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Microfacies and Paleoenvironment of Sinjar Formation (Paleocene-Early Eocene), Sinjar Area, Northern Iraq

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ABSTRACT

Micofacies analysis and faunal evidence from the stratigraphic sequence of Sinjar Limestone Formation (Paleocene-Early Eocene) integrate three units accumulated in different zones on an isolated platform with bank-ramp depositional profile. These include: (1) a bank-rim buildup composed of red algae with subordinate coral boundstones, and interior bank dominated by nummulitic shoal-bar grainstone, (2) a backbank lagoon-bay of finer-grained carbonates punctuated by miliolids-alveolinids shoal bar and green algae, and (3) forebank rudstones-grainstones of red algal-coral and Nummulites. Paleoecological deduction point to a warm-temperate climate with colder periods during the overgrowth of red-algal bank which had not acted as effective barrier to water circulation. The genesis of the Sinjar carbonate bank can be expressed by alveolinids, miliolids and Nummulites as inner-middle ramp deposits of euphotic-mesophotic zone comprising foram shoals-lagoon-bay behind the domain of coralgal bank in meso-oligophotic zone.

السحنات الدقيقة والبيئة الترسيبية القديمة لتكوين سنجار (الباليوسين-الايوسين المبكر)، منطقة سنجار، شمال غرب العراق

الملخص

اوضحت السحنات الدقيقة والحشود الحياتية المشخصة ضمن تكوين سنجار الجيري (الباليوسين-الايوسين المبكر) ان ترسبات هذا التكوين قد تراكمت ضمن ثلاثة مواقع بيئية في رصيف بحري منحدر ضحل المياه تمثل (1) بناء من التراكمات بشكل حواجز لبقايا الطحالب الجيرية الحمراء والقليل من المرجان يرافقها المناطق القريبة ذات سحنات الحجر الجيري الغنية بحشود النيوميولايت، (2) مناطق خلفية لاغونية تحتوي على خلجان يغلب فيها وجود السحنات الجيرية دقيقة الحبيبات يظهر فيها على الاغلب حشود المليوليد والالفيولينا، كما تظهر الطحالب الخضراء في المناطق الاكثر ضحالة، (3) مناطق امامية ممثلة بسحنات الحجر الجيري الحبيبي والرودستون لفتات الطحالب الحمراء والنيوميولايت والقليل من المرجان.

تبين من طبيعة الحشود الحياتية بأن تراكمات الطحالب الحمراء لم تكن تعمل كحواجز فعالة لمنع مرور المياه باتجاه المناطق الضحلة فتكونت مناطق لاغونية شبه محصورة المياه. ان المناخ السائد اثناء ترسيب تكوين سنجار كان مناخا دافئا–معتدل الحرارة تميز ببرودته في المراحل الاولى من زمن الترسيب.

INTRODUCTION

Sinjar Limestone Formation was first described from Jabal Sinjar area (near Mamissa village) by Keller in 1941 at Lat. 36˚ 22□ 33½ N, Long. 41˚ 41□ 23½ E, where it has excellent surface exposures there. The formation consists in its type area of limestone, which is usually recrystallized, white in colour and showing elements of algal reef facies, lagoonal miliolid facies and shoal nummulitic facies (Bellen et al., 1959; Al-Saddiki, 1968). The measured thickness of Sinjar Formation in its type area (near Kersi) is 183 m where as in other areas of northern Iraq it ranges from 100-200 m (Buday, 1980; Al - Surdashy, 1988). The Sinjar Formation is one of the less widespread units of the Paleocene-Lower Eocene cycle, where it is essentially distributed in an arcute form and is to be found mainly in the foothills and southern parts of the high folded zones of Iraq.

In the present study, five sections from different localities in Jabal Sinjar area are logged (Fig.1). Their microfacies and fauna, especially foraminiferal content were studied. Information derived from the biotic content and the microfacies have been used for microfacies and paleoenvironmental analysis. The goal of microfacies analysis is to infer the depositional environment of the studied succession in order to contribute to the paleogeographic configuration of the basin.

LITHOSTRATIGRAPHY AND MATERIALS

Lithologically, the Sinjar Formation consists of white cream colored limestone which is mostly hard, dense and massive. Due to this nature, it is highly resistant to weathering and forms prominent exposures comprising the main ridges of the anticline. The weathered surface of the limestone is mostly light reddish brown, whereas the prevailing colour of the fresh surface is white to cream. Variations to other shades such as pink, light brown and grey are also recorded (Thanoon, 1984). The Shiranish Formation of Upper Cetaceous age underlies Sinjar Limestone Formation unconformably with presence of pebbles (Maala, 1977). The marly limestone of Jaddala Formation (Eocene) overlies Sinjar Limestone Formation unconformably, which is clearly recognized by complete change of fauna and facies (Al-Haj, 2001; Al-Mutwali and Al-Banna, 2002).

The investigated samples were collected along traverses in a direction perpendicular to the strike of beds. Five sections at different sites were chosen with a total number of 73 samples (Fig.1). Two sections are along the main road which cut through the anticline. The first thickest section is from the type locality near the village of Kersi in the northern limb where the upper and lower boundaries of the formation are distinct. The second is along the southern limb where it starts from near Television Tower at the crest of the anticline and ends at the last bend of the road.

The other three sections are taken from: the vicinity of Mamissa village in the core of the anticline (next to the spring which flows from the underlying Shiranish Formation), from the western plunge area near the village of Barat, and from the foot of

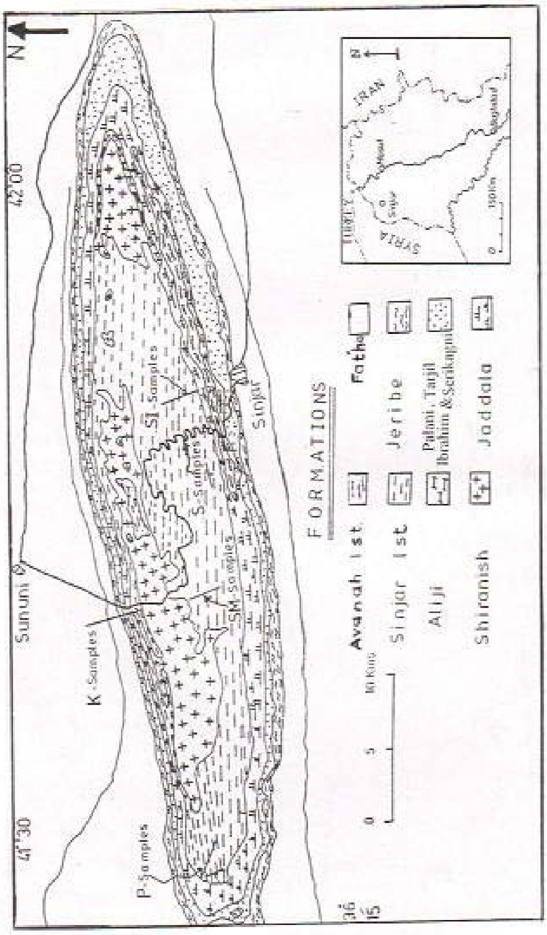

Fig 1: geological map of sinjar area showing the locations of the studied samples.
N.B. the position of the new road between sununi and sinjar through the anticline is not exact and the bends shown are schematic.

the southern limb about 3 kms east of the road. The following designations are used in connection with the samples. (K) for Kersi, (SM) for Mamissa, (P) for the plunge, (S) and (SI) for the southern limb round the bends of the road and 3 km east of that road respectively. The collection is based on the nature and physical characters of the limestone.

MICROFACIES DESCRIPTION

On the basis of litho-biostratigraphic data from outcrops and thin section, the Sinjar Formation in the studied sections embraced many facies as defined by Dunham, 1962 classification and was expended by Embry and Klovan (1972). The microfacies are grouped into seven main association shown in Table (1). A brief resume of the concerned microfacies is described below:

1- Boundstone microfacies (B):

Represent carbonates with original components bound together during deposition. In the present study, it is composed mainly of calcareous algae and coral with an average of 80-90% of the total assemblage. Two submicrofacies are recognized including algal and coralgal boundstone in SI and P sections (Pl.3, Fig.3). The bulk of the assemblage is generally represented by red algae genera Archaeolithothamnium, Lithophyllum, parachaetetes and mesophyllum.

2- Floatstone microfacies (F):

This microfacies contains large grains (more than 2mm in size) which represents more than 10% of the total allochems set in micrite matrix. This microfacies exhibits variable, fossil content which may be dominated by one of the following: algae, coral, Nummulites, Discocyclina, Alveolina and other benthonic forams (Pl.4, Figs. 2and3). It has been recognized in the (S) and (P) sections (Fig.2).

3- Rudstone microfacies (R) :

It is composed of large size grains (more than 2 mm) attaining more than 10% of total allochems cemented together by spary calcite. The biotic components are composed mainly of red algae, coral and bioclasts (Pl.3, Figs.1and2). In addition foraminiferal suite is present which include Alveolina, Nummulites, Doiscocyclina and other benthonic forams (Pl.4, Fig.1). This microfacies comprises many intervals in (P) section and upper part of SI section.

4- Grainstone microfacies (G):

This microfacies contains skeletal components of less than 2 mm affiliated to Nummulites, Discocyclina as in the upper part of Kersi section and of Alveolina and other Miliolids in its middle part (Pl.1, Fig.2), where as its counterpart in P and SI sections is represented essentially by algae and its bioclasts. Some of the skeletal components appear as micritic in intraclasts with high rounding.

5- Packstone microfacies (P):

It represents the most common microfacies within Sinjar Formation, where it is represented in all the studied sections. The fauna is dominated by coralline red algae, Alveolina, Nummulites and Discocyclina with rare coral and Miliolids (Triloculina, Quinqueloculina and Spiroloculina), small biconvex rotaliids (Lackhartia, Rotalia and Kathina), echinoid spines and molluscan shells (Pelecypods and Gastropods)(Pl.1, Fig.1). This microfacies at some intervals is rich with bioclasts which are provided from the a forementioned biota especially the algae and mollusca, some of the bioclasts are

Table 1: Main microfacies and submicrofacies of Sinjar Limestone Formation.

Main Microfacies	Submicrofacies	Symbols
Boundstone (B)	Coralgal	B1
	Algal	B2
Floatstone (F)	Algal	F1
	Nummulitic	F2
	Nummulitic-Discocyclina	F3
	Nummulitic algal	F4
	Coralgal	F5
	Algal Nummulitic	F6
	Alveolinid algal	F7
Rudstone (R)	Coralgal	R1
	Algal	R2
	Algal Nummulitic-Discocyclina	R3
	Discocyclina algal Nummulitic	R4
	Alveolinid algal	R5
	Bioclastic coral	R6
Grainstone (G)	Algal	G1
	Bioclastic algal	G2
	Discicyclina-Nummulitic	G3
	Discicyclina-Nummulitic bioclastic	G4
	Alveolinid intraclastic	G5
Packstone (P)	Bioclastic pelletoidal	P1
	Peloidal miliolidal	P2
	Discocyclina-algal	P3
	Algal Nummulitic	P4
	Alveolinid	P5
	Coralgal	P6
	Bioclastic algal	P7
	Nummulitic algal	P8
	Bioclastic algal foraminiferal	P9
	Alveolina-algal	P10
	Alveolina bioclastic	P11
	Molluscan pelletoidal	P12
	Vuggy algal	P13
	Micritized bioclastic	P14
Wackestone (W)	Algal	W1
	Neomorphosed algal	W2
	Bioclastic	W3
	Bioclastic pelletoidal	W4
	Neomorphosed mollascan	W5
	Vuggy molluscan	W6
	Molluscan pelletoidal	W7
	Alveolinid	W8
	Dasycladacean	W9
Mudstone (M)	Algal	M1
	Bioclastic	M2

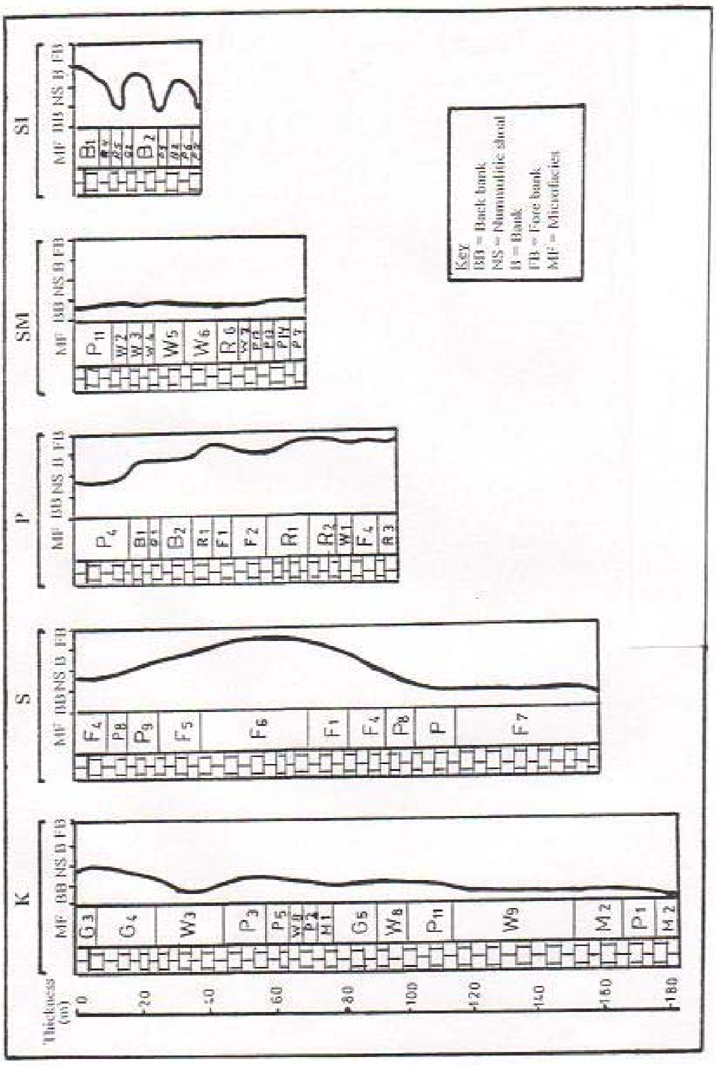

Fig 2: Microfacies and depositional environments of tsections (refer to table 1 for sqmicrofacies symbols).

micritized or with micrite envelops. Pellets and pelletoids are frequently observed in this microfacies at Kersi (K) and Mamissa (SM) sections (Pl.2, Fig.3). The groundmass consists of spar with minor micrites. Neomorphism is inferred to be a near surface phenomena where the algal ridge were exposed to the surface with the development of vuggy packstone microfacies.

6- Wackestone microfacies (W):

The next dominant microfacies after the packstone microfacies. Allochem content various between 10-60%, represented by Algae (Corallinaceae and Dasycladaceae), mollusca, Alveolina, with pelletoids and clasts of algae and mollusca.

This microfacies is common in Mamissa (SM) section represented by allochems composed of benthic foraminifera like Nummulites, Saudia, Alveolina (small), Idalina, Quinqueloculina, Ranikothalia and Spiroloculina, or by abundant bioclasts (Pelecypods and Gaetropods) associated with pelletoidal micrite (Pl.5, Fig.2).

Wackstone microfacies also existed in Kersi (K) section, where the lower part is dominated by dasycladacean algae (Nizza, Cymopolia and Ovulites) and their bioclasts in micrite groundmass (Pl.2, Fig.1). The middle part displays Alveolina globula Hottinger Alveolina aragonensis Hottinger and miliolids (Pl.1, Fig.3). The upper part shows Nummulites signature with its bioclasts.

7- Mudstone microfacies:

It is characterized by very few allochems (less than 10%) and abundant micrite. This microfacies is confined to Kersi section, where it contains bioclasts in its lower part (Pl.2, Fig.2), and algae in the upper part of this section. This microfacies lacks distinctive fossil but with poorly preserved algae in micrite fabric, it may also contain some particles of solitary coral, shell fragments of small mollusca (Gastropods and Pelecypods), with bioclasts of echinoids and recrystallized alge.

ENVIRONMENTAL SUBDIVISIONS

On the basis of depositional textures and fossil content of the microfacies, it appears that the sequence of Sinjar limestone can be conveniently divided into three parts; in addition to outcrop data which define them on their lithology constituents and stratification. Each is allocated to one of the juxtaposed depositional sites.

Lagoon-Back Bank Deposits:

The back bank is the area restricted between shoreline and the back side of the coralgal bank. It appears in the lower and middle parts of K, SM and lower part of S sections, but not observed in the P section (Fig.2). It is represented by packstone, floatstone and rudstone containing mainly miliolids and alveolinids. Common components are pelecypods, gastropods, dasyclad algae with less common pellets and red algae. Miliolids include Triloculina and Quinqueloculina. Other foraminifera are recorded as Textularia, Rotalia, Lockhartia, Kathina, Spiroloculina, Idalina and Cuvillierna. At Kersi, this is typified by high abundance of miliolids, of Alveolinids and dasyclad algae, especially Oviulites and Cymopolia. Regarding the calcareous green algae, it inhibits the back reef area of modern carbonates with lesser amount of molluscs and foraminifera (Blatt, 1982); or as the main ingradients of tidal lakes and proteced lagoon (Ghose, 1977; Haq and Boersma, 1978).

Ancient analogs of lagoonal lithofacies with alveolinids have been described from the Eocene of Tunisia (Bismuth and Bonnifeous, 1981), Upper Miocene reef complex, Spain (Pomar, 1996, 2001b).

In the Sinjar Limestone, particularly at Kersi, the abundance of miliolids grainstone in the lower part which grades upward into alveolinids grainstones-packstones indicate that shoals and barrier bars (shoreface-foreshore) accumulated in the inner and middle-outer lagoon respectively, behind the algal bank-nummulite shoal community or bank-shoal facies.

Coralgal Bank-Nummulites Shoal Deposits:

The main bank component is red algae constituting the massive framework with algal bounstones and rudstones and minor or subdued coral rudstone, which is exquisitely exposed at Kersi, the southern limb (S) and the plunge area (P). The latter area shows a higher appearance of coral. The algal facies are sometimes interleaved with alveolinid-bearing facies of quite lagoon or more importantly with small and large nummulite beds and rotalids of near algal bank as bar, or shoals (Bartholdy et al., 1999; Pautal, 1987).

The red algae which form the essential framework of Sinjar algal bank include Solenomeris, Lithoporella, Archaeolithothamnian, Lithothamnian and Lithophyllum, with minor coral. These algal genera with larger foraminifera are found in the lower Tortonian ramp slope of Spain, but where coral were dominated they form the Miocene Reef Complex (Pomar, 1996, 2001a). Modern analogs of Lithothamnium with ancillary coral build forward and upward on the windward side of the reef strip of Bikini Atoll (Dunbar and Rogers, 1957). Likewise, in the western Nicaraguan Rise; red algae encrust the bank-top and windword margins of the carbonate platform (Peebles et al., 1990). Analogous, extensive red algal bioherms have been described from the Miocene of Malta, where massive form regarded as indicator of low energy conditions (Boscence and Pedley, 1979).Similarly the massive appearance of algal beds in the Sinjar Limestone may be considered as an attribute of algal growth habit where vigorous wave current action is subordinate.

The association of red algae with large foraminiferas has been recorded from the ramp slope facies of the Upper Miocene, Spain, where middle ramp facies is characterized by the superabundance of larger foraminifera (Pomar, 2001b), or as monospecific nummulitic bar (Bartholdy et al., 1999), or large foram shoal (Pautal, 1987; Carozzi, 1989).

In this respect, the coarse Discocyclina-Nummulites grainstone of the present study which are clearly washed and lacking microcrystalline mud indicate current sorting or storm wave action with sufficient energy to winnow away fines from prograding nummulitic shoals. The alignment of smaller Nummulites observed in some beds corroborates such an interpretation which was advocated by Aigner (1982) to designate current action during Nummulites accumulation. With respect to Sinjar succession the most developed counterpart of this association representing "in situ" accumulation, is in the upper part of Kersi section, where stromatolites and sporadic chert were also reported (Al-Haj, 2001). On the other hand, this association displays a subdued appearance of algal-nummulitic-Discocyclina floatstone-rudstone in the P, SI and S section, while it is lacking in Mamisa section. The larger foraminifera in these sections are represented by N. globulus Leymerie, N. atacicus Leymerie, N. planulatus (Lamarck), Assilina, Discocyclina with sporadic Spiroloculina (Pl.5, Fig.5). Locally, as in sections P and S, intraclastic and skeletal bioclastic grainstone, floatstone and mudstone with red algae, coral and large foraminifera components are common, with lesser echinoids indicating deeper offshore marine-slope deposition of forebank association. Bioaccumulation of Nummulites-Discocyclia with red algae and coral represent optimum conditions for the initiation of nummulitic shoals, bars or banks on the shelf edge of outer ramp (Hart, 1987; Moody, 1987 and Pomar, 2001b). The same above fauna when associated with alveolinids and green algae were allocated to carbonate bays-lagoons.

Forebank-Slope Deposits:

These are recorded in Kersi section and to a lesser extent in P and SI sections. They consist of red algal intraclastic grainstone-float and rudstone with sporadic coral fragments and large foraminifera as Nummulites and Discocyclina. The skeletal, intraclastic, fragmentary and rounded character point to proximity to shelf-margin or outer ramp-slope zones as evidenced by the inclusion of some echinoid, bryozoan fragments and very scarce planktonic foraminifera. This association is analogous to the proximal slope-offreef facies which has been described from the Upper Miocene Ramp-Reef of Spain (Pomer, 2001b).

The fortuitous localization or compartmentalization of deposition of the Paleocene-Early Eocene Sinjar carbonate seems to indicate accumulation growth on an isolated platform-bank-ramp environment. Major facies are: (1) a bank rim buildup composed of red algae-coral boundstone and interior bank dominated by nummulitic bar grainstones with a red algal Nummulites fringe, (2) a back-bank lagoonal bay of finer grained carbonate punctuated by miliolid-alveolinid shoals/bars and green algae and (3) forebank rudstone-grainstone of red algal-coral and Nummulites.

PALEOECOLOGY AND DEPOSITIONAL PROFILE

Carbonate platform development depends on carbonate production in the sea which is affected by many factors (depth, nutrients, salinity, temperature, energy transparency, etc.) influencing biological activities (Pomar, 2001a). In shallow shelves, the most important factors are light and nutrients, where primary production is most pronounced (Duxbury and Duxbury, 1997). This is because bathymetric distribution of benthic fauna shows obligate dependence on light penetration into the water column on shallow carbonate platforms. This dependence is a sequal of the endosymbiotic algae (Zooxanthella) with molluscs, corals and large foraminifera, and their photosynthesis (Smith, 1973; Pomar, 2001a). Accordingly, carbonate production would dominate tropical-subtropical zone and decline towards temperate water (Hallam, 1981).

Considering the biotic distribution range and light dependence, three principal groups are suggested (Pomar, 2001a). These are euphotic biota with high light requirement, oligophotic biota with poor light dependence and aphotic biota that are independent of light. Subdivisions include a mesophotic zone between euphotic-oligophotic and upper-lower photic zones.

Micofacies analysis of the Sinjar Limestone, allocates its faunal assemblage to the association of tropical-subtropical regions. The green calcareous algae and subordinate corals recorded in the lagoon-bay facies of Sinjar Formation are typical of euphotic-mesophotic zone, where maximum depth of prolific growth is commonly about 20-30 m depth (Fig.3). On the other hand, red algae span the shallow water environment from the lagoon to shelf break and may extend down shelf, but thrive mostly between 40-90 m in the meso-oligophotic zone, where they are associated with larger foraminifera (Bartholdy et al., 1997; Pomar, 2001a). The presence of red coralline algae in the Sinjar Limestone represented by Lithothamnium, Lithophyllum, Lithoporella associated or interbedded with Nummulites and Discocyclina facies clearly favours their accumulation on outershelf zone which is situated in meso-oligophotic zone (Fig.4). Although red algae and large foraminifera are oligophotic biota, the coralline-algal buildups show deeper accumulation in clear water as in the case of modern Mediterranean (Bosence, 1985). Taking into consideration this approach and its implication on the faunal distribution of the Sinjar Limestone, it permits the recognition, in general, of two zones. The euphotic-mesophotic zone matching the back-bank and characterized by green algae, molluscs, miliolids, alveolinids and solitary/patch reef in the lagoonal-restricted bay environment. The deeper oligophotic zone presumably represented by Nummulites and coralline-algal bank, and forebank facies. This presumptive evidence of depth differentiation (the ability of red algae to the flourish at greater depth than the green algae) can be attributed to the red pigments (phycoerthrin and plucocyanin that masks their green chlorophyll) and enable them to utilize the blue light in photosynthesis (Cloud, 1975; Duxbury and Duxbury, 1997). Thus in deeper oligophotic zone corals loose ground to red algae due to lack of algal symbionts zooxanthellae (green chlorophyll) which play a vital role in corals growth in euphotic zone and molluscs under littoral conditions. Furthermore, the depth range of crustose red algae, which is the case in Sinjar Limestone, is greater than that of nodular, articulate and branched types (Cloud, 1975) and of lower energy conditions and quiet water (Bosence and Pedley, 1979).

The dominance of red algae in the Sinjar Limestone resembles the Miocene coralline algal bioherm from Malta described by Bosence and Pedley (1979) as non-reefal algal limestone. This overgrowth of algae is suggested to indicate colder climate preventing settling and growth of corals which need warm transparent shallow marine water (Burrouith, 1979); or too much nutrients of nitrate and phosphates in the water in which algae thrive (Duxbury and Duxbury, 1997). This is demonstrated in the modern Nicaraguan Rise bioherms, composed of calcareous and coralline algae, while corals are conspicuously absent in these banks, where topographic upwelling associated with current acceleration over the Rise stimulate algal-spong growth and suppressing coral-reef growth (Hallock and Hine, 1990). In contrast the large size and diversity of Nummulites and large foraminifera in general are indicator of low levels nutrients and optimum in climate due to lack of surface mixing despite the high solar radiation at the tropic latitudes (Duxbury and Duxbury, 1977; Bartholdy et al., 1999).

The uncommon coral in Sinjar Limestone and the dominance of coralline red algae with large foraminifera companions would suggest a command by climatic variation or windward bank margin algal bioherm/buildup associated with upwelling – and leeward coral growth (Rosen and Collins, 1990).

This paleoecological deduction based on faunal assemblages and as reflected by the microfacies and their textures allow a predictive interpretation of various depositional profiles. The uncontested view of Henson (1950) is still the most popularly accepted and its advocation by many later investigators (Al-Siddiki, 1968; Maala, 1977; Shathaya, 1980; Al-Haj, 2002) augamented the interpretation where back-reef and Nummulites

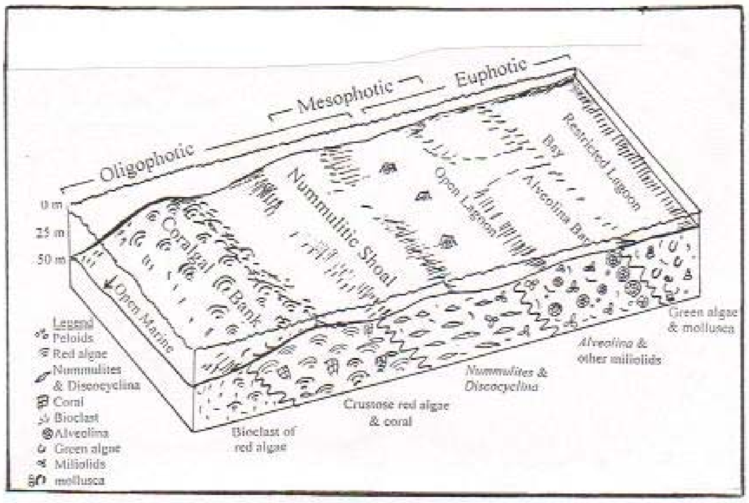

Fig. 3: Block diagram showing depositional model and distribution of faunal assemblages of sinjar formation.

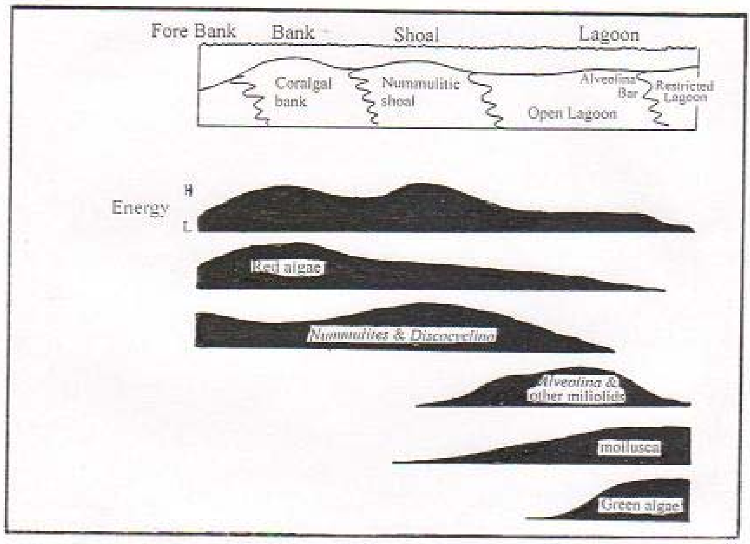

Fig. 4: Two dimentional model showing general depositional systems and distiribution of selected fossils of sinjar formation.

forereef shoal are seperated by coralgal reef. The fact that plausible disagreement may exist show that detailed evidence, precluding interpretation, are matters of subjective assessment. Here the unchallenged model may be modified by a variety of alternative explanation. However, the absence of turbidites beyond the seaward edge of rimmed shelf and non-skeletal oolites and evaporites-dolomite is an evidence of ramp rather than rimmed platform. Thus, another variant of depositional profile to consider is a carbonate platform where large foraminifera (Nummulites) and red algae "in situ" bioaccumulation is in the mesophotic-oligophotic zone with the development of distally steepend ramp profile. In this model (Fig.3) the red coralline algae is supposed to be slightly deeper oligophotic than the euphotic-mesophotic nummulite back/shoal, which has accumulated through episodes of high winnowing (Carozzi, 1981; Aigner, 1982). The energy level of nummulite bank accumulation was too high for the encrusting algae to thrive profusely and either eroded or prevented there form growth at this depth.

Although a rigid rim, throughout the accumulation of Sinjar Limestone, have existed along the isolated platform/bank margin, it was unable to completely restrict water circulation and wave action to back bank/shoal and bank top as implied by rimmed shelves and the absence of dolomite, evaporites and oolite in the lagoon of Sinjar Formation.

In addition, the occurrence of stromatolites accompanying spars chert at the top (in Kersi section) and the red color of the limestones, indicate nearshore intertidal environment and possible surface exposure. The general stratigraphic sequence is an upward shallowing passing from submarine red algal boundstone to preitidal-subtidal nummulitic packstone-grainstone and rudstone overlain by stromatolite with chert nodules.

CONCLUSIONS

An integrated facies analysis and biotic evidence led to improved predictive interpretation of the depositional environment of Sinjar Limestone Formation. The collective evidence suggests lagoon-bay deposition separated from forebank deposits by algal bank-nummulite shoal.

The upbuilding of algal bank preferentially developed in oligophotic zones whereas the nummulite lagoon-bay in mesophotic-euphotic zones. The energy level of nummulitic bank accumulation was too high for the encrusting algae to thrive and were localized near wave base under lower energy conditions. The fortuitous localization of deposition of Sinjar carbonate seems to indicate accumulation on platform dominated by bank-ramp profile. The vulnerable growth of red algae and foraminiferal shoals may indicate colder respites throughout warm temperate paleoenvironmrnt.

REFERENCES

Aigner, T., 1982: Event-stratification in nummulite accumulations and shell beds from the Eocene of Egypt. In: Cyclic and Event Stratification (Ed. by Einsele andA. Seilacher), Springer-Verlg, pp.248-262.

Al-Haj, M.A., 2001: Sedimentary model of Sinjar Formation at Northwest Iraq. (Unpub. M.Sc. Thesis), Mosul University, 141p.

Al-Mutwali, M.M. and Al-Banna, N.Y., 2002: Biostratigraphy of planktic foraminifera of Jaddala Formation (Eocene), Sinjar Area, Northwestern Iraq. Raf. Jour. Sci., 13 (1), pp.28-35.

Al-Saddiki, A., 1968: Stratigraphy and microfacies of Sinjar Formation, Unpublished M. Sc. Thesis, Baghdad University.

Al-Surdashy, M.A., 1988: Lithologic facirs and environmental study of Sinjar Formation in selected sections from Sulaimaniah area, Northeast of Iraq. Unpub. M.Sc. Thesis, Salah Al-Deen Univ.

Bartholdy, J.; Bellas, S.M.; Cosovic, V.P.; Fuèek, V. and Keupp, M., 1999: Processes controlling Eocene Mid-latitude larger foraminifera accumulations: Modelling of the stratigraphic architecture of a fore-arc basin (Podhale Basin, Poland), Geologia Carpathica, 50, 6, pp.435-448.

Bellen, R.C.V., Dunnington, H.V., Wetzel, R. and Morton, D.M., 1959, Lexique stratigraphique international, Asia, Iraq, Inter. Geol. Congr. Comm. Stratig.3, Fasc. 10a-Iraq, Paris, 333p.

Bismuth, H. and Bonnifeous, S., 1981: The biostratigraphy of carbonate deposits of the Middle and Upper Eocene in the offshore Tunisia. Paleogeo. Paleoeclim. Paleoecol., 26, pp.191-211.

Blatt, H., 1982: Sedimentary Petrology. W.H. Freeman and Company, San Francisco,. 564p.

Bosence, D.W.J., 1985: The Coralligene of the Mediterranian- a recent analog for Tertiary coralline algal limestone. In: Paleogeology: Contemporary Research and Applications (ed. by D.F. Toomei M.H. Nicecki), Springer-Verlag, New York, pp.215-225.

Bosence, D.W.J. and Pedley, H.M., 1979: Paleoecology of a Miocene coralline algal bioherm, Malta (non-reefal coralline algal limestone). Bull. Cent. Explor. Prod. Elf. Aquitaine, V. 3, pp.463-470.

Buday, T., 1980, The regional geology of Iraq, stratigraphy and paleogeography, Dar Al-Ktub Pub. House, Mosul, Iraq, 445p.

Burrouilh, F.G., 1979: The rhodolite high enengy platforms and the climatic crisis of the Miocene-Plicocene age in the Pacific Area. Bull. Centr. Explor-Prod. Elf-Aquitaine, V. 3, pp.485-495.

Carozzi, A.V., 1989: Porosity models and oil exploration of Amapa carbonates, Paleogene, Foz Do Amazonas Basin, offshore NW Brazil. Jour. Petroleum Geology, V. 4, pp.3-34.

Cloud, P.E., 1975: Facies relationships of organic reefs. A.A.P.G. Bulletin, V. 36, pp.2125-2149.

Dunbar, C.O. and Rogers, J., 1957: Principles of Stratigraphy. John Wiley and Sons Inc. New York and London, 356p.

Dunham, R.J., 1962: Classification of carbonate rocks according to depositional texture, p.108-121, in: Ham, W.E. (ed.), Classification of carbonate rocks, Tulsa. Okla., A.A.P.G. Memoir –1,.279p.

Duxbury, A.C. and Duxbury, A.B., 1997: An introduction to the world's ocean. Fifth edition, WCB, McGraw-Hill, 504p.

Embry, A.F. Klovan, E.J., 1972: Absolute water depths limits of Late Devonian paleoecological zone. Geol. Rdsch., 6112, Stuttgart.

Ghose, P.K., 1977: Paleoecology of the Cenozoic reefal foraminifera and algae. A brief review. Paleogeo. Paleoclim. Paleoecol., 22, pp.231-256.

Hallam, A., 1981: Facies interpretation and the stratigraphic record. Freeman and Company, 291p.

Hallock, P. and Hine, A.C., 1990: Spong-algal bioherms on the western platforms of the Nicaraguan Rise, Southeastern Caribbean. A.A.P.G. Bulletin, 668p, Association Rownd Table.

Haq, B.U. and Boersma, A. (eds), 1978: Introduction to marine micro-paleontology. Amsterdam, Elsevier.

Hart, M.B., 1987: Micropaleontology of carbonate environments. British Microp. Soc., Ellis Horwood limited.

Henson, F.R.S., 1950: Cretaceous and Tertiary reef formations and associated sediments in Middle East. A.A.P.G. Bulletin, V. 34, pp.215-238.

Maala, K.A., 1977, Geology of Sinjar area, Part 1, No. 860, S.O.M. Library, Baghdad, pp.1-29.

Moody, R.T.J., 1987: The Ypresian carbonates of Tunisia- a model of foraminiferal facies distribution. In: Hart, M.B. (ed.): Micropaleontology of carbonate environments, pp.82-92.

Pautal, L., 1987: Foraminiferal assemblages of some Early Eocene environments (bays) from the northern Corbieres, France. In: Hart, M.B. (ed.): Micropaleontology of carbonate environments, pp.74-81.

Peebles, M.W.; Hallock, P. and Hine, A.C., 1990: Rhodolite and encrusted-grain sedimentation. Thunder and Lightening Knolls, Southeast Carribean Sea. A.A.P.G. Bulletin, V. 74/5, p. 737, Association Round Table.

Pomar, L.; Ward, W.C. and Green, D.G., 1996: Upper Miocene Reefal Complex of the Llucmajor area, Mallorca, Spain. In: Franseen, E., Esteban, M., Ward, W.C. and Rouchy, J.M. (eds.): Models for carbonate stratigraphy from Miocene Reef Complexes of the Mediterranean regions. Soc. Econ. Paleont. Mineral. Concepts in sedimentology and paleontology series, Tulsa, OK, pp.191-225.

Pomar, L., 2001a: Types of carbonate platforms: a genetic approach. Basin Research, 13, pp.313-334.

Pomar, L., 2001b: Ecological control of sedimentary accommodation: evolution from a carbonate ramp to rimmed shelf, Upper Miocene, Balearic islands. Paleogeogr. Paleoclim. Paleoecol., 175, pp.249-272.

Rosen, M.R. and Collins, L.B., 1990: Quaternary sedimentation and diagenesis in a high-latitude reef, Houtman Abrollos Island, Western Australia. A.A.P.G. Bulletin, V. 74/75, p. 751, Association Round Table.

Smith, D.C., 1973: Symbiosis of algae with invertebrates, Oxford Biology Readers, 43p.

Shathaya, H.F., 1980: Biostratigraphy of Sinjar Formation. Unpub. M.Sc. Thesis, Baghdad University.

Thanoon, A.T., 1984: Industrial evaluation of limestone with particular reference to the Sinjar Limestone Formation in NW Iraq. Univ. of Hull, Ph.D. Thesis, 224p.

PLATES

Plate 1:
Fig.1: Alveolinid packstone submicrofacies consisting predominantly of large Alveolina spp. embraced in a micritic matrix, with (1) Alveolina pasticillata Schwager, (2) A. aragonensis Hattinger and (3) A. globosa (Leymerie). Sample No. 11, K. section, X10.

Fig.2: Alveolinid intraclastic grainstone submicrofacies with (1) Indiana sinjarica Grimedale and (2) Kathina selveri Smout. Sample no. 7, K. section, X30.

Fig. 3: Alveolinid wackstone submicrofacies. Sample no. 6, K. section, X30.

Plate 2:
Fig.1: Dasycladacean wackestone submicrofacies with Ovulites sp., Sample no. 4, K. sedtion, X15.

Fig.2: Bioclastic mudstone submicrofacies. Sample no. 3, K. section, X20.

Fig.3: Bioclastic pelletoidal packstone submicrofacies. Sample no. 2, K. section, X10.

Plate 3:
Fig.1: Coralgal rudstone submicrofacies with crustose coralline algae. Sample no. 9, P. section, X20.

Fig.2: Coralgal rudstone submicrofacies with massive, frame-building coral. Sample no. 6, P. section, X10.

Fig.3: Coralgal boundstone submicrofacies showing crustose coralline algae (Archaeolithothamnium). Sample no. 14, P. section, X20.

Plate 4:
Fig.1: Algal Nummulitic-Discocyclina rudstone submicrofacies. Sample no. 1, P. section, X10.

Fig.2: Algal Nummulitic-Discocyclina floatstone submicrofacies. Sample no. 2, P. section, X10.

Fig.3: Algal Nummulitic floatstone submicrofacies. Sample no. 10, S. section, X20.

Plate 5:
Fig.1: Transverse section of coral in bioclastic coral rudstone submicrofacies. Sample no. 6, SM. Section, X20.

Fig.2: Neomorphosed algal wackestone submicrofacies with micritized clasts of algae. Sample no. 12, SM. Section, X20.

Fig.3: Alveolina sp. (E.S.M. Photo). Sample no. 6, SI. Section, X40.

Fig.4: Nummulites atacicus Leymerie. Sample no. 14, S. section, X40.

Plate-1

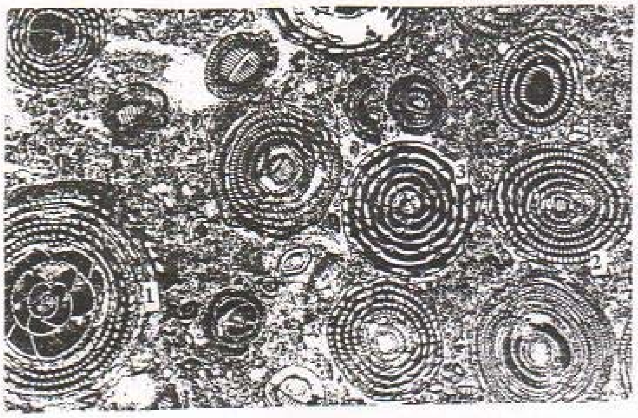

Fig.1

Fig.2

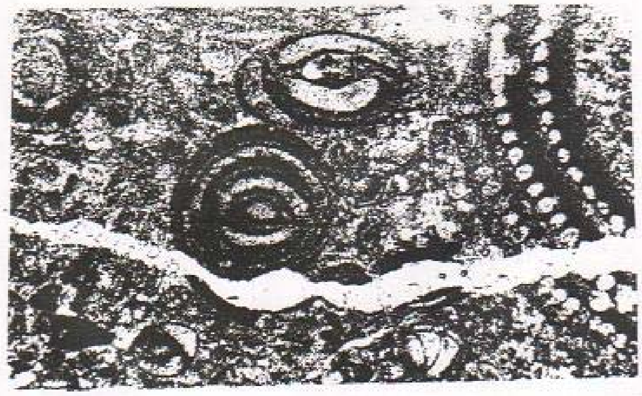

Fig.3

Plate-2

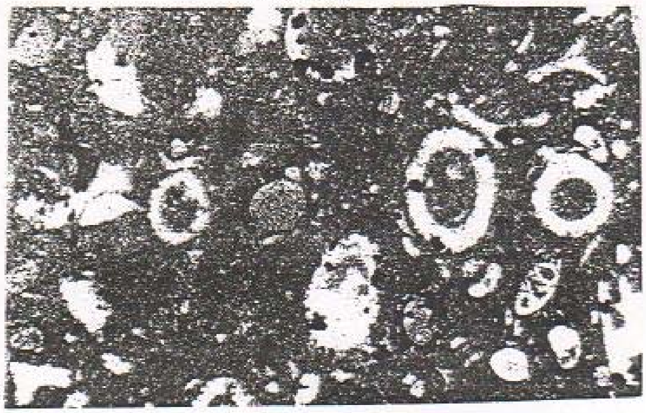

Fig.1

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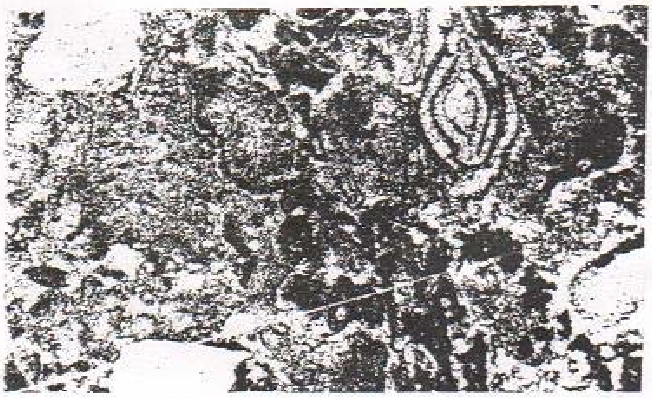
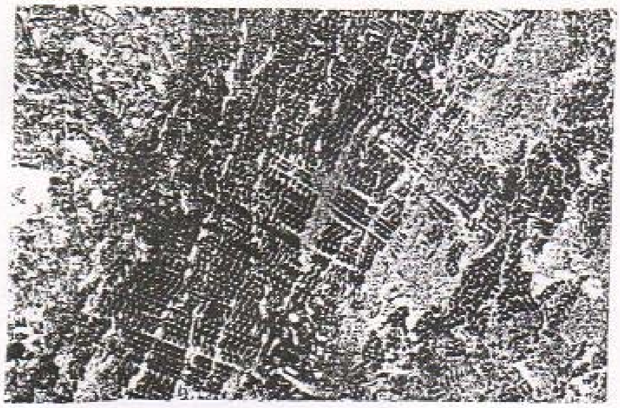


Fig.3

Plate-3

Fig.1



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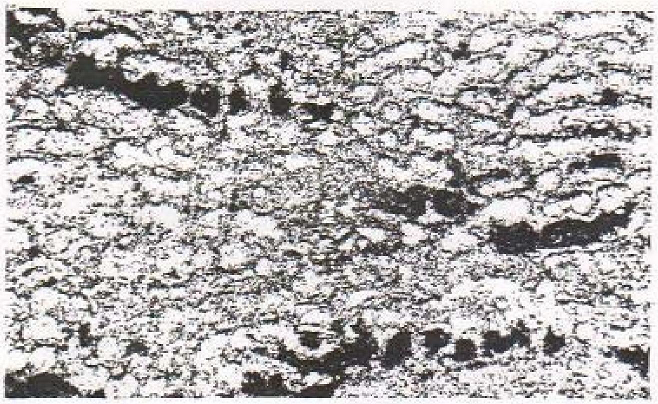

Fig.3

Plate-4

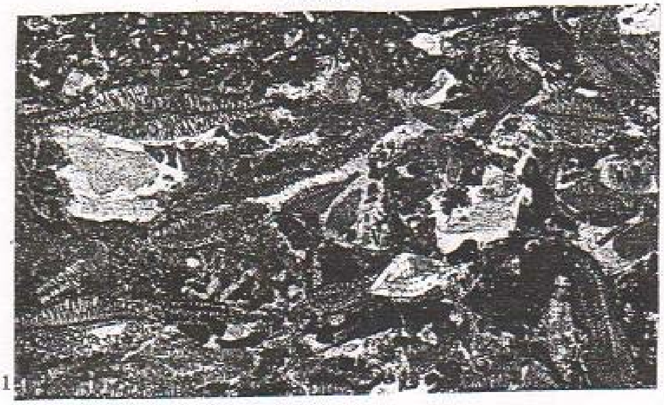

Fig.1

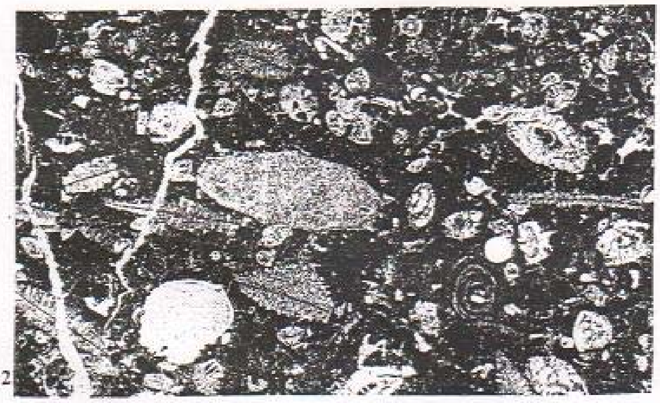

Fig.2

Fig.3

Plate-5

Fig.1

Fig.2

Fig.3

Fig.4