

Facies Analysis And Depositional Environment Of Lower Jurassic (Sehkaniyan Formation), Northeastern Iraq-Kurdistan Region

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Abstract: This study deals with the sedimentology and stratigraphy of Lower Jurassic Sehkaniyan Formation as an implication for its facies analysis and depositional environment in Warte area in the Imbrication Zone, NE Iraqi Kurdistan region. In the study area the formation has a thick succession of shallow water carbonates and thin shale represents a real lower Jurassic unit that overlying the Sarki Formation and underlying the Sargelu Formation. The total of 30 thin sections from the carbonates of Sehkaniyan Formation were petrographically studied under polarizing microscope in-order to finding out their petrographic constituents. The petrographic study demonstrated that most of the carbonate units of Sehkaniyan formation subjected to sever dolomitization, although considerable shallow water skeletal garins (benthic foraminiferas, gastropods, pelecypods, ostracods) and non-skeletal grains (Peloids and ooids) in addition to abundant stromatolites are recognized. Depending on field and petrographic study, the Sehkaniyan Formation subdivided into three units; the lower unit consists of dark grey thick bedded dolomitic limestone and brown to dark brown brecciated dolomitic limestone. The unit comprised of grey to yellowish grey medium to thick bedded limestone and dark grey dolomitic limestone intercalated with thin bedded shale. While, the upper unit consists of dark grey thick bedded dolostone, light grey thick bedded brecciated dolomitic limestone and massive dark grey dolomitic limestone. Three diffract microfacies were recognized that demonstrated a wide range of facies associations, which suggested the deposition of Sehkaniyan Formation in a Shoal, Lagoon and Tidal flat environments in an inner homoclinal ramp setting.

Keywords: *Facies; Lower Jurassic; Northern Iraq; Depositional Environment; Sehkaniyan Formation.*

1. Introduction

The Sehkaniyan Formation is Lower Jurassic shallow marine carbonate succession, deposited as a thick unit and forming most mountainis cliffs in the Thrust, Imbrication and High Folded zones of northeastern Iraq. Despite the importance of Jurassic rocks in producing and storing the hydrocarbons in many Iraqi giant oil fields, there are a considering gap still remained in the facies and depositional environment especially of the northern Iraq's lower Jurassic succession. The Sehkaniyan Formation was first nominated by Morton (1950, in[1]) in the Surdash anticline from the High Folded Zone of northeastern Iraq. In the type locality it is consist of 180m thick carbonate succession and divided in to three units; Lower unit, is 85m of dark saccharoidal dolomite and dolomitic limestones containing subordinate solution breccias. There are 44m of organic and pelletal fossiliferous limestone often dolomitized in the middle division, and 51m of dark, saccharoidal dolomite and dolomitic limestone in the upper division [1]. The local equivalent units of the studied formation are Adaiyah, Mus and Alan formations in middle and southern part of country. While in surrounding countries, is equivalent

with Upper Dolaa Group of Syria, Marrat Formation in Saudi Arabia [2], and the upper portion of Surmeh Formation in Iran [3]. Accordingly, few and limited studies have been done about the sedimentology and stratigraphy of the Sehkaniyan Formation especially in outcropped areas after the first description of the formation by [1]. These are the study of [3] that agreed with many aspects given by [1]. Later [4] studied the Lower Jurassic sequence stratigraphy in the northern and central Iraq and he divided the formation into several third order depositional sequences. [5] studied in detail the stratigraphy and geochemistry of Jurassic formations in northern Iraq and showed that the depositional environment of Sehkaniyan Formation is shallow open and partly restricted marine setting. [6] studied of the paleoclimate, paleosalinity and paleoredox conditions of Lower Jurassic rocks in northeastern Iraq. The aim of this study is to clarifying the microfacies and depositional setting through detail petrographic and microfacies analysis of the Sehkaniyan Formation in the locality of Warte area, Rawanduz district, Northeastern Iraq-Kurdistan Region.

2. Geologic setting

The studied section is placed in the Iraqi northeastern part within the Erbil governorate. The selected section is sited from the south of Warte town in the Imbrication zone and about 38km southeastern of the Rawanduz district. The latitude of the location is approximately $36^{\circ} 29' 41''$ N and the longitude is about $44^{\circ} 45' 01''$ E (Figure 1). The Sehkaniyan Formation is part of the Arabian Plate (AP6) tectonostratographic megasequence started from the upper Permian to the middle Jurassic [7], and deposited during Sinemurian to Aalenian sub cycle. The beginning of this cycle started by regionally widespread considerable transgression throughout the country, associated with Upper Triassic next stage Neo- Tethys openings, which marks the establishing of the formation of an intrashelf basin towards the northern part of Iraq. In this basin dolomitic limestones and shallow-marine shales were deposited, together interbedding with the evaporites (Sehkaniyan, Formation) in north and northeastern part of Iraq and Alan, Mus and Adaiyah formations in the central and southern part of country too [8] (Figure 2). Towards the south of the Arabian, the carbonate facies changed to a clastic succession and founds to have been eroded in outcropped areas [8]. The end of this cycle marked above the Middle Jurassic Sargelu Formation and suggests regional regression. This cycle might be divided into two parts separated by the regressive phases during the Rhaetic and marked in the western parts of Iraq (Ga'ara, Mileh Tharthar etc.) as well as in some of the neighboring countries by an unconformity [1]. The cycle (Upper Permian- Middle Jurassic) is represented by several formations, which belongs essentially to two facies types which are calcareous marine and lagoonal evaporates. The Upper Triassic units of this cycle represented by Kurra Chine, Mulussa, Baluti Shale, and Zor Hauran formations are deposited in a lagoonal depositional setting. Whereas, the Jurassic formations include Lower Jurassic Butmah, Alan. Mus, Adaiyah, Sarki, Sehkaniyan and Uba'id and Aalenian- Bajocian Sargelu, and Muhaiwir formations. The maximum width of the Neo- Tethys basin recorded by [9] within the Middle Jurassic Aalenian -Bajocian were Sargelu Formation deposited in a uniform relatively deep basin extended form NE Syria and whole Unstable and Stable Shelf of Iraq towards the Kuwait [10].

In the Kurdistan region (northern Iraq), the Sehkaniyan Formation crops out mostly on the limbs and cores of numerous anticlines within the Zagros High Folded, Imbricate, and Northern Thrust Zones of northern Iraq [2]. In the studied area, the lower contact of Sehkanian Formation is conformable with the Sarki Formation and the upper contact is conformable with the Middle Jurassic Sargelu Formation. The studied formation in the Warte area from Rawanduz district is cropped out in the core of Handreen anticline in the Imbrication Zone (Figure 3). The Handreen anticline defined as an asymmetrical type, has a fold axis of NW-SE trend or direction. A late Triassic (Baluti Formation) and Jurassic rock successions form the core of the anticline, while Cretaceous rocks form the limbs of anticline [11, 12].

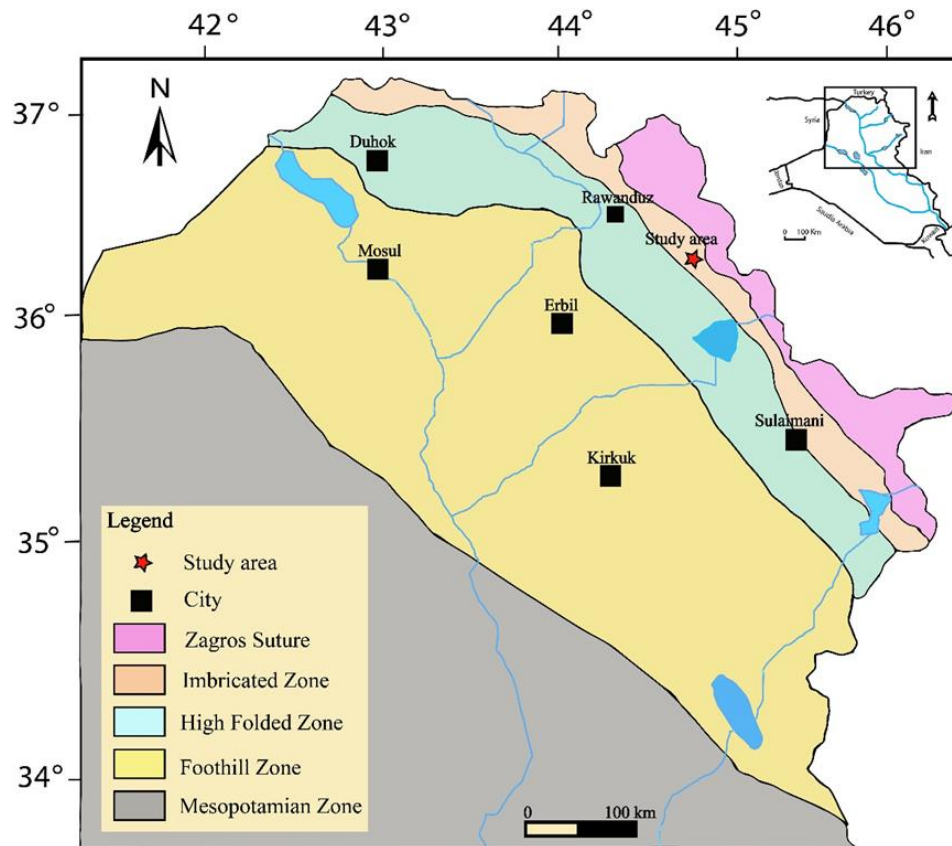


Figure 1: Tectonic map of Northern Iraq, indicating the location of the study (after [2]).

3. Methods and Materials

An outcropped section of Sehkanian Formation was selected in the Warte area from the Rawanduz district for sampling and other field work descriptions. A variety of factors were considered when collecting samples from the studied formation, including facies and color changes. The 210 meters of Sehkanian Formation were measured and described in detail logging lithology, mineralogy, sedimentary structures, fossils content and stratigraphic relationships. Based on vertical and lateral facies changes, 30 samples were collected for petrographic analysis. Several samples were collecting across the underlying contact with the Sarki Formation and overlying contact with the Sargalu Formation in propose to examine the nature and position of the contact between them. The total of 30 carbonate thin sections are made at the workshop of Research Center of Soran University. The Alizarin Red Solution were adopted for pigmenting the thin sections according to Friedman [13] procedure for differentiation between calcite and dolomite minerals. A polarized microscope was used to identify and photograph the most useful constituents of the granules, in order to determine the microfacies types by using the Dunham's [14] classification.

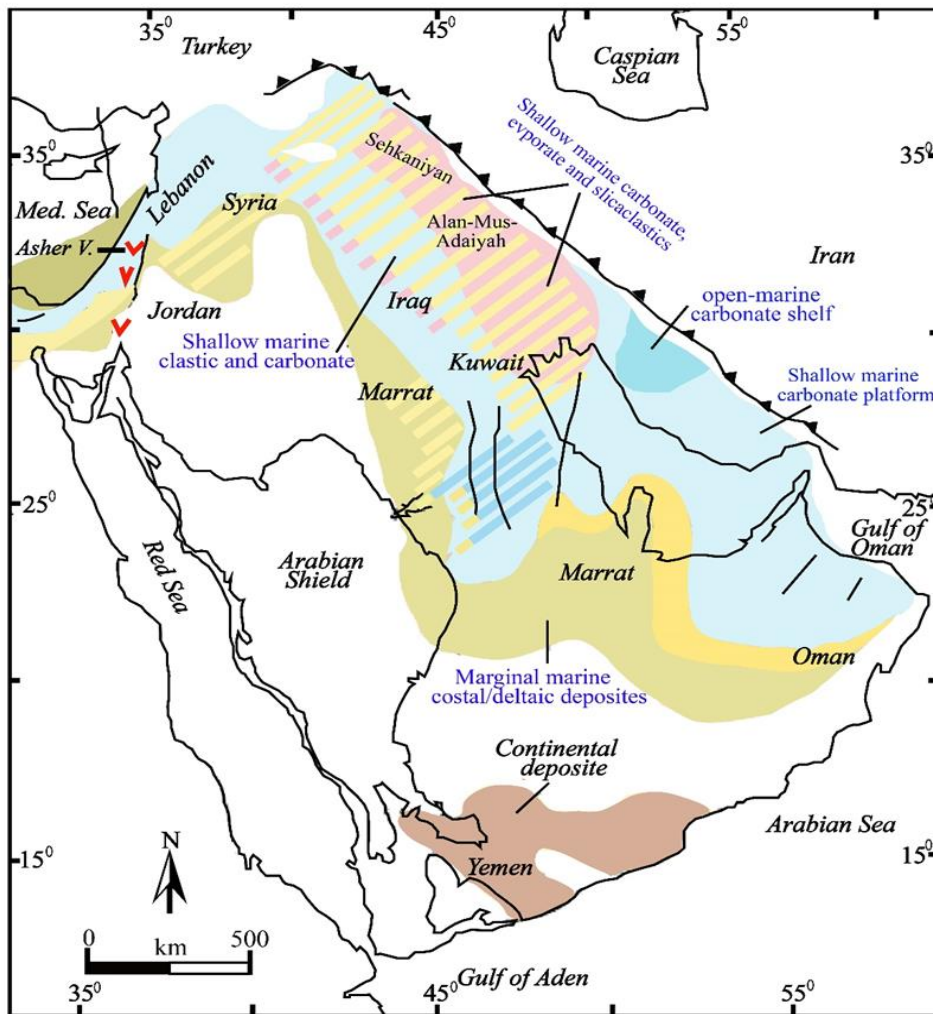


Figure 2: Paleofacies map of Arabian plate in the Early Jurassic. The period involved the deposition of the Sehkaniyan Formation in the imbrication and high folded zone and Adaya, Mus and Alan formations in the foot hill zone of northern Iraq, and their regional equivalents, modified from [8].

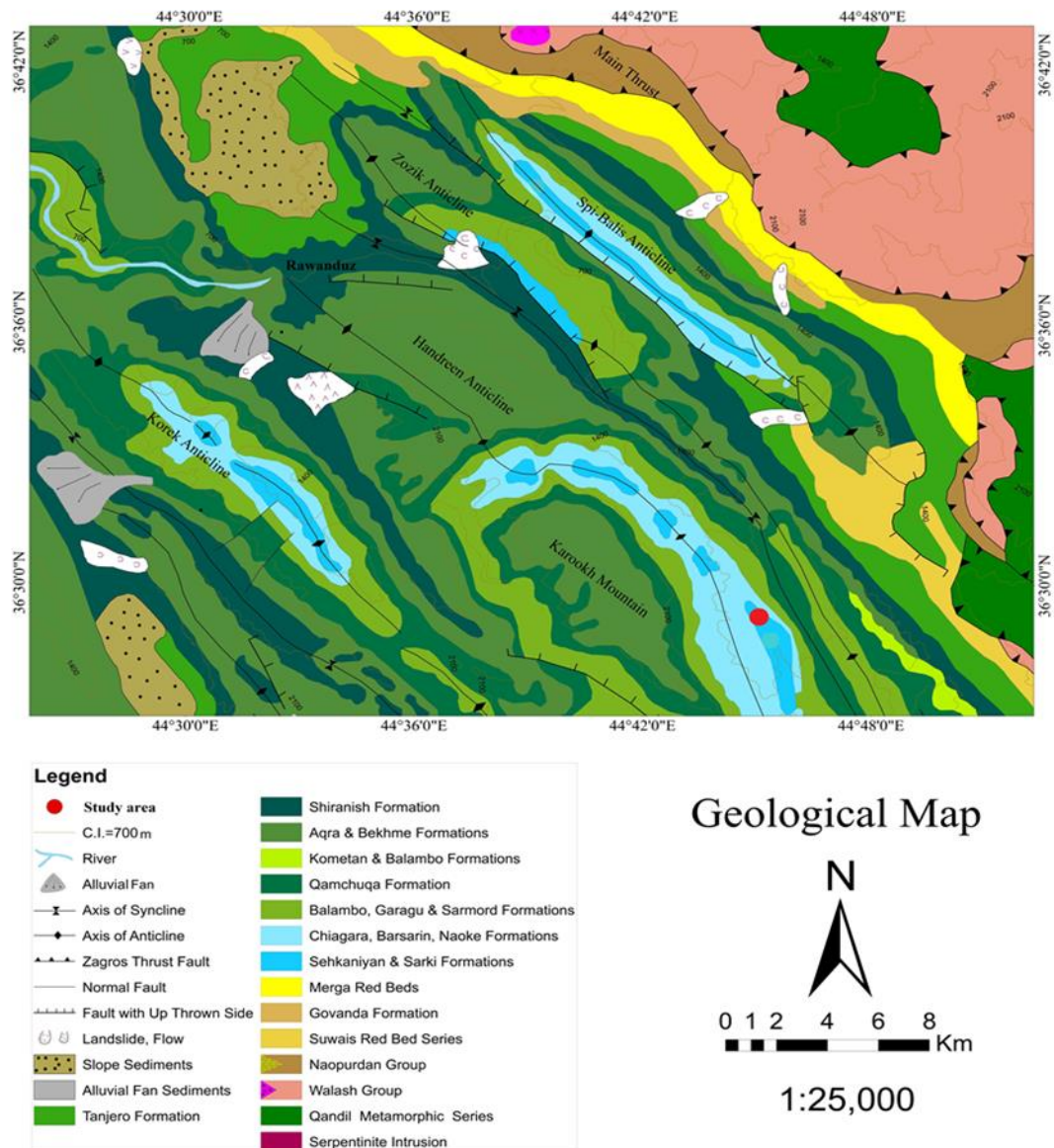


Figure 3: Geological map of the Warte area, after [15].

4. Results

4.1 Lithostratigraphy of Sehkanian Formation

Based on the detailed field work observations, the lithostratigraphy of the Sehkanian Formation is studied. In the studied area, the total thickness of Sehkanian Formation is 210 m, consists of dolomitic limestone, brecciated dolomitic limestone and dolostone with thin shale intercalations (Figure 4). The lower portion of the formation comprises of dark grey thick bedded dolomitic limestone and brown to dark brown brecciated dolomitic limestone (Figure 5a). Towards the middle portion of the formation grey to yellowish grey medium to thick bedded limestone and dark grey dolomitic limestone interbedded with thin bedded shale (Figure 5b). While, the upper portion of Sehkanian Formation consists of dark grey thick bedded dolostone, light grey thick bedded brecciated dolomitic limestone and massive dark grey dolomitic limestone (Figure 5c). The Sehkanian Formation in the Warte outcrop is underlain by the light grey medium to thick bedded dolomitic limestone of Lower Jurassic Sarki Formation with a gradational and conformable contacts (Figure 5a). Whereas, the dark grey

dolomitic limestones of Sargelu Formation are overlying it with a conformable and gradational contact too (Figure 5d).

4.2 Microfacies analysis

Depending on the petrographic constituents and according to Dunham [14] classification, six microfacies types (MF1- MF6) are recognized in the Sehkaniyan Formation. These microfacies types are categorized according to their environmental interpretations by comparing with the standard types of Flügel [16] and facies zones of Wilson [17] into three facies associations which indicating tidal flat, lagoon, and high energy shoal environments within the inner ramp setting (Table 1).

4.2.1 Tidal flat facies association

The tidal flat association refers into two marginal marine zones (supratidal and intertidal flats) [18]. It is occurred in lower and upper portions of the Sehkaniyan Formation. The facies forming approximately 30 m from the lower part and 90 m from the upper part of Sehkaniyan Formation. In the lower part the association comprises of medium to thick bedded dark grey dolomitic limestone-rich dolomudstone. Whereas, in the Upper part the Tidal flat association become thicker and composed of thick bedded dark grey dolomitic limestone and light grey thick bedded brecciated dolomitic limestone with presence of stromatolite- rich dolomudstone with stromatolitic boundstone underlying the Middle Jurassic Sargelu Formation.

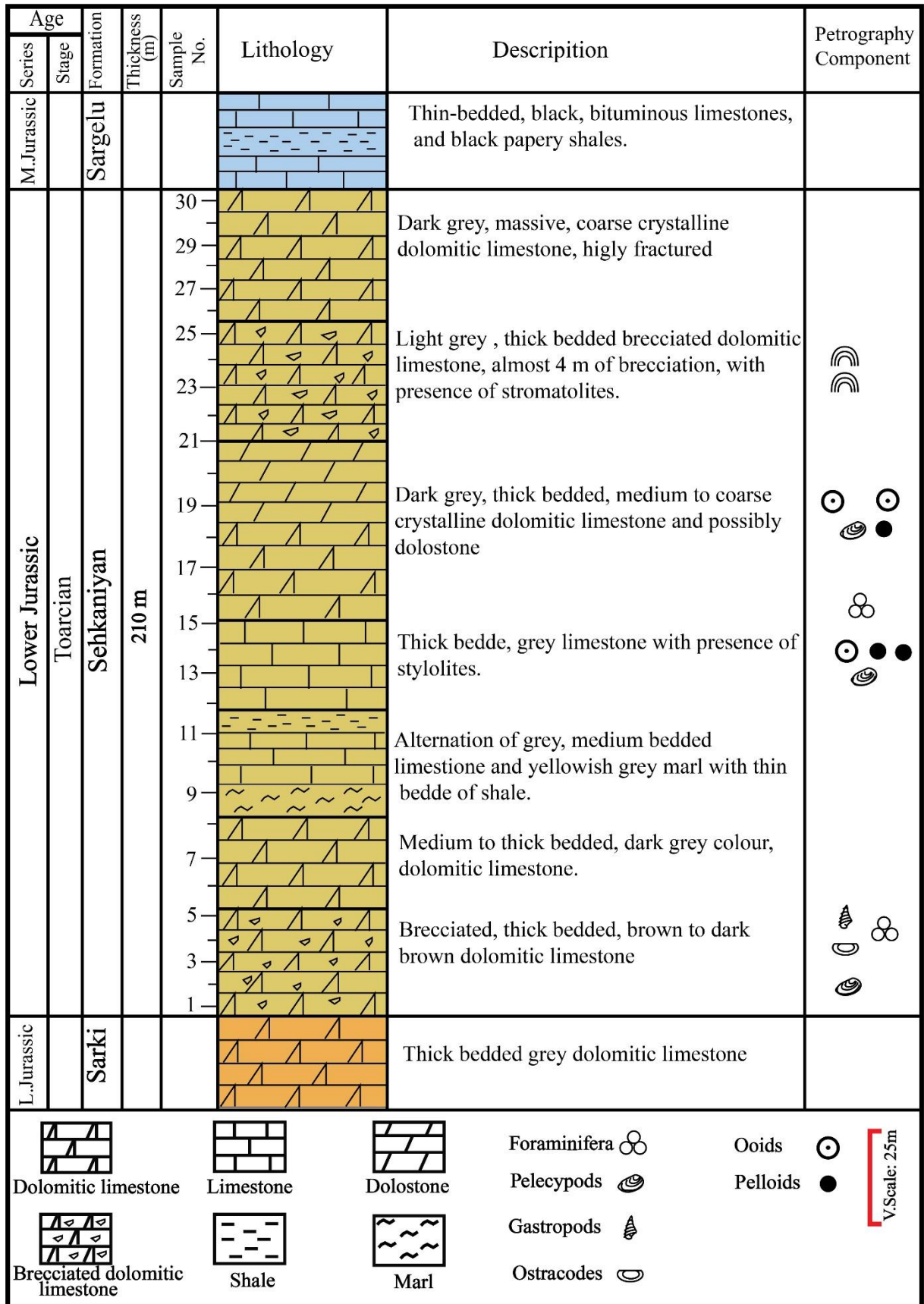


Figure 4: Columnar section of Lower Jurassic Sehkaniyan Formation in the Warte area, Imbricated Zone, NE -Iraq.

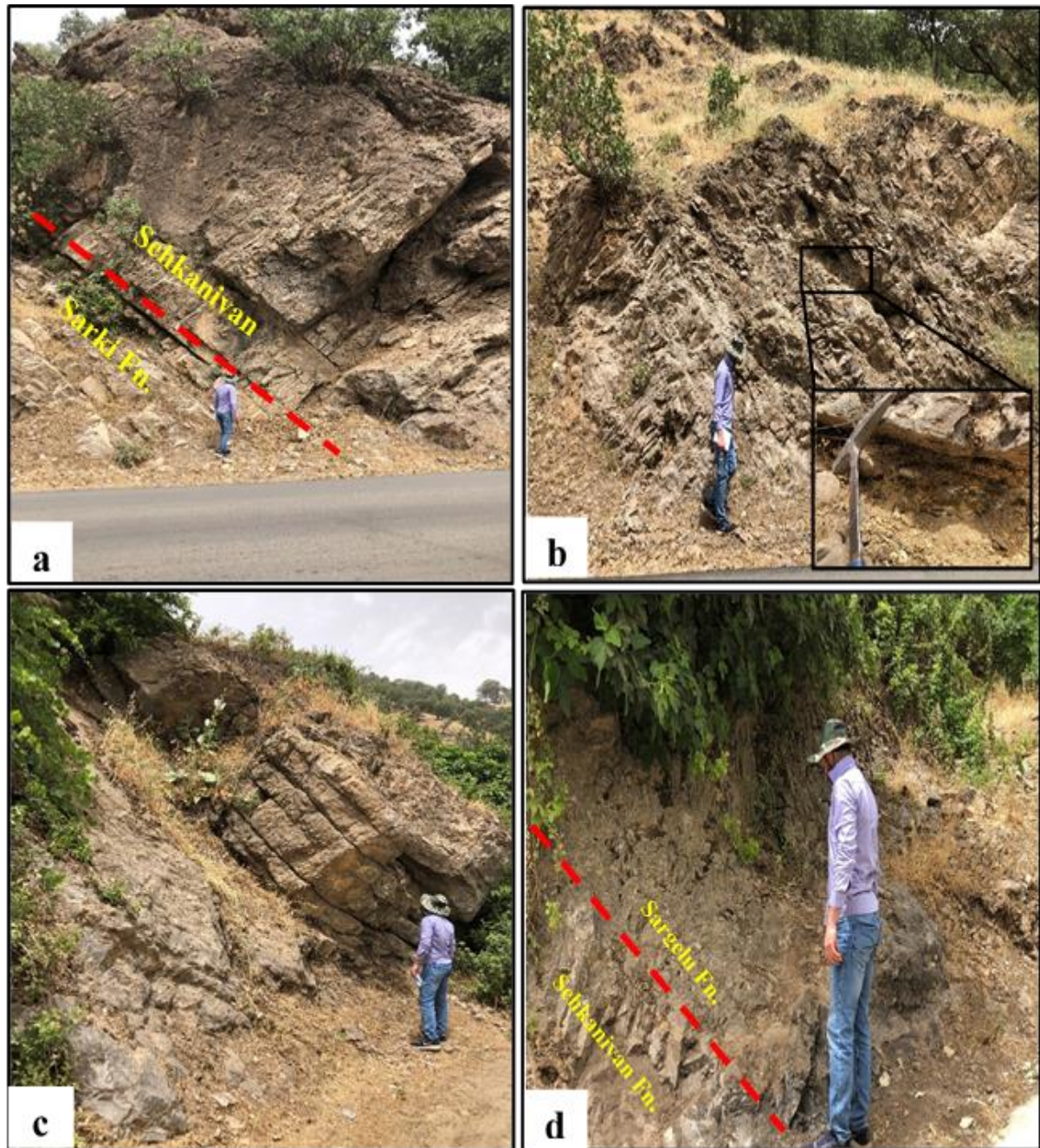


Figure 5: Field photographs displaying: (a) Lower contact of Sehkanliyan Formation with underlying Sarki Formation represented the dolomitic limestone and partly brecciated. (b) Middle unit of the Sehkanliyan Formation in shows the medium to thick bedded limestone and dark grey dolomitic limestone with thin bedded marl and shale. (c) Thick bedded dolostone, light grey thick bedded brecciated dolomitic limestone and massive dark grey dolomitic limestone from upper part. (d) Upper contact of Sehkanliyan Formation with Sargolu Formation and shows thick bedded dolostone, light grey thick bedded brecciated dolomitic limestone and massive dark grey dolomitic limestone.

A. Dolomudstone (MF1)

This microfacies contains very fine crystals of dolomite, ranging from (5-20 μ m) in size. Some veins are noticeable in different directions that were filled by calcite cement (Figure 6 a). The facies is characterized by recrystallization of dolomicrite into dolospirite. This microfacies belongs to standard microfacies (SMF22), represents peritidal zone of inner carbonate ramp [16].

B. Dolomitized stromatolitic boundstone (MF2)

In this facies, wavy lamination (stromatolite) is seen and most of the fibers are compacted together, have a lamina of millimeter in thickness (Figure 6, b). In addition, the facies also contain small amounts of skeletal fragments. Most of the spaces between layers are cement filled. The stromatolites and small number of skeletal fragments suggest an intertidal environment it [18]. This microfacies may belong to the standard microfacies type (SMF20), represented intertidal zone in the inner ramp environment [16].

4.2.2 Lagoon facies association

Lagoon association frequently forming lower and middle portions of the Sehkaniyan Formation. In the lower division it is 60m thick and comprises of thick bedded brown to dark brown dolomitic limestone and dark grey medium to thick bedded brecciated dolomitic limestone within bioclastic organic rich wackestone and packstone microfacies. On the other hand, In the middle part the association is 80m comprises of medium grey bedded limestone interbedded with thin marl and shale within the bioclastic wackestone/packstone and peloidal foraminiferal packstone facies.

A. Bioclastic wackestone /packstone (MF3)

The facies consist mainly of gastropod, bivalves, and ostracod clasts with organic rich micritic matrix within bioclastic wackestone and packstone microfacies (Figure 6, c). Different diagenetic processes affected the facies, these are dolomitization, micritization, and neomorphism. Some of skeletal bioclasts are highly micritized and indicate a low energy shallow lagoon environment. According to [16], this microfacies is similar to the (SMF9) and indicates a lagoon environment in an inner ramp shallow water carbonate and micritic matrix environment.

B. Peloidal- foraminiferal packstone (MF4)

In this facies peloids and foraminifera (*Textularia* sp and *Siphovalvulina* sp) are the main components that form the peloidal foraminiferal packstone microfacies (Figure 6, d). Most of peloids are moderate to well sorted. The bioclasts of the facies are subjected to micritization processes. [17], suggested the presence of peloids in a micritic groundmass, indicating the shallow subtidal (lagoonal) water with a slow sedimentation process. When comparing this microfacies with standard microfacies of [17], it is similar to (SMF16) that indicate a lagoon environment around the carbonate shoals [16].

4.2.3 High energy shoal facies association

It is observed in the middle portion of the formation. Its thickness is near to 20 m and comprises of thick bedded of limestone and dark grey thick bedded dolomitic limestone with thin bedded of shale. The facies characterized by it is richness in ooids, peloids and bioclasts forming the grainstone microfacies. This association included two microfacies types: Ooidal -peloidal grainstone and Ooidal grainstone

A. Peloidal- Ooidal grainstone (MF5)

The major constituents of it are micritized ooids range from (25-30%), peloids (20%) and bioclasts (10%). The ooids and peloids are well to moderately sorted and majority of ooids are micretized (Figure 6, e). The presence of ooids within the sparry calcite cement supposed its originated in a high energy shoal environment [17]. The ooidal-peloidal grainstone microfacies belongs to (SMF15) and represents a high energy shoal within an inner carbonate ramp setting [16].

B. Ooidal grainstone (MF6)

This microfacies is dominated by well sorted micritized ooids, with a proportion ranging between (70-75%). The spaces between the ooids are filled with the sparry calcite cement (Figure 6, f). According to [19], the oolitic grainstone formed in a high energy shoal because of the abundance of ooids and lack of micrite. The facies is similar to the (SMF29) and it is indicative of the high energy shoal environment [16].

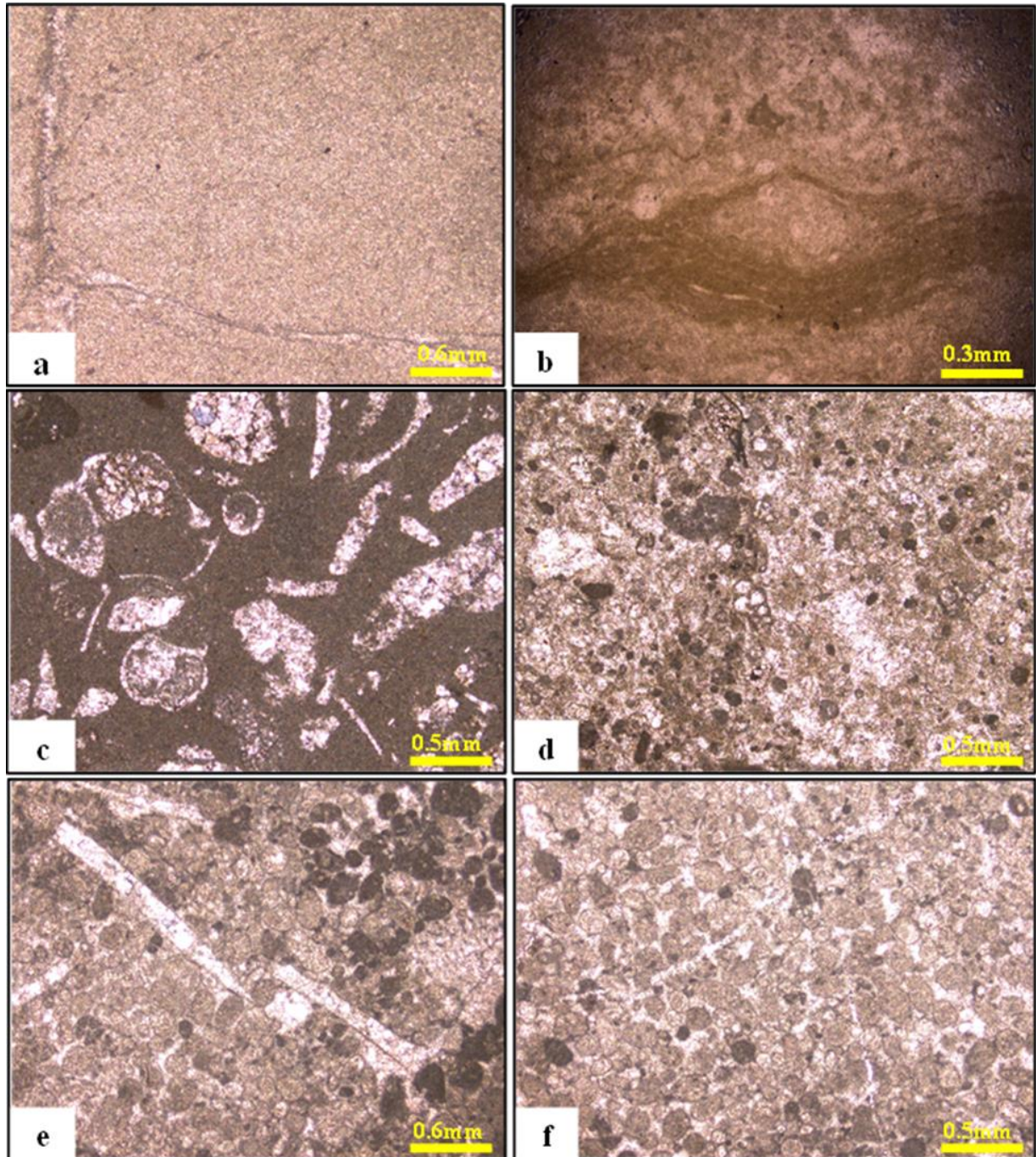


Figure 6: Photomicrographs of Sehkaniyan Formation: (a) Dolomudstone microfacies, which involves microcrystalline dolomite and dolomicrite. WS. 8, X.N. (b) Dolomitized stromatolitic boundstone, the voids are filled by different type of cements. WS. 23, P.P. (c) Bioclastic wackestone /packstone microfacies, main constituents are bivalve and gastropode in micrite groundmass. WS. 3, P.P. (d) Peloidal bioclastic packstone microfacies, the major component are peloids and foraminifera. WS.

11, P.P. (e) Peloidal ooidal grainstone microfacies, the main components are ooids and peloids with bioclast. WS. 18, P.P. (f) Ooidal grainstone microfacies, the sparry calcite cement is filled the pores between grains. WS. 22, P.P. WS: Warte- Sehkaniyan. P.P: plane polarized light. X.N: crossed Nichols.

Table 1: Facies associations and microfacies types of the Sehkaniyan Formation in the northern Iraq.

Facies association	Main Microfacies Dunham (1962)	Diagenesis processes+ Type of grains	Equivalenc e to SMF (Flugel, 2010)	Depositiona l environmen ts
Tidal flat facies association	Dolomudstone	- Dolomitization - Cementation	SMF 23	Tidal flat (Supratidal)
	Dolomitized stromatolitic boundstone	- Dolomitization - Cementation	SMF 20	Tidal flat (Intratidal)
Lagoon facies association	Bioclastic wackestone /packstone	- Dolomitization - Bivalve+Ostracod +Gastropod	SMF 9	Lagoon
	Peloidal- foraminiferal packstone	- Dolomitization - Cementation - Micritization - Peloid+ Foraminifera	SMF 16	Lagoon
High energy shoal facies association	Peloidal ooidal grainstone	- Dolomitization - Cementation -Micritization -Ooid+Peloid	SMF 15	Shoal
	Ooidal grainstone	- Cementation -Micritization -Ooid	SMF 17	Shoal

4.3 Depositional environment

The Lower Jurassic of Northern Iraq is represented by the Sehkaniyan and the underlying Sarki formations. The Sehkaniyan Formation is part of the Arabian Plate 6 (AP6) tectonostratographic megasequence, started from the upper Permian to the middle Jurassic [7], and deposited during Sinemurian to Aalenian sub cycle. The cycle started with the significant regional widespread transgression throughout the country, associated with Upper Triassic next stage Neo- Tethys openings, which marked the formation of an intrashelf basin towards the northern part of Iraq. There is a progressive environmental shift from the tidal flat, lagoon and carbonate shoal as an indicated by the vertical and lateral relations of the sedimentary facies and their concluded depositional settings. According to the sedimentary facies' distribution, the Lower Jurassic Sehkaniyan Formation has been

showed that it deposited in a broad range of depositional environments (tidal flat environment which represent both supratidal and intertidal zones [18], lagoonal environment and carbonate shoals in an inner ramp setting [20]. According to the [19] classification, the sequences of the Sehkaniyan Formation are interpreted as accretions on the inner part of a homoclinal carbonate ramp model. The study does not involve facies associated with rimmed carbonate shelves, such as reefs, slope breaks, off-shore slope deposits, slumping apron, and deep marine facies [21, 19]. In the present study, the inner ramp depositional setting comprises the tidal flat, lagoon and high energy shoal settings. In support of this view, three environmental indicator facies associations are determined depending on the microfacies analysis of the Sehkaniyan Formation (Figure 7).

First: The tidal flat facies deposited with 20 m of thin, medium to thick bedded dark grey dolomitic limestone-rich with dolomudstone covered the underlying lagoonal sediments in the lower part of the studied formation. Tidal flat association (MF1-MF2) distinguish by existence of rhombic dolomites, no allochems and presence of the stromatolites, which indicate deposition in an inner carbonate ramp setting progressed pursuant to arid to semiarid circumstances [17, 21].

Second: Thick lagoonal facies of medium grey bedded limestone with thin bedded of marl and shale within the bioclastic wackestone/packstone and peloidal foraminiferal packstone facies passed to thin high energy shoal sediments rich in ooids and peloidals deposited within the inner ramp environment. A lagoonal facies association (MF3-MF4) categorized by the presence of the specific lagoonal indicator grains such as benthic foraminifera, gastropods and peloids. The presence of micritic matrix indicates the sedimentation occurred in the restricted lagoon and windward side of shoal environment [19, 16, 22].

Third: High energy shoal association (MF5-MF6); there are several attributes of the shoal facies in an inner ramp setting including grain-dominated facies and absence of micrite matrix. In which the grains particularly ooids and peloids deposited in the high-energy zones [21, 19].

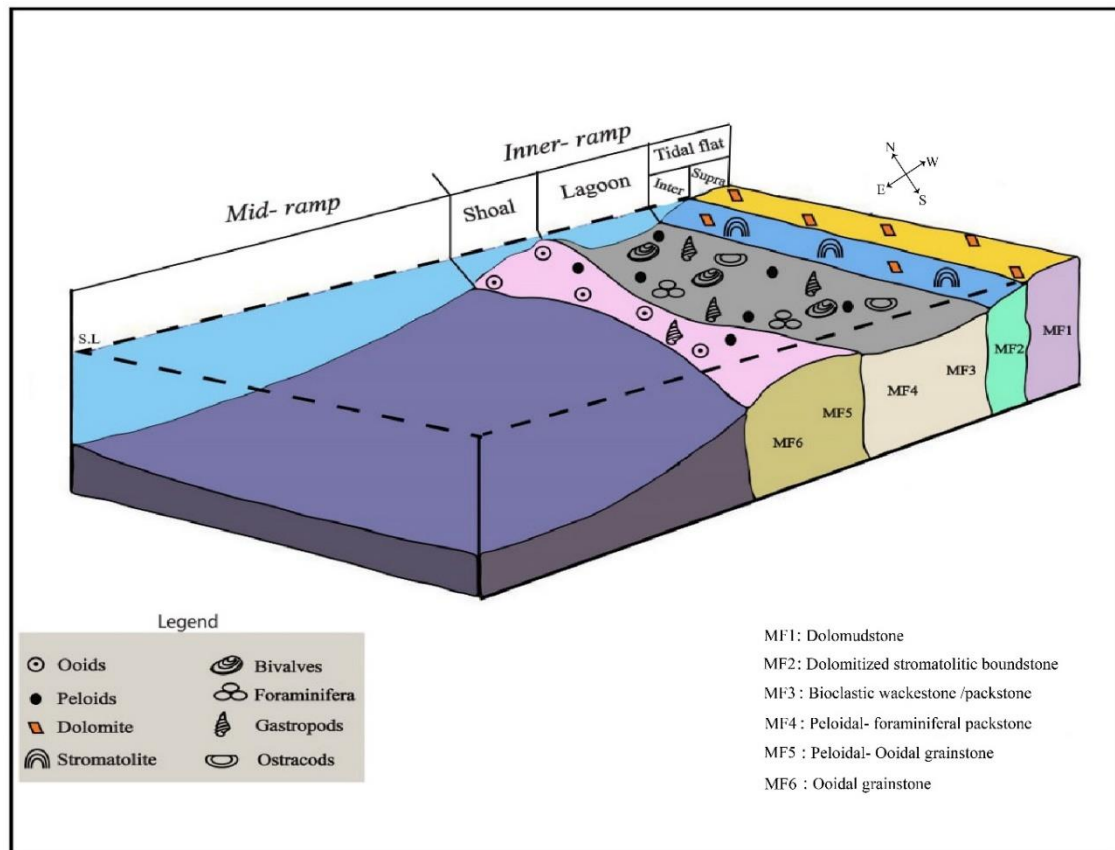


Figure 7: Depositional model of Lower Jurassic Sehkaniyan Formation, NE- Iraq, Kurdistan region.

5. Conclusions

1. The Lower Jurassic Sehkaniyan Formation in the northern Iraq composed of 210 meters of dolomitic, brecciated dolomitic limestone, limestone and dolostones with thin shale intercalations.
2. Based on the field observations, the Sehkaniyan Formation in the studied area was divided into three parts; the lower part consists of dark grey thick bedded dolomitic limestone and brown to dark brown brecciated dolomitic limestone. The middle part comprised of grey to yellowish grey, medium to thick bedded limestone and dark grey dolomitic limestone intercalated with thin bedded shale. While the upper part consists of dark grey thick bedded dolostone, light grey thick bedded brecciated dolomitic limestone and massive dark grey dolomitic limestone.
3. The Sehkaniyan Formation in the studied section is overlain the Lower Jurassic Sarki Formation and underlain the Middle Jurassic Sargelu Formation with a conformable and gradational contacts.
4. Three different main microfacies observed in the Sehkaniyan Formation: lime mudstone, lime wackestone, and lime packstone.
5. Facies analysis of Sehkaniyan Formation established an assemblage of the facies associations, which was accumulated in the tidal flat, lagoon and shoal environments within the inner homoclinal ramp setting.

Authors Contribution

ISA conducted result interpretation and contributed ideas to improve the paper. BAD and SMB wrote the whole manuscript, and GFH contributed to critically reviewing the manuscript.

Conflict of interest

The authors declare no competing interests.

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