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Textural and Mineralogical Characteristics of the Surficial Sediments of Sharm Obhur, Red Sea Coast of Saudi Arabia

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ABSTRACT. The textural characteristics, carbonate and organic carbon contents, and heavy and light fraction components of the Recent bottom sediments of Sharm Obhur have been investigated. Texturally the sediments are sands and muddy sands. Most of the Sharm area is covered with sandy deposits; muddy sand deposits were restricted to the central parts and the head of the Sharm. The grain size displays inverse relation with depth.

The sediments have a high carbonate content (average, 50%) that generally decreases towards the head of the Sharm. Organic carbon content is relatively high (average, 1.2%) attaining maximum values at the entrance and the middle part of the Sharm.

The heavy mineral content of the sediments is generally low (0.2%), comprising mainly amphiboles and epidotes. They have the same mineralogy as that of the Recent sediments of the Saudi Arabian coastal plain, their ultimate sources being the igneous-metamorphic rocks of the Arabian shield. The light fraction largely consists of carbonate grains.

The petrology of these sediments suggests that little material has been transported into the Sharm from the mainland and the bulk is locally derived. Sharm Obhur represents a low energy depositional environment.

Introduction

The western coastal plain of Saudi Arabia has been cut through by numerous drowned estuaries or sharms, which extend onto the inner part of the shelf. One such sharm, Sharm Obhur, is located about 35 km north of Jeddah (Fig. 1). It extends about 10 km inland through coralline limestone, and attains a maximum width of 1.5 km. It is connected with the Red Sea through a narrow mouth. It is generally shallow, with depth increasing gradually from the head to reach a maximum of about 35 m

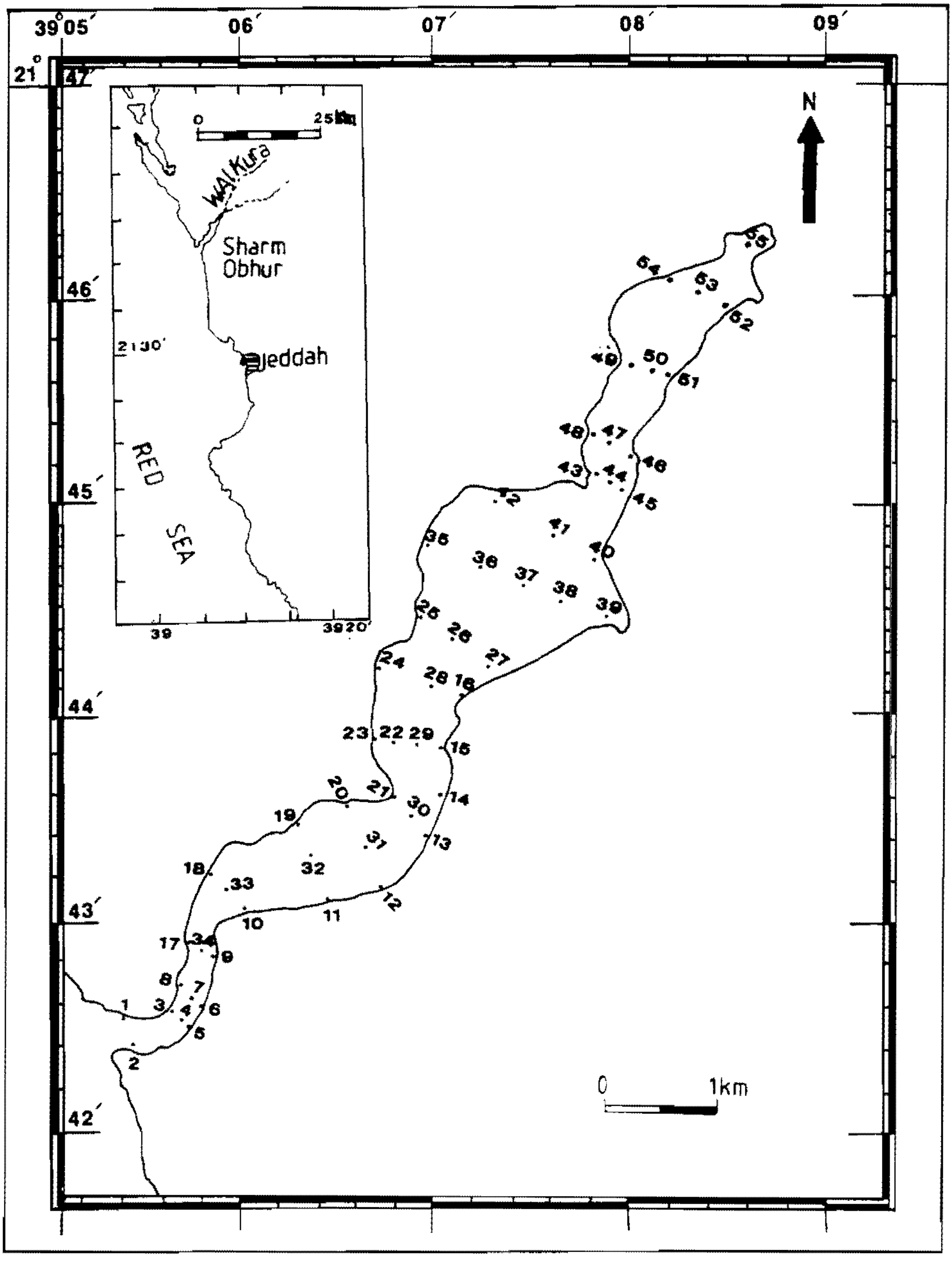

FIG. 1. Study area and location of samples.

near the mouth (Fig. 2). The geology of the area surrounding the sharm is shown in Fig. 3. The water temperature of the sharm varies from 24.4°C in winter to 32.2°C in summer and generally increases towards the head of the sharm. The salinity which ranges between 39.1‰ and 40.2‰, also increases towards the head. The tidal range is very small and variable (around 0.3 m) (Ahmed and Sultan 1993). The shallow nature of the sharm prevents the generation of large waves.

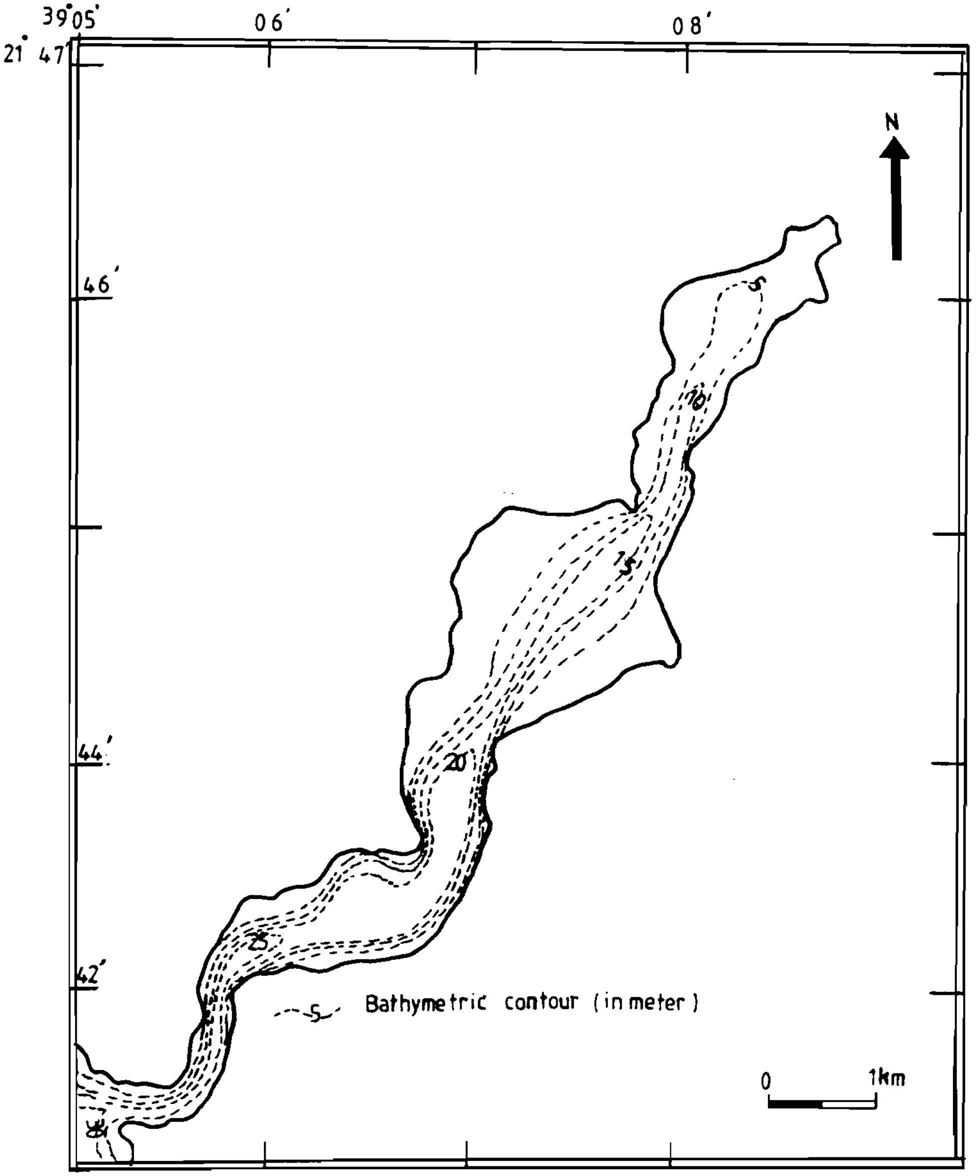

FIG. 2. Bathymetric map of the Sharm Obhur.

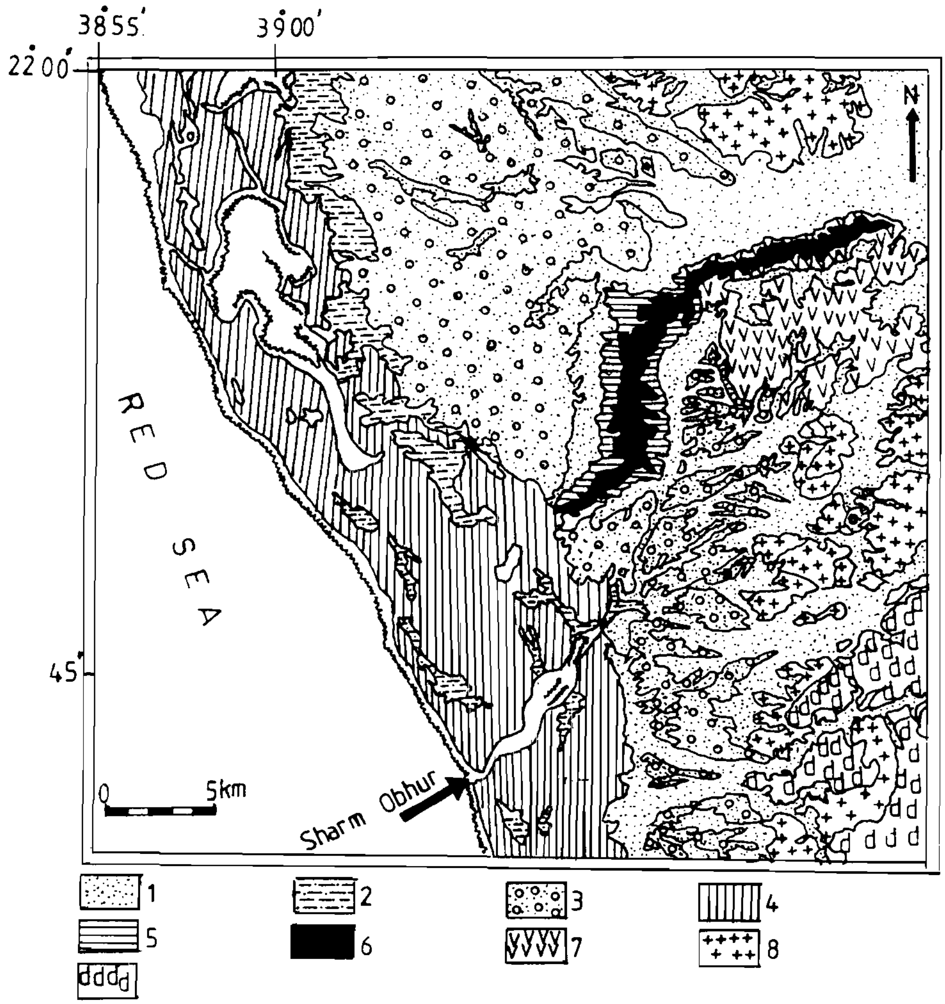

FIG. 3. The geology of the area surrounding the sharm (after Moore and Al-Rehaili 1989). Sabkha deposits, 1; undifferentiated alluvial, talus and eolian deposits, 2; alluvial fan deposits, 3; reefal limestones, 4; Obhur formations, 5; Hammah basalt, 6; Felsic volcanic-lastic rocks, 7; hornblende tonalites, 8; diorites, 9.

In Jeddah area, the prevailing wind throughout the year is N-NNW, only occasionally blowing from the south and SEE (Behairy *et al.*, 1985). Rainfall is scarce and there are no rivers in the area. As a result, very little terrigenous material is supplied from the adjacent landmass.

Various studies have been made on the sediments of the coastal area around Jeddah, notably by Behairy (1980), Bahafzalah and El-Askary (1981), Behairy *et al.* (1982), Behairy and El-Sayed (1983), DurgaPrasada Rao and Behairy (1982), Yusuf (1984) and Abou Ouf and El-Shater (1991). El-Sabrouti (1983) studied the texture and mineralogy of the surface sediments of the same study area. However, his study was concentrated on the carbonate and clay minerals of these sediments. He also identified the heavy and light minerals of the terrigenous fractions. Additionally, the grain size characteristics were described but nothing has been done concerning their relation with the depth and energy in the sharm.

The sharm is a site of increasing urban activities (including land filling to provide more space and sewage dumping), which are exerting an impact upon its ecology. Therefore, the present study was carried out as an integral part of a long-term programme aimed to assess the marine environments around Jeddah. The purpose of the present work is (1) to present a systematic and comprehensive investigation of the texture, carbonate, organic carbon content and mineralogy (heavy and light minerals) of the sediments covering the bottom of the sharm, and (2) to show the extent of the artificial changes that have effected its sediments over the last decade.

Sampling Methods and Analytical Techniques

Fifty-five bottom sediments samples were collected with a grab sampler. Sampling locations are shown in Fig. 1. Grain size analyses of all samples were carried out using standard sieving and sedimentation techniques (Folk 1974). Cumulative curves and histograms were prepared. The percentage of the main size fractions (sand-silt-clay) and the statistical size parameters for the samples analysed were computed using the formulae of Folk and Ward (1957).

The 3-4ϕ size fraction was found to be particularly rich in heavy minerals, and this fraction was selected for heavy-mineral separation using tetrabromoethane. The relative frequency percentages of heavy and light minerals were determined by identifying about 200 grains of each fraction using a polarised microscope.

The carbonate content was determined from powder samples using a calcimeter, and the organic carbon content was determined by the chromic acid method following the technique described by El-Wakeel and Riley (1957).

Results and Discussion

Textural Classes

The percentages of sand, silt and clay of the samples analysed were plotted on a triangular diagram following the textural classification and nomenclature of Flok (1974). On this basis, the bottom sediments of Sharm Obhur were found to consist of two textural classes, namely sand and muddy sand (Fig. 4). Geographically the sharm area is dominated by sands (Fig. 4). Finer sediments (*i.e.* muddy sands) occur in the axial parts and at the head of the sharm. There is an inverse relationship between mean grain size and water depth (Fig. 5) an exception being for samples from the shallow headward part of the sharm where mud is supplied by filling and dumping (Fig. 4).

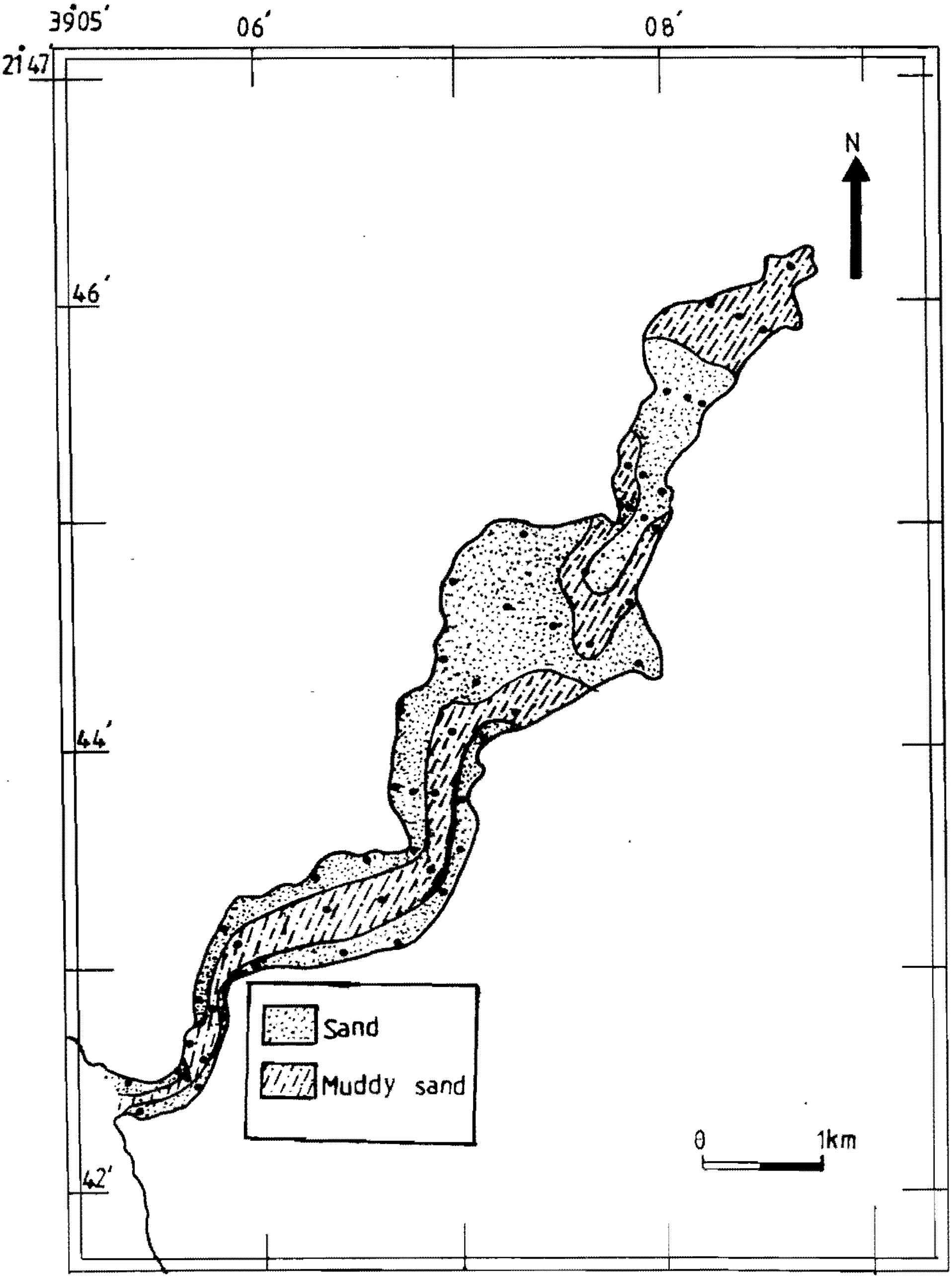

FIG. 4. Lithofacies map of surface sediments of the sharm.

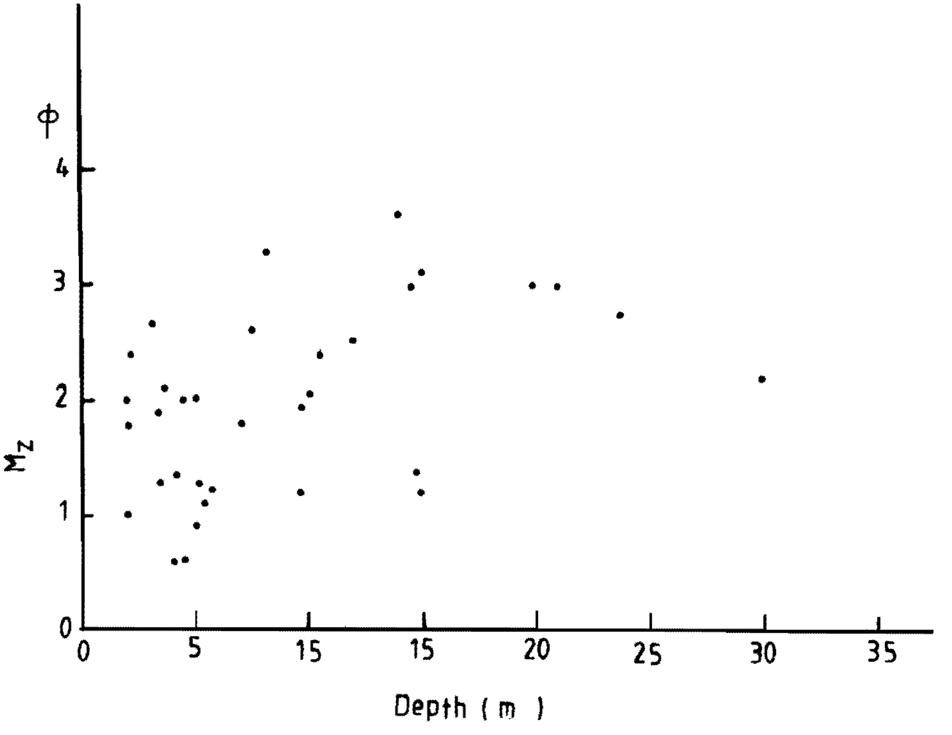

FIG. 5. Plot of mean grain size versus depth.

The average grain size distribution trends of the two textural classes are presented in the form of histograms and cumulative curves (Fig. 6 and 7).

The sandy sediments are, on average, composed of 93% sand and 7% mud (silt and clay) and have a unimodal distribution (Fig. 6a). The cumulative curves, on the other hand, resolve at least two size populations, namely saltated and suspended. The saltated population constitutes more than 90% of the sediments and its finer limit is about 4ϕ (very fine sand). The suspension population is very small ($< 1\%$) and includes all grains finer than $3\text{-}4\phi$. In some samples two saltation sub-populations were noticed separating around $2\text{-}3\phi$. As the sand mainly covers the tidal and subtidal zones, it is believed that the effect of waves similar to the wash-backwash mechanism (Kolmer 1973; Al-Bakri 1980; Khalaf *et al.*, 1984), is responsible for the occurrence of the two saltation subpopulations.

The sand deposits vary in mean size (Mz) from 0.6 to 3.2ϕ, with an average of 1.7ϕ (medium sand). The sorting ranges between 0.36ϕ (well sorted) and 1.2ϕ (poorly sorted) with an average of 1.1ϕ (poorly sorted). The poor-sorting of the sand deposits is mostly due to an abundance of sand sized shells and shell fragments. The *grain size distribution* of the sand deposits are mostly symmetrically skewed and platykurtic.

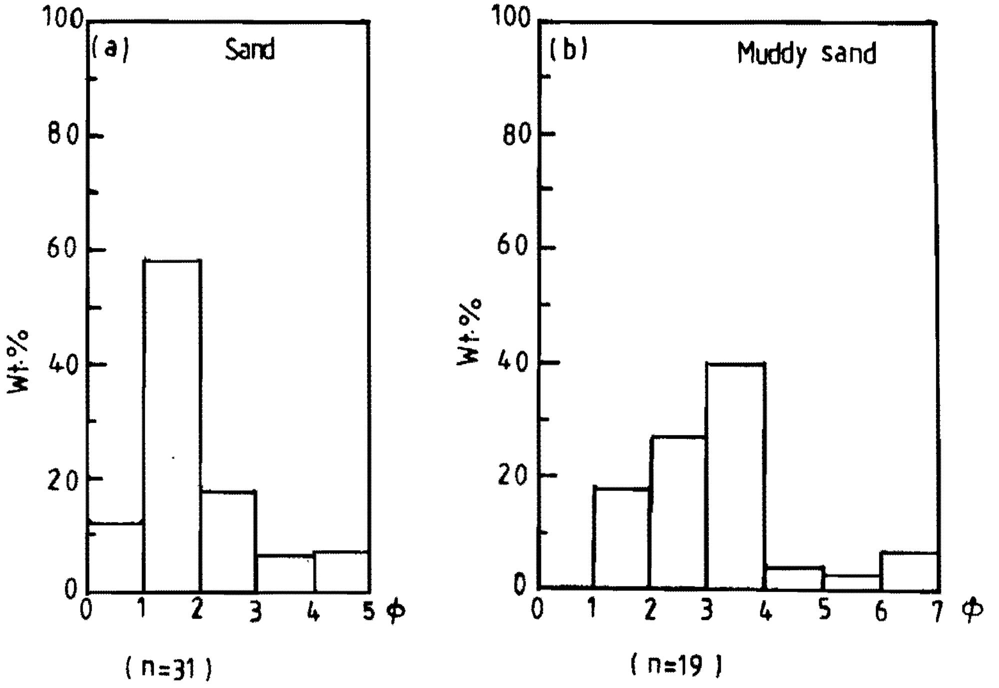

FIG. 6. Histograms of the average grain size distributions of the two textural classes.

The muddy sand deposits, by contrast, comprise on average 83% sand and subordinate amounts of muds (silt and clay). Their histogram is polymodal (Fig. 6b). The relative abundance of mud in these deposits greatly influences their grain size parameters. Their mean size ranges between 1.2 and 7.0ϕ, with an average of 3.2ϕ (very fine sand). They are very poorly sorted (average $\sigma_I = 3.6\phi$), positively skewed and platy to leptokurtic. The polymodal distribution of these deposits may be related partly to the structural breakdown of the skeletal products and partly to the processes operating in the environment (Mallik 1976).

Maps of lithofacies and sorting (Fig. 4 and 8) show that well to moderately-well-sorted coarser sediment is very restricted in extent forming a tongue in the headward part of the sharm. Conversely, the most poorly sorted and finest sediments are found along the central axis of the sharm. This distribution of the texture can be explained by a combination of surface waves including those produced by yachts and pleasure craft together with a gravity potential, *i.e.*, a change in bathymetry that is significant enough to keep sediment in transit (Komar *et al.*, 1972). Thus, resuspension of surface sediments by surface waves would increase the density of the sharm bottom boundary layer by the incorporation of clay and silt. This coarser sediment would probably quickly fall out of suspension. If this dense boundary layer was in an area adjacent to a gravity potential (*i.e.*, an area with a slope of perhaps 2° or more), then

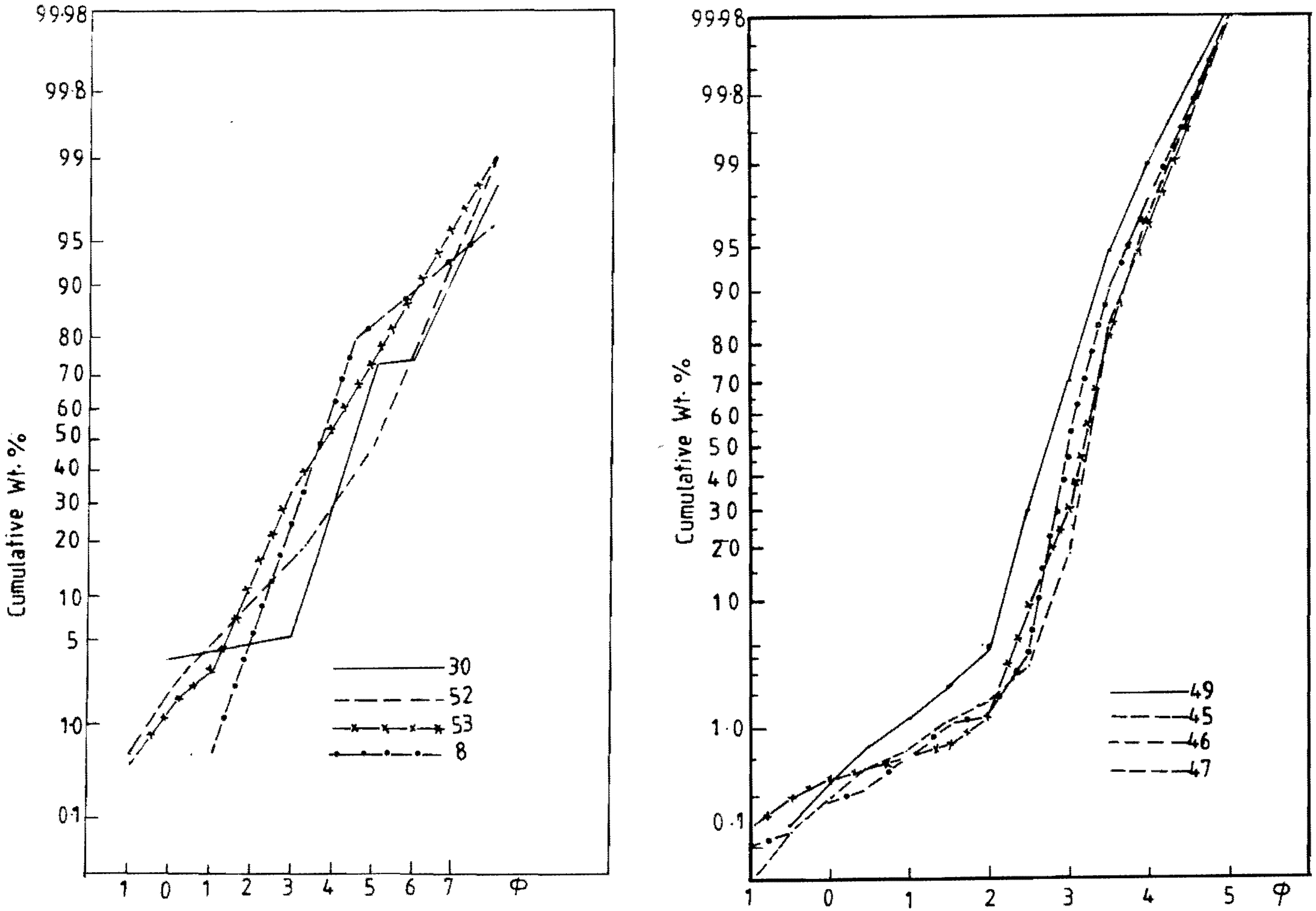

FIG. 7. Cummulative curves showing grain size distribution of the textural classes.

the layer would flow downslope and out of the area. This mechanism would tend to winnow out the fine grain sizes and enhance sorting in the remaining sediment (Fig. 8).

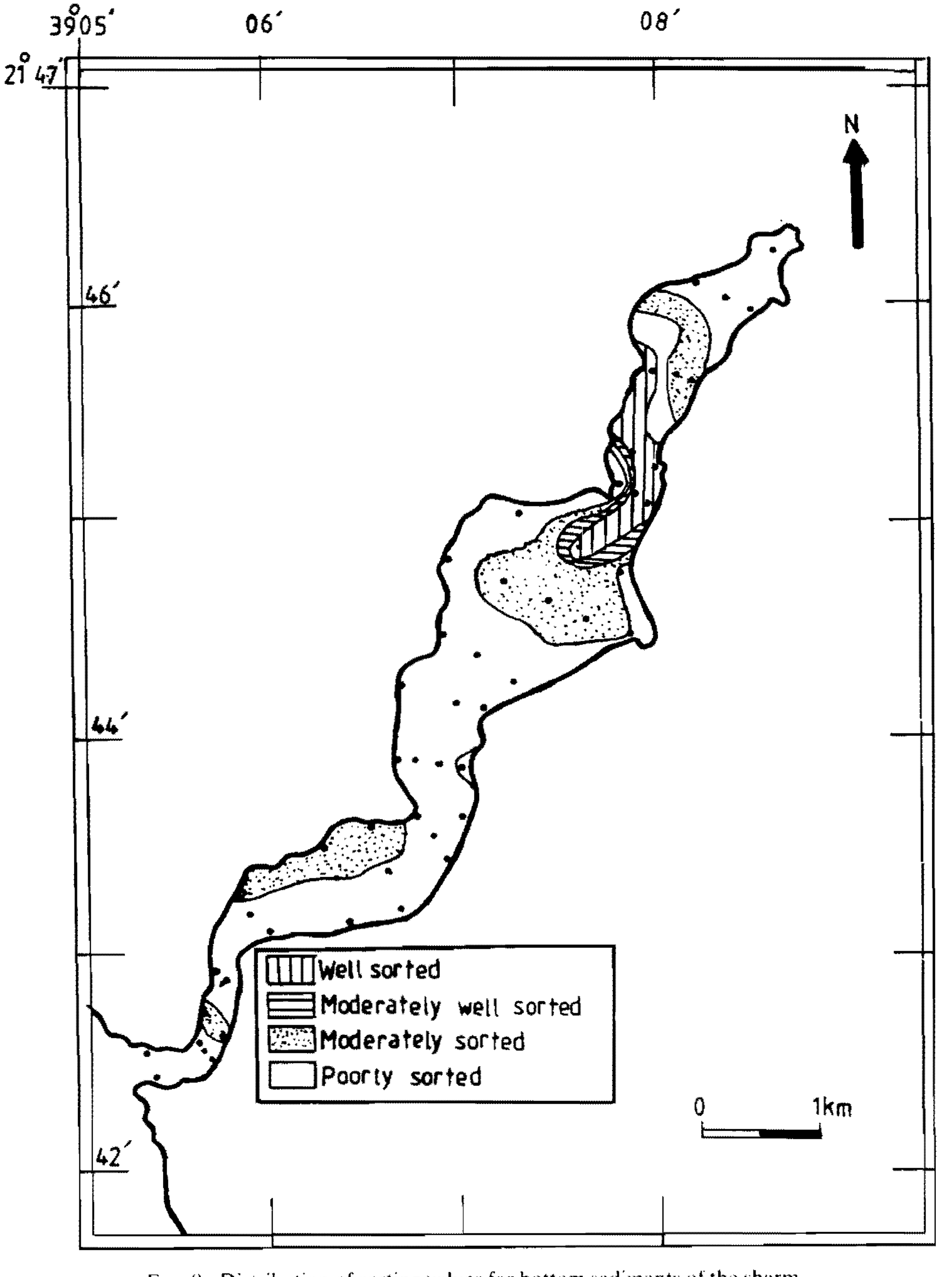

FIG. 8. Distribution of sorting values for bottom sediments of the sharm.

Based on the lithofacies map and the textural parameters of the bottom sediments, the sharm can be considered as a low-energy environment.

A comparison between the present study and that of El-Sabrouti (1983), clearly shows that some changes have occurred in the average grain-size parameters of the bottom sediments of the sharm. The sediments have become finer (average Mz = 2.5ϕ), less-sorted (average $\sigma 1 = 2.4\phi$) and positively skewed (average $SK_I = 0.13\phi$). On the other hand, the distribution of sands and muddy sands in the sharm does not show a significant changes.

Carbonate Content

The bottom sediments of Sharm Obhur are generally rich in carbonate. The histogram of carbonate distribution shows a polymodal distribution (Fig. 9). The total carbonate content ranges between 5 and 93% with an average value of 50%. The carbonate content is higher near the sharm shores and generally decreases towards the axial part of the Sharm (Fig. 10). At head of the Sharm the sediment is observed to have the lowest content of carbonate. The carbonate component originates from two sources: the erosion of carbonate-rich coastal rocks and the mixing of sediments with shell fragments of gastropods, lamellibranchs and other calcareous debris. The low carbonate content characterising the sediments at the head of the sharm may be due to dilution by terrigenous sediments brought in by human activity around the head of the sharm as well as sediment transported by flush floods debouching at the head of the sharm through Wadi Al Kura (Fig. 1).

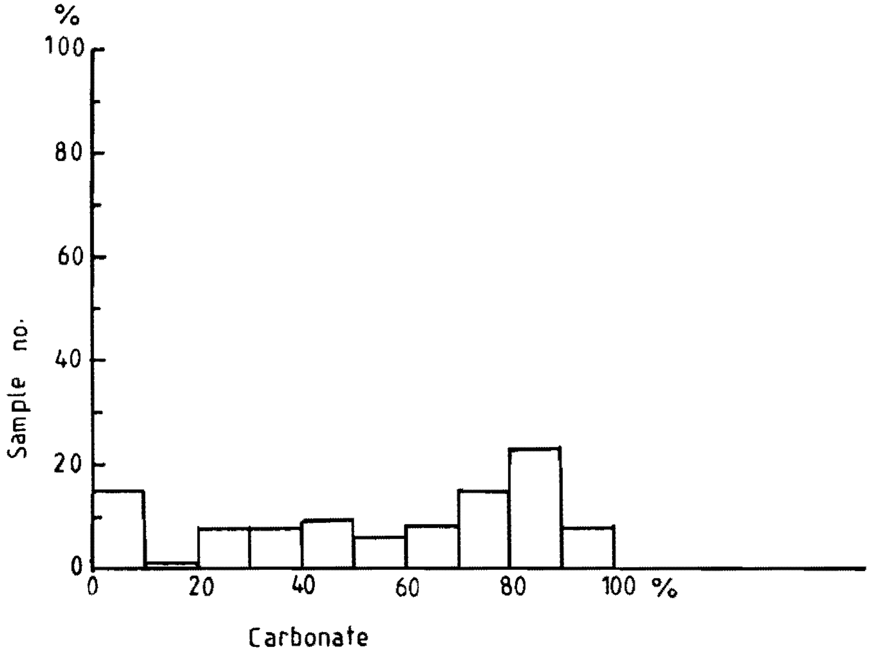

FIG. 9. Total carbonate percentages in the sharm samples.

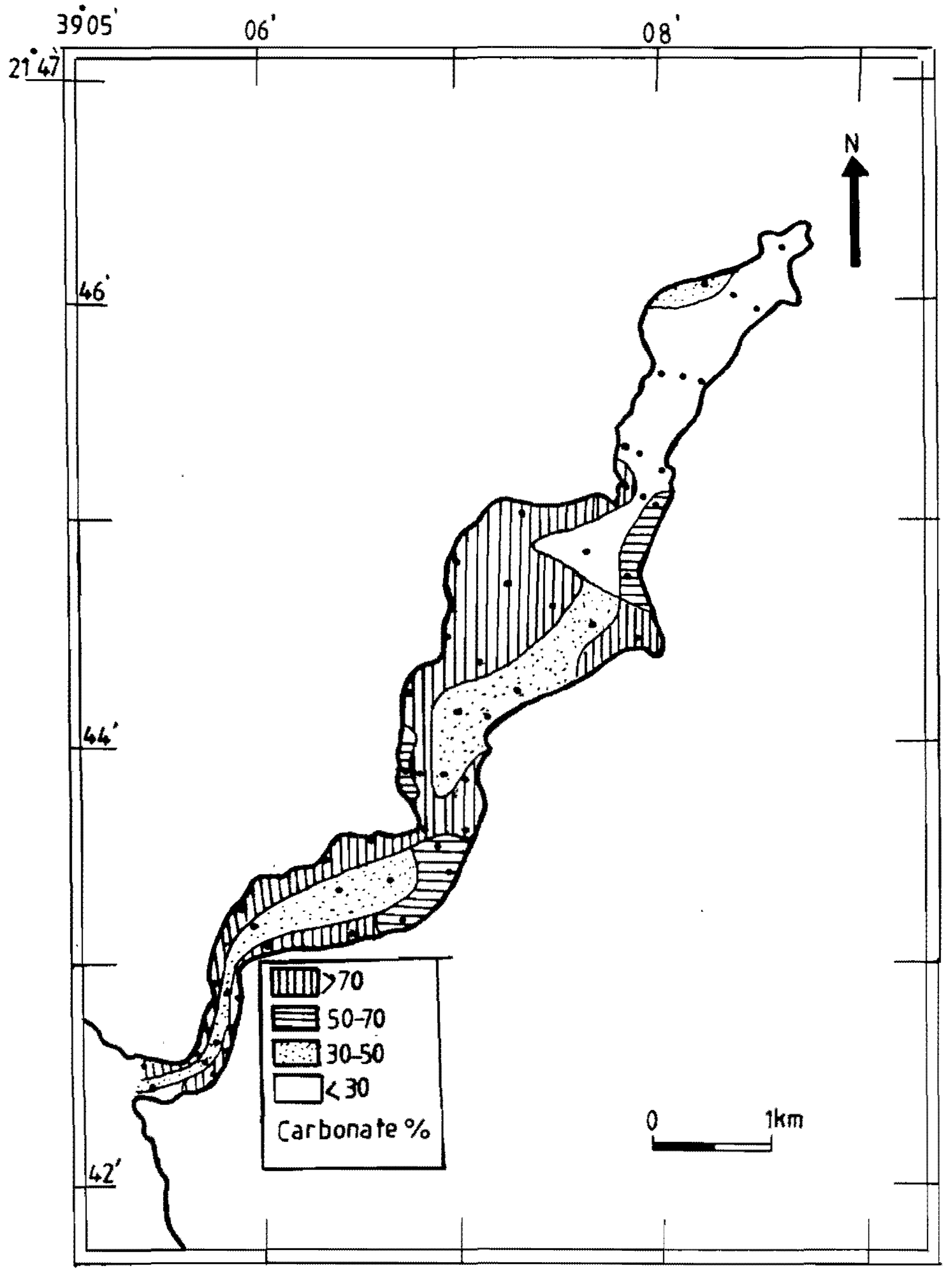

FIG. 10. Distribution of total carbonate of the sharm sediments.

Organic Carbon Content

The organic carbon content in sediments of the sharm ranges from 0.32 to 2.6% with an average value of 1.2%. Some unimodality can be observed in the organic carbon distribution (Fig. 11). The sediments of the sharm can be divided into three regions on the basis of their organic carbon content (Fig. 12). The main region occupies most of the sharm area, particularly the central part which is characterised by organic carbon contents ranging from 1.0 to 2.0%. The nearshore area of the sharm is relatively poor in organic carbon (0.3-0.97%). Some isolated spots in the middle of the sharm and near its mouth are rich in organic carbon (2.09-2.61%).

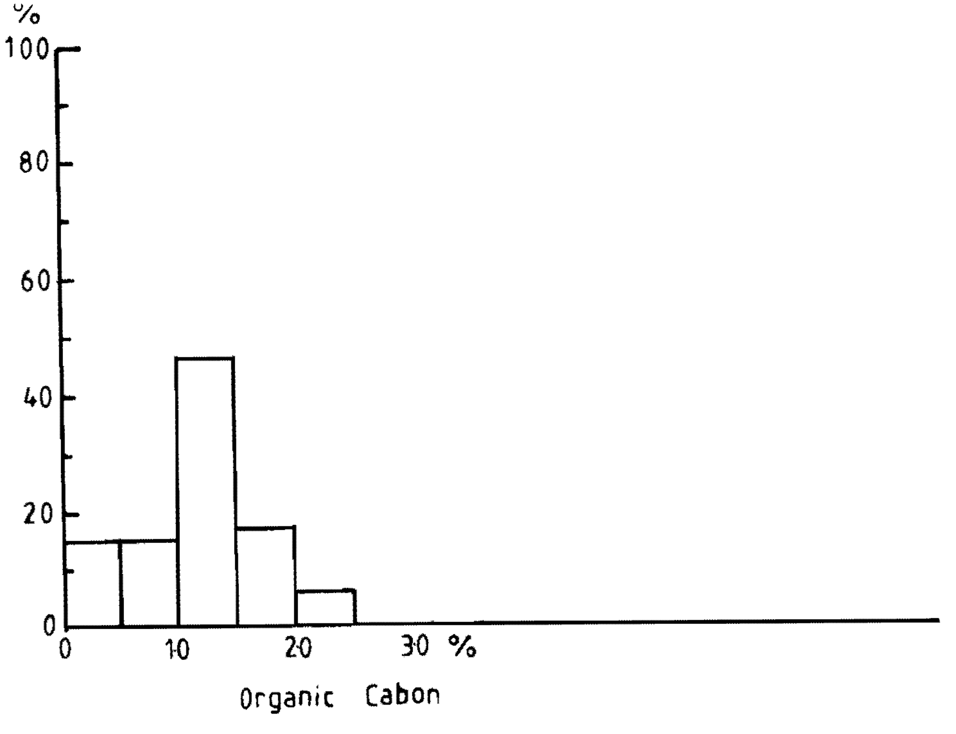

FIG. 11. Organic carbon percentages in the sharm samples.

These results are greater than the organic carbon content of sediments in other parts of the Red Sea. According to Mohamed (1949), organic carbon content of the sediments of the northern Red Sea ranges from 0.06 to 0.45%. Behairy *et al.* (1983) determined the organic carbon in the sediments of the Red Sea in the vicinity of Jeddah, which average 0.4%. El-Sayed and Hosny (1980) reported an average value of the organic carbon (0.32%) for the intertidal reef sediments of Al Ghardaqa.

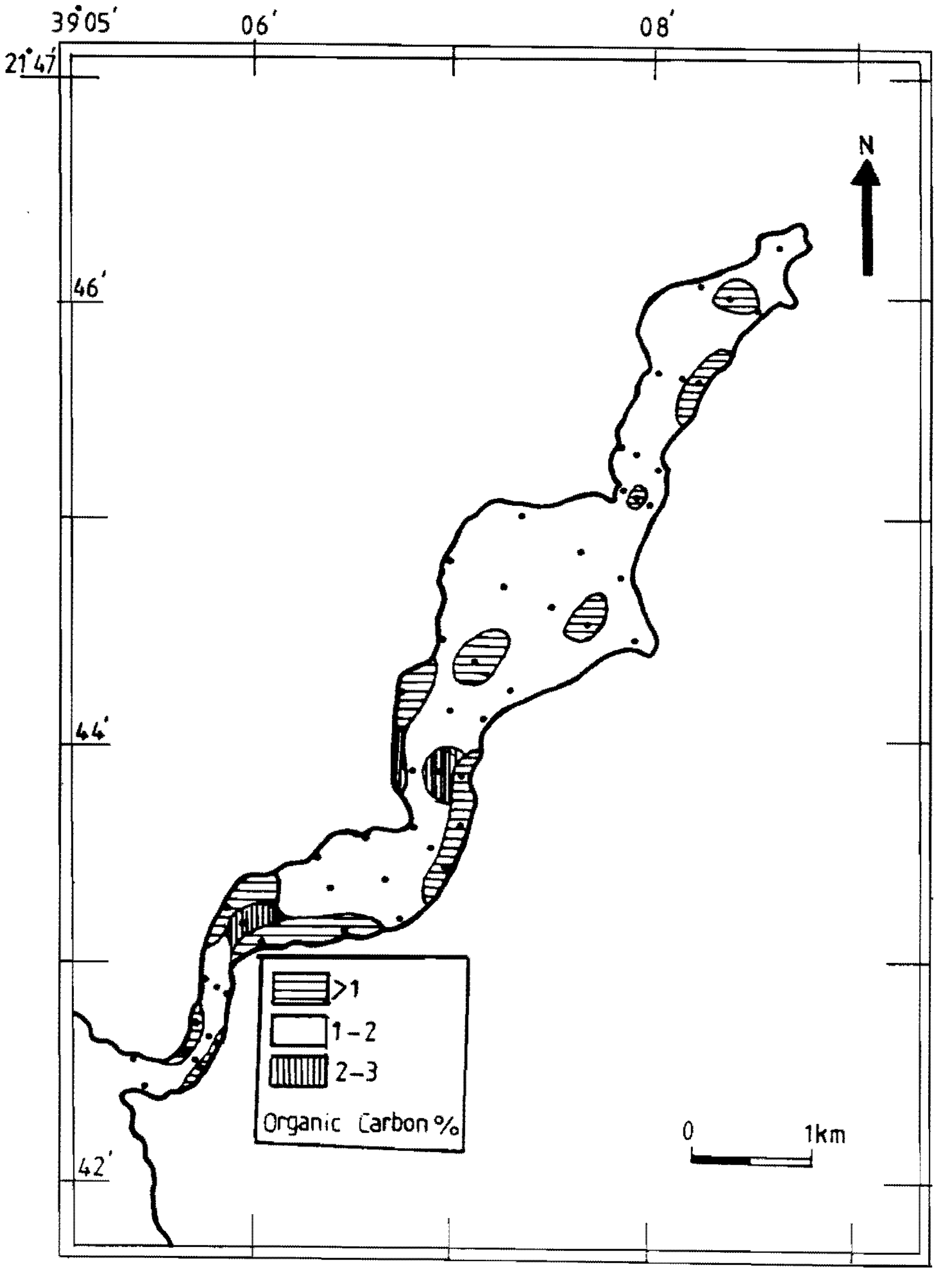

FIG. 12. Distribution of organic carbon of the sharm sediments.

The distribution of the organic carbon is closely related to the grain size distribution, the organic carbon content increasing with a decrease in grain size (Fig. 13). This correlation is expected, and almost universally observed in marine sediments (*e.g.* Trask 1939; Bordoviskiy 1965; Kukal 1971; and Moussa 1973).

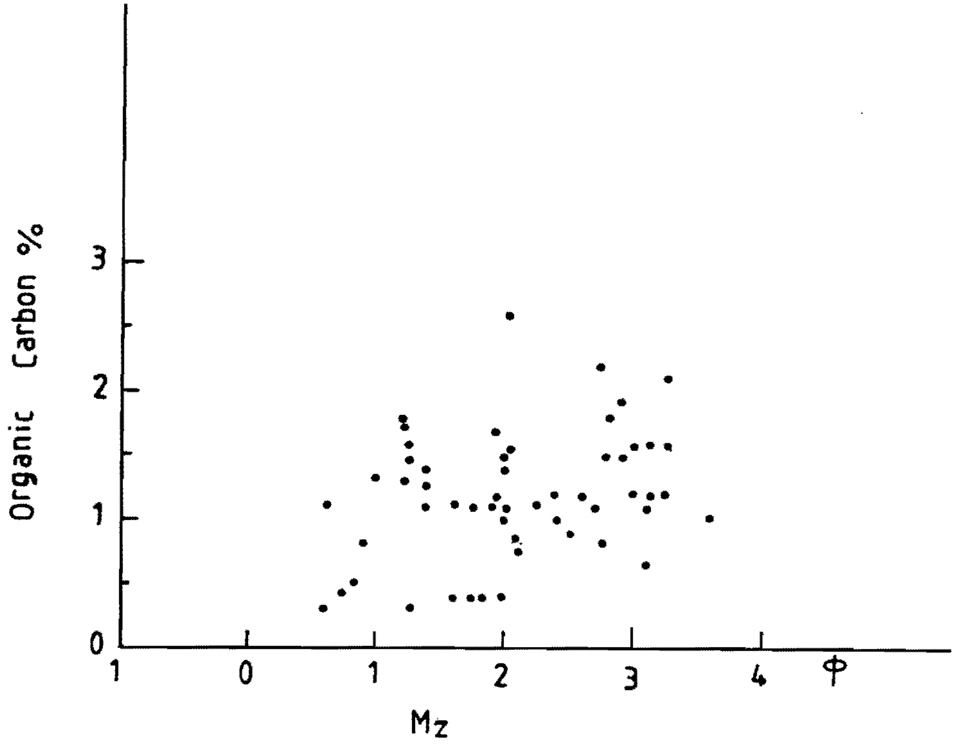

FIG. 13. Relationship between organic carbon and mean grain size.

Mineralogy

Heavy Minerals

Heavy mineral contents of the 3-4ϕ size fractions range from 0 to 2%, with an average of 0.47%. In general, heavy mineral contents are low and increase seaward along each transect. The heavy minerals mainly consist of amphibole, epidote, weathered minerals (alterites), opaques and subordinate amounts of pyroxene, staurolite, kyanite, andalusite, garnet, dolomite, and some other minerals (zircon, tourmaline, rutile, monazite, apatite and sphene).

Amphiboles are the dominant transparent mineral, with a relative frequency ranging from 18 to 90%, averaging 52%. They are mainly green and yellowish green grains of hornblende, with subordinate amounts of actinolite-tremolite, basaltic hornblende and riebeckite. They occur as irregular, prismatic and subrounded grains. The angularity of grains increases towards the head and the shores of the sharm.

Epidotes are the second dominant mineral group and vary from 7.0 to 72%, with an average of 44.5%. They are mainly rounded to subrounded grains of a greenish pistacite variety, with a few colourless, angular to subangular zoisite grains.

The map of heavy mineral facies (Fig. 14) indicates that amphiboles are the most abundant heavy mineral at the head of the sharm as well as in the shallow area of the middle part. However, epidote is dominant in the mouth region of the sharm and in the deeper parts of the central area.

This heavy mineral distribution (Fig. 14) and the presence of both rounded and subrounded grains of epidotes and amphiboles as well as grains of high angularity can be explained on the basis of the breakdown of the raised beaches surrounding the sharm from which the heavy mineral species have been released and mixed together with those brought by flash flooding at the head of the sharm and by winds. El-Shater (1985) and Tag *et al.* (1990) found that the heavy mineral associations (mainly represented by epidotes, amphiboles, chlorite and opaques) in the subtidal and tidal zones along the Red Sea coast are similar, if not identical, to those in the Recent surface sediment of the coastal plain and in raised beaches. These associations, in turn, reflect their ultimate source rocks (igneous-metamorphic rocks of the Arabian shield, Fig. 3).

Light Minerals

The light minerals (Sp. Gr. < 2.85) in the 3-4ϕ size fraction are represented by carbonate grains (shell fragments, pellets, detrital calcite) with subordinate amounts of quartz and feldspars. Gypsum and mica were recorded in minor amounts. Calcite was most found in form of rounded monocrystalline and polycrystalline grains. The polycrystalline calcite grains may have formed from the breakdown of the micritic envelopes of the recent shell. The percentage of calcite tends to decrease towards the shore and the head of the sharm.

Quartz is present in form of clear, monocrystalline subangular to angular grains. Polycrystalline quartz grains of subordinate amounts also do occur. The distribution of quartz is generally negatively correlated with that of the carbonates. Feldspars are represented mainly by rounded to subrounded grains of plagioclase (albite) and potash fledspars (microline and orthoclase). Gypsum, occurring in the form of subrounded grains, was found to be most abundant in the nothern part of the sharm.

Based on the light assemblages of the very fine sand (Fig. 15) the sharm can be subdivided into two areas; the one, which includes the mouth and head areas, where the bottom sediments contain 50-80% fossil and fossil fragments, the other, covering the middle part of the sharm, where the sediments contain more than 80% fossil and fossil fragments.

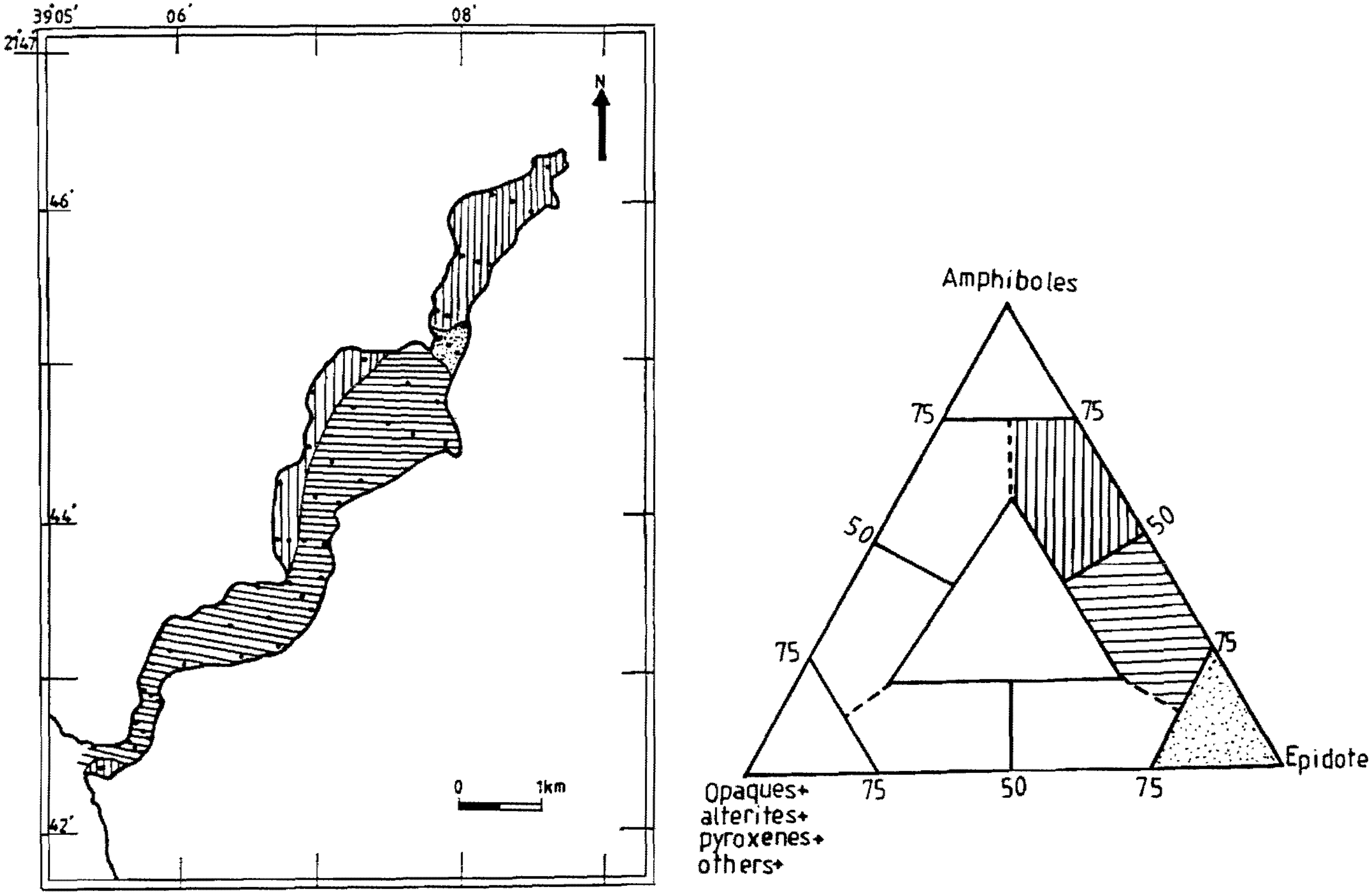

FIG. 14. The heavy mineral facies map of the sharm sediments.

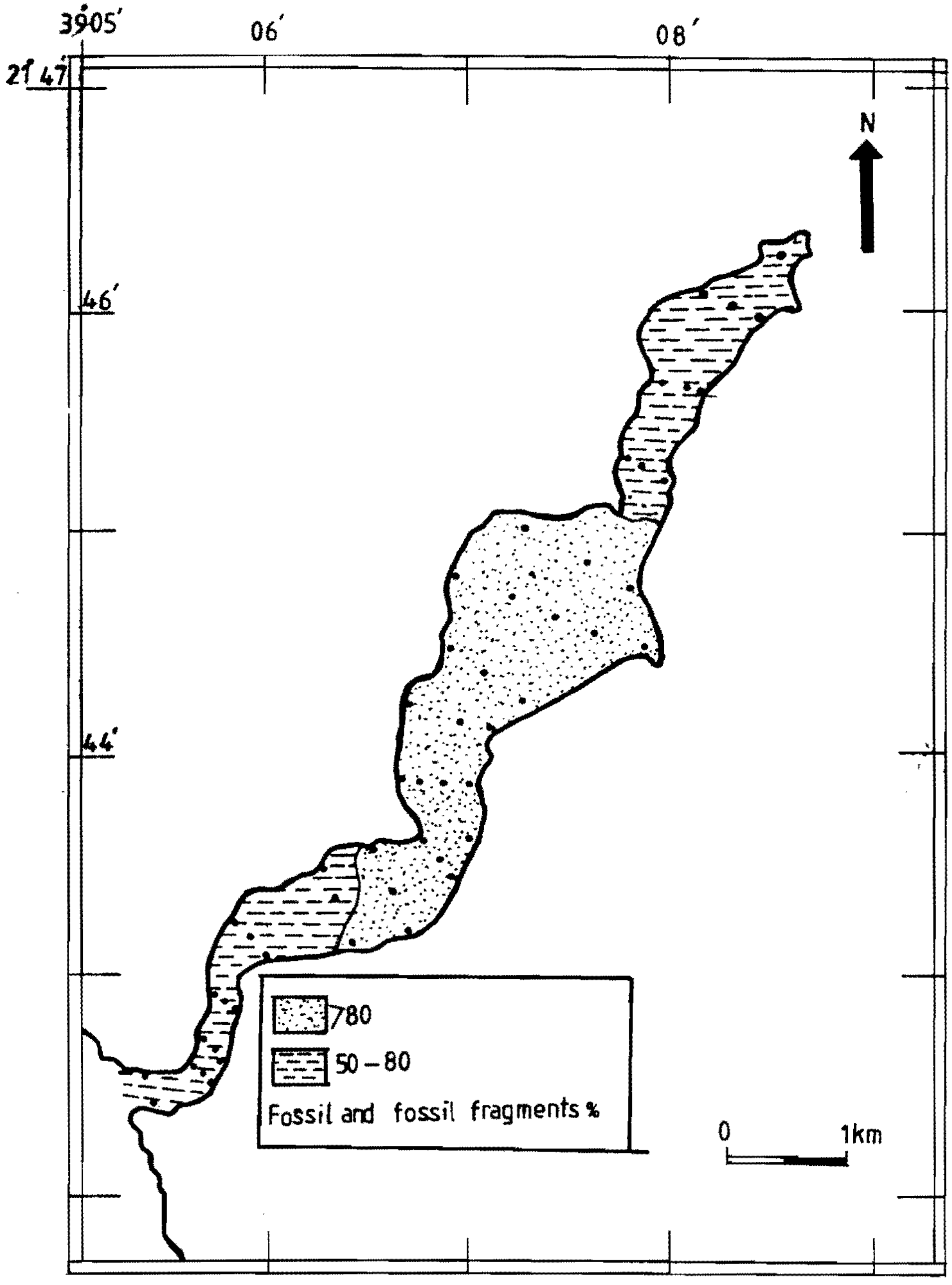

FIG. 15. Distribution of fossil and fossil fragments in the light fraction of the sharm sediments.

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الخصـــائص النسيجيـــة والمعــدنية للرواسب السطحيـــة لشرم أبحـــر ، الساحـــل السعـــودي للبحـــر الأحمـــر

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المستخلص . دُرِسَت الخصـائص النسيجية والمعـدنية ومحتـوى الكـربـونـات والكربون العضوي للرواسب القاعية الحديثة لشرم أبحر ، وقد وجد أن معظم هذه الرواسب إما عبـارة عن رمال أو رمال طينية . وتغطى الرمال معظم أجزاء الشرم ، بينما تتركز الرمال الطينية في الجزء الأوسط من الشرم وكذلك نهايته .

إن هذه الـرواسب غنية بالكـربـونـات (متـوسط محتـواها حوالي ٥٠٪) ويقل محتوى الكربونات عمومًا في اتجاه نهاية الشرم . ويعتبر محتوى الكربون العضوي لهذه الرواسب عاليًا نسبيًا (متوسطه ٢ , ١٪) حيث تكون أعلى قيمة لهذا المحتوى في مدخل الشرم وجزئه الأوسط .

تعتبر هذه الرواسب فقيرة عمومًا في احتوائها على المعادن الثقيلة والتي يكون معظمها عبارة عن معادن الأمفيبول والأبيدوت . إن وجود المعادن الثقيلة هذه في الرواسب يشبه إلى حد كبـير تلك التي في الرواسب الحديثة للسهل الساحلي السعودي ، حيث إن المصدر الأساسي لهذه الرواسب في كلتا الحالتين واحد وهو الصخور النارية والمتحولة للدرع العربي .

إن دراسة هذه الرواسب أكدت أن القليل من المواد القارية نُقلَت إلى الشرم ، وأن غالبية هذه الرواسب داخلية المنشأ ، وعلى وجه العموم يعتبر الشرم بيئة ترسيبية ذات طاقـة منخفضة .