MICROSTRUCTURE STUDY OF DETERIORATED ISLAMIC MONUMENTS IN CAIRO

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ABSTRACT

Many monuments in Greater Cairo area are seriously at risk of being destroyed and in urgent need for restoration. To carry out the restoration work, it is essential to identify the characteristics of the originally used stones, causes of stone deterioration and the suitable repair techniques and materials.

This paper presents a sample of data obtained to characterize the properties of the ancient building stones of several buildings in Cairo. X-Ray Diffraction, (XRD), and Scanning Electron Microscope, (SEM), were used to identify the chemical compositions and causes of deterioration of the building stones. Some physical and mechanical properties of the stones were determined by testing core samples extracted from the walls. Additionally, chemical analysis of soil and ground water, at different depths around the investigated structures, was performed.

The study showed that the main reason of stone deterioration is the rise of humidity due to population expansion. The damage starts at the outer face of the stones and penetrates deeper with time.

KEYWORDS: Monument – Restoration – Blockwork – Limestone – SEM – Cairo.

دراسة التكوين الدقيق للمباني الإسلامية المتدهورة بالقاهرة القديمة

يتعرض كثير من المباني الأثرية بالقاهرة لخطر الانهيار نتيجة تدهور الأحجار الجيرية المستخدمة في البناء. وكان من الضروري للبدء في عمل الترميمات اللازمة استخدام مواد متوافقة مع تلك المواد المستخدمة في المبنى الأصلي. ولذلك ، كان من الواجب معرفة خصائص الأحجار

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المستخدمة في البناء الأصلي وتحديد أسباب تدهورها ثم إصلاح العيوب الموجودة بالوسائل والمواد المناسبة.

يعرض هذا البحث عينة من النتائج التي تم التوصل إليها إثناء عملية توصيف خصائص أحجار البناء ببعض المباني الأثرية بالقاهرة. تم في هذه الدراسة استخدام جهاز قياس حيود الأشعة السينية والتصوير تحت المجهر الإليكتروني. تم أيضا دراسة بعض الخواص الفيزيائية والميكانيكية للعينات المستخرجة من الحوائط والتربة المحيطة بالمباني المختبرة.

وقد وضحت نتائج الدراسة أن السبب الرئيسي لتدهور المباني الأثرية المختبرة هو ارتفاع نسبة الرطوبة بالأحجار نتيجة الامتداد العمراني. يبدأ التدهور بالأحجار على السطح الخارجي ثم يمتد إلى الأعماق الداخلية مع مرور الوقت واستمرار التعرض للظروف المسببة للتدهور.

1. BACKGROUND AND INVESTIGATION TECHNIQUES

Since the Pharaonic era, porous limestone from local quarries have been used in construction. As a result of weathering, many monuments became in an alarming condition [1]. Restoration work in monumental structures started since one century ago [2]. Restoration work included reconstruction, structural reinforcement and renovation of walls.

To make satisfactory restoration, it is important to start the work by a planned investigation program aiming at the determination of the causes of the structural deterioration. The finding of this investigation should be used to determine the suitable method to preserve the damaged structure and to prevent the reoccurrence of the damage or hider its reappearance as long as possible. Once the preservation technique is decided, the identification of the compositions of the restored stones and mortars become essential, as it is essential to use similar materials in the restoration process.

In the following section, the outlines of a restoration study are presented. The studied monuments included three mosques and a tomb in Cairo area detailed as follows;

1- Badr El Deen El Wanai mosque (nearby the Citadel area).
2- Shaikhoon Mosque (nearby the Citadel area).
3- Abedi Beck Mosque (in Misr Alkadima area, beside Nile river).
4- Gani Beck Tomb (nearby the Citadel area).

All tested monuments, except Abedi Beck mosque, are located in elevated areas, and far from the Nile river. Therefore, the monuments supposed to be secure from ground water related hazards.

The investigation was performed in the following order;

a- Extraction of soil, intact stone, damaged stone, and mortar samples from the tested monuments.
b- XRD analysis of the samples.
c- SEM photography of the samples.
d- Chemical analysis of the samples.
e- Humidity distribution.
f- Compressive strength of stones.
g- Recommendation for repair works.

2. INVESTIGATION RESULTS

2.1. XRD Analysis

XRD was used to study the chemical composition of the intact and deteriorated stones of the investigated monuments. Figures 1 shows a sample of XRD results on El Abdi and El Wanai mosques. The XRD diagram shows that the stones are typically composed of Calcite (Cc), Quartz (Q), and varying amounts of Dolomite (D). The deteriorated stones of the tested monuments have almost the same phase content of the intact stone, indicating that, the deterioration process did not alter the chemical composition of the stones.

Figure 2, demonstrates the results of XRD tests on mortars taken from Gani Beck tomb (a), El Wanai mosque (b) and El Abedi mosques (c). Mortars from Gani Beck tomb and El Wanai mosque appeared to be standard ancient mortars as they contained Gypsum (G), Lime, demonstrated as Calcite, (Cc) and quartz (Q). In contrast, El Abedi mosque mortar showed the presence of Ettringite (E) which is an indication of using the contemporary Ordinary Portland Cement (OPC) in mortars. It should be noted that, OPC-mortar use in restoration of ancient monuments is firmly forbidden due to its adverse effects on this type of buildings [3,4,5].

Figure 3, views the XRD test results on soil sample near the foundation of El Wanai mosque. The soil samples have Gypsum (G) content of about 4%, Calcite (Cc) of 14.8% and very strong Quartz (Q).

2.2 SEM Investigation

Several SEM photographs were taken for both intact and deteriorated stones. Figures 4 and 5 demonstrate the state of the body of the stones with 2000 time magnification. It can be seen from figures 4 and 5 that the intact stone body appears to be more dense compared to that of the deteriorated stone.

Further magnification on the damaged stone, figure 6, shows the surface of the calcite and dolomite crystals are clearly etched due to the effect of water.

Studying the findings of both XRD and SEM tests, it can be concluded that the deteriorated stones have the same chemical composition as the intact ones. However, the deteriorated stones appear to have lower density and more porous structure. This finding propose that stone deterioration is a result of the draining out of stone structure due to certain succession of chemical reactions.

2.3 Chemical Analysis

The chemical analysis of undamaged stones showed that the chloride and sulphate contents were low. The chloride content in the investigated monuments ranged from 0.017% to 0.079%. The chloride content in intact mortars were also low as it was in the range of 0.02% approximately. In contrast, the damaged stone contained considerably high chloride contents as it varied from 0.50% up to 5.4%. The mortars around the damaged stones had also remarkably high chloride contents.

The sulphate salt content in stones showed lower variations compared to those recorded for chloride contents. The concentration of sulphate salts in undamaged and damaged stones varied from 0.28% to 0.74% with the exception of the damaged stones of El Abedi mosque that raised up to 1.0%.

Chemical analysis of the soil showed that the concentration of chloride and sulphate salts were moderate as they ranged from 0.18% to 0.28% and from 1.8% to 1.9% respectively.

2.4 Humidity Distribution

Humidity was measured in order to draw the contour lines of stone moisture content and to study the effect of humidity on stone condition. The results showed that the stones closest to the ground surface had the highest moisture content. The dampness of the stones was also, characteristically, higher near places, where water was used for pre-prayer washing.

The damaged stones were located in areas of high humidity. The level of damage is related to stone moisture content as it escalated with the increase of moisture content of stones.

3.1 CONCLUSIONS

1- The chemical and mineralogical analysis of damaged and undamaged stone samples taken from the tested monuments indicated that they were chloride saturated. This can be clearly attributed to the effect of chloride migration from the adjacent soil to the stones which is rendered possible because of the high electrolytic and humidity.

2- The migrated chloride solution is naturally saturated with carbonic acid which could have acted on the calcite phase of the stones, forming soluble calcium bicarbonate. In the presence of chloride ions, calcium bicarbonate converts to the more stable calcium chloride leaving the stone with porous and leached surface.
3- The presence of gypsum in soil also extends the deterioration process as it causes the partial dissolution of the calcium sulphate.
4- The study showed that the conservation of the old monumental structures in Cairo should be directed to the protection of these structures from being damped. The approach of protection of structures is governed by the source of water attach, whether from under ground or due to surface water coming from water usage in the vicinity of the structures.

REFERENCES

1- **Hawass, Z.,** "The Egyptian monuments: problems and solutions", Conservation of Stone and Other Materials, International RILEM UNESCO Congress, Volume 1, Paris, 1993.
2- **William, C.,** "Islamic Monuments in Cairo – A Practical Guide", American University In Cairo Press, 1993.
3- **Pinin'ska. J. and Attia, H.R.,** " Use of geomechanical research in the conservation of stone monuments (Maadi Town Temple, Fayoum, Egypt)", Geological Quarterly, 47 (1), 2003.
4- **Hendry, W.H,** "Structural Masonry", Mac Millan Educational LTD. Hong Kong, 1990.
5- **British Standards Institute**, BS 5628, Part 3, " Material and components, design and workmanship", 1985.

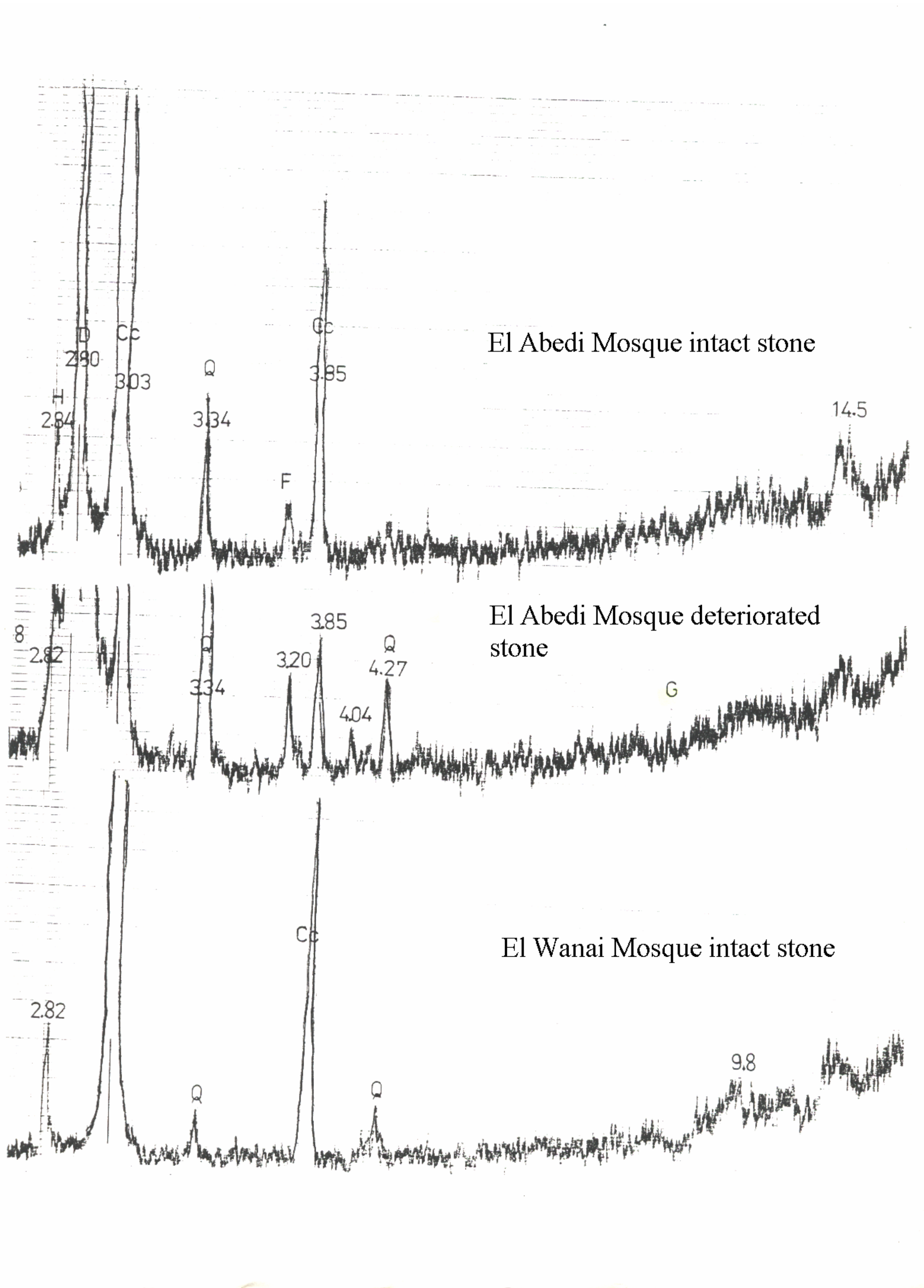

Figure 1: XRD analysis of intact and deteriorated stones from El Abdi and Wanai mosques.

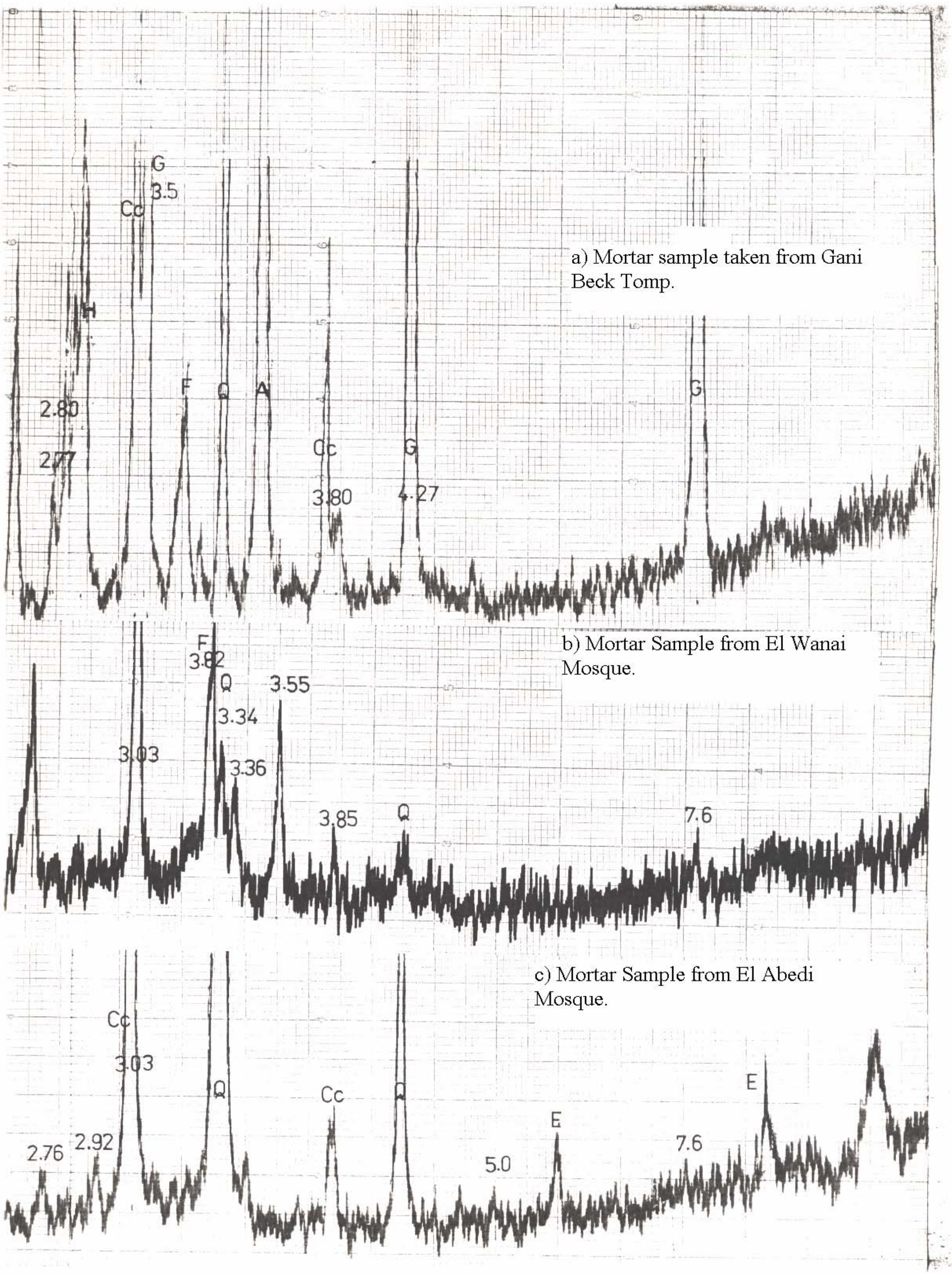

Figure 2: X-Ray Diffraction on mortar samples taken from different locations in the tested monuments.

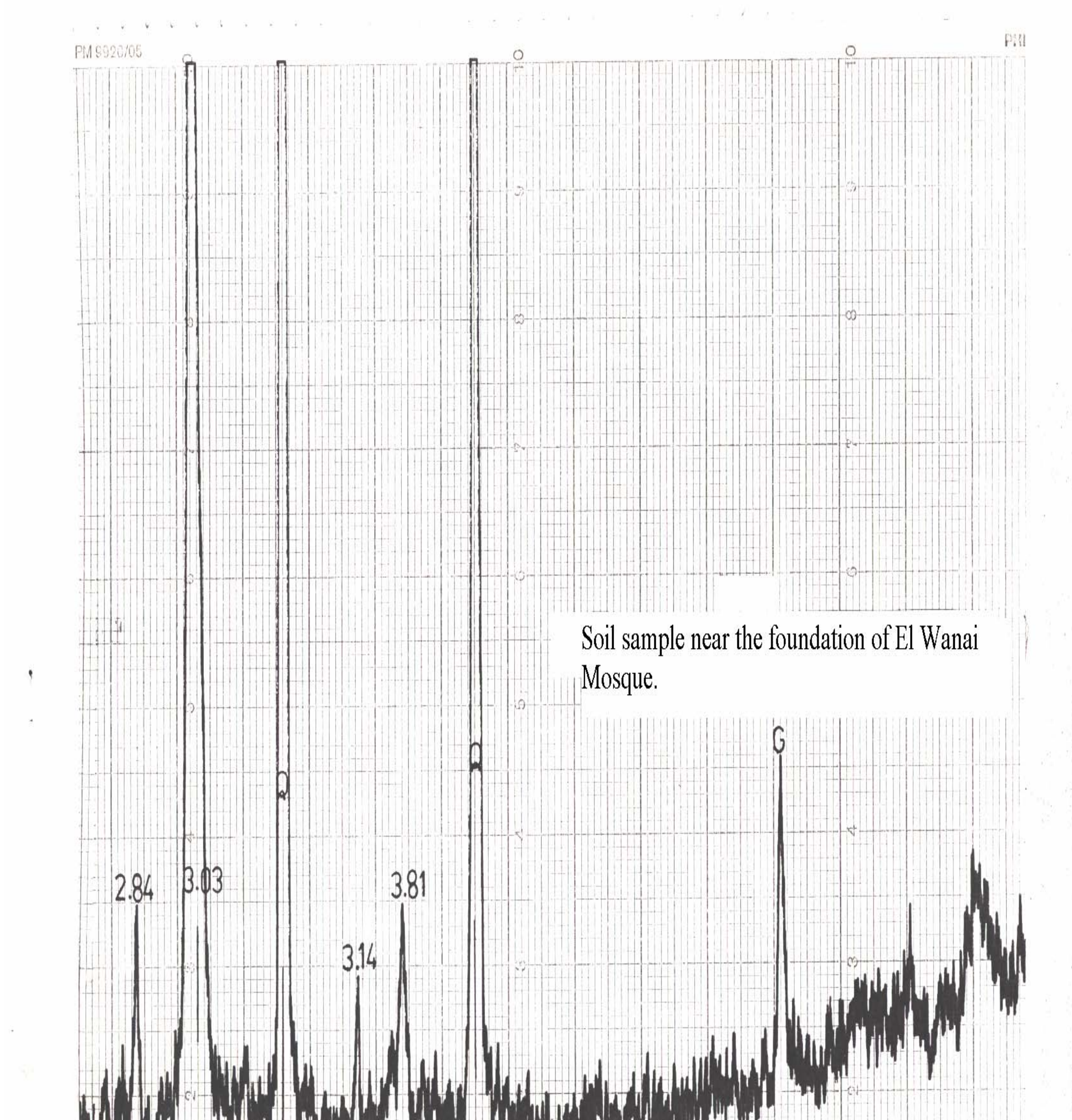

Figure 3: XRD test result on soil sample near the foundation of El Wanai Mosque.

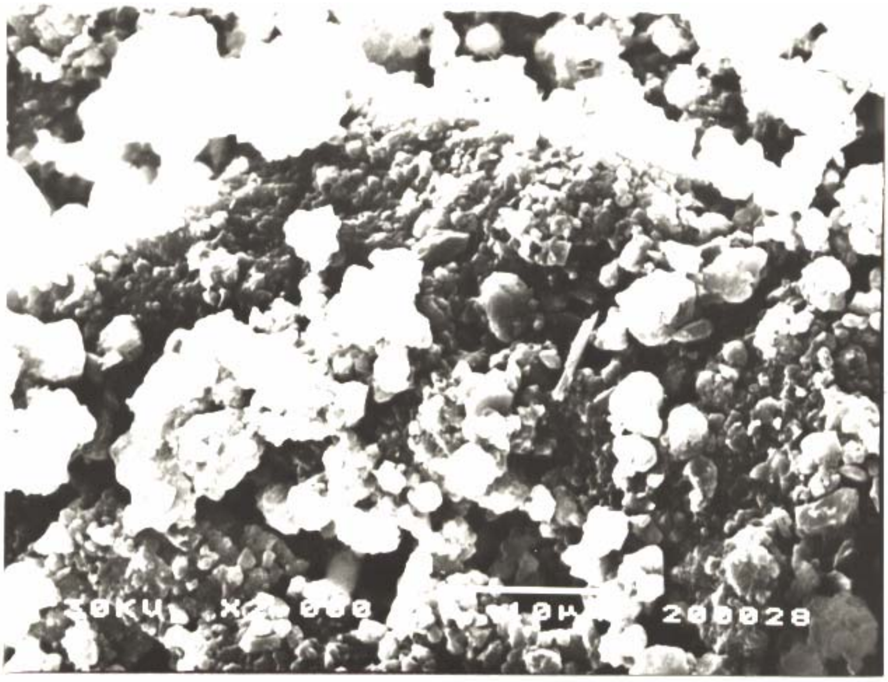

Figure 4: SEM photograph of intact stone from El Abedi mosque.

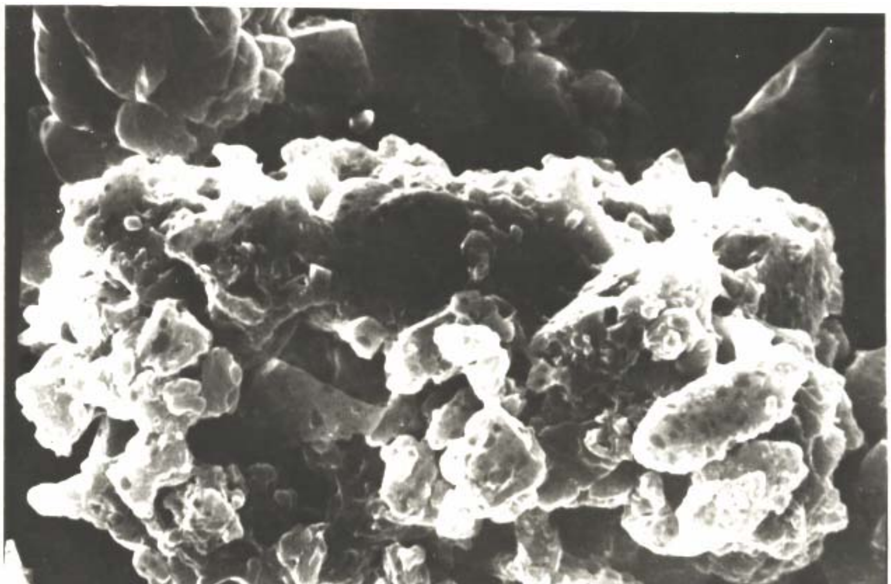

Figure 5: 2000 time magnification of deteriorated stone from El Abedi mosque.

Figure 6: The SEM of damaged stone showing the effect of water on the surface of calcite and dolomite crystals.