IRAQI BULLETIN OF GEOLOGY AND MINING (IBGM)\
IRAQ GEOLOGICAL SURVEY (GEOSURV-IRAQ)

*IBGM (**2025**, Vol 21; Issue 2)* *85-97*

THE SUITABILITY OF THE LIMESTONE BEDS OF THE BEKHME FORMATION FOR CEMENT PRODUCTION EAST OF AQRA TOWN, KURDISTAN REGION OF IRAQ

Varoujan K. Sissakian[1*], Nadhir Al-Ansari[2], Salahalddin S. Ali[3] and Iyda D. Abdulahad[4]

[1] Chief Researcher, Department of Petroleum Engineering, Komar University of Science and Technology, Sulaymaniyah, KRG, Iraq, varoujan49@yahoo.com; varoujan.sissakian@komar.edu.iq.
[2] Professor, Department of Civil, Environmental and Natural Resources Engineering, Lulea University of Technology, Sweden, nadhir.alansari@lut.se. ORCID: 0000-0002-6790-2653
[3] Professor, President of Komar University of Science and Technology, salah.saeed@komar.edu.iq. ORCID: 0000-0002-0337-4839
[4] Senior Chief Geologist, Iraq Geological Survey, Baghdad. **Deceased**
***** Correspondence: e-mail: varoujan49@yahoo.com; varoujan sissakian (ORCID: 0000-0002-9840-5422)

Type of the Paper (Article)
Received: 17/02/2025
Accepted: 08/05/2025
Available online: 27/12/2025

Abstract

The Peris Mountain (anticline) is long and wide, located in the northern part of the Iraqi Kurdistan Region (IKR), and the trend of the anticline is almost east–west. The studied rocks belong to the Bekhme Formation, which consists mainly of limestone. We selected the site for sampling to be relevant for a quarry, taking into consideration the thickness of the exposed rocks, no overburden, favorable quarrying faces, hardness of the rocks, bedding nature, good extension of the outcrops, and a favorable place for the construction of a cement plant. Moreover, it is far from inhabited areas like villages and other residential sites. We sampled the rocks of the Bekhme Formation, and a total of 15 samples were collected. The sample collection was systematically arranged in an interval of (5 to 10) m to represent the studied section. The samples were checked in a laboratory by XRF to measure the percentage of the required oxides and other elements, which are used in the assessment process to indicate the suitability of the studied rocks for cement production. The acquired data showed that the studied rocks can be used in the cement industry.

Keywords: limestone; quarry; cement industry; CaO; MgO; overburden.

1. Introduction

The capital of IKR is Erbil, which is witnessing, like all other towns and cities of the governorate, large extensions in the infrastructure. Therefore, cement is one of the priorities and is needed in large quantities to perform the existing projects. It is worth mentioning that only one cement plant is available in Erbil, which is located 35 km south of Erbil city;

ISSN 1811-4539, EISSN 3005-3714
https://doi.org/10.59150/ibgm2102a05
IBGM: http://ibgm-iq.org/
Academic Scientific Journals: www.iasj.net

accordingly, the amount of cement from the existing cement plants is not enough. Therefore, the amounts of cement are transported from Sulaymaniyah Governorate, which is about 150 km northwest of Erbil city, where 5 cement plants exist. This large difference between the number of existing cement plants is due to the type of exposed rocks within the existing geological formations in Erbil Governorate, as the geological conditions are concerned.

We selected a deep-cut valley that forms a wine glass form, along the southwestern flank of Peris Mountain, about 16 km east of Aqra town (Figure 1), where no village exists, keeping the green environment.

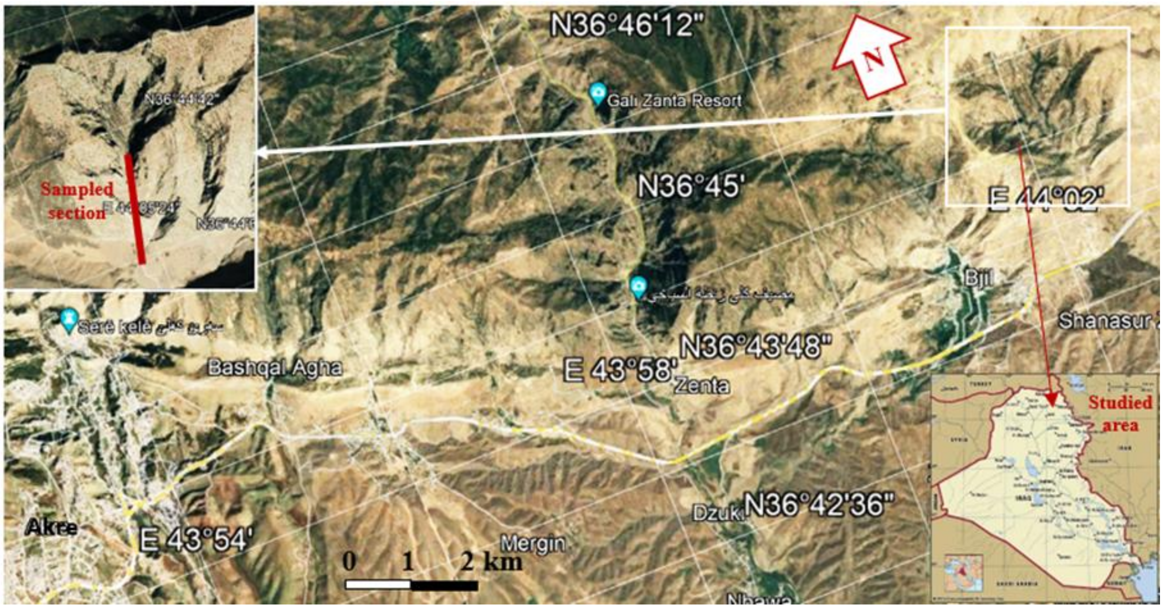

Figure 1. Google Earth image of the location of the studied section.

The samples section is linked to Erbil city via a main road with a distance of about 95 km. It is also located along the main road between Erbil and Aqra-Duhok cities, and furthermore, along the main road to Zakho town and further northwestwards to Turkey. The coordinates of the top and bottom of the section are: 36°44'31.46" N, 44°05'25.64" E, and 36°44'10.26" N, 44°05'23.51" E, respectively, and the elevation of the base and top of the section is 958 m (a.s.l.) and 813 m (a.s.l.), respectively.

Different studies were performed to check the suitability of exposed limestone beds for cement production; among them are: Rufaie &Muhamad (1976) studied the exposed carbonate beds at the Qara Chough anticline and found suitable rocks that can be used in cement production. Etabi and Ahmed (1979) studied carbonate beds at Taslujan and found suitable rocks for cement production. Mansur (1979) evaluated the exposed limestone beds in the Kirkuk, Erbil, and Sulaymaniyah areas, looking for suitable raw materials for cement production. Al-Murib (1980) evaluated the limestone beds at the Qara Chough anticline and found good quality and quantity of rocks that can be used in cement production. Hafidh et al. (2011) and Hafidh and Khlaif (2007) studied the exposed rocks near the Darbandi Khan area and found suitable rocks for the cement industry. Hafidh and Abdul Hassan (2008), Hafidh et al. (2008a, 2008b, and 2008c) studied limestone beds at Qara Chough Mountain, Sartak Bammu vicinity, Agh Jallar vicinity, and west of Sulaimaniyah city. They discovered enormous amounts of deposits that can be used for cement production. Mirza (2012) discussed the mineral phases during Portland cement production. Merza et al. (2016) studied the carbonate rocks of the Naopurdan Group in the Chwarta area for the cement industry. Abdula & Khailany (2016) studied the rocks of the Shiranish Formation in Shaqlawa vicinity for cement production. Sissakian et al. (2019) studied the Pila Spi Formation in the Permian anticline and found good quality and an enormous quantity of deposits suitable for the cement industry. Ghafur et al. (2019) checked the rocks of the Bekhme Formation at Galley Ali Beg Gorge. They found relevant deposits for the cement industry. Fatah et al. (2020) evaluated the suitability of the Aqra Formation for the cement industry. Sissakian et al. (2020) checked the limestone beds of the Pila Spi Formation east of Koya town and found huge deposits, which can be used for cement production. Fatah & Merza (2021) studied the Avroman Limestone for the cement industry. Khudur & Aqrawi (2022) evaluated the limestone of the Jeribe Formation in the Bekhair anticline for cement production. Sissakian & Ghafur (2024) studied rocks of the Shiranish and Bekhme formations on the top of Safeen Mountain and found excellent deposits for cement production. Fatah (2024) studied the chemical specification of the used raw materials in the cement industry at the Gasin cement plant, Sulaiamaniyah. Fatah & Qader (2024) evaluated the limestone of the Kometan Formation for the cement industry. Mohammed & Al-Hazaa (2024) evaluated clay and limestone deposits in the Bazian vicinity for the cement industry. Surdashi & Aqrawi (2024) studied and evaluated Cretaceous-Tertiary limestone and clay deposits in Erbil Governorate for the Portland cement industry.

This research work aims to check the possibility of using the carbonate rocks of the Bekhme Formation for cement production. The studied section is located east of Aqra town along the southwestern limb of the Peris anticline. The enormous amount of limestone beds and the existing quarrying conditions are courageous to performing the current research work.

2. Geology of the Studied Area

The geology of the studied area is briefed, including Geomorphology (Sissakian et al., 2014), Stratigraphy (Sissakian & Al-Jiburi, 2014), and Structural Geology (Fouad, 2015).

2.1. Geomorphology

The following main geomorphological units were recognized:

- **Anticlinal ridges and flat irons** (Figure 2) are recognized in the rocks of the Bekhme Formation, which can serve as a suitable quarrying location.

- **Alluvial Fans**, the deposits of the alluvial fans are well developed and form a continuous belt around the Peris anticline and cover large flat areas (Figure 3). The fans consist of fine materials, although rock fragments of different sizes occur on the top of the alluvial fans. These deposits can be used as clay needed in cement production.

- **Canyons and Wine Glass forms** are well-developed near the studied section (Figures 1 and 4), and they can be used as excellent quarrying faces.

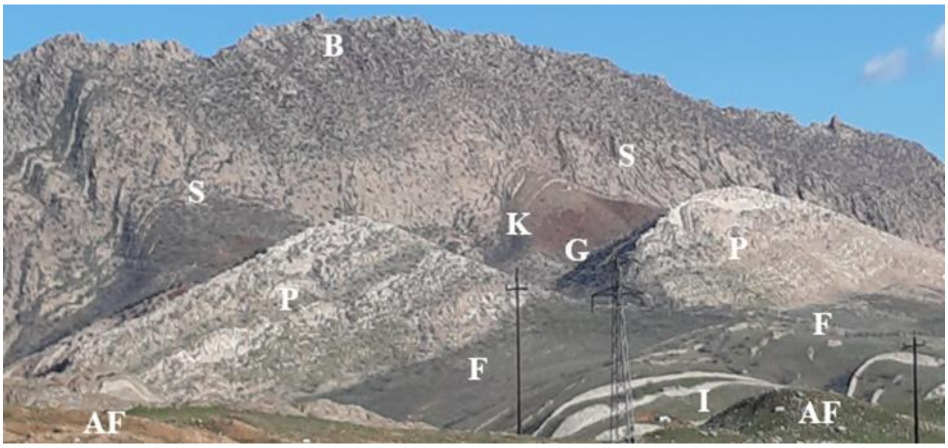

Figure 2. The Bekhme (B), Shiranish (S), Kolosh (K), Gercus (G), Fatha (F), and Injana (I) formations, and Alluvial fans (AF). Note the continuous anticlinal ridges and flat irons.

Figure 3. Alluvial fan sediments and residual soil cover large flat areas.

Figure 4. A canyon developed in the Bekhme Formation, west of the section. Note the thick beds of the Bekhme Formation.

2.2. Tectonics and Structural Geology

The Peris anticline lies within the High Folded Zone, which is located within the Outer Platform of the Arabian Plate. It is developed due to the convergence of the Arabian and Iranian plates (Alavi 2004; Fouad 2015). The collision of both plates has developed tens of anticlines within this zone; some of those anticlines exhibit thrust faults and overturned, such as the Peris anticline (Figure 5). A thrust fault exists along part of the southwestern limb of the anticline, causing a steep high cliff along which the Bekhme Formation overlies the Shiranish Formation (Figure 5).

Figure 5. A long thrust fault, the Bekhme Formation (B) is thrusted over the Shiranish (S) and Kolosh (K) formations, leading to overturned beds.

3. Materials and methods

To select a relevant section for sampling where clear beds are exposed and existing good quarrying conditions, we used the geological map of the Erbil Quadrangle at a scale of 1:250000 to indicate the best locations of the exposures of the Bekhme Formation. Moreover, the selected site is to be far from villages and other residential sites to keep the environment as clean as possible after the quarrying and cement production processes. The limestone beds were sampled, described, and checked in the field. The sampling interval was between (5 – 10) m (Table 1). The samples were collected as channel samples to represent the sampled section. The collected samples were saved in relevant sacks, numbered, and described in the field (Table 1). The total number of the collected samples is 15, with a thickness of 104 m.

3.1. Sample Preparation

We grained to powder the collected 15 samples using an electrical grinder. Then we mixed well each powdered sample well. Ten grams of each powdered sample was pressed into a pellet and dried in an oven for 120 minutes. After drying, the 15 collected samples were mounted in XRF equipment to measure the percentages of the required oxides and other elements, which are used to check whether the samples can be used for cement production or otherwise. The acquired results are presented in Table 2.

Table 1. Field description of the 15 samples within the study area.

Sample No.	Rock Name	Color	Hardness	Thick. (m)	Reaction with HCl	Description
1	Lst.	Light gr.	H	5	H	Th. B.
2	Lst.	Light br.	V H	10	H	Mass.
3	Lst.	Light gr.	H	5	H	Th. B.
4	Lst.	Light gr.	H	5	H	Th. B.
5	Lst.	Light gr.	H	5	H	Th. B.
6	Lst.	Light br.	V H	10	H	Mass.
7	Lst.	Light gr.	H	5	H	Th. B.
8	Lst.	Light gr.	H	5	H	Mass.
9	Lst.	Gr.	H	5	H	Mass.
10	Lst.	Light gr.	H	8	H	Th. B.
11	Lst.	Light gr.	H	5	H	Th. B.
12	Lst.	Light gr.	V H	10	H	Th. B.
13	Lst.	Light br.	H	8	H	Mass.
14	Lst.	Light br.	H	8	H	Th. B.
15	Lst.	Light br.	H	10	H	Th. B.
Total thickness				104		

Lst. = Limestone, gr. = grey, br. = brown, H = High, VH = Very High, Th. B. = Thickly bedded, Mass. = Massive

Table 2. The XRF test results of the collected samples.

Sample No.	CaO %	MgO %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	Na_2O %	K_2O %	SO_3 %	Cl %	L.O.I. %
1	55.24	0.24	0.23	0.86	0.17	0.13	0.12	1.98	1.23	44.34
2	55.58	0.19	0.11	0.86	0.17	0.97	0.78	1.30	2.4	46.05
3	54.98	0.44	0.18	0.78	0.01	0.12	0.25	0.04	0.11	43.13
4	54.89	0.39	0.17	0.76	0.02	1.45	1.21	0.05	0.34	40.59
5	55.09	0.30	0.20	0.75	N.D.	N.D.	N.D.	N.D.	0.34	43.31
6	54.99	0.31	0.19	0.76	0.01	0.13	0.23	0.29	0.14	43.25
7	55.27	0.21	0.19	0.76	0.01	N.D.	N.D.	N.D.	N.D.	43.46
8	55.15	0.24	0.26	0.76	0.02	0.15	0.18	0.25	1.01	42.97
9	55.10	0.22	0.13	0.78	0.02	N.D.	N.D.	N.D.	1.11	42.74
10	55.42	0.18	0.28	0.75	0.02	0.17	0.23	0.03	0.43	42.91
11	55.14	0.19	0.14	0.77	0.02	N.D.	N.D.	0.10	0.54	42.90
12	55.19	0.18	0.21	0.75	0.01	N.D.	N.D.	0.12	0.61	42.93
13	54.42	0.19	0.21	0.71	0.03	0.15	0.22	N.D.	0.46	42.88
14	55.09	0.21	0.18	0.74	0.11	0.18	0.19	0.10	0.52	42.89
15	54.19	0.35	0.27	0.69	0.03	0.15	0.20	0.12	0.63	42.90

3.2. Weighted Percentages (WP) and Weighted Averages (WA)

The acquired results of the oxides, Cl, and L.O.I. (Table 2) of the 15 samples were converted to WP and then to WA. This was done because the sampling interval in the sampled section ranged between 5 and 10 m. Accordingly, to have representative oxide percentages that are used in the assessment of the rocks for cement production, the weighted averages were calculated (IET, 2021).

The WP of the oxides and elements is calculated by equation (1):

$$(WP = (\sum[\mathrm{W1} + \mathrm{W2} + \mathrm{W3} + \mathrm{W4} + \mathrm{Wi}])/\sum[\mathrm{Th1} + \mathrm{Th2} + \mathrm{Th3} + \mathrm{Th4} + \mathrm{Thi}]) \qquad (1)$$

Where W = the percentage of each oxide multiplied by the sample's thickness (Th),

The WA is calculated by equation (2)

$$WA = (\sum[\mathrm{W1} + \mathrm{W2} + \mathrm{W3} + \mathrm{W4} + \mathrm{Wi}])/\sum[\mathrm{Th1} + \mathrm{Th2} + \mathrm{Th3} + \mathrm{Th4} + \mathrm{Thi}]) \qquad (2)$$

Where W = the WP of each oxide multiplied by the sample's thickness (Th).

The acquired results from equations (1 and 2) are presented in Table 2. Then, the total WA of each oxide and other parameters was divided by the thickness of the sampled section (104 m), and the results are shown in Table 3. The averages of the WA were checked with the Iraqi Standards (2016) for the cement industry (Table 4).

Table 3. The WA results for the 15 studied samples.

Sample	**Thick.**					**W A (%)**					
No.	**(m)**	**CaO**	**MgO**	**SiO_2**	**Fe_2O_3**	**Al_2O_3**	**Na_2O**	**K_2O**	**SO_3**	**Cl**	**L.O.l.**
1	5	276.20	1.90	1.15	4.30	0.85	0.65	0.60	9.90	6.15	221.70
2	10	555.80	1.9	0.66	5.16	1.02	5.82	4.68	7.80	14.40	276.90
3	5	274.90	2.20	0.90	3.90	0.05	0.60	1.25	0.20	0.55	215.65
4	5	274.45	1.95	0.85	3.80	0.10	7.25	6.05	0.25	1.70	202.95
5	5	275.45	1.50	1.00	3.75	N.D.	N.D.	N.D.	N.D.	1.70	216.55
6	10	549.90	3.10	1.9	7.60	0.10	1.30	2.30	2.90	1.40	432.50
7	5	276.35	1.05	0.95	3.80	0.05	N.D.	N.D.	N.D.	0.0	217.30
8	5	275.75	1.20	1.30	3.80	0.10	N.D.	N.D.	N.D.	0.0	214.85
9	5	275.50	1.10	0.65	3.90	0.10	N.D.	N.D.	N.D.	5.55	213.70
10	8	277.10	0.90	1.40	3.75	0.10	N.D.	N.D.	N.D.	2.15	214.55
11	5	275.70	0.95	0.70	3.85	0.10	N.D.	N.D.	N.D.	2.70	214.50
12	10	441.52	1.44	1.68	3.75	0.08	N.D.	N.D.	0.96	4.88	343.44
13	8	435.36	1.52	1.68	5.68	0.24	1.20	1.76	N.D.	3.68	343.04
14	8	440.72	1.68	1.44	5.92	0.88	1.44	1.52	0.80	4.16	343.12
15	10	541.90	3.50	2.70	6.90	0.30	1.50	2.00	1.20	6.30	429.00
Total	104	5446. 6	25.89	18.96	69.86	4.07	19.76	20.16	24.01	55.32	4099.75
Average		52.37	0.25	0.18	0.67	0.04	0.19	0.19	0.23	0.53	39.42

Table 4. Iraqi Standards for cement production (Iraqi Standards, 2016).

Iraqi Standard (ISQC, 2016)	
CaO	> 45 %
MgO	< 2 %
SO_3	< 1 %
Cl	0.5 – 1.0 %
$K_2O + Na_2O$	0.5 %
Fe_2O_3	< 0.1% *

4. Results

The acquired data of the WA of the 15 samples (Table 3) were compared with the Iraqi Standards (ISQC 2016) for cement production (Table 4) to designate whether the samples are suitable for cement production or otherwise. The results are mentioned below.

- **Limestone:** The average of the WA of each oxide (Table 3) was compared with the Iraqi Standards (Table 4). The acquired results from the comparison showed that the whole sampled succession (104 m) at Peris Mountain can be used in cement production. However, the Fe2O3 content is higher than 0.1 % (Table 3); therefore, according to the Iraqi specifications, the limestone cannot be used for white cement production (Table 4).

- **Clay Deposit:** The used clay in the raw mix may reach about 40%. The alluvial fan sediments are developed on the slopes of the Peris anticline and include large amounts of clay (Figure 3). The clay deposits include limestone fragments, which are rolled down from the high cliffs of the Bekhme Formation (Figures 2 and 4); their thickness varies from 1 to 12 m. Moreover, many exposed formations south and southwest of the studied site (Figure 3) contain large thicknesses of claystone that are weathered and formed residual clayey soil (Figure 3), which can be used as clay.

- **Gypsum Deposit:** Gypsum is usually added to the clinker in the cement production steps as a retarder for the cementation duration of the concrete or in any other use of the produced cement. Gypsum is not available in commercial amounts to be quarried and used in cement production; however, the Fatha Formation includes many gypsum beds in the studied site (Sissakian & Fouad, 2014). However, gypsum is available in commercial amounts at Agh Jalar vicinity, which is about 120 km SE of the sampled section; accordingly, it forms one of the main negative points as the sampled area is concerned. This negative point exists in the majority of places in the KRI.5.

Discussion

In Erbil, the capital of the Kurdistan Region of Iraq, there is only one cement plant, and another one is under construction and started production in April 2025. Whereas in Sulaimaniyah Governorate, which is smaller than Erbil Governorate, there are five cement plants with an average yearly production of about 5 million tons. Therefore, finding suitable limestone deposits for cement production is very urgent. Therefore, we chose a relevant site for sampling the exposed rocks and checking for their suitability for cement production and relevant quarrying conditions.

The acquired data (Table 2) showed that the sampled succession is excellent for use in the cement industry (Tables 2, 3, and 4). Moreover, the quarrying conditions at the sampling site and nearby surroundings (Figures 1, 2, and 4) are excellent, as indicated by:

- No overburden (Figures 2 and 4), not only in the studied section but also in the majority of Peris Mountain,
- The existence of high cliffs and flat irons (Figures 2 and 4) is very suitable for the quarrying of the limestone beds,
- The alluvial fans' sediments (Figure 3) and the claystone beds within the exposed geological formations (Figure 2) can be used as clay deposits for cement production,
- The flat and large areas along the foothills of Peris Mountain (Figure 3) are suitable sites for the construction of the cement plant,
- There are no villages around the sampled site; therefore, there will be no negative environmental impact on the living people in the villages.
- The presence of a main paved road that runs parallel to Peris Mountain (Figures 1, 3, and 6) and connects the main cities and towns in Erbil Governorate is a positive issue for site selection.
- The presence of a high-tension line (Figure 3) near the site will facilitate the electrical power, and
- No villages or other inhabited sites occur within 5 km of the selected site.

The results of the weighted averages (Table 3) show that the concentration of the calcium carbonate ($CaCO_3$) within the sampled limestone beds is very high (92.57), indicating pure calcium carbonate, which is very suitable for the drug industry (CONGAL, 2021).

The $CaCO_3$ is one of the most popular mineral fillers used in different industries.

Figure 6. The main paved road that runs parallel to Peris Mountain also shows the huge thickness of the Bekhme Formation in the background.

6. Conclusions

The indicated weighted averages from chemical analysis for the 15 collected limestone samples indicated pure limestone with $CaCO_3$ attaining 92.57% (Minimum CaO is 54.19%, whereas maximum MgO is 0.44%). Therefore, it can be used for the cement industry. The existing favorable conditions and the presence of clayey soil near the sampled section and the surroundings are other favorable raw materials for the cement industry. The purity of the calcium carbonates is highly recommended to be used in the drug industry, besides other industrial uses, such as paint, paper, rubber, and plastic.

Acknowledgments

The authors express their gratitude to the involved universities for their continuous support while conducting the current research.

Author Contributions

Conceptualization; methodology including methodological development; investigation; resources; writing initial draft; and writing, reviewing, and editing by Mr. Varoujan Sissakian. Conceptualization; methodology; investigation; writing initial draft; by the Late Iyda Abdulahad. Writing, reviewing, and editing the final version by Dr. Nadhir Al-Ansari and Dr. Salahalddin S. Ali.

Deceased Author

This is to confirm that the Late Iyda Abdulahad was the wife of Mr. Varoujan Sissakian. She passed away on 25 June 2024, suffering from cancer, after the majority of the manuscript was written.

Funding Declaration

All authors declare that there was no funding during the preparation of this manuscript.

References

Abdula, R.A, & Khailany, R.N.S. (2016). Shiranish Formation in Garota (Shaqlawa, North Iraq) as Raw Material for Portland Cement Manufacturing. *Iraqi Bulletin of Geology and Mining*, 12 (1): 65-72.

Alavi, M. (2004). Regional stratigraphy of the Zagros Fold – Thrust Belt of Iran and its proforeland evolution. *American Journal of Science*, 304: 1 – 20.

Al-Bassam, K., & Al-Khafaj, A.A. (2011). Work Procedures of Iraq Geological Survey, Part 13: Mineral Exploration. Iraq Geological Survey Library Report No. 2133.

Al-Murib, S., (1980). Report on prospecting works on limestone for cement industry in southern Qara Chouq Mountain. Iraq Geological Survey Library, report no. 1057

Al-Rufaie, A., & Muhamad, S., (1976). Report on the geological prospecting of limestone deposit suitable for cement purpose at Qara Choug Mountain, Khoshao locality, Arbil. Iraq Geological Survey Library, report no.1786

Etabi, W., & Ahmed, S. (1979). Final report on prospecting exploration of Tasluja limestone deposit suitable for Portland cement. Iraq Geological Survey Library, report no. 961

Fatah, Ch., (2024). Geochemical Specifications for Raw Materials Used in Gasin Cement Factory in Kurdistan Region, NE-Iraq. *Iraqi Bulletin of Geology and Mining*, 20 (1): 127-138.

Fatah, Ch., & Merza, T. (2021). Assessment of Avroman Limestone Formation for Portland Cement Industry, Halabja Area, Kurdistan Region, NE-Iraq. *Iraqi National Journal of Earth Sciences*, 21(2):29-48.

Fatah, Ch., & Qader, B.O. (2024). The Petrography and Geochemistry of Limestone Upper Cretaceous Kometan Formation (Azmir Anticline): A Preliminary Assessment for Cement Production Suitability in the Kurdistan Region, Northeast Iraq. *Iraqi Bulletin of Geology and Mining*, 20 (1): 89-102.

Fatah, Ch., Karim, K.H., & Merza, T. (2020). Geological study of Aqra Formation for possible use as Portland cement in Chwarta-Mawat area, Sulaimani, Iraqi Kurdistan Region. *Journal of Zankoy Sulaimani - Part A*, 22(1):15-25. DOI: 10.17656/jzs.10771

Fouad, S.F. (2015). Tectonic Map of Iraq, scale 1: 1000000, 3rd edition. *Iraqi Bulletin of Geology and Mining*, 11 (1): 1-8.

Ghafur, A.A., Sissakian, V.K., & Bapir, A.M. (2020). Industrial Assessment of the Rocks of the Bekhme Formation in Korek Mountain, Iraqi Kurdistan Region. *Carbonates and Evaporates*, 36 (1): 1 – 10.

Hafidh, SQ., & Khlaif, H.O. (2007). Mineral exploration and reserve estimation in category C1 of the carbonate rocks suitable for cement manufacturing at Tasluja, Sulaimaniyah, on the behalf of Sarchinar Cement Plant. Iraq Geological Survey Library report no. 3038

Hafidh, Sh.Q., & Abdul Hassan, A. (2008). Exploration of limestone suitable for cement industry in categories C1 and B at Sartak, south of Derbendikhan. Iraq Geological Survey Library Report No. 3125 a (In Arabic).

Hafidh, Sh.Q., Ruhman, A., Abid Al-Abaas, F., Rasheed, A.Y., & Qanbar, A.Sh. (2008 a). Preliminary geological studies of limestone suitable for cement industry in Sartak and Kani Kel Vicinity, southeast of Darbandi Khan Southeast of Sulaimaniyah Governorate. Iraq Geological Survey Library Report No. 3125 b.

Hafidh, Sh.Q., Salih, H.A., & Mahmoud, A.A. (2008 b). Preliminary studies on limestone suitable for cement industry, in Agh Jallar vicinity, on the behalf of Mawlawi Co., Iraq Geological Survey Library Report No. 3128 (In Arabic).

Khudur, H., & Aqrawi, A. (2022). Assessment of Limestone of Jeribe Formation for Ordinary Portland Cement Industry in Bekhair Anticline, Duhok Governorate. *Iraqi Kurdistan Region. Iraqi National Journal for Earth Science*, 22 (2): 90-104. DOI: 10.33899/earth.2022.135129.1022.

Hafidh, Sh.Q., Salih, H.A., Abdul Abbas, A.H. (2008 c). Preliminary geological studies on limestone suitable for cement industry, west of Suliamaniyah, on the behalf of Washa Co., Iraq Geological Survey Library Report No. 3127.

Hafidh, Sh.Q., Al-Jiburi, B.S., & Basheer, W.Ph. (2011). Detailed Geological Survey at Scale of 1:5000 in Southern Qara Chauq Mountain, Block /A, for Investigation of Limestone Suitable for Cement Industry in Behalf of Kar Company. Iraq Geological Survey Library Report No. 3400.

Mansour, J., (1976). Reconnaissance of the Kirkuk, Erbil, Sulaimaniyah area on search for raw materials in connection with proposed cement works. Iraq Geological Survey Library, report no. 768.

Merza, T., & Fatah, Ch. (2018). Evaluating the Suitability of Avroman Limestone, Halabja Governorate, for Cement Industry. *Iraqi Bulletin of Geology and Mining*, 14 (1): 103-120.

Merza, T., Mohialdeen, I.J., Hakari, S.S. & Fatah, Ch.M. (2016). Geochemical assessment of Naopurdan limestone for cement making - Chwarta area, Kurdistan Region, NE Iraq. *Journal of Zankoy Sulaimani* - Part A · May 2016. DOI: 10.17656/jzs.10484

Mirza, T., (2012). Composition and phase mineral variation of Portland cement in Mass Factory, Sulaimani, Kurdistan Region, NE- Iraq. *International Journal of Basic & Applied Sciences IJBAS-IJENS*, 12 (06): 109-118.

Mohammed, O.M., & Al-Hazaa, S.H. (2024). Evaluation of Clay Deposits and Limestone for the Manufacture of Ordinary Portland Cement in the Bazian Basin, Northern Iraq. *Iraqi Geological Journal*, 57 (2F), 39-55.

Sissakian, V.K., (2018). The Minerals Wealth in Kurdistan Region: A Critical Review. *University of Kurdistan Helwer Journal of Science and Engineering*, 2(2):23 – 36.

Sissakian, V.K., & Al-Jiburi, B.M. (2014). Stratigraphy of the High Folded Zone. *Iraqi Bulletin of Geology and Mining*, Special Issue 6: 73 – 16.

Sissakian, V.K., & Ghafur, A., (2024). Industrial Assessment of the exposed rocks on Safeen Mountain, Kurdistan Region of Iraq. *Iraqi Geological Journal*, 57 (1A):169- 178.

Sissakian, V.K., Kadhim, T.H., & Abdul Jab'bar, M.F. (2014). Geomorphology of the High Folded Zone. In: Geology of the High Folded Zone. *Iraqi Bulletin of Geology and Mining*, Special Issue 6: 7 – 56.

Sissakian, V.K., Hamoudi, D.A., Omer, H.O., & Niazi, S.A. (2019). Assessment of the Carbonate Rocks of the Pila Spi Formation for Cement Industry, in Permam Mountain, Erbil, Iraqi Kurdistan Region. *University of Kurdistan Helwer Journal of Science and Engineering*, 3 (1), 1 – 9.

Sissakian, V.K., Ahmed, J.M., & Ibrahim, R.K. (2020). Industrial Assessment of the Carbonate Rocks of the Pila Spi Formation at Haibat Sultan Mountain, Iraqi Kurdistan Region. *ARO,* 8 (1) 24 – 30. http://aro.koyauniversity.org/article/view/ARO.10546

Surdashi, A., & Aqrawi, A. (2024). Evaluation of Cretaceous-Tertiary Limestones and Clay for Portland Cement in Erbil, Kurdistan Region of Iraq. Iraqi Geological Journal, 57 (2C): 184-209. https://doi.org/10.46717/igj.57.2C.14ms-2024-9-22

About the author

Varoujan K. Sissakian: Born in Baghdad, 09 October 1949, graduated from the Geology Department, University of Baghdad in 1969 (B.Sc.) and from I.T.C., the Netherlands in 1982 (M.Sc. Engineering Geological mapping). He joined the Iraq Geological Survey (GEOSURV) on 13/11/1971 and retired on 09/10/2012. He was assigned as an Expert in 2004.

He has 125 documented geological reports in the library of GEOSURV, 278 published papers in Iraqi and international journals, and another 16 manuscripts at different reviewing steps. His name is mentioned as an author on the Geological Map of the World, Asian continent at a scale of 1:5000000. His major interests are: Geological mapping, Stratigraphy of Iraq, Geological Hazards, and Site investigation. He is the author of the Geological map of Iraq at a scale of 1:1000000, 3rd & 4th editions (2000 and 2015), Neotectonic map of Iraq at a scale of 1:1000000 (1998), Geological Hazards map of Iraq at a scale of 1:1000000 (2005), and Nine geological maps at a scale of 1:250000 among 36 quadrangles, which cover the whole of Iraq, and