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Island Land Loss and Marsh Vertical Accretion Rate Evidence for Historical Sea-Level Changes in Chesapeake Bay[1]

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ABSTRACT

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Long-term changes in marsh vertical accretion rates based on pollen and radionuclide geochronologies and historical reconstruction of land loss in bay islands were used to investigate changes in sea level in the Chesapeake Bay from colonial times. These records suggest that the rapid submergence of the Bay region documented in local tide-gauge records essentially dates from only the early nineteenth century; whereas, rates of sea-level rise throughout the seventeenth and eighteenth centuries were relatively slow. Land loss and marsh vertical accretion rates have further accelerated since the late nineteenth century. This pattern of sea-level changes in the Chesapeake corresponds with the general changes in global climate of the last several centuries associated with the Little Ice Age. Nevertheless, global eustasy cannot account for a large percentage of the present sea-level trend in the Bay. We hypothesize that enhanced land subsidence rates from anthropogenic groundwater withdrawal and sediment loading are other major factors which may account for the high rate of submergence in especially the mid-Chesapeake region.

ADDITIONAL INDEX WORDS: *Chesapeake Bay islands, ^{210}Pb, ^{137}Cs, pollen geochronology, subsidence.*

INTRODUCTION

Sea-level trends spanning the last few centuries are intriguing because they may be one of the first signals of shifts in global climate (HANSEN *et al.*, 1983). In parts of Europe continuous records of tidal variations extend back to the 17th Century (MÖRNER, 1973). Older, but more incomplete records of sea-level position may be deduced from archaeological and historical evidence from the 9th Century AD onward (ÅSE, 1969 in MÖRNER, 1973). However, along the U.S. Atlantic Coast, a focal point of Holocene sea-level research, details on recent sea-level change before the advent of tide-gauge records are relatively scant. Few existing sea-level curves contain a sufficient number of data points younger than 1000 years, and these are widely spaced. What little information exists for the colonial period and somewhat earlier indicates that sea level stood locally within a meter or so of modern limits by *ca.* 500 yr BP (NATIONAL ACADEMY OF SCIENCES, 1987).

Previous marsh-stratigraphic studies along Maryland's western shore (FROOMER, 1980) suggest that sea level has risen in this area of the Chesapeake Bay at nearly the present rate of 3.0 mm yr^{-1} since at least 1650 AD. This picture of relatively long-term, rapid submergence of the Bay region contradicts the generally slow rates of sea-level rise over the last two millennia along the U.S. Atlantic Coast recorded in sea-level curves (KRAFT *et al.*, 1987). More fundamentally, it is at odds with the broad evidence for global cooling late in this period (the classic Little Ice Age), a time when sea level

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should have fallen as investigations (MEIER, 1984) of the influence of small alpine glaciers on recent eustatic changes indicate. In fact, historical European tidal records (MÖRNER, 1973; HORNER, 1972) show relatively negligible rates of sea-level rise or even falling sea levels throughout the 18th Century.

The Chesapeake Bay is rich in lore and anecdote on the impact of rising sea level on human settlements and structures, stretching back from the loss of the original Jamestown site in Virginia to the relatively recent destruction and/or submergence of famous 19th Century buildings like the Cedar Point Light at the mouth of the Patuxent River in Maryland. Other physical evidence for recent sea-level rise in the Bay is perhaps best exemplified by the rapid disappearance shown on successive 19th and 20th Century maps and charts of once large islands (*cf.* SINGEWALD and SLAUGHTER, 1949) and the parallel loss of substantial areas of coastal marsh (STEVENSON *et al.*, 1986; FINKELSTEIN and HARDAWAY, 1988; KEARNEY *et al.*, 1988). Such changes have coincided with suggestions of dramatic increases in marsh accretion rates in the Nanticoke River inferred from pollen records, a phenomenon largely attributed to sea-level rise (KEARNEY and WARD, 1986).

This paper re-evaluates the sea-level history of the Chesapeake Bay over the last few centuries by a comparison of changes in historical rates of land loss (from shore erosion and submergence) with rates of marsh vertical accretion. Together these new records of shoreline and marsh adjustments to past sea-level variation indicate that the inception of the present sea-level trend in the Chesapeake Bay occurred much more recently than was previously suggested.

STUDY AREA

This study focused on the Eastern Shore of the middle Chesapeake Bay (Figure 1). This area of the Bay consists of a broad, shallow erosional platform (maximum depth, 8-10 m), cut by the ancestral thalwegs of major tributaries such as the Choptank River (KERHIN *et al.*, 1988). Tangier Sound, the major embayment of this part of the middle Bay, is formed by the confluence of the Nanticoke, Wicomico and Manokin Rivers and is bounded by a string of large marshy islands stretching from James' Island to the north to Bloodsworth Island to the south.

Local tide gauge records show that present rates of relative sea level rise (RSL) in the middle Chesapeake Bay average about 3.0 mm yr^{-1} (STEVENSON *et al.*, 1986). Comparatively high rates of subsidence, ranging from 1.6 to 2.0 mm yr^{-1} (HOLDAHL and MORRISON, 1974; BROWN, 1978), account for most of this trend. The high rate of RSL rise is most manifest in rates of shore erosion of up to 3.3 m yr^{-1} (WARD *et al.*, 1988), and extensive areas of submerged upland marsh developed on flat, late Pleistocene terraces (*cf.* KEARNEY *et al.*, 1988).

METHODS

Historical Marsh Accretion Rates

FROOMER (1980) reconstructed the sea-level record of Chesapeake Bay since early colonial times by determining the long-term accretion rates of headwater marshes in small tributaries of the Potomac River estuary in southern Maryland. However, recent studies (KEARNEY and WARD, 1986) of changes in marsh accretion rates along a salinity gradient in the Nanticoke River estuary on Maryland's Eastern Shore documented that marshes toward the heads of estuaries were characterized by recent accretion rates exceeding the rate of RSL rise indicated by local tide-gauge records. This disparity was attributed to upstream fluvial sediment trapping in the estuary, a phenomenon that has been enhanced by the increase in upland erosion and runoff from agricultural land clearance in this region (LOMAX and STEVENSON, 1982). This phenomenon is similar to areas of the Appalachian Piedmont over the last century or so (MEADE and TRIMBLE, 1974).

By comparison, allocthonous sediment inputs in lower estuary marshes and particularly fringe or submerged upland marshes (STEVENSON *et al.*, 1986) along the main Bay shoreline, tend to be predominantly tidally-driven. We focused our investigation on a large submerged upland marsh system in Monie Bay on Maryland's lower Eastern Shore, which other studies (KEARNEY, unpublished data) indicated was stable and accreting on a marsh-wide basis near the present rate of RSL.

In 1986 four sites were chosen for study (see

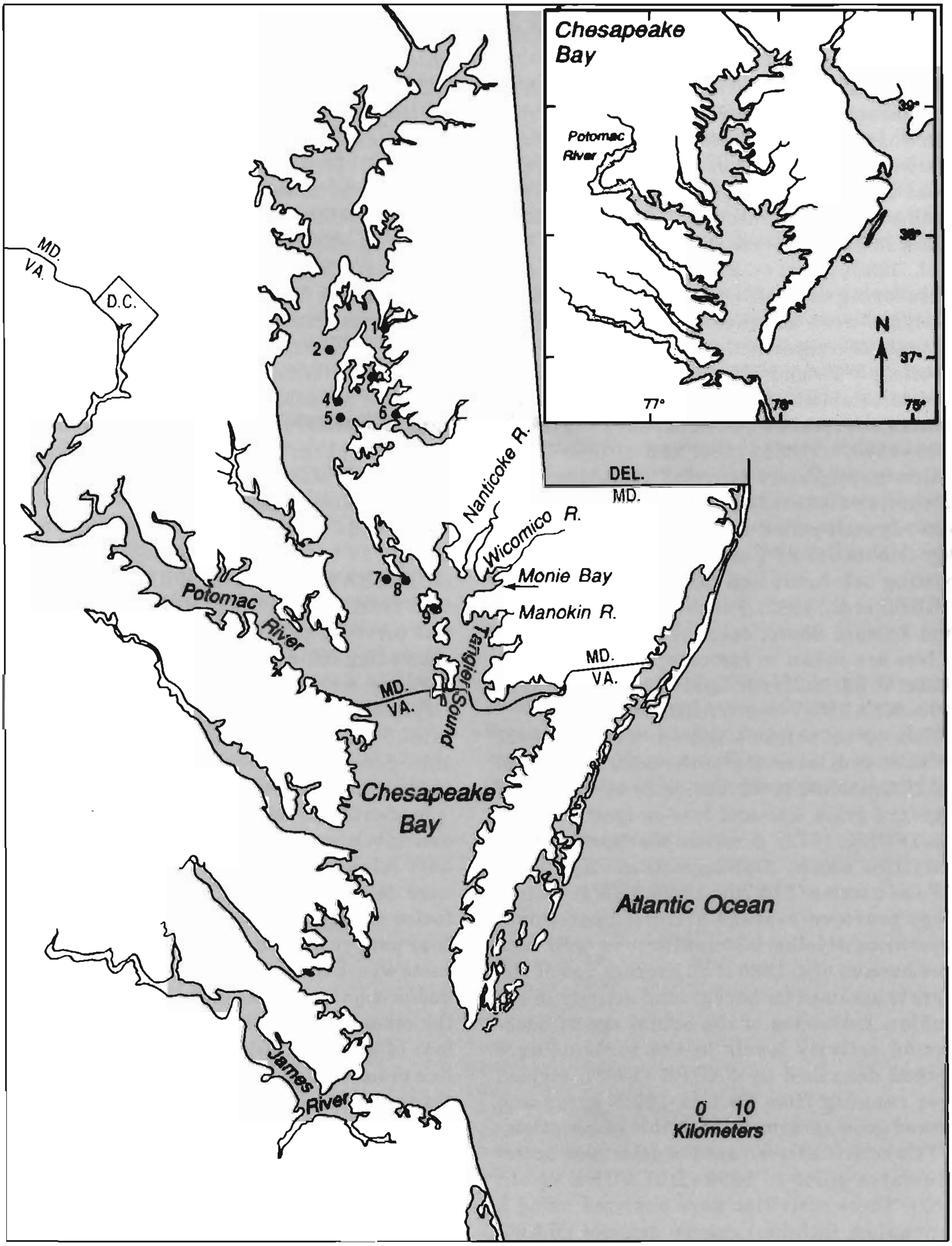

Figure 1. Location of Monie Bay marsh site and some of the major bay islands studied along Maryland's Eastern Shore. (1) Bruff's Island, (2) Poplar Island, (3) Hambleton Island, (4) Tilghman Island, (5) Sharp's Island, (6) While Powells Island, (7) Barren Island, (8) Lower Hooper's Island, (9) Bloodsworth Island.

WARD *et al.*, 1988, for a complete description) which were judged sufficiently distant from major tidal creeks or the Bay shoreline to minimize the influence of any "levee effect" (*cf.* DELAUNE *et al.*, 1983) or storm overwash on the accretionary record. The latter site criterion was especially critical since thick, surficial overwash horizons occur in several shoreline areas of the marsh, possibly reflecting overwash events associated with Tropical Storm Agnes in 1972 or other smaller storms (WARD *et al.*, 1988). Short (< 2 m) cores were taken by vibracoring at each site. Cores retained for analysis were characterized by negligible amounts of compaction. (~ 1–2%).

Pollen, ^{210}Pb and ^{137}Cs geochronologies were used to establish time horizons for estimation of accretion rates over several time intervals: *c.* 1790–1886, *c.* 1886–1986, and *c.* 1963–1986. Pollen stratigraphy provided the oldest time horizon, and is based on diachronous declines in oak: ragweed pollen ratios across Chesapeake Bay tributaries as European colonists cleared existing oak-dominated forests for agriculture (BRUSH *et al.*, 1982). For this area of the Maryland Eastern Shore, oak: ragweed ratios of 10 or less are taken to indicate the initial peak phase of agricultural land clearance around 1790 (KEARNEY and WARD, 1986).

Thin (2 cm thick) sediment samples were taken at 4 cm intervals for the determination of the radionuclide geochronologies as well as for standard grain size and loss-on-ignition analyses (FOLK, 1972). Analysis of supported ^{210}Pb activities was by alpha spectrometry, using ^{208}Po as a tracer (FLYNN, 1968). This geochronology provided average accretion rates over approximately the last century, as well as a time horizon of *c.* 1886 if an average age of 100 years is assumed for background activity in the profiles. Estimates of the actual age of background activity levels in the cores using a method described by FAURE (1986), yielded ages ranging from 99.1 to 102.3 years and showed good agreement with this assumption.

^{137}Cs activities were used to determine accretion rates since *c.* 1963 (DELAUNE *et al.*, 1983). These activities were analyzed using a Germanium (lithium) gamma detector (WARD *et al.*, 1988).

Land Loss Record

Reliable quantitative estimates for long- and short-term rates of shoreline recession in the Chesapeake Bay can only be determined for the period since the middle 19th Century when the first ocean survey nautical charts were produced. Older historical maps and charts are available for as early as the early 17th Century, but the usefulness of such maps as archives of shoreline data is limited to at best a general portrayal of shoreline features; little confidence can be placed in actual shoreline positions.

Historical rates of land loss in the numerous islands of Chesapeake Bay can provide a partial insight into former shoreline trends, at least to the level of indicating gross variations in the rate of shore erosion and/or submergence over time. The phenomenon of the disappearance of Bay islands was recognized at least as early as the 19th Century (MOWBRAY, 1981). Many of the islands were settled by Europeans by the middle 17th Century under separate patents (MOWBRAY, 1981; HARRISON, 1915). At the time of settlement, the acreage of larger islands was surveyed as part of the patent grant. In the succeeding colonial period, resurveys of island acreage were often undertaken as part of Orphan Court probate proceedings or land sales. Such records are archived in county and state government probate and land records, and in the state historical archives in Annapolis.

In identifying islands for study (assuming the availability of adequate historical records), only islands settled under separate patents were selected (see Figure 1). This avoids confusion as to what part of the acreage of the original patent was comprised by the island, in cases where the patent included several islands and/or adjacent areas of the mainland. Among the other criteria for island selection, was the lack of historical evidence for extensive shoreline protection or modification (*e.g.*, bulkheads) throughout most of the settlement history, unless emplacement of the structures occurred relatively late. For example, the shoreline of Bruff's Island (Figure 1) in Talbot County was stabilized by a seawall as early as 1912 when it had already decreased to 60% of its original acreage at the time of settlement in 1678 (HARRISON, 1915).

RESULTS

Marsh Vertical Accretion Record

Consistent changes with depth in the ^{210}Pb and ^{137}Cs activities and oak: ragweed ratios suggest little bioturbation in the cores (Table 1 shows these data for two of the sites). Marker horizons derived from these geochronologies document a general increase in accretion rate at all sites (Figure 2). At two sites (MC4 and MCL15), accretion rates appear to have more than doubled between 1790 (the approximate date of the marker horizon) and the last quarter-century defined by the ^{137}Cs isotope record. The timing of this apparent upward shift in marsh accretionary budgets cannot be delineated precisely, but probably occurred in the latter half of the 19th Century. Comparably-dated sharp increases in marsh accretion rates, based on pollen stratigraphy, have also been reported for the Nanticoke River estuary (KEARNEY and WARD, 1986).

No more than a relative significance can be attached to the observed changes in accretion rates in this marsh because they involve comparisons in rates integrated over long and short intervals, and between compressed and relatively dewatered marsh sediments and loose, recent materials. The former problem is perhaps less tractable and concerns the impact of high magnitude, low frequency events like storms on observed trends, which tends to be diminished in a longer record. By comparison, the baseline trend of a shorter record may be unduly skewed by such events. Thus, the sharp increase in rate indicated by the ^{137}Cs records may partially reflect the heavy flooding and suspended sediment inputs of Tropical Storm Agnes in 1972. This 100 year magnitude storm produced sedimentation rates in parts of the Chesapeake Bay equivalent to decades at the overall long-term rate (SCHUBEL and CARTER, 1984).

The effects of compression and dewatering on length-accretion measurements in older peats compared to recent sediments may fortunately be partially offset by expressing accretion rates in terms of mass accumulation rate (g dw/cm^2/yr). Table 2 shows that marsh accretion rates calculated this way still indicate an acceleration in rate toward the surface. The increase in mass per year is particularly convincing when it is considered that the heavier mineral component of the sediments generally declines upwards.

Land Loss Record

Changes in land area over the last 300 years of those islands finally selected are shown in Figure 3. All the islands are on the lower Eastern Shore of Maryland (Figure 1). It is evident that most islands have declined dramatically in

Table 1. *Changes in ^{210}Pb and ^{137}Cs activities and oak: ragweed ratios for two cores from Monie Bay*

	Core MC4			Core MCL8		
Depth	^{210}Pb	^{137}Cs	Pollen Ratio	^{210}Pb	^{137}Cs	Pollen Ratio
0–2	3.80	1.24	2.6	6.50	1.51	2.6
4–6	5.14	6.33		5.77	5.25	
8–10	4.23	5.82		3.54	4.37	
12–14	4.64	9.67		5.65	14.90	
16–18	4.72	15.16		4.09	17.00	
20–22	4.42	8.54	1.4	3.00	6.39	3.0
24–26	2.84	4.29		2.13	3.97	
28–30	2.33			0.65	2.44	
32–34	1.66			2.78	1.74	
36–38	1.77			0.89		1.0
40–42	0.59			0.25		
44–46	0.66		1.5	0.34		
48–50	0.47			0.30		
60	0.03		7.0	0.03		
70						
80						1.5
90						6.3

N.B. Activities for ^{210}Pb reported as excess flux; all activities listed as dpm/gdw.

Figure 2. Changes in marsh accretion rates based on pollen and radionuclide geochronologies at the Monie Bay sites.

Table 2. *Changes in accretion rates at Monie Bay sites MC 4, MCL 8, and MCL 15 expressed as g dw/cm^2/yr.*

Site	Accretion Rate (g dw/cm^2/yr)	Bulk Density (g/cm^3)	Average % organic (interval)
MC 4			
^{137}Cs	0.37	0.47	21
^{210}Pb	0.16	0.33	23
Pollen	0.11	0.33	23
MCL 8			
^{137}Cs	0.17	0.22	41
^{210}Pb	0.14	0.28	31
Pollen	0.13	0.28	31
MCL 15			
^{137}Cs	0.25	0.32	34
^{210}Pb	0.13	0.32	26
Pollen	0.01	0.30	26

acreage. This land loss appears to have been principally due to shore erosion and not just simple submergence, especially for islands located in higher wave energy areas of the main Bay stem where rates of shore erosion can exceed 3 m/yr (CONKWRIGHT, 1975). In fact, high rates of shore erosion have been responsible for the disappearance of several once-prominent islands since the last century. For example, Sharp's Island, which was over 3.2 km (2 miles) long and about 1 km (0.6 miles) wide around 1850, was last shown as a subaerial feature on the 1942 1:62, 500 USGS map (Figure 4). Sometime after this date (*ca.* 1948), it became a shoal exposed only at low tide. Today, the most recent nautical charts of the Choptank River only record a shoal in the island's former location, indicating extensive transport of sediment out of this area.

The most striking aspect of the history of land loss in these islands is the rapid decrease in land area after the middle of the last century. Rates of land loss during the 17th and 18th Centuries are less certain. However, based on data for Tilghman and Barren Islands, land loss rates in this period appear to have been less than half the most recent trend.

Equally compelling as the sharp decreases in island area was the widespread abandonment of settlements on many of the islands in the first decades of this century (Figure 5). Deciphering human responses to the environment is often conjectural, but it is not difficult to envision depopulation of the islands occurring as progressive erosion and/or submergence made continued habitation untenable. This is particularly true when coupled with major hurricane events, such as in 1933 when two severe storms caused strong tidal surges and inundation (PORE, 1960; STEVENSON *et al.*, 1988). In particular, the effects of these storms may have had a profound impact on the desire of the remaining inhabitants to continue to live on the islands even as land loss rates slowed in the first part of this century.

To a large degree, abandonment of these islands appears to have been precisely for the above reasons. Settlements in the larger islands were generally sizeable, with populations of several dozen or more families, churches, schools, stores, and individual post offices. For example, Lower Hooper's Island supported around 50 families in 1900 (MOWBRAY, 1981). However, by 1930, this island (as was the case with the other islands) had been abandoned because it had become too "wet" (MOWBRAY, 1981). Surveys of the island indicate that the mainland-facing side of the island is progressively converting to marsh and remains above water only at low tide. The timing of island abandonment (Figure 5) between *c.* 1910–1930 is even more striking when it is considered that in several instances new buildings, such as stores, post offices, and houses, were built within a decade before the last inhabitant left the island (MOWBRAY, 1981; HARRISON, 1915). Such behavior suggests that the continued threat to the island's existence was finally perceived after land loss from shore erosion (and/or submergence) became so pervasive that it could no longer be ignored. Not coincidentally, the last phases of island occupation overlap the initiation of a major acceleration in sea-level rise in the Chesapeake Bay around 1930 (Figure 6).

DISCUSSION

In contrast to FROOMER's (1980) conclusion that the RSL trend of the Chesapeake Bay has been steady (and high) for the last several centuries, the marsh accretion and land loss (shore erosion and submergence) records reported here suggest that the present rapid submergence of the Bay region began only in the early 19th Century. Our interpretation nevertheless fits the emerging picture of sea-level trends over the last several centuries from various localities in

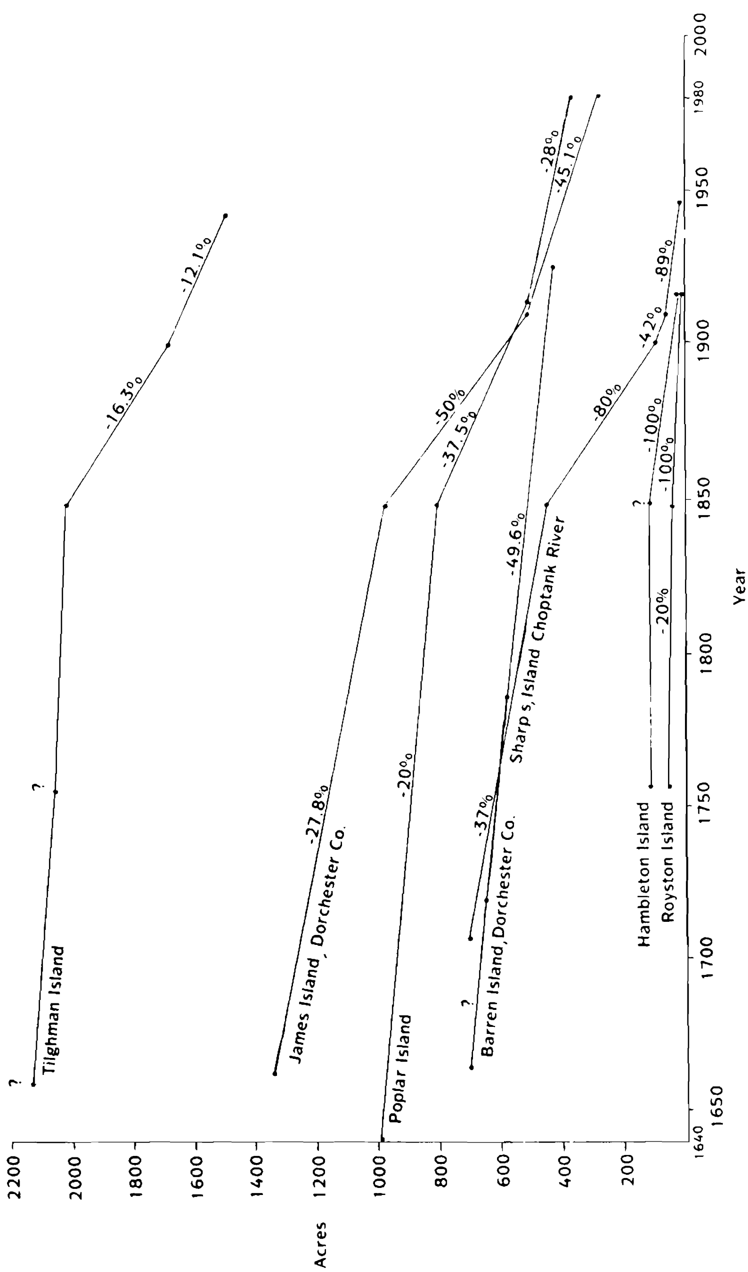

Figure 3. Changes in land area of the bay islands studied over approximately the last 300 years.

Northern Europe, where long-term changes in marsh accretion rates (ALLEN and RAE, 1988) or tide staff and historical records (*e.g.*, MÖRNER, 1973; HORNER, 1972; PIRAZZOLI, 1989) show acceleration in local sea levels largely within the last 200 years. As noted moreover, a recent rise in sea level is consistent with our present understanding of the timing of the Lit-

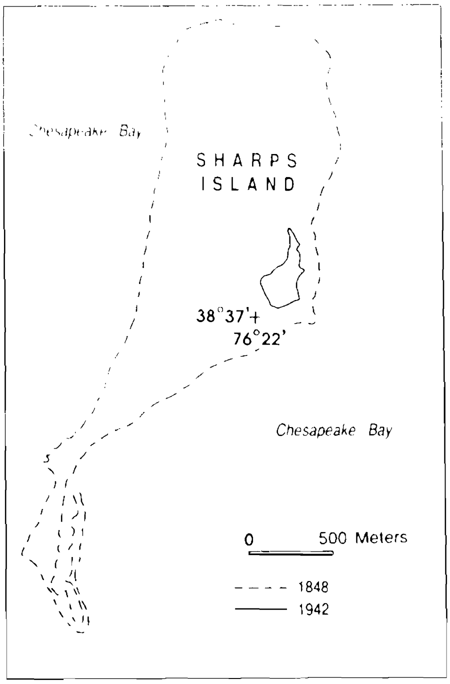

Figure 4. Decline in the size of Sharp's Island between 1848-1942. (Modified from Singewald and Slaughter, 1949.)

tle Ice Age, in particular its termination around 1850 A.D. (GROVE, 1988). Temperatures in the North Atlantic during this cold period may have dropped at times by as much as 3°C in the 18th and 19th Centuries (GRIBBIN and LAMB, 1977), and most glaciers in the Northern Hemisphere reached maximum downvalley extents (GROVE, 1988). A worldwide transgression, either from thermal expansion of ocean waters or limited additions to ocean volume from small glaciers melting (MEIER, 1984), could hardly be favored under such conditions. Indeed, systematic temperature records from England (MANLEY, 1974) indicate few comparatively long warm periods through the late 17th and 18th Centuries, with only one (the late 1740's) where mean temperatures rose more than approximately 0.3°C above previous decadal averages. By comparison, mean temperatures in England have increased by at least 1°C since 1850 (GRIBBIN and LAMB, 1977).

If the relative tracking of recent sea-level changes in the Chesapeake Bay with global climates of the last few centuries argues for a general eustatic cause, the relative significance of the present trend vis-à-vis the late Holocene record of the region is less certain. Tide-gauge records for rates of sea-level rise in the Bay during this century, averaging between 3.3 to 3.9 mm y^{-1} depending on the region considered (STEVENSON *et al.*, 1986), clearly diverge from the picture of relatively slow rates of rise (~ 12 to 15 cm per century) over the last several millennia portrayed in available sea-level curves (NEWMAN *et al.*, 1980). It is tempting to view the present trend as marking a sharp upward inflection in the long-term rate, and as yet another local example of global warming due to anthropogenic modifications of the atmosphere. But such an interpretation must be viewed cautiously when considering sea-level changes along a subsiding coast. With respect to Chesapeake Bay, the present rate of submergence due to subsidence alone (~ 1.6 to > 2 mm yr^{-1}; HOLDAHL and MORRISON, 1974; BROWN, 1978) exceeds both the long-term rate of 1.2 mm yr^{-1} for the mid-Atlantic region over the last several millennia (*cf.* KRAFT *et al.*, 1987) as well as the best estimates for global sea-level rise during this century, ranging from 1.2 to 1.4 mm yr^{-1} (GORNITZ and LEBEDEFF, 1987; BARNETT, 1983).

Thus, explaining the abrupt rise in sea level in the Chesapeake Bay since the middle of the 19th Century cannot be done by invoking purely eustatic sea-level rise. Its origins at least must partly lie in enhanced rates of subsidence, instigated by processes that operate at timescales far too short for the classic long-term isostatic and neotectonic mechanisms of subsidence of the U.S. middle Atlantic Coast (*cf.* CRONIN, 1981). A leading probable factor is subsidence from over-pumping of surficial aquifers. On a global or major coast-wide basis, the importance of anthropogenic withdrawal of groundwater may be a negligible factor, but not in sea level studies near major population centers especially along the U.S. Atlantic seaboard, as Savannah, Georgia demonstrates (GORNITZ and LEBEDEFF, 1987; BRAATZ and AUBREY, 1987).

DAVIS (1987) recently has documented considerable subsidence from large-scale groundwater withdrawal in the lower Chesapeake Bay (and broad areas of the Atlantic Seaboard) since early in this century. Locally, high rates of head decline in this area (*e.g.*, Portsmouth)

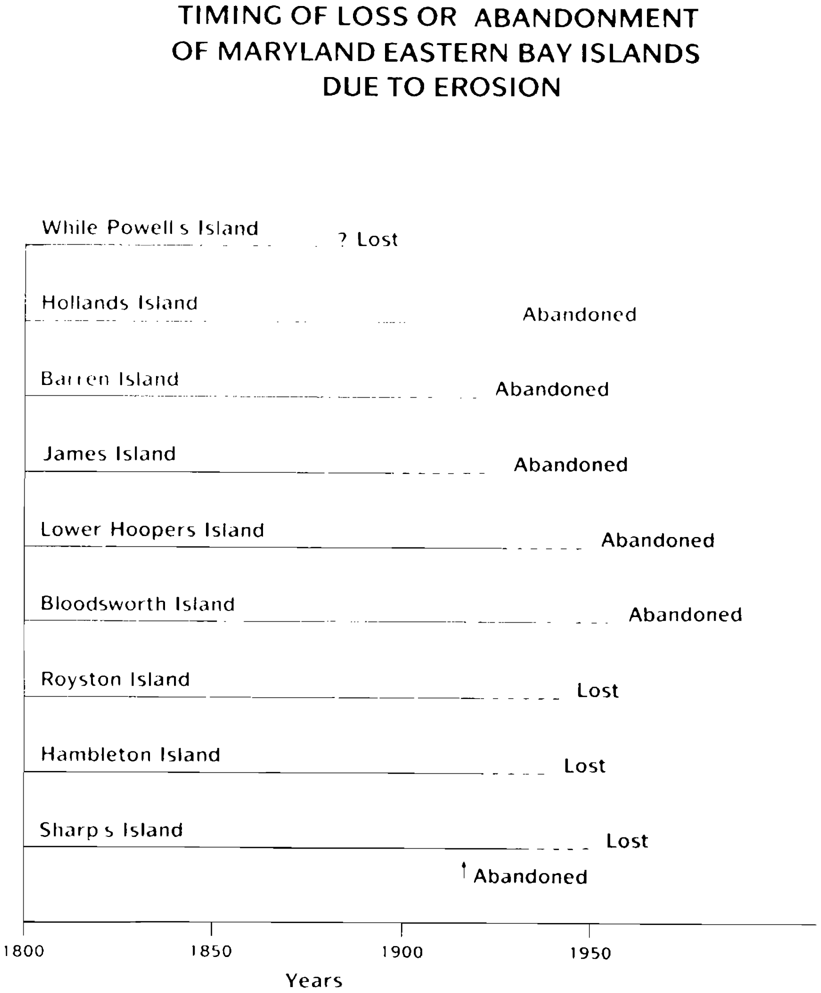

Figure 5. Timing of abandonment and/or disappearance of several major inhabited bay islands along Maryland's Eastern Shore.

have produced an overall subsidence of almost 22 cm since 1918. Elsewhere use of groundwater from lower Cretaceous aquifers also has been extensive, particularly along the southern Delmarva Peninsula, beginning with vegetable and seafood canning operations in the late 19th Century and expanding with development of poultry operations since the 1950s. It is difficult to estimate the actual rates of sediment compaction in this locality from head decline because few data are available. But it is perhaps not coincidental that the timing of initial canning operations corresponds to the rapid acceleration in shore erosion of local Bay islands as well as increased rates of local marsh loss (KEARNEY *et al.*, 1988).

A more speculative factor has been the contribution of river sediment loading to subsidence by isostatically downwarping of the Chesapeake basin. NEWMAN *et al.* (1980) suggested this subsidence mechanism as a possible cause for the anomalously high rates of submergence in Delaware Bay. Recent estimates for sediment budgets in the Virginia and Maryland portions of Chesapeake Bay indicate a net deposition of 800 x 10^6 metric tons of sediment over the last century (BYRNE *et al.*, 1982; KERHIN *et al.*, 1987). Studies of the general

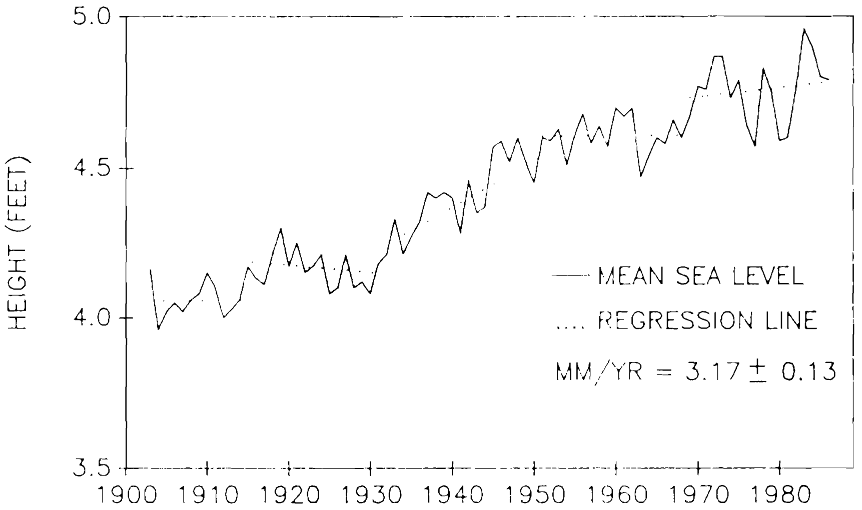

Figure 6. Tide-gauge record mean sea level changes for Baltimore, Maryland since 1900 (data from Lyles *et al.*, 1988).

history of anthropogenically-induced valley alluviation and sediment yields in the Southern Piedmont (TRIMBLE, 1974) as well as long-term subtidal sedimentation rates in Chesapeake Bay tributaries (BRUSH, 1984) document that massive river sediment loading of the Western Shore tributaries and the Bay's upper reaches has largely occurred since the latter half of the 19th Century. This relatively short period is nonetheless sufficient to produce significant isostatic adjustment to such a substantial static load as indicated by dramatic rates of subsidence (up to 17 cm) that resulted from water loading at Lake Meade in less than two decades (*cf.* BLOOM, 1967).

As with the influence of groundwater withdrawal, the ultimate contribution of river sediment loading to recent subsidence is difficult to assess at present. Sediment deposition (*i.e.*, the load) in Chesapeake Bay has not been uniform either temporally or spatially. SCHUBEL and CARTER (1984) have underscored the episodic nature of major fluvial sediment inputs into the Bay, showing that most of the recent sediment deposition was the result of one event, Tropical Storm Agnes in 1972. Some question also exists as to the accuracy of the present mapping of areas of sinks or scour, particularly in the Maryland portion of the Bay (OFFICER *et al.*, 1984). Further refinement moreover is needed in the geodetic levelling net of the area (*cf.* HOLDAHL and MORRISON, 1974). However, the very enormity of the sediment load to the Chesapeake Bay within the last century-and-a-half suggests a probable factor in the present sea level rise of the Chesapeake Bay that is too large to ignore.

CONCLUSIONS

Analyses of long-term changes in rates of marsh accretion and bay island land loss (shore erosion) along the Eastern Shore of Chesapeake Bay reveal that the present rapid submergence of the area began in the 19th Century. However, most of the increase in the local rate of sea-level rise largely dates from the last several decades of the present century. Tide-gauge records show that the average rate of sea-level rise in the Bay over this most recent period has been more than double the long-term trend of the last several thousand years.

The significance of the present rate of sea-level rise in the Chesapeake Bay with respect to the late Holocene sea-level record of the area is not clear. Unquestionably, global eustasy has played a role, but the estimated magnitudes of this increase are insufficient to account for the observed local trends (see PIRAZZOLI, 1989). Enhanced recent rates of subsidence from anthropogenic factors may account for most of the remaining variation, but determining their proportional contribution will be difficult until more studies of the effects of groundwater withdrawals and sediment loading are undertaken in this region.

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□ RESUMEN □

Los cambios a largo plazo en los niveles de deposición vertical de los pantanos basados en la reconstrucción geotecnológica e histórica del polen y los radionucleidos de las pérdidas de tierras en islas de bahías se usaron para estudiar los cambios en el nivel del mar en la Bahía de Chesapeake desde los tiempos coloniales. Estas marcas sugieren que la inmersión rápida de la región de la Bahía documentadas en las lecturas de los sensores locales medidores de las marcas, esencialmente data de principios del siglo XIX. Por el contrario, el nivel del mar aumentó a lo largo de los siglos XVII y XVIII con relativa lentitud. La pérdida de tierras y los índices de deposición vertical en los pantanos se han ido acelerando desde finales del siglo XIX. Este tipo de cambios del nivel del mar en la Bahía de Chesapeake se corresponde con los cambios generales en la climatología global de los últimos siglos, asociados a la "Little Ice Age." Sin embargo, la eustasia global no puede tener en cuenta un alto porcentaje de las actuales tendencias del nivel marino e la Bahía. Nosotros suponemos que un aumento de los niveles de descenso del suelo a partir de la retirada antropogénica de las aguas terrestres y la carga de sedimentos son otros factores mejora que deben ser tenidos en cuenta para el alto índice de sumergencia, especiialmente de la región de Mid-Chesapeake.—*Department of Water Sciences, University of Santander, Cantabria, Spain.*

□ RÉSUMÉ □

La palynologie, la géochronologie des radionucléides et la reconstitution historique permettent de connaitre à long terme les changements des taux d'accrétion verticale des marais. Cette méthode a été appliquée depuis l'époque coloniale à la baie de Chesapeake. La rapide submersion de la baie, visible sur les enregistrements de marégraphes, ne date que du début du 19 ème siècle, alors que la montée du niveau de la mer avait été relativement lente aux 17 ème et 18 ème siècles. Les pertes de terrain et l'accrétion verticale des marais se sont ensuite accélérées jusqu'à la fin du 19 ème. Cet ensemble de modifications du niveau de la mer en baie de Chesapeake correspond à la modification globale du climat des siècles derniers associée au "Petit Age Glaciaire." Néanmoins, l'eustasie globale ne contribue que peu aux variations actuelles du niveau de la mer dans la baie. On peut supposer que la subsidence a été accrue par les retraits anthropogènes de la nappe phréatique et par les charges sédimentaires qui sont d'autres facteurs qui interviennent en faveur d'une forte submersion, surtout dans la région du moyen Chesapeake.—*Catherine Bousquet-Bressolier, Géomorpholgie EPHE, Montrouge, France.*