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Microfacies Analysis and Depositional Environment of Sarki Formation (Early Jurassic), Rawanduz Area, Kurdistan Region, Northern Iraq

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ABSTRACT

A detail sedimentological analysis of the Sarki Formation (Early Jurassic) in Warte and Zarwan sections in the Imbricated Zone, northern Iraq has been conducted for the first time. The Sarki Formation in both studied sections are consisting of dolomite, dolomitic limestone and recrystallized breccia. The petrographic study of the 80 thin sections analyzed in both outcrops showed the skeletal and non-skeletal components. The skeletal components are including ostracods, bivalves and echinoderms. While the main non skeletal grains are peloids, ooids, extraclasts and intraclasts. The diagenetic processes which affected the carbonate rocks of the Sarki Formation was dolomitization, compaction, cementation, micritization, solution and slicification. The result of XRD and SEM of eight samples of dolomite and dolomitic limestone show that the main minerals are dolomite and calcite. In the carbonate rocks nine main microfacies have been identified, which are classified into three facies groupings that correspond to three depositional environments; peritidal, lagoon and high energy shoal within ramp settings.

1. Introduction

The Sarki Formation was initially defined by Dunnington [1] in its type locality in the Chia Gara, south of Amadyia, northern Iraq. It consists of dark grey dolomitic limestone, thick bedded dolomite, and light grey recrystallization breccias in the lower part and almost entirely dolomitic limestone and dark brown dolomite in the upper part. The formation is widely exposed in a High Folded, Imbricated and Northern Thrust zones of Iraq [2, 3]. Sarki Formation is belonging to the part of the Arabian Plate (AP6) tectonostratighraphic megasequence from middle Permian to middle Jurassic [4]. Due to presence of the rare fossils and not age diagnostic the age of the Sarki Formation was determined based on stratigraphic position as is overlaid by lower Jurassic Sehkanyian Formation and underlying the proven upper Triassic Baluti Formation, which defined as the Hettangian-Snimurian age [2, 3]. Butmah Formation is a lateral equivalent unit of the Sarki Formation in the central part of Iraq, whereas in the Western Desert equivalent to the Ubaid Formation. In neighboring countries, the formation is equivalent with Neyriz Formation in southwest of Iran Bellen [2], and upper part of the Dolaa Group in central Syria [5]. The main objective of this paper is to investigate detail sedimentological features of the Sarki Formation in the selected sections in terms the lithology, petrography, mineralogy, diagenesis, and facies analysis in order to recreate the depositional environment of the lower Jurassic Sarki Formation in the imbrications zone of northeastern of Iraqi Kurdistan Region.

2. Study area

Two essential surface sections are chosen for this study in the Imbricated Zone in northern part of Iraq. Warte section is located approximately 39 km east and southeastern Rawanduz Distract in Erbil Governorate which close to Karukh Mountain and 3 km in south of Warte Town, with Latitude 36^0 28' 24" N and Longitude 44^0 45' 14" E (Fig. 1). Whereas, Zarwan section was chosen in Zarwan Village, about 15 km northeastern Rawanduz District in Erbil Governorate, at the Latitude 36^0 38' 44" N and Longitude 44^0 39' 53" E (Fig. 1).

3. Geological setting

Sarki Formation (Early Jurassic) is widely exposed in the limbs and cores of numerous anticlines in various tectonic zones namely Northern Thrust, Imbricated and the High Folded zones of Iraq [2].

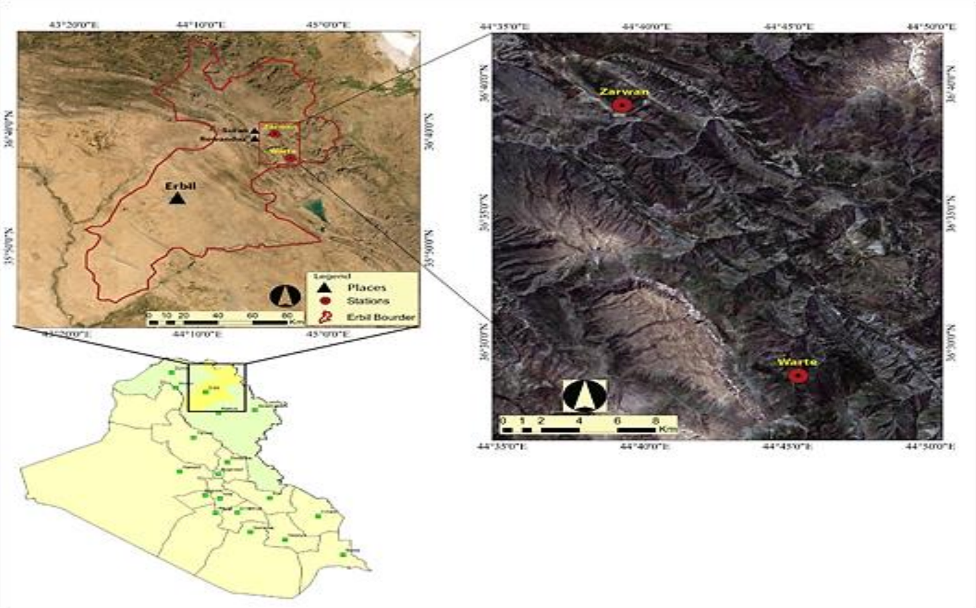

Fig. 1: Location of the studied sections.

The Arabian Plate remained tectonically stable and was positioned at the Equator during the Jurassic Period, allowing the development of a wide shallow shelf on the Neo-Tethys Ocean's western passive margin, on which carbonates deposited and accumulated above the shelf and inner platforms [6]. The Liassic sequence crops out in anticlines of the High Folded Zone and Imbricated Zone in the North and Northeastern parts of Iraq. The three distinct facies are distinguished within the sequence as (1) clastic-carbonate inner shelf Ubaid, Hussainiyat and Amij Formations in the West, (2) carbonate-evaporate inner shelf Butmah, Adaiyah, Mus and Alan Formations in the central Iraq and Foothill Zone, and (3) restricted lagoonal environment of Sarki and Sehkaniyan Formations in the High Folded Zone and Balambo-Tanjiro zones of North and North Eastern Iraq [3]. The Sarki Formarion in both sections located in the Imbricated Zone in Iraq (Fig. 2). Generally, the Imbricated Zone in Iraq was tectonically characterized by numerous folds and faults in various periods from the Paleozoic to Cenozoic sedimentary strata [7]. Sarki Formation from Warte section which is sited in the core of Handreen Anticline, while in Zarwan section exposed at the northeastern limb of Spibalis Anticline (Fig. 2).

4. Methods and Materials: A total of 85 samples were collected from carbonate of the Sarki Formation in both studied sections (Figs. 3 and 4). Additionally, a number of samples were obtained throughout the upper and lower contacts with the Sehkaniyan and Baluti Formations, respectively to verify the nature and location of these boundaries in the selected sections under consideration. Samples were gathered in both sections perpendicularly on the strikes of the beds. The interval between each samples are mainly according to change in lithology and color. The Petroleum Geosciences Department, Faculty of Science, Soran University has provided facilities for preparing of 80 thin sections of selected samples. Comprehensive petrographic investigations as well as a microfacies analysis were carried out. Only a polarized microscope was used for petrographic description, and constituents were identified mostly using Dunham [8] classification scheme. Four samples of dolomite and dolomitic limestone were chosen for X-ray diffraction (XRD) analysis, with the purpose of determining their mineralogy content. Additionally, four dolomite and dolomitic limestone samples were chosen for scanning electron microscope (SEM) analysis, with the purpose of recognize the minerals and define the texture of dolomite minerals. These samples were analyzed in laboratories of the Scientific Research Center-Soran University.

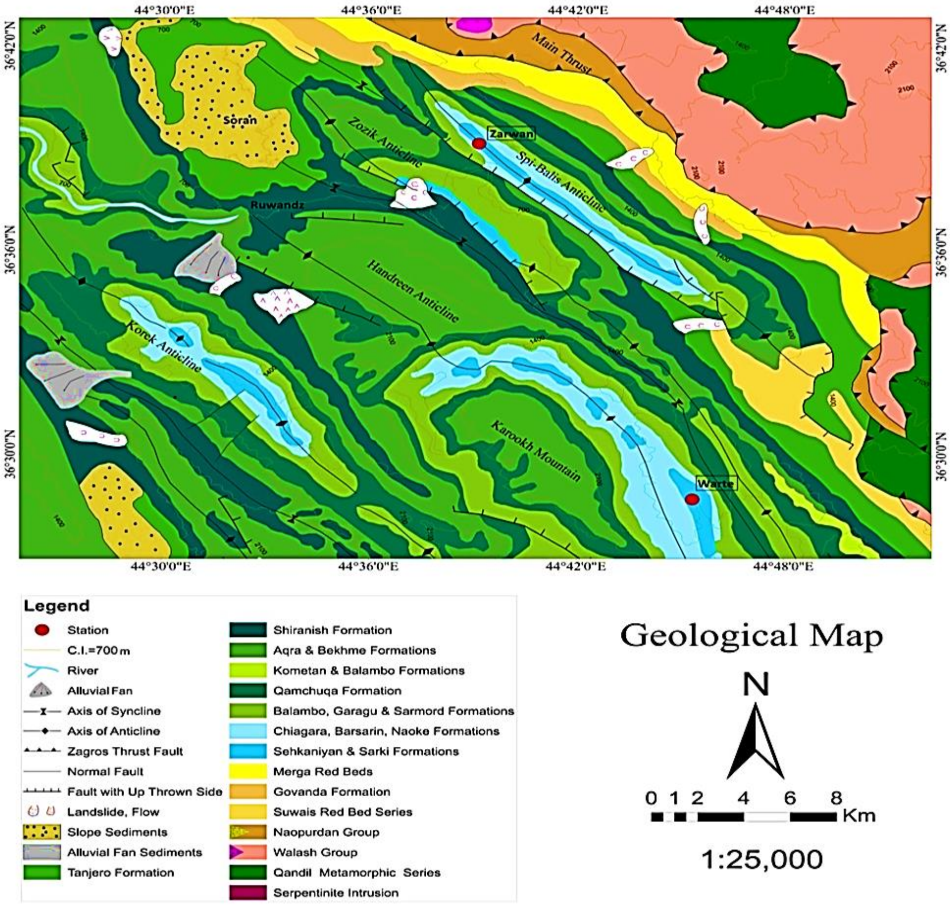

Fig. 2: Geological map of the studied sections, modified from [9].

5. Results

5.1. Lithology

The lithology of the Sarki Formation from both studied sections consists of dark grey dolomitic limestone, dolomite and light grey recrystallized breccia. Generally, the lower part of the Sarki Formation in the Zarwan section mostly composed of the thick bedded recrystallized breccia (Figs. 3 and 4). The Sarki Formation has a total thickness of 176 m in the Warte section. Sarki Formation has a gradational lower contact with Baluti Formation and a conformable upper contact with Sehkaniyan Formation. The thickness of the Sarki Formation from Zarwan section is 115 m. In this section, the top contact of the Sarki Formation is conformable and overlaid by Sehkaniyan Formation, while the lower contact is gradational and underlaid by Baluti Formation. The lower contact of the Sarki Formation in the Zarwan section is not cropped out and it is covered by sedimentary materials. The lithology of the formation in both study sections are shown in the geologic column (Figs. 3 and 4).

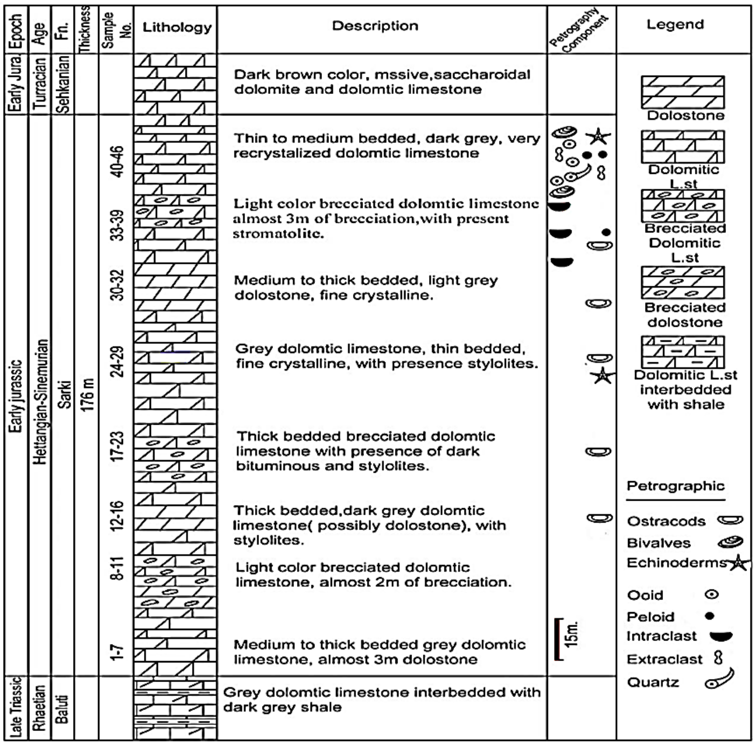

Fig. 3: Columnar section of Sarki Formation in the Warte section, Northeastern Iraq.

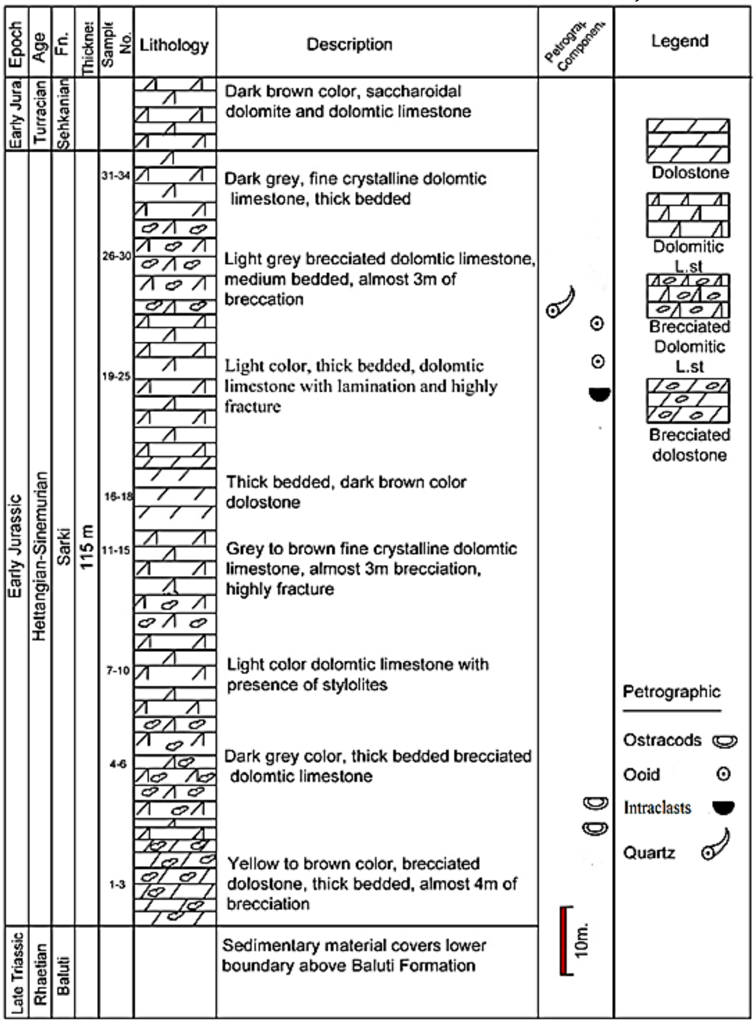

Fig. 4: Columnar section of Sarki Formation in the Zarwan section, Northeastern Iraq.

5.2. Petrography

Petrographic study of the Sarki Formation indicates that few allochems detected and most of them are destroyed due to effect of different diagenetic processes. Petrographic analysis of Sarki Formation shows that skeletal grains are relatively less common in the Zarwan section comparing to Warte section. Most of the skeletal and non- skeletal grains are observed from the upper part of the formation in both selected sections (Figs. 3 and 4). The main skeletal grains include ostracods (Fig. 5a), bivalves (Fig. 5b) and echinoderms (Fig. 5c). Non-skeletal components are comprised of ooids (Fig. 5d), peloids (Fig. 5e), intraclasts (Fig. 5f) and extraclasts (Fig. 5e), which are mainly grains of quartz.

5.3. Mineralogy

The mineralogical composition of selected samples in the Sarki Formation is indicated in (Fig. 6). According to XRD analysis, the main minerals of selected samples of dolomite and dolomitic limestone from Sarki Formation are dolomite, calcite, and small diffraction peaks of quartz. On the other hand, some minerals are identified in the studied sections according to microscopic studies include quartz (Fig. 5g), pyrite (Fig. 5h) and iron oxides (Fig. 7a).

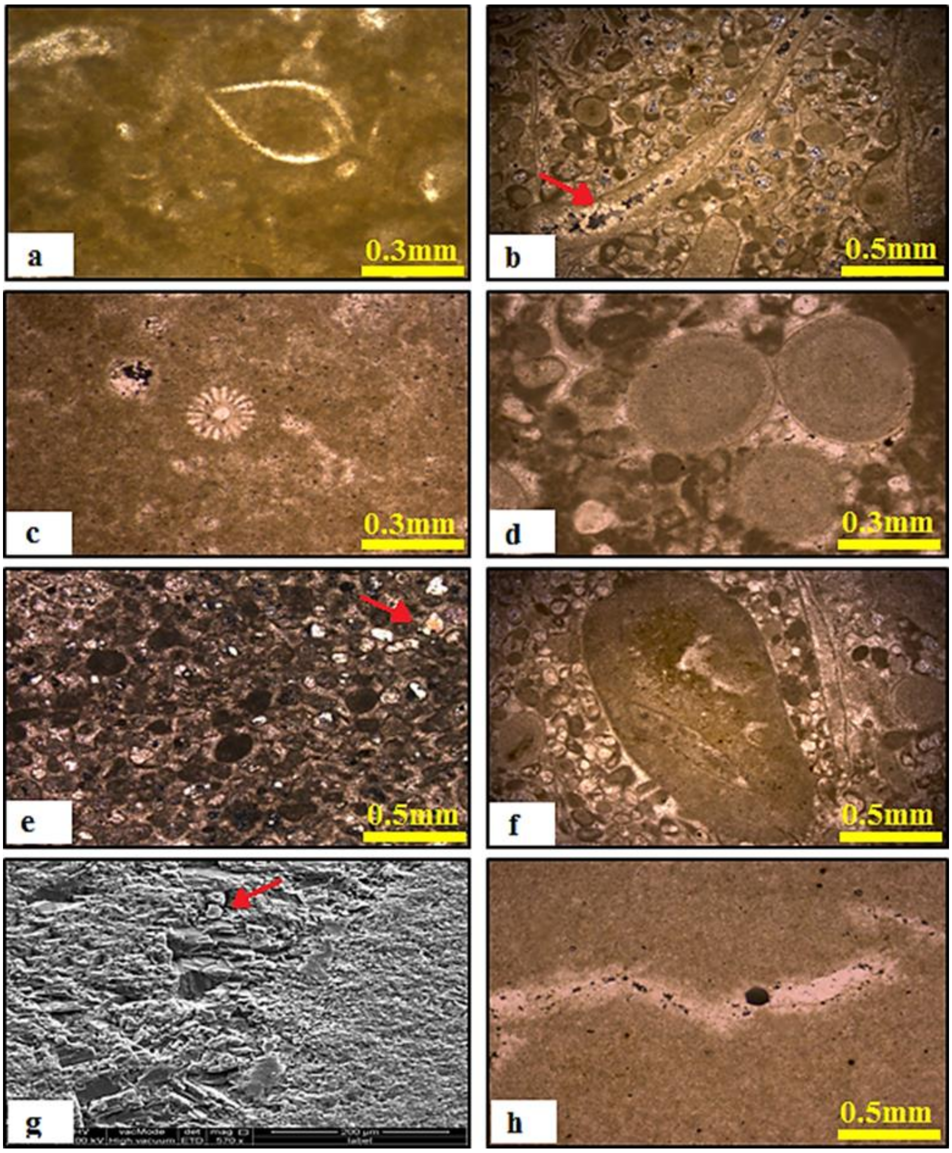

Fig. 5: Photomicrographs of Sarki Formation: (a) Articulated ostracod filled with micrite in bioclastic wackestone facies. WS. 31, P.P. (b) Inarticulate bivalves valve, curved shape, filled by drusy cement (arrow). WS. 42, P.P. (c) Spines of echinoid single crystal calcite, envelope in dolomicritic matrix. WS. 27, P.P. (d) Non-skeleton grains spherical (ooids) filled by micrite (micrite envelope). WS. 42, P.P. (e) Peloids with quartz fragments affected by silicification (arrow) in peloidal packstone microfacies. WS. 45, X.N. (f) An intraclasts surrounding by ooids grain and fragment of bivalves affected by micrtization. WS. 42, P.P. (g) SEM image showing detrital quartz grains (arrow). WS.34. (h) Small cubic pyrite formed in vein of groundmass micritic matrix. WS. 40, P.P., WS: Warte –Sarki, ZS: Zarwan-Sarki, P.P: Plane Polarized light, X.N: Crossed Nichols.

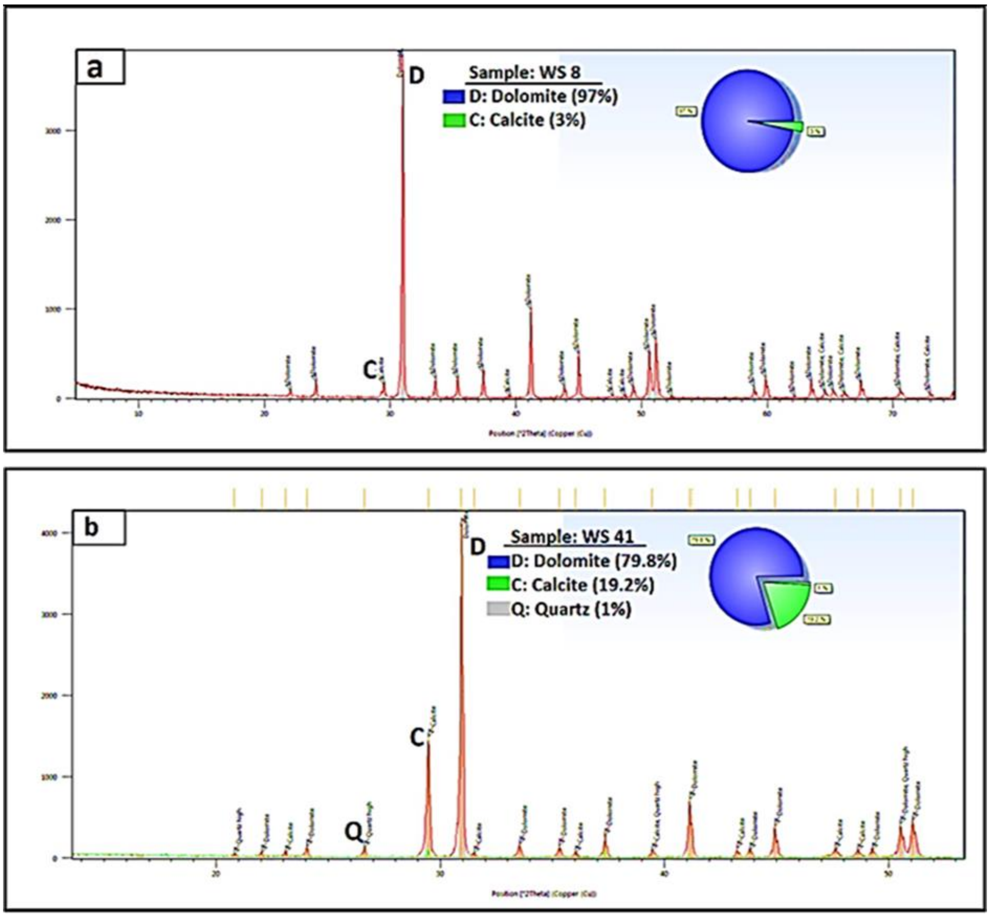

Fig. 6: XRD diffractograms for selected samples of the Sarki Formation.

5.4. Diagenesis processes

Several diagenetic processes have affected the rocks of the Sarki Formation in both sections. The influence of diagenesis varies from section to section; the degree of diagenesis is more extensive in Zarwan section compare to Warte section. The main diagenetic process
has affected on the different part of Sarki Formation to various degrees is **dolomitization**, which occur in both early and late phases. Most of the dolomitization in both studied sections are of early dolomitizaton type, and characterized by fine crystals. This type of dolomitizaton is more common in Warte section particularly in the middle part of the formation but in Zarwan section, this type can be observed in the lower part of the formation. While late dolomitizaton is characterized by coarse crystals size, which are abundant in studied sections particularly in the middle and upper parts of Warte section and the middle part of Zarwan section. According to Gregg and Sibley [10] classification scheme, five textures of dolomite rock have been recognized in Sarki Formation of both sections. They includes (1) Fine crystalline, planer-s (subhedral) dolomites (Fig. 7b and 7c); (2) Fine to medium planar-e (euhedral) to planer-s (subhedral) dolomites (Fig. 7d); (3) Medium to coarse, planar-e (euhedral) to planar-s (subhedral) dolomites (Fig. 7e); (4) Coarse crystalline, planar-s (subhedral) to nonplanar-a (anhedral) dolomites (Fig. 7f); (5) Planar (subhedral) pore-filling dolomite cement (Fig. 7g).

Cementation is the second diagenetic process; three main type of cements were identified; granular cement (Fig. 7h), blocky cement (Fig. 8a) and drusy cement (Fig. 5b) reflecting different diagenetic environments. Granular cement was developed in the vadose zone (meteoric and marine), whereas blocky cement was commonly occurred in meteoric settings, whereas drusy cement indicates deposition in a freshwater phreatic zone [11]. Other diagenetic processes recorded in carbonate of Sarki Formation include:

(1) **Compaction**, Both the mechanical and chemical types of compaction were observed in the both investigated sections.

Most common physical compaction criteria in the Sarki Formation includes: fractures which are commonly filled by calcite cement (Fig. 8b), breaking of grains (Fig. 8c) and plastic bending of particle (Fig. 8d). Chemical compaction is showed by stylolitization, the most common types of stylolites in both studied sections are irregular types, mostly with peak low amplitude (Fig. 8e), and others of high amplitude (Fig. 8f). (2) **Dissolution** in the form of different porosity types: moldic (Fig. 8g), intraparticle (Fig. 8h), intercrystalline (Fig. 7e) and stylolite (Fig. 8e). (3) **Silicification,** where silica replace dolomite and grains (Fig. 8c).

In addition, **micritization** was observed in the studied sections in the form of micritic rims (micrite envelope) around grains (Fig. 5d and 5f). Skeletal grains are commonly affected by micritization process in early diagenetic stage [12].

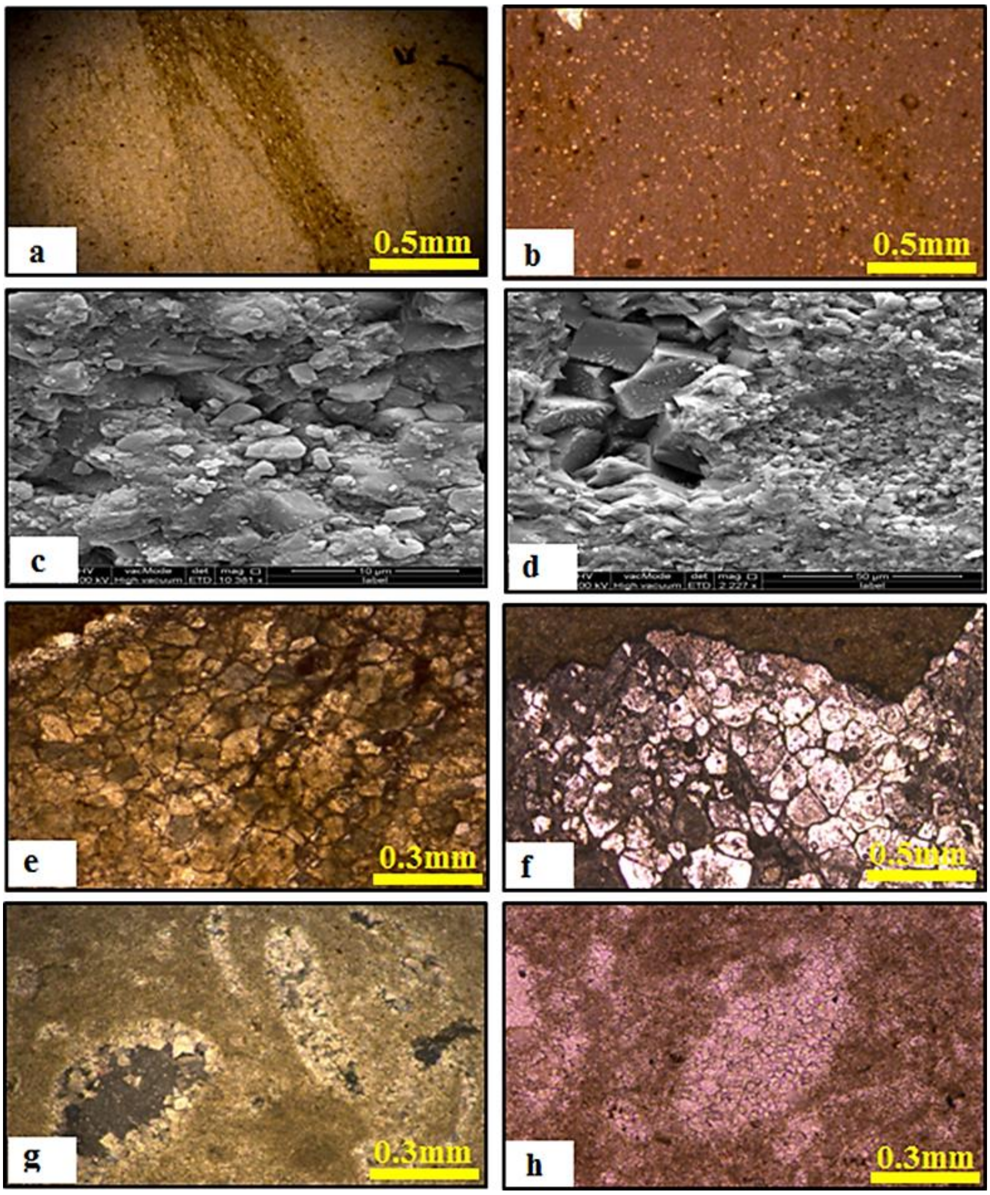

Fig. 7: Photomicrographs of Sarki Formation: (a) Iron oxide developed as fibrous shape in neomorhosed micrite matrix. WS. 17, X.N. (b) Fine crystalline planer-s (subhedral) dolomite. WS. 24, P.P. (c) SEM image of fine crystalline planer-s (subhedral) dolomite. WS. 41. (d) SEM image of fine to medium crystalline planar-e (euhedral) to planar-s (subhedral). dolomite. WS. 42. (e) Medium to coarse, planar-s (subhedral) to planar-e (euhedral) dolomites. ZS. 16, P.P. (f) Coarse crystalline, planar-s (subhedral) to nonplanar-a (anhedral) dolomites, pore between crystals filled by bitumen. ZS. 14, P.P. (g) Planar (euhedral) to planar (subhedral) void-filling dolomite cement. WS. 46, P.P. (h) Articulated ostracod filled by granular cement. WS. 46, P.P., WS: Warte –Sarki, ZS: Zarwan-Sarki, P.P: Plane Polarized light, X.N: Crossed Nichols.

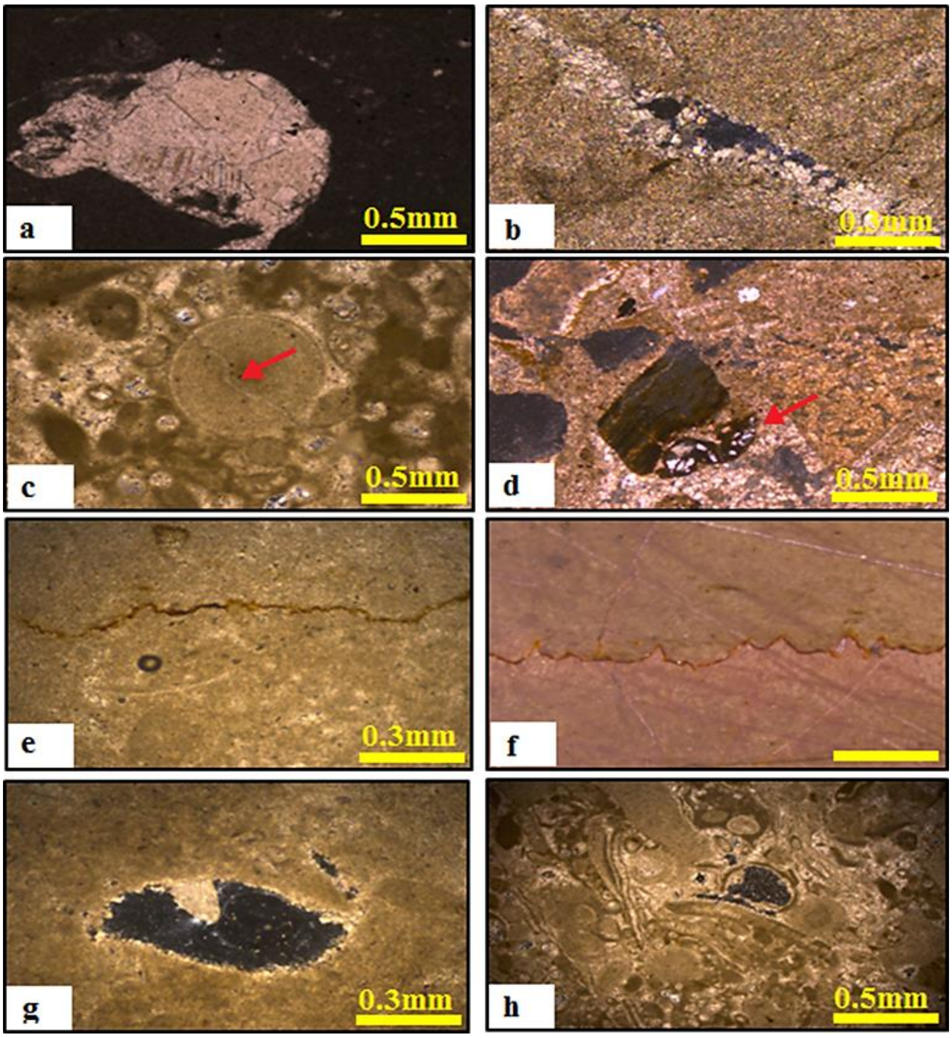

Fig. 8: Photomicrographs of Sarki Formation: (a) Blocky cement filling the mold of previously dissolved bioclast. WS. 38, P.P. (b) A fracture filled by granular cement, may indicate strong tectonic. WS. 14, X.N. (c) Breakage in a ooid grain, derived from compaction processes with silicification of quartz grains (arrow). (d) Deformation and plastic bending of intraclast showing wave appearance (arrow). ZS.6, P.P. (e) Sutured seam stylolite, irregular type with peaks of low amplitude, filled by bitumen SW. 27, X.N. (f) Sutured seam stylolite, irregular type with peaks of high amplitude (columnar stylolite). ZS. 7, P.P. (g) A moldic porosity formed by complete leaching and dissolution of ostracod grain. WS. 27, X.N. (h) Intraparticle porosity formed within ooid grain in ooidal bioclastic grainstone facies. WS. 42, X.N., WS: Warte –Sarki, ZS: Zarwan-Sarki, P.P: Plane Polarized light, X.N: Crossed Nichols.

5.5. Microfacies analysis

In both selected sections, according to standard classification of Dunham [8], nine main types of microfacies were identified in the Sarki Formation, which were corresponded to three depositional environments including; peritidal, lagoon and high energy shoal carbonate.

5.5.1. Dolomitized mudstone

Dolomitized Mudstone microfacies is characterized by a high quantity of micrite with rare (generally less than 10%) of fossil content. This facies is dominated by micrite (lime mud), which has been affected by dolomitization, which consist of microcrystalline dolomite or dolomicrite (Fig. 9a). Some of the observed fractures and stylolitic textures in the dolomitized mudstone microfacies are filled with sparry calcite or micrite. This microfacies corresponded to SMF (23) according to Wilson [13], which represents supratidal subenvironment [14].

5.5.2. Bioclastic wackestone

This microfacies include more than 10% of bioclasts mainly of ostracod grains, range in size between 0.15 to 0.25 mm located in a dark micritic matrix (Fig. 5a). This microfacies is characterized by micrite matrix as affected by neomorphism process to microspar and sparry calcite cement. This facies is affected by number of diagenetic processes like dolomitization, cementation and micritization. It is corresponded to SMF (9) according to Wilson [13], and indicating deposition in lagoon environment [14].

5.5.3. Intraclastic bioclastic packstone

This microfacies is dominated by intraclasts and bioclasts, the main skeletal grains in this microfacies are possibly ostracods range in size between 0.4 to

0.6 mm, and it is highly affected by dolomitization process (Fig. 9c). Micrite groundmass in this facies shows microspar due to the effect of neomorphism process. This microfacies is corresponded to SMF (10) according to Wilson [13], and indicating deposition in moderate to high energy open lagoon [14].

5.5.4. Peloidal packstone

Peloid is a main allochems in this facies, with minor amount of ooids and intraclasts. Most of the peliods in this facies vary from round to subrounded or they may be irregular in the shape (Fig. 5e). This facies is affected by different processes of diagenesis such as dolomitization, cementation, micritization and slicification. This microfacies corresponds to SMF (16) according to Wilson [13], which represent to restricted subtidal lagoonal environment [14].

5.5.5. Ooidal grainstone

Ooid is a main allochem in this microfacies, which well sorted and rounded constitutes more than 70% of total samples and it is estimated to be approximately 0.5mm in diameter, it is highly affected by dolomitization (Fig. 9d). The major diagenetic processes effect of the facies was dolomitization and micritization particularly at Zarwan section highly affected by dolomitization process. This microfacies is parallel to SMF (15) according to Wilson [13], and indicating deposition in a high energy shoal environment [14].

5.5.6. Ooidal bioclastic grainstone

The composition of this microfacies includes ooid and bioclast fragments (valves of pelecypoda), most of the ooids are generally subrounded to elongate in shape (Fig. 9b). Here the bioclasts and some of the ooids have been micritized especially on the rim of grains. This microfacies corresponds to SMF (17) according to Wilson [13], and indicating deposition in shoal environment [14].

5.5.7. Stromatolitic boundstone

Dunham [8] defined the term "bound" to describe carbonate rocks that reveals indications of being bounded through deposition, such as reef limestones and stromatolites. The layers of stromatolite in this facies bound together and spaces mostly filled by different type of cements (Fig. 9e). The main diagenetic processes involved in the facies are cementation and dolomitization. This microfacies is parallel to SMF (20) according to Wilson [13], and indicating deposition in restricted shelf lagoon environment [14].

5.5.8. Recrystallized dolostone: This facies include different sizes of crystalline dolostone, with repetition in various parts of the formation in the nominated sections. The variation in crystal sizes of dolostone in this facies from fine to coarse size indicates different dolomitization events. The crystals of dolostone in the facies are generally characterized by planar subhedral to planer euhedral (Fig. 7e). The increasing crystal size and non-planer to planer crystalline dolomite are evidence of the process of recrystallized dolomite [15]. The facies cannot be compared with any standard facies type but can be compared with the facies belt of deposition, and indicating deposition in supratidal environment.

5.5.9. Recrystallized breccia

The breccia is intraformational produced by syndepositional process and comprises clasts created within depositional basin. Most of the intraclasts are micritic and highly fractured, then filled by sparry calcite cements (Fig. 9f). According to Wilson [13], the facies is probably corresponding to SMF (24), and correlated with facies was interpreted a storm sediment, possibly deposited within tidal flats environment.

5.6. Depositional environment

The depositional settings were proposed for Sarki Formation include restricted marine, lagoon and tidal flats [16]. Depending on the petrographic and facies analysis, the Jurassic Sarki Formation has been concluded to be deposited in peritidal, lagoonal and high energy carbonate shoal. Three facies connections related to three depositional environments can be linked to the studied microfacies.

First, a peritidal facies linkage described by micrite and affected by dolomtization in mudstone without considerable facies alteration and the occurrence of euhedral dolomite crystals, that indicating an inner ramp and formed in peritidal environmental circumstances. Dolomitized mudstone microfacies are represented by microcrystalline dolomite and dolomicrite, which is characterized by fine crystals ranging from 10 to 30 micron and indicates the early diagenetic process. Owing to the existence of microcrystalline and rare fossils, it grows in a peritidal subenvironment. In early diagenetic fine size of crystalline dolomite is also developed in intertidal and supratidal environments and indicating Sabkha evaporation [15, 17]. Moreover, the occurrence of fine-crystal dolomites in Sabkha fine-grained micritic sediments indicate suitable places for nucleation of larger dolomite crystals [10, 18].

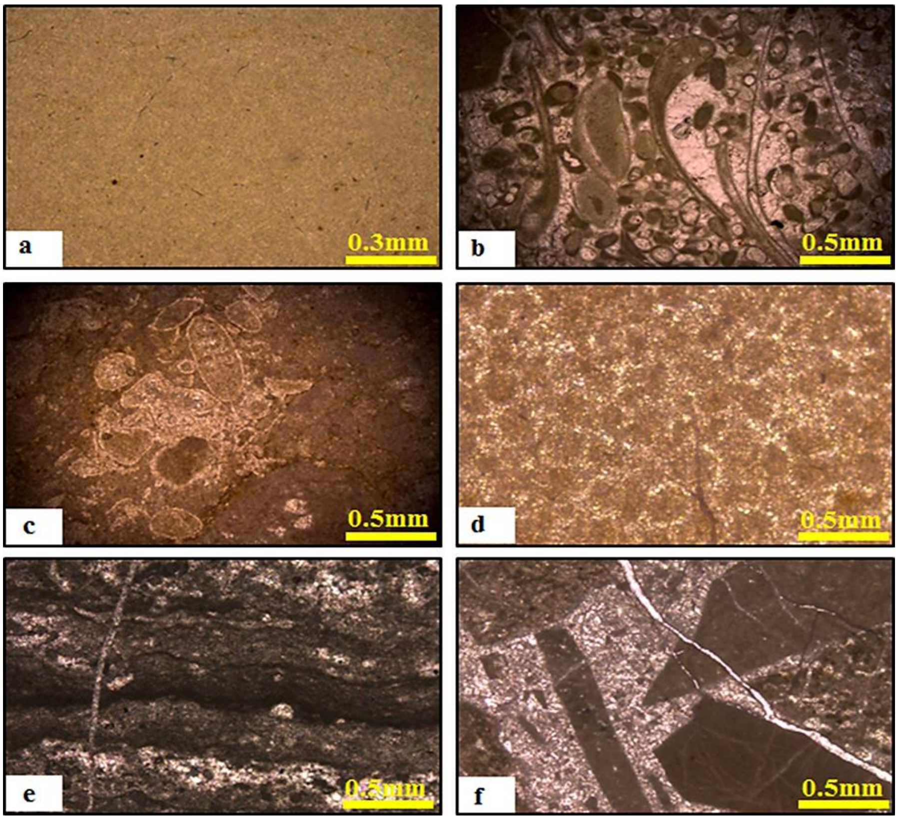

Fig. 9: Photomicrographs of Sarki Formation: (a) Dolomitized mudstone microfacies, which consist of microcrystalline dolomite and dolomicrite. WS. 1, X.N. (b) Ooidal bioclastic microfacies, ooids and valves of bivalve are the main component. WS. 31, P.P. (c) Bioclastic intraclastic packstone microfacies, major components are ostracod and intraclast in micrite groundmass. ZS. 2, P.P. (d) Ooidal grainstone microfacies, the main component are ooids and highly affected by dolomtization. ZS. 23, P.P. (e) Stromatolitic boundstone microfacies, the space mostly filled by different type of cements. WS. 34, P.P. (f) Recrystallize breccia, Most of the clasts are micritic and highly fractured, then filled by sparry calcite cement. ZS. 6, X.N., WS: Warte –Sarki, ZS: Zarwan-Sarki, P.P: Plane Polarized light, X.N: Crossed Nichols.

The source of finely crystalline dolomite has been identified as penecontemporaneous dolomitization of preceding micrite in supratidal flat sediments throughout the regressive phase in upper intertidal to supratidal settings [15, 19]. Increase in crystal size from fine to coarse is the evidence of recrystallized dolomite during the late diagenetic process. The presence of bioclast ghosts, which are cemented by calcite and sometimes dolomitized, is associated with the mixing zone with meteoric water, in which the bioclast shell fragments were leached and replaced with dolomite cement [20]. Dolostone facies are more associated to mixing zone model of dolomitization in supratidal environment and it is refluxed with sea water especially during marine transgression [15, 20].

Second, lagoon facies, this facies is characterized by peloids and micritic matrix, demonstrating that sedimentation occurred behind the shoals in a restricted lagoon zone. The presence of ostracod grains within this facies indicating to deposition in low to moderate energy environment such as open lagoon and intratidal.

The common carbonate mud and fewer amounts of small skeletal components in size with ostracod of wackestone microfacies suggest the deposition of this microfacies in the restricted shelf lagoon setting. The presence of large size intraclasts with peloids in packestone facies from upper part of the formation indicates the restricted subtidal lagoonal water, and it is typical of shelf lagoon environment. Presence of stromatolites in this facies represents low to moderate restricted circulation shelf lagoon; it is typically in an intratidal environment.

Third, the highly energy carbonate shoal facies, in an inner ramp environment comprises the upper part of the formation. A shoal carbonate setting is characterized by accumulation of grains, the absence of micrite and the existence of non-skeletal grains such as ooids, peloids, and intraclasts deposited in a high energy regime.

Owing to the existence of non-skeletal grains such as ooid and the absence of lime mud, grainstone microfacies belts are formed in high energy shoal environment and under the wave action. The existence of skeletal fragments like bivalve in ooiltic bioclastic grainstone distributed in a sparite matrix, which is indicating that this microfacies was deposited in high energy shoal setting. The Sarki Formation is presented with a suggested depositional model in (Fig. 10).

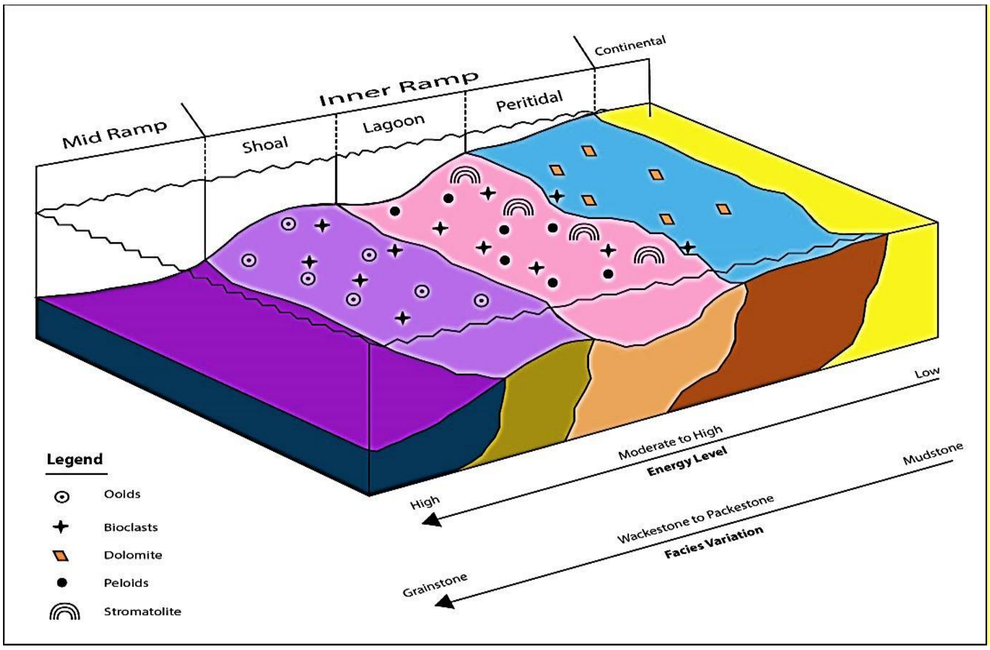

Fig. 10: Proposed depositional model for Lower Jurassic Sarki Formation.

6. Conclusions

1. Litholoically, the carbonate rocks of Sarki Formation mainly composed of dolomite, dolomitic limestone, brecciated dolostone and brecciated dolomitic limestone.
2. Petrographically, the Sarki Formation in studied sections comprised of skeletal fauna including ostracods, bivalves and echinoderms. However, non-skeletal components comprise ooids, peliods, extraclasts and intraclasts. The main minerals were identified in dolomite and dolomitic limestones of the Sarki Formation include dolomite, calcite, quartz, pyrite and iron oxide.
3. The main diagenetic processes that affected the carbonate rocks of the Sarki Formation include dolomitization, compaction, cementation, micritization, solution and slicification.
4. Based on Dunham [8], classification, and detailed microscopic study, nine microfacies were recognized in Sarki Formation from both sections, three facies connections related to three depositional environments can be linked to the studied microfacies. The depositional environments include peritidal, lagoon and high energy carbonate shoal.

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السحنات الدقيقة والبيئة الترسيبية لتكوين ساركي (الجوراسي المبكر)، منطقة راوندوز، إقليم كردستان، شمال العراق

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الملخص

تم إجراء تحليل رسوبي تفصيلي لتكوين ساركي (الجوراسي المبكر) في مقاطع وه رتي و زروان في منطقة متشابكة شمال شرق العراق لأول مرة. يتكون تكوين ساركي في كلا المقطعين المدروسين من الدولوميت والحجر الجيري الدولوميتي والبريشيا المعاد بلورتها. درس التكوين من خلال 80 مقطعا مجهريا و تم تحليلها في كل من نتوءات و تضمنت المكونات الهيكلية وغير الهيكلية. تتكون مكونات الهيكلية من اوستراكود، ذوات الصدفتين، وشوكيات الجلد. في حين أن المكونات الرئيسية غير الهيكلية تشمل peloids، ooids، extraclasts, و intraclasts. إن وجود العمليات التحويرية التي تؤثر على صخور الكربونات في تكوين ساركي يشمل التحلية، الضغط، التدعيم، التحويل الدقيق، الحل ، والتقطيع. تظهر نتيجة XRD و SEM التي أجريناها على ثماني عينات من الدولوميت والحجر الجيري الدولوميتي, أن المعادن الرئيسية هي الدولوميت والكالسيت. في صخور الكربونات في تكوين ساركي ، تم تحديد تسعة السحنات الدقيقة الرئيسية، والتي تم تصنيفها إلى ثلاث مجموعات سحنية تتوافق مع ثلاث بيئات ترسيبية. البيئات الترسيبية هي مياه ضحلة, بحيرة, وبحيرة عالية الطاقة على الجزء الداخلي من المنحدر.