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Biostratigraphy, depositional environment and sequence stratigraphy of Late Cretaceous clastic-evaporite-carbonate deposits, east of Central Iran, Bajestan

Seyed Hossein Hosseini, Mohammad Vahidinia*, Mehdi Najafi and Seyed Reza Mousavi Harami

Ferdowsi University of Mashhad, Faculty of science, Department of Geology, Iran

**Corresponding authors' email: vahidinia@ferdowsi.um.ac.ir*

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Abstract

Late Cretaceous deposits in Chahchool section from Bajestan (NE Iran) attain a thickness of 352 m. Four lithostratigraphic units composed of conglomerates, sandstones, siltstones, shales, marls, gypsum, bioclastic and hippuritic limestones are recognized. Upwards they are followed by Quaternary alluviums and transgressively overlain by Quaternary sediments. In this study, nineteen genera and twelve species of benthic foraminifera, one genus of planktic foraminifera, three genera and four species of calcareous algae and Lingulogavelinella arnagerensis assemblage zone were identified. The Middle Coniacian age of the carbonate deposits is based on determined benthic foraminifera genera, species and biozones. The carbonate deposits conformably overlie clastic-evaporitic sediments which contain no fossils. This succession likely belongs to progression of early Late Cretaceous(?). Twenty four facies have been identified including six siliciclastic lithofacies belong to oxygenated coastal belt-tidal flat consists of 1-Gcm lithofacies as beach channel fill 2-3-two sandstone lithofacies belongs to shoreface and offshore transition 4-siltstone lithofacies belongs to offshore and supratidal 5-6-two shale lithofacies consist of shale devoid of fossils belongs to supratidal and shale with foraminifera belongs to shallow open marine, one evaporative lithofacies belongs to saline, seventeen carbonate faciesfrom sea toward land consist of nine facies most of them micritic belong to open marine, two grain stone facies belong to barrier, five miliolid, ostracoda and peloid facies belong to lagoon and one marl with no fossils facies belongs to supratidal. These sediments deposited in one depositional sequence of III category according to the test composition of foraminifera and facies. This depositional sequence deposited in LST, TST and HST systems tracts. The lower boundary of this sequence is SB1? according to the cover and conglomerate layer in this boundary and the upper boundary of this sequence is SB1 due to erosional evidences or disconformity. The interpretation of sea level fluctuation at the time of deposition corresponded to global eustatic curve and differences are attributed to the regional tectonic.

Keywords: Foraminifera; Late Cretaceous; Facies; Depositional sequence; Bajestan.

1. Introduction

The studied deposits with 352/5 meters thickness are the most complete and diverse Cretaceous deposits in Bajestan region that have never been studied thoroughly so far and thus are chosen for the present study. Within these deposits four lithostratigraphic units composed of conglomerates, sandstones, siltstones, shales, marls, gypsum, bioclastic and hippuritic limestones are recognized. In Bajestan region, as can be seen in its geological map (Ashouri et al; 2008), the Late Cretaceous deposits with very low thickness of Sardar and Jamal formations are only depositional sediments that are exposed in the Bajestan region and also igneous and metamorphic rocks can be seen in the some parts of studied region. The Cretaceous deposits have been located NE from Bajestan and SW from Abdol Abad (58˚22'44" longitude and 34˚34'02" latitude) (Fig. 1). In the study area only Late cretaceous deposits are recorded. Upwards they are followed by Quaternary alluviums and transgressively overlain by Quaternary sediments.

The only study on the studied deposits is survey of carbonate part of them in terms of diagenesis (Mahboubi et al; 2008).

In general, the main objectives of this study are: 1- Determining relative age of these deposits using foraminifera and calcareous alga (carbonate part) as well as their stratigraphic position (evaporite and silici-clastic parts) 2-

Identifying and analyzing facies and also checking vertical and horizontal changes of facies 3- Interpreting depositional paleo environment and offering depositional model 4- Identifying depositional sequences and sequence boundaries by using fossils and other data and comparing sea level fluctuation at the time of deposition with global eustatic curve of Haq et al. (1987) (sequence stratigraphy) 5- Evaluating the effect of regional tectonics on the sea level fluctuation.

2. Methodology

A total of ninety rock samples were collected for preparing thin sections and petrographic studies and eleven marly samples for washing. Thin sections were examined by binocular microscope with transmitted light. The marly samples were washed by washing method, studied by binocular microscope and photographed by Scanning Electronic Microscope (SEM) in the central laboratory of Ferdowsi University of Mashhad (Iran). Isolated benthic foraminifera were identified by using numerous references (e.g. Bolli et al., 1994). Identification of foraminifera in thin sections was performed by referring to references such as Boudagher-Fadel (2008) and their zonation was performed using Packer (1991). The carbonate thin sections are painted by Red Alizarin solution and Potassium Ferrosianid (to separatecalcite from dolomite) according to Dikson (1965) method. Conglomerates are named according to Pettijohn's classification (Pettijohn, 1975), sandstones according to Folk's classification (Folk, 1980) and carbonate deposits using Dunham's classification (Dunham, 1962) and its reformed model by Embry & Klovan (1971). Skeletal and non-skeletal allochems were identified using the studies of Flügel (Flügel, 2010) and frequency percentage of each of them was determined by using comparison charts of Bassel and Bosselini (Flügel, 2010). For assessing, identifying and interpreting clastic and evaporative facies were used Miallfacies (Miall, 2000) and for carbonate facies were used Standard Facies of Flügel (Flügel, 2010). Depositional model of Cretaceous deposits was studied and interpreted by using depositional models which are presented for past and present environments (e.g. Read, 1985; Reading, 1981;Tucker & Wright, 1990; Einsele, 2000).Sequence stratigraphy was studied by sequence stratigraphy methods and principles of Van Wagoner et al. (1988-1990) and Haq et al. (1987). Interpratation and cheking of sea level changes have been done by comparison with global eustatic curve of Haq et al. (1987).

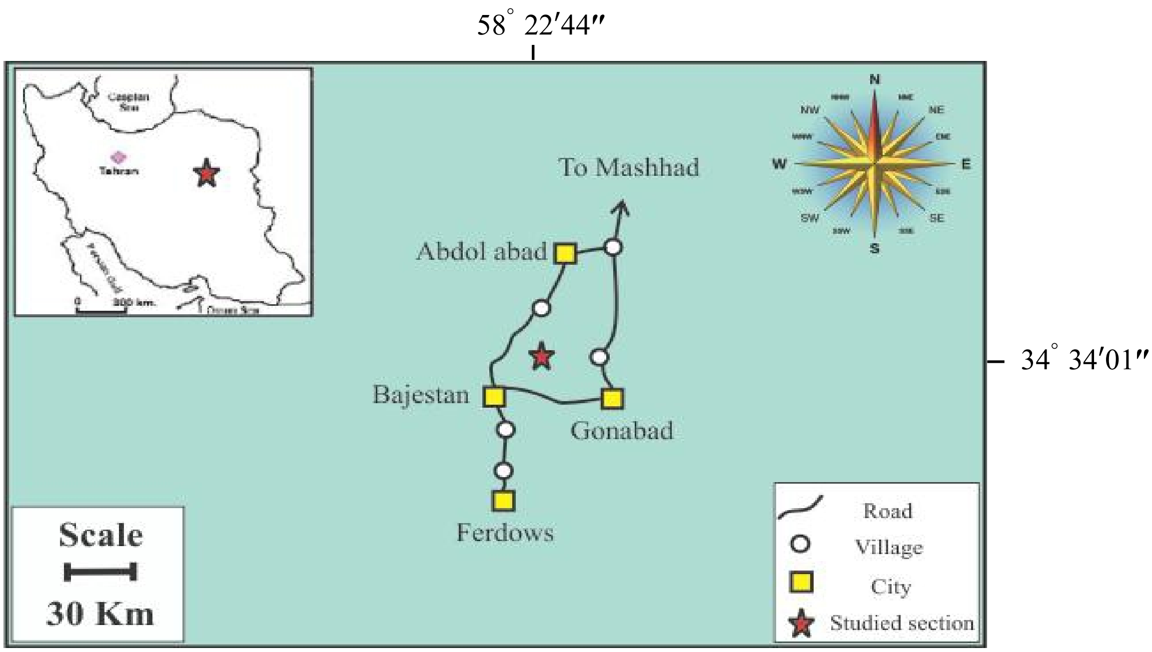

Fig. 1. Location of studied deposits.

3. Discussion and results

3.1.Biostratigraphy

The age of Cretaceous deposits have not been determined accurately in any parts of Bajestan region thus far. In the studied sediments, there are two groups of microfossils including foraminifera (benthic with high frequency and planktonic with low frequency) and calcareous algae which allow the age determination. Study of foraminifera was performed by using isolated samples of washing marls and thin sections of limestone, while algae were studied by using thin sections of limestone. Finally, based on the studies conducted, 9 genera and 12 species of benthic foraminifera, 1 genus of planktonic foraminifera and 1 genus and 4 species of calcareous algae were identified in the sediments as follows (Figs. 2-3).

Benthic foraminifera: *Ammobaculites agglutinans, Anomalina tennessensis, Arenobulimina* sp., *Ataxophragmium* sp., *Cibicidoides* sp., *Gavelinella pertusa1, Gavelinella rochardensis, Maginulinopsis lituola, Marginulina bullata, Murciella cuvillieri, Nodosaria* sp., *Praebulimina reussi, Praedorothia* sp., *Pseudocyclammina massilliensis, Quinqueloculina* sp., *Ramulina* cf., *abscissa, Tritaxia aspera* (juvenile specimen), *Tritaxia tricarinata, Trochammina* sp. , *Vaginulina* sp., *Verneuilinoides* sp.

Planktonic foraminifera*: Heterohelix* sp.

Algae: *Diplopora annulata, Griphoporella curvata, Salpingoporella donataa, Salpingoporella muhbergi, Salpingoporella* sp.

Study of identified genera and species for biozonation shows that these sediments were during one biozone as follows (Fig. 4):

Lingulogavelinella arnagerensis assemblage zone:

Definition: The base of this zone is taken at the highest occurrence of Middle Coniacian taxa and the top of the zone is taken at the first appearance of *Loxostomum eleyi* and *Cibicides beaumontianus* (Packer, 1991).

Microfauna characteristics: The foraminiferal fauna is characterised by abundant calcareous benthic species, dominated by *Gavelinella, Ammobaculites, Praebulimna, Tritaxia* and abundant *Nodosariids*. The agglutinating benthic fauna is comprised mainly of three genera, *Gaudryina, Arenobulimina* and *Ataxophragmium.* The planktonic fauna is characterised by rarer *Heterohelix.*

Age: The presence of *Gavelinella thalmanni* and *Gavelinella pertusa* at the base suggest that deposition of the limestone began in the Middle

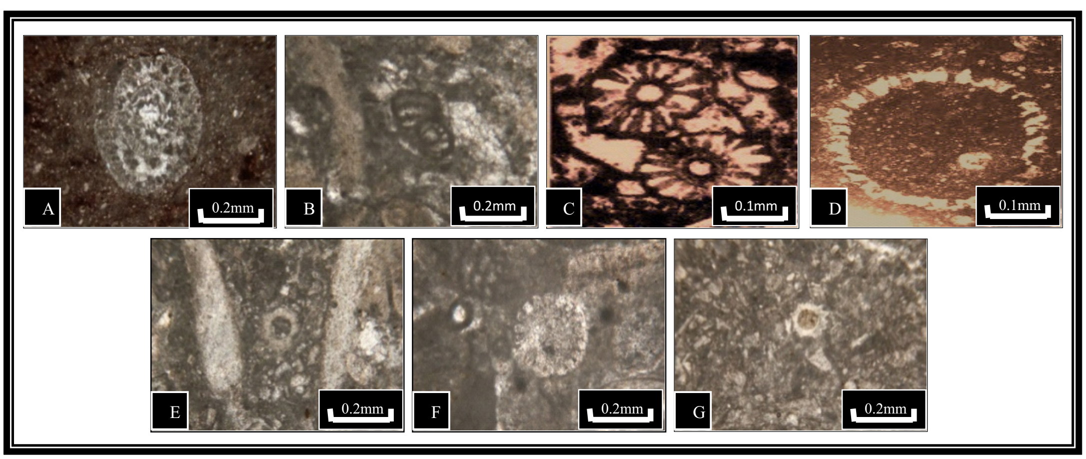

Fig. 2. Benthic foraminifera (A-B) and calcareous algae (C-D-E-F-G) in limestones of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran
A) *Pseudocyclammina massilliensis* (sample CH-90) B) *Murciella cuvillieri* (sample CH-99) C) *Salpingoporella donataa* (sample CH-68) D) *Diplopora annulata* (sample CH-75) E) *Salpingoporella sp.* (sample CH-70) F) *Griphoporella curvata* (sample CH-68) G) *Salpingoporella muhbergi* (sample CH-89).

Coniacian (Packer, 1991).

Gavelinella thalmanni is reported to have its first occurrence in the Middle Coniacian (Hart & Swiecicki, 1987), and *Gavelinella pertusa*is also reported to have its first occurrence in the Middle Coniacian (Edwards, 1981).

However, the relative age of carbonate part of deposits is Middle Coniacian according to the identified genera, species and benthic foraminifera biozone, whereas the age determination of clastic-evaporite deposits located under carbonate deposits is not possible accurately due to unconformity boundary and lack of fossils. These deposits probably belong to progression of ? early Late Cretaceous.

The equivalent carbonate depositsin other depositional basins in Iran are the middle part of Abderaz Formation in the Kopet-Dagh basin, the lower part of Illam Formation and the middle part of Surgah Formation in the Zagros basin, the lower part of Haftooman formation in central Iran basin, the lower part of K2b deposits in the South Alborz basin, the middle part of lagoon-back reef facies in the North Alborz basin.

3.2.Facies analysis and interpretation of depositional environment

Study of facies is one of the most important tools for identification of depositional environment and the factors effective on it (Onyinyechukwu & Odigi; 2016). Paleotological studies led to the recognition of twenty four facies grouped into three facies zones: Clastic facies zone composed of six lithofacies (Fig. 5), evaporative facies zone consisting of one lithofacies (Fig. 5) and carbonate facies zone consisting of seventeen facies (Fig. 7), which are discussed in summary in the following section:

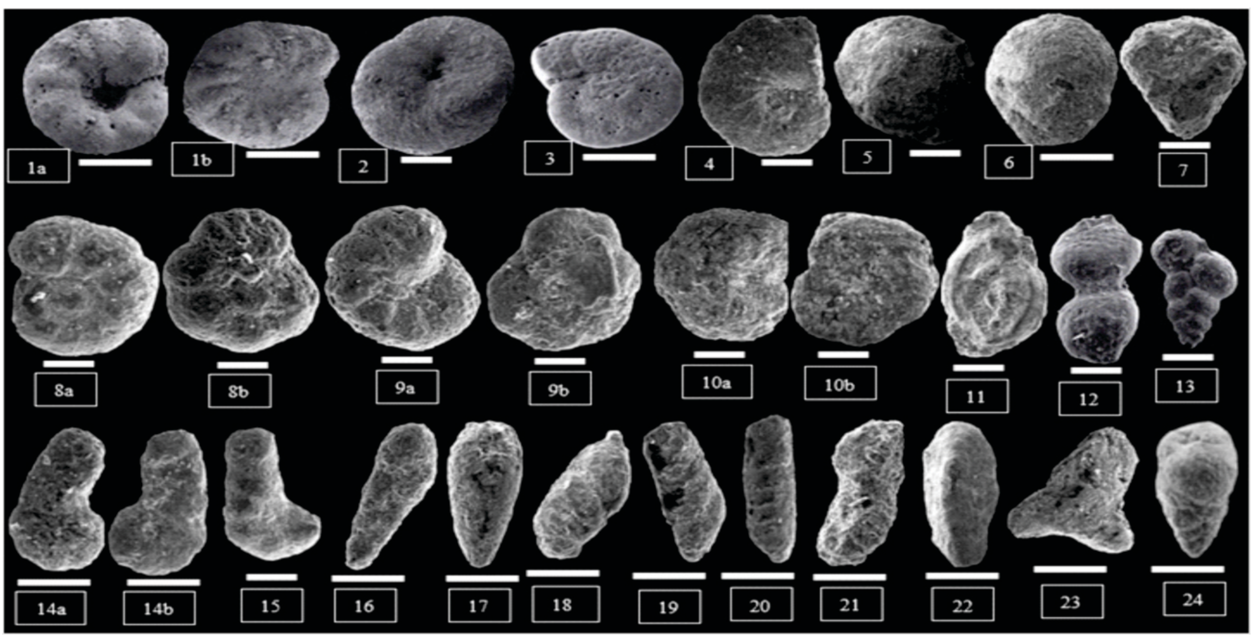

Fig. 3. Isolated benthic and planktonic foraminifera (13) of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran
1a-b) *Gavelinella pertusa1* (sample CH-67) 2) *Ataxophragmium sp.* (sample CH-76) 3-4) *Cibicidoides sp.* (sample CH-72) 5) *Trochammina sp.* (sample CH-70) 6) *Praebulimina reussi* (sample CH-67) 7) *Tritaxia aspera* (juvenile specimen) (sample CH-63) 8a-b) *Gavelinella rochardensis* (sample CH-73) 9a-b) *Anomalina tennessensis* (sample CH-72) 10a-b) *Trochammina sp.* (sample CH-70) 11) *Quinqueloculina sp.* (sample CH-71) 12) *Nodosaria sp.* (sample CH-72) 13) *Heterohelix sp.* (sample CH-96) 14a-b) *Ammobaculites agglutinans* (sample CH-58) 15) *Maginulinopsis lituola* (sample CH-69) 16) *Praedorothia sp.* (sample CH-75) 17) *Verneuilinoides sp.* (sample CH-62) 18) *Marginulina bullata* (sample CH-58) 19-20) *Vaginulina sp.* (sample CH-69) 21) *Ammobaculites sp.* (sample CH-73) 22) *Tritaxia tricarinata* (sample CH-59) 23) *Ramulina* cf. *abscissa* (sample CH-68) 24) *Arenobulimina sp.* (sample CH-59).

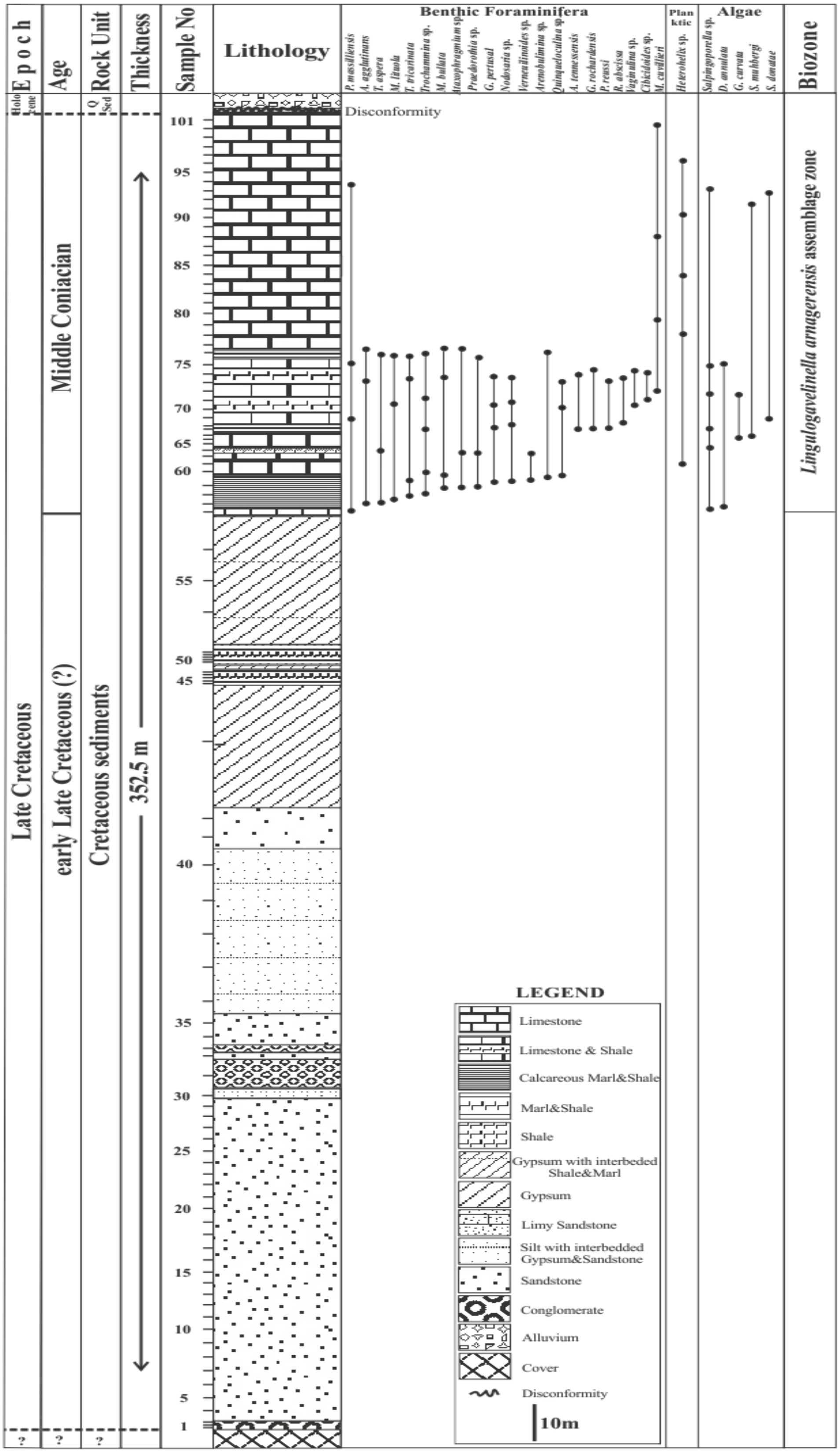

Fig. 4. Biostratigraphic column of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran.

3.2.1. Clastic facieszone (oxygenated beach belt)

This collection is composed of six lithofacies including one conglomerate and microconglomerate lithofacies, two sandstone lithofacies (lower and upper), one siltstone lithofacies and two shale lithofacies comprised of shale with no fossils and shale with fossils (Fig. 5). Microconglomerate and conglomerate lithofacies are orthoconglomerate (Gcm lithofacies), and pebbles inside them, in both field and thin sections, have relatively high roundness and very weak sorting (Figs. 5A-B). These pebbles are derived from the older formations of basin which probably belong to Paleozoic consist of Sardar and Jamal Formations. Furthermore, these facies limited in the field (Fig. 5A) and alternative with coarse grain sandstone. These evidences indicate the existence of beach channel at the beginning of the sediments, where this conglomerate layer at the base of sediments can be filled in the beach channe (Nichols, 2009).

Sandstone lithofacies (S) belongs to two beach sub environments. The lower sandstone correspond to lower shoreface because of high roundness and medium sorting, waveform ripple marks (Fig. 5E), planar cross bedding (Sp) (Fig. 5G), trough cross bedding (St) (Fig. 5H), lack of muddy interlayers and large along (Fig. 5C), while the upper sandstone belongs to middle and upper shoreface and offshore transition because of medium roundness and sorting, relatively high frequency of muddy interlayers (Fig. 5D), asymmetric ripple mark (Fig. 5F), and existence of bioclasts such as echinoderms and bryozoans (Fig. 5I).

Siltstone lithofacies belongs to two sub environments. The massive siltstones with interlayers containing thin-layer sandstone and mud (Fsm facies) (Fig. 5J) belong to offshore, and siltstones with interlayers and veins of gypsum (T3 facies) (Fig. 5K) belong to supratidal (Fig. 5H) (Nichols, 2009).

Red shale without fossil containing veins and gypsum (Fig. 5L) belong to supratidal, but shale with foraminifera lithofacies (Fig. 5I) belong to the shallow parts of open marine (inner ramp) because of the existence of benthic foraminifera such as *Trochammina* sp. and *Nodosaria* sp.(Nichols, 2009). Furthermore, red color of clastic facies and existence of iron oxides in these lithofacies indicate the oxygenated conditions, low rate of organic matter accumulation and high content of oxygen soluble in sea water (Li et al; 2010).

3.2.2. Evaporative facieszone (E) (Salina)

This facies zone consists of seventy eight meters thin to medium layers of gypsum with high thickness, red shale interlayers and marl with no fossils (Figs. 5M-N). Thin section studies indicate crystals that have the shape of timber, low salience and weak birefringence (Fig. 5N). These features put emphasis on the mineralogical composition of gypsum, while crystals of anhydrite have higher salience and stronger birefringence than gypsum. Gypsum crystals are 40 micron to about 1 mm in size with the average size of about 0.2 mm.

Existence of extensive laminations as interbeds composed of organic matters indicate that these evaporative sediments are deposited in out of the water such as salina (Demicco & Hardie, 1994). Interbeds with evaporative deposits indicate the fluctuations of sea level (e.g. Hosseini et al., 2012). Interlayers of marl with ostracoda and red shale with no fossils in evaporative layers (Fig. 5L), indicate that they are formed in supratidal and limited marine environment (Warren, 1989).

3.2.3. Carbonate facies zone (Hemoclinal Carbonate Ramp)

This facies zone is composed of four facies belt based on the formation from sea toward land, which are discussed in summary in the following section (Figs.7-8); (frequency of skeletal and non skeletal allochems of each facies is given in Fig. 8 due to more summary)

3.2.3.1. Open marine belt (O)

This belt contains 9 facies: bioclastic wackestone with pelagic bivalve and foraminifera (O1), coral boundstone (O2), marl with foraminifera (O3), bioclastic mudstone mudstone (O4), bioclastic floatstone (O5), bioclastic packstone (O6), sandy bioclastic packstone (O7), bioclastic packstone to grainstone (O8) and bioclastic grainstone (O9)(Figs. 7A-B-C-D-E-F-G-H-I).The features of this collection in the field are thin to thick beds and existence of horizontal (Fig. 6A) and massive beds structures (Fig. 6B) in them. The characteristics of this collection and evidences of deposition in the open marine are high abundance and large size of bioclasts (Fig. 6C) and high abundance of mud; but in deeper areas, these parameters show reduction and facies move toward low energy environment (Berbier et al., 2012). Also sedimentary structures associated with low energy environment are present (Figs 6A-B).Bioclasts are mainly represented by hippurites (Fig. 6D), bryozoans, bivalves, brachiopods and echinoderms (stenohaline). High frequency of these bioclasts and the relationship of their stratigraphy with neighboring facies indicate that deposition of these facies occurred in shallow to relatively deep open marine (Pomar, 2001 a-b; Ćosović et al., 2004). Furthermore, benthic foraminifera such as *Gavelinella, Ammobaculites, Nodosaria, Tritaxia* exist in this belt, whereas photosynthetic organisms such as algae are not recognized in this belt, which indicates that formation of these facies occurred under optical zone (Flügel, 2010).

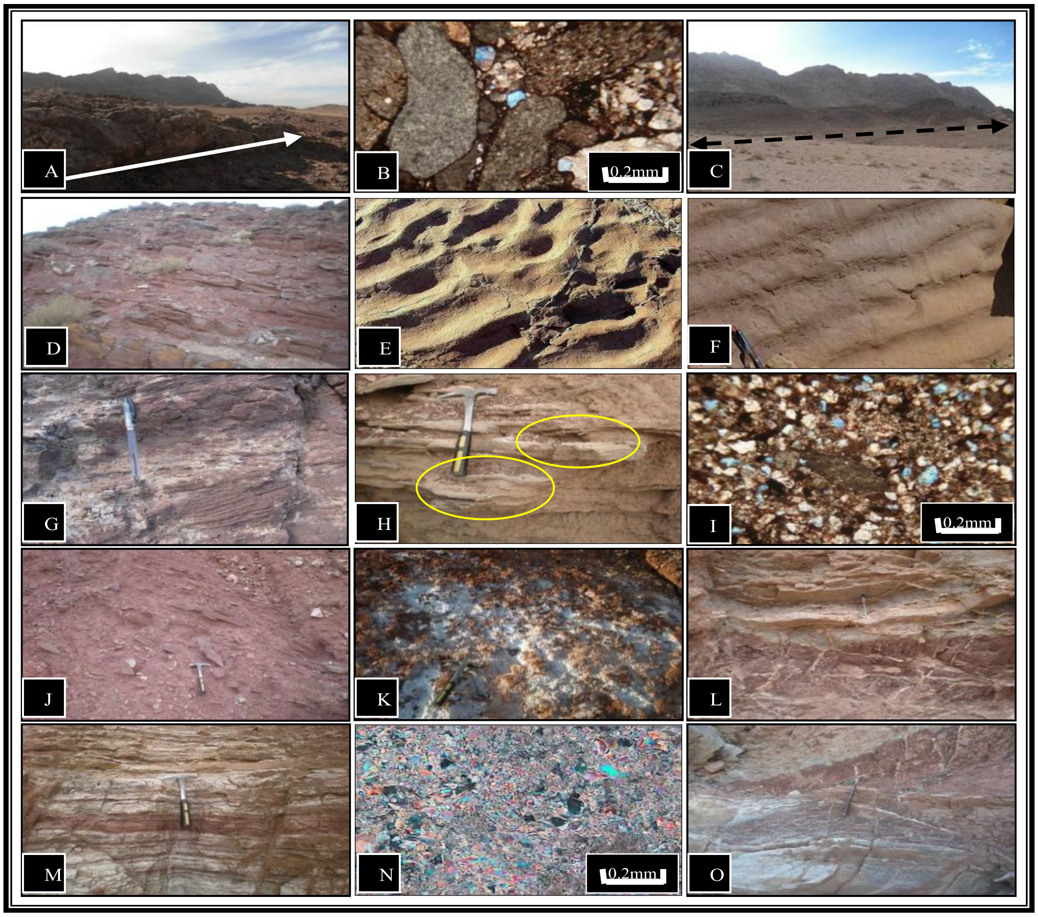

Fig. 5. Clastic and evaporite facies of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran
A) Gcm lithofacies: orthoconglomerate with limited along B) Gcm lithofacies: microscopic image C) sandstone lithofacies with large along D) sandstone lithofacies with interbeds of mudstone E) sandstone with waveform ripple mark F) sandstone with asymmetric rippelmark G) sandstone with planar cross bedding H) sandstone with trough cross bedding I) hybridy sandstone (calclithite) J) siltstone lithofacies with interbeds of thin layers of sandstone K) T3 facies: siltstone lithofacies with interbeds of gypsum L) SH facies: alternation of red shale, green shale and thin layer sandstone M) Evaporite lithofacies N) gypsum: microscopic image of evaporite lithofacies O)T1-T2 facies: red shale and marl with no fossils in the evaporite lithofacies zone.

3.2.3.2. Barrier belt (B)

This belt includes 2 facies that consist of peloid grainstone (B1) and quartz y peloid grainstone (B2) (Figs. 7J-K). The facies are thin to medium beds and represent planar cross bedding (Fig. 6E) and trough cross bedding (Fig 6F) in the field. These facies are deposited in high energy environment, above the waves and barrier belt due to absence or presence of very low calcareous muds and matrix, as well as sorting and in some case high roundness of allochems and sedimentary structures (cross bedding) associated with high energy environment (Palma et al., 2007).

3.2.3.3. Lagoon belt (L)

This belt includes 5 facies: miliolid wackestone to packstone (L1), ostracoda packstone to mudstone (L2), peloid bioclastic packstone to grainstone (L3), ostracoda peloid packstone(L4) and bioclast peloid grainstone to packstone (L5) (Figs. 7L-M-N-O-R).This facies belt are thin to thick beds in the field and represent lamination and horizontal beds structures in them. The characteristic of this belt and evidences of deposition in the lagoon are existence of algae, benthic foraminifera such as miliolids, ostracods, gastropods, bivalve, very high calcareous muds and matrix and sedimentary structures associated with low energy environment (Flügel, 2010).

3.2.3.4. Supratidal belt (T)

Facies of this belt are located intothe gypsum in the middle part of studied deposits and alternative to thin to medium gypsum. These facies have low frequency, and include marl with no fossils (T1), shale with no fossils (T2) and massive siltstones with gypsum interbeds (T3 facies) (Figs. 5K-O). Planar cross bedding and trough cross bedding have seen in these facies belt (T3)in the field. Lack of fossils, lack of lamination, existence of gypsum indicate that the marl, shale and siltstone facies are deposited in supratidal (Berbier et al., 2012). Facies of this belt are equivalent to RMF 19 from Standard Facies of Flügel (Flügel, 2010).

Fig. 6. Field images of carbonate part of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran A) lamination in limestone (horizontal beds) B) massive marl with foraminifera C) bioclastic limestone D) hippuritic limestone E) planar cross bedding in limestone F) trough cross bedding in limestone.

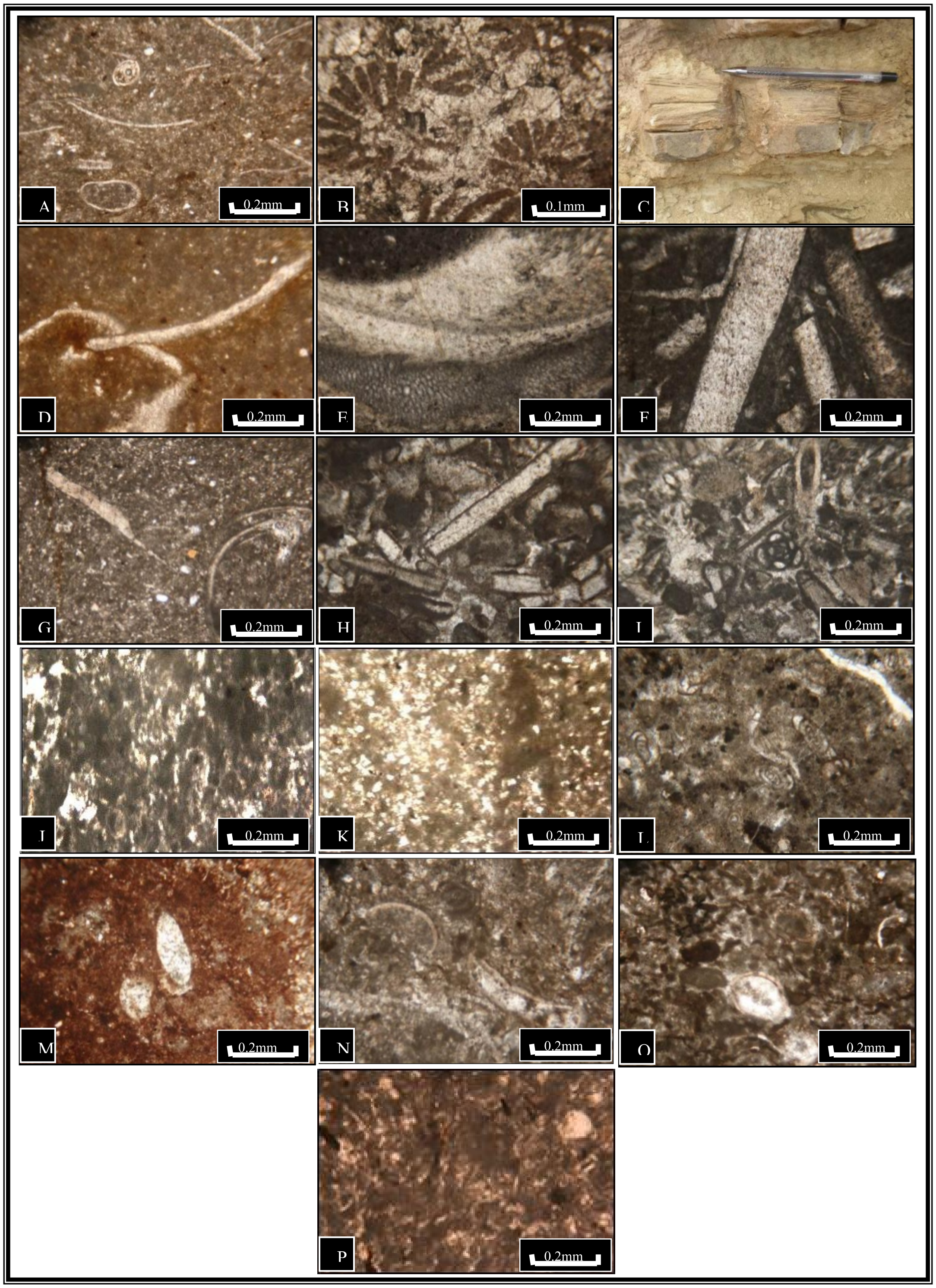

Fig. 7. Carbonate facies of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran. A) O1 facies: bioclastic wackestone with pelagic bivalve and foraminifera B) O2 facies: coral boundstone C) O3 facies: marl with foraminifera D) O4 facies: bioclastic mudstone E) O5 facies: bioclastic floatstone F) O6 facies: bioclastic packstone G) O7 facies: sandy bioclastic wackstone to packstone H) O8 facies: bioclastic packstone to grainstone I) O9 facies: bioclastic grainstone J) B1 facies: peloid grainstone K) B2 facies: quartzy peloid grainstone L) L1 facies: miliolid wackestone to packstone M) L2 facies: ostracoda packstone to mudstone N) L3 facies: peloid bioclastic packstone to grainstone O) L4 facies: ostracoda peloid packstone R) L5 facies: bioclast peloid grainstone to packstone

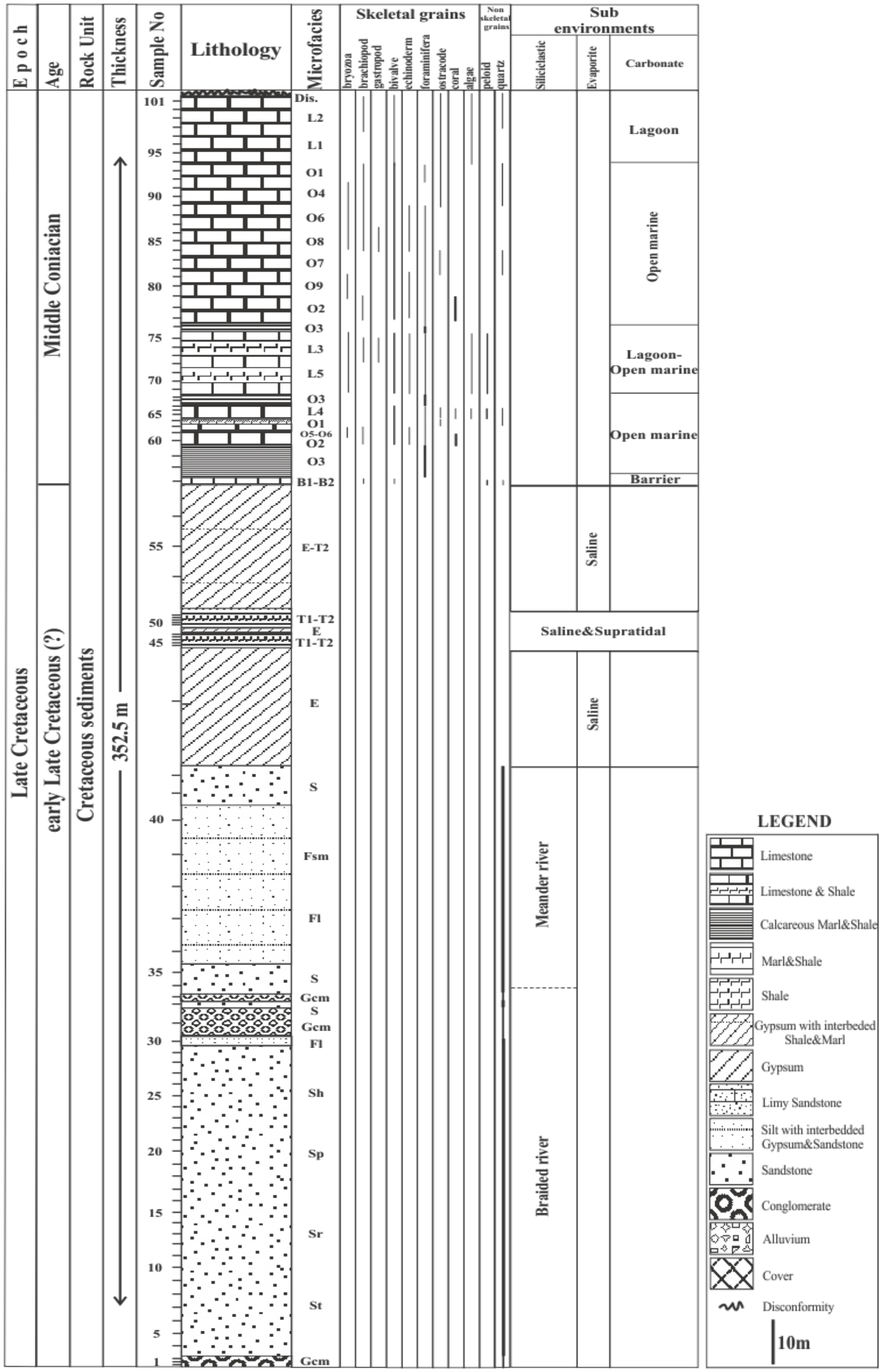

Fig. 8. Facies analysis and depositional environment of Late Cretaceous silici-evaporite-carbonate deposits, Chahchool Section, Bajestan, Iran.

4. Proposed depositional model

According to sub environments related to each of facies and facies belts and studying of their vertical and horizontal changes and using Walter law as well as comparison of studied sediments with past and present environment (Read, 1985; Reading, 1986; Tucker & Wright, 1990; Einsele, 2000), a depositional model is proposed for studied sediments (Figs. 9A-B). The nature of clasticfacies and their high frequency at the lower part indicate that this marine environment was initially shallow clastic pan with large area, then, by limitation and evaporation of sea water was formed salina. Then numerous progression and regression have changed environment intosupratidal-salina and gradually took the form of hemoclinal carbonate ramp (beacause of gradual changes facies, lack of slope change suddenly and lack of reef facies) (Tucker & Wright, 1990; Flügel, 2010) including open marine, barrier, lagoon and supratidal belts by the reduction in the entry of clastic-evaporite deposits from land and progression in sea level (Figs. 9A-B).

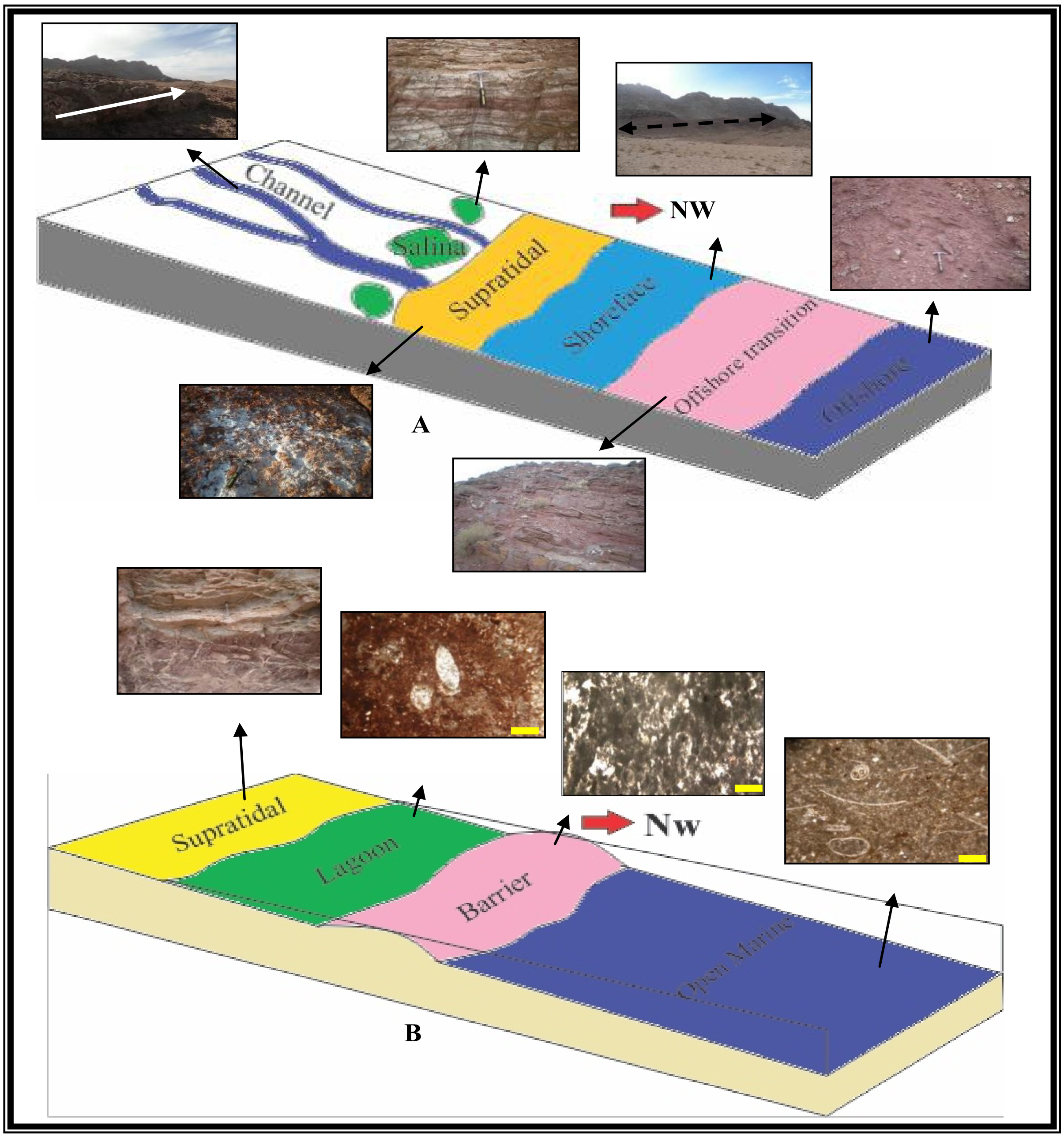

Fig. 9. Depositional model of Late Cretaceous deposits, Chahchool Section, Bajestan, Iran
A)Clastic-evaporite part B) Carbonate part.

5. Sequence stratigraphy

Sequence stratigraphy provides the means of correlation of sedimentary successions based on stratal stacking patterns and key bounding surfaces (Kelechi et al., 2016). Sequence stratigraphic studies have been done by sequence stratigraphic methods and principles of VanWagoner et al. (1988-1990). Interpratation and cheking of sea level fluctuation have been done by comparison with global eustatic curve of Haq et al., (1987).

Studies of sequence stratigraphy indicate that these sediments were deposited in one depositional sequence of III category (Vail et al., 1991) by test composition of benthic foraminifera and present facies (Fig. 10).

The beginning of this depositional sequence consists of 245 meters thick conglomerate, microconglomerate, sandstone, siltstone, grading upward to gypsum and interbeds of red shale and marl with no fossils. This part of sequence showed the retrogression of sea level and deposition in LST systems tract because of existence of channel elements and conglomerate deposits of filling channel (Fig. 5A) that were converted to sandstone and siltstone lithofacies (Fig. 5C). It consists of Gcm, Sr, Sh, Sp, St, Fl, and Fsm lithofacies, that grade toward evaporite deposits. The upper boundary of this systems tract is MRS (Fig. 10).

In continuously, depositional sequence includes 107/5 meters thick marl with fossils, limestone, bioclastic limestone and hippuritic limestone. Marl with foraminifera and the others facies belonging to open marine such as coral boundstone and bioclast packstone on the barrier facies indicate the progression of sea level and deposition of this part of sequence in TST systems tract (Figs 8-10). Furthermore, in this part of the sequence, benthic foraminifera with agglutinate test such as *P. massilliensis, T. aspera, M. bullata, Ataxopharagmium* sp. and *Verneuilinoides* sp. exist (Fig. 4). Frequency of agglutinate genera and spieces show the reduction of both oxygen and calcium carbonate solution, and conversion of favorable conditions to unfavorable ones, which are the result of progressive conditions (TST) (Nagy et al., 2001).

The initial boundary of this systems tract is TS according to the progressive evidences. The MFS of this system tract is located in the boundary where deeper open marine changes into shallower open marine. Besides, in this part of sequence (MFS), benthic foraminifera such as *A. agglutinas, Trochammina* sp., *T. tricarinata, Praedorothia* sp. and *Arenobulimina* sp., with agglutinate test exist with high aboundancy (Fig. 4). In MFS where oxygen and calcium carbonate solution minimize, benthic foraminifera with calcareous test minimizes or do not exist (Nagy et al., 2001).Furthermore, there are diverse and abundant fossil communities in MFS (Brett, 1995; Emery & Myers, 1996).

Deposition of limestones belonging to lagoon facies with miliolid wackestone to packstone and ostracods packstone to mudstone on the open marinefacies indicate the regression of sea level and deposition of this part of sequence in HST systems tract (Figs 8-10). Furthermore, in this systems tract, foraminifera such as *M. cuvillieri, Nodosaria* sp. and *Heterohelix* sp., with calcareous test exist (Fig. 4). The presence of genera with calcareous wall shows the increase in oxygen and calcium carbonate solution indicating the regression of sea level (Nagy et al., 2001). Furthermore, due to the reduction of depth which results in the creation of undesirable environmental conditions as well as dilution of fossil content, Los are observed irregular in HST systems tract (Olson & Thompson, 2005).

The lower boundary of this depositional sequence is not clear due to overlying Quaternary sediments; A conglomerate layer deposited in this boundary suggests the Sb1? and the upper boundary of this sequence is SB1 because of erosional evidences or disconformity. It should be noted that here are several progressive and retrogressive para sequences in each sequence (Fig. 10).

According to studies conducted by Haq et al. (1987), the curve changes of global sea level in the age of studied deposits is the result of fixed sea level in early Late Cretaceous, which continues up to Middle Cenomanian, then sea level retrogressed a little, and finally sea level has begun to progress in Late Cenomanian. Sea level has also retrogressed in Coniacian. The fluctuation occurred in sea level at the time of deposition corresponded with the global eustatic curve and represent differences that can resulted from progression and regression because of tectonic activities in the region (Fig. 10).

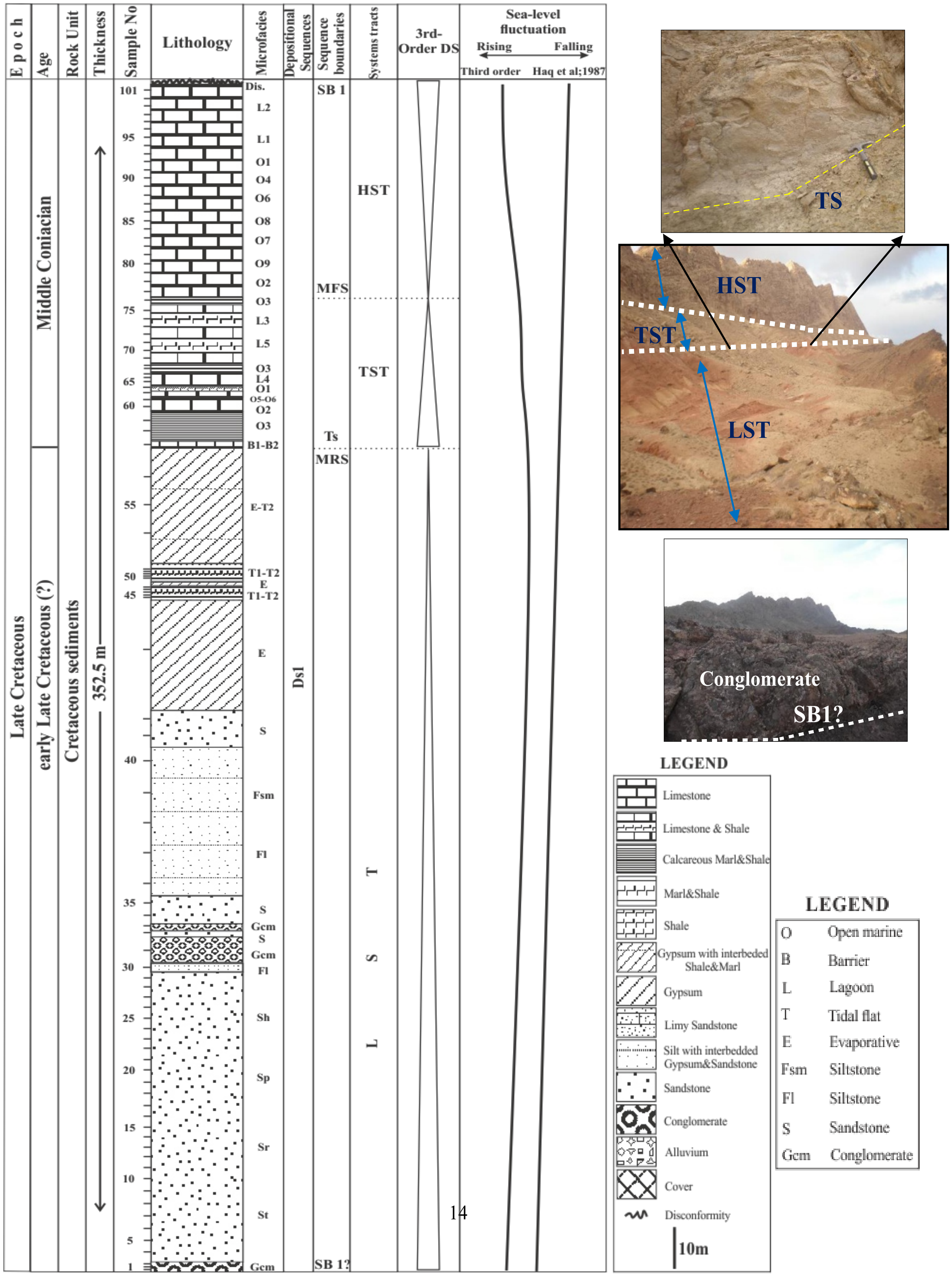

Fig. 10. Sequence stratigraphic column of Late Cretaceous silici-evaporite-carbonate deposits, Chahchool Section, Bajestan, Iran.

4. Conclusion

The present study shows that Late Cretaceous sediments were deposited in four litho stratigraphic units while carbonate part was deposited in Middle Coniacian. The clastic-evaporite deposits overlain by carbonate deposits probably belong to progressive early Late Cretaceous (?). Siliciclastic facies zone is deposited in the channel, shore face, offshore transition, offshore and oxygenated conditions; evaporative facies zone is deposited insalina, inter beds of shale and marl with no fossils in the evaporative facies zone are deposited in supratidal; and the carbonate facies zone deposited in the hemoclinal ramp consists of supratidal, barrier, lagoon and open marine belt (inner ramp to middle ramp). These sediments are deposited in one depositional sequence with erosional sequence boundaries (SB1); The beginning of sequence belongs to clastic deposits, grading upward to salina evaporites and interbeds with shale and marl with no fossils (LST) and so transgressive marl belonging to open marine (TST) overlying by shallower limestone deposits (HST). Changes in sea level at the time of deposition correspond to global eustatic curve of Haq et al. (1987) and differences represent relative sea level changes.

Authors' contribution

Mr. Seyed Hossein Hosseini is the first author and is a PhD student. Mr. Mohammad Vahidinia is the second author and also the first supervisor. Mr. Mehdi Najafi is the third author and a second supervisor. Mr. Seyed Reza Mousavi Harami is the fourth author and the adviser.

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