QUATERNARY GEOLOGY OF THE SOMA DISTRICT, WESTERN TURKEY

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

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ABSTRACT

The subsidence basins of the normal fault-controlled grabens of western Anatolia were filled by the Upper Tertiary-Quaternary sedimentary and volcanosedimentary deposits. In the southern margin of the Bakırçay graben, one of these subsidence basins, a Quaternary sequence exposed reaching to approximately 80 meters and it overlies the basement rocks unconformably.The Quaternary sequence, in ascending order, is composed of Lower clastic unit, Limestone unit, Upper clastic unit and recent fluvial deposits. The Lower clastic unit is dominantly represented by debris-flow conglomerate and channel-form conglomerates and cross-bedded sandstones and fine-grained sandstone/mudstones. The Limestone unit is mainly consisted of algal/oncolitic limestones. The Upper clastic unit, overlying these two units unconformably, deposited in alluvial facies. At the top of sequence, recent fluvial deposits overlie all units unconformably. The Lower clastic unit was accumulated in alluvial fan and fluvial (braided and/or meandering) enviroments. The Limestone unit deposited in paludal and very shallow fresh water lake enviroment conditions. The Upper clastic unit is probably Upper Pleistocene-present day alluvial-fan deposits and was accumulated in active southern margin of Bakırçay graben and around of Soma.

The records of small scale faulting and foldings, fan-like Upper clastic unit of the Quaternary deposits outcropped along the N 60-80 W and N 70-80 E trending fault zone between Kırkağaç and Öveçli (Soma) and nearby and data of shallow-centered earthquakes and depositional and stratigraphic features of the Quaternary units and geomorphological setting point out of this fault zone in active.

ÖZET

Batı Anadolu'nun normal fay-kontrollü graben tipi çöküntü havzaları Üst Tersiyer-Kuvaterner tortul ve volkanotortul kayaları ile doldurulmuştur. Bu çöküntü havzalarından Bakırçay grabeninin güney kenarında yaklaşık 80 metre kalınlığa ulaşan Kuvaterner istifi yüzlek verir ve Neojen ve Neojen-öncesi temel kayalarını uyumsuz olarak örter. Kuvaterner istifi alttan üste dört birimden oluşur; Alt kırıntılı birim, Kireçtaşı birimi, Üst kırıntılı birim ve Akarsu çökelleri. Alt kırıntılı birim egemen olarak döküntü-akması çakıltaşı ve kanal-şekilli çakıltaşları ve çapraz katmanlı kumtaşları ve ince-taneli kumtaşı/çamurtaşlarından oluşur. Kireçtaşı birimi başlıca algal/onkolitik kireçtaşlarından yapılıdır. Bu iki birimi uyumsuz olarak örten Üst kırıntılı birim alüvyonal fasiyeste çökelmiştir. Tüm birimleri uyumsuz olarak örten güncel Akarsu çökelleri en üstte yer alır. Alt kırıntılı birim alüvyonal yelpaze ve akarsu (örgülü ve/veya menderesli) ortamlarında biriktirilmiştir. Kireçtaşı birimi karasal ve çok sığ tatlı sulu göl ortamı koşullarında biriktirilmiştir. Üst kırıntılı birim olasılıkla Üst Pleyistosen-günümüz alüvyonal yelpaze oluşumudur ve Bakırçay grabeninin aktif olan güney kenarında ve Soma çevresinde biriktirilmiştir.

Kırkağaç ve Öveçli (Soma) arasındaki yaklaşık K 60-80 B / K 70-80 D gidişli fay zonu boyunca ve yakın çevresindeki Kuvaterner çökelleri içindeki küçük ölçekli faylanmalar ve kıvrımlanmalar, Üst kırıntılı birimin fay zonundaki yelpaze konumu, sığ odaklı deprem verileri ve fay zonundaki sedimentolojik ve jeomorfolojik özellikler bu fay zonunun aktif olduğuna işaret eder.

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CHAPTER ONE
INTRODUCTION

Western Turkey surrounded by Mediterranen, Aegean Sea and Marmara Sea, includes pre-Quaternary crystalline and volcanic rock assemblages and it is an area of intense seismic activity. Quaternary deposits of western Anatolia accumulated in the graben subsidences of Western Anatolia Graben Complex which has been developed between Miocene and present-day extensional tectonic regime of Neotectonic Period of Western Turkey (Nebert, 1978; Koçyiğit, 1984; Şengör, Görür § Şaroğlu, 1985; Stewart § Hancock, 1988; Barka, 1996). These Quaternary deposits extend paralelly to the graben elongation and they are terrestrial-originated. These terrestrial Quaternary deposits change westward to Quaternary delta deposits and marine deposits of Aegean Sea.

The thickest Quaternary deposits of western Anatolia are present in Bakırçay, Gediz, Küçük Menderes and Büyük Menderes grabens that run paralell to one another from north to south and Simav graben bounding these graben west from west (Fig. 1.1).

The yieldest agriculture fields of western Anatolia locate on these deposits which is represented by alluvial, fluvial and shallow lake sediments and paludal carbonates.

Quaternary deposits are study material, and it is well-observed in the west of Bakırçay graben and in conjuction point of Gediz graben and Bakırçay graben (Fig. 1.1).

The purpose of this study is to obtain Quaternary sequence, research the relation between this sequence and tectonics and interpreta the depositional enviroments of the Quaternary deposits.

1.1 PREVIOUS STUDIES

The Neogene sequence of the Soma district were studied in detail because of its lignite potential. But there is no detailed investigation of the Quaternary deposits in. Most of the previous studies were based on stratigraphy of the lignite-bearing Neogene and

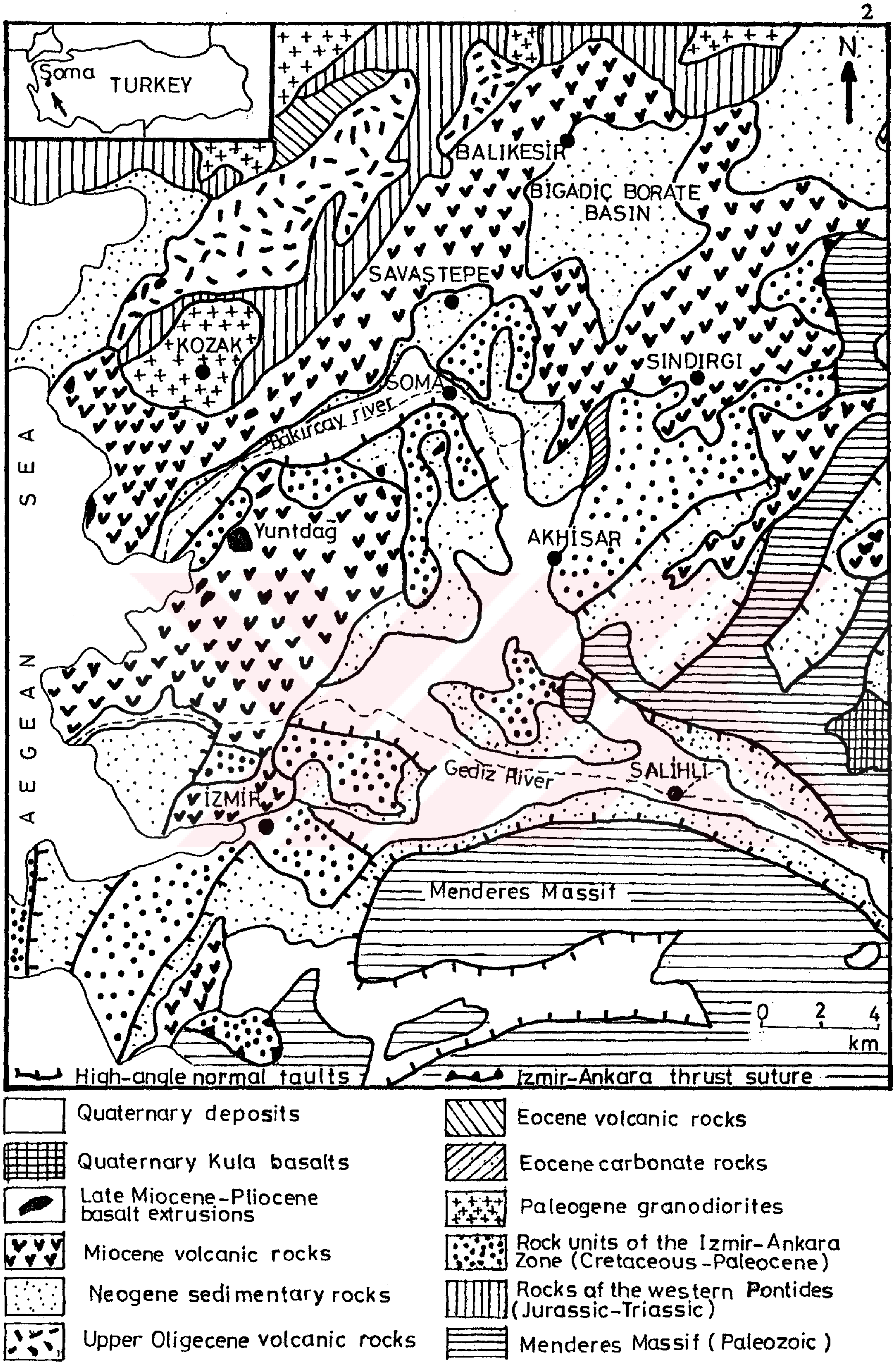


Figure 1.1 Geological Setting of the Quaternary Deposits of Western Turkey and Pre-Quaternary Basement Rock Assemblages.

pre-Neogene basement rocks.

Brinkmann, Fiest, Marr, Nickel, Schlimn § Walter (1970), emphasize that occuring of our present day relief was patterned in Pleistocene and the terraces in Tarhala and Kozanlı may be originated from this period. They pointed out that Soma Mountains had fault lines running in NE to NNE directions. In addition, they interpretad that the tectonic structure of Soma Mountains were completed in three stages and their fractured block structure were formed by Neogene-Quaternary tectogenesis.

Nebert (1978) pointed out that the Quaternary sediments around Soma were composed of a Pleistocene layer succession and Holocene alluvium. According to the author, the structural evolution and our present day tectonomorphic structure of the Soma district were developed in Pleistocene period. The author proposes three sedimentation cycles seperating with unconformities each other and, the last cycle realizied during Pleistocene period.

Akyürek § Soysal (1981) named the carbonate rocks of the Kırkağaç district as "Kırkağaç formation" and the clastic rocks as 'Kınık formation'.

Koçyiğit (1984) proposes three tectonic phases for western Turkey and adjacent areas; Paleotectonic phase, Transitional phase and Neotectonic phase. The Neotectonic phase is extensional tectonic regime-controlled and it represents terrestrial sedimentation, intracontinental volcanism and block faultings. Tha author indicated that the region was divided into several blocks with various dimensions, bounded by oblique-slip normal faults in Neotectonic phase and many of them are still seismically in active.

According to the Şengör et. al (1985), Aegean Region had more intense seismic activity than adjacent areas and Neogene-Quaternary geology presents a very complex tectonic frame. quickly. The workers claime the tectonic frames of Aegean and East Mediterranen were formed as a result of escaping Anatolian plate relative to Black Sea quickly.

Ercan, Satır, Kreuzer,Türkecan, Günay, Çevikbaş, Ateş § Can (1985) point out that Kula basalts and Denizli volcanics originates from the mantle and the other volcanics from continental crust or were the mantle product including crustal assimilation. In addition, they interpreted that the upper contenental crust thickened in Western Anatolia since Eocene time and volcanic rocks were occured by partial melting of the crust.

Akgün, Alişan § Akyol (1986) indicate that Lower and Middle lignite seams of Neogene sequence in Soma area contain Miocene flora. The palynomorph spectra of the flora assemblage indicates that the Mediterranen climate was slightly more humid and hot during the deposition of the coal-bearing formations.

According to Kazancı (1988), fault-controlled alluvial fans were deposited during Pleistocene-Holocene period in Burdur Lake Basin of the southwestern Turkey similar to the study area. The basin and near the adjacent regions are still seismically in active.

Stewart § Hancock (1988), in Corinth Bay and surrounding of Izmir in Aegean Region, point out to the an alternation of the compact breccia sheets and incohesive breccia belts in normal fault zones seperating the pre-Neogene carbonate rocks and Quaternary deposits. In this tectonic zones, there are three types of tectonic contacts representing tectonic reactivation during Quaternary period.

Mercier, Sorel § Vergely (1989) point out to the kinematics of the faults three extensional tectonic regimes in Aegean region. Tensional directions were in NE-SW and N-S direction and these were active during the Upper Miocene, Pliocene-Lower Pleistocene and Middle pleistocene-present day, respectively.

According to the Erdoğan (1990), the rock units of Izmir-Ankara Zone, presents an internal structure which is composed of Triassic-Upper Cretaceous platform type carbonate blocky rocks floating in a Upper Cretaceous-Paleocene flysch-type matrix.

Okay § Siyako (1991) divides the rock units of Izmir-Ankara Zone and Pontid belt (Sakarya Zone) in surrounding Soma-Balıkesir into and they propose a new probable plate margin trending approximately N-S.

According to the Seyitoğlu § Scott (1991), development of Neogene and Quaternary basins in west Turkey is related with crustal extension which began in Early Miocene. This extensional regime were related to escape westward of Anatolian plate because of the North Anatolian fault.

Takahashi § Jux (1991) has proposed the age of the Soma lignite-bearing sequence as Miocene in age.

Paton (1992) indicates of the geomorphologic pattern of western Turkey was predominantly controlled by active normal faults. On footwall basement rocks, drainage patterns are developed perpendicular and obliquately were cut and moved laterally by active normal faults. In these areas, large alluvial fans were formed.

Oral, Reilinger, Toksöz, Barka § Kınık (1993) note that western Turkey moves southwestward relative to Eurasian plate at a rate of approximately 50±20 mm/yr. The authors indicate that numerical models, showing the deformation of western Turkey, cannot be accounted for by only collisional processes.

Kazancı (1993) divides the sedimentary deposits into three major sequences in Suşehri Basin of North Anatoliat fault zone. The middle and upper sequences are Quaternary in age. The middle sequence is made of alluvial and fluvial deposits and Pleistocene in age. The upper sequence is consited of similar depositional rock units and Holocene-present day active fans and cones changing into recent braided river sediments in the basin.

İnci (1994) states that lignite-bearing Neogene sequence the Soma area was formed by two megasequences, which were known as 'Soma formation and Deniş formation', and the Deniş megasequence overlied the Soma megasequence by a depositional unconformity. The author indicates that these precipitation sequences were occured by fluvial/alluvial, shallow carbonate lake and lake-margin mud flat enviroments having similarity to each other.

İnci (1995) notes that Neogene rock units in the study area were formed by upward fining two cycles in Miocene and the basal cycle at the bottom deposited in alluvial, lacustrine and swamp-lake conditions. The upper cycle developed in alluvial-lacustrine depositional system was formed contemporaneously with calc-alkalen and basaltic volcanism of the Western Anatolia. According to the author, the basin is subdivided into two megasegments by extensional faults and hanging wall segment is overlain by thick Quaternary deposits.

Cohen, Dart, Akyüz § Barka (1995) point out the development of the Büyük Menderes and Gediz grabens of western Turkey during Miocene throughout recent extension in the Aegean Region. Field evidence show that extension was primarily accommodated with tilted fault-blocks 0.2-0.8 km in width, bounded by planar faults that were modified by antitethic faultings.

Barka (1996) points out that the Anatolian region was one of the most seismically active part of Alp-Himalayan system. In Western Anatolia, E-W and WNW-ESE trending rifts and the related normal faults are dominant neotectonic features and there are many limestone fault scarps with 50 m height along the normal faults.

According to the İnci (1996), lignite-bearing Deniş formation or megasequence was effected from syn-sedimentary explosive volcanism and developed volcanoclastic alluvial fans or aprons and volcanic alluvial plain deposits in the formation.

1.2 METHODS

The study area has been investigated as dividing into tnree subareas due to the well-outcropped of Quaternary deposits; Bakır subarea, Öveçli subarea and Turgutalp subarea (Fig. 1.2). An area of 100 km^2 , consist of these subareas was mapped geologically in 1/10 000 and 1/25 000 scales.

The information about the basement rocks were collected largely from previous studies. The Quaternary rocks overlaying the basement rock were studied in detail.

Quaternary sedimentary rocks have been transformed to soil cover due to their low-consolidation. Because of the plant and soil cover, it has been largely profitted from Quaternary outcrops on the road-cuts.

The textural features of the carbonate rocks were investigated in polarizan microscope.

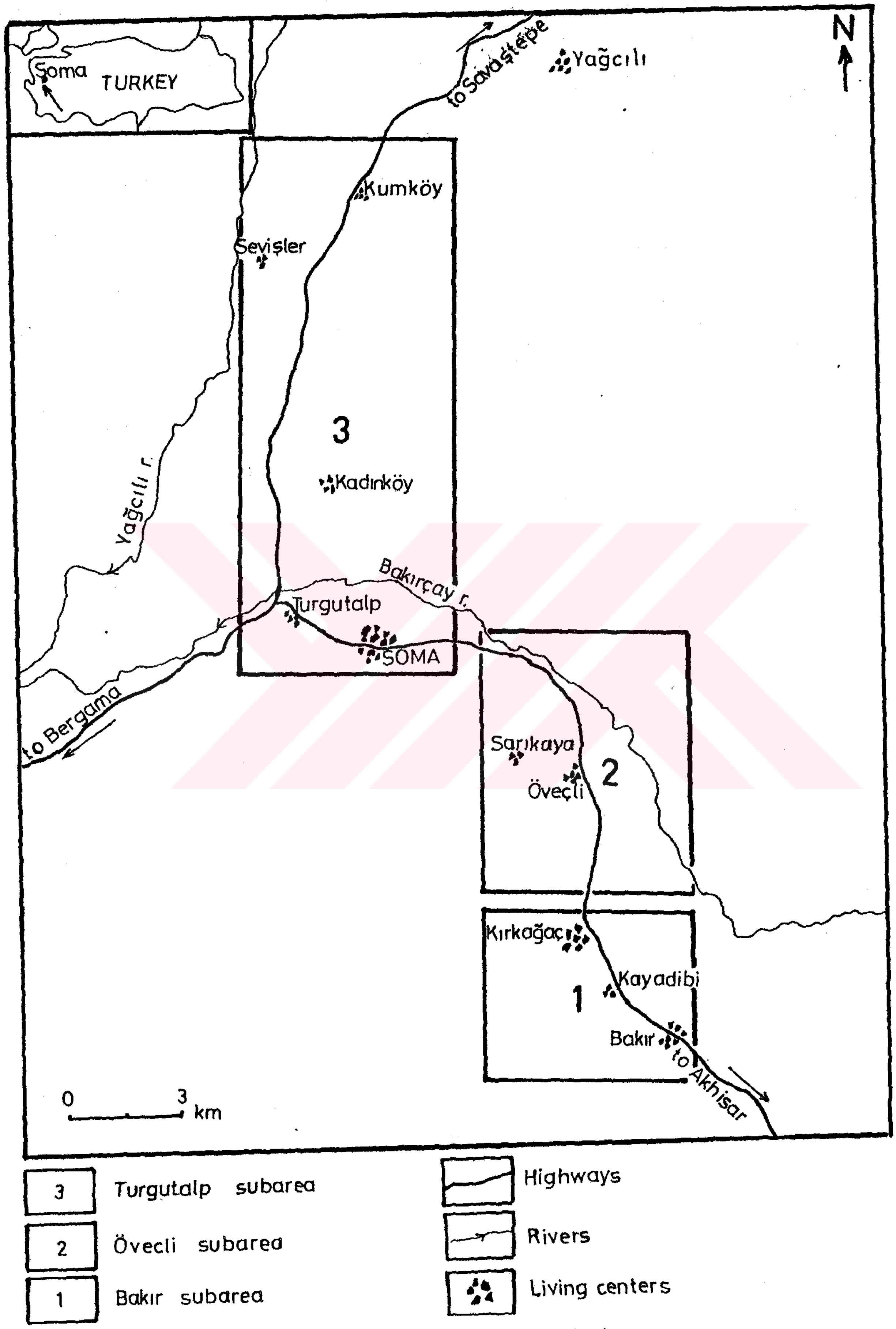


Figure 1.2 The Subareas of the Study Area.

CHAPTER TWO
GEOLOGICAL SETTING AND BASEMENT ROCKS

2.1 GEOLOGICAL SETTING

Neogene graben subsidence areas including Quaternary deposits in western Anatolia exposed on the Paleozoic Menders Massif andTriassic-Lower Tertiary rock assemblages of Izmir-Ankara Zone (Fig. 1.1).

According to the previos studies, the rock sequence of the Menderes Massif has been divided into core and cover series. The Precambrian-Cambrian core series include dominantly gneiss, core schist, migmatite, leptite-gneiss and leucocratic metagranites. The Ordovician-Paleocene cover series comprise micaschist, phyllite, metaquartzite and emery-bearing platform-type marbles. The metamorphic succession has been cut by Miocene post-metamorphic granites entirely and the core series were metamorphized at the boundary between Cambrian and Ordovisian, and both of two series effected from 'Main Menderes Metamorphism' during the Late Eocene (Dora, Candan, Koralay § Akay, 1994).

Izmir-Ankara Zone consist of Bornova melange presenting blocky internal structure. This melange is composed of a flysch matrix and blocks of platform-type carbonate rocks floating in this matrix. The age of the matrix ranges from Campanian to Danian (Erdoğan, 1990). The southern margin of Bakırçay graben including Quaternary deposits in study area is located on the rocks of Izmir-Ankara Zone, but northern margin is located on the rocks of Pontide belt. The southern margin of the graben is distinctly faulted, but the northern margin is problematical.

The Pontid rock units are represented largely by pre-Jurassic rocks of the Sakarya Zone. These rock units are made up of microgneiss, micaschist, marble and metabasics of the Kazdağ Group in ascending order. Nilüfer unit is composed of mainly metatuffs with minor phyllite and marble and overlies the Kazdağ Group with transitional contact. The Nilüfer unit is stratigraphically overlain by the Triassic Hodul unit which is made up of white, arkosic sandstones and siltstones. The Hodul unit is unconformably overlain by the

Liassic sandstones in the Balya region (Okay§Siyako,1991).

The volcanic rocks common in the northern margin of the graben. In the southern margin of the graben, Tertiary Yuntdağ volcanic complex are exposed (Ercan et al.,1985; Savaşçın, 1990). Thus, Bakırçay graben is an intramontane depositional area that is controlled by extensional tectonism and intracontinental volcanism (Fig. 1.1).

As a result, Quaternary sedimentary rocks are surrounded by the rock units of the Izmir-Ankara Zone and Pontid Range and they overly unconformably the lignite-bearing Neogene sedimentary and volcanosedimentary rock units.

2.2 BASEMENT ROCKS

2.2.1 Pre-Neogene Basement Rocks

The Quaternary sequence in the study area overlies the clastic and carbonate rocks, which were described as 'Izmir-Ankara Zone', unconformably at regional scale.

The rocks of Izmir-Ankara Zone are made up of clastic rocks containing blocky carbonates. The clastic rocks named as 'Kınık formation' by Akyürek § Soysal (1981) and described as 'grovak' by Brinkmann et al. (1970). The unit is composed of regularly or irregularly alternating of mainly reddish, brownish and greenish sandstones with brownish and blackish mudstones. Sandstones are better consolidated than mudstones. Mudstones are strongly deformed and fractured. These rocks resemble the rocks of the Izmir-Ankara Zone described as 'Bornova melange' in surrounding Izmir by Erdoğan (1990). Submarine volcanic intercalates and red-colored radiolarites and channel conglomerates are found in sandstones and mudstones.

The carbonate rocks of Izmir-Ankara Zone form a highland in the south of Soma-Kırkağaç fault zone (SKFZ) and named as 'Kırkağaç formation' by Akyürek § Soysal (1981).The limestone blocks are moderately-thick bedded, fractured and include several karstic features. These rocks were brecciated and locally stepped by active fault zone. In surrounding of Kırkağaç, the carbonate rocks display locally algal structures and stromatholitic laminations.

In south of the study area, the Mesozoic carbonate rocks display a comprehensive sequence from Triassic to Cretaceous (Brinkmann et al., 1970). Okay § Siyako (1991) point out the unconformity between neritic Jurassic limestones in flysch zone and

Senonian pelagic limestones near Gelenbe in the east of Soma.

The presence of black-colored mud shales, radiolarite-bearing silisiclastic beds and channel conglomerates in clastic rocks of pre-Neogene basement indicated that these rocks were formed in deep-marine enviroment and flysch facies. The limestone blocks from Triassic to Upper Cretaceous in age, deposited in neritic conditions according to Okay § Siyako (1991).

2.2.2 Neogene Rock Units

The Neogene sequence, which is overlain by the Quaternary deposits, contains economical lignite seams. The sequence was mapped firstly by Nebert (1978) firstly dividing it as Soma formation and Deniş formation seperated an unconformity surface.

Soma formation consists of conglomerate, sandstone, marl and limestones, and displays a fining upward sequence (Fig. 2.1).

Conglomerates and sandstones named as 'basal succession' (m1) by Nebert (1978) and deposited in alluvial facies are present at the lowermost part of the Soma formation. Sand and gravel components were mainly derived from the basement rocks belong to Izmir-Ankara Zone. Conglomerates and sandstones are transitional laterally and vertically each other. Sandstones may change to sandy or silty claystones upward sequence (Nebert,1978).

Marlstone named as 'marl succession' (m2) by Nebert (1978), is a homogeneous unit and contain abundant leaf-fossils. Lignite bed (lower lignite seam) is present at the contact between marlstone and conglomerate/sandstone. The average thickness of the lignite seam is 15 m (Fig. 2.1). The upper part of marls is transitional with green-colored claystones and contains lignite interbeds. Limestone named as ' calcer succession' (m3) by Nebert (1978), overlies the marlstone conformably. The unit contains algal laminations and shows microcrystalline sparit texture. Limestone contain bright lignite beds (middle lignite seam). The contact of limestone and marlstone is also transitional.

Deniş formation consist of volcanoclastic conglomerates, sandstones, marlstones and silicified limestone (Fig. 2.1)

The unit named as 'sand-clay succession' (p1) by Nebert (1978), consists of fluvial deposits which dominantly made of greenish-reddish fine-grained sandstones. The lower

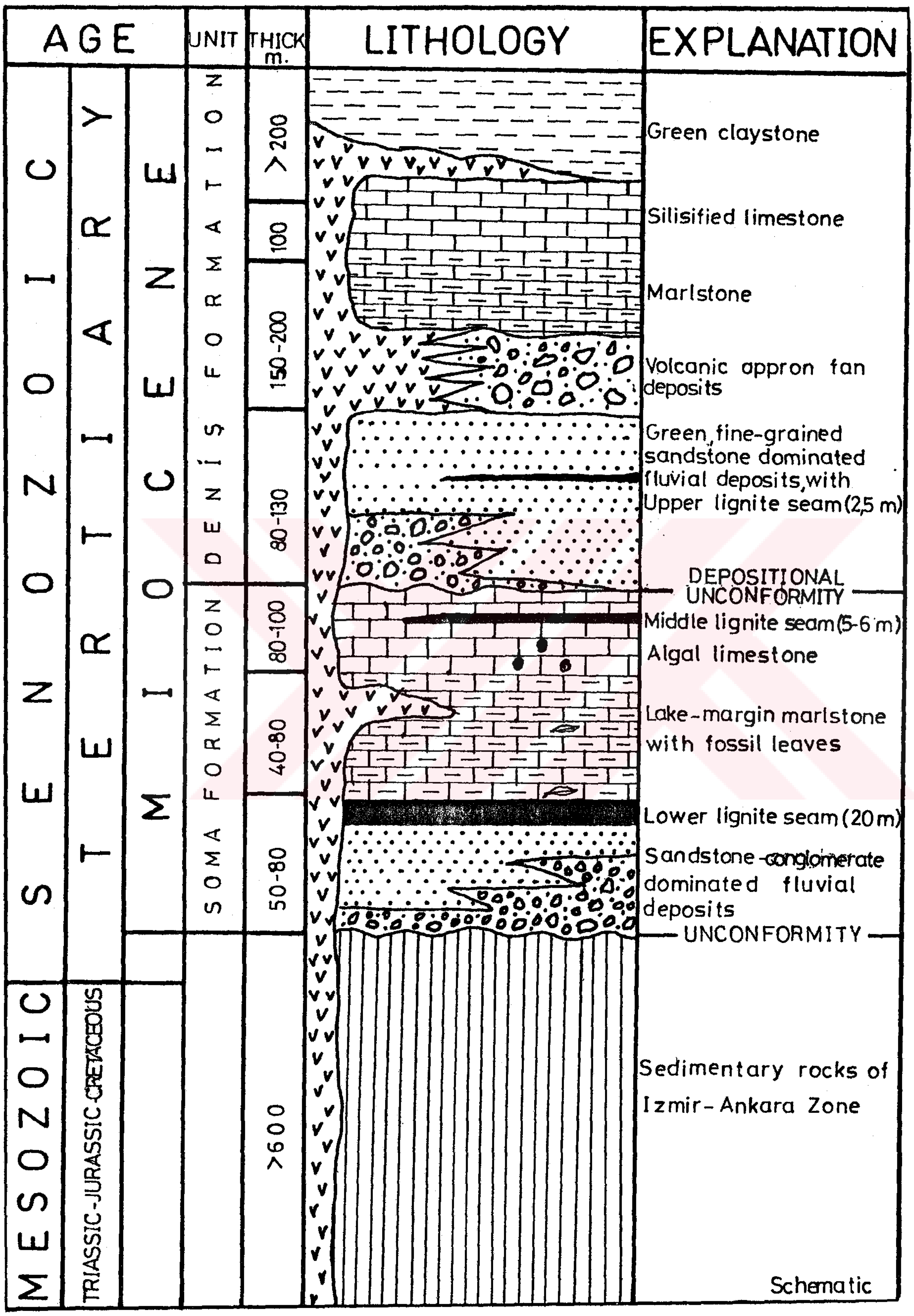


Figure 2.1 The Generalized Stratigraphical Section of the Lignite-bearing Neogene Sequence in Soma Area (Modified from İnci, 1996).

parts of tne unit contain lignite beds (upper lignite seam). The rock units overlying the greenish sandstones are mainly represented by volcanic originated coarse-grained alluvial fans or volcanic aprons at the basin margin and fine-grained alluvial plain deposits in the basin centre (İnci, 1996). The same rock units was named as 'tuff-marl succession' (p2) by Nebert (1978). The uppermost rock unit of the Deniş formation is silicified limestones and they were named as 'calcer succession' (p3) by Nebert (1978).

Soma and Deniş formations have similar rock components, both of them begin with clastics, continue with marls and change into carbonates. These transitional and alternation features indicate cyclical sedimentation. The similar sedimentary features are also present in Quaternary deposits (Tab. 2.1).

Table 2.1 The Similarities and Cycles between Soma Formation, Deniş Formation and Quaternary Deposits.

SOMA FORMATION	DENIŞ FORMATION	QUATERNARY DEPOSITS
Denis formation	Quaternary deposits	Fluvial deposits and Upper clastic unit
UNCONFORMITY	UNCONFORMITY	UNCONFORMITY
Algal limestone (80-100m) with lignite (5-6 m)	Silisified limestone (100 m)	Algal / oncolitic limestone (28 m)
Lake-margin marlstone (40 - 80 m)	Volcanoclastics and marlstone (150-200 m)	
Sandstone-conglomerate dominated alluvial deposits (50-80 m) with lignite (20 m)	Sandstone dominated fluvial deposits (80-130 m) with lignite (2,5m)	Sandstone-conglomerate dominated Lower clastic unit (36 m)
UNCONFORMITY	UNCONFORMITY	UNCONFORMITY
Sedimentary rocks of the Izmir - Ankara Zone	Sedimentary rocks of the İzmir - Ankara Zone or Soma formation	Sedimentary rocks of the Izmir-Ankara Zone or Deniş formation or Soma formation

Deniş formation differs from Soma formation due to its volcanoclastic characteristic despite this similarity between Soma and Deniş formations.

Lower and upper lignite seams were deposited in alluvial plain environments, but middle lignite seams were deposited in mud flat environment that fringed with shallow carbonate lake enviroment (İnci, 1994, 1995 and 1996). The technological features of the lignites are summarized in Table 2.2.

Table 2.2 Some Technological Features of Lignites in Soma Area (Modified from Türkiye Linyit Envanteri, 1983)

LİGNİTE	Thickness(m)	Kcal/kg	Ash(%)	S(%)
Upper seam	3.5	2450	43.00	1.3
Middle seam	4.0	1750	41.00	1.4
Lower seam	15 .0	3150	32.00	1.5

The Soma formation is Miocene and the Deniş formation is Pliocene in age according to some authors (Brinkmann et. al, 1970; Becker § Platen, 1971; Nebert, 1978; Akgün et al.,1986). But, according to Takahashi and Jux (1991), the result of palynological data and some age correlations with lignite-bearing sequence of southwest Anatolia, the sequence in Soma is Miocene in age.

İnci (1994,1995 and 1996) points out the depositional unconformity between the Deniş formation and the Soma formation. The coarse-grained sediments in alluvial facies of the Deniş formation overlies the pre-Neogene basement rocks unconformably, but fine-grained rocks which are lateral equivalent of the coarse-grained rocks deposited in alluvial plain facies rest on paraconcordantly over the limestones (m3) of the Soma formation.

CHAPTER THREE
QUATERNARY GEOLOGY

3.1 STRATIGRAPHY

Quaternary deposits covering the basement rocks unconformably have been investigated by dividing them into four informal rock units. The total thickness of the sequence is more than 76 m (Fig. 3.1).

3.1.1 Lower Clastic Unit

The unit is the lowermost part of the Quaternary sequence and is dominantly composed of conglomerate and sandstone and minor amounts of the sandy claystones.

Conglomerates, due to their bedform, textural features and external geometries consist mainly of the debris-flow and channel-form conglomerates (Fig. 3.2).

Debris-flow conglomerates display massive and/or thick-bedding, poor-sorting, poor consolidation and sandy-matrix supported internal structure. Gravels are generally angular or subangular, poorly-rounded and their grain-sizes range from 3 to 30 cm. Gravel components are dominantly composed of Pre-Neogene and rarely Neogene basement rocks (Fig. 3.3). The matrix consists of fine-grained gravel, sand and reddish fine sand and/or muds. Normal grading is common in conglomerates (Fig. 3.4). The conglomerate includes thin sandstone interbeds. The stratification boundaries are generally uneroded and/or poorly-eroded.

Channel-form conglomerates present characteristicly the multi-storey channel-fills through cross-stratification and massive channel-fillings (Figs. 3.2 and 3,5). The depth of multi-storey channels changes to from 20 to 50 cm and their widths vary between 1 and 1.5 m or more than 1.5 m. The channel base is shallow-eroded and channel fill presents fining

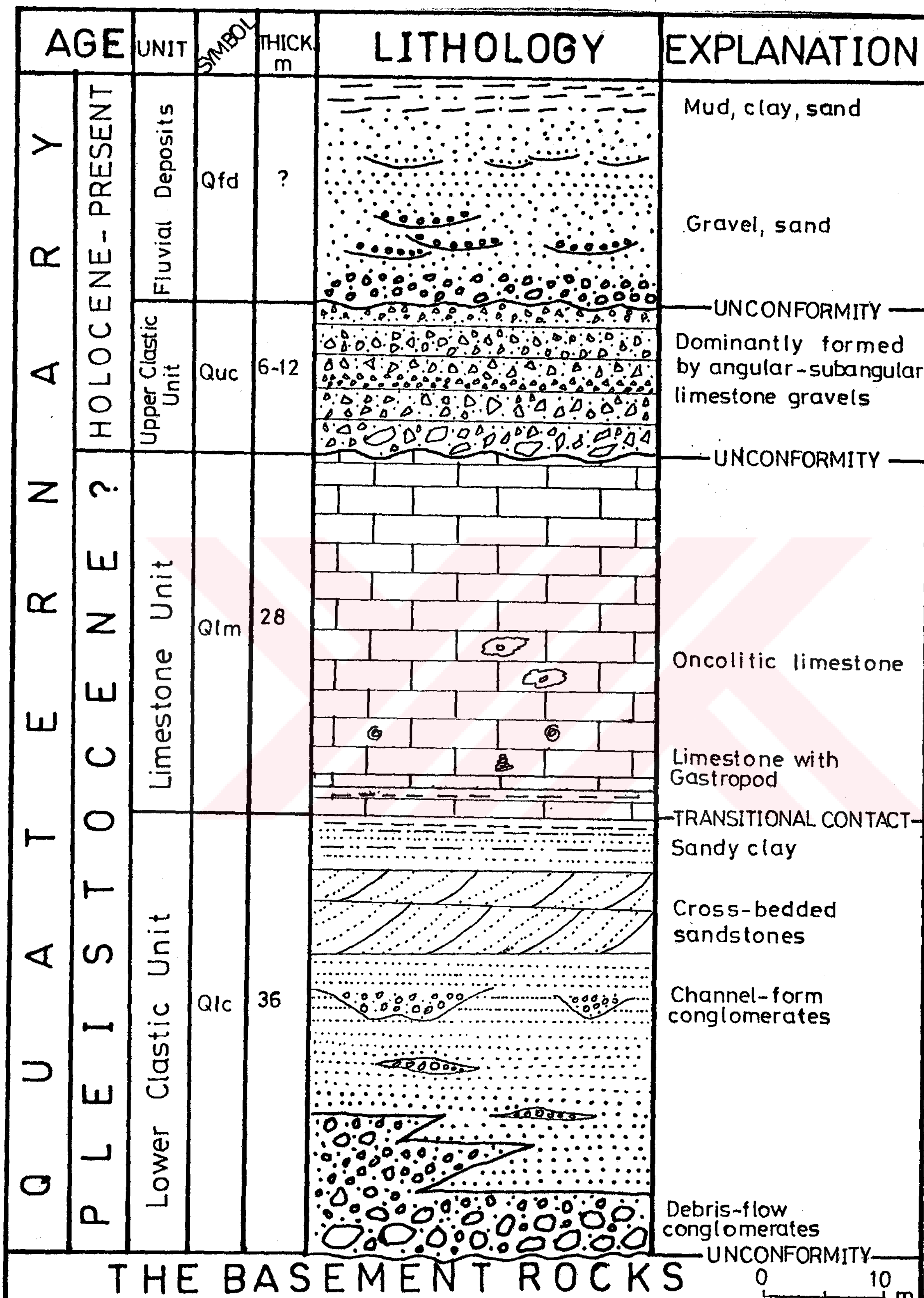


Figure 3.1 The Generalized Stratigraphical Section of Quaternary Rock Units in Study Area.

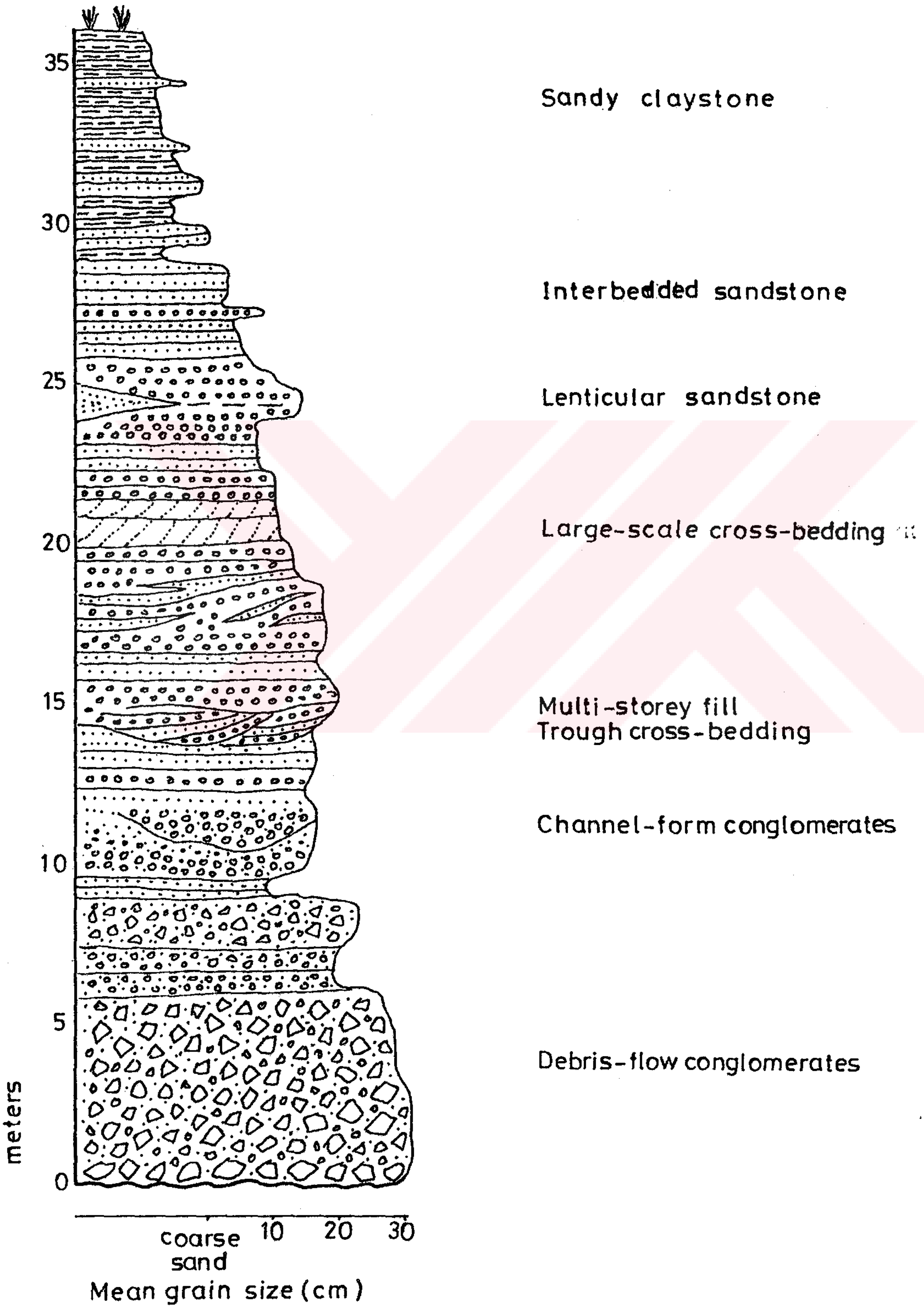


Figure 3.2 Measured Stratigraphical Section of the Lower Clastic Unit.

Figure 3.3 Characteristic High Immature Texture of the Pleistocene (?) Debris-flow Conglomerates. The Photo Shows Basal Clastics which Belong to Pre-Neogene Basement and Neogene Rock Units (Tc,Tuff Clast near the pen). The Pen is 14 cm.

Figure 3.4 Debris-flow Conglomerates Displaying Normal Grading. Arrows Show the Depositional Boundary between Two Conglomerate Beds.

in upward sequences. Thin horizontal bedded and small-scale cross-bedded sandstones also present in the channel fill. Gravel component are mainly composed of pre-Neogene and Neogene basement rocks. Clasts are subrounded, poorly rounded, and moderately consolidated and the grain sizes range from 3 to 20 cm.

Figure 3.5 Multi-storey Channel-form Conglomerates in the Lower Clastic Unit.

Massive channel-fill conglomerates are dominantly composed of pre-Neogene basement rocks. The depths of channels are 1-1.5 m and their widths are between 6 and 8 m. The channel base is deep-eroded, and sometimes changes into thin bedded conglomerates containing of sandstone intercalates and it ends at an erosion bank (Fig. 3.6). The clast components of the channel fill are subrounded, poor rounded and the grain-size ranges from 3 to 13 cm.

The middle part of Lower clastic unit is dominantly composed of sandstones. The sandstones are light-greyish, middle-fine grained and include large scale trough and planar cross-beddings (Figs. 3.7 and 3.8).

Cross-bedded sandstones are in lenticular shapes in conglomerates and the lower contact of the sandstone is transitional with conglomerate. However, the upper contact of the sandstone with conglomerate is erosional (Fig 3.8). Cross-bedded sandstones and conglomerates are dominantly composed of the components of pre-Neogene clastic rocks and Neogene rocks. Cross-beddings are large scale. The lateral and vertical variations

Figure 3.6 Massive Channel-fill Conglomerates. Channel Base Eroded the Sandy Claystones of the Lower Clastic Unit.

Figure 3.7 Conglomerates Change into Fine-grained and Cross-bedded Sandstones Laterally and Vertically.

between sandstones and conglomerates and their geometrical setting indicate lateral accretion deposits.

Figure 3.8 Trough Cross-bedded Sandstones in Lower Clastic Unit. The Lower Conglomerate Bed Sharply Grades into Cross-bedded Sandstones. But the Lower Contact of the Upper Conglomerates is Erosional with the Cross-bedded Sandstones. Arrows Show the Erosional Base. The Scale is 2.5 cm in Diameter.

The upper part of Lower clastic unit is dominantly represented by grey, yellowish, thin and flat-bedded sandy claystones. This rock level locally contain massive channel-filled conglomerates. This sandstones are not very thick may and interprete as overbank deposits.

Lower clastic unit covers the basement rocks unconformably.

The unit was named as 'basal succession' (q1) by Nebert (1978) and considered as Pleistocene in age. The absence of similar rock beds of Lower clastic unit in Neogene sequence and the presence of gravels of marl, tuff and silisified limestone which were derived from Neogene sequence in the unit and its undeformed or less-deformed nature indicate that the Lower clastic unit is Plio-Quaternary in age.

Debris-flow conglomerates may indicate highly viscose and slow-processed sedimentary gravity flows. Formation of channel-form conglomerates indicate the bed-load river courses or center of channels. When stream flow a slow rate, the stream cannot move the clastics on the bars for a long time and the bars reaches a certain thickness. However, the flow may have enough strenght for transportation of clastics along the bar margins. Finally, channels may be filled by massive gravels depending on flow conditions.

Cross-bedded sandstones were formed by redeposition of sandstones in lateral channels by passing from shallow areas.

Consequently, Lower clastic unit, which shows different facies association, may be accumulated in a complex fluvial system and alluvial fan enviroments.

3.1.2 Limestone Unit

The unit is mainly made of gastropod-bearing and oncolitic limestones and it is approximately 28 m thick (Fig. 3.1).

The lower part of the unit comprises whitish-grey and white limestones and calcereous claystones. It contains small and big gastropod fossils and locally algal growths. Limestones are sparitic and locally contains microcrystalline calcite. The thickness of the limestone level which includes gastropod fossils is about 80 cm (Fig. 3.9).

Figure 3.9 The Lower Part of Limestone Unit Containing Gastropod Fossils, is Composed of Alternating of Limestones and Calcereous Claystones. The Gastropod Containing Level is 80 cm . The Photo Taken from Turgutalp.

Gastropod containing limestones can be clarified on packstone characteristic according to limestone claasification of Dunham (1962). Allochems in the texture are composed of gastropods, ooids, oncolites and rock fragments. These allochems are welded by sparry calcite cement indicating that locally micritic in character (Tab. 3.1A and B). Rock fragments were derived from pre-Neogene and Neogene basement rocks (Fig. 3.10).

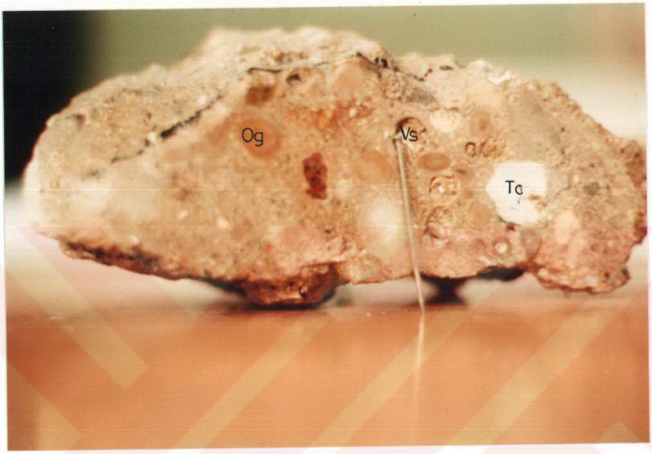


Figure 3.10 Gastropod-bearing Limestone. Tc (Tuff clast of Neogene Rock Units), Vs (Gastropod Valve Space), and Og (Oncolite Grain). The Pin (Scale) is 27 mm.

The upper part of the unit is dominantly composed of oncolitic limestones. Oncolite forms are ellipsoidal, spherical and pipe-like (Figs. 3.11 and 12, Tab. 3.1C,D,H,I). Oncolites are generally hipe-like, display thin layers and their grain-size decrase upward (Fig. 3.12). Oncolitic limestone is grainstone in character. The sharp boundary between allochems and sparry cement, and radial spars around the grains with same-size sparry crystalls support the grainstone texture. (Tab. 3.1C,D and Fig. 3.13). Oncolitic limestone contains ooid grains locally (Tab. 3.1D).

Oncolites are composed of a clastic or carbonate nucleus and irregular algal envelopes, surrounding the nucleus and they reach 1-28 cm in size (Fig. 3.14). The nucleus is generally is a rock clast. Algal envelopes wrap these clasts, in thin and/or thick laminations. Algal envelopes sometimes contain faunal furrows and/or bioturbations (Tab. 3.1E and Fig.3.14).

Figure 3.11 Ellipsoidal and Spherical Oncolites in the Lower Part of Limestone Unit. The Scale is 5 cm in Diameter.

Figure 3.12 Bed-form Oncolitic Limestones Underlying the Sparitic Limestone Beds. Grain-size of the Oncolites Decreases Upward. The Pen (Scale) is 14 cm.

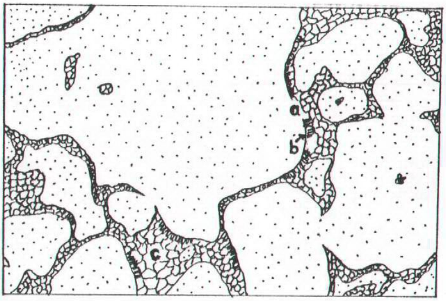


Figure 3.13 Sketch of the Photograph in Table 4.1C Showing Grain-supported Texture of Oncolitic Limestone. Sharp Boundary between Allochems and Orthospar (a), Radial Orthospar at the Membrane of Allochem (b), Large and Same-size Orthospar in Centre (c).

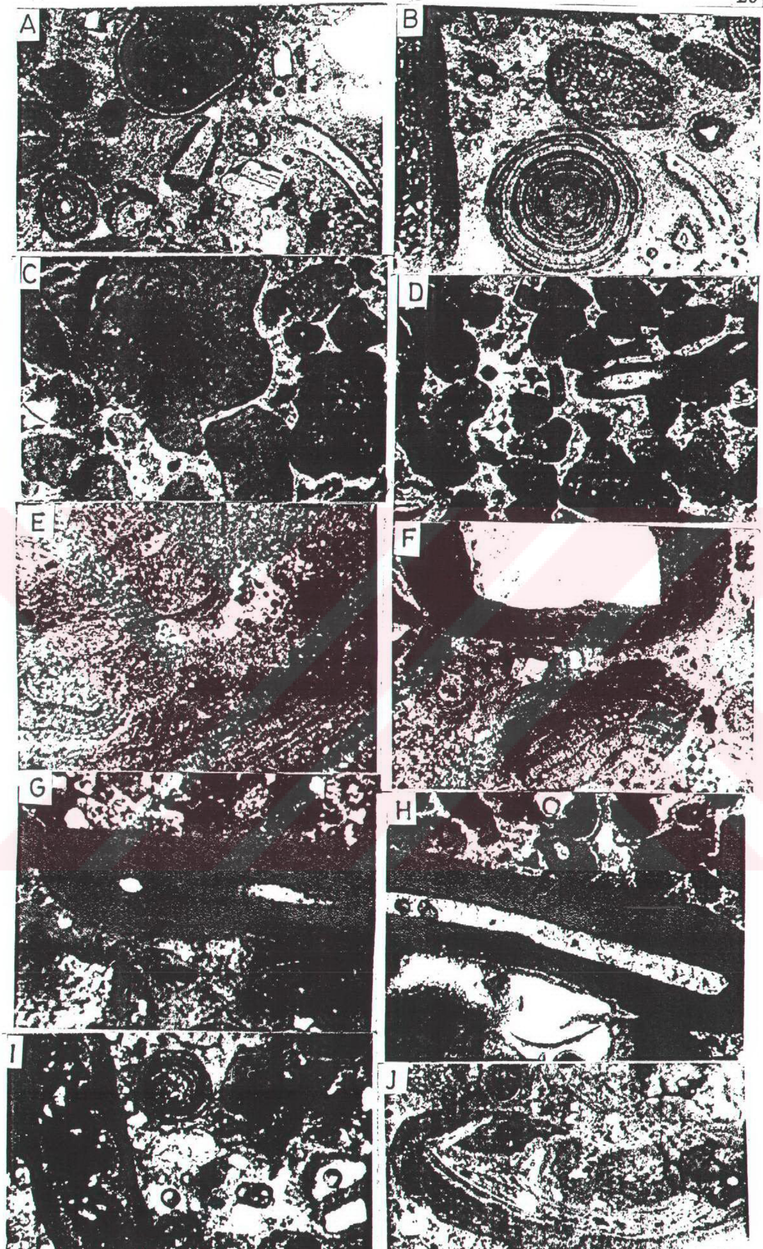
Figure 3.14 An Oncolite Grain from Limestone Unit Including A Clastic Nucleus and Irregular Algal Envelopes.

Cavities originated from bioturbations were filled by pseudospar calcite in pipe-like oncolites due to primarily tubulus-like plants (Tab. 3.1H). Some oncolites contain two nucleuses (Table 3.1G). Some oncolites are developed around the nucleus consisting of oncolite grains (compound oncolites). Locally angular and broken grains are also observed in the texture locally (Tab. 3.1F,I). The Limestone unit overlies the Lower clastic unit by a transitional contact.

The unit, was named as 'calcer succession' (q2) by Nebert (1978) and the age of the unit were considered to be Plio-Quaternary-Late Pleistocene.

Limestone unit indicates a photic shallow water enviroment because of its algal features. The deposition of low-sedimentation conditions may indicate near-shore and shallow lacustrine enviroments. The erosional embeyments and shrinkage cavities around of algal envelopes point out that the flora occasionally stayed out of the water level or very lowstand water conditions in lacustrine environment. Consequently, the limestone unit indicates a very-shallow carbonate lake which adjacent with a carbonate mud flats.due to its oncolitic and gastropod-bearing features and local ooid contents.

Table 3.1 Textural Features of the Limestone Unit and Oncolites. Packstones (A,B), Grainstones (C,D), The Deformation of Algal Envelopes (E), Angular Oncolite (F), The Oncolite İncluding a Pair of Nucleus (G), Pipe-like Oncolile (H), An Ooide and Pipe-like Oncolite (I) and the Deformed Algal Envelopes (J) x 10 (Table in next page)


A
B
C
D
E
F
G
H
I
J

3.1.3 Upper Clastic Unit

The reddish-brown conglomerates consisting mainly of limestone gravels outcrop along the active fault zone between Soma and Kırkağaç town, and it reaches maximum 15-20 m in thickness. The conglomerates have been divided into low consolioated-organized conglomerates and unconsolidated-disorganized conglomerates based on their internal and external features.

Low consolidated-organized conglomerates consist of massive and/or thick bedded conglomerates displaying normal and inverse grading (Figs. 3.15 and 16). Gravels are usually angular and 2-40 cm in size and made of carbonate components of pre-Neogene basement rocks. Bed boundaries are not clear (Figs. 3.15 and 16); normal grading and inverse grading are observed from bottom to the top. In normal-graded beds, grain-size and thickness of the beds are decrease upward. In inverse bed following the normal bedding clear coarsening are displayed towards upward levels and clasts cleaned from their clay-sand matrix (Fig. 3.15). Sedimentary and stratigraphic features of the conglomerates indicate the deposition in alluvial processes. Large scale cross-beddings are observed in the upper part of conglomerates (Fig 3.17). Conglomerates are covered by blackish soil which is generally 0.5-1 m in thickness.

Unconsolidated-disorganized conglomerates display massive and internal structureless and include angular limestone gravels. The matrix is composed of sand and reddish-brown muds. The gravels of unconsolidated-disorganized conglomerates float in the matrix randomly. These conglomerates are observed along the active fault zones and their formation are still continued. Components entirely derived from the carbonate rocks of pre-Neogene basement rocks.

Low consolidated-organized conglomerates and unconsolidated-disorganized conglomerates are defined with their low-consolidation features. However, lateral transitions into the well consolidated conglomerates may also shown in the unit.

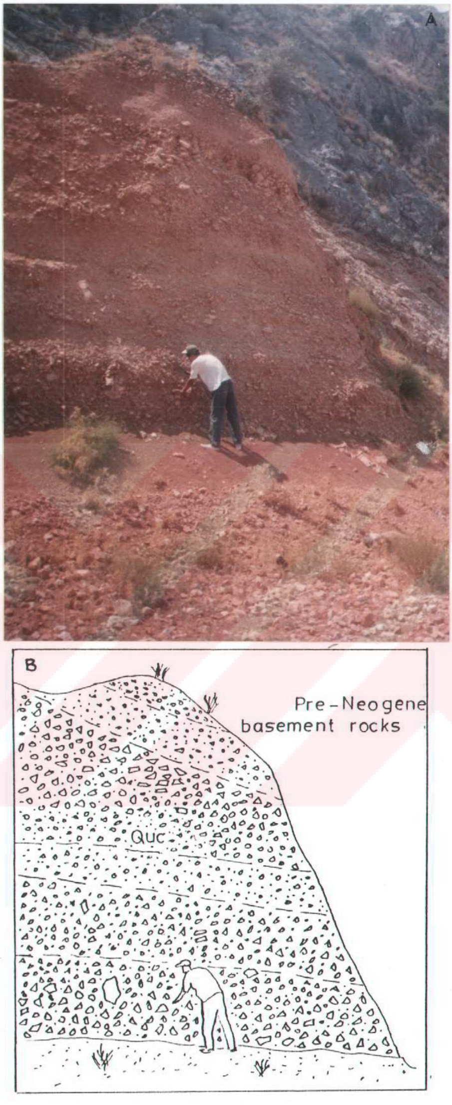


Figure 3.15 (A) Alluvional-fan Deposits in Upper Clastic Unit Displaying Normal and Inverse Grading; the Man (Scale) is 1.80 m. Tne Sketch (B) was Taken from the Photo.

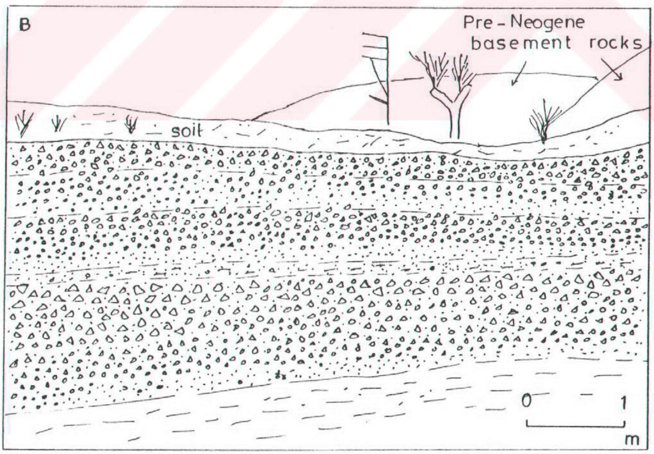


Figure 3.16 (A) Inverse Gradings Intercalated with Reddish-brown Sandy Mud in Upper Clastic Unit. (B) The Sketch of A.

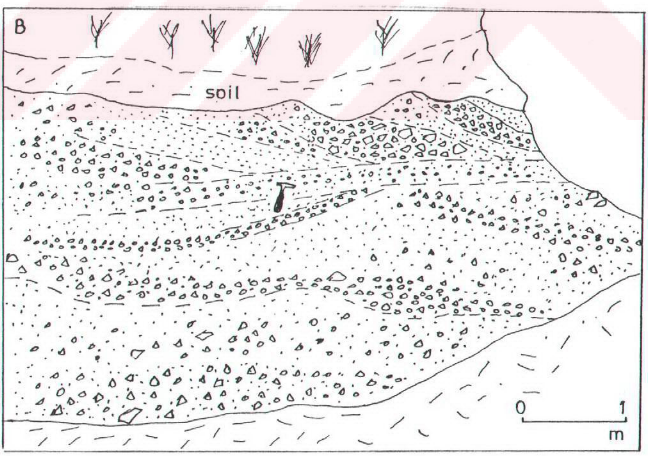


Figure 3.17 (A) Stratal Patterns of the Upper Parts of the Upper Clastic Unit. (B) is Sketch of A. The Photo was Taken from Kırkağaç Dump.

The clasts of the consolidated conglomerates are subangular and welded by carbonate cement (Fig. 3.18).

Figure 3.18 Consolidated Conglomerates Composing of Limestone Clasts that Cemented Carbonate Matrix. The Scale is 5 cm in Diameter.

The Upper Clastic Unit deposited as fans along the active fault zone (Figs. 5.1 and 2). The formation of the unit is still continued and contains historical waterlines. Upper clastic unit overlies the Neogene rock units with angular unconformity (Fig. 3.19). The contact between the Upper clastic unit and the pre-Neogene basement rocks is faulted (Fig. 3.20). The areal extentoin of the unit, its textural features and its depositional features along the fault zone reflect Holocene to present day accumulation in alluvional fan environments.

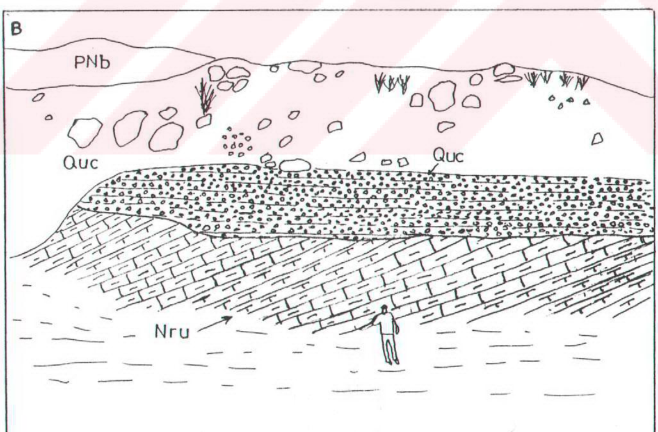


Figure 3.19 (A) Angular Unconformity between Upper ClasticUnit (Quc) and Neogene Rock Units (Nru) Removed by Active Fault. (B) The Sketch of A. The Man is 1.80 m.

Figure 3.20 Faulted Contact between Upper Clastic Unit and Pre-Neogene Basement Rocks.

3.1.4 Fluvial Deposits

The youngest deposits of Quaternary sequence are fluvial deposits deposited by Bakırçay River and Yağcılı River and their tributaries and the flood deposits of these rivers (Fig. 3.1) These deposits are composed of cross-bedded conglomerate, flat-bedded sandstone and siltstones in river channels. Some fluvial terraces present surround the Yağcılı river runing into Sevişler Dam (Fig. 3.21).

The flood deposits of Bakırçay is represented by clayey and silty sediments, and they are covered by soil.

These recent fluvial deposits rest on the Quaternary deposits and basement rocks.

Figure 4.21 Fluvial Terrace Conglomerate Surround of Yağcılı River.

CHAPTER FOUR
STRUCTURAL GEOLOGY

The most important structural elements in the study area are the fault zone between Bakır and Öveçli (SKFZ), small scale faults, open foldings and dipped beds in Quaternary deposits.

The fault zone is best-observed in the area between Bakır and Kırkağaç towns and between Kırağaç and Öveçli towns. The most characteristic feature in tha fault zone which is covered by the Quaternary deposits, is brecciation structure. There are two types white and yellowish-white breccias. First of them is compact breccia sheets. These breccias are found within the footwall of the active slip plane, 30-40 cm in thickness, unsorted, subrounded and strongly recemented with fine material. The other breccia type is incohessive breccia belts. These breccias are poorly-sorted, angular-subangular, thick and their rate of matrix is low. Compact breccia sheets and incohesive breccia belts alternate along the fault planes and they form a small tectonic sequence within the fault zone (Fig. 4.1).

Fault scarp degradations are also observed in the fault zones. Morphological variations developed due to degradations of fault-scarps after the scarp formation. The fault scarps that covered by the Quaternary deposits are found as smaller dipped than net dips. Near the Kırkağaç, the fault scarps dip at 65-80 degrees, because of degradation it appears about 40-45 degrees (Fig. 4.2).

The fault scarps display swellings and sliding fractions. Because of these swellings, the fault plane or surfaces are ondulated (Fig. 4.3). The deviation between fault scrates and dip of the oblique fault plane indicates the oblique slipe displacements. These deviations ranges from 10 to 20 degrees. The apparent heights of the fault scarps reach approximately 65 m (Fig. 4.3). Hematitization and limonitization are observed clearly on the fault scarps (Fig. 4.4).

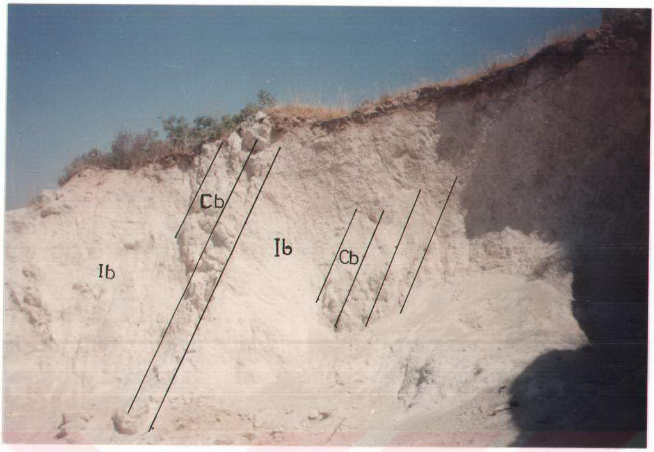


Figure 4.1 Alternation of the Compact Breccia Sheets (Cb) and Incohesive Breccia Belts (Ib) in Parallel to Fault Zone between Kırkağaç and Öveçli Villages.

Figure 4.2 Fault-scarp Degradations in Kırkağaç.

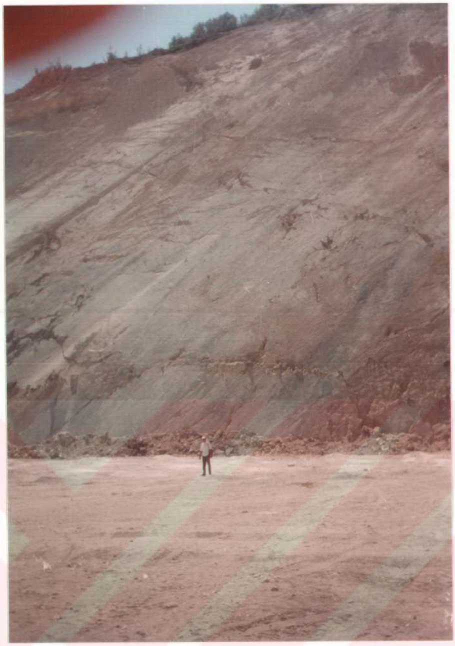


Figure 4.3 Oblique-Slip Fault in Güney Işıklar Coal-mine Area. The Height of the Fault Scarp Reaches to 65 m. The Swellings are Clear.

Soma-Kırkağaç Fault Zone (SKFZ) is active. About of 7500 earhquakes measured by Kandilli Observatory between 1905 and 1995, in surrounding of Soma indicate the actual tectonic activation in study area (Figs. 4.5 and 6). The earthquakes occured between B.C. 2100 and 1976 years, active fault seismology and some structural observations in the field, point out the fault zone in study area have been active since old epocs (Fig. 4.7). According to observations of Kandilli Observatory almost all of the earthquakes are shallow-centered around Soma (Fig. 4.8)

Figure 4.4 Hematitization and Limonitization on the Fault Scarp.

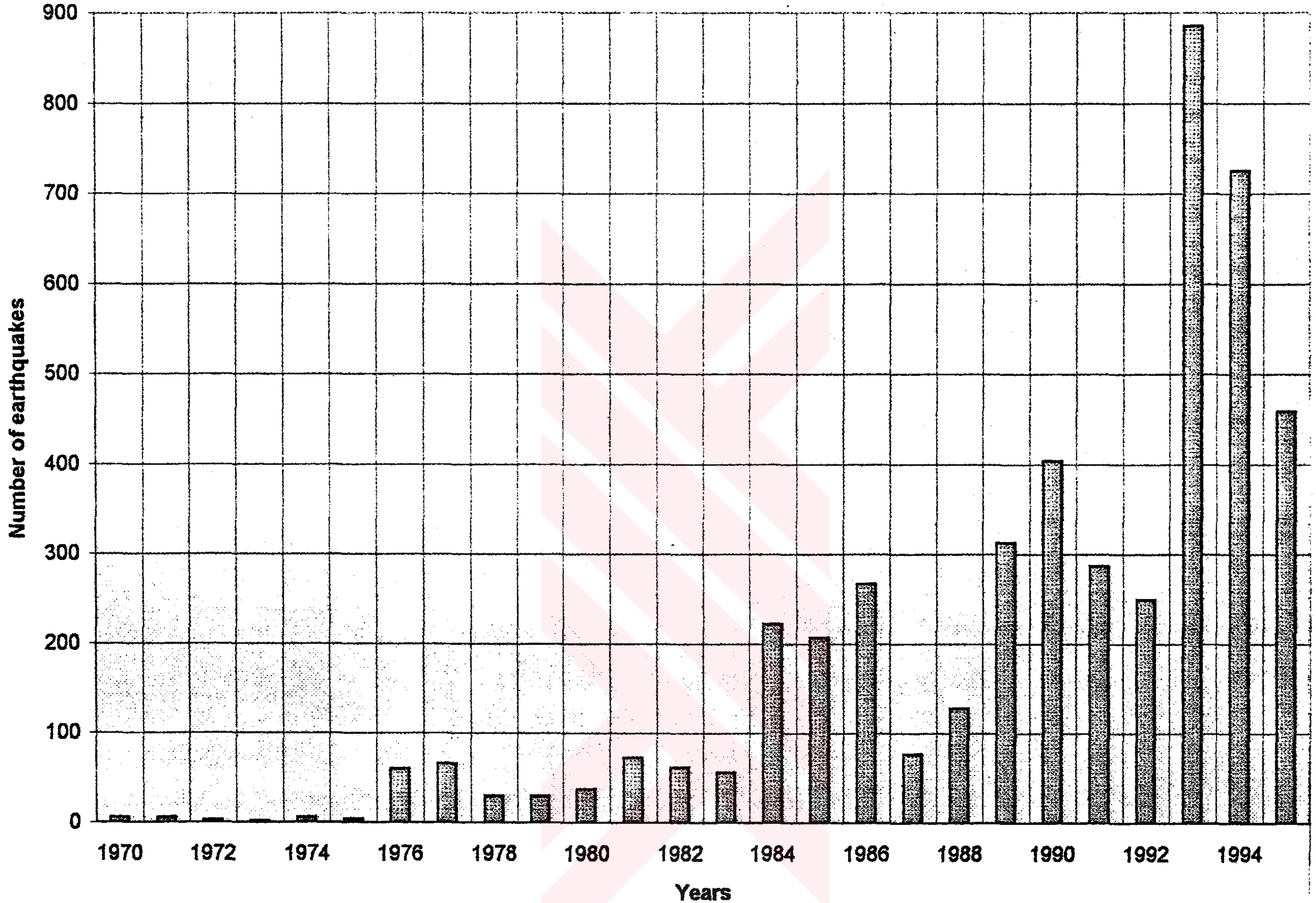


Figure 4.5 Number of Earthquakes According to Years in Soma and Surrounding Areas (Modified from Earthquake Data between 1970 and 1995 Years of Kandilli Observatory).

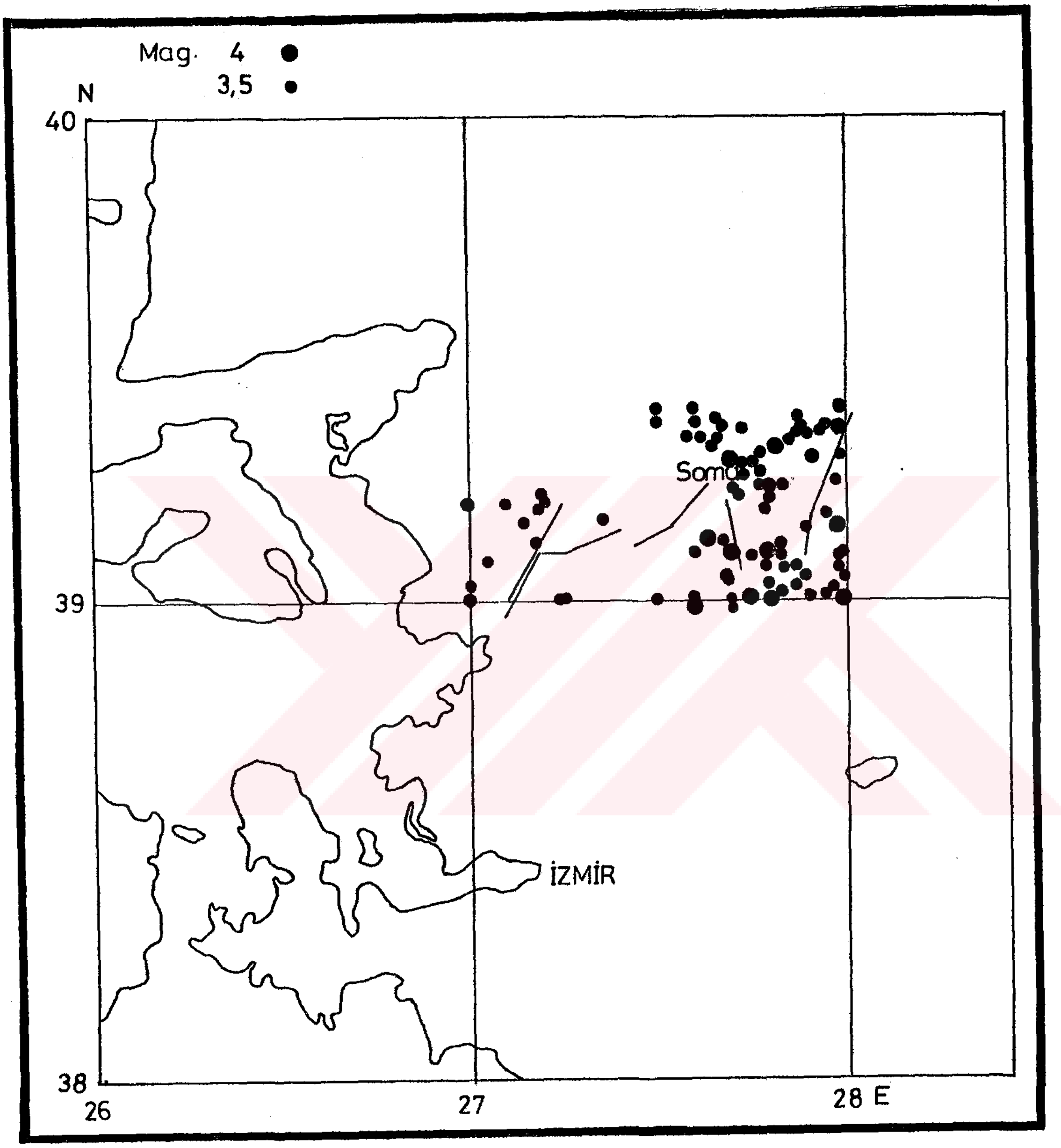


Figure 4.6 Distribution of Earthquakes Having Magnitudes between 3.5 and 4 in Soma and Surrounding Areas (Modified from Earthquake Data since 1903 of Kandilli Observatory).

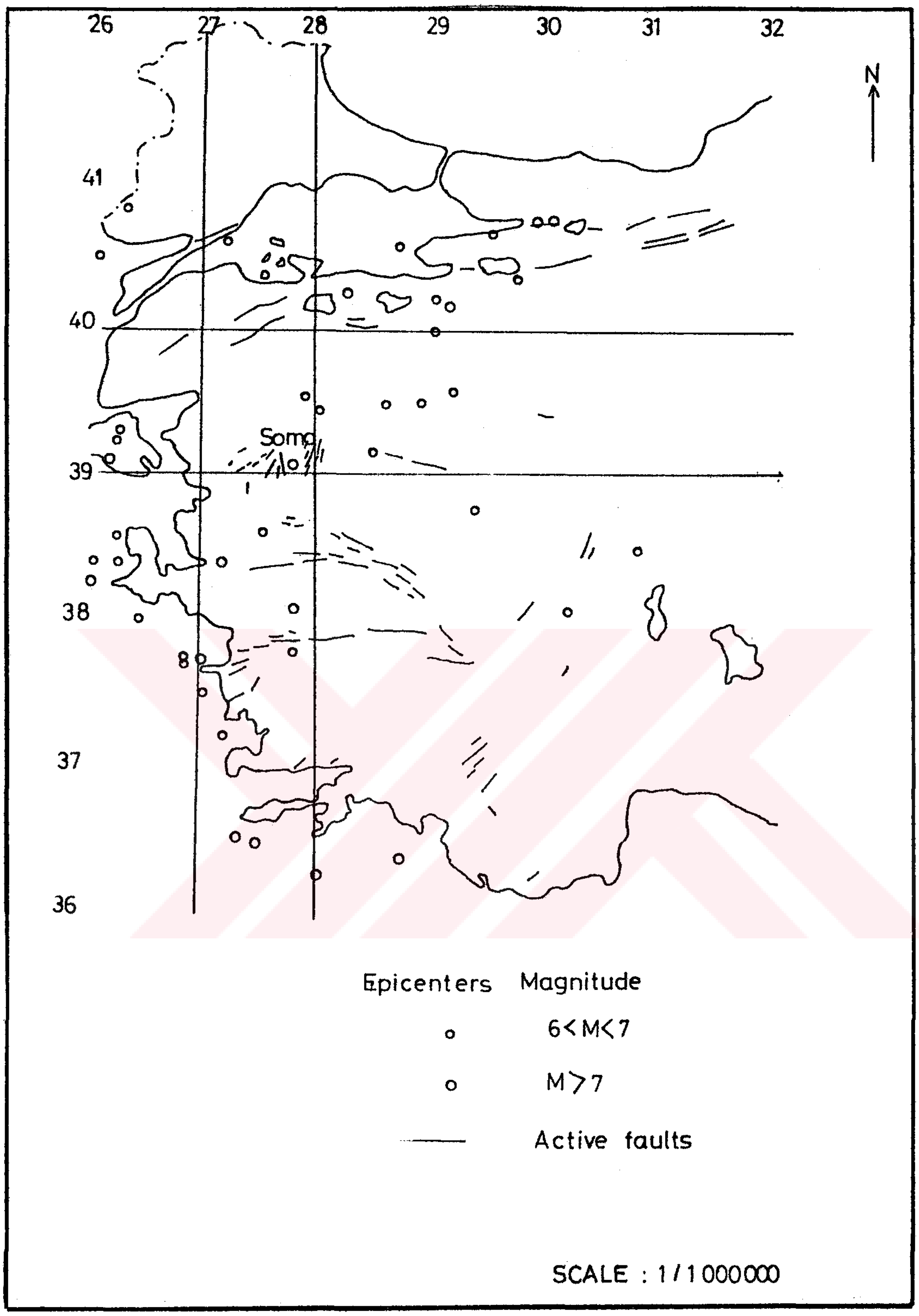


Figure 4.7 The Earthquakes Having Magnitude M> 6.0 Occured between B.C. 2100 and 1976, and Active Faults of Western Turkey (Modified from Deprem Araştırma Bülteni, 1989).

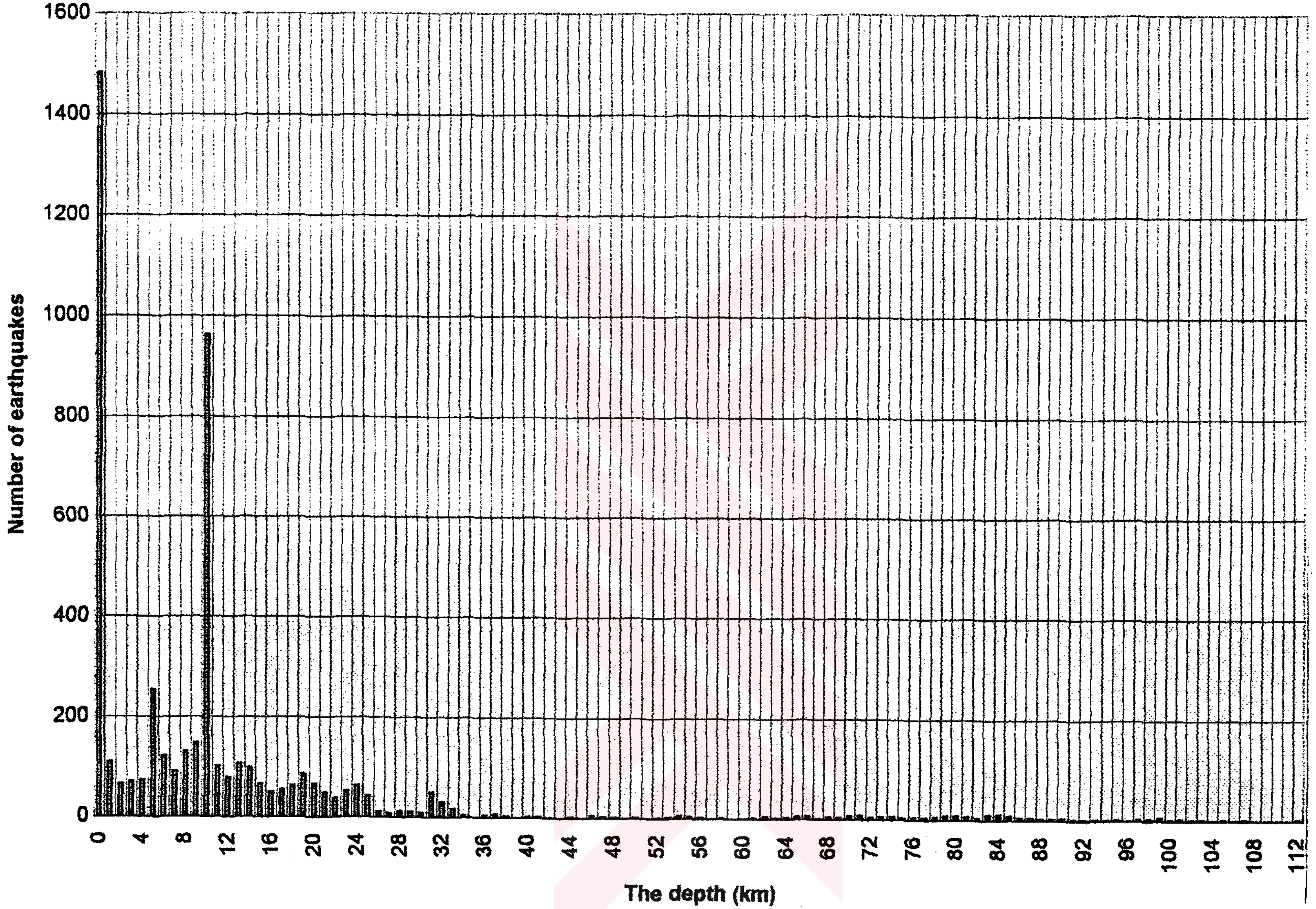


Figure 4.8 The Diagram Showing the Occurence Number of Earthquakes According to their Depths (km). (The Earthquakes in Study Area are Shallow-centered.

In the study area, one of the most important evidence of the active faulting or tectonism is deformations in Quaternary deposits. Small-scale Dip-slip faults observed in the Lower clastic unit have a throw of 1.5 m (Fig. 4.9). Conglomerate and sandstone beds show the dips reaching to 35 degree (Fig. 3.5). These dipped beds gradually change horizontal beds and they form a monoclinal folding in field scale.

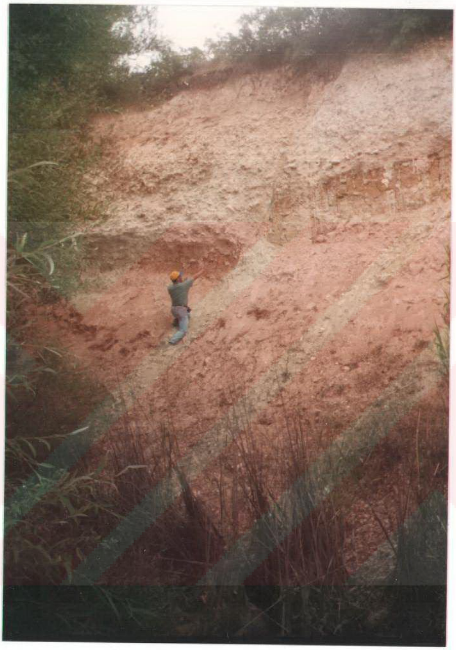


Figure 4.9 Dip-slip Normal Fault in Quaternary Lower Clastic Unit. Fault Slip is Approximately 1.5 m.

The records of active deformation are also observed in the Quaternary Limestone unit. Open fold structures developed commonly in Limestone unit (Fig. 4.10).

In addition, some records of the active faulting or tectonism observed in contact between the Quaternary Upper clastic unit and bedrock. Faulted contact in the study area resembles the 'Type 3 Quaternary/bedrock contact' described by Stewart § Hancock (1988) in Manisa Dağı, Western Anatolia (Fig. 4.11).

Figure 4.10 Open Folding in Quaternary Limestone Unit.

Active antitethic faults were developed in the Soma-Kırkağaç Fault Zone, and Upper clastic unit displays a step-like topography by effect of these active faultings. The slip of the fault is approximately 3.5 m and the Upper clastic unit were terraced by the effect of this fault (Fig. 4.12).

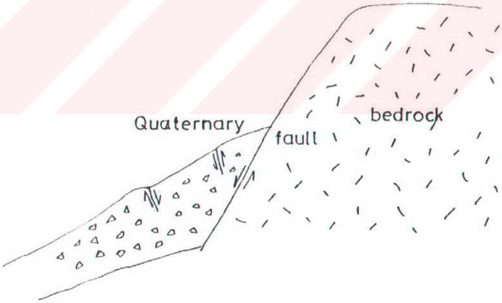


Fig. 4.11 Type 3 Faulted Quaternary/Bedrock Contact (from Stewart § Hancock, 1988).

As geomorphological considerations, the fan or cone like conglomeratic accumulations in fault zones indicate the active tectonism or faultings.

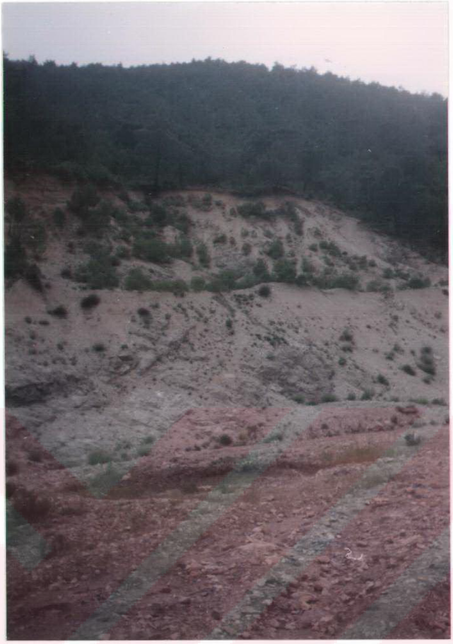


Figure 4.12 The Step-like Structures in the Upper Clastic Unit Originated from Active Fault Displacement. The vertical interval between two terraces of conglomerate is 3.5 m.

CHAPTER FIVE
GEOMORPHOLOGY

The geomorphological pattern of Western Anatolia was revealed by Miocene-present day extensional tectonic regime which is known as 'Neotectonic period' (Nebert,1978; Koçyiğit, 1984; Şengör et. al, 1985; Stewart § Hancock, 1988 and Barka, 1996). The areas south and north of Kırkağaç may subdivided mainly into two geomorphological unites; Soma highland and Bakırçay lowland (Figs. 5.1 and 2).

5.1 Soma Highland

Soma highland comprise of the southwestern Soma-Kırkağaç fault zone (SKFZ) and is dominantly composed of pre-Neogene basement rocks; it rises up step by step from the Bakırçay lowland. The height difference between the Soma highland and Bakırçay lowland is approximately 550 m. The cause of this height difference is Soma-Kırkağaç fault zone. Recent alluvional fans (Upper clastic unit) probably developed around the subsequent faults which cut the major fault. Out of order heights appearing in steeply and continuous hillsides which were splitted by deep valleys, support this possibilitiy. The stepwise-shape topography developed due to the antitethic and syntethic faultings leads the deposition of the recent alluvial fans or cones in the fault zone.

Similar geomorphological features are also observed in north of Kırkağaç (Fig. 5.2). The base of this area changes in a short distance from Bakırçay lowland of 160 m height to Soma highland of 940 m height. The height variations are approximately parallel to Soma-Kırkağaç fault zone, and it displays a stepwise topographic structure.

3.2 Bakırçay Lowland

Bakırçay lowland is a flat area and generally covered by recent fluvial deposits. It is seperated from Soma highland by Kırkağaç-Soma fault zone. The morphological discordance between Bakırçay lowland and Soma highland points out the faultings and isostatic balance in the study area. The depositional fans or cones (Upper clastic unit) developed in the conjuction zone of Bakırçay lowland and stepped hillsides (Figs. 5.1 and 2). These cones occured as a result of the accumulation of materials, which were transported by ephemeral rivers. This accumulation developes by means of decreasing of the river dips suddenly. There is the actual channel of Bakırçay river in north of Kırkağaç. Because of faulting, the stepped and disordered topographic appearence is also observed in this area (Fig. 5.2).

Bakırçay lowland around Soma includes flat and plateau surfaces and is crossed by river valleys originated from the other regions and the basement rocks exposed. Plateau surfaces form high areas change into continuous hillsides. This topographic structure is crossed by Yağcılı river and its distributary channels. The plateau dips approximately 23 degree from north to south. Yağcılı river trending approximately N-S formed a narrow and deep valley. The Sevişler Dam is located in the northern part of this river valley and dam reservoir occupies a large area in the study area.

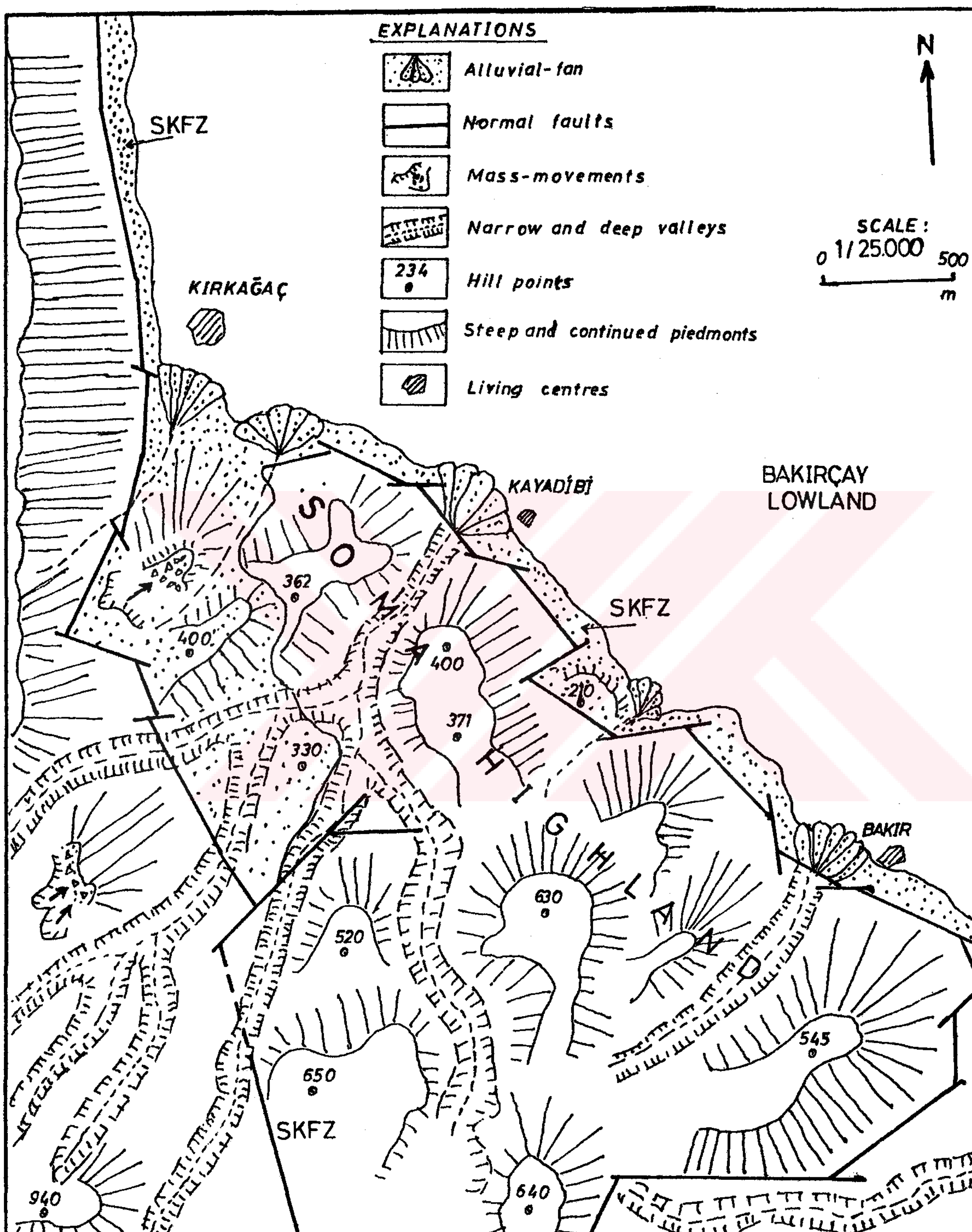


Figure 5.1 Geomorphological Map of Bakır Subarea in 1/25.000 Scale.

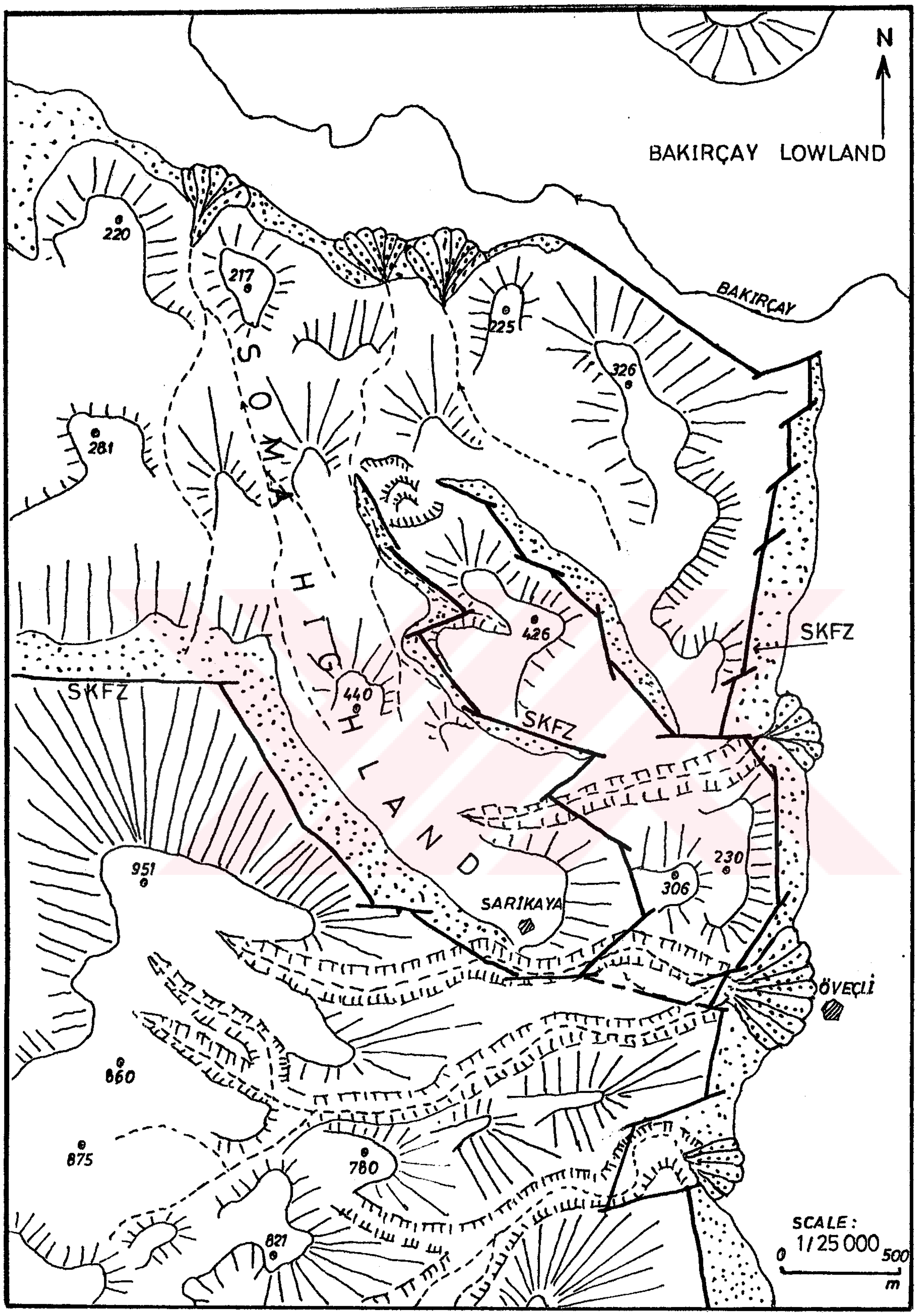


Figure 5.2 Geomorphological Map of Öveçli Subarea in 1/25.000 Scales

CHAPTER FIVE
CONCLUSIONS

An area of total 100 km^2, composed of Bakır, Öveçli and Turgutalp subareas, mapped in 1/10.000 and 1/25.000 scales.

Quaternary sequence overlies the lignite-bearing Neogene and pre-Neogene basement rocks which are composed of rocks of Izmir-Ankara Zone.

The Quaternary sequence is composed of Lower clastic unit, Limestone unit, Upper clastic unit and recent fluvial deposits.

The Lower clastic unit is dominantly composed of debris-flow conglomerates, channel-form conglomerates, cross-bedded sandstones and fine-grained sandstones/ mudstones and deposited in alluvial fan and fluvial enviroments.

The Limestone unit overlies the Lower clastic unit by a transitional contact and consists of algal/oncolitic limestones. The unit was deposited in very shallow carbonate lake and shows paludal conditions.

The Upper clastic unit overlies these two units unconformably and is made of alluvial fan deposits.

The recent fluvial deposits overly all the units unconformably and form the deposits of Bakırçay lowland.

The fault zone, named as Soma-Kırkağaç Fault Zone (SKFZ) in this study, according to areal extent of the Upper clastic unit, stratigraphical and depositional features of the Quaternary deposits and seismological data, should be in active.

The study area displays two geomorphologic unites related to structural development; Soma highland and Bakırçay lowland. These geomorphologic unites are seperated by Soma-Kırkağaç Fault Zone.

Soma and Kırkağaç towns and Bakır, Kayadibi and Öveçli villages locate in this active tectonic zone. Because of recent sedimentary processes, the rock materials originated from open-cast coal mines that located in the Soma highland prograte downward to Bakırçay lowland.

CHAPTER SEVEN
REFERENCES

Abrams, M.J., § Chadwick, O.H. (1994). Tectonic and climatic implications of alluvial fan sequences along the Batinah coast, Oman. Journal of the Geological Society, London, 151, 51-58.

Akgün, F., Alişan, C., § Akyol, E. (1986). A palynologic approach to the Neogene stratigraphy of Soma area. Bulletin of Geological Society of Turkey, 29, 13-25.

Akyürek, B., § Soysal, Y. (1981). Biga Yarımadası güneyinin (Savaştepe-Kırkağaç-Bergama- Ayvalık) temel jeoloji özellikleri. MTA Enstitüsü Dergisi, 95/96, 13-25.

Amorosi, A., Farina, K., Severi, P., Preti, D., Capolare, L., § Di Dio, G. (1996). Genetically related alluvial fan-terrace correlation from the upper Quaternary of the southwestern Po Basin, Italy. Sedimentary Geology, 102, 275-295.

Ayhan, E., Kasnak, E., Öğütçü, Z., Kalafat, D., İnce, Ş., Akkartal, B., Püskülcü, S., Özel, N., Öz, G., Sevimay, K., Kara, M., § Pınar, A. (1989). 1976-1986 yılları arasında Batı Türkiye'de diri fay zonlarının ve depremlerin etkinliği. Deprem Araştırma Bülteni, 64, 5-191.

Barka, A. (1996). Active Faulting in Central and Western Anatolia. "Active faulting studies for seismic hazard assesment". Annles Geofizica (in press).

Becker-Platen, J.D. (1971). Stratigraphic division of the Neogene and oldest Pleistocene in Southwest Anatolia. Newsletter Stratigraphy, 1, 19-22.

Brinkmann, R., Fiest, R., Marr, W.U., Nickel, E., Schlimn, W., § Walter, H.R. (1970). Soma Dağlarının Jeolojisi. MTA Enstitüsü Dergisi, 74, 41-56.

Brooks, M., Clewws, J.E., § Melis, N.S. (1988). Structural development of Neogene basins in western Greece. Basin Research, 1, 129-138.

Cohen, H.A., Dart, C.J., Akyüz, H.S., § Barka, A. (1979). Syn-rift sedimentation and structural development of the Gediz and Büyük Menderes graben, western Turkey. Journal of Gelogical Soceity, London, 152, 629-638.

Dewey, J.F., § Şengör, A.M.C. (1979). Aegean and surrounding regions: Complex multiplate and cotinuum tectonics in a convergent zone. Geological Society of America Bulletin, 90, 84-92.

Dora, O. Ö, Candan, O., Kun, N., Koralay, E., § Akay, C. (1994). New Geologic Finds and Problems in the Ödemiş-Kiraz Submaasif. Abstracts of the Geological Congress of Turkey, 32, Chamber of Geological Engineers of Turkey, Ankara.

Doutsos, T., § Piper, D.J.W. (1990). Listric faulting and morphological evolution of the Quaternary Eastern Corinth Rift, Greece: First stages of continental rifting. Geological Society of America Bulletin, 102, 812-829.

Dunham, R.J. (1962). Classification of carbonate rocks according to depositional texture: in W.E. Ham (ed.) Classification of carbonate rocks. Am. Assc. Petrol Geol., 1, 108-121.

Ellis, P.G., § McClay, K.R. (1988). Listrict extensional fault system-results of analogue model experiments. Basin Research, 1, 55-70.

Ercan, T., Satır, M., Türkecan, A., Günay, E., Çevikbaş, A., Ateş, M., § Can, B. (1985). Interpretation of new chemical, Isotopic and radiometric data on Cenozoic volcanics of western Anatolia. Bulletin of the Geological Society of Turkey, 28, 121-136.

Erdoğan, B. (1990). Stratigraphy and tectonic evolution of İzmir-Ankara Zone between İzmir and Seferihisar. TAGB Bulletin, 2/1, 1-20.

Gökmen, V., Memekoğlu, O., Dağlı, M., Öz, D., § Tunalı, E. (1993). Türkiye Linyit Envanteri, 356 pgs., MTA Genel Müdürlüğü, Ankara.

İnci, U. (1994). The influence of volcanism on alluvial-lacustrine sedimentation: The Deniş Formation (Miocene) in Soma Coal Basin of Western Anatolia. International

Department of Geology Engineering, Ankara.

İnci, U. (1995). Miocene lignite-bearing alluvial lacustrine facies of the Soma Basin, Western Anatolia. International Earth Sciences Colloquium on the Aegean Region, 26, Dokuz Eylül University, Department of Geology Engineering, İzmir.

İnci, U. (1996). Miocene volcanogenic alluvial sedimentation in lignite-bearing Soma Basin, western Turkey, Sedimentology (in review).

Jackson, J., § McKenzie, D. (1993). The geometrical evolution of normal fault systems. Journal of Structural Geology, 5, 471-482.

Kazancı, N. (1988). Repetitive deposition of alluvial fan and fan-delta wedges at a fault controlled margin of Pleistocene-Holocene Burdur Lake graben, southwestern Anatolia, Turkey. Fan Deltas: Sedimentology and Tectonic Settings, 186-196.

Kazancı, N. (1993). An example of tectonically controlled deposition on north Anatolian fault zone: Suşehri Basin (Pleistocene-Holocene), Turkey. Tr.J. of passive continantal margins. Tectonics, 10, 1038-1064.

Koçyiğit, A. (1984) Intra-plate neotectonic development in Southwestern Turkey and adjacent areas. Bulletin of the Geological Society of Turkey, 27, 1-16.

Lister, G.S., Etheridge, M.A., § Symonds, P.A. (1986). Detachment faulting and the evolution of passive continental margins. Geology, 14, 246-250.

Lister, G.S., Etheridge, M.A., § Symonds, P.A. (1991). Detachment models for the formation of passive continental margins. Tectonics, 10, 1038-1064.

Mercier, J.L., Sorel, D., § Vergely, P. (1989). Extensional tectonic regimes in the Aegean basins during Cenozoic. Basin Research, 2, 49-71.

Muffler, L.J.P., Clynne, M.A., § Champion, D.E. (1994). Late Quaternary normal faulting of the Hat Creek Basalt, northern California. Geological Society of America Bulletin, 106, 195-200.

Nebert, K. (1978). Linyit içeren Soma Neojen Bölgesi, Batı Anadolu. MTA Enstitüsü Dergisi, 90, 20-72.

Nemec, W., § Potma, G. (1993). Quaternary alluvial fans in southwestern Crete: sedimentation processes and geomorphic evolution. Spec.Publs. Int.Ass.Sediment, 235-276.

Okay, A.I., § Siyako, M. (1991). The new position of the İzmir-Ankara Neo-Tethyan Suture between İzmir and Balıkesir. Ozan Sungurlu Symposium Proceedings, 333-355, Ankara.

Oral, M.B., Reilinger, R.E., Toksöz, M.N., Barka, A.A., § Kınık, İ. (1993). Preliminary results of 1988 and 1990 GPS measurements in western Turkey and their implications. Contributions of Space Geodesy to Geodynamics: Crustal Dynamic Geodynamics, 23, 407-416.

Paton, S. (1992). Active normal faulting, drainage patterns and sedimentation in southwestern Turkey. Journal of Geological Societty, London, 149, 1031-1044.

Ramos, A., Sopena, A., § Arlucea, M.P. (1986). Evolution of Bundtsandstein fluvial sedimentation in the northwest Iberian Range (central Spain). Journal of Sedimentary Petrology, 56, 862-875.

Savaşcın, Y. (1990). Magmatic activities of Cenozoic compressional and extensional tectonic regimes in western Anatolia. International Earth Sciences Congress on Aegean Region, 2, Dokuz Eylül University, Department of Geology Engineering, İzmir.

Schefer, A., § Stapf, K.R.G. (1978). Permian Saar-Nahe Basin and Recent Lake Constance (Germany): two enviroments of lacustrine algal carbonates. Spec.Publ. int.Ass.Sediment, 2, 83-107.

Seyitoğlu, G., § Scott, B. (1991). Late Cenozoic crustal extension and basin formation in west Turkey. Geol. Mag., 128, 155-166.

Seyitoğlu, G., Scott, B. C., § Rundle C.C. (1992). Timing of Cenozoic extensional tectonics in west Turkey. Journal of Geological Society, London, 149, 533-538.

Stewart, I.S., § Hancock, P.L. (1988). Normal fault zone evolution and fault scarp degradation in the Aegean Region. Basin Reseach, 1, 139-153.

Şengör, A.M.C., Görür, N., § Şaroğlu, F. (1985). Strike-slip faulting and related basin formation in zones of tectonic escape: Turkey as a case study. Society of Economic Palontologists and Mineralogists, Spec. Publ., 37, 227-264.

Takahashi, K., § Jux, U. (1991). Miocene palynomorphs from lignites of Soma Basin (West Anatolia, Turkey). Bull. Faculty of Liberal Arts, Nagasaki Univ., (Natural Science), 32, 7-165.

Trudgill, B., § Cartwright, J. (1984). Relay-ramp forms and normal fault linkages, Canyonlands National Park, Utah. Geological Society of America Bulletin, 106, 1143-1157.

Wernicke, B., § Burcfiel, B.C. (1982). Modes of extensional tectonics. Journal of Structural Geology, 4, 105-115.