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Full Length Research Paper

Structural, petrographic and mineralogical characteristics and diagenetic aspects of Kandira stone from Northwestern Turkey

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Kandira stone is a unique Late Cretaceous (Campanian-Maastrichtian) carbonate rock quarried by small enterprises in Northwestern Turkey. The rock has been used as a construction material in a variety of applications such as cladding and paving, flooring and stairs, roofing and fireplaces. Recently, the demand for this stone in the production of intricately sculpted shapes has raised questions about its workability and durability. Such questions require detailed characterization of structural, petrographic and mineralogical properties of the stone. This paper provides a database on the earlier mentioned properties collected from Kandira stone sampled from quarries. The investigation comprised field measurement and sampling of the Kandira stone, microscopic examination of thin sections, XRD, XRF and SEM studies. The Kandira stone is biomicritic limestone composed mainly of microcrystalline calcite crystals (micrite matrix), pelagic fossils, shell fragments and sponge spicules. Calcite is the sole carbonate mineral and is accompanied by minor quartz and authigenic clay minerals. Diagenetic alteration involved micritization, limited cementation and neomorphism. These processes were variably active in the marine phreatic and limited meteoric phreatic environment. The compact and closed form textural composition results in a stronger, durable stone suitable for masonry and decorative purposes.

Key words: Kandira stone, natural stone, petrographic and mineralogical characteristics, biomicritic limestone, pelagic fossils, diagenesis, Late Cretaceous.

INTRODUCTION

Natural stones have been used throughout human civilization as building or decorative materials. Requisite physical and aesthetic characteristics make some stones better suited than others for the numerous uses in the construction industry for both indoor and outdoor applications. World stone production and the volume of the global stone market will experience a five time increase by 2025 (Gandolfi, 2006). Despite the hazards involved in the quarrying of natural stone, there has been a considerable increase in quarrying and processing facilities. This is despite the impact of economic instabilities that have affected the global trade in natural stones. Technological improvements in the equipment used to quarry and process natural stones have promoted growth in natural stone supply (Arman and Gunduz, 1998).

Kandira stone is a well known natural stone that has been widely used in Izmit and its surrounding regions. The demand for use of natural stone in constructions and recreation areas for the public has increased in line with growing environmental awareness. Thus, natural stones are preferred, with or without processing, as construction materials for many utilities, such as building and garden walls, environmental arrangements, pavements and road

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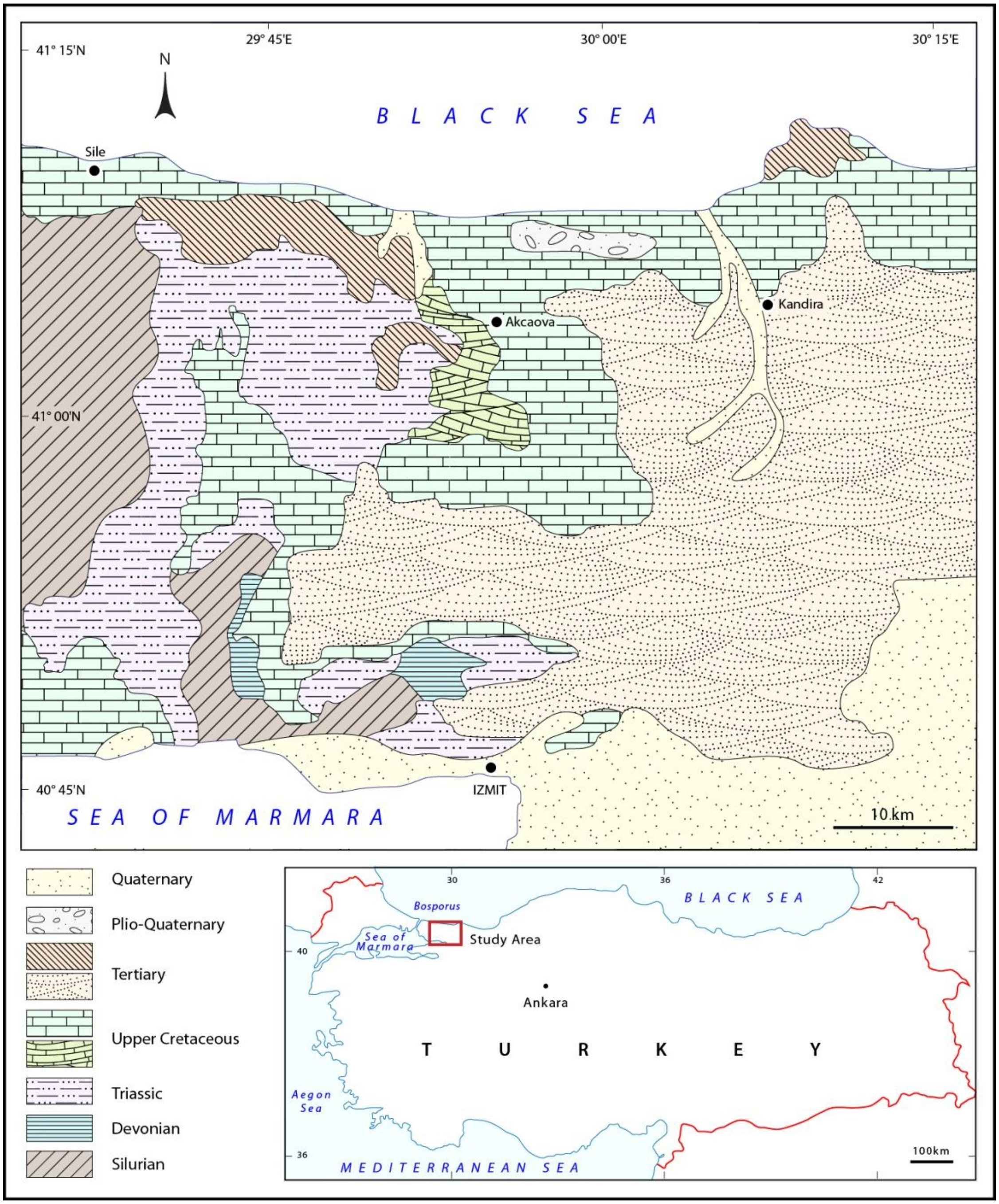

Figure 1. Location of the study area (Kandira District) showing the geology of its surroundings (Ternek et al., 1987).

surfacing, restoration of historical buildings, etc.

Kandira stone is produced from quarries near Akcaova Village which is approximately 20 km west of Kandira county (Figure 1) from which it obtains its name. In this study, structural, mineralogical and petrographic properties of Kandira stone were determined through field studies, laboratory analysis and research of the available literature.

MATERIALS AND METHODS

Detailed field investigations were carried out for the Kandira stone. Collected samples were described microscopically from thin sections. The carbonate contents of the collected samples were determined using the procedure recommended by Ireland (1971). The acid-insoluble residues were separated and identified using binocular microscope. The XRD analysis was carried out on bulk samples using a Philips XRD model PW/1840, with Ni filter, Cu-Kα

Figure 2. General view of one of quarries located on Oren Peak.

radiation (λ=1.542A^o) at 40 kV, 30 mA and scanning speed of 0.02° per second. The diffraction peaks between 2θ =2^o and 2θ = 60° were recorded. The SEM was used to study micro-textures. The preparation of samples followed the procedure recommended by Krinsley and Doornkamp (1973). Elemental analysis were performed using a Rigaku XRF.

GEOLOGICAL SETTING

A geological map of the Kandira region is illustrated in Figure 1 (after Ternek et al., 1987). Extensive exposures of Silurian rocks occupy the south and southwest of Sile County with lesser exposures to the northwest of Izmit. The rocks in the south of Sile County and northwest of Izmit are composed of arkose, greywacke, sandstone, quartzite and slate. Devonian outcrops of greywacke, sandstone and limestone are found in a narrow and limited area to the north and northwest of Izmit. Triassic rocks consist of a variety of layered sandstone, conglomerate, marl, dolomite, shale and nodular limestone cropping out to the north of Izmit Bay. Widespread exposures of Upper Cretaceous rocks are observed in the west, north and northwest of Kandira County, around Sile County and north, northeast and far northwest of Izmit. In this rock sequence, the Akveren Formation lies unconformably upon the Triassic outcrops and is separated from them by a basal conglomerate. This formation includes beige-white limestone, friable and brittle clayey limestone and marl, conglomerate, sandstone with volcanic intercalations and yellow biomicrite layers (Ramazanoglu et al., 2006).

Kandira stone quarries are sited on the Akveren Formation yellow biomicrite layers. The biomicrites contain abundant pelagic fossils and were deposited in a deep marine environment (Tansel, 1989a). Sedimentation in this region continued without interruption during the Late Cretaceous (Campanian-Maastrichtian). There were apparently deeper marine conditions in the southern areas compared to the northern areas. The biomicrites are Maastrichtian-Danian in age (Tansel, 1989b). Tertiary deposits are widespread to the north, northwest and northeast of Izmit. They consist mainly of marl, claystone, argillaceous limestone, sandy limestone and sandstone of flysch facies. Quaternary alluvial deposits are characterized by gravel, sand, silt and clay. These outcrops are found east and northwest of Izmit Bay and along river beds. Some parts of Izmit city also rest on these fluvial deposits.

STRUCTURAL CHARACTERISTICS

The yellow biomicrite is overlain by beige-white marl layers. Biomicrite beds measure between 6 and 120cm in thickness and are traversed by widely spaced cracks. The cracks are north-striking and vertical, and spaced 1-2 m apart. The cracks are open typically with a 1-2mm separation between the crack walls, however, the crack opening may reach 1.5-2.5cm in some places due to surface weathering caused by climatic changes (Figure 2). The contacts between biomicrite and marl are clearly marked by the laminated and ferriferous nature of the marl (Figure 3).

Strikes and dips of the biomicrite layers vary from N40oW; 15^{o}NE to N20^{o}E; 5^{o}NW to N40^{o}E; 5^{o}NW depending on the location. Hardness of the marl layers also varies with location and these layers include small scale folding. The limestone in the Akveren Formation has a micritic texture.

PETROGRAPHIC CHARACTERISTICS

The petrographic characteristics of Kandira stone were investigated by laboratory analyses such as thin sections, SEM and XRD. The textural and compositional characteristics of the Kandira stone reveal a mixture of microcrystalline groundmass calcite crystals (micrite matrix) with grain-size less than 4µm, pelagic fossils, shell fragments, sponge spicules, quartz and clays.

The carbonate components consist of allochems and orthochems where abundant skeletal grains represented by whole tests and shells or shell fragments (debris) make up the allochems. The skeletal grains encompass smaller benthonic (Pseudotextularia Figures 4-3a, 4-7b), planktonics (Globotruncana? photo Figures 4-1a, 4-6a and Rugoglobigerina? Figures 4-1b; 4-8a), shell debris (bryozoa - Figure 4-7a) and rare larger foraminifera (Orbitoides sp. Figures 4-5a, 4-4a, and Smoutina sp. Figure 4-2a) (Abdelghany 2003, 2006). The non-skeletal grains are mainly composed of

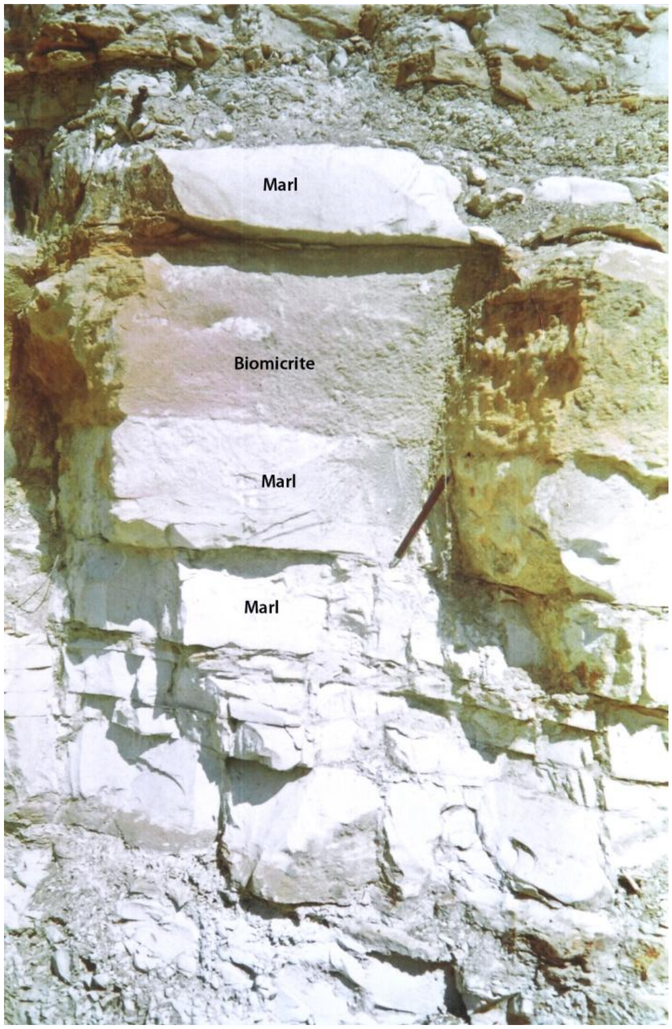

Figure 3. Boundaries between biomicrite and marl.

peloids.

The orthochems are essentially the micrite matrix (microcrystalline calcite crystals) and micro- to mesosparry calcite cement. The non-carbonate constituents make up less than 7% on average of the total mass of the rock, and are represented mainly by limonite and chalcedonic silica. The SEM examination (Figure 5) shows the recrystallized euhedral grains in the micrite surrounded by microcrystalline calcite cement, fossil fragments and authigenic clay minerals. The biomicrite is Late Cretaceous (Campanian-Maastrichtian) in age based on the identified larger foraminifera.

The textural and compositional results obtained guided the naming of the rocks using Folk's classification (1959, 1962) and that of Dunham (1962). According to Folk's nomenclature, the Kandira stone is a biomicrite, while Dunham's classification identifies it as a foraminiferal packstone..

MINERALOGICAL PROPERTIES

The detailed mineral and chemical composition of the studied carbonate rocks were determined using XRD (Figure 6 and Table 1) and XRF analysis (Table 2). The results obtained from diffractograms are in accordance with those of microscopic examination. These results revealed that the Kandira stone consists mainly of calcite with traces of quartz and authigenic clay minerals.

DIAGENESIS ASPECTS

In addition to the primary textural features, such as the fossils and detrital components, several diagenetic (secondary) features are observed in the Kandira rocks. These diagenetic features are the product of several processes which acted upon the rocks at various times during their post-depositional history. These processes occurred under conditions that prevailed during the burial of the sediments.

The diagenetic features displayed by the Kandira stone include micritization, limited cementation and aggrading neomorphism of some crystals. The micritization is represented by micritic envelopes of bioclasts. These envelopes (Figure 4.3b) have varying thickness and their growth appears to have initiated at the outer surfaces of the host grains then progressed towards their cores. Micritic envelopes commonly form in the marine phreatic environment close to the sediment-water interface (May and Perkins, 1979). Micritic envelopes form by a combination of boring (by endolithic algae) and precipitation where ambient waters are supersaturated by calcium carbonate (Bathurst, 1966 and 1975; Hook et al., 1984). The cementation is represented by intragranular

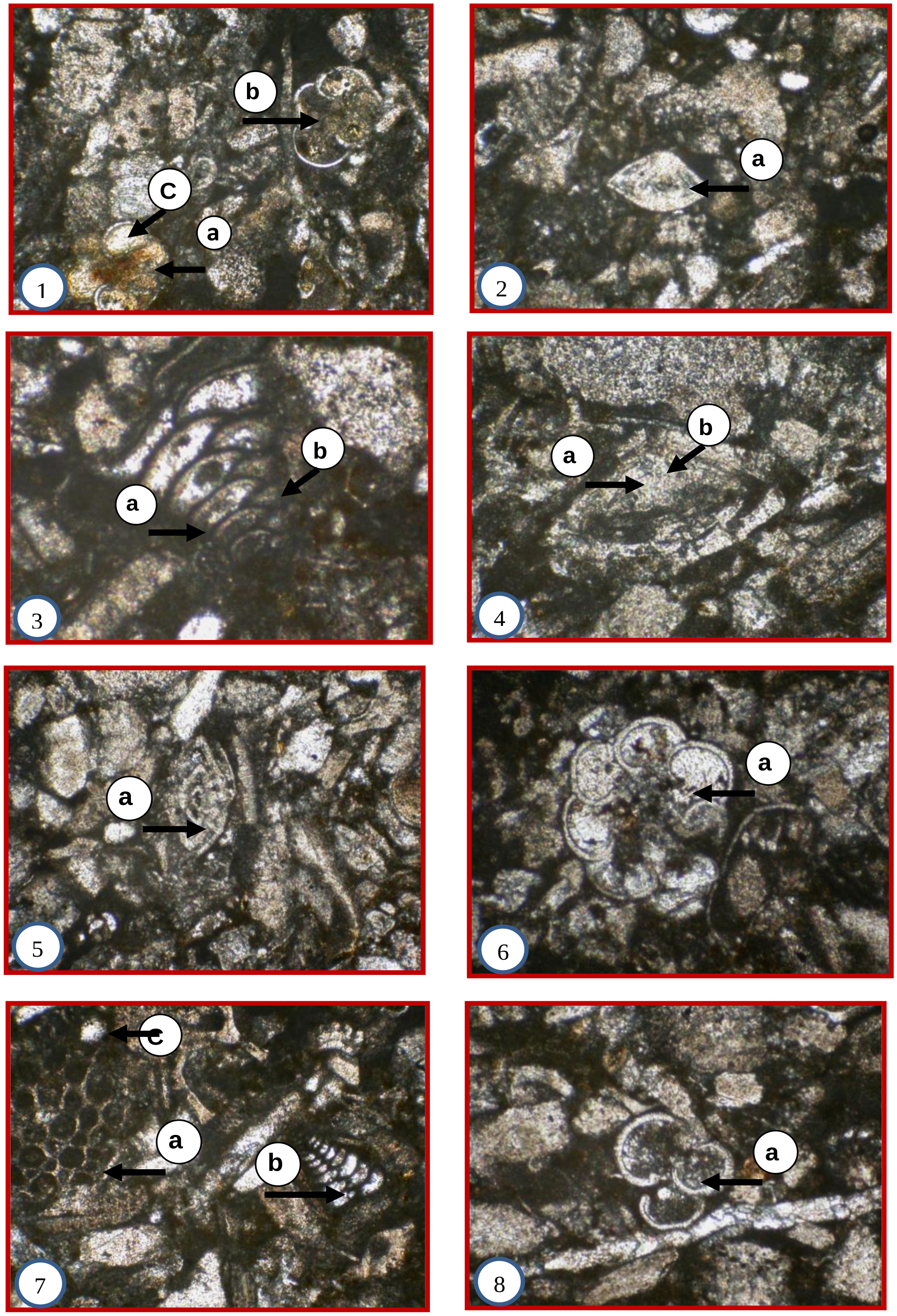

Figure 4. Paleontological elements of the Kandira stone.

micro- to mesosparry calcite crystals. The intergranular cement commonly exists in drusy fillings of skeletal parts including foraminiferal chambers (Figure 4.1c), and bryozoan zoariums (Figure 4.7c). Several studies (for example, Evamy and Shearman, 1965; Bathurst, 1975; Flügel, 1981; Heckel, 1983; Wilkinson et al., 1985) have attributed this type of cementation to the meteoric phreatic environment. The neomorphism recorded in the studied carbonate rocks is of the aggrading type (crystal enlargement) that generates coarse mosaic crystals accompanied by a partial or complete destruction of the original rock textures (Figure 4.4b).

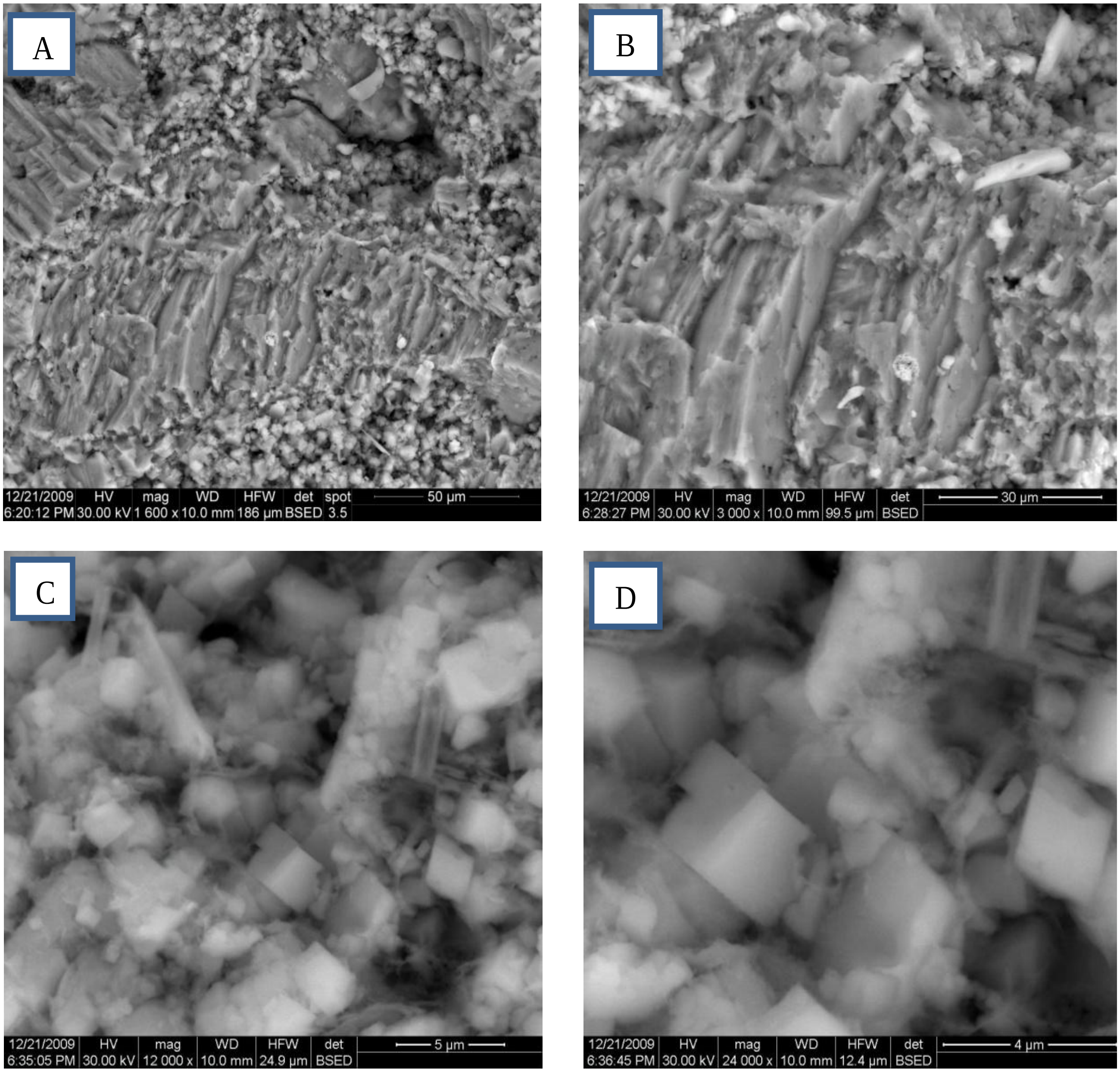

Figure 5. SEM micrographs showing: plate (A and B) represent microcrystalline calcite matrix (micrite) contacted with coarse spary calcite cement. plates (C and D) represent close up of the micrite crystals, here are well crystalline and euhedral, and also can recognize the remnants of nanofossils and traces from authigenic clay minerals.

These crystals may form pseudospar (Folk, 1965) or neospar (Nichols, 1967; Flügel, 1981). Prezbindowski (1985) believed that aggrading neomorphism was strictly related to the meteoric phreatic environment.

DISCUSSION

The Akveren formation is Late Cretaceous in age (Campanian-Maastrichtian) and is composed of beige-white colored limestone, brittle clayey limestone and marl, conglomerate and sandstone with volcanic intercalations. The Kandira stone quarries are partially located within the yellow biomicrite layers of this formation.

Petrographically, the biomicrites are composed of microcrystalline calcite crystals (micrite matrix), pelagic fossils, shell fragments, sponge spicules, quartz and clay. The rock contains abundant skeletal grains embedded in partially recrystallized micritic groundmass. The skeletal grains are represented mainly by smaller benthonic (*Pseudotextularia*), planktonics (*Globotruncana?* and

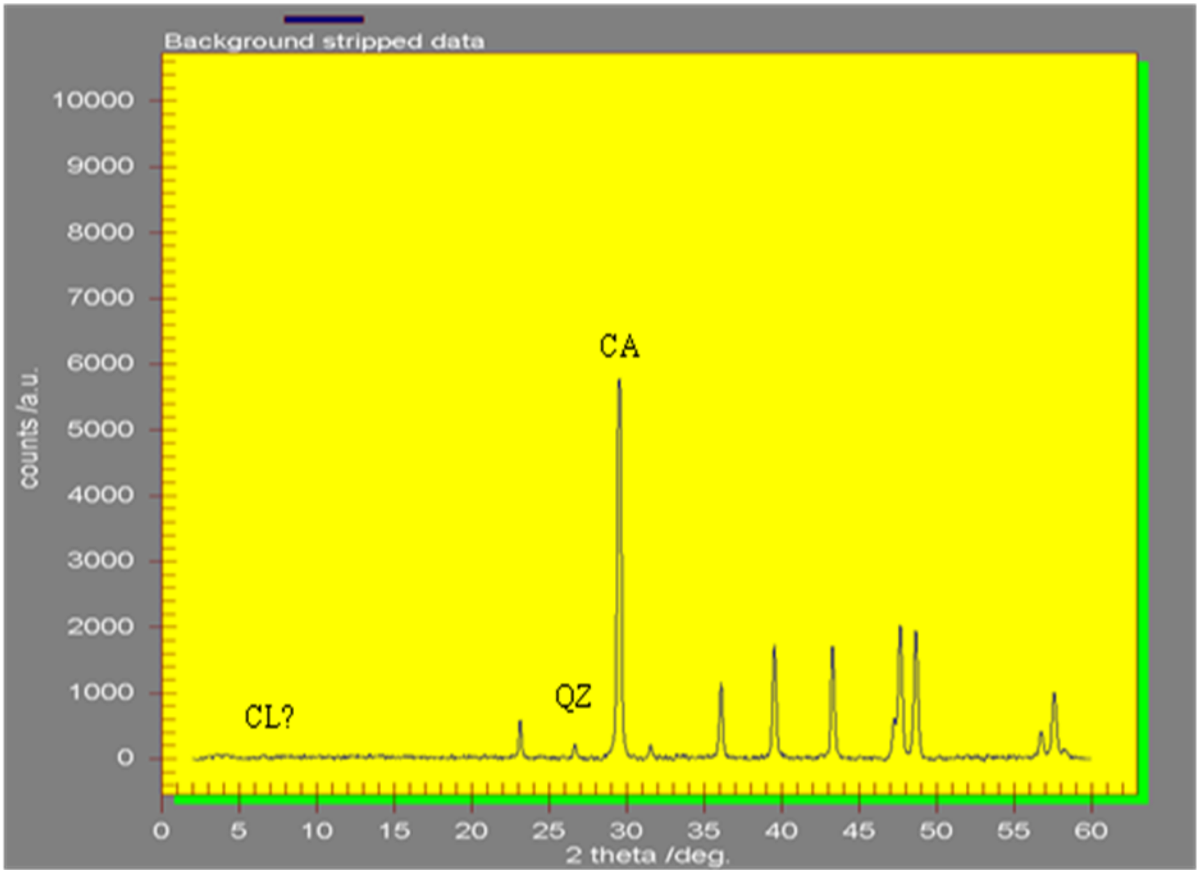

Figure 6. X-Ray diffractogram of the biomicrite Kandira stone (CA= calcite, QZ= quartz, CL? = Clay minerals?)

Table 1. Average mineral composition by XRD.

Minerals	Quartz	Calcite	Clay minerals
Average XRD results (%)	2.87	93.7	2.57

Table 2. Average elemental analysis by XRF.

Oxides	SiO_2	CaO	Al_2O_3	Fe_2O_3
Average XRF results (%)	1.63	52.5	0.17	1.46

Rugoglobigerina?), shell debris (bryozoa) and rare larger foraminifera (*Orbitoides* sp, and *Smoutina* sp.) Thus, the biomicrite is dated to the Late Cretaceous (Campanian-Maastrichtian) based on the identified larger foraminifera.

Mineralogically, the Kandira stone consists of calcite (average 93.7 wt %) with traces of quartz (average 2.87 wt %) and clay minerals (average 2.57 wt %). The chemical composition of the Kandira stone is CaO (average 52.5 wt %), SiO_2 (average 1.63 wt %), Fe_2O_3 (average 1.46 wt %) and Al_2O_3 (average 0.17 wt %).

Diagenesis of Kandira stone played a major role in modifying the original textural and compositional characteristics of the rocks through micritization, limited cementation and neomorphism. These processes were variably active in the marine phreatic and limited meteoric phreatic environment.

From an economic point of view, Kandira stone has been quarried for years within small enterprises in north-western Turkey. There is still demand for this stone and it has been used in different construction applications.

The quality of the Kandira stone is based on its closed and compact textural characteristics. Other textural properties of this stone are that there are/is: (1) no intergranular sparry crystals of calcite or other minerals between the allochems grains; (2) no vuggy or moldic pores; (3) no primary or secondary cementation except for a little microcrystalline calcite that fills the skeletal grains; and (4) no primary or secondary fractures in the rock itself. The absence of the above features results in a strong rock. The rock is very rich in micrite (microcrystalline calcite crystals) yielding a strong, compact and durable stone.

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REFERENCES

Abdelghany O (2003). Late Campanian-Maastrichtian foraminifera from the Simsima Formation, on the Western side of the Northern Oman Mountains. Cretaceous Res., 24(4): 391-405.

Abdelghany O (2006). Early Maastrichtian larger foraminifera of the Qahlah Formation, United Arab Emirates and Sultanate of Oman borders. Cretaceous Res., 27: 898-906.

Arman H, Gunduz Z (1998). Increasing demands for natural stones usage around the world, Sakarya University, Mag. Nat. Sci. Instit., 2(2): 141-144.

Bathurst RGC (1966). Boring algae, micrite envelopes and lithification of molluscan biosparites. J. Geol., 5(1): 15-32.

Bathurst RGC (1975). Carbonate sediments and their diagenesis. 2nd Edition, Amsterdam, Elsevier, pp. 1-658.

Dunham RJ (1962). Classification of carbonate rocks according to depositional texture. In: Ham, W. E. (ed.), Classification of carbonate rocks. Am. Assoc. Petr. Geol. Mem., pp. 108-121.

Evamy BD, Shearman DJ (1965). The development of overgrowths from echinoderm fragments in limestones. Sedimentology, 5: 211-233.

Flügel E (1981). Lower Permian tubiphyles/Archaeolithiporells build up in the Southern Alps (Austria and Italy). Soc. Econ. Paleontol. Mineral. Special Pub., 30: 143-160.

Folk RL (1959). Practical petrographic classification of limestones. AAPGB, 43: 1-38.

Folk RL (1962). Spectral subdivision of limestone types. In: Ham, W.E., (ed), Classification of Carbonate Rocks-A Symposium. Am. Assoc. Petr. Geol. Mem., 1: 62-84.

Folk RL (1965). Some aspects of recrystallization in ancient limestone. Soc. Econ. Paleontol. Mineral. Special Pub., 13: 14-48.

Gandolfi G (2006). Re-engineering of natural stone production chain through knowledge based processes, eco-innovation and new organisational paradigms. Presentation, Pedrini SPA ad unico socio, 21-22 November, Versailles, Italy.

Heckel PH (1983). Diagenetic model for carbonate rocks in mid-continent Pennsylvanian eustatic cyclothems. J. Sediment Pet., 53(3): 733-760.

Hook JE, Golubic S, Milliman JD (1984). Micrite cement in micro borings is not necessarily a shallow-water indicator. J. Sediment Petrol., 54(2): 425-431.

Ireland HA (1971). Insoluble residue. In: C. Carver (ed.): Procedures in sedimentary petrography. John Wiley Intersciences, New York, pp. 479-498.

Krinsley DH, Doornkamp, JC (1973). Atlas of quartz sand surface textures. Cambridge Univ. Press London, pp. 1-91.

May JA, Perkins RD (1979). Endolithic infestation of carbonate substrates below the sediment–water interface. J. Sediment Pet., 49(2): 357-378.

Nichols RAH (1967). The sparite complex: Exsparite v. Neosparite. J. Sediment Petrol. 37(4): 1247-1248.

Prezbindowski DR (1985). Burial cementaion-Is it important? A case study, Stuart City Trend, South Central Texas. In: Schneidermann, N. & Harris, P.M. (des.): Carbonate cements. Soc. Econ. Paleontol. Mineral. Special Pub., 36: 241-264.

Ramazanoglu S, Akinci A, Arman H (2006). Chemical and micro structural properties of Kandira Stone. Kocaeli University, Mag. Appl. Geosci., 6: 100-108.

Tansel I (1989a). Foraminifer biostratigraphy of Earlier Cretaceous sequences around Agva (Istanbul). Geosound, 17: 1-22.

Tansel I (1989b). Palaeocene biostratigraphy Earlier Palaeocene sequences around Agva (Istanbul). Bulletin of Turkish Pet. Geol. Assoc., 1(3): 211-228.

Ternek Z, Erentoz C, Pamir HN (1987). Explanatory text of the geological map of Turkey- Istanbul Sheet. Mineral Research and Exploration.

Wilkinson BH, Smith AL, Lohmann KC (1985). Sparry calcite marine cement in Upper Jurassic limestones of southeastern Wyoming. In: N. Schneidermann and P.M. Harris (eds.). Carbonate cement. Soc. Econ. Paleontol. Mineral. Special Pub., 36: 169-184.