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GEOLOGICAL AND ARCHITECTURAL INVESTIGATION OF REUSED ROCK COLUMNS IN THE GREAT MOSQUE IN DIYARBAKIR OLD CITY (TURKEY)

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ABSTRACT

Cylindrical rock columns in the Great Mosque in Diyarbakir Old City are investigated for their lithology and architecture. The columns belong to four different rock types, namely pre-Tertiary meta-ophiolites, Eocene limestones, Miocene limestones and Plio-Quaternary basalts. The columns from the first three lithologies are reused during the construction and/or renovation of the Great Mosque. Thin sections prepared from 18 columns of this building confirm they are derived from the rocks exposed in the region. The reuse of the columns is approved by inconsistent column lengths, multi-segment column shafts, lithologically mixed columns and presence of thin wedges at the bottom of column bases. These columns are not used to support the main body but rather either for partial support or only for decorative reasons.

KEYWORDS: Reuse, Great Mosque, Column, Diyarbakir

1. INTRODUCTION

Diyarbakir city is located in the southeastern part of Turkey along the western bank of biblical Tigris (Dicle River) (Figure 1). It is an ancient city surrounded by walls. The first city wall is built in 349 AD during the Roman period although "an enclosed city within the walls" is also reported for Hurri period that dates back to 2000 BC (Gabriel, 1940; Can, 1991; Parla 2005). After the year 363 AD a new wall was added to widen the city and was renovated several times in the later periods. The city wall, in its present form, is a continuous structure with a length of 5.5 km surrounding the Old City. All the historical buildings of Diyarbakir are located within the Old City including churches, mosques, hans (caravanserai), fountains, traditional Diyarbakir houses and others public buildings such as madrasahs (old traditional schools) and libraries.

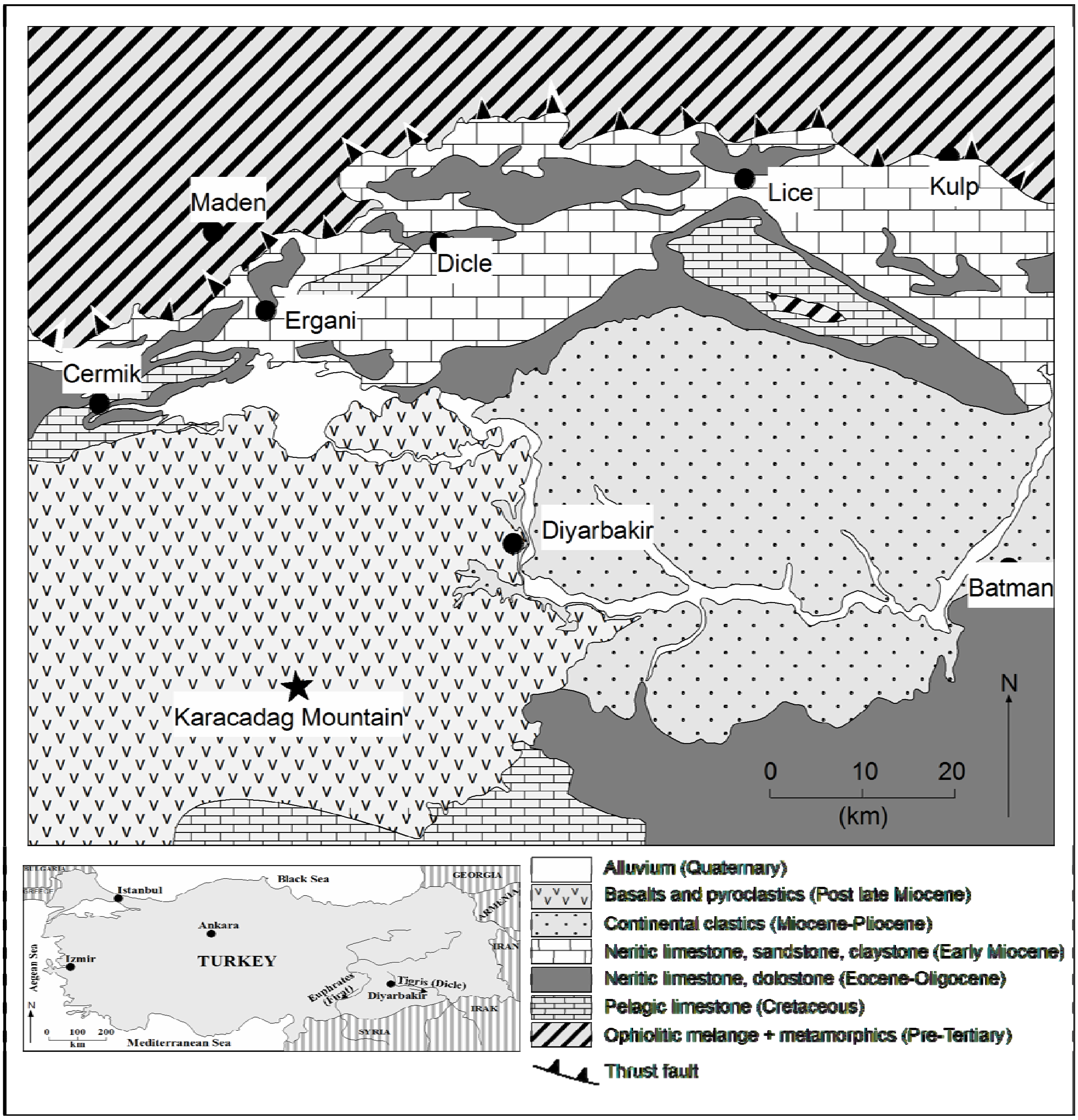

Figure 1. Geological map of Diyarbakir and vicinity simplified from geological maps at 1/100.000 scale prepared by General Directorate of Mineral Research and Exploration of Turkey (Sutcu, 2008).

The most remarkable feature of these building is the use of basaltic rocks as construction material. This is because the city is built over a basaltic plateau formed by lava flows erupted from a strato-volcano 20-25 km southwest of the city. One special and distinct architectural element in these buildings is the cylindrical columns which are made up of different lithologies as well as the basalts. Some of the columns are originally designed and sculptured for the building while some others are reused from pre-existing buildings.

Reuse of architectural elements is a common practice known in the region in the historical buildings. Oney (1970) analyzing the reused material in a number of mosques and other public buildings in different cities of Turkey states that some materials contain certain elements from Greek, Roman, Byzantine and Armenian arts. She claims that the use of such material particularly the columns including the capitals and the bases are more dominant in the mosques and madrasahs. The reason for this clearly is the quality of the ornamentation and the labor. Barkan (1972) and Yoruk (2008) pointed out to economical aspects of reusing pre-existing material in the construction of a new building. They estimate an increase in the cost (4 to 6 times) for the extra processes such as quarrying, transportation and sculpturing. Whether aesthetical or economical, the reuse of ancient existing material is a common tradition in the region.

The purpose of this study is to investigate the rock columns in the Great Mosque in Diyarbakir Old City to shed light on the tradition of reusing ancient material. The scope of the study involves the determination of the rock types in relation to the stratigraphy of the area and investigation of the evidences for the reuse.

2. ROCK SOURCES IN THE REGION

The city of Diyarbakir is located, from geological point of view, close to the line of collision between Arabian and Eurasian plates. This collision led to the formation of a suture zone extending in E-W direction, approximately 50 km north of Diyarbakir which resulted in a complicated geology in the region. Considering the purpose and scope of this study, the details of geological aspects of the area will not be dealt here. Therefore, in this section a brief review of the rock units existing in the area and their distribution will be given with a particular emphasis on their probable source for the columns used in the buildings. For this reason a simplified map is prepared from 1/100.000 scale geological maps of Turkey (Figure 1). Accordingly, six major units are exposed in the area excluding the Quaternary alluvium. These units are explained below considering basically their probable use as building material.

The oldest rocks in the area belong to the allochthonous unit that moved from north to the south over the Miocene units along the thrust fault. This zone is simplified in the geological map and is shown as a single line along Cermik, Ergani, Dicle, Lice to Kulp. The dominant lithologies in this belt are marbles, metaquartzites, gneisses, mica-schists, amphibolites and meta-ophiolites (Genc, 1985). Several columns investigated in this study are known to be derived from the meta-ophiolites. These rocks will be referred to as "M" in the later sections.

Cretaceous period is represented generally by pelagic limestones although some outcrops of shallow marine deposits and reefal limestones (Guven et al, 1991, Sutcu, 2008). There is not any known building stone or column used in the structures being derived from this sequence. This is, most probably, due to its thin bedded nature and inappropriate quarry conditions.

During the Eocene period the area is represented by a carbonate platform where thick limestones are deposited. The eastern part of the area is characterized by shallow environment as indicated by shelf carbonates and reefal limestones whereas in the western part a relatively deeper sequence composed of marl, clayey limestone and chalky limestone alternation. Eocene sequences are exposed both to the north and south of Diyarbakir extending in E-W direction. Some of the columns used in the Great Mosque belong to this lithology that will be referred to as "L1" in this study.

During the Miocene period the region is converted to a very shallow marine environment characterized by thick reefal limestones deposited in a narrow belt parallel to the thrust belt. These limestones can be quarried as large blocks and therefore became a preferred stone used as building material (Erdogan and Yavuz, 2002). Today most of the rock quarries around Diyarbakir are located within this unit particularly along Hazro, Hani, Ergani, Cermik and Cungus line (Figure 1). The unit is also used as columns in the Great Mosque and will be referred to as "L2" in this study.

Volcanic rocks of post late Miocene age cover a wide area particularly in the western part of Diyarbakır (Figure 1) exposed in the form of a typical shield volcano. Eruption history of these volcanics is divided into three phases dated as 11 to 0.01 Ma (Saroglu and Emre, 1987; Haksal, 1981; Ercan et al., 1991; Notsu et al., 1995; Bridgland et al., 2007; Lustrino et al., 2010). Diyarbakir city is located over the lava flows of these volcanics forming a flat plateau over the western bank of Tigris. This is the main reason for the use of basalt as a dominant building material in the city wall as well as other public and private structures in the old city. This rock will be referred to as "B" in the later parts of this study.

Physico-mechanical properties of the rocks used as column in the buildings are summarized in Table I.

Table I Physical properties of rocks used as column in the Great Mosque.

Physical Property	*Plio-Quaternary Basalt (B)*	*Miocene Limestone (L2)*	*Eocene Limestone (L1)*
Uniaxial Compressive Strength (MPa)	86.21 (Kilic et al, 2003)	80.22 (Kilic et al, 2003)	11.18 (Kaya, 2008)
Porosity (%)	1.78 (Dursun, 2008)	1.02 (Ciftepala et al, 2003)	23.55 (Kaya, 2008)
Unit Weight (g/cm^3)	2.638 (Dursun, 2008)	2.611 (Ciftepala et al, 2003)	1.699 (Kaya, 2008)

Properties of the metamorphic rocks are not given in this table since there is no study carried out on those rocks. Therefore the information compiled from the literature covers three units which are extensively used as columns in the buildings.

Only three parameters which are believed to quantify physical properties are selected. These are uniaxial compressive strength, porosity and unit weight. As clearly seen in the table, basaltic rocks and Miocene limestone have almost similar values indicating a stronger, less porous and denser rock type than Eocene limestone.

Marble and Mining Industry Association of Diyarbakir published a catalogue of stones quarried in the vicinity of Diyarbakir (DMMD, 2008). Accordingly, a total economical reserve of 95.000.000 m^3 is estimated around Diyarbakir. There are 34 companies, 43 quarries and 25 processing factories.

Valuable information in this catalogue related to the scope of this study is that most of the quarries belong to two units which are Miocene limestones and Plio-Quaternary basalts, L2 and B, respectively.

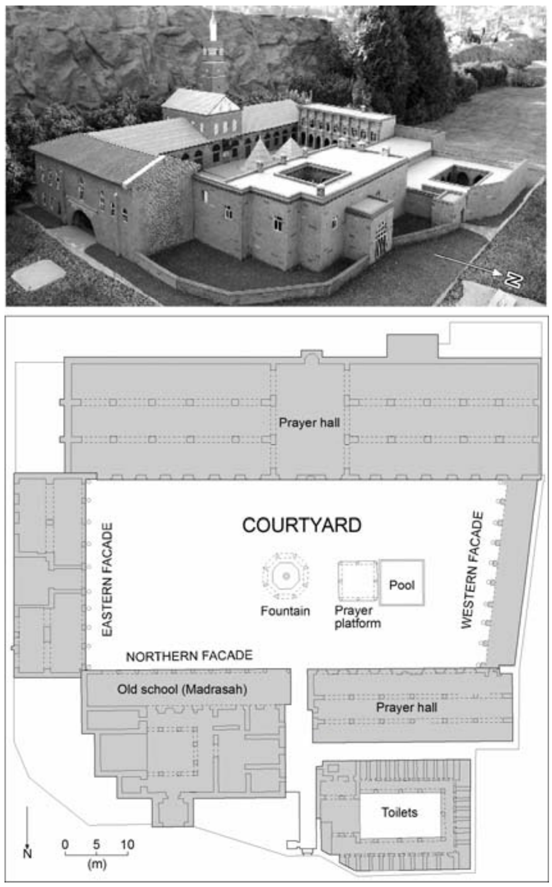

Figure 2. (a) A model of Great Mosque exhibited in Miniaturk, Istanbul, (b) Plan of the Great Mosque (from Tuncer, 1996) showing the major elements and particularly the three facades where the columns are located.

3. COLUMNS OF THE GREAT MOSQUE

Great Mosque is one of the oldest mosques built in Anatolia (Aslanapa, 1971; Akurgal, 1980). Guyer thinks that the church of St. Thomas, supposedly built by the emperor Heraclius, once stood on the site of the Great Mosque of Diyarbakır (Amida). We know from the Zuqnin Chronicle that the "Great church of Amida" started to be built by the emperor Heraclius in 629, but there is no mention that it was actually dedicated to St. Thomas except in the later Islamic accounts. It has been argued that after the capture of Amida in 639, the principal church of St. Thomas was divided between the Muslims and the Christians. However, the chronicle of Zuqnin tells us that the church was restored in 770: "they applied new material in replacement of all the decay that was in it, and made it as glorious as it had been originally" suggesting that the whole building was still used as a church then. There is no archaeology to support or dispute these accounts. However, given the central location of the mosque, it is very likely that the cathedral of the Byzantine city stood at that spot (Keser-Kayaalp, 2009).

The current building was probably first completed in 1092 and rebuilt after the damage caused by an earthquake in 1115 (Sozen, 1987; Abu'l Farac, 1999). Later it has been restored several times and new elements were added (Tuncer, 1996, Beysanoglu, 2003). In its present form it has a courtyard (32*65 m) surrounded with two prayer halls and a madrasah (traditional religious school) (Figure 2). At the middle of the courtyard a fountain, a praying platform and a pool exist. Eastern and western courtyard facades are decorated with two-storey columns suggesting to be inspired by a Roman theater (Sozen, 1971; Aslanapa, 1991).

3.1 Architecture in relation to lithology

The columns used in the mosque are located over three courtyard facades, namely western, eastern, and northern. There are other columns found in the smaller structures in the courtyard such as the fountain and the prayer platform. These columns are not investigated in this study, since they might belong to a later period. The columns within the buildings holding the structures are in the form of pillars made up of basaltic rocks. Therefore, in this study only the columns observed in three facades will be investigated.

Total number of columns used in the courtyard facades is 49. General features of these columns are given in Table II. Western and eastern facades have 20 columns each; 10 in the first and 10 in the second floor. The northern facade has 9 columns all in the first floor. Details on the lithology and the lengths of the columns are shown in Figures 3, 4 and 5 for western, eastern and northern facades, respectively. Following observations can be made based on the information provided in the figures:

Table II Summary information about Great Mosque columns

Location of columns		*Number of columns*	*Shaft characteritics*	*Capital*	*Base*
Western Facade	2nd floor	10	All monolithic All L1	All L1	All L2
	1st floor	10	All multiple pieces, Six single lithology (L2) Four double lithology (L2+M)	All L1	Buried
Eastern Facade	2nd floor	10	Nine monolithic, one two-pieces All single lithology Four L2, six M	All L1	Seven L2, three M Nine wedges below base (all B)
	1st floor	10	All multiple pieces, Seven single lithology (4*L2, 3*M) Three double lithology (L2+M)	Seven L1, three L2	Buried
Northern Facade	1st floor	9	All single, All L2	All L1	Buried

• Number of the pieces used in the shafts of the columns is not consistent. There are 28 monolithic, 17 two-piece and 4 three-piece columns. There is, however, a clear relationship between the location of the columns and the multiple shafts. The columns in the northern facade are all monolithic. In the western and the eastern facades, on the other hand, generally the monolithic columns are located in the second floor facing each other (Figures 3 and 4). There is only one two-piece column in the eastern facade (column no: 3). All other multi-piece columns are located in the first floor of the western and eastern facades.

• Use of the mixed rock types is a common feature observed in Great Mosque. A total of seven columns, three in the eastern facade and four in the western facade, are composed of meta-ophiolites and Miocene limestone shaft segments.

• Lengths of the shafts are not uniform neither in monolithic nor in multi-shaft columns. The bases of the shafts in the first floor are buried during the restoration periods; therefore, the exact lengths can not be determined for 29 columns. Observable average lengths in the first floor are 422 cm, 413 and 181 for the western, eastern and northern facades, respectively. Length of individual segments also shows a great variation from 38 to 309 cm. Other columns that have both a capital and a base show significant variation in the length. These columns (located in the second floors) have average length of 237 cm for the western and 252 cm for the eastern facade.

• Torus at the top and bottom of the shaft provides valuable information on the originality of the column. In normal cases a shaft should have torus both at the top and bottom if the column is originally designed for that location. A shaft segment, therefore, with a torus missing on one or both ends suggests that this segment is cut from a pre-existing longer shaft. A total of 13 column shafts are identified with two toruses. These columns are indicated with a star in Figures 3 and 4. All other shaft segments are missing torus either on one or both ends. It should also be noted that, there is not any consistency in the orientation of the shaft segment if torus is absent.

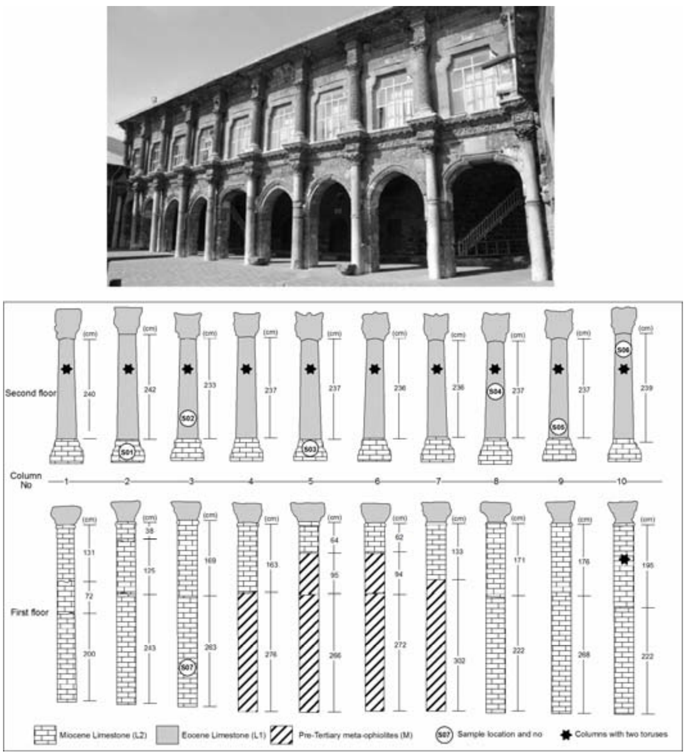

Figure 3. Photograph of the western facade of the Great mosque (above) and details of the columns on this facade (below).

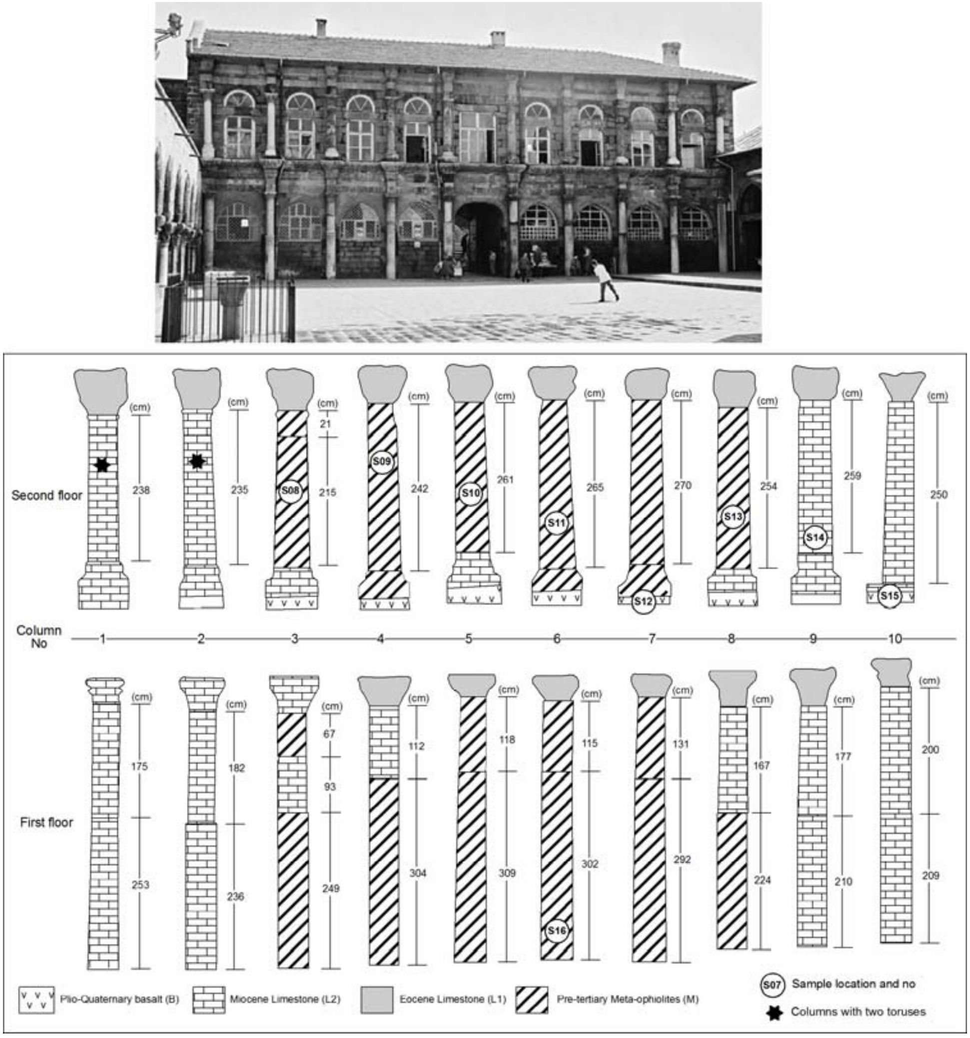

Figure 4. Photograph of the eastern facade of the Great mosque (above) and details of the columns on this facade (below).

• Basalt although is the main lithology in other parts of the mosque is not used at all as a column element (shaft, capital nor base). Thin basalt wedges are used at the bottom of bases in the second floor columns of the eastern facade. These wedges are located beneath nine column bases on the second floor of the eastern facade (Figure 4). These are most probably used to elevate the columns and are unique examples of this lithology used as a material in the columns of the Great Mosque. The thicknesses of the wedges are not consistent and range from 13 to 26 cm. In most of the wedges the thickness gets thinner from right to left (S to N). Maximum difference is about 6 cm in the column no: 5.

• Decorative ornamentation is common in almost all capitals and bases of the columns of the Great Mosque. Details of ornamentation will not be dealt here considering the scope of this study. In the shafts, on the other hand, the ornamentation is observed only in the second floor monolithic shafts of the western facade. It should be noted that these shafts are made up of Eocene limestone (L1).

3.2 Lithologic characterization

Petrographic analyses of the columns are carried out over the samples in order to match the columns to the rock units existing in the region. A total of 18 samples are provided from the columns during the last restoration process. All the samples are collected under the inspection of authorities and are officially recorded. The samples are taken from broken pieces at the outer surface due to fracturing. Basalt and limestone samples (both Eocene and Miocene) are derived from fresh surfaces whereas meta-ophiolitic samples are relatively weathered. Locations of the samples are shown in Figures 3, 4 and 5.

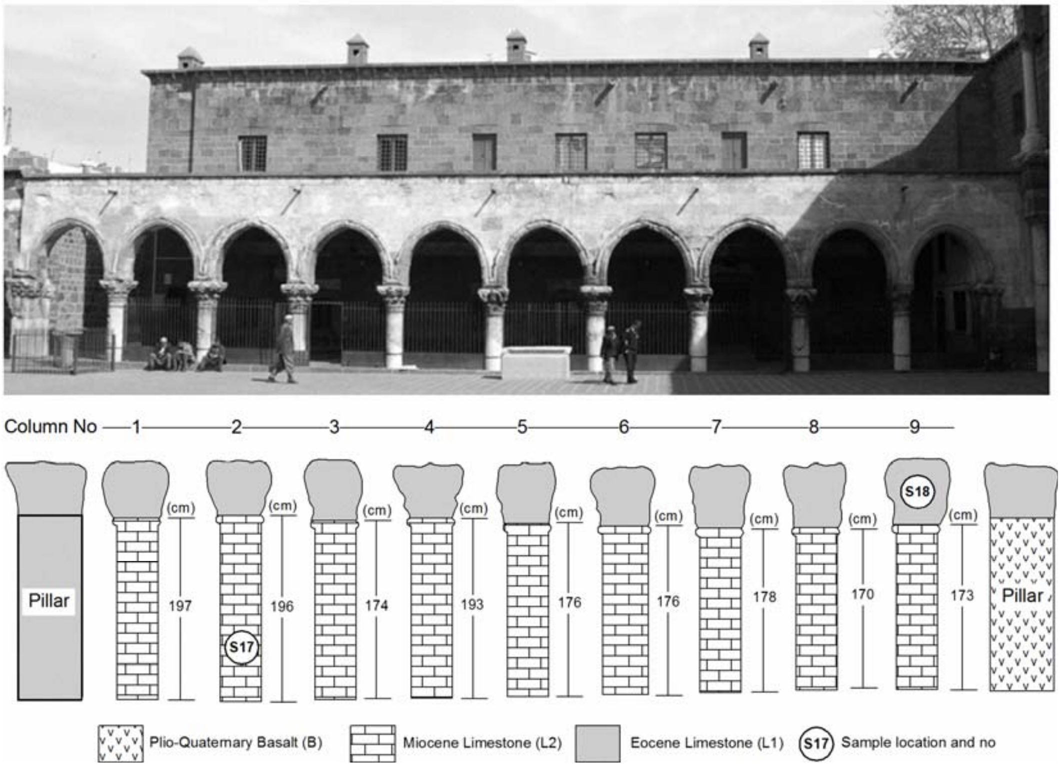

Figure 5. Photograph of the northern facade of the Great mosque (above) and details of the columns on this facade (below).

A short description of the samples is provided in Table III. Thin sections of the samples are prepared are prepared and at the laboratories of the Mineral Research Institute of Turkey in Ankara. Eocene and Miocene limestone samples are analyzed by Dr. I. Omer Yilmaz; meta-ophiolites and basalts by Dr. Fatma Toksoy Koksal (both from Geology Department, Middle East Technical University, Ankara).

Table III Petrographic analyses of Great Mosque columns

Sample No	*Facade*	*Floor*	*Column No*	*Column Element*	*Thin section description*	*Lithology in this study*
S08 S09 S10 S11 S13 S16	Eastern Eastern Eastern Eastern Eastern Eastern	2nd 2nd 2nd 2nd 2nd 1st	3rd 4th 5th 6th 8th 6th	shaft shaft shaft shaft shaft shaft	*Serpentinized Peridotite* primary minerals: olivine + chromite ± clinopyroxene ± orthopyroxene secondary minerals: calcite after clinopyroxene serpentine and talc after olivine (mesh texture) intensely cut by thick veins carbonate (magnesite?) + silica	Pre-Tertiary meta-ophiolites
S02 S04 S05 S06 S18	Western Western Western Western Northern	2nd 2nd 2nd 2nd 1st	3rd 8th 9th 10th 9th	shaft shaft shaft shaft capital	Porous, wackestone to packstone facies with nummulites and intraclasts embedded in neritic microsparitic matrix.	Eocene limestone
S01 S03 S07	Western Western Western	2nd 2nd 1st	2nd 5th 3rd	base base shaft	Grainstone facies with red algea and coral fragments cemented by spary calcite.	Miocene limestone

S14 S17	Eastern Northern	2nd 1st	9th 2nd	shaft shaft		
S12 S15	Eastern Eastern	2nd 2nd	7th 10th	below base below base	*Vesicular olivine-basalt* primary minerals: *phenocryst :* olivine + titaniferous augite *groundmass :* olivine + titaniferous augite + plagioclase + alkali feldspar ± opaque secondary minerals: iddingsite after olivine texture: vesicular, holocrystalline, porphyritic, intergranular to ophitic / subophitic	Plio-Quaternary basalt

Six samples belong to meta-ophiolites, all from the shafts of eastern facade (Figure 4). They all have similar petrographic characteristics and are named as serpentinized peridotites with primary minerals of olivine and/or chromite. The visible color in the column that ranges from green to red depends on the dominance of olivine or chromite, respectively. In most of the sections schistosity is observed which is attributed to the southerly thrusting of ophiolites (Figure 1). In all sections the main rock is cut by carbonate (magnesite?) and/or silica veins (Figure 6). Specific quarries of these rocks in the field are not known; however, they should be in the close vicinity of the E-W trending thrust belt north of Diyarbakir.

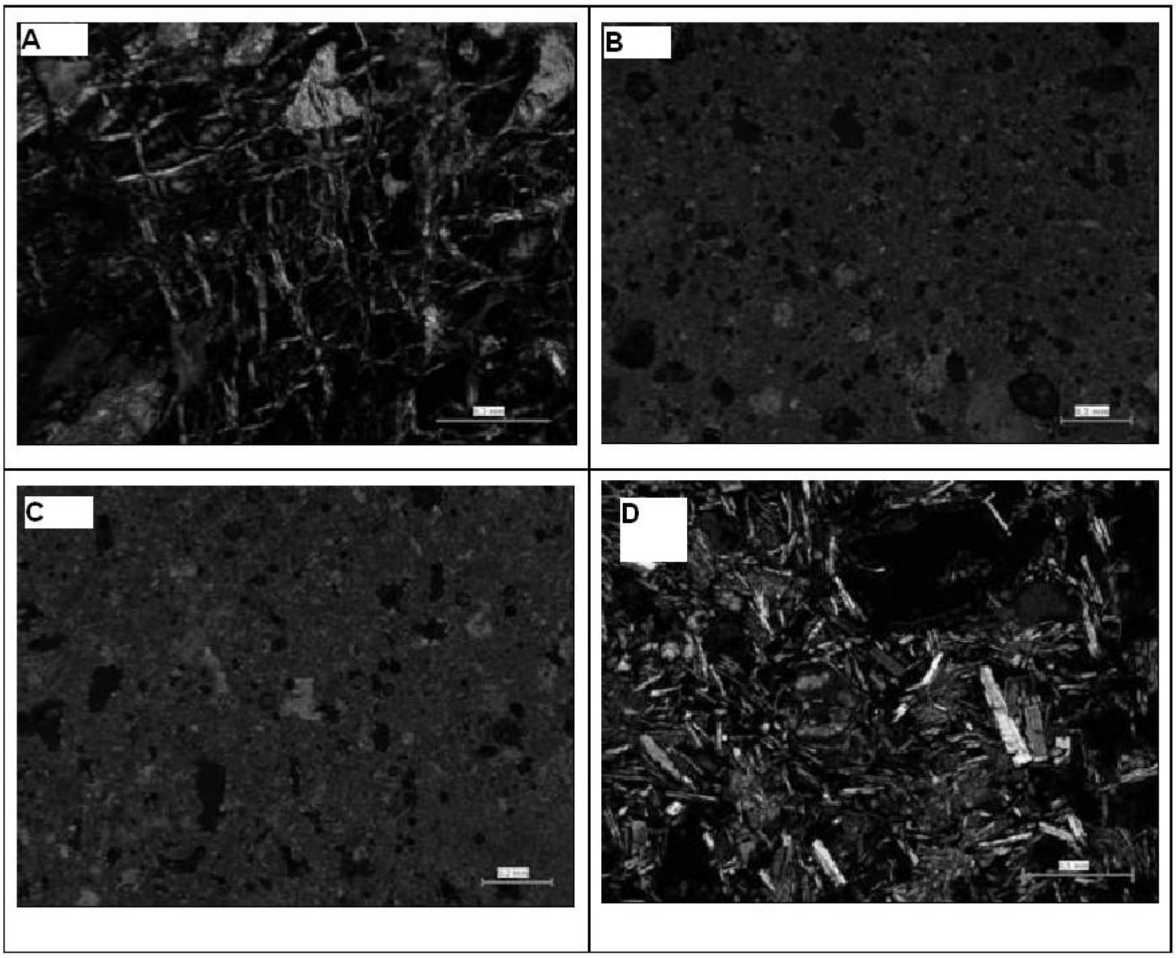

Figure 6. Microphotographs of the samples taken from columns. A) Pre-Tertiary Meta-ophiolites, B) Eocene limestone, C) Miocene limestone, D) Plio-Quaternary basalt

Five samples that belong to Eocene limestone are collected from western and northern facade (Figure 3, 5). They are in the facies of wackestone to packstone with nummulites and intraclasts embedded in neritic and microsparitic matrix. Presence of nummulites approves the age of Eocene for this lithology. Besides, the porous nature of the rock is also consistent with the measurements carried out in the field from this lithology (Table I).

Miocene limestone is represented by five samples collected from different elements of columns of all three facades (Figure 3, 4, 5). They are determined as grainstone facies with red algae and coral fragments cemented by spary calcite. Although the rock is fossiliferous, a specific age can not be assigned due to the time range of the fossils. It can be, however, correlated with the Miocene limestones which is the only known reefal limestone exposed in the region (Erdogan and Yavuz, 2002).

Two samples from Plio-Quaternary basalts are taken from the wedges below the column base in the second floor of the eastern facade. The rock is represented by olivine and augite phenocrysts set in olivine, augite and alkali feldspar groundmass.

4. DISCUSSION

4.1 Evidences for the reuse of columns

Although the tradition of column reuse is already reported in the literature for Diyarbakir Great Mosque (Sinclair, 1989; Aslanapa, 1991; Stierling, 2006), so far no concrete evidences are given. These evidences are listed below based on the data presented in previous sections.

Presence of torus on both sides of the column indicates the original size of the column and therefore implies whether this column is designed for this site or not. If the torus is missing in the shaft it means that the shaft is sliced from an existing longer column to the desired length. Total number of columns with two toruses (original columns) is 13. All other columns made from meta-ophiolites, Eocene Limestone and Miocene limestone are missing the torus indicating that the columns do not originally belong to this building.

Number of shaft pieces is not consistent in the columns and varies from one to three segments. There is not any systematic pattern in the segment number; they are randomly distributed implying no architectural styles.

Segments in the same column may contain multiple lithologies. Three columns in the western and four columns in the eastern facade of Great Mosque are composed of Miocene limestone and meta-ophiolites. This lithological mixture in the Great Mosque columns is missing this harmony and should be related to reuse. However, a careful observation on the use of meta-ophiolites in the Great Mosque suggests an interesting pattern. Location of the meta-ophiolitic columns generates an arch in the central parts of the facades. This arc is observed in both floors of the eastern, and the first floor of the western facade (Figure 7). Diameter of the arch is different because in western facade the arch is made by four columns whereas in the eastern facade by six. Although two arches are almost symmetrical one of them is a bit skewed due to the differential lengths of meta-ophiolitic shafts in columns no: 4 and 7. This arch would also be symmetric if the meta-ophiolitic segment in column 3 would be located to the top of column 4.

The lengths of the columns are another evidence of the reuse. Columns have different total lengths whether monolithic or not. Particularly the second floor columns in the western facade having toruses on both ends are typical examples of length inconsistency. Difference in the column length is compensated by different base and/or capital height. This is best illustrated by the upper levels of the column bases in the second floor of the eastern facade (Figure 4, columns: 4, 5 and 7). The use of basaltic elements at the bottom of column bases in these columns supports the evidence of reuse. They are located below nine columns and have two distinct features: 1) they have different thicknesses ranging from 13 to 27 cm with no systematic spatial distribution; 2) they are in the form of wedges with a variance of a few cm on both edges. The wedge is missed at the bottom of the first column suggesting that these wedges are not for decorative purposes but simply to elevate the columns to fit the facade.

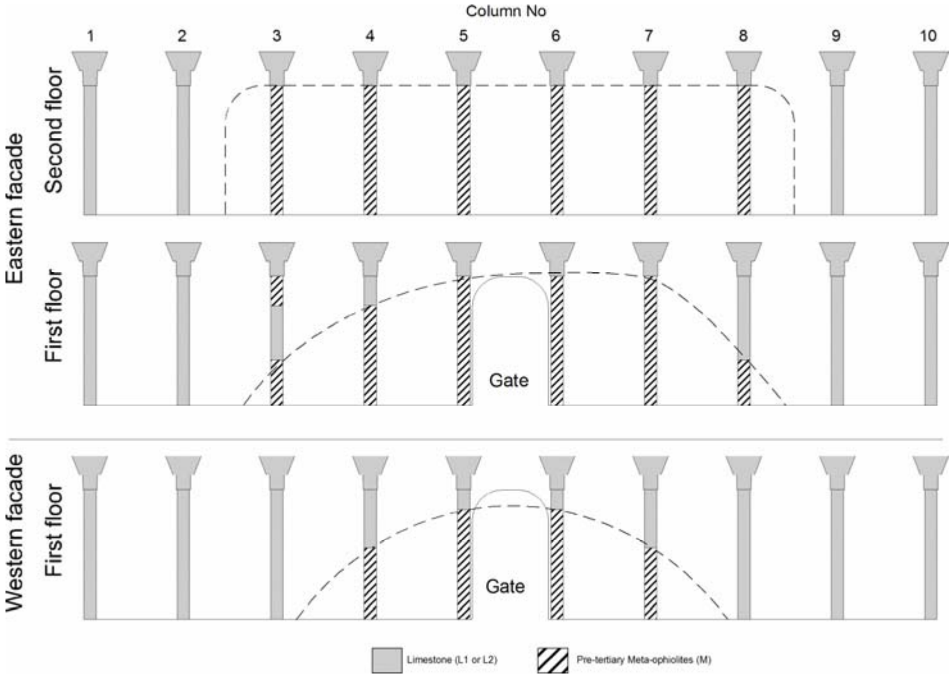

Figure 7. Interpretation of lithologically mixed columns observed in the first floors of western and eastern facades of the Great Mosque. Column shafts made up of meta-ophiolites are located in the central parts of two facades forming a shape of arc by adjusting the lengths in the adjacent columns.

4.2 Lithologic control on the function of columns

The lithology influenced the function of the column and the architectural style in several ways. The most important influence is observed on the typology of the columns. First of all, basalt is the only lithology used in the pillars inside the mosque. Similarly basalt might be the only lithology used as cylindrical column inside the buildings including the churches and traditional Diyarbakir houses (Tuncer, 1999, 2002) that support the main structure.

Use of the limestone as column shaft, on the other hand, is very common in other historical buildings of Diyarbakir (Tuncer, 1996, 1999, 2002). However, this lithology is never used to support the main body. In most of the cases they are located out of the building holding the porch (riwak) which is an extension of the roof and requires only a moderate support. It is interesting that there is no Eocene limestone in these columns; which is determined to be the weakest rock unit in the region. For the use of limestone as columns in the Great Mosque it can be concluded that most of the columns particularly in eastern and western facades are not supporting any structure and are used only for decorative purpose. Relatively strong Miocene limestone is observed only in the northern facade that holds the porch.

Ornamented column shafts belong only to Eocene limestone and they are observed only in the Great Mosque. This might be due to the physical characteristics of this limestone with the lowest strength and highest porosity that make the rock suitable to sculpture.

4.3 Provenance

Petrographic analyses of the samples taken from the columns reveal existence of four rock types. Considering the stratigraphy of the area and the distribution of the rock units in the region, it can be seen that (Figure 1) all the rock types used in the columns exist in the vicinity of Diyarbakir city. Plio-Quaternary basalts are very close to the city which is the most dominant lithology used in historical buildings. Other three lithologies, however, are exposed as scattered outcrops at some distance. The nearest possible quarry is more than 20 km to the north of the city (Figure 1). Considering the scope of this study, the quarries are not investigated, therefore, specific sources of the columns are not known. However, according to the "stone catalogue" of Diyarbakir published by DMMD (2008) all the rock types identified in this study are today being quarried. It should be, however, emphasized that most of the present day quarries are concentrated in Miocene reefal limestone and Plio-Quaternary basalts. Miocene limestones are thick enough in the outcrop and can yield large blocks. Furthermore, their mechanical properties are almost similar to basalts. Possible outcrops of meta-ophiolites are the farthest sources. This might be a reason for the scarcity of these rocks in the columns. Nevertheless, they are given the most credit being located in the most attractive place in the Great Mosque.

5. CONCLUSIONS

Following conclusions are derived about the columns of Diyarbakir Great Mosque, based on 1) their petrographic analysis, 2) presence of their outcrops in the vicinity of Diyarbakir, and 3) function of the column in the building:

- Diyarbakir city is located over Plio-Quaternary basalts. Although basalt is the dominant lithology used in the Great Mosque, the columns (a total of 49) belong to three lithologies, namely, Pre-Tertiary meta-ophiolites, Eocene limestones and Miocene limestones. Possible nearest quarries of these columns are located more than 20 km.

- All columns are reused in the mosque and belong to pre-existing buildings. Inconsistent column lengths, multi-segment column shafts, lithologically mixed columns and presence of thin wedges at the bottom of column bases are evidences of the reuse.

- The function of the columns is not to support the building. Miocene limestones are used for partial support. Other two lithologies (meta-ophiolites and Eocene limestones), on the other hand, are used only for decorative reasons. Arc-shape pattern obtained by meta-ophiolite column segments on both facades is an evidence for this.

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