REPUBLIC OF TURKEY

MUĞLA SITKI KOÇMAN UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF GEOLOGICAL ENGINEERING

GEOLOGICAL PROPERTIES OF MASS WASTING OF ELMALI FORMATION (EOCENE-MIOCENE; MUĞLA-SW TURKEY)

MASTER OF SCIENCE

SELÇUK ORAK

JUNE 2017

MUĞLA

S. ORAK DEPARTMENT OF GEOLOGICAL ENGINEERING MASTER OF SCIENCE MUĞLA 2017

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APPROVAL OF THE THESIS

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Selçuk ORAK

16/06/2017

ABSTRACT

GEOLOGICAL PROPERTIES OF MASS WASTING OF ELMALI FORMATION (EOCENE-MIOCENE; MUĞLA-SW TURKEY)

Selçuk ORAK

Master of Science (M.Sc.)

Graduate School of Natural and Applied Sciences

Department of Geological Engineering

Supervisor: Prof.Dr. Murat GÜL

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This thesis study was carried out in order to determine the factors affecting the development of mass movements observed within the Elmalı Formation (Upper Lutetian-Lower Burdigalian) within Muğla province. While mass movements were reported in this unit to the east of Fethiye district, no movement was reported in the area between Dalaman and Fethiye. Although there have been various investigations on the spreading of Elmalı Formation and the mass movements of the Eşen basin, there has been no detailed study of types, spreads and causes of mass movements.

Apart from the usual engineering geology applications, the effects of general geological-sedimentological features on the unit were investigated. The position, slope and direction of the layers were investigated by field studies, observations were made on river and surface waters, samples were collected for laboratory analyses and detailed measurements were made on representative samples. In the direction of discontinuity measurements made in the field, rose diagrams were created and the principal stress directions of the unit were determined.

In addition, engineering experiments with XRF, XRD, thin section investigations were carried out in the laboratory to classify the grounds in the study area. By making the slope map of the region, the types and reasons of the mass movements observed in the unit were tried to be explained, and the features of the mass movements observed and not observed were evaluated comparatively.

As a result, In the studies conducted in the Çeştepe quarter which is the region of Dalaman, only the translational landslide and creep could be observed as the movement type. However, the studies conducted in Seydikemer district; no movement was observed in the Girmeler quarter, which was attributed to the fact that the natural topography was not disturbed and the slope was so low as not to cause mass movement. Only the rotational landslide was seen in the Karabıyık district while creep, earth flow and rotational slip were observed in Bayır district. In the Dereköy region, mass movements were observed in some places as earth flow and in some places as creep and translational landslide. The main reasons for these movements are evaluated as; topography, surface and underground waters, human influence, and the unit's own lithofacies characteristics.

Keywords: Elmalı Formation, Dalaman, Fethiye, Seydikemer, Landslides

ÖZET

ELMALI FORMAYONU KÜTLE HAREKETLERİNİN JEOLOJİK ÖZELLİKLERİ (EOSEN-MİYOSEN; MUĞLA-GB TÜRKİYE)

Selçuk ORAK

Yüksek Lisans Tezi

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Jeoloji Mühendisliği Anabilim Dalı

Danışman: Prof. Dr. Murat Gül

Haziran 2017, 113 sayfa

Bu tez çalışması, Muğla ili dahilinde Elmalı Formasyonu (Üst Lütesiyen-Alt Burdigaliyen) içinde gözlemlenen kütle hareketlerinin gelişimini etkileyen unsurların belirlenmesi amacıyla yapılmıştır. Fethiye ilçesinin doğusunda bu birim içerisinde kütle hareketleri raporlanmışken, Dalaman-Fethiye arasında kalan bölgede ise birim içerisinde herhangi bir hareket raporlanmamıştır. Elmalı Formasyonunun yayılımı ve kütle hareketlerinin raporlandığı Eşen havzası ile ilgili çeşitli araştırmalar olsa da, kütle hareketlerinin tipleri, yayılımları ve nedenleriyle ilgili detay bir çalışma bulunamamıştır. Çalışmada alışılageldik mühendislik jeolojisi uygulamaları dışında genel jeolojik-sedimantolojik özelliklerin birim üzerindeki etkileri araştırılmıştır.

Arazi çalışmaları ile tabakaların konumu, eğim-doğrultuları irdelenmiş, akarsu ve yüzey sularıyla ilgili gözlemler yapılmış, laboratuvar analizleri için örnekler derlenmiş, temsili örnekler üzerinde detay ölçümler gerçekleştirilmiştir. Arazide yapılan süreksizlik ölçümleri doğrultusunda gül diyagramlar oluşturularak birimin asal gerilme yönleri belirlenmiştir.

Ayrıca İnceleme alanındaki zeminlerin sınıflandırılması için laboratuvarda XRF, XRD, ince kesit incelemeleri ile mühendislik deneyleri yapılmıştır. Bölgenin eğim haritası çıkarılarak, birimde gözlenen kütle hareketlerinin tipleri ve nedenleri ortaya konulmaya çalışılmış, kütle hareketi gözlenen ve gözlenmeyen kısımların özellikleri karşılaştırmalı olarak değerlendirilmiştir.

Sonuç olarak, Dalaman ilçesinin Çeştepe mahallesinde yapılan çalışmalarda, hareket türü olarak translasyonal heyelan ve sünme (krip) gözlemlenmiştir. Seydikemer ilçesindeki çalışmalarda ise; Girmeler mahallesinde doğal topografyanın bozulmaması ve eğimin kütle hareketine yol açmayacak kadar düşük olması nedeniyle herhangi bir hareket gözlemlenmemiştir. Karabıyık Mahallesinde sadece rotasyonal heyelan görülürken Bayır mahallesinde sünme (krip), toprak akması ve rotasyonal heyelanlar gözlenmiştir. Dereköy bölgesinde de, bazı yerlerde toprak akması şeklinde kütle hareketleri görülürken, bazı yerlerde sünme (krip) ve translasyonal heyelanlar gözlemlenmiştir. Bu hareketlerin başlıca sebepleri; topoğrafya, yüzey ve yeraltı suları, insan etkisi ve birimin kendi litofasiyes özellikleri olarak değerlendirilmiştir.

Anahtar Kelimeler: Elmalı Formasyonu, Dalaman, Fethiye, Seydikemer, Heyelanlar

To my family,

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LIST OF ABBREVIATIONS

ABEP	Afet Bilgi Envanteri Projesi (Disaster Information Inventory Project)
AFAD	T.C. Başbakanlık, Afet ve Acil Durum Yönetim Başkanlığı (Republic of Turkey, Prime Ministry, Disaster and Emergency Management)
GEKA	T.C. Güney Ege Kalkınma Ajansı (Republic of Turkey, Southern Aegean Development Agency)
ISRM	International Society for Rock Mechanics
MTA	Maden Tetkik ve Arama (General Directorate of Mineral Research And Exploration
NASA	The National Aeronautics and Space Administration
UCS	Uniaxial Compressive Strength
USCS	Unified Soil Classification System
USGS	United States Geological Survey
YÖK	Yükseköğretim Kurulu (Council of Higher Education)

1.INTRODUCTION

Mass movements are one of the important factors that provide resources to the crushed sedimentary rocks. Mass movements cause significant sedimentary deposits both under atmospheric conditions and under water. Topographically, materials of various sizes derived from the rocks that are degraded by physical-chemical-biological processes in high fields are moved to the storage environment by moving them with the carrier agents. Mass movements can develop rapidly or slowly in excavation areas opened by human beings on the high or low slopes of the Earth (Erguvanlı, 1995).

Many studies have been carried out on the reasons of mass movements, the mechanisms of formation, and the ways that must be observed in the works. The large-scale ones are weighted using remote sensing techniques and geographic information systems. (Erguvanlı, 1995; Gökçeoğlu and Ercanoğlu, 2001; Çan et al., 2013. Hungr et al., 2014). Studies on the characterization of a landslide in a region are based on detailed lithological studies, kinematic analyses and deformation measurements. (Öz, 2009; Alemdağ et al., 2014). Landslide is a general term applied to all modes of downslope movement of a mass of soil and rock material such as slides, debrisflows, rockfalls, topples etc. (Yanrong et al., 2012). The stability of the slopes on the earth depends on the lithological properties of the rocks, the water contents, the discontinuities affecting the slope, the amount of load and the erosion of the toe (Erguvanlı, 1995).

Landslides mainly occur by combination of geological, morphological, human interaction and physical factors, are most commonly triggered by precipitation, but earthquake- and volcano-triggered landslides have killed more people than all other types of landslides combined (Brabb,1984; Duman et al., 2009). Mass movements are considered difficult to predict events. It is seen as an important natural hazard because it causes loss of life and property from time to time (Erguvanlı, 1995).

Mass movements that allow the development of sediments from block size to clay size are referred to by names like flow, fall, side and avalanche, depending on the type and speed of the moving material. (Erguvanlı, 1995). Mass movements are the type of disaster that causes the greatest number of casualties in the World among natural disasters, and it has been reported that about 8,000 people per year are lost their lifes (Ersoy, 2014).

In the Landslide inventory prepared by the MTA, SW- Anatolia is reported as one of the most landslide risky regions. (Duman et al., 2009). In these studies, evaluations were made using slope map and landslide information previously reported in the area.

However, detailed features of the landslides in the Elmalı Formation have not been mentioned. With the first reports of 1964, this region was declared a disaster area, especially Dereköy and its surroundings (Fethiye, Muğla, Figure 1.1.), and the decided to relocation of the village. In the following years, if the work done by both the MTA and the AFAD in relation to the risks in the region were found, the detail features of the region were not mentioned.

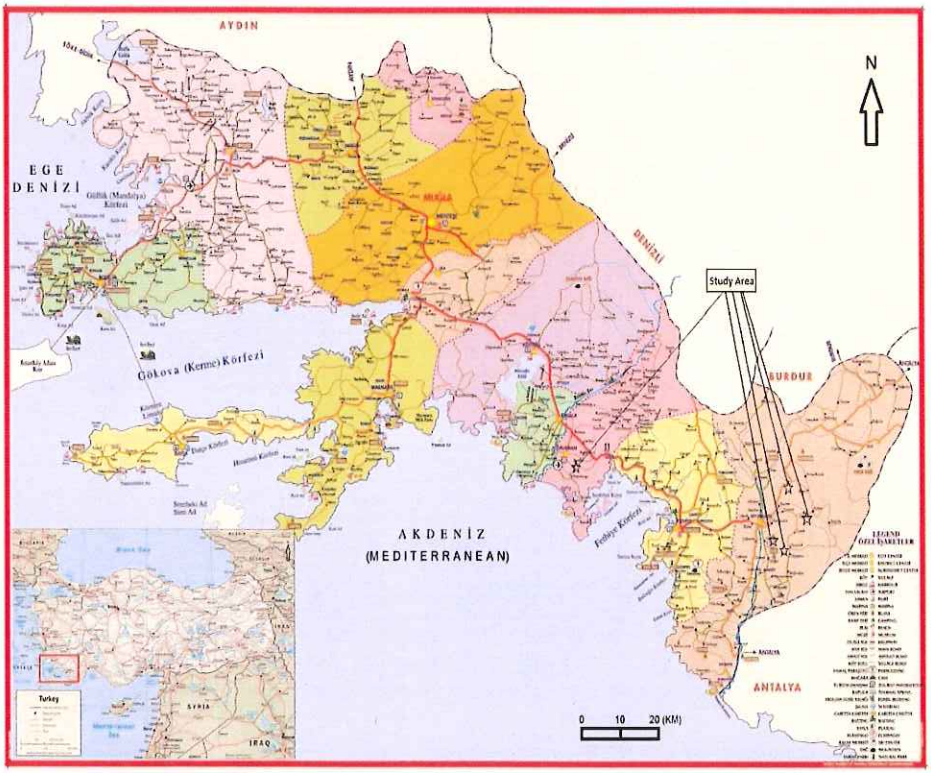


Figure.1.1. Location map of the study area (Modified from the map of the Provincial Culture and Tourism Directorate of Muğla, Access date:15.01.2017)

1.1. Purpose and Scope

This thesis study focuses on the lithological properties of the Elmalı Formation, the investigation of the mass movements observed within the unit and the determination of the general geological features affecting the development of these movements. The Elmalı Formation is classified as a member of the Yeşil Barak Nappe in the Lycian Nappes (Şenel, 1997a).

The mass movements within the unit have been assessed in the 1 / 500.000 scale Turkey Landslide Inventory Map, which is prepared by the MTA and assessed active and passive landslides prepared by the MTA in the project of "Mugla Province Fethiye District Disaster Hazard Analysis in 2013" prepared by the Provincial Disaster and Emergency Directorate of MUĞLA (GEKA, 2013).

With in the unit, especially in the Eşen Valley, it is stated that there are flows and breaks in the parts where the old units unevenly or tectonically overlap. However, detailed information about the types of mass movements in the unit, propagation, factors controlling the formation of movements are not included in the studies by other researchers.

The scope of the thesis is to investigate the development and spread controlling general geological factors of the Upper Lutetian – Lower Burdigalian Elmalı Formation's mass movement where is outcropping in the district of Dalaman, Fethiye and Seydikemer in Mugla Province (Figure 1.2). The key objectives to be achieved within the thesis are; to investigate the general geological properties of the Elmalı Formation (petrographic, lithological), to reveal the geochemical properties of it, to reveal the engineering geology characteristics of the unit, to classify mass movements, and to determine the factors controlling mass movements.

1.2. Geographical Settings of the Study Area

The study areas are located in Fethiye, Seydikemer and Dalaman, which are districts of Muğla Province (SW Turkey). It is the center of the district the same name, as

well as of Muğla Province, which stretches along Turkey's Aegean coast (Figure 1.2).



Figure 1.2. Location map of Fethiye-Dalaman-Seydikemer and surrounding area (Modified from the Google Earth, Access date:24.03.2017)

Fethiye is a city and district of Muğla Province in the Aegean region of Turkey with about 147000 inhabitants (2016) (Figure 1.2). The surface area is 3059 km². It has been the largest area including Muğla province since 2012. The eastern and southeastern provinces of Antalya are surrounded by southern, southernand western Mediterranean, north-western Dalaman, northern Denizli and Burdur (Fethiye Kaymakamlığı, http://www.fethiye.gov.tr/, Access date: 24.03.2017)

Dalaman is located between Köyceğiz, Ortaca and Fethiye districts of the same province and Çameli district of Denizli province in the Mediterranean Region (Figure 1.2). The eastern, northern and western parts of districts are mountainous, the south is flat. The height of district center is 15 m from sea level. According to the results of the 2015 General Population Census of the province with an area of 61,694

hectares; The total population is 37406 (Dalaman Kaymakamlığı, http://www.dalaman.gov.tr/, Access date: 24.03.2017). Çeştepe district is the detaily studied region in Dalaman district.

Seydikemer is one of the 13 districts of Muğla. With the law numbered 6360, which was adopted in the Grand National Assembly of Turkey on 12 November 2012, the Kemer Quarter located in the Fethiye district was transformed into a district and the name changed to Seydikemer (Fig1.2.). According to the year 2015 data, the total population of the region is 60,000 people. (Seydikemer Kaymakamlığı, http://www.seydikemer.gov.tr/, Access date: 24.03.2017). Bayır, Dereköy, Girmeler and Karabıyık are the detaily studied districts in Seydikemer district.

1.2.1. Geomorphology of the study area

The region is divided into two in morphological sense due to E-W directed tectonic line around Fethiye. The Northern part consists of high plateaus and mountains extending in NE - SW trending belts, while the remaining coastal part consists of mountainous – hilly tectonic blocks and depressions between these tectonic blocks (Doğu, 1988).

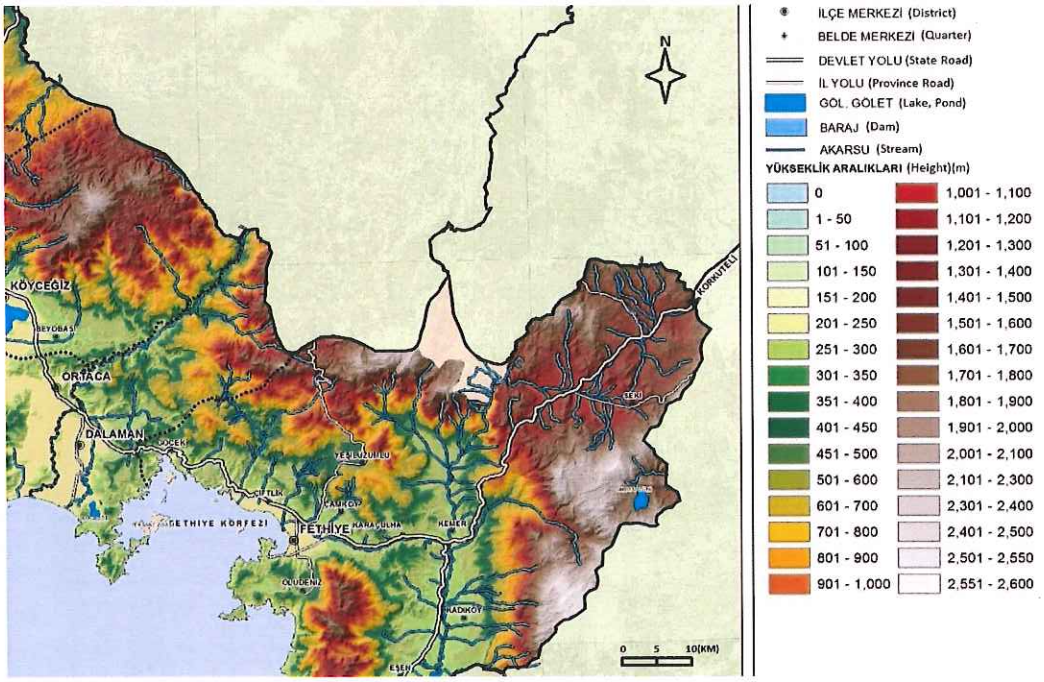


Figure 1.3. Topographical map of Fethiye-Dalaman-Seydikemer and surrounding area (AFAD, 13.01.2011)

The Sandıras Mountain (2295 m.); located between the Namnam and Dalaman Streams, is shaped by tectonic movements, which have been effective since the Miocene end and continued during the Fourth time. The surfaces of the Miocene erosion are found in various elevations in pieces. Mesozoic aged peridodites and serpentines are located on the top of the eruption lying between 1000-1300 m. 2000 m. Several glacial forms developed under the influence of theWürm glaciers in the areas above (Figure 1.3; Doğu, 1998).

The mountainous belt extending in the direction of NE between the Dalaman stream and the Eşen stream begins with the ridges and hills formed on the ophiolites in the north of Fethiye and continues as high mountainous terrain composed of Mesozoic limestones. Although the height of this main ridge of this high and continuous mountain range lies at 1750 m, the height of the broadsprings and tilted peaks rising above it exceeds 2000 meters. Çal Mountain has 2185 meters, Boncuk Mountain has 2418 meters, Yaylacık Mountain has 2114 meters' upgrade.

In this southern hillsides over looking the Gulf of Fethiye, this mountainous valley contains small karstic depression plains such as Nif Plain, Gedre Plain and Üzümlü Plain at 900 meters. Babadag (1960 m) that is rising to the south of Fethiye with a stepfault patch gives a magnificent mountain view because it rises immediately by the sea. The Mesozoic limestones descend to the sea level in this mountainous mass where they are partly flattened (Doğu, 1988). Fethiye - Kemer highway crossing over the threshold, there are over 250 meters high. This threshold, formed on the ophiolites, increases from the area to the north, and the area where the limestone is out is passed.

The Eşen Stream valley, located to the east of Muğla, brings a very wide tectonic groove with a N-S line, the extensions of the Dumanlıdağ and Akdağ from the west to Babadağ (Göçmen, 1977). This tectonic formation has formed a delta with the accumulation of the alluviums that the Eşen River had settled on the base of the Mediterranean Sea, and the ancient Letoon city and Patara Harbor were filled with the development of this delta (Figure 1.4.) (Öner, 1997).

The coastal part, which lies to the south of the E – W directional tectonic line extending from the Bodrum area to Fethiye, consists of mountainous – hilly tectonic blocks and depressions between these tectonic blocks.

The Koycegiz and Dalaman depressions, which were opened between these blocks, were turned into varies as a result of the fact that they were filled with alluviums. And so recent valleys have formed (Figure 1.4).

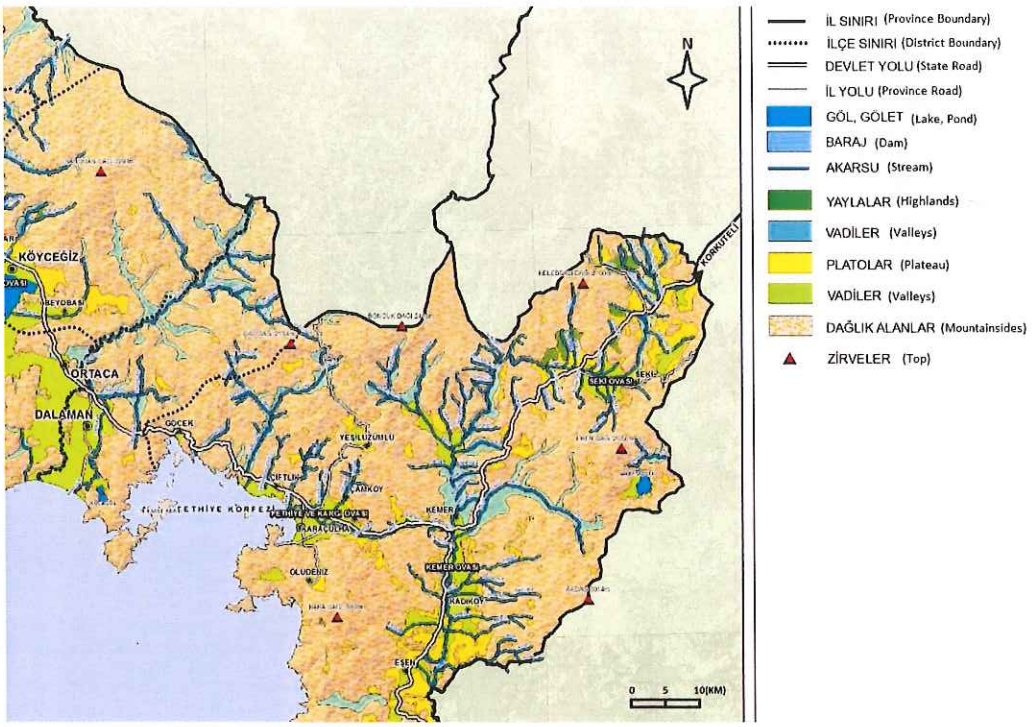


Figure 1.4. Geomorphological map of Fethiye-Dalaman-Seydikemer and surrounding area (AFAD, 13.01.2011)

With the climate oscillations in the Quaternary and local tectonic events, these depressions started to fillup rapidly and the gulf has turned into Köyceğiz Lake by bringing a set of deltas developed by Dalaman River around Dalyan. During the years of M.S.500, the Dalaman Stream developed its delta by changing bed sand flowing in the direction of the present Dalaman Plain (Doğu, 1988). Fethiye Plain, located to the east of Fethiye Gulf, is 5-6 km. The tectonic lines (faults) are formed by the filling of the gulf with the material brought by the small streams and flood waters descending from the high estuaries around the plain. There are two distinct coastal terraces and there is a 2 m terrace corresponding to the Nice level in Fethiye where there is a second terrace with a distinctive steepness from it (Tuncel et al., 1973).

1.2.2. Climate and vegetation cover of the study area

Mediterranean climate prevails in Muğla. Summers are hot and dry, winters are warm and rainy. As you go inward from the shore, the climate of the land is affected and the temperature drops. There is no snow on the coast. On the inside, you can see snow for 1-2 days. The temperature is between + 43.7 °C and -12.6 °C. The amount of rainfall varies between 775 mm and 1180mm.

The city of Fethiye, which has a warm and mild climate, there is much more precipitation in the winter than in the summer months. According to Köppen-Geiger climate classification, it can be called Csa-Mediterranean climate. The average annual temperature of the Fethiye district is 17.7°C. August is the hottest month in Fethiye with an average temperature of 28°C (83°F) and the coldest is January at 10°C (51°F) with the most daily sunshine hours at 13 in June. The wettest month is December with an average of 124.4 mm of rain. The best month to swim in the sea is in August when the average sea temperature is 27°C (80°F) (Figure.1.5).

The total annual rainfall is 983 mm (https://tr.climate-data.org/location/26353/;http://www.holiday-weather.com/fethiye/averages/, Access date: 24.03.2017).

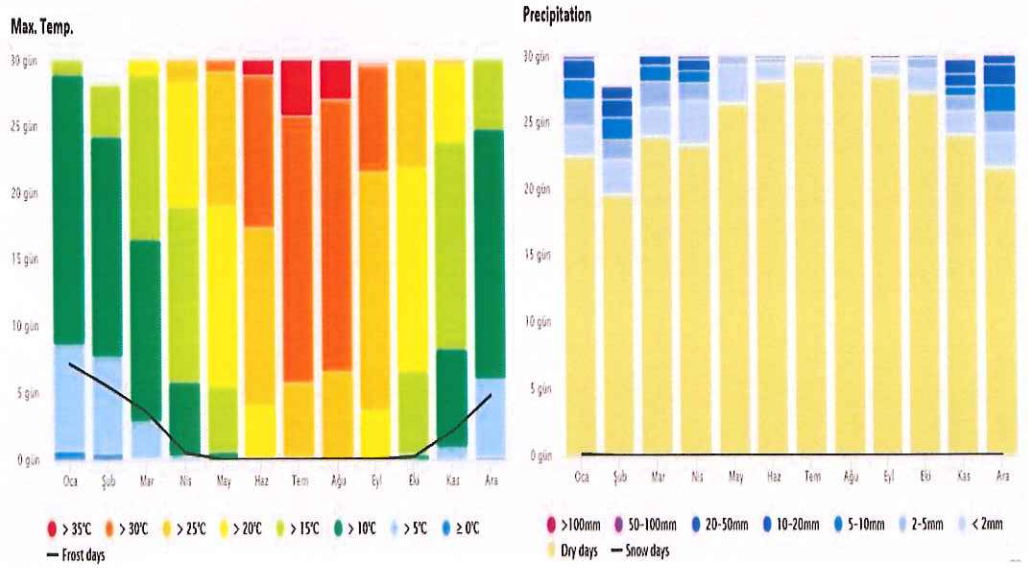


Figure 1.5. Fethiye's temperature and precipitation graphics.
(www.meteoblue.com/tr/hava/tahmin/modelclimate/, Access date: 24.03.2017)

The city of Dalaman has a warm and temperate climate. In the winter months, there is much more precipitation than in the summer months. According to Köppen-Geiger the climate is Csa-Mediterranean climate. The average annual temperature of Dalaman is 18.1 ° C. July is the hottest month in Dalaman with an average temperature of 26°C (79°F) and the coldest is January at10°C (50°F) with the most daily sunshine hours at 13 in July (Figure.1.6). The wettest month is December with an average of 233 mm of rain.

The best month to swim in the sea is in August when the average sea temperature is 26°C (79°F). The total annual rainfall is 1018 mm (https://tr.climate-data.org/location/19315/;http://www.holiday-weather.com/dalaman/averages/) (Access date: 24.03.2017).

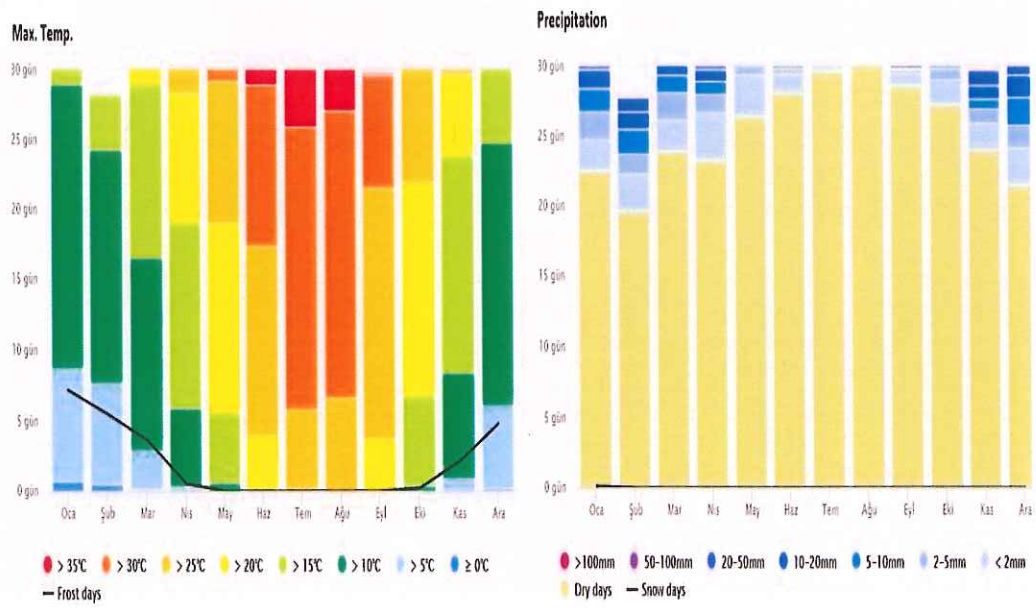


Figure 1.6. Dalaman's temperature and precipitation graphics.

(www.meteoblue.com/tr/hava/tahmin/modelclimate/, Access date: 24.03.2017)

The city of Seydikemer has a warm and temperate climate. In the winter months, there is much more precipitation than in the summer months. According to Köppen-Geiger climate classification, it can be called Csa-Mediterranean climate. The average annual temperature of Seydikemer is 17.3°C. August is the hottest month in Seydikemer with an average temperature of 28°C (83°F) and the coldest is January at 10°C (51°F). The total annual rainfall is 902 mm (Figure.1.7) (https://tr.climate-data.org/location/468915/ Access date: 24.03.2017).

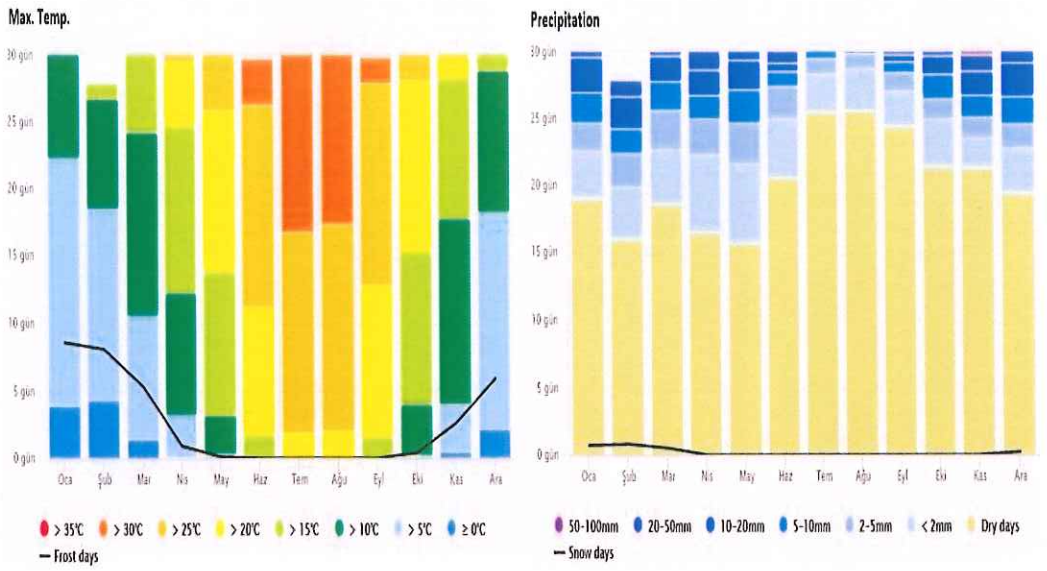


Figure 1.7. Seydikemer's temperature and precipitation graphics.

(www.meteoblue.com/tr/hava/tahmin/modelclimate/, Access date: 24.03.2017)

If we take a look at the vegetation cover of Muğla Province, nearly 75% of the province is covered with forests and bushes. The forests are lush and fertile. Most of the mountains are covered with forests, and the coastal slopes are covered with masks. In the forests there are mostly reddish, larch, pistachio, cedar, juniper and fragrant "everyday" trees which are rare in the world. There are many plane trees, willow and cypress trees on the valley and the water. 4.5% of the province's soil is covered with meadow and mars and 16% is planted with planted areas (http://www.cografya.gen.tr/tr/mugla/iklim.html, Access date: 24.03.2017).

2. MATERIALS AND METHODS

The thesis comprises several different work packages; (1) Desk studies, (2) Field studies, (3) Petrographic studies, (4) Geochemical analysis including XRF and XRD, (5) Geophyscial studies, (6) Laboratory analysis to determine engineering characteristics of Elmalı Formation Units.

2.1. Desk Studies

In the process of office work, studies related to regional geology and work topic have been compiled by compiling YÖK Thesis site, MTA Magazine, Publications of Chamber of Geological Engineers and Universities, Reports of General Directorate of Disaster Affairs and similar reports and foreign articles. All the data obtained from the field and laboratuary studies were brought together and detailed lithological features, structural features, facies differentiation of Elmalı Formation were determined and lateral and vertical distributions of these facies were determined. The types of mass movements in the Elmalı Formation, their propagation and the effects that cause them are determined and interpreted. Attempts have been made to reveal the differences in the observed and unobserved massmovements within the unit.

2.2. Field Studies

Within the scope of the master thesis studies belonging to the Geological Properties of Mass Wasting of Elmalı Formation, 8-day field investigation and observation studies were carried out. In order to determine the lithological characteristics of the unit within the scope of the field studies sedimanter sections were measured and the necessary facies were searched and samples were collected for laboratory analyses.

The lateral and vertical distribution of the unit and its relation to other units have been studied. 22 samples were taken from Girmeler, Karabıyık, Bayır and Dereköy quarters of the Seydikemer district and sent to the laboratory to carry out necessary analyses (Table.2.1).

Detailed cross-sectional measurements were made in the study areas, line-length measurements were made for kinematic analyses, fracture-crack measurements were made and measurements were made on common fracture-crack types and main fracture lines. During the fieldwork, equipment such as geologist hammer, compass, lupe, tapemeasure, gps device and schmidt hammer have been used.

Table.2.1. Samples obtained from the study area and the experiments carried out

SAMPLE NO.	LOCATION	COORDINATE (EUR 50)	SAMPLE PROPERTY	XRD	XRF	THIN SECTION	ENGINEERING EXPERIMENTS
FGS-1	Girmeler	35 713613D/ 4052256K	Fine-grained Sandstone (Litharenite)			X	X
FGS-2	Girmeler	35 713536D/ 4052247K	Dolostone			X	X
FKS-1	Karabıyık	35 715484D/ 4052049K	Sandstone (Litharenite)			X	X
FKS-2	Karabıyık	35 715484D/ 4052049K	Claystone-Siltstone	X	X		X
FKS-3	Karabıyık	35 715484D/ 4052049K	Medium-grained fossiliferous Sandstone (Litharenite)			X	X
FKS-4	Karabıyık	35 715500D/4052113K	Grey-Green Colored Claystone-Siltstone	X	X		X
FKS-5	Karabıyık	35 715183D/4051996K	Sandstone (Litharenite)	X	X	X	X
FBaS-1	Bayır	35 715784D/ 4065906K	Laminated medium grained Sandstone			X	X
FBaS-2	Bayır	35 715635D/ 4062335K	Claystone	X	X	X	X
FBaS-3	Bayır	35 715635D/ 4062335K	Fine-Medium grained Sandstone			X	X
FBaS-4	Bayır	35 715635D/ 4062335K	Fine-grained Sandstone		X	X	X
FBaS-5	Bayır	35 715635D/ 4062335K	Siltstone	X	X	X	X
FBaS-6	Bayır	35 715635D/ 4062335K	Laminated medium grained Sandstone		X	X	X
FDS-1	Dereköy	35 725366D/ 4059608K	Medium grained Sandstone			X	X
FDS-2	Dereköy	35 725366D/ 4059608K	Claystone	X	X		X
FDS-3	Dereköy	35 725366D/ 4059608K	Fine-Medium grained Sandstone			X	X
FDS-4	Dereköy	35 725366D/ 4059608K	Fine grained Sandstone			X	X
FDS-5	Dereköy	35 725366D/ 4059608K	Claystone	X	X		X
FDS-6	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone	X	X		X
FDS-7	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone	X	X	X	X
FDS-8	Dereköy	35 721995D/ 4060729K	Fine grained Sandstone			X	X
FDS-9	Dereköy	35 721995D/ 4060729K	Claystone	X	X		X

2.3. Petrographic Studies

Petrographic examinations of the thin section samples obtained from **16** samples were made. Thin sections were prepared in MTA Laboratory (Table2.1). Sandstones are classified according to Pettijohn et al., 1987.

All thin sections were carefully analyzed with using the Euromex and Motic Binocular Microscope from Muğla Sıtkı KocmanUniversity, Department of Geological Engineering Mineralogy and Petrography Laboratory.

2.4. Geochemical Analysis

The main element properties of lithological units belonging to Elmalı Formation were determined by using XRF method on **12** specimens (Table2.1). XRF analysis made in Mersin University Advanced Technology Education, Research and Application Center (MEİTAM) with using the WD-XRF.

10 specimens were investigated by XRD method in order to determine the small clay minerals that could not be detected by binocular microscope in the unit exposed in the study area (Table2.1). XRD patterns were analysed in Muğla Sıtkı Kocman University, Research and Application Centre for Research Laboratories with using the Rigaku Smart Lab XRD (X-Ray Diffractometer).

2.5. Geophysical Studies

During the field studies geophysical measurements were taken from 5 different regions. Resistivity activities were carried out at two points in Çeştepe Quarter in Dalaman district, one point in Bayır Quarter in Seydikemer district and two points in Dereköy Quarter in Seydikemer district. Measurements were made using Schlumberger (Vertical Electrical Sounding) method AB / 2 = 50-120 m with Geotronic titled equipments.

2.6. Laboratory Experiments

Experiments were carried out on sandstone and claystone specimens, especially from landslide and non-landslide units, to determine the engineering properties of the unit. Experiments were carried out at the Kahramanmaraş Sütçü İmam University, Department of Geological Engineering, Engineering Geology Laboratories. Experiments and sample numbers are presented in the table below (Table.2.2).

Table.2.2. Samples used for engineering geology experiments

Type of Experiment	Lithology	Number of Experiment
Water absorption by weight and volumetric	Sandstone	11
Specific Unit Weight	Sandstone	11
Porosity	Sandstone	11
Uniaxial Compressive Strength Test	Sandstone	11
Relative Density	Claystone	10
Atterberg Limits	Claystone	10

3. PREVIOUS STUDIES

3.1. Previous Studies on Regional and Local Geology

It has been stated by Şenel (1997a, 1997b, 1997c) that Elmalı Formation was first used by Önalan (1979). Önalan (1979) used this term for Eocene-Lower Miocene sandstones and claystones between Elmalı-Kaş. It is emphasized that landslides are observed in the sections where the topography is appropriate in the unit whose thickness is reported between 400-1500 meters (Şenel, 1997a). Within the unit, fewer fossils dating to Upper Lutetian-Lower Burdigalian age were found (Şenel, 1997a). Based on the fossil content and the sedimentation that it contains, the Elmalı formation has been reported to settle on an unstable slope and basin environment (Şenel, 1997a).

When the spreading areas of the unit are examined (Şenel, 1997a), it is seen that especially in the western part of the Dalaman district and Karaağaç village, Elcik village and Sülüklüdağ in the north-western part of Dalaman district. No significant landslide area has been shown in the formation, which is usually associated with other units. Another important area where the formation is exposed is to the east of Fethiye district (Şenel, 1997b). The formation covering large areas in the NE-N-NW-W-SW of the center of Seydikemer district has been shown in various research maps that have formed landslides in Dereköy and Bağlıağaç villages (Şenel, 1997b). However, no details about them have been given by other researchers.

First of all, in order to make 1 / 25.000 scale general geological maps of the region, field geological studies were carried out by many researchers (Kaaden and Metz, 1954; Colin, 1962; Yılmaz, 1966; Graciansky, 1968, 1972; Erakman et al., 1982; Şenel, 1986; Meşhur et al., 1989; Şenel et al., 1994; Şenel et al., 1997; Bilgin et al., 1997).

Also, Collins and Robertson (1998, 1999, 2003) conducted detailed studies on tectonostratigraphy of the units of Lycian nappes. Studies have been carried out by Ersoy (1990) on the analysis of evolution and structural items of the Western Taurus-Lycian Nappes. Alçiçek (2007) investigated the terrestrial deformation developments of the Neogene units exposed in the Eşen River basin, and carried out detailed facies examinations of the units. In this way, the general geological, lithological and lithofacies features of the region have been studied by many researchers and various studies have been carried out.

3.2. Mass Movement Studies

Mass wasting, is defined as the large movement of rock, soil and debris downward due to the force of gravity. In other words, the earth's outer crust is being 'wasted' away on a 'massive' scale and falling to lower elevations. Mass movements, is one of the key elements that resources clastic sedimentary rocks. More or less slope of the Earth, mass movements can be developing as fast or slow in the excavation area was opened by people (Erguvanlı, 1995). As reviewed by Skempton and Hutchinson (1969), the history of a mass movement comprises pre-failure deformations, failure itself and post failure displacements. Many landslides exhibit a number of movement episodes, separated by long or short periods of relative quiescence (Hungr et al., 2014)

Enabling the development of mass movements until the block sizes of clay sediments of varying size range, depending on the type and speed of moving materials is referred to as creep, slide and toppling (Erguvanli, 1995). The various types of landslides can be differentiated by the kinds of material involved and the mode of movement (USGS). Generally, classification of mass movement event is classified by type of motion and the velocity of the movement (Table.3.1). Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material (USGS, https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html, Access date:02.02.2017).

Table.3.1. Classification of slope movements according to Varnes (1978) (USGS; https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html, Access date:02.02.2017)

CLASSIFICATION OF MASS MOVEMENTS						
Dominant Material	Nature of Motion	Velocity				
		Slow (1cm/yr or less)	Moderate (1km/hr or more)			Fast (5km/hr or more)
Rock	Flow					Rock Avalanche
	Slide or Fall			Rock slide		Rock Fall
Unconsolidated	Flow	Creep Solifluction	Earth flow Debris Flow	Mud flow		Debris avalanche Debris flow
	Slide or Fall		Slump		Debris Slide	

Mass movement events as seen as "Rapid" movements that can involve visible movements of material, but "Slow" movements are imperceptible except from their effects such as cracked walls and tilted trees or power poles. Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief. In low-relief areas, landslides occur as cut-and-fill failures (roadway and building excavations), river bluff failures, lateral spreading landslides, collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines. The most common types of landslides are described as follows and are illustrated in Figure 3.1 (USGS; https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html, Access date:02.02.2017).

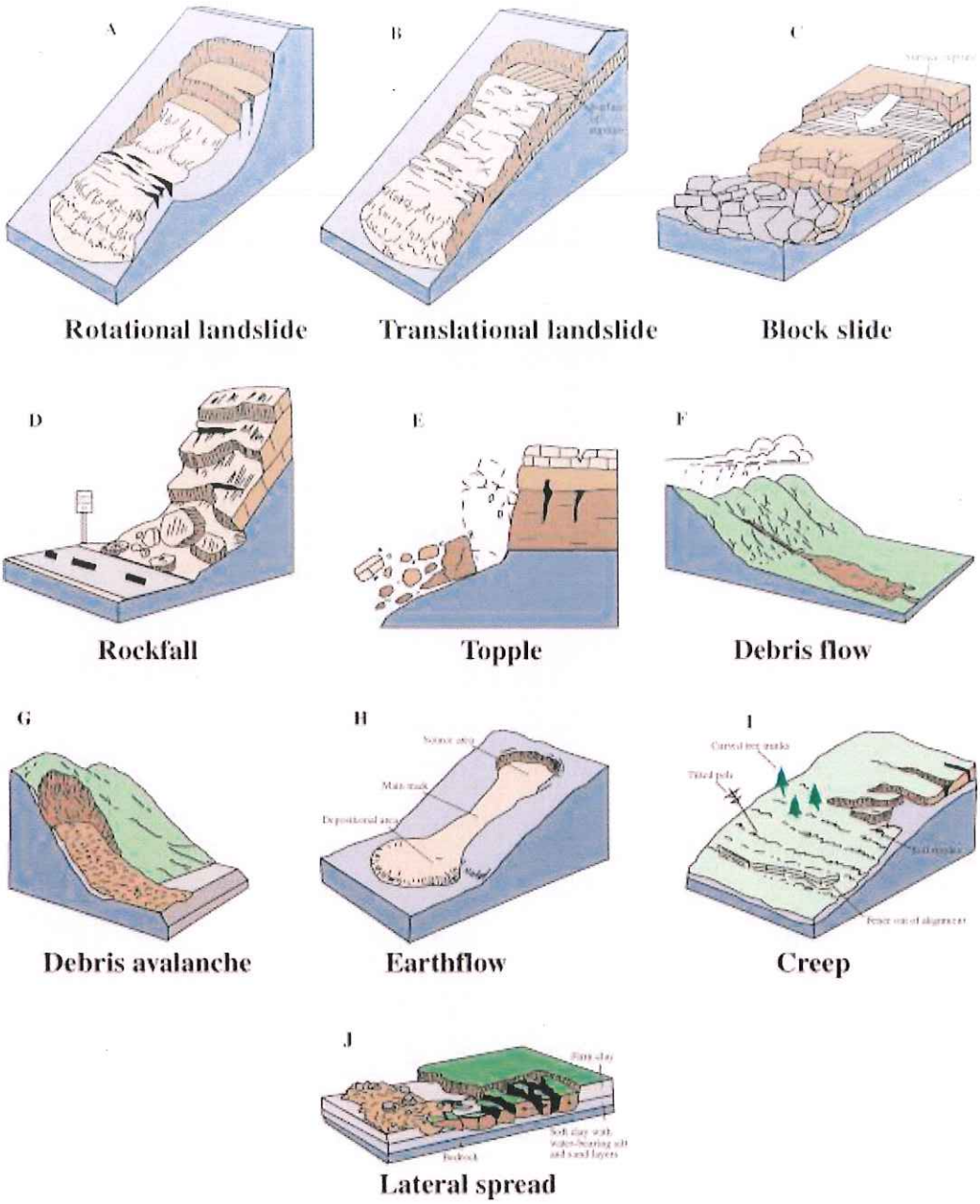


Figure 3.1. The major types of landslide movement (USGS; https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html, Access date:02.02.2017)

3.2.1. Landslides in the World

Landslides are the consequence of diverse and complex processes that probably affect every country that has topographic relief. Many move so slowly that the effects are barely discernible, others move hundreds of kilometres an hour, obliterating everything in their path.

Landslides are most commonly triggered by precipitation, but earthquake- and volcano-triggered landslides have killed more people than all other types of landslides combined (Brabb, 1984).

Tracking when and where landslides occur worldwide has historically been difficult, because of the lack of a centralized database across all nations. However, NASA researchers have published available Global Landslide Catalog, based on media reports and online databases that bring together many sources of information on landslides. NASA scientists have updated the first publicly available catalog of global rainfall-triggered landslides. Using the Global Landslide Catalog, a map has been produced to show the distribution and number of fatalities associated with 5741 rainfall-triggered landslides from 2007-2013 (Figure 3.2) (NASA; https://svs.gsfc.nasa.gov/11854, Access date:02.02.2017).

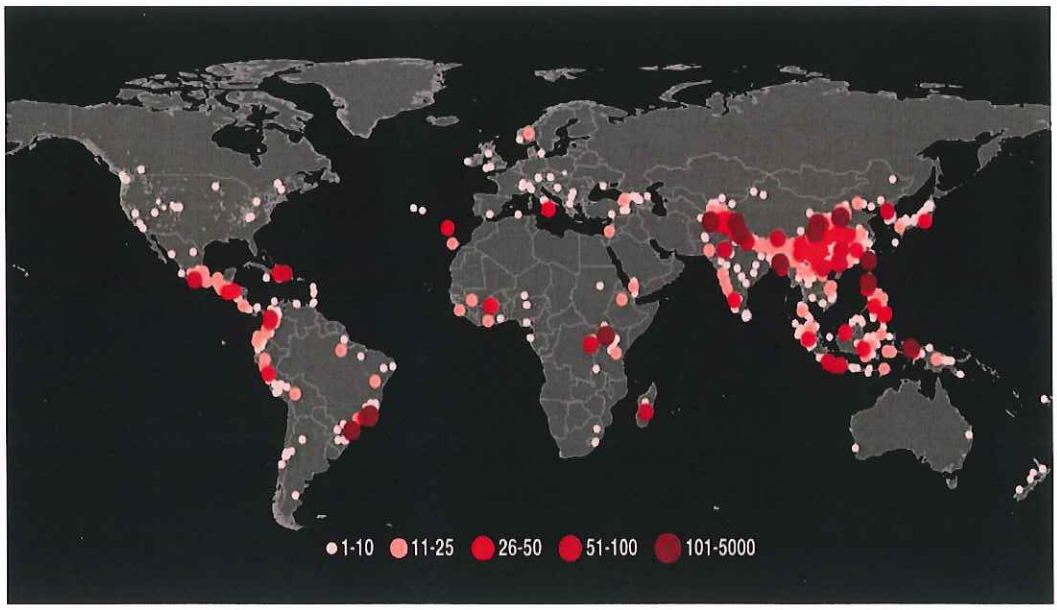


Figure 3.2. Landslide Fatalities from 2007-2013 (NASA; https://svs.gsfc.nasa.gov/11854, Access date:02.02.2017)

According to Ersoy, 2014 The distribution of life losses according to the disaster in 2014 was as follows: 1- Landslide-slip:7849, 2-Storm-typhoon:778, 3-Earthquake:644, 4-Volcano:65, 5-Tornado:51, 6-Extreme winter conditions:28 and Total:9415.

3.2.2. Landslides in Turkey

Earthquakes and landslide hazards take place in the first and second ranges in Turkey, based on the losses from all natural hazards. During the period between 1950 and 2005, by considering the evacuations of the settlements due to the natural disasters, landslides constitute 33% of all evacuations (General Directorate of Mineral Research and Exploration (MTA) landslide inventory, Duman et al. (2009). When the number of houses destructed from natural disasters in Turkey is taken into consideration, the total percentage of landslides is calculated as 10% (Table.3.2) (Ergünay, 1996).

Table.3.2. Number of destroyed houses from natural disasters in Turkey, General Directorate of Disaster Affairs (Ergünay, 1996)

NATURAL DISASTER TYPE	NUMBER OF DEMOLISHED UNITS	PERCENTAGE OF TOTAL
Earthquakes	495,000	76
Landslides	63,000	10
Floods	61,000	9
Rock Fall	26,500	4
Avalanche Fall	5,154	1
TOTAL	650,654	100

Landslides in Turkey are natural disaster events that frequently occur in the Central and Eastern Anatolia Regions, especially in the Black Sea Region. According to the archive information of the General Directorate of Disaster Affairs, 63,000 houses have been relocated and moved to safer places during this period (Ergünay, 1996).

There are three provinces, Trabzon, Kastamonu and Zonguldak, which have the highest risk of landslide in Turkey (Figure 3.3). In the period between 1958 and 2000, 4250 settlement units were affected from the landslides or possible landslides that occurred in Turkey and as a result, 197 people lost their lives (Gökçe, 2008).

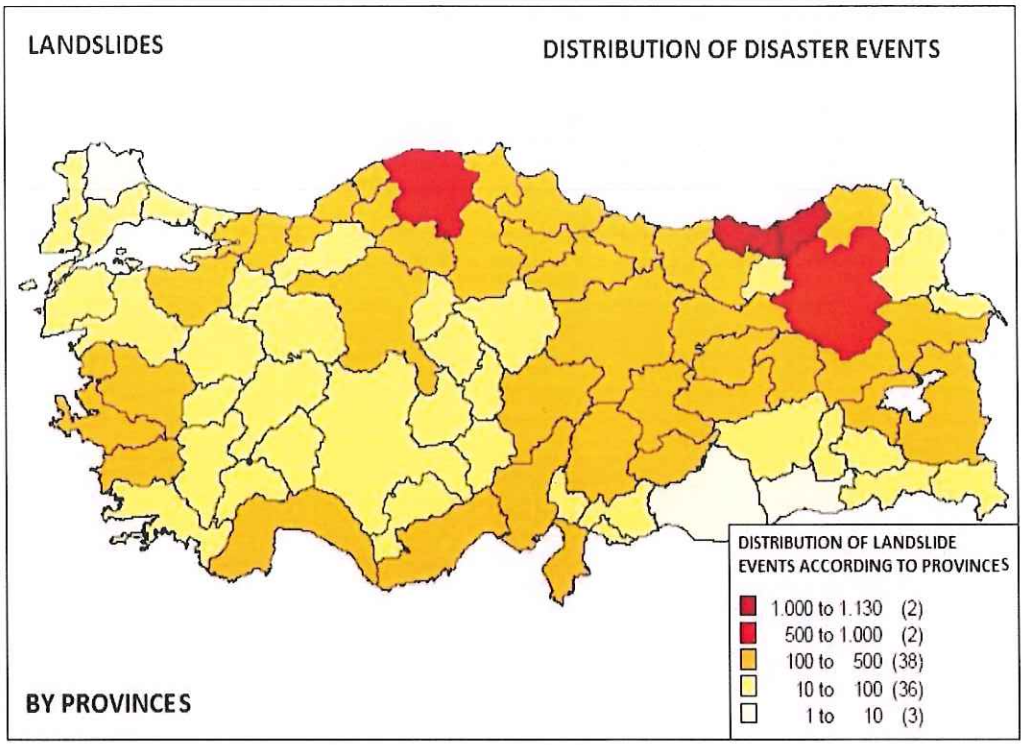


Figure 3.3. Distribution of landslide events according to provinces in Turkey (Gökçe, 2008)

To be able to reveal the spatial and statistical distribution of disaster events in our country, to provide a reference source covering the disasters that have been happening since 1950 in Turkey, to provide convenience in technical staff, office and land examinations, "Disaster Information Inventory Project" (ABEP) was carried out in order to observe the material and moral damages of disasters (Gökçe, 2008).

According to this; The total number of disaster affected by the earthquake is 158,241 and it has a share of 55% according to disaster types; The total number of disaster affected by landslides is 59,345 and it has a share of 21% compared to disaster types; The total number of disaster affected by floods is 22.157 and it has a share of 8% according to disaster types; The total number of disaster affected by rock falls is 19.422 and it has a share of 7% according to disaster types; The total number of disaster affected by the avalanche is 4,384 and it has a share of 2% according to disaster types. 5472 of the 35741 settlements (provincial, district centres, towns, municipalities and villages) in our country registered in the AFAD database, 15,31% of all settlement units were landslide events (Gökçe, 2008).

3.3. Available Geological Surveys and Disaster Affected Areas in Study Area

The Elmalı Formation which planned to examine the thesis is known that is a unit undergoes various types of mass movement. These formations were recognized in the Yeşil Barak Nappes (Şenel, 1997a). Mass movements in the unit, research by "Muğla Governorship Provincial Disaster and the Emergency Management which is 2013 dated Muğla Province Fethiye District Disaster Hazard Analysis" project, depends on MTA prepared by the assessment of active and passive landslide 1 / 500,000 scale was assessed with reference also to Turkey Map for Landslide Inventory (GEKA,2013). The report also intersects with residential areas was emphasized that the features of the Elmalı Formation unit should be examined in more detail.

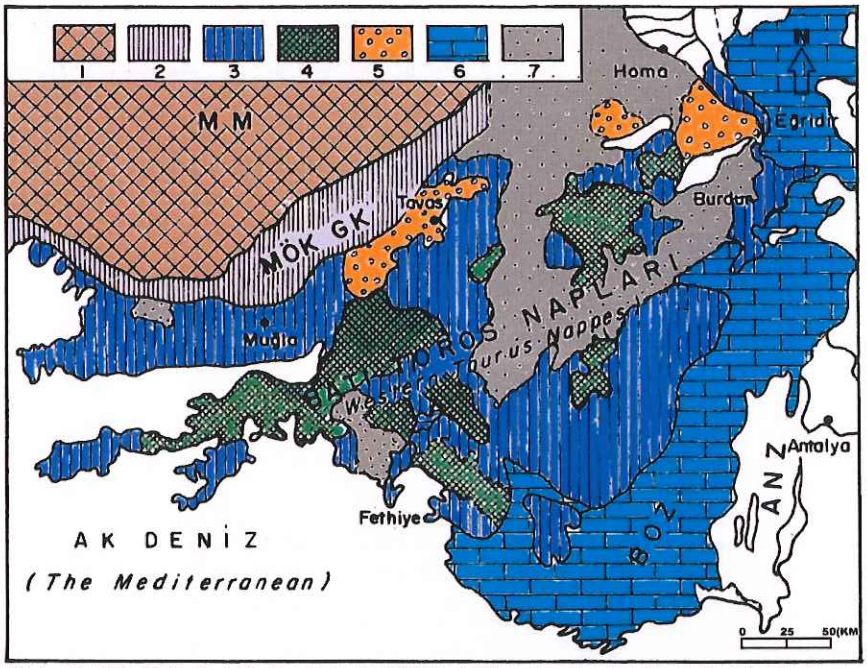
In the studies carried out by MTA, the general geological features of the zone and the more general features of the areas sensitive to the landslide have been put forward; especially the work towards the landslides has been put forward as a superficial evaluation. The work towards to landslide in the region is mostly carried out by AFAD. In the direction of the report dated 08.01.1964 prepared by the geologist Ziya Barut, the DEREKÖY district, which is within the scope of the thesis area on 30.03.1964, was declared as "Disaster Exposed Zone" by the Decision of the Council of Ministers. It was prepared by AFAD in the reports of 21.08.1968, 22.10.1990 and 25.05.2009 concerning the same region. Also in the ÇATAK region, where the Elmalı Formation is observed, in accordance with the report dated 16.06.1994 by İbrahim ŞEREN and Ali ÖZGÜVEN, the decision of the Council of Ministers dated 22.08.2002 and the decision of the Council of Ministers dated 22.07.2002 in respect of the report dated 04.12.1996 by Ayla KIZILTUĞ and Ekrem DEMİRBAŞ are available **(Appendix- A).**

4. GEOLOGY

4.1. Regional Geology

On the south-western part of Turkey (Western Taurus), there are tectonic units defined as Menderes Massif, Lycian Nappes, Beydağları Autochthone and Antalya Nappes from northwest to southeast (Figure 4.1). These tectonic units known as West Taurus Nappes (Ersoy, 1989) or Bozkir Nappes (Özgül, 1976) are commonly referred to as Lycian Nappes (Brunn et al., 1970).

The region is composed of tectonic slices settled on the Beydağları foreland, successively overlying the Late Cretaceous-Middle Miocene compressional phases (Ersoy, 1990).



1-Menderes Massif (MM), 2- Southern Branch of the Circum-Menderes Zone (MÖKGK), 3 and 4- Western Taurus Nappes (Lycian Nappes) with ophiolites (4) together, 5- Mollase of Oligocène age, 6- Bey Dağları Autochthonous Zone, 7- Young neotectonic depozites

Figure 4.1. A simplified map showing the Western Taurus Nappes (Lycian Nappes), (Modified from Ersoy, 1990)

The Menderes Massif is composed of low, middle and high grade metamorphic rocks which are suggested to be located in the Precambrian period (540-560 millon year), based on radiogenic ages, covering very wide granitic masses and presenting gneissic texture in the north of the region (Erdoğan, 2011). Between the Menderes Massif and the Beydağları Autochtonous, Lycian Nappes composed of platform, slope, basin and oceanic crustal rocks are seen. Antalya Nappes consisting of platform, slope, basin and oceanic crustal rocks were planted on the southwest and west of the area. Under the Antalya and Lycian Nappes, the Beydağları Autochthonous is observed as an elevated dome composed of platform type sediments inclined in the southwest direction.

Except for the tectonic units mentioned above, allochthonous the Yeşilbarak nappe, which is represented by the Upper Lutetian-Lower Miocene rock units in the southwest, extends as an intermediate zone between the Beydağları autochtonous and the Lycian nappes at long distances (Figure 4.2) (Ersoy,1990; Şenel,1994).

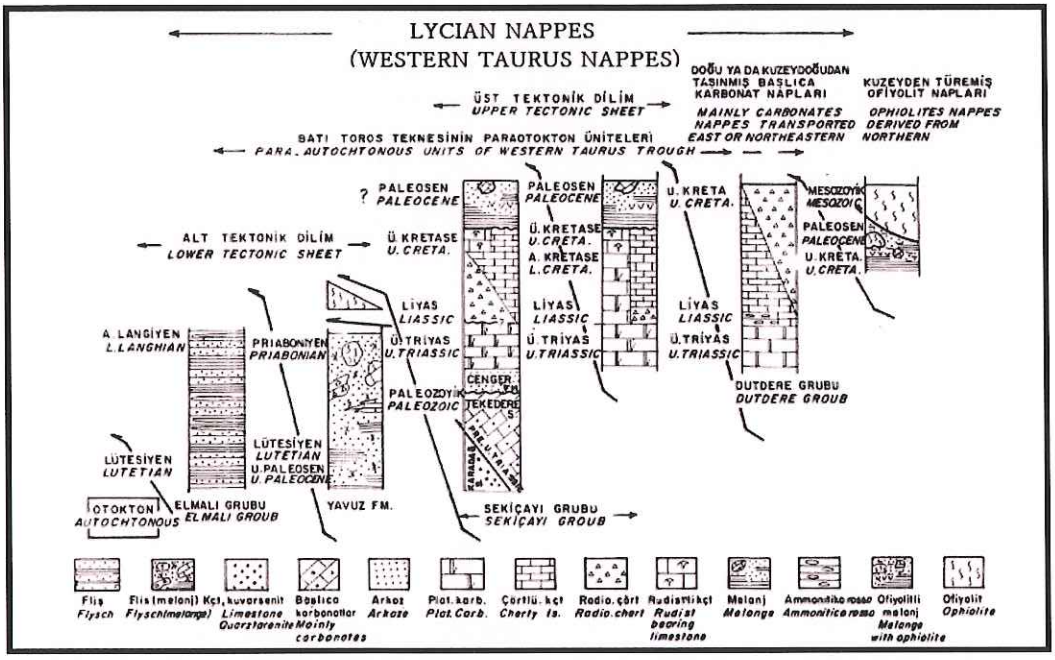


Figure 4.2. Stratigraphic section of allochthonous (Yeşilbarak Nappe and Lycian Nappes) and autochtonous (Beydağları autochtonous) rock units in the region (Ersoy,1990)

4.2. Stratigraphy

Beydağları autochtonous represented by; Upper Cretaceous aged Beydağları Formation consisting of limestones, Upper Paleocene-Middle Eocene aged Dişitaştepe Formation consisting of pelagic limestones and Burdigalian aged Sinekçi formation consisting of algae bearing limestones and claystones (Şenel,1997).

Yeşilbarak Nappe as a tectonic cover over the Beydağları autochtonous, and Lycian nappes as a tectonic cover over the Yeşilbarak nappe (Ersoy,1990; Şenel,1994). Tertiary aged flysch-like sediments continuing in the Lycian Nappes in the region named as Yeşilbarak nappes by Şenel et al. (1994). The Yeşilbarak nappe was observed as tectonic windows under the Lycian nappes in the western Taurus distribution at the front limits of the Lycian nappes (Şenel et al., 1994). The Pliocene lacustrine sediments and the Quaternary terrestrial formations, which have an angular unconformity over the Lycian nappes, are the youngest units of the region (Figure 4.3) (Şenel,1997).

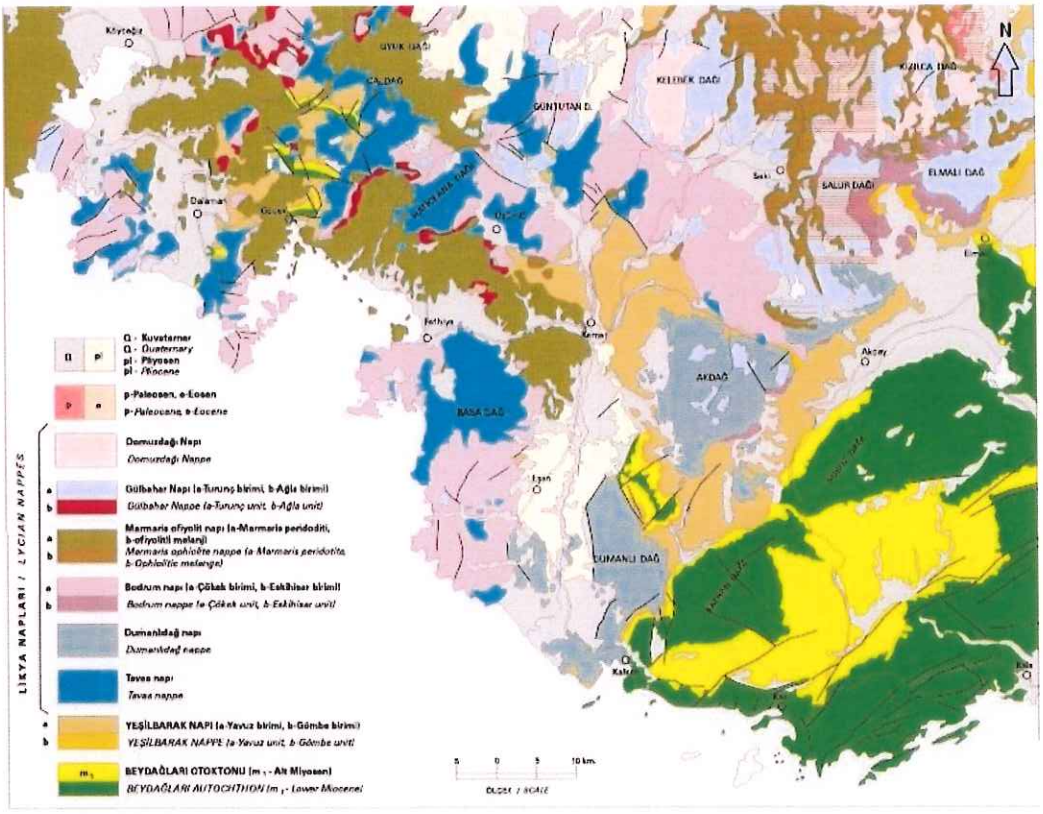


Figure 4.3. The tectonic units of Fethiye Quadrangle (MTA)

Within the scope of the thesis study, the general geological characteristics of the units related to the Elmalı Formation were given and the studies put forward by other researchers were tried to be transferred with general lines. Under the title of 4.2. Stratigraphy, only the headings of the units encountered during the field studies were given and the data of the other formations were excluded from this scope.

For this reason, descriptions of the Dişitaştepe and Sinekçi Formation in Beydağları Autochtonous, Gebeler and Elmalı Formations belonging to Gömbe Unit in Yeşilbarak Nappe, Ağaçlı Formation of Tavas Nappe and Mandırkaya Formation of Dumanlıdağ Nappe, Neoautochtonous Çameli Formation and Quaternary aged Düzçam Formation, Slope debris (talus) and Alluvium units are featured (Figure 4.4).

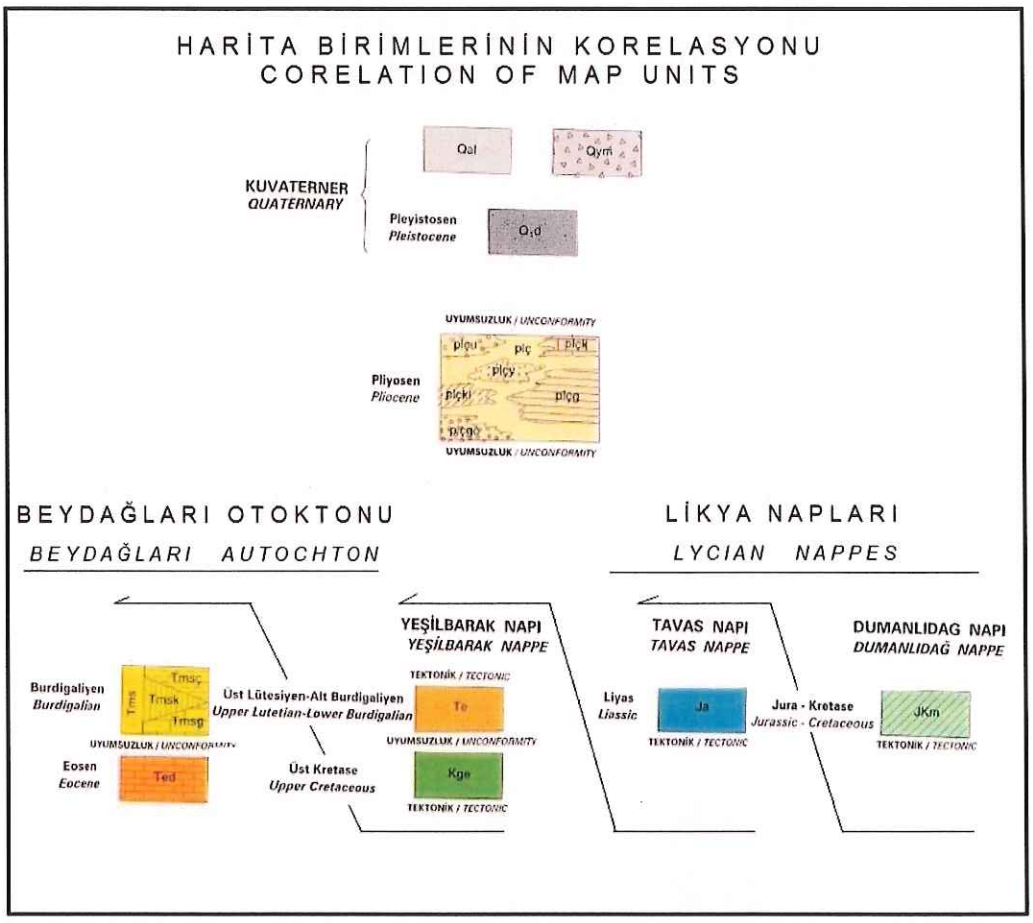


Figure 4.4. Tectonostratigraphic correlation of the units exposed in the study area (Mod. from Şenel et al.,1997)

4.2.1. Dişitaştepe Formation (Ted)

The Dişitaştepe Formation, which is composed of micrites and chert micrites, is composed of medium-thick, local thin-bedded, erosion surface gray, light gray, fracture surface beige, cream, dirty yellow, blackish gray and gray colors, Beige, creamy yellowish coffee, dirty yellow colored, occasionally chert lumpy micrites. The unit also includes calcarenite and bioclastic limestone surfaces.

The base relation of the Dişitaştepe Formation is controversial. Because of the lack of Lower Middle Paleocene, it is accepted that the base relation is unconformable. It is covered unconformably by the Sinekçi Formation on the top. The thickness of the unit ranges from 60 meters to 140 meters (Bilgin et al., 1997). According to fossil forms, the exact age of the unit was not determined, but the age was accepted as Upper Paleocene-Middle Eocene. The Dişitaştepe Formation was deposited in the open shelf environment (Şenel, 1986).

4.2.2. Sinekçi Formation (Tms)

The unit consisting of algae bearing limestones, clayey limestone and claystone, which is overlain from the upper part, was named by Önalan (1979) and the algal rocks at the lower level of the unit is mentioned as Gömüce Member; The clayey limestones in the middle is mentioned as member of Kıbrısdere; The upper sandy-clayey limestones are defined as member of Çayboğazı. The Gömüce Member, which forms the base of the Sinekçi Formation, is represented by medium thick bedded, abrasion surface gray, light gray, beige, cream, light gray, dirty white, dark gray colored, and algae bearing limestones. There are bauxite occurrences at the base. The member of Çayboğazı, consists of fine-medium thick layered gray, light gray, greenish gray, cream, dirty white claystones. Within the Çayboğazı Member, there are turbiditic fine calcarenite, sandy-clayey limestone, sandstone and micro conglomerate levels and in some places siltstone, marl and fine micrit levels. The Sinekçi Formation's age is Burdigalian according to its fossil contents (Şenel et al., 1989). The unit first precipitated in a shallow carbonate shelf, then deepening of the environment in the ending slope-basin environment.

4.2.3. Gebeler Formation (Kge)

This formation which is situated at the base of the Gömbe Unit is named by Şenel et al. (1989). Throughout all the Western Taurus, only the unit, which is exposed at the exit of the hot water of Gebeler (Girmeler) Quarter, about 25 km east of Fethiye, is massive, medium to thick bedded, dark gray, black and dark brown colors. It is composed of limestone, dolomite and dolomitic limestones with cracks and joints, frequent melting gaps. The Gebeler Formation, which can not be observed in the lower part, is covered with angular unconformity by the Elmalı Formation from the top. According to fossil contents of the unit that is considered to be the Cenomanian to Santonian age. Carbonates similar to these carbonate deposits in the shallow carbonate shelf environment are observed in the same aged sections of Beydağları Autochthonous and Dumanlıdağ Nappe (Şenel, 1994).

4.2.4. Elmalı Formation (Te)

This formation, formed by sandstone, siltstone and claystone in general, has first been named by Önalan (1979). The Elmalı Formation, which is the most common surface unit of the Yeşilbarak Nappe throughout the whole generation, shows a very curved structure. The unit is represented by thin sandstones, siltstones and claystones with thin, medium to thick bedded, gray, greenish gray, green, dark gray, light brown, grayish brown and similar colors. The dominant lithology of the unit is sandstone which grain size vary between coarse to fine and composed of various lithologic origins. These sandstones, which are of turbiditic character and present a pillow structure in place, are generally graded and moderately poorly sorted, sometimes well sized. The basal structures were well developed in these sandstones. The siltstones and claystones, which are less in number than the sandstones, are darker in color than the sandstones and have a foliage and shale appearance. Sometimes these are thick enough to differentiate as layers.

In the Elmalı Formation, conglomerate levels and debris flow can be observed even if they are rare. The Elmalı Formation is generally situated on the Lower Miocene clastics of Beydağları Autochthonous with tectonic contact.

The unit is covered tectonically by the Yavuz Unit, which is the upper structural unit of Lycian Nappes or Yeşilbarak Nappe. The Elmalı Formation, which does not measure its thickness due to its very fragile, curved and uneven structure, has a thickness of more than 1000 m in most places.

However, the unit is thought to be thicker (Şenel et al., 1989). The Elmalı Formation is considered to be Upper Lutetian - Lower Burdigalian age due to its fossil content. The Elmalı Formation, which was transgressive in the basement, was deposited in the shelf slope basin environment where turbidite currents were active.

4.2.5. Ağaçlı Formation (Ja)

The Ağaçlı Formation is consisting of algae bearing limestones was named by Şenel et al., (1994). The unit consists of dolomitic, dolomitic limestone and algae bearing limestones with massive appearance, thick, terrestrial middle layer, abrasion surface gray, light gray, occasionally dark gray, fracture surface gray, light gray, sometimes dark gray color. The Formation which is in conformity with the Çenger Formation at the bottom and the Babadağ Formation at the top shows a local incoherence. Thickness of the unit is approximately 450 m. According to its fossil content, the age of formation was determined as Liassic, was deposited in shallow carbonate shelf environment with stagnation (Şenel et al., 1994; Şenel, 1997).

4.2.6. Mandırkaya Formation (Jkm)

The Mandırkaya Formation is consisting of neritic limestones named by Şenel et al., (1986). The unit is medium-thick bedded, beige, cream, light brown colored, in places gastropod, algae, coral etc. It consists of fossiliferous limestones. Dolomite and dolomitic limestones. Pellet levels are evident in the unit. The unit is topped with medium-thick bedded, creamy, light gray and white colored, with some recrystallized, rudistic limestones. The formation shows a thickness of about 700 meters. According to fossil content, the age of formation was determined as Jurassic-Cretaceous. The unit deposited in carbonate-shelf environment (Şenel et al.,1986).

4.2.7. Çameli Formation (Plç)

The Formation is consisting of lacustrine claystone, marl, sandstone rocks named by Erakman (1982). It has tectonic contact with the basic units. The formation is usually composed of fine-medium-thick bedded, dirty white, dirty yellow, light yellow, light gray, greenish gray colored sandstone intercalated claystone, clayey limestone and marls. Apart from these lacustrine facies, the formation includes river deposits, lake coastal facies, delta and / or cloudy fan deposits. Measured stratigraphic sections have a thickness of 506 m. The formation is overlying the Lycian Nappes with angular unconformity, is unconformably overlain by the Quaternary formations at the top (Göktaş, 1990).

4.2.8. Düzçam Formation (Q1d)

It consists of old alluvium deposits. It has a thickness ranging from 30 to 40 m; Red-red brown - yellowish brown colored, cross-bedded mudstone, sandstone and conglomerates, alluvial fan sediments deposited in the upper Pliocene-Pleistocene age. These sediments characterize the terrestrial environment (Şenel et al.,1997).

4.2.9. Quaternary Slope Debris (Colluvial deposits) (Qym)

Slope deposits in geomorphological literature are also often expressed as; Debris slope, talus, scree of rock / gravel on the mountain, slope debris, hillslope or hillside deposits and colluvium deposits (Blikra and Nemec 1998). The main material of the slope debris is coarse-grained and immature gravels, which are expressed as masses deposited on the slopes of the mountains or other inclined surfaces and mostly carried by gravity (Nemec and Kazancı 1999).

4.2.10. Quaternary Alluvium (Qal)

It is deposits of gravel, sand and mud which are seen in river beds, depression areas and plains (Şenel, 1997).

4.3. Tectonic

Four main tectonic events affected western Turkey in Late Cretaceous–Early Eocene times. These are subduction, ophiolite obduction, high pressure/ low temperature metamorphism and continent–continent collision. Some constraints on these four tectonic events can be placed by the age of the Tethyan oceanic lithosphere, as deduced from obducted accretionary complexes and ophiolites (Figure 4.5) (Okay &Tüysüz, 1999). Western Anatolia and its continuation, the Aegean Sea, are under the influence of the mainly N-S and SW-NE directional expansion tectonics. E-W, NE and NW trending faults (Koçyiğit, 1984; Koçyiğit, et al., 2000), which develop under the control of this expansion regime, present the most active fault system in terms of seismicity in Western Anatolia.

Barka et al. (2000) and Yilmaz (2000) emphasize that the NS-oriented expansion in the Aegean region developed at a speed of 3-6 cm per year and that the expansion of the Anatolian plate of the regression regime resulted in a westerly movement in the control of the North Anatolian and Eastern Anatolian Faults.

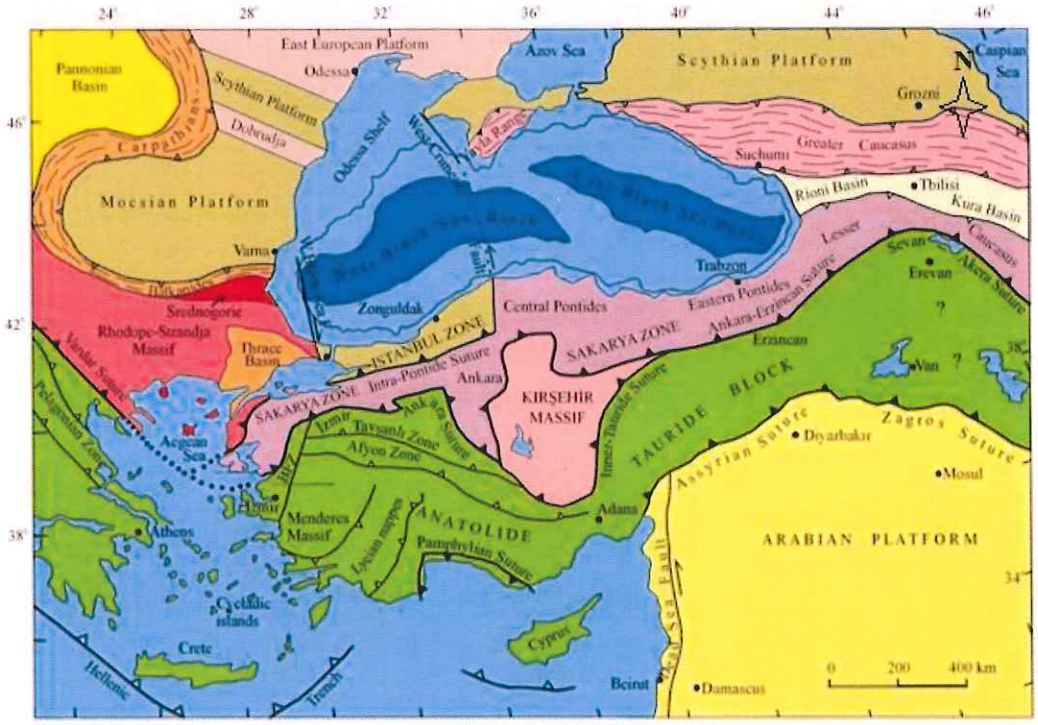


Figure 4.5. Major Active Tectonic Structures Affecting Turkey and Its Near Environment (Okay&Tüysüz, 1999)

The southernmost part of Southwest Turkey, generally referred to as the Lycian Nappes, was developed between the Menderes microcontinent which was added to the north in the beginning and the Beydağları Autochthonous from the south and the closing of the northern branch of Neotethyan along the İzmir-Ankara suture zone in early Tertiary (Şengör and Yılmaz, 1981; Collins and Robertson, 1998; Okay et al., 2001).

Considering the tectonic overlay to the southward of sedimentary formations and sedimentary series comparisons, the Lycian Allochthonous appear as the northern face of the Mesozoic rift and the passive edge (Collins and Robertson, 1999). The Triassic-Upper Cretaceous deep-sea sediments, preserved as blocks from the melange units on the Lycian thrusts, were interpreted as sea sediments collapsing on the Mesozoic (Neotethyan) oceanic crust (Collins and Robertson, 1999).

On the region, there are structural units that have different deformation traces in the area where the Autochthonous (Beydağları Autochthonous) and Allochthonous (Lycian Nappes) rock units are located (Şenel, 1997). Gülbahar Nappe, Domuzdağ Nappe, Marmaris Ophiolite Nappe came together according to the possible north-south direction compression regime developed in Upper Senonian and these units were placed on Bodrum Nappe depending on this compression regime continuing at the end of the Senonian period (Ersoy, 1990; Şenel, 1997). At the end of Eocene due to possible North-South compression regime, these nappes were dragged onto Tavas Nappe by taking Bodrum Nappe under them. The north-south compression regime similar to the Lower Miocene region was developed again and the Lycian Nappes, which had previously settled in the Menderes Massif South ward, were submerged between the Yeşilbarak Nappe in the Lower Langhian, and were placed on the Beydağları Autochthonous from North to South. At the end of the Pliocene and afterwards, large-scale normal faulting occurred in the region (Şenel, 1997).

4.4. Geology of the Study Area in Detail

Within the scope of the thesis, characteristics of the areas to be studied, their general geological-hydrogeological characteristics and slope characteristics were investigated by subtracting 1 / 25.000 scale topographic maps of the region and 1 / 25.000 scale geology maps prepared by MTA. In this context, while the geological features of the thesis area are explained, the work done in the Şerefler (Çeştepe) Quarter belonging to the Dalaman District and the works done in Girmeler, Karabıyık, Bayır and Dereköy Quarters belonging to the Seydikemer District will be separated into five different regions so that each region's own characteristics can be expressed easily. When the spreading areas of the unit are examined (Şenel, 1997a), it is seen that the Dalaman district is in the Karaağaç village, Elcik village and Sülüklüdağ in the western and north-western areas. (Figure 4.6-a, 4.6-b). No significant landslide area has been shown in the formation, which is usually associated with other units.

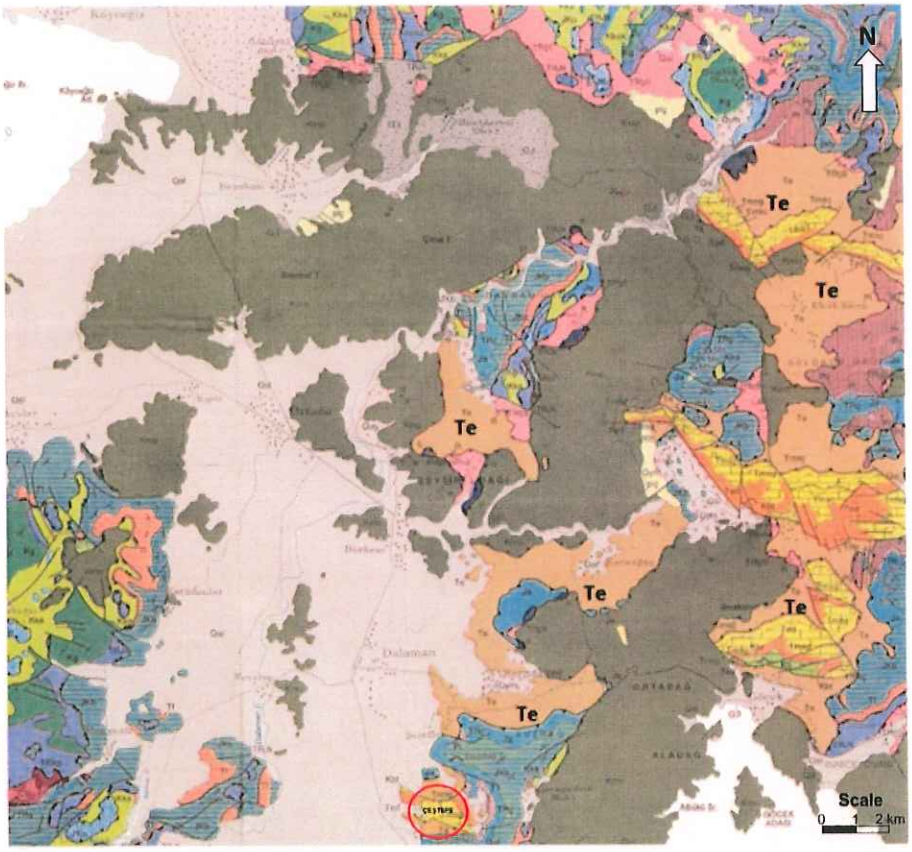


Figure 4.6-a. A general geological map showing the distribution of Elmalı Formation (Te) belonging to Dalaman and its vicinity (Şenel,1997-MTA; see Figure 4.8 for explanation)



Figure 4.6-b. The distribution of Elmalı Formation (Green-scanned area) belonging to Dalaman and its vicinity (Google Earth)

Another important area where the formation is exposed is to the east of Fethiye district (Şenel, 1997b). The landslides in the Dereköy and Bayır villages are shown on the map in the formation which covers wide areas in the NE-N-NW-W-SW of the Seydikemer district center (Şenel, 1997b) (Figure 4.7-a, 4.7-b).

However, no details about them have been given. Therefore, the thesis area was divided into five different regions and detailed discussion was made.

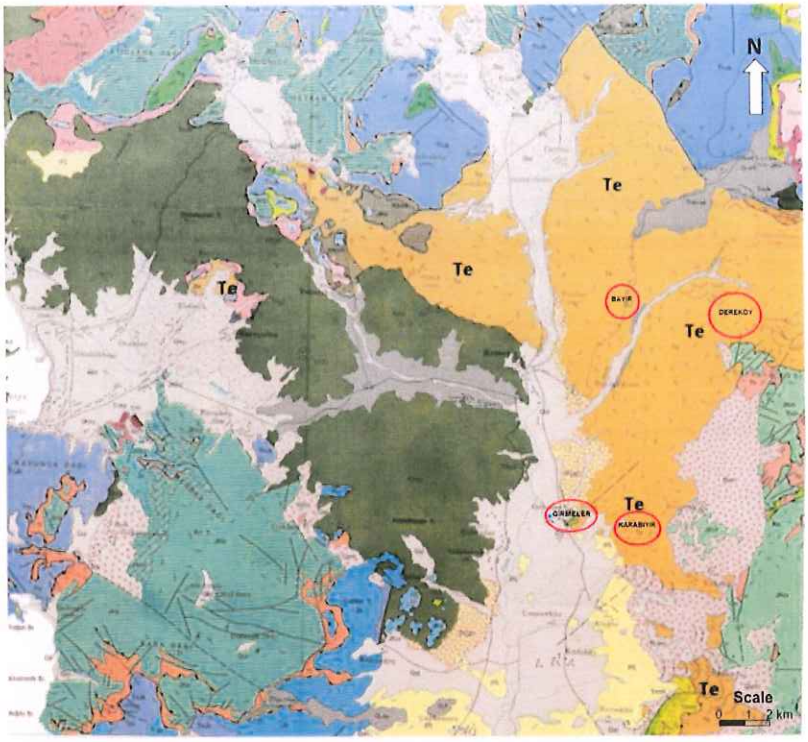


Figure 4.7-a. A general geological map showing the distribution of Elmalı Formation (Te) belonging to Fethiye-Seydikemer and its vicinity (Şenel,1997-MTA; see Figure 4.12, 4.15, 4.18 and 4.23 for explanation)

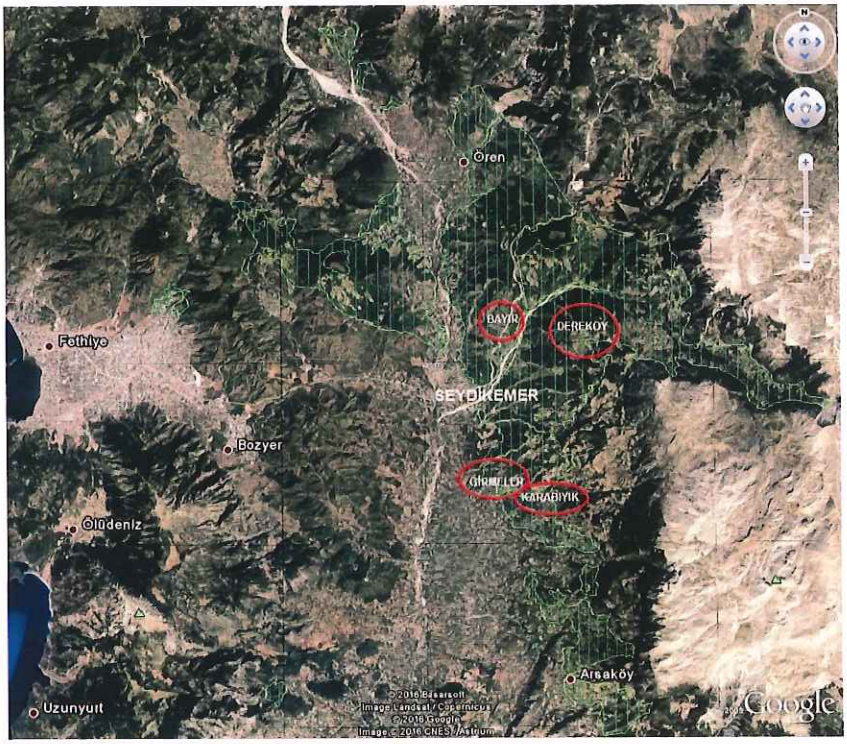
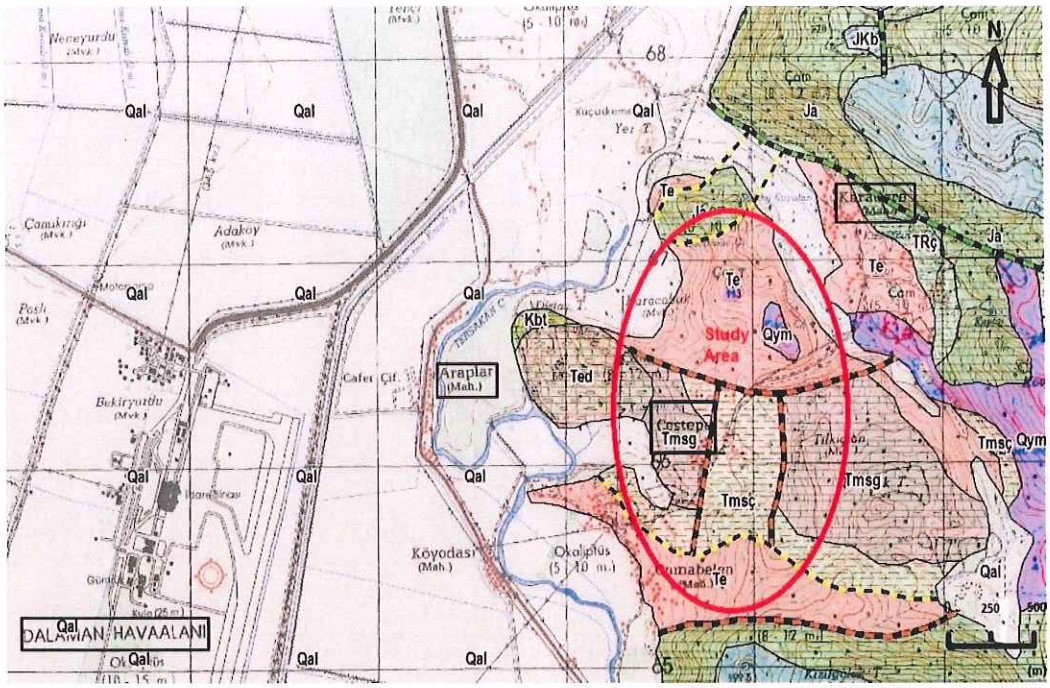


Figure 4.7-b. The distribution of Elmalı Formation (Green-scanned area) belonging to Fethiye-Seydikemer and its vicinity (Google Earth)

4.4.1. Şerefler (Çeştepe) quarter

Şerefler (Çeştepe) quarter is located about 5 km southeast of Dalaman district. In this part of the study area, Middle Eocene- Lower Miocene aged Elmalı Formation belonging to Yeşilbarak Nappe which came with tectonic overlay on the Miocene Sinekçi Formation and Liassic Agaçlı Formation over these units were observed (Figure 4.8).



LEGEND

FAULT	Ja — AĞAÇLI FORMATION, LIASSIC, LIMESTONE,DOLOMITE
NORMAL-REVERSE FAULT	Tmsç — SİNEKÇİ FORMATION-ÇAY BOĞAZI MEMBER, LOW MIOCENE,CLAYSTONE
PROBABLE FAULT	Ted — DİŞİTAŞTEPE FORMATION, EOCENE,LIMESTONE
NAPPES	Te — ELMALI FORMATION, MID EOCENE-LOW MIOCENE, SANDSTONE-MUDSTONE
Qal — QUATERNARY ALLUVIUM	Tmsg — SİNEKÇİ FORMATION-GÖMÜCE MEMBER, MID EOCENE-LOW MIOCENE,LIMESTONE
Qym — QUATERNARY SLOPE DEBRIS	Kbt — BEYDAĞLARI FORMATION, CRETACEOUS,LIMESTONE

Figure 4.8. Geological map of the Şerefler-Çeştepe Quarter (Modified from the 1 / 25,000 scale MTA O21-C1 Quadrangle)

The studies on the southwest slopes of the Çeştepe quarter revealed the Çayboğazı and Gömüce members of the Sinekçi formations tectonically overlies on the Elmalı Formation (Figure 4.9).



Figure 4.9. General Field view of Elmalı Formation in Çeştepe-Şerefler district. (Man for Scale: 175 cm)

Most of Çeştepe quarter is located on Gömüce. The Gömüce Member, which forms the base of the Sinekçi Formation, is represented by medium thick bedded, abrasion gray, light gray, beige, cream, light gray, dirty white, dark gray, and algae bearing limestones (Önalan,1979). In the eastern part of the district, it was observed that Çayboğazı Member came to the Gömüce Member with dip-slip faults (Figure 4.9). It was observed that the Çayboğazı Member was composed of fine-medium thick layered gray, light gray, greenish gray, cream, and dirty white claystones.



Figure 4.10. Small scale reverse fault with calcite veins in Elmalı Formation (Fence for scale: height is approx. 80 cm)

In the examinations carried out by Önalan (1979), it is stated that there is turbiditic fine calcarenite, sandy-clayey limestone, sandstone and micro conglomerate levels and siltstone, marl and fine micrite levels in the Çayboğazı Member. It was observed that Elmalı Formation came over the Çayboğazı and Gömüce Members belonging to the Sinekçi Formation and this unit was observed in both southern and northern parts of the Çeştepe Quarter. Within the Elmalı Formation, alternation in the form of mostly claystone-siltstone with light brown, gray-dark gray color was observed. These levels are quite fine-grained shows brittle-dispersible characteristics. As a result of the tectonic movements of the unit, it has been found that the reverse faulting develops in itself and the calcite veins are formed accordingly (Figure 4.10).

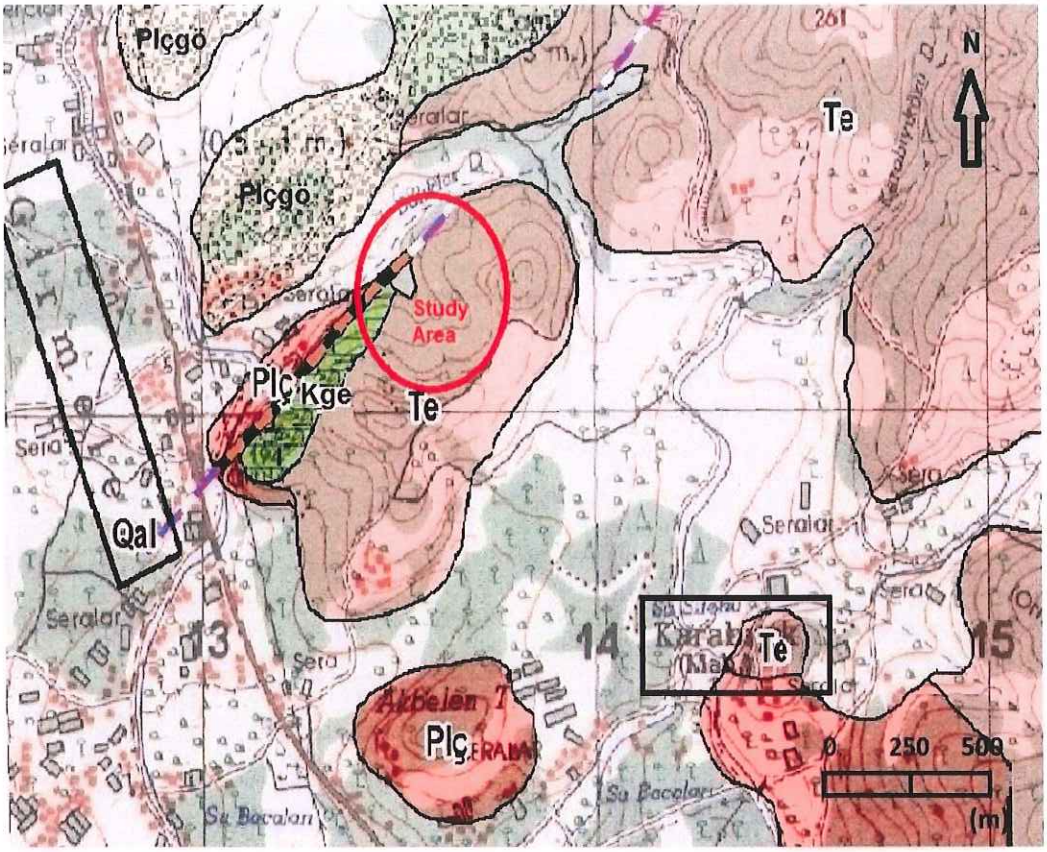


Figure 4.11. The fault scarp over the Jurassic Agacli Formation (Bush for scale: 100 cm)

The Jura aged Agacli formation, which came over all these units, was observed to the northernmost part of the Çeştepe area (Figure 4.11). This unit, which comes with tectonic overthrust to the Elmalı Formation, consists of dolomite, dolomitic limestone and algae bearing limestones with massive appearance, thick, terrestrial middle layer, light gray and sometimes dark gray color (Şenel,1994).

4.4.2. Girmeler (Gebeler) quarter

The Girmeler (Gebeler) Quarter is located about 7 km south of Seydikemer District. In this part of the study area, Middle Eocene- Lower Miocene Elmalı Formation belonging to Yeşilbarak Nappe which came with tectonic overlay on the Cenomanian to Santonian Gebeler Formation was observed (Figure 4.12).



LEGEND

NORMAL-REVERSE FAULT

PROBABLE FAULT

Qal	QUATERNERY ALLUVIUM
Plçgo	GÖÇMENLER CONGLOMERATE MEMBER PLIOCENE, CONGLOMERATE
Plç	ÇAMELİ FORMATION PLIOCENE, MUDSTONE-SANDSTONE-CONGLOMERATE
Te	ELMALI FORMATION MID EOCENE-LOW MIOCENE, SANDSTONE-MUDSTONE
Kge	GEBELER FORMATION CRETACEOUS, LIMESTONE

Figure 4.12. Geological map of the Gebeler (Girmeler) Quarter (Modified from the 1 / 25,000 scale MTA O22-C3 Quadrangle)

The Gebeler Formation which is situated at the base of the Gömbe Unit (Şenel et al., 1989). The unit is massive, medium to thick bedded, dark gray, blackish gray, black and dark brown colors. It is composed of limestone, dolomite and dolomitic limestones with cracks and joints, frequent melting gaps.

The Gebeler Formation, which is composed of the Santonian aged neritic carbonates, is represented by the Elmalı Formation consisting of Upper Lutetian-Lower Miocene sandstones and shales (Şenel,1989).



Figure 4.13. Normal fault and slickenside on the Santonian aged Gebeler Formation (Man for scale:175 cm)

Observations made on the dolomitic limestones belonging to the Gebeler Formation in the study area show that the unit has a massive structure, while presenting a partially cracked-cracked structure (Figure 4.13).

The possibility of obtaining the sample as a result of repeated collisions with geologist's hammer in the field, offers evidence that the dolomitic limestones are a very solid structure within themselves. The unit observed to have a height of approximately 55 meters was found to be 300°/60° (dip/dip direction).

In the study area, the Gebeler Formation, which can not be observed in the lower part, is covered with angular unconformity by the Elmalı Formation from the top (Şenel,1989).

The sandstone-claystone alternation unit of the Elmalı Formation was investigated approximately 150 m to the east of the area where the hot water springs were found (Figure 4.14). The sandstones belonging to Elmalı Formation which is tectonically related to the Gebeler Formation are fine grained and offer blocks of 50cm-100cm size. Also the claystones were found to be very fragmented and locally rich in carbonates.



Figure 4.14. The contact between the Elmalı Fomation and Gebeler Formation (Man for scale:175 cm)

Within the scope of the thesis study, 2 different localities were taken in this region. The sample represented by FGS-1 is fine grained sandstone from 35 713613E/ 405225N(Eur 50) coordinates and sent to thin section analysis. The sample represented by the FGS-2 symbol is the dolomitic limestone from the 35 713536E/ 4052247N(Eur 50) coordinate site and is sent to thin section analysis in the same way.

4.4.3. Karabıyık quarter

Karabıyık quarter is located about 8 km south of Seydikemer district. It is also 1 km away from the Girmeler Quarter. This part of the study area has been completely examined within the Elmalı Formation (Te) and Quaternary alluvium (Qal).

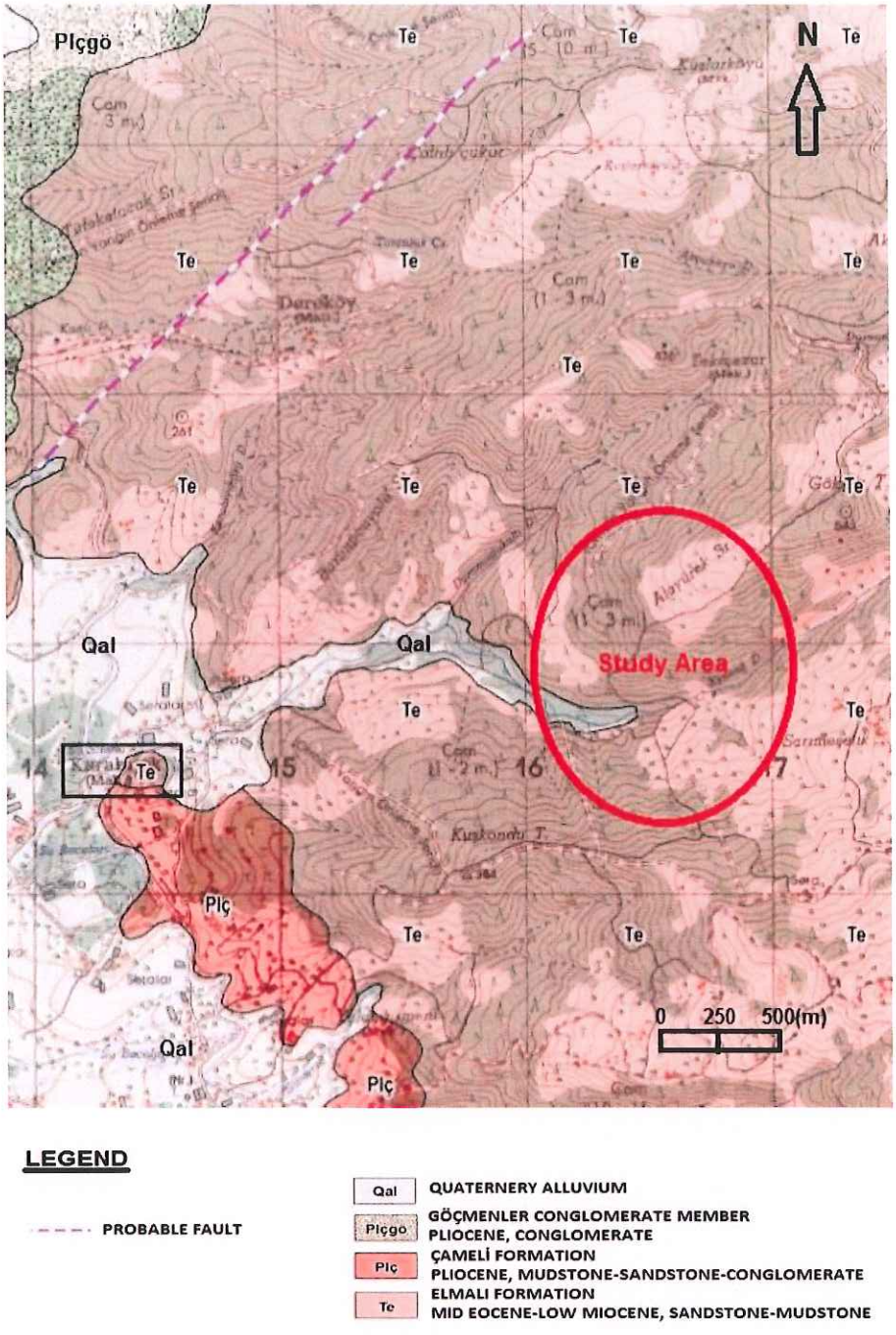


Figure 4.15. Geological map of Karabıyık Quarter (Modified from the 1 / 25,000 scale MTA O22-C3 Quadrangle)

The studies in this section have been carried out in the area between Alayürek ridge and Eynazlı stream approximately 2 km east of Karabıyık Quarter (Figure 4.15). The unit is represented by thin sandstones, siltstones and claystones with thin, medium to thick bedded, gray, greenish gray, green, dark gray, light brown, grayish brown and similar colors. The dominant lithology of the unit is sandstone, which grain size vary between coarse to fine and composed of various lithologic origins. It was observed that the sandstones containing calcite fossil shells were fine to medium grained size (Figure 4.16).



Figure 4.16. Sandstones are containing calcite fossil shells (Hammer for scale: 33 cm)

The siltstones and claystones, which are less in number than the sandstones, are darker in color than the sandstones and have a foliage and shale appearance. Sometimes these are thick enough to differentiate as layers. Within the scope of the thesis study, samples from 5 different locations were taken in this region.

Three of them (FKS-1, FKS-2, FKS-3) were taken from the area where the alluvial unit was observed on the Elmalı formation (Te). It is determined that the coarse-grained gravel represented by the FKS-1 symbol, the sample claystone represented by the FKS-2 symbol, and the sandstone sample represented by the FKS-3 symbol.



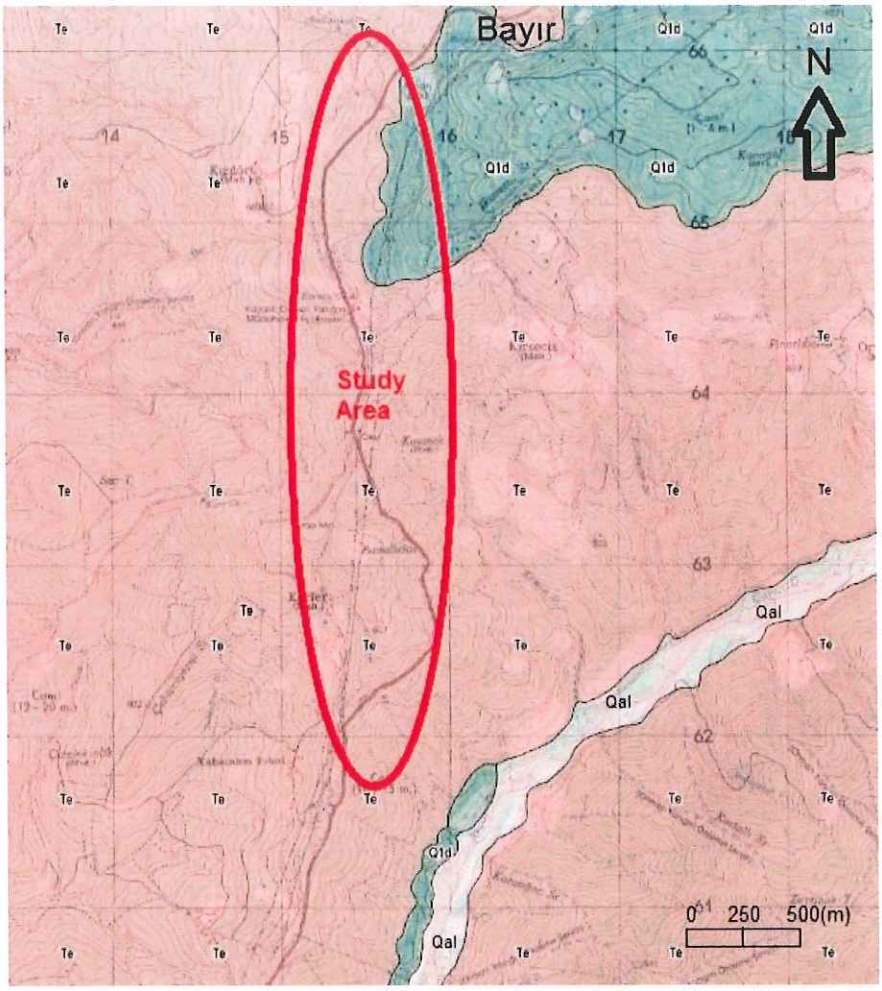
Figure 4.17. The alluvial unit was observed on the Elmalı formation with normal faulting inside (Man for scale:175 cm)

These samples were taken from a coordinate of 35 715484 E / 4052049 N (Eur 50) and the bed attitudes were determined to be 243/38. This area, where fine-grained fossiliferous sandstones and claystones were found, was exposed to normal faulting and the fault location was determined to be 350°/77° (Figure 4.17).

It is also determined that gray clay is represented by FKS-4 and sandstone is represented by FKS-5. It has been determined that the sandstone's layer location is 296°/34°.

4.4.4. Bayır quarter

Bayır quarter is located about 9 km northeast of Seydikemer district. However, the studies in this region have been made between 6th and 9th kilometers of Seydikemer-Antalya highway (Figure 4.18) in case of getting more specimens from the various points on the highway route. Bed attitudes related to Elmalı Formation (Te) were measured, measurements were made with a compass for fracture-crack analysis, and samples were taken from the unit for petrographic examination.



LEGEND

Qal	QUATERNARY, ALLUVIUM
Q1d	DÜZÇAM FORMATION QUATERNARY, OLD ALLUVIUM
Te	ELMALI FORMATION MID EOCENE-LOW MIOCENE, SANDSTONE-MUDSTONE

Figure 4.18. Geological map of Bayır Quarter (Modified from the 1 / 25,000 scale MTA O22-C2 Quadrangle)

This part of the study area has been examined within the Elmalı Formation (Te) and Quaternary Düzçam Formation (Q1d). In the studies in this section, Düzçam formation was observed on the Elmalı formation. The Düzçam Formation, which has a thickness of about 2.50-5.50 m in the study area, contains conglomerate units in dimensions ranging from a few meters to several meters. It consists of old alluvium deposits and reddish brown, grey - yellowish brown colored, cross-bedded mudstone, sandstone and conglomerates. These alluvial fan sediments deposited in the upper Pliocene-Pleistocene age (Şenel et al.,1997).



Figure 4.19. The Quternary Düzçam Formation was observed on the Elmalı Formation (Man for scale:175 cm)

Schmidt hammer tests were carried out on the sandstones belonging to the Elmalı Formation in this area, and in the measurements made with the compass, it was found that the unit had bed attitudes of 160°/46°. Laminated medium grained sandstones were observed on very fine grained claystone levels. FBas-1 sample was taken from this area with coordinates of 35 715784E/4065906N (Eur 50) where the wedge type faiulures were observed (Figure 4.19).

On the other hand, Schmidt Hammer test were carried out on calcite filled cracks bearing fine-to-medium grained sandstones. Fracture-crack measurements of them to form rose diagrams were done on the highway with a coordinate of 35 715445E /4064322N (Eur 50). The bed attitudes obtained from the fracture-crack measurements are 111°/87°, 140°/71°, 169°/79°, 196°/88°, 240°/67°, 175°/78°, 225°/84°, 291°/83°, 286°/61°, 170°/74°, 274°/85°, 181°/72°, 121°/9° and 155°/11° (Figure 4.21).

As a result of these studies made in the Bayır Quarter, by using the VisibleGeology online programme, Rose diagram (Figure 4.20-a) and Three-dimensional (3D) graphic (Figure 4.20-b) were obtained by using the corresponding measures to determine the orientation of the layer planes.

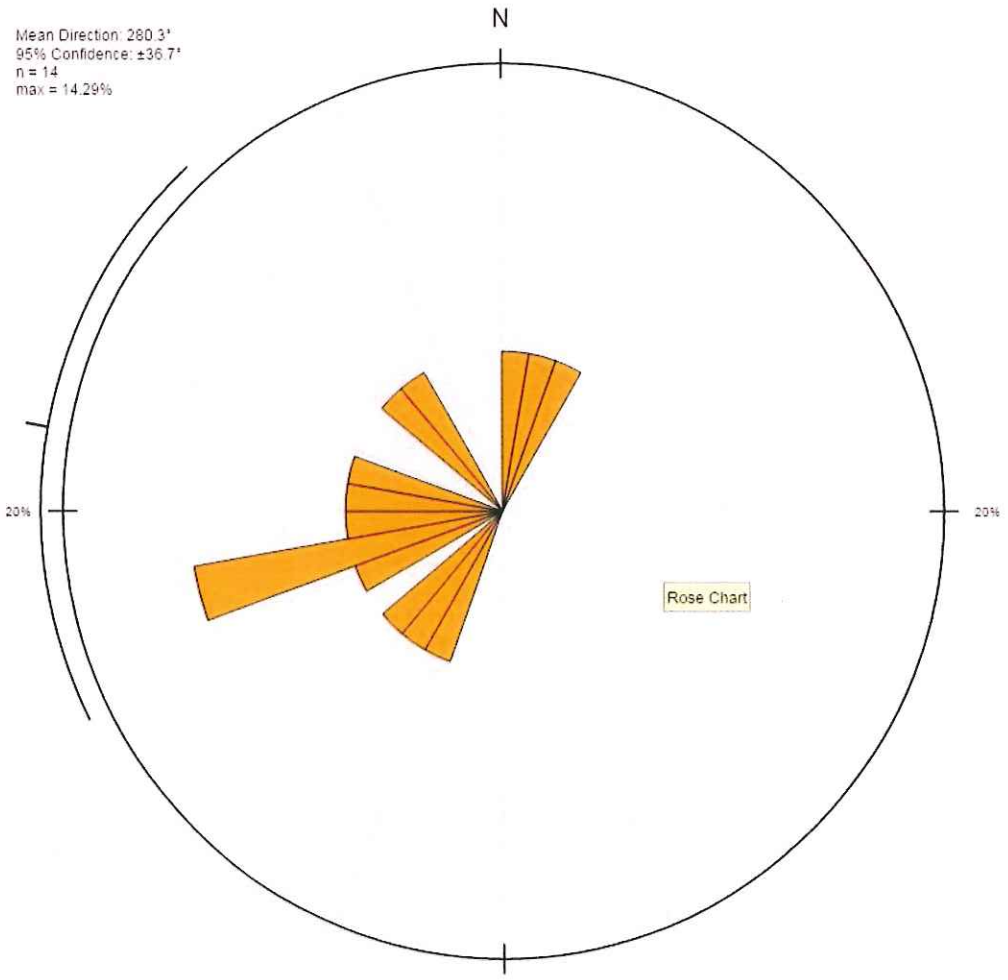


Figure 4.20-a. Rose diagram according to orientation of the layer planes in Bayır Quarter

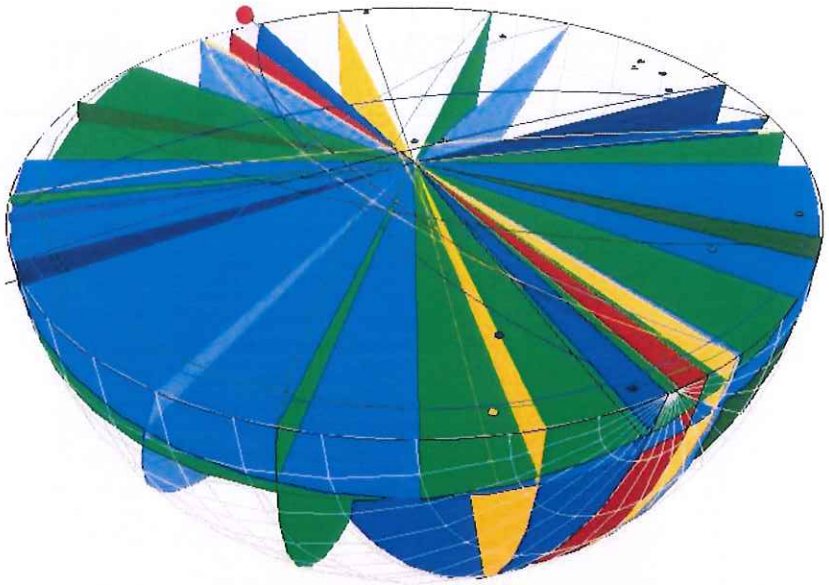


Figure 4.20-b. 3D- diagram according to orientation of the layer planes in Bayır Quarter



Figure 4.21. Fracture-crack measurements on fine to medium grained sandstones (Man for scale:175 cm)

The level of the sandstone-claystone units observed at 30 m west of the highway path where these bed attitudes measurements were made is 35°/18° and 80°/10°. In this section, earth flow occurrences have been determined locally (Figure 4.22).



Figure 4.22. Earth flow occurrences on sandstones-claystones (Traffic sign for scale:125 cm)

Within the scope of the thesis study, samples from 6 different locations were taken in this region. In the 35 715635E/4062335N (Eur 50) coordinate area where the main large scale movements were observed on the road, 5 different point sampling studies were performed.

It is determined that fine grained sandstone-claystone is represented by FBaS-2, sandstone is represented by FBaS-3, fine grained sandstone is represented by FBaS-4, fossiliferous sandstone is represented by FBaS-5 and laminated medium grained sandstone is represented by FBaS-6. Since a clear plane was not observed in this area, fracture-crack analysis could not be performed and bed attitudes measurements could not be performed.

In this area demolished stone-walls and tilted trees has been observed as a result of the mass movements on the Elmalı Formation (Figure 4.23). Observations made in the field concerning mass movements will be discussed in detail in the following chapters.



Figure 4.23. Demolished stone-wall as a result of the mass movements on the Elmalı Formation (Car height for scale:165 cm)

4.4.5. Dereköy quarter

Dereköy Quarter is located about 12 km east of Seydikemer district. The studies in this region was carried out along a line of approximately 5 km from the village center of Dereköy for taking more specimens from the various points. Layers related to Elmalı Formation (Te) were measured in Dereköy Quarter as well as in Bayır Quarter, measurements were made with a compass for fracture-crack analysis and samples were taken from the unit for petrographic examination.

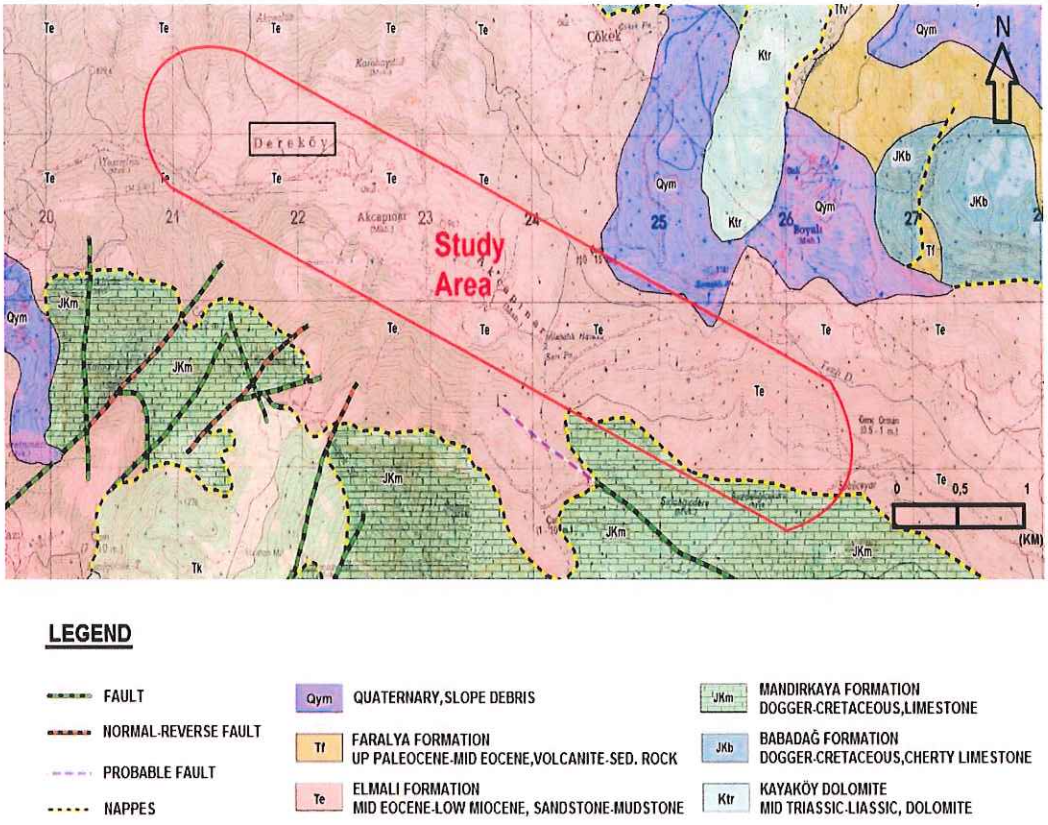


Figure 4.24. Geological map of Dereköy Quarter (Modified from the 1 / 25,000 scale MTA O22-C2 and O23-D1 Quadrangle)

In this part of the study area, the Mandırkaya Formation, which came with a tectonic contact over the Elmalı Formation, was observed. Quaternary slope debris was also observed on these units (Figure 4.24). The Mandırkaya Formation (Jkm) is consisting of neritic limestones Şenel et al., (1986).

The unit is medium-thick bedded, beige, cream, light brown colored. It consists of fossiliferous limestones, dolomite and dolomitic limestones. The formation shows a thickness of about 700 meters. According to the fossil forms the unit is Jurassic-Cretaceous and deposited in carbonate-shelf environment (Şenel et al.,1986). Quaternary slope debris from the Mandırkaya Formation overlies the Elmalı Formation (Figure 4.25). Slope debris; Coarse-grained and immature pebbles, sedimentary masses with limited drainage area that are deposited on mountain slopes and their bottoms or other sloping surfaces and are mostly transported by gravity.



Figure 4.25. Quaternary slope debris contact with the Elmalı Formation (Man for scale:175 cm)

In this part of the study area, the Elmalı Formation contains flute marks (evolved due to turbiditic currents) under the sandstone beds. Flute Marks are the patterns of "V" shaped traces seen at the bottom of the sandstone layers. Generally, turbiditic currents are the result of filling the bottom soft, that is the pits opened on the clayey ground with sand, as a result. The size can range from a few centimeters to a few meters. It is a very common sedimentary structure in turbidites and the current flows. The length varies according to the severity of the turbidite current and the size of the particles being transported.

The Flute Mark structures are the most important sedimentary structures used in the paleo-current studies. These structures are the structures that must be found at the bottom of the sandstone unit and have lost their initial position due to the tectonic evolution of the Elmalı Formation and have a completely reversed bed attitudes (Figure 4.26).



Figure 4.26. The overturned layers formed by the loss of the initial position and flut marks

Within the scope of the thesis study, samples from 9 different locations were taken in this region.

The overturned layers of the Elmalı Formation were observed in 35 725366E/4059608N (Eur 50) coordinate area and 7 samples were obtained in this region. It is determined that sandstone is represented by FDS-1, claystone is represented by FDS-2, sandstone is represented by FDS-3, sandstone is represented by FDS-4, claystone is represented by FDS-5, claystone is represented by FDS-6, claystone is represented by FDS-7 (Figure 4.27).



Figure 4.27. The Schmidt Hammer Tests and structure masurements were made on the Elmalı Formation (Man for scale:175 cm)

Schmidt Hammer Tests were carried out on the sandstones belonging to the Elmalı formation in this area, and in the measurements made with the compass, it was found that the bed attitudes obtained from the fracture-crack measurements are 314°/85°, 15°/86°, 275°/66°, 355°/58°, 323°/74°, 24°/71°, 296°/54°, 284°/89°, 355°/80°, 22°/80°, 205°/47°, 296°/89°, 293°/85°, 44°/63°, 218°/85°, 10°/87°, 345°/56°, 259°/59°, 324°/88°, 23°/75°, 246°/80°, 277°/74°, 299°/82° and 294°/81°. Also, the slope attitude is 324°/57° (dip/dip direction) (Figure 4.26). As a result of these studies made in the Dereköy Quarter, by using the Visible Geology online programme, Rose diagram (Graph.4.28-a) and Three-dimensional (3D) graphic (Graph.4.28-b) were obtained by using the corresponding measures to determine the orientation of the layer planes.

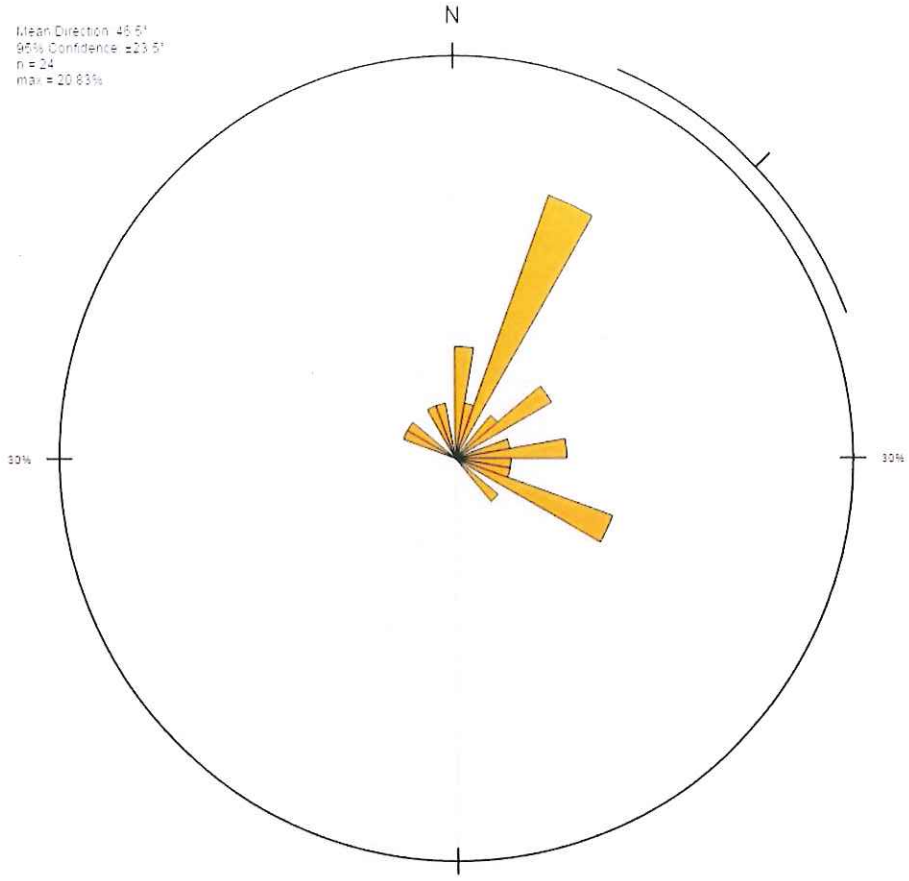


Figure 4.28-a. Rose diagram according to orientation of the layer planes in Dereköy Quarter

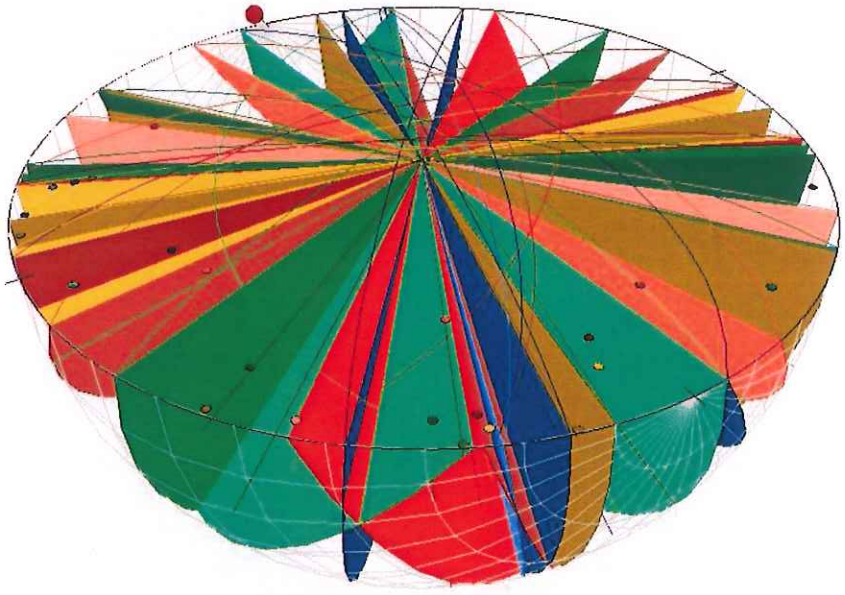


Figure 4.28-b. 3D- diagram according to orientation of the layer planes in Dereköy Quarter

In the 35 721995E/4060729N (Eur 50) coordinate area where the main mass movement were observed in the Elmalı Formation, 2 different samples were taken in this region. It is determined that sandstone is represented by FDS-8 and claystone is represented by FDS-9. Since a clear plane was not observed in this area, fracture-crack analysis could not be performed and bed attitude measurements could not be performed (Figure 4.29).

Also, the Schmidt Hammer Tests were carried out on the sandstones belonging to the Elmalı Formation. In general, this region, the sandstones, which are of turbiditic character and present a fractured structure in place, are generally graded and moderately poorly sorted, sometimes well sized. The basal structures were well developed in these sandstones. The siltstones and claystones, which are less in number than the sandstones, are darker in color than the sandstones and have a foliation surface and shale appearance. Observations made in the field concerning mass movements will be discussed in detail in the following chapters.



Figure 4.29. The main mass movement area in the Elmalı Formation at Dereköy Quarter (Man for scale:175 cm)

5. PETROGRAPHY OF THE ELMALI FORMATION

Within the scope of the thesis study, the samples obtained from the Elmalı Formation were sent to the MTA laboratories and thin sections were prepared with these samples. Samples with thin section application were examined under a microscope and the petrographic properties of the unit were revealed.

Table 5.1.a. Sample properties of Elmalı Formation according to thin section observation

SAMP./TH SECT. NO.	LOCATION	COORDINATE (EUR 50)	SAMPLE PROPERTY	SORT.	ROUND.	SUPPORT.	OTHER PROPERTIES
FGS-1/829	Girmeler	35 713613D/ 4052256K	Fine-grained Sandstone (Litharenite)	MWS	Angular-Subangular	MXS	Fine grained, containing 15% limestone, 15% fossils of miocene, 25% quartz,10% opac minerals, 5% igneous rf and 30% calcite cement
FGS-2/830	Girmeler	35 713536D/ 4052247K	Dolostone				Spacious rhombic / diamond shaped crystal, Under first nichol/normal light dirty yellow-cream colored
FKS-1/831	Karabıyık	35 715484D/ 4052049K	Sandstone (Litharenite)	MPS	Subangular-Subrounded	CS	Medium-coarse grained, containing 75% chert,ophiolite, fosillifereous limestone, silt, volcanicRF, marble,schist and 10% quartz and 15% calcite cement
FKS-3/832	Karabıyık	35 715484D/ 4052049K	Medium-grained fossiliferous Sandstone (Litharenite)	MS	Round-Subrounded	CS	Medium-coarse grained, containing 65% chert,ophiolite, dolostone, mudstone, fosillifereous limestone and 10% quartz, 10% micrite and 15% calcite cement
FKS-5/833	Karabıyık	35 715183D/ 4051996K	Sandstone (Litharenite)	MWS	Subangular-Subrounded	CS	Fine-grained, containing 30% limestone, marble, chert and 35% Quartz-Monocrystaline, 5% Orthoclase, 20% Micrite, 10% Calcite cement
FBaS-1/834	Bayır	35 715784D/ 4065906K	Laminated medium grained Sandstone	MPS	Subangular-Subrounded	CS	Medium-coarse grained, Containing 60% chert,ophiolite,dolostone,mudstone, micaschist, granite, marble,fosillifereous limestone and 10% quartz, 10% micrite and 15% calcite cement
FBaS-2/835	Bayır	35 715635D/ 4062335K	Claystone	MPS	Angular-Subangular	MXS	Matrix Structure
FBaS-3/836	Bayır	35 715635D/ 4062335K	Fine-Medium grained Sandstone	PS	Subangular-Halfround	CS	Medium-fine grained, Containing 45% chert, granite, slate, fossils of miocene, fosillifereous limestone and 20% quartz, 5%plagioclase, 10% micrite and 20% calcite cement

As a result of examinations made on thin sections, the unit's size (sorting), grain support, roundness and other features are presented in detail (Table.5.1.a, 5.1.b). Sandstones are classified according to Pettijohn et al. (1987).

Table 5.1.b. Sample properties of Elmalı Formation according to thin section observation

FBaS-4/837	Bayır	35 715635D/ 4062335K	Fine-grained Sandstone	MPS	Angular-Subangular	MXS	Fine grained, containing 35% chert, granite, fossils of miocene, fosillifereous limestone and 20% quartz,10% matrix and 35% calcite cement
FBaS-5/838	Bayır	35 715635D/ 4062335K	Siltstone				Fine grained, containing 30% muscovite, 20% matrix and 50% calcite cement
FBaS-6/839	Bayır	35 715635D/ 4062335K	Laminated medium grained Sandstone	PS	Round-Subrounded	CS	Medium-coarse grained, containing 65% chert, granite, marble,fosillifereous limestone and 10% quartz, 5% orthoclase,5% micrite and 15% calcite cement
FDS-1/840	Dereköy	35 725366D/ 4059608K	Medium grained Sandstone	PS	Subrounded	CS	Medium grained, Containing 65% chert, granite, marble,fosillifereous limestone of Early Miocene and 10% quartz, 5% orthoclase,5% micrite and 15% calcite cement
FDS-3/841	Dereköy	35 725366D/ 4059608K	Fine-Medium grained Sandstone	PS	Round-Subrounded	CS	Medium grained, Containing 65% chert, granite, marble,fosillifereous limestone of Early Miocene and 10% quartz, 5% orthoclase,5% micrite and 15% calcite cement
FDS-4/842	Dereköy	35 725366D/ 4059608K	Fine grained Sandstone	MS	Angular-Subangular	CS	Medium-fine grained, Containing 50% chert, granite,ophiolite, marble,fosillifereous limestone of Early Miocene and 25% quartz, 5% orthoclase,5% micrite and 15% calcite cement
FDS-7/843	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone	MS	Angular-Subangular	CS	Matrix Structure
FDS-8/844	Dereköy	35 721995D/ 4060729K	Fine grained Sandstone	MS	Angular-Subangular	CS	Fine grained-laminated, containing 50% chert, granite,opac minerals, marble, fosillifereous limestone of Early Miocene and 25% quartz, 5% orthoclase,5% micrite and 15% calcite cement
Definition:For Sorting;MWS:Modereately-Well Sorted, MPS: Moderateley-Poorly Sorted, MS:Moderately Sorted, PS:Poorly Sorted, For Supporting;MXS: Matrix Supported, CS:Clas Supprted							

In the scope of the studies, a total of 16 different samples were examined. However, similar examples are distinguished and thin cross-sectional views of 8 different samples are given in Figure 5.1.

According to thin section analyses the samples include ophiolite rock fragments, quartz, marble, chert, rarely fossils and lesser extent granitic rock fragments. Therefore, it is interpreted that the rocks belonging to Elmalı Formation feed from very different sources during the formation phase.

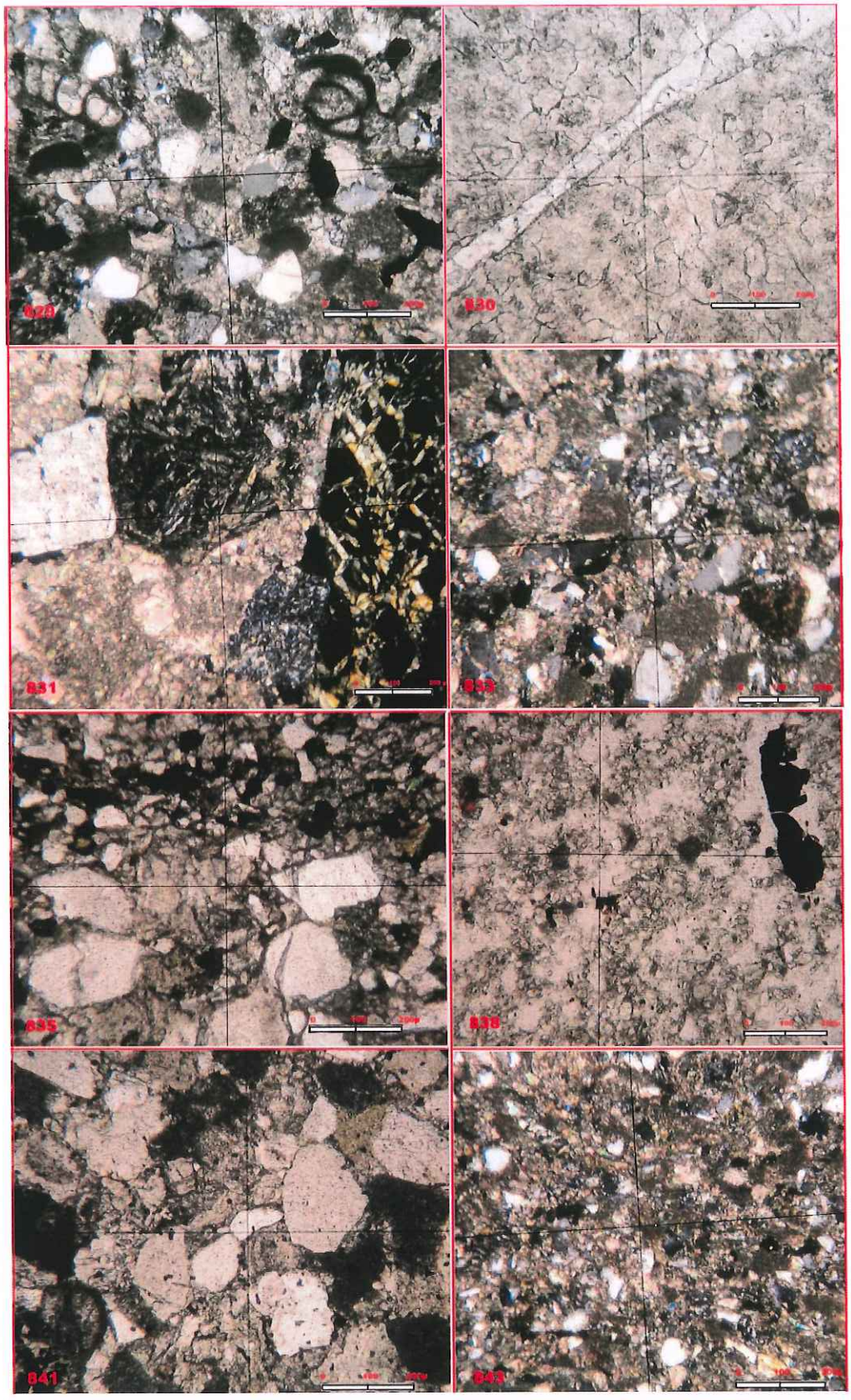
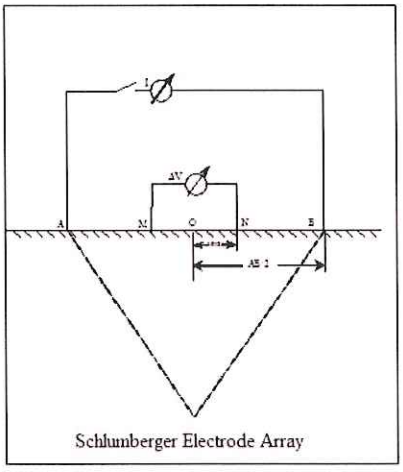


Figure 5.1. (829)-Fine grained Sandstone, (830)-Dolostone, (831)-Sandstone, (833)-Sandstone, (835)- Siltstone, (838)-Siltstone, (841)- Fine-Medium grained sandstone, (843)- Siltstone

6. GEOPHYSICAL PROPERTIES OF THE STUDY AREA

This study was conducted in order to determine the thicknesses and slip planes of the units by making Vertical electrical sounding (VES) works belonging to the geological properties of mass wasting of Elmalı Formation. Vertical electrical sounding (VES) is a geophysical method for investigation of a geological environment (Keller, 1966; Sharma, 1997). The method is based on the estimation of the electrical conductivity or resistivity of the study area. In this context, in order to examine the geological properties of mass wasting of Elmalı Formation in detail, 5 VES works were carried out in total, 2 in Çeştepe Quarter (Dalaman), 1 in Bayır Quarter (Seydikemer) and 2 in Dereköy Quarter (Seydikemer). In this study, Geothronic Resistivity device was used and Schlumberger electrode array was applied (Figure 6.1).



AB	Current Electrodes
A – B	Distances Between the Current Electodes
MN	Potential Electrodes
M – N	Distances Between the Potential Electrodes

Figure 6.1. Schlumberger array and appareance of resistivity (Morrison and Gasperikova, 2012)

6.1. Implementation and Evaluation of the Work

Within the scope of the field works, the real resistivity and thicknesses of the strata were calculated by using double logarithmic graphs as a function of the resistivity readings in the field from the Vertical Electric Sounding (VES) measurements and using Schlumberger's double layered and auxiliary layers.

6.1.1. Çeştepe (Şerefler) quarter

In this part of the study area, VES work was done at 2 different points (Figure 6.2). The study described as VES-4 (Figure 6.3) was made in 35 663012E / 4066785N (Eur 50) and the VES-5 (Figure 6.4) was in 35 662819E / 4066742N (Eur 50). Also, possible lithology of the region has been established depending on the workings of VES-4 (Table.6.1) and VES-5 (Table.6.2).

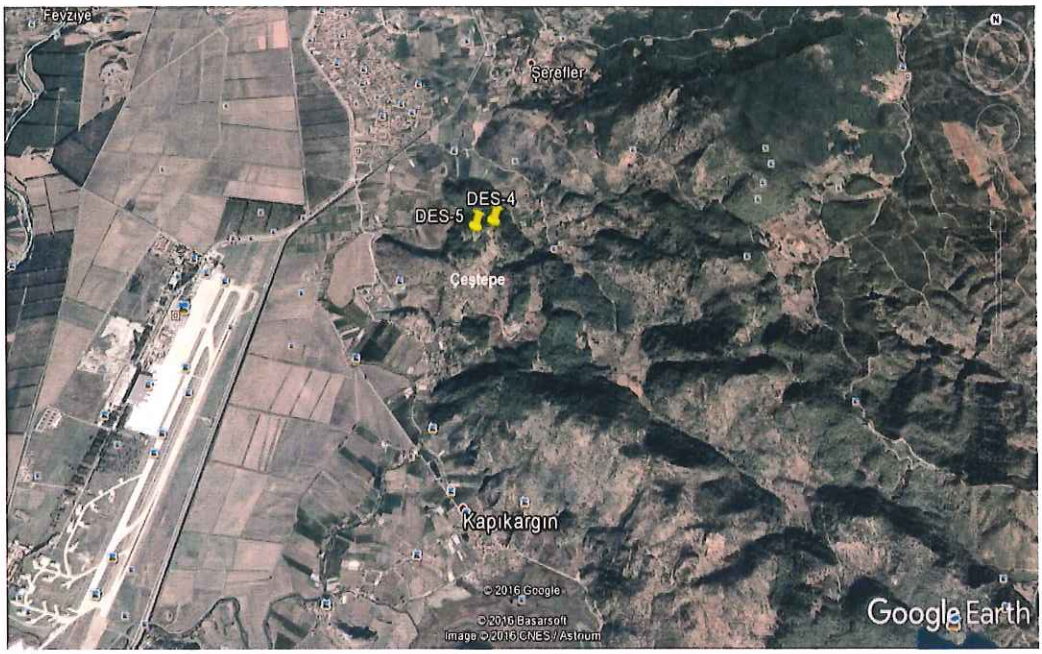


Figure 6.2. VES studies on Elmalı Formation in Şerefler (Çeştepe) Quarter

Table 6.1. Resistivity values, for VES-4; Opening distance: AB/2= 50m

Layer no	Layer thick. (m)	Resistivity (ohm.m)	Possible lithology
1	0-1,5	77,4	Claystone
2	1,5-3,84	46,5	Claystone
3	3,84-	740	Sandstone

Table 6.2. Resistivity values, for VES-5; Opening distance: AB/2= 50m

Layer no	Layer thick. (m)	Resistivity (ohm.m)	Possible lithology
1	0-1,5	77,2	Claystone
2	1,5-6,32	69,9	Claystone
3	6,32-	1062	Sandstone



Figure 6.3. Field view of the VES-4 study (Yellow box height for scale: 30cm)



Figure 6.4. Field view of the VES-5 study (Yellow box height for scale: 30cm)

6.1.2. Bayır quarter

In this part of the study area, VES work was done at 1 point (Figure 6.5). The study described as VES-1 (Figure 6.6) was made in 35 715802E / 4062377N. Also, possible lithology of the region has been demonstrated depending on the working of VES-1 (Table.6.3).



Figure 6.5. VES studies on Elmalı Formation in Bayır Quarter

Table 6.3. Resistivity values for VES-1; Opening distance: AB/2= 120m

Layer no	Layer thick. (m)	Resistivity (ohm.m)	Possible lithology
1	0-1,5	26,8	Claystone
2	1,5-5,68	429	Mudstone
3	5,68-21,6	58,4	Claystone
4	21,6-	3870	Sandstone



Figure 6.6. Field view of the VES-1 study (Yellow box height for scale: 30cm)

6.1.3. Dereköy quarter

In this part of the study area, VES work was done at 2 different points (Figure 6.7). The study described as VES-2 (Figure 6.8) was made in 35 721970E / 4060726N (Eur 50) and the VES-3 (Figure 6.9) was in 35 722002E / 4060729N (Eur 50).

Also, possible lithology of the region has been established depending on the workings of VES-2 (Table 6.4) and VES-3 (Table 6.5).



Figure 6.7. VES studies on Elmalı Formation in Dereköy Quarter

Table 6.4. Resistivity values for VES-2; Opening distance: AB/2= 120m

Layer no	Layer thick. (m)	Resistivity (ohm.m)	Possible lithology
1	0-1,50	124	Mudstone
2	1,50-3,20	6,16	Claystone
3	3,20-55,2	83,2	Mudstone
4	55,2-	2269	Sandstone

Table 6.5. Resistivity values for VES-3; Opening distance: AB/2= 120m

Layer no	Layer thick. (m)	Resistivity (ohm.m)	Possible lithology
1	0-1,74	85,3	Mudstone
2	1,74-7,63	15	Claystone
3	7,63-48,6	112	Mudstone
4	48,6-	1991	Sandstone



Figure 6.8. Field view of the VES-2 study (Yellow box height for scale: 30cm)



Figure 6.9. Field view of the VES-3 study (Yellow box height for scale: 30cm)

6.2. Evaluations of Geophysical Data

VES measurements have been carried out with the support of geotechnical methods in order to distinguish between weaker and harder units, to reveal the geological structure and thus to determine the location of the surface rupture (shear plane). The VES measurement line was chosen to be parallel and perpendicular to the possible slip plane. The Schlumberger array was applied in the measurement and at the end of the measurements, apparent resistivity obtained from the study areas are presented in **Appendix-B**.

In VES-1, it is seen that there are units with relatively low resistivity up to about 22 meters deep. These units correspond to claystone - mudstone units. Below the unit with relatively low impedance is a very high resistivity (3870 ohm-m) unit.

In VES-2, it is seen that there are units with relatively low resistivity up to about 55 meters deep. These units correspond to claystone - mudstone units. Below the unit with relatively low impedance is a very high resistivity (2269 ohm-m) unit.

In VES-3, it is seen that there are units with relatively low depth of about 48 meters' depth. These units correspond to claystone - mudstone units. Below the unit with relatively low impedance is a very high resistivity (1991 ohm-m) unit.

In VES-4, it is seen that there are units with relatively low depth of about 4 meters' depth. These units correspond to claystone - mudstone units. Below the unit with relatively low impedance is a very high resistivity (740 ohm-m) unit.

In VES-5, it is seen that there are units with relatively low depth of about 6 meters' depth. These units correspond to claystone - mudstone units. Below the unit with relatively low impedance is a very high resistivity (1062 ohm-m) unit.

The slip zones belonging to the instabilities observed in the study area were found to be in the form of thin and water saturated shear zones. It was found in transition zones of claystone-mudstone-sandstone layers. As a result of the electrical resistivity measurements, the cross section of the resistivity values showed the abrupt changes in lithological variation levels and the slip zones.

7. GEOCHEMICAL PROPERTIES OF THE ELMALI FORMATION

Within the scope of the thesis study, XRF and XRD experiments were carried out on specimens taken from specific regions in order to reveal the geochemical characteristics of Elmalı Formation. In this section, the interpretation of the data obtained as a result of the XRF and XRD methods will be reviewed.

7.1. XRF Experiments

X-ray fluorescence (XRF) spectrometry is the technique of an elemental analysis with broad application in science and industry. XRF is based on the principle that individual atoms, when excited by an external energy source, emit X-ray photons of a characteristic energy or wavelength. By counting the number of photons of each energy emitted from a sample, the elements present may be identified and quantitated (Guthrie, 2012).

Table.7.1. The regions where the XRF method is applied on the receiving samples

SAMPLE NO.		LOCATION	COORDINATE (EUR 50)	SAMPLE PROPERTY
FKS-2	**F-XRF-1**	Karabıyık	35 715484D/ 4052049K	Claystone-Siltstone
FKS-4	**F-XRF-2**	Karabıyık	35 715500D/4052113K	Greyish green Colored Claystone-Siltstone
FKS-5	**F-XRF-3**	Karabıyık	35 715183D/4051996K	Sandstone (Litharenite)
FBaS-2	**F-XRF-4**	Bayır	35 715635D/ 4062335K	Claystone
FBaS-4	**F-XRF-5**	Bayır	35 715635D/ 4062335K	Fine-grained Sandstone
FBaS-5	**F-XRF-6**	Bayır	35 715635D/ 4062335K	Siltstone
FBaS-6	**F-XRF-7**	Bayır	35 715635D/ 4062335K	Laminated medium grained Sandstone
FDS-2	**F-XRF-8**	Dereköy	35 725366D/ 4059608K	Claystone
FDS-5	**F-XRF-9**	Dereköy	35 725366D/ 4059608K	Claystone
FDS-6	**F-XRF-10**	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone
FDS-7	**F-XRF-11**	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone
FDS-9	**F-XRF-12**	Dereköy	35 721995D/ 4060729K	Claystone

In this context, experiments were carried out on 12 rock samples (Table.7.1) taken from Karabıyık, Bayır and Dereköy Quarters by MEITAM between 24.02.2017-28.02.2017 and the results of the chemical analyses made with WD-XRF instrument were stated in the report prepared on 02.03.2017 (Table.7.2). The chemical properties of the samples taken from the Karabıyık, Dereköy and Bayır quarters were investigated and their major oxidized graphs were prepared (Figure 7.1).

Table.7.2. Chemical properties of samples taken from Karabıyık, Bayır and Dereköy Quarters (MEİTAM)

	1	2	3	4	5	6	7	8	9	10	11	12
WD-XRF	FKS-2	FKS-4	FKS-5	FBaS-2	FBaS-4	FBaS-5	FBaS-6	FDS-2	FDS-5	FDS-6	FDS-7	FDS-9
Na2O	0.25	0.28	0.46	0.66	0.79	0.67	0.57	0.44	0.5	0.61	0.6	0.56
MgO	11.41	8	3.96	4.36	4.31	5.75	2.17	4.21	4.74	5.81	5.16	4.64
Al2O3	5.7	6.79	8.17	12.23	6.53	10.26	4.21	8.86	9.97	9.79	6.47	10.74
SiO2	27.96	29.42	26.51	37.67	29.2	34.19	21.59	26.85	30.57	32.68	27.81	32.39
P2O5	0.081	0.1	0.11	0.11	0.092	0.1	0.066	0.085	0.087	0.091	0.091	0.1
SO3	0.087	0.06	0.049	0.053	0.26	0.47	0.1	0.19	0.19	0.33	0.093	0.08
K2O	0.89	1.34	1.52	2.4	1.18	2.05	0.82	2	2.26	1.94	1.14	2.41
CaO	24.2	25.41	30.3	18.02	32.17	21.62	41.41	27.71	23.86	22.76	31.62	22.11
TiO2	0.43	0.47	0.59	0.75	0.56	0.68	0.31	0.55	0.64	0.61	0.5	0.64
Cr2O3	0.21	0.13	0.05	0.05	0.086	0.059	0.063	0.042	0.045	0.058	0.079	0.043
MnO	0.1	0.1	0.12	0.12	0.11	0.12	0.14	0.14	0.13	0.1	0.13	0.13
Fe2O3	7.07	6.41	5.11	7.63	4.28	6.69	2.84	5.06	6.94	6.26	4.65	6.91
NiO	0.11	0.08	0.051	0.038	0.035	0.042	0.017	0.036	0.04	0.046	0.041	0.036
CuO	0	0	0	0.009	0	0	0	0.009	0.009	0.008	0	0.009
ZnO	0.01	0.012	0.009	0.013	0	0.012	0	0.012	0.013	0.012	0.008	0.013
Rb2O	0	0.007	0.008	0.014	0.006	0.011	0	0.012	0.014	0.011	0.005	0.014
SrO	0.055	0.068	0.064	0.043	0.069	0.051	0.089	0.064	0.075	0.067	0.076	0.055
ZrO2	0.01	0.014	0.023	0.019	0.02	0.018	0.007	0.011	0.014	0.016	0.017	0.014
A.Z.	21.36	21.33	22.91	15.61	20.26	17.17	25.64	22.72	19.95	18.82	21.48	19.08

A.Z.: Ateş Zaylat(Fever Loss)

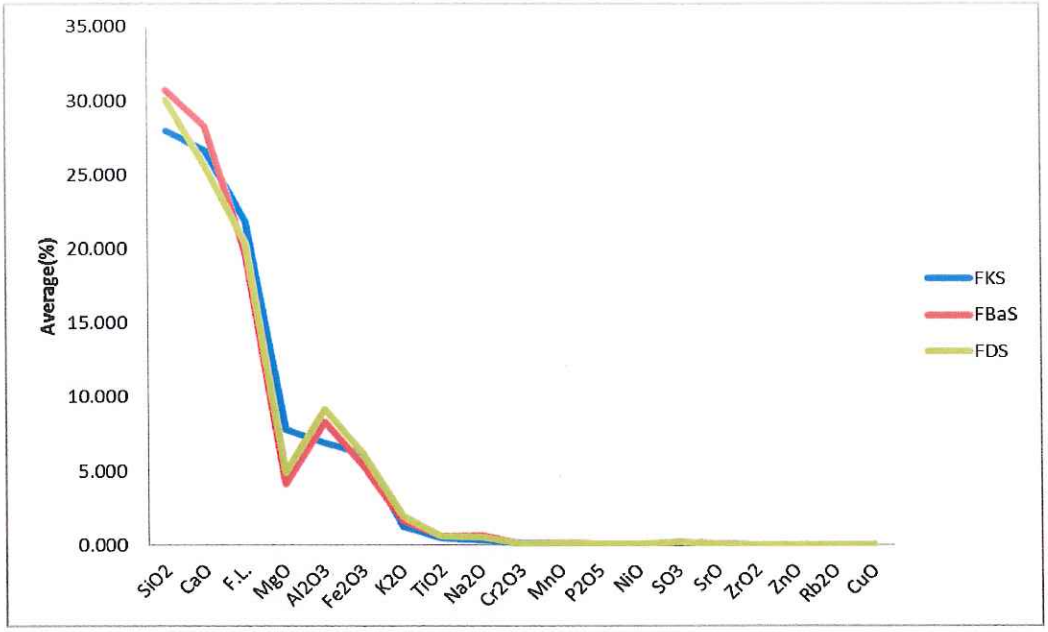
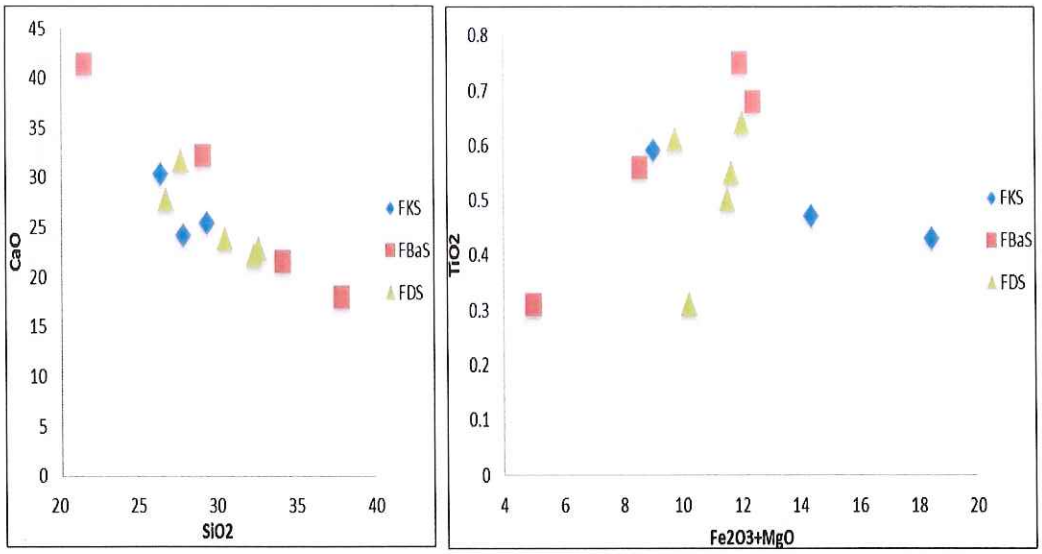


Figure 7.1. Major oxide element comparison of all samples taken from Karabıyık, Bayır and Dereköy Quarters

In order to reveal the geochemical characteristics of the region, the amount of chemical components of the rocks was determined as a result of experiments on 12 samples taken from Karabıyık, Bayır and Dereköy districts.

It is thought that the rocks in the Karabıyık area are fed from a different source while the samples taken from the Bayır and Dereköy districts have a similar source. However, the change in MgO and Al2O3 percentages, as seen in the chart, supports this notion (Fig7.1).

The chemical properties of the rocks in the region were compared with each other to obtain different geochemical tables. These tables are shown as Log (SiO2/Al2O3)-Log(Fe2O3/K2O), SiO2 – CaO, Fe2O3+MgO - TiO2, Fe2O3+MgO - Al2O3/SiO2 and Fe2O3+MgO - Al2O3/CaO+Na2O (Figure 7.2.-7.5) graphics.



(a) (b)

Figure 7.2.a) SiO2-CaO charts of samples taken from Karabıyık, Bayır and Dereköy Quarters, b) Fe2O3+MgO - TiO2 charts of samples taken from Karabıyık, Bayır and Dereköy Quarters

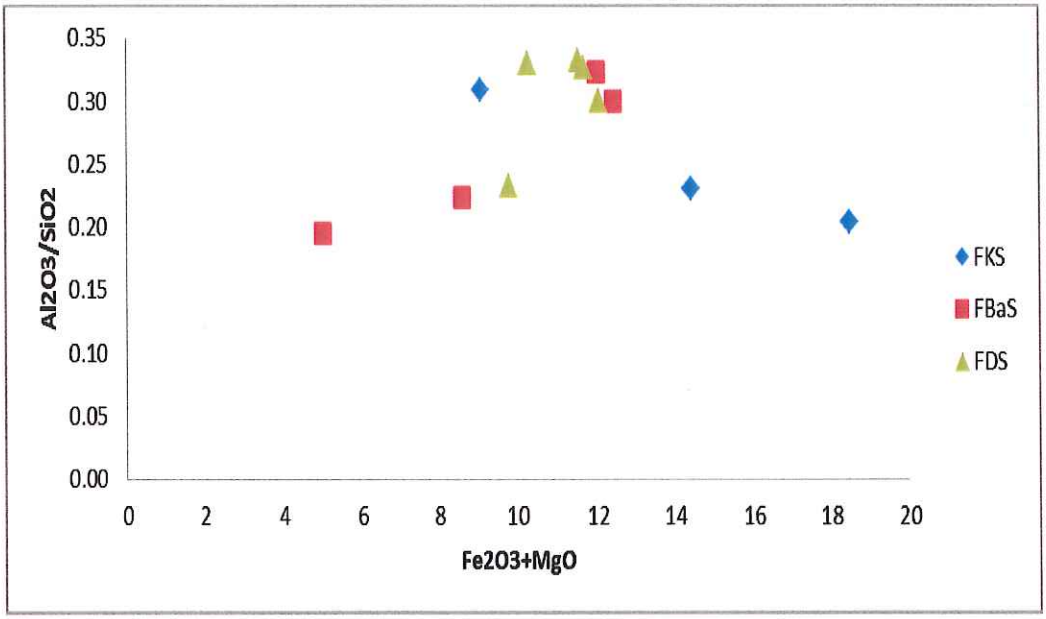


Figure 7.3. Fe2O3+MgO - Al2O3/SiO2 charts of samples taken from Karabıyık, Bayır and Dereköy Quarters

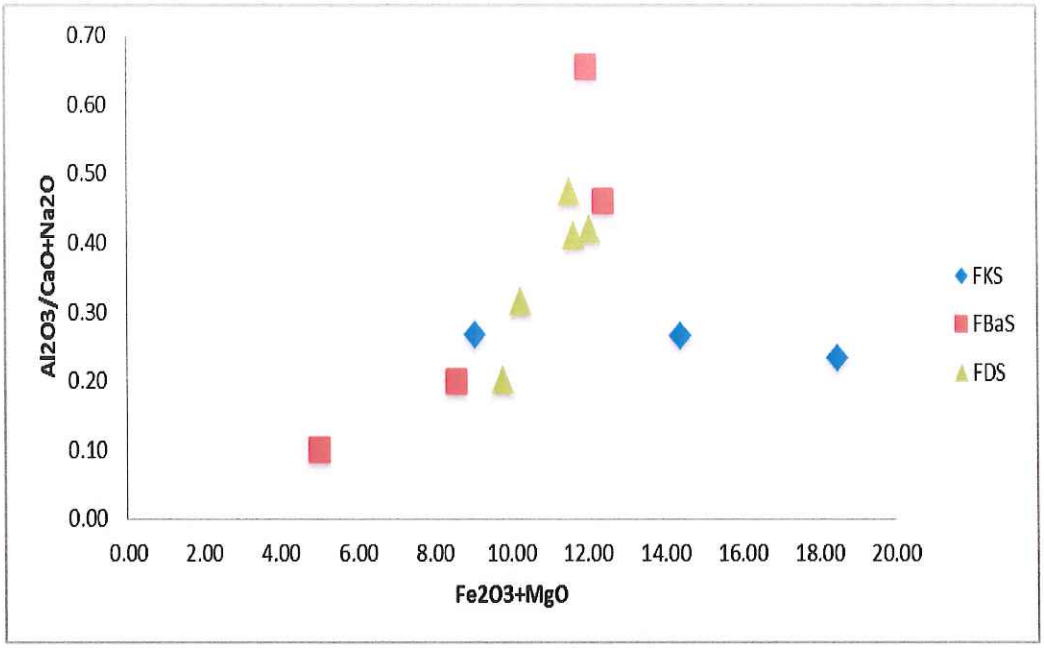


Figure 7.4. Fe_2O_3+MgO - Al_2O_3/CaO+Na_2O charts of samples taken from Karabıyık, Bayır and Dereköy Quarters

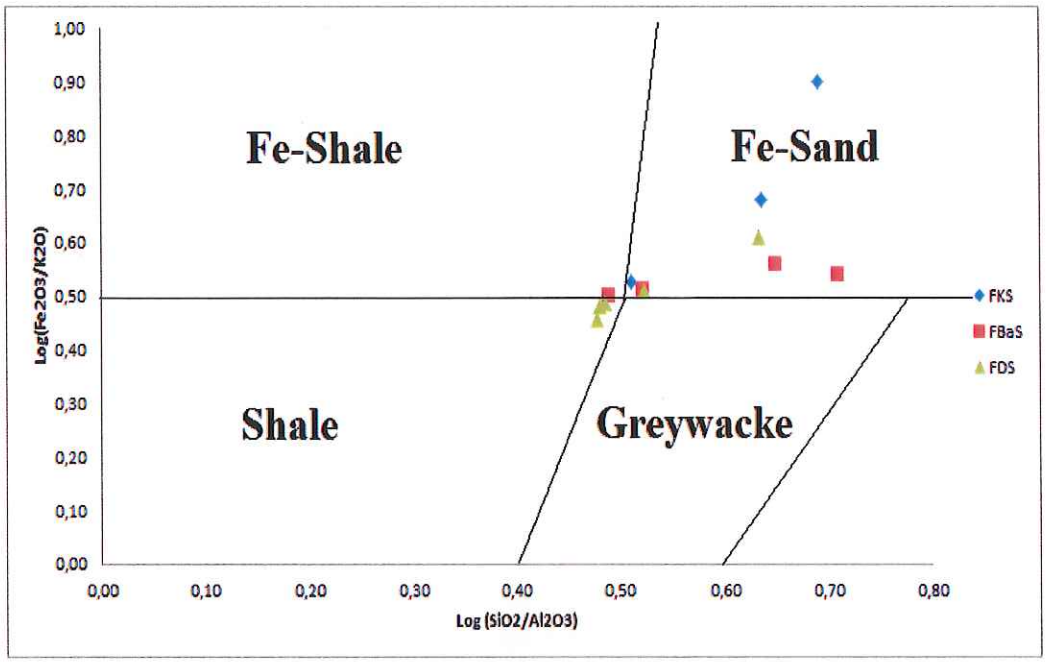


Figure 7.5. Chemical classification scheme for studied samples (Log(SiO_2/Al_2O_3)-Log(Fe_2O_3/K_2O)) taken from Karabıyık, Bayır and Dereköy Quarters (Mod. from Herron, 1988)

The petrographic and geochemical analyses are using for, to build a picture of the nature and composition of the changing source hinterland for sediment transported into the basin. This information is then used to interpret the tectonic evolution of the source areas and basin depocentres through time (Gül et al., 2011).

In this study, positive correlation between Al203, Fe2O3, MgO, SiO2 and TiO2 were points out fed from the especially mafic and ultramafic rocks and granitic rocks. If we take into consideration of thin section of samples ophiolite rock fragments and lesser extent granitic rock fragments are justify with these results. Negative correlation between CaO and SiO2 is point out the different sources. Especially older limestone (fossiliferous limestone) and marble led to high CaO. However, the dolomite was act as a source that led high MgO content.

In addition to all these, the samples are classified according to Log (SiO2/Al2O3)-Log (Fe2O3/K2O) on the basis of geochemical analyses carried out on samples belonging to Elmalı Formation taken from Karabıyık, Bayır and Dereköy Quarters (Figure 7.5). According to chemical classification scheme (Mod. from Herron, 1988), the samples were defined as shale, iron shale (Fe-Shale) and iron sand (Fe-Sand). Also the Fe-Sand and Fe-Shale dominancy emphasized that the Elmalı Formation fed from mainly ophiolitic rocks.

7.2. XRD Experiments

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analyzed material is finely ground, homogenized, and average bulk composition is determined. X-ray powder diffraction is most widely used for the identification of unknown crystalline materials (Dutrow, 1997). 10 specimens were investigated by XRD method in order to determine the small clay minerals that could not be detected by binocular microscope in the unit exposed in the study area (Table.7.3). XRD patterns were analysed in Muğla Sıtkı Kocman University, Research and Application Centre for Research Laboratories with using the Rigaku Smart Lab XRD (X-Ray Diffractometer).

Table.7.3. The regions where the XRD method is applied on the receiving samples

SAMPLE NO.		LOCATION	COORDINATE (EUR 50)	SAMPLE PROPERTY
FKS-2	F-XRD-1	Karabıyık	35 715484D/ 4052049K	Claystone-Siltstone
FKS-4	F-XRD-2	Karabıyık	35 715500D/4052113K	Greyish green Colored Claystone-Siltstone
FKS-5	F-XRD-3	Karabıyık	35 715183D/4051996K	Sandstone (Litharenite)
FBaS-2	F-XRD-4	Bayır	35 715635D/ 4062335K	Claystone
FBaS-5	F-XRD-5	Bayır	35 715635D/ 4062335K	Siltstone
FDS-2	F-XRD-6	Dereköy	35 725366D/ 4059608K	Claystone
FDS-5	F-XRD-7	Dereköy	35 725366D/ 4059608K	Claystone
FDS-6	F-XRD-8	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone
FDS-7	F-XRD-9	Dereköy	35 725366D/ 4059608K	Claystone-Siltstone
FDS-9	F-XRD-10	Dereköy	35 721995D/ 4060729K	Claystone

X-ray diffraction analysis (XRD) is operating by Rigaku Diffractometer equipped with a Cu tube at 40Kv voltage and 30 Ma current. The diffractograms of the bulk powder and the clay-size oriented glass slide were plotted between 2°-72° 2Θ with a scanning rate of 0.5° /min, respectively.

The diffractogram, of the bulk samples reveal the presence of calcite (3.03Å at 30.06° 2Θ), quartz (3,34Å at 26° 2Θ), feldspar (3.19Å at 27.09° 2Θ). Although, Bulk sample X-ray diffractogram are not employed for describing the sized fraction, the diffractogram evaluated for this study reveal some clear peaks between 2°-20° 2Θ which lead us to classify at least the type of possible clay minerals.

In this respect, 14Å peak at - 6° 2Θ reflects the possible presence of the smectite, chlorite or vermiculite to which one exists in the sample further Ethylene Glycol (EG) treatments must be made. 10 Å at 8,8° 2Θ refers to presence of illite 7.20 - 28 Å at 12° 2Θ may be the d (002) reflection of d(001) 14 Å chlorite. Another 7 Å peak at 12.4° 2Θ is kaolinite reflection which will be collapsed by further heating to 550°C. But for bulk analysis, 4.44-4.48 Å at 19.7° - 20° 2Θ is the total clay peak emphasizing that the sample has clay minerals in the composition. According to X-ray diffraction analyses: Quartz, feldspar, calcite and clay were totally identified in the all samples. However, dolomite and chlorite were seen in some samples.

8. ENGINEERING GEOLOGICAL PROPERTIES OF THE ELMALI FORMATION

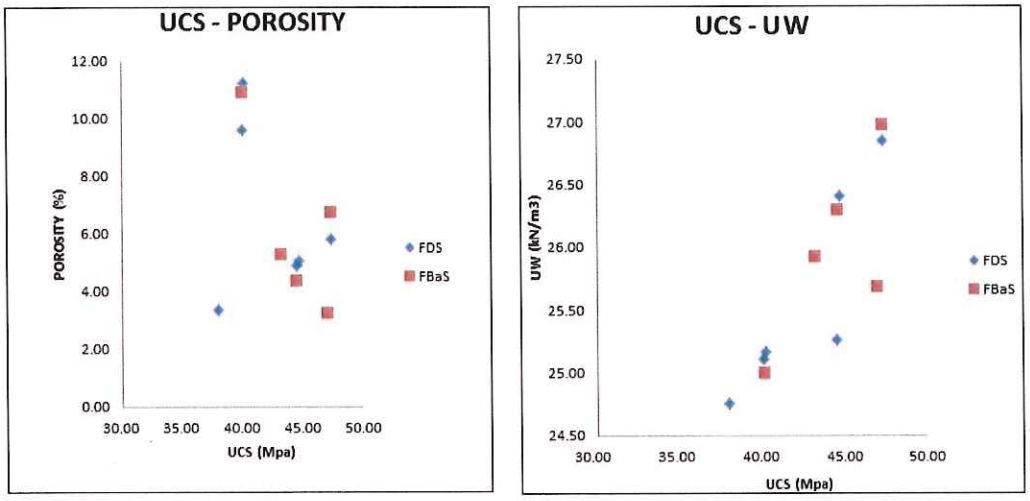
Within the scope of the thesis study, some experiments were carried out on specimens taken from certain regions in order to reveal the engineering properties of Elmalı formation and in-situ tests were carried out. In order to perform engineering experiments within the sandstones belonging to the Elmalı formation, sampling work was carried out at 11 different points from Bayır and Dereköy quarters. These experiments can be expressed as Uniaxial Compressive Strength, Porosity, Unit Weight and Water absorption percent by weight. For claystone-siltstone samples, experiments were carried out on 10 different samples taken from Karabıyık, Bayır and Dereköy quarters. These experiments can be expressed as Atterberg Limits and Relative Density.

8.1. Experiments on Sandstone Samples

Within the scope of this study, sandstone samples from 11 different points were taken from Bayır and Dereköy quarters and the mean, maximum and minimum values and standard deviations of each of these samples were calculated. Experiments such as Uniaxial Compressive Strength, Porosity, Unit Weight and Water absorption percent by Weight were carried out on sandstone samples of Elmalı Formation under this heading were compared within themselves and among each other (Figure 8.1-Figure 8.5), and the obtained data were given in tabular form (Table 8.1).

Table 8.1. Engineering properties of sandstone

Sample No	Uniaxial Compressive Strength sc(Mpa)	Porosity %	Unit Weight (kN/m3)	Water Absorbtion Percent by Weight %
F-D-S-1	44.83	5.07	26.41	1.58
F-D-S-2	38.20	3.38	24.75	0.94
F-D-S-3	47.43	5.83	26.85	1.73
F-D-S-4	40.39	11.23	25.16	3.54
F-D-S-7	40.24	9.62	25.11	2.53
F-D-S-8	44.63	4.89	25.26	1.25
F-Ba-S-1	43.35	5.27	25.92	1.44
F-Ba-S-2	44.68	4.36	26.29	1.02
F-Ba-S-3	47.43	6.73	26.97	2.03
F-Ba-S-5	40.29	10.91	25.00	3.24
F-Ba-S-6	47.12	3.23	25.69	1.00
Average	43.51	6.41	25.76	1.85
Maximum	47.43	11.23	26.97	3.54
Minimum	38.20	3.23	24.75	0.94
Standart Deviation	3.27	2.88	0.77	0.90



(a) (b)

Figure 8.1.a) Comparison of Uniaxial Compressive Strength -Porosity, b) Comparison of Uniaxial Compressive Strength - Unit Weight

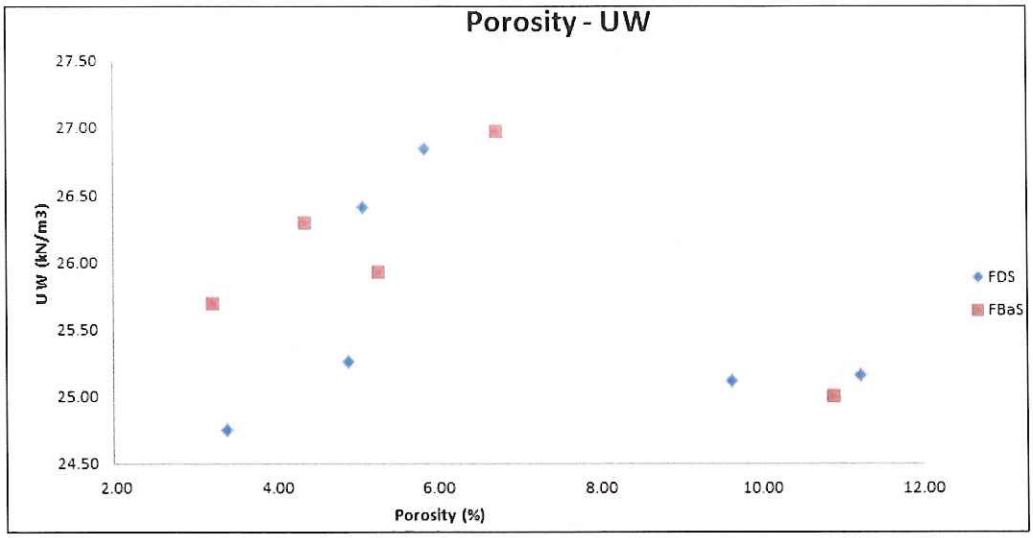


Figure 8.2. Comparison of Porosity- Unit Weight

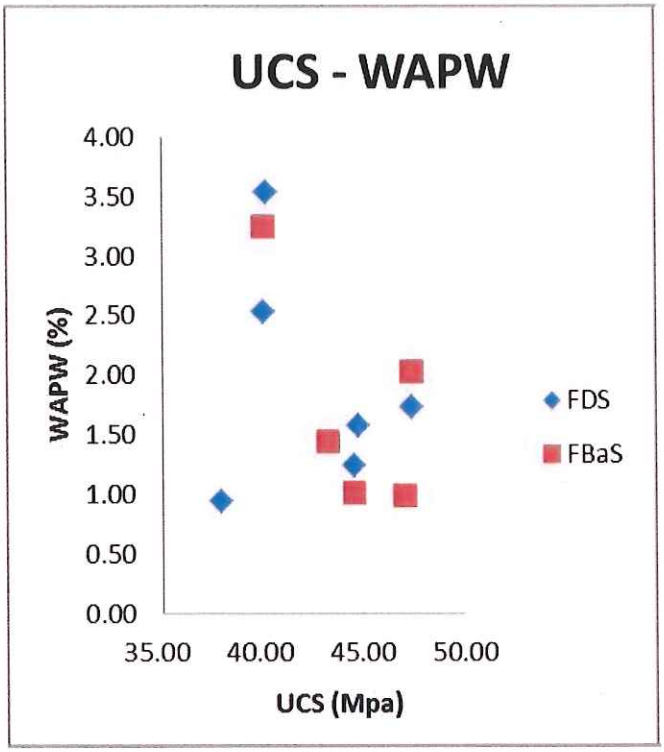


Figure 8.3. Comparison of Uniaxial Compressive Strength - Water absorption percent by Weight

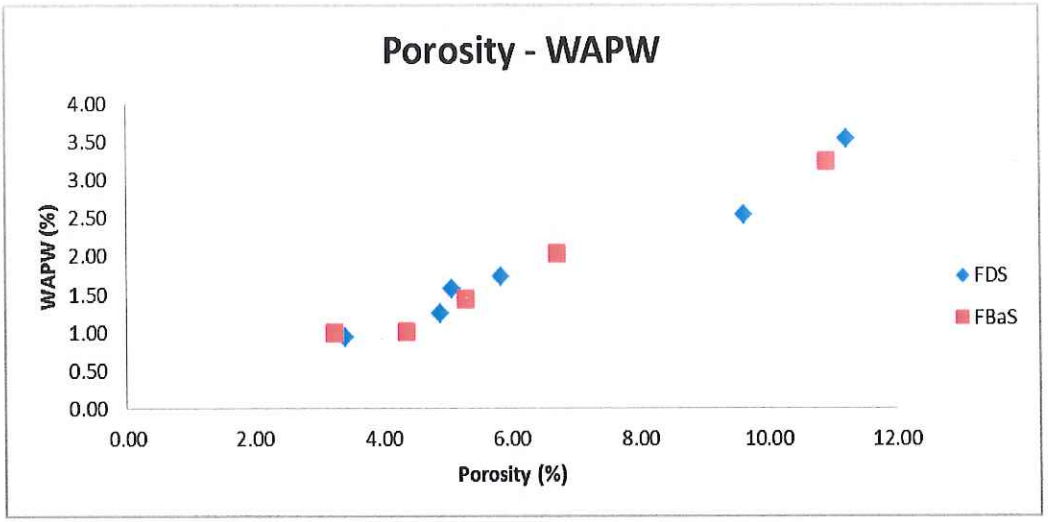


Figure 8.4. Comparison of Porosity- Water absorption percent by Weight

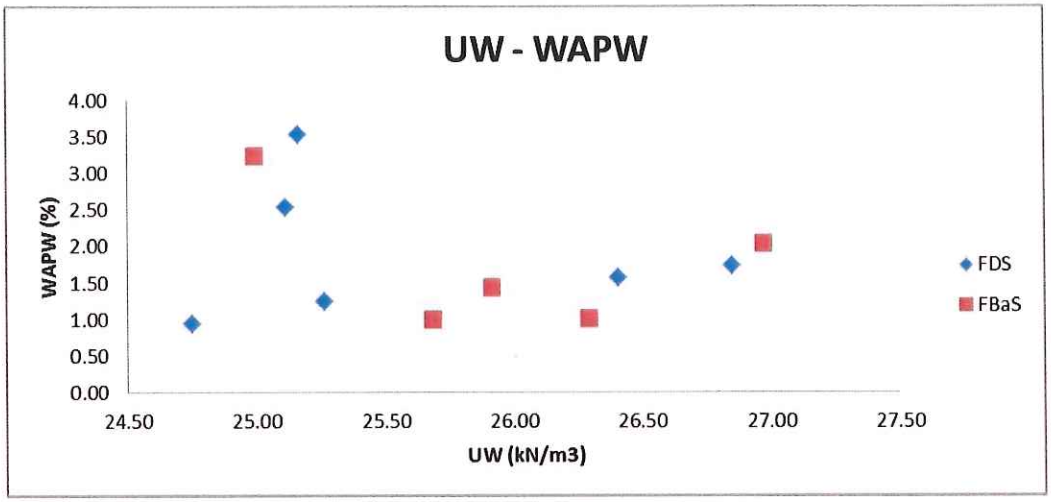


Figure 8.5. Comparison of Unit Weight - Water absorption percent by Weight

As a result of the experiments on the sandstones, the samples were compared within themselves. When comparing porosity with uniaxial compressive strength, it will be seen that as the Porosity decreases, the resistance of the rock increases. However, Uniaxial compressive strength was found to be directly proportional to Unit weight. Except for a few specimens, there was generally a proportional improvement in the Unit weight and Porosity. When a comparison of the Water absorption percent by weight test with the other experiments was made, only a graph compatible with the porosity test could be obtained. It has been found that as the Porosity of the rocks increases, the amount of Water absorption percent by weight increases.

8.2. Experiments on Claystone-Siltstone Samples

In this part of the work, Atterberg Limits experiments and relative density calculations were made on claystones-siltstones of Elmalı Formation taken from Karabıyık, Bayır and Dereköy quarters. Relative density or specific gravity, is the ratio of the density of a substance to the density of a given reference material. As Atterberg Limits; The Liquid Limit (LL) determines the water content at which soil changes from a liquid to a plastic state and the Plastic Limit (PL) is the moisture content above which the soil behaves plastically. In this context, samples were taken from 10 different points and the fine-grained soils were classified according to the USCS using the Liquid Limit and Plasticity index data obtained from the experiments (Table.8.2). The Unified Soil Classification System (USCS) is a soil classification system used in engineering and geology to describe the texture and grain size of a soil. According to the classification made, the samples expressed by the CL symbol are defined as inorganic clays, silty clays, sandy clays of low plasticity. The samples expressed with the ML symbol are defined as inorganic silts, silty or clayey fine sands, with slight plasticity. Furthermore, as shown in Table 8.2, the average relative density of the samples obtained from the study area is determined as 2.82 g/cm^3.

Table.8.2. Classification of the samples obtained from Elmalı Formation according to its relative density and USCS

Sample NO	LL	PL	PI	Relative Density	USCS
FKS-1	27.5	22.4	5.1	2.75	CL-ML
FKS-4	25.4	19.3	6.1	2.87	CL-ML
FKS-5	26.2	19.8	6.4	2.93	CL-ML
FBAS-2	37.2	24.3	12.9	2.72	CL
FBAS-5	25.4	19.8	5.6	2.77	CL-ML
FDS-2	31.5	21.2	10.3	2.91	CL
FDS-5	25.5	19.6	5.9	2.77	CL-ML
FDS-6	25.5	19.2	6.3	2.85	CL-ML
FDS-7	26	19.5	6.5	2.91	CL-ML
FDS-9	30.4	21.6	8.8	2.75	CL
Average	28.06	20.67	7.39	2.82	
Maximum	37.20	24.30	12.90	2.93	
Minimum	25.40	19.20	5.10	2.72	
Standart Deviation	3.89	1.68	2.50	0.08	

The distinction between clay and silt-sized materials has not been fully realized in classifications made according to USCS. For this reason, the properties of the samples were also investigated using the Wiqoyah (2006) and Chen (1975) tables depending on the plasticity index. Cl-Ml type soils have been determined to be silty type soils because of their low plasticity (Table.8.3). It was also determined that the swelling potential of all samples obtained from the study area was low (Table.8.4). Holtz and Kovacs (1981) used previous researcher data, try to determine clay type based on plasticity index and liquid limit. Our three sample namely, FBaS2, FDS2 and FDS9 drop into lower boundary of Illite type of clays, while all other sample drop into lower limit transition between montmorillonite and illite (above A (activity)-line, so illite ratio is higher).

XRD studies have also found clay with poor swelling potential such as illite, vermiculite and kaolinite. Thus, the fact that all the experiments were parallel to each other proved the validity of the studies carried out.

Table.8.3. Soil properties according to their plasticity index, Wiqoyah (2006)

PI	Various	Soil Properties
0	Non plasticity	Sand
< 7	Low plasticity	Silt
7 – 17	Medium plasticity	Silt clay
> 17	High plasticity	Clay

Table.8.4. Relationship between swelling potential and plasticity index, Chen (1975)

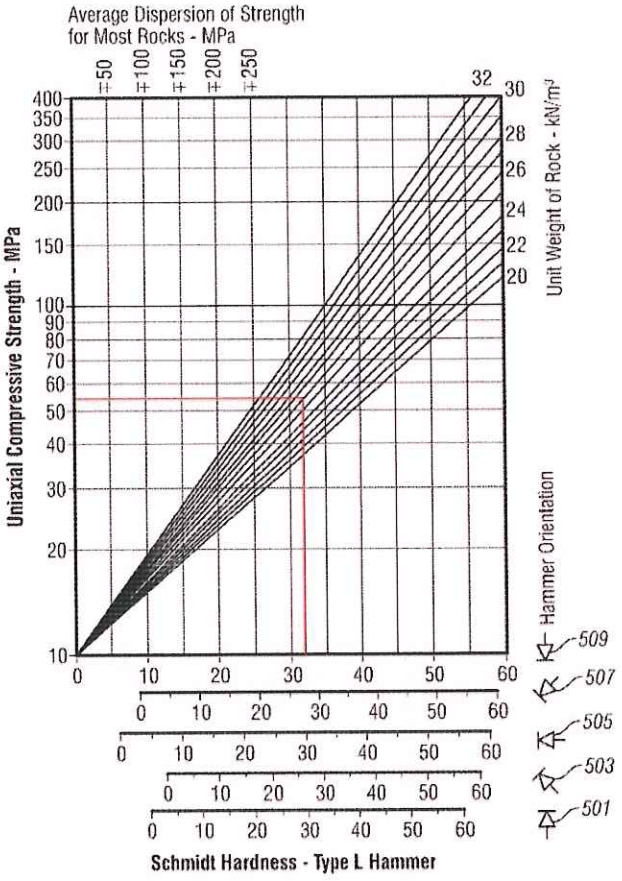
Swelling the potential	Plasticity index
low	0 - 15
medium	10 - 35
high	20 - 55
very high	> 55

8.3. In-situ Tests

The Schmidt hammer rebound test was developed to determine the compressive strength of concrete, and has been used to determine the hardness and compressive strength of rock material (ISRM,1978a). It is actually a measure of surface hardness. The rebound hammer should be considered as a means of determining variations of strength within a structure rather than an accurate means of assessing strength. This experiment was carried out at Bayır and Dereköy locations (Table 8.5). As a result of the experiments carried out on samples taken from the sandstones belonging to Elmalı Formation within the scope of the field studies, the average unit weight of rock was calculated as 25,76 kN/m^3(Table8.1). In addition, the average Schmidt hardness was calculated as 29 for the data obtained from all locations. As a result of these calculations and also according to the hammer orientation (505), the uniaxial compressive strength is about 54 MPa (Table 8.5).

Table 8.5. Calculation of Schmidt hardness and corresponding uniaxial compressive strength

Location	Coordinate(Eur50)	Schmidt Hardness
Bayır	35 715784E/ 4065906N	21
Bayır	35 715445E/ 4064322N	20
Bayır	35 715635E/ 4062335N	36
Bayır	35 715635E/ 4062335N	38
Bayır	35 715635E/ 4062335N	33
Bayır	35 715635E/ 4062335N	37
Dereköy	35 725366E/ 4059608N	26
Dereköy	35 725366E/ 4059608N	26
Dereköy	35 725366E/ 4059608N	35
Dereköy	35 725366E/ 4059608N	23
Dereköy	35 725366E/ 4059608N	32
Dereköy	35 721995E/ 4060729N	28
Dereköy	35 721995E/ 4060729N	23
Average		29



The average uniaxial compressive strength was calculated as 43,51 MPa for the experiments carried out on samples taken from sandstones belonging to Elmalı Formation within the scope of field studies (Table8.1). In addition, according to the Schmidt hammer test results made in the field, the uniaxial compressive strength is about 54 MPa is shown in Table 8.5. All these calculations were made to obtain the resistances of the sandstones belonging to Elmalı Formation and to classify the rocks according to these parameters. According to ISRM (1979), in the direction of the results obtained from the Schmidt hammer experiments, the rocks are in the moderate rock class. In addition, in the direction of the data obtained as a result of engineering experiments, the rocks are in a medium rock class (Fig 8.6).

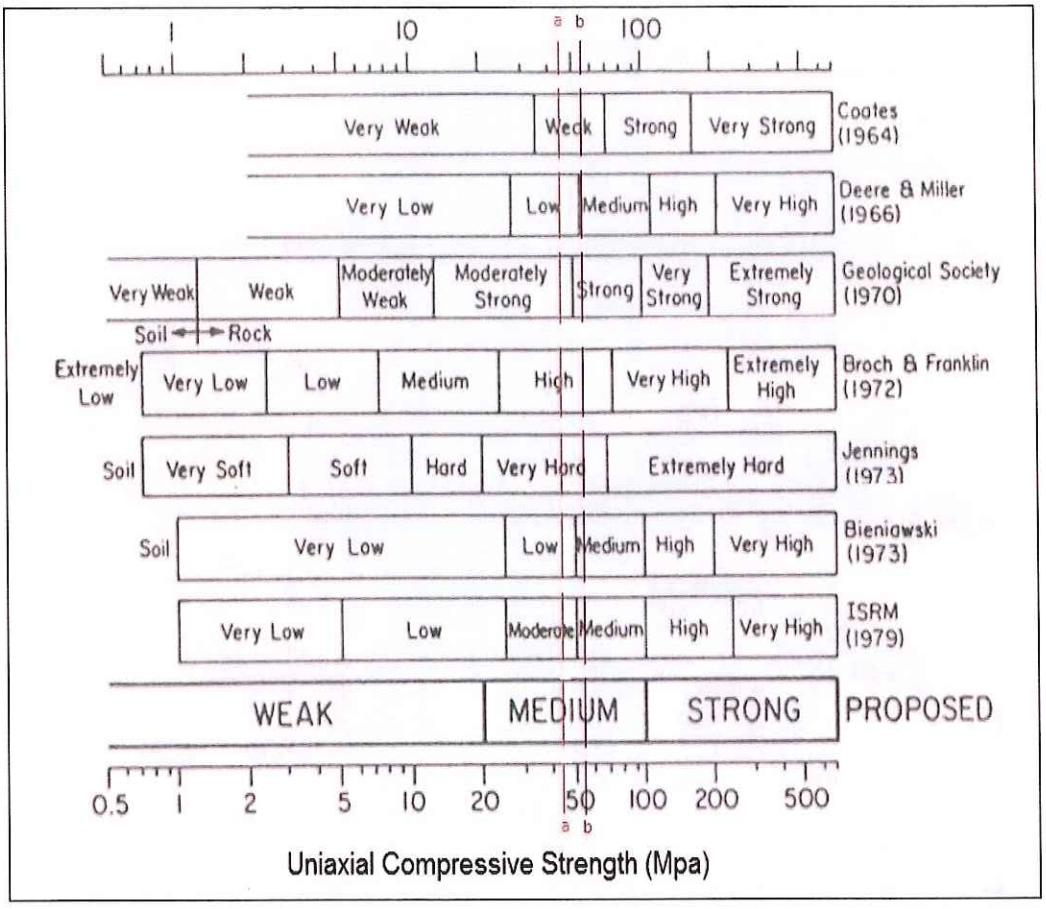


Figure 8.6. Classification of the samples obtained from Elmalı Formation according to Schmidt Hammer Data (b) and Engineering Properties (a) (http.home.iitk.ac.in.pdf, Access date: 2017)

9. MASS WASTING PROPERTIES OF THE ELMALI FORMATION

Within the scope of the thesis study, in order to reveal the properties of mass movements of Elmalı Formation; field studies, in-situ and laboratory studies, including a lot of experimental work and office work done. The aim of all these studies is to examine the details of the geological, lithological and seasonal factors that cause mass movements and to show the effects of landslides on human life and nature.

Landsliding is not only a threat for buildings of any kind and to infrastructure in general but also changes the morphology of the terrain. Landslides often release (destabilize) large amounts of sediments, which not only stay on slopes but also reach the fluvial network (Mikoš et al.,2009). Additionally, the clay or silt matrix exhibits a brittle behaviour when sheared. This is a consequence of overconsolidation and cementation. The initial state of stress (before excavation, in the case of open cuts) is seldom investigated, but it plays a very relevant role to explain stability conditions (Alonso and Pinyol, 2015).

According to Igwe (2015), the amount of rain, nature of slope-material, discontinuities and weathering are the major factors predisposing a slope to failure. Especially the movements due to the swelling properties of the soils break the elements of the structure on them and create many deformations (Yılmaz and Karacan, 1998). For this reason, properties such as the locations of the areas where mass motion is observed, the size of the landslide area, the type of movement, the factors affecting the decay and the relation of the units to the underground and surface waters are examined. In addition, slope maps of 5 different regions were made within the scope of thesis study. However, slope maps of neighbouring quarters are given in a single presentation.

For this reason, three different slope maps were prepared: Çeştepe Quarter (Figure 9.1), Girmeler - Karabıyık Quarters (Figure 9.3) and Bayır - Dereköy Quarters (Figure 9.5). The slope of these regions, in itself, is classified as from flat-near flat areas to very high slope areas.

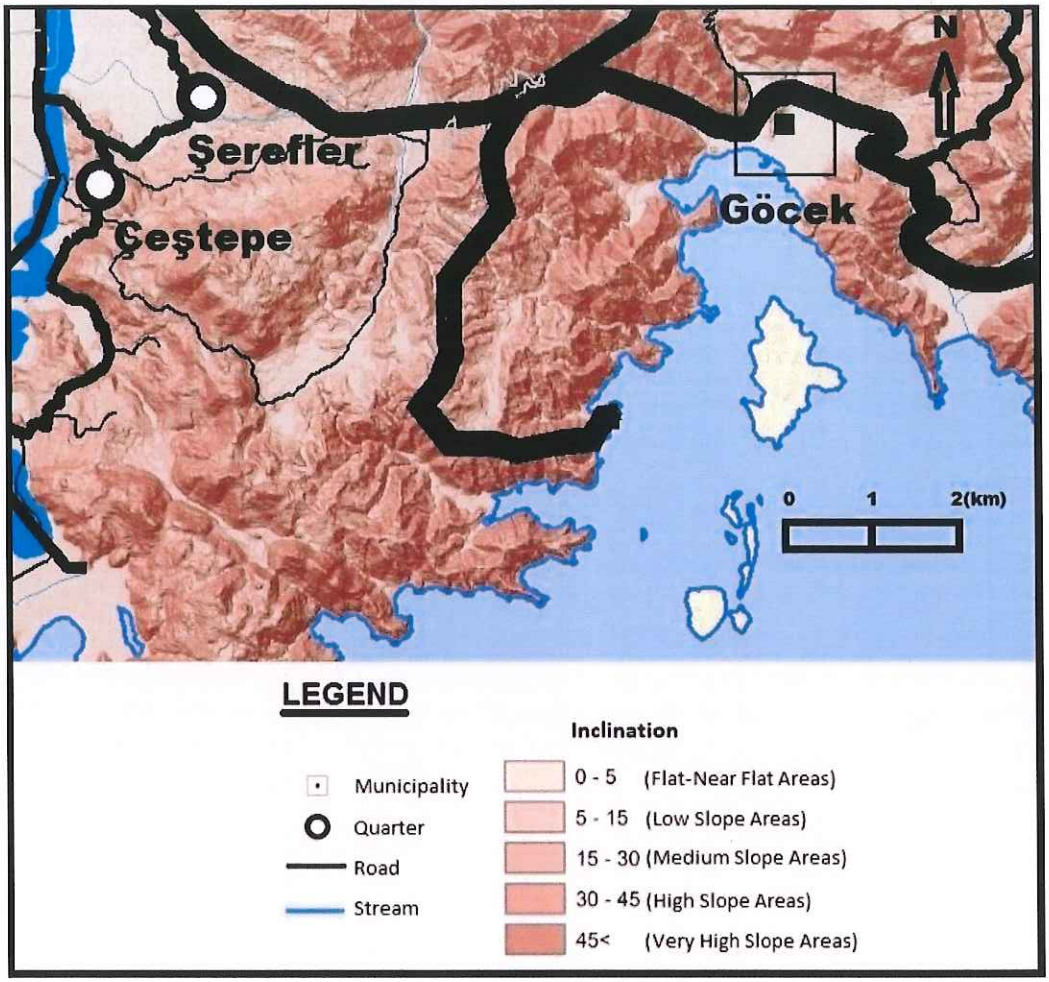


Figure 9.1. Slope map of Çeştepe Quarter and nearest area

In the studies in Çeştepe district, no mass movements were observed where the slope was low. However, the conditions such as road studies have changed the natural topography, mass movements have been observed. It has been determined that the type of movement observed in this region is both translational landslide and creep according to Varnes (1978) classification system, so it can be defined as complex movement (Figure 3.1). As a result of this movement, it has been seen that the garden fence has changed its place and trees have begun to bend due to ground displacement (Figure 9.2).

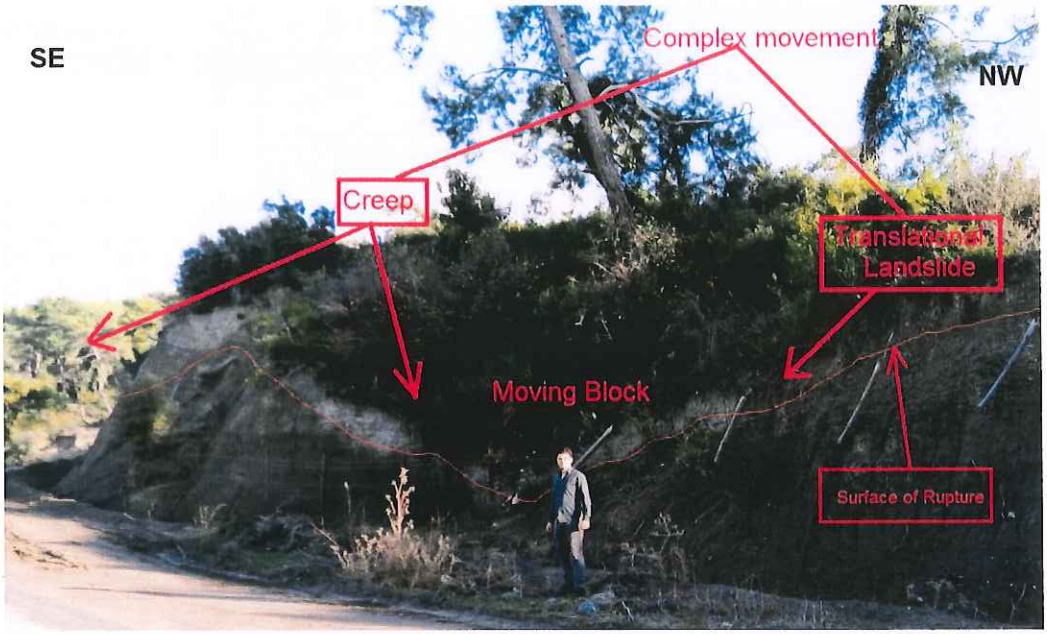


Figure 9.2. Complex movement at Çeştepe Quarter (Man for scale:175cm)

In the studies conducted in the Girmeler Quarter, only the Elmalı Formation was observed to have a tectonic relation with the other formations (Figure 4.14). No observations of mass movements have been made in studies in this region. The reason for this is thought to be that, there is no activity that would disrupt the natural topography.

Observations on the Karabıyık quarter have shown that topography is suitable for mass movements (Figure 9.3). In addition, Eynazlı Stream caused the unit to become unstable by eroding the toe of the unit, and the mass movement occurred for this reason (Figure 9.4). It has been determined that the type of movement observed in this region is rotational landslide. It has been found that the landslide area formed by the mass movement in the district shown in Figure 9.4 is approximately 12 500 m^2 by using the MTA, Geoscience Map Viewer and Drawing Editor.

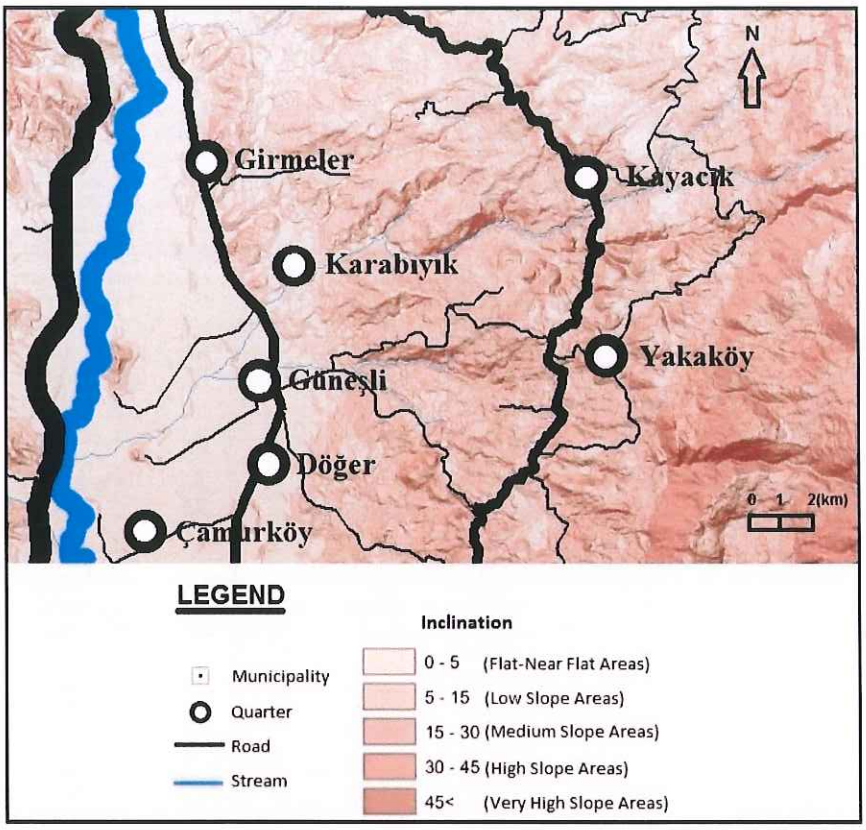


Figure 9.3. Slope map of Girmeler-Karabıyık Quarter and nearest area

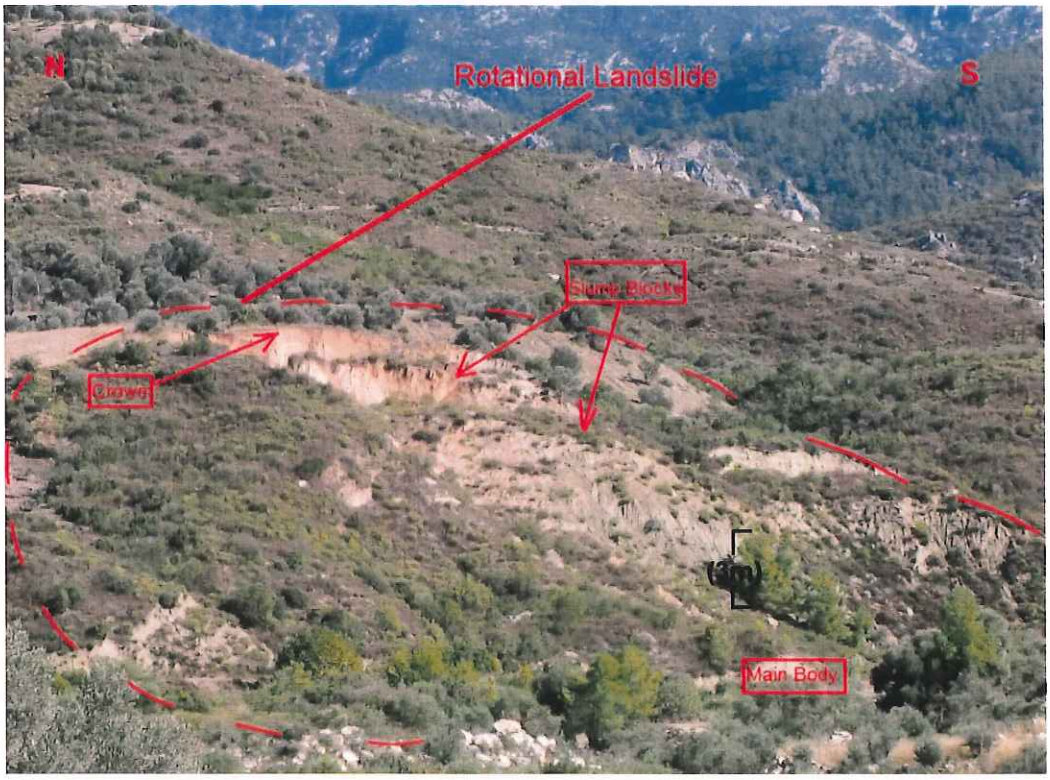


Figure 9.4. Rotational Landslide at Karabıyık Quarter (Tree for scale: 300 cm)

In the scope of the thesis study, the main areas where massive mass movements are seen are Dereköy and Bayır quarters. Thus, contrary to the studies in other regions (Figure 9.1; Figure 9.3), in these regions the directions of mass movements also have given (Figure 9.5).

Observations on the Dereköy quarter have shown that topography is suitable for mass movements (Figure 9.5). The fact that the unit is very fractured and cracked in itself, the porosity of the rock units, the effect of underground and surface waters, and Tezli Stream caused the unit to become unstable by eroding the toe of the unit, so on mass movement occurred.

It is seen that the most important tectonic relation of Elmalı Formation is with Mandırkaya Formation in the examinations made in Dereköy district. A mass movement in the form of earthflow has been observed in areas where this relationship has been observed (Figure 9.6). However, the area shown in Figure 9.7 has been observed to be type of both translational landslide and creep. This proved that the zone was subjected to mass movements in different types depending on the rock structure.

As a result of this movement, it has been seen that the garden fence has changed its place and it has begun to tilt the electricity poles (Figure 9.7). According to the geophysical studies carried out in the region, it was determined that the surface of the rupture (shear plane) is in 48 m deep. Also, it has been calculated that the area of landslide created by this mass movement is approximately 26 500 m^2 by using the MTA, Geoscience Map Viewer and Drawing Editor.

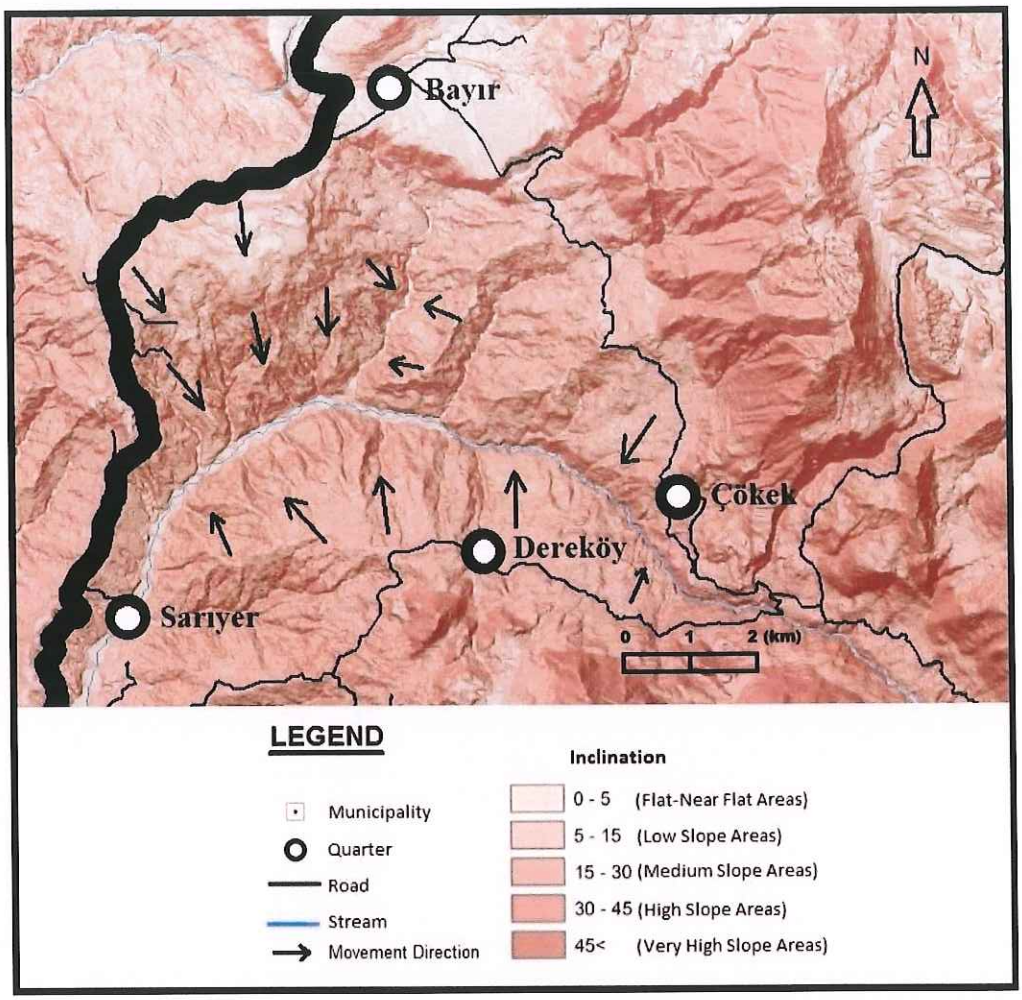


Figure 9.5. Slope map of Dereköy-Bayır Quarter and nearest area



Figure 9.6. Earthflow occurences on the Elmalı Formation at Dereköy Quarter (Car for scale: 165 cm)

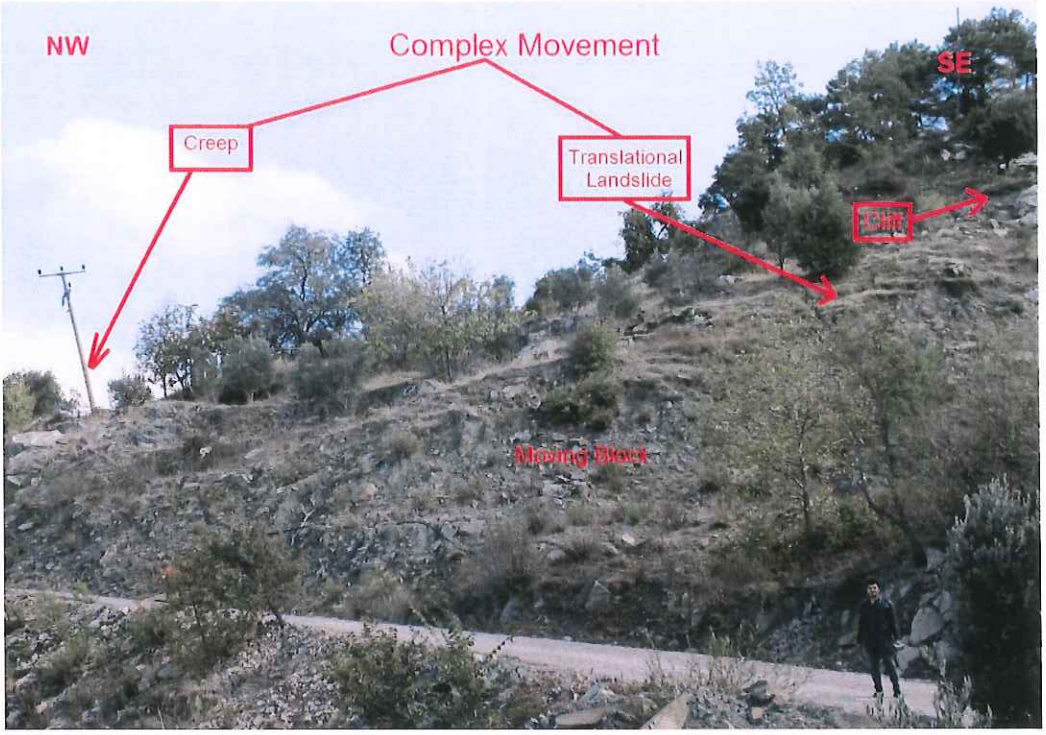


Figure 9.7. Complex movement at Dereköy Quarter (Man for scale: 175cm)

Observations made in the Bayır district also shown that the topographic inclination is suitable for mass movements. Similarly, in this unit, the fact that it is very fractured and cracked in itself, the effect of underground and surface waters and the porosities of rock units are the causes of mass movements. However, Bayır district has a more inclined structure than the Dereköy quarter (Figure 9.5). For this reason, the region has a very suitable position in terms of the development of mass movements.

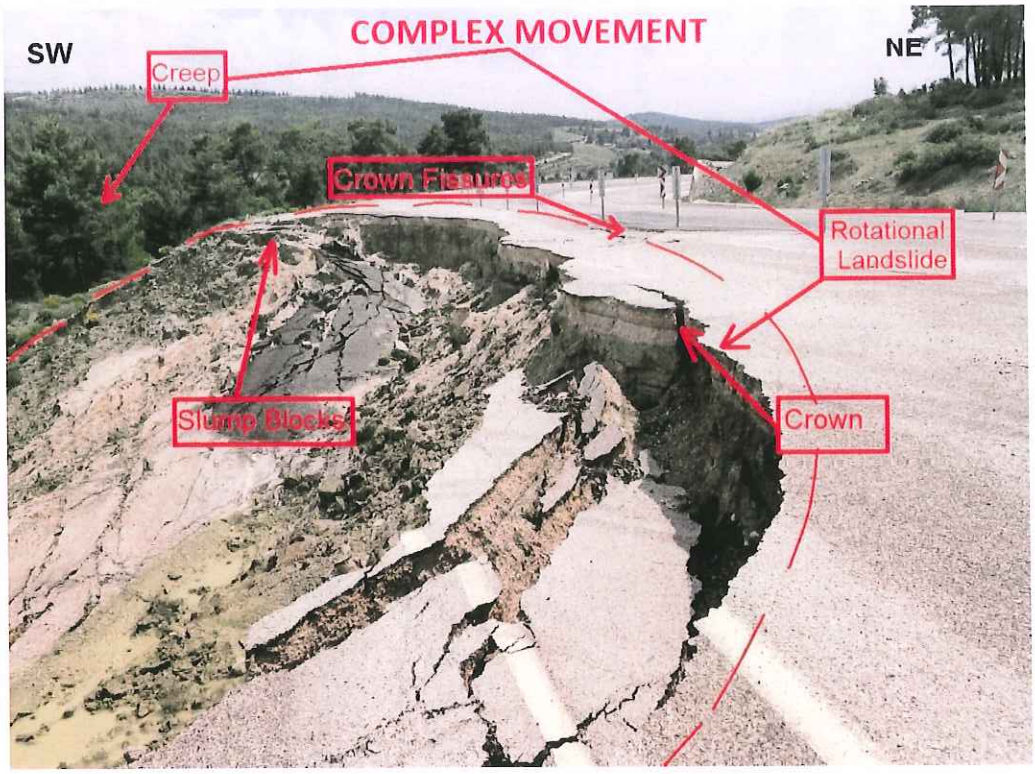


Figure 9.8. Complex movement at Bayır Quarter (Traffic sign for scale: 125 cm)

In the examinations made, it was determined that the mass movements occurrences in this region can be defined as rotational landslide and creep (Figure 9.8). As in other regions, there are also complex movements (rotational landslide, creep and earth flow) in this region. As a result of this movement, it was seen that the retaining walls were collapsed, deformation structures occurred on the road and the trees started to bend. Mass movements are thought to have occurred sooner than they should have been due to road construction work. In case of human impact has caused the natural topography of the region to deteriorate. Surface and rain waters have been used to disintegrate rocks with high porosity and the presence of a clay type material on the ground caused a negative effect on road and retaining structures (Figure 9.9.a-Figure 9.9.b).

According to the geophysical studies carried out in the region, it was determined that the surface of the rupture (shear plane) is 22 meters deep. Also, it has been calculated that the area of landslide created by this mass movement is approximately 21 000 m^2 by using the MTA, Geoscience Map Viewer and Drawing Editor.

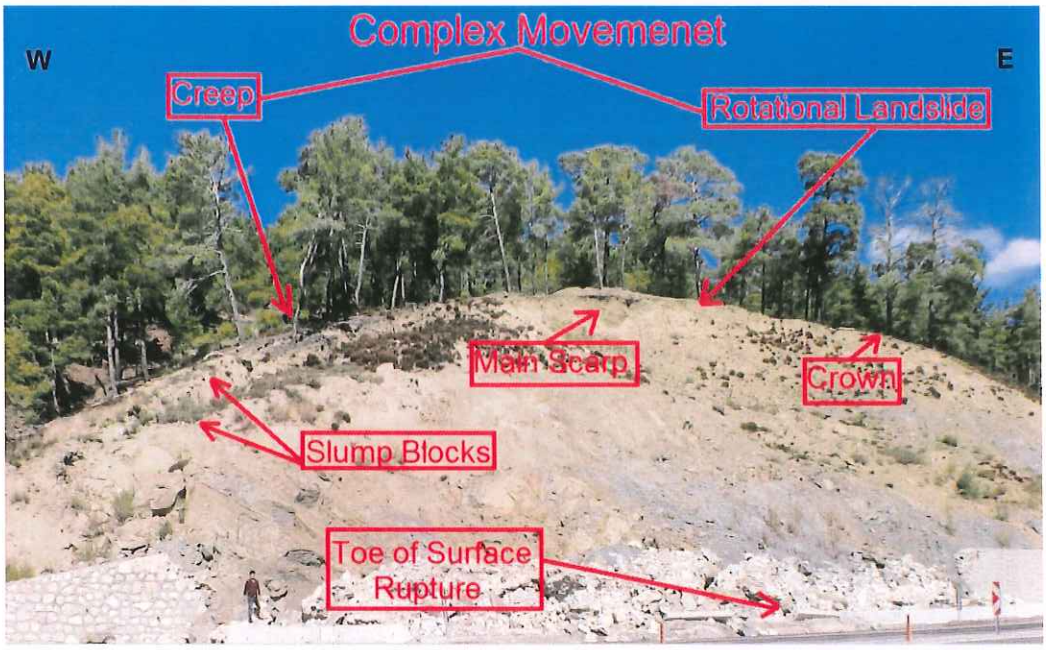


Figure 9.9.a. Demolished stone walls and road at Bayır Quarter (Man for scale: 175cm)

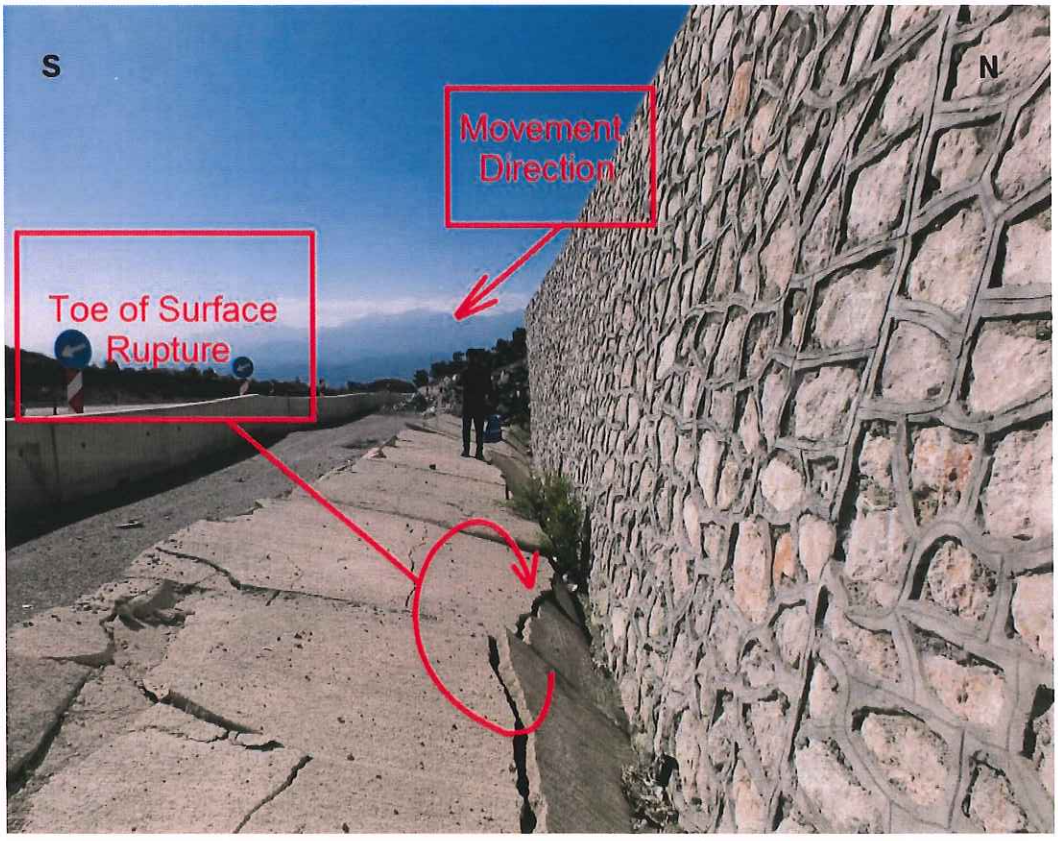


Figure 9.9.b. Demolished stone walls and road at Bayır Quarter (Man for scale: 175cm)

In addition to all these studies, general geological sections of the areas where main landslides are observed within Bayır and Dereköy Quarters have been obtained on a 9.19 km line (Figure 9.10). Black line below the topography surfaces designate potential rotational slide surface (Figure 9.10). Also, the results of the studies are given in a comparative table, taking into account the main factors (Table 9.1).

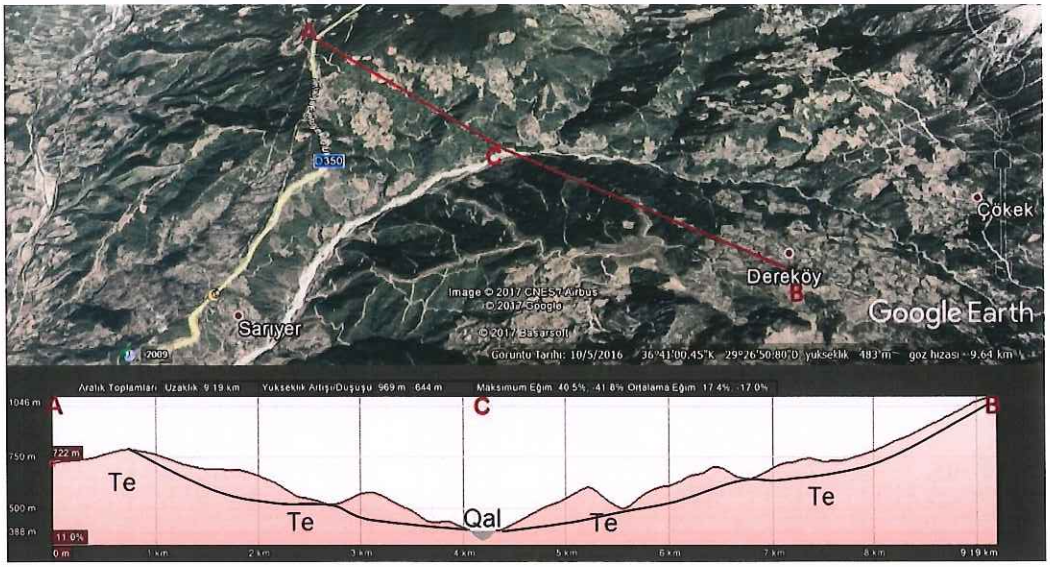


Figure 9.10. A geological section between Bayır and Dereköy Quarters (Te: Elmalı Formation, Qal: Quaternary Alluvium), Mod. from Google Earth, Access date: 03.05.2017

Table.9.1. Comparison chart of study area based on main factors

Location	Water Condition	Topograpy	Human Impact / Road Construction	Landslide Occurence	Type of Landslides
Çeştepe	Nonsuitable	Suitable	Yes	Yes	Complex Movement (Translational Landslide & Creep)
Girmeler	Nonsuitable	Nonsuitable	No	No	None
Karabıyık	Suitable	Suitable	No	Yes	Rotational Landslide
Dereköy	Suitable	Suitable	No	Yes	Complex Movement (Translational Landslide & Creep & Earth flow)
Bayır	Suitable	Suitable	Yes	Yes	Complex Movement (Rotational Landslide & Creep & Earth flow)

10. CONCLUSION AND RECOMMENDATIONS

This thesis study was carried out to determine the lithological properties of Elmalı Formation, to examine the mass movements observed within the unit and to determine the general geological characteristics affecting the development of these movements. In this study, which is made with the Elmalı Formation mass movements, the stable and unstable fields in Dalaman, Seydikemer and Fethiye regions were chosen. As a result of the work done, the following results have been obtained:

- The Upper Lutetian-Lower Burdigalian aged Elmalı Formation consists of sandstone-claystone-siltstones.
- With this thesis, a topic which is predominantly seen as a topic of engineering geology has been evaluated with general geological-sedimentological approaches.
- Due to the tectono - sedimentary characteristics of the unit, each region may contain different types of mass movements within itself. It has been determined that the stability of the landslide changes even at very short distances in the inspections carried out within the unit. For example, in the studies in the Bayir quarter, mass movements were observed in a part of areas with similar slope angles, but no movement was observed in a part.
- Regarding the seismicity of the region, it is thought that the effect on the mass movements of the earthquake that occurred in Fethiye on 24 April 1957 is limited. It is reported that the landslide activity in the Dereköy region was reported for the first time in 1964. However, it is necessary to care the relation between tectonics and earthquakes and the activity of landslides.

- In the studies conducted in the Çeştepe region of Dalaman, only the translational landslide and creep could be observed as the movement type. No movement was observed in the Girmeler quarter, which was attributed to the fact that the natural topography was not disturbed and the slope was so low as not to cause mass movement. Only the rotational landslide was seen in the Karabıyık district while creep, earth flow and rotational slip were observed in Bayır district. In the Dereköy region, mass movements were observed in some places as earth flow and in some places as creep and transitional landslide.
- According to studies in the regions, the mass movements are generally interpreted as complex movements. For this reason, while landslide investigations on the Elmalı formation are being carried out, it would not be the right approach to think that always have the same type of mass movement in the same formation.
- In order to determine the type and effect of the mass movement; porosity, unit weight and geological properties such as layer location, fracture-crack frequency and lithofacies should be taken into consideration. Also tectonism and topography of the area is important. In addition to all these, surface waters and the existence of rivers affecting the toe part of the formation should be investigated in areas where there are no such effects as road work or human influence (housing construction, building load etc.).
- The Elmalı Formation has an internal chaotic structure. Thus, to reduce effect of landslides, additional weight due to new structures on steep slopes must be prevented, or stabilization precautions of slope must be take into consideration before starting road construction and etc. Surface and groundwater must be drained outside of the unstable region. Suitable drainage pipeline, canal or surface impermeable membranes, geotextiles may be used. Critical slope angle and height must be reduced before the engineering application.
- It is thought that the results of this study will contribute to the relevant institutions and organizations (AFAD etc.).

REFERENCES

Alçiçek, M.C., 2007. Tectonic development of an orogen-top rift recorded by its terrestrial sedimentation pattern: The Neogene Eşen Baisn of southwestern Anatolia, Turkey. Sedimentary Geology, 200, 117-140.

Alemdag, S., Akgun, A., Kaya, A., Gokceoglu, C., 2014. A large and rapid planar failure: causes, mechanism, and consequences (Mordut, Gumushane, Turkey). Arab J Geosci 7:1205–1221.

Alonso, E., Pinyol, N.,2015, Slope stability in slightly fissured claystones and marls, Landslides (2015) 12:643–656 DOI 10.1007/s10346-014-0526-5.

Barka, A., Akyüz, S., Altunel, E., Sunal, G., Çakır, Z., Dikbaş, A., Yerli, B., Rockwell, T., Dolan, J., Hartleb, R. et al., 2000. The August 17, 1999 İzmit earthquake, M = 7.4, eastern Marmara region, Turkey: study of surface rupture and slip distribution. In: Barka A, Kozacı Ö, Akyüz S, Altunel E, editors. The 1999 İzmit and Düzce Earthquakes: Preliminary Results. İstanbul, Turkey: İstanbul Technical University, pp. 15–30.

Bilgin, Z.R.; Metin, Y.; Çörekçioğlu, E.; Bilgiç, T. And San, 6., 1997, Bozburun-Marmaris-Köyceğiz-Dalaman-Muğla dolayının jeolojisi. General Directorate of Mineral Research and Exploration, Rep. no: 10008, (unpublished),Ankara.

Blikra, L.H. and Nemec, W. (1998) Post-glacial colluvium in western Norway: depositional processes, facies and paleoclimatic record, Sedimentology 45,909-959.

Brabb,E.E.,1984,Innovative approaches to landslide hazard and risk mapping: Proceedings, 4th International Symposium on Landslides, Toronto. Canada, v.1.p. 307-324.

Brunn, J.H., Dumont, J.F., Graciansky, P., de, Gutnic, M., Juteau, T., Marcoux, J., Monod, O., Poisson, A., 1971, Outline of the geology of the western Taurides. In "Geology and History of Turkey", ed. A.S. Campbell, Petroleum Expl. Soc. Libya, Tripoli., 225-255.

Brunn, J.H., Graciansky, P., de, Gutnic, M., Juteau, T., Lefevre, R., Marcoux, J., Monod, O., Poisson, A., 1971, Structures majeures et correlations stratigraphiques dans les Taurides occidentales. Bull. Geol. Soc. France, 12, 515-556.

Chen, F.H., Foundation on Expansive Soils, Development in Geotechnical Engineering 12,Elsevier Scientific Publishing Company, New York, 1975.

Colin, H., 1962, Fethiye-Antalya-Kaş-Finike (Güneybatı Anadolu) bölgesinde yapılan jeolojik etütler. Bulletin of the Mineral Research and Exploration, 59, 19-59.

Collins, A.S., and Robertson, A.H.F., 1998, Processes of late cretaceous to Late Miocene episodic thrust-sheet translation in the Lycian Taurides, SW Turkey. J. Geol. Soc. London, 155, 759-772.

Collins, A.S., and Robertson, A.H.F., 1999, Evolution of the Lycian allochthon, western Turkey, as a north-facing late paleozoic to Mesozoic rift and passive continental margin. Geol. J., 34, 107-138.

Collins, A.S., Robertson, A.H.F., 2003. Kinematic evidence for Late Mesozoic–Miocene emplacement of the Lycian Allochthon over the Western Anatolide Belt, SW Turkey. Geological Journal 38, 295–310.

Çan, T., Duman, T.Y., Olgun, Ş., Çörekçioğlu, Ş., Gülmez, F.K., Elmacı, H., Hamzaçebi, S., Emre, Ö., 2013. Türkiye Heyelan Veri Tabanı. TMMOB Coğrafi Bilgi Sistemleri Kongresi. 1-6.

Dalaman Kaymakamlığı, http://www.dalaman.gov.tr/, Access date: 24.03.2017.

Doğu, A.F., (1988) "Köyceğiz-Dalaman Çevresindeki Tarihi Yerleşme Alanlarının Jeomorfolojik Birimlerle ilişkisi" AÜ DTCF Dergisi C: 32, S: 1-2, s. 319-328, AnkaraSaraçoğlu, 1988.

Duman, T., Olgun, Ş., Çan, T., Nefeslioğlu, H., Hamzaçebi, S., Durmaz, S., Çörekçioğlu, Ş., 2009. Türkiye Heyelan Envanter Haritası, 1/ 500 000 ölçekli Denizli Paftası, MTA Özel Yayın Serisi:21, 22s.

Dutrow, B., 1997, Better Living Through Minerals X-ray Diffraction of Household Products, in: Brady, J., Mogk, D., and Perkins D. (eds.) Teaching Mineralogy, Mineralogical Society of America, p. 349-359.

Erakman, B.; Meşhur, M.; Gül, M.A.; Alkan, H.; Öztaş, Y. and Akpınar, M., 1982, Fethiye-Köyceğiz-Elmalı-Kalkan arasında kalan alanın jeolojisi. Sixth Petroleum Congress of Turkey,Proceeding, April, 1982, 23-31, Ankara.

Erdoğan, B., Akay, E., Hasözbek, A.,2011, Menderes Masifindeki (Batı Anadolu) Gnaysik Granitlerin Yerleşim Özellikleri ve Masifin Tektonik Evrimindeki Yeri; Yeni Arazi Bulguları Ve Yaş Tayinleri, MTA Dergisi, 142, 167-193.

Erguvanlı, K. (1995). Mühendislik Jeolojisi, Seç Yayın Dağıtım, İstanbul.

Ergünay, O. (1996). "Türkiye'de Afet Zararlarının Azaltılması Konusunda Yapılan ve Yapılması Gereken Çalışmalar Hakkında Rapor" Afet İşleri Genel Müdürlüğü , Ankara.

Ersoy, Ş., 2014. 2014 yılındaki doğa afetlerine küresel bir bakış, TMMOB Jeoloji Mühendisleri Odası Yayınları, No:122.

Ersoy, Ş., 1990, Batı Toros (Likya) naplarının yapısal ögeleri ve evriminin analizi. Jeoloji Müh., 37, 5-16.

Ersoy, Ş., 1989, Fethiye (Muğla)-Gölhisar (Burdur) arasında Güney Dağı ile Kelebek Dağı ve dolayının jeolojisi. Ph.D. Thesis, Istanbul University, 246s. (unpublished), İstanbul.

Fethiye Kaymakamlığı, http://www.fethiye.gov.tr/, Access date: 24.03.2017.

Google Earth, Access date: 08.03.2017; 03.05.2017.

Göçmen, K. 1977. Eşen Çayı Vadisinin Jeomorfolojisi, , İst. Ünv. Coğ. Enst. Der. s: 20-21 , shf: 245-253.

Gökçeoğlu, C., Ercanoğlu, M., 2001. Heyelan duyarlılık haritalarının hazırlanmasında kullanılan parametrelere ilişkin belirsizlikler. Yerbilimleri, 23 189-206.

Göktaş, F., Çakmakoğlu, A., Tan, E., Sütçü, Y.F., ve Sarıkaya, H., 1989, Çivril-Çardak arasının jeolojisi. MTA rapor No. 8701.

Gökçe, O.,2008, Afet olay ve zararlarının il ve ilçelere göre dağılımı (Afet türlerine göre), Bayındırlık ve İskan Bakanlığı, Afet işleri Genel Müdürlüğü.

Graciansky, P.C., 1968, Teke yarımadası (Likya) Toroslarının üst üste gelmiş ünitelerinin stratigrafisi ve Dinaro-Toroslardaki yeri, Bulletin of the Mineral Research and Exploration, 71, 73-59.

Graciansky, P.C.,, 1972, Recherces geologiques dans le Taurus lycien occdental. These, Universite de Paris-Sud, Faculte des Sciences d'Orsay, 731s.

Guthrie, M., 2012, http://archaeometry.missouri.edu/xrf_overview.html, Overview of X-ray Fluorescence, University of Missouri Research Reactor Revised, Jeffrey R. Ferguson, University of Missouri Research Reactor.

Gül M., Gürbüz K., Cronin B.T., "Provenance of the northern part of the Kahramanmaras Peripheral Foreland Basin (Miocene, S Turkey)", JOURNAL OF ASIAN EARTH SCIENCES, vol.40, pp.475-495, 2011.

Herron M. "Geochemical classification of terrigenous sands and shales from core or log data". Journal of Sedimentary Research, 58(5), 1988.

Holtz, R.D., Kovacs, W.D., 1981. An Introduction to Geotechnical Engineering. Prentice Hall, 746p.

https://tr.climate-data.org/location/26353/, Access date: 24.03.2017.

http://www.cografya.gen.tr/tr/mugla/iklim.html, Access date: 24.03.2017.

http://www.holiday-weather.com/fethiye/averages/ Access date: 24.03.2017.

Hungr, O., Leroueil, S., Picarelli, L., 2014. The Varnes classification of landslide types, an update. Landslides (2014) 11:167–194.

Igwe O., 2015, The geotechnical characteristics of landslides on the sedimentary and metamorphic terrains of South-East Nigeria, West Africa, Springer.

ISRM, 1978a. Suggested methods for determining hardness and abrasiveness of rocks. International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts. 15:89-97.

Kaaden, G., Metz, K., 1954, Datça-Muğla-Dalaman çayı (SW Anadolu) arasındaki bölgenin jeolojisi. TJ.K. Bült., vol. V, no. 1-2, s. 71-170, Ankara.

Keller, G.V.,1966, Dipole method for deep resistivity studies: Geophysics, 31(6), 1088-1104.

Koçyiğit, A., 1984, Güneybatı Türkiye ve yakın dolayında levha içi yeni tektonik gelişim. TJK Bül. C.27, 1-16.

Koçyiğit, A. 2000. Güneybatı Türkiye'nin depremselli- ği. BADSEM 2000-Batı Anadolu'nun Depremselliği Sempozyumu, 24-27 Mayıs 2000, izmir, 30-39.

Li, Y., Aydın, A., Xiang, X., Ju, N.,Zhao, J., Özbek, A., 2012, Landslide susceptibility mapping and evaulation along a river valley in China, vol.8, No.4 pp.1022-1030.

Meşhur, M.; Yoldemir, O.; Akpınar, M.; Öztaş, Y., Alkan, H., 1989, Batı Torosların jeolojisi ve petrol olanakları raporu. Turkish Petroleum Corp. General Directorate Rep. no: (inpreparation).

Mikoš, M., Petkovšek A., Majes, B., Mechanisms of landslides in over-consolidated clays and flysch, Landslides (2009) 6:367–371 DOI 10.1007/s10346-009-0171-6.

Morrison, F., and Gasperikova, E., 2012, DC resistivity and IP field systems, data processing and interpretation. The Berkeley course in applied geophysics.

Muğla Valiliği İl Afet ve Acil Durum Müdürlüğü, GEKA projesi 2013 – "Muğla ili Fethiye ilçesi doğal afet tehlikeleri" Danışmanlar: Prof. Dr. Fikret KAÇAROĞLU, Prof. Dr. Ergun KARACAN, Doç. Dr. Murat GÜL, Yard. Doç. Dr. Ersen AKSOY.

Muğla Valiliği İl Afet Ve Acil Durum Müdürlüğü (AFAD), 2011, Muğla İli 1/25.000 Ölçekli Arazi Kullanımına Esas Jeolojik Etüt Raporu.

MTA Yerbilimleri Harita Görüntüleyici ve Çizim Editörü, Geoscience Map Viewer and Drawing Editor, http://yerbilimleri.mta.gov.tr/anasayfa.aspx, Access date: 19.04.2017.

NASA, https://svs.gsfc.nasa.gov/11854, Access date:02.03.2017.

Nemec, W. and Kazancı, N., 1999, Quaternary colluvium in west central Anatolia: Sedimentary facies and palaeoclimatic significance. Sedimentology, 46, 139-170.

Okay, A., Tuysuz, O., 1999. Tethyan sutures of northern Turkey, Geol. Soc. London Spec. Pub., 156, 475–515, doi:10.1144/GSL.SP.1999.156.01.22.

Okay, A., Satır, M., Tüysüz, O., Akyüz, S., Chen, F.: 2001 The tectonics of the Strandja Massif: Variscan and midMesozoic deformation and metamorphism in the northern Aegean. International Journal of Earth Sciences, 90, 217-233.

Önalan, M., 1979, Elmalı-Kaş (Antalya) arasındaki alanın jeolojisi. Ph.D. Thesis, İstanbul University, Monographies, 29, 139p., İstanbul.

Öner, E., 1997, (Eşen Çayı Taşkın-Deltası Ovasının Jeomorfolojisi ve Antik Patara Limanı, Ege Coğ. Dergi, s:9, sf.: 71-89, İzmir.

Öz, D., 2009. Avcılar Heyelan Bölgesindeki Deformasyonların Kinematik Modellerle Araştırılması. Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, FBE Harita Mühendisliği Anabilim Dalı, 116 s.

Özgül, N., 1976, Toroslar'ın bazı temel jeoloji özellikleri, Türkiye Jeoloji Kurumu Bülteni, c. 19, 5-78, Şubat 1976.

Pettijohn, F. J., Potter, P.E., Siever, R.,1987, Sand and Sandstone, 2nd edition, 553 pp ISBN: 978-0-387-96350-1 (Print) 978-1-4612-1066-5 (Online), Springer.

Seydikemer Kaymakamlığı, http://www.seydikemer.gov.tr/, Access date: 24.03.2017.

Sharma P. V., 1997. Environmental and engineering geophysics. Cambridge University Press.

Skempton, A.W. and Hutchinson, J.N., 1969. Stability of natural clay slopes and embankment foundations, Proceedings Seventh International Conference on Soil Mechanics, Oslo, State of the Art Volume, 291-340.

Şenel, M., 1986, Tahtalı Dağ (Antalya) dolayının jeolojisi. Doktora Tezi, İstanbul Üniversitesi, 232 sayfa, katalog no. 16 682.

Şenel, M.;Selçuk, H.; Bilgin, Z.R.; Sen, M.A.; Karaman, T.; Erkan, M.;Dinçer, M.A.; Durukan, E.; Arbas, A.; Kaymakçı, H.; Örçen, S. and Bilgin, C., 1989, Çameli (Denizli)- Yeşilova (Burdur)-Elmalı (Antalya) ve dolayının jeolojisi. General Directorate of Mineral Research and Exploration, Rep. no: 9429, (unpublished), Ankara.

Şenel M., Akdeniz, N., Öztürk, E. M., Özdemir, T., Kadınkız, G., Metin, Y., Öcal, H.,Serdaroğlu, M. ve Örçen, S., 1994, Fethiye (Muğla)-Kalkan (Antalya) ve kuzeyininjeolojisi. MTA Enstitüsü rapor no: 9761, Ankara (Yayımlanmamış).

Şenel, M. 1997a. 1 / 100 000 ölçekli Türkiye Jeoloji Haritaları, No:1, Fethiye – L7 Paftası. Maden Tetkik ve Arama Enstitüsü, Jeoloji Etütleri Dairesi, Ankara, 17s.

Şenel, M. 1997b. 1 / 100 000 ölçekli Türkiye Jeoloji Haritaları, No:1, Fethiye – L8 Paftası. Maden Tetkik ve Arama Enstitüsü, Jeoloji Etütleri Dairesi, Ankara, 22s.

Şenel, M. 1997c. 1 / 100 000 ölçekli Türkiye Jeoloji Haritaları, No:1, Fethiye – L9 Paftası. Maden Tetkik ve Arama Enstitüsü, Jeoloji Etütleri Dairesi, Ankara, 20s.

Şengör, A.M.C. and Yılmaz, Y., 1981. Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics, 75: 181-241.

T.C. Kültür Ve Turizm Bakanlığı, Muğla İl Kültür Ve Turizm Müdürlüğü, Turizm Haritası, Access date: 15.01.2017.

Tuncel, M., Gögmen, K., (1973) "Köyceğiz-Fethiye Yöresinde Bazı Coğrafi Gözlemler" İÜ Coğ. Ens. Der. C: 10, S: 18-19, s. 113-138, İstanbul.

UCS (Uniaxial Compressive Strength), http://home.iitk.ac.in/~sarv/New Folder/Presentation -4.pdf, Access date: 17.04.2017.

USGS, United States Geological Survey, https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html, Access date:02.03.2017.

Visible Geology online programme, http://app.visiblegeology.com/ Access date: 17.04.2017.

www.meteoblue.com/tr/hava/tahmin/modelclimate/, Access date: 24.03.2017.

Wiqoyah, Q., Effect of lime rate, time and soaking treatment on Strong bearing clay, the dynamics of civil engineering, Volume 6, Number 1, January 2006: 16-24, 2006.

Yılmaz, I., Karacan, E., 1998, Zeminlerin şişme özellikleri, Jeoloji Mühendisliği, Sayı: 52, Sf:17-26.

Yılmaz, İ, 1966, Etude geologique de la region contiere comprise entre Dalaman Çay et Yenice Ovası (Province de Muğla, Turquie), These 3 cycle, a la Faculte des Sciences de Grenoble.

Yılmaz, Y. (2000), Ege Bölgesinin aktif tektoniği. Batı Anadolu'nun depremselligi Sempozyumu (BADSEM 2000), 24-27, Mayis 2000, 'İzmir, Bildiriler, 3-14.

APPENDICES

Appendix-A. Landslide occurrences in Muğla Province

Sayı	İlçe	Köy/Belde	Mahalle	Afet Türü	Rapor Tarihi	Bakanlar Kurulu Kararı	
						Tarih	Sayı
1	Fethiye	Dereköy		Heyelan	08.01.1964 21.08.1968 22.10.1990 25.05.2009	30.03.1964	6/2865
2	Merkez	Merkez		Kaya Düşmesi		29.06.1966	
3	Köyceğiz	Merkez		Su Baskını		28.04.1967	
4	Fethiye	Bağlıağaç	Kavacık	Heyelan	01.04.1968 22.04.1983	01.09.1986	86/10984
5	Ula	Gökova		Kaya Düşmesi	28.12.1988 15.02.1989	03.03.1990	90/212
6	Milas			Kaya Düşmesi	03.08.1989	03.03.1990	90/212
7	Merkez	Menteşe		Heyelan	26.09.1995	12.03.1997	97/9416
8	Fethiye	Çatak		Heyelan	16.06.1994 04.12.1996	20.08.1997 22.07.2002	97/9895 2002/4578
9	Kavaklıdere	Çayboyu		Heyelan	22.01.1996	04.05.1998	98/11100
10	Yatağan	Bağyaka	Merkez	Heyelan	25.02.1999	26.04.2000	2000/664
11	Bodrum	Gündoğan	Yukarı	Kaya Düşmesi	05.02.2009	29.06.2009	2009/15159

Source: Muğla Governorship Provincial Disaster and the Emergency Management

Appendix-B. Geophysical data's of the Elmalı formation

REZİSTİVİTE ÖLÇÜ KARNESİ

ETÜD YERİ.....	: SARIYER MEKİİ	NOKTA NO..... :	1
ETÜDÜ YAPTIRAN	:	METOD..... :	Schlumberger
ÖLÇÜYÜ ALAN.....	: TURGUT KARAGÖZ	KOORDİNAT..... :	35 S 715802
TARİH.....	: 06.12.2016		4062377
			496 m.

SIRA NO	AB / 2	MN / 2	I	ΔV	ATT.	VER.	K	ρa
1	3	1	100	38	1000	10	12.57	**47.76**
2	4	1	100	26	1000	10	23.56	**61.25**
3	5	1	100	38	100	2	37.70	**71.63**
4	6.5	1	100	26	100	2	64.80	**84.24**
5	8	1	100	21	100	2	98.96	**103.90**
6	10	1	100	31	100	4	155.51	**120.52**
7	13	1	100	28	100	6	263.89	**123.15**
8	16	1	100	32	100	10	400.55	**128.17**
9	20	1	100	21	100	10	626.75	**131.61**
10	25	1	100	28	10	2	980.18	**137.22**
		5	100	31	100	4	188.50	**146.08**
11	30	5	100	31	100	6	274.89	**142.02**
12	40	5	100	25	100	8	494.80	**154.62**
13	50	5	100	21	100	10	777.54	**163.28**
14	60	5	100	33	10	2	1123.12	**185.31**
15	70	5	100	26	10	2	1531.53	**199.09**
16	80	5	100	23	10	2	2002.77	**220.32**
17	90	5	100	41	10	4	2536.84	**260.02**
18	100	5	100	36	10	4	3133.74	**282.04**
19	120	5	100	30	10	4	4516.04	**338.70**
20	140	5					6149.67	
21	160	5					8034.62	
22	180	5					10170.91	
23	200	5					12558.52	
24	225	20					3944.66	
25	250	20					4877.32	
		50					1884.96	
26	275	50					2297.29	
27	300	50					2748.89	
28	350	50					3769.91	
29	400	50					4948.01	
30	500	50					7775.44	

Appendix-B. *(Cont'd)*

REZİSTİVİTE ÖLÇÜ KARNESİ

ETÜD YERİ.....	: DEREKÖY MEKİİ	NOKTA NO..... :	2
ETÜDÜ YAPTIRAN	:	METOD..... :	Schlumberger
ÖLÇÜYÜ ALAN.....	: TURGUT KARAGÖZ	KOORDİNAT..... :	35 S 721970
TARİH.....	: 06.12.2016		4060726
			892 m.

SIRA NO	AB / 2	MN / 2	I	ΔV	ATT.	VER.	K	ρa
1	3	1	100	30	1000	6	12.57	**62.85**
2	4	1	100	26	100	2	23.56	**30.63**
3	5	1	100	28	100	4	37.70	**26.39**
4	6.5	1	100	26	100	10	64.80	**16.84**
5	8	1	100	22	100	10	98.96	**21.77**
6	10	1	100	25	10	2	155.51	**19.44**
7	13	1	100	20	10	2	263.89	**26.38**
8	16	1	100	32	10	4	400.55	**32.04**
9	20	1	100	24	10	4	626.75	**37.60**
10	25	1	100	27	10	6	980.18	**44.11**
		5	100	25	100	10	188.50	**47.12**
11	30	5	100	32	10	2	274.89	**43.98**
12	40	5	100	44	10	4	494.80	**54.43**
13	50	5	100	35	10	4	777.54	**68.03**
14	60	5	100	25	10	4	1123.12	**70.19**
15	70	5	100	31	10	6	1531.53	**79.12**
16	80	5	100	25	10	6	2002.77	**83.44**
17	90	5	100	30	10	8	2536.84	**95.13**
18	100	5	100	26	10	8	3133.74	**101.84**
19	120	5	100	27	10	10	4516.04	**121.93**
20	140	5					6149.67	
21	160	5					8034.62	
22	180	5					10170.91	
23	200	5					12558.52	
24	225	20					3944.66	
25	250	20					4877.32	
		50					1884.96	
26	275	50					2297.29	
27	300	50					2748.89	
28	350	50					3769.91	
29	400	50					4948.01	
30	500	50					7775.44	

Appendix-B. *(Cont'd)*

REZİSTİVİTE ÖLÇÜ KARNESİ

ETÜD YERİ.....	: DEREKÖY MEKİİ	NOKTA NO..... :	3
ETÜDÜ YAPTIRAN	:	METOD..... :	Schlumberger
ÖLÇÜYÜ ALAN.....	: TURGUT KARAGÖZ	KOORDİNAT..... :	35 S 722002
TARİH.....	: 06.12.2016		4060729
			892 m.

SIRA NO	AB / 2	MN / 2	I	ΔV	ATT.	VER.	K	ρa
1	3	1	100	32	1000	8	12.57	**50.28**
2	4	1	100	28	100	2	23.56	**32.98**
3	5	1	100	32	100	4	37.70	**30.16**
4	6.5	1	100	23	100	6	64.80	**24.84**
5	8	1	100	21	100	10	98.96	**20.78**
6	10	1	100	23	10	2	155.51	**17.88**
7	13	1	100	36	10	4	263.89	**23.75**
8	16	1	100	29	10	4	400.55	**29.04**
9	20	1	100	31	10	6	626.75	**32.38**
10	25	1	100	23	10	6	980.18	**37.57**
		5	100	24	100	10	188.50	**45.24**
11	30	5	100	35	10	2	274.89	**48.10**
12	40	5	100	23	10	2	494.80	**56.90**
13	50	5	100	37	10	4	777.54	**71.92**
14	60	5	100	43	10	6	1123.12	**80.49**
15	70	5	100	35	10	6	1531.53	**89.33**
16	80	5	100	41	10	8	2002.77	**102.64**
17	90	5	100	37	10	8	2536.84	**117.32**
18	100	5	100	33	10	8	3133.74	**129.26**
19	120	5	100	32	10	10	4516.04	**144.51**
20	140	5					6149.67	
21	160	5					8034.62	
22	180	5					10170.91	
23	200	5					12558.52	
24	225	20					3944.66	
25	250	20					4877.32	
		50					1884.96	
26	275	50					2297.29	
27	300	50					2748.89	
28	350	50					3769.91	
29	400	50					4948.01	
30	500	50					7775.44	

Appendix-B. *(Cont'd)*

REZİSTİVİTE ÖLÇÜ KARNESİ

ETÜD YERİ.....	: KAPIKARGIN-DALAMAN	NOKTA NO..... :	4
ETÜDÜ YAPTIRAN	:	METOD..... :	Schlumberger
ÖLÇÜYÜ ALAN.....	: TURGUT KARAGÖZ	KOORDİNAT..... :	35 S 663012
TARİH.....	: 06.12.2016		4066785
			53 m.

SIRA NO	AB / 2	MN / 2	I	ΔV	ATT.	VER.	K	ρa
1	3	1	100	23	1000	4	12.57	**72.27**
2	4	1	100	30	1000	10	23.56	**70.68**
3	5	1	100	38	100	2	37.70	**71.63**
4	6.5	1	100	27	100	2	64.80	**87.48**
5	8	1	100	44	100	4	98.96	**108.85**
6	10	1	100	35	100	4	155.51	**136.07**
7	13	1	100	36	100	6	263.89	**158.33**
8	16	1	100	35	100	8	400.55	**175.24**
9	20	1	100	32	100	10	626.75	**200.56**
10	25	1	100	25	100	10	980.18	**245.04**
		5	100	27	100	2	188.50	**254.47**
11	30	5	100	20	100	2	274.89	**274.89**
12	40	5	100	27	100	4	494.80	**333.99**
13	50	5	100	31	100	6	777.54	**401.72**
14	60	5					1123.12	
15	70	5					1531.53	
16	80	5					2002.77	
17	90	5					2536.84	
18	100	5					3133.74	
19	120	5					4516.04	
20	140	5					6149.67	
21	160	5					8034.62	
22	180	5					10170.91	
23	200	5					12558.52	
24	225	20					3944.66	
25	250	20					4877.32	
		50					1884.96	
26	275	50					2297.29	
27	300	50					2748.89	
28	350	50					3769.91	
29	400	50					4948.01	
30	500	50					7775.44	

Appendix-B. *(Cont'd)*

REZİSTİVİTE ÖLÇÜ KARNESİ

ETÜD YERİ.....	: KAPIKARGIN-DALAMAN	NOKTA NO..... :	5
ETÜDÜ YAPTIRAN	:	METOD..... :	Schlumberger
ÖLÇÜYÜ ALAN.....	: TURGUT KARAGÖZ	KOORDİNAT..... :	35 S 662819
TARİH.....	: 06.12.2016		4066742
			51 m.

SIRA NO	AB / 2	MN / 2	I	ΔV	ATT.	VER.	K	ρa
1	3	1	100	37	1000	6	12.57	**77.51**
2	4	1	100	26	1000	8	23.56	**76.57**
3	5	1	100	20	1000	10	37.70	**75.40**
4	6.5	1	100	24	100	2	64.80	**77.76**
5	8	1	100	36	100	4	98.96	**89.06**
6	10	1	100	27	100	4	155.51	**104.96**
7	13	1	100	30	100	6	263.89	**131.94**
8	16	1	100	25	100	6	400.55	**166.89**
9	20	1	100	32	100	10	626.75	**200.56**
10	25	1	100	24	100	10	980.18	**235.24**
		5	100	25	100	2	188.50	**235.62**
11	30	5	100	40	100	4	274.89	**274.89**
12	40	5	100	26	100	4	494.80	**321.62**
13	50	5	100	31	100	6	777.54	**401.72**
14	60	5					1123.12	
15	70	5					1531.53	
16	80	5					2002.77	
17	90	5					2536.84	
18	100	5					3133.74	
19	120	5					4516.04	
20	140	5					6149.67	
21	160	5					8034.62	
22	180	5					10170.91	
23	200	5					12558.52	
24	225	20					3944.66	
25	250	20					4877.32	
		50					1884.96	
26	275	50					2297.29	
27	300	50					2748.89	
28	350	50					3769.91	
29	400	50					4948.01	
30	500	50					7775.44	

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