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Abundance and Distribution of Benthic Foraminifera in the Northern Oman Sea (Iranian Side) Continental Shelf Sediments

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Abstract: Abundance and distribution of benthic Foraminifera, in the Northern Oman Sea (Iranian side) continental shelf sediments was studied. Sediment samples were gathered in Winter 2006, from eight stations ranging in depth from 30 to 103 m. Environmental conditions including water depth, temperature, dissolved oxygen, salinity, pH, grain size, total organic matter and calcium carbonate concentration were measured and their relationship with the distribution of benthic foraminifera was discussed. Forams were the most abundant meiobenthic group in nearby all the stations. The suborder ROTALIINA was dominant in the northern region while LAGENINA, MILIOLINA and TEXTULARIINA, were being abundant in the northwest region too. LAGENINA were being very abundant in the stations with higher depth. From the total 40 species belonging to 24 genera, *Ammonia beccarii* was common in the whole research region. Water depth, salinity and substrate seemed to be the most important environmental factors controlling the distribution of benthic foraminifera. None or rare structural abnormal and oil polluted individuals, in nearby all stations, leading to the clean benthic environment of the Oman Sea benthic zone.

Key words: Foraminifera, abundance, benthic, continental shelf

INTRODUCTION

Foraminifera are the worldwide tested protozoa, living almost in all of the aquatic environments including marine, brackish or fresh water and are distributed in all latitudes especially in tropics. Forams are benthic or planktonic (holoplanktonic or meroplanktonic) in the mode of life. Marine species are reported from coastal regions to the very deep oceanic zone. Benthic forams live on the substrate surface (epifaunal) or in a few centimeters (6-7 cm) deep layer in the sediments (infaunal). Water temperature, salinity and the structure of the sediments are the important factors controlling the distribution of the benthic foraminifera. Fossil forams are one of the most important instruments using in the geology and paleontology sciences. Several researches on the fossil forams, compared with the recent forms, leading to the understanding of the paleo-environmental conditions of the earth. Forams are useful in the exploration of the petroleum and natural gas sources. They are the well-known indicators for the benthic environmental conditions and the appearance of the pollutants.

The distribution of the benthic foraminifera is affected highly with the environmental conditions of the benthic zone. The diversity of the foraminifera is higher in the tropical and temperate zone compared with the higher latitudes and decreased in higher depths (Fairbridge and Jablonski, 1979).

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Because they have a preservable shell and are abundant, benthic foraminifera are the best meiofaunal group for giving a proxy record of past marine and marginal marine environments (Murray, 2000). The structure of the benthic zone, including the grain size of the sediment particles, pH and concentration of nutrients and organic carbon has an important role on the structure of the benthic foram populations. The patterns of distribution of benthic foraminifera are controlled by those environmental factors that have reached their critical thresholds. For each species, in variable environments, different factors may be limiting distributions both temporally and spatially. For a species or an assemblage to be useful as a proxy its abundance must show a strong correlation with the chosen factor (Murray, 2001). The thickness of the infaunal foram's layer in the sediments is depended on the concentration of dissolved oxygen (Murray, 1979). The study of recent benthic foraminifera on the Guadiana shelf, showed that the spatial distribution of benthic forams is closely associated with sea-bottom sedimentary environments and bathymetry, the number of benthic foram tests and the distribution of several shallowest nearshore species are clearly influenced by the outflow of the estuary and by local hydrodynamic conditions and the deeper water assemblages are more related to low levels of tidal energy and low oxygen environments associated to fine-grained sediments and cold-water filaments related to seasonal upwelling (Mendes *et al*., 2004). Recent calcareous benthic foraminifera in surface sediment samples from the Northern North Sea area are affected by strong current activity and coarse-grained sediments leads to a decrease in the oxygen content in the bottom-waters during part of the year (Kristensen, 2002). From the total 67 species belonging to 31 genera reported in the Eastern side of the Chabahar Gulf, Northeast of the Oman Sea, 3 species were distributed only in sandy sediments, 16 species only in silt-sand and 1 only in sand-silt sediments and the others were distributed in the whole research area (Rahmati, 1997). In the coastal area of the Gheshm island, from the total 40 reported species of 21 genera, 3 species were distributed in sandy floors, 2 in sand-silt, 7 in silt-sand, 2 in mud and the others were distributed in the whole research area without a specific substrate (Farahani, 1998).

The main aim of the present research is to identifying the structure of benthic foram communities of the Northern Oman Sea and relation to the environmental conditions of the benthic zone.

MATERIALS AND METHODS

Sediment samples were collected during winter 2005, from 8 stations in the Northern Oman sea (Table 1, Fig. 1), ranging in depth from 30 to 103 m. Bottom sediments were gathered using a 0.1 m^2 Van Veen Grab. Three samples were gathered in each station by a 6.15 cm^2 area slender sampler. All the sediment samples were being mixed with formalin (4% concentrated solution) in plastic boxes. The benthic environmental factors including water depth, temperature, dissolved Oxygen, salinity and pH were measured by a CTD system during the sampling time.

For the grain size analysis, 25 g of each dried sediment sample (70°C-8 h) was mixed with tap water to a total volume of 250 and 10 mL of sodium hexametaphosphate (6.2 g L^{-1}) to separate the sediment particles. The sediments were then stirred mechanically (15 min), allowed to soak (overnight),

Table 1: Position of sampling stations

Station No.	Longitude (N)	Latitude (E)
N1	27:01.40	56:39.30
N2	26:15.00	56:54.00
N3	25:53.40	57:11.30
N4	25:40.00	57:24.05
N5	25:38.20	57:54.00
N6	25:26.80	58:36.91
M1	26:43.20	56:43.20
M2	26:13.00	56:46.00

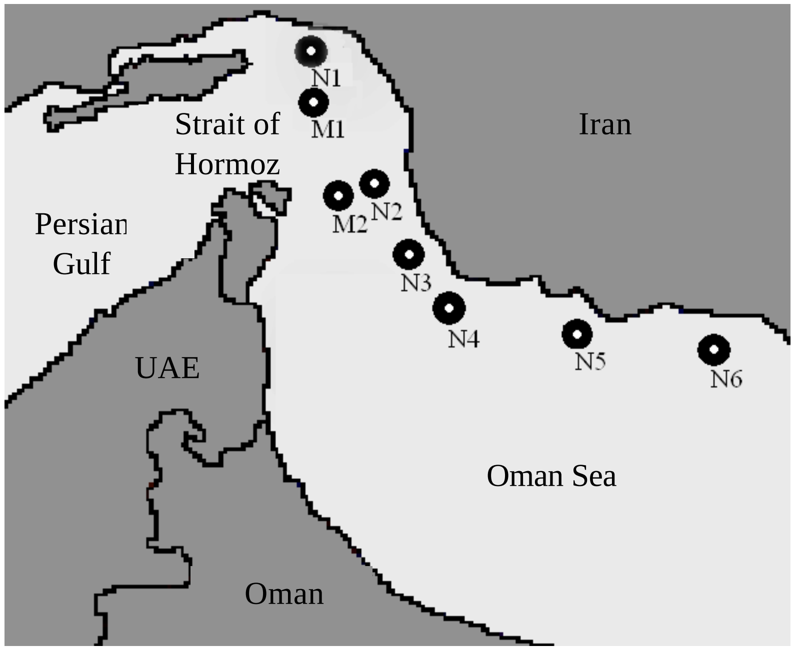

Fig. 1: Location of sampling stations

stirred mechanically again (15 min), washed in a 0.063 mm sieve with tap water and dried again (70°C - overnight). The remaining dried material on the sieve transferred into the uppermost of a stacked series of graded sand sieves (aperture 4, 2, 1, 0.5, 0.25, 0.125 and 0.063 mL), the remaining material on each sieve was then carefully removed and weighted. At the end, the percentage of each particle fraction was calculated.

The Total Organic Matter (TOM) in each sample was measured by calculating the loss of weight during combustion. The sediment samples, each crucible was weighed (C) and half filled with wet sediment and dried in an oven (70°C) to constant weight (about 24 h). After removing from the oven, it was allowed to cool and reweighed (A). It was then placed in a Muffle furnace (550°C-overnight), removed, cooled and reweighed again (B). The total content of organic matter (TOM) was determined by the loss of weight on ignition at this temperature.

$$\text{TOM (\%)} = 100 \text{ (A-B)/(A-C)}$$

Calcium carbonate concentration was measured based on the reaction with HCl 25 g (W_1) of dried sediment (70°C, 8 h) was mixed with HCl (0.1 N) and stirred (until no CO_2 bobbles appearing) and allowed to soak (24 h). The upper liquid phase was discharged and the remaining sediments were filtered (by paper), dried (70°C, 8 h) and reweighed again (W_2). Calcium carbonate percentage was measured by the following formula:

$$CaCO_3 \text{ (\%)} = 100 \, (W_1 - W_2)/W_1$$

For determining foraminifera, sediment samples were being washed in the sieve (aperture 0.063 mm) with tap water, dried (75°C, 8 h), floated by the heavy liquid CCl_4 and the upper layer of the liquid (consist of floated forams and other tested specimens) were filtered by paper and allowed to dry. A stereomicroscope and several studies (Cushman, 1969; Loeblich and Tappan, 1988; Pinxian, 1985, 1997) were used for determining and counting of foraminifera.

RESULTS AND DISCUSSION

The quantities of the environmental factors, including water depth, temperature, dissolved oxygen, salinity, pH, grain size, total organic matter and calcium carbonate concentration, are shown in the Table 2 and 3. Water temperature in the benthic zone was nearby similar in all stations (22.13 to 23.72°C). The dissolved oxygen concentration, decreased with the increase of the depth, was higher in the station N1 with the lowest depth. Salinity was nearby similar in the hole sampling region but in M2 it was considerably higher (related to the dense hypersaline current comes from the Persian Gulf, threw the Strait of Hormoz). The pH was equal in nearby all stations (7.9). The total organic matter percentage was very high in the station M1 (24.53%) and decreased from West to East.

The grain size analysis of the sediments showed that the sedimentary structure of benthic zone, in the most of the sampling stations, consists of very fine sedimentary particles including silt, clay and fine sand. As the most of sedimentary particles of the Oman sea benthic zone (such as silt and clay) are carried by the winds coming from the deserts around the sea and also sinking of a huge value of small particles (such as calcium carbonate and destroyed forams testes) originated in the Oman sea water column, the sedimentary structure of the research region includes very fine sedimentary particles such as clay, silt and very fine sand.

The total organic matter concentration of the Oman sea sediments increases from East to West. That is related to the higher organic matter productivity in the Western parts of the sea because of the higher concentration of the nutrients available for photosynthesis and primary production. Accumulation of the organic particles by the action of currents or sinking is guessed to be the reason for the higher concentration of the total organic matter in the station M1.

Table 2: Water depth, temperature, Dissolved Oxygen (DO), salinity, pH, Total Organic Matter (TOM) and calcium carbonate ($CaCO_3$) of the Oman Sea benthic environment

Station No.	Depth (m)	Temperature (°C)	DO (mg L^{-1})	Salinity (ppt)	pH	TOM (%)	$CaCO_3$ (%)
N1	30.39	22.76	6.17	36.74	7.96	14.93	-
N2	70.60	23.72	3.97	38.00	7.90	14.63	20.26
N3	54.94	22.28	5.39	36.47	7.93	13.79	9.49
N4	63.37	22.13	5.44	36.46	7.95	13.97	16.07
N5	54.08	22.55	5.64	36.54	7.95	12.11	-
N6	48.80	22.54	5.16	36.51	7.94	11.83	16.31
M1	63.01	22.57	5.59	36.91	7.94	24.53	11.56
M2	103.11	22.65	4.93	39.59	7.93	11.75	9.12

Table 3: The grain size analysis and percentage of each size group of the sediment particles

Station	Diameter of sediment particles (mm)							
No.	d<0.063	0.063-0.12	0.12-0.25	0.25-0.5	0.5-1	1-2	2-4	4<d
N1	75.43	20.97	3.60	0.00	0.00	0.00	0.00	0
N2	78.08	21.92	0.00	0.00	0.00	0.00	0.00	0
N3	70.61	29.40	0.00	0.00	0.00	0.00	0.00	0
N4	51.27	48.73	0.00	0.00	0.00	0.00	0.00	0
N5	57.54	42.46	0.00	0.00	0.00	0.00	0.00	0
N6	59.68	27.00	13.32	0.00	0.00	0.00	0.00	0
M1	49.44	16.38	13.92	16.20	4.05	0.00	0.00	0
M2	27.68	16.89	27.42	18.62	6.74	2.14	0.51	0

The cosmopolitan Foraminifera, *Ammonia beccarii*, was common in the all the stations but several rare species (such as *Bolivina variabilis*, *Reophax texana* and *Uvigerina pigmea*) were being found in only one or two stations. The forams *Epodines* sp., *Dentalinoides* sp., *Quinqueloculina contorta*, *Spiroloculina dentata*, *Spiroloculina* sp. I and *Triloculina* sp., were being found only in the station M2. There were also some deposited empty testes of pelagic foraminifera in all the stations, especially in the deepest station M2. There were none or rare structural abnormal or oil polluted individuals in nearby all the sediment samples except in the stations M2 (2 abnormals and 5 oil polluted) and N1 (1 abnormal and 2 oil polluted). The abundance of benthic foram species in the sediment samples are shown in Table 4.

Table 4: Abundance of foraminifera in the sediment samples of the Northern Oman Sea

Foraminifera	N1	N2	N3	N4	N5	N6	M1	M2
Ammonia beccarii	16	1	2	84	73	38	20	369
Amphicoryna scalaris				4			10	
Ammobaculites stenomeca				8				
Ammodiscus semiconstrictus				8				
Bolivina subaenariensis	4	120	14	480	210	165	14	
Bolivina variabilis				1				
Biloculinella globula								9
Bulimina marginata				1	5			
Dentalina communis								27
Dentalinoides sp.								7
Elphidium crispum			15					
Epodines sp.								162
Lagena perlucida	1						8	
Lagena spicata							12	27
Lagena striata							10	
Lagena sp. I					2	1	2	27
Lagena sp. II				4				
Nodosaria affinis				4			1	27
Nonionella sp.					37			
Pyrgo sarsi								9
Quinqueloculina contorta								90
Quinqueloculina costada	5							180
Quinqueloculina sp.	2							
Reophax texana				1				
Septammina bradyi	17	43						
Spiroloculina excavate								27
Spiroloculina dentata								63
Spiroloculina depressa	9				1	1	4	63
Spiroloculina ornata								27
Spiroloculina sp. I	3							90
Spiroloculina sp. II							2	
Spirophthalmidium acutimargo								27
Textularia sagittula								4356
Textularia truncata							2	972
Tetrataxis palaeotrochus								50
Triloculina trigonula				28		7	2	135
Triloculina sp.								90
Uvigerina pigmea				1				
Unidentified sp. I				12				315
Unidentified sp. II								252
No. of benthic foram species	8	3	3	13	6	5	12	24
No. of benthic foram individuals	57	164	31	636	328	212	87	7401
No. of pelagic forams shells	8	5	34	332	25	41	38	45630
Total No. of foraminifera	65	169	65	968	353	253	125	53031
Structural test abnormalities	1	0	0	0	0	0	0	2
Oil polluted individuals	2	0	0	0	0	0	1	5

By the results of the present research, the environmental conditions of the Oman sea benthic zone (including warm water, enough dissolved Oxygen and fine Silt-sand structure of the sediment particles) seems to be very suitable for the benthic foraminifera compared with the other meiobenthic communities. None or rare structural abnormality or oil polluted individuals, in nearby all the stations, leading to the clean benthic environment of the Oman Sea. It is the result of the absence of large cities, dense human communities, pollutant industries and important rivers compared with the huge amount of the Oman sea water volume and its water exchange with the Indian Ocean too. It is difficult to select one of the environmental factors as being of overall importance in the distribution pattern of the benthic foraminifera of the Oman sea benthic zone, but it seems that the composition and distribution of the benthic forams of the Oman Sea is affected by the local combination of the total environmental factors all together.

The huge number of empty tests of the benthic and planktonic forams and also the empty shells of Bivalvia and Gastropoda in the deep station M2 is related perhaps to the sinking or transportation of this empty tests and small shells from other regions to the area. The large amount of the Bivalvia and Gastropoda empty shells in the stations M1 and M2 is related to the accumulation of the shells too. The deep water current coming from the Strait of Hormoz brings small particles and fine empty shells downward the area. This dense hyper saline and warm current originated in the Persian Gulf, due to increasing of the benthic water salinity and temperature in the station M2 compared with the other ones (Table 2). The station N4 has probably the best conditions for the foram populations. The highest foram abundance and diversity in the station N4 (Compared with the N1 to N6) is also related to the fine structure of the sedimentary particles in addition to the higher concentration of total organic matter and calcium carbonate. Composition of foram communities studied in the present research area shows some differentiations with that of the coastal communities. The reason is that the environmental conditions of the coastal zone are more alternating compared with deeper zones. So, Steno species (stenothermal, stenohaline etc.) that are not adapted with the alternating conditions of the environment can not bear it as well as Eury species such as the foraminifer *Ammonia beccarii*.

The cosmopolitan foraminifer *Ammonia beccarii*, is a common foraminifer in the whole of the present research area and is reported in earlier researches in the Persian Gulf and the Oman sea coastal zones (Rahmati, 1997; Farahani, 1998) *A. beccarii* is distributed from coastal zone to the depths up to 100 m. Some species such as *Biloculinella globula*, *Epodines* sp., *Pyrgo sarsi*, *Quinqueloculina contorta*, *Spiroloculina excavate*, *Spiroloculina dentata*, *Spiroloculina omata*, *Spirophthalmidium acutimargo*, *Textularia sagittula*, *Tetrataxis palaeotrochus* and *Triloculina* sp., are found only in the station M2 (up to 100 m deep) seems to be distributed in the higher depths. The species of the genera *Quinqueloqulina*, *Spiroloculina* and *Textularia* and the species *Septammina bradyi*, *Lagena perlucida*, *Lagena spicata*, *Septammina bradyi*, are distributed only in the Western stations of the research region. As the suborders ROTALIINA and TEXTULARIINA had been reported that are abundant in the estuaries and hypersaline lagoons and MILIOLINA are dominant in the environments which have more interaction with the sea environment (Murray, 1968), Considering the abundance of the four major suborders ROTALIINA, LAGENINA, MILIOLINA and TEXTULARIINA (Fig. 2) in the foram communities of the stations N2 to N6, shows that the suborder ROTALINA is dominant in the Northern Oman Sea benthic zone. But, in the northwest region, it is not absolutely dominant and the foram individuals belonging to the other suborders such as LAGENINA, MILIOLINA and TEXTULARIINA are abundant too. The abundance of the suborder LAGENINA is very low in the Northern stations N1 to N6, but is highly increased in the station M1, perhaps in the reflection to the increasing of the depth in the suitable salinity. The depth of the station M2 is the highest one but there is the higher salinity too so it could be a limiting factor

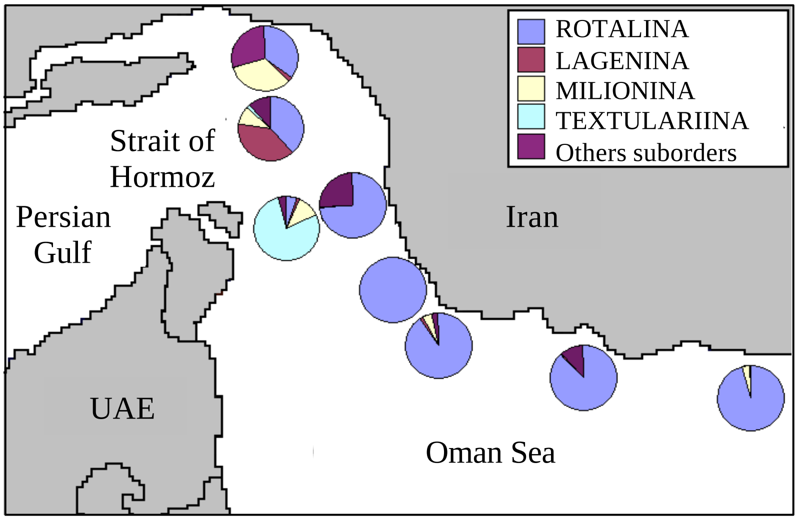

Fig. 2: Composition of benthic foram communities, depended on four suborders ROTALIINA, LAGENINA, MILIOLINA and TEXTULARIINA, in the Northern Oman Sea

for the suborder LAGENINA. LAGENINA had been rare forams in the Northern coastal region of the Oman Sea. TEXTULARIINA is the main suborder in the deepest station M2 at the Northwest region of the Oman Sea sediments. The higher salinity of the benthic environment can be the reason for the higher percentage of the suborder TEXTULARIINA in the station M2 and the suborder ROTALIINA in the whole research region.

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