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Postglacial Submergence and Salt Marsh Evolution in New Hampshire*

HOWARD W. KEENE

Introduction

Four samples of peat from the base of the Hampton-Seabrook, New Hampshire salt marshes (Fig. 1) were submitted for radiocarbon-age determination in order to establish the late postglacial submergence rate, and link this to marsh evolution. A seaward thickening wedge of postglacial sands, silts and salt marsh peat overlies the glacial and bedrock marsh basement (Fig. 2). A thin discontinuous peat layer forms the base of the postglacial sequence and contains the remains of logs, twigs and leaves, with lesser salt-marsh and fresh-water marsh vegetation. The peat is interpreted (Keene, 1970) as a diachronous unit similar to that described in other New England salt marshes (Redfield and Rubin, 1962; McIntire and Morgan, 1963, and Gloom and Stuiver, 1963). This peat formed in an environment analagous to that of the present day inland marsh boundary where the forest lies adjacent to the salt marsh at approximately the level of mean high water.

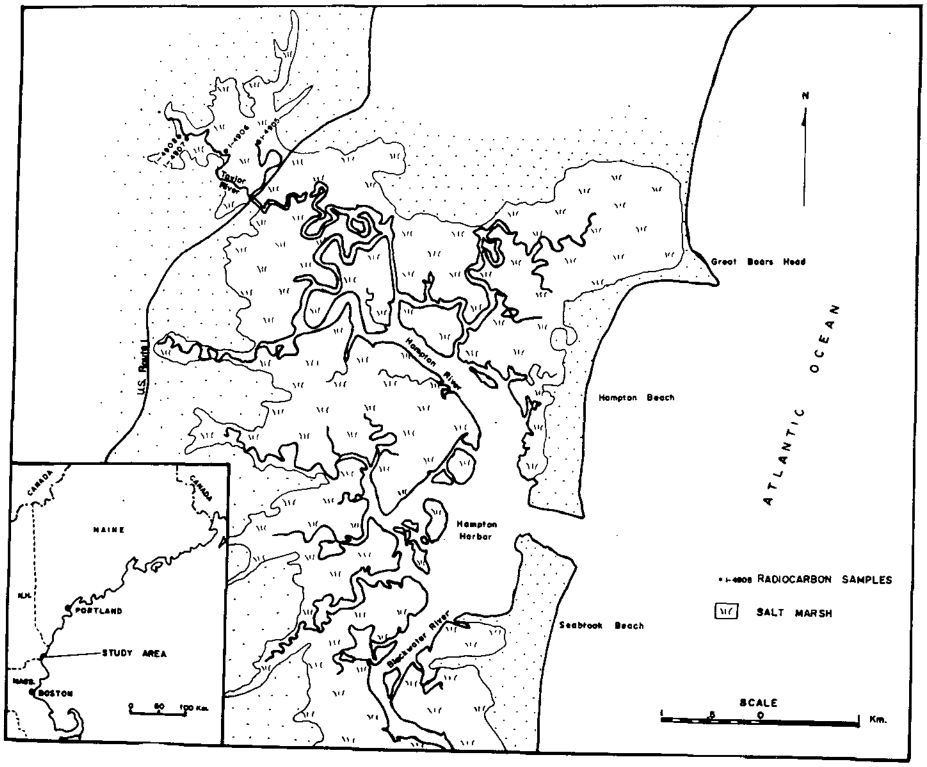

Figure 1 - Index Map.

Sampling

A Davis U.S. Geological Survey piston corer 1.9 cm (3/4 inch) in diameter, was used to collect samples and evaluate the stratigraphy of the marsh. At each sampling locality two adjacent sub-samples from the same elevation were combined in order to obtain enough carbon for the analysis without using a long vertical section. Each sub-sample was 7.5 to 10 cms in length, and was taken from directly above the marsh basement in order to minimize the effects of subsequent compaction within the postglacial sequence. The basal peat layer is assumed to have formed at approximately the level of mean high water. Thus, providing there has been no vertical displacement due to compaction, the age of the sample should represent the time at which mean high water was at the elevation of the sample. The marsh basement beneath the four samples consisted of blue silt-clay, probably equivalent to the late-glacial Presumpscot Formation of Bloom (1963). This deposit is very stiff and compacted, and is assumed to have undergone negligible vertical displacement due to compaction in late postglacial times. The local datum used in measuring sample elevation was the high marsh surface, which is assumed to be at approximately the level of present-day mean high water. The sampling stations (Fig. 1) were located across a buried river valley where there is a steep slope to the marsh basement, and the overlying sediments are relatively fine grained, enabling the corer to reach the basement in most instances.

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* Manuscript received November 10, 1971.

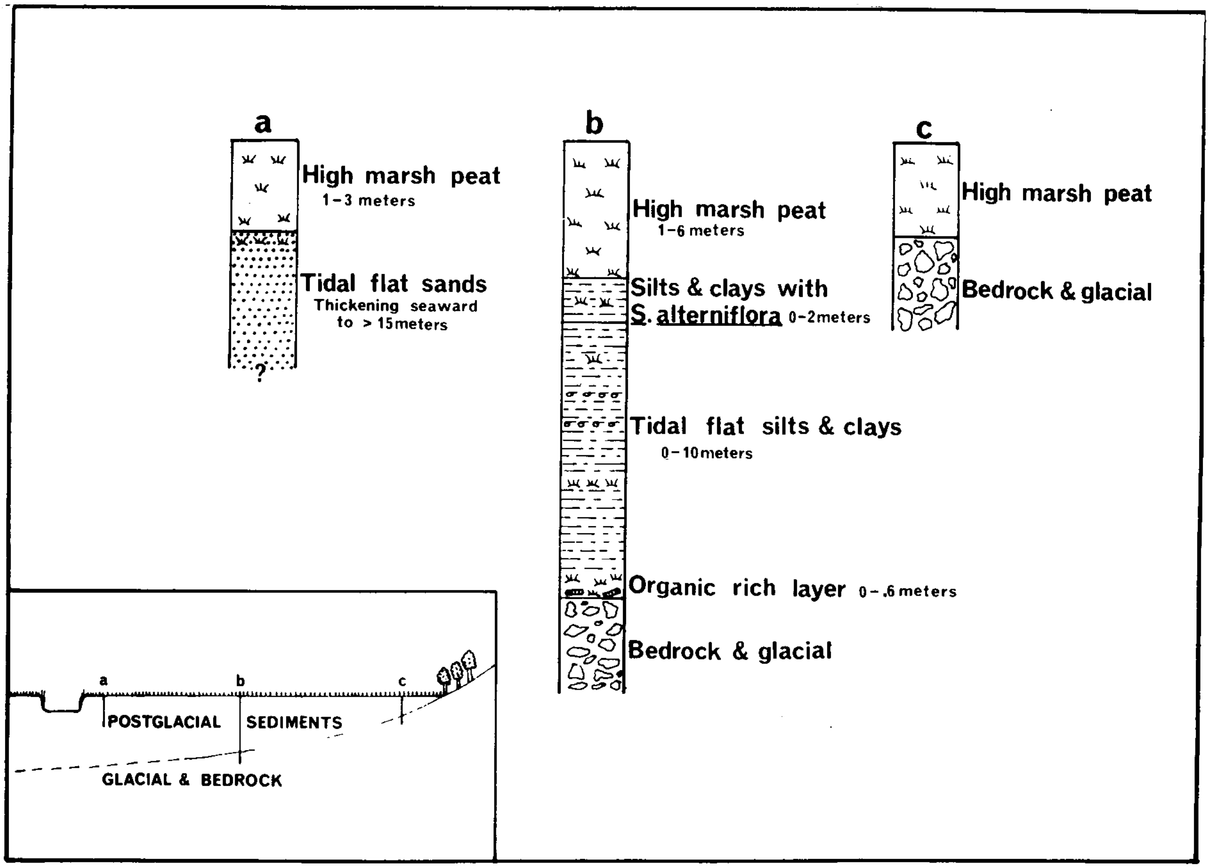

Figure 2 - Generalized Marsh Stratigraphy (location of sections shown diagramatically on the inset).

Postglacial Submergence History

The details of the samples are summarized in Table 1. Figure 3 represents the approximate progress of late postglacial submergence of the New Hampshire coast. Sample I-4905 was obtained from forest litter materials, with salt-marsh peat occurring 45 cm above. The parent material of the sample may have accumulated just before high water level reached this point. Sample I-4906 was obtained from silty forest litter materials with some salt-marsh plant remains mixed, and therefore probably bears a fairly precise relationship to a former high water level. Sample I-4907 was taken from silty forest litter materials with possible fresh-to brackish-water plant remains intermixed. This probably formed at or slightly above the high water level. Sample I-4908 consisted largely of the remains of salt-marsh peat with woody fragments, and therefore probably formed at or slightly below mean high water.

In construction of the submergence curve (Fig. 3) the results of similar studies were considered. The age of Sample I-4907 is much younger than would be expected if the Hampton-Seabrook area has had a similar submergence history to Plum Island, Massachusetts (McIntire and Morgan, 1963). Since Plum Island is close to the present area of study the submergence histories of the two areas should be similar. It is possible that this date is in error due to sample contamination, and was consequently ignored in constructing the curve. Contamination could be due to the following: a) younger rootlets penetrating from above, b) error introduced in sample collection such as core barrel contamination, slumped material from above, or c) introduction of recent carbon during sample preparation. The other three samples are assumed to be reliable. Minor fluctuations in the submergence curve are probable, but cannot be deduced from the data presented here.

From Figure 3 the average rate of submergence between 6850 B.P. and 4000 B.P. was 2.3×10^{-3}m per year. The rate of submergence began to decrease significantly sometime around 4000 B.P., and the average rate since 4000 B.P. has been 1.1×10^{-3}m per year. The submergence curve supports the stratigraphic evidence that submergence has been continuous during the formation of the Hampton-Seabrook marshes. It also supports the data of Redfield and Rubin (1962), McIntire and Morgan (1963) and Bloom and Stuiver (1963) that submergence in New England has been continuous during the last 6000 to 7000 years without a significant stillstand, and that a decrease in the rate of submergence began sometime between 3000 B.P. and 4000 B.P. The submergence data obtained from other salt-marsh studies in New England is summarized in Figure 4. However, it should be noted that the radiocarbon data presented here are effectively based on three dates only, and therefore explanation of regional variation in submergence will not be attempted.

Table 1 - Age and Depth of Samples from Hampton-Seabrook, New Hampshire salt marshes.

SAMPLE NO.*	LOCATION	DEPTH BELOW MARSH SURFACE	AGE
I-4905	Taylor River Marsh Hampton, N.H. 42° 55' 47" N 70° 51' 10" W	11.2 m	6850 ± 155 years before 1950 A.D.
I-4906	Taylor River Marsh, Hampton, N.H. 42° 55' 43" N 70° 51' 23" W	8.4 m	5730 ± 150 years before 1950 A.D.
I-4907	Taylor River Marsh, Hampton Falls, N.H. 42° 55' 47" N 70° 51' 41" W	4.6 m	2865 ± 175 years before 1950 A.D.
I-4908	Taylor River Marsh, Hampton Falls, N.H. 42° 55' 47" N 70° 51' 45" W	2.0 m	2740 ± 310 years before 1950 A.D.

* Samples were submitted to Isotopes Inc., Westwood, New Jersey for age determination. Radiocarbon analysis used carbon dioxide as the counting gas in an internal gas proportional counter.

Salt Marsh Evolution

A chronicled submergence combined with stratigraphic data permit an evaluation of marsh evolution. Away from present major tidal channels and toward the inland marsh boundary, the post-glacial stratigraphy at depths greater than 3 to 4 m below the high marsh surface generally shows silts and clays overlying an organic rich layer with forest debris (Fig. 2b). Toward the centre of the marsh basin, approaching major tidal channels, the silts and clays grade laterally into sandy silts, which in turn grade into fine sands. The upper surface of the silt and clay - sandy silt - fine sand layer rises to a position within 1.5 to 2 m of the marsh surface adjacent to the major tidal channels.

Between 6850 B.P. and approximately 4000 B.P. the rate of submergence was relatively rapid and open estuaries were formed as the ocean transgressed along valleys cut during early post-glacial emergence (McIntire and Morgan, 1963). Thus the high-water line was moving progressively farther inland, overwhelming the forested upland and increasing the estuarine area. Trees adjacent to and overhanging the shallow estuary edge dropped twigs and leaves into the water, and the trees themselves were killed when the high-water level reached their root systems. Forest debris accumulated at or very close to high-water level, resulting in a thin diachronous unit of peat and logs located directly above the marsh basement (organic rich layer shown in Fig. 2). The shallow edge of the estuary was colonized by salt-tolerant vegetation which was rooted in the forest litter layer or the overlying muds. At any one locality this situation was ephemeral because relative sea level was rising fairly rapidly and the high-water line was moving progressively farther inland. As the high-water level moved inland from a locality, the water became too deep at that locality for salt-tolerant vegetation, and the peat became covered by tidal mud flats Thus beyond the peat accumulation at the edge of the estuary mud flats developed, the latter changing leterally into sand flats toward the centre of the estuary. These tidal flats were traversed by a network of deeper channels. Faunal and floral evidence suggest that most of these flats were intertidal, particularly near the inland marsh border, where the silts and clays occur with thin horizons of salt-marsh peat throughout. The latter indicates that an intertidal environment existed at relatively high elevations, where patches or islands of march vegetation were able to colonize from time to time. Toward the centre of the basin peaty horizons disappear and the sediment coarsens to sandy silt. Shells are present in the sandy silt, and resemble present forms which live in the intertidal zone. This was probably a lower intertidal environment

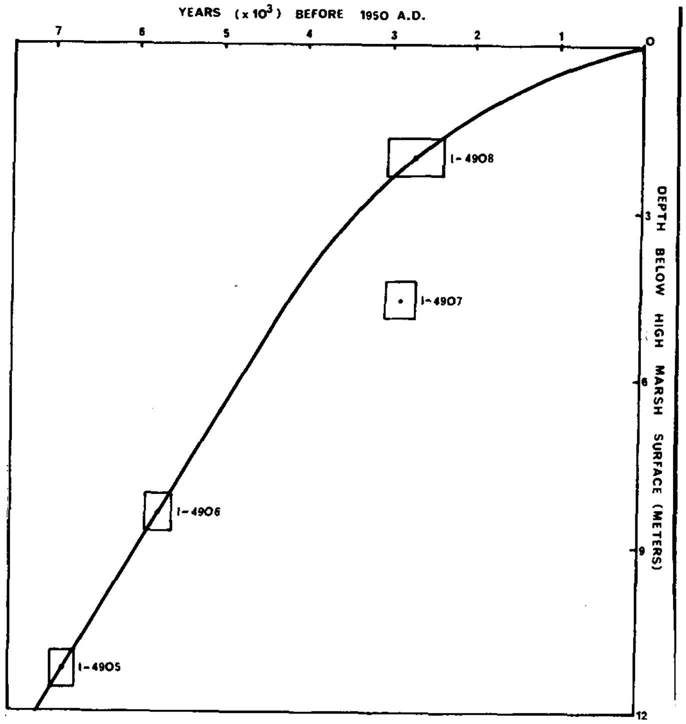

Figure 3 - Submergence curve for Hampton, New Hampshire. Size of rectangles indicate possible errors in depth measurement and statistical errors inherent in the radiocarbon dating technique.

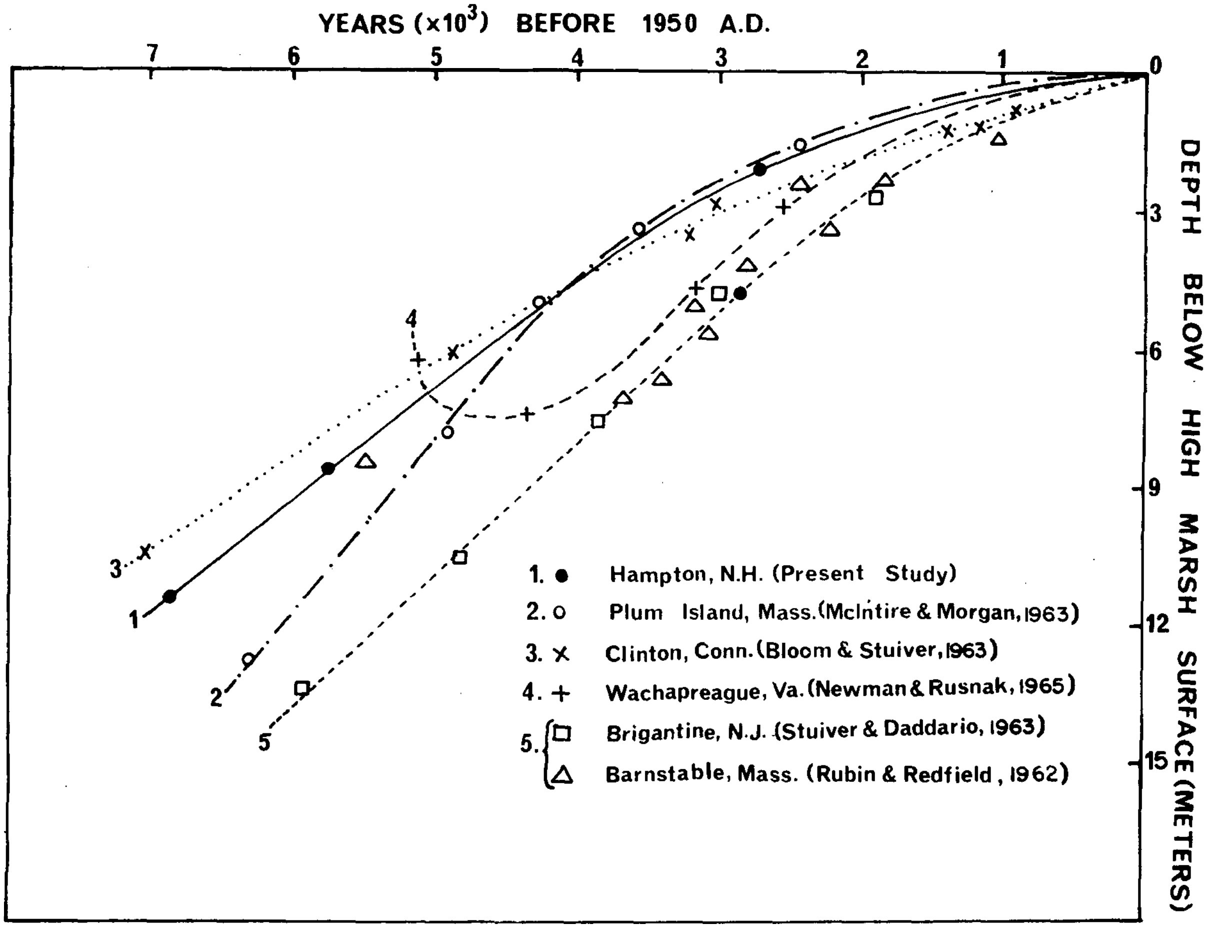

Figure 4 - Submergence curves for Eastern Seabord, U.S.A.

in which the period of inundation during a tidal cycle was too long to permit salt-marsh colonization to take place. Beyond the sandy silts toward the present-day tidal channels, fine sands occur. These sands mostly represent intertidal or slightly sub-tidal sand flats but may, in part, represent material deposited in deep channels.

Approximately 4000 years B.P. there was the beginning of a significant reduction in the rate of submergence. This change began when relative sea level was approximately 4.6 m below the present level (Fig. 3). Soon after the change in rate of submergence began, sedimentation was able to keep pace with and eventually exceed the submergence. This is manifested in the widespread development of salt-marsh peat in the upper 3.3 to 3.7 m of such deposits in the Hampton-Seabrook area. Similar conclusions have been reached elsewhere in New England (Redfield and Rubin, 1962; McIntire and Morgan, 1963 and Bloom and Stuiver, 1963). McCormick (1968) found that a change from fine-grained sediments to salt-marsh peat occurs at a depth of about 4.6 m below the Plum Island marsh surface.

Redfield (1965) proposed a theory of marsh evolution on the basis of studies at Barnstable, Massachusetts. The idealized stratigraphy consists of a thin layer of peat formed high in an intertidal environment and sloping upward over tidal flat sediments toward a similar environment on the banks of the present-day channels. This is overlain by a wedge of high-marsh peat, formed at about mean high water level, and thinning both landward and toward major channels. The stratigraphy of the upper 3 to 4 m of the Hampton-Seabrook marshes is in general accord with Redfield's theory. Tidal-flat silts and clays grade upward into a silty layer with *Spartina alterniflora*, a coarse salt-marsh grass which lives in the present-day high intertidal environment. The *S. alterniflora* layer is indefinable in places, but generally slopes upward toward major tidal channels. Wirey salt-marsh peat with the remains of *Spartina patens* (dominant grass on the present-day near-horizontal marsh surface) occurs in the upper few m of the marsh (Fig. 2), and thins both landward and toward major tidal channels.

The decrease in the submergence rate allowed sedimentation to build up the floor of the estuary to a level where *S. alterniflora* was able to colonize seaward from the edge of the estuary. Beyond the limit of the *S. alterniflora* colonization, the tidal flat continued to grow upward in response to a relatively rising sea level. *S. alterniflora* trapped sediment, and consequently a layer of silty peat developed outward across the rising tidal flat, quickly building up to near high water level. Once near high water level, *S. patens* colonized from the marsh edge across the *S. alterniflora* layer and was able to keep pace with further relative sea-level rises, forming a nearly horizontal marsh surface at approximately the level of mean high water.

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