



Khurmala Formation (Late Paleocene-Early Eocene) in Halabja area, Kurdistan Region, Iraq

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| Article info | Abstract |
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| Original: 10 May 2019 | The studied section of Khurmala Formation (Late Paleocene-Early Eocene) is located in the Nawar Mountains on the northern part of the entrance of Sirwan River in Darbandikhan Lake. The section is mostly composed of dolomitic limestone, with occasional occurrence of sparsely fossiliferous limestone which are white, light grey and yellowish grey in color. The thickness of this section is almost 73 m and a total of 52 samples were collected at intervals of 0.5-3.0 m according to the lithological changes. Fifty-two thin sections were prepared and analyzed under a binocular microscope. The microfacies distinguished are Boundstone with corals, Bindstone with coralline red algae and corals, Bioclastic grainstone, Bioclastic oolitic grainstone, Bioclastic packstone, and Wackestone. These facies were interpreted to be deposited mainly in the shoal and lagoon of inner ramp environment. Although the studied section is not rich in fossils and most of them were destroyed by diagenesis processes, the following have been identified: <i>Spongites sp.</i> , <i>Cymopolia elongata</i> , <i>Mesophyllum sp.</i> , <i>Sporolithon sp.</i> , <i>Idalina sinjarica</i> , <i>Quinqueloculina</i> , <i>Cymopolia sp.</i> and <i>Spongites cf. albanensis</i> Lemoine. |
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| Khurmala Formation. | |
| Paleocene-Eocene. | |
| Microfacies. | |
| Dolomitization. | |

Introduction

The Khurmala Formation (Paleocene-Early Eocene) was described for the first time by Bellen in 1953 in the Kirkuk-114 well (type area), consisting of 185 m and comprising dolomite [1]. According to Ditmar and the Iraqi-Soviet Team (1971) [2], the formation consists of recrystallized limestone with intercalated beds of anhydrite and gypsum. Most of the fossils were destroyed due to the dolomitization processes and recrystallization. However, some forms of miliolids, small valvulinids, alveolinids and small gastropods with fragments of algae can be recognized. Al-Qayim (1995) [3] studied the Khurmala Formation in four regions: Aqra, Shaqlawa, Bakhma, and Haibat-Sultan with thickness of 50 m, 12 m, 40 m and 80 m respectively. Base on the microfacies analysis. He determined restricted lagoonal, open lagoon, estuarine, and tidal facies of dolostone, limestone, coralgal mound and marlstone. Banna et al. (2006) [4] studied the Khurmala Formation (microfacies and environmental deposition) in an outcrop located in the northeast of Dohuk city, consisting of carbonate with clastic sediments and identified four carbonate microfacies belonging to supratidal, intertidal, lagoon and shoal bank environments. The Khurmala Formation also was studied in Dokan area by Al-Lihaibi (2012) [5] from a diagenesis point of view. According to his studies, the main diagenetic processes found in Khurmala Formation were influenced by the periodical fluctuation in sea level. Salih (2013) [6] studied in details some sections of Khurmala Formation (Kalksmaq, Daigala, Hijran, Harir, Junara, Aqra, Bashiqa, Babylo, and BaryBahar sections). According to the above-mentioned author, the

thickness of studied sections range between 6.0-50 m, and their composition, generally consists of thin to medium bedded, some time massive, yellowish gray, light grey to dark gray marl to limestone, marly limestone, gray dolomitized or dolomitic limestone. Karim (2016) [7] studied facies changes between Kolosh and Sinjar or Khurmala Formations in Sulaimani and Duhok area. He evidenced that the contact between Kolosh and Sinjar or Khurmala Formations is gradational in all studied sections in the two mentioned regions.

Recently, Kamal et al. (2018) [8] studied four sections of Khurmala Formation (Zawali, Dari Haji Khidir, Mirede, and Dara Rash) in Sulaimaniya Governorate. In the all studied sections, the dolomitic limestone is underlying the Gercus Formation and overlying the Kolosh Formation. Assad and Balaky (2018) [9] also studied the Khurmala Formation in Zanta Village, Aqra district. They considered the thickness of Khurmala Formation 71 m and distinguished three types of microfacies with two different lithological units of thick dolomitic limestone and stratificated marly limestone. They also interpreted the depositional environment as a shallow marine environment of shelf lagoon with circulation under quiet and semi-restricted conditions.

Geological Setting

The studied section in this research has been named after Nawar Mountains, where the section stretches to the top of this mountain. Petrographically, the section is represented mostly by dolomitic limestone, and some beds are represented by sparsely fossiliferous limestone (white, light grey and yellowish grey in color). The section is located in Zagros Folded Zone [10] at the altitudes and longitudes of 35° 7'44.56"N and 45°52'6.27"E respectively (Fig. 1) at a distance of about 15 km to the southwestern part of Halabja town. In the western part of the Nawar Mountains is the Sirwan valley and the river with same name where it flows into Darbandikhan Lake. The thickness of this section is almost 73 m. The true thickness is difficult to be measured because the boundary between Kolosh and Khurmala formations cannot be exactly recognized. This is due to the intense diagenetic processes and deformation which have affected the rocks and have destroyed their structure and fossils. In the lower part of the succession, the rock appears in the form of blocks. In the upper part, it consists of beds with different thicknesses ranging between 10 cm-1.0 m or even more (Fig. 2). The studied area is a part of western limb of Balambo anticline (Fig. 8). The southwestern part of this limb has been eroded due to weathering and erosion, especially the Sirwan river coming from Iran and flowing into Darbandikhan Lake which passes this region. This has resulted in the formation of Sirwan Valley which gathers runoff of rain from the most parts of this region into Darbandikhan lake. The Sirwan river valley forms a wide bottom with gentle slopes in all its sides along with tributaries flowing into the valley. Generally, the region is covered by complicated geomorphology consisting of deep valleys, plains, hills, and mountains.

In the studied section, the lower boundary of Khurmala Formation is conformable and gradational with Kolosh Formation that reaches approximately 300 m in thickness and consists of beds of conglomerate, gray marl, marly limestone, siltstones, and detrital limestone beds. The conglomerate is composed of sand grains, medium gravels, chert and angular particles derived from green rock. The beds of conglomerate are located in the upper part of Kolosh Formation and are not in contact with Khurmala Formation. The conglomerate represents probably submarine fan channel. In the upper part, the Khurmala Formation gradates into Gercus Formation, that consists of red shales, mudstones, conglomerates, pebbly and marly sandstones.

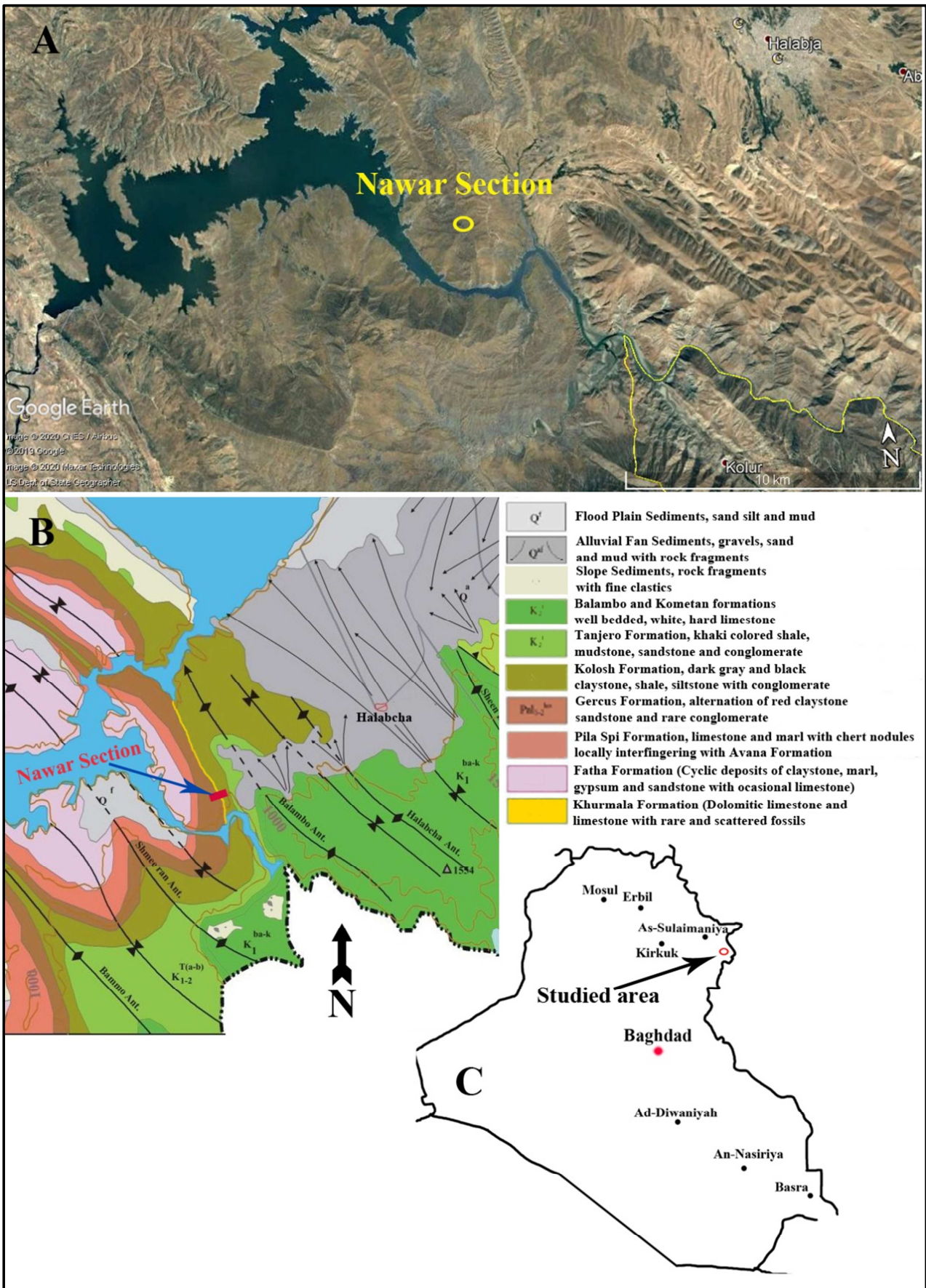


Figure-1: A. Google map showing the location of Nawar Section. B. Sketch of the geological map of Sulaimaniyah Quadrangle, at scale of 1: 250 000 showing location of the studied Nawar Section (modified from Ma'ala 2007) [11]. C. Representative map of Iraq showing the studied area.

Material and Methods

The samples were taken from the bottom to the upper part of the section at intervals of 0.5-3 m. This was due to the lithological composition of the rock so that all changes were included. A total of 52 samples were collected to prepare the thin section in the laboratory. A number of 52 thin sections (3x4 cm) were prepared with epoxy and without coverslips in the author's personal laboratory for thin sections, after which they were studied in detail under the binocular microscope for the determination of microfacies and their classification according to Dunham (1962) [12] and Embry and Klovan (1972) [13], microfossils, the most abundant diagenetic and recrystallization processes.

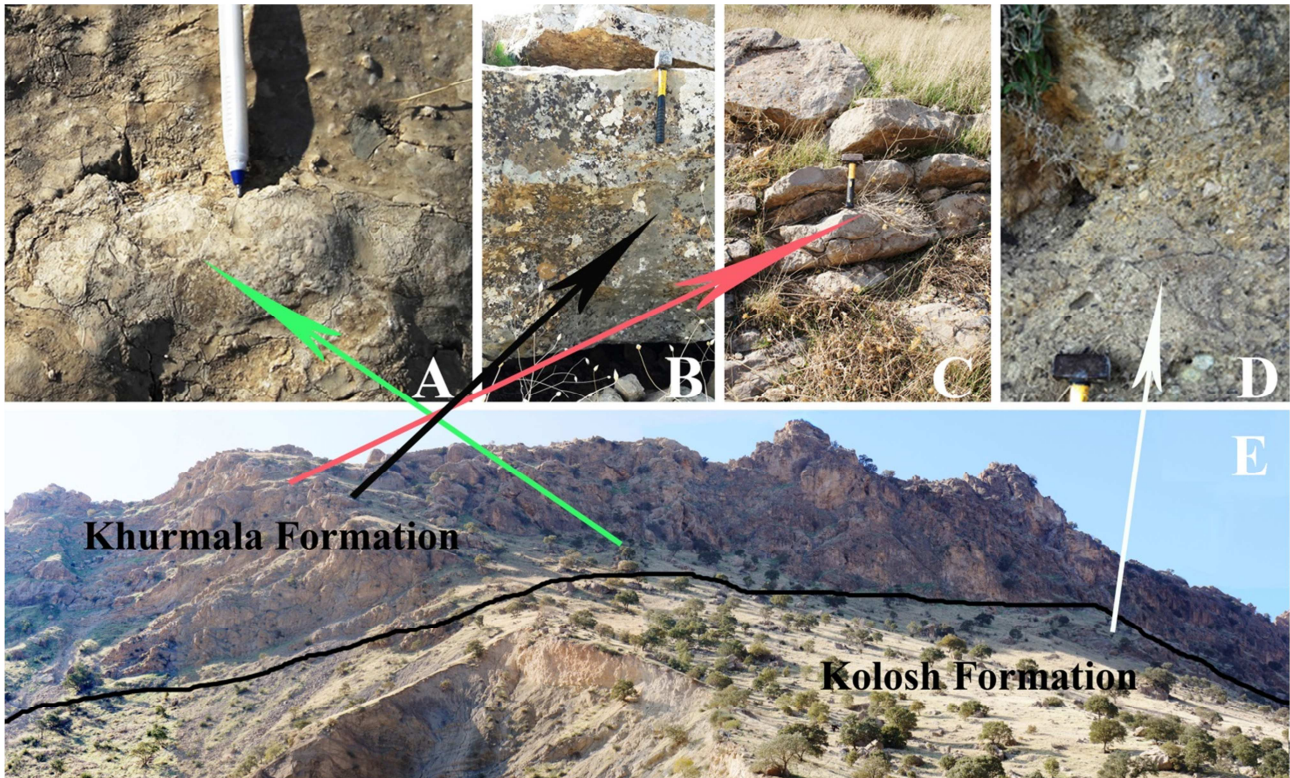


Figure-2: Field photos. A. Fragments of corals, B. Bed of 1 m thickness consisting of bivalves, fragments of ostracods, small gastropods and their fragments with miliolids and fragments of corals, C. Beds of 10 cm to 30 cm thick contain fragments of gastropods and bivalves, D. Conglomerate of sand grains, medium gravels, chert and angular particles in upper part of Kolosh Formation underlying the Khurmala Formation. E. Studied Section showing both Khurmala and Kolosh Formations.

Results and Discussion

A. Microfacies

Based on the dominant bioclasts and other biogenic flora, fragmented or preserved forms and according to the classification of Dunham (1962) [12] and Embry and Klovan (1972) [13] six microfacies types have been identified in the studied section as shown in (Fig. 3)

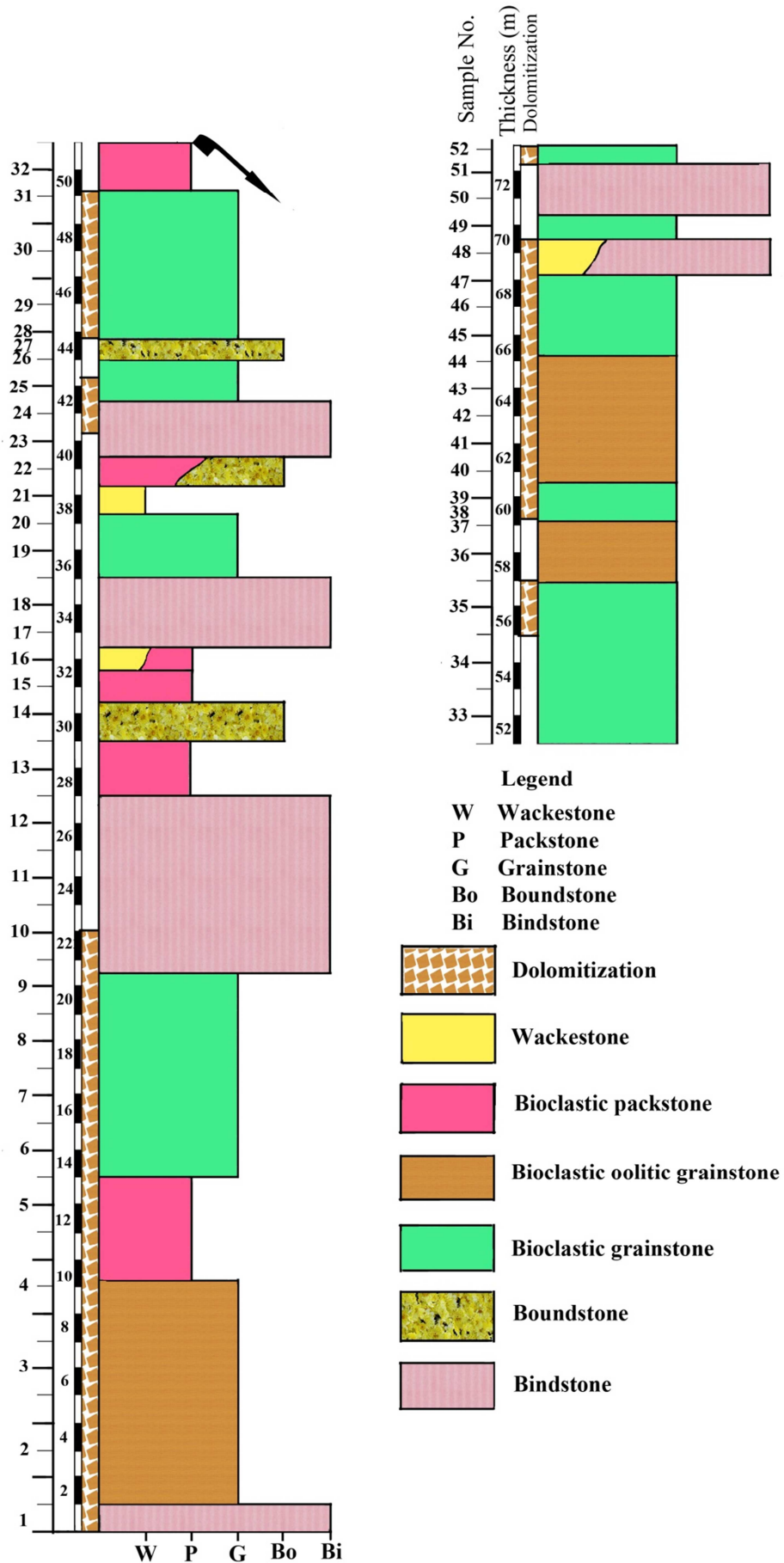


Figure-3: Stratigraphic succession at Nawar Mountain on the northern part of the entrance of Sirwan river in Darbandikhan Lake showing the main microfacies types.

1. *Boundstone with corals Microfacies*

This microfacies is represented by different types of corals with other fragments like gastropods shell, echinoderm plates or small miliolids that are present in small amounts (Fig. 5). This microfacies appears in the middle part of the studied section (Fig. 3) and occurs in three parts with small thicknesses.

2. *Bindstone with coralline red algae and corals Microfacies*

This type of microfacies is characterized by biogenic crusts represented by non-geniculate coralline algae that are the main binders, and is associated with corals contributing to the stabilization of the substrate (Fig. 5). The identifiable coralline algal assemblage includes *Spongites sp.*, *Mesophyllum sp.* and *Sporolithon sp.* (Fig. 6). Other components are small miliolids, bryozoan and gastropods fragments. This microfacies appears in the lower and upper part of the succession along with the middle part where it has the most appreciable thickness.

3. *Bioclastic grainstone Microfacies*

The main constituents of this microfacies are represented by echinoderm, bivalves and ostracods fragments, small gastropods and their fragments, small miliolids, fragments of red algae and corals with sparite filling the pore spaces between the fragments. This microfacies is alternating between the other types identified in the studied section and forms more than a third of it (Fig.4).

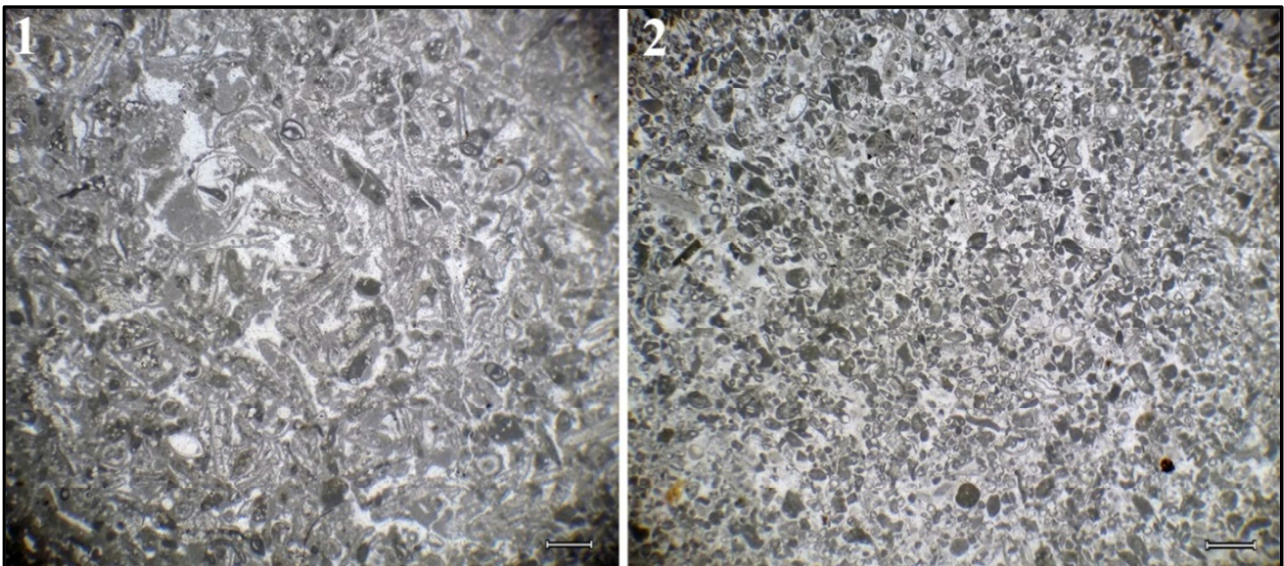


Figure-4: 1- Bioclastic grainstone (sample 45) with abundant fragments of ostracods, bivalves, gastropods, and miliolids with compaction phenomena indicated lagoonal deposition with high energy. 2- Bioclastic oolitic grainstone (sample 37) with abundant oolites formed around small miliolids or fragments of red algae or other small bioclasts. The scale is 1 mm.

4. *Bioclastic oolitic grainstone Microfacies*

This microfacies is characterized by the presence of bioclasts, aggregate grains, and ooids. The bioclasts belong to the gastropods, red and green algae fragments, echinoids plate and small miliolids with sparite cement between them. The ooid coatings are spherical and subspherical and are mostly formed around a biogenic nucleus composed of abovementioned bioclasts. This microfacies occurs in the lower and upper part of the studied section, approximately in equal thickness of eight meters as shown in (Figs. 3 and 4).

5. *Bioclastic packstone Microfacies*

This microfacies is composed of biogenic fragments of gastropods, bivalves, echinoderms, coralline algae, ostracods, branchy form bryozoans, sclerosponges and small miliolids in a micritic matrix (Fig. 5). In the studied section, this microfacies occurs in four levels in the lower two thirds of the succession (Fig. 3).

6. Wackestone Microfacies

According to Dunham (1962) [12], the microfacies with more than 10% skeletal or nonskeletal fragments are categorized as wackestone. This is identified in the middle part of the studied section (Fig. 3). It is also found in the other two levels associated with packstone and bindstone microfacies. This microfacies consists of bioclasts of gastropods, bryozoans and dolomitized green algae (Fig. 5).

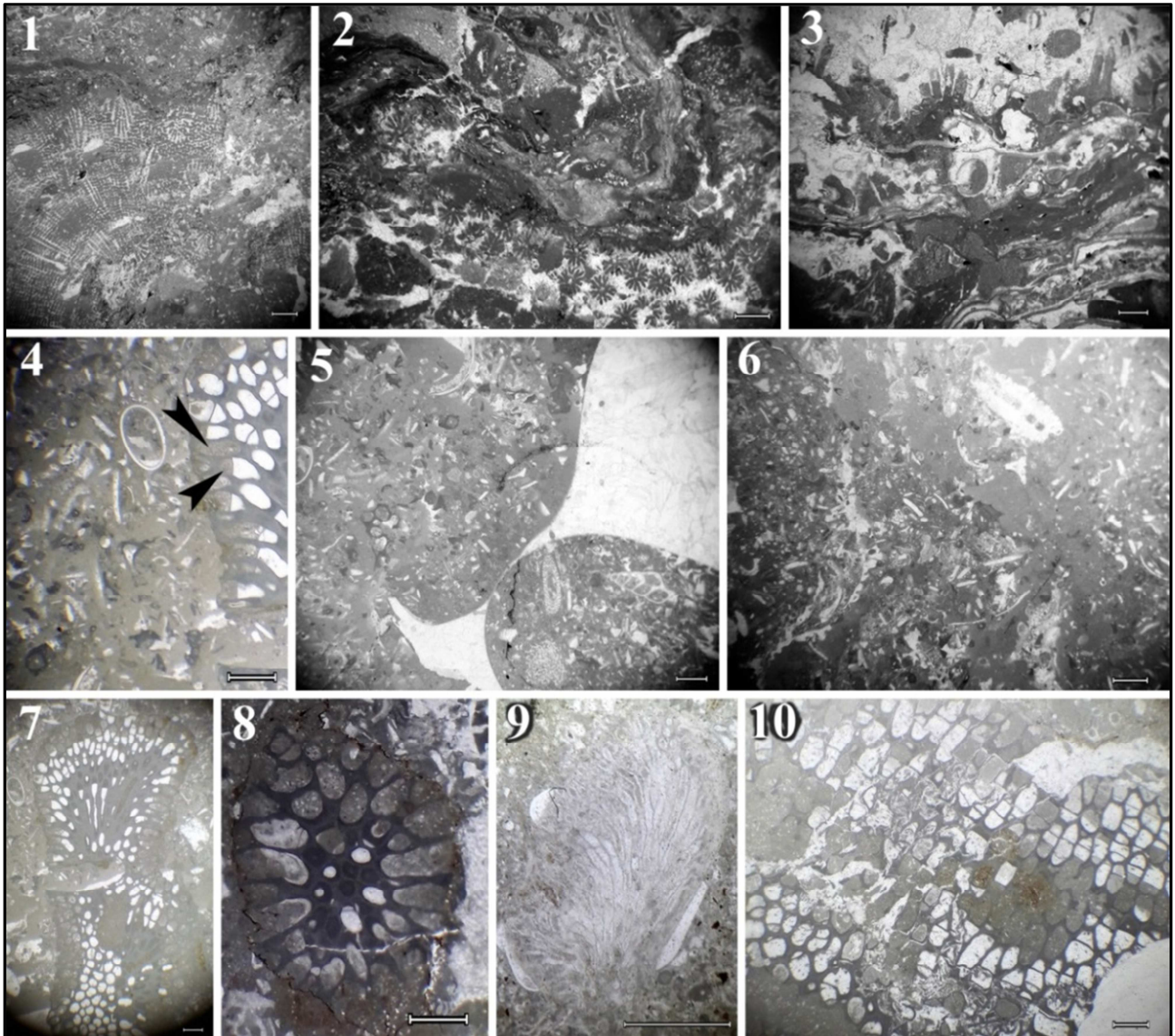


Figure-5: 1-Boundstone with Scleractinian colonial corals microfacies (sample 14). The corals are encrusted by red alga. 2, 3- Bindstone with coral and red algae microfacies (samples 1, 12). 4, 5- Bioclastic packstone microfacies (sample 15) with abundant fragments of gastropods, bivalves, echinoids, ostracods, bryozoans, sclerosponge, red and green algae. Zoecia of sclerosponge were partially or totally filled by mud (black arrows). 6- Bioclastic packstone-wackestone microfacies (sample 16) with green algae, fragments of gastropods, red algae, echinoids, and ostracods. 7, 8, 10- Well preserved form of sclerosponges of the genus *Acanthochaetetes*. 9- Branchy form bryozoans. They are frequent in packstone and wackestone microfacies, but are also present in bindstone microfacies (samples 19, 16, 2, 24). The scale is 1 mm.

B. Microfossils

The limestone in the studied section is not rich in fossils and many of them were partially or even completely destroyed due to dolomitization processes. However, several species of coralline, dasycladals, and miliolids have been identified for the first time in the studied area. The microfossils are represented by

Spongites sp. (sample 10), *Cymopolia ellongata* Defrance (sample 15), *Mesophyllum* sp. (samples 21, 22), *Sporolithon* sp. (sample 49), *Idalina sinjarica* Grimsdale (sample 45), *Quinqueloculina* (sample 22), *Cymopolia* sp.? (sample 16) and *Spongites* cf. *albanensis* Lemoine (Fig. 6).

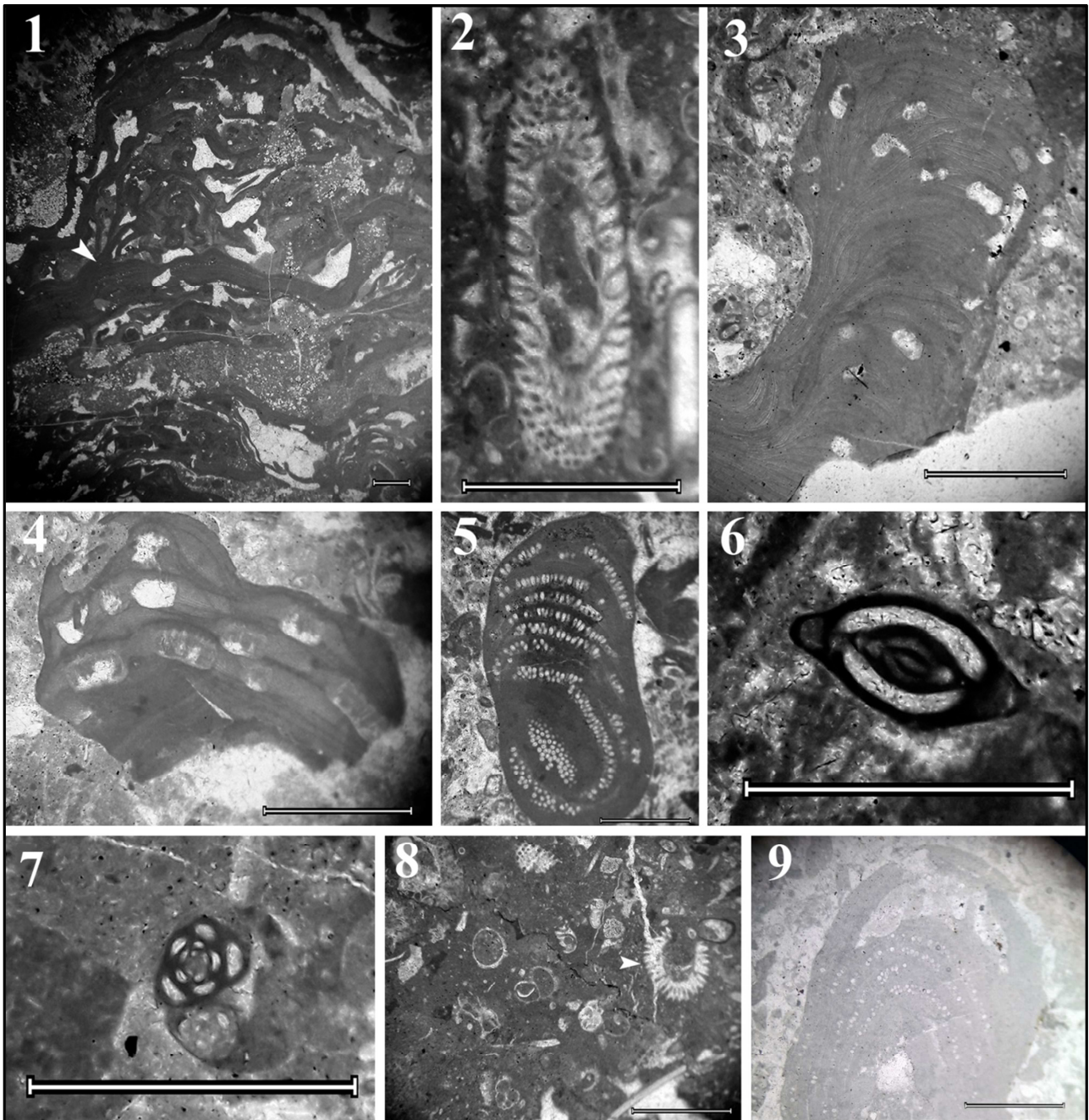


Figure- 6: 1- *Spongites* sp., indicated by arrow encrusting and prominent thalli showing uniporate conceptacles (sample 10). 2- *Cymopolia ellongata* Defrance (sample 15) 3, 4- *Mesophyllum* sp. (samples 21, 22). 5- *Sporolithon* sp. (sample 49). 6- *Idalina sinjarica* Grimsdale (sample 45) 7- *Quinqueloculina* (sample 22) 8- *Cymopolia?* sp.. (sample 16). 9- *Spongites* cf. *albanensis* Lemoine (sample 46). The scale is 1 mm.

C. Diagenesis Processes

The most common diagenetic processes observed in thin sections are dolomitization and stylolitization. **Dolomitization** is a process where crystals of calcite transform into dolomite when limestone comes in contact with a source of magnesium. This replacement of calcite by dolomite leads to the formation of three known dolomite crystals textures, non-planar crystals, planar euhedral crystals and planar subhedral crystals [14] and [15]. Dolomitization has advantages and disadvantages; the most valuable advantage is the

formation and improvement of porosity in carbonate rocks [16] where oil can be accumulated, while the disadvantage is represented by the destruction of structures and fossils in the rocks and the deletion of these documents leads to the loss of information about the formation and age of rocks.

The dolomite crystals recognized in the thin section of this study are mostly of the type euhedral-rhombohedral crystals, fine to medium crystalline in sizes and all are replacive in origin (Fig. 7). As showing in the Stratigraphic succession (Fig. 3) the first third and the last one have been subject to dolomitization and in some places, the limestone has been completely dolomitized, especially in bioclastic grainstone (samples 7, 8, 9).

Stylolitization is a common diagenetic process in carbonate rocks resulting from physicochemical processes induced by overburden, pressure, and temperature [17] or compression by tectonic movement [18]. These processes lead to the formation of irregular surfaces of discontinuity that are very widespread, especially in limestones known as stylolites [19]. The classification of stylolites and their geometry is mostly based on macroscopic observation and microscopic analysis.

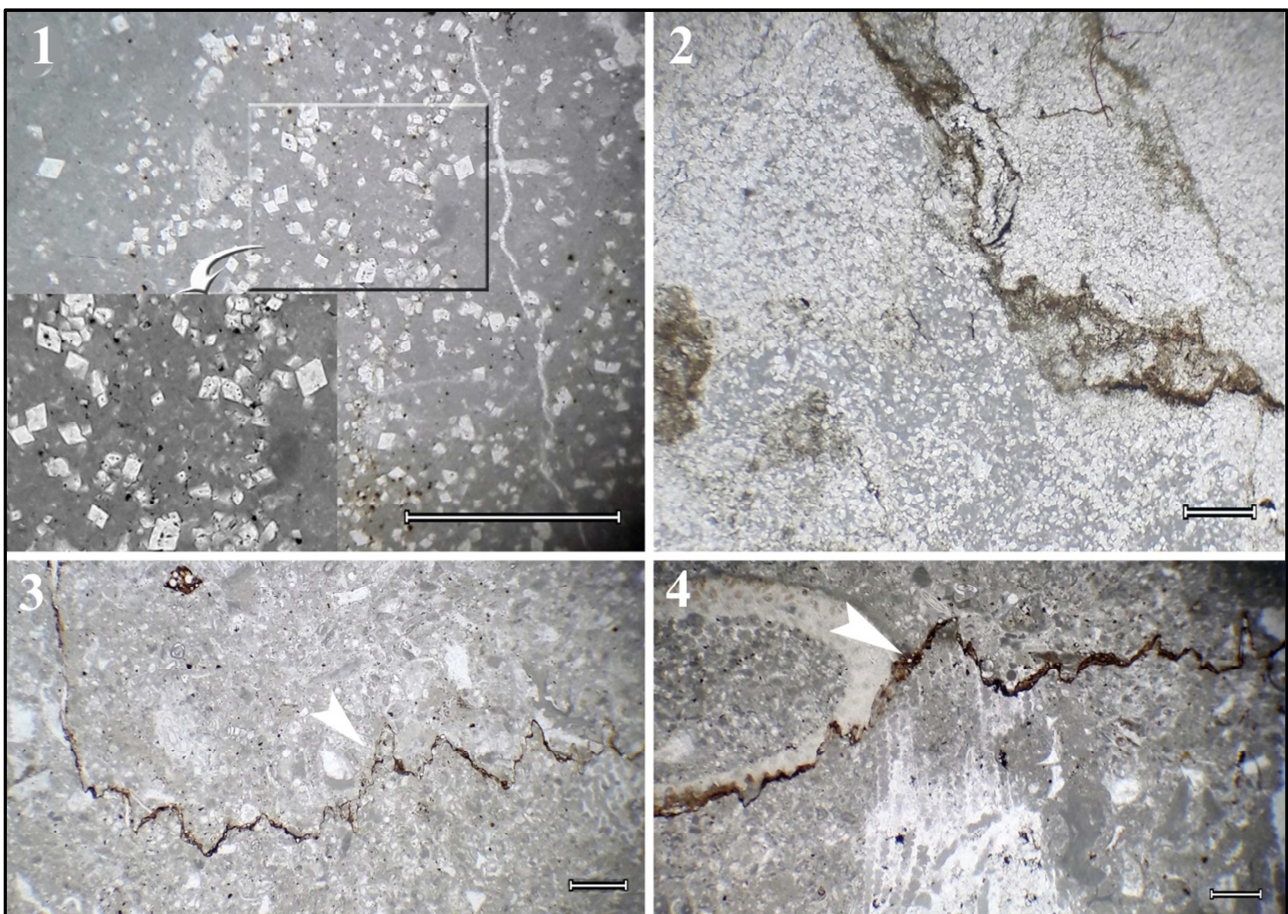


Figure-7: 1- Rhombohedral crystals of dolomite as a result of dolomitization processes (sample 7). 2- Completely dolomitized with fine crystals of dolomite (sample 8). 4, 5- Stylolitization indicated by white arrows (samples 20, 21). The scale is 1 mm.

Stylolitization has veritable effects on the reduction of porosity and permeability of rocks. This is due to the dissolution under pressure and re-sedimentation of its products in the pores and fractures within the rocks. In thin sections of this study, the stylolites, type suture and sharp peak (Fig. 7) were recognized according to the new classification of stylolites investigated by Koehn et al. (2016) [20].

D. Correlation

The correlation of the studied section as a new record of Khurmala Formation located at the western limb of Balambo anticline, in the stratigraphic position between Kolosh Formation at the base and Gercus Formation at the top (Fig. 8) with the sections described by Karim et al. (2018) [8] is an attempt to

understand the similarities between these formations and to confirm the validity of new record of Khurmala Formation at Nawar Mountains (Fig. 9).

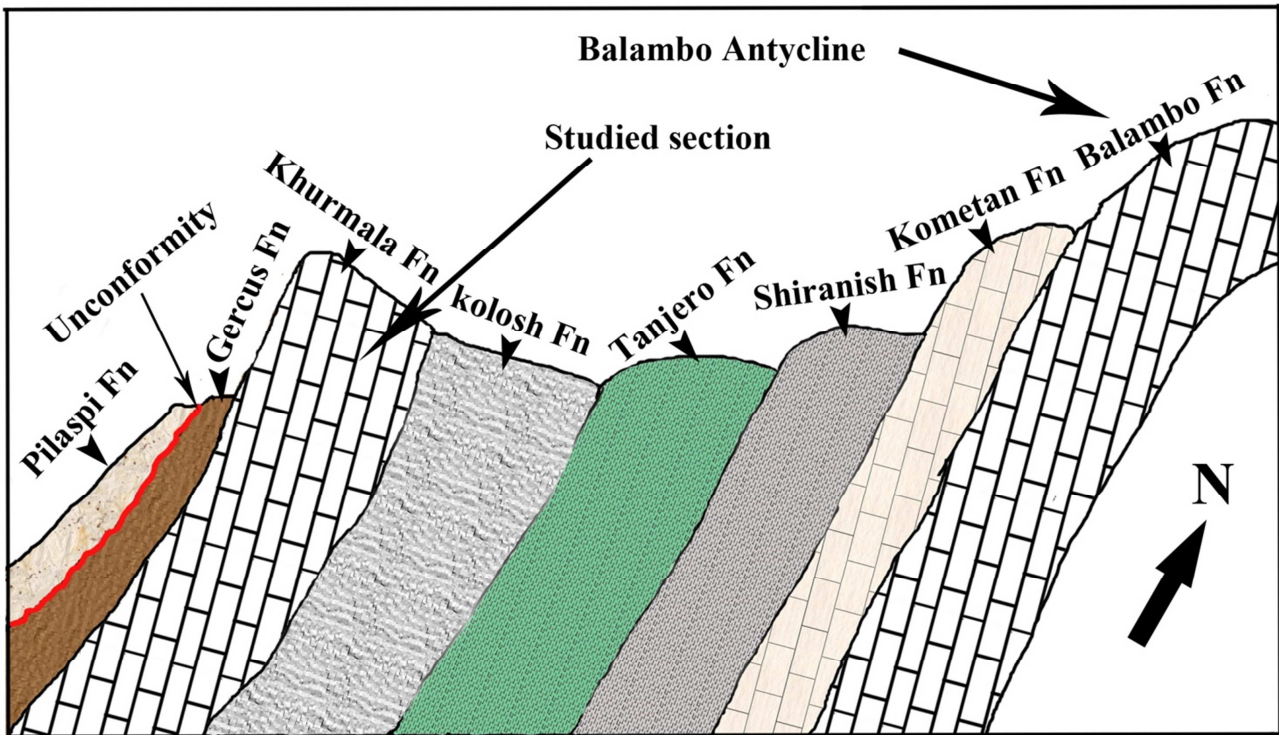


Figure-8: Geologic cross-section illustrates the western limb of the Balambo anticline showing the position of Khurmala Formation.

The poor fossils observed in the studied section have been observed in the other sections as well. The identified fossils were almost similar with the previous sections. Due to the diagenesis processes, especially dolomitization, most fossils were partially or even completely destroyed and are not identifiable. Similar fossils are represented by small miliolids, dasycladals, red algae, gastropods, and corals. There are also similarities related to the composition of rocks in the studied sections, specifically between Zawali and this study section, where rocks mostly consist of dolomitic limestone, white, light grey and yellowish grey limestone with interbedded of marly limestone and thin bedded of fine conglomeratic limestone in the middle part of the section. These are all indications which suggest that the new section can be considered as an extension Khurmala Formation in this region.

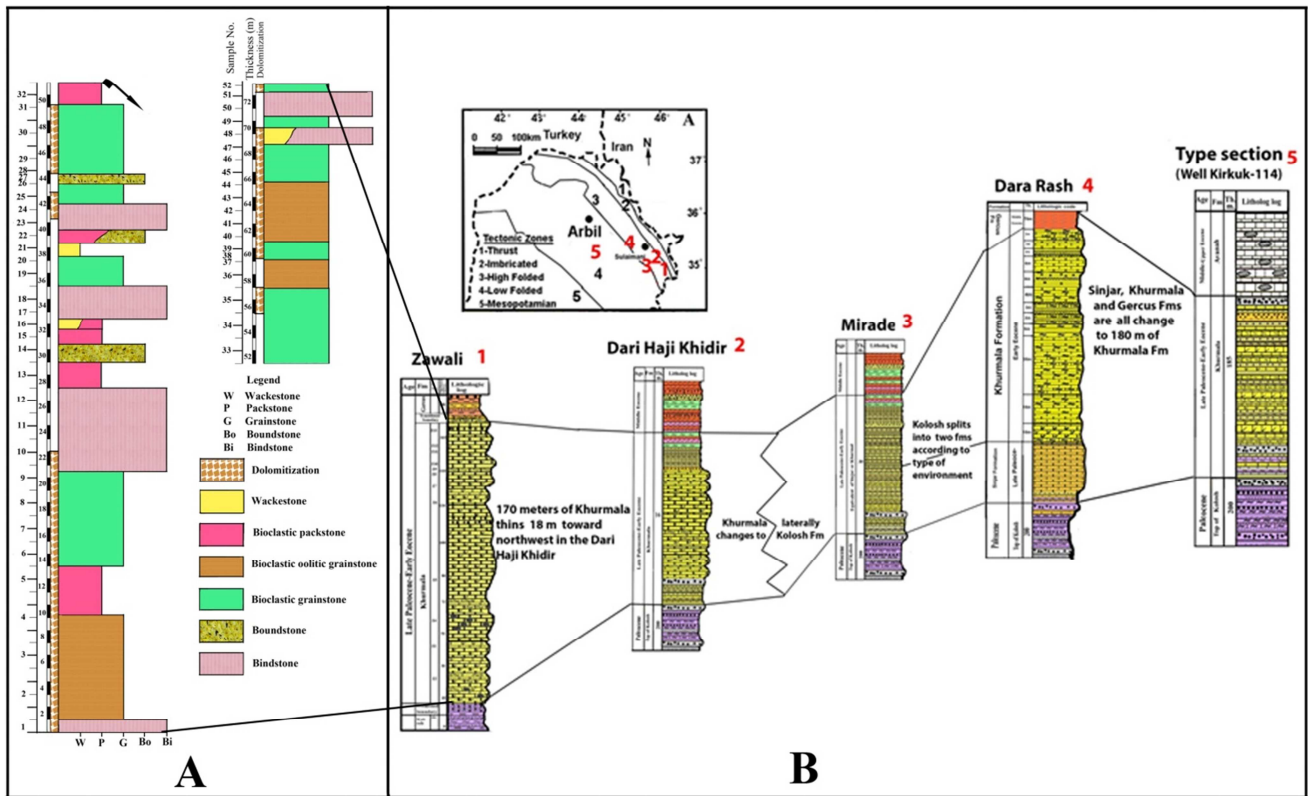


Figure-9: Correlation of the studied section (A) with the sections described by Karim et al. (2018) [8]. (B).

E. Palaeoenvironment

The coral boundstone is generated by high-growing communities [21] and isolated colonies of scleractinian corals lacking framework with a topographic relief [22] represented by the different type of corals. Sometimes the corals are encrusted by bryozoans or red algae represented by non-geniculate coralline algae. This encrustation is a sign of deeper water in the reefal environment [23] with high light and high energy [24]. The coral boundstone microfacies consisting of scleractinian isolated colonial corals with coralline algae in the studied section is similar to patch reef appearing in back reef region. This is because the coral communities were scattered and not continuous [25]. The diversity of corals and their fragments indicates high energy, while the presence of micrite between skeleton of corals indicates that there were also calm phases, especially when the corals are encrusted by coralline and bryozoans [24], the presence of algae demonstrates shallow deposition conditions evidencing the presence of patch reef [26] possibly in the first step of evolution. Such microfacies as boundstone and bindstone with algal mats indicate the restricted setting was found in Upper Paleocene (Pyrenees, Spain) by Scheibner et al. (2007) [27] and in Thanetian, in a protected and restricted environment in the northern Tethys (SW Slovenia) by Zamagni et al. (2008) [28].

The grainstones are mostly found in higher energy and shallow water environment in back-reef or lagoons [29], while the dispersed branching coral fragments within bioclastic grainstone clarify diminutive water energy in the profound part of the lagoonal setting [30]. Bioclastic packstone composed mostly of bivalves, gastropods, fragments of bryozoans, miliolids, and fragments of red algae and corals, sometimes associated with wackestone, is characteristic of back reef or of the lagoonal environment [27]. Most of the mentioned bioclast components belong to the back reef [25]. Such facies with these fauna were considered as patchy distribution in Paleocene-Eocene by Waśkowska et al. (2014) [31] in Outer Carpathian basins (Poland). According to Flügel (2004) [17], the wackestone facies consisting of bioclasts and dolomitized green algae is related to the lagoon environment of an internal ramp. Based on the algal assemblages, Surdashy (2001) [32] assigned back-reef or lagoonal environment to the Khurmala Formation in Haibatsultan and Bekhma area.

The existence of bryozoans indicates suitable conditions for life. They are well-preserved and sometimes the undamaged zoecias were filled with micrite in the packstone and wackestone microfacies, while some of

them are encrusted by the thalli of coralline algae in the bindstone microfacies. This means that the bryozoans lived in the phytal zone in a relatively quiet environment [33]. This calm environment in shallow - marine setting is also indicated by the presence of micritic ooids composed of removed laminae due to an extensive micritization of the cortex. Dasycladacean green algae recognized in oolitic grainstone microfacies points to sedimentation under moderate to low energy conditions in back-reef environments or lagoon in an inner-ramp [34]. According to the microfacies and microfossils identified in the studied section, the paleoenvironments have been assigned to the Inner Ramp, in the shoal and lagoon environments as shown in (Fig. 10).

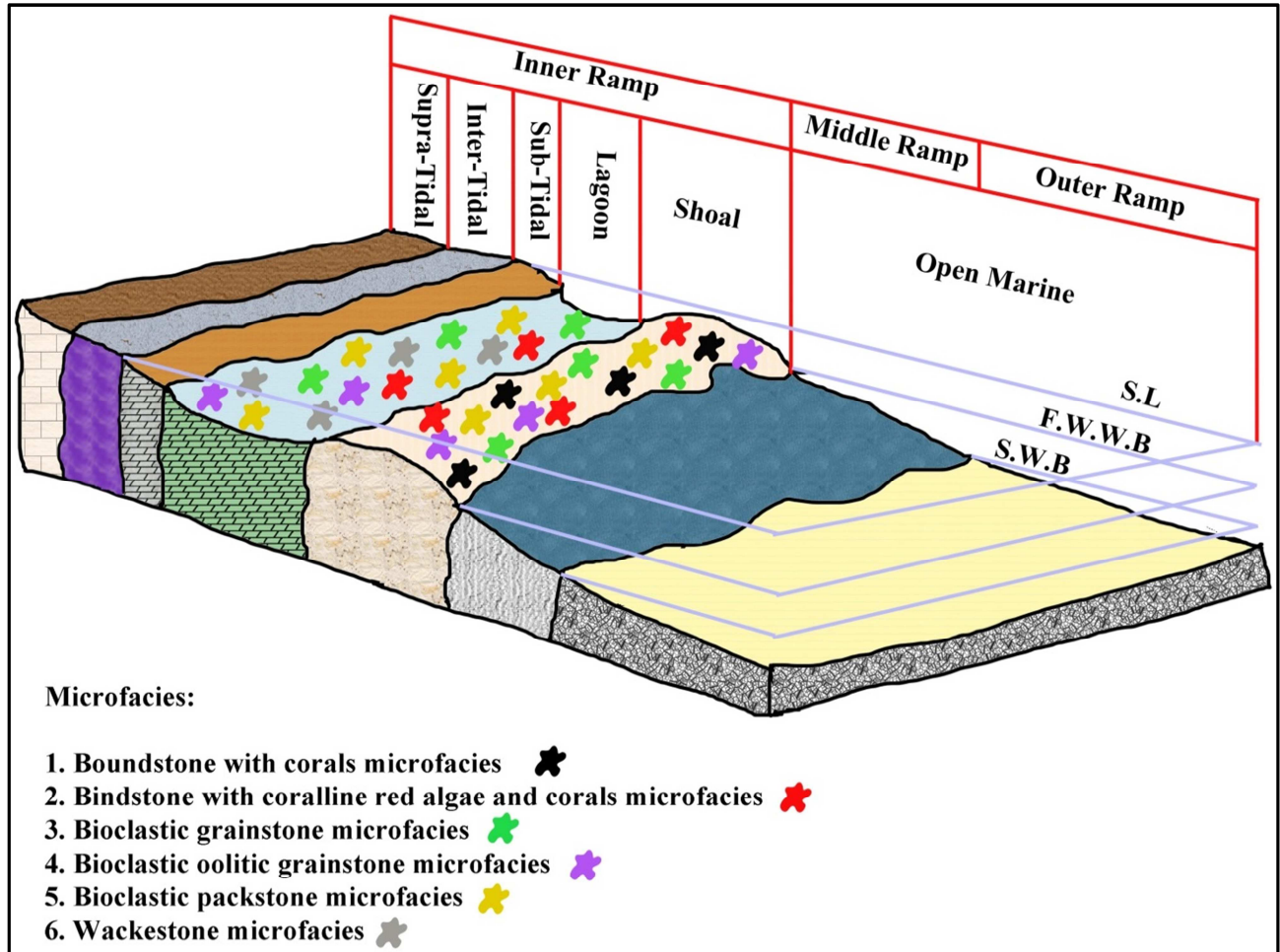


Figure-10: Schematic model for paleoenvironments of the Khurmala Formation in the studied area based on the identified microfacies and their interpretation.

Conclusions

The study of microfacies, microfauna and diagenetic processes in the Nawar Mountains section led to the following conclusions:

- 1- Based on the lithological composition, microfossil types, dolomitization, and correlation with other studied sections in the region, it can be proved for the first time that this section belongs to the Khurmala Formation.
- 2- Identification of six microfacies types in the Khurmala Formation (Late Paleocene-Early Eocene) at Nawar Mountains in Halabja Governorate, included Boundstone with corals Microfacies, Bindstone with red algae and corals Microfacies, Bioclastic grainstone Microfacies, Bioclastic oolitic grainstone Microfacies, bioclastic packstone Microfacies, and wackestone Microfacies.
- 3- The interpretation of the microfacies types shows that the Khurmala Formation in the studied section is deposited mainly in the shoal and lagoon of inner ramp environments.

4- For the first time in the studied area, the following species of microfossils were identified: *Spongites sp.*, *Cymopolia ellongata* DeFrance, *Mesophyllum sp.*, *Sporolithon sp.*, *Idalina sinjarica* Grimsdale, *Quinqueloculina*, *Cymopolia sp.*, and *Spongites cf. albanensis* Lemoine.

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