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Holocene Sea-Level Change in Coastal Maine

Daniel F. Belknap[1,2,3]
R. Craig Shipp[3]
Robert Stuckenrath[6]
Joseph T. Kelley[1,2,5]
Harold W. Borns, Jr.[1,4]

[1]Department of Geological Sciences
[2]Center for Marine Studies
[3]Oceanography Program
[4] Institute for Quaternary Studies
University of Maine
Orono, Maine 04469

[5]Maine Geological Survey
Augusta, Maine 04333

[6](Radiocarbon Laboratory
Smithsonian Environmental Research Center)
Present Address:
Radiocarbon Dating Laboratory
University of Pittsburgh Applied Research Center
Pittsburgh, Pennsylvania 15238

ABSTRACT

Coastal Maine is experiencing differential coastal warping at present, as revealed by tide gauge, releveling, and other data (Anderson et al., 1984). During 1983-1985, salt marshes were cored along the coast to obtain peats for radiocarbon dating, in order to construct local relative sea-level curves and establish the longevity of the warping. Supplementary cores were taken in subtidal environments where seismic profiling suggested the presence of buried datable horizons. Twenty-two localities were examined, and a suite of sixty-eight new radiocarbon dates were obtained. Forty-two of those dates were reliable high salt marsh peats in the age range of 5000-1500 yrs BP. Linear regression of these selected data suggests that local sea level rose relatively uniformly at a rate of 1.44 mm/yr from 5000 to 1500 yrs BP. After 1500 yrs BP, sea level rose at a maximum of 0.5 mm/yr until very recently. There is no consistent difference in local curves among four primary locations along the coast for the 5000-1500 yrs BP time period. Therefore, the present rate of differential warping must be a recent phenomenon. In contrast, there is a consistent difference between the Maine data and published Bay of Fundy sea-level data, suggesting an effect of differential growth in amplitude of tidal range through the late Holocene and/or a combination of residual glacioisostatic, neotectonic, and hydroisostatic factors.

INTRODUCTION

As part of a study of crustal warping in coastal Maine, local relative sea-level curves have been constructed from localities in southern, central, and eastern coastal Maine (Figure 1). These curves are used to investigate the longer-term, late Holocene evidence for postulated along-coast differential crustal warping of up to 9 mm/yr (Anderson et al., 1984). Salt marsh peats, which are produced by plant growth near sea level, can be dated by radiocarbon analysis. When basal high salt marsh peats are sampled in sequence along a sloping surface, problems of compaction are avoided, and a reliable local relative sea-level curve can be constructed (Redfield and Rubin, 1962; Kaye and Barghoorn, 1964; Belknap and Kraft, 1977). To obtain reliable sea-level and time information, peats with identifiable high salt-marsh plant fragments must be obtained. This ensures that the peat accumulated within about 30 cm of mean high water (MHW) in mesotidal (2-4 m tidal range) settings (Bloom, 1964; Thompson, 1973). Typical plants in this range are *Spartina patens* and *Juncus gerardi*. When identified, peats must be cleaned of contamination resulting both from the coring process and from accumulated humic acids. For this study the cleaned peat was then dated by standard radiocarbon analysis at the Smithsonian Institution's Radiation Biology Laboratory. Local relative sea-level curves from several locations along the Maine coast can independently assess a possible crustal warping indicated by releveling, tide gauges, Pleistocene deltas, and historic and archaeological information (Thompson, 1980, 1981; Thompson and Kelley, 1983; Anderson et al., 1984). Variations in sea-level with position along the coast for various time planes allow a check on warping over the late Holocene time frame. The longer-term framework of Maine's late Quaternary sea-level changes has recently been discussed by Belknap et al. (1986a; 1987b).

METHODS

Existing sea-level information in Maine, discussed below, has been suspect due to poor sampling techniques, questionable identification of dated material, and method of preparation. For this project a portable vibracorer, utilizing a 7.6 cm diameter aluminum core tube driven into the sediments by a gasoline-powered cement vibracorer (Lanesky et al., 1979) is used (Figure 2). This method provides a large diameter, continuous core up to 13 m in length on land or in water up to 10 meters deep. The tube is sharpened and serrated, but no core cutter or catcher is used. After coring, the tube is capped, winched out with a tripod and "come-along" winch, and returned to the laboratory. Cores are cut along the edges with a carbide-tipped rotary saw, then split with a knife. Samples for radiocarbon analysis are immediately removed; the outer centimeter is cut off and the undisturbed inner core is wrapped in aluminum foil, placed in plastic bags, and then frozen. The vibracoring technique usually provides a core completely undisturbed except for an outer two-millimeter thick zone, which is liquified during penetration. The cores are described in detail as to sediment texture, structure, color, and preserved organic materials and macrofossils. Subsamples are also taken for future grain-size analysis and microfossil identification. One hemicylinder of the core is destroyed in this process. The other half is photographed, wrapped in plastic tubing, and stored for future study.

Plant fragments sampled from the core are compared to collections from living marsh plants (both standard pressed specimens and preserved rhizome sections) and standard botanical keys (e.g., Gleason, 1963). In general the rhizomes are the most distinguishable macroscopic preserved parts (Johnson, 1925; Allen, 1977; Atwater and Belknap, 1980). Future work may include microscopic sectioning of marsh peats, for a more complete environmental analysis (e.g., Allen, 1977). Table 1 is a listing of the salt marsh plants with recognizable rhizomes used to distinguish environments:

Besides in-place roots and rhizomes, high salt marsh peat is characterized by a well preserved fibrous root mat, an H_2S odor, very little inorganic sediment, high water content, and a yellow-brown color (e.g., Munsell 5Y4/2). Low marsh is often high in inorganic sediment, mud or sand, and dominated by *Spartina alterniflora*, a coarse, pale-yellow rhizome. Detrital materials are evident from broken fragments lying on horizontal bedding planes, a wide diversity of materials, sharp boundaries with no roots penetrating below, and a generally higher inorganic content. The leading edge of the transgression is the salt marsh to upland or salt marsh to fresh marsh boundary. The former is characterized by detrital wood, bark, leaves and a poorly consolidated character, often overlying the Presumpscot Formation, a local Pleistocene glaciomarine mud. Freshwater marsh is mahogany brown (e.g., Munsell 5YR5/1) and has a non-fibrous

TABLE 1. IDENTIFIABLE MARSH PLANTS IN SEDIMENT CORES FROM THE MAINE COAST: PRIMARILY RHIZOMES
(Gradations between environments common.)

Low Marsh: initial colonizer of tidal flats	
	Spartina alterniflora
High Marsh: broad mature marsh, low sedimentation rate	
	Spartina patens
	Distichlis spicata
Higher High Marsh	
	Juncus gerardi
	Limonium nashii
	Solidago sempervirens
Brackish Marsh (also in HHM)	
	Scirpus maritimus
Transitional Fresh Marsh	
	Typha angustifolia

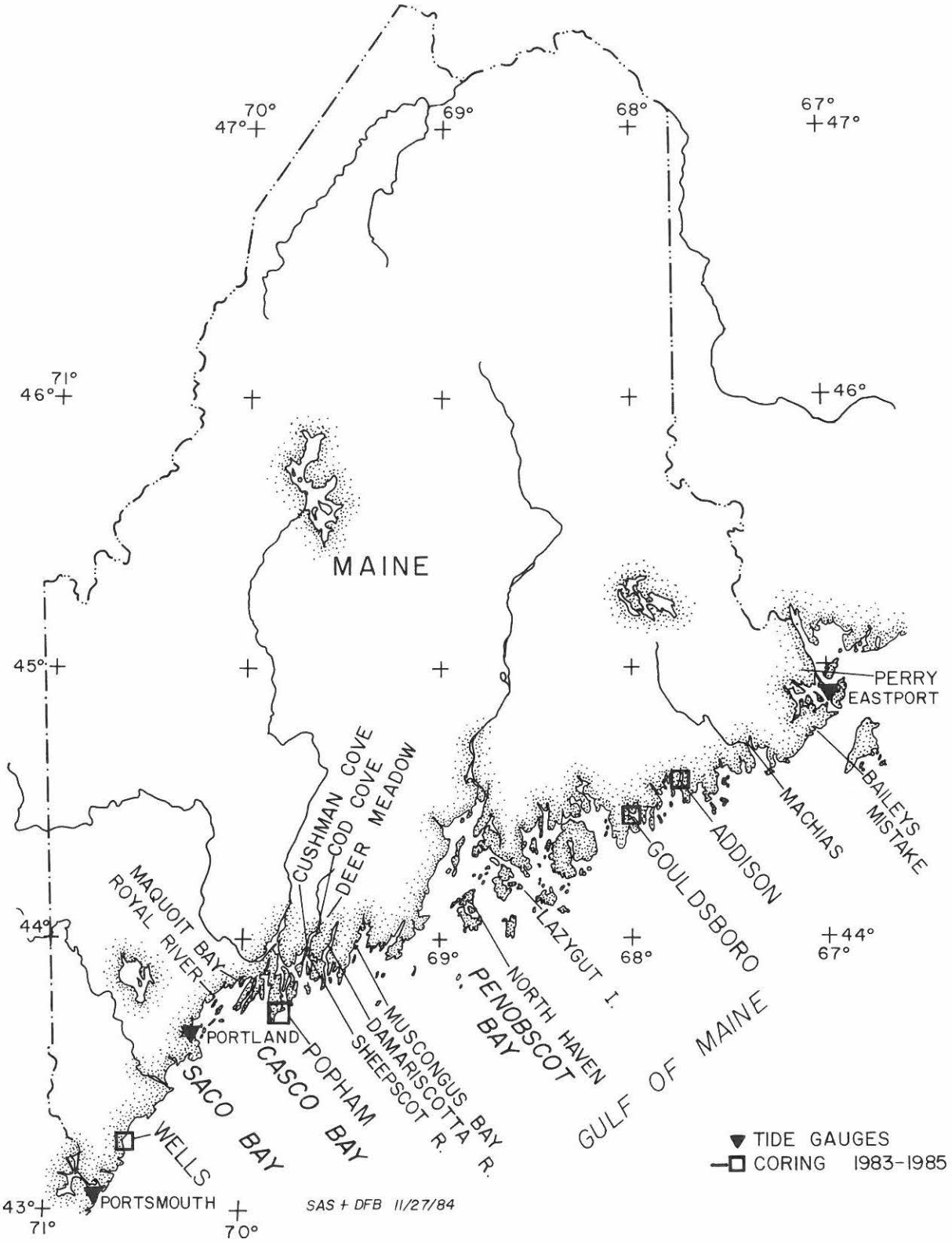

Figure 1. Location map for coring studies and reconnaissance surveys, 1983-1986 field seasons.

crumbly texture, which we refer to as "coffee-grounds." Organic fragments are often unidentifiable and there is little H_2S odor. Salt pannes are identifiable by a blackened, macerated and somewhat stiffer zone, and are particularly noticable in X-ray radiographs. We have identified consequences of colonial diking (Smith and Bridges, 1980; Anderson et al., 1984), particularly from marshes in eastern Maine. The diking temporarily changed the hydrography and ecology of marshes, in some cases leaving desiccated and burned zones overlain by abrupt transition to muddy *S. alterniflora*-rich zones (a consequence of dike abandonment).

Anderson and Borns (1983) have discussed the identification of salt marsh environments using foraminifera, based on the techniques of Scott (1977), Scott and Medioli (1978, 1980) and Smith et al. (1984). While we have preferred to base our identifications primarily on identifiable plant remains (the material actually being dated), we are also in the process of checking the microfossils (Staples, 1988). Although D.B. Scott and coworkers emphasize the precision that foraminifers can give to marsh elevation analyses, they date wood fragments. These wood fragments can easily be transported, and may date older than the peats in which they are found. Addison II cores have been analyzed in detail during earlier phases of the NRC project (Anderson and Race, 1981), showing that the HHW level of rapid increase in total numbers of foraminifera is reached within the bottom 10-20 cm of the core, within the dark brown basal unit. In addition, we have sampled one core (AII-VC-2) at 3 to 30 cm intervals for pollen analysis, to compare it with established local pollen diagrams (Davis et al., 1975).

Figure 2. Vibracorer - gasoline powered vibrator drives aluminum irrigation tubing into the sediment. After capping, the tube is winched out using a "come-along" and tripod.

In the course of correcting ^{14}C data, the stable isotopic ratio of $^{13}C/^{12}C$ is routinely determined. Besides correcting for isotopic fractionation of ^{14}C by various organic pathways, the ratio identifies terrestrial and marine plants (e.g., Sherr, 1982). For example, terrestrial grasses have a $\delta\ ^{13}C$ of -24 to -28 $^{o}/oo$, planktonic diatoms of -20 to -22 $^{o}/oo$, and *Spartina alterniflora* of -13 $^{o}/oo$. Low marsh is thus distinguishable from terrestrial plant environments. *Juncus* on the other hand, has a $\delta\ ^{13}C$ of -26 $^{o}/oo$, a terrestrial signature.

Besides plant and microfaunal remains, sedimentary environments are identified by texture, structures, and sequence, by comparison to modern environments. Identification of subtidal, tidal flat, channel, marsh, and upland deposits by specific sedimentary criteria has allowed more confident description of stratigraphy. Figure 3 is an example of the descriptive core log, for MR-VC-2.

Elevation information is obtained by leveling with a transit or hand-level and tape. Elevations are referred to timing of water levels at stations as predicted from tide tables where benchmarks are unavailable (as is common). On independently leveled stations, we have observed errors of no more than ± 15 cm when using tide-table predictions near main channels. Depth below marsh surface is measured on the rigid core. Compaction of the cored section often occurs during coring, but it is usually less than 5% of core length. It is assumed that most of this compaction occurs in the watery, fibrous sediments of the upper 1-2 meters, based on comparisons with hand-driven cores at the same locations.

Appendix A is a list of all cores taken during the 1983-1985 NRC project. The present discussion focuses on vibracores with available stratigraphic and ^{14}C information.

Selection of materials for dating is the most critical problem in construction of a sea-level curve. Dating of salt marsh peats in a column or encroaching on historic structures can give an indication of sediment accumulation rates, but may not provide direct sea-level information. Movement of the plane of high-water level across a gentle slope is tracked by basal high salt marsh peats, which are not subject to displacement by autocompaction. Peats within the sediment column are subject to displacement below their original position, by as much as 40% (Kaye and Barghoorn, 1964; Belknap and Kraft, 1977). To find the appropriate slope for a basal peat transect, the reconnaissance hand corer (Eijkelkamp or "Dutch" corer) is used to locate the Holocene-Pleistocene boundary along the transect and to establish a preliminary stratigraphic reconstruction. It is important to avoid creek meander belts, salt marsh over freshwater bogs, and areas of displaced peat blocks near tidal flats. Both coring methods allow careful examination for evidence of reworking such as ice-rafted pebbles and mud, flattened matted aerial plant

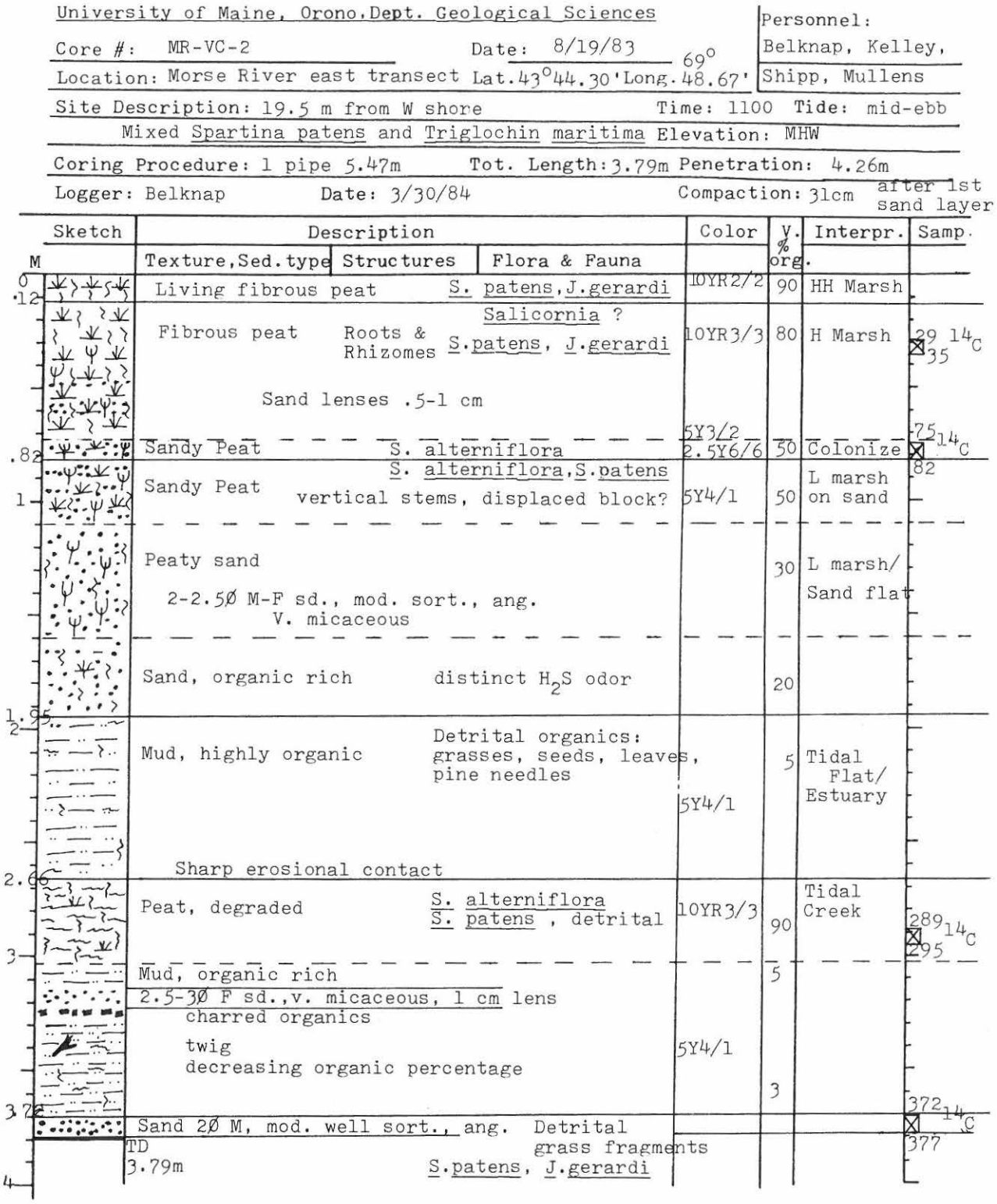

Figure 3. Example of descriptive core log for MR-VC-2, standard method of archiving, describing and sampling cores.

parts (stems and leaves), and sharp discontinuities. This is in marked contrast to coring methods employed by previous workers, such as the Davis corer of Thompson (1973), which disturbs the sediment, and takes discontinuous and very small volume samples, thus requiring multiple reentries to provide sufficient mass for ^{14}C analysis.

A further problem in constructing sea-level curves is contamination of basal peat. The bottom 10-20 cm of Maine marshes is a dark brown color, quite different from the rich yellow-brown salt marsh peats above. This is partly due to detrital bark, seeds, leaves and wood, the remnants of a wrack line at the leading edge of a transgressing marsh. Also, there appears to be a major concentration of humic acids over the base of impermeable Pleistocene till or Presumpscot Formation mud. This is different from the basal peats in Delaware, for example, where the Pleistocene is a permeable sand and gravel and there is little accumulation of humic acid (Kraft, 1971; Belknap and Kraft, 1977). Table 2 is a list of the 1982-83 radiocarbon dates from the Addison marshes. Note the extreme variability of ^{14}C apparent dates on the humic acid fraction which has been removed from the peats. The 1983 dates were not even from the darkest, most basal unit, yet still showed differences between the soluble and insoluble fractions. The variability of this material may call the Thompson (1973) and Anderson and Race (1981) data into question, since they dated the basal material. It appears that there is a significant redistribution of both older and younger humic acids within the marsh, at least along the impermeable basal contact, and that only the insoluble fraction of peats should be dated. In addition, the 1983-1985 dates were taken 5-10 cm above the darkest humic acid impregnated material, avoiding the contaminated peat and sampling only the high marsh material. Compaction displacement should be less than 15 cm for those samples. Other samples within the peat column were dated to provide sedimentation rate and stratigraphic information.

TABLE 2: ADDISON ^{14}C DATES: 1982-1984. ROBERT STUCKENRATH, SMITHSONIAN INSTITUTION, RADIATION BIOLOGY LABORATORY.

Sample #	Type *	Depth MHW	NaOH Insoluble Corrected Age	$\delta^{13}C$ °/oo	NaOH Soluble Corrected Age	$\delta^{13}C$ °/oo
ADDISON I MARSH: ERODING FACE ON PLEASANT RIVER, 1982						
82-1	(W)	74 cm	2220 ± 50	-	-	
82-2	(W)	73	1945 ± 60	-	-	
82-3	(SM)	70	1635 ± 50	-27.7	1595 ± 70	-25.2
82-4	(TOC)	71	20 ± 80	-27.9	865 ± 75	-29.2
82-5	(SM)	30	815 ± 45	-24.4	760 ± 60	-25.0
82-6	(SM)	62-75	720 ± 45	-23.7	955 ± 65	-23.0
ADDISON II MARSH: VIBRACORES, 1983						
VIBRACORE 2 SI-						
6203	(SM)	150-155	145 ± 95	-19.6	910 ± 95	-20.1
6202	(SM)	210-215	820 ± 100	-15.3	4415 ± 220	-15.7
6201	(SM)	270-275	2960 ± 75	-21.1	2815 ± 155	-20.3
6200	(SM)	315-320	3415 ± 110	-23.4	110% modern	-23.4
6199	(SM)	384-393	4095 ±100	-23.0	3850 ± 70	-22.0
VIBRACORE 3						
6207	(SM)	152-157	2595 ± 80	-18.5	137% modern	
6206	(SM)	209-214	1730 ± 75	-17.9	1810 ± 130	-18.3
6205	(SM)	269-274	2815 ± 50	-18.8	1885 ± 100	-19.3
6204	(SM)	295-300	3170 ± 60	-26.6	3145 ± 85	-25.9
VIBRACORE 4						
6210	(SM)	65-70	365 ± 70	-22.8	1040 ± 65	-20.6
6209	(SM)	105-110	1525 ± 75	-28.2	550 ± 145	-27.7
6208	(SM)	165-170	1840 ± 110	-26.9	2170 ± 80	-27.2
VIBRACORE 6						
6529	(SM)	72-76	105.8% modern	-		
6530	(SM)	120-126	2150 ± 50	-		
6531	(SM)	146-154	2780 ± 65	-22.4		
6532	(SM)	172-181	(1745 ± 110) ?? lab questionable			

*W = Wood; SM = Salt Marsh; TOC = Total Organic Carbon

RESULTS

Addison

The most extensive information on Holocene sea-level changes in Maine is from marshes on the Pleasant River, near Addison, Maine (Figure 4). This area was first cored and

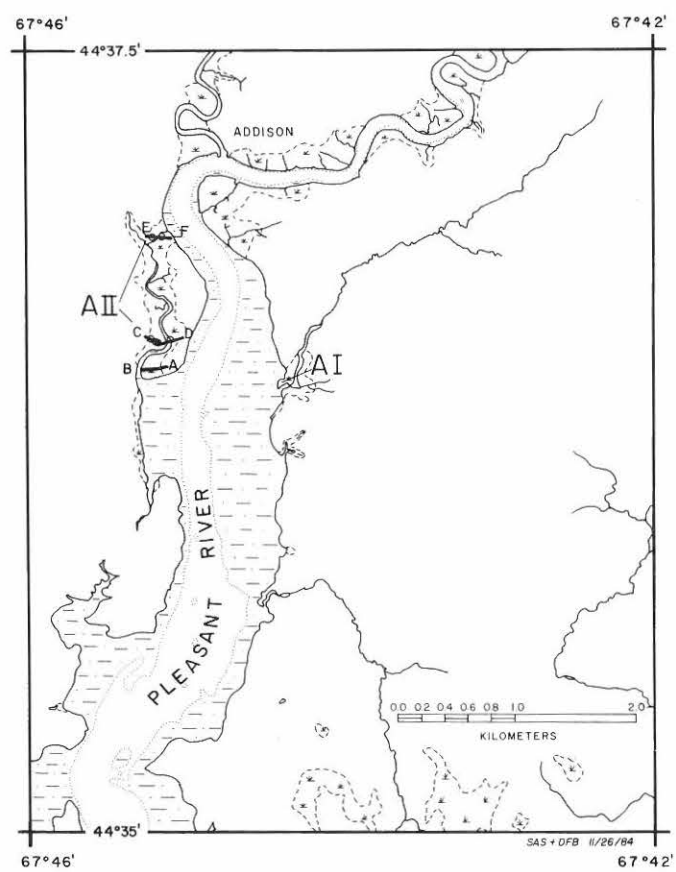

Figure 4. Location map for Addison transects; marshes AI and AII as designated by Thompson (1973).

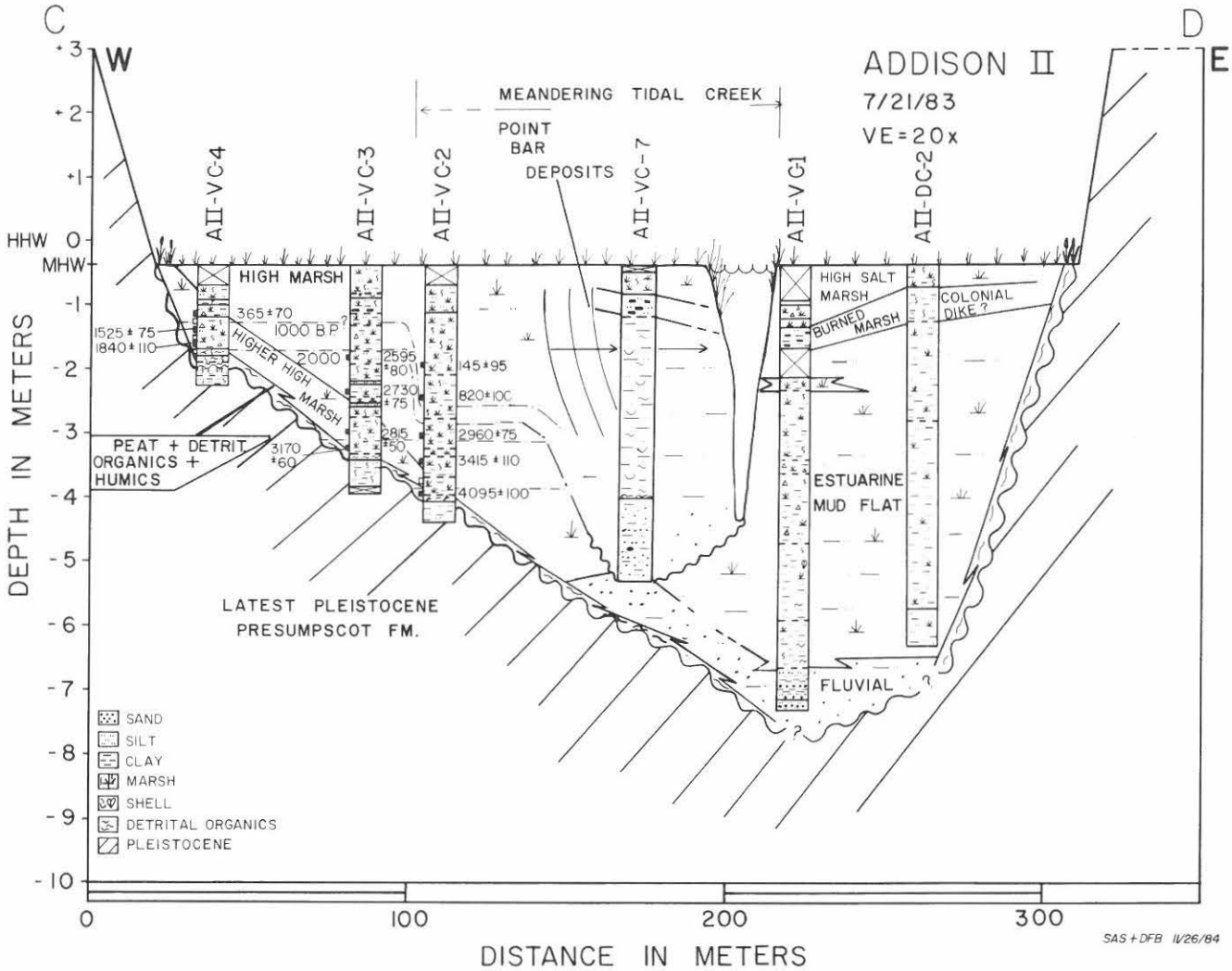

Figure 5. Addison II cross section C-D, based on 1983-1985 cores and radiocarbon dates.

sampled for radiocarbon dating by Thompson (1973), and has been reoccupied for the NRC project by Anderson and Race (1981), Anderson and Borns (1983) and during the present project. During 1983, six vibracores and four Dutch cores were used to refine the stratigraphy of Thompson (1973) and to collect new ^{14}C samples. A seventh core was taken in 1985 to clarify the stratigraphy. Nineteen ^{14}C samples have been dated by the Smithsonian Radiocarbon Laboratory.

The vibracores and Dutch cores were used to compile a stratigraphic cross-section (Figure 5) along the same line as Thompson's (1973) section C-D. Useful high salt marsh peats are found in the upper four meters of the section in vibracores VC-2, VC-3 and VC-4. Thompson's cores on this and the southermost transect showed apparently younger radiocarbon dates in the deeper facies, most likely due to blocks of high marsh slumped several meters down into the migrating tidal creek (the two deepest dates in Figure 7). High salt marsh has evolved from low marsh, which initially prograded over protected tidal flats and creek margins, creating a stable accreting marsh environment within the past 4000 years. This regressive sequence of high salt marsh over prograding low marsh may be due to a general late Holocene expansion of marshes in New England allowed by an inferred slower rate of sea-level rise (Davis, 1910; Bloom, 1964, 1983; Scott and Greenberg, 1983; Oldale, 1985; Scott et al., 1987), or it may be more related to local paleogeography. In general, however, we have found no high marsh environments thicker than 5 meters anywhere in Maine. On Figure 5 the dashed lines are time-lines based on the radiocarbon dates. A general horizontal upgrowth of the marsh is indicated for the period 4000-1000 years BP Above this level, within the past 1000 years, there has been disturbance of the pattern in the marsh east of VC-3 (including VC-2, VC-1, and DC-2). The Addison II creek has shifted position, most recently from west to east on the transect, creating unstable bank margins, with probable slump blocks. Figure 6 shows the modern creek with cut bank to the left (E) and point bar to the right, at the site of

Figure 6. Addison II creek at site of transect C-D, at mid-tide. View towards the south. *Spartina alterniflora* dominates the creek banks. Note the slumped blocks on the cut bank (left), progradation and accumulation on the point bar (right).

transect C-D. An abundance of *S. alterniflora* and mud was noted in the upper two meters of VC-2, suggesting such an environment, with materials accumulating below MHW. Cores VC-1 and DC-2 show a possible, colonial-period influence in their upper one-meter sections. This is a compact, desiccated muddier unit with carbonized grass fragments, indicative of a prolonged period of burning. Over this unit is a muddy peat, rich in *S. alterniflora,* that rapidly grades to a high marsh peat at the present surface. This sequence is interpreted as representing construction of colonial-period dikes (Smith and Bridges, 1980, 1983), a period of desiccation and burning, followed by flooding by seawater after the dikes were abandoned. Due to the artificially low position with respect to sea level, the marsh initially was colonized by low-marsh vegetation and rapidly accumulated inorganic and organic material, until stabilizing at the present high marsh condition.

Thompson's (1973) transect A-B, 200 m south of C-D, shows a stratigraphy of mudflat over peat, which is not common in Maine marshes. It also contains two radiocarbon dates (ca. 2500 yrs BP) 4.1 and 4.6 meters below present MHW, which are of questionable youth. These points are interpreted as displaced peat blocks along the margin of the Addison II creek, not usable for a sea-level curve. A second transect was completed at Addison II in 1983, along the line of Thompson's (1973) transect E-F. This was shallower than the southern transect, and was sampled for supplementary ^{14}C samples.

Figure 7 is a plot of all the Addison sea-level data. The data are listed in Appendix B. The 1982-1983 data are also tabulated in Table 2. There are wide variations in the data, but several trends are obvious if some constraints are placed on the data: first, only insoluble fraction data are used; second, if only salt-marsh peats are considered (circles) the problems with scattered wood and total organic carbon data from 1982 are eliminated; third, the 1973 and 1981 data were disregarded because they were from samples of the most basal, heavily humic acid-contaminated basal unit; fourth, the deepest Thompson (1973) data may not be in place, and the two other queried data were probably contaminated in the field (Thompson, 1973, p. 45), because of the Davis core sampling method.

The 1983-1984 data greater than 1500 years in age, on the other hand, fall on a linear trend with high statistical significance ($r = 0.93, n = 11, p < 0.01$), at a sea-level rise rate of 1.32 mm/year for the period 4100 to 1500 yrs BP An unexplained phenomenon apparent in these new data is that the data from peats within the column and those near the base fall on the same linear trend, indicating little relative displacement due to compaction. This is unexpected, as compared to other studies (Kaye and Barghoorn, 1964; Belknap and Kraft, 1977), and may indicate a continuing interpetive problem. Our preferred explanation is that the samples from 30 cm or greater above the base may behave similarly to the higher samples and that these thin, shallow, highly fibrous marshes may not demonstrate much differential compaction.

Gouldsboro

Gouldsboro Bay (Figure 8) has been extensively investigated by researchers at the Smithsonian Institution since 1981 (Shipp et al., 1985, 1987). Grand Marsh in Gouldsboro Bay has also been cored as part of the NRC project. Sixteen vibracores

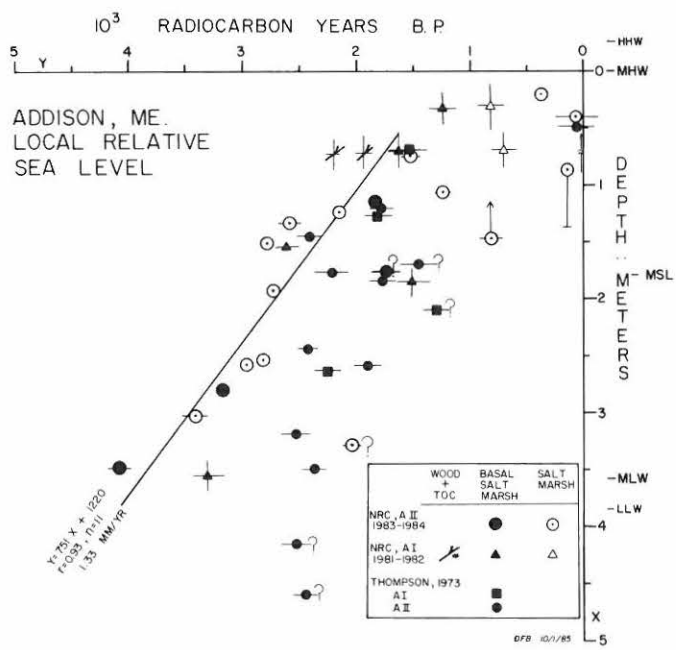

Figure 7. Addison II local relative sea-level data. Newly acquired data older than 1500 yrs BP used for linear regression (NRC 1983-1984: large circles), excepting queried outlier at -3.3 m. Earlier studies used different sampling methods, raising the possibility of humic acid contamination and displaced samples.

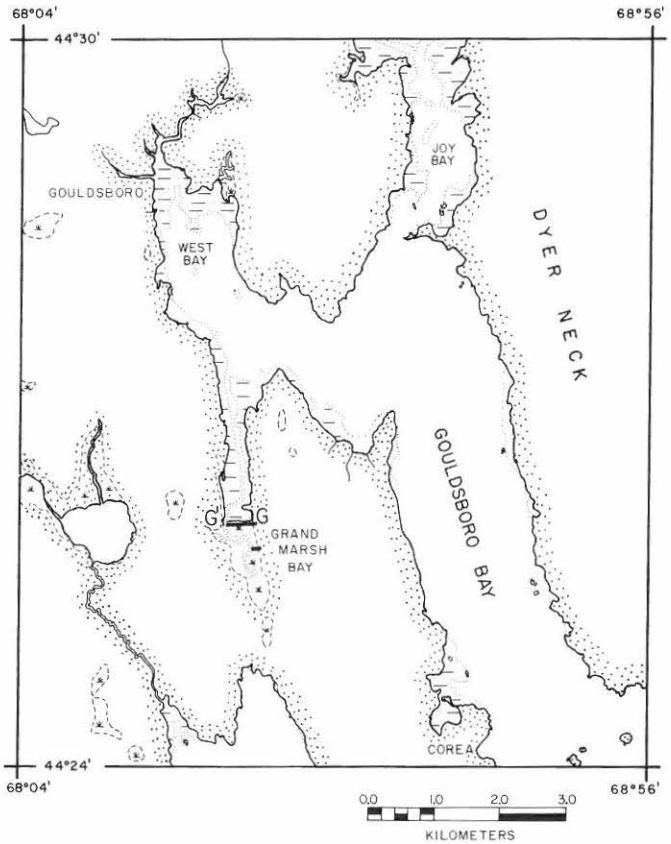

Figure 8. Location map for coring transects in Grand Marsh, Gouldsboro Bay.

(Appendix A) have been used to establish marsh stratigraphy along two transects, and ten radiocarbon samples have been dated. Figure 9 shows the northern transect, another example of a gentle slope with basal peats suitable for construction of a sea-level curve. The marsh in this area demonstrates generally constant upbuilding, but complex episodes of channel migration are evident in VC-44, 44A and 43. The channel in VC-44 was abandoned and filled with marsh after construction of the colonial period dike approximately 150 m north of this location in West Bay.

The suite of radiocarbon dates from Gouldsboro (Appendix B) represent the least ambiguous trends of any sites discussed in this paper. All the samples were from basal high marsh peat, immediately above the heavily humic acid-impregnated zone. The nine data points older than 1500 years BP define a linear rise of sea level at a rate of 1.80 mm/yr, with a regression coefficient $r = 0.90$ (Figure 10). If SI-6540 (4180 ± 70 yrs BP) is excluded, due to possible ice-rafting (?), the regression is even tighter, $r = 0.98$, rising at 1.97 mm/yr.

Penobscot Bay

Three localities were examined in Penobscot Bay (Figure 1), in conjunction with archaeological work by B.J. Bourque of the Maine State Museum (Belknap et al., 1986b). The Turner Farm Site in Fox Island Thorofare on North Haven Island and the Lazygut Island locality were both underwater vibracore transects based on seismic profiling information. They were

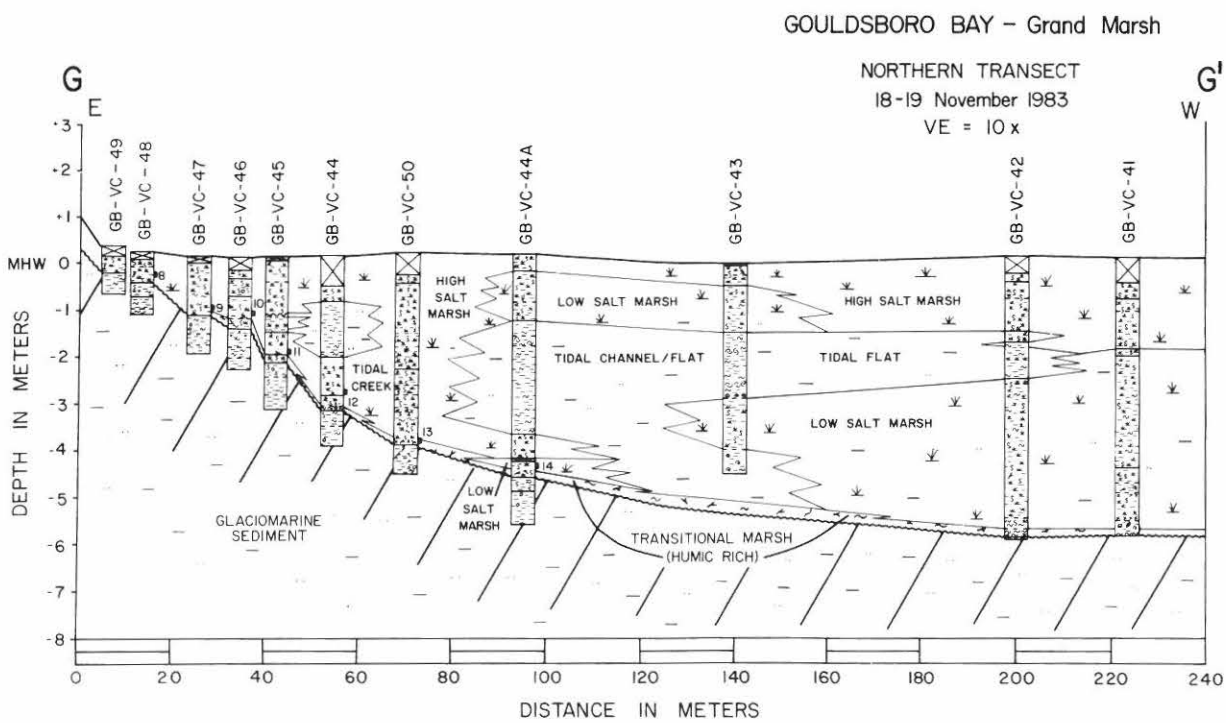

Figure 9. Gouldsboro cross section G-G', based on 1982 Smithsonian Institution and 1983 NRC-MGS vibracores.

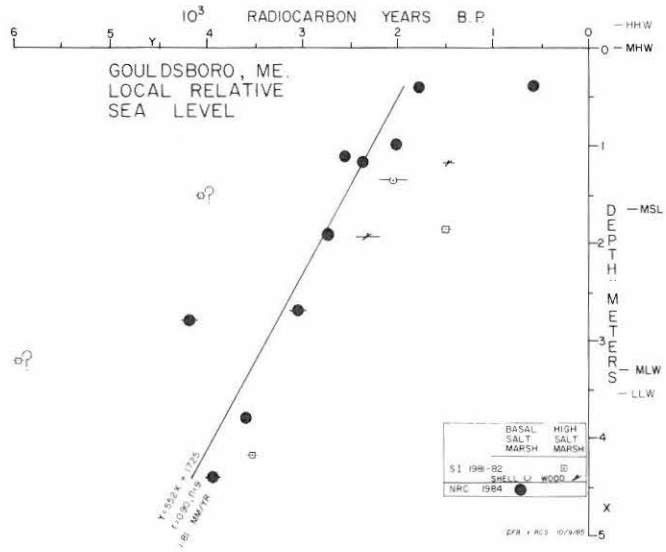

Figure 10. Gouldsboro Bay local relative sea-level curve. The regression line is based on the nine new basal peat points. Previously acquired data is in some cases suspect due to heavy humic saturation and possible ice-rafting.

intended to provide a local relative sea-level curve and paleogeographic reconstructions for archaeological investigations. Each provided datable *Mya arenaria* shells. Marsh Cove, also on North Haven Island, was selected as the only available marsh site for the younger data. The archaeological-geology project is described elsewhere (Belknap et al., 1986b), and is not directly a part of the NRC project, so will not be discussed fully here. Anderson and Race (1981) also dated salt marsh peats at Holt Pond marsh as part of the NRC project. In addition, a study by Ostericher (1965) reports a possibly useful date on a piece of wood on the Pleistocene/Holocene contact at 20 m below MHW in northern Penobscot Bay.

Penobscot Bay sea-level data are presented in Appendix B and plotted in Figure 11, which also includes Damariscotta-Sheepscot data. Regression on the salt marsh data older than 1500 yrs BP yields an r = 0.82, at a rate of rise of 1.08 mm/yr, which is probably less reliable than the curves presented previously.

Damariscotta and Sheepscot Rivers

Both the Damariscotta and Sheepscot Rivers have been intensively studied with the use of high resolution seismic profiling (Belknap et al., 1986a, 1987a). In selected locations, underwater vibracores have been taken (Appendix A) for stratigraphic analysis. Fortuitously, several datable shells and one peat were found. The peat in DR-VC-6 (Appendix B) was dated, and represents the oldest and deepest reliable sea-level indicator in this study (14.94 m below MHW, 6296 ± 55 yrs BP). Anderson and Race (1981) also dated peats from a marsh in the Sheepscot River drainage at South Newcastle.

The Damariscotta-Sheepscot data are plotted with the Penobscot Bay data in Figure 11 for a generalized mid-coast sea-level curve. The importance of this curve is in the deeper, older segments, since we have limited salt marsh data using our new methodology. A curve-fit program suggests that an exponential curve, as shown in Figure 11, fits the 16 data points best, with an r = 0.89.

Popham

The Popham Beach area (Figure 12) is a complex study environment at the mouth of the Kennebec River which is composed of rocky headlands, beaches, barrier spits, tidal inlets, marshes, and tidal flats. Three coring transects with a total of 8 vibracores were completed in 1983, in Atkins Bay and on the Morse River.

Figure 13 is the Atkins Bay transect A-A'. Recovered core samples and the surficial sediments within the area demonstrate that the Kennebec River has supplied a large volume of sand to the system, either in the Holocene (Nelson and Fink, 1978) or through reworking of an early Holocene glacio-fluvial delta (Belknap et al., 1986a). The three vibracores and the Dutch core all refused in sand, and failed to penetrate to the Pleistocene. The

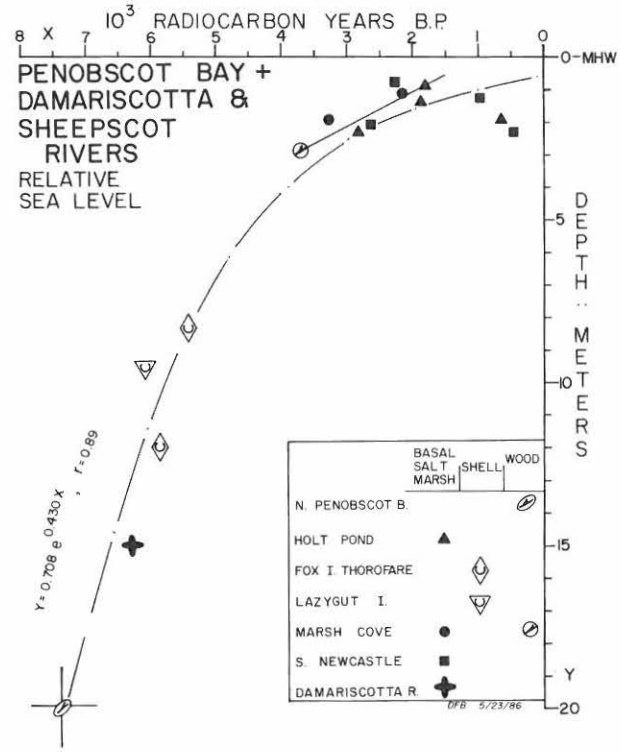

Figure 11. Mid-coast Maine local relative sea-level curve. This curve mixes peat and other data from Penobscot Bay, Damariscotta River and Sheepscot River, and has fewer data points in the 5000-1500 yrs BP range, but deeper and older peats than other areas. An exponential curve fit is shown. Note that the scales and scale ratios differ from other sea-level curves in this paper.

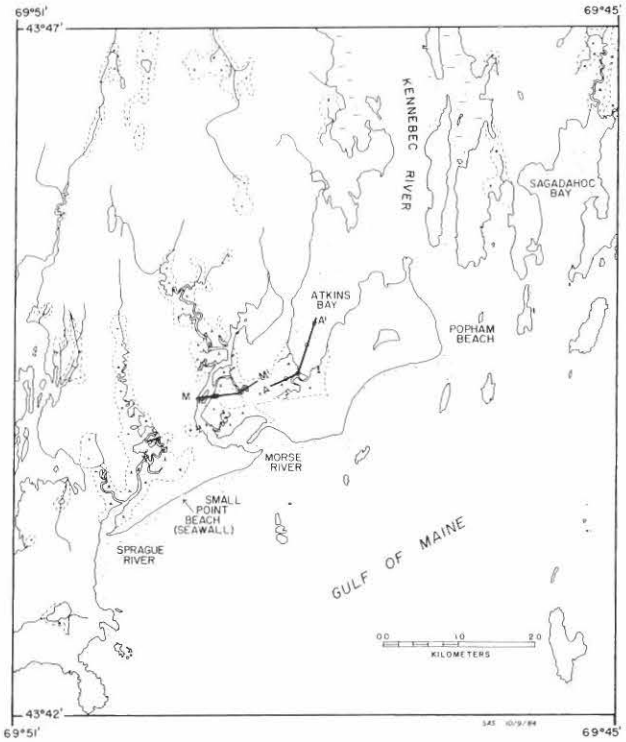

Figure 12. Location map for coring transects M-M' (Morse River) and A-A' (Atkins Bay) in the Popham area.

stratigraphy for this transect demonstrates a regressive sequence of more protected marsh and intertidal flat environments prograding to the northeast into the Atkins Bay subtidal system. The basal sand is probably partly fluvial, perhaps from an earlier abandoned channel of the Kennebec River. The upper section of sand is from a late Holocene tidal delta. The protected flats and marsh prograded and aggraded after the southern link with the open sea was closed. Two radiocarbon dates come from this transect, but due to their position within the column they may not be reliable sea-level indicators. The peat in AB-VC-3 may in fact be a reworked block.

Nelson and Fink (1978) have discussed 2 radiocarbon dates on *S. alterniflora* from this area, as shown in Figure 14. The resulting sea-level trend is distinctly displaced from the Addison data, but shows a similar rate of rise. This may indicate a differential rate of relative sea-level rise between the regions, or it may indicate that the older datum of Nelson and Fink (1978) is not in place, an analogue of the sample from AB-VC-3.

Figure 15 presents the transect on the Morse River, M-M' completed in 1983. MR-VC-1 and 2 are on a small tributary creek, while MR-VC-3, 4, and 5 are to the west on the larger Morse River. The two parts of the transect are separated by a bedrock hill. The main Morse River channel is choked with sand, and has apparently migrated extensively between the confining bedrock walls during the Holocene. Salt marsh is less than

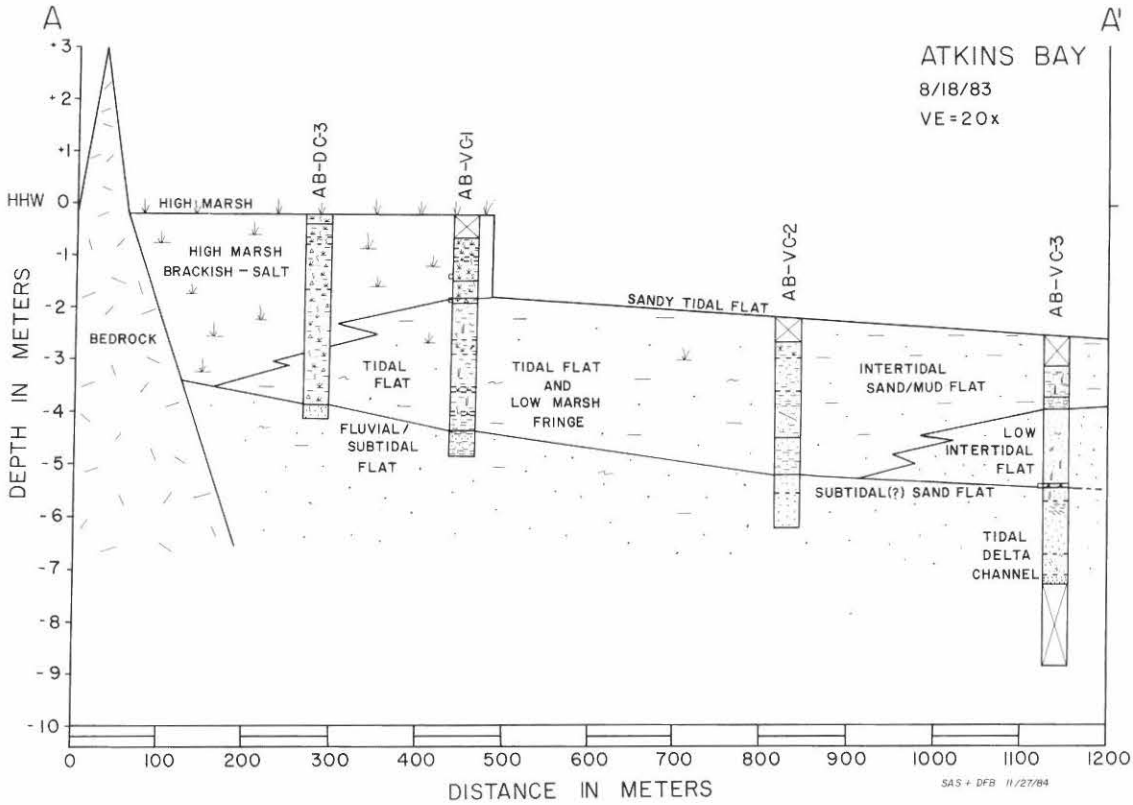

Figure 13. Atkins Bay cross section A-A', based on 1983 Dutch and vibracores.

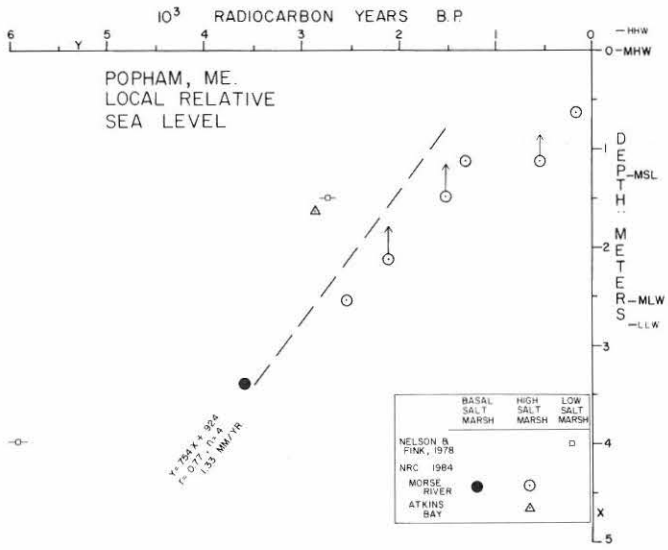

Figure 14. Popham local relative sea-level data. Dashed line is a weakly correlated regression line based on only four high and transitional marsh data points.

two meters thick on this transect. The eastern transect, on the other hand, within a more sheltered position, contains over four meters of salt marsh. It too shows a complex history of tidal creek migration. This area, like Atkins Bay, was strongly influenced by the course of the Kennebec River and the shifting spit and inlet patterns at the coast. The eight radiocarbon samples from these cores are not on a simple smooth slope as at Addison and Gouldsboro and are based on sand. The Popham sea-level data are presented in Appendix B and plotted in Figure 14. Only four data points are reliable high or transitional marsh greater than 1500 yrs BP. SI-6552 was questioned by R. Stuckenrath and is considered unreliable due to its small size. The remainder of the dates are on low marsh. In Figure 14, a regression line through those four points rising 1.33 mm/yr is shown, but the r value of 0.77 indicates relatively weak correlation.

Wells

The final major salt marsh coring locality to be discussed in detail is Wells (Figure 16). This marsh system was cored in

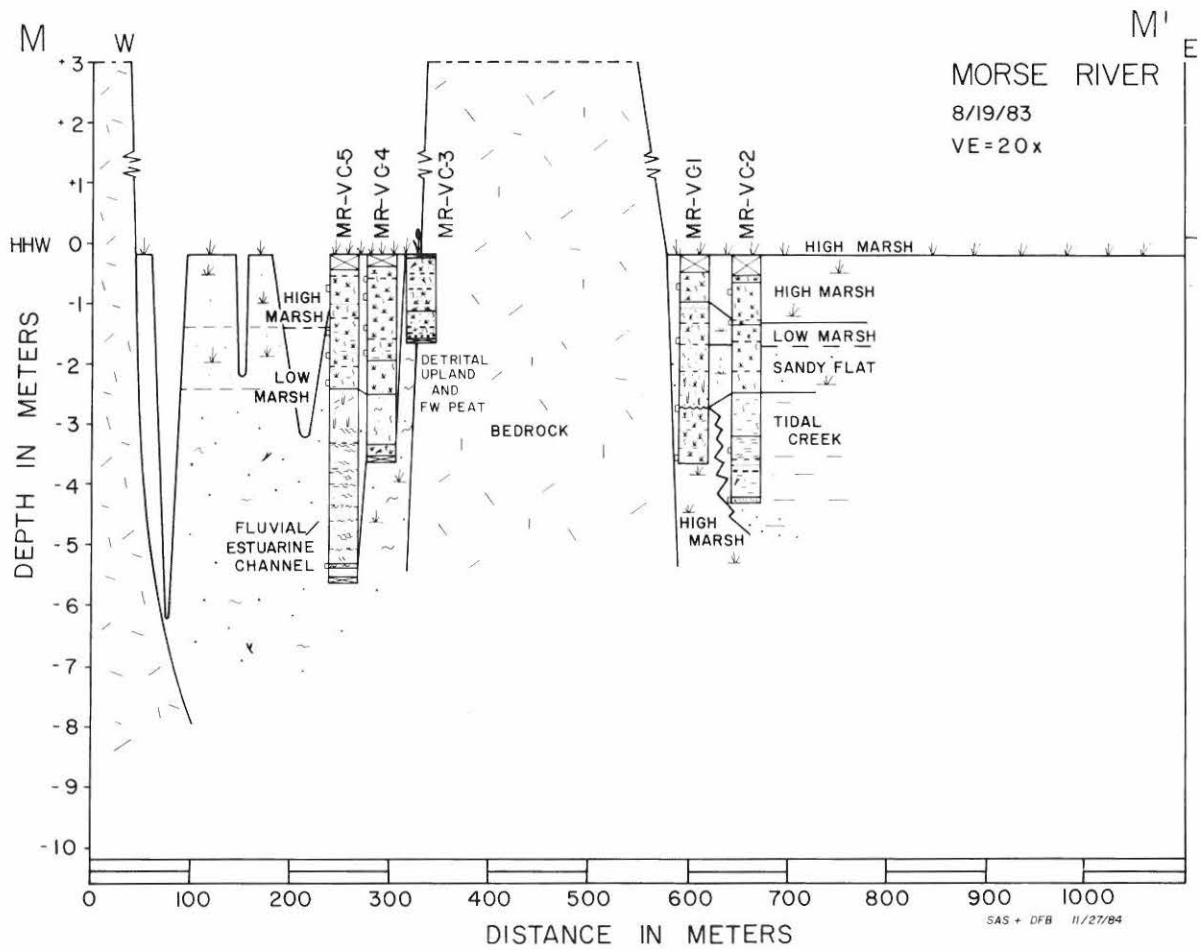

Figure 15. Morse River cross section M-M', based on 1983 vibracores.

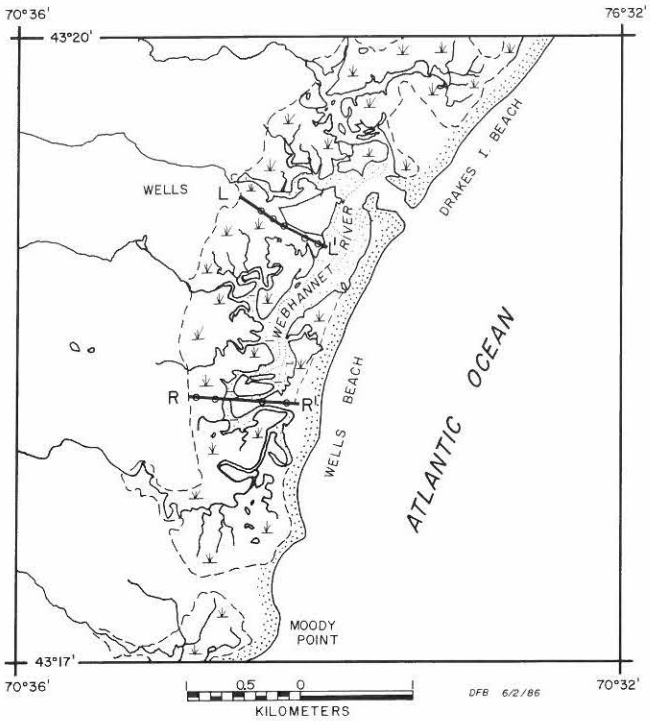

Figure 16. Location map for coring transects L-L' and R-R' in the Webhannet River Marsh, Wells.

the summer of 1984 after extensive reconnaissance Dutch coring, with nine vibracores and twelve ^{14}C samples resulting. Wells has an extensive broad marsh behind a series of barrier spits anchored to rock and till outcrops. The Webhannet River inlet has supplied abundant sand to the system. Backbarrier environments here are confined in the landward direction by a distinct topographic scarp, possibly a former shoreline cut during regression in the late Pleistocene. The evolution of the Wells area has been discussed in detail by Hussey (1970) and McIntire and Morgan (1964), and the geomorphology has been presented by Fink et al. (1985).

Figure 17 shows the northern transect L-L' comprised of eight Dutch cores and five vibracores. All bottomed in sand, at various elevations. There is a second vibracore transect to the south (R-R' on Figure 16) and a north-south Dutch core tie line which have further traced the thickness of Holocene peats. The eastern end of section L-L' is dominated by tidal delta and channel sands, with subordinate muddy channels and peats. The central zone is dominated by high marsh. The landward, western zone is increasingly dominated by brackish to freshwater peat. There is clear evidence of transgression of salt marsh over fresh marsh from W-VC-5 westward.

Construction of a reliable sea-level curve is hampered by the lack of basal peats. However, the salt marsh and transitional marsh (mixed *Spartina patens* and *S. alterniflora*) data follow a

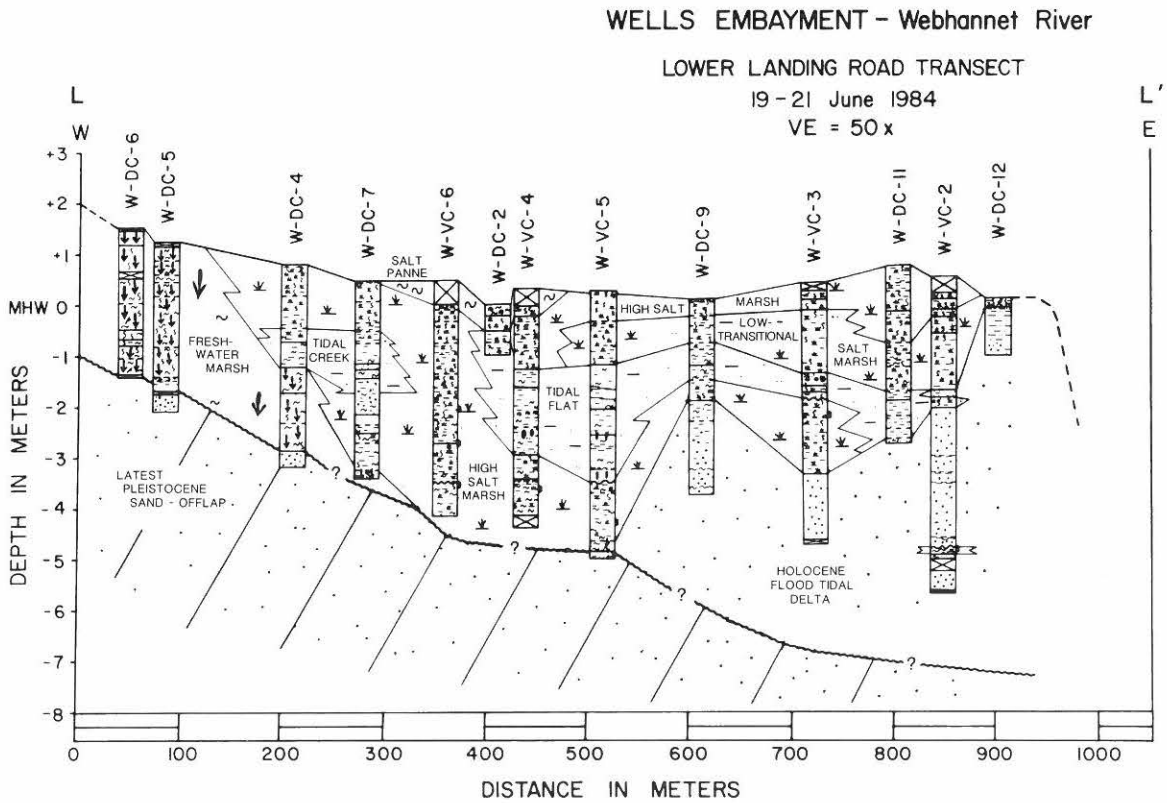

Figure 17. Webhannet River Marsh cross section L-L' (Lower Landing Road), based on 1984 Dutch and vibracores.

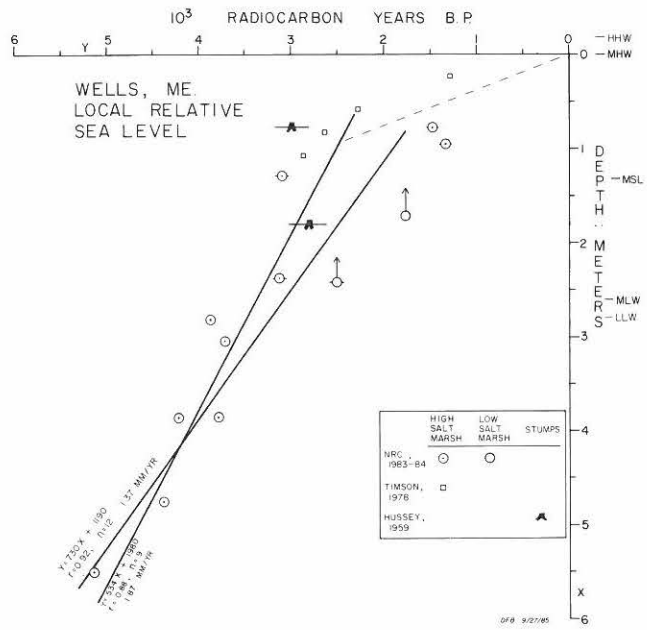

Figure 18. Wells local relative sea-level curve. Regression of data older than 1500 yrs BP slopes 1.87 mm/yr, while regression including dates older than 1300 yrs BP slopes 1.37 mm/yr.

consistent trend (Figure 18). Wells radiocarbon data are listed in Appendix B. The nine new NRC data points greater than 1500 years BP follow a linear trend of 1.87 mm/yr sea-level rise (r = 0.88). After 1500 years BP, the rate of sea-level rise slowed to at most 0.5 mm/yr until recently. Other paleosea-level indicators in the area include peats dated by Timson (1978) and McIntire and Morgan (1964) which closely follow the same trend, and stumps dated by Hussey (1959, 1970), which are consistent with this curve (although they are not always reliable sea-level indicators).

Other Localities

Besides the areas discussed above, we have conducted reconnaissance and detailed surveys at ten other locations (Figure 1 and Appendix A). They were primarily intended to search for thick marsh sequences and datable peats along the coast, in order to compare the various regions in light of the postulated warping.

Cores were taken in Deer Meadow, Cod Cove, and Cushman Cove in the Sheepscot River. Unfortunately, they were not suitable for sea-level information. The Cod Cove and Cushman Cove tidal flat cores contain no datable materials, while the Deer Meadow salt marsh cores all overlie thick freshwater bog peats, and are thus probably displaced by compaction.

A diligent search in the Eastport-Perry area, near the greatest indicated deleveling velocities of Tyler and Ladd (1980), produced no suitable marshes for a sea-level curve. In Perry, a marsh was found with several meters of brackish muddy peat, and also an extensive but very thin low marsh. Neither was usable. Other localities were worse. Machias Bay seems to hold the only prospect for deep marshes near the maximum deleveling; it is presently being investigated.

Hay (1988) has completed a M.S. thesis in northeastern Casco Bay, primarily in Maquoit Bay and the Royal River. Vibracores with ^{21}Pb, ^{137}Cs, ^{14}C, and pollen analyses contribute further to our understanding of Maine's relative sea-level changes. Eight radiocarbon dates have been completed within the Sea Grant project for that area.

DISCUSSION

The Maine coast is undergoing an apparent regional warping, as indicated by the releveling studies of Tyler and Ladd (1980), elevation of deltas (Thompson et al., 1983), historic information (Smith and Bridges, 1980, 1983) and archaeological data (Sanger, 1981), as summarized by Anderson et al. (1984) and furthur discussed in this volume. In addition, tide gauge information (Hicks, 1983) demonstrates the reality of modern, ongoing differential rates of relative sea-level rise along the coast from Portsmouth to Portland and to Eastport (Figure 19). The present difference between Portland and Eastport tide gauge records is 0.9 mm/yr. Reilinger (1987) suggests that the releveling data cited by Anderson et al. (1984) may be contaminated by an erroneous 1943 survey, and that the true velocities are similar to those shown by the tide gauges. Brown (1978) discusses

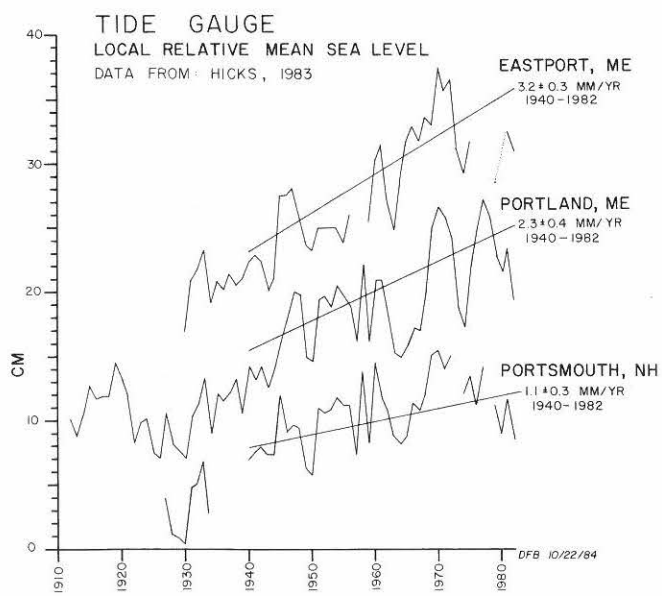

Figure 19. Tide gage records for Maine and New Hampshire, based on data from Hicks et al. (1983) and Hicks (written communication, 1981 and 1982 data). Linear regression for 1940-1982 data, monthly averages averaged to mean annual sea level, reported at 0.01 foot precision, converted to millimeters. Note the along-coast progression of increasing rate of sea-level rise.

differences between releveling and tide gauge data in greater detail. We have cored salt marshes and subtidal sites from widely separated locations along the coast to address the problem of the warping on a longer (6000 year) time scale.

In order to compare the results at various locations along the coast, all the new radiocarbon dates are plotted together in Figure 20. Selection of a datum for this plot is a problem, because of variations in tides along the coast. Although Jardine (1975) recommends Mean Tide Level (MTL) for comparing existing sites, determinations of paleotidal ranges is still underway (e.g., Scott and Greenberg, 1983). In order to reduce proliferation of "correction factors," MHW was retained as the datum. (In any case, a similar plot and regression analysis using the MTL datum revealed little difference between the two methods.) Using all 1983-1985 NRC data that are between 6000 and 1500 yrs BP, that are determined to be free of obvious lab or field problems, and that consist of high or transitional marsh peats (see Appendix B), a linear regression analysis yields a curve rising at 1.44 mm/yr, r = 0.89 for 37 points. The rate of rise slowed to a maximum of 0.5 mm/yr after 1500 yrs BP (until very recently, according to the tide-gage data). There is no consistent trend in slopes of sea-level rise curves along the coast, and regression models reveal that the separate curves are no different from the overall curve.

The Maine curves are similar to the Plum Island and other northeastern Massachusetts data (Redfield, 1967; McIntire and Morgan, 1964; Oldale, 1985), as shown in Figure 21. It is possible to fit linear trends to the Maine data before and after an inflection point at 2500 yrs BP, as with the Massachusetts and Bay of Fundy data. This yields a linear trend of 1.91 mm/yr rise (r = 0.84, n = 34) for data prior to 2500 yrs BP. Linear regression on only the basal peats between 5000 and 2500 yrs BP shows a very similar rate of rise at 2.03 mm/yr with an even tighter fit (r = 0.91, n = 12 omitting the Gouldsboro outlier at 4180 yrs BP). The Maine and northeastern Massachusetts curves differ from the Cape Cod curve (Redfield, 1967), which shows more relative subsidence.

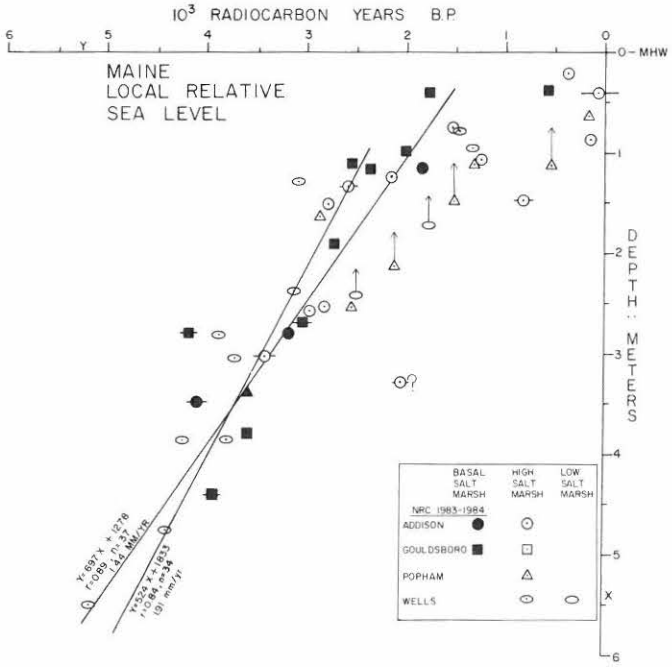

Figure 20. Compilation of all new NRC and related data points for Maine relative sea-level curve. Datum is mean high water (MHW). Linear regression is based on 37 high and transitional marsh peats > 1500 yrs BP. Also shown is an alternative regression with inflection at 2500 yrs BP.

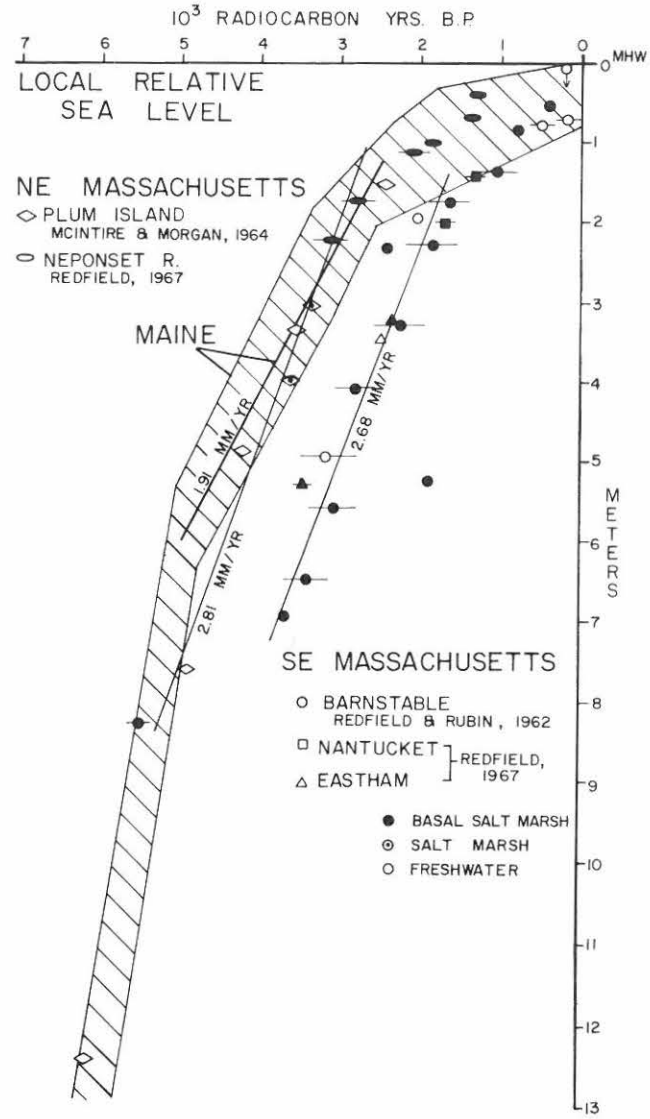

Figure 21. Comparison of Maine relative sea-level curve with published curves from Cape Cod and northeastern Massachusetts (Redfield and Rubin, 1962; McIntire and Morgan, 1964; Redfield, 1967). The Maine curve is shown with the 2500 yrs BP inflection point, and the diagonal hachured envelope is drawn around the basal peat data points from Maine (not shown).

There may be a suggestion of along-coast warping or some other factor, perhaps including Cape Cod, but definitely continuing into Atlantic Canada. Comparison of the Maine curve with the Canadian data of Scott and Greenberg (1983) and Smith et al. (1984), (replotted to MHW and a common scale) shows (Figure 22) a distinctly steeper slope for the latter. The differentially greater enhancement of tidal range in the Bay of Fundy with rising sea level (Grant, 1970; Amos, 1978; Scott and Greenberg, 1983) may explain some of this difference, as the difference between MHW and HHW becomes greater, but there is still a residual when this correction is applied (Figure 22). There may also be a tectonic or isostatic effect causing this warping. Quinlan and Beaumont (1981, 1982) have modeled glacioisostatic responses due to different ice thicknesses that may account for these differences, recently summarized by Scott et al. (1987). We suggest that hydroisostatic loading (Bloom, 1967; Grant, 1970; Belknap and Kraft, 1977) of the Bay of Fundy and the Gulf of Maine with continuing sea-level rise may also play a part in this warping, or may at least be triggering a tectonic mechanism along the margins of the Triassic-Jurassic basins.

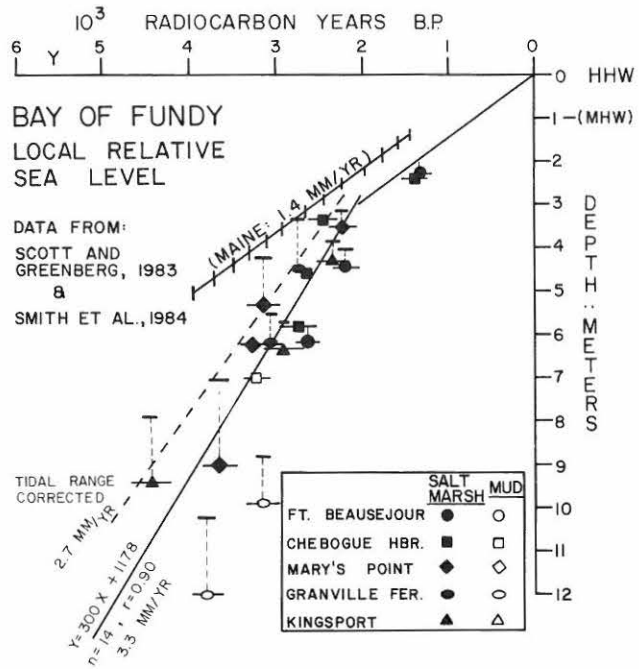

Figure 22. Comparison of local relative sea-level curves for Maine and nearby Atlantic Canada, using MHW as datum. The Canadian data are replotted to a common scale from Scott and Greenberg (1983) and Smith et al. (1984), and show both the uncorrected and tidal range-corrected positions.

CONCLUSIONS

During the 1983-86 field seasons 20 localities in eastern, central and southern coastal Maine were cored for stratigraphic investigation and radiocarbon-datable sea-level indicators. The result of these 68 new dates, of which 42 are reliable salt marsh peat sea-level indicators, is a linear rise of sea-level at a rate of 1.44 mm/yr from 5000 to 1500 yrs BP, followed by a marked slowing to a maximum of 0.5 mm/yr until very recently. A good fit is also obtained for a rise of 1.91 mm/yr from 5000 to 2500 yrs BP and 0.71 mm/yr after 2500 yrs BP, thus showing an inflection point similar to that in published New England and Atlantic Canadian curves. Previous NRC data are comparable to the 1983-1985 data, while some data points collected by other investigators using other methods is not directly comparable. There is no indication of major along-coast warping in the period prior to 1500 yrs BP from at least northeastern Massachusetts to Addison, Maine. The observed along-coast differences in tide-gage, releveling, and other phenomena must be related to a very recent process. On the other hand, there are consistent differences between our data and the Bay of Fundy, suggesting some combination of differential increase in tidal range, residual glacioisostasy, neotectonics and hydroisostatic loading.

ACKNOWLEDGEMENTS

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APPENDIX A: NRC CORING LOCALITIES, MAINE, 1983-1985

Location	Date	Vibracore Length (m) Marsh = M Tidal Flat = TF Subtidal = ST		"Dutch" Core Reconnaissance	
NORTHEAST COAST					
Perry				P-DC-1	6/13/84
				P-DC-2	10/4/85
Baileys Mistake				BM-DC-1	6/13/84
The Rim,				RI-DC-1	8/23/84
East Machias				RI-DC-2	
				RII-DC-1	
				RII-DC-2	
Sanborn Marsh,				SN-DC-1	8/23/84
East Machias				SN-DC-2	
Crocker Point,				CP-DC-1-5	7/5/83
Machiasport					
EAST CENTRAL COAST					
Addison (II)	7/21/83	AII-VC-1	6.40 (M)	AII-DC-1-3	6/29/83
		AII-VC-2	3.71 (M)	AII-DC-5	7/21/83
19 ^{14}C dates		AII-VC-3	3.58 (M)		
	7/22/83	AII-VC-4	1.58 (M)		
		AII-VC-5	3.88 (M)		
		AII-VC-6	2.71 (M)		
	10/3/85	AII-VC-7	4.80 (M)		
Grand Marsh,	10/26/82	GB-C36	4.22 (M)	(R.C. Shipp,	
Gouldsboro Bay		GB-C37	3.20 (M)	Smithsonian Inst.	
		GB-C38	2.27 (M)	Marine Systems Lab.)	
10 ^{14}C dates		GB-C39	1.39 (M)		
		GB-C40	1.04 (M)		
	11/18/83	GB-C41	5.38 (M)		
		GB-C42	5.66 (M)		
		GB-C43	4.48 (M)		
		GB-C44A	5.75 (M)		
		GB-C44	3.42 (M)		
		GB-C45	3.17 (M)		
		GB-C46	2.13 (M)		
		GB-C47	1.19 (M)		
		GB-C48	1.18 (M)		
		GB-C49	0.81 (M)		
		GB-C50	4.25 (M)		
Marsh Cove,	7/27/84	M-VC-1	2.30 (TF)	MC-DC-1-5	7/26/84
North Haven I.		MC-VC-2	2.54 (M)		
		MC-VC-3	2.22 (M)		
3 ^{14}C dates		MC-VC-4	5.14 (M)		
Turner Farm,	7/26/84	TF-VC-1	6.93 (ST)		
North Haven I.		TF-VC-2	4.56 (ST)		
(Fox Island Thorofare)		TF-VC-3	3.33 (ST)		
2 ^{14}C dates					
Lazygut Island	8/8/85	LG-VC-1	2.39 (ST)		
		LG-VC-2	1.40 (ST)		
		LG-VC-3	1.72 (ST)		
	8/9/85	LG-VC-4	1.77 (ST)		
		LG-VC-5	2.19 (ST)		
		LG-VC-6	2.31 (ST)		
		LG-VC-7	1.96 (ST)		
WEST CENTRAL COAST					
Muscongus Bay	7/12/84	MS-VC-1	6.48 (ST)		
		MS-VC-2	4.51 (ST)		
		MS-VC-3	4.19 (ST)		
		MS-VC-4	1.95 (ST)		
	7/20/84	MS-VC-5	2.26 (ST)		
		MS-VC-6	9.04 (ST)		
		MS-VC-7	0.80 (ST)		
WEST CENTRAL COAST (CONTINUED)					
Damariscotta	10/22/83	DR-VC-1	2.15 (ST)		
River		DR-VC-2	4.38 (ST)		
1 ^{14}C date	5/11/84	DR-VC-3	8.00 (ST)		
		GP-VC-1	7.75 (ST)		
		GP-VC-2	7.57 (ST)		
	7/16/84	DR-VC-4	1.93 (ST)		
		DR-VC-5	4.50 (ST)		
		DR-VC-6	7.54 (ST)		
		DR-VC-7	8.41 (ST)		
		DR-VC-8	5.93 (ST)		
		DR-VC-9	5.46 (ST)		
		DR-VC-10	4.66 (ST)		
	7/16/85	DR-VC-11	1.00 (ST)		
	8/5/85	DR-VC-12	2.55 (ST)		
		DR-VC-13	2.80 (ST)		
Deer Meadow	8/11/83	DM-VC-1	3.35 (M)	DM-DC-1-20	June,
Marsh, Edgecomb		DM-VC-2	6.89 (M)		1983
		DM-VC-3	3.63 (M)		
		DM-VC-4	2.72 (M)		
		DM-VC-5	1.35 (M)	MA-DC-1	4/14/84
Cod Cove,	7/29/83	CO-VC-1	9.06 (TF)	CO-DC-1-15	June,
Edgecomb		CO-VC-2	8.53 (TF)		1983
		CO-VC-3	3.55 (M)		
		CO-VC-4	2.81 (M)		
Cushman Cove,	8/16/83	CU-VC-1	6.95 (TF)	CU-DC-1-15	July,
Wiscasset		CU-VC-2	6.88 (TF)		1983
		CU-VC-3	7.29 (TF)		
		CU-VC-4	5.14 (M)		
Sheepscot River	7/19/84	SR-VC-1	6.62 (TF)	SR-HC-1	7/19/84
		SR-VC-2	6.40 (ST)		
		SR-VC-3	4.93 (ST)		
		SR-VC-4	1.98 (ST)		
	10/10/85	SR-VC-5	1.97 (ST)		
		SR-VC-6	2.00 (ST)		
		SR-VC-7	2.75 (ST)		
Atkins Bay,	8/18/83	AB-VC-1	4.20 (M)	AB-DC-1-3	8/18/83
Popham		AB-VC-2	3.56 (TF)		
2 ^{14}C dates		AB-VC-3	4.17 (TF)		
Morse River,	8/19/83	MR-VC-1	3.19 (M)	MR-DC-1-6	8/19/83
Popham		MR-VC-2	3.79 (M)		
8 ^{14}C dates		MR-VC-3	1.35 (M)		
		MR-VC-4	3.25 (M)		
		MR-VC-5	5.19 (M)		
Maquoit Bay,		MQ-DC-1-24	8/84		
Freeport					
SOUTHWEST COAST					
Webhannet River	6/20/84	W-VC-1	2.87 (M)	W-DC-1-7	6/18/84
Marsh, Wells		W-VC-2	5.90 (M)	W-DC-8-17	6/19/84
		W-VC-3	4.95 (M)	W-DC-18-27	6/22/84
12 ^{14}C dates		W-VC-4	4.33 (M)		
	6/21/84	W-VC-5	5.26 (M)		
		W-VC-6	4.14 (M)		
		W-VC-7	6.10 (M)		
		W-VC-8	4.97 (M)		
		W-VC-9	3.40 (M)		
Total:	96 Vibracores				
	136 Dutch cores				
	57 ^{14}C dates				

APPENDIX B: SUMMARY OF RADIOCARBON DATES

ADDISON, ME: AI MARSH

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
THOMPSON, 1973 MS THESIS UMO						
SI-1260		BM	0.69			1550±170
SI-1342		BM	1.31			1820±100
SI-1265		(BM)*	2.10			1305±110
SI-1267		BM	2.63			2255±95
*Contaminated During Sampling						
ANDERSON AND RACE, 1981 NRC REPORT						
SI-4434	AID-1	BM	0.33-0.41			1250±65
SI-4435	AIB-2	BM	1.57-1.67			2610±90
SI-4832	AIA-2	BM	1.87-1.97			1520±110
SI-4833	AIC-3	BM	3.50-3.60			3315±75
BORNS, 1982 NRC						
		HM	0.30 ±	815±45	-24.4	
		BM	0.70 ±	1635±55	-27.7	
		TOC	0.71 ±	20±80	-27.9	
		W	0.73 ±	1945±60		
		W	0.74 ±	2220±50		
		HM	0.62-0.75±	720±45	-23.7	

ADDISON, ME: ADDISON II MARSH

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
THOMPSON, 1973 MS THESIS UMO						
SI-1259		BM	0.49	55±155		
SI-1261		BM	1.21			1785±95
SI-1262		BM	1.45			2415±110
SI-1263		(BM)*	1.70			1445±170
SI-1343		BM	1.85			1780±115
SI-1264		BM	1.76			2220±125
SI-1344		BM	2.43			2440±80
SI-1266		BM	2.58			1910±115
SI-1268		BM	3.18			2545±120
SI-1269		BM	3.48			2385±95
SI-1270		BM	4.15			2545±110
SI-1271		BM	4.58			2460±105
BELKNAP ET AL., 1983-1984 NRC						
SI-6203	AII-VC-2	HM	1.34-1.39	145±95	-19.6	60±95
SI-6202	AII-VC-2	TM	1.94-1.99	820±100	-15.3	665±100
SI-6201	AII-VC-2	HM	2.54-2.59	2960±75	-21.1	2900±75
SI-6200	AII-VC-2	HM	2.99-3.04	3415±110	-23.4	3390±110
SI-6535	AII-VC-2	(TM)	3.25-3.29	2100±75	-21.8	2045±75
SI-6199	AII-VC-2	BHM	3.44-3.50	4095±100	-23.0	4065±100
SI-6207	AII-VC-3	TM	1.30-1.35	2595±80	-18.5	2490±80
SI-6206	AII-VC-3	TM	1.90-1.95	2730±75	-17.9	2615±75
SI-6205	AII-VC-3	HM	2.50-2.55	2815±50	-18.8	2715±50
SI-6204	AII-VC-3	BHM	2.76-2.81	3170±60	-26.6	3195±60
SI-6210	AII-VC-4	HM	0.17-0.22	365±70	-22.8	330±70
SI-6533	AII-VC-4	(HM)*	0.38-0.43	55±190	-22.4	15±90
SI-6209	AII-VC-4	HM	0.72-0.77	1525±75	-28.2	1575±75
SI-6534	AII-VC-4	HM	1.03-1.08	1245±70	-27.1	1275±70
SI-6208	AII-VC-4	BHM	1.12-1.17	1840±110	-26.9	1870±110
SI-6529	AII-VC-6	HM	0.72-0.76			105.8% MODERN
SI-6530	AII-VC-6	HM	1.20-1.26			2150±50
SI-6531	AII-VC-6	HM	1.46-1.54	2780±65	-22.4	2735±65
SI-6532	AII-VC-6	(BHM)*	1.72-1.81	1745±110	-22.3	1700±110

GOULDSBORO, ME.: GRAND MARSH, NRC 1983-1984

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
GOULDSBORO BAY, 1981-1982: SHIPP, SMITHSONIAN INST.						
SI-5417	GB-C2	BM	1.97	1490±45	-	-
SI-5421	GB-C7	(BM)	4.19	3535±50	-	-
SI-5418	GB-C5	(BM)	3.23	5940±70	-	-
SI-5423	GB-C11	S	1.33	2050±105	-	-
SI-5424	GB-C11	(BM)	1.51	4070±50	-	-
SI-5425	GB-C12	W	1.18	1465±50	-	-
SI-5426	GB-C12	W*	1.93	2315±130	-	-
GOULDSBORO BAY, GRAND MARSH, NRC 1983-1984						
North Transect:						
SI-6536	GB-C48	BHM	0.52-0.58	570±50	-25.1	570±50
SI-6537	GB-C47	BHM	0.96-1.03	2010±60	-25.7	2020±60
SI-6538	GB-C46	BHM	1.14-1.20	2325±65	-16.8	2225±65
SI-6539	GB-C45	BHM	1.88-1.94	- - -	- - -	2740±55
SI-6540	GB-C44	BHM	2.76-2.82	4180±70	-16.9	4050±70
SI-6541	GB-C50	BHM	3.76-3.82	3580±75	-24.6	3575±75
SI-6542	GB-C44A	BHM	4.38-4.44	3940±50	-16.6	3805±50
South Transect:						
SI-6543	GB-C39	BHM	0.35-0.42	1775±50	-23.1	1745±50
SI-6544	GB-C38	BHM	1.10-1.16	2550±50	-27.6	2595±50
SI-6545	GB-C37	BHM	2.66-2.72	3045±65	-18.2	2935±65

PENOBSCOT BAY, ME

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
UPPER PENOBSCOT BAY, OSTERICHER, 1965						
W-1306	211	W	20 +			7390±500
HOLT POND MARSH, STONINGTON, ANDERSON AND RACE, 1982						
SI-4596	HD-1	BM(?)	0.83-0.89	1825±55		
SI-4595	HC-3	BM(?)	1.37-1.43	1880±150		
SI-4767	HB-3	BM(?)	1.84-1.94	655±75		
SI-4768	HA-3	BM(?)	2.19-2.29	2835±70		
FOX ISLAND THOROFARE, BELKNAP AND BOURQUE, 1984						
GX-11004	TF-VC-2	S-MA	11.96	5880±105	2.0	
GX-11005	TF-VC-3	S-MA	8.31	5430±100	1.6	
MARSH COVE, NORTH HAVEN, BELKNAP & BOURQUE 1984						
GX-11006	MC-VC-4	HM	1.12	2145±125	-19.0	
GX-11007	MC-VC-4	HM	1.87	3255±150	-27.7	
GX-11008	MC-VC-4	W	2.83	3700±200	-26.3	
LAZYGUT ISLAND, BOURQUE, 1984 PROPOSAL (UNPUB.)						
SI-4650	DREDGE	S-CV	8-11	6100±65		

DAMARISCOTTA AND SHEEPSCOT RIVERS, ME.

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
SOUTH NEWCASTLE MARSH, ANDERSON AND RACE, 1982						
Marsh River, Tributary to Sheepscot River.						
SI-4834	SNF-1	BM(?)	0.75-0.85	2280±50		
SI-4835	SND-2	BM(?)	1.21-1.31	980±100		
SI-4836	SNC-1	BM(?)	2.03-2.13	2630±100		
SI-4837	SNB-1	BM(?)	2.32-2.42	435±75		
DAMARISCOTTA RIVER SUBTIDAL, BELKNAP ET AL. NRC 1984						
SI-6617	DR-VC-6	BHM	14.92-14.96	6295±55	-27.8	6340+55

APPENDIX B: CONTINUED.

POPHAM BEACH, ME: MORSE RIVER MARSH AND ATKINS BAY MARSH AND TIDAL FLAT

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
POPHAM VILLAGE, PHIPPSBURG - NELSON AND FINK, 1978						
		LM	1.49	2740±70	(-12)	
ATKINS BAY - NELSON AND FINK, 1978						
		LM	3.96	5920±100	(-12)	
ATKINS BAY - BELKNAP ET AL., NRC 1983						
SI-6554	AB-VC-1	HM	1.15-1.22	TOO SMALL		-20.8
SI-6555	AB-VC-1	HM	1.58-1.67	2865±70	-23.0	2835±70
MORSE RIVER - BELKNAP ET AL., NRC 1983						
SI-6546	MR-VC-1	HM	0.60-0.66	155±45	-18.9	60±45
SI-6547	MR-VC-1	HM	2.51-2.57	2540±55	-17.0	2410±55
SI-6548	MR-VC-1	(BHM)	3.35-3.42	3585±65	-15.9	3440±65
SI-6549	MR-VC-2	TM	1.08-1.15	540±60	-17.4	420±60
SI-6550	MR-VC-4	HM	1.08-1.14	1305±60	-18.6	1205±60
SI-6551	MR-VC-4	TM	1.43-1.53	1505±80	-19.0	1410±80
SI-6552	MR-VC-5	(TM)*	1.24-1.29	3335±250	-16.9	3205±250
SI-6553	MR-VC-5	LM	2.06-2.16	2115±50	-18.7	2015±50

CASCO BAY, ME: MAQUOIT BAY AND ROYAL RIVER

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
NORTHEASTERN CASCO BAY: SEA GRANT 1985-87						
Maquoit Bay:						
GX-12205	MQM-VC-1	HM	1.88-1.98	2685±170	-13.2	-
GX-12206	MQM-VC-1	HM	2.63-2.73	2865±230	-15.6	-
GX-12207	MQM-VC-1	TM	3.78-3.88	3495±280	-19.3	-
GX-12208	MQM-VC-4	S-CV	2.87-2.97	3790±170	1.0	-
Royal River:						
GX-12209	RR-VC-1	S-MA	5.92-6.02	3265±160	0.3	-
GX-12210	RR-VC-1	S	8.52-8.62	4310±175	-0.5	-
GX-12211	RR-VC-1	W	8.92-9.02	4025±80	-27.0	------

SACO BAY

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
BIDDEFORD POOL, HULMES, 1980						
- -	VC-2	LM	2.65±.30			985±80
SACO BAY, FIELD ET AL., 1979						
GX-2151	121	FWM	13.8			7655±320

WELLS, ME: WEBHANNET RIVER MARSH

Lab #	Core #	Material	Depth MHW (m)	Corrected Age	$\delta^{13}C$	Raw Age
1983-1984 NRC DATA						
SI-6618	W-VC-1	HM	0.72-0.80	1470±55	-16.6	1355±55
SI-6619	W-VC-1	TM	1.25-1.32	3080±70	-20.5	3010±70
SI-6620	W-VC-7	HM	2.76-2.86	3865±55	-18.1	3755±55
SI-6621	W-VC-8	HM	0.92-0.98	1345±55	-17.0	1215±55
SI-6622	W-VC-8	LM	1.69-1.75	1755±55	-17.0	1625±55
SI-6623	W-VC-2	(HM)	5.46-5.54	5135±70	-17.7	5020±70
SI-6624	W-VC-3	TM	2.38-2.44	2495±80	-17.2	2370±80
SI-6625	W-VC-4	HM	3.81-3.89	3780±55	-17.7	3665±55
SI-6626	W-VC-5	HM	4.71-4.78	4380±55	-16.8	4250±55
SI-6627	W-VC-6	HM	2.34-2.40	3105±70	-17.1	2980±70
SI-6628	W-VC-6	TM	3.01-3.07	3705±50	-17.6	3585±50
SI-6629	W-VC-6	HM	3.80-3.86	4220±60	-17.4	4100±60
TIMSON, 1978 (UNPUBLISHED) THE MAINE GEOLOGIST						
			0.23			1290±?
			0.58			2340±?
			0.83			2630±?
			1.07			2860±?
HUSSEY, 1959, 1970						
W-508	W-B	WRS	1.83			2810±200
W-396	W-M	WRS	0.76			2980±180
W-509	KBW	WRS	2.6-3.5	(Kennebunk Beach)		1280±200
W-510	KBE	WRS	1.7-3.5	(Kennebunk Beach)		3250±200
MCINTIRE AND MORGAN, 1964 (Kennebunk Beach)						
- -	- -	BHM(?)	0.8±??			1900±105

HM= High marsh (*S. patens, J. gerardi*)
LM= Low marsh (*S. alterniflora*)
TM= Transitional low to high marsh (*S. alterniflora* +*S. patens*)
BM= Basal marsh (+ terrrestrial and humic compounds)
BHM= Basal high marsh
FWM= Freshwater marsh
S= Shells: MA=*Mya arenaria*; CV=*Crassostrea virginica*
W= Wood
WRS= Wood, rooted stump
TOC= Total organic carbon
*= Contaminated in field; too small; or lab questionable
( )= Questionable