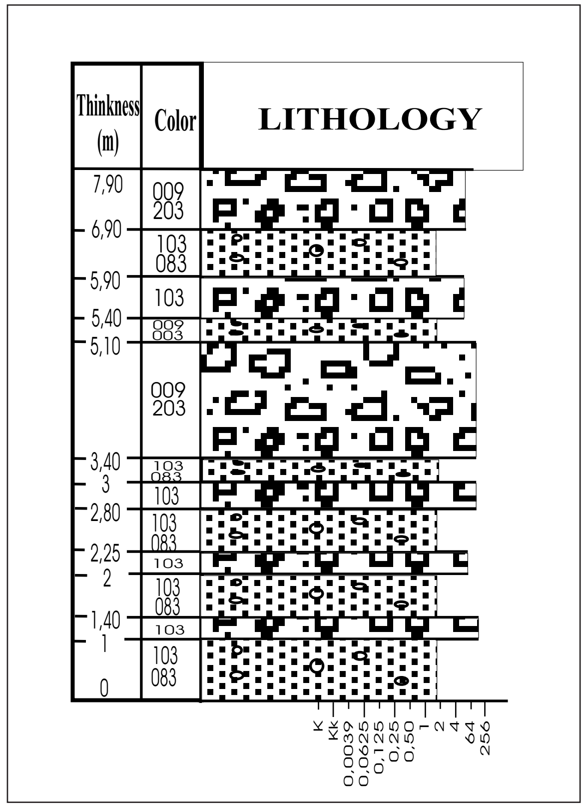

Figure 28- Part of Measured Stratigraphic Section from Aydoğdu Formation (00800/25025) Section XIII (Çaylı). (see Figure 30 for the Explanation).

Figure 29- Angular Unconformity Surface between Suludere Formation (Nsf) and Aydoğdu Formation (Naf). (Axe edge is parallel to stratification of lower Suludere formation).

large gravels together, accumulation of small size gravel and sand size material in the bottom of its front part with respect to current direction, seem to be the indicators of the unit to deposit on a slope with a considerbly high speedand with a flow to cause a sudden material accumulation. Displaying normal gradings in some parts implies a reflection of a drop of current velocity in time.

Sandstones' having scattered gravels, various thick layers and also no sedimentary structures often related to currents indicate that they were formed with materials brought by high energy waters. Rarely observed sedimentary structures created by paleocurrents formed when current velocity slightly decreased and regular current regime occurred

Formation is composed of alluvial fan sediments developed by high-angle normal faults controlling the Kiraz basin.

Alluvium

The unit constitute vast plains which are topographically low parts of the study area. These gray-beige unconsolidated sediments, deposited by recent streams and composed of various-sized clastics, overlay all units unconformably.

GEOLOGICAL EVOLUTION AND PALEOGEOGRAPHY

Kiraz basin began to form at the end of Middle Miocene following active andesitic volcanism dominated in the region. During this period, the region was under the effect of an extensional tectonic regime. Small lakes were formed to host algaes and ostracoda populations. At the beginning these shallow, coastal fresh lakes were connected to open sea and hence were subjected to have surface currents. Coastal carbonates formed on these lakes are located at the bottom of Suludere formation and overlap volcanic rocks unconformably.

Water-borne planktonic and benthonic foraminifers by surface currents from open sea to lakes are found at lower parts of the Suludere formation. Increase of the lacustrine ostracods at upper levels of the formation and meeting only freshwater ostracods at the area is an evidence of the ending open sea contribution. This may be explained in three ways: a- a local sea level fall provided regression of the sea, b- basin floor uplifted/filled and the sea regrade as clastic supply increased due to tectonic activity and/or climatic conditions, and c- the region may be more uplifted than the sea level because of a compression after a tension. Our findings seem to support the second opinion. Grain size and amount of the clastic materials brought to the basin seem to be controlled by regional tectonic activity, various morphology owing to climatic conditions, and stream energy. The increased clastic supply and filled/uplifted basin by tectonic activity are not affected by surface currents from open sea. Thus, channel and flood plain sediments of low curved streams are deposited on the carbonate sediments. In this period, water energy flowing over gentle slope topography was low enough the suspended materials lay down on flood plains. Flood plains having low amount of clastic materials have been stagnant for a period that the limestones get deposited. Occasionally, relatively coarse clastic sediments carried by high-energy waters on an inclined topography were deposited on a river-dominated alluvial fan environment. All of these lacustrine, braided river and alluvial fan sediments form Suludere formation.

It is implied that an angular unconformity between Suludere and Aydoğdu formations reflects a sedimentation break, during the latest Late Miocene. In this period, dominant compressional tectonic regime resulted from thrusting of Menderes Masif rocks onto Suludere formation (Emre and Sözbilir 2006*b*). After this break, sediments began to deposit on an inclined surface on a fault-controlled basin, by a current with very high energy and rapid deposition rate. During this period, the alluvial fan sediments have

Color I	Color II	Color III
0) -	0) -	1) Red
1) Light	1) Pinkish	2) Yellow
2) Dark	2) Reddish	3) Brown
	3) Yellowish	4) Green
	4) Brownish	5) Grey
	5) Greenish	6) White
	6) Greyish	7) Beige
	7) Dırty	8) Cream
	8) Milky	9) Ruddy

Limestone		*Planorbis* sp.	
Silisified limestone		Leaf	
Clayey limestone		Nodule	
Sandy limestone		Fenestral boşluk	
Gravelly limestone		Intraformational conglomerate	
Claystone		Algal coating	
Mudstone			
Limelly mudstone			
Gravelly mudstone			
Sandstone			
Limelly sandstone			
Gravelly sandstone			
Conglomerate	Grain supported		
Conglomerate	Matrix supported		
Conglomerate	Matrix supported		

Figure 30- Explanation for Measured Stratigraphic Sections.

developed due to high-angle normal faults and also current velocity has sometimes fallen. Filling of the new basins, formed after Pleistocene period, by alluvium still continues.

Extensional tectonic regime not only began to form Kiraz basin but also was active during the sedimentation which can be deduced from the coeval faults of the sedimentation (Figure 24). Faults cutting and inclining the sediments are the indicators of the effect of the post-sedimentary N-S, NE-SW and NNE-SSW trended tension forces in the basin (Emre and Sözbilir 2006*b*). As evidenced by Kiraz earthquakes (www.koeri.boun.edu.tr), today still active faults work together and thus provide recent morphology to the study area.

CONCLUSIONS

1- In the study area, Precambrian-Mesozoic schists, marbles, orthogneisses, paragneisses and metagabbros of Ödemiş-Kiraz Submassif belonging to the Menderes Masif form the basement rocks (Candan et al., 2001).

2- Başova andesites of Middle Miocene (14,7±0,1My-14,3±0,1My), intruding metamorphic rocks, are composed of calc-alkaline andesites and basaltic andesites derived from similar sources. Trace element and rare earth element variation graphics of the volcanics resemble the pattern of calc-alkaline arc volcanics or orogenic volcanics. Because Başova volcanics have a similar enrichment of trace elements to that of the continental volcanics, negative Ta-Nb anomalies are probably attributed to have an association with the crustal assimilation (Emre and Sözbilir 2006 *a*).

3- At the end of Middle Miocene, Kiraz basin started to form just after active volcanism in the region. Small freshwater lakes were formed with algae and osracoda populations on this extensional basin. Coastal carbonates formed on these lakes overlap volcanic rocks unconformably. Lacustrine carbonate sediments at the bottom contain very bad preserved planktonic and benthonic foraminifers as well as freshwater fossils. These deposits, started to form on a low energy, in small shallow lakes and continued with superposed channel and flood plain deposits of low curved rivers and river-dominated alluvial fan sediments. At the beginning, the basin was connected to open sea and was subjected to surface currents of the sea. In further periods, clastic supply increased due to tectonic activity and climatic conditions, and therefore the basin floor filled/uplifted, open sea contribution ended and river-dominated alluvial fan sediments deposited.

4- Suludere formation composing the oldest sediments of Kiraz basin overlays metamorphic and volcanic rocks unconformably. This formation has intercalated, lateral and vertical transitive, significant bedded lacustrine and fluvial sediments with ostracod fossils. These fossils give an age of the latest Middle Miocene-Late Miocene.

5- There is a sedimentation break after Late Miocene period. During this break, the active compressional tectonic regime in the region, conclude with a thrusting of Menderes Massif metamorphics onto the Suludere formation (Emre and Sözbilir 2006 *b*). Following this break, Aydoğdu formation of Plio-Pleistocene overlay Suludere formation unconformably. The sequence containing alluvial fan sediments are composed of texturally unmature, few consolidated of lateral and vertical transitions among each other, and of sharp-contacted levels.

6- Alluvium filling basins due to tectonic activities from Pleistocene to Recent overlay the other units unconformably. Alluvium have clay, silt and sand matrices, and is composed of very few consolidated conglomerates, sandstones and siltstones with various-sized gravels.

7- Tectonic regime, formed Kiraz basin, controls the basin evolution and geometry of the sedimentary basin, in addition to the post-sedimentation environment. Products of the tension forces and several kilometer traceable faults, brought different Neogene facies and the younger units together with the older units (Figures 4 and 5). Near these faults, Suludere formation layers reach up to 80° and Aydoğdu formation layers up to 44° slopes (Figure 4). Finally, Kiraz Basin achieved as an asymmetric graben, bordered by these active NW-SE trended faults (Emre and Sözbilir 2006*b*).

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PLATES

PLATE- I

Microscopic Features of Carbonate Levels based on Compositional (Folk, 1959) and Textural (Dunham, 1962) Nomenclatures

a) Recrystallized Limestone

b) Algal Micritic Limestone with Fenestral Voids/ Algal Carbonate Mudstone with Fenestral Voids:
Fenestral voids are discontinuous, irregular, and filled with sparry calcite and/or not.
Voids are probably vesicules.
Carbonate mud changed to microsparry.

c) Sandy Silty Micritic Limestone/ Sandy Silty Clayey Carbonate Mudstone:
Sands are composed of abundant micas and few quartz grains.
Micrite mud commonly changed to fine sparry calcite.

d) Intraclastic Peloidal Biosparite/ Intraclastic Peloidal Grainstone:
Pellets are faecal pellets.
Bioclasts include ostracods and shell fragments of ostracod.
Cement is composed of pseudosparry calcite.

e) Allochemical Recrystallized Limestone:
Identifiable allochems, fine pelecypod (possibly ostracod) shells.
Texture contains local micrite and patches of local sparry calcite. Perhaps primary packstone.

f) Silty Sandy Micritic Limestone/ Silty Sandy Carbonate Mudstone:
Sands and silts are composed of angular quartz and mica grains.
Carbonate muds partially changed to micro-sparry calcite.

PLATE - I

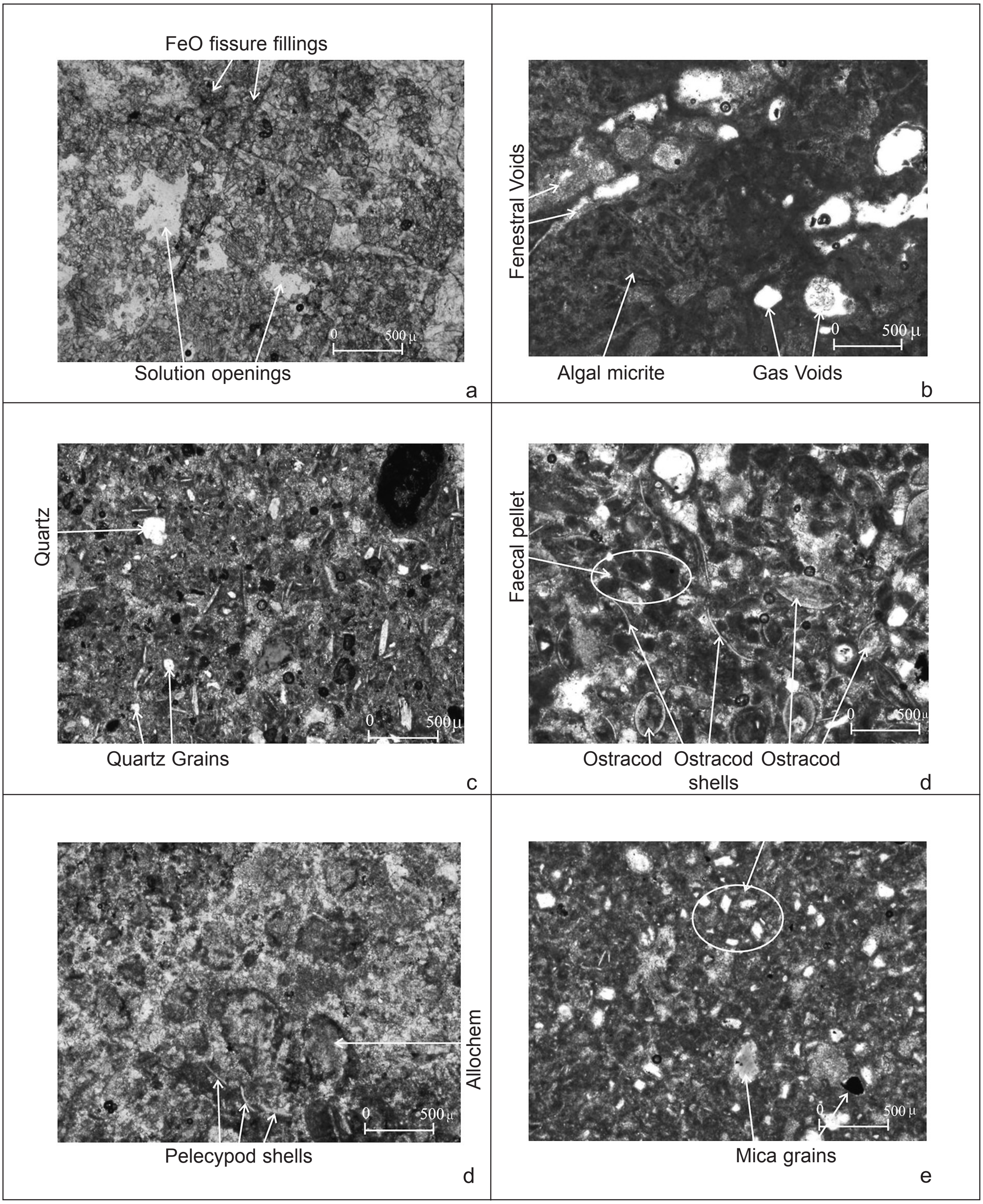

FeO fissure fillings
Solution openings
a
Fenestral Voids
Algal micrite
Gas Voids
b
Quartz
Quartz Grains
c
Faecal pellet
Ostracod
Ostracod shells
Ostracod
d
Allochem
Pelecypod shells
d
Mica grains
e

PLATE- II

Microscopic Features of Carbonate Levels based on Compositional (Folk, 1959) and Textural (Dunham, 1962) Nomenclatures

a) Bioclastic Peloidal Algal Micritic Limestone/Bioclastic Peloidal Algal Carbonate Mudstone:
Contains bioturbation traces and faecal pellets. Rare bioclasts are ostracods.
Bioturbation cavities are filled with sparry calcite.

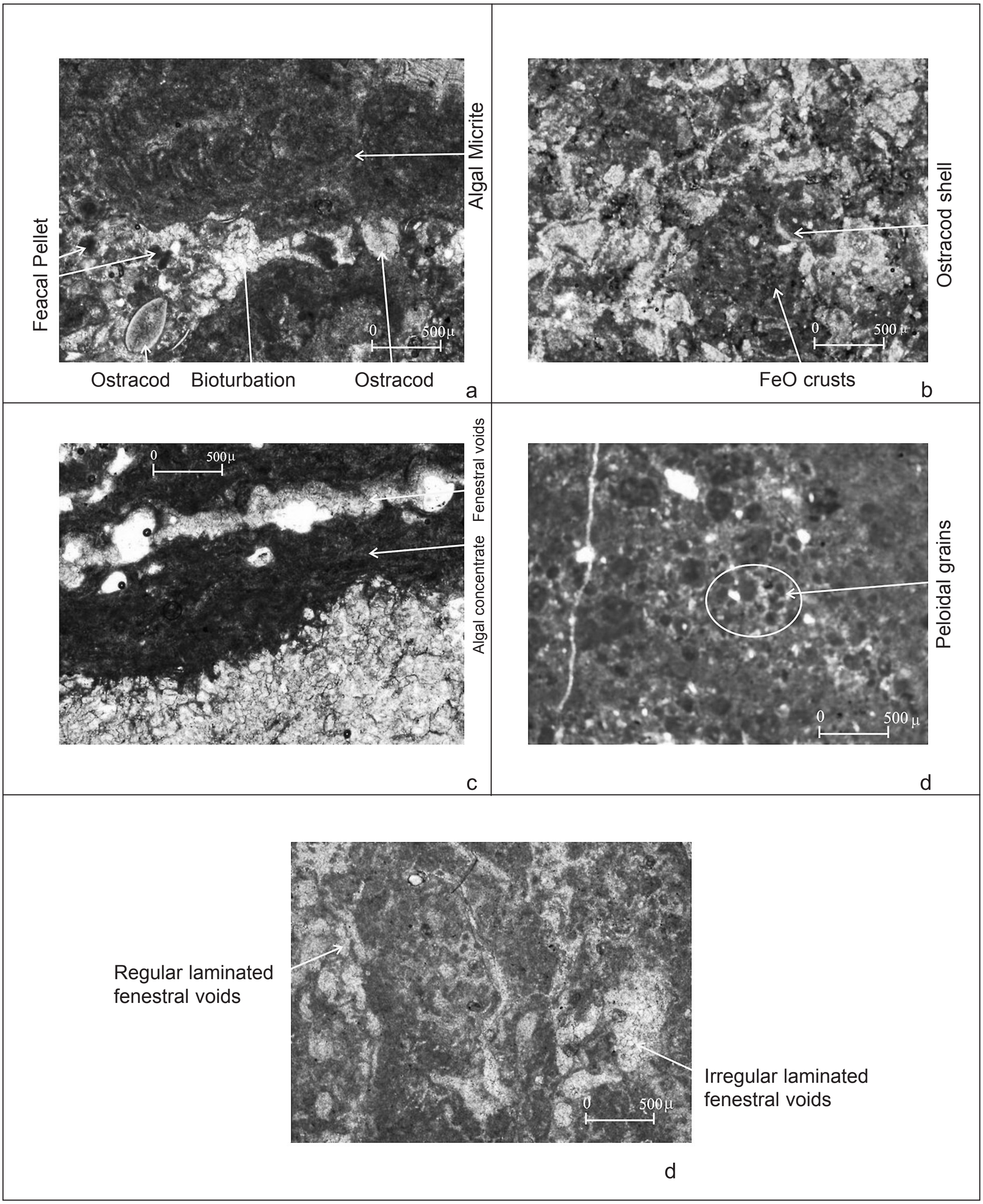
b) Intra-Biomicrite/Intraclastic Bioclastic Wackestone:
Bioclasts: Ostracod shells,
Intraclasts: Fragmented carbonate crust and/or fragments of pore filling.
FeO crusts common.

c) Algal Micritic Limestone with Fenestral Voids/ Algal Carbonate Mudstone and/or Boundstone with Fenestral Voids:
Fenestral voids are continuous and regular laminated, and filled with sparry calcite.

d) Peloidal Intramicrite Intrasparite/ Peloidal Intraclastic Packstone

e) Peloidal Algal Micritic Limestone with Fenestral Voids/Algal Carbonate Mudstone with Fenestral Voids:
Fenestral voids are regular laminated and irregular fenestral, and filled with sparry calcite.

PLATE - II


Algal Micrite
Feacal Pellet
Ostracod
Bioturbation
Ostracod
0 500μ
a
Ostracod shell
FeO crusts
0 500 μ
b
Fenestral voids
Algal concentrate
0 500μ
c
Peloidal grains
0 500 μ
d
Regular laminated
fenestral voids
Irregular laminated
fenestral voids
0 500μ
d

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PRE-NEOGENE STRATIGRAPHY OF THE KARABURUN PENINSULA (W OF İZMİR TURKEY)

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ABSTRACT.- Pre-Neogene rock units in Karaburun Peninsula are represented by a relatively autochthonous succession of Paleozoic-Mesozoic age and various tectonostratigraphic allochthonous units. Küçükbahçe Formation forms the lowermost Paleozoic unit of the "autochthonous" succession and is made up of Cambro? - Ordovician detritic rocks in turbiditic nature. It is overlained by Silurian-Carboniferous aged Dikendağı formation with a graditional contact which is characterized by abundant chert lydite content and Visean-Bashkirian aged Alandere formation which is represented by detritic and carbonate rocks. These units are cut by Karaburun granodiorite of Early Triassic age. The Paleozoic basement is unconformably overlained by a Mesozoic aged succession which commences with the Gerence formation consisting of conglomerate and/or *Naticella* bearing sediments of "vermicular facies" of Scythian age and the succession continues with carbonate dominant detritic deep marine sediments of Anisian age. Toward the end of Anisian, this units first grade into mainly the red micritic carbonates of the "ammonitico rosso facies" and then grade into the neritic carbonates of Camiboğazı formation of Early Ladinian age. The Camiboğazı Formation is gradationally overlained by *Megalodon* bearing Güvercinlik formation of Carnian-Rhaetian age consisting of stromatolitic dolomite, sandstone, mudstone and iron/bauxite pisolite bearing conglomerates. The succession continues with Nohutalan formation which consists of neritic carbonates with *Paleodasycladus* and *Cladocoropsis.* It is unconformably overlained by the Albian-Aptian aged Aktepe formation fossils. After a probable hiatus, Campanian-Maastrichtian aged Balıklıova formation unconformably covers the former units. Balıklıova formation consists of Karahasan limestone member of shallow marine limestones in the lower, and pelagic limestones-marls in the middle, and Haneybaşı member of sandstone-mudstone alternation of flysch facies in its upper levels. Tekedağı formation, İdecik unit, İzmir flysch and Yeniliman serpentinite are tectonically related with relatively autochthonous Paleozoic and Mesozoic rock units. (Late?) Permian aged Tekedağı formation is made up of detritic sediments and bioclastic limestones. Ladinian-(Early) Carnian/(Norian?) aged İdecik unit is made up of detritic sediments and spilitic lavas. Campanian-Early Tertiary (Danian?) aged İzmir flysch is a blocky flysch. All of these units are unconformably overlained by various rock units of Neogene and Quarternary age.

Key words: Karaburun, lydite, Permian, Scythian, ammonitico rosso

INTRODUCTION

1/25.000 scale geological mapping, revision, correlation and compilation studies were conducted between 1996 and 1998 on 1/100.000 scale sheets of K16, K17, L16, L17 of Karaburun Peninsula.

This work contains "Stratigraphy of Pre-Neogene rock units" on 1/25.000 scale sheets of K16-c1,2,3,4, K17-d1,d4, L16-a4,b2,b3,b4,c1, c2,d4 and L17-a1,a2,a3,a4,d1,d2,d3,d4*. Geological mapping of the peninsula were completed, and the studies carried out by Brinkmann et al. (1972), Erdoğan et al. (1990), Kozur (1995, 1998), İşintek et al. (1998 *b*), and İşintek and Altıner (1998) were used to define the Pre-Neogene rock units. Neogene units are simplified as sedimentary, volcanic, pyroclastic and tuff lithologies, and "Uzunkuyu quartz monzodiorite" was identified in this study.

This work was further presented as a report to General Directorate of Mineral Research and Ex-

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ploration (Çakmakoğlu and Bilgin, 2003) and as a "poster" to 57th Geological Congress of Turkey (Çakmakoğlu and Bilgin, 2004).

PREVIOUS WORKS

First detailed geological study and mapping began by Kalafatçıoğlu (1961) and the studies in the Karaburun Peninsula continued for many years. Kalafatçıoğlu (1961) revealed a stratigraphy beginning from Devonian (Figure 3) in his 1/100.000 scale geological map of the peninsula. Between 1965 and 1969, 1/25.000 scale geological mapping, drilling exploration and a mercury mine exploration have been carried out in north of the peninsula. These studies are generally based on the studies of Kalafatçıoğlu (1961); but more detailed informations about the stratigraphy of the peninsula, especially on Paleozoic, have been provided by PhD studies. Detailed studies on the stratigraphy and structural features of Karaburun Peninsula were conducted by Brinkmann et al. (1967,1972,1977), Lechner et al. (1967), Lechner (1969), Salah (1970), Gümüş (1971), Düzbastılar (1978), Konuk (1979), Güvenç and Konuk (1981), Akbulut (1972, 1980), Erdoğan (1985, 1988, 1990 *a, b*), Erdoğan et al. (1985), Güngör (1989), Erdoğan et al. (1990), Erdoğan and Güngör (1992), Koca et al. (1992), Kaya and Kozur (1995 *a, b, c*), Kozur and Kaya (1995), Kozur (1995, 1998), İşintek et al. (1998 *a, b*), İşintek and Altıner (1998, 2001), Kaya and Rezsü (2000), İşintek (2002), from 1967 to present (Figure 3).

"AUTOCHTHONOUS" UNITS

PALEOZOIC

Relatively "autochthonous" Paleozoic succession of Karaburun Peninsula is represented by three distinct formations transitional into each other, from Ordovician(?) to (Middle) Carboniferous. The lowermost Küçükbahçe formation is composed of the intercalations of greenish gray, yellowish brown, fine pebbly conglomerate, sandstone and siltstones. Overlying, Dikendağı formation has intercalations of green, greenish gray, gray and yellowish brown colored sandstone, siltstone and black cherts. At the top of the succession the Alandere formation is represented by siltstone, marl and limestone in the lower levels, and fossiliferous dolomitic limestone and limestone with rare cherts in the upper levels. Karaburun granodiorite of Early Scythian cuts the Dikendağı formation.

Küçükbahçe formation (Ok)

The formation includes slightly oriented sandstones, fine gravelly conglomerates and silt stones. The unit has been defined as "Küçükbahçe formation" of probable Ordovician or Cambro-Ordovician age firstly by Kozur (1998). Among previous researchers, Kalafatçıoğlu (1961) identified the detritic rocks of the old basement as "Devonian graywackes". This definition was later used in more general sense and for various aged rock units by Höll (1966) and many other researchers. Lechner et al. (1967) and Brinkmann et al. (1972) used "Devonian graywackes" and Gümüş (1971) used "Yayla graywacke unit"; and finally Konuk (1979) accepted this unit Triassic in age and defined as the "Karareis Assemblage". Erdoğan et al. (1988, 1990) constituted the"Karareis" and "Gerence" formations of Scythian-Anisian and, "Alandere formation" of Carboniferous in the "Denizgiren Group which first two usually contain detritic and carbonate rock units (Figure 3).

Küçükbahçe formation is a very uniform unit and has an intercalation of fine-grained conglomerate, siltstone and mudstones. Relatively lower parts contain fine-grained conglomerates while upper parts contain both of intercalated sandstone and mudstone levels. Generally greenish gray and yellowish brown colored unit is thin-medium bedded layered and turbiditic. In addition, it has a slightly oriented texture and bears very low grade metamorphic effects.

The base of the Küçükbahçe formation is not observed in the study area and Dikendağı formation overlays this with a gradational contact. (Figures 1 and 2). Because of the both two

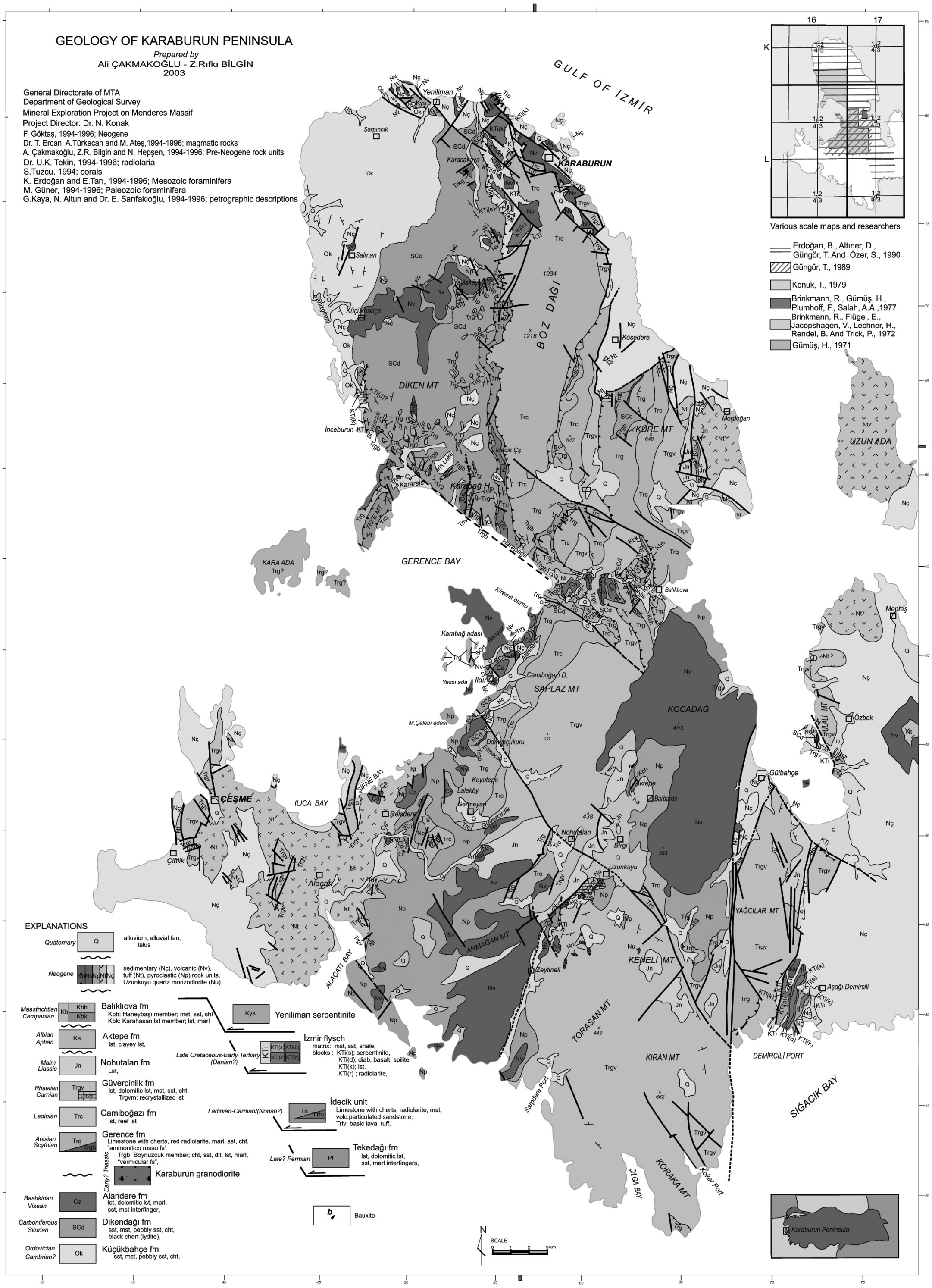

Figure1- Geological Map of Karaburun Peninsula.

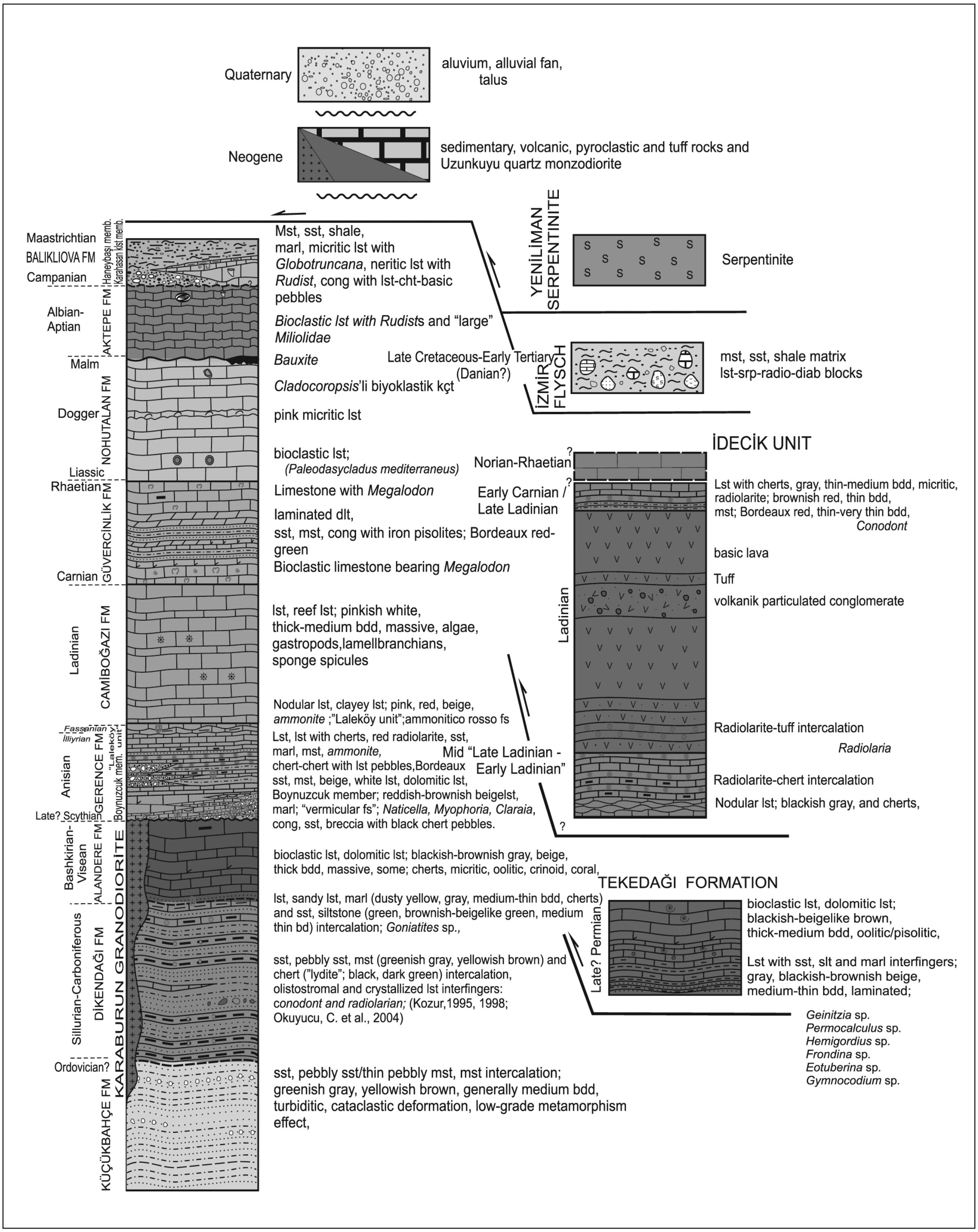

Figure 2- Generalized Stratigraphic Section of Pre-Neogene rock units on Karaburun Peninsula.

formations have similar rock types, the contact can be difficulty identified. However, first levels of the layered black cherts ("lydite":Gümüş, 1971; Brinkmann et al., 1972; Kozur, 1995 and 1998) are accepted as key beds. The formation has no fossils. Gradationally overlaying Dikendağı formation has been intupreted as the lowest levels of Silurian (Kozur, 1995), and Kozur (1995,1998) suggests that the unit would be Ordovician or Cambro-Ordovician. In this study the formation is considered as Ordovician in age.

It is interpreted that the unit have been deposited on a relatively deep marine environment with turbiditic currents.

Dikendağı formation (SCd)

The formation includes the intercalations of greenish gray to yellowish brown colored slightly oriented sandstone, coarse-grained sandstone, siltstone and mudstones with dark green, white and generally black cherts (lydite). The succession is firstly identified as Dikendağı formation in this study. The unit is described as "Devonian graywackes" by Kalafatçıoğlu (1961), Lechner et al. (1967) and Brinkmann et al. (1972), as "Yayla graywacke unit" of probable Devonian-Lower Carboniferous age by Gümüş (1971), and as "Karareis formation" of Lower Triassic by Konuk (1979). Erdoğan et al. (1990) separated the unit into two parts, as "Alandere formation and Scythian-Anisian aged "Denizgiren group". Kozur (1995) described that the unit is usually composed of siliciclastic turbidites and olistostrome, and named the gradational parts of the Alandere formation as "Döşemealtı formation" (Kozur, 1998).

Clastic parts of the unit varies from gray, greenish gray to yellowish brown. Sandstones have various-sized clastics ranging from coarse to fine grains. Grains are poorly to medium sorted and sub-rounded. There are some olistostromal levels within the clastic parts. Gravels and boulders in these levels are various-colored crystallized limestones with no definite age and few sandstones. The unit does not show any significant lateral change.

Based on including conodont, radiolarian, and Ammonite fossils in the uppermost levels (*Goniatites* sp.), the unit has been assigned to Silurian-Carboniferous (Visean) age (Kozur, 1995) (Figure 3). Conodonts and radiolarians of Upper Devonian (Frasnian-Famennian) were determined within the black cherts (lydites), which are just below the several meters thick quartzitic sandstone and marls bearing *Naticella* (Scythian unconformity) (Figure 12) (Okuyucu et al., 2004). In this study, Silurian-Carboniferous (Visean) age is accepted for Dikendağı formation.

Dikendağı formation is gradational with the Küçükbahçe formation in the below, and Alandere formation in the above. Clastic rocks observed at top levels are intercalated with cherty limestones and pass into the Middle Carboniferous limestones (Figure 4). All of these are unconformably overlain by Gerence formation.

Rock type and microfaunal features of the unit indicate that it was deposited on a moving slope/ deep marine environment with turbiditic currents.

Alandere formation (Ca)

The unit includes sandstone and marls, interfingered with limestone, dolomitic limestone with replacement cherts. The unit was described as Lower Carboniferous (Upper Visean-Lower Namurian) "black crystalline compact bedded limestones" by Kalafatçıoğlu (1961), as "Kohlenkalk" by Lechner et al. (1967) and as "Tınaztepe" and "Alandere", formations by Gümüş (1971). Erdoğan et al. (1990) constituted these two formations into "Alandere formation" (Figure 3).

The unit begins by an intercalation of brownish, beige-green medium to thin bedded sandstone, siltstone, and gray, white, dusty yellow, yellow and red, medium to thin bedded lime-

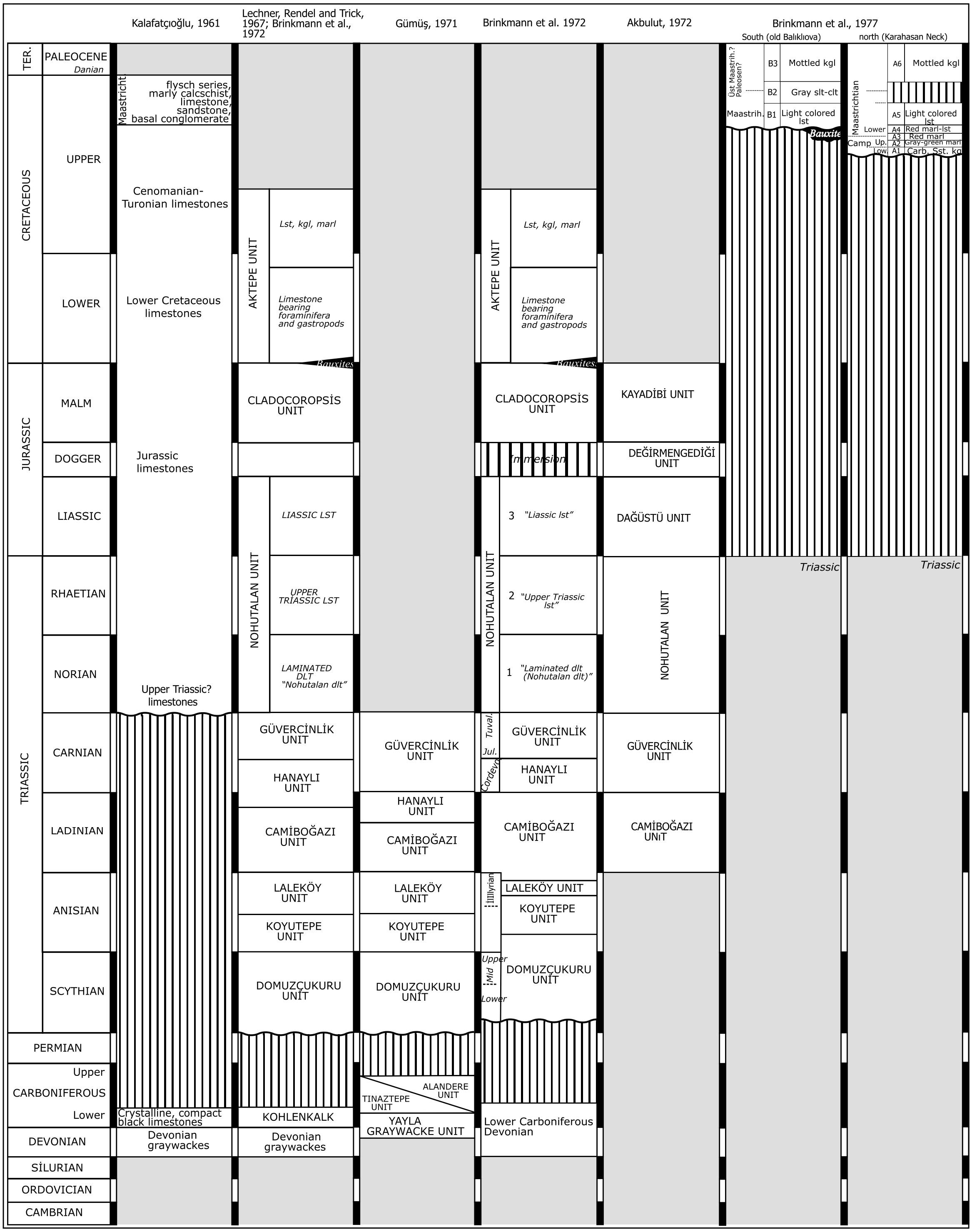

Figure 3- Stratigraphic correlation charts of previous studies.

Figure 3- Contioune.

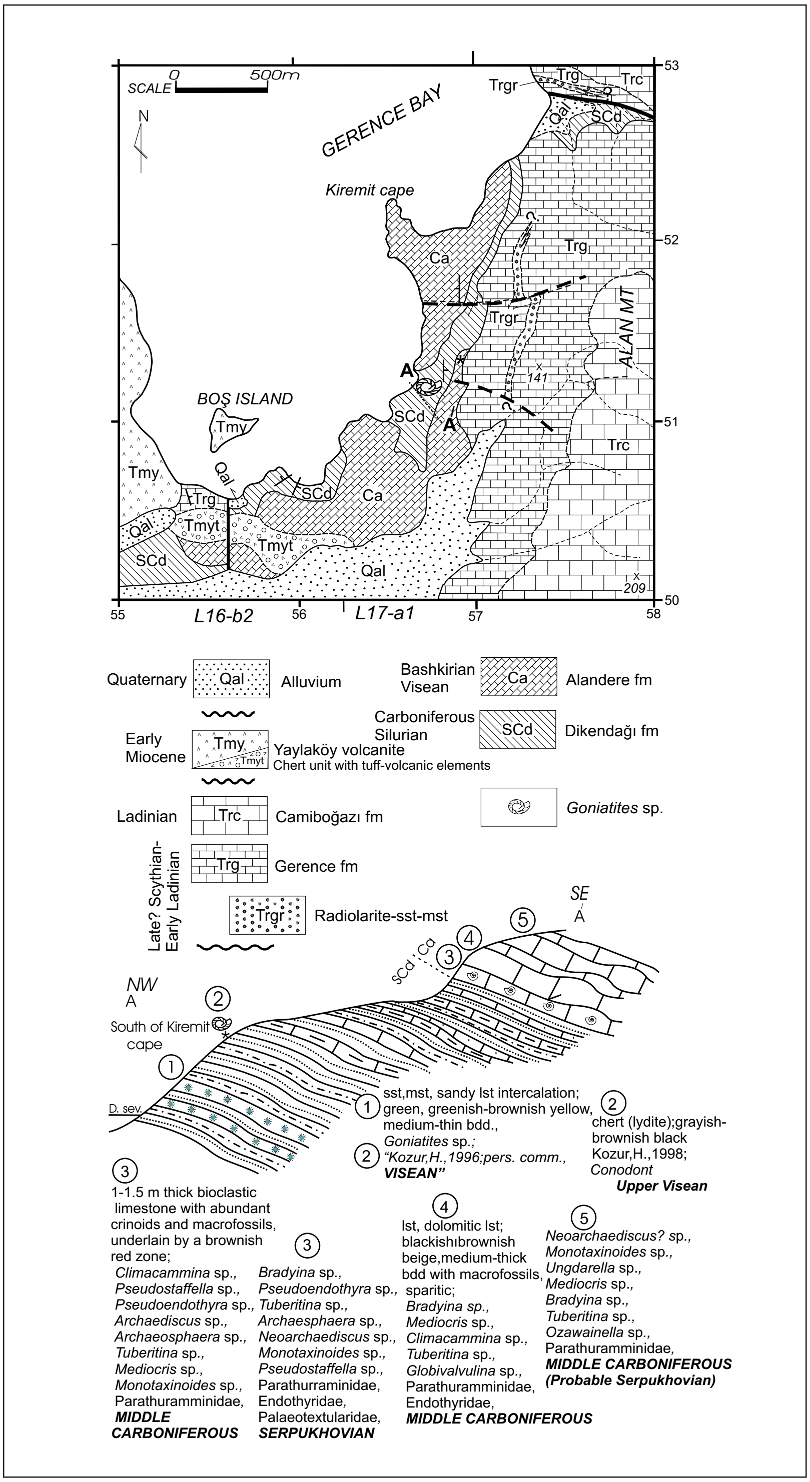

Figure 4- Dikendağı formation and Alandere formation; geological map, stratigraphic relation and fossil content.

stone, sandy limestone and marl with often chert bands. The unit laterally pass into generally grayish black, gray and thick to medium bedded limestones with abundant corals and crinoids. Upward, it passes into the blackish gray and some beige-gray laminated dolomitic limestones with abundant fossils and blackish to brownish replacement cherts. Dolomitic limestones show some crystallized, micritic and oolitic textures. The unit ends by dark gray to grayish-brownish black and some beige thick bedded, massive limestones with secondary calcite fillings, some replacement cherts and silica nodules at top levels.

The unit is gradational with lower Dikendağı formation and is unconformably overlain by Gerence formation of Late (?) Scythian-Early Ladinian age.

Alandere formation is rich in fossils. Fossils of *Archaediscus* sp., *Archaesphaera* sp., *Bradyina* sp., *Climacammina* sp., Endothyridae, *Fusulinella* sp., *Globivalvulina* sp., *Haplopragmella* sp., Lasiodiscidae, *Lasiodiscus* sp., *Mediocris* sp., *Millerella* sp., *Monotaxinoides* sp., *Neoarchaeodiscus* sp., *Ozawainella* sp., Paleotextularidae, Parathuramminidae, *Pseudoendothyra* sp., *Pseudostaffella* sp., *Qasituberitina* sp., *Tuberitina* sp., *Ungdarella* sp. give Lower-Middle Carboniferous age to the unit. The unit has been dated as Lower Carboniferous (Upper Visean-Lower Namurian) by Kalafatçıoğlu (1961), Carboniferous/Visean by Lechner et al. (1967), late Lower Carboniferous-Visean- early Upper Carboniferous by Gümüş (1971), early Middle Carboniferous (Bashkirian) by Erdoğan et al. (1990) and as Serpukhovian-Bashkirian by Kozur (1995). According to these, a time range extending from middle Visean to the end of Bashkirian can be considered for the unit.

The formation was started to deposite in a relatively deep, and later in a shallow marine environment where some reefs also occurred.

Karaburun granodiorite (Trkg)

The unit was firstly defined as "Karaburun intrusives" by Türkecan et al. (1998). In previous studies granite intrusions have been reported at the contact between Devonian and Carboniferous by Lehnert-Thiel (1969) and at the top levels of Paleozoic by Yıldız (1969). At the south of Yeniliman, there are several outcrops intruding Dikendağı formation of Silurian-Carboniferous on an area of about 1 km2 (Figure 1). According to Türkecan et al. (1998) and Ercan et al. (2000), the unit has phenocrysts of plagioclase, quartz, amphibole, pyroxene, and few orthoclases, and Rb/Sr radiometric age obtained from biotites gave 239,9 ± 2,4 m.y., which indicates a Triassic magmatism. It is suggested that the unit might be Scythian in this study.

MESOZOIC

"Autochthonous" Mesozoic is represented by carbonate, clastic and flysch facies rock units extending from Lower Triassic to Campanian-Maastrichtian on Karaburun Peninsula. Mesozoic units overlaying Paleozoic rock units with an unconformity begins with Scythian and by a deepening process at the end of Upper Scythian -pre-Ladinian, a regular succession is formed composing of carbonates and flysch.

Mesozoic succession is represented by the lowermost Gerence formation of Scythian-Lower Ladinian; Camiboğazı formation of Ladinian; Güvercinlik formation of Carnian-Rhaetian; Nohutalanı formation of Liassic-Malm; Aktepe formation of Cretaceous, and Balıklıova formation of Senonian age. However the most of these units display a regular succession, sometimes they are shown in thrusted character as well. Besides they are also accomodated as blocks or tectonic slices within the İzmir flysch.

Gerence formation (Trg)

The formation is generally composed of detritic rocks and carbonates with cherts. The unit was firstly identified as "pelagic Triassic" by Brinkmann et al. (1967), and was differentiated as "Domuzçukuru", "Koyutepe" and "Laleköy" units by Lechner et al. (1967) and Brinkmann et al. (1967, 1972). Assuming that these units are lateral and vertical facies changes of a formation, Erdoğan et al. (1990) named these units as "Gerence formation" of the "Denizgiren group" (Figure 3).

Gerence formation don't exhibit same features everywhere at the base. Generally begins by conglomerate, noduled marls with pelecypod and gastropod fossils, sandstone, clayey-silty limestone, brownish gray to dark gray thin-medium bedded "wrinkled" limestones and abundant calcite veins. Upward it is followed by beige to brown, thick bedded algal limestones in 1-2 m thick, interfingered with pinkish beige limestone levels (Figure 5). These levels correspond to Domuzçukuru unit of Brinkmann et al. (1967, 1972). Especially on the central parts of the Peninsula, near Balıklıova-Ildır, there are conglomerates generally consisting of limestone and a scarce red radiolarite pebbles which are underlain by detritic carbonates of the Domuzçukuru unit. Conglomerates are poorly sorted in general and contain sub-rounded, limestone, green cherts and rare red radiolarite pebbles and rare basic magmatic constituents. Matrix is often silt or clay. Just overlying this, mudstones interlayered with limestones in "ammonitico rosso" facies and red radiolarite are shown. These conglomerates can be interpreted with the "second conglomerate" of the Koyutepe unit of Brinkmann et al. (1967, 1972), and large-scale channel fill shale-conglomerate composition of the Anisian succession of Kaya and Kozur (1995 *b*).

At the central parts of the formation, there are various-colored limestones, marl, sandstone, brownish red to beigelike green radiolarite and red pelagic limestone levels interlayered with these. Detrital parts laterally pass into the limestones which are characterized by chert bands at some places.

The unit continues upward by gray, light gray to brownish pink, yellowish white, fissured and fractured limestones in various thicknesses. Some intraformational breccia levels composing of limestone and chert fragments occur at these levels. Particularly toward the south of Karaburun Peninsula turbiditic limestones regularly increase. At top levels, there are generally pink to pinkish red, medium to thick bedded limestones and clayey limestones ("ammonitico rosso facies") with some ammonite fossils and nodules. These uppermost levels of the formation are described as Laleköy unit by Lechner et al. (1967) and Brinkmann et al. (1967, 1972).

Boynuzcuk member (Trgb)

The unit, which was firstly identified as "Boynuzcuk formation" by Konuk (1979), is composed of breccia, conglomerate, sandstone, pebbly sandstone, mudstone, sandy limestone, nodular limestone and marl from bottom to top; It was evaluated as a member in this study.

Breccias include radiolarite-chert and various limestone pebbles. While near Karareis and Erendede localities they are dominated by radiolarite and chert pebbles, apart from here they changes into generally conglomerates characterized by limestone pebbles. Breccias, contain poorly-sorted, from small to large angular pebbles in green to black colours and have often silica, clay and carbonate cement. On the breccias, there is an intercalation of pebbly and sandy limestone and marls containing brachiopod, pelecypod and gastropod fossils. Reddish-brownish beige to greenish yellow limestones/marls contain characteristic Scythian fossils such as *Naticella/Natica* (*Natiria*) *costata* ("dwarf gastropod"), *Myophoria* sp. and *Claraia* sp. (*Pseudomonotis*), characterizing the "vermicular facies". (Figure 6). Brownish-grayish beige to yellowish dark gray, medium to thin bedded limestones of the unit are cross-cut by abundant calcite veins. Poorly sorted and often grain-supported conglomerates are bordeaux red to brownish yellow in

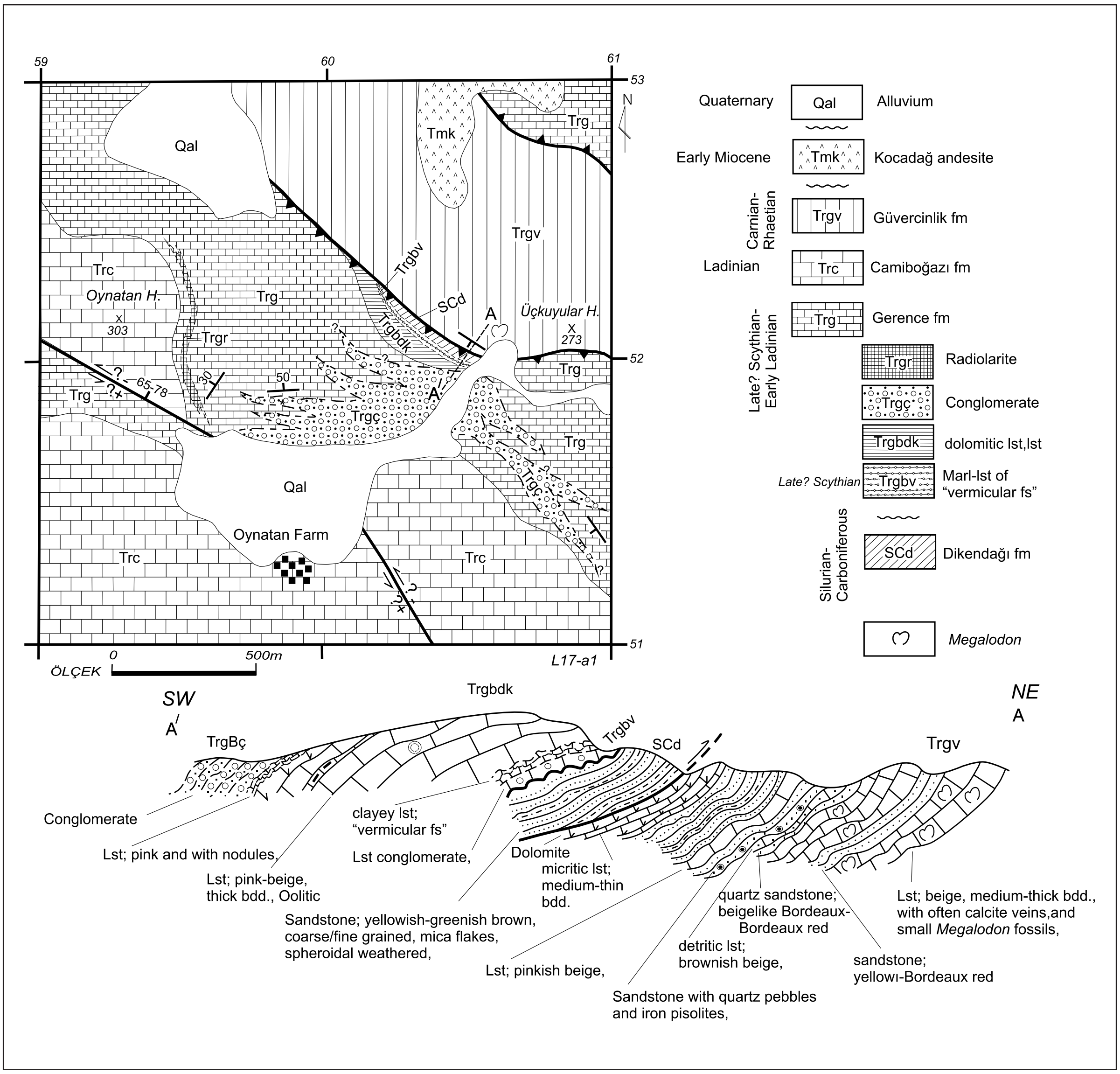

Figure 5- Gerence formation Boynuzcuk member and geological section and map, both are related to submarine channel fills at Oynatan locality.

colours, and medium to thick bedded and some massive, and often contain black chert, white quartz and whitish beige quartzite pebbles and a lesser amount of rounded and sub-rounded pebbles of various limestones. Pebbly sandstones, coarse sandstones and sandstones are shown in bordeaux red to brownish yellow medium-thin bedded layers. (Figures 7 and 8).

Gerence formasyonu unconformably overlays Küçükbahçe, Dikendağı ve Alandere formations. It grades into the overlaying Camiboğazı formation (Figure 8).

Microfossil content of *Cyclogyra*? *mahajeri*, *Spirorbis phlyctaena* and *Meandospira* cf. *pusilla* in the lower levels of the Gerence formation (Fi-

glomina mesotriasica, Variostoma sp. and fossils of ammonite and pelagic pelecypods (*Halobia* sp., *Daonella* sp.), date the unit as Late Scythian-Anisian.

In earlier works, the age of the formation have been considered according to the stratigraphic position of Laleköy unit (Lechner et al. 1967; Brinkmann et al. 1967,1972) including red limestones in ammonitico-rosso facies, or to the corresponding units. Brinkmann et al. (1972) accept Upper Anisian age basing on detailed fossil content, which has been described as "Hallstatt facies". Konuk (1979) gives Lower Carnian age to the Güldağ formation in the "Hallstatt facies" and Upper Scythian-Carnian age to the probable formations in the context of Gerence formation. Erdoğan et al. (1990) suggest Scythian-Late Anisian age for Gerence formation including also Laleköy unit. Koca et al. (1992) state that Laleköy formation contains a rich fauna of Late Anisian age (Pelsonian/Illyrian). Kaya and Kozur (1995*b*) state that Anisian succession has Pelsonian ammonitico-rosso facies, olistostromes and also Early Anisian-Late Aegean red cherts; Kozur and Kaya (1995) state that there is an Illyrian-Early Phassanian and Pelsonian ammonitico-rosso facies. Işıntek et al. (1998 *a*) suggest an Anisian age for the lowest levels of the "Laleköy formation" and Ladinian for rest of the formation. Işıntek and Altıner (2001) consider that Laleköy formation were deposited between Middle Anisian (Pelsonian) and Late Anisian (Illyrian)-Ladinian by considering it in Camiboğazı formation.

In this study, the unit is assigned Late? Scythian-Early Ladinian age basing on previous works and fossil findings.

Gerence formasyonu was deposited on coastal, shallow marine, and stable and relatively deep marine environmental conditions.

Camiboğazı formation (Trc)

The unit includes white, pinkish white to light gray massive limestones and has been identified as "Camiboğazı Unit" containing reef or lagoonal limestones by Lechner et al. (1967); and also with same name and content by Gümüş (1971), Brinkmann et al. (1972) and Erdoğan et al. (1990). İşintek and Altıner (2001) separated Camiboğazı formation into Laleköy, Saplaz and Hanaylı units (Figure 3).

At the bottom, the unit begins by a level of pink colored limestones on the top of Gerence formation (Figure 8) and at the top pass to the Güvercinlik formation. The unit is represented by white, pinkish white to pinkish beige, light gray thick bedded and massive limestones. The escarpments and high hills is characteristic morphological featuresof the unit in the study area. It contains abundant algae, gastropods, lamellibranchias, crinoids, sponge spicules and microfossils.

According to the fosil association composing of *Ammobaculites* sp., *Aulotortus* sp., *Aulotortus* gr. *sinousus, Cayeuxia* sp., *Diplotremina* sp., *Duostamina* sp., *Earlandia* sp., *Earlandia tintinifomis, Endothyra* sp., *Endothyranella* sp., *Endothyranella wirzi, Frondicularia* sp., *Frondicularia woodvardi, Glomospira* sp., *Glomospirella* sp., *Lithocodium* sp., *Macroporella* sp., *Miliolipora* sp., *Ophthalmidium* sp., *Ophthalmidium chialingchiangense, Ophthalmidium fusiforme, Pachyphloide*s sp., *Paraophthalmidium* sp., *Reophax* sp., *Trochammina* sp., *Tubiphytes* sp., *Tubiphytes obscurus, Turriglomina mesotriasica, Turrispirillina minima*, the unit is assigned to the Ladinian-Carnian age.

Camiboğazı formasyonu has been dated as Ladinian by Brinkmann et al. (1967,1972), as Ladinian-Carnian by Erdoğan et al. (1990), and as Middle Anisian (Pelsonian)-Late Anisian (Illyrian)-Carnian by Işıntek and Altıner (2001). "Hanaylı unit" is given as Cordevolian (Lower

Carnian) by Brinkmann et al. (1972) and included in Ladinian-Carnian Camiboğazı formation by Işıntek and Altıner (2001), Lechner et al. (1967) and Brinkmann et al. 1967,1972). So the relative age of Camiboğazı formation would be Ladinian by referring to the age of overlaying Güvercinlik formation.

Facies features and fossil content of the unit point to a shallow marine depositional environment. Brinkmann et al. (1972) also state that there were reef and forereef environments in the depositional area.

Güvercinlik formation (Trgv)

The unit includes oolitic limestones with Megalodon, and green, yellow to red siltstone, sandstone and pisolitic conglomerate with iron and bauxite, and light gray laminated dolomite and white dolomitic limestones. A unit with clastic and evaporitic formation is firstly described by Lechner et al. (1967) and Brinkmann et al. (1967, 1972) in this region. While Erdoğan et al. (1990) described Hanaylı unit as laminated dolomites, Brinkmann et al. 1967,1972) named the same levels as "Upper Triassic limestones". İşintek and Altıner (2001) used Hanaylı unit and Upper Triassic limestones (Lower limestone unit) instead of Camiboğazı and Nohutalan formations respectly (Figure 3).

The unit begins by yellowish milky white, massive-thick bedded oolitic limestones with abundant algae at the bottom, and upward continues by an intercalation of thin-medium bedded, pinkish yellow, sandy oolitic/pisolitic limestones with abundant Megalodon fossils, thick-bedded, milky white oolitic limestones with gastropod and small Megalodon fossils, laminated-stromatolitic dolomite, dolomitic limestones and white, thick-bedded limestones with large Megalodon fossils, and greenish-yellowish yellow to brownish red, bordeaux red sandstone, siltstone, mudstone, pebbly sandstone and marl, clayey-sandy limestone, dolomite and white dolomitic limestones; and ends by laminated dolomite and white medium-thick bedded limestones with few replacement cherts. Coquina limestone levels (biorudite) are encountered. The presence of clastic interfingers is the characteristic of the Güvercinlik formation. Matrix is composed of silica and contain iron oxides. Some have cross-beddings. Laterally, Iron/bauxite bearing pisolitic (especially at south of Gönemse), quartz pebbly sandstones are distinctive rock type in the unit. At south of Ulalı Mountain, iron bearing bauxite level is also within the unit. "Uzunkuyu intrusion" of 15,4 ± 0,5 m.y. age has been described as monzodiorite by Türkecan et al. (1998). Ercan et al. (2000) showed recrystallized features around Uzunkuyu-Palamutboğazı (Figure 1; L17-a4) due to its contact metamorphism (Trgvm).

The unit is gradational with lower Camiboğazı formation and upper Nohutalanı formation.

It is suggested that the thickness of the formation is about 250-300 m. There is no significant lateral change in Güvercinlik formation.

According to *Ammobaculites radstadtensis, Auloconus permodiscoides, Aulotortus communis, Aulotortus friedly, Aulotortus gaschei, Aulotortus impressa, Aulotortus sinousus, Aulotortus* sp., *Aulotortus tumidus, Aulotortus turgida, Calcitornella* sp., *Cayeuxia* sp., *Diplopora* cf *annulata, Diplopora* sp., *Duostamina* sp., *Earlandia* sp., *Endothyra* sp., *Endothyranella* sp., *Frondicularia* sp., *Frondicularia woodvardi, Galeanella* sp., *Glomospira* sp., *Glomospirella grandis, Glomospirella parallela, Glomospirella* sp., *Griphoporella* sp., *Lamelliconus multispirus, Lamelliconus procerus, Macroporella retica, Megalodon, Microcodium, Miliolipora cuvillieri, Miliolipora* sp., *Ophthalmidium* sp., *Paraophthalmidium* sp., *Planiinvoluta* sp., *Pokljukosmilia tuvalica, Reophax* sp., *Spiriamphorella districh, Spirorbis phlyctaena, "Tetrataxis" nana?, Thaumatoporella parvovesiculifera, Thecosmilia* sp.,*Triadodiscus eomesozoicus, Triasina hantkeni, Trochammina alpina, Trochammina jaunensis, Trochammina* sp., *Tubiphytes* sp., *Turriglomina mesotriasica, Volzeia badiotica* fossils, the unit is given as Middle-Upper Triassic in age. Hanaylı unit is given as Lower Carnian (Cordevolian), and Güvercinlik unit as Carnian (Julian-Tuvalian) and "laminated dolomites" as Norian, and "white limestones" as Rhaetian by Brinkmann et al. (1967, 1972). The unit is also interpreted as Norian-Rhaetian by Erdoğan et al. (1990), and as Norian by Işıntek and Altıner (2001). According to the ages of under and overlaying formations and fossil content the age of the Güvercinlik formation has been evaluated as Carnian-Rhaetian.

It is suggested that Güvercinlik formation was deposited in various subenvironments (tidal flat, continental and reef environments) of a very shallow marine environment.

Nohutalan formation (Jn)

The unit, which is composed of limestone, dolomitic limestone and limestone with *Cladocoropsis*, has been differentiated as Nohutalan formation. Brinkmann et al. (1972) studied the unit by separating into three distinct facies, which are "laminated dolomites" (Nohutalan dolomite), "light colored micritic, biopelsparitic/oosparitic limestones", (Nohutalan unit) and *Cladocoropsis* bearing Malm limestones (*Cladocoropsis* unit). Erdoğan et al. (1990) considered the Liassic-Malm and Cretaceous "Aktepe unit", described by Lechner et al. (1967) and Brinkmann et al. (1972) in the Nohutalan formation. Rhaetian-Middle Liassic "Nohutalan formation" was separated into "Kimmeridgian limestones" and "Aktepe formation" by Işıntek et al. (1998 *b*) and Işıntek and Altıner, (1998). Nohutalan formation was also separated into Rhaetian "lower limestone" and Liassic "upper limestone" units by Işıntek and Altıner 2001. In this study, because of Rhaetian limestones is included in Güvercinlik formation and lack of a break between Liassic and Malm and also at Jurassic-Cretaceous boundary (İşintek and Altıner, 1998, 2001), Aktepe formation was separated and Liassic-Malm limestones are accepted as Nohutalan formation (Figure 3).

Nohutalan formation is a uniform unit which is composed of limestone, dolomitic limestone and dolomites. It is generally gray and medium to thick bedded. At the bottom, there are gray, light gray limestones and intercalated smoky dolomite and dolomitic limestones. The central parts of the unit contain gray, light gray to white limestones with rare replacement cherts and rare nodules. These parts show some oolitic, micritic and bioclastic features. It contains pinkish beige micritic-biomicrosparitic limestone with about 2 m thick, passing Malm levels bearing *Cladocoropsis*. This level with no identifiable fossils is similar to Toarcian-Dogger "ammonitico rosso" facies of West Taurids (M. Şenel, 1997; pers. comm.). However İşintek (2002) suggests a time gap approximately lasted 25 million years, by noticing to the bauxite formation between Liassic and Kimmeridgian. Upper levels include gray to brownish gray limestones with abundant algae. The most characteristic feature of these levels is the presence of abundant *Cladocoropsis* sp. Fossils (Figure 9).

Lower contact of the unit is gradational with Güvercinlik formation. The distinction can be made owing to fossil content, color change varying from pinkish white to gray, and bedding thickness varying from medium to thick. It is unconformably overlain by Aktepe formation. Local bauxites are observed at the contact between Nohutalan and Aktepe formations by Brinkmann et al. (1972). Besides, "Aktepe formation directly overlays Liassic limestones of Nohutalan formation with an erosional contact (İşintek and Altıner, 1998).

Brinkmann et al. (1972) measured the unit thickness as 500 m. (250 m for Nohutalan and 250 m for Cladocoropsis bearing portion); Erdoğan et al. (1990) estimated this 500 m. or more. The formation has no lateral change.

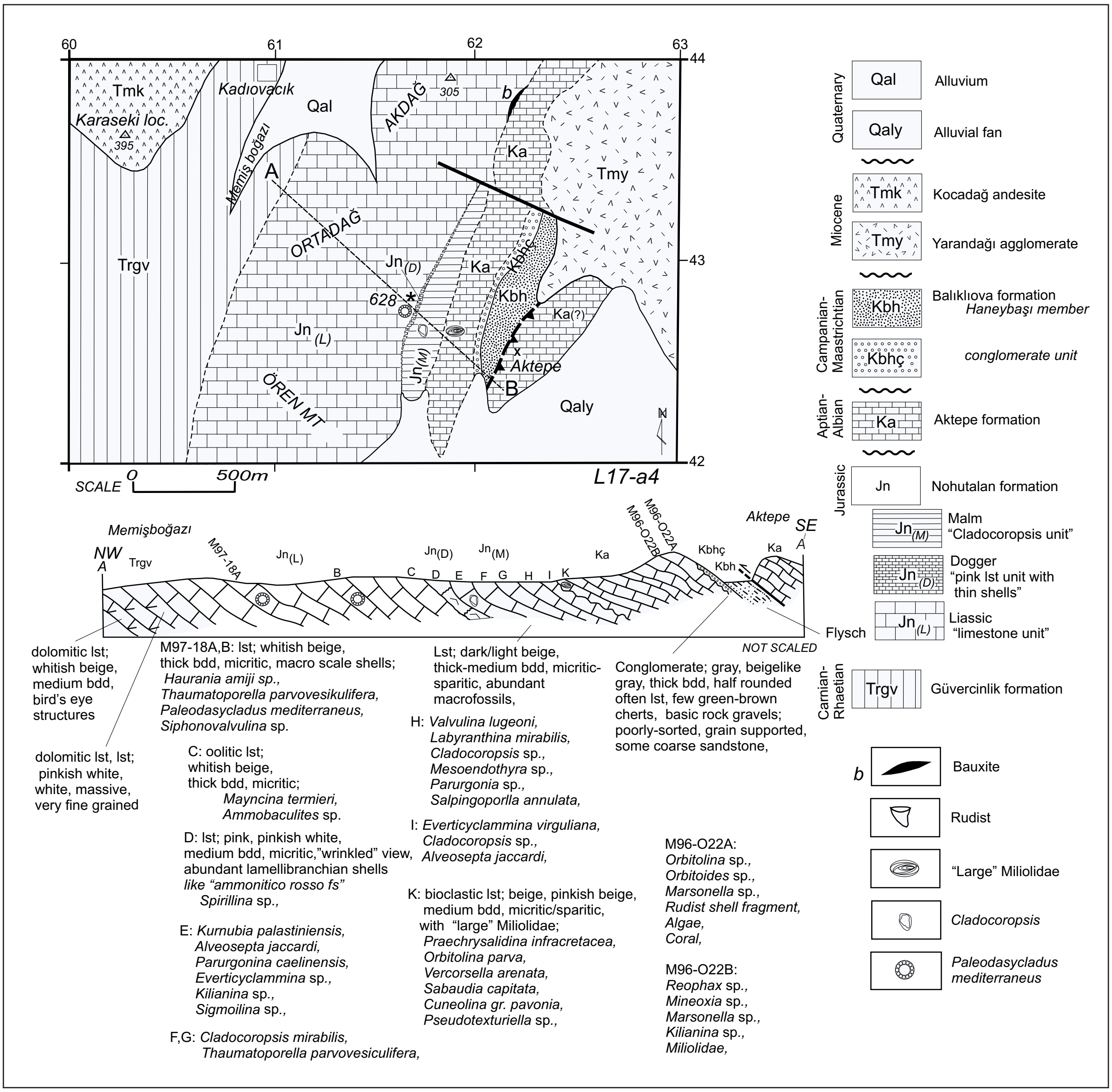

Figure 9- Geological section and map of Nohutalan and Aktepe formations between Kadıovacık and Barboros villages.

The determined fossils are *Acicularia* sp., *Actinoporella* sp., *Agerina* sp., *Agerina martana, Alveosepta jaccardi, Ammobaculites* sp., *Bolivinopsis* sp., *Cayeuxia* sp., *Cayeuxia piae, Cladocoropsis mirabilis, Clypeina jurassica, Conicokurnubia* sp., *Conicospirillina* sp., *Earlandia* sp., *Everticyclamina* sp., *Everticyclammina virguliana, Favreina* sp., *Glomospira* sp., *Glomospirella* sp., *Haurania amiji, Haurania desarta, Kilianina* sp., *Koskinobullina socialis, Kurnubia* sp., *Kurnubia palastiniensis, Labyrinthina mirabilis, Labyrinthina recoarensis, Lenticulina* sp., *Lituosepta compressa, Mayncina termieri, Mesoendothyra* sp., *Nautiloculina* sp., *Neotrocholina* sp., *Ophthalmidium* sp., *Orbitopsella praecursor* (A and B forms), *Orbitopsella primaeva,* *Paleodasycladus mediterraneus, Parurgonina caelinensis, Pseudocyclammina liassica, Protopeneroplis striata, Reophax* sp., *Salpingoporella annulata, Sigmoilina* sp., *Siphonovalvulina* sp., *Spirillina* sp., Textularidae*, Thaumatoporella parvovesiculifera,* Tintinidae*, Trochammina* sp., *Trocholina elongata, Tubiphytes* sp., *Tubiphytes morronensis, Valvulinidae, Verneulina* sp. in the formation. Most of these forms indicate Liassic/ Middle Liassic and Kimmeridgian, and some indicate Tithonian, Berriasian and Valanginian. While Nohutalan unit is given as Upper Triassic (Upper Rhaetian)-Liassic and Cladocoropsis unit is given as Malm by Brinkmann et al. (1972), Erdoğan et al. (1990) evaluated the unit Liassic-Albian in age. İşintek et al. (1998*b*) and İşintek and Altıner (1998, 2001) mentioned that the formation is Rhaetian-Liassic. In this study, the age of the Nohutalan formation has been assigned to Jurassic (Liassic-Malm).

Nohutalanı formation was deposited in shallow marine conditions. Upper parts reflect reef environment.

Aktepe formation (Ka)

The formation which includes generally beige, Aptian-Albian limestones, was firstly described as "Aktepe unit" by Lechner et al. (1967) and later by Brinkmann et al. 1972). Erdoğan et al. (1990) consider the unit that was included in Nohutalan formation; İşintek ve Altıner (1998) presented the Aktepe formation as "Aptian-Albian limestones" (Figure 3).

The unit often contains brownish-whitish to pinkish beige, medium to thin bedded, some wrinkled, bioclastic limestones and clayey limestones with abundant yellow calcite veinlets. Often it includes gastropod shells. The most distinctive feature is the presence of identifiable large miliolids.

Aktepe formation unconformably overlays Nohutalanı formation at the bottom, and bauxite formations (İşintek ve Altıner, 1998) are the indicators of this unconformity. However the upper contact is controversial but in this study, taking into consider the age of the (Campanian-Maastrichtian) conglomerate and sandstones of the Haneybaşı member just above the unit, it is suggested that there is a time gap between Aktepe formation and overlaying unit (Figure 9).

Brinkmann et al. (1972) stated that the unit has a thickness of 250 m. The unit which has a limited extent, has no lateral change.

According to *Bolivinopsis* sp., *Cuneolina* sp., *Cuneolina camposaurii, Cuneolina pavonia, Cyclogyra* sp., *Debarina* sp., *Debarina hahounerensis, Glomospirella* sp.*, Miliolidae, Nezzazata* sp., *Nummoloculina heimi, Ophthalmidium* sp*., Orbitolina* sp., *Orbitolina parva, Praechrysalidina infracretacea, Praeorbitolina lotzei, Pseudocyclammina* sp., *Pseudocyclammina hedbergi, Pseudorhapydionina dubai, Pseudotextulariella* sp., *Pseudotextulariella*? *scarsellai, Sabaudia* sp., *Sabaudia capitata, Sabaudia minuta, Vercorsella arenata* and rudist shells, Aktepe formation is assigned to Aptian-Albian age. The unit has been reported as Lower Cretaceous by Lechner et al. (1967), Barremian to Aptian by Brinkmann et al. (1972) basing on Palaeodictyoconus sp. fossils. While Erdoğan et al. (1990) claimed that Nohutalan and Aktepe formations reach to Albian, İşintek and Altıner (1998) stated that Aktepe formation limestones was Aptian-Albian. In this study the formation has been accepted as Aptian-Albian in age.

Aktepe formation was deposited in a shallow marine environment, particularly at backreef conditions.

Balıklıova formation (Kb)

The formation is composed of carbonate and clastic rock units, and identified as the latest Upper Cretaceous ("Höhere Oberkreide") by Brinkmann et al. (1977). The unit has been described as "Balıklıova unit" of Late Cretaceous age by dividing into lower "Karahasan limestone member" of carbonates, and upper "Haneybaşı member" of clastic rocks in flysch facies by Erdoğan et al. (1985). In this study the formation name made by Güngör (1989) were preserved as well as member names.

The unit begins by conglomerates or clastic-bioclastic limestones, continues with marn and micritic limestones, and ends with sandstone and mudstones in flysch facies (Figure 10).

Karahasan limestone member (Kbk)

The unit begins with a conglomerate level including pink to pinkish beige, poorly-sorted, sub-rounded limestone pebbles with a thickness of 2-3 meters. Light to dark beige, massive-thick bedded litho-bioclastic limestones at the bottom are common. The lowermost limestone level has bauxite gravels and rudist shells (Figure 10). Upward, there are beige, medium-thick micrites bearing Globotruncana with green cherts/radiolarite clasts, and brownish pink to red, thin-medium bedded, wrinkled limestones with nodules, and also bordeaux red to brownish beige (mottled), thin bedded marls and clastic limestones.

Haneybaşı member (Kbh)

Haneybaşı member in flysch facies, is composed of green, brownish, yellow red, greenish in colour, very thin to medium bedded sandstone and mudstone alternations which, overlays micritic limestones and marls of Karahasan limestone member. Sandstones contain red radiolarite and serpentinite clasts. At southwest of Kadıovacık village, gray to beigelike gray, poorly-sorted conglomerates with a thickness of about 5-10 m are just above the Aktepe formation, and include often sub-rounded limestone, and green to brown, rounded and sub-rounded chert and a few basic rock pebbles (diabase?). This conglomerate level is accepted as a basal conglomerate at the bottom of Karahasan limestone which laterally gets thinner and disappears. Overlying this, brownish yellow to greenish beige sandstones are present.

The formation, unconformably underlain by Gerence, Nohutalan and Aktepe formations, and is also unconformably overlain by Neogene rock units.

Based on the fossils of *Calcarinidae, Disyclina* sp., *Globigerina* sp., *Globotruncaniidae, Globotruncana* sp., *Globotruncana linneiana,* Miliolidae, *Minouxia* sp., *Nacellaria* sp., *Nodosaridae, Nodosaria* sp., *Nummofallotia* sp., *Ophthalmidium* sp., *Radiolaria* sp., *Rosita* sp., *Rotalidae, Rotalia* sp., *Textularia* sp. provided from limestones, the unit has been dated as Senonian. Brinkmann et al. (1977) suggest that neritic and pelagic carbonates are Lower?-Upper Campanian-Lower Maastrichtian. Lower neritic limetones are given as Santonian-Campanian, and upper pelagic limestones as Late Campanian and Early-Middle Maastrichtian by Erdoğan et al. (1985); The lowest parts of Karahasan limestone member are given as Campanian, upper pelagic limestones as Maastrichtian by Erdoğan (1990*b*), and Balıklıova formation as Campanian-Maastrichtian by Erdoğan et al. (1990). In this study, Campanian-Maastrichtian age is adopted for the unit.

Bottom levels of the unit characterize shallow marine, reef and foreslope environments and upward a deepening shelf conditions become dominant.

ALLOCHTHONOUS UNITS

(Late) Permian Tekedağı formation including limestones, dolomitic limestones, sandstones, siltstone and marl interfingers, and ?-Ladinian-Early Carnian (Norian?) İdecik unit composed of basic volcanic rocks, turbidites and carbonates, Late Cretaceous-Early Tertiary (Danian?) Izmir flysch and the Yeniliman serpentinite tectonically rest on the "Autochthonous" rock units.

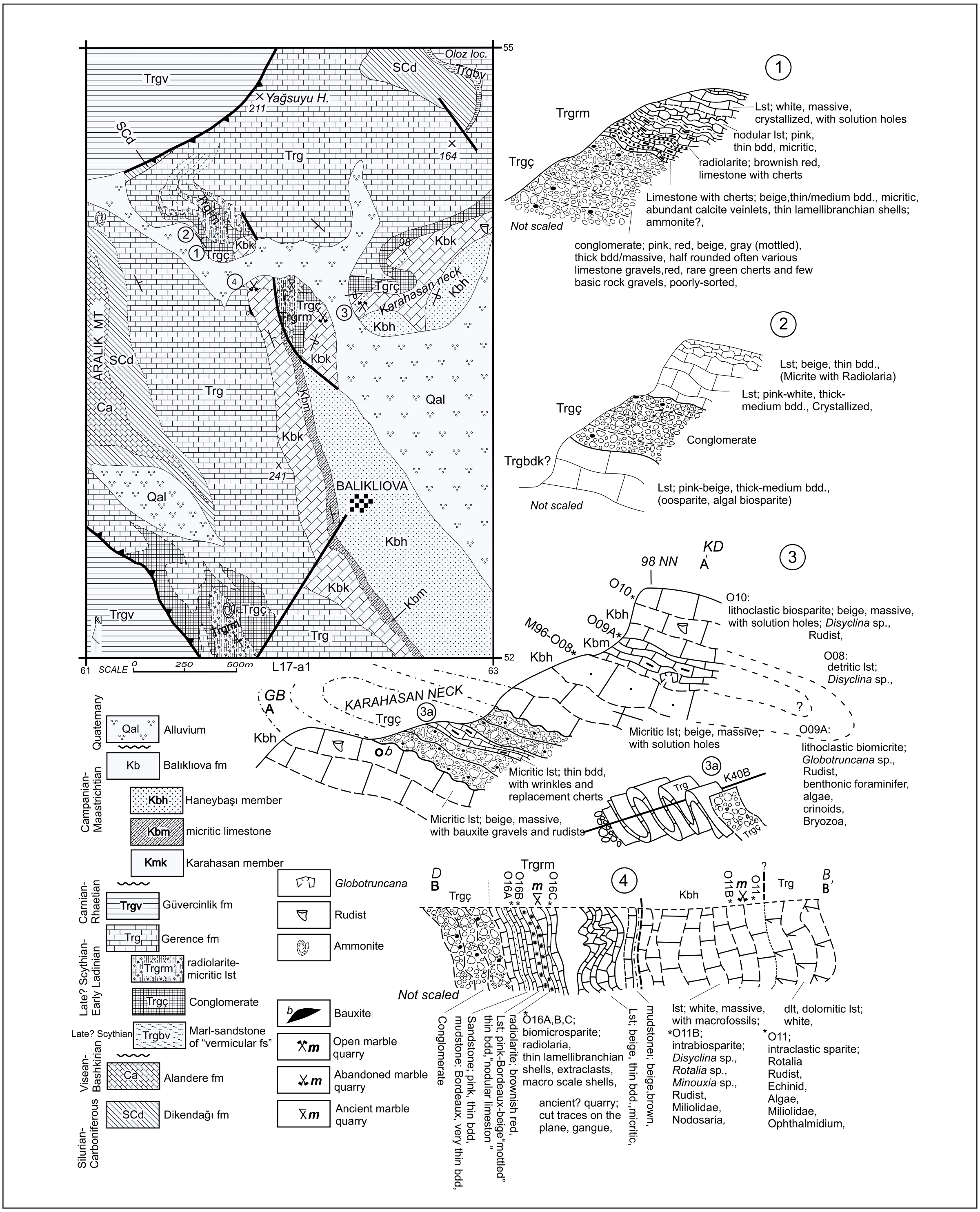

Figure 10- Geological section and detailed geological map of Balıkova formation and Gerence formation araound Balıkova village.

Tekedağı formation (Pt)

The unit of (Late?) Permian age, composed of limestones, sandstone, siltstone and marl interfingers, was firstly described in the study area and called as Tekedağı formation. Garrasi and Weitschat (1968) described Permo-Carboniferous "Tekekaradağ limestones" on Tekedağı Peninsula, which comprises this unit.

Probable lower parts of the formation contain brownish to grayish black limestones and dusty white sandstone and siltstones with mica flakes, and blackish, gray to dark gray, wrinkled laminated clayey limestone-marl interfingers. Because of allochthonous position, succession style is not certainly identifiable. Probable lower parts of limestones are thin to medium bedded, folded, flexured, wrinkled and some oolitic and pisolitic. Probably, upward it passes into the brownish black, thick to medium bedded fosilli feraus limestones, (e.g. gastropods and benthonic microfossils) (Figure 11).

Lower and upper contact of the unit is tectonically related to the limestones of Gerence formation (bearing ammonite, Halobia and Daonella fossils). Tekedağı formation, outcrops as a small tectonic slice in the study area and has no lateral change.

According to the *Eotuberitina* sp., *Frondina* sp., *Geinitzina* sp., *Globivalvulina* sp., *Gymnocodium* sp., *Hemigordius* sp., *Permocalculus* sp., *Pseudovermiporella* sp. fossils the original age of the observable central parts of the unit, has been supposed as (Late?) Permian in age.

Rock type, macroscopic and microscopic faunal features show that Tekedağı formation was deposited in a shallow marine environment.

İdecik unit (Tri)

Including altered greenish brown basic lavas, pyroclastic/volcanoclastic rocks, limestones with nodules and cherts, and red radiolarites, the unit is redescribed as a separated structural-stratigraphic unit namely İdecik unit, due to its stratigraphic position. It is suggested that the "Güldağ", "İdecik" ve "Kayadibi" formations are included in Karareis assemblage by Konuk (1979). The unit has been evaluated as a part of Karareis formation of the Denizgiren group by Erdoğan et al. (1990) (Figure 3).

The unit begins with green basic tuffs resting on gray limestones with some nodules and cherts, and continues by an intercalation of red pelagic limestones and green to yellowish-brownish beige chert and radiolarites with radiolarias. Upward, green tuffs increase and pass into green, brownish green lavas mixed with cherty limestone clasts, (Figure 12).

It is supposed that the unit is tectonically related with lower Dikendağı formation and upper Camiboğazı and Gerence formations with respect to structural and stratigraphic position.

Idecik unit has a visible thickness of about 100 meters. Lateral change is locally, for instance as turbiditic levels within the unit.

Determined *Triassocampe* sp., *Triassocampe ex* gr *scalaris, Pentaspongodiscus mesotriassicus, Pseudostylosphaera* sp., *Pseudostylosphaera fragilis, Parasepsagon variabilis, Sepsagon? aequispinosus, Pseudostylosphaera coccostyla, Actinommidae, Eptingium* sp. cf. *manfredi radiolarian* fossils from red radiolarites at the lower levels of the volcanic rocks, date the unit as middle of Early Ladinian-Late Ladinian; determined conodonts in limestones just above the unit give Early Carnian age (Kozur, 1996; pers. comm.) (Figure 13). Konuk (1979) proposed Carnian age for Güldağ, İdecik and Kayadibi formations. Kozur and Kaya (1995) reported that submarine tuffs are intercalated with the clastic rocks below the Late Ladinian carbonates, and Kaya and Rezsü (2000) reported that Ladinian/Carnian mafic volcanoclastic unit was present.

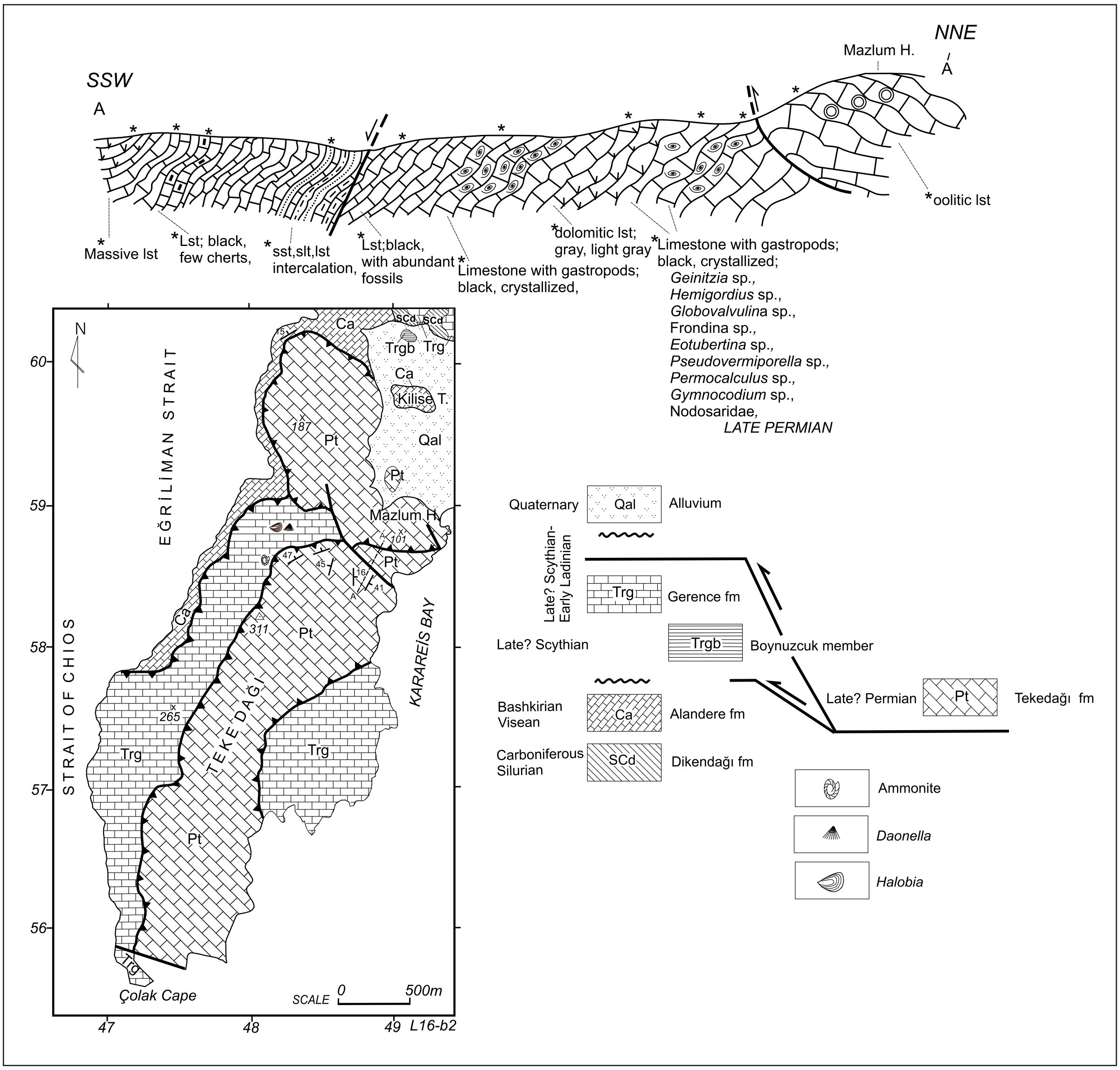

Figure 11- Geological section and map of Tekedağı formation at Karareis Bay- Tekedağı.

According to these data, İdecik unit should be Ladinian-Carnian. At upper levels, limestones with *Galeanella* sp. fossils may be considered to reach Norian (perhaps to younger ages), as shown by Konuk (1979) (Figure 12).

İdecik unit was deposited on an unstable, relatively deep marine environment dominated by active volcanism.

İzmir flysch (KTi)

İzmir flysch is generally composed of a clastic matrix and boulders of various rock types. The unit has a wide distribution in West Anatolia and is named as "İzmir flysch formation" by Öngür (1972), and "Izmir flysch" group by Eşder (1988). Most of the earlier works mentioned the unit, such as "Cretaceous flysch" by Parejas (1940), Brinkmann (1966), Brinkmann and İzdar (1971); as "Upper Cretaceous flysch" by Akartuna (1962); "Bornova flysch" by Konuk (1977); "Erdemirçay formation" by Konak et al. (1980); "Flysch assemblages" by Yağmurlu (1980); "Cretaceous-Paleogene flysch" by Başarır and Konuk (1981); "Belkahve" and "Çaldağ" formations by Akdeniz et al. (1986); and "Bornova complex" by Erdoğan (1985, 1990 *a, b*) and Erdoğan and Güngör (1992).

It is accepted that Izmir flysch is differed from Haneybaşı member of flysch facies of the Balıklıova formation because of tectonic relation with underlying units and its blocky/olistostromal structure and stratigraphy in the study area as suggested by Erdoğan et al (1990).

The green, brownish green to brownish yellow, pinkish beige olistostromal levels including limestone clasts and blocks with a sandstone-mudstone dominated matrix, and radiolarites (KTir), and generally altered basic volcanic rocks (KTiv), ultrabasic rocks (KTiu), and limestone blocks of various age (KTik) are shown in the unit often relating with Camiboğazı formation. Around Kalecik Mahallesi (K16-c2, c3); Lower Devonian (Fenninger, Von A.1983; Gusic et al. 1984), Anisian-Ladinian (Yarımkaya Ridge, Çöplen Hill; Gusic et al. 1984), Triassic, Triassic-Jurassic?, Triassic-Liassic?, ?-Liassic limestone and Liassic-Lower Cretaceous radiolarite blocks; between İnceburun and Azmak Burnu (K16-c3) Dogger-Kimmeridgian?, Tithonian-?, Carnian?-Liassic, ?-Liassic, Malm, Oxfordian?-Kimmeridgian limestone blocks; at Çalılık locality, in the west of Aşağı Demircili Mahallesi (L17-d2) a Carnian (probably Julian) limestone block interfingered with radiolarite are presented too. All of these are the blocks in various age within the İzmir flysch.

The unit overlap Paleozoic and Mesozoic rock units with a tectonic contact, and is unconformably overlain by Neogene units.

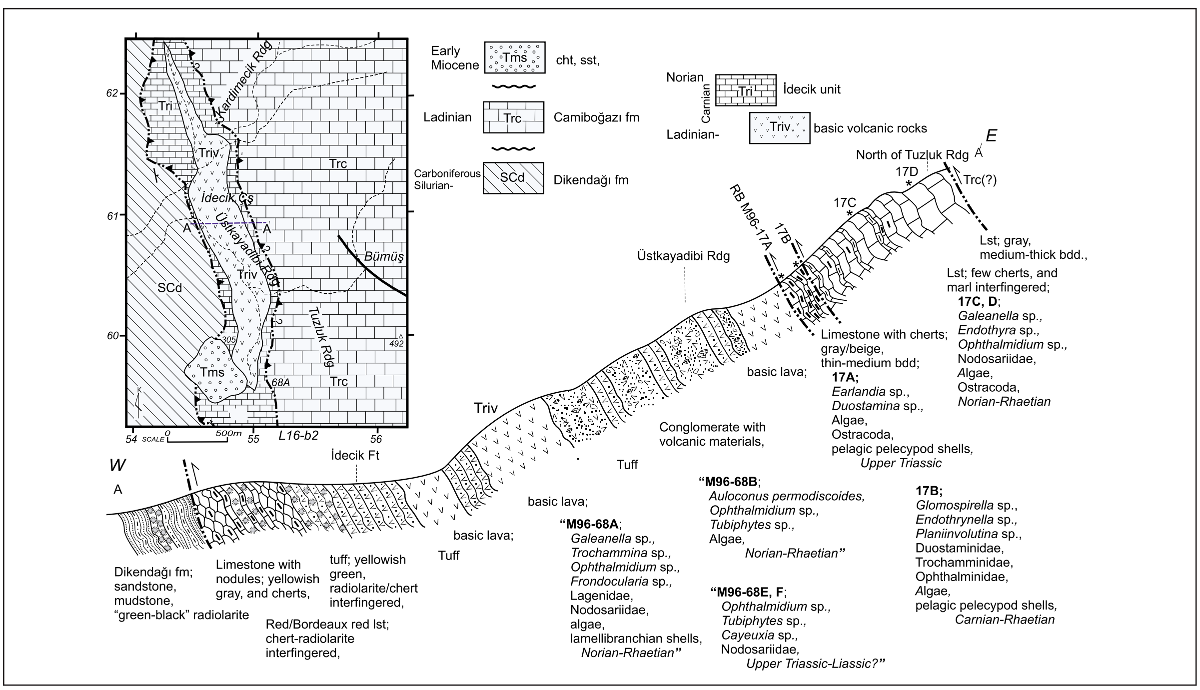

Figure 12- Type section and geological map of İdecik unit at Tuzla locality.

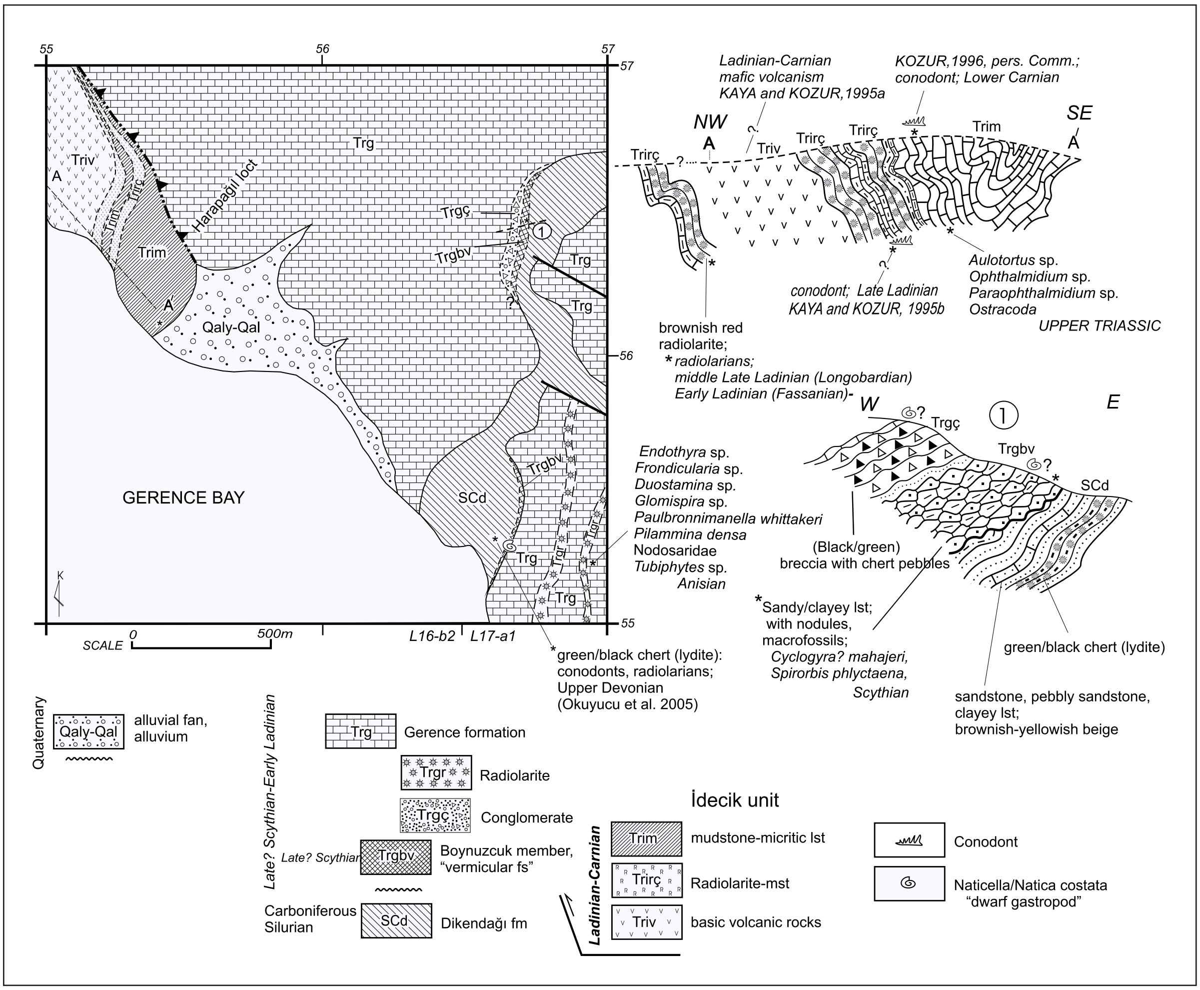

Figure 13- Geological section and map of İdecik unit at Harapağıl locality.

No fossils were determined within the matrix. But, limestone clasts and blocks include A*gerina*? sp., *Calcitornella*? sp., *Campbelliella* cf. *striata, Cayeuxia* sp., *Cladocoropsis mirabilis, Clypeina*? sp., *Diplopora*? sp., *Endothyra* sp., *Frondicularia* sp., *Glomospira*? sp., *Lituosepta* sp., *Meandospira*? sp., *Mesoendothyra* sp., *Mesoendothyra croatica, Ophtalmidium* sp., *Paleodacycladus mediterraneus, Radiolaria* sp., *Salpingoporella annulata, Siphonovalvulina* sp., *Teutloporella*? sp., *Thaumatoporella parvovesiculifera, Tubiphytes* sp., *Valvulina* sp., *pelecypods* (*Daonella* sp., *Halobia* sp.) and ammonite shell sections ranging from Triassic to Tithonian; radiolarite blocks contain *Podobursa* sp., *Praeconocaryomma* sp., *Syringocapsa* sp. ranging from Liassic to Lower Cretaceous, and *Capnuchosphaera* sp., H*indeosphaera bispinosa, Orbiculiforma* sp., *Spongostylus tortilis, Triassocampe* sp. of Carnian age (probably Julian).

İşintek et al. (2000) reported that limestone blocks of Barremian-Albian Liassic-probable Dogger carbonates (with a bauxite zone), are presented within the Izmir flysch which is included in the "Taurids Bornova Flysch Zone".

The unit is generally accepted as Late Cretaceous. However, younger ages such as "Upper Maastrichtian-Paleocene" by Konuk (1977), "end of Cretaceous-Paleocene" by Yağmurlu (1980), "Eocene" by Düzbastılar (1980), "Paleocene-Eocene" by Başarır and Konuk (1981) and by Başarır (1989), Danian/Lower Paleocene by Özer and İrtem (1982), "Late Cretaceous-Paleocene" by Erdoğan (1985), Campanian-Paleocene (with "Belkahve formation" content) by Akdeniz et al. (1986), "Campanian-Danian" by Erdoğan (1990 *a,b*), and "Late Cretaceous-Early Paleocene" by Kaya and Rezsü (2000) have been proposed. With respect to this view and obtained data, Campanian-Early Tertiary (Danian?) age has been adopted for the unit in this study.

İzmir flysch were deposited on an unstable basin/slope environment.

Yeniliman serpentinite (Kys)

The unit includes green to brownish green serpentinites and cover an area of about 2 km², just to the south of Yeniliman Village (K16-c2). The unit rests on Ordovician Küçükbahçe formation by a tectonic contact. It is unconformably overlain by Early Miocene "Salman formation" composed of conglomerates, sandstones and mudstones (Aras et al. 1999). Erdoğan (1990 *b*) reports a serpentinite block included in Maastrichtian-Danian Bornova complex too.

DISCUSSION, CONCLUSION AND PROPOSALS

1/25.000 scale geological maps of the peninsula were completed by means of this study and 1/100.000 scale geological maps were prepared by revision and compilation of the previous works.

Paleozoic deposits are mapped by differentiating into three distinct formations.

Some rock types which accepted earlier as Paleozoic/Lower Triassic, are shown that they are included in İzmir flysch of Late Cretaceous-Early Tertiary (Danian?) and it is determined that these rocks show a large extension on Karaburun Peninsula.

It is understood that Scythian is common in the study area and can be separated into sedimentary facies rather than "vermicular facies" in several meters thick.

Gerence formation extending from north to south in the peninsula has a facies change from clastics dominated to turbiditic carbonates.

Allochthonous (Late?) Permian on the peninsula was firstly proved with fossils.

Dogger, may be interpreted by basing on rock type/facies similarities with those of West Taurides. However, it is reported that there is a stratigraphic break between Liassic and Malm (Kimmeridgian) by İşintek (2002).

It was also shown that the Anisian olistostromal facies is common in the studied area.

The basic volcanism identified as Triassic-Anisian by Erdoğan et al. (1990) have been considered as younger (like Konuk, 1979; Kozur, 1995, 1998; Kozur and Kaya, 1995; Kaya and Rezsü, 2000 and Çakmakoğlu and Bilgin, 2003) according to new fossil findings. Radiolarian, conodont and other fossils of the İdecik unit and *Galeanella* sp. (Konuk 1979) (exampled in this study) point to the Norian-Rhaetian range of the structural constituents. While the Gerence formation of Anisian points to a deep marine environment, Ladinian and later reveals shallow marine conditions. However the environment of the basic volcanic rocks is controversial like Idecik unit, Carnian has a deep, but Norian-Rhaetian has a shallow marine conditions.

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"LIGNITIC SANDSTONES" OF THE TRAKYA BASIN

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ABTRACT.- Uppermost Eocene - Lowermost Miocene Yenimuhacir Group of the Trakya Basin consists of clastic sediments representing deltaic facies associations with a total thickness of 3500 meters. Major facies associations of prodelta, delta front and delta plain can be differentiated both in the field and in the oil exploration wells, and they are named as Mezardere, Osmancık and Danişmen formations respectively. The unit described as "lignitic sandstones" in early studies, represents delta front and delta plain environments of the system forming the Yenimuhacir Group. They are the equivalent of Osmancık and Danişmen formations described in this paper.

Key words: Trakya, Yenimuhacir, deltaic fasies, sekans stratigrafi, seismic data

INTRODUCTION

A unit named as "lignitic sandstones" by the previous investigators is seen in a large area extending from S of Uzunköprü to Keşan, Malkara, Tekirdağ, Marmara Ereğlisi and Büyükçekmece in the Thrace region (Figure 1, Ternek, 1949, Koop et al., 1969, Lebküchner, 1974). This unit has been described as Danişmen formation in Boer, 1954, Beer and Wright, 1960, Umut et al., 1983, 1984, Sümengen et al., 1987, Umut, 1988 *a, b,* İmik, 1988, Sümengen and Terlemez, 1991, Şentürk and Karaköse, 1998, Şentürk et al., 1988 *a, b,* Duman et al., 2004 or Osmancık formation in Kasar et al., 1983, Atalık, 1992. It is indicated as Oligocene-Lower Miocene clastics on İstanbul sheet of 1/500,000 scale Turkish Geological Maps published by MTA (Türkecan and Yurtsever, 2002).

The unit mentioned as lignitic sandstones are two discrete formations including delta front and delta plain facies rather than a single unit. Knowing detailed stratigraphy of the oil and gas productive reservoir sandstones of Oligocene and overlying claystone and shales which have been investigated by national and foreign companies in drillholes, is very important for economic expectations of the investments. It is obvious that well defined stratigraphy contributes lots of benefits to the expensive drilling explorations.

For this purpose, this paper, aimed to reveal the stratigraphy of Oligocene, which the unit described, as a single formation and named differently in southern Thrace in 1949, but, accepted as the same unit, hereby, with conducting field as well as subsurface data, the units seemingly to be as two individual formations will be exlained in the article.

GENERAL STRATIGRAPHY

Whether or not pre-Tertiary sedimentary units are present and how the sedimentation begun are certainly not obvious at the base of Tertiary units exposing on different basement rocks in different regions of Thrace and the vicinity, but the estimated maximum thickness of the Tertiary sequence seems to be about 9.000 meters, near Muratlı (Koop et al., 1969, Turgut et al., 1991, Siyako, 2005, 2006). It is possible to obtain the information of the basin evaluation and the stratigraphy in this region by the southern outcrops and geophysical as well as borehole data (Figure 2). According to the data, the Thrace Tertiary Basin, where generally clastics have deposited, seems to be a considerably fast subsiding and is filled

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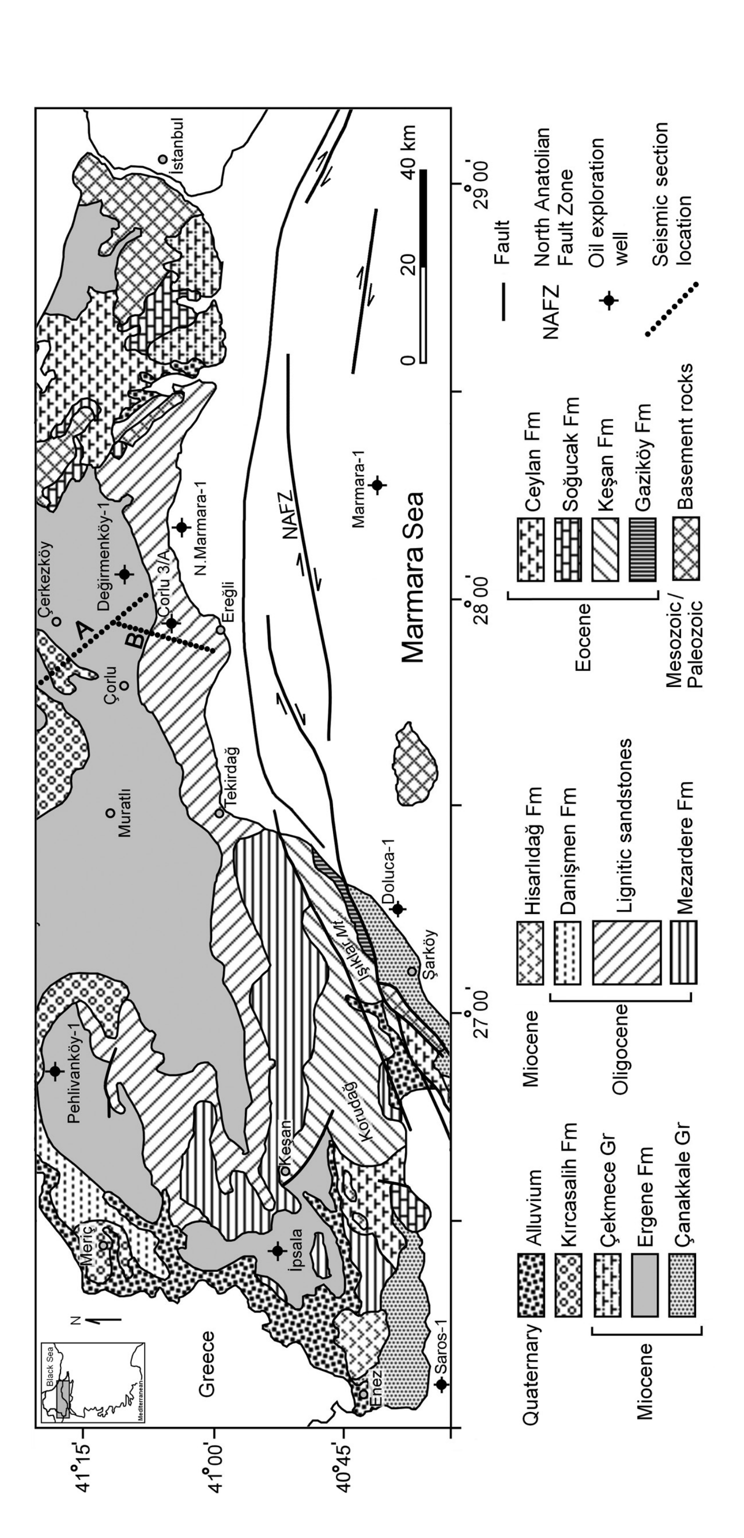

Figure 1- Geological map of the southern Thrace (Siyako, 2005).

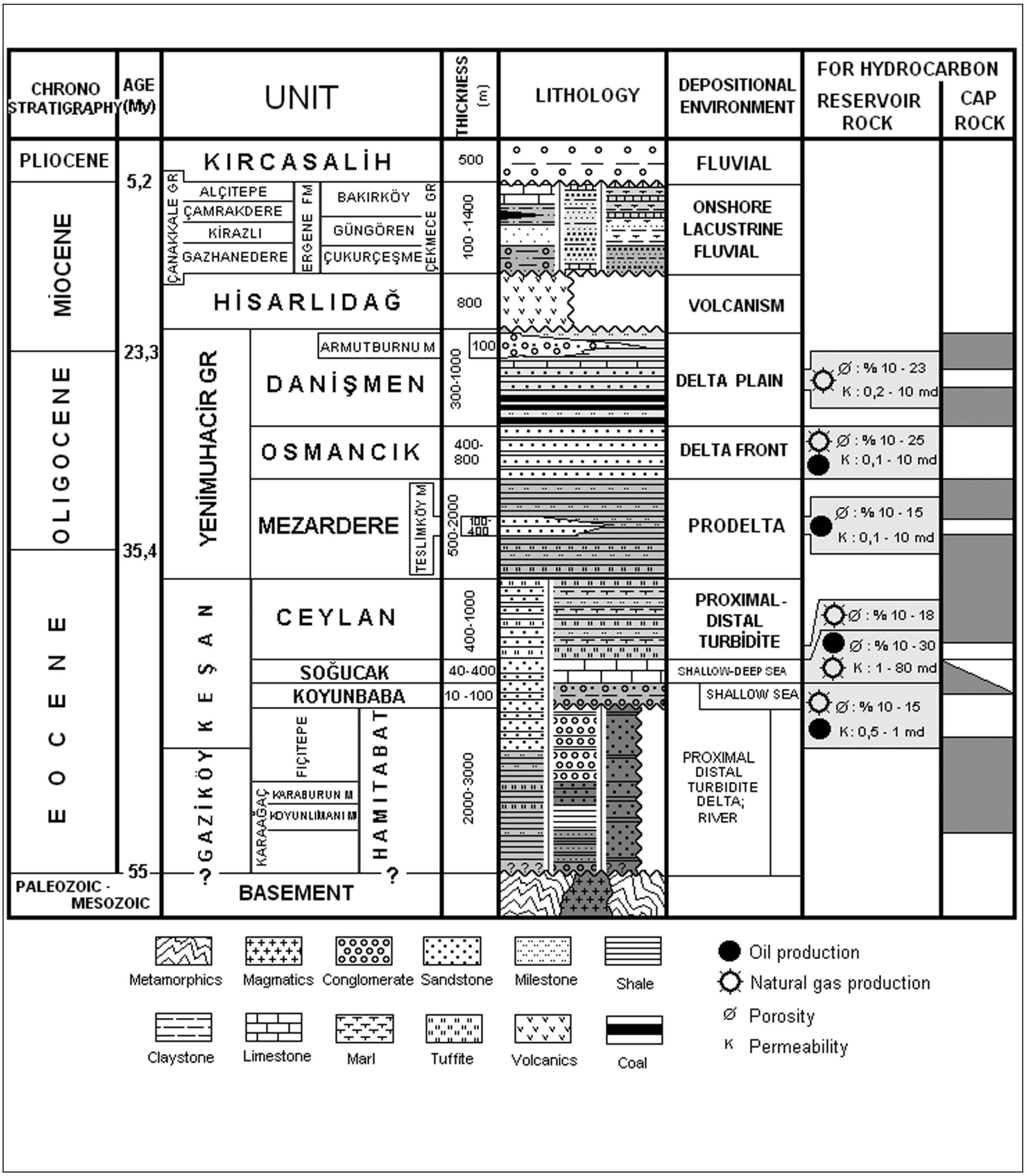

Figure 2- Generalized stratigraphic section of Tertiary sequence in Thrace (pers. comm. with Hasan Emiroğlu, 2004).

while subsiding, basin which partially showed continuous sedimentation and partially ceased sedimentation and erosion phases. Some portions of the basin have a partially continuous sedimentation, and some have occasionally breaks and erosional phases. Probably the sedimentation commenced in Early Miocene has continued up to the recent if the sedimentation breaks and erosions are not taken into considerations (Figure 2).

It is understood that various units deposited at terrestrial and marine environments are in lateral and vertical transition with each other on the basin during Early-Middle Eocene time interval (Figure 2, Siyako, 2005, 2006). Keşan Formation and Ceylan Formation corresponding to top levels of this unit are deposited at Late Eocene. Both of these units are composed of turbidites deposited in the marine environment despite their contrasting lithologies. A delta system named as Yenimuhacir Group started to evolve while the environment were shallowing at the end of Late Eocene - the beginning of Early Oligocene (Kasar et al., 1983, Saner, 1985, Sümengen and Terlemez, 1991, Atalık, 1992, Siyako, 2005, 2006). Mezardere (Ünal, 1967, Kasar et al., 1983), Osmancık (Ünal, 1967, Kasar et al., 1983, Siyako, 2005, 2006) and Danişmen formations (Boer, 1954, Beer and Wright, 1960, Ünal, 1967, Kasar et al., 1983, Siyako, 2005, 2006) were deposited in this system until Early Miocene. At the end of this stage, region is completely filled, uplifted and then, turned to be terrestrial, and after an erosional phase the sedimentation of younger Miocene-Pliocene aged units have taken places.

Yenimuhacir Group

Formations constituting of Yenimuhacir Group are transitional in a classic delta system laterally and vertically, and are units needed to be mapped as distinct units, i.e. prodelta, delta front and delta plain deposits, respectively.

Of these units, Mezardere Formation, representing prodelta facies is in gradual transitional with lower Keşan and Ceylan Formations and overlying Osmancık Formation. Its lithology mainly consists of shales, marls and tuffites. Tuffites, which may be distinguished as guide levels, may be traced over much longer distances. Often sandstone fragments are observed within the unit. These concentrated levels are mapped with a unit called as Teslimköy Member (Figure 2, Kasar et al., 1983). Mezardere formation has a thickness of 1540 meters at its local, type section (Kasar et al., 1983). Based on palynological studies, it is reported that its age is Late Eocene-Early Oligocene and it may extend to Late Oligocene in E of the basin (Ediger and Alişan, 1989, Batı et al., 1993, 2002).

Osmancık Formation, which is included in a delta front facies, is an upward coarsening and shallowing sequence, and is composed of sandstone and shale lithologies. The unit also contains few conglomerates, lamellibranchian shell aggregates and tuffite levels. Distribution and thicknesses of rarely observed lignite levels in the wells and in the field are not as large and great as that of Danişmen Formation (Siyako, 2005, 2006). The outcrop thickness of Osmancık Formation seems to be about 800 meter (Temel and Çiftçi, 2002) and the same value is also taken in the wells drilled in the northern and eastern Thrace. Based on palynomorphs obtained from palynological studies conducted in the field and well samples, the age of unit, ranges from Early to Late Oligocene (Ediger and Alişan, 1989, Batı et al., 1993, 2002).

Danişmen Formation, the uppermost unit of Yenimuhacir Group, represents delta plain facies in this system. Locally thin laminated claystones and shales, sandstones, conglomerates and coals deposited on lacustrine, marsh, floodplain and fluvial environments compose of the main dominant lithology. There are rare tuffite and limestone levels. Borehole data show that Danişmen Formation has 1000 meter maximum thickness, but original thickness might have been thicker due to its upper levels' being eroded (Siyako, 2005, 2006). The parts in Danişmen Formation which is of Conglomerate-dominated and easily mappable, are named as Armutburnu Member (N.V.Turkse Shell, 1969, Saner, 1985, Siyako et al., 1989, Temel and Çiftçi, 2002, Siyako, 2005, 2006). Danişmen Formation is of Late Oligocene-Early Miocene (Batı et al., 1993) and Late Oligocene ages (Batı, 1996, Batı et al., 2002).

Lignitic sandstones

Lignitic sandstones, exposed on a vast area in the southern Thrace, comprise both of Osmancık and Danişmen Formations, as described above. Their reference sections may be seen on Keşan-Uzunköprü, Malkara-Hayrabolu, Keşan-Tekirdağ roads and on coasts of northern Marmara Sea (between Tekirdağ and İstanbul) (Figure 1). Sümengen and Terlemez (1991), studied the regions between Keşan and Tekirdağ, reported all of lignitic sandstones as Danişmen Formation and subdivided it into two facies, one as delta front and the second as delta plain, on their generalized stratigraphic sections. Atalık (1992), who has studied measurement of the detailed stratigraphic sections on all of the exposed lignitic sandstones, described the whole unit as Osmancık Formation and subdivided it into 16 characteristic lithofacies. The described facies correspond to prodelta, delta front and delta plain environments, and those of more detailed subsections.

As understood from the previous works, there are several unmapped formations on the outcrops of the lignitic sandstone. If the start of the measured sections by Atalık (1992) is accepted as Mezardere formation with prodelta facies, two more formations remain which they correspond to the real Osmancık and Danişmen Formations, described previously (Siyako, 2005, 2006).

Based on subsurface studies by the well records and seismic sections, carried out at TPAO, Danişmen, Osmancık and Mezardere Formations are separated from each other by traceable levels over long distances like an indicator layer and described as sequence boundary (Figure 3, pers. comm. with A. Kadir Yılmaz and İsmail Abalıoğlu, 2004, Siyako, 2005, 2006). Besides, the basement of the coal levels, observed as the lower part of Danişmen Formation, is described as the contact between Danişmen and Osmancık Formations by means of performed drilling exploration studies (pers. comm. with Hasan Emiroğlu, 2004, Siyako, 2005, 2006).

The separation of Osmancık and Danişmen Formations outcrops were partially done on the lignitic sandstone outcrops in a small area shown on the unpublished geological maps of F29-c and d sheets found at the archives of TPAO Exploration Department (Figure 4, Bürkan, 1992). Here, folded Oligocene units, being formed by a strike and slip fault, are seen. Although with its distinctive and resistant litjology, Armutburnu member beloging to Danişmen Formation can be mapped easily, the contact between Osmancık and Danişmen Formations was not discerned due to their unconsolidated and fragmented lithology. However, as shown on figure 3, there is a distinctive contact between the two units. As in the seismic section of figure 5, the correlations performed among the other sections reveal that the contact was discerned,

Using similar methods and detailed sedimentological-stratigraphical works in the field, it is likely that this contact is mapped on all of the exposed lignitic sandstone in southern Thrace (Siyako, 2005).

CONCLUSIONS

It is a pity that inspite of Thrace's being an oil, natural gas, and coal production territory from Oligocene clastics, there is still shortage of basic stratigraphic-sedimentological knowledge within the geological maps as well as models. In this article, not only scientific significance of the

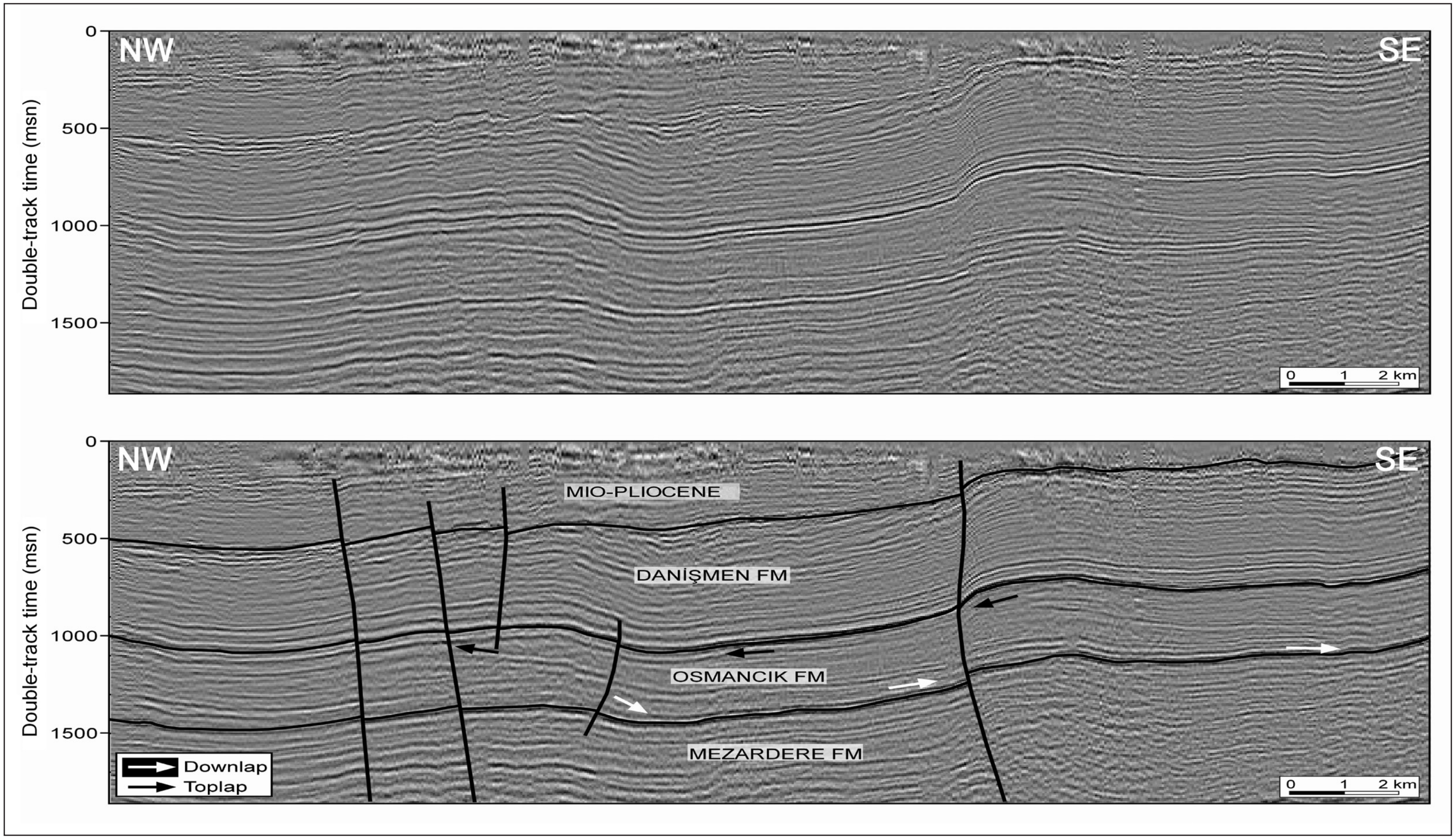

Figure 3- Sequence boundaries between Danişmen, Osmancık and Mezardere Formations and "toplap"s and "downlap"s, which are indicators of these boundaries, are seen on the interpreted and uninterpreted seismic section A. See figure 1 for the location of the section (Siyako, 2005).

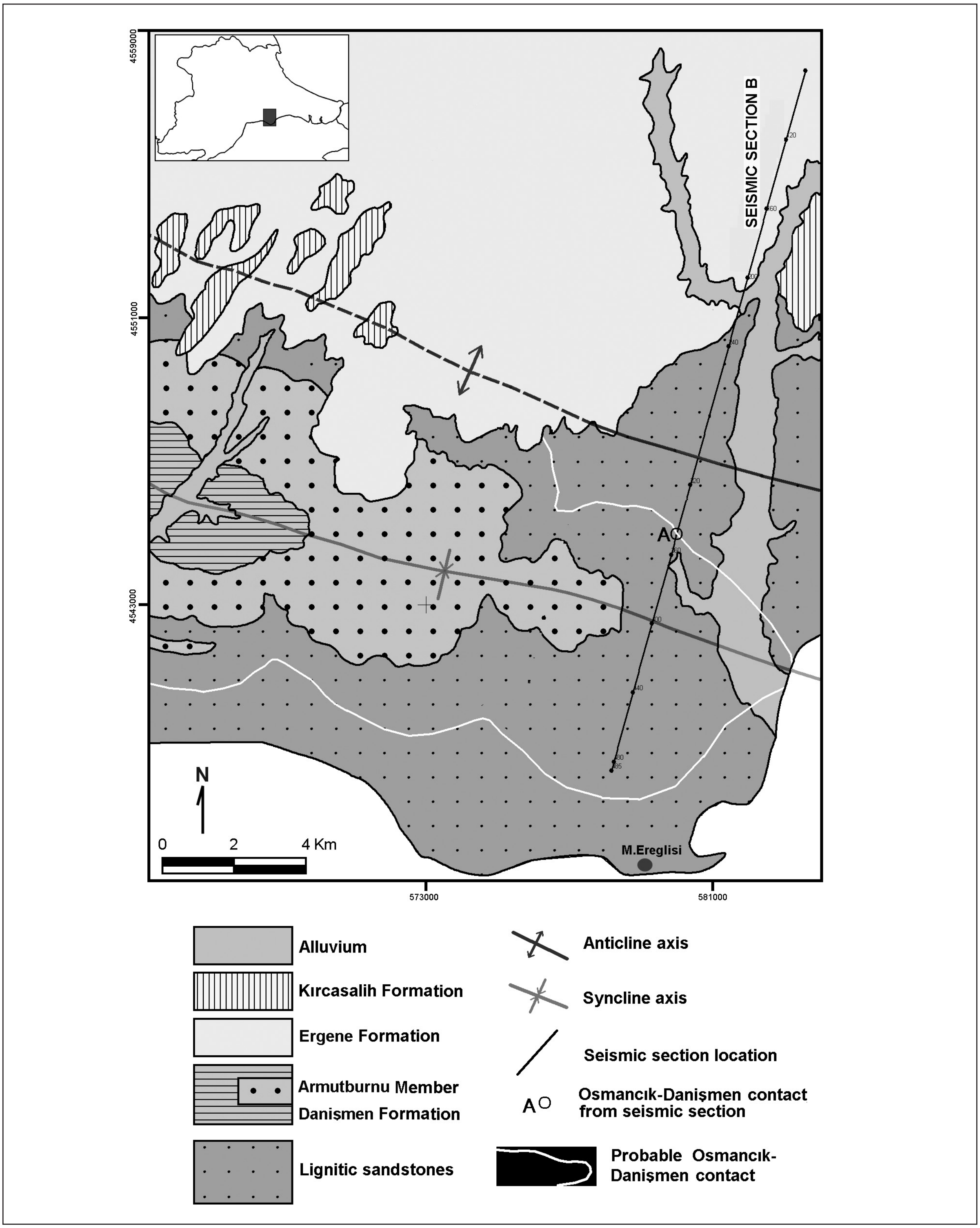

Figure 4- Geological map of northern Marmara Ereğlisi (Bürkan, 1992, Siyako, 2005)..

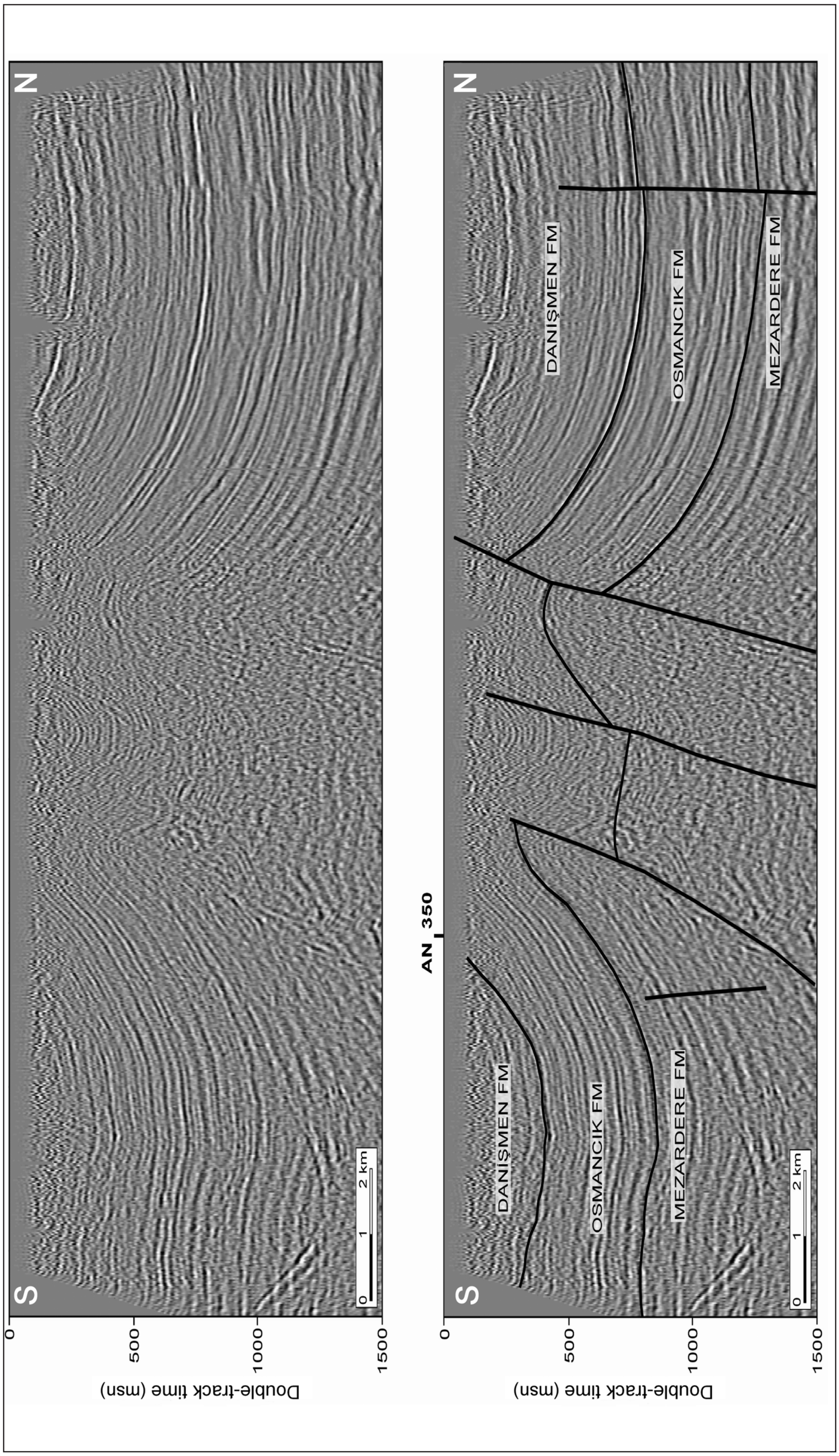

Figure 5- Seismic section B indicating separability of Osmancık and Danişmen Formations from each other in the field. See figures 1 and 3 for location of the section (Siyako, 2005).

separability of lignitic sandstones at least into two formations, an issue being not difficult to solve but ignored as well or unperceived for many years, also having their economic importances are emphasized.

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A NEW APPROACHING TO PETROGENESIS AND AGE DATA OF ALKALINE VOLCANICS CUTTING THROUGH DAĞKÜPLÜ OPHIOLITE, NORTHWESTERN SİVRİHİSAR (ESKİŞEHİR)

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Abstract.- In northwestern Anatolia, the ophiolite nappes related with Neotethyan Ocean, the continent fragments, granitoids and volcanic rocks were found along İzmir - Ankara - Erzincan Suture Zone (İAEKZ) as a results of the collision of Sakarya Continent and Anatolid - Taurid Platform. In northwestern Sivrihisar (Eskişehir), phonolites and trachytes with alkaline characteristic cut the ophiolite nappe. Late Cretaceous aged ophiolite nappe containing ultramafic - mafic rocks thrusted over Anatolid - Taurid Platform. Alkaline volcanics were ranged as domes close and parallel to the ophiolite thrust line. According to $^{39}Ar/^{40}Ar$ geochronological data on phonolites the age of these rocks are determined as 23-25 Ma (Late Oligocene - Early Miocene). Alkaline volcanics show enrichment in LILE (Ba, Sr, Rb, Th) and HFSE (Nb,Ta, Hf, Zr) relative to MORB. Also, light rare earth elements (LREE) have higher values than those of HREE values. However, Pb contents of alkaline rocks are considerably high. According to the geochemical results, phonolites and trachytes were generated from asthenospheric magma, enriched with fluid-melting processes linked to the previous subducted slab. These alkaline lavas have used the deep strike-slip faults created by extensional regime during the ascending and have undergone to a crustal contamination.

Key words: Sivrihisar, Ophiolite, Alcalen volcanics, Petrogeneses.

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REJUVENATION OF THE PRE-CAMBRIAN NAJD FAULT SYSTEM AND ITS IMPORTANCE IN THE OIL PROVINCE OF SAUDI ARABIA.

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ABSTRACT.- Structural interpretation covering the Central Saudi Arabia was carried out through Landsat, Radar images, topographic maps and seismic data. Existing geology maps provide materialized evidence for this study. A strong northwest trending lineament system has been mapped in the region and is interpreted as being related to the reactivated Najd Fault System. Elongate hills, strait-going creeks, offset along valley and ridges, and pull-apart basins are evident, indicating rejuvenation of the Najd transtensional sinistral movement. Geological map shows evidence indicating a northwestward dragging on the sedimentary cover along a NW trending regional lineament in the region which extend from South Ghawar to An Nafud Basin in Saudi Arabia. Northeast trending structures in Saudi Arabia are related to the pre-Permian structuring and Oman-Masirah stress regime. The Ghawar (Saudi Arabia), Dukhan (Qatar) and other north-northwest trending anticlines were reshaped by the rejuvenated Najd stress regime. The northwest trending sinistral Najd Fault was initiated in Precambrian and was reactivated at various times, probably during Paleozoic and late Jurassic times, and continuously, though of variable intensity, from late Cretaceous to the late Tertiary time. The Carboniferous, Late Cretaceous and Tertiary events are overprinted on one another in the region. The Oman stress regime and the stress regime that is related to oblique obduction of the Masirah Ophiolite are the principal controlling event for the anticline structures in Central Arabia. Dominant structural elements of the area are N-S anticline axis that suggests approximate E-W compressional stress direction, which is consistent with Oman and reactivated Najd tectonic regimes. The effect of the Tertiary orogenic overprint of the Oman-Masirah stress regime in eastern Arabia was to favor a slight renewed movement along the old basement faults such as the Najd Trend. Reactivated Najd system, Oman principal horizontal stress regime and obduction of the Masirah Ophiolite onto the Arabian continent have produced a combined effect on the structures in Eastern Arabian Plate. The Zagros stress regime may have produced little effect in the region.

Key words: rejuvenation, Najd Fault, Saudi Arabia, Ghawar

INTRODUCTION

The tectonic elements of the Arabian Peninsula is simplified from the geologic map of the Saudi Arabia (USGS and ARAMCO, 1963). Figure 1 shows "Western Arabian/Najd Fault System" (WAFS), "Eastern Arabian/Najd Fault System" (EAFS) and the other structural elements of the region.

Structural interpretation covering the central Saudi Arabia region was carried out through Landsat images, L-band Radar imagery and topographic maps (Perinçek et al., 1998*b*). Existing geological maps provided materialized evidence for the regional study. A strong northwest trending lineament system has been mapped in the region and is interpreted as being related to the reactivated Najd Fault System (Perinçek et al., 1998 *a-b*, Husseini, 2000). This apparently extends from Qatar and south Ghawar to An-Nafud Basin and finally reaches to Palmyra Fold Belt (Figures. 1, 2 and 3). The Dead Sea Fault Zone and rejuvenation of the Najd Fault system may have produced a combined effect on the structures in the Palmyra Fold Belt causing rejuvenation along the pre-Tertiary faults (Figures 1 and 3).

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Figure 1- Tectonic elements of the Arabian Peninsula. Numbers refer to tectonic features. 1- EAFS, Eastern Arabian / Najd Fault System, 2- WAFS, Western Arabian / Najd Fault System (light gray), 3- DSF, Dead Sea Fault, 4- EAF, East Anatolian Fault, 5- Bitlis/ Zagros Suture Zone, 6- Limit of Zagros Type Folds, 7- Palmyra Fold Belt, 8- Masirah Fault.

Figure 2- The petroleum fields of Saudi Arabia, Qatar and Bahrain (Husseini, 1995, 1997). Dragging on the southern end of Dukhan field, offset in the middle of Abqaiq and northern Ghawar structures are evident which probably related to rejuvenated Najd Fault zone. The lineaments picked from the topographic maps and Land Sat images in the southern end of Ghawar and Khurais structures could be related to the reactivated Najd Fault System. Tinat, Dilam, Raghib and Abu Markhah fields are aligned with same fault zone (Perinçek et al., 1998*b*, 2000*a*-*b*).

The Ghawar structure is bounded by normal faults, along which repeated movements have taken place, cutting all pre-Permian strata, and flexuring and fracturing the overlying units ranging from Permian to Miocene period. Four events overprinted in the Central Saudi Arabia on the Ghawar Field (Wender et al., 1998): (1) The Carboniferous Event, in which initial faulting occurred and caused extensive erosion along the crest of the Ghawar anticline. (2) Early Triassic Event (Zagros Rifting). (3) The Late Cretaceous Event, in which rejuvenation of pre-Permian age faults caused folding, fracturing, and minor faulting. This event was followed by extensive erosion and the upper portion of the Middle Cretaceous (Wasia Formation) was removed from the apex of the Ghawar structure. (4) The Miocene Event, which was the final folding event for the Ghawar, Harmaliyah and Abqaiq structures (Wender et al., 1998, Perinçek et al., 1998 *a-b*, Saner et al., 2002 and 2005).

The Ghawar oil field is 225 km long and 30 - 35 km wide, an asymmetric, NNE-SSW striking anticline in the Eastern Province of Saudi Arabia (Figure 2). The highest part of the anticline, north-south trending En Nala axis was first detected by Steineke and Kock in 1935 during surface mapping in the area (Arabian American Oil Company Staff, 1959). The En Nala and some other parallel arches are believed to be basement uplifts reactivated since the Precambrian (Ayres et al., 1982), whereas some oilfield structures are of salt doming origin (Edgell, 1991). The Ghawar area is characterized by a rougher topography when compared to the surrounding, rather smooth, flat areas. This rough geomorphology of the structure can also be noticed on the

Figure 3- Reactivated Najd Fault System extends from Qatar to Damascus in Syria and to Oman in Jordan. The Dead Sea Fault Zone and rejuvenation of the Najd Fault System may have produced a combined effect on the structures in the Palmyra Fold Belt (Figure 1). Palmyra Fold Belt located near Damascus. Landsat image (Google) shows northwestern extend of the Najd Fault System (black) which represented by three fault zone (1-Al Karak-At Tubayq, 2-Sirhan-Al Jawf and 3-Khawr Umm). North-northeast trending Dead Sea Fault Zone (white) has two junction points with Najd Fault Zone near Amman and Damascus.

satellite images. A geomorphologic elevation map of the area and a subsurface structural contour map of the top Arab-D (Upper Jurassic) reservoir reveal very similar geometric shapes. A match between the directions of some topographic lineaments and projected surface traces of subsurface faults from seismic cross sections can be observed in the Ghawar area (Saner et al., 2002 and 2005). These topographic lineaments are inline with the Najd Fault System. However, at the field locations, Surface indications suggest that the structure has been active until the present day. Several investigators indicated that Ghawar structure started forming in the Jurassic and remained active during sedimentation in the Cretaceous and Tertiary periods (Arabian American Oil Company Staff, 1959, İbrahim et al., 1981). Plate movements and related tectonic stresses prevalent during Hercynian and Alpine orogenesis stages appear to be responsible for structural developments (Billo, 1983, Marzouk and El Sattar, 1995). The Ghawar anticline is a simple fold in the south, develops two crestal closures in the center, and is bifurcated in the north. Several oil fields have been identified within the Ghawar Field.

The northwest-trending sinistral Najd Fault was initiated in the Precambrian (Husseini, 2000) and was reactivated at various times in the region, probably during Paleozoic and late Jurassic times, and continuously, though of variable intensity, from late Cretaceous to the present (Halsey, 1980, Perinçek et al., 1998 *b*, 2000 *a-b*). A model has been proposed for the plate, stress and tectonic conditions during the Permian, which suggests interplate, non-orogenic rifting, controlled by Precambrian trends of crustal weakness (Halsey, 1980). In Late Cenozoic time, the orogenic event was severe in the Zagros but less effective in eastern Arabia, causing renewed movement along the old basement faults. Halsey (1980) also concluded that collision of the continental portions of the Arabian and Iranian plates probably began during Pliocene time and continues today, resulting in the Zagros orogeny, with the Zagros crush zone marking the suture between the two plates. Eastern Saudi Arabia and the Arabian Gulf retain their original Atlantic style margin character only slightly disturbed by Zagros deformation.

Northwest trending fault and north south trending basement structural grain are apparent all over the west-southwestern Arabian plate, from the Red Sea to the Gulf of Arabia (Figures 1 and 2). Beydoun (1991) suggested that these structures might all be related to the late Proterozoic Najd Fault System exposed in Saudi Arabia (Stoesser and Camp, 1985, Agar, 1987, Husseini, 1989).

The Carboniferous, Late Cretaceous and Tertiary (Miocene) events are overprinted on one another in the region (Halsey, 1980, Wender et al., 1998). The E-W Oman stress regime and ESE-WNW stress regime that is related to oblique obduction of the Masirah Ophiolite (Loosveld et al., 1996) are the principal controlling events for the anticline structures in Central Arabia (Figure 4). The effect of the Tertiary orogenic overprint of the Oman-Masirah stress regime on the Arabian plate in eastern Arabia was to favor a slight renewed movement along the old basement faults such as the Najd trend (Perinçek et al., 1998 *a-b*). Rejuvenation of those faults caused pervasive fracturing in the brittle rocks of the sedimentary cover (Halsey, 1980).

Rejuvenation of the sinistral Najd Fault system in the Miocene caused faulting and folding in the region. The Najd and Oman principal horizontal stress regime (Figure 4) and the obduction of the Masirah Ophiolite (Loosveld et al., 1996) onto the Arabian continent have produced a combined effect on the structures in Eastern Saudi Arabian (Perinçek et al., 1998 *a-b*). The Zagros stress regime (Figure 4) may have produced little effect in the region (Perinçek et al., 1998 *a-b*).

REJUVENATION OF THE PRE-CAMBRIAN NAJD FAULT SYSTEM

Structural interpretation covering the central Saudi Arabia region was carried out through Landsat images, L-band Radar images, topographic maps and seismic data (Perinçek et al., 1998 *b*). Seismic mapping from 3D volumes provided a detailed structural map in the Ghawar Area. A strong NW trending lineament system has been mapped in the region and is interpreted as being related to the reactivated NW trending sinistral Najd Fault system (Figures 1 and 5).

Ghawar structure is recognizable from satellite images (Halbouty, 1980). This is the evidence of Late Tertiary tectonic activity deforming the young sedimentary cover. Therefore, structural traces are expected to be apparent in the surface formations of Mio-Pliocene age. Study of surface

Figure 4- Stress diagram for deformation related to Najd Fault System and Oman, Zagros, Masirah stress regimes.

Figure 5- Major structural trends in Arabian Peninsula and Arabian Gulf. Dominant structural trends are N-S anticlines including Ghawar Field, NW Najd trends (WAFS), EAFS: Eastern Arabian/Najd Fault System (dotted), and WAFS: Western Arabian/Najd Fault System, NW-SE Zagros fold (gray). Limit of Zagros Type Folds (dotted). Dashed gray line shows southwestern limit of Infra-Cambrian Hormuz Salt basin. Pre-Cambrian (light gray), Cambrian - Ordovician (gray), Silurian-Devonian (dark gray), Permian (dark gray), Triassic-Jurassic (gray), Cretaceous (gray), Tertiary (gray) Tertiary-Quaternary (light gray). (After USGS and ARAMCO, 1963., Edgell, 1992., Al-Laboun, 1998, Perinçek et al., 1998*b*, 2000*a-b*).

structural elements provides important information for interpreting the subsurface structural model and development. The aim of the surface studies in the Ghawar area is to investigate structural features cropping out in the field, to establish a correlation between the surface and subsurface structural features of the Ghawar field (Saner et al., 2002, 2005).

The surface topography resembles the subsurface structural maps of the Ghawar field. High-resolution elevation data measured during 3-D seismic survey was used to construct a detailed topographic contour map of the area (Perinçek et al., 1998 *a-b*, Saner et al., 2002, 2005). This map and a subsurface structural contour map of the Arab-D reservoir are very similar in shape (Figure 6 in Saner et al., 2005). A comparison of the two maps provides evidence that the structure is active until the Mio-Pliocene time. Saner et al. (2005) indicated that Growth of the Ghawar structure was active in the Pleistocene and probably even in the Quaternary.

Figure 6- Elevation contours and simplified geological map of the Al Habl region-west of Ghawar area. Offset along the ridges may provide evidence for sinistral movements, on the NW trending fault system, Perinçek et al., 1998*b*, 2000*a-b*).

Interpretation of the 3D seismic data reveals that the Ghawar Structure is an anticline that consists of isolated highs. Axis of the each high is shifted towards the northwest and several of them are easily documented along the NW trending fault, suggesting sinistral movement. Sinistral event could be related to rejuvenation of the Najd Fault system. Fault rejuvenation is believed to occurred at various times in the region, in particularly during the Late Cretaceous and late Tertiary.

Dominant structural elements of the central-eastern Arabian plate are NNE-SSW Ghawar, NW Najd trends, E-W Oman stress and related N-S trend, ESE-WNW Neogene stress, which is related to oblique obduction of the Masirah Ophiolite, Zagros stress regime and related NW-SE trending structures. Most of N-S trending structures in eastern Saudi Arabia suggests approximate E-W compressional stress direction, which is consistent with Oman and reactivated Najd tectonic regimes (Figure 4).

The Oman stress regime and oblique obduction of the Masirah Ophiolite, acted during Mesozoic and Tertiary times (Loosveld et al., 1996) and they have had a major effect in the region as observed on the Harmaliyah and Abqaiq structures. On the other hand, the sinistral Najd Fault System and the related E-W stress regime, which were reactivated in Late Cretaceous, Miocene and recent times, may have produced many of the structural features (faults, folds and joints) within Ghawar Field (Perinçek et al., 1998 *a*). The reactivated Najd Fault System controlled to the thickness and distribution of the lower Aruma Formation in Late Cretaceous.

A simplified geology map shows evidence indicating a northwestward drag on the sedimentary cover along a NW trending regional lineament in the region, which extends from south Ghawar to An-Nafud Basin on the eastern portion of the Arabian plate (Figure 5). Elongate hills, straight-trending creeks, offset along valley and ridges (Figures 6, 7) and pull apart basins

Figure 7- Al Barak - At Tubayq Fault Zone, East of Tabuk region. Straight-trending creeks, offset along valley are evident, indicating reju venation of the Najd Fault Zone.

(Figure 8) are evident, indicating rejuvenation of the Najd transtensional sinistral movement (Perinçek et al., 1998 *b*, 2000 *a-b*).

The Najd and Oman principal horizontal stress regime and the obduction of the Masirah Ophiolite onto the Arabian continent have produced a combined effect on the structures in Eastern Saudi Arabia (Figure 4), which have produced many of the structural features. Some of the pre-Coniacian faults were reactivated and the base Aruma unconformity was breached and refolded. The reactivated Najd Fault system created a local transtensional regime, which led the formation of normal faulting and grabens during the Cenomanian-Turonian. Sediments of the Aruma Formation (Coniacian-Maastrichtian) first filled the graben and then sealed the pre-Coniacian fault system which is evident in the northern Ghawar Field (Perinçek et al., 1998 *a*).

Figure 8- Structural elements of the An-Nafud Basin. Left bending-stepping and splay along the East Arabian Fault System probably responsible the formation of a pull-apart basin in the region. Pre-Quaternary basement (gray), Quaternary alluvium and related deposits (dotted white) and Quaternary eolian sand (white).

In conclusion, the Oman and reactivated Najd tectonic regimes caused deformation and erosion and removed the upper part of the Cretaceous (Wasia formation) from the uplifted areas, including Ghawar high. Later same tectonic events controlled the thickness and distribution of the lower Aruma formation in the Late Cretaceous. The Zagros stress regime, which acted in the NE-SW direction (Figure 4) during the early Tertiary period and continued to the present may have produced little effect in the region (Perinçek et al., 1998 *a-b*). However, the Zagros stress regime may have produced or enhanced NE-trending lineaments. Saner et al., 2005 indicated that the trend of Ghawar anticline (NNE-SSW) does not concur with the Zagros stress direction, and this complicates the interpretation of structure axis, and Zagros stress directions interrelations.

Northeast trending structures such as Abqaiq-Harmaliyah-Shaybah are related to the Oman-Masirah stress regime (figure 4). The Ghawar-Khurais-Tinat-Dilam-Dukhan (Qatar) and other north-northwest trending anticlines were reshaped by the rejuvenated Najd stress regime (Perinçek et al., 1998 *a-b*). However, Pre-Khuff basement structural grain has controlled the formation of the structures since Carboniferous (Edgell, 1992, Wender et al., 1998). Wender et al., (1998) stated that growth history of the Ghawar structure is different from the N NE trending Harmaliyah and Abqaiq structures.

Perinçek et al., 1998 *a-b*, Perinçek et al., 2000 *c*, Saner et al., 2002, 2005 and a study conducted for Saudi Aramco provides an integrated use of seismic map and surface geological information on the Ghawar Field. The Ghawar oil field is an asymmetric anticline that started forming in the Jurassic and remained active during sedimentation in the Cretaceous and Tertiary periods. Surface structural lineament interpretation and its collaboration to subsurface structural features has been investigated. Lineaments from Landsat images over the Ghawar Field reveal prominent structural trends in N55°W, N35°E and N15°W directions (Hariri et al., 1998). The lineaments picked from the high-resolution topographic map show prominent trends mainly to N35°W and secondary trends in N45°E and N85°E directions. The major NW topographic lineaments within Ghawar vicinity could be related to the reactivated sinistral Najd Fault Zone. Perinçek et al. (1998 *a*), Saner et al., (2005) used 3D seismic survey shot-point elevation data to produce high-resolution topographic map. A field study was conducted for ground truthing of lineaments picked from Landsat images and topographic maps. So far no fault planes have been observed in the field. However, surface projections of some faults, seen in seismic cross sections, match with topographic lineaments (Perinçek et al., 1998 *a-b*, figure 13 in Saner et al., 2005). Refered surface lineaments and subsurface faults represent Najd Fault System. Data for the lineaments are presented in the form of map and rose diagrams. The elevation data is an effective tool for structural interpretation of the Ghawar anticline that can be identified on topographic maps (Saner et al., 2002, 2005).

Seismic subsurface mapping indicates that the axis of the anticline of the northern Ghawar Field (Figure 2) is shifted towards the west. The west shifting is clearly documented along the NW trending fault. Dragging on the north-south trending Ghawar anticline is also evident. These observations provide evidence and suggest a sinistral movement along the northwest trending fault zone. Left lateral strike-slip event could be related to rejuvenation of the Najd Fault System (Perinçek et al., 1998 *b*, 2000 *a-b*)

Perinçek et al. (1998 *b*) conducted a study on the Ghawar Field reveals that the extensional east-west graben bounding faults are probably open, permeable and provide a conduit to fluid flow. The extensional graben system is more permeable because of their preferential susceptibility to solution widening. North-south faults could be seals and constitute barriers or restrictions to lateral flow. However, NW and NE-trending faults may be conduits or barriers (Perinçek et al., 2000 *c*). Northwest trending faults generally have strike-slip component. Local extensional regime is expected along the sinistral northwest trending fault system adjacent to the left stepping or left bending areas. The E-W trending grabens are one of the major structural features in the central Ghawar Field. It is believed that E-W grabens are parallel and N-S high angle faults are perpendicular to the major compression direction which suggests approximately E-W compressional stress direction. This compressional direction is consistent with Oman and reactivated Najd tectonic regimes (Figure 4).

CONCLUSIONS

Conclusions and interrelationship highlights of this study are as follows:

North-northeast trending structures in Saudi Arabia are related to the pre-Permian structuring and Oman-Masirah stress regime.

Dominant structural elements of the area are north-south anticline axis that suggests approximate East-West compressional stress direction. This compression direction is consistent with Oman and reactivated Najd tectonic stress regimes.

A strong northwest trending lineament system has been mapped in the region and is interpreted as being related to the reactivated Najd Fault system. A simplified geology map shows evidence indicating a northwestward drag on the sedimentary cover along a NW trending regional lineament in the region. Elongate hills, straight-trending creeks, offset along valley and ridges, and pull-apart basins are evident, indicating rejuvenation of the Najd transtensional sinistral movement.

Reactivated Najd Fault system apparently extends from Qatar and south Ghawar to An-Nafud Basin and finally reaches to Palmyra Fold Belt near Damascus. The Dead Sea Fault Zone and rejuvenation of the Najd Fault System may have produced a combined effect on the structures in the Palmyra Fold Belt causing rejuvenation along the pre-Tertiary faults.

The northwest trending sinistral Najd Fault was initiated in Precambrian and was reactivated at various times in the region, in particularly during the Jurassic, late Cretaceous and late Tertiary. The sinistral Najd Fault system and the related E-W stress regime, which were reactivated continuously, though of variable intensity, may have produced many of the structural features (faults, folds and joints) in the region.

The fault rejuvenation occurred at various times in the Ghawar structure. Repeated movements have taken place, cutting all pre-Permian strata, flexuring and faulting of overlying units ranging from Permian to Tertiary age.

Reactivated Najd system, Oman principal horizontal stress regime and obduction of the Masirah Ophiolite onto the Arabian continent have produced a combined effect on the structures in Eastern Arabian Plate. The Zagros stress regime may have produced little effect in the region.

The Oman and reactivated Najd tectonic regimes, caused deformation and erosion and removed the upper part of the Cretaceous (Wasia formation) from the uplifted areas, including Ghawar high. Later same tectonic events controlled the thickness and distribution of the lower Aruma Formation in the Late Cretaceous.

The match between topographic lineaments and the trace of the fault on the surface infers that some topographic lineaments are projections of deep seated faults. NW-trending topographic lineaments are mapped as part of the Najd Fault system.

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THE FORMATION CONDITIONS OF IRONOXIDE DEPOSITS IN HASANCELEBI (MALATYA); A MICROTHERMOMETRIC APPROACH

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ABSTRACT This study intends to carry out microthermometric analyses on scapolite, phlogopite, fluorit, barite and calcite in metasomatic zones within the Hasançelebi ironoxide deposits, and to understand the T-P conditions of alterations/metasomatism by determining homogenization temperatures and salinity (% NaCl-equivalent) of the associated minerals. The relative density of the fluids forming the hydrothermal system was calculated by using salinity and homogenization temperature values of the minerals, and the microthermometric parameters were compared with the known hydrothermal systems. The homogenization and salinity (% NaCl-equivalent) of the minerals are as follows; scapolite (310-390°C, 10-21), phlogopite (>700°C, 25), barite (190-380°C and 80-170°C, 4,7-13), fluorite (150-380°C, 4,7-13), and calcite (80-320°C), respectively. It is present a relationships that are the density of the fluid inclusions with the mid-high salinity degrees and the low homogenezation temperatures. A significant relationships is present between paragenesis (order of formation) of the minerals above and the density of the fluids presumed to form these minerals; the inclusions with the lowest density is correlated with the highest homogenization temperature while the inclusions with higher densities are correlated with higher homogenization temperatures.

Key words: Hasancelebi, Malatya, fluid inclusions, ironoxide, scapolite, phlogopite fluorite, barite, ironoxide-Cu-Au deposits.