ORGANIC MATTER ANALYSIS OF SEDIMENTS FROM SIMPSON BAY, ALASKA USING ELEMENTAL, STABLE ISOTOPIC, AND MOLECULAR SIGNATURES

A Senior Scholars Thesis

by

CHRISTINA PONDELL

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2008

Major: Marine Science

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Associate Dean for Undergraduate Research:	Robert C. Webb

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ABSTRACT

Organic Matter Analysis of Sediments from Simpson Bay, Alaska using Elemental, Stable Isotopic, and Molecular Signatures. (April 2008)

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Sediment samples from Simpson Bay, Alaska were analyzed to determine the influence of earthquake events on the accumulated organic matter. Radiochemical analysis of ^{210}Pb activity in the sediment dated the cores and determined the depths of the layers from 1964 and 1974, two years where large earthquakes affected this region. Organic carbon (OC) to total nitrogen ratio (C/N) variation suggests a change in the source of organic matter in the targeted earthquake layers. However, the stable profiles for lignin-derived biomarkers and stable carbon isotopes imply that the earthquake events did not disrupt the drainage basin of Simpson Bay enough to change the signatures of the organic matter deposited shortly after these occurrences. The OC, C/N and biomarker signatures were then used to determine the geographic distribution of sediments and organic matter throughout the bay. Organic carbon and lignin biomarker concentrations suggest sources of organic matter to the system from the East Bay and from the North Bay. Biomarker analysis also implies that the source from the East Bay has a higher terrestrial organic matter input than the source in the North Bay. Stable carbon isotopic data imply that the dominant source of organic carbon in the open portions of the bay has a marine source, due to the fact that terrigenous material is deposited at the mouths of the rivers and creeks that feed the system.

ACKNOWLEDGMENTS

I would like to thank Dr. Patrick Louchouarn and Dr. Timothy Dellapenna for their support and encouragement during this project and Chris Noll for his guidance and insight. The Coastal Geology Lab at Texas A&M University at Galveston funded this project.

I would also like to thank my family and Robert for their continued support.

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CHAPTER I

INTRODUCTION

In March of 1964, the second largest recorded earthquake devastated the region of Prince William Sound, Alaska. The earthquake's epicenter was located 120km southwest of Anchorage and had a magnitude of 9.2. This earthquake resulted in 125 fatalities and $311 million in property loss throughout the region (Stover and Coffman 2007). However, this earthquake remains just one in thousands that influence Alaska because of its close proximity to the subduction zone between the Pacific and North American plates. Hundreds of earthquakes affect this area every year, and depending on the severity of the earthquake, proof of the event exists not only in the historic record but also in the sediment record. By coupling the historical and sedimentological records of known events, we can develop methods to identify these event signatures so that a chronology of events can be determined beyond the limited historical records.

Underwater events caused by earthquakes carry sediments to the sea floor and are characterized by a number of mass transport mechanisms, each with their own unique signatures. These earthquake induced rapidly deposited layers (RDL) are often characterized by a fining upwards in the grain size, low organic carbon content (< 1%), high inorganic carbon content (> 2%), high carbon to nitrogen (C/N) ratios, and low $\delta^{13}C$

This thesis follows the style of Limnology and Oceanography.

values ($< -27^{0}/_{00}$) (St-Onge et al. 2004; St-Onge and Hillaire-Marcel 2001). Together, these features alert researchers to the possibility of the presence of one of these earthquakes RDL; however, individually these characteristics may imply the occurrence of many different events. The environment from which the cores were collected determines the materials that is deposited in the sediment record, and therefore influences the characteristic features of earthquake RDL (Becker, et al. 2005).

Detection of the earthquake RDL is only possible if the typical sedimentation patterns in the area have been determined. This is achieved by analyzing the sediment cores both vertically, showing temporal changes, and geographically, showing spatial changes in the sedimentary properties. Then the signatures for various biomarkers can be determined for sedimentation under normal conditions, and the anomalous signatures describing the earthquake depositional layers are better defined.

The study area, Simpson Bay, is a fjord located in Prince William Sound along the south central coast of Alaska. The bay can be divided into three basins, each with its own watershed. North Bay has the largest watershed and is connected to the West Bay by a shallow sill. West Bay and East Bay open directly into Prince William Sound. The circulation in this region is mainly tidal dominated, but the rivers at the head of East Bay and North Bay carry large loads creating high sedimentation rates (Noll 2005).

This project studied Simpson Bay because earthquakes frequently influence the region and because the environment surrounding Simpson Bay and the basin itself are pristine environments, removed from anthropological impacts such as mining or deforestation. The data collected from this area will offer information that can act as a reference for regions affected by human activity by providing data that describes sedimentation under pristine conditions.

In this study, sediment cores were collected from Simpson Bay to determine trends in the geographical distribution and the historical sediment record. The sediment was analyzed for organic carbon and lignin content, stable carbon isotopes, and radioisotope activity to locate and date layers deposited from earthquakes.

CHAPTER II

METHODS

Sampling Area

Simpson Bay is a pristine fjord in northeast Prince William Sound, Alaska (Fig.1). Twenty-one cores were taken to sample the specific sedimentary environments found throughout the system. Sediment was sampled using a box core, and each core was subsampled at centimeter intervals. Subsamples were analyzed for radiochemical signatures. Four cores were chosen based on their location in the bay for elemental and lignin biomarker analysis, and samples were chosen to represent the trends throughout the length of the core based on grain size analysis, water content, and other geotechnical properties. The top sample of each core was analyzed for elemental and lignin biomarker signatures as well as isotopic analysis to map the spatial distribution of these proxies. Nine samples were analyzed from the delta area in the northern arm of Simpson Bay. During the analysis, the cores were divided into two areas, based on inferred dispersion patterns. The North Bay includes cores 1, 2, 3, 4, 5, 6, 15, 16, 17, 18 and 20 while cores 7, 8, 9, 10, 11, 12, 13 and 28 were collected from the East Bay.

Radiochemical Analysis

Sedimentation rates were determined by radiochemical analysis of ^{210}Pb activity using the method developed by Nittrouer and others (1979). Activity was determined by

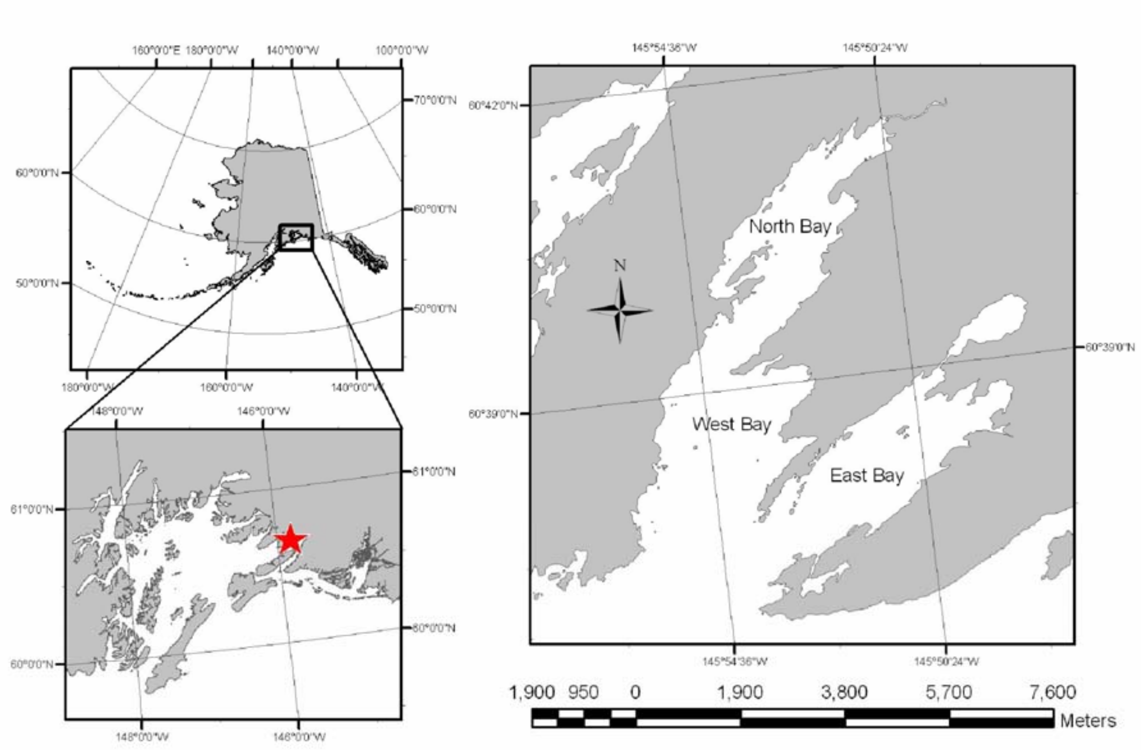


Fig. 1. Location of Simpson Bay, Alaska. Of the cores analyzed in this study, SBBC1 was collected from the delta in North Bay, SBBC3 from the sill separating North Bay from West Bay, SBBC10 from the East Bay delta, and SBBC28 from the mouth of Simpson Bay.

measuring the alpha emission of the daughter species, ^{210}Po, assuming equilibrium between these two isotopes (Nittrouer et al. 1979; Santschi et al. 2001; Matthews, et al. 2007). The sediment samples were wet sieved through a #400 sieve to remove grains larger than 38μm. Approximately 1g of dried, pulverized sediment was spiked with ^{209}Po as a tracer and digested with concentrated HCl, HNO_3, and HF. The remaining sample was repeatedly evaporated in HCl and HNO_3 to produce a chloride evaporate and the remaining solid was dissolved in 1.5N HCl. Ascorbic acid was added to each sample to complex the interfering iron, and the Po isotopes auto-deposited overnight onto a silver disk suspended in the solution (Nittrouer, et al. 1979; Nittrouer and Sternberg 1981). ^{210}Po and ^{209}Po activity was measured on a surface barrier alpha detector with Canberra α-analyst and Genie-2000 data acquisition software. ^{210}Pb activity is reported as excess ^{210}Pb by subtracting the supported value from the total measured activity.

Elemental and Carbon Isotope Analysis

Organic carbon, total nitrogen and C/N ratios were measured using a Perkin Elmer Series II CHNS/O Analyzer. 2-4mg of pulverized sediment were fumigated for 24 hours with concentrated HCl to remove the inorganic carbon from the sample. After drying for 24 hours at 40°C, the samples were packed and analyzed. To determine carbon isotope values, dried, pulverized samples were acidified using the same method as the organic carbon samples. After drying overnight, ~30mg of sample were packed and shipped to the geology lab at the University of California—Davis for isotopic analysis.

Biomarker Analysis

Sediment samples were analyzed for lignin biomarkers using the CuO oxidation method outlined in Hedges and Ertel (1982). At least 4mg of organic carbon (`400mg bulk sample) were included for each sediment sample. Samples were digested with approximately 330mg of CuO and about 50mg of $Fe(NH_4)_2(SO_4)_2*6H_2O$ in presparged 2 mol L^{-1} NaOH. To ensure oxidation occurred in the absence of oxygen, oxidation bombs were purged with argon gas and sealed during the purge. Oxidation was performed at 150°C for 90 minutes then samples were spiked with an ethyl vanillin internal standard. The solution was decanted from the bombs into new test tubes and rinsed twice more with 1N NaOH. Then a liquid-liquid extraction was preformed three times using ethyl acetate. The ethyl acetate solution was evaporated and the remaining solid was diluted in pyridine. Samples were then converted to trimethylsilyl derivatives and analyzed on a GC/MS.

CHAPTER III

RESULTS

Core SBBC1

Biomarker Analysis

Lignin content in core SBBC1 remained constant throughout the length of the core with carbon-normalized yields of the sum of eight lignin-derived, exclusively terrestrial biomarkers (Lambda8) averaging 1.69mg/g and the mass-normalized concentrations of those same eight biomarkers (Sigma8) averaging 0.15mg/100 mg OC. Peaks in both Lambda8 and Sigma8 occur at depths of 2.5cm, with values of 2.03mg/g and 0.20mg/100mg OC, and 15.5cm, with values of 2.78mg/g and 0.19mg/100mg OC, respectively; and minimum sigma8 values of 0.12 mg/g at 19.5cm and 29.5cm and minimum values of 1.42 mg/ 100 mg OC at 29.5cm. The acid to aldehyde ratios from syringyl, (Ad/Al)s, and vanillyl phenol classes, (Ad/Al)v, range from 0.27 to 0.34 with an average of 0.31 and 0.36 to 0.48 with an average of 0.44, respectively. Values for the ratio of 3,5-dihydroxybenzoic acid over vanillyl phenols, 3,5Bd/V, average at 0.9 with a maximum of 0.10 and a minimum of 0.07 and the P/(V+S), the ratio of p-hydroxyl phenols to the sum of vanillyl and syringyl phenols range from 0.15 at 2.5cm to 0.20 at 26.5cm and an average value of 0.17. (Fig. 2)

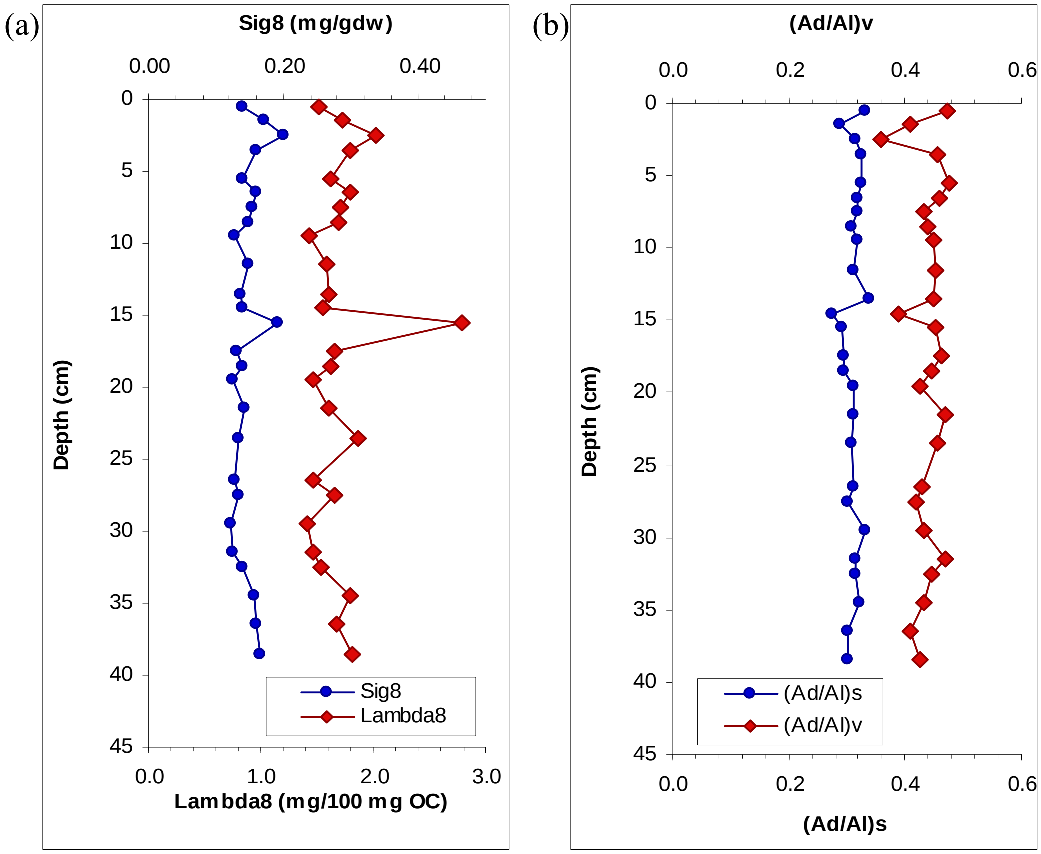


Fig. 2. Biomarker analysis for SBBC1. Vertical profiles of (a) the mass- and carbon normalized yields of eight lignin-derived oxidation products, Sig8 and lambda8 and (b) acid to aldehyde ratios for syringyl and vanillyl phenols, (Ad/Al)v and (Ad/Al)s.

(c)

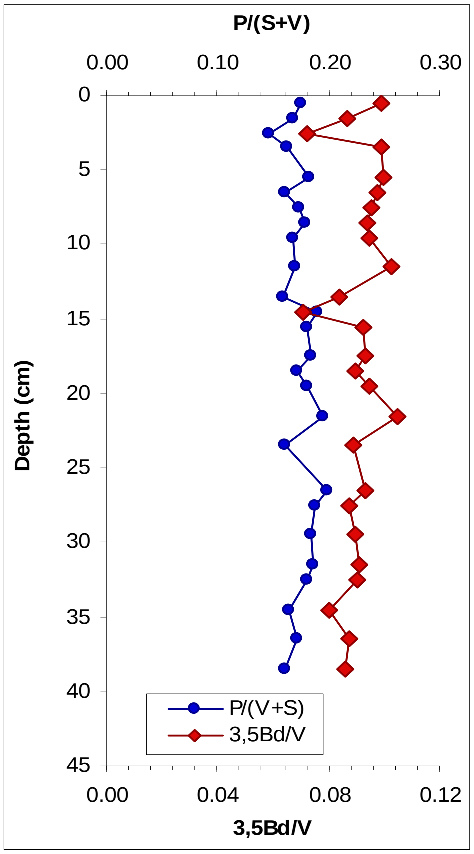


Fig. 2. continued. (c) Ratios of p-hydroxyl phenols to the sum of syringyl and vanillyl phenols, P/(S+V), and of 3,5-dihydroxybenzoic acid over vanillyl phenols, 3,5-Bd/V, are shown in these plots.

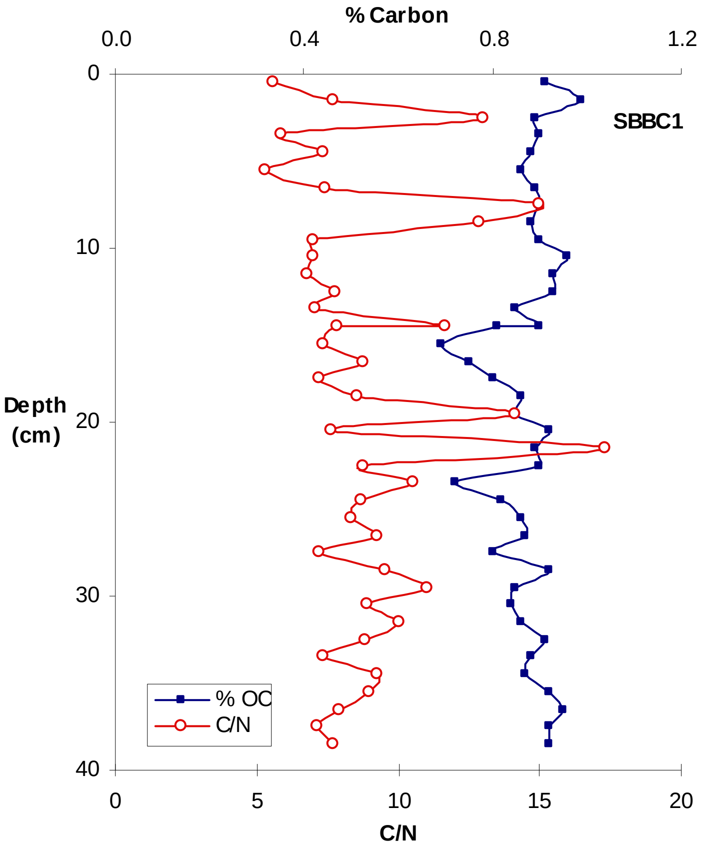


Fig. 3. Organic carbon (OC) and carbon to nitrogen ratios (C/N) for SBBC1.

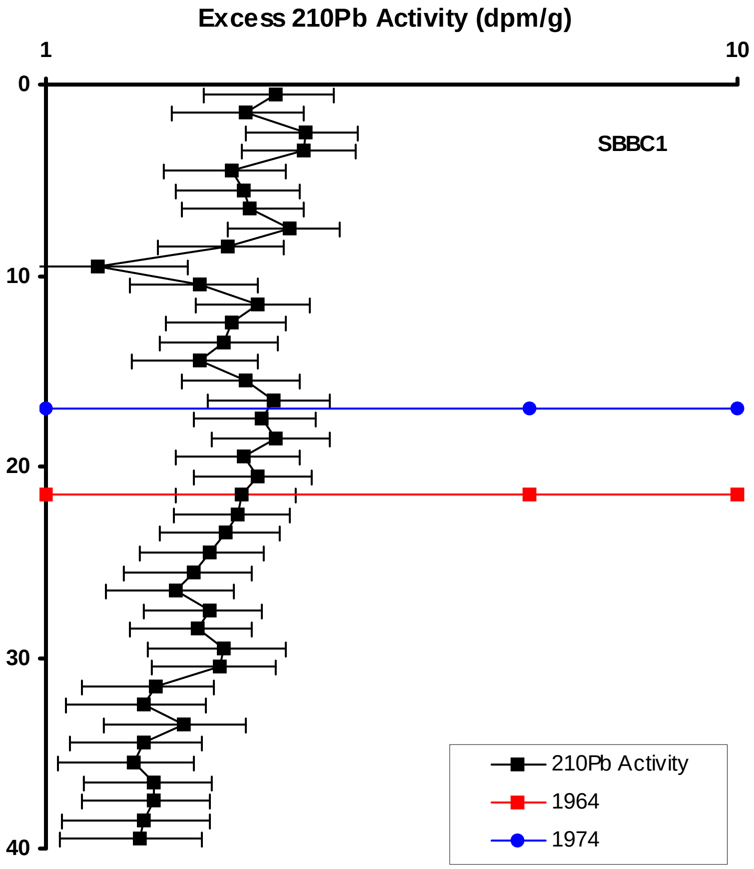


Fig. 4. Excess ^{210}Pb for SBBC1. Downcore ^{210}Pb activity for core SBBC1 with the depths marked for both earthquake layers. Excess ^{210}Pb profile from C.J. Noll, unpublished.

Elemental Analysis

Organic carbon content for SBBC1 averaged 0.87%, and total nitrogen averaged 0.12%. At 15.5cm depth the organic carbon content decreases to a minimum of 0.69%, then gradually increases to 0.92% over 5cm. This sharp decrease followed by a gradual increase is seen again between 23.5cm and 28.5cm with organic carbon increasing from 0.72% to 0.92%. C/N ratios averaged 8.88 and had peaks of 12.98, 15.00, 12.83, 11.67, 14.17 and 17.31 at 2.5cm, 7.5cm, 8.5cm, 14.5cm, 19.5cm and 21.5cm, respectively. (Fig. 3)

Radiochemical Analysis

Profiles of $^{210}Pb_{xs}$ activity show a considerable amount of variation which do not correlate to other indices (grain size, water content, etc…). The sedimentation rate of this core was calculated as 0.68cm/yr, but due to the non-steady state nature of delta front sedimentation (turbidity currents, hyperpycnal flows, and seasonal changes in discharge), this rate may not be indicative of long-term accumulation. (Fig. 4)

Core SBBC3

Biomarker Analysis

Sigma8 values in core 3 showed little variability, ranging from 0.07 to 0.08 mg/g throughout the entire core. Lamdba8 values averaged 0.59mg/ 100mg OC with a variation between 0.52 and 0.67 mg/ 100 mg OC. (Ad/Al)s values ranged from 0.32 to

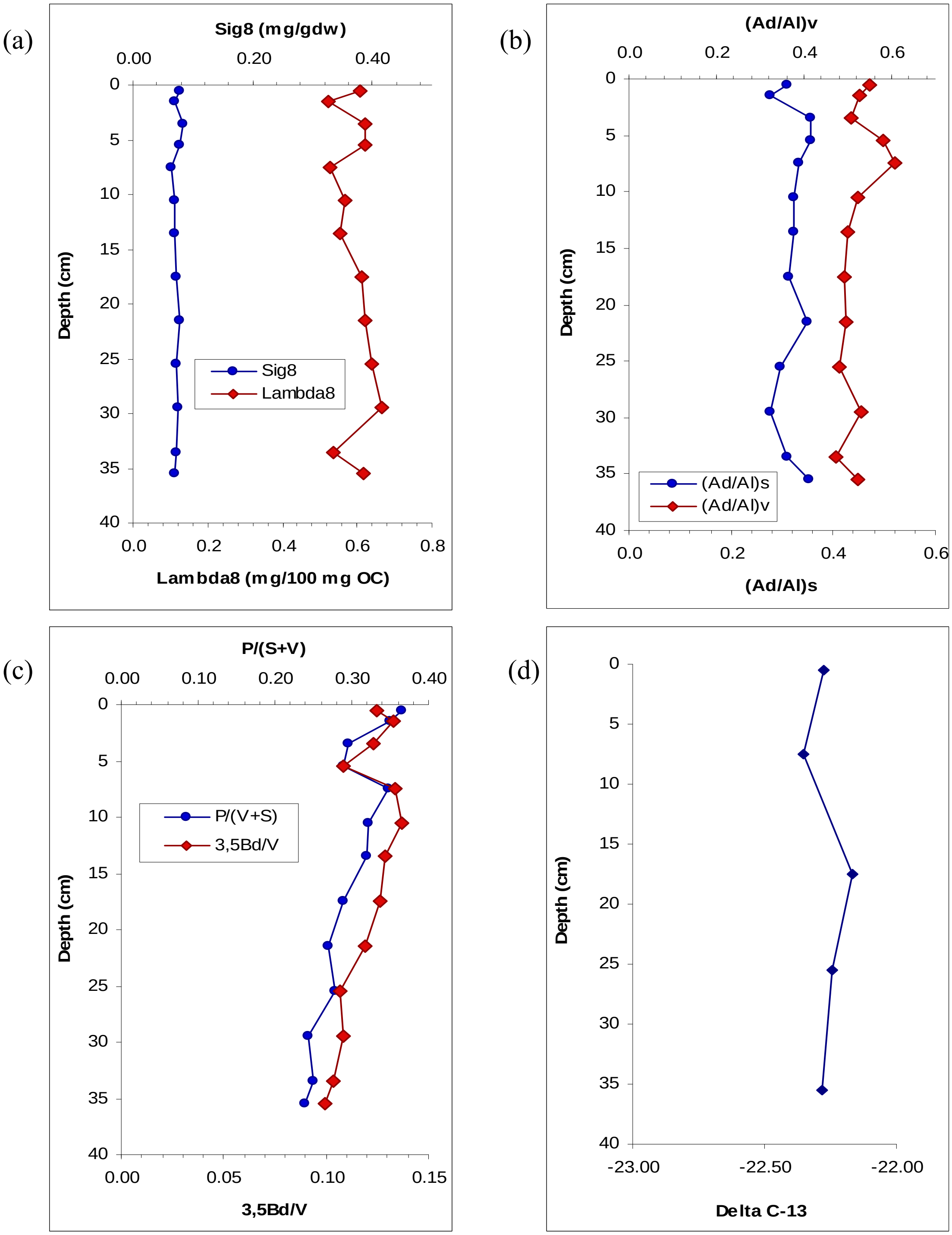


Fig. 5. Biomarker analysis for SBBC3. Vertical profiles of (a) the mass- and carbon normalized yields of eight lignin-derived oxidation products, Sig8 and lambda8, (b) acid to aldehyde ratios for syringyl and vanillyl phenols, (Ad/Al)v and (Ad/Al)s, and (c) ratios of p-hydroxyl phenols to the sum of syringyl and vanillyl phenols, P/(S+V), and of 3,5-dihydroxybenzoic acid over vanillyl phenols, 3,5-Bd/V, are shown in these plots.

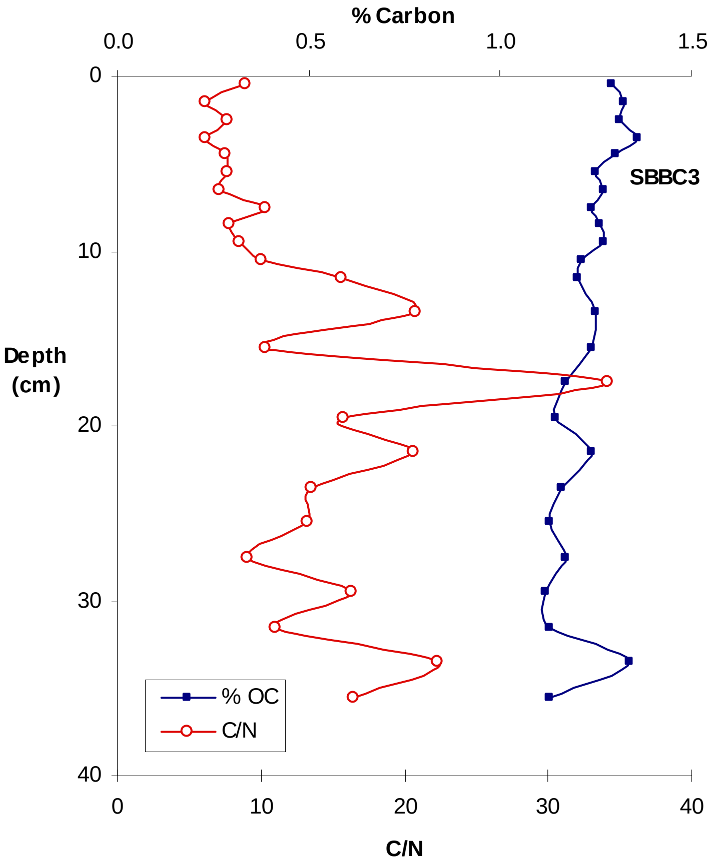


Fig. 6. Organic carbon (OC) and carbon to nitrogen ratios (C/N) for SBBC3.

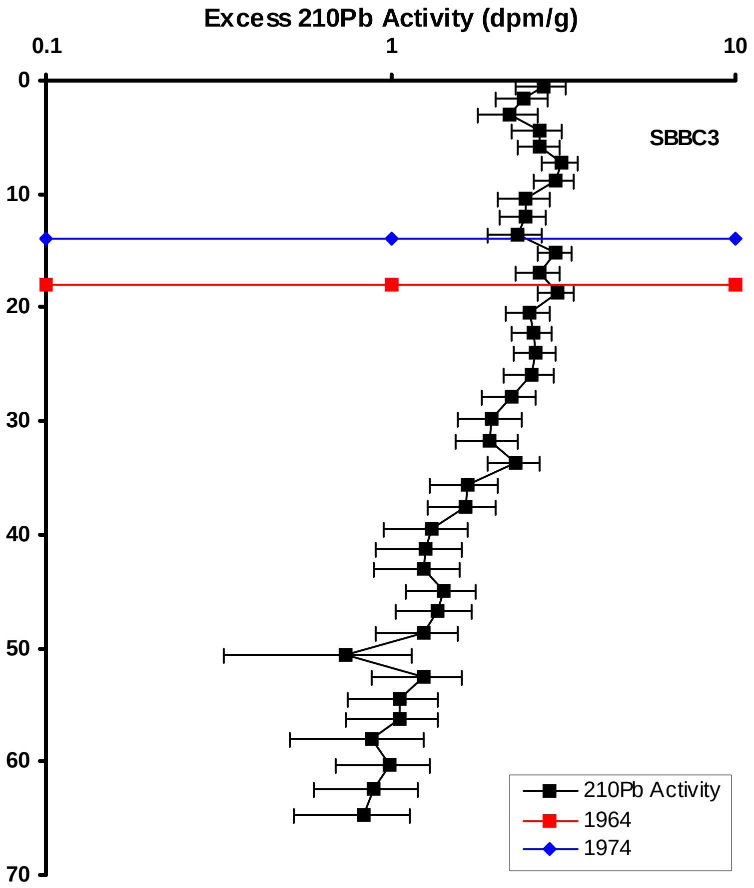


Fig. 7. Excess ^{210}Pb for SBBC3. Downcore ^{210}Pb activity for core SBBC3 with the depths marked for both earthquake layers. Excess ^{210}Pb profile from C.J. Noll, unpublished.

0.42 with an average of 0.39, and (Ad/Al)v ratios ranged from 0.41 to 0.52 with an average of 0.45. P/(V+S) and 3,5Bd/V values started at 0.36 and 0.12 and gradually decreased to values of 0.24 and 0.10, respectively. (Fig. 5)

Elemental Analysis

Organic carbon content averaged 1.23% and total nitrogen averaged 0.14%. At the top of the core, the organic carbon content is 1.29% and decreases throughout the length of the core to 1.13% at the bottom, with a peak of 1.34% at 33.5cm. C/N ratios showed large variations at the bottom of the core. The average C/N value is 12.79 and there are peaks in the C/N values at 17.5 cm with a value of 34.13, at 33.5cm with a value 22.33, and a large peak between 10.5cm and 13.5cm with the values of 10.08, 15.56, and 20.83. (Fig. 6)

Radiochemical Analysis

$^{210}Pb_{xs}$ profiles show a more steady state decrease in activity with depth than is found near the delta. The calculated sedimentation rate is 0.86cm/yr. (Fig. 7)

Isotopic analysis

Samples were analyzed for stable carbon isotopes as a representative core for the whole area of the bay. The five samples that were tested show little variation and the values ranged from -22.35‰ to -22.17‰, with an average value of -22.26‰. (Fig. 5)

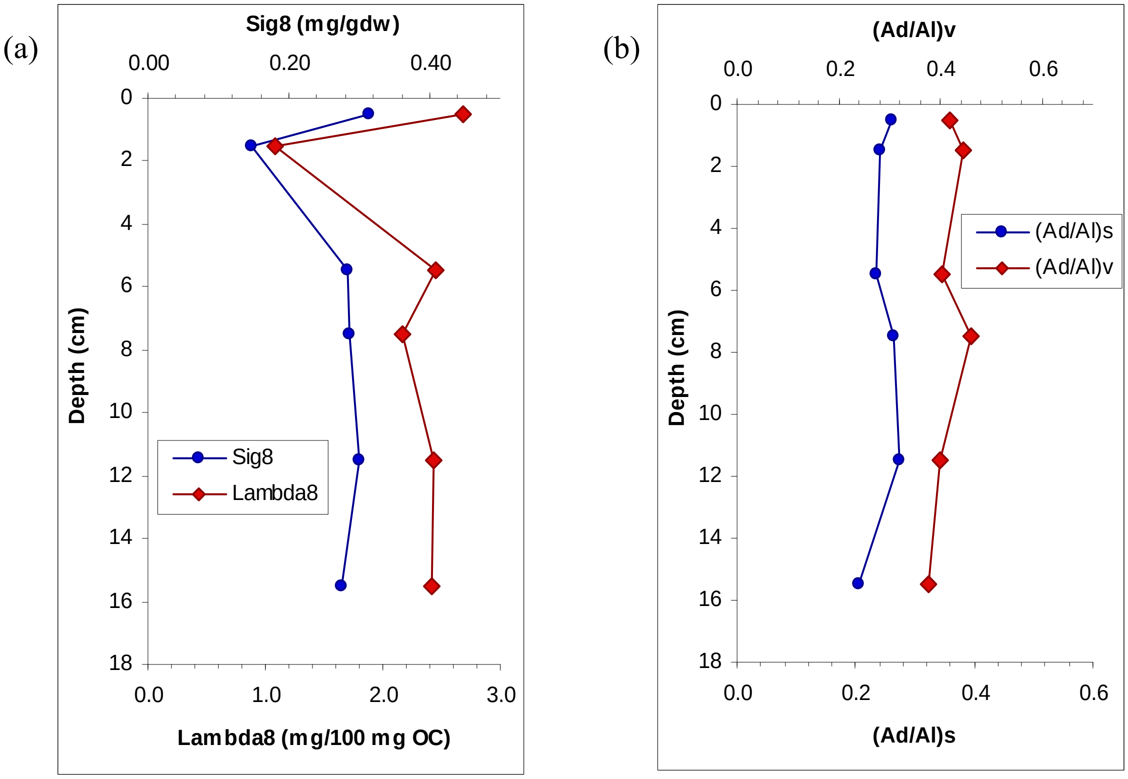


Fig. 8. Biomarker analysis for SBBC10. Vertical profiles of (a) the mass- and carbon normalized yields of eight lignin-derived oxidation products, Sig8 and lambda8 and (b) acid to aldehyde ratios for syringyl and vanillyl phenols, (Ad/Al)v and (Ad/Al)s.

(c)

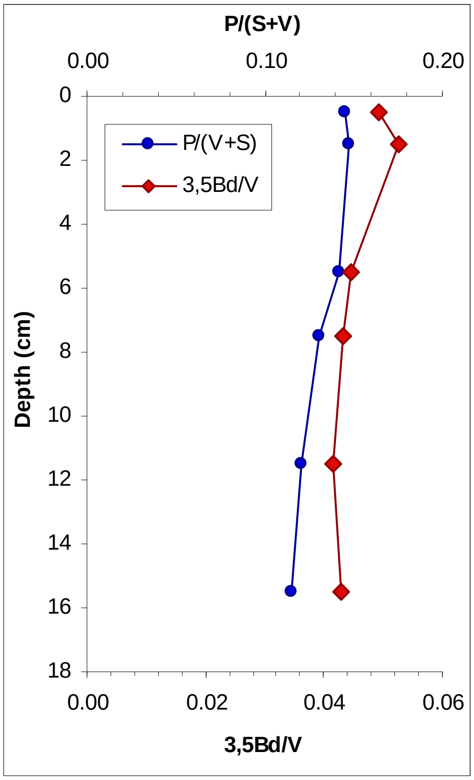


Fig. 8. continued. (c) Ratios of p-hydroxyl phenols to the sum of syringyl and vanillyl phenols, P/(S+V), and of 3,5-dihydroxybenzoic acid over vanillyl phenols, 3,5-Bd/V, are shown in these plots.

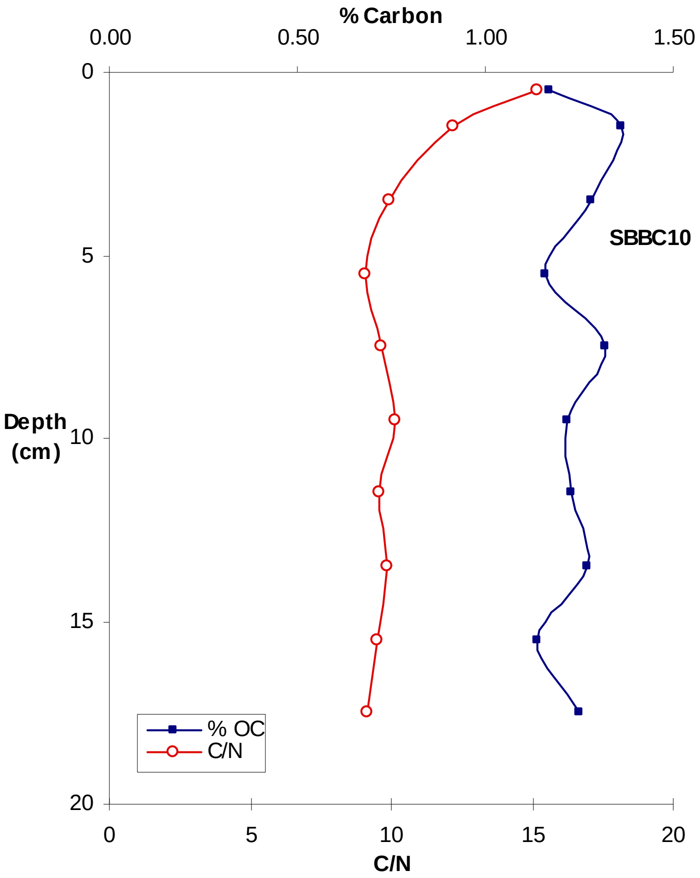


Fig. 9. Organic carbon (OC) and carbon to nitrogen ratios (C/N) for SBBC10.

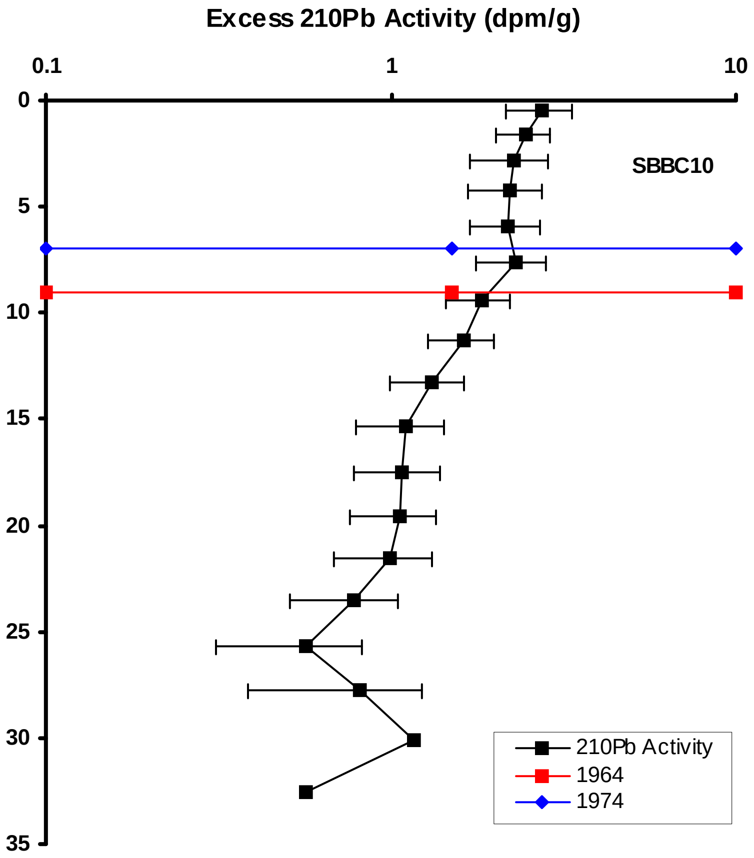


Fig. 10. Excess ^{210}Pb for SBBC10. Downcore ^{210}Pb activity for core SBBC10 with the depths marked for both earthquake layers. Excess ^{210}Pb profile from C.J. Noll, unpublished.

Core SBBC10

Biomarker Analysis

Simga8 and Lambda8 values remained constant throughout the core, except the sample at 1.5 cm, which showed a decrease in the vales for each measurement. Sigma8 values averaged 0.27 mg/g with a minimum value of 0.15 mg/g at 1.5cm and a maximum value of 0.31 mg/g at 0.5 cm. Lambda8 values ranged from 0.52 mg/100 mg OC at 1.5cm to 2.68 mg/100 mg OC at 0.5cm, with an average of 2.20 mg/ 100 mg OC. The (Ad/Al)s values range from 0.24 to 0.32 and the (Ad/Al)v values are between 0.32 and 0.39. 3,5Bd/V values averaged at 0.046 with a minimum of 0.04 and a maximum of 0.05, and P/(V+S) values range from 0.12 to 0.15 with an average of 0.13. (Fig. 8)

Elemental Analysis

Organic carbon values average at 1.24% and total nitrogen values average at 0.14%. Organic carbon values peak at 1.5cm with an organic carbon content of 1.36%, then again at 7.5cm with a value of 1.32%. At 15.5cm organic carbon values reach a minimum of 1.14%. C/N ratios start at 15.17 and decrease to 9.05 at 5.5cm. The values show little variation around 9.6 throughout the rest of the core. (Fig. 9)

Radiochemical Analysis

Excess ^{210}Pb displays a log linear decrease with depth from which an accumulation rate of 0.33cm/yr was calculated. (Fig. 10)

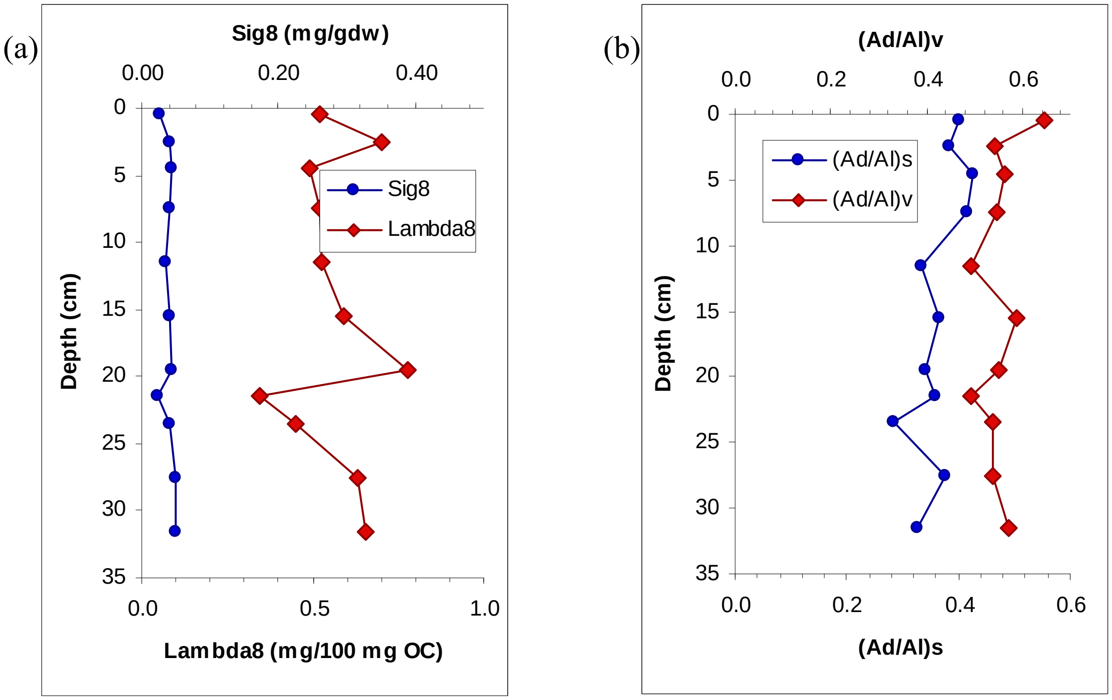


Fig. 11. Biomarker analysis for SBBC28. Vertical profiles of (a) the mass- and carbon normalized yields of eight lignin-derived oxidation products, Sig8 and lambda8 and (b) acid to aldehyde ratios for syringyl and vanillyl phenols, (Ad/Al)v and (Ad/Al)s.

(c)

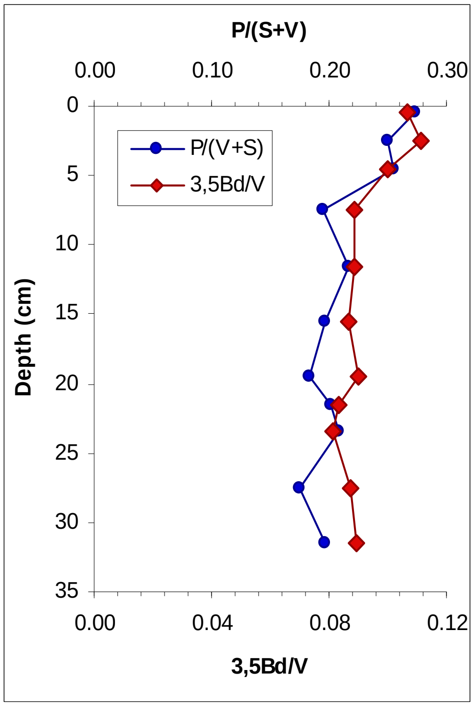


Fig. 11. continued. (c) Ratios of p-hydroxyl phenols to the sum of syringyl and vanillyl phenols, P/(S+V), and of 3,5-dihydroxybenzoic acid over vanillyl phenols, 3,5-Bd/V, are shown in these plots.

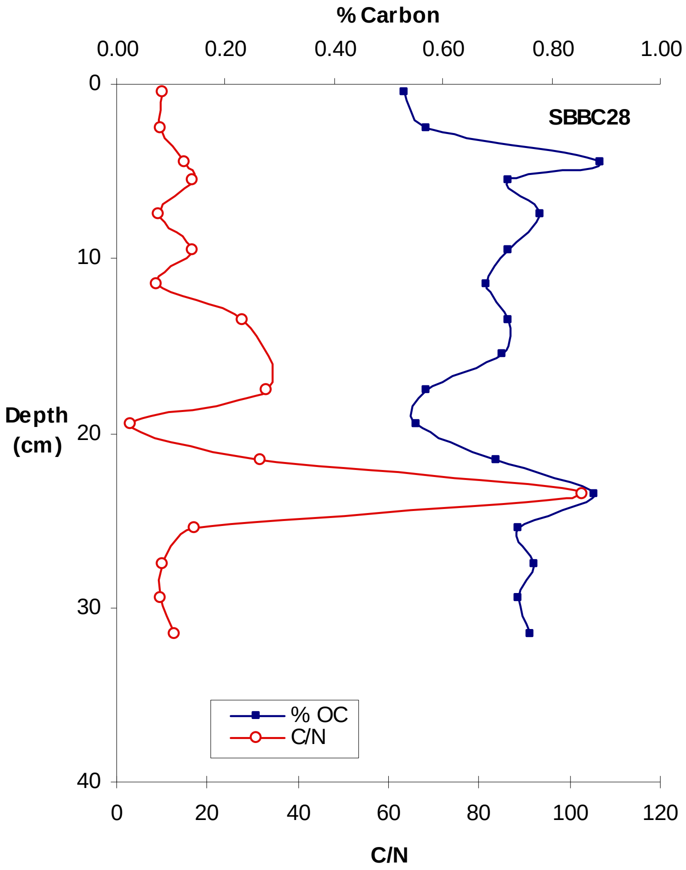


Fig. 12. Organic carbon (OC) and carbon to nitrogen ratios (C/N) for SBBC28.

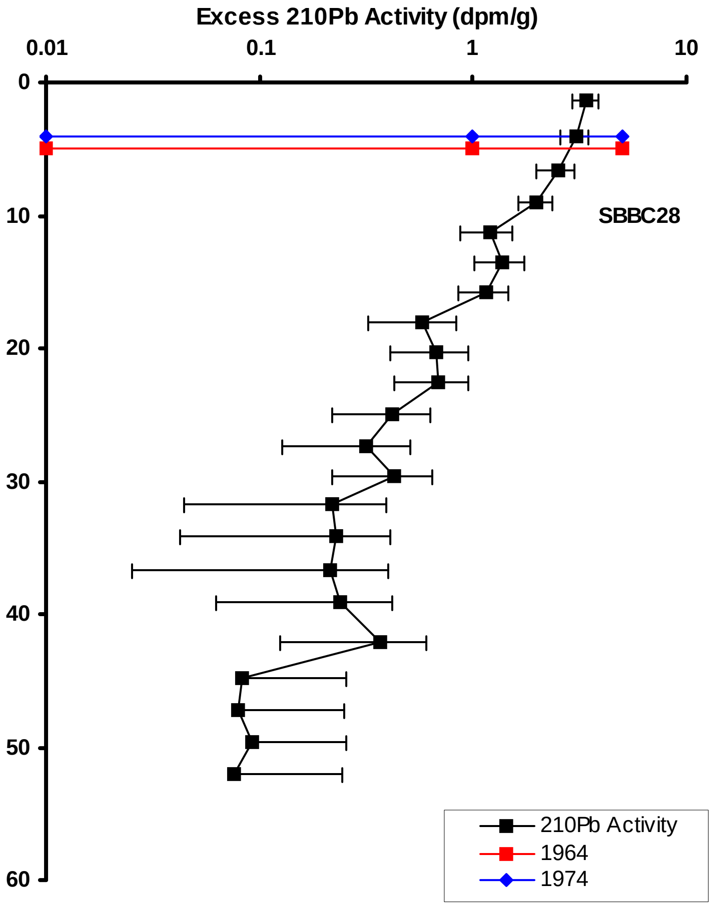


Fig. 13. Excess ^{210}Pb for SBBC28. Downcore ^{210}Pb activity for core SBBC28 with the depths marked for both earthquake layers. Excess ^{210}Pb profile from C.J. Noll, unpublished.

Core SBBC28

Biomarker Analysis

The sigma8 values for this core range from 0.02 to 0.05 mg/g with an average of 0.04 mg/g, and the lambda8 values range from 1.09 to 2.68 mg/ 100 mg OC with an average of 2.20 mg/ 100 mg OC. The acid/aldehyde ratios varied between 0.24 and 0.32 for (Ad/Al)s values, and 0.32 and 0.39 for (Ad/Al)v values. Values for 3,5Bd/V measurements range from 0.04 to 0.05 and P/(V+S) values range between 0.12 and 0.15 with an average of 0.134. (Fig. 11)

Elemental Analysis

Organic carbon values average at 0.71% and total nitrogen values average at 0.06%. Organic carbon peaks at 4.5cm with 0.89% and 23.5cm with 0.88%. C/N ratios averaged at 20.92 and show considerable variability and the values peak between 13.5cm and 17.5cm with values of 28.00 and 33.25 and they peak again at 23.5cm with a value of 106.67. C/N ratios reach a minimum value of 3.21 at 19.5cm. (Fig. 12)

Radiochemical Analysis

Excess ^{210}Pb displays a log linear decrease with depth from which an accumulation rate of 0.28cm/yr was calculated. (Fig. 13)

Delta Samples

Biomarker Analysis

These samples vary in lignin content with the maximum sigma8 and lambda8 values of 5.86 mg/g and 7.29 mg/ 100 mg OC and minimum values of 0.14 m/g and 1.81 mg/ 100 mg OC, respectively. (Ad/Al)s values range from 0.27 to 0.40 and (Ad/Al)v values range from 0.32 to 0.54. 3,5Bd/V values range from 0.05 to 0.12 and P/(V+S) values range from 0.15 and 0.22.

Elemental Analysis

Organic carbon values ranged from 0.63% to 8.03%. C/N ratios ranged from 12.74 to 30.33.

Isotopic Analysis

The stable carbon isotope values range from -27.32‰ to -23.50‰.

North Bay Samples

Biomarker Analysis

Sigma8 values show a slight decreasing trend as they move away from the delta, with 0.56 mg/g at the closest sample and 0.07mg/g at the farthest sample. The slope of the linear regression for these samples is m=-0.006 and the R^2 value is 0.2007. Lambda8 values also show a decrease, m=-0.0406 and R^2=0.0544, as the distance from the delta increases. Values start at 1.53 mg/100 mg OC and end at 0.77mg/ 100 mg OC. (Ad/Al)v values are fairly stable, m=-0.0009 and R^2=0.0038, from near the delta, 0.47, to the mouth of the bay, 0.49. (Ad/Al)s values show a slight increase, m=0.0133 and R^2=0.2702, from the delta, 0.33, to the mouth, 0.47. 3,5BD/V and P/(V+S) both show a decrease with distance, excluding the closest sample which was much lower than the sample closest to it. 3,5Bd/V started at 0.10 at 0.56km, then increased to 0.14 at 2.07km, and decreased to 0.08 at 6.67km. The plot for P'(V+S) looked similar to that of 3,5Bd/V with the sample at 0.56km of 0.17, 0.55 at 2.07km, and 0.23 at 6.67km. 3,5Bd/V had a slope of m=-0.0079 and R^2=0.4294 and P/(V+S) had a slope of m=-0.0166 and R^2=-0.0959. (Fig. 14)

Elemental Analysis

Organic carbon content decreased between the second closest core to the delta, 1.76%, and the farthest core from the delta, 0.87%. The core closest to the delta had lower values of 0.91%. The slope of the linear regression for these data is m=-0.0645 with R^2=0.2075. C/N ratios show an increasing trend starting at 5.6 at 0.56km and ending at 8.5 at 6.67km. Linear regression analysis gives a slope of m=0.7363 and R^2=0.0924. (Fig. 15)

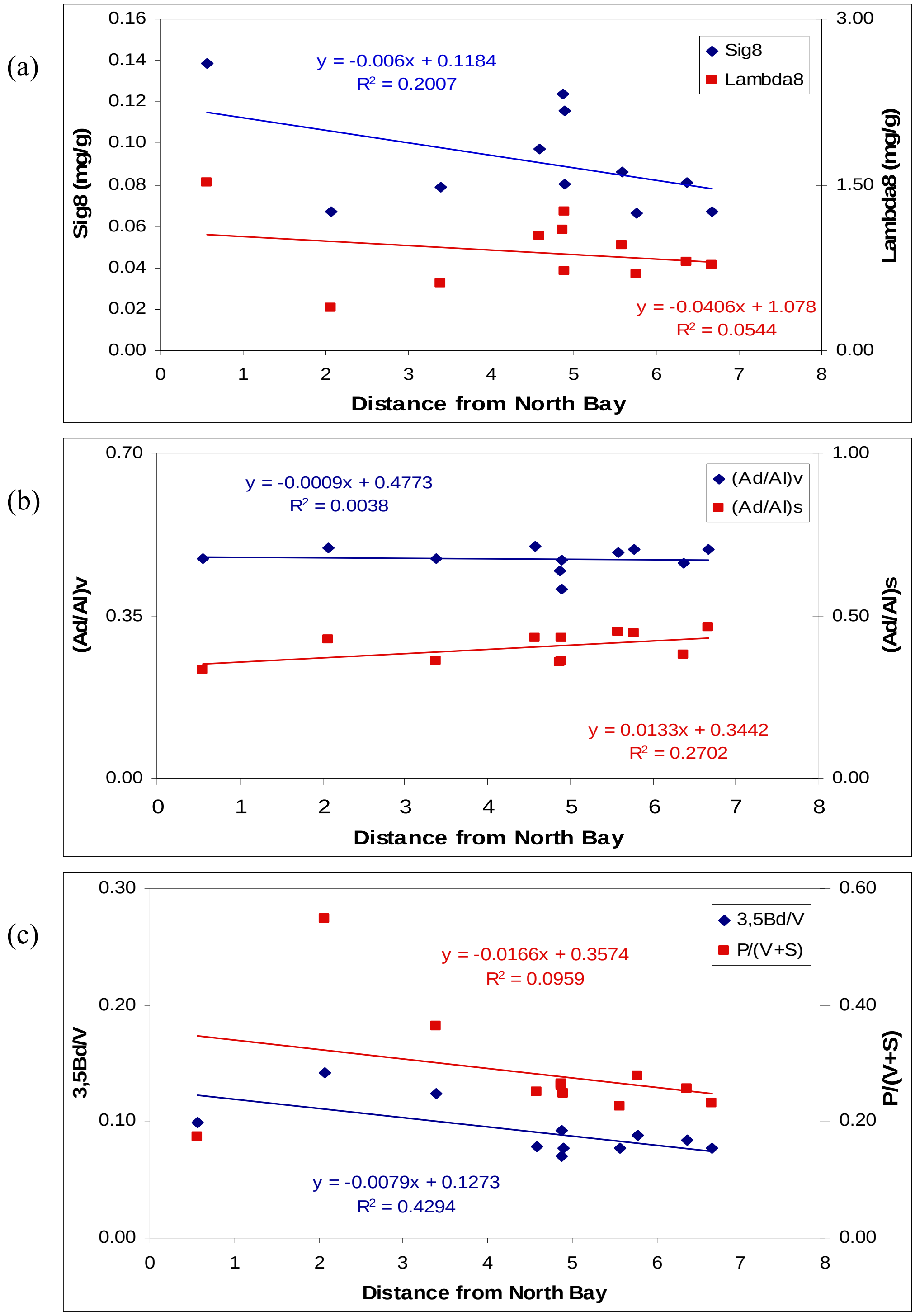


Fig. 14. Lignin-derived biomarkers for North Bay samples. Lignin-derived biomarkers throughout the North Bay show trends in (a) lignin concentration, (b) lignin degradation, and (c) the plant source of the lignin biomarkers.

Isotopic Analysis

Stable carbon isotope values range from -22.38‰ to -22.04‰, except for core 1. The stable carbon isotopic signature for core 1 is -24.58‰.

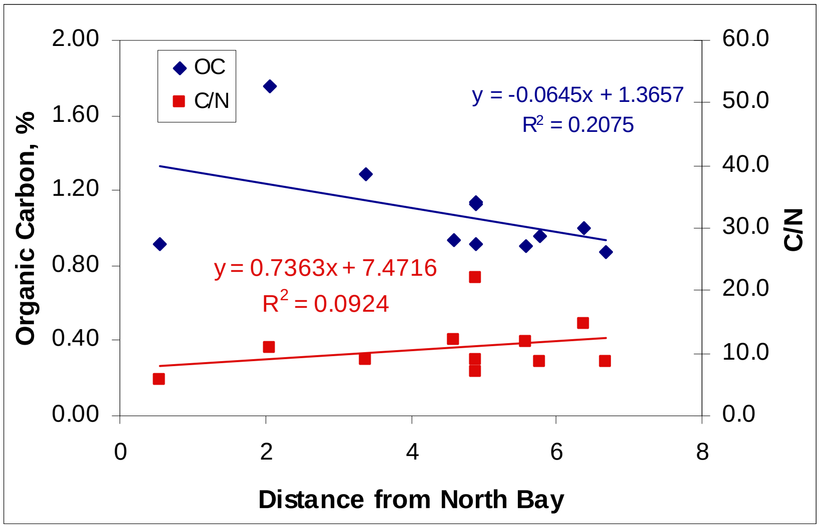
East Bay Samples

Biomarker Analysis

Sigma8 values showed a decreasing trend with increasing distance from the delta, m=-0.0544 and R^2=0.834. Values started at 0.25 mg/g at 1.55km from the delta and ended at 0.05 mg/g at 6.1km from the delta. Lambda8 values decreased as distance increased, m=-0.367 and R^2=0.7461, with values of 1.69 mg/100 mg OC at 1.55km and 0.58mg/100 mg OC at 6.1km. (Ad/Al)v increased from 0.38 at 1.55km to 0.64 at 6.1km with a slope of m=0.0583 and R^2=0.9451, and (Ad/Al)s increased from 0.39 at 1.55km to 0.50 at 6.1km with a slope of m=0.0331 and R^2=0.8029. 3,5Bd/V values showed an increasing trend, m=0.0145 and R^2=0.9883, starting at 0.05 near the delta and ending at 0.11 near the mouth of the bay. P/(V+S) increases from 0.16 at 1.55km to 0.29 at 6.1km with a slope of m=0.03 and R^2=0.9788. (Fig. 16)

The ratio of cinnamyl to vanillyl phenols (C/V) for the samples in both north and east bay vary between 0.12 and 0.40, with the highest value being in the delta of north bay. Typical C/V ratios are around 0.16. Syringyl to Vanillyl (S/V) ratios for samples from

(a)



(b)

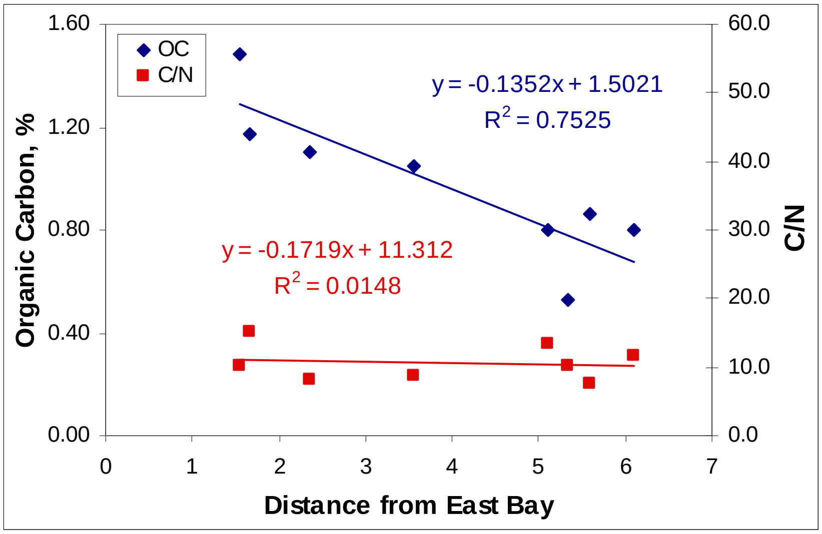


Fig. 15. Organic carbon and carbon to nitrogen ratios for North Bay and East Bay. Geographical variation in organic carbon content and carbon to nitrogen ratios throughout (a) the North Bay and (b) the East Bay are shown and a linear regression analysis was performed for each data set.

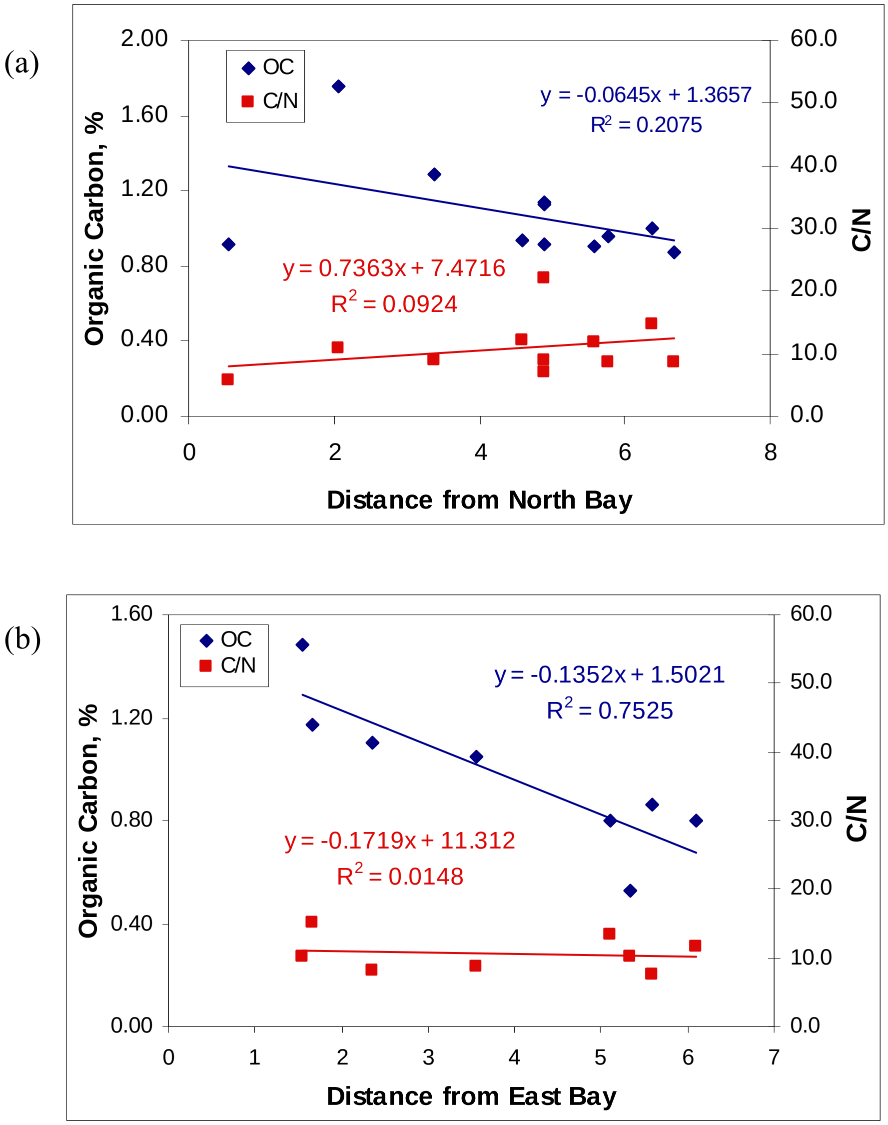


Fig. 16. Lignin-derived biomarkers for East Bay samples. Lignin-derived biomarkers throughout the East Bay show trends in (a) lignin concentration, (b) lignin degradation, and (c) the plant source of the lignin biomarkers.

both bays range between 0.10 and 0.19, with the highest ratios in the North Bay. (Fig. 17)

Elemental Analysis

Organic carbon content shows a decreasing trend as the distance from the delta increases with a slope of m=-0.1352 and R^2=0.7525. Values start at 1.48% at 1.55km and ends at 0.80% at 6.1km. C/N ratios do not show much variation with a slope of -0.1719 and R^2=0.0148. C/N ratios are 10.2 at 1.55km and 11.7 at 6.1km. (Fig. 15)

Isotopic Analysis

Stable carbon isotopic signatures range from -22.66‰ to -22.01‰, except SBBC11 with a less depleted signature of -19.47‰.

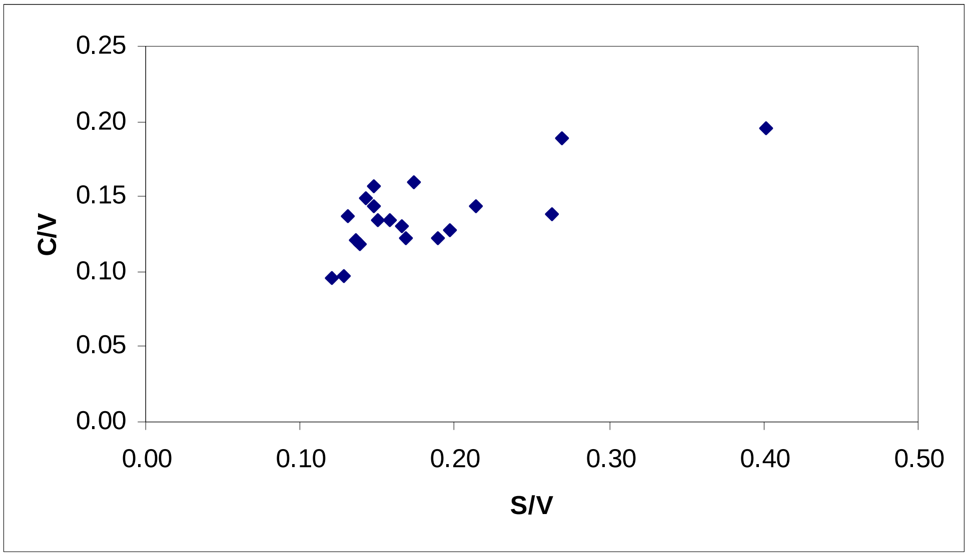


Fig. 17. Lignin plant source for Simpson Bay. The plot of the ratios of cinammyl phenols to vanillyl phenols (C/V) versus the ratio of syringyl phenols to vanillyl phenols (S/V) shows the source of lignin material. These lignin biomarkers have low S/V and C/V ratios indicating a source of gymnosperm needles throughout the bay.

CHAPTER IV

DISCUSSION

Searching for Earthquake Evidence in Box Cores

These four cores were selected based on their location in Simpson Bay. SBBC1 and SBBC10 are at the heads of the bays close to the sediment source, while core 28 is in the mouth of the bay, and SBBC3 is behind a sill separating the northern and western parts of the system. They were chosen to represent the entire bay, and while the lignin analysis showed no evidence of the earthquakes, the analysis does show changes in the down core sediment distribution throughout the bay.

SBBC1

Using the sedimentation rates calculated from the ^{210}Pb data, the depth of the 1964 and 1974 earthquake layers were are at 21.5cm and 17cm, respectively. At the 17cm layer there is a decrease in organic carbon content, which is expected in an earthquake RDL; however the C/N values decrease to less than 8 giving a more marine dominated signal (St. Onge and Hillaire-Marcel 2001; Martinotti, et al. 1997). The 1964 earthquake layer does show a large peak in the C/N value of 17.31, but the organic carbon content does not show any change. The carbon nitrogen ratios, however, may not be reliable due to difficulties with the instrumentation creating questionable nitrogen values. This is seen when comparing C/N values to lignin values. The results should be similar, but the C/N profiles are extremely variable, while the lignin signatures are constant throughout the core (Meyers 1994). In SBBC1 peaks in lambda8 and sigma8 are not seen in either of the earthquake layers, but there are peaks at 15.5cm and 2.5cm, suggesting that there was a change in the sediment depositional environment during these times that would have caused an increase in terrestrial organic matter. This sample was collected closest to the delta in the North Bay, and the river that feeds into this delta drains a very large area of the surrounding terrain; therefore, SBBC1 is more susceptible to changes in the source of material delivered to the bay than any other core collected. The largest changes in source material should occur here, but instead the data is relatively constant with no significant changes in organic content or lignin material.

The lignin signatures do show that this area is close to the source. The low acid/aldehyde ratios, (Ad/Al)v and (Ad/Al)s, between 0.3 and 0.5, indicate that the organic matter in this core is not degraded (Louchouarn et al. 2006). These ratios remain constant throughout the core, which suggests that the source material has not changed. The lignin values at this location are higher than all the other cores in North Bay, indicating that this core receives the most amount of terrestrial material and, therefore, this core is closest to the source of that material.

SBBC3

Sedimentation rates show that the two earthquake layers are at depths of 14cm for the 1974 event and 18cm for 1964. In the 1974 layer, organic carbon has peaks at 1.25, but decreases at the 1964 layer. C/N values peak at both depths to 20.83 at 14cm and 34.13

at 18cm. Both of these C/N peaks indicate an influx of terrestrial material; however, the lignin values do not show any change at these depths. Sigma8 values remain constant at 0.08 and lambda8 values vary a little around 0.6, but the variation does not near the depths in question.

This core shows similar results to those found in SBBC1, except the stable carbon isotopic data further demonstrates the unreliability of the C/N ratios. The $\delta^{13}C$ values for SBBC3 are approximately -22.26‰, a value that is a typical signature of marine algae (Meyers 1994). Both the lignin and isotopic signatures show no change at the depths where the evidence of the earthquakes should be, unlike the C/N ratios which give a strong terrestrial signature at both earthquake depths.

SBBC10

The depths of 7.0 cm and 9.0 cm were calculated to be the layers where the 1974 and 1964 earthquakes occurred, respectively. At 7.0cm the organic carbon content decreases from 1.22% and at 9.0cm the organic carbon content is increasing to 1.22%. The C/N ratios are relatively constant around 10 at both depths. None of these data provide conclusive evidence that there was earthquake activity at these depths.

The lignin analysis has similar results with both lambda8 and sigma8 values remaining relatively constant throughout the core, with no significant changes at either 7.0cm or 9.0cm. The low acid/aldehyde ratios of approximately 0.3 suggest fairly fresh, undegraded material in this location (Gordon and Goñi 2003). SBBC10 is taken from the head of East Bay. East Bay has a smaller river that drains a smaller watershed than is found in North Bay, however, the lignin values are higher in this core were found in SBBC1 at the head of the delta in the North Bay.

SBBC28

The depths of the earthquake layers in SBBC28 were calculated to be 4.0cm for the 1974 earthquake and 5.0cm for the 1964 earthquake. Organic carbon content peaks at 4.5cm with a value of 0.89% and the C/N ratios peaks slightly with a value of 14.83. While this value is a terrestrial signature, it does not necessarily indicate that this material was deposited during an earthquake event. Most of the C/N ratios in this core are above 12, suggesting a terrestrial origin, but these high values could also be the result of erroneous nitrogen values.

This becomes more evident when examining the lignin signatures. The lambda8 values remain constant 0.04 mg/g, and while there is a peak in the sigma8 values at 2.5cm, at 4.5cm the values decrease again to 0.49mg/ 100 mg OC. At this location, the organic material is slightly more degraded with acid/aldehyde values between 0.35 and 0.6. This core is located in mouth of the bay, and is one of the farthest cores from the source of the organic material. The lignin concentrations here are expected to be low with slightly higher acid/aldehyde ratios because this core is the farthest from the source of terrigenous organic material (Gordon and Goñi 2003).

The Distribution of Sediment in Simpson Bay

The lignin content in the cores from this bay are high in the area around the deltas in both North Bay and East Bay. Generally, the lignin concentration decreases in samples farther from the delta. This trend is better defined in the East Bay than in the North Bay (Gordon and Goñi 2003). The linear regression analysis performed on these two sets of data show a strong correlation between both sigma8 and lambda8 and the distance from the delta. The samples from the North Bay also show this correlation; however, it is not as strong as the correlation in the East Bay. The net change in cores from East Bay is much greater than the change seen in the North Bay. While the river that empties into the North Bay drains a larger area than the one in the East Bay, the river in the East Bay seems to input sediment with a stronger terrestrial signature.

The variations in carbon content of samples from Simpson Bay are similar to the variations in lignin concentrations. Carbon content shows a decrease in organic carbon in samples farther from the source of terrigenous organic material. The C/N ratios show very weak trends in both bays, which could be a result of erroneous nitrogen vales that would have skewed the C/N ratios over the bay. The trends in the acid/aldehyde ratios show an increasing trend as the distance from the delta increases, and this correlation is stronger in the East Bay than it is in the West Bay. This shows that the organic matter becomes more degraded as it moves farther from the delta, indicating that the source of organic material is in the delta (Louchouarn, et al. 2006).

The lignin analysis also shows that the organic matter from the river all comes from the same source on land, and this can be seen in the 3,5Bd/V and P/(V+S) ratios. These values remain relatively low and constant in all the samples taken from the bay. The C/V and S/V ratios also tell of the source of the organic material. The values of both ratios are close to zero for all samples, indicating a source of gymnosperm needles and agreeing with the information already known about the Simpson Bay region (Louchouarn, et al. 2006).

The stable carbon isotopic signatures varied little throughout the core, with a majority of the samples around -22.5‰. Two samples differed from the rest, and these samples were SBBC1 and SBBC11. Both of these cores were close to the river delta, with SBBC1 in the North Bay and SBBC11 in the East Bay. SBBC1 had a more depleted signature of -24.58‰ and SBBC11 had a less depleted value of -19.47‰. Except for SBBC1, all of the signatures were indicative of the marine algae. These signatures are compared to the signatures from the nine samples taken in the delta. The mixing curve shows that these nine samples and the one sample from SBBC1 were all terrestrial signatures, while the remaining samples show marine signatures (Meyers 1994). (Fig. 18)

The depleted δ^{13}C value for SBBC1 shows that because it is close to the river, this location receives terrestrially derived sediment (Gordon and Goñi 2003). This is not the case for SBBC11, which is close to the delta in the East Bay. The biomarker and

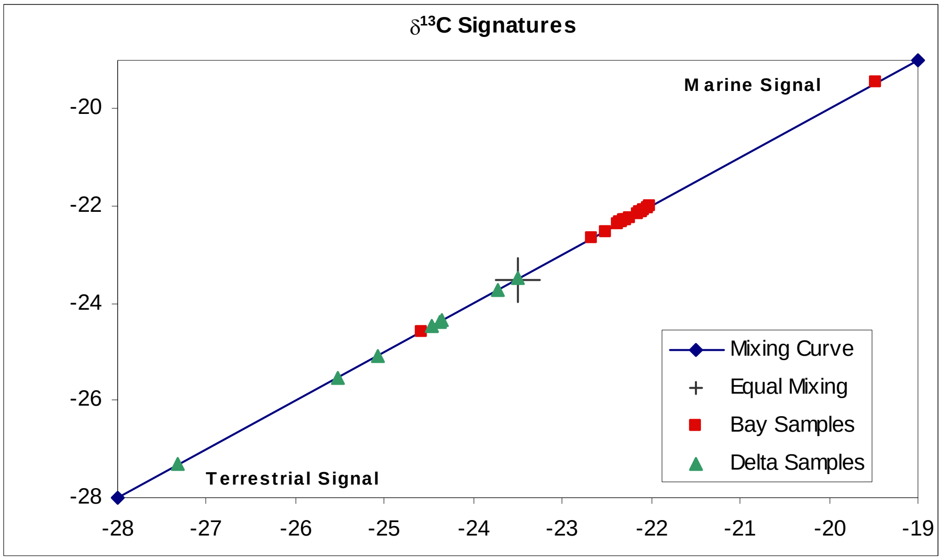


Fig. 18. Mixing curve for δ^{13}C signatures. All the samples taken from the first 1cm in each core, including the nine samples taken in the delta, are represented in this plot.

organic carbon data indicates that the river in East Bay has a larger input of terrestrial organic matter to the system, but the stable carbon isotopes indicate that this sample is more strongly influenced by the primary productivity of the marine algae in the water column (Meyers 1994).

The isotopic data shows that the dominant source of organic carbon is marine derived, which could be why the evidence of previous earthquake action cannot be found in the sediment record. C/N and $^{210}Pb_{xs}$ from SBBC1 show some variation around the identified earthquake layers, but signatures from the rest of the tested cores remain fairly stable which can be explained when considering the location. The bulk of the terrestrial material is deposited near the mouth of the delta, as evidenced by the high lignin concentrations in this core, so any influx of material from earthquakes would quickly fall out of the water column. The organic matter from the earthquake run off would not be distributed throughout the rest of the bay, and no evidence of the earthquake event would be left behind in areas far from the river delta.

CHAPTER V

SUMMARY AND FUTURE WORK

Signatures from the lignin biomarker analysis, elemental organic carbon analysis, and stable carbon isotopic analysis of four cores spread throughout the area of Simpson Bay do not show evidence from the earthquakes that ripped through this region in the last 50 years. Lignin signatures indicate the presence of terrestrial derived material, and they are expected to peak during an earthquake event that would cause a lot of terrestrial material to be transported to the bay sediments. Organic matter concentrations and stable carbon isotopic signatures are expected to decrease during an earthquake event, but this evidence was not seen. Instead, the profiles for all three analyses showed a relatively stable environment, like that of a pristine area that has been unaffected by anthropological or natural events.

The Simpson Bay area is a complex system where the inputs and outputs do not seem to balance each other. This analysis gave insight into the distribution of sediment in the bay, but there are still many questions to answer. These answers may be found by testing the sediments for different biomarkers. A more in depth study of the sources and sinks of organic matter in this basin would help to determine how this area supports the wildlife that inhabits the area. Simpson Bay's pristine environment is ideal for determining how the environment can react to various influences without dealing with the factors that anthropological impacts have on the ecosystem.

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