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MINERALOGICAL, PHYSICAL AND MECHANICAL PROPERTIES OF LIMESTONE ROCKS IN MA’AN AREA, SOUTH JORDAN

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ABSTRACT. Jordan limestone has a broad distribution and occurs in several stratigraphic levels. It is used for construction of composite wall for aesthetic purposes, as thin polished tiles (marble), floor tiles and monumental architecture or dry stonewalling that characterizes the countryside `of Jordan buildings.
The main goal of this study is to characterize the limestone rocks in Ma’an area in southern part of Jordan and to assess their suitability for building stone. For this purpose a detailed geological, petrographic and physico-mechanical tests were carried out on some representative samples of this area aiming at establishing a better understanding of the important properties of these rocks. It is shown that the controlling factor of the classification of Ma'an area limestone is the uniaxial unconfined compressive stress.
Keywords: Jordan; petrographic; physico-mechanical; limestone; classification.

МИНЕРАЛОЖКИ И ФИЗИКО-МЕХАНИЧНИ СВОЙСТВА НА ВАРОВИКОВИ СКАЛИ ОТ РАЙОНА НА МА’АН, ЮЖНА ЙОРДАНИЯ

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РЕЗЮМЕ. Варовиковите скали са широко разпространени в различни стратиграфски хоризонти на Йордания. Те се използват при строителство на сгради с естетически издържани стени, както и за фино полиране на керамични стенни и подови плочки, за архитектурни паметници или за сухо облицоване на външните стени на зданията, което е много характерно за сградите в Йордания.
Основната задача на това проучване е да характеризира варовиковите скали от областта Ма’ан, Южна Йордания и да определи тяхната полезност като строителна суровина. За тази цел бяха проведени детайлни геоложки, петрографски и физико-механични анализи на някои представителни проби от тази област, с цел по-задълбочено изясняване на основните качества на тези скали. Установено бе, че контролният параметър, класифициращ варовиковите скали от района на Ма’ан е едноосовото, неограничено натиск-натоварване.
Ключови думи: Йордания, петрографски, физико-механически, варовикови скали, класификация.

Introduction

Limestone rocks, which are dominantly of limestone lithologies, covering most of Jordan, are quarried from different horizons of Upper Cretaceous and Tertiary.

These rocks are mainly used for building stone. It is estimated that Jordan annual production of building stones is about 10 million linear meters produced from more than 130 quarries. More than 3 million of this production is produced from Ma’an area. This indicates the importance of this area as a main source of Jordanian building stone and the necessity to investigate the occurrences of these rocks in Ma’an area.

The main objective of this work is to characterize the limestone rocks in Ma’an area in order to assess their suitability for building stones. Therefore detailed geological, petrographic and physico-mechanical tests were carried out on some selected limestone samples from this area.

Geological setting

The limestone package in the study area is located in the upper part of the Umm Rijam Chert-Limestone Formation (URC) which represents the uppermost unit of the Belqa Group as shown in Figure 1.

The URC, which reach up to 50 m in thickness in Ma’an area, is predominantly consisting of chalk, bedded chert and limestone (Figure. 2). A prominent package of 5-12 m thick consisting of chalk and chalky limestone marks the basal part, whereas the middle part consists of chalk and chalky limestone alternated with phosphatic limestone, thin chert beds with local limestone and chert concretions.

The upper part of URC represents the economic part where building stones are mined by open quarrying. However, this package composed of chalk and chalky limestone, predominantly nummulitic type (Tarawneh, 2004).

The term Ma’an stone refers to the upper part of the URC due to the abundance of specific foraminifera known as nummulitic limestone. The presence of *Nummulites gizehensis*

in Ma'an and Gharandal areas suggests a middle Eocene age and upper Eocene (Bender, 1974; Wetzel Morton, 1959). The Tethys Ocean covered most of Europe, North Africa and SW Asia including the study area during Eocene. Sub-aqueous marine transgression drowned emergent highs and led to deposition of such nummulitic limestone in the study area.

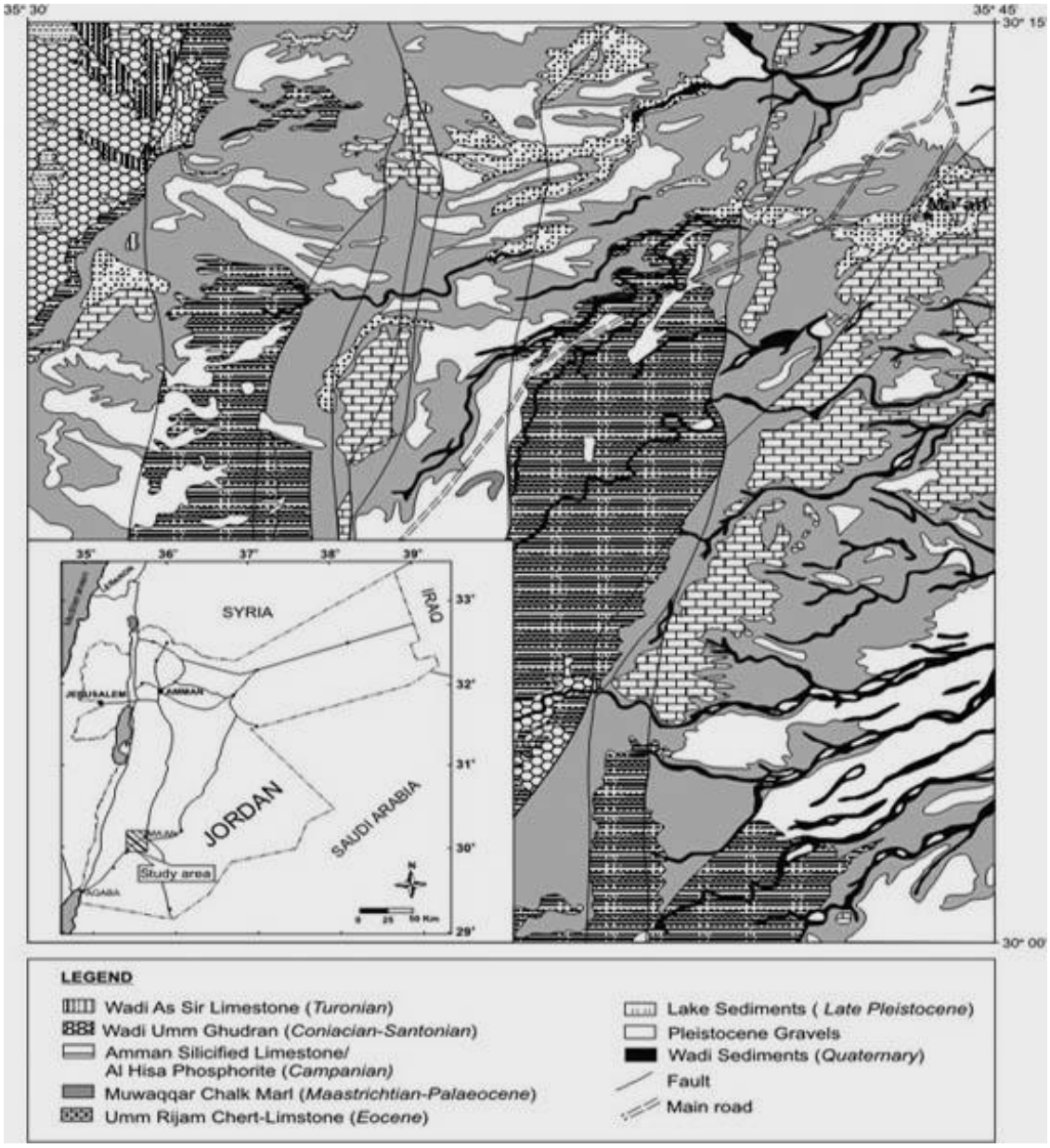

Fig. 1. Geological map of the study area (Tarawneh, 2004)

This facies is a precursor of the widespread regression on the Arabian platform in the late Eocene (Bender, 1974). The nummulitic grianstones were probably deposited in shallow water (Powell, 1988).

Four beds of nummulitic limestone are recognized in the study area as shown in Figure 2,. Their thickness is in the range between 0.4-0.8 m. Due to the influence of geological structures in the area, the basal bed shows lateral changes in thickness (up to 0.8 m thick) (Tarawneh, 2004). The nummulitic limestone has a broad distribution in Ma'an area and located at different stratigraphic levels up to 25 m below the ground surface.

Everywhere in the study area the exploited nummulitic limestone is characterized by its purity and homogeneity. In some cases the nummulitic limestone bed is influenced by imperfections that include coloration due to the iron and manganese solution. Sometimes this bed is characterized by the presence of chert, silicification and cavities filled with weak shelly materials (Moh'd, 1996).

The nummulitic limestone beds are alternated with thin beds of reddish chalk rich in Thalassinoids burrows, which is very specific particularly for beds of the upper part of the URC in the study area.

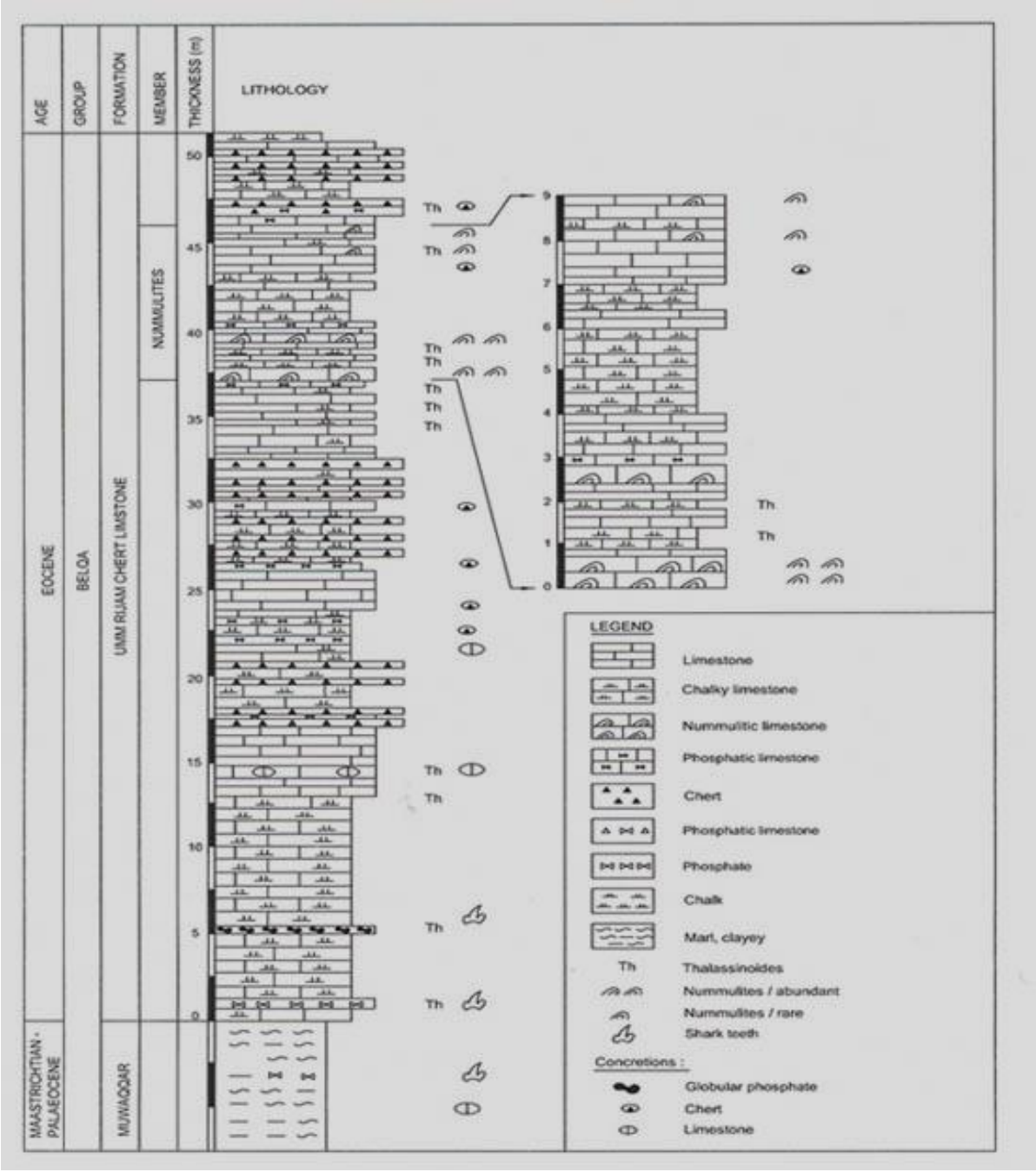

Fig. 2. Columnar lithological section of the Eocene rocks in the study area

Results and discussion

Mineralogical Study

Representative limestone samples were collected from four locations ;(Jurdaneh (JRD), Ma,anSateh (MaS), Jabal Al Juththa (JTH) and Al Jazeera (JZ) areas. The samples were studied by using polarizing microscope type Leitz Laborlux 12 pols.

Visual inspection of these samples shows that the nummulitic limestone is characterized by different degree of coloration. It is mostly white to grayish white in Jabal Al Juththa, reddish to reddish white in Ma'an Sateh, whereas in Al Jazeera area it is mostly white color. The limestone rocks are classified as biosparite according to Folk (1959; 1962) and packstone to grainstone by Dunham (1962).

Generally, the limestone understudy is quite homogenous in its internal texture and structure. The results of petrographic studies indicate that fossils forms 50-80 % of the limestone. These Fossils include large foraminifera, mostly Nummulites with diameter up to 1 cm and show different chamber arrangements. Discocyclina occurs with fussiform chambers arrangements and some specimens have maximum diameter that exceeds 2 mm. Planktonic foraminifera which represent 25-35% of the rock has a circular and ellipsoidal form with diameter of up to 0.5 mm.

Most of the foraminifera test walls are composed of calcite and show a variety of shapes and walls structures. The walls

are thick and have a radial fibrous structure, or pillars that characterize the large types of foraminifera. The matrix consists of micrite, sparite to microsparite with little blue-stained ferrous calcite cement. Most of the studied samples consist of unidentified fragmented bioclasts in a pink stained microsparitic calcite.

Physical and Mechanical Study

The representative samples were tested and used to investigate the physical and mechanical properties of the limestone according to the Jordanian standards laboratory tests. The results show that Ma'an limestone can be classified into different categories according to uniaxial unconfined compressive stress values (CS), water absorption percentage (WA), surface abrasion (SA) , seismic velocity (SV) and specific gravity (SG) as shown in Table 1 (American Society for Testing and Materials, 1983).

Table 1
Results of the physico-mechanical properties of the studied samples

Sample No	CS (N/mm^2)	WA %	SV (m/s)	SA (mm)	SG
JTH1	58.74	2.46	5501.53	27.6	2.46
JTH2	54.79	2.78	5225.28	30.1	2.78
JTH3	49.54	2.64	5667.13	30.3	2.64
JTH4	44.08	2.59	4920.03	30.8	2.59
JZ1	50.67	2.66	5366.85	31.4	2.66
JZ2	79.41	2.66	5726.58	27.37	2.66
JZ3	62.32	2.61	5724.7	32.1	2.61
JRD1	49.99	2.54	4255.32	33.19	2.54
JRD2	60.91	2.57	4909.88	31.78	2.57
MaS1	27.64	2.52	5049.5	34.1	2.52
MaS2	63.15	2.64	5401.25	30.48	2.64
MaS3	59.96	2.62	5238.2	31.45	2.62

However, the studied limestone is classified locally as Juththa, Jazeera, Jardaneh and Ma'an Sateh building stones.

The results revealed that the controlling factor in the classification process is the uniaxial unconfined compressive stress test which is an expression of the ultimate compression stress that can be sustained by the given specimen before failure under unconfined condition. According to Ross and Butlin (1989) the test should be implemented on the specimen in a location perpendicular to the bedding plane. Fig. 3 shows the effect of uniaxial unconfined compressive stress on Ma'an limestone.

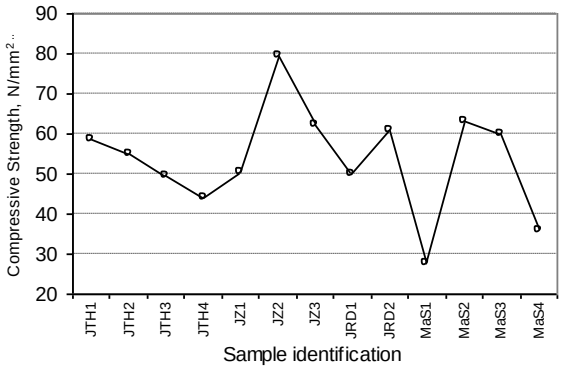

Fig. 3. The effect of uniaxial unconfined compressive stress

Different tests in this study indicate almost similar results for different limestone types except the uniaxial unconfined test distinguish between the studied limestone. So limestone in class A descended to the rank of class B and class C (Tables 1 and 2). The results also revealed that all types of Ma'an limestone have a very low water absorption less than 1.7%, which fulfill the Jordanian standards.

The building limestone in the studied area is generally within the category of class A as shown in Table 2. Generally, this indicates that the water absorption is not the effective factor in the classification of Ma'an limestone (Fig. 4). The results also shown that abrasion resistance of Ma'an limestone in different locations is not the effective factor implemented in the classification of Ma'an limestone into different categories. Abrasion resistance test can be used to determine the suitability of limestone for durability aspects. Generally, the more resistant to the metal disc abrasion is more durable against mechanical abrasion in nature (American Society for Testing and Materials. 1983, Brown, 1981, Malaga-Starzec, 2006).

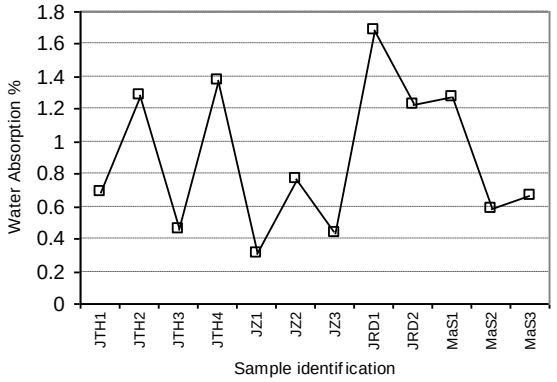

Fig. 4. Samples water absorption, %

Referring to the limits indicated in Table 2 and based on the factor D value (Richardson, 1991), the stone durability can be subdivided into five classes; a value less than 4 indicating the best durability class A, 4 to 5 class B, 5 to 7.5 class C, 7.5 to 12.5 class D, and over 12.5 the poorest class E. The results of this study show that almost all the tested samples are within the range of class A, whereas few of them match within class B and C. Accordind to the classification by durability factor Moh'd (2003) found that Ma'anSateh and Jazeera limestone in Ma'an area are of class A.

Table 2
Classification of different types of building limestone

	Class A	Class B	Class C
SA, mm	<33	33-37	37-44
CS, N/mm^2	>55	28-55	12-28
WA, %	<3	3-4.2	4.2-7.5
SV, m/s	2500-6000 for limestone rocks		

The grove length ranges between 27.37-34.1 mm (Table 1). Therefore, the compatibility of the results is given by the factor of water absorption percentage and the disc abrasion factor (Fig. 5). The test of seismic velocity was compared with the

specific gravity of Ma'an limestone and no odd results have been observed referring to the Jordanian standards. The results of the 2 tests fall between 4255-5726 m/s 2.46-2.78 as shown in Fig. 6 and 7.

Field evidences indicate that it is not difficult to recognize the lateral variation within the same mineable limestone bed in each quarry according to the Jordanian standard.

Traditionally, the customers and contractors working in the construction sector recognize the type of building limestone according to the production area (i.e. Jardaneh, Al Juhttha, Jazeera and Ma'anSateh limestone). The customers proclaim for instance that Ma'anSateh limestone is of class A, whereas Jardaneh limestone is known to be of less rank.

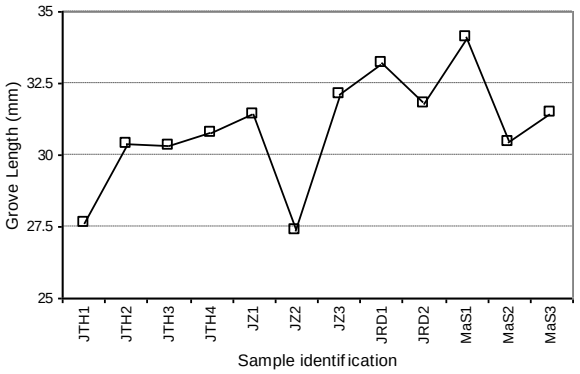

Fig. 5. Surface abrasion results

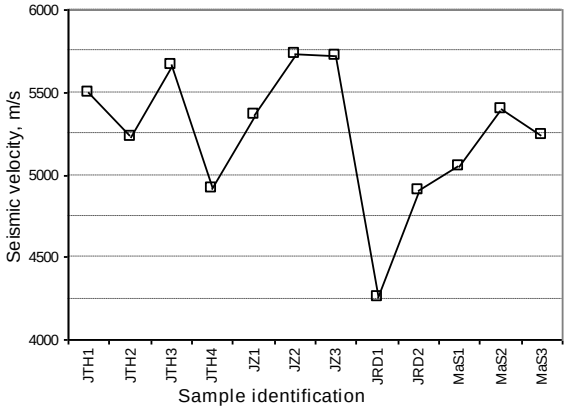

Fig. 6. Seismic velocity

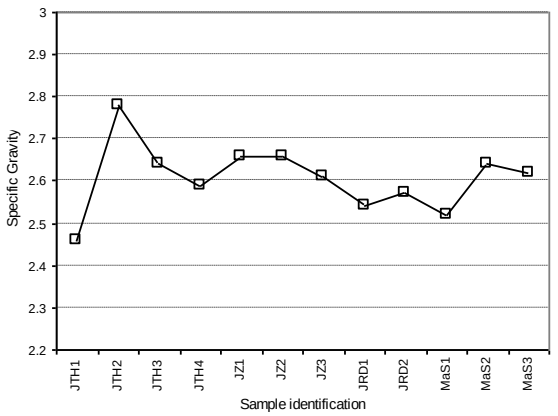

Fig. 7. Specific gravity

On the contrary, the previous results obtained indicated the presence of class A building limestone in many quarries of the study area. Consequently, class B limestone is present in the same manner. This means that, lateral and vertical changes in the physical and mechanical properties of the mineable limestone bed are present. Based on the results of this study, it is clear that the local name of Ma'an limestone used by the customers and contractors is not correct and not related to the scientific classification of building stones.

To overcome this problem, the producer and customers should refer to the scientific classification and engineering tests in each location. The local names of limestone currently used in Ma'an area should not be the only factor used to evaluate the price of the limestone produced from Ma'an area. The price of the limestone should be also reevaluated according to the physical and mechanical properties in each location in the area.

Conclusions

Based on the results obtained from the study, the following conclusion could be drawn:

The mineable nummulitic limestone bed has a broad distribution in the studied area and characterized by its purity and homogeneity, despite the variations in color.

The economic nummulitic limestone bed shows lateral changes in thickness (up to 0.8m).

The results of the petrographic studies indicate that the limestone consists mostly of fossils, which form up to 80% of the rock.

The controlling factor in the classification of limestone in Ma'an area is the uniaxial unconfined compressive test. The physical and mechanical properties of the limestone in the study area vary laterally and vertically.

The price of building stones produced from the study area should be comparable according to the Jordanian standard classification. It can be argued that the scientific classification of limestone with respect to the Jordanian standard is different from the conventional classification known for commercial purposes.

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