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Carbonate Sequence stratigraphy of Turonian Wadi Es Sir Formation in Irbid, north Jordan

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Abstract

This study investigates the Sequence stratigraphy and depositional environment of Wadi Es Sir Formation (Turonian) in Irbid City. The Wadi Es Sir Formation consists of thick bedded to massive limestone, dolomitic limestone and dolomite. Based on Petrographic study Eight facies wreeidentified in the studied sections These are mudstone, gastropoda peloidal packstone, algal-lithoclast wackestone to packstone, peloidal foraminifera wackestone to packstone, bioclastic wackestone to packstone foraminifera wackestone, rudist framestone and pelletal grainstone. These facies weredeposited on the followingenvironments: restricted marine, shallow open marine and shoal environments.Sequence stratigraphystudy in Wadi Es Sir Formation identified forth-order cycles which are asymmetrical and consist of transgressive systems tract (TST) represented by shallow open marine and sometime shoal facies, followed by highstand systems tract (HST) represented by restricted marine facies. They are bounded below by a transgressive surface (Ts) and above by marine flooding surface (mfs). They represent successive episodes of relative sea level rise and stillstands. The nature of these cycles (composition and symmetry) reflects the combined effect of local tectonics and eustasy.

Keywords: *Sequence stratigraphy, Microfacies, Wadi Es Sir Formation, Irbid*

1. Introduction

The Upper Cretaceous rocks in Jordan represent 60% of the sediments consists of limestone and marl (Abed 1982). Their thickness increase extremely north, south-southeast wards wards (Khoury and Khalili 1986).These rocks are of great economic value since it contains many good aquifers, as well as the phosphate deposits which are considered to be the most 353 natural resource in Jordan. Consequently this succession attracted the attention of many workers (Abed and Amireh 1999; Abed et al. 2005; Powell and Moh 2012; Ghasem Shirazi et al. 2014a). Quennel (1951) subdivided the Upper Cretaceous into Ajlun and Belqa series. These have been subdivided into subunits (Masri 1963), which has been selected to this study and exposed in northern Jordan. Throughout Jordan WadiEs Sir limestone represents the uppermost of the Ajlun Group Formation (Powell 1988), and was named massive limestone by Bender (1974).

WadiEs Sir Formation can be used as index horizon during geological survey. It consists of well bedded massive limestone, dolomitic limestone and dolomite, locally white intercalated beds of gypsum and chert-nodules (Powell 1989). The limestone is mostly shelly wackestone, occasionally with ooids, peloids and partially dolomitized (Powell 1989).

This study has been conducted to reconstructof depositional environment and sequence development of WadiEs Sir Formation in North Jordan.

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2. Geological setting

Sections investigated in the present study are exposed in north Jordan near Irbid city. The first section is at WadiSammu and was measured in detail in 32°30'N, 35°42' E, and the second section in Wadi Al Husn and was measured in detail in 32° 26' N, 35°51' E. (Fig1). At the beginning of the Cretaceous, particularly during early Cenomanian marine transgression left a large part of Jordan scene for carbonate production and deposition (Bender 1974). This major transgression can be traced wide over the Mediterranean area (Sharland et al. 2001; Salari and Yazdi 2017).This carbonate deposition continued from the Cenomanian to the Eocene with thickness of more than 1000 m. in North Jordan and decreasing towards south and southeast (Powell 1989; Abed 2000; Powell and Moh 2012; Jehangir Khan et al. 2021). Throughout the Middle East during Turonian shallow eperic sea covered wide carbonate platform which was delimited on the NW by so called "Hing Line" and on the NE by the geosynclines occurring in the area of Iraq-Iran border (Moh'd 1985) (Fig 2).

Turonian age represented by limestone, dolomitic limestone, marl and their combination biohermal, rudist buildups is common (Yasin 1992; Ghasem Shirazi et al. 2014b). It has been assigned to the Wadi Es Sir Formation on the presence of Foraminifera (Basha 1978). The Wadi Es Sir Formation was deposited on a wide carbonate platform extended from near present Mediterranean coastline of Ras En naqab north-northeast of Zakimat Al Hasah (Powell 1989).

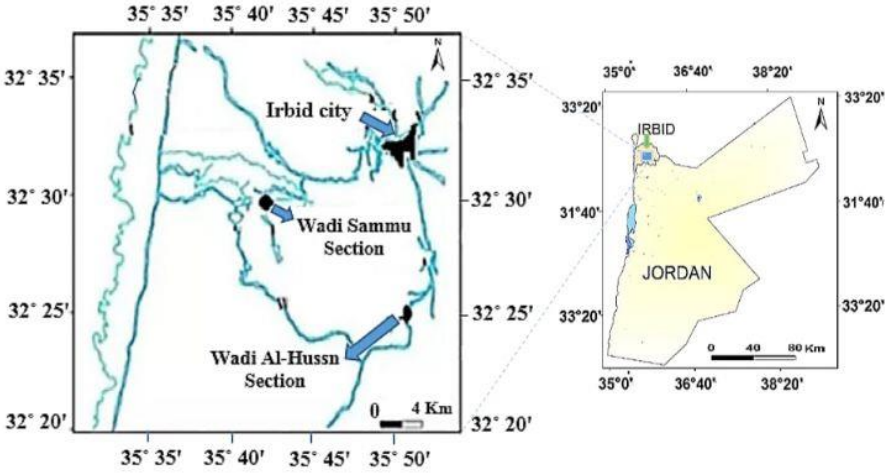

Fig 1. Location map of study area

The formation boundaries are conformable with the overlying Shueib Formation consisting of limestone interbedded with shale deposited in restricted marine shelf lagoon and the underlying Ghurdan Formation (mostly Coniacian) which composed of chalky limestone of deep water deposits (Bandel and Salameh 2013). The area has tectonically evolved in a long time of deformation phases. The tectonic history started during late Paleozoic-early Mesozoic time that led to the development of the Eastern Mediterranean basin and its associated passive margins, followed by a sequence of rifting and subsidence. Then, the convergence between Eurasia and Afro-Arabia occurred in the late Mesozoic (Garfunkel 1998).

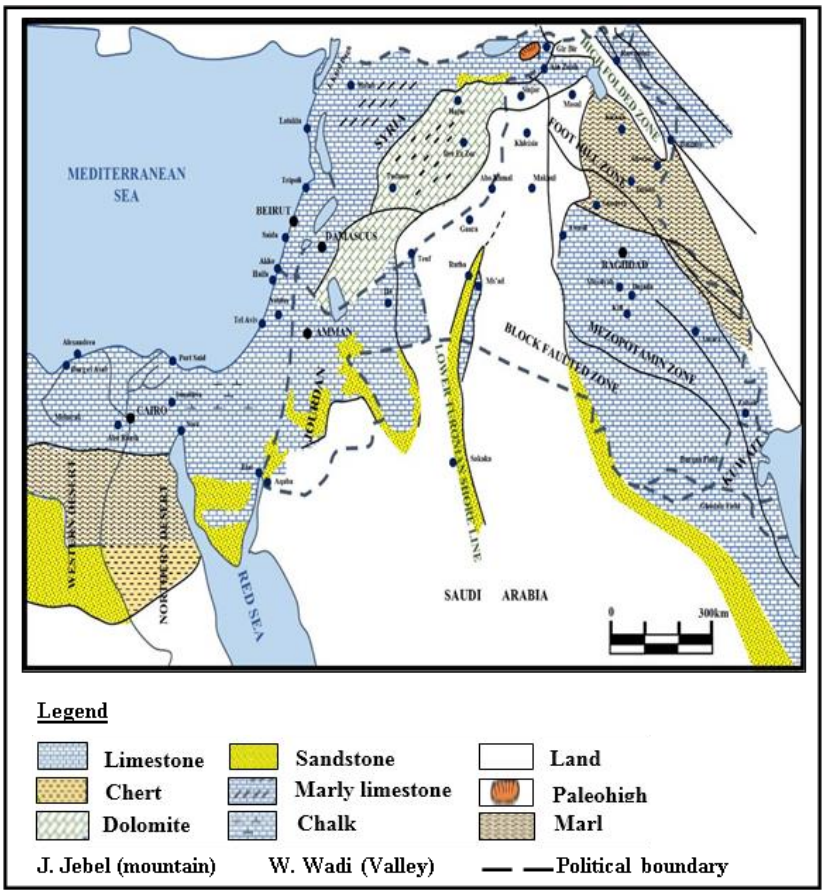

Fig 2. Paleogeographic map of Turonian in the Middle East (modified after Moh'd 1985)

3. Methodology

The present study is based on 62 thin sections representing WadiEs Sir Formation, were selected from collected samples and stained using Alizarin red S (Dickson 1966). Petrographic studies were carried out for facies analysis and pale environmental reconstruction of Wadi Es Sir Formation. Sequence stratigraphy of studied interval was interpreted by analyzing the facies proposed by Wilson (1975) and Flugel (2010). Sequence boundaries were delineated by using sequence stratigraphic techniques based on marine flooding surface (Haq et al. 1988; Sarg 1988; Van wagner et al. 1990; Handford and Loucks 1993; Emery and Mayers 1996).

4. Microfacies analysis and depositional environment

Microfacies analysis of Wadi Sir Formation reflects three different facies association which are restricted marine, shallow open marine and shoal environments.

4.1. Restricted marine environment

4.1.1. Mudstones

This microfacies is pure or occasionally fossiliferous and peloidal mudstone. Bioclasts are from ostracods and foraminifera shells. This facies comprise 20% of the total thickness of the studied sections. Pure mudstone appears in the upper part of the studied sections. This microfacies assigned to standard microfacies type (SMF) No. 23 and facies belt 8. These mudstones are later bedded with dolomite which is light to dark grey coloured hard to very hard, microcrystalline and massive. In thin section dolomite occur in the form of rhombs 15-25%mm. in diameter (plate1.A).

4.1.2. Shallow open marineenvironment

Five microfacies are associated with this environment:

4.1.2.1. Gastropodapeloidalpackstone

This microfacies is only restricted to a few thin beds (2.5 m) in Sammu section. Gastropoda dominated the skeletal components of this facies (plate1. B), but other types of grains like foraminifera (milliolida) and ostracoda skeletons are present. Milliolida tests are often completely micritized and their structure is damaged and can be hard differentiated from peloids. In general peloids in this facies are well sorted have size ranging from 0.1 to 0.7 mm, they are mostly spherical to oval in shape. These clasts are usually embedded in sparry calcite cement. This microfacies assigned to standard microfacies type (SMF) No. 19 and facies belt 8.

4.1.2.2. Peloidal, foraminifera wackestone to packstone

This is a very important facies, since it comprises between 20 to 30% of the total thickness of Wadi Sir Formation in study area. In the field this microfacies forms thick bedded microcrystalline limestone while under microscope it characterized by great abundance of foraminifera (milliolida and rotalida) and peloids (plate 1.C). In general peloids are medium to well sorted mostly elliptical to spherical shaped and grain size ranging from 0, 05 to 0. 4 mm. Most of peloids are fecal pellets in origin. Milliolida are often completely micritized and cannot be differentiated from peloids. Echinoderm, molluscan fragments and sponge speicules are also present. Due to micritization process the fossils are not well preserved. This microfacies assigned to standard microfacies type (SMF) no. 9 and facies belt 7.

4.1.2.3. Algal-lithoclast wackestone to packstone

This microfacies is characterized by the great abundance of coralline algae, green algae and blue green algae (plate1.D) with other kind of fossils mostly small benthic foraminifera (milliolida) which are often completely micritized and ostracoda filled with blocky calcite, the remaining carbonate components consist of intraclast and peloids. This microfacies assigned to standard microfacies type (SMF) No. 12 and facies belt 6.

4.1.2.4. Foraminifera wackestone

This is occur spastically in all studied section, it comprises 15-30 % of the total thickness of Wadi Sir Formation and it composed to about 10-20 % of grains embedded in micritic groundmass. The grains consist of entirely of fossils dominated by foraminifera (plate 1.E) beside few ostracoda, molluscan fragments. The fossils are mostly filled with sparry calcite cement but micrite filling was also observed. This microfacies assigned to standard microfacies type (SMF) no. 19 and facies belt 8.

4.1.2.5. Bioclastic wackestone to packstone

It consists of angular to rounded mainly fragmented skeletons. Bioclasts are gastropoda, echinoderms, ostracoda and small benthic foraminifera, these bioclasts are embedded in micrite matrix (plate 1.F, G). This microfacies assigned to standard microfacies type (SMF) no. 9 and facies belt 7.

4.1.3. Shoalenvironment

4.1.3.1. Rudistedframestone

It is only restricted to the upper part of Sammu section and characterized by brownish colour in the field. However, in this section this facies consist of large shell fragment of rudists, most of them are many millimeters in length and characterized by lamellar structure (plate1.H). These rudists are partially silicified. This microfacies assigned to standard microfacies type (SMF) no. 7 and facies belt 5.

4.1.3.2 .Pelletalgrainstone

This microfacies consists mainly of equal sized (0.1 mm), well sorted pellets. Bioclaste of ostracoda, molluscan fragments and echinodermsare present as a minor constituent's matrix of this facies consists of micrite, microsparite and sparite within voids. This microfacies assigned to standard microfacies type (SMF) No. 16 and facies belt 7 and 8.

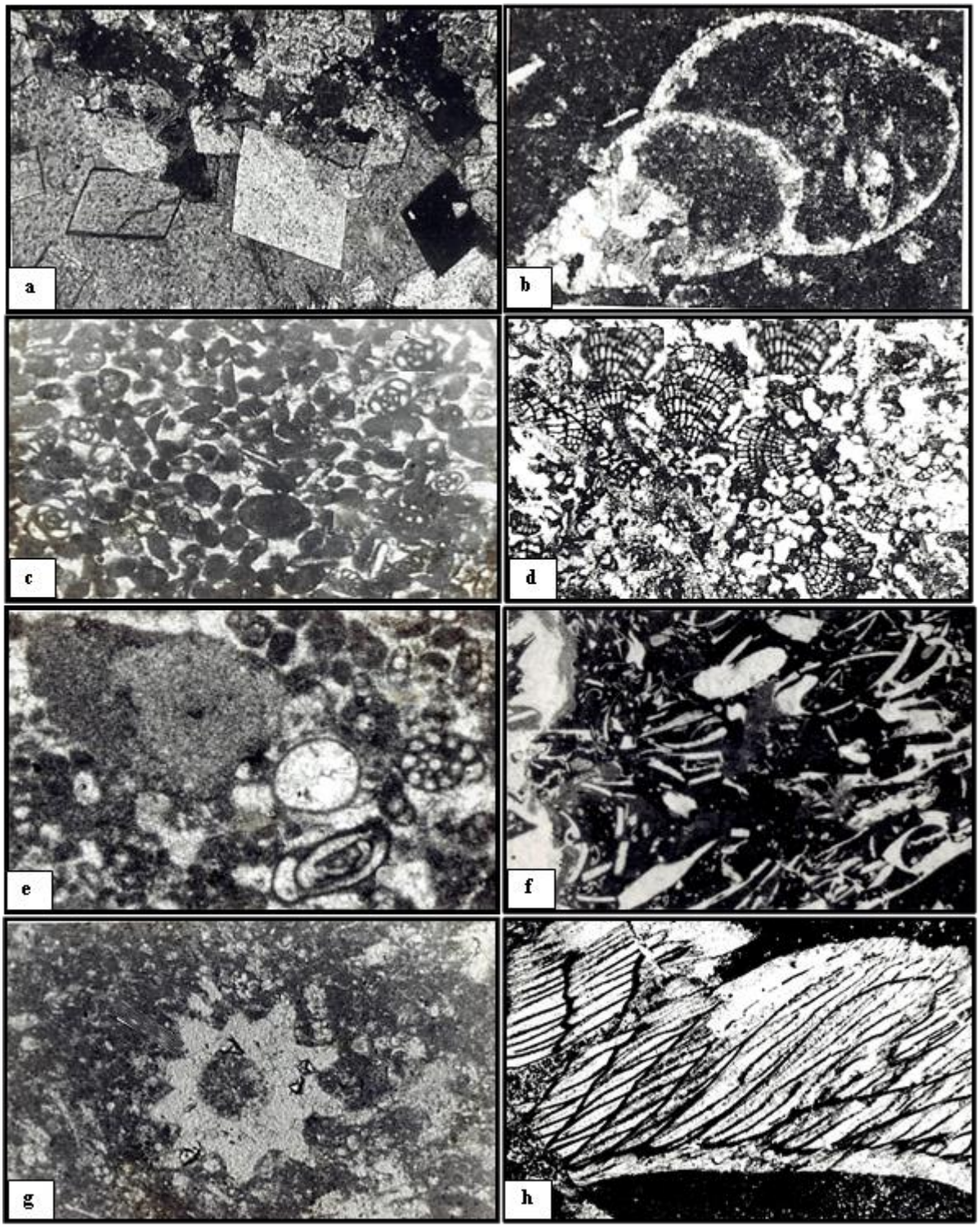

Plate 1
a: Rhombohedral form of dolomite 15-25% mm.in diameter; PPL: X4.
b: Gastropoda peloidal packstone; PPL; X6.
c:Foraminifera peloidal packstone. Peloids and intraclast around miliolids (1); PPL;X25. d:Algal lithoclastic wackestone to packstone; PPL; X25. e:Small benthic foraminifera, miliolids, rotaliids, and intraclasts, PPL: X40.
f: Bioclasts of molluscan shells, echinoderms and ostracods; PPL; X12.
g: Echinoid-spines; PPL: X25
h:Rudest with cross lamellar microstructure; PPL; X6.

5. Sequence stratigraphy

The studied succession consist of five 4th order cycles, the uppermost cycle is incomplete. These cycles are generally asymmetrical and consist of transgressive systems tract (TST) represented by shallow open marine and sometime shoal facies, followed by highstand systems tract (HST) represented by restricted marine facies. They are bounded below by a transgressive surface (Ts) and above by marine flooding (mf). They represent successive episodes of relative sea level rise and stillstands. The combined effect of local tectonics and eustasy reflect the nature of these cycles (composition and symmetry). The first is 12.7 meters thick, the TST system tract is approximately 11 meters thick consisting of lime mudstone in the lower part overlain by foraminifera peloidal wackestone to Packstone representingshallow open marine environment, followed by shoal deposits of peloidal packstone facies in Wadi Al Husn section (Fig 3). The (HST) of this cycle with a thickness of about 1.5 meters is made of mudstone facies representing restricted marine environment. In Wadi Sammu section (Fig 4) the first cycle begins with 5.6 meters of (TST) systems tract of gastropoda peloidal packstone facies followed by mudstone to wackestone facies and peloidal foraminifera wackestone to packstone facies which represent shallow open marine environment.

This is followed by HST of restricted marine environment which consist of alternating dolomite and mudstone facies of 9.6 meters thick. The second cycle is asymmetrical and begins in Wadi Al Husn section with 1.5 meters of Peloidal Foraminifera Wackestone to Packstone facies representing TST, followed by an HST of restricted marine environment. In the second section this cycle begins with 1.0 meter of Bioclastic Wackestone to Packstone overlain by Mudstone facies of restricted marine environment with 6.5 meters thickness. The third cycle is about 2.2 meters in Wadi Al Husn section (Fig 3) and started with 1.6 meter (TST) of shallow open marine environment, followed by 0.5 meter (HST) mudstone. This cycle in wadi Summa section (Fig 4) is 7.3 meters in which (TST) facies are approximately 0.6 meter and made mostly of Bioclastic wackestone to packstone microfacies.

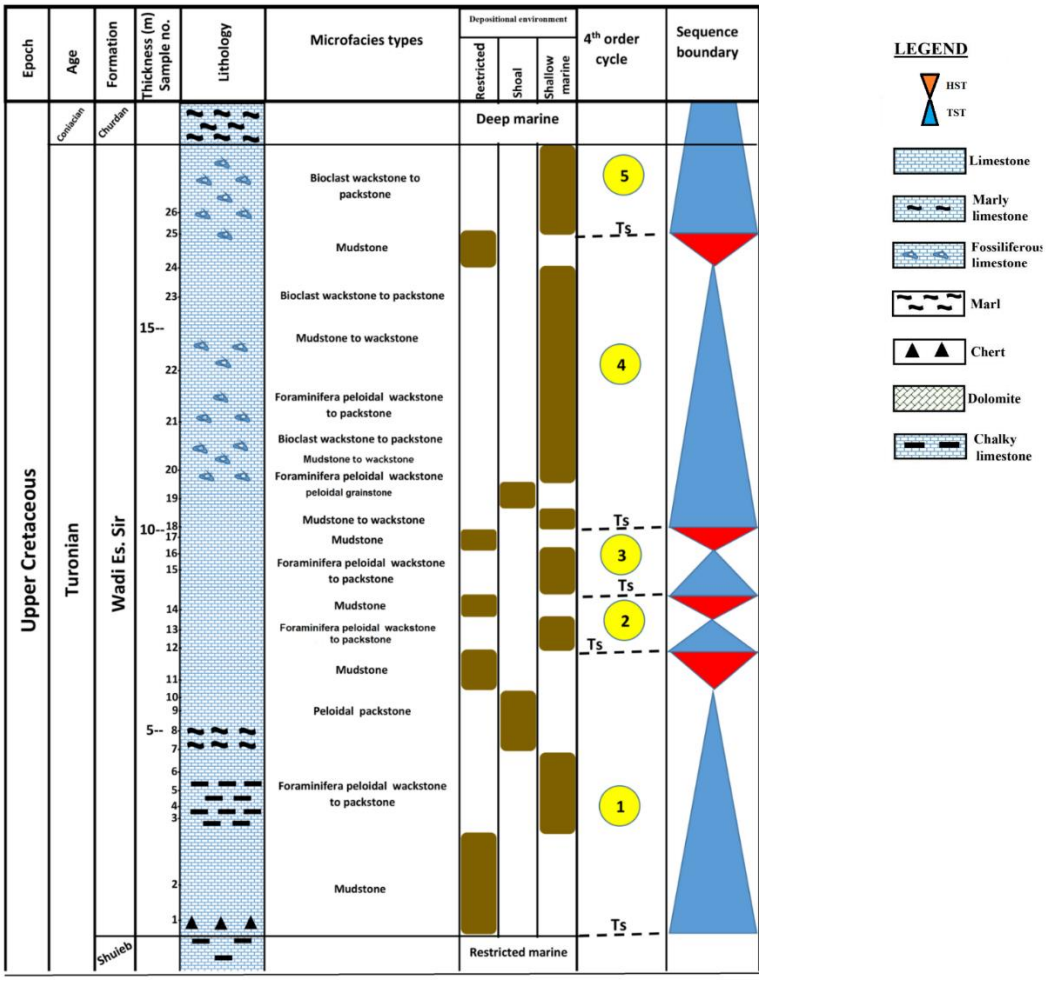

Fig3. Sequence stratigraphy and depositional environment of Wadi El-Husn section

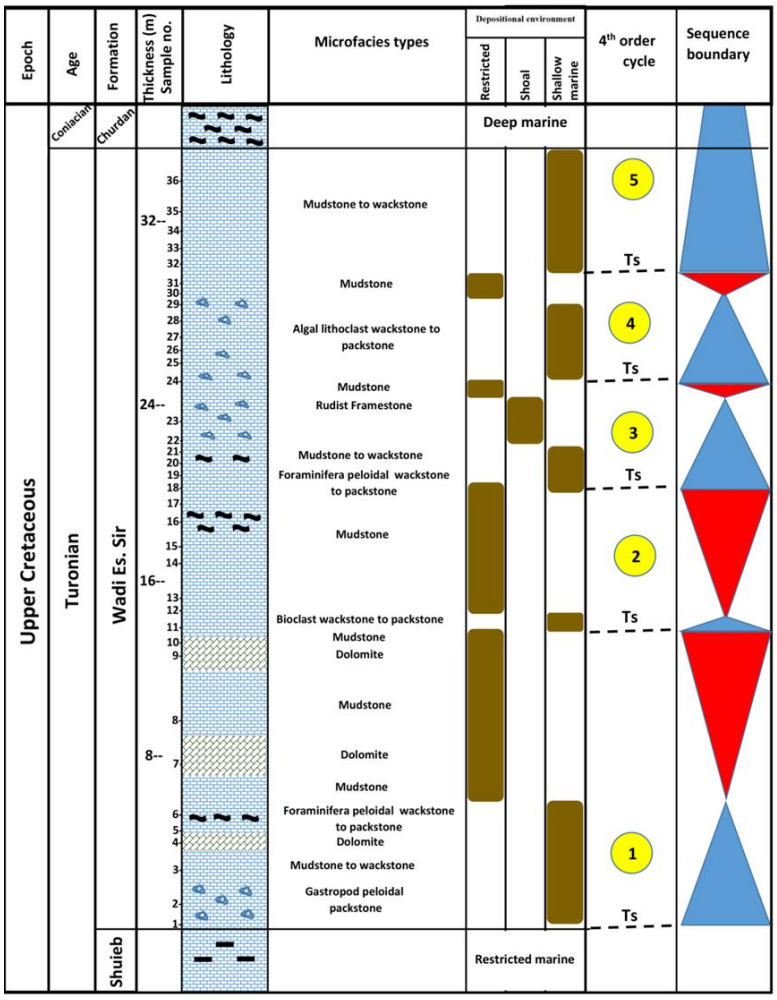

Fig 4. Sequence stratigraphy and depositional environment of Wadi Summa section

The thickness of (HST) of this sequence cycle is 6.7 meters deposited in restricted marine environment.

The fourth cycle in Wadi Al Husn section with a thickness of 13.5 meters includes (TST) and (HST). The (TST) is with thickness of 12 meters and consist of mudstone to wackestone, followed by shoal facies represented by peloidal packstone. This is followed by alternating peloidal Foraminifera wackestone to packstone, mudstone to wackestone and bioclastic wackestone to packstone of shallow open marine environment. It is overlain by 1.5 meters of HST restricted marine mudstone. The fifth cycle is incomplete and consists of shallow open marine bioclastic wackestone to packstone of (TST). In wadi Summa, this cycle begins with 3.5 meters of (TST) of algal lithoclast wackestone to Packstone deposit in shallow open marine. Overlain by 1.5 meters of (HST) facies, this cycle is followed by 8 meters of (TST) mudstone to wackestone facies of (TST) fifth cycle.

6. Conclusion

The Wadi Sir Formation in North Jordan (Irbid) consists of well bedded limestone, dolomitic limestone, and dolomite. Eight microfacies types were recognized including mudstone, gastropoda peloidal packstone, algal-lithoclast wackestone to packstone, peloidal foraminifera wackestone to packstone, bioclastic wackestone to packstone foraminifer wackestone, rudist framestone and pelletal grainstone. The depositional environment of Wadi Es Sir succession ranging from restricted marine, shallow open marine, and shoal environments.

Wadi Es Sir Formation represents successive episodes of relative sea level rise and stillstands. In this study five forth order cycles were identified, generally asymmetrical consist of transgressive systems tract (TST) represented by shallow open marine and sometime shoal facies, followed by highstand systems tract (HST represented by restricted marine facies. It is bounded below by a transgressive surface (Ts) and above by marine flooding (mf). The combined effect of local tectonics and eustasy reflect the nature of these cycles (composition and symmetry).

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