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Sedimentology and Sequence Stratigraphy of Barsarin Formation (Late Kimmeridgian), Northern Iraq

Nabil Y. Al-Banna [*1], Israa M. Al-Neimi [2]

[1]*Petroleum and Mining Engineering College, University of Mosul, Iraq*
[2]*Department of geology- Science College, University of Mosul, Iraq*

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Correspondence:
Name : Nabil Y. Al-Banna
nabil.albanna@uomosul.edu.iq

ABSTRACT

The Barsarin Formation deposits in northern and northeastern Iraq. Two surface sections, the first at northern Amadiya City on the southern limb of the Matin anticline and the second in Derash valley on the northern limb of the Gara anticline, formed the basis for our study. Many diagenetic processes are effected on the studied rocks: dolomitization, dedolomitization, stylolization, carbonate cementation, and secondary porosity. Nine main facies were distinguished throughout the Barsarin Formation, which represent homoclinal ramp platform with depositional environments extended from oolitic bank to supratidal. According to previous biostratigraphic study in conjunction with benthonic foraminifera distribution in the studied sections, the age of Barsarin Formation considers to be Late Kimmeridgian. Sequence stratigraphic analysis as calibrated by facies, delineated four depositional sequences of 4th order and 3rd order, they are deposited in about 2.2 million years, their maximum flooding surfaces show good correlation of the northern Arabian platform with other parts of the Arabian platform.

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الطباقية الرسوبية وطباقية التتابع لتكوين برسرين (الكامبريجيان المتاخر) شمالي العراق

نبيل يوسف البنا[1] , إسراء محمد النعيمي[2]

[1] كلية هندسة النفط والتعدين ، جامعة الموصل، نينوى، العراق

[2] كلية العلوم ، قسم علوم الارض ، جامعة الموصل، نينوى، العراق

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المراسلة:

الاسم: **نبيل يوسف البنا**

nabil.albanna@uomosul.edu.iq

الملخص

تتواجد ترسبات تكوين برسرين في شمال وشمال شرقي العراق، وقد اعتمدت الدراسة على مقطعين سطحيين الاول: شمالي مدينة العمادية على الجناح الجنوبي لطية متين والثاني: في وادي ديرش على الجناح الشمالي لطية جياكارا في محافظة دهوك، تأثرت صخور الدراسة بالعديد من العمليات التحويرية منها الدلمتة والديدلمتة والسمنت الكاربوناتي والمسامية الثانوية. شخصت تسعة سحنات رئيسية في تكوين برسرين والتي اوضحت بيئة منصة المنحدر المائل (homoclinal) التي تمتد بيئاتها الترسيبية من الركام السرئي الى البيئات فوق المدية. طبقاً للدراسات السابقة والمتحجرات المشخصة والمنتشرة في مقاطع الدراسة فان عمر تكوين برسرين هو الكامبريجيان المتأخر، ان طباقية التتابع المحددة من السحنات الرسوبية تشير الى تواجد اربعة تتابعات من المرتبة الرابعة والثالثة المترسبة في فترة زمنية تقارب 2.2 مليون سنة، ان سطوح الطغيان المشخصة في مقاطع الدراسة تشير الى مضاهاة جيدة مع سطوح الطغيان للكامبريجيان المتأخر في الصفيحة العربية.

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Introduction

The palaeogeography during the Late Jurassic is controlled by the effect of Late Jurassic activity along the Arabian Plate margin prior to the opening of the Southern Neo-Tethys. Differential subsidence led to periodic isolation of the intera-shelf basin from the Neo-Tethys. Three distinct facies can be recognized these are: A clastic – carbonate inner shelf represented by Najmah and Saggar formations, a carbonate–evaporite inner shelf represented by the Najmah and Gotnia formations, and a restricted basin represented by the Naokelekan, Barsarin and Gotnia formations (Fig. 1) (Jassim and Buday, 2006). The Barsarin Formation was defined by Wetzel (1950, in Bellen et al., 1959) from the type section near Barsarin Village in Rawanduz area northern Iraq; it is 17 m thick and comprises laminated limestone and dolomitic limestone, some fluffy–textured, locally cherty, alternated in normal beds and in brecciated, crumbled and contorted beds. The present study was based on 68 samples and 82 samples collected from Amedia and Gara surface sections respectively, the study involved field lithological description, identification of some benthonic foraminifera, daigenitic processes, and facies were recognized and used to interpret the sequence stratigraphy of Barsarin Formation. Barsarin Formation is one of the Upper Jurassic oil source rocks in Iraq (Aqrawi et al., 2010). Therefore, it is important to study their facies analysis and diagenetic processes.

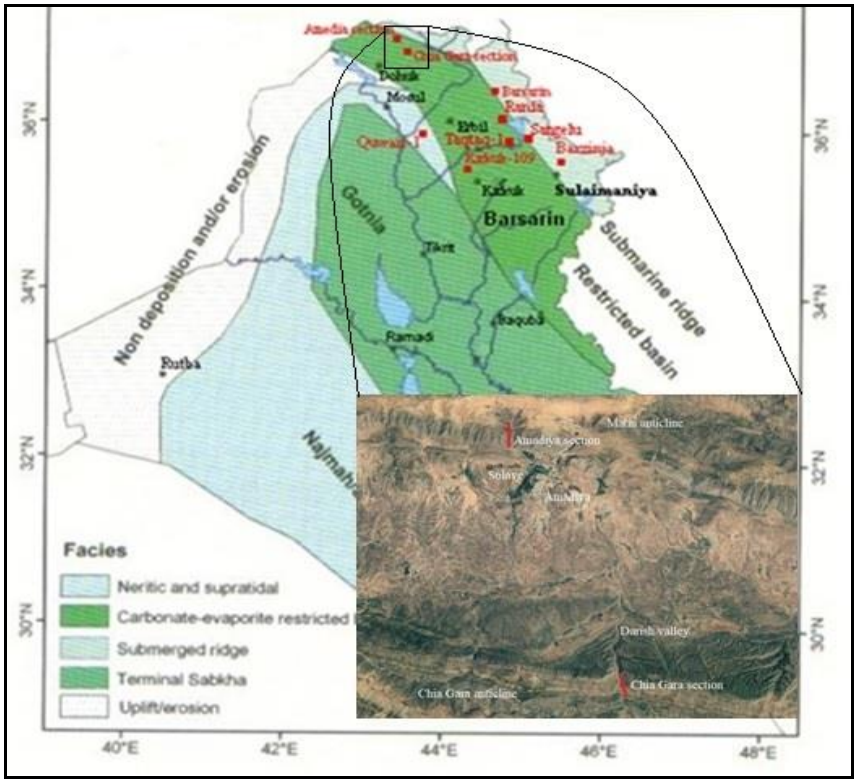


Fig. 1. Palaeogeography of Late Jurassic time, (after Jassim and Buday, 2006) red color points represent other localities mentioned in this research.

Studied sections

Location: Two surface sections of the Barsarin Formation, first at northern Amadiya City on the southern limb of the Matin anticline and the second in Derash valley on the northern limb of the Gara anticline. The midpoint coordinates of the sections are 37° 07‾ 21‾ N, 43° 30‾ 56‾ E, and 36° 59‾ 48‾ N, 43° 32‾ 21‾ E, respectively (Fig. 1).

Lithology and thicknesses: Amadiya section show high dolostone ridge of Barsarin Formation between the low relief rocks of Naokelekan and Chia Gara formations (Fig. 2), it is 160 m thick, the lower contact is conformable marked by sharp contact with the dark shale bed of Naokelekan Formation without any sedimentary evidences of unconformity, the upper contact is conformable with Chia Gara Formation assigned by the appearance of Radiolarian shaley limestones with billow structure of Chia Gara Formation. The Gara section appears as high ridge of dolostone beds of Barsarin Formation, forming a sharp cliff on the left side of Derash valley (Fig. 3), it is 210 m thick, the lower contact is gradational and conformable marked by alternating beds of Dolostones and Dark shales of Barsarin and Naokelekan formations respectively, the upper contact is conformable marked by the appearance of overlaying Radiolarian shaley limestones of Chia Gara Formation.

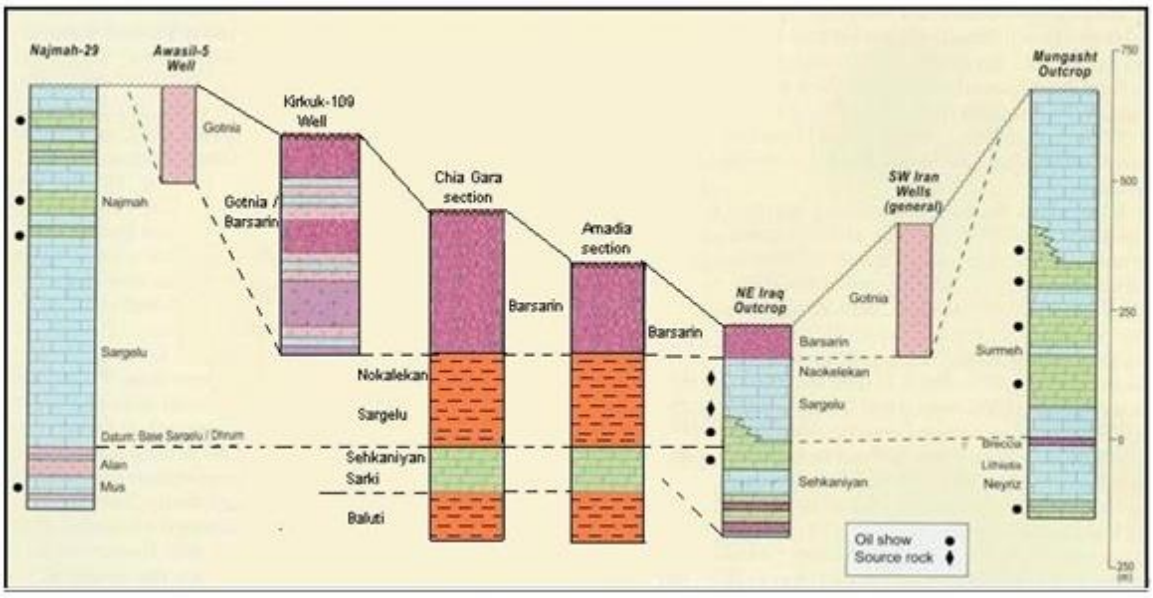


Fig. 2. Correlation section between studied sections of the Barsarin Formation and other sections in northern Iraq. (Modify after Aqrawi et al., 2010)

Generally, the thicknesses of Barsarin Formation range between 10 m (at Rania and Sargelu) and 59 m (at RuKuchuk) in northeastern Iraq (van Bellen et al., 1959), Spath (1950, in van Bellen et al., 1959) stated "This order of thicknesses is surprisingly small for a rock unit that spans an age range involving most of Kimmeridgian time, and extreme stratal condensation". Recently, 63 m thick of Barsarin Formation were recorded near Barzinja City in the Sulaimanyia government, which increased toward the west (Daoud and Karim, 2010). In Taq Taq well -1 75m thick, and in Kirkuk well-109, 283 m thick, dolomite unit affiliates to the Barsarin Formation by Iraqi petroleum company geologists (IPC) (Baban and Ahmade, 2008) (Fig. 4).

Diagenetic processes

They are all the diagenetic processes that took place on the rocks from deposition to metamorphism (Flugel, 1982); some of these processes are recognized abundantly in the studied carbonate rocks:



Fig. 3. Amadiya section shows high dolostone ridge of Barsarin

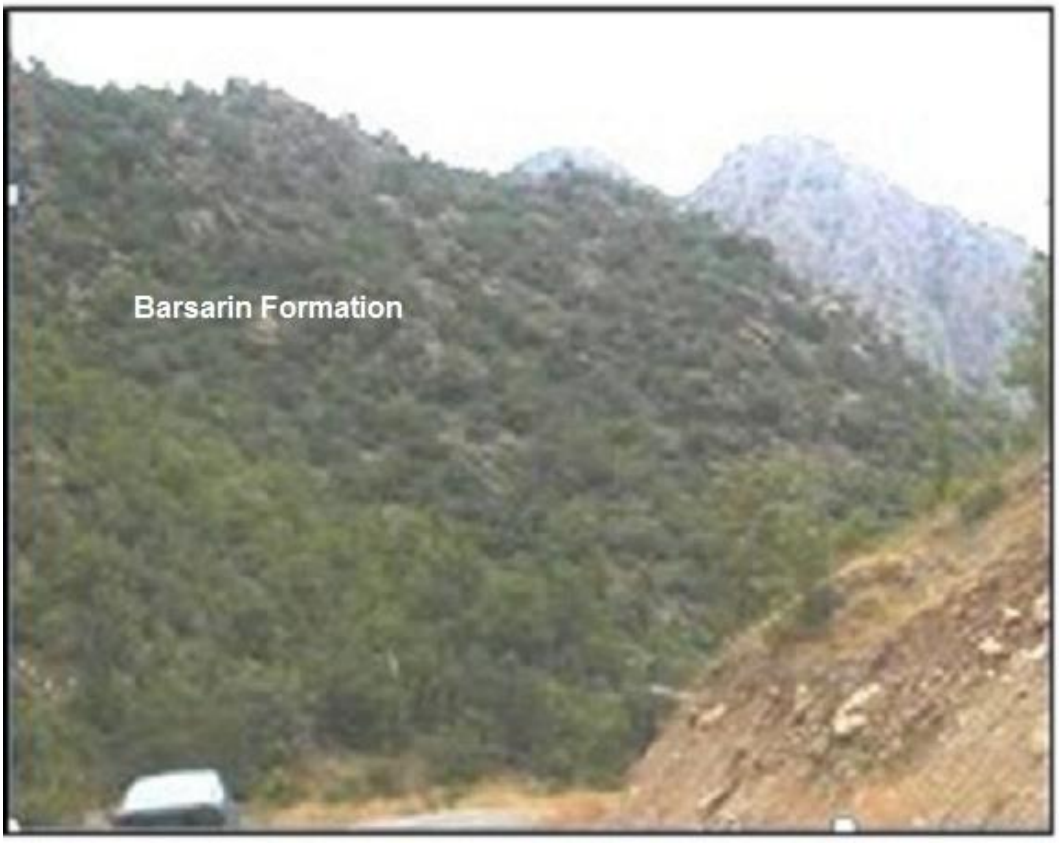


Fig. 4. High ridge of dolostones of Barsarin Formation forming a sharp cliff on the left side of Derash valley

Dolomite and Dolomitization

The dominant lithology of the Barsarin Formation is dolostone, which occurs in various types and fabrics indicated to the precursor limestone. The classification of dolomite had been given by many authors (Gregg and Sibley, 1984; Randazzo and Zakhos, 1984; Sibley and Gregg, 1987), according to Randazzo and Zakhos (1984) many dolomite fabrics are

recognized; Aphanotopic fabric (Fig. 5a), suture mosaic fabric (Fig. 5b), micro-suture mosaic fabric, sieve mosaic fabric (Fig. 5c), micro-sieve mosaic fabric, and fogged mosaic fabric (Fig. 5d), in addition to a cloudy center clear rim texture. These fabric textures are used in the nomenclature of dolostone facies. The various types of dolomite fabric and association diagenetic evidence indicate more than one dolomitization model. Mohmood et al. (2018) interpreted the origin of dolomite in the Barsarin Formation: Occurrence of aphanotopic fabric dolomite beds with fenestrae structure filled by gypsum (Fig. 5a) indicate to syndepositional dolomitization of lime mudstone deposited in tidal flat zone by evaporation pumping model (Hus and Siegnthaler, 1969), when the climate is arid to semiarid and evaporation of water is suitable to concentrate Mg++ for dolomitization.

The late dolomitization model (deep-burial model) resolves the presence of other type of dolomite fabric that contain saddle dolomite cement (Fig. 5e), and dolomite cement as vein filling, pore lining or filling after dolomitization of the early calcite cement, it is common as coarse dolomite crystals, which increase in size inward (drusy cement) (Fig. 5f), present of stylolite (Fig. 5g), microfracture healing, a cloudy center-clear rim texture, and Xinotopic nature of suture mosaic fabric, all these features of dolomite indicate a late diagenetic dolomitization in deep burial environment (Illing et al., 1965; Wanless, 1979; Amthor and Friedman, 1991; Machel, 2004).

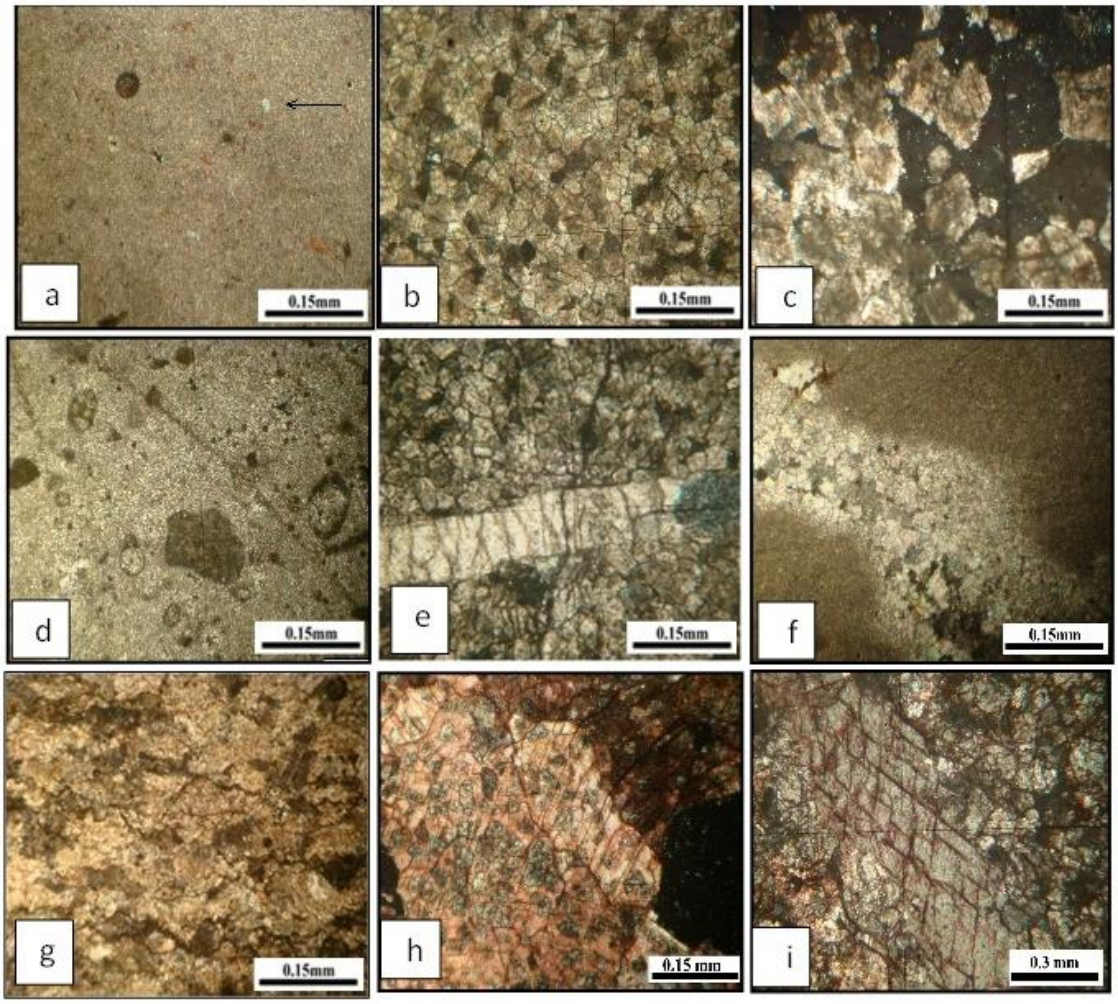


Fig. 5. a. Aphanotopic fabric with fenestra structure filled by gypsum, Gara section sample 25. b. Suture mosaic fabric, Amedia section 7. c. Sieve mosaic fabric, Amedia section 52. d. Fogged mosaic fabric, Amedia section 37. e. Saddle dolomite cement, Amedia section 40. f. Dolomite crystals increase in size

inward (drusy cement), Gara section sample 31. g. Low angle stylolite, Amedia section 64. h. Small rhombs of dolomite in large calcite crystals (Poikilotopic texture), Amadiya section, sample 10. i. Composite calcite rhombs, Amedia section sample 4.

Dedolomitization

It is reverse process of dolomitization, in which the Ca^{++} replace Mg^{++} in the dolomite crystals, a new recrystallized limestone rock is formed, present of small rhombs of dolomite in large calcite crystals (Poikilotopic texture) (Fig. 5h), Composite calcite rhombs (Fig. 5i), and rhombic pores are the main evidences of dedolomitization of dolostone rock. The percentage of the residual dolomite (small rhombs of dolomite) reflected by the calcimetric analysis done by Al-Banna and Hadi (2012) for the studied samples, they are ranging between 12% - 36% (Fig.8). Dedolomitization is surface or near surface diagenetic process (Al-Hashimi and Hemingwy, 1973; Heckle, 1983), happening where the rich Ca^{++} surface water penetrated previous dolostone rock, when there are low gas pressure of CO_2 and the temperature < 50 ^{O}C (Yanateva, 1955, in Evamy, 1967; De Groot, 1967).

Stylolitization:

One of the late diagenetic process as the result of pressure solution, involving solution around points of contact between mineral grains in response to pressure, they point to progressive burial diagenesis (Flugel, 1982; 2004), which found in lithified and consolidated sediments. The stylolite formed after first cementation stage and contributed to additional lithification of the sediment due to the $CaCO_3$ released by dissolution under pressure (Bathurst, 1975).

Stylolites are abundant in limestone and dolomite more than other kinds of rocks, according to Logan and Semeniuk (1976), different types of stylolites are recognized in the studied rocks: Irregular, peaks low amplitude (Fig. 6g), Hummoky, Smooth, Parallel set and Irregular anastomosing sets of stylolites (Fig. 6a).

Cementation:

A sufficient amount of dissolved carbonates is available for cement formation in shallow marine environments and in zones permeated with freshwater, depending on the various stabilities of carbonate minerals (Flugel, 1982).

Two generation of calcite cement are identified in dolostone of Barsarin Formation. The early diagenetic calcite cement is dolomitized, represented by vein filling or fracture healing, vugs lining or filling with coarse crystals increase in size inward (drusy cement, Fig. 5f). All these types of dolomite cement in addition to saddle dolomite (Fig. 6b) and coarsely crystalline fabric point to deep-burial environment (Amthor and Fridman, 1991; Machel, 2004).

The late diagenetic calcite cement appears as fracture and vugs filled by spary calcite cement point to the end product of diagenetic processes (Fig. 6c). The percentage of the calcite cement in the studied dolostone samples are reflected by the calcimetric analysis done by Al-Banna and Hadi (2012) for the studied samples, they are ranging between 12%-24% (Fig. 8).

Porosity:

Secondary porosity is the most effective porosity in the studied rocks due to the intensive dolomitization of Barsarin Formation, according to Choquett and pray (1970) classification, different types of porosity were recognized: fenestrae (Fig. 5a), intercrystal (Fig. 5c), moldic, fracture (Fig. 6d), channel and vugs porosity. Accordingly, Barsarin

Formation has primary production potential that reaches 4.56 kg/ton in Kirkuk-109 (Aqrawi et al., 2010 p. 156).

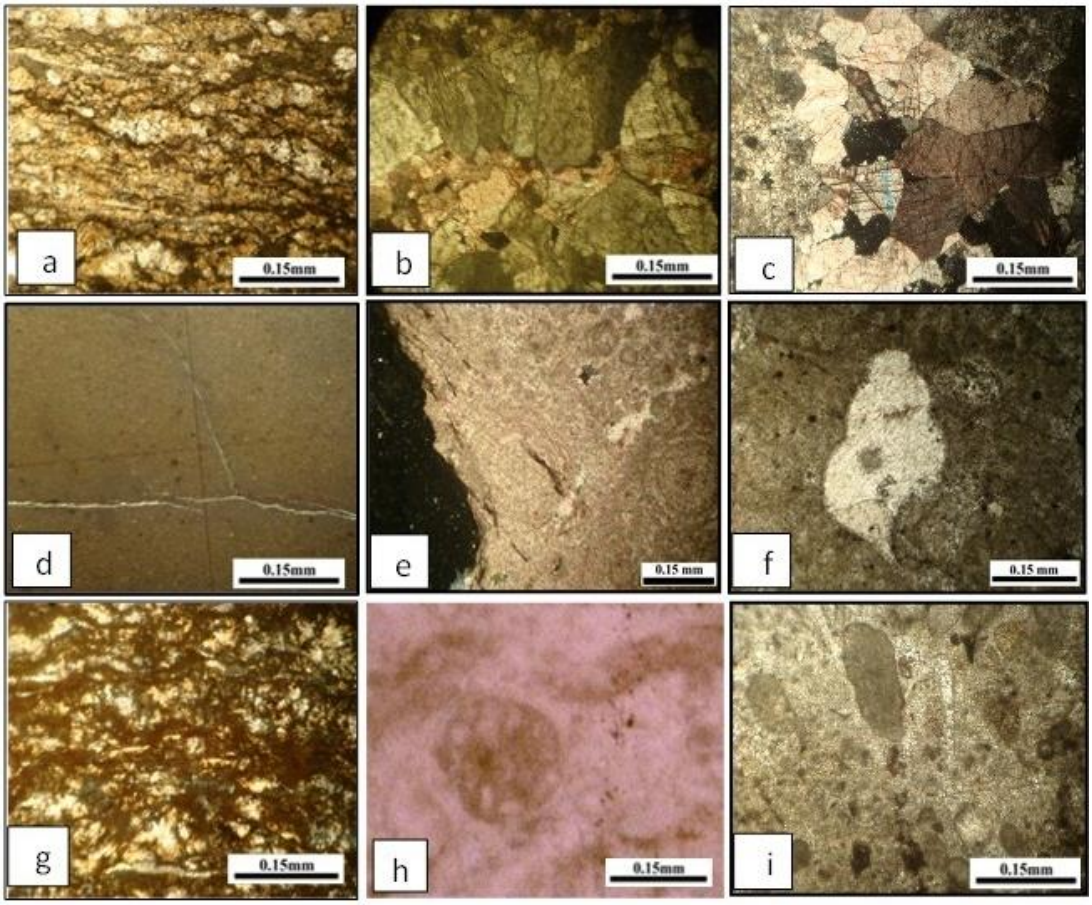


Fig. 6. a. Irregular anastomosing sets of stylolite, Amadiya section sample 55. b. Saddle dolomite, Amadiya section sample 40. c. Spary calcite cement filled vug, Gara section sample 5. d. Fractures, Gara section sample 7. e. Gastropods in Benthonic lime wackestone facies, Amadiya section sample 30. f. Tangential structure ooids in Oolitic lime wackestone facies, Amadiya section sample 65. g. Wavy stromatolites in Algal lime boundstone facies, Amadiya section sample 57. h. *Nautiloculinaoolithica* Mohler, Gara section sample 49. i. *Kurnubiapalastiniensis* Henson, Gara section sample 49.

Facies analysis and depositional environment

The Barsarin Formation consists mainly of dolomites, the limestones recognized in the upper part of Amadiya section. Nine facies were identified in Barsarin Formation denoted as B1-B9. The sedimentological and biological evidences are used to determined their depositional environments and bathymetry.

Lime mudstone facies (B1):

The facies is hard, brown and thickly bedded dolomite, the aphanotopic texture with rareallochems as ghost of fossils superior the fabric of the facies. The secondary gypsum filled fenestrae structures are abundant, this kind of texture was produced by syndepositional dolomitization of lime mudstone, when the rate of nucleation is very high (Hus and Siegenthaler, 1969; Randazzo and Zakhos, 1984), stylolites and solution lines are recorded in

the facies. The sedimentological evidence points to a supratidal environment (Shinn et al., 1965; Scholle et al., 1983; Warren, 2000; Flugel, 2004).

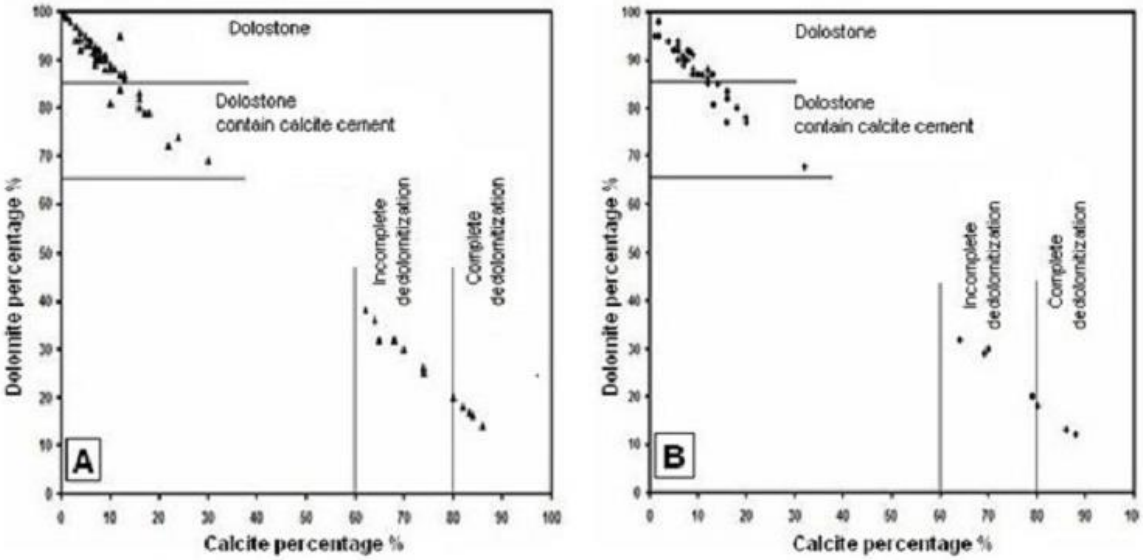


Fig. 7. Relationship between calcite and dolomite minerals percentage %, A: samples of Gara section, B: samples of Amedia section. (after Al-Banna and Hadi, 2012).

Oolitic lime wackestone facies (B2):

The main allochems contain of the facies are Ooid grains; consisting of lithoclasts or bioclasts as nucleus coated by micrite layers producing tangential Ooids (Fig. 6e), their diameter reachs up to 1mm, the matrix consists of micrite indicate to low energy water environment (Flugel, 2004). The facies present in the upper part of the Amedia section are 1.5 m thick and extend laterally for several hundred meters; stylolites and calcite cement are recorded. The sedimentological features indicated to shoal bank and Ooids bar environment that enclose semirestricted lagoon (Wilson, 1975; Flugel, 2004; Al-Banna et al., 2006).

Mollusca lime wackestone facies (B3):

This facies consists mainly of benthonic foraminifera, gastropods (Fig. 6f), pelecypods, and ostracods. The allochems reach up to 20% of the total facies content. The facies affected by dolomitization forming fogged mosaic texture, drusy and granular dolomite cement are recognized in the facies. The matrix appears as fine crystalline dolomite, as indicated by the precursor micrite. The sedimentological and biological evidences in addition to the absent of any of evaporate mineral sign to subtidal of semirestricted environment of the facies (Flugel, 2004; Al-Banna et al., 2006).

Bioclasts lime wackestone facies (B4):

Bioclasts of algae and mollusca are the main allochems of the facies, in addition to other anonymous bioclasts. The matrix is micrite, locally affected by recrystallization to produce microspar. The facies is affected by solution process forming vugs porosity, which are filled by gypsum or calcite, extensive dolomitization recognized in some part of the facies. All the sedimentological evidence points to an open marine environment below the base wave (Wilson, 1975; Flugel, 2004).

Algal lime boundstone facies (B5):

It is a diagnostic facies of Barsarin Formation, it recognizes throughout the two studied sections, Planar and wavey stromatolites are the abundant types in the formation (Fig. 9a). It consists of dark and light lamina (Fig. 6g), the presence of laminations implies that the nature or size of the carbonate material deposited varied through time, these changes in types of the sediments may be achieved by current deposition or by variation in the types of organism that lived and accumulated at a given place (Blatt et al., 1980).

The facies contains fenestrae structure within the light lamina filled by gypsum, and scatter of chert grains found in the facies, generally the facies is dolomitized. All the sedimentological evidences indicated to tidal flat environment (Wilson, 1975; Blatt et al., 1980), especially in the upper part of the intertidal, and lower part of supratidal (Logan, 1961; Illing 1965, Walker and James, 1992).

Suture mosaic dolostone facies (B6):

It is a diagenetic facies consist of grey to dark grey tough dolostones, represented by fine to coarse crystalline idiotopic fabric embrace anhedral to subhedral crystals, with patches of coarse euhedral crystals. The facies affected by many diagenetic process lead to record stylolite, carbonate cement (granular, blocky and drusy cement), inter crystal and vugg porosity, and extensive dolomitization that destroy the original texture of the limestone, suture mosaic texture is the last stage production of the heterogeneous dolomitization of lime mudstone (Randdos and Zakhos, 1984). Horizontal lamination, small scale cross bedding is distribution in the facies along the studied sections (Fig. 9b, 9c), they indicted to shallow marine environment within intertidal zone (Blatt et al., 1980) all the sedimentary evidences were point to transitional zone environment (tidal flat environment) (Reineck and Singh, 1980; Walker and James, 1992; Selley, 1982; 2005).

Sieve mosaic dolostone facies (B7):

This diagenetic facies typified by tough sometimes soft dolostone, consist of fine to coarse euhedral to subhedral rhombic crystals of dolostone with high porosity (intercrystals and vuggy). The present of high porosity is due to the resistance of low Mg++ calcite grains to the primary stage of dolomitization and dissolved in the final stage of dolomitization forming high porosity. Granular and drusy cement are recognized, and scatter of chert grains is found in different intervals of the facies. Bioturbation was recorded at the upper part of the studied sections, represented by <1 cm diameter of feeding and dwelling types of benthonic vertebrate burrows, in the shallow transitional zone (Seilacher, 1967; Fery,1975; Boggs, 2006). Sieve mosaic texture formed by heterogeneous dolomitization of lime wackestone rock (Randdos and Zakhos, 1984) that deposits in the subtidal environment (Walker and James, 1992), according to warren (2000) the present of chert grains in this facies give an evidence of dolomitization in shallow semirestricted environment.



Fig. 8. a. Wavy stromatolites, Amadiya section at interval 57m. b. Horizontal lamination and small scale cross bedding, Gara section at interval 145m. c. Small scale cross bedding, Gara section at interval 180m. d. Interaformational breccia, Gara section at interval 162m.

Dedolomite facies (B8):

It consists of mainly coarse calcite crystals embrace small etching edges dolomite crystals (poikilotopic texture) (Fig. 6h), in addition to composite calcite rhombs and rhombic pores, all resulted from dedolomitization of dolostone (Evamy, 1967; Amin, 1975; Clark, 1980). The dedolomitization process is the replacement of Mg++ by Ca++ in dolomite crystals where there is a sufficient amount of Ca++, low pressure CO2, and a temperature <50 oC. The incongruent solubility of dolomite under low CO2 pressure forms CaCO3 that is necessary to form the large calcite crystals (Evamy, 1967). The high percentage of Ca++ may be produced by the dissolution of previous carbonates or/and gypsum and anhydrite near the surface (Tucker, 1981). All the sedimentological evidence indicates a surface or near-surface diagenetic environment of this facies (Evamy, 1967; DeGuoot, 1967; Al-Hashimi and Hemingway, 1973).

Interaformational Breccia facies (B9):

It consists 4-8 m thick beds of interaformational breccia embrace 2-4cm diameter of angular pebbles of dolomite connected together by dolomitic calcite cement (Fig. 9d), scatter grains of chert are present. The origin of this facies is thinly alternating beds of carbonate, gypsum, and anhydrite, the breccias may have formed by dissolution process of evaporate beds leaves caverns between carbonate beds, the compaction process destroys these carbonate beds to small angular pebbles, which connected later by calcite cement. All the sedimentological evidence indicates a supratidal environment origin for this facies (Scholle et al., 1983).

Depositional environment of Barsarin Formation

The Barsarin Formation facies evidences point to a wide range of depositional environments extended from Oolitic bank to supratidal (Fig. 10), they formed homoclinal ramp platform (Read, 1985). The Ooid sand shoals bank produced by low energy waves (facies B2) enclose semirestricted lagoon characterized by the deposition of lime wackestone (facies B3 and facies B7) in the deeper part of the lagoon, while facies B4 deposited below the wave base of the lagoon. The tidal flat deposits of the homoclinal ramp embraces a thick and wide spectrum of depositional facies represented by intertidal facies include facies B6, and bioturbation part of facies B7, in addition to algal lime facies (B5), which is deposited in the upper part of the intertidal zone. The supratidal environmental evidences of Homoclinal ramp represented by algal lime bound facies (B5), lime mudstone facies (B1) that dolomitized to aphanotopic texture dolomite by the evaporation pumping model and interaformational breccia facies (B9) that assigned to alternating beds of limestone and evaporite deposited in the supratidal environment. The tidal flat deposits indicate the dominance of arid and semiarid climates during the deposition of the Barsarin Formation (Hus and Siegnthaler, 1969; Scholle et al., 1983).

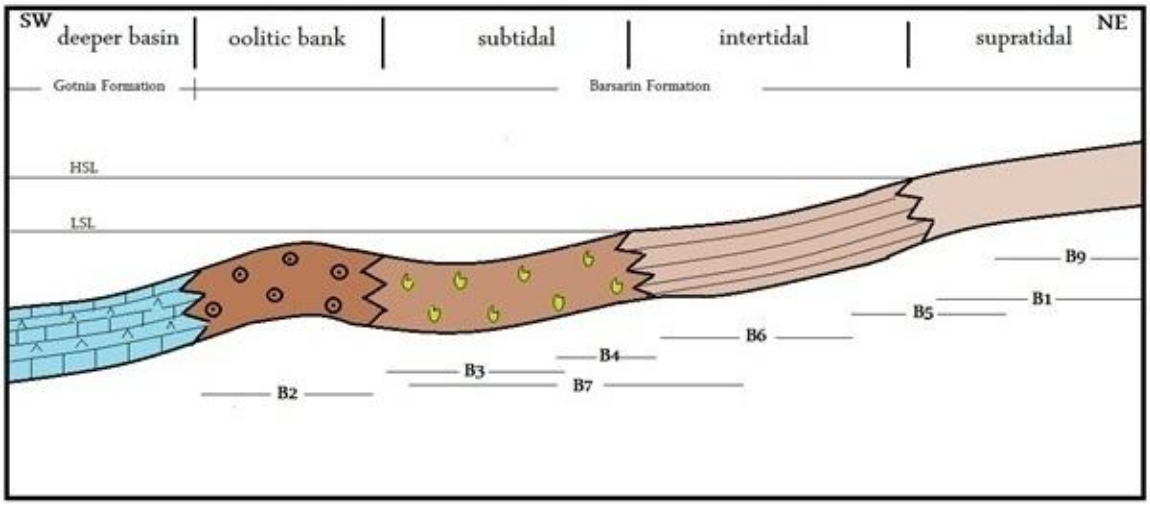


Fig. 9. Facies distribution and environmental model of Barsarin Formation in the studied area.

Age Determination:

Bellen et al. (1959) mentioned that no fossils were recognized in the type section of Barsarin Formation, therefore they estimated the age as possibly Kimmeridgian?, since it occurs below Middle Tithonian and above Lower Kimmeridgian ammonite Zones. Kaddouri (1986) recorded predominantly of foraminifera in Barsarin Formation, i.e. *Clypeina jurassica* and *Nautiloculina oolithica* in the Bnazi area, and *Kurnubia palastiniensis* at well Quwair-1, they pointed to Kimmeridgian-Tithonian age. In this study two benthonic foraminifera species were recognized; the first *Nautiloculina oolithica* Mohler (Fig. 6h), which is distributed from Late Kimmeridgian to Lower Cretaceous in Switzerland, France, Yugoslavia, N. Caucasus and Egypt (Loeblich and Tappan, 1988 p.71), the second is *Kurnubia palastiniensis* Henson (Fig. 6i) that is distributed from Early Jurassic (Lias) to Late Jurassic (Kimmeridgian) (Loeblich and Tappan, 1988) in SW Asia, Morocco, Yugoslavia and Crete. Accordingly, we can estimate the age of Barsarin Formation to be Late Kimmeridgian and follow the most recent conventions of the International Commission on Stratigraphy (ICS) as documented in Gradstein et al. (2004), Late Kimmeridgian have a depositional duration of ca. 2.2 My.

Sequence stratigraphy

Our sequence stratigraphic analyses interpreted four depositional sequences, designated Barsarin Sequence 1 to 4 in both studied sections (Fig. 11 and 12). The sequences that vary in thickness from 9m to 77m, are interpreted in term of sequence boundary (SB), transgression systems tract (TST), maximum flooding surface (MFS) or interval (MFI) and high stand systems tract (HST).

Sequence stratigraphy of Amedia section:

Barsarin Sequence 1

This sequence, 64 m thick, commences with the deposition of facies B6 followed by facies B5 and facies B8 (showing in completed dedolomitization), the alternating of the three facies show gradational retrogradational stacking pattern corresponds to TST, this pattern is overlain by facies 4 that represents MFI of the sequence (Fig. 11), it is followed by facies B5 forming progradational stacking pattern equates with the HST of the sequence. The upper boundary of the sequence is a Type-2 SB.

Barsarin Sequence 2

Sequence 2, 70 m thick, begins with the deposition of facies B5, it is followed by facies 6 and facies 4 showing increasing in water depth upward and interpreted as the TST. The top of Facies B4 is picked as the MFS. The overlying facies B6 is interpreted as the HST of the sequence; the sequence is ended by SB Type -2.

Barsarin Sequence 3

The sequence is 17m thick, it starts with the deposition of facies B7 followed by facies B4, the two forming a retrogradational stacking pattern that indicates the TST of the sequence. The upper surface of the facies B4 reflects the MFS, it is followed by facies B5 and facies B8 the both forming a progradational stacking pattern that point to the HST of the sequence. The upper contact is a Type -1 SB, represented by the upper surface of facies B8 that indicates to the exposure of the marine shelf.

Barsarin Sequence 4

Sequence 2 is 9 m thick, it begins with deposition of the facies B1 followed by facies B2, the two facies forming a retrogradational stacking pattern that reflects the TST, the MFI is represented by a 1.5 m thick Oolitic bank deposit (facies B2), it is overlain by facies B5 indicative of an HST that is ended by SB Type-2.

Sequence stratigraphy of Gara section

Barsarin Sequence 1

The sequence is 77m thick, it commences with the deposition of facies B1 followed by facies B5 and facies B4, the three facies show increase in a depositional water depth upward lead to the TST of the sequence. The top of facies 4 assigned as MFS, it is overlain by facies B1 and facies B9 in a progradational stacking pattern indicates to HST. The sequence is ended by a Type-2 SB.

Barsarin Sequence 2

This sequence 21 m thick, starts with the deposition of facies B5 followed by facies B7 that depicts a retrogradational stacking pattern, both facies point to the TST. The upper surface of facies B7 corresponds to the MFS, which is followed by facies B6 and facies B8 in a progradational stacking pattern to indicate HST of the sequence, that was ended by Type-1 SB.

BarsarinSequence 3

Barsarin sequence 3 is 44 m thick, it begins with deposition of facies B6 followed by facies B3, the two show increase in a depositional water depth upward indicates to the TST. The MFS is positioned in the top of facies B3 that is followed by the deposition of facies B6, facies B5, and facies B9, they show decrease in water depth upward. It is assigned to the HST. The sequence is ended by Type-2 SB.

BarsarinSequence 4

Sequence 4, 75 m thick, commences with the deposition of thick beds of facies B6 and facies B5, they followed by a deposition of facies B7, the three facies form a retrogradational stacking pattern that indicates the TST. The MFS of the sequence is represented at the upper surface of facies B7, it is followed by facies B6 and facies B9 that collectively forms the HST that was ended by SB Type-2.

Correlation to Arabian Plate maximum flooding surfaces

Sharland et al. (2001) considered four MFS`s related to Late Kimmeridgian deposits of Arabian Plate these are:

MFS J70:

The best dated example of the J70 MFS is in Yemen, where occurs as an organic – rich shale within the upper Madbi shale, it is recorded as reference section (Toland et al., 1995; Howarth and Morris, 1998) that implies age at 152.2 Ma. (Simmons et al, 2007). MFS J70 is recognized within lower Jubaila Formation in KSA (Wilson, 1985), and in limestone of Member 1, upper Najmah Formation of Kuwait (Yousif and Nouman, 1997), in southern Iraq it is recorded in the intra-top Najmah Formation (Sadooni, 1997). It seems possible to correlate MFS of Barsarin Sequence 1 with the MFS J70.

MFS J80:

This MFS is best represented in Abu Dabi, where it is expressed near the base of the Arab C carbonate, this position is recorded as reference section of the MFS J80 (Al-Silwadi et al., 1996), dating at 151.8 Ma. (Simmons et al, 2007).

The MFS J80 marks in Kuwait near base of carbonate at base of 4^{th} anhydrite of Gotnia Formation in Kurnubia jurassica Zone (Yousif and Nouman, 1997), also it is recorded at upper Madbi shale of Yemen (Simmouns and Al-Thour, 1994). In Iraq it is founded at Barsarin and Gotnia formations (Sadooni, 1997). It is possible to correlated MFS of Barsarin Sequence 2 of this study with MFS J80.

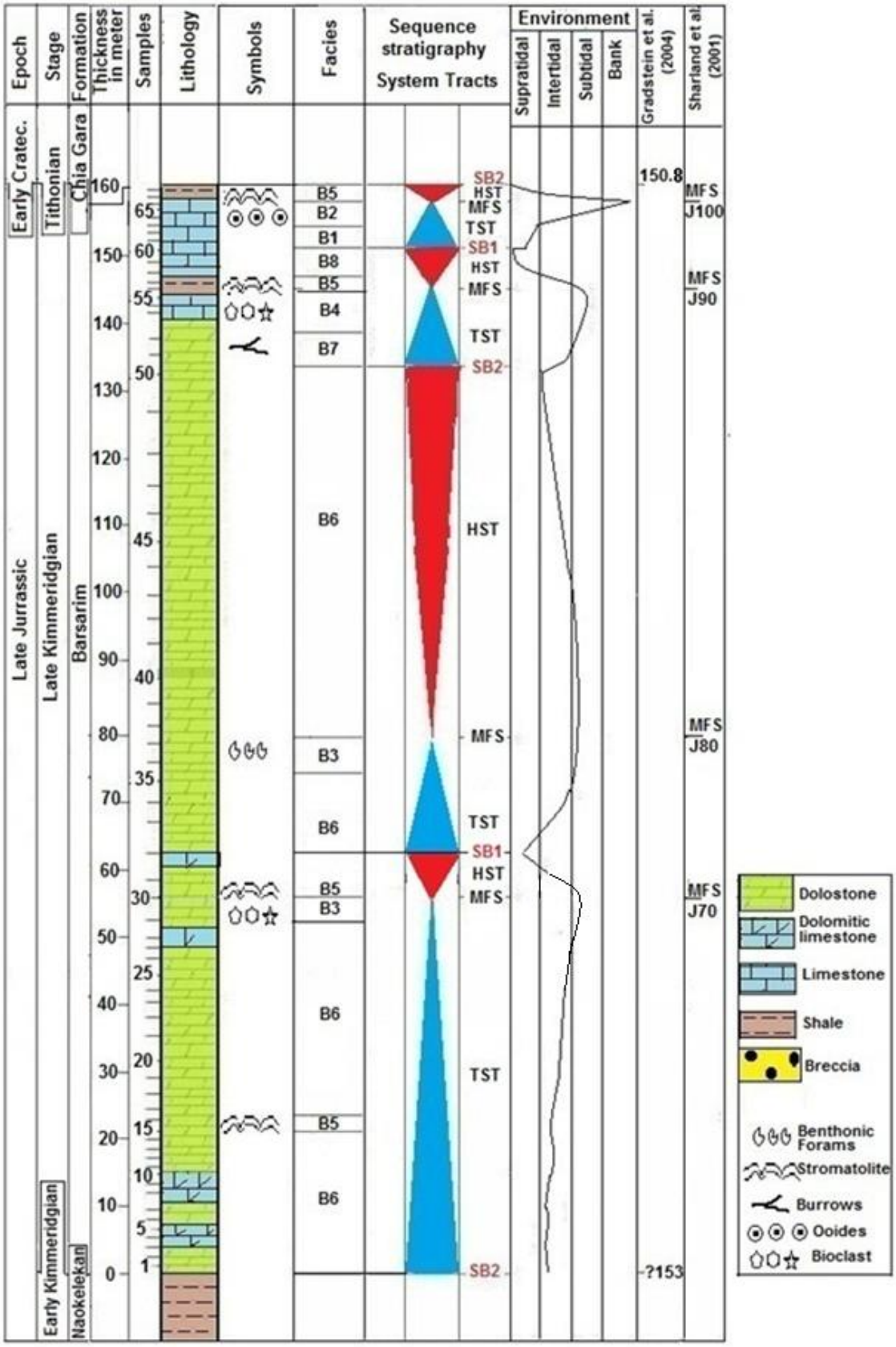


Fig. 10. Lithology and sequence stratigraophy of Amadiya section, Northern Iraq.

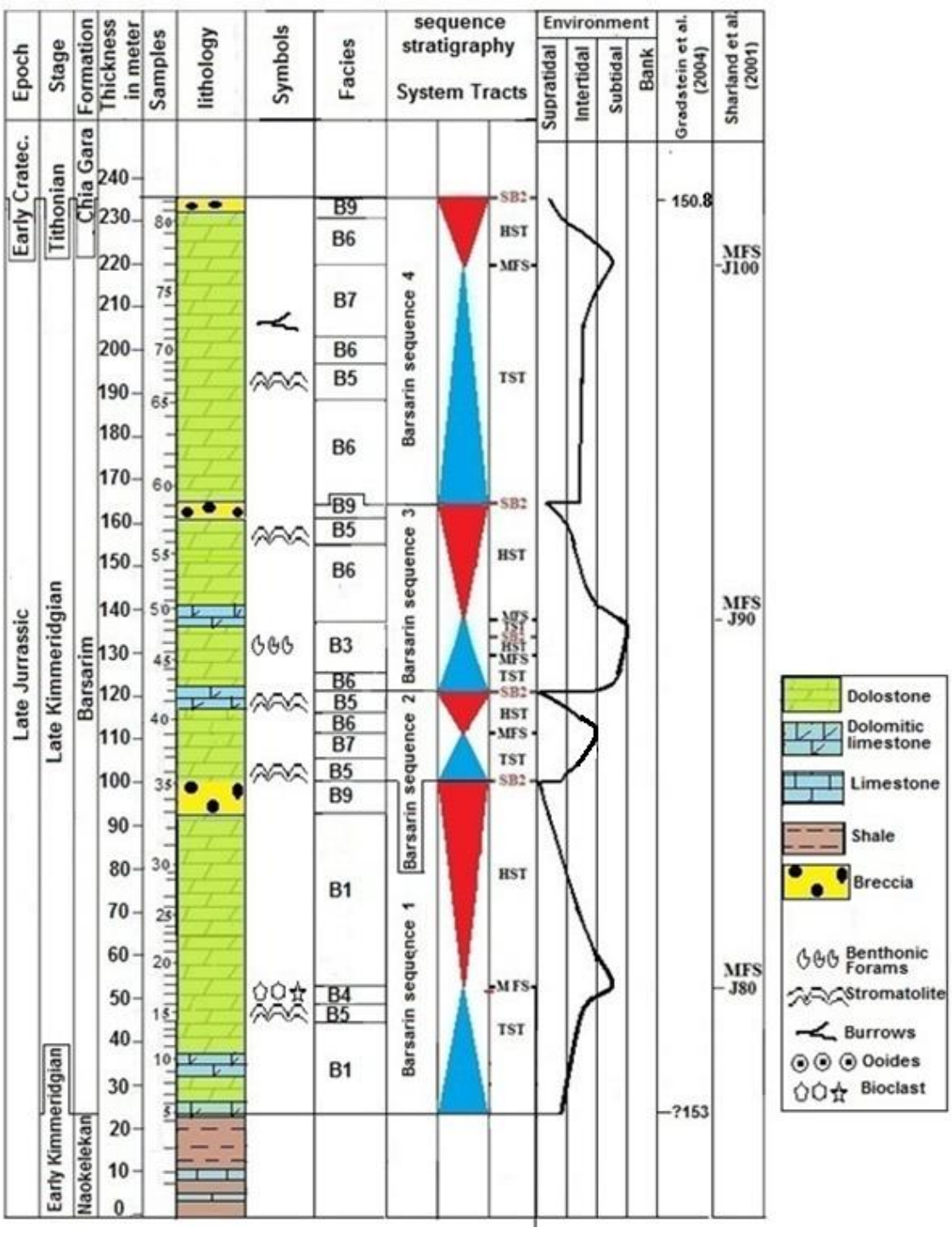


Fig. 11. Lithology and sequence stratigraohy of Gara section, Northern Iraq.

MFS J90:

J90 MFS reference section represents near base of Arab B carbonate in Abu Dhabi (Al-Siwadi et al., 1996), it is dated at 151.4 Ma. (Simmons et al, 2007).

The J90 MFS assigns in KSA near base of Arab B carbonate (Wilson, 1985), it represents near base carbonate of 3rd Anhydrite of Gotnia Formation in Kuwait (Yousif and Nouman, 1997), and within the upper Madbi Formation of Yemen (Simmouns and Al-Thour, 1994), it is also found in intra-Gotnia Formation calcareous shale (van Bellen et al., 1959) and

expected to be present within Barsarin Formation (Sharland et al., 2001) of Iraq. In this study MFS Barsarin sequence 3 might equate with MFS J90.

MFS J100:

It is best represented near the base of the Arab A carbonate of Abu Dhabi; it records as a reference section (Al-Siwadi et al., 1996), dating at 151.0 Ma. (Simmons et al., 2007). J100 MFS is reported near base of Arab B carbonate of KSA (Wilson, 1985), and near base of argillaceous carbonate of 2nd Anhydrite of Gotnia Formation in Kuwaite (Yousif and Nouman, 1997), while in Iraq it is marked in intra-Gotnia Formation calcareous shale interbedded within anhydrites and salt (van Bellen et al., 1959), and expected to be present within Barsarin Formation (Sharland et al., 2001). It seems possible to correlate the MFS of Barsarin Sequence 4 with the MFS J100.

Conclusion

The studied sections of Barsarin Formation represented by 160m thick beds of dolostone section in amadiya, while in Gara section it reaches to 210m thich, they are mainly suffering from diagenitic prosses represented by dolomitization, Dedolomitization, stylolite, cement and secondary porosity. Facies analysis indicate arrange of depositional environment extended from oolitic bar, semirestricted lagoon, tidal flat to superatidal.

sequence stratigraphic analyses interpreted four depositional sequences, designated Barsarin Formation Sequence 1 to 4 in both studied sections, their MFS'S show good correlation with Arabian plate MFS'S (J70, J80, J90, J100) of Sharland et al. (2001).

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