M. ZEYBEK DEPT. OF GEOLOGICAL ENGR. MASTER THESIS MUĞLA 2017

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MUĞLA SITKI KOÇMAN UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF GEOLOGICAL ENGINEERING

GEOLOGICAL FACTORS CONTROLLING CAVE OCCURENCES WITHIN CLASTIC SEDIMENTS OF YATAĞAN FORMATION (UPPER MIOCENE-PLIOCENE, SW TURKEY)

MASTER OF SCIENCE THESIS

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APPROVAL OF THE THESIS

The thesis submitted by **Mutlu ZEYBEK** with the title of "**Geological Factors Controlling Cave Formation Within Clastic Sediments of Yatağan Formation (Upper Miocene-Pliocene; SW Turkey)**" has been unanimously accepted by jury members on the 16th of June, 2017 to fulfil the requirements for degree of Master of Science in the Department of Geological Engineering.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mutlu Zeybek

16/06/2017

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ABSTRACT

GEOLOGICAL FACTORS CONTROLLING CAVE OCCURENCES WITHIN CLASTIC SEDIMENTS OF YATAĞAN FORMATION (UPPER MIOCENE-PLIOCENE, SW TURKEY)

Mutlu Zeybek

Master of Science (M.Sc.)

Department of Geological Engineering

Supervisor: Prof. Dr. Murat Gül

June 2017, 89 pages

This study aims to investigate geological factors controlling cave occurences within Upper Miocene-Pliocene clastic sediments of Yatağan Formation. The most significant outcrops of it observed on the foothills of Asartepe in north of the central Muğla province and in Damlam stream of Yerkesik town. Geotechnic experiments are performed in the: (1) In situ resistance tests using Schmit Hammer; (2) Specific gravity, porosity, bulk density and point load strength index, slake tests. Many different special internal structures (e.g., stalactite-flowstone-travertine formations) observed in the at the Damlam Deresi cave formation where the water leaking. However, most of the structures were not realized in the Asartepe cave occurences due to absence of continuous leakages in structural elements (cracks, fissure, fractures and joints). Without cave parts are relatively more durable than within cave parts for both of the occurences (Asartepe and Damlam). Three different types of mudstones within these occurences (Asartepe and Damlam) are classified according to the Unified Soil Classification System (USCS) based on dominant grain size: (1) SM ("silty sands, sand-silt mixtures") for Asartepe cave occurences, (2) CL (“Inorganic clays of low to medium plasticity, gravelly / sandy / silty / lean clays”) and SC (“Clayey sands, sand-clay mixtures”) for Damlam Deresi cave occurences. Cave development (cave sizes) in both sections generally appears in relation to lithological difference, differential weathering, strength difference, water content, distribution of cracks, rock weakening of water movement along cracks, anthropogenic factors and so on.

Keywords: Cave Formation, Yatağan Formation, Asartepe cave, Damlam cave, Muğla

ÖZET

YATAĞAN FORMASYONU (ÜST MİYOSEN-PLİYOSEN, MUĞLA, GB TÜRKİYE) KIRINTILI SEDİMANLARI İÇİNDEKİ MAĞARA OLUŞUMUNU KONTROL EDEN JEOLOJİK FAKTÖRLER

Mutlu Zeybek

Yüksek Lisans Tezi
Jeoloji Mühendisliği Anabilim Dalı
Tez Yöneticisi: Prof. Dr. Murat Gül
Haziran 2017, 89 Sayfa

Bu çalışma; Muğla ili ve çevresindeki Üst Miyosen-Pliyosen yaşlı kırıntılılardan oluşan Yatağan Formasyonu'nda gözlenen mağaraların oluşumunu kontrol eden jeolojik faktörlerin belirlenmesini hedeflemektedir. Yatağan Formasyonu en belirgin yüzlek alanları, Yerkesik Beldesinin Damlam Deresindeki ve Muğla'nın merkezinin kuzeyindeki Asar Tepe'de bulunmaktadır. Çalışmada yapılan jeoteknik deneyler: (1) Schmidt Çekici ile yerinde dayanım testleri, (2) alınacak örnekler üzerinde özgül ağırlık, porosite, birim hacim ağırlık ve nokta yük dayanım indeksi ve suda dağılmaya karşı dayanım testleridir. Böylelikle, mağara gelişimleri üzerine birimin fiziksel-mekanik özelliklerinin etkisi belirlenmiştir. Su sızıntılarının belirgin olduğu Damlam Deresi mağaralarında birçok farklı özel içyapıların (örn. sarkıt-akmataşı-traverten oluşumları) varlığı gözlenmiştir. Fakat yapısal elemanlar (çatlaklar, yarıklar, kırıklar ve eklemler) içerisinde sürekli sızıntı olmaması nedeniyle Asartepe mağarası oluşumunda bu içyapıların birçoğuna rastlanılmamıştır. Bu oluşumlar (Asartepe ve Damlam) için; mağarasız kısımlar, mağaralı kısımlardan daha dayanıklıdır. Baskın tane boyutuna dayalı Birleşik Toprak Sınıflandırma Sistemine (USCS) göre, bu oluşumlar (Asar ve Damlam) içinde çamurtaşlarının üç farklı türü: (1) Asartepe mağarası oluşumları için SM ("silt kumları, kum-silt karışımları"), (2) Damlam Deresi Mağarası oluşumları için CL ("Düşük ile orta derecede plastisite, çakıllı / kumlu / siltli / yağsız killer" içeren inorganik killer) ve SC ("killi kumları, kum kil karışımları") olarak sınıflandırılmıştır. Her iki kesimdeki mağara gelişimi genellikle litolojik farklılık, ayrımsal bozuşma, mukavemet farkı, su içeriği, çatlakların dağılımı, çatlaklar boyunca su hareketine bağlı kaya zayıflaması, antropojenik faktörler vb. ile ilişkili olarak ortaya çıkmıştır.

Anahtar Kelimeler: Mağara Oluşumu, Yatağan Formasyonu, Asartepe Mağarası, Damlam Deresi Mağarası, Muğla.

To All Vulnerable Humans

ACKNOWLEDGEMENTS

I would like to express my sincere gratitute to my supervisor, an honorary Prof. Dr. Murat Gül for his support, suggestions and patience during various stages of this research. I would also like to thank Prof. Dr. Ergun Karacan and Prof. Dr. Fikret Kaçaroğlu for being particularly very constructive in their comments and suggestions. And then, my special thanks goes to my colleagues Mr. Iliya Danladi Bauchi for his critical review on the manuscript and Mr. Mohammed Saidu for his technical support. Geolab company in Ankara is also acknowledged for all sample analyses. Last but not the least, I woud love to thank my parents for their encouragement, support and patience during my research.

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ABBREVIATIONS

Ca^{++}	Calcium Ion
^{137}Cs	Cesium Isotope (137)
^{210}Pb	Lead Isotope (210)
CO_2	Carbon Dioxide
H_2C0_3	Carbonic Acid
Mg++	Magnesium Ion
Na^+	Sodium Ion
$ClSO_4^-$	Chlorosulfuric Acid
^{0}	Degree
^0C	Degree Celsius
mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
3D	Three Dimension
g	Gram
MPa	Megapascal
kN	kilonewtons
%	Percentage
V	Volume
Wd	Dry Weight
Ws	Saturated Weight
Gs	Specific Gravity
Wn	Moisture Content
De	Core Diameter
Is	Point Load Stength Index
Is_{50}	Point Load Stength Index (for De=50mm)
F	Size Correction Factor
P	Failure Load
$ɣ_n$	Natural Unit Weight
A	Weight of "Drum+Sample"

B	Weight of "Drum+Retained Sample" (1st Cycle)
C	Weight of "Drum+Retained Sample" (2nd Cycle)
D	Weight of Drum
STLV	Special Threshold Limit Value
MGS	Maximum Grain Size
WGS84	The World Geodetic System
LL	Liquid Limit
PL	Plastic Limit
Pl	Plastic Index
UTM	Universal Transverse Mercator
USCS	Unified Soil Classification System
SM	Silty-Sands, Sand-Silt Mixtures
CL	Inorganic Clays of Low to Medium Plasticity, Gravelly / Sandy / Silty / Lean Clays
SC	Clayey Sands, Sand-Clay Mixtures
ACO	Asartepe Cave Occurences
DCO	Damlam Cave Occurences
MSKU	Muğla Sıtkı Koçman University
DEM	Digital Elevation Map
YÖK	Turkish Higher Education
MTA	Mineral Research & Exploration General Directorate
TS	Turkish Standard
E	East
W	West
NW	Northwest
SE	Southeast
SW	Southwest
Q	Flow Rate

1.INTRODUCTION

The term"*karst*" is a characteristic topography with large and small gaps in rocks such as eternalized limestone, similar carbonated rocks besides gypsum and anhydrite, which are developed under the influence of surface and ground waters (Palmer, 1991). It is stated that karstic formations are effective in about 10-20% of the earth (Palmer, 1991). Space development relevant to karstification can be found in melting components of conglomerates and sandstones (Busche and Sponholz, 1992; Bergada et al., 1997; Kranjc, 2005; Aubrecht et al., 2008; Breitenbach et al., 2010; Lipar and Ferk, 2011). Caves, one of the karstic forms, is the name given to underground cavities with width and expansion on the surface in which at least one person can creep into (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara). A series of physico-chemical processes resulting in the erosion of dissolved rocks are called karstification, whereas surface and underground shapes resulting from these processes are called karstic formations (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara). Carbon dioxide (CO_2) atmospheric waters that fall on carbonated rocks turn into saturated carbonic acid (H_2C0_3) as they pass through the cracks of soils and rocks (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara). These waters, which are highly solvent or acidic, begin to dissolve where they pass through and karstic caves eventually form (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara).

Caves that develop due to karstification are able to be used for many purposes such as recreational purposes, settlement purposes, hiding purposes, cold storage and water supply in addition to providing valuable information about palaeoclimate records (Bergada et al., 1997; Kranjc, 2005). For recretional purposes, in particularly, different types of stalactites, stalagmites, and flowstones in the caverns have an important place (Busche and Sponholz, 1992; Aubrecht et al., 2008). Cave development within sedimentary rocks can be effective with a number of factors such as component, grain size, topography, hydrological conditions, strength of units, fracture and crack systems, and different types of degradation (Palmer, 1991; Bergada et al., 1997; Kranjc, 2005; Breitenbach et al., 2010; Awadh et al., 2013).

Mugla province and its surrounding are located within western Taurus mountains (SW Turkey), which have carbonate formations (Güldalı et al., 1984; Nazik, 1996; Özel et al., 1996; Tuncer et al., 2005). On the other hand, Yatağan Formation contains clastic rocks in various size and including dissolved rock fragments. Those units have cave occurences in various sizes. In addition to these carbonated components, eroded and transported materials are resulting in karstification within caves. In this study, investigation of the factors controlling the occurences of caves, natural hazards that may occur in caves and special structure inside the cave in the carbonate clast rich Upper Miocene-Pliocene conglomerates were carried out.

1.1. Purpose and Scope

Two of the most important cavern region in the Muğla province (e.g., Asartepe and Damlam cave occurences) are investigated according to sedimentological, geotechnical, and hydrogeological features and properties.

There are several objectives in this study and are given below:

- Firstly, to investigate general features, lateral and vertical spread within clastic units of the cave occurences and to measure their geometric parameters (width-length-depth), and internal structures of caves.

- Secondly, to survey geological factors controlling cave occurences and places without cave occurences within clastic sediments of Yatağan Formation (Upper Miocene-Pliocene).

- Thirdly, to perform in situ resistance tests using a device (Schmit Hammer) and to research some geotechnical and hydrogeological feautures. In addition, to determine the effect of physical-mechanical properties of the units on development of the cave occurences.

- Finally, to evaluate controlling factors of cave occurences in Yatağan Formation.

1.2. Geographical Setting

The two main study areas (Figures 1.1. and 1.2.) are roughly located at the foothills of Asartepe in the North of the center of the Muğla province, and at the Damlam deresi within the southwestern of the Yerkesik town in the southwestern of the Muğla province. The Universal Transverse Mercator (UTM) (zone 35) coordinates of the study areas are approximately given 4470000-4475000 Easting and 3155000-3160000 Northing in N20c1 quadrangle of Turkey for Asartepe Cave Occurences (ACO), as well as 4452500-44575000 Easting and 3145000-3150000 Northing in N20c4 quadrangle of Turkey for Damlam Cave Occurences (DCO) respectively.

The ACO is only 500 metres from the center of the Muğla province. The DCO is approximately 30 kilometers (30 minutes by bus) from center of the Muğla province.

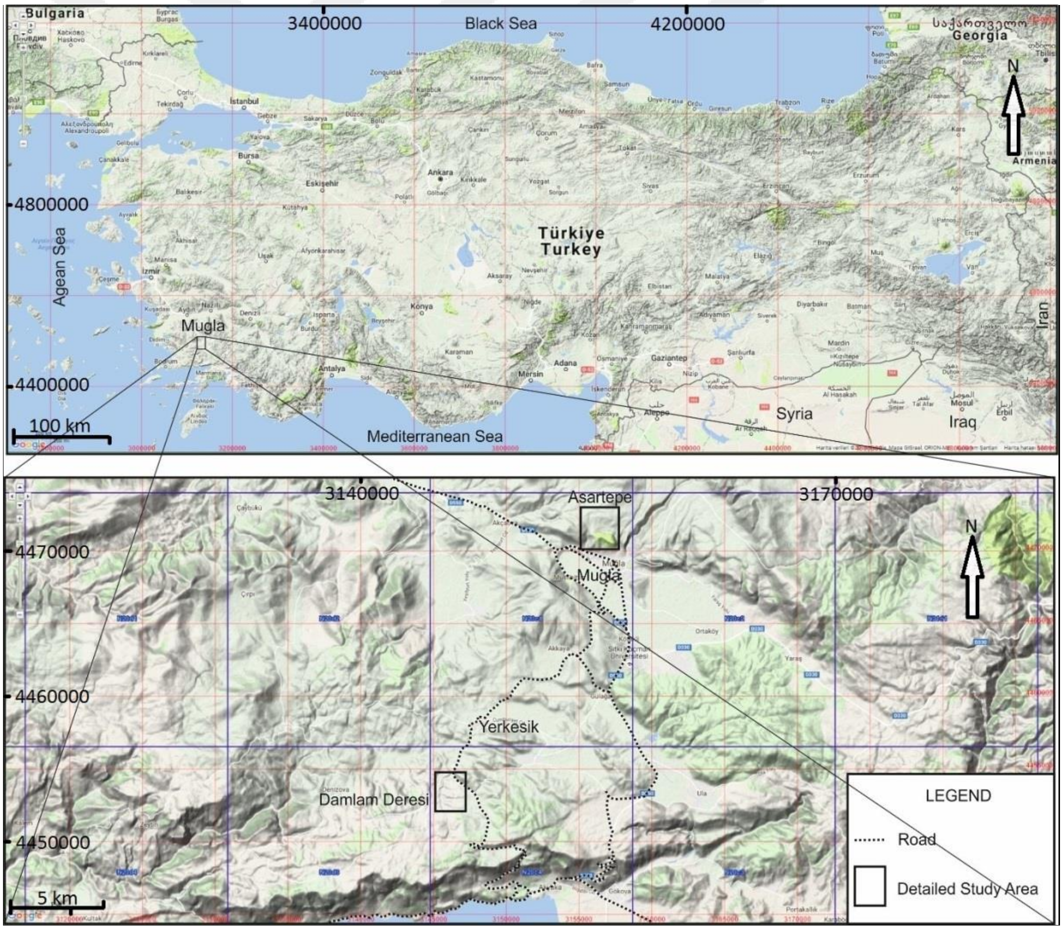

Figure 1.1. Geographical setting of the study areas (Modified from www.google.com.tr/map)

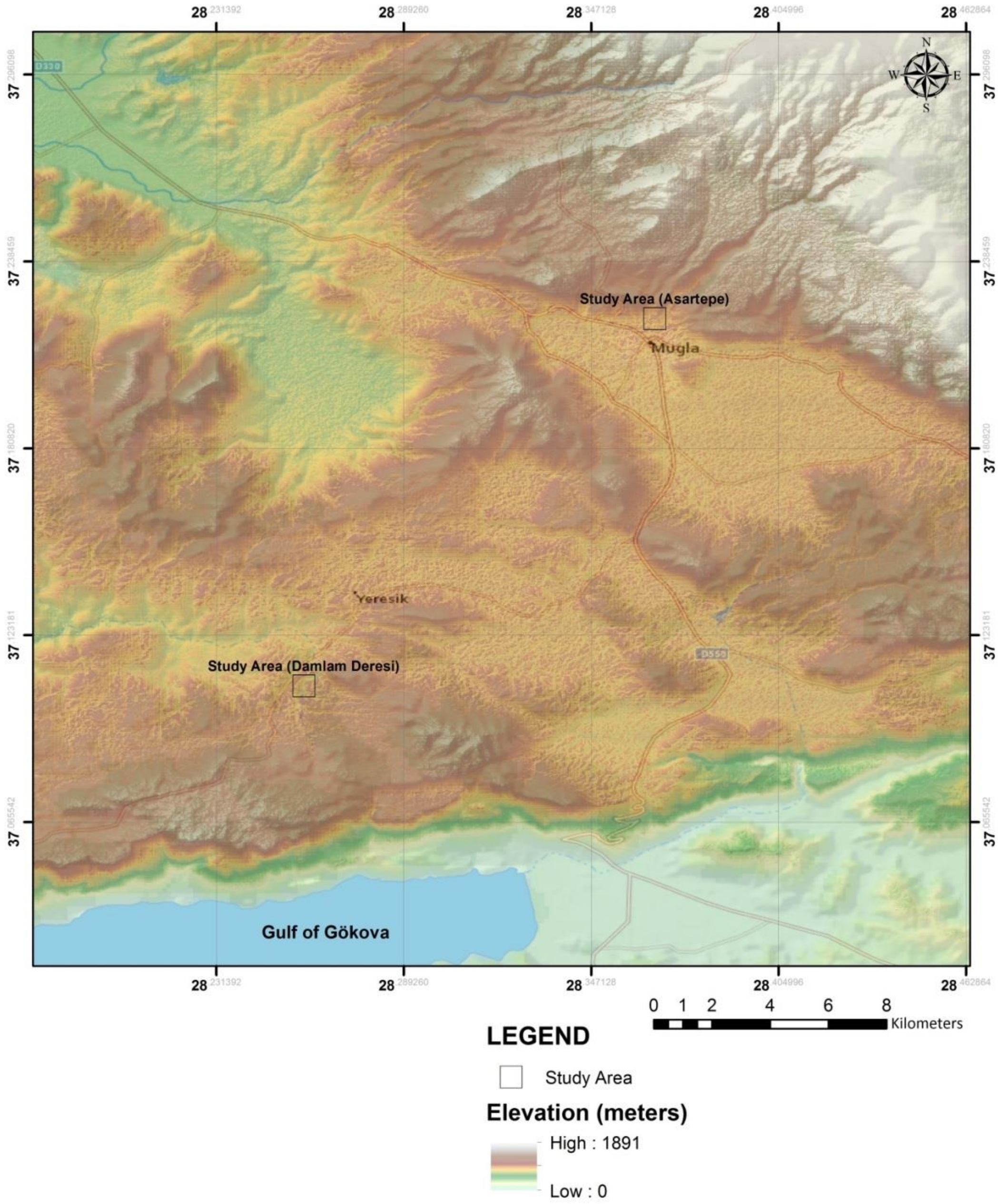

Figure 1.2. Digital Elevation Map (DEM) of the study areas (Modified from https://gdex.cr.usgs.gov/gdex/)

1.3. Climatic Condition

Mugla and its surroundings are hot and dry in summers, warm and rainy with a subtropical Mediterranean climate in winter. The measurements between 1980 and 2010 years showed that the average annual precipitation was around 817.5 mm (Access date: 25.08.2016, http://www.mgm.gov.tr/veridegerlendirme/yillik-toplam-yagis-verileri.aspx?m=MUGLA#sfB). It has been observed that the rainfall between 2011-

2015 years is above the average value (Figure 1.3.) (Access date: 25.08.2016, http://www.mgm.gov.tr/veridegerlendirme/yillik-toplam-yagisverileri.aspx?m =MUGLA#sfB).

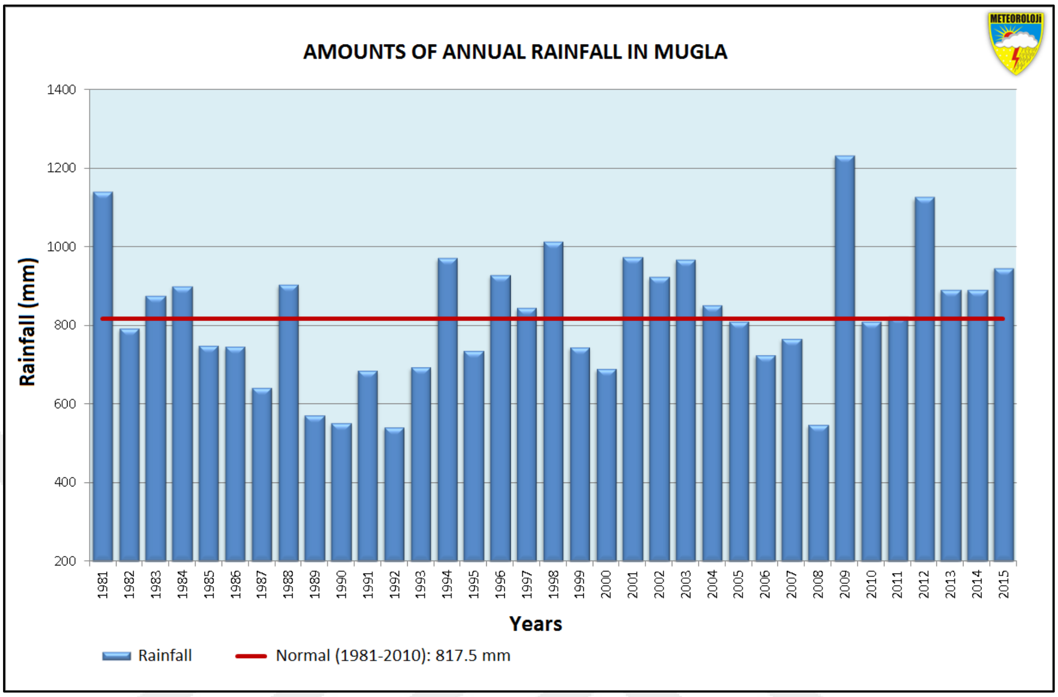

Figure 1.3. Amounts of annual rainfall in Mugla (Access date: 25.08.2016, http://www.mgm.gov.tr/veridegerlendirme/yillik-toplam-yagis-verileri.aspx?m=MUGLA#sfB)

According to observations made between 1950-2015 in Muğla, the average temperature varies between 5.5-26.3°C (Access date: 25.08.2016, http://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik. aspx?m=MUG-LA) . The lowest temperature in the year was -11 ° C in spite of the fact that the highest temperature was 42.1°C (Access date: 25.08.2016, http://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik. aspx?m=MUG-LA).

2. MATERIALS AND METHODS

The cave occurences that were the subject of this study were formed within cave occurences in the Upper Miocene-Pliocene clastics. The units of Yatagan Formation are outcropped on the quadrangles of N20c1 and N20c4 in the scale of 1 / 25.000. The units is formed in wide areas as plateau in the central and northern parts of the Muğla Province. The geometric parameters (depth-height-width) (Figure 2.1.) of the cave were measured in all the voids or gaps that were determined during the field studies in each region. In addition, measurements of cracks and fractures were made, and the lithology changes were determined and noted. The term mudstone is used because silt and clay have not been distinguished, they represent grains under 1/16 mm in grain size. Moreover, for the in situ testing of rock strengths, Schmidt hammer was applied horizontally and vertically on the bedding surface of the outcrops. Furthermore, some samples were systematically collected during field studies in each region to determine the physico-mechanical properties of the samples such as density, void ratio and so on. Measurements of flow rate were carefully made in the identified water sources in each region. Consequently, the drainage networks and stratigraphical sections of both of the studied areas were clearly drawn to better understand the working prenciples of hydrogeological and sedimentelogical systems respectively.

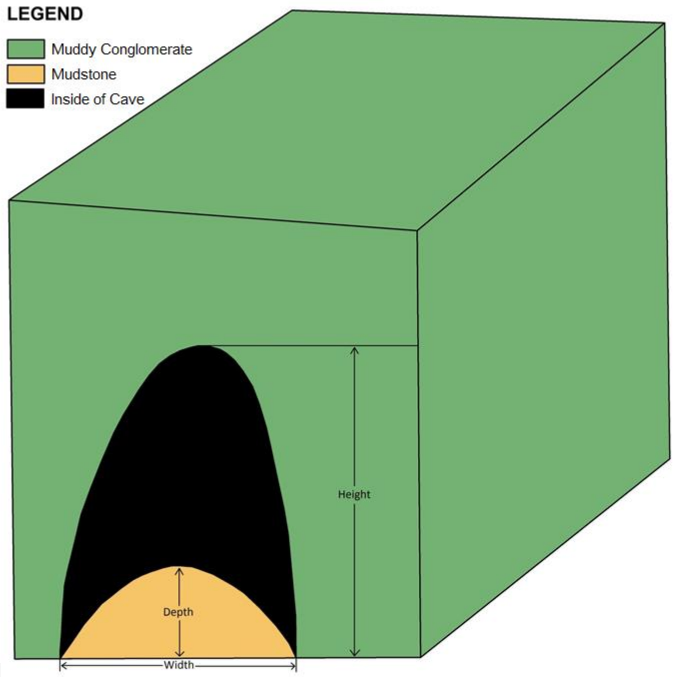

Figure 2.1. Geometric parameters (depth-height-width)

2.1. Material

One of two study areas, Asartepe cave occurences was mapped using small part of quadrangle sheet of N20c1. Another one, Damlam Deresi cave occurences was mapped using small part of quadrangle sheet of N20c4 at the Damlam stream. The study area of the Asartepe cave occurences is almost 8000m^2 whereas the Damlam Deresi cave occurences is near 4800m^2. Finally, a total of 17 samples for the Asartepe cave occurences and 20 samples for the Damlam Deresi cave occurences were seperately collected from the study areas.

2.2. Methods of Study

This research has been performed in three main stages including office works, field works, and laboratory works.

2.2.1. Office works

Most of database of this research was collected from the website of the Turkish Higher Education (known YÖK in Turkish), journal of Mineral Research & Exploration General Directorate (known MTA in Turkish), publications of the Chamber of Geological Engineers of Turkey, and international journal articles. The preliminaries were collected before field works are performed.

2.2.2. Field works

There are several research works done especially in Yatağan Formation. Firstly, caves and cave-like spaces were particularly determined in the area where the Yatağan Formation outcropped. Secondly, where cave is discovered, the Yatağan Formation was examined in detail. Thirdly, lithological variations were determined in lateral and vertical directions of the units. Moreover, measuring one piece of generalized cross-section, determinating maximum-minimum-average grain size and the rate of matrix / grain, detecting their component type, determinating matrix-supported / clast supported structures as well as compulating for thin sections of samples were systematically carried out in the area where caves concentrated. Furthermore, the geometric (depth-height-width) parameters of the caves were measured carefully. Also, the presence of the internal structures of the caves (stalactite-flowstone-travertine occurences, etc.) were investigated. The relationship between cave occurences and the structures were investigated after measurement of stratigraphy, fractures and cracks and determining their effects through surface and ground water distribution. The matrix component of conglomerates and grain strength were examined with Schmidt hammer. The matrixes and grains of the consolidated and the non-consolidated conglomerates were applied to be parallel and perpendicular to bedding with the Schmidt Hammer. Detection of fractured and cracked system ranges of block size were realized in the cave occurences. Flows of the sources of surface waters were measured in the study areas.

2.2.3. Laboratory works

The laboratory works include sample selection, thin section preparation, petrographic studies as well as geotechnical and hydrogeological experiments with analytical works. Geological samples were used for petrographic studies. Petrographic thin sections are examined either under a polarized or light microscope at the Muğla Sıtkı Koçman University (also known MSKU) in southwestern Turkey.

A total of 4 thin sections are a mixture of both of fresh and altered rocks. The whole thin sections under microscope were petrographically distinguished from each other. A total of 4 thin sections of the fresh (unaltered) rocks were selected from a total of 37 samples in order to determine their petrographical characteristics. The thin sections for petrographical works were prepared at the Geolab company in Ankara, Turkey (http://www.geolab.com.tr).

Geotechnical laboratory works are performed at the Geolab company in Ankara, Turkey (http://www.geolab.com.tr). The laboratory works are composed of (1) physical and mechanical prooperties of rocks, (2) soil test, (3) Point load strength index test of rocks, and (4) Slake durability test of rocks. All experiments were carried out according to Turkish Standards of ISRM (2007) and ASTM at the Geolab company.

3. PREVIOUS STUDY

3.1. Karst Terminology

The "karst" term is originally handed out from German to English (https://en.wikipedia.org/wiki/Karst). Gams (1993) briefly mentioned that the limestone region northeast of Trieste Bay is named "kras" in Slovenian, "Karst" in German, and "carso" in Italian, from a pre-Indo-European word "karra" meaning stony. Gillieson (1996) also expressed that "Karstic Terrain" is able to be cropped out with some complex physicochemical processes such as weathering, hydraulic action, tectonic movements, melt water and the evacuation of molten rock (lava).

Monroe (1970) technically defined the karst terminology according to illustrated in the bock diagram (Figure 3.1.). The karst is a terrain, generally underlain by limestone or dolomite, in which the topography is chiefly formed by the dissolving of rock and may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves (Monroe, 1970).

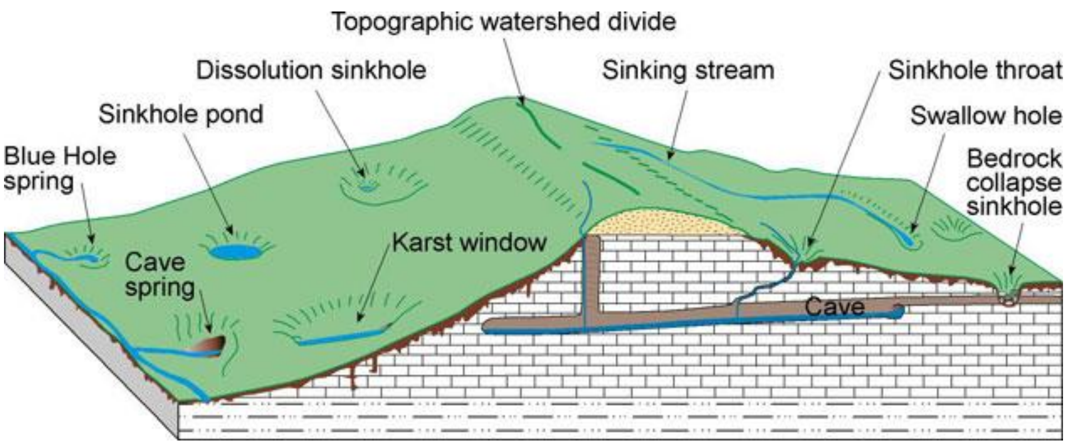

Figure 3.1. Generalized block diagram showing typical karst landscape in Kentucky. (Access date: 25.08.2016, https://www.uky.edu/KGS/water/general/karst/karst_landscape.htm)

3.2. Previous Karst and Cave Studies

Palmer (1991) mentioned that karst landscapes, in which dissolution of bedrock by water is one of the the dominant geomorphic processes, occuppy approximately

10%-20% of the Earth's land area. Palmer (1991) also classified common patterns of solutional caves as examples of "*branchwork*" (passages that joints tributaries), "*network*" (angular grids of intersecting fissures), "*anastomastic*" (curvilinear tubes that intersect braided pattern), "*ramiform*" (resemble ink blots or Rorschach patterns) and "*spongework*" (random three dimensional patterns like pores with varied size in a sponge) caves in accordance with field observation or plan-view maps.

Busche & Sponholz (1992) examined in detail morphological and micromorphological aspects of the sandstone karst of eastern Niger. This research is to show the morphological effects of silicate karstification on the plateau landscape in eastarn Niger and also to figure out clearly the micromorphology of the lining of cave walls accompanied with high intesive karstification (Busche & Sponholz, 1992).

Bergada et al. (1997) observed karst in conglomerates in Catalonia (Spain) assosicated with morphological forms and sedimentary sequence types recorded on archeologial sites. Moreover, this study area has caves, which are horizontal chanel of a karst system concentrated in both carbonates and fissures (Bergada et al., 1997). Generally, the cavites looks like an echelon with the oldest conduits in the highest levels (Bergada et al., 1997). However, vertical cavites in the area could be connected to horizontal conduits in the lowest levels (Bergada et al., 1997). On the other hand, horizontal cavites in the area are able to show great topographical complexity (Bergada et al., 1997).

Al-Fares et al. (2002) analyzed the karst aquifer structure of the Lamalou area (Herault, France) with ground penetrating radar (GPR). Synthetic model in 3D showing the general structure of the shallow part of the Lamalou karstic aquifer were carried out from the interpretations of the whole set of GPR profiles, in particular the profile 5 radargramme and the cored drillings (Al-Fares et al., 2002). The profiles represent epikarst (fractured and karstified yellow limestone), infiltration zone (gray massive and compact limestone), main room of the cave, bedding plane, pothole, and karren (Al-Fares et al., 2002).

Urich (2002) informed land use in karst terrain with reviewing of impacts of primary activities on temperate karst ecosystems. Matrix of anthropogenic (human) activities, effects and impacts on karst terrain was schematically outlined on a figure (Urich, 2002) reproduced from Williams & Robinson (1993). A model karst system taken from Gillieson (1996) was redrawn in detail with respect to *allogenic inputs* (water, CO_2, humic acids, pollutants, gravels, suspended sediments, humus, Uranium?) , *authigenic inputs* (cave breakdown, authigenic fluvial sediment, calcite, gypsum, phosphate minerals), *atmospheric inputs* (water, CO_2, solutes, Ca^{++}, Mg^{++}, Na^{+}, $ClSO_4^{-}$, dust, smoke, ^{230}Pb, ^{137}Cs), *hydrothermal input, cave system outputs* (water, solutes, Ca^{++}, Mg^{++}, HCO_3, fine sediments, organic acids) as well as *entrance facies* (cave breakdown, fluvial + hillslope sediments, calcite, bone, polen, phosphate minerals) (Urich, 2002).

Dearborn (2004) published a huge book referred to as "*Encyclopedia of Caves and Karst Science*". The book indicated the main karst areas of sub-Saharan Africa, outline map of the cave systems within the Aggtelek karst beneath the border between Hungary and Slovakia, the main karst regions in Central and North America, main areas of carbonate and quartzite karst in South America, Appalachian karst in the United States, Talus Caves in Turkey, Valleys in Karst of France and Yangshuo Karst in China (Dearborn, 2004).

Kranjc (2005) clarified that folk tales and tradition show evidence that people in Udin Boršt (Gorenjsko, Slovenia) were aware of caves from the past. This research paper displays interestingly "Speleological Map of Slovenia" in the seventieth century (Kranjc, 2005).

Ford and Williams (2007) explained in detail karst hydrogeology and geomorphology as explained below. The term karst was described as a special style of landscape containing caves and extensive under-ground water systems that is developed on especially soluble rocks such as limestone, marble, and gypsum (Ford and Williams, 2007). Global distribution of major outcrops of carbonate rocks was accurately shown on the detail map of World (Ford and Williams, 2007). A compressive karst system was illustrated in a cross-section (Ford and Williams, 2007). Recognition of lineaments in karst terrain was dramatically drawn on an aerial photograph (Ford and Williams, 2007). A schematic representation of rate-controlling mechanisms was schematically displayed for calcite dissolution as a function of pH and temperature in a diagram (Ford and Williams, 2007). Three end members of karst denudation systems were classified as: (a) autogenic and (b) allogenic are end-members with (c) the mixed autogenic–allogenic intermediate case being the most common (Ford and Williams, 2007). The effect of scale on the hydraulic conductivity of karst system was graphically represented in shematic diagram according to order of size of samples as examples of karstic network, macrofissures, pores and microfissures (Ford and Williams, 2007). The relationship between (a) surface solution doline topography, (b) underlying relief on the subcutaneous (epikarst) water table and (c) vertical hydraulic conductivity in computational models was drawn near the base of the epikarst (Ford and Williams, 2007). A conceptual model of the temperature distributions or gradients was given within a karstified massif in connection with rates of water flow and air flow (Ford and Williams, 2007). The relationship between types of recharge and pre-solutional-porosity was perfectly sketched within cave patterns (Ford and Williams, 2007). Karst aquifers were classified as a conceptual three-dimensional field model of recharge, storage and transmission in the aquifers categorized in five groups such as (1) *hypersensitive karst aquifers*, (2) *very sensitive karst aquifers*, (3) *moderately sensitive aquifers*, (4) *slightly sensitive non-karst aquifers* and (5) *non-aquifers* (Ford and Williams, 2007). Ideal porous aquifer has parallel equipotentials, parallel flow lines, seepage face and convex water table, but, ideal karst aquifer has aquipotentials form throughs, tributary flow lines, spring, conduit, and concave water table (Ford and Williams, 2007).

Ford and Williams (2007) defined that the term cave is a natural underground opening in rock that is large enough for human entry, but it is not a genetic definition as narated below. Caves could be classified in three groups as the following given in order: (1) *isolated caves*, (2) *protocaves*, and (3) *integrated cave system* (Ford and Williams, 2007). Moreover, dissolution caves could be classified in accordence with internal characteristics and in relation to external factors (Ford and Williams, 2007). The internal characteristics consist of (1) *size*: aggregate length or depth or volume, (2) *measure of vertical or horizontal dimensions*, (3) *plan form*: entrance or niche (abri), chamber (room), linear passage, branchwork, network, anastomosis, spongework, ramiform; multiphase branchworks, rectilinear combinations (4) *passage cross-section form*: circular or elliptical, by role in fluvial system: allogenic river caves, holokarst drains, canyon, breakdown, compound, (5) *relation to local or regional water table*: vadose, water-table cave, phreatic, compound, relict, (6) *categories of deposits*: speleothem cave, gypsum (crystal) cave, sand cave, ice cave, archaeological site, etc (Ford and Williams, 2007). The relation to external factors are composed of (1) *modes of geological control*: rock type (limestone, gypsum, etc.); joint-guided, fault-guided, etc.; horizontal strata, steeply dipping, folded, etc., (3) *topographic setting*: mountain caves, plateau caves, etc., (4) *relation to topography*: underdrain valley or valley flank, meander cut-off (short cut), connect poljes, foot cave, etc., (5) *role in fluvial system*: allogenic river caves, holokarst drains, short-cut caves, combinations, sea cave, etc., (6) *aquifer type*: ideal pipe cave ---> continuum ---> perfect spongework cave, (7) *role in geomorphological and hydrological cycles*: active cave ---> episodic ---> relict cave (preserved, intercepted, truncated, destroyed), (8) *climatic setting*: humid tropical, semi-arid, mediterranean, temperate, alpine, arctic, etc (Ford and Williams, 2007). On the other hand, karst solution caves are also classified in seven groups; (1) *Branchwork caves* (80% of known caves?), (2) *Maze caves and outlet basal injection caves*, (3) *Combinations of previous types 1 and 2*, (4) *Hydrothermal caves* (~10% of known caves?), (5) *Carlsbad-type cavities and gypsum replacement caves*, (6) *Coastal mixing zone cavities*, and (7) *Hybrid caves* (Ford and Williams, 2007).

Aubrecht et al. (2008) emphasized that there are some arguments for not only a low degree of lithification but also a complete lack of lithification occurring in the arenites which can result in cave formation on the southern edge of the Meghalaya Plateau in India. This study shows that schematic overview of cave genesis in the arenites from well-lithified arenites to poorly-lithified arenites (Aubrecht et al., 2008). The study observed the main controlling factors of cave formation in the arenites depending upon the presence of poorly lithified to completely unlithified bodies, pH values of the water samples, the chemical composition of the water, the strongest dissolution/reprecipitation agent related to the condensed atmospheric moisture with extremely low EC and high SiO_2–Si concentration, the siliceous speleothems as well as the influence of biogenic processes (e.g., microbes, cyanobacteria, fungi and lichens) within the arenite complexes (Aubrecht et al., 2008).

Williams (2008) dealt with World heritage caves and karst. The geographical distribution of World Heritage properties with outstanding karst values were plotted on a world map depicting the distribution of carbonate rocks after the World map (Williams, 2008) was modified from Ford and Williams (2007). The climatic context of World Heritage properties with outstanding karst values were schematically plotted in connection with average annual temperature (°C) on the y axis versus average annual precipitation (mm) on the x axis of two dimensional diagram (Williams, 2008). The management cycle proposed by the World Commission on Protected Areas was illustrated as a framework for assessing management effectiveness of protected areas (Williams, 2008) taken from Hockings et al. (2006).

Lewin and Woodward (2009) handled karst geomorphology and environmental change accompanying with illustrational diagrams. The distribution of the major outcrops of carbonate rocks (limestones, dolomites, and marble) in the Mediterranean region and the key sites were exoterically signified on the map (Lewin and Woodward, 2009). Furthermore, the tectonic setting for the deposition and deformation of Mediterranean limestones were clearly shown within Alpine system on the map (Lewin and Woodward, 2009). The development of vadose and phreatic cave systems in a karst drainage system was expressed in the cross-section (Lewin and Woodward, 2009). Geological processes of a typical karst system in the vadose and phreatic zones were illustrated in the Mediterranean region after the processes (Lewin and Woodward, 2009) carried out by Ford and Williams (2007). The vertical cross sections with zonation of karst landscapes and processes in 'European folded mountain regions' (Lewin and Woodward, 2009) were modified after Jakucs (1977).

Breitenbach et al. (2010) reported that two caves developed in sandstone host rock are described from southern Meghalaya, northeastern India. These caves are relatively unusual in that they are developed in sandstone, rather than being parts of a classical limestone karst, but they are also typical of features related to the region's sandstone morphology (Breitenbach et al., 2010). Some limestone in this study area were probably from the presence of the cave-bearing sandstone, as stalagmites and stalactites (Breitenbach et al., 2010). Active sandstone karstification is seem in the caves (Breitenbach et al., 2010). Consequently, this research work noticed that the sandstone karst in detailed survey could help in modelling regional erosion rates and provide pointers to the momentum of ongoing river incision (Breitenbach et al., 2010).

Slabe (2010) represented introduction to the Dinaric Karst (Kras) that is is the major morphological type of landscape of the Dinarsko gorovje (Dinaric mountains) positioned between the Panonian Basin in the northeast and the Adriatic Sea in the southwest, extending over approximately 60,000 km^2 and forming the largest continuous karst landscape in Europe. Digital elevation model of Kras plateau, Planinsko polje (Planina polje), and blind valleys of Matarsko podolje in Slovenia was carried out on a map (Slabe, 2010). Plan and cross-section of cave Ulica pečina and unfoofed cave in Slovania were diagrammatically made on a sketch (Slabe, 2010).

Lipar and Ferk (2011) remarked eogenic (early diagenetic) caves in conglomerate as examples from Udin Boršt in Slovenia. This eogenic caves are divided by in four general types such as "*linear stream caves*", "*shelter caves*", "*breakdown caves*", and "*vadose shaft*" (Lipar and Ferk, 2011). This research tries to describe geological, morphological and genetic characteristics of the caves assosicated with porosity types (e.g., vuggy or matrix, fracture (fissures), conduit porosity) that are a strong influence on the cave type or particularly its morphology (Lipar and Ferk, 2011). And also the research contains detailed speoleogical analysis of the caves and morphological analysis of the conglomerate terrace in the main aim of this work (Lipar and Ferk, 2011). In conclusion, four general types of the eogenic caves are defined as: (1) "*the linear stream caves*" (influced by fissure porosity, dominantly matrix porosity and bedding material types); (2) "*the shelter caves*" (penetrated by matrix porosity and physical weathering); (3) "*the breakdown caves*" (composed of collapsed domes with rubble floors), and (4) "*the vadose shaft*" (formed by sinking vertical water) (Lipar and Ferk, 2011).

Grimes (2012) handled modern karst and paleokarst-like features associated with Proterozoic sandstone units in the Judbarra / Gregory National Park, Northern Territory, Australia. Grimes (2012) also illustrated both geological map of the karst area and schematic cross-sectional sketch of the paleokarst body. Brecciated rocks and dolomitic outcrops in this body should be investigated to be an evidence concerning the presence of mineralisation and alteration that might support an older hypogene origin of the paleokarst (Grimes, 2012).

Awadh et al. (2013) worked about chemical and physical control processes on the development of caves in the Injana Formation in central Iraq. This research aims to assess the genesis of caves and diagnose the factors affecting the building and the destruction of these caves through geologic time (Awadh et al., 2013). Microscopic studies petrographically play important roles to learn cave-forming factors in this study (Awadh et al., 2013). These caves could have been used as homes for the ancient human for their protection and improvement of lives (Awadh et al., 2013). Similarly, these caves can be recommended to discover the ancient civilization in this area for futher contributions in terms of the archaeological investigation (Awadh et al., 2013). Finally, they may be affected by some factors that include mineral constituents, fractures, and joints, chemical weathering, sedimentary structures, mechanical weathering and perhaps ancient activities of humans, who probably lived in these caves (Awadh et al., 2013).

Basso et al. (2013) focused interestingly on morphometric analysis of sinkholes in a karst coastal area of southern Apulia in Italy. The main morphometric parameters are composed of shape of the sinkhole, azimuth and length of maximum and minimum axes, depth, elongation ratio, and distance from the shorelines (Basso et al., 2013). A simplified sinkhole was modelled in a cross section with respect to its plan view (Basso et al., 2013).

Bakalowicz (2016) clarified the *epikarst* (called the shallow, superficial part of karst areas) with the skin of karst related to erosion and human activities. Bakalowicz (2016) also portrayed the functional scheme of a karstic aquifer showing the distribution of infiltration water according to the different types of underground flows.

Caves can reach several meters, kilometers in length and hundreds of meters in depth or height (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara). Caves can be divided into two; natural and man-made (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara). Cave tombs, underground cities made in volcanic tuffs or marls, and rock houses and temples formed by man-made excavations are called man-made caverns (http://www.mta.gov.tr/v3.0/arastirmalar/karst-magara).

3.3. Previous Studies about the Study Area

Abdülselamoglu (1965) had performed comparisons among the Neogene formations that surfaced around Muğla-Yatağan district. According to Abdülselamoglu (1965), they are composed of conglomerate, sandstone and lacustrine limestones deposited in terrestrial facies of the formations.

Becker-Platen (1970) revealed the general geology and biostratigraphy of the area stationed between Denizli and Mugla provinces. In this study, Cenozoic sedimentary rocks were distinguished as lithostratigraphic or sub-discipline of stratigraphic units (Becker-Platen, 1970).

Eroskay and Günay (1979) completed a research Project named "Tecto-Genetic classification and hydrogeological properties of the karst regions in Turkey" including the Mugla region.

Kayan (1979) exhibited geomorphology of neogene basin of the Muğla-Yatağan.

Leflef and Hakyemez (1979) prepared a report as sedimantological and paleogeographical studies of Tertiary basins in Muğla basin and its surroundings. Among the Oligocene and Quaternary deposits were distinguished as alluvial fans, meander-like river sediments, lacustrine sediments, coastal sediments, mudslides and lignite occurrences at different locations in the basin (Leflef and Hakyemez, 1979).

Atalay (1980) carried out both of detailed geological map of Mugla basin and detailed stratigraphical section of Yatagan deposits referred to continental Neogene. Atalay (1980) also groupped the Yatağan Formation into 3, which are: (1) Madenler Member, (2) Bayır Member and (3) Bozarmut Member. The most characteristic of the Yatağan Formation is a terrestrial sedimentary stream (including alternation of volcanic tuff, silt, sand, clay, marl, conglomerate and freshwater limestone) of its origin that is orange color ranging from light to dark (Atalay, 1980).

Göktaş (1982) reported sedimentological and paleogeographic investigation of Senozoic aged sedimentary rocks in Mugla region that included Yatagan formation.

Hakyemez and Örçen (1982) performed sedimentological and biostratigraphic examination of the Senozoic sedimentary rocks between Muğla-Denizli (Southwestern Anatolia).

Konak et al. (1987) prepared geology of the south of the Menderes massive using a special guide book for the field excursition along western Anatolia, Turkey.

Hakyemez and Leflef (1989) wrote a preliminary report on the sedimentological and paleographic survey of the Tertiary basins of Mugla and its vicinity.

Ünal and Göktaş (1990) consummated lignite study of Muğla-Kavaklıdere-Yerkesik districts.

Şahin et al. (1993) carried out site selection study of organized industrial zone of Muğla.

Eren (1995) propounded compilation of N20 sheet of Aydın within 1/100 000 scale included Muğla province.

Aktimur et al. (1996) drew a detailed stratigraphical section and detailed geological maps of the Mugla Basin accompanying with geomorphological map, engineering geology map besides TM-satallite images.

Göktaş (1998) mentioned stratigraphy, sedimentology and regional correlation of neogene sedimentation in Mugla and its surroundings (SW Anatolia).

Querol et al. (1999) figured out location of the Miocene Mugla Basin in Southwestern of Turkey (Fig. 3.3). The Mugla Basin is basically categorized in two main groups: (1) Milas and Yatağan sub-basins, (2) NW-SE basement complex (Querol et al., 1999). Querol et al. (1999) also exhibits basic stratigraphic section of the Muğla Basin included Yatağan formation. The Yatağan formation contains clast-supported conglomerates and pebbly sandstones in conjuction with several thick tuff levels (Querol et al., 1999).

Gürer and Yılmaz (2002) illustrated 3D-geological models of Mugla basin and its surroundings with respect to different geological times.

Açıkel (2012) showed simply geological and hydrogeological cross-sections of the Muğla province that were modified from the MTA maps.

Gürer et al. (2013) revealed the simplified geological map of the Muğla province. Two main study areas (Asartepe and Damlam Deresi) are mostly seen within Yatağan Formation in addition to partially in Menderes Massive Cover and Lycian Nappes with respect to the map (Gürer et al., 2013).

Günay et al. (2015) represented that karst regions of Turkey composed of Taurus karst region. As a result, the study areas (Asartepe and Damlam Deresi) are obviously taken place in the Taurus karst region.

Şahin (2015) at the Asartepe cave and Canbaz (2015) at the Damlam cave in the Mugla province were to measure basically the geometric (width-length-depth) parameters of these caves and to do in situ strength experimentation with Schmidt hammer in / around the caves as well as applied point load tests on the samples taken from the fields.

Gül (2015) worked on Quaternary colluvium development in front of the Gereme Formation limestone and Yatağan Formation conglomerate. Gül (2015) also reported that the colluvial wedge development is controlled by recent seismic activities and local climatic factors, which also strongly affect the Yatağan Formation.

Gül et al. (2016) published a research article dealing with rock fall hazard assessment in Asar Hill, ancient Mabolla City, Muğla, SW Turkey. This research is composed of contour map and kinematic analysis of Asartepe as well as its statistical evolution of the end point, bounce height, total kinetic energy, and translational velocity distribution of two blocks along three different profiles (Gül et al., 2016). Gül et al. (2016) also mentioned karstic cave development and their threat to native.

4. HYDROGEOLOGICAL SETTING

Açıkel (2012) performed drainage networks, locations of plains (Figure 4.1.), and hydrogeological conceptual model (Figure 4.2.) of the Muğla province as shown respectively below. Açıkel (2012) demonstrated that Muğla Basin karst aquifer, Ula Basin karst aquifer, and Köprüçay karst aquifer systems interact with Gökova coastal alluvium aquifer related to Gökova graben formed main faults and these faults intersecting secondary fault.

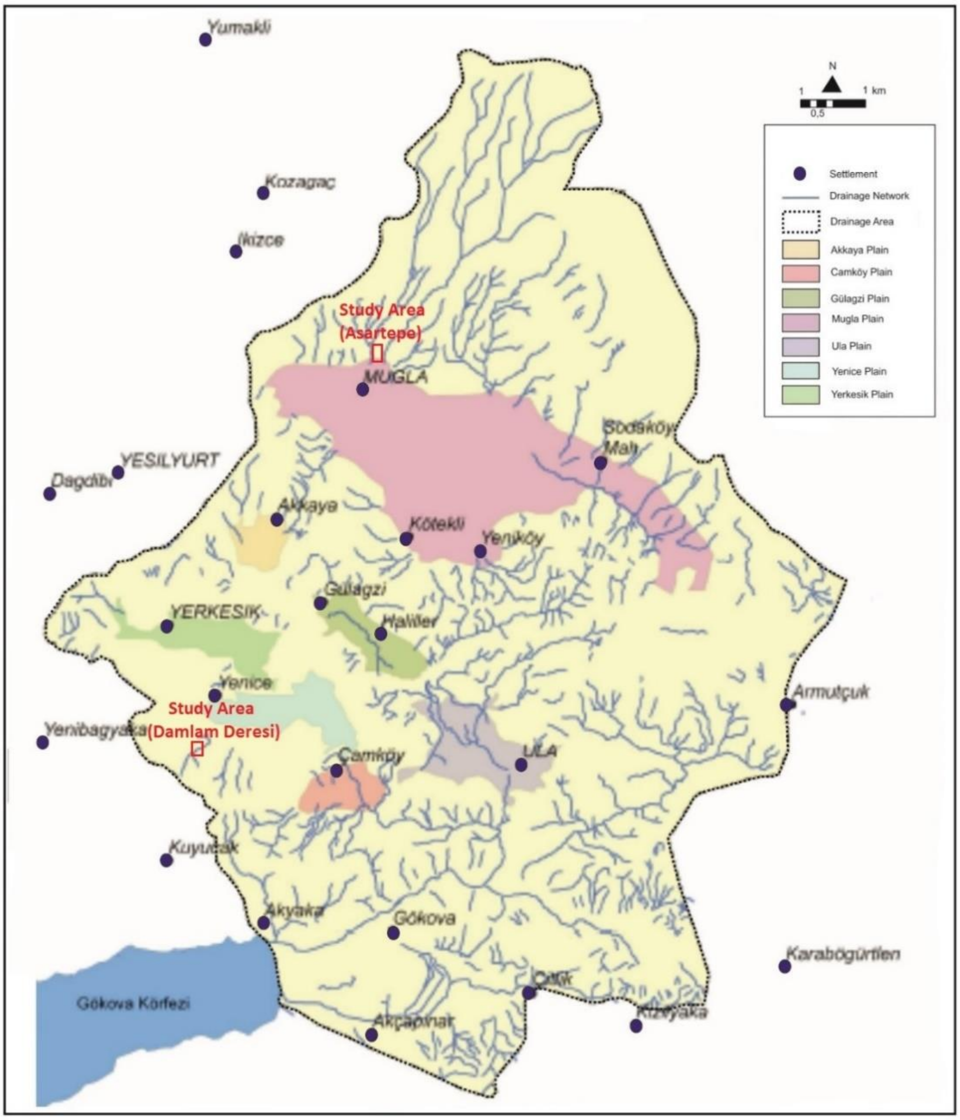

Figure 4.1. Drainage networks and locations of plains in the Muğla province, southwestern Turkey (Açıkel, 2012).

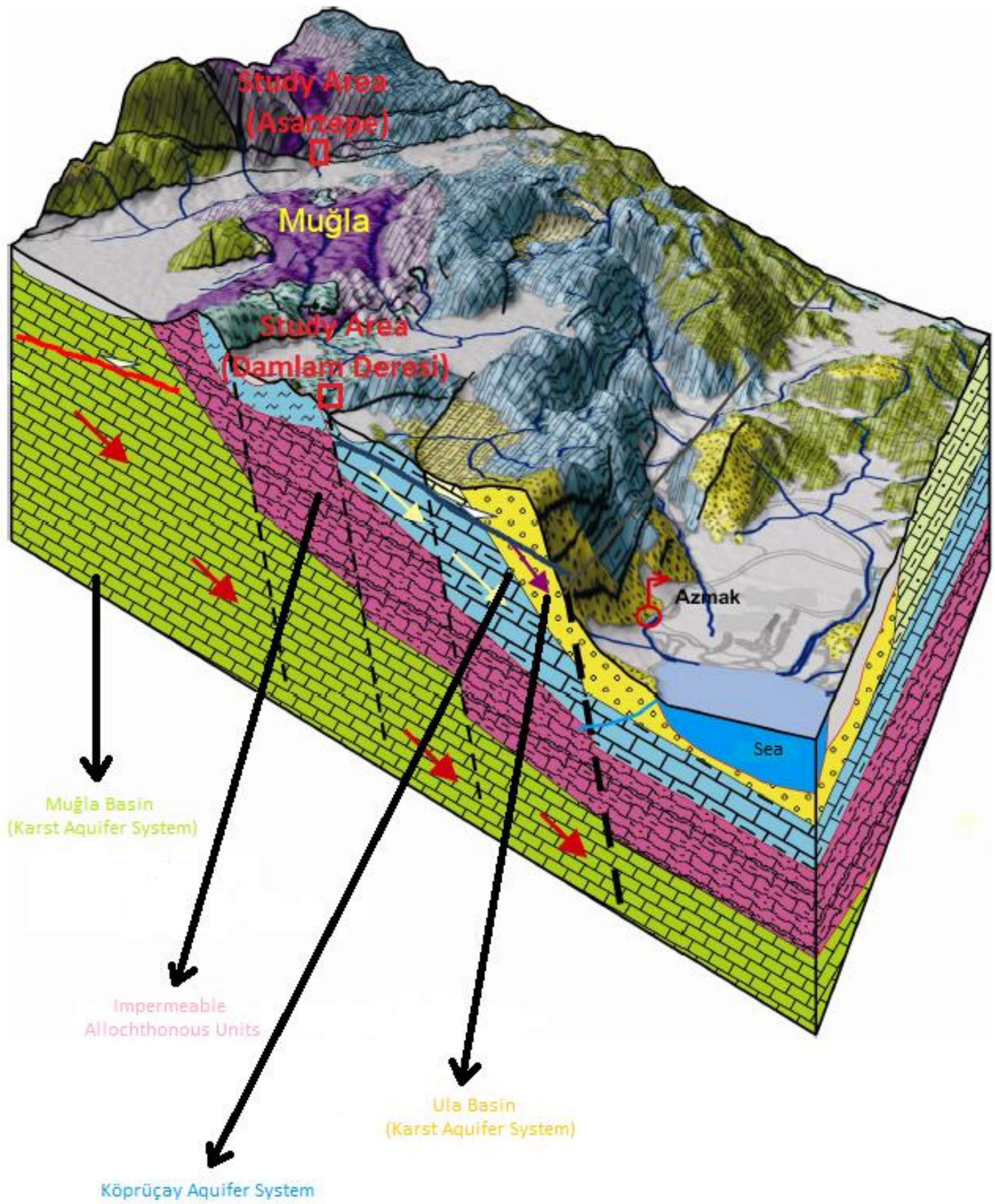

Figure 4.2. Hydrogeological Conceptual Model of the Muğla province, SW Turkey (Taken from Açıkel (2012) after the geological map of the Muğla province were carried out by MTA)

4.1. Detailed Hydrogeological Setting

Detailed hydrogeological maps are carefully drawn for study areas (e.g., Asartepe and Damlam Deresi) and their surroundings according to topographic maps (Figure 4.3. and Figure 4.4. respectively). In addition, a flow direction of hydrogeological surface water near the Asartepe cave occurences is from north to south. In contrast, a flow direction of hydrogeological surface water within the Damlam Deresi cave occurences is from southwest to northeast.

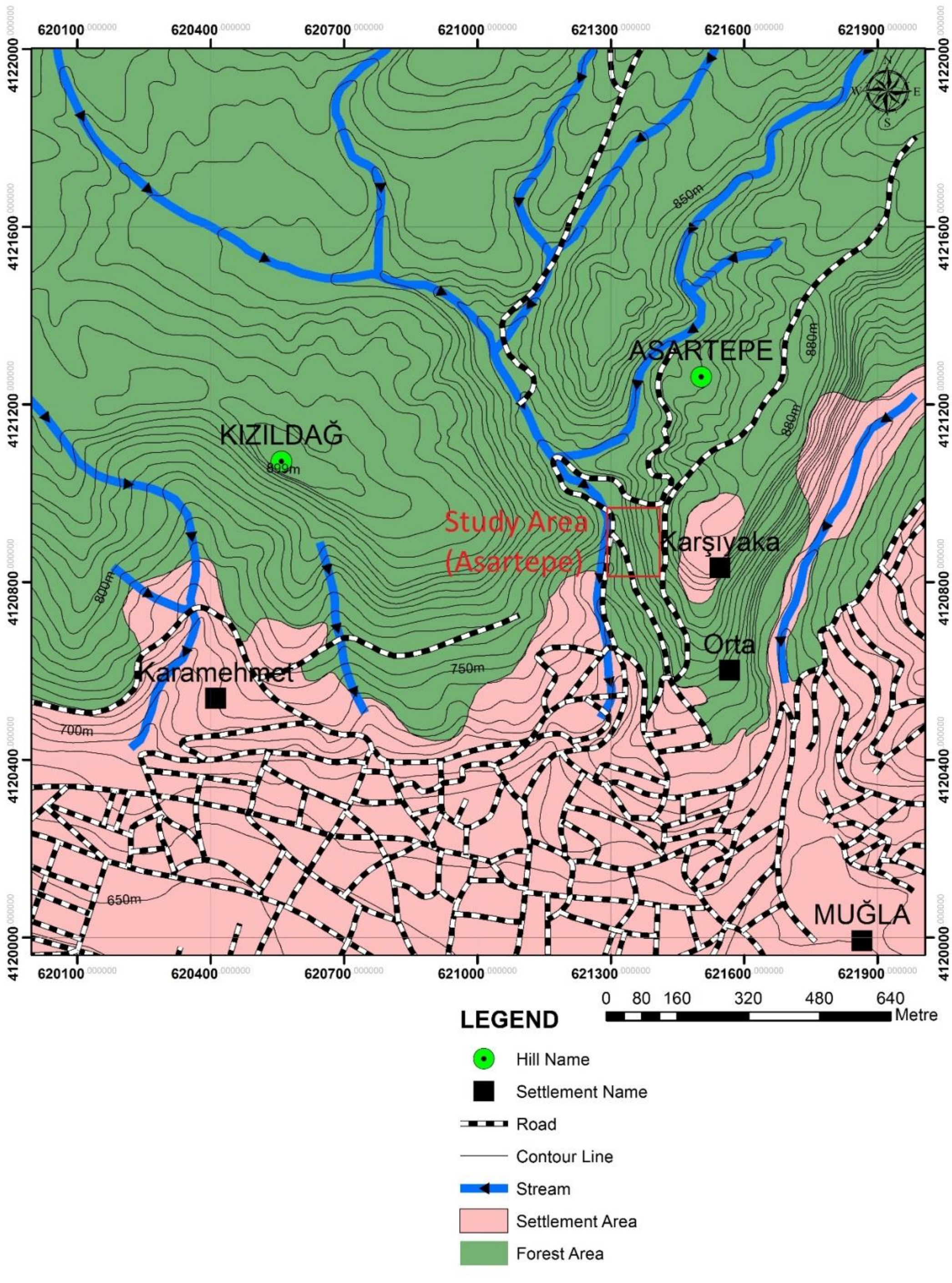

Figure 4.3. Hydrogeological Map is drawn from topographic raster map of Muğla province (The map is modified from a basemap of General Command of Mapping (http://www.hgk.msb.gov.tr))

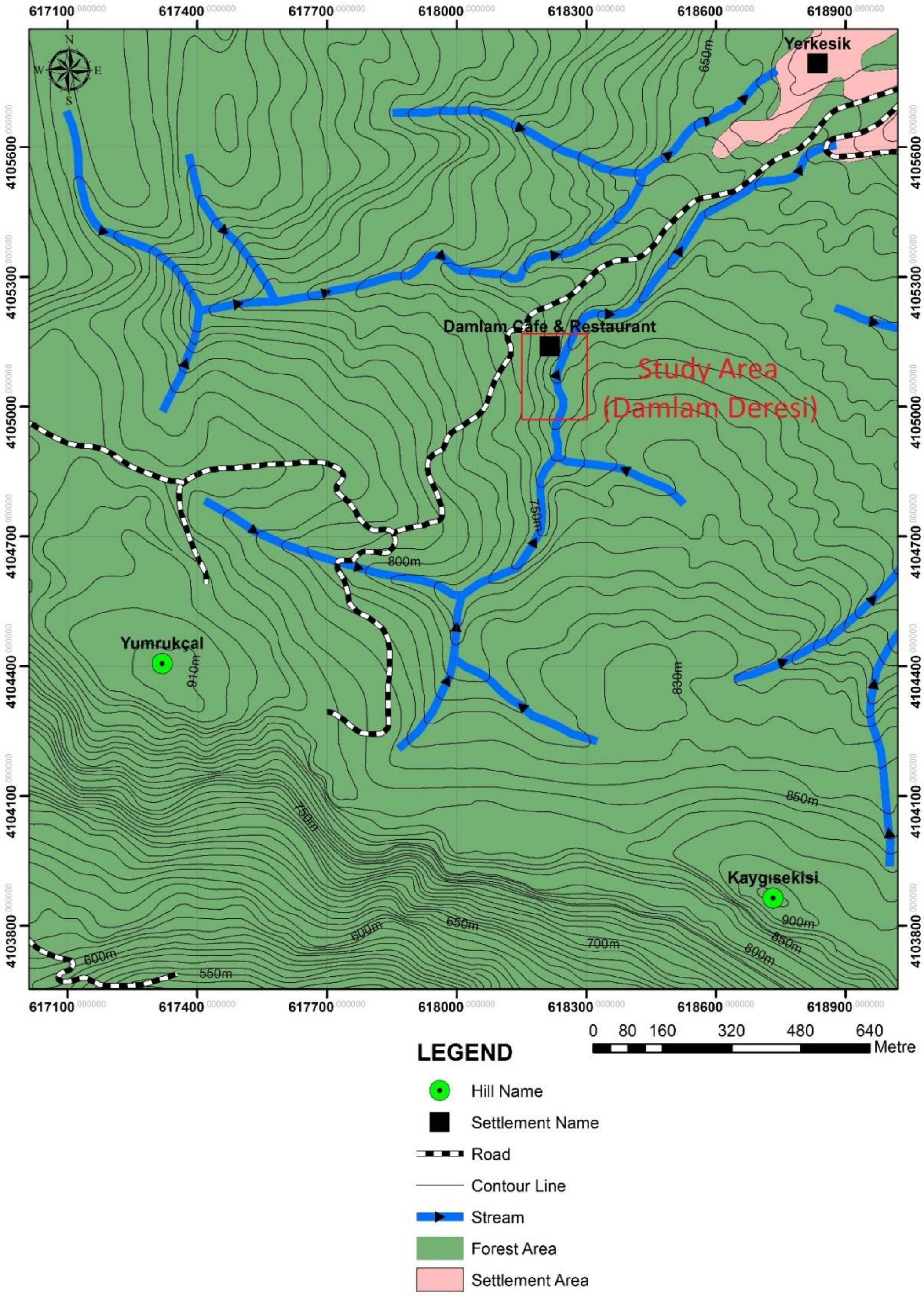

Figure 4.4. Hydrogeological Map is drawn from topographic raster map of Muğla province (The map is modified from a basemap of General Command of Mapping (http://www.hgk.msb.gov.tr))

5. GEOLOGICAL SETTING

5.1. Regional Geology

The study areas (Asartepe and Damlam Deresi) are located in the Muğla basin. The basin, which has surface area of about 300 km^2, is underlain by Lycian Nappes (mainly limestones) that are complex nappe accumulation with both oceanic and continental affinities (Querol et al., 1999). In addition, the areas are situated within Yatağan Formation that is part of the Muğla Basin (Figure 5.1.). The Yatağan Formation is composed of Upper Miocene aged clast supported conglomerates and pebbly sandstones (Querol et al., 1999). Gürer et al. (2013) have recently illustrated simple geological map and geological cross-section of the Muğla region given respectively below (Figure 5.1. and Figure 5.2.).

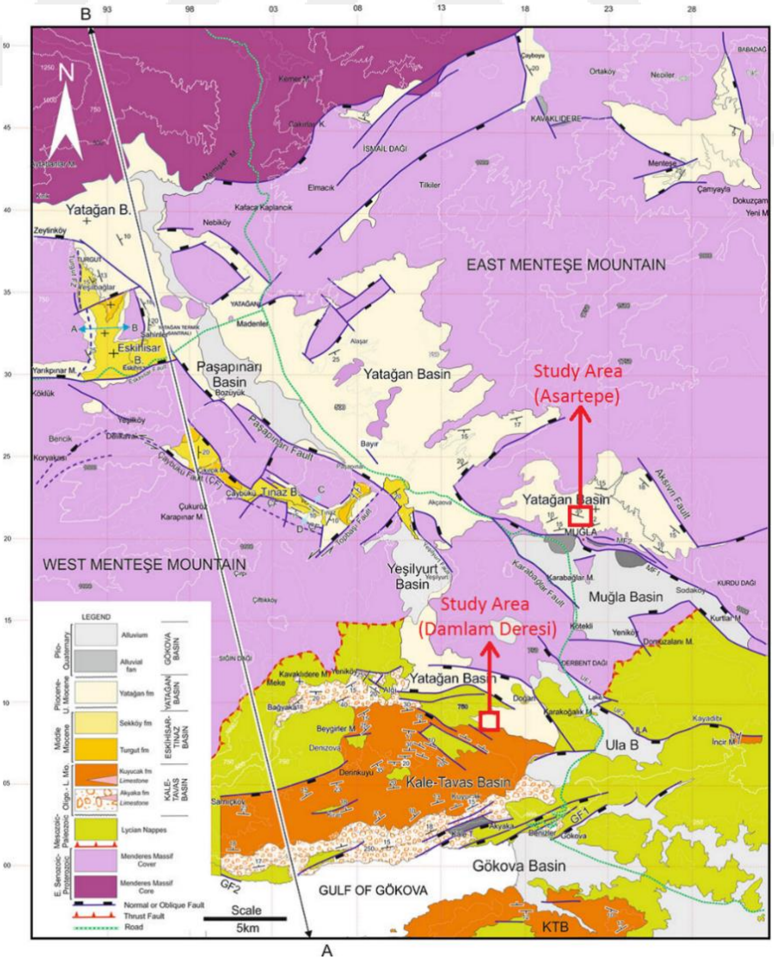

Figure 5.1. Geological map of the Mugla region in Southwestern Anatolia, (Gürer et al., 2013).

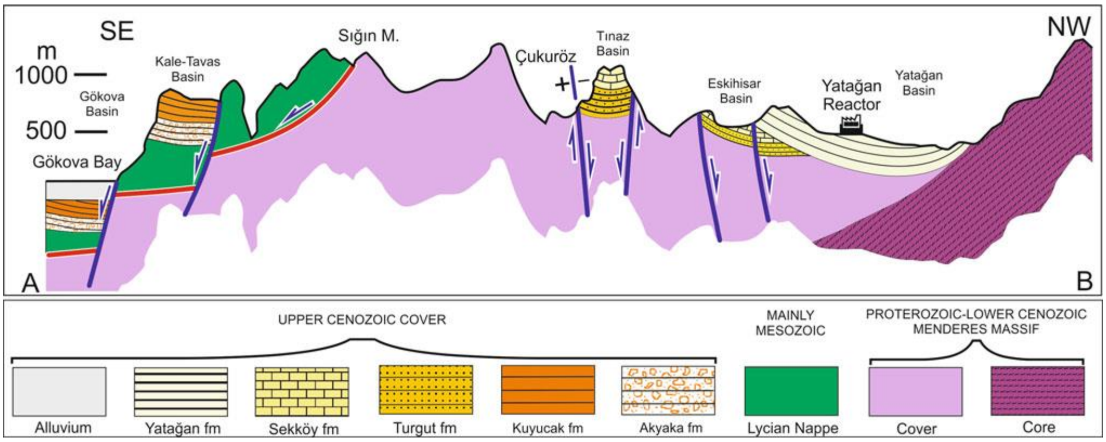

Figure 5.2. Geological cross-section of the Muğla region (Gürer et al., 2013)

5.2. Local Geological Setting

Detailed geological setting of two main study areas (e.g. Asartepe and Damlam Deresi cave occurences) were carried out in Yatağan Formation (Figure 5.3. and Figure 5.4. respectively). These study areas are composed of both muddy conglomerate and mudstone in the Yatağan Formation.

5.2.1. Asartepe cave occurences

12 caves are located in Yatağan Formation in Asartepe region (Figure 5.3.). The caves are systematically named from the starting Cave 1 to the ending Cave 12 in accordance with their locations.

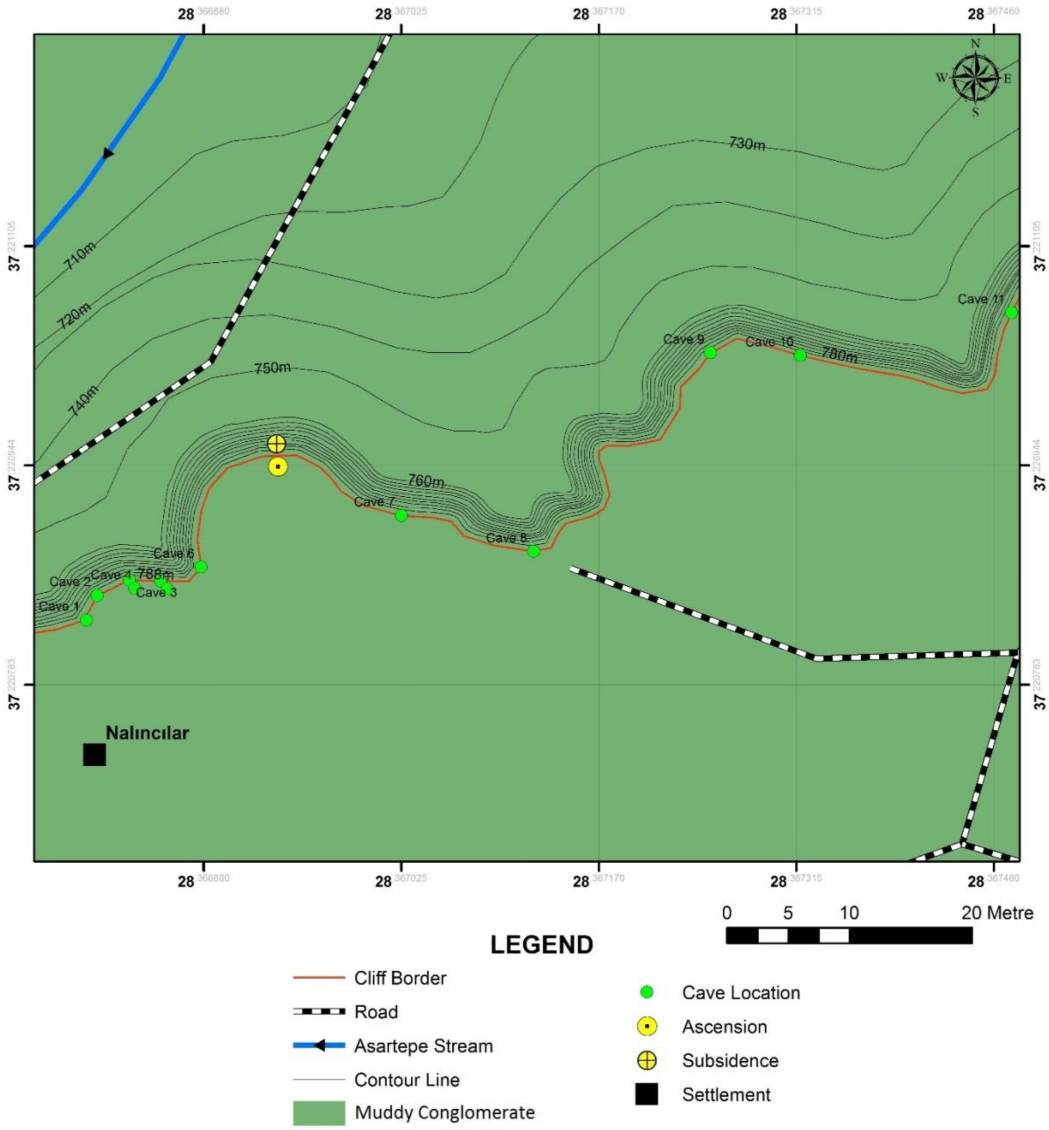

Figure 5.3. Detailed geological map of Asartepe cave occurences (1/200 scale) (Modified from Gürer et al. (2013) in connection with https://www.google.com/earth/ after http://www.mta.gov.tr)

5.2.2. Damlam Deresi cave occurences

Total of 5 caves and 2 terranes were separated in Yatağan Formation within Damlam Deresi site (Figure 5.4.). All of these caves and terranes were formed on two main steep slopes within the occurences (Figure 5.4.). The caves are systematically named from the starting Cave 1 to the ending Cave 5 in accordance their locations.

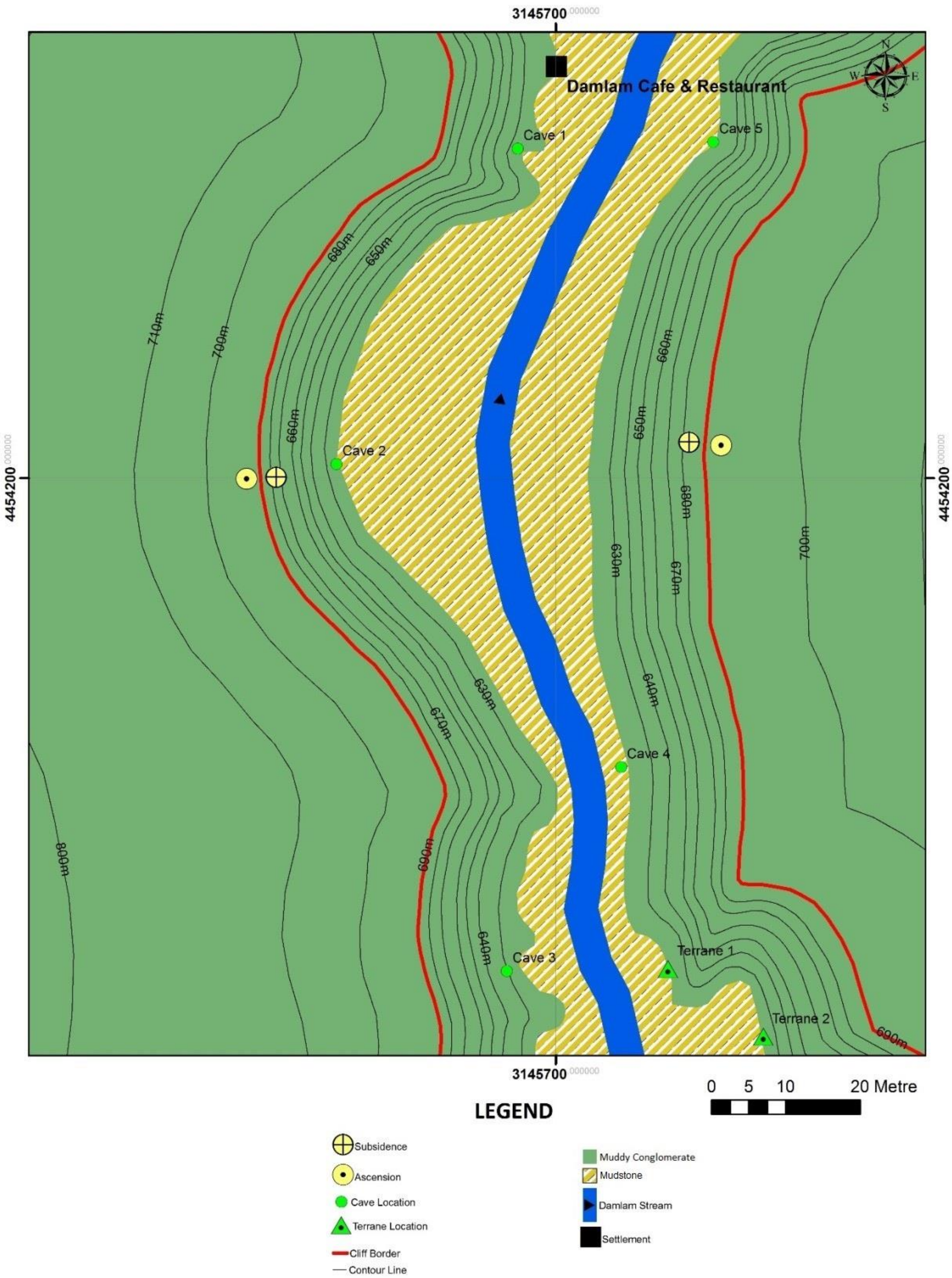

Figure 5.4. Detailed geological map of Damlam Deresi cave occurences (1/200 scale) (Modified from Gürer et al. (2013) in connection with https://www.google.com/earth/ after http://www.mta.gov.tr)

6. ASARTEPE CAVE OCCURENCES

6.1. Cave Locations

12 caves are distinguished on the southern and southeastern skirts of Asartepe, approximately 500 m north of the center of Mugla Province (Figure 6.1. to Figure 6.4.). The caverns are situated on a steep-rocky slope of 75-80° at an elevation of about 50 m. This rocky steep slope is restricted to Basmacı or Asartepe stream.

Asartepe and its surroundings have been measured as representing 12 caverns (Table 6.1.). However, the number of caves in similar dimensions is more than the measured caverns. Some of them are not reachable in the upper sections of the steepest topography of Asartepe because of the fact that their mouth is closed due to their use as a warehouse-barn. Also, some of these caverns have not been measured due to their location in the surrounding private land areas.

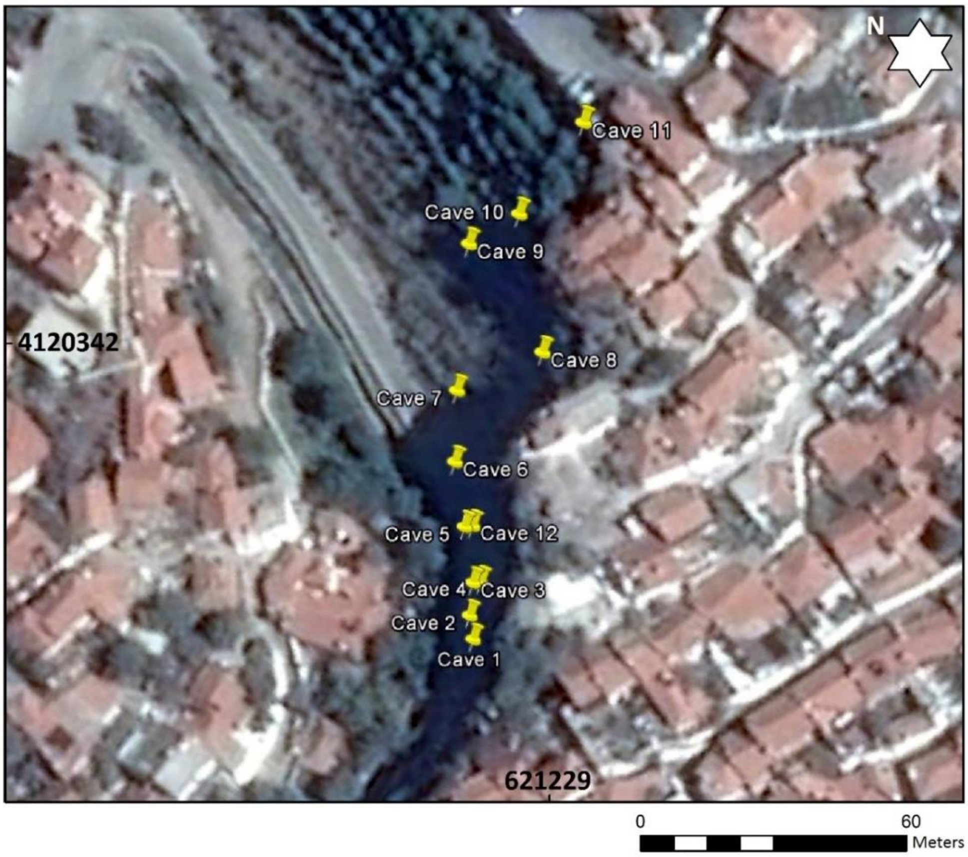

Figure 6.1. Asartepe Caves locations (Modified from https://www.google.com/earth/)

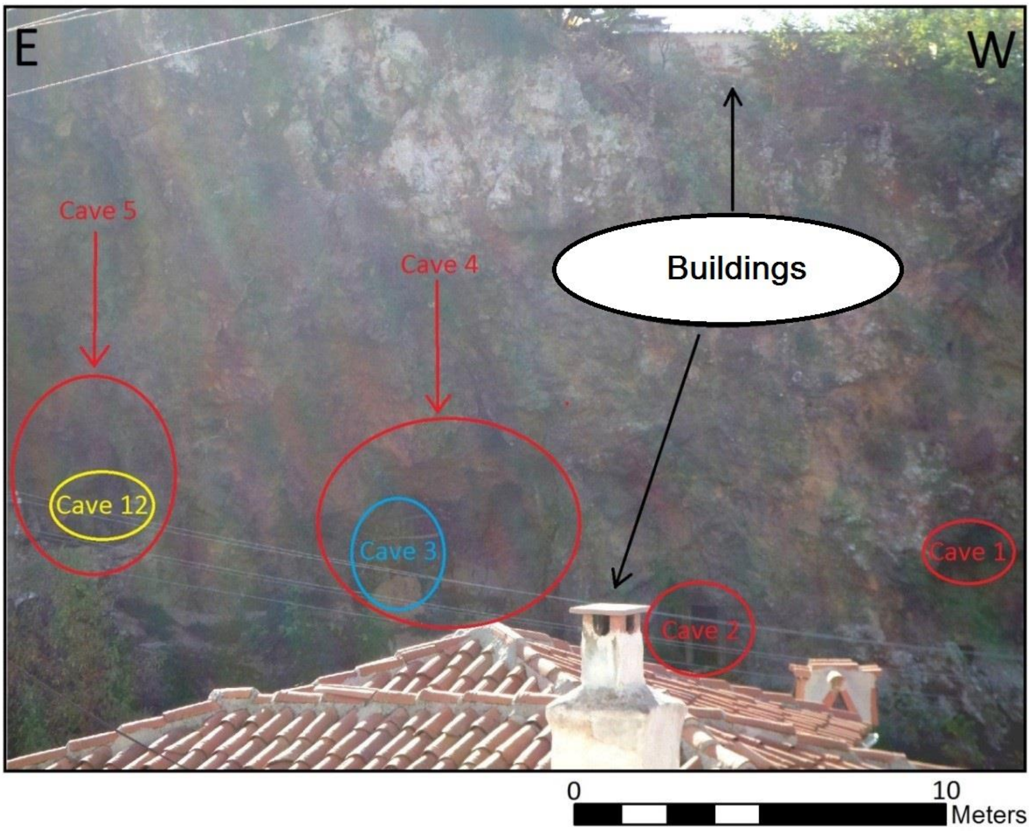

Figure 6.2. Field view of the Caves 1-5 and Cave 12 of Asartepe

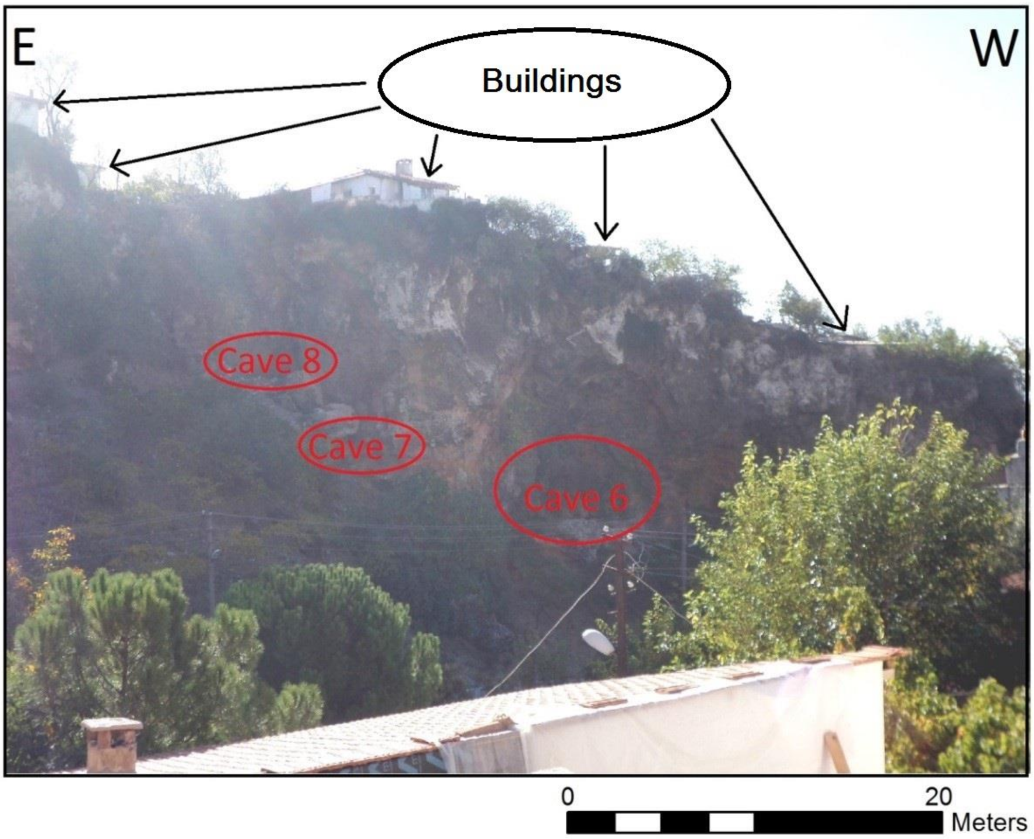

Figure 6.3. Field view of the Caves 6-8 of Asartepe

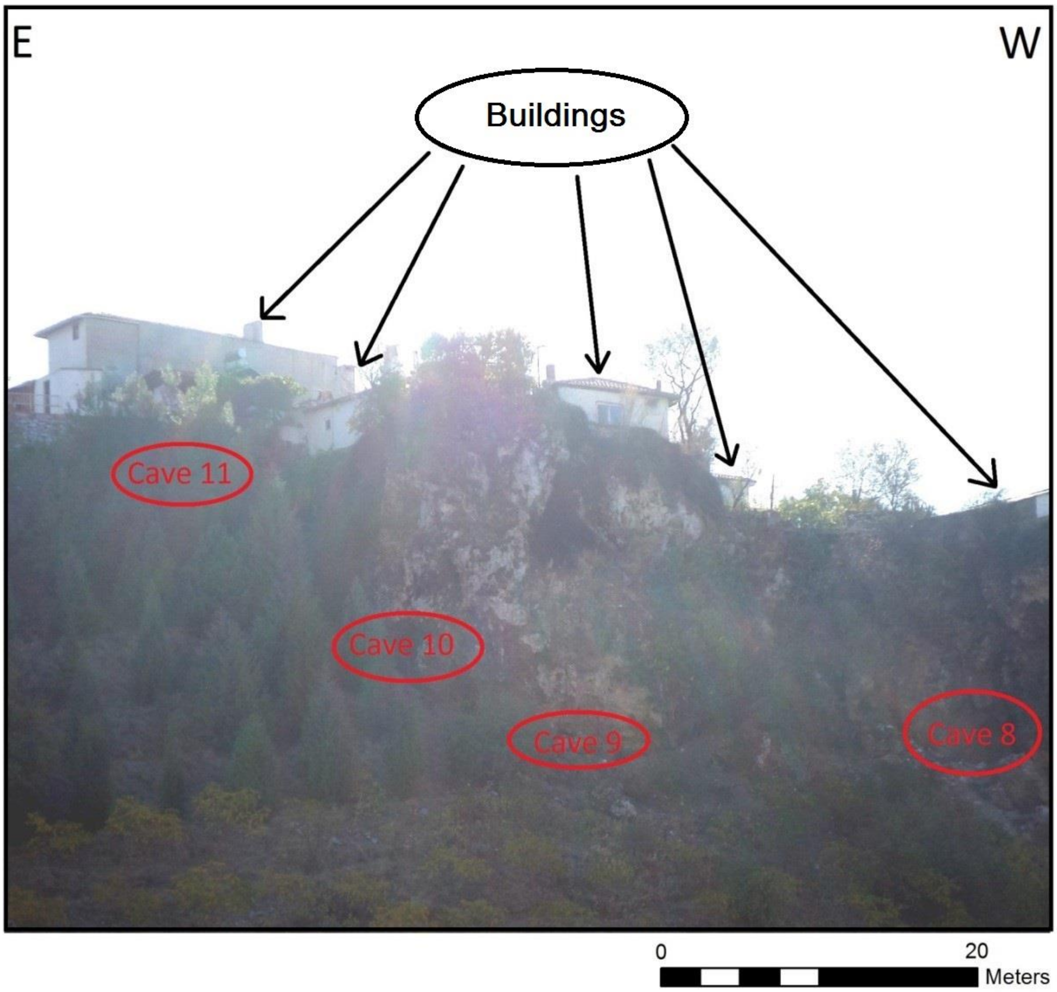

Figure 6.4. Field view of the Caves 8-12 of Asartepe

On the karstic cavities in this area, there are 1-2 storey houses, which are also still used actively. It is thought that not only a number of caves move up to depth of 10 m into slope but also some caves locked their mouths due to used as warehouse or barn purposes are deeper than such this distance into the slope of the conglomeratic occurences. Considering the active seismicity of the zone, and the efficiency of surface and underground waters, it can be believed that the caves will continue to grow into the slope over time and face the danger of collapsing ceilings. Finally, stabilization of caves should be made in connection with transport of the settlement from this unsafe area to another safe place, and removal of the water from the environment with proper drainage system.

6.1.1. Internal structures

The insides of the cave occurences do not have a distinct internal structure except for the white colored calcite veneered flowstone observed in the restricted area. Some caves include one or two step structure(s) that might have evolved due to differential weathering and/or antropogenic effect.

6.2. Sedimentological Conditions

The muddy conglomerate and mudstone alternations are clearly seeming on stratigraphic section of the Asartepe cave occurences between 0 m and 25 m from bottom to top (Figure 6.6.).

Maximum grain size of white colored muddy conglomerates in the Asartepe cave occurences (Figure 6.5. and Figure 6.6.) is 15 cm between 0 m and 5 m depths. The clast-supported conglomerates are composed of poorly-sorted and moderately-rounded grains. Moreover, 10% cement and 90% clasts are constituents of the formed conglomerates. Furthermore, grain distributions of the conglomerates are more or less inhomogeneous. They consist of 80% fine grained- and 20% coarse grained- clasts.

Three thin and reddish-brown colored mudstone layers are shown between 5 m and 10 m levels in the formation. At the same time, two thin and white colored muddy conglomerates are realized between 5 m to 10 m levels. In addition, maximum grain size ranges of the conglomerates are 9.5 cm and 10.5 cm.

Maximum grain size of white colored muddy conglomerates is 14 cm between 10 m to 15 m levels. The conglomerates are composed of poorly-sorted and poorly-rounded grains. Moreover, 50% matrix and 50% clast-supported conglomerates are obviously shown in the formation. Furthermore, grain distributions of the conglomerates are more or less inhomogeneous. They consist of 20% fine grained- and 80% coarse grained clasts.

Red-brown colored mudstone layer (Figure 6.5.) is observed between 15 m and up to 16 m levels of the occurences. Maximum grain size of white colored muddy conglomerates is 22 cm between 16 m to 25 m levels. The conglomerates are composed of well-sorted and well-rounded grains. Moreover, 50% matrix and 50% clast-supported conglomerates are obviously shown in the occurences. Furhermore, grain distributions of the conglomerates are more or less homogeneous. They consist of 98% fine grained- and 2% coarse grained-clasts.

Whole conglomerates's grains metioned above occurred from cobbly dolomitic limestone of Lycian Nappes. These conglomerates are located between two mudstone layers.

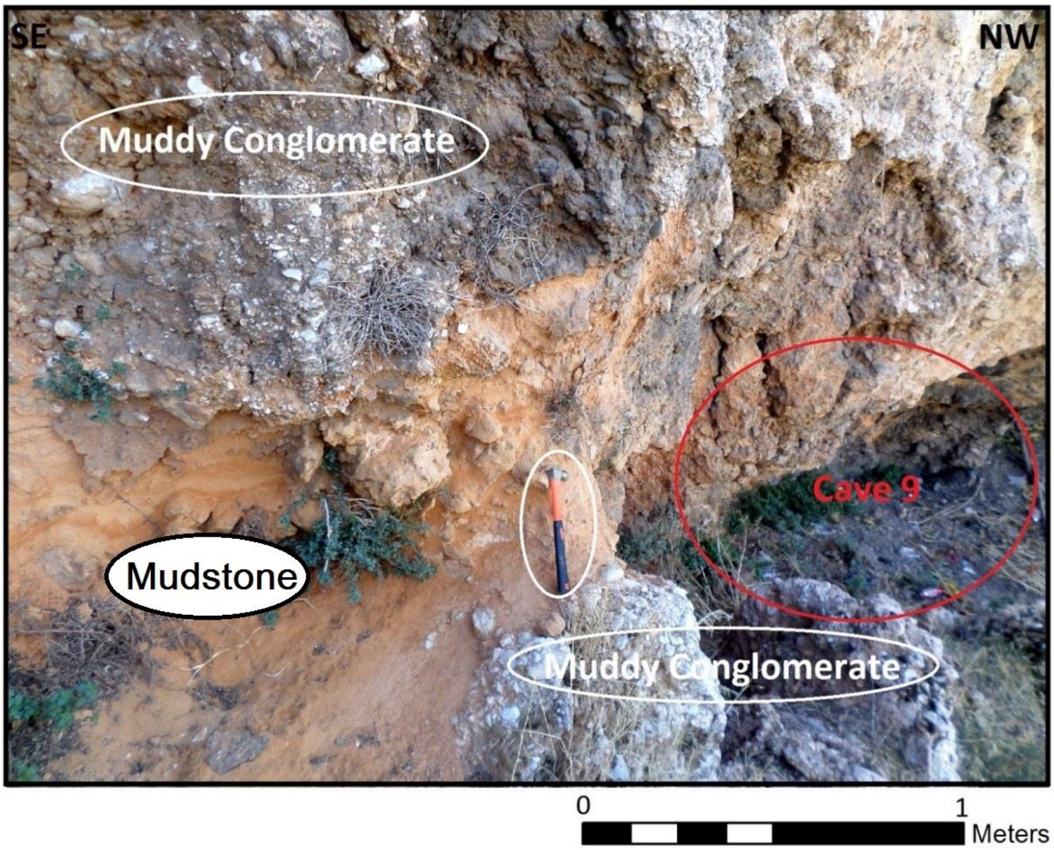

Figure 6.5. Mudstone layer is located between two layers of the muddy conglomerates at Asartepe cave occurences.

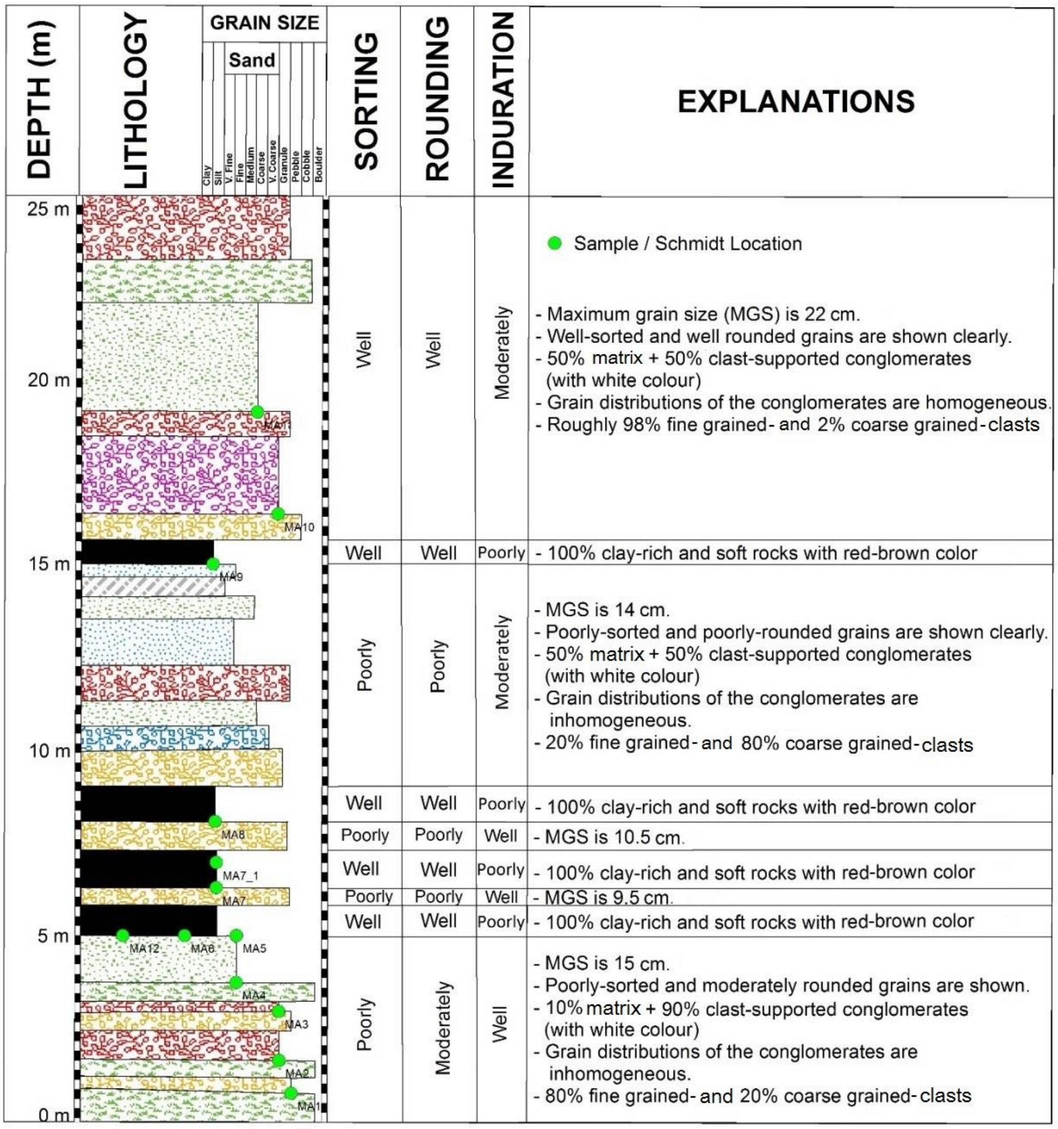

Figure 6.6. Detailed stratigraphic section of Asartepe cave occurences

Quite high and wide caves in total of between 12 and 15 m are seen in the slope of the steep rocky part of the Asartepe. The caves in width and height of 1-15 m are located in large caves or in scraps outside large caves. The caves are located into conglomerate package that has its thickness of 20-22m. It is observed not only predominantly pebble-sized gravels, but also cobble-sized gravels in a rather poorly sorted unit. Generally, matrix supported muddy conglomerates are made up of rounded and subrounded granules, pebbles and cobbles. In thicknesses ranging from 2-5 m thick, red colored and pebbly sandstone, and mudstone formations were observed between 10 cm-100 cm thick layers that are between roughly layered and imbricated gravel layers. All of the gravels are white-gray colored limestone granules, pebbles, and cobbles.

6.3. Hydrogeological Condition

The Basmacı or Asartepe stream is either the most important water source or supply in the area. The stream, which has a drainage network of 5.453 km^2, varies in flow rates and also dries in very hot days in summer. A flow direction of hydrogeological surface water near the Asartepe cave occurences is from north to south. Numerous small and large sources have been identified near the base of the caverns. One of those sources, which provides constinuous discharge, is used in watering or the irrigation of the fruit gardens. Another one of them has been turned into a water fountain for drinking and usege purpose and its flow rate is measured as 1.2 lt/s. In addition, the flow rate (Q) of the water is 0.5 liters per 4 second on date of 29.09.2016 and 0.5 liters per 3.5 second on date of 20.01.2017 for Asartepe cave occurences. Damp areas extending along the cracks and spreading into the cave have been identified. Red colored thin units and a white colored thin carbonate layer over the conglomerate matrix were found. There are no observed leakages and temporary welds following cracks in the cave after the humidity or excessive rainfall in the cave.

6.4. Structural Properties

The strike and dip angle of cliff border in Asartepe was carefully measured as N 15-35° W / 75-80° SW when the occurences of the cave were considered as parallel to the main structural elements. The cave occurences is located in lower level of the Yatağan Formation between B and C profiles of Gül et al. (2016). Gül et al. (2016) reported that in the vicinity of Asartepe, sets of joint developed in 3-4 different directions, which means that the conglomeratic rocks are dramatically broken up in different sizes and the continuity of some joint systems is up to 20 m (Figure 6.7 and Figure 6.8). 3-4 joint sets were also observed during the field study.

The cave occurences in the region have undergone different decomposition due to either different strength of the units or influx and infiltration of underground-water leaked along cracks, joints and fractures based on systematically continuous repetitive active tectonism. In the first stage, the conglomeratic sides of the occurences are regularly fragmented after the fine grained level is weakened.

Secondly, they have caused the development of dramatically depressed or collapsed pebbles in the cave floor.

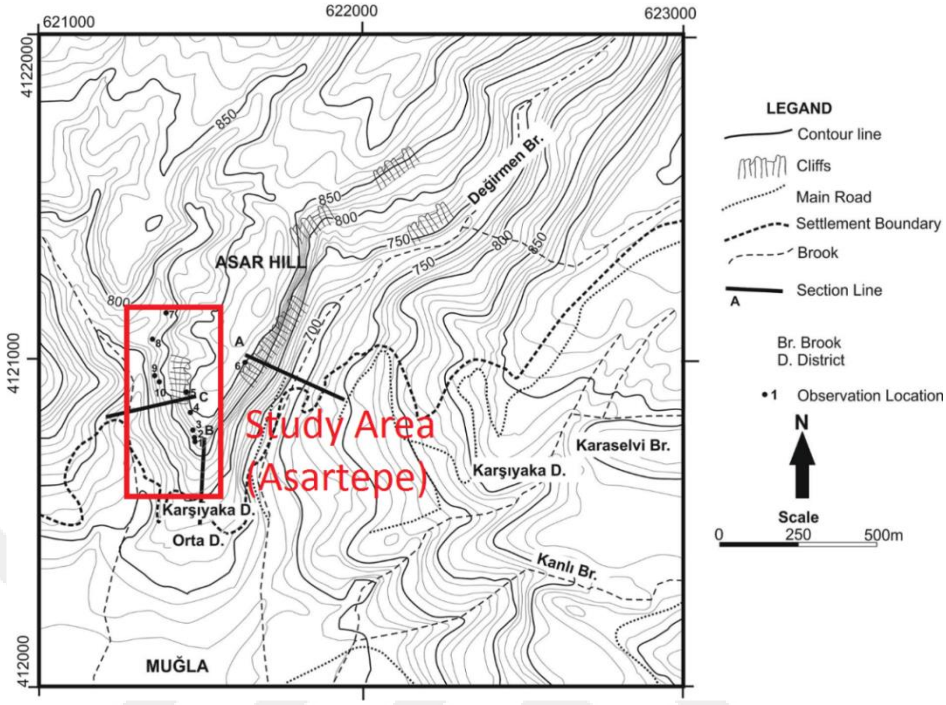

Figure 6.7. Countour map of Asartepe and its surrounding (taken from Gül et al., 2016)

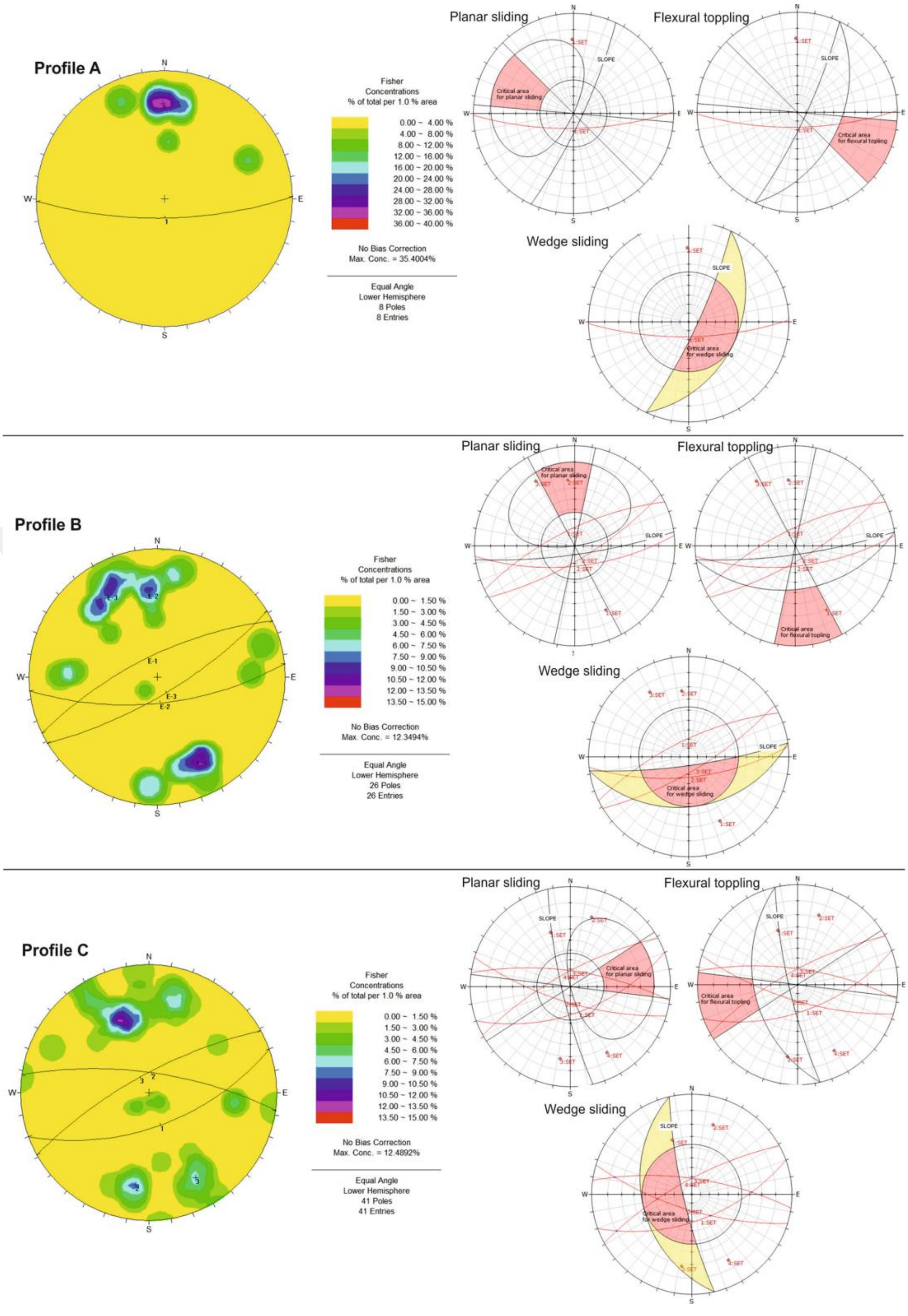

Figure 6.8. Kinematic analyses results based on DIPS application (Gül et al., 2016)

6.5. In-Situ- and Laboratory-Test

According to the classification systems of Anon (1979), the muddy conglomerates in Asartepe are carried out in experiments and defined as low density (1.9 g/cm^3) and medium porosity rock (6.4%) for conglomerates, and medium density (2.5 g/cm^3) and low porosity rocks (4.0%) for mudstones. The matrixes of the conglomerates are in soft rock class and their grains are very hard rock, whereas mudstones have been evaluated in very soft rock while all the conglomeratic pages are completely defined as hard rocks (Gül et al., 2016) in accordance with the classification system of De Beer (1967).

In this study, variable resistance results were obtained with Schmidt hammer tests performed on flat surfaces of the conglomeratic unit. The strengths of the unit were measured between 6.635-30.225 MPa (Table 6.1.). The measurements were geostatistically assessed (Table 6.1. to Table 6.5.). According to the results of the point load index test carried out in the laboratory on hand samples taken from the field, the strengths of the unit varied between 1.14-5.43 MPa (Table 6.4.).

Geotechnical database was obtained and given below (Table 6.1. to Table 6.5.). The database is made up of the Rebound Number, Physical and Mechanical Properties of rocks, soil physical properties, point load strength indexes of the rocks, and slake durability indexes of rocks (Figure 6.9. to Figure 6.14.).

It is a positive relationship between Rebound Number and Porosity (%) (Figure 6.9.). The Asartepe cave formation can be classified as “medium to high strength and porosity (%)” according to graph of Rebound Number versus Porosity (%).

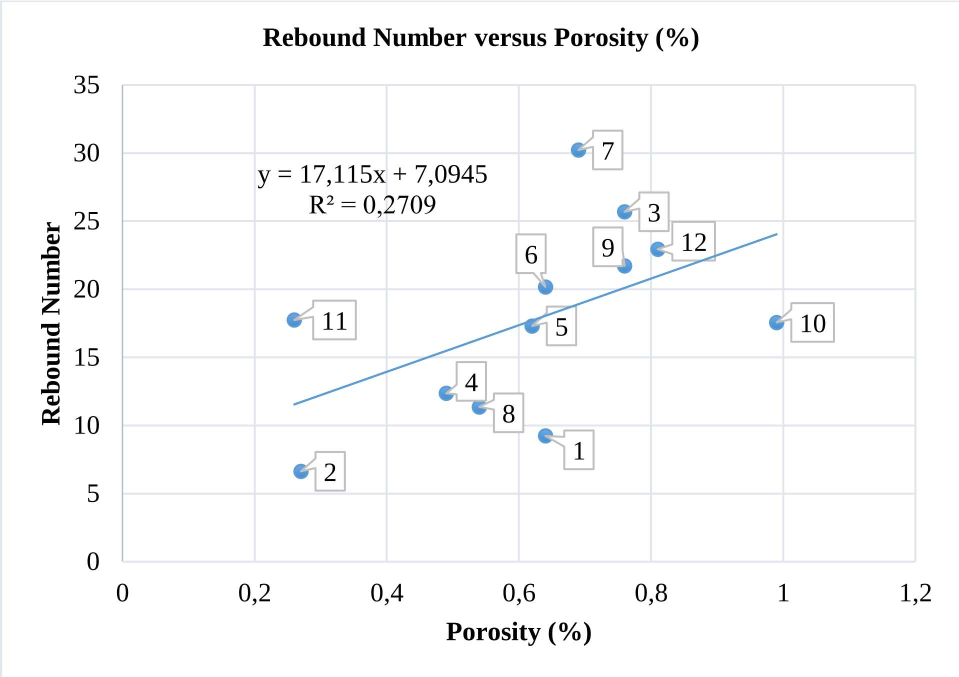

Figure 6.9. Schmidt Hammer rebound number versus porosity values of Asartepe Cave Occurences

It is a negative relationship between Porosity (%) and Dry Unit Weights (kN/m^3) (Figure 6.10.). The Asartepe cave occurences may be grouped as "medium to high Porosity (%) and Dry Unit Weights (kN/m^3)" with respect to graph of Porosity (%) versus Dry Unit Weights (kN/m^3).

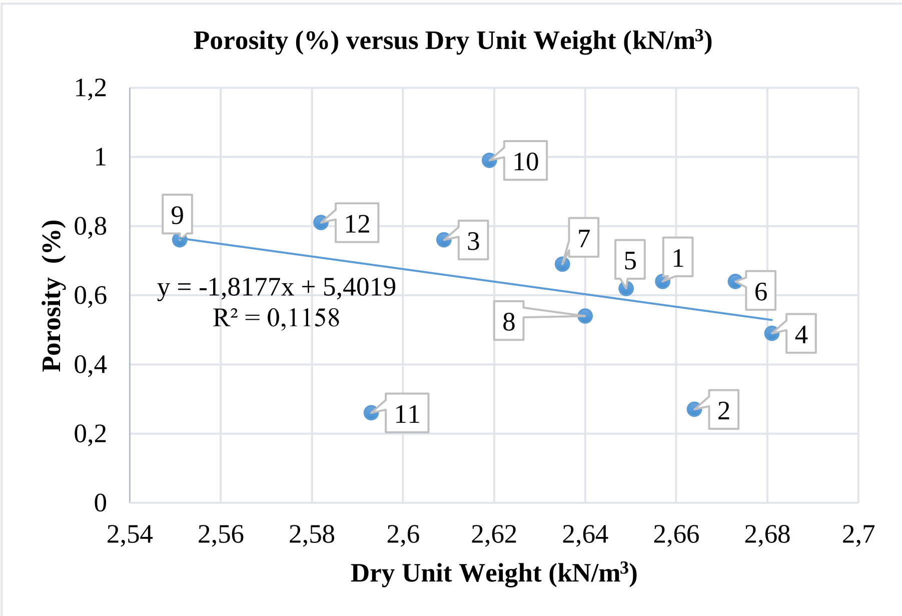

Figure 6.10. Porosity versus Dry Unit Weight graph for Asartepe Cave Occurences

It is a negative relationship between Dry Unit Weight (kN/m^3) and Water Absorption on Weight (%) (Figure 6.11.). The Asartepe cave occurences are able to be categorized as “medium to high Dry Unit Weight (kN/m^3) and Water Absorption on Weight (%)” in accordance with graph of Dry Unit Weight (kN/m^3) versus Water Absorption on Weight (%).

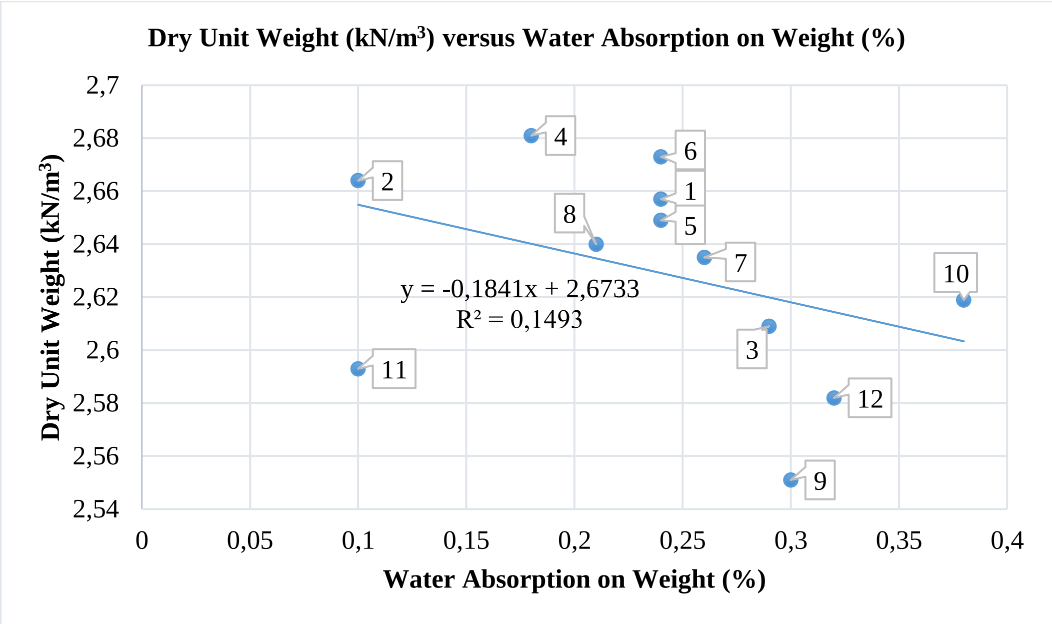

Figure 6.11. Dry Unit Weight versus Water Absorption by Weight graph for Asartepe Cave Occurences

It is a positive relationship between Point Load Strength Index (Is) and Dry Unit Weight (kN/m3) (Figure 6.12.). The Asartepe cave formation can be classified as “medium to high Point Load Strength Index (Is) and Dry Unit Weight (kN/m^3)” according to graph of Point Load Strength Index (Is) versus Dry Unit Weight (kN/m^3).

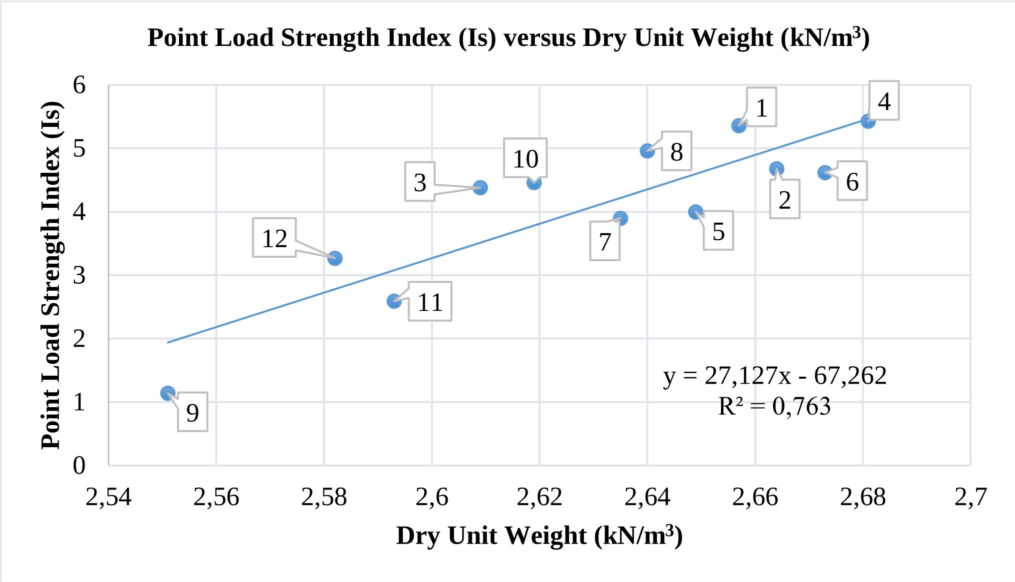

Figure 6.12. Point Load Strength Index versus Dry Unit Weight graph for Asartepe Cave Occurences

It is a negative relationship on the graphs of Dry Unit Weight (kN/m^3) versus Water Absorption on Volume (%), and Point Load Strength Index (Is) versus Porosity (%) (Figures 6.13. and 6.14.). The Asartepe cave occurences has medium to high durability.

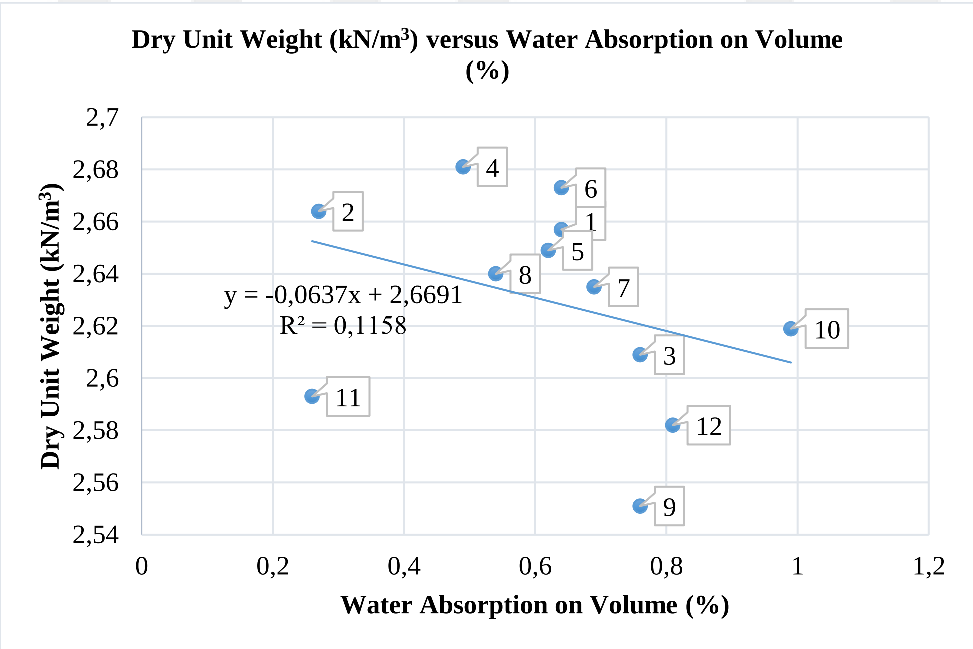

Figure 6.13. Dry Unit Weight versus Water Absorption by Volume graph for Asartepe Cave Occurences

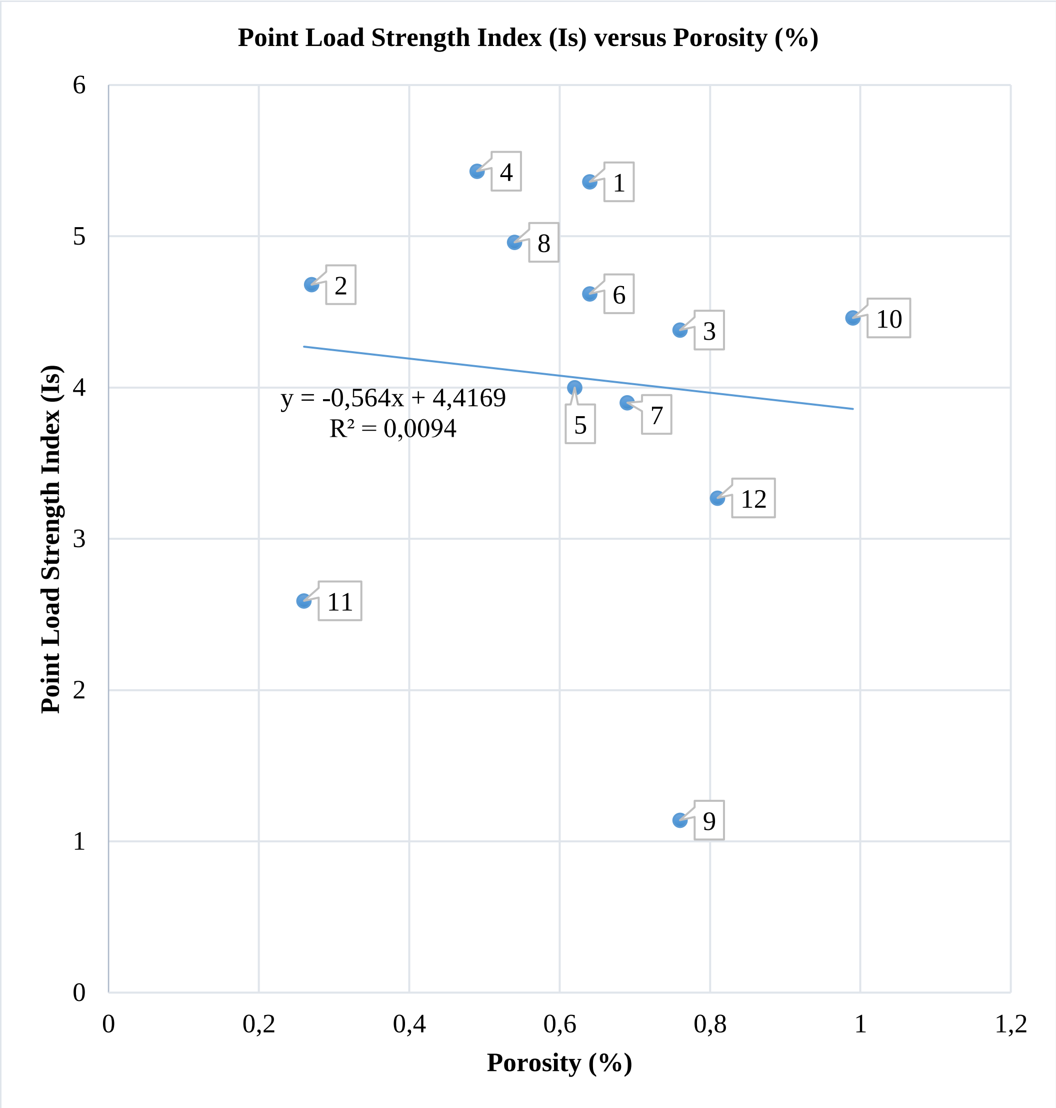

Figure 6.14. Point Load Strength Index versus Porosity graph for Asartepe Cave Occurences

Table 6.1. Rebound Number for Asartepe Cave Occurences

Descriptions and Measurements			Geometric Parameters of Cave (metre)			Coordinates (x,y,z) (WGS84-UTM)		
Occurence Name		Rebound Number	Width (m)	Height (m)	Depth (m)	x	y	z (metre)
Outcrops	**Outcrop 1**	22,94	2,32	1,27	No Data	35621253	4120260	692
	Outcrop 2		1,71	1,15	No Data	35621132	4120266	693
Cave 1		9,23	13,34	7,68	4,98	35621249	4120240	695
Cave 2		6,63	4,21	2,69	3,38	35621249	4120240	695
Cave 3		25,69	3,39	2,78	2,12	35621253	4120243	696
Cave 4		12,36	2,88	2,18	6,83	35621263	4120249	707
Cave 5		17,31	8,85	15,8	5,51	35621263	4120249	708
Cave 6		20,17	14,89	15,88	9,71	35621310	4120425	709
Cave 7		30,22	3,15	1,82	2,72	35621336	4120448	710
Cave 8		11,37	4,96	2,96	6,58	35611824	4107675	712
Cave 9		21,72	2,55	2,35	1,47	35621329	4120435	713
Cave 10		17,56	2,35	1,64	1,58	35621336	4120290	714
Cave 11		17,74	2,24	1,38	5,74	35621214	4120254	718
Elements								
Minimum		6,63	1,71	1,15	1,47			
Maximum		30,22	14,89	15,88	9,71			
Arithmetic Mean		17,74	5,14	4,58	4,60			
Median		17,65	3,15	2,35	4,98			
Standard Deviation		6,96	4,39	5,26	2,59			

Table 6.2. Physical and Mechanical Properties of conglomeratic limestones within Asartepe cave occurences

Sample Number	Occurence Name	Volume (V) (cm^3)	Dry Weight (Wd) (g)	Saturated Weight (Ws) (g)	Volume of Void (cm^3)	Porosity (%)	Void Rate	Water Absorption Weight (%)	Water Absorption Volume (%)	Specific Gravity (Gs)	Saturated Unit Weight (kN/m^3)	Dry Unit Weight (kN/m^3)
MA1	**Cave 1**	124,30	330,30	331,10	0,80	0,64	0,006	0,24	0,64	2,67	2,66	2,65
MA2	**Cave 2**	112,20	298,90	299,20	0,30	0,27	0,003	0,1	0,27	2,67	2,66	2,66
MA3	**Cave 3**	105,60	275,50	276,30	0,80	0,76	0,005	0,29	0,76	2,62	2,61	2,60
MA4	**Cave 4**	101,30	271,60	272,10	0,50	0,49	0,010	0,18	0,49	2,69	2,68	2,68
MA5	**Cave 5**	112,30	297,50	298,20	0,70	0,62	0,010	0,24	0,62	2,66	2,65	2,64
MA6	**Cave 6**	110,20	294,60	295,30	0,70	0,64	0,010	0,24	0,64	2,69	2,68	2,67
MA7	**Cave 7**	100,80	265,60	266,30	0,70	0,69	0,010	0,26	0,69	2,65	2,64	2,63
MA8	**Cave 8**	110,70	292,30	292,90	0,60	0,54	0,010	0,21	0,54	2,65	2,64	2,64
MA9	**Cave 9**	105,30	268,60	269,40	0,80	0,76	0,010	0,3	0,76	2,57	2,55	2,55
MA10	**Cave 10**	101,30	265,30	266,30	1	0,99	0,010	0,38	0,99	2,64	2,62	2,61
MA11	**Cave 11**	113,30	293,80	294,10	0,30	0,26	0	0,1	0,26	2,60	2,59	2,59
MA12	**Cave 12**	110,10	284,60	285,50	0,90	0,81	0,010	0,32	0,81	2,58	2,57	2,58
Elements												
Minimum		100,80	265,30	266,30	0,30	0,26	0	0,1	0,26	2,57	2,55	2,55
Maximum		124,30	330,30	331,10	1	0,99	0,010	0,38	0,99	2,69	2,68	2,68
Arithmetic Mean		108,95	286,55	287,22	0,67	0,62	0,007	0,23	0,62	2,64	2,63	2,62
Median		110,15	288,45	289,20	0,70	0,64	0,010	0,24	0,64	2,65	2,64	2,63
Standard Deviation		6,67	18,82	18,77	0,21	0,21	0,003	0,08	0,21	0,04	0,04	0,03

Table 6.3. Soil Test Result for Asartepe cave occurences

Method		TS 1900-1					-
Sample Number	Occurence Name	Moisture Content	Specific Gravity	Grain Size Distribution (Sieve Analysis)			Unified Soil Classification System (USCS)
		Wn	Gs	Gravel	Sand	Silt + Clay	
		(%)	(-)	(%)	(%)	(%)	
MA7_1	**Cave 7**	7,70	2,59	0	74,20	25,80	SM
(SM= Silty sands, sand-silt mixtures)							

Table 6.4. Point Load Stength Index Test Result for Asartepe cave occurences

Sample Number	Occurence Name	Physical Properties of Samples										
		Width (mm)	Thickness (mm)	Volume (cm^3)	Sample of Weight (g)	Failure Load (P) (kN)	Unit Weight (g/cm^3)	Core Diameter (De) (mm)	Core Diameter in Square (De^2) (mm^2)	Point Load Strength Index (Is) ($Is=Px1000/De^2$) (MPa)	Size Correction Factor (F)	Point Load Strength Index (Is_{50}) ($Is_{50}=Px1000/De^2$) (De=50mm) (MPa)
MA1	**Cave 1**	61,46	43,55	65	172,50	18,28	2,654	58,39	3409,40	5,36	1,07	7,31
MA2	**Cave 2**	51,20	40,10	45	119,60	12,25	2,658	51,14	2615,40	4,68	1,01	4,9
MA3	**Cave 3**	52,25	39,80	50	130,20	11,61	2,604	51,47	2649,10	4,38	1,01	4,64
MA4	**Cave 4**	68,35	45,30	45	120,20	21,41	2,671	62,80	3944,30	5,43	1,11	8,56
MA5	**Cave 5**	59,70	45,90	60	158	13,97	2,633	59,08	3490,70	4	1,08	5,58
MA6	**Cave 6**	52,70	39,20	65	172	12,15	2,646	51,30	2631,60	4,62	1,01	4,86
MA7	**Cave 7**	59,50	39,60	55	144,50	11,71	2,627	54,79	3001,50	3,9	1,04	4,68
MA8	**Cave 8**	50,15	34,80	50	131,30	11,03	2,626	47,15	2223,20	4,96	0,97	4,41
MA9	**Cave 9**	60,80	30,50	75	188	2,69	2,507	48,60	2362,30	1,14	0,99	1,07
MA10	**Cave 10**	51,25	34,30	65	169,90	10	2,614	47,32	2239,30	4,46	0,98	4
MA11	**Cave 11**	55,85	39,60	60	155	7,30	2,583	53,08	2817,40	2,59	1,03	2,92
MA12	**Cave 12**	62,75	35,70	45	115	9,33	2,556	53,42	2853,70	3,27	1,03	3,73
Elements												
Minimum		50,15	30,50	45	115	2,69	2,507	47,15	2223,20	1,14	0,97	1,07
Maximum		68,35	45,90	75	188	21,41	2,671	62,80	3944,30	5,43	1,11	8,56
Arithmetic Mean		57,16	39,02	56,66	148,01	11,81	2,614	53,21	2853,15	4,06	1,02	4,72
Median		57,67	39,60	57,50	149,75	11,66	2,626	52,27	2733,25	4,42	1,02	4,66
Standard Deviation		5,76	4,60	9,84	24,64	4,79	0,047	4,85	530,14	1,23	0,04	1,91

Table 6.5. Slake Durability Test Result for Asartepe cave occurences

Sample Number	Occurence Name	Physical Properties of Samples								Classification
		Slaking Fluid Temperature (^{0}C)	Drum Number	Weight of "Drum+Sample" (A) (g)	Weight of "Drum+Retained Sample" (1st Cycle) (B) (g)	Weight of "Drum+Retained Sample" (2nd Cycle) (C) (g)	Weight of Drum (D) (g)	Slake Durability Index (1st Cycle) Id(1)=[(B-D)/(A-B)]x100	Slake Durability Index (2nd Cycle) Id(2)=[(C-D)/(A-C)]x100	
MA1	**Cave 1**	20	1	2315,60	2285,50	2271,20	1844,40	93,60	90,60	Medium-High Slake Durability
MA2	**Cave 2**	20	2	2295,20	2265,30	2250,80	1865,90	93	89,70	Medium-High Slake Durability
MA3	**Cave 3**	20	1	2310,30	2258,50	2246,80	1844,40	88,90	86,40	Medium- High Slake Durability
MA4	**Cave 4**	20	2	2352,10	2342,50	2330,30	1865,90	98	95,50	High Slake Durability
MA5	**Cave 5**	20	1	2385,60	2336,90	2330,60	1844,40	91	89,80	Medium-High Slake Durability
MA6	**Cave 6**	20	2	2401,30	2367,80	2352,20	1865,90	93,70	90,80	Medium-High Slake Durability
MA7	**Cave 7**	20	1	2374,60	2325	2314,10	1844,40	90,60	88,60	Medium-High Slake Durability
MA8	**Cave 8**	20	2	2348,90	2322,10	2312,60	1865,90	94,50	92,50	Medium-High Slake Durability
MA9	**Cave 9**	20	1	2484,60	2348,60	2324,20	1844,40	78,80	74,90	Medium Slake Durability
MA10	**Cave 10**	20	2	2418,90	2374,10	2351,20	1865,90	91,90	87,80	Medium-High Slake Durability
MA11	**Cave 11**	20	1	2461,30	2361,20	2335,10	1844,40	83,80	79,50	Medium Slake Durability
MA12	**Cave 12**	20	2	2394,70	2325,10	2311,10	1865,90	86,80	84,20	Medium Slake Durability
Elements										
Minimum		20	1	2295,20	2258,50	2246,80	1844,40	78,80	74,90	
Maximum		20	2	2484,60	2374,10	2352,20	1865,90	98	95,50	
Arithmetic Mean		20	1,5	2378,59	2326,05	2310,85	1855,15	90,38	87,52	
Median		20	1,5	2380,10	2331	2319,15	1855,15	91,45	89,15	
Standard Deviation		0	0,52	58,55	38,25	35,88	11,22	5,20	5,68	

6.6. Petrographical Studies

A total of 2 thin sections of units of Asartepe cave site were selected from a total of 17 samples (e.g. hand-specimens) in order to determine their petrographical characteristics and properties. The thin sections of the limestones were carefully examined under light microscope to better understanding paragenetic sequences of the occurences according to spatial and temporal relationships.

Whether thin sections (modified from Gül et al., 2013) given below are binding or not, they are completely formed from calcite minerals. Their macro features resemble limestone-marls. Those thin sections presented below show fine levels clearly (see Figure 6.15 and Figure 6.16).

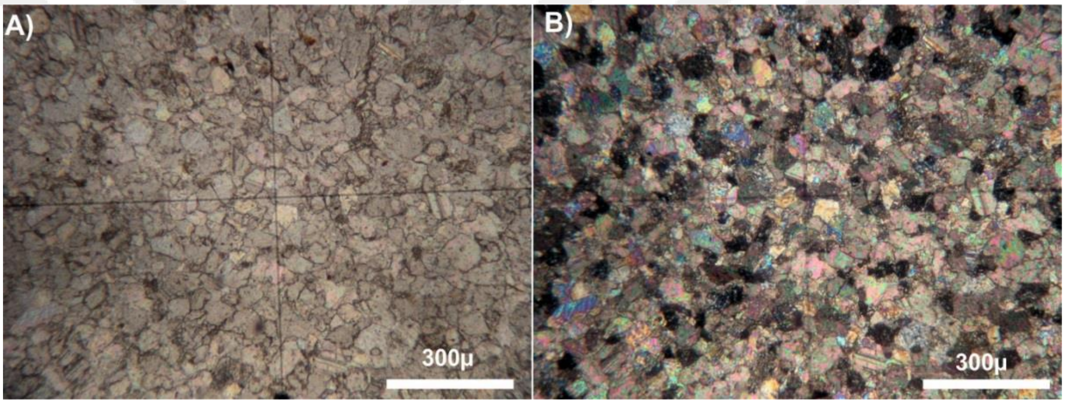

Figure 6.15. Thin-section views of calcarenite-calcilutite levels of Yatağan Formation; A) Normal light. B) Polarized light.

According to its thin sections named as H05-3 and H05-4 respectively, intraclastic limestone images of the Gereme Formation can be classified as intra-sparite (Folk, 1962) and grainstone (Dunham, 1962).

Thin sections of the Gereme Formation referred to H06-1 and H06-2 belong to dolomitic (rhombohedral crystals) limestone images.

In H07-1 and H07-2 thin sections, our main desired sections are the appearance conglomerates of the Yatağan Formation, and then the crystallized limestone pebbles of the Gereme Formation are connected by a clay sized binder.

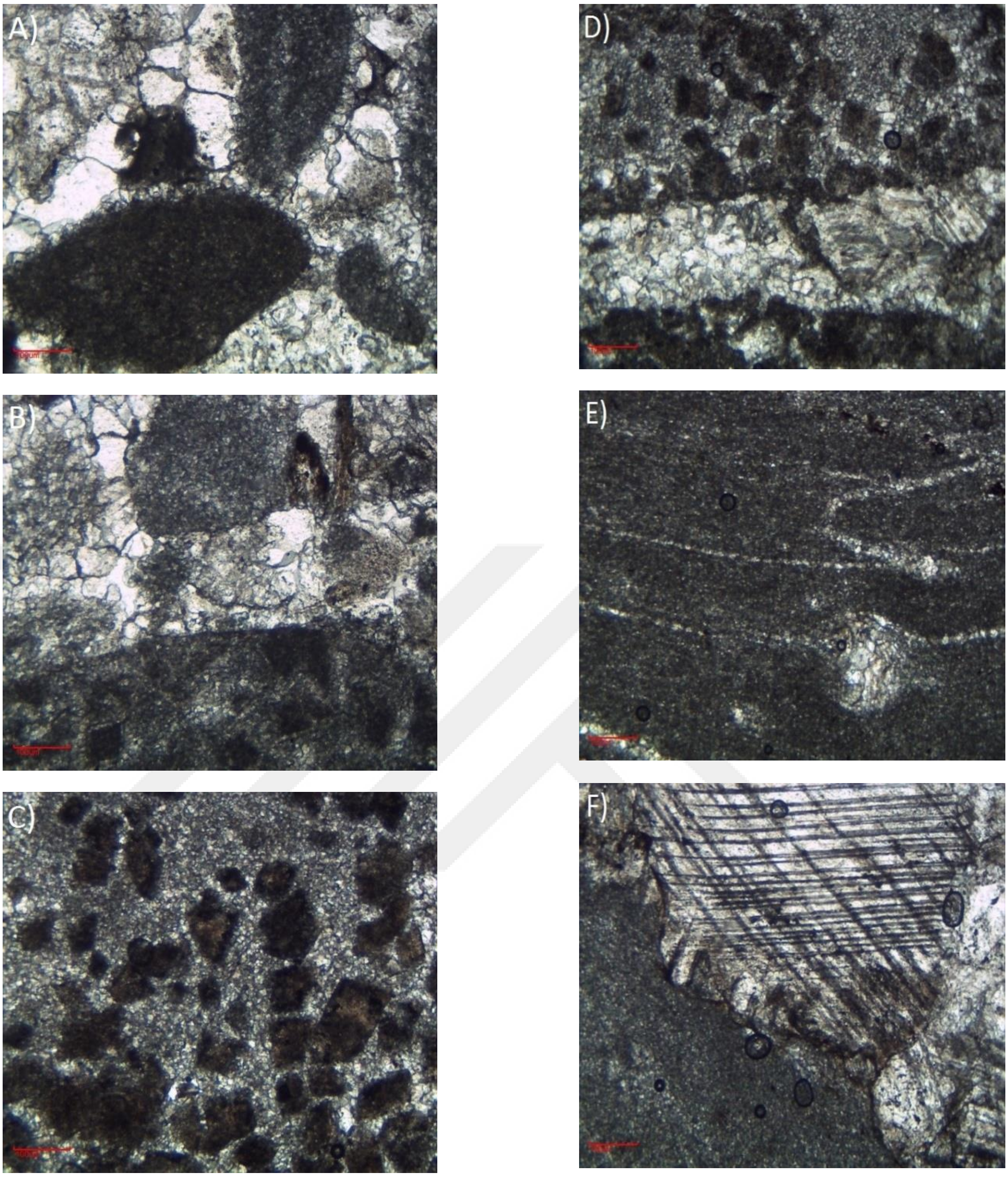

Figure 6.16. Microphotos of thin sections of older rocks: A) H05-3, B) H05-4, C) H06-1, D) H06-2, E) H07-1, F) H07-2

6.7. Interpretation

-Total of 12 caves were picked out within Asartepe cave occurences. All of these caves were formed on a steep slope within the occurences. In these occurences, special structures are not observed, except flowstone.

-Cave 6 is the largest geometric-sized cave, whereas, cave 10 is the smallest one.

-In addition, a flow direction of hydrogeological surface water near the occurences is from north to south. The flow rate (Q) of the water is 0.5 liters per 4 second on date of 29.09.2016 and 0.5 liters per 3.5 second on date of 20.01.2017 for Asartepe cave occurences.

-Special Threshold Limit Value (STLV) of Rebound Number is 22.945 in places without cave occurences. In contrast, cave 7 has the greatest of STLV of Rebound Number (30.225) whereas cave 2 has the smallest one (6.635) in cavern parts of the occurences.

-In the occurences, Cave 12 has the largest of porosity (0.81), however, Cave 11 has the smallest one (0.26).

-Moreover, Cave 1 has the biggest of failure load (P) (18.28 kN) but Cave 11 has the smallest one (10 kN).

-In addition, Cave 4 has the highest point load strength index (I_{S50}) (8.564 MPa), nevertheless, Cave 11 has the lowest one (2.92 MPa).

-Furthermore, Cave 4 has the highest of slake durability index for 1st and 2nd cycle (98-95.5 respectively), whereas Cave 9 has the lowest one (78.80-74.90 accordingly).

-Without cave occurences are more durable than within cave occurences on the muddy conglomeratic levels according to Rebound number.

-Cave development (cave sizes) in both sections generally appears in relation to lithological difference, differential weathering, strength difference, water content, distribution of cracks, rock weakening of water movement along cracks, anthropogenic factors and so on.

-The geological factors controlling cave occurences can be ranked with respect to the importance: (1) Lithological differences affecting either their resistances or strengths, (2) Crack-joint sets give rise to weakness of the conglomeratic rocks accompanying with suitable ways to water circulation, (3) Water content leads to weakness of the rocks, disseminating fine muddy levels, washing matrix of the conglomeratic rocks as well as growth of caves.

7. DAMLAM DERESİ CAVE OCCURENCES

7.1. Cave Locations

Total of 5 caves and 2 terranes were uncovered within Damlam Deresi cave site (Figure 7.1.). All of these caves and terranes were formed on two main steep slopes within the occurences (Figure 7.1. to Figure 7.7.). The caves are systematically named from the starting Cave 1 to the ending Cave 5 in accordance with more or less their different locations.

Figure 7.1. Damlam Deresi Cave locations (Modified from https://www.google.com/earth/)

The Damlam Caves are observed along the Damlam Deresi stream valley, which is located about 20 km from the center of Mugla Province. It has been used since the past as a recreation area, because it is cool especially in summer. The presence of numerous large and small caves has been identified within the conglomeratic occurences formed by the muddy conglomerates sloping of 70-85° on both sides of the valley.

Although many large and small caves were found in the Damlam Stream, measurements of these caves in total of 5 were done carefully. The number of 3 called Cave 3, which is used particularly in the recreation part, is the largest cave measured in Yatağan Formation.

Figure 7.2. Field view of the Cave 1 and Cave 5 of the Damlam Deresi Cave Occurences

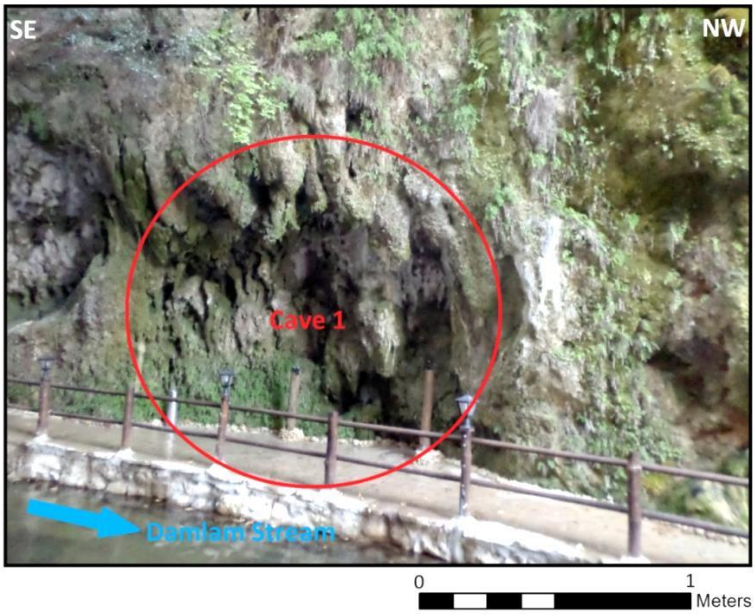

Figure 7.3. Field view of the Cave 1 of the Damlam Deresi Cave Occurences

Figure 7.4. Field view of the Cave 2 of the Damlam Deresi Cave Occurences

Figure 7.5. Field view of the Cave 3 of the Damlam Deresi Cave Occurences

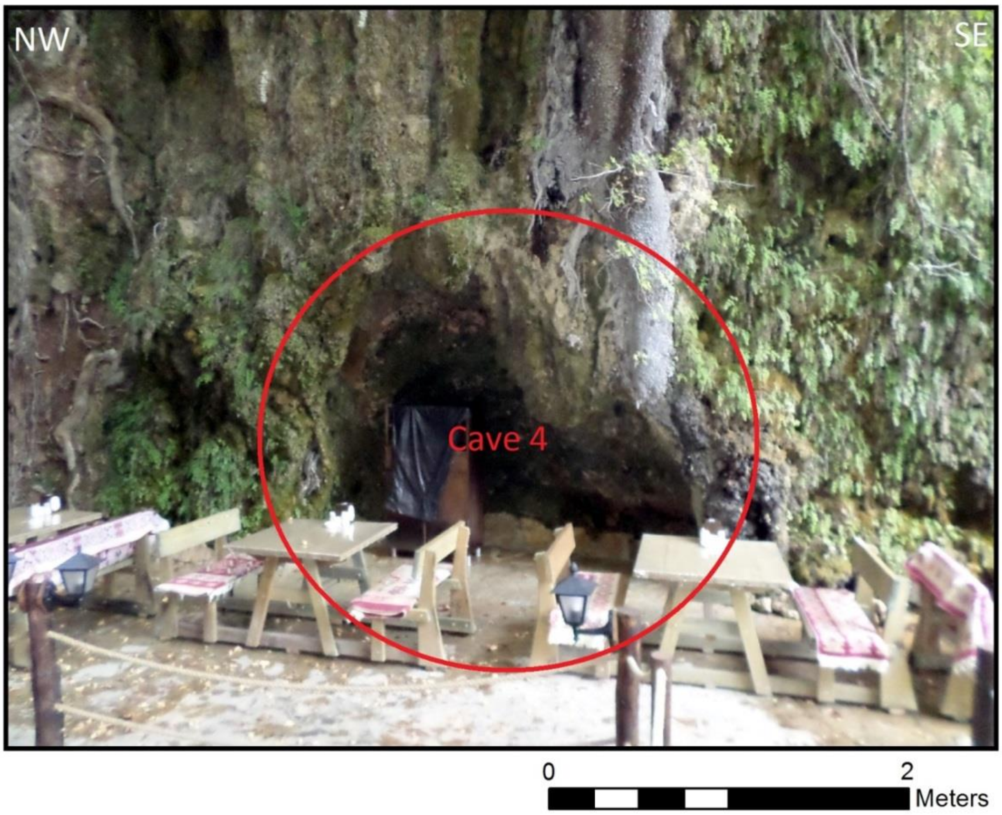

Figure 7.6. Field view of the Cave 4 of the Damlam Deresi Cave Occurences

Figure 7.7. Field view of the Cave 5 of the Damlam Deresi Cave Occurences

7.1.1. Internal structures of caves

The presence of special structures (e.g., stalactite-flowstone-travertine occurences) situated in the caves are investigated at the Damlam Deresi cave occurences (Figure 7.8. and Figure 7.9.). In this area, many different internal structures were observed inside the caves. In all of the caves where the water leakages were found, stalactites were observed which did not exceed 10-12 cm in size and did not exceed 1-2 cm in diameter, hanging from the ceiling of the cave. Flowstone occurences consisting of calcite, not more than half a centimeter thick, were evolved during the flow of groundwater over the mudstone and conglomerate strata. In some parts of these occurences they cover the entire valley wall. The normally white colored flowstone occurences have a green exterior appearance due to the overlying vegetation. The thick portions of the flowstone occurrences were simply called travertine. Because of the strength (durability) differences of these cavern units (mudstone can be easily broken down and crushed by hand) and the conglomerate levels are permeable, leaking water weakens the mudstone at the first stage and weakens the conglomerate matrix at the second stage. Firstly, moistening, softening and abrading of fine-grained detritus are washed and transported in order to leave voids behind in the cavern units. Ground and surface waters (that rich in carbonates for passing through rich levels of carbonates) go out of the unit and cause calcite deposits under the influence of atmospheric conditions on the surface. The calcite deposits allow a very small stalactite-soda straw, covering shaped flowstone and travertine occurences in thick deposits on the cave ceiling and walls.

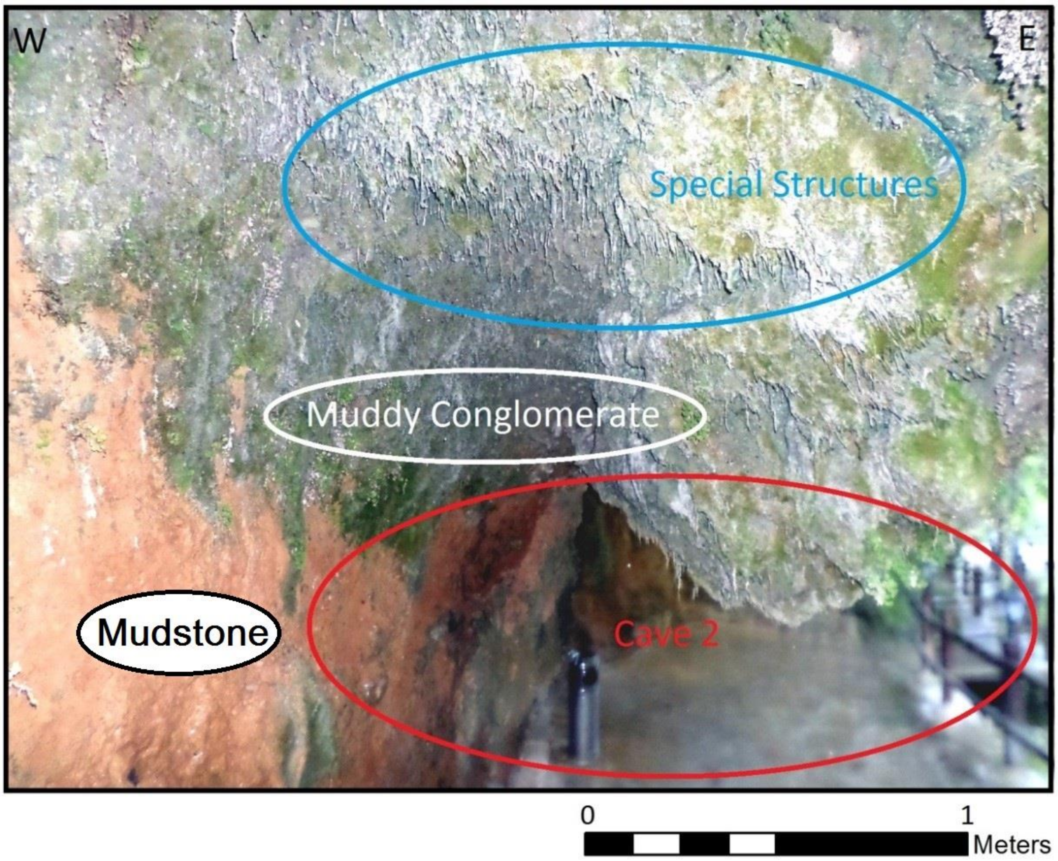

Figure 7.8. Special structures (e.g., stalactite-occurences) in Damlam Deresi cave occurences

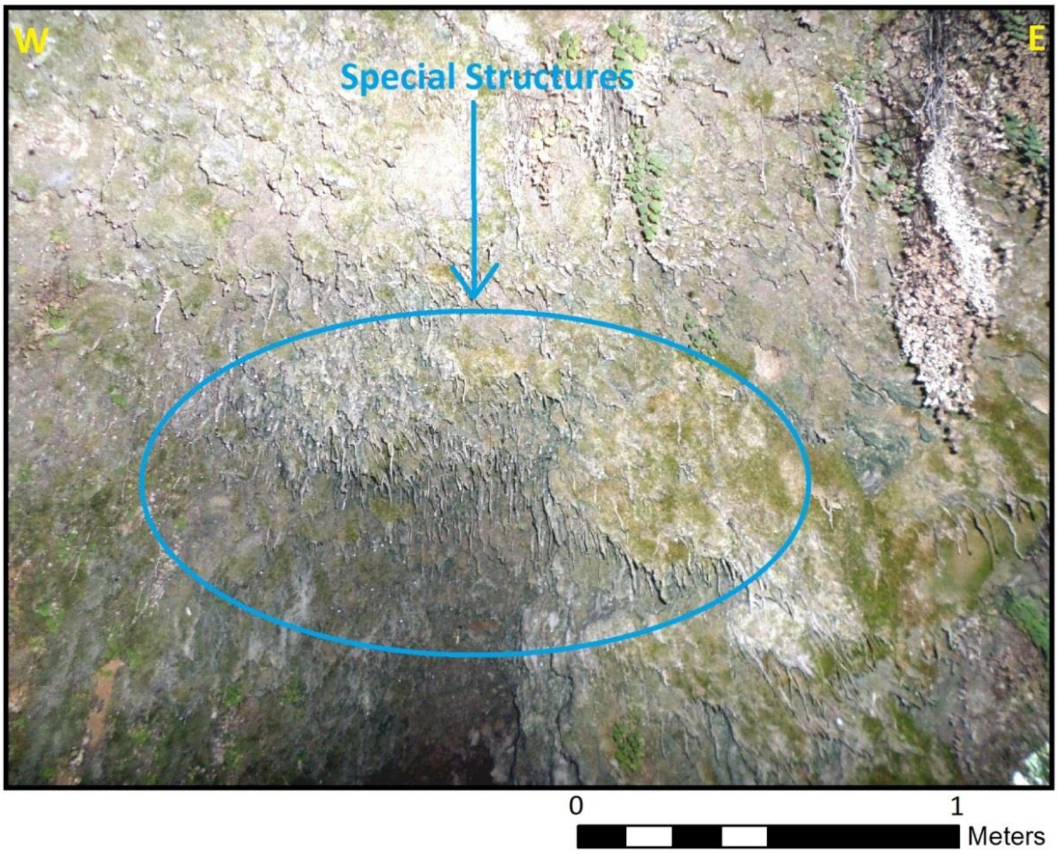

Figure 7.9. Special structures (e.g., stalactite-occurences) (in Cave 2) in Damlam Deresi cave occurences

7.2. Sedimentological Conditions

The muddy conglomerate and mudstone alternations are clearly seen on stratigraphic section of the Damlam cave occurences between 0 m and 25 m from bottom to top (Figure 7.10. and Figure 7.11.).

Red-brown colored mudstone layer in the Damlam Deresi cave occurences are observed between 0 m and 5 m levels.

Maximum grain size of light-brown colored muddy conglomerates in the occurences is 15 cm between 5 m and up to 12 m levels. The conglomerates are composed of well-sorted and well-rounded grains. Moreover, 50% matrix and 50% clast-supported conglomerates are shown in the formation. Furthermore, grain distributions of the conglomerates are more or less homogeneous. They consist of 95% fine grained- and 5% coarse grained-clasts.

Pale-brown colored mudstone layer in the formation is observed between 12 m and 15 m levels.

Maximum grain size of white colored muddy conglomerates in the formation is 14 cm between 15 m and up to 18 m levels. The conglomerates are composed of poorly-sorted and well-rounded grains. Moreover, 40% matrix and 60% clast-supported conglomerates are shown in the formation. Furthermore, grain distributions of the conglomerates are more or less homogeneous. They consist of 95% fine grained- and 5% coarse grained-clasts.

Light-brown colored mudstone layer in the formation is observed between 18 m and 20 m levels.

Maximum grain size of white colored muddy conglomerates in the occurences is 8 cm between 20 m and 25 m levels. The conglomerates are composed of moderately-sorted and well-rounded grains. Moreover, 60% matrix and 40% clast-supported conglomerates are shown in the occurences. Furthermore, grain distributions of the conglomerates are more or less homogeneous. They consist of 90% fine grained- and 10% coarse grained-clasts.

In whole, the conglomerates's grains metioned above may derived from cobbly dolomitic limestone of Lycian Nappes. These conglomerates are settled between two mudstone layers.

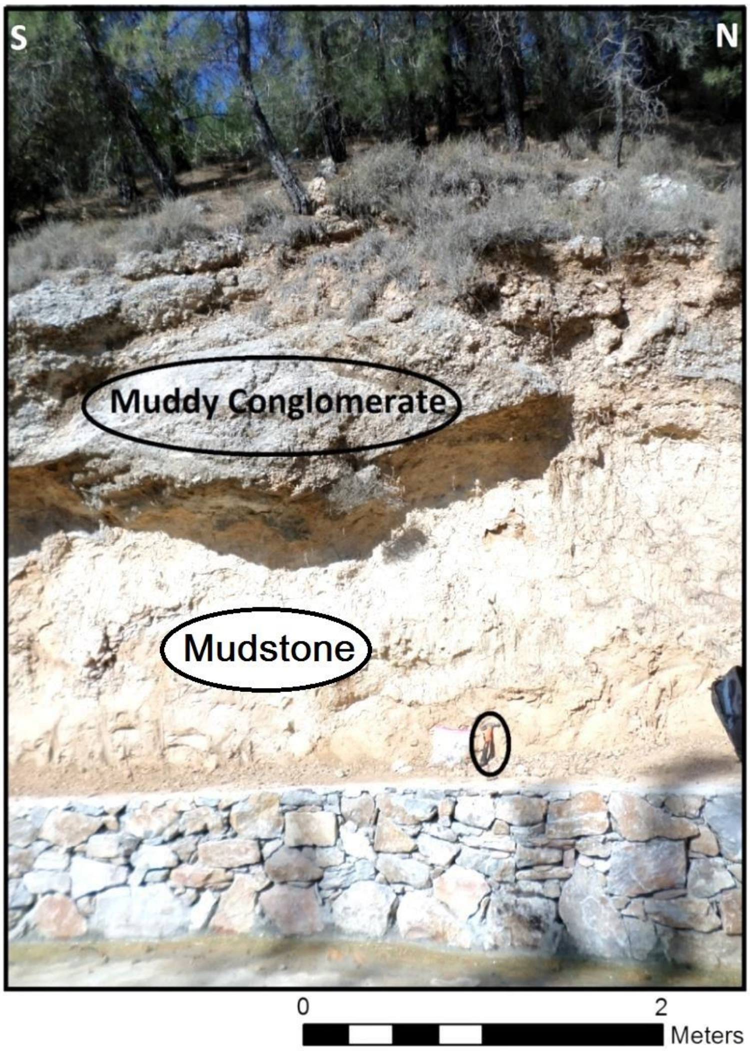

Figure 7.10. The light-brown colored mudstone layer is covered by the muddy conglomerate layer.

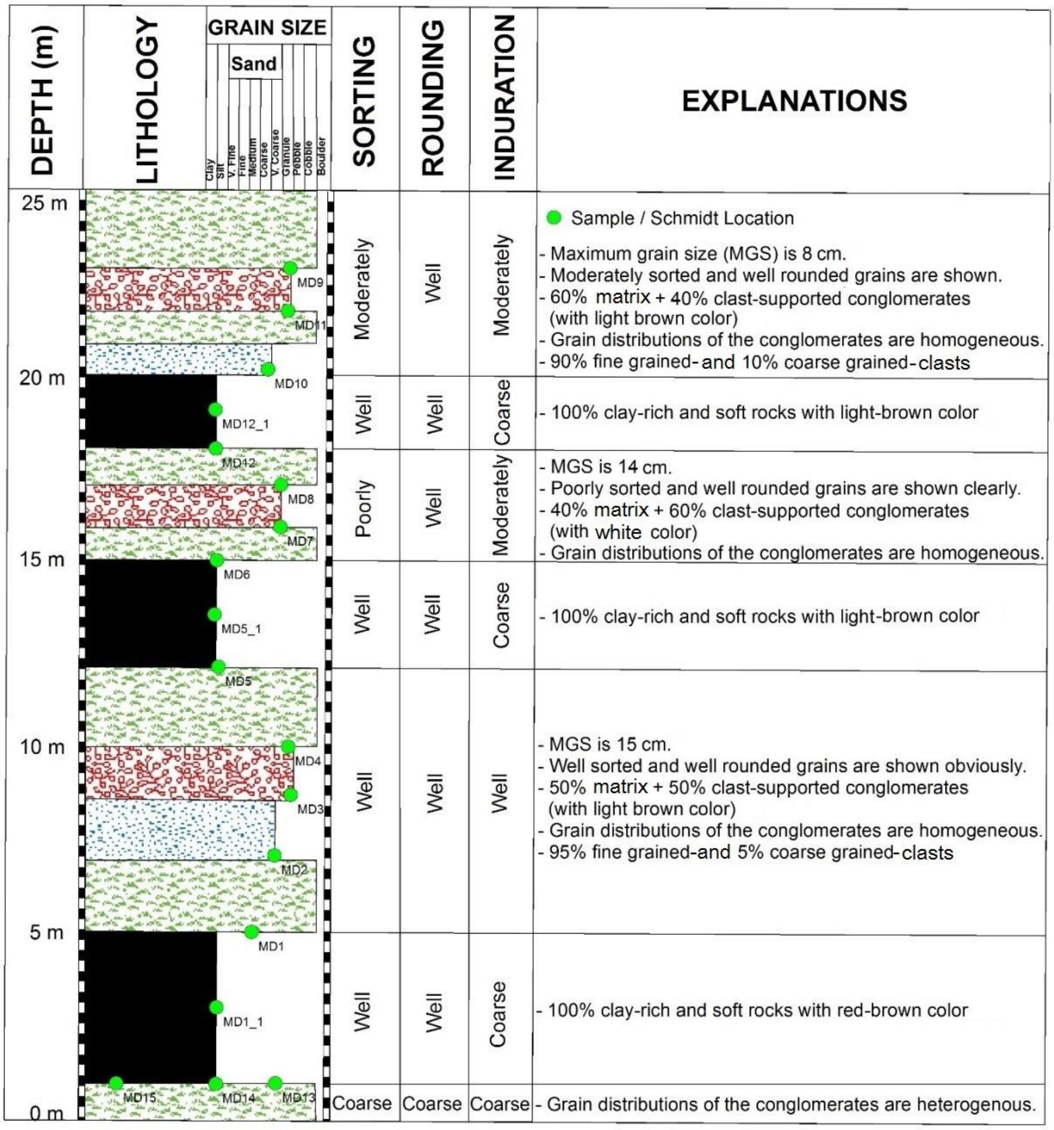

Figure 7.11. Detailed stratigraphic section of Damlam Deresi cave occurences

7.3. Hydrogeological Condition

Flow rate (Q) of the Damlam cave occurences was clearly measured as 0.5 lt/s during the most obvious time of leaks. In addition, the flow rate (Q) of the water is 0.5 liters per 21.6 second on date of 23.09.2016 for the cave occurences. The Damlam stream flowing through the cave development has a drainage network of 4.758 km^2. The river flow is from southwest to northeast. Finally, there are leakages and temporary welds following cracks in the cave after the humidity or excessive rainfall in the cave.

7.4. Structural Properties

The largest cave 3 extends along a wed or dump mudstone unit limited to the lower and upper conglomerates, whereas all other caves are located within the conglomerate and mudstone alternations. The conglomerates are found at the base of Damlam stream, when some units which are determined to obtain the inclination of N75°E / 18°SE, are guardedly examined in detail. They are placed beneath a mudstone level in the thickness of about 95 cm.

In the largest Cave 3, some breccias are moved into this moist mudstone (Measurement of Schmidt Hammer has not been able to be taken unfortunately) at the ending of its softening, erosion and washing. Medium-sorting sized grains, semi-rounding and rounding sized grains, located in the mudstone ceiling, has a maximum grain size of 24 cm and average grain size of 4 cm in the conglomeratic packages. Addionally, their matrixes are unexpectedly seen in impresively red colored mudstones. Although there are varying quantities from the conglomerates, it is constantly known that some waters spill into the valley from various points.

Over this formation, there are mudstone levels in 10-30 cm thick and an alternation of pebbles in 50 cm - 3 m thick with a rocky steep area of about 20 m which forms the walls of steep valleys. In the occurences, it was determined that erosional conglomerate levels were mostly detected to become matrix-supported and grain-supported at the base. The majority of the conglomerate grains were found to be limestone. As it is at Asartepe, the presence of a structural element with a definite system was detected here.

7.5. In-Situ- and Laboratory-Test

In this study, variable resistance results were obtained with Schmidt Hammer tests performed on flat surfaces of the conglomeratic unit. The strengths of the unit were measured between 8.535-24.48 MPa (Table 7.1.). The measurements were geostatistically assessed (Table 7.1. to Table 7.5.). According to the results of the point load index test carried out in the laboratory on hand samples taken from the field, the strengths of the unit varied between 0.77-5.48 MPa (Table 7.4.).

Geotechnical database was obtained and given below (Table 7.2. to Table 7.5.). The database is made up of the Rebound Number, Physical and Mechanical Properties of rocks, soil physical properties, point load strength indexes of the rocks, and slake durability indexes of rocks (Figure 7.12. to Figure 7.17.).

It is a positive relationship between Rebound Number and Porosity (%) (Figure 7.12.). The Damlam cave occurences can be classified as “medium to high strength and porosity (%)” according to graph of Rebound Number versus Porosity (%).

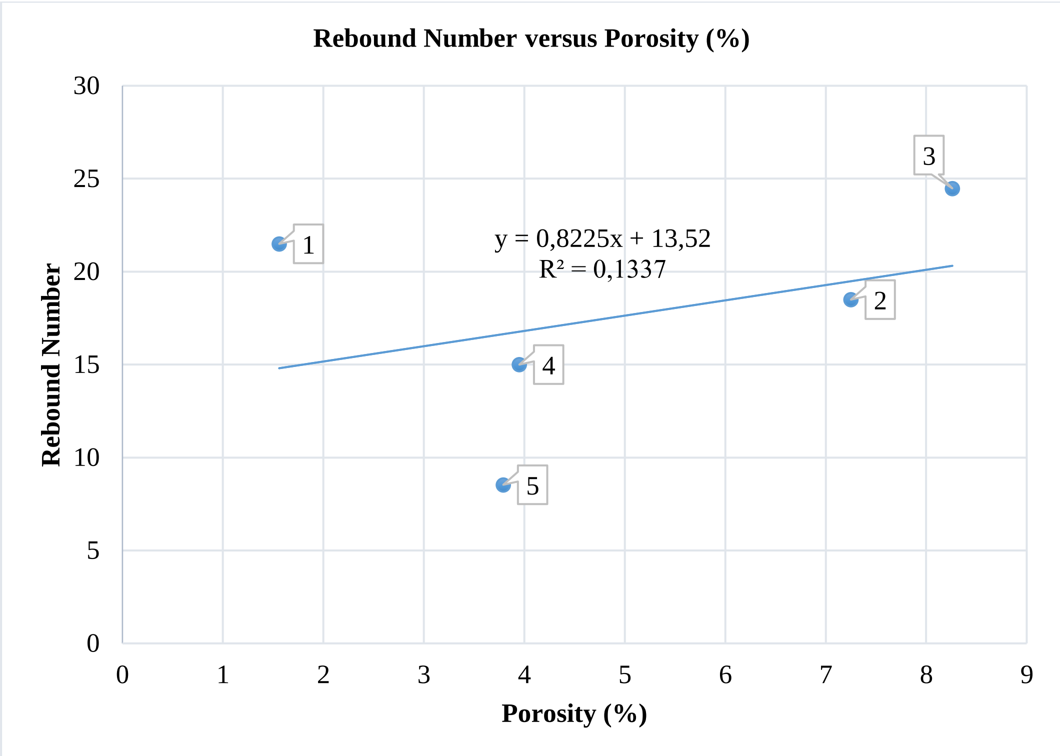

Figure 7.12. Schmidt Hammer Rebound Number versus Porosity graph for Damlam Cave Occurences

It is a negative relationship between Porosity (%) and Dry Unit Weights (kN/m^3) (Figure 7.13.). The Damlam cave occurences may be grouped as “medium to high Porosity (%) and Dry Unit Weights (kN/m^3)” with respect to graph of Porosity (%) versus Dry Unit Weights (kN/m^3).

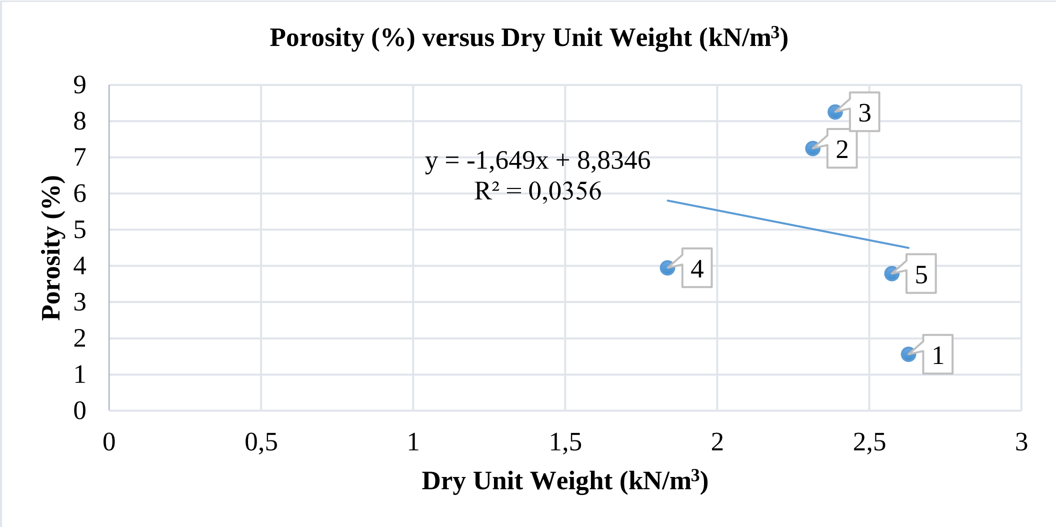

Figure 7.13. Porosity versus Dry Unit Weigth graph for Damlam Cave Occurences

It is a negative relationship between Dry Unit Weight (kN/m^3) and Water Absorption on Weight (%) (Figure 7.14.). The Damlam cave occurences are able to be categorized as "medium to high Dry Unit Weight (kN/m^3) and Water Absorption on Weight (%)" in accordance with graph of Dry Unit Weight (kN/m^3) versus Water Absorption on Weight (%).

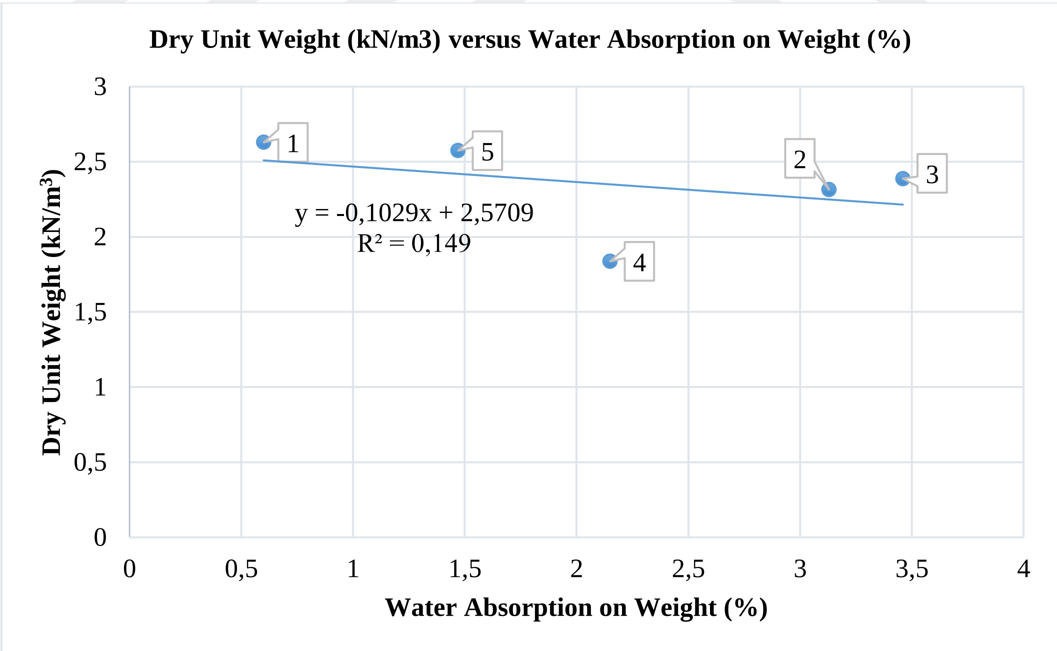

Figure 7.14. Dry Unit Weigth versus Water Absorption by Weight graph for Damlam Cave Occurences

It is a positive relationship between Point Load Strength Index (Is) and Dry Unit Weight (kN/m^3) (Figure 7.15.). The Damlam cave occurences can be classified as "medium to high Point Load Strength Index (Is) and Dry Unit Weight (kN/m^3)" according to graph of Point Load Strength Index (Is) versus Dry Unit Weight (kN/m^3).

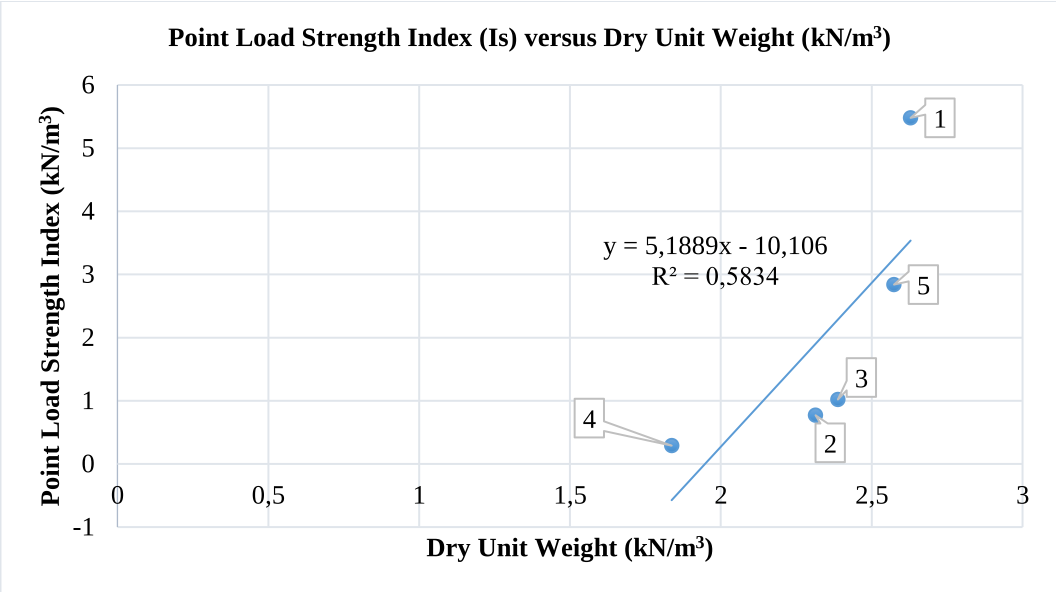

Figure 7.15. Point Load Strength Index versus Dry Unit Weigth graph for Damlam Cave Occurences

It is a negative relationship on the graphs of Dry Unit Weight (kN/m^3) versus Water Absorption on Volume (%), and Point Load Strength Index (Is) versus Porosity (%) (Figure 7.16. and 7.17.). The Damlam cave occurences has medium to high durability.

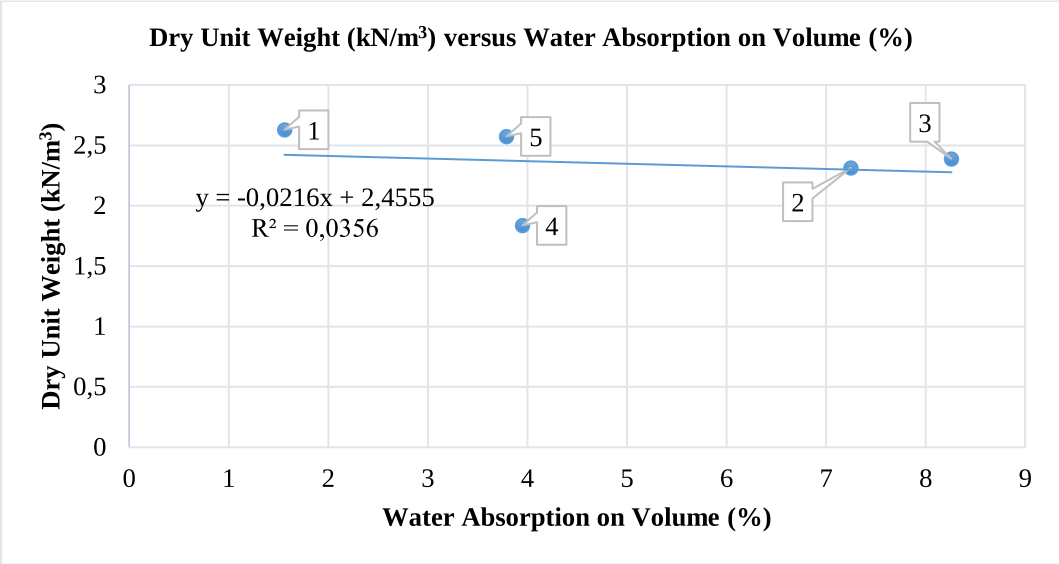

Figure 7.16. Dry Unit Weigth versus Water Absorption by Volume graph for Damlam Cave Occurences

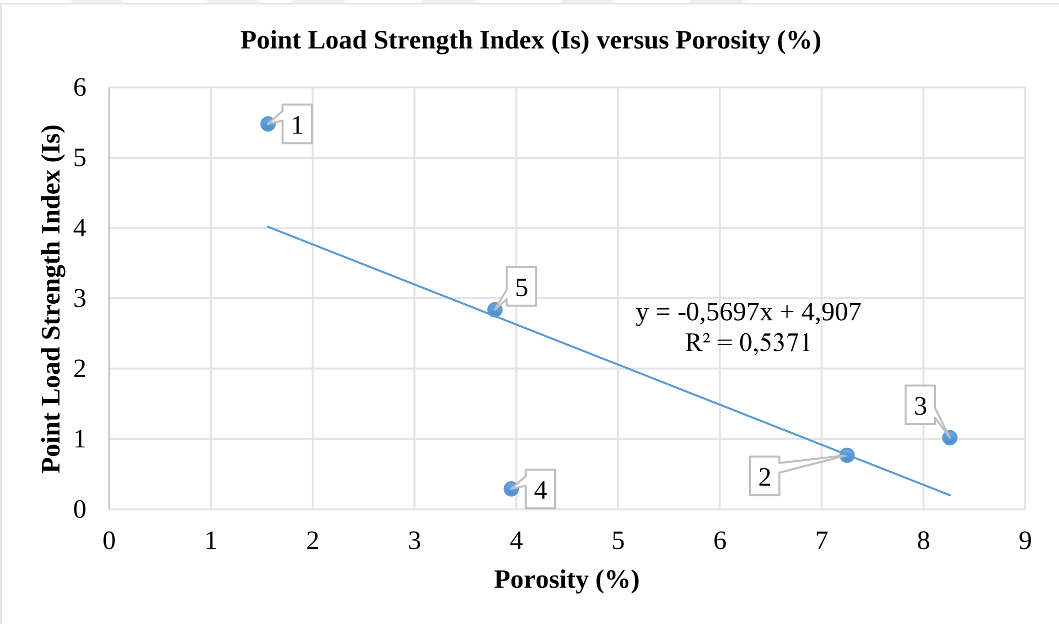

Figure 7.17. Point Load Strength Index versus Porosity graph for Damlam Cave Occurences

Holtz and Kovacs (1981) listed previous researcher data, try to determine clay type based on atterberg limits of plasticity index and liquid limit. Four sample namely, MD1_1, MD5_1, MD7 and MD10 drop into lower boundary of Illite type of clays (Table 7.3.).

Table 7.1. Rebound Number for Damlam Deresi Cave Occurences

Descriptions and Measurements			Geometric Parameters of Cave (metre)			Coordinates (x,y,z) (WGS84-UTM)		
Occurence Name		Rebound Number	Width (m)	Height (m)	Depth (m)	x	y	z (metre)
Cave 1		21,49	6,80	3,90	2,10	35611852	4107858	628
Cave 2		18,49	14,70	15,16	3,73	35611859	4107865	628
Cave 3		24,48	19,36	27	4,73	35611890	4107884	628
Cave 4		15	4,16	2,83	2,01	3561165	4107874	628
Cave 5		8,53	6,66	4,50	3,46	35611804	4107537	628
Outcrops	Outcrop 1	23,49	No data obtained due to covered surface			35611796	4107668	628
	Outcrop 2					36611801	4107666	630
	Outcrop 3					35611803	4107674	634
	Outcrop 4					35611840	4107697	640
	Outcrop 5					35611815	4107712	642
	Outcrop 6					35611871	4107724	643
	Outcrop 7					35611836	4107726	644
	Outcrop 8					35611905	4107755	645
	Outcrop 9					35611939	4107767	647
Terrane 1		15				35611830	4107554	658
Terrane 2		19,41				35611797	4107545	671
Elements								
Minimum		8,53	4,16	2,83	2,01			
Maximum		24,48	19,36	27	4,73			
Arithmetic Mean		18,23	10,33	10,67	3,20			
Median		18,95	6,80	4,50	3,46			
Standard Deviation		5,26	6,41	10,39	1,15			

Table 7.2. Physical and Mechanical Properties of conglomeratic limestones within Damlam Deresi cave occurences

Sample Number	Occurence Name	Volume (V) (cm^3)	Dry Weight (Wd) (g)	Saturated Weight (Ws) (g)	Volume of Void (cm^3)	Porosity (%)	Void Rate	Water Absorption Weight (%)	Water Absorption Volume (%)	Specific Gravity (Gs)	Saturated Unit Weight (kN/m^3)	Dry Unit Weight (kN/m^3)
MD1	**Cave 1**	102,30	268,90	270,50	1,60	1,56	0,01	0,60	1,56	2,67	2,64	2,62
MD2	**Cave 2**	104,80	242,50	250,10	7,60	7,25	0,07	3,13	7,25	2,49	2,38	2,31
MD3	**Cave 3**	112,90	168,90	278,20	9,30	8,26	0,09	3,46	8,26	2,60	2,47	2,38
MD4	**Cave 4**	108,90	200,10	204,40	4,30	3,95	0,04	2,15	3,95	1,91	1,87	1,83
MD5	**Cave 5**	121,30	312,20	316,80	4,60	3,79	0,04	1,47	3,79	2,67	2,61	2,57
Elements												
Minimum		102,30	168,90	204,40	1,60	1,56	0,01	0,60	1,56	1,91	1,87	1,83
Maximum		121,30	312,20	316,80	9,30	8,26	0,09	3,46	8,26	2,67	2,64	2,62
Arithmetic Mean		110,04	238,52	264	5,48	4,96	0,05	2,16	4,96	2,47	2,39	2,34
Median		108,90	242,50	270,50	4,60	3,95	0,04	2,15	3,95	2,60	2,47	2,38
Standard Deviation		7,47	56,32	41,16	3,01	2,74	0,03	1,17	2,74	0,32	0,30	0,31

Table 7.3. Soil Test Result for Damlam Deresi cave occurences

Method		TS 1900-1									-	Coordinates (x,y,z) (WGS84-UTM)		
Sample Number	Occurence Name	Moisture Content	Natural Unit Weight	Specific Gravity	Atterberg Limits			Grain Size Distribution (Sieve Analysis)			Unified Soil Classification System (USCS)	x	y	z (metre)
		W_n	γ_n	G_s	LL	PL	PI	Gravel	Sand	Silt + Clay				
		(%)	(g/cm^3)	(-)	(%)	(%)	(%)	(%)	(%)	(%)				
MD1_1	**Cave 1**	27,90	1,76	2,63	37,50	24,40	13,10	0	27,01	72,90	CL	35611852	4107858	628
MD5_1	**Cave 5**	26,60	1,80	2,67	40,10	24,70	15,40	0	21	79	CL	35611804	4107537	628
MD7	**Soil 7**	20,90	1,83	2,62	36,20	23,80	12,50	8,20	22,40	69,40	CL	36611801	4107666	630
MD10	**Soil 10**	16,40	1,86	2,60	32,30	22,40	9,90	5,70	50,40	43,90	SC	35611815	4107712	642
(CL= Inorganic clays of low to medium plasticity, gravelly / sandy / silty / lean clays)														
(SC= Clayey sands, sand-clay mixtures)														
Elements														
Minimum		16,40	1,76	2,60	32,30	22,40	9,90	0	21	43,90				
Maximum		27,90	1,86	2,67	40,10	24,70	15,40	8,20	50,40	79				
Arithmetic Mean		22,95	1,81	2,63	36,52	23,82	12,72	3,47	30,20	66,30				
Median		23,75	1,81	2,62	36,85	24,10	12,80	2,85	24,70	71,15				
Standard Deviation		5,32	0,04	0,02	3,25	1,02	2,26	4,14	13,70	15,45				

Table 7.4. Point Load Stength Index Test Result for Damlam Deresi cave occurences

Sample Number	Occurence Name	Physical Properties of Samples										
		Width (mm)	Thickness (mm)	Volume (cm^3)	Sample of Weight (g)	Failure Load (P) (kN)	Unit Weight (g/cm^3)	Core Diameter (De) (mm)	Core Diameter in Square (De^2) (mm^2)	Point Load Strength Index (Is) ($Is=Px1000/De^2$) (MPa)	Size Correction Factor (F)	Point Load Strength Index (Is_{50}) ($Is_{50}=Px1000/De^2$) (De=50mm) (MPa)
MD1	**Cave 1**	59,31	45,60	85	221,10	18,87	2,60	58,70	3445,30	5,48	1,07	7,54
MD2	**Cave 2**	74,88	53,60	100	235,20	3,92	2,35	71,50	5112,50	0,77	1,17	1,56
MD3	**Cave 3**	80,78	60,40	50	120,50	6,37	2,41	78,84	6215	1,02	1,23	2,54
MD4	**Cave 4**	87,95	65,90	60	108,60	2,11	1,81	85,93	7383,30	0,29	1,28	0,84
MD5	**Cave 5**	84,23	63,90	50	128,50	19,45	2,57	82,80	6856,40	2,84	1,25	7,78
Elements												
Minimum		59,31	45,60	50	108,60	2,11	1,81	58,70	3445,30	0,29	1,07	0,84
Maximum		87,95	65,90	100	235,20	19,45	2,60	85,93	7383,30	5,48	1,28	7,78
Arithmetic Mean		77,43	57,88	69	162,78	10,14	2,34	75,55	5802,50	2,08	1,2	4,05
Median		80,78	60,40	60	128,50	6,37	2,41	78,84	6215	1,02	1,23	2,54
Standard Deviation		11,21	8,30	22,47	60,29	8,37	0,31	10,85	1566,22	2,13	0,08	3,34

Table 7.5. Slake Durability Test Result for Damlam Deresi cave occurences

Sample Number	Occurence Name	Physical Properties of Samples								Classification
		Slaking Fluid Temperature (^{0}C)	Drum Number	Weight of "Drum+Sample" (A) (g)	Weight of "Drum+Retained Sample" (1st Cycle) (B) (g)	Weight of "Drum+Retained Sample" (2nd Cycle) (C) (g)	Weight of Drum (D) (g)	Slake Durability Index (1st Cycle) Id(1)=[(B-D)/(A-B)]x100	Slake Durability Index (2nd Cycle) Id(2)=[(C-D)/(A-C)]x100	
MD1	**Cave 1**	20	1	2362,60	2305,80	2289,90	1844,40	89	86	Medium-High Slake Durability
MD2	**Cave 2**	20	2	2242,50	2169,20	2156,30	1865,90	80,50	77,10	Medium Slake Durability
MD3	**Cave 3**	20	1	2206,20	2125,10	2106,50	1844,40	77,60	72,40	Medium Slake Durability
MD5	**Cave 5**	20	1	2295,60	2265,60	2252,10	1844,40	93,40	90,40	Medium-High Slake Durability
Elements										
Minimum		20	1	2206,20	2125,10	2106,50	1844,40	77,60	72,40	
Maximum		20	2	2362,60	2305,80	2289,90	1865,90	93,40	90,40	
Arithmetic Mean		20	1,25	2276,72	2216,42	2201,20	1849,77	85,12	81,47	
Median		20	1	2269,05	2217,40	2204,20	1844,40	84,75	81,55	
Standard Deviation		0	0,50	68,00	83,61	84,54	10,75	7,33	8,19	

7.6. Petrographical Studies

A total of 2 thin sections of units of the Damlam cave site were selected from a total of 20 samples (e.g. hand-specimens) in order to determine their petrographical characteristics and properties. The thin sections of the limestones were carefully examined under light microscope to better understanding paragenetic sequences of the occurences according to spatial and temporal relationships.

Whether thin sections (modified from Gül et al., 2013) given below are binding or not, they are completely formed from calcium carbonate. Their macro features resemble limestone-marls. These thin sections following below show fine levels clearly.

7.7. Interpretation

- Total of 5 caves and 2 terranes were uncovered within Damlam Deresi cave occurences. All of these caves and terranes were formed on two main steep slopes within the formation. In this formation, special structures (e.g., stalactite-flowstone-travertine occurences) are obviously found out.

- Cave 3 is the largest geometric-sized cave, whereas Cave 4 is the smallest one.

- In addition, a flow direction of hydrogeological surface water within the occurences is from southwest to northeast. The flow rate (Q) of the water is 0.5 liters per 21.61 second on date of 23.09.2016 for Damlam Deresi cave occurences.

- Special Threshold Limit Value (STLV) of Rebound Number is 23.49 in places without cave occurences and is 19.415 for terranes. In contrast, cave 3 has the greatest of STLV of Rebound Number (24.48) whilst cave 5 has the smallest one (8.535) in cavern parts of the occurences.

- In the formation, Cave 3 has the largest of porosite (8.26), however Cave 1 has the smallest one (1.56).

- In addition, Cave 5 has the biggest of failure load (P) (19.45 kN), yet Cave 4 has the smallest one (2.11 kN).

- Moreover, Cave 1 has the highest of point load strength index (I_{S50}) (7.548 MPa), nevertheless, Cave 11 has the smallest one (0.844 MPa).

- Furthermore, Cave 5 has the hugest of slake durability index for 1st and 2nd cycle (93.4-90.4 respectively), whereas, Cave 3 is the smallest one (77.6-72.4 repectively).

- Without cave occurences are more durable than within cave occurences on the muddy conglomeratic levels according to Rebound number.

- Cave development (cave sizes) in both sections generally appears in relation to lithological difference, differential weathering, strength difference, water content, distribution of cracks, rock weakening of water movement along cracks, anthropogenic factors and so on.

- The geological factors controlling cave occurences can be ranked with respect to the importance: (1) Lithological differences affecting either their resistances or strengths, (2) Crack-joint sets give rise to weakness of the conglomeratic rocks accompanying with suitable ways to water circulation, (3) Water content leads to weakness of the rocks, disseminating fine muddy levels, washing matrix of the conglomeratic rocks as well as growth of caves, and (4) plant roots.

Due to the low temperature in the valley in summer, this area which is important for local tourism needs to be protected by taking care of special structures inside the cave. The special structures in the cave formation, which are already limited in number, would be under risk of getting lost if attention were not given during recrational usage.

8. RESULTS AND DISCUSSION

In the Yatağan formation (included Asartepe and Damlam Deresi cave occurences), two main units are distinguished as mudstone and muddy conglomerate. On both occurences (Asartepe and Damlam Deresi cave occurences), different grain size were observed from the size of mudstone-like material to the size of cobble-sized material. In both of these occurences, caves tend to form at the junction of mudstone and muddy conglomeratic layers.

In general, the thickness of the mudstone layer of Asartepe (between 0-1 m) is much thinner than the mudstone layer (between 0-4 m) of the Damlam Deresi. In addition, on the geological stratigraphic section of 0-25 m thickness; there are total of 4 mudstone layers on the Asartepe and total of 3 mudstone layers on the Damlam Deresi.

Generally, thickness of the muddy conglomeratic layer of Asartepe (0-8 m) is thicker than the muddy conglomerate layer (0-7 m) of the Damlam Deresi. In addition, on a geological stratigraphic section of 0-25 m thickness; there are total of 3 muddy conglomeratic layers in the Asartepe and total of 4 muddy conglomeratic layers in the Damlam Deresi.

Finally, there are no leakages and temporary moist following cracks in the Asartepe cave occurences after the humidity or excessive rainfall in the Asartepe in spite of being more intense structural elements (cracks, fissure, fractures and joints). However, structural elements (cracks, fissure, fractures, and joints) of the Damlam Deresi cave occurences has seeming leakages and and temporary moisture. As a result, in terms of hydrogeology, the Damlam Deresi is more active than the Asartepe.

The presence of many different special internal structures (e.g., stalactite- flowstone-travertine formations) observed in the caves are investigated at the Damlam Deresi cave occurences where the water leaks were found. However, the structures were not realized in the Asartepe cave occurences due to the absence of continuous leakages in structural elements (cracks, fissure, fractures and joints).

The Asartepe and Damlam Deresi caves can be classified as: (1) "*branchwork*" (passages of watersprings that joints tributaries) according to Palmer (1991) and Ford and Williams (2007) (Figure 8.1.); (2) "*linear stream cave*" (influced by fissure porosity, dominantly matrix porosity and bedding material types) that is one of eogenic (early diagenetic) caves in conglomerate as examples from Udin Boršt in Slovenia and the linear stream cave is bigger than 1 m and a few meter wide of its entrances in accordance with Lipar and Ferk (2011).

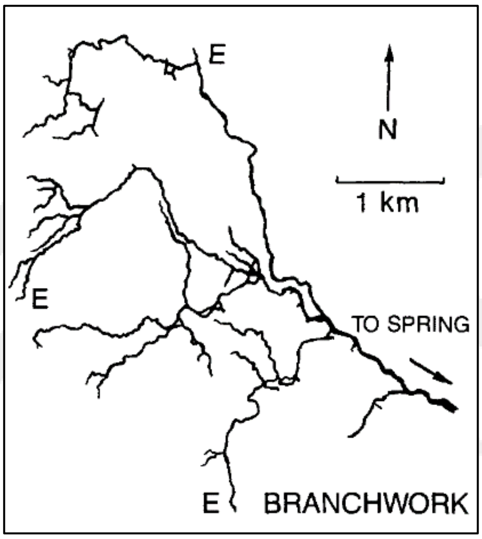

Figure 8.1. Flow Patterns of a branchwork cave (Palmer, 1991; Ford and Williams, 2007)

In the Upper Miocene-Pliocene Yatağan Formation, older clastic rocks and cave occurences with varying height, length and depth in the scapes forming the edge of the valley were observed.

The effects of surface and groundwater are observed in the cave occurences cropped out in different regions within the Yatağan Formation. In these occurences, active occurence waters in coarse-crumbly-permeable parts can cause small source developments. The occurence water also moisturize, loosen and reduce the strength of the fine-grained levels between clay-fine-sandy-matrix, and coarse-grained layers between coarse crumbly granules. Also, the water washes and distances the grains.

Experimental and laboratory observations made in both areas showed that coarse grained levels are of low strength compared to fine grained levels in the occurences. In addition, the strength of the matrix zone in the coarse-grained level is lower than in the fine-grained zone. The strength of the occurences can be further reduced due to the influence on matrix and fine-grained levels of the occurence water. Therefore, the fine-grained levels eroded by the effect of physical decay are removed, and then the cave occurences are developing and growing by removing coarse grains, which disappear from the matrix or watery and / or anthropogenic factors along the slope from the environment.

Broken cracks and stratification planes due to the complex tectonic history of the region affect the development of underground water circulation and caves. Despite similarities in their occurences, there are differences in both cave sites. For example, in the Damlam Deresi caves, there exist wider surface area and more intense surface and groundwater activities than in Asartepe caves and then the ground conditions (such as temperature-humidity) have led to the development of either special structures or occurences such as stalactites, flowstone and travertine in this region. The root extensions of the plants in the region contribute to the development of these occurences.

In Asartepe caves we observed much more anthropogenic effect than in Damlam Deresi caves. The region within Yatagan formation, which has hosted various civilizations since antiquity, antique tombs, settlement rooms, stables (barns), storages and some objects are built for similar purposes. For these purposes, existing gaps can be expanded as new gaps are created or as being in the surveyed areas in detail.

It is home to caves of various ages, thicknesses and cruder units which are exposed in various regions of the world as the formation that makes up of the subject of this work (Busche and Sponholz, 1992; Bergada et al., 1997; Kranjc, 2005; Aubrecht et al., 2008; Breitenbach et al., 2010; Lipar and Ferk, 2011). The use of these cavernous structures depending on the characteristics of the region may be used for temporarily recreational purposes, as well as permanently the use of animals and people for shelter or housing (Busche and Sponholz, 1992; Bergada et al., 1997; Kranjc, 2005; Aubrecht et al., 2008).

In Upper Miocene-Pliocene Injana Formation (Najaf-Karbala-Iraq; Awadh et al., 2013), cave occurences were found in various sizes within the delineated units similar to the study area. Cave development is attributed to the effectiveness of physical and chemical degradation that develops in different types and shapes through the agency of the distribution of the joints, and the water leaking from the more permeable coarse-grained levels above that causes relaxation and softening in the underlying clayey levels. Although similar features are observed in the study area, the clayey layers are not as thick as in this region and there are no clay loams. It is thought that physical decay is more active in the field of investigation. It is emphasized that the caves, which develop in the conglomerates of Udin Boršt (Lipar and Ferk 2011), are of eojenetic character, and that the karstification events developing after sedimentation are effective. The similar situation is thought to be eogenetic of Asar Tepe and Damlam Deresi Caves, where cave occurences are still continuing. Asartepe and Damlam Deresi caverns are considerated to be caves in the shelter cave class which develops in dissolved rocks such as carbonate rocks in the classifications made by Lipar and Ferk (2011). In the Udine Boršt region, there are no isolated, linear, breakdown and vadoz caves in the study areas (Asartepe and Damlam Deresi). Caves in the Venezuela Roraima Group (Aubrecht et al. 2008), which are similar to caves in the study areas, are found in various features within the studied caves, while the clastic rocks are developed as a result of the weakening and washing of the water in connection with the interaction with water. Bergada et al. (1997) suggests that cave occurences in this region, which are different from the complex tectonic history related to the morphology, petrology, and hydrology, became active of the cave morphology and surface relief. Busche and Sponholz (1992) found karst forms such as karst tubes, endorheic plateau deposits (doline, uvala), shaft, small karen formations, and caverns in Niger sandstones. The absence of similar complex cave interior-structures that is similar to other areas in the study area can be attributed to the relatively young caves or to the rapid disappearance of structures resulting from their development in relatively loose units. Damlamderesi is used for recreational purposes, but it is not clear whether there is a study on the preservation of the internal structures, and biological-ecological characteristics.

Consequently, some future research suggestions should be: (1) determination of the continuity of caves by Ground-penetrating radar (GPR), (2) detection of cover thickness, (3) specifying the amount of expansion determined by continuous measurement in caves, (4) identifying the risk of collapse, (5) including the ecological-environmental effect of the recreation area.

9. CONCLUSION

A flow direction of hydrogeological surface water near the Asartepe cave occurences is from north to south. In contrast, a flow direction of hydrogeological surface water within the Damlam Deresi cave occurences is from southwest to northeast. Hydraulic activity of the flow rate (Q) of the Asartepe hotspring (1.2 lt/s) is much higher than that of the flow rate of the Damlam Deresi hotspring (0.5lt/s).

The Asartepe and Damlam Deresi caves can be named as: (1) "*branchwork*" (passages of watersprings that joints tributaries) according to classification of Palmer (1991); Ford and Williams (2007), and (2) "*linear stream cave*" (influced by fissure porosity, dominantly matrix porosity and bedding material types) in accordance with classification of Lipar and Ferk (2011).

Petrographic thin sections for both of the occurences (Asartepe and Damlam Deresi) are completely formed from calcite minerals. Their macro features resemble limestone-marls. These thin sections show clearly calcarenite-calcilutite parts of Yatağan Formation within fine sized levels.

Mudstone-sized material to cobble-sized gravel were observed within the stratigraphic sequences of the occurences (Asartepe and Damlam Deresi). As a result, all caves in both of sides tend to form in a contact between mudstone and muddy conglomeratic layers.

Three different types of mudstones within these occurences are classified according to the Unified Soil Classification System (USCS) based on dominant grain size: (1) SM ("*silty sands, sand-silt mixtures*") for Asartepe cave occurences, (2) CL ("*Inorganic clays of low to medium plasticity, gravelly / sandy / silty / lean clays"*) and SC *("Clayey sands, sand-clay mixtures")* for Damlam Deresi cave occurences.

Cave development (cave sizes) in both sections generally appears in relation to lithological difference, differential weathering, strength difference, water content, distribution of cracks, rock weakening of water movement along cracks, anthropogenic (human) factors and so on (Table 9.1).

Geometrically the largest cave dimensions compared to relatively small ones has the highest collapse risk within study areas (Asartepe and Damlam Deresi). Consequently, the risk is mainly controlled by geometric properties of caves in connection with both of their physicochemical and mechanical features mentioned above.

Table 9.1. Comparison of features and controlling factors of cave occurences in Yatağan Formation

Controlling Factors and Features of Cave Occurences	Asartepe Cave Occurences	Damlam Deresi Cave Occurences
Type of the river	Temporary-seasonal (ephemeral) river	Perminant (perennial) river
Size variation ranges of caves	Depth:1.71-4.18, Length:1.15-15.88, Width:1.47-9.71	Depth:4.16-19.36, Length:2.83-27, Width:2.01-4.73
Internal Structure(s)	Flowstone	Stalactite, flowstone, travertine
Usage purpose(s)	Barn, warehouse	Recreation
Hydrogeological Condition	Observed surface water (No groundwater)	Observed surface water and groundwater
Vegetation effect	Absence of the roots of trees	Presence of the roots of trees (Waters are following up along capillary cracks caused by the roots of trees)
Lithological similarities and differences	Mudstone-muddy conglomerate alternation (Maximum grain size is 22 cm)	Mudstone-muddy conglomerate alternation (Maximum grain size is 15 cm)
Structural Properties	3-4 joint sets in different direction were developed by main fault (15-35° W / 75-80° SW)	Some structural elements (fissure, cracks, joints, etc.) in different direction were developed by main fault (N75°E / 18°SE).
Strength of rocks	Without cave parts are more durable than within cave parts. Mudstone has not any strength value that means “zero” by Schmidt Hammer due to a too soft rock. Strength values for grains of muddy conglomerates are between 6.63 and 30.22.	Without cave parts are more durable than within cave parts. Mudstone has not any strength value that means “zero” by Schmidt Hammer due to a too soft rock. Strength values for grains of muddy conglomerates are between 8.53 and 24.48.
Clay type(s) (according to the Unified Soil Classification System (USCS))	SM ("*silty sands, sand-silt mixtures*")	CL (“Inorganic clays of low to medium plasticity, gravelly / sandy / silty / lean clays”) and SC (“Clayey sands, sand-clay mixtures”)
Environmental Impact	Asartepe cave occurences are under collapsing risk.	Some Damlam Deresi cave occurences are under collapsing risk. It is against the risk of disappearance of special structures (stalactite, flowstone, travertine, etc.) at recreation area of Damlam Deresi cave occurences.

REFERENCES

Abdüsselamoglu, S., 1965. Mugla-Yatagan çevresinde görülen formasyonların korelasyonları hakkında rapor M.T.A. Rap no: 3497 Ankara.

Açıkel, S., 2012. Conceptual Modelling of Hydrodynamics of Discharge and Salt Water Mixing in Gökova-Azmak (Muğla) Karst Springs: Hacettepe University (published PhD thesis).

Aktimur, H.T., Sarıaslan, M.M., Keçer, M., Sönmez, M., Uysal, Ş., Özmutaf, Ş., 1996. Muğla İlinin (Merkez İlçesinin) Arazi Kullanım Potansiyeli: Maden Tetkik ve Arama Genel Müdürlüğü, Ankara, Turkey (in Turkish).

Al-Fares, W., Bakalowicz, M., Guerin, R., Dukhan, M., 2002. Analysis of the karst aquifer structure of the Lamalou area (Herault, France) with ground penetrating radar. Journal of Applied Geophysics 51(2–4), 97–106.

Atalay, Z., 1980. Stratigraphy of continental Neogene in the region of Mugla-Yatagan, Turkey: Bulletin of the Geological Society of Turkey, V.23, S3-99.

Aubrecht, R., Lánczos, T., Šmída, B., Brewer-Carías, C., Mayoral, F., Schlögl, J., Audy, M., Vlček, L., Kováčik, Ľ., Gregor, M., 2008. Venezuelan sand stone caves: a new view on their genesis, hydrogeology and speleothems. Geologica Croatica, 61/2-3, 345-362.

Awadh, S.M., Abood, Z.S., Eisa, M.J., 2013. Chemical and physical control processes on the development of caves in the Injana Formation, Central Iraq. Arab J Geosci (2013) 6:3765–3772.

Becker-Platen, J.D., 1970. Lithostratigraphische Untersuchungen in Kanozoikum Südwest Anatoliaen (Turkie)), Beihr. Geol.Jahrbuch 97, 1-244.

Bakalowicz, M., 2016. The Epikarst, The Skin of Karst: Karst Waters Institute Special Publication 9., HydroSciences, CNRS, Universite Montpellier II, cc MSE, F-34095 Montpellier, France.

Basso, A., Bruno, E., Parise, M., Pepe, M., 2013. Morphometric analysis of sinkholes in a karst coastal area of southern Apulia (Italy): Environ Earth Sci., 70:2545–2559.

Bergada, M.M., Cervello, J.M., Serrat, D., 1997. Karst in conglomerates in Catalonia (Spain): morphological forms and sedimentary sequence types recorded on archaeological sites [Le karst en conglomérats en Catalogne (Espagne): Morphologies et sequences sédimentaires en rapport à quelquessites archéologiques.]. In: Quaternaire, 8 (2-3), 1997.267-277.doi: 10.3406/quate.1997.1579.

Breitenbach, S.F.M., Donges, J.F., Daly, B.K., Kohn, T., Kohn, T., 2010. Two sandstone caves on the southern edge of the Meghalaya Plateau, India. Cave and Karst Science, Transactions of the British Cave Research Association, 37, 2, 49-52.

Busche, D., Sponholz, B., 1992. Morphological and micromorphological aspects of the sandstone karst of eastern Niger. Z. Geomorph. N. F., 85, 1-18.

Canbaz, E., 2015. Karstification of Damlam Deres, Yerkesik, Muğla: Muğla Sıtkı Koçman University (Unpublished Bsc thesis).

Dearborn, F., 2004. Encyclopedia of Caves and Karst Science: An Imprint of the Taylor and Francis Group 29 West 35 Street New York, NY 10001–2299.

Dunham, R.J., 1962. Classification of carbonate rocks according to their depositional texture. In W.E. Ham (Ed.), Classification of Carbonate Rocks - A Symposium. Tulsa, OK, American Association of Petroleum Geologists Memoir 1, p. 108-121.

Eren, B., 1995. 1/100 000 ölçekli Aydın N20 paftasının derlenmesi: MTA İzmir Bölge Müdürlüğü (in Turkish).

Eroskay, S.O., Günay, G., 1979. Tecto-Genetic classification and hydrogeological properties of the karst regions in Turkey. In: Günay G (ed) Karst hydrogeology Proceedings, Oymapinar-Antalya, Turkey, UNDP Project TUR/77/015, pp 1–41.

Folk, R.L., 1962. Spectral subdivision of limestone types. In W.E. Ham (Ed.), Classification of Carbonate Rocks - A Symposium. Tulsa, OK, American Association of Petroleum Geologists Memoir 1, p. 62-84.

Ford, D., Williams, P., 2007. Karst Geomorphology and Hydrology. Unwin Hyman, London. P. 601.

Gams, I., 1993. Origin of the term "karst," and the transformation of the Classical Karst (kras): Environmental Geology, 21:110-114.

Gillieson, D., 1996: Caves: processes, development and management. Blackwell, Oxford, UK. 324 p.

Grimes, K.G., 2012. Karst and Paleokarst Features involving Sandstones of the Judbarra / Gregory National Park, Northern Territory, Australia. Helictite, 41: 67-73.

Göktaş, F., 1982. Muğla ve yöresindeki Senozoyik yaşlı çökel kayaların sedimantolojik ve paleocoğrafik incelenmesi: MTA, Ankara, Turkey, No:519 (in Turkish).

Göktaş, F., 1998. Muğla ve çevresindeki (GB Anadolu) neojen tortullaşmasının stratigrafisi, sedimentolojisi ve bölgesel korelasyonu: MTA rapor No.10225 (in Turkish).

Günay, G., Güner, N., Törk, K., 2015. Turkish karst aquifers: Environ Earth Sci (2015) 74:217–226.

Gül, M., Özbek, A., Karacan, E., 2016. Rock fall hazard assessment in Asar Hill, ancient Mabolla City, Mugla—SW Turkey: Environ Earth Sci. 75:1310.

Gül, M., 2015. Lithological properties and environmental importance of the Quaternary colluviums (Mug˘la, SW Turkey): Environ Earth Sci (2015) 74:4089–4108.

Gül., M., Karacan., E., Aksoy., E., 2013. Muğla Kenti Yerleşim Alanı Genel Jeolojik ve Temel Mühendislik Jeolojisi Özellikleri.

Güldalı, N., Nazik, L., Soylu, C., Aksoy, B., 1984. Fethiye-Köyceğiz-Marmaris ve Muğla çevresinin doğal mağaraları, MTA Arşiv No: 7586.

Gürer, Ö.F., Yılmaz, Y., 2002. Geology of the Ören and Surrounding Areas, SW Anatolia. Turkish Journal of Earth Sciences, Vol. 11, 2002, pp. 1-13.

Gürer, Ö.F., Sanğu, E., Özburan, M., Gürbüz, A., Filoreau, N.S., 2013. Complex basin evolution in the Gökova Gulf region: implications on the Late Cenozoic tectonics of southwest Turkey: Int J Earth Sci (Geol Rundsch), 102:2199–2221.

Hakyemez, H.Y., Leflef, D., 1979. Muğla ve civarındaki Tersiyer havzalarının sedimantoljik ve palecoğrafik etüdüne ilişkin ön rapor: MTA derleme No.6552, Ankara (in Tunkish).

Hakyemez, H.Y., Örçen, S., 1982. Muğla-Denizli arasındaki (Güneybatı Anadolu) Senezoyik yaşlı çökel kayaların sedimantolojik ve biyostratigrafi incelemesi: MTA derleme No.7311, Ankara (in Turkish).

Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J., 2006. Evaluating Effectiveness: A Framework for Assessing the Management of Protected Areas. 2nd Edition. Best Practice Protected Area Guidelines Series 14, IUCN, Gland, Switzerland and Cambridge, UK, 105 pp.

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

Jakucs, L., 1977. Morphogenetics of karst regions. Unwin Hyman, London.

Kayan, İ., 1979. Muğla-Yatağan neojen havzasının jeomorfolojisi: TÜBİTAK, No.179, Ankara (in Turkish).

Konak, N., Akdeniz, N., Öztürk, E.M., 1987. Geology of the south of the Menderes massive: Guide book for the field excursition along western Anatolia, Turkey: MTA yayıyını, Ankara.

Kranjc, A., 2005. Conglomerate Karst in Slovenia: history of cave knowledge and research of Udin Boršt (Gorenjsko). ActaCarsologica, 34/2-15, 521-532.

Leflef, D., Hakyemez, Y., 1979. Muğla ve civarı Tersiyer havzalarının sedimantolojik ve paleocoğrafik etüdüne ilişkin ön rapor. 13s. MTA Arsiv No: 6562, Ankara.

Lewin, J., Woodward, J., 2009. Karst Geomorphology and Environmental Change: 10-Woodward-C10 9780199268030-Jamie-Woodward (Typeset by SPi, Chennai) 288 of 318.

Monroe, W. H., 1970. A Glossary of Karst Terminology: Geological Survey Water-Supply Paper, USA.

Nazik, L., 1996. Gökçeler Manisa Ve Yerküpe Menteşe Kavaklidere Mağaralarinin Ön Araştirma Raporu. MTA Raporu No: 9896 (unpublished).

Lipar, M., Ferk, M., 2011. Eogenetic caves in conglomerate: an example from Udin Boršt, Slovenia. International Journal of Speleology,40(1), 53-64. Tampa, FL (USA). ISSN 0392-6672. DOI: 10.5038/1827-806X.40.1.7.

Palmer, A.N., 1991. Origin and morphology of limestone caves. Geological Society of America Bulletin, 103, 1-21.

Özel, E., Nazik, L., Mengi, H., Kutlay, H., Derici, Ş., Törk, K., Aksoy, B., 1996. Yerkupe Mağarasi Kavaklidere Muğla Araştirma Raporu Mimari Ve Elektrifikasyon Uygulama Projesi. MTA Rapor No: 10048.

Querol, X., Alastuey, A., Plana, F., Lopez-Soler, A., Tuncali E., Toprak S., Ocakoglu F., Koker A., 1999. Coal geology and coal quality of the Miocene Mugla basin, southwestern Anatolia, Turkey: International Journal of Coal Geology 41. 311–332.

Şahin, E., 2015. Karstification of Asartepe, Merkez, Muğla: Muğla Sıtkı Koçman University (Unpublished Bsc thesis).

Şahin, İ., Arıcan, T., 1993. Muğla Organize Sanayi Bölgesi yer seçimi etüdü: Sanayi ve Ticaret Bakanlığı Küçük Sanatlar ve Sanayi Bölgeleri ve Siteleri Genel Müdürlüğü.

Slabe, T., 2010. Introduction to the Dinaric Karst: Collegium Graphicum d.o.o., Ljubljana.

Tuncer, K., Törk, K., Nazik, L., Kutlay, H., Özel, E., Acar, C., 2005. Muğla Gökçeler Milas İntepe Gelme Çingerek Marmaris Ve Girmeler Fethiye Mağaralari Değerlendirme Ve Öneriler Raporu. MTA Rapor No: 10712. (unpublished).

Urich, P.B., 2002. Land use in karst terrain: review of impacts of primary activities on temperate karst ecosystems: Science for Conservation 198, Wellington, New Zealand.

Ünal, D., Göktaş, F., 1990. Muğla-Kavaklıdere-Yerkesik linyit.

Williams, B.E., Robinson, R., 1993. Grouting beneath an existing dam founded on karst terrane. pp. 255–258 in Beck, B.F. (Ed.) Applied karst geology. Proceedings of the 4th conference on sinkholes and the engineering and environmental impacts of karst. AA Balkema, Panama City.

Williams, P., 2008. World Heritage Caves and Karst: International Union for Conservation of Nature, Programme on Protected Areas, Rue Mauverney 28, CH-1196 Gland, Switzerland.

https://gdex.cr.usgs.gov/gdex/ (Access Date: 13.05.2017)

http://www.geolab.com.tr (Access Date: 13.05.2017)

https://www.google.com/earth/ (Access Date: 15.05.2017)

http://www.google.com.tr/map (Access Date: 13.05.2017)

http://www.hgk.msb.gov.tr (Access Date: 17.05.2017)

http://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m =MUGLA (Access Date: 13.05.2017)

http://www.mgm.gov.tr/veridegerlendirme/yillik-toplam-yagis-verileri.aspx?m=MUGLA#sfB (Access Date: 19.05.2017)

http://www.mta.gov.tr (Access Date: 13.05.2017) https://www.uky.edu/KGS/water/general/karst/karst_landscape.htm (Access Date: 13.05.2017)

https://en.wikipedia.org/wiki/Karst (Access Date: 13.05.2017)

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