MINERAL RESOURCES AND OCCURRENCES

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ABSTRACT

The economic potential and mineral occurrences of the Southern Desert is reviewed. The Iraqi Southern Desert is unlike to the Western Desert, which is rich in mineral resources and industrial rocks; it possesses no mineral resources, but few varieties of industrial rocks. Many occurrences of limestone, dolomitic limestone, dolomite, sandstone, clay and other materials like gypcrete, gravel and salt, as well as some showings of carnotite were recorded in the Southern Desert, during the Regional Geological Survey that carried out by GEOSURV. Those deposits and occurrences belong to Umm Er Radhuma, Dammam, Euphrates, Ghar, Nfayil, Zahra, Dibdibba formations and Quaternary sediments. The limestone deposits are suitable for chemical, White cement and Portland cement industries and marble alternatives. The dolomite is suitable for chemical, steel, metallurgy and glass industries; the dolomitic limestone is suitable for filler, road construction and as building materials. The clays are suitable for cement industry and the sandstone and gravel are suitable for building purposes. Sodium chloride salt, in Samawa Saltpan is thought to be most probably originated from leaching of deep seated salt horizons by groundwater and ascends upwards through faults to be redeposited in depression and extracted by dissolution and evaporation. Sulphur was found only in the sinkholes of Al-Kibritiya, located southwest of Al-Shbicha.

المـوارد والشـواهد المعدنيـة

رافع زائر جاسم

المستخلص

تختلف الصحراء الجنوبية العراقية عن الصحراء الغربية الغنية بالمصادر المعدنية وترسبات الصخور الصناعية، حيث إنها لا تحتوي على ترسبات معدنية ولكنها تحتوي على أنواع اقل من الصخور الصناعية. خلال المسح الجيولوجي الإقليمي في الصحراء الجنوبية الذي نفذته الشركة العامة للمسح الجيولوجي والتعدين تم تحديد العديد من مواقع تواجد ترسبات صخور الحجر الجيري و الحجر الجيري المدلمت والدولومايت والصخور الفوسفاتية والحجر الرملي والأطيان، إضافة إلى الجبس الثانوي والحصى والملح. تنتمي هذه الترسبات إلى تكوينات أم الرضومة والدمام والفرات والنفايل والغار والزهرة والدبدبة وترسبات العصر الرباعي. أثبتت التحاليل الكيميائية والفحوصات الفيزيائية صلاحية بعض ترسبات الحجر الجيري للصناعات الكيميائية والإسمنت الأبيض والإسمنت البورتلاندي وأيضا كبدائل للرخام. كذلك صلاحية الحجر الجيري المدلمت في إنشاء الطرق وكمواد بناء، وصلاحية الدولومايت للصناعات الكيميائية والحديد الصلب والصناعات المعدنية وصناعة الزجاج وأيضا صلاحية الحجر الطيني العائد لتكوين النفايل وترسبات الطين الحديثة لأغراض صناعة الإسمنت والرمل والحصى لأغراض البناء. أما الملح فتتم إذابته بواسطة المياه الجوفية الصاعدة التي ترسب منها الأملاح ثانية في ما يسمى الآن مملحة السماوة ومملحة أم الطيكان والتي يتم استخراج الملح منها بالإذابة والتبخير. وجد الكبريت في الصحراء الجنوبية في خسفات الكبريتية الواقعة إلى الجنوب الغربي من منطقة الشبجة.

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INTRODUCTION

The Iraqi Southern Desert covers about 76000 Km^2. The area is limited almost by Euphrates River from the north and east, Iraqi-Saudi Arabia International Borders from the south, southeast and southwest, Wadi Al-Khir from the west and the Kuwait International Borders from the east (Fig.1). This area is a part of the Stable Shelf of the Arabian Platform, which is characterized by shallow basement ranging in depth from (5 – 9) Km (C.G.G., 1976 and Buday and Jassim, 1987) and (4 – 8) Km according to Jassim and Buday in Jassim and Goff (2006).

The Southern Desert was subjected to a regional program of geological mapping and mineral investigation during late seventies and early eighties of the last century. These surveys showed that the involved area is dominated by carbonates of marine origin and detrital fluviatile sediments. The carbonate rocks belong to Umm Er Radhuma, Dammam, Euphrates, Ghar, Nfayil and Zahra formations, covering almost the western and northwestern parts of the involved area. While the eastern and southeastern parts are covered by the detrital sediments of Dibdibba Formation (Fig.2). Claystone is present in Nfayil Formation and as depression fill Quaternary sediments. Recent clays and other valley fill sediments are distributed in different parts of the Southern Desert.

Chemical analysis of samples; collected from the surveyed areas carried out by Al-Mubarak and Amin (1983), Al-Ani and Ma'ala (1983a and b), Al-Sharbati and Ma'ala (1983a and b) and Al-Sharbati and Al-Ani (1983) revealed the possibility of using different limestones in chemical industries, White cement and Portland cement industries and marble alternatives; dolomite for chemical industries and dolomitic limestone for road construction and building materials; clays for cement industry and sandstones for building purposes. Other materials like iron oxide, gypcrete, gravels and uranium are present in small amounts and limited localities. Salt is extracted from Samawa Saltpan after precipitation of the salt from the pumped brine in special artificial basins.

MINEROGENIC HISTORY

The oldest exposed rocks in the Southern Desert belong to Umm Er Radhuma Formation (Early – Late Paleocene), it posses limestone, claystone and phosphates. Phosphates are exposed in the area midway between Al-Sahan (along Wadi Al-Khir) and Al-Shbicha (Jassim *et al*., 1987). This phosphate represents the southern boundary of the Tethyan Phosphorite Belt (Late Cretaceous – Paleocene) (Mohammad and Jassim, 1990). It is present as thin horizon associated with claystone and dolomite (Jassim *et al*., 1987). These facies represent seaward migration from the shallow subtidal to relatively deeper sediments, which appear to have been developed during stages of transportation and equatorial upwelling current, reworking – winnowing related with regression phase, transportation and accumulation stages probably related with this sea level fall or linked with short local transgression (Mohammad and Jassim, 1990).

High grade limestone suitable for chemical, white and, Portland cement industries and building stones are found in Dammam, Euphrates, Nfayil and Zahra formations. Pliocene – Pleistocene fluviatile sand and clay deposits belong to Dibdibba and Zahra formations. Dibdibba sands cover vast area in the eastern part of the Southern Desert (Jassim *et al*., 1987). Palygorskite is observed in high concentration in one sample that belongs to Zahra Formation in Al-Sahan area, near Wadi Al-Khir (Jassim *et al*., 1987). Quaternary sediments are not well developed in the Southern Desert, except in the northern part, where the sediments of Euphrates River are deposited. The Quaternary sediments represent valley and depression fill sediments, composed of clays and gravels. The minerogenic stratigraphy of the Southern Desert is listed in Table (1).

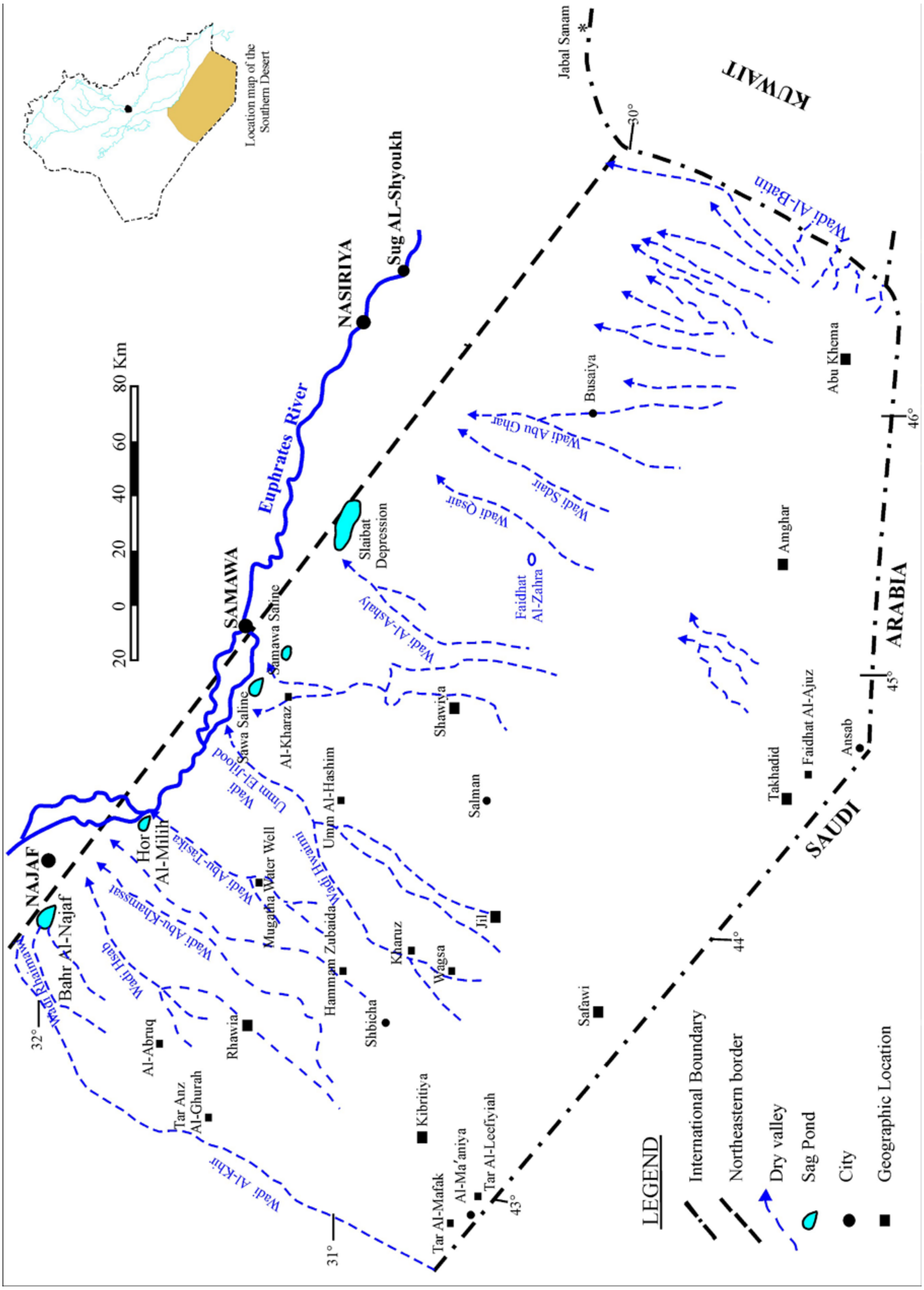

Fig.1: Location map of the Iraqi Southern Desert

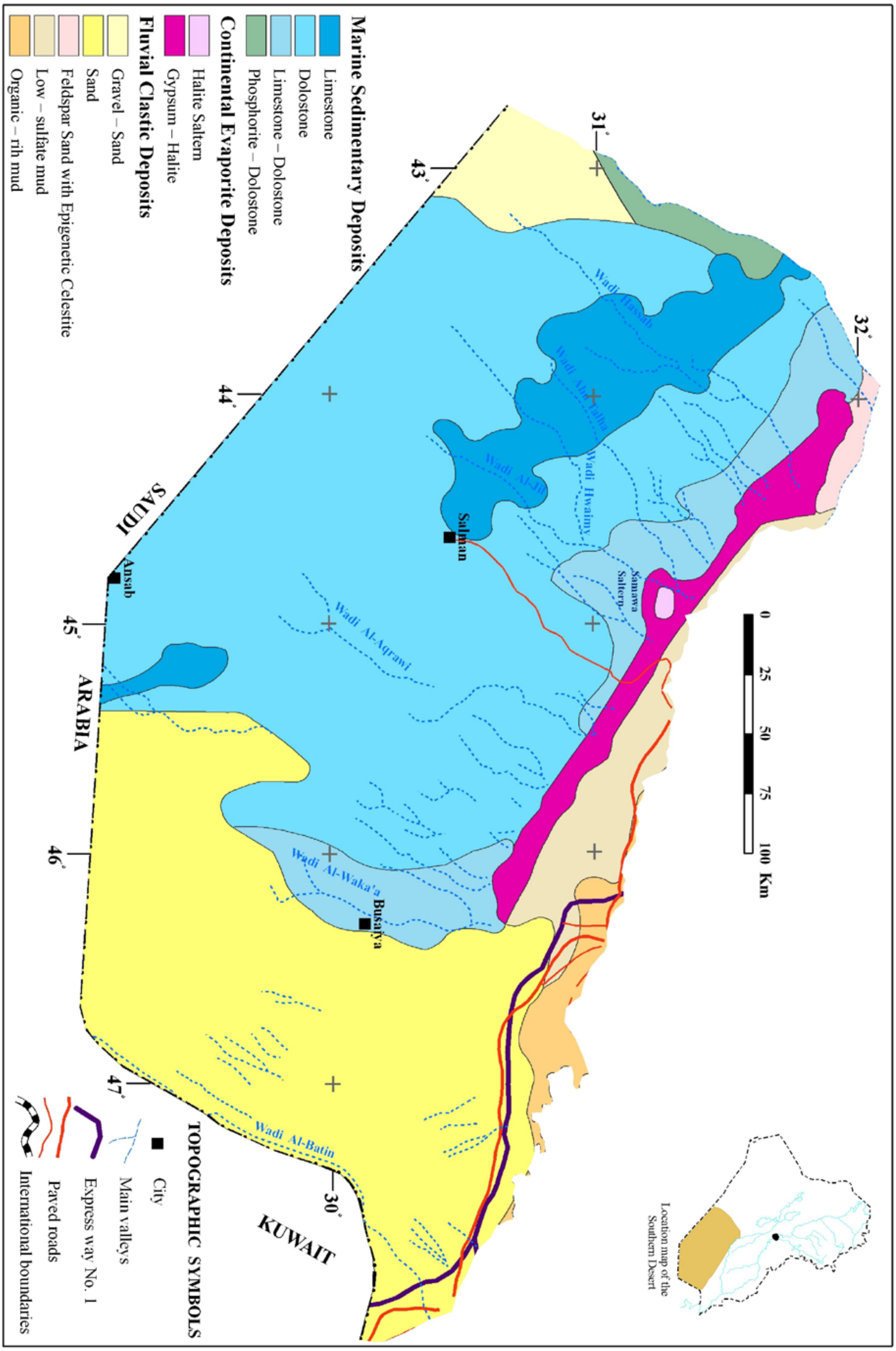

Fig.2: Minerogenic map of the Iraqi Southern Desert (after Al-Bassam, 2007)

Table 1: Minerogenic Stratigraphy of the Southern Desert

Age	Geological Unit	Raw Materials
Quaternary	Depression fill sediments	**Clays** and **gypcrete** for cement **Gravel** for constructions **Sodium chloride salt**
Pliocene – Pleistocene	Zahra Formation	**Limestone** for chemical, White cement and Portland cement industries
Pliocene – Pleistocene	Dibdibba Formation	**Sand** for constructions purposes
Middle Miocene	Nfayil Formation	**Claystone** for cement **Limestone** for cement and chemical industries **Dolomitic limestone** for constructions
Early Miocene	Euphrates Formation	**Limestone** for cement
Early Miocene	Ghar Formation	**Limestone** for cement and chemical industries **Dolomitic Limestone** for road construction
Eocene	Dammam Formation (Shawiya and Chabd Units)	**Limestone** for chemical, White cement, Portland cement industries and marble alternative **Dolomite** for chemical, steel and glass industries **Dolomitic limestone** for road construction
Paleocene	Umm Er Radhuma (Upper Chalky Unit)	**Limestone** for chemical, White cement and Portland cement industries **Attapulgite** for industrial uses Phosphate **Phosphate,** non-economic

- **Limestone**

Many limestone occurrences of good potential in term of reserve and quality were recorded in the Southern Desert (Fig.2). These limestones belong to Umm Er Radhuma, Dammam, Euphrates, Ghar, Nfayil and Zahra formations. According to the quality of the limestone, it could be used in chemical, White cement and Portland cement industries. The limestone occurrences were grouped into three classes according to their chemical composition, especially the CaO% content (Lang, 1976 in Al-Mubarak and Amin, 1983) (Table 2).

Table 2: Chemical composition and classes of limestone according to CaO content (Lang, 1976 in Al-Mubarak and Amin, 1983)

Component (%)	**Class**		
	I CaO % > 55	**II CaO % = 54 – 55**	**III CaO % = 51 – 54**
CaO	> 55	54 – 55	51 – 54
MgO	0.3 – 2.5	1.0 – 1.5	2.0
Al_2O_3	0.1 – 0.4	---	---
Fe_2O_3	0.1 – 0.5	0.1	---
$SO_3^=$	---	1.0	1.0
$Na_2O + K_2O$	---	2.0	0.05
Cl^-	---	---	0.5 – 1.0
SiO_2	0.2 – 1.5	---	---

Class (I) is used in chemical industries, **Class (II)** for white cement and **Class (III)** for Portland cement, limestone could be used also as marble alternative, in some locations due to its physical properties and appearance.

Limestones for chemical, White and Portland cement industries were found in southwest of Busaiya area within Dammam Formation, Shawiya and Chabd Units. Those of Shawiya Unit range in thickness between (5 – 15) m are gray, bedded, massive, hard and nummulitic, alternating with white chalky limestone; exposed on the surface (without overburden). While, those of Chabd Unit has thickness about (10 – 11) m, they are grayish white, fossiliferous limestone alternating with dolomitic limestone and without overburden. Limestone is also found at the upper part of Zahra Formation; it is (1 – 1.5) m thick, massive, recrystallized limestone. The results of chemical analyses are shown in Table (3).

Table 3: Chemical analyses of limestones from Dammam Formation (Shawiya and Chabd Units) and Zahra Formation, southwest of Busaiya (Al-Sharbati and Ma'ala, 1983)

Component (%)	**Dammam Formation**		**Zahra Formation**
	Shawiya Unit	**Chabd Unit**	
CaO	54.26 – 55.86	54.61 – 55.24	48.25 – 55.04
MgO	0.22 – 1.11	0.31 – 0.38	0.28 – 0.69
Al_2O_3	0.05 – 0.85	0.04 – 0.94	0.08 – 1.65
Fe_2O_3	0.04 – 0.14	0.04 – 0.08	0.04 – 0.28
$SO_3^=$	< 0.07 – 0.21	< 0.07 – 0.1	< 0.07 – 0.33
L.O.I	43.2 – 44.58	43.10 – 43.57	38.89 – 43.39
I.R.	0.21 – 1.01	0.2 – 1.16	0.54 – 11.03

Note: The samples with high I.R. are not suitable for cement industry

The high quality limestones mentioned in Table (2) were found in south of Wagsa, Safawi, Takhadid, Tar Al-Leefiyah and Tar Al-Mafak areas (Fig.1), within the Upper Chalky Unit of Umm Er Radhuma Formation. They are about 12 m thick, well bedded, chalky limestone, hard to fairly hard, suitable for white cement industry due to their chemical composition:

CaO % = 54.56 – 55.89

MgO % = 0.45 – 0.64

I.R. % = 1.29 – 1.33

Overburden thickness = (0 – 2.0) m

Limestone is also exposed in Tar Anz Al-Ghurah to Al-Salman area (Fig.1) within Shawiya Unit of Dammam Formation, its thickness range from (4.0 – 25) m. It is found in the northeastern part of the area and gradually thinning and wedging out towards the southeastern part. It is suitable for white cement industry (Table 4).

The limestone of Upper Huweimi Unit of Dammam Formation is exposed near Al-Salman town to Takhadid vicinity (Fig.1) with thickness of (1.5 – 5.0) m; it is thickly bedded and massive, yellowish gray, crystallized, fossiliferous and dolomitic limestone, with nummulitic limestone. The upper bed is yellowish creamy and chalky limestone with chert nodules. It is overlain by Shawiya Unit, characterized by good grade in Al-Salman area and becomes relatively of lower grade near Takhadid Water Well (Fig.1) (Table 5) (Al-Mubarak and Amin, 1983).

In Wadi Al-Khir, Wadi Rahimawi, Hammam Zubaida, west of Ash-Shanafiyah town, Kharaz village and Umm Al-Hashim (Fig.1), the limestones belong to Lower, Middle and Upper Members of Euphrates Formation. Their thickness ranges from (5 – 15) m; thinly bedded, recrystallized limestone. The chemical composition is shown in Table (6) (Al-Mubarak and Amin, 1983).

In South of Samawa area, the limestones belong to Chabd Unit of Dammam Formation, Upper Member of Euphrates Formation and Ghar format. Chabd Unit has thickness of (2.5 – 3.0) m; it is greenish and whitish gray, massive, sugary and highly recrystallized. The Euphrates limestone is in the Upper Member, with thickness about 6 m; composed of shelly limestone and coquina interbeds. While, that of Ghar Formation is about 5 m thick, greenish gray massive sandy marly limestone (Table 7)

In north of Busaiya, the limestone belongs to the Upper Member of Euphrates Formation with a thickness of about (0.7 – 1.5) m, composed of fossiliferous limestone. It is also present in the Nfayil Formation with a thickness of (1 – 1.5) m, composed of thickly bedded, whitish grey, fossiliferous limestone, interbeds with thin layer of claystone and sandstone with overburden of about 0.5 m of sand sheet (Table 8).

In northwest of Busaiya, the limestone belongs to Shawiya Unit of Dammam Formation with a thickness of 15 m; of light grey, bedded and massive, hard nummulitic limestone, alternating with white chalky limestone. In Chabd Unit of Dammam Formation, the limestone exists in the lower part with thickness of (10 – 11) m, grayish white, fossiliferous limestone; alternating with dolomitic limestone. Limestone is also present in the upper part of Zahra Formation, with thickness of (1 – 1.5) m, composed of massive recrystallized limestone, without overburden.

In Al-Salman vicinity, the limestones of Shawiya and Chabd Units of Dammam Formation were studied for their suitability as marble alternative; in ten locations of Shawiya Unit exposures, near Al-Salman Town were found suitable (Arteen and Abdul Ameer, 2001)

Table 4: Chemical analysis of limestones of Dammam Formation (Shawiya Unit), Southern Desert (Al-Mubarak and Amin, 1983)

Locality	Sample No.	Thick. (m)	CaO	MgO	Al_2O_3	Fe_2O_3	$SO_3^=$	Cl^-	P_2O_5	K_2O	Na_2O	I.R.	L.O.I.
			(%)										
Tar Anz Al-Ghurah North Tel Abruq	6	10.0	53.03	0.03	0.06	0.06	0.07	0.09	0.12	0.01	0.04	1.64	42.5
North of Tel Abruq	7	18.5	54.74	0.34	0.09	0.55	0.07	0.05	0.04	0.01	0.03	1.9	43.5
Southeast Tel Abruq	2	7.0	54.5	0.35	0.11	0.14	0.07	0.03	0.09	0.07	0.03	0.84	43.6
Wadi Hussab area	3	7.0	54.0	0.23	0.14	0.11	0.07	0.02	0.09	0.09	0.02	2.1	42.5
Umm Al-Sanel, Shbicha area	9	12.5	54.2	0.4	0.12	0.05	0.07	0.02	0.05	0.01	0.05	1.43	42.89
Umm Al-Sanel, Shbicha area	12	7.5	55.2	0.45	0.07	0.04	0.07	0.03	0.03	0.04	1.05	1.05	42.8
Faidat Al-Ajuz	3	4.5	53.4	0.52	0.15	0.1	0.07	0.05	0.02	0.03	0.08	3.3	43.0

Note: The locations in the table are shown in Fig. (1)

Table 5: Chemical analysis of limestones of Dammam Formation (Upper part of Upper Huweimi Unit), Southern Desert (Al-Mubarak and Amin, 1983)

Locality	Thick. (m)	CaO	MgO	Al_2O_3	Fe_2O_3	$SO_3^=$	Cl^-	P_2O_5	K_2O	Na_2O	I.R.	L.O.I.
		(%)										
SE Takhadid water wells (Section 1)	1.5	53.2	1.2	0.07	0.07	0.07	0.85	0.05	0.03	0.06	1.66	43.47
SE Takhadid water wells (Section 2)	3.5	51.5	2.35	0.05	0.08	0.04	0.05	0.07	0.01	0.01	1.2	43.42
Al-Salman Area	5	55.0	0.33	0.06	0.05	0.07	0.02	0.01	0.01	0.05	0.5	43.36

Note: The locations in the table are shown in Fig. (1)

Table 6: Chemical analysis of limestones of Euphrates Formation
(Al-Mubarak and Amin, 1983)

Locality	Sample No.	Thick. (m)	CaO	MgO	Al_2O_3	Fe_2O_3	$SO_3^=$	Cl^-	P_2O_5	K_2O	Na_2O	I.R.	L.O.I.
			(%)										
North of Wadi Abu Khamssat	11	15.0	54.37	0.31	0.14	0.18	0.19	0.08	0.03	0.04	0.07	1.2	42.8
Wadi Rahimawi	4	4.0	53.0	0.38	0.18	0.20	0.95	0.04	0.02	0.05	0.03	3.37	41.67
West of Rahimawi	9	10	53.8	0.67	0.2	0.21	0.59	0.06	0.04	0.02	0.05	1.9	42.4
Hamam Zubaida	10	5.0	54.96	0.2	0.08	0.04	0.07	0.01	0.01	0.01	0.06	0.98	43.3
West Ash Shanafiyah Town	7	7.0	53.14	0.62	0.34	0.18	1.16	0.02	0.01	0.45	0.06	1.8	42.0
West of Mugatha water wells	2	9	52.0	0.45	0.16	0.1	0.2	0.01	0.01	0.1	0.05	4.9	41.48
Wadi Umm El-Jelood	5	5	53.42	0.47	0.10	0.08	0.23	0.04	0.01	0.03	0.06	2.3	42.16
South of Al-Kharaz Village	2	---	52.25	0.42	0.15	0.11	0.07	0.01	0.01	0.03	0.06	3.5	42.0
Faidat Umm Al-Hashim	2	---	54.0	0.55	0.14	0.08	0.3	0.02	0.01	0.07	0.02	1.4	43.5

Note: The locations in the table are shown in Fig. (1)

Table 7: Chemical analysis of limestones of Euphrates and Ghar formations,
south of Samawa (Al-Ani and Ma'ala1983a)

Component (%)	Euphrates Fn.	Ghar Fn.
CaO	51.03 – 54.51	50.75 – 54.27
MgO	0.042 – 0.78	0.59 – 0.94
$SO_3^=$	< 0.07 – 1.0	0.24 – 0.66
I.R.	1.2 – 4.4	1.3 – 4.9

Table 8: Chemical analysis of limestones of Nfayil Formation, north of Busaiya area (Al-Ani and Ma'ala, 1983b)

Component	Average Concentration (%)
SiO_2	9.05
CaO	48.94
MgO	0.73
Al_2O_3	0.55
$SO_3^=$	0.07
Fe_2O_3	0.36

- **Dolomite**

Dolomite deposits belong stratigraphically to Wagsa**,** Sharaf and Shbicha – Lower Huweimi and Upper Huweimi Units of Dammam Formation (Al-Mubarak and Amin, 1983). They are found in South of Samawa (Khadary Area) (El-Koomy, 1982) (Fig.1). The dolomite in this area is white to dark brown, moderately hard. The deposit is formed by the dolomitization and recrystallization of the Middle Member of Dammam Formation carbonate. The reserve of the deposit on C_1 category is 188 287 612 ton. The average percentage of the chemical composition is shown in Table (12) (El-Koomy, 1981). The dolomite deposits and occurrences, based on the chemical analysis, were found to be suitable for chemical, steel, metallurgy and glass industries, according to the mentioned specifications by Lang (1976) in Al-Mubarak and Amin (1983) for the aforementioned industries (Tables 9, 10 and 11).

Table 9: Specifications of dolomite suitable for steel industry (after Lang, 1976 in Al-Mubarak and Amin, 1983)

Component (%)	USSR Standard	
	Grade I	Grade II
MgO	19.0	17.0
SiO_2	3.5	6.0
$Al_2O_3 + Fe_2O_3 + Mn_3O_4$	4.0	5.0

Table 10: Specifications of dolomite for metallurgical industry (after Lang, 1976 in Al-Mubarak and Amin, 1983)

Component (%)	Grade			
	I	II	III	IV
MgO (min.)	20.5	19.0	17.5	15
CaO (max.)	28.0	31.5	35.0	---
SiO_2 (max.)	1.5	2.5	3.5	3.5
Al_2O_3 (max.)	1.0	1.5	2.5	3.0
$SO_3^=$ (max.)	0.5	7.0	7.5	---
Moisture (max.)	2.0	4.0	6.0	7.0

Table 11: Specifications of dolomite for glass industry
(after Lang, 1979 in Al-Mubarak and Amin, 1983)

Component (%)	Grade				Hungarian Standard
	I	II	III	IV	
MgO (min.)	20.5	19.0	17.5	15.0	17.7
CaO (max.)	28.0	31.5	35.0	39.0	36.0
I.R. (max.)	1.0	2.0	5.0	7.0	---
$Al_2O_3 + Fe_2O_3$	0.3	1.0	2.0	3.0	0.2
Fe_2O_3	0.05	0.1	0.5	0.8	---
$SO_3^{=}$ (max.)	0.5	1.0	1.5	---	---
Moisture (max.)	2.0	1.0	---	---	---
L.O.I	45.0	42.0	40.0	---	---

Table 12: Average percentages of chemical composition of dolomite, in Khadary Area
(after Lang, 1979 in Al-Mubarak and Amin, 1983)

Component	Concentration (%)
MgO	20.4
CaO	29.76
I.R.	2.08
Al_2O_3	0.26
Fe_2O_3	0.15
$SO_3^{=}$	0.28
Na_2O	0.35
K_2O	0.2
L.O.I.	45.0
Cl^{-}	0.03

- **Dolomitic limestone**

Dolomitic limestone is found in many parts of the Southern Desert. Its occurrences are in South of Samawa and north, northwest, south, southwest of Busaiya (Fig.2). It belongs to Dammam Formation (Top of Chabd Unit and top of Ghanimi Unit) and Ghar Formation. Dolomitic limestone is suitable for road construction and as building material.

Dolomitic limestone suitable for road construction is present in three locations south of Samawa and belongs to the top of Chabd Unit of Dammam Formation. In the first locality, it bedded with a thickness of (1.5 – 3) m, exposed on the surface. In the second locality, it also bedded with a thickness of (3 – 5) m and an overburden of (5 – 7) m. In the third locality, it is 5 m thick, massive, very hard, finely recrystallized, with chert nodules, the overburden is about 3m thick; belongs to Zahra Formation. It is also present in north of Busaiya at the top of Ghanimi Unit of Dammam Formation and the lower part of Ghar Formation. The former forms surface exposures of thickly bedded, very hard and non-porous, whereas, the later is about (1 – 7) m thick and massive, with no overburden. In northwest of Busaiya, the dolomitic limestone is suitable for road construction; it is found at the top of Ghanimi Unit of Dammam Formation as a surface exposure, thickly bedded, very hard and non-porous. In south Busaiya, it is found in the lower part of Ghar Formation as thick, massive, very hard, and non-porous dolomitic limestone with a thickness of 6 m.

In southwest of Busaiya, it is found as surface exposures of thickly bedded, very hard and non-porous dolomitic limestone; belongs to the top of Ghanimi Unit. It is also found at the upper part of Ghar Formation with a thickness of (2 – 6) m, massive with chert nodules and without overburden.

The dolomitic limestone useful for building material is found in south of Samawa, as well bedded and hard with thickness of 15 m, and belongs to Radhuma – Barbak Unit of Dammam Formation. In north, northwest and southwest of Busaiya (Fig.1), it has been found at the top of Radhuma – Barbak Unit and the base of Ghanimi Unit of Dammam Formation, as surface exposures, thickly bedded. While, in south of Busaiya it belongs to the lower part of Ghar Formation, as thickly bedded and massive, very hard and non-porous with a thickness of 6 m.

- **Sand and Sandstone**

Sands and sandstones are mainly found north, south and southwest of Busaiya (Fig.1), at the base of Dibdibba Formation and the upper part of Ghar Formation. They are mainly poorly sorted; the grains of the sandstone are silicates cemented by calcareous materials. They are useful for building purposes and thermostone blocks manufacturing.

In north Busaiya, the sandstone is found in the base of Dibdibba Formation as coarse and fine grained quartz, cemented by calcite. In south Busaiya it is about 80 m thick, belongs to Dibdibba Formation, unconsolidated, poorly sorted sand useful for thermostone blocks manufacturing. In the same area, the sandstone is found at the upper part of Ghar Formation as massive, partly consolidated, fine grained, calcareous sandstone with a thickness of (6 – 12) m without overburden; useful for thermostone blocks manufacturing. Sands in this area are present as loose sand accumulated within deflation depressions as a result of desert wind action. These depressions cover areas about (1 – 20) Km^2. The average thickness of the sand sheets in depressions varies from few centimeters up to 1 m; this sand could be used for building purposes.

In southwest Busaiya the sandstone is found at the base of Dibdibba Formation as coarse grained quartz, cemented by calcareous material, which increases with gypsiferous materials upward (Al-Sharbati and Ma'ala, 1983a). The chemical analysis of the Dibdibba sandstone, which is cemented by calcareous materials, is:

$$SiO_2\,\% = 61.65;\ CaO\,\% = 14.44;\ Al_2O_3\,\% = 3.26$$

- **Clays and Claystones**

Clays were recorded to be present in Quaternary sediments in many areas called as "faidhat" in the Southern Desert. They are present in south of Samawa, north and southwest of Busaiya. The chemical analysis of the recent clays from faidhat and dry lakes are shown in Table (13). Clay suitable for cement industry is present in faidhat south of Samawa and north of Busaiya; it is reddish brown, loose and calcareous with a thickness of less than 1.5 m.

The claystone was found in the upper part of Nfayil Formation that is exposed in north of Busaiya. It is massive and accompanied by sandstone. The chemical analysis is shown in Table (14). It is worth mentioning that the author during the field work in Al-Sahan area, in 1987 collected a claystone sample, the XRD examination showed it is composed of about 98% palygorskite. This sample was taken from a claystone bed that belongs to Zahra Formation, overlying the phosphate bed of Umm Er Radhuma Formation. The thickness of the claystone bed is more than 5 m.

▪ **Salt**

Salt is found in the Southern Desert filling the "Memlaha" Depression. The presence of salt (Al-Samawa Saltren) depends on the natural dissolution of the rock salt that is mixed with clays by the rain water and the runoff water, which drain to the saltren depression via an ephemeral stream. Artificially, water is pumped from boreholes drilled in the Dammam Formation into the playa sediments. The brine is pumped to a number of artificial basins for solar evaporation leading to the precipitation of salt, then is harvested. The estimated reserve of salt in Al-Samawa saltren is about 53 690 981 Ton (Al-Badri *et al.*, 1985). The chemical analysis of the washed salt extracted from Samawa Saltren is:

NaCl = 97% (min.); Mg^{+2} = 0.2% (max.); I.R. = 1% (max.); Moisture = 5% (max.)

Salt is also thought to be present in the south west of Basra in Jabal Sanam; it is deduced from geophysical evidences as a salt plug (Al-Sharbati and Ma'ala, 1983b; Buddy, 1980; Jassim and Buday in Jassim and Goff, 2006) this postulation has not proved yet.

Table 13: Chemical analysis of the recent clays from dry lakes in the Southern Desert

Component	Concentration (%)		
	Shaikhiya dry lake	Salhubiya dry lake	North of Busaiya
SiO_2	40.8	41.52	---
Fe_2O_3	4.8	4.4	2.17 – 5.23
Al_2O_3	8.45	8.12	4.3 – 10
CaO	17.88	18.45	---
MgO	4.95	4.6	---
$SO_3^{=}$	---	---	0.0 – 3.7
L.O.I	18.66	18.86	-
K_2O	1.3	1.14	1.2 – 1.9
Na_2O	0.8	0.85	---
Cl^{-}	0.03	0.07	---
Mineral content	Calcite, Quartz, Dolomite, Palygorskite, Kaolinite, Montmorillonite, Chlorite, Illite and Mica		

Note: The locations in the table are shown in Fig. (1)

Table 14: Chemical and mineralogical analysis of claystones from Nfayil Formation in Busaiya area

Component	Concentration (%)
SiO_2	42.96 – 47.27
Al_2O_3	10.82 – 10.92
Fe_2O_3	4.86 – 8.83
CaO	4.41 – 5.11
MgO	6.89 – 10.81
Na_2O	1.03 – 1.63
K_2O	2.67 – 2.69
$SO_3^{=}$	0.11 – 0.38
Mineral content (from XRD analysis)	Dolomite, Palygorskite and Kaolinite

▪ **Phosphate**

Phosphate deposit in the western part of the Southern Desert represents the southern boundary of the Tethyan phosphogenic province (Mohammad and Jassim, 1990). It is marine sedimentary deposit, found at the upper part of Umm Er Radhuma Formation. This phosphate exposure extends from Al-Sahan area, along Wadi Al-Khir, eastwards till the midway between Al-Sahan and Shbicha. The phosphate, in this area is the extension of that in Al-Nukhaib area. Its thickness is about 0.5 m, overlain by phosphatic chert and ocher mudstone beds (Jassim *et al*., 1987and Mohammad and Jassim, 1990). It is represented by phosphatic facies, includes P_2O_5 of (4.47 – 13.0) wt.%. The phosphate contains bone, coprolite and shark teeth, it is silicified in the upper part.

▪ **Sulphur**

Sulphur is present only in Al-Kibritiya sink holes, southwest of Shbicha (Fig.1). The sulphur was observed in the sinkholes with an emission of hydrogen sulphide gas (H_2S) and was previously exploited by the local people. It has been thought to be formed as a result of early diagenetic processes of the underlain gypsum rocks, which probably belong to Rus Formation, where the gypsum bed is affected chemically and replaced partly or totally by sulphur mineral (Al-Mubarak and Amin, 1988). It is well known that gypsum converts to calcite and sulphur librating CO_2 and H_2S when are in contact with hydrocarbons and water in the presence of sulphate-reducing bacteria (Bates, 1969); therefore most probably the gypsum of Rus Formation had been in contact with the escaping gas from oil structure beneath, through fractures and weakness zones.

CONCLUSIONS

The followings could be concluded from the available data in the Southern Desert, concerning the raw materials, industrial rocks and other deposits:

- The Southern Desert lacks metallic ore deposits.
- Presence of good reserves of limestones suitable for chemical, White cement, Portland cement industries and marble alternatives.
- Presence of good reserves of dolomites suitable for chemical, steel, metallurgy and glass industries.
- The present dolomitic limestone is suitable for road construction and as building materials.
- The present clays and claystones are suitable for cement industry.
- High purity attapulgite was reported to be present in the claystone beds of Zahra Formation.
- The present sandstone and gravel are suitable for building purposes.
- Phosphate was found at the western part of the Southern Desert, representing the southern boundary of the Tethyan Phosphorite Belt.
- The origin of salt in Al-Samawa Saltren is thought to be the groundwater rich in sodium chloride salts migrated through faults and redeposited in the sediments filling the saltren depression.
- Sulphur is present only in Al-Kibritiya sinkhole, southwest of Shbicha; most probably it was formed by the contact of gypsum of Rus Formation, in the presence of water and sulphate-reducing bacteria, with the escaping gas from oil structure beneath, through fractures and faults.

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