This book explores archaeological excavations and investigations into the history of the Lykos valley, Turkey. The contributions discuss the latest discoveries at the Ploutonion of Hierapolis; the excavations of the tabernae in Tripolis; the Lykos Valley in prehistory and the second millennium BC; the origins of the marble used in Hierapolis; and archaeo-botanic studies in Hierapolis, among others. Taken together, all the articles gathered here reveal the strong connections between the cities of the valley.

Professor Celal Şimşek studied Archaeology at the Faculty of Science and Arts at Selçuk University, Turkey, before going on to complete his Master's and PhD Studies at the Institute of Social Sciences at the same university. He worked as an archaeologist at the museums of Adıyaman and Denizli from 1988 to 1997, before founding the Institute of Archaeology at the Faculty of Science and Arts at Pamukkale University, Turkey, of which he is currently Director. He is also the Chair of the Archaeology Department at Pamukkale University, and has directed excavations and restorations at the ancient city of Laodikeia on the Lykos since 2003.

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Celal Şimşek and Francesco D'Andria

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Laodikeia and Hierapolis in Phrygia

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PREFACE

The Upper Maeander basin in southwestern Anatolia stands out with its unusual, colorful, rich and vivid character. The River Maeander rises near Dinar (Kelainai / Apameia) and is joined by the Işıklı (Eumeneia) tributary. It flows, having nourished many ancient civilizations on both banks for millennia, until it reaches the Aegean near Miletos. This geography steps forth, rich with archaeological remains.

The Kocabaş (or Denizli) Man, a *Homo erectus* from the northeast of the Lykos Valley, is dated to 1.2 million years ago, which is important evidence of continuous human life in the Lykos landscape. This evidence is further verified by the recent surveys by Assoc. Prof. Dr. Kadriye Özçelik of Ankara University, which have recovered numerous hand axes dating from 750,000 to 250,000 BC. The density of settlements in the concerned region accelerated in the Bronze Age. In the Upper Maeander Valley, Beycesultan, where the British Institute of Archaeology at Ankara (BIAA) started excavations in the 1950s, currently continued by Prof. Dr. Eşref Abay, is an important prehistoric site.

Kolossai, in the Lykos Valley, was an important settlement in the Classical period and earlier but Hierapolis, Laodikeia and Tripolis appeared on the stage in the Hellenistic period. Laodikeia, located in the middle of the valley, was particularly active during the Roman Imperial period as a metropolis in trade, arts, culture and sports.

The Lykos Valley is also located at the crossroads of routes connecting Southern, Western and Central Anatolia. Within the valley, Laodikeia is situated as the main junction. This geographical location, fertile land, favorable climate, and the Lykos River, which is connected to a lake in the middle of the plain and which flows into the Maeander River near Sarayköy in the west, all facilitated and contributed to the overseas trade of the region's cities.

With Christianity spreading rapidly in the early Christian period, Laodikeia, Kolossai and Hierapolis assumed a leading position. Laodikeia was one of the "Seven Churches" cited in the book of Revelation, and Hierapolis was the city where the Apostle Philip was martyred. It was also in this period that the Church of the Archangel Michael was built at Kolossai. The cities of the Lykos Valley lost their importance due to seismic activity in the region, its location as a route for marching armies, and epidemics of plague from the seventh century AD onwards.

Excavations of Hellenistic and Roman periods have been undertaken at Hierapolis by the Italian Archaeological Mission, uninterrupted since 1957. Currently the head of excavations is Prof. Dr. Francesco D'Andria. Excavations at Laodikeia have been conducted by Prof. Dr. Celal Şimşek of Pamukkale University since 2003. A brand new excavation in the valley is the site of Tripolis, undertaken by Assoc. Prof. Dr. Bahadır Duman since 2012. Excavations and research conducted at these three leading cities have made a great contribution to the archaeology of the region.

Excavations and restorations conducted at Hierapolis, Laodikeia and Tripolis, the cities in the Lykos Valley, have paved the way for an enormous amount of new data to be obtained, interpreted and presented to academia. In this book, *Landscape and History in the Lykos Valley: Laodikeia and Hierapolis in Phrygia*, published by Cambridge Scholars Press, Celal Şimşek presents the work and progress in Laodikeia, while Francesco D'Andria presents the latest discoveries at the *Ploutonion* of Hierapolis. Bahadır Duman presents the data from the excavations of the tabernae in Tripolis; Tamer Koralay, Kıymet Deniz and Yusuf Kaan Kadıoğlu present their analyses of the polychrome travertine quarries near Tripolis and their use in the city; Erim Konakçı, Ali Ozan and Fulya Dedeoğlu focus on the Lykos Valley in prehistory and the second millennium BC; Giuseppe Scardozzi explores the origins of the marble used in Hierapolis through analyses conducted within the frame work of the Marble Quarries in Phrygia Project; and Girolamo Fiorentino presents the archaeo-botanic studies in Hierapolis. Each article here is equally important, and they reveal the strong connections between the cities of the valley.

I would like to thank the contributing scholars as well as archaeologist Ayşegül Arığ and the Cambridge Scholars Press team for their efforts in the publishing process.

Prof. Dr. Celal ŞİMŞEK
Laodikeia Excavation House
Denizli, TR 2016

THE PROVENANCE OF BANDED TRAVERTINE FROM THE ANCIENT CITY OF TRIPOLIS (YENİCE/BULDAN - DENİZLİ) BASED ON MINERO-PETROGRAPHIC AND GEOCHEMICAL CHARACTERIZATION

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BAHADIR DUMAN**
KIYMET DENİZ***
YUSUF KAĞAN KADIOĞLU****

Introduction

Nowadays, the number of interdisciplinary studies that offer solutions to scientific and technical problems is increasing. This interdisciplinary study is significant because its results reveal the importance of cooperative work between the sciences of geology and archaeology. Connecting the data that has been obtained from archaeological excavations to studies from different scientific fields enables, significant conclusions to be formed. In studies of, geology and geological formations, thin sections of rock samples have been analyzed with optical microscopes. These have been

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widely used in order to discover the minero-petrographic characteristics of these rocks. The data from minero-petrographic studies forms a technical and scientific basis for a range of planned research projects. For instance, detailed analysis of rock samples from the buildings of the excavation fields tells us a great deal about the ancient quarry business. Similarly, the designation of the provenance of the rocks that were used in buildings helps select the right materials for the protection and restoration of these buildings, as well as helping to ensure that correct application procedures are followed. Travertine is a land-based carbonate rock, formed through the precipitation of carbonate minerals (calcite, dolomite, aragonite etc...) that come from a solution in magmatic and meteoric waters and/or from geothermally heated hot springs[1]. It was used extensively as a building material in the Mediterranean region during the ancient Greek and Roman periods because of its softness and low weight, which made it perfect for carving intricate detail[2]. The purpose of this study is to determine the minero-petrographic characteristics of the rocks that were used in the buildings of the ancient city of Tripolis and to obtain information about the probable provenance of these rocks.

Historical Background of the Ancient City of Tripolis

The ancient city of Tripolis lies within the borders of the province of Denizli, the county of Buldan and the town of Yenicekent. During the Hellenistic period, it was located at the intersection of the Lydia, Phrygia and Karia regions, near the Maeander River (Fig. 1a). Prior to this, it was within the borders of the Lydia region that, for a short time, had the establishment name of Apollonia and then Antoniopolis. During the first century BC, it became the intersection for people from all three regions and, thus, it was renamed Tripolis[3]. The Lykos (Çürüksu) Valley, within the borders of which the ancient city of Tripolis was located, had been under the rule of the Seleukos Dynasty until the Battle of Magnesia between the Seleukos Kingdom and the Romans in 190 BC. With the help of Pergamon, the Romans won this battle and, when they signed the Apameia (Dinar) Peace Treaty in 188 BC, Seleukos land in that region was given to Pergamon. After the death of King Attalos III in 133 BC, Pergamon was included within the Roman Empire, which was in

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[1] Guo – Riding 1998, 163-180; Pentecost 2005, 446; Özkul *et al.* 2013, 179-204.
[2] Reedy 2008, 256; Rapp 2009, 348; Ingham 2010, 192.
[3] http://www.pau.edu.tr/tripolis

accordance with the King's will[4]. The ancient city had its most magnificent times during its Roman period. From the second century AD, new buildings were added to the city and public structures, such as city gates, streets, baths, stadiums, theatres and parliament buildings, were constructed. In the ancient city of Tripolis, which was represented at the level of episcopacy in the Council of Nicaea (İznik) in 325 AD, significant damage was observed after the earthquake in 494 AD. At the end of the sixth and the beginning of the seventh century AD, people living in Tripolis had to move 5 km north of the city to Direbol (Narlıdere), and to the safer mountain slopes, because of Sassanian raids which affected the whole of Anatolia. After this compulsory migration, no settlement is indicated by data until the 13th century. In the first half of the 13th century, Tripolis changed hands a few times between the Byzantines and the Turks, and fell under the domination of the Turks around 1304-1306 (İnançoğulları and Germiyanoğulları). Finally, Denizli and its surrounding area came under the domination of the Ottoman Empire in 1429. Although the history of Tripolis goes back to the Hellenistic period, the archaeological materials found during the surface examinations around the city prove that settlement in this region goes back 5000 years[5].

The Geological Structure of the Ancient City of Tripolis and Its Surroundings

The research area, which includes the ancient city of Tripolis and its surroundings, is represented on the 1/25000 Uşak L21-c3 topographic map. The ancient city of Tripolis is located in a region where extensional tectonics are dominant. Its altitude above sea level is 220 m, increasing towards the northern part of the city (Fig. 1b). The ancient city is bordered on its eastern side by the Maeander River which, with its 51 m^3/s flow, is the greatest river in the region. In and around the study area, there are additional streams connected to the Maeander River. The flow of these streams changes seasonally and, especially in the rainy season, they carry sediments from higher altitudes and deposit them on the remains of the ancient city, where the slope gets lower. This makes the excavations more difficult. The climate of the city of Denizli shows variety, since its geographical location is between the Aegean, Middle Anatolia and Mediterranean regions. Generally, it observes the main features of the climates of the Aegean region and the southern part of Middle Anatolia,

[4] Şimşek 2007, 384; 2013, 530.
[5] Duman 2013, 179-200.

although it is a little colder than the general climate of the Aegean region, with temperatures up to 40 °C in the shade during summers and down to -15 °C during winters. According to the calculations of the Güney Meteorological Station for the years 1975-2006, the 32-year average temperature is 10.9 ºC. During these 32 years, the coldest month is January, going down to -0.1 ºC on average; the hottest month is July, which experiences an average of 22.2 ºC. Precipitation is 47.32 kg/m^2 annually; 40% from rain during winter, 21% during spring and 33% during autumn[6].

Today, in order to overcome problems with, time and money in the construction business, it is desirable that raw materials come from the surroundings of the area in which they will be used. It was also natural for ancient civilizations to bear in mind these considerations, and use the construction materials that were available closest to their cities. It is therefore appropriate to firstly investigate the geological structures and rock units of the ancient cities and their surroundings. The ancient city of Tripolis is in the Maeander Graben in West Anatolia, which was formed by normal faults in a roughly east-west direction under the effect of active extensional tectonics. The geological units of the study area are as follows from the oldest to the youngest:

- Paleozoic metamorphic rocks;
- Upper Pliocene Kızılburun formation;
- Pliocene Sazak, Kolonkaya and Tosunlar formation;
- Quaternary terrestrial rocks[7].

There are discordances and gaps among the rocks in this region. The majority of rocks in Tripolis and its surroundings are composed of metamorphic rocks identified as Maeander Massif. It is possible to identify two rock series, separated by their degree of metamorphism. This is the core series, composed of high grade metamorphic rock such as augen-gneiss, migmatite, amphibolite, eclogite and the cover series of quartzite, mica schist, phyllite and marbles. Schists and quartzites that form the cover series are thin-middle layered and are mostly composed of quartz, muscovite and biotite minerals. A number of researchers state that the core series of the Maeander Massive is an old crystalline block belonging to the

[6] http://www.dmi.gov.tr
[7] Şimşek 1984, 145-162; Sun 1990, 86; Gökgöz 1994, 263; Gökgöz 1998, 115-156; Çakır 1999, 67-80; Bülbül 2000, 97; Alçiçek 2007, 304; Koralay *et al.* 2013, 499-506; Erten *et al*. 2014, 504-518.

Pan African basement, and that its age is between 0.8 and 2 billion years[8]. There is no consensus over the age of the cover series of the Massive, which is the result of differences in definitions and distinctions. While some researchers accept the existence of a sequence from the Cambrian to the Eocene in the cover series, others mention a sequence from the Upper Carboniferous to the Upper Cretaceous Eocene[9]. Neogene sediments are composed of Kızılburun, Sazak, Kolankaya and Tosunlar formations, from oldest to youngest[10]. The Middle Miocene Kızılburun formation is composed of coarse and fine-grained conglomerate, sandstone and mudstone which is almost 300 m in thickness. The Middle Miocene Sazak formation compatibly rests on the Kızılburun formation. The Sazak formation has a thickness of 150-300 m and is composed of limestone, grey colored marl, laminated siltstone-mudstone, argillaceous limestone, cherty limestone, selenitic gypsum, gypsum arenite, gypsum halite and gypsum mudstone lithologies. The Middle Late Miocene Kolonkaya formation consists of marl, mudstone (clay-silt sequence) and dominantly, sandstones. It has a thickness of 500 m. The sandstones are light brown, yellowish and grey in color and are a little hardened, middle-thick layered, and include a large amount of Gastropod and Lamellibranch fossils. Pliocene sediments are represented by the Tosunlar formation and are 500 m thick. This formation is generally reddish-orange and/or yellowish-white colored, middle-thick layered, and loose carbonate-clay cemented. It is mainly composed of semi-round pebble stone-sandstone sequences, formed by rock lithologies of former formations and partly marl and calcic levels[11]. The Quaternary sediments in Tripolis and its surroundings are composed of alluvium, travertine-cemented terrace deposits, and travertine formations (Fig. 2).

Material and Methods

The mineralogical and petrographic characteristics of the banded travertine samples from the ancient city of Tripolis have been identified at

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[8] Konak 1985, 33; Satır – Friedrichsen 1986; 703-714; Oberhänsli *et al.* 1997, 135-150; Yılmaz *et al.* 1998, 210-336; Bozkurt – Satır 2000, 285-296; Erdoğan – Güngör 2004, 15-36; Candan *et al.* 2007, 8-13; Candan *et al.* 2011, 123-167; Koralay *et al*. 2011, 69-121.

[9] Konak 1985, 33; Erdoğan – Güngör 1992, 9-34; Yılmaz *et al.* 1998, 210-336.

[10] Şimşek 1984, 145-162; Sun 1990, 86; Gökgöz 1994, 263; Alçiçek 2007, 304; Erten et al. 2014, 504-518.

[11] Şimşek 1984, 145-162; Sun 1990, 86; Gökgöz 1994, 263; Alçiçek 2007, 304; Erten *et al.* 2014, 504-518.

Pamukkale University's Department of Geological Engineering, Optical Mineralogy Laboratory, using a "Leica DM750P" polarizing microscope.

X-Ray Diffractometer (XRD) analysis was applied, in order to specify the carbonate minerals (calcite/dolomite/aragonite etc...) and the unidentified smaller components, which could not be distinguished during the microscopic examinitions of the banded travertine samples. The XRD analysis was performed at Ankara University's Earth Sciences Research and Application Centre (YEBİM) Laboratory, using an "Inel Equinox 1000" with CoKα radiation. In this study, four banded travertine samples were analyzed by XRD to determine their mineralogical composition. The analyzed samples were finely ground using a tungsten carbide crushing vessel. Then, a few milligrams of the powder were placed in a sample holder and put in the XRD machine.

To determine the geochemical characteristics of the banded travertine samples, X-Ray Fluorescence (XRF) analysis was performed. For XRF analysis, seven banded travertine samples were finely ground in a tungsten carbide crushing vessel, until they reached the dimensions of 150-200 mesh. Then 3.9 g of powdered sample was homogeneously mixed with 0.9 g of wax. The sample powder was pressed at 20 N in an automatic pressing machine, to get a pressed disc. The XRF analysis was performed at Ankara University's YEBİM Laboratory, with a "Spectro XLAB 2000 PEDXRF (Polarized Energy Dispersive XRF)" machine. The analyses were calibrated by using the standards drawn up by USGS for sedimentary rocks (limestone).

Minero-Petrographic Properties of the Banded Travertines

Natural building stones have been widely used in buildings and monuments since ancient times, due to their easy extraction, easy shaping and endurance. Historical buildings constructed with natural stones have survived, regardless of the age or the conditions to which they have been exposed. Moreover, they carry information from the time of their construction up until the modern age. Natural building stones, which have since been replaced by artificial variations as a result of changing and improving technology, were especially widely used in ancient buildings and monuments. 35% of the natural building stones in the ancient city of Tripolis are composed of banded travertine and rocks combined with travertine.

Banded travertine samples were utilized in a widespread manner in column structures, cladding, floors and walls (Figs. 3a, b, c). The most typical properties of banded travertine samples are that they show bands of white, yellowish-white, greenish-white, red and reddish-brown (Figs. 4a, b, c). The width of the colored bands varies and they are generally sequenced parallel to each other. Yellowish-white and reddish-brown sequences are dominant among the banded travertine samples. In some samples, there are elliptical spaces between the color bands. In these spaces, small euhedral crystal structures are observed[12].

The optical microscope examinations established that the banded travertine samples were formed by long thin needle-shaped carbonate crystals (Fig. 5a). In the needle-shaped carbonate crystals, transverse fractures (which are formed vertically towards the long axis of the crystals) are widely observed (Fig. 5b). The colored bands are separated by levels composed of fine-grained carbonate slurry, Fe-oxide minerals and/or elliptical cavities (Figs. 5c, d). Under the microscope, clay minerals precipitate along each band with dark color (Fig. 5e). Needle-shaped carbonate crystals have developed on these levels. It was quite difficult to distinguish carbonate minerals (calcite/dolomite/aragonite etc...) under the microscope[13], so XRD analysis was used. According to the whole-rock powder XRD results, calcite is the dominant carbonate mineral in the banded travertine samples, while smaller amounts of dolomite peaks were also found (Fig. 6).

Geochemical Characteristics of the Banded Travertines

Major and trace element analyses were conducted, with the purpose of identifying the geochemical characteristics of the banded travertines. The geochemical analysis results of the banded travertine samples are given in Table 1 and shown in the box-plot diagrams. The MgO content of the banded travertine samples ranges from 0.02 to 0.22 wt%; the Al_2O_3 content 0.03-0.12 wt%; the SiO_2 content 0.20-0.60 wt%; the P_2O_5 content 0.004-0.023 wt%; the SO_3 content 0.01-0.70 wt%; the Ca content 41.52-44.58 wt%; the TiO_2 content 0.002-0.006 wt%; the MnO content 0.003-0.026 wt%; and the Fe_2O_3 content 0.06-1.23 wt% (Fig. 7).

Trace elements, which are known to be relatively resistant to chemical events such as alteration, metamorphism and metasomatism, are widely used for nomenclature, tectonic classification and for determining distinctive characteristics[14]. The Co content of the samples ranges from

[12] Koralay 2015, 6-7.
[13] Koralay 2015, 6-7.
[14] Rollinson 1993, 352.

10.5 ppm to 27.6 ppm; the Cu content from 1.5 to 2.3 ppm; the Zn content from 0.9 to 8.1 ppm; the Rb content from 0.8 to 3.1 ppm; the Sr content from 722.2 to 5090 ppm; the Zr content from 9.8 to 29.0 ppm; the Nb content from 3.4 to 4.2 ppm; the Ba content from 17.9 to 77.0 ppm; the Pb content from 1.0 to 26.4 ppm; the Th content from 1.1 to 1.9 ppm; and the U content from 9.8 to 14.0 ppm (Fig. 7).

The Mg/Ca ratio for the banded travertine samples ranges from 0.0003 to 0.0030; the Mn/Sr ratio from 0.0005 to 0.0103; the Sr/Ca ratio from 0.017 to 0.114; the Rb/Sr ratio from 0.0006 to 0.0014; the Zr/Ti ratio from 2.8 to 20.2; and the Nb/Y ratio range from 3.8 to 5.3. In general, the banded travertine samples display limited compositional variation, in terms of major oxide and trace elements.

Possible Provenance of the Banded Travertine Samples

In determining the provenance of building stones in ancient cities, multiple instrumental analysis techniques (Optical Microscope, X-Ray Diffractometry (XRD); X-Ray Fluorescence (XRF); Confocal Raman Spectrometry (CRS); Cathodoluminescence (CL); Electron Paramagnetic Resonance (EPR); C-O stable isotope and U-Th isotope analyses) yielded significant results in these studies demonstrating that valuable results can be obtained by conducting similar analyses on rock samples from ancient cities and from their possible provenance, and then evaluating them together[15].

In discussion of the possible provenance of the banded travertine in this study, the minero-petrographic characteristics of samples from the ancient city of Tripolis, the geological formation of the region, the ancient quarries around the city, and the grave stone epitaph that was brought to light as a result of the excavations, are the only aspects taken into consideration. Accordingly, it is possible to cite the ancient quarries that are located almost 3 km northeast of the ancient city as the provenance of the banded travertines and the travertine type of the building stones. These ancient quarries are located on the eastern side of the valley through which the Maeander River flows (Figs. 8a, b, c, d). Three partly-preserved ancient travertine quarries have been identified towards the upper part of the slope, starting from the bank of the river. There are some clear cutting marks in different directions on the quarry faces, left by sharp tools which aimed to extract blocks and columns (Figs. 8b, c, d). Moreover, there are small cavities, all sequenced in a line, with certain intervals on the main

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15 Attanasio *et al.* 2000, 257-272; Attanasio 2003, 284; Rapp – Hill 1998, 274; Koralay – Kılınçarslan 2015.

rock block. Wooden wedges must have been nailed into these cavities. The wedges must have been widened by constantly being wetted, and the widening wedges must have caused cracks, which separated the rocks from the main block.

In addition to the geological and minero- petrographic observations, it is important to note a funerary inscription, which was found in the excavations in Tripolis. It state that "*…Hereunder I lie, young of age, in a tomb, by the name of Eutyches, stonecutter;…*" (Fig. 8e). This stone proves that there were stone craftsmen who worked in those quarries and lived in the ancient city of Tripolis (*Personal Communication from Bahadır Duman*). In addition, this is significant archaeological evidence that indicates the provenance for the banded travertines may be those quarries.

Results and Discussion

The results of this study, which aimed to identify the minero-petrographic and geochemical characteristics, as well as the possible provenance of the banded travertine samples from the ancient city of Tripolis, can be summarized as follows:

I) Banded travertine and travertine combinational building stones constitute 35% of the building stones in the ancient city of Tripolis.

II) The banded travertine was used for columns, wall blocks, and cladding of walls and floors in Tripolis city. The typical feature of banded travertine is its white, yellowish-white, greenish-white, red and reddish-brown colored banded structure.

III) According to the microscopic investigation, the banded travertine displays a banded texture and is composed of needle-shaped (or bladed) carbonate minerals (mostly calcite in composition) and a small amount of accessory minerals (Fe-oxides). This result is also supported by XRD studies.

IV) Major and trace element analyses were conducted to determine the geochemical properties of banded travertine samples. The banded travertine samples display limited compositional distribution in terms of major and trace element content.

V) The provenance of the banded travertines, which were widely used in many buildings in the ancient city, must be the ancient quarries located almost 3 km northeast of the ancient city. The geological characteristics of the banded travertine in those quarries show great similarities with the building stones of the ancient city.

VI) This study presents, for the first time, the minero-petrographical identification of the banded travertine building stones of the ancient city of Tripolis, which is located in Denizli Graben. Data gathered as a result of this study will form a significant basis for the protection and restoration work that continues in the ancient city. Clear information regarding the provenances of the banded travertine building stones, necessary for protection and restoration work, can be obtained from original analysis (via Confocal Raman Spectrometry (CRS), Cathodoluminescence (CL), Electron Paramagnetic Resonance (EPR), C-O stable isotope and U-Th isotope analyses) of rock samples. These should be increased and the data from these analyses should be evaluated together.

Abbreviations and Bibliography

Alçiçek 2007	H. Alçiçek, *Denizli Havzası (Sarayköy-Buldan Bölgesi, GB Türkiye) Neojen Çökellerinin Sedimantolojik İncelenmesi* (Ankara Universitesi, Fen Bilimleri Enstitüsü, Jeoloji Mühendisliği Anabilim Dalı, Unpublished Doctoral Thesis), Ankara, 2007.
Attanasio 2003	D. Attanasio, *Ancient white marbles: Analysis and Identification by Paramagnetic Resonance Spectroscopy*, L'Erma di Bretschneider, Roma, 2003.
Attanasio *et al.* 2000	D. Attanasio – G. Armiento – M. Brilli – M.C. Emanuele – R. Platania – B. Turi, "Multi method marble provenance determinations: the Carrara marbles as a case study for the combined use of isotopic, electron spin resonance and petrographic data", *Archaeometry 42*, 2000, 257-272.
Bozkurt – Satır 2000	E. Bozkurt – M. Satır, "The southern Menderes Massif (Western Turkey): geochronology and exhumation history", *Geological Journal 35*, 2000, 285-296.
Bülbül 2000	A. Bülbül, *Kamara ve Çizmeli (Yenice-Buldan) Sıcak ve Mineralli Sularının Hidrojeolojisi* (Pamukkale Universitesi, Fen Bilimleri Enstitüsü, Jeoloji Mühendisliği Anabilim Dalı, Unpublished M.Sc. Thesis), Denizli, 2000.
Çakır 1999	Z. Çakır, "Along - Strike Discontinuity of Active Normal Faults and Its Influence on Quaternary Travertine Deposition: Examples From Western Turkey", *Turkish Journal of Earth Sciences 8*, 1999, 67-80.
Candan *et al.* 2007	F. Chen – R. Oberhansli – M. Çetinkaplan – C. Akal – M. Satır – O. Kaya, "Menderes Masifi'nin Pan-Afrikan temelin stratigrafisi ve örtü - çekirdek serilerinin ilksel dokanak ilişkisi (In Turkish)", *Menderes Masifi Kolokyumu*, Izmir, 2007, 8-14.

Candan *et al.* 2011 — O. Candan – R. Oberhänsli – O.Ö. Dora – M. Çetinkaplan – E. Koralay – G. Rimmelé – F. Chen – C. Akal, "Menderes Masifi'nin Pan-Afrikan Temel ve Paleozoik-Erken Tersiyer Örtü Serilerinin Polimetamorfik Evrimi (In Turkish)", *MTA Dergisi, 142*, 2011, 123-167.

Duman 2013 — B. Duman, "Son Arkeolojik Araştırmalar ve Yeni Bulgular Işığında Tripolis ad Maeaundrum (In Turkish)", *Cedrus 1*, Antalya, 2013, 179-200.

Erdoğan – Güngör 2004 — B. Erdoğan – T. Güngör, "The problem of the core-cover boundary of the Menderes massif and an emplacement mechanism for regionally extensive gneissic granites, Western Anatolia (Turkey)". *Turkish Journal of Earth Sciences 13*, 2004, 15-36.

Erdoğan – Güngör 1992 — B. Erdoğan – T. Güngör, "Menderes Masifi kuzey kanadının stratigrafisi ve tektonik evrimi (In Turkish)", *Türkiye Petrol Jeologları Derneği Bülten 4/I*, 1992, 9-34.

Erten *et al.* 2014 — H. Erten – Ş. Şen – M. Görmüş, "Middle and late Miocene Cricetidae (Rodentia, Mammalia) from Denizli Basin (southwestern Turkey) and a new species of Megacricetodon", *Journal of Paleontology 88(3)*, 2014, 504-518.

Gökgöz 1994 — A. Gökgöz, *Pamukkale - Karahayıt - Gölemezli Hidrotermal Karstının Hidrojeolojisi* (Süleyman Demirel Universitesi Fen Bilimleri Enstitüsü, Jeoloji Mühendisliği Anabilim Dalı, unpublished doctoral thesis), Isparta, 1994.

Gökgöz 1998 — A. Gökgöz, "Geochemistry of the Kızıldere–Tekkehamam–Buldan–Pamukkale geothermal fields", *United Nations University, Geothermal Training Programme, Reports*, Reykjavik, Iceland, 1998, 115-156.

Guo – Riding 1998 — L. Guo – R. Riding, "Hot-spring travertine facies and sequences, Late Pleistocene Rapolano Terme, Italy", *Sedimentology 45*, 1998, 163-180.

Ingham 2010 J. Ingham, *Geomaterials Under the Microscope: A Colour Guide, CRC Press*, 2010.

Konak 1985 N. Konak, "A Discussion on the Core-Cover Relationship on the Basis of Recent Observations (Menderes Massif)", *The Geology Congress of Turkey Abstracts 33*, 1985.

Koralay *et al.* 2011 O.E. Koralay – O. Candan – C. Akal – O.Ö. Dora – F. Chen – M. Satır – R. Oberhanslı, "Menderes Masifindeki Pan Afrikan ve Triyas Yaşlı Metagranitoyidlerin Jeolojisi ve Jeokronolojisi, Batı Anadolu, Türkiye (In Turkish)", *MTA Dergisi 142*, 2011, 69-121.

Koralay 2015 T. Koralay, "Minerologic, Petrographic and Geochemical Properties of Traverten Building Stones in Tripolis Antique City (Yenice/Buldan Denizli)", *Travertine - Tufa Workshop November 5-8*, Denizli Turkey, 6-7 (inside USB).

Koralay – Kılınçarslan 2015 T. Koralay – S. Kılınçarslan, "A multi-analytical approach for determining the origin of the marbles in Temple-A from Laodicea ad Lycum (Denizli-Western Anatolia, Turkey)", *Journal of Cultural Heritage,* http://dx.doi.org/10.1016/j.culher.2015.05.005

Koralay *et al.* 2013 T. Koralay – Y.K. Kadıoğlu – Y. Jiang – S.Y. Jiang, "Determination of Tourmaline Composition in Pegmatite from Buldan - Denizli (Western Anatolia-Turkey) Using XRD, XRF and Confocal Raman Spectroscopy", *Spectroscopy Letters, 46*, 2013, 499-506.

Oberhänsli *et al.* 1997 R. Oberhänsli – O. Candan – O.Ö. Dora – S. Dürr, "Eclogites within the Menderes Massif / Western Turkey", *Lithos 41*, 1997, 135-150.

Özkul *et al.* 2013 M. Özkul – S. Kele – A. Gökgöz – C.C. Shen – B. Jones – M.O. Baykara – I. Fórizs – T. Németh – Y. W. Chang – M.C. Alçiçek, "Comparison of the Quaternary travertine sites in the Denizli extensional basin based on

	their depositional and geochemical data", *Sedimentary Geology 294*, 2013, 179-204.
Pentecost 2005	A. Pentecost, *Travertine*, Springer Verlag, 2005.
Rapp 2009	G. Rapp, *Archaeo-mineralogy*, Springer Verlag, 2009.
Rapp – Hill 1998	G. Rapp – C.L. Hill, *Geoarchaeology,* Yale University Press, 1998.
Reedy 2008	C.L. Reedy, *Thin-Section Petrography of Stone and Ceramic Cultral Materials*, Archetype Publication Ltd, 2008.
Rollinson 1993	H.R. Rollinson, *Using geochemical data: Evaluation, presentation, interpretation*, New York, 1993.

http://www.dmi.gov.tr
http://www.pau.edu.tr/tripolis

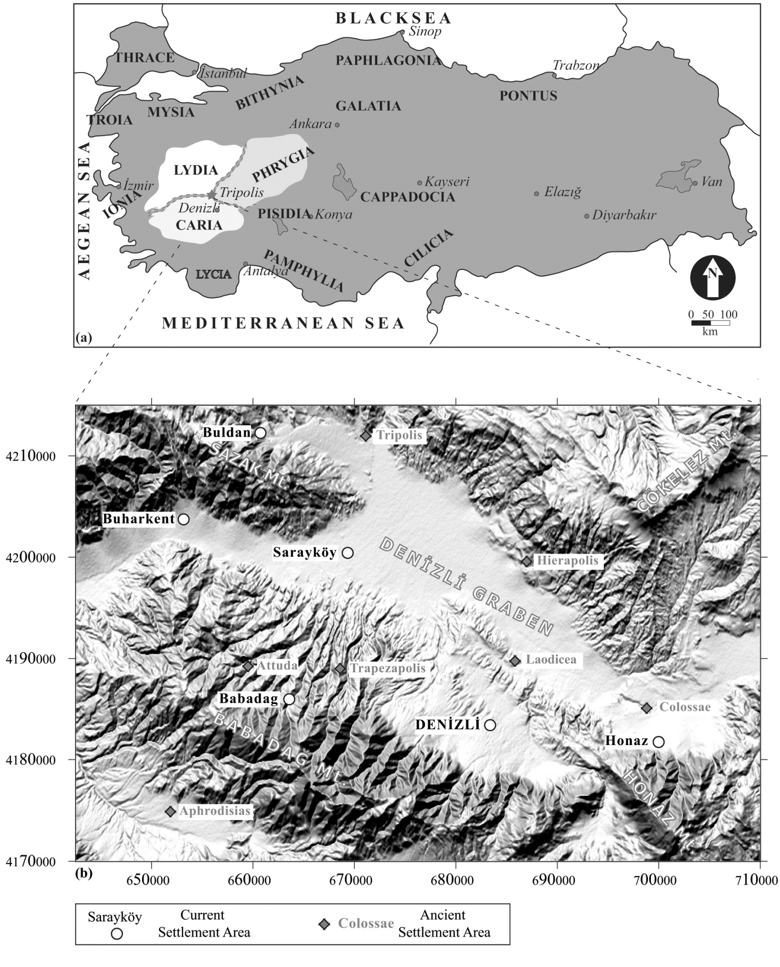

Fig. 1. a) Simplified map of Asia Minor, showing the distribution of the ancient regions (modified from http://www.arkeolojidunyasi.com/antik_bolgeler.html); b) Digital Elevation Model (DEM) of Denizli Graben.

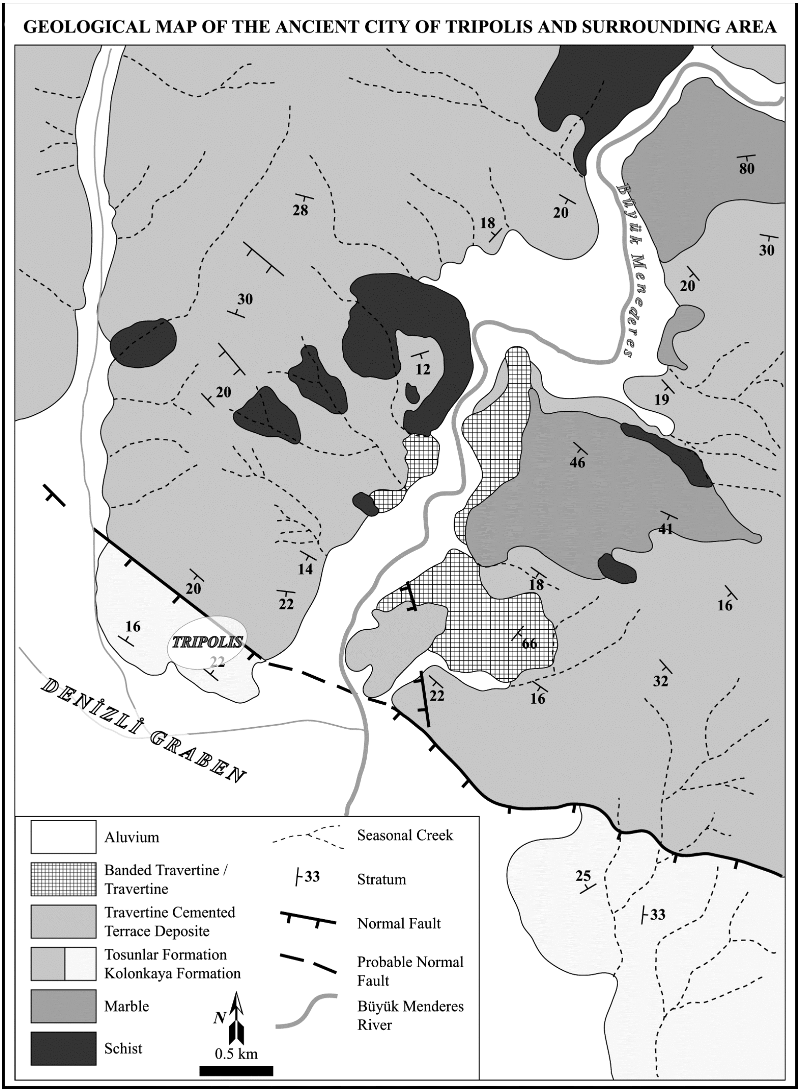

Fig. 2. Geological map of the ancient city of Tripolis and surrounding area.

Fig. 3. Banded travertine blocks used for different purposes a) columns; b) column; c) paving.

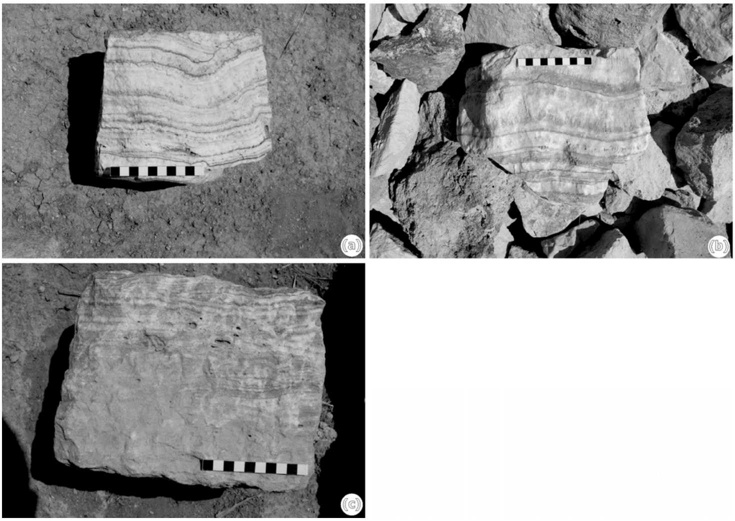

Fig. 4. Specimens of banded travertines: a) white, yellowish-white, greenish-white, red and reddish-brown colored banded structure; b) the colored bands, ranging between 0.5 and 5 cm in width, are generally parallel to each other; c) elliptical small cavities between colored bands.

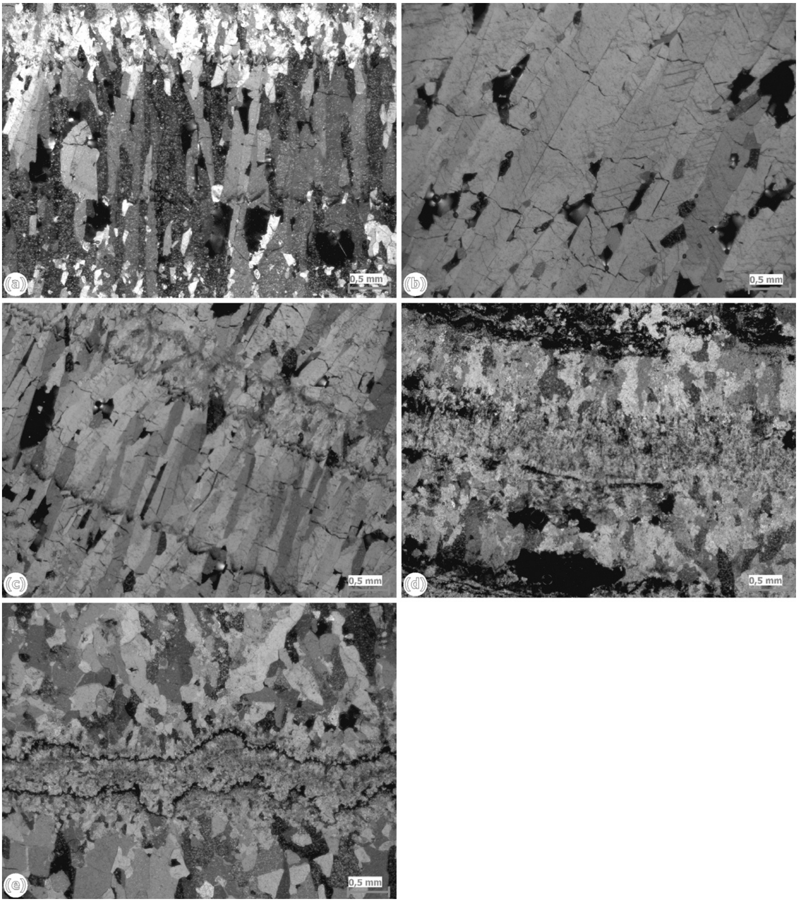

Fig. 5. Microphotographs of banded travertine samples: a, b, c) banded texture, microcracks and iron-oxide bands in needle-shaped carbonate minerals; d, e) colored bands are separated by levels composed of fine-grained carbonate slurry, iron-oxide minerals and/or elliptical cavities.

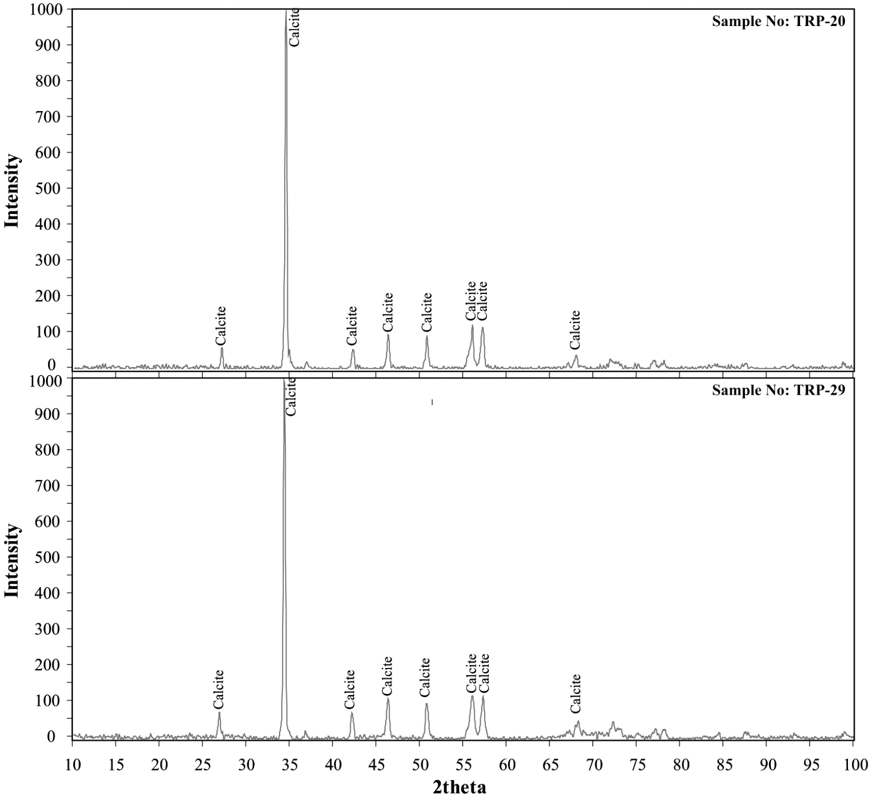

Fig. 6. XRD graphics of selected banded travertine samples.

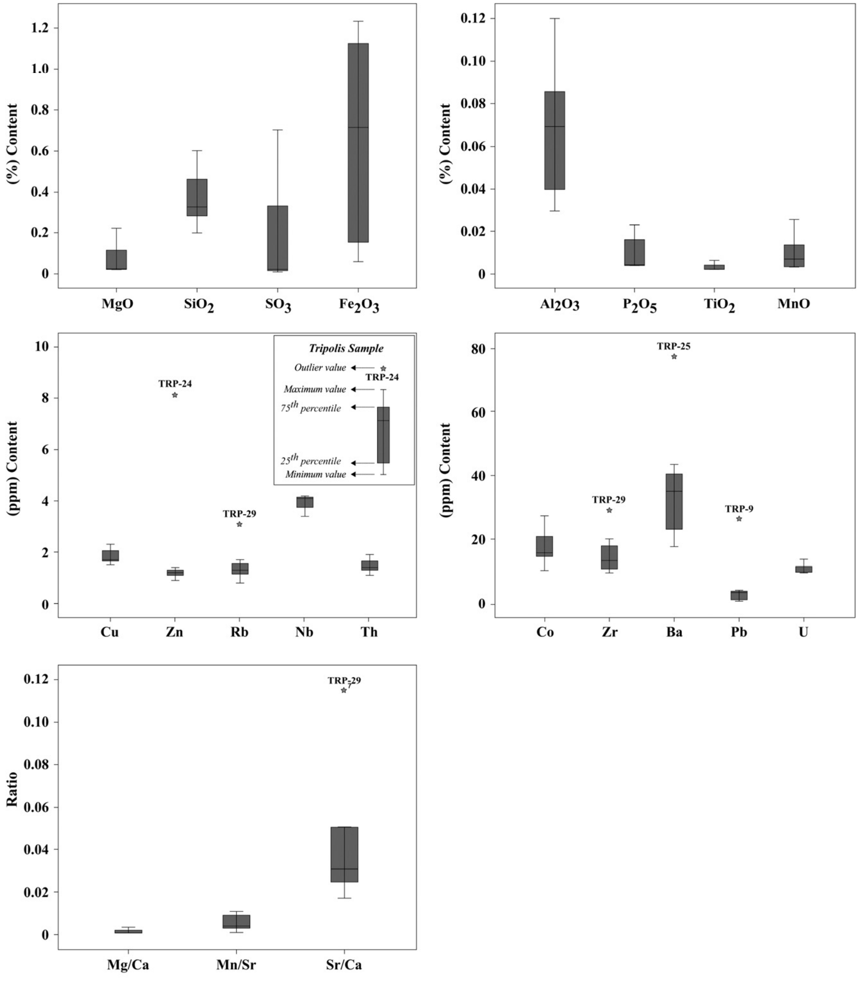

Fig. 7. Content boxplots of selected major and trace element and elemental ratios in Tripolis banded travertine samples.

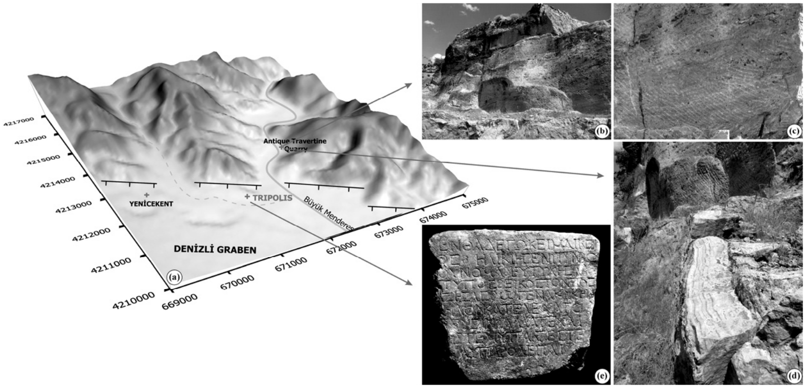

Fig. 8. a) location map of ancient banded travertine quarries; b, c) work-faces bearing cutting marks left by pickaxes and pointed chisels (Fig. 6c taken from Prof. Dr. Mehmet ÖZKUL); d) raw banded travertine block in ancient quarry; e) funerary inscription of the stonecutter, Eutyches.

Table 1. Major oxide (%) and trace (ppm) element analyses of the banded travertine samples.

Elements		**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
MgO	(%)	0.02	0.22	0.08	0.09
Al_2O_3	(%)	0.03	0.12	0.07	0.03
SiO_2	(%)	0.20	0.60	0.37	0.14
P_2O_5	(%)	0.004	0.023	0.010	0.009
SO_3	(%)	0.01	0.70	0.21	0.32
Ca	(%)	41.52	44.58	43.30	1.21
TiO_2	(%)	0.002	0.006	0.003	0.002
MnO	(%)	0.003	0.026	0.010	0.009
Fe_2O_3	(%)	0.06	1.23	0.65	0.52
Co	(ppm)	10.5	27.6	18.0	5.8
Ni	(ppm)	4.3	8.7	5.1	1.6
Cu	(ppm)	1.5	2.3	1.8	0.3
Zn	(ppm)	0.9	8.1	2.1	2.6
Rb	(ppm)	0.8	3.1	1.5	0.8
Sr	(ppm)	722.2	5090.0	1934.3	1501.2
Y	(ppm)	0.8	1.1	0.9	0.1
Zr	(ppm)	9.8	29.0	15.8	6.9
Nb	(ppm)	3.4	4.2	3.9	0.3
Ba	(ppm)	17.9	77.0	36.9	20.0
Pb	(ppm)	1.0	26.4	6.0	9.1
Th	(ppm)	1.1	1.9	1.5	0.3
U	(ppm)	9.8	14.0	11.0	1.9
Mg/Ca		0.0003	0.0030	0.0011	0.0012
Mn/Sr		0.0005	0.0103	0.0052	0.0039
Rb/Sr		0.0006	0.0014	0.0009	0.0004
Sr/Ca		0.017	0.114	0.044	0.033
Zr/Ti		2.8	20.2	9.1	5.6
Nb/Y		3.8	5.3	4.5	0.4