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LIMESTONE IN ISLAMIC RELIGIOUS ARCHITECTURE: İSTANBUL AND TURKISH THRACE

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INTRODUCTION

Mankind has always used stone as building material to create monuments and other structures throughout history. Since limestone is one of the most common building materials used for so many centuries, because the availability and easy to work on (Yıldırım, 2007). In general, stone was the most widely used durable material. The deterioration of building stone thus causes causing irreparable loss to our cultural heritage. Besides chemical and physical factors, microorganisms play a major role in rock decay.

Cultural property covers a wide diversity of archeological monuments and sites as well as historic buildings and objects deemed to have significance for both the local and the international communities. Islamic architecture encompasses a wide range of both secular and religious styles from the foundation of Islam to the present day, influencing the design and construction of buildings and structures in Islamic culture. Most of these monuments like mosques, caravanserais, palaces, hamams, madrasas and tombs date back to the periods of the Byzantine and Ottomans. The Tertiary porous limestones from quarries in Thrace Basin represent the characteristical stone type used for the construction of the Islamic monuments.

The geological dimensions include sediment-fingerprints of vertical sea level fluctuations and lateral coastline change, which result in the coastal zone from internal (mainly the coastal sedimentary budget) forces. The archaeological dimension includes human fingerprints (e.g., archaeological artifacts, faunistic remains from cultural layers). Both dimensions will be addressed through integration of existing data as a result of this paper. The area under consideration comprises a panhandle-like eastern extension of the Thrace Basin in northwest Turkey, where faulting on the south and north margins has deformed and exposed part of the sedimentary strata (**Figure 1**).

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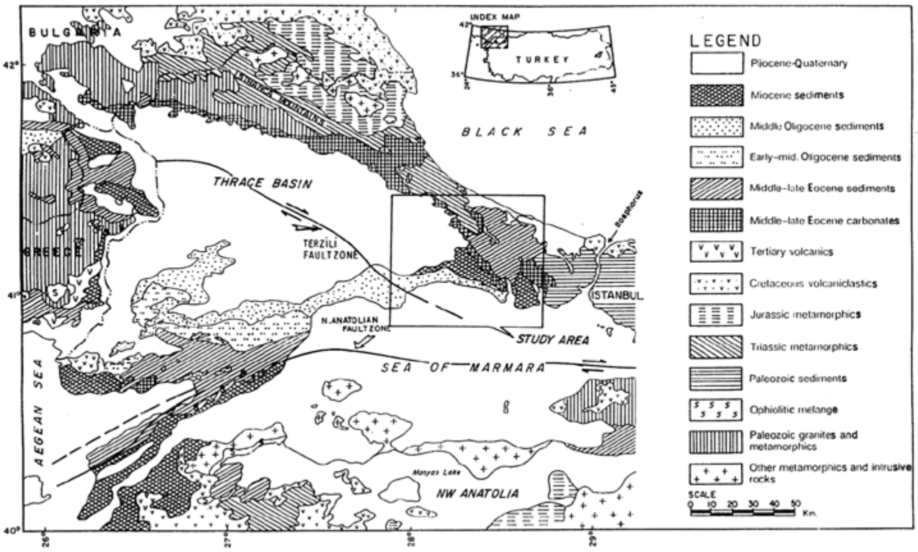

Figure 1. Simplified geological map of the Thrace Basin and vicinity, and location of the study area (Turgut, Eseller, 2000).

Limestone is one of the most commonly found stones in building construction in Turkey is due to its ability to be cut and shaped easily, its “warm” colour and its abundance. Whole structures such as mosques, castles, palaces and fortresses were built only with limestone blocks or limestone pieces combined with other types of stone. Although various types of stones have been used as a building material for at least 10.000 years in Anatolia, carbonate rocks especially limestone had been extensively used as building stone material because of their well quality and availability in İstanbul. In general, limestone is a stone that is composed of calcium carbonate and crystalline limestone, which consists of minerals of calcite and aragonite. They are formed by inorganic chemical precipitation and/or with the contribution of organisms and organic processes (Küçükkaya, 2003). Pure Limestone contains % 56 CaO and % 44 CO2.

Many Islamic monuments in İstanbul and Turkish Thrace are seriously in danger by damage and, as a result, are in need of intervention. Stone weathering represents a significant reason of damage. Air pollution as a consequence of the rapid expansion of İstanbul and rising water table in combination with increasing water pollution due to insufficient or leaking sewage system are considered as important weathering factors. The size and type of fossil remnants in sedimentary rocks have been affected to the selection process of well quality stone building material (Turgut, Gökselin, 2000).

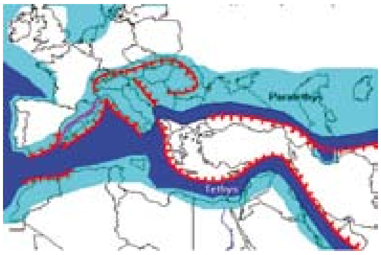

Figure 2. Turkey, Greece, and Iran are small pieces of continental crust that are being crunched by the convergence of Africa and Eurasia. 20 million years ago the plates looked something like this (Dutch 2005).

MATERIALS AND METHOD

Geological Setting of Eastern Thrace Basin

Turkey, Greece, and Iran were small pieces of continental crust that are being crunched by the convergence of Africa and Eurasia (**Figure 2**) 20 million years ago (Aksu et al. 2000). The eastern Thrace Basin forms the eastern portion of the Turkish Thrace Basin in Turkey. The pre-Tertiary crystalline basement shows platform and deep basin depositional morphology that results in facies pattern and thickness distribution localization during the early stages of basin development in Middle to Late Eocene time. Normal fault controlled early and lateral / reverse fault

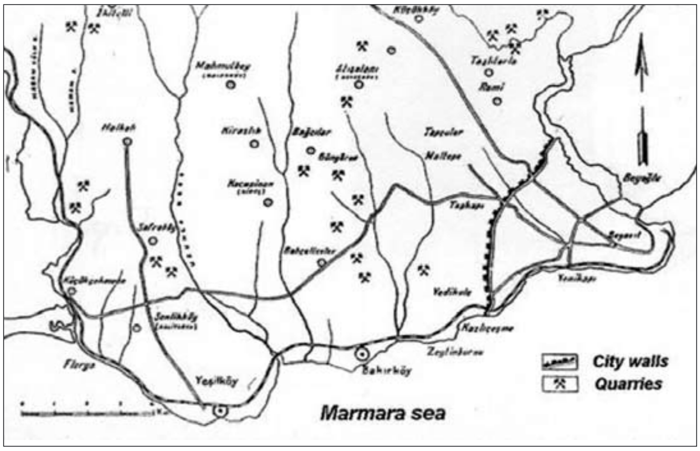

Figure 3. Antique Limestone Quarries in the west of City Walls of İstanbul (Aric, 1955).

controlled later stage tectonic events characterize basin geometry and the present topography, respectively. The early stage normal faulting caused subsidence and sediment accumulation in the Late Eocene and Early Oligocene, while later stage tectonic events caused intense deformation and structuration in the Early to Middle Miocene. As a result, southeastern and northern regions were folded or uplifted and deeply eroded. Okay describe an Upper Eocene olistostromal sequence with ophiolitic clasts and large blocks of Eocene limestone in the southern Thrace basin, and the Eocene olistostromes in terms of the origin of the Thrace basin, its development during the Eocene, and the evolution of the Intra-Pontide suture (Okay et al., 2010).

The eastern Thrace Basin rock suites can be reviewed as two main subgroups; the basement related pre-Tertiary crystalline rocks, which are made up of metamorphic and granitic assemblages, and which provide an acoustic basement on seismic sections; and the Tertiary sedimentary successions that consist of interbedded clastic and carbonate rocks of mostly marine origin (Aksu et al., 2000).

On the Corridor, Bakırköy area is composed of folded Paleozoic greywacke, fine miraculous sandstone and shales as Upper Devonian; over them the sand, clay, marl and limestone beds of upper Miocene (Sarmatian) lie uncomfortably (Sayars, 1962). The Sarmatian, the youngest formation of İstanbul is composed of three lithological levels from the bottom to the top: Mactra Limestone, Clays and marls and Sands and gravel. The eastern part of the Sarmatian Basin lies to the Küçükçekmece Region and the thickness of Sarmatian is increasing from the north to the south, it is about 80-90 m. near Topkapı (**Figure 3**) and more than 120 m. around. Yedikule fixed by some well logs (Sayars, 1962). Determination of the location of three Ancient limestone quarries in İstanbul and identification of geological texture will be explained under the spots of old documents.

Limestone as a Building Material

Limestone is widely distributed throughout Mesopotamia, where it was used from a very early date for artefact and the buildings because it can be dressed to a fine finish. It also had significant secondary uses for mortar and plaster as well as contributing to the lime content in clays employed in the manufacture of mudbricks. The walls of Ottoman buildings were built with a rubble stone core enclosed by a facing of stone or brick and stone. In some of the earlier buildings rubble stone was used on the exterior of

Figure 4. Mactra Sarmatimactra from Pınarhisar quarries on left (Küçükkaya 2004) and fossil limestone used on the wall of Sultanahmet Mosque in İstanbul.

buildings either contained within layers of brick or plastered over. Later on the use of cut limestone became more usual, first in conjunction with brick and later on its own. Immediately after the conquest of Constantinople there seems to have been a reversion to brick and stone due to a shortage of cut limestone (Petersen, 1995). However, from the beginning of the sixteenth century onwards most important buildings were faced in cut limestone, although subsidiary structures continued to use brick and stone. In spite of metamorphic rocks and igneous rocks have traditionally been used as building material in Anatolia. As sedimentary rock the limestone had been used as the main building material during the periods of Roman, Byzantine and Ottoman in İstanbul and Thrace Basin (**Figure 4**) (Pehlivanoğlu, 2000).

During Byzantine Empire and Ottoman Empire in İstanbul, limestone has been given various names. While the term "*küfeki*" was commonly used in the 16th century, "*Mactra Bulgaria*" "Bakırköy Limestone" and "lumesel kalkeri" replaced it in the early 20th century. İstanbul limestone useful for building is including sea animal fossils. They are mined in an area that contains Neogene formation (Sarmatian) and lies from Haliç (Golden Horn) to Küçükçekmece Lake. They cover approximately three forth the interior part of the ancient walls of the city (MTA, 1999). These building stones were mostly porous materials relation with the size of the holes of the fossils of marine origin.

Mactra is a genus of bivalve marine molluscs, some species of which (*Mactra caspia*, *M.bulgarica* etc.) remained, at the end of Sarmatian time, the only representants of molluscs in the Khersonian marine-brackish Sea. Khersonian is the name of the upper part of Sarmatian stage. There are so many type mactra of Sarmatian time such as Mactra Olorina, Mactra Lilacea, Mactra Sarmatiamctra, etc. On the top of the Yarımburgaz Cave, located near the northern shore of the Küçükçekmece lagoon, which are formations poorly cemented sediments of Miocene (Sarmatian) age containing pebbles; sands and clay are to be found (Meriç et al., 1991).

Limestones, which are the eastern extension of thick-bedded bivalve marine molluscs, have been quarried at Bakırkoy, Haznedar, Sefakoy for hundreds of years. This Sarmatian layers all dipping generally to the south as in the region between Haliç (Golden Horn) and Küçükçekmece with the 5°-10° or rarely 15°-20°, contain local foldings and faulting (Erguvanlı, 1981). Mactra Limestone in Bakırköy Quarry is in the Bakirkoy coast at sea level. Insufficient stone layer, containing high porosity lies on the top of the geological formation together with better quality limestone that contains calcite minerals (Aric, 1955). Mactra Limestone (**Figure 5**) in Safrakoy and Bahçelievler Quarry was some quarries in the north of Bahçelievler, Tabyatepe. Under 40 cm agricultural soil, there are two meters thickness, thin limestone and clay and below 2,50 m., dense mactra limestone which contains (Aric, 1955). Mactra Limestone in Haznedar (Güngören) Quarry had been active for a long time at the location of 1 km. southwest of the Brick Fabric in Haznedar and the 250 m. south of the city road. These old quarries had been visited by Tchihatche (1851) and Chaput (1938) a long time ago. Stone blocks that were used for construction are 3,5-4.0 m thickness, white, dense mactra limestone. Well quality building stone layers could be determined under low quality limestone layers

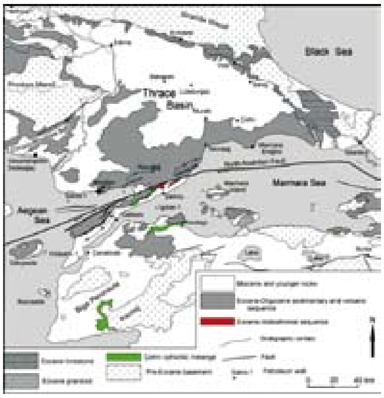

Figure 5. Tectonic map of the Marmara and Thrace region showing the Eocene-Oligocene outcrops and the location of the cities of Thrace Region (compiled from Okay et al. 2010).

Limestone is a sedimentary rock, and along with shale, is one of the best preservers of fossils. Fossil limestone is made up of the accumulation of oyster sea shells over ages and as the classical building stone used during

Figure 6. Hagia Sophia a former Orthodox basilica constructed between 537 (left) and the Mosque of Suleyman the Magnificent from İstanbul were constructed from limestone blocks (finished in 1558).

Figure 7. The Blue Mosque (or Sultan Ahmet Mosque) was built between 1609 and 1616 (left) and Sehzade Mosque built in 1548, both have been built with Limestone in İstanbul.

the Byzantium and Ottoman Empire Era for buildings in İstanbul such as Hagia Sophia (**Figure 6**), the Mosque of Süleyman the Magnificent (**Figure 6**) and the Walls of Constantinople surrounding the old city of İstanbul (**Figure 7-8**).

Turkish Thrace region takes part in the northwestern Turkey and consists of Kırklareli, Tekirdağ, Edirne and the European parts of Çanakkale and İstanbul cities (**Figure 5**). The mosques, caravanserais, bazaars, bridges and other unique works of Ottoman architecture are worth seeing in Edirne of Thrace, which was one of the seven largest cities in Europe in the eighteenth century and served as the capital city of the Ottoman State for approximately a century. As such it was graced with fine mosques, baths and caravanserais, including the Selimiye Mosque (Selimiye Cami), masterwork of the architect Sinan (**Figure 9**). Edirne was briefly the capital of the Ottoman Empire represents the entire spectrum of islamic Ottoman architecture over the centuries. The Eski Camii (Old Mosque) (**Figure 11-12**), the Üç Şerefeli Cami (Three-Level Mosque) and the II. Bayazit Külliyesi (Second Beyazit Complex (**1**)) (**Figure 12**) are the another buildings, which exemplifies different styles of the islamic architecture build by the Ottomans used limestone blocks.

Kirklareli is another city in Eastern Thrace, which has numerous ottoman monuments, including the 14th century Mosque of Hızır Bey (**2**), Beyazid Mosque from 16th century and Kapan Mosque from 17th century. Other

Figure 8. The Walls of Constantinople surrounding the old city of Istanbul from 5th century run about 6.5 kilometers between the Golden Horn and the Sea of Marmara was built of brick and limestone.

1. Religious and social place, where in most cases there is a mosque, a madrasa, a hosptital, a refectory, a tomb, a library, and more.

2. This Hızırbey Külliye (Complex) consists of the Mosque, Bath and Arasta (Bazaar).

3. Constructed in 1570 that is a magnificent Ottoman piece of art with its mosque, hamam, theology school and caravansary.

Figure 9. The ottoman Selimiye Mosque of Edirne (left) is one of numerous impressive Islamic buildings constructed from Limestone was built by architect Mimar Sinan between 1568 and 1574 and the Üç Serefeli Mosque, named after its unusual minaret with three balconies (serefe), was built between 1437 and 1447.

monuments within Kırklareli are; the Sokullu Mehmet Paşa Kulliye (**3**) in Luleburgaz province is an exquisite work of Sinan that dates from 1570, the Cedid Ali Paşa Mosque (**4**) of Babaeski province, the Serbetdar Hasan Bey Mosque from 14th century (Şarapdar Hasan Bey Camii) (**Figure 11**) at Vize province and the Kucuk Ayasofya Mosque (**5**) (Gazi Süleyman Paşa Camii) (**Figure 10**) at Vize province, are several, in which can observe different features of medieval architecture of Eastern Thrace that built in limestone (Dal, Gültekin, 2010).

Limestone Weathering on Historical Monuments

Damage caused to objects of cultural heritage is one of the most serious detrimental effects of air pollutants (Siegesmund, Snethlage, and Ruedrich, 2008). Pollution exacerbates the others are extremely vulnerable. Limestones, calcareous sandstones, and marble are among those at high risk. On the other hand, not only air pollution has effects on Cultural Heritage but also climate change has a significant influence. The environment plays a relevant role in the type and degree of deterioration experienced by cultural property. Relative humidity, high temperatures and pollution usually enhance weathering and biodeterioration effects on stones (**Figure 13**). Weathering, the breakdown of rocks resulting from their direct contact with the prevailing atmospheric conditions may be due to mechanical or chemical effects. Under natural conditions, mechanical and chemical processes of weathering usually take place concurrently. The main parameters were grouped as temperature parameters (**6**), water

Figure 10. In the Small Hagia Sophia Church in Kırklareli stone damage was observed, which may superpose the heterogeneous distribution of different limestone varieties in the walls (at left, before turned into a mosque).

4. It is thought to be Mimar Sinan's piece of art, constructed between 1561-1565 as a complex (külliye), composed of mosque, theology school, hamam, caravansary and library but only mosque had reached today.

5. This Small Hagia Sophia was formerly constructed in 6th century as church during the Byzantine Period, which is turned into a mosque by Gazi Süleyman Paşa on 16th Century.

6. Range, freeze thaw and thermal shock.

7. Cycles of precipitation and humidity.

8. Wind, wind driven rain, sand and salt.

9. SO_2, NO_2, pH, etc.

Figure 11. Eski Camii (Old Mosque) in Edirne was built of good quality limestone, but is being deteriored by pollutants, sulfuric acid and carbon from domestic furnaces, which have combined with acid precipitation from long-range sources (left) and Şerbetdar Hasan Bey (Paşa) Camii at Vize province (Dal 2008).

parameters (**7**), wind parameters (**8**) and the pollution parameters (**9**). Air pollution has been widely documented as the main factor responsible for decay of building stones in urban areas. High levels of SO_2 in the polluted atmosphere conduct to the well-known sulphation mechanisms in a variety of lithological types used as buildings materials such as granite, sandstone and limestone. Biological colonization by bacteria, algae, fungi and lichens is frequently regarded as playing a significant role in physical and chemical stone decay only in rural, unpolluted areas (**Figure 11**).

The decay of Ottoman limestone buildings the Selimiye Mosque and Üç Şerefeli Mosque at Edirne have been investigated using a variety of analytical techniques (Dal, 2005). These have included the mineralogical and petrographic examination using thin-section analysis (Dal, Gültekin, 2006). The results suggest that the mineralogy of deteriored limestone,

Figure 12. Acid precipitation attack the surface of the limestone and the reaction products run down the façade of II. Bayazit Külliyesi (left) (Dal, 2005) and detail of the minaret of Old Mosque from Edirne: flaking and delamination are visible which cause material loss.

Figure 13. Accumulating black crusts at the north façade of Hızırbey Külliye from Kirklareli (left) and Gazi Turhan Bey Külliye Uzunköprü province in Edirne.

in particular the clay content and the magnesium content, are important factors in determining the nature and degree of any decay. The results also indicate that different types of limestone were used at different part of buildings (Dal, Gültekin, 2007).

Sedimentary carbonate stones are named as dolomitic limestone, which is just an irregular mixture of calcium and magnesium carbonates. The other types of materials often called dolomite, a true chemically uniform calcium magnesium carbonate with the chemical formula $CaMg(CO_3)_2$ relaited to their $MgCO_3$ concentration (Dal, 2007). Mg concentration increases the deterioration rate in soft and porous dolomitic limestones (Dal 2005). Magnesium carbonate based limestones may be particularly damaging in such situations because the magnesium sulfate from the runoff expands on hydration approximately four times more than calcium sulfate (Weaver 1991). The building stone used in Edirne are subject to deterioration from acid rains, sulphur and carbon incrustation which cause erosion or dark deposition on the surfaces (**Figure 12**). The pore structure of the dolomitic limestones tends to increase slightly in the initial stages of deterioration of limestones because their water absorption causing rapid deterioration under ambient atmosphere conditions (Dal, 2005, 2006).

Since Byzantine times local limestone have been used in İstanbul for monument construction. In the course of time, all natural stones are affected by weathering. The limestone weathering was assessed with respect to weathering forms and weathering products and they are the evident product of weathering processes that are initiated and controlled by interacting weathering factors.

Stone decay takes many different forms. One of the problems inherent in discussing stone decay is finding a common language. A significant advance in this area is the recent publication of a stone decay glossary by the ICOMOS Stone Committee under the editorship of Véronique Vergès- Belmin (2008). The ICOMOS-ISCS Illustrated Glossary on Stone Deterioration Patterns (Vergès-Belmin 2008) helps define and clarify usage across languages and within the stone community, providing useful definitions of terms such as scaling, spalling, and flaking. Weathering is generally defined as the result of natural atmospheric phenomena, while decay is “any chemical or physical modification of the intrinsic stone properties leading to a loss of value or to the impairment of use,” degradation is “decline in condition, quality, or functional capacity,” and deterioration is the “process of making or becoming worse or lower in quality, value, character, etc” (Doehne and Price, 2010).

Fitzner has produced an important classification of weathering forms as a basis for mapping the deterioration across a building facade (Fitzner, Heinrichs and Kownatzki, 1997). This system has also been presented in case studies.

The study of weathering forms on limestone monuments in İstanbul, Edirne and Kırklareli has shown a wide range of weathering forms and their intensities. Visible stone damage was found on all historical monuments in Turkish Thrace. Unfortunately limestone is particularly susceptible to salt weathering that ultimately causes it’s breaking (Cardell et al., 2003). During the field studies, various observations on the weathering state of the building stones used in the Eastern Thrace have been performed. Based on the field observations, it is possible to conclude that the building stones have different degrees of weathering. Considerable weathering damage not only affects the outer walls, but also walls in the interior of many Islamic monuments.

All of the research was dedicated to the study of the morphologies of deterioration, and to the causes and mechanisms of stone decay. The deterioration macro-morphologies observed on the original of the Islamic monuments were studied according to standard definitions listed in the Illustrated glossary on stone deterioration patterns (Vergès-Belmin 2008) recommendation. A wide range of weathering forms was observed characterizing loss of stone material, discoloration, deposits, detachment and fissures. The most evident of the deterioration phenomena were a very evident brown patina covering most of the stone surface flaking, and subordinately, exfoliation, powdering, cracking and losses which were variously distributed over the façade of monuments (**Figure 12**), but mostly concentrated in its lower part where a strong water capillary-rise reaches. Localized white salt efflorescence was also observed.

In some cases deterioration is seen only on a few blocks in the same masonry structure and the others can stay in a good condition even both of these stones are mined in the same quarry. Different characteristics and qualifications can be seen even if the rock comes from the same quarry (Erguvanlı, 1955). Sometimes soft material can be seen in some sections although the general stone character is strong. In the basis of these differences, there is some causes relation with petrology. For example, in most cases, there are some marl (clay) layers that are not resistant to the weathering. The rock that is loaded with internal press under the upper layers must not be used immediately after quarry; because of the environment condition changes and the pressures of the upper layers disappear. Just after mining the stone moves on the opposite direction of the bedding. If this is not taken into consideration, it creates problems and deformations on the architectural elements. Suitable application of stone must be similar to the position of original bedding. In other cases the rock cannot be resistant and breaks.

Blocks containing different quality layers should be used carefully in the construction. Microscopic studies give the best information for determination of porosity and mechanical properties together with chemical properties. Laboratory experiments help in determination of the qualification of the suitable stone and their resistance to internal causes and weathering. Even, the mining of the stone from quarry is important. Some hairy cracks may be formed because of explosions, which cause degradation in time (Erguvanlı, 1955). The stone that can be removed from the ground in 'lump' form, is of value as a building material; very great care must be exercised when transferring apparent volumes of stone in the ground into quantities of products suitable to sale. In addition to allowing for cavities, deduction must be made for the volume of material that will not be acceptable as building material due to its soft or broken nature (Jefferson, 1993).

Considerations for Conservation Treatments

All the interventions intended for to maintenance of the historical meanings of the archaeological and historical objects are commonly considered as conservation treatments. Conservation steps of stone can be justified if the loss of the stone superficial layer brings about the loss of any eventual historical artistic value or they can be justified if the material erosion is jeopardizing the overall structural stability of the object or its neighborhood.

There is an increasing emphasis on doing something not only to the stone itself but also to the environment in which the stone is found. This reflects a growing awareness of the importance of preventive conservation, of the principle of minimum intervention, and of the need to limit the use of materials that might prove harmful to either the stone or to the environment.

Preventive conservation measures of more immediate effect are usually concerned with keeping water out of the stone and with controlling the relative humidity and temperature of the air around the stone. This is relatively easy for stone artifacts within a museum, and it may also be feasible for stone masonry that is exposed on the interior of a building (Price, 2007). It is less easy for stonework on the outside of a building, although a dramatic example of this approach is most of the monuments in İstanbul, Edirne and Kırklareli.

Stone conservation mostly includes different scientific procedures, which vary along simple cleaning and heavy intervention works as consolidation or complete restoration. Some basic principles have been established, and accepted, by most conservators. The treatment should be reversible so that at any time it should be possible to revert to the status before the treatment. All the applied chemicals should guarantee the maximum durability and the chemical lifelessness. The chemicals used in the conservation treatment should be compatible with the substrate. It follows that methods based on compatible materials should be preferred, so that the original features of the materials are not changed or vaguely changed.

Cleaning is often one of the first steps to be undertaken after a condition survey has been completed. As expected, carbonate materials are the most reactive to acidic pollution and thus have received the lion's share of attention in studies of stone cleaning. By removing the dirt, one can better see the condition of the underlying stone and thus judge what further conservation may be necessary.

After evaluating the state of the present case study it could be argued that the most suitable methods for treating of weathering form are divided into three essential steps. The different conservation procedures of these steps are applicable on outdoor monuments.

The choice of suitable cleaning technique is often very controversial especially when the building has a historic or cultural value. Cleaning is a positive action that can help eliminate all surface crusts accumulated on the masonry surfaces as dirts, crusts, bird droppings, etc weathering products or different salt crystals. In this regard, a large number of cleaning techniques have been and are still developed for cleaning historic monuments. In situations where soluble salts are a major contributor to decay, it makes sense to try to remove the salts. The removal of water-soluble salts sounds tantalizingly easy, but it can prove difficult in practice.

Where stone is severely weakened by decay, some form of consolidation may be necessary to restore some strength. Ideally, one might hope to make the stone at least as strong as it was originally (Snethlage, 2008).

The strengthening and stabilizing of stone materials is a decisive step for the conservation of outdoor architectural monuments. Over the past a range of synthetic adhesives, consolidants, and protective materials have been applied on monuments as an attempt to increase their long-term preservation. Such a treatment needs preliminary laboratory research to find out the best materials for the types of stones.

Consolidation of stone materials is the physical addition or application of some adhesive or supportive materials into the actual fabric of cultural property. These consolidants should have several characteristics such as reversibility index, minimum value of shrinkage, maximum amount of penetration, strengthening and quick evaporation time and characterized by thermal stability and resistance to UV radiation, and mechanical, chemical and physical compatibility with the original materials. There are several types of materials used for achieving this goal such as ethyl silicate (**10**) as well as Paraloid B 72 (**11**) that are classified as active consolidant and water repellents which can be applied through different suitable techniques. They lead to both strengthening the stone surface and stabilizing the powdered or exfoliated surfaces. The choice of ethyl silicate is based on the fact that this consolidant is very fluid, chemically compatible with the silicatic composition of the stones and, as shown by preliminary tests made on a small scale in the lab, it does not alter their colour. The acrylic consolidant Paraloid B72, produced by Röhm and Hass, is described by the manufacturer as an ethyl-meth-acrylate copolymer, but is identified in the literature as an ethyl-methacrylate/methyl-acrylate copolymer (PEMA-PMA).

In the most difficult situations, e.g. in heavily flaking areas, the only possibility of success is to rely on the use of small amounts of strong adhesives, such as an epoxy resin (**12**), used to bridge together in a few points the two parts of a flake, and of a putty that may be made with stone powder mixed with ethyl silicate, with fibres added to strengthen the paste if necessary, and pigments to match the colour. Only in very limited areas with deep stone loss, should stone be replaced with the similar rock. Selwitz (1992) has reviewed the use of epoxies as consolidants, indicating successes and failures. Where possible, potential preservation products should be tested on appropiate samples before field application to the stone of historic monuments.A single product may show varying effects on slightly different types of limestone. The different porosity of the

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10. Such as Wacker H and OH 100; Tegovakon V manufactured by Goldschmidt.

11. The acrylic consolidant Paraloid B72, produced by Röhm and Hass, is described by the manufacturer as an ethyl-meth-acrylate copolymer, but is identified in the literature as an ethyl-methacrylate/methyl-acrylate copolymer (PEMA-PMA).

12. Such as Araldite 2020, Araldite AY-103, Kemapoxy SF-401 and Transparent Epoxy Quicksett.

limestones and their pore size distribution appear to be determining factors in the behaviour of these protective treatments.

The peculiarity of the research in cultural heritage, where basic studies are usually associated to applied research and conservation workshops, resides in its multidisciplinarity. The co-operation with conservators, institutions for diagnostics, and experimentation of innovative methodologies is fundamental in the definition of the conservation procedures for the conservation of the works of art. During the last twenty-five years, the role of scientists to this field has grown up. The facts of a work of art are no longer restricted to humanists. The involvement of chemists and physicists is becoming principal for the prediction of the degradation insight and for the rescue of cultural heritage.

RESULTS AND DISCUSSION

This investigation has confirmed that a number of factors, especially in combination, may be essentially decisive the durability of limestone monuments. Selection of the high quality stone and determination of the appropriate skill are the main factors for the conservation process of limestone building material in İstanbul. Erguvanlı, mentioned in 1981,

> "Investigations on limestone from different quarries in İstanbul show that limestone quality, as a natural building material, in Haznedar and Sefaköy Quarries are better than Bakirkoy but, well selected stones and the best quality limestone were used in Antique period in İstanbul".

Contrary to 16th century's successful and high quality stone works, in 18th and 19th centuries, even they were in modern time, petrography hadn't been taken very much account. Early Ottoman, just after Byzantine Empire, could find Ancient quarries and they should have been used until 16th century. Unfortunately from 17th century to 19th century, attention for the selection of well quality stone hasn't been observed in Ottoman Architecture. So many decoration elements of the last century palaces are still under restoration because of their insufficient limestone building materials. Endless demands for the buildings have been threatening the cultural and historic districts even today. As a result of expansion of old urban district, industrial buildings and apartment blocks covered Ancient quarries including well quality building stone in Bakırköy and Sefaköy area which were exist until 1930s.

Acid rain, pollutants and climate tend to act together in very complex ways to damage the materials from which the buildings are made. The earlier study clarifies that the buildings as well as all the surrounding area have been exposed to destructive deterioration factors mostly due to air pollution and different sources of moisture containing different destructive ions. Regarding the limestones, which deserve further investigation, a complementary direction should be explored concerning the extrinsic and intrinsic causes of limestone decay. The role of pollution in the limestone deterioration is the most important factor of weathering, through the buildings still located in urban environments. Through identification and understanding of deterioration processes, we will be able to solve some of these associated problems and in this manner prevent further damage to monuments. To this end, there is a need for detailed information not only on the type, intensity, and extent of weathering damage, but also on the distribution and specific effects of the different factors on monuments.

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Anahtar Sözcükler: kireçtaşı; İslam mimarisi; paleontoloji; kireçtaşı ocakları; Trakya Havzası; bozunma; taş korunması.

İSLAM DİNİ MİMARİSİNDE KİREÇTAŞI: İSTANBUL VE TÜRKİYE TRAKYASINDAN ÖRNEKLER

Bu çalışmada, İstanbul ve Trakya’daki Türk İslam mimarisinde kullanılan kireçtaşının litolojik özellikleri ile taş bozunmalarının değerlendirilmesi ve korunmasıyla ilgili bazı öneriler üzerinde durulmuştur. Makalede, Trakya’da yaygın olarak kullanılan kireçtaşının davranışını karakterize etmek için disiplinlerarası bir yaklaşım sunulmuştur. Araştırmada özellikle başta Doğu Trakya Havza’sında farklı kireçtaşı ocaklarından alınarak geleneksel yapıların yapımında kullanılmış olan yapı taşlarının paleontolojik yapısı incelenerek fosillerin saptanmasıyla eski jeolojik dönemlerdeki yaşam biçimleri incelenmiştir. Günümüzde, kireçtaşlarının ayrışmaya karşı tepkilerinin tam olarak bilinmesi, anıtların korunmasıyla ilgili çalışmalarda en önemli veri olarak değerlendirilmektedir. Ortamdaki karmaşık kimyasal, mineralojik, biyolojik verilere paleontolojik parametrelerin de eklenmesiyle, kültür varlıkları geri dönüşü olmayan bir bozunma sürecine girmektedirler.

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