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Beach Erosion Variabiltiy during a Northeast Monsoon: The Kuala Setiu Coastline, Terengganu, Malaysia

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ABSTRAK

Pada umumya diterima ramai bahawa ombak besar pada musim tengkujuhlah yang menyebabkan berlakunya hakisan di beberapa kawasan pesisiran pantai di negeri-negeri pantai timur semenanjung Malaysia. Bagaimanapun, kajian ini yang meneliti 9 profil pantai sebelum dan selepas satu musim tengkujuh disepanjang 25 km pantai mendapati hanya dua stesen pemerhatian - kedua- duanya di sisi mulut muara sungai Setiu - dari sembilan stesen mengalami hakisan. Stesen-stesen lain mengalami endapan atau perubahan yang tidak ketara. Ini bermakna andaian yang menyatakan hakisan pantai adalah semata-mata diakibatkan oleh ombak besar dimusim tengkujuh tidak boleh dibuat secara menyeluruh pada semua pantai yang terhakis. Disesetengah pantai andaian ini mungkin benar sebahagianya sahaja. Analisa biasan ombak menunjukkan, selain dari ombak besar musim tengkujuh, batimetri luar pantai dan lindungan pulau-pulau merupakan faktor-faktor khas tempatan yang boleh mempengaruhi penumpuan atau penyebaran tenaga ombak untuk mengakibatkan hakisan atau mendapan di sesuatu bahagian pantai. Pengaruh kedua-dua faktor tersebut keatas ombak musim tengkujuh mestilah diambil untuk keberkesanan sesuatu polisi pengurusan pantai atau langkah-langkah pengawalan hakisan.

ABSTRACT

It is widely accepted that beach erosion occurring along the coastline of the east coast states of Peninsular Malaysia is caused solely by the large waves of the northeast monsoon seasons. However, this study, which monitored 9 beach profile stations before and after a NE monsoon along a 25-km stretch of the Kuala Setiu coastline showed that only 2 of the 9 stations — located on both sides of the Setiu estuary river mouth — were eroded. The others showed accretion or negligible changes. Thus the assumption that the monsoon waves are the sole cause of beach erosion cannot be applied to all eroding coastlines. For some coastlines, the assumption may be only partly true. Wave refraction analyses show that, beside the large monsoon waves, the offshore bottom bathymetry and island shelters act as site-specific factors either to help focus or disperse the energy of the monsoon waves to cause localized erosion or accretion. It is thus imperative that the modifying effect of bottom topography and island shelters on monsoonal waves be considered if proper beach management policies and erosion mitigation measures are to be effective.

Keywords: beach, erosion, monsoon

INTRODUCTION

Approximately 30% of Malaysia's coastline is experiencing erosion. Among the more seriously affected is the coastline bordering the South China Sea. The coastline of Terengganu has been reported to experience severe erosion. But the erosion is limited to only certain sections. Among the areas reported and observed by the authors to experience erosion are the areas near the mouth of the Terengganu estuary, Setiu estuary and Chendering (Stanley Consultants *et al.* 1985; McAlister and Nathan 1987). Speculations concerning the cause of beach erosion range from man's interference with nature to natural causes. The widely accepted hypothesis among many local researchers is that the erosion along Terengganu's coastline is primarily due to the large waves that batter the coastline during the northeast monsoon. During this season, which occurs annually from November to February, the waves are larger than normal due to the strong onshore winds and thus can cause comparatively more damage (Hill 1966; Wong 1979, 1981; Mastura 1987; Husain and Yaakob 1988). Studies on the changes in beach profile caused by the northeast monsoon waves by Wong (1979, 1981) showed that the sands and beach slopes at a section of the eastern Johor coast are generally coarser and slightly steeper after the northeast monsoon, indicating the erosive nature of the forces occurring during this season. Wong's studies concerning beach profile changes that occur during the monsoon and non-monsoon seasons have been useful in detailing the sequential changes occurring on beaches during the monsoon seasons. Other studies by Raj (1982, 1985) and Phillips (1985) concerning sediment transport rates and direction add to the understanding of the coastal processes of the area. They reported that the direction of longshore transport for the Setiu area is dominantly northwards. None of the studies have, however, offered any explanation to account for the observation by Zakaria (1970) who studied the Kelantan coastline and reported that during the northeast monsoon there is a large variability in erosion rates even on beaches found within a short section of the coastline and battered by the same monsoonal waves. Our study found not only erosion but also accretion occurring within a short 25-km stretch of beach during a single northeast monsoon season. There has been little effort to explain this erosional discrimination characteristic of the north-east monsoon waves on the coastlines of the east coast states of Peninsular Malaysia.

On this basis, this study attempts to identify the causes for the discriminatory erosional processes occurring within a short stretch of beach. This beach was observed to experience both erosion and accretion.

STUDY AREA

The study area is approximately 50 km north of Kuala Terengganu, located between Penarek (5° 36.42' N, 102° 49' E) and Setiu Lama (5° 41' N, 102° 43' E) *(Fig. 1)*. A 25-km stretch of beach, 15 km northwards and 10 km southwards of the Kuala Setiu estuary was chosen for this study. From personal observations spanning a period of two years and also from personal communications with the local villagers, this stretch of beach is stable in nature for most of the time with significant changes (erosion and accretion) occurring only during the monsoon months. There is sparse habitation on this stretch of beach, thus eliminating one factor that could contribute to erosion and complicating analysis of the erosion—accretion pattern. Sand materials make up the entire component of these beaches.

As with all coastlines bordering the South China Sea, the beaches here are annually subjected to the northeast monsoon weather when strong winds blow onshore from a northeast direction. Visual observations made during the northeast monsoon season (November to January) under study showed that the mean and the longest one-third wave periods were 8 and 10 seconds, respectively. Maximum and significant wave heights observed were 3.5 m and 3.2 m, respectively. These figures are close to those reported by the Malaysian Meteorological Service (1986-1989) and Mastura (1987). It is this type of large and long period wave that is most destructive and responsible for erosion during storm conditions (Sato *et al.* 1987).

METHODS AND MATERIALS

Nine profile and sampling stations, approximately 2 to 3 km apart, were set up on the 25-km stretch of beach. *Fig. 1* shows the location of the stations on the beaches north and south of the Kuala Setiu Estuary.

Beach profiles were surveyed twice, once in October 1990, just before the start of the monsoon season, and once in January 1991, at the peak of the northeast monsoon season (Wrytki 1961). The profiles were surveyed relative to a fixed marker using a transit level, metric staff and tapes following the method described by Mallik *et al.* (1987).

Beach sand samples were also collected twice, once each during the months of October, 1990 and January, 1991. At each station, approximately 300-gram sand samples were collected from three sites: the foreshore, the midshore and the backshore. The sand samples were brought back to the laboratory, air dried and sieved for 30 minutes using a sieve set and shaker. Their sedimentological characteristics of mean, sorting, skew and kurtosis were calculated using the graphical measures of Folk and Ward (1957) and Folk (1980).

Wave refraction diagrams for the 8- and 10-second wave periods, which are the mean and significant wave periods of the monsoon under study, were constructed using the graphic procedures described in the *Shore*

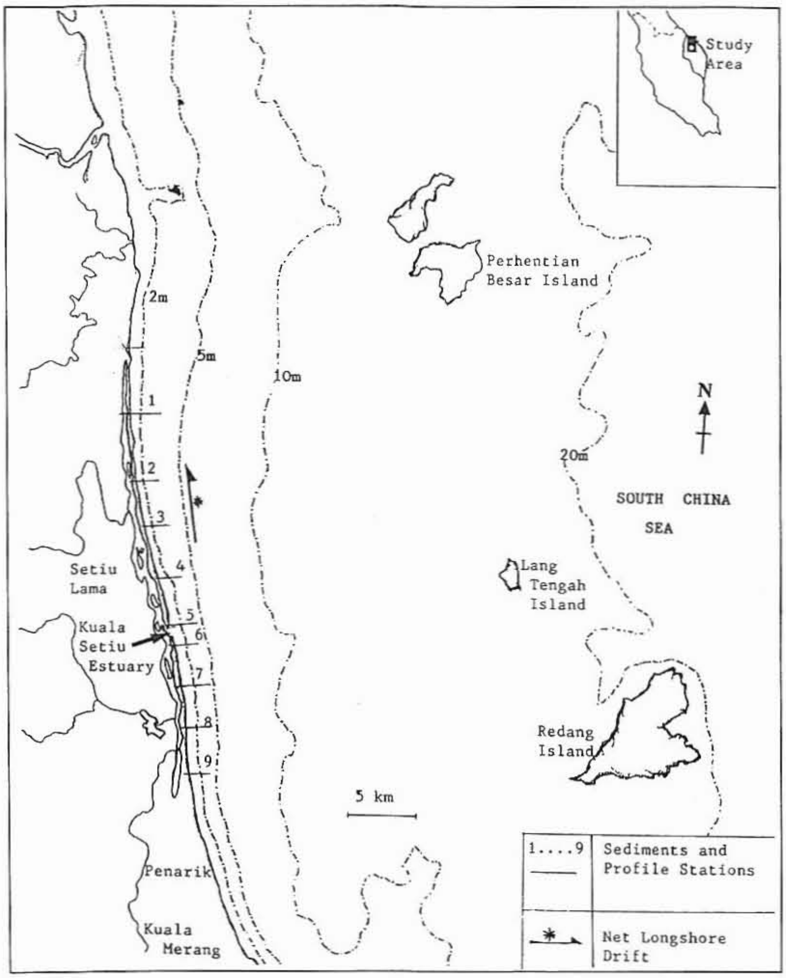

Fig. 1. Location map showing the Setiu coastline, shallow water bathymetry, netshore drift direction and relative position of sampling stations and offshore islands (From Raj 1982 and Philips 1985)

Protection Manual (Coastal Erosion Research Center 1984). Using the procedures described by the above-mentioned manual, the deep-water wavelengths (L_o) for the 8- and 10- second wave periods were calculated to be 99.30 m and 155.15 m respectively. The wave approach angle used in constructing the refraction diagram was 45°. This angle was chosen as it represents the mean approach angle of the deep-water waves during the northeast monsoon season under study.

RESULTS AND DISCUSSION

In general, the profile shape of stations showed little difference between stations and between the months of October and January, despite the larger waves occurring during the months of November to January. The profiles show the beach morphology from the backshore to the foreshore to be simple, following either a convex profile or a slightly concave profile *(Fig. 2)*. Significant change in profile shape from October to January only occurred at three stations: 5, 6 and 7. At stations 5 and 6 the convex midshore region became concave; the reverse is true for station 7. All other stations showed negligible change. No formation of berms is evident for either month. This shape of beach fits the description of a reflective beach, which usually occurs in microtidal areas with predominant waves of <1 m (Wright and Short 1983). Wright and Short (1983) also mentioned that in response to larger wave conditions, the reflective morphology evolves to a dissipative morphology by forming berms, becoming flatter and wider. These transformations are not evident for the January profiles of all stations, despite the observation that predominant waves between the months of November to January were larger (2.2 m) and reached a maximum height of 3.5 m. But, comparison of composite sediment characteristics at all stations shows that the mean grain size is on the average coarser in January than October. The average sedimentological characteristics of sorting, skew and kurtosis show that the sediment collected during the month of January is better sorted, less negatively skewed and more peaked than the sediment collected during the month of October (Table. 1). This could be attributed to the erosive capacity of the northeast monsoon waves as mentioned by Wong (1981) and Mastura (1987). The stronger and larger northeast monsoon waves serve to suspend and carry away the finer beach sediments either offshore or as longshore drift. With the removal of the finer sediment, the remaining sediment on the beach will therefore be coarser, better sorted and more peaked comparative to the period before the advent of the large northeast monsoon waves. This does not mean that the northeast monsoon waves can cause erosion; it only serves to show that the January waves are larger than those occurring during October. Additionally, the stability (reflective morphology) of the beach profile both before and during the peak of the monsoon season shows that the area is predominantly non-erosive, despite the larger waves reported (Malaysian Meteorological Service 1986-1990) and observed to occur during the northeast monsoon season. This is clear when comparison is made between the October and January profiles.

Accretion is evident at stations 1, 2, 7 and 9 while erosion is evident at only two stations, 5 and 6. Other stations (3, 4 and 8) show negligible changes. There is no spatial trend either in accretion or erosion. The accretion at stations 1 and 7 occurred primarily in the midshore region, while at stations 2 and 9 accretion occurred at both the midshore and

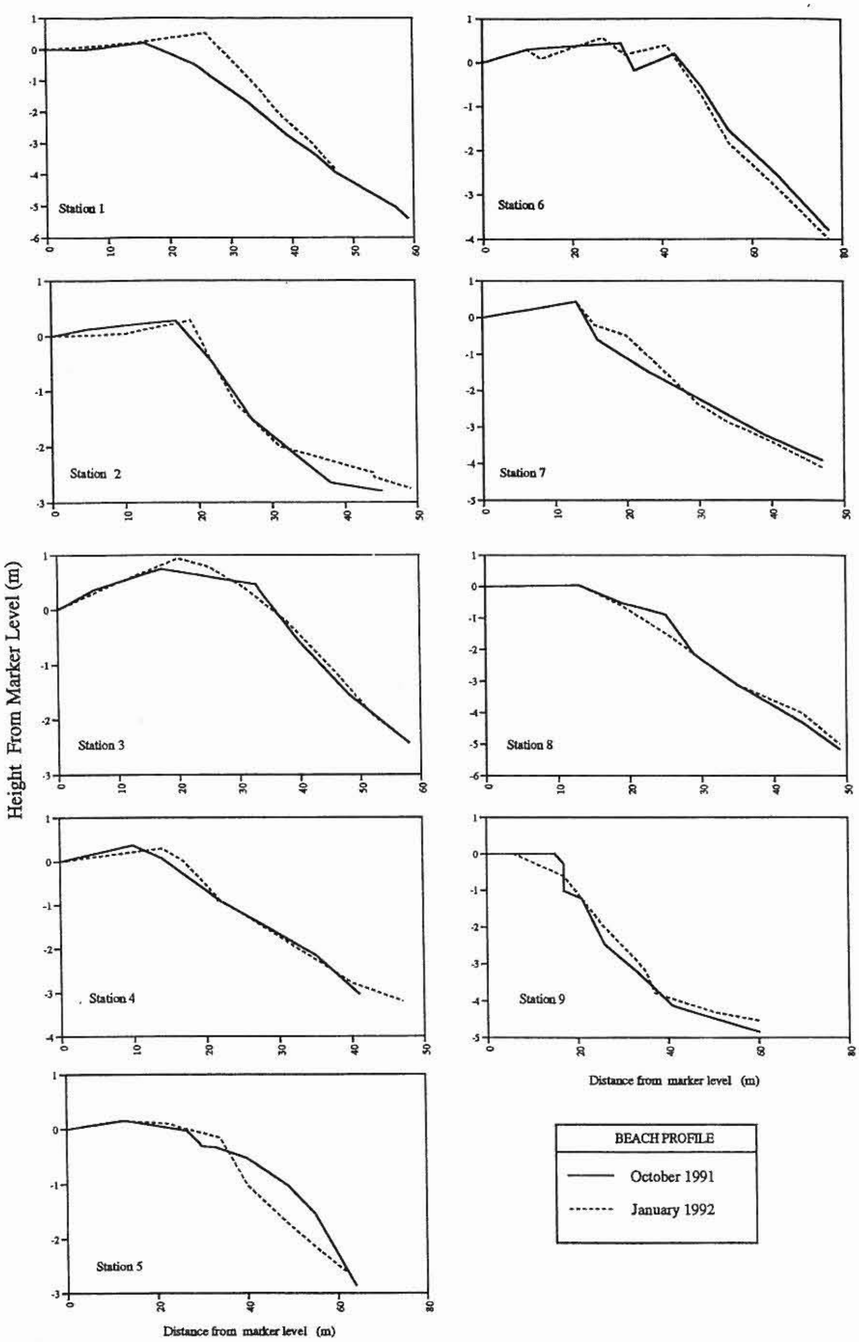

Fig. 2. Beach profiles of October 1991 and January 1992

Table 1
Sedimentological characteristics for the months of October 1991 and January 1992

	Mean (ϕ)		Sorting (ϕ)		Skewness		Kurtosis	
Stations	Oct	Jan	Oct	Jan	Oct	Jan	Oct	Jan
1	1.89	1.38	0.78	0.68	0.11	0.10	0.77	0.98
2	1.50	1.22	0.77	0.61	-0.24	0.11	0.96	1.02
3	1.40	0.10	0.80	0.7	-0.1	0.02	0.80	0.96
4	1.32	0.83	0.70	0.62	-0.08	-0.03	1.09	0.35
5	1.40	0.70	0.70	0.60	-0.16	0.21	0.95	1.22
6	1.05	1.11	0.88	0.62	-0.04	-0.02	0.94	1.07
7	0.80	0.83	.084	0.59	-0.26	0.06	1.11	1.42
8	0.45	0.40	.067	0.57	-0.34	-0.09	1.10	1.29
9	0.33	0.25	.066	-0.60	-0.06	-0.02	1.09	1.18
Average	1.127	0.87	0.54	0.621	-0.13	0.025	0.98	1.165

foreshore regions. It should be noted that at all the accreting stations there is no evidence of backshore retreat or erosion to suggest that sediments deposited on the midshore region are from those areas.

Erosion, on the other hand, occurred at only two stations (5 and 6), located on either side of the mouth of the estuary. Erosion at these two stations occurred primarily from the foreshore to the midshore region only.

It seems that during the northeast monsoon not only is the erosion rate on the beaches variable, but it is dominated by accretion despite the observation and reports that waves and sediments during this season are larger and coarser, respectively, than normal. This is clearly contrary to the supposition that the east coast beaches of Peninsular Malaysia should experience erosion during the northeast monsoon season. Since storms and large waves are predominantly erosive (King 1972; Dolan *et al.* 1983; Kuhn and Shepard 1983; Mallik *et al.* 1987; Tilmans 1991), site-specific factors must be evoked to account for the discrepancy between observed and expected trend of erosion on this stretch of coastline.

As mentioned above, since there is no erosion occurring on the upper or backshore areas to account for the sediments deposited on the midshore region, It is very likely that the sediments originated from offshore. Deposition at the foreshore region, near the water's edge at stations 2 and 9, beside the midshore region, lends support to this supposition. For deposition to occur during the northeast monsoon season, most of the energy of the larger waves occurring during this season must have been spent offshore through erosion and shoreward transportation of offshore bottom sediments. This may take the form of shoreward migration and erosion of offshore bars as reported by Zakaria and Jamaluddin (1980) for the Kelantan coast during the northeast monsoon season. Since the Setiu coastline is close to the Kelantan coast, it may be exposed to similar nearshore processes which result in shoreward migration and erosion of offshore bars.

Using the latest bathymetry map of the area surveyed by the Royal Malaysian Navy in 1991, wave energy dispersion and convergence were andysed using wave refraction diagrams for the 8- and 10- second waves approaching the shoreline from the NE direction *(Fig. 3 and 4)*. The 8- and 10- second waves were chosen as they represent the mean and the significant wave periods of the northeast monsoon season under study.

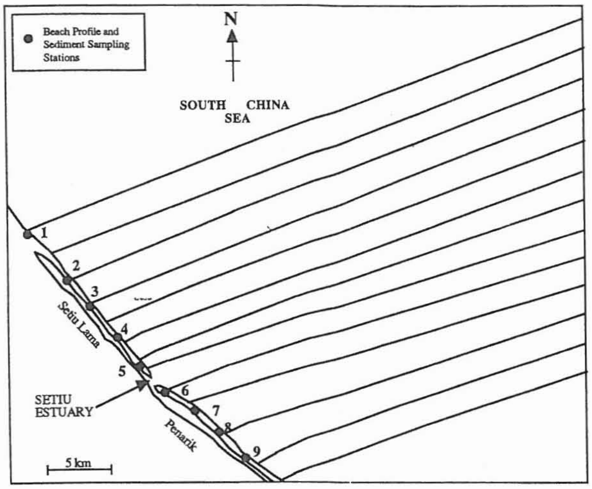

Fig. 3. Wave refraction for T=8 seconds; Lo = 99.30 m; Wave approach angle = 45 degrees

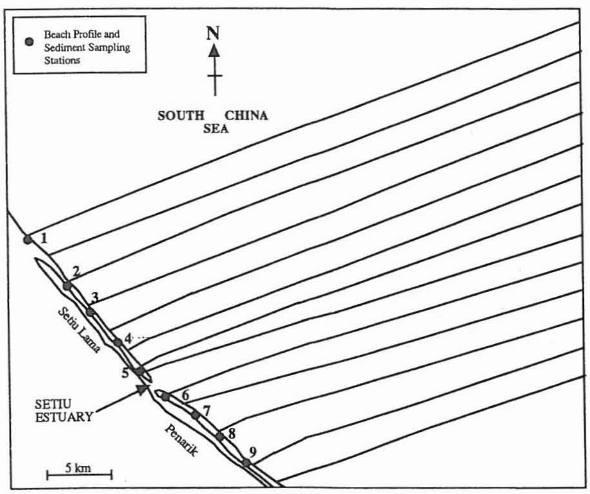

Fig. 4. Wave refraction for T = 10 seconds; Lo = 155.15 m; Wave approach angle = 45 degrees

For the 8-second wave refraction, wave energy seems to be fairly distributed along the coastline except at stations 5 and 6 whose refraction index (R.I.) was 2.87 and 2.25 respectively. At other stations, the R.I. values are either less than 1.00, indicating divergence of wave energy, or close to 1.00, indicating no change in the concentration of offshore wave energy at the coastline. Although the R.I. values for the 10-second wave refraction differ from those of the 8-second wave refraction analysis, the same trend of wave energy dispersion and concentration seems to occur at the coastline. The R.I. at stations 5 and 6 is slightly higher with values of 3.00 and 2.50 respectively, indicating a much more concentrated wave energy at these two sites. The R.I. values of less or close to 1.00 at other sites still indicate divergence or no change of offshore wave concentration occurring at the coastline. Convergence of wave energy results in higher and more energetic waves arriving at the shoreline (Coastal Erosion Research Center 1984) and may thus account for the midshore erosion at the two stations. At the other stations, there seems to be either no change or divergence in the wave rays at the shore. Divergence results in waves arriving at the shoreline to be smaller and less energetic, making sediment deposition close to or on the shore possible. Seabed sediments deposited near the shoreline will be picked up by oncoming waves and deposited on the beach. This mechanism may account for the accretion on the midshore region of beaches at stations 1, 2, 7 and 9.

Since wave refraction patterns are dependent upon the wave period and the offshore bathymetry (Coastal Erosion Research Center 1984; Cheong 1991), it is reasonable to postulate that the offshore bottom bathymetry is one of the site-specific factors determining the erosion accretion pattern on this stretch of beach during the northeast monsoon season. Additionally, the relatively long period of waves during this season means that shoaling happens earlier and further offshore in the deeper waters. This results in the disturbance of a longer stretch of offshore sediments and can result in shoreward transportation of offshore sediments by the northeast monsoon waves. These sediments can be deposited on the beaches resulting in accretion when the wave energy is dispersed at the shoreline . This mechanism can be used to explain the midshore accretion observed on the beach at stations 1, 2, 7 and 9 since there was no profile change observed.

The consequences of earlier shoaling for the long period waves are earlier bottom disturbance and shoreward transport of sediment. More importantly, this results in the reduction of wave energy prior to reaching the coastline. This can account for the predominant accretion and the less destructive capacity of the monsoon waves in this area. The reduction in energy due to shoaling is augmented by the sheltering effect of this part of the coastline by two islands Redang and Lang Tengah, which are located approximately 15 km and 10 km offshore in a NE direction. The effectiveness of these island shelters in reducing the amount of wave energy can be seen by the 2, 5 and 10 m contour lines, which increase in width northward, starting from Kuala Merang *(Fig. 1)*. Both islands act as a natural wave barrier dispersing some of the wave energy behind the islands, thus reducing the wave energy arriving at the Setiu shoreline. This will cause both the sediment transported alongshore and the sediment transported shoreward to experience lower energy and thus earlier deposition. Since the predominant direction of longshore sediment transport along this coastline is in a northerly direction (Raj 1982; Phillips 1985) earlier deposition of the longshore sediments would have resulted in the northwards increasing width of the 2, 5 and 10 m contour lines. Additionally, sediments transported shoreward also experience earlier deposition due to the reduction in wave energy and contribute toward the northward increasing width of the 2, 5 and 10 m contour lines.

The island shelters and the offshore bathymetry seem to be two site-specific factors contributing to the varying accretion erosion effect of the northeast monsoon waves. The island shelters act as wavebreakers, thus reducing the destructiveness of the waves on the coastline. The offshore bathymetry, on the other hand, not only aids in reducing the energy of the long period monsoon waves by causing earlier shoaling but, more importantly, influences the refraction pattern to result in divergence or convergence of wave energy to cause accretion or erosion. Thus, accretion can be the result of the combination of several factors: reduction in energy due to the effect of island shelters, earlier wave shoaling and sediment transport and divergence of wave energy at the shoreline. Erosion, on the other hand, seems to be solely the result of wave energy convergence, the direct consequence of the offshore bathymetry for the type of wave found during this season.

CONCLUSION

This study shows that although the larger waves of the northeast monsoons may, in general, be erosional in nature, their net effect on specific stretches of coastlines may be dependent upon site-specific factors including the bathymetry of the offshore areas fronting the coastline and the effect of island shelters. The shape of the offshore bathymetry affects wave shoaling and subsequently the refraction pattern and direction of the wave rays, determining whether the wave energy will be focused or dispersed at the shoreline. The effect of islands found close to the shoreline serves to limit the wind fetch, thus limiting the wave energy arriving at the coastline. These two factors have been found to be responsible for causing a variable accretion-erosion trend within a short 25-km section of the Setiu coastline. Erosion, which occurred at only two stations during the northeast monsoon season, is the result not only of the larger monsoon waves but also of the focusing of the wave energy in these areas by the wave refraction pattern, which is dependent upon the shape of the offshore contours. Accretion, on the other hand, may be caused by the shoreward movement of offshore materials because of the earlier shoaling activity of the long wave periods of the northeast monsoon season and the dispersal of wave energy at the shoreline.

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