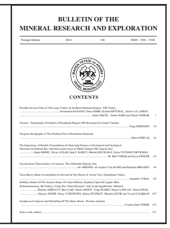
Bulletin of MTA (2014) 148: 1-17

Bulletin of the Mineral Research and Exploration

http://bulletin.mta.gov.tr


BULLETIN OF THE
MINERAL RESEARCH AND EXPLORATION

CONTENTS

POSSIBLE INCISION TIME OF THE LARGE VALLEYS IN SOUTHERN MARMARA REGION, NW TURKEY

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Keywords:
Marmara, morphology, large valleys, erosion rate, incision time

ABSTRACT

Surface water and sediments derived from the southern Marmara region (= Susurluk Drainage basin- SDB) transport to lakes Manyas and Ulubat first and then go to the Sea of Marmara via the Kocasu River only. The present drainage system of the SDB provides a good opportunity to study erosion rate and subsequently occurrence times of large-scale valleys in the region. To achieve it, depositional characteristics and ion contents of the ancient lacustrine sediment have been investigated and re-interpreted using cores taken from Lake Ulubat. The boron content of these sediments increased upward suddenly at 4 m depth, most probably due to starting of erosion at Emet borate beds in the drainage basin. Taking into consideration equilibrium between natural erosion and sedimentation, the incision rate in the Emet valley was found to be 1.4 cm.yr-1. From here one can calculate a time span of 75 kyr for the formation of the whole valley itself. However, it is known that working of the geological processes was not monotonous in the past; hence, this date is not absolute. Newertheless, formation of the large valleys of the southern Marmara region should not be older than 300 kyr. An important reason rapid erosion was likely lowered base-level as the Marmara Sea was a closed lake during the last Glacial Period. High altitudinal difference between source and depositional areas caused acceleration of for erosion.

1. Introduction

Eastern and southern parts of the Marmara region are characterized with rivers in deep valleys and step like drainage systems (Figure 1). Geology, rock types and active faults in the region are the reason for the morphology (Figure 2, 3). In general the valley slopes are with low and high angles, mountain tops are relatively long and with sharp edged ridges (Figure 4, 6). This is the reason why the region's morphology has drawn attention and has been studied relatively well (Ardel 1943; Erinç 1955; Darkot and Tuncel 1981). In previous work morphologies of the Marmara region were described but nothing notable had been said how and with what processes these morphologies had developed. In the works the origin of the rough land forms were claimed to be related to the young tectonics and that these structures had torn the Oligo-Miocene peneplaines (Pamir 1938; Erinç 1973; Erol 1981; Emre et al., 1998; Yılmaz et al., 2010). The information from these studies enables us to indirectly learn the development time of the landform in the region and it could be stated that present-day morphologies have developed since Late

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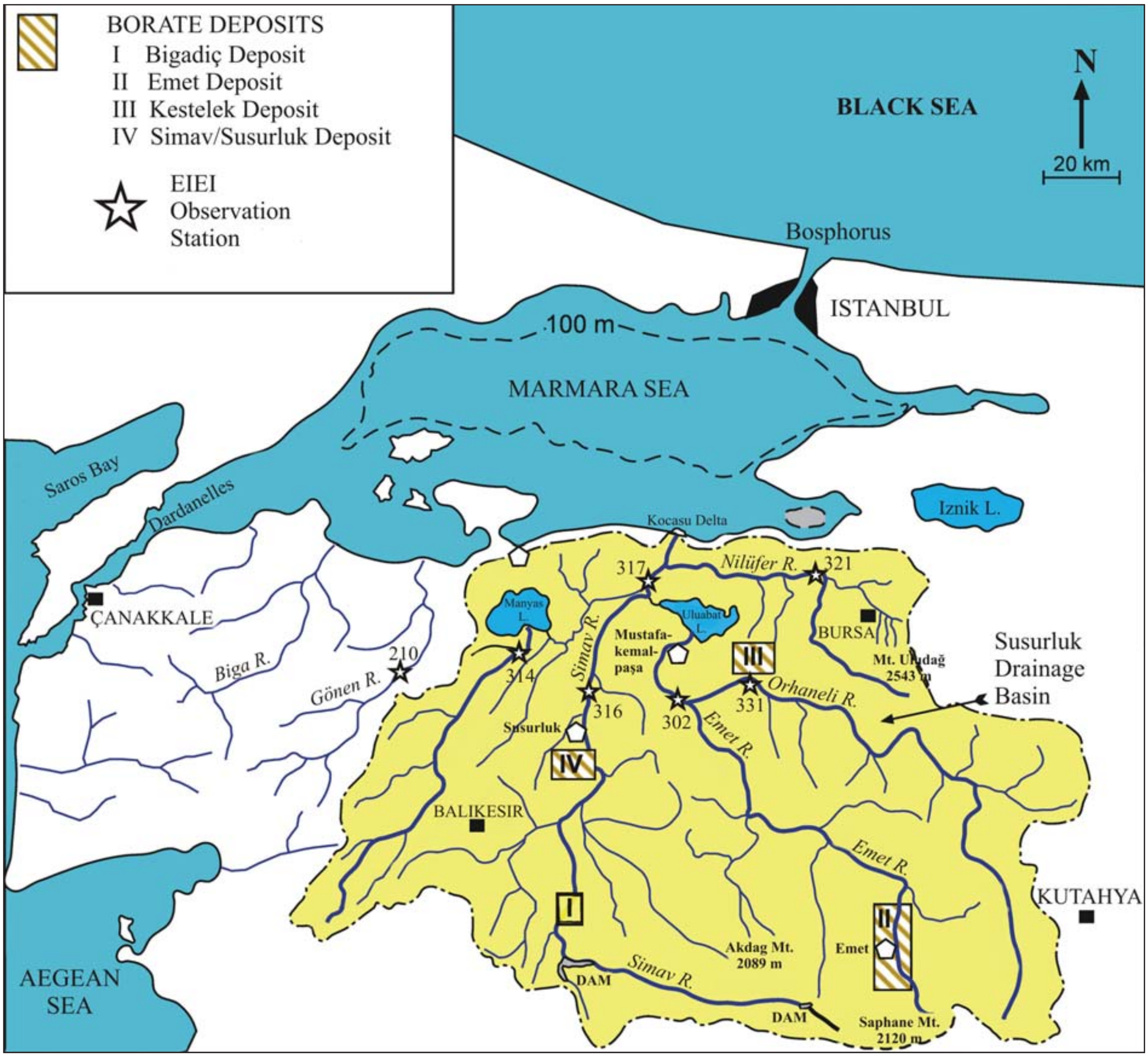

Figure 1- Boundaries of the Susurluk drainage basin in the Southern Marmara region

Miocene. On the other hand detailed geology of the region is well known (Bingöl et al., 1973; Ergül et al., 1980; Gözler et al., 1985; Ercan et al., 1990).

In these studies, apart from describing location, morphologies have not been dealt with. Emre et al., (1998) carried out detailed studies on the notectonic period morphological evaluations of the Southern and more particularly the Eastern Marmara regions, they related the developments and landforms in the Neogen and Quaternary to the regional stratigraphy but they did not give an age in figures. Yılmaz et al, (2010) generalized all of this evolution approach to the whole of the Marmara Sea region. Generation of land forms is slow and includes various complicated processes because of this in many of the geomorphological studies workers try to avoid giving an age for the development time of the medium to large scale landforms. On the other hand not knowing the development ages of the land forms makes them not to be considered as geological data but as a geological problem. The same problem exists in the Susurluk drainage basin (SDB) (SDB is a hydrologic definition and it should be understood as 'water collection area'). There are numerous canyons and/or large valleys in the area. The ages of these features are also not known.

In this study from the deposition rate in the Ulubat Lake an attempt was made to estimate the development ages of the big valleys in the region. Lake sediments have been used as data. General characteristics of the lake deposits, factors controlling deposition and deposition rate have been studied in previous works (Kazancı et al., 2006; 2010). Here the

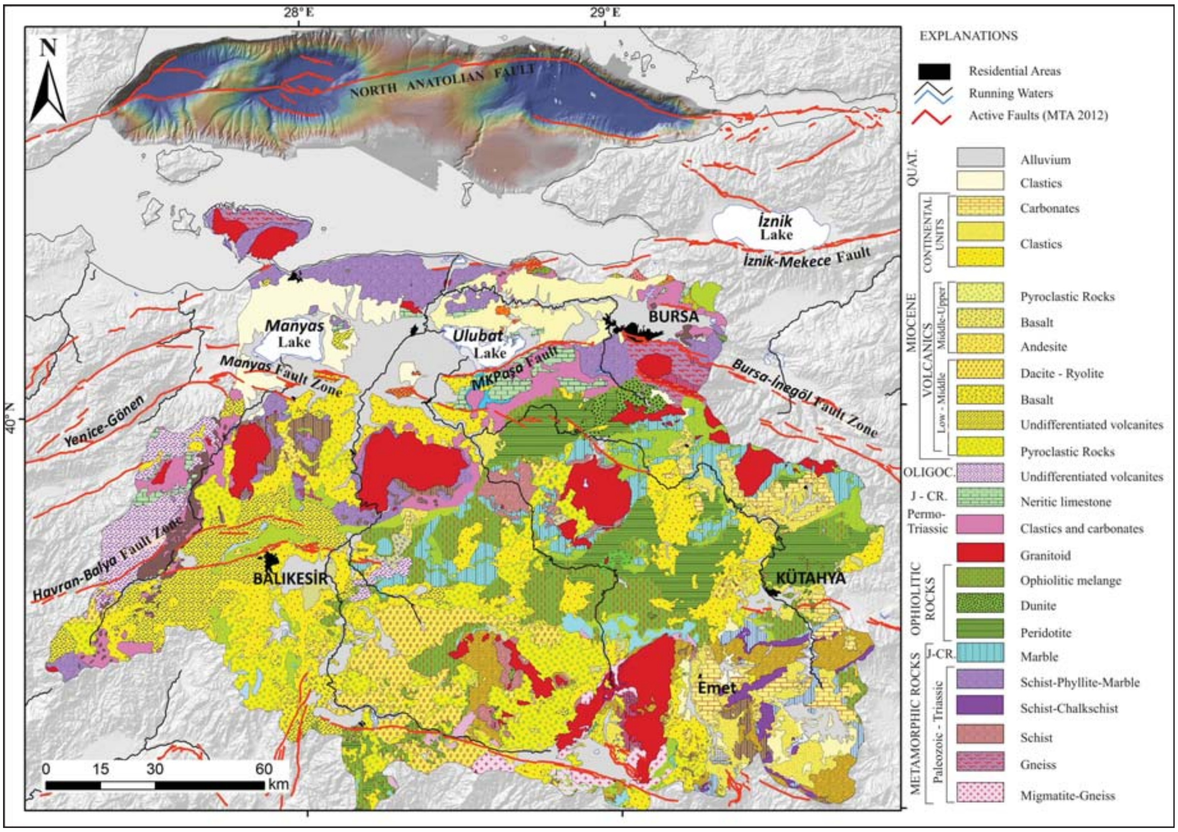

Figure 2- Simplified geological map of the Southern Marmara Region (MTA, 2002 has been used for the distribution of the units; Emre et al., (2012) has been used for the tectonic lineaments. This reference is given as “MTA, 2012” in the reference list).

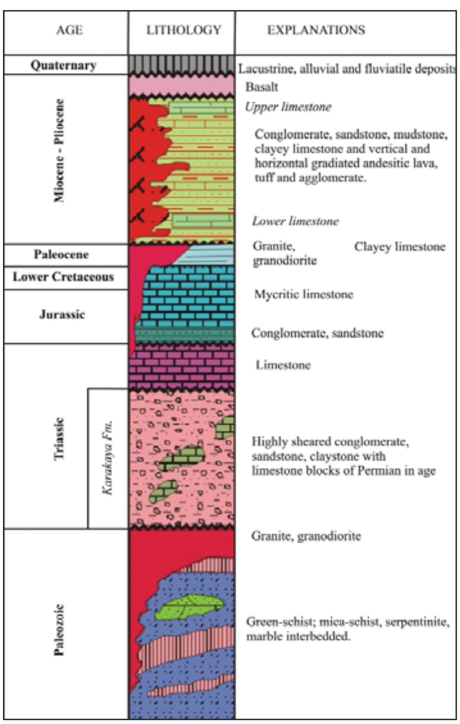

Figure 3- Generalized stratigraphic column of the study area (compiled from previous work. For details look at the text, not to scale).

established balance on the erosion, transport, and deposition for the Ulubat Lake is used to give the age of the landforms in the region. In a particular area if the landforms are not crosscutting one another then they are in general of the same age (Chorley et al., 1984). For example in a karstic region with large and small caves, valleys with differing orientations or volcanic or intrusion features in a volcanic terrain will have developed within the same period of time. Within this period of time, the development time of various size features may be short or may be long. The important thing is, not to know the development age of one single form but the development period of similar forms. Although it may not be absolute but still with knowing the deposition rate or erosion rate development ages may be estimated (Einsele, 1992; Einsele and Hinderer 1998).

In this study age estimations have been attempted for the erosion related medium and large scale land forms in the Southern part of the Marmara Sea, particularly in the Susurluk drainage basin (SDB) (Figures 1, 2) Most distinct valleys in the region have been carved by Simav Stream, Emet Stream and Orhaneli Stream (Figures 1, 4). Rock units subjected

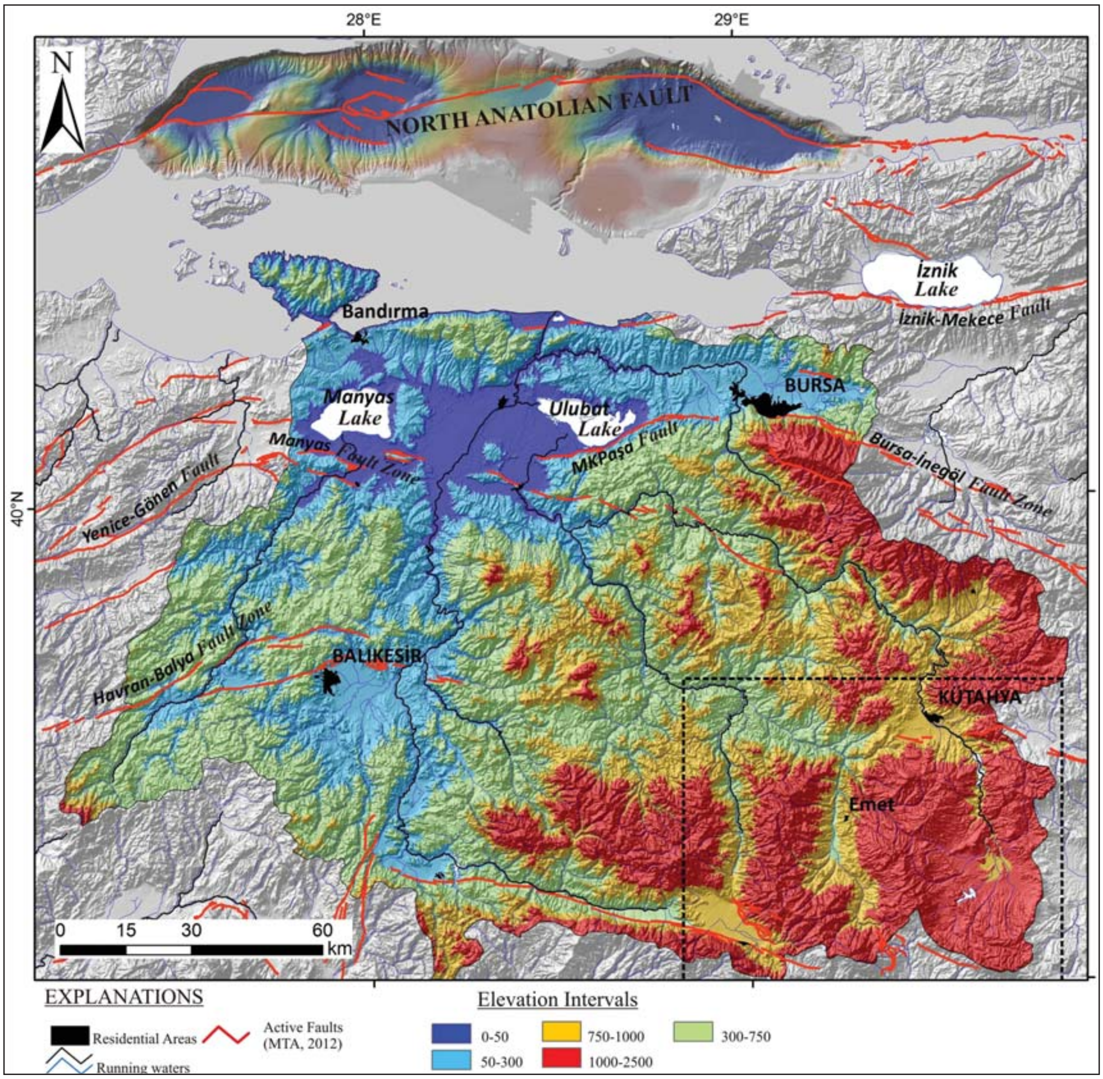

Figure 4- General topographic characters and physographic elements of the Southern Marmara region. Active faults have been taken from Emre et al., 2012. Dotted rectangle is the figure 5 area. Colours in the sea area are not to scale.

to erosion in the region, host particulary boron and many other industrial raw material and mineral deposits (Ergül et al., 1980; Helvacı, 1984, 1986; Ercan et al., 1990).

At present all of the eroded materials with their minerals and trace elements are first transported into Manyas and Ulubat Lakes, the remaining parts are transported into the Marmara Sea through Karacabey pass and deposited there forming the Kocasu delta (Figures 1, 2). When the sea level is low, these materials are carried on farther and were deposited on the Southern Marmara shelf and in the İmralı trench (Emre et al., 1998; Sorlien et al., 2012).

In summary, depositions in the Southern half of the Marmara Sea and in the Ulubat lake on one hand and incision and fragmentation of the SDB on the other form two sides of an erosion-deposition balance. In this study trace elements present in the deposits have been used to estimate caving rate of the Emet Stream valley.

2. Geography

Southern Marmara region mentioned in this study is roughly described as the region surrounded by Çanakkale-Edremit-Balıkesir-Kütahya-İznik Lake-Marmara Sea, in North Western Turkey (Figure 1). As mentioned in the introduction, the Susurluk drainage basin covers about 2/3 of this part (28.000

km^2, Figure 1). Leaving the area between Çanakkale-Edremit-Manyas Lake outside, in the remaining parts of the study area, topography increases from north towards south, reaching an elevation of 2089 m at the drainage dividing line at Akdağ and 2120 m elevation at Şaphanedağ. With 2543 m elevation, Uludağ in Bursa is the highest peak in Western Turkey and is located in the eastern border of the drainage basin (Figures 1, 4).

Manyas Lake and Ulubat Lake are two distinct geographical elements in the study area. These two lakes are situated in the Southern Marmara basin and are 150 km^2 and 138 km^2 areas respectively. The name of the Lake is actually 'Uluabat' but in short it is used as 'Ulubat'. In this study 'Ulubat' name is used. The main streams discharging their waters into the Manyas Lake are Kocaçay (162 km), Simav/Susurluk Stream (321 km), Emet Stream (278 km), Orhaneli Çayı (276 km) and Nilüfer Stream (172 km). Emet and Orhaneli (Stream) streams join together and form the Mustafakemalpaşa Stream and discharges its water content into the Ulubat Lake. The streams leaving the Manyas and Ulubat lakes and the Simav Stream and Nilüfer Stream before reaching to the sea they join together and become the Kocasu River. This Kocasu River has a rather large delta developed in the Marmara Sea (Kazancı et al., 1999). Biga Stream and the Gönen Stream are the other important running waters in the region but outside the SDB basin. They also flow through the big valleys. Kazdağı and neighbouring peaks are important topographical heights in the drainage basins. In this part the general slope is westwards (Figure 4). The region receives in general more rain than Turkey's average (Erdoğan, 1988).

3. General Geology

The Southern Marmara region has rock units from Paleozoc to Quaternary (MTA 2002) (Figures 2, 3). Uludağ and Menderes metamorphic massifs are within the region. They attained their topographic heights in Neotectonic period (Ergül et al., 1980; Yılaz et al., 1990; Okay, 2008). Basement rocks are overlain by Neogene sediments with low topography and Quaternary sediments (deposits) in the low plains (Figures 2, 4).

The stratigraphy of the area has previously been well studied (Bingöl et al., 1973; Gözler et al., 1985; Yılmas et al., 1990; Okay et al., 1991). Late Tertiary volcanics, detritic sedimentary rock, clayey limestones and evaporites are the main units present in the study area (Figures 2, 3), Metamorphic rocks and carbonates are present in lesser amount and form the higher grounds in the southern parts (Yalçınkaya and Avşar, 1980). Miocene units in general have at the bottom stream-lake sediments, towards the upper parts lava flows, tuff and clayey limestones and marls alternate with tuffites. These Miocene lake deposits cover relatively extensive areas around Simav and Emet (Baş, 1987; Ercan et al., 1990). These units host mainly borate and various other mineral deposits (Helvacı and Firman, 1977; Yalçınkaya and Avşar 1980) (Figure 2). Borate bearing Neogene sediments (Borate deposits) sit on the lake limestones (in the local stratigraphy they are called 'Alt Kireçtaşı-meaning Lower limestone which has clayey marl lithology (Figure 3). On top of the borate deposits there are limestones with silicified parts which are resistant and have protected the borate deposit from erosions (Helvacı, 1986). At the very top of the succession the units are lava flows, volcanic breccias and agglomerates. In places where these hard resistant units were broken, fragmented, large deep valleys developed (Figures 4, 6).

Topographicaly lower parts of the Southern Marmara region are mainly covered with thin Quaternary, mostly alluvial and fluvial sedimentation (Emre et al., 1997*a*, *b*, 1998; Kazancı et al., 1997, 1998). Karacabey-Manyas plains which are a typical example of the young cover, has extensive coverage within the SDH. The plain's base is Late Pleistocene –Holocene and has discordant contact relation with the units below and consists of loosely cemented sediments. To the south of the town Mustafakemalpaşa in the thickest part, drillings intercepted 40 m thick young sediments. The upper part (Middle –Late Holocene) is the same age as Manyas and Ulubat Lakes (Emre et al., 1997*b*).

In summary; in the stratigraphy of the Southern Marmara, it is noticeable that Middle-Late Neogene sediments cover large areas and drainage systems with deep valleys primarily developed in these units (Figures 2, 3).

3.1. Morphotectonic Characters

Three main group of landforms with different development processes and ages control the morphology of the Northwestern Anatolia. They are from north towards south Kocaeli-Trakya (Thrace) peneplaine, Marmara Sea and Southern Marmata plateous (Pamir, 1938; Şaroğlu et al., 1987; Emre et al., 1998; Yılmaz et al., 2010). Distinct topographic

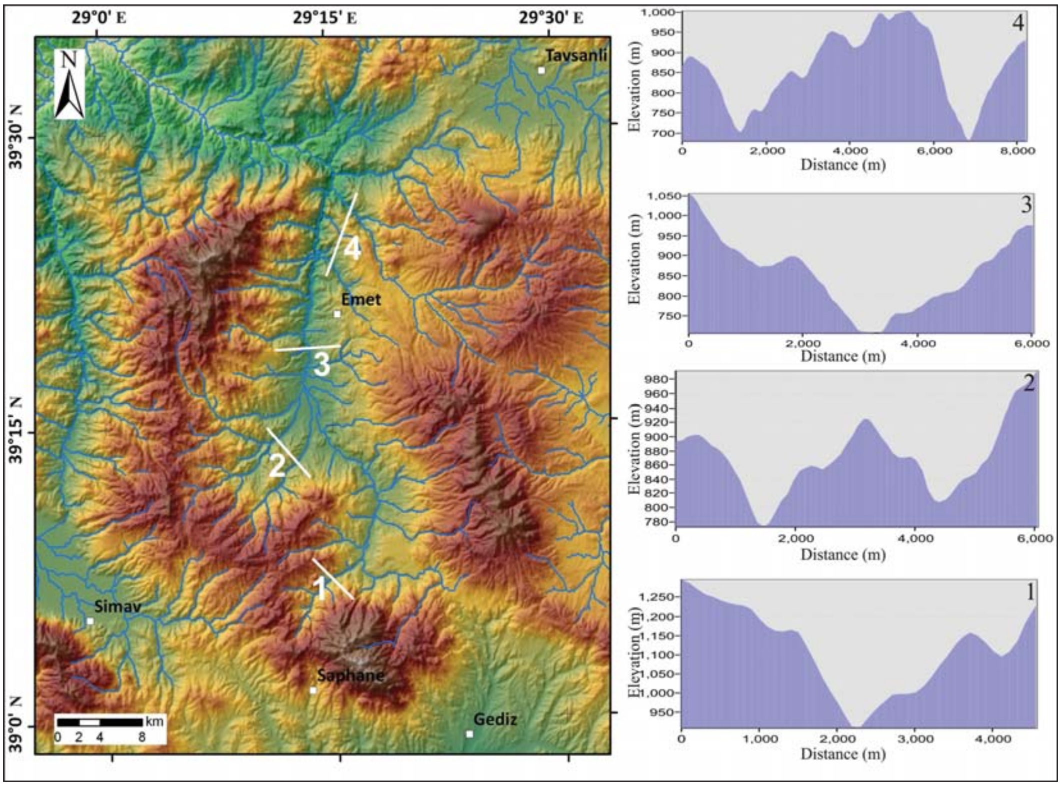

Figure 5- Secondary cleavages in the Emet valley and topographical sections.

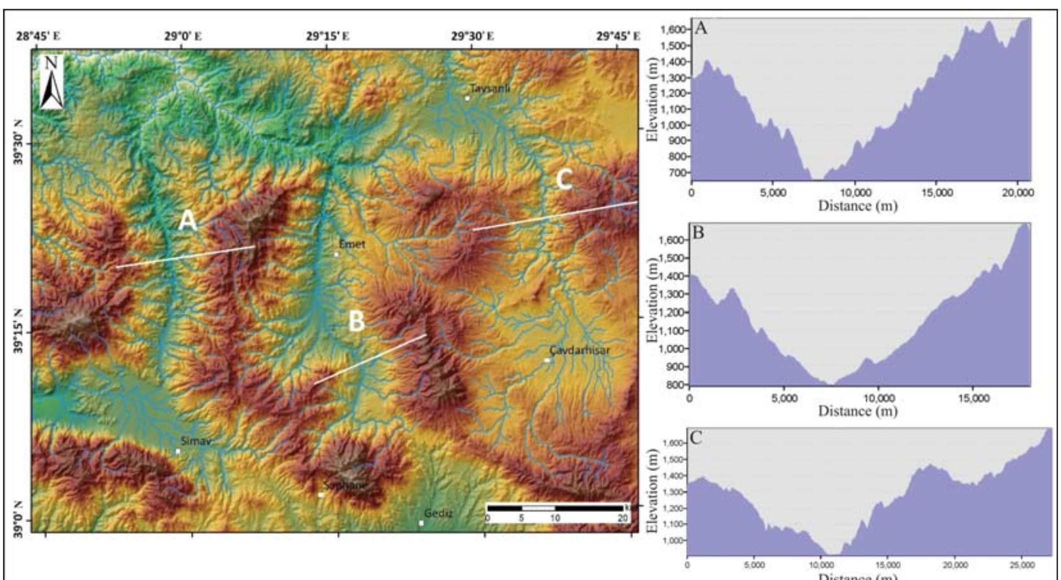

Figure 6- Large valleys in the Susurluk drainage basin and their topographic sections. A Alapur valley, B Emet valley, C Orhaneli valley. Note that valley depths change between 700 and 1200 meters.

disharmonies provide transitions among these reliefs. Oligocene-Miocene Kocaeli-Trakya peneplaine is a residual topography representing Paleotectonic morphology in the region. It helps to understand the Neotectonic period morphological changes and is kind of key area for that matter (Emre et al., 1998). The Marmara Sea basin between the Kocaeli-Trakya peneplaine and the Southern Marmara plateous actually consists of numbers of tectonic depressions developed in the Northern Anatolian Fault Zone

(NAF) (Figure 4). These tectonic depressions were flooded through İstanbul and Çanakkale straights and acquired marine form. Thickness of the filled in material in this marine basin located along the NAF system is about 6 km, indicating a high rate of tectonic subsidence.

The Southern Marmara plains of the study area are the most distinct landform in the region. Gently sloping plains/slopes with 200 - 800 m elevations are common morphological features (Figure 4). The heights made of crytalline units form irregular mountainous parts (Figure 2). As some of these heights consist of erosion resistant rock units, so they represent residual Pre-Paleotectonic period topography. On the other hand some of these heights like Uludağ and Kazdağ are surrounded by active faults and they are the landforms which gained their heights in the Neotectonic period. Erosional and tectonic depressions/basins filled with Quaternary sediments are the morphologic landforms buried in the low height belt in the gently sloping plains/slopes in the Southern Marmara regions. Manyas and Ulubat Lakes are located in the Karacabey-Manyas depression. Karacabey–Manyas depression, Balıkesir plain, Simav plain, Tavşanlı plain are some of the important examples of these features (Figures 2, 4).

Physiographic extensions in the region within the above explained general form developed in the Neotectonic period and are in accord with the present day active fault zones (Şaroğlu et al., 1987). MTA recently published an updated 'The Active Fault Map Series'. These maps provide the opportunity to make correlations between morphological features with the active faults in the region (Emre et al., 2005, 2011 *a*, *b*, c; Emre and Doğan, 2010). NAF is in the form of a plate boundary. Northwestern Anatolia is situated in the transition zone between the NAF and Aegean graben systems which has developed within the Western Turkey tectonic tension regime. The NAF zone is the main tectonic structure separating the Kocaeli-Trakya peneplaine and the Southern Marmara plains (Emre and Doğan, 2010). The faults controlling the present-day morphologies in the Southern Marmara are in two groups. The fault in the north extending between Geyve and Bandırma is the southern branch of the NAF. This fault is separating the Marmara Sea basin and the Southern Marmara plains (Emre et al., 2005). Geomorphologic evolution and running water cleavages (stream valleys) are the results of climatical processes and tectonics.

4. Material and Method

In this part first of all hypothetic approaches will be explained as they formed the basis of the interpretations. Field and laboratory data will be dealt with later

In the geographic use land forms are explained on the base of average elevation of the location and according to this average value land forms are described as plains, hills, mountains, ridges and valleys. Ridges and valleys are the main elements showing land reliefs in a region. Running water valleys have developed by means of lateral and deep scouring and are the channels in the drainage basin transporting and depositing materials altered and eroded in the denudation process. So knowing the occurring and developing ages of running water valleys is important. That is the same as knowing the starting age and evolution processes of the landforms in that particular area. In other words with this, ages of landforms are made known.

In this sudy to give ages to the valleys Emet borate deposits cut through by Emet Çayı (Emet stream) is a suitable guide (reference) (Figure 1). In this area the first borate operation started in 1956 and since 1970 the number of pits has increased. In different locations Espey 1, Espey 2, Killik, Hamamköy, Hisarcık mines started operating and have been operating with differing production rates. Mineralogical and chemical data on these deposits are given in Helvacı (1984, 1986) and Helvacı and Alonso (2000). According to these studies there is more than one kind of mineral in these deposits colemanite being the most important mineral. The generation of borate mineralization is related to the introduction of the volcanics into the lake environment.

At present the entrances of operating borate mines (Espey 1, 2, Hisarcık, Killik, and Hamamköy) are in the Emet Çayı valley and they are about 15 m above the present base of the valley. In other words, naturally or artificially the valley base has been scoured 15 m down through the borate deposits. As this is the discharge area for the river, the waters started cutting through the borate deposits and the boron element flowed into the Ulubat Lake. The rate of accumulation would be more than when it first started. With this approach, recent excessive boron accumulation in the lake has resulted during the time span for this 15 m deep down abrasions. Erosion depth obtained from this correlation would be generalized to the total valley depth. With this correlation the valley development time span and abrasion rate would probably be estimated.

In the SDB there are borate deposits (Kestelek deposit). At present the mine is operating by open pit methods, the drainage of it is by means of the Orhaneli Çayı (Figure 1). Here the mine is below the thalweg elevation. To reach the mine, excavation is necessary. (The borate deposit has not been subjected to the natural erosion yet). So in this study the source of boron ion in the Ulubat lake is considered to be the Emet deposits.

The data used in this study have been obtained from the work carried out in the Southern Marmara region during 1995-2005. Findings of these studies have previpusly been reported in Kazancı and Görür, 1997; Kazancı et al., 1998; 2003 and also in the papers on; Limnology, Paleo-limnology, Environment and Environmental Pollutions, Lakes Geology, Active Tectonics, Geological Evolution of the coasts of the Marmara (Emre et al., 1998; Leroy et al., 2002; Kazancı et al., 2004, 2006, 2010). In this study some data on the Ulubat Lake have been interpreted on the development of land forms.

The first limnology studies on the Ulubat Lake was carried out during 1997-1998, the drillings in the lake were conducted in 2002 and 2004 (Figure 7). Field methods and results achieved have been given in detail in Toprak (2004) and Kazancı et al., (2004). Some of the processes and prominent findings are; in the lake 1-10 m long 12 separate core samples from 5 different locations were taken by using ‘52 mm diameter Livingstone corer’ sampler (AK02LV1-12, AK04LV1-3). In the lake near to the shore, in the shallow parts 1.2 – 1.8 m long 5 core samples were taken in 2 m long plastic tubes (AK02PVC1-5). Every recovered core samples, at 2 cm intervals; grain size, magnetic susceptibility, organic material contents, carbonate contents, pH, heavy metal contents, arsenic (As) and boron (B) contents were analysed (Figure 8). Additionaly the upper parts of the core samples near to the lake surface were analysed for Pb^{210}, Pb^{214} and Cs^{137} isotopes in the Physics Department at Dublin University. The lower parts of the cores were analysed for ^{14}C (Poznan, Poland). And each given their age separately. Ages given in the first two methods showed variations with short intervals. Ages given in the last method showed variations with long time intervals. Both methods are considered to be reliable (Leroy et al., 2002; Kazancı et al., 2004). As the analyses on the cores were conducted with 2 cm intervals, this showed that all these analyses results have changes all along the core lengths, meaning how the environmental conditions in the lake have changed in time from the past to the present. In this study critical data were the boron content of the cores (Figure 7).

Boron contents in the lake sediments with the other pollutants were analysed in the laboratories in the Gebze High Technological Institute. In general in whole of the cores (B) contents show sudden increase at the 400 cm and 50 cm depths (Kazancı et al., 2004; Toprak, 2004). This sudden increase shows that there were sudden boron introduction to the lake, indicating larger amount introducted to the lake from the source area. These changes have also been reported in other studies (Turgut, 2005), (Figure 8).

5. Findings

5.1. Susurluk Drainage Basin and Emet Stream

In the Susurluk drainage basin in the Southern Marmara region, there are numerous and differing types of valleys, namely short, long, deep and shallow valleys (Figure 4). This drainage web discharging into the Marmara Sea is set up on the Southern Marmara Plateau with elevations between 200 and 800 m. Large rivers flow into deep and narrow valleys buried into the plateau surface (Figure 4). Some joining troughs developed along their lengths through tectonic and erosional processes joining the basins and superimposed and buried meanders in the Pre Neogene basement rocks are the common character of the large rivers in the SDB basin. Orhaneli Stream, Emet Stream and Simav Stream basins are the water collecting channels (Figures 1, 4). Because of this, the data collected along the Emet River can be generalized for all running water in the basins.

The Emet Stream valley is one of the deepest cleft in the area. It traverses the middle and Southeastern parts of the SDB which represents at least 2/3 of the whole of the area (Figures 1, 4, 6). Second character of this part is; all of the waters and the sediments collected from the eroded parts are first transported into the Ulubat Lake and afterwards to the Marmara Sea through one channel (The Kocasu River) (Figure 1), That is to say Ulubat Lake and the Kocasu delta are the lithological representative of the whole of the SDB (Kazancı et al., 1999). EİEİ and DSİ have quality control observation stations at the locations where streams reach and leave the lakes. In addition

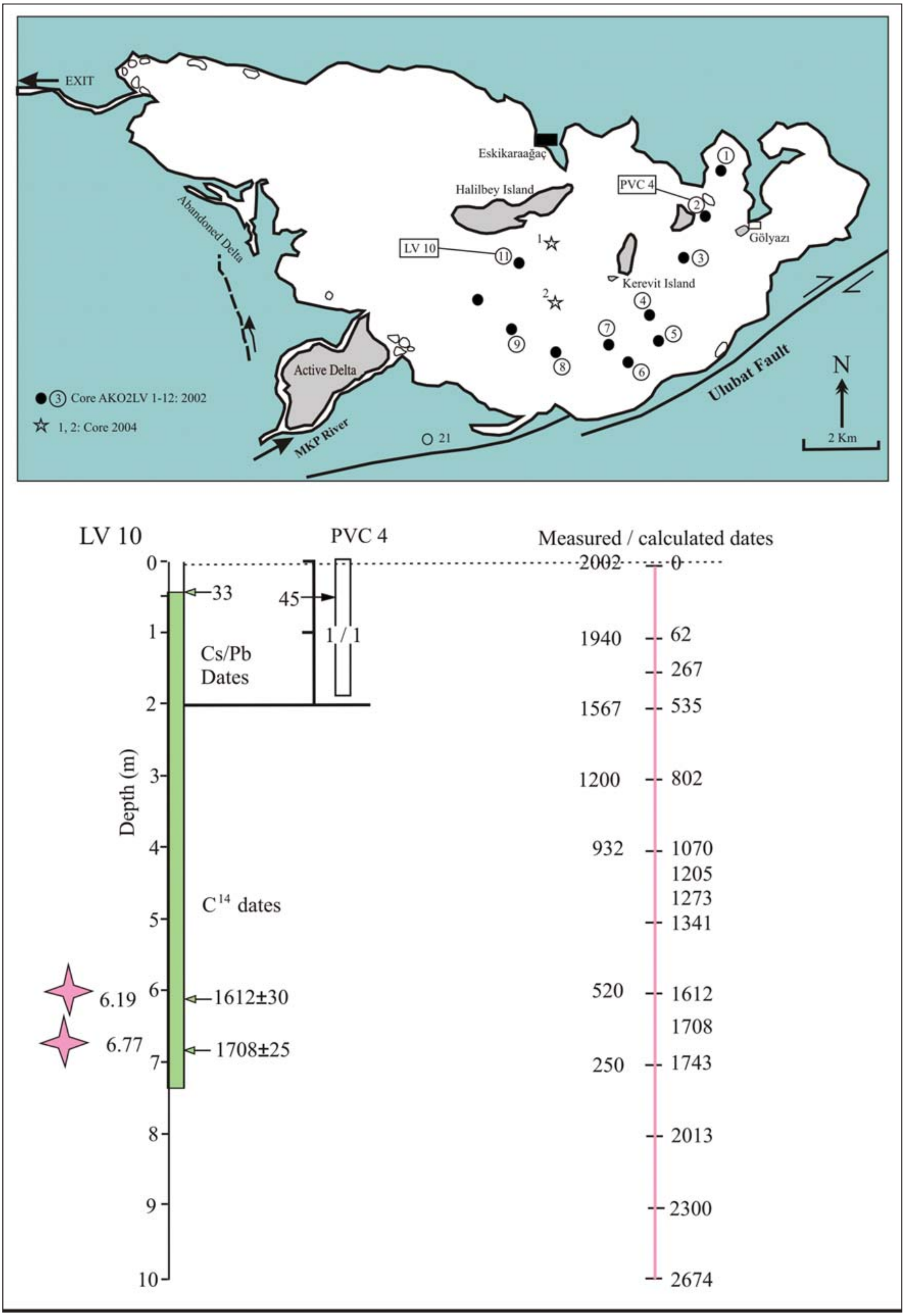

Figure 7- Drilling locations in the Ulubat lake and depth-age relations obtained from the recovered cores.

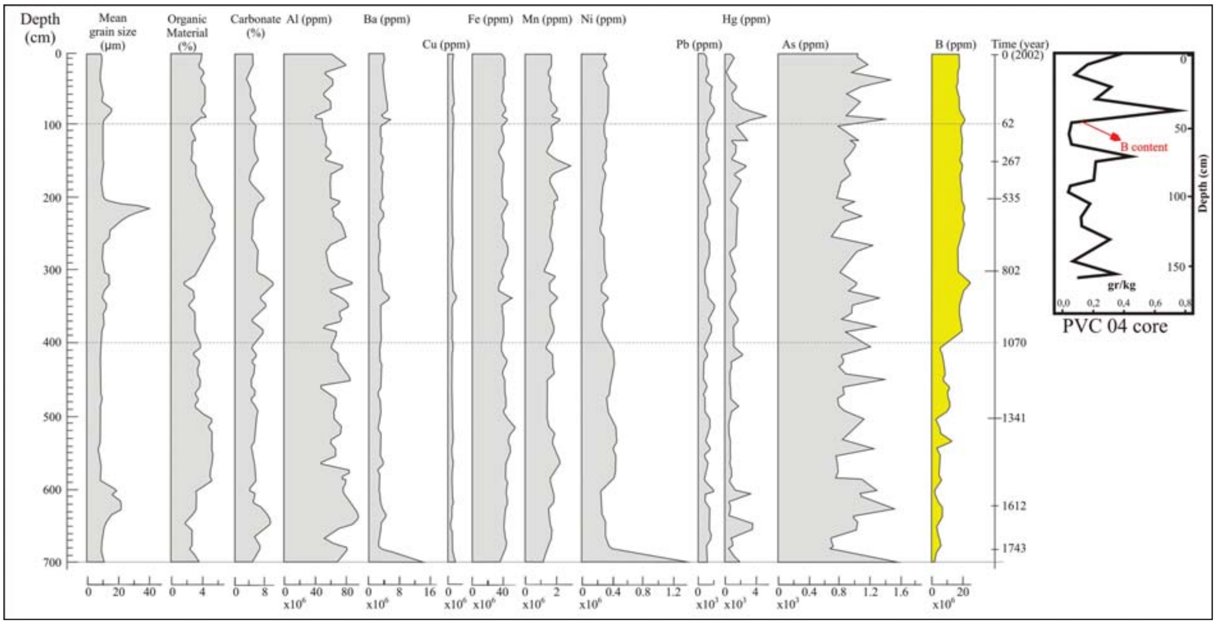

Figure 8- Grain characters of the Ulubat lake sediments and vertical distributions of some of the elements

to all other data, analyses of EİEİ and DSİ have also been taken into considerations (Figure 1) (EİEİ 1993; 1996; 2000). In short all available data have been collected to evaluate the hydrologic, sedimantologic and climatologic characters of the SDB. In recent years numbers of large and small dams have been constructed so the amount of sediments transported into the lakes has decreased. The total amount of material the Kocasu River transports is estimated to be 464,950 ton/year, and the eroded amount is 115 ton/year/km^2. Same estimations for Mustafakemalpaşa Stream (MKP) are; 1,258,143 ton/year and 167 ton/year/km^2 (EİE 1993; Kazancı et al., 2004).

SDB could be divided into four morphological areas. First one is the alluvium plains acting as pre sedimentation basin before rivers reach the final discharge point, the Marmara Sea. Manyas-Karacabey plains are situated in the area morphologicaly known as Southern Marmara Depression. It extends E-W direction, is tectonic in origin, and has been shaped and achieved their plain character by the channel floodings of the Kocaçay and MKP Stream (Emre et al., 1997 b). This depression gently slopes eastwards, the Manyas lake is situated at the west end (average elevation of the water level is 14 m) and the Ulubat Lake (average elevation of the water level is 2 m) (Figure 1). They both are shallow fresh water lakes. They used to be considered very old and tectonically developed but it has since been shown that they developed in Holocene as a result of blockage of their course (Emre et al., 1997 a).

The second morphological area is the hill side which is of eroded origin zone (slope zone) extending to the present day valley base and the plains. This zone also reflects the subject of study ‘sinking (burial) of running waters. Valley slopes have high angles. In some parts they are escarpments and have tectonic origin and in some parts they have rugged topography of ridges and hills, which are the remains of high plains. About 20-25% of the SDB is made of these kinds of areas.

Third morphological unit are the ‘erosion plains’. Erosion plains have 200-800 m elevations and their heights in general increase from north to south. Erosions developed on the basement rocks and Miocene-Early Pliocene successions. The SDB erosion plains were shaped after Early Pliocene and it could be said that regional scale ‘sinkings of running water’ have developed after this period. These plains form about 55-60% of the study area.

The fouth morphological area is the ‘high ridges-mountains’, heights on the erosion plains (Figures 1, 4, 6). This area is mostly forest covered and they form about 12-15% of the study area. Akdağ (2089 m), Şaphanedağ (2120 m), and Uludağ (2543 m) are the prominent peaks and they form the water dividing lines (Figures 1, 2).

Medium and large size valleys are situated in the hill side zone in the study area. Development age of these features will be a subject of this work. The

Simav valley, Emet valley, Orhaneli valleys are the most noticeable in the SDB and are quite alike with their slope morphologies (Figures 4, 6). Their lengths vary. For example although they have the same name the Simav Stream is longer but Simav valley is shorter (about 45 km) than others. Digital topographical data analyses show that Orhaneli Streamvalley is 220 km long; Emet Stream valley is 225 km long. The end of the two valleys is the place where the waters meet and there onwards it becomes the Mustafakemalpaşa Stream (Figures 1, 4). At the source area the elevation of the valley base of the Emet valley is 1250 m but about 30 km down the valley towards Emet town it drops down to 750 m elevation. Still, despite of this fast fallin the elevation, the average slope angle of the Emet valley is 004%.. Elevations of the valley hill sides are 1650-1250 m. Despite of the deep valleys there are no g troughs because the land is made of loose Neogene units (Figure 2).

The Bursa meteorology station reports that the 52 years average rainfall in the area is 710 mm. Based on the EİEİ's data, it has been calculated that Mustafakemalpaşa Stream carry 1.3 x 10^6 tons of suspended materials a year and erosion rate is quite high (Kazancı et al., 2004). Among these transported materials boron and some other heavy elements have been scoured from the borate deposits within the Emet valley.

5.2. Ulubat Lake sediments and their age

As it was mentioned in the previous part the subject of this study is the lake bottom sediments of the shallow Ulubat Lake (maximum depth 2.5 m). Ulubat Lake is a fresh water lake and occupies 138 km^2 areas. The Limnological characters of the lake have been studied previously (Kazancı et al., 1998; 2006; Çelenli, 2000; Toprak, 2004). Water level of the lake shows climatical variation and because of the pesticides the lake is getting increasingly polluted. There is no lake protection management. So this is speeding up eutrofication Çelenli, 2000; Dalkıran et al., 2006; Reed et al., 2008; Kazancı et al., 2010).

Sedimentation is transported to the lake by means of the Mustafakemalpaşa Stream and this river has built up a delta at the south shore (Figure 7). With the incoming material this delta is enlarging and is in the impact area of the Ulubat fault (Emre et al., 1997*b*). The amount of material transported into the lake is about 1.3 x 10^6 tons of suspended materials. Within thelast 30 years sediment accumulation in the lake floor has reached 1.6 cm/year (Kazancı et al., 2004). Materials on the lake floor are; silt bearing mud. It is bluish gray coloured and in places has abundant organic material. The drillings carried out in 2002 near to the south shore, recovered most 7.8 m long core. In 2004 10 m long cores were recovered in drillings carried out in the central part of the lake, as the drills started intercepting hard rocks so they could not advance any longer. Around the lake area Pleistocene rocks of a type unlike the lake type are present. Based on the non lake type detritial sediments encountered in the drill cores is considered to be the basement rocks of the lake floor on which the lake developed. This suggests that the maximum thickness of the deep sediments of the Ulubat Lake is about10 m.

In the above section detail information have been given on the characters of the drillings, core names, and core samples for analyses were taken at 2 cm and 10 cm. Total organic material and total carbonate contents show variations in cycles but mineralogical contents are sporadic (Figure 8). In the lake sediments evaporites and some other chemical sediments indicating closed environments have not been detected, indicating that the lake in the past was in the same condition as it is now. Pollen analyses indicate that before the lake was formed the area was marsh land for a short period. The area then acquired fresh water and the marsh developed into the lake (Kazancı et al., 2004).

The most interesting point on the subject is the sudden increase in Boron content found in the cores between 400 cm and 50 cm depths (Figure 8). The boron content is from lower parts up are on average 0.6 g/kg. At the 400 cm level it shoots up to 1.8 g/kg. The boron content decreases between 100-50 cm levels and between 50 cm-0.00 levels again show increase (Figure 8) This must be directly related to the borate deposits in the source areas.

To be able to understand the changes, depth-age model of the lake sediments has been set up (Figure 7). The age of the sediments from the upper part to 45 cm down have been determined by Pb^{210} method and have been found to be 33 years and 40 years by the Cs^{137} method, deposition rates were 1.6 cm/year and 1.48 cm/ year. At the 619 cm level, plant seeds with the ^{14}C method have given 1612± 30 years (calibrated) age and at 677 cm level, plant remains gave 1708± 25 years (calibrated) age. These values represent 0.37 cm/year (400 cm/1070 year; 1000 cm/2674 year) deposition rate. In general the oldest sediments in the lake were 2670 years old. In the same way according to the deposition rates, the dates of the 400 cm and 50 cm levels where boron contents showed sudden increase were, according to the Gregorian calendar, AD 932 and AD 1971 (Figure 7).

6. Discussion and Conclusions

Erosion and deposition rate in SDB. It has been known for over 2 centuries that climate and erosion in connection with it play important role in land forming processes, to be able to make it understandable various models have been proposed (Chorley et al., 1984, p. 19-42 and documents in it). In a particular area if sediments developed by erosions are swept away and are deposited in a particular place, then for that particular place the denudation rate could be calculated (Einsele, 1992). Major and trace element contents act as a guide to erosion-accumulation balance, so if these elements are present then reliable calculations can be made (Einsele and Hinderer, 1998).

The material eroded from the Emet valley transported and accumulated into the Ulubat Lake has high boron contents. High boron content helps to understand the role of the climatological-lithological changes in the development processes of the valley. As stated previously the age of the sediments in the Ulubat Lake, down to 45 cm from the top has been found to be 33 years (or according to the sampling date 2004-33 = 1971) and age of the sediments at 400 cm level has been found to be 1070 years (as a date (2004-1070 =934). The year 1971 (33 years old) coincides with the intensive open pit borate mining activities in the source areas. This time connection explains the relation of high boron contents in the Emet Stream with the open pit borate mining, causing sudden increase in the boron content in the deposited materials in the lake. This topical approach could be extended to the sudden boron increases 400 cm of depth cores. At present borate deposits are about 15 m above the valley base. This approach indicates that during last 1070 years borate deposits have been abraided 15 m down from the upper most elevation (Figure 9). From this, abrasion rate of the rivers within the borate deposits has been calculated to be (1500 cm/1070 year) 1.4 cm/year.

This abrasion rate calculated for the most recent part of the Emet Stream valley may be found quite high for the wide intervalled geological events, but there are examples of relatively short periods in the literature (Clayton, 1998; Einsele and Hinderer, 1998; Wilson et al., 2003).

Taking the calculated abrasion rate and the lithological succesion into consideration it has been calculated that it has taken 75,000 years of abrasion for the valley to become 650 m deep as it is to day. In

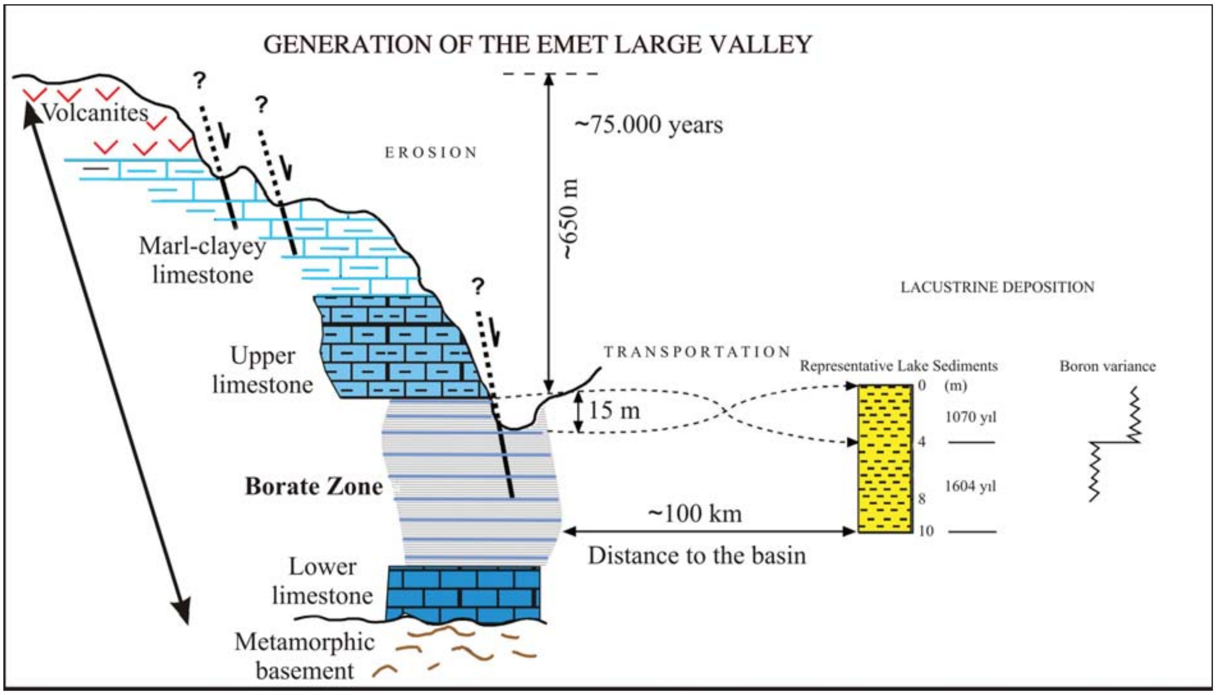

Figure 9- Generation processes of the Emet valley and the age.

the Emet area the borate-bearing Neogene succession in the upper parts have relatively eosion-resistant limestones with silica intercalations (Figure 9). The Schmidt hammer tests conducted on these limestone samples showed that these limestones were at least twice more erosion-resistant than the borate-bearing units. This indicates that the erosion rate of the silicified limestones was half rate of the others (0.7 cm/year), in other words they were eroded twice as late. Geological studies show that with foldings and repetitions the thickness of the limestones is estimated to be at most 400 m (Helvacı and Firman, 1977; Helvacı, 1986). When necessary calculations are made (400 m/0.7 cm/year), the abrading age of the resistant successions has been found to be 57,000 years. The remaining borate-bearing succession with volcanics (about 250 m thick) with the normal abrading rate would be about 16,500 years. With all these calculations the valley has processed its development within 73,000 - 75,000 years (Figure 9). In these calculations it is assumed that erosion continued uninterrupted right through. This point is discussed in the next section.

Incision age of the Emet River valley. The Resistance of rocks to mechanical loads can easily be measured by various methods in the laboratories (2 and 3 axis stress tests) and in the field (Schmidt hammer). The data obtained from these tests are taken into consideration when studying the engineering structures. In general hard rocks have higher mechanical resistance. But resistance being high or low does not necessarily mean that it is more or less resistant or resistant to the natural erosion (abrasion). Natural erosion resistance depends on various parameters, among those ‘slope angle’; ‘climate’; ‘rain type’ are most important (Ghorley et al., 1984; Selby, 1994). In a particular area natural erosion can be expressed indirectly with ‘erosion or transported sediment load’. On this subject ‘transportation of a unit amount of sediment load from a unit area’ can be very meaningful (Selby, 1994). Emet Stream in its course downstream joins the MKP Stream. The erosion caused by the Emet Stream and MKP Stream(=swept sediment load from a unit area) with 167 ton/year/km^2 which is relatively quite a high value. Even half of this value is considered to be quite high erosion rate for narrow strech of lands (Selby, 1994).

Radiometric dating carried out on the core samples recovered from the lake showed that the emplacement age of the Ulubat Lake is 2670 years and average deposition rate of deposits has been found to be 0.37 cm/year. The variation of boron contents in the lake sediments has a direct connection with the erosion rate in the borate deposits in the resource area. From this connection abrasion rate in the Emet Valley (1.4 cm/year) which is about 4 times more than the deposition rate in the lake. It was supposed that, within the same drainage system, deposition would be equal to the erosion rate. But as the Ulubat Lake is an open lake, so it is now believed that large amount of material is re-transported to the Marmara Sea. This is how the differences can be explained.

The SDB is characterised with the presence of numerous valleys, because of this, topography in the district is rather rugged. It is in fact one of the most rugged land in the Northwestern Turkey (Figures 4, 6). V-type valleys and sharp ridges are the reason of the Neogene units covering large areas. The presence of numerous shallow and deep valleys in the region clearly shows that in the regional geomorphic system erosion was highly effective. This can be seen more clearly in studying the areal photographs and in field works. Most important of all is to know the erosion period and the reasons for trigering this much erosion. Conditions in the study area (drainage) was carried in one stream only. The presence of boron ion and variations on its abundancy, dating of the Ulubat Lake sediments, abrading of the borate successions on the Emet valley floor made it possible to calculate the rate of abrasion. In the previous part with retrospective calculation of the erosion rate, generation and development age of the 650 m deep Emet valley was found to be 75000 years. The handicap in this calculations is that it was assumed that erosions continued regularly at the same rate, like non stop sawing. Changing climatical conditions, movements on the interface and general floor levels, tectonics, anthropogenic effects would change abrasion rates. On the other hand however much there may be some missing points in the calculations generation age would not be taken any further than 300,000 years back from Middle Pleistocene. Otherwise it would not be possible to explain the accumulation rate in the lakes.

From the records of the EİEİ observation stations in the area, erosion-deposition rates in the area are quite well known. These informations could be generalized for the entire Southern Marmara region. For example, stratigraphy of the sediments in the Ulubat Lake is similar to those in the İznik Lake as it is in the Manyas Lake (Leroy et al., 2002; Ülgen et al., 2012). On the other hand within a wide period interval it is not possible to know at what intervals and speeds erosions have developed. Excessively high and low temperatures, torrential rains, floods, hurricanes, etc may cause replacement of large amount of materials, but they are not long-lasting events and they do not represent the whole of the erosion time. Various age determinations showed that during the ice age in various parts of Anatolia rates of erosions and accumulations showed many variations (Landmann et al., 1996; Eastwood et al., 1999; Fortugne et al., 1999). So it is possible to say that large-scale valleys within relatively wide span of time interval (last 300,000 years) developed with varying erosions rates. What is certain is that, in Western Anatolia during the last 20,000 years, erosion rates have increased and changed considerably. It is noticeable that Prehistorical cultural remains for example tools made of stones are rarely found in Turkey, less than expected (leaving aside that excavations for these items are not as much as it should be) it is probable these items were subjected to high rate erosions and transportations. Many of the stone-made hand axes were probably carried away from their original sites and were buried under the lake and/or under sea sediments.

The SDB area basal elevations of the medium and large valleys are between 600 – 700 metres (Figures 5, 6). Depths of the valleys are at least that much. In most places they exceeds 1000 m and these deep valleys are quite close to the sea (Figures 1, 4 – 6). Considering the necessary erosion-transportation balance it is difficult to explain the develoment of valleys with a base close to the sea level with the present day morphology. It should be considered that during the last ice age and the period before that the Marmara Sea was a small closed lake (Smith et al., 1995; Aksu et al., 1999; Çağatay et al., 2000). That means the base level was much lower than what it is to day. When the previous landforms before the valley had developed are considered with reference to their base, they are 2500 – 3000 m lower now. Because of this height difference the Emet valley and their equals have been deeply abraided. At the present time sea level/base level elevation ratio is at maximum, so relative the abraiding rate is at minimum. Even then still abrasion rate is still 1.4 cm/year. It is understandable that erosion rate in the past was higher.

Are the valleys abraiding in the SDH related to the tectonic or to the climate? It is known that erosion-transport-deposition dynamics act according to a known base/ base level ratio, abrasion does not go below this level. Leaving some exceptional cases aside, reasons for deep abrasions (= base level dropping down) when either climate or tectonics being more effective (Chorley et al., 1984), increase in the sea level (= base level) cause drawning (flooding) of the running water valleys with alluvium (abrasions are reduced at the base but it can cause lateral abrasion). When this point is considered, the water level in the Marmara Sea is the base level for SDB, so it could be concluded that water level in the Marmara Sea is effective in the development of the valleys. In the Marmara depressions there are overlapping delta successions, these show that water level was very changeable, indicating that they went down to the basin's floor (Sorlien et al., 2012). Seismological records show that Kocasu Çayı followed a large submarine canyon at -85 m level and discharged its water into a lake in Çınarcık basin. This may show that during the last ice age deep abrasions must have caused the level of the SDB lakes to deepen. On the other hand seismological records also indicate extensive mass movements along the northern shore of the Marmara Sea. In this part, slope instabilities are related to seismic activities (Görür and Çağatay, 2010). An important point is if long lasting water level changes in the Marmara Sea are related to the tectonic or to the climate, this point should be explained.

There has been general agreement that terraces in the Marmara Sea were built by tectonic forces (Sakınç and Yaltırak, 1997; Kazancı et al., 2003). According to seismic data, the most extensive terrace area is at -85 m level and it is seen almost everywhere. Its development age is reported to be 11.000 years (Sorlien et al., 2012). Continuation of this to the deeper parts, in the south of the Çınarcık and Central Marmara pull-apart basins where the presence of a series of deltas has been discovered (Sorlien et al., 2012). These must have been built by the sediments transported from the SDB during the period while the shelf was outside and/or the water level was low. So it is clear that, waters sweeping the SDB have been discharged into the basins, developed during this deposition period along the NAF zone. As a result a 6 km thick basin fills has developed (Sorlien et al., 2012). This devopment of deltaic successions one on top of another reflects changes of water levels. At the same time this much of a thick accumulation of infill could also indicate sinking of the basin floor, in another words reflecs tectonic subsidence. Tectonics provided accumulation basins for the large amount of material transported from the SDB where deep valleys developed. Generations of the sediments have developed under the control of local and global climate changes and to the changes of the sea levels.

In summary; the high number of earthquakes having taken place shows that the study area is located in a tectonically active region (Soysal et al., 1981; Ambraseys and Finkel, 1991; Ambraseys, 2009). Abrupt height changes in the field, hanging valleys, land distortions indicate that tectonics were also effective in the past. But the effects of these tectonic activities on the evolution of the landforms have not been directly measurable. It is common that tectonics trigger mass movements and back space the hill sides. SDB is a place where almost all geomorphologic elements (lithology, climate, tectonics, erosion etc.) can be observed. In Early Neogene the İstanbul and Çanakkale straights had not developed yet, but the Southern Marmara region had large plains sloping gently towards the Black Sea. Following the development of the Marmara Sea, particularly during the last 300,000 years the Southern Marmara region, the study area, has been its subjected to great many changes and has acquired present day form. In these changes easily eroding lithologies and climate effects have been the main agents.

Acknowledgement

Large numbers of earthscientists and organizations gave support during 1995-2005 and we are very grateful to all who contributed. The data obtained have been used in this study. This was a part of a joint project with DPT (State Planning Organization) - TUBİTAK (Scientific, Technic Research Organization of Turkey) – University. Within the scope of a sea research project: geological mapping of the Neogene and Quaternary units in the Southern Marmara region, study of sea shore sediments, long and short term sea level changes in the Çayırova and Hersek plains, tsunami research and limnologic study of the Ulubat Lake have been carried out (TUBİTAK-YDABÇAĞ. 456/G, 598/G, 103Y102). MTA actively participated in the studies and gave valuable support. NATO gave support to the drillings in the Lake (EST.CLG.978645). GYTE gave support and numerous lake sediments were analysed by SEM, XRF, XRD, AAS methods without any charge. Some trace elements analyses were carried out at the Brunel University with financial support from NATO (NATO-CLG 978645).

Large numbers of researchers and university students took part in the above mentioned projects; while they were working on their research they gave support to this project by suggesting some ideas. Dr. Alper Gürbüz (N.Ü) helped drawing some of the figures and read the manuscript and gave some suggestions. Two referees and the Bulletin editor made some critical remarks and helped to improve the final text. Authors acknowledge gratefully all individual and organizational supports provided.

Received: 06.08.2013
Accepted: 30.10.2013
Published: June 2014

References

Aksu, A.E., Hiscott, R.N., Yaşar, D. 1999. Oscillating Quaternary water levels of the Marmara Sea and vigorous outflows into the Aegean Sea from the Marmara Sea-Black Sea drainage corridor. *Marine Geology* 153, 275–302.

Ambraseys, N. 2009. Earthquakes in the Mediterranean and Middle East; a Multidisciplinary Study of Seismicity up to 1900. *Cambridge University Press*, ISBN 978-0-521-87292-8.

Ambraseys, N., Finkel, C. 1991. Long-term seismicity of Istanbul and the Marmara Sea region. *Terra Nova* 3, 527-539.

Ardel, A. 1943. Marmara bölgesinin güneydoğu havzalarının morfolojik karakterleri. *Türk Coğrafya Dergisi* 2, 160-171.

Baş, H. 1987. Tavşanlı - Domaniç (Kütahya) volkanitlerinin özellikleri ve batı Anadolu Senozoyik volkanizmasındaki önemi. *Türkiye Jeoloji Bülteni* 30, 67-80.

Bingöl, E., Akyürek, B., Korkmazer, B. 1973. Biga Yarımadasının jeolojisi ve Karakaya Formasyonunun bazı özellikleri. *Cumhuriyetin 50. Yılı Yerbilimleri Kongresi Tebliğleri Kitabı*, s. 70-76, Ankara.

Chorley, R.J., Schumm, S.A., Sugden, D.E. 1984. Geomorphology. Methuen, London, 605 s.

Clayton, K. M. 1998. The rate of denudation of some British lowland landscapes. *Earth Surface Processes and Landforms* 22, 721-731.

Çağatay, M.N., Görür, N., Algan, O., Eastoe, C., Tchapalyga, A., Ongan, D., Kuhn, T., Kuscu, I. 2000. Last glacial-Holocene palaeoceanography of the Sea of Marmara: timing of last connections with the Mediterranean and the Black Seas. *Marine Geology* 167, 191-206.

Çelenli, A. 2000. Uluabat Gölü Çevre Jeokimyası. *İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul, Doktora Tezi* (unpublished).

Dalkıran, N., Karacaoğlu, D., Dere, S., Şentürk, E., Torunoğlu, T. 2006. Factors affecting the current status of a eutrophic shallow lake (Lake Uluabat, Turkey): Relationships between water physical and chemical variables. *Chemical Ecology* 22, 279-298.

Darkot, B., Tuncel, M. 1981. Marmara Bölgesi coğrafyası. *İstanbul Üniversitesi Coğrafya Enstitüsü Yayını*, No 118, İstanbul.

Eastwood, W. J., Roberts, C. N., Lamb, H. F., Tibby, J.C. 1999. Holocene environmental change in southwest Turkey; a palaeoecological record of lake and catchment-related changes. *Quaternary Science Reviews* 18, 671-695.

EIE, 1993. Türkiye Akarsularında Sediment Gözlemleri ve Sediment Taşınım Miktarları. *EIEI Genel Müdürlüğü*, Yayın no 87-44, Ankara.

EIE, 1996. Türkiye Akarsularında Su Kalitesi Gözlemleri. *EIEI Genel Müdürlüğü*, Yayın no 96-4, Ankara.

EIE, 2000. Türkiye Akarsularinda Suspanse Sediment Gözlemleri ve Sediment Taşınım Miktarları. *EIEI Genel Müdürlüğü*, Yayın no 20-17, Ankara.

Einsele, G. 1992. Sedimentary Basins: Evolution, Facies and Sediment Budget. *Springer*, Berlin, 628 pp.

Einsele, G. Hinderer, M. 1998. Quantifying denudation and sediment accumulation systems (open and closed lakes): basic concepts and first results. *Palaegeography, Palaeoclimatology, Palaeoecology* 140, 7-21.

Emre, Ö., Erkal, T., Kazancı, N., Görmüş, S., Görür, N., Kuşçu, I. 1997*a*. Güney Marmara'nın Neojen ve Kuvaterner'deki morfotektoniği. İç: Güney Marmara Bölgesinin Neojen ve Kuvaterner Evrimi (Ed. N.Kazancı ve N. Görür), Araştırma Projesi sonuç raporu. TUBITAK, YDABCAG-426/G, Ankara, s. 36-68.

Emre, Ö., Kazancı, N., Erkal, T., Karabıyıkoğlu, M., Kuşçu, İ. 1997*b*. Ulubat ve Manyas Göllerinin oluşumu ve yerleşim tarihcesi. Iç: Güney Marmara Bolgesinin Neojen ve Kuvaterner Evrimi (Ed. N.Kazancı ve N.Görür), *Araştırma Projesi Sonuç Raporu*. *TÜBITAK*, YDABCAG-426/G, Ankara, s. 116-134.

Emre, Ö., Erkal, T., Tchapalyga, A., Kazancı, N., Keçer, M., Ünay, E. 1998. Doğu Marmara Bölgesi'nin Neojen ve Kuvaterner'deki evrimi. *Maden Tetkik ve Arama Dergisi* 120, 119-145.

Emre, Ö., Özalp, S., Doğan, A., Özaksoy, V., Yıldırım, C., Göktaş, F. 2005. İzmir yakın çevresinin diri fayları ve deprem potansiyelleri. *MTA Raporu*, No 10754, Ankara (unpublished).

Emre, Ö., Doğan, A. 2010. 1/250.000 Ölçekli Türkiye Diri Fay Haritası, Ayvalık (NJ 35-2) paftası, *Maden Tetkik ve Arama, Türkiye Diri Fay Haritası Serisi*, no 2, 32 s. Ankara.

Emre, Ö., Doğan, A., Özalp, S. ve Yıldırım, C. 2011*a*. 1/250.000 Ölçekli Türkiye Diri Fay Haritası, Bandirma (NK 35-11B) paftası. *Maden Tetkik ve Arama, Türkiye Diri Fay Haritası Serisi*, no 3, 55 s. Ankara.

Emre, Ö., Doğan, A., Özalp, S. 2011*b*. 1.250.000 Ölçekli Türkiye Diri Fay Haritası, Balıkesir (Nj 35-3) paftası. *Maden Tetkik ve Arama, Türkiye Diri Fay Haritası Serisi*, no 4, 35 s. Ankara.

Emre, Ö., Duman, T.Y., Özalp, S. 2011*c*. 1/250.000 Ölçekli Türkiye Diri Fay Haritası, Kütahya (Nj 35-4) paftası. *Maden Tetkik ve Arama, Türkiye Diri Fay Haritası Serisi*, No 4, Ankara.

Emre, Ö., Duman, T.Y., Özalp, S. 2012. Türkiye 1/250.000 ölçekli diri fay haritası. *Maden Tetkik ve Arama Genel Müdürlüğü*, Ankara.

Ercan, T., Ergül, E., Akçaören, E., Çetin, A., Granit, S., Asutay, J. 1990. Balıkesir Bandırma arasının jeolojisi, Tersiyer volkanizmasının petrolojisi ve bölgesel yayılımı. *Maden Tetkik ve Arama Dergisi* 110, 113-130.

Erdoğan, T. 1988. Balıkesir İklim Etüdü. Devlet Meteoroloji İşleri Genel Müdürlügü, Ankara.

Ergül, E., Öztürk, Z., Akçaören, F., Gözler, M.Z. 1980. Balıkesir ili – Marmara Denizi arasının jeolojisi. *Maden Tetkik ve Arama Genel Müdürlüğü Raporu*, no 6760, Ankara (unpublished)

Erinç, S. 1955. Orta Ege Bölgesi'nin jeomorfolojisi. *Maden Tetkik ve Arama Genel Müdürlüğü Raporu* No: 2217 (unpublished).

Erinç, S. 1973. Türkiye'nin şekillenmesinde neotektoniğin rolü ve jeomorfoloji-jeodinamik ilişkileri. *Jeomorfoloji Dergisi* 5, 11-26.

Erol, O. 1981. Neotectonic and geomorphological evolution of Turkey. Z. Geomorph. N.F. Suppl. Bd, 40, 193-211.

Fontugne, M., Kuzucuoğlu, C., Karabıyıkoğlu, M., Hatté, C., Pastre, J. F. 1999. From Pleniglacial to Holocene: a 14C chronostratigraphy of environmental changes in the Konya Plain, Turkey. *Quaternary Science Reviews* 18, 573-591.

Görür, N., Çağatay, N. 2010. Geohazards rooted from the northern margin of the Sea of Marmara since the late Pleistocene: a review of recent results. *Natural Hazards* 54, 583-603.

Gözler, M.Z., Ergül, E., Akçaören, F., Genç, Ş., Akat, U., Acar, Ş. 1985. Çanakkale Boğazı doğusu – Marmara Denizi güneyi – Bandırma – Balıkesir – Edremit ve Ege Denizi arasındaki alanın jeolojisi ve kompilasyonu. *MTA Raporu*, no 7430, Ankara (unpublished).

Helvacı, C. 1984. Occurrence of rare borate minerals: veatchite-A, tunnellite, terrugite and cahnite in the Emet borate deposits, Turkey: *Mineral Deposita* 19, 217-226.

Helvacı, C. 1986. Geochemistry and origin of the Emet borate deposits, western Turkey. Bulletin of the Faculty of Engineering, Cumhuriyet University, Serie A- *Earth sciences* 3, 49-73.

Helvacı, C., Firman, R.J. 1977. Emet borat yataklarının jeolojik konumu ve mineralojisi. *Jeoloji Mühendisliği Dergisi* 2, 17-28.

Helvacı, C., Alonso, R.N. 2000. Borate deposits of Turkey and Argentina; a summary and geological comparison. Turkish Journal of Earth Sciences 24, 1-27.

Kazancı, N., Bayhan, E., Suliman, N., Sahbaz, A., Ileri, Ö., Özdogan, M., Temel, A., Ekmekçi, M. 1997.

Manyas Gölü ve Güncel tortullari. Iç: Güney Marmara Bolgesinin Neojen ve Kuvaterner Evrimi (Ed. N.Kazancı ve N.Görür), Araştırma Projesi sonuç raporu. *TÜBITAK*, *YDABCAG-426/G*, Ankara, s. 192-238.

Kazancı, N., Görür, N. (Ed), 1997. Güney Marmara Bölgesi'nin Neojen ve Kuvaterner Evrimi. Deniz Araştırmaları Programı, Araştırma Projesi Sonuç Raporu. *TÜBITAK, YDABCAG-426/G*, Ankara, 240 s (unpublished).

Kazancı, N, Ileri, O., Suliman, N., Özdoğan, M., Bayhan, E., Şahbaz, A., Gencer, A, Ergin, M., Erkmen, C. 1998. Ulubat Gölü'nde guncel tortullasma. İç: Marmara Denizi Güneyi Kıyı ve Kıyı Ardı Istiflerinin Stratigrafisi, Sedimantolojisi ve Morfotektonigi. *TÜBITAK Raporu*, YDABCAG – 598/G, pp. 99 - 145.

Kazancı, N., Emre, Ö., Erkal, T., Ileri, Ö., Ergin, M., Görür, N. 1999. Kocasu ve Gönen Çayı deltalarının (Marmara Denizi güney kıyıları) güncel morfolojileri ve tortul fasiyesleri. *MTA Dergisi* 121: 1-18.

Kazancı, N., Kırman, E., Emre, Ö., Keçer, M., İleri, Ö., Doğan, A., İslamoğlu, Y., Alçiçek, M.C., Varol, B., Erkal, T., Ertutaç, K., Uysal, F., Özalp, S., Gül, A., Duman, T.Y. 2003. Doğu Marmara Kıyılarında Denizel Geç Kuvaterner Tortulları Ve Deniz Seviyesi Değişimleri. Deniz Araştırmaları Programı Araştırma Projesi Sonuç Raporu, Proje No: *TÜBITAK- YDABÇAG* 100 Y 077. Ankara, 117s (unpublished).

Kazancı N., Leroy S. A. G., Ileri O., Emre O., Kibar, M., Öncel, S. 2004. Late Holocene erosion in NW Anatolia from sediments of Lake Manyas, Lake Ulubat and the southern shelf of the Marmara Sea, Turkey. *Catena* 57, 277-308.

Kazancı N., Toprak, Ö., Leroy S. A. G., Öncel S., Ileri Ö., Emre Ö., Costa P., Erturaç, K. ve McGee E. 2006. Boron content of Lake Ulubat sediment: a key to interpret the morphological history of NW Anatolia, Turkey. *Applied Geochemistry* 21, 234 - 251.

Kazancı, N., Leroy, S. A. G., Öncel, S., İleri, Ö., Toprak, Ö, Costa, P., Sayılı, S., Turgut, C., Kibar, M. 2010. Wind control on deposition of heavy metals: the case study of Lake Ulubat in Anatolia, Turkey. *Journal of Paleolimnology* 43, 89–110.

Landmann, G., Reimer, A., Lemcke, G., Kempe, S. 1996. Dating Late Glacial abrupt climate changes in the 14,570 yr long continuous varve record of Lake Van, Turkey. *Palaeogeography, Palaeoclimatology, Palaeoecology* 122, 107-118.

Leroy, S.A.G., Kazancı, N., Ileri, Ö., Kibar, M., Emre, Ö., McGee, E., Griffiths H.I. 2002. Abrupt environmental changes within a late Holocene lacustrine sequence south of the Marmara Sea (Lake Manyas, N-W Turkey). *Marine Geology* 190, 531-552.

MTA, 2002. 1/500 000 Ölçekli Türkiye Jeoloji Haritaları, İstanbul ve İzmir paftaları. *Maden Tetkik ve Arama Genel Müdürlüğü*, Ankara.

Okay, A.İ. 2008. Geology of Turkey: A synopsis. *Anschnitt* 21, 19-42.

Okay, A.I., Siyako, M., Burkan, K.A. 1991. Biga Yarımadasının jeolojisi ve tektonik evrimi. *Türkiye Petrol Jeologları Derneği Bülteni* 2, 83-121.

Pamir, H. N. 1938, İstanbul Boğazı'nın teşekkülü meselesi. *Maden Tetkik ve Arama Dergisi* 3-4, 61-68.

Reed, J. M., Leng , M. J., Ryana, S., Black, S., Altınsaçlı¸ S., Griffiths, H.I. 2008. Recent habitat degradation in karstic Lake Uluabat, western Turkey: A coupled limnological – palaeolimnological approach. *Biological Conservation* 141, 2765-2783.

Sakınç, M., Yaltırak, C. 1997. Güney Trakya sahillerinin denizel Pleyistosen çökelleri ve Paleocoğrafyası. *MTA Dergisi* 119, 43-62.

Selby, M.J. 1994. Hillslope sediment transport and deposition. İç: Pye K. (Ed) Sediment Transport adn depositiona Processes. *Blackwell Pub.*, *London*, s. 61-88.

Smith, A.D., Taymaz, T., Oktay, F., Yüce, H., Alpar, B., Başaran, H., Jackson, J.A., Kara, S., Şimşek M. 1995. High-resolution seismic profiling in the Sea of Marmara (northwest Turkey): Late Quaternary sedimentation and sea-level changes. *Geological Society of America Bulletin* 107/8, 923-936.

Sorlien, C.C, Akhun, S.D., Seeber, L., Steckler, M.S., Shillington, D.J., Kurt, H., Çifçi, G., Poyraz, D.T., Gürçay, S., Dondurur, D., İmren, C., Perinçek, E., Okay, S., Küçük, H.M., Diebold, J.D. 2012. Uniform basin growth over the last 500 ka, North Anatolian Fault, Marmara Sea, Turkey. *Tectonophysics* 518–521, 1–16.

Soysal, H., Sipahioğlu, S., Kolçak, D., Altınok, Y. 1981. Earthquake Catalogue of Turkey and its Surrounding, BC2100-AD1900. Tech. Sci. Res. Council of Turkey (*TUBITAK*), Project Rep. No 341, Ankara (in Turkish).

Şaroğlu, F. Emre, Ö., Boray, A. 1987. Türkiye'nin diri fayları ve depremselliği. *Maden Tetkik ve Arama Genel Müdürlüğü Raporu* No: 8174 (unpublished).

Toprak, Ö. 2004. Ulubat Gölü tortullarının organik madde ve ağır metal içeriği. Yüsek Lisans Tezi, *Gebze Yüksek Teknoloji Enstitüsü*, Gebze, Kocaeli, 117 s (unpublished).

Turgut, C. 2005. Ulubat Gölü çökellerinde ve göl suyunda metal konsantrasyonlarının incelenmesi. Yüksek Lisans tezi, *Gebze Yüksek Teknoloji Enstitüsü*, Gebze, Kocaeli, 92 s (unpublished).

Ülgen, U.B., Franz, S.O., Biltekin, D., Çağatay, M.N., Roeser, P.A., Doner, L., Thein, J. 2012. Climatic and environmental evolution of Lake İznik (NW Turkey) over the last ~ 4700 years. *Quaternary International* 274, 88-101.

Wilson, C.G., Matisoff, G., Whiting, P.J. 2003. Short-term erosion rates from an inventory balance. *Earth Surf. Proc. Landforms* 9, 967-977.

Yalçınkaya, S., Avşar, Ö.P. 1980. Mustafakemalpaşa (Bursa) dolayının jeolojisi. *Maden Tetkik ve Arama Raporu* Derleme no: 6717, Ankara (unpublished).

Yılmaz, Y., Gökaşan, E., Erbay, A.Y. 2010. Morphotectonic development of the Marmara Region. *Tectonophysics* 488, 51-70.

Yılmaz, Y., Gürpınar, O., Genç, S.C., Bozcu, M., Yılmaz, K., Şeker, H., Yiğitbaş, E., Keskin, M. 1990. Armutlu Yarımadası ve civarının jeolojisi. *TPAO Raporu*, no 2796, 210 s, Ankara (unpublished).