

RECORD OF KHURMALA FORMATION (LATE PALEOCENE – EARLY EOCENE) IN THE SULAIMANIAH GOVERNORATE, KURDISTAN REGION, NORTHEAST IRAQ

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Received: 16 May 2017; accepted: 15 November 2017

ABSTRACT

The present study focuses on the field, petrography and stratigraphic analyses of a thick and sparsely fossiliferous dolomitic limestone succession in the west, north, and northwest of Darbandikhan town from Sulaimaniah governorate. The succession thins toward northwest and east and located in the stratigraphic position of and Khurmala (or Sinjar) Formation (Late Paleocene – Early Eocene) between Kolosh and Gercus formations at the base and top respectively. The Khurmala Formation is a lagoonal crystallized limestone, dolomite with interbeds of different clastic rocks. It also contains an occasional occurrence of gypsum and rare gastropods, miliolids, and algae in some beds. Previous studies found the formation and described in Duhok, Kirkuk and Erbil Governorates while in Sulaimani area it not proved until now. The present article studied four different sections of succession (previously and indicated as Sinjar Formation) and correlated them stratigraphically with each other and with Khurmala Formation in its type section in the well K-114. The study showed that these sections belong to Khurmala Formation. The sections reveal many evidences and signs of the occurrence of Khurmala Formation in between Kolosh and Gercus formations. These signs are the occurrence of 160 m of dolomitic limestone (80%) with beds of sparsely fossiliferous limestone (18%) and conglomeratic limestone (2%) in Zawali section on Shameran Mountain. The fossiliferous intervals contain lagoonal sparse and small miliolids, gastropods, pelecypods green and red algae. The formation laterally changes to Kolosh (in Mirade section) or partly to Sinjar Formation (in Dara Rash section). In the Mirade section, neither Sinjar nor Khurmala Formation is deposited and yellow marly limestone, sandstone and few beds of conglomerate occupy their stratigraphic position.

Keywords: Khurmala Formation; Sinjar Formation; Zawali Mountain, Darbandikhan, Iraqi Geology

INTRODUCTION

The present study aimed to study the origin of a thick and sparsely fossiliferous dolomitic limestone succession (Hereafter, this study refers to it as “dolomitic succession”) in the west, north, and northwest of Darbandikhan town from Sulaimani governorate. The succession is located in the stratigraphic position of Khurmala (or Sinjar) Formation (Late Paleocene – Early Eocene). Khurmala Formation (Paleocene – Lower Eocene) was first described by Bellen *et al.* (1959) in the Kirkuk-114 well where about 185 m thick. According to same authors, the formation consists of dolomite, sub oolitic in parts, and finely recrystallized limestone. The chemical limestone probably interfingering strongly with material from the Kolosh Formation, which is containing detrital chert, flint, radiolarite, and green rocks of silt and sand size. The above authors have further added that anhydrite, which is probably secondary, occurs occasionally and fossils are obliterated by recrystallization and dolomitization.

The Kolosh Formation underlies this unit and it grades into the Khurmala Formation through interdigitation. The overlying formation is Avanah Formation, which has unconformable, perhaps erosional contact (Bellen *et al.*, 1959). In well Chemchemical-2, Ditmar and Iraqi – Soviet Team (1971) noticed that the formation is composed of recrystallized limestone, with occasional argillaceous bed and beds of anhydrite and gypsum. According to Jassim and Goff (2006), the formation was deposited in a restricted lagoonal environment. Fossils mostly dwarf and obliterated by crystallization. The aim of this study is to record the new outcrops of the Khurmala Formation in Sulaimanyiah area and indicating the more accurate stratigraphic position which according to Buday (1980) has a slight obscure stratigraphical position.

In addition to above studies, there are many others ones that are concerned with Khurmala Formation. These studies are such as: Al-Surdashy (1988); Al-Qayim and Nisan (1989); Al-Berzanji (1989); Al-Sakry (1999); Al-Surdashy and Lawa (1993); Al-Qayim (1995); Lawa (2004); Al-Sakry (2006); Ahmed (2008); Jaff (2008); Salih and Abdullah (2009); Salih (2010) and Salih (2013). These studies have studied petrography, facies, and environment of the Sinjar and Khurmala formations but none of them has mentioned the occurrence of Khurmala Formation in Sulaimani Governorate. Three of these studies have included one chapter of sequence stratigraphies such as Lawa (2004); Al-Sakr (2006) and Jaff (2008).

METHODOLOGY

The study of the dolomitic succession depends on the fieldwork and microscopic studies. During the fieldwork, the stratigraphic units are differentiated and four different sections are selected for the study on the left and right side of the Darbandikhan lake (or Sirwan fault) (Fig. 1). In the field, the lithology of the section is inspected and described from the base to the top of the sections by the eyes and hand lens. From the sections, the authors took 35 samples according to the change of the lithology for the lab studies. The names and locations of the sections are Zawali, Dari Haji Khidir, Mirede and Dara Rash sections which are located at the altitudes and longitudes of (35° 06' 45.06" N 45° 49' 25.23" E), (35° 14' 51.81" N 45° 46' 59.98" E), (35° 14' 39.09" N 45° 41' 21.32" E) and (35° 21' 53.44" N 45° 29' 20.7" E), respectively. These sections are correlated mutually and with the type section of the Khurmala Formation in K-114 well in Kirkuk oil field. The studied sections are plotted on a topographic map and the Google earth images. The previous geological map is modified to show the location and distribution of the stratigraphic units that are under consideration.

In the lab, the thin sections are prepared from the samples and they are studied under the stereo, and petrographic microscopes for indication of their lithology and fossils of content the samples are studied. The thin sections preparation and their petrographic study are achieved in the laboratories of Department of Geology, University of Sulaimani.

GEOLOGICAL SETTING

The studied area is located in the Kurdistan Region, northeastern Iraq, about 40 km to the south and the southeast of Sulaimaniya City which include the area around Darbandikhan and Zarayen towns (Fig. 1). The area is located in the southeastern boundary of Sharazoor plain and Darbandikhan Lake nearly occupies the center of the area. The area located in the High Folded Zone as a part of Western Zagros fold-thrust belt. Many authors such as Buday and Jassim (1987); Lawa (2004); Jassim and Goff (2006); Ibrahim (2009); Aqrawi *et al.* (2010); Al-Qayim *et al.* (2012) and Lawa *et al.* (2013) mentioned passing of Khanaqin (or Sirwan) fault through the studied area. Karim *et al.* (2016) have studied the area on both sides of the fault and conclude that are no stratigraphic and structural surface expressions of the fault. They found that the

curvature of the anticlines and wideness of the synclines are attributed to deposition of a thick and massive succession of the conglomerate of Upper Bakhtiari Formation in the north and south of the Darbandikhan dam.

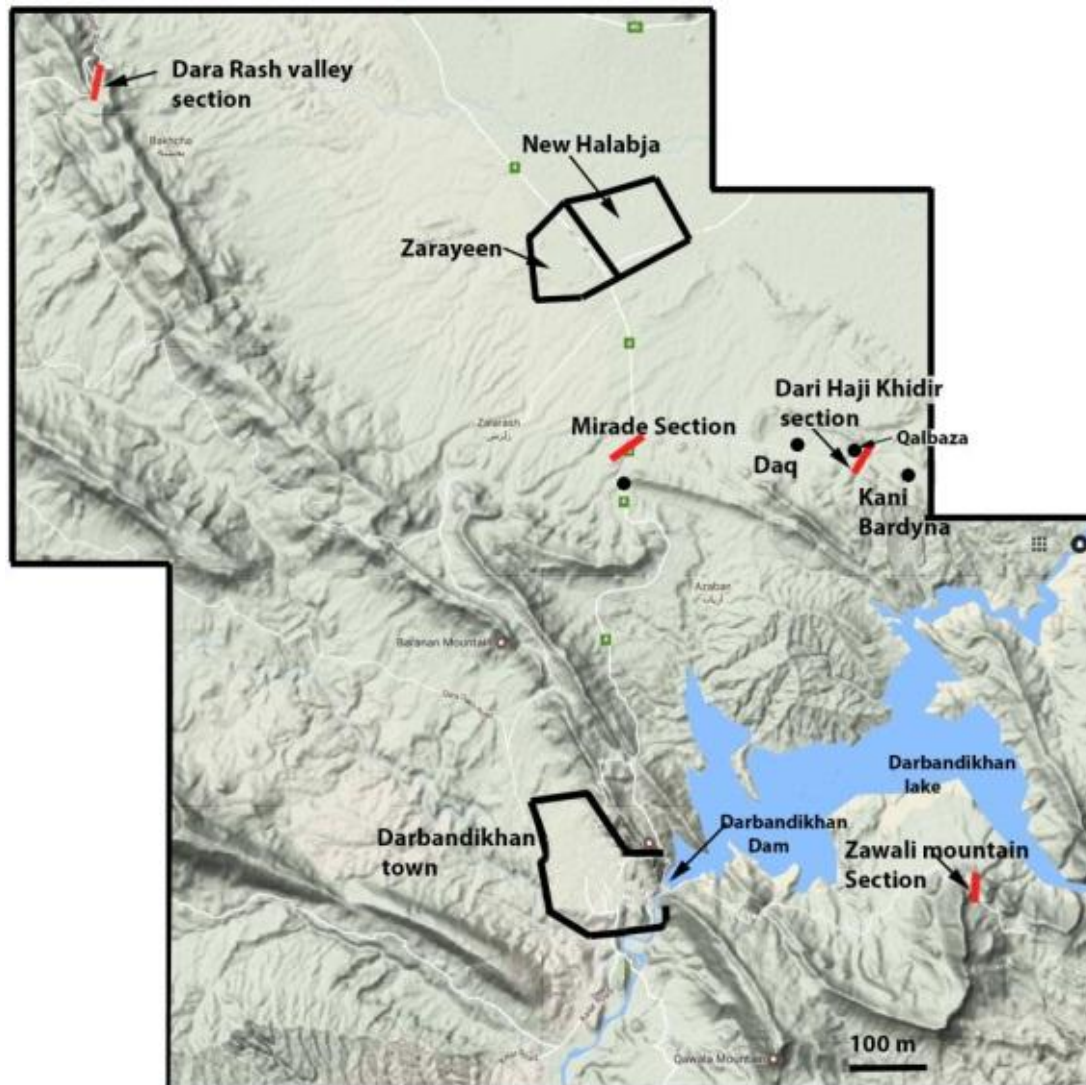


Fig. 1: Google terrain image shows the location of the studied sections, Zawali, Dari Haji Khidir, Mirede and Dara Rash sections

There are two main mountains (anticlines) series with the trends of northwest-southeast and have many local names. The southern one is elongated from Iranian border at the southeast of Darbandikhan town toward northwest and south of Sulaimani city. These mountains are called Sartak-Bamo, Zimnako or Khushk, Birkey, and Baranan mountains. The northern one is called Zawali (or Shameran), Bard Asin (or Ahmad brnaw) and Shafa Rash Mountains and two of the studied sections are located on the northeastern side (limb) the northern series. In some places, the southern and

northern series are formed from two limbs of the large anticline and its core is eroded forming a strike valley (or subsequent valley). In the area, extensive outcrops of the Sinjar or Khurmala, Gercus and PilaSpi formations are exposed along the two structures (Figs. 1 and 2).

The area is a part of the Sirwan valley which collects runoff from most parts of northeast of Kurdistan region into Darbandikhan lake (Fig. 1). The Sirwan river valley has a broad bottom with gentle sides and classified as a consequent river, which meets with many subsequent tributaries. In the area, Sirwan River has a highly meandering course which controlled by local structure, lithology and coarse accumulation of alluvial fan sediments.

Most areas of the valley consist of local plains, which are hilly and mostly sloping gently toward the Diala River. These plains are mainly covered by sporadic small and large blocks of limestone of Sinjar and PilaSpi formations and Oligocene rocks such as the area around Darbandikhan town. Other parts of the areas are covered by badlands that consisted of numerous small valleys and canyons, which are deep and steep, sided.

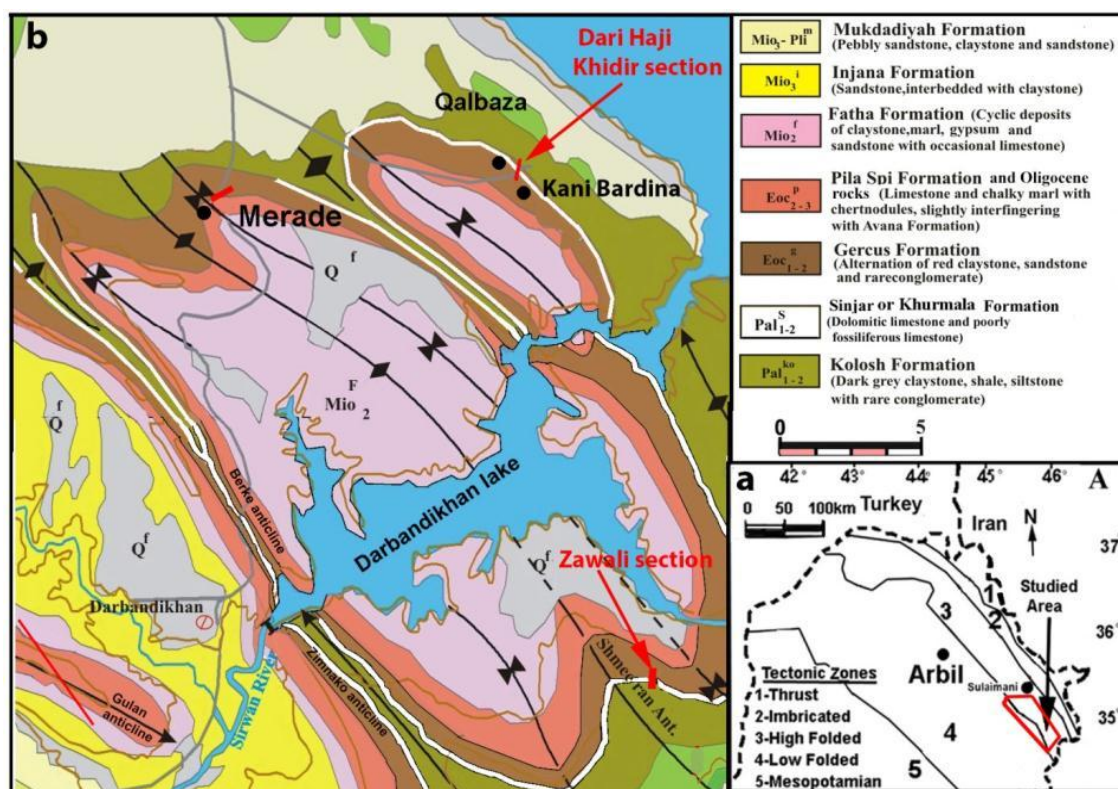


Fig. 2: a) Location map of the studied area shows five tectonic zones (Buday, 1980)
b) Geological map of the studied area shows the location of the two sampled sections (modified from Sissakian, 2000)

STRATIGRAPHY

In all sections, Kolosh and Gercus formations bound the dolomitic succession from base and top respectively. The Sinjar does not occur in the studied sections but its position occupied by the dolomitic succession. It gradually and laterally changes Sinjar Formation outside the studied area toward Baranan and Sartak Bamo mountains at west and southeast of the studied area. The study specifies the main characteristic of these two formations in the below sections.

1. Kolosh Formation (Middle Paleocene – Early Eocene)

The formation consists of black to grey marl, sandstone and thin beds of conglomerate. Its thickness reaches of about 400 m in the studied area, while its thickness in its type locality, and according to Bellen *et al.* (1959), is of about 700 meters. It is exposed in the core of the anticline such as Birke, Zimnako, and Zawali. Due to the softness, it is intensely deformed by upwards flow and accumulation in the cores of the above anticlines. On outcrops, the softness has driven many slipped blocks of Sinjar Formation on Kolosh Formation along the northwestern limbs of the above-mentioned anticlines. Its boundaries are gradational with both Sinjar and Tanjero Formations (Fig. 3).

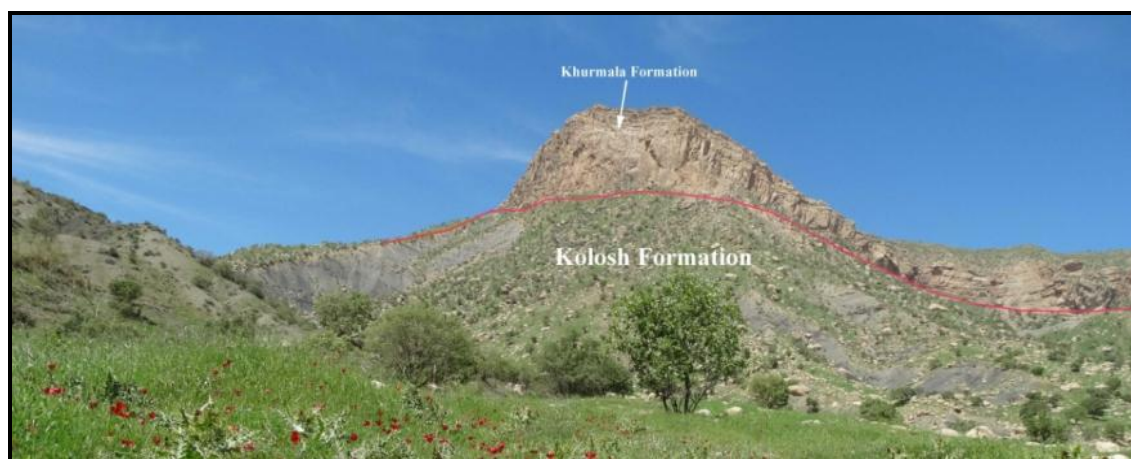


Fig. 3: Kolosh and Khurmala Formations on the Zawali Mountain or anticline

2. Sinjar Formation (Late Paleocene – Early Eocene)

At the southern boundary of the studied area, this formation mainly consists of about 40 meters of grey to milky massive to well bedded detrital and biogenic limestone. It has gradational contact with both Kolosh and Gercus Formations. In the studied area, it only exposed on both limbs of the Zimnako, Berki and

Baranananticlines. Its main fossil content is nummulites, alveolina and discosyclina with rare coral, green algae, pelecypods and gastropods. On both sides of the Khanaqin fault, the formation is relatively thin and has about 10 – 40 m thickness and the limestone occasionally associated with conglomerates (Karim *et al.*, 2016). In the studied sections, it replaced by the dolomitic succession that consists mainly of dolomitic limestone and the fossils of previously assigned Sinjar formation are not present. The present ones are similar to those that are present in Khurmala Formation.

3. Gercus Formation

In the studied area, the thickness of this formation is variable from place to another; the maximum thickness is located near the Darbandikhan dam and near Mirade village, where it may reach more than 200 m. It is composed of red claystone, sandstone and lenses of conglomerate (Fig. 4). Its boundary is gradational with underlying Sinjar Formation while it is unconformable with the overlying Pila Spi Formation as there is a bed of conglomerate between the two formations, which is of about three m thick and described by Ameen (2006).

In the studied area, on Zawali anticline, the formation shows more carbonate constituent than that of Mirade as half of its lithology consists of marl and marly limestone with few beds of fossiliferous limestone (Fig. 5) and the other half consists of conglomerate and sandstone with few beds of red claystone. According to Khanaqa and Karim (2015), it rapidly changes to dolomitic limestone and marly limestone of the Khurmala Formation toward southwest. This change is due to passing from clastic dominated coastal area to carbonated dominated inner shelf of Eocene Foreland basin.



Fig. 4: Alternation of red claystone, sandstone and marl of Gercus Formation at 200 m of the north of Mirade village



Fig. 5: Marl and marly limestone succession inside Gercus Formation above the studied section on Zawali anticline

RESULTS

For finding the origin of the dolomitic succession, the study tries to find its stratigraphic affinity especially about 80% of its thickness comprised of unfossiliferous dolomitic limestone and this property is not characteristics of Sinjar Formation. Therefore, it is more likely belongs to Khurmala Formation and for proving its affinity, four sections are described, sampled and correlated as shown in the below sections.

1. Zawali (Shameran) mountain section

This section is located on the Zawali anticline about 3 Km to the southeast of Shameran village on the left side of Darbandikhan lake (Sirwan fault) at the latitude and longitude of $35^{\circ} 06' 45.06''$ N $45^{\circ} 49' 25.23''$ E respectively (Fig. 6). In this section, Sinjar Formation is changed laterally to Khurmala Formation that is the topic of the present study. It has about 170 m of thickness and does not contain the characteristic lithology and fossils of Sinjar Formation. The section is described in the field by eyes and hand lens and fourteen samples, which are taken and selected according to the change of lithology (lithoclasts, bioclasts fossils, and allochems).

Sample description of Zawali section

The sample numbers begin with Capital letter (Z) refers to Zawali Mountain in the northeast of Darbandikhan town.

Z1: Alternation of friable thin beds of light brown calcareous shale and sandstone.

Note: Between Z1 and Z2 there is a transitional boundary between Kolosh and Khurmala formations, which is represented by three meters of massive, light brown to buff dolomitic sandy limestone.

Z2 and Z3: Buff massive to well bedded, flintery, vugmarly limestone, recrystallized and dolomitic no signs of fossils.

Z4: Light gray, well-bedded limestone, contains abundant white spots, which are dasyclacean algae (Figs. 7 and 8).

Note: between Z4 and Z5 there is a partially covered interval about 8 thick but it may be marly limestone, the sample is not taken in this interval.

Note: There is a fifty cm thick conglomeratic limestone, which contains gravel of chert.

Z5: Well bedded to massive, light gray, highly recrystallized, vugy and flintery dolomitic limestone. It contains sporadic shells of pelecypod and gastropod with different gray spots which may ghost of forams.

Z6: Highly recrystallized gray dolomitic limestone with evenly distributed oval vugy that may represent mold of dasycladacean green algae.

Z7: Well bedded gray fossiliferous limestone contains smallmillioids, rare nummulites, and red algae clasts.

Z8, Z9 and Z10: Well bedded gray to brown fossiliferous and detrital limestone contain milioids and other forams.

Z11 and Z12: Different colors (black, gray and yellow) dolomitic limestone, it is soft and porous, the last 2 m contain forams and red algae.

Z13: Well bedded gray to light yellow fossiliferous limestone, it contains pelecypods and gastropods (Fig. 9), millioids, red algae with a bed of conglomerate (20 cm) at the top.

Note: The above Z13, the transitional boundary begins between the Khurmala and Gercus formations. The boundary consists of an alternation of marl, shale, sandstone, and conglomerate with several beds of marly limestone. In this area, the Gercus Formation has not typical lithology as it contains no red claystone.

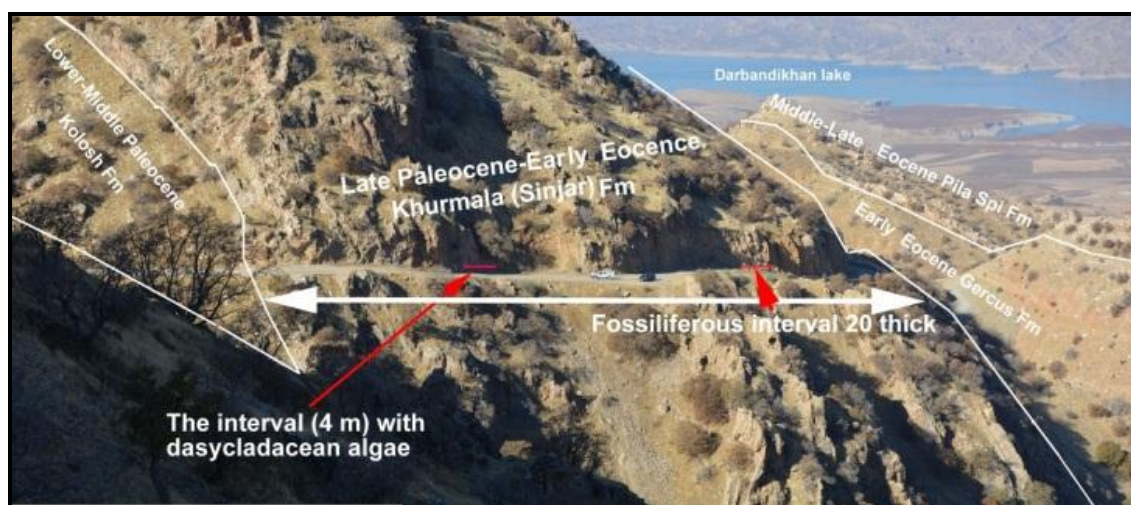


Fig. 6: The studied section on the northeastern limb of Zawali (Shameran) anticline

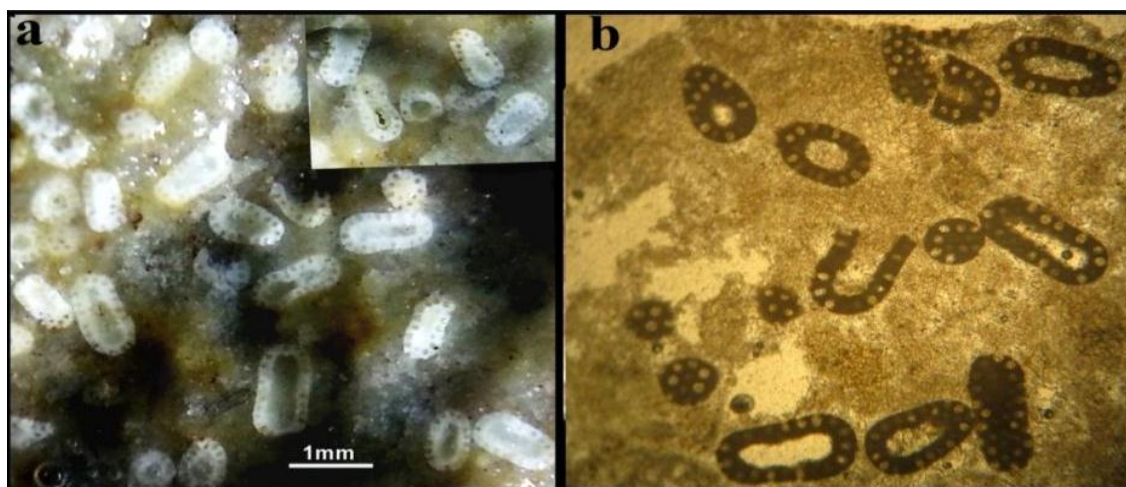


Fig. 7: Dasycladacean green algae on the Zawali anticline inside Khurmala Formation at 60 and 65 intervals, a) Under stereoscope microscope, b) under polarizer microscope, XP, X10.S.no. Z4

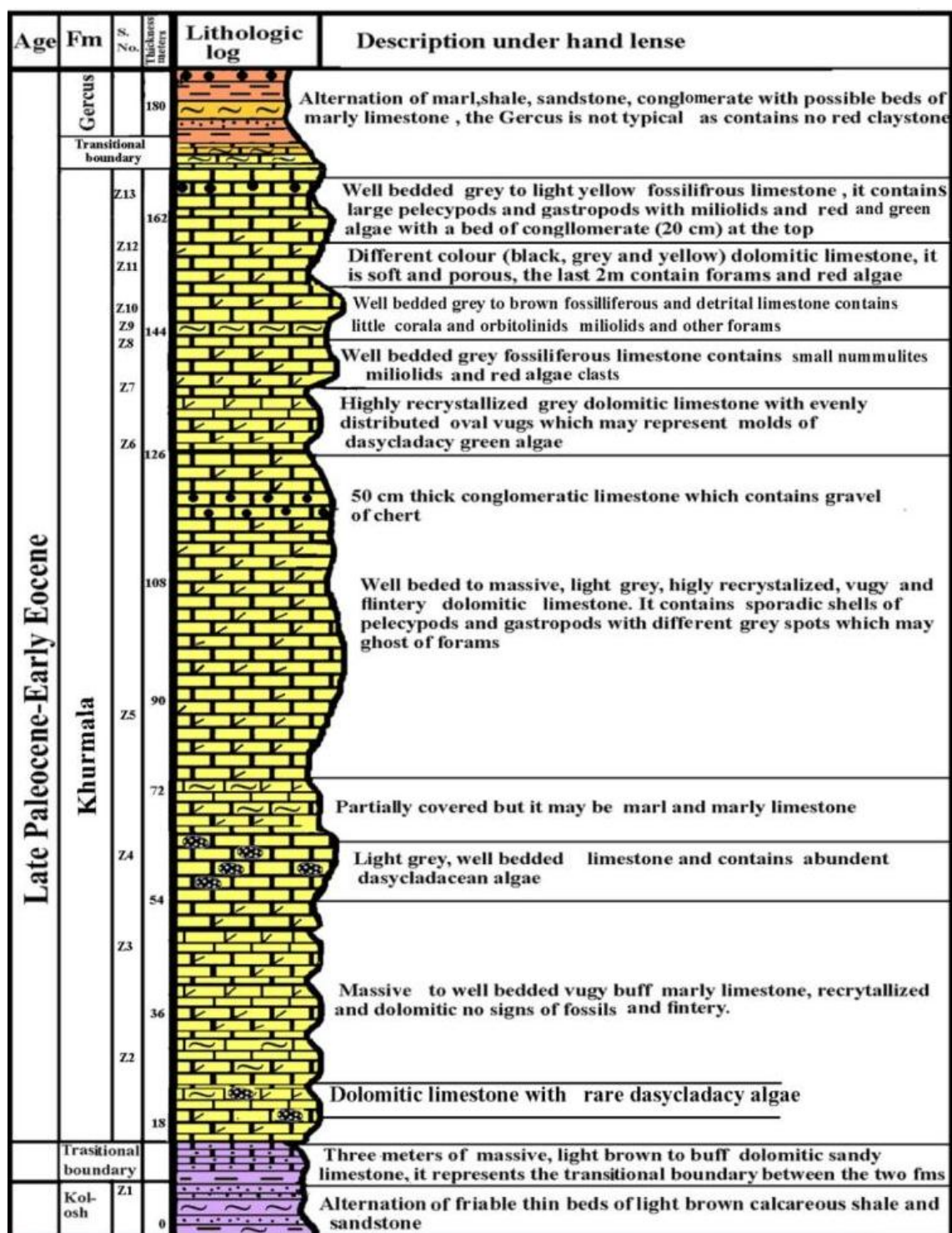


Fig. 8: Stratigraphic column of the studied section on the Northeastern limb of Zawali (Shameran) anticline



**Fig. 9: a) Ten cm thick conglomeratic limestone bed inside Khurmala Formation
b) Gastropod and pelecypod in the upper part of the formation**

2. Dari Haji Khidir section

This section is located on the right side of the Darbandikhan Lake (Sirwan or Khanaqin fault) on the northern side of the paved road between Qalbaza and KaniBardina at 8 Km to the southeast of Zarayeen town (Figs. 10 and 11). Its GPS location coincides with the latitude and longitude of $35^{\circ} 14' 51.81''$ N $45^{\circ} 46' 59.98''$ E respectively. The section consists mainly of sixteen m of vugy, partially recrystallized dolomitic and chalky limestone with few thin beds of algal and detrital sandy limestone. Ten samples are taken from this section and all thin sections are barren of fossils except for ghosts of plant debris and some detrital carbonate grains. Toward west and at 200 m to the north of Mirade village; it thins out and become zero in thickness (Fig. 12). At this placed it is represented by about 30 m of light grey to yellow succession of clastic sediments of sandstone marl and marly limestone with few bed of conglomerates see figure (16) Mirade section.



Fig. 10: Dari Haji Khidir section shows Khurmala Formation (16 m thick) between Qalbaza and Kani Bardina villages, it consists of vugy, chalky and partially recrystallized dolomitic limestone and marly limestone

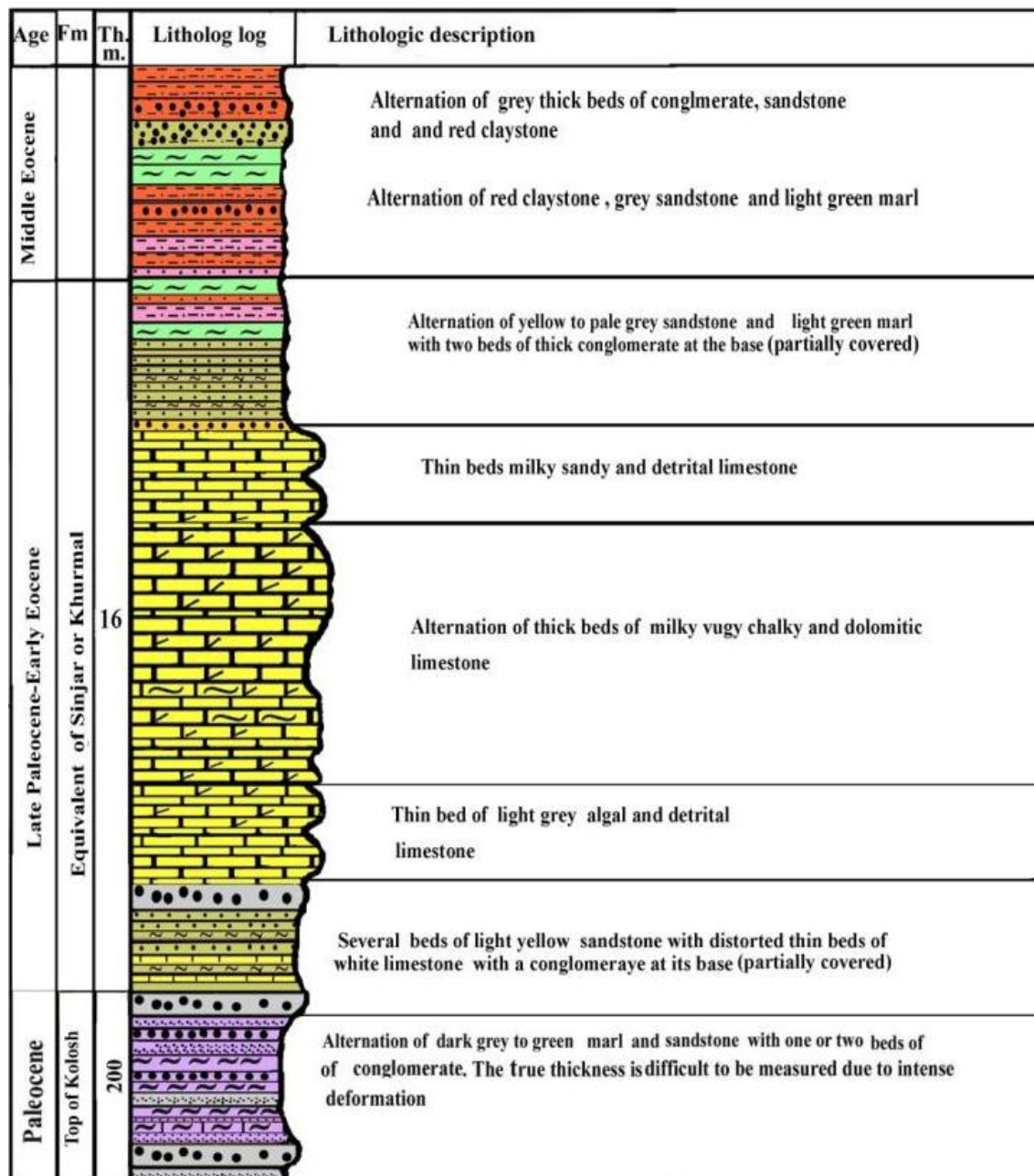


Fig. 11: Stratigraphic column of Dari Haji Khidir (Khurmala Formation) between Qalbaza and Kani Bardina villages



Fig. 12: Light grey to yellow succession (30 m) of sandstone marl and marly limestone of Mirade section. It represents equivalent of Khurmala Formation according to lateral tracing by the authors

3. Dara Rash valley section

This section is located at 25 Km to the south of Sulaimani City and runs along the paved road between the latter city and Qaradagh town on the Baranan mountains. The sampled section is located in the Dara Rash valley at the top of Sinjar Formation and its thickness is about 60 m (Fig. 13).

As mentioned previously, near Mirade village the Sinjar or Khurmala Formation is disappeared and replaced by clastic sediments. Toward the east of the village, Sinjar Formation is gradually appearing again and thickened along the latter mountain. In the Dara Rash valley both Sinjar and Khurmala, exist between Kolosh and Gercus Formations. The Khurmala Formation consists of dolomitic limestone and marly limestone with several beds of sandstone and conglomerate at its upper parts but it does not contain gypsum and anhydrite. This succession contains lagoonal fossils such as miliolids and other dwarfed fossils with detrital chert and brown plant debris (Fig. 14).

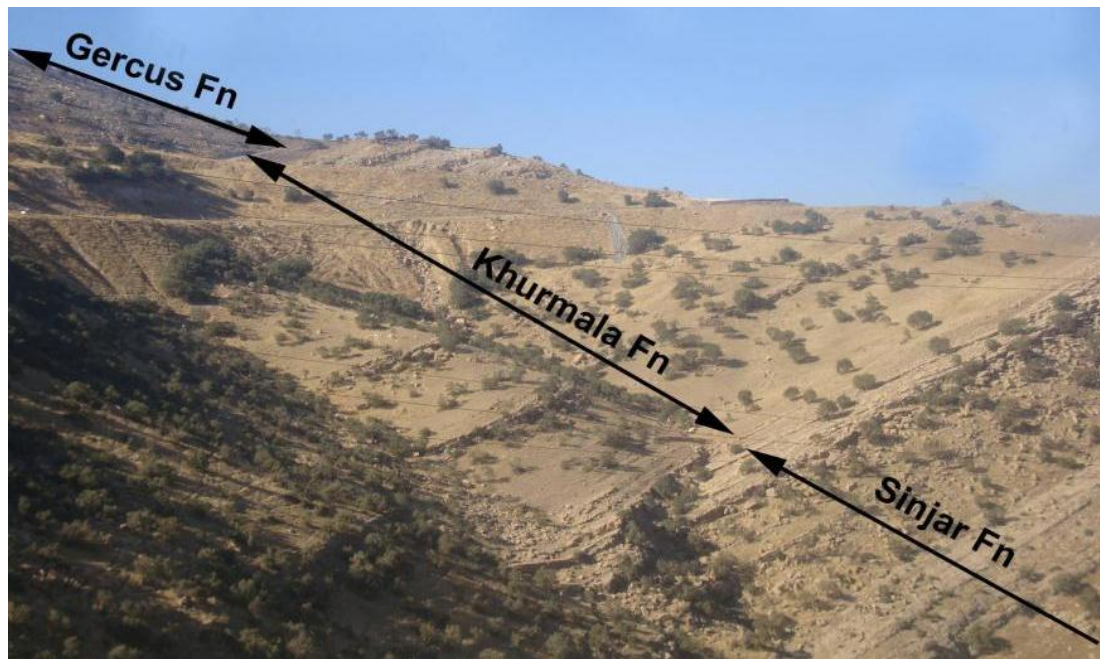


Fig. 13: Dara Rash section

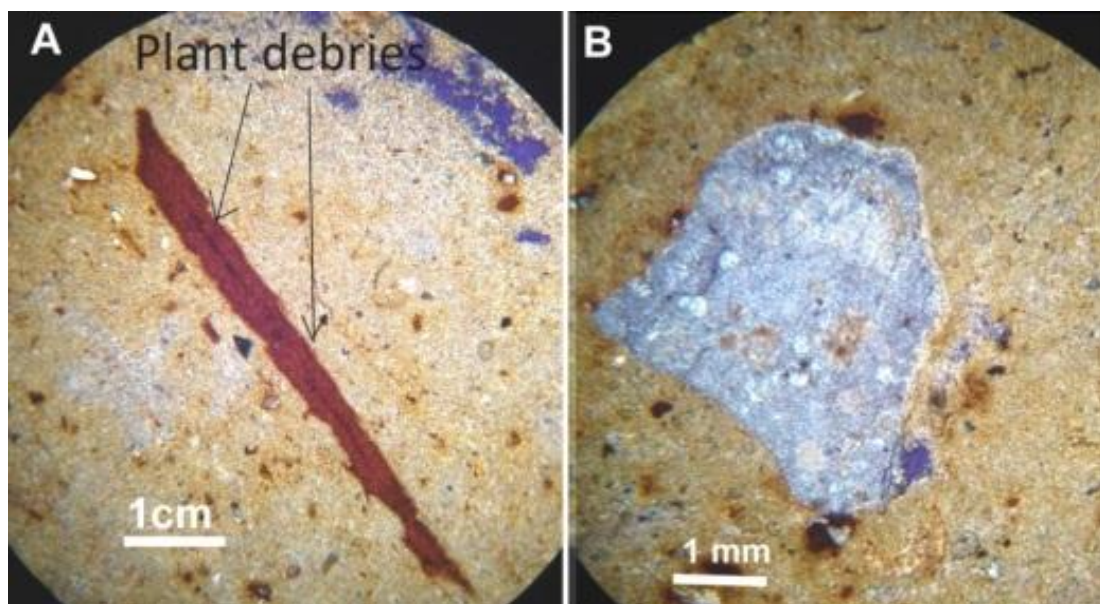


Fig. 14: Dara Rash section contains A) plant debris and B) chert detrital Grains (extraclasts) sample No.5 and 7

DISCUSSION

The formation is found and described previously in the Duhok and Arbil governorates while in Sulaimani Governorate not proved previously. Conversely, during fieldwork in the southeast and southwest of the Sulaimani Governorate, the authors found many evidences and signs that show the occurrence of this formation in the

stratigraphic position between Kolosh and Gercus formations on the Zawali (Shameran) mountains (anticline) at 15 Km northeast of Darbandikhan town. In the same stratigraphic position, it is found at the southern boundary of the Sharazoor plain between Qalbaza and KaniBardina villages (Fig. 6 and 10).

These signs are the occurrence of about 160 m of unfossiliferous dolomitic limestone (80%) (Fig. 15), fossiliferous limestone (18%) and conglomeratic limestone (2%) according to the percentage of the thickness of the section. The second evidence is neither reefal facies (coral and algal build up) nor fore reef facies (nummulite forams) are found in all four studied sections. The third evidence is presence of sparse and small miliolids (Fig. 16-9), gastropods, pelecypods (Fig. 9b), green algae and rare red algae (Fig. 16) which mentioned by Bellen *et al.* (1959) to be present in its type section.

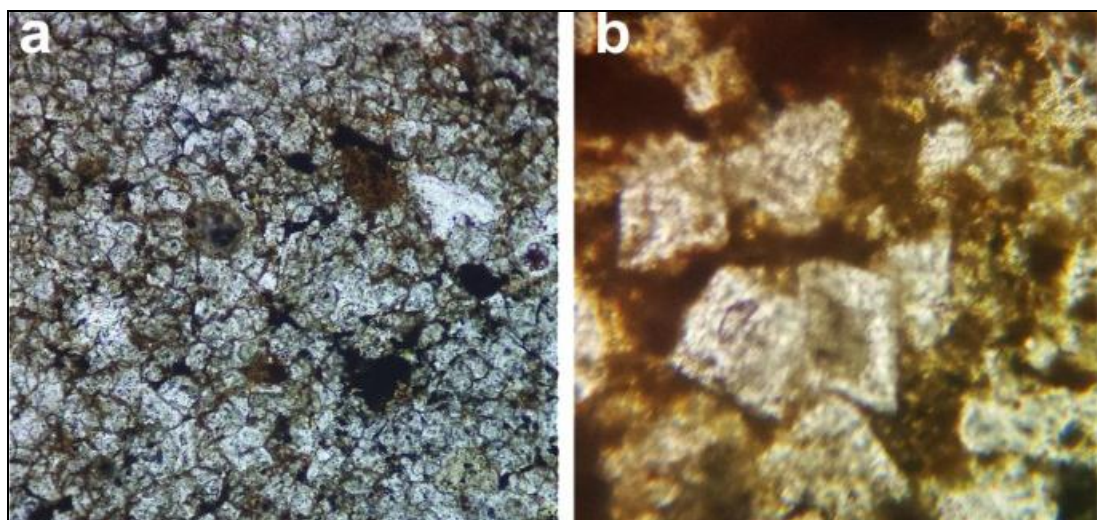


Fig. 15 most of the thickness of the studied section comprised of dolomitic limestone and dolomite, a) interlocking rhombs of dolomite crystals, PPL, 150X, normal light, s.no. Z6, Zawali section, b) isolated dolomite crystals, PPL, X300, s.no. Z2.

The fourth evidence is the occurrence of Khurmala Formation in bore holes in the nearby areas such as in well Chemchemal-2 where it is composed of recrystallized limestones, with occasional argillaceous bed, and beds of anhydrite and gypsum (Bellen *et al.*, 1959).

The first possible occurrence of the formation is mentioned by Karim (1997) in SartakBamo area about 25 Km to the southeast of Darbandikhan town. He referred to a succession of marly limestone (about 20 m thick) as Khurmala Formation above Sinjar

Formation. The latter study further found Gypsum nodules and dwarfed fossils in it. Lawa (2004) referred to similar succession with gypsum nodules on the southwestern limb of Sagrama (or Sagerma) anticline and he assigned it as a new formation and called it "Sagerma Formation". The name of this new formation is mentioned by Ameen (2008), Lawa and Albayati, (2008) and appeared in the Cenozoic stratigraphic column of Middle East by Al-Husseini (2008).

The lagoonal environment in all described section is clear from lithology and fossils content, furthermore, each of the middle and upper parts of Zawali, Mirade and Dara Rash sections contain thin or medium beds of conglomeratic limestone that contain sporadic chert gravels. This means that the basin of formation was connected with a source area and intermittently had supplied by freshwater. It is possible that the lagoon is bordered and separated from open sea at the south-west (Jaddala open basin) by a barrier. This barrier was considered by Karim *et al.* (2008) as a local uplift in the Foreland basin after deposition of Kolosh Formation during late Paleocene (Fig. 17).

According to descriptions of previous sections, neither Khurmala nor Sinjar are present in Mirade section and its stratigraphic position is occupied by clastic succession about 30 m thick. The reason for non-deposition of Khurmala (or Sinjar) Formation is, according to field evidence, is resulted from two factors. The first is during history from Maastrichtian to Pliocene Darbandikhan and Sirwan valley was a subarial or submarine paleo depression for clastic discharge during deposition of Tanjero, Kolosh, Sinjar, Gercus, Lower Fars, and Upper Fars and Bakhtiary Formations.

During deposition of these formations, the Sirwan valley (including Merade village) was more clastic dominant than other areas of the same tectonic position. This type of paleo-depression is shown in a paleogeographic model of Paleocene – Eocene by Karim *et al.* (2008) (Fig. 17B). The second factor is that the Mirade is more close to the coastal area during Paleocene and Eocene; therefore, the clastic is more deposited than other areas to the south. The evidence for this factor is a low thickness of both Khurmala (18 m) and PilaSpi Formation (12 m) in the area between Qalbaza and KaniBardina villages (Fig. 1 and 2).

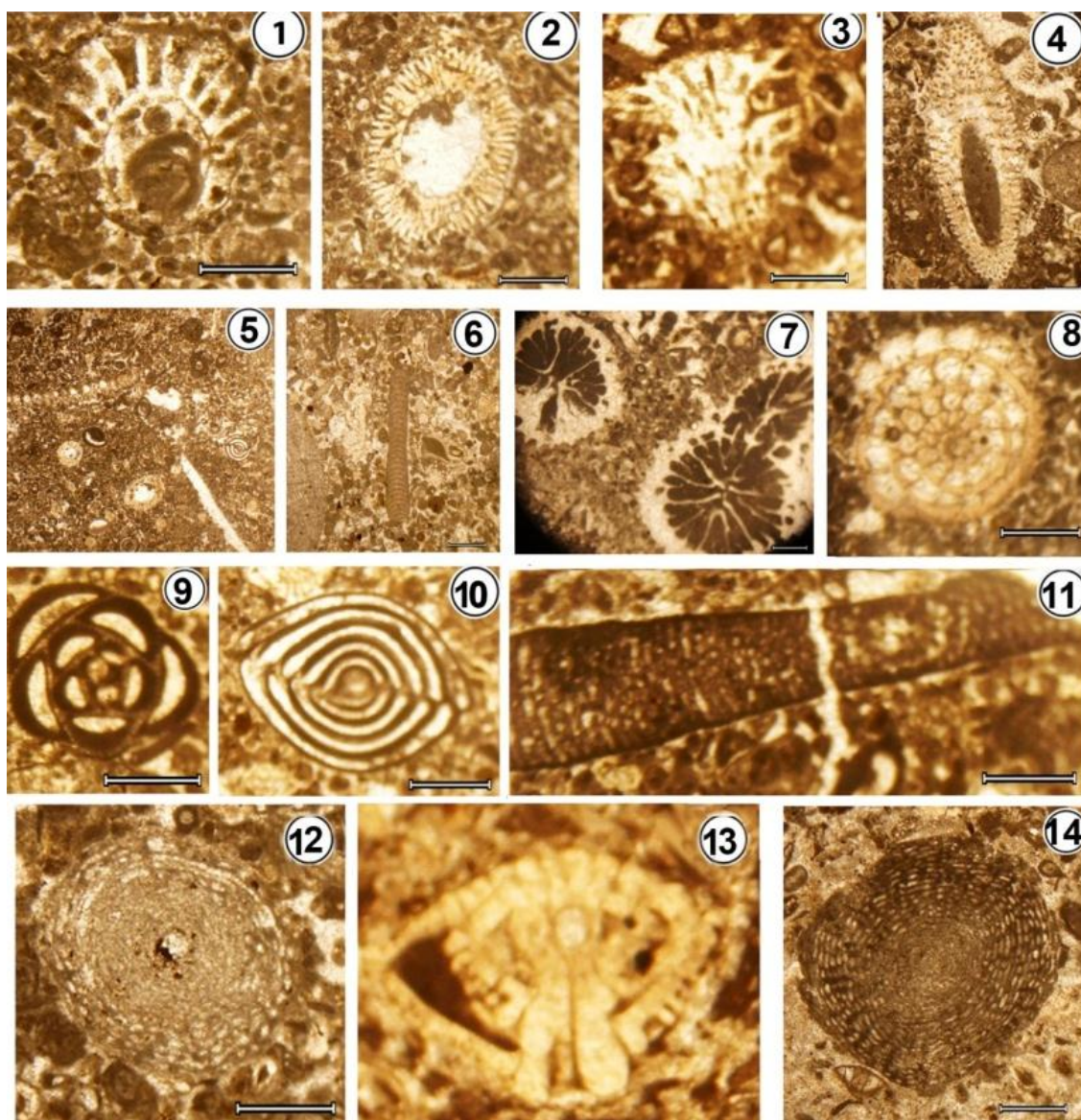


Fig. 16: Few beds of the Zawali Formation and other section contain fossils which are shown in these photos:

Green algae: **1)** *Clypeina* (Z7-Z13), **2)** *Cymopolia sp.* (Z7-Z13), **3)** *Hamulusella* (Z7-Z13), **4)** *Cymopolia ellongata* DeFrance, oblique section (Z7-Z13), **5)** Chalky limestone with dasycladals and forams (Z7-Z13), **6)** Fragment of red algae (Z7-Z13), **7)** *Corals* (Z7-Z13), **8)** Nummulite (Z7-Z13).

Miliolids: **9)** *Austrotrillinaeocaenica n. sp.* (Z7-Z13), **10)** *Biloculina* (Z7-Z13), Soritids: **11 and 12)** *Orbitolites* (Z7-Z13), Rotalids: **13)** *Lockhartia* (Z7-Z13), **14)** *Sphaerogypsina* (Z7-Z13). The bar is 0.5 mm. All photos are taken under PPL setting of polarizer microscope

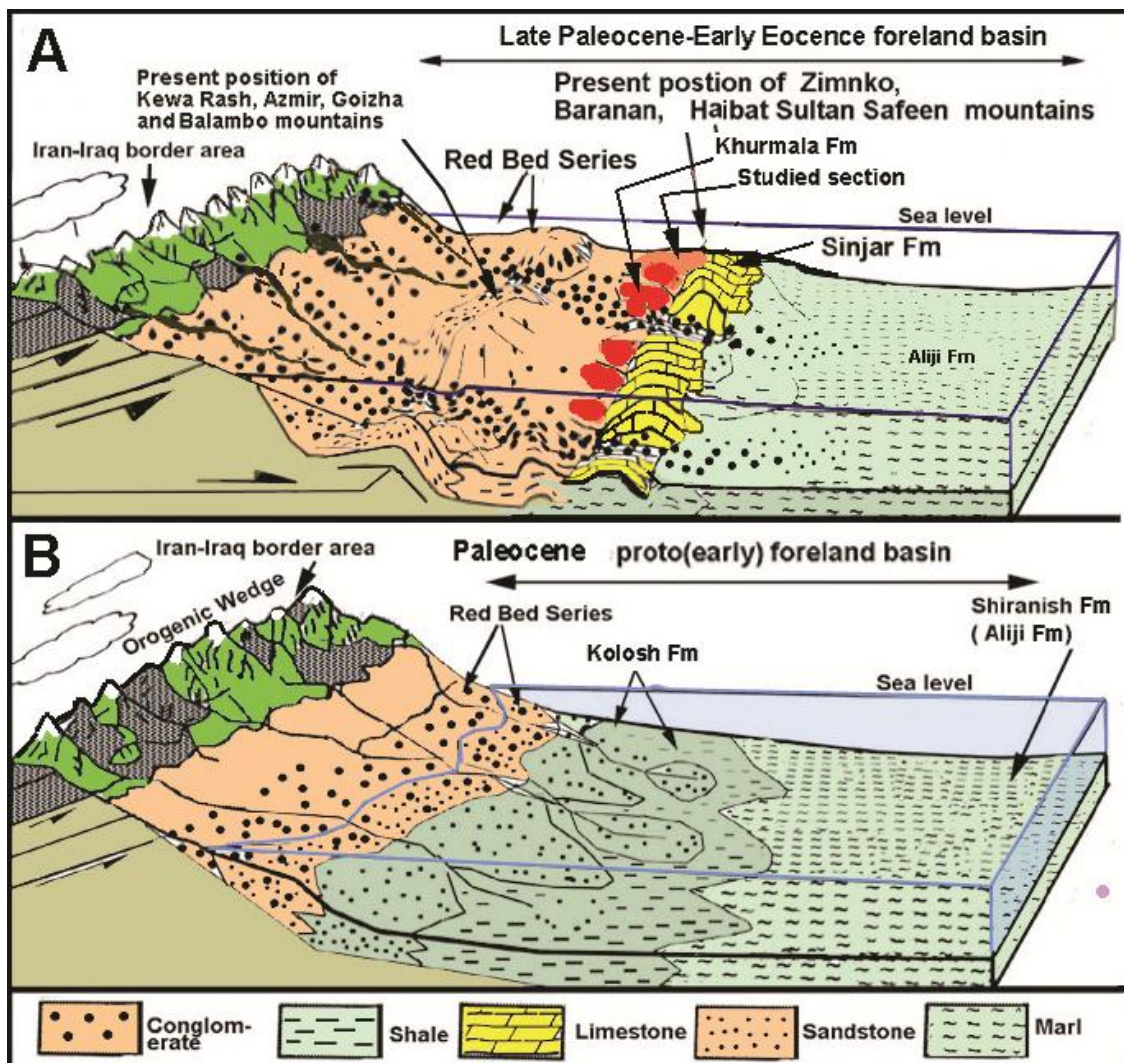


Fig. 17: Tectonic and paleogeographic model during: a) Paleocene, b) Eocene which shows the position of deposition in a lagoon paleo high (modified from Karim *et al.*, 2008)

Correlation of five sections

The stratigraphic column the four-studied section is drawn and correlated with each other. Moreover, the column of the type section of the Khurmala Formation, in the well-K114, is drawn according to the description of Bellen *et al.* (1959). This column is correlated to with the four other ones (Fig. 18). The correlation shows extraordinary facies change between the columns, which is characteristics of the near shore (or shelf) of the foreland basin.

From the description of the type section by Bellen *et al.* (1959), it is clear that Gercus Formation is absent in the type section of the formation; this absence does not mean that deposition is stopped or the area is uplifted but it means decrease of the

clastic sediments influx and increase of carbonate sedimentation during deposition of Gercus Formation. Due to this high content of carbonate, Bellen *et al.* (1959) had combined the Gercus Formation with Khurmala Formation. In the studied section, similar content of carbonate is present in the Gercus Formation which represented by marl, marly limestone, and few beds of fossiliferous limestone in both Zawali and Dara Rash sections (Fig. 10). Moreover, Khanaqa and Karim (2015) observed in the field that the latter formation is changed lateral toward southwest to Khurmala Formation on the southwestern limb of Sagma (Qaradagh) anticline. The sedimentation in Miradesection is opposite to that of the type section as neither Khurmala nor Sinjar Formation is deposited in their stratigraphic position between Kolosh and Gercus Formation. Their position is occupied by 30 m of light grey to a yellow succession of clastic sediments of sandstone marl and marly limestone with few beds of conglomerates (Fig. 18-3).

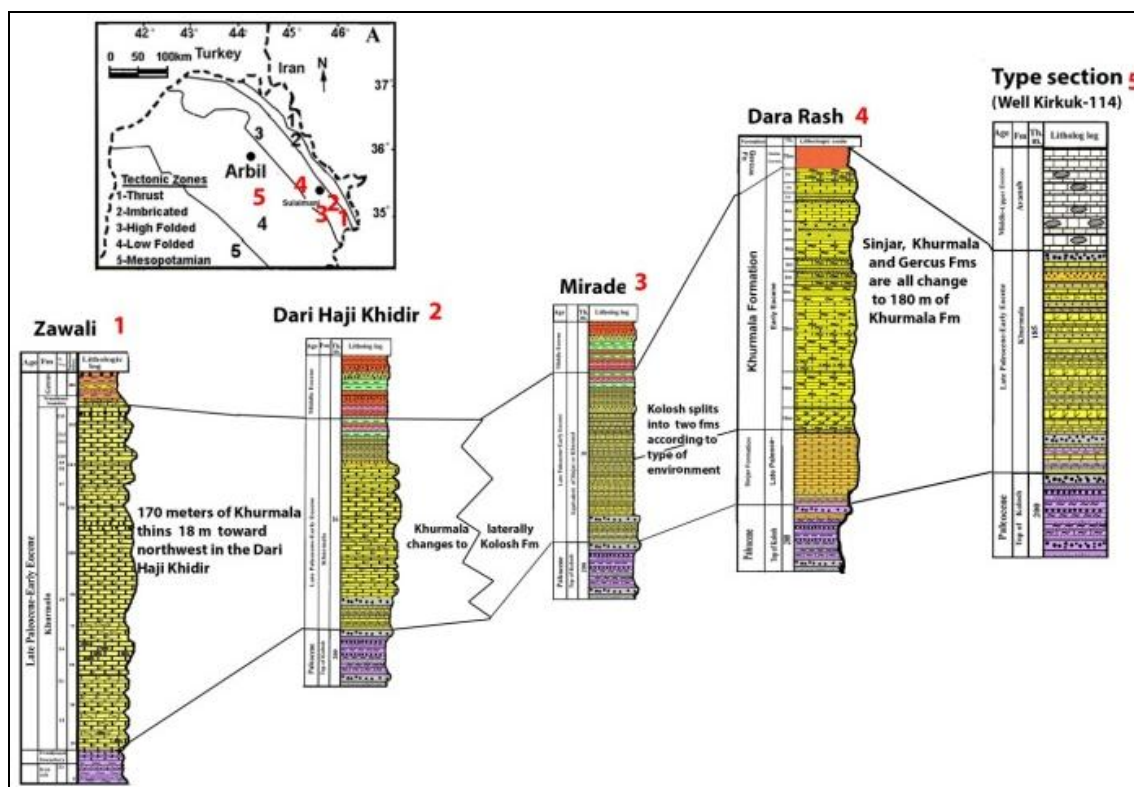


Fig. 18: Correlation of the four-studied section with the type section of the Khurmala Formation

CONCLUSIONS

This study has the following conclusions:

1. A thick dolomitic limestone succession is found and studied stratigraphically and lithologically in the stratigraphic position of Sinjar Formation in Sulaimanyiah Governorate
2. Many evidences are cited that proved that the dolomitic succession affinity belongs to Khurmala Formation
3. The new environment and lithological study suggest that the studied succession is more suitable to be called Khurmala Formation than Sinjar Formations.
4. The environment is indicated as back reef or lagoon.
5. The Zawali section is suitable to be assigned as surface type section (or supplementary section) of the Khurmala Formation

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