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Diagenesis using scanning electron microscopy of carbonates of Kirthar Formation, Lower Indus Basin, Sindh, Pakistan

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Abstract

Diagenesis of the carbonate rocks has revealed different aspects of the sedimentology of the Kirthar Formation which is one of the significant rock units of the Lower Indus Basin. The formation is extensively distributed through the area that is the upper part of the Southern Indus Basin, and it is broadly dispersed in the Sindh Province. It comprises limestones, in places associated with shale and minor marl beds. The limestone is light grey, cream-coloured or chalky white, weathers in grey, brown or cream colours. One of the most extensively used tools in the area of earth sciences, which includes anything from materials to environmental research, is the scanning electron microscope. The investigation shows that after deposition, carbonates of the Kirthar Formation have been exposed to a range of diagenetic processes that brought about changes in porosity, mineralogy, chemistry, and texture. Unlike other carbonate minerals, the ones studied here are less prone to dissolution, recrystallization, and replacement. The present investigation of diagenesis is done with the assistance of scanning electron microscopy which has uncovered the understanding of various diagenetic processes, for example, cementation, dissolution, neomorphism and so on within the carbonates of the Kirthar Formation. Furthermore, the activities of the organisms on carbonates have also brought diagenetic changes to the textures through biogenic processes. Sediments have been reworked by leaving signs of microbes in certain locations.

Keywords: Diagenesis, Kirthar Formation, Scanning Electron Microscopy

1. Introduction

The purpose of this research is to use a scanning electron microscope to investigate the diagenetic characteristics of carbonates of the Kirthar Formation.

1.1 Kirthar Formation

The name “Khirthar” was suggested by Blanford (1876). He utilized the term Khirthar got from the “Khirthar range” to portray Eocene layers between his “Ranikot Group” and the “Nari” in western Sindh. Later, Noetling (1903) isolated the lower part with the “Laki Series” and held the term “Khirthar” from the upper part. The Khirthar Formation of the present study is comparable to the “Khirthar” of Noetling (1903) and the “Spintangi Limestone” of Oldham (1890).

The Canadian Report has characterized the rock unit as the “Brahui Limestone” (Hunting Survey Corporation, 1961) that is separated into two members one is Kirthar which is the lower part and possesses fossils of Eocene, and the other is Gorag, which is the upper part and bears Oligocene fossils. Both the individuals are characterized on the fossil content premise. Kirthar Formation comprises limestones, associated with shale and some marl. The limestone is light grey, cream-coloured or chalky-white, weathers in grey, brown or cream colours. The formation is thick-bedded to massive, occasionally nodular and incidentally contains algal and coralline features. The shale bed is calcareous, olive, orangish, yellow, dim, delicate and gritty.

The Formation is solely cliffy with monstrously composed of limestone. It is generally spread all through the area for example upper side of the “Lower Indus Basin”. The unit is generally distributed in all of Sindh for example Pab Range, Khirthar Range, west of Laki Range, Thano Bula Khan, Kot Digi (District Khairpur) and Rohri. Its lower stratigraphic contact is conformed with Tiyon Formation and the upper contact of the formation is generally unconformable with the overlying Nari Formation. Nonetheless, as per Hunting Survey Corporation (1961), it has conformable contact with the Nari Formation nearby around Gaj River. The two of its lower (stratigraphic) and upper limits are proved time intrusive. As per Hunting Survey Corporation (1961), the type section/locality of the Kirthar Formation is the Gaj River Section: (Lat. 26º 56’ 10” N and Long. 67º 09’ 06” E).

1.2 Scanning Electron Microscopy

The benefits of the SEM as an imaging apparatus such as high known spatial resolution, the enormous profundity of the field, and easy specimens preparation make it a significant tool in different parts of geology. Concerning the study of sedimentology, especially diagenesis in carbonate rocks, three-dimensional pictures of individual sediments and between developments might be gotten. Information on texture and also porosity can likewise be created. Other than the availability and strength proportion of various types of mineral particles can likewise be searched out in the provisions of their chemically opt investigation or the more explicitly Electron Microprobe Analysis with the assistance of an extra accessory connection called Energy Dispersive X-Ray Spectrometer (EDS) whenever appended. Electron microprobe examination is in this manner done simply with the creation of EDS. The chemical testing of minerals, as well as rocks, has evolved as a daily practice by utilizing Electron Probe Microanalysis (EPMA) (Reed and Romanenko, 1995).

1.3 Diagenesis

After the deposition, carbonates particles are exposed to an assortment of diagenetic activities that achieve changes in porosity, mineralogy, and chemistry. The carbonate origin minerals are by and large more powerless to disintegration, recrystallization, and substitution than do most silicate origin minerals. The diagenetic processes assume a vital part in numerous physical, and chemical changes as well in the carbonates. Indeed, even at moderate burial depths as shallow as possible 100m, compaction might diminish the depositionally original thickness of carbonate sediment grains by as much as one-half, going with the porosity decrease of 0 to 60 percent of original pore volumes (Shinn and Robbin, 1983).

2. Materials and Methods

In total, three areas were picked for this important study. The necessary fieldwork was completed for the proper collection of samples and measurements of desired sections. Other than the other geological and also physiographic qualities were likewise taken into the note. Fresh specimens were gathered for investigation. The sample collection and field information was carefully organized as lithologic logs. Corel draw and Xara computer software packages were used to foster an obvious pictorial tale of various sedimentary skylines of the Kirthar Formation. Following is the depiction of lithological logs of the areas:

1- Gadularo Section:
Lat. 25º 25/ 20// N
Long. 67º 48/ 45// E

The region of this particular section is located around 75 km southwest of the city Hyderabad, 5 km northwest of town Thano Bola Khan, Gadularo is structurally a doubly plunging anticline as displayed in (Fig. 1A). Here the Nari Formation unconformably lies in the Kirthar Formation, whereas the underlying Tiyon Formation is totally missing. The area involves numerous limestone horizons that are thickly-bedded, compact and hard with high fossil content (Fig. 2A).

2- Kambho Jabal Section:

Lat. 25º 33/ 96// N
Long. 67º 47/ 714// E

The area is situated around 15 km close to Bachani town, which is situated in taluka Thano Bola Khan. Structurally Kambho Jabal is an enormous north-south moving anticline (Fig. 1B). Both the lower and upper stratigraphic contacts are clearly observable with Tiyon and Nari Formations individually. There available are different limestone rock units inside the formation, which are primarily hard, compact and enormous in nature. It is profoundly fossiliferous comprising bigger foraminifer shells, bivalves, echinoids, and gastropods fossils (Fig. 2B).

3- Watawaro Rojh Jabal:

Lat. 25º 10/ 20// N
Long. 67º 40/ 05// E

The section lies about 20 km southwest of Thano Bula Khan as shown in (Fig. 1C). Upper and lower contacts of the Kirthar Formation are present in the area. The limestone of the Kirthar Formation mostly is massive and thick and nodular in places and contains fossils of bivalves, echinoids, worm burrows and gastropods (Fig. 2C)

2.1 SEM Analysis

Representative and chosen specimens which were efficiently gathered from allotted units were examined under the Scanning Electron Microscope (SEM) Laboratory, available at the "Center for Pure and Applied Geology, University of Sindh, Jamshoro".

The method was instated with the cutting of chips of rock samples followed by the cleaning of similar chips with fine grit on the clean glass surface. The cleaned and flat chips were then put on a sample stub of SEM, utilizing a conductive twofold-sided carbon conductive tape. Then at that point, it was inserted in the chamber of the "JEOL JSM-6490 LV" Scanning Electron Microscope which is additionally outfitted with an additional and significant extra part of "Bruker EDS".

All appropriate functional controls of SEM were set to acquire the fine focusing resolution at high and wanted magnifications of the samples. Photomicrographs of the chosen positions were captured for study and interpretation. Then after the investigation was trailed by the elemental accusation of the samples, both qualitative and also quantitative. For that EDS was initiated. In the wake of arriving at an optimal magnification of x90, the samples were then chemically analyzed. The elemental composition was determined in the form of different spectra heights for qualitative review and simultaneously the test investigation was accomplished in tabular form for the quantitative study.

3. Results

Different diagenetic processes within the limestone microfacies of the Kirthar Formation in the present study have been interpreted and discussed. Each process has been elaborated in the light of Scanning Electron Microscopy results. The systematic description is given below:

3.1 Biogenic Alteration

The paleo-activities of the fossil organisms on the carbonate residues may likewise bring diagenetic changes to the surface texture. Living beings in such depositional conditions adjust residue by boring, burrowing, and sediments ingesting exercises, similarly to the siliciclastics conditions. These activities may destroy primary sedimentary structures (Demicco and Hardie, 1994) in carbonate sediments and leave behind spotted sheet material and different sorts of organic traces. In this work, the greater part of the hints of the fossils found inside the realms of limestone microfacies, have a place with foraminifer microfossils (Fig. 3).

3.2 Cementation

Out of the most significant cycles of limestone, diagenesis is the process of cementation. The bonding agent in limestone facies used to be calcite or the lesser steady aragonite. Cement assumes a vital part in limestones and is viewed as the dynamic reason for the quality and level of the auxiliary porosity and porousness (Fig. 4). The habit of the limestone rocks i.e., compact or loose is likewise fundamentally an element of kind of bonding cement. In the facies of the Kirthar Formation, the prevailing cement is calcite.

3.3 Dissolution

Next to cementation, dissolution is likewise accepted as a significant diagenetic process. The presence of pore spaces and the optional permeability favours the invasion of fluids inside and in this manner cause the action of dissolution. Aragonite is promptly broken down by liquids than

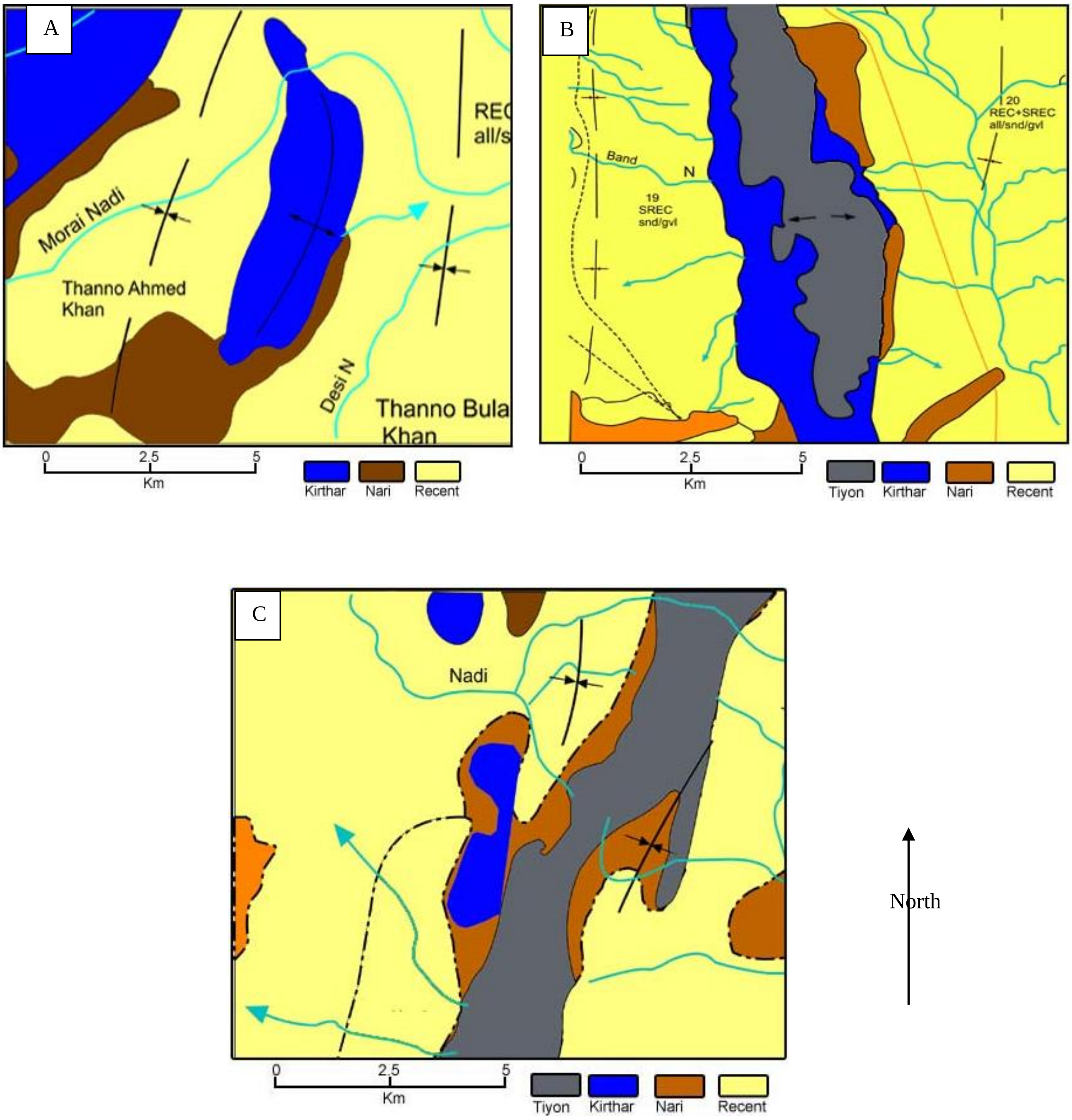


Fig. 1: Geological map shows (A) Gadularo Anticline, (B) Kambho Jabal and (C) Watawaro Rojh Jabal, along with Formations in different colours.

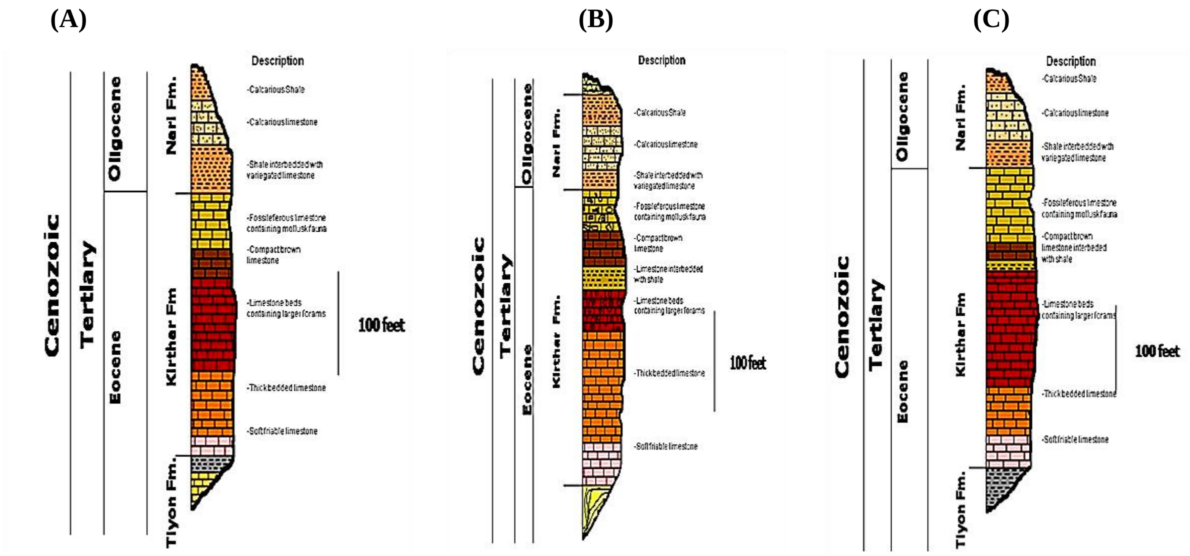


Fig. 2: Shows lithologic logs of (A) Gadularo Anticline, (B) Kambho Jabal and (C) Wataware Rojh Jabal.

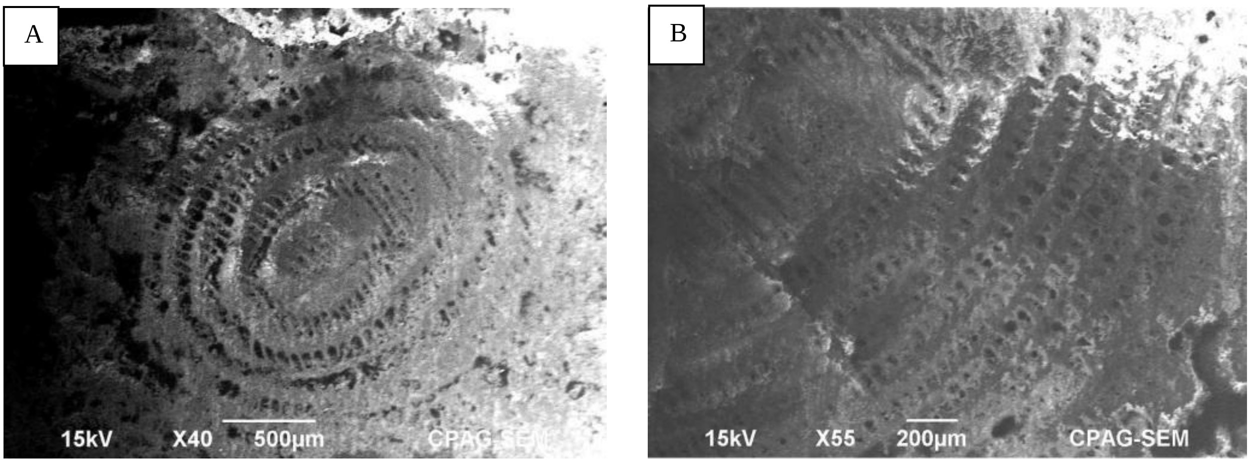


Fig. 3: Electron photomicrographs of traces of foraminifera microfossils (A, B).

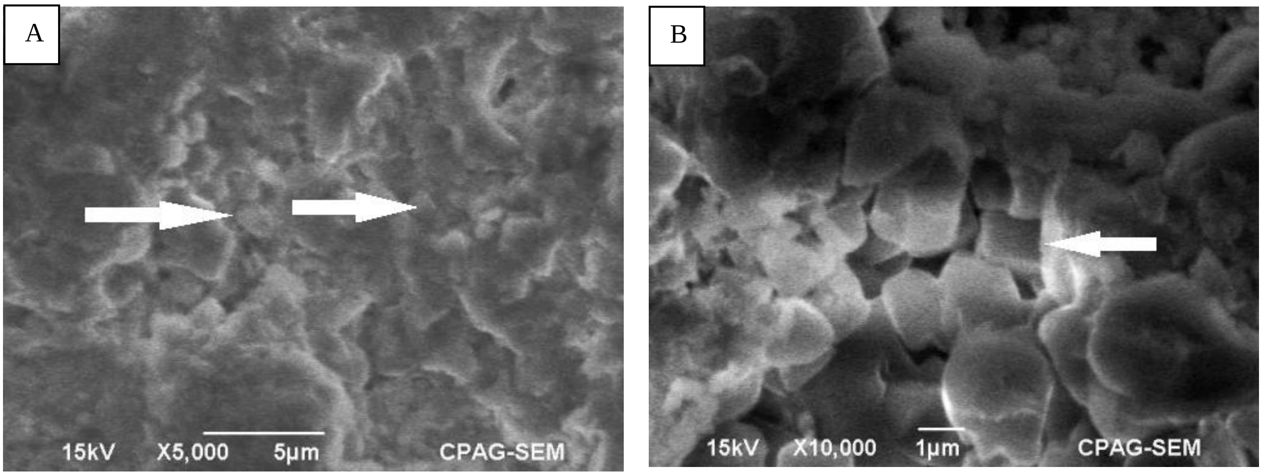


Fig. 4: An Electron photomicrograph shows the cement (A, B, arrows).

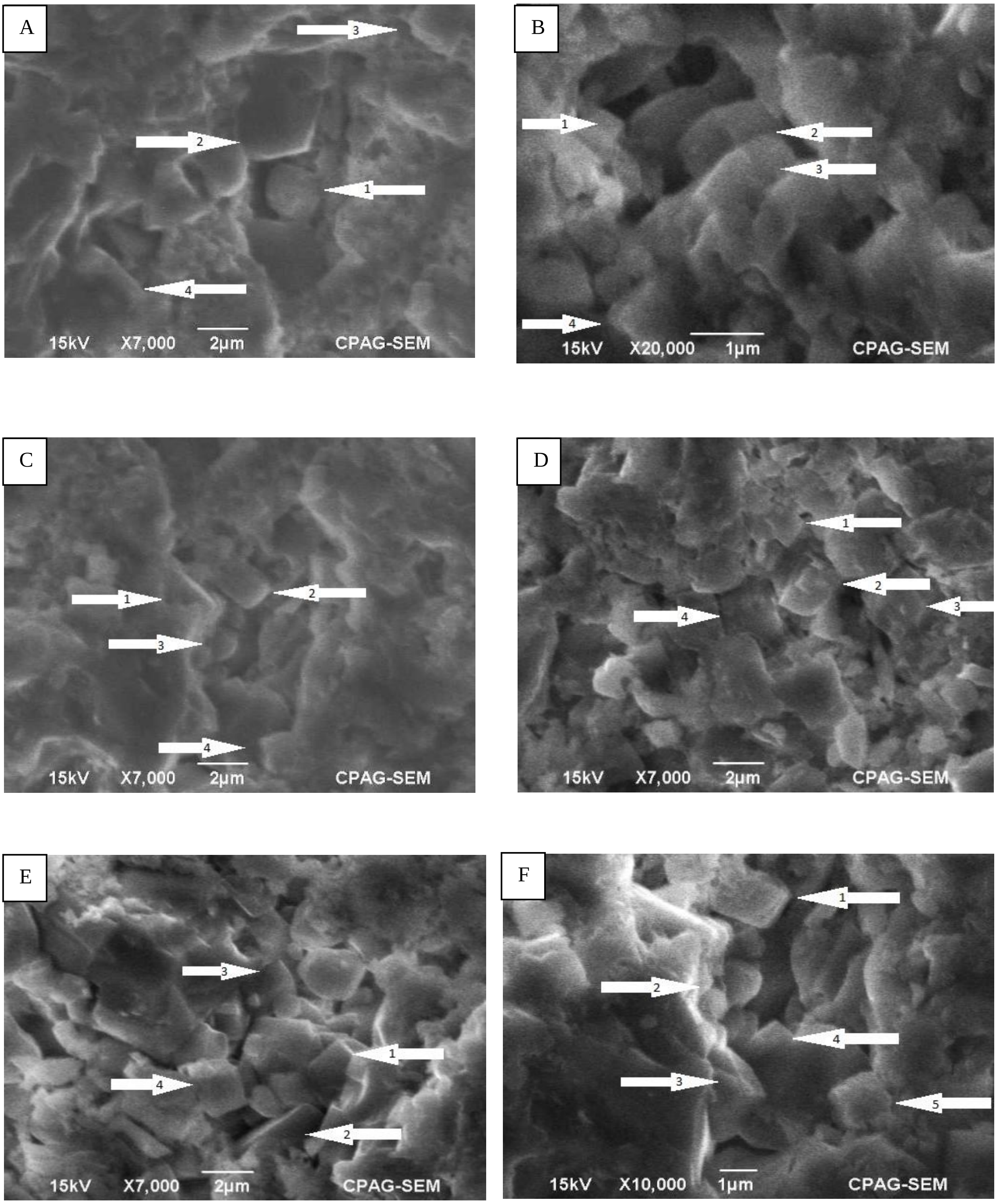
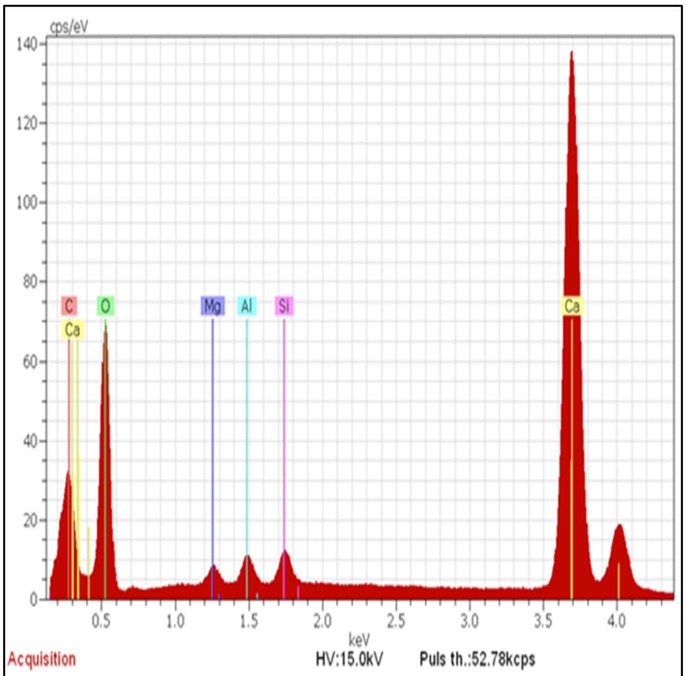


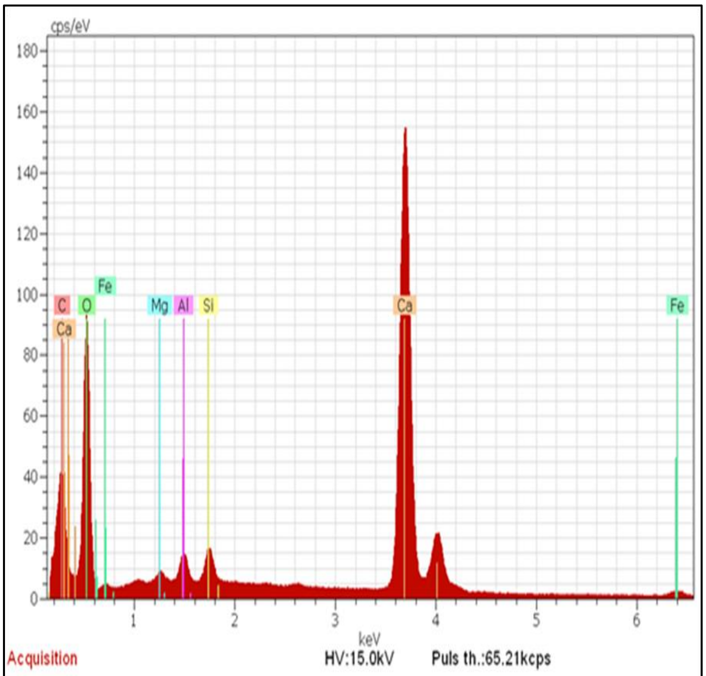
Fig. 5: An Electron photomicrograph shows the dissolution of calcite cubes (A, B, Arrows), Neomorphism (C, D, Arrows), compaction (E, F Arrows).



Spectrum: Acquisition

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	8.62	8.78	15.13	1.1
Oxygen	K-series	46.92	47.80	61.81	5.3
Magnesium	K-series	0.61	0.62	0.53	0.1
Aluminium	K-series	0.83	0.84	0.64	0.1
Silicon	K-series	1.05	1.07	0.79	0.1
Calcium	K-series	40.14	40.89	21.11	1.2
	Total:	98.16	100.00	100.00	

Fig. 6: An EDX Spectrum and Acquisition table of limestone specimen shows the presence of Aluminum, Magnesium and Silicon in the limestone of the Kirthar Formation.



Spectrum: Acquisition

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	9.22	9.67	16.36	1.1
Oxygen	K-series	47.08	49.38	62.69	5.2
Magnesium	K-series	0.32	0.34	0.28	0.0
Aluminium	K-series	0.71	0.75	0.56	0.1
Silicon	K-series	0.89	0.94	0.68	0.1
Calcium	K-series	35.09	36.81	18.65	1.1
Iron	K-series	2.02	2.12	0.77	0.1
	Total:	95.33	100.00	100.00	

Fig. 7: An EDX Spectrum and Acquisition table of limestone specimens shows the presence of silicon and magnesium along with other elements.

the calcite relies on the forcefulness of the liquids which, if intense, can likewise disintegrate the calcite grains. (Fig. 5 A, B) shows the process of dissolution of calcite microcrystals in the Kirthar Formation.

3.4 Neomorphism

The change of one mineral into another is a common process in many carbonate hierarchies. "Neomorphism" is a term utilized by Folk (1965) to cover the joined cycles of reversal (e.g., change of aragonite to calcite) and also recrystallization. The way that the less stable aragonite is an unsteady mineral when contrasted with calcite makes the genuinely positive ground be changed into a steadier chemical compound i.e., calcite. So many such inversion and recrystallization clues are found in present examinations (Fig. 5 C, D). As infers to the course of neomorphism, it may be seen that the entire surface and texture of limestone is obliterated, and recrystallization is occurring.

3.5 Compaction

The well-known peculiarity of carbonate rocks is the tight packing of the grains which resulted into so many physical and chemical alterations. The course of compaction is straightforwardly corresponding to the depth of burial, the more the depth, the higher the compaction. The most impacted property of the limestone is porosity with the rising overburden pressure of sediments, which in most cases, remarkably decreases the original pore spaces. In the scanning electron microscopy of the chosen samples, the depth was seen which shows the reduction in pore spaces and dissolution of calcite crystals (Fig. 5 E, F). At profound burials of the carbonates, chemical compaction may likewise occur bringing about precipitation and dissolution of some non-carbonate origin minerals such as the clay minerals. This phenomenon is clearly observed in the EDS analysis of a couple of samples (Fig. 6).

3.6 Replacement

The process of replacement is common in carbonates and, more specifically, limestone rocks, as it is in most siliciclastic rocks. It is the process by which one mineral dissolve and another mineral precipitates at the same time. Dolomitization of some $CaCO_3$ sediments is one type of replacement. Likewise, numerous different types of noncarbonate minerals replace carbonate minerals during diagenesis, including microcrystalline grains of quartz. The process of replacement is very well seen in the current investigation. The EDS analysis was carried out for the determination of the presence of other minerals. The existence of silicon and magnesium alongside different other elements are indications of the replacement processes (Fig. 7).

4. Conclusion

Practically every single diagenetic process has been seen in the current investigation. Scanning Electron Microscopy with an assistance of an EDS has uncovered the micro-level features of carbonates of the Kirthar Formation. The paleo-temperature conditions during the deposition of the Kirthar Formation used to be in the warm to medium range, nevertheless, cool water also prevailed in certain cases. The diagenetic processes such as cementation and compaction caused by overburden and rising pressure and temperature have resulted in tight packing of the limestone component of the Kirthar Formation, resulting in mineral dissolution and alteration in places. Therefore, the deduced environment of deposition of the Kirthar Formation in view of diagenetic processes is the shallow shelf and categorically the Epeiric Shelf Environment.

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