Scientific Journal for the Faculty of Science-Sirte University Vol. 4, No. 2 (2024) 15-32

Scientific Journal for the Faculty of Science-Sirte University

Journal home page: http://journal.su.edu.ly/index.php/JSFSU/index

DOI: 10.37375/issn.2789-858X

Mineral Composition of Coastal Landforms in Wadi Al-Suwani at Al-Bardia Region, East of Tobruk City, Libya

Mohamed Masoud[1] and Belkasim Khameiss[2]

[1]*Faculty of Natural Resources and Environmental Sciences, University of Tobruk, Tobruk-Libya.*

[2]*Kansas Geological Survey, University of Kansas, Lawrence. KS. USA.*

DOI: 10.37375/ sjfssu.v4i2.2906

ARTICLE INFO:

Received 11 August 2024.

Accepted 28 August 2024.

Published 26 October 2024.

Keywords: *Wadi Al Suwani, Sabkha, Cliffs, Beach, Tobruk, Al Bardia*

A B S T R A C T

This study investigates the mineralogical composition of coastal geomorphological units, including sabkhas, rock cliffs, and beach sands, along the Wadi Al-Suwani shoreline near Burdi village in east of Libya. The research aimed to characterize these landforms, focusing on their geochemical and mineralogical properties, to better understand the processes shaping this unique coastal landscape. A total of fifteen samples were collected during field trips in August and September 2022, spanning various geomorphological units such as sabkhas, rock cliffs, and beaches. X-ray diffraction (XRD) analysis revealed that intertidal sabkha sediments predominantly contain terrigenous minerals like quartz (40.7%-69.7%), microcline (34.6%-39.0%), and albite (7.7%-13.7%), with minor occurrences of carbonate minerals such as calcite (9.5%-30.6%) and dolomite (1.3%-5.4%). The supratidal sabkha sediments were primarily composed of quartz (45.7%-69.7%) and lesser amounts of microcline and calcite, while halite was notably absent. Beach sands exhibited a mineralogical profile dominated by quartz (41.2%-78.2%) and calcite (19.1%-50.4%), with traces of dolomite and hematite. In contrast, the rock cliffs of the Al-Abraq, Al-Faidiyah, and Al-Jaghbub Formations were overwhelmingly composed of calcite (83.4%-97.9%), indicative of their shallow marine origin, with minor quartz and halite content. The findings underscore the complexity of depositional processes in the region, shaped by a combination of terrigenous input, marine biogenic activity, and evaporative conditions. This research provides valuable insights into the coastal geomorphology of the Al-Bardia region, with broader implications for understanding similar coastal environments globally.

1. Introduction

Al-Burdi (also spelled Alburdi, Bardia, Bardiyah, or Bardiya) is a town located on the Mediterranean coast in east of Libya, approximately 40 km from the Egyptian border. The area is a notable tourist destination due to its historical significance in World War II and its unique mountainous landscape, including Brill's masterwork.

The sabkha sediments in Wadi Elsahal and Wadi Toburag are primarily intertidal, consisting mainly of calcareous mud with minor calcareous sandy mud (Masoud, 2020). The coastal zone around Burdi is marked by distinct landforms, including sabkhas, rock cliffs, and carbonate sand-covered beaches. Sabkhas, or salt flats, can be both continental and coastal (Kinsman, 1969).

Corresponding author: **E-mail:** Elwrfally2017@gmail.com

The Al Burdi coastline is predominantly characterized by a bioclastic, highly calcareous sandstone that transitions into fossiliferous sandy limestone, indicative of shallow marine facies. The geological sequence studied consists of five rock units, listed from oldest to youngest: the Darnah, Al Bayda, Al Abraq, Al Faidiyah, and Al Jaghbub formations. Various scholars have contributed to the understanding of the stratigraphy and depositional history of these formations, both in outcrop and subsurface studies across northern Cyrenaica (Barr and Hammuda, 1971; Barr and Weegar, 1972; Klen, 1974; Röhlich, 1974; Zert, 1974; El Khoudary, 1976; Banerjee, 1980; Barr and Berggren, 1980; Eliagoubi and Powell, 1980; Duronio et al., 1991; El Hawat and Shelmani, 1993; Abdulsamad and Barbieri, 1999; Elwerfalli et al., 2000; Yanilmaz et al., 2008; Abdulsamad et al., 2009; Abdulsamad and El Zanati, 2013).

El Hawat and Abdulsamad (2004) noted that Pleistocene deposits in the coastal regions consist of beach-dune calcarenite complexes, sabkha carbonates, evaporites, and lagoonal clays. These Quaternary deposits overlay the Tertiary carbonate rocks that encircle the study area from northeast to southwest. The Quaternary sediments are found along the coastal plain and extend to the beach within the study area. Unlike marine sabkhas, which are coastal salt flats influenced primarily by seawater brines, continental sabkhas are inland salt flats dominated by continental brines and processes (Prudêncio et al., 2007). Sabkha deposits are commonly found in arid regions worldwide and are largely controlled by the availability and distribution of water-soluble salts derived from parent rocks (Fookes et al., 1985; Sanford and Wood, 2001). Grain size and mineralogy are crucial for understanding the origin and nature of sand deposits (Kasper-Zubillaga and Zolezzi-Ruiz, 2007; Li et al., 2015; Wang et al., 2017).

The primary aim of this study is to conduct a comprehensive characterization of the beach sands, sabkhas, and rock cliffs along the Al-Suwani shoreline near Burdi village in eastern Libya, with a focus on their geochemical and mineralogical properties. By analyzing the mineral content, chemical composition, and spatial distribution of these coastal landforms, the research seeks to unravel the underlying processes that have shaped this diverse and dynamic landscape. Understanding the mineralogical and geochemical signatures of these landforms is crucial, as it provides insights into the sedimentary environments, sources of sediments, and post-depositional alterations that have occurred over time. This study also aims to contribute to the broader understanding of coastal geomorphology in arid regions, particularly in how such environments evolve under the influence of both marine and terrestrial processes. Through this detailed investigation, the research intends to offer a clearer picture of the interactions between geological formations, sediment transport, and environmental factors in shaping the unique coastal features of the Al-Suwani shoreline.

1.1 Location of the study area

Wadi Al-Suwani is situated in the central part of the Burdi region, extending approximately 5 km in length and varying in width from 2.5 km at its entrance to 1 km at its end. The Al Bardia sheet, located just west of the Libyan-Egyptian border, is the first geological sheet in the region, spanning between longitudes 24° 00′ and 25° 00′ east and latitudes 31° 00′ north and the Mediterranean Sea at nearly 32° 00′ north. This area is characterized by diverse geomorphological features, including sand beaches, rock cliffs, and sabkhas Figure 1.

1.2. Stratigraphy

Al Abraq Formation. The type of section of the lower Oligocene Al Abraq Formation (Röhlich, 1974) is approximately 36 m thick and is located 4 km north of the village of Al Abraq, northern Cyrenaica (Banerjee, 1980). Typically, the formation consists of limestone (partly calcarenite) interbedded with dolomitic limestone, dolomite, and marl. According to Banerjee,1980 the lithology of the Al Abraq Formation is variable in Cyrenaica due to relative sea level change in the Oligocene-Miocene, as attested by major slump structures (contorted bedding) west of Wadi al Kuf. Elsewhere in Cyrenaica, the basal part of the Al Abraq formation is nummulitic with marly or clayey siltstone containing glauconitic grains, and intercalations of algal limestone (Abdulsamad et al., 2009). In the study area, the thickness of this rock unit is approximately 10 m in Wadi El Raheb. Both contacts with the underlying Al Bayda Formation (Algal Limestone Member) and the overlying Al Faidiyah Formation are disconformable Lithologically, the rock unit is chiefly represented by yellowish marly limestone enriched in small and thick reticulate nummulites and echinoids, particularly in the lower levels. At the al Bardia section, however, a 2 m thick section of similar lithology with exceptionally well-preserved and large-sized echinoids has been observed and ascribed to the Al Abraq Formation (Abdulsamad et al., 2009). The lower contact is covered while the upper contact is disconformable and easily recognized below the typical base layer of the Al Faidiyah Formation, which is a green clay. Figure 5 show rock cliffs made up of the three formations and Figures 6 and 7 show Fossiliferous in Al Al Faidiyah and Jaghbub formations.

Fig. 1. The town of Al Burdi is located on the Mediterranean coast in eastern Libya

2. Methodology

2.1 Sample Collection

During two field trips to the study area in August and September of 2022, a total of fifteen samples were collected from various geomorphological units along the Al-Suwani shore zone, including sabkhas, rock cliffs, and beaches as shown? in Figure 2. Specifically, six samples were taken from the sabkha deposits. For these sabkha samples, two cores with a diameter of 5.0 cm were drilled to a depth of 0 to 35 cm. Additionally, three samples were collected from beach sand, and six were gathered from rock cliffs, distributed among three formations: Al Abraq, Al Faidiyah, and Al Jaghbub. The samples were selected based on differences in lithology, color, texture, and sedimentary formations. Figures 3 and 4 illustrate the sample collection from the various geomorphological units.

2.2 Lab -Methodology

Rock cliffs, beaches and Sabkha sediments were obtained from the supratidal and intertidal flats at the mouths of Wadi by inserting a small plastic tube into the deposits. After collection, the samples were dried, and a small portion of each was ground in an electric mortar. The resulting powder was placed into a sample holder, and the mineralogy of the sediments was determined using the X-ray diffraction (XRD) method. The identification of minerals was carried out following the guidelines of Chao (1969) and Chen (1977), using the tables of important lines in X-ray powder diffraction patterns. The major peak heights for each mineral were measured, and the proportions of each mineral were calculated according to methods described by Carver (1971), Milliman (1974), and Tucker (1988). Oriented clay samples (untreated, glycolated, and heated) were prepared by separating the clay fractions from sabkha sediments using the sedimentation technique, as outlined by Folk (1968) and Brown (1972).

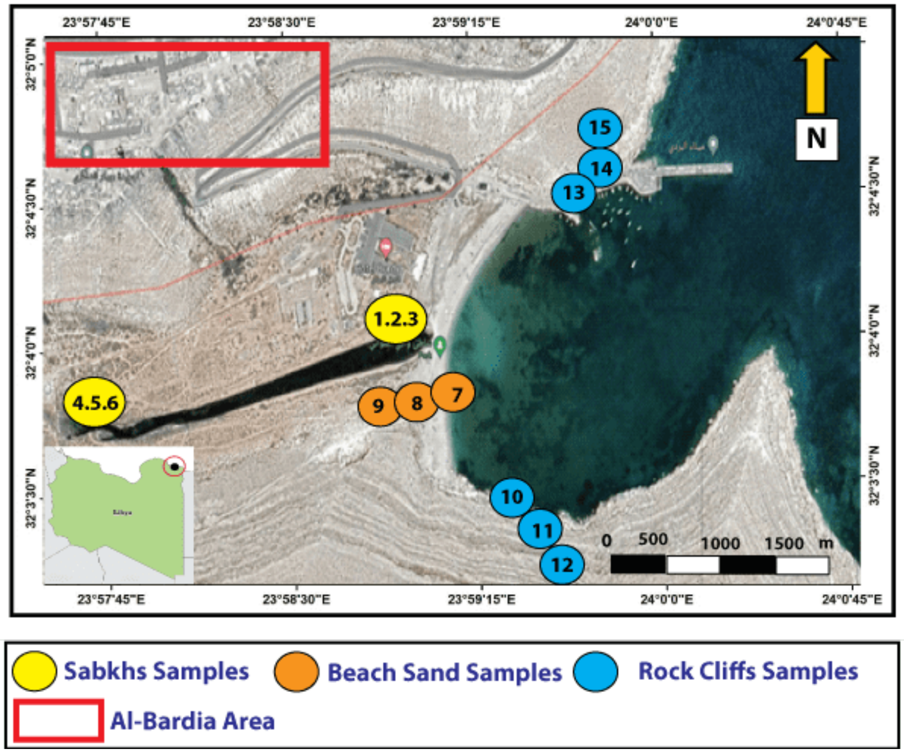

Fig.2. Satellite image showing the location of the sample collection.

Fig.3. A. Illustrates the Wadi Al-Suwani sabkha.

B) bury the tube in the ground to collect samples; C) remove the core from the ground to maintain samples.

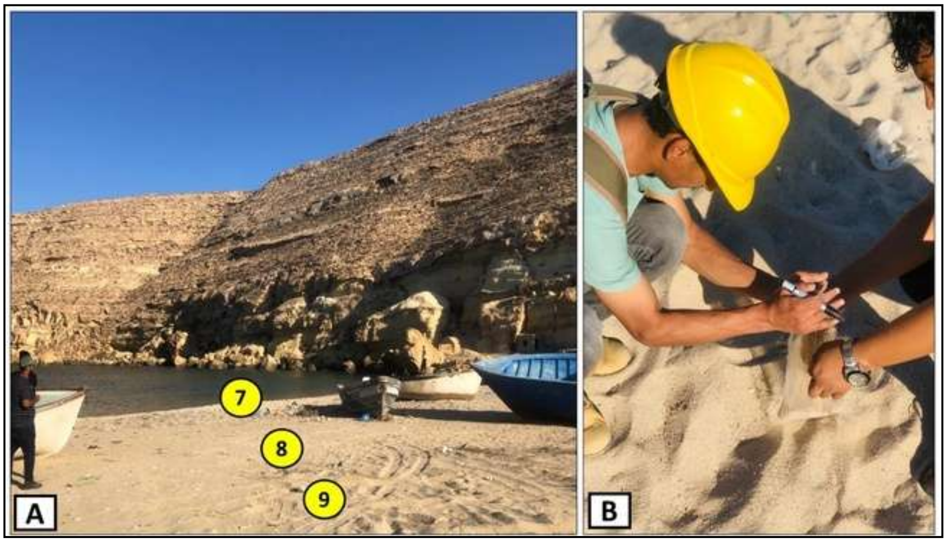

Fig.4.A. The beach was divided into three sections: the beginning, middle, and ending; B) beach sand samples needed to be taken and placed in specified bags.

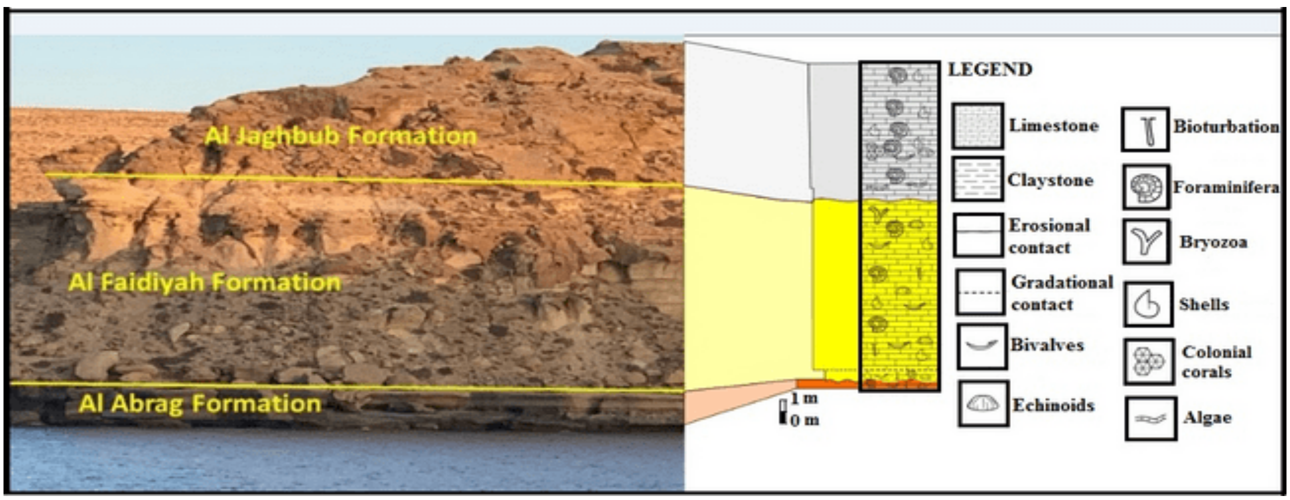

Figure.5. Shows the rock cliffs made up of the Al-Abraq Formation, Al Faidiyah, and Al Jaghbub Formations.

Fig.6. Fossiliferous limestone of the Al Faidiyah Formation, A, and B) Assortment of echinoids (*scutella* sp.,), C) Echinoids (eroded and fragments of Clypeaster spp.), D) echinoids (*scutella* sp.,) and molds of Turritella gastropods.

Fig.7. Fossiliferous limestone of the Al Gaghbub Formation,A) Bivalvia (*Cardium* sp.,), B) Mollusca debris of fragmented and detached Bivalvial shells; C) bioturbation burrows, D) Bivalvia fragments of *pectin* sp.,

3. Results:

Table. 1. Data of bulk mineralogy determined for Al-Suwani sabkha deposits.

S. No.	Depth(cm)	Location			Carbonate minerals		Evaporite minerals	Detrital minerals			
					Calcite (%)	Dolomite (%)	Halite (%)	Quartz (%)	Albite (%)	Microcline (%)	Hematite (%)
1	0-6 cm	W. Al-Suwani sabkha	Intertidal	Core	10.2	0	1.6	40.7	8.0	39.0	0.5
2	12-18 cm				12.5	1.7	3.4	38.5	7.7	36.2	0
3	20-32 cm				30.6	5.4	3.7	46.6	13.7	0	0
4	0-7 cm	W. Al-Suwani sabkha	Supratidal	Core	9.5	1.3	0	46.7	4.2	38.3	0
5	13-19 cm				16.4	3.1	0	69.7	10.8	0	0
6	22-34 cm				16.8	2.2	0	45.7	0	34.6	0.7

3.1 Bulk mineralogy of Sabkha deposits:

Six samples from two cores were chosen for XRD analysis in order to study the mineralogical composition of the Sabkha sediments. The percentages of bulk minerals obtained are summarised in Table 1 and graphically represented in Figure 14. It is found that the mineralogy of intertidal sediments is characterized by the dominance of terrigenous minerals such as quartz, microcline, albite, and Hematite, as well as the presence of carbonate minerals including calcite and dolomite. while only halite appears from the evaporite minerals in the intertidal sabkha sediment is a unique type of sedimentary deposit that forms in arid coastal environments, typically characterized by high salinity and shallow water. The minerals found in sabkha sediment can vary depending on the specific location and the geological processes involved. However, there are several common minerals that are frequently encountered in sabkha sediment. Figures 8,9&10.

The bulk mineralogy determined in the Supratidal sediments are composed mainly of quartz with amount ranging from 45.7 to 69.7% with a subordinate amount of Microcline and calcite. Halite and dolomite arranged in decreasing order of abundance. The bulk mineralogy found in supratidal sabkha sediments is dominated by quartz, with minor amounts of microcline, calcite, albite, and hematite arranged in decreasing order of abundance. The role of eolian transportation is important in transporting weathered and terrigenous materials from nearby land. Dolomite is a mineral that can be found in sabkha sediment, particularly in areas where the seawater interacts with magnesium-rich groundwater. It is a calcium magnesium carbonate mineral that often occurs as white, gray, or pinkish crystals or as finely crystallinemasses.(Warren,J.K.,2000).Figures 11, 12 & 13.

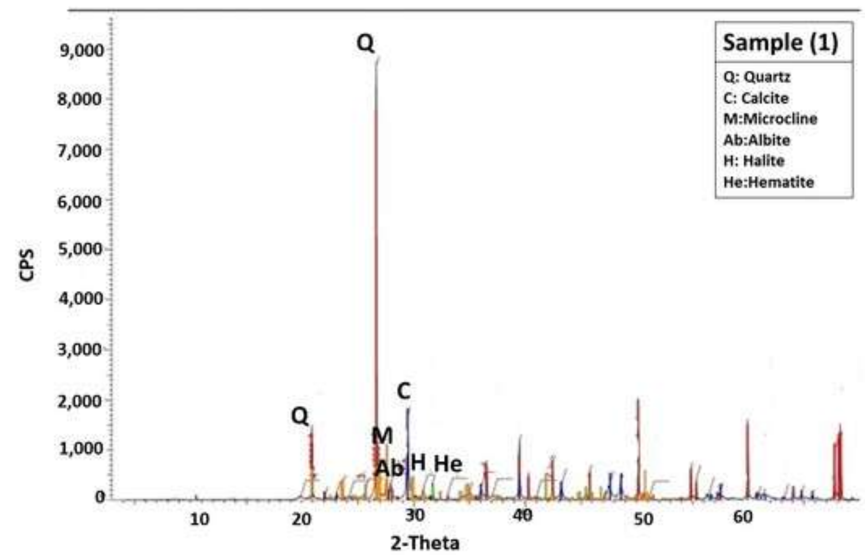

Fig.8. A typical X-ray diffraction pattern shows the total mineral components identified in Al-Suwani-intertidal sabkha.

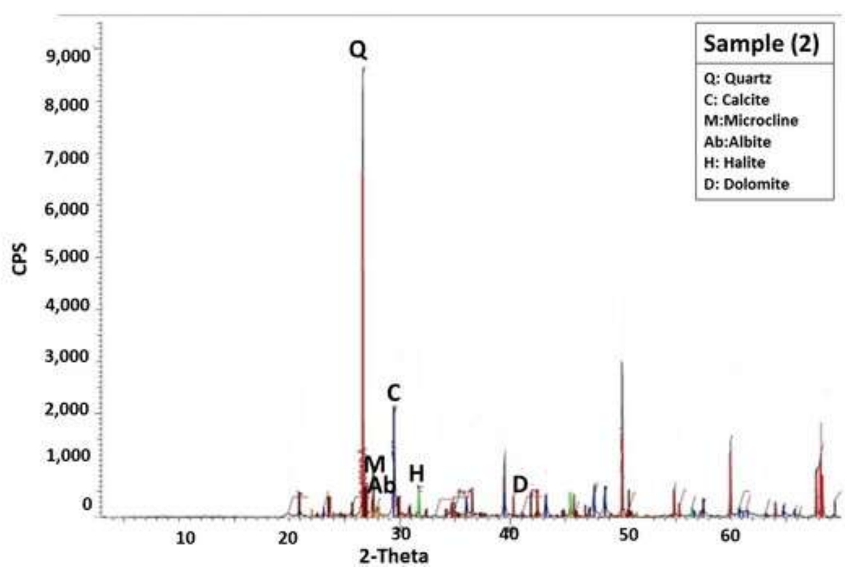

Fig. 9. A typical X-ray diffraction pattern shows the total mineral components identified in Al-Suwani intertidal sabkha.

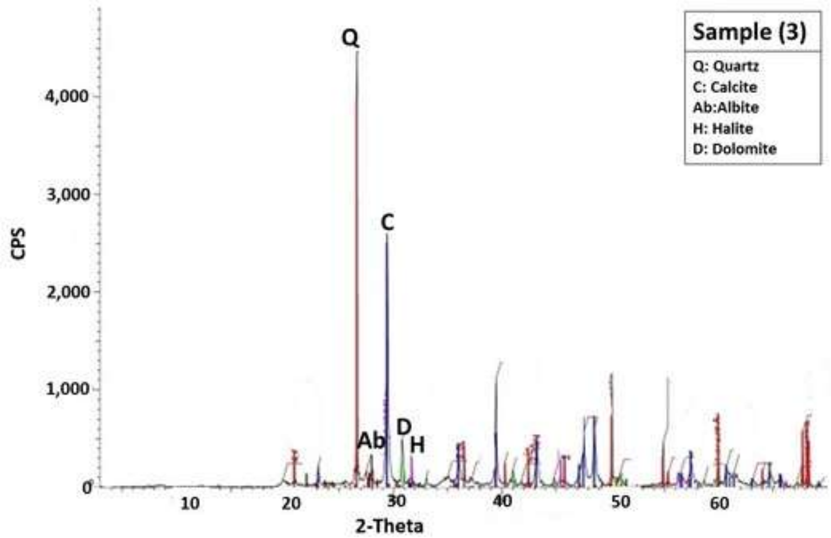

Fig.10. A typical X-ray diffraction pattern shows the total mineral components identified in Al-Suwani intertidal sabkha.

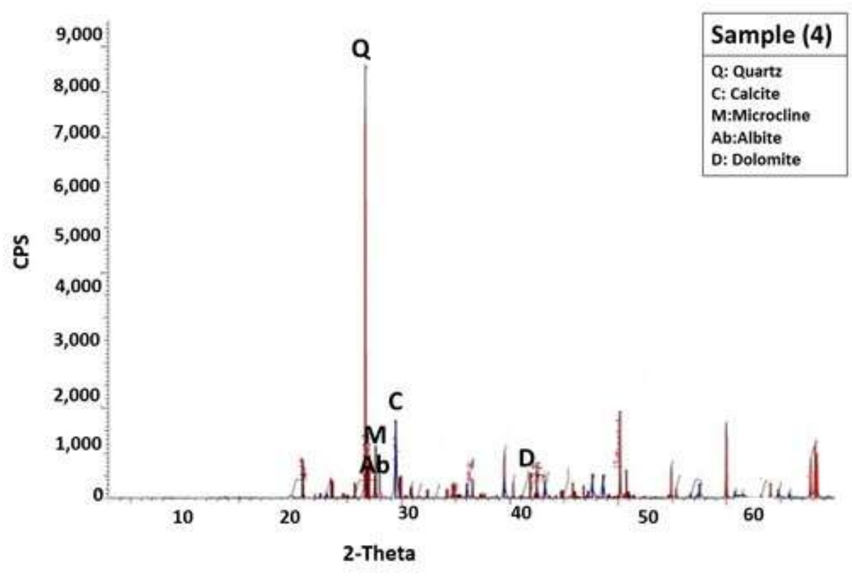

Fig.11. Typical X-ray diffraction pattern showing the total mineral components identified in Al-Suwani Supratidal sabkha.

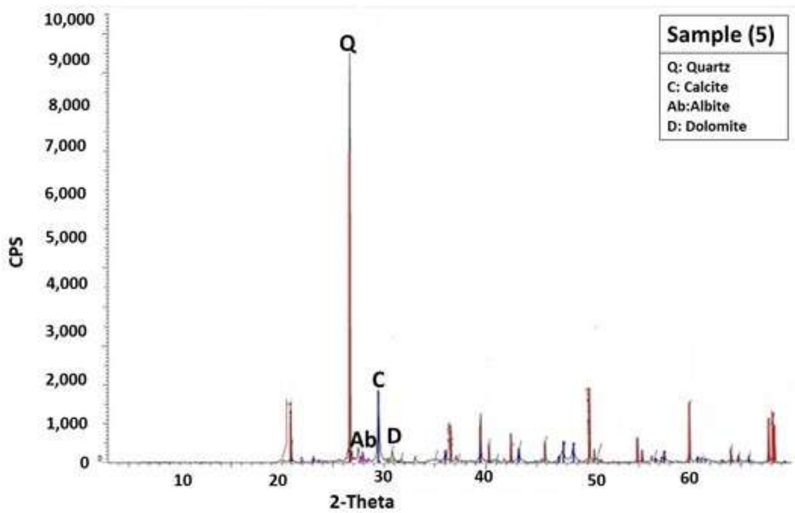

Fig.12. Typical X-ray diffraction pattern showing the total mineral components identified in Al-Suwani Supratidal sabkha.

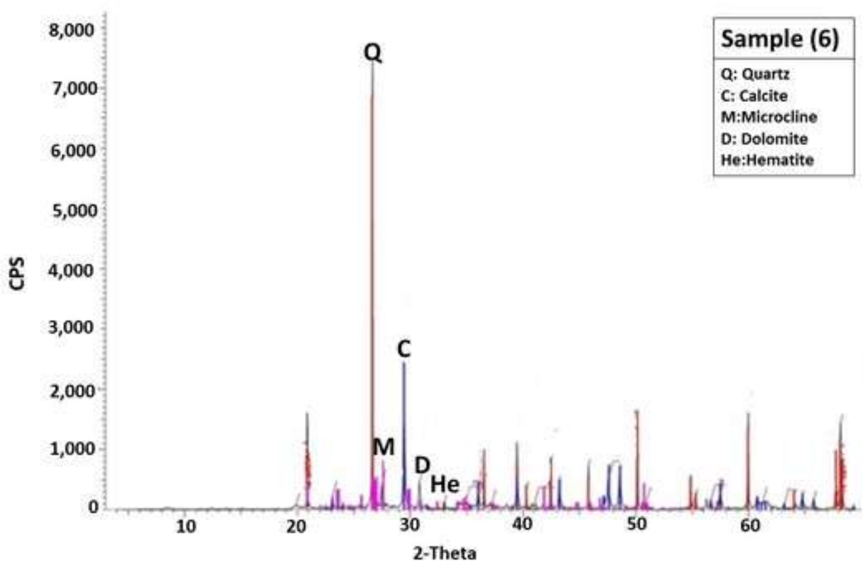

Fig.13. Typical X-ray diffraction pattern showing the total mineral components identified in Al-Suwani Supratidal sabkha.

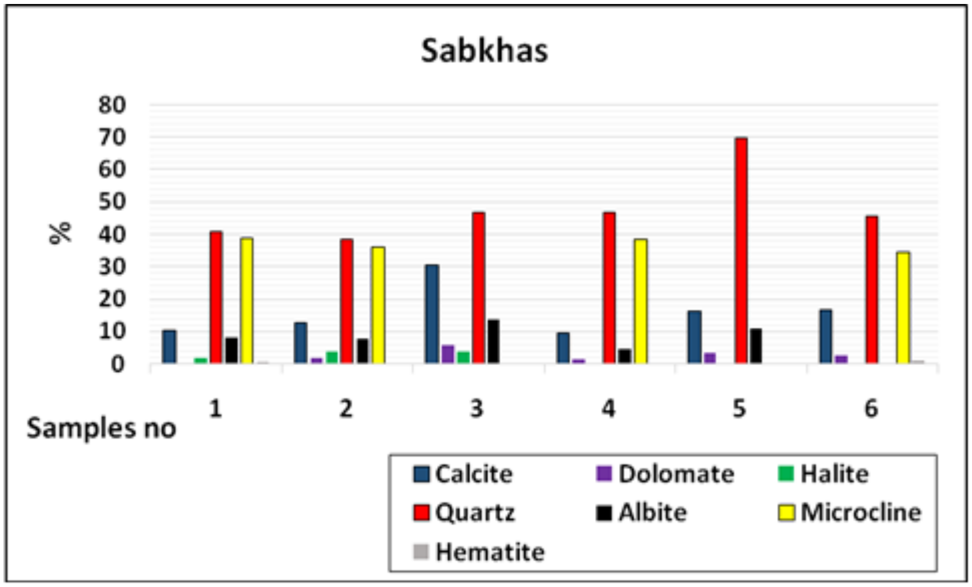

Fig.14. Bar graph representation showing the relative percentages of the bulk minerals in the Al-Suwani intertidal and supratidal sabkhas.

3.2 Bulk minerals of Beach sand:

Three samples of beach sand were collected and separated into three parts: the first part was gathered from the front of the beach, the second part came from the middle, and the third part was from the back of the beach, not far from the front of the sabkha. data obtained for bulk mineralogy is given in Table.2. The distribution of mineral components is represented graphically in the bar graph. Figure 18. Their X-ray diffraction patterns are given in Figures 15to17. According to the findings, calcite and quartz are the most prevalent minerals, whereas dolomite and hematite are less common and only occur in trace amounts .Halite has not been observed. When we walk away from the beach, it is apparent that the percentage of minerals gradually rises, except quartz, whose percentage falls.

Table .2. Data of bulk mineralogy determined in beach sand and Rock cliffs.

S. No.	Geomorpholog ic units	Location	Carbonate minerals		Evaporite minerals	Detrital minerals	
			Calcite (%)	Dolomite (%)	Halite (%)	Hematite (%)	Quartz (%)
7	Beach sand	Shore line	19.1	1.8	0	0.9	78.2
8	Beach sand	Medal	38.5	3.8	0	0	57.7
9	Beach sand	Back shore	50.4	6.8	0	1.6	41.2
10	Rock Cliffs	Al Abrag Formation	96.5	0	0	0	3.5
11	Rock Cliffs	Al FaidiyahFormation	95.1	0	3.3	0	1.6
12	Rock Cliffs	Al Jaghbub Formation	97.9	0	0	0	2.1
13	Rock Cliffs	Al AbragFormation	96.5	0	2.2	0	1.3
14	Rock Cliffs	Al Faidiyah Formation	83.4	0	0	0	16.6
15	Rock Cliffs	Al Jaghbub Formation	94.5	0	0	0	5.5

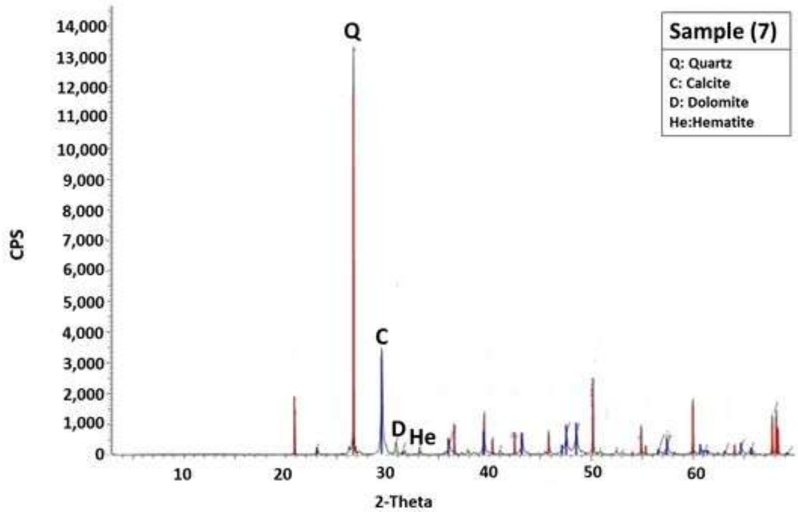

Fig. 15. A typical X-ray diffraction pattern shows the total mineral components identified in Beach sand.

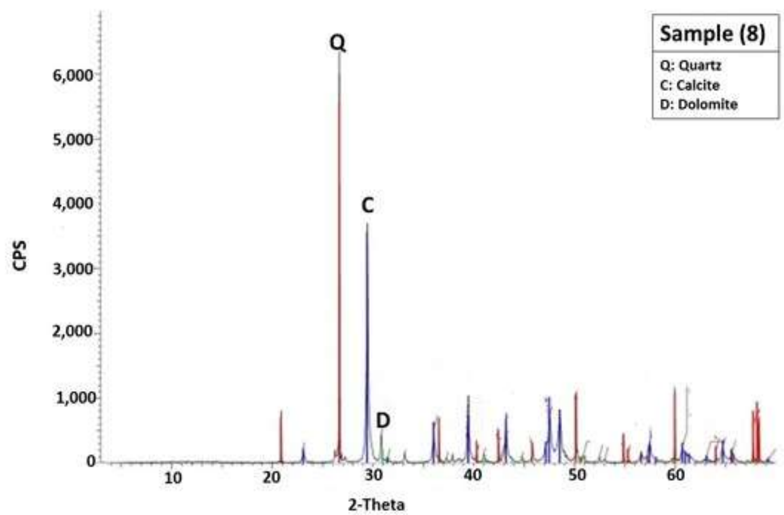

Fig.16. A typical X-ray diffraction pattern shows the total mineral components identified in Beach sand

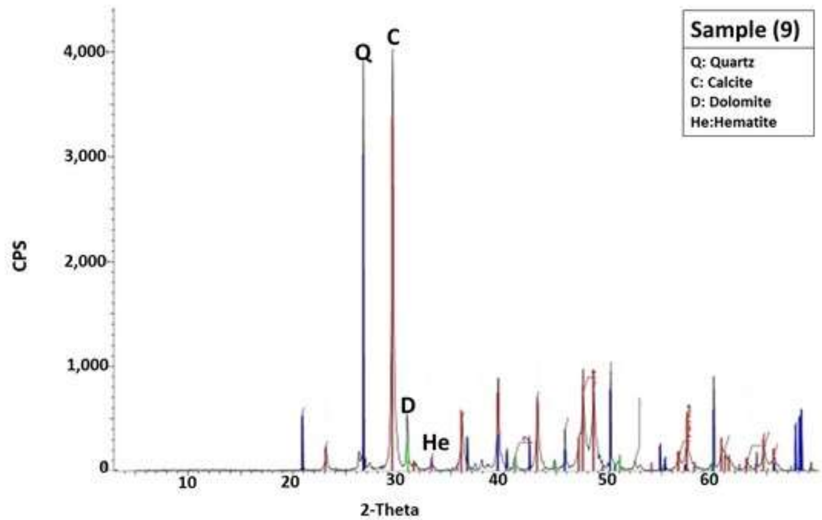

Fig. 17. A typical X-ray diffraction pattern showing the total mineral components identified in Beach sand.

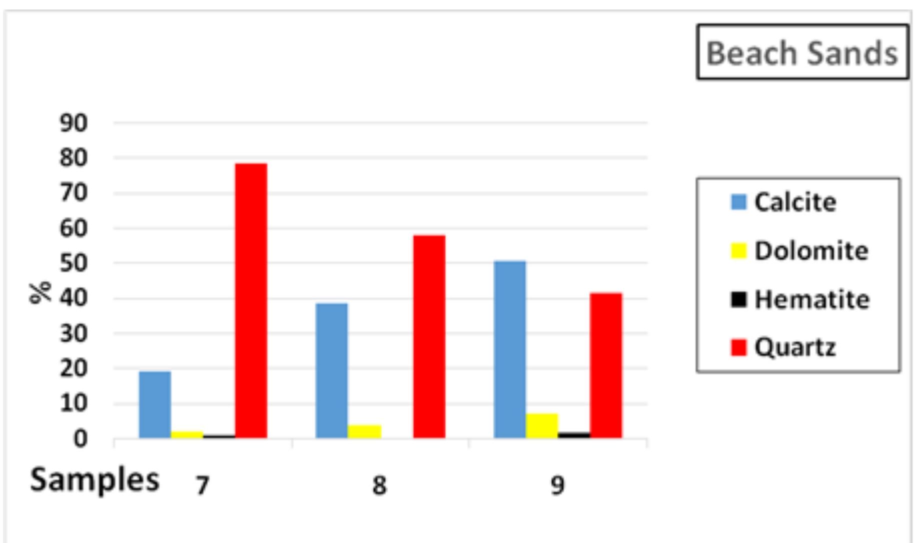

Fig .18. Bar graph representation showing the relative percentages of the bulk minerals in the Beach sand sediments.

3.3 Bulk minerals of Rock cliffs

Six rock samples were taken from the Al-Abraq Formation, Al-Fadiya Formation, and Al- and Jaghbub Formation, three major rock formations that were exposed in the study region in the rocky coastline to the right and left of the valley. In Table .2, data collected for bulk mineralogy are presented. A bar graph Figure 23 shows the distribution of the mineral components graphically. Figurs19 to 24 show their X-ray diffraction patterns.Calcite is the most common carbonate mineral found in the rock cliff terraces of three formations, while Quartz is found in trace amounts in all samples, with Halite showing up in the Al Faidiyah and Al-Abrag formations. Figure 25 shows the relative percentages of the bulk minerals in the Rockcliffs.

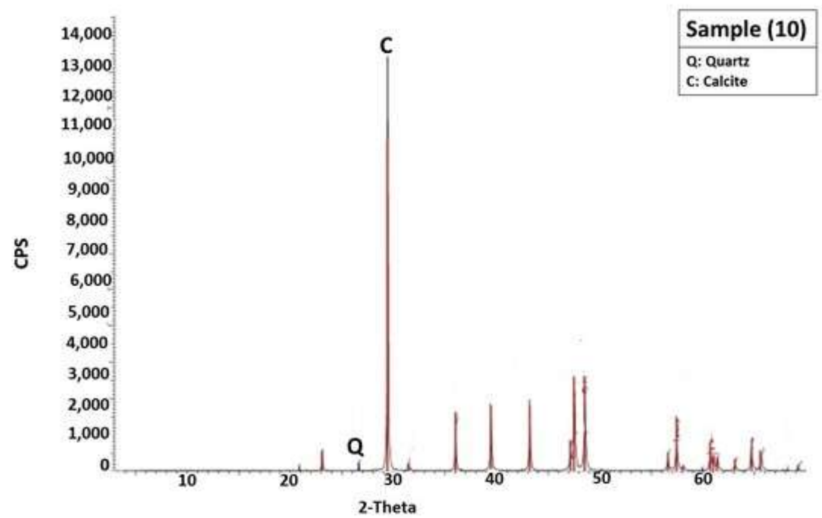

Fig. 19. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs of Al Abrag Formation.

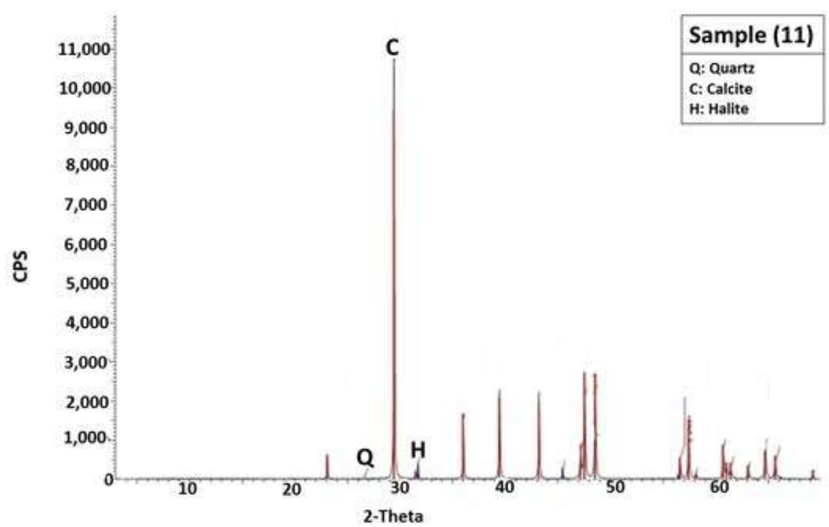

Fig.20. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs of Al Faidiyah Formation.

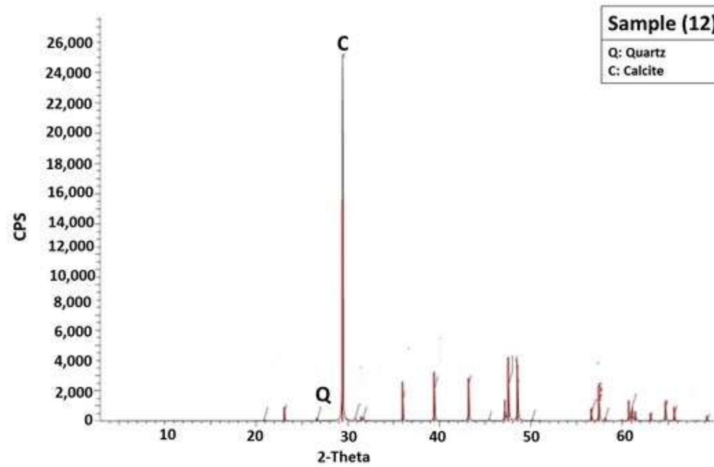

Fig. 21. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs of Al Jaghbub Formation.

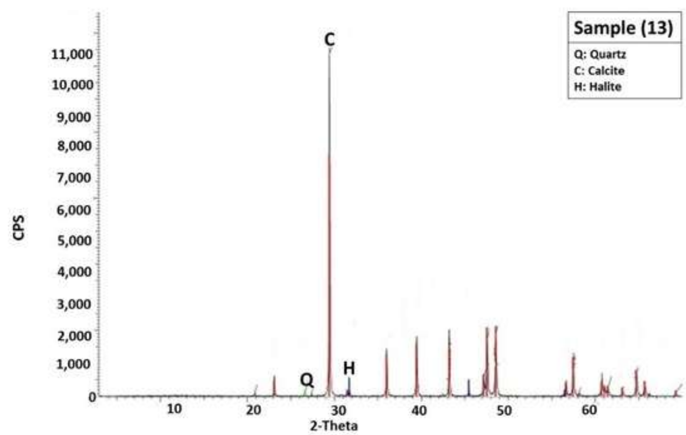

Fig. 22. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs of Al Abrag Formation.

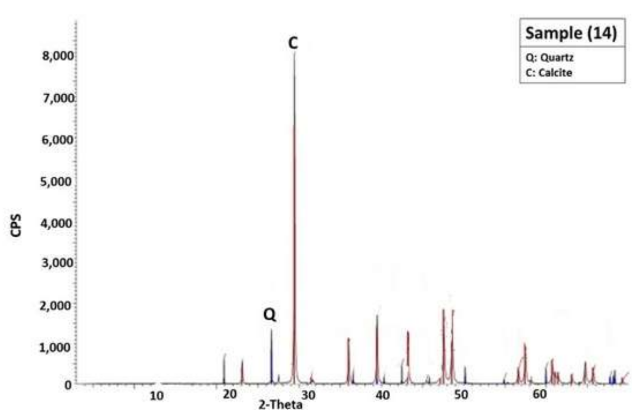

Fig. 23. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs of Al Faidiyah Formation.

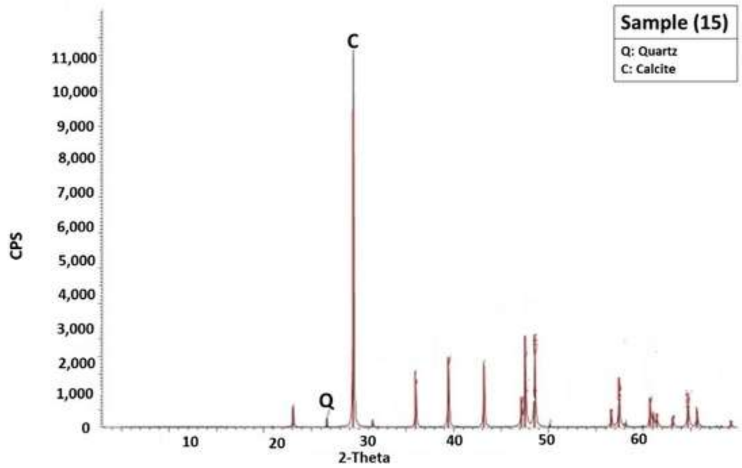

Fig. 24. X-ray diffraction pattern showing the bulk mineral components identified in rock cliffs ofAl Jaghbub Formation.

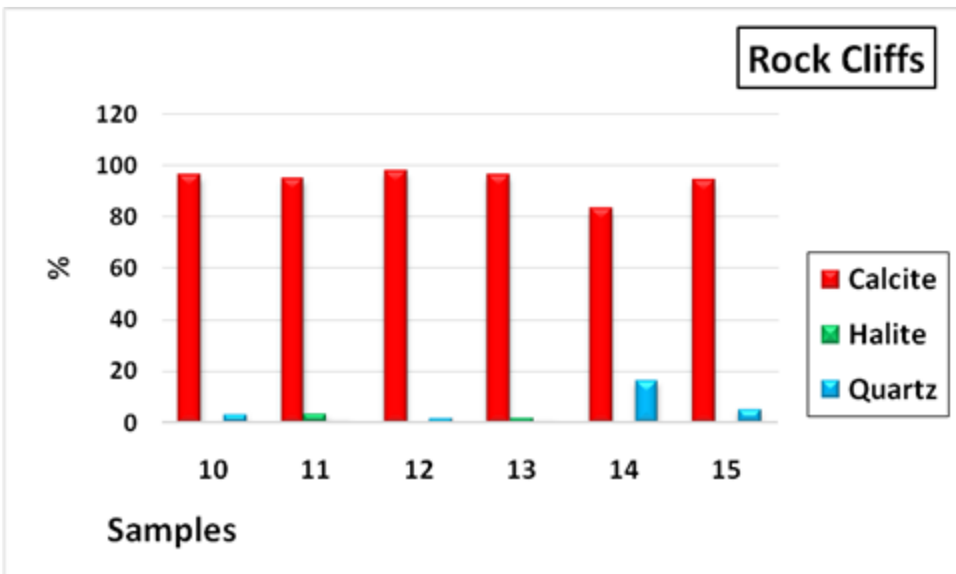

Fig.25. Bar graph representation showing the relative percentages of the bulk minerals in the Rockcliffs.

4. Discussion:

The present study offers a detailed examination of the mineralogical composition of the coastal landforms along Wadi Al-Suwani, situated in the Al-Bardia region of east of Libya. With its rich geological history, this area is ideal for studying the geomorphological units of beach sand, rocky cliffs, and sabkha. The findings of this research are precious for filling existing gaps in our understanding of the region's geology and the processes that have shaped its current landscape.

The mineralogical analysis conducted on the sabkha deposits revealed a predominance of terrigenous minerals such as quartz, microcline, albite, and hematite, alongside carbonate minerals like calcite and dolomite. These findings are consistent with the characteristics of sabkha environments, which are typically influenced by a combination of aeolian processes and the deposition of evaporite minerals such as halite. The dominance of quartz in intertidal and supratidal sabkha sediments underscores the importance of terrigenous input, likely from adjacent landmasses, in shaping the sedimentary composition of these coastal flats.

On the other hand, the beach sands displayed a distinct mineralogical profile, with quartz and calcite as the most abundant minerals. This distribution pattern aligns with the typical composition of beach environments, where quartz, being a durable mineral, tends to accumulate as less resistant minerals are eroded. The presence of calcite, particularly in the middle and backshore sections of the beach, suggests the influence of biogenic processes, likely from the breakdown of marine organisms' shells, which are rich in calcium carbonate. The absence of halite in the beach sands is notable, reflecting the lesser influence of evaporative processes in this geomorphological unit compared to the sabkha.

The rocky cliffs along the Wadi Al-Suwani coastline, composed of the Al-Abraq, Al-Faidiyah, and Al-Jaghbub Formations, are predominantly characterized by calcite. This is indicative of the carbonate-rich nature of these rock units, which are representative of shallow marine environments that prevailed during their deposition. The minor presence of quartz in these formations further supports the interpretation of a carbonate-dominated depositional environment, where siliciclastic input was minimal. The detection of halite in the Al-Faidiyah and Al-Abraq Formations, though in trace amounts, suggests episodes of increased salinity, possibly linked to evaporative conditions in restricted marine settings during the time of deposition.

The discovery of echinoid and bivalve fossils within the Al-Faidiyah and Al-Jaghbub Formations adds a paleontological dimension to the study, offering insights into the ancient marine ecosystems that once thrived in this region. The presence of these fossils, particularly the well-preserved echinoids, highlights the potential for further paleobiological investigations that could provide more detailed reconstructions of the paleoenvironmental conditions during the Oligocene-Miocene periods.

Overall, the mineralogical and paleontological findings from the Wadi Al-Suwani region not only enhance our understanding of the local geology but also contribute to broader geological knowledge by offering comparisons with similar coastal environments elsewhere. The study's results underscore the complexity of the depositional processes and the diverse influences—ranging from terrigenous input and marine biogenic activity to evaporative conditions—that have collectively shaped the current landscape of the Al-Bardia coastline. Future research could build on these findings by exploring the temporal variations in sedimentary processes and their relation to climatic and sea-level changes during the Tertiary and Quaternary periods

5. Conclusions:

This study provides valuable insights into the mineral composition and geological characteristics of the coastal landforms along Wadi Al-Suwani in the Al-Bardia region. By analyzing samples from the sabkhas, beach sands, and rock cliffs, the research identifies distinct mineral distributions across these geomorphological units.

Sabkha Deposits: The mineralogical analysis reveals that quartz is the dominant mineral in both intertidal and supratidal sabkhas, with lesser amounts of calcite, dolomite, albite, microcline, and hematite. The presence of halite in the intertidal sabkha highlights the influence of evaporative processes in these arid coastal environments. The role of eolian transportation is also significant in the deposition of terrigenous minerals, such as quartz, within these sabkhas.

Beach Sands: The beach sands exhibit a gradient in mineral composition, with quartz being the most abundant mineral near the shore, while calcite increases in concentration as one moves inland. The absence of halite in these samples suggests that the beach sands are primarily composed of detrital and carbonate minerals, influenced by both marine and terrestrial processes.

Rock Cliffs: The rock cliffs, composed of the Al Abraq, Al Faidiyah, and Al Jaghbub formations, are predominantly made up of calcite, with trace amounts of quartz and occasional occurrences of halite. The high calcite content reflects the carbonate nature of these formations, which are characterized by fossiliferous limestone. The discovery of fossils, particularly echinoids and bivalves, in these formations further enhances our understanding of the region's paleoenvironment.

In summary, the study underscores the complex interplay between geological processes, mineral composition, and geomorphological features in shaping the coastal landscape of Wadi Al-Suwani. The findings contribute to a more comprehensive understanding of the region's geology, which is essential for future research and potential resource exploration in the Al-Bardia area.

Conflict of Interests:

The authors declare that there is no conflict of interests regarding the publication of this paper. The research was conducted independently, and no financial or personal relationships influenced the outcomes of the study.

6. References

Abdulsamad, E.O., and Barbieri, R., 1999. Foraminiferal distribution and palaeoecological interpretation of the Eocene - Miocene carbonates at Al Jabal al Akhdar (northeastLibya*).Journal micropaleontology*, 18: 45-65.

Abdulsamad, E.O., Bu-Argoub, F.M. And Tmalla, A.F.A.,2009. A stratigraphic review of the Eocene to Miocene rock units in the Al Jabal Al

Akhdar, NE Libya. *Marine Petroleum Geology*,26:1228-1239.

Abdulsamad, E.O. And El Zanati, S.M., 2013. Miocene benthic foraminifera from the Soluq area, NE Libya: biostratigraphy and environmental significance. *Journal of Mediterranean Earth Sciences*,5:245-256.

Barr, F.T. And Hammuda, O.S., 1971. Biostratigraphy and planktonic zonation of the Upper Cretaceous Atrun Limestone and HilalShale, Northeastern Libya. In: Farinacci, A., Ed., *Proceedings of the Second International Conference on Planktonic Microfossils, I:27-40. Roma: Tecnoscienza.*

Barr, F.T. And Weegar, A.A., 1972. Stratigraphic Nomenclature ofthe Sirte Basin, Libya. Tripoli: *Petroleum Exploration Society of Libya,* 179 p

Banerjee, S., 1980. Stratigraphic Lexicon of Libya. *Department of Geological Researches and Mining*, Bulletin, 13:1-300.

Brown, G., 1972. The -X-ray Identification and Crystal Structures of Clay Minerals – Mineralogical Society. London

Carver, R.,1971. Procedures in Sedimentary Petrology. *Wiley Interscience*, London, 441.

Chao, G. Y.,1969. 2ɵ (Cu) table for common minerals: Geological.Carleton University, Ottawa, Canada,69-2.

Chen,1977. Table of key lines in X-ray powder diffraction patterns of minerals in clays and associated rocks. Department of Natural *Resources. Geological Survey. Occasional paper 21*. Bloomington, Indiana ,67 .

Duronio, P., Dakshe, A., and Bellini, E., 1991. Stratigraphy of the offshore Cyrenaica Libya. In: Salem, M.J., Hammuda, O.S. and Eliagoubi, B.A., *Eds., e Geology of Libya*, IV: 1589-1620. Amsterdam: Elsevier.

El Hawat, A.S. and Abdulsamad, E.O. (2004). *The Geology of Cyrenaica: A Field Seminar. Geology of East Libya, Field Trip, ESSL*, Tripoli, Libya, 130 .

El-Hawat, A.S. And Shelmani, M.A., 1993. Short notes and guidebook on the geology of Al Jabal al Akhdar. *Earth Sciences Society of Libya (ESSL), Special Publication*: 1-70.

El Khoudary, R.H., 1976. Contribution to the stratigraphy and micropaleontology of Jabal Al Akhdar: Upper Eocene planktonic foraminifera from Wadi Bakur, SE Tukrah, NE Libya. Libyan Journal of Science, 6B: 57-79

Elwerfalli, A., Muftah, A., and El-Hawat, A.S., 2000. Aguidebook on the geology of Al Jabal al Akhdar. Earth *Sciences Society of Libya (Essl*). 1-71.

Eliagoubi,B.A.,and Powell, J.D.,1980. Biostratigraphy andpalaeoenvironment of Upper Cretaceous foraminifera of North-central and Northwestern Libya. In: Salem, M.J. and Busrewil, M.T.,Eds., *Geology of Libya, I:. London: Academic Press.*137-153.

Folk, R.,1968. Petrology of Sedimentary Rocks. *Hemphil Pub*. Co., Austin, Texas, 184 .

Fookes, P. G., French, W. J., and Rice, S. M. M. 1985. The influence of ground and groundwater geochemistry on construction in the Middle East. Quarterly *Journal of Engineering Geology and Hydrogeology, 18 (2),* (101-127).

Kinsman, D. J.,1969. Modes of formation, sedimentary associations, and diagnostic features of shallow- water and supratidal evaporation. Bull. Am. *Ass. Petrel. Geol*. Vol 53 (4), 830-840.

Klen, L., 1974. Geological map of Libya, 1:250 000. Sheet Benghazi (NI 34-14). Explanatory booklet, *Industrial Research Centre, T*ripoli: 56 .

Masoud. A. M. M.,2020. Sedimentological and Environmental Studies on the Shore Zone of Tobruk City, Libya. Unpublished M.Sc. *Thesis, Mansoura University*, Egypt, 162.

Milliman, J.,1974. Marine Carbonates. *Springer-Verlag,* New York, 375 .

Prudêncio, M. I., Gonzalez, M. I., Dias, M. I., Galan, E., and Ruiz, F., 2007. Geochemistry of sediments from El Melah lagoon (NE Tunisia): a contribution for the evaluation of anthropogenic inputs. *Journal of Arid Environments,* 69 (2), 285-298.

Sanford, W. E., and Wood, W. W.,2001. Hydrology of the coastal sabkhas of Abu Dhabi, United Arab Emirates. *Hydrogeology Journal*, 9 (4), 358-366.

Tucker, M.,.1988. Techniques in Sedimentology. Blackwell Scientific Pub., 383.

Warren, J. K., 2000. Dolomite: occurrence, evolution, and economically important associations. *Earth-Science Reviews.* Volume 52, Issues 1–3, November 2000, 1-81.

Wang, X., H. Wei, F. Khormali, M. Taheri, M. Kehl, M.Frechen, T. Lauer, F. Chen. ,2017. Grain-size-distribution of Pleistocene loess deposits in northern Iran and its palaeoclimatic implications. *QuaternaryI nternational,* 429, 41-51.

Yanilmaz, E.,Huffman, D., Martin, M. And Gutteridge, P., 2008. Facies analysis and depositional systems of defined sedimentary sequences from Precambrian to Late Miocene in NE Libya.In: Salem, M.J., Ed., *Geology of East Libya, VI. Malta: Gutenberg Press Ltd*., 3–84.

ZERT, B., 1974. Geological map of Libya, 1:250 000. Sheet Dernah (NI34-16). *Explanatory booklet, Industrial Research Centre,* Tripoli: 49.