

The Grain-Size Trends on a Recent Reef Island, Red Sea, Saudi Arabia

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ABSTRACT. Eqah Island is a reef composed of argonite and calcite aged 1740 ± 60 years. The Island is covered by medium to fine skeletal and non-skeletal carbonate sand of marine origin. The analysis of the surficial sediments shows a significant change in mean grain size along the beach (seaward side) which represents fining in the direction of the wave-driven movement and as a result, the increases in supply rate of fine sand particles from the north to the south direction. The beach against the land has larger grain sizes. This is due to the steep foreshore slope of the beach. The grain size distribution of the sediments are polymodal and well to moderately sorted.

The purpose of this study was to determine the age of the coral reef beneath the loose sediment of the island and to find out the grain size distribution, sorting and composition of the beach sediments as well as the relationship between the mean grain sizes and the longshore transport of the beach (Island) sediments on the island.

The Eqah Island is an off-shores island in the Red Sea 3 km from the main land and 45 km north of Jeddah, on the Saudi Arabian coast (Fig. 1). It is surrounded by many shoal reefs with a north-westerly orientation parallel to the shoreline. The Island is dominated by medium to fine sand and consists of reef debris, foraminifera, and molluscan shell fragments which generally form the major components in the bioclastic sediments.

Guilcher (1986) suggested that currents have an influence in the growth and the direction of the reefs in the Red Sea. However, the Eqah Island has a straight frontal face

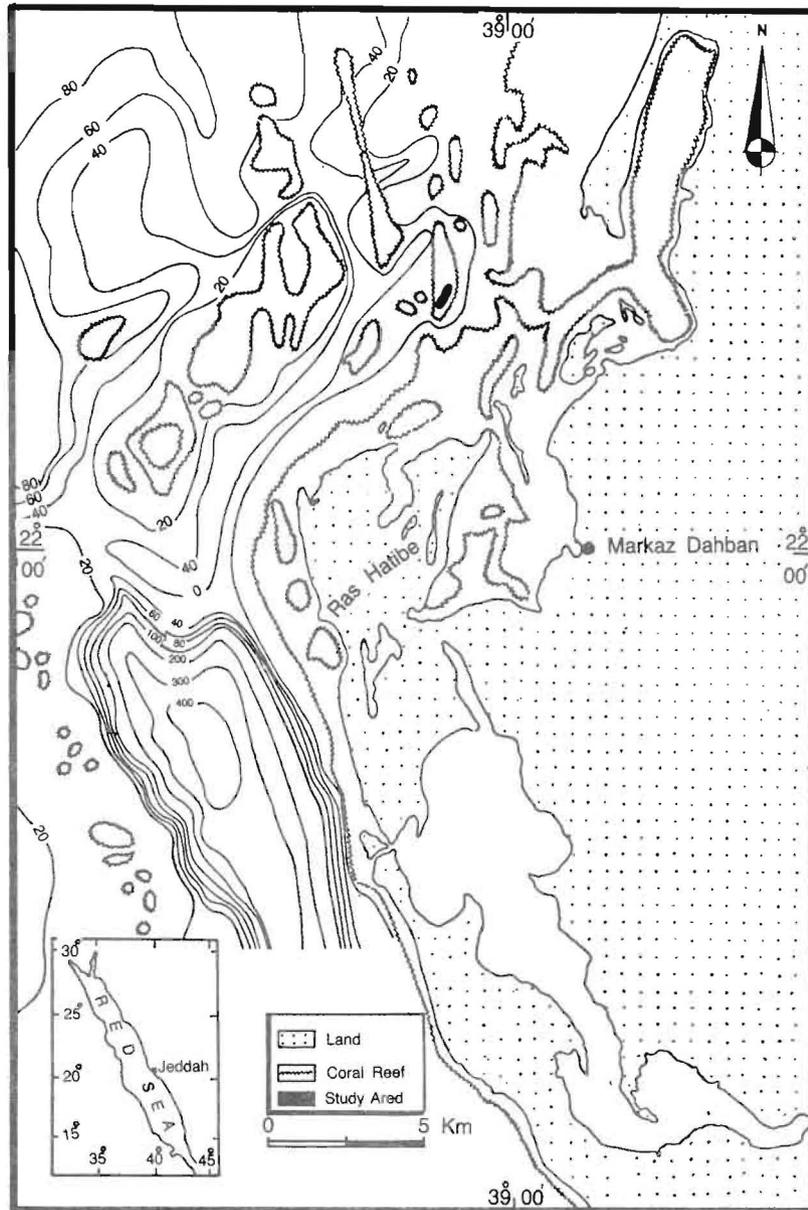


Fig. 1: Location map of the Eqah Island. (after Ramsay 1984)

and a convex on-shore face. The latter is strongly effected by the current which passes the canyon to the east of the Island at ebb tide.

The annual prevailing wind direction, and the longshore transport caused by the northwesterly waves, are shown in Fig. 2. The annual mean wind velocity during 1986 ranged from 5 knots to 9 knots with extremes of 24 to 36 knots.

The Island occurs on the south east of the reef and has resulted from a retreat of the loose sediments due to the predominantly north westerly waves. However, the Island is protected from strong wave action by two shoal reefs.

- a) The shoal reefs surrounding Eqah Island break the strong waves reducing the energy impacting on the Island.
- b) The shoals reef of the Island itself, forms a second defence. It breaks the waves which pass through the outer shoal reefs as well as the waves which form behind these shoal reefs.

Many studies in different parts of the world with similar conditions to those in the study area have revealed that the carbonate sediments are composed of skeletal and non-skeletal materials (e.g. Folk and Robles 1964, Chappel and Smith 1967, Wass *et al.* 1970, Braithwait 1973, Shidler and Smith 1984, Heathershow and Codd 1986, and Hoskin *et al.* 1986. Bahafzallah and El-Askary 1981) have shown that the beach sand to the north and south of Jeddah are predominantly of medium grain sized sand and are composed mainly of carbonate sediments of foraminifera, ostracods, microgastropods, micropelecypads, nonskeletal quartz and heavy mineral grains. More recent work has been done on the shore zone between Jeddah and Yanbu on the Red Sea coast of Saudi Arabia by Durgaprasada and Behairy 1984, 1986. They found that the coast is covered by skeletal carbonate sand, with the near shore sediments containing benthic foraminifera, algal fragments and molluscas. Grain sizes are multimodal.

The Study Area

The Island is one kilometer long and 100 meters wide in the south, increasing to 120 meters in the north. The on-shore face of the beach has a steep slope of 1:5 while the off-shore face has gentle slopes of 1:12. The basement of the Island is constructed of recent carbonate reef. Wave erosion on carbonate reef has produced a distinct type of clastic carbonate sediment on the island, burying the carbonate reef. The northern and the western tidal flat areas extend for 150 and 50 meters respectively, whereas the eastern and the southern intertidal flats are only 3 to 5 meters. The tidal flat ridges rising about 0.5 meter above the high tidal water mark in the north, increasing to 1.5 meters in the south. These ridges are constructed of the sediments thrown up from the shallow subtidal areas during storms.

The Island is mainly flat and is covered by extensive halophytes (Fig. 3) such as *Atriplex* Sp. along the west coast. A scattering of *Halopeplis perfoliata* (Forssk). Bunge ex Ung.-Sternb. and *Zygophyllum coccineum* L. plants grow in the middle and on the eastern end of the island.

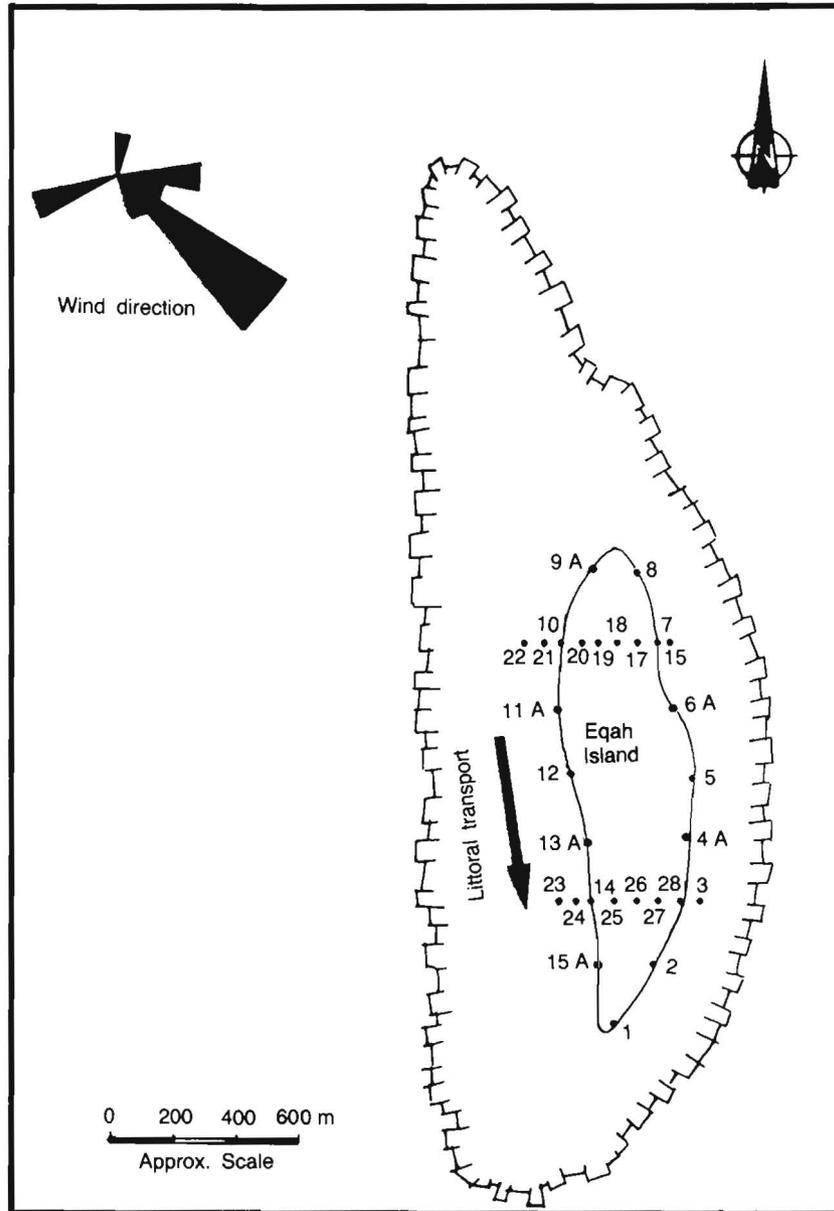


Fig. 2: The littoral transport wind direction and the location of the collected samples. The annual prevailing wind direction were measured by MEPA 1986.

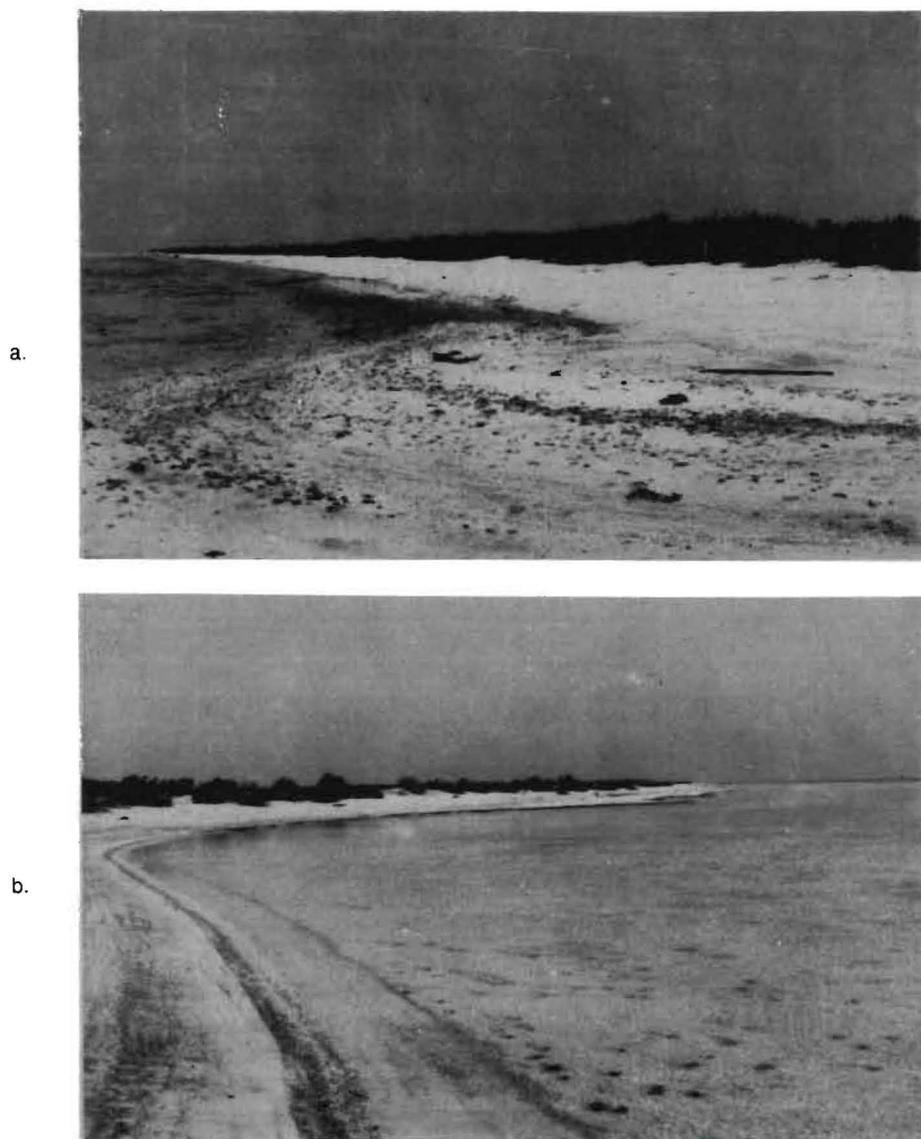


Fig. 3: a. Front face of the Eqah beach looking from south to north, showing straight coast line and the ridges are covered by *Atriplex Sp.* plant.

b. Leeface is covered by *Zygothallum coccineum L.* plant.

Methods

A total of 28 samples of surface sediments 150 meters apart were collected along the high water mark by scrapping up the top 3 cm of the sand. Samples were also collected from two profiles across the island, with the samples on each profile being 20 meters apart (Fig. 2). The samples were washed and dried in an oven at 90° F overnight. Sub-samples of 50 grams were obtained with a splitter and were passed through a nest of sieves at quarter Phi. The sieves were shaken mechanically for 30 minutes. Each fraction was examined under a binocular microscope to make sure that all the sediments were completely disaggregated. The texture parameters were calculated according to the formulae of Folk and Ward 1957. The analysis of the standard deviation is according to Friedman 1968. Furthermore, reef samples were collected from the A sites. Dating of the reef samples was carried out in Scottish Universities Research and Reactor Center U.K. using the trace elements of ^{238}u , ^{234}u and ^{230}th .

Coral Reef

The coral reef of the island is mainly composed of aragonite and calcite. This conforms with Friedman's 1968 findings that framework builders of the Red Sea reef synthesize skeletons of aragonite and high Mg calcite identical to those off the Bermuda coast. Behairy and El-Sayed 1984 also found that in the Red Sea the cement reefs are predominantly the same minerals.

The dating of the reef gave an age of 1740 ± 60 years.B.P. indicating that sediments blanketing the reef are of very recent origin.

Sediment Characteristics

Mean Grain Size

The mean grain sizes of the island sediments are shown in Fig. 4. The values ranged between 1.15 and 2.57 phi. However, the island is characterized by medium to fine sand. The off-shore face of the island has medium to fine sand with considerable variation around the mean, grading from 1.33 Phi in the north to 2.07 Phi in the south.

The on-shore face was characterized by only medium grain sized sand. Variation was random with values ranging between 1.08 Phi to 1.54 Phi.

Both sample profiles showed random variation in grain sizes. Each had one sample of fine sand, as shown in Fig. 4 (no. 14, 16). With the rest of the samples being medium sands ranging from 1.28 Phi to 2.57 Phi.

The percentage of dust particles of finer than 0.63 Phi in the sediments found in the main body of the island varied from 0.06% to 6.2%. These fine particles may be transported principally as suspension and trapped by vegetated surface.

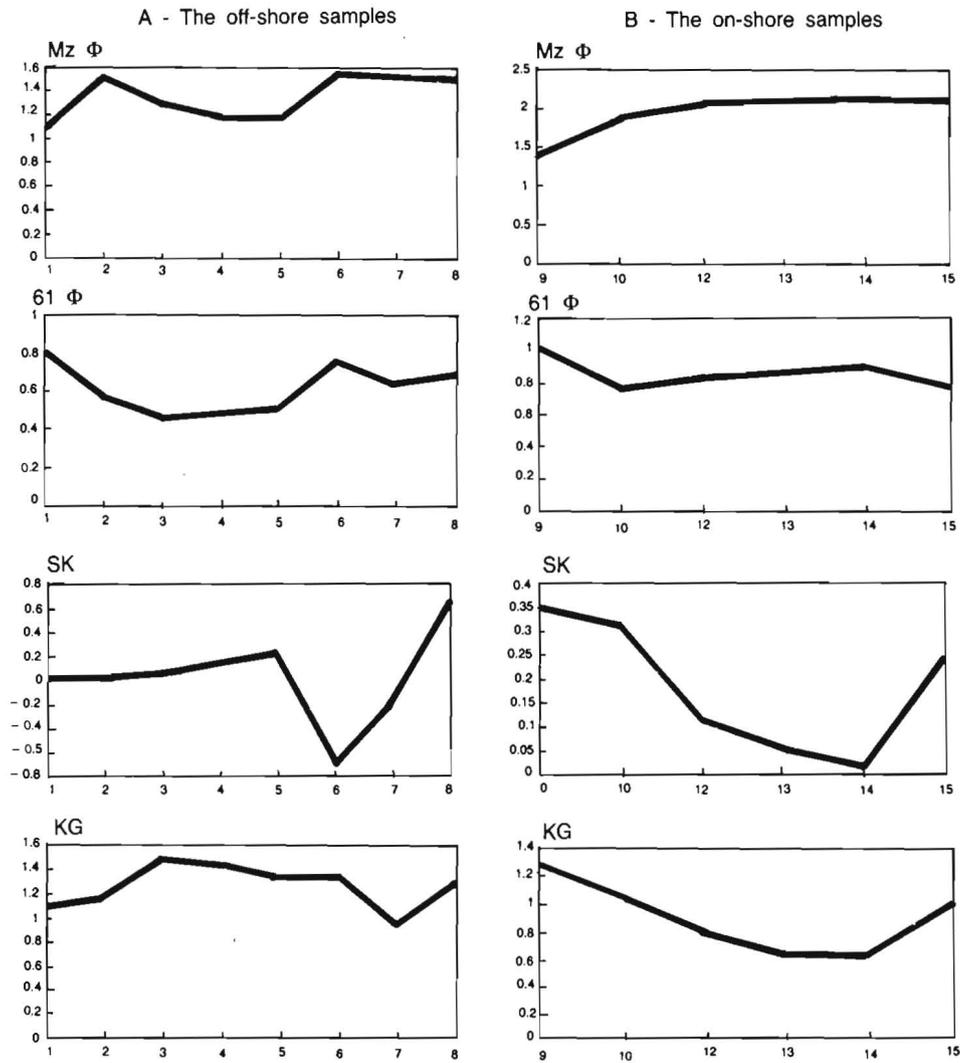


Fig. 4 (A & B) The mean Grain size (Mz) sorting (61), Skewness (SK) and Kurtosis (KG) of the littoral sediments.

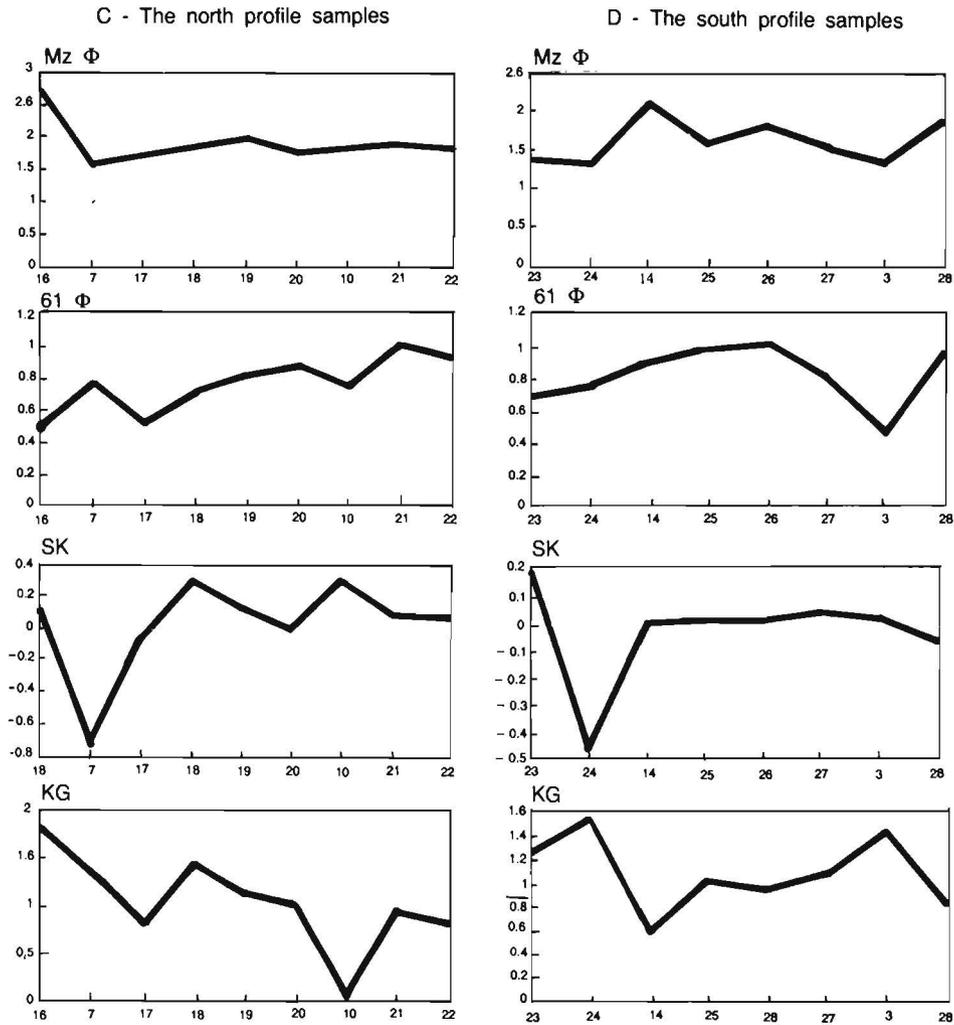


Fig. 4(C & D). The sediments of the main body of the Island.

Sorting

The Eqah sediments range from well to moderately sorted (0.27 Phi to 1.02 Phi). The grain size varied randomly on the seaward face, the landward face and in both profiles. But in the northern the sorting on the main body of the Island increases progressively from east to west as shown in Fig. 4.

Skewness

The analysed sediments ranged widely from -0.72, 1.02. Most of these sediments showed nearly symmetrical skewness. Sample no. 8 has moderate positive skewness while sample no. 6 has moderate negative skewness.

The distribution of the sediment particles is polymodal in all samples. The histogram of the sediment (Fig. 5) shows progressively finer particles from north to south. This is the result of the distribution of the proportions of coarse grains with a mode of from 0.0 to 1.0 Phi, which decreases and the very fine sand with a mode of 3.0 to 4.0 Phi which increases from the north to the south.

Kurtosis

The kurtosis values of the sediment on the island ranged from 0.60 to 1.54, and included platykurtic, mesokurtic and leptokurtic samples (Fig. 4).

The kurtosis values from the seaward face of the island increases relative to the increasing mean size of the particles (except for sample no. 15).

Discussion

The age of 1740 ± 60 years B.P. for the reefal rocks of the island suggests that the loose sediments were probably deposited shortly after this.

Eqah island is covered by calcareous sand with mean grain sizes that range from medium to fine particles. The distributions of the sediment are polymodal and well to moderately sorted.

Year round wave action on Eqah island is predominantly from the north west. This causes long-shore transport action along the beach face. The principle of the long shore transport has been discussed in some detail by Al-Mansi 1990.

The significant but progressive difference in the mean grain size of the surficial sediments from medium sized grains to fine sand on the off-shore face is apparently due to the direction of the longshore transport action. The north of the island loses the fine sediments by longshore drift, so coarser grains are more dominant here. This mechanism accounts for the progressively smaller mean grain sizes from north to south, which is likely to correspond with the more rapid migration of the fine particles compared with the coarser ones. This conclusion is supported by various studies from different beaches done by Yasso 1965, Fox 1978, and Duane and James 1980. Moreover, similar work by

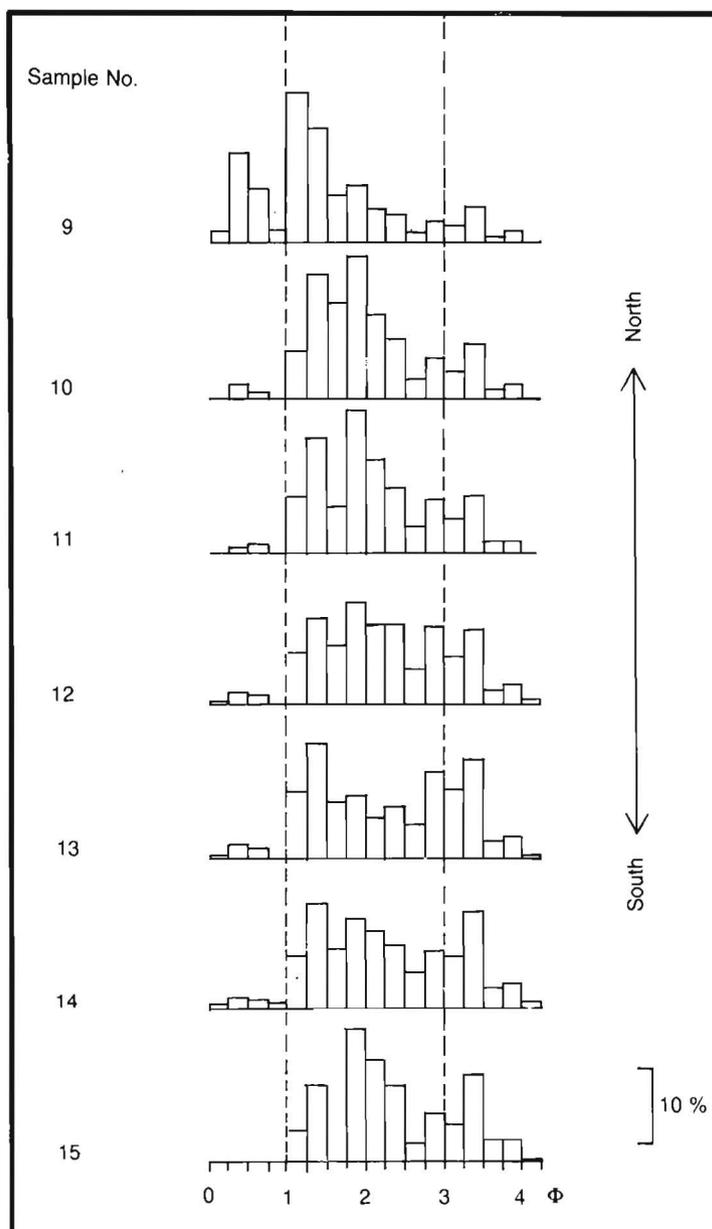


Fig. 5: Histogram of the collected samples taken at 150 meter spacing from the on-shore face of the Eqah Island.

Sample No. 15 is located at the south, while sample No. 9 is located at the north.

Blackley and Heathershow 1982 demonstrated a minimum transport rate for sand of 2.25 Phi in diameter and above.

Contradictory results have been observed by McCave 1978 on East Anglian beaches. He found that the mean grain size increased in the direction of wave-driven littoral sand transport. It would appear from McCave's study that the coarse particles migrate more rapidly than the fine ones. His results correspond to the observations of Watson 1972. Somewhat similarly, Komar 1977 found that the rate of transport was minimal for sand at 1.75 Phi diameter. The coarser particles migrated more rapidly than finer particles.

The differences of the results between the Eqah beach and East Anglian beach may be due to the different nature of the wave action (energy, heights and period) tidal current regimes and the nature of the shore, especially the composition of the sediments.

The landward face of the island was characterized by only medium sand particles with a random distribution of particles sizes ranging from 1.08 to 1.54 Phi. The grain size in this face appears to be coarser than in the front face, inspite of the permanent wave attacking the front face. This difference is due to the high gradient of the beach slope caused by retreat of the loose sediment on the island to the edge of the fringing reef. In the offshore face results indicate that mean grain size is decreasing along the beach which induce fining of particles in the direction of the wave-driven movement.

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اتجاهات أحجام الحبيبات لجزيرة شعابية حديثة في البحر الأحمر - المملكة العربية السعودية

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ص.ب. ٦١٦٨١ - الرياض ١١٥٧٥ - المملكة العربية السعودية

تقع جزيرة العيقة في البحر الأحمر حيث تبعد عن شمال مدينة جدة بـ ٤٥ كم، وعن الشاطئ بـ ٣ كم، يبلغ طول الجزيرة ١٠٠٠ م ويتراوح عرضها من ١٠٠ م في الشمال إلى ١٢٠ م في الجنوب. ويختلف ميل واجهات الشاطئ beach face في الجزيرة حيث ينحدر بشدة في الشرق (١ : ٥) بينما يكون الانحدار معتدلاً في الغرب (١ : ١٢). ويحيط بالجزيرة تجمعات مرجانية ضحلة ممتدة في اتجاه شمال - جنوب، مشكلة حواجز مرجانية تؤدي إلى إضعاف طاقة الموج القادمة من الاتجاه الشمالي الغربي السائد. تنمو بعض الأشجار المقاومة للأملاح من نوعي *Halopeplis perfoliata*, *Zygophyllum coccineum* L.، متناثرة بشكل عشوائي في وسط الجزيرة وفي طرفها الشرقي بينما تنمو تجمعات كثيفة من نوع *Atriplex* sp. على طول الشاطئ الغربي. وقد ساعدت هذه الشجيرات المتكاثفة النامية في الغرب على تكوين حواجز رملية ناتجة عن تثبيتها لحبيبات الرسوبيات التي تقذفها الرياح أثناء الجزر من منطقة المد والجزر intertidal zone ويوجد أدنى ارتفاع لهذه الحواجز الرملية في الشمال ويزداد ارتفاعها كلما اتجهنا جنوباً حتى تصل إلى ١,٥ م في أقصى الجنوب.

جمعت ٢٨ عينة رملية سطحية مبيّنة أماكنها بالأرقام على خريطة في شكل ٢ وتم الحصول من كل عينة منها على ٥٠ جراماً بعد غسلها وتجفيفها ونخلها

بمجموعة من المناخل يبلغ الفرق بين المنخل والذي يليه (١/٤ ريع فاي). كما جمعت عينات من الشعاب المكوّنة للجزيرة مبيّنة مواقعها بالأحرف، من بعض المواقع التي جمعت منها العينات الرملية لاستخدامها في تحديد أعمارها باستعمال النظائر المشعّة من المعادن النادرة ^{238}U , ^{234}U , ^{230}Th الموجودة في هذه الشعاب، وقد أُجريت هذه التقديرات في الجامعة الاسكتلندية للأبحاث والمفاعل الرئيسي بالمملكة المتحدة.

دلّ تحليل عينات الشعاب المرجانية على تكوّنها من معادن الارجونيات والكالسايت قبل ١٧٤٠ ± ٦٠ سنة. تميّز جزيرة العيقة رسوبيات متكوّنة من فتاتيات هيكلية وغير هيكلية كربونانية حديثة أقل عمراً من شعابها يبلغ متوسط أحجام رمالها من متوسط إلى دقيق وهي عديدة المنوالية ذات فرز يتراوح من جيد إلى متوسط. كما دلّت تحاليل الرسوبيات السطحية على حدوث اختلاف تدرّجي واضح في متوسط أحجام حبيباتها حيث تصغر أحجامها كلّما اتجهنا من الشمال إلى الجنوب وذلك في الشاطئ المقابل للبحر نتيجة حركتها الساحلية الطويلة بفعل الموج. أمّا في الشاطئ المقابل للأرض فإنه يتميّز بوجود حبيبات رملية ذات أحجام أكبر ناتجة عن الانحدار الشديد للشاطئ.