Assessment of Carbonate Rocks, Western Desert of Iraq as Dimension Stones for Building

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Abstract

The current study aimed to assess the Carbonate rocks as dimension stones for building. Carbonate rocks collected from the Mauddud Formation (Albian- Cenomanian), within the Western Desert of Iraq are studied petrographically, mineralogically and geochemically. Physical and mechanical properties of selected samples are found to assess their suitability as building stones. Field work is carried out and evaluated sampling of three sites of carbonate rocks. Petrography and mineralogy of these rocks are studied using polarized microscope and XRD technique.Three microfacies (peloidal wackstone-packstone, peloidal packstone and crystalline carbonate) are distinguished. Dolomitization, cementation and recrystallization are themain diagenetic processaffecting the physical and chemical properties of them. Dolomite is the predominant mineral in the 1M and 2M sites, whereas calcite is the most predominant mineral in the 3M site, so it is classified as limestone. Chemically samples are analyzedfor SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3, Na_2O, K_2O, TiO_2, MnO and LOI. CaO and MgO are the most predominant oxides confirming the abundance of calcite and dolomiteso it is classified as a calcitic dolomite for 1M and 2M sites while classified as limestone for 3M site. The results of analysis physical and mechanical properties (bulk density, water absorption, compressive strength, modulus of rupture and abrasion resistance) are indicate that selected rocks are suitable as dimension stones for building according to American Standard for Testing Materials (ASTM) specification.

Key words: Carbonate rocks, Dimension stones، Western Desert of Iraq, Physical and mechanical properties, ASTM.

الملخص

تم تقييم الصخور الكاربوناتية كصخوربعدية للبناء. تم جمع الصخور الكاربوناتية من تكوين مودود (الباين-سينومانين) من الصحراء الغربية العراقية وقد تم دراستها بتروغرافيا، معدنيا وجيوكيميائيا. الخواص الفيزيائية والميكانيكية للنماذج المختارة تم ايجادها لتقييم ملائمتها كصخور بناء. تم تنفيذ العمل الحقلي والتقييم بنمذجة ثلاثة مواقع من الصخور الكاربوناتية. تم دراسة البتروغرافية والمعدنية لهذه الصخور باستخدام المجهر المستقطب وتقنية الاشعة السينية الحائدة وقد تم تمييز ثلاث سحنات دقيقة (دمالق الواكي-المرزوم، دمالق المرزوم والكاربوني المتبلور). الدلمتة، السمنتة واعادة التبلورهي العمليات التحويرية الرئيسة والمؤثرة على الخواص الفيزيائية والكيميائية لها. الدولومايت هو المعدن الغالب في المواقع 1M و2M بينما الكالسايت هو المعدن الغالب في موقع 3M.تم تحليل النماذج كيميائيا لاوكسيد السليكون، اوكسيد الالمنيوم، اوكسيد الكالسيوم، اوكسيد المغنيسيوم، اوكسيد الحديديك، اوكسيد الصوديوم، اوكسيد البوتاسيوم، اوكسيد التتانيوم، اوكسيد المنغنيز ومفقودات الحرق. وكانا اوكسيدي الكالسيوم والمغنيسيوم هما الاوكسيدين الغالبين مؤكدين وفرة الكالسايت والدولومايتلذلك صنف كدولومايت كالسيتيفي المواقع 1M و2M بينما صنف على انه لايمستون فى الموقع 3M. اشارت نتائج تحليلات الخواص الفيزيائية والميكانيكية (الكثافة الكلية ، الامتصاص المائي، قوة الضغط، معايير الكسر ومقاومة الحك) ان الصخور المختارة كانت مناسبة كصخور بعدية للبناء اعتمادا على المواصفات الامريكية القياسيةلاختبار المواد.

الكلمات المفتاحية: الصخور الكاربوناتية، الصخور البعدية، الصحراء الغربية العراقية، الخواص الفيزيائية والميكانيكية، ، المواصفات الامريكية لاختبار المواد.

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1- Introduction

The Western Desert of Iraq is one of the most interesting physiographic provinces in the region. Many important industries in Iraq are based on the mineral resources of the Western Desert. The phosphate fertilizer industry is based on Akashat phosphorites deposit. Refractories and ceramic industries are based on Dwuekhla kaolinitic claystone deposit and the Hussainiyat bauxite and flint clay deposits, glass industry use quartz-sand from Rutbah. Cement industry uses many limestone and clay deposits as well as ironstones from South Hussainiyat deposit and montmorillonite claystones from the Safra mine are used as drilling mud. Subsurface potential for mineral deposits is still not explored and the possibility of finding new mineral deposits is still valid in view of the geological history of the Western Desert and the diversity of its lithostratigraphic units (Al-Bassam et al., 1999). Fluvial and fluviomarine deposits of quartz-sand are characteristic features of the Rutbah Formation (Cenomanian) (Al-Azzawi et al., 1996). Many industries are developed using the natural resource of the Western Desert but there is more that can be proved, tested and applied.

Generally, the landscape of the Western Desert of Iraqis not complex, but is characterized by the varied forms; the study area is hilly to semi flat area. The lithology and hardness of rocks have played a role in the development of different landforms, for example, the hard rocks give the desert a plateau form. Interbedded rocks of variable hardness have accelerated the dissection of the plateau into steps or minor plateaus. The soluble rocks have led in forming of karst units and features. Finally, the soft rocks contributed in development of eolian units. The Western Desert of Iraq is covered by various geological formations ranging from Paleozoic (Premo-carboniferous) to Cenozoic in age.

This study includes Mauddud Formation which was recognized in the Iraqi Western Desert for the first time by Al-Mubarak and Amin (1983). It represents the upper part of the first sedimentary cycle of the Cretaceous.It is exposed east of Rutbah town by 11 Km and extends eastwards till about 70 Km, near Jabal Arainbah and extends northeastwards till Faidhat Tlaihah. There, it disappears due to tectonic reason and appears again north of Faidhat Tlaihah and extends northwards for about 45 Km as dissected segments by NW – SE trending faults (Sissakian and Mohammed, 2007).

Al-Mubarak and Amin (1983) described the lithology of MauddudFormation NW of Kilo 160 vicinity as alternation of thick horizons of fossiliferous marl to marly limestone with thin horizons of fossiliferous limestone. Both of them have common yellow color. They described the thickness of Mauddud Formation as 5–8 m east of Rutbah town. It increases eastwards to 14 m, and then in the extreme northeastern part reaches to 52 m as a maximum thickness.

Al-Azzawi and Dawood (1996) described it between Rutbah town and Kilo-160vicinity as sandy dolostone or dolostone of yellow and red colors, overlain by yellow, pink, red and gray dolostone or dolomitic limestone. They described the thickness of Mauddud Formation NW of Kilo-160 vicinity to be 9 m and then decrease to4–5 m in the southwestern part.

Albian – Cenomanian, is the geological age of Mauddud Formation (Al-Mutter, 1988; Al-Mubarak and Amin, 1983; Basi et al., 1987; Yousif and Raji, 1989 and Al-Azzawi and Dawood, 1996). The depositional environment of Mauddud Formation is marine, tropical to subtropical, central shelf – inner shelf of 50 – 100 m depth, reef – back reef facies with normal salinity (Karim and Ctyroky, 1981).

Mauddud Formation is underlain by Nahr Umr Formation which indicated by the presence of some silt and shale admixture in the lower part (Buday, 1980). It is conformable marked by the first appearance of the dolostone horizon (Al-Azzawi and Dawood, 1996).

The sampling sites in this study are from Mauddud Formation which outcrops at about 40-60 km east of Rutbah town (Fig1) (Table1).

This study aimed to assess Mauddud Formation samples as dimension stone for building by studying the petrography, mineralogy, and geochemistry in addition to found their main physical and mechanical properties and comparing the results with American Standard for Testing Materials(ASTM) specification.

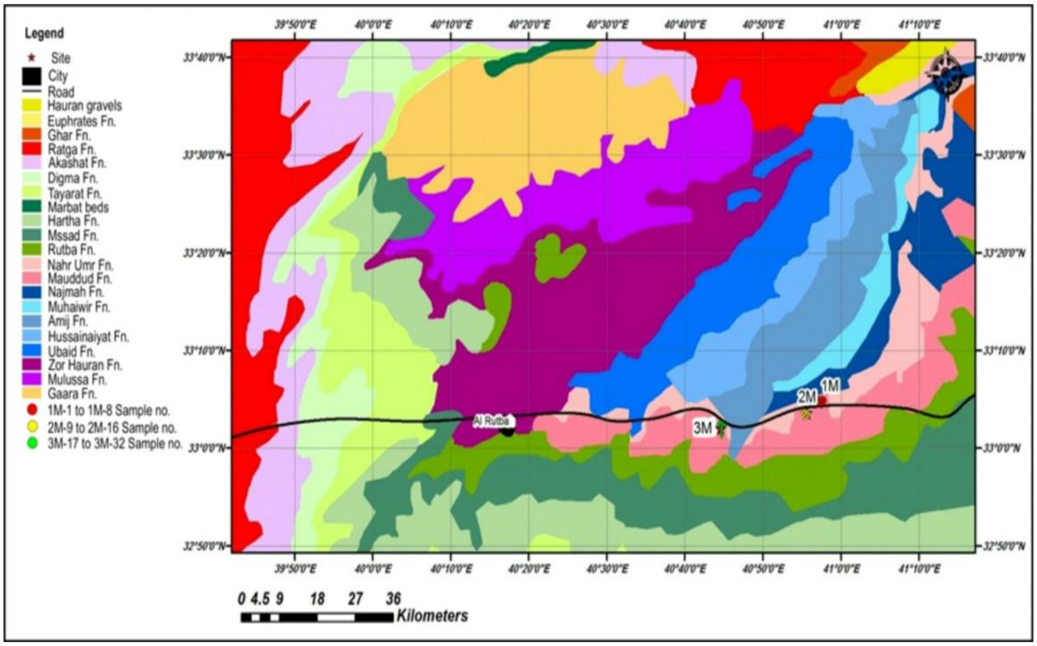

Figure 1: Location map of the study area (Sissakian, 2000).

Table 1: Coordinates of sampling sites of Mauddud (M) with simple description.

Formation	Site no.	Sample no.	Location		Elev. (m)	Description
			Longitude E	Latitude N		
Mauddud	1M	1M-1 to 1M-8	40º 59′ 222″	33˚ 05′ 620″	562	Carbonate rocks (surface sample) with pink to violet in color.
	2M	2M-9 to 2M-16	40º 58′ 328″	33º 02′ 920″	575	Carbonate rocks (surface sample) with pale reddish to yellow in color.

	3M	3M-17 to 3M-32	40º 44′ 460″	33º 03′ 010″	609	Carbonates samples collected from outcrop section and surface Carbonate rocks (surface sample) with pale red in color.

Carbonate rocks of Mauddud Formation have not been studied as building stones despite its bright colors, significant quantities and the possibility of extracting and transporting to its proximity to the main street. This problem made it necessary to work this research.

2- Materials and Methods

2-1 Field work

Three sites (1M, 2M and 3M) of carbonate rocks belonging to Mauddud Formation are selected. Eight samples are collected from site 1M and site 2M, while 16 samples (8 samples are collected from an outcrop section with a sampling interval of 1m and another 8 samples are surface samples) collected from site 3M.

The carbonate samples are chosen according to their attractive appearance and color variation. The collected samples are free of fractures, voids and other weakness features characterized by large-sized blocks (Figure 2), mostly free from cracks and fractures. This is what gives it strength and durability, and makes it suitable for mining extraction. In addition to the surface sampling, the outcrop section is also sampled in site 3M (Figure 3). Carbonate rocks of Mauddud Formation have a wide range of colors including orange, violet, reddish orange, graded yellow, dark brown and light brown (Figure 4). These carbonates are readily available and relatively easy to cut into blocks or elaborate carving.

Figure 2: Large blocks of carbonate rocks of Mauddud Formation in site 1M.

Figure3: Outcrop section of Mauddud Formation, site 3M.

Figure 4: Common colorsin the carbonate rocks of Mauddud Formation.

2-2Laboratory work

a- Preparing 32 thin sections in the lab. A part of each thin section is stained using Alizarin Red stain (ARS) solution. This technique is used for distinguishing between dolomite and calcite (Dickson, 1965 in Hutchison, 1974).

b- Preparing selected samples for XRD testing.

c- Chemical analysis for major oxides by the following methods:

- SiO_2 and L.O.I are analyzed using gravimetric method.

- Fe_2O_3, CaO, MgO and MnO are analyzed using titration.

- Na_2O and K_2O are analyzed using the flame photometric method.
- Al_2O_3 andTiO_2 are analyzed using the colorimetric method.

d- Physical properties of samples are found which include bulk density, porosity and water absorption according to ASTM C97-02test method.

e- Mechanical properties of samples are found according many test methods as follow:

- Compressive strength according to ASTM C170-90test method.
- Modulus of rupture according toC99-87test method.
- Abrasion resistance according to ASTM C241-90test method.

3- Results and Discussion

3-1 Petrography

Thin sections are examined under polarized microscope to diagnose carbonate minerals and the diagenetic processes affecting these minerals. Carbonate rocks are volumetrically made up of depositional products affected diagenetically. The depositional products include carbonate particles (grains) and groundmass (micrite and cement) (Flugel, 2004).

The diagenetic processes refer to physical, chemical and biological changes that happened after deposition. The understanding of these processes and their products has high economic importance, because diagenetic criteria change many of the petrophysical properties of carbonate rocks and determine their value for use in industry (Flugel, 2010).

In the Mauddud Formation, peloids are the main non-skeletal grains; they range in size from silt to sand grade. Spherical and oval shapes are predominant.

Recrystallization affected the micrite groundmass of Mauddud Formation and converted microcrystalline calcite to microsparite, and thento sparite.

Three microfacies are found according to Dunhum's classification as follow:

a- Peloidal wackstone-packstonefor site 1M.

Peloids are the main non-skeletal grain composed of micrite and lacking the internal structure, groundmass neomorphosed from microsparite to sparite. This microfacies had been affected at various levels by dissolution and dolomitization creating vugy and interpartical porosity type. Cementation of blocky calcite cement is the main cement type (Figure 5).

b- Peloidal packstone for site 2M.

Peloids are still the main non-skeletal grain, groundmass neomorphosed from microsparite to sparite. This microfacies had been affected at various levels by dolomitization forming scattered rhombs of fine size dolomite. Interpartical porosity is the main porosity type. Cementation as diagenetic process is dominated with blocky cement (Figure 6).

c- Crystalline carbonate site 3M.

The primary texture was destroyed by crystallization or replacement; therefore, the original texture is not recognized and the current texture can be described as submosaic texture. Thus, crystalline carbonate rock is the actual name for this facies. The grains are enlarged with interlock contact (Figure 7).

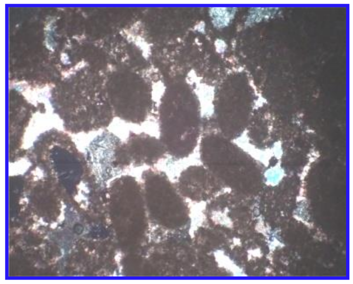

Figure 5: Photomicrograph of peloidal wackstone-packstone, site1M (sample no. 1M-6), PPL, 10X.

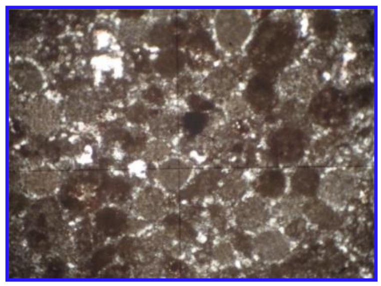

Figure 6: Photomicrograph of Peloidal packstone, site 2M (sample no. 2M-14), PPL, 10X.

Figure 7: Photomicrograph of crystalline carbonate, site 3M (sample no.3M-27), PPL,10X.

Raymond (1995) defined diagenesis as all physical, chemical, and biological processes that collectively result in the transformation of sediment into sedimentary rocks. Diagenesis may continue to operate after the sediment has become a rock, altering the rock texture and mineralogy. These processes give sedimentary rocks many characteristics observed in outcrops, hand specimen, and in thin section. Dissolution is considered as one of the most important diagenetic process in Mauddud Formation especially in the site 1M. The porosity was studied in the Mauddud Formation according to (Choquette and Pray, 1970), the observation illustrates that vuggy and interpartical were the types of porosity in all sites but with different proportion (Figure 8). The neomorphism (recrystallization) was by partial and total changes of the microsparite to sparite. This process was noticed in wackstone – packstone microfacies at site 1M, in packstone microfacies at site 2M and in crystalline carbonate at site 3M (Figure 9).

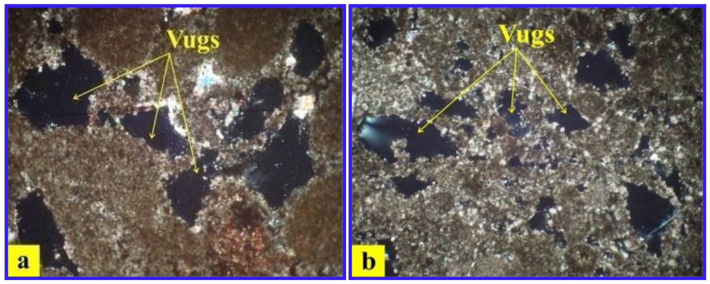

Figure 8: Photomicrograph of vuggy porosity, a: Site1M (sample no.1M-2), XPL, 10X; b: Site 2M, (sample no. 2M-15), XPL, 10X.

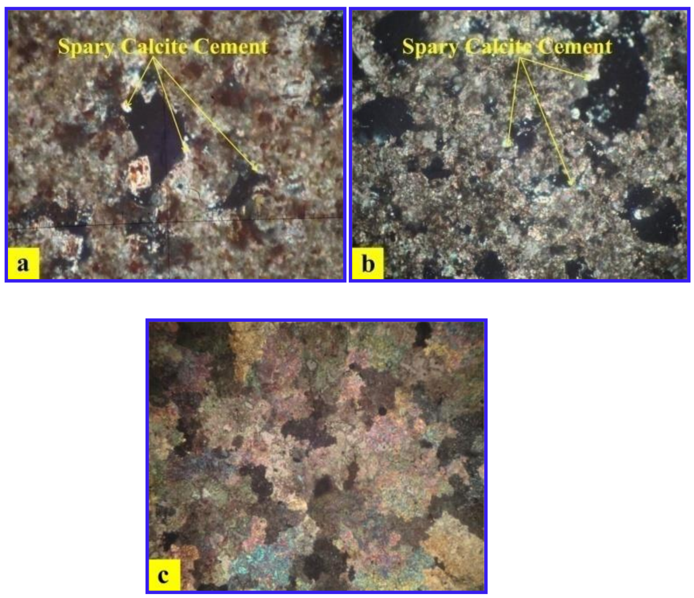

Figure 9: photomicrograph of neomorphism diagenetic process. a: Sparry calcite cement, site1M (sample no. 1M-3), XPL, 10X. b: Sparry calcite cement, site 2M (sample no. 2M-16), XPL, 10X. c: Recrystallization of calcite, site 3M (sample no. 3M-26), XPL, 10X.

Dolomitization is one of the replacement processes (Blatt et al., 1980). Scattered, fine to coarse grained dolomite rhombs occur within wackstone-packstone microfacies site 1M and packstone microfacies site 2M (Figure 10).

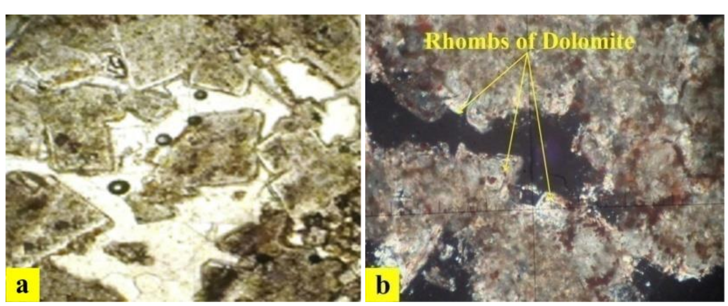

Figure 10: Photomicrograph of dolomitization process, a: Dolomite site 2M (sample no.2M-10), PPL; b: Site 1M (sample no.1M-4) XPL, 10X.

According to Flugel (1982) dolomitization can be divided into two types: early diagenetic dolomitization and the late diagenetic dolomitization. The most important effect of dolomitization particularly in the late diagenetic stage is increasing of porosity. Dolomitization can cause increasing in porosity up to 13 % (Bathurst, 1975; Boggs,2006).Early dolomitization is of less importance, because it is often obliterated by other subsequent processes. Early dolomitization process was affected Mauddud Formation which caused the porosity but less than dissolution effect.

Dedolomitization is considered to be formed by calcitization of dolomite rhombs (Evamy, 1967). The selective leaching of dolomite rhombohedron occurs and the pores partially filled by calcite drust. The calcitization process is referred to dedolomitization and predominantly takes place through contact with meteoric waters (Tucker, 1981).

It was observed that the dolomitization and dedolomitization are the main diagenetic process affected the Mauddud Formation in site 3M (Figure 11). The dedolomitization increased upwards.

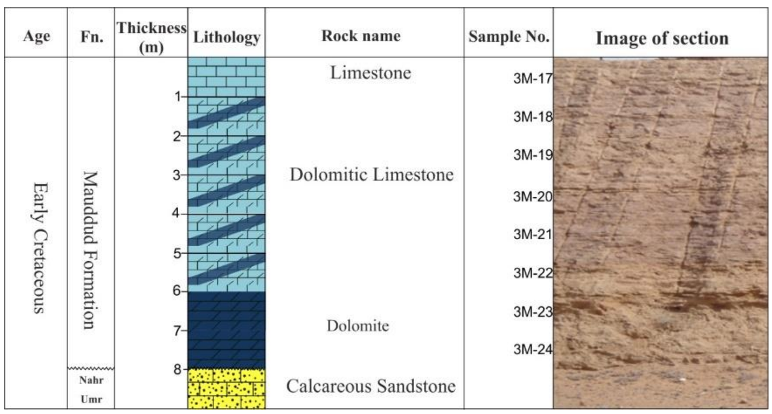

Figure 11: Cross section and lithology description of Mauddud Formation (site 3M) display the dolomite and dolomitic limestone are the main rocks.

Cementation is defined as a diagenetic process of cavity filling or open space filling through chemical precipitation of material from a solution on a free surface (Flugel, 1982). Calcite cement is a common diagenetic feature filling both interparticle and vugy pores.

The main type of cement found in the Mauddud Formation is blocky calcite cement that consists of fine to medium grained crystals without preferred orientation (Figure 12). Some calcite cements are recrystallized.Silicification process was also observed for some samples in site 3M.

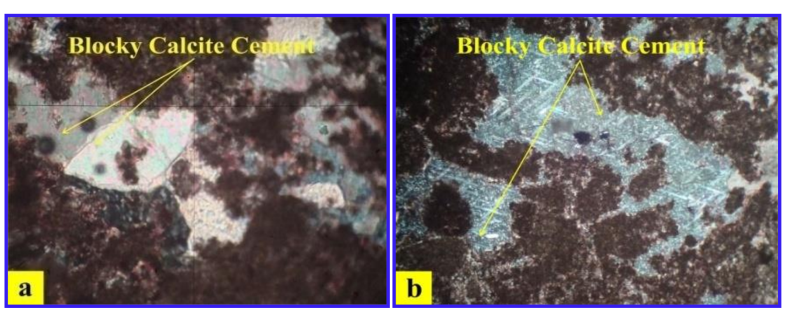

Figure 12: Photomicrograph of blocky calcite cement, a: Site 1M (sample no.1M-5), XPL, 10X. b: Site 2M, (sample no. 2M-12), XPL, 10X.

3-2 Mineralogy

The XRD technique is also used to diagnose the mineral constituents in the selected samples Dolomite is the main mineral in sites 1M and 2M. It was identified by the (hkl) (104) reflection: d space= 2.89˚A (the major peak), 2ϴ= 30.99˚as well as other less intense by the (hkl) (113) reflection: d space= 2.19˚A, 2ϴ=41.18˚ and by the (hkl) (202) reflection: d space= 2.02˚A, 2ϴ=44.99˚ (Figure 13) and (Figure 14).

Calcite is the main mineral in the site3M. It is identified by the (hkl) (104) reflection: d space= 3.04˚A (the major peak), 2ϴ= 29.40˚ which represent the main high intensity peak (Hutchison, 1974).As well as other less intense peaks the (hkl) (108) reflection: d space= 1.91˚A, 2ϴ= 47.63˚ and the (hkl) (116) reflection: d space= 1.87˚A, 2ϴ= 48.63˚(Figure 15).Peaks of calcite in such d-space and 2ϴ are quite clear also in site 1M and site 2M by fewer ratios than dolomite (Figure13) and (Figure 14).

3-3 Geochemistry

A total of 24 samples collected from three sites from Mauddud Formation are analyzed for SiO_2, Al_2O_3, CaO, MgO, Fe_2O_3, Na_2O, K_2O, TiO_2, MnO and L.O.I (Table 2).

The prevalence of CaO, MgO and L.O.I reflects the abundance of calcite and dolomite minerals. The low content of SiO_2, Al_2O_3 and K_2O oxides reflects the low content of clay minerals in Mauddud Formation.

According to chemical analysis the percentage of Dolomite, Calcite, Quartz and others are calculated confirming the results of XRD technique (Table3).

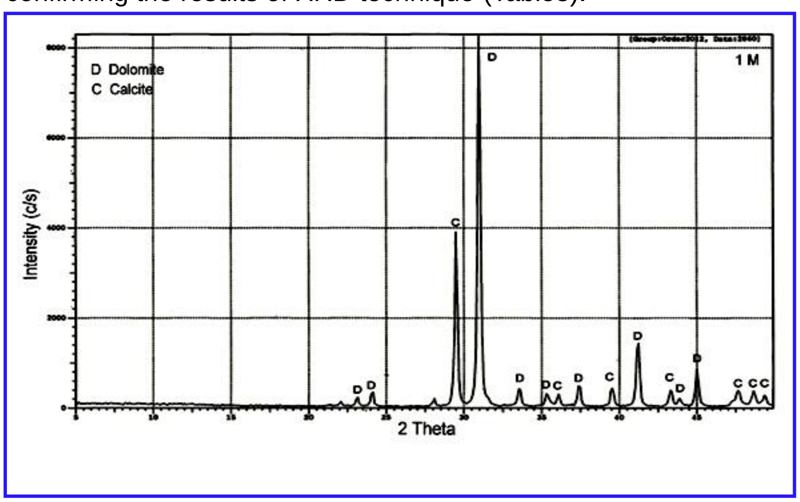

Figure 13: X-ray diffractogram of site 1M (sample no. 1M-6) of Mauddud Formation.

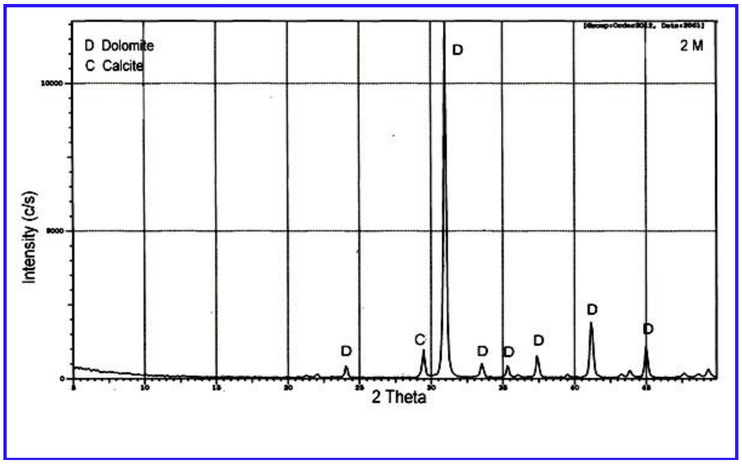

Figure 14: X-ray diffractogram of site 2M (sample no. 2M-14) of Mauddud Formation.

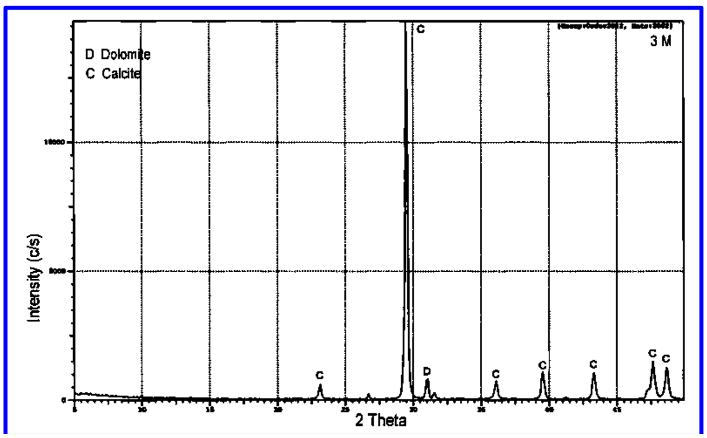

Figure 15: X-ray diffractogram of site 3M (sample no. 3M-30) of Mauddud Formation.

Table 2: Chemical analysis of Mauddud Formation collected samples.

Site no.	Sample no.	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	Na_2O	K_2O	TiO_2	MnO	L.O.I	Total
		%										%
1 M	M-1	1.35	0.48	37.09	14.21	2.00	0.01	0.02	0.02	0.02	44.75	99.95
	M-2	1.15	0.32	39.10	13.32	0.66	0.01	0.02	0.01	0.01	45.30	99.90
	M-3	1.26	0.28	39.12	13.35	0.50	0.01	0.02	0.01	0.01	45.38	99.94
	M-4	1.40	0.62	37.50	13.97	1.88	0.01	0.02	0.02	0.01	44.52	99.95
	M-5	1.32	0.71	37.70	14.20	0.70	0.01	0.02	0.01	0.02	45.27	99.96
	M-6	0.95	0.27	37.20	14.27	2.30	0.02	0.02	0.01	0.02	44.90	99.96
	M-7	0.85	0.20	38.50	13.50	1.80	0.01	0.01	0.02	0.01	45.00	99.90
	M-8	1.20	0.40	37.70	14.30	0.96	0.02	0.01	0.02	0.01	45.30	99.92
	Range	0.85-1.40	0.20-0.71	37.09-39.12	13.32-14.30	0.50-2.30	0.01-0.02	0.01-0.02	0.01-0.02	0.01-0.02	44.52-45.38	
	Average	1.185	0.41	37.98	13.89	1.35	0.012	0.02	0.015	0.013	45.05	

2 M	M-9	2.18	0.77	33.60	17.23	0.78	0.01	0.02	0.02	0.01	45.30	99.92
	M-10	3.21	1.38	31.79	17.58	1.60	0.02	0.05	0.02	0.02	44.30	99.97
	M-11	3.30	1.97	32.24	16.72	1.91	0.02	0.05	0.02	0.03	43.70	99.96
	M-12	3.42	2.10	32.30	16.85	1.22	0.03	0.1	0.03	0.03	43.85	99.93
	M-13	2.50	1.40	33.40	17.12	0.38	0.02	0.05	0.02	0.02	45.00	99.91
	M-14	0.78	0.28	33.60	17.23	2.66	0.02	0.03	0.01	0.02	45.27	99.90
	M-15	1.49	0.35	32.05	18.20	2.62	0.02	0.03	0.01	0.02	45.18	99.97
	M-16	3.30	1.75	31.20	17.42	2.55	0.02	0.03	0.02	0.02	43.30	99.91
	Range	0.78-3.42	0.28-2.10	31.20-33.60	16.72-18.20	0.38-2.66	0.01-0.03	0.02-0.1	0.01-0.03	0.01-0.03	43.60-45.30	
	Average	2.50	1.25	32.52	17.29	1.71	0.02	0.04	0.018	0.021	44.52	
3 M	M-25	2.85	1.15	52.69	0.60	0.52	0.02	0.03	0.03	0.02	42.00	99.91
	M-26	0.23	0.12	54.98	0.65	0.05	0.01	0.02	0.01	0.01	43.82	99.90
	M-27	2.99	0.39	52.97	0.85	0.14	0.02	0.03	0.02	0.01	42.50	99.92
	M-28	1.73	0.24	53.15	0.78	0.39	0.01	0.03	0.02	0.01	43.60	99.96
	M-29	1.99	0.17	53.00	0.88	0.25	0.01	0.02	0.02	0.01	43.63	99.98
	M-30	1.46	0.45	52.97	0.85	1.62	0.01	0.03	0.03	0.01	42.49	99.92
	M-31	3.41	1.25	52.10	0.47	1.45	0.02	0.05	0.03	0.02	41.10	99.90
	M-32	1.17	1.05	53.72	0.37	0.95	0.01	0.03	0.03	0.01	42.60	99.94
	Range	0.23-3.41	0.12-1.25	52.10-54.98	0.37-0.88	0.05-1.62	0.01-0.02	0.02-0.05	0.01-0.03	0.01-0.02	41.10-43.82	
	Average	1.97	0.60	53.19	0.68	0.67	0.013	0.03	0.023	0.012	42.71	

Table 3: Mineralogical composition (%) in Mauddud Formation.

Site no.	Sample no.	Dolomite	Calcite	Quartz	Others	Total
		%				
1 M	1M-1	65.36	30.71	1.35	2.58	100
	1M-2	61.27	36.53	1.15	1.05	100
	1M-3	61.41	36.48	1.26	0.85	100
	1M-4	64.26	32.05	1.40	2.29	100
	1M-5	65.32	31.82	1.32	1.54	100
	1M-6	65.64	30.76	0.95	2.65	100
	1M-7	62.10	35.00	0.85	2.05	100
	1M-8	65.78	31.57	1.20	1.45	100
	Range	61.27-65.78	30.70-36.52	0.85-1.40	0.84-2.65	
	Average	63.89	33.11	1.18	1.80	
2 M	2M-9	79.25	16.94	2.18	1.63	100
	2M-10	80.86	12.83	3.21	3.10	100
	2M-11	76.91	15.78	3.30	4.01	100
	2M-12	77.51	15.55	3.42	3.52	100
	2M-13	78.75	16.85	2.50	1.90	100
	2M-14	79.25	16.94	0.78	3.03	100
	2M-15	83.72	11.73	1.49	3.06	100
	2M-16	80.13	12.17	3.30	4.40	100
	Range	76.91-83.72	11.73-16.92	0.78-3.42	1.63-4.40	
	Average	79.54	14.84	2.52	3.08	

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3 M	3M-25	2.76	92.58	2.85	1.81	100
	3M-26	2.99	96.55	0.23	0.23	100
	3M-27	3.91	92.46	2.99	0.64	100
	3M-28	3.58	92.98	1.73	1.71	100
	3M-29	4.04	92.44	1.99	1.52	100
	3M-30	3.91	92.46	1.46	2.17	100
	3M-31	2.16	91.87	3.41	2.56	100
	3M-32	1.70	95.01	1.17	2.12	100
	Range	**1.70-4.04**	**91.86-96.55**	**0.23-3.41**	**0.23-2.83**	
	Average	**3.13**	**93.29**	**1.97**	**1.59**	

According to the results in Table 3 and the classification of Tucker (1985) who divided carbonate rocks on the basis of mineral content Mauddud Formation samples can be classified as: calcitic dolomite in site 1M and site 2M, and Limestone in site 3M.

3-4 Physical and Mechanical properties

Attractive appearance of the rock is not enough to evaluate the carbonates of Mauddud Formation as dimension stones. There are many property requirements that must be measured to determine their suitability for this purpose. Physical and mechanical properties reflect the main parameter that affect carbonate rocks as building stone, on the other hand reflects the suitability of its use as decorative stone for external and internal cladding. According to ASTM C568-03(Table 4), there are many properties must be tested to meet the requirements. The properties are discussed as follow:

3-4-1 Bulk Density

The bulk density is an important parameter when calculating the weight of the stone in the wall and construction elements (Spry, 1989).In carbonate rocks of the Mauddud Formation, bulk density is measured as 2165, 2180 and 2590 kg/m^3 for site 1M, site 2M and site 3M respectively, these values classified the samples as medium density for sites 1M, 2M and high density for site 3M (Table 5).

3-4-2Water absorption

Water absorption is the proportion of water able to be absorbed in stone under specific immersion condition. The value obtained provides some indication of the stones performance in the service, particularly its strength, durability and stain resistance (Spry, 1989).

Water is one of the main factors involved in most of weathering processes (Siegesmund, 1996). Almost all of the weathering processes taking place at structures and buildings are controlled by the presence of water and thus the characteristics of water have an immense impact on the long term stability of dimension stones. The presence of water also has a significant effect on the peterophysical and mechanical properties of rocks. This is mainly influenced by moisture content, which on the other hand is controlled by the effective porosity (Siegesmund et al., 2010).

The values of water absorption of carbonate rocks (Mauddud Formation) are 7.50%, 3.99%, 1.81% for sites 1M, 2M and 3M, respectively (Table 5).

3-4-3 Compressive strength

Natural stone is generally strong in compression, but it can vary with a wide range. Stone less than 7 MPa are comparatively weak, while those greater than 140 MPa are considered very strong (Quick, 2000).

The compression strength values of the carbonate of Mauddud Formation are measured to be 30.24, 34.52 and 55.23 MPa for site 1M, site 2M and site 3M, respectively (Table 5). Compressive strength values are positively proportional with bulk density (Table 5). This indicates that the strength of rock can reflect the density which is a reflection of mineral type, pore space, cement, and compaction.

3-4-4 Modulus of rupture

The ASTM C99-87 test procedure is used to determine the modulus of rupture, which is an important test used for assessing the dimension stone. For example as bench, table or tile which may expose to pressure in the middle of face surface. The modulus ofrupture values of Mauddud Formation samples are 4.2, 5.7 and 7.5 MPa for sites 1M, 2M, 3M, respectively (Table 5).

3-4-5 Abrasion resistance

Wind is one of the effective natural agents on building stone with time since wind carries dust particles. The abrasion caused by these deteriorates the stones; therefore, the abrasion resistance test is important to evaluate decoration stone.

The abrasion resistance values for the carbonates of Mauddud Formation are 10.1 for site 1M, 10.3 for site 2M, and 11.0 for site 3M (Table 5).

According to ASTM C568-03 (Table 4), the measurement results of physical and mechanical properties which include bulk density, water absorption, compressive strength, modulus of rupture and abrasion resistance (Table 5) confirm the suitability of carbonate rocks as dimension stone.

Depending on the application, the building and decorative stone is influenced by various factors, and must therefore meet different demands on its properties, and relating the external factors which influence the stone to its properties.

Density is an important factor for estimating the weight of building stone for purposes of building design, the bulk density of natural stone can be predicated from its mineral content, cement type, and nature of texture. Porosity can reduce the density of building materials but can also reduce their durability and strength. Absorption is a measure of how much liquid the stone can contain in its pores. This property is used as an indirect measure of how susceptible to weathering (mainly weathering by frost or salt crystallization) a specific stone type is. It is also important for estimating the stone susceptibility to dirt, grease and other pollutants. Strength properties such as compressive strength, modulus of rupture are important while using the natural stone as load bearing building elements (compressive strength), while modulus of rupture is important when it is used for paving, flooring and benches. Abrasion resistance hardness measurement gives an impression of how resistant a rock type is to the daily wear of floors and pavements.

The actual assessment of natural stones as dimension stone is closely linked with their mineral constituents and depositional texture and the type of diagenetic processes which can predicate the physical and mechanical properties affecting their quality.

Table 4: Values of the test requirements of physical and mechanical properties of limestone as dimension *stone according to ASTM C 568-03.

Physical and mechanical property	Test requirements	Classification
Density **Max (kg/m^3)**	1760 2160 2560	**Low density** **Medium density** **High density**
Water absorption **Max (%)**	12 7.5 3	**Low density** **Medium density** **High density**
Compressive strength **Min (MPa)**	12 28 55	**Low density** **Medium density** **High density**
Modulus of rupture **Min (MPa)**	2.9 3.4 6.9	**Low density** **Medium density** **High density**
Abrasion resistance **Min**	10 10 10	**Low density** **Medium density** **High density**

Table5: physical and Mechanical properties of Mauddud Formation Samples.

Properties	Unit	Mauddud Formation		
		Site 1M	Site 2M	Site 3M
Bulk density	(kg/m^3)	2165	2180	**2590**
Water absorption	(%)	7.50	3.99	**1.81**
Compressive strength	(MPa)	30.24	34.52	**55.23**
Modulus of rupture	(MPa)	4.2	5.7	**7.5**
Abrasion resistance	---	10.1	10.3	**11**

4- Conclusions

The measurement results of physical and mechanical properties of the studied rocks with peloidal wackstone- packstone, peloidal packstone and crystalline carbonate microfacies confirm their suitability as dimension stone according to ASTM C568-03. The predominant diagenetic processes, type of minerals and their arrangements could be reflecting many properties especially bulk density which in turn gives the properties values according to their low, medium and high density.

5- Recommendations

The transporting block or stones from the quarry is made by road. The studied sites are located near the main network road giving vehicles access to transport the raw materials from quarries. It is also located near the highway offering links to Syria, Jordan as well as Iraqi governorates. The other advantage of the carbonate rocks is the Mauddud Formations in the study area is exposed on the surface; the bed heights and joint spacing in the lower beds are of sufficient size to allow blocks of a commercially attractive size to be extracted. Consequently, this study recommends the investment of this raw material and at the same time, to reserve the carbonates rocks for the quarry opening.

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