NEOTECTONIC EVOLUTION OF THE İNEGÖL (BURSA) BASIN

A MASTER'S THESIS

in

Geological Engineering

Middle East Technical University

by

Nuretdin KAYMAKCI

September, 1991

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Approval of the Graduate School of Natural and Applied sciences.

for Prof.Dr. Alpay ANKARA

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science in Geological Engineering.

Prof.Dr. Vedat DOYURAN

Chairman of the Department

We certify that we have read this thesis and in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Geological Engineering.

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ABSTRACT

NEOTECTONIC EVOLUTION OF THE İNEGÖL (BURSA) BASIN

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M.Sc. in GEO.E.
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The İnegöl basin is located approximately 45 kilometers east of Bursa. The rock units exposing in and around the İnegöl basin are subdivided into two categories: 1) basement rocks and 2) cover rocks. The basement rocks are the pre-Permian Kıran complex, Pazarcık complex, Mahmudiye mafics-ultramafics, Mesozoic Kocadere marble, Triassic Karakaya group, Lower to Middle Liassic Bayırköy Formation, Callovian to Valanginian Bilecik group, Cretaceous Kabalar group, and Eocene Gemlik group. The cover rocks include Middle to Upper Miocene İnegöl group and Plio-Quaternary alluvial deposits and travertine. The İnegöl group is composed of buff to yellow fluvio-lacustrine clastics and limestone intercalations.

The İnegöl basin is shaped by a number of subparallel normal faults with considerable amounts of strike-slip component. Although the surrounding regions are seismically very active, the activity of the faults in the study area is questionable. However, the displaced and deformed Plio-Quaternary alluvial fan deposits at the northwestern corner of the study area suggest that the boundary faults of the basin might have been active till the beginning of Holocene. Since the southern margin of the İnegöl basin is bounded by active oblique-slip normal faults it can be classified as a half graben.

Keywords: İnegöl basin, basement rocks, İnegöl group, alluvial deposits, normal fault, half graben, İnegöl Bursa.

Science Code: 606 01 01

ÖZET

İNEGÖL (BURSA) HAVZASININ NEOTEKTONİK EVRİMİ

Kaymakcı, Nuretdin

Yüksek Lisans Tezi, Jeoloji Müh. Böl.

Tez Yöneticisi: Prof.Dr. Ali Koçyiğit

Eylül 1991, 73 sayfa

İnegöl havzası Bursanın yaklaşık 45 kilometre doğusunda yer alır. İnceleme alanında yüzeyleyen kaya birimleri temel ve örtü birimleri olmak üzere ikiye ayrılır. Temel birimleri Permiyen öncesi Kıran karmaşığı, Pazarcık karmaşığı, Mahmudiye mafit-ultramafiti, Mesozoyik Kocadere mermeri, Triyas Karakaya grubu, Alt ve Orta Liyas Bayırköy Formasyonu, Kalloviyen-Valenjiyan Bilecik grubu, Kratese Kabalar grubu ve Eosen Gemlik grubu'ndan oluşur. Örtü birimleri Orta ve Üst Miyosen İnegöl grubu ve Pliyo-Kuvaterner alüvyon ile traverteni içerir. İnegöl grubu krem ve sarı renkli akarsu ve gölsel kırıntılılarla kireçtaşı ardalanmasından oluşur.

Çalışma alanı önemli miktarda yanal bileşeni olan çok sayıda verev atımlı normal faylarla şekillenir. Genel olarak bölge sismik bakımdan çok aktif olmasına rağmen çalışma alanındaki fayların aktivitesi kesin olarak ortaya konulamamıştır. Bununla birlikte, havzanın kuzey köşesinde yüzeyleyen ötelenmiş ve kısmen deforme olmuş Pliyo-Kuvaterner alüvyon yelpazesi, havzanın kenar faylarının en azından Holosen'in başlangıcına kadar aktif olmuş

olabileceğini gösterir. Yalnızca güney kenarı aktif verev atımlı normal faylarla sınırlı olan İnegöl havzası, bir yarı graben olarak sınıflandırılabilir.

Anahtar kelimeler: İnegöl havzası, temel kayaları, İnegöl grubu, alüvyon birikintileri, normal fay, yarı graben, İnegöl, Bursa.

Bilim Kodu: 606 01 01

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1. INTRODUCTION

1.1. Purpose and Scope

The continued post collisional convergence of the Arabian plate in the south and the Eurasian Plate in the north has caused the westward escape of the Anatolian block along the North Anatolian and East Anatolian intracontinental transform faults after latest Middle Miocene (Mc Kenzie, 1972; Dewey and Şengör, 1979; Şengör et al., 1985; Koçyiğit, 1989). In general the beginning of westward escape of the Anatolian block initiated the neotectonic period in Türkiye. However, it is hard to say that beginning of neotectonic period is contemporaneous throughout Türkiye. Besides, beginning of this period becomes older toward the west (Koçyiğit, 1984).

The active tectonic scheme of Türkiye is characterized by a complex family of structures, the largest of which belongs to conjugate strike-slip faults occured all over Türkiye, and the tensional fault systems at the western Anatolia (Philipson, 1910, 1915; Mc Kenzie, 1972; Dewey and Şengör, 1979; Kaya, 1979; Koçyiğit, 1984, 1985a, 1985b; Koçyiğit et al.,1985; Şengör et al., 1985; Koçyiğit, 1988; Koçyiğit and Rojay, 1988; Koçyiğit, 1991) where generally E-W, WNW-ESE, and NE-SW trending horsts and grabens bounded by oblique-slip normal faults shape the region.

Although, there is a number of studies explaining the origin and mechanism of the strike-slip and tensional regimes in Türkiye, the number of studies conducted to understand the role of interactions of these regimes in relation to active tectonic scheme of Türkiye is limited. One of the best places where this kind of interaction and related structures are well exposed is the İnegöl basin. It is situated in a zone in the northernmost part of the Aegean horst-graben system where the strike-slip and tensional tectonic regimes interact. Therefore, the purposes of this study are (1) to study mostly the neotectonical characteristics of the İnegöl basin; (2) to describe its sedimentologic and tectonic evolution, and (3) to delineate an approximate boundary between areas under the control of tensional and strike-slip regimes in the study area. For this reason, our study is concentrated mainly on the stratigraphy, sedimentology, and structural geology of the İnegöl basin and its fill.

1.2. Location

The study area is the İnegöl basin. İt is located within the southern part of the Marmara Region between lattitudes 39°,55'-40°,10' North and the longtitudes 20°,24'-29°,45' East. Main settlement within the study area is the İnegöl county. The study area covers approximately 416 square kilometers. It is about 34 km long and 26 km wide across the E-W and N-S directions respectively (Figure 1 and Plate 1). It is included in the 1:25 000 scale topographic map sheets of Bursa H22-c1,c2,c3,c4; H23-c3,c4,d3,d4; Kütahya İ22-b2, and İ23-a1,a2.

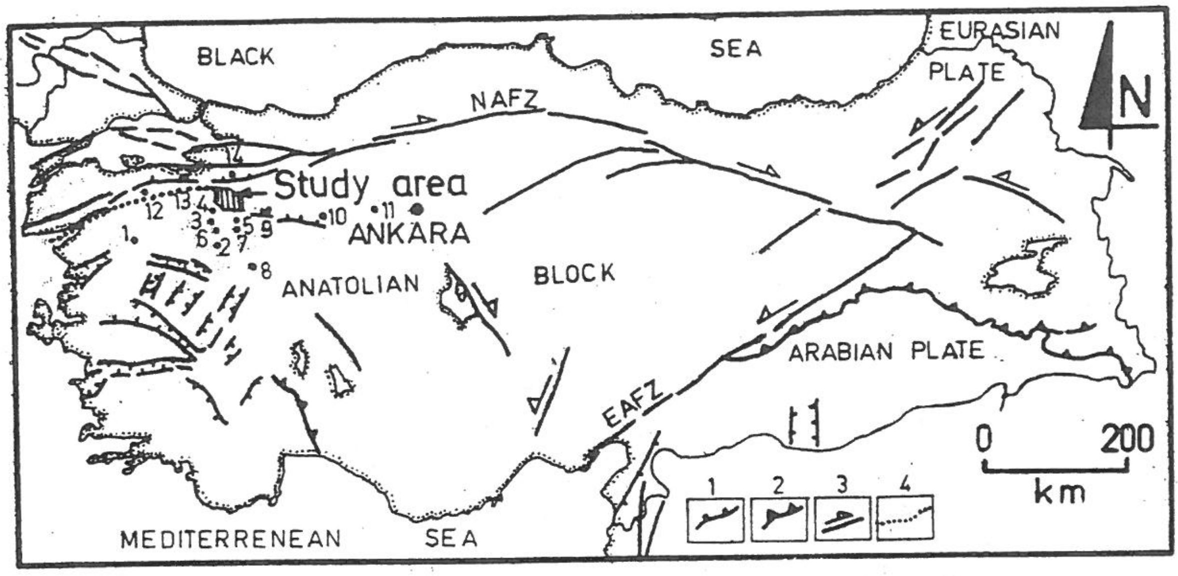


Figure 1. Simplified neotectonic map showing the major structures and location of the study area. EAFZ: East Anatolian Fault Zone, NAFZ: North Anatolian Fault Zone, 1: normal fault; 2: thrust fault; 3: strike-slip fault, 4: approximate boundary of extensional and strike-slip regimes (modified from Şengör et al., 1985 and Koçyiğit, 1989).

1.3. Methods of Study

This study includes four stages. The initial stage includes the collection of related previous studies. This stage also includes aerial photograph studies conducted to delineate the linear features.

The second stage includes the field studies. It is conducted in the summer of 1990. It took about 2 months. During this work, boundaries of the rock stratigraphic units and structural features were plotted on to 1:25 000 scale topographic map sheets, mezoscopic scale features were entered in the notebook, two reference sections were measured in order to better describe the rock units, and 217 spot and systematic samples were collected for laboratory studies.

The third stage includes the laboratory studies. During this stage microscopic studies were carried out. For this purpose 153 thin sections were prepared and 64 samples were washed for paleontological studies.

The last stage includes the preparation of structural and statistical diagrams for structural interpretations. It also includes preparation of cross-sections and redrawing of maps at 1:50 000 scale.

In order the name to rock stratigraphic units the rules of North American Commission on Stratigraphic Nomenclature (1983) and Türkiye Stratigrafi Komitesi (1986) were followed.

Finally, for the classification of sedimentary rocks Folk (1974), for igneous rocks Henrich (1956), and for metamorphic rocks Winkler (1974) were applied.

1.4. Previous works

Depending on the major subject of the study, the previous works can be classified into four groups.

(1) The studies mainly concerning the general geological aspects and geological evolution of the region (Eroskay, 1965; Bingöl et al., 1975; Brinkman, 1976; Yılmaz, 1981; Bargu, 1982; Ketin, 1984; Genç, 1986; Genç et al., 1986; and Koçyiğit et al., 1991).

(2) The studies concentrated mainly onto metamorphosed rocks of the region and their relations with the plutonic rock assamblages of the region (Ketin, 1947; Kaaden, 1960; Öztunalı, 1973; Ayaroğlu, 1979; Yılmaz, 1979;

Tekeli, 1981; Servais, 1982; Şentürk and Karaköse, 1982; and Okay, 1984).

(3) The studies carried out onto the post-Triassic cover rocks and their palaeogeographic distribution in the region (Granit and Tintant, 1960; Altınlı, 1965; 1966; 1975a,b; Altınlı and Yetiş, 1972; Altınlı et al., 1970; Görür et al., 1983; and Altıner et al., 1989).

(4) The studies concentrated mainly onto the geochemistry and geochronology of the plutonic rock asamblages of the region (Bürküt, 1966; Çoğulu et al., 1965; Çoğulu and Krummenacher, 1967; Ataman, 1973; and Bingöl et al., 1982).

Above mentioned classification is not strict. Besides, most of the studies could be included in more than one class, however, they are classified according to the major subject that they are concentrated on.

1.5. Regional Geological Setting

The study area is located at the northern margin of the Anatolian block where the strike-slip tectonic regime and west Anatolian tensional tectonic regime interfere. The major structures in the region are the North Anatolian Fault Zone at the north and İnegöl-Kuyucak fault set within the study area.

Tectonically lowest units in the region are northern most extension of the Taurus-Anatolid platform at the south and Sakarya microcontinent of Pontides at the north (Şengör and Yılmaz, 1981). In the study area these tectonostratigraphic units consist of the Kıran complex and Kocadere marble in the south (Afyon Zone of Okay, 1984) which belong to Taurides; the Pazarcık complex, Mahmudiye mafics-ultramafics, Karakaya group, and their cover units the Bayırköy Formation, Bilecik, Kabalar, and Gemlik groups in the north.

Upper Tertiary post-tectonic continental molassic deposits (inegöl group) covered the region till the begining of Neotectonic period (Figure 2).

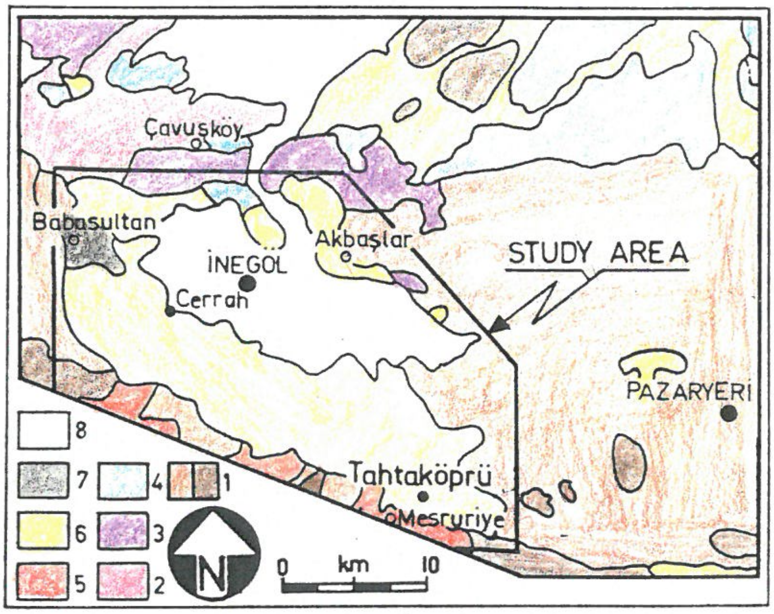


Figure 2. Map showing the regional geological setting of the study area (modified from Ternek, 1964). 1: pre-Permian metamorphics 2: Triassic spilites and clastics, 3: Permian and Triassic limestones, 4: Jurassic-Cretaceous units, 5: Tahtaköprü Granodiorite, 6: Upper Tertiary units 7: Plio-Quaternary units, and 8: Alluvium

The study area is dominated by NW-SE, N-S, and NE-SW trending normal faults which indicates that the study area is under the control of tensional stresses. Therefore, the study area has to be northernmost part of the West Anatolian horst-graben system of tensional origin.

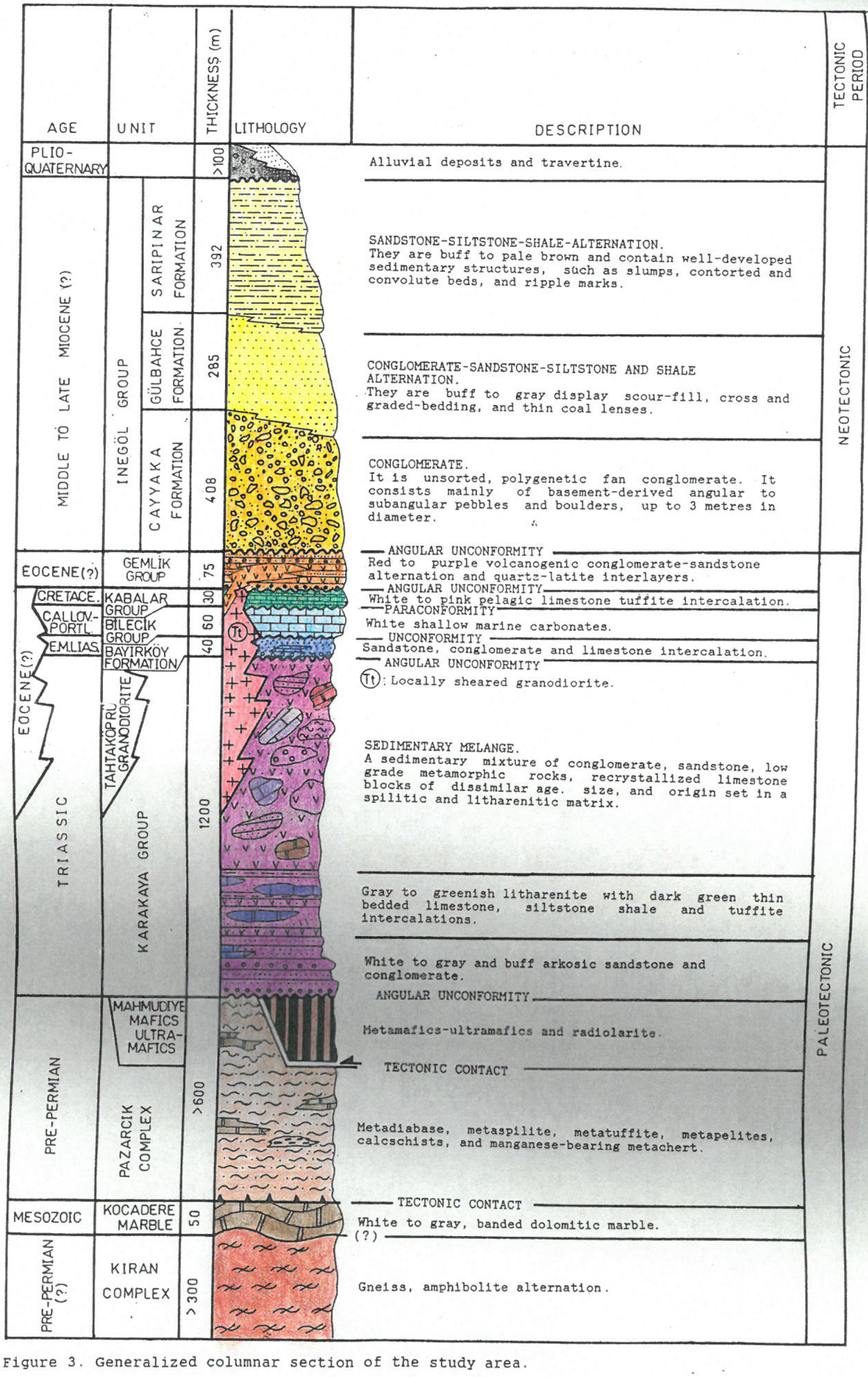


Figure 3. Generalized columnar section of the study area.

2. STRATIGRAPHY

The rock stratigraphic units exposing in the study area include (1) pre-Miocene basement units and (2) post-Lower Miocene cover units. Since, this study is concentrated on the neotectonic characteristics of the İnegöl Basin, no detailed study has been carried out on the basement rocks.

2.1. Basement Units

The basement units comprise the pre-Permian Kıran complex, Mesozoic Kocadere marble, pre-Permian Pazarcık complex and Mahmudiye mafics-ultramafics, Triassic Karakaya group, Middle to Upper Jurassic Bilecik group, Cretaceous Kabalar group, and Eocene Gemlik group (Figure 3).

2.1.1. Kıran Complex

The Kıran complex is first named informally in this study. It is composed of alternation of amphibolites and gneisses (Ketin, 1947). According to Ketin (1947), it comprises the Abukuma type of amphibolite metamorphic facies.

The Kıran complex exposes in the westernmost part of the study area around west of Kıran and southwest of Babasultan villages (Plate 1). Its maximum observable thickness is more than 300 meters..

The lower boundary of the Kıran complex is not seen, however, it is overlain by the Kocadere marble. It also displays tectonic boundary relationships both with the Mahmudiye mafics-ultramafics around Tuzlatepe and the İnegöl group in the northwest of Kıran and southwest of Babasultan villages.

No fossil have been found in the samples collected from the Kıran complex. However, its metamorphic facies are different than those of overlying Pazarcık complex, Mahmudiye mafics-ultramafics, and the Alpine metamorphics exposing in nearby regions (Ketin, 1947; Okay, 1984, Koçyiğit et al., 1991). Therefore, the age of the Kıran complex should be pre-Permian.

The Kıran complex can be correlated with the amphibolites and gneissses of the Uludağ Metamorphics of Ketin (1947).

2.1.2. Kocadere Marble

The Kocadere marble was first named by Koçyiğit et al. (1991). It is composed of banded marbles with low grade metamorphic clastic intercalation.

The Kocadere marble exposes as isolated patch-like outcrops at the southern margin of the İnegöl basin, and is more than 60 meters.

The Kocadere marble overlies the Kıran complex and is overlain tectonically by the Mahmudiye mafics-ultramafics. It has also both erosional and tectonic contact relationships with the İnegöl group around 1 kilometer west of Kıran village in the western part of the study area.

No fossil has been found within the Kocadere marble. However, a Mesozoic age is given to this unit by Koçyiğit et al. (1991).

2.1.3. Pazarcık Complex

The Pazarcık complex was first named by Koçyiğit et al. (1991). It comprises low grade metamorphosed of mafic volcanics, clastics, and limestone.

The Pazarcık complex is exposed in the northeastern and southern part of the study area.

The Pazarcık complex overlies tectonically the Bilecik group and Gemlik group in the northeast of Kozluören village, and the Kocadere marble around west of Tuzla hill. It is overlain tectonically by the Mahmudiye mafics-ultramafics and both unconformably and tectonically by the Karakaya group (Koçyiğit et al., 1991). The Pazarcık complex also displays unconformable and tectonic boundary relationships with the İnegöl group in various parts of the study area.

The Pazarcık complex is composed of more than 500 meters thick metabasics, greenschists, phyllite, calc-schist, recrystallized limestone, and meta radiolarian cherts. The diagnostic metamorphic minerals identified within the samples collected from The Pazarcık complex include chlorite, phengite, actinolite, muscovite, albite, sericite, stilpnomelane, chloritoide, epidote, sphene, hornblende, and Na-amphiboles.

No fossil has been found within the unit, However, it is intruded by the Bozüyük granitoid around Bozüyük. The radiometric age of this intrusive body is 282 million years which corresponds to the Late Carboniferous-Early Permian boundary (Servais, 1982). Therefore the age of the Pazarcık complex may be at least Late Carboniferous pre-Permian.

2.1.4. Mahmudiye Mafics-Ultramafics

The Mahmudiye mafics-ultramafics was first named by Koçyiğit et al. (1991). It comprises low grade metamorphics of mafic and ultramafics.

The Mahmudiye mafics-ultramafics are exposed around Çiftlikköy, Yarıkkaya hill to the west, Fevziye, and Elmaçayır villages to the southwest of the study area. It is more than 200 meters thick.

The Mahmudiye mafics-ultramafics overlies tectonically the Kıran complex, Kocadere marble, and Pazarcık complex. However, it is overlain both unconformably and tectonically by the Karakaya group (Koçyiğit et al., 1991). The unit also displays tectonic and unconformable relationships with the İnegöl group.

The Mahmudiye mafics-ultramafics is composed of ultramafic rocks, serpentinites, radiolarian cherts, recrystallized limestone lenses, listwaenites, low grade metamorphosed mafic volcanics, diabase, and gabbro. The characteristic metamorphic minerals are the chlorite, actinolite, phengite, epidote, serpentine, some talc, and biotite. In some samples relict pyroxenes have also been observed.

The Mahmudiye mafics-ultramafics and the Pazarcık complex alltogether were intruded by the Bozüyük granitoid. Therefore the age of this unit should also be pre-Permian.

2.1.5. Karakaya Group

The Karakaya group was first named by Genç et al. (1986). It is characterized by basic volcanics, limestones and litharenites.

The Karakaya group is exposed in the northern and northwestern part of the study area. Its total thickness is more than 1.2 kilometers.

The Karakaya group shows both unconformable and tectonic relationships with the Pazarcık complex, the Bilecik, Kabalar, and İnegöl groups around north of Eymir village and Kocapınar hill in the northern part of the study area. It is overlain unconformably by the Bayırköy Formation (Altınlı, 1965; Genç et al., 1986).

The Karakaya group comprises three distinct facies these are well-sorted, well-rounded arkosic sandstones and conglomerates at the bottom and it continues upward with the sandstone, shale-marl, tuffite, spilite alternation and also includes limestone lenses. At the top, it is made up of a tectonic mixture of blocks of various size and origin set in a spilitic-litharenitic matrix. The blocks comprises Permian limestones, Triassic limestones, and a number of undifferentiated recrystallized limestsone blocks. The Karakaya group also includes various blocks derived from the Pazarcık complex, Mahmudiye Mafics-Ultrafics and the lower levels of the Karakaya group itself (Plate 1, Figure 3).

The age of the Karakaya group is given as Triassic by Bingöl _et al_. (1975). In some of the limestone blocks of the Karakaya group, the following fauna have been determined by Demir Altıner (Middle East Technical University):

Bradina(?) sp.
Climacammina sp.
Globivalvulina(?) sp.
Lasiodiscus _Tenuis_ REICHEL
Lasiodiscus(?) sp.
Neoendothyra sp.
Palaeotextularidae
Palaeotextularia sp.
Staffella sp.
Tetrataxis sp.
Fusulineacean Fragments
Tubiphytes _Obscurus_ MASLOV

Thus, the blocks including the above-listed fossil assamblage is Permian in age. However, in some other limestone blocks of the Karakaya group the following fauna have been determined by Demir Altıner (Middle East Technical University):

Meandrospira(?) sp.
Earlandia(?) sp.

These fossils indicate that these limestone blocks are possibly Triassic in age. Consequently, the Karakaya group also includes Triassic blocks .

To some extend the Karakaya group can be correlated with the Karakaya Formation of Bingöl et al. (1975).

2.1.6. Bayırköy Formation

The Bayırköy Formation was first named by Granit and Tintant (1960) as Bayırköy sandstone. However, Altınlı (1973) changed it to Bayırköy Formation because it includes the facies other than sandstone. It comprises various clastics and fossiliferous shallow marine limestones.

It is exposed around northeast of Kozluören village.

The Bayırköy Formation overlies unconformably the Karakaya group around northeast of Kozluören village. However, it is overlain tectonically by the Pazarcık complex and unconformably by the Bilecik, Gemlik, and İnegöl groups in the same region. Its maximum observable thickness is about 40 meters.

It is composed of green, buff, yellow rounded to well rounded, well sorted sandstones and conglomerates with micritic limestone matrix. It contains abundant ammonites, belemnites, pelecypoda, and crinoid fragments.

In the samples collected from the Bayırköy Formation, the following fauna have been determined by Demir Altıner (Middle East Technical University):

Nodasariidae

Ophthalmidium martanum (FARINACCI)

Ophthalmidium spp.

Sigmoilina sp.

According to the fauna listed above, the age of the Bayırköy Formation is Liassic.

2.1.7. Bilecik Group

The unit was first named by Altınlı (1973) as Bilecik formation. However, Altıner *et al*. (1989) raised it into group rank. It comprises shelf type of carbonates.

The Bilecik group is exposed in the northeast of Kozluören village, 3 kilometers east of Şehitler village, and northwest of Hamzabey village in the northwestern and northern part of the study area.

The Bilecik group overlies unconformably the Bayırköy Formation northeast of Kozluören village and the Karakaya group around 3 kilometers east of Şehitler village, near east of Karalar village, and northwest of Hamzabey village. At the top it is overlain tectonically by the Karakaya group northwest of Hamzabey village and by the Pazarcık complex northeast of Kozluören village. Its thickness is about 60 meters.

The Bilecik group is composed of micritic and sparitic limestones and dolomites, such as biomicrites, oomicrites, pelmicrites, intramicrites, dolomicrites, oosparites, intrasparites, pelsparites, sandy micrites, etc. (Altınlı, 1973).

Following fossils have been determined in the samples by Demir Altıner (Middle East Technical University):

Ataxophragmiidae

Glomospira(?) sp.

Mesoendothyra(?) sp.

Textulariidae

Textularia sp.

Valvulina sp.

Tubiphytes morronensis CRESENTI

According to this fossil assemblage, the age of the Bilecik group is Callovian to Valanginian.

2.1.8. Kabalar Group

The Kabalar group was first named by Altıner *et al.* (1989). It is composed of *Globotruncana*-bearing white, pink and pinkish pelagic limestones, marl, and tuffite alternation.

The Kabalar group is exposed northwest of Şehitler village and east of Akbaşlar village.

The Kabalar group overlies unconformably the Karakaya group around Şehitler, and 2 kilometers east of Akbaşlar villages. At the same places it is also overlain tectonically by the Karakaya group. Its maximum observable thickness is about 30 meters.

In the samples collected from the Kabalar group, the following fauna have been determined by Demir Altıner (Middle East Technical University):

Calcisphaeorula innominata BONET

Dicarinella cf. *concavata* (BROTZEN)

Globigerinelloides spp.

Globotruncana linneiana (D'ORBIGNY)

Hedbergella sp.

Heterohelix sp.

Marginotruncana coronata (BOLLI)

Marginotruncana pseudolinneiana PESSAGNO

Pithonella ovalis KAUFMAN

According to above-listed fauna, the age of the group is Hauterivian to Maastrichtian.

2.1.9. Gemlik Group

The Gemlik group was first named by Genç *et al*. (1986). It comprises red, purple, green, and buff volcanic breccia, sandstone, tuffite, quartz-latitite and volcanogenic, cross bedded, well rounded, poorly sorted conglomerate.

The Gemlik group is exposed only northeast of Kozluören village at the northwestern corner of the study area. It is well observable in the upstream part of the Karadere stream.

The Gemlik group unconformably overlies the Pazarcık complex, Bayırköy Formation, and Bilecik group northeast of Kozluören village. At the same locality it is tectonically overlain by the same units. It is about 75 meters thick.

In the study area no fossil have been found within the samples of the Gemlik group. However, based on the lithostratigraphic correlation between the Gemlik group of Genç _et al_. (1986) and its outcrops in the study area, an Eocene age was assigned to our outcrops.

2.2. Cover Units

The cover units comprise the Middle to Upper Miocene İnegöl group and Plio-Quaternary alluvial deposits.

2.2.1. İnegöl Group

The İnegöl group was first named by Genç _et al_. (1986) as İnegöl formation. However Koçyiğit _et al_. (1991) raised it into group rank by dividing it into four distinct mappable lithostratigraphic units. It is composed mostly of buff, yellow, brown, red and gray fluvial clastics and lacustrine limestones and marls.

The İnegöl group is exposed almost all over the study area except at the central part of the İnegöl basin where alluvial sedimentation is still going on. Although, the İnegöl group is well exposed and continuous in the southern half of the study area, it occurs in isolated and patch-like outcrops at the northern margin of the basin.

Although the age of the İnegöl group could not be determined by palaeontological tools, based on the regional lithostratigraphic correlations between nearby basins in northwest Anatolia (Figure 4) and based on vertebrate fossils listed in Genç (1986) Middle to late Miocene has been assigned to this unit.

The İnegöl group is divided into four formations as Çayyaka, Gülbahçe, Sarıpınar, and Akpınar formations. In

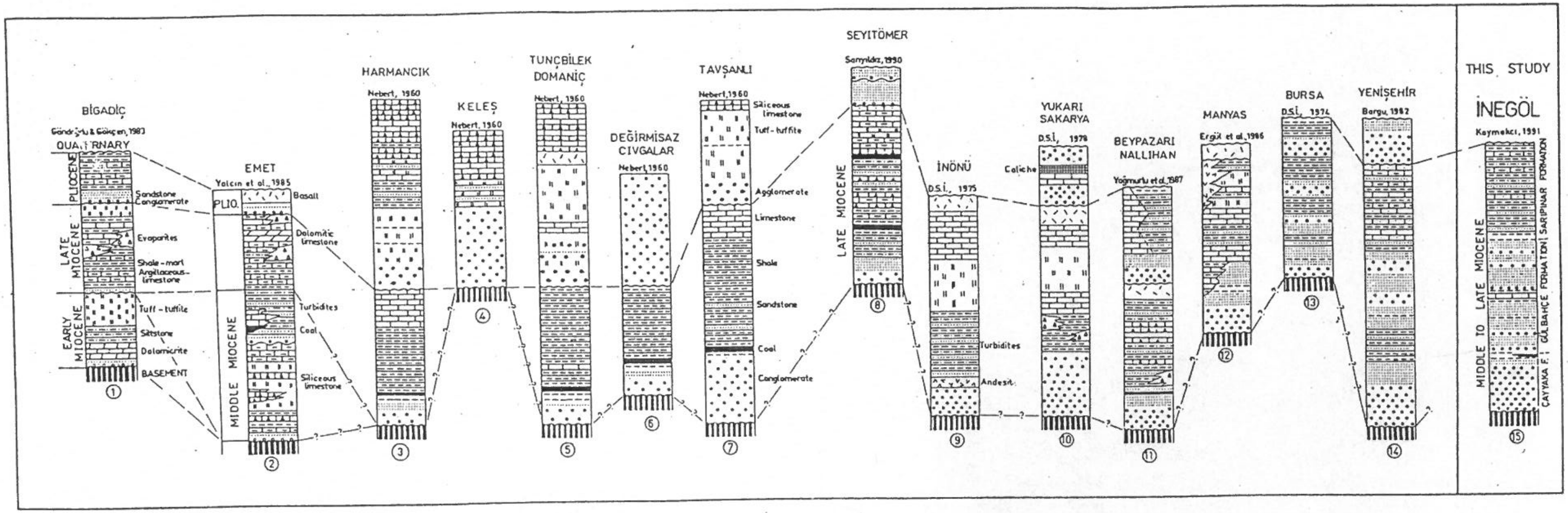


Figure 4. Lithostratigraphic correlation of the cover units of the İnegöl basin and nearby basins. The numbers show the locations of basins in Figure 1.

the study area the Akpınar formation does not have mappable outcrops, so, it was included in the Gülbahçe formation.

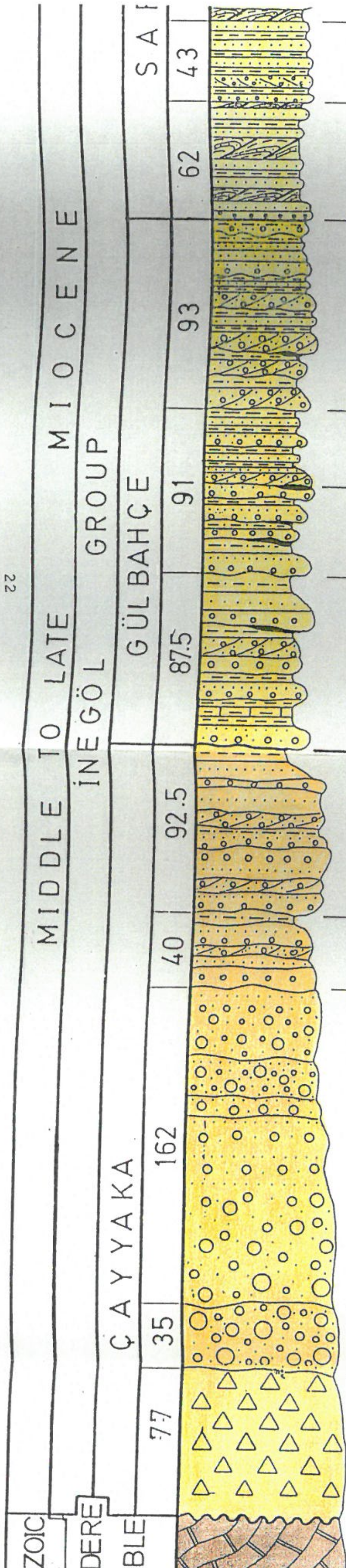
2.2.1.1. Çayyaka formation

The type locality of the formation is the Çayyaka village located at the southern margin of the İnegöl basin, approximately 10 kilometers south of İnegöl County. It consists mainly of fining-upward sequence of polygenic conglomerates and sandstones.

The Çayyaka formation constitutes the base of the İnegöl group, and is exposed in a narrow and long belt between Sulhiye village to the east and Kayapınar village to the west at the southern margin of the study area (Plate 1). It also crops out in a narrow and U-shaped belt through the Yarıkkaya hill, Çiftlikköy, and Kıran villages in the southwest of study area.

The Çayyaka formation overlies nonconformably various metamorphics of basement, while it displays both vertical and lateral gradations with the Gülbahçe and Sarıpınar formations (Plate 1, Figures 5 and 6). In contrast, it is also overlain tectonically by the Tahtaköprü granodiorite and the Pazarcık complex at south of Sulhiye village in the southeastern margin of the İnegöl basin.

In order to better describe the Çayyaka formation, two reference sections were measured. One of them is in Çayyaka village and the second one is in Kirazlık hill (Plate 1, Figures 5 and 6). In the Çayyaka section, the Çayyaka formation rests with a 77 meter thick, red to purple,



PEBBLY SANDSTONE-SILTSTONE-SHALE ALTERNATION.
Primary structures; antidunes, sand dunes, ripples, convolute bedding, scour-fill.

SANDSTONE-SILTSTONE-SHALE ALTERNATION.
Primary structures: scour-fill, slumps, contorted and convolute bedding, antidunes, sand dunes, ripple marks, load casts, and sand dikes.

CONGLOMERATE-SANDSTONE AND SHALE ALTERNATION.
Primary structures; cross and graded bedding, imbrication, scour-fill, synsedimentary normal faults, burrows, and coal lenses.

SANDSTONE-SHALE-CONGLOMERATE ALTERNATION.
Primary structures; cross and graded bedding, ripple marks, scour-fill, and synsedimentary normal faults.

SANDSTONE-SILTSTONE-SHALE-CONGLOMERATE ALTERNATION.
Primary structures; scour-fill, ripple marks, burrows and bioturbation. Plant roots and coal.

CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE ALTERNATION AND ARGILLACEOUS LIMESTONE-COAL LENSE INTERCALATIONS.
Primary structures; cross and graded bedding, laminations, and synsedimentary normal faults.

CONGLOMERATE-SANDSTONE-SILTSTONE AND SHALE ALTERNATION.
Conglomerates are buff to pale brown, they are moderately sorted and polygenic, including granite, schist, phyllite, greenschit, and marble pebbles.
Sandstones are buff to brown and composed mainly of angular quartz, feldspar and rock fragments.
Siltstones are buff to greenish and they are mostly laminated.

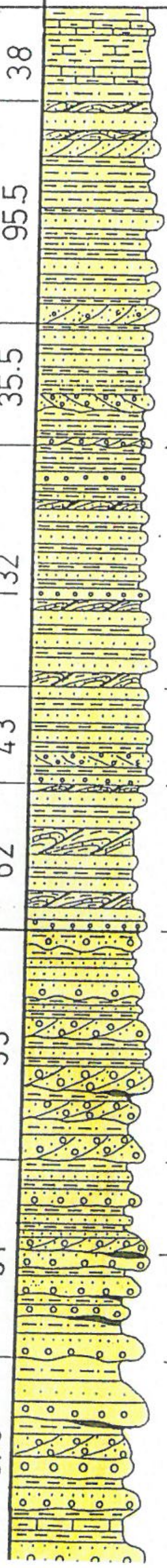
CONGLOMERATE-SANDSTONE AND SILTSTONE ALTERNATION.
They are buff to green to grey.
Primary structures; cross and graded bedding, and laminations.

CONGLOMERATE AND SANDSTONE ALTERNATION.
They are buff to pale brown, moderate to poorly sorted, grain supported, polygenic.
Primary structures; cross and graded bedding.

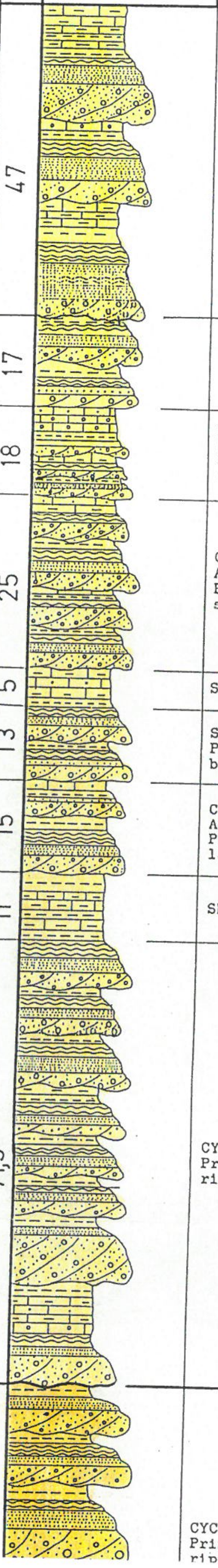
CONGLOMERATE.
It is buff to pale brown, unsorted, matrix supported, and polygenic conglomerate. Clasts are derived from granite, motamorphics and marble.

BRECCIA.
It is red to purple, unsorted, grain supported, porous and monogenic. Clasts are derived from marble.

Figure 5. Combined measured type section of the Çayyaka, Gülbahçe, and Sarıpınar formations (south and west of Çayyaka, around and northwest of Gülbahçe, and south west of Sarıpınar villages).



AGE	GROUP	FORMATION	THICKNESS (m)	DESCRIPTION
LATE MIOCENE	GÖL GROUP	SARIPINAR	38	SILTSTONE-MICRITIC LIMESTONE-SHALE-ARGILLACEOUS LIMESTONE AND SANDY LIMESTONE ALTERNATION
			95.5	PEBBLY SANDSTONE-SANDSTONE-SILTSTONE-SHALE ALTERNATION. Primary structures; antidunes, ripple marks, scour-fill, load casts, sand dikes, and convolute bedding.
			35.5	CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE ALTERNATION. Primary structures; antidunes, ripple marks, sand dikes, load casts, and convolute bedding.
			132	SANDSTONE-PEBBLY SANDSTONE-SILTSTONE AND SHALE ALTERNATION. Primary structures; scour-fill, slumps, contorted and convolute bedding, antidunes, ripple marks, load casts, and sand dikes.
			43	PEBBLY SANDSTONE-SILTSTONE-SHALE ALTERNATION. Primary structures; antidunes, sand dunes, ripples, convolute bedding, scour-fill.
			62	SANDSTONE-SILTSTONE-SHALE ALTERNATION. Primary structures: scour-fill, slumps, contorted and convolute bedding, antidunes, sand dunes, ripple marks, load casts, and sand dikes.
		GÜLBAHÇE	93	CONGLOMERATE-SANDSTONE AND SHALE ALTERNATION. Primary structures; cross and graded bedding, imbrication, scour-fill, synsedimentary normal faults, burrows, and coal lenses.
			91	SANDSTONE-SHALE-CONGLOMERATE ALTERNATION. Primary structures; cross and graded bedding, ripple marks, scour-fill, and synsedimentary normal faults.
				SANDSTONE-SILTSTONE-SHALE-CONGLOMERATE ALTERNATION. Primary structures; scour-fill, ripple marks, burrows and bioturbation. Plant roots and coal.
			87.5	CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE ALTERNATION AND ARGILLACEOUS LIMESTONE-COAL LENSE INTERCALATIONS. Primary structures; cross and graded bedding, laminations, and synsedimentary normal faults.

AGE	GROUP	FORMATION	THICKNESS (m)	LITHOLOGY	DESCRIPTION
MIDDLE TO LATE MIOCENE	İNEGÖL	GÜLBAHÇE	47		CYCLIC CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE-SANDY, ARGILLACEOUS, AND ONCHOIDAL LIMESTONE ALTERNATIONS Primary structures; ripples, cross bedding, scour-fill, laminations, and bioturbation.
			17		CONGLOMERATE-SANSTONE-SHALE ALTERNATIONS Primary structures; cross and graded bedding, ripples, laminations, scour-fill, and bioturbation.
			18		SANDSTONE-SILTSTONE-SHALE-ARGILLACEOUS, SANDY, AND ONCHOIDAL LIMESTONE ALTERNATIONS. Primary structures; cross bedding, ripples, laminations, scour-fill, dunos, bioturbation.
			25		CONGLOMERATE-SANDSTONE-SHALE-ARGILLACEOUS LIMESTONE ALTERNATIONS. Primary structures; cross and graded bedding, ripples, scour-fill, laminations, and bioturbation.
			5		SANDY AND ARGILLACEOUS LIMESTONE
			13		SANDSTONE-SHALE ALTERNATION Primary structures; cross beddding, ripples, laminations, burrows.
			15		CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE-SANDY LIMESTONE ALTERNATIONS. Primary structures; ripples, cross bedding, sand dunes, laminations, and burrows.
			11		SHALE-ARGILLACEOUS AND SANDY LIMESTONE ALTERNATIONS
			71,5		CYCLIC CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE ALTERNATIONS Primary structures; cross and graded bedding, scour-fill, ripples, laminations, bioturbation, dunes, and antidunes.
					CYCLIC CONGLOMERATE-SANDSTONE-SILTSTONE-SHALE ALTERNATION Primary structures; bioturbation, cross and gradded bedding, ripples, scour-fill, and laminations.

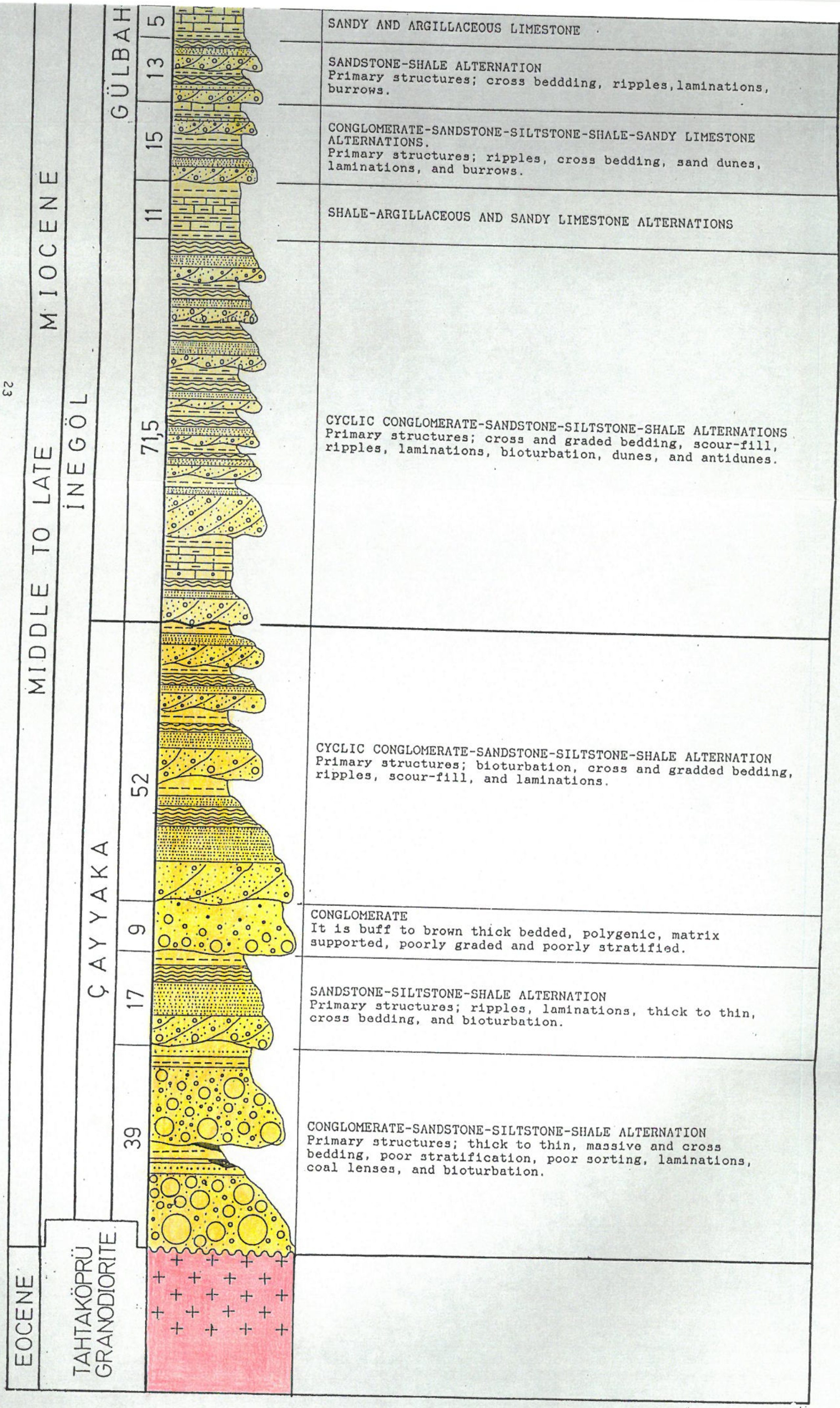


Figure 6. Kirazlık hill measured type section of the Çayyaka and Gülbahçe formations s.

unsorted, grain-supported, and partly porous breccia on the erosional surface of the Kocadere marble. It is composed wholly of angular marble fragments set in a red, sandy-clayey matrix. This breccia is a local lithofacies of the Çayyaka formation, because it is exposed only in a limited area where the Çayyaka formation comes in contact with the marbles of the basement rocks (Kocadere marble) (Plate 1, Figures 5, and 7).

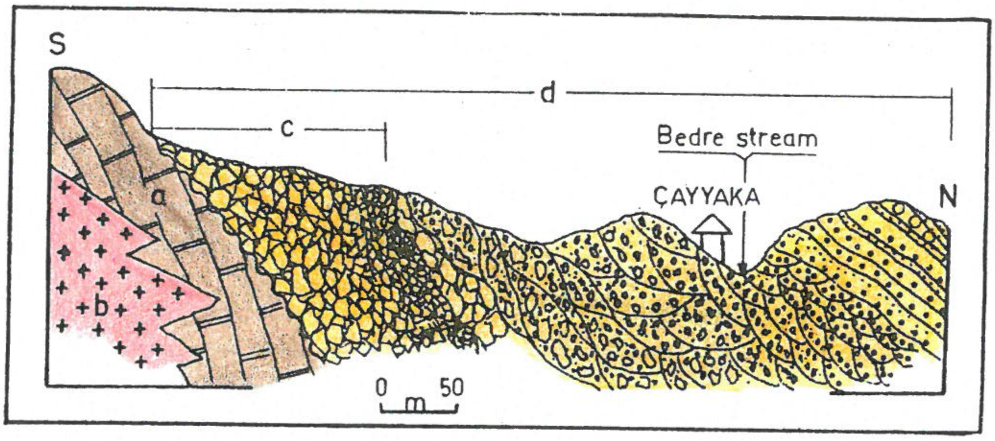


Figure 7. Sketch cross-section showing the boundary relationships of the Çayyaka formation and underlying basement units. a) Kocadere marble, b) Tahtaköprü granodiorite, c) red breccia, d) Çayyaka formation.

The Çayyaka formation continues upward with buff to pale brown, very thick, unsorted, poorly stratified, matrix-supported, poorly graded, partly consolidated, polygenic conglomerates, minor amounts of sandstone, siltstone and shale alternation (Figure 8). In this section, the Çayyaka formation was measured to be 406.5 meters (Figure 5).

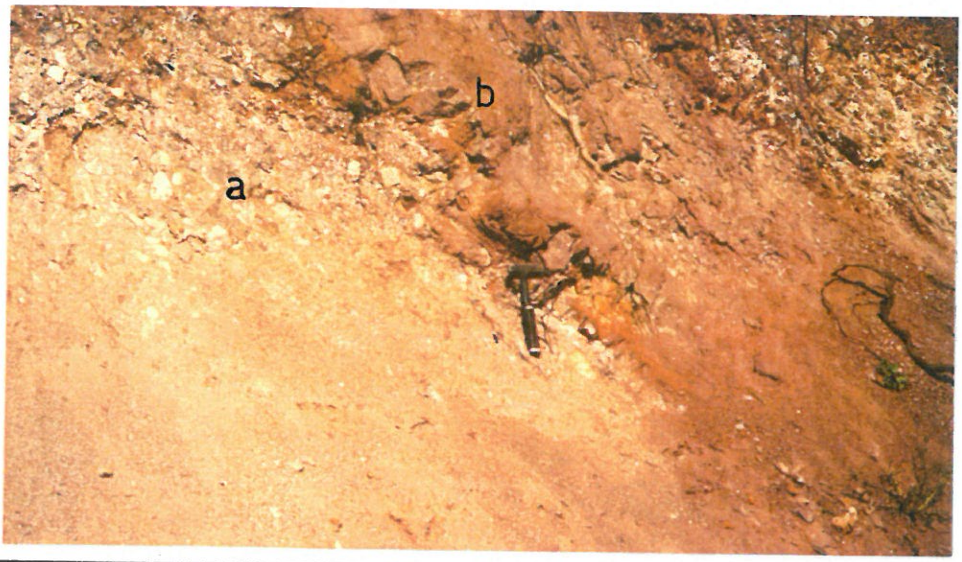


Figure 8. General view of the Çayyaka formation. a: conglomerate, b: sandstone (south of Çayyaka village, view to east).

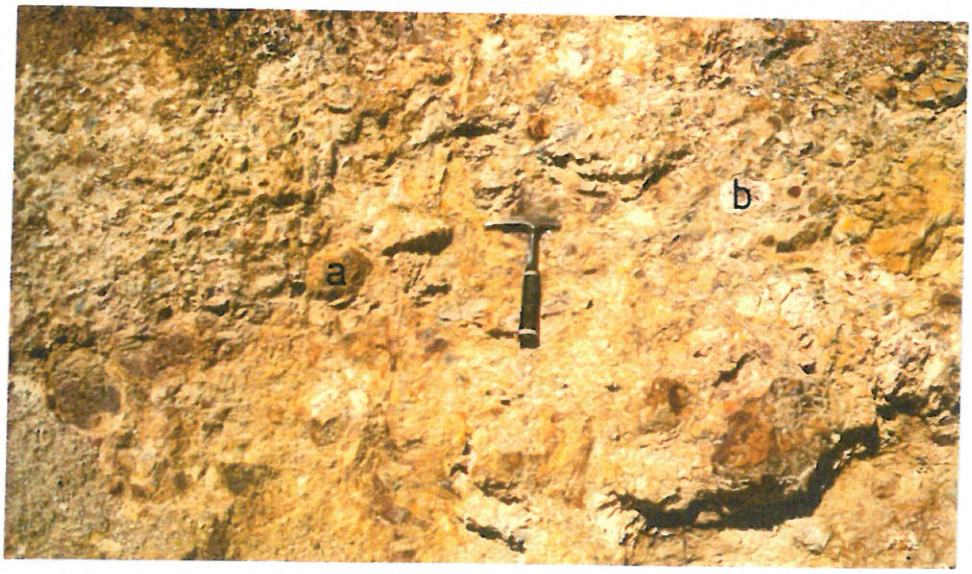


Figure 9. General view of the conglomerates of the Çayyaka formation. a: clast(s) derived from metamorphics, b: clast(s) derived from marble (south of Kirazlık hill, view to northwest).

The conglomerates are composed of fragments derived mainly from granodiorite, and various metamorphic rocks (Figure 9). The amount of pebbles of metamorphic rocks within the conglomerate increases wherever the conglomerates become grain-supported, better sorted, and better rounded. The size of the pebbles reaches up to 1.5 meter in diameter. Especially, at the upper levels of the Çayyaka formation, large scale cross bedding and scour-fill structures are observed. Toward top, the pebbles become more rounded, and show imbrication that indicates northward and northwestward transportation (Allen, 1982).

Sandstones are buff to yellow, mostly massive (i.e. structureles) thin bedded and partly consolidated. At the lower levels of the formation no internal structures were observed. However, toward top, they display rarely cross-bedding, and lamination. Main constituents of the sandstones are lithic fragments, quartz, and feldspars in decreasing order. The cement is generally clay and hematite. Thus, as a whole they can be classified as "feldspathic litharenite".

Siltstones and shales are buff to gray to green, partly consolidated, thinly bedded or laminated. Their maximum thickness reaches up to 50 cm.

The red coloration, lack of sorting, and monogenic character of the breccia at the bottom of the Çayyaka formation indicate that it is a rock fall or piedmont alluvial fan deposited under the tectonic control during the initial stage of basin formation (Larsen and Steel, 1978).

Consequently, the large fragments, lack of sorting, alternation of parallel and large scale planar to trough cross-bedded stratification, frequent lateral variations in these facies indicate that the Çayyaka formation was deposited as an alluvial fan by debris flows and braided rivers under the control of a tectonic regime coeval with the sedimentation during the early stage in the development of İnegöl basin (Larsen and Steel, 1978; Reading, 1978; Walker, 1979; Allen, 1982).

2.2.1.2. Gülbahçe formation

The type locality of the unit is Gülbahçe village (Plate 1). It consists mainly of cyclic alternation of sandstone, polygenic conglomerate, siltstone and shale with lacustrine limestone intercalations (Figure 10). Locally it also includes some coal lenses of up to 15 cm thick.

Figure 10. General view of the Gülbahçe formation (near south of Gülbahçe village, view to west).

The Gülbahçe formation crops out mainly around Turgutalp, Gülbahçe, Hayriye, Hilmiye, Tahtaköprü, Hacıkara, Sulhiye, Aşağıballık, Yukarıballık, Maden, and

Konurlar villages in the southern and southeastern part of the study area. The outcrop pattern of the Gülbahçe formation resembles an E-W trending and westward pinching large scale alluvial fan (Plate 1).

Both at bottom and at top, the Gülbahçe formation shows lateral and vertical gradations with the Sarıpınar formation above and Çayyaka formation below. In contrast, it rests directly on the erosional surface of the metamorphics of the Pazarcık complex at the eastern margin of the İnegöl basin (Plate 1).

In order to better describe the Gülbahçe formation two sections were measured, one of them is located at the west of Gülbahçe and Sarıpınar villages, and the other one is in Kirazlık hill (Plate 1, Figures 5 and 6).

In the Gülbahçe-Sarıpınar section, the Gülbahçe formation consists of more than 15 cycles of conglomerate, sandstone, siltstone, and red shale alternation with more than seven coal lenses (Figure 5). On the other hand within the Kirazlık hill section the Gülbahçe formation is characterized by more than 24 cycles of conglomerate, sandstone, siltstone, shale, and lacustrine limestone alternation (Figure 6). In these sections the measured thickness of the Gülbahçe formation ranges between 222.5 meters and 271.5 meters.

The conglomerates are buff to brown. They are loose, partly consolidated, thick, cross and graded-bedded, grain-supported, poor to moderately sorted. Pebbles are subangular to subrounded. As a whole, they are very low to low mature rocks.

Sandstones are buff, yellow and gray. They are thin-to-thick bedded, cross-bedded or cross-laminated. Sandstones are composed of quartz, lithic fragments and intensely altered feldspars. They also contain biotite, muscovite, iron oxides, epidote and zircon in minor amounts. As a whole sandstones can be classified as subarkose or lithic subarkose.

Siltstones are gray to buff, thin-to-medium bedded or plane or ripple laminated. They are also loose and partly consolidated.

Shales and marls are red, buff, gray, greenish, mostly and thin bedded or laminated, medium-bedded shales are also common. Red shales mostly include carbonate concretions.

At the Kirazlık hill section, shales and marls alternate with the lacustrine limestones. These limestones are generally thin bedded, porous. They include pisolithic, sandy, argillaceous varieties. They also include abundant fresh water ostracods, algae, and onchoids. However, no key fossil could be found to date the Gülbahçe formation.

The common synsedimentary structures are cross (Figure 11) and graded-bedding, scoure and fills, dunes and ripples, pebble imbrication, mezoscopic cale growth faults of normal type and convolute bedding.

Above-mentioned litho and biofacies and mezoscopic synsedimentary structure of the Gülbahçe formation strongly suggest that it was deposited in a tectonically active depositional setting of braided to meandering river, flood plain and fresh water lakes (Reading, 1978; Walker, 1979; Allen, 1982).

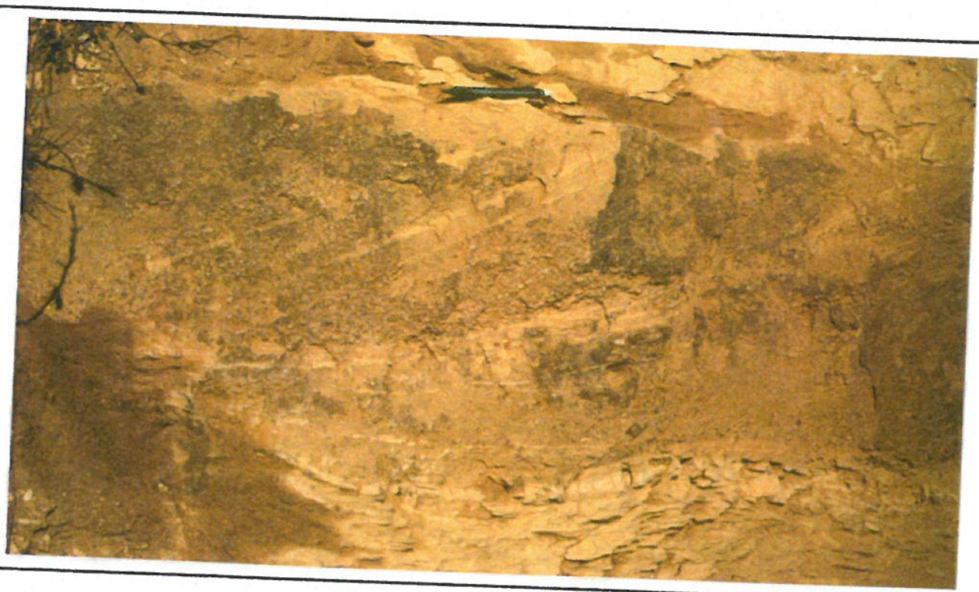


Figure 11. Cross bedding within the Gülbahçe formation (200 meters south of Gülbahçe village, view to west).

2.2.1.3. Sarıpınar formation

The type locality of the Sarıpınar formation is 1.5 kilometers southwest of Sarıpınar village. In general It is composed of lacustrine turbidites, such as conglomerate, sandstone, siltstone, and shale alternation with lacustrine limestone intercalations.

The Sarıpınar formation is widely exposed throough Kıran, Kayapınar, Sarıpınar, south of Cerrah and Hocaköy, İsaören, Deydinler, Ortaköy, and Hamamlı villages in the southern part of the study area. In addition, the Sarıpınar formation also crops out in patch-like isolated outcrops around south of Şehitler, Karalar, Hamzabey, Alanyurt, Kozluca, Akbaşlar, Süpürtü, Yiğit, and Eymir villages at the northern margin of the İnegöl basin (Plate 1) where unmapable outcrops of both the Çayyaka and Gülbahçe formations were included in the Sarıpınar formation.

At the bottom the Sarıpınar formation displays both vertical and lateral gradations both with the Çayyaka and Gülbahçe formations. In contrast, it is overlain unconformably by Plio-Quaternary and Quaternary sediments at the top across the depocenter of the İnegöl basin (Plate 1).

In order to better describe the Sarıpınar formation, a reference section was measured 1.5 kilometers southwest of Sarıpınar village along the road Gülbahçe to Hocaköy villages (Plate 1, Figure 5).

In the Sarıpınar section the Sarıpınar formation starts with conglomerate, sandstone, siltstone, and shale-marl alternation. In these levels contorted and convolute bedding (Figure 12), ripple marks, slumps (Figure 13), and laminations are common synsedimentary structures. Toward top, the unit continues with more regularly bedded facies. The dominant lithologies are pebbly sandstone, siltstone, and shale alternation. It displays well-developed dunes, ripples, cross-bedding, cross-lamination, scour-fill structures, load structures (flame structures) and onion shaped weathering in marls. Near the top, the Sarıpınar formation is composed of cyclic alternation of conglomerate, sandstone, siltstone, and shale-marl. In these levels conglomerates are thicker and cross bedded,

Figure 12. General view of the convolute bedding within the Sarıpınar formation (2 kilometers South west of Sarıpınar village, view to northwest).

Figure 13. General view of the syndepositional slumping within the Sarıpınar formation (1 kilometer west of Sarıpınar village, view to east).

Figure 14. General view of the syndepositional horst-graben pattern developed within the Sarıpınar formation (500 meters south of Kayapınar village,view to north).
F: synsedimentary normal faults.

diagnostic sedimentary structures are load structures, water escape structures, scour and fill, and some normal type of growth faults displaying horst-graben pattern (Figure 14).

The topmost of the Sarıpınar formation consists of cyclic alternation of thin-to-medium bedded shale-marl, and argillaceous lacustrine limestone. In Gülbahçe-Sarıpınar section, the thickness of the Sarıpınar formation was measured as 406.5 meters.

The conglomerates are buff to yellow, polygenic, medium to thick bedded. Some thin beds are also encountered. They are cross-bedded, poorly to moderately sorted toward top, and generally grain-supported, mostly graded, pebbles are subrounded to rounded, and their maximum size may reaches up to 10 cm in diameter. However, their average size is generally around 1cm.

Sandstones are buff and yellow, thin bedded, moderately sorted. They display ripple lamination and cross bedding. Main constituents of sandstones are quartz, lithic fragments, and intensely altered feldspars. In minor amounts muscovite, biotite, epidote and iron oxides are also present. They either have clayey matrix or are cemented by calcite or secondary silica.

The organisation of facies, synsedimentary structures, and fossil content indicate that the Sarıpınar formation was deposited in deep lacustrine environment which is deep enough for the formation of turbidity currents that deposited the Sarıpınar formation (Reading, 1978; Walker, 1979; Allen, 1982).

2.2.2. Alluvial Deposits

The alluvial sediments are divided into two: (1) a Plio-Quaternary alluvial fan-apron deposits, namely the Akıncılar formation and (2) active basinal deposits.

2.2.2.1. Akıncılar formation

The Akıncılar formation was named for the first time in this study. The type locality of the formation is Kozluören village sited northwest of the İnegöl basin, approximately 10 kilometers west of İnegöl county. It consists mainly of alluvial fan and apron deposits.

The Akıncılar formation is exposed around south of Kozluören, Babasultan east and southeast of Akıncılar villages in the northwestern part of the study area (Plate

1). The outcrop pattern of the Akıncılar formation resembles an alluvial fan whose tip is at the southwest.

The Akıncılar formation rests nonconformably on the erosional surface of the Mahmudiye mafics-ultramafics, Kocadere marble, Gemlik group, and İnegöl group at the northwestern part of the İnegöl basin.

The Akıncılar formation is composed of degraded debris flow-dominated alluvial fan-apron sediments (Larsen and Steel, 1978; Reading, 1978; Walker, 1979). It is structureles (crudely bedded) and composed of partly consolidated, poorly stratified, poorly graded, generally grain-supported conglomerates comprising subangular to subrounded pebbles derived from the Kıran complex, Kocadere marble, Mahmudiye mafics-ultramafics, and Gemlik and İnegöl groups. The thickness of the formation increases toward the northeast from about 2 meters to 20 meters (D.S.İ., 1978). However, along the faults and deeply incised streams the Akıncılar formation is eroded and thinned thus, within the formation unmappable outcrops of the basement units are exposed.

The Akıncılar formation is being degraded, partly consolidated, but retains its original fan shaped geometry. Therefore, the Akıncılar formation is Plio-Quaternary in age.

2.2.2.2. Alluvium

There are a number of streams entering to the basin from southern and northeastern margin of the basin. Most of them die out and leave their load as soon as they enter the basin. Only a few of them cross the basin to flow out along the gorge connecting İnegöl basin to Yenişehir basin which is located at the north of the İnegöl basin. The streams have braided (low sinisoity) character at the basin margins, especially at the eastern and western margins. Therefore, pebble imbrication, planar to trough cross bedding, intercalation of thin beds of sand and silt is characteristic at the basin margins. Besides, toward the axial part of the İnegöl basin, the sinisoity of the streams increases and they gain meandering river character. Thus, it is composed of gravel, sand, silt and clay sized sediments derived from various metamorphics, granitoids, and marble. According to drilling data of D.S.İ. (1978) the thickness of the alluvium is 2 to 38 meters in the western margin, 60 to more than 100 meters at the eastern margin, and more than 100 meters at the axis of the new depositional center of the İnegöl basin.

3.STRUCTURAL GEOLOGY

The geological structures observed within the study area are of pre-Alpine and Alpine origins. Basically, these structures are faults, folds, unconformities, bedding, and joints. They are described in detail in the order of their importance.

3.1. Faults

Based on the age and tectonic characteristics, the faults developed in the study area are divided into three: (1) neotectonic faults and (2) paleotectonic faults.

3.1.1. Neotectonic Faults

The study area is dominated by approximately NW-SE, N-S, and NE-SW trending normal faults with considerable amount of lateral components. They occur either as isolated single fault or in sets. So, based on their trend, size, distribution, and mutual relations, they are classified into (1) Akıncılar Cerrah fault set (2) İsaören-Hacıkara-Tahtaköprü fault set, (3) Kınık-Özlüce fault set, (4) Kıran fault set, (5) Gülbahçe fault set, (6) Elmaçayır fault, (7) Maden-Konurlar fault set, (8) Hilmiye fault set, (9) Sulhiye reverse fault and (10) Syndepositional Mezoscopic faults. There is also a number of NW-trending individual faults. They occur mainly around Şehitler, SE of Karalar, Hamzabey, Fındıklı, Akbaşlar, north of Kulaca, Yiğit, Eymir, Yukarıballık, and İhsaniye, villages in the northern, northeastern, and eastern part of the study area.

3.1.1.1. Akıncılar-Cerrah Fault Set (ACFS)

It is an approximately 15 kilometers long and 3 kilometers wide belt extending from Fındıcak hill to the northwest to the north of Sarıpınar village in the southeast. Although, the faults within the ACFS are generally parallel to each other and well-defined, some of the faults deviate from the main trend. For example, faults within the ACFS around Çiftlikköy trend 290°N, in the south of Cerrah village a single fault trends 255°N, and around northeast of Sarıpınar village the trend of another fault is 340°N, whereas the main trend of the ACFS is 315°N (Plate 1).

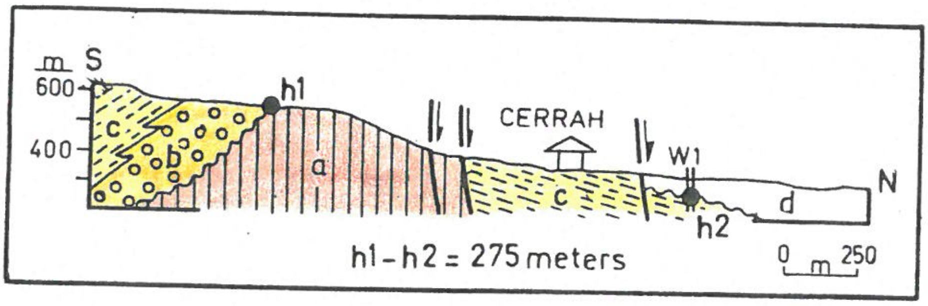


Figure 15. Sketch cross-section showing the normal fault contact (ACFS) between the basement and Sarıpınar formation. South of Cerrah village. a: Mahmudiye mafics-ultrafics, b: Çayyaka formation, c: Sarıpınar formation, d: alluvium, h1,2: elevations of piercing points.

To the south of Cerrah village, the minimum throw amount of ACFS is about 275 meters (Figure 15). The significancy of the ACFS comes from that, it defines the southern boundary of the Quaternary configuration of the İnegöl basin in the area around Cerrah village.

Truncation and offset of the Plio-Quaternary (?) and older units, well preserved fault scarps, a wide shear zone, and mechanical indicators like slip lineations are the main evidences for the presence of the ACFS.

3.1.1.2. İsaören-Hacıkara-Tahtaköprü Fault Set (İHTFS)

It is an approximately 15 kilometers long, 2 kilometers wide and northward convex fault zone extending from İsaören village to Tahtaköprü town. This zone may also run far beyond the study area to join the Kuyupınar fault set of Koçyiğit et al. (1991). The İHTFS is not continous. Its segments are well-marked. They are mostly parallel and en echelon in aerial distribution pattern. Within the fault zone, some of the faults deviate from the mean fault trend. For example, the faults observed around Karatepe hill trends EW, whereas to the east of Konurlar village the mean trend of the faults is 280°N.

The well-developed and preserved fault scarps, and presence of numerous mezoscopic normal faults in, especially in the Kirazlık hill and southwest of Gündüzlü village are the field evidences for the presence of the İHTFS.

3.1.1.3. Kınık-Özlüce Fault Set (KÖFS).

The Kınık fault set is a linear belt extending from Aşağıballık village in the west to Gebemeşe hill in the east. It is approximately 6 kilometers long and 2 kilometers wide zone trending 285°N. The faults within this zone display parallel and en echelon pattern. They are indicated by the well-preserved fault scarps marked by the step-like morphology.

In the Kınık and Özlüce areas, the KÖFS defines the Plio-Quaternary configuration of the İnegöl basin and the normal step-faulted basement rocks (Plate 1).

Well marked linearity of both the faults and mineral water springs, crushed zone, fault scarps and presence of mechanical surfaces are the evidences for the presence of the KÖFS.

3.1.1.4. Kıran Fault Set (KFS)

The Kıran fault set consists of three parallel N-S trending approximately 3 kilometers long en echelon faults where seperation is about 500 meters. The KFS defines the westernmost termination of the İnegöl basin.

Well-developed fault scarps, and mechanical surfaces are the evidences for the presence of the KFS.

3.1.1.5. Gülbahçe Fault Set (GFS)

The Gülbahçe fault set is an approximately 4 kilometers wide fault zone extending from the north of Kıran village in the west to Gülbahçe village in the east.

The faults constituting the GFS are almost parallel and trend approximately 315°N which is also the axial trend of the İnegöl basin. The GFS displays well developed steplike topography which, in generally, steps downward from south.

Well-marked linearity of faults, truncated and offset features, well-developed and preserved fault scarps, step-like topography and presence of slickensides are the conclusive evidences for the presence of GSF.

3.1.1.6. Elmaçayır fault (EF)

The Elmaçayır fault is an oblique-slip normal fault. It is one of the faults defining the southernmost termination of the İnegöl basin. It is also a fault contact along which various rock units of both the basement and İnegöl group are tectonically juxtoposed. It extends from the NW of Fevziye village up to Tuzla hill. It is well-marked by the well-developed fault scarps, parallel alignment of mineral water springs, very wide shear zone and mechanical surfaces.

3.1.1.7. Maden Fault Set (MFS)

Maden fault set consists of six almost parallel fault segments. The MFS extends in E-W direction from 2 kilometers west of Maden village to Konurlar village. It is approximately 6 kilometers long and 2 kilometers wide.

The MFS displays steplike morphology, well-developed fault scarps and offseted and displaced strata. These are the main field evidences of the MFS.

3.1.1.8. Hilmiye Fault Set (HFS)

The Hilmiye fault set is well exposed around Hilmiye village and consists of 9 fault segments of unequal length (Plate 1). Two of these segments trend in approximately E-W direction, while rest of them strike in approximately NE-SW direction. Lengths of the fault segments range from 0.5 kilometers to 6 kilometers. Three southernmost fault segments of the HFS cut across the basement and they define locally the southern margin of the İnegöl basin in this region. Excluding the three segments at the south which are oblique-slip normal faults, the character of the rest of the faults in the HFS could not be determined. However, the amount of throw of these three fault is more

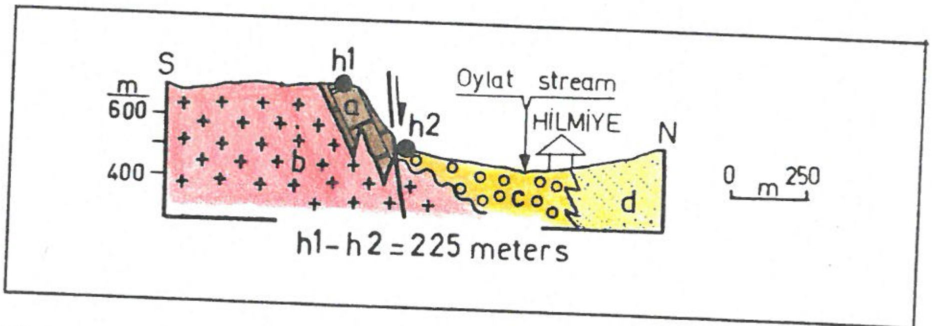


Figure 16. Sketch geological cross-section showing the normal fault contact (HFS) between the basement rocks and the İnegöl group. a: Kocadere marble, b: Tahtaköprü granodiorite, c: Çayyaka formation, d: Gülbahçe formation, h1,2: elevations of piercing points (south of Hilmiye village).

than 225 meters (Figure 16). The well-developed fault scarps, truncation and offsetted rock units of both the basement and İnegöl group, well-preserved mechanical surfaces are the indicators for the presence of the HFS.

3.1.1.9. Sulhiye Reverse Fault (SRF)

The Sulhiye reverse fault is observed at the southeastern corner of the study area where it extends from southeast of Sulhiye village to further east outside of the study area. Along the SRF the pre-Permian Pazarcık Complex and Eocene Tahtaköprü granodiorite pushed from south to north on to the İnegöl group (Figure 17). However, it over rides only the marginal deposits (Çayyaka formation) of the İnegöl group. Therefore, its displacement is not more than the thickness of the Çayyaka formation which is less than 200 meters at this locality.

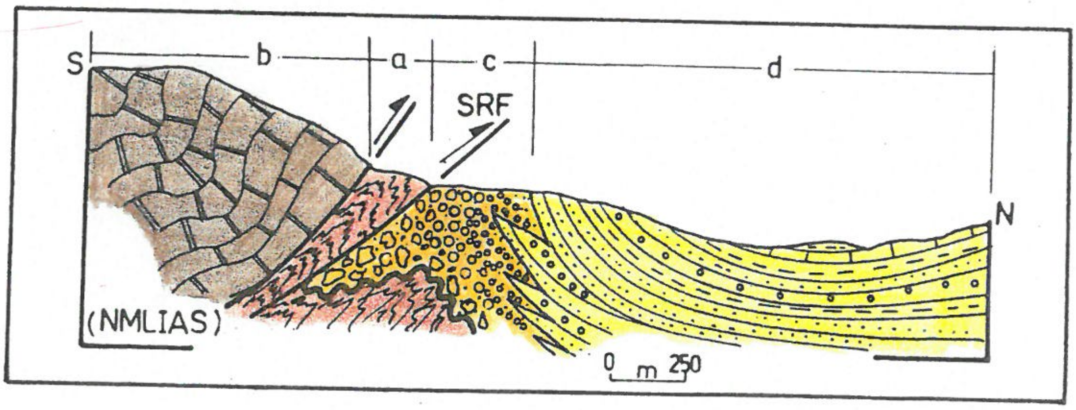


Figure 17. Sketch cross-section showing the Sulhiye reverse fault and the northernmost limit of the İzmir-Ankara Suture (NMLIAS). a: Pazarcık Complex, b: Kocadere marble, c: Çayyaka formation d: Gülbahçe formation (500 meters south of Sulhiye village).

The well-obseved crushed zone and south-dipping beds of the İnegöl group near contact are the main field evidences of this structure.

3.1.1.10. Syndepositional Mezoscopic Faults

The syndepositional mezoscopic faults are confined only into the İnegöl group. They occur either individually or in sets (Figures 14 and 18). They are accompanied frequently by the slump structures.

In order to determine the general trend of the mezoscopic faults, stereographic plotting techniques were used. For this purpose, "Mellis method of contouring" is applied (Figure 19) because the field data is not sufficient to prepare "Schmidt contouring method". To do this, the faults were restored to their original position

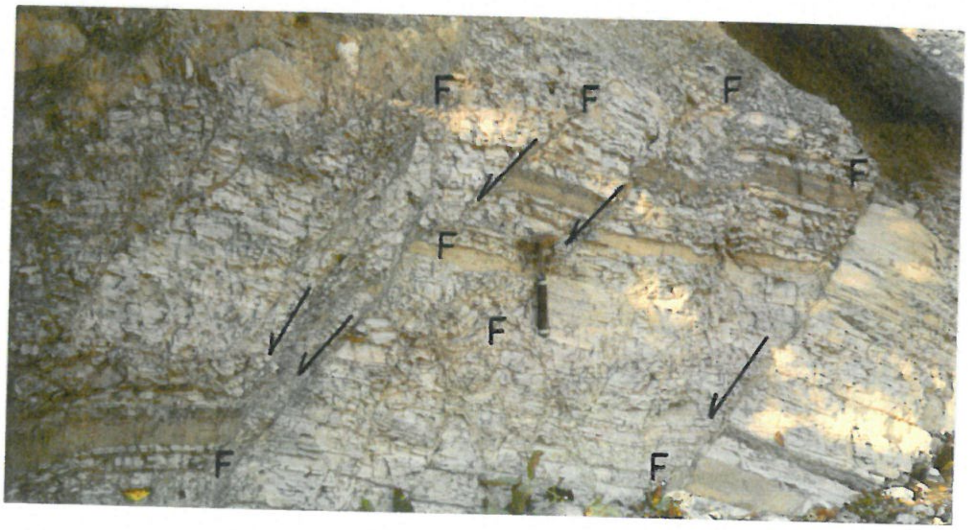


Figure 18. General view of the syndepositional mezoscopic normal faults (F) developed within the İnegöl group. Arrows show the movement of hanging wall block (500 meters southwest of Kayapınar village, view to northeast).

by rotating them about the attitude of the beds cut by each fault. However, the faults have not given any general trend, for this reason, "M Planes" of the faults lineations lineations were plotted. As seen in Figure 20, although the ġ1 is vertical or subvertical the orientations of the ġ2 and ġ3 are not obvious which means that; the ġ2 and ġ3 are almost equal to each other. If ġ2 and ġ3 are close to each other the faults must have been formed at the surficial conditions (Engelder and Marshak, 1988). It is stated that

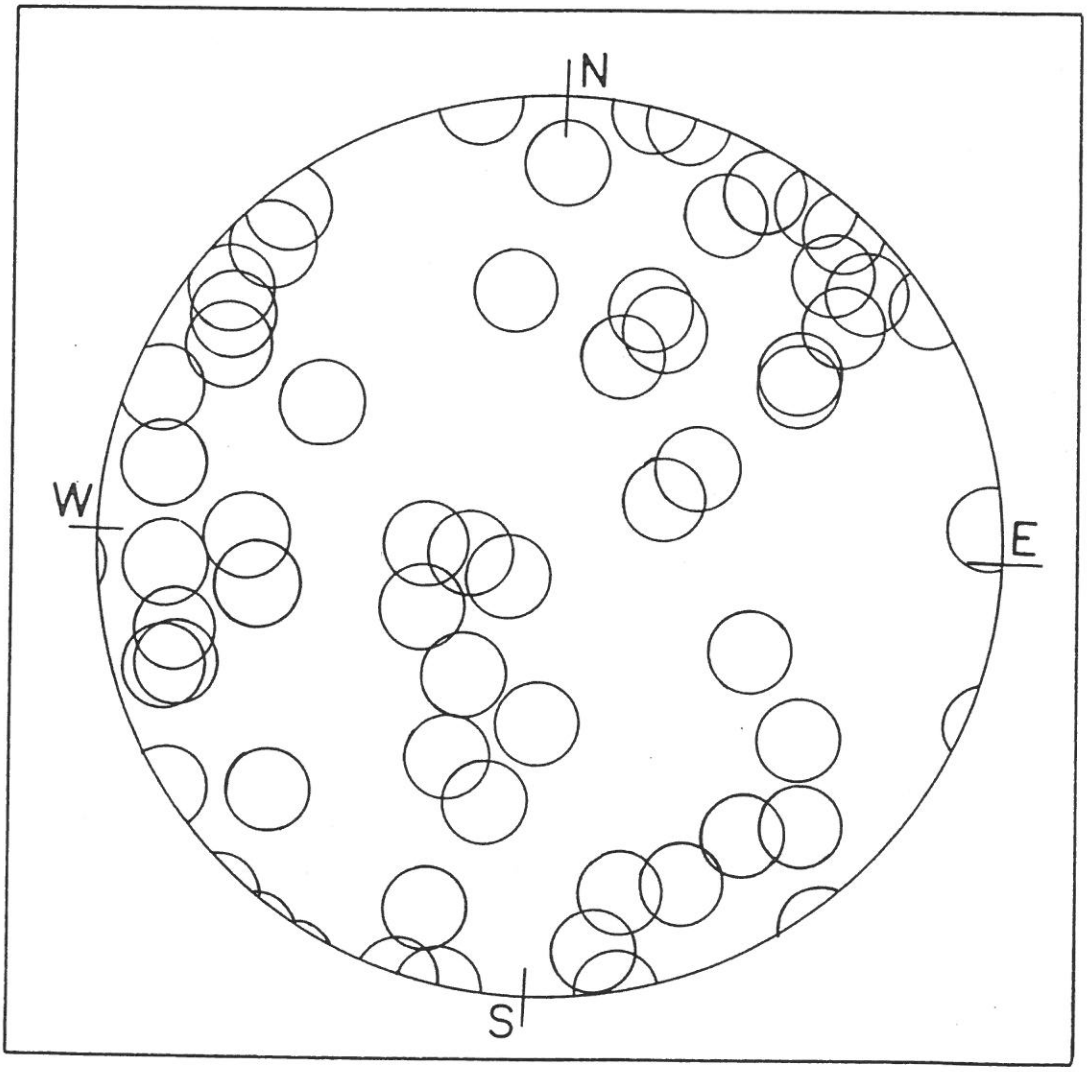


Figure 19. Mellis contour diagram of the syndepositional normal faults studied within the İnegöl group (47 measurements, each circle is 1% of the total area, Lambert equal area net, lower hemisphere projection).

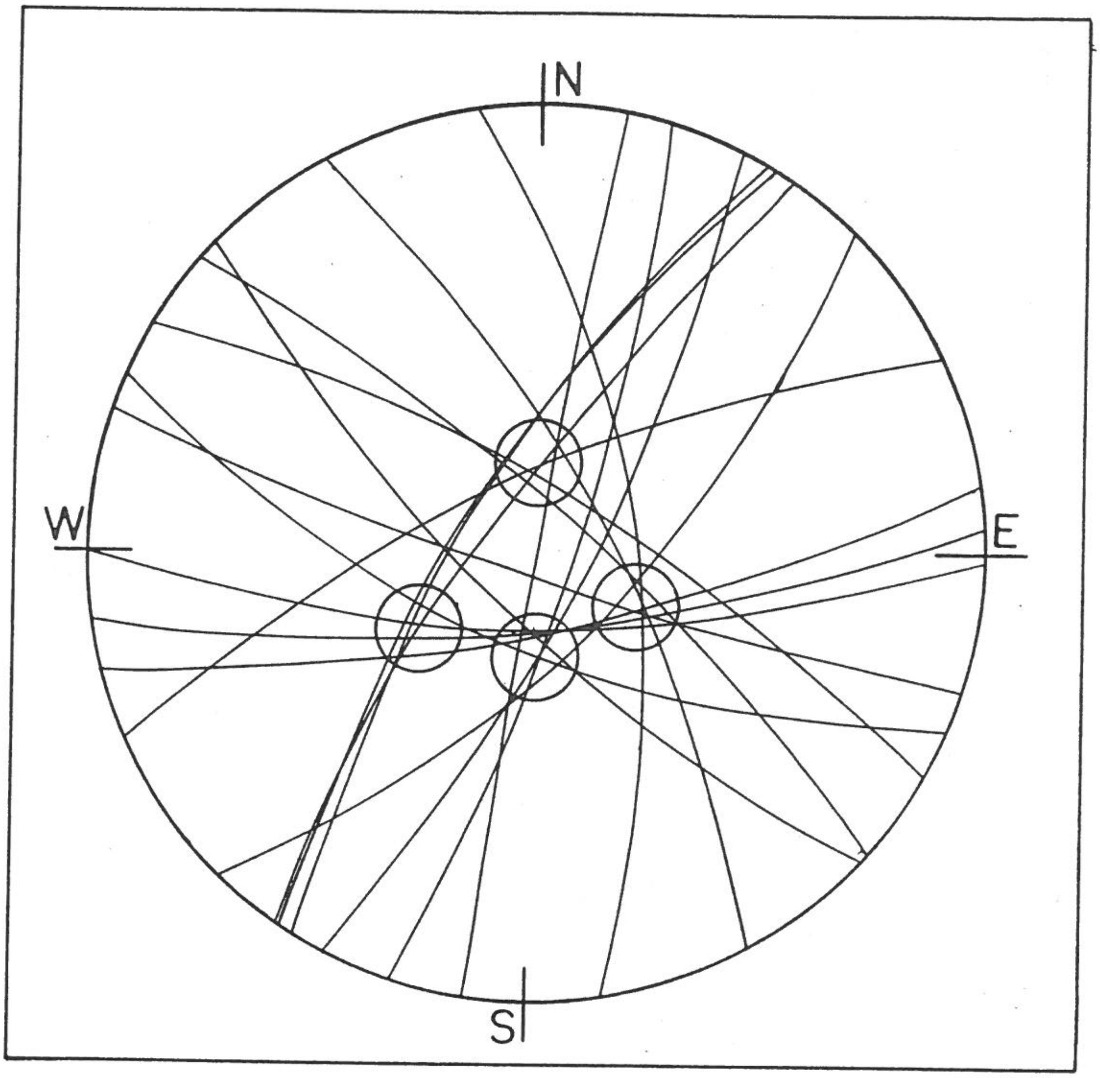


Figure 20. M plane diagram of the syndepositional normal faults studied within the İnegöl group. Circles show the possible orientaions of major principal stress (ġ1) (Lambert equal area net, lower hemisphere projection).

when the difference in the magnitudes of ġ2 and ġ3 is high, the trends of resultant structures would tend to be parallel. However, if the difference in these stresses is not great, then it would create more randomly oriented structures (Engelder and Marshak, 1988).

As a conclusion, the syndepositional mezoscopic faults observed in the İnegöl group are resulted from sedimentary processes rather than tectonic processes.

3.1.1.11. Analyses of the Neotectonic Faults

The faults are distributed throughout the study area. However, they are concentrated in two regions (1) around Akıncılar Çiftlikköy, Cerrah, Hocaköy, Sarıpınar, Gülbahçe Turgutalp, and Kıran villages in the southern part of the study area, and (2) around İsaören, Deydinler, Ortaköy, Hamamlı, Aşağıballık, Kınık, Özlüce, İhsaniye, Sulhiye, Tahtaköprü, Hacıkara, Hilmiye, Hayriye, Konurlar, and Maden villages (Plate 1). The length weighted rose diagrams prepared for these two areas have shown a major difference in the trends of faults in both areas. In the first area, the mean trend is between N40°W and N50°W (Figure 21a). However, in the second area it is N60°W and N70°W (Figure 21b). In addition, the mean trend of the faults throughout the İnegöl basin is also between N40°W and N50°W (Figure 21c). Thus, it is obviously seen that the faults in the first area are more regularly arranged so that they are almost parallel or subparallel. On the contrary, the faults in the second area are more randomly but also northwesterly-oriented.

When we combine all the data related to the faults, the orientation of the stresses that are responsible for the formation of these faults, are as follows: ġ1=174°N/68°; ġ2=324°N/21°; ġ3=056°N/10° (Figure 22).

As seen in Figure 23, this conclusion is compatible with the stress orientations indicated by the geophysical data. Thus, the study area is under the control of

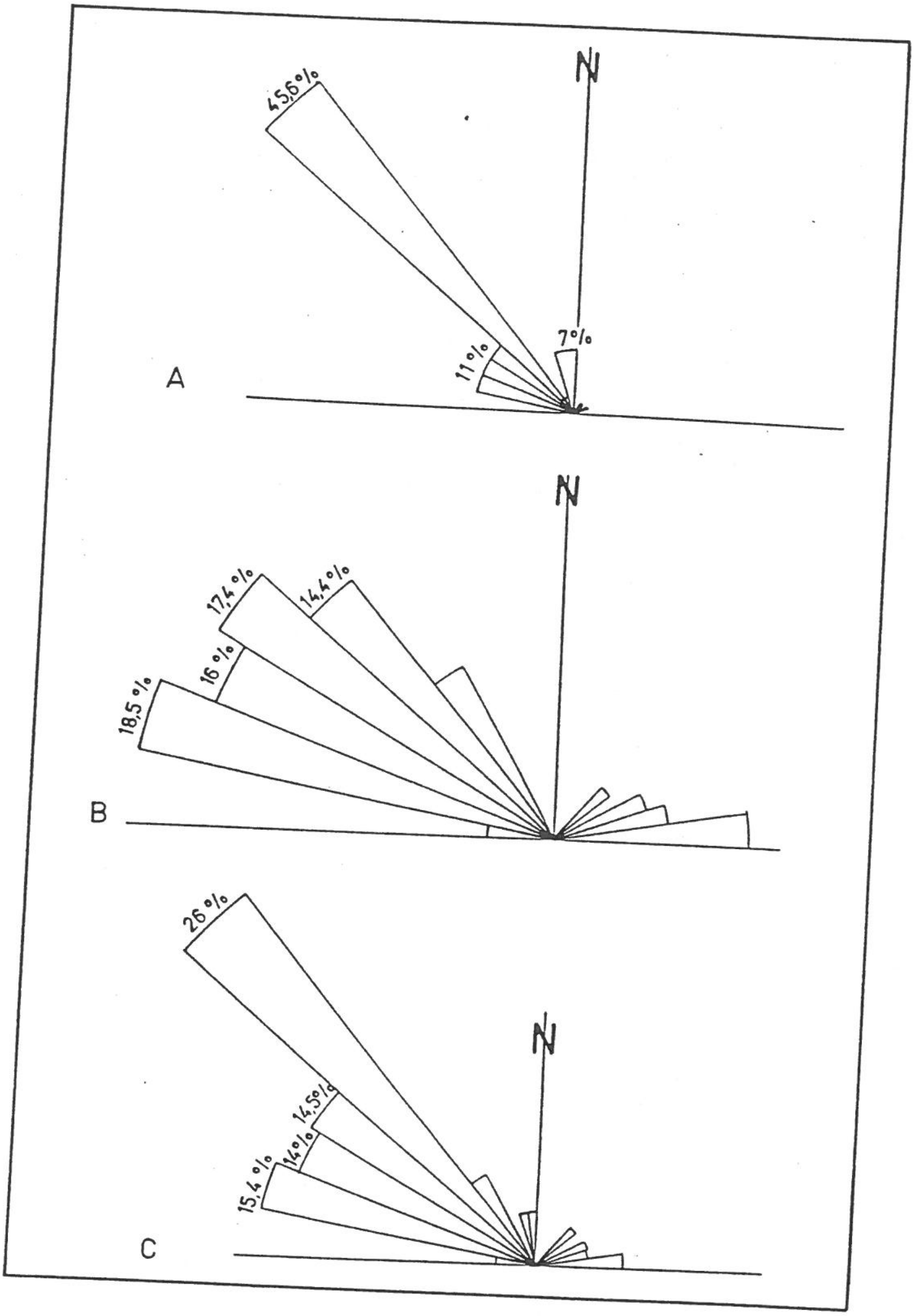


Figure 21. Rose diagrams drawn using the trends of neotectonic fault traces within the İnegöl basin. A: rose diagram for the faults developed to the west of an imaginary line from Çayyaka to Hamzabey villages, B: rose diagram for the east of this line, C: rose diagram for total area. Numbers are the persentages of each set.

approximately NE-SW oriented extension as in the Western Anatolia. However, southern boundary of the Yenişehir Basin is controlled by the strike-slip faults (Koçyiğit _et_ _al_., 1991) so, the approximate boundary of the strike-slip and tensional tectonic regimes (Koçyiğit, 1989) should be in somewhee between southern margin of the Yenişehir Basin and northern margin of the İnegöl basin.

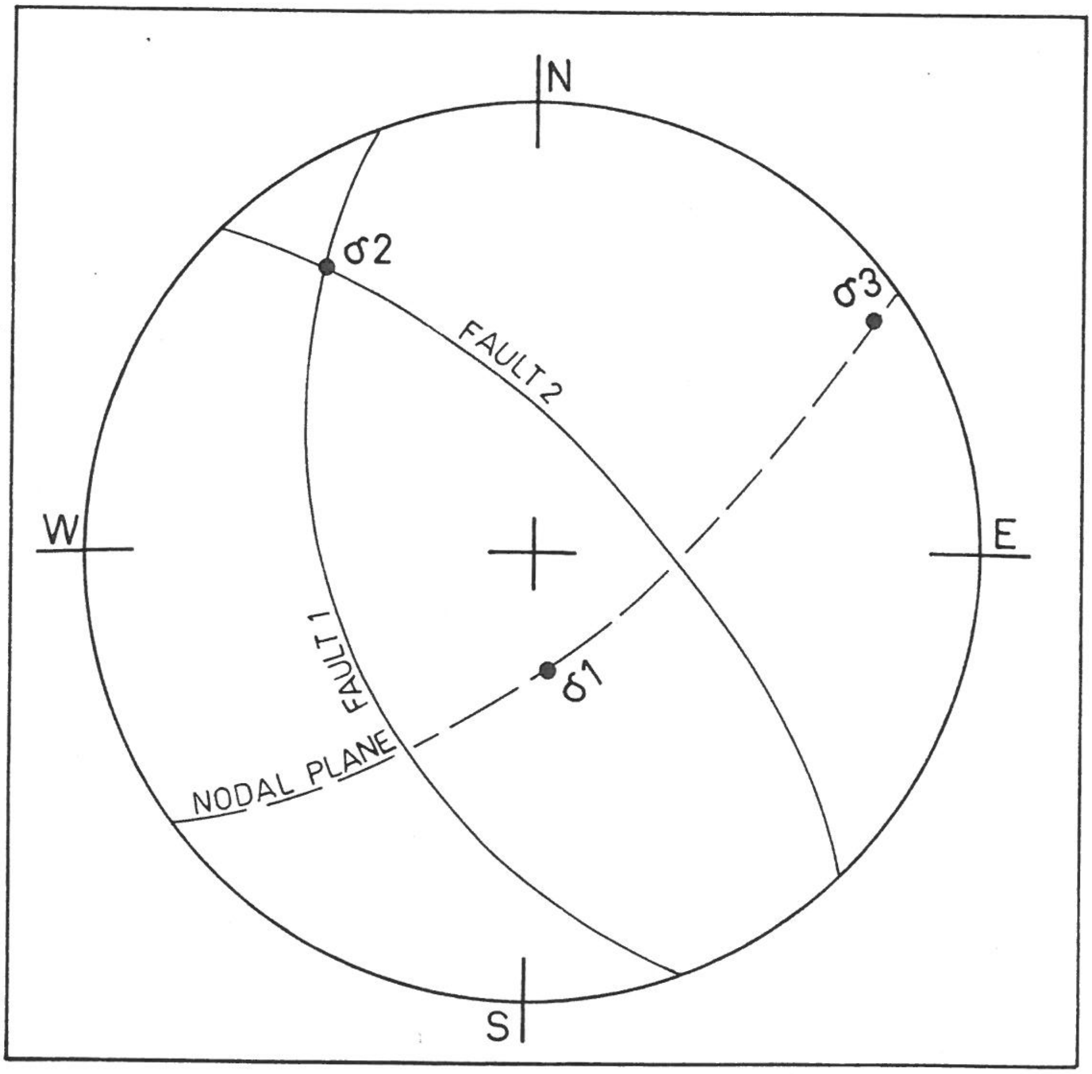


Figure 22. Stereographic projection of the mean trends of the neotectonic faults observed in the İnegöl basin and the orientation of principal stresses responsible for the development of these faults (Lambert equal area net, lower hemisphere projection).

3.1.2. Paleotectonic Faults

In the study area, the paleotectonic faults are generally compressional in character, and they occur in

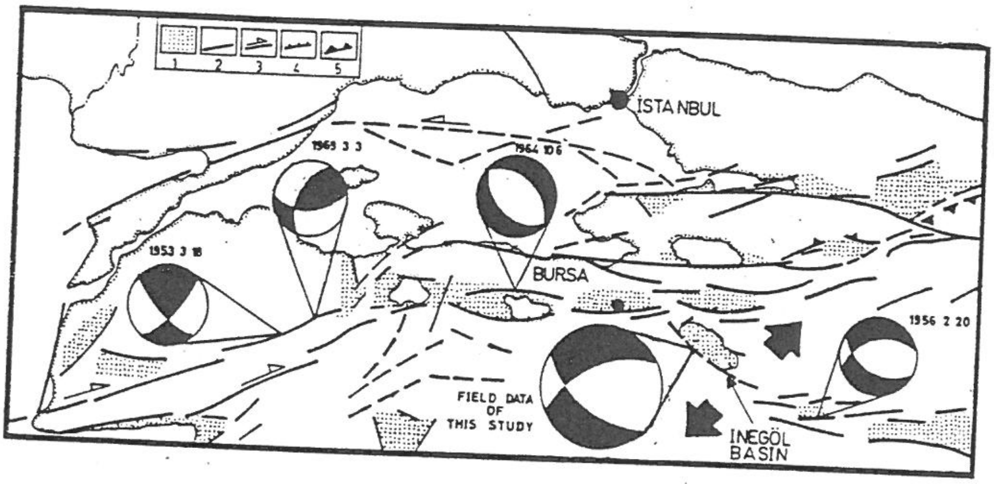


Figure 23. Simplified neotectonic map of northwestern Anatolia and fault plane solutions of some earthquakes occurred within the region. 1: basin, 2: oblique-slip normal fault, 3: strike-slip fault, 4: normal fault, 5: reverse fault. Black arrows show the direction of extension. (Compiled from Mc Kenzie, 1978; Şengör et al., 1985; Koçyiğit, 1988; Barka and Kidd, 1988; Koçyiğit and Rojay, 1988).

reverse or thrust faults. They are namely the Kozluören thrust faults, 2) Şehitler thrust fault, 3) Altıntaş reverse fault, and 4) Aysini thrust fault.

3.1.2.1. Kozluören Thrust Faults (KTF)

The Kozluören thrust faults are observed around northeast of Kozluören village at the northwestern corner of the study area (Plate 1). The KTF occur in a northward-dipping broad imbricate fan in which the pre-Permian Pazarcık Complex thrusts onto the Lower-Middle Liassic Bayırköy Formation and the Callovian to Valanginian Bilecik group. Within the same structure, the Bayırköy Formation and the Bilecik group thrusted over the Eocene Gemlik group from north to south. Due to the thrusting, more than 200 meter wide imbricate and shear zone was created (Figure 24).

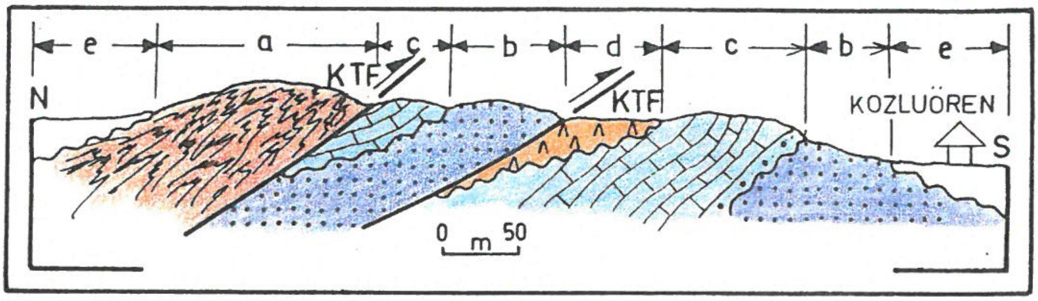


Figure 24. Sketch geological cross-section showing the Kozluören thrust faults. a: Pazarcık Complex, b: Bayırköy Formation, c: Bilecik group, d: Gemlik group, and e: alluvium.

Repetation of the units, dipping of younger unit beneath the older ones, and the development of imbricate zone are the main indicators for the presence of the Kozluören thrust faults. According to the field data, the age of thrusting is younger than Eocene.

3.1.2.2. Şehitler Thrust Fault (ŞTF)

The Şehitler thrust fault is observed to the NW of Şehitler village (Plate 1). Along the ŞTF, the Triassic Karakaya group thrusts onto the Upper Cretaceous Üzümlü formation of the Kabalar group (Altıner et al. 1989) from north to south (Figure 25).

Dipping of Üzümlü formation beneath the Triassic Karakaya group and the well-developed drag folds near fault plane are the field evidences of the ŞTF. The age of the thrusting seems to be post Cretaceous but pre-Miocene.

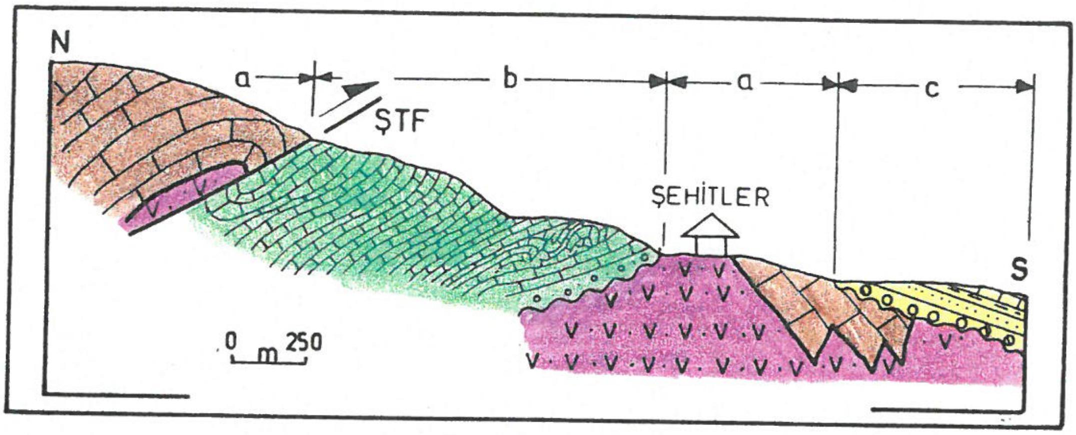


Figure 25. Sketch geological cross-section showing Şehitler thrust fault (ŞTF). a) Karakaya group, b) Kabalar group, c) Sarıpınar formation.

3.1.2.3. Altıntaş Reverse Fault (ARF)

The Altıntaş reverse fault is observed to the northwest of Hamzabey village. Along the ARF the Triassic Karakaya group over rides, from north to south, the rocks of Callovian to Valanginian Bilecik group. The fault has considerable amount of right-lateral slip component. The age of faulting is not clear.

The dipping of the younger Bilecik group beneath the older Karakaya group, well-developed fault scarps and the well preserved mechanical surfaces are the field evidences for the presence of the ARF.

3.1.3.4. Aysini Thrust Fault (ATF)

The Aysini thrust fault is observed in approximately 1.5 kilometers east of Akbaşlar village. It strikes in the NE-SW direction. Along the ATF the rocks of the Triassic

Karakaya group thrusts onto the Upper Cretaceous Üzümlü fomation from north to south. (Figure 26).

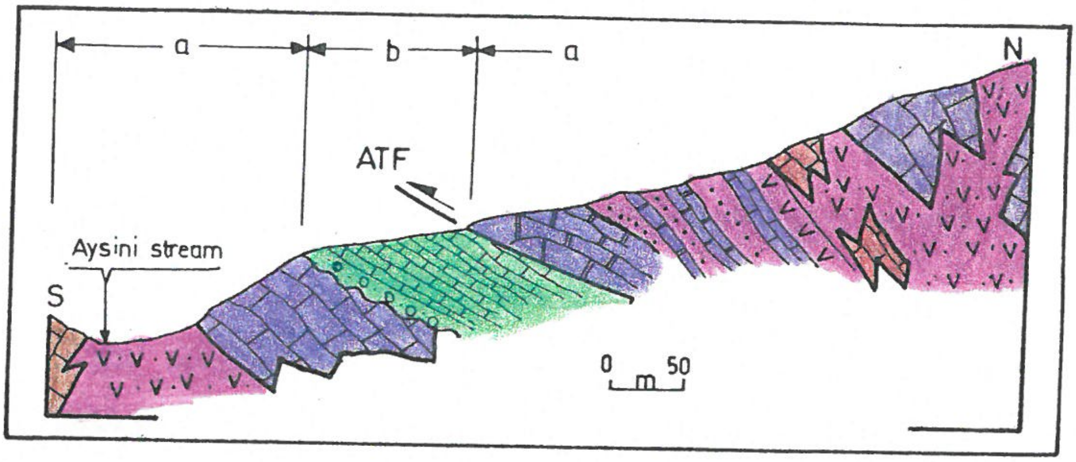


Figure 26. Sketch geological cross-section showing the Aysini thrust fault. a: Karakaya group, b: Kabalar group.

Dipping of the younger Üzümlü formation below the older Karakaya group is the evidence for the presence of the ATF.

3.2. Folds

The folds observed in the study area are confined to three rock units of dissimilar age. So, they have at least three different origins: (1) the first group of folds are observed within the pre-Permian Pazarcık complex (2) the second group of folds are observed within the Upper Cretaceous Üzümlü formation, and (3) the third group of folds are observed within the Middle to Upper Miocene İnegöl group.

The first group of folds seen within the pre-Permian Pazarcık complex range in size from microscopic scales to mappable regional scale. They are generally two types 1) cylindrical and (2) noncylindrical. The cylindrical folds are generally asymmetric in shape and plunging. Mesoscopic scale ones are generally overturned in the direction of main tectonic transport. The wavelengths and amplitudes of them are variable. However, the ratio of wavelength versus amplitude (strain ratio) is as high as Rs=4.

The noncylindrical folds of the Pazarcık Complex are generally angular like chevron and box folds.

The second group of folds observed within the Üzümlü formation are cylidrical in the shape and originally overturned slump folds.

The youngest third group of folds occured in the İnegöl group are much more wide spread than the first two groups of folds. They are also cylindrical, generally asymmetric in the shape, and plunging folds. Along the folds no thickness variation was observed. Therefore, Busk (1929) method of reconstruction was applied to draw the cross-sections and from which the strain ratios were calculated. The strain ratios are between Rs=1,2-1,9. This much of strain ratio implies intense deformation of the İnegöl group. Thus, the İnegöl group must have undergone to an intense episods of the Alpine Orogeny at the time of Middle-Late Miocene.

Within the İnegöl group, a number of slump folds are also observed. They are asymmetric, in the shape and distrupted pattern (Figure 27).

3.3. Bedding

Bedding is not well-developed within the Çayyaka formation, whereas, it is well-developed within the

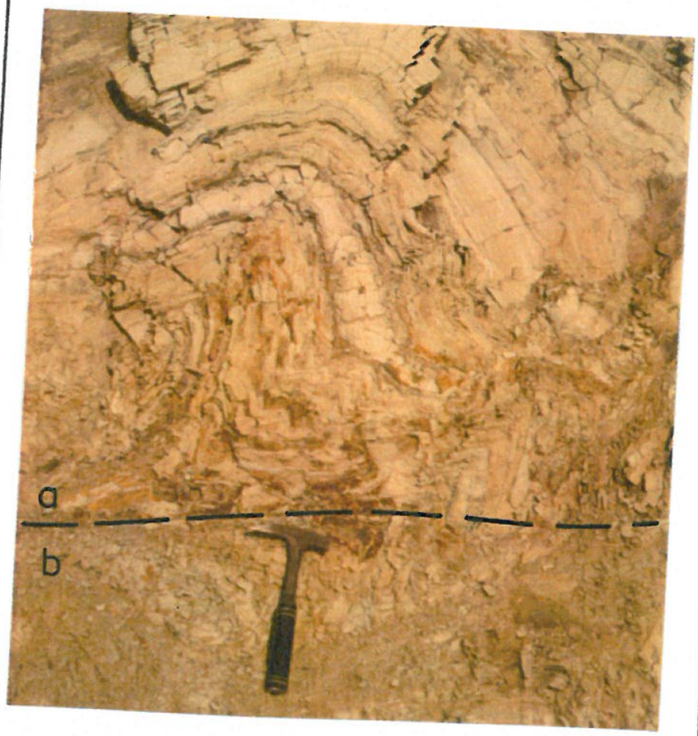


Figure 27. Close-up view of a disrupted slump fold. a: intensely folded strata; b: dismembered base (2 kilometers north of Gülbahçe village, view to west).

Gülbahçe and Sarıpınar formations of the İnegöl group. In general, the thickness of the bedding decreases toward top of the group, starting from the Çayyaka formation, upto the Sarıpınar formation.

In order to determine the general trend(s) of the bedding of the İnegöl group, a rose diagram (Figure 28) based on the trends, and a contour diagram (Figure 29) based on both dip and strikes of the beds have been prepared. These diagrams suggest that: (1) in general, the beds strike NW-SE which is also parallel to the axial trend of the İnegöl basin, and (2) the bed attitudes of the İnegöl basin, as a whole, defines a broad gently plunging asymmetric cylinderical fold (synclinorium) whose attitude is (Ò) N50°W, 10°NW.

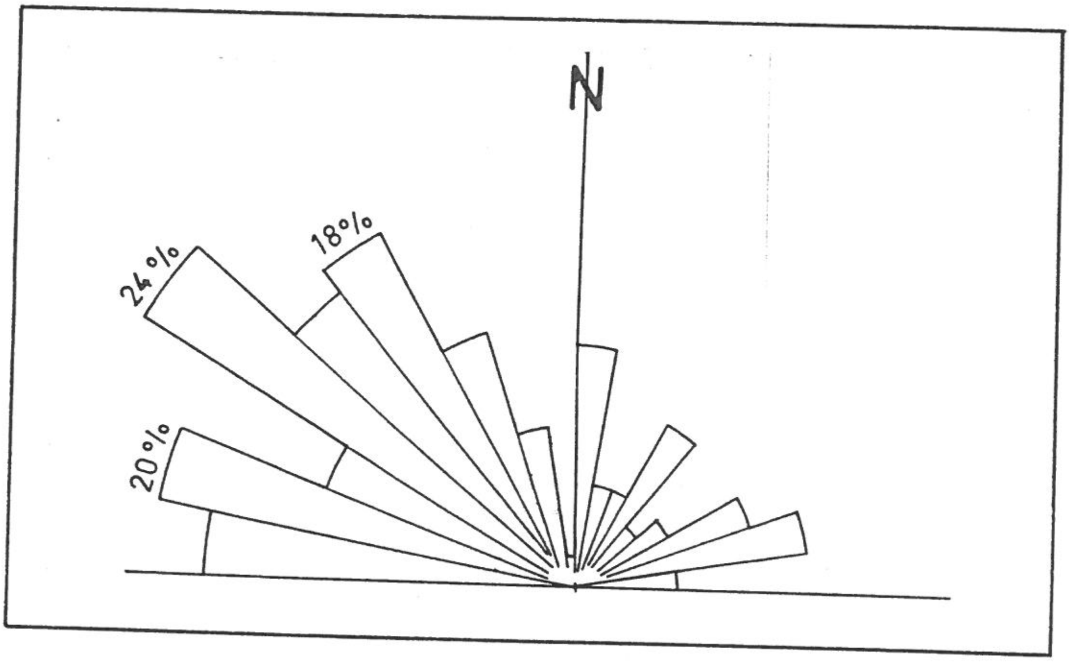


Figure 28. Rose diagram drawn from the strikes of beds of the İnegöl group. Numbers are the percentages of each set.

3.4. Unconformities

In the study area four unconformities are well observed. The oldest of them is observed northeast of Kozluören village. It is a nonconformity where a well-marked erosional surface separates the underlying pre-Permian Pazarcık complex from the overlying Lower to Middle Liassic Bayırköy Formation. At the same locality two more unconformities were observed. One of them is sited between the Lower to Middle Liassic Bayırköy Formation and Callovian to Valanginian Bilecik group; the second one is between the Eocene Gemlik group and underlying Middle Liassic Bayırköy Formation and the Callovian to Valanginian Bilecik group.

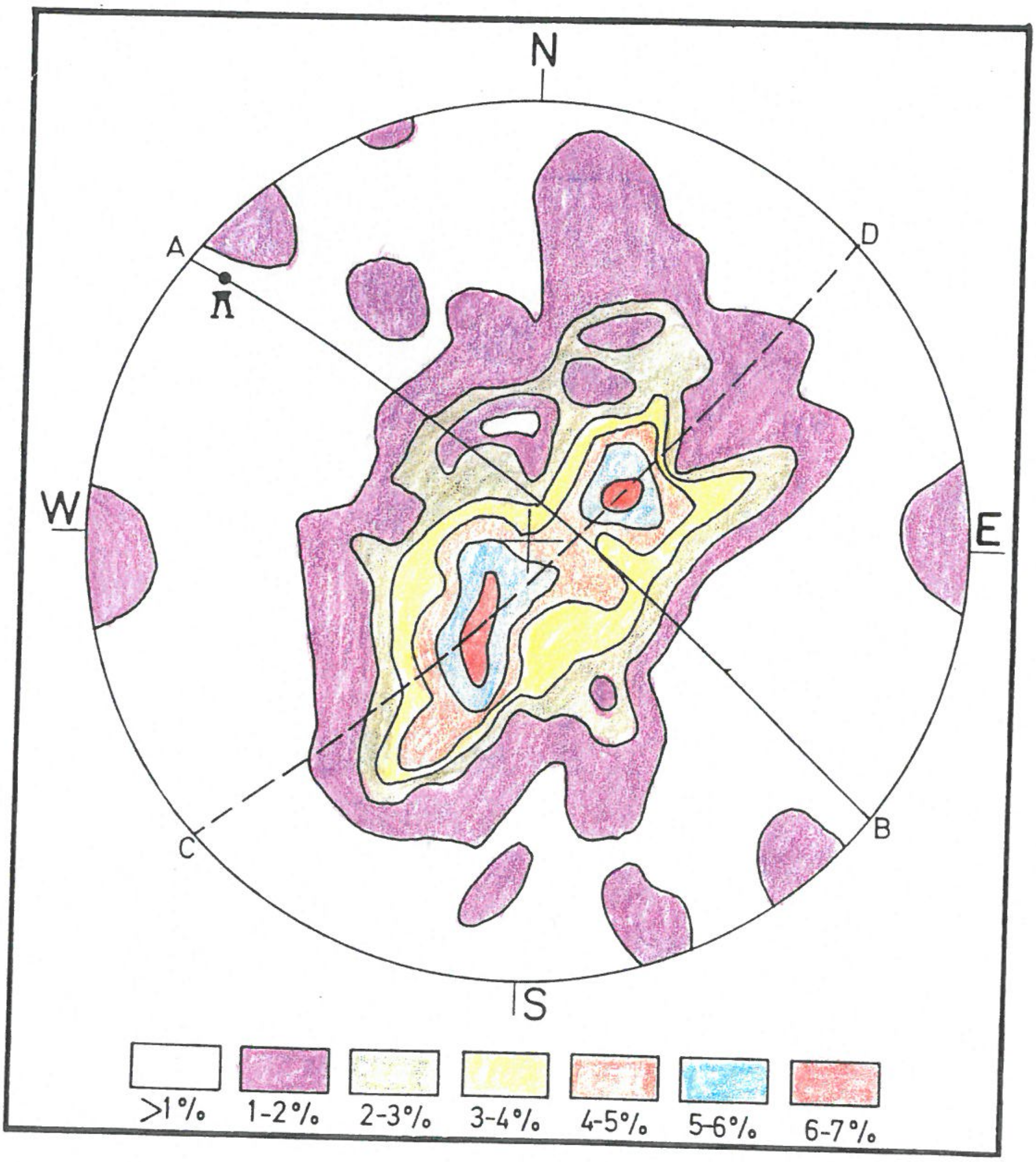


Figure 29. Contour diagram of the bed attitudes of the İnegöl group. AB arc is the fold axial plane, CD arc is the ò plane.

The time gaps, outstanding red coloration, fold pattern, and base conglomerates composed of the pebbles derived from the underlying units are the conclusive field evidences of these unconformities.

Other unconformities are sited between the overlying Middle to Upper Miocene İnegöl group and the underlying various basement rocks of dissimilar origin and facies, e.g., near west of Kıran village, the pre-Permian Kıran complex is overlain nonconformably by the fluvial

Figure 30. Close-up view of the boundary relationships of the İnegöl group and the Pazarcık complex. Pp: Pazarcık complex; Ti: İnegöl group (Yiğit village, view to west)

conglomerates of the Çayyaka formation, while the basal conglomerates of the İnegöl group rests nonconformably on the metamorphics of the pre-Permian Pazarcık complex around Yiğit village at the northeastern margin of the İnegöl basin (Figure 30). In addition, the Mahmudiye mafics-ultrafics arond Çiftlikköy, the Kocadere marble south of Çayyaka village, the Triassic Karakaya group in the area between Kozluca and Hamzabey villages, and the Eocene Gemlik group, in the northeast of Kozluören village are also overlain unconformably by the basal conglomerates of the İnegöl group.

The youngest unconformity is observed between overlying alluvial sediments and the basement rocks.

3.5. Joints

Two types of joints are observed within the study area. (1) the joints developed in a direction perpendicular to the bedding or foliation planes, and 2) the joints develped obliquely to the bedding or foliation planes. In this study only joints of the İnegöl group have been studied, because, the fine study of the basement rocks is outside the aim of this study.

The joints developed within te İnegöl group are generally widely spaced, irregular, and generally open, tensional joints. Walls of the joints are mostly smooth. Common filling material in veins is calcite.

The rose diagram of the joints measured in the İnegöl group (Figure 31) shows that they have irregular distribution pattern; i.e., there are more than one dominant trends. These are N50°-60°W, N80°-90°W, N0°-10°E, N30°-40°E respectively.

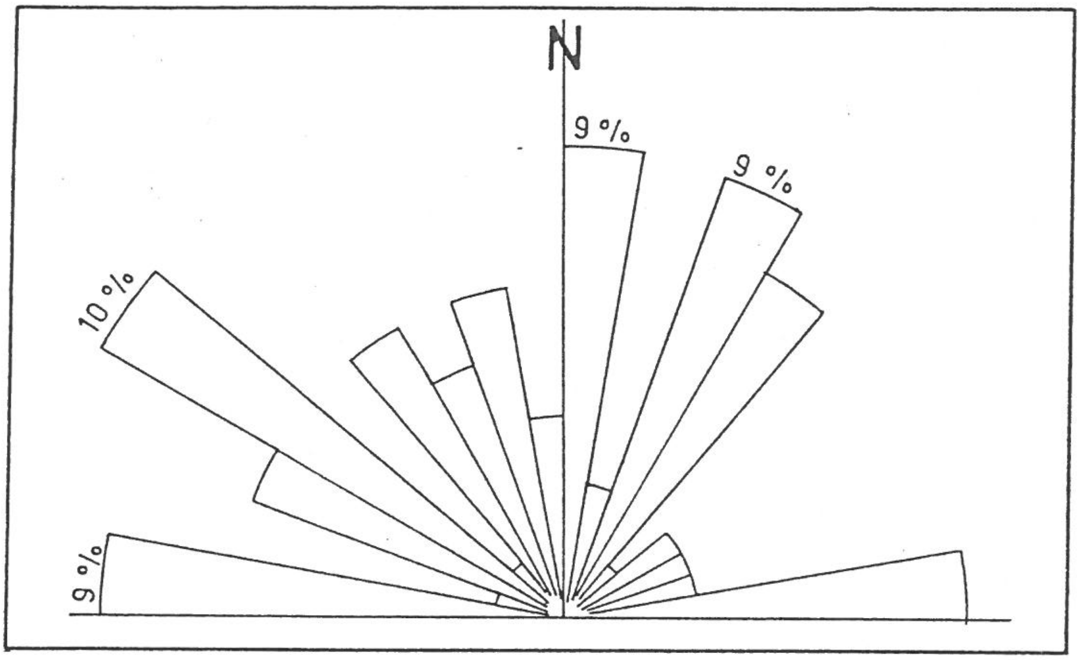


Figure 31. Rose diagram drawn from the strikes of joints of the İnegöl group. Numbers show the percentages of each set.

4. IGNEOUS ROCKS

One of the widespread acidic plutons of western Anatolia is well-exposed at the southern margin of the İnegöl basin in the study area. It was previously named as the Tahtaköprü granodiorite by Koçyiğit et al. (1991).

4.1. Tahtaköprü Granodiorite

The type locality of this pluton is Tahtaköprü town sited southeast of the İnegöl basin. Compositionally, it is gray-pinkish granodiorite.

Along its contacts the Tahtaköprü Granodiorite is always intensely altered, sheared, and foliated. However, towards the interiors of its outcrops, it becomes fresh and nonfoliated.

In terms of the microscopic studies, following minerals in thin sections of the Tahtaköprü granodiorite are identified: the felsic minerals are quartz, plagioclase and orthoclase. Mafic minerals are biotite and hornblende. Apathite and sphene are the common accessories. Seritization and kaolinitization are common within the feldspars. In addition, chloritization of mafic minerals are also common. In some samples graphic texture was observed.

According to previous works the Tahtaköprü granodiorite is Eocene in age (Ataman, 1973).

5. EVOLUTION OF THE BASIN

The İnegöl basin is an approximately rhomb shaped depression whose long axis is oriented in NW-SE direction. It displays step-like morphology that steps down from south to north. At the southern margin it is bounded by a number of parallel to subparallel oblique-slip normal faults those trending generally in NW-SE direction. Therefore, the southern margin of the basin is well-defined, less degraded, and steeper(12°) than the degraded, not well-defined, and gentler northern margin(4°). The lowest point of the basin is around İnegöl county and its elevation is about 250 meters above from the mean sea level. Elevation difference between surrounding mountain peaks reaches up to 2.2 kilometers. The highest peak around the region is Mt. Uludağ. It has peak elevation of about 2450 meters. The drainage display trellis pattern and the main draining agents of the basin emenates from the southern margin and flow down to northwards.

As earlier stated, the axes of folds developed within the İnegöl group are generally parallel to both the traces of faults and the axis of the basin. They are cut by these younger tensional faults in places. Besides, the İnegöl group is intensely deformed and folded. At the southeastern corner of the study area the Sulhiye reverse fault also cuts the İnegöl group but its displacement is limited to the thickness of the Çayyaka formation. All these information suggest that the İnegöl group was deposited in an intermontane basin, or a syncline by a high energy fluvial system under the control of a compressional tectonic regime (Figure 32a). Due to the tectonic activity prevailed at the southern margin, only the southeastern side of the basin was shaped by the thrusting (Figure 32b). A reverse fault cuts across the lowermost unit of the İnegöl group. This conforms that these compressional conditions might have continued up to the begining Pliocene. Then, the regime changed and the compressional conditions were replaced by a tensional tectonic regime. Finally, the study area began to experience the same tectonic regime with western Anatolia. This transition must be the initiation of the Neotectonic regime in the study area. Later on, some new oblique-slip normal faults formed, while some of the compressional structures inherited from the earlier tectonic regime were continuing their activity in a new nature during the neotectonic period (Figure 32c). During this period, the alluvial fan conglomerates exposing at the northwestern corner of the study area were accumulated. At the latest stage, the Akıncılar-Cerrah fault set, the İsaören-Hacıkara-Tahtaöprü fault set, and the Kınık-Özlüce fault set alltogether gained their maximum throw. Thus, the Plio-Quaternary configuration of the İnegöl basin appeared completely and was seperated from its pre-Pliocene configuration by an intervening and WNW-ESE trending horst structure shaped by the newly formed step-like normal faults. During Quaternary, the Middle-Late Miocene configuration of the İnegöl basin becomes the site of erosion, while the Quaternary alluvial sedimentation is continuing in its new configuration. In addition, no deformation has been observed within the Late Quaternary sediments. Therefore, the Quaternary activity of faults within the İnegöl basin is uncertain. Whereas, in the nearby regions, such as the Yenişehir, Geyve, Bursa, and İznik basins, the seismic activity is still going on (Mc Kenzie, 1978) (Figure 23), so the study area, the İnegöl basin, may be in a tectonically quite period.

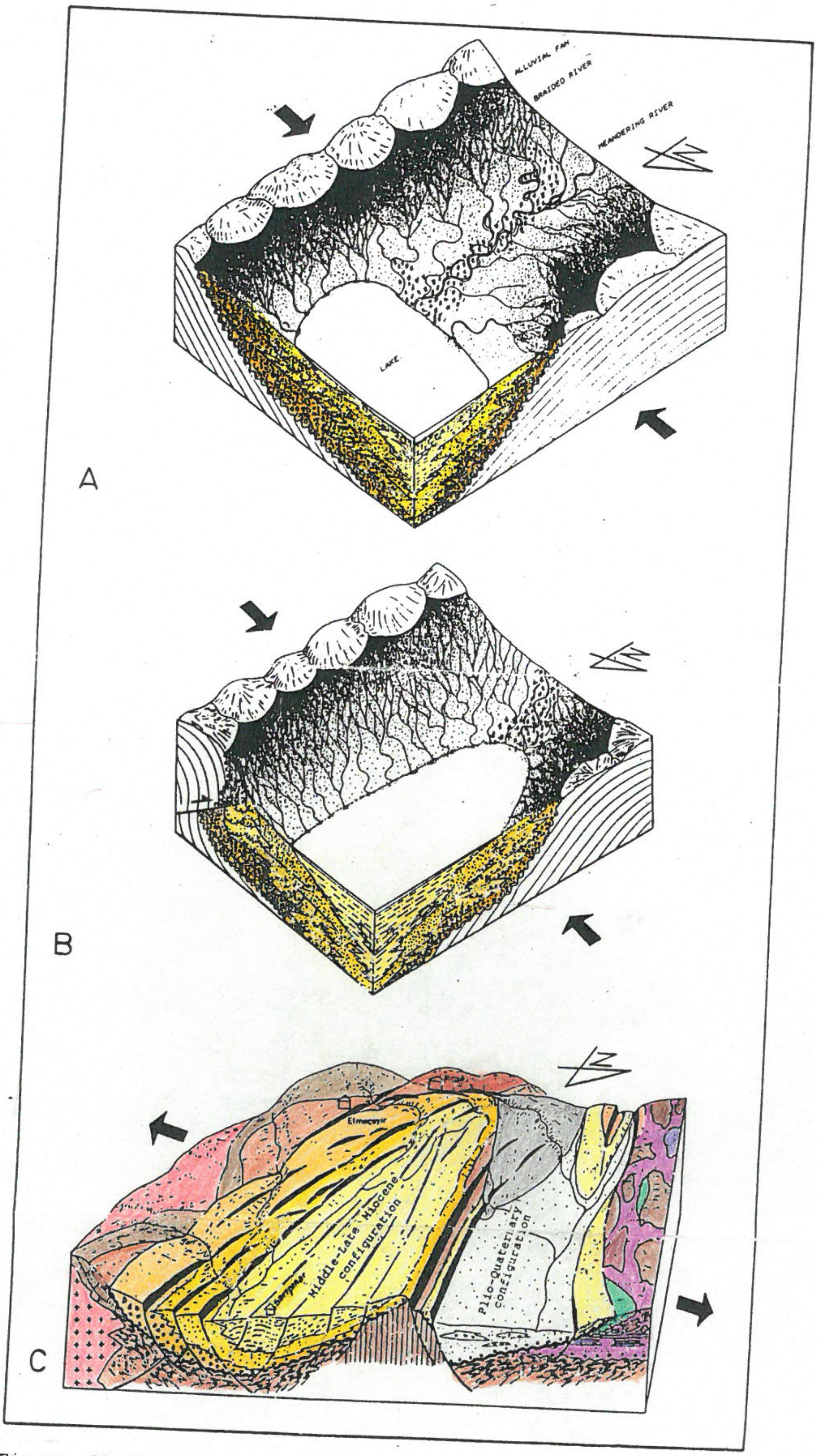


Figure 32. Tentative models explaining the evolution of the İnegöl basin. Arrows show the directions of the active principal stresses. (See the text for further explanations).

6. CONCLUSIONS

By this study following conclusions are deduced:

1) The İnegöl group is divided into three rockstratigraphic units, namely the Çayyaka, Gülbahçe, and Sarıpınar formations. The Çayyaka formation is composed of alluvial fan-braided river conglomerate, the Gülbahçe formation consists of meandering river-shallow lacustrine deposits, the Sarıpınar formation consists of shallow to deep lacustrine associations.

2) The thickness and grain size of the İnegöl group decrease toward northeast which indicates that the İnegöl group was deposited in an assymmetric basin with the southwestern active margin at the time of sedimentation.

3) In general, the sediments constituting the İnegöl group was transported from south to north.

4) The mezoscopic faults observed within the Inegöl group are also related to tectono-sedimentary processes.

5) The NW-SE trending reverse faults and folds observed within the Inegöl group are the record of a NE-SW directed compressional tectonic regime.

6) The NW-SE trending normal faults cutting also the Plio-Quaternary units are the indication of a NE-SW directed extension.

7) The study area has undergone two types of tectonic regimes, namely the earlier NE-SW directed compressional,

and then NE-SW directed tensional regimes; the earlier one was superimposed by the new latter tensional regime which is still prevailing.

8) The faults observed within the İnegöl basin are oblique-slip normal faults.

9) The İnegöl Basin was shifted toward north at least during Quaternary. Thus, the uplifted southern half of the basin become a site of erosion, while sedimentation is still taking place at only its northern half.

10) The southwestern margin of the Plio-quaternary configuration of the İnegöl Basin is well-defined and it has a minimum throw of 275 meters. However, the throw of northeastern margin is almost zero. This is also another indication of the asymmetrical evolution of the İnegöl basin.

11) Plio-Quaternary configuration of the Inegöl Basin is NW-SE trending asymmetric half graben.

12) Fault plane solution obtained from field data is compatible with those of some earthquakes occured in nearby regions.

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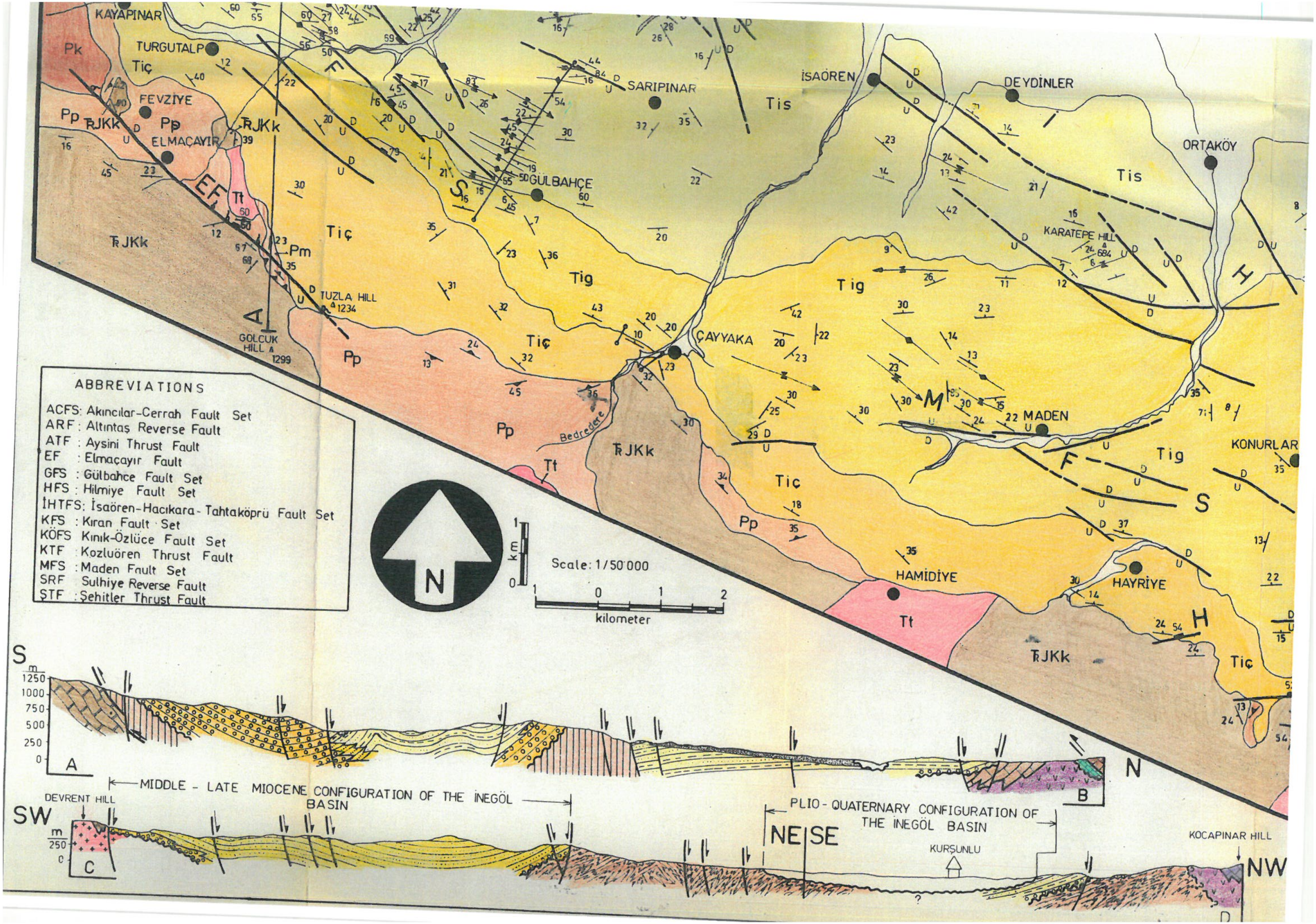
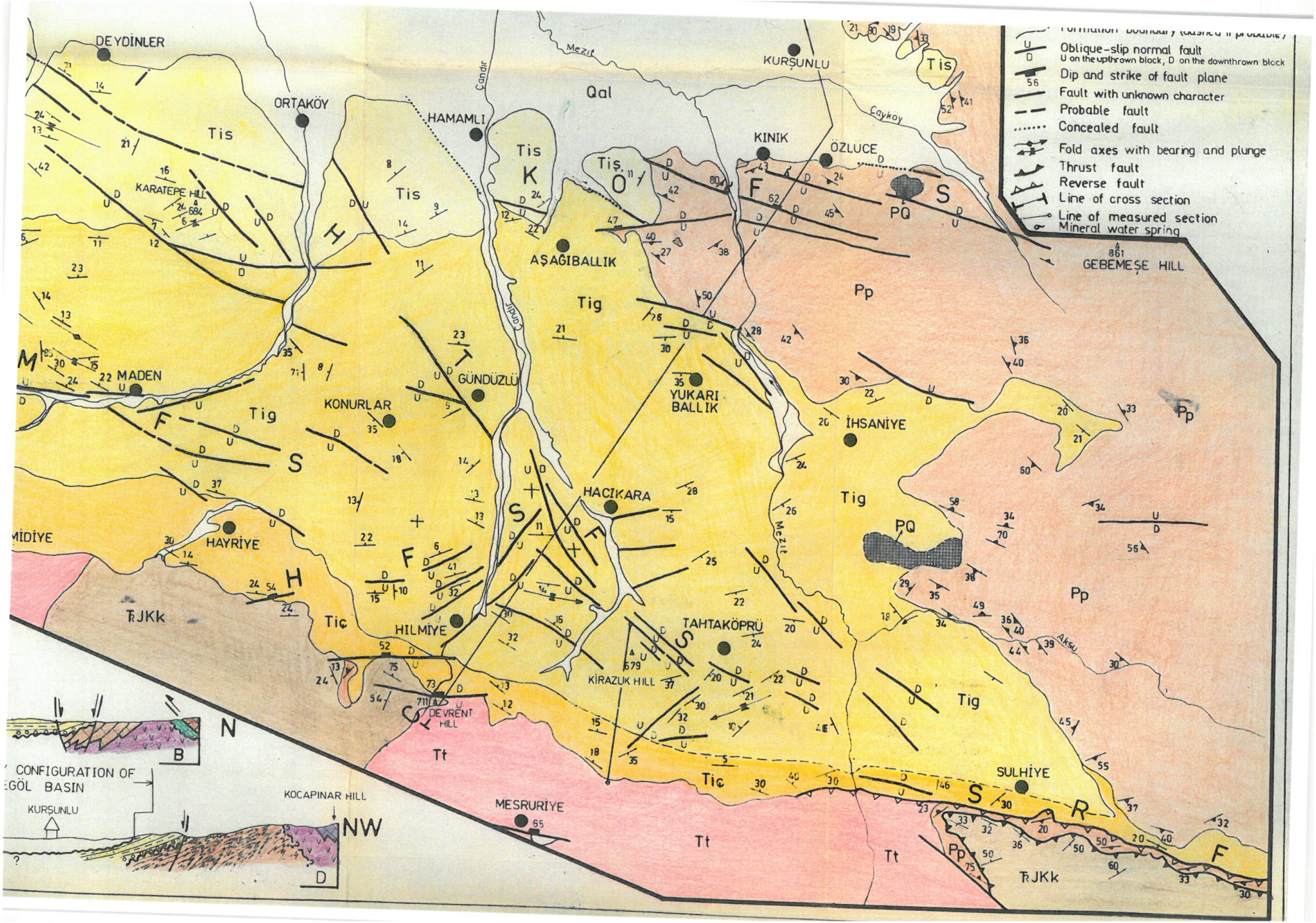


ABBREVIATIONS
ACFS: Akıncılar-Cerrah Fault Set
ARF: Altıntaş Reverse Fault
ATF: Aysini Thrust Fault
EF: Elmaçayır Fault
GFS: Gülbahce Fault Set
HFS: Hilmiye Fault Set
İHTFS: İsaören-Hacıkara-Tahtaköprü Fault Set
KFS: Kıran Fault Set
KÖFS: Kınık-Özlüce Fault Set
KTF: Kozluören Thrust Fault
MFS: Maden Fault Set
SRF: Sulhiye Reverse Fault
ŞTF: Şehitler Thrust Fault
Scale: 1/50 000
kilometer
N
KAYAPINAR
TURGUTALP
FEVZİYE
ELMAÇAYIR
GÜLBAHÇE
SARIPINAR
İSAÖREN
DEYDİNLER
ORTAKÖY
KARATEPE HILL
ÇAYYAKA
MADEN
KONURLAR
HAMİDİYE
HAYRİYE
TUZLA HILL 1234
GOLCUK HILL 1299
Bedredere
MIDDLE - LATE MIOCENE CONFIGURATION OF THE İNEGÖL BASIN
PLIO-QUATERNARY CONFIGURATION OF THE İNEGÖL BASIN
DEVRENT HILL
KURŞUNLU
KOCAPINAR HILL
S
N
SW
NW
NE
SE


Oblique-slip normal fault
U on the upthrown block, D on the downthrown block
Dip and strike of fault plane
Fault with unknown character
Probable fault
Concealed fault
Fold axes with bearing and plunge
Thrust fault
Reverse fault
Line of cross section
Line of measured section
Mineral water spring
DEYDİNLER
ORTAKÖY
HAMAMLI
KURŞUNLU
KINIK
ÖZLUCE
GEBEMEŞE HILL
KARATEPE HILL
MADEN
KONURLAR
GÜNDÜZLÜ
AŞAĞIBALLIK
YUKARI BALLIK
İHSANİYE
HACIKARA
HAYRİYE
HİLMİYE
TAHTAKÖPRÜ
KİRAZLIK HILL
DEVRENT HILL
MESRURİYE
SULHİYE
Mezit
Candır
Çaykoy
Aksu
Qal
Tis
Tig
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CONFIGURATION OF
EGÖL BASIN
KURŞUNLU
KOCAPINAR HILL
NW
N
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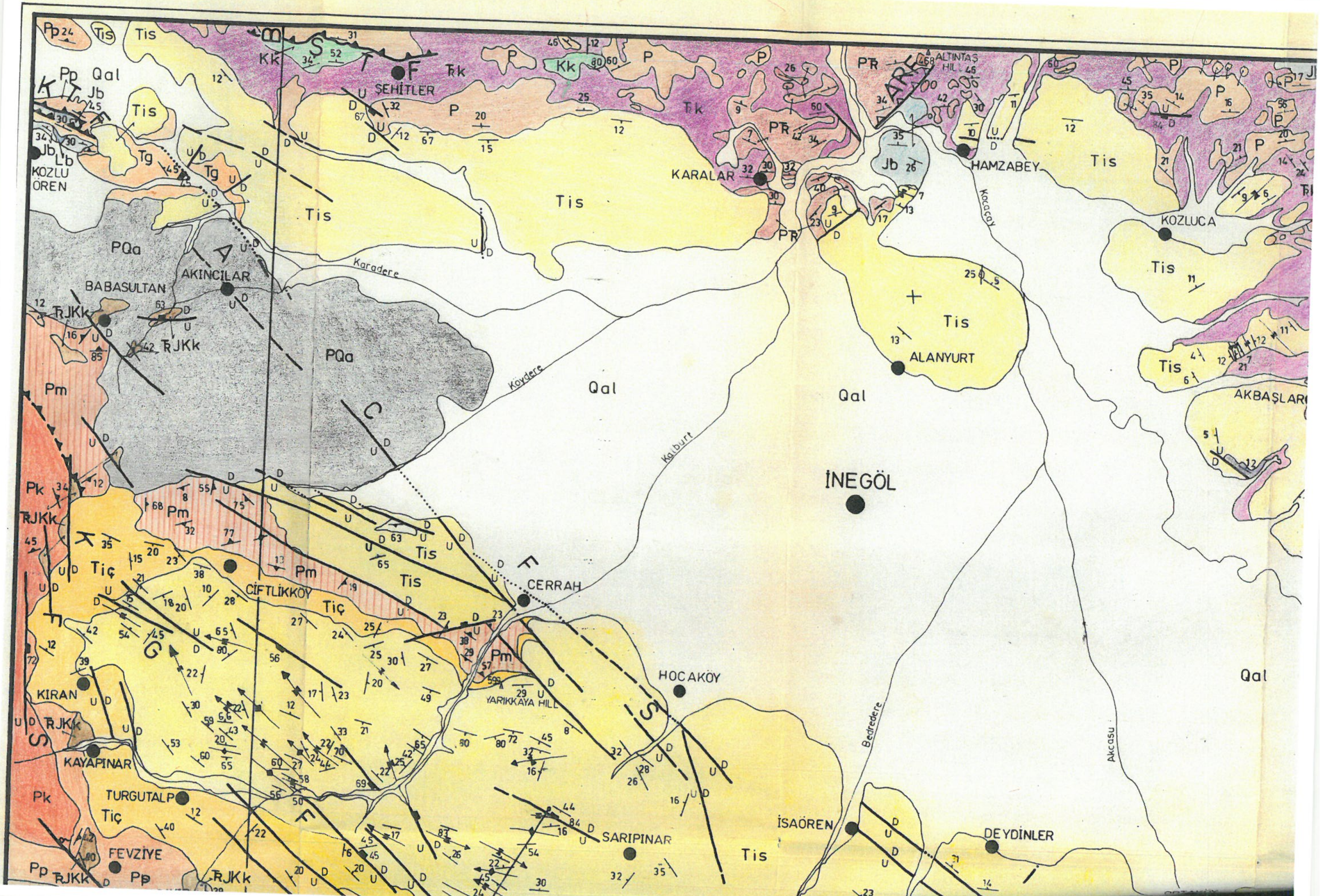
İNEGÖL
KOZLUCA
HAMZABEY
ALTINTAŞ HİLL
KARALAR
ŞEHİTLER
KOZLU ÖREN
BABASULTAN
AKINCILAR
ALANYURT
AKBAŞLAR
CERRAH
HOCAKÖY
YARIKKAYA HİLL
ÇİFTLİKKÖY
KIRAN
KAYAPINAR
TURGUTALP
FEVZİYE
SARIPINAR
İSAÖREN
DEYDİNLER
Karadere
Köydere
Kalburt
Kocaçay
Bedredere
Akcasu
Qal
Tis
Tiç
PQa
Pm
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P
PR
Tk
Kk
Jb
Lb
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PLATE I. GEOLOGICAL MAP AND SOME CROSS SECTIONS OF THE STUDY AREA