MINERAL RESOURCES OF THE HIGH FOLDED ZONE

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ABSTRACT

The High Folded Zone is one the main Metallogenic Zones in Iraq; it is rich in non-metallic deposits and industrial rocks. All the mineral deposits in this zone are sedimentary in origin including marine and continental sediments. They range in age from Triassic to Pleistocene, occurring mostly as bedded thick sedimentary strata deposits. Previous work in the area indicates that all of these economic deposits are building raw materials such as limestone, gypsum, clays, sand, gravels and orthomarble. The formation of the mineral deposits and industrial rocks in the High Folded Zone was controlled by paleogeographic, tectonic and structural factors.

This study gives the type, location, specification, reserves of the main mineral, industrial rock deposits, and their chemical composition. These mineral deposits provide a very promising potential for future development of the region.

الموارد المعدنية لنطاق الطيات العالية

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المستخلص

يعتبر نطاق الطيات العالية من الأنطقة التمعدنية الرئيسية في العراق ويتميز بكونه غني بالرواسب المعدنية غير الفلزية والصخور الصناعية. أن جميع هذه الترسبات ذات أصل رسوبي بما في ذلك الرواسب البحرية والقارية. يتراوح عمر هذه الترسبات من الترياسي الى البلايستوسين وتظهر على شكل رواسب متطبقة سميكة. أظهرت الأعمال السابقة في المنطقة أن معظم هذه المواد هي رواسب اقتصادية وتستخدم لأغراض البناء مثل رواسب الحجر الجيري والجبس والأطيان والرمال والحصى بالإضافة الى المرمر ذو الأصل الرسوبي. إن تكوين هذه الترسبات المعدنية والصخور الصناعية في منطقة نطاق الطيات العالية تحكمت بها عوامل الجغرافيا القديمة والبنيوية والتركيبة.

في هذه الدراسة، تم عرض نوع وموقع والمواصفات بالإضافة الى الاحتياطي لكل من هذه الترسبات المعدنية، إضافة الى التحليل الكيميائي لها. إن الترسبات المعدنية تتيح إمكانيات واسعة ومشجعة من ناحية تطوير هذه المنطقة وتقدمها في المستقبل.

INTRODUCTION

▪ General Geology

This work is a review of Iraq Geological Survey works during the last decades on the area known physiographically as, the High Folded Zone. It covers most of the Iraqi Kurdistan Region and lies on the Turkish border in the NW and Darbandi Khan – Halabja area near the Iranian border in the SE. It is considered as one of the main Metallogenic Zones in Iraq (Al-Bassam, 2007). The width of the zone varies from (25 – 50) Km. Tectonically it was uplifted in the Cretaceous and Paleogene Periods, and strongly deformed in the Late Neogene. The zone was the marginal part of the Paleogene Mollase Basin (Jassim and Goff, 2006). According to the Geological map of the area (Sissakian and Fouad, 2012) (Fig.1). Mesozoic

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Limeston represent the core of the main folds in the region, usually of pre Late Cretaceous age, with Paleogene and Neogene limestones and clastics on the limbs of the folds. In north Iraq, the north boundary of the zone is the Imbricate Zone. In NE Iraq, the boundary is more complex and runs from Amadiya to the area west of Rawandooz, to the SE passing through Qalat Dizah, and then to Sirwan gorge on the Iranian border. The anticlines of the High Folded Zone generally trend NW – SE in NE Iraq and E – W in the north and northwest of Iraq.

The High Folded Zone has a basement depth of about 8 Km, while in the neighboring Low Folded Zone, the depth is 13 Km. The sedimentary cover of the High Folded Zone comprises a possible Infracambrian section, (Paleozoic 1500 – 5000 m), Triassic (200 – 500 m), Jurassic (1100 m) Early Cretaceous (250 – 1200 m), Late Cretaceous (800 m) and Paleogene (1000 – 1500 m) (Jassim and Goff, 2006).

Neogene sediments occur only locally in the trough of some synclines. The High Folded Zone is separated by narrow deep synclines; the structures are mostly asymmetrical, with steep SW or S limbs with reverse faults. Narrow synclines are characteristic features of the High Folded Zone. The amplitude of the anticlines exceeds 2000 m a.s.l. in most of the high structures.

The elevated tectonic structures presented by asymmetrical anticlines and synclines, which are built by Cretaceous and Early Tertiary sediments. The structural units gradually pass into Imbricate Zone in which the same geological formations are found but the latter are more strongly folded and thrusted.

The studied mineral deposits in this zone are limited to construction materials, mainly limestone for cement and as orthomarble for building. Dolomite was mentioned in different locations, but detailed works have not been carried out. Gypsum is also studied for cement as a retarder. Quaternary clays are used in cement industry to correct lime saturation. There are some efforts to use Pre Quaternary clay in bricks industry. Sand and gravel have limited distribution due to the mountainous relief and are very near to the source areas.

- **Previous Work**

Geologic work in Iraq have been executed in the High Folded Zone since the late fifties of the past century, carried out by many foreign companies including the Site Investigation Company to implements a program for metallic minerals, building material, ground water exploration and geological mapping of the north and northeast of Iraq . This program lasted until 1958. Mineral exploration was resumed from 1961 through contract with Soviet State Companies who mapped NE Iraq for metallic deposits.

Since the early seventies, GEOSURV Iraq took responsibility for regional and detailed geological survey for metallic and non-metallic material such as, industrial clays, limestone, gypsum, gravel, marble, and other raw materials. Exploration for raw material for cement industry started as early as the fifties of the past century (Leitch, 1954), and the work culminated in the seventies and eighties. Many occurrences of limestone have been documented during geological survey work in the study area (Jaber and Al-Ubaidi, 1973; Etabi and Ahmed, 1979; Mansour *et al*., 1979; Hafidh *et al*., 2008). Dolomite also was explored and few occurrences were mentioned (Smidth and Comp, 1952; McCarty, 1956; Mansour, 1976 and Taufiq and Domas, 1977), beside that many occurrences of orthomarble have been documented in the area (Mansour *et al*., 1979) and for Zebra Type marble (Al-Ani *et al*., 1991). Gravel and sand, which are used as construction material, were explored and

many localities were mentioned especially in Dohuk and Sulaimaniyah Governorates (Al-Hussain, 1979 and Younan, 1980). Gypsum, another construction raw material, was explored in the Fatha deposits (Taufiq and Domas, 1977; Touni, 1979 and Mansour *et al*., 1979). GEOSURV geologist studied Clay's deposits exploration for cement and brick industry in the seventies and early eighties of the past century to meet the construction demands of the area (Toma and Butris, 1978 and Nadir, 1981).

SPECIFICATION OF THE MINERAL RESOURCES

Mineral resource can be defined as a concentration or occurrence of material of economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction (ECE, 2009). The following industrial rocks and mineral recourses occur in the High Folded Zone.

▪ Limestone

The uses of limestone are numerous and according to their chemical and physical properties, can be used in various branches of industry (cement, chemical, glass, metallurgy, lime, fillers, etc.) and as building materials.

Northern Iraq is very rich in carbonate – bearing formations, their geological age ranges from Paleozoic to Neogene. Paleozoic age, Harur and Chia Zairi limestone formations to which Carboniferous and Permian age is ascribed. Mirga Mir (Early Triassic) Gelikhana (Middle Triassic) and Kurra china formations (Late Triassic) represent Triassic limestone (Mansour *et al*., 1979).

Jurassic formations crop out in the High Folded Zone, especially within Amadiya Area between Rawandooz and Ranya and east of Sulaimaniyah. Several formations in this zone enclose thin limestone beds such as Naokelekan and Barsarin (Fig.1).

The largest limestone reserves are found in continuous belt of Cretaceous formations extending from Halabcha to Amadiya. There are three main limestones formations; namely Balambo, Qamchuqa, Bekhme – Aqra formations. Their individual thickness varies greatly and may locally reach 900 m as in Balambo Formation (Mansour *et al*., 1979). Similarly are limestone formations of Paleogene age, which are widely distributed. They extend from Halabcha Northwestward to Koisangaq, Ain Sifni, Amadiya and reach the Syrian border in Dohuk area. The principal limestone bearing units are Pilas Spi, Sinjar, Khurmala, Shiranish, Bekhme – Aqra, Kometan, Qamchuqa, Balambo, and Jurassic formations. Limestone reserves are enormous, but many of their sequences were extensively affected by dolomitization.

As shown above, the High Folded Zone is rich in limestone – bearing formations, but the quality of the limestone varies from one formation to other and even within the same formation from one place to other (Mansour *et al*., 1979). Some limestones are highly affected by dolomization process; the resultant high grade dolomite, though of economic value, but are much less in demand than the high-grade limestone. Clayey limestone represents a valuable raw material for cement industry. Thinly bedded limestone enables it to be quarried in blocks and can be used as construction material. Only part of the northeast area has been explored in detail. There is vast area especially between Zakho and Halabcha have not been mapped yet as the other parts of Iraq. The missing information can and will be presented only after all remaining territory of the High Folded Zone is covered by adequate geological mapping. The main studied areas of limestone deposits are:

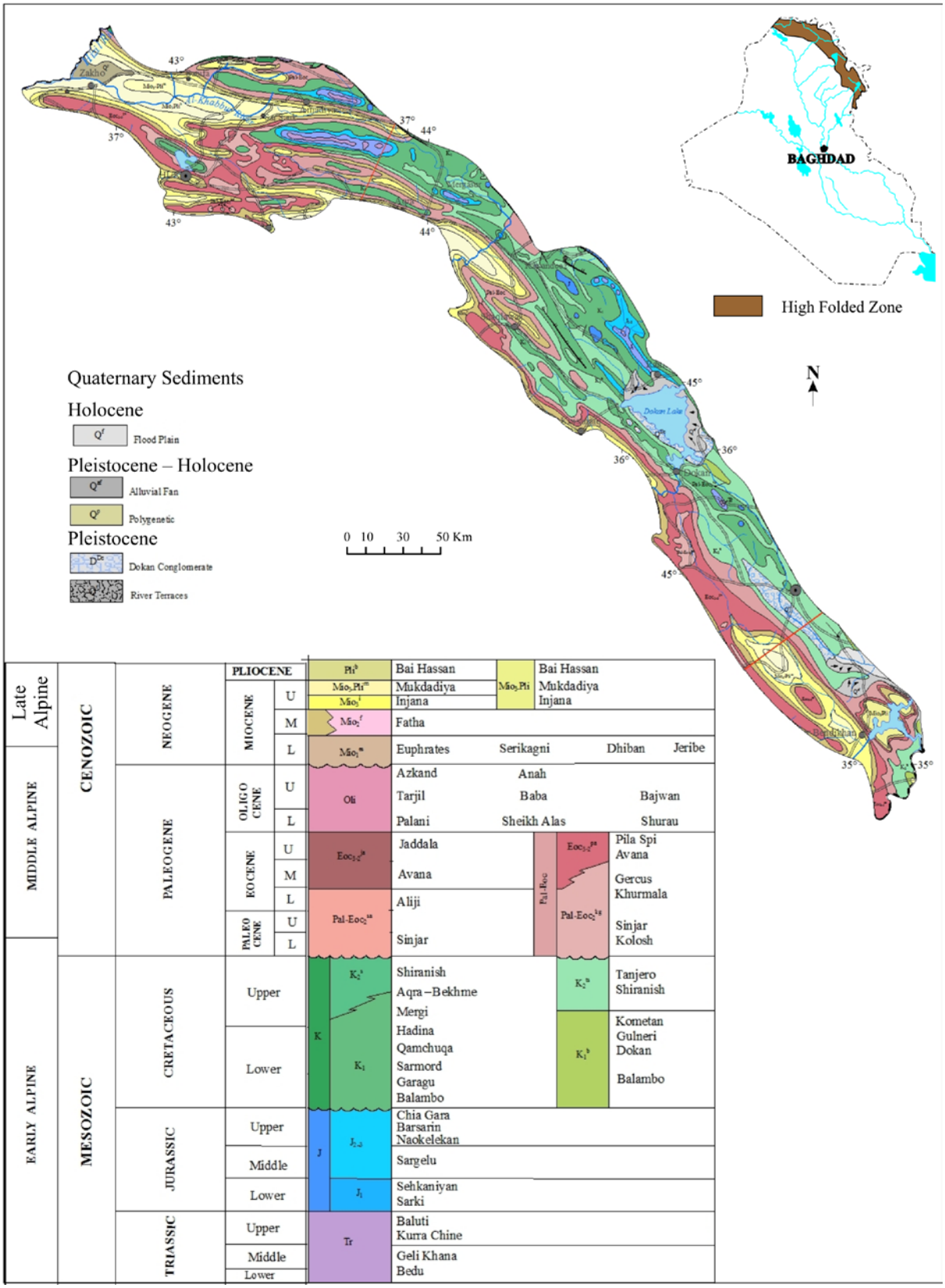

Fig.1: Geological Map of the High Folded Zone (Sissakian, and Fouad 2012)

– Tasluja Limestone Deposit (Sulaimaniyah): The deposit belongs to Sinjar Formation of Paleocene – Eocene age (Fig.2). The reserve was estimated by about 70 million tons and can be enlarged if needed (Etabi and Ahmed, 1979). The deposit is situated about 32 Km west of Sulaimaniyah city (Fig.3). The average chemical composition (%) of the limestone is:

CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	SO_3
54.7	0.41	0.68	0.10	0.16	0.28

Fig.2: Limestone of Sinjar Formation

– Serchinar Limestone Deposit (Sulaimaniyah): It is located 10 Km NW of Sulaimaniyah city (Fig.3), and belongs to Balambo Formation (Cretaceous). The calculated reserve is about 20 million tons, and can be enlarged (Leitch, 1954). The average concentration of chemical composition(%) of the limestone is as follows:

CaO	MgO	SiO_2
47.6	0.6	11.0

– Kani Gena Limestone Deposit: It is situated about 20 Km W of Sulaimaniyah city (Fig.3), within Sinjar Formation (Paleocene – Eocene). The limestone is of high grade, low in silica and magnesia. The calculated reserve is about 56 million tons, (Jaber and Al-Ubaidi, 1973). The average chemical concentration composition (%) of the deposit is:

CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	SO_3
55.0	0.14	0.33	0.3	0.4	0.1

– Bazian Limestone Deposit (Sulaimaniyah): The limestone belongs to Sinjar Formation (Paleocene – Eocene) age. Six exposed sections were studied in the north and south of Wadi Al-Kabir; 1 Km apart (Fig.3). The geological reserve is estimated as 1073.6 million tons (Hafidh *et al*., 2008). The average chemical concentration composition (%) of the deposit is:

CaO	SiO_2	Fe_2O_3	Al_2O_3	MgO	I.R.	SO_3	L.O.I	Na_2O	K_2O	Cl
54.32	0.61	0.23	0.16	0.57	0.87	0.07	43.22	0.06	0.2	0.07

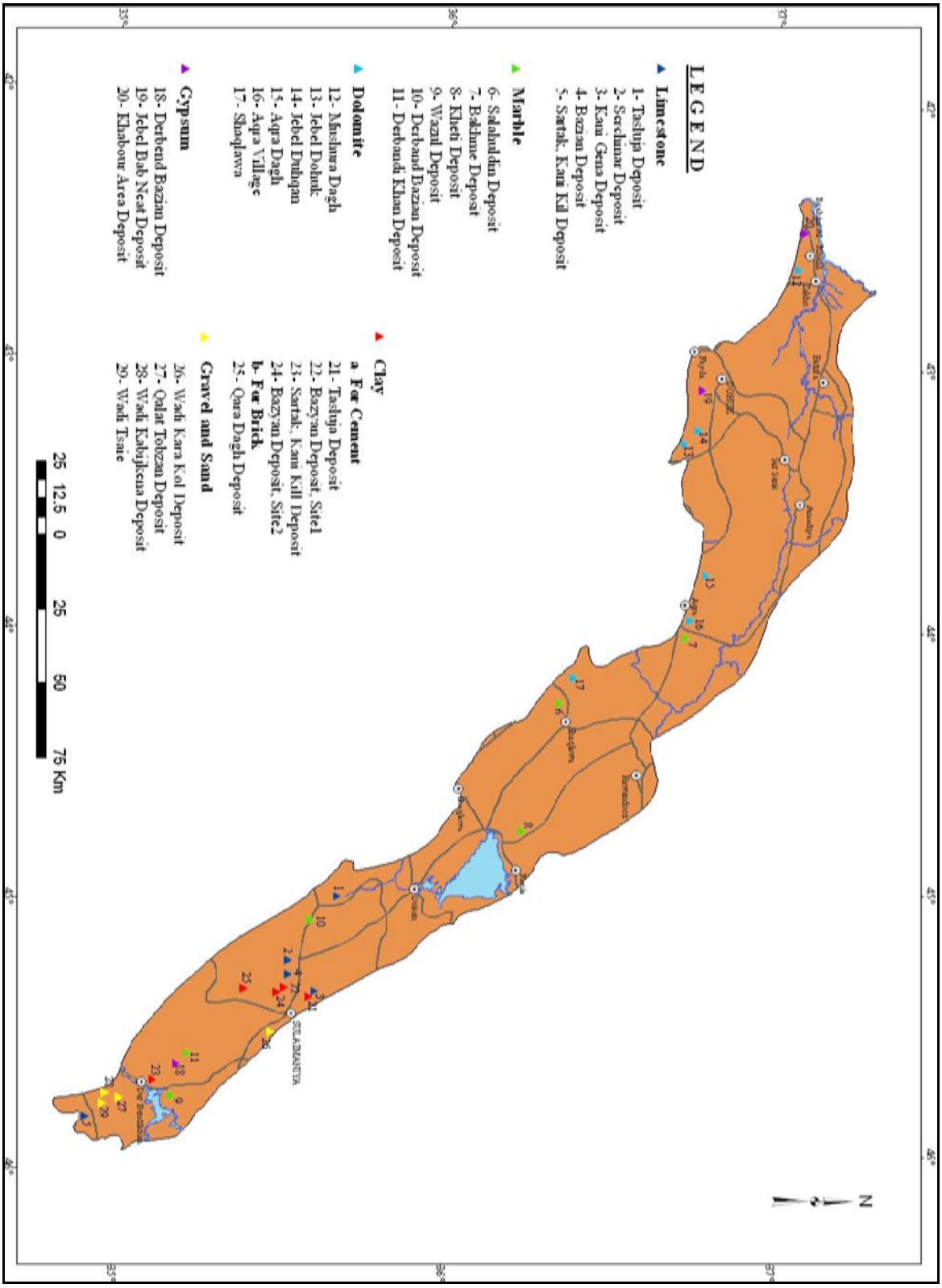

Fig.3: Location map of mineral deposits and industrial rocks in High Folded Zone

– Sartak and Kani Kel Limestone Deposit (Sulaimaniyah): It is located in the vicinity of Darbandi Khan in Sulaimaniyah Governorate (Fig.3). Seven exposed sections were studied, 1 Km apart, (Fig.4). The estimated geological reserve is 1433 million tons, with average thickness of 80 m (Hafidh *et al*., 2008). The average chemical concentration composition (%) is:

CaO	SiO_2	Fe_2O_3	Al_2O_3	MgO	I.R.	SO_3	L.O.I	Na_2O	K_2O	Cl
51.8	3.4	0.1	0.18	1.18	3.3	0.07	42.0	0.09	0.02	0.05

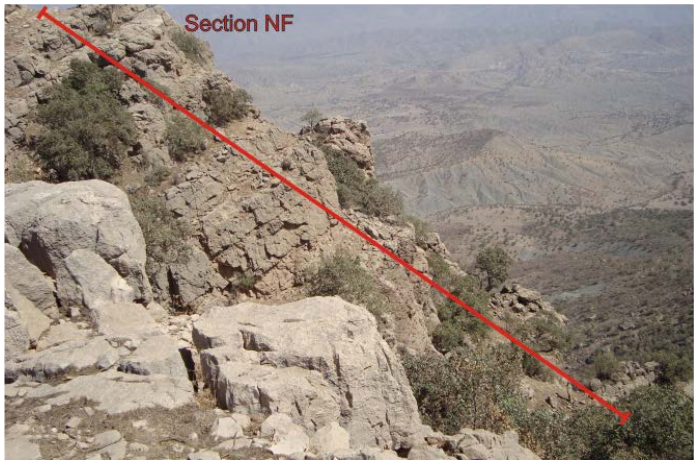

Fig.4: Geological section along Sinjar, Khurmala, and Pila Spi formations in Sartak and Kani Kel investigated areas

▪ **Marble**

The studies of recrystallized limestone show that they are susceptible to being polished, which allow for a broad interpretation of the word "Marble". Marble in this article is used for any calcareous or other rock of hardness, which can be readily polished for decorative purposes.

The recorded occurrences of marble in Iraq indicate considerable reserves and it would appear that great demand within Iraq could be met from local resources located mainly in NE parts of Erbil and Sulaimaniyah Governorates.

Carbonate rocks extensively build the northern part of Iraq and many localities were studied for possible use as ornamental stones. It seems that real marble is lacking in the High Folded Zone and few localities that have been found are of lower quality. Instead, there is the orthomarble and the main formations that include orthomarble are Pila Spi and Sinjar. The main localities that lie within the High Folded Zone are described hereinafter:

– Salahuldin Marble Deposit: This deposit is located in Kani Spilik valley, about 38 Km NE of Erbil city (Fig.3), it belongs to the Pila Spi Formation (Eocene) (Fig.1). There are two productive horizons; the upper one is 1.6 m thick and the lower horizon consists of crystallized dolomitic limestone of 3 m thick, and their color is mainly golden yellow; some time with violet veins. The reserve was estimated by about 6480 tons (Mansour *et al*., 1979).

– Bekhme Marble Deposit: It is located about 60 Km NNE of Erbil city on the NW bank of the Great Zab River (Fig.3). The deposit belongs to the Sinjar Formation (Paleocene –

Eocene). It is fine crystalline, fossiliferous, grey white limestone. The rock polishes well and occurs as a massive body. The industrial bed is about 30 m thick and extends about 7 Km to the SE of Bekhme village. The reserve of the rock available is huge (Mansour *et al*., 1979).

– Darbandi Bazian Marble Deposit: It lies about 65 Km east of Kirkuk city along the road to Sulaimaniyah city, Fig. (3). The deposits belong to the Pila Spi Formation, which is composed of dolomitic limestone, fine crystalline, yellowish to grey in color. The industrial bed is about 20 m thick. The presence of chert nodules limits the exploitation of the marble.

– Darbandi Khan Marble Deposit: It is located about 70 Km SE of Sulaimaniyah city (Fig.3). It belongs to the Pila Spi Formation. The thickness of the industrial bed is about 30 m; composed of white to purple color with red veins, tough, fine crystalline massive dolomitic limestone. The strata are dipping (60 – 70)° SW. The reserve was estimated to be several million tons (Mansour *et al*., 1979).

– Wazul Marble Deposit: It is situated about 15 Km east of the main road between Sulaimaniyah and Darbandi Khan towns (Fig.3). The deposits belong to the Pila Spi Formation and are composed of dolomitic limestone; the dip reaches 80° towards SW.

– Kheti Marble Deposit: This deposit consists of a succession of banded limestone beds, which are called "Zebra type" of black and white lamina with thickness of (2 – 3) cm and patches of black and white shapes and random brown and white patches, which become clear after polishing (Fig.5). It is located nearby Kheti village (Fig.6), in Erbil Governorate, 25 Km away from Rania town (Fig.3) The estimated reserve is about 158880 tons (Al-Ani *et al.*, 1991).

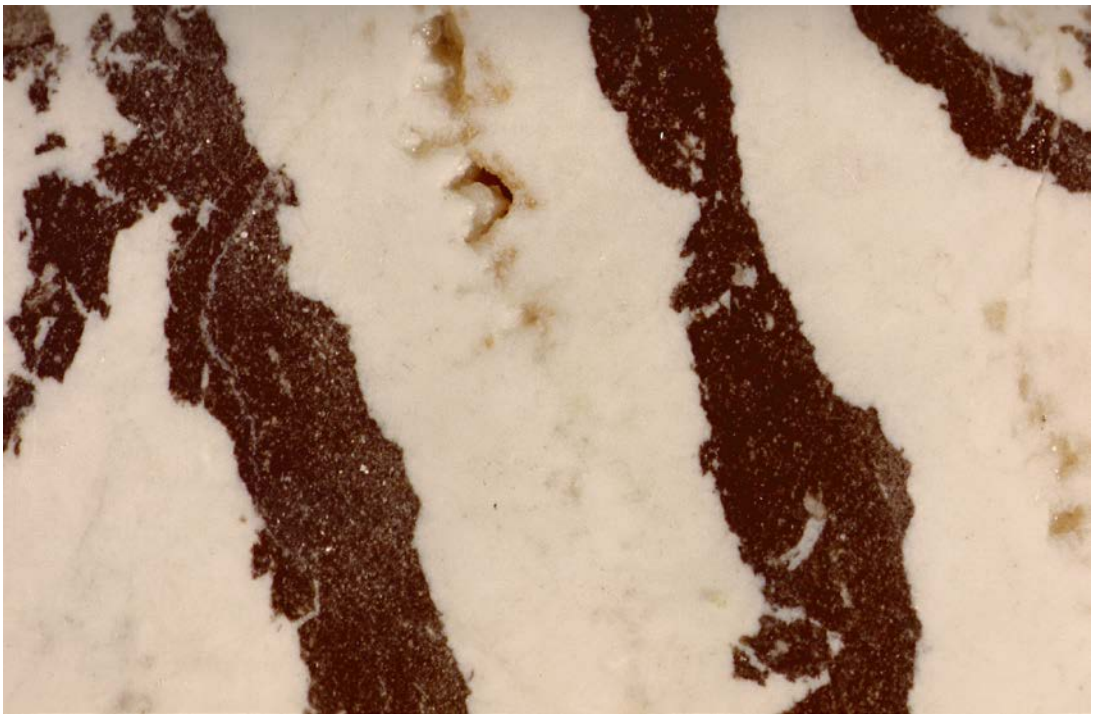

Fig.5: Orthomarble (zebra type limestone) after polishing in Kheti area

Fig.6: Limestone beds (Zebra type) near Kheti village, Erbil Governorate

▪ **Dolomite**

The main use of dolomite is as building stone as well as in metallurgy, glass industry, and refractory. From genetic point of view, dolomite deposits and occurrences most probably formed as result of secondary dolomitization of carbonate sediments in the course of the digenetic process.

No detail work was executed in the High Folded Zone concerning dolomite occurrences, although some reports gave few analysis in which it seems that some samples from the Euphrates Formation within Jebel Duhkan is the best one to look after, as shown in Table (1) (Smidth and Comp, 1952; McCarty, 1956; Mansour, 1976 and Taufiq and Domas, 1977).

Table 1: Concentration of dolomite rocks in different localities in the High Folded Zone

Map Sheet	Formation	Locality	MgO	CaO	Fe_2O_3	I.R	SO_3
			(%)				
J-38-S/NW	Avana	Mushura Dagh	16.63	35.33	0.08		1.49
J-38-T/NW	Pila Spi	Jebel Dohuk	19.01	32.92	0.15	0.46	
J-38-T/NW	Euphrates	Jebel DuhKan	20.57	30.66		0.82	0.11
J-38-T/SW	Aqra	Aqra Dagh	18.24	29.68			
J-38-T/NE	Aqra	Aqra Village	17.42	29.44			
J-38-U/SW	Pila Spi	Shaqlawa	19.00	28.38			

▪ **Gypsum**

Gypsum deposit within the High Folded Zone is represented by gypsum – anhydrite deposits, which are closely related with rocks of the Fatha Formation (Fig.1). Gypsum beds extend as belt from Bist (from SE – Darbandi Khan – Darbandi Bazian – Koisanjaq – Salahuldin – Aqra – Ain Sifni – Dohuk – Amadiya and near the Syrian border in Zakho and Dohuk area in NW). They appear as thin highly inclined gypsum strata (Mansour *et al*., 1979). The Gypsum quality varies from one place to another with lateral variation in thickness. Mining condition is unfavorable due to the high angle of dip with increasing of overburden within a short distance (Fig.7). The main studied localities are:

Fig.7: Gypsum Rocks within Fatha Formation

– Darbandi Bazian: The deposit is located 4 Km NW of Darbandi Bazian (Fig.3), within the Fatha Formation (Fig.1). Three gypsum horizons were recognized alternating with clay and limestone. The chemical composition (percent) of gypsum beds range as follows:

SO_3	CaO	MgO	$IR + R_2O_3$	H_2O
44.3 – 45.5	31.8 – 32.4	0.01 – 0.18	0.77 – 2.8	15.75 – 19.97

The calculated reserve of the gypsum is 9 million tons in categories C_1 and C_2 (Touni, 1979).

– Jebel Bab Neat Locality: It is a small anticline situated about 28 Km S – SE of Dohuk City (Fig.3). The deposit belongs to Fatha Formation. It consists of alternation of relatively thick gypsum bed with red clay and thin intercalations of limestone beds. Average dip of the beds is 10°. The reserve is small and can be used for the local need only. Two samples were analyzed; and their chemical composition (percent) is shown below (Taufiq and Domas, 1977):

SO_3	CaO	MgO	Al_2O_3	Fe_2O_3	L.O.I	I.R
46 – 56.24	32.8 – 39.7	*T – 0.61	T – 0.14	T – 0.01	20.4 – 20.5	0.12 – 0.16

*T = Trace

– Khabour Area: It is located on the western plunge of Bekhair anticline (Fig.3). The Fatha Formation crops out in the area with a maximum thickness reaching to 32 m, and the total gypsum deposit is 10.5 m thick, which includes 3 beds of (2 – 3) m each. Six samples were collected from northern flank and analyzed, their main chemical components (percent) ranges as follows:

SO_3	CaO	I.R	H_2O
43.09 – 45.41	30.94 – 32.51	1.9 – 2.57	17.83 – 18.71

The composition of gypsum in this locality is good for plaster (Juss) industry but it has limited extension and small reserve (Mansour *et al*., 1979).

▪ **Clays**

The main prospected deposits of clay are of Quaternary age, they have been deposited under fluvial environments, and they fill mainly relief depressions or settle as river deposits. Their main uses are as corrective material for Portland cement industry. The main studied deposits for cement industries are located near the cement factories in Sulaimaniyah Governorate; they are briefly described hereinafter.

– Clay For Cement: The following deposits are recorded.

– **Tasluja Clay Deposit:** This is Quaternary sediments, located 27 Km NW of Sulaimaniyah city (Fig.3). The clay is brown in color, and the thickness of the clay bed is about 3 m. The average chemical composition (percentage) of the clay is shown below.

SiO_2	CaO	MgO	Al_2O_3	Fe_2O_3	SO_3	Cl	$K_2O + Na_2O$
39.97	18.72	3.23	10.19	5.42	0.07	0.06	1.8

The calculated reserve of the clay is 30 million tons (Nadir, 1981).

– **Bazian clay Deposit:** This is a Quaternary clay located 30 Km W of Sulaimaniyah (Fig.3). The clay is brown in color, and the average thickness of the beds is (5 – 7) m, with chemical composition in percent is shown below:

SiO_2	CaO	MgO	Al_2O_3	Fe_2O_3	SO_3	Cl	Na_2O	K_2O	L.O.I.
36.8	21.0	3.1	9.5	4.7	0.19	0.03	0.1	0.5	20.5

The reserve was calculated to be about 31 million tons (Toma and Butris, 1978).

Another locality studied for clay deposit is in Bazian vicinity (Fig.3). The average thickness of the clay bed is 2 m, and can reach 10 m as noticed in nearby water well. The weighted average percentage of the main chemical compound is shown below

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	L.O.I.	Na_2O	K_2O
37.31	10.41	4.45	18.37	3.7	< 0.07	0.62	18.65	0.15	0.19

The estimated reserve is 7.2 million tons (Hafidh *et al*., 2008).

– **Sartak and Kani Kel Clay Deposit:** It is located in the vicinity of Darbandi Khan within Sulaimaniyah governorate (Fig.4). The average thickness of the claystone is 6 m (some localities reach 10 m, covering an area about four Km^2). The calculated reserve was found to be 57,600,000 tons (Hafidh *et al*., 2008). The weighted average percentages of the main chemical compounds are shown below.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl	L.O.I.
42.8	7.03	2.8	22.18	2.54	< 0.07	0.46	0.5	0.05	21.77

– **Qara Dagh Clay Deposit:** The claystone belongs to Injana Formation (Late Miocene) (Fig.8). The studied area is located near Alyawa village (Fig.3). Two samples were collected from the face of a clay bed. The average percentage chemical analysis is given below, and found suitable for brick industry:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Cl	O. M	L.O.I.
39.68	7.79	3.5	20.44	4.0	0.75	1.25	0.07	0.09	0.26	21.01

Thickness of the clay bed reaches 12 m. The first test on the clay failed to meet the Iraqi specification, then effort were made to find a proper treatments to raise specifications of the product of the brick by adding sand to the clay in ratios of 1:3, 1:4, 1:5 and homogenize after grinding and burning by 950 °C for two hours. The resulting products fulfilled the required specification concerning compressive strength, water absorption, and effloresce.

Fig.8: Clay Deposits within Injana Formation.

- **Gravel and Sand**

The gravel and sand are used mainly as construction materials. Most of the deposits mentioned in the High Folded Zone are alluvial valley filling of Quaternary age. The valley fill is usually a mixture of gravel and sand. Their distribution is very limited due to the mountainous relief of the largest part of the High Folded Zone.

The investigated gravel and sand deposits were mentioned by Younan (1980) within Sulaimaniyah Governorate. Four locations were investigated in the vicinity of Darbandi Khan Region; Wadi Kara Kol (31 Km SE of Sulaimaniyah), Qalat Tobzan (27 Km S of Darbandi Khan), Wadi Kabijkena (32 Km S of Darbandi Khan), and Wadi Tsaie (about 50 Km south of Darbandi Khan) (Fig.3).

The gravel of these deposits is about 70%, clay is around 1% and the rest is sand. The SO_3 content is less than 0.4% for all deposits. The thickness of the deposits varies between (1.4 – 2.4) m. The total reserve was calculated to be about 13 million cubic meters. Some other localities were mentioned by Al-Hussian (1979) are listed in the Table (2).

Table 2: Some localities of gravel and sand deposits in the High Folded Zone (Al-Hussian, 1979)

	locality	Gravel	Sand	Clay
		(%)		
Dohuk	Khanek	70	29	0.6
	Zakho	82	17	0.5
	Upper Kamauna	71	28	1.8
Sulaimaniyah	Said Sadik	75	25	0.26
	Dokan	76	22	1.7
	Tanjero	66	33	0.5

CONCLUSIONS

- Generally, the mineral deposits within the High Folded Zone are scarcely studied and only several deposits of raw materials for the cement industry have been studied in details so far. They are situated near Sulaimaniyah city. Limestone formations belong to Jurassic, Cretaceous and Tertiary age. They are very widely spread in this zone and can be used also for building stone and as marble substitute.
- The investigated industrial recourses of the limestone deposits are not very big as compared to the potential of the area.
- Large deposits of marble (orthomarble) with good decorative properties can be found in the area.
- Dolomite deposits are of limited information but with high potential, especially in the Pila Spi Formation.
- Deposits of Quaternary clays have limited distribution due to the mountainous relief of the majority of the area, hence special attention should be made to some geological formations, e.g Injana, Mukdadiya, Shiranish, Gercus, Kolosh, and Tanjero, which could be the main source of clay raw material.

REFERENCES

Al-Ani, S.A., Saleh, B.M. and Hassan, M., 1991. Detailed geotechnical investigation of the Banded Marble (Zebra Type) of Kheti area. GEOSURV, int. rep. no. 1984.

Al-Bassam, K., 2007. Minerogenic Map of Iraq, scale 1: 1000 000. Explanatory text, GEOSURV, 25 pp.

Al-Hussian, T., 1979. Deposits of gravel and sand in Iraq. GEOSURV, int. rep. no. 979.

Economic Commission for Europe (ECE), 2009. Mapping of the United Nation Framework Classification for Fossil Energy and Mineral Resources. UN publication, Energy Series no.3, 73pp.

Etabi, W. and Ahmed, S., 1979. Final report on prospecting exploration of Tasluja limestone deposit suitable for Portland cement. GEOSURV, int. rep. no. 961.

Hafidh, Sh.Q. Ruhman, A., Abid Al-Abaas, F., Rasheed A.Y. and Qanbar, A.Sh., 2008. Preliminary geological studies of limestone suitable for cement industry in Sartak and Kani Kel Vicinity southeast of Darbandi Khan Southeast of Sulaimaniyah Governorate. GEOSURV, int. rep. no. 3125.

Jaber, F.S. and Al-Ubaidi, H., 1973. Kani China recrystalline limestone. GEOSURV, int. rep. no. 524.

Jassim, S.Z. and Goff, J.C., 2006. GEOLOGY OF IRAQ. Dolin, Prague and Moravian Museum, Brno, Czech Republic. 314pp.

Leitch, H.C.B., 1954. Report on investigation for cement material in Hammam Al-Alil. GEOSURV, int. rep. no. 55.

Mansour, J., 1976. Reconnaissance of the Kirkuk, Erbil, Sulaimaniyah area on search for raw materials in connection with proposed cement works. GEOSURV, int. rep. no. 768.

Mansour, J., Zaidan, S. and Ibrahim, S., 1979. Iraqi Marble, GEOSURV, int. rep. no. 942.

Mc Carthy, M.J., 1956. Report on geological reconnaissance of the area; Mosul, Dohuk, Aqra, including also Jebel Atshan. GEOSURV, int. re. no. 268

Nadir, B., 1981. Report on clay deposit for cement industry, Karbala Governorate, Ain Al-Zarga area. GEOSURV, int. rep. no. 1140.

Sissakian, V.K., and Fouad, S. F., 2012. Geological Map of Iraq, 4rd edit, scale 1: 1000 000, GEOSURV, Baghdad, Iraq.

Smidth and Comp., 1952. Search for raw materials and general investigation in connection with the proposed new cement works in N Iraq. GEOSURV, int. rep. no. 52.

Taufiq, J.M. and Domas, J., 1977. Report of the regional geological mapping of Duhok – Ain Zala area. GEOSURV, int. rep. no. 837.

Toma, N., and Butris, J., 1978. Report in the Bazian clay deposit for cement industry. GEOSURV, int. rep. no. 900.

Touni, S., 1979. Report on gypsum deposits of Darbandi Bazian area, Chum Chamal, Sulaimaniyah Governorate. GEOSURV, int. rep. no. 955.

Younan, J., 1980. Gravel and sand deposits in Darbandi Khan – Kalar area, Sulaimaniyah Governorate. GEOSURV, int. rep. no. 715.

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