Maine Geological Survey
DEPARTMENT OF CONSERVATION
Walter A. Anderson, State Geologist

OPEN-FILE NO. 85-73

Title: Sea-Level Rise in Passamaquoddy Bay: Archaeology and Sediment Cores

Author: David Sanger

Date: 1985

Financial Support: Preparation of this report was supported by funds furnished by the Nuclear Regulatory Commission, Grant No. NRC-G-04-82-009.

Contents: 11 page report

INTRODUCTION

This report is a description of work undertaken in Passamaquoddy Bay, New Brunswick, Canada, under a contract between the Maine Geological Survey and the University of Maine, Orono. The report is preliminary in that additional data in the form of radiocarbon dates and sediment analyses of cores may be expected.

Interest in sea-level rise in Passamaquoddy Bay is not new. A century ago, naturalists such as W.F. Ganong (1899) and G.F. Mathew (1884) noted evidence for the rise and its effect on the land, especially the archaeological sites in the area. It was not until the advent of radiocarbon dating that any means of measuring the rate of sea-level rise prior to about 1650 (and the onset of effective historic records) could be developed.

This report includes two kinds of evidence of sea-level change. First, the interpretations from archaeological investigations are presented. Second, the stratigraphy of sediment cores from sub tidal deposits is discussed.

THE ARCHAEOLOGICAL EVIDENCE

Evidence for sea-level rise in Passamaquoddy Bay is graphically documented in the analysis of archaeological sites. Although the emphasis in this section is on the prehistory of the area (pre-A.D. 1600), one more recent site provides an illustration of the effects of sea-level rise on an important archaeological site.

In the winter of 1604-05, a French expedition under the command of deMonts and Champlain developed a temporary settlement on St. Croix Island in the estuarine portion of the St. Croix River (Fig. 1). A contemporary sketch map may be compared with one drawn by the surveyor Wright nearly 200 years later, and then with the island as it appeared at the end of the 19th century (Ganong, 1899). Since 1600 a substantial portion of St. Croix Island has eroded.

Although erosion of the St. Croix Island shoreline is the result of water action, it is probably not a consequence of sea-level rise alone. Erosion is a product of, among other things, the geological composition of the sediments, wave action, and rise in mean high-tide level. In another region of the Maine coast, Douglas Kellogg has shown how these factors interrelate and how very detailed, local studies must be undertaken before the role of any one agent can be assessed (Kellogg, 1982).

Indian sites of the prehistoric (pre-A.D. 1600) period abound in Passamaquoddy Bay. They have been the object of much research for over a century (Davis, 1978). Most of the sites are shell midden sites composed of mounds of soft-shell clam (Mya arenaria) mixed with other remains of occupation. The well-preserved evidence indicates that these people focused their activities on the marine resources, although the terrestrial possibilities were not overlooked.

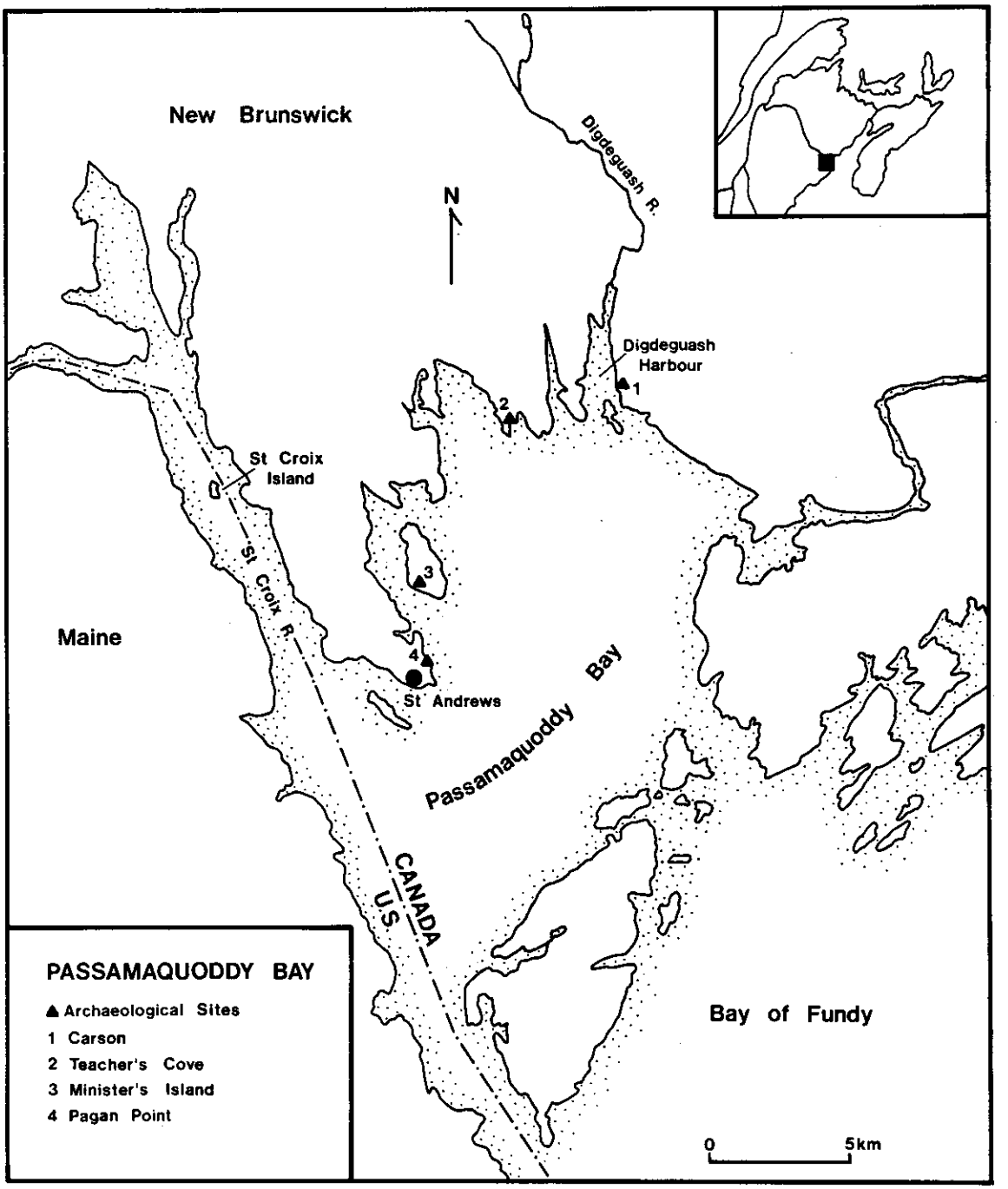
New Brunswick
Digdeguash R.
N
Digdeguash Harbour
1
2
St Croix Island
St Croix R.
3
Maine
4
St Andrews
Passamaquoddy Bay
CANADA
U.S.
Bay of Fundy
0
5km
PASSAMAQUODDY BAY
▲ Archaeological Sites
1 Carson
2 Teacher's Cove
3 Minister's Island
4 Pagan Point

Figure 1

All sites thus far located are on modern shorelines. No shell midden sites are found inland despite many modern activities that would have revealed the presence of such. This situation is not confined to Passamaquoddy Bay; it pertains to the nearly 1800 sites known from the coast of Maine. All the evidence to date indicates that people living in the shell midden sites established those sites at or near the contemporary shoreline. For people with a marine economic focus, gathering large quantities of intertidal shellfish, and dependent on landing and launching watercraft, the advantages of settlement on a beach are obvious. This observation is extremely important for any discussion of sea-level rise using archaeological sites as data. These conclusions on settlement patterns are intended to apply only to the coast of Maine from the Boothbay region to Passamaquoddy Bay.

If sea level has been rising at a constant rate over the past thousands of years we would expect to find a series of short-term occupations, each one drowned by sea-level rise. In a high-energy, inshore environment like Passamaquoddy Bay, little would remain of such sites because the unconsolidated matrix of the shell middens is very susceptible to erosion. The anticipated result of the living pattern and sea-level rise would be to find the remnants of short-term, very late prehistoric occupations. That is not, in fact, the situation in Passamaquoddy Bay.

Shell middens around Passamaquoddy Bay are badly eroded. The erosion has progressed during the past 15 years of observation; elderly residents of the area recall that sites were once more extensive, and sites reported 100 years ago cannot be located at the present time. Erosion is worse where the substrate is softer. For example, relatively few sites are located on the Perry Formation sandstone and sandstone conglomerates, whereas considerably more sites occur on the more resistant volcanic rocks of the Mascarene Formation.

In Penobscot Bay on the central Maine coast, radiocarbon dates in excess of 5000 yr B.P. exist for shell midden sites (Bourque, 1976). The presence of still older coastal occupations is evident from scattered artifacts that are dated to at least 8000 years ago elsewhere in the Northeast (Sanger, 1975). Thus, it would seem that at least some human occupation occured on the coast by 8000 years ago; however, intact archaeological sites are no older than 5000 years. The evidence for coastal occupation in Passamaquoddy Bay is much more recent.

The oldest radiocarbon date for a site in Passamaquoddy Bay is approximately 2400 yr B.P., a charcoal date from the Minister's Island site. This date does not refer to the shell midden occupation at the site but rather to a Late Archaic, non-shell component, underlying the more recent shell midden which is no older than 1200 yr B.P. according to a suite of radiocarbon dates. The lowest levels of the Minister's Island site contain artifacts that are generally similar to those found at several locations in Passamaquoddy Bay, and in every instance such occupations are shell free (Davis, 1978; Kingsbury and Hadlock, 1951; Sanger, 1973, n.d.).

In addition to the Minister's Island site, a Ceramic Period (2000 yr B.P. - 350 yr B.P.) shell midden occupation, with two radiocarbon dates, occurs over a non-shell living floor at the Teacher's Cove site (Davis, 1978). At the Carson site in Digdeguash Harbour, another shell midden, dated by three radiocarbon determinations, overlies Late Archaic artifacts. Shell middens begin to appear in the record around 2000 yr B.P. and continue up to the beginning of the historic period. Such middens may have occupation that is relatively short-lived, or they may show multiple habitation spanning most of the Ceramic Period. The chronology is controlled through approximately 20 radiocarbon dates.

The fact that such prolonged occupation occurs at single loci indicates a period of relatively stable sea level. If sea level was rising at a constant rate comparable to the 9 mm per year suggested by modern data (Tyler and Ladd, 1980), it would mean that at the time of occupation several sites were located well back from the shoreline. Furthermore, through time, people would have continued to live at the same place. In order for this to have occurred, the earlier inhabitants of the area must have lived considerably inland from the then-active shore zone, even though they too exploited the marine environment. As discussed earlier, there is no evidence from anywhere in the immediate area to suggest that this was ever the settlement pattern. The following figures, though rough estimates, indicate something of the distances involved. At 2000 yr B.P., assuming a constant sea-level rise of 9 mm per year, the distances from the sites to the shore would have been: Minister's Island — 800 m; Teacher's Cove — 1200 m; Pagan Point — 800 m (see Fig. 1 for the location of these sites).

On the other hand, if the prehistoric inhabitants of Passamaquoddy Bay lived on or near the active shoreline, then it must be concluded that the 9 mm per year sea-level rise rate cannot possibly be assigned to the period 2000 yr B.P. to the present. The conclusion has to be that sea level was rising at a much slower rate from 2000 yr B.P. until recent centuries, at which time the rate accelerated dramatically.

The archaeological evidence can also be utililzed to infer something of sea-level rise prior to 2000 yr B.P. or slightly earlier, although the situation is more equivocal. The presence of non-shell occupations beneath shell middens poses a problem. If people were living in the marine environment, why were they not taking the obvious intertidal shellfish? Explanations range from lack of knowledge to environmental change. The fact that by at least 5000 yr B.P. people at the mouth of the Penobscot were taking clams suggests that lack of knowledge is not the explanation. It suggests that environmental change is more likely.

There are two major competing hypotheses. One is that due to a scarcity of suitable intertidal zones it was not possible to develop a settlement pattern to exploit shellfish. The other is that the older sites with an intertidal zone exploitation pattern have been eroded away due to sea-level rise.

In fact, these alternatives are not unrelated. A period of rapidly rising sea level might tend to discourage the establishment of extensive, fine-grained, intertidal sediments of the sort needed to support clams. Their absence, in turn, would eliminate ground fish from the flats in search of prey. The inshore environments would be much less attractive for people than the more stable intertidal mud flats of later times.

If people did occupy the littoral zone of Passamaquoddy Bay 5000 years ago, then the lack of evidence for their presence could reflect erosion due to sea-level rise. The few components dated to around 2500 years ago could represent people living near a shoreline that was beginning to stabilize after a period of very rapid sea-level rise.

In conclusion, the archaeological evidence suggests that:

1. The modern sea-level rise of 9 mm per year is a recent phenomenon that is probably no more than a few hundred years old;

2. Prior to the recent acceleration in sea-level rise there was a period of relative stability from at least 2000 years ago and possibly since 3000 years ago;

3. Before 2500 to 3000 years ago the sea-level rise might have been greater once again.

SEDIMENT CORING

In 1977 an attempt was made to ascertain the presence or absence of shellfish, particularly soft-shell clam (Mya arenaria), in the sediments beneath the Digdeguash Harbour region of Passamaquoddy Bay. The interest stemmed from the realization that archaeological components older than 2000 years in the region lacked shellfish remains, despite the fact that in the central Maine coastal region the history of shellfish procurement extends back to at least 5000 years ago (Bourque, 1976). As mentioned earlier in this report, the issue has traditionally been one of technology and knowledge of the resource as opposed to environmental explanations. In order to test the environmental hypothesis, a group from the Institute for Quaternary Studies decided to core in Passamaquoddy Bay, seeking submerged intertidal deposits that might contain shellfish. Institute members Harold Borns, Jr., Thomas Kellogg, and David Sanger spent a day in October, 1977, and recovered sediment cores from Digdeguash Harbour.

Digdeguash Harbour was selected by Sanger for several reasons. First, the Harbour area is the location of a number of archaeological shell middens (Fig. 2). These Ceramic Period middens all have occupations that date by radiocarbon to between 1200 and 300 years ago (Sanger, 1971, 1981). Despite the relative recency of these sites that so obviously depended upon the intertidal resources, there are limited possibilities in the Harbour today for an intensive shellfish procurement subsistence

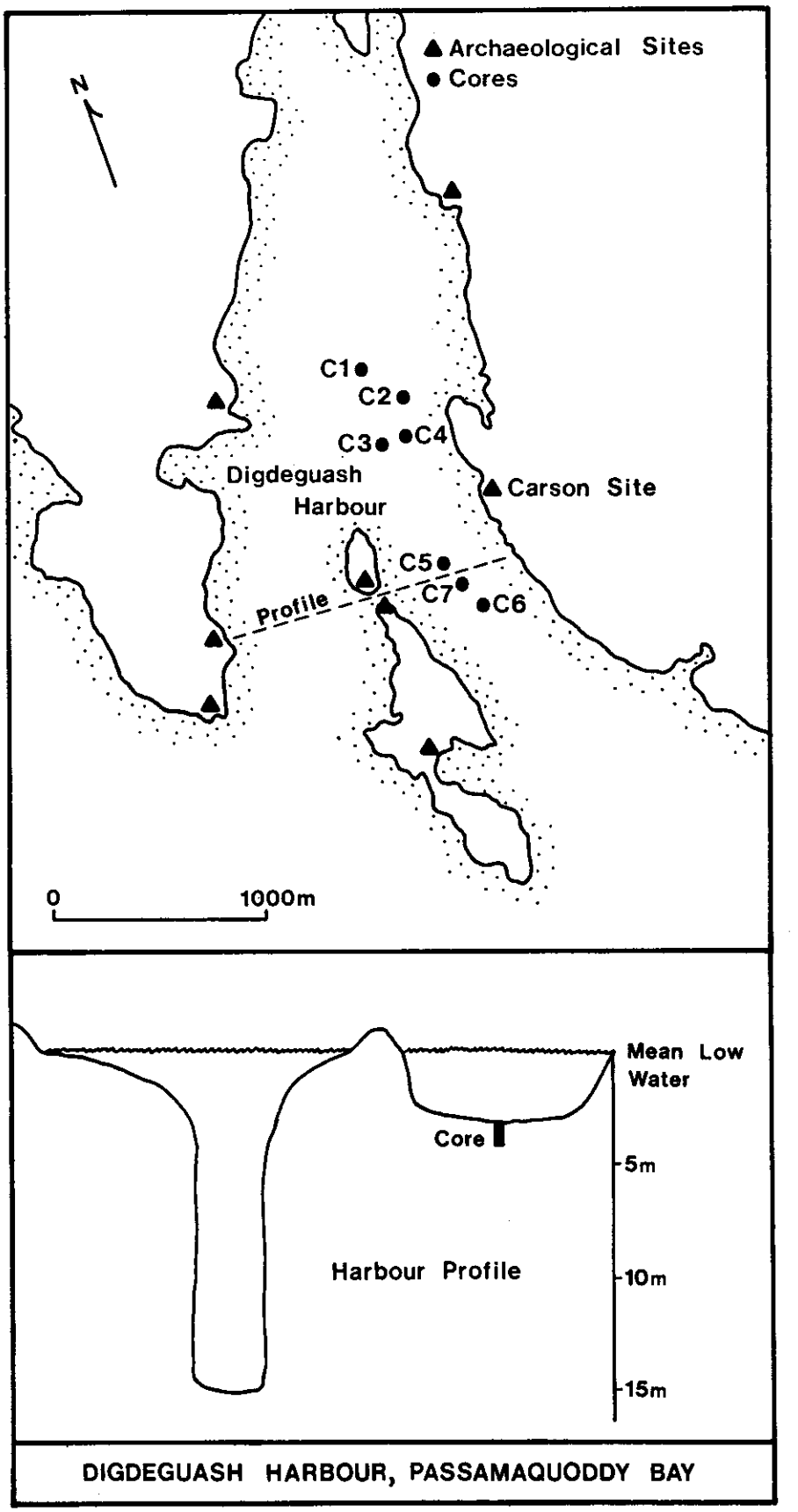
Archaeological Sites
Cores
N
C1
C2
C3
C4
Digdeguash
Harbour
Carson Site
C5
C7
C6
Profile
0
1000m
Mean Low
Water
Core
5m
10m
15m
Harbour Profile
DIGDEGUASH HARBOUR, PASSAMAQUODDY BAY

Figure 2

pattern. We hoped that by establishing a date for the presence of shellfish in intertidal sediments we would determine whether the absence of older sites was dependent upon the absence of suitable intertidal zones in reasonably close proximity to the sites.

Second, Digdeguash Harbour is a drowned valley. The channel is the Digdeguash River (Fig. 2). A profile taken from the marine chart in the area of coring illustrates the deep channel and the relatively flat, shallow banks that have been inundated by rising sea levels (Fig. 2). It is assumed that as the mean sea level rose the river valley became flooded, and eventually the water overflowed the banks and drowned the flat area on either side, especially to the east. Such inundation should have resulted in an ideal intertidal zone, a gently sloping, fine sediment area, well suited to the clam. Because of the generally flat characteristic of the Harbour bottom, once the mean water level rose over the banks of the valley a widespread water zone would have been created almost instantaneously, thus simplifying the task of locating a beginning point for the creation of intertidal habitat.

Third, it was important to select an area for coring that did not have a high accumulation of modern sediment derived from agriculture and other processes that lead to siltation of estuaries. The Digdeguash River drains an area of relatively limited cultivation.

With the cooperation of the Huntsman Marine Laboratory, a piston corer was dropped in several places in the Harbour east of Long Island. Core 2 had Mya embedded in silt at 51 cm below the top of the sediment. Unfortunately, accurate time and water depth were not recorded; however, it was close to high tide. Assuming high tide, and using the position of the core, depth of water was close to 10 m. If the clams colonized the area as soon as it became available, then a date on the clams should indicate the time of flooding of the valley at that point. A measurement from current mean high tide down to the clam-bearing horizon gives a rough figure of sea-level rise, assuming that tidal amplitude has not changed drastically. With this many uncertainties and assumptions, the calculations of sea-level rise have to be treated with caution.

TABLE 1

RADIOCARBON DATES FROM CORE 2A - DIGDEGUASH HARBOUR

Depth from top of core (cm)	Material dated	Date in C14 Years (B.P.)	Lab. No. (SI-)
40-50	organic in sed.	6560 ± 150	4022
51	Mya arenaria	5375 ± 75	3927
55-65	organic in sed.	5225 ± 135	4023

Sample SI-3927 was analyzed first. The date of greater than 5000 years was totally unexpected because of the then available sea-level curves for the Gulf of Maine, especially as reviewed by Grant (1970). In an attempt to solve the apparent problem of 5000 year old clam shells in Digdeguash Harbour, samples of organic material from the sediment were dated. Sample SI-4022, although stratigraphically above samples SI-3927 and SI-4023, dates nearly 1000 years older for reasons that are not clear. The other two samples, the original clam date of 5375 $\pm$ 75 and the organics from the sediments below at 5225 $\pm$ 135 are "statistically indistinguishable" (letter report from R. Stuckenrath, April, 1979).

Despite the unfortunate lack of pertinent data regarding exact water depth and time of tide, the recovery and dating of an intertidal species at greater than 5000 years is significant. It suggests a sea-level rise rate of less than 25% of the recent 9 mm per year rate, if the rate is calculated in a simple linear fashion from the shell date to the present.

Because of the nature of the Harbour area, however, it is hard to reconstruct a series of events that could account for the presence of a 5000 year old clam unless intertidal sediments were nearby. Furthermore, a group of paired charcoal and clam radiocarbon dates from archaeological sites in the area agreed within 1 standard deviation, thus conveying confidence in clam shell dates in the particular environment (Sanger, 1981). Until other data emerge, it seems most reasonable to assume, however tentatively, that the 5000 year old date is correct and, in addition, provides a limiting date for the presence of an intertidal zone.

In August, 1982, a return to Digdeguash Harbour resulted in the recovery of 8 sediment cores. Profiting from the mistakes of the earlier expedition, additional crew members plotted coring locations on charts, supplemented depth-sounder water depth measurements with a lead line, and noted precise time of tide. Thomas Kellogg supervised the actual coring, while Harold Borns organized the time and place documentation. Coring equipment was identical to that used in 1977. Some coring locations were selected to duplicate, if possible, sites cored in the earlier project.

The core tubes were opened, described, and examined for possible sequential accumulations of clam shells that might indicate a series of buried intertidal zones. Core 3, taken in a water depth of nearly 3 m, was selected because it had 5 distinct layers of clam shells underlain by a fine, sticky, grey sediment that appears to be re-worked Pleistocene marine clay. Samples from the 5 layers were submitted to the Smithsonian Laboratory for radiocarbon analysis, and portions were saved for amino acid dating by Daniel Belknap of UMO. The radiocarbon dates (letter report by R. Stuckenrath, August, 1983) are as follows.

TABLE 2

RADIOCARBON DATES FROM CORE 3(82) - DIGDEGUASH HARBOUR

Depth from top of core (cm)	Material dated	Date in C14 Years (B.P.)	Lab. No. (SI-)
2-10	Mya	2935 ± 215	5892
22-30	Mya	4185 ± 70	5893
39-47	Mya	3705 ± 60	5894
55-60	Mya	395 ± 155	5895
65-70	Mya	3715 ± 205	5896

The dates from Core 3 are problematic. They come from shallower water than the core taken in 1977 and are correspondingly younger. Sample SI-5895 is a real problem. The possible explanations range from coring to laboratory difficulties, to some sort of stratigraphic or depositional problem. It is unlikely to be a laboratory related factor as amino-acid research (Table 3) also shows the same samples as being anomalous with respect to the other shells and the depth. At this time, sample SI-5895 is best excluded from further discussion.

Samples SI-5892 and 5896 have high error ranges due to small sample size and the need to dilute the samples for dating. Considering the spread of clams through nearly 70 cm of deposit, the range of dates (excluding SI-5895) is not great. All could be accommodated within a maximum date range of approximately 2700 to 4250 yr B.P. or less.

Sample SI-5896, which rests directly on the clay that forms the bottom of Core 3, may be the most useful of the suite of dates in that the shells are most likely to be *in situ* and not the product of redeposition from channel erosion in the mud flat. Until additional samples are dated from other cores, it would be premature to base a sea-level rise curve on the clearly equivocal data currently available. The preliminary results of the amino acid determinations provided by Daniel Belknap (letter report, January, 1984) indicate similar problems of potential reworking.

TABLE 3

AMINO ACID DETERMINATIONS FROM CORE 3(82) - DIGDEGUASH HARBOUR

Depth from top of core (cm)	D/L Leu	Model Age* (Years B.P.)	Sample No.
2-10	too small	no useful date	
22-30	.033	500 ± 500	DFB-83-75
39-47	.052	4500 ± 1500	DFB-83-76
55-60	.059	6500 ± 1500	DFB-83-77
65-70	.040	1500 ± 1000	DFB-83-78

*For model calculation multiply D/L by 0.85, use temperature model of 10 degree(C) for Mercenaria

CONCLUSIONS

Although there remain uncertainties, the results of the analysis of archaeological site ages and the dates on sediment cores from Digdeguash Harbour reinforce the observation that the modern rate of 9 mm per year for sea-level rise in Passamaquoddy Bay is a recent phenomenon. Just how recent is not yet clear. Data from the archaeological sites alone are not adequate for the construction of a quantitative sea-level rise curve; however, they can, and do, provide an independent way of assessing the validity of conclusions generated by other data sets.

ACKNOWLEDGEMENTS

The research described here was supported by a great many agencies and institutions. In addition to the NRC funding through the Maine Geological Survey that supported the second (1982) coring project, there are the NSF, National Museums of Canada, Province of New Brunswick, and University of Maine.

The coring teams included Harold W. Borns, Jr., Margaret Borns, Thomas Kellogg, Kjell Bjorklund, and David Sanger. Our thanks to the crew of the vessel supplied by the Huntsman Marine Laboratory at St. Andrews. Our thanks also to Daniel Belknap for the amino acid dates and to R. Stuckenrath of the Smithsonian Institution for the radiocarbon dates.

Stephen A. Bicknell drafted the figures and Ms. Carol McGowen typed the manuscript.

REFERENCES

Bourque, B. J., 1976, The Turner Farm Site: A preliminary report: Man in the Northeast, v. 11, p. 21-30.

Davis, S., 1978, Teacher's Cove: A prehistoric site on Passamaquoddy Bay, New Brunswick: Number 1, Historical Resources Administration, Fredericton, New Brunswick.

Ganong, W., 1899, A monograph of historic sites in the Province of New Brunswick: Trans. Royal. Soc. Canada, Second Series, Vol. V, Sec. II, p. 213-357.

Kellogg, D., 1982, Environmental factors in archaeological site location for the Boothbay, Maine, region: M.S. thesis, University of Maine, Orono.

Kingsbury, I., and Hadlock, W., 1951, An early occupation site, Eastport, Maine: Massachusetts Archaeological Society Bulletin, v. XII, no. 2, p. 22-26.

Mathew, G., 1884, Discoveries at a village of the stone age at Bocabec: Bulletin of the Natural History Society of New Brunswick, No. III.

Sanger, D., 1971, Prehistory of Passamaquoddy Bay: A summary: Bulletin of the Maine Archaeological Society, v. 12, no. 2, p. 14-19.

Sanger, D., 1973, The prehistoric components on St. Croix Island: Report to the National Park Service, Ms on file, Univ. of Maine archaeology laboratory, Orono, Maine.

Sanger, D., 1975, Culture change as an adaptive process in the Maine-Maritimes region: Arctic Anthropology, v. XII, no. 2, p. 60-75.

Sanger, D., 1981, Unscrambling messages in the midden: Archaeology of Eastern North America, v. 9, p. 37-42.

Sanger, D., n.d., The first 10,000 years of Maritimes history: Ms on file, Univ. of Maine archaeology laboratory, Orono, Maine.

Tyler, D., and Ladd, J. W., 1980, Vertical crustal movement in Maine: Maine Geological Survey Open-File Report 80-34, 53 p.