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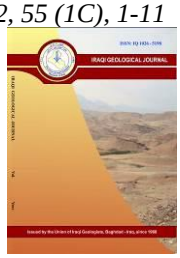

Suitability of the Carbonate Successions for Different Industrial Uses, Pira Magroon Anticline, Northern Part of Iraq, Kurdistan Region

Ala A. Ghafur[1], Varoujan K. Sissakian[1,*], Diyar S. Khalil[2] and Sarhang A. Omer[2]

[1] University of Kurdistan Hewler, KRG, Iraq
[2] Mineral Resource Engineer, Sulaimani, KRG, Iraq
* **Correspondence**: f.khajeek@ukh.edu.krd

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Abstract

Many geological formations are exposed in the Pira Magroon anticline (Mountain); in the northeastern part of the Kurdistan Region, Iraq. The components of the exposed formations are carbonate rocks, especially limestone, which might be utilized for different industrial uses. To have an industrial assessment for the exposed limestone beds in the Pira Magroon anticline, Zewe Gorge has been chosen for sampling, where the Shiranish and Kometan formations are exposed in the outlet of the gorge. Eleven samples have been collected within the Shiranish and Kometan Formations starting from the bottom of the Kometan Formation, with different sampling intervals. Thereafter, the samples were prepared to be tested by XRF machine; in order to show the concentrations of the main oxides in the collected samples. The weighted averages were calculated from the concentrations of the oxides, and then the averages were indicated. Accordingly, the data was compared with the Iraqi and other industrial standards, to know the usage of the tested rocks for different industries. The acquired data showed that the carbonate successions of the Kometan and Shiranish Formations of the Zewe Gorge in the Pira Magroon Anticline, can be used in cement production.

Keywords: Kometan Formation, Shiranish Formation; Carbonate succession; Industrial assessment; Cement industry

1. Introduction

One of the widest spread exposed rocks in the (Iraqi Kurdistan Region) IKR is limestone, which with other carbonate rocks form about 73 % of the whole coverage area of the IKR (Sissakian and Saeed, 2012). However, these huge deposits are not well studied everywhere in the IKR (Sissakian, 2018) and accordingly not widely utilized for industrial uses; apart from cement production and construction uses. For the former, six cement plants exist in the IKR, with 5 of them located in the Sulaimaniyah Province and only 1 in the Erbil Province (Fig. 1). They all use limestone beds from the Sinjar Formation with daily production that ranges from 3500-6000 tons/ day (Sissakian, 2018). A region like the IKR, is witnessing development in infrastructure and needs enormous quantities of cement for infrastructure development; accordingly, the production of the already existing cement factories in the IKR is not enough. Not only for the IKR but for the whole Iraqi territory; keeping in mind that the majority of the existing cement plants in Iraq (apart from IKR) are either of out of service or are producing less

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quantities than they were designed for. This encourages the construction of more cement plants in the IKR; accordingly, more suitable limestone deposits apart from the Sinjar Formation, should be identified through thorough investigation and investment.



Fig. 1. Map showing the studied section and the existing five cement plants. T= Tasluja, M= Mass, L= Lafarge, D= Delta, and G= Gasin, K= KAR

A region like the IKR, is witnessing development in infrastructure and needs enormous quantities of cement for infrastructure development; accordingly, the production of the already existing cement factories in the IKR is not enough. Not only for the IKR but for the whole Iraqi territory; keeping in mind that the majority of the existing cement plants in Iraq (apart from IKR) are either of out of service or are producing less quantities than they were designed for. This encourages the construction of more cement plants in the IKR; accordingly, more suitable limestone deposits apart from the Sinjar Formation, should be identified through thorough investigation and investment. Fig. 2 shows the geological map of the investigated research area. It is located at the Zewe Gorge within the Pira Magroon Mountain (anticline). The gorge is about 25 km northwest of Sulaimaniyah city (Fig. 1). The area can be reached through a paved road from Sulaimaniyah city and from other destinations too. We have chosen the studied sections, taking in consideration the opportunity for plant construction nearby. The rocks of the Pila Spi Formation in the south western limb of the Permam anticline, near Al-Maseef were studied and evaluated by Sissakian et al. (2019). They reported about the presence of very good quality and quantity of limestone suitable for the cement production. The existing rocks within the Pila Spi Formation (Upper Eocene) at Haibat Sultan Mountain, 17 km east of Koya town were studied and evaluated by Sissakian et al. (2020) they concluded that excellent deposit exists for cement production. The exposed beds of the Bekhme Formation (Upper Cretaceous) at Galley Ali Beg Gorge were studied and evaluated by Ghafur et al. (2021), they indicated the presence of excellent deposits for the cement production. Awad and A. Al- Owaidi (2021) have studied the exposed marl beds within the Euphrates Formation in the quarries of the Kufa Cement plant (Central part of Iraq), they found the marl beds as an excellent substitute for the claystone beds whicha are the second raw mix in cement production. Sissakian et al.

(2022) have studied and evaluated the exposed rocks in the Shakrook anticline and have found that they ate suitable for cement production.

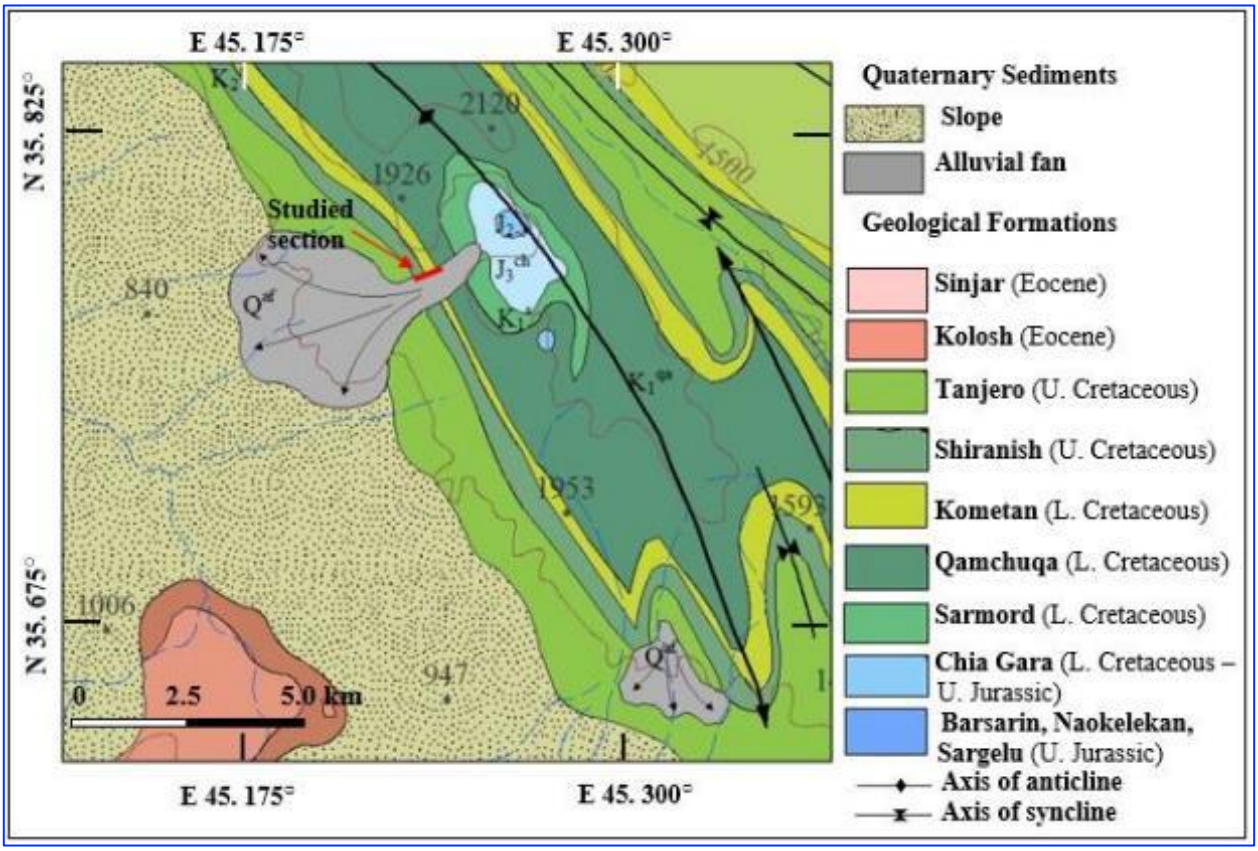

Fig. 2. Geological map of part of the Pira Magrron anticline including the studied section (From Sissakian and Fouad, 2015)

From reviewing the aforementioned literature, it is clear that the carbonate successions in the Zewe Gorge consists mainly of limestone. Therefore, we have selected the Zewe Gorge to be the studied area, besides considering quarrying aspects as are mentioned in the discussion of the current research work. The main aim of the current research is to find a suitable deposit for cement production rather than those currently available within the Sinjar Formation, which is utilized by the earlier mentioned cement plants (Fig. 1), besides other mentioned industries in the Discussion Section. Within the chosen studied section, the Kometan and Shiranish formations are well exposed with huge thicknesses at different parts of the IKR (Sissakian and Fouad, 2015).

2. Data Used and Methodology

Geological maps of a scale of 1:100000 and 1:250000 were used to indicate the best exposed sections that can be easily accessed, and where carbonate rocks could be found within the exposed geological formations. Accordingly, we have chosen the Zewe section for sampling (Fig. 1), where different geological formations are exposed. The studies of Ghafur et al. (2019 and 2020) and Sissakian et al. (2022) have been considered for recognizing the exposed geological formations that are the Kometan and Shiranish formations. However, only the lower part of the Shiranish Formation was considered, because the lithology of the formation changes to be more marl intercalations. Eleven samples were collected totalling to 108 m from the Zewe Gorge section from the Kometan (Sample No. 1-8) and Shiranish (Sample No.9 – 11) formations. The samples were described in the field and tested by HCl acid. The intervals from which the samples were collected were measured by a measuring tape

(Table 1). Each sample was kept in a plastic bag, and labelled. The 11 collected samples were transported to the chemical laboratory of the University of Kurdistan Hewler in Erbil, IKR for analysis.

The samples were uploaded into an XRF equipment to show the concentration of main oxides. before subjecting the samples to an XRF test, the samples were treated as follows:

- Each sample was crushed alone using an electrical machine.
- Then the samples were powdered by means of an electrical machine.
- The ground samples were quartered with a hand used separator, and 200 gm from one quarter was selected randomly, weighted, and kept in a plastic bag.
- From each powdered and weighted sample, special pellet was prepared by means of pressing the sample in a special container.
- The prepared pellets were dried in an electrical oven (120 C^{o}) for one hour.
- The dried pellets were mounted in the XRF equipment (Fig. 3) and the concentrations of the main oxides were measured. The results are shown in Table 1.
- From the concentration of the main oxides, the weighted averages of each oxide is calculated and presented in Table 2.



Fig. 3. The used XRF machine

The acquired concentrations' results of the main oxides from the XRF test are shown in Table 1. For the industrial assessment of the collected samples, the weighted averages should be known. This is attributed to the fact that the sampling interval is not uniform; accordingly, for industrial assessment the weighted averages should be calculated. The weighted averages of the oxides in the samples are calculated as follows (IET, 2021).

$$Weighted\ Percentage = \frac{\sum C1+C2+C3+C4+Ci}{\sum T1+T2+T3+T4+Ti} \quad (1)$$

Where Wc is the weighted percentage, C is the concentration of each oxide, and T is the thickness of each sample.

$$Weighted\ Average = \frac{\sum W1+W2+W3+W4+Wi}{\sum T1+T2+T3+T4+Ti} \quad (2)$$

Where W = the weighted percentage of each oxide multiplied by the sample's thickness (T). The calculated data of each oxide at each sample is shown in Table 2.

Then, the acquired weighted averages of the collected samples were compared with Iraqi and International standards (Table 3) to know the usage of the exposed rocks in the study area for different industrial uses.

Table 1. The acquired data of the collected samples using XRF equipment

Sample No.	Thick. (m)	Field description	CaO%	MgO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	Na_2O %	L.O.I. %
1	5	Limestone, well bedded, light grey, hard.	48.96	1.68	3.56	1.04	0.42	0.59	42.0
2	5	Limestone, well bedded, light grey, hard.	51.34	1.61	2.06	0.68	0.38	0.54	42.90
3	10	Limestone, thickly bedded, light grey, hard.	52.17	1.47	1.83	0.32	0.34	0.55	43.10
4	10	Limestone, thickly bedded, light grey, hard.	51.51	1.54	1.80	0.58	0.36	0.58	43.20
5	12	Limestone, thickly bedded, light creamy, hard.	52.15	1.33	1.98	0.53	0.36	0. 07	42.50
6	9	Limestone, thickly bedded, light creamy, hard.	51.12	1.30	2.4	0.69	0.37	0.53	42.50
7	10	Limestone, thickly bedded, light grey, hard.	52.81	1.33	1.46	0.52	0.34	0.08	43.18
8	12	Limestone, thickly bedded, light grey, hard.	51.64	1.40	2.1	0.77	0.37	0.07	42.64
9	10	Limestone, well bedded, light grey, hard.	52.03	1.32	2.01	0.71	0.35	0.07	43.01
10	15	Limestone, well bedded, light grey, hard	50.93	1.27	2.77	0.99	0.37	0.07	42.07
11	10	Limestone, well thinly bedded, white, hard	51.08	1.23	2.60	0.92	0.37	0.07	42.60

Table 2. Weighted percentages and averages of the oxides in the collected samples

Sample	Thick. (m)	CaO		MgO		SiO_2		Fe_2O_3		Al_2O_3		Na_2O		L. O. I.	
		%	Wa%	%	Wa%	%	Wa%	%	Wa%	%	Wa%	%	Wa%	%	Wa%
1	5	48.96	244.8	1.68	8.4	3.56	17.8	0.42	2.1	1.04	5.2	0.59	2.95	42.0	210.0
2	5	51.34	256.7	1.61	8.05	2.06	10.3	0.38	1.9	0.68	3.4	0.54	2.7	42.90	214.5
3	10	52.17	520.7	1.47	14.7	1.83	18.3	0.34	3.4	0.32	3.2	0.55	5.5	43.10	431.0
4	10	51.51	515.1	1.54	15.4	1.80	18.0	0.36	3.6	0.58	5.8	0.58	5.8	43.20	432.0
5	12	52.15	628.8	1.33	15.96	1.98	23.76	0.36	4.32	0.53	6.36	0.07	0.84	42.50	510.0
6	9	51.12	460.08	1.30	11.7	2.40	21.6	0.37	3.33	0.69	6.21	0.53	4.77	42.50	382.5
7	10	52.81	528.1	1.33	13.3	1.46	14.6	0.34	3.4	0.52	5.2	0.08	0.8	43.18	431.8
8	12	51.64	619.68	1.40	16.8	2.10	25.2	0.37	4.44	0.77	9.24	0.07	0.84	42.64	506.16
9	10	52.03	520.3	1.32	13.2	2.01	20.1	0.35	3.5	0.71	7.1	0.07	0.7	43.01	430.1
10	15	50.93	763.95	1.27	18.6	2.77	41.55	0.37	5.55	0.99	14.85	0.07	1.05	42.07	631.05
11	10	51.08	510.8	1.23	12.3	2.60	26.0	0.37	3.7	0.92	9.2	0.07	0.7	42.60	426.0
Total	108		5569.01		148.41		237.21		39.24		75.76		20.85		4605.01
Average			51.56		1.37		2.20		0.36		0.70		0.19		42.64

Table 3. Iraqi and International standards of some industries (After Al-Bassam and Al-Khafaji, 2011, in Sissakian, 2018)

Limestone							
Cement Industry				**Glass Industry**			
CaO	> 45 %	SO_3	< 1 %	$CaCO_3$	> 98 %	MgO	< 2 %
MgO	< 2 %	$K_2O + Na_2O$	0.05 %	SiO_2	< 2.0 %	L.O.I.	> 43%
Cl	0.5 – 1.0%	Fe_2O_3	< 0.1 % *	Fe_2O_3	< 0.06 %		
Paints Industry				**Sugar Industry**			
$CaCO_3$	> 99.5 %	Fe_2O_3	< 0.05 %	SiO_2	< 0.66 %	MgO	< 0.4 %
SiO_2	< 0.1 %	L.O.I.	> 43.5 %	Al_2O_3	< 0.27 %	CaO	> 55 %
Al_2O_3	< 0.05 %			Fe_2O_3	< 0.09 %		
Steel Industry				**Paper Industry**			
$CaCO_3$	92.0 – 95.0 %	$CaSO_4$	0.5 – 0.8 %	$CaCO_3$	> 90 %	SO3	< 1 %
$MgCO_3$	1.3 –1.9 %	Al_2O_3	1 – 2 %	SiO_2	< 1.5 %	I.R. (in HCl)	< 4.5 %
P	0.05 – 0.09 %	SiO_2	1.5 – 3.5 %	MgO	< 1.5 %		

3. Geological Setting

The three main geological aspects of the studied section and near surrounding are briefed hereinafter based on Fouad (2015), Sissakian et al. (2014) and Sissakian and Al-Jiburi (2014), respectively.

3.1. Geomorphology

The studied site lies; physiographically within the High Mountainous Province (Sissakian and Fouad, 2015). The main existing units are:

- Structural Units: The anticlinal ridges are the main unit; they extend along the whole length of the anticline (Fig. 4 a). They exist within the Qamchuqa and Kometan formations.
- Structural-Denudational Units: The fault escarpments form the main unit (Fig. 4 b), which are well developed within the Kometan and Shiranish formations; like Zewe Gorge. Other units are erosional scarps. They occur within the Qamchuqa, Kometan and Shiranish formations.
- Alluvial Units: Alluvial fans are well developed along the southwestern limb of the Pira Magroon anticline, and are capped by thick calcrete (Fig. 5a). The recent fans colliding together forming Bajada. Slope sediments are deposited along the foothills of the Pira Magroon anticline. Valley fill sediments are well developed in large valleys like Zewe (Fig. 5b).

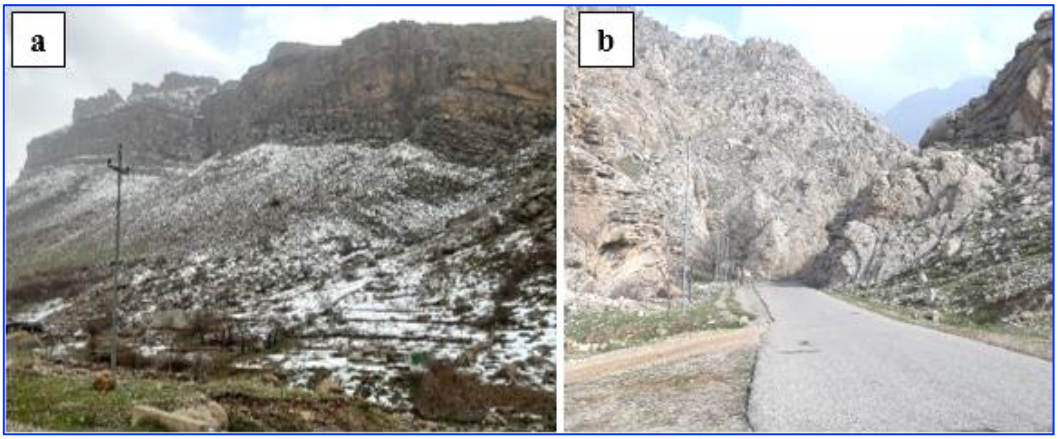

Fig. 4. a) Structural ridges within the Kometan Formation, andb) Fault escarpment (Zewe Gorge) within Kometan and Shiranish formations.

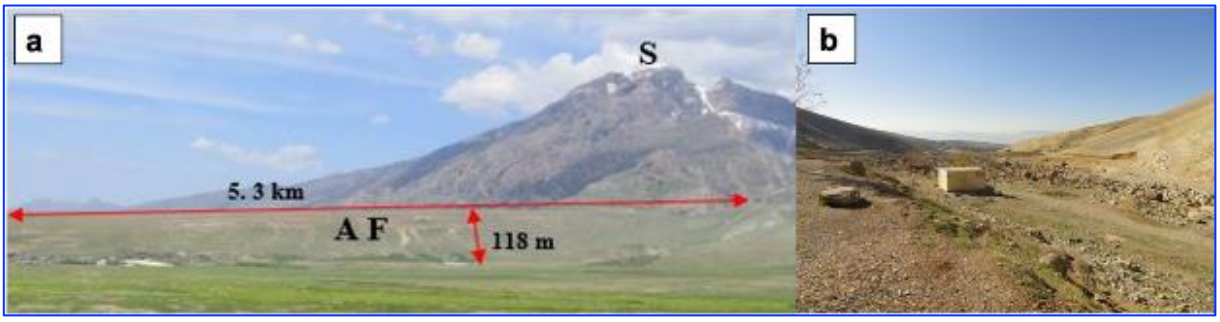

Fig. 5. a) Zewe alluvial fan (AF) capped by calcrete, (S) is the summit of Pira Magroon Mountain, and b) Valley fill sediments in Zewe valley

3.2. Tectonics and Structural Geology

The studied site lies within the Pira Magroon anticline, which lies within the High Folded Zone of the Outer Platform of the Arabian Plate. The zone belongs to the Zagros Thrust- Fold Belt (Fouad, 2015). The High Folded Zone is characterised by intense folding and faulting (Fig. 6) due to the collision of the Arabian and Iranian plates (Alavi, 2004, Fouad, 2015). The trend of the Pira Magroon anticline is in the NW – SE direction and it is a narrow asymmetrical and double plunging anticline. The northeastern flank is steeper. However, in the studied site, the southwestern limb is steeper and faulted, and overturned; like in the Zewe Gorge (Fig. 6). The exposed rocks belong to Jurassic and Cretaceous periods, such as the Chia Gara, Sarmord, Qamchuqa, Kometan and Shiranish formations (Sissakian and Fouad, 2015).

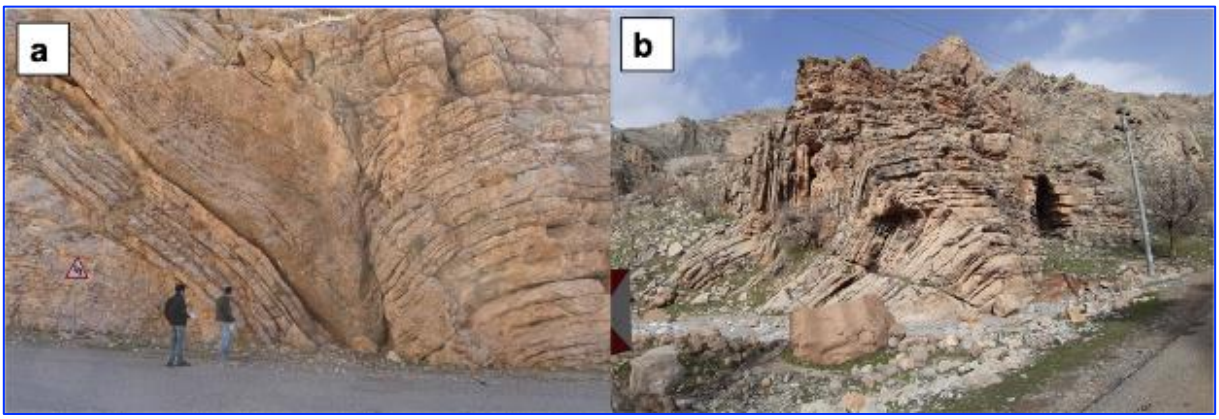

Fig. 6. Zewe Gorge a) Fault escarpment in the Kometan Formation, b) Intensley folded and faulted rocks of the Kometan and Shiranish Formations

3.3. Stratigraphy

The studied section is located within the Kometan and Shiranish formations (Ghafur et al., 2019 and 2020); however, previously was considered as the Qamchuqa Formation (Fig. 6) (Sissakian and Fouad, 2015). The details of the formation are given depending on Ghafur et al. (2020). The exposed formations in the studied section are described hereinafter. The geological map of the studied section and surrounding area is shown in Fig. 6.

- **Kometan Formation** (Loer Cretaceous): The formation consists of white, well and thinly bedded, farly hard to hrd marly limestone highly deformed (Fig. 6). The thickness of the formation is about 170 m.

- **Shiranish Formation** (Upper Cretaceous): The formation consists of alternation of white to light grey, bedded, fairly hard marly limestone and marl, followed upwards by bluish grey, thinly to thickly bedded, fine crystalline, conchoidally fractured marl. The thickness of the formation is about 250 m.

4. Results

To have an industrial assessment of the exposed rocks at Zewe Gorge within the sampled and studied section (Figs.1 & 2), we have compared the acquired data (Table 2) with the Iraqi standards (Table 3) to indicate the usage of the exposed rocks in the studied section for many industrial uses. The compared results indicated the following.

4.1. Cement Industry

The most common industry in the IKR which utilize limestone, is the cement production (Sissakian, 2018). Accordingly, we have compared the acquired data (Table 2) with the required Iraqi specifications for the cement production (Table 3). The result of the comparison is shown in Table 4.

Table 4. Comparison of the acquired weighted averages of the oxides of the analysed rocks with the Iraqi Specification for cement industry

Oxides %				Suitability	
Standard		**Analyzed samples**			
CaO	> 45 %	CaO	51.56	Yes	
MgO	< 2 %	MgO	1.37	Yes	
SO_3	< 1 %	SO_3	-----		
Cl	0.5 – 1.0 %	Cl	------		N A
$K_2O + Na_2O$	0.05 %	$K_2O + Na_2O$	0.19		N S
Fe_2O_3	< 0.1% *	Fe_2O_3	0.36	Yes	

* For white cement only, N A= Not analysed, N S = Near to Standard.

Note: The K_2O, SO_3, P_2O_5 and Cl were not detected by the used XRD machine, which means their concentrations are Nill.

4.2. Paper Industry

In the IKR there is no paper industry; however, we have checked the acquired data of the tested rocks (Table 2) with the standards to indicate th suitability of the exposed rocks in the studied section with those which can be used in the paper industry (Table 3). The comparison results are presented in Table 5.

Table 5. Comparison of the acquired data of the analysed rocks with the requirements of paper industry (From Al-Bassam and Al-Khafaji, 2011 in Sissakian, 2018).

Oxides %				Suitability	
Standard		**Analyzed samples**			
$CaCO_3$	> 90 %	$CaCO_3$	94.20	Yes	
SiO_2	< 1.5 %	SiO_2	2.2	No	
MgO	< 1.5 %	MgO	1.37	Yes	
SO_3	< 1.0 %	SO_3	-----		N A
I.R (in HCl)	< 4.5 %	I.R (in HCl)	2.2	Yes	

$CaCO_3$ = CaO + L.O.I.; N A= Not analysed.

4.3. Other Industries

We also have compared the acquired concentration values of the main oxides (Table 2) with the required specifications for the paint, glass and steel industries (Table 3), and found that the studied rocks cannot be used in production of the three industries.

5. Discussion

5.1. Industrial Assessments

The acquired concentrations of the main oxides of the collected samples, and their weighted averages (Table 2) indicate that the samples are limestone since the maximum and minimum CaO and MgO concentrations are 52.81% (Sample No. 7), 48.96 (Sample No. 1), 1.68 % (Sample No. 1), and 1.23 % (Sample No. 11), respectively (Table 2). Therefore, we have discussed the industrial assessments of the collected samples by comparing the results with the required specifications, for the possible uses of limestone (Table 3). The summary of the industrial assessments of this research work is discussed below:

5.1.1. Cement Industry

The weighted averages of the two main two oxides (CaO and MgO), which control the cement industry are within the required standards (Tables 2 and 4). However, SO_3 and Cl^- were not detected; indicating that the concentrations are very low, which means they are within the required standards (Tables 3, and 5). It is worth mentioning that the quality of the studied limestone beds is suitable for standard cement, but not for white cement due to percentage of Fe_2O_3 being just above the limit of standard white cement.

5.1.2. Paper industry

The acquired results from the tested rock samples are (almost) within the limits of the required specifications for the paper production (Tables 2, and 5). However, the SiO_2 concentrations is higher than the required standard. Therefore, the slightly higher concentrations will affect on the smoothness of the produced paper. It is worth mentioning that in different types of papers there is no need for such smoothness, this means the tested limestone beds can be used as a raw material for paper production, especially those which are used for hard work, such as hard covers. The SO_3 concentration was not detected (Tables 2 and 5), this is attributed to a rare concentration.

5.2. Quarrying Conditions

The quarrying conditions were considered before selecting a relevant area for sampling, besides the consideration of many other aspects; as mentioned below:

- No overburden or very thin (Fig. 6),
- No innerburden (Fig. 6),
- Clear bedding and intense jointing (Figs. 4 and 6) which will facilitate quarrying,
- Available area for plant construction (Fig. 5 a),
- Relevant thickness of the exposed limestone (Fig. 6),
- Possibility of quarrying by bulldozers and excavators due to bedding nature (Fig. 6),
- Availability of main roads near the quarry area (Fig. 4 b) and being close to the main road running between Sulaimaniyah city and Dokan town.

- The Kometan and Shiranish formations have wider exposure areas than that of the Sinjar Formation from where the limestone is quarried and used in all five existing cement plants in the Sulaimaniyah Governorate (Fig. 1).
- The required clay; which is used as raw material in the cement production is available at the recent alluvial fans as well as in the Kolosh Formation which is exposed south of the studied area (Fig. 2 & 5 a).

5.3. Geological Reserve Estimation for a Cement Plant

The exposed rocks in the studied section showed homogenous lithology; as the concentration of the main oxides are concerned (Table 2). Therefore, the whole exposed carbonate successions along the studied section can be considered as one unit for industrial assessment, and can be quarried systematically. Moreover, the aforementioned quarrying aspects are very suitable for the establishment of a quarry. The acquired result is motivating for construction of a cement plant (Tables 2 and 5); therefore, a geological reserve estimation can be considered by assuming a unit area of one cubic meter. The average density of the limestone is about 2,400 kg/ m3. The weight of 1 m^3 of limestone will be = 1 m^3 X 2400 kg. m^3 = 2.4 tons. The second raw material for the raw mix in cement production is clay, which is available near to Zewe Gorge, where recent alluvial fans cover large areas. The added clay to the raw mix for cement industry is about 30 – 40 % of the used limestone. Therefore, 35% of 2.4 tons = 0.84 tons. Total used raw mix = 2.4 + 0.84 = 3.24 tons

If we suggest a cement factory with a production of 3,500 tons/ day, then the required raw mix amount will be about 7,000 tons/day. Therefore, the annual used raw mix will be = 300 true working days X 7000 tons of raw mix = 2,100,000 tons. If we consider 30 years of production, then the total required amount of raw mix = 2,100,000 X 30 years = 63,000,000 tons. Accordingly, the required volume of the rocks in the assumed quarry will be= 63,000,000 ÷ 2.4 = 26,250,000 m^3

Therefore, the required quarry area with average thickness of 100 m = 26250000 ÷ 100 = 262500 m^2 = 0.263 km^2. It is worth to mention that the suggested clay deposit is used already in many cement plants at the Sulaimaniyah vicinity, Bazian district. Therefore, we have recommended using these clay deposits as the second main raw material used in the cement industry. We have to emphasize that this is a preliminary reserve estimation with a Low Level of Confidence according to JORC (1999). Therefore, the estimated reserve and quarry area are not relevant for investment, unless necessary site exploration is performed to indicate the reserves with a High Level of Confidence according to JORC (1999). The detailed site investigation should include drilling of boreholes located in net of (150 – 300) m separations; as the first step drilling, which should be in continuous coring method to a depth which shall include the whole sampled thicken with a core sampling of one-meter intervals, then analysing all the collected core samples to calculate the concentration of the main oxides. If the results are encouraging, then the spacing of the boreholes should be decreased to 100 – 150 m, and the sampling and analysing method should be repeated to have final reserve estimation that can be used for investment.

6. Conclusions

We can conclude from the acquired results of the current research work; the weighted averages of the main oxides and calculated thickness that the exposed beds within the Kometan and Shiranish formations in the studied section are pure limestone. The exposed limestone can be used for cement production with clay available within the recent alluvial fan sediments. Moreover, the limestone can be also considered in the paper industry, however, the produced paper will not be smooth.

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