Biostratigraphy and depositional history of Coniacian-Santonian succession in East of Ramhormoz area (Tange-Bulfaris section)

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Abstract

This study is focused on the biostratigraphy, sedimentary environments, facies distribution, and sequence stratigraphy of the Coniacian–Santonian sediments of Tange-Bulfaris section. Five assemblage zones have been recognized by distribution of the foraminifera in the study area. Assemblage zone 1(Chara Ostracods zone) is Coniacian in age and occurs in the lower part of the succession. Assemblage zone 2 (*Valvulammina – Dicyclina* zone) and Assemblage zone 3 (*Rotalia* cf. *skourensis*- Algae zone) are Coniacian – Santonian in age. *Dicarinella concavata* interval zone suggests a Coniacian to earliest Santonian age. *Dicarinella asymetrica* total range zone is Santonian in age. These sediments are subdivided into eight microfacies types belonging to various sedimentary environments, ranging from continental lacustrine to very shallow and relatively deep-water (hemipelagic to pelagic) marine environments. The observed facies patterns indicate a carbonate open shelf depositional environment. The inner shelf facies is characterized by wackestone–packstone, dominated by various taxa including miliolids, Rotalia, bryozoa, mollusca, ostracods and green algae. The middle shelf is represented by wackestone-packstone with a diverse assemblage of echinoid, corallinacean and bryozoans. Basinwards is dominated by argillaceous packstone characterized by planktonic foraminifera. Based on field observations, microfacies analysis and sequence stratigraphic concept, one-third-order sequence in the study section was identified. Shallow brackish to fresh-water ponds or lakes (MF 1) were deposited during short periods of very low sea level. The establishment of an open shelf carbonate platform took place during the transgressive system tract. MF (2,3,4,5,6,7) are deposited during the transgressive system tract. Appearance of deeper fauna and glauconite are interpreted as a maximum flooding surface (MF. 8).

Key words*:* Coniacian-Santonian, Tange-Bulfaris, Biozonation, Sequence stratigraphy, Zagros Mountains.

Introduction

The Coniacian–Santonian sediments were deposited on the Arabian plate, NE passive margin of Gondwanaland (James and Wynd, 1965; Motiei, 1993; Alavi, 2004). These sediments were subdivided into two formations i.e., the Surgah and Ilam (Bourgeois, 1969). The Surgah and Ilam formations were defined by Wynd (1965). The type section of both formations is in the north-western part of the Kabir Kuh Anticline at Tang-e Garab in Lurestan (Fig. 1). At the type section, the Surgah Formation consists of 176 m of grey to dark grey, pyritic, shale with subordinate, fine-grained, thin-bedded limestone of Turonian to Early Santonian age (James & Wynd 1965). The Surgah Formation is only well developed in the Lurestan area. In the Dezful embayment, it is questionably represented in the Ab-e Teymur and Darquain oil fields by a thin interval of shale beds between the Sarvak and Ilam formations (Desbordes, 1972). It is not present in the Fars Province (James & Wynd 1965). At its type section, the Ilam Formation consists of 190 m of grey, well bedded, fine-grained, argillaceous limestone with thin, black, fissile shale, with Santonian to Campanian age (James & Wynd 1965; Wynd 1965). In the study area, the Coniacian–Santonian sediments are lithologically different from the Surgah and Ilam formations in the type sections in Lurestan. Lithologically, they are composed of thick-bedded limestone, to chalky nodular bedded to pelagic shale and marl. Thus, for simplicity we use the Coniacian– Santonian succession instead of the Ilam and Surgah formations in this paper. In the study area, the Coniacian–Santonian succession unconformably overlies the Cenomanian to Turonian Sarvak Formation (Fig. 2). The Coniacian–Santonian succession is overlain by a transitional boundary with the Gurpi Formation, which is Upper Santonian to Maastrichtian in age (Bourgeois, 1969; Hart, 1970). The present study focuses on the facies analysis, environmental interpretation, interpreted relative sea-level changes and sequence stratigraphic framework of the Coniacian–Santonian succession.

Methods and study area

One stratigraphic section of the Coniacian–

Santonian interval were measured and sampled from the Tange-Bulfaris section (75 m thick). Fossils and facies characteristics were described in thin sections from 40 samples. All thin-sections were studied under the microscope for biostratigraphy and facies analysis. The classification of carbonate rocks followed the nomenclature of Dunham (1962) and Embry and Klovan (1971). Facies definition is based on lithological characterstics including depositional texture, grain size, grain composition, and fossil content. Wilson (1975) and Flügel (2004) facies belts and sedimentary models were also used.

For sequence stratigraphic interpretation, the concepts developed by many investigators (Posamentier et al., 1988; Emery and Myers, 1996; Catuneanu, 2006) were used. The study area is located about 60 km East of Ramhormoz city. The section was measured in detail at 31˚10′ N and 49˚ 56′ E (Fig. 3).

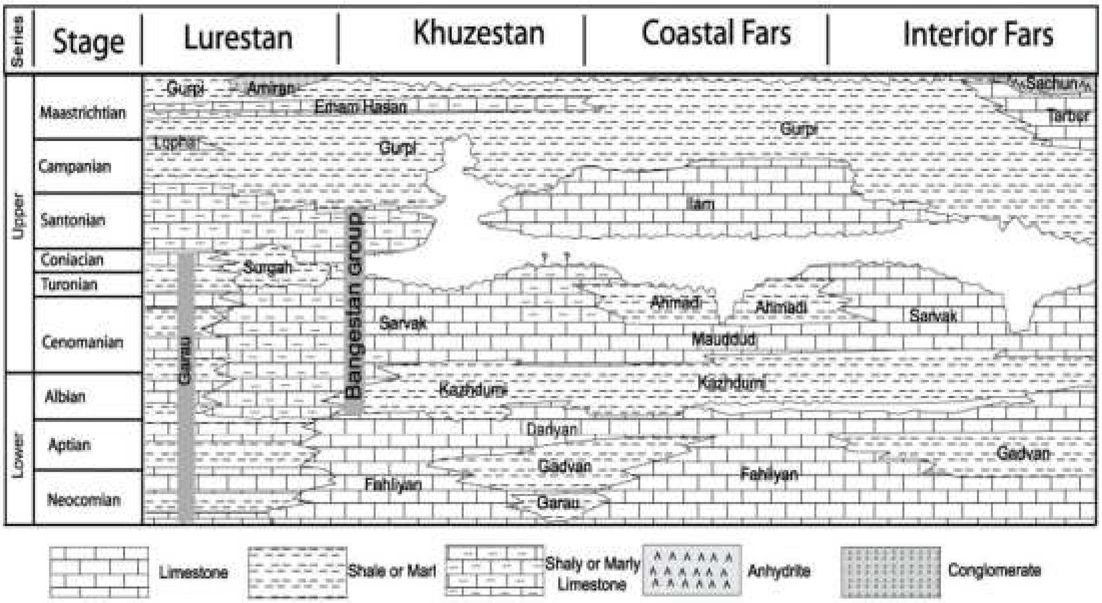

Figure 1: Correlation chart of the Cretaceous deposits of southwest Iran (adopted from James & Wynd, 1965)

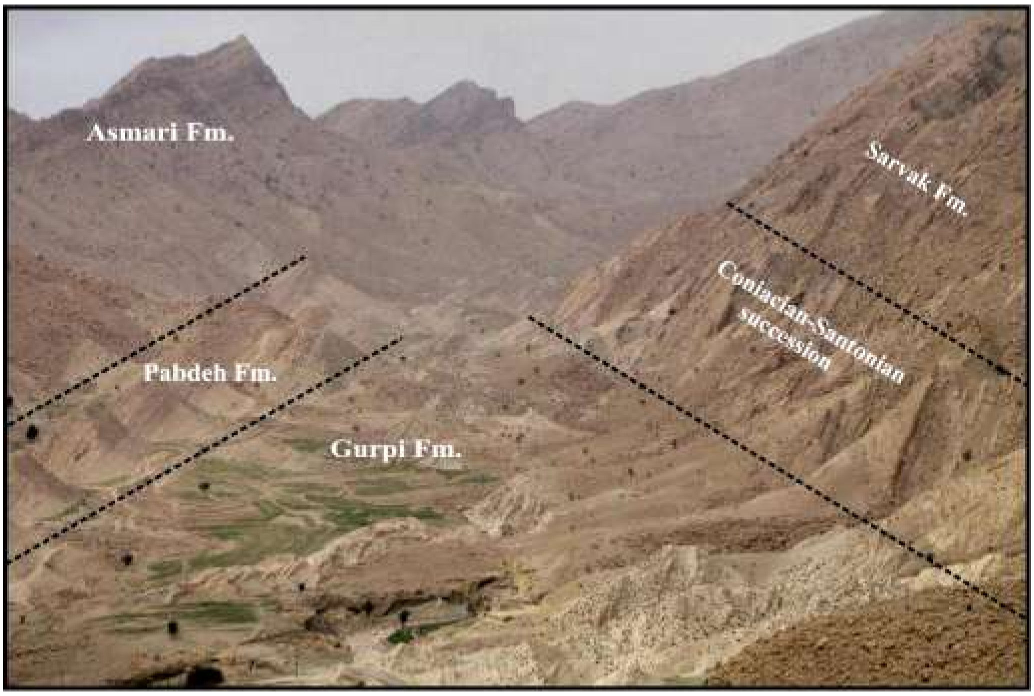

Figure 2: Photograph of the studied section

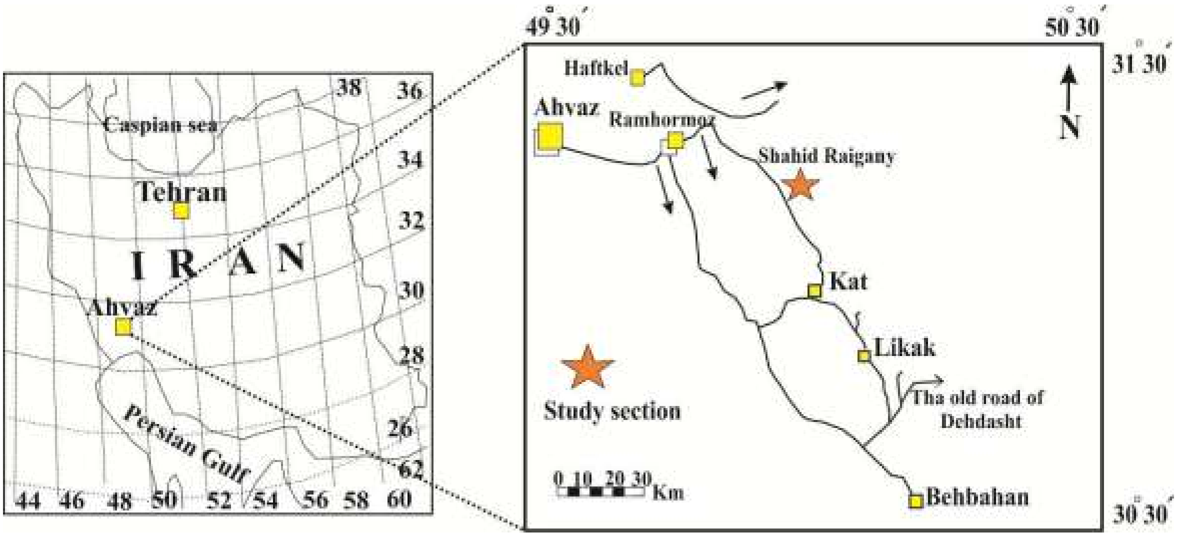

Figure. 3: Location map of the studied area in the Zagros region, east of Ramhormoz area (Tange-Bulfaris section).

Biostratigraphy

A total of 37 foraminifer genera and species were encountered in the study area and their distribution have been plotted (Fig. 4,5,6). From base to top five assemblages were recognized in the study area as follows:

Chara ostracods zone (Khalili, 1974) (Fig. 4)

This biozone is recognised at the lowermost part of the succession and extends through a thickness of 8 m in the stratigraphic column.

The most important charactristic of this biozone is abundance of charophyts and lake of marine fauna. This biozone correspond to the Chara-Ostracods zone of Khalili (1974). This biozone is useful for recognition of sedimentary environment (Motiei, 1372). In the studied area, this biozone is attributed to the Coniacian based on its stratigraphical position. This biozone is also reported by Ghabeishavi (1387) in the Tang Band, Zagros,Iran

Valvulammina – Dicyclina assemblage zone (Wynd, 1965)(Fig. 4)

The most important foraminifera in this assemblage are marked by:

Dicyclina schlumbergeri, *Nezzazatinella picardi, Valvulammina* sp., *Cuneolina* sp., miliolids and textularids. This assemblage can be correlated with biozone 29 of Wynd, (1965). Based on stratigraphical position, the age of the assemblage is Coniacian-Santonian.

Rotalia cf. *skourensis*- Algae assemblage zone (Wynd, 1965) (Fig. 4)

This biozone contains some benthic foraminifera with abundant green algae, echinoid debris and bryozoans. Associated fauna are *Rotalia skourensis*, miliolids, textularids.

In the study area, this assemblage is attributed to the Coniacian-Santonian based on stratigraphical position.

Dicarinella concavata interval zone (Sigal 1955) (Fig. 4)

This biozone is composed of an interval with the first occurrences of *Dicarinella concavata* and the first occurrences of *Dicarinella asymetrica* (Robaszynski & Caron 1995). This biozone can be correlated with *Globotruncana concavata/ venricosa carinata* zone (Wynd, 1965). Associated fauna in this biozone are:

Dicarinella primitiva, *Marginotruncana sigali*, *Globotruncana lapparenti*, *Globotruncana fornicata*, *Heterohelix* sp., *Muricohedbergella* sp.

According to Premoli Silva & Verga (2004), the age of this biozone is Late Turonian to the earliest Santonian. The lower boundary of this biozone is not defined therefore the Coniacian to earliest Santonian is considered for the age of this biozone.

Dicarinella asymetrica total range zone (Postuma, 1971) (Fig. 4)

This biozone is defined by the total range zone of *Dicarinella asymetrica* (Caron, 1985). Associated fauna are:

Contusotruncana fornicata, Macro-globigerinelloides sp., *Muricohedbergella* sp., *Rugoglobigerina rugosa, Heterohelix* sp., *Globotruncana lapparenti, Globotruncana bulloides, Dicarinella concavata, Globotruncana arca, Archaeoglobigerina* sp., *Marginotruncana coronata.*

The age of this biozone is Santonian (Premoli Silva & Verga, 2004)**.**

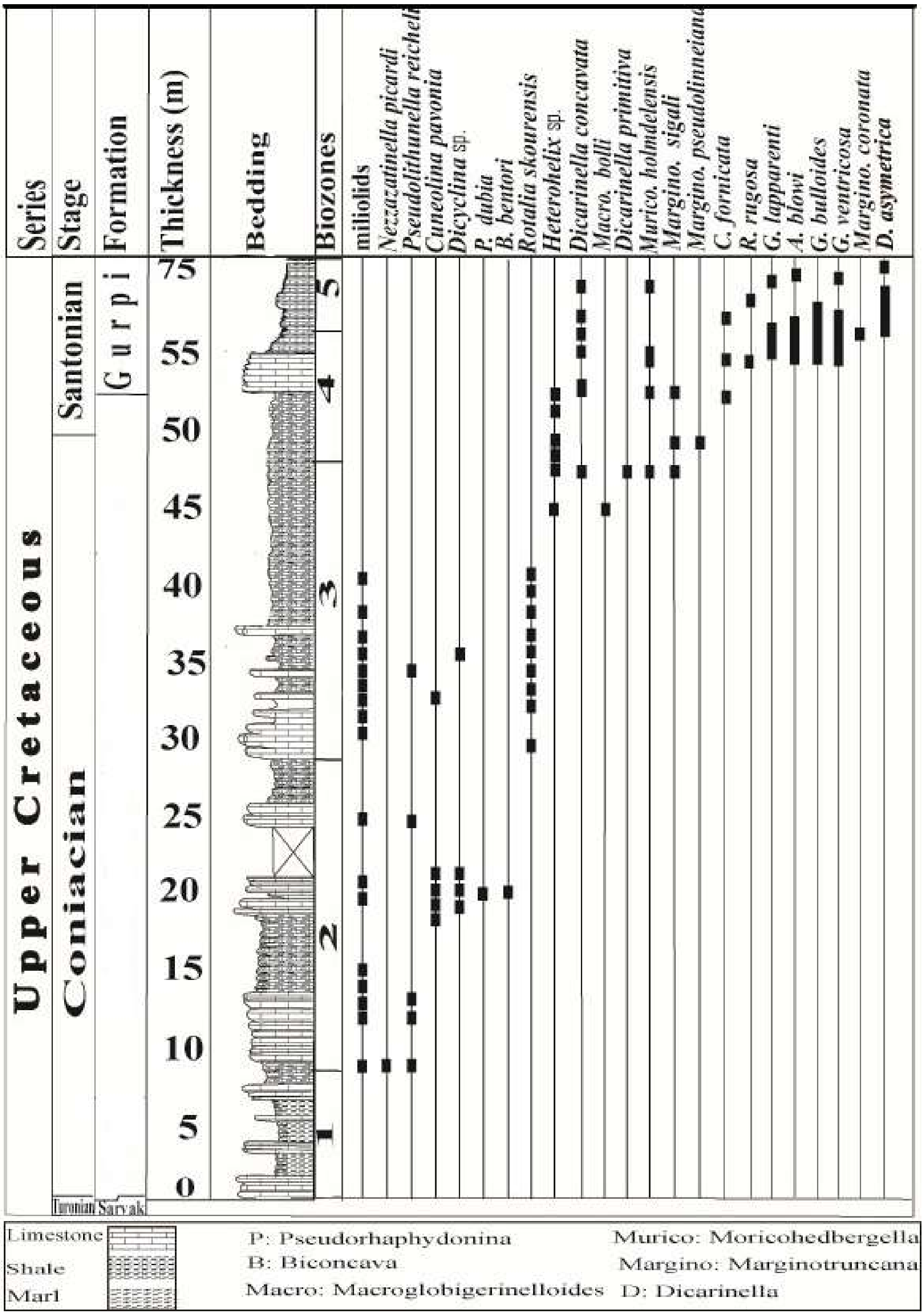

Figure 4: Biozonation of Coniacian-Santonian succession

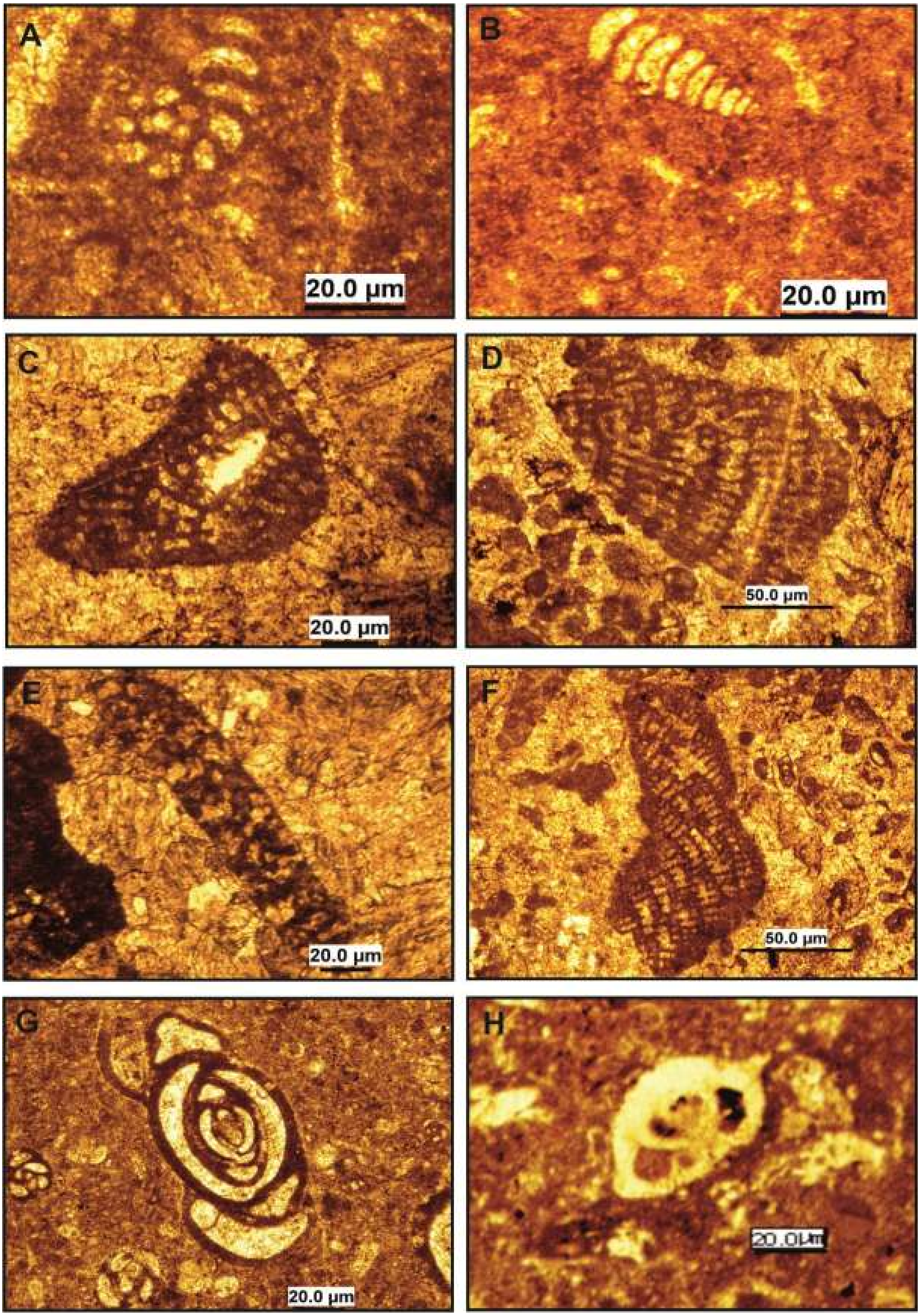

Figure 5: A&B: *Pseudolituonella* sp., C&D: *Cuneolina pavonia*, E&F: *Dicyclina* sp., G: miliolids, H: *Rotalia* sp.,

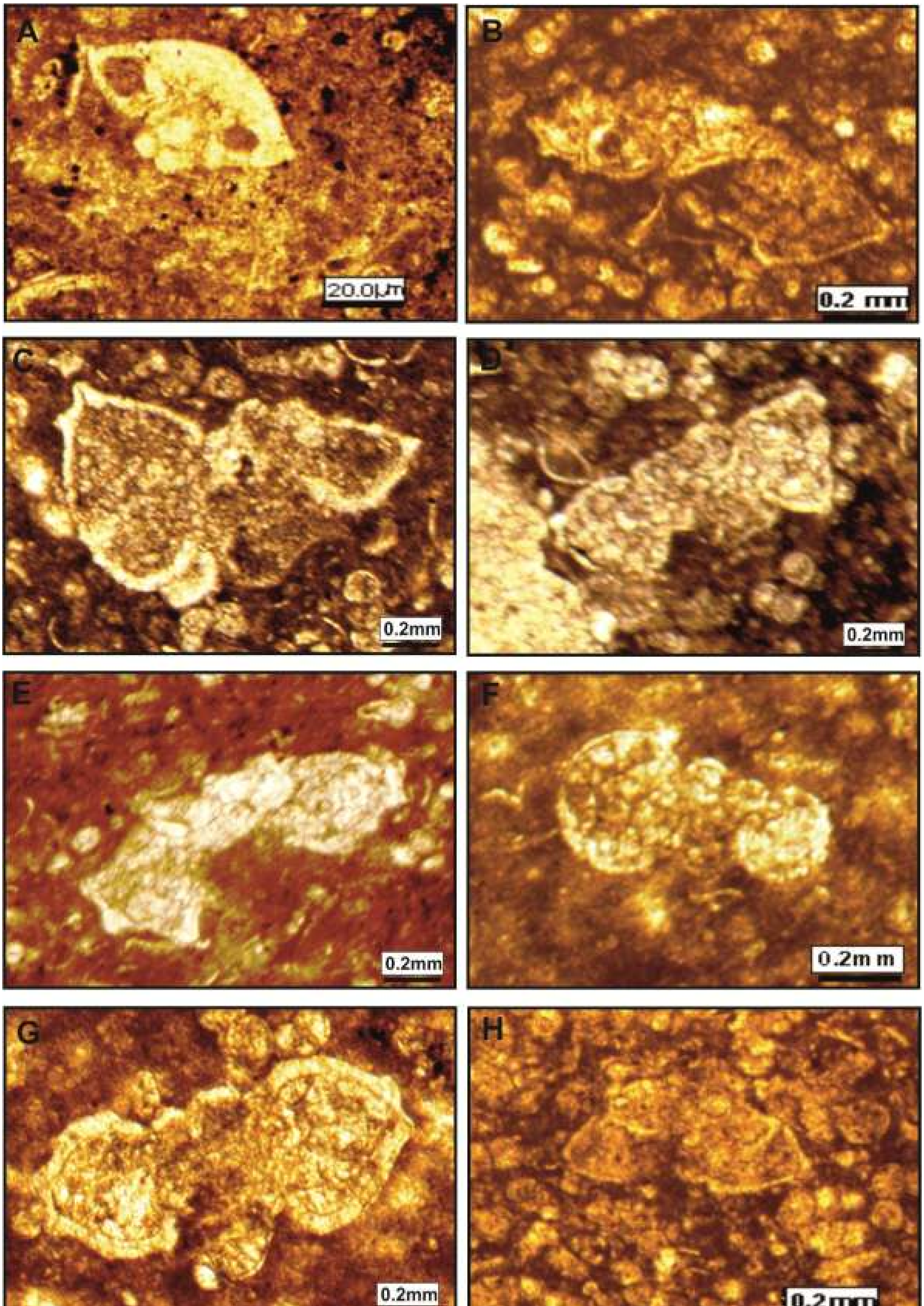

Figure 6: A: *Rotalia* sp., B: *Marginotruncana coronata*, C: *Dicarinella concavata*, D: *Dicarinella asymetrica*, E: *Globotruncana lapparenti*, F: *Rugoglobigerina rugosa*, G: *Globotruncana bulloides*, H: *Contusotruncana fornicata*,

Microfacies analysis
Facies analysis of the Coniacian-Santonian succession in the study area resulted in the recognition of eight microfacies types (Fig. 7), which characterize platform development. Each of the microfacies exhibits typical skeletal and non-skeletal components and textures. The environmental interpretations of the microfacies are discussed in the following paragraphs.

MF1. Charophyt wackestone
This microfacies is characterized by a high abundance of charophyts in a mud-supported texture. Ostracods are rare. In our studied section, this facies is represented by thin-bedded limestones in the lower part of the succession
(Fig. 8A).

Interpretation:
High amounts of charophyts are interpreted as indicators of fresh to brackish water environment (Flugel, 2004). The presence of charophyts and ostracods and the absence of marine fauna and flora are indicators of fresh to brackish water conditions (Flugel, 2004). This facies was also defined by Khalili (1974), Hart (1970), and Bolz (1977) to represent fresh to brackish water environments.
A similar microfacies was reported from the lacustrine environment by Bernaus *et al.,* (2003) in the Organya basin and Ghabeishavi *et al.*, (2009) in the Zagros Basin.

MF2. Ostracod mollusca wackestone –packstone
The main component in this microfacies is mollusca debris such as gastropods and bivalve (mostly larger than 2mm), Ostracod is the common skeletal components. Echinoid debris is also present. This facies is represented by grey limestone-forming beds 20–30 cm thick (Fig. 8B). The skeletal components are generally well preserved and do not show abrasion.

Interpretation:
The limited number of grain types; the absence of grain reworking, abrasion, rounding, and sorting; the lack of desiccation structures and other features indicating tidal flat environment (e.g., microbial laminae and/or fenestrate), interpreted that sedimentation took place in low energy restricted shallow-subtidal environments. Some components of the shallow open-marine environment were transported by storm wave into the lagoon (e.g., echinid debris).

MF3. Bioclastic miliolids green algae wackestone -packstone
This facies is characterized by the abundance of miliolids and green algae with a wackestone to packstone texture. In some samples, green algae have not seen, therefore the name of this facies changes to bioclastic miliolids wackestone – packstone. This facies is represented by light grey limestones of 40–90 cm thick (Fig. 8C).

Interpretation:
This microfacies is interpreted to be deposited in the restricted shallow subtidal environments. This interpretation is supported by the low diversity and abundance of imperforate foraminifera (Geel, 2000, Romero *et al*., 2002; Schulze *et al*., 2005).

MF4. Benthic foraminifera bioclastic – intraclast grainstone
This microfacies consists mainly of benthic foraminifera such as *Cuneolina* and *Dicyclina*. The predominant non-skeletal carbonate grains are intraclasts. Most of the intraclasts are subangular to angular, ranging in size from 0.4 to 1 mm. Some intraclasts are internally homogeneous and consist of micrites, while others display internal compositions such as pelloids and fossil fragments. Megascopically, it is medium-bedded to thick-bedded limestone (Fig. 8D).

Interpretation:
This facies was deposited in a shelf lagoon. The shelf lagoon condition is suggested by the rare to absent normal marine biota and abundant skeletal components of restricted biota (imperforate foraminifera). The subtidal origin is supported by the lack of subaerial exposure and stratigraphic position. The presence of sparry calcite cement indicates that this microfacies is deposited in a moderate to high energy environment.

MF 5. Miliolids Rotalia bioclastic wackestone - packstone
This facies is predominantly composed of miliolids and *Rotalia*. Additional components are echinoderm fragments, dasycladasea, bryozoa and intraclast. Grains are poorly sorted and are medium to coarse sand in size. This facies is represented by

cream limestones. Bed thickness is about 60 cm (Fig. 8E).

Interpretation:
The features of biota (co-occurrence of normal marine fauna and protected fauna) and stratigraphic position of this microfacies indicate that deposition took place in the open lagoon environment. Open lagoon shallow subtidal environments are characterised by microfacies types that include mixed open marine bioclasts and protected environment bioclasts. Nebelsick *et al.,* (2001) and Vaziri-Moghaddam *et al.,* (2006) considered similar facies representative of a shelf lagoon.

MF6. Bioclastic echinoid corallinacean packstone
This microfacies consists mainly of diverse fauna, including echinoid and corallinacean. Bryozoan and some benthic foraminifera such as Rotalia are also present. In a few samples with increasing bryozoans and mud, the name of this microfacies changes to bioclastic bryozoans echinoid wackestone. This microfacies comprises poorly to moderately sorted, packstones. Megascopically, it is medium-bedded to thick-bedded limestones (Fig. 8F).

Interpretation:
The presence of high diverse stenohaline fauna such as red algae, bryozoan, and echinoid indicate that this facies was deposited in the shallow open marine environment near a fair-water wave base in the proximal middle shelf.

MF7. Bioclastic oligosteginids wackestone – packstone
This microfacies is dominated by oligostegins and non keeled planktonic foraminifera. Echinoid debris is also present. The matrix consists of dense micrite. This microfacies comprises grey to slightly brownish thick- to medium-bedded limestones (Fig. 8G).

Interpretation:
Mud-supported textures with the planktonic biota, scarce benthic remains, and absence of characteristic sedimentary structures in microfacies indicate deposition in relatively open-marine environment with water depth below the fair weather wave base. The abundance of planktonic opportunistic foraminifers, e.g., heterohelicids and hedbergbellids are indicating eutrophic low-oxygenated waters (Arthur *et al.*, 1987; Luciani and Cobianchi, 1999; Aguilara-Franco and Hernández Romano, 2004). Shallow-marine benthic remains had been transported basin wards by storm-currents.

MF8. Bioclastic planktonic foraminifera packstone
The main components of this facies are keeled planktonic foaminifera (such as *Dicarinella concavata* and *Dicarinella asymetrica*) and echinoid debris. Glauconite is present in some part of this facies (Fig. 8H).

Interpretation:
This facies indicates deposition in an open marine, low-energy environment. Open marine, deep subtidal environments are indicated by large amounts of well-preserved planktonic foraminifers and the lack of abraded detritus. The low-energy hydrodynamic character indicates deposition below the storm wave base (Wilson, 1975; Flügel, 2004). The presence of glauconite indicates deeper water and less oxygenated or reducing conditions with a low sedimentation rate (Odin & Matter 1981).

Sedimentary environment:
The Coniacian-Santonian succession of the studied area represents that sedimentation has taken place on the open marine carbonate shelf on the basis of the distribution of the biota, textures and vertical facies relationships (Fig. 9). The carbonate shelf environments are separated into: (1) shallow brackish to fresh water ponds or lakes (2) the inner shelf, (3) the middle shelf and (4) the outer shelf (Flügel, 2004). The shallow brackish to fresh water ponds or lakes is composed by only one microfacies, Charophyt wackestone. The lower boundary of the Coniacian–Santonian succession is an unconformity with bauxite and iron oxide development in emergent areas and charophyte facies in areas that remained submerged. The depositional area was at least partially separated from the open sea when the Charophyt beds were deposited (Hart, 1970, Ghabeishavi *et al.,* 2009). Deposition of brackish to fresh water sediments in the topographically lower position during the low sea level has been reported in the Organyá basin

(Bernaus *et al.,* 2003). The lake sedimentation ended with the initiation of marine transgression and sedimentation of the first marine sediments (MF 2-4). The continuous transgression led to the establishment of an open shelf carbonate platform.

The inner shelf facies types are highly variable but contain abundant imperforated tests of foraminifera (e.g., miliolids, *Cuneolina* sp., *Dicyclina* sp., textularids), dasycladacean and gastropods.

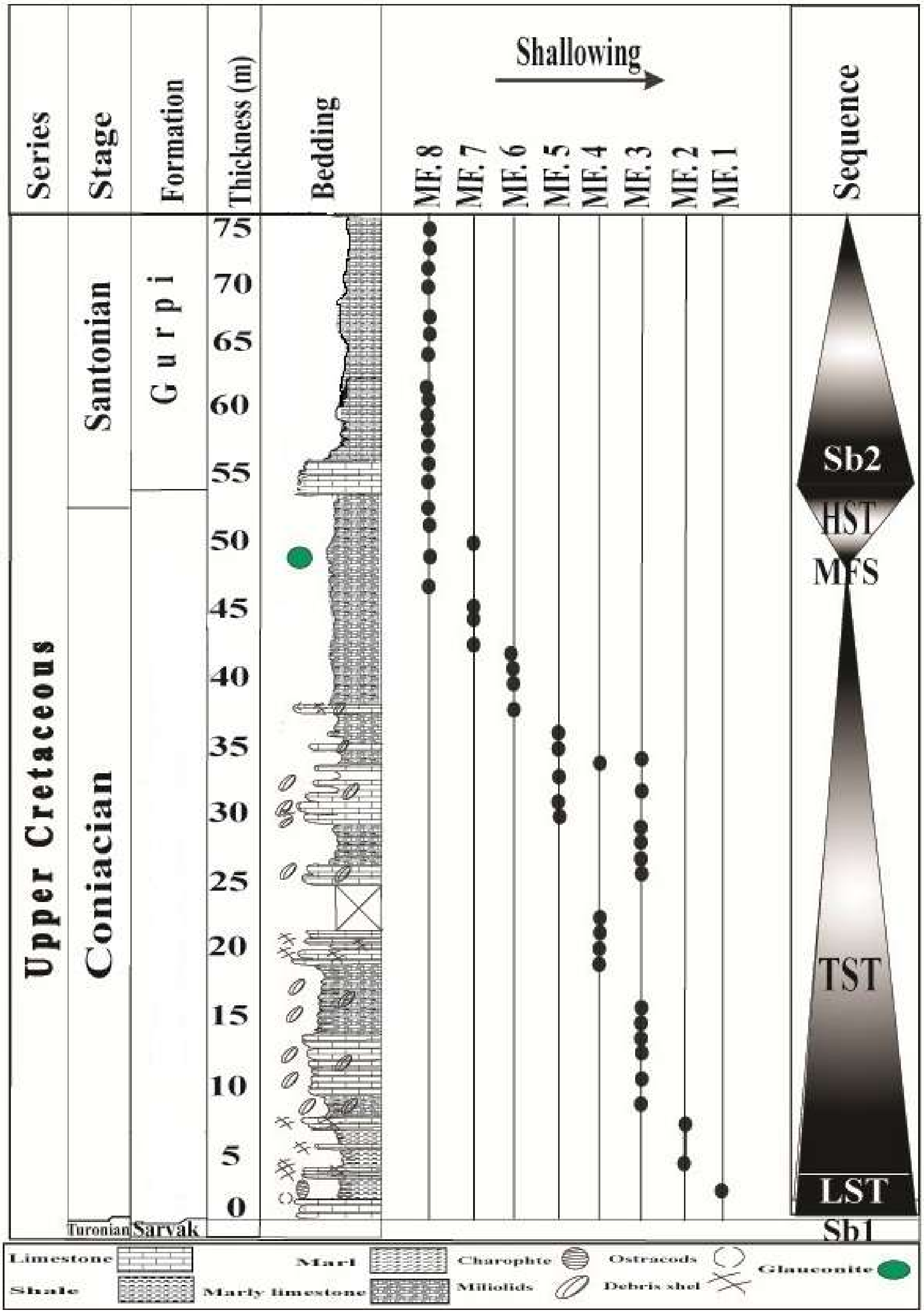

Figure7: Micrfacies distribution and sequence of the Coniacian-Santonian succession in East of Ramhormoz area (Tange-Bulfaris section). TST: transgressive systems tract; HST: highstand systems tract; mfs: maximum flooding surface; SB: sequence boundary.

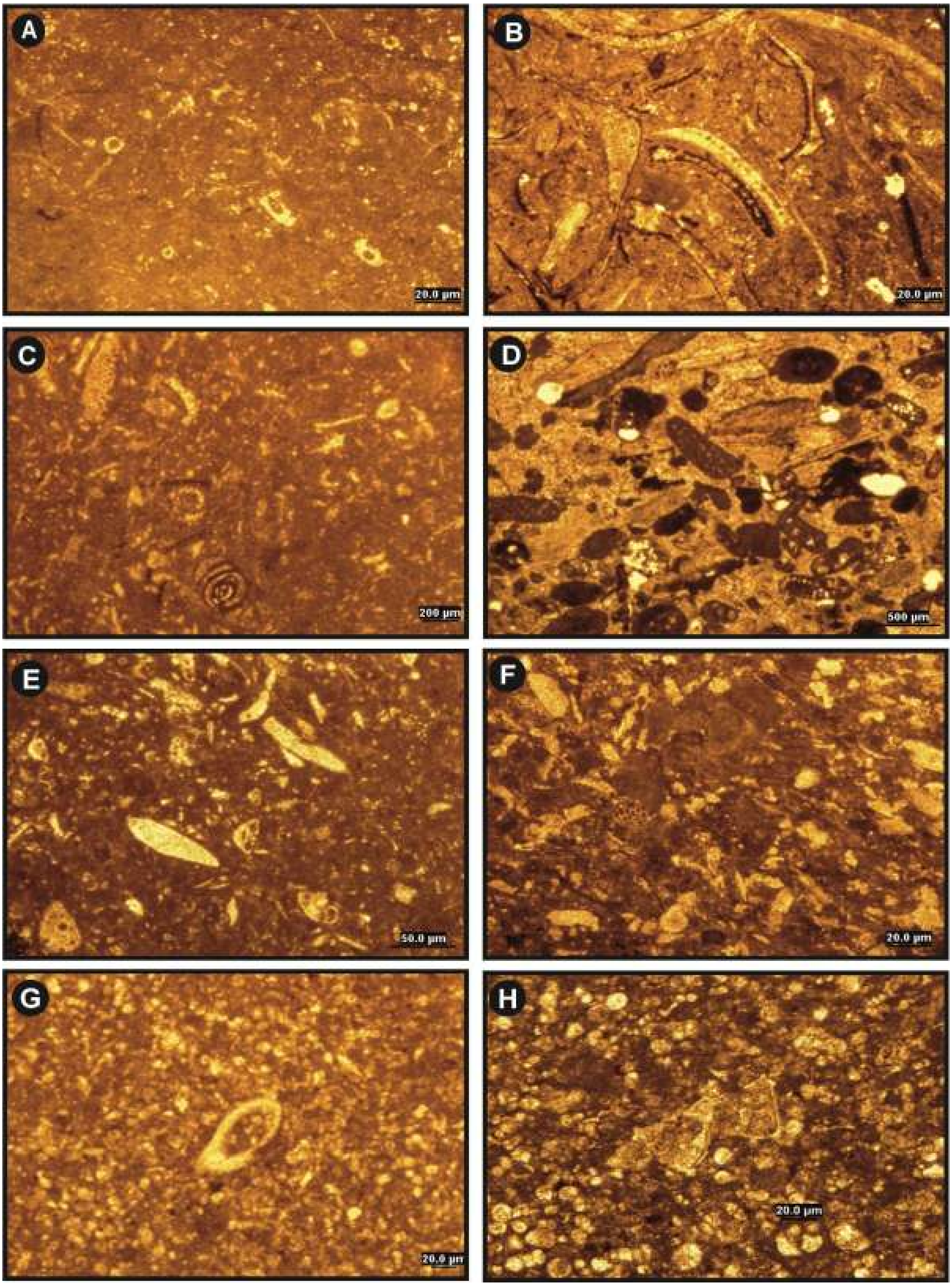

Figure 8: Microfacies types of Coniacian-Santonian succession A- MF1: Charophyt wackestone, B- MF2: Ostracod mollusca wackestone – packstone, C- MF3: Bioclastic miliolids green algae wackestone – packstone, D- MF4: Benthic foraminifera bioclastic - intraclast grainstone, E- MF5: Miliolids Rotalia bioclastic wackestone –packstone, F- MF6: Bioclastic echinoid corallinacean packstone, G- MF7: Bioclastic oligosteginids wackestone – packstone, H- MF8. Bioclastic planktonic foraminifera packstone

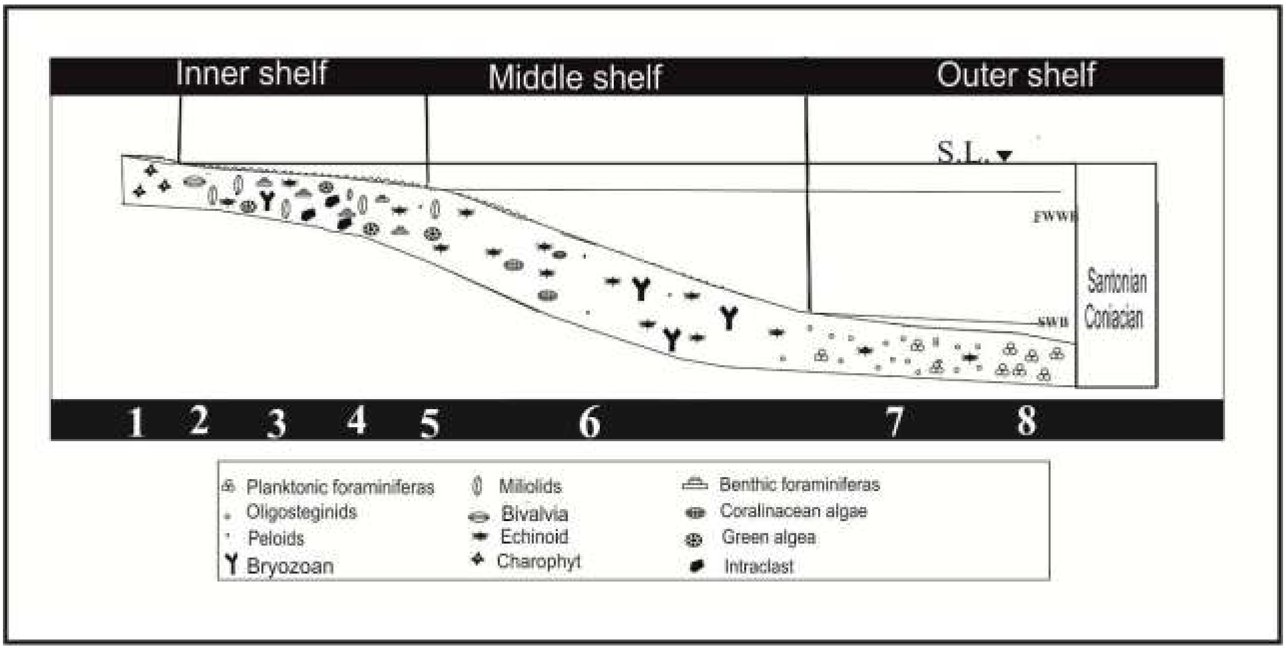

Figure 9: Depositional model for the Coniacian-Santonian succession in East of Ramhormoz area (Tange-Bulfaris section)

Restricted shallow subtidal environments of deposition are characterized by low-diversity benthic foraminiferal assemblages (MF2-4). The foraminiferal associations are commonly dominated by imperforated foraminifera. Restricted conditions are suggested by lack of normal marine biota and the presence of restricted biota (imperforated foraminifera) (Reiss & Hottinger, 1984, Hottinger, 1997).

The middle shelf is characterized by coarse grained skeletal wackestone-packstones. Skeletal grains are dominantly corallinacean, bryozoa and echinoid fragments. Deposition took place in shallow water near the fair-weather wave base. Indicators of the outer shelf deeper water facies are high amounts of oligosteginids and planktonic foraminifers.

Sequence strtigraphy

Facies analysis and field observation led to recognition of one third-order sequences in the Coniacian-Santonian succession (Fig. 7).

The basal boundary in this sequence is sharp and clearly defined as type I sequence boundary.

This surface is an unconformity between Sarvak Formation and the Coniacian-Santonian succession with no irregular erosional surface or iron oxide and bauxite. This unconformity has been described by many workers in the Fars, Dezful, and Lurestan areas (James & Wynd 1965; Wood & Lacassagne 1965; Khalili 1974; Bolz, 1977). Karst bauxite has been reported on this boundary in the northern flank of the Bangestan anticline (Zarasvandi *et al.,* 2008). In the study area, this unconformity is defined by the sedimentation of brackish to fresh water (MF 1) directly on the Sarvak Formation with no irregular erosion surface or iron oxide and bauxite. Shallow brackish to fresh-water ponds or lakes (MF 1) were deposited during short periods of very low sea level, while karst bauxite and iron oxide was deposited in emergent area. This surface was reported by Ghabeishavi *et al.,* (2009) in Tange Band and Tange Bulfaris. Shallow brakish to fresh water ponds or lakes (MF1) was deposited during short periods of very low sea level that is interpreted as the lowstand system tract (LST). Microfacies 2,3,4,5,6,7 are interpreted as a transgressive system tract (TST).

Above this succession the strata show an increase in deeper water fauna. These beds are interpreted to be equivalent to the maximum flooding surface and are characterized by a low rate of sedimentation, glauconiterich beds, and a change in microfossil assemblage (from calcispheres to planktonic foraminifers).

The upper boundary of this sequence is defined as a type II sequence boundary that shows no clear evidence of subaerial exposure. This sequence boundary is between the Coniacian-Santonian succession and Gurpi Formation. In the type section Gurpi overlies the Ilam Formation with an iron oxide zone (Motiei, 1382).

Conclusion

The Coniacian-Santonian succession in the study area yielded benthic and planktonic foraminifera. Based mainly on the distribution of the foraminifera, five assemblage biozones are recognized. Assemblage 1 represents the Coniacian age. Assemblage 2 and 3 are Coniacian – Santonian in age. Assemblage 4 is the Coniacian to earliest Santonian in age and assemblage 5 represents the Santonian age.

Microfacies analysis led to the recognition of 8 microfacies. Microfacies vary in lateral and vertical distribution, and show that carbonates were deposited on a carbonate open shelf platform. Variation in relative sea level led to the deposition of one –third order sequence.

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