

Biostratigraphy and paleoecology of the Qom Formation in Chenar area (northwestern Kashan), Iran

Elham Behforouzi* and Amrollah Safari

Department of Geology, Faculty of Sciences, University of Isfahan, Isfahan, Iran, 81746-73441.

** elibehforouzi@yahoo.com*

ABSTRACT

A study of large benthic foraminifera from the 147 m-thick Qom Formation in the Chenar area (northwestern Kashan) is reported. One hundred and twelve thin sections were prepared and the distribution of benthic foraminifera was analyzed to reconstruct paleoenvironmental conditions. Study of these sections led to the identification of 28 genera and 38 species. On the basis of the recognized foraminifera, the section is comparable to Lepidocyclina- Operculina- Ditrupa Assemblage zone, and the age of the Qom Formation in the studied section is assigned to the Oligocene.

Evidence of sea level changes is observed from bottom to top of the studied section. On the basis of large benthic foraminifera assemblages and microfacies features, three major depositional environments (inner shelf, middle shelf and outer shelf) were defined. The inner shelf facies is characterized by wackstone-packstone, dominated by miliolid and small perforate foraminifera. The middle shelf facies is represented by packstone-grainstone with diverse assemblage of large perforate benthic foraminifera. Outer shelf facies is dominated by large perforate benthic foraminifera as well as planktic foraminifera. The distribution of the Oligocene large benthic foraminifera in the studied area indicates that shallow marine carbonate sediments of the Qom Formation were deposited in a photic zone of tropical to sub-tropical environments. Finally, the correlation between the study area and some other sections of Central Iran indicates that sedimentation of the Qom Formation is continued from Late Rupelian to Chattian in northwest and Late Rupelian to Aquitanian in southeast direction.

Key words: biostratigraphy, benthic foraminifera, Qom Formation, Oligocene, Aquitanian, Iran.

RESUMEN

Se reporta el estudio de foraminíferos bentónicos grandes de la Formación Qom, con 147 m de espesor, en el área de Chenar (noroeste de Kashan). Ciento doce secciones delgadas fueron preparadas y la distribución de foraminíferos bentónicos fue analizada para reconstruir las condiciones paleoambientales. El estudio de esas secciones llevó a la identificación de 28 géneros y 38 especies. Con base en los foraminíferos identificados, la sección es atribuible a la zona de Lepidocyclina- Operculina- Ditrupa y la edad de la Formación Qom en la sección estudiada es asignable al Oligoceno.

Evidencias de cambios del nivel del mar pueden ser observados desde la base y hacia a cima de la sección estudiada. Con base en los ensambles de foraminíferos bentónicos grandes y en las características de las microfacies, tres ambientes de depósito fueron definidos (plataforma interna, media y externa). Las facies de plataforma interna se caracterizan por wackstone-packstone, dominada por miliólidos y

pequeños foraminíferos perforados. La plataforma media está representada por packstone-grainstone, con diversos ensambles de foraminíferos bentónicos grandes perforados. Las facies de plataforma externa están dominadas por foraminíferos bentónicos perforados grandes, así como por foraminíferos planctónicos. La distribución de los foraminíferos bentónicos grandes del Oligoceno indica que los sedimentos marinos carbonatados someros de la Formación Qom fueron depositados en la zona fótica de un ambiente tropical a sub-tropical. Finalmente, la correlación entre el área estudiada y otras secciones de Irán Central indica que la sedimentación de la Formación Qom fue continua en dirección noroeste desde el Rupeliano Tardío al Chattiano, y lo fue en dirección sureste del Rupeliano Tardío al Aquitaniano.

Palabras clave: bioestratigrafía, foraminíferos bentónicos, Formación Qom, Oligoceno, Aquitaniano, Irán.

INTRODUCTION

In this study, the foraminifera assemblage in the stratigraphic section located at Chenar village, 50 km northwest of Kashan, is described. The study area exposes Cenozoic sediments and is located at 51°09'02"E longitude and 34°05'37"N latitude (Figure 1).

Due to the high evolution rate, abundance, widespread distribution and abrupt extinction of species, benthic foraminifera are considered an important tool for the study of the biostratigraphy and evolution of genera and species, relative depth or paleoenvironmental reconstruction (Vaziri-Moghaddam *et al.*, 2010). Considering the distribution of foraminifera and analyzing some factors like light, temperature, nutrient supply, substrate, hydrodynamic energy, depth, water locomotion and symbiosis, the paleoenvironment could be reconstructed. There are some similarities between the benthic foraminifera assemblages of Qom Formation and Asmari Formation and due to lack of a formal proposed biozonation in the Qom Formation, the biozonation offered by Wynd (1965) and Laursen *et al.* (2009) for the Asmari Formation were used in this investigation.

Geological investigation of the Qom Formation in Central Iran started with the work of Tietze (1875). Subsequent workers such as Stahl (1911), Riben (1935), Furon and Marie (1939), Furon (1941), Furrer and Soder (1955), Gansser (1955), Dozy (1944, 1955), Abaie *et al.* (1964) and Bozorgnia (1966) reported on the marine sediments of the Qom Formation. A few foraminiferal species were illustrated by Furon and Marie (1939), Furon (1941), Furrer and Soder (1955), Abaie *et al.* (1964) and Bozorgnia (1966). Rahimzade (1994) collected the names of most researchers, part of whose work covered the Qom Formation.

Furrer and Soder (1955) divided the Qom Formation into six members; Abaie *et al.* (1964) increased the number of members to ten. Abaie *et al.* (1964) noted that two members, c-1 and c-3, were the main objectives in exploration wells, due to fracture development enhancing porosity/permeability and hydrocarbon shows. Bozorgnia (1966) proposed and introduction ten members for the Qom Formation and distinguished several local basins of deposi-

tion in Central Iran, on the basis of its lithological characters. Rahaghi (1973, 1976, and 1980) suggested Oligo-Miocene age for the Qom Formation. Okhravi and Amini (1998) reconstructed palaeoenvironment of the f-member of the Qom Formation based on microfacies analysis. Based on echinoderms and microfossils, Khaksar and Maghfouri-Moghaddam (2007) proposed Middle to Late Oligocene age for the Qom Formation. Aalaeobiogeographic reconstruction of the Qom Formation was proposed by Reuter *et al.*, 2007.

METHODS AND STUDY AREA

Field work was concentrated on an outcrop of the Qom Formation, located 10 km to the north of Chenar village. A

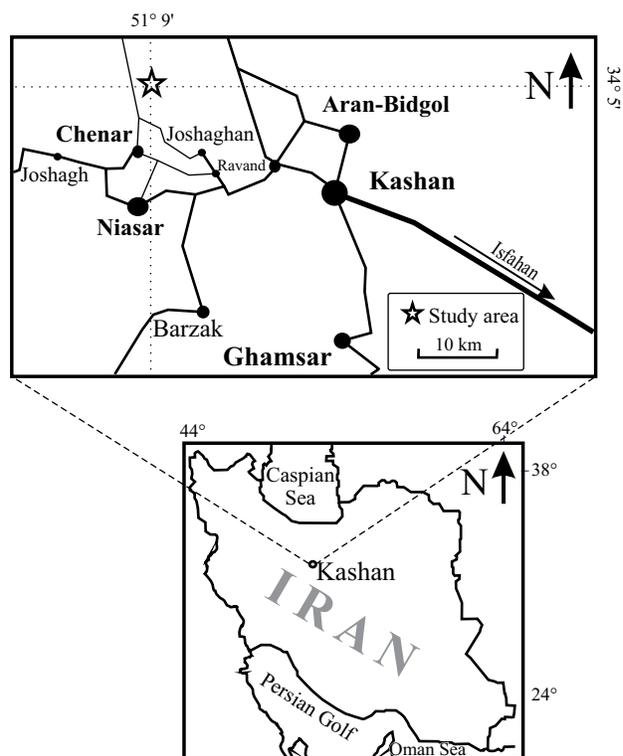


Figure 1. Location map of the studied area in central Iran.

147 m thick section was measured in detail, and a total of 112 specimens were sampled during the detailed field investigation. Samples were taken from the carbonate and marly layers almost every meter according to facies variation. Thin sections were provided for harder lithologies whilst softer lithologies were disaggregated and the foraminifera picked and analyzed. Disaggregated samples were wet sieved through a 151 μm . Thin sections were studied under the microscope for the analysis of benthic foraminifera. Taxonomic classification was based on Loeblich and Tappan (1988), Adams and Bourgeois (1967) and Adams (1969).

GEOLOGICAL SETTING

On the basis of the sedimentary sequence, magmatism, metamorphism, structural setting and intensity of deformation, Iranian plateau has been subdivided into eight continental fragments, including, Zagros, Sanandaj-Sirjan, Urumieh-Dokhtar, Central Iran, Alborz, Kopeh-Dagh, Lut and Makran (Heydari *et al.*, 2003). The study area is located in the Central Iran basin (Figure 2).

During the Early Paleogene, the Tethyan seaway was a wide ocean that connected the two major oceanic realms, the Atlantic and the Pacific (Schustr and Wielandt, 1999). The subduction and final collision of the African-Arabian plate around Eocene-Oligocene boundary was accompanied by the vanishing of the Tethyan seaway, the disconnection of the Atlantic and the Pacific Ocean and the birth of the Indian Ocean and the Mediterranean. As a consequence, Central-Iranian paleogeography changed dramatically by the development of a volcanic arc which separated a fore arc from a back arc basin during Eocene times. Marine sedimentation of the Qom Formation began during the Oligocene and continued to the end of the Early Miocene in the Esfahan-Sirjan fore arc and in the Qom back arc basin (Schustr and Wielandt, 1999).

BIOSTRATIGRAPHY OF FORAMINIFERA

Larger benthic foraminifera are widely distributed in the Tertiary carbonate platform of the Qom Formation. They developed complicated internal structures which can be identified when they are randomly thin sectioned. These organisms can provide complete and detailed evidence for biostratigraphic analysis of the shelf limestone because of rapid diversification, abrupt extinction and abundance (Beavingtone-Penny and Racey, 2004).

The sedimentary deposits of the study area yielded abundant larger benthic foraminifera, therefore, biostratigraphic zonation is based on these organisms. So far, a formal biostratigraphic framework has not yet been established for the Qom Formation. However, based on foraminiferal similarities a general agreement exists to correlate the Qom Formation (Central Iran Basin) with

its coeval counterpart in the Zagros basin in southwest Iran (Asmari Formation) (Stöcklin 1952; Bozorgnia 1966 and Kashfi 1988). Therefore, biozonations established for the Qom Formation in this work are largely based on the biozonations of Wynd (1965) and Laursen *et al.* (2009), which was used for the Asmari Formation that comprises an Oligocene to Early Miocene carbonate sequence (Table 1).

From base to top a two foraminifera assemblages were recognized in the studied section (Figure 3):

Assemblage 1: Is characterized by the presence of *Lepidocyclina* sp., *Eulepidina* sp., *Eulepidina dilatata*, *Eulepidina elephantina*, *Nephrolepidina* cf. *marginata*, *Nephrolepidina* cf. *touroueri*, *Nephrolepidina* sp., *Operculina complanata*, *Operculina* sp., *Sphaerogypsina globulosa*, *Haplophragmium slingri*, *Planorbulina* sp., *Neorotalia viennoti*, *Neorotalia* sp., *Valvulinid* sp., *Amphistegina* sp., *Amphistegina lessonii*, *Elphidium* sp., *Bigenerina* sp., *Textularia* sp., *Discorbis* sp., *Quinqueloculina* sp., *Triluculina trigouenula*, *Globorotalia* cf. *nana*, *Globorotalia siakensis* (Figures 4 and 5). This assemblage

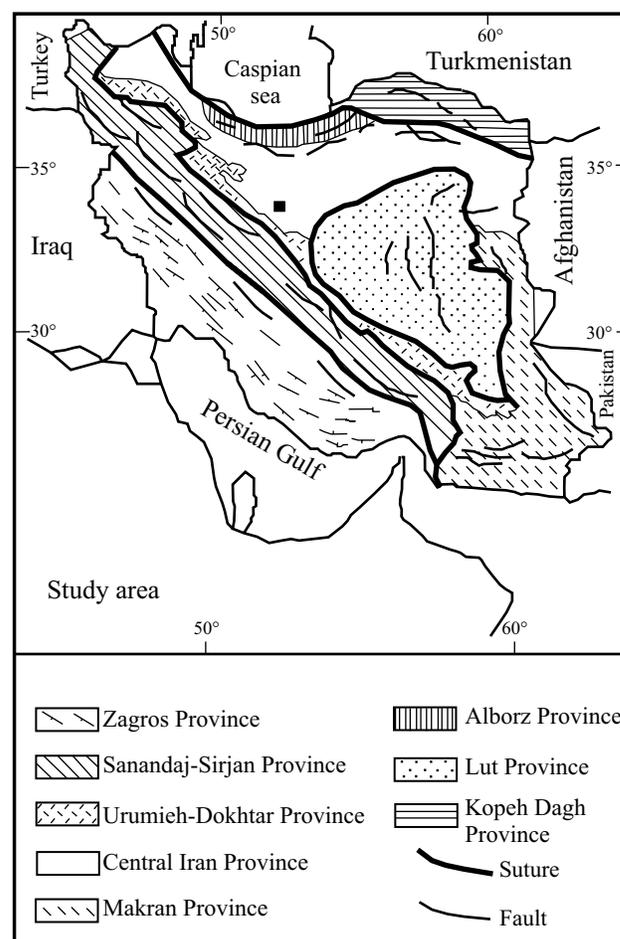


Figure 2. Subdivisions of the Zagros orogenic belt (adopted from Heydari *et al.*, 2003), and zonation in Asmari Formation (Laursen *et al.*, 2009 and Wynd, 1965).

Table 1. Zonation in Asmari Formation (Laursen *et al.*, 2009 and Wynd, 1965).

Epoch	Stage	Biozonation of Laursen <i>et al.</i> (2009)		Biozonation of Wynd (1965)
Miocene	Burdigalian	<i>Borelis melo curdica</i> - <i>Borelis melo melo</i>		<i>Borelis melo curdica</i> Assemblage zone (zone 61)
	Aquitanian	<i>Miogypsina</i> - <i>Elphidium</i> sp. 14 <i>Peneroplis farsenensis</i>		Assemblage zone (zone 59) <i>Archaia</i> <i>operculinoformis</i> Assemblage zone (zone 58) <i>Nummulites intermedius</i> - <i>Nummulites vascus</i> Assemblage zone (zone 57)
Oligocene	Chattian	<i>Archaia hensoni</i> - <i>Miogypsinoides complanatus</i>	<i>Lepidocyclina</i> - <i>Operculina</i> - <i>Ditrupa</i>	<i>Lepidocyclina</i> - <i>Operculina</i> - <i>Ditrupa</i> Assemblage zone (zone 56) <i>Globigerina</i> spp. Assemblage zone (zone 55)
	Rupelian	<i>Nummulites vascus</i> - <i>Nummulites fichteli</i>		
		<i>Globigerina</i> - <i>Turborotalia cerroazulensis</i> <i>Hantkenia</i>		

corresponds to the “*Lepidocyclina-Operculina-Ditrupa* assemblage zone”. Assemblage zone of Wynd (1965) and Laursen *et al.* (2009) applied for the Asmari Formation. This assemblage is attributed to the Oligocene and is correlated with the lower part of the Asmari Formation.

Assemblage 2: *Lepidocyclina-Operculina-Ditrupa* assemblage zone. The assemblage has this associated fauna: *Planorbulina* sp., *Eulepidina dilatata*, *Haplophragmium slingri*, *Rotalia viennoti*, and algae. This zone ranges from the Rupelian into the Chattian (Laursen *et al.*, 2009).

PALEOECOLOGY

In this section, an attempt to investigate factors that influence the benthic foraminifera distribution in the Qom Formation is presented. In this regards, environmental agents such as nutrient supply, light, temperature, water locomotion, substrate, salinity, hydrodynamic energy, depth and symbiosis are very significant. In terms of the paleoecology, paleoecological constraints proposed by Hallock and Glenn (1986) include three families observed in studied section (Nummulitidea, Amphisteginidea and Peneroplidea).

Nutrient supply

Large benthic foraminifera are highly adapted to stable, oligotrophic and nutrient-deficient conditions, but they cannot respond competitively when nutrient resources become abundant (Hallock, 1985). Inorganic, “biolimiting” nutrients enter shallow-water communities principally by turnover or upwelling of deeper waters, by run-off from land

or by advection from areas of upwelling or runoff (Hallock and Schlager, 1986).

Large symbiont-bearing benthic foraminifera are compatible to nutrient deficiency conditions and in such situation, the algal symbiont uses organic waste substances of the host and CO₂ originated from host respiration for photosynthesis (Beavingtone-Penney and Racey, 2004). And so, the produced substances supplies nutrient for the host.

In the studied section, semi-restricted lagoon environments inferred by the presence of perforate and imperforate foraminifera indicate mesotrophic to eutrophic conditions and shallow to deep marine environments point to mesotrophic to oligotrophic conditions. Show that *Lepidocyclina* harboured endosymbiotic algae to provide sufficient light for the photosynthesis of the symbionts (Chaproniere, 1975). Numerous chambers of twenty tests of *Nephrolepidina* cf. *tourner* indicated in sample (B16) (Figure 6).

Light

The abundance of robust and thick tests of *Operculina* in the study area reflects increasing light intensity (Figure 7). Light intensity and hydrodynamic force control test morphology through symbiotic interactions. In shallow, well-lit waters the calcification rate in foraminiferal test is enhanced by photosynthetic symbionts, in order to prevent photoinhibition of symbiotic algae within the test or test damage in turbulent water (Beavingtone-Penney and Racey, 2004).

Larger foraminifera are sensitive to changes in environmental factors including light intensity and hydrodynamic force along depth gradients which are

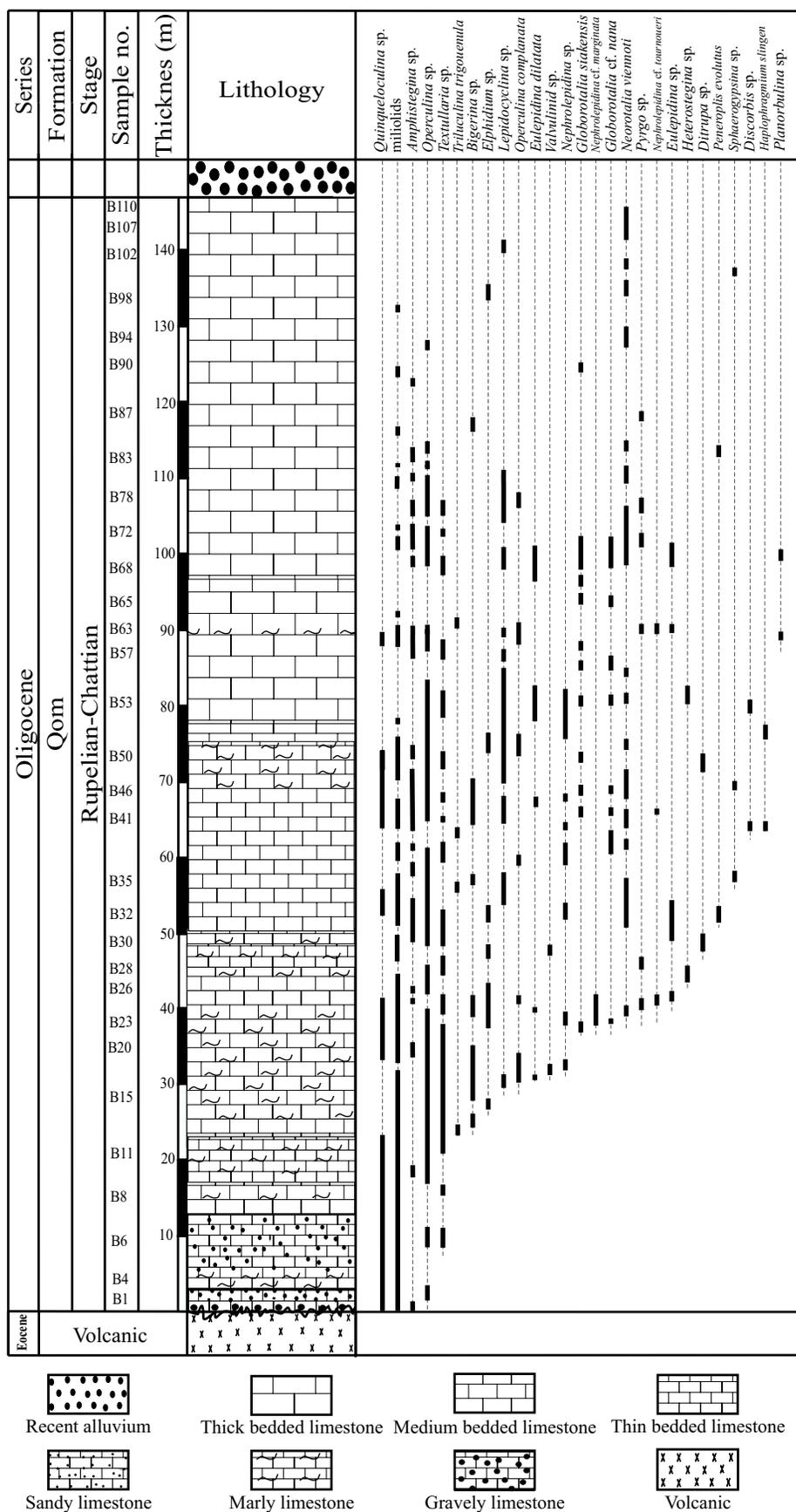


Figure 3. Lithostratigraphic column and vertical distribution of some benthic foraminifers in Chenar area, northwest Kashan.

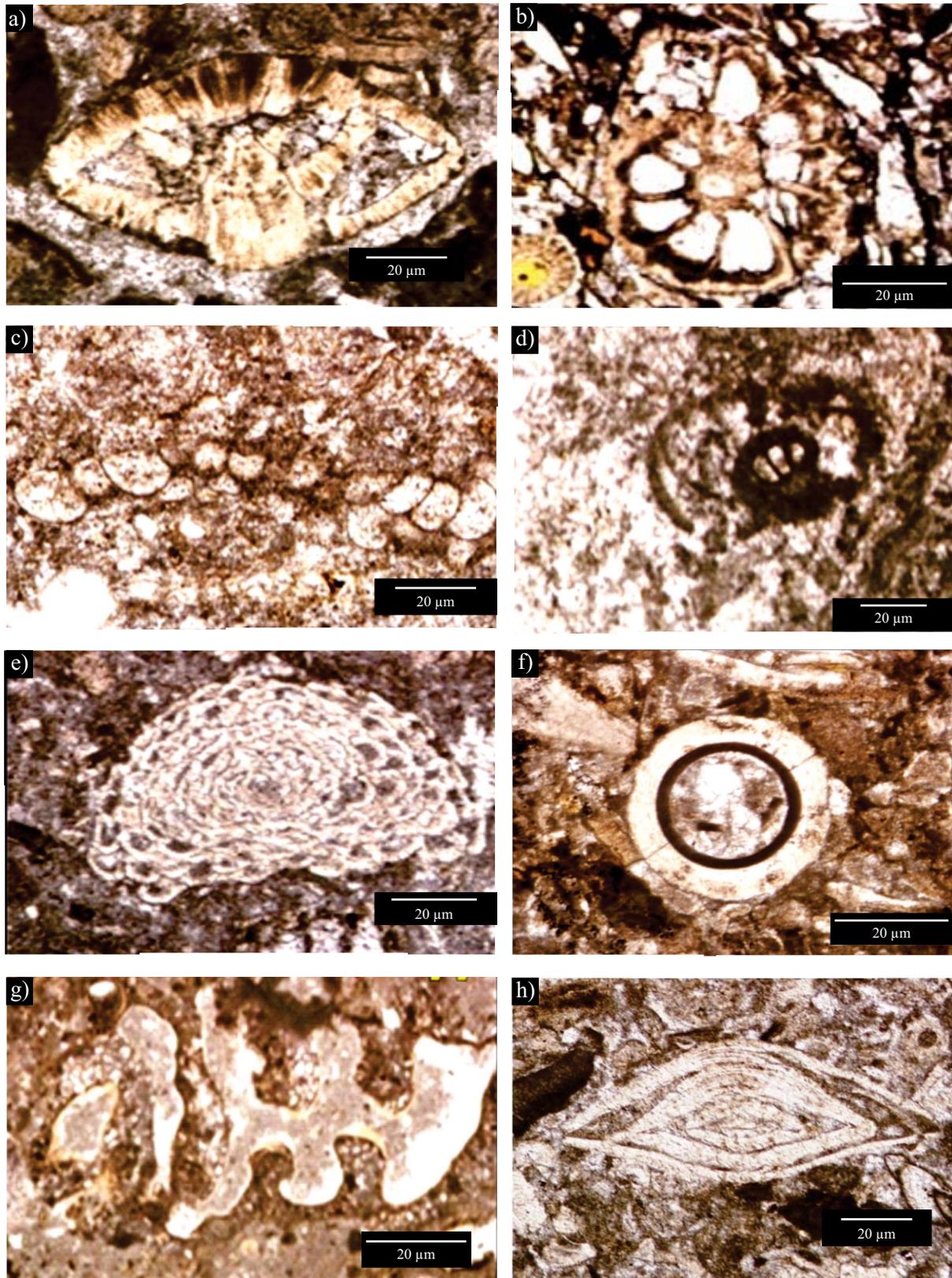


Figure 4. a) *Neorotalia viennoti*, subaxial section (sample No. B72), b) *Neorotalia viennoti*, equatorial section (sample No. B102), c) *Planorbulina* sp., subaxial section (sample No. B98), d) *Elphidium* sp., subaxial section (sample No. B76), e) *Sphaerogypsina* sp., axial section (sample No. B68), f) *Ditrupa* sp. (sample No. B73), g) *Haplophragmium* sp., subaxial section (sample No. B63), h) *Amphistegina* sp., subaxial section (sample No. B34).

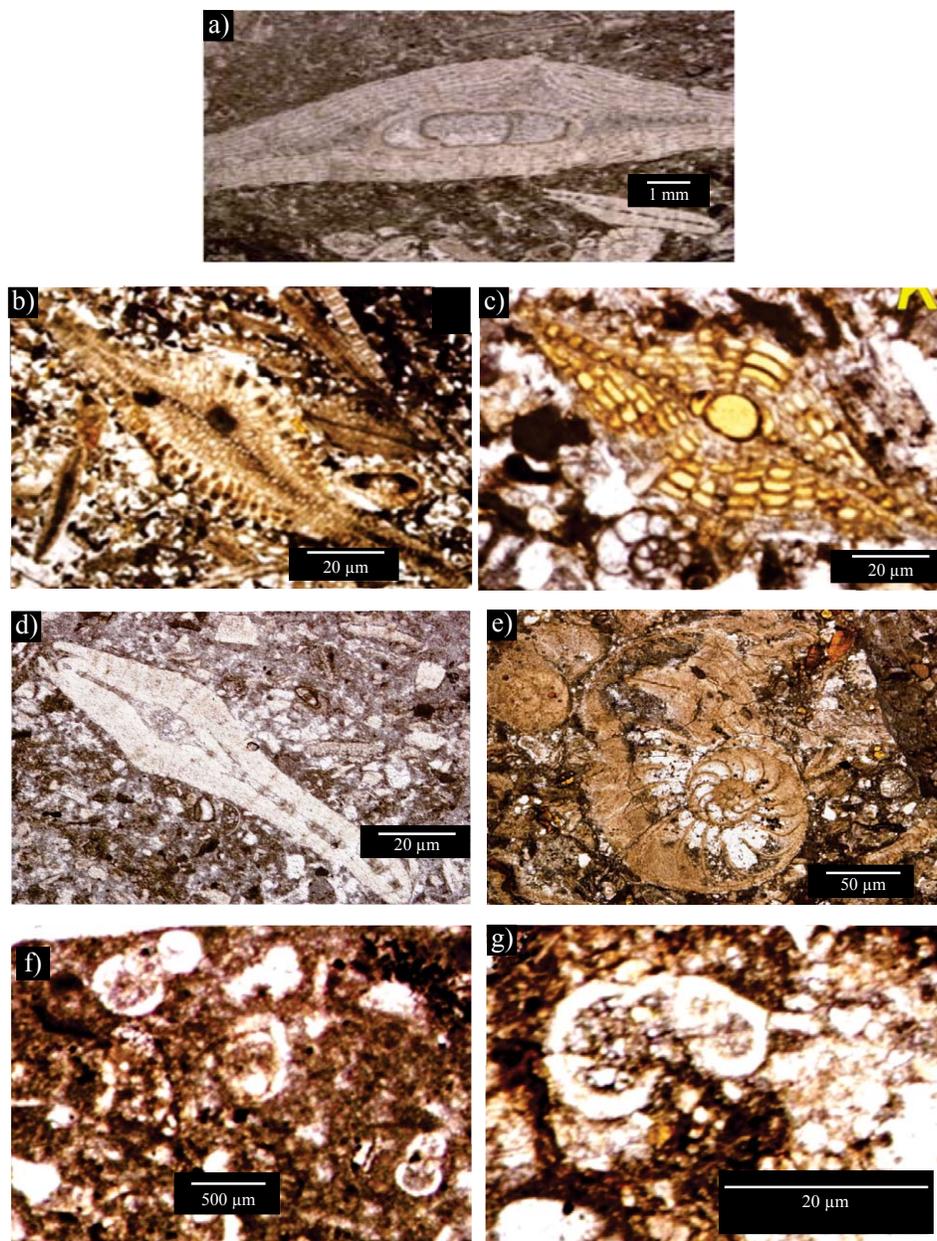


Figure 5. a) *Eulepidina* cf. *dilatata*, axial section (sample No. B80), b) *Nephrolepidina* cf. *marginata*, axial section (sample No. B38), c) *Nephrolepidina* cf. *tournoueri*, axial section (sample No. B65), d) *Operculina* sp., axial section (sample No. B55), e) *Operculina* sp., equatorial section (sample No. B70), f) *Globorotalia siakensis*, axial section (sample No. B97), g) *Globorotalia* cf. *nana*, subaxial section (sample No. B86).

mirrored by changes in test shape and size of symbiont-bearing foraminifera (Beavingtone-Penney and Racey, 2004). The shallow dwelling microperforated hyaline foraminifera produce small, robust and ovate tests and increase calcification rate which brings about a thick wall structure to prevent photoinhibition of the endosymbiont within the test in highly illuminated shallow waters, or test damages in mobile substrates, while hyaline foraminifera from greater depths shifts to larger, thinner and more transparent test to thrive in strongly reduced light intensity (Beavingtone-Penney and Racey, 2004). On the basis of the dependence of carbonate production to light penetration,

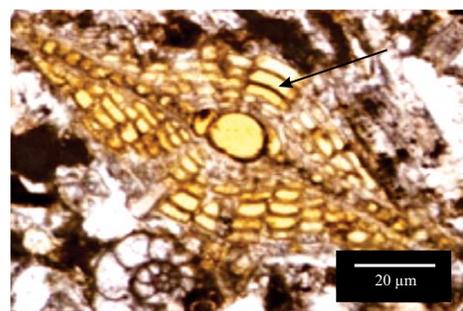


Figure 6. *Lepidocyclina* test. Small pores and lateral chamberlets, which resulted from algal symbiosis replacement (sample B16).

three different groups of benthic organisms could be considered.

Red algae and some hyaline benthic foraminifera such as *Heterostegina*, *Operculina* and *Lepidocyclina* identified in the Qom Formation samples are indicators of dysphotic zones. Bassi *et al.* (2007) divided the photic zone into upper and lower parts; in this classification, *Neorotalia* live in the upper part of the upper photic zone, and *Heterostegina*, *Operculina* and *Lepidocyclina* are dominant in the lower part of the upper photic zone, whilst in the lower photic zone *Lepidocyclina* is developed.

Light-independent biota includes bryozoans, mollusks, crinoids, brachiopods and sponges that are widespread in studied section (sample B12). Organisms that compose the light-dependent biota identified include green algae, reef-builder corals and miliolids constituting indicators of photic zone.

Several large foraminifers that host algal symbionts present a more evolved skeletal structure than those without symbiont. This process is also seen in *Lepidocyclina* (Figure 4). Large benthic foraminifers host unicellular eukaryotic algal symbionts that are dependent on light and nutrient and are therefore restricted to euphotic zone (Romero *et al.*, 2002). Symbiont-bearing large foraminifera are restricted to warm water of tropical realms where water temperature is higher than 14–18 °C in the coldest months of the year (Renema, 2006).

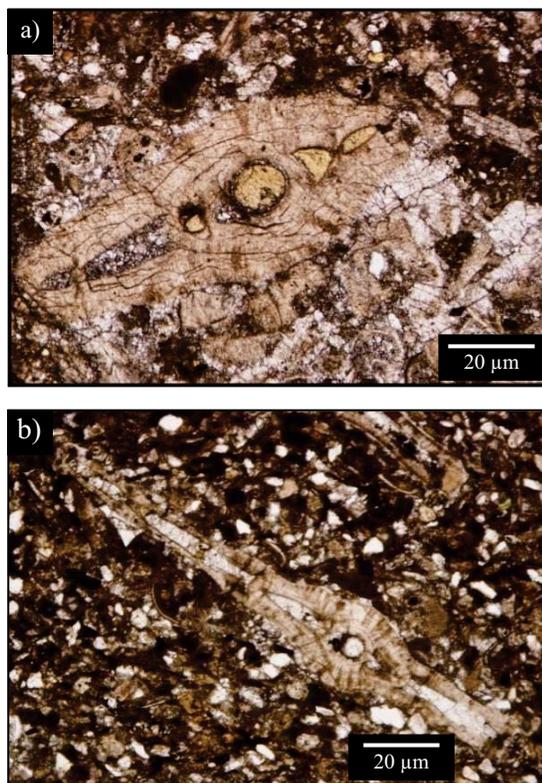


Figure 7. a) *Operculina* with thick test, which is indicator of shallow depth and increasing light intensity (sample B12); b) *Operculina* with thin test from high deep and decreasing light intensity (sample B16).

Water motion

This factor influences the test shape (diameter/thickness ratio). Generally, light intensity and water motion promotes the formation of secondary layers in foraminiferal tests. On the contrary, when the light intensity and the hydrodynamics are weak the growth rate decreases. In the studied area, *Amphistegina* from lagoon environment with high energy and intense light are thicker than those of deeper environments with lower energy (Beavingtone-Penney and Racey, 2004) (Figure 8).

Substrate nature

Substrate nature also depends on water turbulence. Foraminifera which live on a coarse grain substrate have thicker tests and are fusiform. *Amphistegina* also prefer hard substrates with high energy (Figure 8), while *Operculina* live on soft and muddy substrates and have thin shells (Figure 8).

Salinity

High salinity plays a preventative role in growth and evolution of large foraminifera, but medium degree of salinity is not so effective. In semi-restricted lagoon environment,

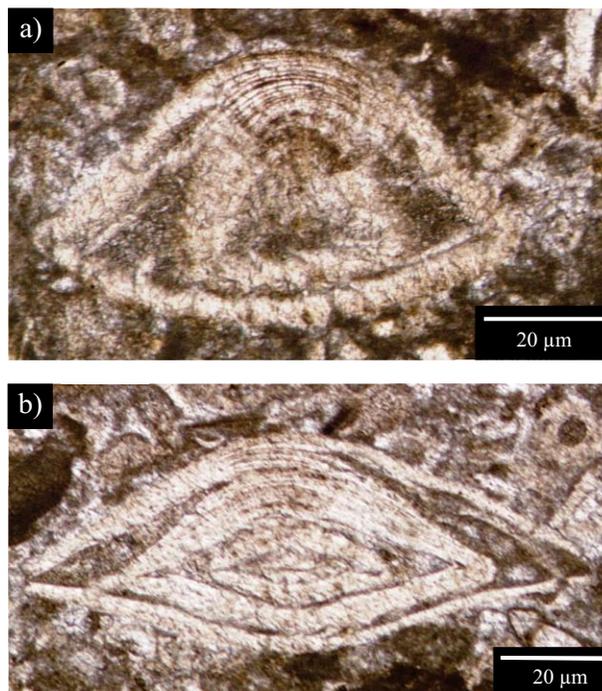


Figure 8. a) *Amphistegina* (sample B12) with thick test and small size which is an indicator of increasing hydrodynamic regime; b) *Amphistegina* (sample B17) with thin test and large size indicate decreasing hydrodynamic regime.

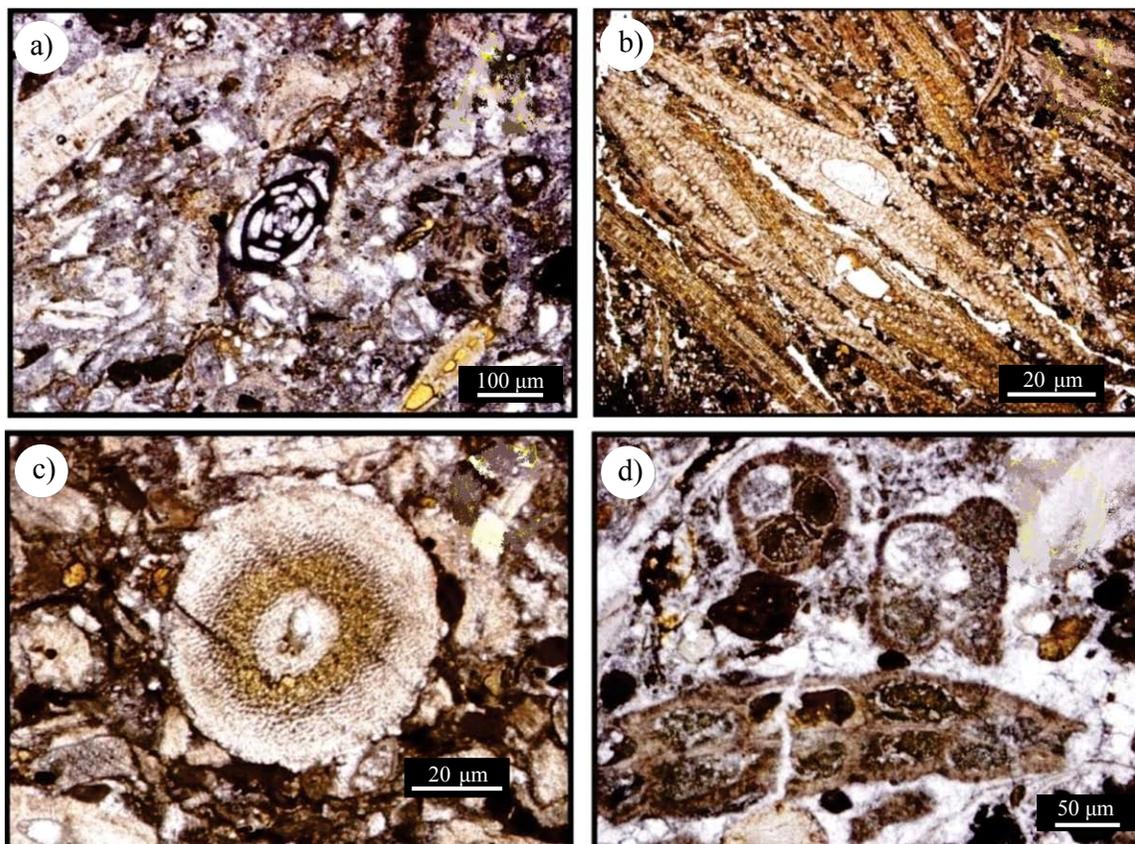


Figure 9. a) Perforate foraminifera in association with imperforate foraminifera (sample B9 to B12); b) Perforate foraminifera (sample B13 to B17); c) echinoid; d) bryozoans.

because of the connection with open marine environments and low percent of salinity, perforate and imperforate foraminifera can be observed together (Figure 9a), whereas, considering normal salinity in shallow parts of open marine of the studied section, only perforate foraminifera have been found (Figure 9b). The presence of stenohaline organisms (echinoid and bryozoan) is an indicator of marine normal salinity (Figure 9c, 9d).

Hydrodynamic energy and depth

The occurrence of benthic organisms reflects their compatibility in high or low energy environments (Flügel, 2004). For instance, in shallow environments within the photic zone, with increasing water motion, benthic foraminifera shape changes. It means that high energy causes the test to be thick (increasing in carbonate production) and decreases its growth rate and eventually reduces their test size (Beavingtone-Penney and Racey, 2004). Haynes (1965) stated that the shape of large foraminifera changes under the influence of hydrodynamic conditions and its symbiotic relationship with algae. The author expressed that species with free life (non-epizoan) and spherical species are indicators of reef environment cleaned by flows, while

fragile thin tests with maximum surface/volume ratio could be found in calm environments with low light. Generally, foraminifera in compatibility with high energy, creates lamellar and thick tests like *Amphistegina*. The elongated *Operculina* with thin test found in this work is an indicator of deep environments (Beavingtone-Penney and Racey, 2004). In this research, a comparison is shown between thick *Amphistegina* with lamellar tests in high energy lagoon environment and elongated *Amphistegina* that is indicator of low energy environment (Figures 10 and 11).

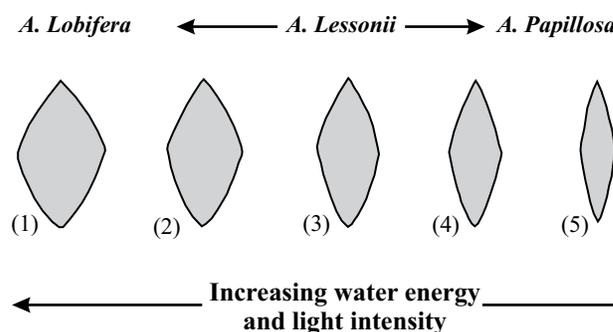


Figure 10. Change in the shape and size of *Amphistegina* test due to change in light intensity and hydrodynamic energy (Beavingtone-Penney and Racey, 2004).

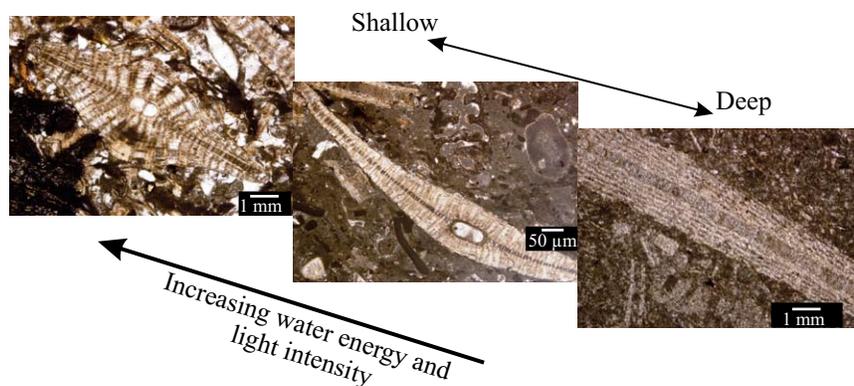


Figure 11. Changes in shape and size of *Lepidocyclina* tests that results, from right to left, from decreasing depth, and increasing light intensity and hydrodynamic energy (samples B37, B39, B41).

CONCLUSION

On the basis of the foraminifera recognized in the studied section, the Qom Formation is comparable to the *Lepidocyclina-Operculina-Ditrupe* Assemblage Zone. The age of the Qom Formation in the studied section is Oligocene.

The carbonate rocks of the study area contain a photozoan association composed predominantly of large benthic foraminifera and coralline red algae in association with corals, heterotrophs. This photozoan assemblage indicates oligotrophic conditions. Moreover, the abundance and association of large benthic foraminifera with coralline red algae are referred to as foralgal facies developed in shallow, warm water environments of the photic zone where oligotrophic condition was prevalent.

Based on the paleoecology and lithology, three distinct depositional setting can be recognized: inner shelf, middle shelf and outer shelf.

Inner shelf facies contain abundant imperforate tests of foraminifera. Middle shelf facies are characterized by abundant large perforate foraminifer tests. Toward the basin, planktic foraminifera and large foraminifers with perforate tests occur contemporaneously. Basin (outer shelf) facies is marked by high planktic foraminifera contents embedded in wackstone.

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