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# CHARACTERIZATION AND PROVENANCE STUDY OF MARBLE FROM UDHRUH, SOUTHERN JORDAN

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## ABSTRACT

This paper analyses and discusses marble found at the Roman site of Udhruh in southern Jordan. Marble is highly valued in Roman culture, and while its use in architecture was widespread across the empire, there were only a relatively few high quality sources. Southern Jordan was not one of these, and so Udhruh's marble was sufficiently highly regarded to be transported into the region from distant sources. Marble from the site was studied and then sampled followed by petrological, mineralogical, and geochemical investigation techniques to identify the possible source of marble. Results indicate that Udhruh's marble is quite hard calcitic marble exhibits exhibit xenoblastic texture, and the chemical composition indicates marble quarries in Greece with a probable contribution from Petra.

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**KEYWORDS:** Udhruh, Petra, Roman Empire, Marble provenance, Trade relations, Quarry.

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## 1. INTRODUCTION

It is difficult to imagine Roman civilization without marble. It was used in statues, monuments, reliefs, and inscriptions. Preferences for various kinds of marble changed through time, a result of the influence of local traditions, transportation, economic conditions, and aesthetic tastes. Studies of the identification of marble provenances can thus reveal much about the history, trade, technology and aesthetics of both the Romans and the Greeks. The multidisciplinary study of the various aspects of Roman and Greek valuations and use of marble is a growing field in classical studies. Geochemists and geologists are able to determine the sources of marble, and archaeologists are studying the changing patterns of use and importation, including how the improvement in quarrying techniques and the preliminary dressing of the marble influenced the final shape of the artifacts made from it.

Historians now understand how quarry organization and bureaucracy controlled marble production and trade, while art historians can tell how the techniques and styles of sculpture were affected by the physical characteristics of the raw material. Engineers and architects too are interested in both the techniques used to quarry marble, and its use in building construction (Herz and Waelkens, 1988). Rome's early Augustan-era demand for marble was satisfied by the Luna quarries on the Italian peninsula, although soon more distant quarries in the Mediterranean were being exploited (Ward-Perkins *et al* 1965). Marble supplied to Palestine during this time primarily originated in the quarries of Asia Minor, especially Ntanxxara and Afyan, while Greek marbles were much more rare (Fischer 1988). The evidence presented here appears to belong to one of these rare sites.

Udhruh was a Roman legionary fortress in southern Jordan, and lies about 15 km east of Petra and approximately 25 km northwest of Ma'an (Fig. 1). It was abandoned during the 4<sup>th</sup> century AD, but the associated settlement flourished into the Byzantine, and early and late Islamic periods. In the Byzantine era, a church was constructed outside the walls of the fortress, near the southwestern corner tower, and within the curtain walls evidence confirms the exist-

ence of a Christian community. Throughout the subsequent Islamic periods, Udhruh was an urban centre according to historical and archaeological sources. In the early twentieth century, the eastern side of the fortress became the core of a newly-established traditional village. In the 2008-2009 seasons of archaeological excavations by the Department of Archaeology at Al-Hussein Bin Talal University, marble was discovered in an area which yielded significant material culture and architectural remains. Given the site's history of continuous occupation for almost 2,000 years, the marble could date to any of the aforementioned periods. Identification could not rely solely on visual inspection, but required detailed scientific analysis.

The marble traded in the Mediterranean region obtained from different sources. While the most common source of green banded marble was Carystia, Crece (Cipollino Verde) (Sutherland and Sutherland 2002; Lazzarini 2007), Al-Bashaireh and Al-Housan (2015) found that the marble used in chancel screens of Byzantine churches in Rihab, north of Jordan, is mainly obtained from Proconnesos with minor sources from Docimium and Turkey. Abu-Jaber *et al.* (2012) discussed the marble sources at Qasr al-Bint and the Colonnaded Street baths in Nabataean Petra, and concluded that such marbles are most likely to have been imported from several places - Thasos, Penteli, Proconnesos, and Docimium in Greece. This evidence throws light on the trade relations of the time and also helps with understanding the phasing of marble use at Udhruh and the range of possible sources.

## 2. MATERIALS AND METHODS

### 2.1 SITE LOCATION

The ruins of the fortress can be seen on the edge of the modern road between Udhruh and Ma'an. Topographically, the site was located on a gentle slope at the top of Wadi Udhruh, and is almost encircled by a series of hills: Tell Jraideh lies northeast, Tell Udhruh (Dubais) east, Tell Abara (Abu Ar'a) southwest and with two hills to the south and southeast (Killick, 1986; 1987a; 1987b; Shqiarat *et al.* 2011; Abudanah *et al.* 2010a; 2010b; 2010c).

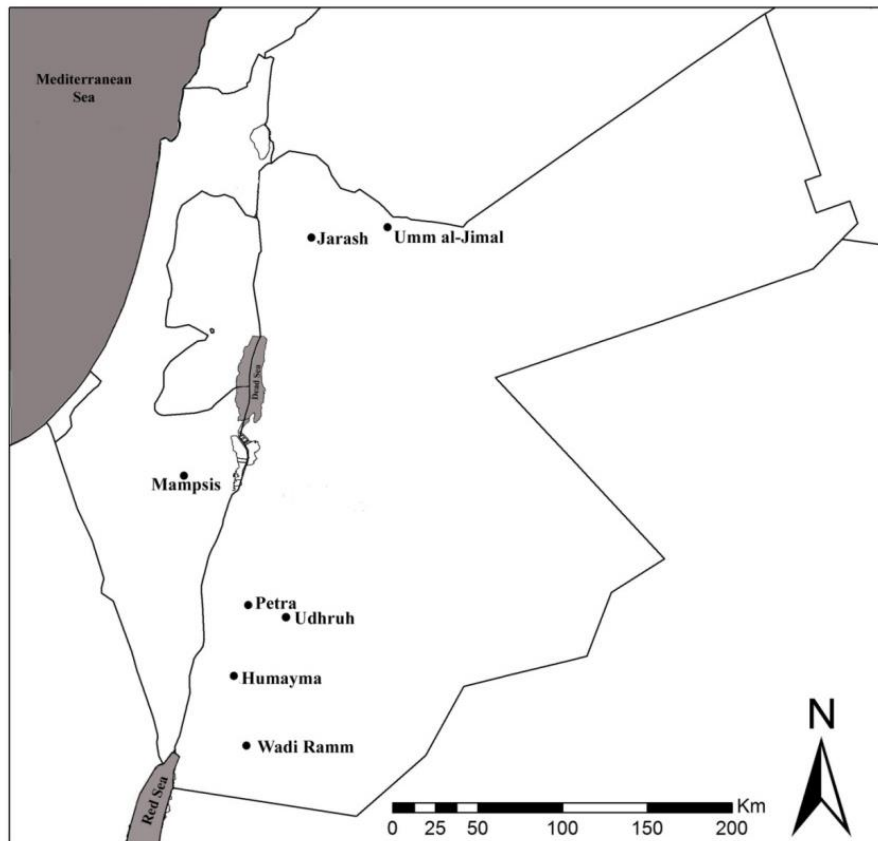


Figure 1: Location of Udhruh Marble site.

## 2.2 EXCAVATIONS AT UDHRUH

Since 2005 the Department of Antiquities Office at Ma'an has been carrying out technical work at Udhruh including restoration of some walls and clearing the rubble and dump outside the curtain wall of the Roman fortress. In 2008 and 2009, Al-Hussein Bin Talal University and the Department of Antiquities agreed to conduct a joint project of excavations at the site. The main purpose of the project was to train the archaeology students at Al-Hussein Bin Talal University on the methods and techniques of archaeological excavations. It was also hoped that these investigations would reveal important information regarding the site's history (Fig.2). Each fieldwork team consisted of 17 students and two archaeologists from the Department of Archaeology along with eight workers employed by the Department of Antiquities.

The 2008 season focused on an area inside the fortress on the eastern side along the curtain wall of the fortress. It also lies between two interval towers and parallel to a two-room traditional house built on the external face of the fortress's perimeter wall. It had the smallest quantity of debris and was relatively flat. At the beginning of the 2009 season one area (02) was chosen for excavation. Towards the end of the project, the team decided to excavate the interval tower which is contiguous to the excavation area, and it was excavated as an open area. This area was located inside the fortress on the eastern side along the curtain wall and very close to it. Five squares, 4×4m each, were planned for excavation. The eastern line of baulks was located almost in the middle of the thick curtain wall between the two rows. Therefore, at least 1m of the curtain wall was included within the squares.



Figure 2: Aerial photograph shows the excavated area in Udhruh during 2008 and 2009 Seasons (Courtesy of David Kennedy).

### 2.3 SAMPLING, MINERALOGICAL AND CHEMICAL ANALYSES

Five marble samples were collected from the squares (Fig. 2). The field observations show that this marble type is hard and light in color, made mainly of sugary like crystals. Marble samples were studied under TWLM and their mineralogical composition was analyzed using the XRD technique. Quantitative chemical analysis was performed using X-Ray Fluorescence Spectrometer (XRF).

**XRF analysis:** Quantitative analysis of major oxides and trace elements was performed using X-Ray Fluorescence Spectrometer (XRF) type SHIMADZU EDX-7000/8000 X-ray Fluorescence Spectrometer instrument available at the Laboratories of AHU. Samples were crushed then powdered (grain size of the powder < 50  $\mu$ ) in an agate mortar. The powdered sample is filled in a thin film covered 10 mL cell, then pressed using press machine. The pressed sample cell is mounted in the instrument. The software used to detect minerals is PCEDX-Navi-PCEDX-Main.mna [EDX-7000].

**XRD Analysis:** Marble samples were analyzed using the SHIMADZU LabX XRD-6100 X-Ray Diffractometer available at the laboratories of Engineering Faculty at Al-Hussein Bin Talal University (AHU). Mineral identification carried out via ICDD PDF-2/Release 2013 RDB and comparison with literature. Sample was crushed then finely ground using lab scale grinding machine available at the laboratories of Mining Engineering department. For the X-ray diffraction method, the size and uniformity of sample particles are important in the determination of

the diffraction pattern accuracy. The size was reduced to less than 75 microns. About 1 gram of each sample was fed randomly to metal mount cavity. Sample powder then pressed by powder press block followed by cleaning of surplus powder. The complete sample holder then placed in special rack for analysis. Operation and experimentation conditions are as follows: radiation: Co K $\alpha$ ., wave length 1.78896 angstrom, generation voltage is 40 kV, current 45 mA, scanning speed 1.2o/min, step size 0.02o.

**Petrography and Microscopy:** Five samples were selected for petrographic study. Stereo-microscopic inspection for hand specimens was carried out. High similarity was observed between the samples. Standard thin sections of the marble samples were prepared. Half of each thin section was stained using staining test solution (Alizarin Red S) and then studied using the polarizing microscope available at the laboratories of Geology Directorate - the Natural Resources Authority. Marble samples were photographed using digital camera (Canon PowerShot S70).

## 3. RESULTS AND DISCUSSION

### 3.1 EXCAVATION RESULTS

The results of the excavations 2008-2009 seasons are useful to understand the history of the site, especially in the periods postdating the Roman. New materials were revealed. In the excavation area, area 02 season 2009, there is more evidence from the Roman, Byzantine and probably the early Islamic period and less evidence regarding the late Islamic period. Sub-

stantial parts of the curtain wall of the fortress were exposed. The same wall was seized in later periods, and new buildings were constructed against it. It is also obvious that new structures were for domestic use. Their walls were associated with stratified floors and hearths. It has also become clear that the stonework of the two faces of the perimeter wall are not the same, large blocks used in the external side while smaller blocks were used for the internal. The digging in the open area, the interval tower, revealed new information concerning the fate of the towers and the apparent long-term use of the site. This tower was converted into a lime oven. Besides the pieces of marble, the archaeological finds included architecture, pottery, glass, coins and personal objects.

### 3.2 MINERALOGIC AND CHEMICAL COMPOSITION

High degree of similarity was observed between the marble samples. The chemical composition of the studied marble samples is presented in Table 1. The dominant oxide is calcium monoxide which forms greater than 98.5% in each marble sample. Other oxides are present in minor quantities. Majoring of CaO in Udhruh marble indicates that they were derived from calcitic sources. The similarity in the chemical composition results of the studied marble samples would indicate that they were brought

from the same source or closer resources with the same marble province.

Table 1: Chemical composition (major elements oxides) of Udhruch Marble.

Analyte (%)	Sample NO				
	1	2	3	4	5
CaO	98.94	98.98	98.52	99.23	98.99
SiO <sub>2</sub>	0.69	0.67	0.88	0.50	0.62
SO <sub>3</sub>	0.21	0.20	0.45	0.12	0.24
NiO	0.05	0.06	0.03	0.06	0.04
SrO	0.04	0.04	0.07	0.05	0.06
Fe <sub>2</sub> O <sub>3</sub>	0.04	0.02	0.06	0.01	0.01
CuO	0.04	0.03	---	0.03	0.04

Mineralogic analysis via XRD showed that the major mineral phase in Udhruh marble is calcite (Fig.3). Dolomite is relatively rare. Therefore, Udhruh marble is calcitic marble not dolomitic marble. The calcitic marbles are very common and most of Greece ancient marble quarries are of this type, while the dolomitic marbles were restricted for statues (Abu-Jaber et al., 2012). Other mineralogical components and impurities are also present. They are mainly quartz and clay minerals.

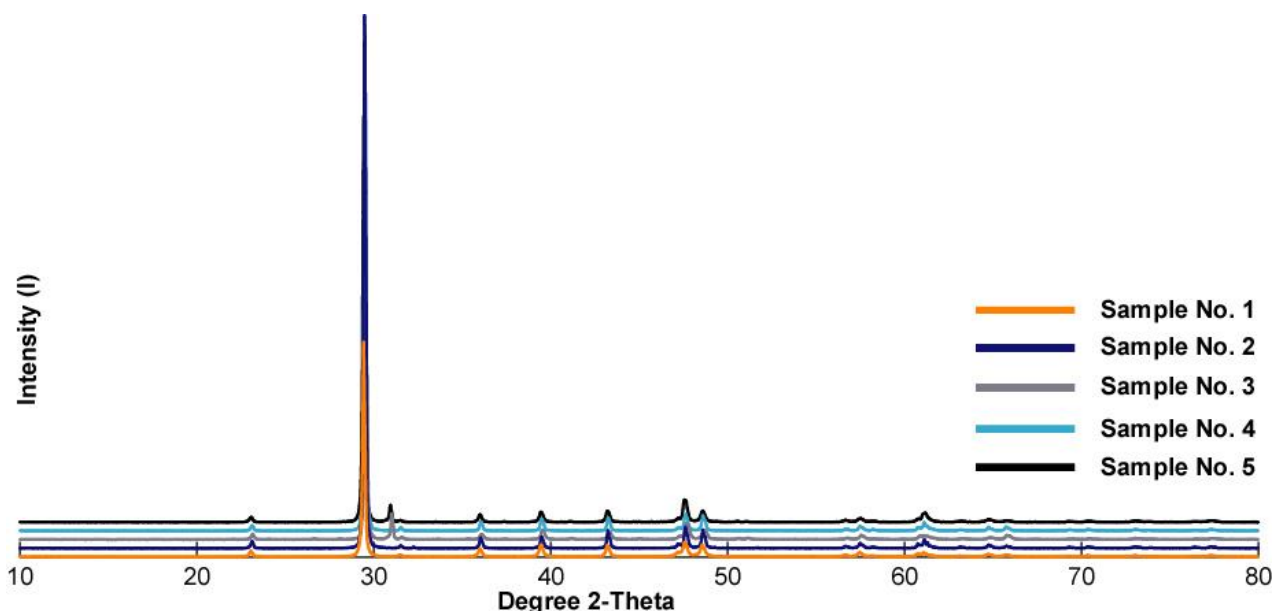


Figure 3: XRD diffractograms for Udhruh marble samples. The main mineral phase is calcite.

### 3.3 PETROGRAPHY OF UDHRUH MARBLE

The hand specimens of Udhruh marble show white to grayish white colors, fine to medium-grained, medium hard to hard (Fig. 4-A, B). The grey

color probably due to the presence of graphite (Abu Jaber *et. al*, 2012). Some hand specimens show darker bands (Fig. 4-C) that could be related to the presence of iron-oxides as stains.



Figure 4: [A] Fine to medium-grained, medium hard marble, [B] Medium-grained and hard marble, [C] Shows dark bands of staining iron-oxides. Scale unit is 1mm.

Under microscope, the marble samples show mosaic fabric. Calcite occurs as a major constituent and forms about 97%. It occurs as fine to medium-grained, anhedral to subhedral aggregates (Fig. 5 and Fig. 6). Calcite crystals can be identified by their rhombic cleavage (Fig. 5). They exhibit a xenoblastic texture where the grain boundaries are irregular (Fig. 5 and 6). Dolomite rarely exist and forms less than 3%. No account has been considered for dolo-

mite in different marble sources (e.g. Penteli type) Lazzarini (2004), (Lazzarini and Mariottini, 1987). The petrographical characteristics of Udhruh marble are most likely to match that of Pentelic type marbles reported by Lazzarini (2004), therefore, Udhruh marble might have been extracted from the quarries on Mount Pentelicus, some 16 km northeast of Athens in Greece.



Figure 5: Rhombohedral cleavage in Calcite crystals. 4x, XPL.

Four regional areas are considered as sources of marble in the Mediterranean basin; Greece, Turkey, Italy, and North Africa (Herz 1998; Marbles 1982; Jobbins 1990). In Jordan, Burton MacDonald in his survey in 1979 South Wadi El Hasa, noted that the natural resources of the region include chert, bitumen's, gypsum, building stone and the raw materials for glass and cement (MacDonald, 1980). The subsequent survey conducted in 1981 (MacDonald et al., 1982), MacDonald provided no evidence of marble quarrying in the Jordan region, but the 1982 survey recorded an alabaster quarry at site 1016 (MacDonald et al. 1983). At the end of the first century B.C

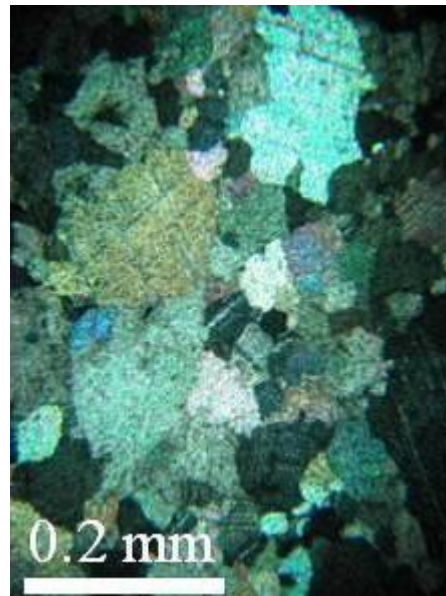


Figure 6: High interference colored calcite (vary colored), first order colored (grayish) dolomite also present. The marble microstructure for xenoblastic texture. 4x, XPL.

and into the begging of the second, the marble trade in and around the Mediterranean Sea fall under the control of a Roman Imperial quarry system within the maritime port city of Gaza (Fisher 1998, 1996; Fant 1988). Udhruh would have had the closest contact with what would have been in Gaza. Pensabence (1978) suggested that finding these different kinds of marble together is not problematic because "there must have been Ports in Asia Minor which acted as collecting points for the export of marble from the nearby regions".

The discovery of marble at Udhruh is not unexpected considering the history of the site and the

number of buildings and features. The site was obviously a major urban centre in the vicinity of Petra throughout the first millennium AD. The Byzantine church is the most possible candidate source of the marble pieces analysed in this paper as marble was common in churches. Marble artifacts and objects were popular in Byzantine churches as they had certain function and use. Recent excavations in the church of Udhruh revealed a number of marble slabs and pieces. The slabs appear to have been parts of the chancel screens which were evidently used in the church, particularly in the eastern end of the aisles. The continuous use of the site in later periods and the abandonment of some buildings suggest that some materials were removed and reused in other parts of the site. One of the marble slabs which were discovered in the excavations of 2009 had a faint painting of a Greek letter.

Generally speaking, marble was not uncommon in the area taking into consideration the prosperity and wealth of Petra, 15 km west of Udhruh. Nabataean material culture, statues in particular, show that marble was among the favorite materials. In Petra, Marble was also found in association with archaeological features and material culture (statues) from the Roman period. The use of marble is also well attested in all of the Byzantine churches of Petra. This discussion leaves no doubt that marble was being imported to Petra from different sources for a long time. Abu Jaber et al. (2012) identified the possible sources of marble in Petra to be most likely from the quarries of Thasos, Penteli, Prokennesos and Dokimeion.

Based on the results discussed above, the Greek marble province is most likely the source of marble in Udhruh site. However, the proximity and persis-

tent contact between Udhruh and Petra might have played a role in the process of using and reusing marble in Udhruh. Udhruh itself. In a political and historical context, it belonged to Petra and regardless of the sources of marble and whether it was a first-hand use or reused at Udhruh, Petra seems to have been the trade location of Udhruh marble, which was originally imported from the Mediterranean marble provinces. Petra was a caravan city for many centuries and a wide variety of goods and materials including marble were imported from all over the ancient world.

#### 4. CONCLUSIONS

The procurement and trade in marble became an important element of the economics of the Roman Empire with the marble quarries being imperialized during the second century AD. Udhruh site was obviously a major urban centre in the vicinity of Petra throughout the first millennium AD. Marble artifacts and objects were popular in Byzantine churches. Recent excavations in the church of Udhruh revealed a number of marble slabs and pieces. Udhruh marble is calcitic marble shows mosaic fabric and xenoblastic texture quite similar in its characteristics to the Pentelic marble type marbles from Greece. The proximity and persistent contact between Udhruh and Petra might have played a role in the process of using and reusing marble in Udhruh and it seems that Petra has contributed to the source of Udhruh marble. Petra was a caravan city many centuries and a wide variety of goods and materials including marble were imported from all over the ancient world.

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