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Late Holocene Sedimentation and Erosion of Estuarine Fringing Marshes, York River, Virginia[1]

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ABSTRACT

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Eleven vibracores and three ^{14}C dates in conjunction with historical maps and charts were used to determine the late Holocene accretion and erosion of fringing York River estuarine salt marshes. Cyclical stages of marsh accretion and erosion were recognized, hypothetically beginning with an expansive marsh associated with a meandering tidal river. With rapid sea-level rise from the Holocene marine transgression, these marshes were drowned. A reduction in the rate of sea-level rise and low wave energy allowed fringing marshes to develop over the low-energy, estuarine sediments. Subsequent increased rates of sea-level rise along with relatively large storm waves from a large fetch over relatively deeper estuarine waters result in the present erosion of the marshes.

The results from this region are not in agreement with previous studies elsewhere that point to late Holocene and modern-day marsh accretion. The present local rate of sea-level rise may be too great for marsh expansion. However, the exposure to storm-waves was also of significant importance in the maintenance or erosion of the fringing marshes.

ADDITIONAL INDEX WORDS: *Fringing salt marshes, erosion, accretion, sea-level change, storm waves, estuarine stratigraphy.*

INTRODUCTION

Vertical and lateral accretion of marshes, partially as a function of sea-level rise, has recently been challenged (STEPHENSON *et al.*, 1986). Although numerous studies point to march accretion (REDFIELD, 1972; MCCAFFREY and THOMSON, 1980; STUMPF, 1983), many marshes in the southeastern United States are presently disappearing (HEFNER and BROWN, 1985). With this in mind, we describe the evolution and present erosion of fringing marshes along an estuarine margin in Virginia, southeastern U.S.A.

Estuarine margins along many of Virginia's tidal rivers are presently eroding. Along the York River estuary, fringing marshes and beaches are eroding at a mean rate of 0.21 m/yr (BYRNE and ANDERSON, 1978). Many interacting and associated factors contribute to this erosion. In fact, previous studies elsewhere report that sea-level rise, coastal subsidence, marsh dissection, compaction, sediment input, animal grazing, wave energy, and man's activities are collectively or individually responsible for the loss of shoreline marshland (DELAUNE *et al.*, 1983; BAUMANN *et al.*, 1984; ORSON *et al.*, 1985; STEPHENSON *et al.*, 1985; PHILIPS, 1986). Recent studies (KEARNEY and WARD, 1986) have moved away from extrapolating net sedimentation rates from individual ^{14}C dates (REDFIELD, 1972) and toward a time-series approach that specifically examines marsh development. Nevertheless, more studies that utilize relatively deep cores (> 2.0 m) and provide information pertaining to longer term estuarine development are needed. This allows past erosional-accretional marsh cycles to be identified and potentially used as a predictive model. In addition, a longer term geological history may provide insight into which factors, of those mentioned above, are affecting coastal evolution.

We report on the late Holocene estuarine and marsh sediments deposited along the York Riv-

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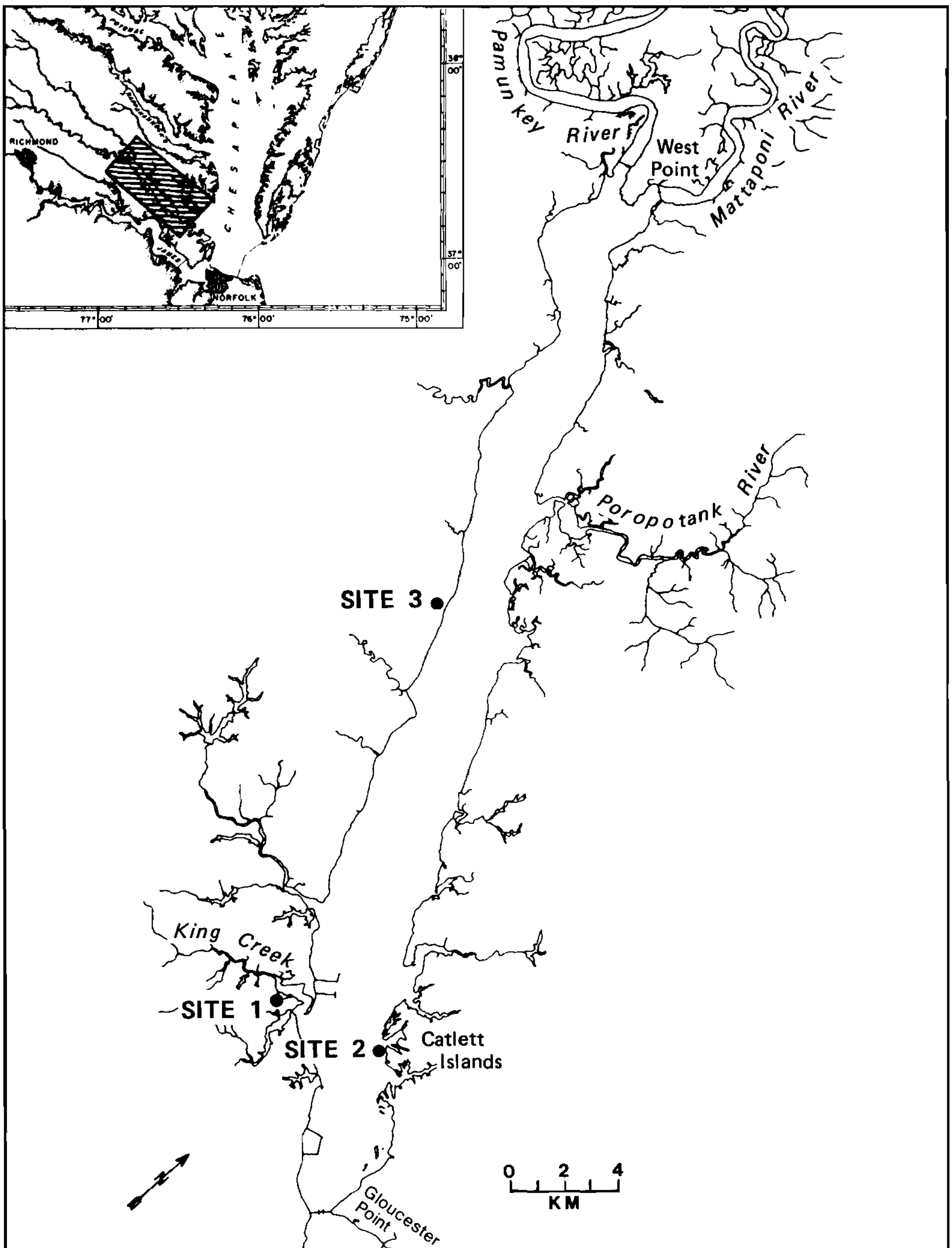
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er's margin (Figure 1). The purpose was to identify depositional and erosional trends and the factors that cause them in this environment. Stratigraphic and sedimentologic data, in conjunction with ^{14}C dates, provide a late Holocene depositional history of the region.

PHYSICAL SETTING AND METHODS

The York River's estuary trends northwest-southeast from West Point to the Chesapeake Bay (Figure 1). Unlike its tidal, generally fresh water tributaries, the Pamunkey and Mattaponi Rivers (Figure 1), the York River presently does not meander. Fringing the shoreline are salt marshes, generally between 10 and 200 m in width, or narrow sandy beaches. Coastal structures, placed to protect mainland development or federally owned land, are prevalent along much of the shoreline. Landward of the marshes and beaches are steep mainland scarps. Because of this steep profile, relative sea level rise of approximately 3.6 mm/yr (HICKS *et al.*, 1983) is not appreciably inundating the mainland and subsequently allowing the creation of new marshland. Instead, sea-level rise appears only to contribute to shoreline erosion. However, the longer term late Holocene sea-level rise rate of 1.1 to 2.0 mm/yr (FINKELSTEIN and FERLAND, in press) previously may have provided conditions more conducive to marsh accretion and expansion.

The average width of the York River is 3 km with an average depth of approximately 6 m, although depths of over 26 m are present. Wide submerged terraces are adjacent to the fringing marshes and beaches and slope less than two degrees. The terrace edge generally exists at a depth of 4 to 5 m below mean sea level (CARRON, 1976). ROSEN (1976) attributed the existence of the terrace to the decrease in the rate of sea-level rise that occurred approximately 3,000 years BP. The mean tidal range within the York River is 0.9 m and wave energy is normally low. However occasional strong northwest or southwest winds, prevalent in winter and summer, respectively, along with tropical or extratropical storms can create low period, choppy waves of 1.0 m height. These waves undercut then overtop and erode the fringing, estuarine marshes.

Figure 1. A regional map of the study area. The three coring sites are labeled 1, 2, and 3 and correspond to the King Creek site, the Catlett Island site, and the wide exposed marsh site, respectively. (*Facing page*).

To determine the evolution of the fringing estuarine marshes, eleven vibracores from three sites were collected. The cores range in depth from two to six meters. To find the absolute age of subsurface organic muds, three samples were collected from site 3 and ^{14}C dated (Table 1). An historical perspective of marsh evolution was determined from historical maps and charts and previous baseline studies (BYRNE and ANDERSON, 1978).

The sites chosen for study collectively describe the geomorphic environments of the marsh shoreline from the York River estuary (Figure 1). Site 1 is a fringing marsh along King Creek, a small drowned tributary from which three cores were retrieved (Figure 2A). Although, less exposed than site 2 or 3, King Creek is approximately 300 m wide at this point. Site 2 (Figure 2B) is on the marsh adjacent to the Catlett Islands. These islands are a part of a chain of small beach-ridges that are adjacent to the York River's estuary but separated from the mainland and each other by salt marsh. The beach ridges may reflect the last Pleistocene shoreline. Four cores were taken from the marsh, three seaward and one landward of the island. Site 3 is a typical but generally wide, 140 m, estuarine fringing marsh (Figure 2C). Four cores where taken here, three across the fringing marsh and one offshore.

RESULTS

Sedimentology and Stratigraphy

The stratigraphy of the study area is shown in cross-sections A-A′, B-B′ and C-C′ (Figure 3). Each of these cross-sections is constructed using the core data from site 1, 2, and 3, respectively. Four depositional units, marsh, high energy estuarine or active channel fill, low energy estuarine fill, and Pleistocene shoreline sand, are recognized in the cores. Marsh sediments mainly consist of mud and contain a large amount of salt marsh vegetation including mostly, but not exclusively, *Spartina alterniflora*. The marsh sediments occur both in the subsurface and as eroding, fringing, salt marshes. Below the modern salt marshes and the encroaching estuarine waters are estuarine filling sediments. Two types of estuarine sedi-

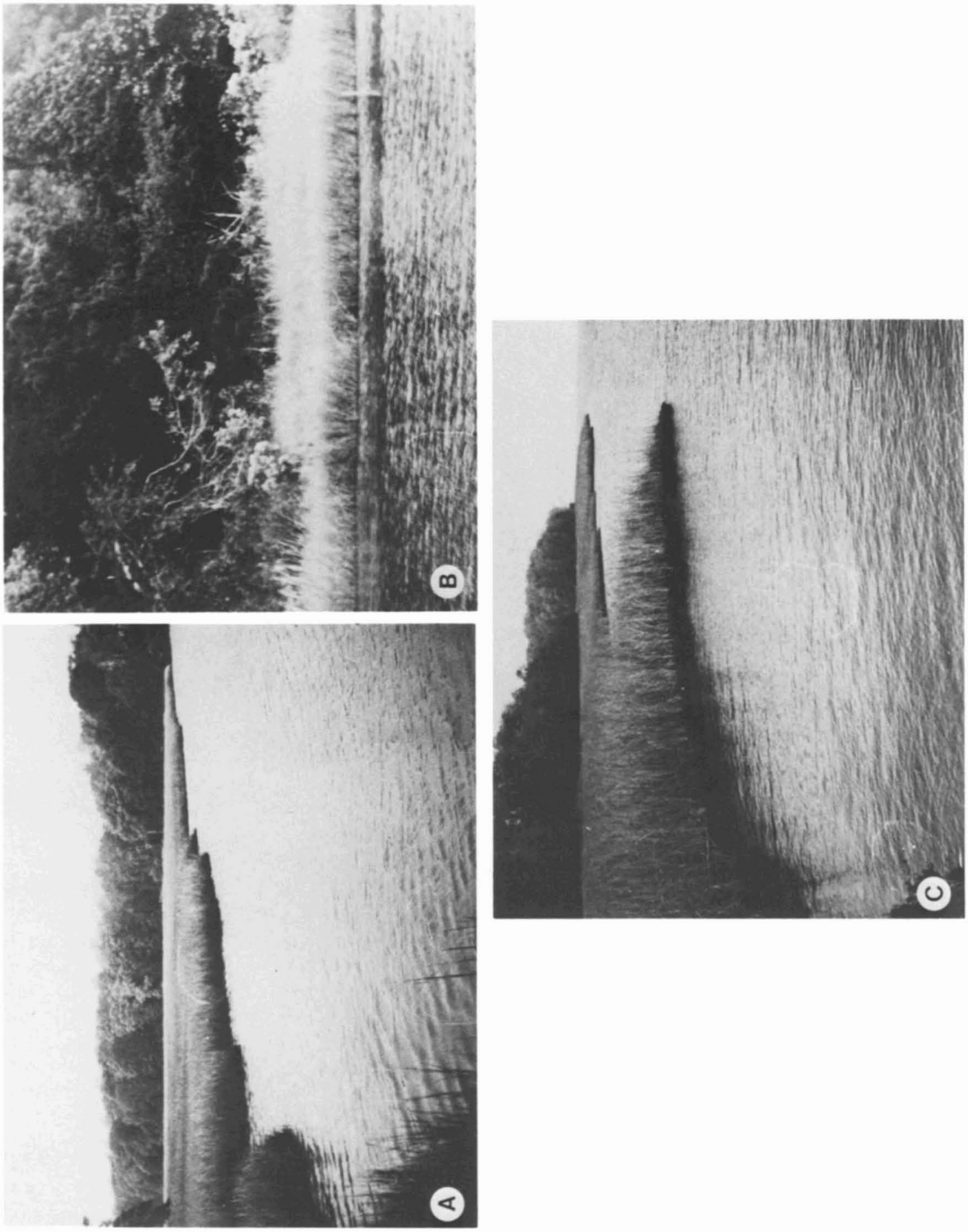
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Table 1. *Radiocarbon age dates*

Core Number	Depth Below MSL	Lab Number	Dated Material	$_{14}$C Age Yrs. BP
3–1	230 cm	Beta-18808	Organic-rich mud	2,040 ± 70
3–2	94 cm	Beta-19730	Organic-rich mud	450 ± 80
3–2	240 cm	Beta-18809	Organic-rich mud	1,930 ± 80

mentation are recognized: (1) relatively higher energy sedimentation or active channel fill that consists of approximately equal amounts of sand and mud with scattered physical sedimentary structures and (2) lower energy sedimentation mostly of mud that is heavily bioturbated. The latter is presently accumulating on the floor of the York River estuary. Compaction of estuarine and marsh sediments was not considered. Pleistocene sands, medium grained and oxidized, are landward and usually considerably below the fringing marshes and comprise the mainland shoreline. These shoreline sands dip steeply below the present estuary, probably due to erosion from the entrenched Pleistocene river during lower sea level and the subsequent Holocene marine transgression.

The fringing marsh of sites 1 and 2 shows a relatively simple stratigraphy of marsh over lower energy, estuarine fill unconformably atop Pleistocene sands. The marsh is being eroded and removed leaving a stratigraphic sequence of estuarine fill over Pleistocene sand. Site 3, at which the more ubiquitous straight shoreline fringing marsh is found, exhibits a somewhat more complex stratigraphy. Here, higher energy estuarine fill grades upward into its lower energy equivalent and then into salt marsh. Above this salt marsh, in the two middle cores, is first an erosional contact to active channel fill sediments which, in turn, grade into modern salt marsh. Marsh samples from above and below the erosional contact in core 3-2 have been ^{14}C dated at 450 ± 80 and 1,930 ± 80 years BP, respectively. As recognized in core 3-1, the upper salt marsh and channel fill is being eroded by the marine transgression leaving a new estuarine fill to lie above the deeper and presumably older marsh deposit.

Sea-Level History

The rise of sea level following late Wisconsinan deglaciation created the York River estuary. The early and mid Holocene evolution of the estuary is not examined in this study. However, the tidal tributaries of the York River, the Pamunkey and Mattaponi Rivers, exhibit meandering channels and adjacent widespread marshes; this morphology may be analogous to an earlier York River. The fringing marshes recognized today and those in the subsurface owe some of their accretional and erosional evolution to sea-level rise. Rates of local late Holocene and historical sea-level rise, discussed below, may help to determine its effect.

Three ^{14}C dates (Table 1) from older salt marsh sediments, used as sea-level indicators, in cores 3-1 and 3-2 provide sea-level change information (Figure 3). These dates of 2.040 ± 70 years BP at 2.3 m, 1,930 ± 80 years BP at 2.4 m, and 450 ± 80 years at 0.94 m indicate an overall rate of sea-level rise of approximately 1.2 mm/yr since 2,000 years BP but 2.1 mm/yr since 450 years BP. This is roughly similar to NICHOLS' (1972) overall sea-level rise rate of 1.6 mm/yr for the past 9,000 years in the James and Rappahannock Rivers. However, NICHOLS (1972) shows sea level to be approximately 4.0 m below present level 2,000 year BP; this depth and subsequent sea-level rise rate is somewhat greater than that shown in this study. Present local relative sea-level rise rates of 3.6 mm/yr (HICKS *et al.*, 1983) or subsidence rates of 2.8 mm/yr (HOLDAHL and MORRISON, 1974) point to a much more rapid inundation of the mainland. Historical erosion of these fringing marshes appears to be the result.

Figure 2. Photographs of sites (by C. S. Hardaway). (1) Looking northwest up King Creek (A), (2) looking east across Catlett Islands (B), and (3) looking north up York River (C). (*Facing page*).

DISCUSSION

The cyclical nature of marsh formation and erosion, recognized from the stratigraphy, is a result of some episodic mechanism. Sea-level change is the most convenient explanation for the evolution of the three sites. Here, relatively rapid sea-level rise during early and mid-Holocene time resulted in deposition of subaqueous estuarine sediments adjacent to the Pleistocene

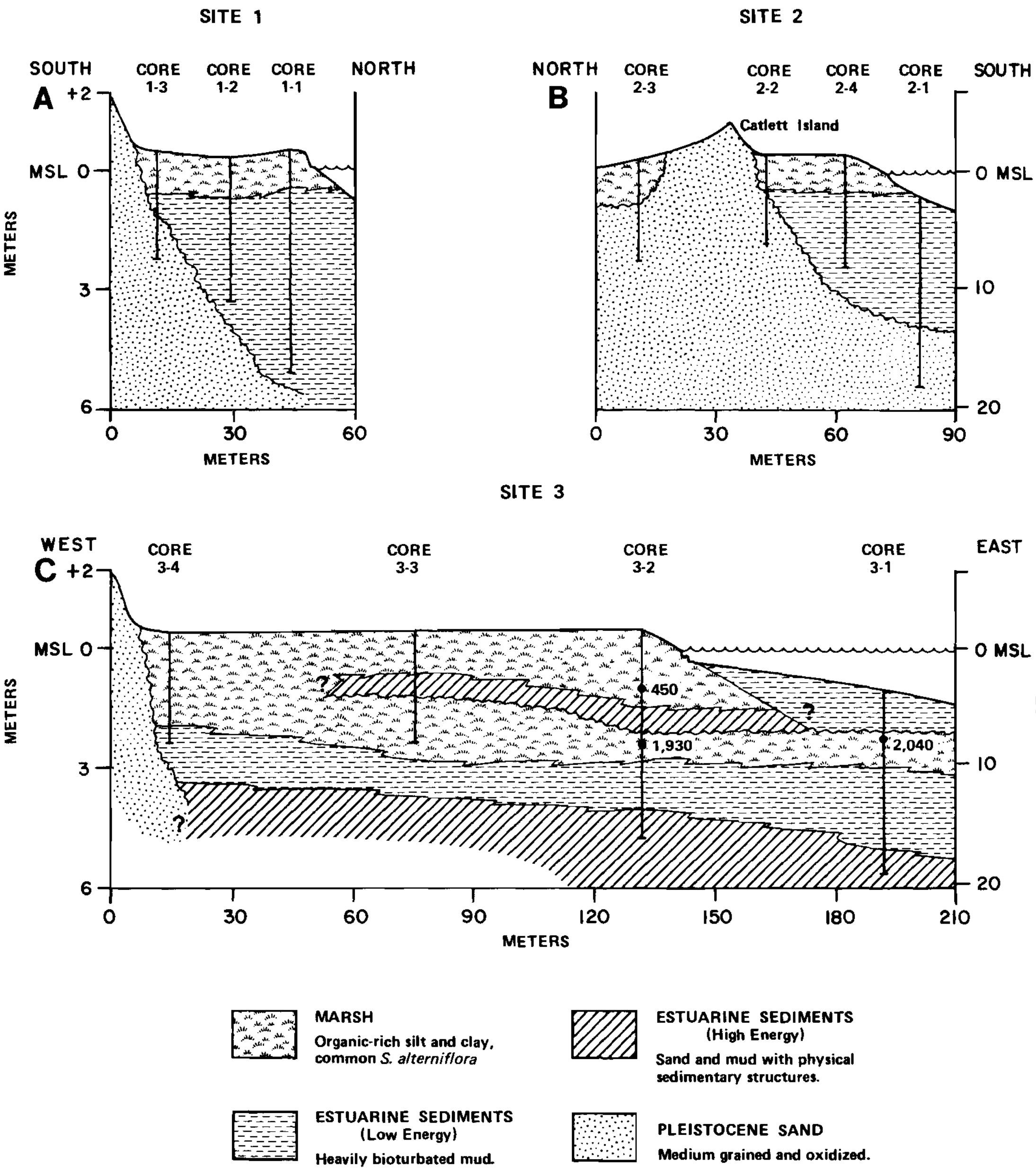

Figure 3. Cross-sections A-A′, B-B′, and C-C′ from sites 1, 2 and 3, respectively. Note the general transition from estuarine sediments to salt marsh. Marshes of site 3 were previously eroded by a tidal channel but have reestablished themselves above the channel-fill sediments. Marshes from all three sites are eroding.

mainland. Following a late Holocene decrease in the rise of sea level, circa 2,000 years BP, marshes developed atop the estuarine sediments. With the historical increase of sea level, marshes are presently retreating (Figure 4).

An additional explanation for this erosion may be recognized from the present estuarine morphology. Initially, the morphology of the York River estuary was probably analogous to the present Mattaponi and Pamunkey Rivers, *i.e.*, dominated by a meandering river with a wide expanse of marsh located between the channel and upland scarp. CARRON (1976) recognized submerged meanders in a York River subbottom study. With increasing estuarine water level the entire river valley became flooded, the York River channel straightened, and much of the marshland overtopped. Fringing marshes eventually developed under moderate estuarine water levels and reduced sea-level rise rates. Soon, wide and deeper estuarine water levels negatively affected these same marshes; the marshes were attacked by relatively large waves caused by a larger fetch over relatively deeper water (Figure 4). Episodes of numerous severe storms or calm weather conditions, on the order of centuries, may have contributed to periods of fringing marsh erosion or progradation, respectively. KNUTSON *et al.* (1981) recognized wave stress as the principal factor in marsh development. With respect to the relatively high storm wave activity, new marsh development riverward of existing fringing marshes is almost impossible (HARDAWAY *et al.*, 1984).

The fringing marshes are not presently expanding in a landward direction due to a relatively steep mainland slope or prograding seaward because of erosion. The disappearance of fringing estuarine marshes is a function of sea-level rise and episodic high wave energy. Other studies (FINKELSTEIN and FERLAND, in press) show salt marshes accreting depsite a relatively high sea-level rise rate; however, their marsh sites are well protected from severe storm waves. York River salt marshes during mid to late Holocene time were greatly affected by sea-level rise; today their exposure appears equally important in determining accretion or erosion. Taking into account other studies, the erosion or accretion of salt marshes appears to be site specific. In this study the marshes are clearly eroding; however if sea-level rise should slow and the estuary fill, conditions may again be appropriate for marsh accretion.

CONCLUSIONS

Fringing marshes along the York River estuary are eroding. Although a modern rate of sea-level rise greater than at any time during the past 2,000 years contributes to this erosion, exposure to relatively high wave energy also is important. The morphologic change from hypothetical marsh dominated, meandering tidal river to an open, deeper water estuary occurred sometime during the middle Holocene. The initial development of the fringing marshes, approximately 2,000 years BP, is a reflection of the lower than present estuarine water levels and resulting wave energy, and a reduced rate of sea-level rise.

The fringing marshland accreted subsequent to 2,000 years BP until the historical period. The present combination of a relatively high rate of sea level rise, deeper estuarine water levels, and a large fetch results in erosion of the fringing salt marshes. Shorter-term cycles of marsh erosion and accretion may coincide with episodes of high and low storm activity, respectively. Finally, the relatively steep Pleistocene shoreline prohibits much inundation of the mainland and new marsh development.

Further collection of cores is suggested; thereby providing a better understanding of the estuarine stratigraphy in the shore-parallel direction. These cores would allow more ^{14}C dates which would facilitate the development of a better local sea-level curve. In addition, the collection of shallow high-resolution seismic subbottom records from the York River would confirm the hypothesis of a former meandering York River and follow its Holocene depositional evolution.

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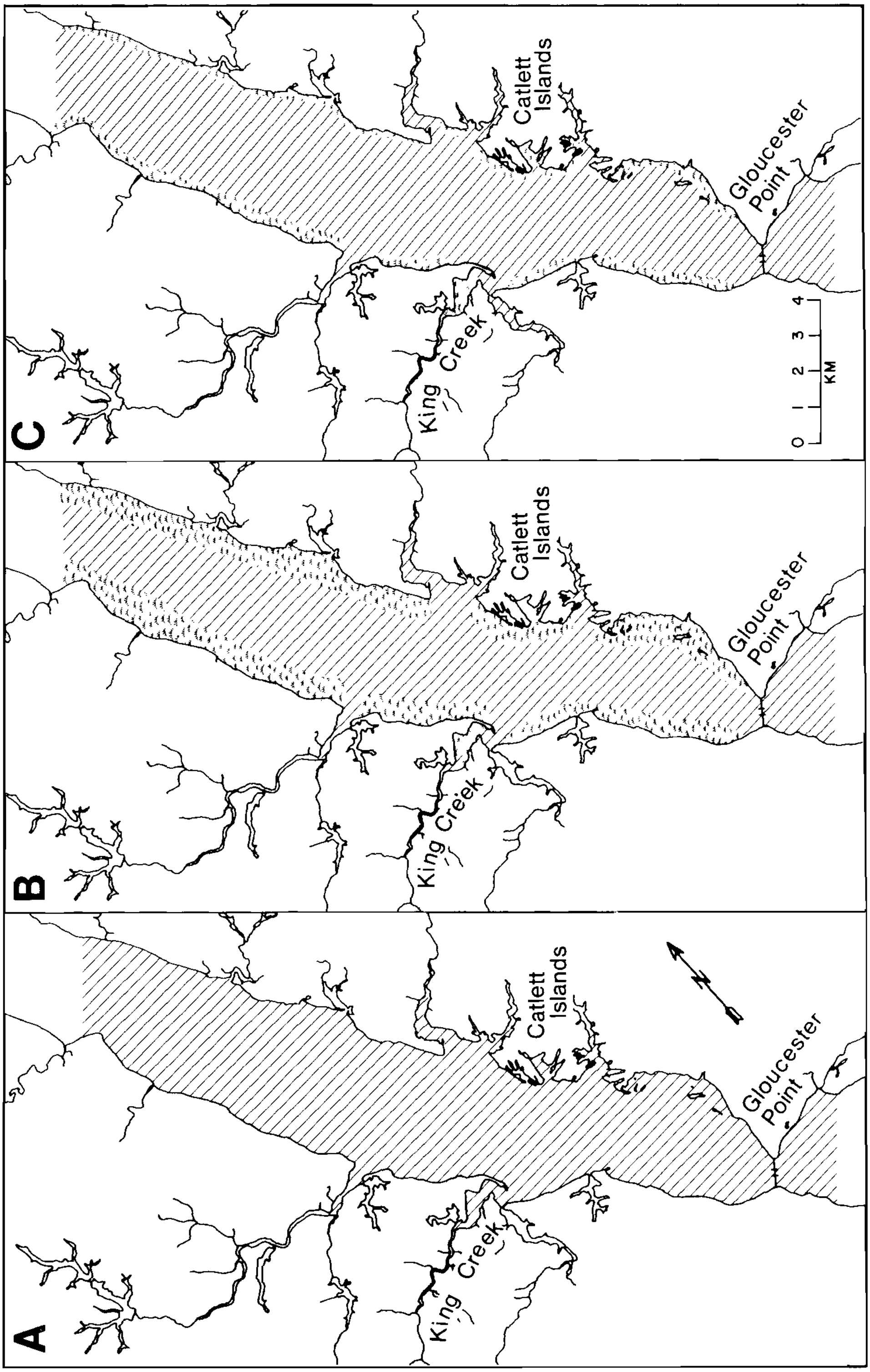
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□ RESUMEN □

Once muestras y tres dotaciones con Carbono 14, además de mapas y cartas históricas, han sido utilizados para determinar la erosión y sedimentación en el último periodo del Holoceno en las marismas de la Ria de York. Se han reconocido estados ciclicos de sedimentación-erosión, que comenzaron, hipotéticamente, con marismas en expansión asociadas con una ria de marea con meandros. Con el rápido ascenso del nivel del mar en el Holoceno, estas marismas fueron anegadas. Una reducción en la tasa de crecimiento del nivel del mar y escasa energia de oleaje permitieron a las marismas desarrollarse sobre los sedimentos del estuario. Posteriores incrementos de la tasa de elevación del nivel del mar y fuertes temporales dan como resultado la presente erosión de las marismas.

Los resultados encontrados en esta región no están acuerdo con estudios previos en otros lugares referentes al último periodo del Holoceno. La actual tasa de elevación del nivel del mar puede ser demasiado grande para la expansión de las marismas. Sin embargo, la exposición a temporales fue de importancia significativa en el mantenimiento de la erosión de las marismas.—*Department of Water Sciences, University of Santander, Santander, Spain.*

□ RÉSUMÉ □

Onze carottages par vibration et trois datations au carbone 14 ont permis, en complément de cartes historiques, de détermine l'accroissement et l'érosion des marais salants en bordure de l'estuaire de la riviére York à l'holocène récent. Des stades cycliques d'accroissement et d'érosion ont été identifiés, dont on pense qu'ils débutèrent lors de la mise en place d'un marais avec un méandre intertidal de la rivière. Avec la rapide élévation du niveau de la mer lors de la transgression holocène, ces marais furent inondés. Une diminution de la vitesse d'élévation du niveau marin, conjointement à des vagues de faible énergie, ont permis aux marais

Figure 4. A schematic diagram showing the late Holocene evolution of the York River estuary. (A). The relatively rapid rise in sea level prior to 2,000 years BP results in brackish to marine water inundation and deposition of estuarine sediments. (B). The lower rate of sea-level rise and relatively shallow estuarine water depths provide conditions favorable for salt marsh growth approximately 2,000 years BP. (C). The present morphology of the York River characterized by narrow fringing marshes that are eroding due to the more rapid rise in sea level and storm waves generated across relatively deep estuarine waters. (*Facing page*).

de s'étendre sur les sédiments estuariens de mode calme. Par la suite des élévations du niveau de la mer à des vitesses croissantes, conjointement à des vagues de tempête et une épaisseur d'eau plus importante, contribuent à l'érosion des marais.

Les résultats obtenus dans la région prospectée ne concordent pas avec ceux établis ailleurs que date l'accroissement des marais à l'holocène récent et à l'actuel. La vitesse actuelle d'élévation du niveau de la mer semble être tropp importante pour une expansion des marais. Cependant, l'exposition aux vagues de tempêtes était un élément significatif quant au mantient ou quat à l'érosion des marais frangeants.—*Catherine Bressolier, Labo. de. Géomorphologie, UA910, Montrouge, France.*

□ ZUSAMMENFASSUNG □

11 Bohrungen und drei ^{14}C-Daten wurden in Verbindung mit historischen und Seekarten benutzt, um den jungholozänen Anwuchs oder die Abtragung von Salzmarschen am Rande des York River-Ästuars zu bestimmen. Es konnte ein zyklischer Wechsel von Auf- und Ab-bau der Marsch erkannt werden, wobei angenommen wird, daß die Abfolge mit ausgedehnten Marschenbildungen an einem mäandrierenden Tidefluß begannen. Mit dem raschen holozänen Meeresspiegelanstieg wurden diese Marschen überflutet. Eine Verringerung im Betrag des Meeresspiegelanstieges und geringe Wellenenergie ermöglichten eine Ausbildung von randlichen Marschen im Ästuar, welche dort auch bei geringer Wellenenergie sedimentiert wurden. Ein nachfolgender beschleunigter Meeresspiegelanstieg im Zusammenhang mit relativ starken Sturmwellen und längerem Fetch und wider tiefer werdendem Wasser führten zur geenwärtigen Erosion der Marschen.

Die Ergebnisse aus dieser Studie stimmen nicht überein mit früheren Arbeiten aus anderen Gebieten, welche ein jungholozänes und gegenwärtiges Marschenwachstum ausweisen, der gegenwärtige lokale Betrag des Meeresspiegelanstiegs ist wahrscheinlich für eine Marschenbildung zu groß. Außerdem ist auch die Exposition zu den Sturmwellen wichtig für Ablagerungen oder Erosion der Marschenstreifen.—*Dieter Kelletat, Essen, FRG.*