ISTANBUL TECHNICAL UNIVERSITY★EURASIA INSTITUTE OF EARTH SCIENCES

LATE QUATERNARY GLACIATIONS AND COSMOGENIC ^{36}Cl GEOCHRONOLOGY OF MOUNT DEDEGÖL

M.Sc. THESIS

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Geodynamics Programme

Thesis Advisor: Assoc. Prof. Dr. Mehmet Akif SARIKAYA

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ AVRASYA YER BİLİMLERİ ENSTİTÜSÜ

DEDEGÖL DAĞI’NIN GEÇ KUVATERNER BUZULLAŞMASI VE KOZMOJENİK ^{36}Cl JEOKRONOLOJİSİ

YÜKSEK LİSANS TEZİ

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Katı Yer Bilimleri Anabilim Dalı

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Haziran 2017

Oğuzhan KÖSE, a M.Sc. student of İTU Eurasia Institute of Earth Science student ID 602151001, successfully defended the thesis entitled “LATE QUATERNARY GLACIATIONS AND COSMOGENIC ^{36}Cl GEOCHRONOLOGY OF MOUNT DEDEGÖL”, which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 5 May 2017
Date of Defense : 8 June 2017

…to my family,

FOREWORD

A huge thank to my supervisor at Istanbul Technical University, Mehmet Akif Sarıkaya. He was always there when I needed help. He encouraged me to research about cosmogenic exposure dating method. This work would not be completed without his help. I also would like to thank Attila Çiner for his guiding comments and advice.

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June 2017

Oğuzhan Köse
(Geographer)

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ABBREVIATIONS

AMS **:** Accelerated Mass Spectometer
DEM **:** Digital Elevation Model
ELA **:** Equilibrium Line Altitude
GIS **:** Geographic Information System
GPS **:** Global Positioning System
ICP-MS **:** Inductively Coupled Plasma – Mass Spectometer
LG **:** Late Glacial
LGM **:** Last Glacial Maximum
OSL : Optically Stimulated Luminescence
Prec **:** Precipitation
Temp : Temperature

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LATE QUATERNARY GLACIATIONS AND COSMOGENIC ^{36}Cl GEOCHRONOLOGY OF MOUNT DEDEGÖL

SUMMARY

Recent years experienced a significant advance in the glacial geochronology of the Turkish mountains. These studies suggested that major glacial advances were occurred in the Late Pleistocene and partly in Holocene. Maximum extent of MIS-2 (Marine Isotope Stage) glaciers happened during the Last Glacial Maximum (LGM, i.e. 21 ka ago). Glaciers were as large as 6 km in length in some mountains.

The extend and timing of paleoglaciers on the northern side of the Dedegöl Mountain (37.64°N, 31.27°E, 2992 m), on the western Taurus Range, was not known. Zahno et al (2009) used cosmogenic surface exposure dating method with cosmogenic ^{10}Be and ^{26}Al to date a glacier expansion out of the Muslu Valley, located on the eastern part of the Mount Dedegöl. They dated to maximum extent of paleo-glaciers to 24.3±1.8 ka ago and gave evidence for pronounced glacier advances prior to the global Last Glacial Maximum (LGM). According to Zahno et al (2009), the glacier retreated which driven by climatically was no later than 17.7±1.4 ka ago. Çılğın (2015) used OSL (Optically stimulated Luminescence) dating method to date the moraines in Mount Dedegöl. OSL age results revealed that at least two glacial stages occurred during late Pleistocene in the Mount Dedegöl. In this study, I focused on geomorphological evidence of the Quaternary glaciers on the northern valleys of Mount Dedegöl.

The main goal of this study was to determine the glacial geomorphology and obtain the landform ages of glacial deposits of northern Mount Dedegöl. Therefore, to achieve these goals geomorphological maps of the study area were first prepared. Later, rock samples from moraines were taken for cosmogenic surface exposure dating.

Main glacial valleys and moraine borders were positioned using the GPS. Both erosional and accumulation landforms such as lateral moraines and cirques formed by glaciers were determined. These landforms were sketched with direct observation to analyze the surface morphologies. The height, length and width properties of the moraines and sample locations noted during the field studies. After the field studies, the data obtained from the field and from the GIS database structure were compared and produced the final glacial geomorphological maps in GIS software (ArcMap 10.3). Based on digital cartographic symbols, sample locations, all moraine types, cirques, and other glacial landforms were drawn for each glacial valley.

The cosmogenic ^{36}Cl dating method was used in the Mount Dedegöl in order to determine the surface exposure ages of moraines. In this way, the length of time that any rock has been exposed to the cosmic radiation can be estimated. Samples for cosmogenic ^{36}Cl dating were collected from the top of the boulders on the crest of the moraines. A hammer and chisel were used to take samples from upper few centimeters of the boulders. The boulders were selected according to their positions. Boulders were sampled based on their appearance, size, preservation and position on the crest. Stable boulders with strong roots in the moraine matrix were preferred.

The sample preparation of collected rock samples was done in order to measure minute amount of cosmogenic ^{36}Cl in rocks by AMS (Accelerated Mass Spectrometer). The laboratory methods consist of four preparation stages: (1) crushing, grinding and sieving, (2) leaching and digestion, (3) chemical separation and (4) target preparation.

Final target samples prepared at ITU/Kozmo-Lab in İstanbul were taken to ASTER AMS lab, France (The French National Facility, CEREGE, Aix en Provence). Surface exposure of the samples were measured by the 36Cl Exposure Age Calculator v2.0 (http://cronus.cosmogenicnuclides.rocks/2.0/html/cl/).

Rock samples were collected from a total of 20 boulders in the Mount Dedegöl. There were eight samples in Sayacak Valley, five samples in the Kisbe Valley and seven samples in Karagöl Valley in total.

Cosmogenic ^{36}Cl ages obtained from the moraines on Mount Dedegöl have contributed new information to glacial geochronology of Turkey. Twenty boulders from moraines in three glacial valleys of the Mount Dedegöl were dated by ^{36}Cl surface exposure dating. Moraine ages from the Mount Dedegöl indicates that there are three glacial stages identified by dating of 20 samples. Pre-LGM moraines; 29.1 ± 1.7 ka and Early Holocene moraines 10.9 ± 0.8 ka were deposited in Sayacak Valley. In Karagöl Valley, LG (Late Glacial); 13.5 ± 0.7 ka and 16.4 ± 1.1 ka were deposited. There are only Early Holocene moraines; 11.6 ± 0.7 ka were identified in Kisbe Valleys.

Surface exposure ages with cosmogenic ^{36}Cl reveal that there is no glacier retreat earlier than 32.4 ± 3.3 ka ago in the Mount Dedegöl. The oldest age obtained from hummocky moraines in the Sayacak Valley give substantial evidence about ice accumulation prior to the global LGM (21 ± 2 ka). Pre-LGM ages from hummocky moraines in the Sayacak Valley are 24.6 ± 2.3 ka, 32.4 ± 3.3 and 30.3 ± 3.2 ka ago. Consequently, the timing of maximum glaciation on Mount Dedegöl can be considered as the average of both ages which is 29.1 ± 1.7 ka.

The youngest glacial stage occured during the Early Holocene in the mount Dedegöl. There are only Early Holocene moraines were identified in Kisbe Valleys with ages 11.6 ± 0.7 ka. In Sayacak Early Holocene ages are obtained from right lateral moraine (10.9 ± 0.8 ka).

Late Glacial moraines in the Karagöl Valley are well preserved. In Karagöl Valley, a terminal moraine was dated to 15.6 ± 1.4 ka to 17.2 ± 1.7 ka ago. Thus, it can be considered that Late Glacial glaciation in Karagöl valley occured 16.4 ± 1.1 ka ago, which is the avarage age of the terminal moraine ages.

DEDEGÖL DAGI’NIN GEÇ KUVATERNER BUZULLAŞMASI VE KOZMOJENİK ^{36}Cl JEOKRONOLOJİSİ

ÖZET

Son yıllarda, Türkiye’de bulunan dağlar hakkında yapılan araştırmalar, buzul jeokronolojisinde kayda değer bir ilerleme kaydetti. Bu çalışmalar, büyük buzul ilerlemelerinin Geç Pleistosen’de ve kısmen de Holosen’de gerçekleştiğini göstermektedir. MIS-2 buzullarının maksimum yayılımı, Son Buzul Maksimumu (LGM, yani 21 bin yıl önce) sırasında meydana gelmiştir. Bazı dağlarda buzulların uzunluğu 6 km'ye ulaşmıştır.

Batı Toroslar bölgesinde bulunan Dedegöl Dağı’nın kuzeyinde (37.64°N, 31.27°E, 2992 m) geçmiş buzulların yayılımı ve ne zaman aktif oldukları bilinmiyordu. Zahno vd. (2009), Dedegöl Dağı'nın doğu kesiminde yer alan Muslu Vadisi'nde kozmojenik ^{10}Be ve ^{26}Al ile kozmojenik tarihlendirme yöntemini kullanmıştır. Yapılan çalışmada LGM buzullarının 29.6 ± 1.9 bin yıl önce geri çekildiğini ve küresel Son Buzul Maksimumundan sonra ortadan kaybolduğunu öngörmüştür. Zahno vd. (2009) göre, buzulların geri çekilişleri 17.7 ± 1.4 bin yıldan fazla değildir. Çılğın (2015), Dedegöl Dağı’ndaki moren depolarını OSL tarihlendirme methodunu kullanarak tarihlendirmiş ve birden fazla buzullaşmanın var olduğu kanıtına ulaşmıştır.

Bu çalışmanın temel amacı Dedegöl Dağı’nın kuzey vadilerinde buzul jeomorfolojisini belirlemek ve kozmojenik tarihlendirme ile buzul jeokronolojisine elde etmektir. Bu amaçla çalışma alanının jeomorfolojik haritaları hazırlandı. Daha sonra, kozmojenik yüzey tarihlendirme için morenlerden kaya örnekleri alınmıştır.

Ana buzul vadileri ve moren sınırları GPS kullanılarak haritalandırılmıştır. Buzullar tarafından oluşturulan yanal morenler ve sirkler gibi hem aşınım hem de birikim şekilleri belirlenmiştir. Bu yer şekilleri, yüzey morfolojilerini analiz etmek için doğrudan gözlem ile çizilmiştir. Arazi çalışması sırasında morenlerin yükseklik, uzunluk ve genişlik özellikleri ile numune yerleri not edilmiştir. Arazi çalışmalarından sonra arazi ve CBS veri tabanı yapısından elde edilen veriler CBS (Coğrafi Bilgi Sistemleri) yazılımında (ArcMap 10.3) topoğrafya haritaları ile karşılaştırılmış ve yeni haritalar üretilmiştir. Her buzul vadisi için, örnek lokasyonlarına, tüm moren tiplerine, sirklere ve diğer buzul yer şekillerine dayanılarak jeomorfoloji haritaları hazırlanmıştır.

Dedegöl Dağı’nda kozmojenik ^{36}Cl tarihlendirme yöntemi, morenlerin kozmik radyasyona maruz kalma yaşlarını belirlemek için kullanılmıştır. Bu şekilde, herhangi bir kayaç yüzeyinin yeryüzünde maruz kaldığı zaman süresi belirlenebilir. (Davis ve Schaeffer, 1955; Phillips vd, 1986; Zreda vd, 1991; Zreda ve Phillips, 2000). Kozmojenik ^{36}Cl tarihlendirmesi için numuneler, morenlerin üzerindeki bloklardan toplanmıştır. Blokların üst birkaç santimetresinden çekiç ve keski kullanılarak numuneler alınmıştır. Bloklar konumlarına göre seçilmiştir. Bloklar, görünüşleri, boyutları, korunmaları ve sırttaki konumlarına göre örneklenmiştir. Moren matrisinde güçlü kökleri olan dayanaklı bloklar tercih edilmiştir.

ITU/Kozmo-Lab'da hazırlanan nihai hedef numuneler ASTER AMS laboratuvarına (Fransız Ulusal Tesisi, CEREGE, Aix en Provence) gönderilmiştir. Elde edilen sonuçlardan yüzey yaşlarını elde etmek için ^{36}Cl Exposure Age Calculator v2.0. CRONUS Calculator kozmojenik yüzey hesaplama yazılımı kullanılmıştır (http://cronus.cosmogenicnuclides.rocks/2.0/html/cl/).

Dedegöl Dağı'ndaki morenlerden toplam 20 numune toplanmıştır. Sayacak, Kisbe ve Karagöl vadilerinden 20 örnek tarihlendirilmiştir. Sayacak Vadisinde sekiz örnek, Kisbe Vadisi'nde beş örnek ve Karagöl Vadisi'nde yedi örnek tarihlendirilmiştir.

Dedegöl Dağı’ndaki morenlerden elde edilen kozmojenik ^{36}Cl yaş verileri Türkiye buzul jeokronolojisine katkıda bulunmuştur. Dedegöl Dağının kuzey vadilerindeki morenlerden alınan 20 örnek kozmojenik ^{36}Cl tarihlendirme yöntemiyle tarihlendirilmiştir. Elde edilen bu yaşlar Dedegöl Dağı’nda en az 3 farklı buzullaşma döneminin kanıtlarını ortaya koymuştur. Son Buzul (Late Glacial) morenleri; 29.1 ± 1.7 bin yıl ve Erken Holosen morenleri 10.9 ± 0.8 bin yıl önce Sayacak Vadisi’nde depolanmıştır. Karagöl Vadisi’nde ise, Geç Buzul (Late Glacial) dönemine ait morenler; 13.5 ± 0.7 ve 16.4 ± 1.1 bin yıl önce depolanmıştır. Kisbe Vadi’sinde sadece Holosen morenleri; 11.6 ± 0.7 bin yıl önce depolanmışlardır.

Kozmojenik yüzey tarihlendirme sonuçları Dedegöl Dağı’nda maksimum buzul ilerlemesinin 32.4 ± 3.3 bin yıl önce olduğunu ortaya koymuştur. Elde edilen yaşlara göre en yaşlı morenler Sayacak vadisi’ndeki hummocky morenlerdir. Bu yaşlar Son Buzul Maksimumu (21 ± 2 bin yıl öncesi) öncesi buzul yayılımının olduğunu kanıtlamıştır. En yaşlı morenlerden alına bu örneklerin ortalaması alındığında, Dedegöl Dağı’nda maksimum buzul ilerlemesi 29.1 ± 1.7 bin yıl önce olmuştur.

Karagöl Vadisi’nde iyi korunmuş Geç Buzul (Late Glacial) morenleri ortalama15.4 ± 0.9 bin yıl öncesi olarak tarihlendirilmiştir. Elde edilen yaşlar ise 13.5 ± 0.7 ve 16.4 ± 1.1 bin yıldır. Karagöl Vadisi cephe moreninden elde edilen bu yaşlar Geç Buzul döneminin kanıtlarını sunmuştur.

Dedegöl Dağı’nda Erken Holosen dönemine ait morenler tarihlendirilmiştir. Kisbe Vadisi’nde yalnız Erken Holosen morenleri (11.6 ± 0.7 bin yıl) tespit edilmiştir. Sayacak Vadisi sağ yanal moreni 10.9 ± 0.8 bin yıl, Karagöl Vadisi hummocky morenleri ise 11.6 ± 0.7 bin yıl olarak tarihlendirilmiştir.

1. INTRODUCTION

1.1 Study Area

The Mount Dedegöl (37.37° - 37.43° N and 31.13° - 31.21° E) is located in the western Taurus Mountain Range and covers approximately 150 km^2. It is geography located in the Turkish Seven Lake District which are a series of shallow tectonic lakes within the Mediterranean Region of Turkey. Study area is situated near the province boundaries of Isparta and Konya cities (Figure 1.1).

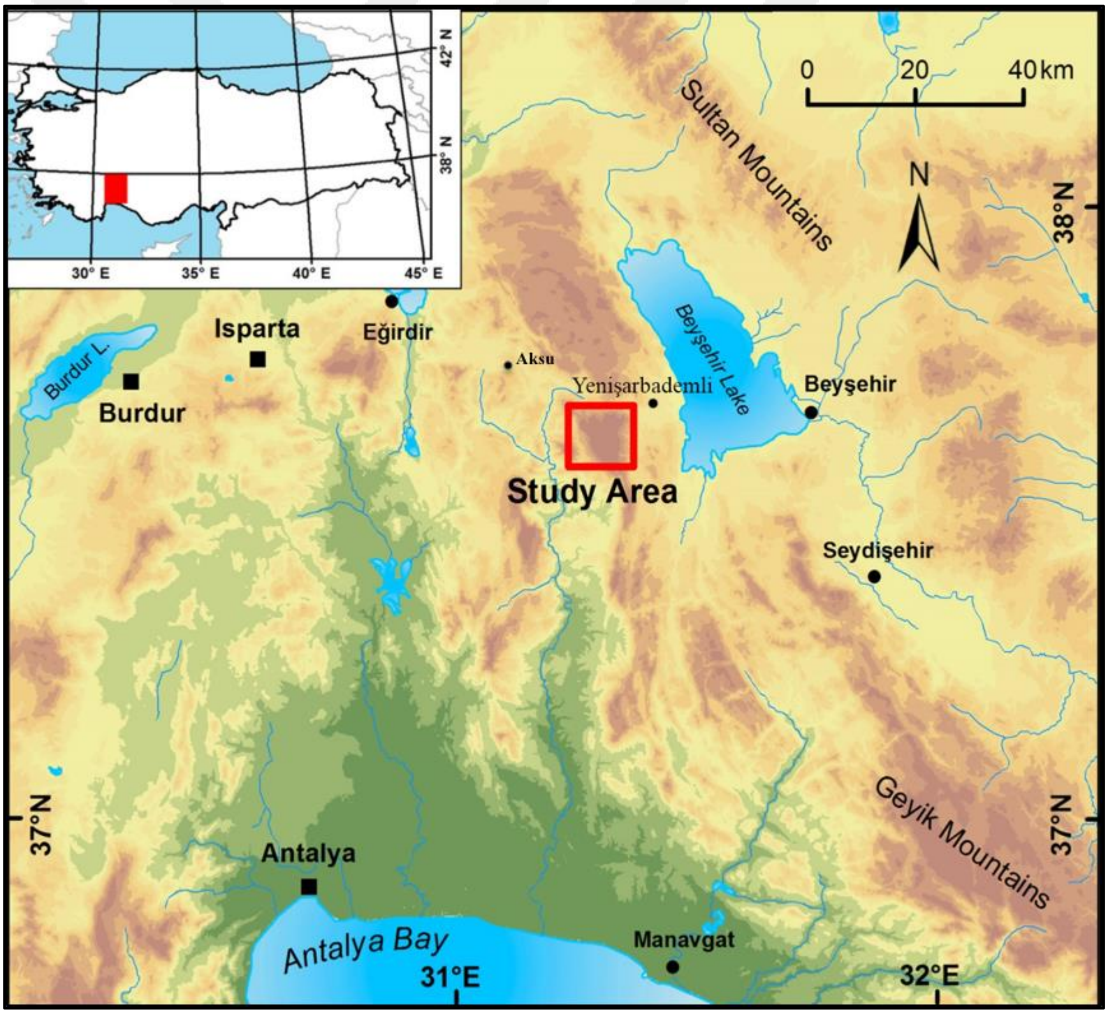


Figure 1.1 The location of Mount Dedegöl

The mountain is located 15 km west of Beyşehir Lake, the largest fresh water lake of Turkey. It lies north-south direction. The highest Dedegül peak rises to an elevation of about 2997 m (a.s.l) (above sea level). Main settlements located nearby the Mount Dedegöl are Yanişarbademli and Aksu districts on the northeastern and northwestern part of the mountain, respectively.

The study area mostly consists of glacial landforms. There are 6 main glacial valleys in the mountain. These are (1) Sayacak, (2) Kisbe, (3) Karagöl, (4) Karçukuru, (5) Elmadere and (6) Muslu Valleys. On the north side of the mountain, three glacial valleys (Sayacak, Kisbe and Elmadere Valleys) lie between 1500 and 2800 m (a.s.l.). Sayacak Valley located between Kisbe and Elmadere is the largest glacial valley in the Mount Dedegöl whereas Elmadere is smaller than others. The western margins of Dedegöl has a steep structural escarpment. Karçukuru Valley which lie between 1600 and 2800 m (a.s.l.) is the only valley on the west. The Eastern flank of the mountain was incised by Muslu and Karagöl Valleys. Karagöl Valley on the north of Muslu consist of three tributaries (Figure 1.2).

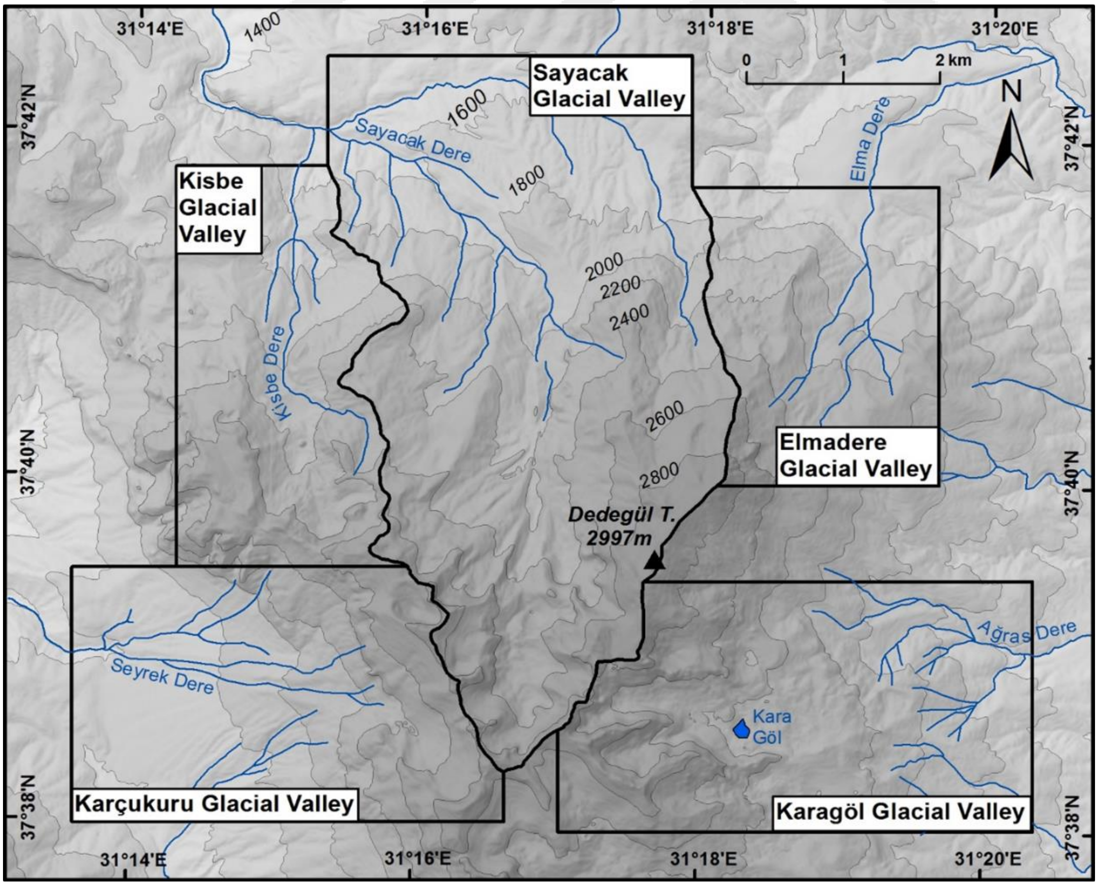


Figure 1.2 Northern glacial valleys of Mt. Dedegöl

Dipoyraz (Dedegöl) mountain that stands between Eğirdir and Beyşehir lakes, consists of the ten peaks (2800-3000m). It is the highest massif of the Western Taurus Mountains. This great massif functions as a bridge between the autochthonous carbonate series on the Beyşehir side of Taurus on the south, and the calcareous massif of the Anamas Mountains on the north, (Dumont and Monod, 1976).

The Mount Dedegöl is generally covered with dense karstic landforms such as dolines and uvalas. In the upper parts of the mountain glacial landforms were largely developed. The moraines in the glacial valleys are located as low as 1800 m (a.s.l.). There is also a lake in the study area named Karagöl (2450 m a.s.l.) and it was formed as tarn lake behind a terminal moraine in the Karagöl Valley. Due to the intense karstification, there are several caves. One of them is Pınargözü cave which is situated between the Sayacak and Elmadere valleys.

Intensely developed vegetation is generally located in the lowlands. Overall vegetation consists of pine trees and bushes in scrub. Forest vegetation reaches approximately up to 1800 m (a.s.l.), and they do not exist in higher parts of the Mount Dedegöl.

Because of intense karstification in the study area, there is no common drainage network. Small seasonal streams developed along the main valleys. These streams are generally fed by water formed as a result of melting snow. The average annual precipitation is about 500 mm and annual temperature is between 0.8 – 12 ^{o}C in the mountain (Çılğın 2012). Agriculture, animal husbandry and transhumance is the main source of livelihood in the region.

1.2 Purpose of Study

The goal of the study is to understand the timing of Quaternary glacial activities of the Mount Dedegöl by using the cosmogenic ^{36}Cl surface exposure dating method and to make a geochronological synthesis of the Mount Dedegöl and surrounding region. To carry out these goals, two specific objectives were proposed; (1) to determine the glacial geomorphology of Elmadere, Sayacak, Kisbe, Karagöl and Karçukuru Valleys of the Mount Dedegöl and, (2) to determine the landform ages associated with the Late Quaternary glaciers by cosmogenic ^{36}Cl dating.

1.3 Geology

The first geological studies about the Mount Dedegöl were revealed by Tromp (1941), Altınlı (1944), and Blumenthal (1947; 1949; 1951). Later, with studies by Robertson (1994), Şenel (1996), Şenel et al (1991; 1992; 1996; 1998). Özgür et al (1991) the stratigraphic and structural characteristics of the region revealed with a 1/100.000 geological map.

Precambrian, Paleozoic, Mesozoic and Cenozoic rock outcrops exist in the study area (Şenel 1997). These units consist of Bozburun and Karlık Formations in the Precambrian and Muslu Limestone, Karagöl Formation, Kartoz Limestone, Dipoyraz Formation, Kasımlar Formation, Menteşe Dolomite, Beydağları Formations in the Mesozoic. The most dominant units in the region belongs to the Mesozoic era. Neoautochthonous Miocene-Quaternary rock units also exposed in the region. Furthermore, most of the rock types in the region formed by sedimentary rocks.

Bozburun Formation which includes both continental and marine prone deposits is consist of schists with 1500 m thickness. According to Kröner and Şengör (1990), Bozburun Formation occurred in the Precambrian and they obtained ages between 2522 ± 3 and 657 ± 5 Myr. The outcrops of these units located in large areas in the east of the Mount Dedegöl.

Karlık Formation named by Dumont and Lys (1973) occurred in Precambrian and consists of clastic rock units. They generally include sandstones and conglomerates with limestone. Outcrops of the units are located in upper parts of Elmadere Valley, in the northeast of the Mount Dedegöl.

Muslu limestone is a unit in Mesozoic that is made of thick layered limestones under which Karagöl Formation is found (Dumont 1976). These limestones exposed in east and southwest of the study area. On the other hand, Karagöl formation consists of conglomerate, sandstone, siltstone, claystone, and limestone (Dumont 1976) which lie along the east and west side of the mountain.

Dipoyraz Formation which is the largest extension located in the center of mountain consists of dolomite, dolomitic limestone, and reef limestones. According to Dumont and Monod (1976), Dipoyraz Formation also occurred in Mesozoic era. Macro and micro fossil rich formation is classified into different facies such as thick layered, gray, dark gray, black, red, and pink colored reef limestone. Dipoyraz Mountain massif extends for 5 to 6 km in width and 12 km in length. This massif stratigraphically lies under the Kasımlar Formation. Kasımlar Formation consists of sandstone and shale. These units exposed in the east, north and west side of the study area (Figure 1.3).

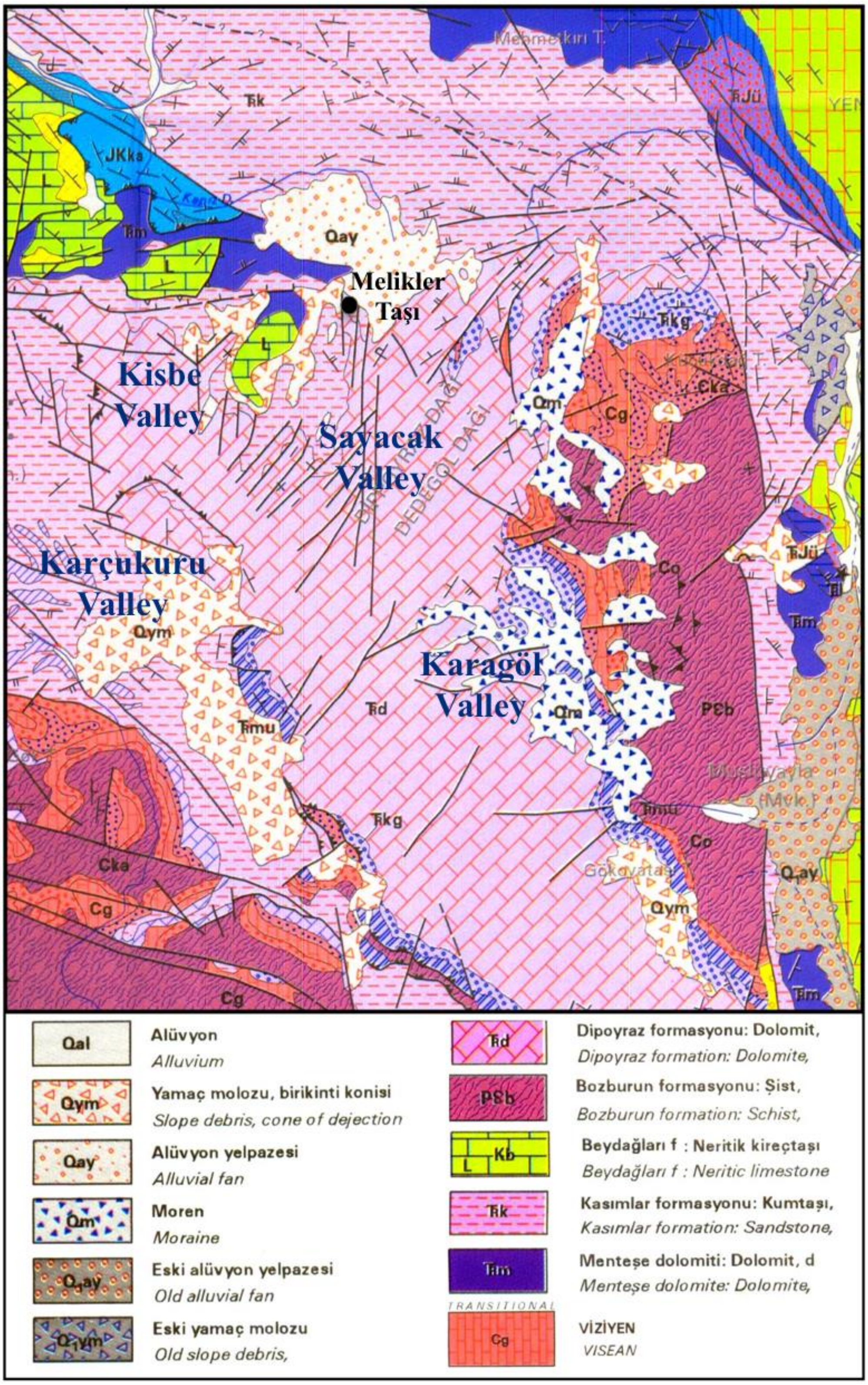


Figure 1.3 Geological map of the study area, (MTA, No:15 Isparta M26)

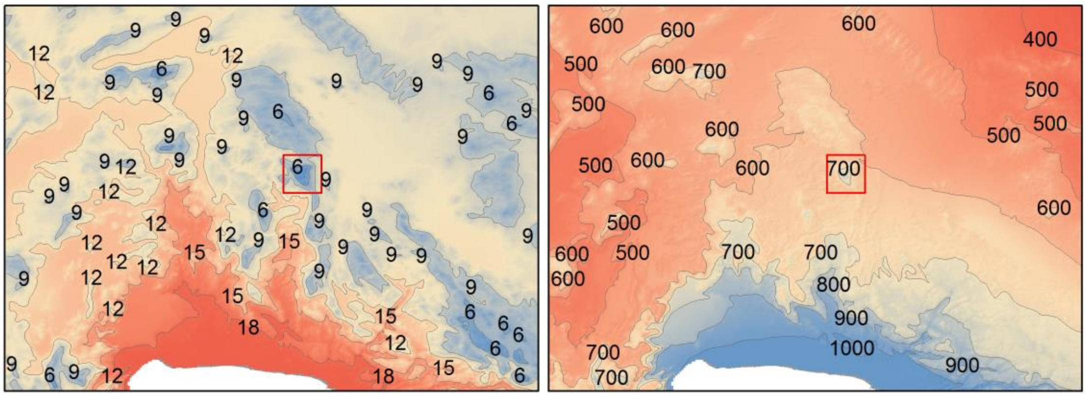
1.4 Climate

Climate is one of the major factor that drive geomorphological processes and provides direct information about these processes such as; fluvial and glacial. Furthermore, fully understanding the present climate of the study area will be beneficial to estimate the paleoclimate of the area.

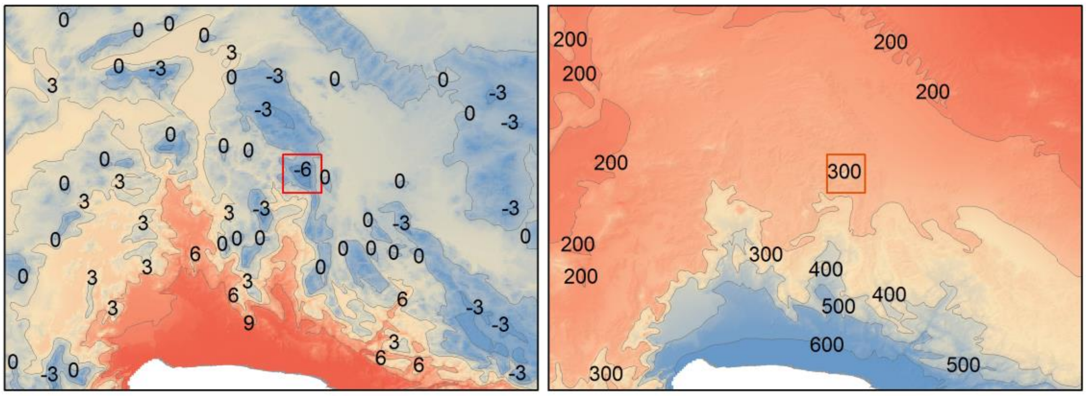
Turkey has different climatic characteristics due to its geographic location and its distribution of landforms. While temperate climate is dominant in the coastal areas, continental climate predominates the inner parts of the country. It is mostly because of the Northern Anatolian and Taurus Mountain Ranges which prevent the occurrence of temperate weather in the inner Anatolia.

Although the Dedegöl Mountain situated in The Mediterranean Region, the Mediterranean type climate is not predominant on the Mount Dedegöl. The study area is located in a transition zone between the continental and Mediterranean type climate zones. Since average elevation is greater than 2000 m a.s.l, the study area can be considered in the highland climate zone. Thus, the mountain climate is dominant in the study area. The study area has above 500 mm yearly precipitation values in high elevations. The annual average temperature is about 10 – 13 ^{o}C in low elevations and 5 – 8 ^{o}C around 2000 m (Atalay, 2010).

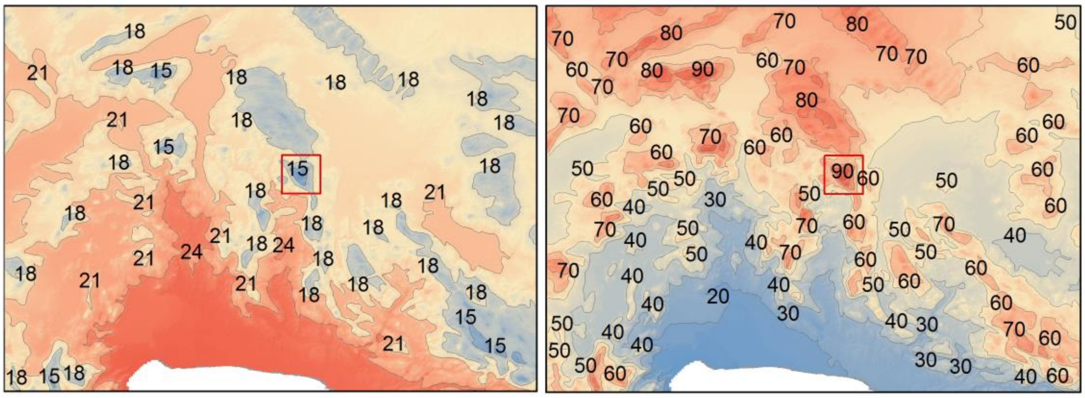
There is no meteorological station in the mountain to observe the temperature and precipitation rates. For this reason, temperature and precipitation data has provided from stations around study area; Eğirdir, Beyşehir, Aksu, Sütçüler, Yenişarbademli and Kasımlar (Çılğın, 2012). While high precipitation rates concentrate on the southwest escarpments and high parts of the mountain, minimum precipitation rates are observed on the east and northeast flank of the mountain (Figure 1.4).



Yearly average Temp, °C   Yearly sum Prec, mm



Winter average Temp, °C   Winter sum Prec, mm



Summer average Temp, °C   Summer sum Prec, mm

Figure 1.4 Present air temperature and precipitation maps of the study area

1.5 Previous Studies

During the Quaternary, the Earth has experienced the glacial and interglacial periods. During the glacial periods, some parts of the earth's surface has been covered by ice sheets and glaciers. Thus the Pleistocene is considered to be synonymous with the 'Ice Age' (Turoğlu, 2011). Recent studies in Quaternary glaciations of Turkey has revealed significant information about the mountain glaciers that developed during the Quaternary. Regarding topography, there are many mountains which lie above the Pleistocene snowline and these mountains had suitable climatic conditions for glaciers and ice caps to grow (Çiner, 2004; Sarıkaya, 2011). Especially, in northern and eastern Anatolia, elevation of many mountains is higher than the Paleo- equilibrium line altitude (Paleo-ELA).

Early systematic studies about the Quaternary glaciations in Turkey has begun with Maunsell (1901), Bobek (1940), Louis (1944). Later, Turkish physical geographers like Sırrı Erinç and Reşat İzbırak (Erinç, 1944; 1951; 1952; İzbırak, 1951) published landmark papers. Besides review papers were published about the recent and paleo-glaciers in Turkey by Messerli (1964, 1967), Birman (1968), and Atalay (1987). Thanks to cosmogenic surface exposure dating method, the Quaternary glacial studies has accelerated in the recent decades (Sarıkaya, 2012). In the past, landforms related to palaeoglacier activity such as moraines can be dated relatively (Doğu et al., 1993; 1994; 1999). Now, the cosmogenic isotopes and OSL can be used to date moraines quantitatively (Akçar et al., 2007, 2008; Bayrakdar, 2012; Sarıkaya et al., 2008, 2009; Sarıkaya, 2009; Zahno et al., 2009; 2010; Zreda et al., 2011; Akçar et al., 2014; Rebel et al., 2014; Sarıkaya et al., 2014).

Landforms that originated by the result of Turkey’s Quaternary glaciations are mainly classified in 3 different regions: (1) Taurus mountains, (2) Eastern Black Sea mountains and, (3) high volcanic mountains within the Anatolia (Kurter, 1980; Çiner, 2004; Sarıkaya et al., 2011).

Taurus Mountains located along the coastal Mediterranean extends to the southeast of Turkey. Taurus Mountains includes the best studied glaciers which can be subdivided into three sub-sections: (1) the South-eastern Taurus, (2) the Central Taurus and (3) the Western Taurus (Çiner, 2004; Sarıkaya et al., 2011).

The south-eastern Taurus mountains contain the largest glaciers. It has the two-thirds of the recent glaciers in Turkey. The modern snowline varies between 3100 and 3600 m a.s.l. (Bobek, 1940; Messerli, 1967). However, LGM snowline was estimated to either 2100 m a.s.l. (Wright, 1962) or 2800 m a.s.l. (Messerli, 1967). Uludoruk Glacier (4 km length and 8 km^2) on Reşko Tepe (4168 m a.s.l.) in Cilo Mountain is the largest valley glaciers in Turkey. (Erinç, 1952; Kurter, 1991; Çiner, 2003; Turoğlu, 2011).

The Central Taurus Mountains, where Aladağlar and Bolkar Mountains were located, is another range where glaciers were found. Moraines in these mountains were dated using cosmogenic ^{36}Cl and ages indicate large Holocene-Pleistocene glaciers and rapid deglaciation (Zreda et al., 2006). The modern snowline varies between 3200 and 3700 m a.s.l. whereas LGM snowline was estimated to 1900 and 2600 m a.s.l. (Messerli, 1967; Ege and Tonbul, 2005).

In The Western Taurus range, the modern snowline elevation is estimated to be between 3000 and 3750 m a.s.l., whereas the LGM snowline varies between 2200 and 2600 m a.s.l., except on Mount Sandıras, where the glacial-period snowline stood at 2000 m a.s.l. (Sarıkaya et al., 2011). Çiner (2003). In general, ELA was around 2200 m and 2350-2400 m in the Mount Dedegöl. On the other hand, present snowline located around 3300-3500 m.

Eastern Black Sea mountains are also known as Pontic Mountains consist of several peaks that lies above current snowline (Erinç, 1952). The highest mountain in the Eastern Black Sea is Kaçkar Mountain (3932 m a.s.l.) which has 6 recent glaciers. There are published cosmogenic age results from the Kavron Valley in Kaçkar Mountains. Kavron palaeoglaciers advanced at least 21.5±1.6 ka ago (recalculated by Zahno et al. (2009) with the LGM glaciation continuing until 15.6±1.2 ka ago based on ^{10}Be ages. Moreover, similar results were obtained from the nearby Verçenik Valley (Akçar et al., 2008).

One of the High Volcanic mountains within the Anatolia is Mount Ağrı (also known as Mount Ararat, 5137 m a.s.l.). It is located in the far east of Turkey and supports an ice cap of 5.6 km^2 (Sarıkaya, 2012). Another volcanic mountain, Mount Erciyes, located in central Anatolia has evidence of four periods of glacial activity during the last 22 ka (Sarıkaya et al., 2009). Cosmogenic ^{36}Cl surface exposure dating results showed that LGM glaciers reached 6 km in length and descended to 2150 m a.s.l. (Sarıkaya et al., 2009).

Mount Süphan (4053 m a.s.l.), situated to the north of the Lake Van in the Eastern Turkey is the third highest peak of the country, rising to over 2400 m above the lake level. During the LGM, the summit of Mount Süphan was covered by an ice cap, with outlet glaciers descending to 2650–2700 m a.s.l. on the northern slope and 2950–3000 m a.s.l. on the south side (Kesici, 2005).

There have been very few studies conducted on The Mount Dedegöl. One of the main study about glacial geomorphology of the Mount Dedegöl belongs to Çılğın (2015). Six glacial valleys have studied. He produced glacial geomorphology maps. The physical location of the both accumulational and erosional landforms of each valley was determined.

According to Çılğın (2015), LGM snowline was estimated approximately 2230 m a.s.l and the estimate of LGM cooling is about 10 – 11 ^{o}C. A glacier reconstruction of the LGM on Mount Dedegöl shows that glaciers lied between maximum 2820 m a.s.l. and minimum 1480 m a.s.l. and covered approximately 21.2 km^2. The height, length, thickness and area of former glaciers in each valley were determined based on the glacier reconstruction.

Çılğın (2015) performed OSL dating method and obtained two samples in Sayacak; one sample is in Elmadere and two samples are in Karagöl valley. OSL ages shows the evidence of different glacial periods in between 148±13 and 2.6±0.1 ka.

Zahno et al (2009) used cosmogenic surface exposure dating method with cosmogenic ^{10}Be and ^{26}Al to date a glacier expansion out of the Muslu Valley, located on the eastern part of the Mount Dedegöl. They dated to maximum extent of paleo-glaciers to 24.3±1.8 ka ago and gave evidence for pronounced glacier advances prior to the global Last Glacial Maximum (LGM). According to Zahno et al (2009), the glacier retreats which was no longer than 17.7±1.4 ka ago.

2. METHODOLOGY

2.1 Cosmogenic Surface Exposure Dating Method

The cosmogenic ^{36}Cl dating method was used in the Mount Dedegöl in order to determine the surface exposure ages of moraines. In this way, the length of time that any rock has been exposed on the Earth's surface can be estimated (Davis and Schaeffer, 1955; Phillips et al., 1986; Zreda et al., 1991; Zreda and Phillips, 2000).

Cosmogenic surface exposure dating method depends on the interactions between cosmic rays and nuclides in rocks. When rocks are exposed at surface or near surface, cosmic ray particles which are secondary fast neutrons, thermal neutrons and negative slow muons start to bombard and interact with three main nuclides (^{35}Cl, ^{39}K and ^{40}Ca) to cause formation of cosmogenic ^{36}Cl. Therefore, measured ^{36}Cl concentrations in rocks can be used to quantify the exposure time of exposed rocks. (Davis and Schaeffer, 1955; Phillips et al., 1986; Zreda et al., 1991; Zreda and Phillips, 2000; Owen et al., 2001; Sarıkaya et al., 2008).

Many environmental factors influence the cosmogenic nuclide concentration in the dated boulders. First, changes in the cosmic-ray flux cause the change in the cosmogenic nuclide production rate. Second, erosional processes include soil erosion, stream dissection, erosion of boulder surface and spalling may result in younger ages than the true boulder age. Third, shielding such as snow, vegetation or soil cover can affect the intensity of cosmic radiations which reduce cosmic rays reaching the surface. Chemical weathering, geometry of the boulder and elevation changes may also effect the cosmogenic nuclides in the dated boulder (Zreda and Phillips, 2000). Thus, one should consider all of above consideration in mind during the sampling.

There are several applications of cosmogenic surface exposure dating in the Quaternary geochronology. Dating of Quaternary glaciations, volcanic eruptions, paleolake shorelines, rate of erosion, fault rapture ages and the frequency of tectonic movements can be applied by this method (Zreda et al., 1991; Zreda and Phillips, 2000; Martini et al. 2001; Sarıkaya et al. 2008).

2.2 Field Studies

The main goal of this study was to determine the glacial geomorphology and obtain the landform ages of glacial deposits of the Mount Dedegöl. Therefore, to achieve these goals glacial geomorphological maps of the study area were first prepared. Later, rock samples from moraines were taken for cosmogenic surface exposure dating. Here, I describe the field methodology that I applied in this thesis.

2.2.1 Glacial geomorphological mapping

In the geomorphological mapping processes various vector and raster data types were used to product purposeful maps.

Before the field studies, the base maps such as topographic data (1:25000), aerial photos and digital elevation models (DEM) were obtained. Satellite images from the Google Earth Pro software were also used for mapping purposes. Geographic information system (GIS) database structure has been prepared in GIS software for mapping. A draft map was created for field studies. Settlements, roads, rivers, lakes, main glacial valleys, hills and contour lines were drawn on these maps.

During the field studies, hand-held GPS were used to determine the exact positioning of geomorphic boundaries and point of interests. Main glacial valleys and moraine borders were positioned using the GPS in order to validate pre-mapping draft. Both erosional and accumulation landforms such as lateral moraines and cirques formed by glaciers were determined. These landforms were sketched with direct observation to analyze the surface morphologies. The height, length and width properties of the moraines and sample locations noted during the field trip.

After the field studies, the data obtained from the field and from the GIS database structure were compared and produced the final maps in GIS software (ArcMap 10.3). Based on digital cartographic symbols, sample locations, all moraine types, cirques, and other glacial landforms were drawn for each glacial valley.

2.2.2 Sampling for cosmogenic exposure dating

Samples for cosmogenic ^{36}Cl dating were collected from the top of the boulders on the crest of the moraines. A hammer and chisel were used to take samples from upper few centimeters of the boulders (Figure 2.1). The boulders were selected according to their positions. Boulders were sampled based on their appearance, size, preservation and position on the crest. Stable boulders with strong roots in the moraine matrix were preferred. They should have not be rolled and were not covered with soil or vegetation during the exposure histories.

Figure 2.1 Sampling for cosmogenic exposure dating

A poor sampling strategy is one of the common errors in cosmogenic surface exposure dating and may result erroneous ages. For example, movement and rolling of a boulder downslope may result in large errors when the age of the rock calculated. Therefore, detailed and careful sampling strategy must be applied in the field.

About 500 - 800 grams of rock samples were taken within a few centimeters thickness on the top flat surfaces of the boulders. The sample thicknesses, coordinates of sampling site (latitude, longitude and GPS elevations), the time of sampling were noted. All samples were labeled with sample names (DEXX-NN: DE for Mt. Dedegöl; XX for two digit of the year and NN is for the sample number) and taken their photos and videos from different aspects as much as possible including a visual scale. Physical characteristics of the boulders such as size, shape, lithology, lichen cover, glacial polish and visible cracks were recorded. Topo measurements at 0 ^{o}, 45 ^{o}, 90 ^{o}, 135 ^{o}, 180 ^{o}, 225 ^{o}, 270 ^{o}, 315 ^{o} from azimuth North were done. Azimuth angles of topographic barriers with regular azimuth intervals (in 45° from north) were taken by inclinometer. The sketch of all moraines and the boulders were drawn. Finally, samples were put inside plastic bags, wrapped with plastic folio and duck taped to keep them safe during the transportation to the sample preparation laboratory.

2.3 Laboratory Methods

The sample preparation of collected rock samples was done in order to measure minute amount of cosmogenic ^{36}Cl in rocks by AMS (Accelerated Mass Spectrometer). The laboratory methods consist of four preparation stages: (1) crushing, grinding and sieving, (2) leaching and digestion, (3) chemical separation and (4) target preparation (Figure 2.2).

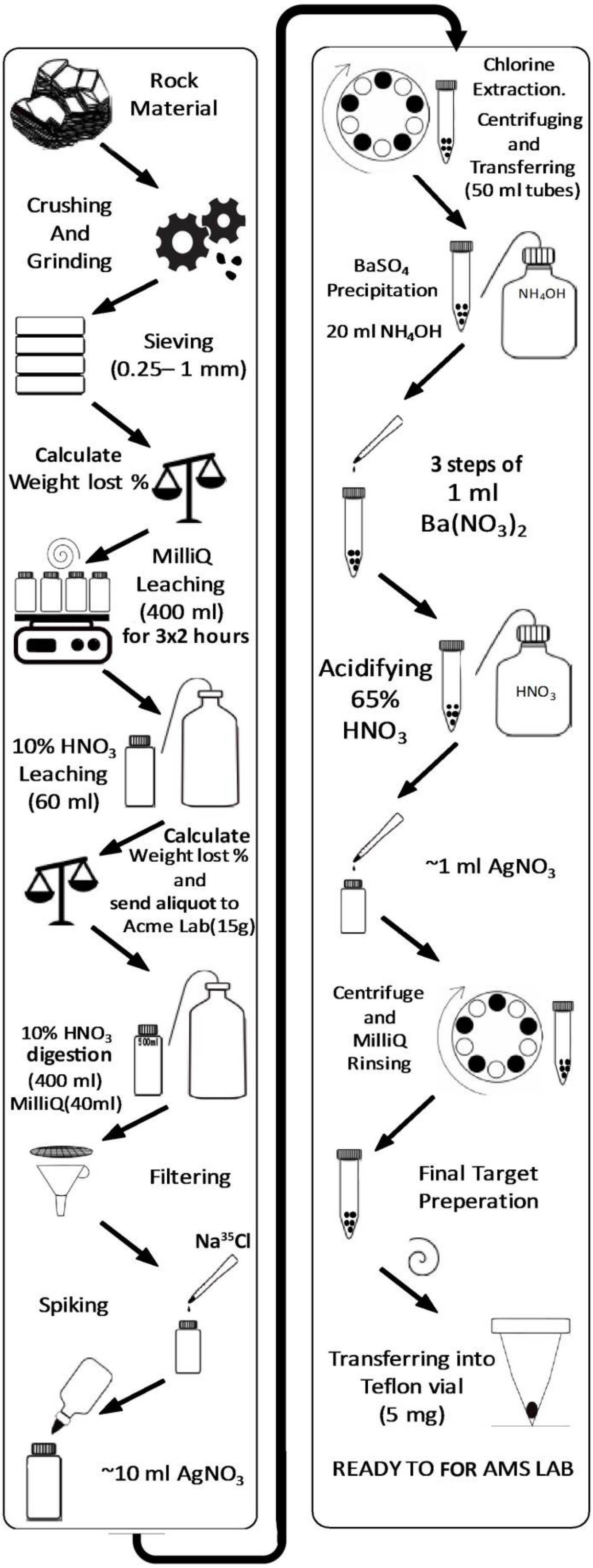


Figure 2.2 ^{36}Cl workflow in ITU/Kozmo-lab

2.3.1 Crushing, grounding and sieving

This section known as the physical pretreatment stage that enables to maximize the yield of required grain size by reducing the grain size of a sample to its mineral size (Sarıkaya, 2009). First, collected samples from the field were cleaned to get rid of extraneous materials, such as lichens, secondary carbonates and atmospheric dust. After the inventorial weight measurements of each samples, the rock densities are calculated by measuring the weights and volumes from a piece of rock sample. Later, they were brought to crushing-grinding-sieving laboratory.

First, a jaw crusher was used to crush the rocks (Figure 2.3). The jaw crusher has ~5 cm input and ~1 cm output size. If the samples are bigger than the feeding size of the crusher, they were first broken into suitable fragments by hummer. After all of samples were crushed in jaw crusher, their sizes reduced to maximum 1 cm in diameter. Thus, all samples were ready for the disc mill machine.

A disc mill machine was used for grinding stage (Figure 2.3). The distance between two discs determines the output size of the machine. I set the distance of the discs between 0.6 to 1 mm in order to ensure minimum loss rates. When the samples were crushed at this stage, grain size were reduced to less than 1 mm in diameter which are suitable for sieving stage.

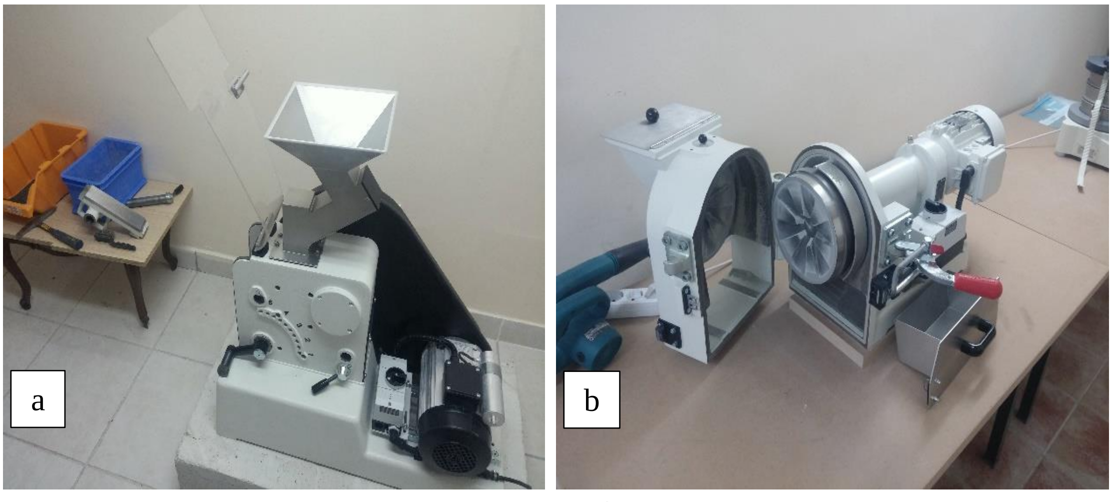


Figure 2.3 (a) Jawcrusher and (b) disc mill for crushing and grounding samples

In the sieving stage, rock fragments were poured into a set of sieves in order to separate sample grains between 1 mm and 0.25 mm in diameter. The sieve set consists of a collection pan at the bottom, a 0.25 mm opening size sieve (250 micron) on top of that pan and then a 1 mm size sieve, and a lid on the top of all (Figure 2.4). After sieving all of the samples, the remaining sample grains above 1 mm were crushed in disc mill again and sieving repeated. Sample grains under 0.25 mm were not used in analysis and discarded (Figure 2.4).

Figure 2.4 Sieve set with shaking machine

All parts of the jaw crusher, disc mill and sieves were cleaned with compressed air gun in order to prevent cross contamination, before turning on the machines for the next sample. The crushed rock samples were poured into new clean bags with their sample names, labeled with “un-leached” and the grain-size (0.25 – 1 mm) labeled.

2.3.2 Leaching and digestion

Lithology of the rocks should be determined whether if they are carbonate or silicate origin, before leaching the samples. 5% of HNO_3 is dropped on to the samples in order to identify the rock type. If it reacts vigorously, it is a carbonate (Sarıkaya, 2009). All of my samples were reacted, thus they were all carbonates which is in accordance my field observations.

Leaching processes consist of two steps: (1) leaching with milli-Q and (2) leaching with 10% HNO_3. The aim of the leaching stage is to remove secondary carbonates, dust and organic particles from ground samples and also remove the outer layer of the sample grains.

In leaching with milli-Q process, first of all, a clean 500 ml HDPE bottle with cap was weighed and labeled with the sample ID. Later, ~60 g un-leached 0.25 – 1.00 mm grain size sample was added and the sample's weight was recorded. Third, the bottle was filled with milli-Q up to approximately 4/5 (~400 ml) of the bottle. Then, 10 bottles as a set were placed on the table shaker and shaken 2 hours at speed 230 rpm (round per minute). After the shaking operation, the solution was discharged from the bottle and remained sample rinsed with milli-Q. Filling with milli-Q, shaking and rinsing operations were repeated two more times. Remained samples dried overnight at 80^{o}C in the oven. Finally, the dried sample's weight was measured and weight loss after milli-Q leaching were calculated.

In leaching with HNO_3 process, a diluted HNO_3 were used. First, according to remained sample weight, ~1 ml milli-Q and ~ 1 ml 10% HNO3 were added per gram of sample (~ 60 ml per bottle). After waiting overnight, the solution was discharged and rinsed at least 3 times with milli-Q. Then, remained samples dried overnight at 80^{o}C (min. 12 hours). After HNO_3 leaching, the total weight loss was calculated. Finally, ~15 g per sample aliquots were taken for measurements of the whole rock chemistry of samples. They were sent to Acme Lab. (ActLabs Inc., Ontario Canada).

Digestion stage includes spiking and total dissolution. There are three type of chlorine isotopes (^{35,36,37}Cl) in the natural environment. Whereas ^{35}Cl and ^{37}Cl isotopes are stable, ^{36}Cl is radioactive. The process in this stage is to add a known amount of spike solution into thedissolved samples in order to measure a reliable Radiogenic/Stable (R/S) ratio. Therefore, AMS can measure the ratio of R/S: radioactive to stable;

$^{36}Cl/(^{35}Cl+^{37}Cl)$ (Sarıkaya, 2009). Firstly, ~40 ml milli-Q added and recorded. Secondly, the bottle was filled with 10% HNO_3 up to approximately 4/5 (~400 ml) of the bottle (i. e. 100 ml acid slowly added in every 5 min). Thirdly, the sample solution rested overnight were transferred into new 500 ml labeled bottle. Filter papers and funnels were used during the transferring the solution. Then, ~10 ml of 0.1 M $AgNO_3$ solution added in to the bottle and rested overnight in a dark place. Next, ~1 g spike solution added into the bottle. The concentration and the $^{35}Cl/^{37}Cl$ ratio of the spike solution were recorded for calculations. Finally, ~10 ml of 0.1 M $AgNO_3$ solution added in to the bottle and rested overnight in a dark and cold place.

2.3.3 Chemical separation

There are four goals of the Cl extraction stage: (1) to separate Cl from the rock sample that is digested, (2) to collect as much as Cl as possible, (3) to remove the isobar ^{36}S that is an important problem in AMS measurements of ^{36}Cl, (4) and prepare the suitable target form (AgCl) (Sarıkaya, 2009).

In chlorine extraction, first, the acid solution in the bottle were discharged without disturbing the sediment. Then, left about 100-150 ml solution in the bottle were transferred into a new labeled 50 ml centrifuge tubes. After centrifuging 15 min at 3000 rpm, the sediments were collected in one tube.

In precipitation method ($BaSO_4$ precipitation), 20 ml of concentrated (25%) NH_4OH added to dissolved the AgCl. To remove the ^{36}S, $BaSO_4$ was applied. To achieve this, AgCl were dissolved under basic conditions, and 1 ml of saturated $Ba(NO_3)_2$ were added to precipitate $BaSO_4$. After the samples rested overnight, they were centrifuged 15 min. at 3000 rpm. When the solution was re-acidified with concentrated HNO_3 (65%), AgCl re-precipitated. Finally, ~1 ml $AgNO_3$ added to increase the yield of AgCl precipitation. Each of $BaSO_4$ adding step is called “Barium steps” and were applied 3 times (Figure 2.5).

Figure 2.5 Chemical separation; acidifying

2.3.4 Target Preparation

Target preparation process is the final step that enables AgCl to be ready for AMS (Accelerated Mass Spectrometry). After the centrifuge 15 min at 3000 rpm, the acid solution was discharged and the remained sediments were rinsed in milli-Q. Centrifuge, discharging acid and rinsing in milli-Q operations were repeated until the pH of the solution is neutral. Then, final sediment dried 24 hours at 60 ^{o}C. Final AgCl target were transferred into the teflon vial (5 ml) without touching it barehand. Finally, the weight of the final AgCl target were recorded and vials were stored in a dark place.

2.3.5 Cathoding

Prepared AgCl samples were placed into a cathode (sample target holder) by pouring the AgCl directly from the vial tube into the cathode. After the sample transferred to the sample port, cathode mounted an exclusive metal ring in order to compress. All of the samples were compressed by press machine with a press-pin, then dried at 80 ^{o}C. When I ensured that the surface of the cathodes appear smooth, then put into a cathode wheel and placed into the AMS (Figure 2.6).

Figure 2.6 Cathoding process, France
(Centre National de la Recherche Scientifique, CEREGE)

2.4 Analytical Measurements

2.4.1 Total rock chemistry measurements

Geochemical methods are applied to measure the total element concentrations of samples. To provide data for suitable sample classifications, several options are available such as ICP-ES, ICP-MS, LA-ICP-MS and XRF. Sometimes a range of major and trace elements are determined by more than one technique in order to ensure the analytical precision and accuracy. For example, after acid digestion, some trace elements are measured both by XRF and ICP-MS options. However, in my study I applied ICP-MS measurements of all samples in a commercial laboratory.

To do this, rock samples were dried at 80^o C after the leaching with HNO_3 process. Then, 15 gram sub-samples were taken from each 20 samples. All sub-samples were send to the Acme Lab (ActLabs Inc., Ontario Canada) to provide the total element concentrations.

In order to calculate cosmogenic production rates, major elements (K_2O, CaO) and trace elements (U, Th, Sm, Gd) which have high thermal neutron cross-sections taken into the account. (Table 2.2).

2.4.2 Accelerator mass spectometry measurements

Accelerator mass spectrometry (AMS) method is used to account the number of atoms which have low isotopic concentrations (Hellborg et al., 2007). The most common studied isotope with AMS is ^{14}C. The stable isotope ^{3}He and the radioactive nuclides ^{14}C, ^{10}Be, ^{26}Al, and ^{36}Cl are widely used cosmogenic isotopes. Basically, an AMS system includes; (1) Production of negative ions, (2) Acceleration of negative ions, (3) Recharging process of all ions, (4) Acceleration of positive ions, (5) The removal process of unwanted ions, (6) Counting process, (7) Computer control.

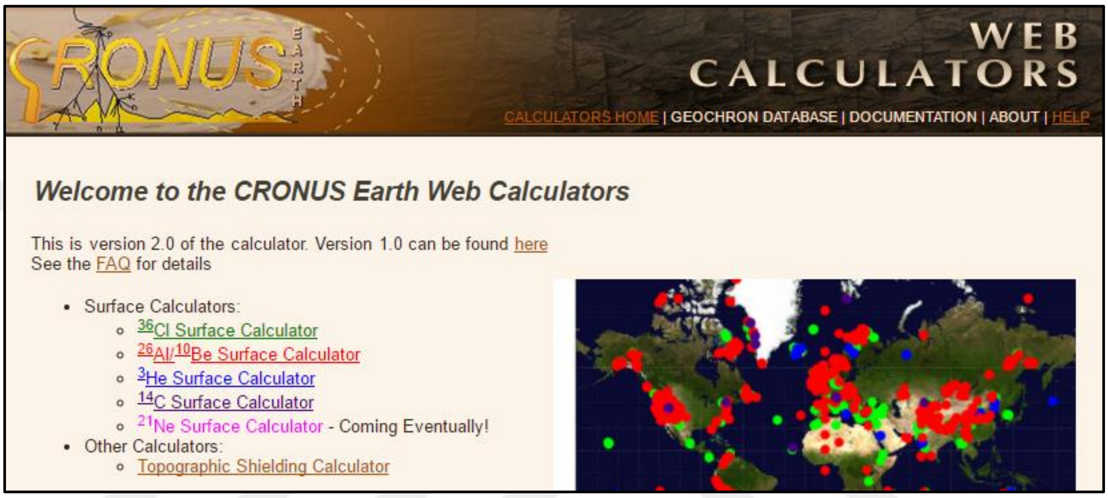
Final target samples prepared at ITU/Kozmo-Lab in İstanbul were taken to ASTER AMS lab, France (Centre National de la Recherche Scientifique, CEREGE, Aix en Provence). AMS can measure the ratio of R/S: radioactive to stable; ^{36}Cl / ^{37}Cl and ^{36}Cl / ^{37}Cl, S/S: stable to stable (^{35}Cl / ^{37}Cl) ratios. When the results arrived, I calculated the exposure age of all samples (Figure 2.7).

Figure 2.7 AMS lab, Aix en Provence - France

(Centre National de la Recherche Scientifique, CEREGE)

2.5 Age Calculations

Surface exposure ages from the collected samples are measured by web based software (http://cronus.cosmogenicnuclides.rocks/2.0/html/cl/). Data are entered into the software in order to calculate the ages of the surface. Entered data into the software are data include the height, location, density, thickness and azimuthal increments of the sample using a handheld clinometer (Figure 2.8). Sample locations, attributes and local corrections to production rates is shown in Table 2.1.



Welcome to the CRONUS Earth Web Calculators

This is version 2.0 of the calculator. Version 1.0 can be found here
See the FAQ for details

- Surface Calculators:
  - ^{36}Cl Surface Calculator
  - ^{26}Al/^{10}Be Surface Calculator
  - ^{3}He Surface Calculator
  - ^{14}C Surface Calculator
  - ^{21}Ne Surface Calculator - Coming Eventually!
- Other Calculators:
  - Topographic Shielding Calculator

Figure 2.8 Cronus Earth Web Calculators (http://cronus.cosmogenicnuclides.rocks/2.0/html/cl/)

Table 2.1: Sample locations, attributes and local corrections to production rates.

Sample ID	**Latitude** **(WGS84)** **^{O}N (DD)**	**Longitude** **(WGS84)** **^{O}E (DD)**	**Elevation (m)** (GPS)	**Boulder size (m)** (W x Lx H)	**Thickness (cm)**	**Topography correction factor (-)**
DED05-801	37.64414	31.30400	2378	2.5 x 1.5 x 1.2	1	0.96534
DED05-802	37.64710	31.30895	2395	3 x 2 x 1	2	0.99684
DED05-803	37.64370	31.31770	2288	2.5 x 1 x 1.2	3	0.99937
DED05-804	37.64626	31.31860	2195	0.9 x 0.7 x 0.3	2	0.99742
DED05-805	37.64877	31.32414	2081	1.5 x 0.6x 0.3	2	0.99771
DED05-806	37.64846	31.32515	2072	1.5 x 1.5 x 0.6	2	0.99837
DED05-807	37.64822	31.32548	2072	6 x 3 x 2	2	0.99745
DED15-808	37.68941	31.28121	1897	1.4 x 2 x 1	4	0.98125
DED15-809	37.68866	31.28268	1916	2. 2 x 1.5 x 1.2	3	0.98151
DED15-810	37.68649	31.28452	1949	8 x 7 x 6	3	0.99612
DED15-811	37.69255	31.28193	1863	1.2 x 6 x 5	5	0.99902
DED15-812	37.69218	31.28130	1865	2 x 1.1 x 6	3	0.99824
DED15-813	37.69149	31.28103	1870	2.3 x 2.4 x 6	3	0.99827
DED15-814	37.69317	31.28031	1840	1.1 x 7 x 6	3	0.99868
DED15-815	37.69419	31.28051	1833	9 x 6 x 3	3	0.99801
DED15-816	37.68177	31.25368	1899	1.1 x 1.1 x 0.4	3	0.96772
DED15-817	37.68260	31.25043	1892	1.1 x 1.1 x 4	1.5	0.98322
DED15-818	37.68355	31.25291	1882	1.2 x 1.6 x 8	5	0.99315
DED15-819	37.68255	31.24982	1908	1 x 2 x 3	4	0.99408
DED15-820	37.68399	31.25015	1873	7x 4 x 4	2	0.99333

Table 2.2: Total rock chemistry measurements (major and trace elements)

Sample ID	Major elements											Trace elements			
	SiO_2 (%)	TiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MnO (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	P_2O_5 (%)	CO_2 (%)	Sm (ppm)	Gd (ppm)	U (ppm)	Th (ppm)
DED05-801	0.31	0.00	0.13	0.06	0.01	0.39	56.10	0.03	0.04	0.02	43.45	0.10	0.10	0.80	0.10
DED05-802	0.21	0.00	0.11	0.04	0.01	0.42	55.87	0.03	0.03	0.01	43.67	0.10	0.10	0.20	0.10
DED05-803	0.22	0.00	0.11	0.03	0.00	0.42	56.10	0.03	0.04	0.01	43.64	0.10	0.10	1.10	0.10
DED05-804	0.34	0.00	0.20	0.06	0.01	0.44	55.80	0.03	0.02	0.01	43.61	0.10	0.10	0.10	0.10
DED05-805	0.68	0.01	0.29	0.21	0.01	0.89	54.81	0.03	0.07	0.03	43.46	0.20	0.20	0.20	0.20
DED05-806	0.21	0.00	0.11	0.03	0.01	0.32	55.94	0.03	0.05	0.02	43.66	0.10	0.10	0.30	0.10
DED05-807	0.83	0.01	0.52	0.30	0.01	0.55	54.95	0.03	0.09	0.03	43.06	0.40	0.30	0.20	0.40
DED15-808	0.47	0.01	0.16	0.12	0.01	0.44	55.15	0.01	0.03	0.02	43.60	0.27	0.31	1.30	0.20
DED15-809	0.56	0.01	0.14	0.11	0.02	0.40	54.70	0.02	0.03	0.02	44.00	0.19	0.16	0.20	0.20
DED15-810	0.53	0.01	0.14	0.06	0.01	0.24	55.20	0.01	0.03	0.01	43.70	0.32	0.43	0.30	0.20
DED15-811	0.41	0.01	0.05	0.11	0.01	0.34	55.75	0.01	0.01	0.02	43.30	0.07	0.10	1.40	0.20
DED15-812	0.36	0.01	0.01	0.39	0.02	0.41	54.68	0.01	0.01	0.04	44.00	0.11	0.15	1.20	0.20
DED15-813	2.00	0.01	0.07	0.21	0.02	0.61	54.02	0.02	0.01	0.03	42.90	0.09	0.17	0.80	0.20
DED15-814	0.81	0.02	0.42	0.53	0.03	0.55	54.62	0.02	0.06	0.04	42.80	0.30	0.37	4.40	0.20
DED15-815	0.69	0.01	0.12	0.25	0.02	0.78	54.71	0.03	0.02	0.04	43.30	0.22	0.37	0.20	0.20
DED15-816	12.22	0.01	0.40	0.43	0.03	0.60	47.52	0.02	0.08	0.03	38.50	0.80	0.95	0.50	0.30
DED15-817	1.04	0.01	0.28	0.22	0.02	0.48	54.31	0.01	0.05	0.02	43.50	0.24	0.27	0.20	0.20
DED15-818	0.24	0.01	0.12	0.08	0.02	0.28	55.64	0.01	0.02	0.03	43.50	0.25	0.33	0.30	0.20
DED15-819	0.35	0.01	0.11	0.05	0.01	0.62	55.20	0.01	0.02	0.01	43.50	0.31	0.26	3.00	0.20
DED15-820	1.04	0.02	0.50	0.23	0.03	0.61	54.29	0.01	0.10	0.02	43.10	0.52	0.46	0.20	0.30

3. RESULTS

3.1 Glacial Geomorphology

3.1.1 Sayacak Valley

This valley is located in the Sayacak Dere and its tributaries on the north side of the Mount Dedegöl. To the east, the highest part of the crests are located around 2900 m (a.s.l.) Ridges have 2300-2400 m (a.s.l.) belongs to on the west Kisbe Valley and on the east Elmadere Valley. Sayacak Valley includes a complex topography which affected by numerous faults and karstic systems (Figure 3.1).

The length of the Sayacak Valley is about 5 km. The width of the valley in Melikler Taşı is about 800 and 900 m but in the middle part of the valley reaches about 2700 m. Main glacial erosional landforms in the Sayacak Valley such as cirques, striations, and whaleback structures located above 1950 m.

Upper parts of the Sayacak Valley lies from 2300 m (a.s.l.) to the highest peak of Dedegül Tepe. 15 cirques observed in the valley. These cirques are separated by aretes. Lateral moraines have deposited between 1950 and 1600 m (a.s.l.). According to Çılğın (2015), in front of these moraines, there are hummocky moraines occurred due to the push of right lateral moraine. From 1700 m, accumulated hummocky moraines are became to deformed moraines due to the fluvial erosion (Figure 3.2).

Figure 3.1 Lateral moraines in the Sayacak Valley (Looking to the east)

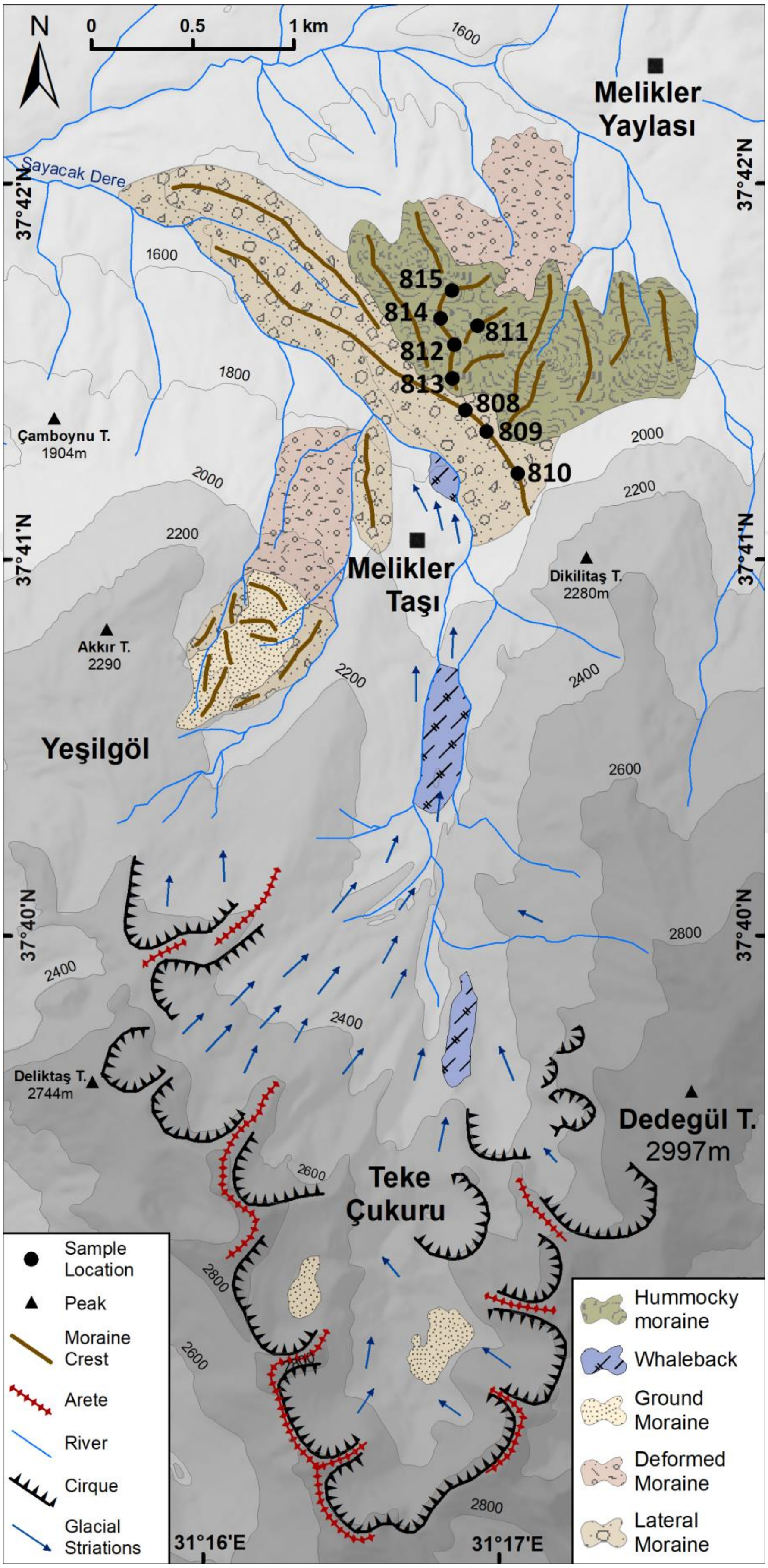


Figure 3.2 Glacial geomorphology map of the Sayacak valley (modified from Çılğın, 2012)

3.1.1 Kisbe Valley

Kisbe Valley extends from south to north like Sayacak Valley and covers approximately 11 km^2. East edge of the valley is bordered with Sayacak Valley and west edge of the valley is consist of a ridge which is located 2360 m a.s.l. There are no glacial landforms have observed on the east of the valley (Figure 3.3).

Figure 3.3 Lateral moraines in the Kisbe Valley (looking to the South)

There are numerous glacial erosional and accumulation landforms identified in the Kisbe Valley. Erosional landforms are cirques, aretes, glacial scratches and striations. Accumulation landforms have observed at different elevations such as ground moraines and lateral moraines.

The left lateral moraine at the bottom of the valley is situated between 1690 and 1955 m (a.s.l). The left lateral moraine has 950 m length and 250 width. The right lateral moraine has also same width but is 800 m in length. The maximum thickness of both lateral moraines is about 60 m (Figure 3.4).

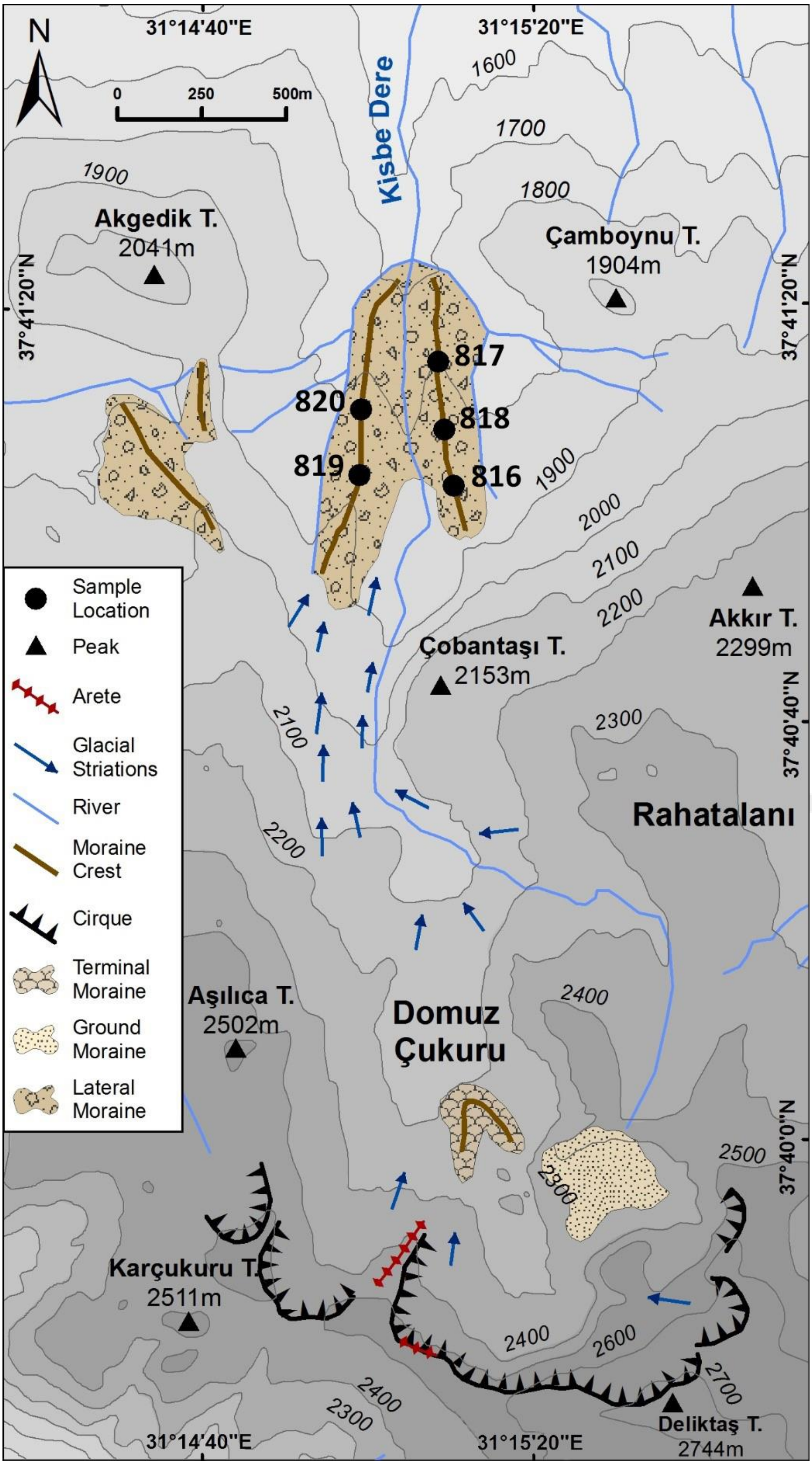


Figure 3.4 Glacial geomorphology map of the Kisbe Valley (modified from Çılğın, 2012)

3.1.2 Elmadere Valley

The valley is in the northeast direction. It is located on the east of the Sayacak Valley. Glacial landforms have determined between Kartal Tepe (2983 m) and 1900 m a.s.l. The length of the valley is approximately 3 km and the width is 1500 m (Figure 3.5)

Figure 3.5 Elmadere Valley (looking to the South)

Figure 3.6 Recessional moraines in Elmadere Valley (looking to the South)

Elmadere Valley is not a typical U-shaped valley. However, it has a complex glacial geomorphology. There are different types of moraines such as lateral, recessional and terminal moraines. Five crescent ridges of the recessional moraines have observed between 2150 and 2425 m a.s.l. In upper part of the recessional moraines, there are two lateral moraines that are 370 m in length at 2380 m a.s.l. There are very young lateral moraines between 2500 and 2600 m a.s.l. (Figure 3.7). At 2750 m a.s.l, there are terminal moraines which are highly eroded (Figure 3.6).

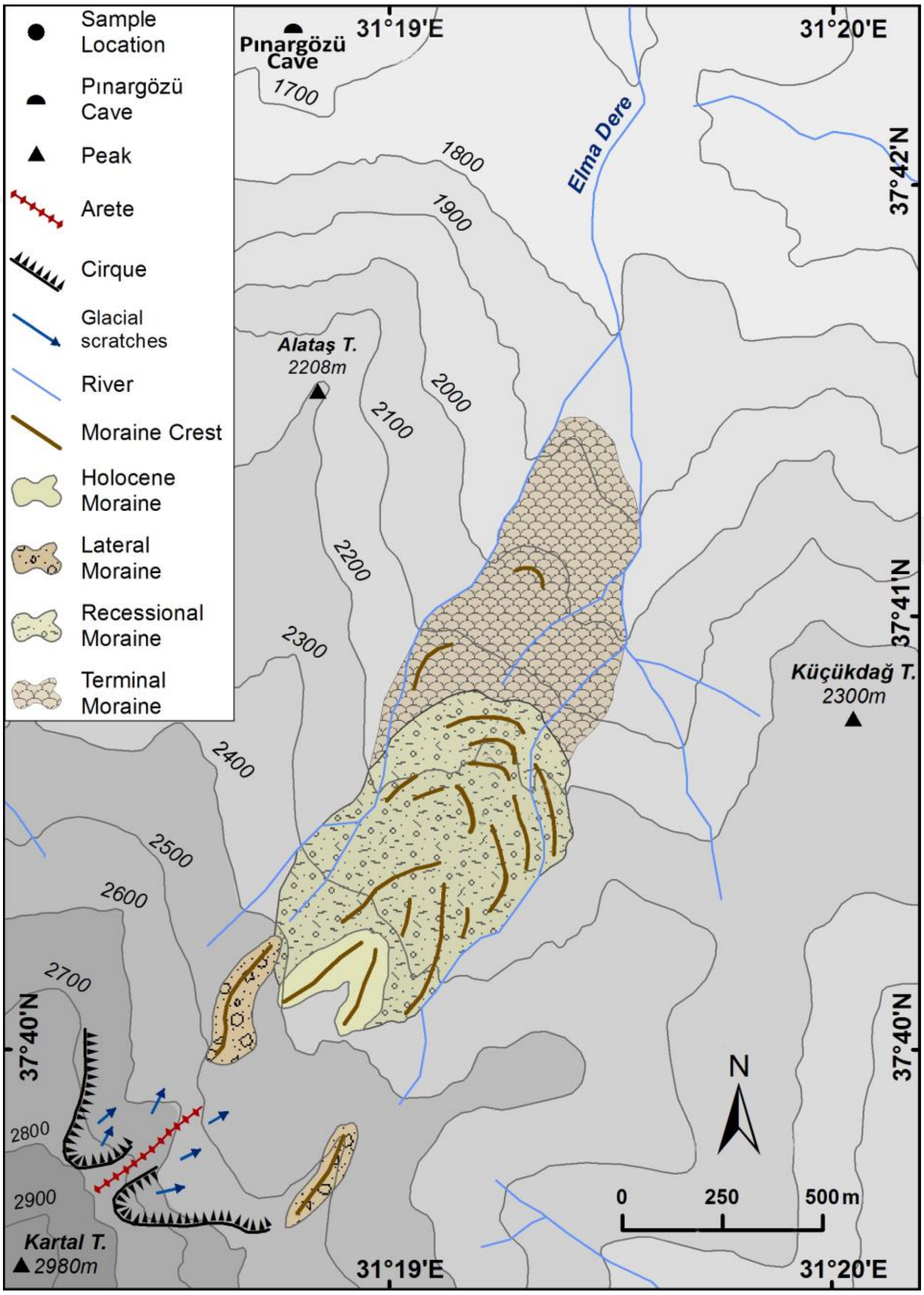


Figure 3.7 Glacial geomorphology map of the Elmadere Valley (modified from Çılğın, 2012).

3.1.3 Karagöl Valley

Karagöl valley is located on eastern flank of the Mount Dedegöl. It is situated in the east side of the Sayacak Valley and north of the Muslu Valley. It covers approximately 21 km^2. Karagöl is the only lake located in the study area. The lake covers 21200 m^2 with 2352 m elevation. Glacial landforms have effected to form Karagöl Lake (Figure 3.8).

Figure 3.8 Karagöl Lake and hummocky moraines (looking to the East)

There are four cirques observed between 2536 and 2700 m a.s.l. These cirques are higher than the other glacier valleys. Glacial striations are mostly seen on bedrock, around hummocky moraines (Figure 3.9).

Figure 3.9 Glacial striations in the Karagöl Valley (looking to the West)

There are numerous moraine deposits such as ground, hummocky, medial, terminal and lateral moraines. Ground moraines are generally located around the bottom of the cirques between 2000 and 2500 m. There are also ground moraines near the hummocky moraines (Figure 3.10).

Hummocky moraines have observed only east side of the Karagöl Lake. These moraines consist of 5-15 m peaks and troughs. They have 1 km length between 2200 and 2400 m (Figure 3.10).

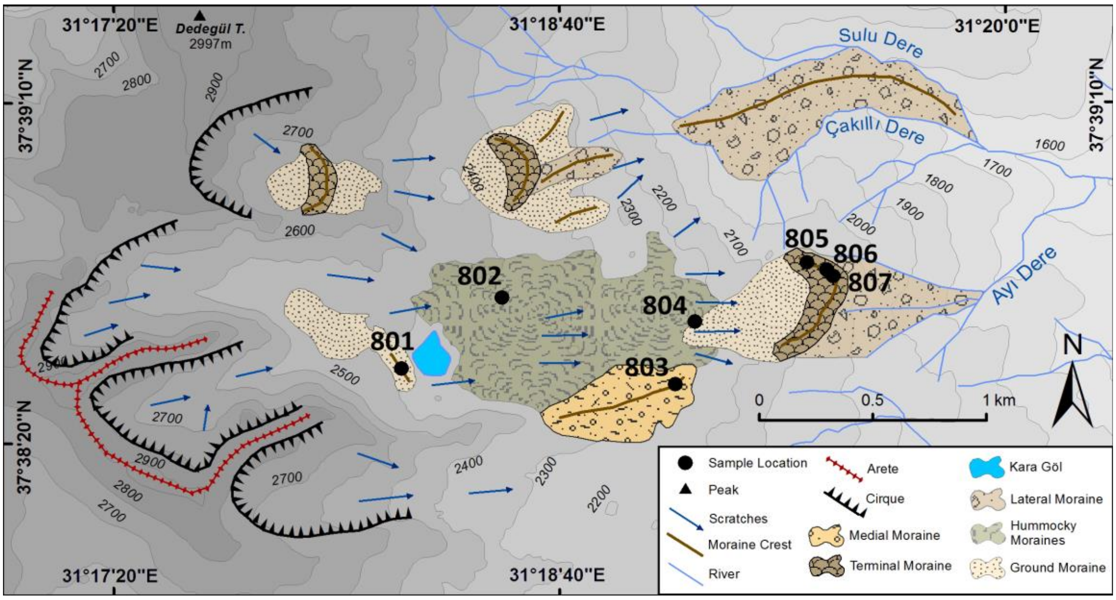


Figure 3.10 Glacial geomorphology map of the Karagöl Valley (modified from Çılğın, 2012).

3.1.4 Karçukuru Valley

Karçukuru valley is the only glacial valley which is located on the western flank of the Mount Dedegöl and covers approximately 10 km^2 area. The east edge of the valley consists of aretes which are separated from the Sayacak and Kisbe valleys. On the other hand, at the western edge of the valley, there is a sandur plain which has 1800 m elevation.

Glacial erosional landforms seen in the Karçukuru Valley are cirques, glacial striations, glacial troughs and aretes. Glacial accumulation landforms are ground moraines, lateral moraines and sandur plains (Figure 3.11).

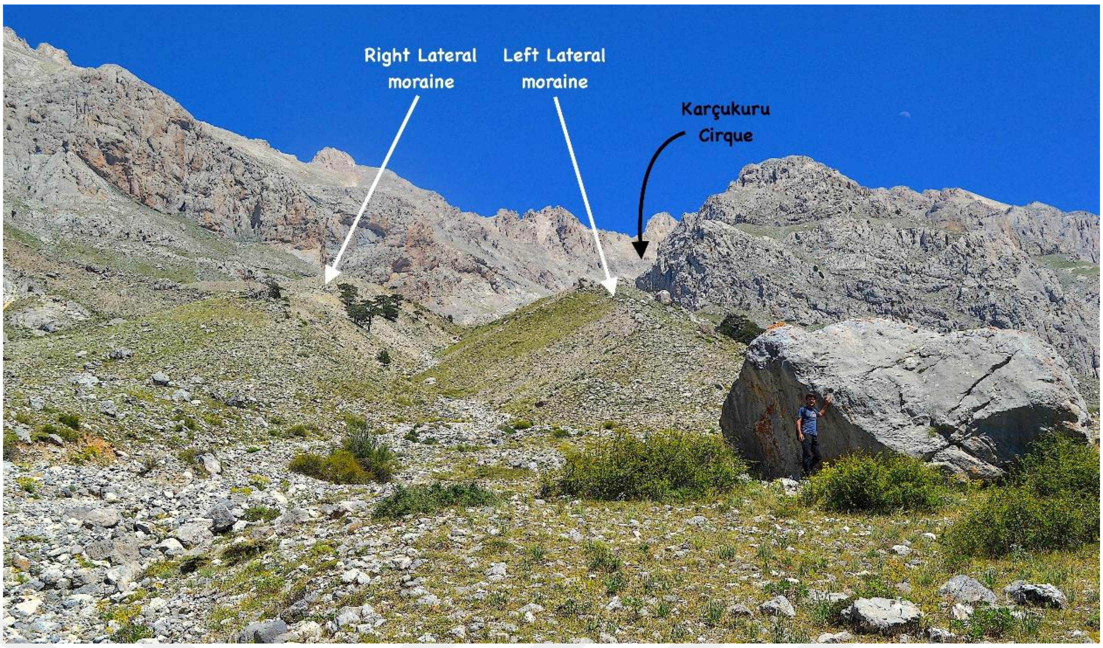


Figure 3.11 Lateral moraies in Karçukuru Valley (looking to the East)

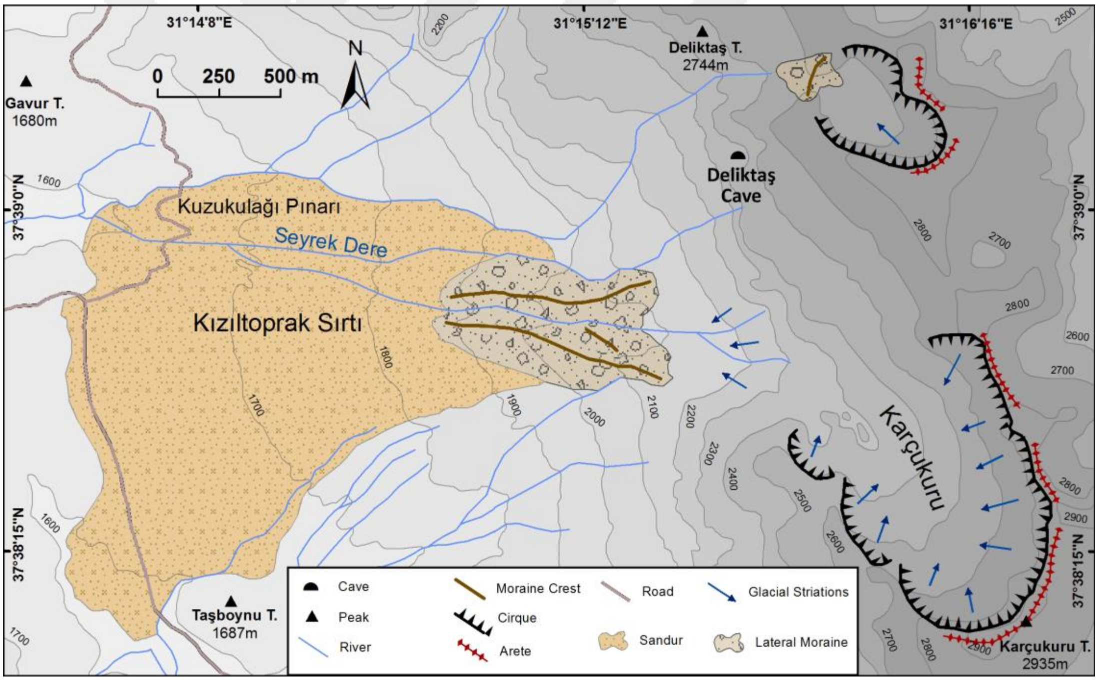


Figure 3.12 Glacial geomorphology map of the Karçukuru Valley
(modified from Çılğın, 2012)

Lateral moraines are deposited between 2150 and 1850 m a.s.l. There are two main lateral moraines which have 1200 m length. There is a sandur plain in front of the lateral moraines (Figure 3.12).

3.2 Cosmogenic Surface Exposure Age Results

Rock samples were collected from the Mount Dedegöl. 20 samples were dated from Sayacak, Kisbe and Karagöl valleys. There are eight samples in Sayacak Valley, five samples in Kisbe Valley and seven samples in Karagöl Valley were collected in total (Table 3.1).

Table 3.1: Cosmogenic exposure ages of the samples

Glacial Valleys	Sample ID	without erosion correction	erosion corrected (10 mm ka^{-1})	Landform Age
		Age (ka)	Age (ka)	Age (ka)
Karagöl	DED05-801	10.7 ± 1.0	11.0 ± 1.0	13.5 ± 0.7
	DED05-802	14.3 ± 1.3	15.4 ± 1.5	
	DED05-803	NA	NA	
	DED05-804	13.0 ± 1.2	14.0 ± 1.3	
	DED05-805	10.2 ± 0.9	10.6 ± 1.0 *	16.4 ± 1.1
	DED05-806	15.3 ± 1.2	15.6 ± 1.4	
	DED05-807	15.4 ± 1.4	17.2 ± 1.7	
Sayacak	DED15-808	10.4 ± 1.0	10.8 ± 1.1	10.9 ± 0.8
	DED15-809	18.8 ± 1.5	20.3 ± 1.7 *	
	DED15-810	11.0 ± 1.0	10.9 ± 1.1	
	DED15-811	21.1 ± 1.6	24.6 ± 2.3	29.1 ± 1.7
	DED15-812	28.5 ± 2.3	32.4 ± 3.3	
	DED15-813	27.6 ± 2.2	30.3 ± 3.2	
	DED15-814	NA	NA	
	DED15-815	16.0 ± 1.3	17.4 ± 1.6 *	
Kisbe	DED15-816	11.1 ± 1.0	12.1 ± 1.1	11.6 ± 0.7
	DED15-817	NA	NA	
	DED15-818	5.5 ± 0.5	5.7 ± 0.5 *	
	DED15-819	10.3 ± 0.9	11.0 ± 1.0	
	DED15-820	5.7 ± 0.5	6.0 ± 0.5 *	

NA: Not available

* Outlier

3.2.1 Sayacak Valley

There are eight samples collected in Sayacak Valley. Three samples (DED15-808, 809 and 810) obtained from the main lateral moraine which is well-preserved. The ages are 10.8 ± 1.1 ka, 20.3 ± 1.7 and 10.9 ± 1.1 ka respectively. Sample DED15-809 is considered an outlier due to its older age. Therefore, sample 809 has removed from further consideration. The remained two samples which are 808 and 810 have an average age of 10.9 ± 0.8 ka (without erosion correction).

Five boulders were sampled from the hummocky moraines which behind the right lateral moraine. Samples DED15-811, 812 and 813 were collected from the top of the hummocky crest behind the right lateral moraine of the Sayacak Valley. Their ages are 24.6 ± 2.3 ka, 32.4 ± 3.3 ka and 30.3 ± 3.2 ka, respectively. The average of these ages is 29.1 ± 1.7 ka. In the following crests of the hummocky moraine, two boulders were also sampled (DED15- 814 and 815). The age of sample 814 could not be measured by AMS. The age of the sample 815 is 17.4 ± 1.6 (Figure 3.13).

3.2.2 Kisbe Valley

Four samples were collected in the Kisbe valley. Samples DED15-816, 817 and 818 were from the right lateral moraine. The age of sample 817 could not be measured by AMS. Other two sample’s (816 and 818) ages are 12.1 ± 1.1 ka and 5.7 ± 0.5 ka respectively. Samples from the left lateral moraine 819 and 820 (11.1 ± 1.0 ka and 6.0 ± 0.5), respectively have similar ages. The young ages from both lateral moraines are located on lower parts of the moraines (Figure 3.14). Thus, those ages are considered as the samples from the eroding part of the moraine.

3.2.3 Karagöl Valley

Seven samples were collected in the Karagöl Valley. Sample DED05-801 were from the ground moraine near the Karagöl Lake and it gave 11.0 ± 1.0 ka. Samples 802 and 804 were collected from hummocky moraines which have 15.4 ± 1.5 ka and 14.0 ± 1.3 ka respectively. There are also three samples (805, 806 and 807) collected from a terminal moraine. Their ages are 10.6 ± 1.0, 15.6 ± 1.4 ka and 17.2 ± 1.7 ka (Table 3.1). Sample 803 collected from medial moraine could not be measured by AMS (Figure 3.15).

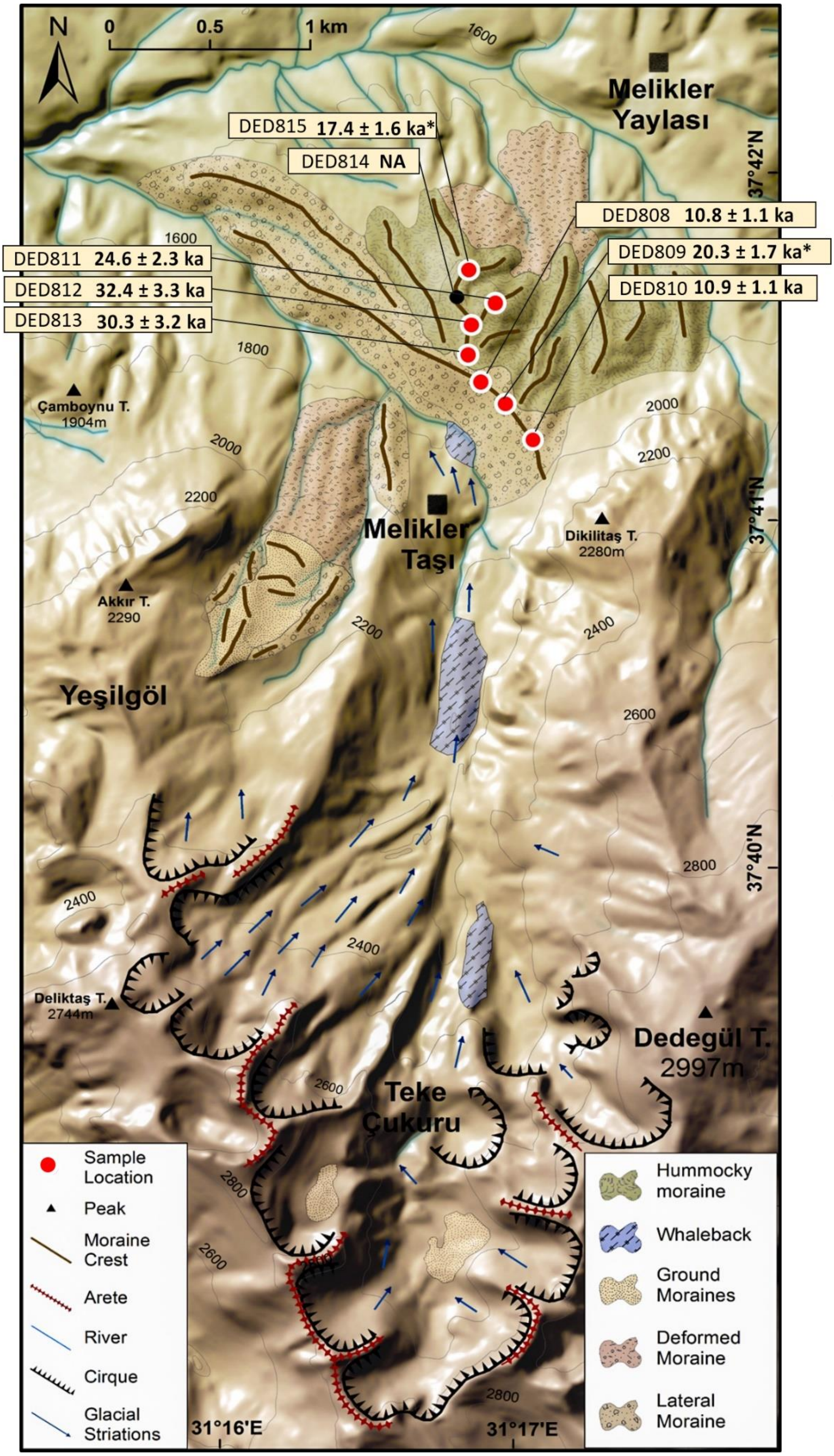


Figure 3.13 Map of cosmogenic exposure age results in the Sayacak Valley

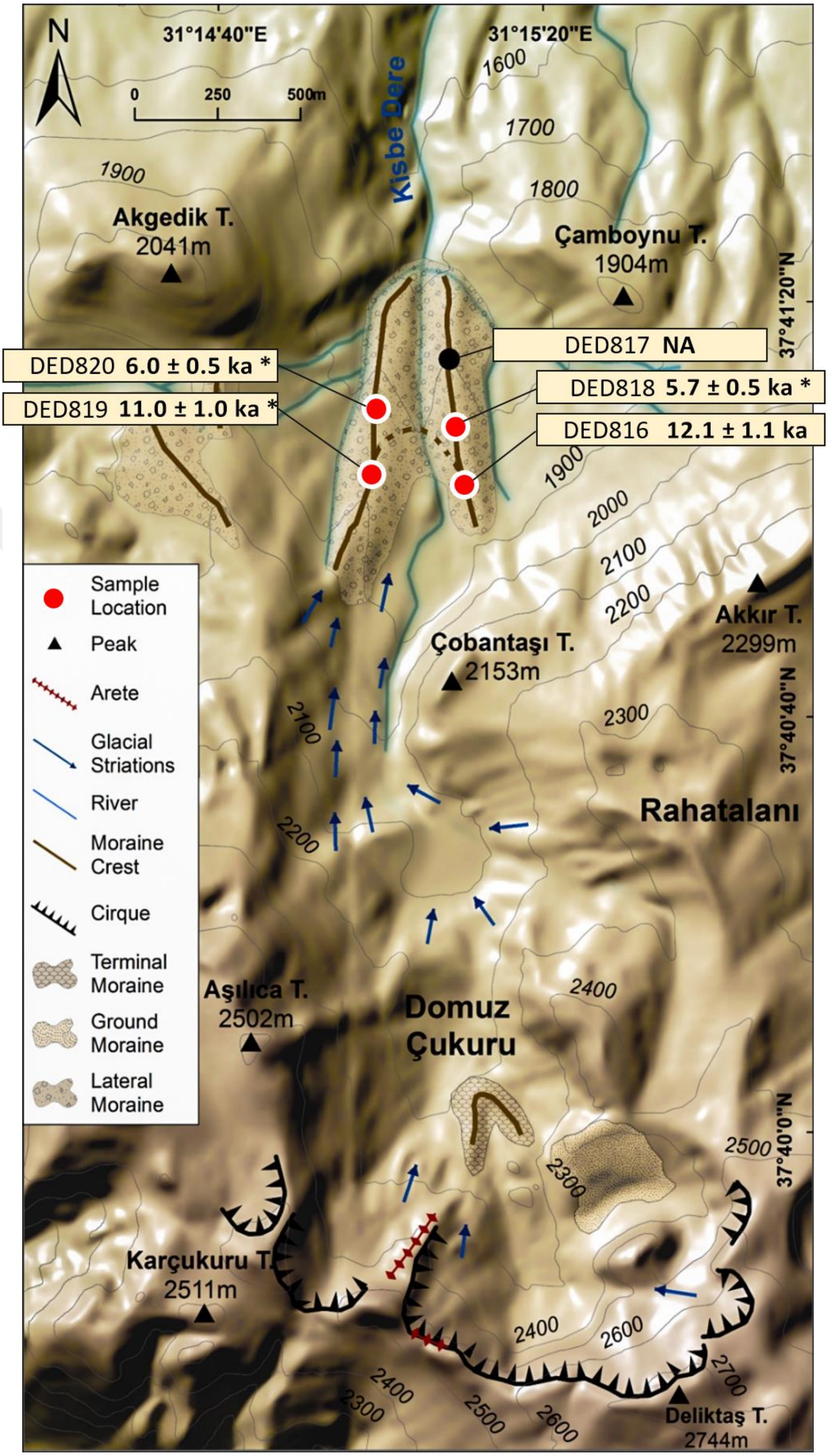


Figure 3.14 Map of cosmogenic exposure age results in Kisbe Valley

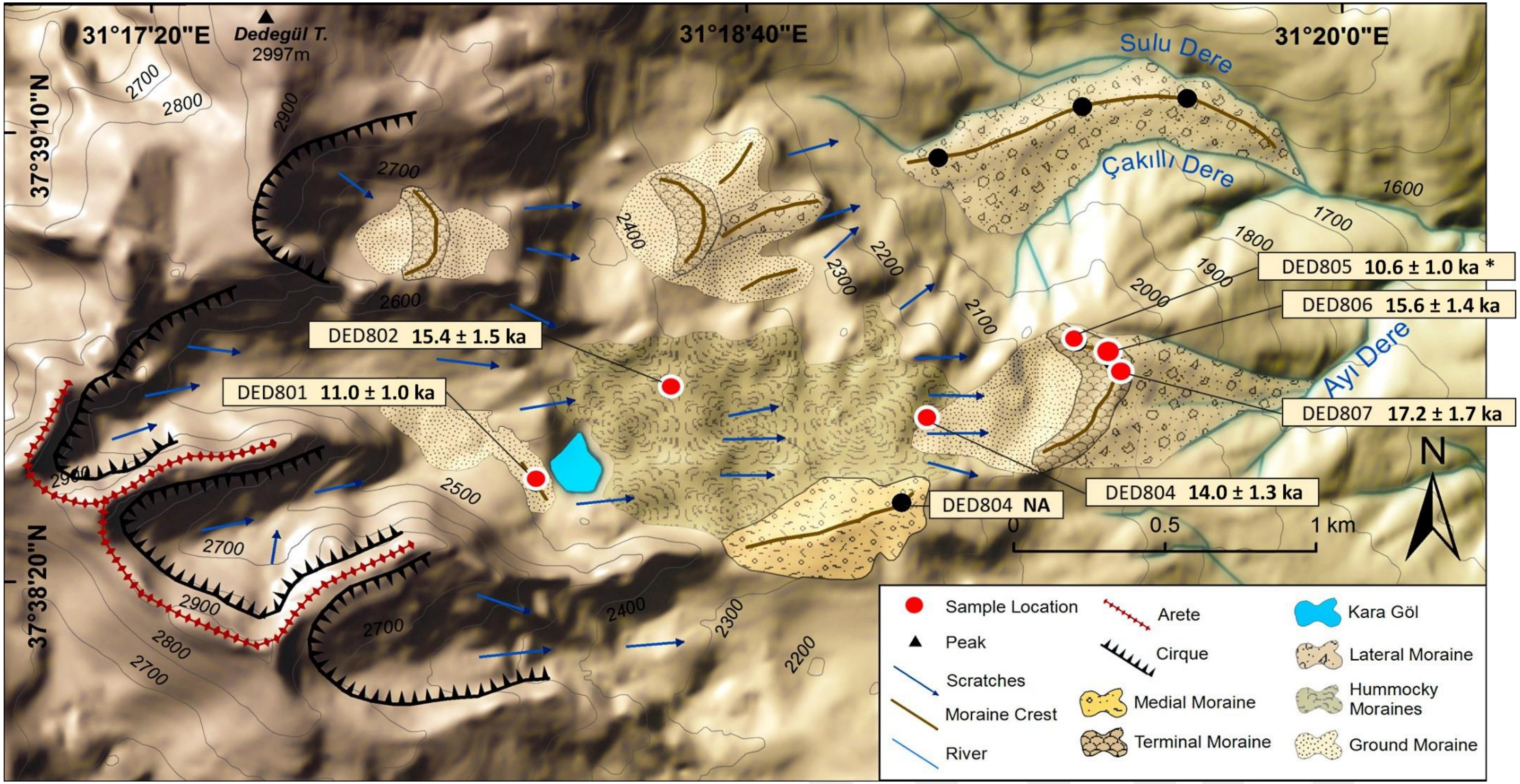


Figure 3.15 Map of cosmogenic exposure age results in the Kisbe Valley

4. DISCUSSION

4.1 Glacial Chronologies in Mount Dedegöl

Main Valleys were glaciated during the Late Quaternary in Mount Dedegöl. Up to now, the Muslu Valley have been dated by using cosmogenic ^{10}Be and ^{26}Al on the eastern side (Zahno et al, 2009). In this study, the Sayacak, Kisbe and Karagöl valleys on the northern side have been dated by using cosmogenic ^{36}Cl dating method. The results revealed Pre-LGM glacial deposits occured in the Mount Dedegöl and deglaciations starting from LGM, followed by the Late Glacial stages. Early Holocene stages are also well preserved.

In northern side of the Mount Dedegöl, local LGM moraines are only in Sayacak Valley where a hummocky moraine field yielded pre-LGM ages of 24.6 ± 2.3 ka, 32.4 ± 3.3 and 30.3 ± 3.2 ka, respectively. These ages are a few thousand years younger than Pre-LGM ages yielded from lateral moraines in Muslu Valley (Zahno et al, 2009) (29.6 ± 1.9 ka).

After the LGM, glacial development during the Late Glacial is represented in the Karagöl Valley and they are well preserved with ages varying from 15.6 ± 1.4 ka to 17.2 ± 1.7 ka ago (average of 16.4 ± 1.1). There is also similar Late Glacial age from Muslu Valley (Zahno et al, 2009) which is 15.2 ± 1.1 ka.

Early Holocene deglaciation evidences are well represented in the Mount Dedegöl. There are smilar ages obtained in Kisbe (with ages 11.6 ± 0.7 ka) and Sayacak (with ages 10.9 ± 0.8 ka) valleys (Figure 4.1).

Çılğın (2012), has obtained 5 OSL ages from different valleys in the Mount Dedegöl. These ages are 48.8 ± 5.1 ka, 76.0 ± 7.0 ka, 15.6 ± 1.7 ka, 2.6 ± 0.1 ka and 148 ± 13 ka. However, OSL age results are not consistent with each other and ^{36}Cl age results. Therefore, this region is more suitable for ^{36}Cl dating method.

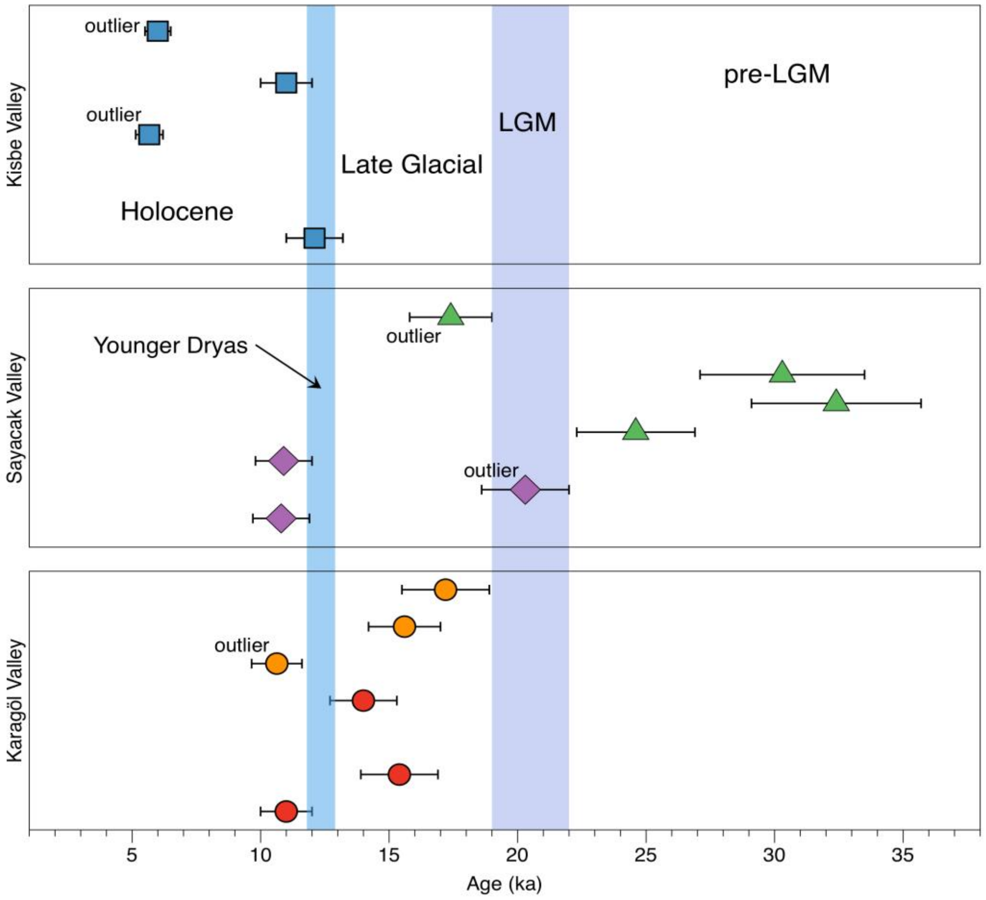


Figure 4.1 Cosmogenic surface exposure ages of the study area.

4.2 Comperison with glacial chronologies in Turkey

Recently, Sarıkaya and Çiner (2015) published a summary of glacial advances from 14 mountains in the Eastern Mediterranean Mountains. The oldest glacial geochronological records reported from pre-LGM glaciers (MIS 3; at around 29-35 ka) come from Mount Akdağ (35.1 ± 2.5 ka) and Mount Bolkar (46.0 ± 7.0 ka) in the Taurus Mountains. In this study revealed that pre- LGM glacier started to retreat in the Sayacak Valley is 29.1 ± 1.7 ka ago.

After the LGM, Late- glacial ages seen in Erciyes Volcano (15.8 ± 1.6 ka) (Sarıkaya et al., 2009). In the eastern Black Sea Mountains, Late-glacial advances are 17.0 ± 1.1 ka and 17.2 ± 1.2 ka in Kavron and Verçenik valleys (Akçar et al., 2007, 2008). Mount Sandıras has also Late- glacial ages (16.5 ± 0.9 ka) (Sarıkaya et al., 2008). On the southern sector of Geyikdağ (~70 km southeast of Dedegöl), Late-glacial advances occurred between 13.7 ± 0.8 ka and 14.9 ± 2.3 ka (Sarıkaya and Çiner, 2017). Mount Dedegöl also shows similar glacial chronologies (16.4 ± 1.1 ka) (Figure 4.2).

In Holocene, glaciers were observed on high mountains like Mount Bolkar and Erciyes Volcano. Mount Bolkar have the presence of glaciers during the early Holocene (9.0 ± 0.9 ka and 8.5 ± 1.8 ka respectively) (Çiner and Sarıkaya, 2015). Holocene advances in the Erciyes Volcano are dated to 10.6 ± 0.9 ka and to 3.9 ± 0.6 ka ago (Sarıkaya et al., 2009). In Sayacak Valley, Early Holocene ages are obtained from right lateral moraine (10.9 ± 0.8 ka)

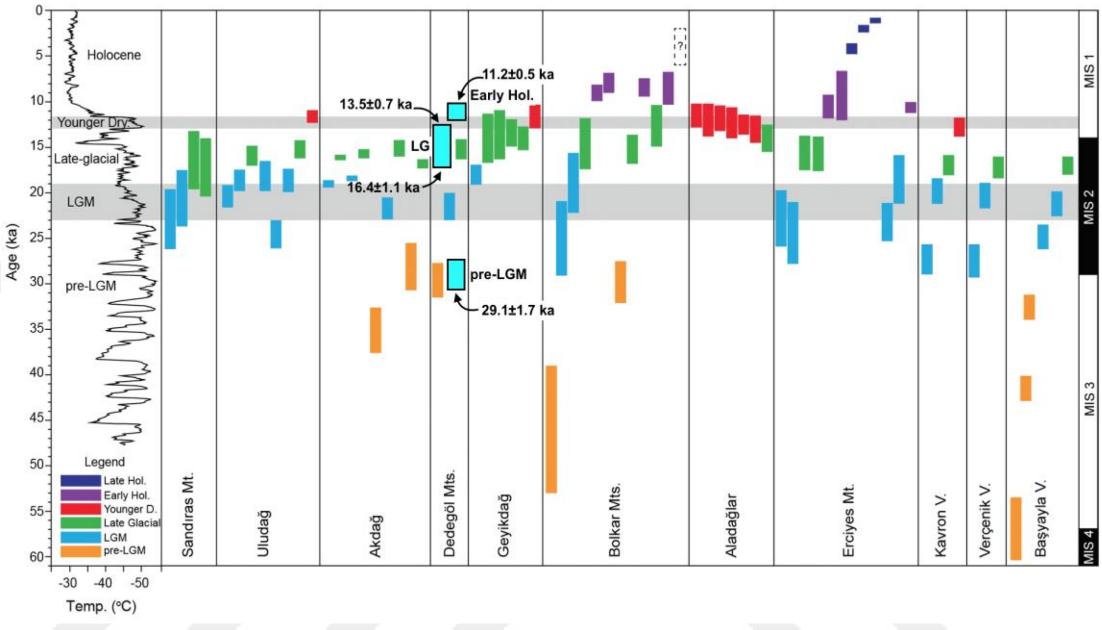


Figure 4.2 Correlation of glacial chronology from cosmogenic dating of mountains in Turkey. Adapted from Sarıkaya and Çiner (2015)

4.3 Comperison with glacial chronologies in Europe

The LGM in the Alps lasted approximately from 30 ka to 19 ka, and glaciers in the Northern Alps reached their maximum extent by 24 ka (Clark et al., 2009; Hughes and Woodward, 2008; Shakun and Carlson, 2010; Hughes et al., 2013; Ivy-Osch, 2015). On the other hand, in the Southern Alps, the LGM is estimated at 21.5 ka ago (Darnault et al., 2012; Jorda et al., 2000) and consistent with the glacial geochronology of the Mount Dedegöl. At the onset of the Holocene, glaciers were in their expanded positions into the earliest Holocene in Switzerland (Ivy-Ochs et al., 1996; Kelly et al., 2004; Schindelwig et al., 2008) and in Italy (Federici et al., 2008; Giraudi and Frezzotti, 1997; Hormes et al., 2008). Consequently, glacial geochronology obtained from the Mount Dedegöl is comparable with glaciations in Europe.

5. CONCLUSIONS

Glacial geomorphology of the five northern valleys of the Mount Dedegöl was investigated; Sayacak, Kisbe, Karagöl, Karçukuru and Elmadere valleys. Main glacial landforms such as moraines and cirques were mapped for each glacial alleys. These glacial landforms extends to 1500 m; lower parts of the Mount Dedegöl. Detailed geomorphological maps of the study area revealed at least two different glacial stages.

Cosmogenic ^{36}Cl ages obtained from the moraines on Mount Dedegöl have contributed new information to glacial geochronology of Turkey. Twenty boulders from moraines in three glacial valleys of the Mount Dedegöl were dated by ^{36}Cl surface exposure dating. Moraine ages from the Mount Dedegöl indicates that there are three glacial stages identified by dating of 20 samples. Pre-LGM moraines; 29.1 ± 1.7 ka and Early Holocene moraines 10.9 ± 0.8 ka were deposited in Sayacak Valley. In Karagöl Valley, LG (Late Glacial); 13.5 ± 0.7 ka and 16.4 ± 1.1 ka were deposited. There are only Early Holocene moraines; 11.6 ± 0.7 ka were identified in Kisbe Valleys.

Surface exposure ages with cosmogenic ^{36}Cl reveal that there is no glacier retreat earlier than 32.4 ± 3.3 ka ago in the Mount Dedegöl. The oldest age obtained from hummocky moraines in the Sayacak Valley give substantial evidence about ice accumulation prior to the global LGM (21 ± 2 ka). Pre-LGM ages from hummocky moraines in the Sayacak Valley are 24.6 ± 2.3 ka, 32.4 ± 3.3 and 30.3 ± 3.2 ka ago. Consequently, the timing of maximum glaciation on Mount Dedegöl can be considered as the average of both ages which is 29.1 ± 1.7 ka.

The youngest glacial stage occured during the Early Holocene in the mount Dedegöl. There are only Early Holocene moraines were identified in Kisbe Valleys with ages 11.6 ± 0.7 ka. In Sayacak Early Holocene ages are obtained from right lateral moraine (10.9 ± 0.8 ka).

Late Glacial moraines in the Karagöl Valley are well preserved. In Karagöl Valley, a terminal moraine was dated to 15.6 ± 1.4 ka to 17.2 ± 1.7 ka ago. Thus, it can be considered that Late Glacial glaciation in Karagöl valley occured 16.4 ± 1.1 ka ago, which is the avarage age of the terminal moraine ages.

My study confirms that the glacial geochronology obtained from the northern glacial valleys of the Mount Dedegöl is consistent with the geochronologies obtained from Mount Dedegöl bye other studies and ages from the western Taurus and Anatolia mountains.

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APPENDIX A
FIELD DESCRIPTION OF MOUNT DEDEGÖL SAMPLES

DED05-801	Collected in Dedegöl Mountain, Karagöl Valley, 2005. 2.5×1.5×1.2m (length×width×height). Topo measurements at 19,0,0,20,25,46,25,20. Limestone. Sample was collected at elevation of 2378 m. Latitude And Longitude is 37,644135 and 31,303995. IMG_1037.

DED05-802	Collected in Dedegöl Mountain, Karagöl Valley, 2005. 3×2×1 m. [2,2,3,0,14,19,22,13]. Limestone. 2395 Elevation. Lomgitude and Latitude is 31,308949 and 37,6471. IMG_1042.

DED05-803 Collected in Dedegöl Mountain, Karagöl Valley, 2005. Block Shape. 2.5×1×1.2 m. [0,0,0,0,3,6,16,14]. Limestone. Elevation is 2288 m. Longitude is 31,317696 and longitude is 37,6437. IMG_1050

DED05-804 Collected in Dedegöl Mountain, Karagöl Valley, 2005. Rooted boulder on the older lateral. 0.9×0.7×0.3 m. [3,0,0,8,16,15,17,20]. Limestone. Elevation is 2195 m. Longitude is 31,318602 and latitude is 37,646255. IMG_1054

DED05-805

Collected in 2005. Left lateral in the terminal complex. 1.5x0.6x0.3m. [3,0,0,2,6,17,18,19]. Elevation is 2081 m. Longitude is 31,324144 and longitude is 37,648766. IMG_1061

DED05-806

Collected in 2005. Left lateral in the terminal complex. 1.5x1.5x60cm. Limestone. [5,0,0,0,8,16,17,16]. Elevation is 2072. Longitude is 31,32515 and latitude is 37,648464. IMG_1063

DED05-807	Collected in Dedegöl Mountain, Karagöl Valley, 2005. 6x3x2 m. Limestone. [4,0,0,0,0,10,20,21]. Elevation is 2072 m. Longitude is 31,325483 and latitude is 37,648216. IMG_1066

DED15-808	Collected in 2015. Sayacak Valley-right lateral moraine. 140x200x100 m. Limestone. Rounded, smooth boulder. Rooted boulder on the older lateral. [0 0 16 42 20 19 3 0]. Longitude is 31,28121 and latitude is 37,68941. Elevation is 1897. See pictures DSC5043-48, video-49.

DED15-809

Collected in 2015. Sayacak Valley-right lateral moraine. 220x150x120 m. Rounded boulder. Cracks on top/ lichens. [0 0 30 36 20 20 0 0]. Longitude s 31,28268 and latitude is 37,68866. Elevation is 1916. See picture DSG5057-65 video.

DED15-810

Collected in 2015. Sayacak Valley-right lateral moraine. 80x70x60 m. Preservation is good. Rooted. [0 0 25 20 15 10 0 0]. Longitude is 31,28452 and latitude is 37,68649. Elevation is 1949. See pictures DSG5072-76.

DED15-811	Collected in 2015. Sayacak Valley-Push Moraine Complex. 120x60x50 m. Limestone. Flat top. More soil, more vegetation, small boulders. Rooted. [0 0 7 20 10 10 5 0]. Longitude is 31,28193 and latitude is 37,69255. Elevation is 1863. See picture DSG5077-80 video.

DED15-812	Collected in 2015. Sayacak Valley-Push Moraine Complex. 200x110x60 m. Flat top. Preservation is good. Rooted. [5 0 9 22 13 12 3 0]. Longitude is 31,2813 and latitude is 37,69218. Elevation is 1865. See picture DSG5081-85 video.

DED15-813

Collected in 2015. Sayacak Valley-Push Moraine Complex. 230x240x60 m. Flat top. [0 0 0 24 10 14 3 0]. Longitude is 31,28103 and latitude is 37,69149. Elevation is 1870. See picture DSG5086-91 video.

DED15-814

Collected in 2015. Sayacak Valley-Push Moraine Complex 2. 110x70x60 m. Rounded. [0 0 10 20 10 15 3 0]. Longitude is 31,28031 and latitude is 37,69317. Elevation is 1840. See picture DSG5092-96.

DED15-815	Collected in 2015. Sayacak Valley-Push Moraine Complex 2. 90x60x30 m. Flat top. Rooted. [0 0 0 20 20 10 0 0]. Longitude is 31,28051 and latitude is 37,69419. Elevation is 1833. See picture DSG5097-102.

DED15-816	Collected in 2015. Kisbe Valley-right Lateral Moraine. 110x110x35 m. Limestone. Flat top. Preservation is digged pits. Rooted. [0 4 33 35 37 17 8 6]. Longitude is 31,25368 and latitude is 37,68177. Elevation is 1899. See picture DSG5217-22 video.

DED15-817	Collected in 2015. Kisbe Valley-right Lateral Moraine. 106x110x40 m. Limestone. Rounded shape. Rooted. [0 2 14 29 32 26 10 8]. Longitude is 31,25043 and latitude is 37,6826. Elevation is 1892. See picture DSG5244-48 video.

DED15-818	Collected in 2015. Kisbe Valley-right Lateral Moraine. 120x160x80 m. Limestone. [0 3 16 22 27 17 8 9]. Longitude is 31,25291 and latitude is 37,68355. Elevation is 1882. See picture DSG5235-43 video.

DED15-819

Collected in 2015. Location is Kisbe Valley-Left Lateral Moraine. 100x200x30 m. Limestone. Flat top. Rooted. [1 0 18 26 20 17 4 8]. Longitude is 31,24982 and latitude is 37,68255. Elevation is 1908. See picture DSG5273-79 video.

DED15-820

Collected in 2015. Kisbe Valley-Left Lateral Moraine. 70x45x40 m. Limestone. Rounded shape. Rooted. [0 3 20 26 20 18 6 12]. Longitude is 31,25015 and latitude is 37,68399. Elevation is 1873 m. See picture DSG5285-90 video.

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Oğuzhan Köse, M. Akif Sarıkaya, Attila Çiner, Ömer L. Şen, Adem Candaş 2017. COSMOGENIC 36Cl GEOCHRONOLOGY OF THE NORTHERN VALLEYS OF MOUNT DEDEGÖL, WESTERN TAURUS MOUNTAINS (TURKEY), Poster, EGU 2017, European Geosciences Union General Assembly, Apr 23-28, 2017 Vienna, Austria.

Oğuzhan Köse, M. Akif Sarıkaya, Attila Çiner, Ömer L. Şen, Adem Candaş 2016. Kozmojenik İzotoplar ve Buzul Akış Modelleriyle Dedegöl Dağları'ında Geç Kuvaterner Paleoiklim Koşullarının Belirlenmesi. Poster, TURQUA 2016, Turkey Quaternary Symposium, May 08-11, 2016 Istanbul, Turkey.

Oğuzhan Köse, M. Akif Sarıkaya, Attila Çiner, Ömer L. Şen, Adem Candaş 2016. QUATERNARY GLACIATION AND PALEOCLIMATE OF THE DEDEGÖL MOUNTAIN USING COSMOGENIC SURFACE EXPOSURE DATING: PRELIMINARY RESULTS, Poster, 69th Geological Congress of Turkey 2016, April 11-15, Ankara, Turkey.