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Mississippi Basin Carbon Project Process Studies

**DETAILED DESCRIPTIONS FOR SAMPLING, SAMPLE PREPARATION AND
ANALYSES OF CORES FROM ST. BERNARD PARISH, LOUISIANA**

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INTRODUCTION - *H.W. Markewich*

The Mississippi Basin Carbon Project (MBCP) is part of the U.S. Geological Survey (USGS) effort in global change research. The project is motivated by the need to increase our understanding of the role of terrestrial carbon in the global carbon cycle, particularly in the temperate latitudes of North America. The primary goal of the MBCP is to quantify the interactive effects of land-use, erosion, sedimentation, and soil development on carbon storage and nutrient cycles within the Mississippi River basin. Site specific studies are directed at estimating rates of carbon accumulation, decomposition, erosion, transport, and deposition; and particularly at assessing the sensitivity of these rates to climatic, hydrologic, topographic and land-use gradients.

Figure 1. Mississippi Basin Carbon Project core localities in the Mississippi River deltaic plain are indicated by circles and diamonds. The St. Bernard core locality is in the easternmost part of the study area. Triangles indicate localities for which surface and near-surface organic carbon data are available from the National Soil Survey Laboratory in Lincoln, Nebraska (NSSL, 1994)

The Mississippi Delta region of Louisiana was the first area investigated by the MBCP. The first sampling site was a marsh on the southwestern edge of Lake Borgne, St. Bernard Parish (fig. 1). Other cores of Mississippi River deltaic and fluvial sediments are from marsh, swamp, levee, and floodplain environments scattered throughout the Mississippi deltaic plain and alluvial valley. Most of the core localities in Louisiana are shown on figure 1. The St. Bernard, St. Mary, and Terrebonne cores were taken to evaluate rates of organic matter and sediment accumulation and transport in a marsh environment. Two short cores, each approximately 1 m in length, and one long core, approximately 3 m in length, were taken at the St. Bernard Parish locality in March 1996. The analytical results from studies of the St. Bernard core samples are published in Markewich (1998), U.S. Geological Survey Open File Report 98-36, which is available from the USGS Information Services, Box 25286, Denver Federal Center, Denver CO 80225-0046, Tel: 303-202-4200; Fax 303-202-4695; but is also “on line” at <http://geochange.er.usgs.gov/pub/carbon/of98-36>.

Data for bulk physical characteristics, as well as organic and inorganic constituent analyses, of the St. Bernard core samples were acquired using a variety of analytical techniques that are generally described in Markewich (1998). This report, in contrast, gives the specifics of the techniques used, several of which were selected by trial and error. Most of the field and laboratory methods used in acquisition and analyses of the St. Bernard core are considered common or standard techniques. However, to fit the needs of this study, some of these techniques required minor to extensive modification. Therefore, this paper describes each method used and includes some discussion of the problems encountered. Our hope is that the descriptions and comments might be useful to others working in similar organic-rich environments.

Based on findings from the collection and analyses of the St. Bernard core samples, we have since altered several field and laboratory techniques in order to obtain less compressed sample material,

to recover specific constituents from samples, and to minimize analytical error. Discussion of these modifications will be included in future reports.

FIELD AND SAMPLING METHODS

Coring and Sampling of Cores - *T.L. Fries L.D. Britsch, D.L. Dillon, J.P. McGeehin and H.W. Markewich*

Coring

During a preliminary sampling trip in February 1996, 1-m long test cores were taken at two sites south of the Mississippi River near New Orleans. The cores were taken by hand pushing a sharpened, 3-in (7.62 cm) inside diameter, aluminum irrigation pipe into the marsh. The sampling tube was then capped, to maintain a vacuum, and removed from the marsh. Measurement of ^{137}Cs at 4 cm long sections taken from these cores produced acceptable peaks in the ^{137}Cs versus depth curves (fig. 2, in section *^{137}Cs Measurement*), indicating that this coring method did not mix material from different depths. Although compaction using this method was greater than twenty-five percent, the hand-pushed tube was initially adopted as the method to be used for shallow sampling in marsh environments of the Mississippi Delta.

When the method outlined above was used at the St. Bernard Parish core locality near Chalmette, Louisiana (St. Bernard Parish, 29°58'53" N, 89°55'27" W; sampled 03/18/1996) (Markewich, 1998), it was impossible to get a satisfactory sample. The marsh material would not stay in the sampling tube when the tubes were excavated. The poor recovery was due to a number of factors. Water levels in the marsh were unusually high. Strong winds had been gusting for several days preceding and during sampling, stacking water into the marsh in the area of the sample locality. Therefore, when the tube was pushed into the marsh peat, a continuous "water-sleeve" developed between the inside wall of the tube and the peat, resulting in the peat flowing out of the tube.

Instead of using the hand-pushed tube to acquire the short (1-m) cores at the St. Bernard Parish site, a vibracore device was equipped to handle the 3-in (7.62 cm) inside diameter aluminum sampling tubes. The vibracore technique allows retrieval of continuous, undisturbed samples from unconsolidated saturated sediments. The vibracore works on the principle of liquefaction in fine-grained sediments by displacing sediment to allow passage of the core barrel (Smith, 1984). The

effectiveness of the vibrocore in relation to penetration and recovery is directly related to the engineering properties of the material being sampled. The vibrocore works best in saturated organic sediments, clays, silty clays, silts, and fine sands, but is very inefficient in firm clays and medium to coarse sands. The vibrocore system is portable allowing retrieval of relatively long (up to 10 m) undisturbed samples in marsh settings.

At the St. Bernard core site, marsh locations with little to no grass at the surface were selected and two shallow cores were taken (SB1a, SB1b) at locations separated by approximately 3 meters. This coring was done using a 5 ft (1.5 m) long section of pipe and coring was stopped at a depth of approximately 1m. The core was retrieved by first capping the tube to maintain a slight vacuum, shoveling out material directly along one side of the tube and then removing the sampling tube from the marsh. The sharpened tube bottom and tube top were cut flush and the top and bottom marked. Two inches (5.08 cm) of material was removed from each end to allow for expansion when the core was frozen. The cavities left when the material was removed were filled with polystyrene, and the core ends were capped with aluminum foil and duct tape. Although this approach was more difficult than hand pushed sampling, it produced intact cores with less than ten percent compaction. The short cores were used primarily for isotopic and detailed elemental chemical analyses. By taking short vibrocores, rather than using the upper portion of the long vibrocore (SB1c) from the same locality, the potential for contamination due to the mixing of shallow and deep material was reduced.

One long core (SB1c) was taken within a few meters of cores SB1a and SB1b, using the vibrocore apparatus equipped with a 15 ft (4.58 m), 3-in (7.62 cm) inside diameter, aluminum sampling tube. The sampling tube had been cut to a point and sharpened on one end, as was done for the short cores. When the sampling tube had been driven approximately 4 m into the marsh sediment, the tube was capped to provide suction on the sample by creating a slight vacuum. The tube was then pulled from the marsh sediment using a winch and steel cable. Compaction for the long core was about 30 percent. The sampling tube was trimmed at both ends, as with the short cores, but no sample material was removed since the long core was to be sampled in the COE sediment laboratory in New Orleans, LA. Top and bottom were marked on tube ends, and the ends of the tube were sealed with aluminum foil and duct tape.

Sampling of Cores

All cores were transported to the COE sediment laboratory in New Orleans, LA, while laying horizontal in order to minimize compaction. The long core, SB1c, was split lengthwise, described, photographed and sampled at the COE sediment laboratory two days after coring was completed. Samples were taken for ^{14}C measurements, pollen analysis, clay mineralogy, mercury determination, carbon determinations, inorganic constituents/fractionation, moisture, and bulk density (BD). With the exception of bulk density samples, material was taken in 3- to 4-cm blocks cut from the core at interval boundaries and at midpoints of intervals. The surfaces of these sample blocks were scraped to remove any contamination. BD samples for core SB1c were taken in each interval by taking a 1-cm diameter sample at right angles to the long axis of the core. Sample dimensions and weight were recorded and the sample was then placed in pre-weighed plastic bag. The remaining material from core SB1c was wrapped and archived for later use.

To facilitate shipping to the USGS laboratory in Menlo Park, CA, the two short cores SB1a and SB1b, were each cut into two shorter pieces, recapped and labeled accordingly. They were then packed in dry ice and shipped. Core SB1a was sampled for the same analytical techniques as core SB1c. Core SB1b was sampled for ^{137}Cs analysis.

Sampling specifics for each analytical method are described in the following subsections.

Sampling for ^{14}C age determinations.--Samples of peat, wood, grass, seeds and organic sediment were collected from the St. Bernard cores for ^{14}C analysis. The SB1c core was sampled at the COE sediment laboratory in New Orleans; the SB1a core was sampled at the USGS laboratory in Menlo Park. After the cores were split open, sampling locations were selected based on two sets of criteria.

For the long St. Bernard (SB1c) core, samples were selected for ^{14}C dating based on visually observed stratigraphic changes in the core material. Sampling started at about 30 cm (uncorrected for compaction) to minimize dating materials at or above the modern detection limit

of ^{14}C . Sampling continued to the bottom of the core. Corrected depths were calculated by applying a linear correction for compaction which was measured in the field.

Before sample material was removed from the SB1c core tube, the split surfaces were prepared by removing the top few millimeters of material that may have been dragged into place when the core was sliced open lengthwise. Sample depths were accurately noted and the sample material (mostly peat) was sliced into thin semi-circular wedges, approximately 3 cm deep. The samples were removed from the core, laid out on a piece of clean paper and trimmed along the curved surface that was in contact with the core tube to remove material that may have been dragged into place during the coring process. The samples were dried and transported to the USGS ^{14}C laboratory in Reston, VA.

The shorter SB1a core was sampled to analyze for ^{14}C activity related to atmospheric bomb testing. At the COE sediment laboratory in New Orleans, core SB1a was cut into two shorter pieces, recapped, labeled, packed in dry ice and shipped to the USGS laboratory in Menlo Park. The procedures for sampling the SB1a core were more systematic than for the SB1c core; the procedures are described in the following subsection.

Sampling for C, C isotopes, N, N isotopes, and elemental analysis.--The SB1c core was sampled as described above) at the COE sediment laboratory in New Orleans, LA. Samples for total carbon (TC), organic carbon (OC) and inorganic (carbonate) carbon (IC) by difference were sent to the USGS laboratory in Denver, CO for analysis.

After the frozen SB1a core was received at the USGS laboratory in Menlo Park, CA, it was marked along a center line and the aluminum tubing sliced open using a circular saw equipped with a metal cutting blade set to just penetrate the tubing wall. The core was then placed in the refrigerator section of a standard refrigerator-freezer overnight to soften enough that the core material could be cut.

When the SB1a core material had softened sufficiently, one half of the split aluminum tube was removed and samples were taken in 1 in (2.54 cm) sections from 5 to 30 cm. (The upper most 5 cm of material had been removed in the field.). Sampling was accomplished by making vertical

slices at 1 in intervals using a serrated knife, washing and drying the knife and then cutting horizontally along the cut edges of the aluminum tube until the vertical cut was intersected. Each section was then removed. The surface of each sample was scraped to eliminate contamination from the aluminum housing and adjoining sample section. Each core sample was placed in a pre-weighed aluminum pan and the total pan and sample weight recorded. Each sample was oven-dried to a constant weight at 65 °C and the weight recorded. These samples were shipped to, and processed in, the USGS ¹⁴C laboratory in Reston, VA for ¹³C and ¹⁴C analyses.

The remaining half of the SB1a core was turned out of its open, aluminum half-tube housing onto a sheet of aluminum foil and it was sliced into 1-in (2.54-cm) sections. The aluminum housing was marked and retained for measurement to obtain accurate volume estimates of each 1-in (2.54-cm) section. Each core sample was placed in a pre-weighed aluminum pan and the total pan and sample weight recorded.

After scraping the outer surface of each SB1a core sample to remove any contamination, approximately one quarter of each sample section was removed, placed in a preweighed container and the total pan and sample weight recorded. These splits were first allowed to air dry to constant weight and were later oven dried to constant weight at 65 °C. The weight of this split and of the total sample weight taken initially, were used to calculate bulk density (BD). These dried BD splits were then bagged and stored for future reference.

The remaining material for each sample was split into three approximately equal sections. One section was placed in a labeled whirl-pack and returned to the freezer for later use in carbon fractionation studies. A second section was placed in a polyethylene tube and centrifuged for 30 minutes at 700RCF (g) and the pH of the liquid phase measured using pH strips. This section was then air-dried to constant weight and submitted to the USGS laboratory in Denver, CO for the determination of TC, IC, and OC by difference. The third section was air-dried to constant weight and retained for the determination of total nitrogen (TN), TN, carbon (N) and nitrogen (N) isotopes and inorganic constituents.

Sampling for ^{137}Cs analysis.--Material from the other short core, SB1b, was used for ^{137}Cs measurements. At the USGS laboratory in Menlo Park, the whole frozen core was cut into 2-cm sections on a band saw. Each saw cut consumed 1 mm of sample length and each 2-cm measurement was made from the edge of the previous cut. As each section was cut the sample and the resulting aluminum ring were transferred to a pre-weighed plastic bag already marked with identification information. Air was removed from the bag, the bag was sealed, and the side of the bag corresponding to the top of the sample was marked. The sample/ring/bag combination was then weighed and the weight recorded.

The samples were shipped to the National Oceanic and Atmospheric Administration Great Lakes Research Laboratory in Ann Arbor, MI, for ^{137}Cs measurements. Upon completion of ^{137}Cs measurements the entire sample/ring/bag combination was returned to Menlo Park, CA where the bags were split open, and the sample/ring/bag combinations were allowed to air dry. When the samples reached constant weight the aluminum rings were removed, cleaned, dried and weighed. A dry sample weight was then calculated for use in ^{137}Cs calculations. Dry sample material was then archived.

LABORATORY METHODS

Bulk Density - Sampling and Calculations - *T.L. Fries*

Bulk density values were calculated using the air dry and, for most samples, the oven-dry (65 °C) weight and the volume of the sample (Parent and Caron 1993). For core SB1a, a comparison of OC storage between air-dried and oven-dried samples showed, for cumulative storage, a maximum relative deviation less than 1.5 percent (table 1).

Bulk density (BD) was calculated as:

$$\text{BD} = (\text{sample dry weight})/(\text{volume of sample})$$

Dry weights for the BD splits taken from the SB1a core were used to calculate the dry weight of the entire half-core sample. The weight loss for the section taken for BD was applied to weight of the entire half-core section. To calculate the volume for the half-core the inside diameter of 3 in (7.62 cm) was used and the 1 in (2.54 cm) nominal length of the slice was corrected for

compaction. The correction for compaction assumes that compaction was linear over the entire core length (Jackson and others, 1995). Therefore the volume, in a in^3 , of an individual half-core section from the SB1a core would be:

$$V = 0.5 \times (\text{area}) \times (\text{length}) \times (1/(1-[\text{percent compaction}/100]))$$

where:

area = cross sectional area of core

length = length of sample section

percent compaction = $100 \times \text{length of core lost} / \text{true length of core}$

BD calculations for the SB1b core were based on the dry weight of the samples submitted for ^{137}Cs measurements and the volume of a full section of the 3 in (7.62 cm) inside diameter sampling tube, corrected for compaction. The compaction correction for SB1b also assumed linear compaction over the entire core length. In addition to the BD procedure outlined above a second method was tried, using core SB1c. SB1c core length was about 3 m (4 m after correction for compaction; Markewich, 1998). It was sampled prior to shipping, while in the COE, New Orleans District, sediment laboratory. Samples were taken using a 1-cm inside diameter hand held coring device. Sample plugs, 3 to 4 cm in length, were taken normal to the axis of the core. The samples were air dried. Volumes were calculated using both whole core and sample core compaction factors, and assuming that the true shape of the cross-section was elliptical. BD determined by the two methods are given in table 2.

Table 1. Comparison of OC storage based on air-dry vs. oven-dry (65 °C) samples for core SB1a.

mid point of sample compaction corrected depth (cm)	depth to sample top compaction corrected depth (cm)	depth to sample bottom compaction corrected depth (cm)	OC air-dried incremental storage ($\text{kg m}^{-2} \text{cm}^{-1}$)	OC oven-dried incremental storage ($\text{kg m}^{-2} \text{cm}^{-1}$)	OC air-dried cumulative storage (kg m^{-2}) ¹	OC oven-dried cumulative storage (kg m^{-2}) ¹	OC cumulative relative deviation (percent)
	0.00	5.45			0.00	0.00	
6.8	5.45	8.18	0.29	0.28	0.78	0.77	0.92
9.5	8.18	10.90	0.28	0.28	1.55	1.53	0.93
12.3	10.90	13.63	0.15	0.15	1.96	1.94	1.15
15.0	13.63	16.35	0.24	0.24	2.62	2.59	1.17
17.7	16.35	19.08	0.26	0.26	3.34	3.30	1.14

20.4	19.08	21.80	0.27	0.27	4.07	4.03	1.12
23.2	21.80	24.53	0.24	0.24	4.72	4.67	1.13
25.9	24.53	27.25	0.25	0.25	5.40	5.34	1.13
28.6	27.25	29.98	0.27	0.27	6.14	6.07	1.11
31.3	29.98	32.71	0.30	0.30	6.96	6.88	1.16
34.1	32.71	35.43	0.19	0.19	7.47	7.39	1.17
36.8	35.43	38.16	0.23	0.22	8.09	8.00	1.14
39.5	38.16	40.88	0.25	0.25	8.77	8.68	1.13
42.2	40.88	43.61	0.27	0.27	9.50	9.41	1.04
45.0	43.61	46.33	0.23	0.23	10.14	10.04	1.05
47.7	46.33	49.06	0.24	0.23	10.79	10.67	1.07
50.4	49.06	51.78	0.23	0.23	11.43	11.30	1.08
53.1	51.78	54.51	0.26	0.25	12.13	12.00	1.09
55.8	54.51	57.23	0.28	0.27	12.88	12.74	1.10
58.6	57.23	59.96	0.29	0.28	13.66	13.51	1.10
61.3	59.96	62.68	0.32	0.32	14.54	14.38	1.10
64.0	62.68	65.41	0.33	0.33	15.44	15.27	1.10
66.7	65.41	68.14	0.37	0.36	16.45	16.27	1.10
69.5	68.14	70.86	0.31	0.31	17.29	17.10	1.11
72.2	70.86	73.59	0.35	0.35	18.25	18.05	1.11
74.9	73.59	76.31	0.30	0.30	19.06	18.85	1.11
77.6	76.31	79.04	0.36	0.36	20.06	19.83	1.15
80.4	79.04	81.76	0.27	0.26	20.78	20.54	1.18
83.1	81.76	84.49	0.33	0.33	21.68	21.43	1.17
85.8	84.49	87.21	0.31	0.30	22.52	22.26	1.17
88.5	87.21	89.94	0.32	0.32	23.39	23.12	1.16
91.3	89.94	92.66	0.37	0.37	24.41	24.12	1.18
94.0	92.66	95.39	0.34	0.33	25.33	25.02	1.20
96.7	95.39	98.12	0.35	0.35	26.29	25.97	1.23

1/ storage values represent the mass of OC per square meter from surface to bottom of lowermost sample

Table 2. Bulk density (BD) determined by sampling 3 in inside diameter cores (cores SB1a and SB1b) and by subsampling one of the cores (SB1c) using a 1-cm inside diameter hand-held coring device. Data are for the upper one meter of core.

SB1a mid point of sample compaction corrected depth (cm)	SB1a air-dry BD (g/cm ³)	SB1b mid point of sample compaction corrected depth (cm)	SB1b air-dry BD (g/cm ³)	SB1c mid point of sample compaction corrected depth (cm)	SB1c air-dry BD (g/cm ³)
12.3	0.102	11.3	0.07		
15.0	0.162	13.6	0.14	14.1	0.14
17.7	0.101	15.9	0.13		
61.3	0.091	59.7	0.10		
64.0	0.087	62.0	0.10	63.5	0.086
66.7	0.094				

TC, TN, ¹³C, ¹⁵N, and Inorganic Elemental Analysis - T.L. Fries and H.W. Markewich

Sample preparation.--Samples from the SB1c core were the first to be processed during this study and were subjected to a number of variable conditions during sampling and processing. Some SB1c samples were oven dried at the COE laboratory in New Orleans at 110 °C. Samples from the SB1c core, that were to be analyzed for carbon content (TC, IC and OC by difference) at the USGS laboratory in Denver, CO, were oven dried at 40 °C. SB1c core samples, with carbon content greater than 10 percent by weight, and that required a drying step, were first air-dried to constant weight and a subsample then oven dried at 65 °C. For samples oven dried at 40 °C a correction was applied to compensate for the small differences between dry weight at 40 °C and dry weight at 65 °C.

Low carbon samples were subjected to an additional drying step at 110 °C.

Samples taken for mercury determinations were freeze-dried, rather than air or oven dried, prior to further preparation.

After air-drying, organic-matter rich samples from cores SB1a and SB1c were weighed, and the weighed sample gently crushed to break up large blocks of material. Crushing was done by hand, using either an agate mortar and pestle or a ceramic mallet and plate. Crushed sample material was then sieved using a 2 mm sieve. The portion of the sample that did not pass through the 2 mm sieve was collected, weighed and bagged for storage. Material that passed through the 2 mm sieve was collected and pulverized using a Cyclone Sample mill equipped with a 0.5 mm screen. The milled material was collected from the Cyclone mill, homogenized by rolling and quartering, and then placed in labeled glass bottles for use in analytical procedures.

Material that appeared to have low organic matter content, based on physical appearance and bulk density measurements, was crushed and sieved like the organic -matter rich samples. However, after sieving, the material that passed the 2 mm sieve was ground by hand to pass a 60 mesh screen (250 µm diameter screen openings), using an agate mortar and pestle. The ground sample material was then mixed well and placed in the same style glass bottle used for the organic rich material.

TC, TN, ^{13}C , ^{15}N , and inorganic elemental analyses were carried out using air-dry sample material. TC, TN and inorganic elemental data were corrected to an oven-dry basis using the data for air-dry and oven-dry moisture contents.

All archive sample material was stored after air-drying to constant weight because it was found that samples that had been air dried maintained a more constant weight over time than samples that had been oven dried.

Data from these analyses are shown in tables 10 A-C and 11 A-C in Markewich (1998).

TC, IC, OC by difference, TN, ^{13}C and ^{15}N .-- TC was determined by measuring the carbon dioxide (CO_2) produced by combusting the sample in a stream of oxygen (O_2). TC measurements were made using either a UIC CO_2 coulometer or a Fisons NA1500 elemental analyzer(EA)/Optima isotope ratio mass spectrometer (IRMS). IC was determined by measuring the CO_2 generated by heating a sample at 105°C in acid. A UIC coulometer was used for this measurement. Organic carbon was calculated as the difference between TC and IC. A Fisons NA1500 EA/Optima IRMS was also used for the determination of TN, ^{15}N and most ^{13}C measurements.

In the coulometric procedure for TC approximately 100 mg of sample was introduced into a furnace and combusted at 960°C in a stream of CO_2 -free oxygen. Gases generated by the combustion process were passed through a series of catalysts, to insure complete oxidation, and scrubbers, to remove components that would interfere with the CO_2 measurement. The carrier gas and CO_2 were then bubbled through a partially aqueous solution containing ethanalamine and a colorimetric indicator. The CO_2 was quantitatively absorbed and converted to a strong, titratable acid by the ethanalamine. The amount of CO_2 evolved from the sample was measured by integrating the amount of current required to electrically generate enough base to titrate the acid.

Inorganic carbon was determined by measuring the CO₂ generated by treating approximately 100 mg of sample with 2N perchloric acid (HClO₄) and heating the mixture at 105 °C. The evolved gases were first passed through an acidic (pH3) saturated silver sulfate (Ag₂SO₄) solution containing 3 percent hydrogen peroxide (H₂O₂) to remove contaminants and then into an ethanolamine/indicator solution. From this point the procedure was identical to that described for the determination of TC by coulometry.

The procedure using the Fisons NA1500 EA/Optima IRMS for the determination of total carbon, TN, ¹³C and ¹⁵N employed a Fisons NA1500 elemental analyser for sample combustion and separation of CO₂ and N₂ from other combustion products. The gas stream from the elemental analyser then entered the Optima IRMS which was used to obtain analytical data for TC, TN, ¹³C and ¹⁵N. For this analysis between 1 and 10 mg of sample, depending on the estimated carbon concentration, was loaded into a tin capsule and the capsule tightly crimped to exclude atmospheric gases. Samples were then combusted in a process similar to that described for the coulometric TC procedure but optimized to produce quantitative yields of nitrogen (N₂) as well as CO₂. The combustion products next passed through a chromatographic column where CO₂ and N₂ were separated and then introduced into the mass spectrometer for measurement. Elemental concentrations were calculated based on instrument responses for calibration standards. Isotope ratio measurements were corrected for fractionation effects and calibrated based on materials with known values.

In the early stages of this study, the Fisons NA1500 EA/Optima IRMS was used only to obtain TN and ¹⁵N data. However, TC data for samples analyzed using the coulometric method, and ¹³C data for samples analyzed in a conventional extraction line/mass spectrometer lab, showed excellent agreement with data for the same samples analyzed using the EA/IRMS instrument. As a result of this data comparison(table 3) the EA/IRMS was used for most TC, IC, ¹³C, and ¹⁵N analyses of the St. Bernard cores.

Table 3. Comparison of TC values obtained by EA/IRMS instrument and the coulometric method.

SB1c sample number	SB1c mid point of sample compaction corrected depth (cm)	Total Carbon (TC) coulometric (percent)	Total Carbon (TC) EA/IRMS (percent)
SB1c(21.5)	30.3	31.92	31.92
SB1c(40)	56.4	33.99	33.81
SB1c(65)	91.7	32.67	32.99
SB1c(79)	111.4	20.94	20.88
SB1c(83)	117.0	10.89	10.88
SB1c(97)	136.8	21.16	21.40
SB1c(110)	155.1	26.10	26.87
SB1c(128)	180.5	21.59	21.66
SB1c(145)	204.5	10.26	9.64
SB1c(177)	249.6	38.18	38.27
SB1c(202)	284.8	37.67	37.07
SB1c(229)	322.9	12.61	12.19
SB1c(250)	352.5	37.28	36.66
SB1c(265)	373.7	32.73	32.48
SB1c(284)	400.4	1.85	1.72

In addition to calibration materials, three standard materials were routinely included in all sample runs. These materials were a well analyzed sample of ethylenediaminetetracetic acid (EDTA) obtained from Fisons Instruments, S.p.a., a marine sediment (MESS-1) issued by the Chemistry Division of the Canadian National Research Council and a river sediment (NBS1645) issued by the National Bureau of Standards, now known as National Institute of Standards and Technology. Precision estimates, expressed as relative standard deviation, were 3.6-6.5 percent for TC, 3.7-6.5 percent for TN, 1.4-2.9 percent for ^{13}C , and 20-47 percent for ^{15}N , based on results for the standard materials (table 4). Approximately 3 percent of all samples were also analyzed in duplicate. For these duplicate runs the range, expressed as a percentage of the average of the duplicate runs, was less than 1 percent for TC less than 2 percent for TN, less than 1 percent for ^{13}C and about 15 percent for ^{15}N .

Table 4. Precision for TC, TN, ^{13}C , and ^{15}N analyses expressed as relative standard deviation (rsd)

Sample I.D.	Total %C (%rsd)	total %N (%rsd)	$\delta^{13}\text{C}$ (%rsd)	$\delta^{15}\text{N}$ (%rsd)
EDTA	3.6	3.7	1.5	--
MESS-1	4.0	3.9	2.9	20.1
NBS-1645	6.5	6.5	1.4	47.2

Because pH measurements made on core SB1a indicated that no inorganic carbon (IC) should be present, inorganic carbon was initially determined on only a selected set of samples. Results for this set of samples indicated negligible amounts of IC. Inorganic carbon was later run on all samples from this core as well as on samples from the SB1c core. Inorganic carbon was less than 0.01 percent for all samples except a for a gray clay sample from a depth of about 400 cm in core SB1c, which contained 0.01 percent inorganic carbon.

The uncertainty in the IC determinations, expressed as relative standard deviation, is approximately 5 percent. The range of values for samples run in duplicate was less than one percent of the carbon value.

Inorganic Elemental Analysis.--Inorganic elemental analysis was carried out by extracting approximately 100 mg of air dried sample with concentrated nitric acid (HNO_3). This procedure provides a near total extraction for many elements including Cu, Pb, Zn, Mn and Fe (Luoma 1981; Graney and others, 1995). Elemental concentrations were determined using a Perkin-Elmer 6000 inductively coupled plasma mass spectrometer (ICP-MS).

Sample material was weighed into teflon sample vials and wetted with 1 to 2 mL of deionized water. Each vial was then placed on balance, 10 mL of concentrated HNO_3 was added, the weight recorded and the vial tightly capped. Each vial was then shaken vigorously and placed in an aluminum block, heated at 95°C for 12 hours. The vials were then removed from the heating block and allowed to cool.

When all undissolved material had settled, 5 mL of the HNO_3 solution was transferred to another teflon vial. This vial was placed in the heating block and the solution taken to dryness at 95°C . The vial was then removed from the heating block, capped and allowed to cool.

After cooling, 15 mL of 1 percent HNO_3 was added to each vial. The vials were then capped, shaken vigorously and placed in the heating block for 1 hour at 95°C . The vials were then removed from the heating block, allowed to cool and the solutions prepared for analysis. If necessary, solutions were diluted with 1 percent HNO_3 as required for the analysis.

Volumetric operations were tracked by weighing all solutions as they were added or transferred. Blanks were included to monitor contamination and where appropriate blank subtraction was used to calculate final results.

Each sample was prepared for analysis by placing 100 uL of internal standard solution, containing 500 ppb (parts per billion) each of Sc, Rh and Tm, and 10 mL of sample solution in a clean plastic test tube. Standards and blanks were prepared in a similar manner.

Precision for these analyses was generally better than 10 percent relative standard deviation (table 5). Notable exceptions were Zn and As for which relative standard deviations were 38 percent and 16 percent respectively .

Table 5. Precision for TC, TN, ^{13}C , and ^{15}N analyses expressed as relative standard deviation (rsd)

Element	%rsd	Element	%rsd	Element	%rsd	Element	%rsd
Li	3.6	Ti	8.0	Cu	4.5	Cd	3.6
Na	4.6	V	8.6	Zn	37.6	Sn	11.7
Mg	7.2	Cr	7.8	As	16.1	Ba	2.6
Al	3.1	Mn	6.9	Sr	2.6	La	2.6
P	7.8	Fe	7.5	Y	3.0	Ce	5.2
K	5.2	Co	5.8	Mo	3.9	Pb	3.3
Ca	6.1	Ni	7.5	Ag	2.6	Th	4.5
						U	3.6

Carbon Fractionation - T.L. Fries

Sample material from cores SB1a and SB1c to be used for carbon fractionation experiments was removed from cold storage and allowed to come to room temperature before further treatment was carried out. Samples were weighed and then gently mixed using a stirring rod. A representative split was removed for moisture determination and a second split was taken for the fractionation experiment. Most samples contained more than 80 percent water by weight and were greater than 30 percent organic carbon on a dry weight basis. Exceptions were noted in clay/organic clay layers at uncorrected depths intervals of 82.5-86.5 cm, 140.5-162.5 cm and 218-233.5 cm. Light manual pressure was used in mixing all samples and large, woody, fragments were manually removed.

Approximately 1 g of wet sample was placed in a 50 mL centrifuge tube and 25 mL of lithium metatungstate (trade name, manufactured by BHP Minerals, Sunnyvale, CA 94089) (density = 1.8 g cm^{-3}) was added. The tubes were then shaken by hand until all sample material was in suspension and they were then placed on a motorized shaker for one hour. The tubes were then removed from the shaker and transferred to a centrifuge where the samples were run at 2500 rpm for 20 minutes.

The low density material was removed from the test tube using suction and collected on a dry, preweighed, 47 mm diameter, 45 μm pore-size glass fiber filter. The collected material was washed with deionized water, allowed to air dry, and weighed.

Most of the lithium metatungstate was then decanted from the centrifuge tube and the remaining high density material collected using the same techniques described for the low density fraction.

This fractionation procedure was set up to separate the sample material into a low density fraction and high density fraction and is similar to procedures used for carbon fractionation in soils (Trumbore, 1989). The low density fraction should contain relatively unmodified plant material and the higher density fraction should include decomposed plant and animal matter as well as clays and associated organic matter.

The high density fraction can be further separated by treatment with 6 Normal (N) hydrochloric acid (HCl) into hydrolyzable and non-hydrolyzable fractions. The hydrolyzable fraction should include those compounds that are most easily decomposed by microbial action and the non-hydrolyzable fraction should include long-lived products of the decomposition process.

The procedure described above was designed to provide data that might allow differences in organic matter composition, and associated inorganic components, to be detected and related to transport or in-situ production. The limited amount of sample material available and the high percentage of the total sample in the low density fraction made it impossible to carry the procedure beyond the initial density fractionation for most samples.

For the available sample size only those samples with less than 10 percent TC, dry weight basis, contained sufficient high density material for further fractionation. With the exception of the interdistributary clay sample from the base of the SB1c core, the high density material from these low carbon samples contained less than 10 percent of the sample's TC. These samples of high density carbon were all from sections of the core that had been visually described as clay. The low carbon content and small sample size made further fractionation impossible.

Samples with sufficient material in each fraction were analyzed for TC and HNO₃ leachable Al to determine the distribution of these constituents between light and heavy fractions. Methods used for these analyses are described in sections *TC, IC, OC by difference, TN, ¹³C and ¹⁵N and Inorganic Elemental Analysis*, respectively.

Data from these analyses (table 6) indicate that virtually all of the carbon is associated with the light fraction (< 1.8 g cm⁻³) while Al is found predominately in the heavy fraction (> 1.8 g cm⁻³).

Table 6. Distribution of Al and C between low and high density fractions

Sample I.D.	Corrected depth (cm) ¹	% of sample with p<1.8	% Al in light fraction	% C in light fraction	% Al in heavy fraction	% C in heavy fraction
SB1c-84	118	47	0.2	95	98	<10
SB1c-108	152	94	0.6	99	--	--
SB1c-158	223	43	0.3	97	102	<10
SB1c-194	274	108	1.0	102	--	--
SB1c-227	321	28	0.6	96	96	<10
SB1c-251	354	95	0.6	99	--	--
SB1c-280	395	3	--	--	101	90

¹/Depths were corrected for compaction by multiplying original depths by 1.41. Corrected depths have been rounded to the nearest whole number

This indicates that even during periods of high sediment transport into the area from which the SB1c core was taken, the amount of carbon carried by the sediment is small compared to the total amount of carbon accumulated. This does not exclude a scenario in which large amounts of carbon containing material, not associated with sediment, could be transported and deposited in this area.

¹³⁷Cs Measurement -T.L. Fries and J.L. Robbins

Measurement of ¹³⁷Cs was carried out by the NOAA Great Lakes Research Laboratory in Ann Arbor, MI (John Robbins and Nancy Morehead) to develop an estimate of a mean linear rate of soil accumulation over the last 30 years. Samples from the SB1b core were prepared as described above and were analyzed by placing the sample/ring/bag assemblage directly on a gamma counter. Each 2-cm section was counted for up to one day and data was recorded for both ¹³⁷Cs and ⁴⁰K (Appendix C).

A plot of ¹³⁷Cs count rates versus depth (fig. 2) for core SB1b, St. Bernard Parish, LA, shows a characteristic shape with a peak normally associated with the peak fallout years of 1963-1964. Because a large portion of the shallow material from this core was discarded in the field and another section was lost during preparation it was not possible to accurately model and date deposition throughout the core. A date of 1964 ± 0.5 can probably be assigned to the peak ¹³⁷Cs count rate.

Figure 2. ¹³⁷Cs activity in decays per minute for the surface 70 cm of core SB1b.

Peak ¹³⁷Cs activity was found at a compaction corrected center-of-section depth of 15.9 cm (midpoint of sample). Since the ¹³⁷Cs peak could be located anywhere in the sample interval (14.75-17.05 cm) and the compaction corrected length of this interval is 2.3 cm, the uncertainty in the depth estimate is approximately 14 percent (± 1.15 cm).

Sample Handling and Analysis for ¹⁴C Age Determinations - J.P. McGeehin

As described in *Coring and Sampling of Cores*, samples of peat, wood, grass, seeds and organic sediment were collected from the St. Bernard cores for ¹⁴C analysis. Most of the ¹⁴C analyses for the SB1c core were done on bulk peat, although, in some cases, discrete, well-preserved grass pieces were picked out at the same depth interval as the bulk peat, allowing for a cross comparison of dates by different organic materials. For the SB1a core (used for analysis of ¹⁴C related to atmospheric bomb testing), the peat showed little sign of degradation in the upper 30 cm and contained a considerable amount of loose grass pieces. In this core, subsamples of bulk

peat and discrete grass pieces were picked for each depth interval and the $\Delta^{14}\text{C}$ values compared. One interval of the SB1a core contained enough grass seeds for a ^{14}C analysis. The seeds were hand picked and processed in addition to the grass and bulk peat materials at this interval (table 7; fig. 3)

Samples from core SB1a were dried at 65 °C at the USGS laboratory in Menlo Park, CA, and shipped to the USGS carbon laboratory in Reston, VA. Samples from SB1c were dried at 110 °C at the COE sediment laboratory in New Orleans, LA, and brought to the USGS carbon laboratory in Reston, VA. All of the samples for ^{14}C analysis were chemically treated to remove any potential contaminants. A contaminant is defined here as any carbonaceous compound that contains ^{14}C activity which does not reflect the true ^{14}C activity of the sample. Generally, this added carbon is the result of post-deposition factors, such as prolonged contact of the sample with percolating water. The standard ^{14}C AAA pretreatment (acid, alkali, acid) was used to minimize any potential contamination in the St. Bernard sample materials.

The samples were first soaked in a warm 1N HCl solution for one hour. The HCl removes inorganic carbon contaminants such as limestone or shells. After neutralizing the samples with distilled water rinses, the samples were soaked in a warm solution of 2 percent sodium hydroxide (NaOH) for two hours. The NaOH extracts humic acid contaminants which are the degraded and transported by-products of humus produced by active soil horizons. Care was taken when performing the NaOH component of this pretreatment, since carbon-bearing materials will exchange modern CO_2 from the atmosphere if left in a alkaline solution for an extended period. Therefore, a second HCl wash of equal strength and duration as the first was performed on the samples to assure that the final pH of the samples after pretreatment is safely out of the alkaline range. The samples were then dried in a convection oven at 80 °C overnight.

Table 7. Data for ^{14}C age determinations for peat samples from core SB1a,

Corrected depth sample mid-point (cm) ¹	Original depth sample mid-point (in ²)	Lab I.D. (WW-nnn) ³	Material	Fraction moder ⁴	Age (yr BP \pm one sigma ⁵)		$\Delta^{14}\text{C}$ parts per thousand \pm one standard deviation)		$\delta^{13}\text{C}$ (parts per thousand)	$\delta^{13}\text{C}$ la ⁶
6.8	2.7	796	peat	1.1304	>MODERN		124.1	9.1	-18.5	D
9.5	3.5	797	peat	1.2081	>MODERN		201.4	8.2	-17.9	D
12.3	4.5	798	peat	1.2698	>MODERN		262.7	7.0	-17.5	D
15.0	5.5	763	peat	1.5288	>MODERN		520.3	8.4	-17.2	D
17.7	6.5	764	peat	1.2950	>MODERN		287.8	7.1	-26.8	D
20.4	7.5	765	peat	1.0319	>MODERN		26.2	6.7	-17.3	D
23.2	8.5	766	peat	0.9889	90	60	-16.5	6.5	-17.2	D
25.9	9.5	767	peat	0.9699	250	60	-35.5	6.3	-24.1	D
28.5	10.5	768	peat	0.9546	370	50	-50.7	5.3	-22.2	D
31.3	11.5	769	peat	0.9515	400	50	-53.7	5.3	-21.2	D
34.0	12.5	770	peat	0.9488	420	60	-56.4	5.9	-20.6	D
36.7	13.5	771	peat	0.9497	410	60	-55.6	6.2	-22.4	D
6.8	2.5	799	grass	1.1203	>MODERN		114.1	7.1	-16.5	D
9.5	3.5	800	grass	1.1892	>MODERN		182.6	7.6	-14.5	D
12.3	4.5	801	grass	1.2398	>MODERN		232.9	8.0	-16.1	D
15.0	5.5	772	grass	1.5530	>MODERN		544.4	10.0	-15.9	D
17.7	6.5	773	grass	1.5518	>MODERN		543.2	9.9	-17.0	D
20.4	7.5	774	grass	1.4642	>MODERN		456.0	9.4	-16.7	D
23.2	8.5	775	grass	1.1208	>MODERN		114.6	6.3	-15.4	D
25.9	9.5	776	grass	0.9726	220	60	-32.8	6.4	-17.3	D
28.5	10.5	777	grass	0.9729	220	50	-32.5	5.5	-14.9	D
31.3	11.5	778	grass	0.9673	270	50	-38.1	5.5	-14.0	D
34.0	12.5	779	grass	0.9661	280	50	-39.3	5.5	-15.0	D
36.7	13.5	780	grass	0.9725	220	50	-32.9	5.4	-14.3	D
25.9	9.5	781	seeds	0.9693	250	60	-36.0	6.1	-27.8	D

1/Corrected depth equals original depth (midpoint of sample interval) converted to cm (2.54 cm in⁻¹) and multiplied by 1.0743 to correct for compaction.

2/Top 2 inches (5.08 cm) discarded in the field.

3/ ^{14}C data are archived in a world-wide database indexed by U.S. Geological Survey laboratory I.D. numbers "WW-nnn" where "WW" indicates AMS ages.

4/Ratio of the ^{14}C activity of the sample to the activity of the modern standard, which is used in various calculations related to radiocarbon ages.

5/ ^{14}C age determinations not calibrated to tree-ring ages and not corrected for ^{14}C enrichment by seawater.

6/R=Reston, VA; D=Denver, CO; M=Menlo Park, CA.

Source: U.S. Geological Survey Open-File Report 98-36. Carbon storage and late Holocene chronostratigraphy of a Mississippi River deltaic marsh, St. Bernard Parish, Louisiana (H.W. Markewich, ed.).

Figure 3. ^{14}C , in parts per thousand, vs. depth below ground surface for the surface 40 cm of core SB1a, St. Bernard Parish, Louisiana.

Carbon was extracted first in the form of CO_2 and then as graphite. About 6-10 mg of sample material was selected from each interval and combusted in a sealed Vycor glass tube with copper oxide and silver at 900 °C for 6 hours. The tubes were placed on a high vacuum extraction line

and cracked in a break seal apparatus. The resultant CO₂ was then purified of volatile gases and sent through a cold trap to remove water. The purified and dried CO₂ was converted to graphite by placing a measured volume (equivalent to 1 mg carbon) in a chamber with approximately 5 mg of 63 mesh spherical iron, hydrogen and zinc as a catalyst at 575 °C for ten hours. The sample carbon (precipitated on the iron) was pressed into aluminum targets and sent to the Lawrence Livermore Center for Accelerator Mass Spectrometry (CAMS) for ¹⁴C dating using their FN tandem accelerator.

All ¹⁴C core samples were also analyzed for δ¹³C using mass spectrometry at USGS laboratories in Reston, VA, Denver, CO, and Menlo Park, CA. ¹⁴C ages were adjusted to account for naturally occurring fractionation effects. Results were reported as a Fraction Modern, Age in years BP, Δ¹⁴C, or all three (table 7).

Processing for Microscopic Stratigraphic Markers - *J.H. Wrenn, J.B. Pracht, and C.M. Fraticelli*

Historic records of the New Orleans area were examined to identify natural and cultural events that might have left micro-particulate evidence of their occurring in the stratigraphic record. Various micro-particles, including pollen, phytoliths, charcoal, opaque carbonaceous spherules, and fungal spores, were isolated from St. Bernard SB1c core samples for comparison with historic. The recovered populations were examined to ascertain the presence of potentially time significant markers. These markers are discussed in Markewich (1998).

Palynologic sample processing is as much an art as it is a technical exercise. Not all rocks, even those of the same lithology, react the same way to the involved processing procedures commonly used in palynology. The procedures listed below represent the general techniques used during the project. A longer period of acid digestion, a repetition of oxidation, or heavy liquid separation was occasionally required to successfully extract the fossils from the core samples.

The key to high quality sample processing is observing the post-acid digestion residue with a microscope after each processing step. This permits an informed decision to be made regarding

the next step to be taken with that particular residue. Processing "blind" can result in poor preparations."

The extraction and concentration of these micro-particles from sediments required the three different processing techniques detailed below. The centrifuge used is the International Equipment Co. (IEC) Clinic Centrifuge IEC with a 6-place swing out bucket centrifuge head for 15ml centrifuge tubes. The centrifuge has a 6.125-inch radius on the swing arm (center of axel to tip of bucket). Standard spin time was three minutes, but it is a rather variable standard (depending on the sample being processed)

Pollen and Fungal Spore Processing

Twenty-two, 0.9 mL samples were selected from the St. Bernard SB1c core and each was processed according to the methods of Faegri and Iversen (1964):

Seven mL of 10 percent hydrochloric acid (HCl) added to dissolve carbonates.

Two *Lycopodium* spore tablets added to each sample as marker grains; an additional 8 mL of 10 percent HCL added to assist in the dissolution of the marker tablets.

Sample centrifuged for 3 minutes at 1800 rpm and HCl decanted. (A clinical table top centrifuge and 12 or 15 mL centrifuge tubes were used in all centrifuging steps.)

Sample rinsed with distilled water, centrifuged 3 minutes at 1800 rpm, and water decanted

10 mL of 10 percent potassium hydroxide (KOH) added and sample heated in a hot water bath for 5 minutes. This step removes naturally oxidized organic debris.

Sample centrifuged 3 minutes at 1800 rpm and the KOH decanted.

Sample rinsed with distilled water and heated in a hot water bath for 2-5 minutes.

Sample centrifuged for 3 minutes at 1800 rpm and the water decanted.

10 mL of 50 percent hydrofluoric acid (HF) added to sample, and sample heated in a hot water bath for 5 minutes. This step removed silicate minerals.

Sample centrifuged 3 minutes at 1800 rpm, and the HF decanted.

Sample rinsed with distilled water, centrifuged 3 minutes at 1800 rpm and the water decanted. Repeated three times.

10 mL of glacial acetic (GA) acid added to sample in order to dehydrate (preparation for acetolysis).

Sample centrifuged 3 minutes at 1800 rpm and GA acid decanted.

10 mL of acetolysis solution (9 parts acetic anhydride: 1 part sulfuric acid) added to sample, which was then heated in hot water bath for 5 minutes. Acetolysis helps to dissolve cellulose.

Samples centrifuged and the acetolysis solution decanted.

10 mL of GA acid added to the sample; it was then centrifuged 3 minutes at 1800 rpm and the GA decanted.

Sample rinsed with distilled water, centrifuged 3 minutes at 1800 rpm, and the water decanted.

Sample stained with Safranin, rinsed with 10 mL tertiary butyl alcohol, centrifuged 3 minutes at 1800 rpm and the alcohol decanted.

Sample residue transferred to a 1 avoirdupois dram (1.7718 g) screw top vial, mounting medium (oil) added, and slides prepared.

Analysis consisted of identifying and counting 300 pollen grains (except the sparse samples at 272 cm and 245 cm in which the total number of grains was <300). The *Lycopodium* spores tablets added to each sample permitted calculation of pollen concentrations (Benninghoff, 1962; Stockmarr, 1971; Maher, 1981). The tablets were from batch 124961 (with a mean of 12,542 spores/tablet) produced by the Department of Quaternary Geology, Lund University, Sweden. *Lycopodium* markers were counted simultaneously, but outside, the pollen counts.

All samples were examined for the presence of the fungal spore *Sporomiella*. The morphology of the fungal spore was determined from a reference slide kindly provided by Dr. Owen Davis (Department of Geosciences, University of Arizona, Tucson, Arizona). No other fungal spores were tracked during this project, though they were abundant in many samples.

Phytolith Processing

New phytolith extraction techniques were developed using a microwave digestion unit. This resulted in a much more rapid preparation of phytolith samples..

Processing procedures were as follows:

Dry sample for twenty-four hours at 60 °C.

Sample material was placed in a digestion vessel of a ProLabo Model 401 focused microwave digestion unit. 10 mL of 70 percent HNO₃ was added and the sample was heated at 20 percent power for 20 minutes. This step removes pyrite and some organic material.

The sample was centrifuged 3 minutes at 1800 rpm and the HNO₃ decanted .

The sample was rinsed with distilled water, centrifuged 3 minutes at 1800 rpm and decanted.

10 mL of bleach was added and the sample heated at 20 percent power for 20 minutes. This step removed the remaining plant and organic material.

The samples were rinsed with distilled water, centrifuged 3 minutes at 1800 rpm and decanted.

Following the final washing, the samples were deflocculated as necessary with an ultrasonic cell disrupter. Sonication was limited to 15 seconds to preclude breakage of phytoliths.

The final step prior to slide making was sieving the residue through a 10 µm screen. Slides were made of the >10 µm size fraction. The less than 10 µm fraction was examined, but the few phytoliths noted were excluded from this study.

Each slide was described and counted on the basis of phytolith types, diatoms (centric and pennate), sponge spicules, inertinite, and other noteworthy forms.

CENEX Phytolith Reference Collection

Some phytoliths are more diagnostic of the plant taxa that produced them than are the pollen of that taxa. This is particularly true of members of the Gramineae family, which includes many

cultigens (e.g. corn, rice sugarcane). To facilitate the identification of any such phytoliths that might be recovered from the St. Bernard core, modern plant specimens were selected from the LSU Herbarium and processed to build a phytolith reference collection.

Leaves, blades, and/or fronds were taken from taxa and rinsed with distilled water several times. Each specimen was soaked in 10 percent HCl for 10 minutes to remove the silica-based insecticide used by the herbarium, as well as naturally-occurring surficial mineralization and rinsed several times with distilled water to remove the HCl.

The plant fragments were laid flat on a microscope slide, covered and held in place with a cover-slip, and placed in a Thermolyne furnace at 500 °C for 6 hours. This treatment effectively ashed the organic component of the samples, exposing the siliceous phytoliths in growth position.

After cooling, the samples were covered with Cargille Meltmount (No =1.539) and a clean cover slip was attached.

The plants processed for the CENEX Phytolith Reference Slide Collection are listed in table 8.

Table 8. Plants processed for the CENEX Phytolith Reference Slide Collection

Genus species	Common Name	CENEX Reference #
<i>Indigofera suffruticosa</i>	Indigo	7
<i>Indigofera spicata</i>	Indigo	5-6
<i>Orza sativa</i>	Rice	3-4
<i>Saccharum officinarum</i>	Sugarcane	1-2
<i>Gossypium hirsutum</i>	Cotton	9

Charcoal/OCS Processing

Samples were prepared for charcoal and opaque carbonaceous spherule (OCS) analysis by acid digestion to remove mineral matter and oxidation to remove kerogen. These procedures are similar to traditional palynologic processing techniques (Barss and Williams, 1973), though our intent was to destroy all organic matter, palynomorphs included, and recover only inert charcoal. In reality, highly resistant or inert plant fragments remained in the some sample residues even after the extensive and harsh treatment described below. Data are given in table 9.

A ProLabo Focused Microwave Digestion Unit, Model 401, was used to heat the samples and accelerate the digestion process. (See Jones and Ellin, 1998, for a discussion of microwave sample processing as applied to palynology.) Operation of the unit is computer controlled and acids are automatically pumped into the digestion vessel, in the programmed sequence and the sample heated for a preset time interval for each digestion step. Residues were visually inspected after each post-acid digestion step to determine the next appropriate procedure.

The steps used are noted below. However, they are probably much more complicated than necessary. We are currently working to simplify the process.

Subsamples were collected from the upper 70 cm of the St. Bernard SB1c core at 10 cm intervals (10, 20, 30 cm, and so on; measurements uncorrected for compaction), using a 1.2 mL sampling spoon.

Each sample was placed in a solution of 15 mL distilled H₂O and 15mL household bleach (5.25 percent sodium hypochlorite) to soak overnight. (This removed or softened up much of the plant matter in the peat samples.)

Residue was washed in distilled water by repeated centrifuging (2,800 rpm for 3 minutes) to remove bleach.

Residue placed in a PTFE (microwave and HF resistant plastic) digestion vessel and heated in 10 mL of concentrated HCl for 20 minutes to digest calcareous material.

Concentrated HF (10 mL) was added directly to the residue and heated for 20 minutes to dissolve silicates in the sample.

Concentrated HCl (10 mL) was added to the residue to dissolve any CaF₂ that might have formed during the previous step.

Residue washed in distilled water by repeated centrifuging (the same IEC clinic centrifuge as used for pollen processing; 2,800 rpm for 3 minutes) until neutral pH was established.

Residue placed in concentrated HNO₃ for 90 minutes.

Residue washed in distilled water by repeated centrifuging (2,800 rpm for 3 minutes) until neutral pH was established.

Residue placed in KOH and heated in a hot water bath for 90 minutes.

Residue washed in distilled water by repeated centrifuging (2,800 rpm for 3 minutes) until neutral pH was established.

Residue was placed in 25 mL of Schutlz' solution (1 cc potassium chlorate [KClO₃] and 50 mL HNO₃) for 1 hour to remove remaining plant matter.

Residue washed in distilled water by repeated centrifuging (2,800 rpm for 3 minutes) until neutral pH was established.

A *Lycopodium* spore tablet was dissolved in HCl and added to each residue to provide a reference against which to compare counts. (See discussion above in the section Pollen and Fungal Spore Processing for information on the *Lycopodium* tablets.)

Sample sieved through 45 µm and 10 µm sieves with distilled water. Slides of the +10 and +45 µm fractions were prepared using Permout mounting medium.

Table 9. Charcoal data for core SB1c

Sample Depths cm	Charcoal Fragments Sampled	Probability of Charcoal Being Sampled	Estimated Area of Charcoal mm ² / Slide	Standard Deviation (95%)	Markers Sampled/ Total Markers	Volume of Sample mm ²	Area of Charcoal mm ² / sediment mm ³	Area of Charcoal cm ² / sediment cm ³
14	430	0.08	52.76	± 2.44	4 / 12542	1200	137.87	13.79
28	400	0.20	56.77	±2.55	3 / 12542	1200	197.79	19.78
42	333	0.06	53.57	±2.85	9 / 12542	1200	62.21	6.22
56	133	0.02	21.75	±1.87	26 / 12542	1200	8.75	0.87
71	304	0.06	54.15	±3.02	1 / 12542	1200	565.10	56.60
85	400	0.08	77.02	±3.69	11 / 12542	1200	73.18	7.32

1 Samples from (corrected) cm depth below surface: 4, 11, 18, 32, 44, 69, 85, 106, 127, 166, 195, 205, 214, 235, 265, 285, 305, 316, 379, 384, and 396. Depths were corrected for compaction by multiplying original depths by 1.41. Corrected depths have been rounded to the nearest whole number.

2 Samples from (corrected) cm depth below surface: 14, 28, 42, 56, 85, 99, 197, 296, 381. Depths were corrected for compaction by multiplying original depths by 1.41. Corrected depths have been rounded to the nearest whole number.

Calculations - G.R. Buell and T.L. Fries

Mass Accumulation

Mass accumulations of matrix material (mostly peat and biogenic silica), organic carbon (OC), and of major and minor elements were computed both from surface to depth and in reverse, depending on the use of the cumulative mass curves. Accumulation was started at the bottom of the core for graphical display of patterns with depth and age; and at the top of the core for derivation of decay and rate constants.

Incremental masses for each core interval were computed as

$$m_i = \rho_b \times 10 \times (d_{\text{corr}_b} - d_{\text{corr}_t}) \times f \quad (1)$$

where

m_i = incremental mass,

in kg m^{-2} (total matrix, OC);

in g m^{-2} (major/minor elements)

ρ_b = dry-bulk density, in g/cm^3

d_{corr_b} = compaction-corrected depth of bottom of interval, in cm

d_{corr_t} = compaction-corrected depth of top of interval, in cm

$f = 1$ for total matrix mass (1a)

$f = c_{\text{ppc}} / 100$ for organic carbon (1b)

$f = c_{\text{ppc}} \times 10$ for Al, Fe, Na, K, Ca, Mg (1c)

where

c_{ppc} = concentration, in percent

$f = c_{\text{ppm}} / 1000$ (1d)

for major elements not listed in (1c) and minor elements

where

c_{ppm} = concentration, in mg kg^{-1} .

Cumulative masses for each core interval were computed as

$$m_{\text{cn}} = \sum_{i=1}^n m_i \quad (2)$$

where

n = the n th core interval from either the top or bottom of the core

m_{cn} = cumulative mass through core interval n

m_i = incremental mass for core interval i .

Interpolation of Missing Data

Computations such as cumulative mass estimates require data for all intervals of the core.

However, both constraints on time and money preclude analysis of every core section and, for many questions, subsampling provides sufficient data for scientifically useful answers. Values for unsampled intervals were computed by linear interpolation (based on compaction-corrected depths) between adjacent sampled intervals. However, interpolation was not done across stratigraphically distinct subsections of core. For example, intervals in clay-rich layers were assigned values based only on data from within that layer.

OC mass-accumulation rate

Mass-accumulation rates for OC were computed for age intervals defined by depths at which ages were assigned based on ^{137}Cs , bomb-spike ^{14}C , ^{14}C decay, and diagnostic stratigraphic markers.

First, cumulative masses were computed for the depths at which ages were assigned. Computation was done by linear interpolation between cumulative masses for sampled depths as determined by equation (2). Minimum and maximum mass-accumulation rates were then computed as

$$\text{mar}_{\min} = (\text{oc}_b - \text{oc}_t) / [(\text{age}_b - \text{ageerr}_b) - (\text{age}_t + \text{ageerr}_t)] \quad (3a) \text{ and}$$

$$\text{mar}_{\max} = (\text{oc}_b - \text{oc}_t) / [(\text{age}_b + \text{ageerr}_b) - (\text{age}_t - \text{ageerr}_t)] \quad (3b)$$

where

mar_{\min} = minimum mass-accumulation rate, in $\text{kg m}^{-2} \text{yr}^{-1}$

mar_{\max} = maximum mass-accumulation rate, in $\text{kg m}^{-2} \text{yr}^{-1}$

oc_b = cumulative OC mass at bottom of age interval

oc_t = cumulative OC mass at top of age interval, in kg m^{-2}

age_b = age assigned to bottom of age interval, in yr BP

ageerr_b = analytical error in bottom age determination, in yr

age_t = age assigned to top of age interval in yr BP

ageerr_t = analytical error in top age determination, in yr.

The mass-accumulation rates computed by equations (3a) and (3b) provide a range in estimated rate based on analytical error in the in the ^{14}C method (discussed in *Appendix B, The ^{14}C Method*).

Normalized Concentrations of Minor Elements

Concentrations of minor elements in the cores were normalized to aluminum (Al) and OC to minimize the variances associated with source material (aluminum) and the diluent or concentration effect of organic matter (measured as OC). Conservative crustal elements such as titanium (Ti) and Al are commonly used to remove variations in minor-element concentrations due to variations in mineral-phase source material (Horowitz, 1991). The extent to which organic matter either ‘dilutes’ or ‘concentrates’ a minor element depends on the combined effects of phase partitioning, geochemical cycling, atmospheric and fluvial transport, and the nature and source of the organic material.

Normalization is done according to the formula

$$c_n = c / ([\text{Al}] / 10000) / [\text{oc}] \quad (4)$$

where

c_n = normalized ‘concentration’ (dimensionless)

c = measured concentration, in mg kg^{-1}

$[\text{Al}]$ = Al concentration, in mg kg^{-1}

$[\text{oc}]$ = OC concentration, in percent.

Patterns with depth (and age) in the normalized data can provide information on variations related to human influences on the environment such as land disturbance, agricultural practices, and industrial production, if something also is known about the hydrologic and atmospheric transport processes affecting minor-element redistribution.

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APPENDICES**Appendix A - Units of Measure*****Length***

m, metre

cm, centimeter

mm, millimeter

 μm , micrometer

in, inch

ft, foot

Temperature $^{\circ}\text{C}$, degrees Celsius***Radioactivity***Curie, 3.7×10^{10} disintegrations per secondfCi, femto (10^{-15}) Curie***Mass (Weight)***

g, gram

mg, milligram

Volume

mL, milliliter

 μL , microliter in^3 , cubic inch***Concentration*** ‰ , parts per thousand***Energy***

keV, kilo electron volts

Force

RCF(g), relative centrifugal force x gravity

Appendix B - The ^{14}C Method *J.P. McGeehin* ***^{14}C Carbon Production and Age Determinations***

The radioactive isotope of carbon, ^{14}C , originates in the upper atmosphere from the collision of cosmic ray produced neutrons with elemental nitrogen. The newly formed ^{14}C atom quickly oxidizes to $^{14}\text{CO}_2$ and is readily distributed throughout the earth's atmosphere. A small percentage of this radioactive carbon ends up in the biosphere where metabolic processes keep the ^{14}C content of living organisms in equilibrium with the ^{14}C content in the atmosphere. When an organism dies its ^{14}C content diminishes with a half-life of about 5730 years, however, the original "Libby" half-life of 5568 is still used in most ^{14}C calculations.

The radiocarbon age of a sample may be calculated using the following simplified equation (Stuiver and Polach, 1977):

$$^{14}\text{C Age} = - 8033 \ln(A_{\text{SN}}/A_{\text{ON}}) \quad (1)$$

where 8033 refers to the Libby mean-life of a ^{14}C atom, A_{ON} the activity of the modern standard (e.g. NBS Oxalic Acid I), and A_{SN} the sample's current activity. Both A_{SN} and A_{ON} are normalized to a common $\delta^{13}\text{C}$ value of -25 ‰ (See discussion on $\delta^{13}\text{C}$ values). The $A_{\text{SN}}/A_{\text{ON}}$ ratio is then corrected for background activity (the contamination added from the sample graphitization process, as measured by a blank sample, such as coal, which should have no remaining ^{14}C atoms). The resultant $A_{\text{SN}}/A_{\text{ON}}$ ratio, normalized and corrected, is referred to as the Fraction Modern (F). Standard radiocarbon ages are reported as “years BP” or “years before present” referring to the 1950 zero year for radiocarbon dating.

Equation (1) was developed for proportional gas counting and the specific activities involved refer to the ratios of ^{14}C atoms to total carbon atoms in a sample or standard [$^{14}\text{C}/(^{13}\text{C} + ^{12}\text{C})$]. At Lawrence Livermore Laboratory's Center for Accelerator Mass Spectrometry (CAMS), as in other AMS labs, samples are dated by atom counting, and the ratios are measured as $^{14}\text{C}/^{13}\text{C}$. Therefore, Equation (1) can be modified to read (Donahue and others, 1990):

$$^{14}\text{C Age} = - 8033 \ln [(^{14}\text{C}/^{13}\text{C})_{\text{SN}}/(^{14}\text{C}/^{13}\text{C})_{\text{on}}] \quad (2)$$

The ratio $(^{14}\text{C}/^{13}\text{C})_{\text{SN}}/(^{14}\text{C}/^{13}\text{C})_{\text{on}}$ is the atom-counted fraction modern (F) of a sample dated by AMS. Equation (2) can thus be changed to read

$$^{14}\text{C Age} = - 8033 \ln F \quad (3)$$

Fractionation effects and $\delta^{13}\text{C}$ Measurements.-- Carbon-bearing materials may be either depleted or enriched in ^{14}C relative to other carbon isotopes as a function of the carbon reservoir from which the samples were derived. This means that different organic materials living and dying contemporaneously would show discrepant ^{14}C ages as a function of their metabolically-controlled carbon isotope ratios. The stable carbon isotope ratio, $^{13}\text{C}/^{12}\text{C}$, is used to correct for metabolic fractionation effects in both the ^{14}C sample and standards. This ratio is measured in parts per thousand (‰) deviation from a calcium carbonate belemnite standard (PDB) using the following equation:

$$\delta^{13}\text{C} (\text{‰}) = (^{13}\text{C}:^{12}\text{C}_{\text{sample}} - ^{13}\text{C}:^{12}\text{C}_{\text{std}} / ^{13}\text{C}:^{12}\text{C}_{\text{std}}) 1000 \quad (4)$$

Generally speaking, the amount of $^{14}\text{C}/^{12}\text{C}$ fractionation in a sample (proportional counting) is twice that of the $^{13}\text{C}/^{12}\text{C}$ measured by the $\delta^{13}\text{C}$ value in the same sample (Craig, 1954). By convention, fractionation differences are compensated for in an age calculation by normalizing all samples and standards to a value of -25‰ (the $\delta^{13}\text{C}$ value for ^{14}C dateable terrestrial wood). The age correction for fractionation effects is thus:

$$8033 \ln \left[\frac{1 + 2(\delta^{13}\text{C})}{1000} \right] \quad (5)$$

Each $\delta^{13}\text{C}$ per mil variation from -25‰ equates to a difference in the ^{14}C age of approximately 16 years for a proportionally counted sample or 8 years for a AMS date (as function of the $^{14}\text{C}/^{13}\text{C}$ ratio counting method). For example, an AMS dated sample of a C_4 grass, such as we find in the St. Bernard core peats, could have a $\delta^{13}\text{C}$ value of approximately -17‰ which would result in a 64 year correction because of the normalization process.

Atmospheric Bomb ^{14}C and $\Delta^{14}\text{C}$ Measurements.-- In addition to reporting ages in “years BP,” sample results may also be reported as a $\Delta^{14}\text{C}$ value, which refers to the deviation (in parts per thousand) of the sample ^{14}C counts relative to the ^{14}C counts of the absolute modern standard (corrected for decay from 1950 to the year of measurement). This is the accepted reporting method for samples containing elevated ^{14}C levels as a result of above-ground atmospheric bomb testing in the 1950s and 1960s. Atmospheric ^{14}C levels jumped dramatically during this period, peaking in the northern hemisphere between 1964 and 1965 with $\Delta^{14}\text{C}$ levels over 900‰ (fig. B1).

Fig. B1. Plot of atmospheric ^{14}C bomb activity; $\Delta^{14}\text{C}$ (‰) vs. calendar year. Data from Levin and others (1985) represent yearly mean ^{14}C levels measured from tropospheric CO_2 samples taken at mountain stations in Austria and Germany. Data from Burchuladze and others (1989) represent the measured ^{14}C levels in Georgian (eastern Europe) wines prepared from annually grown grapes.

The increased levels of atmospheric ^{14}C are mirrored proportionally in the $^{14}\text{CO}_2$ of organisms extant during this period. The formula for $\Delta^{14}\text{C}$ is (Stuiver and Polach, 1977):

$$\ddot{\Delta}^{14}\text{C} = [F(1/e^{\ddot{\epsilon}(y-1950)}) - 1]1000 \quad (6)$$

where the symbol e is the base of the natural logarithm. It is approximately equal to 2.71828. The symbol $\ddot{\epsilon}$ represents the ^{14}C decay constant and is equal to $1/8267 \text{ yr}^{-1}$. For the year 1997 the function $1/e^{\ddot{\epsilon}(y-1950)}$ can be calculated at 0.99433, reducing Equation (6) to

$$\ddot{\Delta}^{14}\text{C} = [0.99433F - 1]1000 \text{ ‰} \quad (7)$$

Bomb carbon provides a useful radiocarbon marker for very recent samples (mid-1950s and younger). Because bomb carbon in the atmosphere has peaked and is decreasing rapidly, values for $\Delta^{14}\text{C}$ have a pre- and post-peak component. A single measured $\Delta^{14}\text{C}$ level above the absolute modern standard could represent atmospheric bomb carbon as values were increasing during the early 1960's. Conversely, the same $\Delta^{14}\text{C}$ value could represent bomb carbon as values were decreasing in the atmosphere after 1965. Therefore, it is necessary to analyze numerous samples from a stratigraphic unit in order to determine what part of the curve the $\Delta^{14}\text{C}$ values represent.

Uncertainty of ^{14}C Results

The expression of uncertainty in an AMS radiocarbon age is derived from the equation (Donahue and others, 1997):

$$\Delta(\text{Age}) = - 8033(S) \quad (8)$$

where S is the error or uncertainty in the ^{14}C counting statistics. The value for S for an individual sample (S_{ST}) is determined from the combined statistical deviation of the count rates of the sample and the modern standard, and thus can be given as follows

$$S_{\text{ST}} = \left\{ \left(\frac{\sqrt{^{14}\text{C}_S}}{^{14}\text{C}_S} \right)^2 + \left(\frac{\sqrt{^{14}\text{C}_{\text{OX}}}}{^{14}\text{C}_{\text{OX}}} \right)^2 \right\}^{1/2} \quad (9)$$

Equation (9) represents the uncertainty associated with the counting statistics only. Systematic error associated with the AMS instrumentation can also be calculated based on long-term measurements of the ratio of two different Oxalic Acid modern standards. The ages and the count rates of the two Oxalic Acids are known, and thus, the ratio between them has been precisely determined. The calculated value of instrumentation error is combined with the counting-statistical error, resulting in a total error (S_{TOTAL}) as follows

$$S_{\text{TOTAL}} = \left(S_{\text{ST}}^2 + S_{\text{RME}}^2 \right)^{1/2} \quad (10)$$

where S_{ST} equals the counting-statistical error and S_{RME} equals the random machine error. The total error assigned to a sample age is given as one standard deviation (one sigma). At Lawrence Livermore Laboratory, the combined one sigma counting and instrumentation error for a near modern sample is approximately equal to 0.7 percent or 55 ^{14}C years (Roberts and others, 1997).

Fig. B1. Plot of atmospheric ^{14}C bomb activity; $\Delta^{14}\text{C}$ (‰) vs. calendar year.

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Appendix C -The ^{137}Cs Method T.L. Fries and J.L. Robbins

^{137}Cs does not occur naturally; it is a fission product generated during nuclear testing, or in nuclear reactors. Atmospheric testing of nuclear weapons, beginning during the period 1952-1954 (Robbins and others, 1978) resulted in deposition of ^{137}Cs on a global scale with ^{137}Cs fallout peaking in 1963-1964 and dropping below detection limits by 1983-1984 (Cambray and others, 1985). Figure C1 is a plot of ^{90}Sr atmospheric (surface air) concentration for a mean latitude of 51°N latitude from 1950-1975, which mirrors ^{137}Cs deposition during this period (Sarmiento and Gwinn, 1986). Other characteristics of the ^{137}Cs fallout (^{90}Sr concentration) profile (fig. C1) include a major peak in 1958 and very minor peaks in 1971 and 1974. All peaks are related to above ground testing of nuclear weapons. The low rates during the period 1958-1961 are attributable to a testing moratorium. Worldwide, there are local areas enriched in ^{137}Cs . These areas of enrichment are the result of local events, such as the failure of a nuclear power generating station (such as at Chernobyl). Usually, these events do not contribute significantly to global ^{137}Cs fallout.

Fig. C1. Variation in atmospheric ^{90}Sr ; fCi m^{-3} vs. calendar year.

Fallout of ^{137}Cs has been greater in the northern hemisphere than in the southern hemisphere as a result of the more intensive above ground testing in the northern hemisphere. ^{137}Cs fallout patterns vary not only with latitude, but also as a function of precipitation on regional or even local scales. As ^{137}Cs is removed from the atmosphere by rain and dry fallout, it is deposited in water systems, on land or on vegetation. In water the ^{137}Cs is rapidly absorbed by suspended

matter, with a particularly high affinity for clay particles, and ultimately is deposited as part of the sediment record. On land ^{137}Cs is deposited directly from the atmosphere and indirectly as a result of transport from vegetation and erosional processes.

Although partial mobilization of ^{137}Cs in reservoir sediments has been observed under conditions of thermal stratification and hypolimnetic anoxia (Evans and others, 1983) or in environments characterized by low pH, low clay and high organic matter content and or low redox values and high salinity (Longmore and others, 1986) ^{137}Cs is normally strongly absorbed to cation exchange sites and is relatively immobile. Redistribution of ^{137}Cs is usually the result of physical processes including cultivation, erosion and bioturbation. Chemical and biological processes account for very limited amount of ^{137}Cs movement in the environment. Because ^{137}Cs fallout patterns are well understood and this tracer is strongly absorbed by soil particles, it provides a unique marker for tracing erosion, transport and deposition over a wide range of scales (Ritchie and McHenry, 1990). With a half-life of 30.17 years, a large total amount of deposited fallout, no natural background concentration and a recent, well defined source, it is singularly useful for investigating events that have occurred during the last 40 years.

Decay of ^{137}Cs takes place by gamma emission at 661.6 keV, allowing the relatively simple, non-destructive measurement of ^{137}Cs concentrations. Samples are analyzed using a high purity germanium (HPGe) detector for gamma-ray detection and a multichannel analyzer to analyze and quantify the gamma-ray spectrum. The system is normally calibrated using sample material spiked with a standard solution of gamma-emitting radionuclides. Different weights of material are then counted using a standard geometry to obtain a detector efficiency function. In addition to ^{137}Cs , ^{40}K (1460.7 keV) is also routinely determined as a measure of total potassium content.

A number of methods exist for developing chronologies based on ^{137}Cs profiles. These approaches are generally divided between those that account for post-depositional redistribution processes such as the Dynamic Mixing (DYNMX) model (Robbins, 1986) or the Rapid Steady-State Mixing (RSSM) model (Robbins and others, 1977) and those that do not model tracer or particle redistribution, such as the System Time-Averaging (STA) model (Robbins and others, in prep.) or simply basing chronologies on date assignments made to radiocesium profile maxima.

The latter approach has been used in studies of accretion in Louisiana salt marshes (Delaune and others, 1978) and was applied to the ^{137}Cs data from the SB1b core.

Calculating mean sediment accumulation rates based on dates assigned to radiocesium profile maxima also assumes that there has been no post depositional mixing of sediments or of ^{137}Cs . In this approach the maximum fallout date of 1964 ± 0.5 year is assigned to the cumulative dry weight at the midpoint of the interval which contains the ^{137}Cs peak. In many instances ^{137}Cs profiles will show at least some system time-averaging (STA) influence, which would effectively move the profile peak date closer to the present. For instance, a 5 year averaging time constant would move the peak to 1964.8; a 50 year time constant would move the peak to 1966.5. However, for this core no STA influence was included in the assigned peak date. The mean sediment accumulation rate, calculated as $\text{g cm}^{-2}\text{yr}^{-1}$ is the mean rate between the peak fallout year and the date the sample was taken. Since the profile peak can occur anywhere within the sampling interval, the minimum uncertainty in the date assignment is the half width of the sampling interval, measured in g cm^{-2} , divided by the mean accumulation rate.

In general, all ^{137}Cs model calculations assume that the mass accumulation rate is constant. When age-depth relations are developed they are based on that assumption. Finally, all model calculations are based on the cumulative dry weight of sediment as the measure of depth.

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