Foraminiferal biozonation and morphogroups from shale member of the Aitamir Formation in Maraveh Tappeh section, northwest Koppeh-Dagh Basin

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Abstract

The Aitamir Formation is divided into two members the lower sandstone and the upper shale. 32 genera and 57 species of foraminifera have been recognized. According to identified foraminifera *Rotalipora appenninica* Interval Zone, *Rotalipora globotruncanoides* (*Rotalipora brotzeni*) interval zone and *Whiteinella aumalensis-Dicarinella canaliculata* assemblage zone are proposed and a late Albian-late Cenomanian age is attributed for upper shale member of the Aitamir Formation. Palaeoecological studies led to recognition of three calcareous, two agglutinated benthic and three planktonic foraminifera morphogroups. In the lower one third of shale member, the planktonic foraminifera are more abundant than agglutinated benthic foraminifera, while in the upper one third, the frecuency of all morphogroups increase. Calcareous benthic morphogroups could be attributed to aerobic, shallow to slightly deep water, oligotrophic environment; while the agglutinated benthic morphogroups show aerobic, mesotrophic to eutrophic condition that are characterized by a dominance of arenaceous shallow infaunal specimens which are active deposit feeders. Planktonic foraminifera morphogroups with trochospiral and smooth test show that may have lived near the surface water in the aerobic to semi aerobic environmental conditions. The increasing number of planktonic foraminifera and specially keeled species could suggest recovery in paleoenvironmental conditions.

Keywords: *Foraminifera, Biostratigraphy, Morphogroups, Aitamir Formation, Koppeh-Dagh*

Introduction

The Koppeh-Dagh sedimentary basin is located in north-east Iran, southern Turkmenistan and Afghanistan and is composed of mostly Mesozoic and Cenozoic sedimentary successions. The Iranian part of the Koppeh-Dagh Basin is geographically located between 35° 30' and 38° 15' N latitude and 54° 00' and 61° 13' E longitude. Fifteen formations have been introduced in the Koppeh- Dagh Basin. The Cretaceous formations include Shurijeh, Zard, Tirgan, Sarcheshmeh, Sanganeh, Aitamir, Abderaz, Abtalkh, Neyzar and Kalat (Afshar-Harb, 1994) (Figure 1). In this paper, we introduce foraminifera contents from the late Albian- late Cenomanian interval of the Aitamir Formation in the western Koppeh-Dagh Basin that have not been reported in detail so far it is important for correlation between Iran and other countries in the region. The foraminifera assemblage have been used to interpret the biostratigraphic and palaeoecological conditions.

Material and methods

In order to study foraminifera, a total of 89 samples both hard and soft were collected from the MaravehTappeh section. The shale and marls samples were crushed to small particles (2-3cm diameters), soaked in tap water with diluted hydrogen peroxide 10% for 48 hours, Then washed and the residue was sieved at 125µm, 80µm and 60µm then all of foraminifera were picked under a binocular microscope, while SEM was used at Tehran University for taxonomic identification of foraminifera assemblages. The real thickness has been calculd and stratigraphical section was drawn by using computer software packages. Excel software has also been used for drawing charts and graphs.

Stratigraphy

Aitamir Formation

The thickness of this formation at the type locality (at the village of Aitamir, 70 kilometers, north -east of Gonbad Kavous) is about 1000 m and is divided into two members (Afshar-Harb, 1979). The lower sandstone member consists of glauconitic coarse to fine grained sandstones with some interbeds of silty sandstones while the upper shale member is composed of green to greenish grey and grey shales with intercalations of marlstone and limestone beds. Based on foraminifera assemblage, the Aitamir Formation is Cenomanian in age (Kalantari, 1969). However Seyed-Emami (1980), Seyed-Emami and Aryai (1981), Seyed-Emami *et al.* (1984), Immel *et al.* (1997), Mosavinia *et al.* (2007) and Mosavinia and Wilmsen (2011), based on ammonites, reported a late Albian–middle Cenomanian age for this formation in the Koppeh-Dagh basin.

The measured section of the Aitamir Formation is located about 35 kilometers west of Maraveh Tappeh and near Cherla at 37°48' N latitude and 55°36' E longitudes (Figure 2). Aitamir Formation, with 1070 m in thickness at this location, conformably overlies the Sanganeh Formation and underlies limestones of the Abderaz Formation (Turonian age) (Figure 3). The lower sandstone member is 711 and the upper shale member is 359 m in thick (Figure 3).

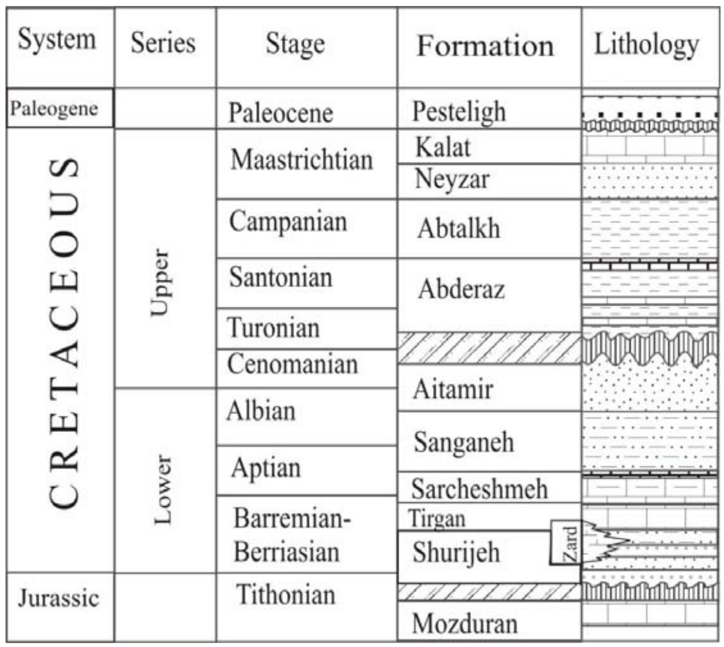

Figure 1. General stratigraphical column for the Cretaceous successions of the Koppeh-Dagh Basin (modified from Kalantari, 1987; Immel *et al.,* 1997).

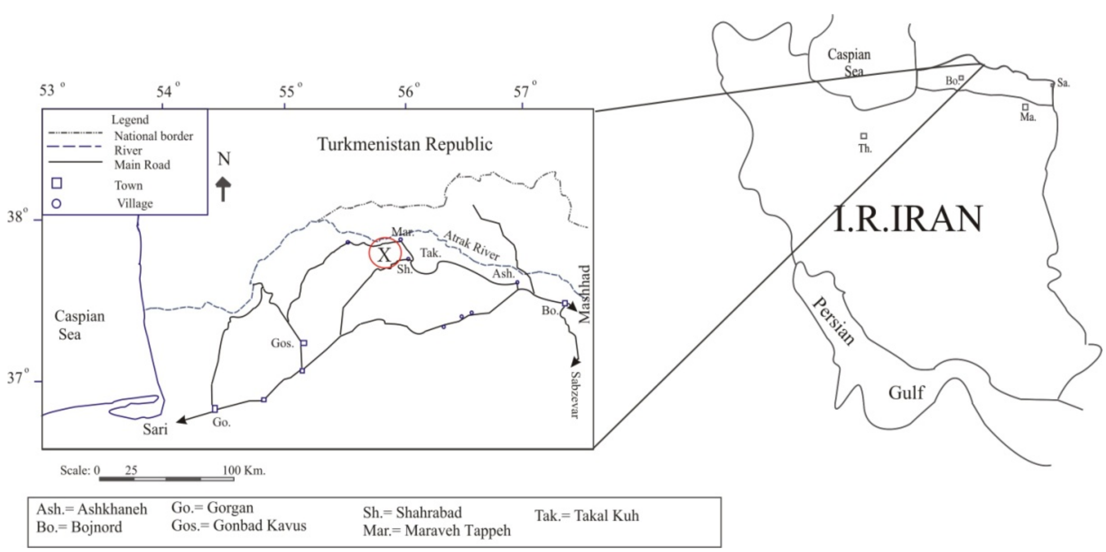

Figure 2. Geographical names and their positions, location of measured section is shown with circle

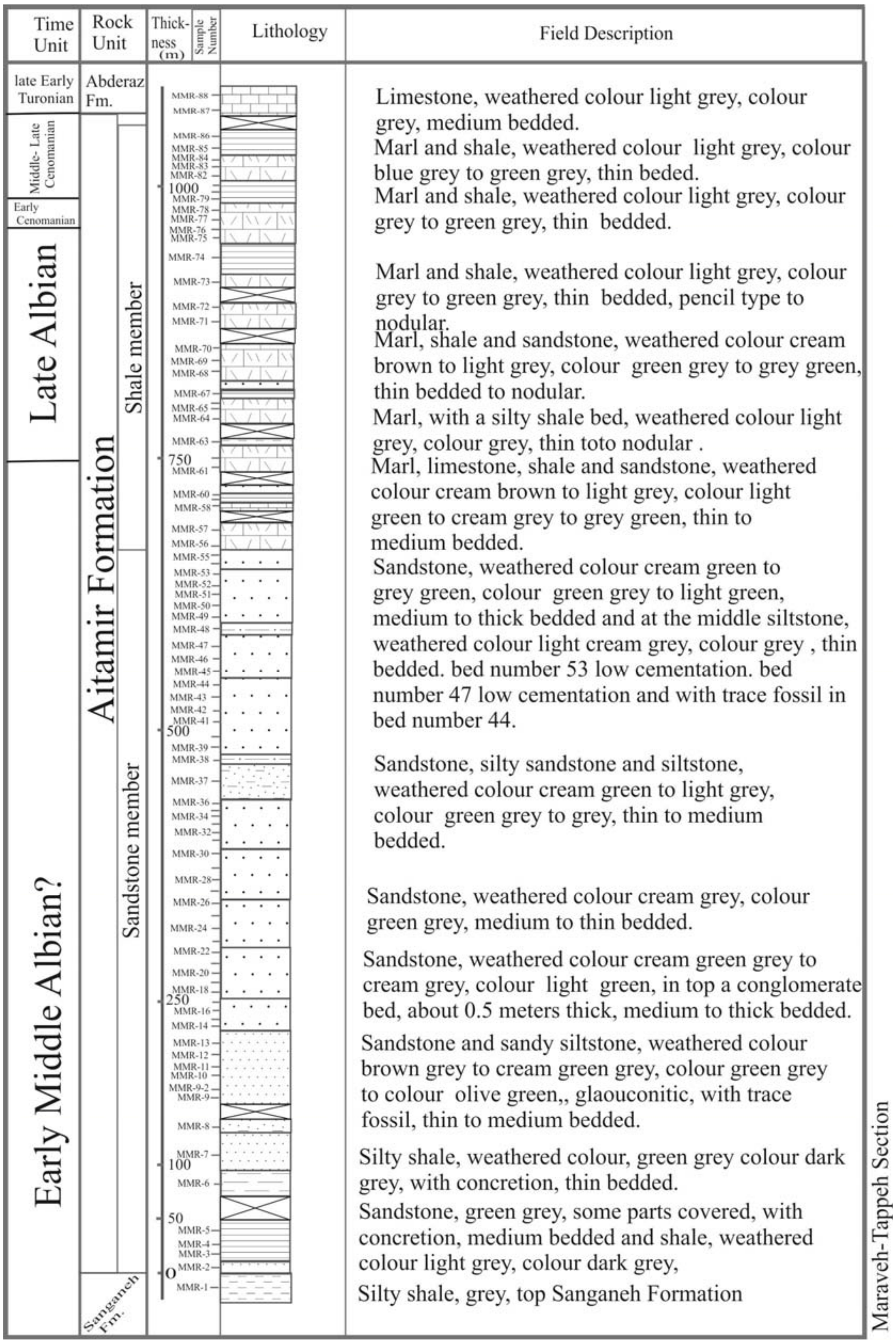

Figure 3. Stratigraphic column of the Aitamir Formation in Maraveh Tappeh section

The measured section of the Aitamir Formation is located about 35 kilometers west of Maraveh Tappeh and near Cherla at 37°48' N latitude and 55°36' E longitudes (Figure 2). Aitamir Formation, with 1070 m in thickness at this location, conformably overlies the Sanganeh Formation and underlies limestones of the Abderaz Formation (Turonian age) (Figure 3). The lower sandstone member is 711 and the upper shale member is 359 m in thick (Figure 3).

The assemblage of foraminifera and biostratigraphy

Bed-by-bed sampling at the MaravehTappeh section for biostratigraphic studies provides a firm basis for a biozonation of the Aitamir Formation with the late Albian-late Cenomanian age. This study led to identification of 22 genera and 34 species of benthic foraminifera and 10 genera and 23 species of planktonic foraminifera. In this study, three biozones are suggested that are coincident with global biozones (Figure 5).

Rotalipora appenninica Interval Zone

This zone is an interval zone that was introduced by Bronnimann (1952). Postuma (1971) placed this zone in the lowermost part of Cenomanian. Premoli Silva and Verga (2004) stated that this zone has an age of the late Albian. This biozone is defined based on the first appearance of *Rotalipora appenninica* Renz, 1936 up to the first appearance of *Rotalipora globotruncanoides* Sigal, 1948. Thickness of this zone is 215 meters in the section.

The assemblage fauna in this biozone include *Astacolus* sp., *Berthelina baltica, Berthelina intermedia, Berthelina kaptarenkae, Darbyella* sp., *Laevidentalina legumen, Haplophragmoides concavus*, *Muricohedbergella delrioensis, Muricohedbergella* sp.1, *Muricohedbergella* sp.2, *Lenticulina* sp.1, *Lenticulina* sp.2, *Lenticulina subalata, Lingulogavelinella asterigerinoides, Muricohedbergella* sp.6, *Praeglobotruncana* sp. cf. *P. gautierensis, Recurvoides* sp., *Saracenaria* sp., *Spiroplectammina* sp. and *Vaginulina recta.* A late Albian age is attributed to this biozone (Figure 5).

Rotalipora globotruncanoides (*Rotalipora brotzeni*) interval zone

This zone is an interval zone that was introduced by Lehmann (1966) for the first time. This biozone is also reported by Bolli (1966) and Caron (1985).

Figure 4. Lower part of shale member with limestone beds

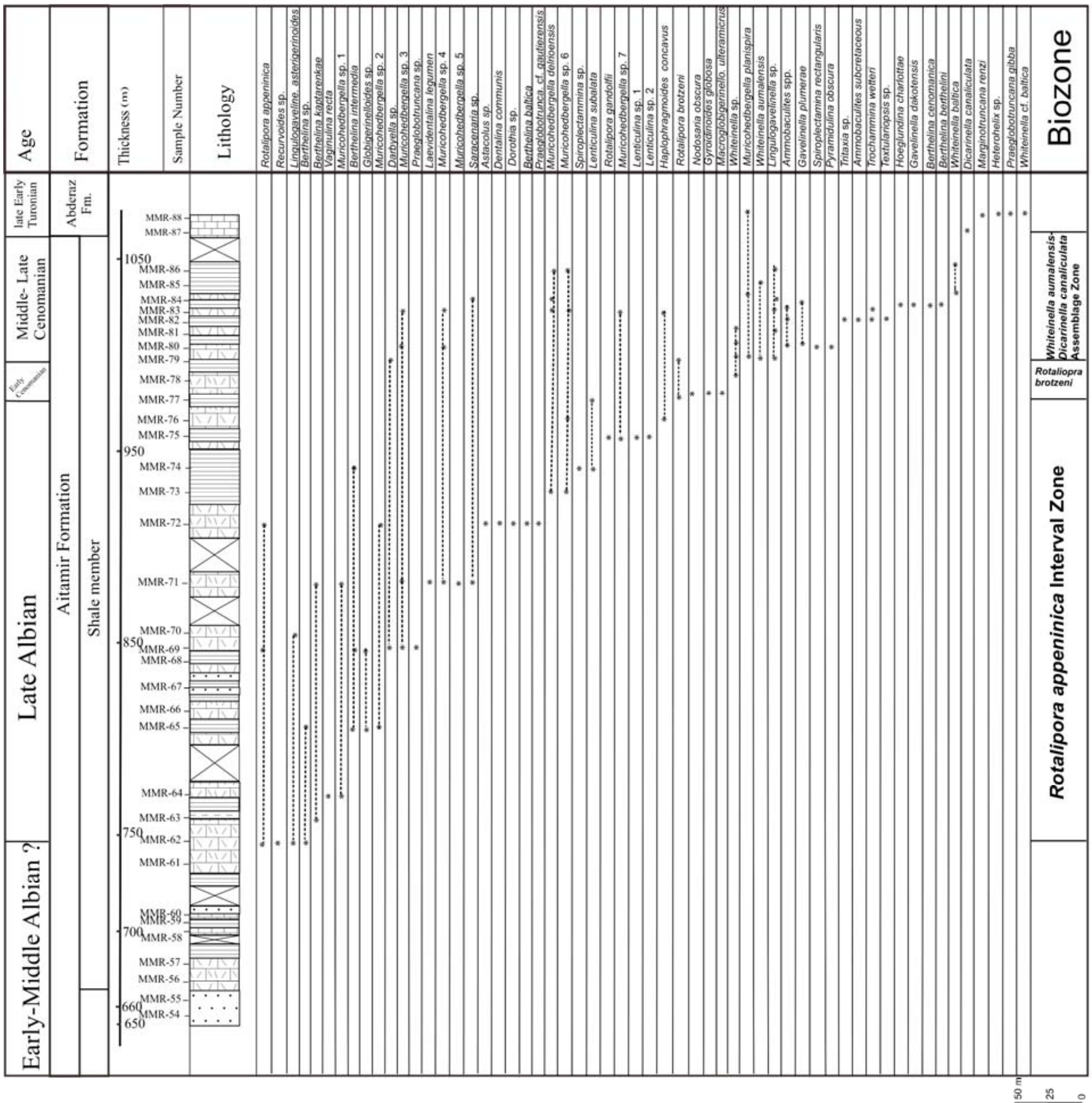

Figure 5. Foraminifera range chart of the Aitamir Formation in MaravehTappeh section

As Wonders (1980) mentioned, *globotruncanoides* Sigal, 1948 is synonymous with *brotzeni* Sigal, 1948, therefore Premoli Silva and Verga (2004) and Nishi *et al.*, (2003) used *globotruncanoides* instead of *brotzeni*.This biozone is defined as the first occurrence of *Rotalipora brotzeni* (sample 77) up to first occurrence of *Whiteinella aumalensis* (sample 79) with a 15 m thickness. The assemblage fauna in this biozone includes *lingulogavelinella* sp., *Gyroidinoides globosa, Lenticulina subalata, Muricohedbergella planispira, Nodosaria obscura* and *Darbyella* sp. Based on the presence of *Rotalipora brotzeni*, an early Cenomanian age is attributed to this biozone.

Whiteinella aumalensis- Dicarinella canaliculata assemblage zone

Rotalipora cushmani and *Rotalipora reicheli* are introduced as index fossils for this biozone with middle –late Cenomanian age. These index foraminifera have not been found at this locality. However Longoria (1984), Leckie (1985), Nishi *et* *al.,* (2003), Premoli Silva and Verga (2004), Keller and Padro (2004) and Grosheny *et al*. (2006) stated that *Dicarinella* and *Whiteinella* in association with *Rotalipora cushmani* and *Rotalipora reicheli* biozone can be used for appearnce of this biozone. Therefore this biozone is starts with the first occurrence of *Whiteinella aumalensis* Sigal, 1952 up to first occurrence of *Dicarinella canaliculata* Reuss, 1854. The thickness of this biozone is about 55 m and includes the uppermost part of the Aitamir Formation.

The assemblage fauna in this biozone includes *Ammobaculites subcretaceous, Ammobaculites* sp.1, *Ammobaculites* sp.2, *Ammobaculites* sp.3, *Berthelina cenomanica, Dicarinella canaliculata, Gavelinella dakotensis, Gavelinella plumerae, Haplophragmoides concavus, Muricohedbergella* sp. 6, *Lingulogavelinella* sp., *Hoeglundina charlottae, Muricohedbergella delrioensis, Praeglobotruncana gibba, Pyramidulina obscura, Saracenaria* sp., *Spiroplectammina rectangularis, Textulariopsis* sp., *Trochammina wetteri* and *Whiteinella baltica.* Based on the assemblage fauna and occurrence of *Dicarinella canaliculata* and *Whiteinella aumalensis*, middle-late Cenomanian age is suggested for this biozone.

In the lowermost part of the Abderaz Formation, *Marginotruncana renzi, Whiteinella baltica and Praeglobotruncana gibba* have been recognized. The age of the above foraminifera in order are Turonian-Coniacian (Tur *et al*. 2001; Premoli Silva & Verga, 2004), Cenomanian- Turonian (Tur *et al.* 2001; Keller and Pardo, 2004; Samuel et al., 2009) and Cenomaian- Santonian (Hiroshi *et al*. 2003; Keller & Pardo, 2004; Grosheny *et al*. 2006. Accoring to co-occurrence of these foraminifera together, Turonian age is suggested for the base of Abderaz Foramtion (Figure 5). Therefore, the boundary between the Aitamir and Abderaz formations is most probably continuous (Figure 6).

Foraminifera morphogroups

Previous studies of benthic morphological groups by Koutsoukos and Hart 1990) and Nagy (1992) show a strong relationship between environmental conditions and morphotypes. According to Corliss and Chen (1988), Koutsoukos and Hart (1990) and Coccioni and Galeotti (1993), there is an acceptable relationship between test morphology and inferred habitat of foraminifera fauna. Friedrich *et al*. (2003) believed that the benthic foraminifera assemblages as well as stable isotope data can be used to interpret the oxygen content of bottom waters, organic matter flux to the sea floor, and sea-level changes during the L Aptian time. Erbacher *et al.,* (1998) stated that benthic foraminifera can serve as a sensitive tool to provide a better understanding of the conditions at the sea floor during the early Cretaceous.

The planktonic morphogroups are reld to sea level changes. Eicher and Worstell, (1970) and Eicher, (1967) have shown that globular morphotypes (such as *Hedbergella*, *Heterohelix*) were the first planktonic foraminifera that appeared in transgression and the last to disappear during the regression. These globular forms were habitant in surface waters. Those that are keeled bioconvex and keeled plano-convex such as *Rotalipora* inhabit in deeper waters (Hart & Bailey, 1979**;** Leckie, 1987).

Another approach is the successive appearance and disappearance of species or genera along the slope of the basin, e.g. water depth, however other factors are also influencing species distribution. These may include the rise and fall of oxygen minimum zones (Jarvis *et al.,* 1988; Leary *et al.,* 1989; Koutsoukos & Hart, 1990) or nutrient supply (Premoli Silva & Sliter, 1999).

The benthic foraminifera assemblage of the Aitamir Formation in Marveh Tappeh section allowed to distinguish three calcareous (CM1-CM3) and two agglutinated morphogroups (AGM1-AGM2) (Figures 8 and 9). This classification is based on morphology, life position, feeding habitat and environmental conditions.

Calcareous benthic morphogroup 1 (CM1)

This morphogroup consists of taxa with planispiral to trochospiral test shape which are typical for aerobic and eutrophic to mesotrophic environments. Most of these taxa are epifaunal forms, active deposit feeders and have been identified in the middle-outer shelf to upper slope deposits (Coccioni and Galeotti, 1993; Widmark, 1997; Grunert, 2011). *Lingulogavelinella*, *Gyroidinoides*, *Berthelina* and *Gavelinella* are the common examples of this group (Figure 7). The abundance of this morphogroup changes between 8.33 and 33.3 percent. This morphogroup is the most abundant among calcareous benthic morphogroups and distributed nearly in all parts of the shale member, however it is more abundant in upper one third of the shale member than the other parts (Figure 8).

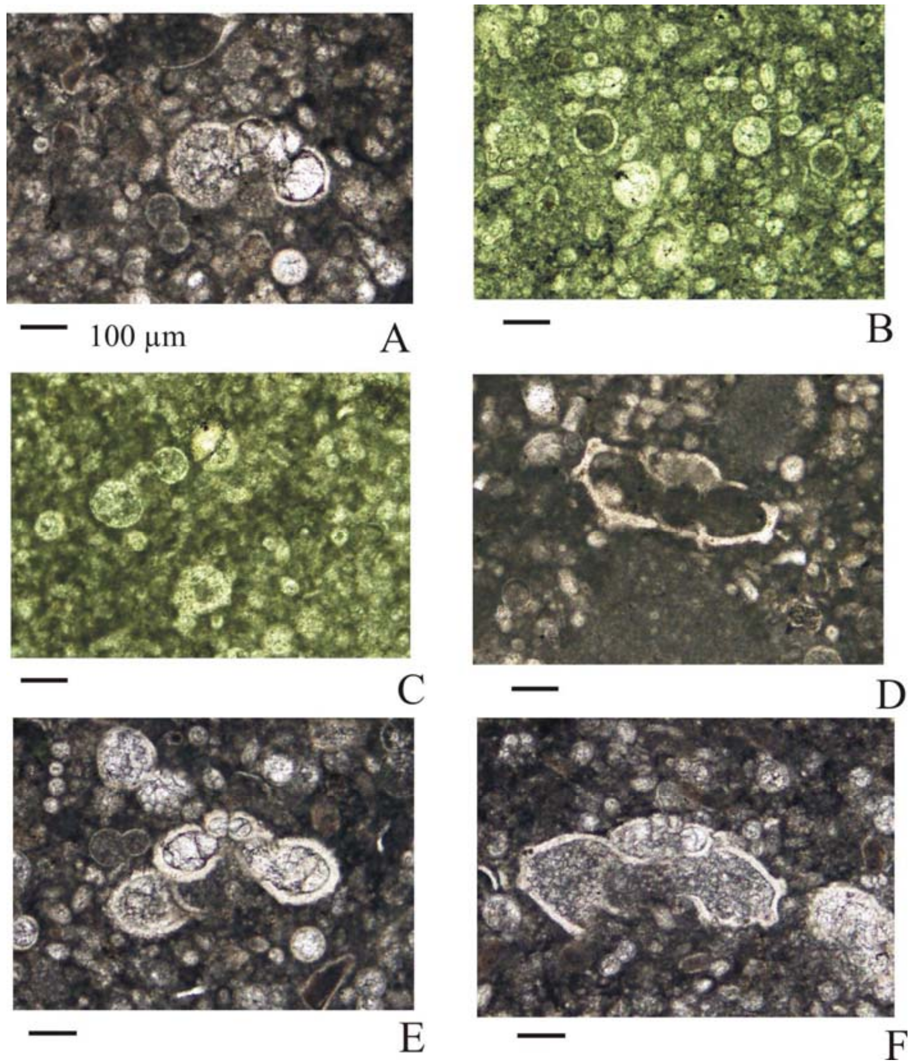

Figure 6. Some selected micrographs of microfossils in thin section- A- *Whiteinella* sp.cf. *W. baltica,* sample no. MMR-88, early Turonian; B- *Calcisphaerulla innominata* and *Pithonella ovalis*, sample no. MMR-88, early Turonian; C- *Muricohedbergella planispira*, sample no. MMR-88, early Turonian; D- *Dicarinella canaliculata*, sample no. MMR-87, early Cenomanian; E- *Praeglobotruncana gibba,* sample no. MMR-88, early Turonian; F- *Marginotruncana renzi*, sample no. MMR-88, early Turonian.

Calcareous benthic morphogroup 2 (CM2)

Test shape in this morphogroup is elongated and flattened to straight periphery. Life position show that they are shallow to deep infaunal, deposit feeder, live in the neritic to upper bathyal, aerbic to dysaerobic and mesotrophic to eutrophic environment conditions (Ruckheim *et al*. 2006; Grunert, 2011). The most taxa belong to this group are *Nodosaria, Laevidentalina* and *Pyramidulina*. This morphogroup seems to be indicative of well oxygenated environment and seems to have preferred meso-eutrophic living conditions (Figure 9). The abundance of this morphogroup changes between 8.33 and 16.6 percent. This morphogroup is distributed in sample numbers 68, 75, 77 and 79 and co-occurrs with CM1.

Calcareous benthic morphogroup 3 (CM3)

The foraminifera fauna in this morphogroup are dominated by taxa such as *Lenticulina*, *Astacolus, Darbyella, Saracenaria* and *Hoeglodina* which could have the following specific characteristics: biconvex test shape, active deposit feeders, eutrophic to mesotrophic conditions as is the case for epifaunal to deep infaunal assemblages. They can be found in a wide range of environment from sublithoral to upper bathyal and aerobic to dysaerobic conditions (Widmark, 1997; Ruckheim *et al.* 2006) (Figure 10).

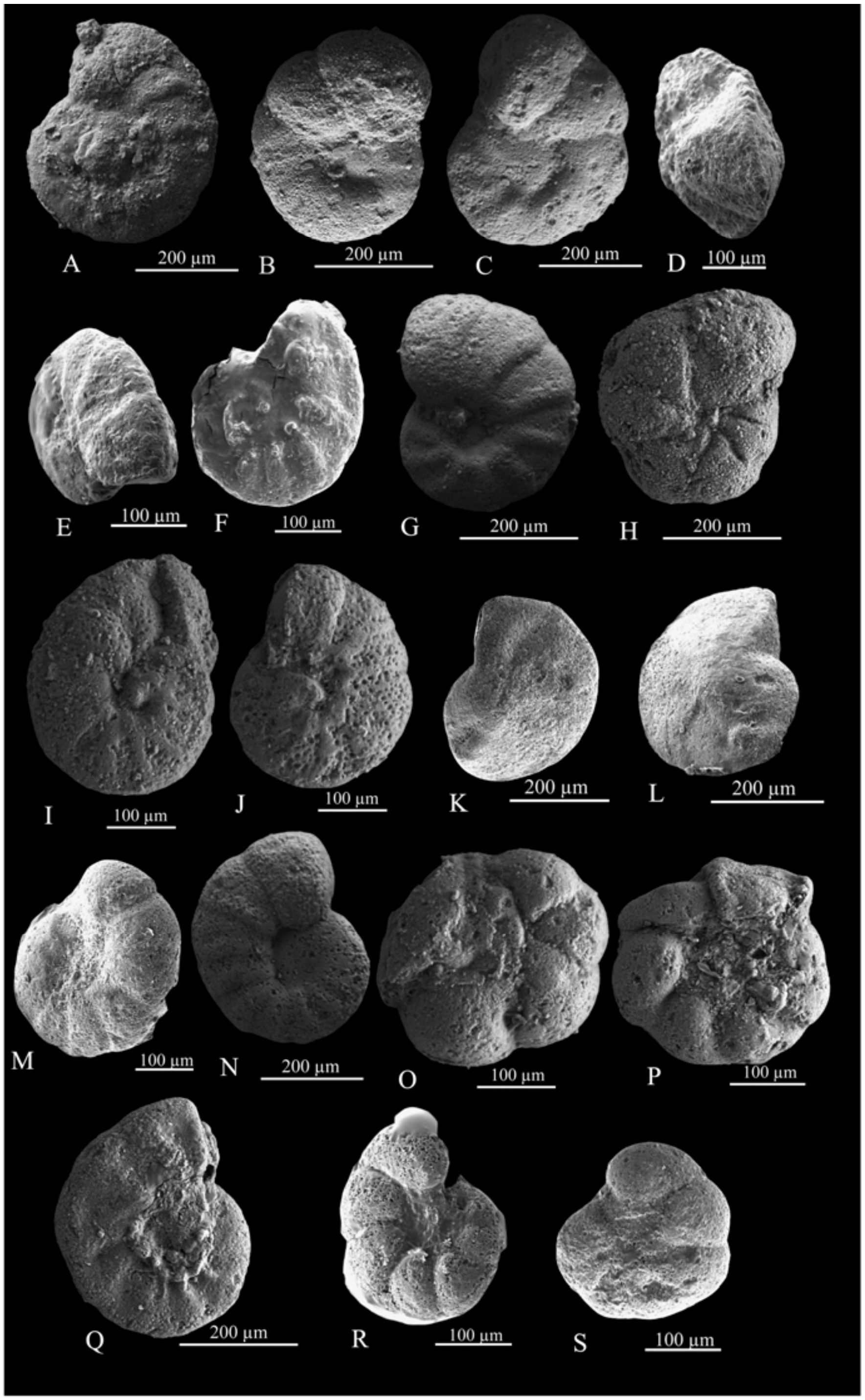

Figure 7. A-*Berthelina* sp., sample no. MMR-62-4-7 Age: Late Albian; B- *Lingulogavelinella asterigerinoides asterigerinoidels*, sample no. MMR-62-4-5, Age: Late Albian; C- *Berthelina kaptarenkae*, sample no. MMR-63-4-4, Age: Late Albian; D, E, F- *Berthelina intermedia,* sample no. MMR-65-1, Age: Late Albian; G-*Berthelina baltica*, sample no. MMR-72-3-7 Age: Late Albian; H- *Gavelinella dakotensis,* sample no. MMR-83-1-16, Age: Middle-Late Cenomanian; I, J-*Gavelinella plumerae,* sample no. MMR-80-2-10 and MMR-80-2-8, Age: Middle-Late Cenomanian; K, L-*Gyroidinoides globosa,* sample no. MMR-77-3, Age: Early Cenomanian; M-*Berthelina intermedia,* sample no. MMR-74-3, Age: Late Albian; N- *Berthelina belorussica,* sample no. MMR-79-2-14, Age: Middle-Late Cenomanian; O, P- *Lingulogavelinella* sp.2, sample no. MMR-81-1-27, and MMR-81-2-1 Age: Middle-Late Cenomanian; Q- *Berthelina cenomanica,* sample no. MMR-83-1-20, Age: Middle-Late Cenomanian; R, S- *Lingulogavelinella* sp.1, sample no. MMR-79-2 ser 1, 2, Age: Middle Cenomanian

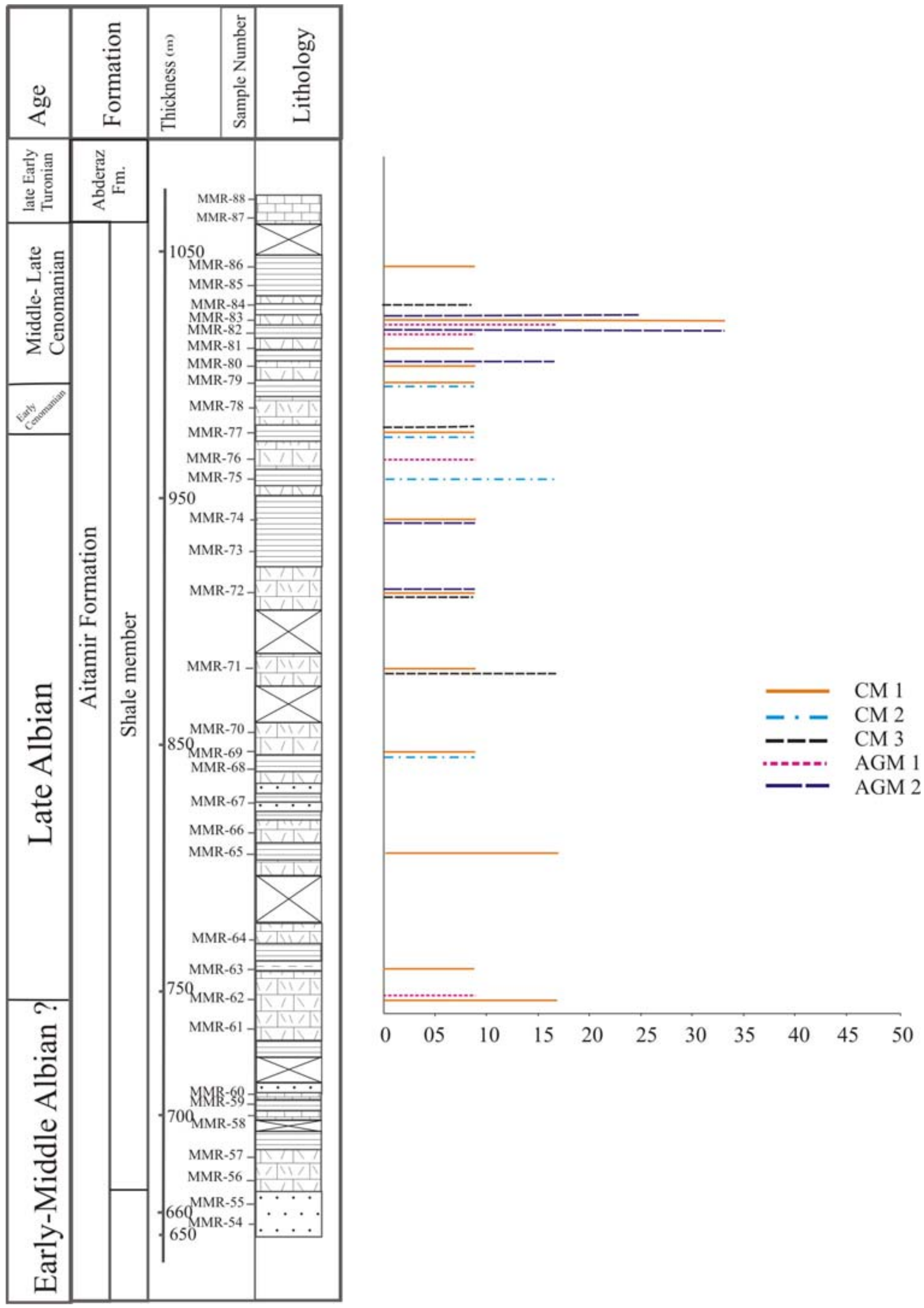

Figure 8. Relative abundance benthic foraminifera morphogroups in MaravehTappeh section

The abundance of this morphogroup changes between 8.33 and 16.6 percent. This morphogroup is mostly distributed in middle part of the shale member and co-occurrs with CM1 parts (Figure 8).

As stated above, two agglutinated morphogroups of benthic foraminifera were also identified as follows:

Agglutinated morphogroup 1 (AGM1)

This morphogroup includes the forms with rounded planispiral test shape. Koutsoukos and Hart (1990) suggested that aerobic, mesotrophic to eutrophic environmental conditions are characterized by a dominance of arenaceous shallow infaunal specimens which are active deposit feeders. These fauna can live in inner shelf to upper bathyal environment. *Haplophragmoides*, *Trochammina* are typical genera in this morphogroup (Figure 11 A_E). The abundance of this morphogroup changes between 8.33 and 16.6 percent. It is further expanded in upper one third of the shale member and has the greatest expansion in sample number 83 (Figure 8).

Agglutinated morphogroup 2 (AGM2)

This morphogroup includes the elongated or sub_cylindrical test shape which is indicative of the following characteristics of environmental conditions. All of these taxa are potentially shallow to deep infaunal and active deposit feeders with mesotrophic to eutrophic conditions, which are present in a wide range of marine environments from inner shelf to upper bathyal (Ruckheim et al., 2006). These faunas appear to be typical for moderately low levels of oxygen. *Ammobaculites*, *Textulariopsis*, *Spiroplectammina* and *Gaudryina* could be classified in this morphogroup (Figure 11, F-N). The abundance of this morphogroup changes between 8.33 and 33.3 percent. This morphogroup is distributed in middle and upper part of the sequence and its abundance is in sample number 83 and is mostly co-occurring with AGM 1 and CM1.

Diversity and specific distribution of benthic assemblage foraminifera are mainly influenced by oceanic circulation patterns, oxygenation, nutrient availability and surface fertility (Van der Zwaan *et al*. 1999). The preservation of benthic foraminifera in MaravehTappeh section varies from good to poor throughout the studied interval.

In brief, the abundance and diversity of benthic foraminifera, both calcareous and agglutinated, are increasing towards the upper part of the studied sequence (Figure 8). It could be suggested that there was a better current water circulation, presence of more oxygen and nutrient during deposition of the upper part of shale member as it was stated by Van der Zwaan *et al*. (1999). Calcareous foraminifera are mostly occur in marlstone beds and agglutinated foraminifera occur in shale beds (Figure 8).

Planktonic morphogroup 1 (PM-1)

This morphogroup includes trochospiral forms, which are living in surface or near surface as suspention feeding (Price and Hart, 2002). They are living in shallow epicontinental seas in a pelagic, aerobic and highly eutrophic environments. *Hedbergella* and *Muricohedbergella* are examples of this morophogroups (Herb, 1974; Leckie, 1987) (Figure 12).

From point of view of paleobiogeography and distribution pattern, species of *Hedbergella* belongs to shallow and open marine environment (Hart and Bailey, 1979; Leckie, 1985).

*Hedbergella planispira*in in association with biserial forms such as *Heterohelix* is a proxy for normal salinity surface and low oxygen waters (Eicher 1969; Eicher and Worstell, 1970; Leckie, 1987).

Keller and Pardo (2004) studied foraminifera of Pueblo Basin of Colorado and concluded that the abundance of *Hedbergella* (*Muricohedbergella*) *delrioensis* coincides with increases of oxygen level. This species lived in rich nutrient and normal salinity seas.

The abundance of this morphogroup changes between 8 and 25 percent. This morphogroup is mostly distributed in middle and upper parts of the sequence and its maximum abundance is in sample numbers 73 and 83.

Planktonic Morphogroup 2 (PM-2)

The shell is trochospiral with globular chambers and have occupied in the lower part of the surface mixed layer, normal marine salinity, (Norris and Wilson, 1998). Representatives of aerobic-dysaerobic, mesotrophic to oligotrophic habitat. *Whiteinella* is a well-known fossil of this morphogroup and the abundance of this morphogroup is about 8 percent and could be seen in upper one third of shale member (Samples 78-88) (Figure 13 A-F).

This morphogroup includes trochospiral forms that are floating in nearly deep water of upper part of bathyal to lower part of surface water (Norris and Wilson, 1998). Representatives of *Rotalipora* and *Praeglobotruncana* are the most abundant specimens that belong to this morphogroup. According to Keller and Pardo (2004) and Leckie (1987), normal salinity, aerobic and oligotrophic environment are the characters for their habitat (Figure 13 G-L).

This morphogroup is dominant in lower one third of the section. Planktonic morphogroup 1 is the most abundant in comparison with all major groups of planktonic foraminifera (Figure 14).

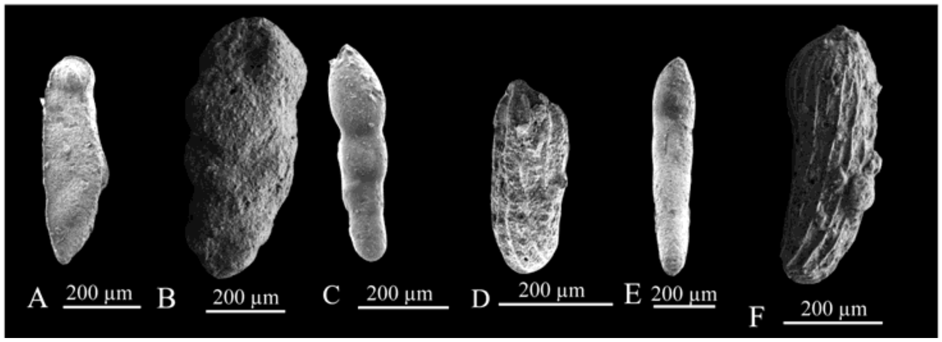

Figure 9. Selected calcareous benthic morphogroup foraminifera CM2, A: *Vaginulina recta*, sample no. MMR-64-2, late Albian; B: *Dorothia gradata*, sample no. MMR-72-3-4, late Albian; C: *Laevidentalina legumen,* sample no. MMR-71-1 ser 3, late Albian; D: *Nodosaria obscura,* sample no. MMR-77-1-ser-1, early Cenomanian; E: *Laevidentalina communis,* sample no. MMR-72-1, late Albian; F: *Pyramidulina obscura,* sample no. MMR-80-2-4, middle-late Cenomanian

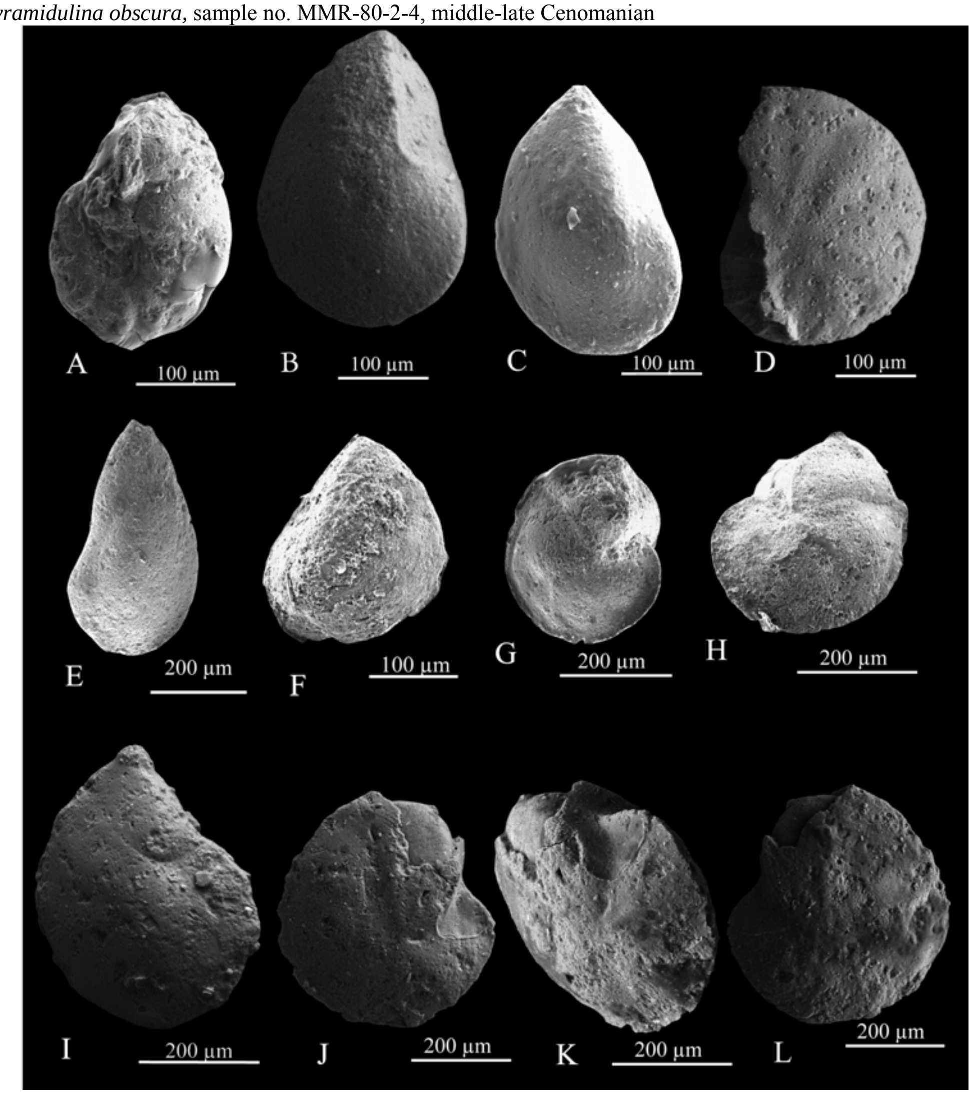

Figure 10. Selected calcareous benthic morphogroup foraminifera CM-3, A: *Recuvoides* sp., sample no. 62-3, l Albian; B, C: *Saracenaria* sp.2, sample no. MMR-71-3-11, l Albian; D-*Lenticulina* sp.1, sample no. MMR-75-2-23, l Albian; E: *Astacolus* sp. sample no. MMR-72-2 ser3, l Albian; F: *Lenticulina* sp.2, sample no. MMR-75-ser 1, Age: l Albian; G, H: *Lenticulina subalata,* sample no. MMR-74-2, l Albian; I-*Darbyella* sp., sample no. MMR-69-3 l Albian.;J, K, L: *Hoeglundina charlottae,* sample no. MMR-83-1-17 MMR-83-1, middle- l Cenomanian

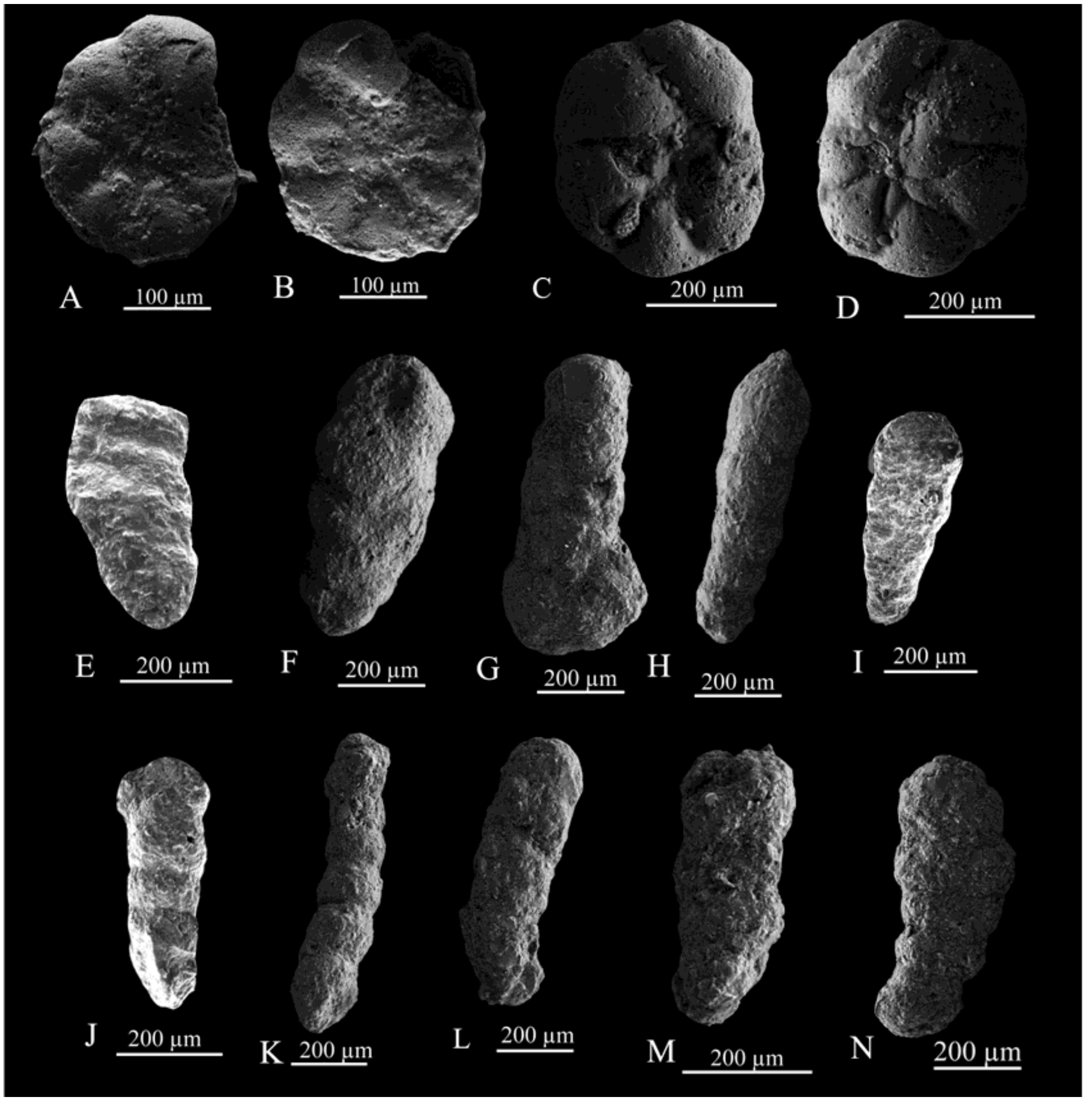

Figure 11. Selected agglutinated benthic morphogroup foraminifera AGM 1-2, A: Berthelina baltica, sample no. MMR-72-3-7 l Albian; B, C: Trochammina wetteri, sample no. MMR-83-2 ser 1, ser 2, middle-l Cenomanian; D, E: Haplophragmoides concavus, sample no. MMR-83-9 and MMR-83-10 middle-l Cenomanian; F-Gaudryina sp., sample no. MMR-4-2, early-middle Albian; G: Dorothia gradata, sample no. MMR-72-3-4, l Albian; H- Ammobaculites sp. 2, sample no. MR-83-1-14 middle-l Cenomanian; I- Spiroplectammina rectangularis, sample no. MMR-80-2-7, middle-l Cenomanian; J-Spiroplectammina sp.1 sample no. MMR-74-1, l Albian; K-Pseudoclavulina sp, sample no. MMR-82, middle-l Cenomanian; L-Ammobaculites parvispirasample no. MMR-82-1-22, middle-l Cenomanian; Ammobaculites subcretaceous, sample no. MMR-82-1-24-82-1-25, middle-l Cenomanian; N: Spiroplectammina sp.2 sample no. MMR-82-1-22, middle-l Cenomanian; O: Ammobaculites subcretaceous, sample no. MMR-82-1-24, MMR-82-1-25, Age: middle-l Cenomanian

Discussion

The preservation of benthic and planktonic foraminifera in the upper shale member of Aitamir Formation is good. The most abundant calcareous and the agglutinated benthic foraminifera assemblages in order are *Lingulogavelinella, Berthelina, Gavelinella, Laevidentalina, Lenticulina, Ammobaculites* and *Gaudryina.* The most abundant planktonic foraminifera is *Muricohedbergella*.

The abundance of calcareous benthic foraminifera varies from 8.3 to 33.3 the agglutinated benthic foraminifera from 8.3 to 41.6 and the planktonic foraminifera from 8.3 to 41.6 percent respectively (Figure 15).

The shale member could be divided into three portions. In the lower part of the shale member (samples 62-70, Figure 8), the maximum abundance of benthic foraminifera is in morphogroup (CM1) such as *Lingulogavelinella* and *Berthelina* with 8.3-

16.6 percent that could be attributed to high rates of calcium carbonate production in the environment. These genera with planispiral to trochospiral forms lived in aerobic, shallow to slightly deep water, oligotrophic environment (Ruckheim *et al.* 2006). The abundance of agglutinated benthic foraminifera is about 8.3 percent. The morphogroup (PM1) is the most abundant morphogroup among all groups in the lower one third (samples 62-70) of the shale member with 8.3- 25 percent. The representative genus is *Muricohedbergella* with trochospiral and smooth test that have seen near the surface water in the aerobic to semi aerobic environment (Price and Hart, 2002) (Figure 15).

On the other hand, the precence of *Rotalipora* in some beds of this part indicates a deeper environment.

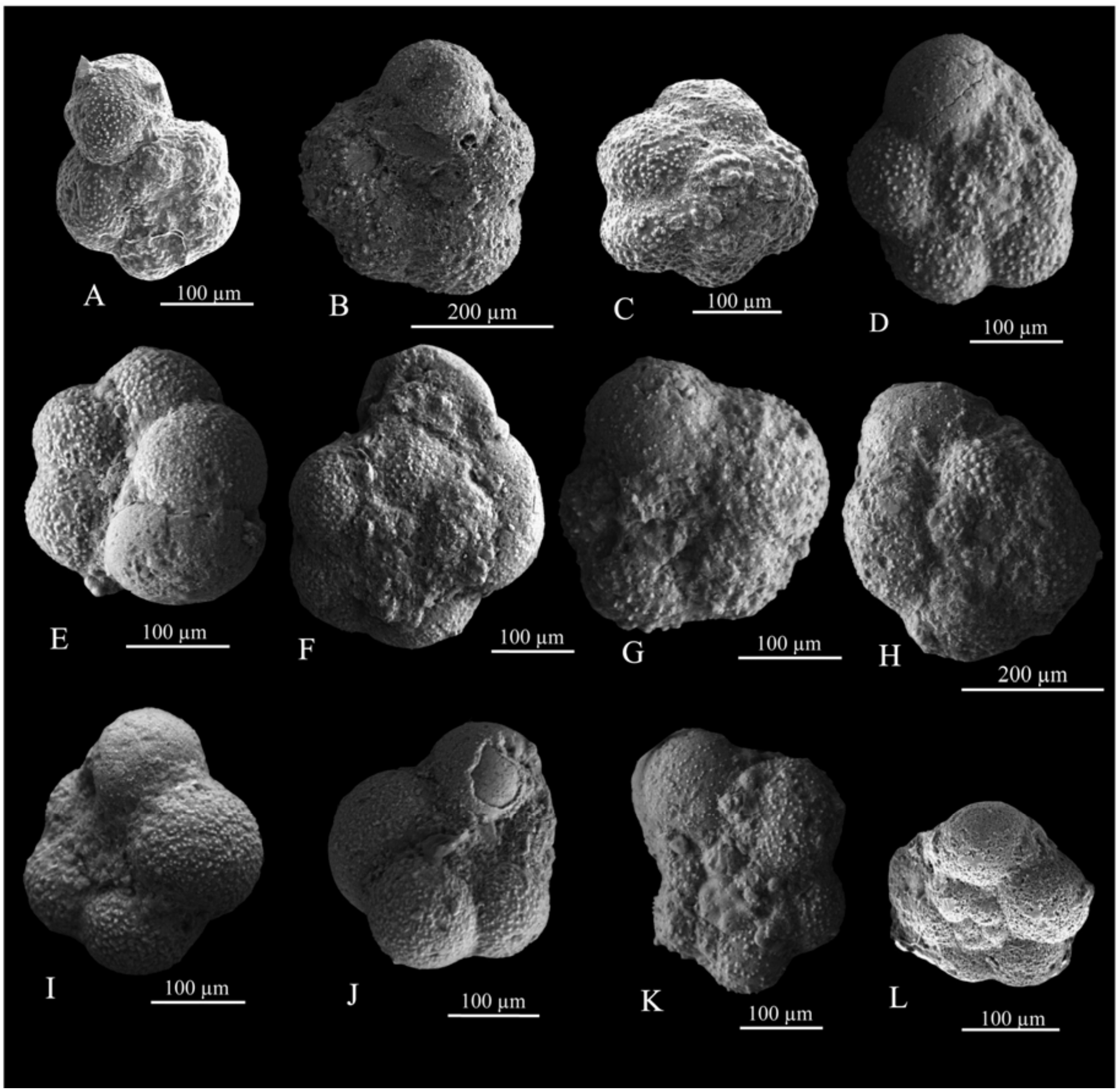

Figure 12. Selected planktonic morphogroup foraminifera PM1, A: *Muricohedbergella* sp.6, sample no. MMR-65-3, L Albian; B, C: *Muricohedbergella delrioensis,* sample no. MMR-84-1-13, 84-1 ser 1, 3, middle Cenomanian; D: *Muricohedbergella* sp.6*,* sample no. MMR-73-3-1, l Albian; E: *Muricohedbergella* sp.4, sample no. MMR-75-2-22, l Albian; F : *Muricohedbergella delrioensis,* sample no. MMR-76-2-21, l Albian; G, H: *Muricohedbergella delrioensis*, sample no. MMR-73-3-2 and MMR-73-3-3, l Albian; I: *Muricohedbergella* sp. 3, sample no. MMR-71-3-9, l Albian; J: *Muricohedbergella* sp. 3, sample no. MMR-80-2-9, Age: middle-l Cenomanian; K- *Muricohedbergella* sp. 5, sample no. MMR-69-3-13, l Albian; L: *Muricohedbergella planispira,* sample no.79-1 ser 1, 3, middle-l Cenomanian

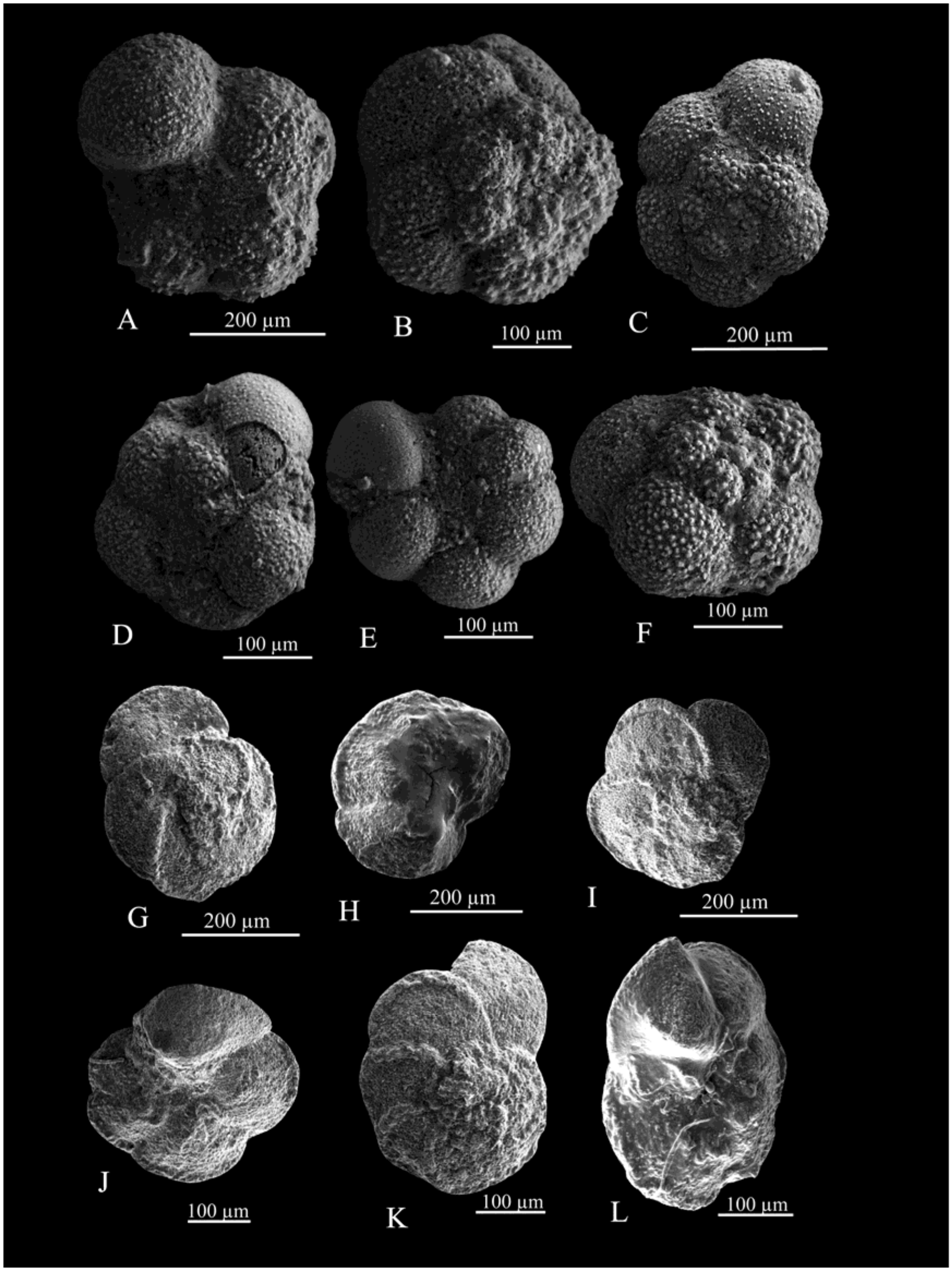

Figure 13. Selected planktonic morphogroup foraminifera PM 2-3, A, B: *Whiteinella aumalensis,* sample no. MMR-78-2-15, MMR-78-2-16, middle-l Cenomanian; C-*Whiteinella baltica,* sample no. MMR-84-1-10, middle-l Cenomanian; D, E- *Whiteinella* sp.*,* sample no. MMR-81-2-2 and MMR-81-2-3, middle-l Cenomanian; F: *Whiteinella aumalensis*, sample no. MMR-83-1-18, middle-l Cenomanian; G, H: *Rotalipora appenninica*, sample no. MMR-62-2, l Albian; I, J: *Rotalipora gondolfii,* sample no. MMR-75-, l Albian; K, L: *Rotalipora brotzeni*, sample no. MMR-77-, early Cenomanian

Therefore in the lower one third of the shale member, planktonic foraminifera are more abundant than benthic foraminifera. Based on foraminifera content, it could be assumed that most of fauna belong to the aerobic to semi aerobic, oligotrophic and shallow to nearly deep water environment.

In the middle part of upper shale member (samples 71-79), the abundance of calcareous benthic foraminifera varies from 8.3 to 25 percent. The most abundant benthic foraminifera are within morphogroup (CM2) such as *Saracenaria, Nodosaria, Planularia*, *Laevidentalina* and *Pyramidulina* with with shapes drawn and staright margin which represent shallow to top of the deep water eutrophic and aerobic environmental condition (Rückheim *et al*. 2006). In the upper most part of upper shale member (samples 80-87) the abundance of the calcareous, agglutinated and planktonic foraminifera varies from 8.3 to 33.3, 16 to 41.6 and 16 to 33 percent respectively.

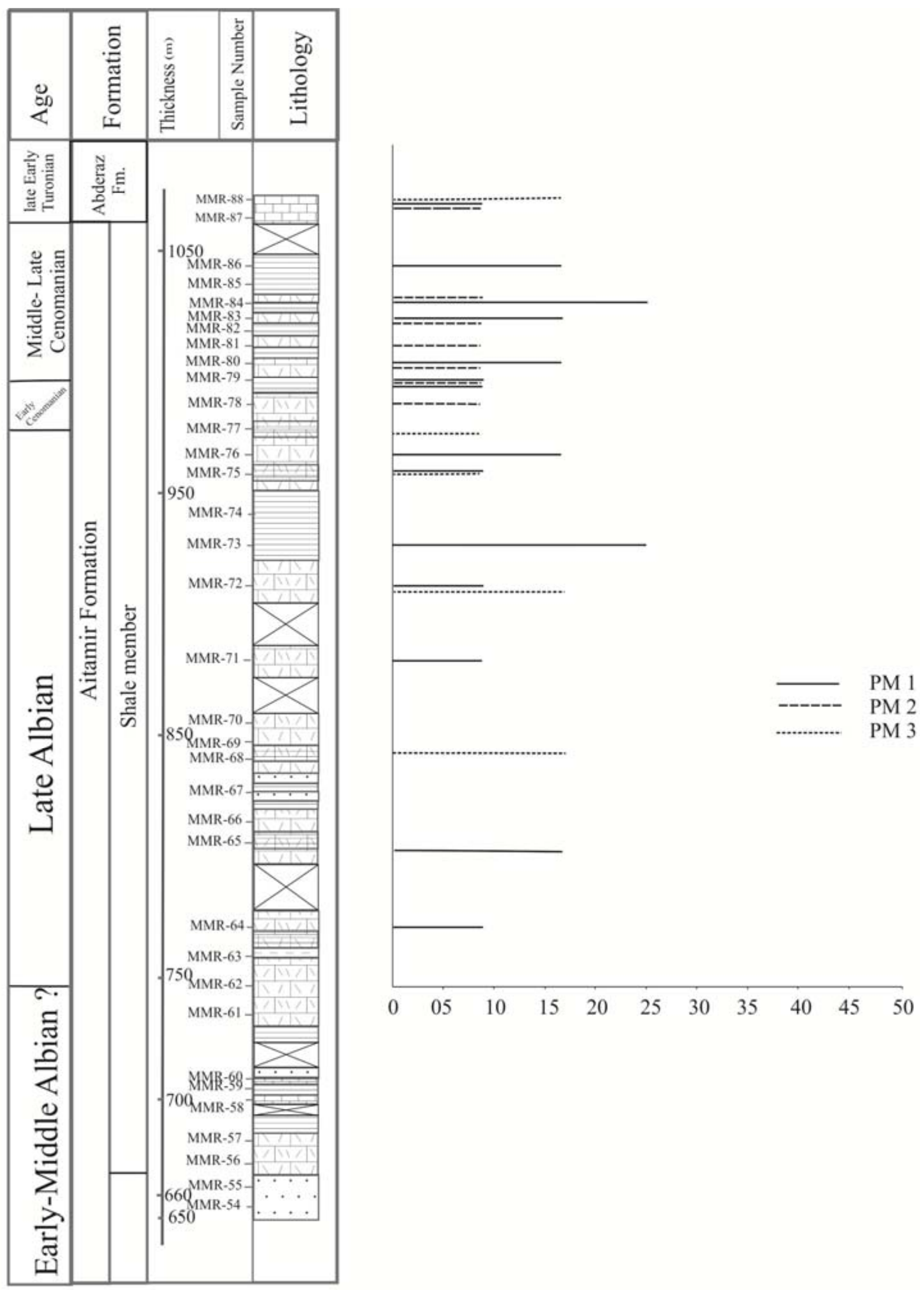

Figure 14. Relative abundance of planktonic foraminifera morphogroups in MaravehTappeh section

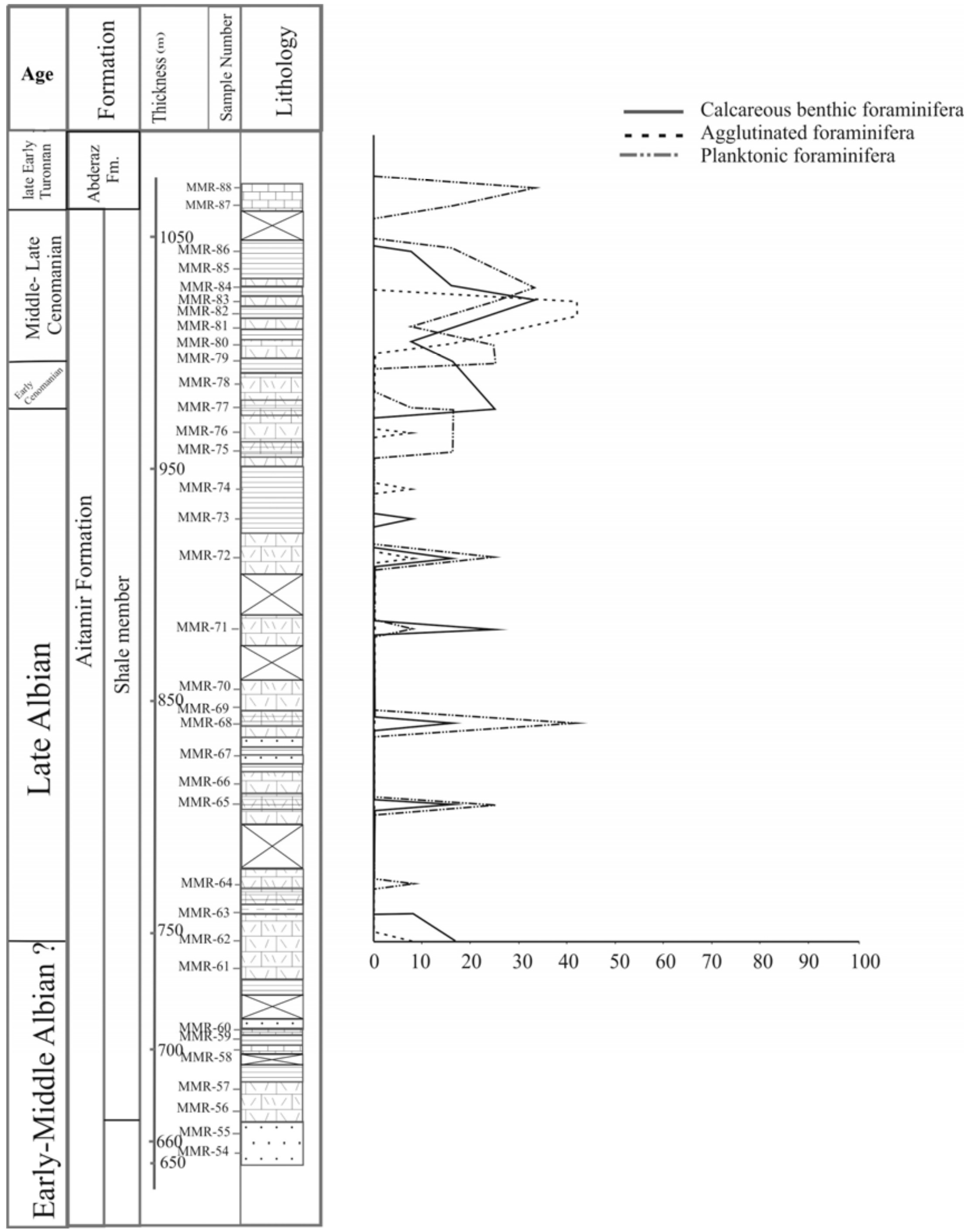

Figure 15. Relative abundance of benthic and planktonic foraminifera in MaravehTappeh section

Conclusions

The Aitamir Formation has a thickness of 1070 m in the Maraveh Tappeh section and consists of two members. The lower sandstone member is composed of glauconitic coarse to fine grained sandstones with some silty sandstone beds and upper shale member is composed of green, greenish grey and grey shales with intercalations of marlstones and thin bedded shales to marly shales. It is conformably overlies the Sanganeh and conformably underlies the Abderaz formations.

The biostratigraphic studies led to identification of 22 genera and 34 species of benthic foraminifera and 10 genera and 23 species of planktonic foraminifera. Based on foraminifera assemblages, three biozones are suggested as follows: *Rotalipora appenninica* Interval Zone, *Rotalipora brotzeni* Interval Zone and *Dicarinella canaliculata* assemblage zone. These biozones coincide with global biozones.

Based on foraminifera fauna a late Albian- late Cenomanian age is suggested for upper shale member of the Aitamir Formation at this locality.

Palaeoecological studies led to recognition of three calcareous benthic two agglutinated benthic and four planktonic foraminifera morphogroups.

4- There are three peaks of benthic calcareous and three peaks of agglutinated benthic foraminifera on the graph in sample numbers 62, 65, 83 and 71, 80, 83. The composition of benthic foraminifera assemblage indicates aerobic to dysaerobic bottom-water conditions

According to identified morphogroups in the Maraveh Tappeh section, during the L Albian-L Cenomanian times, the western Koppeh-Dagh Basin has been shallow to fairly deep during deposition of the Aitamir Formation.

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References

Afshar-Harb, A., 1979. The stratigraphy, tectonics and petroleum geology of the KopetDagh region, northern Iran. Unpublished Ph.D. Thesis, Imperial College of Science and Technology, London.

Afshar-Harb, A., 1994. Geology of Kopet-Dagh. In: Hushmandzadeh, A. (Ed.), Treatise on the Geology of Iran. Geological Survey of Iran, Tehran, 275 p. (in Persian).

Bolli, H.M., 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. BoletinInformativo AsociacionVenezolana de Geologia, Mineriay Petroleo, 9: 9-32.

Bronnimann, P., 1952. Globigerinidae from the Upper Cretaceous (Cenomanian- Maestrichtian) of Trinidad. Bull. Am. Paleontol. 34: 5-71.

Caron, M., 1985. Cretaceous Planktic foraminifera. In: Bolli, H.M., Saunders, J., Perch-Nielsen, K., (Eds) Plankton Stratigraphy, 1: 17-86, Cambridge University

Coccioni, R., Galeotti, S., 1993. Orbitally induced cycles in benthonic foraminiferal morphogroups and trophic structure distribution patterns from the L Albian Amadeus Segment (central Italy). Journal of Micropaleontology, 12: 227-239.

Corliss, B.H., Chen, C., 1988. Morphotype patterns of Norwegian sea deep sea benthic foraminifera and ecological implications. Geology, 16: 716-719.

Eicher, D.L., 1967. Foraminifera from Belle Fourche shale and equivalents, Wyoming and Montana. J. Paleno., 41(1): 167-188, 6 Abb., Taf. 17-18; Tulsa.

Eicher, D.L., 1969. Paleobathymetry of the CretaceousGreenhorn Sea in eastern Colorado. AAPG Bulletin, 52: 1075–1090.

Eicher, D.L., Worstell, P., 1970. Cenomanian and Touronian foraminifera from the Great Plains, United States. Micropaleontology, 16: 269-324.

Erbacher, J., Gerth, W., Schmiedl, G., Hemleben, Ch., 1998. Benthic foraminiferal assemblages of Aptian- Albian black shale intervals in the Vocontian Basin, SE France. Cretaceous Research, 19: 805-826.

Friedrich, O., Reichelt, K., Herrle, J. O., Lehmann, J., Pross, J., Hemleben, C., 2003. Formation of the L Aptian NiveauFallot black shale in the Vocontian Basin (SE France): evidence from foraminifera, palynomorphs, and stable isotopes. Marine Micropaleontology, 49: 65-85.

Grosheny, D., Beaudoin, B., Morel, L., Desmares, D., 2006. High-resolution biotratigraphy and chemostratigraphy of the Cenomanian/Turonian boundary event in the VocontianBasin, southeast France. Cretaceous Research, 27: 629-640.

Grunert, P., 2011. Integrated facies analysis and stratigraphy of the Early Miocene north Alpine foreland basin (Upper Austria). Unpublished PhD thesis, Karl FranzensUniversität Graz.

Hart, M B., Bailey, H W., 1979. The distribution of planktonic Foraminiferida in the Mid-Cretaceous of NW Europe. Int. Union Geol. Sci. Ser. A, 6: 527-542.

Herb, R., 1974. Cretaceous planktonic foraminifera from the eastern Indian Ocean. Init. Rep. DSDP, 26: 745– 769.

Jarvis, I., Carson, G.A., Cooper, M. K. E., Hart, M B., Leary, P N., Tocher, B.A., Horne, D. and Rosenfeld, A., 1988. Microfossil assemblages and the Cenomanian-Turonian (L Cretaceous) Oceanic Anoxic Event. Cretaceous Research, 9: 3-103.

Immel, H., Seyed-Emami, K., Afshar-Harb, A., 1997. Kreide-Ammonit enausdemiranischenteil des Koppeh-Dagh (NE-Iran). Zitteliana, 21: 159-190.

Kalantari, A., 1969. Foraminifera from the middle Jurassic-Cretaceous successions of KopetDagh region (NE-Iran), 298 pp. Exploration and Production, NIOC, Geological Laboratory Publication 3, Tehran (Ph.D. thesis, London University).

Kalantari, A., 1987. Biofacies Map of Kopet Dagh Region.Exploration andProduction, National Iranian Oil Company, Tehran.

Keller, G., Pardo A., 2004. Age and paleoenvironment of the Cenomanian–Turonian global stratotype section and point at Pueblo, Colorado. Marine Micropaleontology, 51 : 95–128.

Koutsoukos, E.A.M., Hart, M.B., 1990. Cretaceous foraminiferal morphogroup distribution patterns, palaeocommunities and trophic structures: a case study from the Sergipe Basin, Brasil. Trans. R. Soc. Edinb. Earth Sci., 81: 221-246.

Leary, P.N., Carson, G.A., Cooper, M.K.E., Hart, M B., Horne, D., Jarvis, I., Rosenfeld, A., Tocher, B A., 1989. The biotic response to the l Cenomanian oceanic anoxic event; integrated evidence from Dover, SE England. Journal of the Geological Society, London, 146: 311-317.

Leckie, R.M., 1985. Foraminifera of the Cenomanian-Turonian boundary interval Greenhorn Formation, Rock Cabyon Atlantic, Peublo, Colorado.In Pratt, L M., Kauffman, E G., and Zelt, F., (eds.), Fine-Grained Deposits and Biofacies of the Cretaceous Western Interior Seaway Evidence of Cyclic Sedimentary Processes. Soc. Econ Min. and Paleontol. Field Trip Guide book 4: 139-149.

Leckie, R.M., 1987. Paleoecology of Mid-Cretaceous foraminifera A comparison of open ocean and epicontinental sea assemblages. Micropaleontology, 33: 164-176.

Lehmann, R., 1966. Les foraminiferespelagiques du Cretace du Bassin cotier de Tarfaya Planomalinidae et Globotruncanidae du Sondage de Puer Cansado (Albien superieur, Cenomanien inferieur). Notes Mem. Serv. geol. Maroc. 175, Paleontologie, 153-67.

Longoria, J.F., 1984. Cretaceous biochronology from the Gulf of Mexico Region based on planktonic microfossils. Micropaleontology, 30: 225-242.

Mosavinia, A., Wilmsen, M., AsgharAryai, A., Chahida, M.R., Lehmann, J. 2007. Mortoniceratinae (Ammonitina) from the upper Albian (Cretaceous) of the Atamir Formation, Koppeh-Dagh Mountains, NE Iran. Neues Jahrbuch für Geologie und Palontologie, Abhandlungen, 246 (8): 3–95.

Mosavinia, A., Wilmsen, M., 2011. Cenomanian Acanthoceratoidea (Cretaceous Ammonoidea) from the KoppehDagh, NE Iran, taxonomy and stratigraphic implications; Acta Geologica Polonica, 61 (2): 175–192.

Nagy, J., 1992. Environmental significance of foraminiferal morphogroups in Jurassic North Sea deltas. Palaeogeogr. Palaeoclimatol. Palaeoecol. 95: 111– 134.

Nishi, H., Takashima, R., Hatsugai, T., Saito, T., Moriya, K., Ennyu, A., Sakaif, T., 2003.Planktonic foraminiferal zonation in the Cretaceous Yezo Group, Central Hokkaido, Japan. Journal of Asian Earth Sciences, 21: 867–886.

Norris, R.D., Wilson, P.A., 1998. Low-latitude sea-surface temperatures for the mid-Cretaceous and the evolution of planktic foraminifera. Geology 26: 823–826.

Postuma, J.A., 1971. Manual of planktonic foraminifera. Elsevier Publishing Company, 420 pp.

Premoli Silva Sliter, W.V., 1999. Cretaceous paleoceanography evidence from planktonic foraminiferal evolution. Geological Society of America Special Paper, 332: 301-328.

Premoli Silva, I., Verga, D., 2004. Practical manual of Cretaceous planktonic foraminifera. International School on planktonic foraminifera, 3 course, Cretaceous. Universities of Perugia and Milan, Perguia, 283 pp.

Price, G.D., Hart, M.B., 2002. Isotopic evidence for early to mid-Cretaceous ocean temperature variability. Mar. Micropaleontol 46: 45–58.

Rückheim, S., Bornemann, A., Mutterlose J., 2006. Planktic foraminifera from the mid-Cretaceous (Barremian–earlyAlbian) of the North Sea Basin: Palaeoecological and palaeoceanographic implications. Marine Micropaleontology 58: 83– 102.

Seyed-Emami, K., 1980. Parahoplitidae (Ammonoidea) ausdem Nordost und Zentraliran. Neues Jahrbuch für Geologie und Paläeontologie Monatsheftte, 1980, 719-737.

Seyed-Emami, K., Aryai, A. A., 1981. Ammoniten ausdem unteren Cenoman von Nordostiran (Koppeh-Dagh). Mitteilungen der Bayerischen Staatssammlung für Paläontologie und Historische Geologie, 21: 23-39.

Seyed-Emami, K., Forster, R., Mojtahedi, A., 1984. Ammonitena usdemmittleren Cenoman von Nordost-Iran (Koppeh-Dagh). Neues Jahrbuch für Geologie und Paläontologie Monatsheftte1984, 159-172.

Van der Zwaan, G.J., Duijnstee, I.A.P., den Dulk, M., Ernst, S.R., Jannink, N.T., Kouwenhoven, T.J., 1999. Benthic foraminifers: proxies or problems? A review of paleoecological concepts. Earth-Sci. Rev., 46: 213– 236.

Widmark, J.G.V., 1997. Deep-sea benthic foraminifera from Cretaceous-Paleogene boundary strata in the South Atlantic -taxonomy and paleoecology. Fossils and Strata, 43: 1-94.

Wonders, A.A., 1980. Middle and l Cretaceous planktonic foraminifera of the Western Mediterranean area. Utrecht Micropaleontology Bulletin, 24: 1-158.