Palynofacies Patterns in Channel Deposits of the Rajang River and Delta, Sarawak, East Malaysia

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The Rajang River and its delta accumulate siliciclastic sediments and dispersed organic matter within river and tidal channels as rhythmically stratified sand, silt, and organic drapes. These deposits were vibracored and subsampled, resulting in a data set composed of 84 samples taken from 45 cores. Palynofacies preparations of this sediment facies were examined from throughout the alluvial valley and delta to determine if a single organic matter assemblage characterized these deposits. An underlying assumption of palynofacies analyses in ancient transitional settings is that each lithofacies or depositional environment is characterized by a specific organic matter (OM) assemblage. This specific hypothesis is not supported by the present investigation. However, the present investigation has demonstrated that the resultant dispersed OM assemblages within a single sediment facies is heavily influenced by the geochemistry of the system.

Three distinct palynofacies assemblages in this data set have been identified using nonparametric and multivariate statistical analyses. One assemblage, characterized by high amounts of Heterogenous and Homogenous (mainly dammar) Unstructured OM, moderate amounts of Structured OM and Finely Dispersed Unstructured OM, and low amounts of Black Indeterminate OM, is restricted to depositional sites that are principally found in freshwater settings. The second assemblage, characterized by the highest quantities of Heterogenous Unstructured OM and Indeterminate Black and the least amount of Finely Dispersed Unstructured OM, is found in channels of the lower delta plain. The distribution of this palynofacies assemblage conforms to the limit of saline influence during the wet season. The third group, characterized by the highest quantitative amount of Finely Dispersed Unstructured OM, is found either in barforms or in black-water tidal channels that are sediment starved. These results indicate that OM assemblages preserved in a single sediment facies characteristic of transitional zones vary in response to the abiotic processes operating within the system.

INTRODUCTION

The composition of dispersed organic matter assemblages, or palynofacies (sensu Combaz, 1964; 'palynolithofacies' sensu Traverse, 1994), in terrestrial and marine strata has been used with varying success as an aid in identifying ancient environments of deposition. This approach has been applied to Carboniferous (Van der Laar and Fermont, 1990; Highton et al., 1991), Jurassic (Van der Zwan, 1990; Gorin and Feist-Burkhardt, 1990), Cretaceous (Paisley and others, 1991; Habib and others, 1994), and Tertiary (Boulter and Riddick, 1986; Lenoir and Hart, 1988; Poumot, 1989; Pasley and Hazel, 1990; Oboh, 1992) strata. Few studies, though, have been conducted in modern environments to determine either the degree of validity of the ancient recognized patterns (Lorente, 1990; Van Waveren, 1989a, 1989b; Van Wavern and Vischer, 1994; Caratini, 1994; Hart, 1994) or assemblage variability inherent in any particular depositional setting. An underlying assumption to the applicability of the technique has been that each depositional environment, or lithofacies representative of that regime, has one unique organic matter assemblage that is distinct from other contemporaneous settings. The present investigation was designed to test this hypothesis in a modern deltaic setting, the Rajang River delta, Sarawak, East Malaysia.

The Rajang River delta is a peat-accumulating coastal-deltaic system located in an embayment formed by the folded Mesozoic and Cenozoic strata of the Central Borneo Massif on the western coast of Borneo (Staub and Esterle,

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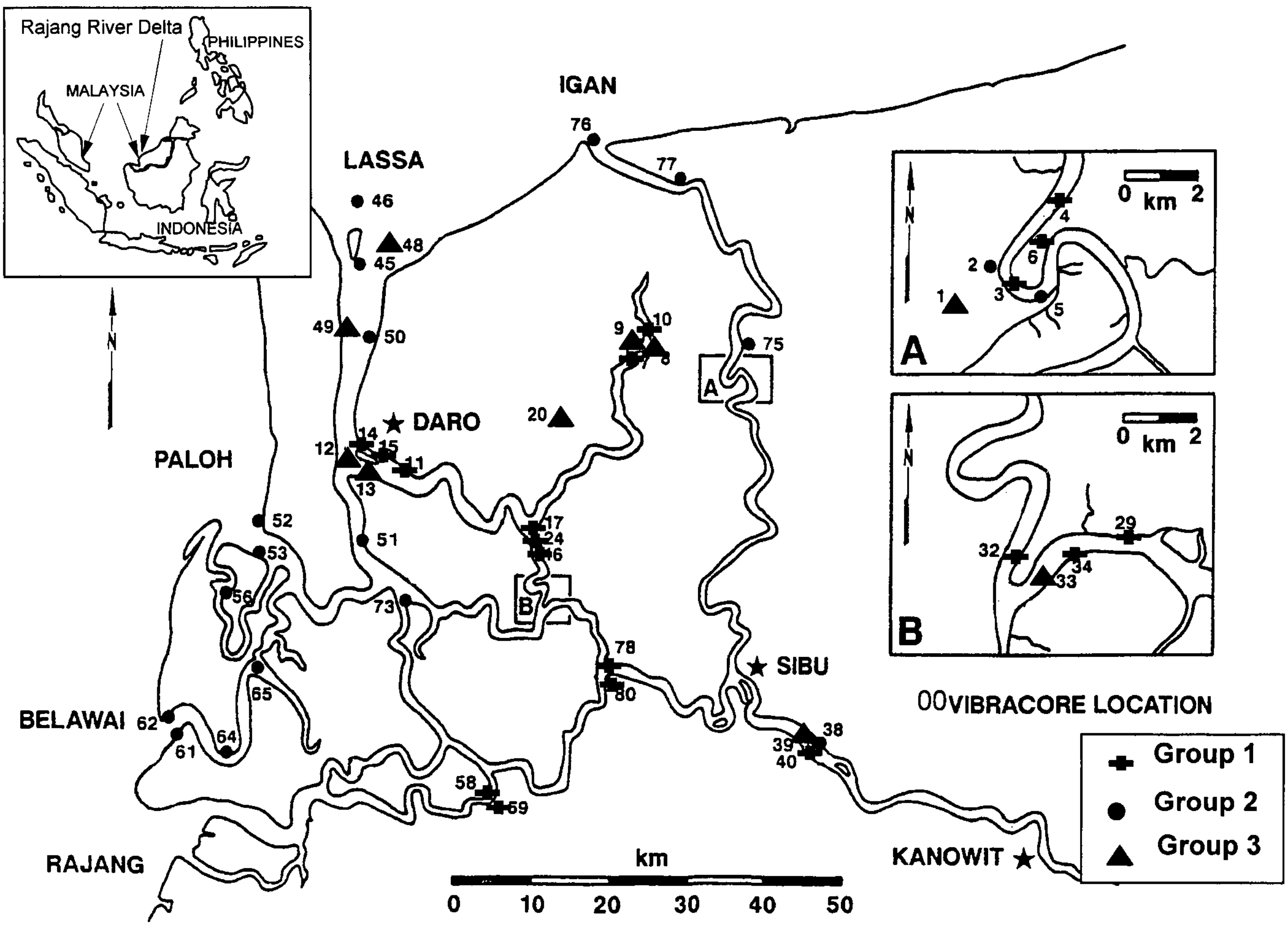

FIGURE 1—Locality map of southeast Asia depicting the position of the Rajang River in Sarawak, East Malaysia. Enlargment of the Rajang River, the delta, and distributary channels. Locations of vibracores used in this investigation are plotted in addition to the distribution of palynofacies groups as determined by multivariate analyses (see Figure 6). Scale is in km.

1993; Staub and Esterle, 1994). The delta covers an area of 6500 km^2 and is divided into an "abandoned" tidally flushed delta plain, and an actively accreting rectilinear delta/coastal plain (Staub and Esterle, 1993; Staub et al., submitted). The Rajang River cuts a relatively straight path westward after emerging from the upland area, and is flanked by an alluvial floodplain that covers approximately 400 km^2. The river begins to bifurcate in a 180° pattern beginning at the approximate position of Sibu (Fig. 1), resulting in five main distributary channels. The Rajang, Belawai, and Paloh are found in the tidally flushed delta plain, whereas the Igan and Lassa are located in the actively accreting delta plain.

The delta and alluvial valley are affected by semidirunal tides that range from meso- to macro-tidal amplitudes, increasing in range from northeast to southwest. The effect of the tidal prism extends 120 km inland, to the approximate position of Kanowit. Winds and waves from the northeast monsoon dominate from December to March and from the southwest monsoon during the middle months of the year. Other physiographic data are available in Staub and Esterle (1993) and Staub et al., (submitted).

Tropical vegetation covers all available sites of colonization and provides biomass to accumulating sediments. Riparian vegetation in the distal reaches is composed of marine to brackish water-fed mangroves (*Rhizophora, Avicennia, Sonneratia*) and *Nipa*; the proximal parts of the delta are fringed by dipterocarp forests and cultivated lands (Scott, 1985). Peat swamp forests occur adjacent to riparian vegetation and are dominated by dipterocarps (Anderson and Müller, 1975) in which several ecological catenas have been identified (Anderson, 1961, 1983). Peat deposits greater than 1 m thick cover about 50% of the delta plain surface, 80% of the adjacent coastal plain, and 75% of the alluvial valley. The maximum peat thicknesses are in excess of 20 m, with all peats having accumulated within the past 7000 to 7500 years (Staub and Esterle, 1994).

River and tidal channels, and some rooted sediments

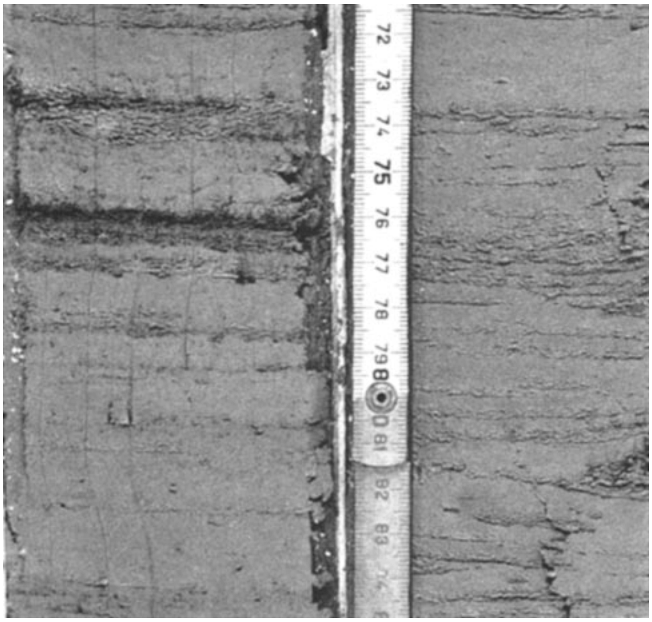

FIGURE 2—Photograph of vibracore 73 illustrating the rhythmically stratified sand, silt and organic drapes. Scale is in centimeters.

underlying peat deposits, are characterized by a single sediment facies comprised of interbedded sand (olive gray 5Y4/1 to dusky yellow 10YR2/2; Goddard et al., 1980), silt (olive 5Y4/1 to light 5Y6/2 gray) and organic detritus (black) that show rhythmic heterolithic stratification (Staub et al., 1994, submitted; Fig. 2). Individual beds range from a few millimeters to centimeters in thickness and reflect the influence of tidal activity at a particular site within the river system. Conformable or disconformable reactivation surfaces may be present in many of the rhythmically bedded sediments, and bioturbation is often encountered where there is marine influence. Bioturbation may be found as complete homogenization of sediment or as isolated cylindrical, centimeter-scale backfilled burrows that are horizontal to subvertical. The presence of this facies from as far inland as Kanowit to the distal parts of the delta provides an opportunity to assess whether or not a single, distinct palynofacies assemblage characterizes this rhythmic sediment and, hence, can be used to interpret similar fluvio-deltaic channel settings in the rock record.

METHODOLOGY

Eighty vibracores were recovered from across the Rajang River delta and within river deposits of the alluvial valley during two field seasons in 1992 and 1993. Vibracores, ranging from less than 3 meters to greater than 7 meters in length, were recovered from all sedimentary environments, including a variety of barforms in fluvial- and tidal-dominated river channels (including black-water channels), ombrogenous peat swamps and their underlying soils, distributary mouth bars and beaches. Representative sediment samples (1.5 cm wide, 1.2 cm thick, covering a 5–15 cm interval) were collected from all facies from each vibracore for grain-size (conducted at Southern Illinois University @ Carbondale; Staub et al., submitted) and palynofacies (conducted at Auburn University) analyses. Palynofacies preparations of the rhythmically stratified sand, silt, and organic matter were made according to standardized procedures (see: Lorente and Ran, 1991). Eighty four (84) samples from forty five (45) cores distributed in the Rajang River and throughout the delta plain were processed and examined. To minimize the bias between samples, a quantity of sediment equal to the displacement in water of 1.5 ml was processed. Two glycerine jelly strew mounts were made from each sample residue. Slides and labelled residues, stored in methanol, are housed at Auburn University.

Three hundred (300) phytoclasts per sample were point counted using a Swift Automatic Point Count Stage (Model F 415C, set at a $\frac{1}{6}$ mm advance) mounted on a Zeiss Axioskop equipped with epifluorescence (propagating 420 μm wavelength). Phytoclasts were assessed using a 40× Plan Neofluor objective. An individual phytoclast was counted if it occurred directly beneath the center cross hairs of the ocular. A Dolan-Jenner Fiber-Lite (Series 180) was used to assess opaque clasts. Phytoclast classification followed that as adopted by the 3rd Amsterdam Palynological Organic Matter Classification Workshop held in Cocodrie, Louisiana, in November 1993 (see: Lorente and Ran, 1991; Fig. 3). This is a multi-level classification scheme that was developed to accommodate all approaches of palynological organic matter investigations, from the most basic (transmitted white light only) to the advanced (epifluorescence and reflected white light). Four principal OM categories are recognized: (1) Structured OM includes all non-palynomorph particles with structure, and/or shape, that reflects tissue organization; (2) Palynomorph OM constitutes the resistant phytoclasts that form the basis of traditional palynology (see Traverse, 1988); (3) Unstructured OM includes all particles that have form but lack cellular structure; and (4) Indeterminate OM that encompasses residual particles, that reflect nothing about their origin in transmitted light, and can be described using a color scale.

To determine whether or not palynofacies assemblages in core samples of the rhythmically bedded, heterolithic sediment facies differed throughout the area, data were analyzed based upon different physiographic and geomorphological categories (Fig. 4). Palynofacies assemblages were compared between depositional sites within (1) meso- and macrotidal influences (Fig. 4A) and (2) exclusively freshwater, brackish-influenced (salinities ranging from <1 ppt to 29 ppt; unpublished data from field notes 22 July–10 August 1992), river mouth (ranging from <1 ppt to 32 ppt), and beach (>27 ppt) settings (Fig. 4B). Palynofacies assemblages were also compared between identified environments of deposition (Fig. 4C; Staub and Esterle, 1993) and barforms within these settings (Fig. 4D).

All samples from a single core were tested to determine

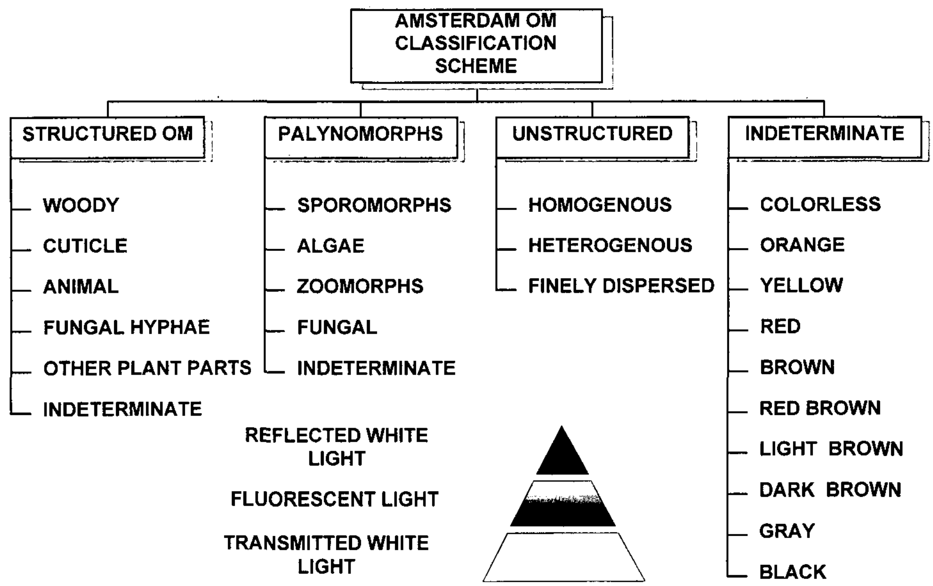

FIGURE 3—Phytoclast classification as adopted by the 3rd Amsterdam Palynological Organic Matter Classification Workshop held in Cocodrie, La. (November 1993). The classification scheme is designed for use by investigators that may have access to one (basic transmitted white light) or more of the three light sources needed to conduct palynofacies analysis, as illustrated in the broken triangle.

if their origin from the same population was supported statistically. It was believed that phytoclast categories were normally distributed in the sample population and statistically evaluated using the t-test and ANOVA (Feng, 1994). Subsequently, it was determined that these data do not conform to a normalized distribution and have been analyzed herein using the nonparametric Mann-Whitney U-test (StatMost v. 2.50; $P = 0.05$). Where the number of samples in any group was less than 8, the U-value was calculated and used with the tables published by Siegel (1956) to determine the probability of association. The palynodebris categories used for these analyses included the Total Structured OM (cuticle/epidermis, other plant parts, fungal hyphae, and indeterminate), Total Palynological (spores/pollen, fungal spores, and algae), Total Unstructured OM and its component categories (Heterogenous, Homogenous, and Fine Dispersed), and Indeterminate.

Multivariate statistical analyses have been applied to the data in order to identify groups of palynodebris types and samples. In these analyses, the individual palynodebris categories identified in the analyses (cited above) were used rather than the composite data (such as Total SOM). Principal Component Analysis (PCA) was used as an ordination technique to determine if a continuum of one or more dimensions existed in the seemingly homogenous data set. Data were log-transformed to reduce skewness. Cluster Analysis (MVSP Plus v. 2.0; Kovach, 1990) was used to divide the core data into discrete groups that differ in some meaningful way. The Spearman rank-order correlation coefficient, a non-parametric statistic, was used to calculate the coefficient (similarity) matrix. Data were entered randomly to avoid any potential bias in the calculations and an agglomerative clustering technique was employed (Kovach, 1988). In this technique all of the data are originally separate. The algorithm scans the similarity matrix for the most similar objects, combines these into a group, and then recalculates the similarity between the new group and all other groups or objects. Group similarities calculated from the similary matrix utilized the Unweighted Pair Group Average (UPGMA) parameter using the Average-Linkage method. Results of the cluster analyses are presented as dendrograms.

RESULTS

Eighty four (84) samples from forty five (45) cores were point counted. Identified palynodebris included Structured (woody, cuticle/epidermis, fungal hyphae, and other plant parts), Palynomorph (pollen & spores, fungal spores, algae, and foraminiferal test linings), Unstructured (homogenous, heterogenous, and fine-dispersed), and Indeterminate (black) organic matter (OM; Fig. 5).

Structured OM is the second most abundant phytoclast category in the samples ($\bar{x} = 14.1\% \pm 5.2\%$ [5.9–33.2%]), exhibiting a wide variety of colors and preservational states. Structured OM clasts range in coloration from light to yellowish tan to dark brown, and are generally fluorescent. Cell walls may be thick (in the case of endodermis) or thin (epidermis) depending upon the histology of the original particle, and the cell structure may range from partially to well-preserved. Where degradation has proceeded, cell walls often can be identified in seemingly unstructured clasts using fluorescence. Other plant parts are the most commonly encountered SOM, whereas woody phytoclasts are rare in the preparations. Fungal hyphae are the second most abundant type of SOM, characterized by an

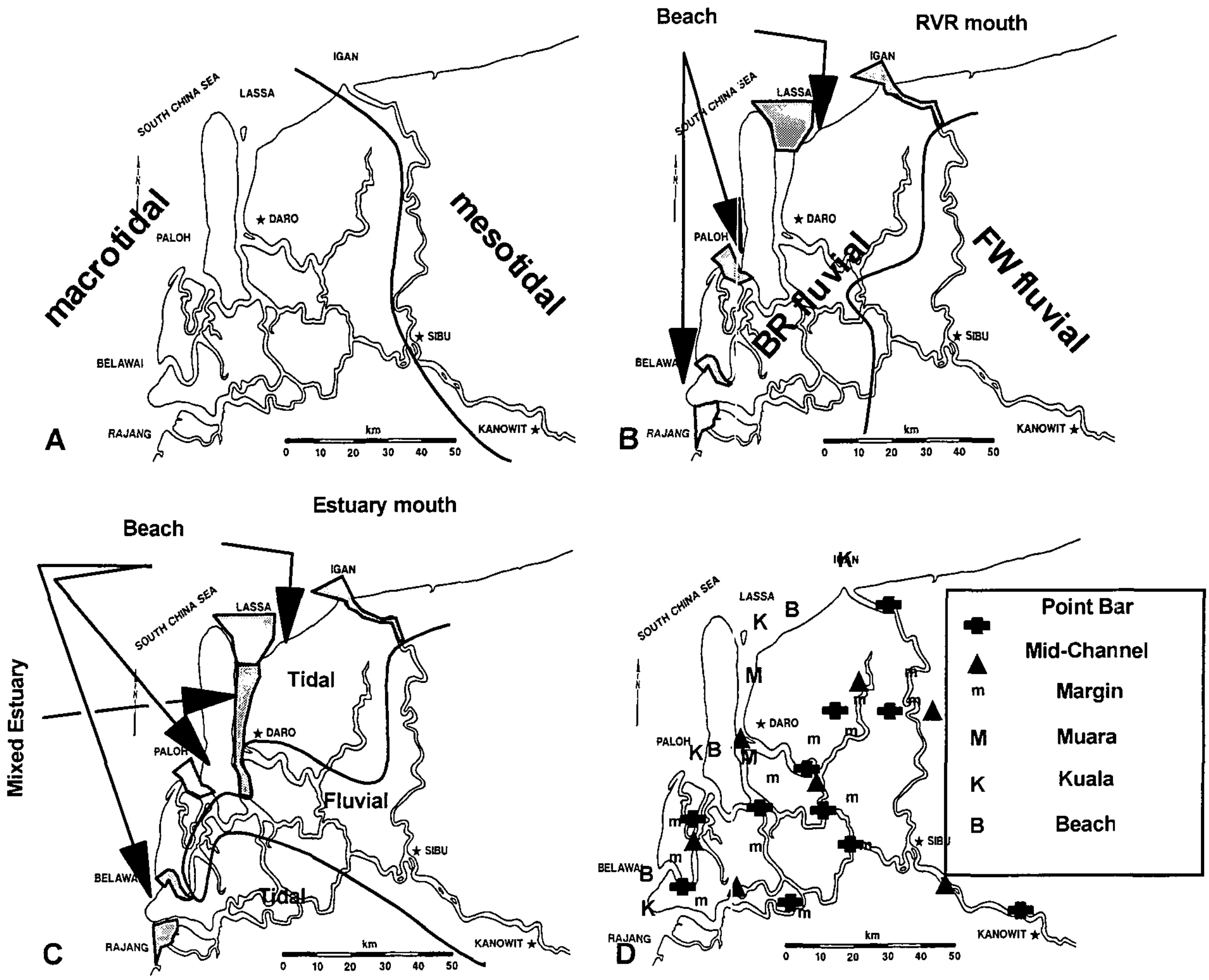

FIGURE 4—Subdivisions of the data set used in the Mann-Whitney nonparametric tests to evaluate the effects of different parameters on equivalence of recovered palynofacies assemblages. A—Division of samples influenced by mesotidal and macrotidal processes in the delta (see Figure 1 for sample sites within these subdivisions). B—Division of depositional sites deposited under varying salinity influence at the time of vibracore collection during the dry season. See text for salinity ranges associated with each subdivision. C—Division of the data set according to identified environments of deposition. D—Localities of the various barforms vibracored, sampled, and compared.

elongate, tubular shape and deep brown color (non-fluorescent due to the presence of chitin).

Palynomorphs represent a very small quantitative share of palynofacies assemblages ($\bar{x}$ = 0.7% ± .53% [0–2.6%]). Pollen (angiosperm and the gymnosperm *Dacrydium*) and spores (club mosses and ferns) are well-preserved, light-brown in color, semi-transparent and fluoresce strongly. Well-preserved fungal spores, on the other hand, are deep brown in color, display a wide diversity of shape (see: Elsik, 1993), and do not fluoresce. Unicellular or colonial algae and marine microfossils are very rare in the palynofacies counts (the frequency of foraminifera recovered in preparations made exclusively for these microfossils is similar to other coastal sites and ranges from sparce to abundant depending on the salinity, S. Murphy, pers. comm., 7/95). Algae appear to be of a freshwater origin (*Pediastrum*), while the marine palynomorphs include acritarchs and foraminiferal test linings.

Unstructured OM is the most abundant palynofacies category in the samples ($\bar{x}$ = 83.3% ± 6.4% [63.6–92.2%]). All three components, Heterogenous, Homogenous, and Finely Dispersed OM, are found in varying quantities. Heterogenous OM is the most common type of unstructured clast in the preparations ($\bar{x}$ = 38.1% ± 13.5% [5.6–61.6%]) and occurs in a variety of colors and textures. These clasts are composed of different sizes and kinds of particles and may or may not fluoresce. Textures vary from granular (composed of small, equidimensional particles enclosed within a matrix), aggregate (comprised of a mixture of structured OM, spores, homogenous unstructured and/or small unstructured OM), to fluffy (transparent to semi-transparent clasts that display the appearance

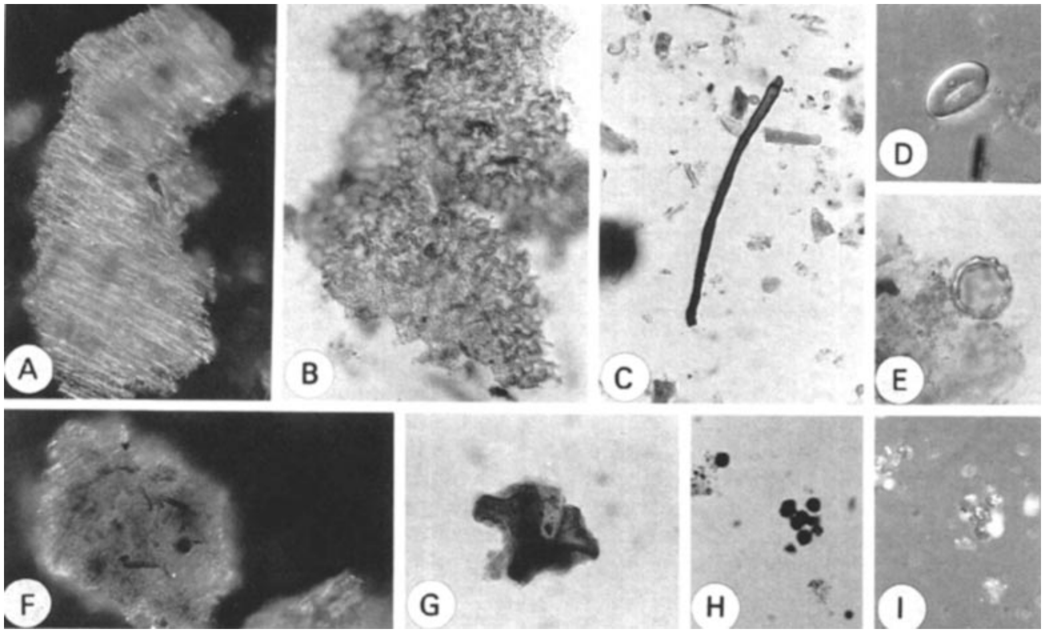

FIGURE 5—Typical phytoclasts encountered in palynofacies preparations (1:10–20 indicates the number of the vibracore and sample interval as measured from the bottom of the core upwards). (A) Structured OM—Other Plant Part (29:55–65; DIC); (B) Stuctured OM—Cuticle (29:55–65; TL); (C) Structured OM—Fungal hyphae (29:55–65; TL); (D) Palynological OM—Monolete spore (29:55–65: DIC); (E) Palynological OM—Pollen (29:55–65; DIC); (F) Unstructured OM—Heterogenous aggregate (29:55–65; DIC); (G) Unstructured OM—Homogenous vitreous (29: 55–65); (H) Indeterminate—Black (46:140–148; TL); (I) Indeterminate—Pyrite (46:140–148; RL).

of clouds). Homogenous clasts ($\bar{x}$ = 25.9% ± 8.9% [4–46.4%]) generally are orange to reddish brown in color and display a definitive outline and uniform composition. Most particles are vitreous in texture (dammar droplets or filled resin ducts, Gastaldo et al., 1993) and fluoresce. Finely dispersed OM (19.34% ± 15.8% [1.8–83.6%]) are defined as clasts that are less than 5μm in diameter and not embedded in an obvious matrix. These particles vary in coloration from dark brownish to transparent.

The Indeterminate OM category generally comprises a small proportion of the preparations ($\bar{x}$ = 1.13% ± 3.18 [0–21.6%]), and only one type of clast has been recognized. Black indeterminate clasts have been found to vary in proportion throughout the delta. Under transmitted light, these resistant clasts are opaque and provide no clues as to their identity. Neither do the particles fluoresce. Under reflected white light, though, it is apparent that the vast majority of these particles are pyrite framboids.

Nonparametric Statistical Analyses

Samples from an individual core were analyzed to determine if each of the seven main variables described above originated from the same population (Feng, 1994). Confidence intervals at the 95% ad 90% intervals were calculated for all samples less one in a core and the omitted sample was compared to these statistics. It was determined that all samples recovered from a single core had originated statistically from the same population with very few exceptions (CORE 1: total structured and unstructured debris in sample C1/190–205, indeterminate in C1/235–250, and heterogenous in C1/430–445; CORE 8: homogenous in C8/27–27.5, total structured and unstructured in C8/28–29, and heterogenous, finely dispersed, and indeterminate in C8/32.1–33). Therefore, it was considered that all samples had originated from the same population within any single core.

Results from the nonparametric Mann-Whitney U test show that overall there is some variation in the palynofacies assemblages from throughout the delta, and that certain variables from different physiographic or geomorphologic settings are significantly different. When populations from meso-tidally influenced depositional sites are compared to those from macro-tidally influenced sites (Fig. 4A), there is no statistically significant difference in any of the seven phytoclast categories (Table 1). The range of tidal influence on a particular depositional site does not influence the resultant buried palynofacies assemblage.

When palynodebris categories are compared with respect to the waters in which they were deposited (Fig. 4B), several statistically significant discrepancies are found (Table 2). There is a statistically significant difference in nearly all first-order categories between the freshwater fluvial data set and the brackish and river mouth data sets. Structured OM is ranked higher (more abundant) in the freshwater sites than in the brackish fluvial or river mouth sites, and this result is almost the same (P = 0.054) for the comparison with beach samples. The same rela-

TABLE 1—Mann-Whitney Rank test comparing vibracore samples recovered from mesotidally and macrotidally influenced channels. Calculated z scores and probability that the data sets originate from the same population are given. z score ≥1.96 is significant at 0.05. Cells that are cross-hatched indicate statistically significant differences in the populations.

	STRUCTURED	PALY	HOMOGENOUS	HETEROGENOUS	FINE DISPERSED	TOTAL UN-STRUCTURED	BLACK
MESO:MACRO	.515 (z) .60 (p)	.98 - .38	.47 - .63	.74 - .45	.51 - .61	.66 - .50	1.13 - .25

tionship holds for the Palynological component. Conversely, Total Unstructured OM is ranked higher (more abundant) in sites where beach, brackish fluvial, and river mouth waters influenced deposition. A statistically significant difference in the Black Indeterminate category exists between samples deposited under freshwater fluvial, brackish water fluvial and river mouth influences. Samples from river mouth settings are ranked higher (more abundant) than those from either of these other settings. When individual Unstructured OM categories are evaluated, Heterogenous Unstructured OM is significantly different for the freshwater fluvial and river mouth comparisons and Fine Dispersed Unstructured OM is significant for the brackish fluvial and river mouth comparisons. Samples that represent deposition under the influence of river mouth waters have higher ranked samples (more abundant) than those of the freshwater fluvial data set for the Heterogenous category, and lower ranked (less abundant) samples than those of the brackish fluvial data set for the Fine Dispersed category.

Results from the comparison of depositional environments differ from those presented above due to the reorganization of samples to conform to these subdivisions (Fig. 4C). Fluvial sites include those that were deposited within the active distributaries (Igan, Lassa, Paloh, and Belawai), whereas tidal environments of deposition are those within inactive (Rajang) or abandoned (interior Lassa) distributaries. The distinction between estuary mouth and fine-grained estuary (within the Lassa) is based upon the classification of Postma (1980; see: Staub et al., submitted), and beach deposits occur along the seaward margin of the delta. When comparisons are made of these data sets, the overall palynofacies aspect of the delta appears to be more homogenous (Table 3). There is no clear demar-

TABLE 2—Mann-Whitney Rank test comparing vibracore samples recovered from depositional sites with various salinity influences that include freshwater fluvial, brackish water fluvial, river mouth, and beach settings. Calculated z scores and probability that the data sets originate from the same population are given. z score ≥1.96 is significant at 0.05. Cells that are cross-hatched indicate statistically significant differences in the populations.

	STRUCTURED	PALY	HOMOGENOUS	HETEROGENOUS	FINE DISPERSED	TOTAL UN-STRUCTURED	BLACK
FWFLUVIAL - BEACH	1.92 (z) .054 (p)	2.12 - .03	.53 - .59	1.92 - .054	1.59 - .11	2.25 - .03	0 - 100
FWFLUVIAL - BRACKISH	3.35 - 0.00	3.35 - 0.00	1.56 - .11	.60 - .54	1.34 - .18	3.42 - 0.00	1.15 - .25
FWFLUVIAL - RVR MOUTH	3.14 - 0.00	3.13 - 0.00	1.20 - .23	2.5 - .01	1.12 - .26	2.06 - .04	2.38 - .02
BEACH - BRACKISH	.53 - .59	1.46 - .14	1.12 - .25	1.46 - .14	1.72 - .08	.66 - .50	.06 - .95
BEACH - RVR MOUTH	.14 - .88	.87 - .38	1.17 - .24	.29 - .77	.58 - .55	1.46 - .14	1.46 - .14
BRACKISH - RVR MOUTH	.92 - .35	1.20 - .23	.57 - .56	1.71 - .09	2.06 - .04	.47 - .63	2.66 - 0.00

TABLE 3—Mann-Whitney Rank test comparing vibracore samples recovered from identified environments of deposition that include fluvial channels, tidal channels, fine-grained estuary (Muara), estuary mouth (Kuala), and beaches. Calculated z scores and probability that the data sets originate from the same population are given. z score ≥1.96 is significant at 0.05. Cells that are cross-hatched indicate statistically significant differences in the populations.

	STRUCTURED	PALY	HOMOGENOUS	HETEROGENOUS	FINE DISPERSED	TOTAL UN-STRUCTURED	BLACK
BEACH - TIDAL	.29 (z) - .77 (P)	1.61 - .11	.59 - .56	2.09 - .04	1.46 - .14	.58 - .56	1.30 - .19
BEACH - ESTUARY MOUTH	.39 - .69	.91 - .36	.91 - .36	.52 - .60	.78 - .43	1.56 - .12	1.30 - .19
BEACH - ESTUARY	1.73 - .08	.87 - .39	1.73 - .08	.46 - .64	1.15 - .24	1.73 - .08	.86 - .39
BEACH - FLUVIAL	1.25 - .21	2.08 - .03	.69 - .48	1.66 - .10	1.57 - .11	1.66 - .10	0 - 1.00
TIDAL - ESTUARY MOUTH	.35 - .73	1.94 - .05	.81 - .42	2.01 - .04	1.39 - .16	.69 - .49	2.66 - .01
TIDAL - ESTUARY	.57 - .57	.69 - .49	.80 - .42	1.48 - .14	.57 - .57	.80 - .43	1.82 - .07
TIDAL - FLUVIAL	1.44 - .15	.02 - .98	.16 - .87	1.93 - .05	1.73 - .08	1.83 - .07	1.20 - .22
ESTUARY MOUTH - ESTUARY	1.63 - .10	.20 - .84	1.12 - .26	.10 - .92	2.75 - .01	.61 - .54	.40 - .68
ESTUARY MOUTH - FLUVIAL	1.63 - .10	.20 - .84	1.12 - .26	.10 - .92	2.75 - .01	.61 - .54	.40 - .68
ESTUARY - FLUVIAL	1.15 - .25	1.11 - .27	1.85 - .06	.77 - .44	.19 - .85	1.15 - .25	1.23 - .21

cation within the delta as when samples were compared relative to salinity. The relationships between Structured OM, Palynological and Black Indeterminate categories within the fluvial and estuarine mouth environments is again evident, but otherwise there appears to be no parallel differences for the other comparisons.

In an attempt to determine if palynofacies assemblages differed relative to the type of channel structure or barform from which they were collected (Fig. 4D), the Mann-Whitney test was conducted comparing channel margin, point bar, midchannel bar, Muara (estuarine barforms), Kuala (mouth bar), and beach sites (Table 4). Once again, the assemblages appear to be statistically homogenous with few exceptions. Midchannel bars differ from the Kuala in the ranking (abundance) of Structured OM and Fine Dispersed Unstructured OM. The midchannel bars ranked higher in SOM while the Kuala ranked higher in Fine Dispersed UOM. Black Indeterminate is ranked statistically higher in the Kuala than in point bars. Channel margin samples statistically differ from beach samples with respect to their palynological component (more abundant in channel margins). This sample set differs from the

TABLE 4—Mann-Whitney Rank test comparing vibracore samples recovered from channel barforms from throughout the delta and alluvial valley and include channel margins, estuary mouth (Kuala), fine-grained estuary (Muara), point bars, and mid-channel bars. Calculated z scores and probability that the data sets originate from the same population are given. z score ≥1.96 is significant at 0.05. Cells that are cross-hatched indicate statistically significant differences in the populations.

	STRUCTURED	PALY	HOMOGENOUS	HETEROGENOUS	FINE DISPERSED	TOTAL UN-STRUCTURED	BLACK
CHANNEL MARGIN - KUALA	1.55 (z) - .12 (P)	1.82 - .07	1.64 - .10	2.19 - .03	1.83 - .07	.91 - .36	1.73 - .08
CHANNEL MARGIN - MUARA	.51 - .60	1.03 - .30	2.06 - .04	1.03 - .30	.50 - .63	.53 - .59	1.16 - .25
CHANNEL MARGIN - BEACH	.66 - .51	2.0 - .04	.17 - .87	1.67 - .09	1.69 - .10	1.66 - .10	.16 - .87
CHANNEL MARGIN - POINT BAR	.56 - .57	.14 - .88	1.17 - .24	.75 - .45	.64 - .52	.80 - .42	.84 - .40
CHANNEL MARGIN - MID CHANNEL BAR	.57 - .56	1.64 - .10	1.65 - .10	1.40 - .16	.13 - .89	.61 - .54	.33 - .74
KUALA - MUARA	1.34 - .17	.14 - .88	1.34 - .18	.45 - .65	.74 - .46	.44 - .65	.59 - .55
KUALA - BEACH	.58 - .56	.77 - .43	1.16 - .24	0 - 1.00	.74 - .46	1.16 - .25	1.55 -.12
KUALA - POINT BAR	1.89 - .06	1.47 - .14	.73 - .46	1.89 - .06	1.58 - .11	.73 - .46	2.00 - .04
KUALA - MID CHANNEL BAR	2.22 - .03	1.11 - .27	.41 - .68	1.71 - .09	2.26 - .02	.56 - .58	1.94 - .05
MUARA - BEACH	1.73 - .08	.86 - .39	1.73 - .08	0 - 1.00	1.15 - .25	1.73 - .08	.86 - .38
MUARA - POINT BAR	.87 - .39	.72 - .47	1.73 - .08	1.01 - .31	.29 - .77	1.15 - .25	1.15 - .25
MUARA MID CHANNEL BAR	.76 - .45	.40 - .68	1.14 - .25	.76 - .45	.63 - .53	.76 - .45	1.13 - .26
BEACH - POINT BAR	1.46 - .14	1.73 - .08	.46 - .65	1.83 - .07	1.46 - .14	1.46 - .14	0 - 1.00
BEACH - MID CHANNEL BAR	1.58 - .11	1.58 - .11	.95 - .34	1.43 - .15	1.90 - .06	1.42 - .15	0 - 1.00
POINT BAR - MID CHANNEL BAR	.16 - .87	1.15 - .24	.67 - .50	.61 - .53	.95 - .34	.62 - .54	.29 - .76

Muara and Kuala with respect to its Homogenous and Heterogenous Unstructured OM, with both of these categories more abundant in channel margins.

Multivariate Statistical Analyses

Results from PCA analyses were disappointing, as more than 90% of the total variance in the data set was accounted for by the first PCA axis. The most abundant phytodebris categories clustered together, while the least abundant categories clustered on the plots of the first three PCA axes (Feng, 1994). The results were deemed unproductive, similar to that as found by Oboh (1992).

Results from the UPGMA cluster analyses are illustrated in Figure 6 as dendrograms. The lengths of the dendrogram branches depend on the average similarity of each group as they are fused. Two separate cluster analyses were conducted, one utilizing the palynodebris categories and one for the core data. Two weakly linked clusters of palynodebris have been identified. Four palynodebris categories occur in relatively high abundance throughout all the cores and three of these, Heterogenous and Finely Dispersed OM and Indeterminate Black, are linked in the first group. The remainder of the palynodebris categories are linked into a second group. These clusters form the basis for distinguishing the dominant components of the groups identified from the core data.

Three groups, or core clusters, are linked in the core cluster analysis. Each group can be characterized by the abundance of specific palynodebris categories. Group 1 is characterized by high amounts of Heterogenous and Homogenous Unstructured OM, moderate amounts of Finely Dispersed OM and Other Structured Plant Parts, and low amounts of Black Indeterminate material. When compared with the other groups, Group 1 has a higher quantitative share of Other Structured Plant Parts and Homogenous (resin) Unstructured OM. Group 2 is characterized by having the highest quantity of Heterogenous Unstructured OM and Indeterminate Black (pyrite), and the least quantitative share of Finely Dispersed Unstructured OM. On average, this category has moderate to high amounts of Other Structured Plant Parts and Homogenous and Finely Dispersed Unstructured OM, and low amounts of Cuticle and Fungal Hyphae. Group 3 is characterized by the highest quantitative share of Finely Dispersed and moderate amounts of Heterogenous Unstructured OM. There are moderate amounts of Other Structured Plant Parts and relatively low quantities of Homogenous Unstructured OM and Black Indeterminate.

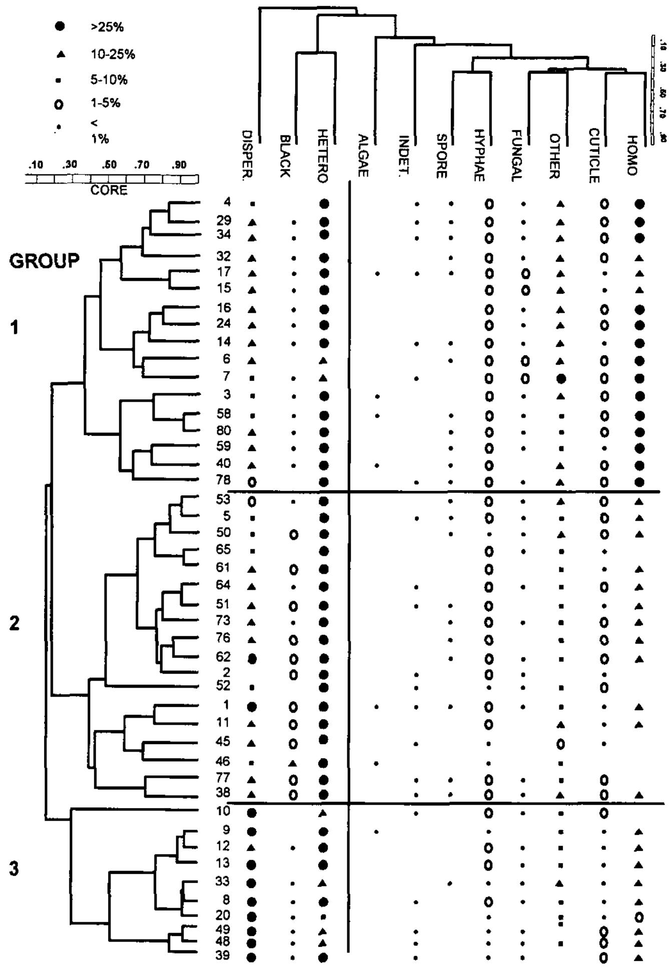

FIGURE 6—Dendrogram of cluster analyses in which two weakly linked palynodebris clusters can be identified and three clusters of vibracores samples. The three groups of vibracores are plotted on Figure 1 where it can be seen that Group 1, characterized by high amounts of Heterogenous and Homogenous (mainly dammar) Unstructured OM, moderate amounts of Structured OM and Finely Dispersed Unstructured OM, and low amounts of Black Indeterminate OM, is restricted to depositional sites principally in exclusively freshwater settings. Group 2, characterized by the highest quantities of Heterogenous Unstructured OM and Indeterminate Black and the least amount of Finely Dispersed UOM, is found in channels of the lower delta plain and the distribution conforms to the limit of saline influence during the wet season. Group 3, characterized by the highest quantitative amount of Finely Dispersed UOM, is found either in barforms or in black-water tidal channels that are sediment starved.

When these clusters are plotted according to the position of the vibracore in the delta (Fig. 1), a distinctive pattern emerges that parallels, in part, the results of the Mann-Whitney tests when comparing site of deposition and salinity of waters affecting that site. Group 1 is more common to the interior of the delta where there is moderate to no saline influence, whereas Group 2 is characteristic of the distal parts of the delta where moderate to high saline influence exists. The distribution of Group 3 is sporadic within the delta, being found in high energy areas where physical degradation of the organic matter is common (front margin of channel bars and beaches) or where sedimentation rates are low and biological degradation rates are high (black water channels within the abandonded Lassa). When these core clusters are evaluated on a smaller scale, for example within a single barform, it can be seen that the palynofacies assemblages characterize particular depositional sites within the barform (Fig. 1). Where the physical processes are least energetic (point bars, proximal ends of lateral channel bars and protected sites [interior] of midchannel bars), the palynofacies assemblages are characteristic of Group 1. Where the physical processes are strongest (downstream end and exterior side of midchannel bars), Group 3 palynofacies assemblages occur.

DISCUSSION

The palynofacies of the Rajang River's heterolithic rhythmic sediment facies found throughout channels of the delta and alluvial valley is principally composed of terrestrial-derived organic matter. Marine-derived OM is exclusively encountered in estuarine settings and plays a minor quantitative role in these sediments. The high proportion of Unstructured OM in the preparations is an indication of the high rate of organic matter degradation in this tropical setting. Gastaldo and Staub (1994; submitted) have demonstrated that the high proportion of Unstructured OM found in these sediments is a reflection of supply from the water column and not the result of early OM diagenesis following burial.

Staub et al. (1994; submitted) have shown that most siliciclastic sediments within the delta are the result of tidally influenced depositional processes that occur during the dry season (April to November), and that distributary mouth bar and coastal sediments are emplaced during the wet season (December to March). The heterolithic rhythmically stratified sediments examined in this study are the result of dry season deposition. This fact alone should support the contention that the palynofacies assemblages recovered from these sediments would be homogenous throughout the delta, and on a quick overview of the data this hypothesis would appear to be supported allowing for varying amounts of Structured and Unstructured OM.

The environment of deposition, as determined from geomorphological and sedimentological criteria, does not influence the palynofacies assemblage as determined from the Mann-Whitney U-tests. Palynofacies assemblages recovered from these settings are essentially identical, showing little statistical variance.

The effects of tidal influences operating during the dry season appear to have the most bearing on palynofacies assemblage composition. Results from the Mann-Whitney U-tests indicate that tidal amplitude has no significance relative to the resultant palynofacies assemblages. Rather, the presence of saline waters in the channels of the lower delta plain is the impetus for an alteration of palynofacies character that allows for statistically significant separation of these assemblages from those further inland. This assemblage modification is the result of an increased amount of Unstructured OM and pyrite genesis (Black Indeterminate OM residue). These results do not support the hypothesis that palynofacies assemblages are homogenous throughout the channel sediments of the delta and alluvial plain.

Structured and Palynological OM are statistically more abundant in sites where there is no saline influence. Their higher abundance reflects settling of these denser phytoclasts from the water column during flood slack, probably most effective during the King tides when flood slack is of the longest duration. In effect, more Structured and Palynological OM is trapped within the freshwater channels than is exported down river. Their presence within the brackish-influenced channels and river mouths is probably, in part, a function of SOM and pollen/spores introduced by riparian vegetation in the lower delta plain and, in part, ebb slack processes that allow for the settling of these clasts from the deeper parts of the freshwater water column.

Total Unstructured OM, on the other hand, is more abundant in sites influenced by marine waters than in the freshwater settings. This may be due to their less dense character and propensity to remain in the water column for longer periods of time, if it is assumed that equal amounts of all palynodebris categories are contributed from riparian vegetation lining the waterways throughout the course of the river channels. If more UOM originated within the mangroves and fringing *Nipa* colonies of the lower delta plain, then this contribution alone could account for its increased abundance in these sites. Preliminary examination of palynofacies assemblages from rooted silts taken throughout the delta indicates that there is no statistical difference in OM category abundances (Pedentchouk et al., 1995). Essentially, these rooted sediments exhibit a homogenous palynofacies character regardless of the colonizing vegetation. Presently, we can not consider the possibility of increased UOM contribution from lower delta plain vegetation as being responsible for the statistical difference between freshwater and brackish-influenced settings. The longer residency time of the Unstructured OM phytoclast category in the water column appears to be the most parsimoneous explanation to account for its higher abundance in the lower delta plain.

The emplacement of Unstructured OM in the saline-influenced parts of the delta may occur either during flood slack (with their origin from palynodebris that had been transported to the delta front and then reintroduced to this site as the result of tidal bore) or ebb slack (with the palynodebris falling from the freshwater suspension load). Because it is not possible at this point in time to distinguish UOM that has been resident in the marine realm from that in the freshwater realm, it is not possible to provide an unequivocal answer to the processes responsible for emplacement of these phytoclasts. It is apparent, though, that some palynological clasts are of marine origin (acritarchs, some foram test linings) and have been introduced into the brackish-water sites by tidal processes, while some other clasts (taxa) are indicative of brackish-water habits.

When palynofacies assemblages recovered from channel barforms are compared, a similar pattern can be seen. Mid channel barforms, those developed in direct response to the effects of tidal processes operating in the delta, statistically have a higher abundance of Structured OM than do barforms in the Kuala (mixed estuary). Barforms in the Kuala have a statistically higher abundance of Fine Dispersed OM than mid channel bars, but both Homogenous and Heterogenous UOM are more abundant in channel margins than in the saline-influenced Kuala and Muara.

The Black Indeterminate palynodebris which in many, but not all, cases represents authigenic pyrite is characteristic of those areas where there is the influence of marine waters. Results of the Mann-Whitney U-test indicate that there is a statistical difference between freshwater, brackish water and river mouth environments, with the latter characterized by a higher abundance of these particles. The river mouth (Kuala) is also statistically different from point bars with respect to this palynodebris category. The strong influence of marine waters in these sites promotes pyrite genesis.

The general palynofacies assemblage pattern detected using the Mann-Whitney U-tests is confirmed in the UPGMA cluster analysis. Group 1, characterized by a greater abundance of SOM and Homogenous Unstructured OM (dammar), is found to be restricted to the freshwater channels of the interior parts of the delta and alluvial valley. A discrepancy with the Mann-Whitney results exists with respect to the assignment of the palynofacies from the mid-channel barform near Daro (Figs. 1, 3B), where these assemblages were considered to be part of the brackish-influenced channels in the nonparametric analysis but cluster with the freshwater samples in the multivariate analysis. This latter assignment is more realistic as the Lassa and Igan Rivers are the main distributaries operating during the dry season (Staub and Esterle, 1993; Staub et al., submitted).

Group 2, on the other hand, is restricted to the saline-influenced lower delta plain. This palynofacies cluster is characterized by the highest quantities of Heterogenous Unstructured OM and Indeterminate Black particles. This group tracks, relatively well, the limits of salt incursion not during the dry season, but during the wet season (Staub et al., submitted). The continuous, year-long influence of saline waters in this zone is probably responsible for the higher proportion of pyrite in these organic-rich sediments. The presence of freshwater in the Lassa during the wet season may alter the pore water chemistry enough to retard the development of high quantities of pyrite in these sediments. Black Indeterminate clasts are found in the sediments recovered from the midchannel bar near Daro and into the abandonded arm of the Lassa, but the quantitative share of this category is low (Feng, 1994).

Group 3, characterized by the highest quantitative share of Finely Dispersed OM (particles $<5\ \mu m$) is not restricted to a particular geographical region within the delta/alluvial plain, but appears to be site specific. Cores that are characterized by this assemblage occur either within the sediment-starved channels of the abandonded Lassa distributary (Cores 8, 9, 10, and 20) or on the downstream side of midchannel (Cores 39, 12, 13, and 48) or lateral (Core 33 and 49) barforms. The high quantitative share of Finely Dispersed OM may be either a function of biological and/or physical degradation processes. Biological degradation of OM occurs through catabolysis and microbial activity whereby cellular contents depolymerize resulting in coagulation of the residuum (Gastaldo, 1994). As the residency time of OM increases either on the soil-air or sediment-water interface before burial, the transformation of once structured debris to unstructured debris continues. This ultimately results in the liberation of the remaining cellular contents and the disassociation of cell walls. This process accounts for the high proportion of Finely Dispersed OM in the black-water tidal channels of the Lassa. Physical degradation is invoked for those sites on the downstream end of barforms where the greatest amount of energy is expended during diurnal flood tides. Organic matter deposited in these settings have the highest probability of being reentrained, reworked, and physically broken into smaller pieces. This process, in combination with intracellular catabolic activity, accounts for the high proportion of this palynodebris category in the barforms.

Both Groups 1 and 2 may also be characteristic assemblages of the barforms, depending upon the position in the bar from which the sample was recovered. An examination of the midchannel barform examined between Sibu and Kanowit demonstrates the extreme case (Fig. 1). Core 39, taken from the downstream end of the barform is characterized by Group 3 (high proportion of Finely Dispersed OM). The assemblage recovered from Core 40, taken on the interior side of the barform, is assigned to Group 2, that group that is the principal assemblage found in freshwater settings. Core 38, taken on the exterior (midchannel) side of the barform is characterized by a palynofacies assemblage high in Unstructured Heterogenous and Black Indeterminate (non-pyritic). The other midchannel barforms examined exhibited a disparity between downstream Group 3 assemblages and upstream or interior side Group 2 assemblages (Fig. 1). The variability in the proportions of OM components within a single barform was not expected.

CONCLUSIONS

Palynofacies assemblages analyzed from a single sediment facies, characterized by rhythmically bedded sand and silt, recovered from river and tidal channels in the Rajang River and Rajang River delta are not homogenous throughout the regime as hypothesized. Statistical analyses reveal that two major assemblage patterns exist within these sediments, with a third assemblage identified after applying multivariate statistical analyses. The two palynofacies assemblages coincide with the effects of saline-water influence in the delta. The first assemblage, characterized by high amounts of Heterogenous and Homogenous (mainly dammar) Unstructured OM, moderate amounts of Structured OM and Finely Dispersed Unstructured OM, and low amounts of Black Indeterminate OM, is restricted to depositional sites that are principally found in freshwater settings. The exception to this is in the midchannel barform of the Lassa near Daro, but the assemblage composition can be explained by the active distributary status of this river. The second assemblage, characterized by the highest quantities of Heterogenous Unstructured OM and Indeterminate Black and the least amount of Finely Dispersed UOM, is found in channels of the lower delta plain. The distribution of this palynofacies assemblage conforms to the limit of saline influence during the wet season. The third group, characterized by the highest quantitative amount of Finely Dispersed UOM, is found either in barforms or in black-water tidal channels that are sediment starved.

A general assumption has prevailed in the use of palynofacies assemblages to interpret ancient depositional environments. That assumption is that each lithofacies is characterized by a single palynofacies assemblage, allowing similar lithofacies to be distinguished (e.g., Hart et al., 1994). The present investigation has shown that the accumulation of organic matter and the resultant dispersed OM assemblages in a single sediment facies is heavily influenced by the geochemistry of the system. Caution must be exercised when using palynofacies assemblages as absolute proxies for interpreting the depositional setting of the sediments in which they are preserved, until results from more actualistic studies have been published.

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LITERATURE CITED

ANDERSON, J.A.R., 1961, The ecology and forest types of peat swamp forests of Sarawak and Brunei in relation to their silviculture: Unpublished Ph.D. Thesis, University of Edinburgh, Scotland, 117 p.

ANDERSON, J.A.R., 1983, The tropical swamps of western Malesia, *in* GORE, A.P.J. ed., Mires: Swamp Bog, Fen, and Moor. Ecosystems of the World, Regional Studies 4B: Elsevier, Amsterdam, p. 181–200.

ANDERSON, J.A.R., and MÜLLER, J., 1975, Palynological study of a Holocene peat deposit and a Miocene coal deposit from NW Borneo: Review of Paleobotany and Palynology, v. 19, p. 291–351.

BOULTER, M.C. and RIDDICK, A., 1986, Classification and analysis of palynodebris from the Paleocene sediments of the Fortiesfield: Sedimentology v. 33 p. 871–886.

CARATINI, C., 1994, Palynofacies of some recent marine sediments: The role of transportation: *in* TRAVERSE, A., ed., Sedimentation of Organic Particles: Cambridge, Cambridge University Press, p. 129–140.

COMBAZ, A., 1964, Les Palynofacies: Review Micropaleontology, 7(3): 205–218.

ELSIK, W.C., 1993, The morphology, taxonomy, classification and geologic occurrence of fungal palynomorphs: American Association of Stratigraphic Palynologists, Shortcourse, 236 p.

FENG W., 1994, Palynofacies analysis of channel deposits of the Rajang River delta, Sarawak, East Malaysia: Unpublished M.S. Thesis, Auburn University, AL, 82 p.

GASTALDO, R.A., 1994, The genesis and sedimentation of phytoclasts with examples from coastal environments, *in* TRAVERSE, A. ed. Sedimentation of Organic Particles: Cambridge University Press, Chapter 7, pp. 103–127.

GASTALDO, R.A., and STAUB, J.R., 1994, A Comparison of Water Column and Grab Sample Palynofacies Assemblages from the Rajang River Delta, Sarawak, East Malaysia: 4th International Paleobotanical and Palynological Conference, Kerkrade, The Netherlands, Abstracts, p. 27–28.

GASTALDO, R.A., and STAUB, J.R., submitted, Water Column and Grab Sample Palynofacies Assemblages from the Rajang River Delta, Sarawak, East Malaysia: Palynology.

GASTALDO, R.A., ALLEN, G.P., and HUC, A.Y., 1993, Detrital peat formation in the tropical Mahakam River delta, Kalimantan, eastern Borneo: Formation, plant composition, and geochemistry, *in* COBB J.C. and CECIL, C.B. Eds. Modern and Ancient Coal-forming Environments: Geological Society of America Special Paper v. 286, p. 107–118.

GODDARD, E.N., TRASK, P.D., DE FORD, R.K., ROVE, O.N., SINGEWALD, J.T., and OVERBECK, R.M., 1980, Rock-Color Chart: Geological Society of America.

GORIN, G.E. and FEIST-BURKHARDT, S., 1990, Organic facies of early to middle Jurassic sediments in the Jura mountains, Switzerland: Review of Palaeobotany and Palynology, v. 65, p. 349–355.

HABIB, D, ESHET, Y., and VAN PELT, R., 1994, Palynology of sedimentary cycles: *in* TRAVERSE, A., ed., Sedimentation of Organic Particles, Cambridge: Cambridge University Press, p. 311–336.

HART, G.F., 1994, Maceral palynofacies of the Louisiana deltaic plain in terms of organic constituents and hydrocarbon potential: *in* TRAVERSE, A., ed., Sedimentation of Organic Particles: Cambridge, Cambridge University Press, p. 141–176.

HART, G.F., PASLEY, M.A., and GREGORY, W.A., 1994, Particulate organic matter, maceral facies models, and applications to sequence stratigraphy: *in* TRAVERSE, A., ed., Sedimentation of Organic Particles: Cambridge, Cambridge University Press, p. 337–390.

HIGHTON, P.J.C., PEARSON, A., and SCOTT, A.C., 1991, Palynofacies and palynodebris and their use in Coal Measure palaeoecology and palaeoenvironmental analysis: Neues Jahrbuch für Geologie und Paläontologie Abhandelungen, v. 183, p. 135–169.

KOVACH, W.L., 1988, Multivariate methods for analyzing paleoecological data, *in* DIMICHELE W.A. and WING, S.H. eds, Methods and Applications of Plant Paleoecology, Paleontological Society Special Publication, v. 3, p. 72–104.

KOVACH, W.L., 1990, Multi-Variate Statistical Package Plus—Version 2.0: "Berlian-Ber," Abermagwr, Wales. 45 p.

LENOIR, E.A., and HART, G.F., 1988, Palynofacies of some Miocene sands from the Gulf of Mexico, offshore Louisiana, U.S.A.: Palynology, v. 12, p. 151–65.

LORENTE, M.A., 1990, Textual characteristics of organic matter in several subenvironments of the Orinoco Upper Delta: Geologie en Mijnbouw, v. 69, p. 263–278.

LORENTE M.A., and RAN, E.T.H., Eds., 1991, Open workshop on organic matter classification: Hugo De Vries-Laboratory, University of Amsterdam, Special issue. 72 p.

OBOH, F.E., 1992, Multivariate statistical analyses of palymodebris from the Middle Miocene of the Niger Delta and their environmental significance: Palaios v. 7, p. 559–573.

PASLEY, M.A., and HAZEL, J.E., 1990, Use of organic petrology and graphic correlation of biostratigraphic data in sequence stratigraphic interpretations: Example from the Eocene-Oligocene boundary section, St Stephens Quarry, Alabama: Transactions Gulf Coast Association of Geological Societies v. 40, p. 661–683.

PASLEY, M.A., GREGORY, W.A., and HART, G.F., 1991, Organic matter variations in transgressive and regressive shales: Organic Geochemistry, v. 17, p. 483–509.

PEDENTCHOUK, N., GASTALDO, R.A., and STAUB, J.R., 1995, Differences in organic matter content (Palynofacies) among various sediment facies in the Rajang River delta, Sarawak, East Malaysia: Geological Society of American, Abstracts with Program v. 27, no. 6, p. 140.

POSTMA, H., 1980, Sediment transport and sedimentation, *in* OLAUSSON E. and CATO I. eds., Chemistry and Biochemistry of Estuaries: J. Wiley, Chesterfield, p. 153–186.

Poumot, Cl., 1989, Palynological evidence for eustatic events in the tropical Neogene: Bulletin Centres Recherches Exploration Elf-Aquitaine, v. 13, p. 437–453.

Scott, I.M., 1985, The Soils of Central Sarawak Lowlands, East Malaysia: Department of Agriculture, Sarawak, East Malaysia, Soil Memoir 2, 293 p.

Siegel, S., 1956, Nonparametric Statistics for the Behavioral Sciences: McGraw-Hill Book Company, New York, 312 p.

StatMost, 1994, StatMost: Statistical Analysis and Graphics, V. 2.50. Salt Lake City, UT 290 p.

Staub, J.R., and Esterle, J.S., 1993. Provenance and sediment dispersal in the Rajang River delta/coastal plain system, Sarawak, East Malaysia: Sedimentary Geology, v. 85, p. 191–201.

Staub, J.R., and Esterle, J.S., 1994, Peat accumulating depositional systems of Sarawak, East Malaysia: Sedimentary Geology, v. 89, p. 91–106.

Staub, J.R. Padgett, R.J., Among, H.L., and Gastaldo, R.A., 1994, Monsoonal control of sediment and peat distribution in the Rajang River delta, Sarawak, East Malaysia: Geological Society of America, Abstracts with Program v. 26, p. A97.

Staub, J.R., Among, H.L., Padgett, R.J., and Gastaldo, R.A., submitted, Monsoons and sediment distribution patterns: An example of climate control from the Rajang River delta, Sarawak, East Malaysia: Journal of Sedimentary Research.

Traverse, A., 1988, Paleopalynology: Unwin Hyman, Boston, 600 p.

Traverse, A., 1994, Sedimentation of palynomorphs and palynodebris: An introduction: *in* Traverse, A., ed., Sedimentation of Organic Particles: Cambridge, Cambridge University Press, p. 1–9.

Van de Laar, J.G.M., and Fermont, W.J.J., 1990, The impact of marine transgressions on palynofacies: The Carboniferous Aegir marine band in borehole Kemperkoul-1: Medelingen Rijks Geologische Dienst, v. 45, p. 75–90.

Van der Zwan, C.J., 1990, Palynostratigraphy and palynofacies reconstruction of the Upper Jurassic to lowermost Cretaceous of the Draugen Field, offshore mid Norway: Review of Palaeobotany and Palynology v. 62, p. 157–186.

Van Waveren, I., 1989a, Pattern analysis of organic component abundances from deltaic and open marine deposits: palynofacies distribution (East Java, Indonesia): Netherlands Journal Sea Research, v. 23, p. 441–447.

Van Waveren, I., 1989b, Palynofacies analysis of surface sediments from the northeastern Banda Sea (Indonesia): Netherlands Journal Sea Research, v. 23, p. 501–509.

Van Waveren, I., and Visscher, H., 1994, Analysis of the composition and selective preservation of organic matter in surficial deep-sea sediments from a high-productivity area (Banda Sea, Indonesia): Palaeogeography, Paleoclimatology, Palaeoecology, v. 112, p. 85–111.

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