Research Article

Industrial Assessment of Limestone Beds of the Qamchuqa Formation for Cement Industry, Kurdistan Region, North Iraq

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Abstract
The Qamchuqa Formation is widely exposed in Iraqi Kurdistan Region (IKR); north of Iraq. The formation along with the Bekhme Formation form the bulk of the main mountains (anticlines) in the IKR. Among those anticlines is the Ranya anticline, which has a NW–SE trend, where the Qamchuqa Formations has a thickness of about 700 m. The main lithological facies of the formation are: limestone, dolomitic limestone and dolomite. We have sampled the upper most 89 meters of the northeastern limb, by collecting 10 samples of different sampling intervals that range from (3–12) m. The ten rock samples were tested by an XRF to measure the concentration of the oxides in each sample. The XRF results showed that the 10 rock samples are limestone with different percentages of oxides. The weighted averages of the oxides in the collected samples have been calculated, and the results showed that the limestone beds along the studied section in the upper part of the Qamchuqa Formation are suitable for cement industry. The average concentration of CaO and MgO is 55.13% and 0.26%, respectively.
Keywords: Qamchuqa Formation, Limestone, Cement industry, Reserve Estimation, IKR.

1. Introduction

Generally, the exposed rocks in IKR are not well evaluated for industrial uses; this is attributed to the fact that the rocks are not well studied and investigated, as carefully as all other metallic and non-metallic minerals" (Sissakian, 2018). However, there are very few studies which were carried out, dealing with different metallic and nonmetallic minerals and industrial rocks. Five cement plants are concentrated in the Bazian vicinity; southwest of Sulaimaniyah city (Figure 1).

There are six cement plants in the IKR; 5 of them are located in the Sulaimaniyah Province and only 1 in the Erbil Province (Figure 1). Those cement plants which are located in the Sulaimaniyah Governorate use the limestone from the Sinjar Formation (Eocene age), whereas the one in Erbil Governorate uses limestone from the Anah and Euphrates formations (Upper Oligocene and Lower Miocene, respectively). It is known that the limestone of the Sinjar Formation is better than those of the Anah and Euphrates formations; as far as the cement industry is concerned. This is attributed to the low thickness of the Anah and Euphrates formations and high MgO content as compared to the rocks of the Sinjar Formation (Al-Bassam, 2012).

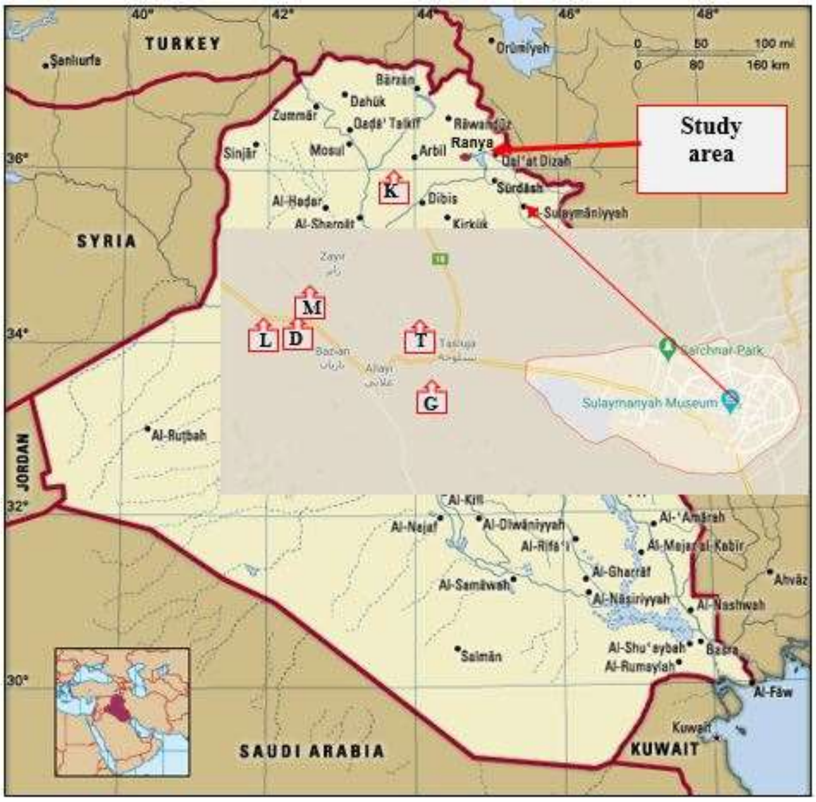

Figure 1. Location Map of the Six Existing Cement Plants In IKR. Plants' Names: K= KAR, T= Tasluja, M= Mass, L= Lafarge, D= Delta, and G= Gasin. The location of the study area also is shown, NE of Ranya town.

1.1. Previous Work

The Iraq Geological Survey (GEOSURV) has conducted different researches to indicate the suitability of the limestone beds within different formations in the whole Iraqi territory including the IKR. Majority of the constructed cement plants in IKR have used the data of the carried out work by GEOSURV. The achieved results from the scientific reports were presented by the owners of those companies to the Ministry of Natural Resources (Erbil) to get licenses, which were used either to construct a new cement plant or to keep the license for future use.

Sissakian *et al.* (2019) studied the limestone beds of the Pila Spi Formation in Permam anticline, near Al-Maseef and mentioned about very good quality and quantity of rocks, suitable for cement industry. Sissakian *et al.* (2020) studied the exposed rocks of the Pila Spi Formation (Upper Eocene) at Haibat Sultan Mountain, 17 km east of Koya town and concluded on the existence of excellent deposit for the cement production. Ghafur *et al.* (2021) studied the limestone beds of the Bekhme Formation (Upper Cretaceous) at Galley Ali Beg gorge and reported on some excellent deposits, which can be used for the cement production.

1.2. Location

The studied section is located northeast of Ranya town (Figures 1 and 2), in a long mountain range, which forms the northeastern limb of the Ranya anticline. The mountain is called Kiwa Rash, and is located east of Dukan Lake. The section is accessible by many roads from Sulaimaniyah city or Erbil city, via Ranya. We have found the location to be suitable for the construction of a cement plant. The location is against the main wind direction toward the Ranya town and about 10 km far from the city. The only inhabitants which are in the affected area is a small village called Sarsian (Figure 2) which will be affected by wind and the fallen cement dust. This village can be relocated because it is located within a large alluvial fan that is covered by clayey soil which is very suitable for the cement production to be mixed with the limestone as the main raw mix (Sissakian et al., 2021).

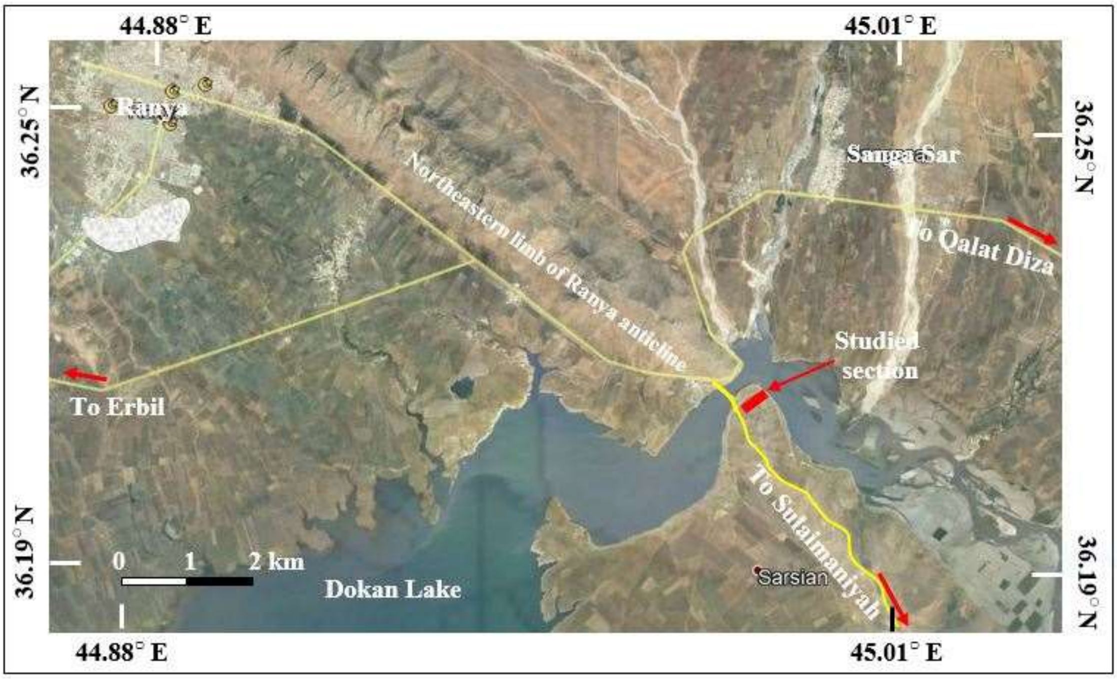

Figure 2. Satellite Image Showing the Studied Section and the Surrounding Area.

1.3. Aim

The aim of this study is to indicate the suitability of the rocks of the Qamchuqa Formation in the Ranya vicinity, in Ranya anticline for cement industry. The preliminary evaluation depends on the acquired results, from subjecting the collected rock samples to a XRF test. The indicated concentrations of the main oxides were used to perform an industrial assessment for the exsiting beds in the upper part of the Qamchuqa Formation, through the collected 10 samples which represent the upper 89 m of the formation. This was achieved by comparing the results, with the standard specification for cement industry.

2. Data Used and Methodology

In order to conduct this research work, different materials have been used; like a geological map at a scale of 1:100000 and satellite imagery, which were used to indicate the exposures of the Qamchuqa Formation in the vicinity of the Ranya town. Moreover, the maps were used to select a relevant area; not only for sampling but also to make sure that the selected area is far from inhabited centers such as the Ranya town, and that there is relevant space for any industrial sites; such as a cement plant.

We collected 10 samples from the upper exposed 89 m of the Qamchuqa Formation in different sampling intervals; where ever there was a major lithological change. The samples were tested in the field by a hand lens for description and then checked by diluted (5%) Hydrochloric acid (HCl) (Table 1). The samples were numbered and kept in proper sample bags; then they were sent to the chemical laboratory of the University of Kurdistan Hewler and were tested by XRF. The results were used for industrial assessment as the cement industry is concerned. The sampling interval was measured by a measuring tape, whereas the hardness was measured by the hammer blows (Hack & Huisman, 2002).

The collected 10 samples were crushed, ground, powdered, and then divided into 4 parts using a mechanical splitter. From one of the four divided parts of each sample, 200 gm was dried using an electrical oven for 24 hours. The dried sample was prepared as a pellet then mounted in the XRF equipment (Figure 3) to be analyzed. The acquired data from the XRF test are presented in Table (2). Six oxides (CaO, MgO, SiO_2, Fe_2O_3, Al_2O_3, Na_2O) and L.O.I. were analyzed for the collected samples, and the results are shown in Table (2).

Table 1. Field Description of the Samples.

Sample No.	Rock type	Color	Hardness	Thickness (m)	Reaction with HCl	Notes
1	Limestone	Grey	Hard	3	Slight	Bedded
2	Limestone	Light Grey	Hard	3	High	Bedded
3	Limestone	Grey	Hard	9	Slight	Well Bedded
4	Limestone	Light Grey	Very Hard	10	High	Thickly bedded to massive
5	Limestone	Greyish brown	Hard	10	Very High	Thickly bedded to massive
6	Limestone	Grey	Very Hard	10	Slight	Thickly bedded to massive
7	Limestone	Light Grey	Hard	12	High	Thickly bedded to massive
8	Limestone	Greyish brown	Hard	10	Very High	Thickly bedded to massive
9	Limestone	Grey	Very Hard	12	Slight	Thickly bedded to massive
10	Limestone	Light Grey	Hard	10	High	Thickly bedded to massive

Figure 3. The Used XRF Equipment.

Table 2. The Concentrations of Main Oxides Within the 10 Rock Samples.

Sample No.	CaO %	MgO %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	Na_2O %	L.O.I. %
1	54.52	1.33	0.37	0.31	0.18	0.07	43.97
2	54.77	1.19	0.28	0.31	0.17	0.06	43.56
3	54.43	1.37	0.31	0.31	0.22	0.07	43.85
4	54.57	1.39	0.19	0.30	0.16	0.10	43.82
5	53.79	1.35	0.94	0.35	0.21	0.06	43.60
6	53.99	1.31	0.76	0.32	0.31	0.09	53.71
7	54.52	1.32	0.29	0.30	0.19	0.10	43.70
8	54.82	1.22	0.13	0.30	0.13	0.10	43.92
9	54.80	1.22	0.16	0.30	0.14	0.09	43.30
10	54.94	1.15	0.13	0.30	0.13	0.14	53.65

The results from the XRF test (Table 2) were compared with the standards for cement industry, as shown in Table (3).

Table 3. Iraqi Standards No.5 for Cement Production, 1984 (ISQC, 2016).

Iraqi Standard	
CaO	> 45 %
MgO	< 2 %
SO_3	< 1 %
Cl	0.5 – 1.0 %
$K_2O + Na_2O$	0.05 %
Fe_2O_3	< 0.1% *

* For white cement only

3. Geology of the Studied Site

The concerned site lies along the northeastern limb of the Ranya anticline, north east of Ranya town. The main geological aspects (Geomorphology, Tectonics and Structural Geology, and Stratigraphy) are briefed hereinafter, depending on Sissakian *et al.* (2014), Fouad (2015), and Sissakian & Al-Jeburi (2014), respectively.

3.1. Geomorphology

The studied site lies physiographically within the High Mountainous Province. The following geomorphological units are developed:

Structural Geological Units: The anticlinal ridges extend longitudinally surounding the anticline. They exist within the Qamchuqa Formation and are potential areas to locate quarries.

Structural – Denudational Units: The flatirons are the main units, they exist within the Qamchuqa Formation; along with the fault and erosional scarps.

Alluvial Units: The alluvial fans are the main geomorphological unit which cover vast areas (Figure 4), and they can be used as a good source for clay deposit, besides being suitable areas for locations of industrial sites. The colluvial deposits exist along the foothills of the Ranya anticline. Flood plain sediments and river terraces are also developed in the studied site.

3.2. Tectonics and Structural Geology

The studied site lies within the High Folded Zone, Outer Platform of the Arabian Plate, which is a part of the Zagros Thrust – Fold Belt. The belt suffers from the stresses exerted by the collision of the Arabian and Iranian plates. Only Ranya anticline exists in the studied site, it has the following charactersitics.

Ranya Anticline: It forms en-echelon plunge with the Korak anticline. The length of the anticline is 45 km trending NW – SE and the southwestern limb is steeper. The axis of the anticline is dissected by faults, which have almost the trend of the axis causing ambiguity of the trend of the axis. Thick alluvial fan sediments cover the south eastern plunge. The oldest exposed formations in the Ranya anticline are of a Lower Jurassic age (Figure 4).

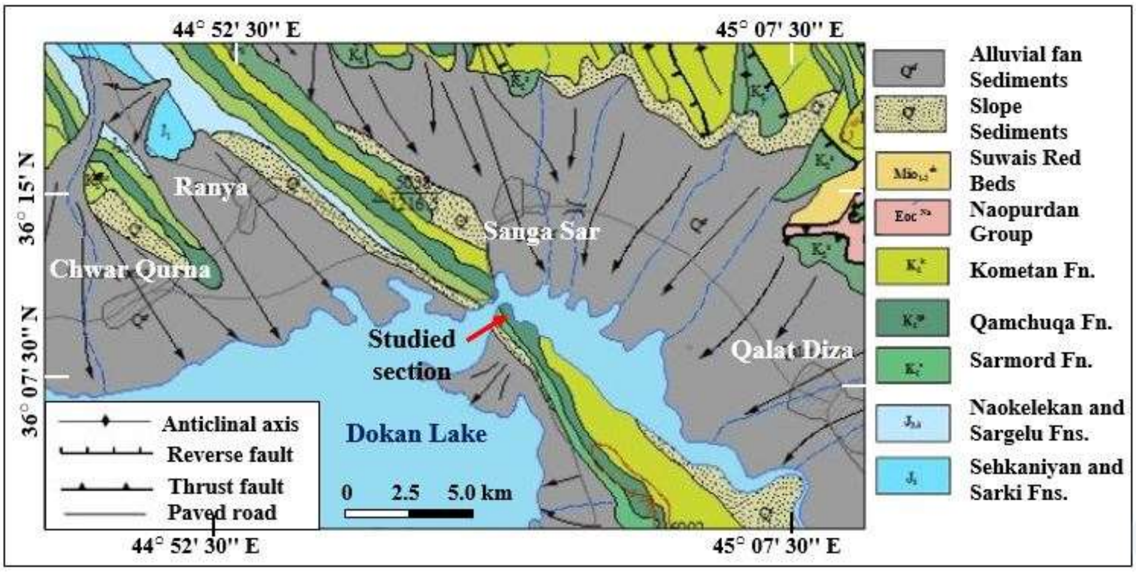

Figure 4. Geological Map of the Studied Site (Sissakian & Fouad, 2015).

3.3. Stratigraphy

The studied section lies within the Qamchuqa Formation. Although many formations are exposed surrounding the studied section (Figure 4), we have described the exposed Qamchuqa Formation only, because it is the target of the current research work.

Qamchuqa Formation (Lower Cretaceous): The formation comprises of massive (Figure 5) limestone, dolomitic limestone and dolomite, usually light and dark grey, and brownish grey, and hard to very hard (Table 1). The thickness of the formation in Ranya it is around 500 m, however, we have only sampled the uppermost 89 m only.

4. Results

The 10 rock samples were uploaded into an XRF equipment to indicate the concentrations of the main oxides (Table 4). The main oxides weighted averages were calculated from the XRF test results for each sample (Table 4). The weighted averages which are used in the industrial assessments were calculated because the sampling interval is not uniform (Tables 1 and 4).

The weighted percentage of each oxide in each sample is calculated by the following equation (IET, 2021)

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

Where C = the percentage of each oxide multiplied by the sample's thickness (T),

The weighted average is calculated as follows:

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

Where W = the weighted percentage of each oxide multiplied by the sample's thickness (T).

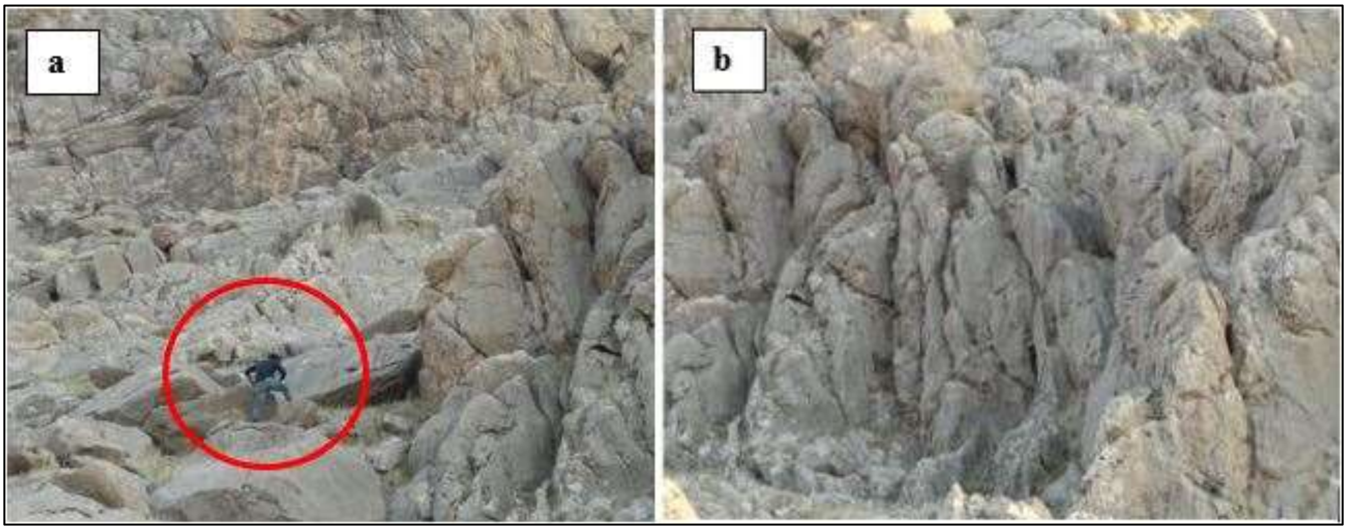

Figure 5. Well Bedded and Massive Beds of the Qamchuqa Formation, a) Sampling Of The Beds; the third author is encircled in red, b) Close up View of the Sampled Beds.

Table 4. The Concentration of Oxides with Weighted Percentages and Averages of the 10 Samples.

Sample No.	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	3	54.52	163.56	1.33	3.99	0.37	1.11	0.31	0.93	0.18	0.54	0.07	0.21	43.97	131.91
2	3	54.77	164.31	1.19	3.57	0.28	0.84	0.31	0.93	0.17	0.51	0.06	0.18	43.56	130.68
3	9	54.43	489.87	1.37	12.33	0.31	2.79	0.31	2.79	0.22	1.98	0.07	0.63	43.85	304.65
4	10	54.57	545.70	1.39	13.90	0.19	1.90	0.30	3.00	0.16	1.60	0.10	1.00	43.82	438.20
5	10	53.79	537.90	1.35	13.50	0.94	9.40	0.35	3.50	0.21	2.10	0.06	0.60	43.60	436.00
6	10	53.99	539.90	1.31	13.10	0.76	7.60	0.32	3.20	0.31	3.10	0.09	0.90	53.71	537.10
7	12	54.52	654.24	1.32	15.84	0.29	3.48	0.30	3.60	0.19	2.28	0.10	1.20	43.70	524.40
8	10	54.82	548.20	1.22	12.10	0.13	1.30	0.30	3.00	0.13	1.30	0.10	1.00	43.92	439.20
9	12	54.86	657.60	1.22	14.64	0.16	1.92	0.30	3.60	0.14	1.68	0.09	1.08	43.30	519.60
10	10	54.94	549.40	1.15	11.50	0.13	1.30	0.30	3.00	0.13	1.30	0.14	1.40	53.65	536.50
Total			4850.68		114.47		31.64		27.55		16.39		8.20		4088.20
Average			54.50		1.29		0.35		0.31		0.18		0.09		45.93

K_2O, MnO, SO_3, and Cl were also analyzed but all of them were below the detection limits of the XRF equipment.

5. Discussion

5.1. Industrial Assessments

The concentrations of the main oxides of the collected 10 samples, and their weighted averages (Table 4) indicate that the 10 samples are pure limestone since the maximum and minimum CaO and MgO concentrations are 54.94% (Sample No. 10), 53.79 (Sample No. 5), 1.39 % (Sample No. 4), and 1.15 % (Sample No. 10), respectively (Table 4). Therefore, we have discussed the industrial assessments of the collected samples by comparing the results with the Iraqi Standards for cement industry (Table 3).

- **Cement Industry:** The main two oxides which control the cement production are CaO and MgO, and both are within the required standards (Table 3, 4 and 5). However, concentrations of SO_3 and Cl^- were not recorded; meaning undictable concentrations. Accordingly, the concentrations will be within the limits of the used standards (Tables 3, 4 and 5). As for white cement the Fe_2O_3 needs to be less than the recorded percentage.

Table 5. Comparison of the Standard of Cement Industry and the Current Study's Results.

Cement Standards		Current Study		Legend	
CaO	> 45.00	54.94		Standards	
MgO	< 2.00	1.29			
Fe_2O_3	< 0.10*	0.31			Within the range
SO_3	< 1.00				
Cl	0.50 – 1.00				Not detected
L.O.I.	> 43.00	46.22			

5.2. Quarrying Conditions

Before selecting a relevant area for sampling, the quarrying conditions were considered, besides considering available relevant area to be the site for a plant. The following aspects were considered:

- No overburden or very thin (Figure 6a),
- No innerburden (Figure 5a),
- Clear bedding and intense jointing (Figure 5a and 6a) which will facilitate quarrying,
- Available water and electricity sources for plant construction (Figure 6b),
- Available area for plant construction (Figure 6b),
- Relevant thickness of the exposed limestone (Figure 7a),
- Possibility of quarrying by bulldozers and excavators (Figure 7b), and
- Availability of main roads nearby the quarry area (Figure 2).

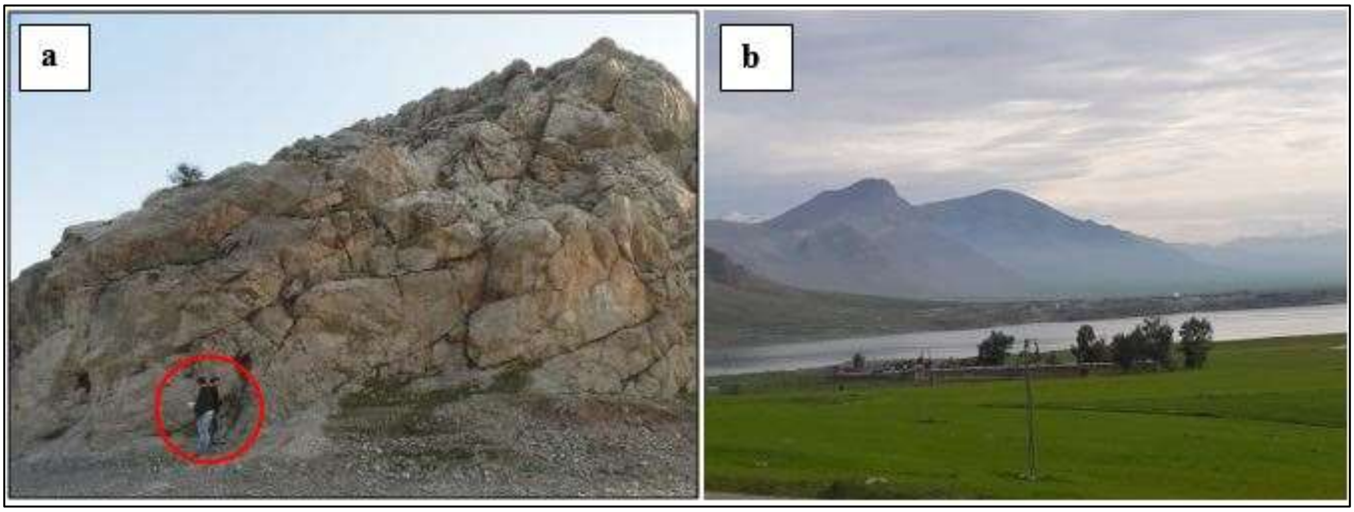

Figure 6. a) The Uppermost Part of the Sampled Section, Note the Absence of Overburden, B) Dokan Lake and Alluvial Fans (Occupied as Agricultural Fields).

5.3. Geological Reserve Estimation for a Cement Plant

The acquired results from analyzing of the 10 collected limestone samples showed very interesting and encouraging results for different industries; however, the results are more suitable for the construction of a cement plant (Tables 3, 4 and 5), besides the available mentioned quarrying conditions. Consequently, a geological reserve estimation can be considered by using the acquired chemical data for the weighted averages of Cao and MgO concentrations, which are 54.50% and 1.29%, respectively.

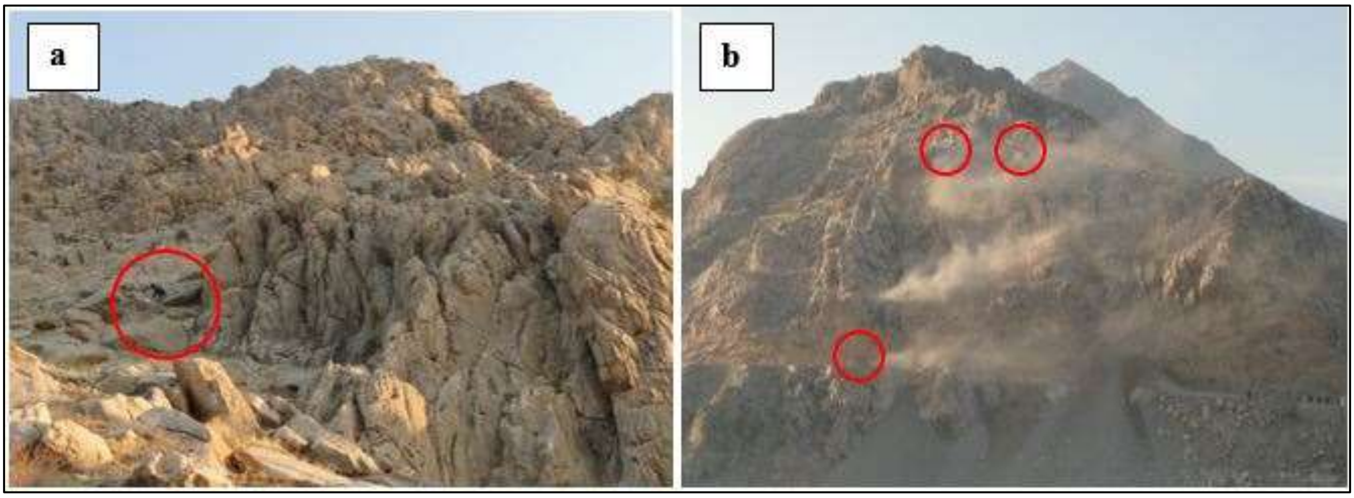

Figure 7. a) The Upper Part of the Sampled Section, Compare the Thickness of the Sampled Section with the Author's Height; circled by red, b) Mechanical Ripping of the Rocks by Bulldozers and Excavators; circled by red (During the Widining of the Road in the Opposite Side of the Sampled Section).

This is an assumption about a quarry area of 0.5 km^2, then the geological reserve can be calculated as follows:
The surface area = 250,000 m^2
The thickness of the sampled part = 89 m, and we will consider it 90 m,
The volume of the limestone within the supposed quarry = 250,000 X 90 = 22,500, 000 m^3
The average density of the limestone is about 2,400 kg/ m3,
The weight of the limestone which can be quarried = 2400 X 22,500,000 = 54 X 10^9 kg,
= 54,000,000 tons.

The second raw material for the raw mix in cement production is clay, which is available in the sampled area where huge alluvial fans cover the whole flat area (Figures 2, 4 and 6b). The added clay to the raw mix is about 30 – 40 % of the used limestone.
Therefore, 35% of 54,000,000 = 18,900,000 tons
Total used raw mix = 54,000,000 + 18,900,000 = 72,900,000 tons
If the daily production of a cement plant is 3,500 tons, then the used quantitiy of the raw mix is about 7,000 tons/day, accordingly means:
72,900,000 ÷ 7,000 = about 10410 days, which is about 29 years.

The acquired result of the tested samples showed that the limestone beds are homogeneous along the sampled section (Table 4). This means the limestone beds surrounding the sampled section have almost the same chemical composition. Therefore, the area of the suggested quarry can be extended; consequently, the calculated geologic reserves will be more than the estimated. However, we have to emphasize that this is a prelimenary reserve estimation with a Low Level of Confidence according to JORC (1999). Therefore, it cannot be used for investments, unless, relevant site investigation is carried out to estimate the reserve with High Level of Confidence according to JORC (1999) which accordingly can be used for investment. The detailed site investigation should include boreholes' drilling of continuous core with spacing not more than 150 m and core sampling of one-meter interval, and the analyzing of all collected samples.

6. Conclusions

From the acquired results of the this study, the following can be concluded: the exposed beds within the Qamchuqa Formation in the studied section are pure limestone. The exposed limestone can be used for cement production using available clay within the alluvial fan sediments. However, the acquired results cannot be used for investment of the rocks in the studied section, since the curried out work is a preliminary evaluation for the studied rocks.

Acknowledgment

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