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Benthic Foraminifera Distribution in Surface Sediments of Qatari Waters, Arabian Gulf

Abstract: Benthic foraminifera from surface samples collected from the sea floor of Qatari waters, Arabian Gulf, were analyzed during this study. Thirty-nine species were identified and two foraminiferal assemblages were recognized. The Upper offshore assemblage is characterized by *Quinqueloculina poeyana*, *Quinqueloculina peregrina*, *Quinqueloculina spp.*, *Textularina cushmani*, *Textularina foliacea* and *Textularina spp.*, and occupies a water depth between 5 and 20m. The lower offshore assemblage is characterized by *Quinqueloculina poeyana*, *Quinqueloculina pergina*, *Quinqueloculina spp.*, *Ammonia beccarii*, *Cibicides cf. C. fletcheri* and *Eponides murrayi*, and occupies a water depth more than 20m. Benthic foraminiferal assemblages were more abundant and diverse in the lower offshore area than in the upper offshore area.

انتشار الفورامينيفيرا القاعية في الرواسب السطحية للمياه الإقليمية القطرية، الخليج العربي
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المستخلص: في هذه الدراسة تم تحليل عينات الفورامينيفيرا القاعية التي جمعت من الرواسب السطحية للمياه الإقليمية القطرية في الخليج العربي. حيث تم التعرف على أنواع الفورامينيفيرا القاعية و تحديد مجموعتين منها حسب انتشارها في هذه الرواسب السطحية. وقد وجد بأن مجموعة الفورامينيفيرا القاعية في رواسب المنطقة البعيدة عن الشاطئ العلوية، تتميز بوجود الأنواع

Quinqueloculina poeyana, *Quinqueloculina peregrina*, *Quinqueloculina spp.*, *Textularina cushmani*, *Textularina foliacea* and *Textularina spp.*,

وتقع عند عمق يمتد من 5 إلى 20 متر. بينما تتميز مجموعة الفورامينيفيرا القاعية في رواسب المنطقة البعيدة عن الشاطئ السفلية بوجود الأنواع

Quinqueloculina poeyana, *Quinqueloculina pergina*, *Quinqueloculina spp.*, *Ammonia beccarii*, *Cibicides cf. C. fletcheri* and *Eponides murrayi*,

وتقع عند عمق أكثر من 20 متر. ولوحظ بأن مجموعة المنطقة البعيدة عن الشاطئ السفلية هي أكثر تنوعا وانتشارا عن مجموعة المنطقة العلوية البعيدة عن الشاطئ.

Introduction

Distribution patterns of benthic foraminifera and the factors controlling their distribution have been the subject of several studies in various places. However, very little work has been done with the foraminifera from the Arabian Gulf. Houbolt (1957) described the foraminifera from the sediments of the Arabian Gulf near the Qatar Peninsula. Although his work was primarily general and descriptive, it

has provided good data for subsequent work. Murray (1965 a, b; 1966 a, b, c; 1970 a, b) contributed an important series concerned with the distribution of foraminifera in the Arabian Gulf. Recent foraminifera from the northern part of the Arabian Gulf have also been studied by Anber (1974). Shublak (1977) and Ahmed (1991) also studied recent foraminifera from northern part of the Arabian Gulf.

The present study was undertaken to determine the distribution of foraminifera off the Qatari coast in the Arabian Gulf and to investigate the effect of sediment types, if any, upon the foraminiferal distribution.

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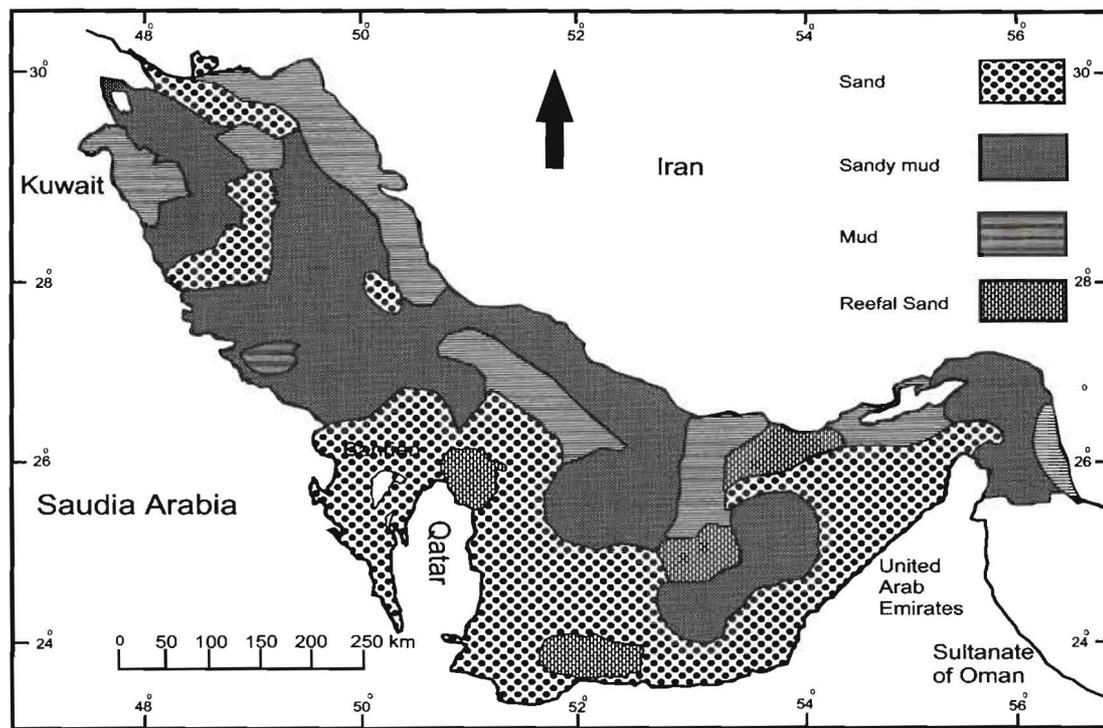


Fig. 1. Map of the Arabian Gulf region showing principal bathymetric provinces and the study area (Modified after Purser 1973).

The Study Area

The area considered herein is part of the Arabian Gulf region. The Arabian Gulf is a long shallow sea, which is in open connection with the Indian Ocean via the Strait of Hormuz (Fig. 1). The floor of the Arabian Gulf slopes gently from the Arabian shore towards the axis of the basin, which lies close to the Iranian coast. The relatively linear character of the Arabian coast is modified by the Qatar Peninsula whose presence strongly influences the marine current pattern of sedimentation along the southeast side of the Arabian Gulf. Shoals extend into the sea from the Arabian coast, and numerous salt-dome islands that attain topographic elevations of up to 161m (Kassler, 1973) characterize the southern part of the Gulf. In the study area, coral reefs are found along the coast and around small islands.

Because the Arabian Gulf is almost surrounded by land its climate is mainly continental. This arid, subtropical climate is marked by seasonal fluctuations. In summer months, temperatures are very high, but they are moderate in winter times. Despite a relatively high air humidity there is little rainfall over the Arabian Gulf. Strong winds, called locally "Shamal", blowing mainly from the northwest, generate wave and surface currents, which play important roles in sediment transportation.

Oceanography

The high evaporation in the Gulf water causes water currents to enter the Arabian Gulf through the Straits of Hormuz. These currents change directions as they move inside the Gulf (Hartmann *et al.*, 1971), and thus play a major role in the distribution of salinity, temperature and nutrients within the Arabian Gulf (Purser and Siebold, 1973). The Gulf is meso-tidal in the extreme northwest and southeast and micro-tidal near the Qatar peninsula (Evans, 1995). The tidal currents generally flow eastwards and northeastwards and ebb in the opposite direction. Winds are the most effective force producing variation in energy level in the Gulf (Al-Ghadban, *et al.*, 1996). High-energy waves produced by NW "Shamal" winds result in south-flowing coastal and longshore currents in the northern part of the Gulf. When these south-flowing currents reach shoals, they are diverted seaward, producing southward sediment transport.

The salinity gradient is more or less variable; its measured value has ranged from 37‰ at the entrance to 70‰ in the coastal water. The temperature gradient in the Gulf may also range from 20°C to 38°C, and during most parts of the year, temperatures are higher on the surface than bottom waters.

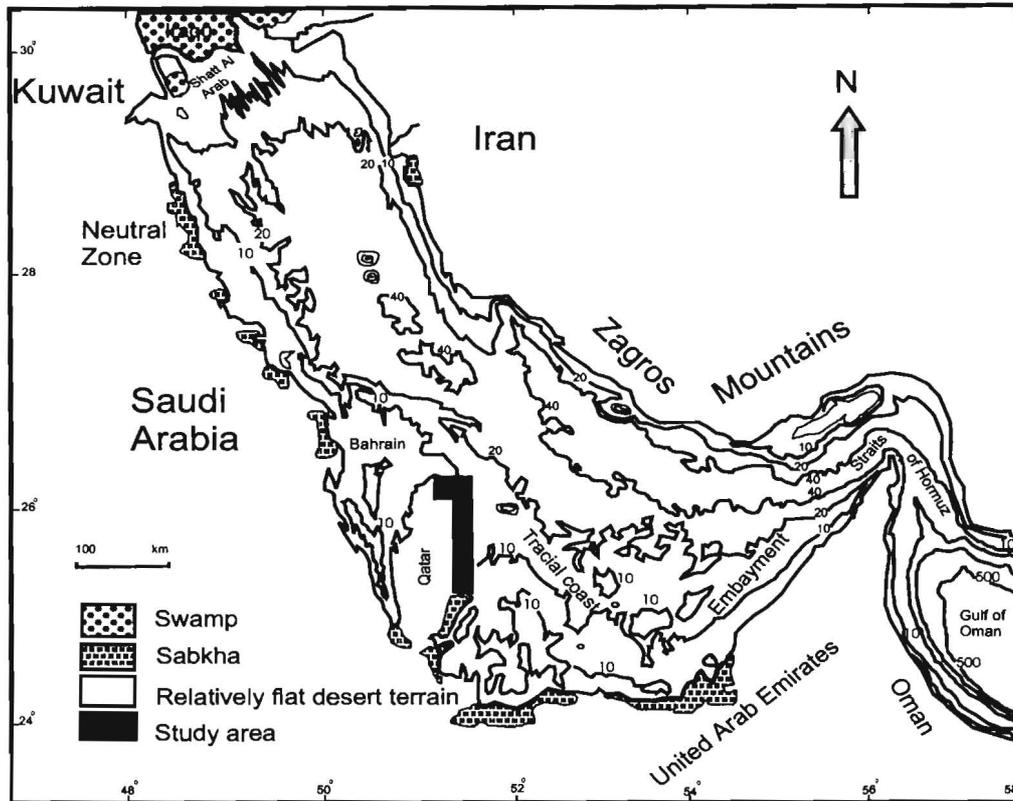


Fig. 2. Map showing the distribution of the sediments in the Arabian Gulf (after Al-Ghadban *et al.* 1996).

Sediments

In general, throughout the Arabian Gulf the sediments show a simple pattern of textural type. Sediments on the gently inclined Arabian sea floor grade from impure carbonate mud near the center of the basin to high-energy bioclastic and ooidal sand in the nearshore area (Wagner and van der Togt, 1973). Fig 2 shows the distribution of sediment types. The band of coarse-grained, nearshore sediment in the western side of the Arabian Gulf is readily apparent. The occurrences of these relatively coarse-grained sediments have been interpreted as the products of in-situ breakdown of the rocky bottom and coastal material both by organic activity and wave and current action (Al-Ghadban *et al.*, 1996).

In the present study area, carbonate sediments are an important constituent of the bottom materials (Fig. 3). Skeletal carbonate sand and muddy sand cover the floor of the shelf. According to Houbolt (1957), in the high-energy zone the carbonate particles are exposed to strong water movement during strong Shamal wind periods and are thus rounded. He pointed out that the boundary of the rounded carbonate particles is about 10 fathoms deep in the northern side and a little higher in the southern side. Seaward of this approximate

boundary, the sediment is dominantly skeletal carbonate sand. The sediment consists of molluscan debris, benthic foraminifera and other various skeletal particles. These skeletal particles are further broken down into finer debris. The finer debris are constantly removed by winnowing to be deposited in a more sheltered area. Apparently the finer sediments are found in the much deeper water further seaward, where water turbulence is low. Marls dominate the deeper water in the study area.

Methods

The surface sediment samples were collected during April 1998 on board Mukhtabar Al-Bihar, using a grab sampler along five profiles extending seaward from the Qatari coast. (Fig. 4) It was originally planned to collect samples at 17 stations representing different depths. But, because of the hard substrate, samples could be recovered from only 9 stations. In the laboratory the samples were wet-sieved in a 63 μm sieve. After sieving, the foraminifera were concentrated by the flotation method employing carbon tetrachloride, a solution of greater density than that of the foraminiferal test. If more than approximately 500 foraminifera were present, the sample was split until approximately 500 specimens remained. All specimens were

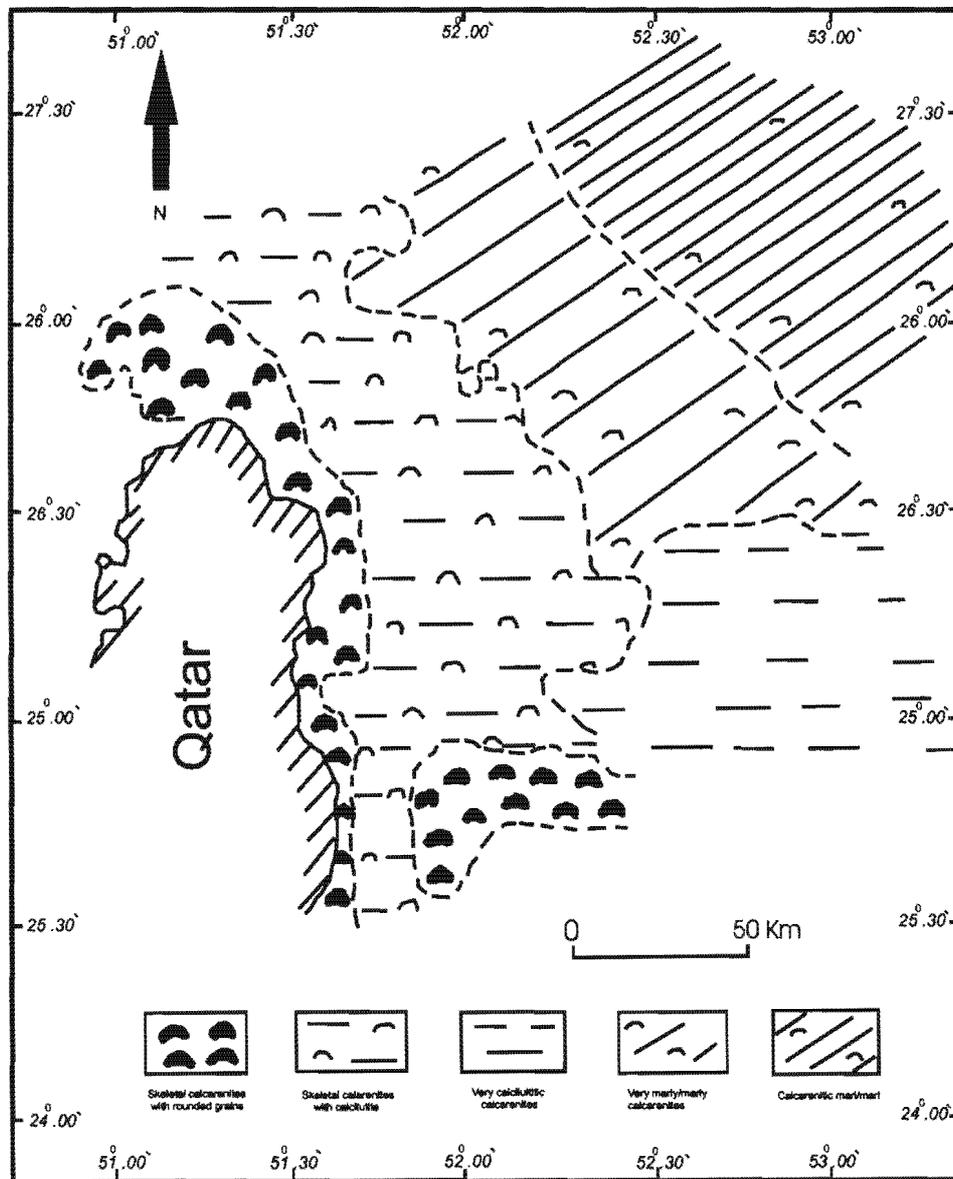


Fig. 3. Map showing the distribution of the sediments in the study area (after Houbolt 1957 and Evans 1995).

sorted, identified, and counted. The samples were not preserved or stained, and therefore, the count represents total (live plus dead) individuals. In naming the species, taxonomic names were adopted from Loeblich and Tappan (1987); additional literature was consulted when necessary to confirm questionable identifications.

Results

Foraminiferal Distribution and Diversity

As mentioned previously, throughout the study area the sediment is skeletal sand composed mainly of molluscan shell debris together with foraminifera and a varying amount of mud. The distribution pattern of the foraminifera indicates that the majority of foraminifera in these sediments are

small and many of them may be juvenile. The most common species identified are listed in Table 1. Altogether 39 species are present. Generally, calcareous imperforate forms (suborder Miliolina) dominated by the species *Quinqueloculina poeyana*, *Quinqueloculina peregrina* and *Quinqueloculina* spp. *Cibicides* cf. *C. fletcheri* and *Ammonia beccarii* dominated the species of the suborder Rotaliina. *Textularia foliacea*, *Textularia* spp. and *Textularia cushmani* represented the suborder Textularina.

The distribution of the diversity of the foraminiferal fauna in all samples have been calculated using the Yule-Simpson Index (Simpson, 1949), according to the following formula:

$$\text{Diversity} = \frac{N(N-1)}{\sum_{I=1}^k n_I(n_I-1)}$$

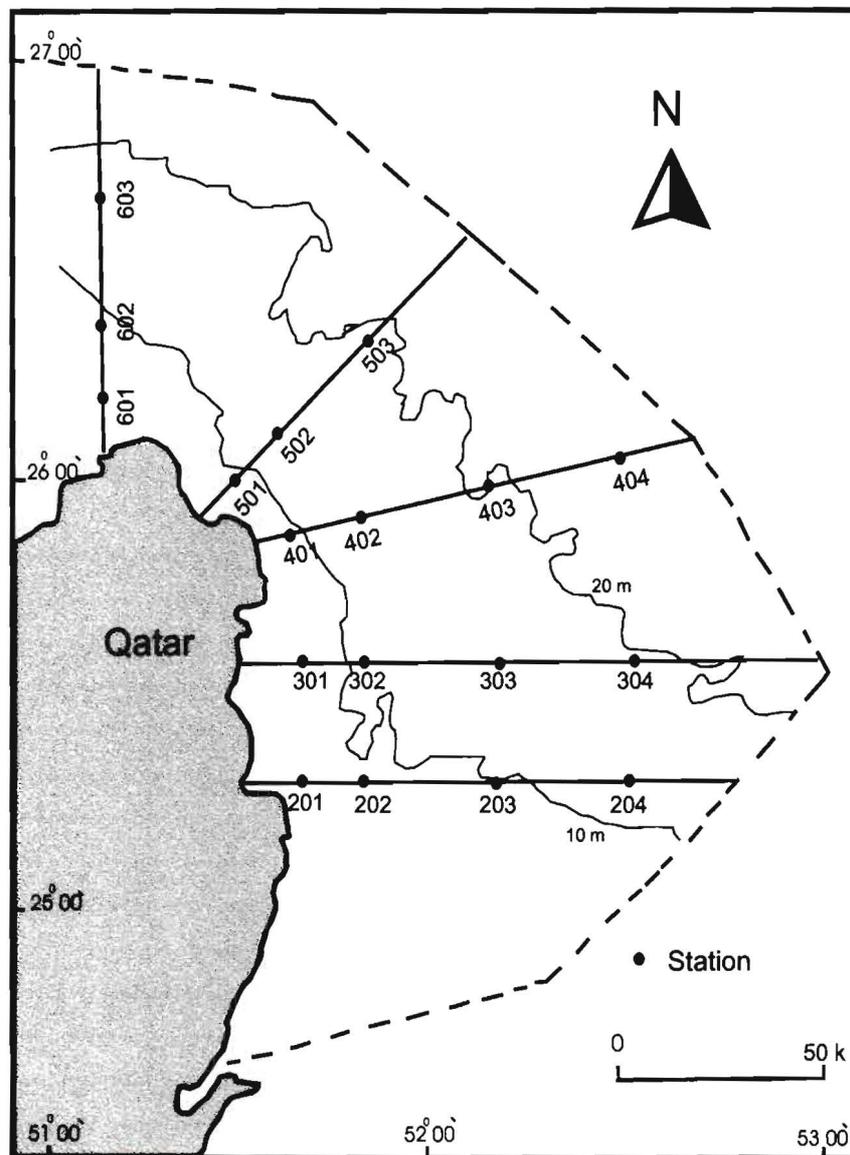


Fig. 4. Map showing the study area and sample locations.

Where N is the total number of tests picked in the sample, k is the number of species in the same samples and n_i is the number of individuals in the i^{th} species. The diversity index calculated for the samples of the studied area is given in Table 2. Diversity indices showed that diversity values increase with increase of water depth.

Benthic Foraminiferal Assemblages

Stations from which foraminifera test samples were taken lay almost entirely in the offshore area of the shelf. Therefore, the nine stations were reduced to two major depositional sites: 1) the upper offshore area, and 2) the lower offshore area. This subdivision is based mainly on change in sediment texture with depth. The upper offshore area occurs

at 5 to 20 m water depths. Sediments in this area range from coarse-grained skeletal sand toward the landward side to muddy-fine skeletal sand in the seaward side.

In this study four samples, from stations 201, 301, 401 and 602, were recovered from the upper offshore area. These samples indicated that foraminiferal distribution in this area varied considerably. The diversity value of assemblages from sediments of this area (Table 2) also indicated that the number of species seems to increase with increase in water depth and sediment reworking. Furthermore, the foraminifera of the suborder *Miliolina* and *Textulariina* reached high concentrations, while *Rotalliina* occur only sporadically. These assemblages were characterized mainly by the abundance of the genera

Table 1. Percentage of benthic foraminifera tests recovered from collected samples

Station No.	Upper offshore assemblage				Lower offshore assemblage					
	201	301	401	602	402	502	304	403	603	
Water depth (m)	10	10	11	20	26	28	32	38	40	
No.	Species									
1	<i>Ammonia beccarii</i>	0.0	0.0	0.0	1.0	12.6	7.0	8.9	13.4	11.8
2	<i>Ammonia elegans</i>	0.0	0.0	0.0	0.0	2.5	0.4	1.0	2.1	1.5
3	<i>Ammonia sadoensis</i>	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	0.0
4	<i>Articulina sagar</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4
5	<i>Bolivina plicata</i>	0.2	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
6	<i>Bolivina sp.</i>	0.4	0.0	0.4	1.1	0.0	0.0	0.0	1.4	2.3
7	<i>Cibicides cf. C. fletcheri</i>	0.0	0.0	0.0	0.0	8.5	2.1	2.5	4.1	1.5
8	<i>Cibicides subhaidingeri</i>	0.0	0.0	0.0	0.0	0.0	2.3	0.0	1.4	1.0
9	<i>Elphidium crispum</i>	0.0	0.0	0.0	0.8	0.0	0.0	4.7	5.8	9.9
10	<i>Eponides murrayi</i>	0.0	0.0	0.0	0.0	0.0	2.3	4.1	1.4	0.8
11	<i>Flourilus grateloupi</i>	0.0	0.0	0.9	0.4	0.6	0.0	0.0	0.0	0.0
12	<i>Lagena oceanica</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
13	<i>Lagena spirata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0
14	<i>Loxostomum albarossi</i>	0.0	0.4	0.4	1.1	1.4	0.4	0.0	0.9	0.4
15	<i>Loxostomum mayeri</i>	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
16	<i>Massilina secans</i>	0.0	0.0	1.7	2.3	0.0	0.0	0.0	0.0	0.0
17	<i>Nonion spp.</i>	1.1	0.6	0.7	4.6	1.2	2.9	6.4	5.8	8.0
18	<i>Nonionella pulchella</i>	0.0	0.0	0.4	0.0	2.1	0.0	0.0	1.4	3.8
19	<i>Peneroplis planatus</i>	1.7	2.4	4.6	1.3	0.0	0.4	0.0	0.0	0.0
20	<i>Peneroplis pertusus</i>	2.4	2.4	3.9	1.5	0.0	0.0	0.0	0.0	0.0
21	<i>Quinqueloculina bicarinata</i>	0.0	0.0	0.4	0.0	0.2	0.4	0.4	1.4	1.1
22	<i>Quinqueloculina buchiana</i>	0.0	3.4	0.7	5.4	0.0	0.0	1.0	0.0	0.0
23	<i>Quinqueloculina incisa</i>	0.0	0.0	1.1	4.0	0.8	1.6	1.2	2.6	1.3
24	<i>Quinqueloculina neostriatula</i>	0.0	0.0	0.4	0.0	0.2	0.6	1.0	0.0	0.0
25	<i>Quinqueloculina pergerina</i>	14.6	10.7	16.1	18.7	22.3	18.1	23.5	19.9	25.6
26	<i>Quinqueloculina poeyana</i>	27.9	26.0	29.8	22.9	31.3	23.1	17.3	13.0	18.1
27	<i>Quinqueloculina spp.</i>	9.2	10.8	7.4	5.7	2.5	12.8	9.9	13.6	2.9
28	<i>Spiroloculina angulata</i>	0.0	0.0	0.4	0.8	0.8	0.4	0.4	0.0	0.0
29	<i>Spiroloculina exvata</i>	1.1	1.2	0.4	1.5	11.8	10.3	14.0	0.9	0.8
30	<i>Spiroloculina pulchella</i>	0.0	0.0	0.4	1.0	3.7	2.5	0.4	0.2	1.3
31	<i>Spiroloculina laevigata</i>	0.4	0.2	0.7	0.4	2.5	0.0	0.0	0.0	0.0
32	<i>Spirolina rotundata</i>	2.4	1.8	0.4	0.4	2.5	4.7	4.9	2.9	3.1
33	<i>Triloculina affinis</i>	1.1	0.4	0.2	0.4	0.8	1.4	0.0	1.4	1.3
34	<i>Triloculina barnardi</i>	0.9	1.2	0.2	0.6	0.4	0.2	0.0	0.7	0.4
35	<i>Triloculina marioni</i>	1.3	1.8	1.1	2.3	0.4	0.8	0.6	0.3	0.0
36	<i>Triloculina selene</i>	0.4	1.0	1.5	0.0	0.0	0.2	0.0	0.2	0.4
37	<i>Textularia cushmani</i>	6.1	3.4	7.2	0.8	1.6	0.0	1.2	0.0	0.0
38	<i>Textularia foliacea</i>	12.2	8.3	10.2	1.5	1.0	0.0	0.8	0.0	0.0
39	<i>Textularia spp.</i>	8.1	4.7	2.4	0.0	1.0	1.4	2.1	0.0	0.0

Quinqueloculina and *Textularina*. The species of these genera occur in both large and small forms. Most of the large forms are broken and abraded, while the small forms show little damage.

The lower offshore is the zone in which the sediment texture break occurs, essentially along the 21 m depth line. This area is characterized by the presence of fine carbonate sand and muddy to marly

skeletal sand. In this study, stations 304, 402, 403, 502, 602, and 603 occur in the lower offshore area. Samples from these stations indicate foraminifera tests are more diverse and more abundant per unit volume of sediment than those of the upper offshore area. Here, benthic foraminiferal distribution is similar to that of the upper offshore in that *Quinqueloculina* were still found dominant at each

site while *Textularina* are less abundant and replaced by *Rotaliida* species. Among the suborder Miliolina, the species *Quinqueloculina poeyana* and *Quinqueloculina peregrina* remained dominant and accounted for the preponderance of Miliolina species. *Spiroloculina rotundata* and *Spiroloculina excavata* were more abundant than in the upper offshore zone. Among the Rotalida, the taxa *Cibicides subhaidingeri*, *Ammonia beccarii*, and *Eponoides murrayi* were the dominant species. In general, the Rotalida were more abundant here than in the upper offshore zone.

The increase in number of foraminiferal tests in the lower offshore may be due to increased water depth and low rate of physical reworking of the bottom sediment. Therefore, the increase in number of species indicates that different physical conditions exist between upper and lower offshore zones.

Table 2. Diversity values (Yule-Simpson index) calculated for the sample studied

Upper Offshore Assemblages		Lower Offshore Assemblages	
Sample No	Diversity Value	Sample No	Diversity Value
201	6.2	402	6.8
301	6.2	502	7.3
401	6.8	304	8.2
602	7	403	8.9
		603	8.0

Discussion and Summary

Benthic foraminiferal analysis during the study indicates that benthic foraminiferal distribution on the nearshore shelf off the Qatari coast is related to water depth, sediment texture and current transports. Coarser sediments usually contain larger foraminifera, while fine-grained sediments contain large numbers of small foraminifera. Little is known about the biology and ecology of the benthic foraminifera in the Qatari waters. However, certain studies have demonstrated that surface sediment assemblages can be strongly affected by taphonomic processes (Loubere, 1989). The large number of broken specimens and of small juveniles and small size tests recovered during this study indicate substantial foraminifera transport. The occurrence of small astronomical numbers of tiny foraminifera in the sediments can only be explained by current transport (Murray, 1991). Size sorting and transport is further indicated by broken and abraded species.

Little is known about detailed hydrologic regimes on the shelf off the Qatari coast, although sediment starvation and possible landward transport of fine particles is responsible for many tests accumulating in the offshore area. Murray (1966) has indicated ebb tidal currents draining the lagoon and bank transport of juvenile foraminifera from the shore area to open sea.

Foraminiferal assemblages within the study area may be characterized partly by the most abundant species in each. In the upper offshore area, 3 species of the suborder Miliolina and 3 species of the suborder Textulariina represent the six most abundant species. These are *Quinqueloculina poeyana*, *Quinqueloculina peregrina*, *Quinqueloculina spp.*, *Textularina cushmani*, *Textularina foliacea* and *Textularina spp.* Foraminiferal assemblages within this area varied considerably from station to station. Only small accumulations of these most common species occur at shallow water depths within the area.

The latter area is characterized by relatively high levels of wave or current energy and by occurrence of skeletal sand. Test accumulations in fine sediment typical of these shallow waters may be allochthonous, due to current transporting of tests. However, large test accumulations are found in the deeper water part of the upper offshore area. Here, levels of wave or current energy are relatively low, and the substrate is characterized by muddy fine sand. Thus, requisite conditions of test accumulations in this part of the area are more equitable, because of low rates of wave action and sediment deposition.

In contrast, in the lower offshore area, the most abundant species are represented by 3 species of the suborder Miliolina and by 3 species of the suborder Rotaliina. These are *Quinqueloculina poeyana*, *Quinqueloculina peregrina*, *Quinqueloculina spp.*, *Ammonia beccarii* and *Cibicides cf. C. fletcheri*. Here, except for species *Ammonia beccarii* and *Cibicides cf. C. fletcheri*, all dominant species are the same as the most common species found in the upper offshore area. However, within this area, species are more abundant per unit volume of sediment than those of the upper offshore area.

The increase in the number of species in the lower offshore area may be due to the increase of water depth and low rate of sediment deposition due to reduced sediment supply. In addition, here benthic foraminiferal assemblages are more protected against wave action and sediment reworking. Sediments in the lower offshore zone

range from muddy fine sand on the landward side to marly on the seaward side. Major foraminiferal accumulations are present in the muddy fine sand sediments of the area.

Thus, some differences are discernible between upper and lower offshore foraminiferal assemblages. These differences may be related to the physical conditions prevailing in the area and to sediment texture.

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