Distribution and Paleoecology of the Middle Jurassic Foraminifera from Eastern Alborz (Goznawwi section)

Tayebe Sarbandi Farahani[1], Mehdi Yazdi[1]*, Mahmoud Reza Majidifard[2]
[1] *Department of Geology, Faculty of Science, University of Isfahan, P.O. Box, 81746-73441, Isfahan, Iran.*
[2] *Research Institute for Earth Sciences, Geological Survey of Iran, P.O. Box, 1385-1494, Tehran, Iran.*
**Corresponding author, e-mail: meh.yazdi@gmail.com*
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Abstract

Analysis of benthic foraminiferal assemblages was performed in Callovian deposits of the Farsian Formation Northeastern Alborz; Iran. The sequence of Callovian at the Goznawwi area consists mainly of soft marls, which contain high-diversity calcareous assemblages. In this foraminiferal succession nine morphogroups were differentiated according to shell architecture (general shape, mode of coiling and number of chambers), integrated with the supposed microhabitat (epifauna, shallow infauna and deep infauna) and feeding strategy (suspension-feeder, herbivore, bacterivore, etc.). Based on foraminiferal assemblage, we have distinguished nine type of morphogroups, including seven calcareous benthic and two agglutinated benthic morphogroups. The environmental evolution of the analyzed section is interpreted by using the stratigraphic distribution of morphogroups, combined with species diversities and sedimentary data, in a sequence stratigraphic framework. Palaeoecological analysis of the foraminiferal assemblages based on morphogroups analysis and macroinvertebrate has shown that this sediment was deposited on the open marine, deeper of the shelf water, with normal saline (euhaline), with sub-oxyed (or dysoxic) condition and eutrophic environment.

Keywords: *Foraminifera, Morphogroup, Farsian Formation, Iran*.

Introduction

Benthic foraminifera are good indicators of physical and chemical features of the sea-bottom. The composition of benthic foraminiferal assemblages is a valuable tool for interpreting water mass and sediment properties, as shown in numerous studies (*e.g*., Murray, 1991, 2001; Sjoerdsma & Van der Zwaan, 1992; Jorissen *et al*., 1995; Jorissen, 1999; Van der Zwaan *et al*., 1999; Abu-Zied *et al*., 2008; Reolid *et al*., 2012; Talib *et al*., 2012). The analysis of foraminiferal morphogroups is especially useful for interpreting the major factors that control the ecosedimentary environment (Nagy, 1992; Nagy *et al*., 1995, 2009; Reolid *et al*., 2008b). Benthic habitat fluctuations in nutrient availability and oxygenation rate are limiting palaeoenvironmental parameters, exerting considerable control on the composition and relative abundance of foraminiferal assemblages and morphogroups (Sjoerdsma & Van der Zwaan, 1992; Jorissen *et al*., 1995; Van der Zwaan *et al*., 1999), particularly in shelf and marginal marine environments (*e.g*., Bernhard, 1986; Corliss & Chen, 1988; Nagy, 1992; Tyszka, 1994; Fugagnoli, 2004; Reolid *et al*., 2008b; Reolid *et al*., 2012).

Studies on recent and ancient benthic foraminiferal assemblages demonstrate that the characteristics of the foraminiferal test (chamber arrangement, mode of coiling, features of aperture, position of perforation) are directly related to lifestyles and trophic strategies (*e.g*., Nagy, 1992; Tyszka, 1994; Nagy *et al*., 2009; Jones, 2014). On the basis of modern faunas, morphogroups of benthic foraminifera were proposed by Jones & Charnock (1985). Subsequent studies have proposed analogous morphological groupings in fossil assemblages (Nagy, 1992; Tyszka, 1994; Kuhnt *et al*. 1996; Nagy *et al*., 2009; Reolid *et al*., 2010, 2012; Smolen, 2012), in order to interpret palaeoenvironmental conditions, such as nutrient availability or redox conditions (Nagy, 1992; Tyszka, 1994; Nagy *et al*., 1995, 2009; Reolid *et al*., 2008a, 2010, 2012). Furthermore, the pervious study about the Jurassic isolated foraminiferal assemblage in Iran; mostly is not performed and only at Korkhurd area introduced by Kalantari (1969) from Chaman Bid Formation.

The type locality of the Farsian Formation was coined by the Stampfli (1978). At type locality, near the Farsian village, for the main part, it consists of red and yellow limestone, silt and marl. Stampfli (1978) considered the red sediments to be a transitional unit sandwiched between the Shemshak Group and the Lar Formation. In the Goznawwi section, the Farsian Formation scarcely studied and the present contribution constitutes the first morphogroup analysis of foraminiferal assemblages from Iran. This research involves palaeoecologic analysis of foraminiferal assemblages, according to the differentiated morphogroups, and their stratigraphic evolution as a response to change in environment of conditions during the sedimentation of Farsian Formation.

Geological setting

The Middle and Late Jurassic (Magu Group) is one of the most extensive lithostratigraphical units in the Iran Plate (Aghanabati, 1998). The Iran Plate; composed of the central-east Iranian microcontinent, northwestern Iran and the Alborz Mountains (Aghanabati, 1998). The Alborz belt is a 1500 km-long mountain system extending from Azerbaijan to Afghanistan, flanking in its central part the southern coast of the Caspian Sea. The belt was affected by several successive tectonic events, from the Eo-Cimmerian orogeny to the Late Tertiary–Quaternary intracontinental transgression (Allen *et al*., 2003). The result of Early Cimmerian orogeny is detached the north eastern margin of Gondwana during the Early Permian (Stampfli & Borel, 2002) and moved northwards during the Triassic, thereby gradually closing the Palaeotethys Ocean. It collided with Eurasia towards the end of the period (*e.g*., Stampfli & Borel, 2002), although the precise age of collision is still under debate (*e.g.* Sengor *et al*., 1988; Sengor, 1990; Alavi *et al*., 1997; Saidi *et al*., 1997; Seyed-Emami, 2003; Golonka, 2004). Denudation of this mountain chain produced large quantities of sediment that collected in an extensive foreland basin situated to the south. This elongated basin is named the Greater Caucasus-Proto-Caspian back-arc basin (Golonka, 2004). In this basin, at Jurassic time, marine sedimentation began in the Late Bajocian and Bathonian time interval when the Northern Alborz, Kopet–Dagh, and Central Iran basins formed on the Iranian Plate (Aghanabati, 1998). Initial siliciclastic deposits have been termed the Shemshak Group by various authors (*e. g.* Asserto, 1966; Bragin *et al*., 1976; Nabavi & Seyed-Emami, 1977; Fakhr, 1977; Nabavi, 1980; Seyed-Emami & Nabavi, 1985; Repin, 1987; Seyed-Emami, 1987; Seyed-Emami & Hosainzadeh, 2006; Seyed-Emami & Wilmsen, 2007; Fursich *et al*., 2005; Fursich *et al*., 2009a; Vaez-Javadi, 2016 and …). The group is followed by another carbonate unit, the Dalichai–Lar basin-carbonate platform complex named as Magu Group, from which it is separated by another unconformity, reflecting the so-called Mid- Cimmerian tectonic event (Wilmsen *et al*., 2009). In the north margin Alborz belt; Middle Jurassic introduce by carbonates of Farsian Formation; equivalent with Dalichai Formation in the south margin; possibly reflecting lower rates of subsidence (Fursich *et al.,* 2009 b). The growing deposition of carbonates was also facilitated by southward migration of the Iranian plate, which had occupied a fairly high latitudinal position of approximately N 44´ during the Early Jurassic (Dercourt *et al.,* 2000), to a lower latitude of ca. 20–30´ N during the Middle Callovian (Thierry, 2000; Seyed-Emami *et al*., 2008; Wilmsen *et al*., 2010; Ghasemi-Nejad *et al.,* 2012).

Materials and methods

The succession studied preserves an essentially continuous benthic foraminiferal record from 16 levels. Most of the samples were collected from soft marl that characterizes the main body of the Farsian Formation. A smaller number of samples were taken from clay sandy limestone and fine-grained claystone from the uppermost part of the formation. In the laboratory, the rock samples were disintegrated using the leached in synthetic light vinegar method described by Yazdi (non. published). In this method; the samples were crushed, washed and leached in synthetic light vinegar (for 24 hours) in diluted water. Residue out of washed samples were separated and dried, the dried residue then was picked under binocular microscope. Some of the samples required two repetitions of this step of the procedure to obtain an adequate degree of disintegration.

Locality, stratigraphy and lithology of the study section

In this research, the carbonate outcrops of the Farsian Formation were measured in Goznawwi area, located in 22 km of south eastern Azadshar (Fig. 1). The geography coordinates of the section are 36° 57ˡ 53ˡˡ N and 55 ° 27ˡ 00ˡˡ E. Delta plain to marginal marine clastic of Dansirit Formation and carbonate ramp of the Lar Formation are respectively the older and younger sedimentary successions deposited before and after the sedimentation of the carbonate settings of the Farsian Formation (Fig. 2, 3).

In the investigated area, the Farsian Formation consists of 109m thickness; including marl, sandstone and claystone, in follow described bed by bed:

Bed1 (9 m); consist of yellow marl without any fossils.

Bed 2 (21m); including milky fine to coarse grained siliceous sandstone, ferruginous thin bedded clay levels and calcareous sand levels.

Bed 3; measured by with 62 m thickness, consists of gray-bluish marl with richness in fauna. The biota including foraminifera, ammonite, belemnite, echinoid debris, starfish (Marginalia and Terminalia fragments), bivalve, gastropod, brachiopod, coral, shark tooth, marine worm tubs, ostracod, and frequented scattered wood petrified (Fig. 4).

Those layers are bioturbation and the coprolite is frequencies. Secondary structural sedimentary *e.g.,* Septarian concretion (Fig.4), ferriferous nuggets and crystals of gypsum, perite and limonite are occurred. In this bed; we collected 12 samples (G_1 to G_{12}) for washing and extracted many of foraminiferal assemblage from them (Fig. 5).

Bed 4 (8m); consists of alternation of brown gypsiferous clay-sandy-limestone and gray claystone with foraminifera, ammonite and belemnite. The foraminiferal assemblage yelled from one sample (G_{13}).

Bed 5 (2m); consists of gray bioclastic sandy limestone. The two samples (G_{14} and G_{15}) are gathered from this bed.

Bed 6 (1m); including blue claystone with foraminifera and ammonite; the foraminifera collected from sample G_{16}.

Bed 7 (6m); alternation of yellow to brown claystone with intercalation of thin bedded red sandstone.

From the basal sediments of the Farsian Formation towards the upper parts; in despite of 30m in the base, the Foraminifera in this study are identified in through the stratigraphical column.

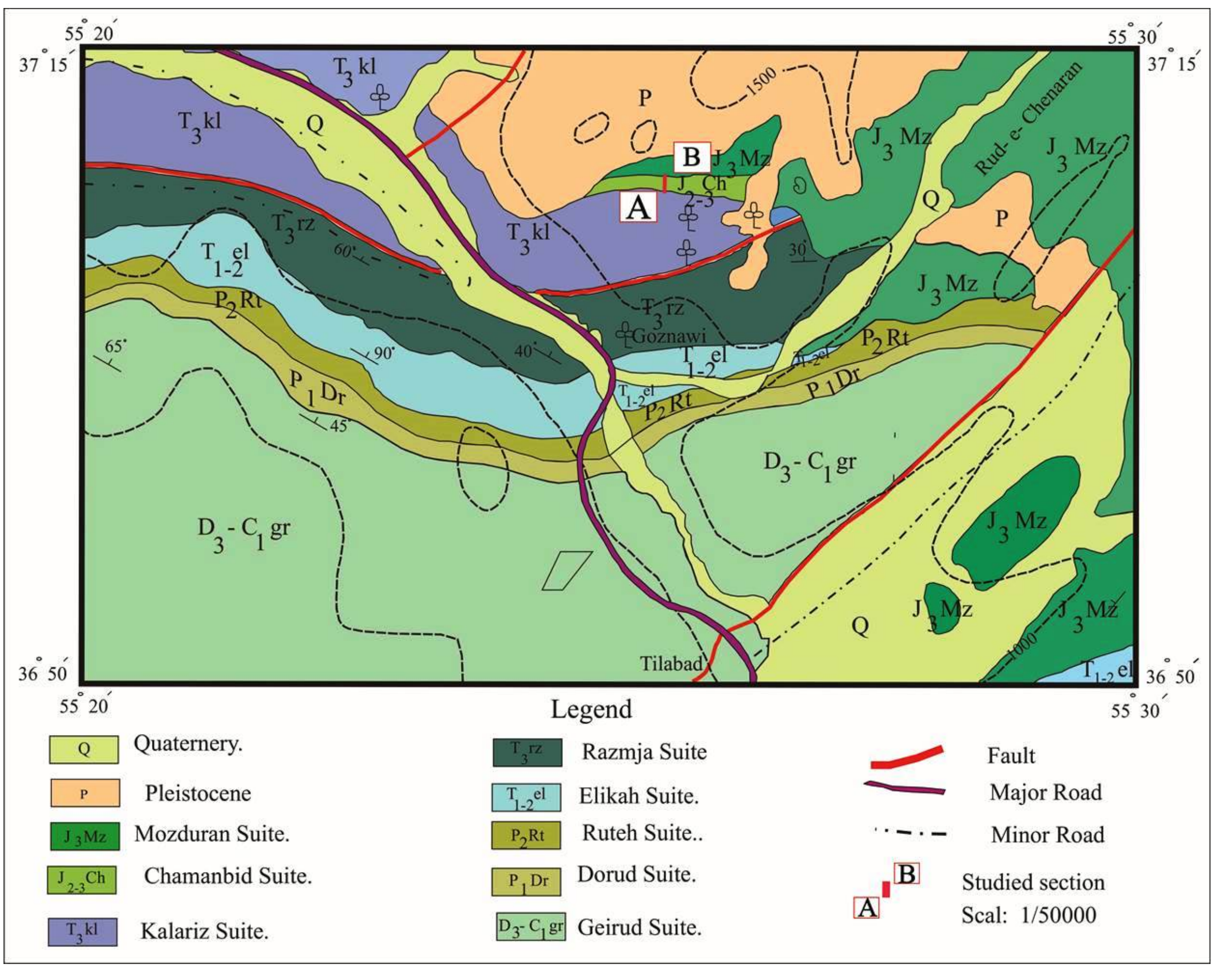

Figure 1. Ggeological map of the studied section in the Goznawwi area (Pavlov & Razavi, 1977).

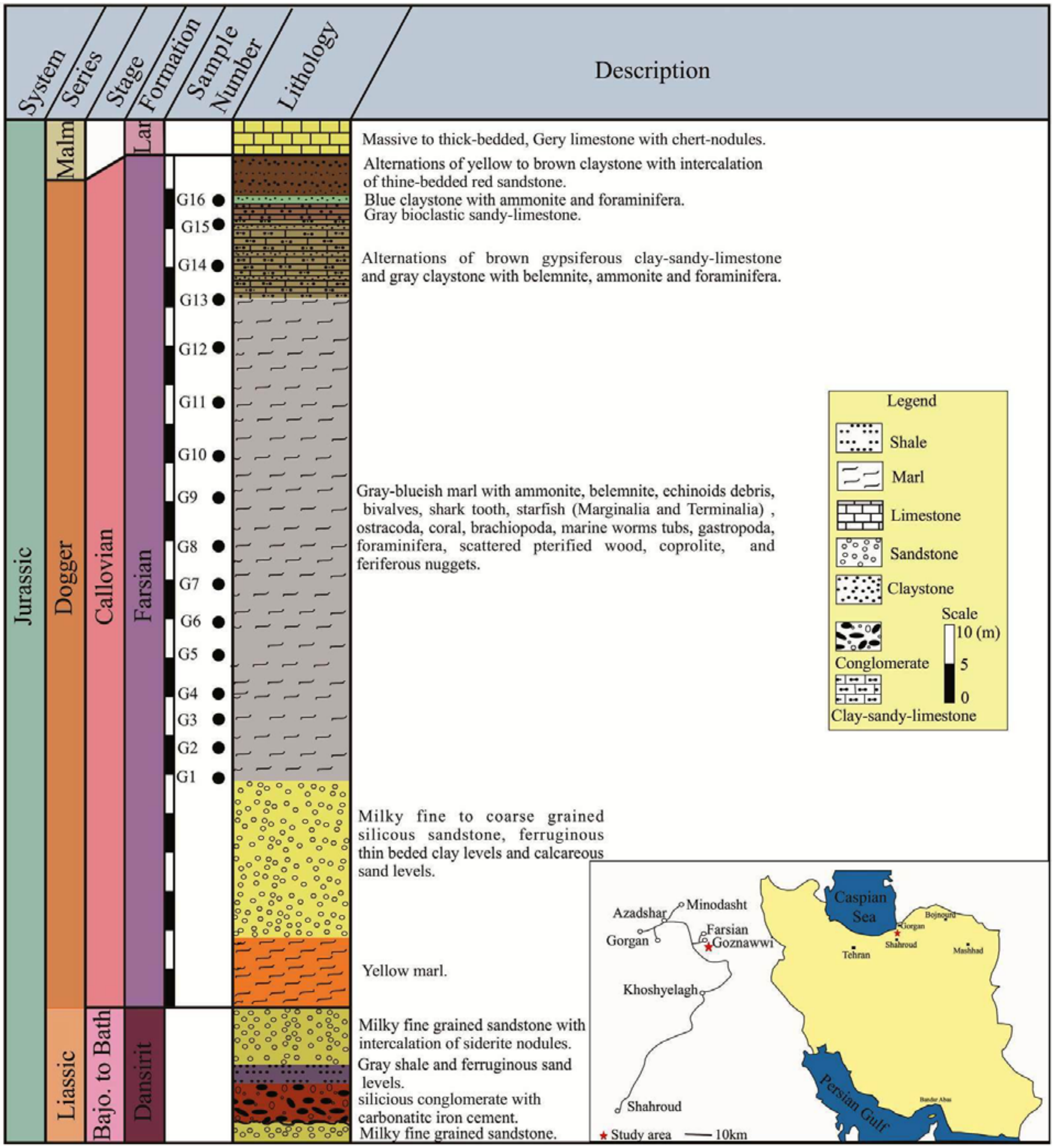

Figure 2. Lithostratigraphic column and location map of the Farsian Formation at the Goznawwi area.

The first identified foraminiferal assemblage almost appears in the middle to upper parts of this sequence (Fig. 5) and is composed of 39 species including; *Bathysiphon* sp., *Saccammina compacta*, *Reophax sterkii*, *Haurania deserta*, *Ophthalmidium* aff. *carinatum*, *Quinqueloculina* sp., *Vinelloidea tibia*, *Prodentalina* cf. *fragilis*, *P. subsiliqua*, *Dentalina pseudocommunis*, *D. bicornis*, *D. terquemi*, *D. conferva*, *D. quenstedti*, *D. guembeli*, *D. jurensis*, *D.* cf. *multivariabilis*, *Laevidentalina* aff. *sarthacensis*, *Nodosaria simplex*, *N. fontinensis*, *N. plicatilis*, *N.* aff. *biloculina*, *Pseudonodosaria sowerbyi*, *P.* aff. *volgata*, *Clarifovae brandi*, *Lenticulina subalata*, *L. munsteri*, *L. quenstedti*, *Astacolus filose*, *Marginulina costata, M. epicharis*, *Marginulina* sp., *Vaginulinopsis bozorgnia*, *Planularia beierrana*, *Vaginulina anomala*, *Lagena* sp., *Bullopora rostrate*, *Ramulina apheilolocula*, *Trocholina* sp.

Figure 3. Field photographs of the Farsian Formation at the Goznawwi area; A- Lower continental deposit, B- Close up the pointe A in the figure of A, C- Maine part of the Farsian Formation, with dominant of marl in the lithology, D- Ferriferous nuggets, E- A total view of the Paleozoic to Mesozoic sediments in the Goznawwi area, F- The Dansirit, Farsian and Lar Formations in the northwest of Goznawwi village.

Benthic foraminiferal morphogroups

Based on test shape and chamber arrangement, as well as on microhabits (feeding strategy and/or living position), nine morphogroups within the benthic foraminifers have been distinguished; two in agglutinated (ag_1–ag_2; Table 1) and seven in calcareous foraminifera (c_1–c_7; Table 1).

The grouping is based on models proposed earlier for agglutinated (Jones & Charnock, 1985; Nagy, 1992; Tyszka, 1994; Kuhnt *et al*., 1996; Nagy *et al*., 2009; Reolid *et al*., 2010, 2012; Smolen, 2012) and calcareous assemblages (Bernhard, 1986; Koutsoukos *et al*., 1990; Szydlo, 2004; Reolid *et al*., 2008a, 2008b; Reolid *et al*., 2012; Smolen, 2012).

Morphogroups of agglutinated foraminifers

Morphogroup ag_1: Consists of multilocular foraminifera with subcylindrical or tapered morphotypes. The majority of species belong to infaunal deposit feeders, detritivorous and microbial scavengers (Jones & Charnock, 1985; Kaminski *et al.,* 1988; Nagy, 1992; Reolid *et al.,* 2008b). In the studied succession this morphogroup includes representatives of the genera *Reophax* and *Bathysiphon*, which are the most frequent in samples of G3 and G4 at level 35 to 40 m of the stratigraphic column.

Morphogroup ag_2: Composed of one morphotype with usually globular tests (also irregular in shape), which often live at or just below the sediment surface. Extant foraminifera of this morphotype represent suspension feeding and or passive deposit feeding, shallow infauna. Modern representatives of *Saccammina*, for instance, live with the test partially exposed, and the aperture submerged in the sediment (Christiansen, 1971). Recent of this morphotype; is common in the bathyal and abyssal zone (Murray, 2006).

Morphogroups of calcareous foraminifera

Morphogroup c_1: Composed of forms lenticular in shape, with multilocular, planispirally coiled smooth and or coarsely ornamented tests. The genera of *Clarifovea* and *Lenticulina* are belonging here. Included taxa are deep infaunal active deposit feeders having both herbivorous and detritivorous diet. They are selected the r-strategist for their life (Reolid *et al*., 2012). They prefer well ventilated shelf environments with high oxygen content in the bottom waters (Bernhard, 1986; Koutsoukos *et al*., 1990, Smolen, 2012). Jurassic᾽s *Lenticulina* had a higher ecological tolerance and opportunistic behavior than extant forms (Rey *et al*., 1994, Tyszka, 1994, Reolid *et al*., 2008b).

In the studied succession a mass occurrence of morphogroup c_1 is observed in throughout stratigraphic column.

Morphogroup c_2: Composed of multilocular, elongated flattened morphotypes with a planispiraly coiled that followed by an uncoiled part.

Table 1. Morphogroups of benthic foraminifers distinguished in the Callovian deposit from the Goznawwi section.

	Morphtypes test shapes	**Life position**	**Feeding strategy**	**Genus (in this paper)**
Ag_1	Subcylindrical multilocular	Infaunal, free?	deposit feeders, detritivorous, bacterial scavenger,	*Reophax* *Bathysiphon*
Ag_2	Globular	Shallow infauna, Common in bathyal and abyssal	Suspension feeding and/ or Passive deposit feeding	*Saccamina*
C_1	Lenticuluar, planispiraly coiled, multilocular	Deep infaunal (r-strategist).	active deposit feeders, detritivorous, herbivorous	*Lenticulina* *Clarifovae*
C_2	Elongated flattened	shallow infaunal (k-strategist)	active deposit feeders, omnivorous	*Astacolus* *Planularia* *Vaginolinopsis*
C_3	elongate, straight to arcuate, multilocular	Shallow to deep infaunal (k-strategist)	deposit feeders, herbivorous, omnivorous, bacterial detrival scavenger	*Pseudonodosaria* *Nodosaria* *Dentalina* *Prodentalina* *Leavidentalina* *Marginulina* *Vaginulina*
C_4	Fusiform in outline, multilocular	epifaunal	active deposit feeders, detritivorous, herbivorous	*Ophtalmidium* *Quinqueloculina*
C_5	globular to ovate, discoidal to conical	epifaunal	deposit feeders, herbivorous, omnivorous, bacterial detrival scavenger	*Lagena* *Trocholina* *Vinelloidea*
C_6	sphaerical	Infauna	Deposit feeding	*Ramulina*
C_7	globular	Epifaunal, free?		*Bullopora*

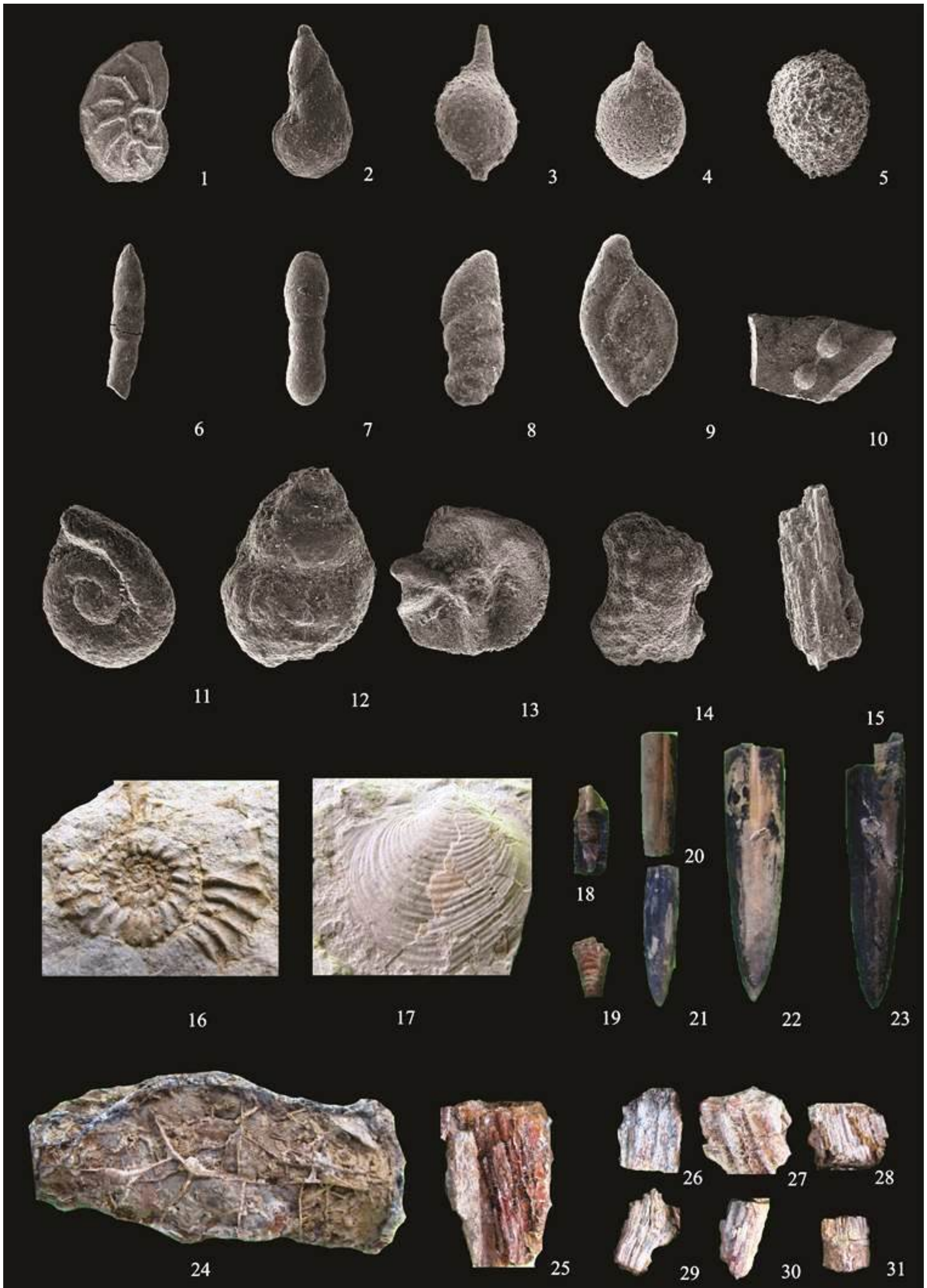

Figure 4. Assemblage of foraminifera and macrofauna (in microscopic and macroscopic scale) collected from Goznawwi section; 1: *Clarifovae brandi* (× 35); 2: *Lenticulina subelata* (× 42) (morpogroup c1); 3: *Ramulina ophilolocula* (morphogrup c6, × 69); 4: *Lagena* sp. (morpogroup c5, × 68); 5: *Saccamina compacta* (morpogroup ag2, × 97); 6: *Dentalina* sp. (morpogroup c3, × 45); 7: *Nodosaria simplex* (morpogroup c3, × 59); 8- *Planularia beierana* (morpogroup c2, × 70); 9- *Quinqueloculina* sp. (morpogroup c4, × 84); 10- *Bullopora rostrate* (morpogroup c7, × 84); 11-12: Gastropods 11-(× 25 and 12 × 20); 13: Element of Crinoid (18×); 14: Sponge(× 28); 15: Wood changed to pyrite (× 22); 16: Ammonite (from Peltoceratidae), (size of vision, 5×4.5 cm); 17: Bivalve (size of vision1.3×0.9 cm); 18-23- Belemnite (size of vision: 18- length, 2 cm and average of width, 0.6 cm; 19- length, 1.8 cm and average of width, 0.5cm; 20- length, 3.3 cm and average of width, 0.7cm; 21: length, 3.3 cm and average of width, 0.8cm; 22- length, 7 cm and average of width, 1.7cm; 23: length, 6 cm and average of width, 1.4cm); 24: Septarian concretion (size of vision, 12×5 cm); 25: 31 Scattered pieces of wood (size of vision: 25- 8×4 cm; 26: 2×2 cm; 27: 2.5×2 cm; 28: 2.2×1.8 cm; 29: 2.5 × 1.5 cm; 30: 2 × 1.2 cm; 31: 2 × 2cm).

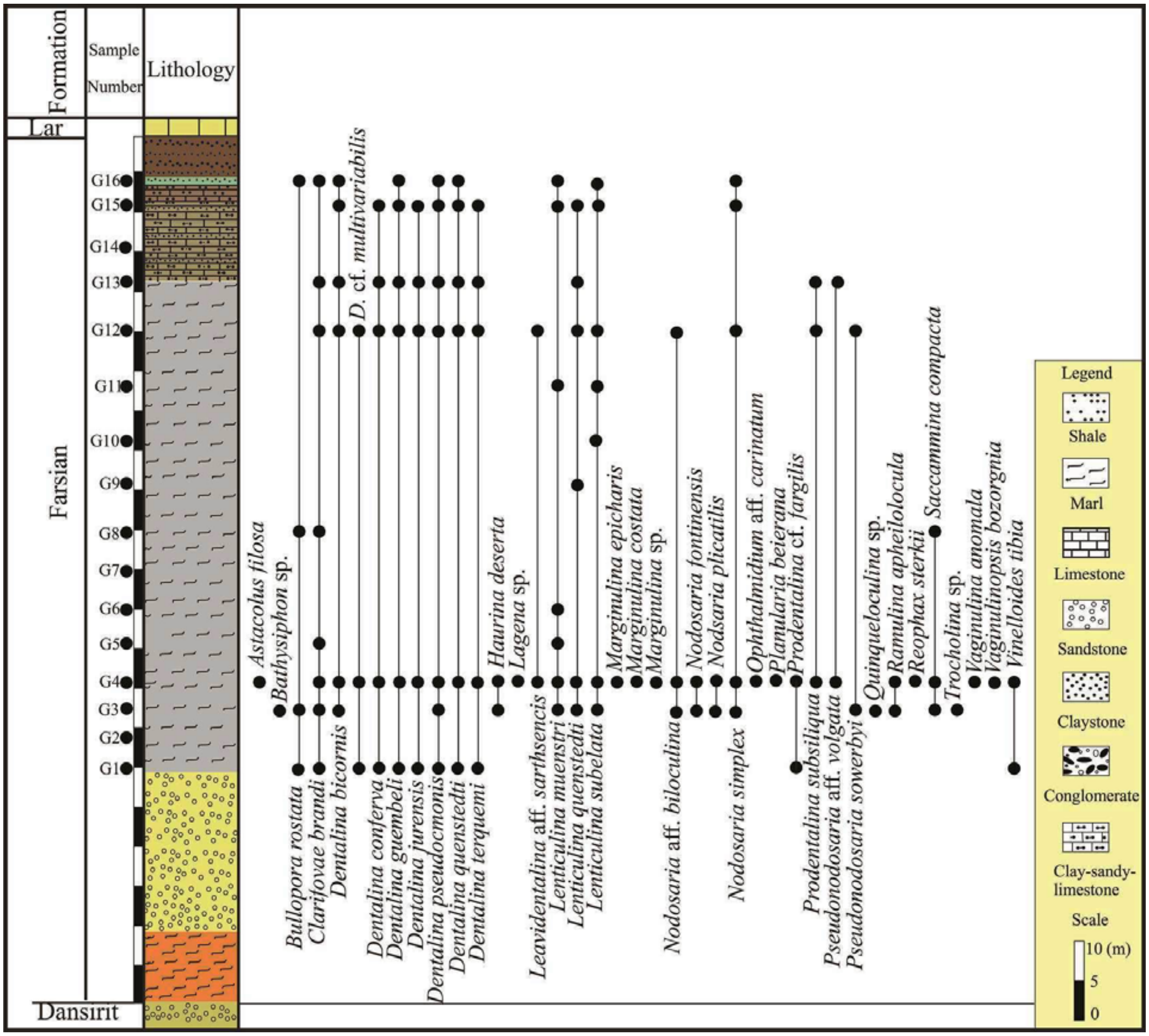

Figure 5. The stratigraphic distribution of foraminiferal species at Goznawwi section.

In the material studied, morphogroup c_2 is represented by *Astacolus*, *Planularia* and *Vaginolinopsis*. Extant counterparts inhabit shelf environments where they live in the sediment surface as deposit feeders, active detritivorous or omnivorous shallow infaunal taxa. They are selected the k-strategist for their life (Reolid *et al*., 2012). In the Jurassic, a moderate frequency of small-sized taxa is reported from environments with depleted oxygen content (Reolid *et al*., 2012).

Morphogroup c_3: Represented by elongate, straight to arcuate morphotypes, with multilocular smooth or ornamented tests, of the genera *Pseudonodosaria*, *Nodosaria*, *Dentalina*, *Prodentalina*, *Leavidentalina*, *Marginulina* and *Vaginulina*. These are Shallow to deep infaunal (k-strategist, Reolid *et al*., 2012), having the deposit feeders, herbivorous, omnivorous, bacterial detrital scavenger. Morphogroup c*3* occurs most frequently in through the secession in this study.

Morphogroup c_4: Composed of benthic calcareous foraminifera with porcellaneous tests. These are multilocular taxa with an elongate test of fusiform and truncate outline, represented by miliolids belonging to the genera of *Ophthalmidium* and *Quinqueloculina*. Recent foraminifera with similar morphology are epifaunal, active deposit feeders (both detritivorous and herbivorous). They prefer shallow, well ventilated and oxygenated shelf environments (Koutsoukos *et al*., 1990). Morphogroup c_4 is frequent in the base of blue marl, occurrence in level 35 to 40 m in the stratigraphic chart.

Morphogroup c_5: Composed of diverse morphotypes of conical and globular to ovate shells. Their representatives, *Lagena*, *Trocholina* and *Vinelloidea*, are active deposit feeders (herbivorous, omnivorous, and microbial scavengers), and they are epifaunal. Some are shallow omnivorous infauna living at the water-sediment interface (Koutsoukos *et al*., 1990). They prefer well oxygenated environments, although can tolerate depleted oxygen content (Szydło, 2005; Reolid *et al*., 2008b). In the studied material morphogroup c_5 is rare.

Morphogroup c_6: Consists of sphaerical forms living as infaunal deposit feeding. *Ramulina* is the representative genus of this morphogroup. In this study, Morphogroup c_6 is occurs in level 35 to 40 m.

Morphogroup c_7: Consists of globular form living as epifaunal and/or? Free. The genius of *Bollupora* is present in the morphogroup c_7 and occurs throughout the succession.

Discussion

Paleoenvironmental implications

Foraminifera are extremely sensitive to environmental fluctuations and are used worldwide as reliable palaeoecological indicators. This agrees well with numerous reports emphasizing that benthic foraminifera are very good indicators of the nature of the sea bottom (*e.g.,* Rey *et al*., 1994; Tyszka, 1994; Nagy *et al*., 1995; Fugagnoli, 2004; Gaur & Talib, 2009; Reolid *et al*., 2010; Talib *et al*., 2012; Smolen, 2012). Palaeoecological interpretations of Jurassic foraminiferal assemblages are difficult to make due to a general lack of direct modern-day analogues (Ballent & Whatley, 1999).

The predominant the group of foraminifera in the Jurassic sediments were the Lagenina and Textularina, which are believed to have occupied a far more diverse range of habitats than their living representatives (Nagy *et al*., 1990). These groups in the Recent, occupy deeper water settings than in the Jurassic (Ballent & Whatley, 1999). In the Callovian, at the Goznawwi area, foraminiferal assemblages are shows significant changes in their morphogroup composition (Table1). The foraminiferal assemblage consisting four suborders include; Textularina, Miliolina, Involutinina and Lagenina, among them the Textularina is seldom and the Lagenina are abundances. These changes are recorded by fluctuating frequencies of particular morphotypes, which apparently reflect fluctuating palaeoenvironmental conditions during sedimentation in this area.

It seems to be currently accepted among authors that Textularina-dominated faunas develop under conditions divergent from those of a normal marine shelf. In Jurassic shelf to marginal marine areas such divergences, Nagy *et al*., (1990) were mentioned to two factors that controlled Textularina-dominated faunas; one of them, runoff from land areas to the basin and other high organic supply to the bottom waters. The runoff will promote brackish conditions and high sedimentation rates, both of which are assumed to produce low diversity Textularina-dominated faunas (Nagy *et al*., 1990). An extensive supply of organic matter (locally mainly land-derived) to the bottom sediments potentially results in oxygen deficiency commonly associated with low pH, both possible producers of low diversity agglutinated faunas. The ubiquity of terrestrial elements (wood scattered, *Xexenozylon* sp. (personal communication, 2017, Professor Philip., University of Lion, France) in all of the samples in this study, a part of displaying significant vertical fluctuations in its content. The high frequency of wood fragments of lowland occur in samples collected from the succession, especially from there samples (G_3, G_4 and G_8), at Goznawwi area, which may be related to an increased influx of terrestrial organic matter from the surrounding land. At sample number G_8; the morphgroupe ag_2 is increase (with 40%), which shows decrease in oxygenation than lower and upper layers, and also through the succession. On the other hand, with increase in organic matter content or with increase in nutrient supply, the morphogroup ag_1 and ag_2 (from textularids) is increase (total with 40% at G_8, and 31% at G_3), at these two points (38m and 60 m from the base succession), oxygenate are decrease. Numerous authors have shown that an increase in the organic matter content of the sediment produces an increase in the metabolic activity of the microbiota, consuming the oxygen of the pore water (Jones, 2014). The degree of oxygenation controlled the structure of the benthic foraminiferal communities. Under conditions of very high organic influx, the redox boundary may be close to the sediment-water interface, favoring opportunistic forms dominated by epifaunal, detritus feeders and shallow infaunal forms (Kuhnt *et al*., 1996;

Fugagnoli, 2004; Reolid *et al*., 2008b, 2010). In this area, these wood fragments (in post sedimentation phenomena) are pyrityzied, which the pyritization interpreted as redox potential condition after sedimentation (Fig.4).

In the Jurassic sediments at Goznawwi basin, Textularina introduced by two morphotype; sub-cylindrical or tapered, elongate forms which make up morphogroup ag_1, tend to live infaunally under normal conditions. A good example is the genus *Reophax*, which modern has been found burrowing to a sediment depth of 15 cm in the deep Panama basin (Kaminski *et al*., 1988). Under normal marine conditions, the genus is able to live in lowered oxygen levels (-0.5 mill) off southern California (Kaminski *et al*., 1995). So also *Reophax* spp., prefer a cold–temperate environment (Ola & Bamisile, 2014). Second morphogroup (ag_2) include globular, shallow infaunal belong to *Saccamina*. Both morohogroups (ag_1 and ag_2) are occurrence in the base and middle of succession.

As maintained; the dominant tax in the Goznawwi area consistent of Lagenina (with 83%); among them the Nodosariidae and Vaginulinidae are dominant taxa. Many of authors believe that preferred habitat of Jurassic Lagenina seems to have been shelf waters of normal marine salinity and oxygenation (Bielecka & Pozaryski, 1954; Wall, 1960; Johnson, 1976; Nagy et al., 1990; Bhalla & Talib, 1991; Talib & Gaur, 2005; Talib et al. 2012). Ancient Nodosariids are interpreted on the basis of analogy with their modern counterpart as marine, shallow to deep, and as having been tolerant only of normal salinity; and are further interpreted as characteristic of deep marine, upper bathyal environments (Jones, 2014). The dominance of vaginulinids in the studied foraminiferal assemblage suggests shallow water, open marine environment, most probably the deeper shelf (Barnard, 1948; Coleman, 1981; Bhalla & Abbas, 1984; Gaur & Talib, 2009).

Of the lenticular, biconvex, planispirally coiled Vaginulinid (morphogroup c_1), the representatives of *Clarifovea* and *Lenticulina* (with 100-200μ in size) are the most abundant and richest taxonomically nearly at throughout the succession (Figs. 6, 7). This morphogroup consist of 100 percentage of total sample from G_5 (level 42m), G_6 (level 45m), G_9 (62m), G_{10} (67m) and G_{11} (level 74m). In the early Jurassic, the lenticular morphogroup predominates in oxic sediments (Bernhard, 1986); however, the cosmopolitan *Lenticulina* successfully occupied a wide range of microhabitats during the Jurassic (Bernhard, 1986; Corliss & Chen, 1988; Koutsoukos *et al*., 1990; Rey *at al*. 1994; Tyszka, 1994). Studies on Recent foraminifers inhabiting oxygen restricted environments demonstrate that such forms are frequently of small size because of their rapid reproduction in stress conditions (Phleger & Soutar, 1973; Fugagnoli, 2004). In total, *Lenticulina* (morphogroup c_1), *Dentalina* and *Nodosaria* (agency of morphogroup c_3) assign to sub-oxyed environment (Jones, 2014). At the Goznawwi region, normal oxygen values are also indicated by the presence of unornamented tests of flattened genera like *Planularia* and *Astacolus* (from morphogroup c_2), and *Vaginulina* (from morphogroup c_5) (Bernhard, 1986). Alike morphogroup c_1, morphogroup c_3 is also dominant at the Goznawwi area, course at the G_1 (with 67.5 percentage), G_4 (with 33 precentage), G_{12} (84%), G_{15} (93%) and G_{16} (86%). As seen at figure 6 and figure 7, the morphogroups c_3 were increased at top of the succession, occur at uppermost of the gray-blueish marl (bed 3), gray bioclastic sandy-limeston (bed 5) and blue clayston (bed 6).

The high frequency of both the planoconvex (c_1) and the elongate (c_2 and c_3) morphogroups, together with the presence of seven other morphogroups, and the relatively high species diversity interpreted as intensive exploitation of both the epifaunal and infaunal niches. It is of interest to note, that the infaunal component (morphogroups c_1-c_3, c_6 and ag_1-ag_2) makes up 90% of total the assemblages (Figs. 6, 7).

This component suggests that the redox boundary was situated below the sediment-water interfaces, which are in accordance with the presence of bioturbation the marls. In additional, at the middle part of Goznawwi succession, foraminiferal assemblage imply to unstable condition because abundant of infounal opportunistic taxa i.e., *Lenticulina* and *Clarifivea*. These taxa selected r-strategists and also the ornamentation in *Clarifovea* is very sharp; interpreted as low dissolved oxygen condition.

In the base and upper parts of succession improved the ecological condition; due to dominant fauna with k-strategists (i.e., *Dentalina*, *Nodosaria*, *Lavidentalina*, *Marginulina*, *Prodentalina*, *Pseudonodosaria*, *Vaginulina*); thus pointing to a stable and constant benthic environment (see the Fig. 7).

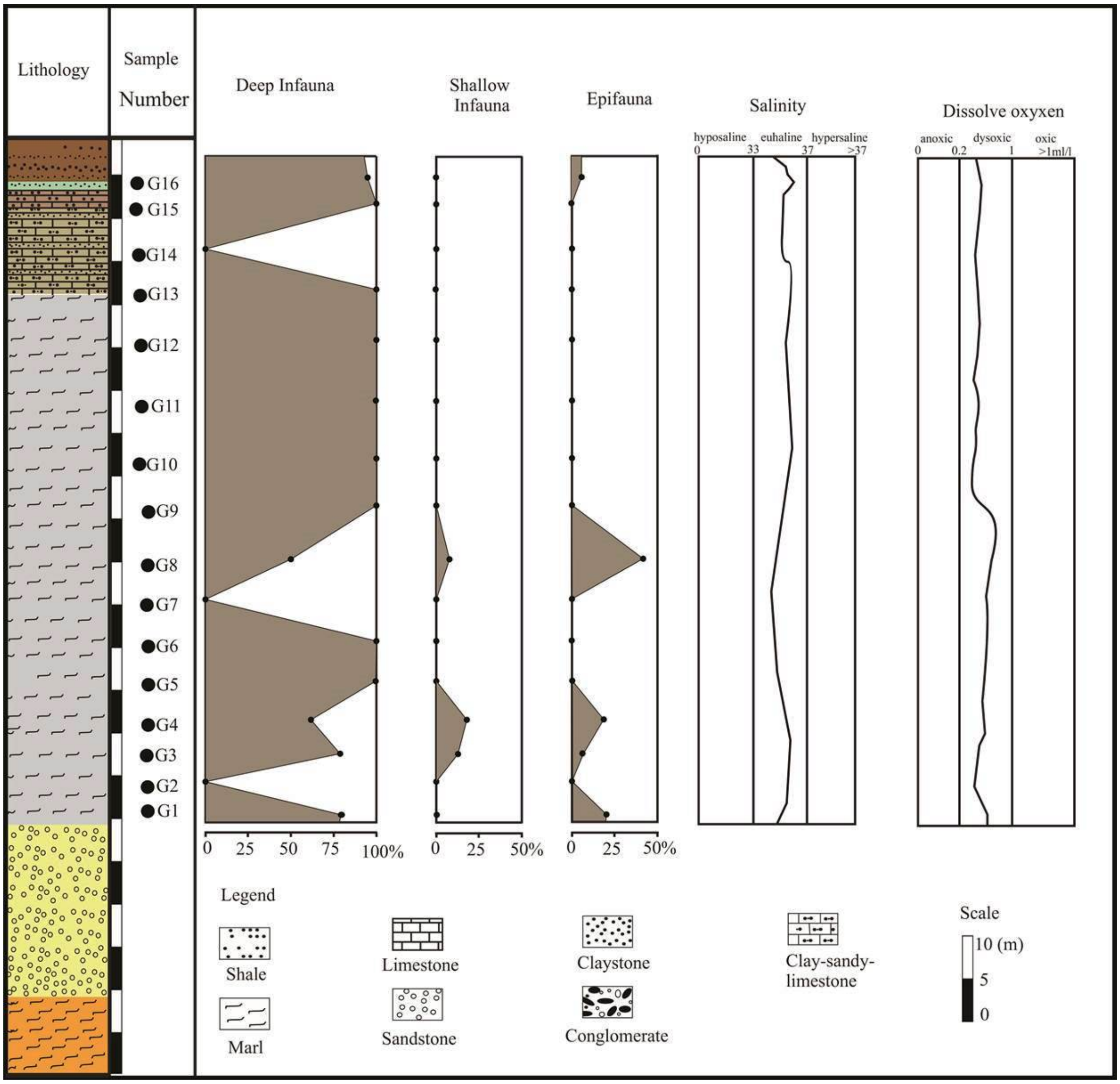

Figure 6. The sedimentary features and analysis of morph-groups categories show in the Goznawwi section, salinity rate and dissolved oxyxen is based on Foraminiferal distribution.

In additional, the pick of the Infaunal morphotypes were introduced the eutrophic condition and low oxygenated (Kaminski *et al*., 1988). These conditions were visible at the Goznawwi area (fig. 7).

In the base of section; the degree of dysoxia was, however, moderate as suggested by the relatively high species diversities. Further evidence for this is provided by observation of bioturbation preserved in marls, indicating the presence of a burrowing infauna. The absence of textural lamination in the Goznawwi sediments provides further evidence for the presence of bioturbation.

Furthermore, benthic foraminifera are the principal group of use in palaeobathymetric interpretation in the region. Many of arthouse suggested that the upper bathyal zone were distinguished by *Lenticulina*, *Bathysiphon* and *Reophax* and also *Dentalina guembeli* may be interpreted as the neritic to the bathyal zone. But; according to Stampfli (1978), based on occurrence of the *Lenticulina* and *Nodosaria*, the Farsian Formation was deposited in infra-littoral to circa-littoral environments. These taxa were exited in the Goznawwi area and in total; the Farsian Formation was deposited at littoral (neritic) zone; deeper of the shelf water.

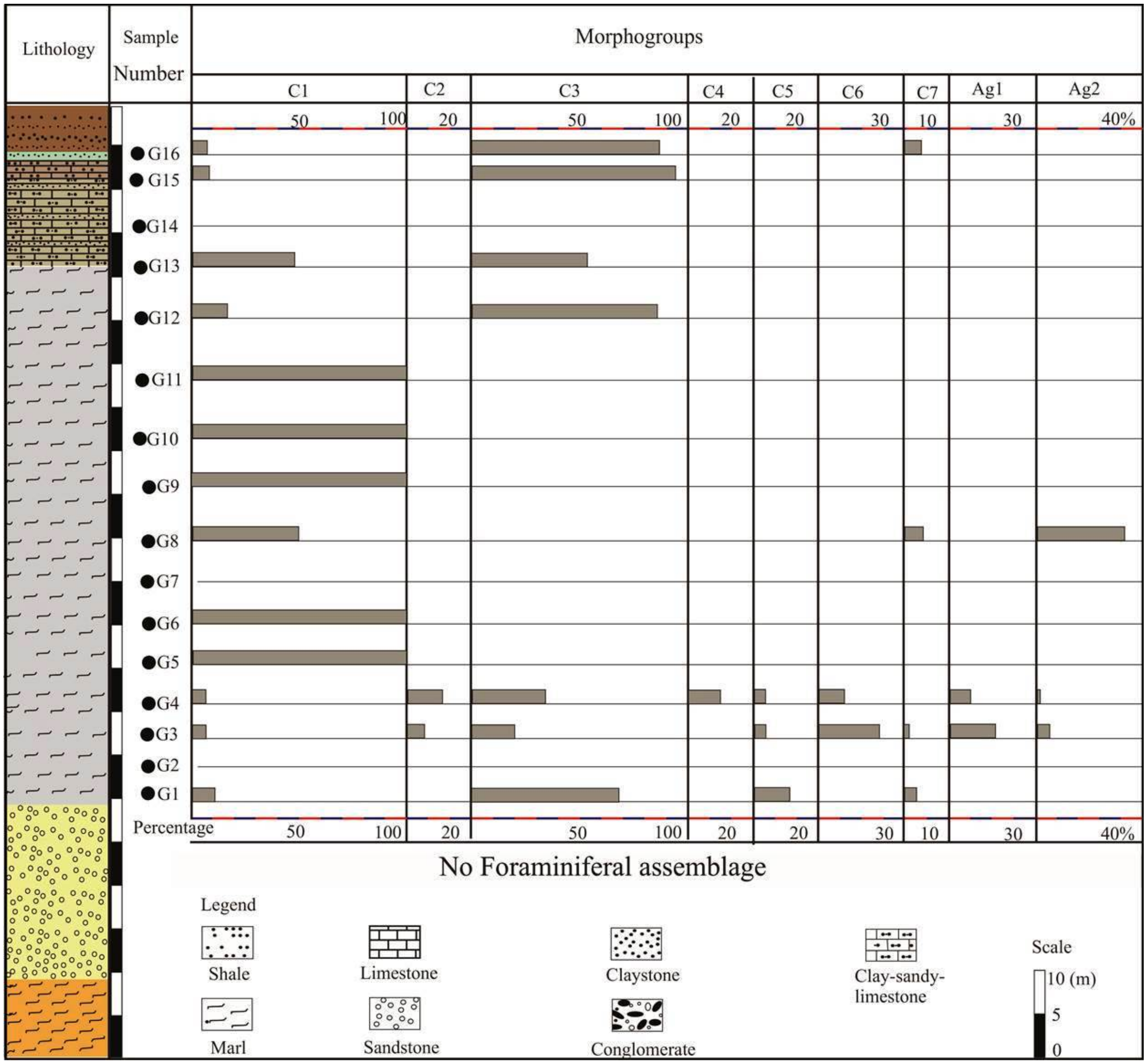

Figure 7. Distribution of calcareous and agglutinated foraminiferal morph-groups in the Goznawwi section based on percentage

Ammonites (Phyloceratidea, Oppelidea, Perisphanctidea and Peltoceratidea belong Callovian age), belemnites, Crinoide´s elements, sponge, bivalves and gastropod are observed throughout the Farsian Formation; are common levels. The presence of this fossil group suggests normal marine salinity conditions at least in the deeper parts of the water column. The comparatively high diversity displayed by the foraminiferal assemblages also rules out brackish conditions (Fig. 4).

Conclusion

Callovian deposits, composing the upper half of the Farsian Formation in the Goznawwi section, eastern Alborz, consist mainly of marls. This sedimentary succession contains an essentially continuous foraminiferal record, composed almost exclusively of calcareous taxa forming high-diversity assemblage, but only in the three levels (G_2, G_7 and G_{14}) foraminiferal species aren’t observed in this section. In the foraminiferal succession, nine morphogroups have been differentiated, based on morphological features combined with inferred microhabitat preferences and feeding strategies. Palaeoecological analysis of the foraminiferal assemblages based on morphogroups analysis performed in the Goznawwi area for the first time from Iran. In this area, middle Jurassic sediments (Callovian stage) show an initial phase of unstabilization of the benthic environment (levels of G_1 to G_4). Certain species are affected while others remain constant, and some opportunistic forms increase (*Clarifovea* and *Lenticulina*), (with r-strategist) under these new conditions (levels of G_5, G_6 and levels G_9 to G_{11}). In these levels, the morphogroups of c_1 is dominants, in following, toward the upper part of the Farsian Formation, in levels of G_{12} to G_{16} the morphogrup c_1 (with r-strategist) replaced by members of morphgroup c3 (with k-strategist).

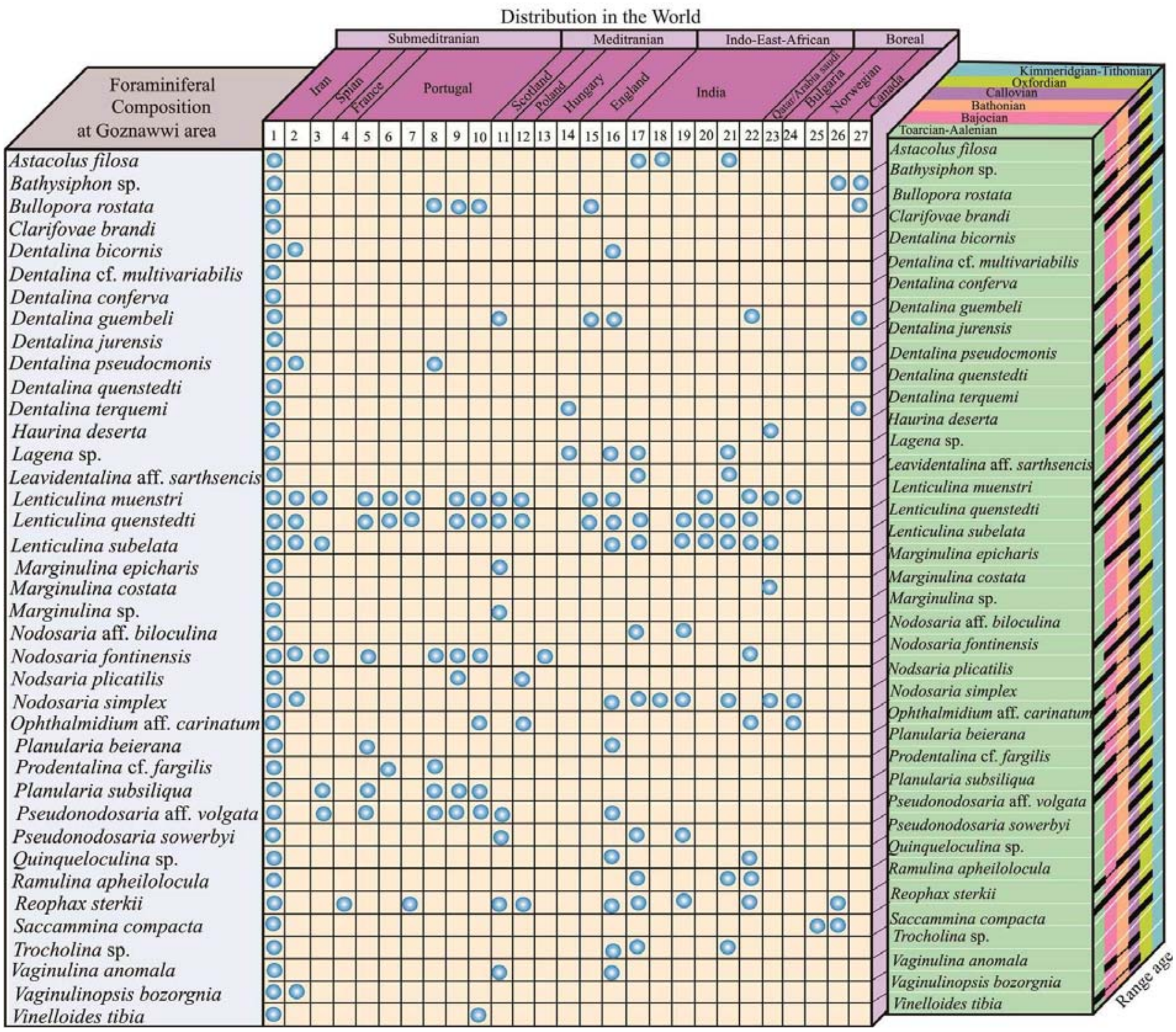

Figure 8. Blok-diagram of the distribution of Foraminiferal assemblage at Goznawwi area and correlation with the stratigraphical distribution of them in 26 localities in the World: 1. Goznawwi area in this paper; 2. kourkhord mountain at Kopet Dagh, Iran (Kalantari, 1969); 3. Spain, Fuentelsaz section (Hererro & Canales, 1997); 4. France (Bouhamdi *et al*., 2000); 5. Portugal, Murtinheira (Canales & Henriques, 2008); 6. Portugal, Lusitanian Basin (Henriques, *et al*., 2016); 7. Purtugal, (Stam, 1986); 8. Portugal, Sao Giao section (Henriques & Canales, 2013); 9. Portugal, Cape Mondeago area (Canales and Henriques, 2013); 10. Portugal, Maria Pares and the Zambujal de Alcaria sections (Figueiredo *et al*., 2014); 11- Scotland, Brora section (Gordon, 1965); 12.Poland, Gnaszyn area (Smolen, 2012); 13. Hungary, Villany mountains (Gorog *et al*., 2012); 14. Hungary (Szinger *et al*., 2007); 15. England, Oxford Clay (Barnard, 1953); 16. England, Dorset (Henderson, 1997); 17. India, Kutach region, Gujrat section (Sabeeha, 2015); 18- India, Kutach region, Jumara section (Gaur & Talib, 2009); 19. India, Kutach region, Keera Dome-section (Talib *et al*., 2012); 20- India, Rajasthan area (Talib *et al*., 2014); 21- India, Kutach region, Jumara Dome-section (Talib & Gaur, 2008); 22. India, Jhura, Kamaguna and Jumara Dome sections (Alhussein, 2014); 23. Qatar and Arabia Saudi, compsite section (Al -Saad, 2008); 24. Bulgaria (Metodiev *et al*., 2004); 25. Norwege (Basov *et al*., 2008); 26. Norwegian (Nagy *et al*., 1990); 27. Canada, Queen Charlotte Islands (Kottachchi *et al*., 2002).

This condition interpreted as an optimal ecological redound to dominance assemblage consisting of high-diversity k-strategists and to lesser extent low-diversity r-strategists, which evidences a stable and constant benthic environment with good oxygen and nutrient availability in the infaunal microhabitats. But, throughout at the Goznawwi area, based on the ratio of the infaunal/epiphaunal; eutrophic condition is dominant.

Palaeobathymetricaly, two genera of *Bathysiphon* and *Reophax* occur at the base sediment and also *Dentalina guembeli* and *Lenticulina*, which dominance in throughout the section; may be interpreted as the littoral (or neritic zone). Also, the presence of macrofossil *e.g.* ammonite, belemnite, Crinoide´s elements, sponge, bivalves and gastropod suggests normal marine salinity conditions at least in the deeper parts of the water column. The comparatively high diversity displayed by the foraminiferal assemblages also rules out brackish conditions. Also, for the distribution of Foraminiferal assemblage in this research and correlation with the stratigraphical distribution of them in 26 localities in the World, see the figure 8.

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