MICROFOSSILS AND CARBONATE MICROFACIES OF SINJAR FORMATION, WEST OF SULAIMANIYAH CITY, KURDISTAN REGION, NE IRAQ

Hyam D. Salih[*] and Yaseen K. Abdullah[**]

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ABSTRACT

This research is concerned with the study of the microfacies analysis of Sinjar Formation from Baranan Mountain, southwest of Sulaimaniyah city, NE Iraq. The topic of the research represents the first approach in the area for identification carbonate microfacies and microfossils. Thus, the study is applied to an area extremely rich in Paleocene – Eocene paleoflora and paleofauna, mainly represented by red and green algae, corals, and especially large benthic foraminifera (rotallids, discocyclinids and soritids). Two sections were measured in the field, Hazar Merd Section, 135 m thick and Qazan Section, 75 m thick; within the two sections 368 samples were collected. The studying of the thin sections (about 400) allowed us to present some results on the facies succession, micropaleontological content, age and reconstruction of the paleoenvironment of Sinjar Formation.

دراسة المتحجرات الدقيقة والسحنات المجهرية الكلسية لتكوين سنجار في جنوب غرب مدينة السليمانية، إقليم كردستان، شمال شرق العراق

هيـام داود صالح و ياسين كاكا عبدالله

المستخلص

يتعلق البحث بدراسة السحنات المجهرية لتكوين سنجار في سلسلة برانان الجبلية في الجنوب الغربي من مدينة السليمانية، شمال شرق العراق. الهدف من البحث هو تشخيص السحنات المجهرية والمتحجرات الدقيقة في منطقة غنية جداً بالمتحجرات النباتية الدقيقة (micropaleoflora) والمتحجرات الحيوانية الدقيقة (micropaleofauna) العائدة للباليوسين – الإيوسين وبشكل رئيسي متمثلة بالطحالب الحمراء والخضراء والمجاميع المرجانية، وبالأخص المنخريات القاعية الكبيرة مثل soritids، discocyclinids و rotaliids. تم اختيار مقطعين في موقع الدراسة وهما مقطع هزار ميرد وبسمك 135 م ومقطع قازان وبسمك 75 م. وتم جمع 368 نموذج صخاري لتحضير الشرائح الرقيقة ودراستها مجهرياً. ان الدراسة المجهرية للشرائح الرقيقة (حوالي 400 شريحة) سمحت لنا بالتوصل إلى عدة نتائج منها: تعاقب السحنات، المحتوى المستحاثي، العمر وإعادة بناء البيئة القديمة لتكوين سنجار.

[*] University of Sulaimaniyah, College of Engineering, e-mail: dhyam12@yahoo.com
[**] Kalar Technical Institute, Kalar, Sulaimaniyah Governorate

GEOLOGICAL SETTING AND PREVIOUS STUDIES

Baranan Mountain is located in the southwest of Sulaimaniyah city, northeast of Iraq. It is in the High Folded Zone of the Unstable Shelf.

Some of the studied rocks, represented by several depositional cycles, are deep water cycle and others shallow (shoal) water cycle. The Sinjar Formation was deposited predominantly in a shallow marine environment (Buday, 1980), reef, fore-reef and lagoonal environments through cycles (Late Paleocene – Early Eocene). It is overlain by Gercus Formation (Bellen *et al*., 1959) and underlain by Kolosh Formation (Al-Surdashy, 1988). The contact between Sinjar and Gercus formations is gradational (Jassim *et al*., 1975). In the studied area, this contact is represented by siliciclastic components in uppermost part of the Hazar Merd Section, while the contact between Sinjar and Kolosh formations is conformable (Al-Surdashy, 1988), but it is covered by soil in the studied sections.

There are no adequate studies, especially in Baranan Mountain to explain the environmental situation, constituents, structures and other unclear subjects, which are related to the studied area. The Sinjar Formation was first described from the Jabal Sinjar area, near Mannista village by Keller (1941) in Buday (1980). Bellen *et al*. (1959) regarded that the Sinjar Formation in the type area comprises of 176 m thick limestone of algal reef, lagoonal miliolid (back reef) and nummulitic shoal facies (fore-reef). Elliot (1956) described some green algae, within this formation. Al-Saddiki (1968) considered the Sinjar Formation in the type section to be the sole section, which contains three different facies that indicate the reef (algae facies), back-reef (miliolids) and fore-reef (nummulites and discosyclinids). In other localities, the Sinjar Formation was described by Al-Sayyab and Al-Saddiki (1970), Jassim *et al*. (1975); Al-Kufaishi (1977); Ebrahim and Nadir (1981); Al-Etaby and Muhamad (1979); Jabr and Al-Ubaydi (1973); Shathaya (1980); Al-Khafaji (1980); Mallick and Al-Qayim (1985) and Al-Fadhli and Mallick (1980). Al-Surdashy (1988) and Lawa (2004) studied Sinjar Formation in several sections in Sulaimaniyah area and determined some microfacies and microfossils.

LOCATION OF THE STUDIED SECTIONS

Two sections have been selected from Baranan Mountain, southwest of Sulaimaniyah city (Fig.1), these are:

- **Hazar Merd Section**

This section is located at the south of Hazar Merd village and (1 – 1.5) Km south of Hazar Merd Cave (Fig.2). Generally, the limestones occur as layers between (0.1 – 1) m thick and banks of several meters when corals and algae are present, forming boundstone facies, light grey and grey in color. The total thickness of the formation in the section is about 135 m. The samples were collected from each individual bank, at intervals selected to reflect all lithological changes (Fig.4). A total of 217 samples were collected along the whole section.

- **Qazan Section**

This section is located about (1.5 – 2) Km south of Qazan village (Fig.3). The section is 75 m thick; it includes grey and light grey, fine crystalline limestone, with stratification ranging from tens of centimetres to meters and massive limestone when corals and algae are present, forming boundstone microfacies. A total of 151 samples were collected, representing all lithological changes along the succession in the section (Fig.5).

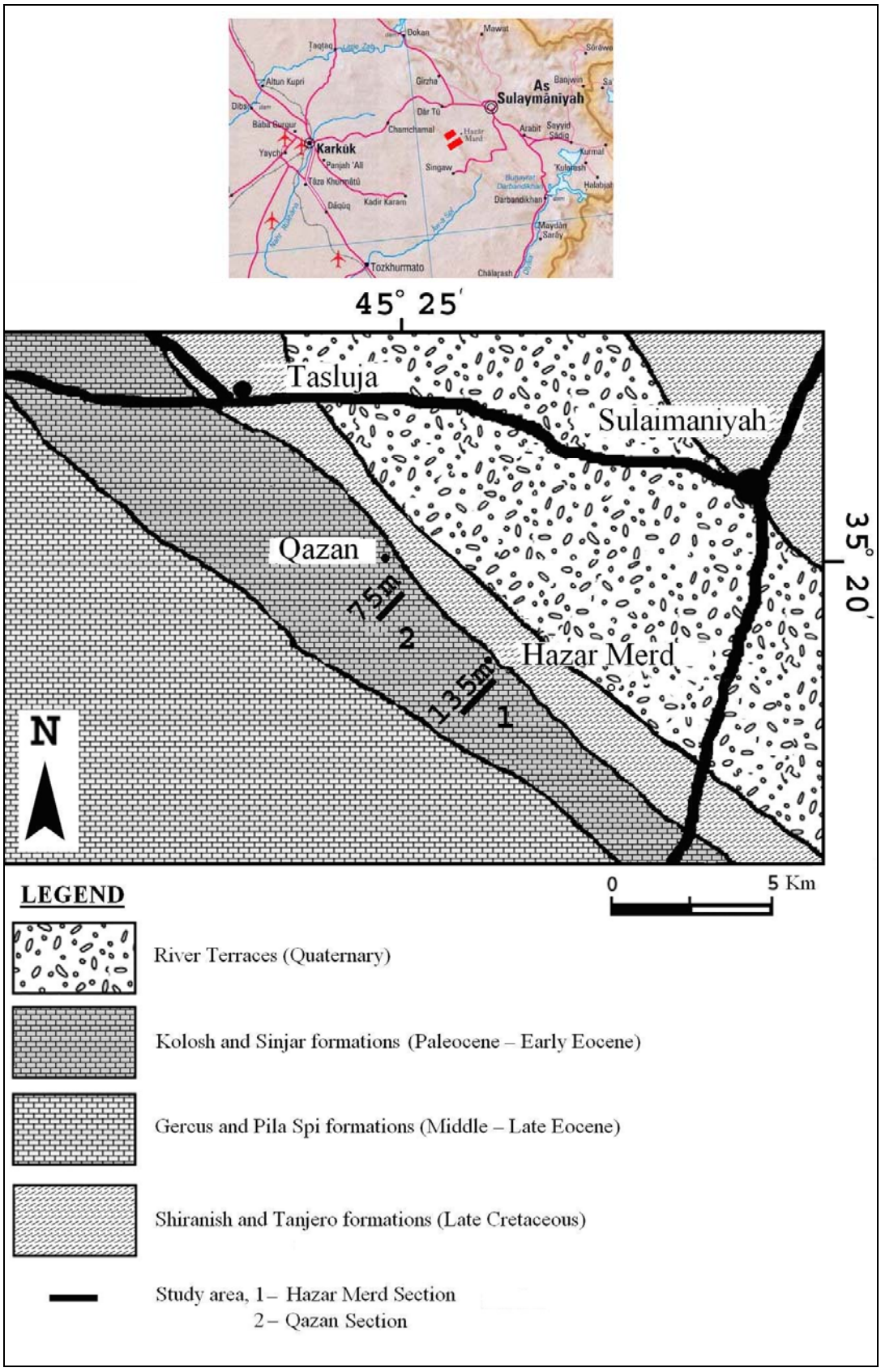
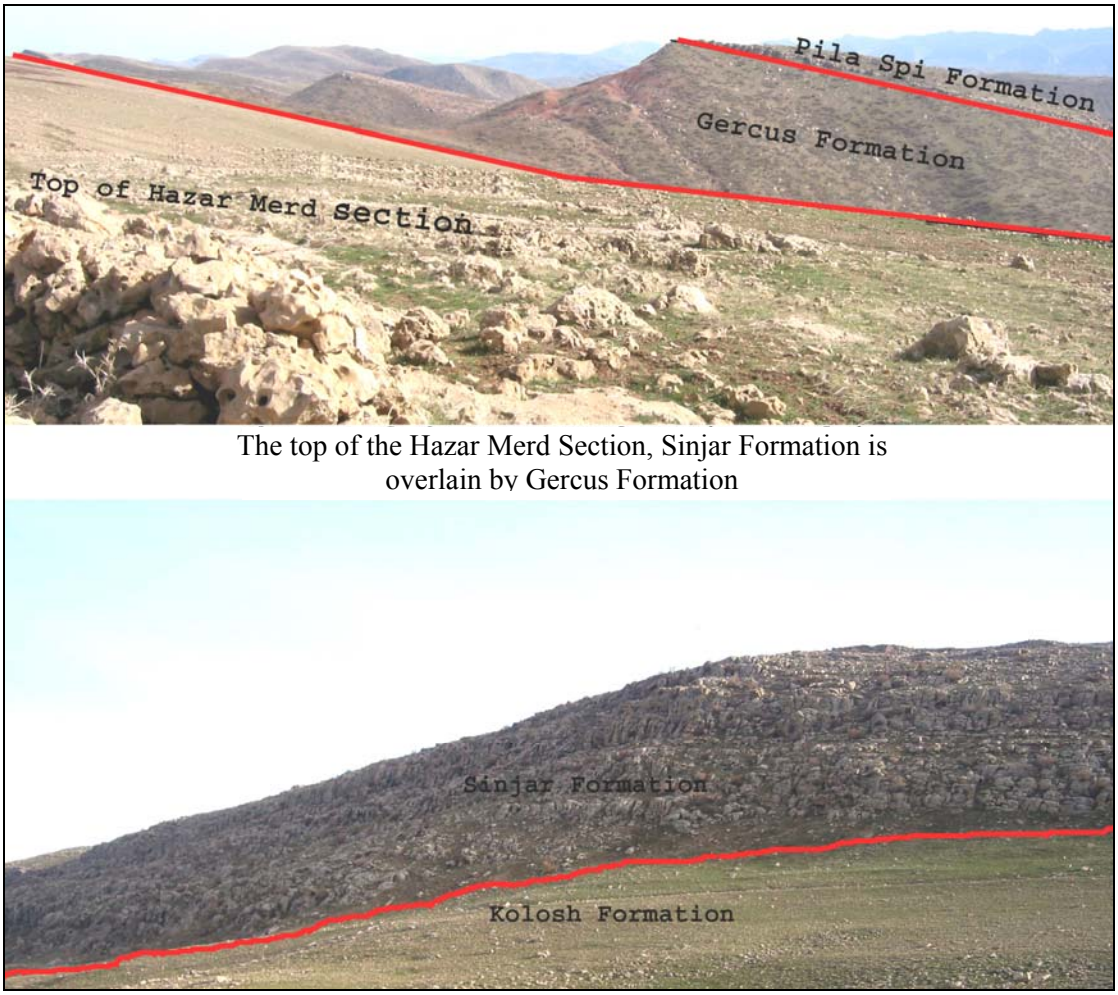


Fig.1: General geologic map of the study area showing location of the studied sections (after Sissakian, 2000)



The top of the Hazar Merd Section, Sinjar Formation is overlain by Gercus Formation

Fig.2: Hazar Merd Section

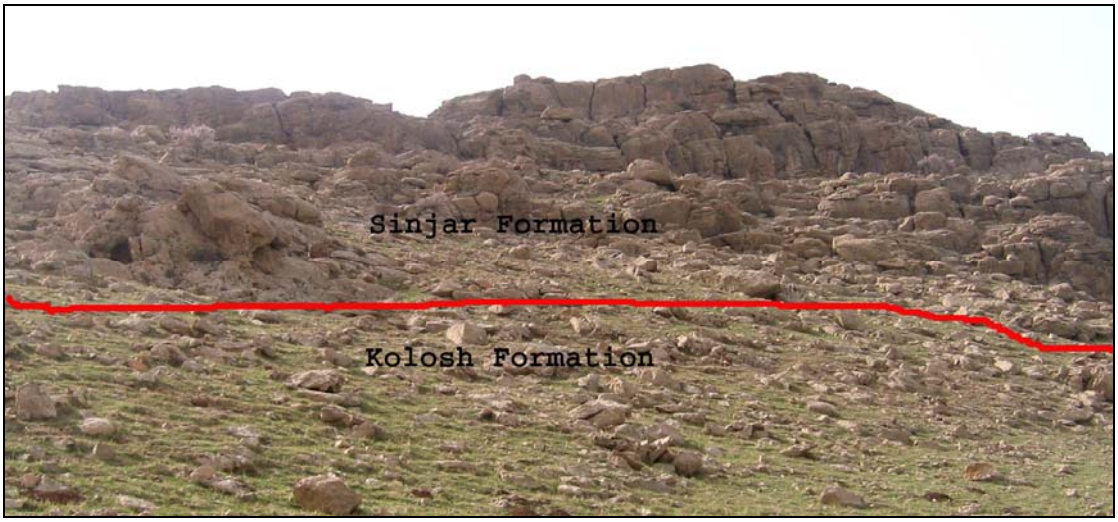


Fig.3: Qazan Section

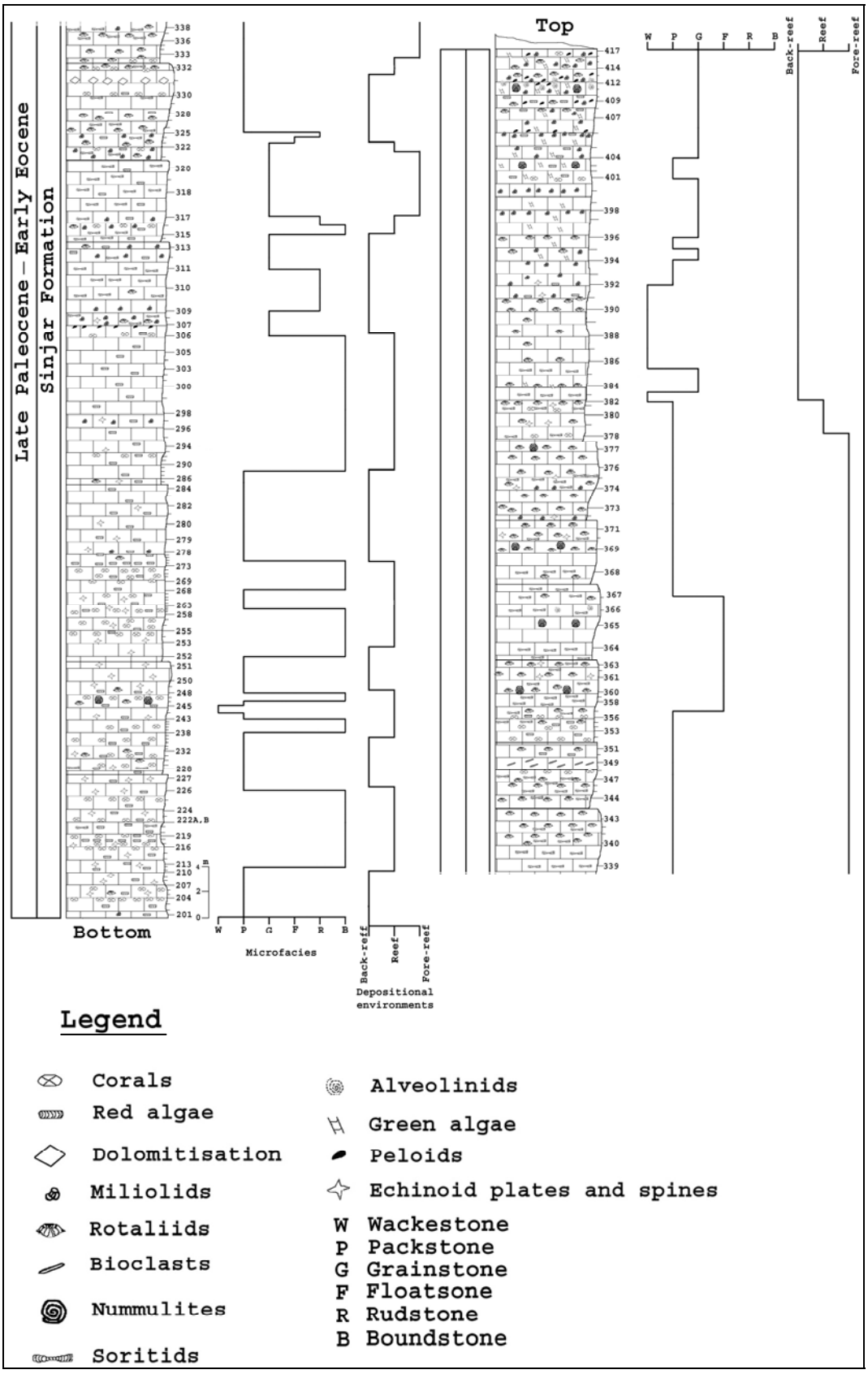


Fig.4: Lithological column of Hazar Merd Section
showing microfacies and depositional environments

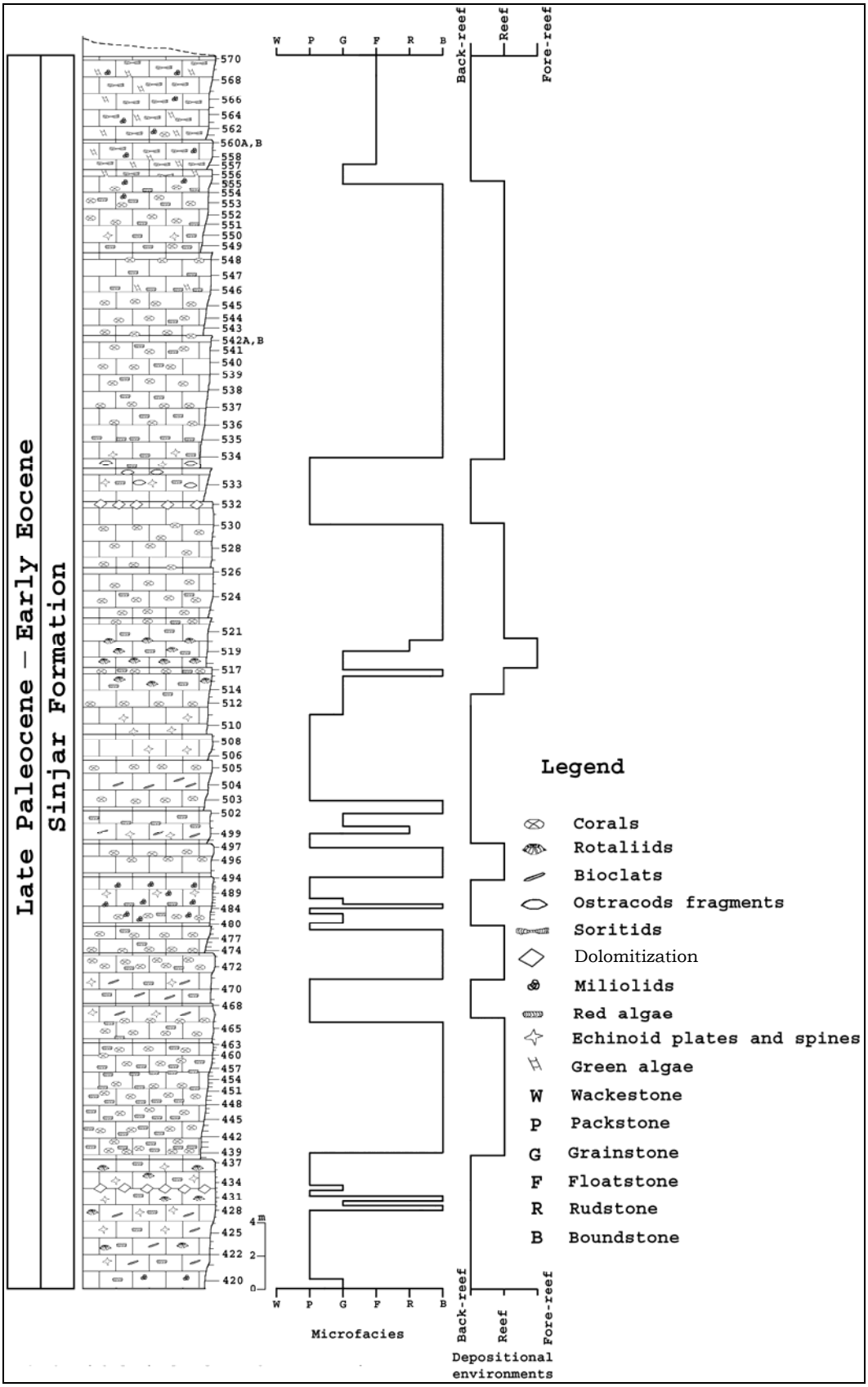


Fig.5: Lithological column of Qazan Section
showing microfacies and depositional environments

MICROFOSSILS

The studying of about 400 thin sections allowed us to identify the micropaleontological association in both Hazar Merd and Qazan Sections. The microfossil assemblages in Hazar Merd Section consist of the following algae and foraminifers: *Sporolithon* sp. (Fig.6.1 and 6.2), *Titanoderma*, *Misccellanea* sp. (Fig.6.3), *Orbitolites complanatus*, LAMARCK, *Discocyclina* sp. (Fig.6.4), *Peneroplis* sp. (Fig.6.5), *Kathina subspherica* SIREL (Fig.6.6), *pseudohatigerina* sp. (Fig.6.7 and 6.8), *Discocyclina varians* KAUFFMAN (Fig.6.9), *Quinqueloculina, Saudia labyrinthica* GRIMSDALE (Fig.6.10), *Operculina salsa* (Fig.6.11), *Alveolina* sp., *Assilina* sp. (Fig.6.12), *Idalina sinjarica* GRIMSDALE (Fig.6.13 and 7.3), *Cymopolia* sp. (Fig.6.13, 7.3 and 7.7), *Biloculina* (Fig.7.1), *Miliola* (Fig.7.2), *Textularia* sp., *Nummulite* sp., *Triloculina* (Fig.7.4). The gastropods appear in some thin sections, they are filled completely by green algae, peloids, fragments of red algae, small forams and sometimes by bioclasts (Fig.7.5). *Cibicides nammalensis, Cymopolia ellongata* DEFRANCE (Fig.7.6 and 7.8), *Dissocladella* (Fig.7.9), *Alveolina globosa* LEYMERIE (Fig.7.10 and 7.11), *Alveolina primaeva* REICHEL (Fig.7.12), *Glomalveolina* sp. (Fig.7.13), and *Amphiroa iroquensis* JOHNSON (Fig.7.14).

The micropaleontological association in Qazan Section consists of the following microfossils: *Kathina* sp. (Fig.8.1), *Parachaetetes* (Fig.8.2), *Pseudohatigerina* sp. (Fig.8.3), *Amphiroa iraquensis* (Fig.8.4), *Discocyclina, Polystrata alba* (Fig.8.5), *Quinqueloculina, Acicularia* (Fig.8.6), *Opertorbitolites transitorius* HOTTINGER (Fig.8.7), *Orbitolites complanatus* LAMARCK (Fig.8.8 and 8.11), *Biloculina* (Fig.8.9), *Saudia labyrinthica,* GRIMEDALE (Fig.8.10 and 8.11), *Clypeina* (Fig.8.12), *Idalina sinjarica* GRIMEDALE (Fig.8.13), *Morozovella angulata* (Fig.8.14), and *Clypenia meriendae* (Fig.8.15).

The presence of *Alveolina primaeva, Saudia labyrinthica* and *Miscellanea* sp. appear to be restricted to the Late Paleocene. *Idalina sinjarica* and *Operculina salsa* indicate the Late Paleocene – Early Eocene. Besides, *Assilina* sp. and *Miliola* that indicate the Early – Middle Eocene and *Cymopolia* sp. has also the most numerous species, particularly during Paleocene and Middle Eocene (Génot, 1991). Based on the aforementioned microfossils association we have assigned a Late Paleocene – Early Eocene age to the Sinjar Formation from the Baranan Mountain.

MICROFACIES

The laboratory identification included the study of about 400 thin sections of limestones from two sections:

- **Hazar Merd Section**

The facies associations identified in the Hazar Merd Section consist of two main types: **Bioconstructed** and **Bioaccumulated** microfacies, each of them presents several subtypes:

- **Bioconstructed Microfacies**, reaches 17.75% of the total section and comprises four subtypes: Coralliferous boundstone (Fig.9.1 and 9.2), Boundstone – packstone (Fig.9.3 and 9.4), Bryozoans boundstone and Boundstone – grainstone, mostly occur in the lower part of the section. These facies mainly contain corals and red algae, fragments of ostracods, bryozoans, echinoid plates and spines, and some foraminiferas are also present. Occasionally, the bioclasts and fine fragments of ostracods are bound by microbial micrite, especially between *Titanoderma* filaments forming some levels of bindstone.
- **Bioaccumulated Microfacies** comprises five main microfacies: Wackestone, packstone, grainstone, floatstone and rudstone. The **Wackestone** includes only three levels in the lower and middle parts of the section, successively consisting of bioclastic wackestone, soritids – rotaliids wackestone and rotaliids wackestone. The components of this facies consist of some gastropods, fragments of bryozoans, echinoid plates, rotaliids and soritids.

Sometimes, this facies is affected by dolomitization processes. The **Packstone microfacies** (Figs.9.5 and 10.1) represents 48.4% of the total section and it is widespread in the lower and medium parts of Hazar Merd Section, whereas, it decreases in the upper part and is lacking in the top of the section. This facies is represented by bioclastic packstone in the lower and middle parts, foraminiferous packstone in the lower part**,** rotaliids packstone in the middle part and towards upper part**,** soritids and rotaliids packstone towards the upper part**,** discocyclinids packstone in the lower part, and discocyclinids and miliolids packstone towards the upper part of the section. Generally, this facies consists of corals and red algae fragments, echinoid plates and spines, fragments of ostracods, rotaliids, miliolids, some gastropods and other foraminiferas. The **Grainstone microfacies** (Figs.9.6 and 10.2) reaches about 20% of the total section and comprises three subtypes in three different levels: Foraminiferous grainstone in the middle part, rotaliids grainstone towards the upper part and miliolids grainstone in the upper part of the section. Generally, the grainstones contain soritids, miliolids, red algae fragments, green algae, gastropods and solitary corals, occasionally the micrite cover the small forams and red algae fragments and forms so-called micrite envelopes around these bioclasts. The miliolids grainstone mainly consists of miliolids together with green algae, occasionally; the algal peloids (red algae peloids) occur and form two levels of peloidal grainstone. The **Floatstone microfacies** (Fig.9.7) reaches 7% of the total section and consists of soritids (orbitolites) floatstone**,** soritids and rotaliids floatstone. Both microfacies are identified in the middle part and towards the upper part of the succession. The **Rudstone microfacies** (Fig.9.8), mostly consists of soritids and appears only in two levels in the middle part.

▪ **Qazan Section**

– **Bioconstructed Microfacies**, the percentage of boundstone facies in the Qazan Section (Fig.10.3 and 10.4) reaches about 55% of the total section. This facies mainly consists of coral, red algae and sometimes contains forams and echinoid plates. In some levels, the skeletons of coral are filled by microbial peloids introduced by red algae. The **Bioconstructed microfacies** appears in the first third of the middle part (intercalated with grainstone and packstone) and 18 m towards the uppermost part of the succession. The reddish color of micrite is caused by organic matter due to oxidation process.

– **Bioaccumulated Microfacies** comprises of three main types of grainstone, bioclastic packstone and soritids floatstone. The **grainstone** reaches about 8% of the total section and comprises rotaliids – miliolids grainstone, in the first level of the section, rotaliids grainstone in the middle part with thickness of 2 m, and some levels intercalated with boundstone and packstone, and foraminiferous grainstone in thin layer towards the upper part of the section. This facies consists of forams (miliolids, peneroplids and soritids), green algae (dasycladales), intraclasts, fragments of corals and red algae. The **bioclastic packstone** (Fig.10.5) forms 28.2% of the total section and appears in several levels in the middle part and towards the upper part of the succession. This facies consists of red algae fragments, echinoid spines and plates, bioclasts, textulariids, coral fragments, gastropods, ostracods, and ghosts of nummulites, due to dolomitization. Other diagenetic processes are represented by dissolution under pressure producing stylolites. The **Soritids floatstone** (Fig.10.6) occur in the uppermost part of the section. The coarse floatstone facies most frequently contains large amount of soritids with red algae, green algae, miliolids and gastropods. In this part of the section, *Saudia labyrinthica, Orbitolites complanatus, Biloculina, Quinquiloculina, Clypenia meriendae, Morozovella angulata, clypeina, Idalina sinjarica* and *Discocyclina* were identified.

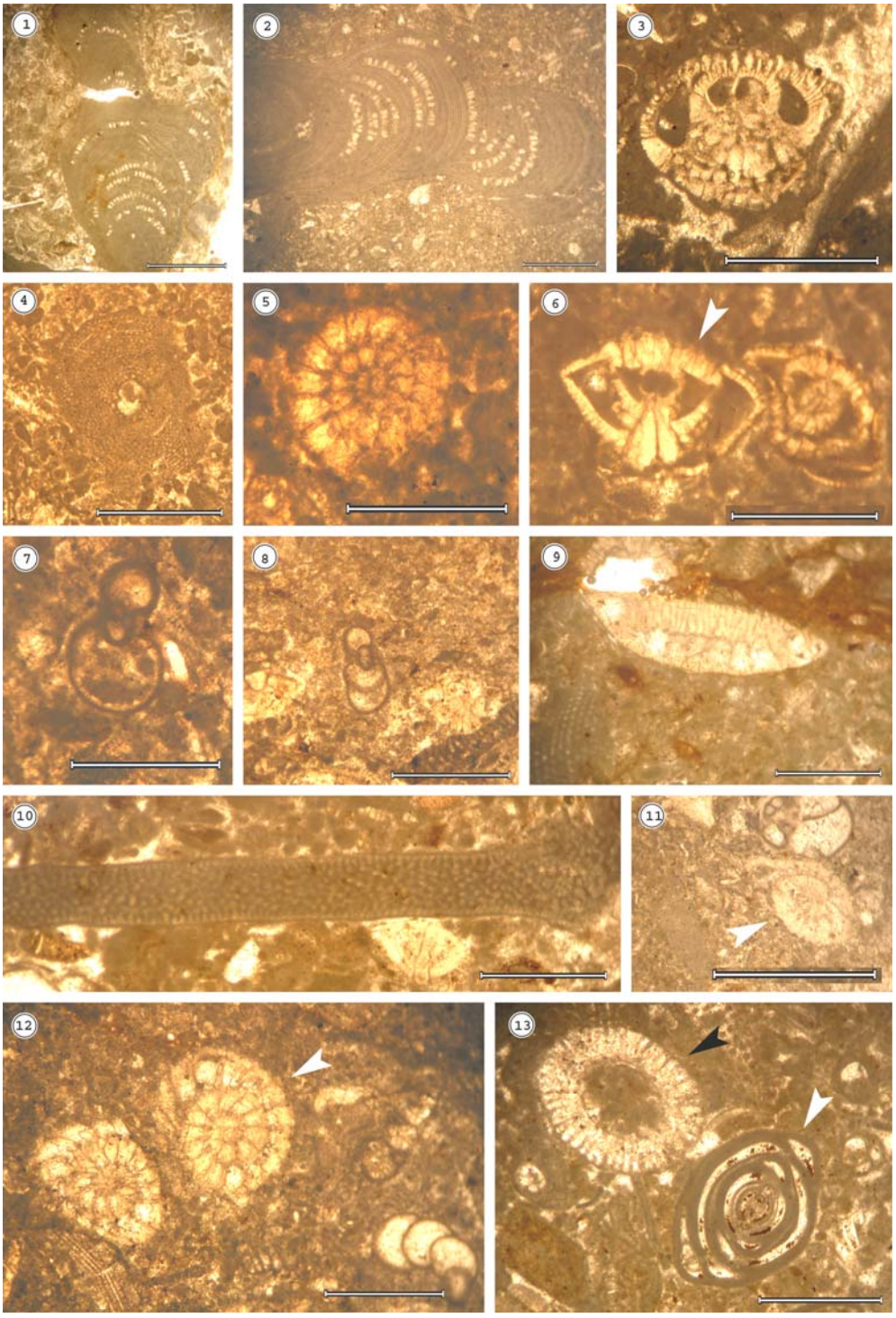


Fig.6: Common fossil types in Sinjar Formation, Hazar Merd Section

1 and **2)** *Sporolithon*, (S.Nos.222 and 350). **3)** *Miscellanea* sp. CARTER (S.No.297). **4)** *Discocyclina* sp. (S.No.307). **5)** *Peneroplis* sp., axial section (S.No.319). **6)** *Kathina subspherica* SIREL, subaxial section (S.No.357). **7** and **8)** *Pseudohatigerina* sp. (S.Nos.320 and 360). **9)** *Discocyclina varians* KAUFFMAN (S.No.366). **10)** *Saudia labyrinthica* GRIMSDALE (S.No.337). **11)** *Operculina salsa* (S.No.382). **12)** *Assilina* sp. (S.No.382). **13)** *Idalina sinjarica* GRIMSDALE, axial section (white arrow), *Symopolia* sp. (black arrow) (S.No.307).

Note: The bar scale is 1mm for all figures

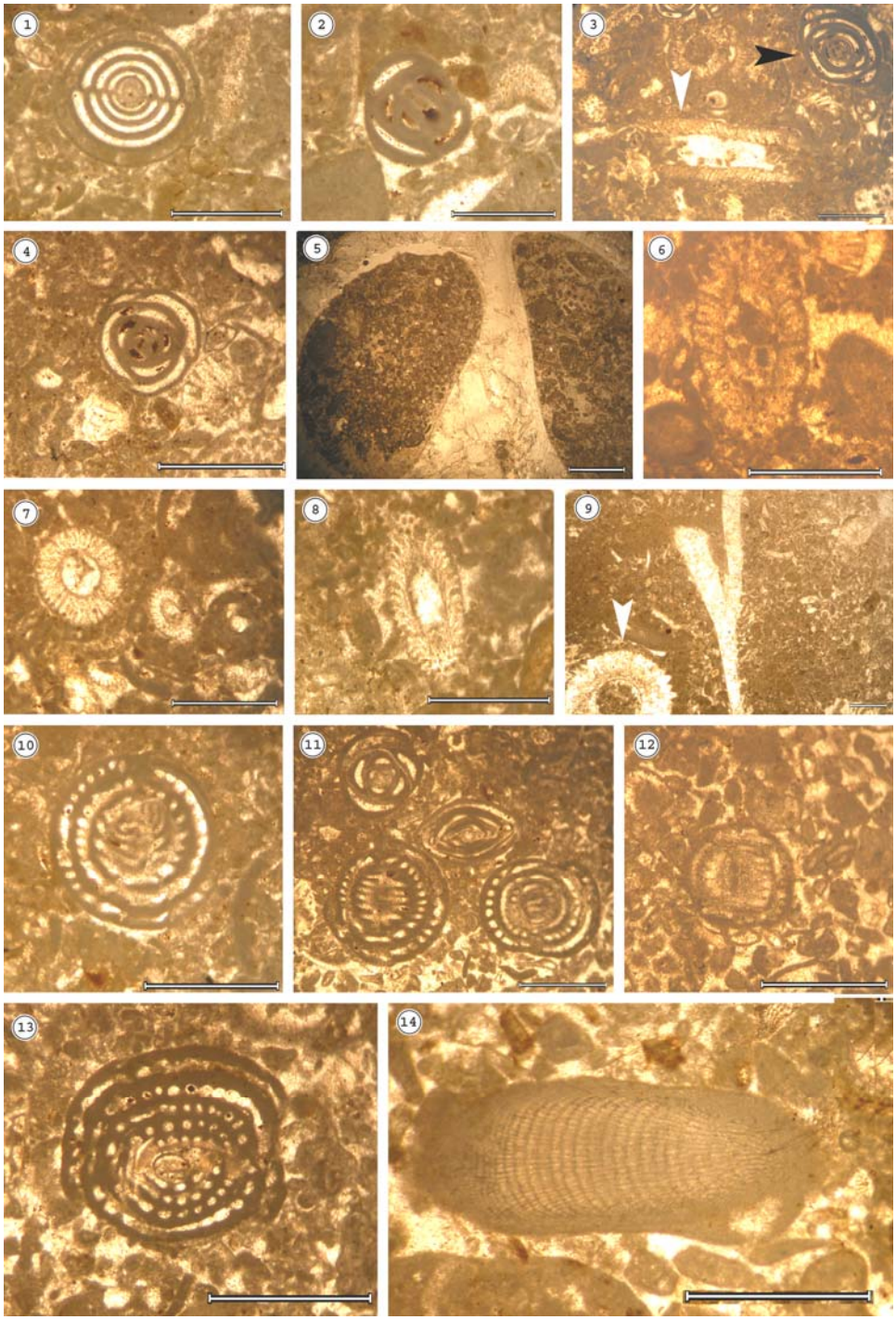


Fig.7: Common fossil types in Sinjar Formation, Hazar Merd Section

1) *Biloculina* (S.No.393). **2)** *Miliola* (S.No.393). **3)** *Symopolia* sp. (white arrow), *Idalina sinjarica* GRIMSDALE (black arrow) (S.No. 393). **4)** *Triloculina* (S.No.393). **5)** Gastropod filled by green algae, peloids and forams (S.No.400). **6** and **8)** *Symopolia ellongata* DEFRANCE, Oblique sections (S.No.393). **7)** *Symopolia* sp. (S.No.393). **9)** *Dissocladella* inside the shell of gastropod. Gastropod's shell is filled by green algae, red algae fragments and small forams (S.No.404). **10** and **11)** *Alveolina globosa* LEYNERIE (S.No.411). **12)** *Alveolina primaeva* REICHEL (S.No.412). **13)** *Glomalveolina* sp. REICHEL and RENZ (S.No.411). **14)** *Amphiroa iraquensis* (S.No.416).

Note: The bar scale is 1mm for all figures

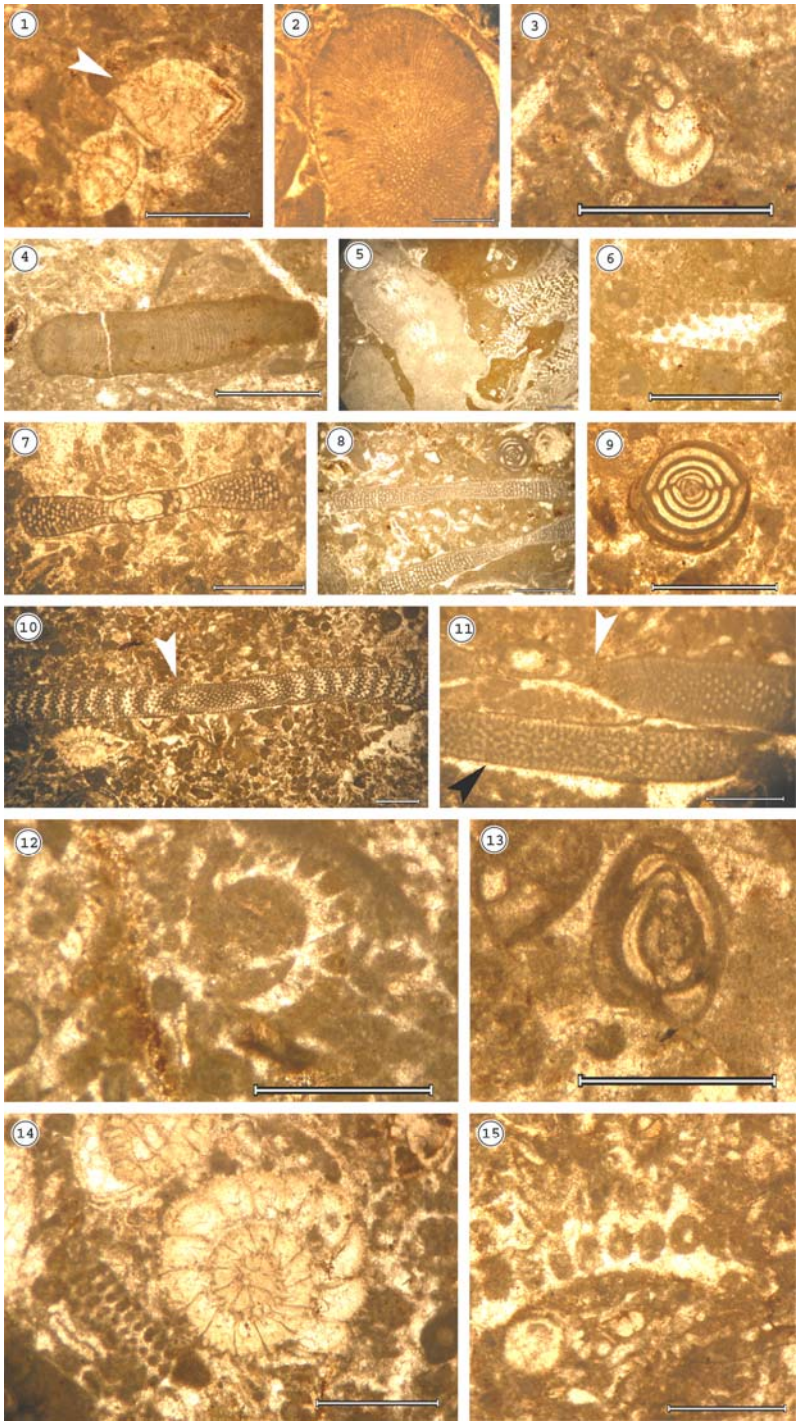


Fig.8: Common fossil types in Sinjar Formation, Qazan Section

1) *Kathina* sp. (S.No.432). **2)** *Parachaetetes* (S.No.453). **3)** *Pseudohatigerina* sp. (S.No.487). **4)** *Amphiroa iraquensis* (S.No.489). **5)** *Polystrata alba* (S.No.542A). **6)** *Acicularia* (green algae) (S.No.546). **7)** *Opertorbitolites transitorius* HOTTINGER (S.No.557). **8)** *Orbitolites complanatus* (S.No.558). **9)** *Biloculina* (S.No.558). **10)** *Saudia labyrinthica* GRIMSDALE (S.No.564). **11)** *Orbitolites complanatus* (white arrow) and *Saudia labyrinthica* GRIMSDALE (black arrow) (S.No.566). **12)** *Clypeina* (S.No.564). **13)** *Idalina sinjarica* GRIMSDALE (S.No.570). **14)** *Morozovella angulata* (S.No.564). **15)** *Clypenia meriendae* (S.No.564).

Note: The bar scale is 1mm for all figures

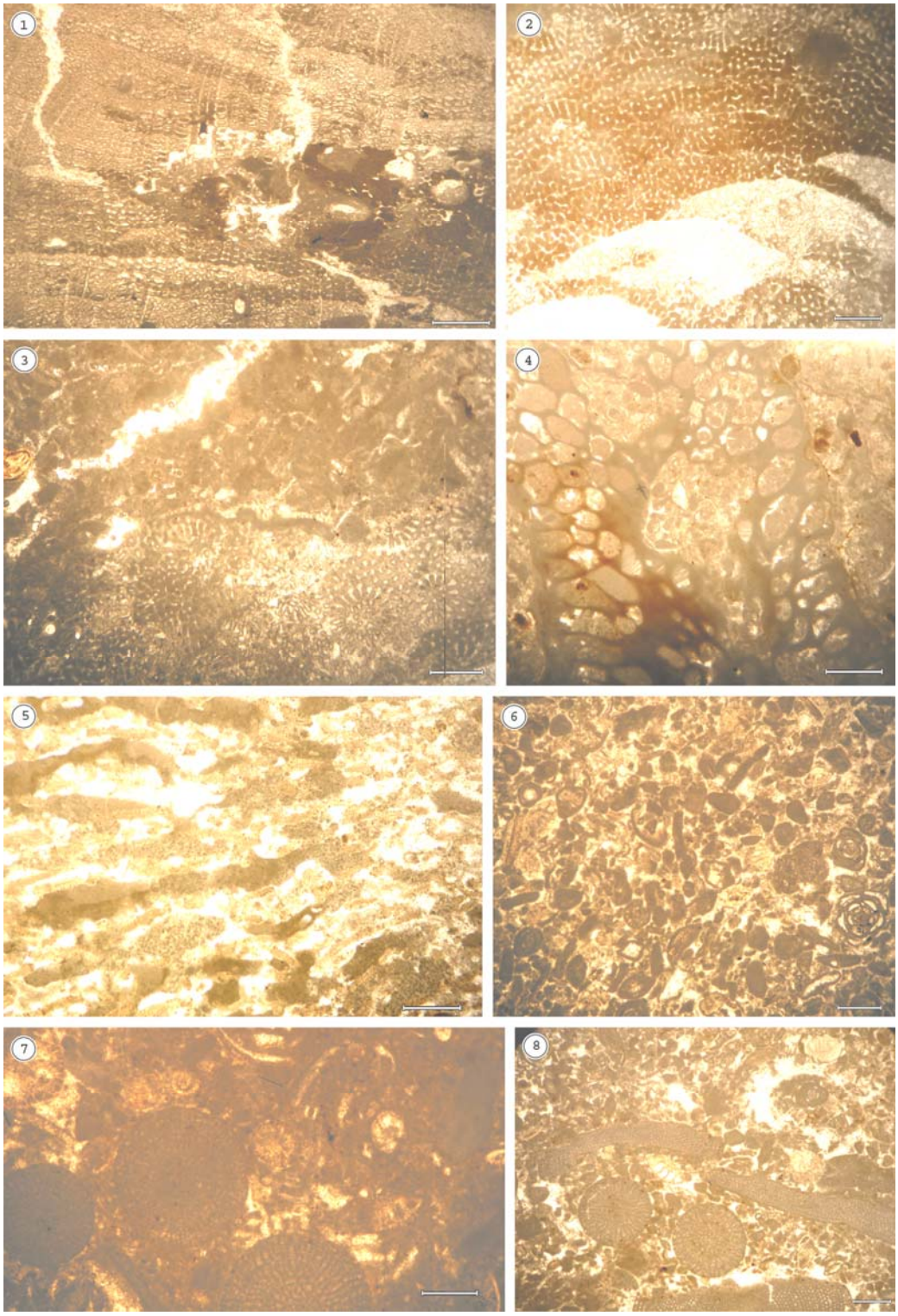


Fig.9: Common microfacies types in Sinjar Formation, Hazar Merd Section

1 and **2)** Coralligenous boundstone (S.Nos.204 and 219). **3)** Boundstone – packstone (S.No.230). **4)** Bryozoans in boundstone – packstone (S.No.238). **5)** Discocyclinids packstone (S.No.265). **6)** Rotaliids – miliolids grainstone (S.No.312). **7)** Rotaliids floatstone, it also contains discocyclinids (S.No.324). **8)** Rotaliids rudstone with some discocyclinids and soritids (S.No.325).

Note: The bar scale is 1mm for all figures

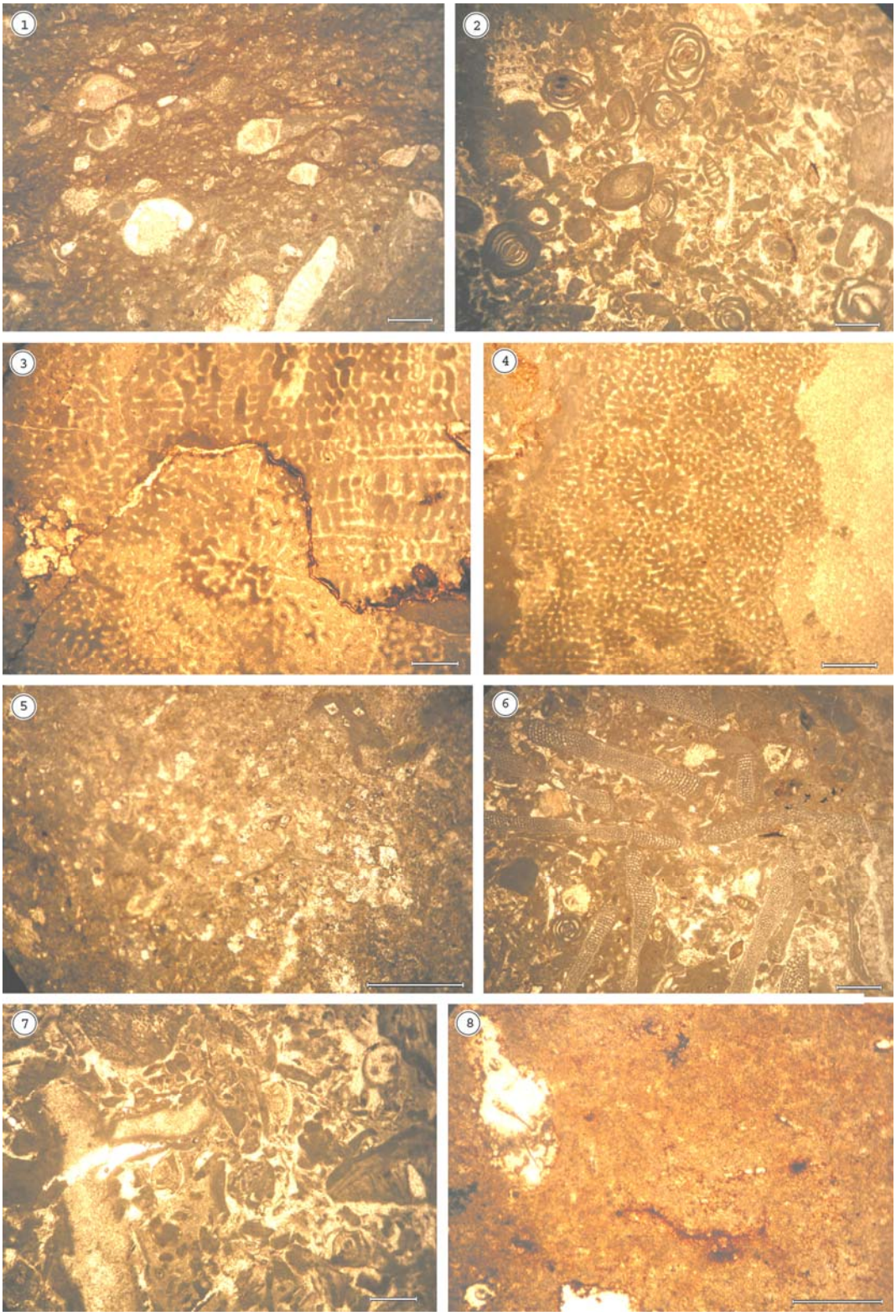


Fig.10: **1)** Rotaliids packstone (S.No.332, Hazar Merd Section). **2)** Miliolids grainstone (S.No.395, Hazrar Merd Section). **3** and **4)** Coralligenous boundstone (S.Nos.443 and 465, Qazan Section). **5)** Dolomitized bioclastic packstone (S.No.532, Qazan Section). **6)** Soritids floatstone (S.No.558, Qazan Section). **7)** Rudstone with large fragments of red algae (S.No.500, Qazan Section). **8)** Completely dolomitized (S.No.433, Qazan Section).

Note: The bar scale is 1mm for all figures

PALEOECOLOGICAL CONSIDERATIONS

The vertical stacking of the identified facies types reflects cyclic changes of the water depth. Based on the microfacial and micropaleontological features, three main carbonate depositional systems have been identified in both Hazar Merd and Qazan Sections.

- **Reef**

Reefs consist of colonial organisms and represent the most complex organogeneous depositional structures. They show high mechanical resistance due to the encrusting organisms and relatively high dome-type geometries as compared to the neighbouring sediments (Flügel, 1982). The internal structure of the rocks formed in the reef differs according to the genesis and position within the reef structure. In the central facies, the in-situ deposition is dominating, thus the typical resulting rocks are boundstones (bafflestones, bindstones or framestones); in the marginal areas the allochtonous material prevails, and floatstones or rudstones form (Flügel, 2004).

In both Hazar Merd and Qazan Sections, reef facies are present in the first half part and goes up to the upper part of Qazan Section, represented by boundstone consisting especially of corals, red algae as well as bryozoans, echinoid plates and spines with mollusks and foraminiferas (rotaliids, miliolids and soritids), as shown in Figs. (4 and 5). Concerning the genus *Polystrata*, there are contradictory opinions. Some authors (Bassi, 1997 and Lund *et al*., 2000) consider the species that belong to this genus live in relatively deep waters, while Denizot (1968) found *Polystrata* in reef facies deposits. The presence of *Sporolithon*, which prefers warm and shallower depositional environments (Prica, 2005) indicates that the coralgal bioconstructions in Sinjar Formation are formed in warm and illuminated water. Generally, this facies has been deposited on the submerged heights in the inner platform and probably due to tectonic origin (Al-Rawi, 1979).

- **Fore-reef**

The external side (fore-reef) represents the exposed part to open sea and submitted to the winds and waves energies. They consist of clastic deposits derived from the central area and show stratification that is distally thinning and curving, and will be interlocked with the basinal deposits. In the proximal areas, the sediments are represented by poorly sorted, poorly reworked, coarse, ruditic and arenitic (rudstones and floatstones) deposits (Flügel, 1982 and 2004). The rocks in this facies mainly consist of reefal bioclast, like fragments of red algae, corals, bryozoans, and are rich in forams (rotaliids, alveolinids, discocyclinids, soritids and nummulites), and other fragments, which were transported by physical factors as water current, waves and attractive forces. These facies appear in most parts of Hazar Merd Section (Fig.4), but in a discrete manner due to progradation and retrogradation patterns during sediments deposition, whereas, it is restricted in the middle part (few meters) of Qazan Section (Fig.5).

- **Back-reef**

The back-reef facies are bordered by extended area from coast to reef, from back side. They consist of small forams, which have thin wall as *Milliola* and *Peneroplids* (Forman and Schlanger 1957 and Henson, 1957), and represented by lagoon and shore-zone complex. The peloids grainstone of algal origin with dasycladales (green algae), which are growing in warm, shallow water (Valet, 1979 and Flügel, 1982), and in lagoonal water behind reefs (Génot, 1987 and Dieni *et al*., 1985) appear in the upper part of Hazar Merd Section indicating also back-reef environment.

Brasier (1975) concluded that the high numbers and qualities of *Milliola* indicate to a protected environment from back-reef and the widespread of miliolids never indicates fore-reef. In other aspect, the presence of fine crystalline dolomites as shown in the lower and middle parts of Qazan Section and in the middle part of the Hazar Merd Section indicates this facies. The back-reef facies is widespread in the first half of both Hazar Merd and Qazan Sections; interlayered with boundstone. So, the size of forams in the back-reef differs (smaller and with thin walls) from those in fore-reef (Ager, 1963).

CONCLUSIONS

- Twenty five microfacies were identified from Hazar Merd and Qazan Sections.
- Thirty five microfossils of algae and foraminifera were identified in both Hazar Merd and Qazan Sections; some of them are good indicators for the age and paleoenvironment.
- The presence of green algae (dasycladales) and red algae such as *Sporolithon* indicate that the limestones of Sinjar Formation are formed in warm, shallow and illuminated water.
- Based on the microfossils association of *Alveolina primaeva*, *Saudia labyrinthica*, *Miscellanea* sp., *Idalina sinjarica*, *Operculina salsa*, *Assilina* and *Miliola* we have assigned a Late Paleocene – Early Eocene age to the Sinjar Formation from the Baranan Mountain.

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