STRATIGRAPHICAL POSITION AND DEPOSITIONAL ENVIRONMENTS OF COAL BEARING SANDSTONE AROUND LAITRENGEW AREA, MEGHALAYA

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Abstract

The coal-bearing sandstone in the area around 31/2 Mile Stone along Shillong-Shella National Highway was previously thought to be as equivalent with Therria Formation. Based on statistical and micropalaeontological study of these sediments, it has been established that the sediments are a continuation of the Lakadong Sandstone Member exposed in the southern extreme of the area around Lower Cherrapunji and are of Thanetian age. Both the sedimentological and palynological studies reveal that the sediments were deposited in beach environments, where some shallow lagoons were formed in locally developed deltaic conditions.

Introduction

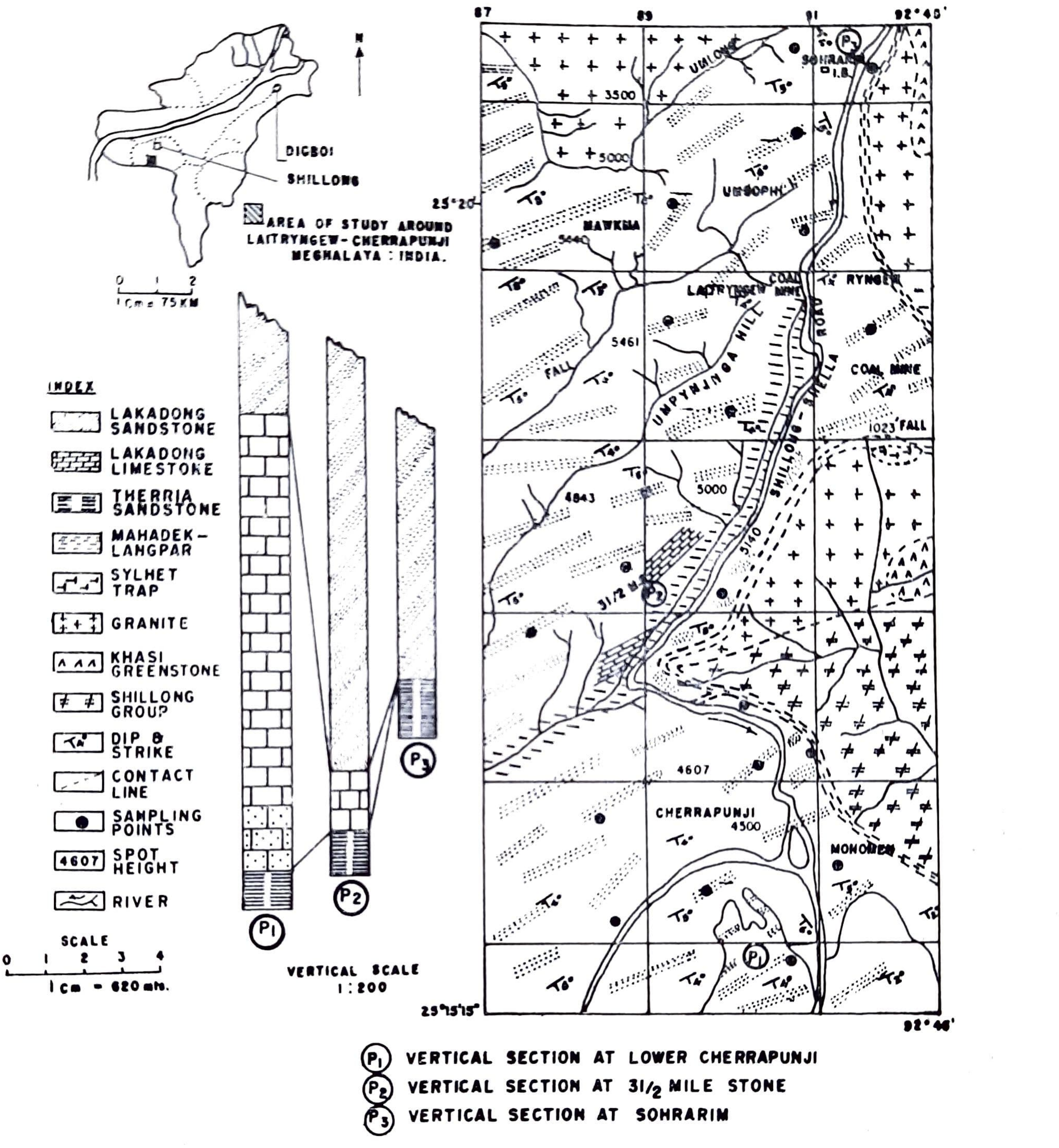
The areas under discussion is located on the south-western slope of the Shillong Plateau, Meghalaya measuring approximately 32 sq kms and is defined by latitudes 25°15'30"N – 25°20'30"N, Longitudes 91°-40'0"E – 91°45"0'E. It covers the vicinity of Cherrapunji and Laitryngew Mile Stone 25 to Mile Stone 34 and about 1 km on either side of the Shillong-Shella National Highway.

The stratigraphic succession of the area is as follows:

Jaintia Group	Sylhet Formation	Lakadong Sandstone Member Lakadong Limestone Member	Thanetian
	Therria Formation		
	Langpar Formation		Danian
	Mahadek Formation		Maestrichtian
		Sylhet Trap	Pre-Cretaceous
		Mylliem Granite Khasi Greenstone Shillong Group	Pre-Cambrian

Medlicott (1869), who first recorded the rich coal deposits around Laitryngew Village, appears to have correlated the coal-bearing sediments of Laitryngew area with the Lakadong Sandstone Member of the Sylhet Formation. Palmer (1923) has not mentioned the age of this sandstone but Ghose (1940) is of the view that the Laitryngew coal-bearing sandstone is equivalent to Lakadong Sandstone. On the other hand, Evans (1964) considered the Laitryngew Sandstone as younger than Lakadong Sandstone and possibly equivalent to the Kopili Formation of the Jaintia Group and therefore Upper Eocene (Priabonian) in age.

MAP AROUND LAITRYNGEW CHERRAPUNJI



Text-figure 1

Dutta *et al.* (1964) who recorded a few invertebrate fossils, viz , *Solariella* cf. *S. radiatula* Forb. *Exogyra* cf. *E. suborbiculata* Lam., *Cardium* of pilatum Stol, etc. from the limestone below the coal bearing sandstone exposed at Mile Stone 31/2 considered the limestone to be of Danian age and equated it with the Langpar Formation. Since the coal-bearing sandstone immediately overlies the limestone it was considered to be the equivalent to Therria Formation (former Cherra Sand-stone Stage).

Sah and Dutta (1966) and Dutta and Sah (1970) did a detailed palynological study of the coal-bearing sediments around the Laitryngew-Cherrapunji area. Based on information revealed by the palynological study together with the record of microforams, Dutta *et al.* (1964) assigned a Palaeocene age to the sediments around

31/2 Mile Stone and equated them with the Therria Formation while the sediments around Cherrapunji were considered as equivalents of the Lakadong Sandstone.

It is interesting to note that the limestone at M.S. (31/2) shows the occurrence not only of uppermost Cretaceous forms but has also yielded typical Palaeocene forms, such as, *Miscellanea miscella*, *Discocyclina ranikotensis*, etc. which have been recorded from the Lakadong Limestone Member.

There are, thus, divergent views on the stratigraphical status of the Laitryngew coal-bearing sandstone. The object of this note is to approach the problem on the basis of statistical and palynological studies.

Consideration of depositional environments on sedimentology

The results of the textural parameters of the coal-bearing sandstone under discussion, following different moments (Dixon & Massey, 1957) have been illustrated in Table 1. The sandstones are medium to fine-grained, negative to positively skewed and well to very-well sorted. No significant variation in texture has been observed in the sediments from different sections.

Kuenen (1956) observed that the saltation movement depends on the physical characteristics of the particles and local variations of drag effects on the beds by current velocities where different types of sorting take place. The resulted laminations are due to particles of different attributes, such as size having their own sorting action. The amount of suspension fines varies according to the flow intensity of depositing medium. It increases with decrease in flow intensity as in the case of river sands deposited from unidirectional flow. Sometimes it decreases even in undirectional flow if high intensity prevails, as in the upper flow regime of beach (Friedman, 1967). Accordingly, the variation in rolling and suspension populations is a function of flow intensity in depositing medium. This is reflected in the present study by skewness and standard-deviation values. Most of the samples from the lower half of each section are well to very well-sorted, negatively skewed, medium-grained, whereas most of the samples from the upper level in all the sections are well-sorted, negative to positively skewed and medium to fine-grained. The sediments consisting largely of the saltation population are well-sorted; addition of rolling population makes them very well-sorted and negatively skewed, but the addition of a very low quantity of suspension fines yields well-sorted, slightly positively skewed sediments. As the occurrence of grain-size variation in sediments is a function of the flow intensity in a depositing medium, high to medium

Table 1—Results of moment statistics for outcrop samples used in the present study, average values in parenthesis

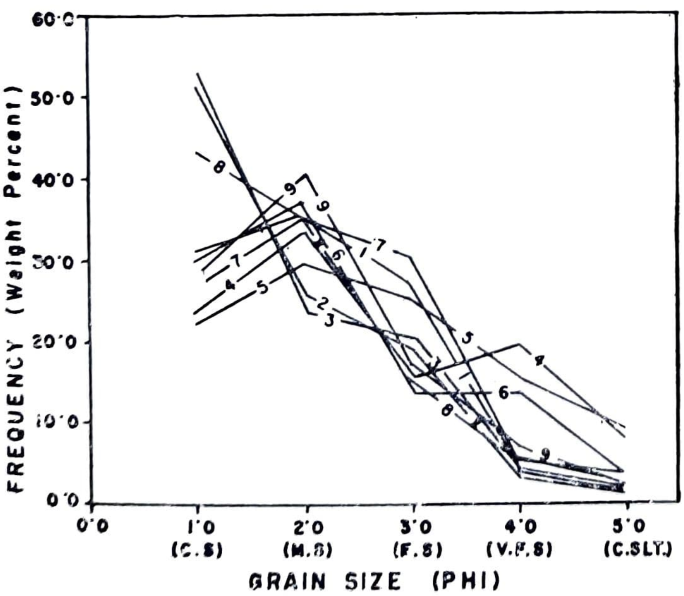
Section	Mean $\times\phi$	Standard-deviation $\phi\delta$	Skewness α_3
I	1.42 tc 2.40(1.89)	0.291 to 0.527(0.396)	—1.40 to 1.50(0.359)
II	1.352 to 2.198(1.678)	0.309 to 0.635(0.479)	—0.376 to 1.438(0.284)
III	1.112 to 2.442(1.653)	0 227 to 0.668(0.480)	—1.423 to 1.857(0.275)
IV	1.519 to 2.870(2.004)	0.245 to 0.542(0.407)	—1.301 to 1.623(-.004)
V	1.555 to 2.364(1.963)	0.346 to 0.488(0.421)	—0.783 to 1.474(0.315)
VI	1.571 to 2.833(2.001)	0.271 to 0.642(0.405)	—1.335 to 1.341(0.206)
VII	1.561 to 2.906(2.008)	0.227 to 0.535(0.419)	—1.149 to 1.557(0.109)
VIII	1.074 to 2.131(1.682)	0.269 to 0.605(0.472)	—1.489 to 1.619(0.318)
IX	1.601 to 2.397(1.989)	0.340 to 0.494(0.403)	—1.131 to 1.733(0.599)

N. B. Sections I,II,III and IV from the area south of 31/2 Mile Post and Sections V,VI,VII,VIII and IX from the area north of 31/2 Mile Post.

intensity flows of upper shoreface-beach environments may have been responsible for the deposition of the present sediments.

The average weight percentages of different size fractions (coarse sand to silt) for the samples from each section have been plotted in Text-figure 2. All the samples range in size from 0.0 phi to 5.0 phi. From Table 1, it is apparent that some sections are rich in medium-grained fractions and others in fine-grained sands. The frequency distribution shown in Text-figure 2 based on an average percent are for coarse-grained sand in sections II, III and VIII and medium to fine grained for the remaining sections of Table 1. The section/wise variation in standard-deviation and skewness values for the sediments is negligible.

The sandstones are quartz-dominated, poor in matrix and contain low percentage of heavy minerals commonly of stable type like tour-maline, zircon and opaques as inferred from thin section and heavy mineral studies of the sediments. The quartz grains are sub-rounded to well-rounded. The underlying carbonates near Cherrapunji (33 mile-stone) and Umstew (31/2 milestone) are fossili-ferous and are of biomicrite and sparite type. The texture of lower portion of carbonates is masked by dolomitization. Some of the dolomite samples display sugary texture.



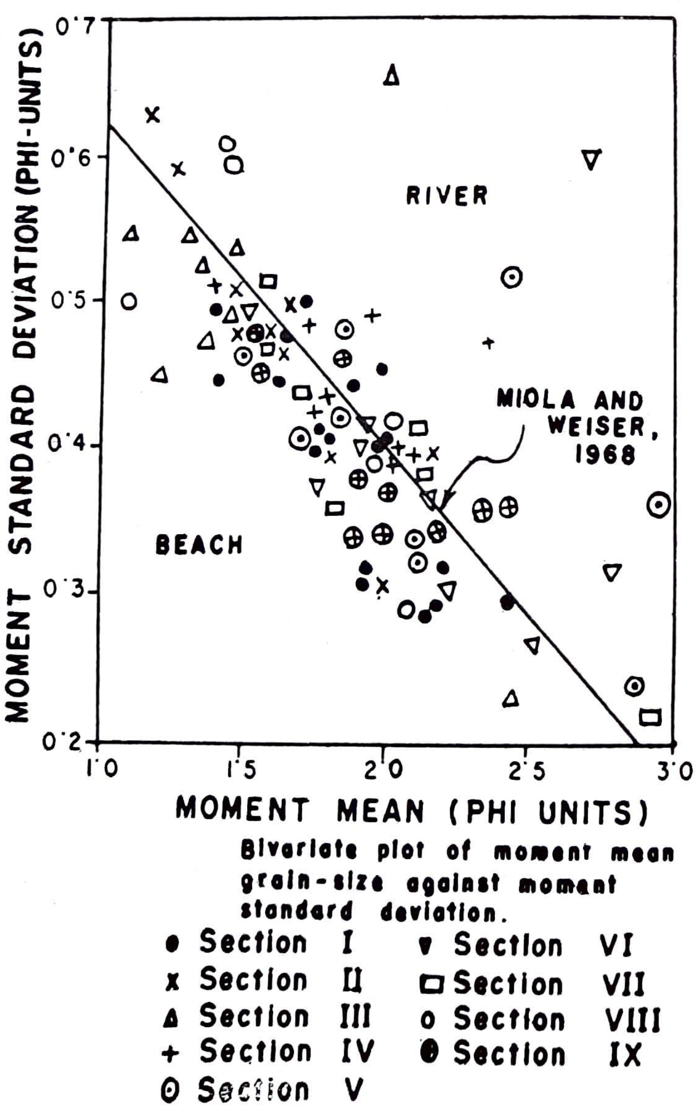
Text-figure 2—Frequency distribution of sands for 9 sections of Lakadong sandstone unit represented by 9 respective curves; C.S. = Coarse sand; M.S. = Medium sand; F.S. = Fine sand; V.F.S. = Very fine sand; C.SLT. = Coarse silt.

The sandstone unit thins out towards the south and rests conformably over carbonates, the thickening portion towards the north is underlain by the durable, medium to fine-grained, southerly dipping (6° to 12°) Therria Formation. At a few places, the blanket type sediments exhibit through cross-lamination.

Accumulation of this quartz-arenite type sandstone strongly suggests supply of detritus to a stable depositional area undergoing very slow subsidence at a steady rate as for instance in the case of St. Peter sandstone reported by Krumbein and Sloss (1963). During the deposition of these sandstones some shallow lagoons were formed in locally developed deltaic conditions, as evidenced by the occurrence of thin, discontinuous sulfur rich coal seams at different levels. The occurrence of suspended particles in lagoon deposits is found to be associated with coal deposits represented by carbonaceous shales. The record of normal geomorphic features and sedimentary environments of the palaeocoastal plain was probably destroyed by continuing transgression, and reworking of deltaic deposits resulting in sheets of quartz-arenite sandstone. The sedimentary record of regression on a stable shelf is rarely preserved, because the deposits formed do not normally remain long below base level and are subjected to weathering and erosion. Therefore, the deposition of these sediments is possibly controlled by transgression phases (Cambrian-Early Ordovician sandstones, Galesville, Jorden, Bell *et. al*, 1956, in Krumbein & Sloss, 1963).

Presumably, the shallow depressions were either the result of processes such as downward encroachment of tidal channeling or due to the subsidence and coastal retreat of reworked sediments from abandoned river mouth The sediments later filled these lagoonal depressions along with the coal-forming materials. Thus, the topography on which the lagoonal depressions were formed, affected directly the variation in thickness and lateral continuity of a coal seam. Those environments that co-existed laterally with the lagoon such as peat growth, plant decay and water flow directly affected the lateral continuity of the coal-forming deposits. After the deposition of the peat, the area was flooded with fluvial sediments which were subsequently reworked by higher energy beach processes and provided sites for the deposition of coal-forming materials. Following the burial of peat (coal) the post-depositional tidal channeling processes could have modified the upper surface of the deposits resulting in impersistent coal seams. The sediments associated with the coal seams in the upper level of the sandstone unit may be deposited swiftly by rapid fluvial processes as inferred from the results of textural parameters such as, relatively higher values of standard-deviation and slightly negative to positive skwness for the sediments. The impers stent patchy occurrence of coal are probably a function of the size of intervening lagoons, the rate of basin subsidence and the sediment influx relationship to the rate of peat accumulation.

Most of the samples belong to the coal-bearing sediments of a beach environment, whereas the rest are in the river environment (Text-fig. 3). Similar inference can be



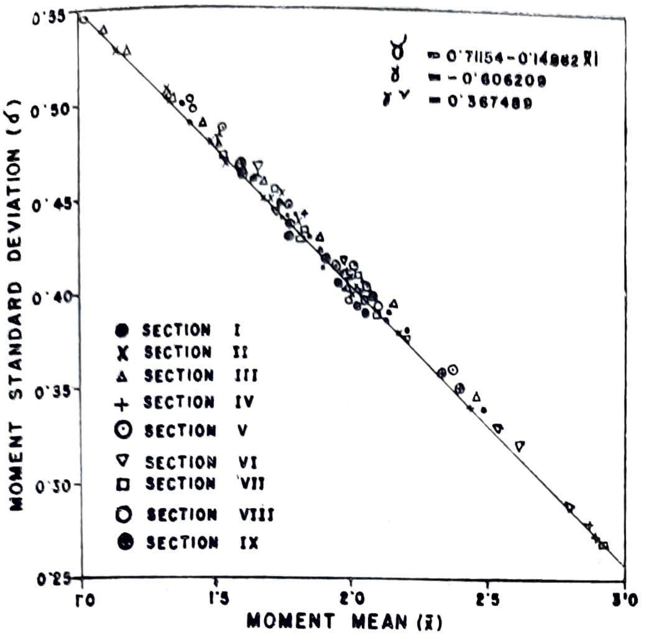
Text-figure 3

drawn from other bivariate plots like mean versus skewness, standard deviation versus skewness, but the best distinction can be viewed from the plot of mean grain-size versus standard deviation as both are the function of wave energy and mobility (Nordstrom, 1977).

Because of the decreasing water depths with increasing energy conditions and extensive reworking, the sediments in the upper shoreface-beach environments are well to very well sorted and impoverished in clay fraction containing only physically most stable minerals (Davis & Ethriege, 1975). The almost absence of clay in the present sediments indicates their maturity. This matured sandstone body may either be the product of erosion and recycling of the older matured sandstones or subjected to long continued mechanical maturation under stable tectonic states in a single cycle of erosion, transportation and deposition. The sediments must have been continuously reworked before ultimate burial. Slow subsidence permits long exposure to mechanical energy before ultimate burial under conditions of tectonic stability. Therefore, either wave action or tidal current circulation or both were sufficient to produce the well-sorted medium to fine-grained blanket type quartz-arenite Lakadong sandstone. The higher energy and low mobility processes gave rise to quartz-arenite sediments. The low mobility reflects the limited inputs of sands to the final depositional sites, which were better sorted under the influence of higher energy processes. Energy and mobility are the critical factors that are related to exposure (Nordstrom, 197), which again is related to the rate of subsidence.

The exposure of pyritous shales within the Lakadong Sandstone Member near Laitryngew and the presence of high sulphur in coal (as recorded by Coal Survey Laboratory, Jorhat) signifying the depositional sites were influenced by marine to brackish water environments. This view is supported by the occurrenee of brackish water palynomorphs preserved in the shales.

The regression line appears to be straight in the mean grain-size versus standard deviation plot (Text-fig. 4). The lack of remarkable change and the low value of slope for the line possibly may be due to the dominance of a single population in grain size distribution, that is saltation population,



Text-figure 4—Plot of moment mean and moment standard deviation.

which consists of medium to fine-grained sediments. The small range of standard diviation values and vast majority of saltation population in each of the sections (Table 1, fig. 3) clearly shows that during different times the sediments from all the sections underwent similar modes of transportation and were deposited under overall similar environmental energy processes.

Presumably, the sediments towards the base were reworked steadily along gently sloping upper-shoreface-beach environments in association with lagoonal deposits, whereas the sediments in progressively higher levels were the result of rapid removal by higher to moderate energy processes while the lagoon sediments kept pace with them.

Stratigraphical position

The occurrence of typical forams, such as *Discocylina ranikotensis*, *Miscellanea miscella* together with calcareous algae *Distichoplax hiserials* in the limestone below the coal-bearing sandstone suggests the age of the limestone as Thanetian. Therefore, it may be safely deduced that it is a continuation of the Lakadong Limestone exposed in the vicinity of the area and not of Langpar as regarded earlier (Dutta *et al.*, 1964; Dutta & Sah, 1970). Since the Lakadong coal-bearing sandstone conformably overlies the Lakadong Limestone in the Khasi and Jaintia Hills, they are regarded as Thanetian in age.

The presence of Upper Cretaceous forms reported by Dutta *et al.* (1964) from the limestone are possibly long ranging and not index fossils. It is possible that those forms are found in Upper Cretaceous sediments in South India while in this part they might range in the younger sediments. Further, the forms recorded by Dutta *et al.* (1964) are comparable to and not identical species.

R-Mode factor analysis: Results and discussions

In the present study R-mode factor analysis has been considered to represent the grouped moment grain-size textural parameters in depicting any possible textural distinction that lies among the sediments in the area north of 31/2 Mile Stone from those of south.

The R-mode technique is concerned with inter-relationships between variables. In the present study, eigenvalues taken from a standardized variance-covariance matrix, have been employed following Eckart-Young Theorem (1936) which assumes that all the variables are weighed equally and allows for the convert of the principal component vectors into factors.

In factors analysis, the vector formed by multiplying an eigenvector by its corresponding square root of eigenvalue, is referred to as a factor. Eaeh factor is weighed proportionally to the square root of the amount of variance contributed by that variable to the factor.

In the present study, factor I accounts for 95.69% of the total variance. Similarly, factor II accounts for 3.22% of the total variance (Table 2). Factors III and IV share only 1.05% and 0.04% of the total variance of our data respectively and are considered insignificant. The eigenvalues represent the proportions of the total variance accounted for the eigenvectors. Thus two factors are to be rotated.

The results show that factor I bears the relative importnace of different variables. Now, with the resulted data, first and second variables have been projected on the R-mode factor axes by computing their factor scores. The results of the two involving factors have been tabulated in Table 3. Two factors denote size and sorting.

Text-figure 5 shows that there is no significant textural variation in the sediments

Table 2—Eigenvectors and eigenvalues of R-mode

Variable	Eigenvectors			
	I	II	III	IV
Mean	0.36949	−0.47821	0.78367	−0.14370
Standard-deviation	0.07132	−0.01714	0.15758	−0.98477
Skewness	0.02789	−0.86272	0.49559	−0.09658
Kurtosis	0.92608	−0.16348	0.33973	−0.01560
Eigenvalues	1394.946	46.984	15.297	0.558
Variance contributed by each variable in percentage	95.69	3.22	1.05	0.04

Table 3—Loadings of the first two R-mode factors

	Loading			
	I	II	III	IV
Factor I	13.7999	2.6637	1.0415	34.5880
Factor II	-3.2779	0.1193	5.9135	1.1205

between the northern and southern portion of 31/2 Mile Stone in the area. The samples with vast majority of medium grained fraction are comparatively well sorted whereas those containing a vast majority of fine to very fine fractions are very well sorted. Accordingly, the former community occupies the upper half and the latter one lies in the lower half of Text-figure 5 along factor axis II. But the samples from different sections belonging to both the sectors do not illustrate definite trends separately, they reflect a common depositional environment for the sediments as a whole.

Application of multivariate F-test to clastic fractions of different sections

The effectiveness of a classification scheme is dependant on the relation between group variations. Factors like hydraulic selectivity affect in fractionation of resulting sediments. There is no unconformable relationships observed amongst different sections in the field and no distinction could be made between the sediments from northern and southern sections of the 31/2 Mile Stone as in preceding analytical approaches. But on account of the sporadic distributions of different sections possibly belonging to the same stratigraphic unit, it is necessary to follow the sectionwise discriminant analysis In this study, recourse has been taken to the magnitude of F-value in finding out a significant distinction among the sections from the textural standpoint. The weight percent of five grain-size fractions from each sample has been entered as a variable in this analysis.

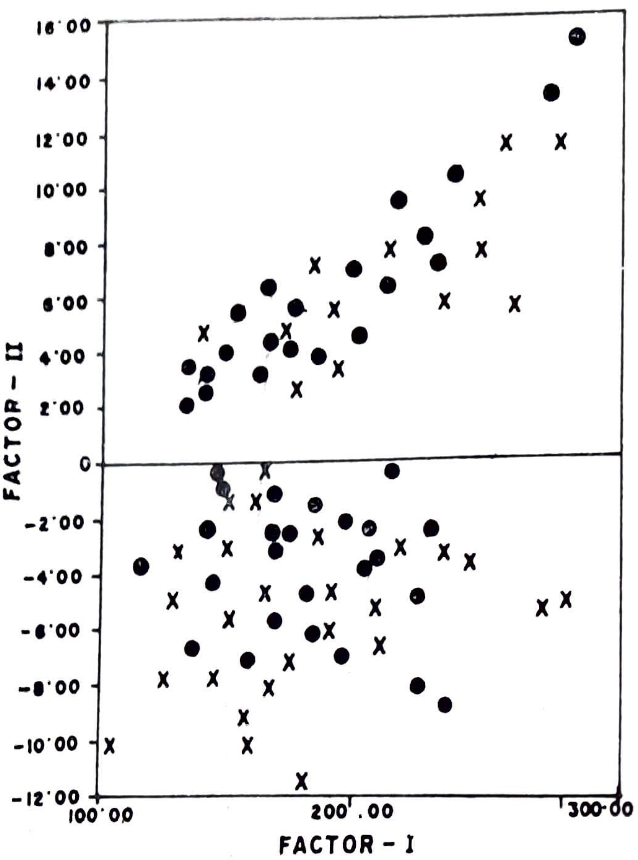
The critical information for evaluating the relative importance of each variable is shown in Table 4. The positive sign of the "Surplus Percent" column indicates that the variables acted in separating the sections and negative signs signifying the variables acted to draw the sections together. The Mahalanobis D^2 statistic represents a measure of the separation between the two

Table 4—Discriminant analysis data comparing grain-size fractions from different exposed sections of the sandstone unit

Comparing	Constant 1*	Surplus per cent	Mahalarolis distance (D)	Calculated F-statistics	Tabulated 2* F-values
I and II	1.—0.031 2. 0.023 3.—0.023 4.—0.054 5. 0.830	—20.427 11.460 7.395 1.310 0.897	1.2630	1.493	F(.05,5,21)
II and III	1.0.009 2. 0.0004 3. 0.030 4.—0.144 5.—0.460	—1.100 1.060 0.580 —0.400 —0.1 0	0.1714	0.1418	F(.05,5,1[illegible]) —4.60
III and IV	1.—0.019 2.—0.013 3.—0.038 4.—0.0325 5.—0.0236	28.890 —9.455 —3.580 —15.820 —6.940	1.4896	1.079	F(.15,5,13) —4.66
IV and V	1.—0.002 2. 0.018 3.—0.045 4. 0.032 5.—0.025	3.190 3.555 —10.270 3.750 —0.280	0.6468	0.364	F(.05,5,10) —4.74
V and VI	1.—0.002 2.—0.020 3. 0.032 4.—0.300 5. 0.080	—9.840 —7.350 10.730 1.440 4.830	0.4644	0.2167	F(.05,5,8 —4.82
VI and VII	1.—0.012 2. 0.037 3.—0.075 4.—0.010 5. 0.290	3.600 1.550 —15.300 9.200 1.107	1.3907	0.7820	F(.05,5,10) —4.74
VII and VIII	1.—0.006 2.—0.030 3. 0.060 4. 0.170 5.—0.405	—16.430 —0.020 14.450 1.590 0.455	1.0460	0.5212	F(.05,5,9) —4.78
VIII and IX	1. 0.010 2. 0.007 3. 0.010 4.—0.150 5. 0.300	16.873 —7.260 —6.140 —3.810 2.220	0.7956	0.4260	F(.05,5,10) —4.74

1* Serial number from 1 to 5 in "Constant" column represent variables:
X_1—$<1\phi$, X_2—1—2ϕ, X_3—2—3ϕ, X_4—3—4ϕ, X_5—4—5ϕ

2* F—Test F-value (a,b,c) is calculated for the 100 (5-a)% confidence level for a distribution with b and c degree of freedom (b is the number of variable and c+b+1 is the number of samples).



Text-figure 5—R-Mode factor scores of samples from the area of study; ●, south of 31/2 mile stone; ×, north of 31/2 mile stone.

multivariate means, expressed in units of pooled variance. Its magnitude thus serves as a measure of the efficiency with which the variables serve to distinguish the sections in question. The statistical significance of the Mahalanobis distance is usually tested by the F-test operating on the null hypothesis $H_0 : D_1 = D_2$ (i.e., the average discriminant scores for sections 1 and 2 are same). If we accept this hypothesis it would indicate that all samples were subjected to the same energy processes. The magnitude of calculated F-values for the samples in different comparing section are much less than the tabulated values of F at 5% significant level, revealed that there is less than five percent chance that the samples in different sections were subjected to different transportation and depositional processes.

Various combinations of transporting modes of sediment lead to differences in grain-size distributions. Again, textural variability among sediments represents different situations that existed during the supply and deposition of sediments. The results of this approach are shown in Table 4. They clearly reveal that the sediments of the studied sections are laterally homogeneous from the extreme north to the south throughtout the area and that the sedimentation processes from different sections were closely alike.

Conclusions

The above study based on statistical and micropalaeontological considerations lead to the conclusion that the coal-bearing sandstone of the area around 31/2 Mile Stone is a continuation of Lakadong Sandstone Member exposed on the southern part of the area and is of Thanetian in age.

The study suggests that the sediments were deposited under tactonically stable depositional area of upper shoreface beach environments during which some shallow legoons were formed in locally developed deltaic conditions. This view is further supported by the occurrence of high relative frequencies of the pollen-grain belonging to Arecaceae family together with those of Rhizophoraceae Chenopodiaceae etc.

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