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Beach changes on a monsoon coast, Peninsular Malaysia

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Abstract: The northeast monsoon (November–February) has a greater impact than the southwest monsoon (May–August) on the east coast of Peninsular Malaysia. Beach changes from the southwest monsoon to the northeast monsoon are abrupt, compared to the gradual recovery of the beach from the northeast monsoon to the southwest monsoon. Although its impact varies yearly, the northeast monsoon leaves behind a beach in which the backshore and the upper foreshore are relatively undisturbed by low wave action in the succeeding monsoon until the onset of the next northeast monsoon.

The impact of the northeast monsoon on the beaches is essentially erosional; the foreshore and backshore are cut back, ridges are flattened and the beach profile is smoothed out. In contrast, the beaches are accretional during the southwest monsoon; accretion takes place on the foreshore and decreases in intensity landward. Ridges, bars, berms and cuspate features are more common during the southwest monsoon than during the northeast monsoon.

Foreshores with sand less than 0.5 mm diameter tend to build a relatively steeper gradient in the southwest monsoon than in the northeast monsoon; foreshores with sand more than 0.5 mm diameter are unable to build a relatively steeper gradient in the southwest monsoon and in fact have a slightly lower gradient in the southwest monsoon.

Beach cusps of the northeast monsoon are found at a higher level on the beach and are spaced 24.38–30.48 metres (80–100 feet); they remain in a degraded form and are succeeded in the southwest monsoon by another series at a lower level on the beach with spacings at 15.24–18.29 metres (50–60 feet).

The ridge and runnel topography is more common in the southwest monsoon than in the northeast monsoon. For beaches with such topography in both monsoons, the ridges and runnels are more pronounced and of a higher amplitude in the southwest monsoon than in the northeast monsoon. Under constructive wave action, the ridges migrate upbeach and eventually merge with the upper foreshore or the berms. Where there is an abundant supply of fine sand, the ridge topography is further enhanced by aeolian action. Beach vegetation also helps to maintain the height and configuration of the ridges. The alternation of 'cut' during the northeast monsoon and 'fill' during the southwest monsoon in an area of active ridge formation will eventually produce a successive series of parallel ridges.

The monsoons also affect the direction and magnitude of the littoral transport. The nearshore topography acts as a reservoir for material removed from the beaches during the northeast monsoon and a source of migratory forms moving landward and upbeach during the southwest monsoon.

INTRODUCTION

That almost all beach changes in nature follow some kind of regularity has been noted in many studies. In areas of seasonal variable wave energy, an annual cycle of erosion in winter and accretion in summer is present in beach changes (Shepard, 1950; Darling, 1964). Shorter cycles of erosion-accretion have been recorded for a fortnightly tidal cycle (Inman and Filloux, 1960) and for a single tidal cycle (Duncan, 1964; Otvos, 1965; Strahler, 1966).

This paper presents the results of numerous observations and four beach surveys conducted at twenty-two locations on the east coast of Peninsular Malaysia over a two-year period. Except for one location, JAS, which was surveyed a month or two later in the first three surveys, the surveys were carried out in March 1975 (Survey I), August 1975 (Survey II), March 1976 (Survey III) and August/September 1976 (Survey IV). The surveys were timed to investigate the effects of the monsoons, which have long been known to mariners (Wheatley, 1961) and are noted in sailing manuals (Hydrographic Department, 1964). Knowledge of the seasonal beach changes on this coast have been limited to one study at Sri Pantai by Hill (1966) and passing comments by Nossin (1965), Swan (1968), Zakaria (1970) and Koopmans (1972).

The objective of this paper is primarily to show the impact of the monsoons on a coast dominated by one monsoon season. In particular, it will describe the profiles resulting from each season, the changes between the monsoons and the major features formed on the beach profiles. Seasonal changes of the beach vegetation have been discussed elsewhere (Wong, 1978).

STUDY AREA

The east coast of Peninsular Malaysia is backed by a Quarternary coastal plain for most of its length, except between Dungun and Kuantan and along the Johore coast where the highlands form major headlands and stretches of cliffs (Fig. 1). Of the east coast 92.3 per cent have beaches and 7.7 per cent are without beaches (Swan, 1968: p 129). The coast is cut by a number of rivers, the largest of which are Sungai Pahang and Sungai Kelantan, at where the coastal plain is widest.

Individual stretches of beaches between the estuaries and headlands are mainly concave in plan (Fig. 1). Between Kuantan and Dungun and south of Jason Bay, the beaches take a distinctive J-shape in which the upcoast northern end in the lee of the headland is curved and the downcoast southern end, which is exposed to the northeast monsoon, is straight. Straight stretches of beaches are found along the Trengganu coast where barriers extend along the coast.

A series of sandy ridges known locally as 'permatang' is found along the east coast. Although most investigators recognized two series, the inland and older series and the coastal and younger series, their origin and sequence of the formation are still not fully understood (Fitch, 1952: 60; Nossin, 1961, 1964a, 1964b; Teh, 1976) on account of insufficient knowledge of the Pleistocene history of the coast. Along the present coast, the formation of these ridges goes on.

The marine environment of the east coast is seasonal in character and dictated by the monsoons. Strong waves are prevalent during the northeast monsoon (November–February) when the winds are onshore; during the southwest monsoon (May–August) the winds are offshore and weak (Fig. 2). Available wave data reported by ships off the east coast in the area bounded by 0–10°N and 100–110°E show that

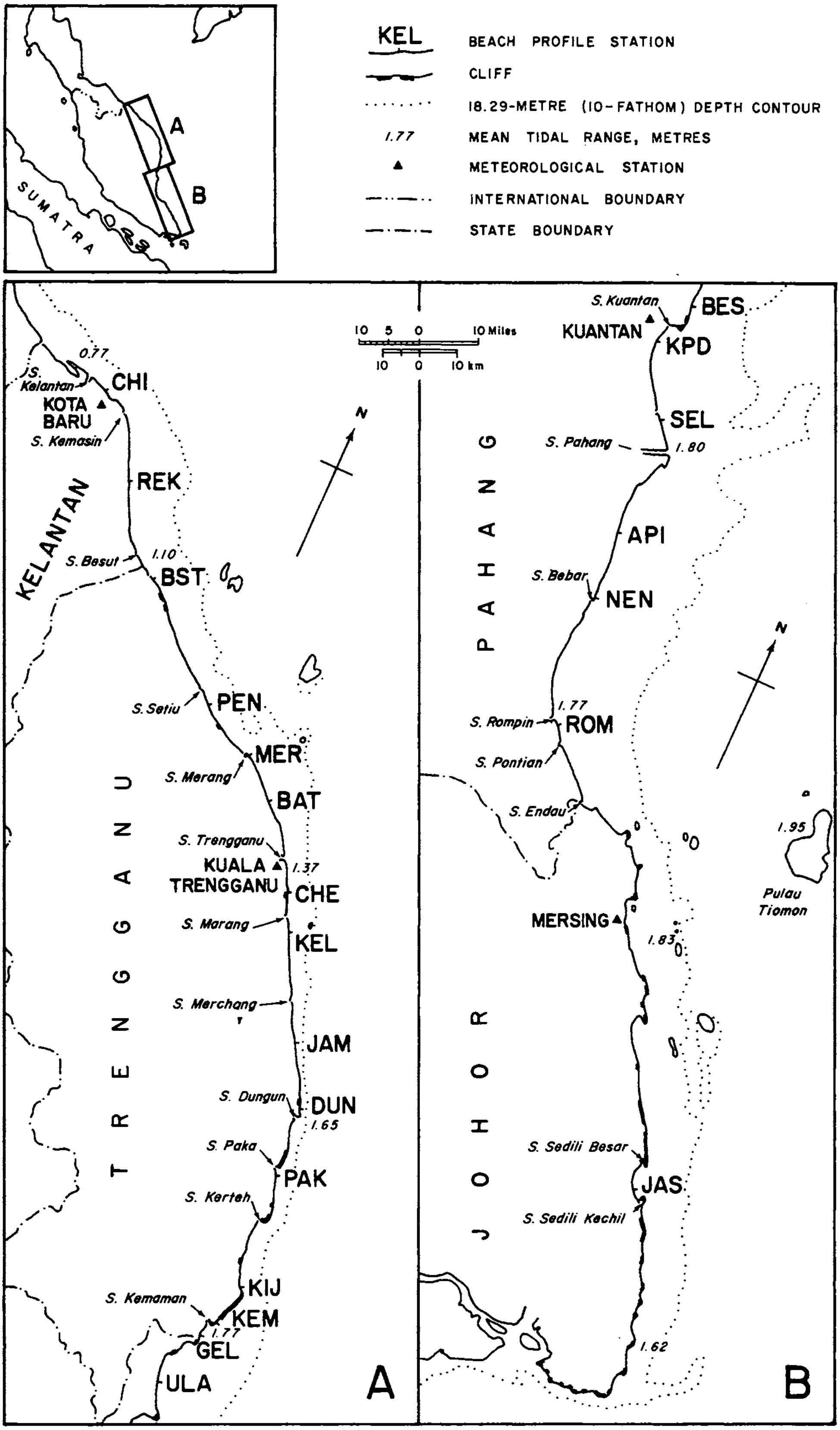

Fig. 1. Study area: east coast, Peninsular Malaysia.

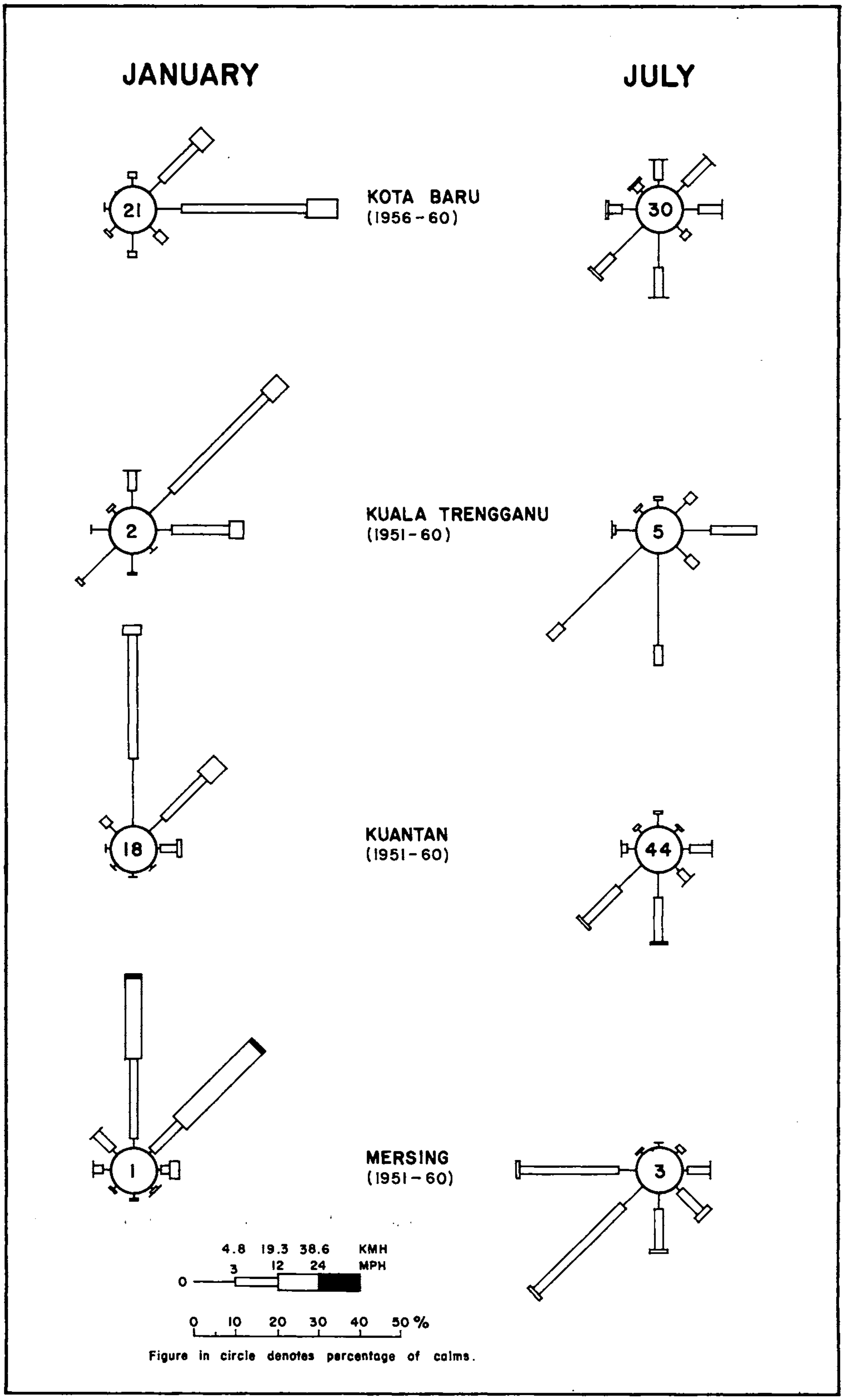

Fig. 2. Wind roses for January and July at Kota Baru, Kuala Trengganu, Kuantan and Mersing. See Figure 1 for location of these meteorological stations.

between December and February, 73 per cent of the waves are more than 0.46 metres (1.5 feet) compared to 48 per cent between May and September; the prevailing wave direction is from the north during December to February and from the south during May to September. For both monsoons, the prevailing wave period is 5 seconds or less (Hogben and Lumb, 1967). However, in many coastal stretches, especially concave curves between pronounced headlands, the character of the beach is determined locally by the degree of exposure, the supply of material from the cliffs or rivers and the littoral drift.

These tides are semi-diurnal and meso-tidal. The minimum mean range is 0.76 metre (2.5 feet) at Tumpat; this increases southward to a maximum to 1.95 metres (6.4 feet) at Kuantan and then decreases southward to 1.62 metres (5.3 feet) at Tanjong Penawar (Admiralty charts 3839, 769, 770, 771) (Fig. 1). The tidal range is important as it influence the area of beach exposed, assuming beach gradient remains unchanged.

METHOD

Selection of Stations. Topographic sheets of the east coast of 1:63,360 scale and information from the relevant pilots (Hydrographic Department, 1958, 1964) were first examined for the selection of stations representing suitable coastal stretches, i.e. those clearly separated by estuaries or prominent headlands or along large bays and be exposed as possible to the northeast monsoon. Locally sheltered stretches and small bays were excluded from consideration. Initially, thirty-odd stations were selected but practical problems of accessibility by vehicle reduced the number to twenty-two for profiling (Fig. 1, Table 1).

Beach Profiling. At each station marked by a tree or some other feature, a profile normal to the coast was laid out by a 30.48 metre (100-feet) tape. The changes in height along the profile were measured by two 1.52 metre (5 feet) graduated staves according to a method adapted from Emery (1961) and values were read to the nearest 0.006 metre (0.02 feet). Elevation changes were not taken at fixed horizontal distances but as determined by ground configuration and within the limits of visibility of figures on the staves 7.62 metre or (25 feet maximum). After each 30.48 metre (100-feet) stretch and profiling was measured, the tape was removed to the next 30.48 metre (100-feet) stretch and profiling carried on to beyond the prevailing water level as permitted by wave action. Along with the values of height differences and distances along each profile, other topographic details were recorded, e.g. crest, trough, swash mark, sand scarp, beach cusp, step. One disadvantage of this method of measurement is that since the method is dependent on the horizon being visible, a high ridge may prevent profiling from being carried out on the lee of the ridge; in such cases, the Abney level is used to continue the profile landward from the ridge. This happened only at one station (NEN). On the other hand, the method is rapid and sufficient to give a quantitative picture of the beach profile.

Profile data were plotted on graph paper and comparison of profiles of each station were first carried out on the basis of changes from the northeast to the southwest monsoons of each year (surveys I to II, III to IV) and then from the southwest to the northeast monsoons (surveys II to III). Comparison was also made

TABLE 1

BEACH PROFILE STATIONS, PENINSULAR MALAYSIA

Station	Name
JAS	Jason Bay
ROM	Kuala Rompin
NEN	Nenasi
API	Kuala Api Api
SEL	Kampung Tanjong Selangor
KPD	Kampung Kempadang
BES	Beserah
ULA	Kampung Sungei Ular
GEL	Kampung Geliga Besar
KEM	Kemaman Motel
KIJ	Kijal
PAK	Paka
DUN	Dungun
JAM	Kampung Jambu Bongkok
KEL	Kampung Kelulut
CHE	Kampung Cenering
BAT	Batu Rakit
MER	Kampung Merang
PEN	Kampung Penarek
BST	Kuala Besut
REK	Kampung Kuala Rekang
CHI	Pantai Cinta Berahi

between profiles of surveys I and III to give some idea of the extent of change by the northeast monsoons on the beach.

Sand Samples. Sand samples were taken from the middle of various zones or features along the beach profiles, e.g. crest of ridge, bottom of trough, mid-berm, mid-tide location on foreshore, top of bar. At where the mid-tide sample was taken, the slope of the beach face was measured by an Abney level.

In the laboratory, the sand samples were washed carefully to remove the salt, dried in the oven and representative splits taken for sieving through standard 20.32-cm (8-inch) sieves spaced at $\frac{1}{2}$ phi intervals. Each sample was sieved for 15 minutes on an Endecotts sieve shaker. The grain size data were reduced to percentages and plotted on logarithm probability paper from which grain size measures of Folk and Ward (1957) were computed.

PROFILE STATIONS

Distribution. The distribution of profile stations along the east coast is uneven. Due to inaccessibility from land, the Jason Bay–Mersing stretch and the coast south of Jason Bay have no stations. Along part of the Trengganu coast, lagoons separate the beaches from the mainland and limit the number of profile stations.

Taking 724 km (450 miles) as the total length of the east coast, the twenty-two stations would give an average of one station for about every 32 km (20 miles); excluding the stretches of 'hard' coasts this average distance between stations would be smaller. Although not all sandy stretches have representative profile stations, the twenty-two stations should be adequate enough to form the basis for generalizations on beach changes on the east coast.

Description. The profiles of the twenty-two stations vary in character; the foreshore width can be less than 30.48 metres (100 feet) to more than 121.9 metres (400 feet). Values of foreshore slopes at the mid-tide zone ranged from 1°40′ to 12°. On the whole, the stations have steep foreshores; only JAS, ROM, KPD, BES and REK averaged less than 5°while the rest averaged more than 5°. In terms of grain size, the stations can be divided into seven fine sand, seven medium sand and eight coarse sand beaches, based on the average of mean grain sizes of samples collected during the four surveys from the foreshore and backshore zones of the profiles; these values do not differ very much from the average median grain size of four samples from the mid-zone of each station (Table 2).

TABLE 2

GRAIN SIZES OF BEACH PROFILE STATIONS,
PENINSULAR MALAYSIA, 1975–1976

	Foreshore and Backshore					Mid-tide Zone
Station	Number of samples	Mean Size mm				Median Size, mm
		Min.	Max.	Av.	Type	Average
JAS	8	0.08	0.15	0.13	fine	0.12
ROM	9	0.14	0.23	0.19	fine	0.23
NEN	10	0.28	0.62	0.51	coarse	0.53
API	4	0.49	0.95	0.72	coarse	0.72
SEL	11	0.21	0.88	0.40	medium	0.40
KPD	15	0.15	0.23	0.20	fine	0.21
BES	9	0.13	0.17	0.15	fine	0.15
ULA	9	0.20	0.40	0.24	fine	0.27
GEL	7	0.41	1.13	0.65	coarse	0.65
KEM	10	0.25	0.41	0.31	medium	0.33
KIJ	7	0.33	0.66	0.44	medium	0.46
PAK	5	0.44	0.90	0.69	coarse	0.69
DUN	8	0.46	1.04	0.73	coarse	0.70
JAM	7	0.41	0.70	0.57	coarse	0.55
KEL	6	0.49	1.13	0.68	coarse	0.67
CHE	7	0.19	0.30	0.22	fine	0.25
BAT	8	0.27	0.47	0.37	medium	0.35
MER	5	0.31	0.66	0.44	medium	0.45
PEN	8	0.40	0.59	0.49	medium	0.47
BST	7	0.33	0.46	0.40	medium	0.38
REK	8	0.15	0.27	0.20	fine	0.21
CHI	6	0.39	0.86	0.55	coarse	0.55

Not all profiles possess the 'permatang' (sand ridge) in the backshore. NEN, BES, ULA and KEM each has a distinctive sand ridge with heights up to a maximum of 2.44 metres (8 feet); a low sand ridge of less than 0.91 metres (3 feet) is found at JAS, GEL, PEN and REK. At SEL, ROM and KHD here aggradation is dominant, a wide belt of sand ridges developed; zonation in terms of ridge development is best seen at KPD. Along the Trengganu coast, especially where the foreshores are steep, the ridges are less distinctive or absent and are replaced by storm berms, e.g. KEL, PAK.

Coastal erosion is prevalent at three stations: API, MER and CHI. API has a foreshore fronting a 1.52 metre (5-feet) scarp which had eroded a couple of feet during the two-year survey. At MER , erosion has reached the base of the old sand ridge and worked around the base of the coconut trees. At CHI, the coastal belt of coconut trees has been penetrated by erosion resulting in widespread collapse of the palms and the formation of scarps.

BEACH CHANGES

Accretion and Erosion. In comparing the beach profile at the end of the southwest monsoon with that at the end of the northeast monsoon (surveys I & II, III & IV) the southwest monsoon beach profile is predominantly accretional in character. Accretion took place mainly on the foreshore or the lower foreshore and usually decreased from the foreshore to the backshore. Accretional forms such as ridges, bars, berms and cuspate features were profiled or observed during the southwest monsoons (Figs. 3–5). Erosion during the southwest monsoon was less common and was limited to the foreshore or the cutting back of the northeast monsoon berm. Equally less common was erosion and accretion occurring on the same profile, in which case, erosion was generally on the upper foreshore and accretion on the lower foreshore.

In comparing the beach profile of the northeast monsoon with that of the preceeding southwest monsoon (surveys II & III) the northeast monsoon beach profile is essentially the result of erosion. Erosion cut back the foreshore and backshore, flattened the ridges on the foreshore or smoothed out the foreshore (Fig. 3). Erosion could be accompanied by accretion during the northeast monsoon in which berm crests and berms were formed in the backshore. Only two stations, PAK and BST, showed accretion at the end of the northeast monsoon.

Foreshore Slope and Grain Size. Since the beaches are erosional during the northeast monsoon, it is to be expected that they would be combed down to a lower gradient by the higher waves, and during the southwest monsoon, the foreshore would increase in gradient as a result of accretion. Values of mean grain size and foreshore gradient for each profile station were averaged for the northeast monsoon and for the southwest monsoon; these are plotted in figure 6.

The relationship between foreshore slope and grain size varies linearly for each monsoon but grain size becomes critical at a certain size. Foreshores with sand less than 0.5 mm median diameter were able to build a relatively steeper slope in the southwest monsoon than in the northeast monsoon; foreshores with sand more than 0.5 mm median diameter were unable to build a relatively steeper slope in the south-

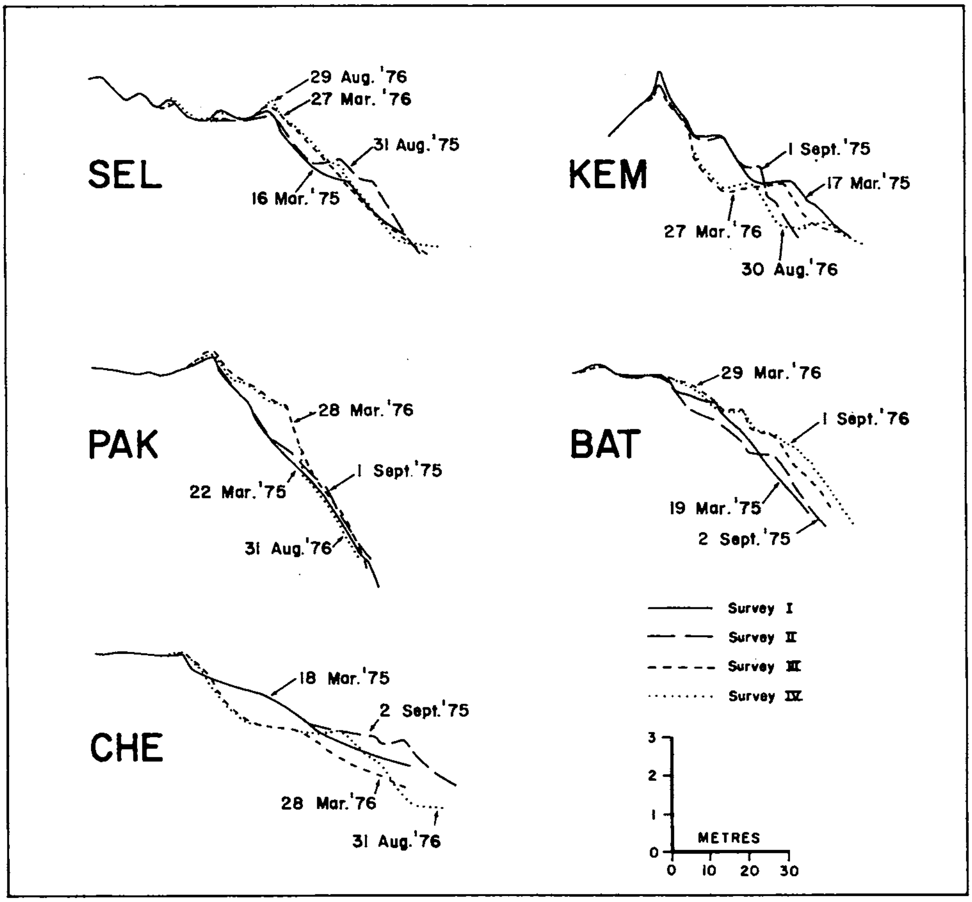

Fig. 3. Beach profiles at the end of each monsoon in 1975 and 1976 (Surveys I, II, III and IV) at SEL, PAK, CHE, KEM and BAT.

west monsoon than in the northeast monsoon and, in fact, had a slightly lower slope in the southwest monsoon. In general, this means a larger seasonal difference in foreshore slope is expected for beaches composed of sand less than 0.5 mm and a smaller seasonal difference for beaches composed of sand more than 0.5 mm.

Severity of the Northeast Monsoon. In comparing the beach profiles from one monsoon to the next (i.e. surveys I to II, II to III, III to IV) it was found that the beach changes from the southwest monsoon to the northeast monsoon were more pronounced than those from the northeast monsoon to the southwest monsoon, except where the ridges and bars were very marked during the southwest monsoon. In general, the northeast monsoon at the end of each season left behind a beach in which the backshore and the upper foreshore were relatively undisturbed by normal wave action in the succeeding southwest monsoon until the onset of the next northeast monsoon (Figs. 3 5). Any large-scale change to the backshore during the southwest monsoon would come from the occasional storm or locally through a resumption of man's activities after the northeast monsoon, e.g. fishing, turtle watching, recreation.

Features formed on the backshore and upper foreshore of the east coast beaches by the northeast monsoon are therefore more likely to be preserved through the succeeding southwest monsoon than features formed during the southwest monsoon and succeeded by the northeast monsoon. The more common features were swash marks, overwash fans and beach cusps and the less common were 'winter' berms, berm crests and sand scarps. At JAS, wind and wave action during the 1975/76 northeast monsoon swept over the low sand ridge and left behind elongated overwash fans on the leeward side of the ridge; these fans were aligned at about 30° N, 12.19–15.24 metres (40–50 feet) in length and about 0.3048 metre (1 foot) in thickness.

The intensity of the northeast monsoon varies from year to year, so that when beach profiles obtained at the end of two northeast monsoons are compared, accretion, erosion, accretion and erosion or no change between the profiles can be expected. Comparing beach profiles of surveys I and III, no significant changes were found in two stations, erosion in seven stations, accretion in five stations and both erosion and accretion in the rest. It is evident that waves during the northeast monsoon could reach a higher level on the beach and further inland, as aresult of which erosion or accretion could occur on the backshore and the sand ridges.

Ridges, runnels and nearshore topography. During profiling, ridges and runnels were measured across the gentle and wide foreshore of several stations. Because profiling did not go far beyond the water's line and depending on the stage of tide and wave condition at the time of profiling, not all ridges were measured. For example, in survey II, although one ridge was shown on the beach profile of ROM, a second ridge was just about to appear above the water level and a third was still under water. From their incidence on beach profiles and observations made, the ridges and runnels were more common during the southwest monsoon than during the northeast monsoon and for a few stations in which such topography was recorded on their foreshores in both monsoons, the ridges and runnels were more pronounced and of a higher amplitude in the southwest monsoon than in the northeast monsoon. Examples of ridges recorded at various positions on the foreshores of stations during the southwest monsoon are shown in figure 4.

The ridges varied in height from station to station. At ULA, KPD and ROM the height of the ridge crest above the runnel was almost 0.91 metres (3 feet), while at BES and JAS the ridges were low and subdued. The configuration of each ridge changed depending on its position on the foreshore with respect to the tides and wave action. The ridges were best developed between the high and low neap tides; as they migrated upslope, their crests would be flattened by swash action, e.g. at KPD, and when they merged with the upper foreshore or the berm their configuration was destroyed. At BES, the ridges thinned out as cones of swash deposits when they migrated upslope.

The ridges and runnels measured on the profiles did not resemble the ridge and runnel topography found in areas with a more considerable tidal range (King, 1972: 340). In plan view, the ridges were usually not parallel to the shore but obliquely and

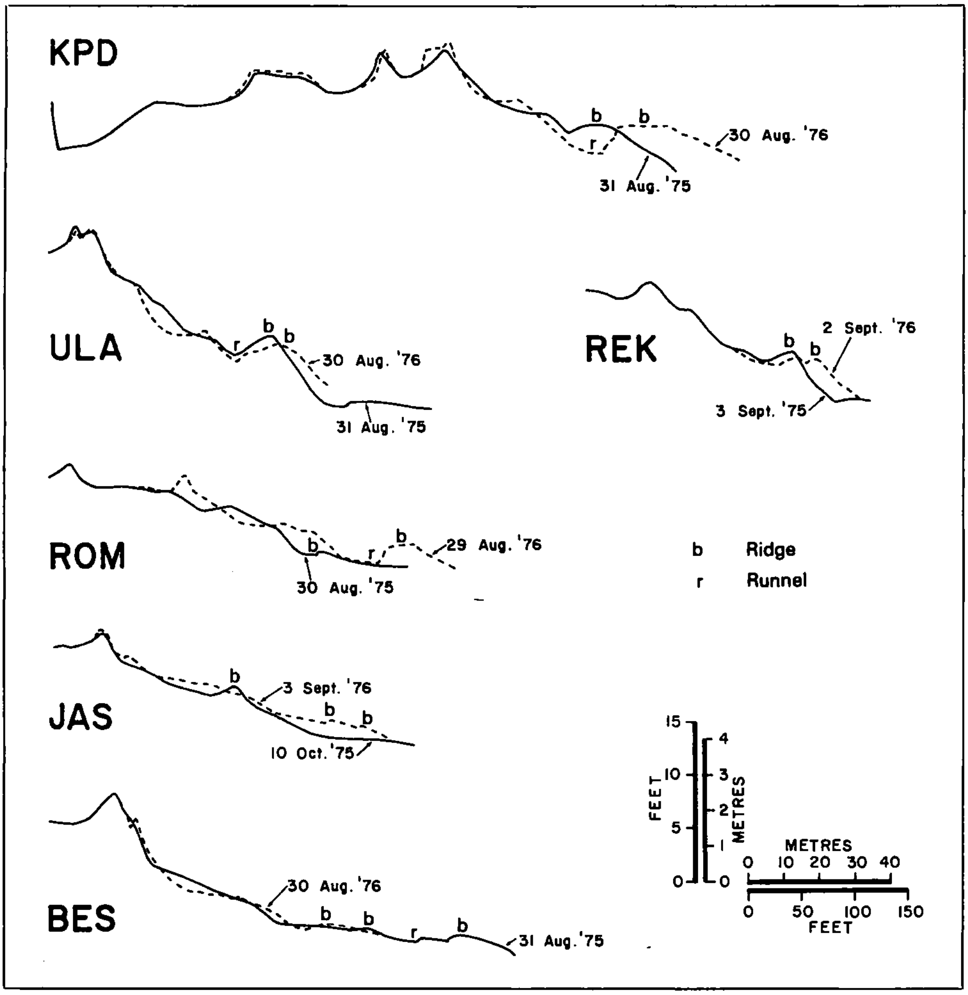

Fig. 4. Beach profiles at the end of each southwest monsoon in 1975 (Survey II) and 1976 (Survey IV) at KPD, ULA, ROM, JAS, BES, and REK.

usually attached to the shore at one end. At ROM, KPD, BES, ULA and KEM in survey IV, the ridges were attached obliquely to the foreshore at their southern ends while their northern ends were moving northward under the influence of longshore drift generated by the southeast waves. Separating the foreshore and each ridge at its seaward end was a runnel which would be enclosed when the free end of the ridge moved landward faster than the ridge proper and finally disappeared when the ridge merged with the upper foreshore. Crenulate shaped features on the landward side of the ridge indicated swash action and bed load transport of material. In survey IV of KPD, marine algae flourished in the runnel enclosed by the ridge, an indication of the slow movement of the ridge, the ridge was subsequently removed by the onset of the northeast monsoon.

Along with the ridge and runnel topography at a few stations were apices attached to the foreshores and spaced more or less at regular intervals. For example, in survey II, apices at ULA were spaced at 85.34 metres (280 feet) apart and along the beach at KEM and the Kemaman Motel, the attached apices were well developed. The apices were also well developed at stations with steep foreshores; these features apparently did not migrate upslope on the steep foreshores but could be eroded to form terrace-like formations backed by steep sand scarps as at DUN and PEN (Fig. 5). At DUN these apices were spaced at about 182.88 metres (600 feet) apart. Although ridges and runnels were not found on the steep foreshores, a variety of accretional and migratory forms could be found on the low-tide terrace. For example, during survey IV a variety of shoals, attached and unattached as well as linear or crescentic ridges (or more like bars) were found along the Nenasi coast.

Based on profile measurements and observations, the nearshore topography which was partly exposed at low tide, was well developed during the southwest monsoon than during the northeast monsoon and consisted of a variety of migratory and accretional forms. At stations with gentle foreshores, these moved landward and formed the ridge and runnel topography while at stations with steep foreshores the ridge and runnel topography was virtually absent. Examination of aerial photographs (1:25,000, 1966/67; photograph No. 193 of sortie C87, No. 3 and No. 75 of C67 and No. 100 and No. 109 of C87) of parts of the Kelantan–Trengganu coast indicated two series of nearshore topographic forms, an inner series consisting of a variety of linear, cuspate and transverse ridges and bars partly exposed at low tide and an outer series consisting of linear bars only and under water all the time.

Wind Action. Wind action is important especially on beaches with fine to medium sand. Wide berms of fine sand provide readily sources of material for drying and removal by wind throughout the year. During the northeast monsoon, the wind is strong enough to blow coarse material further inland.

Evidences of wind action are commonly in the form of wind ripples on the backshores as recorded at ROM, ULA, CHE and REK; small blowouts were present at SEL, KPD and ROM; small foredunes were found at BES and ULA. Accretion in progress behind clumps of *Spinifex littoreus* had been observed at KPD and BES.

The most distinctive evidence of wind action is at KPD, where the ridges have aeolian cappings. In some cases, the cappings are so thick and the ridges are high enough 1.52 metres or (5 feet) that the term 'sand dune' is appropriate. These dunes are stabilized by *Spinifex littoreus* which is a good sand binder and has the ability and vigour to survive through repeated burial by sand (Wong, 1978).

Minor Seasonal Features. During profiling, beach cusps were found at a number of stations, viz. NEN, SEL, ULA, GEL, KEM, BES, KIJ, DUN, JAM, KEL, PEN. Although the origin and formation of beach cusps are still not fully understood, it is believed that their size is related to wave energy (Komar, 1976). Usually, the beach cusps were found at two levels on the forshore, an upper series spaced at 24.38–30.48 metres (80–100 feet) apart and formed during the northeast monsoon but remained behind in a degraded form through the succeeding southwest monsoon, and a lower series spaced at 15.24–18.29 metres (50–60 feet) apart and formed during the

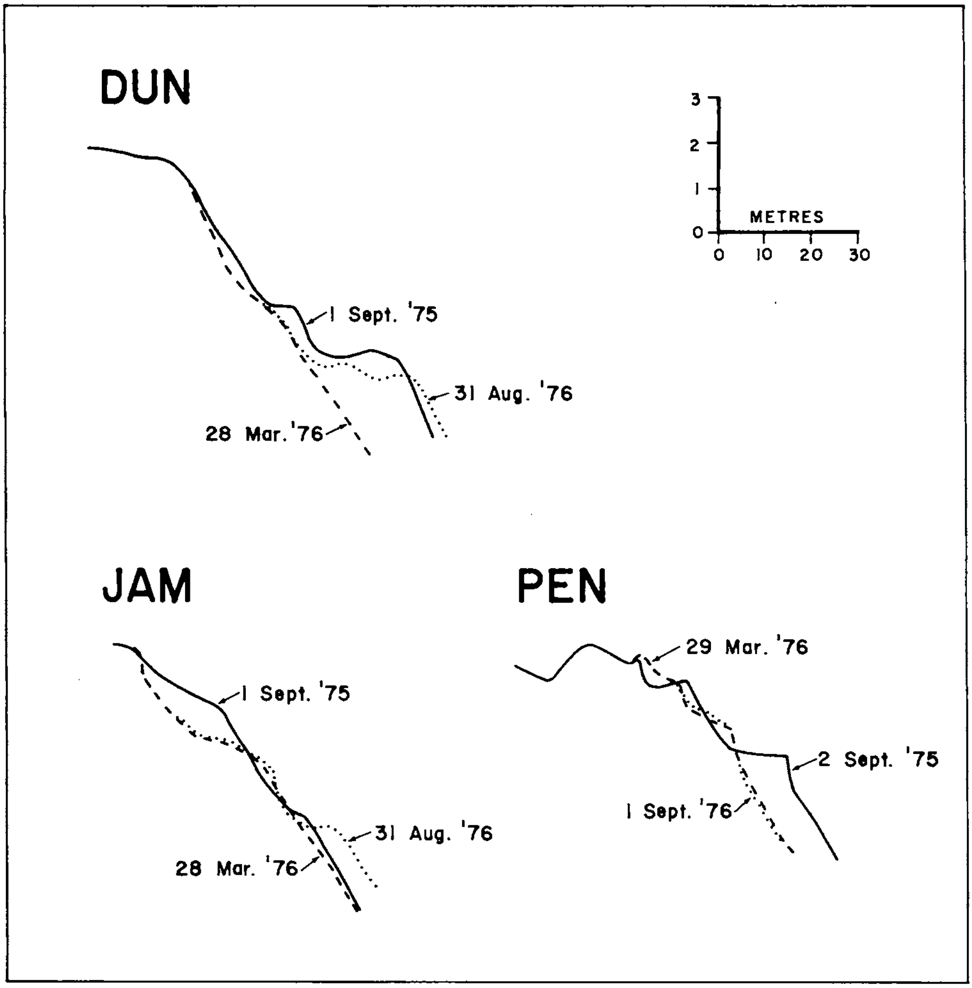

Fig. 5. Beach profiles at the end of the northeast monsoon in 1976 (Survey III) and the preceeding and succeeding southwest monsoons (Survey II and IV) at DUN, JAM and PEN.

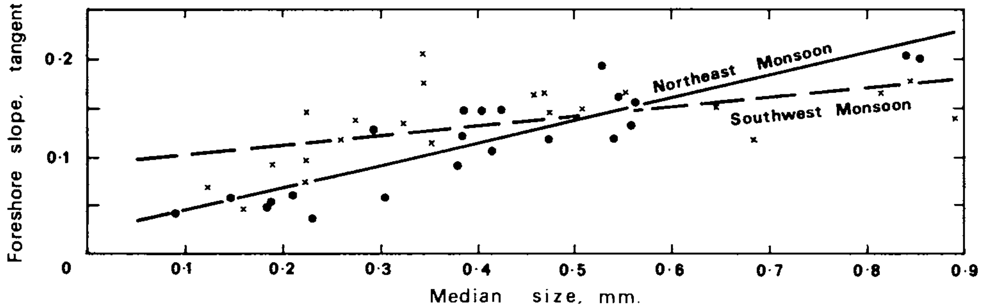

Fig. 6. Relationship between foreshore slope and median size of twenty-two beaches during the northeast monsoon and the southwest monsoon in 1975 and 1976.

southwest monsoon. On 5 December, 1976 11.27 kilometres (seven miles) north of ULA at Chendor Motel, three series of beach cusps were observed; the highest series spaced at about 30.48 metres (100 feet) apart were formed by the northeast monsoon, the middle series spaced at about 24.38 metres (80 feet) apart were formed by the southwest monsoon, and the lowest series spaced at about 7.62 metres (25 feet) apart were formed by the waves at the prevailing high tide level.

Sand scarps were found at some stations; these were due to waves combing down the lower foreshore. The most common scarps were those formed by such waves at neap tides as at NEN, KEM, PAK, JAM, BAT, MER and BST. Sometimes, beach cusps were truncated leaving behind prominent sand scarps at where the apices were partly removed.

DISCUSSION

Although this study covers only a period of two years and the interval between surveys is 5–7 months, the results show clearly the contrasting character of the beaches at the end of the northeast and southwest monsoons and thus indicate their seasonal difference. Shorter cycles of changes are not measured but they exist, for example, changes resulting from an isolated storm during the southwest monsoon or a period of constructive wave action during the northeast monsoon.

Separated by the 5–7 month interval, the beach profiles of the four surveys show sharp seasonal changes. In actuality, the beach changes from the southwest monsoon to the northeast monsoon are likely to be abrupt with the onset of the first storm or high energy waves than the beach changes from the northeast monsoon to the southwest monsoon in which recovery is gradual. It should be noted that the beach profiles taken at 5–7 months intervals have with them the influence of shorter cyclic as well as non-cyclic factors on the foreshore and backshore and the profiles cannot distinguish the nature and extent of such influences. The assumption is that the beach profile taken at the end of each monsoon is the result of the cumulative effects of the monsoon and best indicates the seasonal character. At the same time, the long term effect of the monsoons on the beaches cannot be determined from a two-year survey although at a few stations, long term erosion is likely to occur. The beach profiles should be regarded as examples of seasonal changes rather than indicating any minimum or maximum changes resulting from the monsoons.

Along the east coast, beach changes are variable within any season and sometimes contrary to the seasonal tendencies as indicated by the surveys. The variation is due to a combination of related long-term factors which influence the seasonal tendencies. Firstly, the geological character of the coast determines the nature and supply of beach material, whether the material is derived from the headlands, rivers or reworked from material transported alongshore or from the nearshore zone. Secondly, the shape of the beach and its orientation to the wave approach determine whether the beach is essentially exposed, semi-exposed or protected from the northeast monsoon. Thirdly, the width of the 18.29 metre (10-fathom) offshore shelf at which the prevailing 5-second waves would begin to undergo refraction at that depth, influences the amount of energy reaching the shore; the wider the shelf, the more likely is wave energy reduced on reaching the beach. Fourthly, the tidal range determines the extent of beach exposed to wave action. The combination of these factors account for the difference in beach response to the northeast or the southwest monsoon; a combination which results in the beach receiving the full impact of the northeast monsoon to the ameliorating effects of the southwest monsoon.

Of all the topographic forms on the beach profiles, the most distinctive and changeable is perhaps the ridge. The genesis of the ridge lies in the deeper waters and it becomes part of the nearshore topography before it migrates upbeach and eventually forms part of the beach where it may be built up to become the youngest beach ridge. The prevalence of these ridges must imply that there is an ample supply of material at sea or reworked material from the coast. For fine material, the ridge topography is more pronounced and this is partly explained by the action of wind and the role of the herbaceous belt (Wong, 1978). During the southwest monsoon, the ridges are built upward and landward and during the northeast monsoon, the ridges are cut back. The alternation of cut and fill in an area of adequate sand and ridge formation will eventually produce successive parallel ridges as shown at KPD.

Longshore transport is important along the east coast as evident in the extension of barriers and spits. The direction and magnitude of the transport is likely to be influenced by the monsoons; according to Tjia (1970) monsoon controlled currents are predominantly southward throughout the year from about station JAM to station NEN, whereas the other coastal stretches are subjected to mainly a NNW longshore current. Landsat 1 (ERTS A) imagery show sediment moving in opposite directions along sections of the coast but this has not been fully explained (GSM Newsletter 1976). Beach profile data and observations show a series of nearshore forms, such as giant cusps, various types of cusp-bars, transverse bars and shoals, along some sections of the coast which are likely to be related to the littoral transport; these nearshore topographic forms act as reservoirs of material removed from the beaches during the northeast monsoon while giving rise to migratory forms moving upslope during the southwest monsoon.

CONCLUSION

On the east coast of Peninsular Malaysia, the seasonal impact of the monsoons is distinctive, although the effects may vary locally. Erosion prevails during the northeast monsoon while accretion predominates during the southwest monsoon. Foreshore gradient varies seasonally but is dependent on grain size. On beaches where the ridge and runnel topography develops, such topography is more pronounced in the southwest monsoon than in the northeast monsoon. Foreshore changes are related to the nearshore topographic forms which also vary seasonally. Wind plays an important role where the beach material is fine.

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