

***Particle Mixing and Sediment Accumulation Rates of Peconic Estuary Sediments: A  
Sediment Accretion Study in Support of the Peconic Estuary Program  
Program Office Summary – August 15, 2000***

This study is based on the premise that water quality parameters in an estuary are linked indirectly or directly to the decomposition of organic matter. To understand the fate of organic matter in the Peconics, one must understand the distribution of carbon in the sediment. Organic matter in estuarine sediments is added or produced at the sediment-water interface and may be distributed to depth by animals that live in the sediment, burial, or sediment accumulation.

This study used radionuclide tracers of different half-lives (Thorium-234, 24 days; Beryllium-7, 53 days; Lead-210, 22 years; Carbon-14, 5568 years) to determine the rate of mixing and sediment accumulation in the Peconics. Many of these radionuclides associate strongly with particles, and their property of radioactivity makes them useful chronometers for estuarine sediment dynamics. Sediment cores were collected three times at each of ten stations in the Peconic Estuary System (see Figure 1 and Table 1 of the report).

**Particle Mixing Rates**

The range of particle mixing rates found in the Peconic Estuary was similar to Long Island Sound. Benthic organisms were found to mix the upper few centimeters of sediment on time scales of weeks to months. In five of the seven stations where mixing rates in the fall and spring were compared, the fall rates were greater, again similar to the Long Island Sound. The fall cores reflect the mixing processes during the summer, while the spring cores represent winter conditions. The activity of the animals that live in the sediment decreases as the temperature drops in the winter, hence mixing is reduced. Station 1 (Meetinghouse Creek) and Station 8 (Noyack Bay) had the greatest mixing. The x-radiographs are described in detail in shown in Appendix I of the report.

**Sources of Carbon to the Sediments**

Isotopes are fractionated during a variety of processes, including photosynthetic pathways. Photosynthesis not only fractionates the stable carbon isotopes carbon-12 and carbon-13, but the type of carbon metabolism in the plant determines the magnitude of the fractionation. There are at least four sources of organic carbon to the Peconic Estuary sediments: terrestrial plants (employs the C3 method of photosynthesis), terrestrial marsh grasses (employs the C4 method of photosynthesis), phytoplankton (marine C3 plants) and submerged aquatic vegetation (marine C4 plants). The stable carbon isotope signatures from the sediment samples taken in Reeves Bay, Little Peconic Bay, Noyack Bay, and West Neck Bay are shown in Table 6a of the report. The signatures for the organic sources to the Peconic Estuary are also shown. Thus, based on carbon-12 and carbon-13 (non-radioactive carbon), this study finds that the carbon in the cores primarily originated from terrestrial plants and terrestrial marsh grasses rather than from marine grasses or plankton. Low in situ production or rapid turnover of marine carbon could account for the sedimentary carbon being dominated by terrestrial organic carbon.

### Sediment Core Profiles

While many estuaries show distinct gradients in total organic carbon as a function of depth in the sediments, the Peconic samples generally show little systematic change of carbon levels with depth that cannot be accounted for by changes in sediment grain size (shown in Figure 3 of the report). Site-to-site organic carbon variation most likely results from local sources of particulate organic carbon inputs.

Based on radiocarbon analysis, sediment core profiles indicate that the sedimentary organic carbon reservoir is old (approximately 1550 years before present), even in the upper three centimeters. An old age for the organic matter near the core top suggests that little marine carbon is present in the sediments or that any marine particulate organic carbon is rapidly taken up and is not accumulated in Peconic sediments. Thus, although the sediments serve as a repository for refractory organic carbon from terrestrial plants, they do not serve a similar role for marine plants. The latter possibility implies that sediments in certain portions of the Estuary have the capability to respond quickly to changes in estuarine productivity caused by nutrient loadings. In cases where increases in nutrient loadings cause increases in estuarine production, the resultant remineralization of organic matter in the surface sediments could have rapid effects on water column parameters like dissolved oxygen. In contrast, in cases where management decisions lead to a decrease in nutrient loadings, the positive effects on water quality should be rapid.

### Sediment Accumulation Rates

Sediment accumulation rates were found to be between 0.03 to 0.11 cm/year, using radiocarbon (carbon-14) determinations. Using the radiocarbon rates as the best approximation (and assuming that these rates are unaffected by mixing), carbon burial rates were estimated at 0.3 to 1.8 mg C/cm<sup>2</sup>/year.

The information from this report will be useful in refining the sedimentary sub-model in the Three-Dimensional Hydrodynamic and Water Quality Model of the Peconic Estuary by Tetra-Tech, Inc.

**Particle mixing and sediment accumulation rates of Peconic  
Estuary sediments: A sediment accretion study in support of  
the Peconic Estuary Program**

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**Final Report of Project #0014400498181563**

**Revised 6/26/00**

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**Summary**

Naturally occurring radionuclides provide important information on the dynamic processes, including mixing by burrowing organisms, sediment accretion and carbon storage, that characterize the sediments of the Peconic Estuary. Our sampling of ten stations in the estuary shows that the highest concentrations of particle-reactive radionuclides are associated with the fine-grained sediments. This is partly caused by the high surface area to volume ratio of such sediments and their consequent enhanced ability to adsorb radionuclides (as well as other particle-reactive chemical species). For example, sediments sampled in Flanders Bay and portions of Great Peconic Bay are coarse grained and show low activities of  $^{210}\text{Pb}$  (half-life = 22 y), a natural radionuclide supplied from the atmosphere. Because the Peconic estuary is a relatively shallow system, some sites such as Meetinghouse Creek and East Creek show physical disturbances related to either the influence of currents, storms or human activities. Other sites (e. g. portions of Great Peconic Bay) show evidence of stable communities of benthic organisms that mix the upper few centimeters of the sediment on time scales of weeks to months, as indicated by distributions of  $^7\text{Be}$ , a short-lived (half-life = 53 d) radionuclide supplied to the estuary from the atmosphere. Inventories of these two radionuclides in Peconic sediments approach values expected from direct atmospheric supply, indicating that the estuary is efficient in retaining chemical species that associate with and are deposited in the sediments.

On the longer term, distributions of  $^{210}\text{Pb}$  and radiocarbon ( $^{14}\text{C}$ ; half-life = 5730 y) in Peconic sediments show that they are accreting slowly, at rates of 0.03 - 0.1 cm per year. Measurements of radiocarbon and stable  $^{13}\text{C}$  in particulate organic carbon of the sediments sampled provides important clues to the sources and storage of carbon in Peconic sediments. Although organic carbon varies from site to site in the sediments of the estuary, there is relatively little variation with depth in the sediment column that can be interpreted as due to remineralization of POC within the sediments. Rather the site-to-site variation, as well as the depth variation in a core, is controlled by grain size changes in the sediments and proximity to local sources of POC input. Radiocarbon ages at depth in four cores analyzed for this radionuclide are old (~2000 years), although there is sufficient precision on the ages ( $\pm$  ~50 years) to estimate sediment accumulation rates from the depth gradients.

The stable isotopic ( $\delta^{13}\text{C}$ ) composition, together with the radiocarbon data, of the organic matter suggests that it is composed of the remains of terrestrial plants (including marsh grasses) that do not decompose readily once they become buried in the sediments. In one core from Little Peconic Bay, radiocarbon was analyzed in greater detail. An old age for the organic matter near the core top suggests either that little marine carbon is present or any marine POC is decomposed quickly and efficiently in surface sediments and is not available for burial. Thus, although the sediments serve as a repository for refractory terrestrial organic carbon, they do not serve a similar role for *in situ* production. The latter possibility implies that the sediments in certain portions of the estuary have the capability to respond quickly to changes in estuarine productivity caused by changes in nutrient loadings. In cases in which increases in nutrient loadings cause increases in estuarine production, the resultant remineralization of organic matter in the surface sediments could have rapid effects on water column parameters such as dissolved oxygen or organic nutrients. In contrast, in cases in which management decisions lead to a decrease in nutrient loadings and concomitant decreases in estuarine production, the positive effects on water quality should be rapid as well. A complete characterization of Peconic sediments using the carbon isotopes was beyond the scope of this study, but because of the great potential of these tracers, we recommend that the PEP consider supplemental funding to permit these analyses on archived samples.

## Executive Summary

This report presents the application of natural radionuclides to determine sediment mixing and accumulation patterns in the Peconic Estuary. Cores were collected at ten stations throughout the estuary. Box cores were collected by diver during fall, 1997 and spring, 1998 for characterization of particle mixing processes near the sediment-water interface. Gravity cores were collected once for determination of sediment accumulation rates using longer lived radionuclides. The short-lived radionuclides  $^{234}\text{Th}$  and  $^7\text{Be}$  were used to determine particle mixing rates. Activities of excess  $^{234}\text{Th}$  were low because the shallow water depths in the estuary resulted in low production of this radionuclide from  $^{238}\text{U}$  in the overlying water column.  $^7\text{Be}$  was present at all stations, although its activity was reduced at stations characterized by coarse-grained sediment.  $^7\text{Be}$  was distributed to ~3-5 cm by particle mixing and mixing rates calculated from the  $^7\text{Be}$  data ranged from 0.1 to 247  $\text{cm}^2/\text{y}$ , comparable to other estuarine environments.

Excess  $^{210}\text{Pb}$  was present in the upper 15 to 20 cm of all stations except those with coarse-grained sediment. Sediment accumulation rates calculated from the depth gradients of excess  $^{210}\text{Pb}$  range from 0.09 to 0.20  $\text{cm}/\text{y}$ . Four gravity cores were chosen for radiocarbon determination. The sediment accumulation rates calculated from these stations range from 0.03 to 0.11  $\text{cm}/\text{y}$ . These are consistently less than, but within a factor of three of, the  $^{210}\text{Pb}$  rates at the same stations. Using the  $^{14}\text{C}$  rates as the best approximation to the true long-term accumulation rate in the estuary, we estimate carbon burial rates of 0.3 to 1.8  $\text{mg C}/\text{cm}^2/\text{y}$ .

The radiocarbon ages at depth in the sediments are older than expected from sediment accumulation and decay of material with zero age deposited at the sediment-

water interface. This suggests that the sedimentary organic carbon reservoir at depth in the sediments is dominated by old terrestrial carbon. The  $\delta^{13}\text{C}$  of the organic carbon suggests that it is a mixture of terrestrial grasses and other vegetation. The radiocarbon age profile in a core from Little Peconic Bay (station 7) indicates that the age of the sedimentary organic carbon reservoir is old (~1550 years BP) even in the upper 3 cm, suggesting that labile marine carbon is low in concentration or is rapidly decomposed and is not accumulated in Peconic sediments. This result is consistent with depth profiles of organic carbon content in Peconic sediments, which show little systematic change of carbon with depth that cannot be accounted for by changes in sediment grain size.

## I. Introduction

Many of the biogeochemical reactions that affect water quality in an estuary are directly or indirectly linked to the decomposition of organic matter. Such decomposition can take place in the estuarine water column or in bottom sediments, and when the estuary is shallow, as in the Peconics, the coupling of these two zones is intense. A complete understanding of the fate of organic matter in the Peconic Estuary thus requires knowledge of the distributions of carbon in the sedimentary reservoir. Organic matter in estuarine sediments is added or produced at the sediment-water interface and can be distributed to depth by the particle mixing by benthic fauna and by burial, or sediment accumulation. Profiles of organic carbon distributions in estuarine sediments, coupled with information on the dynamics of particle transport processes (mixing by infauna and accumulation), can be used to infer turnover times of the sedimentary organic carbon reservoir.

This study was undertaken with Peconic Estuary Program funding to provide this information. One of the most widely used approaches for determining particle mixing and sediment accumulation rates of estuarine sediments is with natural radionuclides. Many of these radionuclides associate strongly with particles, and their property of radioactivity makes them useful chronometers for estuarine sediment dynamics. A critical element of this application is the use of multiple tracers of different half-life so that the processes of particle mixing and sediment accumulation can be resolved. Accordingly, we chose to determine distributions of the following radionuclides in Peconic sediments:

- $^{234}\text{Th}$  (half-life = 24.1 days):  $^{234}\text{Th}$  is produced from decay of dissolved  $^{238}\text{U}$  in the water column and is rapidly scavenged to sediments. Our work on  $^{234}\text{Th}$  in the Venice Lagoon shows that it is scavenged on time scales of hours from this shallow water environment (Cochran et al. 1994).  $^{234}\text{Th}$  scavenged from the overlying water column to the bottom sediments is referred to as "excess"  $^{234}\text{Th}$  to differentiate it from  $^{234}\text{Th}$  that is supported by  $^{238}\text{U}$  contained in the constituent minerals of the sediments. In practice excess  $^{234}\text{Th}$  is calculated by subtracting the  $^{238}\text{U}$  activity from the measured  $^{234}\text{Th}$  activity. The short half-life of  $^{234}\text{Th}$  makes it suitable for determining particle mixing rates in estuarine sediments and it is typically confined to the upper few centimeters of the sediment column.

- $^7\text{Be}$  (half-life = 53 days):  $^7\text{Be}$  is produced naturally in the atmosphere from nuclear reactions of cosmic rays with atmospheric gases. It is added to the estuary by precipitation (wet and dry) and, like  $^{234}\text{Th}$ , is rapidly scavenged onto particles. Its

distribution in the sediments is similar to that of  $^{234}\text{Th}$  and it also a useful tracer of particle mixing rate.

- $^{210}\text{Pb}$  (half-life = 22.3 years):  $^{210}\text{Pb}$  is also produced in the atmosphere but from decay of the  $^{222}\text{Rn}$  gas that has emanated from rocks and soils.  $^{210}\text{Pb}$  is often used to determine accumulation rates of estuarine sediments. This application is complicated by the fact that excess activity of this radionuclide (relative to its grandparent  $^{226}\text{Ra}$ ) is often confined to the upper 15-20 cm, a zone in which particle mixing by organisms is likely to be important.

- $^{14}\text{C}$  (half-life = 5568 years): Radiocarbon is added to the estuary by gas exchange of  $\text{CO}_2$  as well as in association with terrestrial organic matter. It is produced naturally in the atmosphere, but has also been produced in association with atmospheric testing of atomic weapons. If particle mixing is confined to the upper 10-20, accumulation rates can be determined from the distribution of radiocarbon ages at depth in the sediments.

This report presents data on the sediment distributions of the above radionuclides, plus information on C and N in Peconic Estuary sediments.

## II. Sampling sites, bulk sediment properties and X-radiography of cores

Sediment cores were collected three times at each of ten stations in the Peconic estuary system (Fig. 1, Table 1). The stations are among those characterized previously for toxic contaminants and were chosen in consultation with program management personnel. We initially attempted to reoccupy the sampling locations given in the Toxics Report. However the locations listed in the "seconds" column (of "degrees"- "minutes"-

"seconds") were clearly not seconds because they exceeded 60" in several instances. We thus chose the closest approximation to the sites assuming that "seconds" corresponded to decimal minutes. Small Plexiglas box cores (~250 cm<sup>2</sup> surface area) for radiochemical analyses were collected by diver in September, 1997 and April, 1998. Logistical support (vessel and divers) provided by the Cornell Cooperative Extension marine program in Riverhead was critical to the success of the sampling. Where possible, smaller box cores were taken to examine sediment structures by X-radiography.

The box cores were emplaced in the sediment by divers and excavated in situ until bottom plates could be attached to retain the core. Cores were transported to the Marine Sciences Research Center for further processing. The radiochemical cores were extruded and sectioned into sampling intervals of one to three centimeters. Samples were weighed wet, dried at 80°C and weighed again to determine water content. Cores for X-radiography were not sampled but were X-rayed intact using a veterinary X-ray unit.

One set of gravity cores (10-cm diameter) was collected in November, 1997. The Suffolk County DHS vessel was used in the sampling, and the cores recovered were typically 50 cm long. Despite repeated attempts, it proved not possible to collect gravity cores at three sandy stations (3, 4 and 5). The sandy sediment at these stations prevented the cores from sealing and the sediment invariably washed out of the core tube during recovery. The successful cores were returned to MSRC, SUNY-Stony Brook and extruded in intervals of three to five centimeters. Water contents were determined as for the box cores.

Bulk sediment properties determined include % water (as g H<sub>2</sub>O per g wet sediment x 100) and dry bulk density ( $\rho_{dry}$ , as g dry sediment per cm<sup>3</sup> wet sediment). The latter was calculated as:

$$\rho_{dry} = \rho_{sed} \left( 1 - \frac{\frac{W}{\rho_{H_2O}}}{\frac{W}{\rho_{H_2O}} + \frac{1-W}{\rho_{sed}}} \right) \quad (1)$$

where  $\rho_{sed}$  is the sediment grain density (assumed to be 2.65 g sed/cm<sup>3</sup> sediment),  $\rho_{H_2O}$  is the density of water (taken as 1.02 g H<sub>2</sub>O/cm<sup>3</sup> water) and W is the % H<sub>2</sub>O (g H<sub>2</sub>O/g wet sediment).

Values of % H<sub>2</sub>O and bulk density are given in Tables 2 and 3. Water content in the 0-1 cm interval of the box cores ranges from 20.1 to 86.5% in fall, 1997 and 19.4 to 82.3% in spring, 1998. Three of the stations (3, 4 and 5) have water contents typical of coarse-grained sands (~20%). Water contents are generally similar at both occupations of the same station, given the possibility of seasonal differences in mixing by the benthic fauna. One exception to this pattern is seen at station 4, which has greater water content in the upper 3 cm in the core taken in September, 1997. Indeed, the water depth at this station is significantly greater in the fall than in the spring sampling. This likely reflects small-scale spatial variation in water depth and in sediment properties at this site. The other stations have similar water depths (allowing for variations in tide at time of sampling) and similar sediment properties.

Bulk densities calculated from the water content data range from 0.15 to 1.6 g/cm<sup>3</sup> in the fall and from 0.2 to 1.8 g/cm<sup>3</sup> in the spring (Table 2). Lower values are indicative of high water content, fine-grained sediment, as typified by station 13 (East

Creek). Higher values correspond to coarse-grained, low water content sediment as at station 4 (Great Peconic Bay west). Sediment property data for the gravity cores are given in Table 3. The X-radiographs of the X-ray cores taken with the box cores are shown in Fig. 2.

Sedimentary organic carbon and nitrogen were determined on the box core and gravity core samples using a Carlo Erba CHNS Analyzer. Calcium carbonate was removed from the samples by acid fuming prior to combustion to eliminate C from  $\text{CO}_3$ . Carbon and nitrogen data are given in Tables 2 and 3. Several patterns are evident in these data. High C and N concentrations are associated with fine-grained sediment. Stations 2 and 13 typify this trend with surficial water contents as great as 82%, C 5-6% and N 0.4 - 0.6%. The opposite extreme is seen at stations 3, 4 and 5, where the sediments are coarse grained and have ~0.1% C and 0.01% N. The remaining stations are intermediate, with C 1-3% and N 0.2 - 0.4%. The average values of C and N in the upper few centimeters as sampled with the box cores are strikingly similar in the fall and spring cores and the values agree well with those measured in the 0-3 cm interval of the gravity cores taken at the same stations. Indeed there is no clear sense from these data that the sedimentary organic C or N profiles vary significantly over time as might be expected if there had been input of organic matter from a plankton bloom during the time covered by our sampling.

Many estuaries show distinct gradients in organic carbon as a function of depth in the sediments. Such gradients often show up near the interface as freshly deposited organic carbon is mixed and decomposed and over deeper depths as more refractory organic matter breaks down. These patterns are generally not observed in Peconic

estuary sediments (Fig. 3). In general gradients are weak near the sediment water interface (based on the box core data, Table 2) and where present (for example the spring box core from station 13), may reverse at depth (gravity core from station 13, Fig. 3). Large scale gradients as seen in the gravity cores often reflect the effects of mixing or grain size changes. Station 1, for example shows sedimentary organic carbon content of 1.5 – 2.5% in the upper 10 cm, with values progressively increasing to ~6% below 20 cm. This pattern is reflected in the water content which increases over the same interval and likely reflects downcore decreases in grain size. Other similar variation of organic carbon with grain size is evident in cores from stations 8 and 13. These profiles emphasize that core sedimentology exercises a fundamental control on carbon content in these cores. Such a control is likely possible because much of the organic carbon is “old” and likely refractory in Peconic sediments (see below).

### **III. Dynamics near the sediment-water interface: particle mixing rates**

Estuarine sediments deposited below an oxic water column are commonly mixed by the benthic fauna. In estuaries such as Long Island Sound, particle mixing can extend to a depth of one meter or more in the sediment column (Benninger et al. 1979) and complicates interpretations of profiles of long-lived radionuclides used to determine sediment accumulation rates. Particle mixing can be evaluated using a variety of radionuclides with different half-lives. The distributions of short-lived radionuclides such as  $^{234}\text{Th}$  and  $^7\text{Be}$  are dominated by mixing and are thus effective tracers for quantifying this process.

Activities of  $^{234}\text{Th}$ ,  $^7\text{Be}$  and  $^{210}\text{Pb}$  were determined on the box core samples by nondestructive gamma spectrometry using an intrinsic germanium gamma detector.

Gamma emissions at 46 keV ( $^{210}\text{Pb}$ ), 63 keV ( $^{234}\text{Th}$ ) and 477 keV ( $^7\text{Be}$ ) were used to calculate activities. The detector was standardized using standards of known activity (principally NIST River Sediment). Self-absorption of  $^{210}\text{Pb}$  and  $^{234}\text{Th}$  gammas by the sample was corrected using standards containing  $^{210}\text{Pb}$  and  $^{234}\text{Th}$  that were made up to simulate the range of densities observed in the samples. Supported levels of  $^{234}\text{Th}$  were determined using the average  $^{234}\text{Th}$  activity below the surficial samples. Errors associated with the activities are one sigma, calculated from counting uncertainties.

Table 4 gives radiochemical data from the box cores. Several features are evident in the data. The first is that there is very little evidence of excess  $^{234}\text{Th}$  in the sediment. This is largely due to the shallow depth of water in the Peconic Bay system. The mean water depth of the sites sampled is 3.7 m. The production of  $^{234}\text{Th}$  is controlled by the  $^{238}\text{U}$  in the overlying water, and for a water column of 3.7 m, the expected inventory of  $^{234}\text{Th}$  in bottom sediments is just  $0.5 \text{ dpm cm}^{-2}$ . If this  $^{234}\text{Th}$  is distributed over the top 3 cm, the expected mean activity of excess  $^{234}\text{Th}$  in the sediments (assuming a dry bulk density of  $0.5 \text{ g sediment/cm}^3$  wet sediment) is just  $0.3 \text{ dpm g}^{-1}$ . Typical  $^{238}\text{U}$  activities in fine-grained sediments are  $\sim 2 \text{ dpm g}^{-1}$ , implying that the excess  $^{234}\text{Th}$  is  $\sim 10\%$  of the total. This value is barely detectable within the uncertainties of the measurements. Given these uncertainties, we have not calculated particle mixing rates from the excess  $^{234}\text{Th}$  data.

Beryllium-7 is not subject to the same constraints as  $^{234}\text{Th}$ .  $^7\text{Be}$  is added to estuaries dominantly from the atmosphere and, due to its short half-life, there is no "background" activity of this radionuclide in estuarine sediments. The mean flux of  $^7\text{Be}$  to the east coast of the USA is  $0.041 \pm 0.009 \text{ dpm cm}^{-2} \text{ d}^{-1}$ , equivalent to an inventory of

$3.1 \pm 0.7$  dpm  $\text{cm}^{-2}$ . The rapid removal of  $^7\text{Be}$  from estuarine waters ensures that the inventory of this radionuclide in sediments is that supported by the atmospheric input. Significant activities of  $^7\text{Be}$  are observed at all stations except those characterized by coarse-grained sediment (3, 4 and 5).

Inventories of  $^7\text{Be}$  are calculated from the data as:

$$I_{\text{Be}} = \sum_i \rho_{\text{dry}}^i \Delta x^i A_{\text{Be}}^i \quad (2)$$

where  $I_{\text{Be}}$  is the  $^7\text{Be}$  inventory (dpm/ $\text{cm}^2$ ),  $\rho_{\text{dry}}$  is the dry bulk density (g sed/ $\text{cm}^3$  wet sediment),  $\Delta x$  is the sampling interval (cm) and  $A_{\text{Be}}$  is the  $^7\text{Be}$  activity (dpm/g) of the  $i$ th depth interval. The inventories vary from station to station, with low values observed at the stations where the sediment is sandy (3 and 5) and at station 13. The latter is fine-grained, but the  $^7\text{Be}$  inventories are low both in the fall and spring at this site. The mean values of the inventory, 2.0 and 2.5 dpm/ $\text{cm}^2$  in fall, 1997 and spring 1998 respectively are comparable to the atmospheric flux. A slightly greater mean inventory in the spring, as well as greater specific activities at some of the stations, could be due to seasonal variations in  $^7\text{Be}$  input. Greater  $^7\text{Be}$  fluxes to the earth's surface in the spring are commonly attributed to enhanced deposition of  $^7\text{Be}$  produced in the stratosphere relative to other times of the year (Canuel et al. 1990).

The determination of short-term (seasonal time scale) particle mixing rates in estuarine sediments is relatively straightforward using short-lived natural radionuclides such as  $^7\text{Be}$ . Determination of longer term accumulation rates is more problematic, however because the estuarine sediment record can be perturbed to significant depths by particle mixing. These mixing events, when integrated over the half-lives of longer lived radionuclides such as  $^{210}\text{Pb}$  or  $^{14}\text{C}$ , can alter the radionuclide depth gradients and produce

apparent accumulation rates that are too high. The general diagenetic equation applied to radionuclides incorporates terms for both mixing and accumulation:

$$\frac{\partial A}{\partial t} = D_B \frac{\partial^2 A}{\partial x^2} - S \frac{\partial A}{\partial x} - \lambda A \quad (3)$$

where  $D_B$  is the particle mixing coefficient,  $S$  is the sediment accumulation rate,  $\lambda$  is the radioactive decay constant,  $A$  is the radionuclide activity and  $x$  is depth in the sediment column.

At steady-state,  $\partial A/\partial t = 0$  and the solution for eqn 3 for the conditions  $A = A_0$  at  $x = 0$ ,  $A \rightarrow 0$  as  $x \rightarrow \infty$  is:

$$A(z) = A_0 \exp\left[-\frac{S + \sqrt{S^2 + 4\lambda D_B}}{2D_B} x\right] \quad (4)$$

The relative importance of the parameters  $D_B$  and  $S$  in governing the radionuclide profiles depends on the magnitudes of the terms containing them and that of  $\lambda$  in eqn 4. Because the density of faunal abundance decreases with increasing depth in the sediment column, the terms containing  $S$  and  $\lambda$  become progressively more important in controlling the gradients of longer-lived radionuclides. By using tracers of progressively increasing half-life and thus deeper penetration in the sediment column, it is possible to resolve  $D_B$  and  $S$ . In particular,  $S$  is often unimportant compared with  $D_B$  in transporting short-lived radionuclides in the upper few centimeters of the sediment column, and the gradients of these tracers can be used to estimate  $D_B$ . Successful evaluation of  $S$  thus requires a multiple tracer approach.

Particle mixing rates have been calculated from the  $^7\text{Be}$  profiles using the diagenetic equation applied to short-lived radionuclides (eqn 3). If sediment

accumulation is sufficiently slow relative to particle mixing, it can be neglected, and eqn 4 simplifies to:

$$A(x) = A_0 \left[ \exp - x \sqrt{\frac{\lambda}{D_B}} \right] \quad (5)$$

where  $A(x)$  is the  $^7\text{Be}$  activity at depth  $x$  (cm),  $A_0$  is the activity at the sediment-water interface,  $\lambda$  is the decay constant ( $\text{y}^{-1}$ ) and  $D_B$  is the particle mixing coefficient ( $\text{cm}^2 \text{y}^{-1}$ ).

Particle mixing rates calculated from the  $^7\text{Be}$  profiles are given in Table 5. Rates are not calculated if the  $^7\text{Be}$  activities are very low ( $<0.3$  dpm/g) throughout the core or if the only significant activity is in the 0-1 cm depth interval. The values range from 0.1 to 247  $\text{cm}^2/\text{y}$  in the fall and 0.2 to 30  $\text{cm}^2/\text{y}$  in the spring. The range of rates (equivalent to  $0.003 \times 10^{-6}$  to  $7.8 \times 10^{-6}$   $\text{cm}^2/\text{sec}$ ) is similar to that observed in Long Island Sound (Aller et al. 1980). The stations with the greatest mixing are Station 1 (Meetinghouse Creek) and station 8 (Noyack Bay). In five out of the seven stations at which we can compare mixing in the fall and spring, the fall rates are greater. This is similar to the pattern in near-interface particle mixing observed in Long Island Sound (Aller and Cochran, 1976). The 53-day half-life of  $^7\text{Be}$  ensures that the fall cores reflect mixing processes over the summer, while the spring cores reflect winter conditions. The activity of the benthic fauna decreases as the water temperature drops in the winter, hence the mixing is reduced.

Although particle mixing by the benthic fauna plays an important role in controlling depth gradients in  $^7\text{Be}$ , in shallow waters other factors can be important. The water depths at some of the stations (1, 2, 4 and 13) are less than 2 m, and in such shallow waters, storms and even boating activities can disrupt the bottom, causing

physical mixing of the sediment. The depth of  $^7\text{Be}$  penetration into the sediment column is not notably deeper at these stations than at others, however.

#### IV. Sources of organic carbon to Peconic Estuary sediments

Carbon isotopes are useful tracers for the source(s) of carbon in estuarine sediments. Natural carbon comprises three isotopes:  $^{12}\text{C}$ ,  $^{13}\text{C}$  and  $^{14}\text{C}$ . The proportions of  $^{13}\text{C}$  to  $^{12}\text{C}$  vary in organic matter due to fractionation relative to the  $\text{CO}_2$  reservoir used (atmospheric  $\text{CO}_2$  for terrestrial plants vs. dissolved inorganic carbon for estuarine plants) and the metabolic pathway for organic matter synthesis ( $\text{C}_3$  vs.  $\text{C}_4$  plants). The ratio of  $^{13}\text{C}$  to  $^{12}\text{C}$  is expressed as the per mil difference in the measured ratio relative to a standard (written as  $\delta^{13}\text{C}$ ). Carbon-14 is affected by both the fractionation process described above as well as radioactive decay. Its values are normalized to a reference  $\delta^{13}\text{C}$  value and resultant  $\Delta^{14}\text{C}$  values are converted into radiocarbon ages.

Samples for radiocarbon analysis were submitted to the National Ocean Sciences Accelerator Mass Spectrometry Facility at the Woods Hole Oceanographic Institution. Although the analyses are expensive, the technique requires only milligram quantities of carbon and typically has a precision of ~3% on sample ages of ~2000 y BP. The radiocarbon data are given in Table 6, together with measurements of the organic carbon concentrations and isotopic composition ( $\delta^{13}\text{C}$ ) of the sediments. Although the carbon isotopic data for this study are limited, they provide insights into carbon sources and cycling in the estuary.

As summarized in Table 6a, the values of  $\delta^{13}\text{C}$  range from -17 to -20.4 ‰. Radiocarbon ages of the sedimentary organic matter range from 1340 to 2140 years BP.

There are at least four sources of organic carbon to Peconic estuary sediments: terrestrial C3 plants, terrestrial marsh grasses (C4), phytoplankton (marine C3 plants) and submerged aquatic vegetation (marine C4 plants). Each source will have a different isotopic signature, as indicated in Table 6b. The radiocarbon ages at depth in the four gravity cores analyzed are typically greater than would be predicted if organic matter with radiocarbon age = 0 were buried and the radiocarbon decayed with time. In core 7, it is possible to follow the increase in radiocarbon age with depth in the sediments. Using the samples below 29 cm to define the trend and extrapolating to the sediment-water interface yields an age of 1720 years BP for the initial age of the carbon buried at depth (Fig. 5). A similar pattern was observed in the sediments of Long Island Sound (Benoit et al. 1979) and was interpreted to represent old, refractory terrestrial material that was transported into the estuary, deposited and buried by sediment accumulation. The  $\delta^{13}\text{C}$  of this material is isotopically heavier than terrestrial C3 plants (most land plants,  $\sim -26\text{‰}$ ). Such an isotopic composition could be produced by a mixture of terrestrial C3 material with terrestrial marsh grasses (C4 plants,  $\sim -17\text{‰}$ ). The  $\delta^{13}\text{C}$  values of the sedimentary organic carbon also could be produced by a mixture of phytoplankton (marine C3 plants,  $\sim -20\text{‰}$ ) and sea grasses (marine C4 plants,  $-14\text{‰}$ ). The initial radiocarbon age of such material should be zero age, or even "future" age given the contamination of the contemporary  $\text{CO}_2$  reservoirs by bomb radiocarbon. However, the surficial sample from core 7 yields a radiocarbon age of 1550 years BP, close to the extrapolated value of 1720 years BP and significantly different from that expected from the marine carbon reservoir. The slightly younger age relative to the extrapolated value may arise from a small fraction of marine carbon present in this sample. Interestingly the presence of a small

amount of sewage-derived carbon would produce a similar effect. Such material would have a terrestrial C3  $\delta^{13}\text{C}$  signature and low radiocarbon age. The similar pattern of radiocarbon age with depth in a Long Island Sound sediment core was interpreted by Benoit et al (1979) to result from rapid decomposition of marine C in the upper centimeters of the sediment column such that only the refractory C remained to be buried. Turekian et al (1980) estimated a residence time of plankton-derived carbon of 2.2 years in the upper 5 cm of Long Island Sound sediments. In the case of the Peconic estuary, low in situ production or rapid turnover of marine carbon could account for the sedimentary carbon reservoir being dominated by terrestrial organic material. A precise evaluation of the sources and turnover rate of marine carbon requires an estimate of annual production in the system and additional details on the carbon isotopic composition of organic matter in both box and gravity cores.

#### **V. Sediment accumulation rates and organic carbon burial in the Peconic Estuary**

The longer term storage of particulate organic carbon in Peconic Estuary sediments can be determined from knowledge of the rate of sediment accumulation and organic carbon content of the sediments. As pointed out earlier in this report, particle mixing in estuarine sediments makes it difficult to extract rates of sediment accumulation from radionuclide profiles. In order to do so, we use longer lived radionuclides that are present to greater depths in the sediment column and whose distributions are less dominated by mixing than are those of the short-lived radionuclides such as  $^7\text{Be}$ . Both  $^{210}\text{Pb}$  (half-life = 22.3 y), a natural radionuclide in the  $^{238}\text{U}$  decay series, and  $^{14}\text{C}$  (half-life

= 5568 y) can be used to determine accumulation chronologies of estuarine sediments. In the present study we have analyzed the gravity cores for  $^{210}\text{Pb}$  and have analyzed selected samples for radiocarbon.

Lead-210 in gravity core sediments was measured by gamma spectrometry in a fashion analogous to that described in Section III for the box cores. Radium-226, the grandparent of  $^{210}\text{Pb}$ , was measured simultaneously through the gamma emission of  $^{214}\text{Bi}$ . The  $^{210}\text{Pb}$  data are given in Table 7 and are plotted in Fig 6. Inventories of excess  $^{210}\text{Pb}$  in the sediments range from 12.2 to 36.9 dpm/cm<sup>2</sup>. The mean,  $21.5 \pm 7.9$  dpm/cm<sup>2</sup> compares with a values of 22 – 38 dpm/cm<sup>2</sup> in marsh and soil deposits from the northeastern US (Graustein and Turekian 1986). Thus the dominant source of  $^{210}\text{Pb}$  to the Peconic system appears to be direct atmospheric deposition.

The depth distribution of excess  $^{210}\text{Pb}$  (i. e. that unsupported by  $^{226}\text{Ra}$ ) may be used to determine sediment accumulation rates, providing mixing is low. In the cores analyzed, excess  $^{210}\text{Pb}$  is confined to the upper 10 to 15 cm of the sediment column. We have shown that the upper few (0-5) cm of the sediments are mixed on time scales of months, as seen in the  $^7\text{Be}$  profiles. If we apply the  $^7\text{Be}$  mixing rates to the upper 10-15 cm of the sediment column, we can use eqn 4 to determine values of S, the sediment accumulation rate. Another approach that sets upper limits on the rate of accumulation is to assume that mixing is unimportant below the upper few cm and calculate sediment accumulation rates from:

$$A(x) = A_0 \exp\left[-\frac{\lambda x}{S}\right] \quad (6)$$

where  $A(x)$  and  $A_0$  are activities of excess  $^{210}\text{Pb}$  at depth  $x$  and depth 0, respectively,  $\lambda$  is the decay constant and  $s$  is the sediment accumulation rate. The excess  $^{210}\text{Pb}$  profiles in

the Peconic cores show regular decreases in activity, and upper limits on S may be calculated from plots of  $\ln A$  vs  $x$ . (Fig. 6). Values of S determined from these plots are given in Table 7 and range from 0.09 to 0.20 cm/y.

The reliability of these rates can be determined by comparison to rates calculated with a longer lived radionuclide such as  $^{14}\text{C}$ . As noted above, radiocarbon has multiple sources to estuaries, including input from atmospheric testing of atomic weapons (primarily in the 1950's and early 1960's) and natural production from the interaction of cosmic rays with atmospheric gases. Our strategy for radiocarbon analyses has been to test a few of the cores by analyzing samples from deeper depths ( $> \sim 30$  cm) in the cores that are likely to be less affected by particle mixing. Comparison of the calculated accumulation rates can be used to evaluate the importance of mixing in affecting the  $^{210}\text{Pb}$  profiles. Sediment accumulation rates determined from the age differences in each core are given in Table 8. One core (core 7) was selected for more detailed radiocarbon analysis. A linear relationship in radiocarbon age vs. depth holds for the three samples at depth in this core and intersects the sediment water interface at  $\sim 1700$  years. As noted earlier in this report, this age corresponds to that of the refractory, terrestrial organic carbon that is input to the system and is ultimately buried.

Burial rates of particulate organic carbon in Peconic sediments can be calculated from the radiocarbon accumulation rates, assuming that these rates are relatively unaffected by mixing:

$$J_{\text{burial}} = C_{\infty} \rho_{\text{dry}} S \quad (7)$$

where  $J_{\text{burial}}$  is the burial rate of organic carbon ( $\text{g C}/\text{cm}^2/\text{y}$ ),  $C_{\infty}$  is the organic carbon content at depth ( $\text{gC}/\text{g dry sed}$ ),  $\rho_{\text{dry}}$  is the dry bulk density ( $\text{g sed}/\text{cm}^3$  wet sed) and S is

the sediment accumulation rate derived from  $^{14}\text{C}$  (cm/y). Rates of organic carbon burial calculated from the radiocarbon data range from 0.34 to 1.8 mg C/cm<sup>2</sup>/y. However, we emphasize that this material appears to be primarily terrestrial rather than marine particulate organic carbon.

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## **VII. Acknowledgements**

This project was funded by the Peconic Estuary Program. The cost of the radiocarbon determinations was offset by support from the National Science Foundations to the National Ocean Accelerator Mass Spectrometry Facility. The sampling was made possible by the superb cooperation of Chris Smith and his colleagues at the Cornell Cooperative Extension in Riverhead and by the Suffolk County Department of Health Services.

## CORE LOCATIONS/DATES

STATION NUMBER	DATE SAMPLED	LOCATION	LATITUDE	LONGITUDE	WATER DEPTH (m)	NOTES
<b>Gravity Cores</b>						
1	11/18/97	Meetinghouse Creek East	40 55.619N	72 36.606W	2.0	
2	11/18/97	Reeves Bay	40 54.510N	72 36.885W	1.4	
3	11/18/97	Flanders Bay	40 55.202N	72 35.321W	2.4	No Core
4	11/18/97	Great Peconic Bay West	40 55.766N	72 36.509W	0.9	No Core
5	11/18/97	Great Peconic Bay North	40 58.425N	72 31.425W	2.4	No Core
6	11/18/97	Great Peconic Bay	40 56.002N	72 30.294W	7.0	
7	11/18/97	Little Peconic Bay	40 59.616N	72 25.067W	8.2	
8	11/18/97	Noyac Bay	41 00.786N	72 20.553W	6.4	
9	11/18/97	West Neck Bay	41 03.786N	72 21.679W	4.1	
13	11/18/97	East Creek	40 56.617N	72 34.228W	2.0	
<b>Box Cores Fall 1997</b>						
1	9/8/97	Meetinghouse Creek East	40 55.372N	72 36.368W	1.8	SAV Present, Numerous Shells, Anoxic to surfa
2	9/16/97	Reeves Bay	40 54.303N	72 36.533W	1.2	SAV Present, RPD at 1mm.
3	9/8/97	Flanders Bay	40 55.202N	72 35.173W	2.1	SAV Present, Oxidized Fe Stain, RPD at 10mm.
4	9/8/97	Great Peconic Bay West	40 55.462N	72 36.311W	5.2	Nassarius Abundant, RPD at 15mm.
5	9/8/97	Great Peconic Bay North	40 58.255N	72 31.262W	1.8	Sloped Interface, RPD at 10mm.
6	9/8/97	Great Peconic Bay	40 56.025N	72 30.163W	6.7	Abundant Nassarius and Polychaetes
7	9/10/97	Little Peconic Bay	40 59.394N	72 25.000W	7.6	
8	9/10/97	Noyac Bay	41 00.566N	72 20.537W	6.7	Silty Mud, RPD at 30mm.
9	9/10/97	West Neck Bay	41 03.484N	72 21.312W	4.0	Mud, RPD at 20mm, abundant polychaetes.
13	9/8/97	East Creek	40 56.368N	72 34.135W	1.8	SAV present, RPD at 10mm, abundant Nassarius
<b>Box Cores Spring 1998</b>						
1	4/16/98	Meetinghouse Creek East	40 55.610N	72 36.634W	1.8	SAV present
2	4/16/98	Reeves Bay	40 54.510N	72 36.942W	1.5	SAV Present
3	4/16/98	Flanders Bay	40 55.226N	72 35.295W	2.4	SAV Present
4	4/16/98	Great Peconic Bay West	40 55.773N	72 36.513W	1.2	
5	4/29/98	Great Peconic Bay North	40 58.429N	72 31.423W	2.1	Sandy
6	4/16/98	Great Peconic Bay	40 56.012N	72 30.310W	7.3	
7	4/29/98	Little Peconic Bay	40 59.648N	72 25.109W	7.4	SAV present, RPD at 10mm
8	4/29/98	Noyac Bay	41 00.789N	72 20.554W	6.1	RPD at 10mm, Flocculent interface.
9	4/29/98	West Neck Bay	41 03.876N	72 21.651W	3.1	Abundant Polychaetes
13	4/16/98	East Creek	40 56.368N	72 34.135W	1.8	SAV Present

NOTES: SAV - Submerged Aquatic Vegetation, RPD - Redox Potential Discontinuity.

**Table 2: Physical/chemical properties of Peconic Estuary box cores**

Station	Depth (cm)	Water content (%)	Dry bulk density (g dry/cm <sup>3</sup> wet)	Sedimentary Organic C (%)	Sedimentary Organic N (%)
Fall, 1997					
Station 1	0-1	62.6	0.495	2.60	0.285
	1-2	59.7	0.547	3.02	0.282
	2-3	58.4	0.570	2.92	0.305
	3-4	57.1	0.594	2.72	0.235
	4-5	49.3	0.751	1.74	0.127
	5-7	42.9	0.898	1.95	0.161
	7-10.5	39.3	0.988	na	na
Station 2	0-1	64.2	0.468	5.07	0.469
	1-2	59.4	0.552	4.44	0.394
	2-3	58.8	0.600	3.72	0.277
	3-4	58.2	0.612	6.80	0.603
	4-5	59.3	0.554	5.24	0.457
	5-7	72.0	0.345	6.69	0.607
	7-10	70.0	0.375	na	na
Station 3	0-1	20.2	1.599	0.13	0.002
	1-2	19.2	1.638	0.10	0.005
	2-3	18.7	1.659	-0.01	-0.004
	3-4	19.2	1.638	-0.01	-0.008
	4-5	19.9	1.610	-0.01	-0.006
	5-6	19.9	1.610	na	na
Station 4	0-1	47.7	0.786	0.43	0.025
	1-2	41.0	0.945	1.65	0.129
	2-3	34.9	1.107	0.72	0.048
	3-4	22.8	1.499	0.78	0.048
	4-5	25.8	1.392	0.58	0.028
	5-7	24.8	1.427	0.47	0.028
	7-9	23.1	1.488	na	na
Station 5	0-1	20.1	1.603	0.07	0.001
	1-2	19.2	1.638	0.06	0.001
	2-3	19.4	1.630	0.06	0.009
	3-4	19.7	1.618	0.05	0.005
	4-5	20.5	1.587	0.05	0.006
	5-6.9	24.1	1.452	na	na

**Table 2: Physical/chemical properties of Peconic Estuary box cores**

Station	Depth (cm)	Water content (%)	Dry bulk density (g dry/cm <sup>3</sup> wet)	Sedimentary Organic C (%)	Sedimentary Organic N (%)
Station 6	0-1	61.2	0.520	1.90	0.184
	1-2	57.8	0.581	1.96	0.159
	2-3	57.2	0.593	1.92	0.181
	3-4	56.4	0.608	2.01	0.189
	4-5	55.2	0.631	2.13	0.200
	5-7	55.4	0.627	na	na
	7-9	54.0	0.654	na	na
	9-11	52.4	0.687	na	na
Station 7	0-1	61.7	0.511	1.61	0.147
	1-2	55.6	0.623	na	na
	2-3	52.9	0.676	1.44	0.128
	3-4	51.5	0.705	1.48	0.153
	4-5	50.2	0.732	1.45	0.152
	5-7	49.6	0.745	na	na
	7-10	46.0	0.825	na	na
Station 8	0-1	61.6	0.513	2.08	0.240
	1-2	60.3	0.536	2.17	0.236
	2-3	59.1	0.557	1.82	0.160
	3-4	58.3	0.572	1.95	0.223
	4-5	57.8	0.581	1.66	0.155
	5-7	58.7	0.585	1.88	0.210
	7-10	57.2	0.593	na	na
Station 9	0-1	68.4	0.400	3.07	0.312
	1-2	64.5	0.463	2.99	0.249
	2-3	63.3	0.483	2.84	0.285
	3-4	62.5	0.497	2.74	0.221
	4-5	61.6	0.513	2.94	0.291
	5-7	61.5	0.515	na	na
	7-10	60.4	0.534	na	na
Station 13	0-1	86.5	0.150	3.83	0.297
	1-2	85.4	0.164	3.01	0.229
	2-3	82.3	0.203	5.02	0.461
	3-4	75.3	0.297	4.56	0.421
	4-5	70.3	0.371	4.12	0.366
	5-7	71.9	0.347	2.44	0.267
	7-9	71.7	0.349	na	na

**Table 2: Physical/chemical properties of Peconic Estuary box cores**

Station	Depth (cm)	Water content (%)	Dry bulk density (g dry/cm <sup>3</sup> wet)	Sedimentary Organic C (%)	Sedimentary Organic N (%)
Spring, 1998					
Station 1	0-1	61.8	0.509	1.92	0.200
	1-2	68.7	0.395	2.52	0.230
	2-3	61.4	0.516	2.04	0.220
	3-4	57.2	0.593	2.80	0.270
	4-5	55.3	0.629	na	na
	5-7	57.2	0.593	na	na
Station 2	0-1	79.4	0.241	6.30	0.540
	1-2	76.3	0.283	5.72	0.510
	2-3	76.6	0.279	5.78	0.520
	3-4	76.5	0.280	5.80	0.560
	4-5	73.1	0.329	na	na
	5-7	73.9	0.317	na	na
Station 3	0-1	22.0	1.529	0.10	0.010
	1-2	19.1	1.643	0.10	0.008
	2-3	18.9	1.651	0.69	0.010
	3-4	18.6	1.663	0.06	0.004
	4-5	19.0	1.647	na	na
Station 4	0-1	19.4	1.630	0.21	0.020
	1-2	18.8	1.655	0.12	0.010
	2-3	18.5	1.667	0.11	0.010
	3-4	17.8	1.696	0.13	0.010
	4-5	17.5	1.708	na	na
	5-7	17.3	1.717	na	na
Station 5	0-1	24.1	1.452	0.08	0.006
	1-2	22.4	1.514	0.08	0.006
	2-3	21.2	1.560	0.05	0.004
	3-4	19.5	1.626	na	na
	4-5	14.5	1.840	na	na
	5-7	21.4	1.552	na	na
Station 6	0-1	67.8	0.410	1.62	0.180
	1-2	63.2	0.485	1.70	0.190
	2-3	59.9	0.543	1.71	0.180
	3-4	58.7	0.565	1.72	0.200
	4-5	57.7	0.583	na	na
	5-7	56.3	0.610	na	na

**Table 2: Physical/chemical properties of Peconic Estuary box cores**

Station	Depth (cm)	Water content (%)	Dry bulk density (g dry/cm <sup>3</sup> wet)	Sedimentary Organic C (%)	Sedimentary Organic N (%)
Station 7	0-1	46.3	0.818	1.53	0.200
	1-2	85.4	0.164	1.50	0.180
	2-3	71.3	0.355	1.38	0.160
Station 8	0-1	74.6	0.307	2.04	0.250
	1-2	66.5	0.430	1.93	0.250
	2-3	61.5	0.515	2.12	0.250
	3-4	60.4	0.534	na	na
	4-5	na	na	na	na
	5-7	59.0	0.559	na	na
Station 9	0-1	74.6	0.307	3.00	0.350
	1-2	67.1	0.421	2.73	0.310
	2-3	63.1	0.487	2.64	0.280
	3-4	63.0	0.489	na	na
	4-5	64.0	0.472	na	na
	5-7	63.7	0.477	na	na
Station 13	0-1	82.3	0.203	5.28	0.620
	1-2	75.1	0.300	4.58	0.530
	2-3	74.2	0.313	3.70	0.420
	3-4	72.8	0.333	na	na
	4-5	71.4	0.354	na	na
	5-7	69.3	0.386	na	na

na= not analyzed

**Table 3: Physical/chemical properties of Peconic Estuary gravity cores**

Station	Depth (cm)	Water content (%)	Dry bulk density (g dry/cm <sup>3</sup> wet)	Sedimentary Organic C (%)	Sedimentary Organic N (%)
1	0-3	55.1	0.842	2.43	0.371
	3-6	40.6	0.804	1.68	0.140
	6-9	42.1	0.766	1.60	0.121
	9-14	46.6	0.721	1.81	0.119
	14-19	54.2	0.613	3.21	0.171
	19-24	62.3	0.443	6.22	0.419
	24-29	60.4	0.409	5.59	0.391
	29-34	57.2	0.522	5.92	0.328
	34-36	63.2	0.454	na	na
2	0-3	71.6	0.274	6.74	0.459
	3-6	79.8	0.208	6.80	0.618
	6-8	75.0	0.265	6.37	0.396
	9-14	74.2	0.278	5.59	0.292
	14-19	71.9	0.312	5.10	0.501
	19-24	69.3	0.329	5.09	0.450
	24-29	68.7	0.358	5.14	0.546
	29-34	68.1	0.414	5.30	0.521
	34-39	66.0	0.386	5.88	0.380
	39-44	66.3	0.375	6.32	0.425
44-49	69.1	0.318	nd	nd	
6	0-3	59.8	0.426	1.84	0.393
	3-6	56.4	0.549	1.85	0.279
	6-9	53.5	0.624	1.77	0.306
	9-14	51.0	0.681	1.47	0.226
	14-19	51.9	0.647	1.57	0.234
	19-24	50.4	0.681	1.56	0.342
	24-29	50.4	0.704	1.51	0.252
	29-32	36.8	1.362	1.83	0.389
7	0-3	54.6	0.653	1.12	0.276
	3-6	49.7	0.700	1.55	0.309
	6-9	49.4	0.785	2.81	0.532
	9-14	47.4	0.800	1.57	0.600
	14-19	46.8	0.749	1.96	0.477
	19-24	44.6	0.812	1.34	0.447
	24-29	44.7	0.835	3.68	0.930
	29-34	48.4	0.755	1.37	0.363
	34-39	47.2	0.761	1.21	0.247
	39-44	46.4	0.795	2.17	0.556
	44-49	45.8	0.806	1.89	0.241
	49-52.5	44.3	0.519	3.21	0.672

**Table 3: Physical/chemical properties of Peconic Estuary gravity cores**

Station	Depth (cm)	Water content	Dry bulk density	Sedimentary Organic C	Sedimentary Organic N
8	0-3	62.9	0.492	1.71	0.167
	3-6	61.4	0.511	na	na
	6-9	56.6	0.653	1.61	0.182
	9-14	54.7	0.596	1.67	0.181
	14-19	52.2	0.727	1.45	0.154
	19-24	47.7	0.659	1.11	0.094
	24-29	44.0	0.880	1.15	0.096
	29-34	49.6	0.727	0.97	0.083
	34-39	52.7	0.641	1.47	0.159
	39-44	50.6	0.698	1.48	0.162
	44-49	50.8	0.681	1.35	0.120
9	0-3	64.3	0.577	2.60	0.275
	3-6	60.4	0.577	2.42	0.253
	6-9	56.2	0.606	2.29	0.235
	9-14	57.0	0.579	2.27	0.234
	14-19	54.1	0.630	1.62	0.167
	19-24	52.8	0.630	1.89	0.190
	24-29	53.1	0.647	1.99	0.197
	29-34	53.8	0.613	2.07	0.205
	34-39	51.7	0.653	1.92	0.188
	39-44	50.4	0.715	1.98	0.190
	44-49	50.5	0.662	2.12	0.201
13	0-3	77.4	0.265	3.85	0.398
	3-6	73.7	0.341	na	na
	6-9	69.1	0.407	4.47	0.338
	9-14	68.5	0.414	5.39	0.378
	14-19	65.3	0.431	5.13	0.368
	19-24	38.6	0.965	1.18	0.063
	24-29	23.9	1.192	0.52	0.020

**Table 4: Radiochemical data for Peconic Estuary box cores**

Station	Depth (cm)	Dry bulk density (g dry/cm <sup>3</sup> wet)	<sup>234</sup> Th (dpm/g)	error	<sup>7</sup> Be (dpm/g)	error	<sup>210</sup> Pb (dpm/g)	error	<sup>226</sup> Ra (dpm/g)	error
Fall, 1997										
Station 1	0-1	0.495	1.69	0.30	1.16	0.32	6.87	0.37	1.01	0.07
	1-2	0.547	2.26	0.34	0.09	0.43	7.71	0.46	1.26	0.08
	2-3	0.570	1.73	0.29	0.79	0.38	6.21	0.36	0.83	0.06
	3-4	0.594	nm		0.60		nm		nm	
	4-5	0.751	1.36	0.21	0.30	0.24	5.78	0.27	0.97	0.05
	Inventory					1.66	0.16			
Station 2	0-1	0.468	1.07	0.40	2.64	0.48	9.00	0.56	1.21	0.18
	1-2	0.552	1.58	0.45	0.62	0.52	10.64	0.58	1.29	0.10
	2-3	0.600	nm		0.64				nm	
	3-4	0.612	2.52	0.43	0.66	0.77	12.12	0.58	1.21	0.10
	4-5	0.554	1.86	0.36	0.66	0.41	7.55	0.45	1.09	0.08
	Inventory					2.73	0.41			
Station 3	0-1	1.599	0.41	0.12	0.29	0.12	0.48	0.13	0.19	0.03
	1-2	1.638	0.32	0.12	0.25	0.15	0.47	0.14	0.27	0.03
	2-3	1.659	0.36	0.11	0.13	0.16	0.66	0.13	0.25	0.03
	3-4	1.638	0.34	0.13	0.33	0.22	0.45	0.15	0.28	0.03
	4-5	1.610	0.34	0.12	0.13	0.13	0.79	0.13	0.30	0.02
	Inventory					1.84	0.34			
Station 4	0-1	0.786	1.54	0.22	0.97	0.21	3.99	0.26	0.85	0.05
	1-2	0.945	1.21	0.21	0.89	0.23	3.82	0.24	0.88	0.05
	2-3	1.107	1.12	0.19	0.30	0.27	3.40	0.24	0.79	0.04
	3-4	1.499	1.08	0.12	0.25	0.22	3.21	0.15	0.73	0.03
	4-5	1.392	0.69	0.19	0.24	0.21	2.25	0.21	0.71	0.04
	5-7	1.427	0.85	0.15	0.39	0.28	1.55	0.17	0.55	0.03
Inventory					3.76	0.49				
Station 5	0-1	1.603	0.38	0.13	0.09	0.13	0.70	0.14	0.26	0.03
	1-2	1.638	0.30	0.12	-0.01	0.13	0.35	0.13	0.32	0.02
	2-3	1.630	0.52	0.09	0.10	0.13	0.49	0.1	0.29	0.02
	3-4	1.618	0.27	0.14	0.27	0.23	0.37	0.15	0.37	0.03
	4-5	1.567	0.46	0.12	0.00	0.17	0.60	0.13	0.24	0.03
	Inventory					0.74	0.35			
Station 6	0-1	0.520	2.43	0.24	0.55	0.24	5.77	0.29	1.55	0.05
	1-2	0.581	2.24	0.29	0.06	0.32	6.32	0.32	1.71	0.06
	2-3	0.593	2.00	0.25	-0.01	0.39	6.70	0.3	1.41	0.06
	3-4	0.608	nm		0.28				nm	
	4-5	0.631	2.78	0.25	0.57	0.33	6.63	0.31	1.52	0.06
	Inventory					0.85	0.15			



**Table 4: Radiochemical data for Peconic Estuary box cores**

Station	Depth (cm)	Dry bulk density (g dry/cm <sup>3</sup> wet)	<sup>234</sup> Th (dpm/g)	error	<sup>7</sup> Be (dpm/g)	error	<sup>210</sup> Pb (dpm/g)	error	<sup>226</sup> Ra (dpm/g)	error
Station 3	0-1	1.529	0.61	0.09	0.27	0.08	0.82	0.05		
	1-2	1.643	0.73	0.08	0.13	0.06	0.57	0.04		
	2-3	1.651	0.42	0.08	0.06		0.85	0.04		
	3-4	1.663	nm		0.00		nm			
	4-5	1.647	0.45	0.11	0.00	0.00	1.35	0.07		
	Inventory					0.73	0.02			
Station 4	0-1	1.630	0.79	0.06	0.27	0.05	1.36	0.04		
	1-2	1.655	0.73	0.05	0.15	0.04	1.19	0.03		
	2-3	1.667	1.19	0.06	0.19	0.06	1.75	0.04		
	3-4	1.696	nm		0.10		nm			
	4-5	1.708	0.87	0.07	0.00	0.00	1.22	0.04		
	Inventory					1.17	0.02			
Station 5	0-1	1.452	0.36	0.06	0.44	0.09	0.40	0.03		
	1-2	1.514	0.23	0.07	0.33	0.08	0.36	0.02		
	2-3	1.560	0.42	0.03	0.20	0.04	0.44	0.01		
	Inventory					1.45	0.04			
Station 6	0-1	0.410	6.30	0.31	5.80	0.29	11.03	0.3		
	1-2	0.485	1.96	0.16	1.41	0.14	5.98	0.14		
	2-3	0.543	2.74	0.19	0.05	0.23	6.26	0.18		
	3-4	0.565	nm		0.10		nm			
	4-5	0.583	2.66	0.16	0.15	0.22	7.31	0.18		
	Inventory					3.23	0.05			
Station 7	0-1	0.51	2.87	0.17	8.04	0.24	7.15	0.14		
	1-2	0.62	2.10	0.08	1.48	0.12	7.04	0.07		
	2-3	0.68	2.34	0.15	0.14	0.18	6.44	0.13		
	Inventory					5.11	0.04			
Station 8	0-1	0.307	3.58	0.25	10.47	0.42	8.72	0.24		
	1-2	0.430	2.85	0.17	6.47	0.26	8.89	0.18		
	2-3	0.515	2.22	0.16	2.04	0.20	8.40	0.17		
	Inventory					7.05	0.04			
Station 9	0-1	0.307	2.51	0.15	5.97	0.24	6.76	0.14		
	1-2	0.421	2.67	0.16	1.67	0.22	5.88	0.15		
	2-3	0.487	3.12	0.19	0.04	0.22	4.93	0.15		
	Inventory					2.56	0.03			
Station 13	0-1	0.203	0.56	0.13	0.74	0.07	nm			
	1-2	0.300	2.28	0.16	0.28	0.20	7.51	0.19		
	2-3	0.313	2.48	0.15	0.00	0.00	8.34	0.15		
	Inventory					0.23	0.00			

*Numbers in italics are interpolated or estimated*

**Table 5: Particle mixing rates in Peconic Estuary sediments**

Station	Fall, 1997 (cm <sup>2</sup> /y)	Spring, 1998 (cm <sup>2</sup> /y)	Remarks*
1	247	24	Poorly sorted shell hash, dominated by physical mixing
2	2.3	2.9	
3	nd	nd	
4	12.8	0.4	Medium-coarse sand, highly bioturbated
5	nd	30.3	Fine sand, moderate bioturbation
6	nd	0.8	Stable mud deposit, well developed benthic community
7	8.7	1.2	Shell deposit, high energy conditions, bioturbated
8	41.2	6.9	Muddy deposit, moderate bioturbation, intermittent physical disturbance
9	0.1	0.2	Muddy deposit, bioturbated
13	8.1	0.4	Muddy deposit, physical depositional control, bioturbation in upper few cm.

nd- not determinable

\*Based on sediment X-radiography

**Table 6a: Radiocarbon analyses of Peconic estuary sediments**

Station	Depth (cm)	Organic carbon % (g C/g sed)	$\delta^{13}\text{C}$ ‰	Radiocarbon age (years BP)	error
2	29-34	5.10	-17.14	1340	50
	44-49	6.18	-17.00	1510	55
7	0-3	1.18	-20.42	1550	55
	29-34	1.19	-19.56	1980	55
	39-44	1.46	-19.38	2090	55
	49-52	1.48	-19.35	2140	55
8	29-34	1.51	-18.60	1780	55
	44-49	1.65	-18.82	1960	55
9	29-34	2.16	-18.64	1410	55
	44-48.5	2.35	-19.12	1930	70

**Table 6b: Carbon isotopic composition of carbon sources in Peconic Estuary**

Source	$\delta^{13}\text{C}$ (‰)
Terrestrial plants (C3)	-26
Terrestrial marsh grasses (C4)	-17
Plankton	-20
Marine grasses (C4)	-14

TABLE 7: PECONIC ESTUARY GRAVITY CORES: <sup>210</sup>Pb DATA

Station	Depth (cm)	Density (g dry/cm <sup>3</sup> wet)	<sup>210</sup> Pb (dpm/g)	<sup>226</sup> Ra (dpm/g)	Excess <sup>210</sup> Pb (dpm/g)
1	0-3	0.842	4.84 ± 0.17	1.31 ± 0.05	3.53 ± 0.18
	3-6	0.804	2.36 ± 0.05	1.03 ± 0.02	1.33 ± 0.05
	6-9	0.766	1.44 ± 0.08	0.78 ± 0.04	0.67 ± 0.09
	9-14	0.721	0.94 ± 0.06	0.97 ± 0.03	-0.04 ± 0.06
	14-19	0.613	1.39 ± 0.08	0.90 ± 0.03	0.49 ± 0.08
	19-24	0.443	0.89 ± 0.03	0.86 ± 0.02	0.03 ± 0.03
	Inventory (dpm/cm <sup>2</sup> )				
2	0-3	0.274	8.98 ± 0.42	1.37 ± 0.09	7.61 ± 0.43
	3-6	0.208	ND	ND	4.75
	6-9	0.265	3.38 ± 0.18	1.49 ± 0.09	1.89 ± 0.20
	9-14	0.278	2.35 ± 0.10	1.43 ± 0.05	0.92 ± 0.12
	14-19	0.312	1.71 ± 0.06	1.45 ± 0.03	0.26 ± 0.06
	19-24	0.329	1.63 ± 0.09	1.58 ± 0.06	0.05 ± 0.11
	24-29	0.358	1.41 ± 0.08	1.46 ± 0.05	-0.05 ± 0.10
Inventory (dpm/cm <sup>2</sup> )					12.2
6	0-3	0.426	6.53 ± 0.15	1.74 ± 0.04	4.80 ± 0.16
	3-6	0.549	5.80 ± 0.16	2.02 ± 0.06	3.78 ± 0.17
	6-9	0.624	3.11 ± 0.06	1.92 ± 0.03	1.19 ± 0.07
	9-14	0.681	2.17 ± 0.09	1.63 ± 0.04	0.54 ± 0.10
	14-19	0.647	2.48 ± 0.07	1.54 ± 0.03	0.93 ± 0.07
	19-24	0.681	1.76 ± 0.05	1.59 ± 0.02	0.17 ± 0.05
	24-29	0.704	1.79 ± 0.09	1.56 ± 0.04	0.23 ± 0.10
	29-32	1.362	1.39 ± 0.08	1.05 ± 0.04	0.33 ± 0.09
Inventory (dpm/cm <sup>2</sup> )					20.8
7	0-3	0.653	4.95 ± 0.17	1.43 ± 0.05	3.52 ± 0.17
	3-6	0.700	4.25 ± 0.08	1.47 ± 0.03	2.79 ± 0.09
	6-9	0.785	3.28 ± 0.12	1.52 ± 0.05	1.76 ± 0.13
	9-14	0.800	2.42 ± 0.06	1.66 ± 0.03	0.76 ± 0.07
	14-19	0.749	1.73 ± 0.07	1.49 ± 0.04	0.24 ± 0.08
	19-24	0.812	1.51 ± 0.08	1.46 ± 0.04	0.05 ± 0.09
	24-29	0.835	1.77 ± 0.06	1.52 ± 0.03	0.26 ± 0.07
Inventory (dpm/cm <sup>2</sup> )					21.5

TABLE 7: PECONIC ESTUARY GRAVITY CORES:  $^{210}\text{Pb}$  DATA

Station	Depth (cm)	Density (g dry/cm <sup>3</sup> wet)	$^{210}\text{Pb}$ (dpm/g)	$^{226}\text{Ra}$ (dpm/g)	Excess $^{210}\text{Pb}$ (dpm/g)
8	0-3	0.492	8.88 ± 0.26	1.78 ± 0.06	7.10 ± 0.26
	3-6	0.511	7.70 ± 0.24	1.83 ± 0.06	5.87 ± 0.25
	6-9	0.653	5.39 ± 0.16	1.89 ± 0.06	3.50 ± 0.17
	9-14	0.596	3.59 ± 0.07	1.65 ± 0.03	1.95 ± 0.07
	14-19	0.727	2.92 ± 0.10	1.80 ± 0.05	1.13 ± 0.11
	19-24	0.659	1.98 ± 0.09	1.67 ± 0.05	0.30 ± 0.10
	24-29	0.880	1.51 ± 0.07	1.45 ± 0.04	0.05 ± 0.08
	29-34	0.727	1.84 ± 0.08	1.69 ± 0.05	0.16 ± 0.10
	Inventory (dpm/cm <sup>2</sup> )				36.9
9	0-3	0.577	6.90 ± 0.11	1.62 ± 0.03	5.28 ± 0.11
	3-6	0.577	4.38 ± 0.08	1.79 ± 0.03	2.59 ± 0.09
	6-9	0.606	3.10 ± 0.11	1.79 ± 0.05	1.31 ± 0.12
	9-14	0.579	2.14 ± 0.09	1.60 ± 0.04	0.54 ± 0.10
	14-19	0.630	2.01 ± 0.09	1.70 ± 0.04	0.31 ± 0.10
	19-24	0.630	2.00 ± 0.08	1.79 ± 0.04	0.21 ± 0.10
	24-29	0.647	2.02 ± 0.09	1.65 ± 0.05	0.37 ± 0.10
	29-34	0.613	0.63 ± 0.03	1.63 ± 0.02	-1.00 ± 0.04
	Inventory (dpm/cm <sup>2</sup> )				20.1
13	0-3	0.265	11.74 ± 0.41	1.57 ± 0.08	10.17 ± 0.42
	3-6	0.341	9.68 ± 0.33	1.53 ± 0.07	8.15 ± 0.34
	6-9	0.407	4.07 ± 0.08	2.06 ± 0.04	2.01 ± 0.09
	9-14	0.414	2.11 ± 0.09	1.78 ± 0.05	0.33 ± 0.10
	14-19	0.431	2.60 ± 0.11	1.66 ± 0.05	0.94 ± 0.12
	19-24	0.965	1.17 ± 0.07	0.79 ± 0.03	0.38 ± 0.07
	24-29	1.192	0.69 ± 0.03	0.57 ± 0.01	0.13 ± 0.03
	Inventory (dpm/cm <sup>2</sup> )				24.0

ND = not determined; values in italics are interpolated

**Table 8: Sediment accumulation rates (calculated from  $^{210}\text{Pb}$  and  $^{14}\text{C}$  distributions) and carbon accumulation rates in Peconic Estuary sediments**

Station	$^{210}\text{Pb}$ rate (cm/y)	Depth Interval (cm)	$^{14}\text{C}$ rate (cm/y)	Depth Interval (cm)	Organic C (g C/g sed)	Dry Bulk Density (g sed/cm <sup>3</sup> )	C Accumulation <sup>1</sup> (mg C/cm <sup>2</sup> /y)
1	0.11	0-15	nm				
2	0.14	0-20	0.09	29-49	0.0564	0.35	1.777
6	0.13	0-14	nm				
7	0.20	0-20	0.11	29-52	0.0138	0.75	1.139
8	0.20	0-20	0.08	29-49	0.0158	0.57	0.720
9	0.14	0-14	0.03	29-49	0.0225	0.50	0.338
13	0.09	0-14	nm				

<sup>1</sup>Uses  $^{14}\text{C}$  rate  
 nm = not measured

## List of Figures

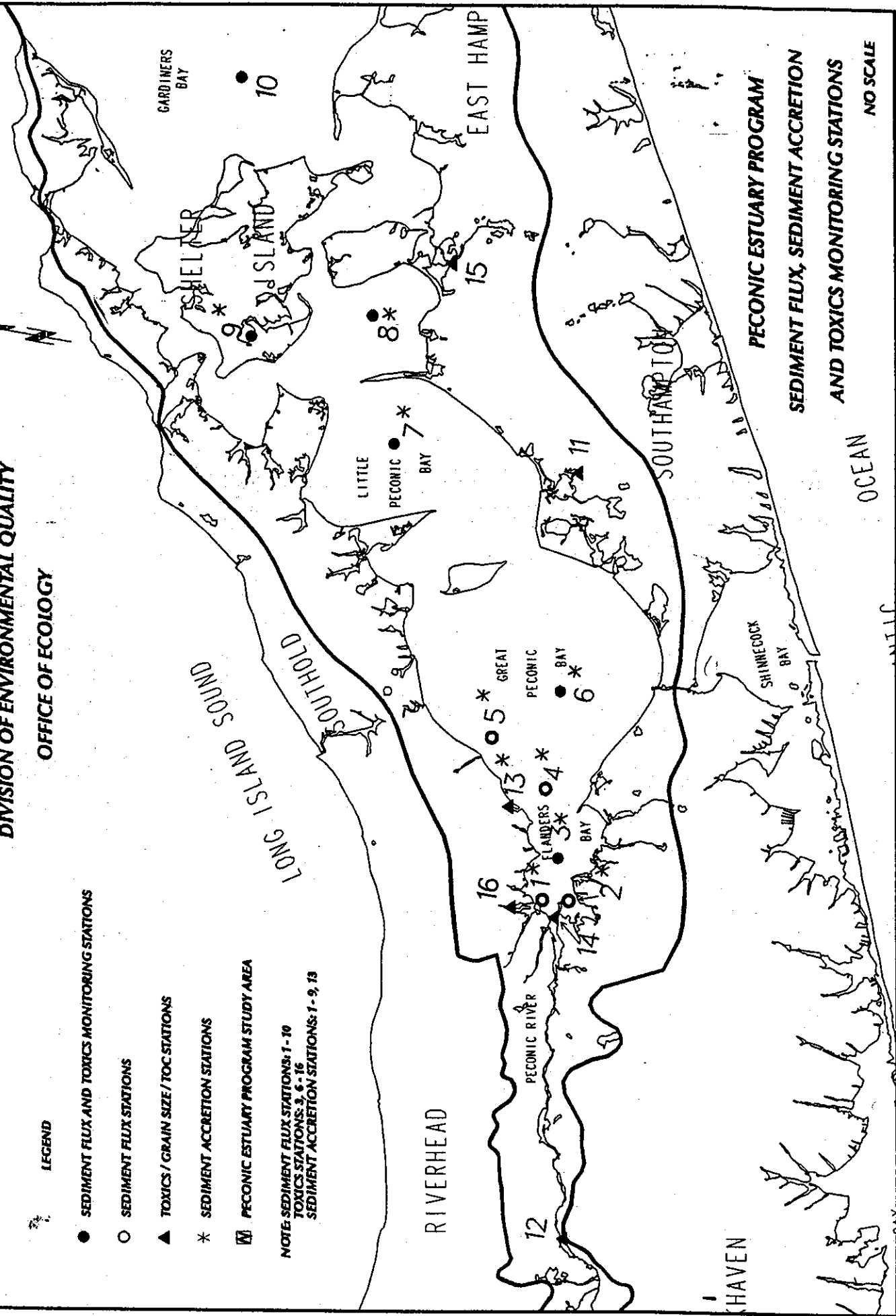
- Figure 1: Map of the Peconic Estuary showing coring locations.
- Figure 2a,b,c,d: X-radiographs of box cores. The images are digitally enhanced prints of the original negatives at the various stations in fall, 1997 and spring, 1998.
- Figure 3: Profiles of organic carbon in Peconic gravity cores. Also plotted are equivalent concentrations obtained from box cores collected in fall, 1997 (open squares) and spring, 1998 (open diamonds).
- Figure 4: Depth profiles of  $^7\text{Be}$  in Peconic box cores collected in fall 1997 (filled circles) and spring 1998 (open circles).
- Figure 5: Radiocarbon age vs. depth in a gravity core from station 7. Note that the trend in radiocarbon age obtained from the samples at depths  $>29$  cm intercepts the interface at 1721 years. The measured radiocarbon age of organic carbon in the 0-3 cm interval is  $1550 \pm 55$  years BP.
- Figure 6: Distributions of total  $^{210}\text{Pb}$  in gravity and box cores. The near-constant value at depth in the gravity cores is the  $^{226}\text{Ra}$ -supported activity. Box core data are from fall 1997 (open squares) and spring 1998 (open diamonds). Data from types of cores generally agree, given spatial variation and the possibility of loss of a few centimeters of surficial sediment from the gravity cores.

SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES  
 DIVISION OF ENVIRONMENTAL QUALITY  
 OFFICE OF ECOLOGY

LEGEND

- SEDIMENT FLUX AND TOXICS MONITORING STATIONS
- SEDIMENT FLUX STATIONS
- ▲ TOXICS / GRAIN SIZE / TOC STATIONS
- \* SEDIMENT ACCRETION STATIONS
- ▣ PECONIC ESTUARY PROGRAM STUDY AREA

NOTE: SEDIMENT FLUX STATIONS: 1 - 10  
 TOXICS STATIONS: 3, 6 - 16  
 SEDIMENT ACCRETION STATIONS: 1 - 9, 13



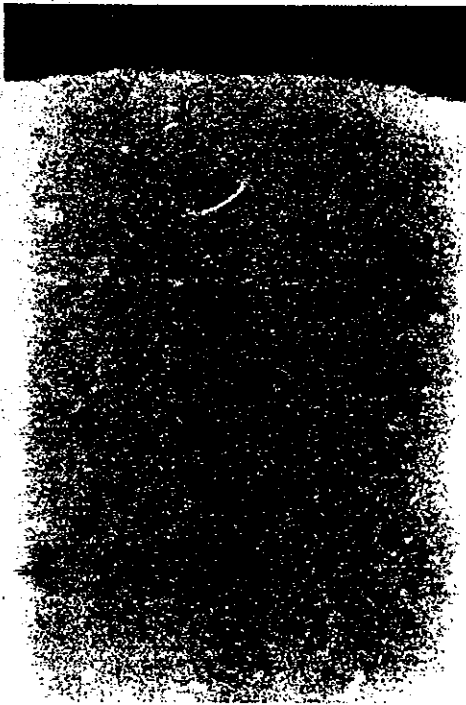
PECONIC ESTUARY PROGRAM  
 SEDIMENT FLUX, SEDIMENT ACCRETION  
 AND TOXICS MONITORING STATIONS  
 NO SCALE



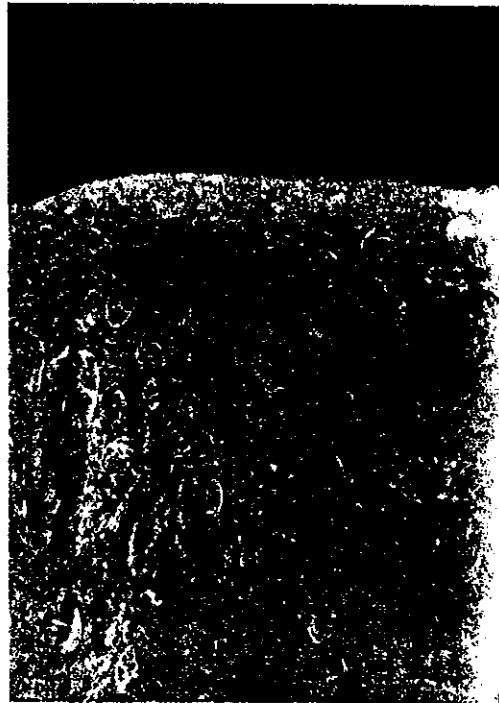
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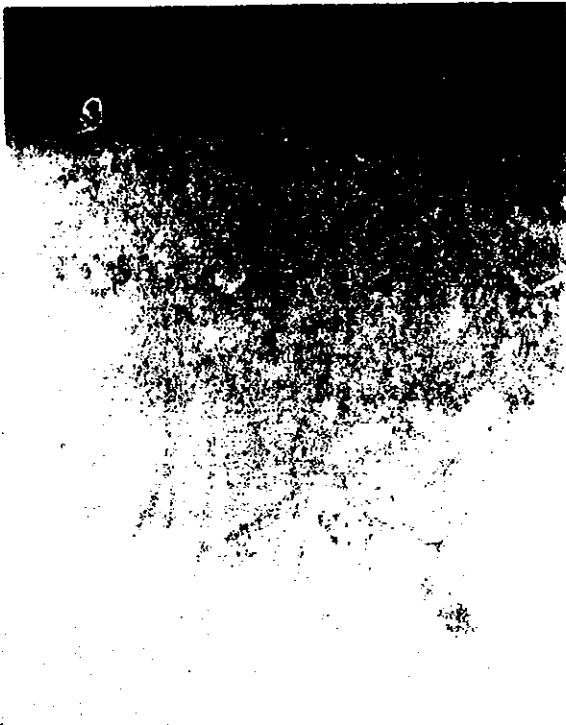
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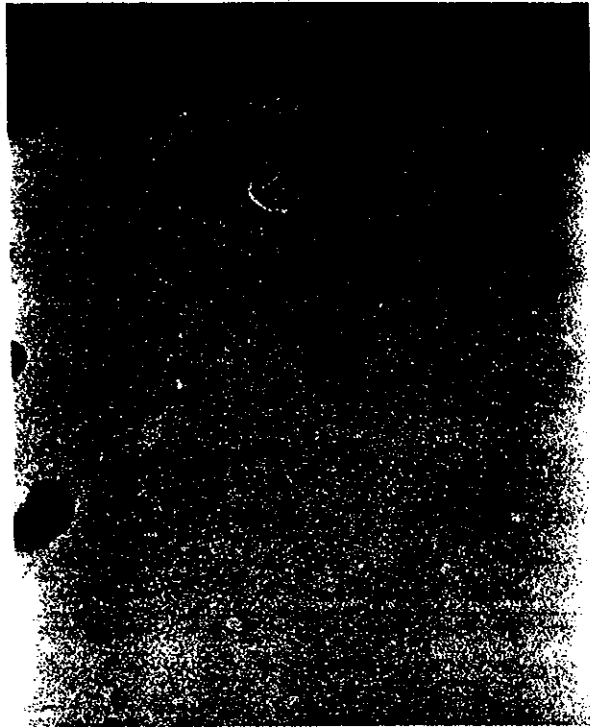
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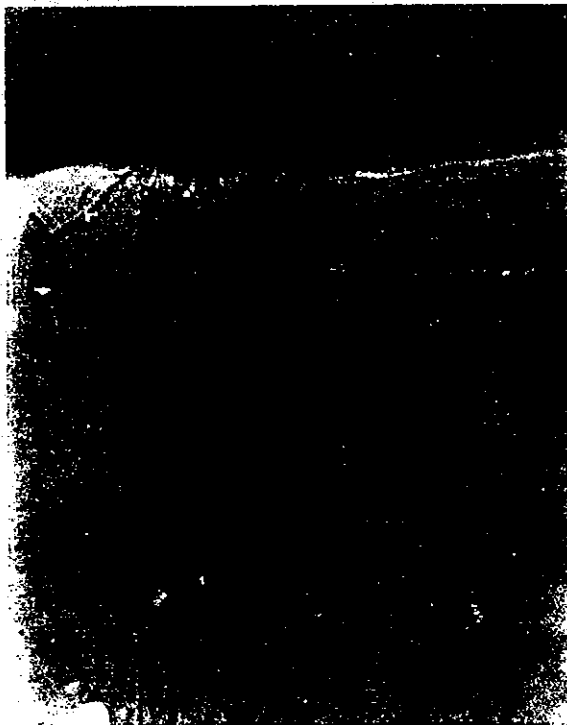
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Stn 4 FALL



Stn 5 FALL



Stn 6 FALL



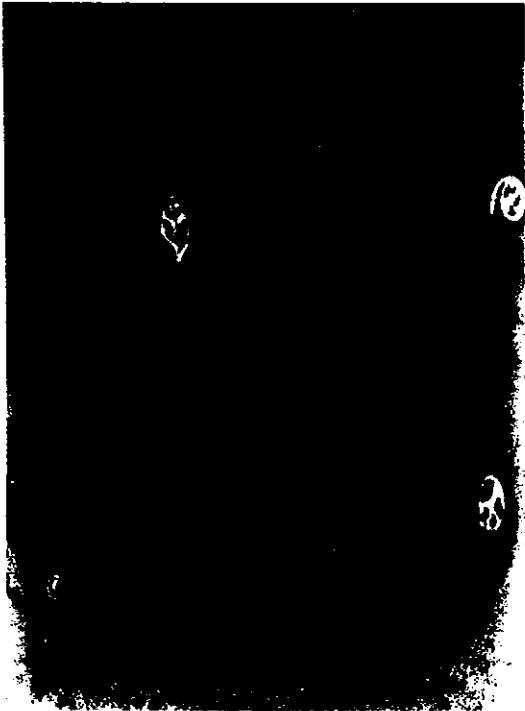
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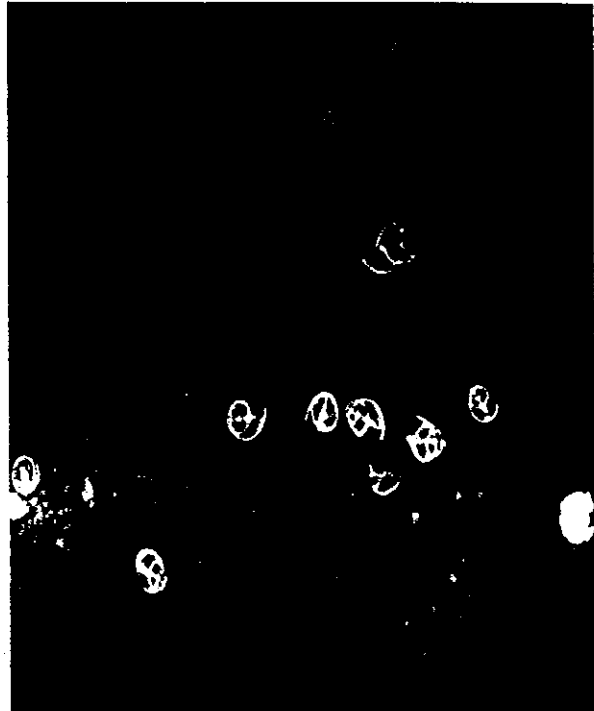
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Stn 8 FALL



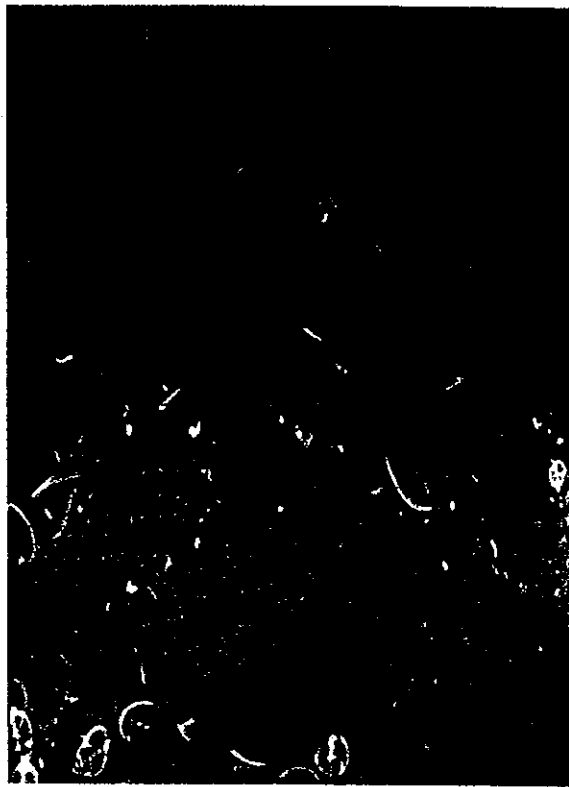
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Stn 13 SPRING



Stn 9 FALL



Stn 2 SPRING

Figure 2d.



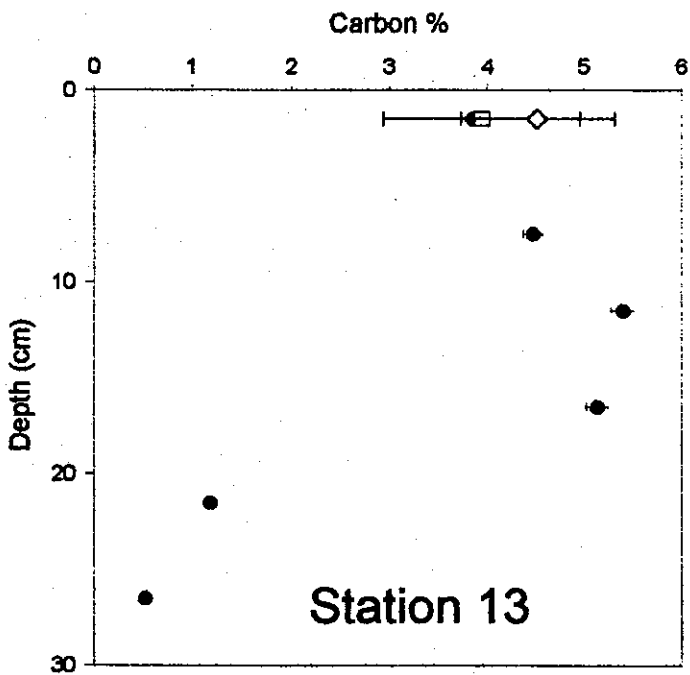
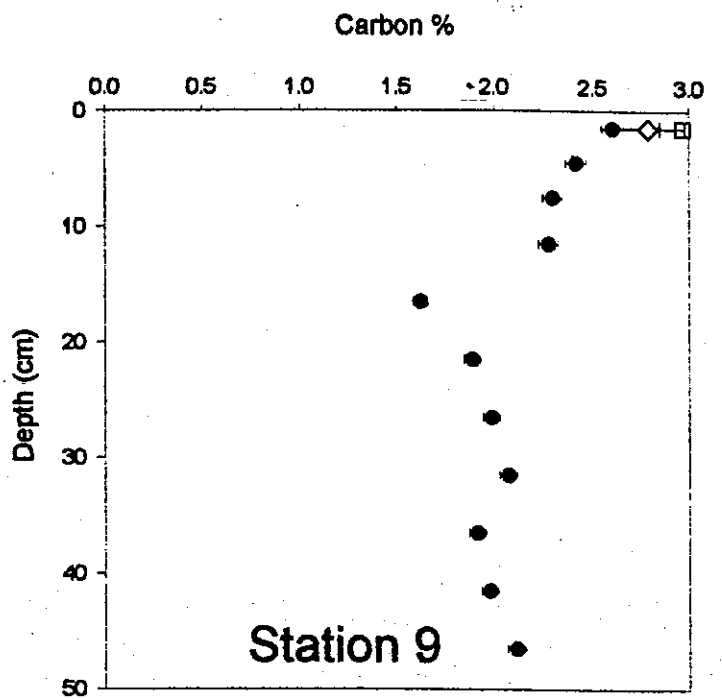
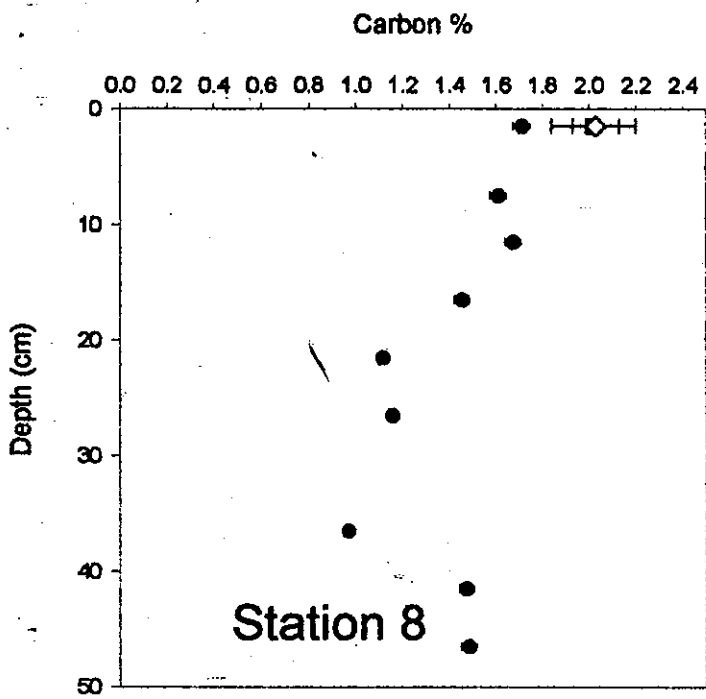


Figure 3 - continued

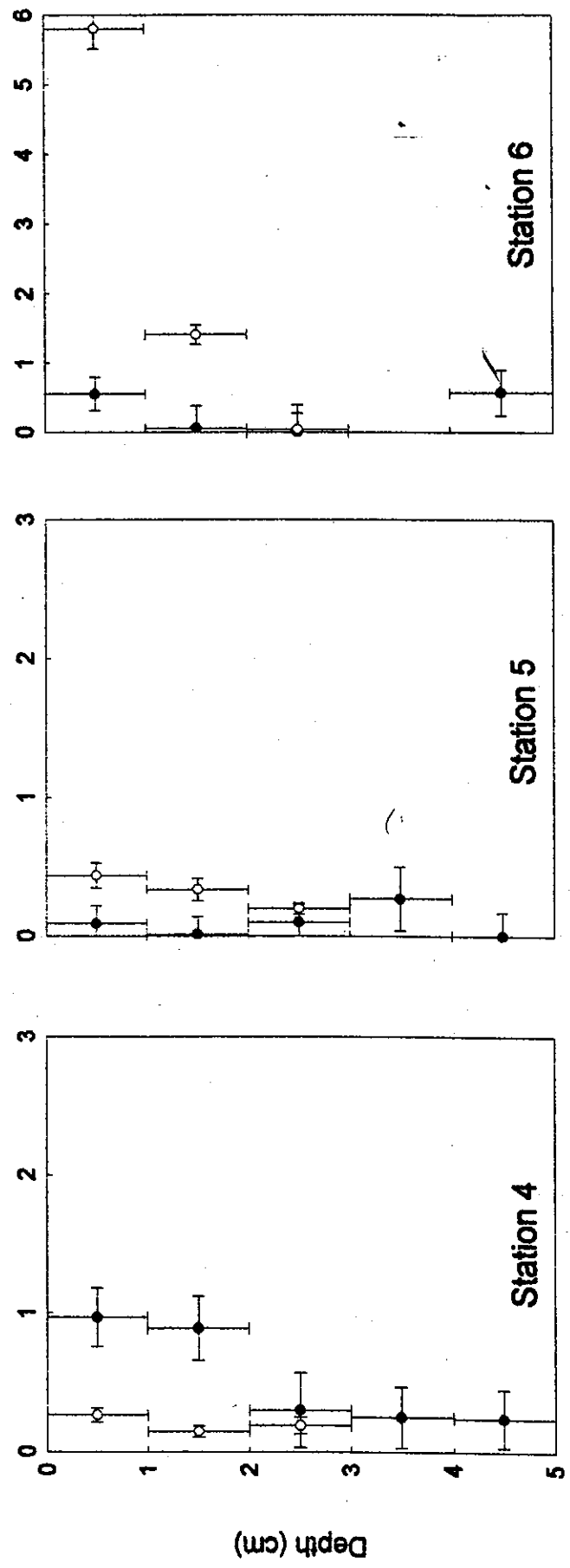
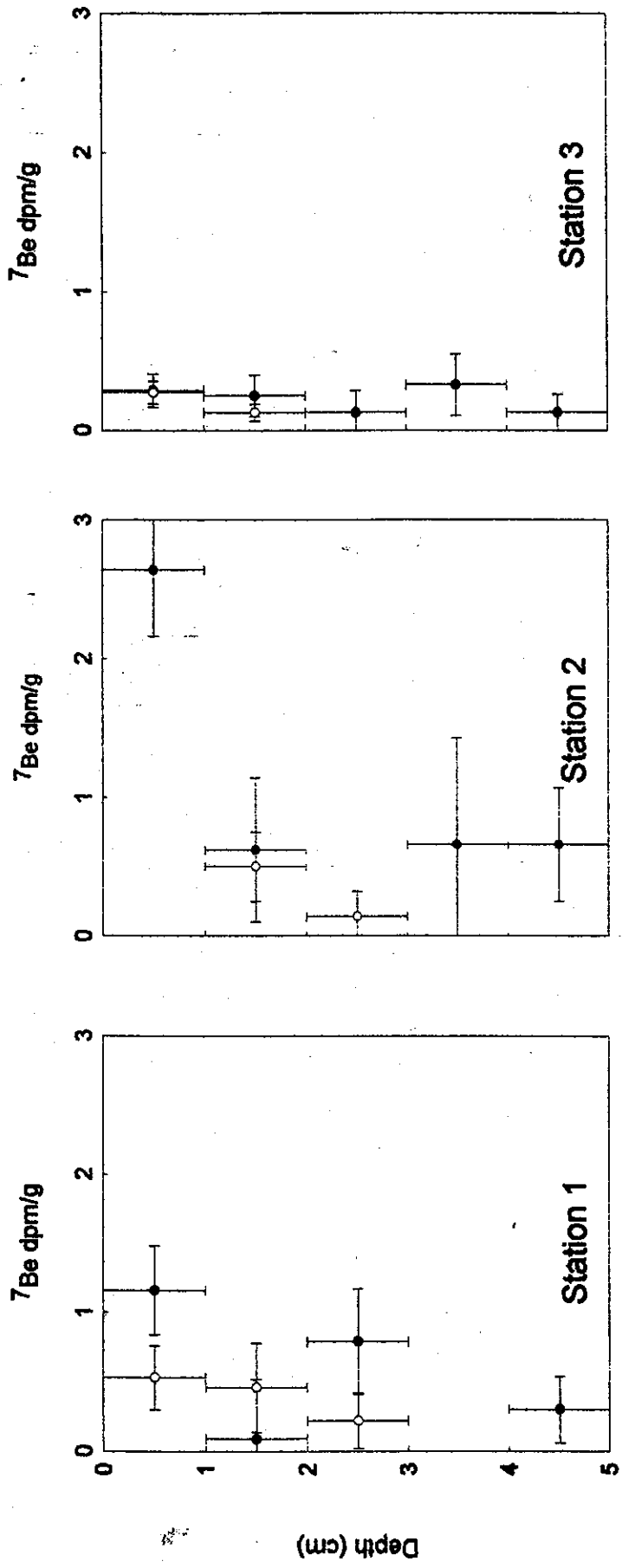


Figure 4

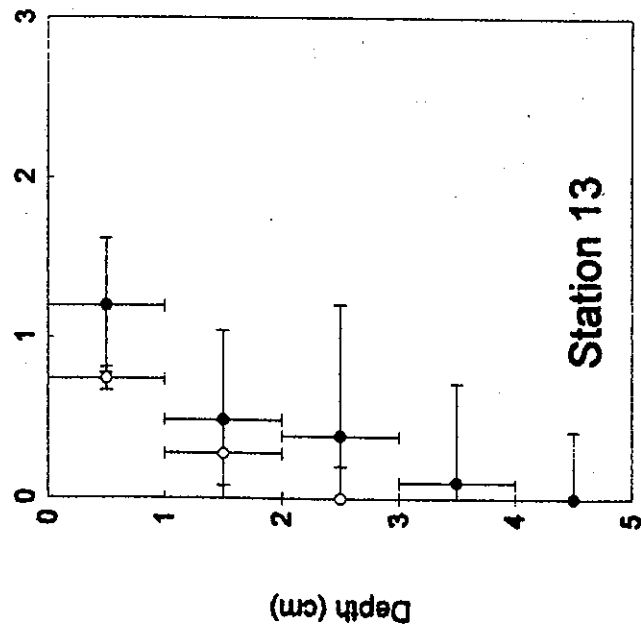
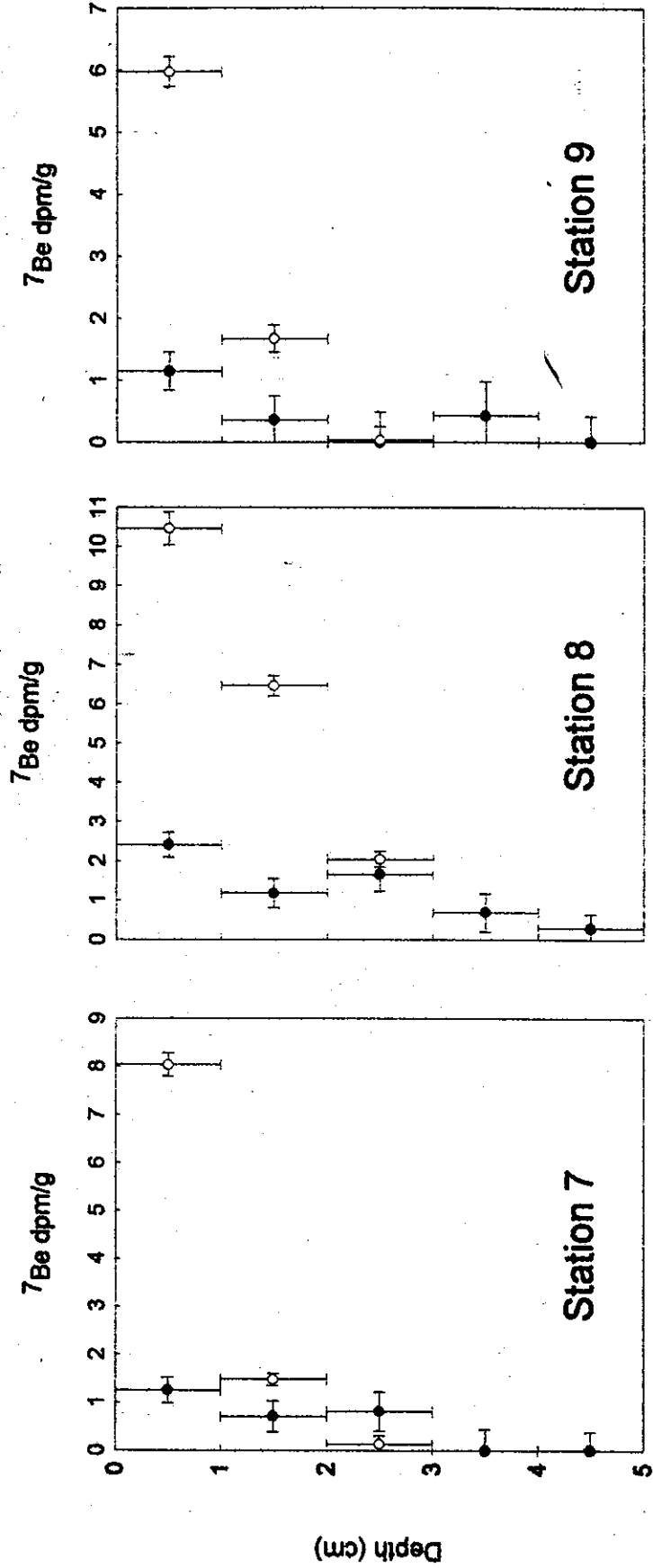


Figure 4 - continued

# Station 7

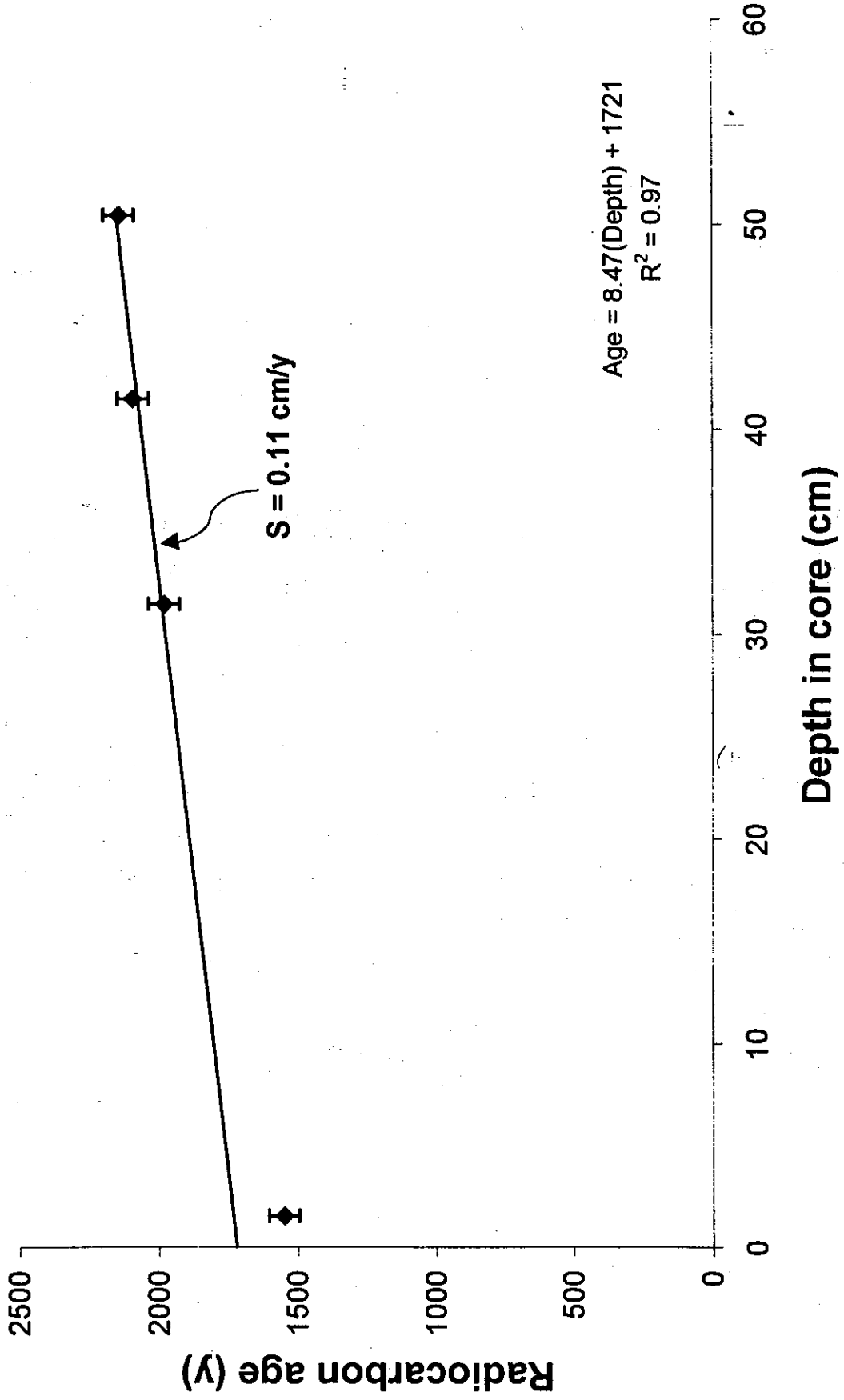


Figure 5

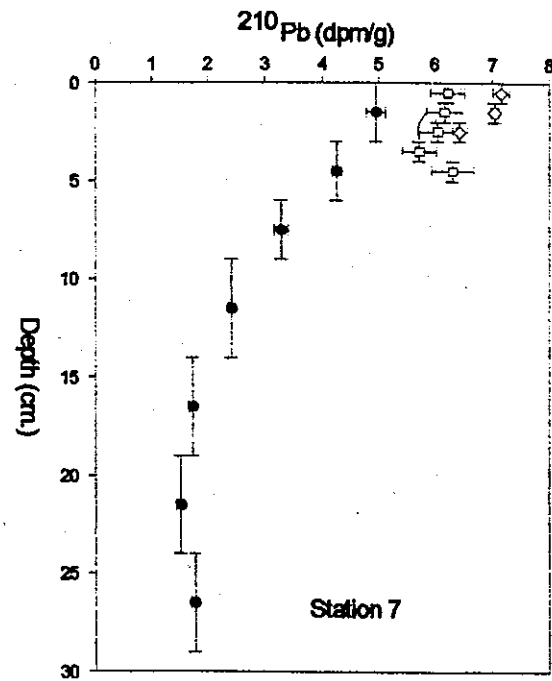
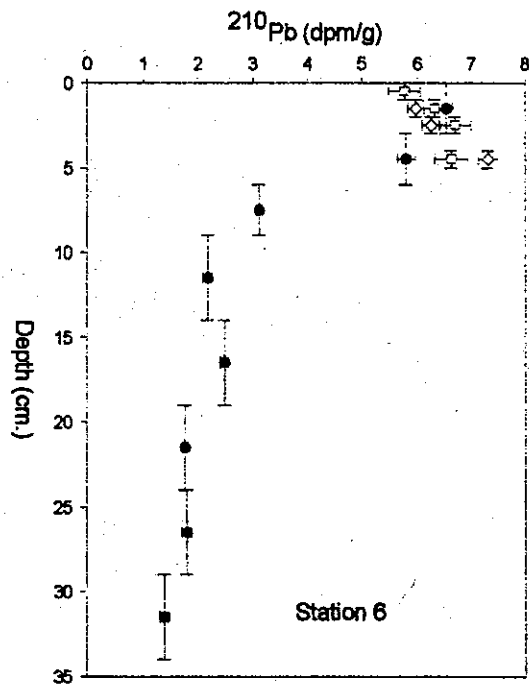
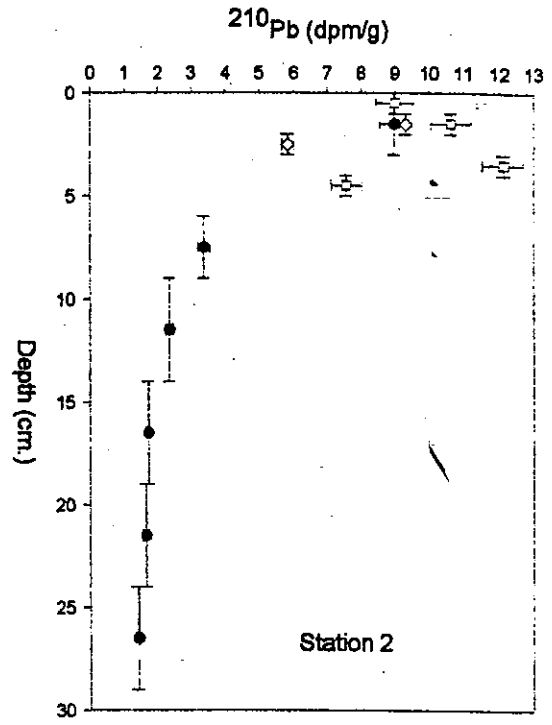
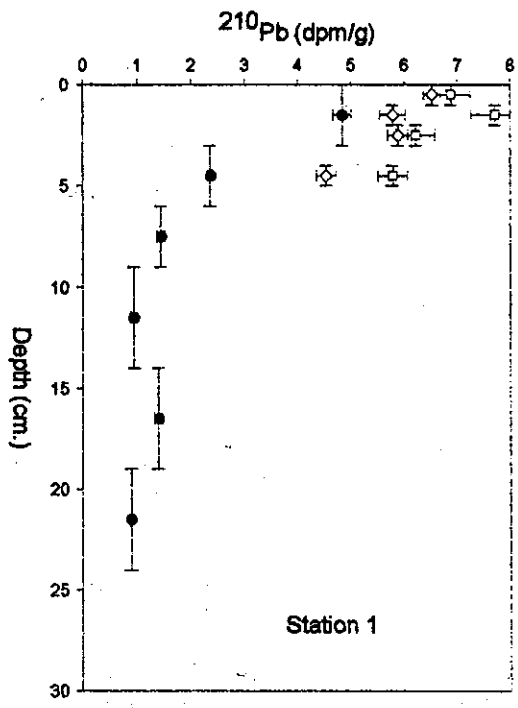


Figure 6

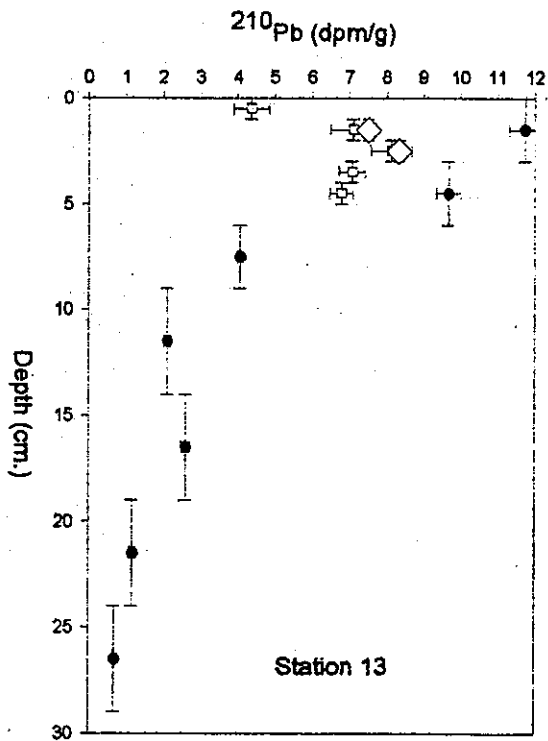
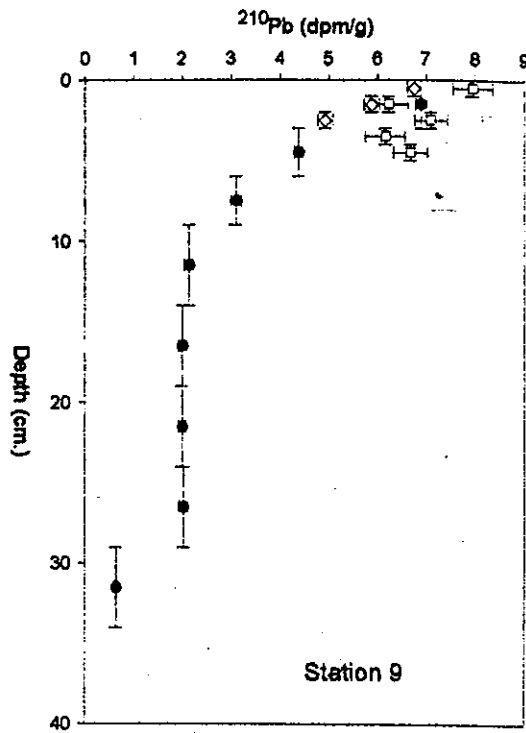
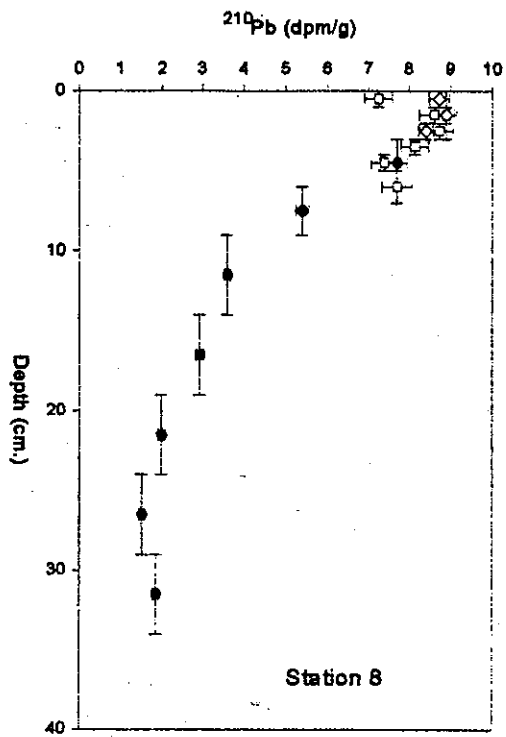


Figure 6 - continued

## Appendix I: Interpretation of X-radiographs

### Stn 1 FALL

Sediments at this site consist of a poorly sorted shell hash consisting of intact and disarticulated bivalve shells. There are small vertical burrows present to the right side and intact (living) *Nassariid* shells at the surface. The transverse dark area near the middle of the film may have resulted during the coring process, from dragging a shell to depth. The sediments at this site are dominantly disturbed by physical processes.

### Stn 1 SPRING

This is a poorly sorted shell hash with an isolated burrow structure near the upper center. The dark area near the middle field is possibly part of a larger biogenic structure although it may also be anthropogenic in origin (anchor mark etc.).

### Stn 3 FALL

This is a bioturbated fine sand as evidenced by its homogeneity and the presence of bifurcated unlined burrows, possibly *Capitella* or *Nereids*. There is little grain size variation except for some large sand grains, randomly distributed.

### Stn 3 SPRING

This is a sandy shell hash deposited under strong current conditions. The shells are lineated and stacked near the surface, underlain by shell rich clasts. The lineation and stacking of the shells indicates strong current flow.

#### **Stn 4 FALL**

This is a medium to coarse sand, highly bioturbated as indicated by the dense network of burrows near the surface. Near the bottom there is evidence of a possibly biogenic lag deposit of poorly sorted shell material and possibly aggregated shells. The near surface burrow structures are not currently active and may be relict.

#### **Stn 5 FALL**

This is a moderately bioturbated fine sand as evidenced by the presence of burrow structures near the surface, possibly made by *Spionid* worms. The dark spots in the central left field are probably coring artifacts.

#### **Stn 6 FALL**

This is a highly stable muddy bottom as evidenced by the presence of intact agglutinated tube structures formed by *Moldanid* worms passing through the sediment water interface. Dark areas near the upper center field are feeding voids, and there are horizontal burrows. The small surface layer is probably caused by sediment resuspension during coring.

#### **Stn 6 SPRING**

Similar to the fall conditions at this station the presence of agglutinated worm tubes is indicative of a stable bottom with a well developed benthic community.

#### **Stn 7 FALL**

This is a shell deposit formed under high energy conditions as evidenced by the presence of large numbers of disarticulated bivalve shells, some of which, especially in the upper left are stacked in both directions indicating strong currents from at least two directions (tidal flow). *Nephtys* and *Moldanid* tubes are present near the surface.

### **Stn 8 FALL**

This is a moderately bioturbated fine grained sediment that has been subject to intermittent physical disturbance. Beneath the upper third of the field is a shell lag deposit with truncated burrows indicating past erosion. There is some shell armoring near the surface. The separation near the bottom is probably a coring artifact.

### **Stn 9 FALL**

This is a dominantly muddy deposit that shows evidence of washin of coarse grained materials. There is extensive cross cut bioturbation with articulated (living?) bivalves and a well developed spectrum of infaunal sizes, indicating a well established benthic community. The agglutinated tube structures on the left field are formed by *Moldanid* worms.

### **Stn 13 FALL**

This muddy sediment shows evidence of physical depositional control due to the presence of multiple laminations. Near the base there is evidence of methane gas bubbles and terrestrial plant debris. The uninterrupted laminations indicate that bioturbation has not recently been effective below 4 cm. at this site. Abundant *Nassareid* shells.

### **Stn 13 SPRING**

This is a dominantly fine grained deposit showing evidence of periodic washins of coarser material. There are abundant *Nassareid* shells and alternating fine and coarse grained layers. Relict infaunal feeding tubes are truncated in the vertical (center field), indicating some erosional processes, then repopulated by infauna.