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Facies, sedimentary environments and sequence stratigraphy of Cretaceous deposits in the northwest of Azerbaijan, Iran

Rahim Mahari*[1], Rahim Shabanian[2], Farahnaz Reihani[2], Hamideh Shetabifard[2], Somaieh Sadigh Janbahan[1]

1. Department of Geology, Tabriz Branch, Islamic Azad University, Tabriz, Iran.
2. Department of Geology, Payam noor University of Tabriz, Tabriz, Iran.

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Abstract

The Cretaceous deposits in Morakan, located in the northeast of Khoy, a town in western Azerbaijan province, Iran, are primarily made up of carbonate rocks. These deposits, which are of 717 meters thick, lie on the clastic facies of Jurassic and are covered with beneath the pelagic beds of the Upper Cretaceous. To investigate the facies, sedimentary environment and sequential stratigraphy of these successions, a stratigraphic section was made in the south of Morakan village. Carbonate facies in this section have deposited in open marine, bar, lagoon, and tidal flat facies belts. The study of these facies and comparing them with old and modern sedimentary environments reveals that these succes-sions have deposited in a carbonated platform of rimmed shelf type. The study of the vertical succes-sion of microfacies shows four main sequences in the form of system tracts of TST and HST, which are made up of shallowing and deepening parasequences. The first lower boundary of the sequences is the type SB1 unconformity, and other identified sequences are the type SB2 unconformity.

Keywords: *Cretaceous; sequence stratigraphy; microfacies; sedimentary environments; Azerbaijan*

1. Introduction

The term 'Cretaceous' originates from the chalk deposits of northern Europe. With an age of 75 million years, it is the longest period in Mesozoic. In Iran, the boundary between Jurassic and Cretaceous has not been precisely specified, but recent findings suggest that unlike the existing beliefs, in many parts of Iran, the boundary of Tithonian (the Upper Jurassic) and Berriasian stages (the Lower Cretaceous) is gradual and is deep environment type (Aghanabati 2006). The *Orbitolina* limestone is the most typical layers of the lower Cretaceous of Iran, which is distributed in Alborz, Kopet-Dagh, Central Iran, and Zagros Mounts. The deposits of the upper Cretaceous of Iran do not have the same facies features, and it seems that, unlike the identical sedimentary conditions of the lower Cretaceous, the sedimentary basins of the upper Cretaceous were separate from each other, and each has been affected by specific conditions (Aghanabati 2006). The diversity of the upper Cretaceous facies is also seen in north east of Iran. The study of this diversity at different parts of the area will be of great importance in the development of a basic knowledge for the interpretation of paleogeography.

2. Geographical position of study area

The study cross section is located at latitude 38°41′67″N, and longitude 44°43′32″E. It is situated in the south of Morakan village, northeast of Khoy, a town in the western Azerbaijan province, NW Iran (Fig 1).

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*Corresponding author.
E-mail address (es): mahari@iaut.ac.ir

3. Methodology

In this research, in order to identify facies and their vertical and horizontal changes, some field studies were carried out. Having chosen an appropriate cross-section in a direction that the lower and upper boundaries of layers were discernable, measuring and sampling were carried out in an intersecting to the layers strike. From the collected samples, 160 thin sections were prepared and surveyed under microscopic examination. Finally, using Dunham method (Dunham 1962; Wright 1992), the rocks were labeled, and to interpret the facies as well as to present a sedimentary model and stratigraphic sequence, the methods developed by Wilson (1975), Flugel (1982, 2004, 2010), Reading (2009) and Lasemi (1995).

4. Lithostratigraphy

The sample cross-section is of 717 meters thick. The Cretaceous successions in the stratigraphical section in Morakan are placed with the disconformity between the clastic sediments of the Lower Jurassic, and at the top, are covered by medium to thin-bedded pelagic limestones of the Upper Cretaceous (Fig 2). The Cretaceous succession in the stratigraphic section of Morakan includes a considerably thick layer of marine sediments. These sediments, in the lower part, start with alternation of thin-bedded limestone and marl, and in the middle part, include cream to gray, thick –bedded rudist limestone, and the final part of these layers culminates in the alternate flish-like clastic - marine deposits. The topmost part of the Cretaceous layers includes pelagic limestone with a regular layer structure (Fig 3).

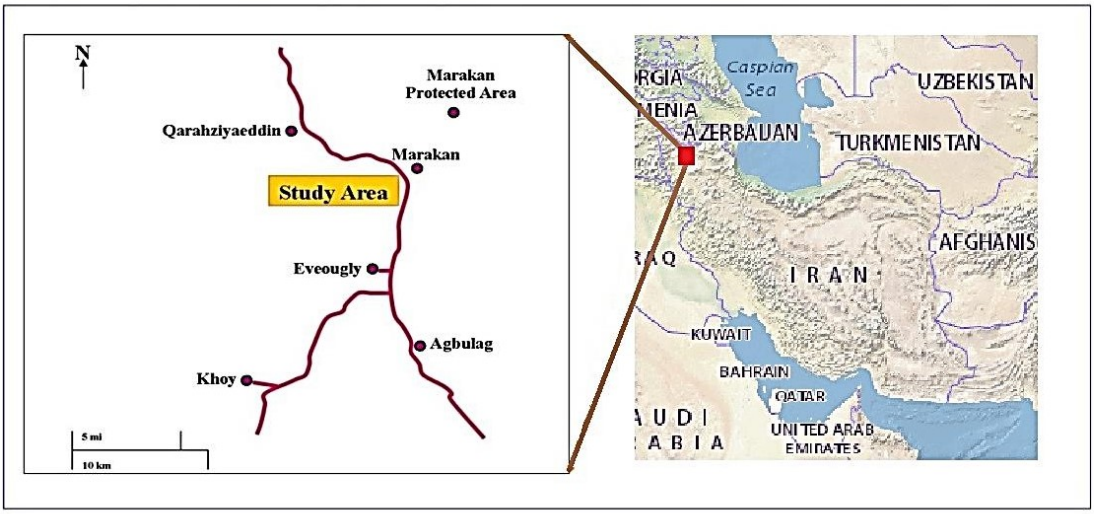

Fig 1. Location of the study area in north-west of Iran.

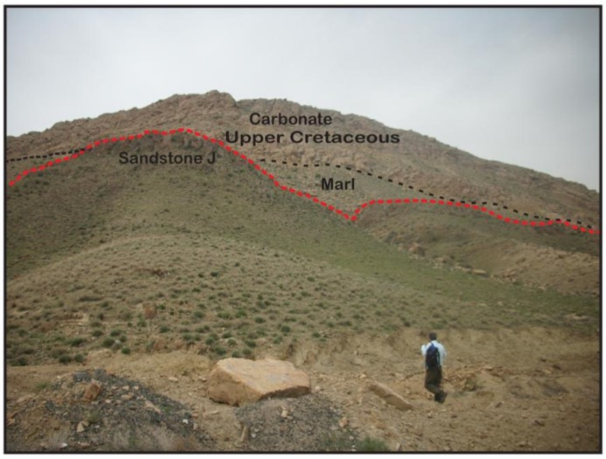

Fig 2. Boundary between upper Jurasic sandstones and upper Cretaceous carbonates

5. Description of sedimentary facies

The microscopic study of Cretaceous successions in the Morakan area led to the identification of 12 different microfacies of the Open marine (A), Bar (B), Lagoon (C), and Tidal flat (D) environmental belts (Fig 4).

5.1. Group A: Open Marine Microfacies

Micofacies (A1): Radiolarian-Oligosteginids Packstone Facies: This facies is primarily made up of radiolaria and oligosteginids. It also includes a small percentage of planktonic foraminifera which lies in the micritic matrix in the form of packstone. Another facies with similar features has been reported to exist in the open marine environment of the Sarvak Formation situated in the Khouzestan and Lorestan provinces, Iran (Sharma et al. 2011) (Fig 5).

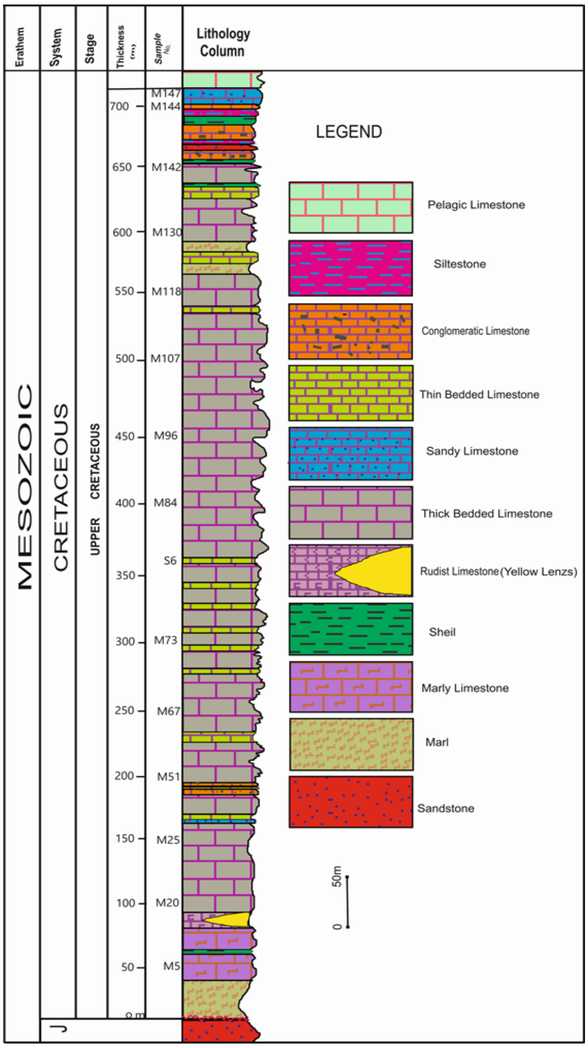

Fig 3. Stratigraphy column of Cretaceous deposits in northwest of Iran

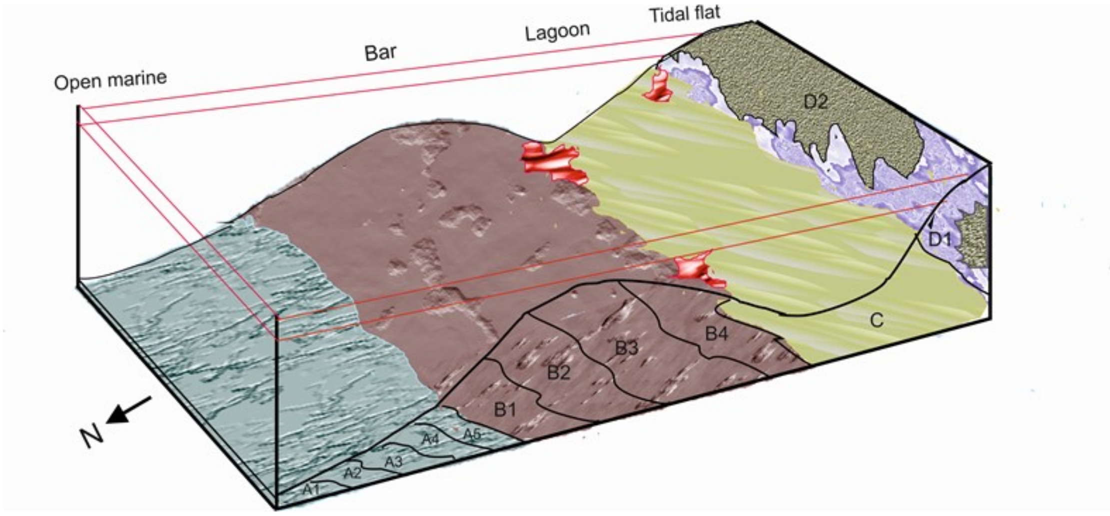

Fig 4. Sedimentary Model of Cretaceous Deposits in Morakan

Microfacies (A2): Marl: This facies is seen in the described color range of cream to gray and is inlaid with layers of other adjacent facies (Geybshavi 2009).Open marine marl can be deposited in deep or shallow environments and also coasts but hasn't found any evidences. So, it can be interpreted based on its placement between other facieses that the facies has been deposited in deep marine environment (Fig 5).

Microfacies (A3): Open marine Mudstone: This facies is totally made up of micrite and does not contain allochem. Such as open marine marl (A_2) this facies can form in similar environment (Fig 5).

Mirofacies (A4): Open marine bioclast wackstone: This facies is mainly made up of micrite and contains bioclasts of open marine organisms like brachiopoda, echinoderm and Rudist fragments, and benthic foraminifera (*Cuneolina*). Resedimented carbonate facies (Calciturbidite) (T) is a subfacies of the facies (A4), which is indicative of a high sea level (Highstand) and high level of carbonate sediment production. The substantial thickness of the sediment and the steep slope in front of the platform leads to the reduction of the stability of these sediments and their movement to a deeper part of the basin (Schlager 1992) (Fig 5).

Microfacies (A5): Open marine Bioclast Packstone: This microfacies is primarily consisting of open marine organism fragments like brachiopoda, echinoderm and fragments of bivalve (rudist), which lie in a micrite matrix (Fig 5).

5.2. Group B: Barrier Microfacies

Microfacies (B1): Rudist Rudstone: This facies is completely made up of big fragments of rudist along with pieces of gastropoda, benthic foraminifera, bryozoans and pieces of red algae. A similar facies has been reported to be located in Khouzestan province, Iran (Husinec et al. 2006; Geybshavi 2009) (Figs 6,7).

Microfacies (B2): Rudist Grainstone: The main allochem is a great amount of rudist fragments. Its other skeletal constituents include fragments of bivalves (lamellibranchia). Among non-skeletal allochems is intraclast. The matrix of this facies is sparite (Fig 7).

Microfacies (B3): Framestone-Boundstone: This facies includes a series of whole and broken reef-producing rudists along with coral pieces making up the main body of the bioclastic bar (Fig 7). This facies for its coarse rudist fragments can be deposited in rudist fore reef (Flugel 1982, 2010). In addition the facies has open marine bioclastic allochems thus its sedimentary environment can be identified as fore reef.

Microfacies (B4): Bioclast Packstone: Allochems consist of bioclasts of bivalve (rudist) along with benthic foraminiferous, which lie compressed in a micrite matrix. Intraclast and aggregates are among non-skeletal constituents (Fig 7).

5.3. Group C: Lagoon Microfacies

Micrifacies (C): Bioclast Packstone Wackstone: is mainly made up of benthic foraminifera (Miliolids) and benthic foraminifera (*Cuneolina*) along with pieces of ostracoda and bivalvia in a microcrystalline carbonate matrix. Non-skeletal constituents are Intraclast and pellet (Fig 7).

5.4. Group (D): Tidal Flat Microfacies

Microfacies (D1): Bioclast Packstone Grainstone: includes rounded pieces of bivalve, red algae, and benthic foraminifera, ostracoda, Cyanophyta, and rudist fragments. Non-skeletal constituents of pellet, intraclast and aggregates comprise about 30-40 percent of the facies. Fenestral fabric has also been observed (Fig 7).

Microfacies (D2): Litharenite-Calcarenite: is made up of lithoclast of quartz, chert, pellet, intraclast with some bioclastic pieces. Sorting, rounding and high maturity of this facies can be indicated of energetic environment. This group is extensively in the tidal flat (Fig 7).

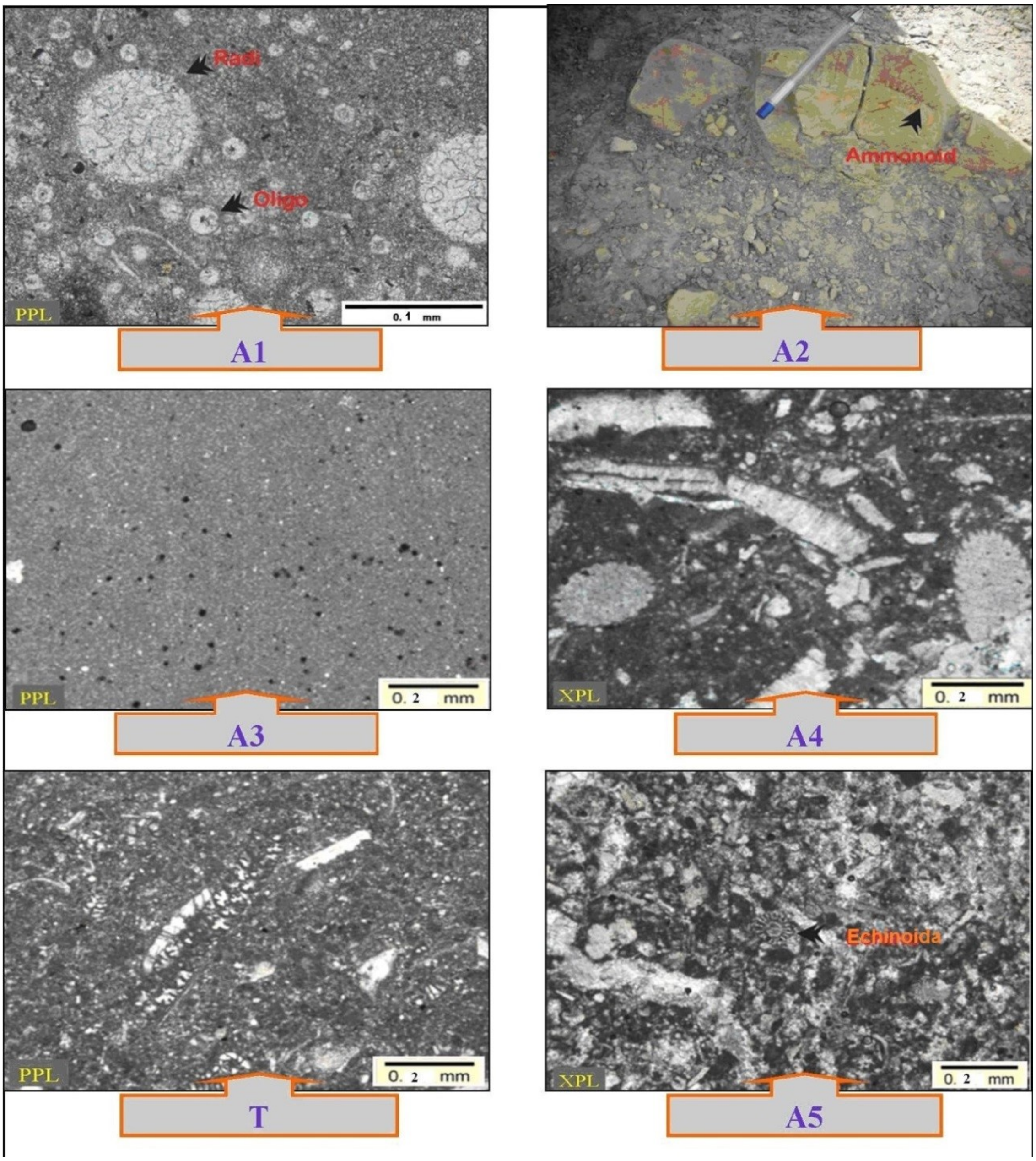

Fig 5. Microscopically figures of microfacies. A_1: Open marine radiolarian-oligosteginids packstone with micritic matrix; A_2: Open marine cream to gray marl; A_3: Open marine mudstone with micrite matrix; A_4: Open marine bioclast wackstone with rudist and brachiopoda fragments; T: Open marine resedimental carbonates (calciturbidite); A_5: Open marine bioclast packstone with brachiopoda, echinoderm and rudist allochems in micrite matrix.

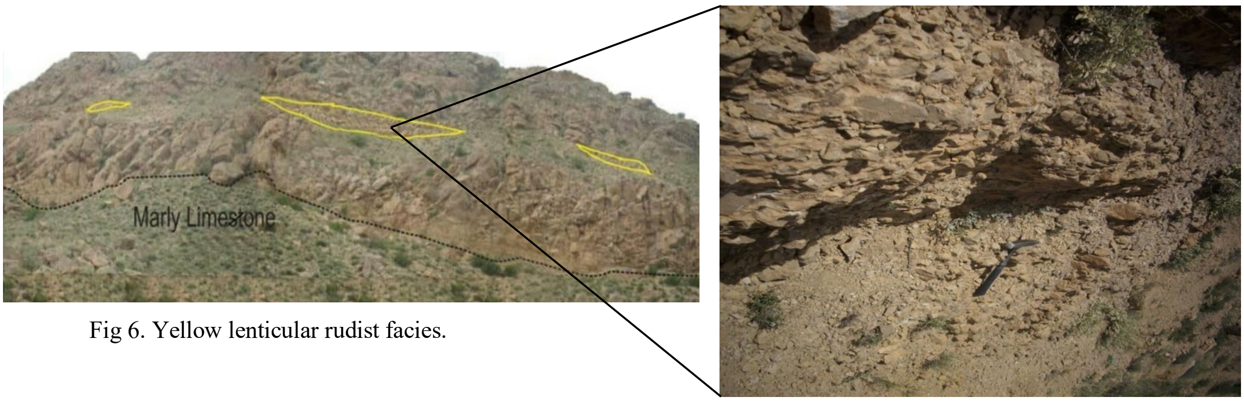

Fig 6. Yellow lenticular rudist facies.

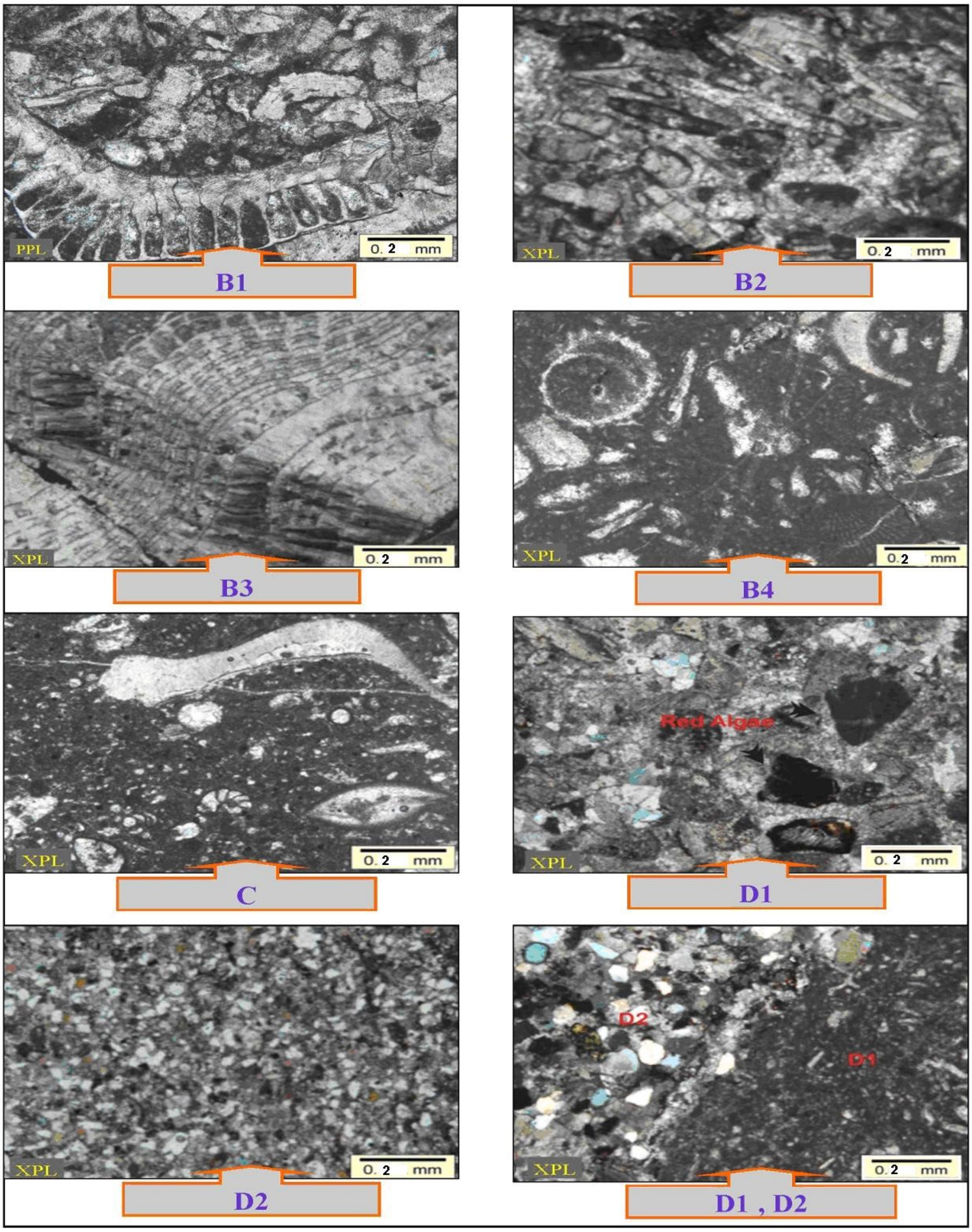

Fig 7. Microscopically figures of facieses. B1: Barrier rudist rudstone with gastropoda, benthic foraminifera, bryozoan and red algae fragments; B2: Barrier rudist grainstone with fragments of bivalves in sparite matrix. B3: Barrier framestone-boundstone with rudist and coral pieces; B4: Barrier packstone with rudist allochems; C: Lagoon bioclast packstone wackstone with bentic foraminifera, ostracoda and bivalvia fragments in microcrystalline carbonate matrix; D1: Tidal flat bioclast packstone grainstone with fragments of bivalve, red algae, bentic foraminifera, rudist and ostracoda; D2: Tidal flat litharenite- calcarenite with some bioclastic pieces. D1, D2: Vicinity of tidal flat bioclast packstone grainstone (D1) and tidal flat litharenite-calcarenite (D2).

6. Discussion

6.1. Interpretation of the sedimentary environment

The frequency of micrite, oligosteginids, radiolaria, and the skeleton of the open marine organisms show the sedimentation of group a facies beneath the wave base in the open marine. A1, A2, A3 facies have deposited in the deeper part of the open marine. The existence of sub-facies T in the facies A4 is suggestive of the displacement of the deposits which are dependent on shallow environments, and the re-sedimentation of these deposits in the deep part of basin.

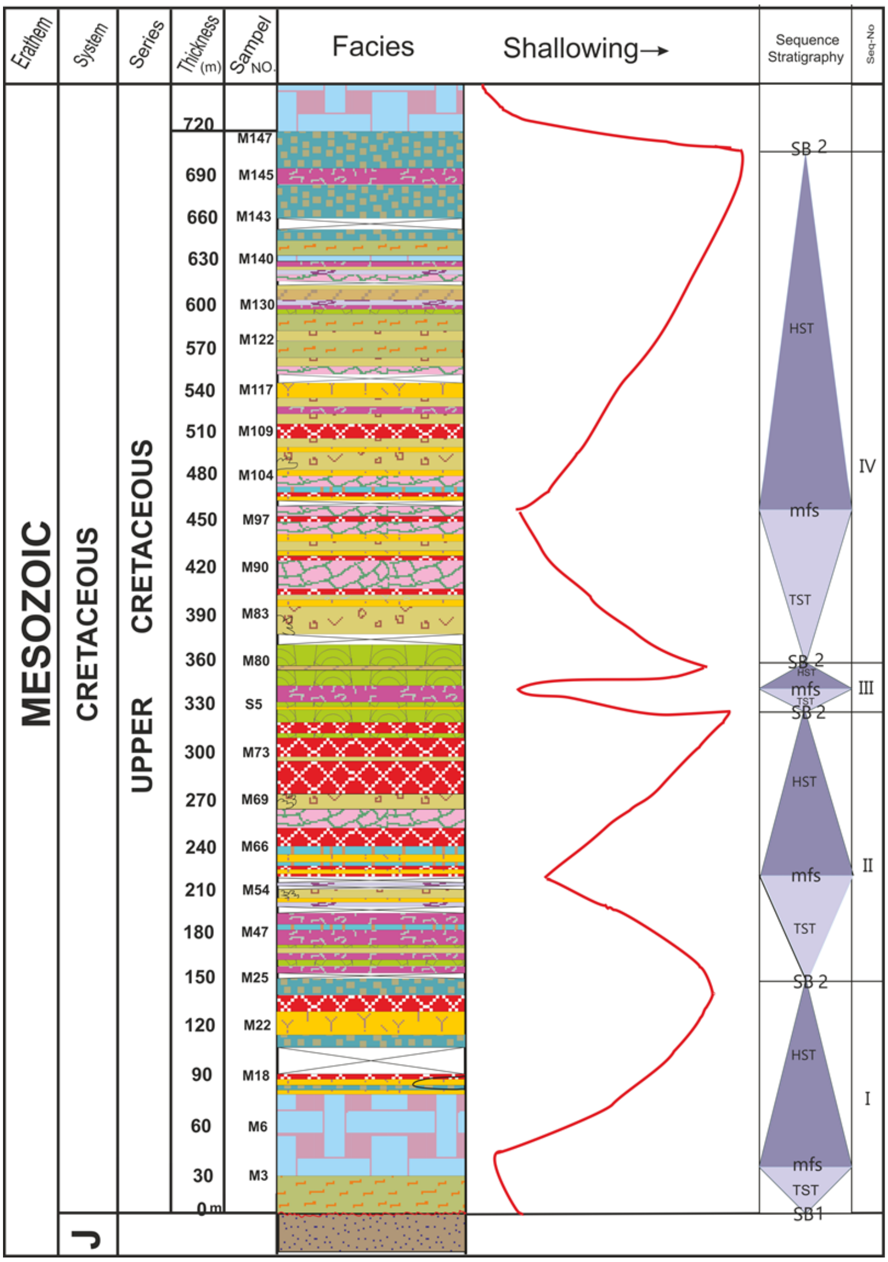

Fig 8. Microfacies column, sea level changes and sequence stratigraphy of Createaceous deposits in northwest of Iran

The facies A4, A5, due to the difference in their amount of allochems, have separated from each other. The existence of rudist fragments along with the whole rudists is indicative of a shoal reef in the bar (B). The facies B1 has deposited in the part near the open marine belt of barrier facies. B2, because of having sparite and rudist fragments, is indicative of considerable displacement and deposition in the carbonate bar environment. B3, also containing whole rudists and coral make up the bar boundstone. Group C facies, having miliolids-*Cuneolina* and ostracoda, is related to a lagoon environment with a relatively free rotation of water. The facies D1 is suggestive of the energetic parts of the tidal flat. In this flat, there exist vast amounts of sandy limestone and lime sandstone. Their horizontal and vertical changes and analogy with old and modern sedimentary environments such as (Rankey et al. 2010; Saha et al. 2011) show that these facies were deposited in a rimmed shelf carbonate platform (Read 1985) (Fig 4) in beside of Neotethys (Berra and Angiolini 2014). The sedimentation environment of the open marine facies belts of these successions is similar to the modern sediments of the deep environment of Bahamas platform sedimentary environment of limestone with reworked allochems of these successions is analogous to the reworking sediments (Pomar 2001) of the old environment of Chamanbid (Lasemi 1995) Tirgan (Javanbaht et al. 2011) formations as well as the modern environment far from Bahamas platform (Eberli 1991). The facies which are dependent on facies belt of bar also corresponds with the bars of the modern belts in Bahamas (Hine 1977) (Fig 8).

6.2. Sequence Stratigraphy

Sequence stratigraphy is used to study sedimentary facies and their vertical and horizantal changes, and to pinpoint sedimentary environments which are dependent on the relative changes of the sea level, thereby identifying the sediments of a basin in the form of the sequences lying between their unconformities and equivalent conformities (Sloss 1963; Emery and Myers 1996; Geel 2000; Abyat et al. 2012). The conducted studies have identified four 3rd degree sedimentary sequences for the sediments of the section similar to Tirgan Formation in northeast of Iran (Saffar et al. 2010; Jahanbakht et al. 2011) and Fahliyan Formation in south of Iran (Adabi et al. 2010) involved in the present study.

6.2.1. Sedimentary sequence 1

This sequence is as old as the upper Cenomanian-Turonian and includes the lower part of the successions. The lower boundary is of the type SB1 and the upper one is of the type SB2. The sequence is 150 meters thick at the section involved in the study, and the maximum flooding surface (mfs) in the thin-sections involved in the study includes the facies containing radiolaria and oligosteginids. This sequence includes the system tracts of TST (transgressive system tract) and HST (highstand system track). TST is subject to the progression of the sea level and includes open marine facies (e.g. marl facies). The system tract HST, which is related to the highest sea level, includes rudist-packstone and tidal flat facies (Fig 9).

6.2.2. Sedimentary sequence 2

This sedimentary sequence is as old as the early lower Coniacian and includes the part close to the middle of the cross-section. The sequence is 180 meters thick at the section and has lower and upper boundaries of the type SB2. The maximum flooding surface (mfs) at the thin-sections involved in the study includes open marine bioclast wackstone facies. The sequence has system tracts of TST and HST. The system tract TST includes open marine bioclast-packstone and bar rudist grainstone. The system tract HST includes rudist boundstone as well as lagoon bioclaste packstone-wackstone (Fig 10).

6.2.3. Sedimentary sequence 3

This sequence with thickness of 50 m and the middle Early Coniacian age constitutes the middle part of the studied section. The lower and upper boundaries of the sequence, like the sedimentary sequence 2, are of the type SB2. The maximum flooding surface (mfs) in the above-mentioned succession is made up of mudstone open marine facies. This infers to start of Laramian unconformity (LST). The TST system tract consists of packstone-grainstone tidal flat facies, and open marine mudstone. The HST system tract contains lagoon bioclaste packstone-wackstone. The thickness of this sequence is less than the other sequences (Fig 10)

6.2.4. Sedimentary sequence 4

This sequence with thickness of 337 m and the late Early and Late Coniacian age constitutes the upper part of the studied section. The lower and upper boundaries of the sequence are of the type SB2. The maximum flooding surface (mfs) in the succession is open marine bioclast wackstone. The TST system tract includes bioclaste packstone open marine as well as rudist rudstone. The HST system tract involves open marine mudstone, sandy limestone, and limysandstone (Fig 10) Sequence differences in basins (Azerbaijan basin and Zagros basin), the sequences developed by the Cretaceous sequences at the Morakan studied section are comparable with the investigated sequences in the Sarvak formation in northwest of Fars province, situated in the southwest of Iran.

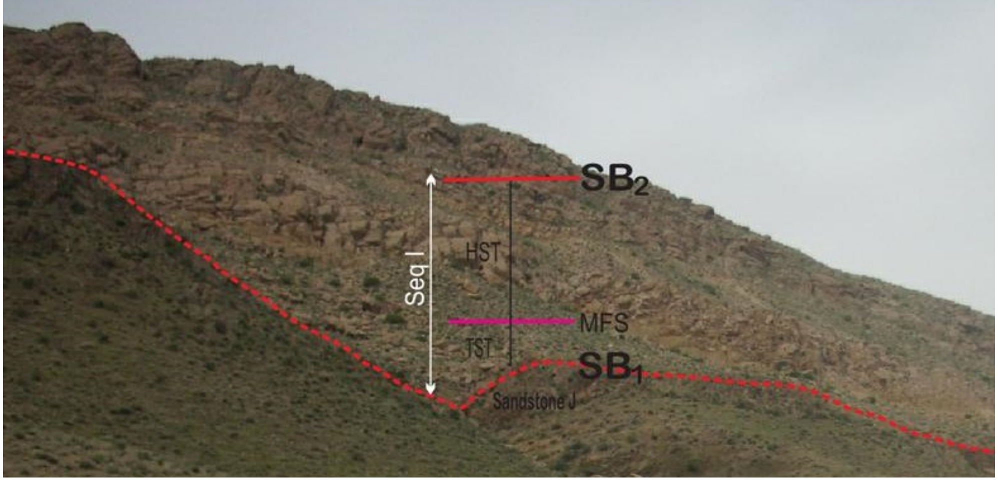

Fig 9. Sequence 1.

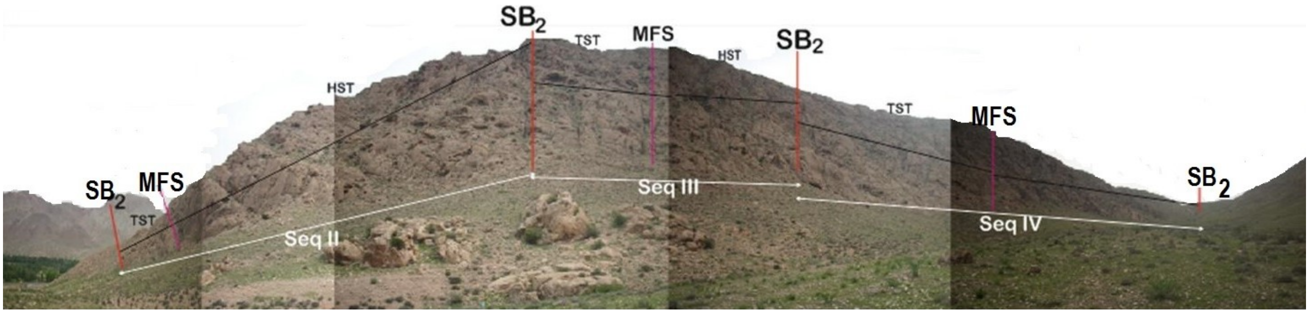

Fig 10. Sedimentary sequences of 2, 3 and 4

7. Conclusions

The sediments of the Cretaceous successions at Morakan section have deposited in open marine facies belts, bar, lagoon and tidal flat environments. Vertical and horizontal changes of the facies and comparing them with old and modern environments show that the facies of these successions have deposited in a carbonate platform of the rimmed shelf type. Sequence stratigraphy of these successions indicates that Cretaceous deposits at the Morakan section contain four sedimentary sequences (3rd deg). The sedimentary sequence 1 has a lower boundary SB1 and upper boundary SB2 and the sequences 2, 3, and 4 have lower and upper boundaries of the type SB2.

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