DETERMINING RECENT SEDIMENTATION RATES OF THE LAVACA-NAVIDAD RIVER SYSTEM, TEXAS

by

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DETERMINING RECENT SEDIMENTATION RATES OF THE LAVACA-NAVIDAD RIVER SYSTEM, TEXAS

INTRODUCTION

Replacement of wetlands by water and barren flats in the lower alluvial valley and delta of the Lavaca River suggests that relative sea-level rise and possible reductions in sediment supply have rendered the Lavaca-Navidad fluvial-deltaic system incapable of maintaining sufficient elevation to prevent its submergence. The Lavaca-Navidad River System transports a significant load of suspended sediment (Longley, 1992a) and therefore should have the potential for delivering enough sediment to offset subsidence and submergence.

Objectives

The principal objectives of this study were to determine past rates of sedimentation and relative sea-level rise for a fluvially dominated area along the Lavaca and Navidad Rivers upstream from the Lavaca River delta. This information will be used by the Texas Water Development Board to determine the frequency, duration, and magnitude of river flooding necessary to offset submergence of wetlands (Longley, 1992b). Sedimentation rates are based on activities of ^{210}Pb and ^{137}Cs measured in 10 cores collected in the study area (fig. 1). Rates of relative sea-level rise are based on National Ocean Service (NOS) benchmark releveling surveys, USGS reports, NOS tide gauge data, and data on relative sea level rise presented by Paine (1993).

Natural Environments in the Study Area

Natural environments of the Lavaca-Navidad River system and alluvial valley in the study area (fig. 1), consist of brackish to fresh marshes, transitional areas, flats, open water (including lakes and abandoned river channels), fluvial woodlands, and uplands (White and others, 1989). These habitats have developed on alluvial valley fill within the entrenched valleys. The confluence of the Lavaca and Navidad Rivers is located approximately 16 to 17 km upstream from the mouth of the

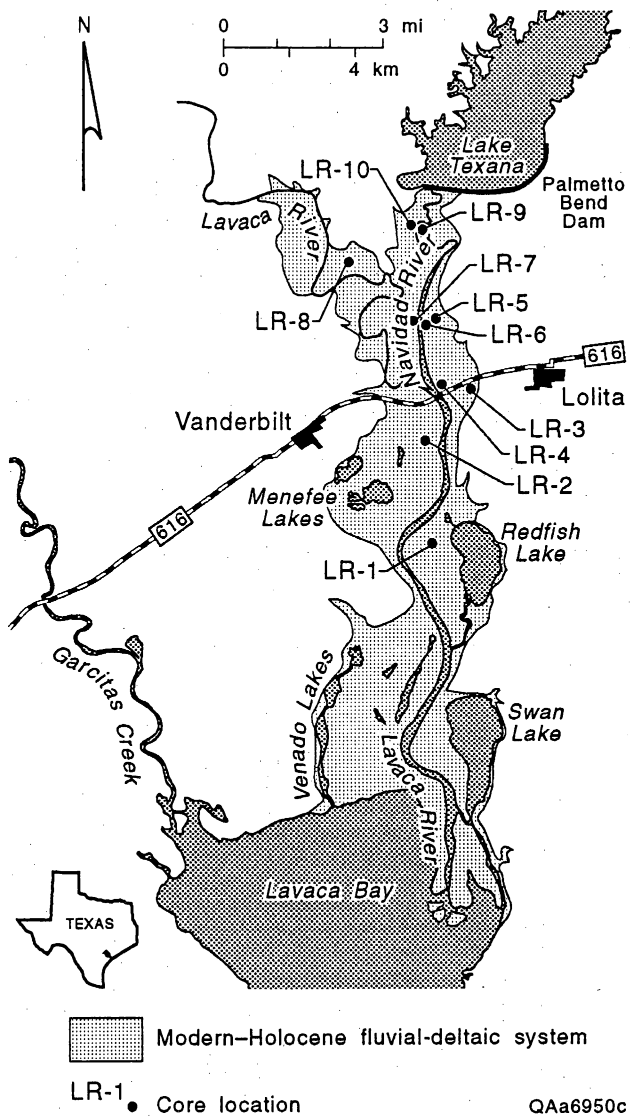


Figure 1. Index map of study area showing locations of coring sites.

Lavaca River. Inland parts of the alluvial valley are dominated by fluvial processes in contrast to deltaic areas where estuarine processes are more influential. The Lavaca River delta is generally characterized by salinities below 20 ppt, with salinities decreasing up the valley. In the study area, which is upstream of the delta, marshes are reflective of brackish to fresh conditions.

Modern-Holocene Valley Fill Deposits

Holocene sediments in the Lavaca River valley are dominated by thick sand sequences locally exceeding 18 m in thickness, which are overlain by thinner mud deposits varying in thickness from approximately 2.5 to 6 m (fig. 2). The maximum thickness of Holocene deposits is approximately 25 m at FM 616. The depth of the modern river channel is slightly greater than the thickness of the mud deposits; consequently the channel is floored by sandy sediments and bars within and on the flanks of the channel are sand rich.

Human Modifications Potentially Affecting Sedimentation

Among major human modifications in the Lavaca and Navidad River alluvial valley are the Missouri-Pacific Railroad (completed before 1930), FM 616 (constructed in the early 1950's), and Lake Texana completed in 1980 and located approximately 8 km upstream from the confluence of the Lavaca and Navidad Rivers (fig. 1). Other modifications within the project area include oil and gas fields such as at Menefee Flats, and artificially modified natural levees produced by spoil disposal associated with a dredged channel that extends from Lavaca Bay to Red Bluff on the Navidad. Major alterations caused by Missouri-Pacific railroad and FM 616 include approximately 2.5 km of elevated road fill that crosses the valley, which is about 3 km in width in this area. Openings totaling approximately 0.7 km in length occur at bridges over the Lavaca River and over drainage to the east and west of the river. About 70 percent of the valley is effectively dammed by the road fill.

The effects of human modifications in the study area on marsh sedimentation are not fully understood. It is obvious that flow patterns during flood events have been altered substantially by the Missouri-Pacific Railroad and FM 616, which extend across the valley diverting flow through the three bridge openings. Intuitively, one would expect sedimentation rates to be slightly higher upstream of the Missouri-Pacific due to the partial damming effect of the railroad, which during flood events may locally reduce currents and elevate water levels for longer periods of time upstream allowing more sediments to settle. However, variations in sedimentation rates, which are minimal, seem to be influenced more by the geomorphic setting and relationship of a site to the river and relict channels, rather than by location upstream or downstream of the railroad embankment. There is also

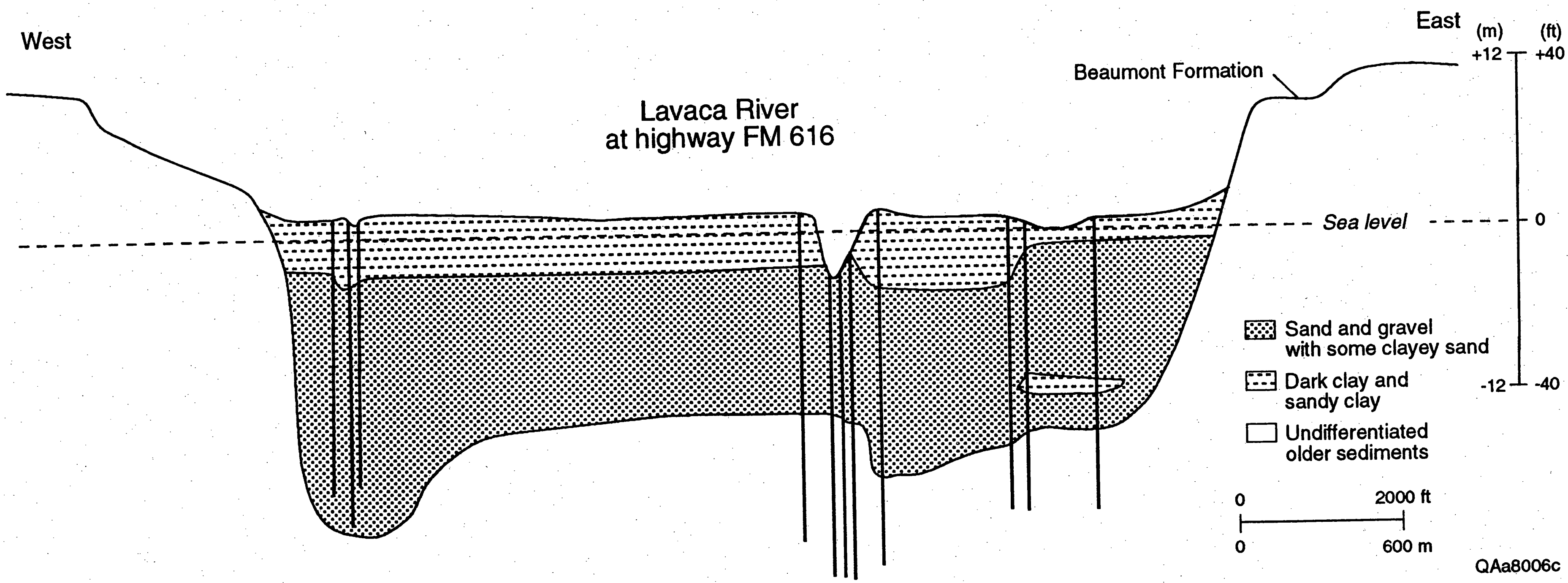


Figure 2. Cross section of Holocene sediments in the Lavaca River entrenched valley at FM 616. The lithology and thickness of sediments are based on geotechnical surveys made by the Texas Department of Transportation along FM 616.

the possibility that deposition of sediments downstream from FM 616 during hurricanes may compensate for reductions in sediment supplied to these downstream sites during river flood events.

Historical Wetland Losses

Losses of marsh habitats in the Lavaca River valley amounted to more than 1,400 acres between the 1930's and 1979 (White and Calnan, 1990). Losses were due primarily to the replacement of emergent vegetation by water and barren flats, and were most pronounced in the Menefee Flats area and downstream near Venado Lakes on the western side of the valley (fig. 3). Among the probable causes for the losses are subsidence and relative sea-level rise, compartmentalization of marshes by roads, levees, and canals, and possibly disposal of brine (Mackin, 1971). Rates of relative sea-level rise at benchmarks in the Lavaca River valley along FM 616 are approximately 5 times higher (Paine, 1993) than regional sea-level rise in the Gulf of Mexico (Gornitz and Lebedeff, 1987), and 2 to 4 times higher than preliminary estimates of recent sedimentation rates in alluvial valley marshes and transitional areas. A more detailed discussion of subsidence and sea-level rise rates are presented in a later section titled "Relative Sea-Level Rise".

METHODS

Field Methods

Site Selection

Ten sites were selected for coring in the Lavaca-Navidad alluvial valley system (fig. 1). Criteria used in selecting sites included location with respect to the modern Lavaca and Navidad River channels and abandoned channels, location with respect to the estuarine system, relative elevations, susceptibility to flooding, types of wetland vegetation, and location with respect to existing human modifications. The approach was to sample several different environments but avoid local human alterations that may have affected sedimentation rates.

Coring sites were positioned across the alluvial valley north and south of FM 616. Three sites are located downstream from FM 616 and the confluence of the Lavaca and Navidad Rivers, and 7 are upstream. Five sites are located within 300 m of the river. All sites are more than 12 km north

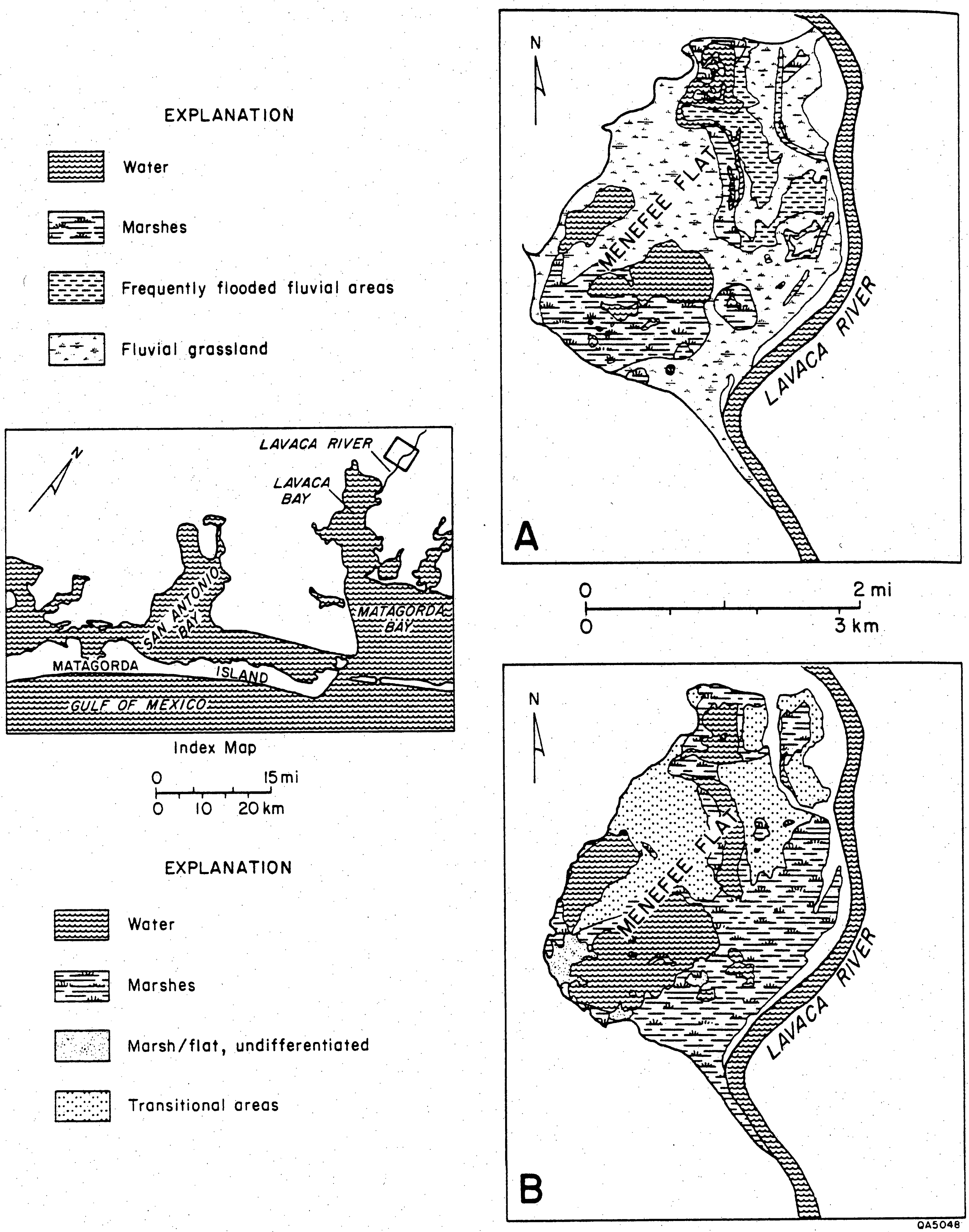


Figure 3. Changes in wetlands between 1956 (A) and 1979 (B) in the Menefee Flats area along the Lavaca River. Among the changes that occurred during this 26-year period was an increase in open water and a corresponding decrease in marshes. From White and others, 1989.

(upstream) of the mouth of the Lavaca River, which places them in wetland areas thought to be influenced more by riverine sedimentary processes than by estuarine processes.

Site Description

Wetland coring sites included brackish-water marshes characterized by an assemblage of *Distichlis spicata*, *Paspalum vaginatum*, and *Juncus romerianus*, fresh-water marshes dominated by *Zizaniopsis miliacea*, transitional areas with virtually homogeneous stands of *Spartina spartinae*, transitional areas with mixtures of short grasses including *Cynodon dactylon* and unidentified composites, and fluvial woodlands with abundant *Sabal minor* (table 1). Estimated elevations range from greater than 1.5 m (5 ft) to less than 0.45 m (1.5 ft). Coring site LR-8 had the highest estimated elevation, and sites LR-2, LR-3, and LR-6 the lowest (table 1). Sites in transitional areas (LR-4, LR-5, LR-7, LR-8 and LR-10) were generally at higher elevations, and were the most difficult to core because of increasing stiffness of clay with depth. Low marshes composed predominantly of *Scirpus californicus*, *Zizaniopsis miliacea*, and *Distichlis-Paspalum* were less difficult to core because of softer and less compacted sediments. Sites were cored in mid-March of 1994 (table 1). When possible, cores were taken at sites with no evidence of surface disturbance such as crawfish burrows and cattle trails. However, effects of cattle and deer tracks were difficult to avoid in transitional areas where grazing was widespread.

Coring Methods

Cores were taken by twisting, and where necessary driving, a thin walled, sharpened metal tube, 1-m long and 11.5 cm in diameter, into the marsh substrate. Lengths of cores varied depending on the difficulty of penetrating the substrate and the amount of compression. Some sediment compression occurred in deeper sections of cores where stiff clayey sediments were encountered, especially in transitional area levee-flank environments. Cores were dug out of the marsh soils to minimize loss of material during extraction from the substrate. The end of each core was covered with rubber caps that were tightened down with ring clamps and taped. The cores were transported to the BEG Core Research Center for processing.

Sediment Compression Caused by Coring

The volume of unconsolidated sediments normally decreases with depth as a result of physical compaction, dewatering, and loss of organic matter. For some depth-dependent relationships, the natural compaction is taken into account and the data are normalized to equate values near the top of

Table 1. Date of collection, location information, habitats, and vegetation at coring sites.

Core Number	Date Core Collected	Distance from River (m)	Estimated Elevation (m)	Habitat	Vegetation
LR-1	15-Mar-94	540	0.60	High to Low Brackish Marsh	*Distichlis/Paspalum, Juncus*
LR-2	15-Mar-94	450	0.45	Low Fresh to Brackish Marsh	*Scirpus californicus*
LR-3	16-Mar-94	1050	0.45	Low Fresh Marsh	*Zizaniopsis miliacea*
LR-4	17-Mar-94	300	1.20	Transitional Area	*Spartina spartinae*
LR-5	15-Mar-94	360	0.90	Transitional Area	*Cynodon dactylon*
LR-6	15-Mar-94	90	0.45	Low Fresh Marsh	*Zizaniopsis miliacea*
LR-7	15-Mar-94	120	0.90	Transitional Area	*Spartina spartinae, Acacia farnesiana, composites*
LR-8	16-Mar-94	390	1.50	High Fresh Marsh to Transitional Area	Composites
LR-9	16-Mar-94	45	0.90	Fluvial Woodland	*Sabal minor*
LR-10	16-Mar-94	90	1.20	Fluvial Woodland/Transitional Area	Woodlands/composites

the core with those near the bottom of the core. Physical properties affected by natural compaction, such as water content and bulk density, are used to remove the effect of compaction so that data throughout the core can be compared on a post-compaction basis.

In the wetland literature, few references are made to artificial compaction of wetland sediments caused by the coring operation. Some reports do not address the issue of artificial compaction, and others give only vague qualitative descriptions such as minor compaction. Few studies actually attempt to quantify the magnitude of artificial compaction and to adjust those depth-dependent parameters derived from the core.

In this report we distinguish between natural compaction and artificial compaction by referring to artificial compaction as "compression." Compression commonly results during coring even if steps are taken to minimize it. Adjusting the stratigraphy of the core to remove the effects of compression is necessary because any vertical displacement of the cored sediments with respect to their natural position will result in the calculation of inaccurate sedimentation rates. Sedimentation rates calculated from compressed cores will underestimate the actual rates of sedimentation.

Penetration of the core barrel into unconsolidated sediments typically causes some minor compression of the sediments. The amount of compression depends on the composition and textures of the sediments, their water content, and other physical properties such as bedding. Some muds are susceptible to high compression, whereas well-sorted, water-saturated sands are essentially incompressible. The observed compression can occur in one of two forms. The simplest form of compression is the physical foreshortening of the sediment column as the water and void space are reduced. For this type of compression all the strata are represented and the stratigraphy of the core and surrounding uncompressed sediments is the same except that the strata within the compressed intervals are closer together. The most complex type of compression involves drag along the core barrel and expulsion of sediment so that some strata are bypassed and are not recovered in the core barrel. This type of compression can occur where stiff sediments overlie a zone of soft sediment and the soft sediments are driven aside as the core barrel is shoved into the ground. Drag and bypassing of sediments are observed as distorted strata in the cores. The amount of distortion observed in the core and in the x-radiographs of the core reflects the degree of sediment compression.

Compression of each core from the Lavaca River was anticipated because the wetland sediments are composed predominantly of mud. As the core barrel was driven into the ground, the amount of sediment compression was estimated by periodically measuring the distance to the sediment surface on the outside and inside of the core barrel (fig. 4). By making these two measurements and knowing the length of the core barrel, total penetration of the core barrel, and core length, the amount

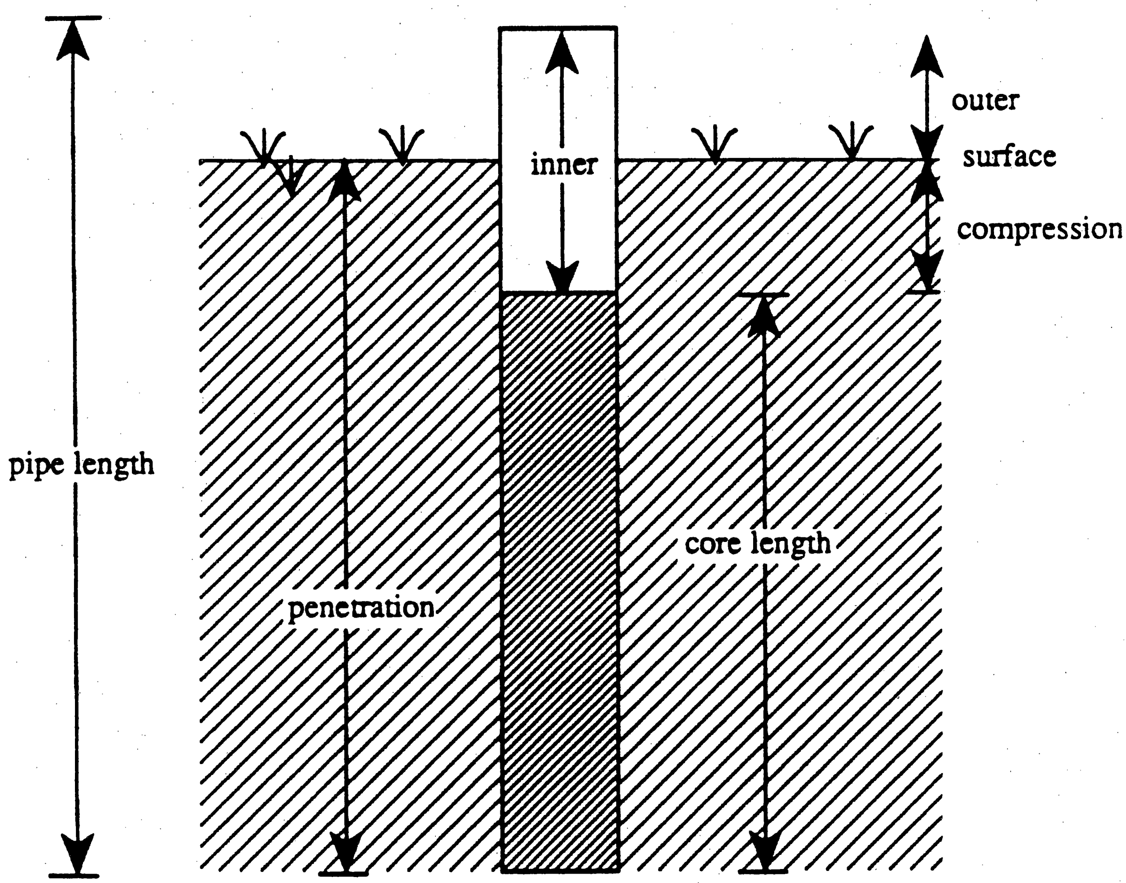


Figure 4. Illustration showing sediment compression that may occur during coring.

of sediment compression can be calculated (table 2 and Appendix A). The interval thickness and the amount of compression for each interval also can be derived from these measurements (table 2) and used to illustrate the percent sediment compression and the depths at which it occurs. The field measurements and derived data also can be used to reconstruct the interval thickness before compression and to calculate restored depths that are corrected for compression (Appendix A). The depth corrections are used to adjust the core depths so that the lengths of the compressed intervals are restored to their uncompressed lengths. This is done by calculating the amount of compression (C_i) for each interval (i), calculating the amount of compression for each one centimeter depth increment in the interval being corrected, and adding the fractional proportion of compression to each depth increment. This procedure assumes that the compression is uniformly distributed throughout the interval. The corrected depths have the numerical effect of "stretching" the core to its uncompressed length.

The depth correction equation is given by:

$$D_c = P_{i-1} + (D_u - D_{u,i-1})(1+(C_i - C_{i-1})/(D_{u,i} - D_{u,i-1}))$$

where D_c = corrected depth

D_u = uncorrected depth

$C_i = I_i - O_i$ = compression of interval i

$P_i = O_0 - O_i$ = penetration of interval i

and the uncorrected depth of the lower boundary of the core for which corrections are being made is $D_{u,i} = P_i - C_i$.

Before applying the above equation, the appropriate interval (i) for D_u must be determined so that the proper values for compression and penetration are used to calculate the correction factor.

Core compression normally increases with depth, but it is not linear. In fact, the compression curve for each core is different (Appendix A), and some cores are compressed more in the middle than at the top or the bottom. Although compression is not linear for the entire core, it is assumed to be linear over the interval being corrected. This assumption is necessary because we do not have any information that would permit a more accurate correction.

Table 2. Total compression and penetration of Lavaca River cores and percent compression calculated for each interval.

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total compression Ci	Total penetration Pi	Depth of compressed interval (Du,i)	Interval compression %
			LR 1			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	85.0	85.0	0.0	16.0	16.0	0.0
2	79.4	79.4	0.0	21.6	21.6	0.0
3	74.2	74.2	0.0	26.8	26.8	0.0
4	67.6	67.6	0.0	33.4	33.4	0.0
5	62.4	62.4	0.0	38.6	38.6	0.0
6	56.4	56.4	0.0	44.6	44.6	0.0
7	51.0	51.0	0.0	50.0	50.0	0.0
8	47.0	47.0	0.0	54.0	54.0	0.0
9	42.8	42.8	0.0	58.2	58.2	0.0
10	41.0	41.0	0.0	60.0	60.0	0.0
11	34.4	34.4	0.0	66.6	66.6	0.0
12	27.4	27.4	0.0	73.6	73.6	0.0
13	19.0	19.0	0.0	82.0	82.0	0.0
14	13.0	13.0	0.0	88.0	88.0	0.0
			LR 2			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	78.8	78.8	0.0	22.2	22.2	0.0
2	72.0	72.0	0.0	29.0	29.0	0.0
3	66.4	67.0	0.6	34.6	34.0	10.7
4	63.8	65.0	1.2	37.2	36.0	23.1
5	49.6	51.0	1.4	51.4	50.0	1.4
6	42.2	44.2	2.0	58.8	56.8	8.1
7	39.0	41.0	2.0	62.0	60.0	0.0
8	33.6	35.6	2.0	67.4	65.4	0.0
9	26.6	30.4	3.8	74.4	70.6	25.7
			LR 3			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	85.6	85.6	0.0	15.4	15.4	0.0
2	74.0	74.0	0.0	27.0	27.0	0.0
3	69.4	69.4	0.0	31.6	31.6	0.0
4	54.0	54.0	0.0	47.0	47.0	0.0
5	49.2	49.6	0.4	51.8	51.4	8.3
6	43.0	44.0	1.0	58.0	57.0	9.7
7	35.0	36.0	1.0	66.0	65.0	0.0

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total compression Ci	Total penetration Pi	Depth of compressed interval (Du,i)	Interval compression %
			LR 4			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	87.2	87.2	0.0	13.8	13.8	0.0
2	77.8	78.6	0.8	23.2	22.4	8.5
3	72.4	73.2	0.8	28.6	27.8	0.0
4	65.0	65.8	0.8	36.0	35.2	0.0
5	63.2	64.0	0.8	37.8	37.0	0.0
6	61.6	62.4	0.8	39.4	38.6	0.0
7	55.8	57.0	1.2	45.2	44.0	6.9
8	47.6	50.2	2.6	53.4	50.8	17.1
9	42.2	46.2	4.0	58.8	54.8	25.9
10	38.4	42.8	4.4	62.6	58.2	10.5
			LR 5			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	91.0	91.0	0.0	10.0	10.0	0.0
2	86.0	86.0	0.0	15.0	15.0	0.0
3	80.6	80.6	0.0	20.4	20.4	0.0
4	68.2	68.6	0.4	32.8	32.4	3.2
5	57.2	58.0	0.8	43.8	43.0	3.6
6	44.6	45.6	1.0	56.4	55.4	1.6
7	40.6	41.6	1.0	60.4	59.4	0.0
8	37.2	38.4	1.2	63.8	62.6	5.9
9	30.0	31.4	1.4	71.0	69.6	2.8
			LR 6			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	78.6	78.6	0.0	22.4	22.4	0.0
2	68.0	68.2	0.2	33.0	32.8	1.9
3	63.0	63.2	0.2	38.0	37.8	0.0
4	51.8	52.0	0.2	49.2	49.0	0.0
5	49.0	49.2	0.2	52.0	51.8	0.0
6	43.0	43.6	0.6	58.0	57.4	6.7
7	38.0	40.0	2.0	63.0	61.0	28.0
8	35.6	37.8	2.2	65.4	63.2	8.3

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total compression Ci	Total penetration Pi	Depth of compressed interval (Du,i)	Interval compression %
			LR 7			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	83.0	83.0	0.0	18.0	18.0	0.0
2	78.6	78.6	0.0	22.4	22.4	0.0
3	67.0	68.2	1.2	34.0	32.8	10.3
4	64.0	66.0	2.0	37.0	35.0	26.7
5	58.0	62.0	4.0	43.0	39.0	33.3
6	54.8	59.4	4.6	46.2	41.6	18.8
7	51.2	57.0	5.8	49.8	44.0	33.3
8	46.6	53.0	6.4	54.4	48.0	13.0
			LR 8			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	83.0	83.0	0.0	18.0	18.0	0.0
2	70.0	70.0	0.0	31.0	31.0	0.0
3	56.6	56.6	0.0	44.4	44.4	0.0
4	53.2	53.2	0.0	47.8	47.8	0.0
5	52.8	52.8	0.0	48.2	48.2	0.0
6	47.6	48.6	1.0	53.4	52.4	19.2
7	38.0	43.8	5.8	63.0	57.2	50.0
			LR 9			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	79.0	79.0	0.0	22.0	22.0	0.0
2	69.8	69.8	0.0	31.2	31.2	0.0
3	54.8	55.0	0.2	46.2	46.0	1.3
4	51.6	51.8	0.2	49.4	49.2	0.0
5	50.0	50.2	0.2	51.0	50.8	0.0
6	46.4	46.6	0.2	54.6	54.4	0.0
7	40.2	42.4	2.2	60.8	58.6	32.3

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total compression Ci	Total penetration Pi	Depth of compressed interval (Du,i)	Interval compression %
			LR 10			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	78.6	79.0	0.4	22.4	22.0	1.8
2	74.6	75.4	0.8	26.4	25.6	10.0
3	69.4	70.4	1.0	31.6	30.6	3.8
4	67.0	68.0	1.0	34.0	33.0	0.0
5	57.8	59.4	1.6	43.2	41.6	6.5
6	53.6	55.2	1.6	47.4	45.8	0.0
7	49.6	53.0	3.4	51.4	48.0	45.0
8	44.0	49.6	5.6	57.0	51.4	39.3
9	40.6	47.0	6.4	60.4	54.0	23.5

Most cores from the Lavaca-Navidad River system underwent some compression, and most of the cores are compressed from 2 to 6 cm (table 2 and Appendix A). Core 1 is the least compressed (0 cm), whereas cores 7 and 10 are the most compressed (6.4 cm). Core lengths estimated from the compression and penetration measurements generally agree within 1 cm of the actual core length. Larger discrepancies between the depth of penetration and the length of core recovered suggest that some of the sediment dropped out of the end of the core barrel as it was being retrieved.

Laboratory Methods

Core Preparation and Handling

Cores were split in half by first cutting horizontally down each side of the metal tube and then by cutting the core in half with a thin wire. The top section of each core was cut with a fine-toothed band saw to limit disturbance of the root-matted zone. The two half cores were then separated, each half retained in the half tube. One half of the core was wrapped in plastic wrap and sealed in an air tight clear plastic liner. This half of the core was transported to the USGS laboratory in Denver for x-radiography, and analysis of ^{210}Pb, ^{137}Cs and ^{7}Be activity, moisture content, loss on ignition, and bulk density.

The other halves of the cores were archived and retained in the BEG Core Research Center where they were subsampled for other physical and chemical analysis. Immediately after the cores were split, a measured volume of material was collected from near the top, middle, and bottom of each core for analysis of moisture content, total organic carbon (TOC), and bulk density.

Each half core was trimmed with an osmotic knife and physically described. Information recorded on core description sheets included core depth, sediment color, sediment type (visual description), nature of contacts, textural trends, sedimentary structures, state of oxidation, and presence of accessories (organic material and caliche nodules). The cores were then photographed to produce large format color prints and 35 mm slides.

After receiving preliminary results of ^{210}Pb activity for cores, cores LR-3 and LR-5 were subsampled at various horizons (based on ^{210}Pb distribution) for textural and geochemical analysis. When not in use, the half cores were covered with plastic wrap, placed in labeled boxes and stored in a climate controlled room. The archived core half serves as a permanent record of the sediment types encountered and the types of material sampled for textural and geochemical analyses.

Analytical Methods

^{210}Pb Analysis (USGS). Isotopic analysis of cores (Appendix B) was completed under the supervision of Dr. Charles Holmes of the U.S. Geological Survey using procedures developed by the USGS (Holmes and Martin, 1976; Martin and Rice, 1981), which is a modified version of that described by Flynn (1968) (Appendix C). The specific activity of ^{210}Pb was measured indirectly by determining the activity of the granddaughter isotope ^{210}Po. Samples were analyzed at 1-cm intervals down to a depth of 36 cm, below which analysis occurred at 2-cm intervals. Variations from this analysis occurred in cores LR-1, which was sampled at 2-cm intervals throughout the core because of $CaCO_3$ nodules that interfered with the 1-cm sampling, and cores LR-3 and LR -4, which were sampled at 1-cm intervals to a depth of 25 cm below which the core was sampled at 2-cm intervals. LR-5 was sampled only to a depth of 34 cm because of low activities below that depth, apparently caused by sandy sediments. Logarithmic plots of excess ^{210}Pb activity against depth were among the methods used to determine preliminary variations in sedimentation rates.

^{137}Cs Analysis (USGS). Isotopic analyses of ^{137}Cs and ^{7}Be were completed under the supervision of Dr. Charles Holmes at the USGS. For ^{137}Cs analysis, a representative sample was ground and placed in a counting cup. The cup was placed in a high-resolution planar gamma-ray detector (germanium, lithium-drifted) from which a spectrum was accumulated for 24 hours. The resulting value was compared to a standard of known value and reported as ^{137}Cs in dpm/g. The isotopes ^{214}Bi and ^{7}Be were also determined as part of the ^{137}Cs analysis process. Six cores were analyzed and results are presented in the "Results" section of this report.

Bulk Density, Moisture Content, and Organic Matter (USGS). Samples were collected by slicing the half core into in 1- or 2-cm wafers in order to determine volumes for bulk density measurements. Samples collected along the core were weighed then dried at a temperature of 60^{o} C for 24 hours and reweighed to determine moisture content and dry bulk density. The samples were then reheated to 450^{o} C for 12 hours to determine organic matter as estimated from weight loss-on-ignition (LOI). The remaining sediment was assumed to be mineral matter, and its percent by weight was determined. Wet and dry bulk densities, water content, LOI, and mineral (inorganic) matter are presented in Appendix B. It was assumed that sediments in the cores were carbonate free, but 4 cores (LR-1, LR-3, LR-4, LR-5) contain minor concentrations of carbonates in the form of nodules and tiny fragments of $CaCO_3$, which are most abundant in the lower half of the cores.

Bulk Density (BEG). A measured volume of material was obtained by subsampling each half core with a cork borer of known diameter (1.17 cm), and measuring the thickness of the half core, usually about 5 cm. The measurement of length was made from the thickness of the half core rather than from the removed sample plug because of compression. Three subsamples were taken from each core near the top, middle, and bottom of the core. Additional subsamples for bulk density analysis were collected from cores LR-1 (8 total), LR-2 (6 total), and LR-3 (9 total, 3 of which were taken near the base of the core by subsampling 1 and 2-cm sections of the half core instead of using the cork borer). The subsamples were placed in pre-weighed containers and weighed to determine total weight, then dried at 105^{o} C to constant weight. A total of 44 subsamples were analyzed. From these data dry bulk density and moisture content were determined (Appendix D).

Organic Carbon (BEG). The three subsamples collected from the top, middle, and bottom of each core for bulk density measurements were also analyzed for total organic carbon (TOC). Additional organic carbon samples were collected at selected horizons in three other cores (Appendix D). The dried solids were pulverized in a diamonite mortar and pestle and analyzed for total carbon content using a coulometric carbon analyzer (950^{o} C, pure oxygen atmosphere, standard scrubbers, approximately 50 mg sample size, blank corrected). In the absence of carbonates, the recovered carbon is assumed to be all organic carbon.

Textural Analysis (University of Wisconsin). Samples were taken at specified 1 to 2 cm intervals along selected cores for analyses of percent sand, silt, and clay (Appendix E). Disaggregated samples were wet sieved to separate particles larger than sand size (gross organics), sand, and mud (silt and clay). After the large particles were removed, sand was separated with a 270 mesh (53 micron) sieve. Sand percent was determined after treating the sample with hydrogen peroxide to remove remaining organics. Percent silt and clay were determined using hydrometer or pipette measurements (Gee and Bauder, 1986).

Total Aluminum (BEG/AnalySys Inc.). Cores LR-3 and LR-5 were subsampled at various depths for analysis of total aluminum by AnalySys Inc. Aluminum, through metal/aluminum ratios, has been used by some researchers to normalize ^{210}Pb. Samples were digested and analyzed in accordance with EPA procedures 3051, 6010, and 200.5. Sediment samples were treated in HNO_3 and microwaved to achieve total digestion. Aluminum was analyzed by Inductively Coupled Plasma—Atomic Emission Spectroscopy.

Salinity (Chlorinity) (BEG). For sediments with a high salt content, excess ^{210}Pb activities should be determined on a salt free basis (Church and others, 1981). Total chloride was measured in sediments from the bayward most core by ion chromatography following BEG procedures (Specific Work Instruction 1.15: Determination of anions by ion chromatography). Chlorinity was converted to salinity using a factor of 1.80655 (Duxbury, 1971).

RESULTS

Results of the ^{210}Pb analysis and counting dates are presented in Appendix B along with measurements of water content, loss on ignition, mineral matter, dry bulk density and wet bulk density. Bulk density was determined for each sample by the USGS. A few samples from each core were also analyzed for bulk density by BEG. In general, bulk densities measured by the USGS were higher by an average of about 1.7 times those determined by BEG. The reason for this difference is not clear, but may be related to the variation in methods used to take subsamples of the cores (see methods section). Because USGS measurements were made on every sample that was analyzed for ^{210}Pb, the USGS bulk densities provide the most complete data for analysis of cumulative inorganic mass and for determination of dates and sedimentation rates.

^{210}Pb Activity Profiles

The objective of this investigation was to determine sedimentation rates based on ^{210}Pb activity. Accordingly, results of other physical and chemical analysis are discussed primarily in terms of their influence on or relationship with the distribution of ^{210}Pb activity within a core. ^{210}Pb activity profiles were completed for each core and examined carefully to determine trends and probable causes for variations in trends.

Variations in ^{210}Pb and Probable Causes

Plots of ^{210}Pb activity against depth indicate some scatter and local variations from linear trends for many cores. Pronounced variations in slope of the plots should define variations in sedimentation rates, which can be correlated with sediment deposition by the Lavaca and Navidad Rivers. But local variations in excess ^{210}Pb activity involving individual samples or a few samples are not fully understood. Some are apparently related to bioturbation, textural and organic properties, presence of carbonates, and other changes in sediment chemistry.

Bioturbation. According to some researchers, for example Nittrouer and others (1979), the relatively uniform ^{210}Pb activity in near surface layers of some cores indicates a zone of bioturbation and mixing of sediments (fig. 5). In Lavaca River cores, distinct evidence of bioturbation was not apparent in either x-rays or dressed and described cores. Below the root zones, cores are homogeneous in appearance and log normal profiles of ^{210}Pb show that activities generally decline in a relatively linear fashion to depths of about 20 cm, below which there is a flattening of the profile and an increase in nonlinearity for most cores. We believe that the flattening and nonlinearity occur as background or supported ^{210}Pb levels are approached and reached at depth. Varying from this general trend is LR-9, which is nonlinear along most of its profile. The nonlinearity may be a result of bioturbation, physical mixing, lithology changes, or erosion and deposition during flood events. Crayfish burrows were observed in the vicinity of LR-9, although there were no surface manifestations of burrowing at the exact location of the coring site. Core LR-9 is located in a meander bend of the Navidad River at a site that is possibly subject to rather strong currents during flooding. This observation is supported by textural analysis, which shows a relatively high percentage of sand (18-56 percent) in the upper half of the core. Still, the site is heavily vegetated, which should help minimize physical mixing of sediment and enhance sediment deposition. The specific reason for the "saw-tooth" nature of the ^{210}Pb profile is not totally clear, but may be related to textural variations as noted in the next section.

Texture. Textural variations can influence excess ^{210}Pb activity (fig. 6). Activity levels are higher in finer sediments, apparently because Pb, like many other metals, is sequestered by fine-grained particles such as clay minerals, organic matter, and Fe-Mn oxides (Nittrouer and others, 1979). Sediment in cores taken in this study consist primarily of homogeneous mud (silt and clay), but sand was higher than expected in some cores. Sand is a minor constituent overall (less than 20 %) except in cores LR-1, LR-5, LR-6, and LR-9 where it generally composes more than 20 percent of the sediment in samples analyzed (Appendix E). Concentrations of sand in LR-4 exceed 20 percent in sediments at depths greater than 30 cm. Sand was most abundant in core LR-5 (fig. 7).

The nonlinearity of the ^{210}Pb profile in LR-9 may be due in large part to textural variations. Sand is relatively abundant, ranging from 15 to 56 percent, in those sediments analyzed. When ^{210}Pb is calculated on a sand free basis and plotted against depth, the profile becomes more linear, with R^2 increasing from 0.424 to 0.760 for 6 samples analyzed in the top 35 cm (fig. 8). Nonlinearity in the lower part of core LR-6 may also be due to textural variations. The drop in ^{210}Pb activity at 45 cm in core LR-6 is probably the result of sand content in samples taken below this depth. Statistical correlation of ^{210}Pb activity with sediment textures (sand, silt, clay, or mud), however, may show only a moderate correlation (figs. 9 and 10). Where sand is concentrated there is commonly a corresponding decrease in the ^{210}Pb activity.

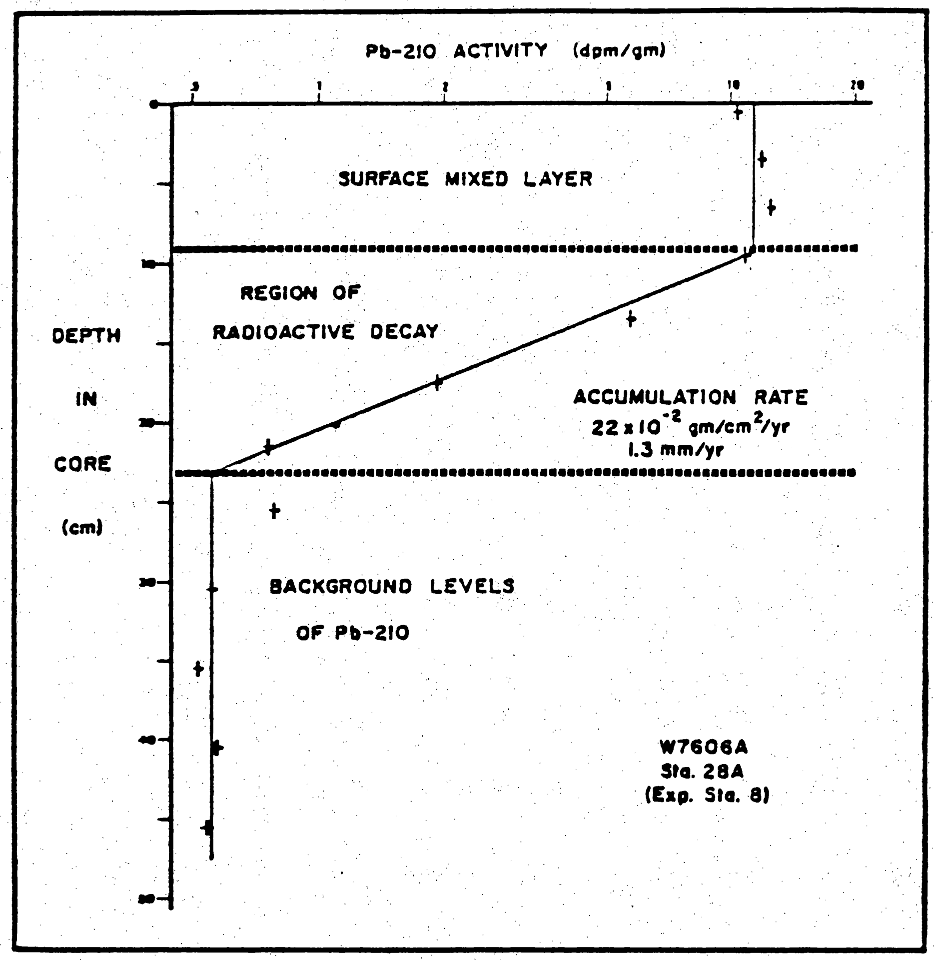


Figure 5. Profile of ^{210}Pb activity of a sediment core from the Washington continental shelf showing the mixed surface layer. Bioturbation in marsh surface layers can produce similar "flat" activities. From Nittrouer and others, (1979)

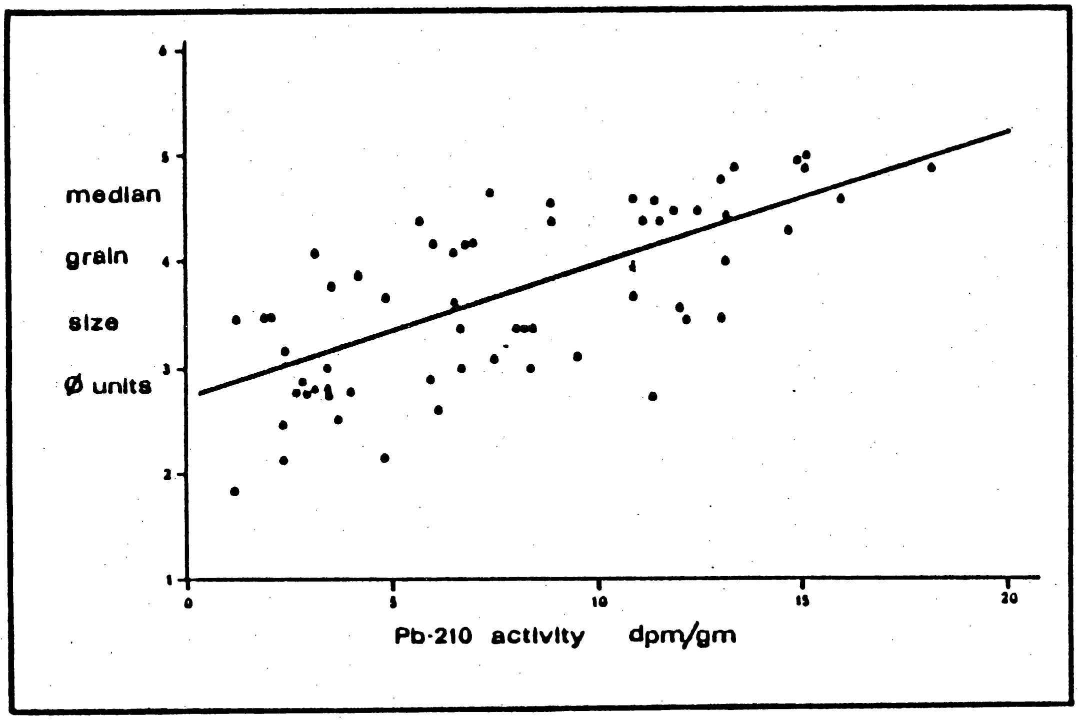


Figure 6. Relationship between grain size and initial ^{210}Pb activity. From Nittrouer and others (1979).

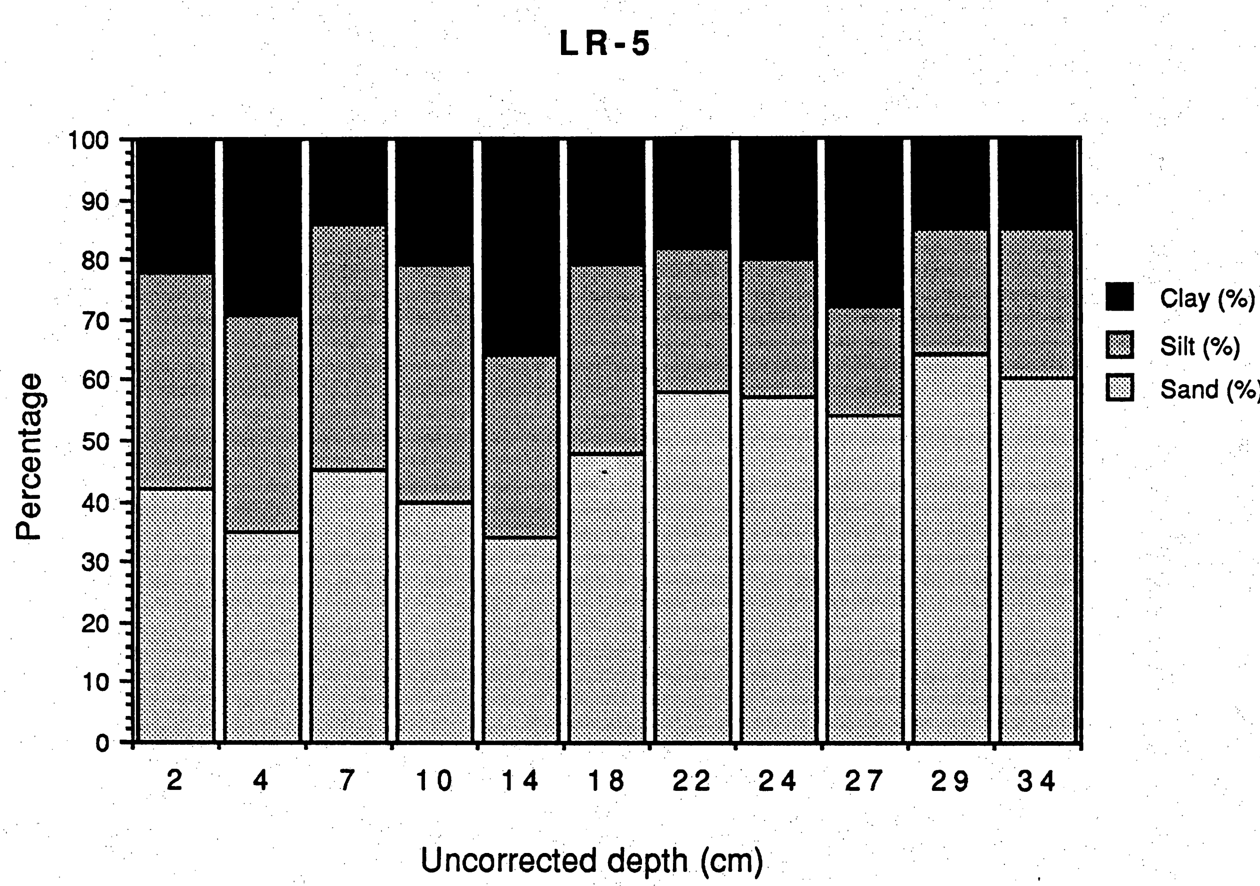


Figure 7. Distribution of sand, silt and clay at selected intervals in core LR-5.

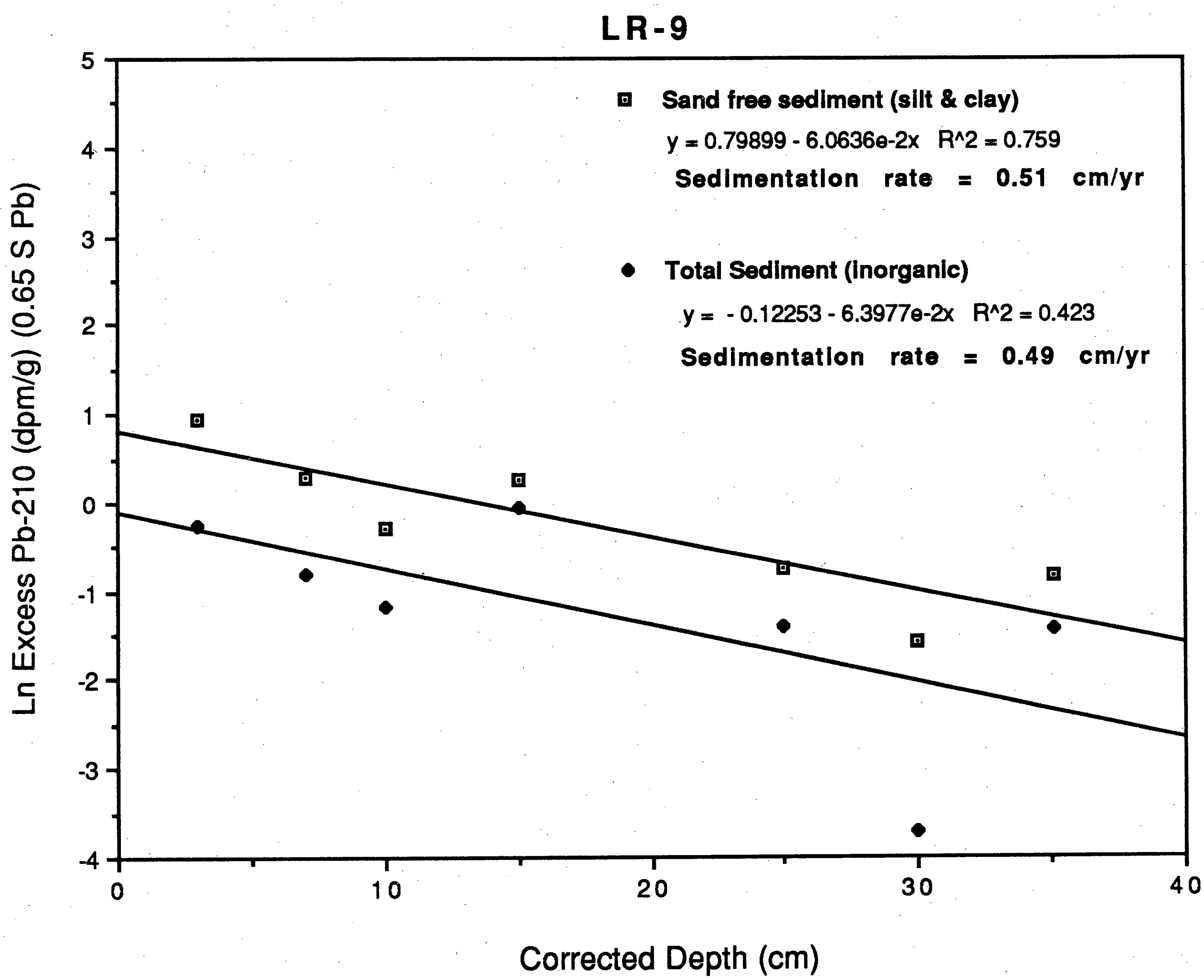


Figure 8. Effect of sand on ^{210}Pb profiles and sedimentation rates in core LR-9.

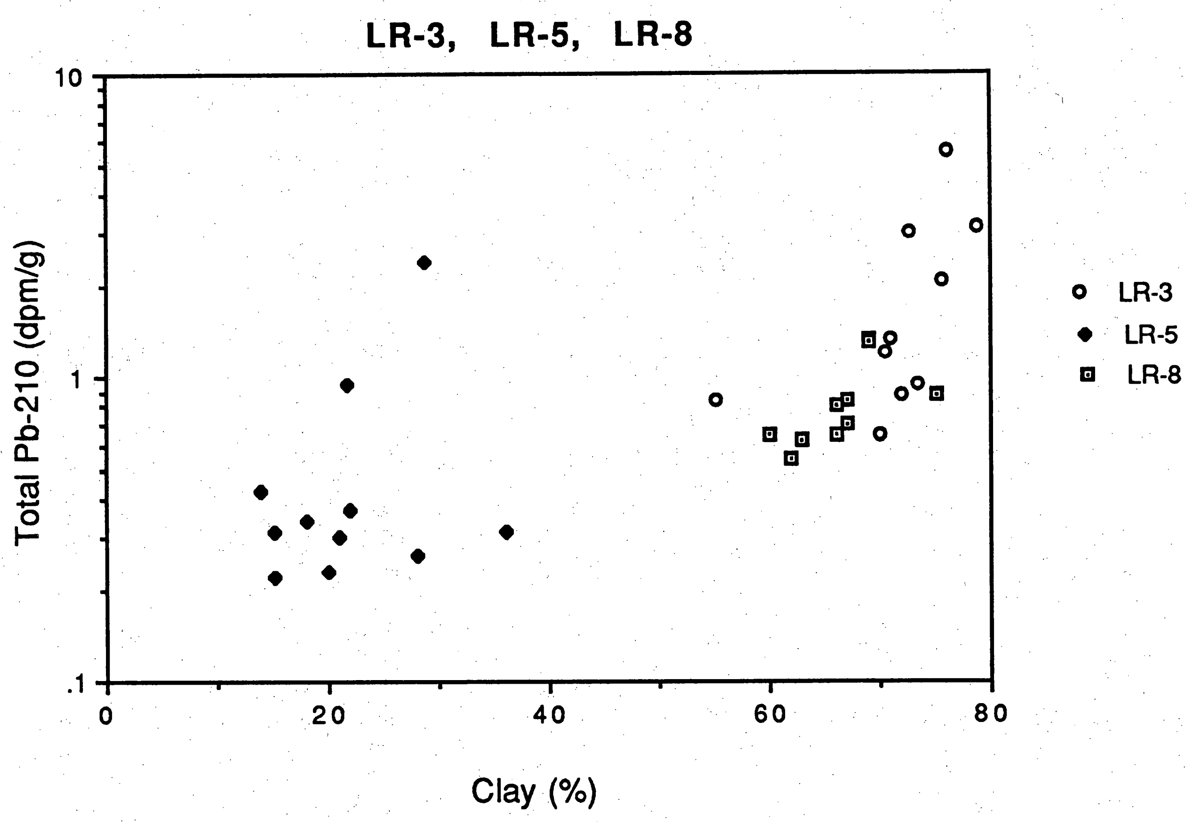


Figure 9. Relationship between clay percent and ^{210}Pb activity in cores LR-3, 5, and 8.

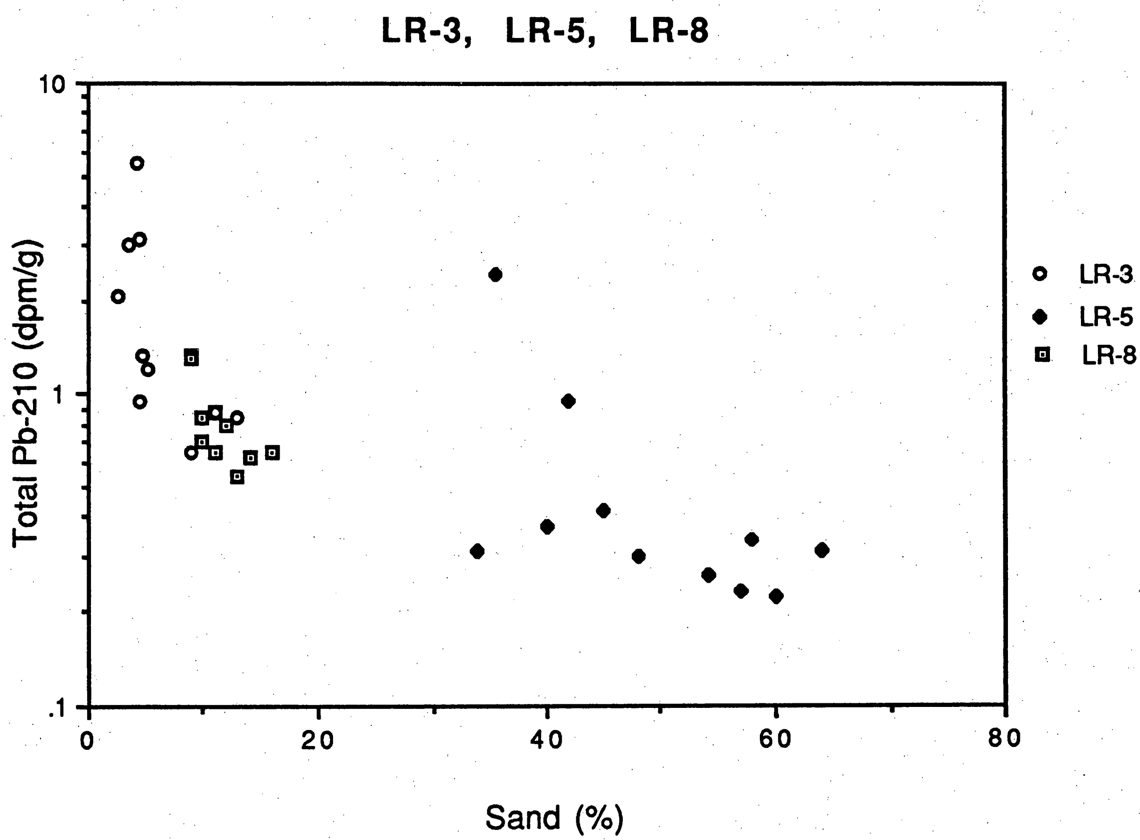


Figure 10. Relationship between sand percent and ^{210}Pb activity in cores LR-3, 5, and 8.

To determine the effect of sand on sedimentation, rates were calculated for cores LR-3 and LR-5 and LR-9 on a sand free basis using the constant flux : constant sedimentation rate "model" (Oldfield and Appleby, 1984). Rates varied by only 0.03 to 0.05 cm/yr in cores LR-3 and LR-5 from those rates in which sand was not considered (figs. 11 and 12). For core LR-9, the sedimentation rate increased from 0.49 cm/yr to 0.51 cm/yr when calculated on a sand free basis (fig. 8). Aluminum was also used to normalize ^{210}Pb content to evaluate possible rate changes in cores LR-3 and LR-5, as discussed in the following paragraph. Because of the high correlation between aluminum and percent mud and because calculated sedimentation rates were not substantially different using these two methods of normalization, we decided that textural data would be the most informative of the two parameters, and analyzed other cores for texture only (Appendix E).

Aluminum. The assumed uniform flux of aluminum from crustal rock sources to the sediments allows aluminum to be used as a normalizing agent to compensate for variations in lithology, salt, $CaCO_3$, water or organic matter content especially in the upper parts of cores (Bruland and others, 1974). Total aluminum was analyzed in 19 sediment subsamples, 10 from core LR-3 and 9 from LR-5. Sediments from the same horizons in these cores were also analyzed for texture. Aluminum content in core LR-5 is much lower than in LR-3 because of more abundant sand in LR-5 (table 3). Correspondingly, the "dilutional" effect of the sand is also apparent in the concentration of ^{210}Pb, which is much lower in LR-5 than in LR-3. Aluminum has a relatively high positive correlation with ^{210}Pb (fig. 13) and with percent mud (fig. 14).

Sedimentation rates for cores LR-3 and LR-5 were calculated using aluminum normalized values of ^{210}Pb (e.g., excess $^{210}Pb/Al$ ratios ; Bruland and others, 1974) to determine if the rates were different from those using non-normalized values. As with texture, discussed previously, rates were determined using the constant flux : constant sedimentation method (Oldfield and Appleby, 1984). In general we found that the sedimentation rates based on excess ^{210}Pb, without correction, were only slightly different (0.1 to 0.5 mm/yr) from rates based on "corrected" or normalized excess ^{210}Pb using aluminum content (figs. 11 and 12).

Organics (Weight Loss-On-Ignition). The association between ^{210}Pb activity and organic content based on weight loss-on-ignition (LOI), varied from core to core, but overall there was a positive correlation. The square of the correlation coefficient (R^2) ranged from 0.884 to 0.935 in 4 of the cores. Core LR-3 had the highest positive correlation (R^2 = 0.935, fig. 15), and LR-5 and LR-9 the lowest (R^2 = 0.125 and 0.147 respectively). In core LR-5, elimination of one anomalous sample at 29 cm yields a much higher correlation, R^2 = 0.840 (fig. 16). The plot of LOI against ^{210}Pb in core LR-9 shows very broad

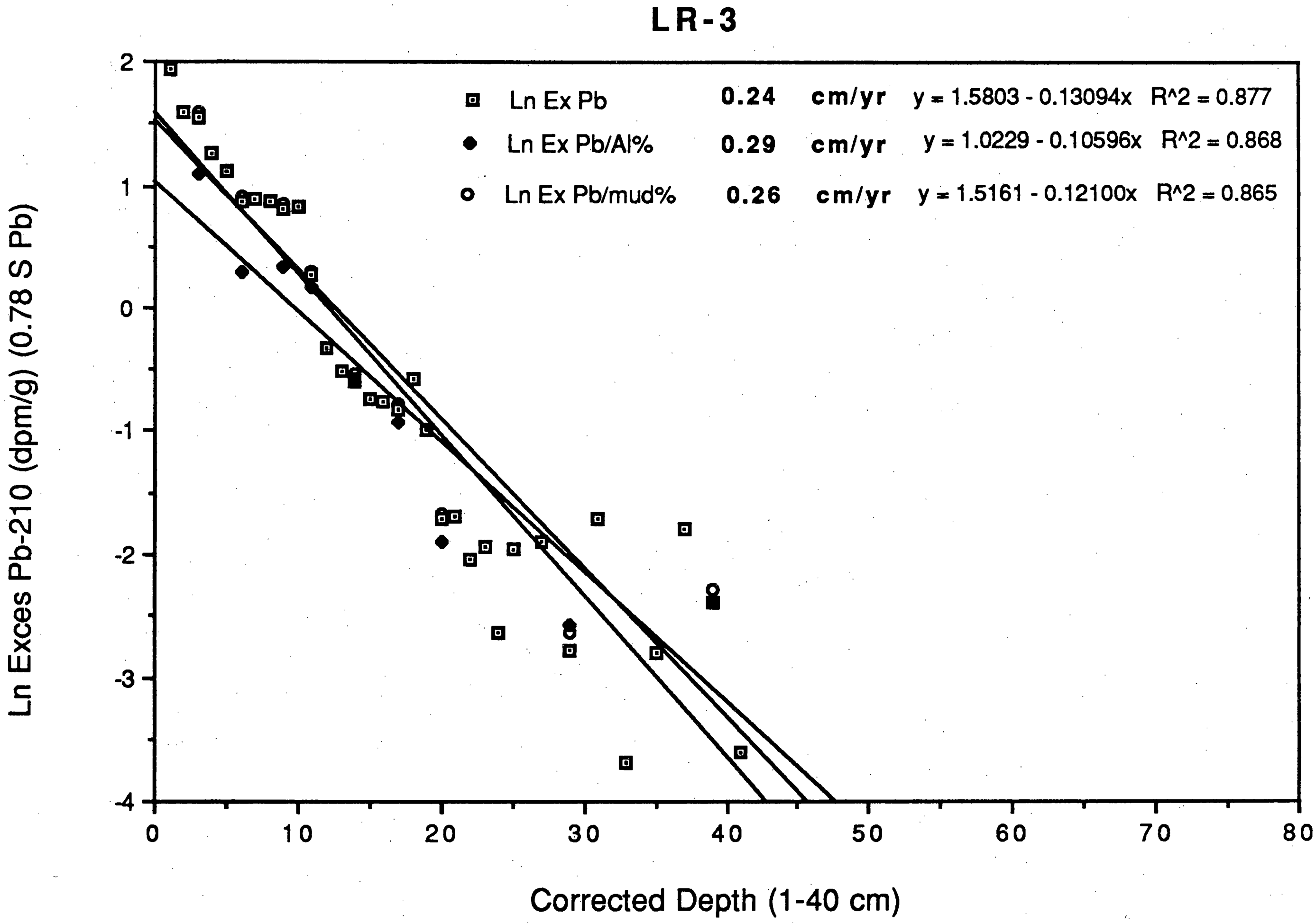


Figure 11. Effect of sand on the sedimentation rate in core LR-3. The low sand content in this core has only a slight effect (0.2 mm/yr) on the sedimentation rate.

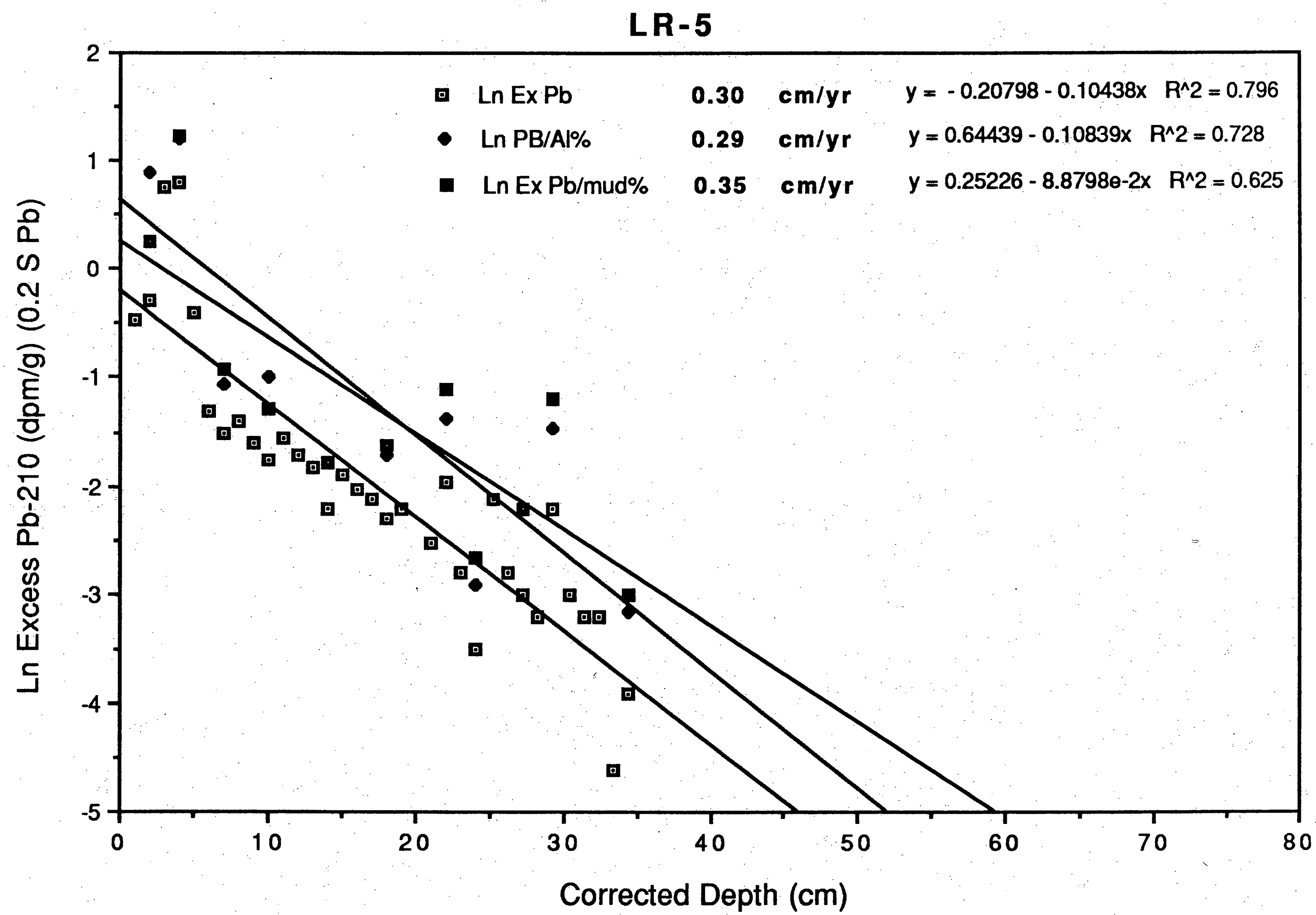


Figure 12. Effect of sand on the sedimentation rate in core LR-5. The relative high percentage of sand in this core causes a variation of approximately 0.5 mm/yr in the sedimentation rate .

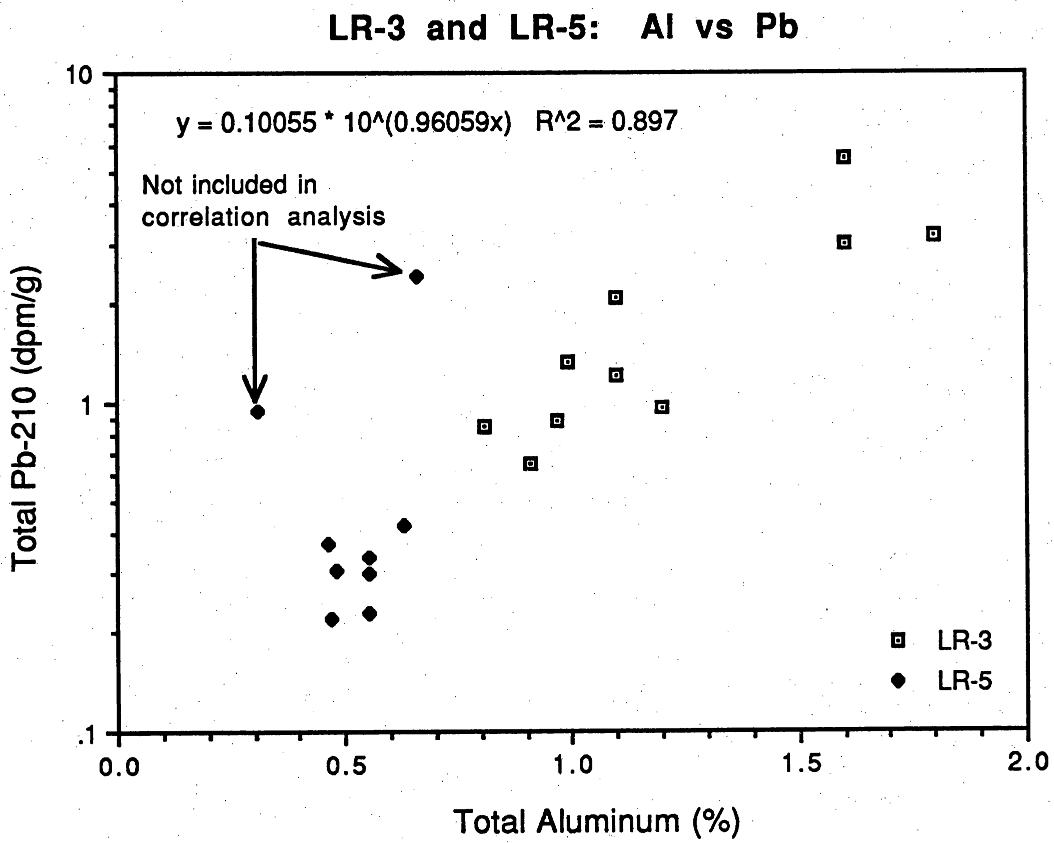


Figure 13. Correlation between aluminum and ^{210}Pb.

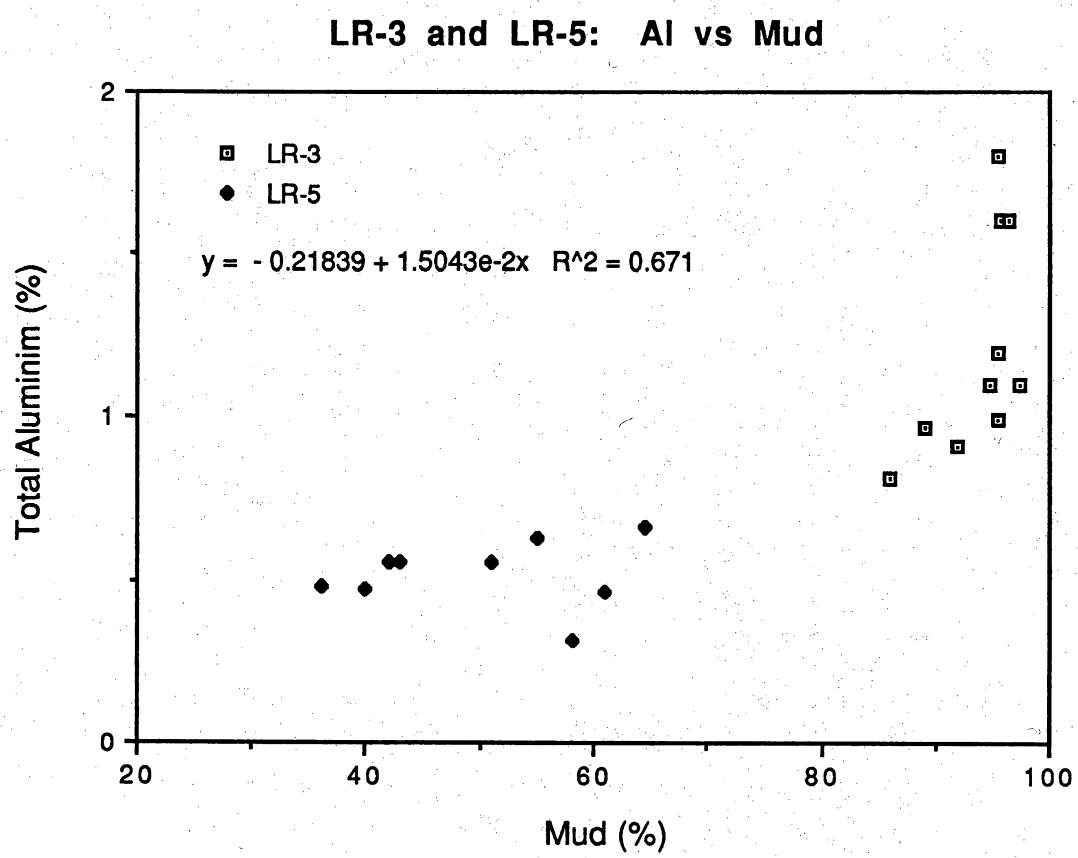


Figure 14. Correlation between aluminum and mud.

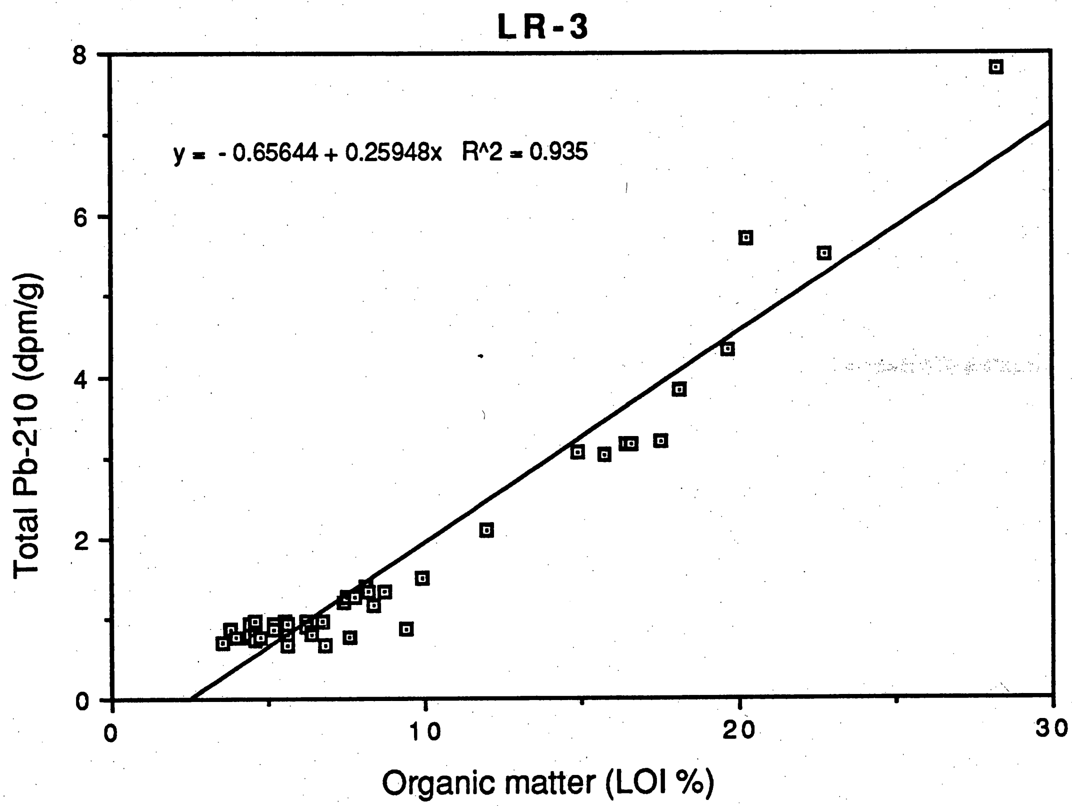


Figure 15. Relationship between ^{210}Pb activity and percent organic matter (weight loss- on-ignition, LOI) for core LR 3.

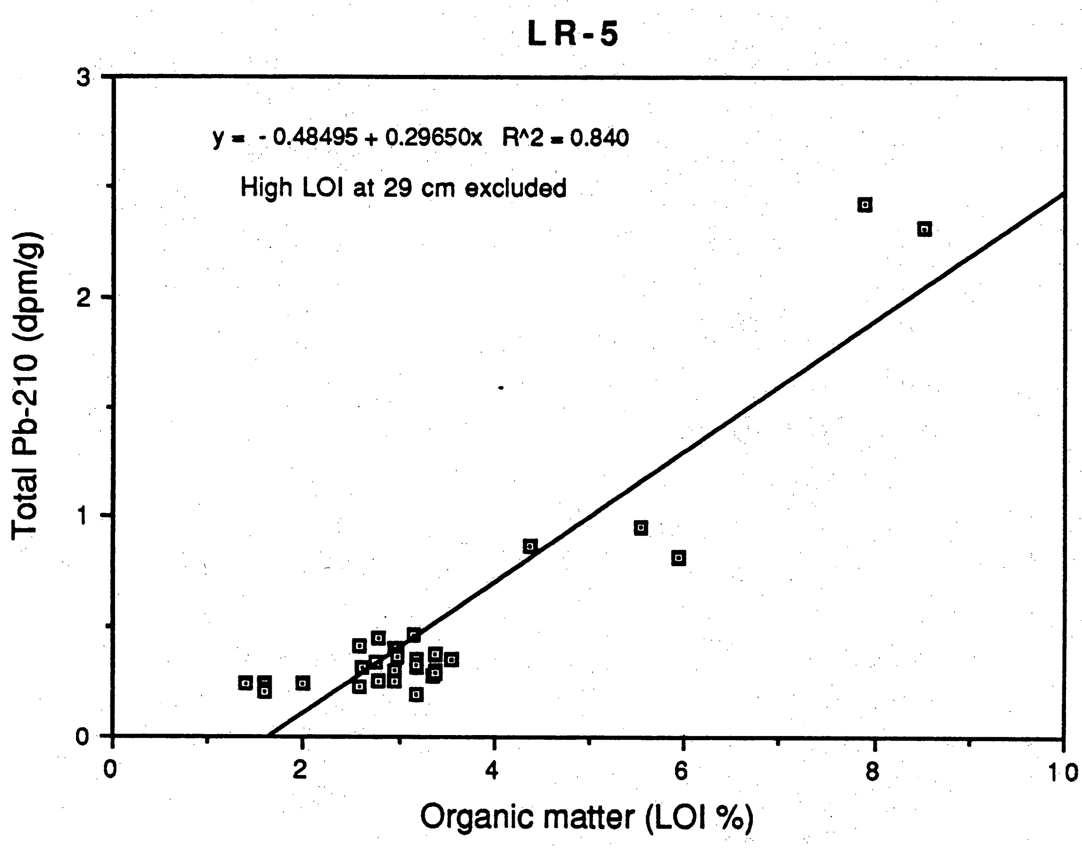


Figure 16. Relationship between ^{210}Pb activity and percent organic matter (LOI) for core LR 5.

scatter and the low R^2 is therefore not the result of just a few samples. This particular core was taken in a fluvial woodland of dwarf palmettos and deep roots apparently affected the LOI distribution throughout the core.

Table 3. Aluminum and textural content in cores LR-3 and LR-5.

Core No.- Uncorrected depth (cm)	Al (%)	Sand (%)	Silt (%)	Clay (%)
LR-3-3	1.60	4	20	76
LR-3-6	1.80	4	17	79
LR-3-9	1.60	4	24	73
LR-3-11	1.10	3	22	76
LR-3-14	0.99	5	25	71
LR-3-17	1.10	5	24	70
LR-3-20	1.20	5	22	73
LR-3-29	0.81	13	31	55
LR-3-39	0.97	11	17	72
LR-5-2	0.31	42	37	22
LR-5-4	0.66	36	36	29
LR-5-7	0.63	45	41	14
LR-5-10	0.46	40	39	22
LR-5-18	0.55	48	30	21
LR-5-22	0.55	58	24	18
LR-5-24	0.55	57	23	20
LR-5-29	0.48	64	21	15
LR-5-34	0.47	60	25	15

Although there is only a moderately positive correlation between ^{210}Pb and organics for all sediments analyzed (R^2 averaging between 0.6 and 0.7), there is a strong positive association between LOI and ^{210}Pb activity in sediments that have LOI concentrations of more than 8 percent. The correlation (R^2) between LOI and total ^{210}Pb in sediments from the top 10 cm of all cores (including the top 20 cm in core LR-1) is 0.88 (fig. 17). LOI concentrations in most of these sediments are greater than 8 percent.

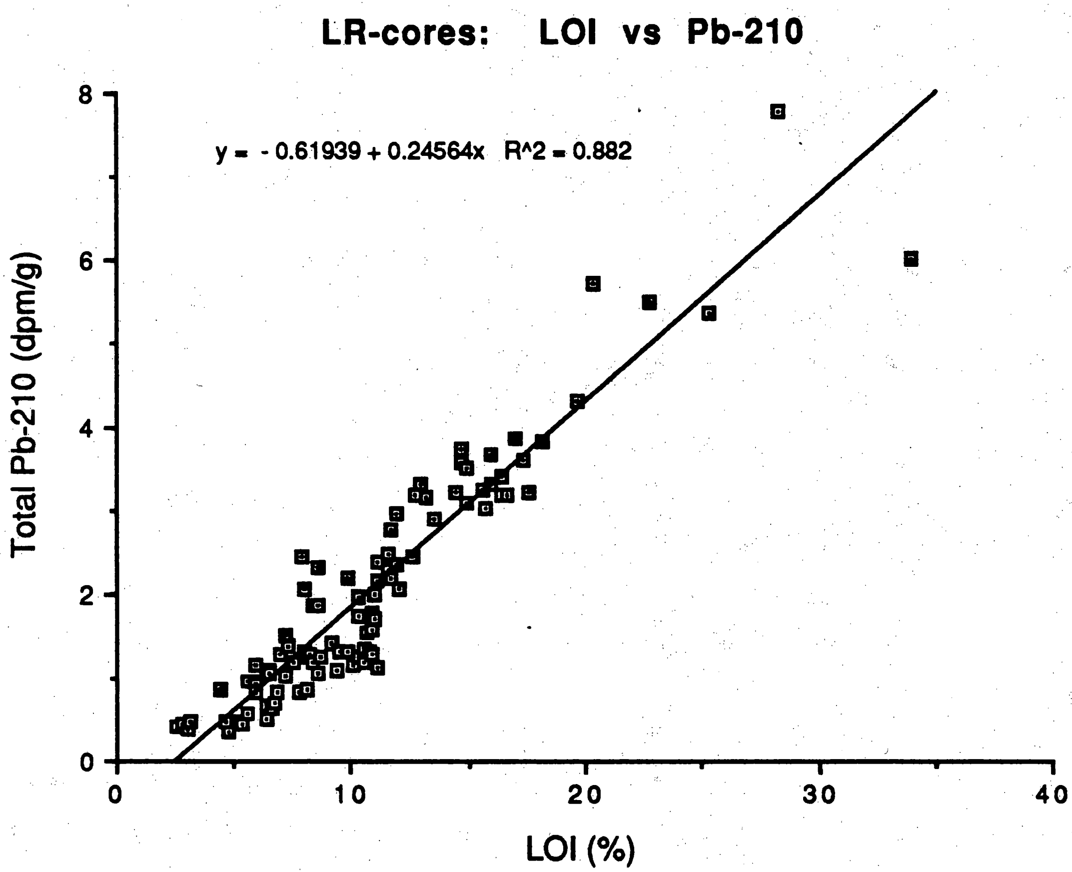


Figure 17. Relationship between ^{210}Pb activity and percent organic matter (LOI) in the top 10 cm of Lavaca River cores.

Calcium Carbonate (Caliche Nodules). Caliche nodules can influence ^{210}Pb activity. Fortunately, large nodules (1-2 cm in diameter) were found in only three cores, LR-1, LR-4, and LR-5. Analysis of nodules from Trinity River cores (White and Morton, 1993) indicated that the nodules are "hot spots" where ^{210}Pb activity is substantially higher than in surrounding sediments (Dr. Charles Holmes, personal communication, 1993). The $CaCO_3$ nodules may be the cause of fluctuating ^{210}Pb activity below 30 cm in core LR-1 and below 20 cm in cores LR-4 and LR-5. Core LR-5 is unique because the high concentration of sand in sediments appears to have had a greater influence (dilutional effect) on ^{210}Pb activity than has the $CaCO_3$.

There are similarities in the distribution of ^{210}Pb in Trinity River core TR-6 and LR-1 and LR-4. In each of the three cores as revealed by ^{210}Pb profiles, ^{210}Pb activity drops precipitously in the upper part of the core, then "levels off", with ^{210}Pb activity fluctuating up and down in the lower part of the core (fig. 18). It is possible that changes in ^{210}Pb activity have occurred as a result of diagenesis associated with carbonates as suggested by Allen and others (1993). In comparing the ^{210}Pb dating technique with other dating methods in an oxic estuarine salt-marsh sequence, Allen and others (1993) concluded that early diagenetic loss of ^{210}Pb from the system may occur in Pb-bearing carbonates below about 30 to 40 cm. The dramatic decline of ^{210}Pb activity in the upper parts of the cores, and the substantially lower activities in the lower parts of the cores (compared to other cores) may reflect loss of ^{210}Pb.

Salinity. For sediments with a high salt content, as found in salt marshes, ^{210}Pb content should be calculated on a salt-free basis. In such cases, the weight of the salt is subtracted from the sample weight before determining ^{210}Pb activity on a per gram basis. To determine if salt content should be a consideration in Lavaca River cores, chlorinity was analyzed in four subsamples from core LR-1. Core LR-1 was selected for the analysis because it was collected from the most bayward site near Redfish Lake (fig. 1) and is characterized by salt tolerant vegetation (table 1) suggesting that it had the greatest potential of all sites to contain saline sediments. Samples that were analyzed were collected from depths of 6, 12, 20, and 55 cm. Chlorinity was converted to salinity using a factor of 1.80655 (Duxbury, 1971).

Results show that sediments from 6 cm are the most saline, but the salt content (table 4) is so low that it should have an insignificant effect on ^{210}Pb activity. Accordingly, we concluded that it is unnecessary to recalculate the ^{210}Pb on a salt-free basis for any sediments or cores.

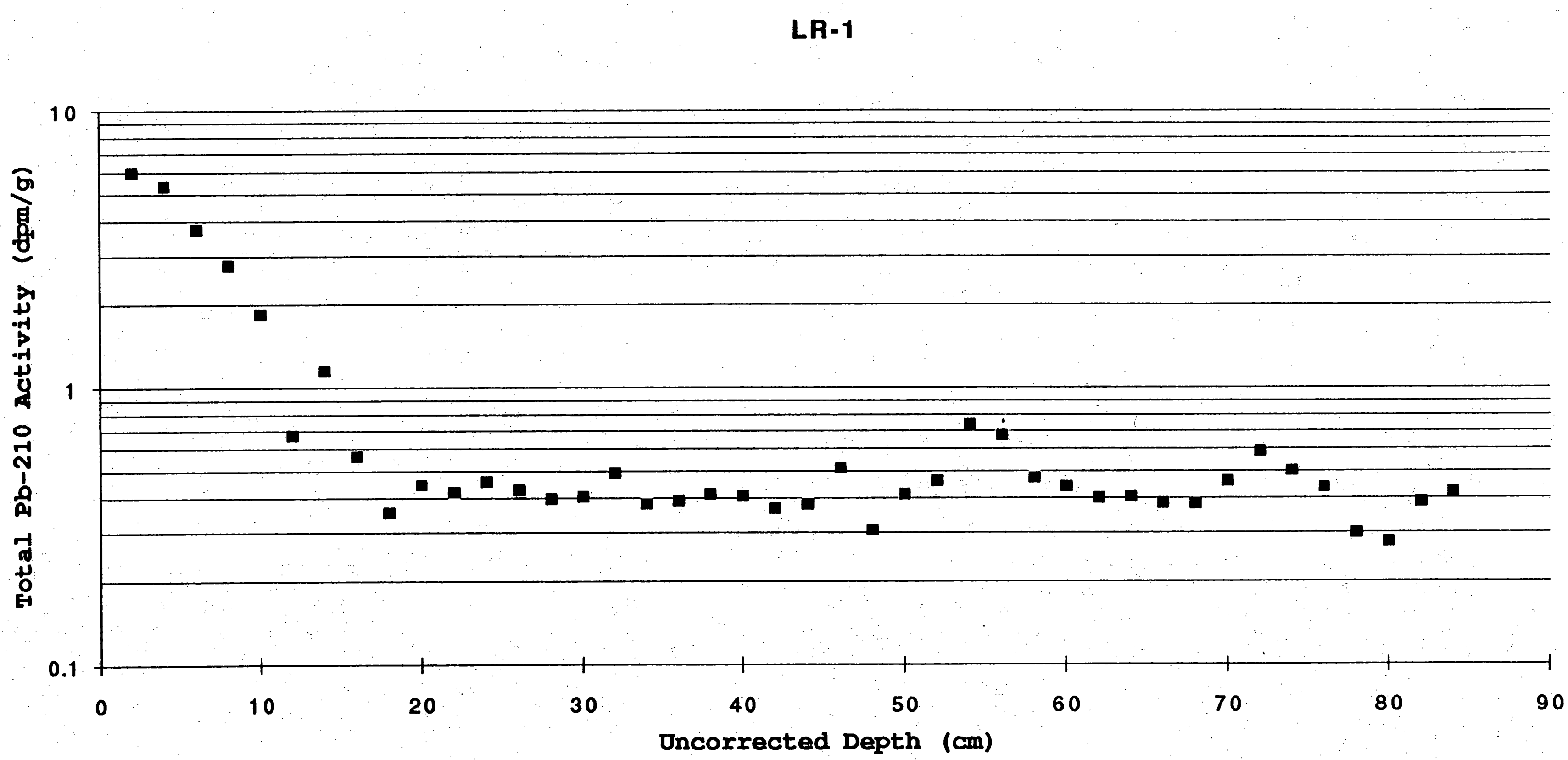


Figure 18. Profile of total ^{210}Pb activity in core LR-1. The profile shows a steep decline in activity in the upper few centimeters of sediments and then flattens out at depth.

Table 4. Salinity of samples analyzed in core LR-1.

Core Sample	Cl/dry mass (mg/kg or ppm)	Salinity (Cl x 1.80655) (ppm)	Cl/water fract (mg/kg or ppm)
LR-1-6 cm	2,670	4,823	2,350
LR-1-12 cm	1,840	3,324	4,000
LR-1-20 cm	2,270	4,101	6,730
LR-1-55 cm	740	1,337	2,610

Visible Physical and Chemical Variations. Cores from the Lavaca-Navidad River system did not show as much variation in visible physical and chemical characteristics as cores in the Trinity River system. In several instances in Trinity River cores, changes in ^{210}Pb activity corresponded with visible changes in the cores, for example, color changes at boundaries between oxidized and reduced zones. This relationship suggests that changes in activity may be related to physical or chemical variations in the core. Most cores in the Lavaca River system were homogeneous in appearance. The exception was core LR-5, which contained high percentages of sand, and was substantially different in appearance than other cores. LR-6 was the only core that had evidence of oxidation, primarily oxidized root traces. In contrast, almost all cores from the Trinity River system showed evidence of oxidation in the upper halves of the cores.

Accuracy of Analysis at Low ^{210}Pb Concentrations. Fluctuations in ^{210}Pb activity in the lower part of a core may be a result of low concentrations of ^{210}Pb as background levels are approached. According to Dr. Charles Holmes (USGS), the analytical variance (error bar) for samples with activities below approximately 0.5 disintegration's per minute per gram (dpm/g) is larger than for samples with higher concentrations. Therefore some of the sample to sample variations are simply related to counting errors.

Determination of Excess (Unsupported) ^{210}Pb

Excess, or unsupported, ^{210}Pb, is the difference between total ^{210}Pb activity and supported activity. Concentrations of ^{226}Ra and ^{214}Bi in cores can provide a measure of supported ^{210}Pb activity. Alternatively, supported ^{210}Pb can be estimated by assuming that constant activities at depth are equivalent to supported ^{210}Pb. Activity profiles of ^{210}Pb for Lavaca River cores indicate that supported ^{210}Pb activities may have been reached in most cores at depths of less than 30 cm.

^{226}Ra. One method used by researchers to determine supported ^{210}Pb activities is to analyze ^{226}Ra from which supported ^{210}Pb is derived and with which it is assumed to be in equilibrium. In some settings, however, ^{226}Ra may be unusable because of possible disequilibrium between ^{226}Ra and ^{210}Pb (Brenner and others, 1994). Still, in many coastal settings ^{226}Ra has been used to estimate supported ^{210}Pb. The USGS sent 10 sediment samples from 7 cores to Hazen Research, Inc, Golden, Colorado, for analysis of ^{226}Ra. Unfortunately, results have such a large error range, that they are considered inadequate for determining supported ^{210}Pb activities (table 5).

Table 5. Activities of ^{226}Ra in selected sediment samples from Lavaca River cores, based on analysis reported by Hazen Research, Inc.

Core No.	Depth	^{226}Ra pCi/g (± precision)	^{226}Ra dpm/g (± precision)
LR-2	4-5 cm	1.1 (± 0.8)	2.4 (± 1.8)
LR-2	46-48 cm	1.0 (± 0.9)	2.2 (± 2.0)
LR-3	2-3 cm	0.4 (± 0.7)	0.9 (± 1.6)
LR-3	47-49 cm	0.8 (± 0.8)	1.8 (± 1.8)
LR-4	18-19 cm	1.3 (±0.9)	2.9 (± 2.0)
LR-4	49-51 cm	1.5 (±1.0)	3.3 (± 2.2)
LR-5	33-34 cm	0.7 (±0.7)	1.6 (± 1.6)
LR-6	54-56 cm	0.9 (± 0.8)	2.0 (± 1.8)
LR-7	36-38 cm	0.2 (± 0.5)	0.4 (± 1.1)
LR-8	32-33 cm	0.4 (±0.6)	0.9 (± 1.3)

^{214}Bi. Another method for deriving supported ^{210}Pb is to use ^{214}Bi activities, which were determined during ^{137}Cs analyses. According to Dr. Charles Holmes, ^{214}Bi is in equilibrium with supported ^{210}Pb (fig. 19). This relationship between ^{226}Ra, ^{214}Pb and ^{214}Bi is also reported by Appleby and others (1988) and Brenner and others (1994). Supported ^{210}Pb (^{226}Ra) concentrations were thus determined from gamma emissions of ^{214}Bi (Dr. Charles Holmes, personal communication, 1994). The average of the ^{214}Bi activities (table 6) can be used as supported ^{210}Pb for 6 cores in which ^{214}Bi was measured. In cores LR-4, LR-5, LR-7, and LR-9 for which ^{214}Bi was not determined, supported ^{210}Pb activities can be estimated from ^{214}Bi in other cores or from ^{210}Pb profiles (table 6).

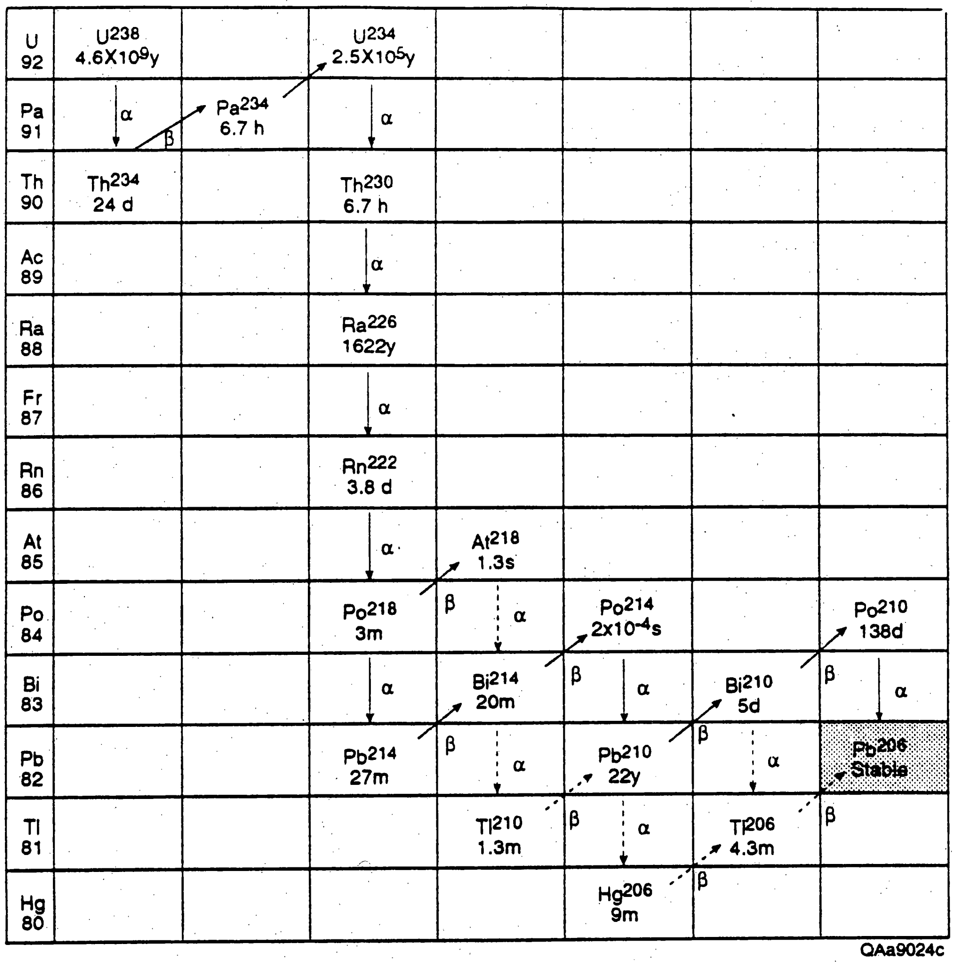


Figure 19. The relationship between various isotopic elements including ^{226}Ra, ^{214}Bi, and ^{210}Pb. Solid arrows indicate major decay modes. From Robbins (1978).

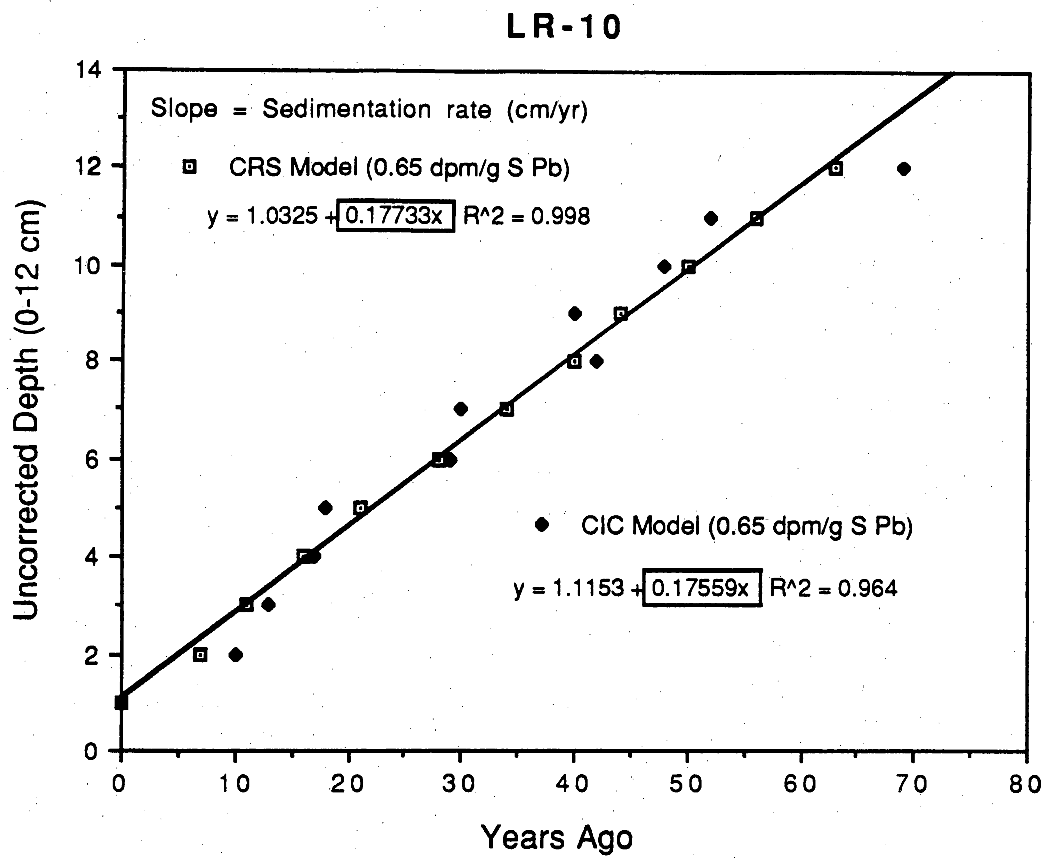
The isotope ^{214}Bi is one of several short-lived intermediate daughters of ^{226}Ra; these daughters decay in a matter of minutes into ^{210}Pb (fig. 19). ^{214}Bi, as with the other intermediate daughters, is assumed to be in equilibrium with ^{226}Ra. It is used to determine ^{226}Ra because it has a strong gamma emission and is easy to measure. ^{226}Ra occurs in minerals in the sediments and is the source of the supported ^{210}Pb through the decay chain, including ^{222}Rn, shown in figure 19. The source of the "excess," or unsupported, ^{210}Pb is from ^{222}Rn that has outgassed into the atmosphere from multiple source areas (Robbins, 1978). Although there may be some "leakage" of ^{222}Rn into the atmosphere from the sediments measured in cores, it is apparently insignificant relative to the entire system. Atmospheric ^{222}Rn decays (as it does in the sediments) through the intermediate daughters including ^{214}Bi (fig. 19), but because of the short half-lives of these isotopes relative to ^{210}Pb, only the ^{210}Pb is effectively deposited from the atmosphere into the sediments, where it constitutes the "excess" or unsupported component of total ^{210}Pb. ^{214}Bi from atmospheric ^{222}Rn does not become a significant part of the sediment and, thus, is not part of the ^{214}Bi measured in the sediment to determine supported ^{210}Pb.

Supported ^{210}Pb Based on Activity Profiles. The concentration of ^{210}Pb in most Lavaca-Navidad river cores approaches a constant level at depths of between 15 to 25 cm. Estimates of supported ^{210}Pb concentrations can be made from the total ^{210}Pb activity in the lower part of each profile where it becomes "flat" as excess ^{210}Pb approaches zero. Preliminary estimates on this basis range from 0.25 dpm/g in core LR-5, where high sand content has diluted ^{210}Pb activity, to 0.95 in LR-2 (table 6).

Table 6. Estimated supported ^{210}Pb levels based on average ^{214}Bi activities and total ^{210}Pb profiles. Cumulative residual excess ^{210}Pb was determined using the average ^{214}Bi values for supported ^{210}Pb.

Core Number	Supported ^{210}Pb based on total ^{210}Pb profile (dpm/g)	Supported ^{210}Pb based on average ^{214}Bi (dpm/g)	Supported ^{210}Pb based on ^{214}Bi data in nearby cores (dpm/g)	Cumulative excess ^{210}Pb using average ^{214}Bi for supported ^{210}Pb (dpm/cm^2)
LR-1	0.45	0.67		10.41 (17.6 sand free)
LR-2	0.95	0.79		31.83
LR-3	0.85	0.77		18.50
LR-4	0.45		0.67 (from LR-1)	5.62
LR-5	0.25			12.95 (0.2 SPb)
LR-6	0.65	0.56		16.76
LR-7	0.60		0.56	18.44
LR-8	0.65	0.55		12.46
LR-9	0.70		0.65	16.79
LR-10	0.45	0.65		16.19

Estimates of supported ^{210}Pb levels based on total ^{210}Pb activity profiles vary from those based on average ^{214}Bi. For example, the LR-10 profile indicates a supported ^{210}Pb activity of approximately 0.45 dpm/g, whereas the average ^{214}Bi activity is 0.65 dpm/g. Using 0.65 dpm/g as the supported ^{210}Pb activity for LR-10, however, produces the best agreement in sedimentation rates for the CRS, CIC, and constant flux : constant sedimentation models (Oldfield and Appleby, 1984). In fact the sedimentation rate derived from each of these methods is 0.18 cm/yr for the upper 12 cm of the core (fig. 20). In all but two cores, LR-1 and LR-10, the estimated supported ^{210}Pb activity based on the average ^{214}Bi is lower than that based on the total ^{210}Pb profile (table 6).



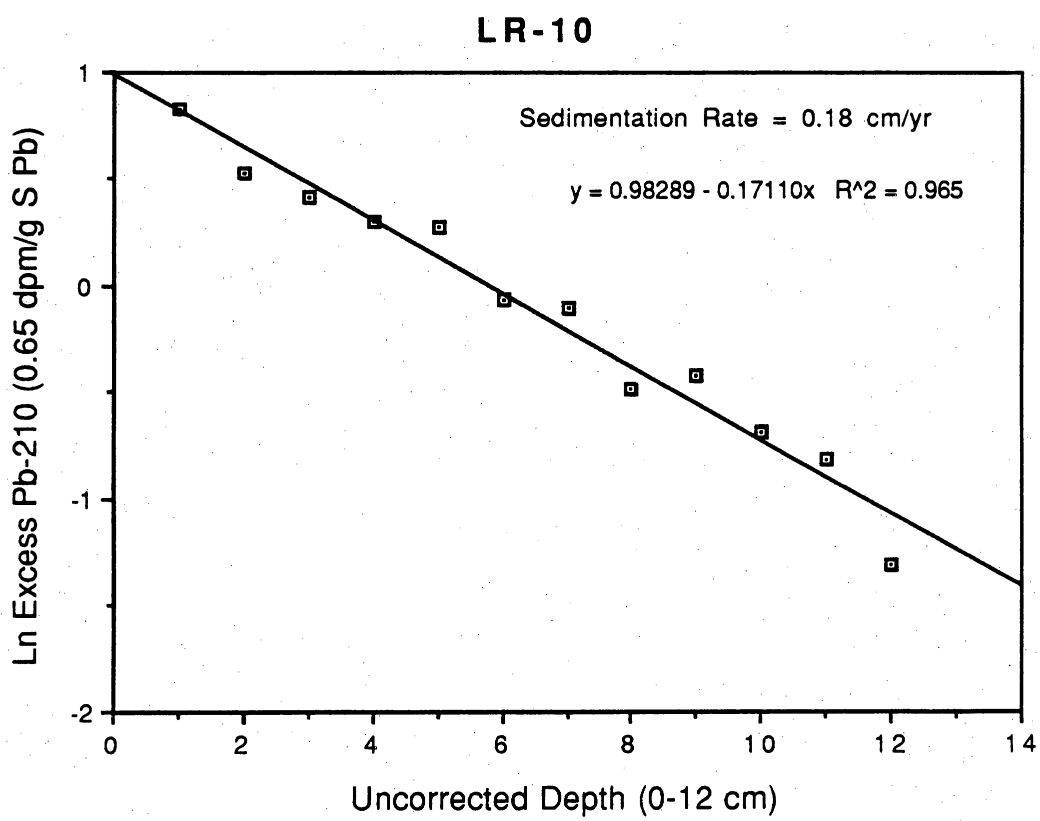


Figure 20. Estimated sedimentation rates for core LR-10 using a supported ^{210}Pb level of 0.65 dpm/g.

Cumulative Inventories of Excess ^{210}Pb Activity

Preliminary estimates of the total unsupported residual, or cumulative, excess ^{210}Pb for Lavaca-Navidad river system cores were made using average ^{214}Bi activities (tables 6) as a measure of supported ^{210}Pb. Based on these data, cumulative inventories of excess ^{210}Pb for all cores range from 6 to 32 dpm/cm^2 (table 6). Cores LR-1 and LR-4 have the lowest inventories of 11 and 6 dpm/cm^2, respectively. Both LR-1 and LR-4 have abundant $CaCO_3$ nodules at depths below 16 cm (LR-4) and 25 cm (LR-1), where possible losses in Pb due to "early diagenetic reactivity of Pb-bearing carbonates" may have occurred (Allen and others, 1993). Also, calculation of ^{210}Pb on a sand free basis increases the total inventory of excess Pb^{210} in these two cores, especially in core LR-1 where sand content averages approximately 35 percent. Assuming a 30 percent content for all samples in core LR-1 yields a total inventory of 17.55 dpm/cm^2 when calculated on a sand free basis.

For core LR-10, using a supported ^{210}Pb level of 0.45 dpm/g (derived from the total ^{210}Pb profile) yields a cumulative residual unsupported ^{210}Pb activity of 22 dpm/cm^2, which agrees with some cumulative inventories reported in the literature for lake sediments. Using 0.65 dpm/g from the ^{214}Bi data reduces the cumulative inventory to 16 dpm/cm^2, but this value does not appear to be unreasonably low for marsh sediments. Total excess ^{210}Pb for cores from Lake Michigan coastal wetlands (Kadlec and Robbins, 1984) have a high variability in which total inventory of excess ^{210}Pb for 8 cores ranges from 3.1 to 42.7 dpm/cm^2, and includes inventories in other cores of 6.22, 8.86, 13.8, 12.9, and 22.5 dpm/cm^2. Using supported ^{210}Pb levels based on average ^{214}Bi activities (and estimates derived from these data) yields cumulative residual excess ^{210}Pb activities of 16 to 18 dpm/cm^2 in 5 of the Lavaca River cores (LR-3, 6, 7, 9, and 10).

An interesting comparison of excess ^{210}Pb inventories was made in core LR-8 using the two supported ^{210}Pb levels, 0.55 dpm/g and 0.65 dpm/g (table 6). The cumulative residual excess ^{210}Pb inventories are 12.46 dpm/cm^2 and 8.03 dpm/cm^2, respectively. Of interest is the observation that when calculated on a sand free basis the latter value increases to 12.32 dpm/cm^2, e.g., almost equivalent to the former. It is possible that similar results may be obtained in other cores when the lower inventory is calculated on a sand free basis.

Analysis of Surficial Sediment and Water Samples for ^{210}Pb and ^{7}Be

A total of 9 water samples and 8 surficial sediment samples were collected from the Lavaca and Navidad rivers (fig. 21) and analyzed for ^{210}Pb and ^{7}Be. Concentrations of these isotopes in water samples were too low for analysis. Because of the dominance of sand along the rivers, sediments

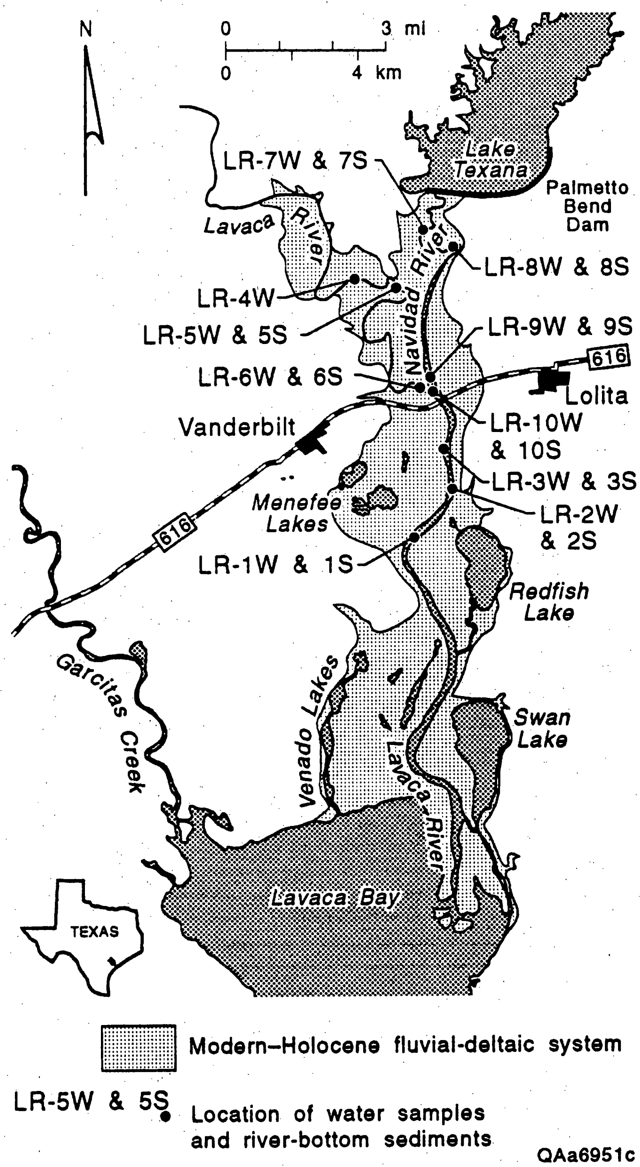


Figure 21. Map showing locations of sites sampled for water and surficial sediments.

composed primarily of silt and clay (muds) were difficult to locate and sample. Samples were collected from the river bottom using a clam-shell grab sampler. The amount of sand in each sample was measured in the laboratory in order to calculate total ^{210}Pb on a sand free basis (table 7). One purpose of the analyses was to try to determine the value of ^{210}Pb in surficial sediments to help establish surface activities for developing models (Oldfield and Appleby, 1984). Concentrations of the ^{210}Pb in surficial sediments were lower than expected and were not as useful as expected. However, ^{210}Pb profiles in the Lavaca-Navidad River system are relatively linear in the upper part of the cores, and the sample from the top cm is typically the highest value. This was not the pattern in Trinity River cores where profiles were nonlinear and characterized by depressed activities near the surface. Because of the very short half-life of ^{7}Be, it was measured to verify if the sediments analyzed were recently deposited.

Table 7. Concentration of ^{210}Pb in surficial sediment samples collected along the Lavaca and Navidad Rivers (LR) and the Trinity River (TR).

Sample Number	Sample Weight (g)	Total Pb-210 (dpm/g)	Sand (%)	Percent fines	Total Pb-210 (dpm/g) Sand Free basis
LR-1S	4.57	1.76	8.09	87.86	2.0081
LR-2S	4.71	1.18	48.27	52.48	2.2507
LR-3S	4.91	0.90	49.74	48.69	1.8496
LR-5S	4.64	1.79	14.00	82.12	2.1825
LR-6S	4.99	0.50	58.80	42.63	1.1617
LR-7S	5.00	0.23	88.98	7.24	3.1862
LR-8S	4.93	0.42	69.64	29.87	1.4130
LR-9S	0.88	2.33			
LR-10S	4.82	0.53	44.99	53.76	0.9871
TR-10B	4.82	0.57	21.25	77.67	0.7378
TR-20B	4.69	1.18	29.21	69.96	1.6848
TR-30B	4.86	0.70	38.80	65.87	1.0642
TR-40B	4.90	0.53	37.04	61.11	0.8660

^{137}Cs Analyses

More than 80 samples were analyzed to determine the distribution of ^{137}Cs in 6 cores (table 8). This isotope has a relatively long half life of 30.2 years (Callender and Robbins, 1993). Because ^{137}Cs is a fallout product of atmospheric nuclear explosions, it has been used to establish the dates, 1963–1964, when nuclear testing reached a maximum, and, 1954, when testing first began. Theoretically, the peak concentration of ^{137}Cs tags sediments that were deposited in 1963–1964, and the first measurable concentrations tag sediments that were deposited in 1954.

Results of the distribution of ^{137}Cs in Lavaca River cores and their utility in establishing dates are questionable. In most cores, concentrations of ^{137}Cs are rather uniform with depth (table 8). Well-defined peaks that isolate the mid-1960's horizon do not exist. In addition, measurable concentrations occur deeper than expected in most cores based on preliminary dates and estimates of sedimentation rates derived from ^{210}Pb data. Dr. Charles Holmes believes that the extended depth to which ^{137}Cs has been deposited (table 8) indicates that ^{137}Cs has been mobilized and redeposited in deeper layers.

Perhaps the closest agreement between possible dates derived from ^{137}Cs and ^{210}Pb data is found in core LR-3. In this core, peak concentrations of ^{137}Cs occur at depths of 9.5 cm and 13.5 cm, and concentrations drop significantly (from 0.6 to 0.1 dpm/g) at depths between 15.5 and 17.5 cm. The CRS model (using 0.77 dpm/g as the supported ^{210}Pb level; table 6) indicates that 1964 occurs at a depth of about 12 cm, or between the two ^{137}Cs peaks (fig. 22). The date 1954 occurs at a depth of about 15 cm, which is about 2 cm above the level where ^{137}Cs concentrations fall from 0.6 to 0.1 dpm/g.

In core LR-2, concentrations of ^{137}Cs reach a weakly defined peak at a depth of about 13 cm (fig. 23A). This depth coincides with the year 1963 based on the CRS model and a supported ^{210}Pb activity of 0.95 dpm/g (table 6). However, the date 1954 occurs between 16 and 17 cm, about 10 cm above the depth in which concentration of ^{137}Cs approaches zero. Using the CRS model and a supported ^{210}Pb level of 0.79 dpm/g (table 6), the 1963 date is at a depth of approximately 19 cm, whereas 1954 is between 23 and 24 cm.

Agreement of the CRS and CIC models for the upper 12 cm of core LR-10 suggested that it is a good candidate for ^{137}Cs dating. The sedimentation rate (0.18 cm/yr) derived from the models indicates that the peak concentration of ^{137}Cs should occur at a depth of approximately 5.5 cm. A slightly higher concentration does occur at 5.5 cm, and the level of activity decreases below that depth (fig. 23B). Still, the relatively constant activity above 5.5 cm and the depth at which ^{137}Cs first appears suggest that it has been redistributed after initial deposition.

Table 8. Concentrations of ^{137}Cs, ^{7}Be, and ^{214}Bi in sediments from 6 cores.

LR-1

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
2	0.69	0.00	0.44
4	0.99	0.00	0.55
6	1.08	0.00	0.74
8	1.14	0.00	0.66
10	1.25	0.00	0.70
31	0.02	0.00	0.83
35	0	0.00	0.68
51	0	0.00	0.74
		Average	0.67

LR-2

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
1	0.51	0.07	0.66
2	0.50	0.05	0.76
3	0.71	0.00	0.72
4	0.94	0.00	0.73
5	0.82	0.00	0.68
6	0.73	0.00	0.67
7	0.59	0.00	0.72
8	0.74	0.00	0.83
9	1.09	0.00	0.64
11	0.94	0.00	0.89
12	0.93	0.00	0.87
13	1.16	0.00	0.70
14	0.99	0.00	1.02
15	0.84	0.00	0.96
16	0.96	0.00	0.68
17	1.04	0.00	0.66
18	0.99	0.00	0.98
19	0.97	0.00	0.89
20	0.79	0.00	1.02
21.5	0.51	0.00	0.82
25.5	0.53	0.00	0.88
29.5	0.18	0.00	0.70
		Average	0.79

LR-3

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
1.5	0.599	0.118	0.59
3.5	0.755	0.088	0.54
5.5	0.599	0.000	0.71
7.5	0.644	0.000	0.71
9.5	1.043	0.000	0.86
11.5	0.577	0.000	0.71
13.5	0.888	0.000	0.85
15.5	0.577	0.000	0.90
17.5	0.144	0.000	0.97
19.5	0.095	0.000	0.91
20.5	0.15	0.000	0.76
26	0	0.000	0.9
30	0	0.000	0.64
		Average	0.77

LR-6

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
0.5	1.00	0.00	0.66
1.5	2.22	0.00	3.72
2.5	0.77	0.00	0.79
3.5	0.60	0.00	0.71
4.5	0.68	0.00	0.58
5.5	0.64	0.00	0.58
6.5	0.81	0.00	0.58
7.5	0.81	0.00	0.61
8.5	0.67	0.00	0.48
9.5	0.69	0.00	0.47
10.5	0.67	0.00	0.53
12.5	0.74	0.00	0.56
14.5			
16.5			
18.5	0.01	0.00	0.47
20.5	0.14	0.00	0.56
25.5	0	0.00	0.48
30.5	0	0.00	0.39
51.0	0	0.00	0.54
		Average (excl. 2nd value)	0.56

LR-8

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
0.50	0.56	0.56	0.56
1.50	0.14	0.00	0.35
2.50	0.57	0.00	0.49
3.50	0.38	0.00	0.52
4.50	0.43	0.00	0.54
5.50	0.41	0.00	0.91
6.50	0.43	0.00	0.54
7.50	0.32	0.00	0.58
8.50	0.18	0.00	0.53
9.50	0.17	0.00	0.60
10.50	0.00	0.00	0.54
15.50	0.00	0.00	0.42
20.50	0.00	0.00	0.55
		Average	0.55

LR-10

Uncorr Depth (cm)	Cs-137 (dpm/g)	Be-7 (dpm/g)	Bi-214 (dpm/g)
0.5	0.78	0.04	0.77
1.5	0.73	0.00	0.55
2.5	0.71	0.00	0.73
3.5	0.82	0.00	0.65
4.5	0.71	0.00	0.51
10.5	0.41	0.00	0.64
13.5	0.60	0.00	0.60
16.5	0.19	0.00	0.69
30.5	0.00	0.00	0.74
		Average	0.65

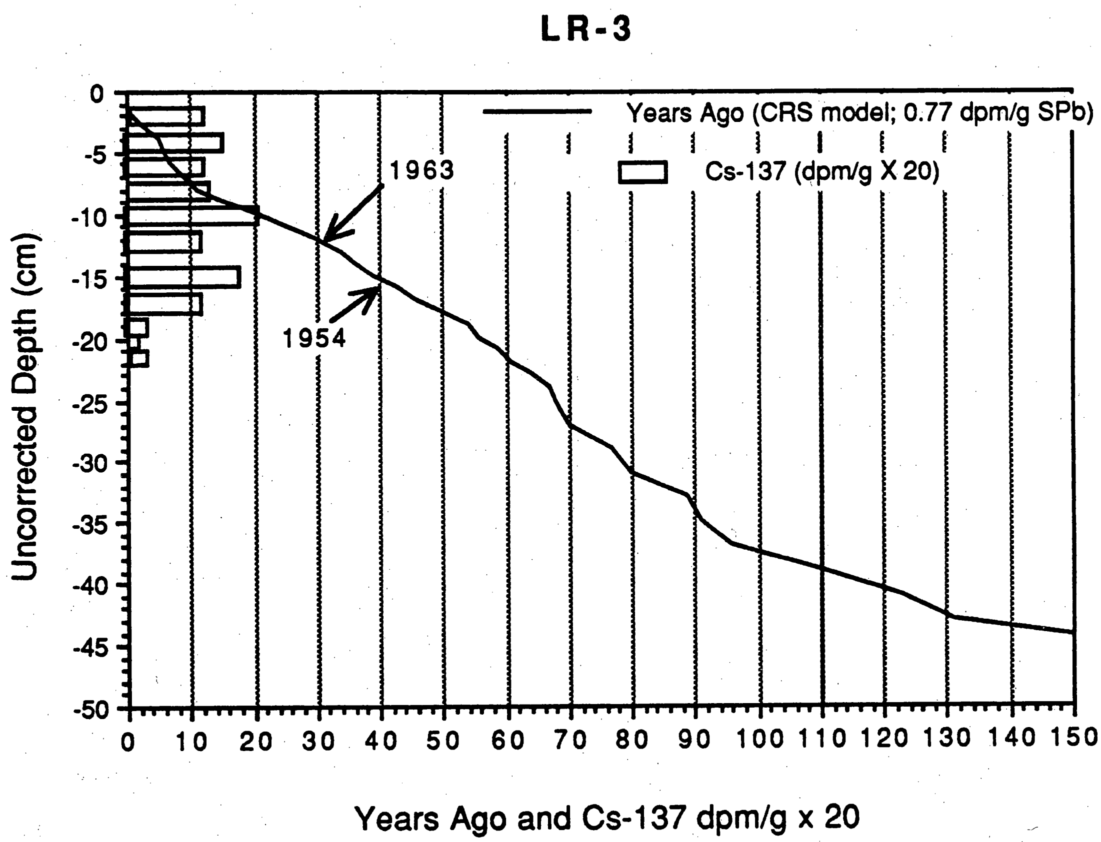
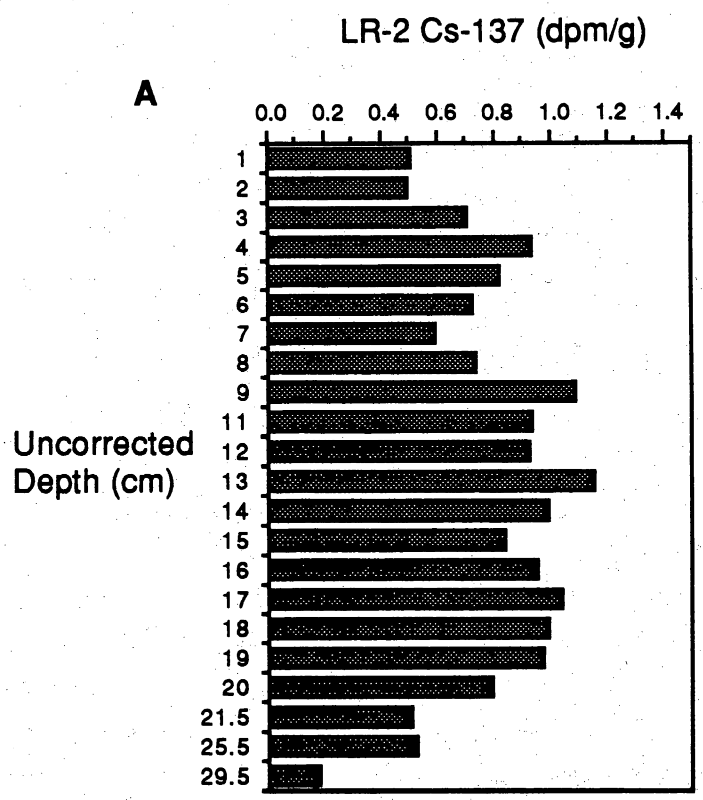


Figure 22. Distribution of ^{137}Cs relative to dates derived from the CRS model in core LR-3.



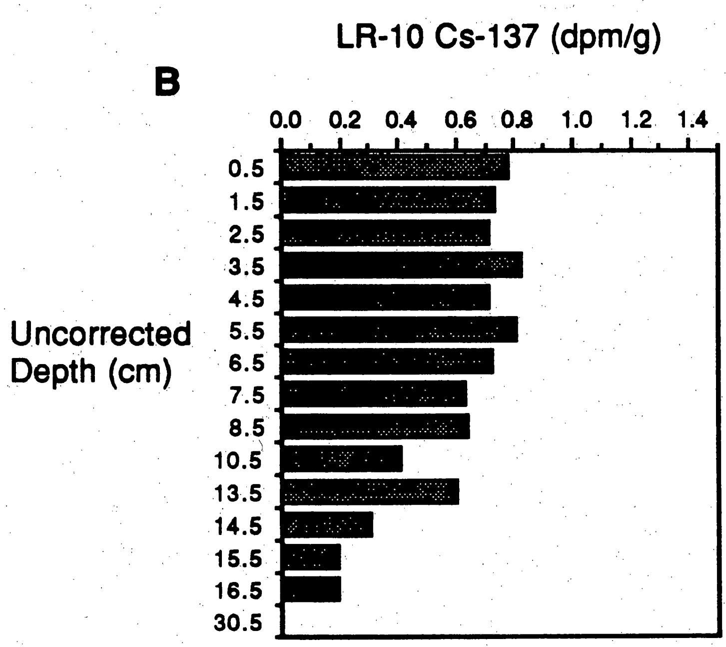


Figure 23. Distribution of ^{137}Cs in cores LR-2 (A) and LR-10 (B).

Annotated Plots of Probable Causes for Variance in ^{210}Pb Activity

Plots of total ^{210}Pb activity against depth (figs. 24 to 33) are annotated to indicate probable causes of local variations in excess ^{210}Pb activity. The plots were compared with the actual cores, core descriptions, x-radiographs, organic matter (LOI), and textural properties in an effort to explain some of the variations in ^{210}Pb activity. Note that depths used in these illustrations are actual core depths and are not corrected for compression.

RELATIVE SEA-LEVEL RISE

Relative sea-level rise as used here is the relative vertical rise in water level with respect to the land surface, whether it is caused by a rise in mean-water level or subsidence of the land surface. Along the Texas coast both processes are part of the relative sea-level rise equation. Subsidence, especially associated with pumpage of ground water and oil and gas, is the overriding component.

Eustatic Sea-Level Rise and Subsidence

Over the past century, sea level has been rising on a worldwide (eustatic) basis at a rate of about 1.2 mm/yr, with a rate in the Gulf of Mexico and Caribbean region of 2.4 mm/yr (Gornitz and others, 1982; Gornitz and Lebedeff, 1987). Adding compactional subsidence to these rates yields a relative sea-level rise that locally exceeds 10 mm/yr (Swanson and Thurlow, 1973; Penland and others, 1988).

Rates of "natural" compactional subsidence and eustatic sea-level rise, which together may range up to 12 mm/yr in the Galveston area (Swanson and Thurlow, 1973; Gornitz and Lebedeff, 1987; Penland and others, 1988), are locally dwarfed by human-induced subsidence, for example in the Houston area, where subsidence rates at some locations exceed 100 mm/yr (Gabrysch and Coplin, 1990). The major cause of human-induced subsidence is the withdrawal of underground fluids, principally ground water, oil, and gas (Winslow and Doyel, 1954; Gabrysch, 1969; Gabrysch, 1984, Gabrysch and Bonnet, 1975; Pratt and Johnson, 1926; Kreitler, 1977; Verbeek and Clanton, 1981; Kreitler and others, 1988).

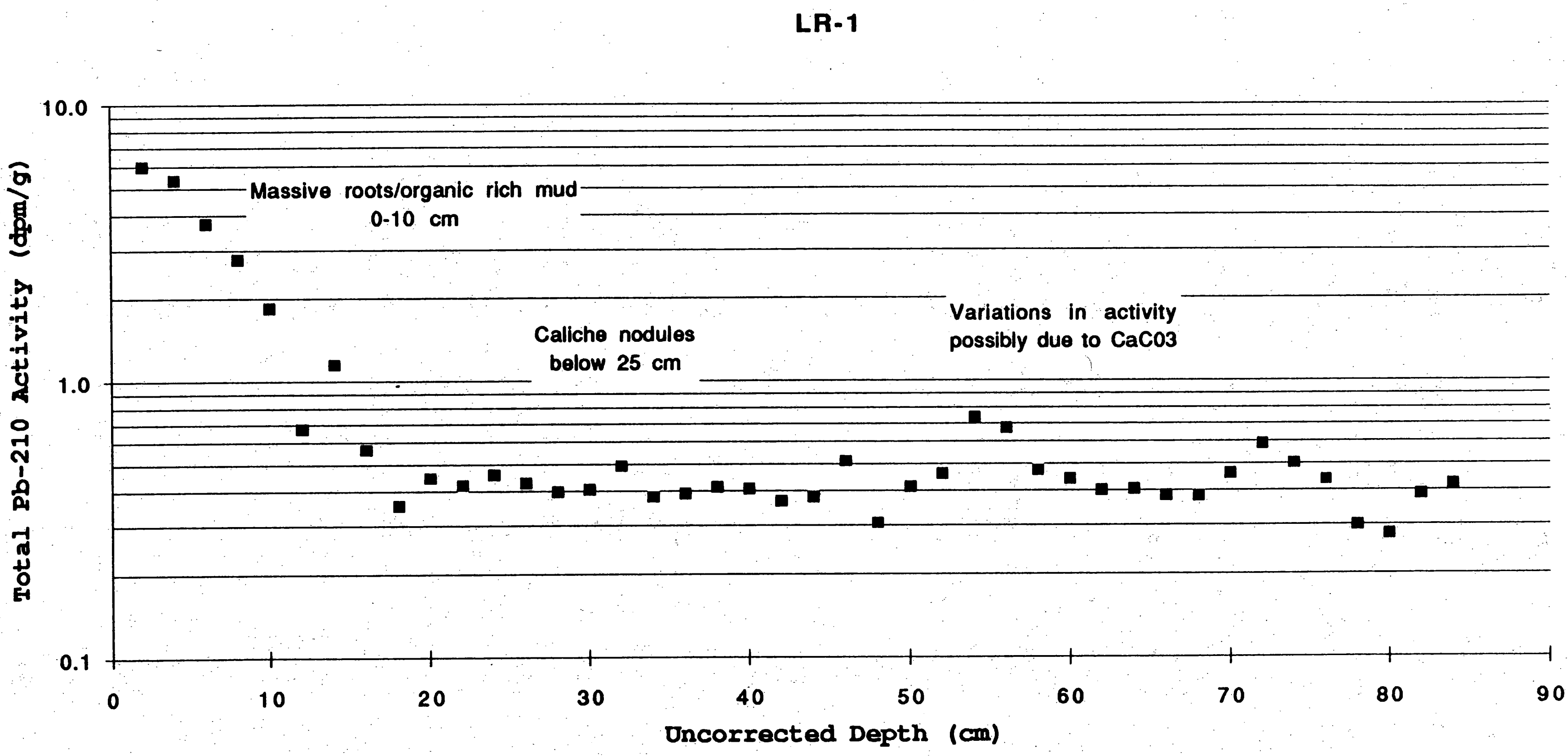


Figure 24. Core LR-1 annotated profile.

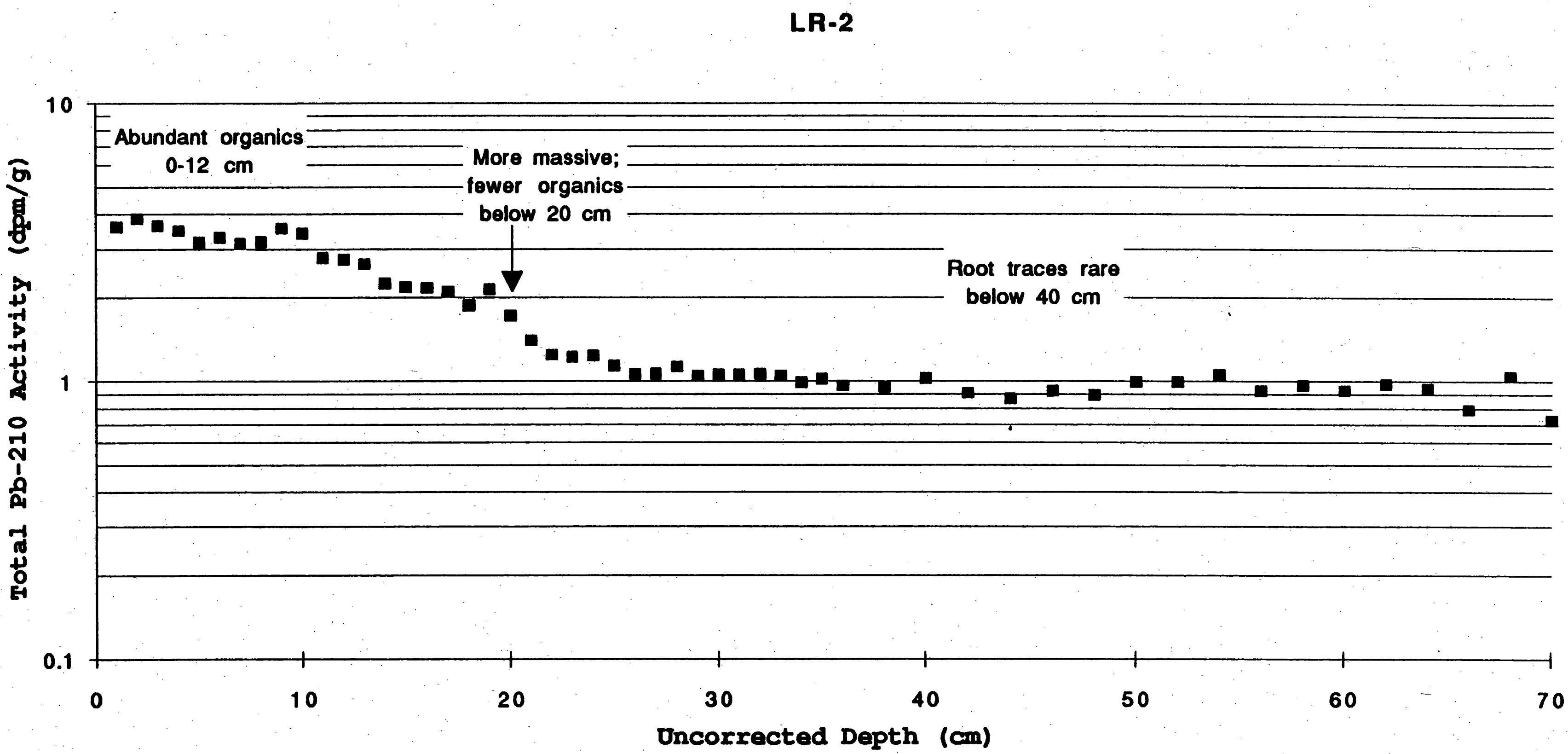


Figure 25. Core LR-2 annotated profile.

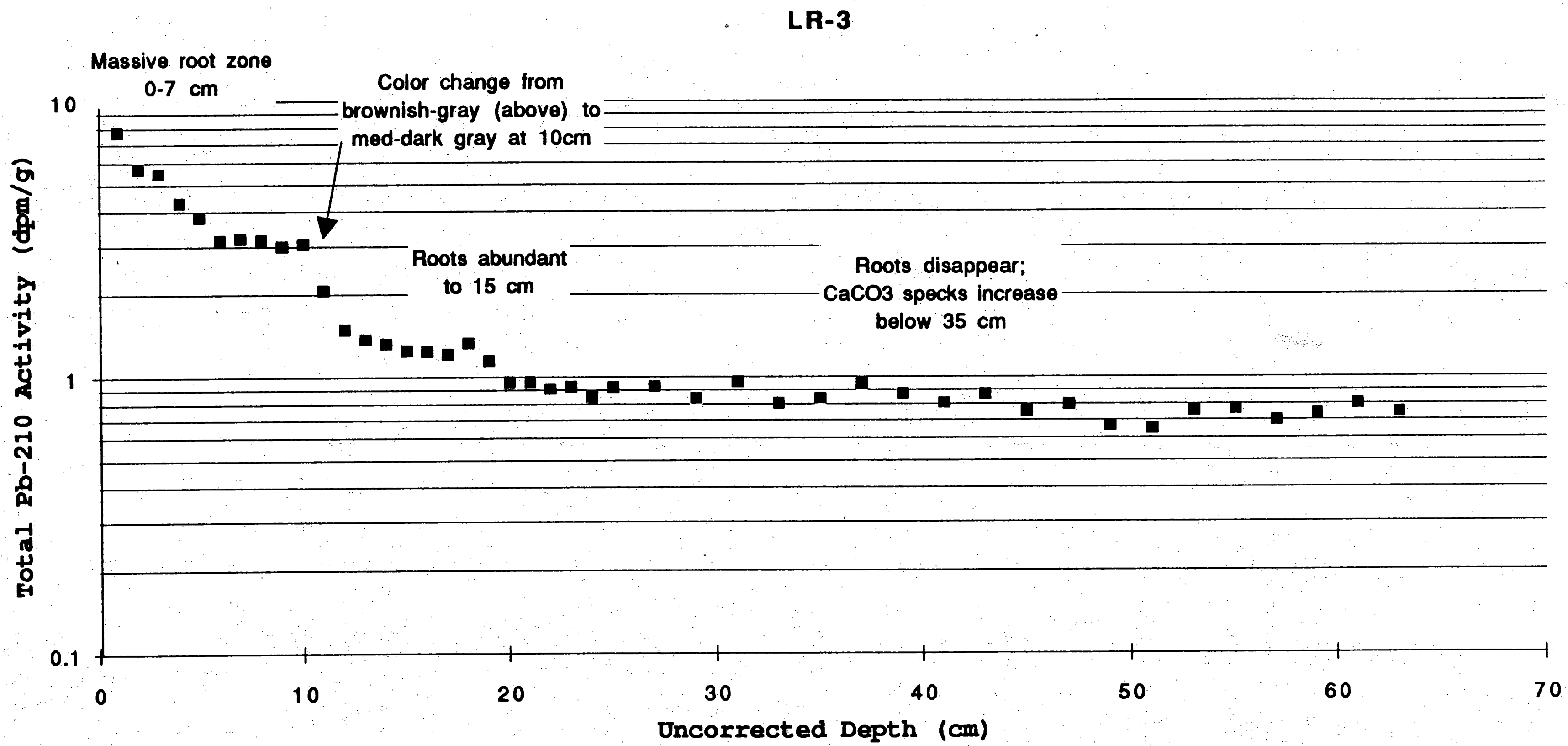


Figure 26. Core LR-3 annotated profile.

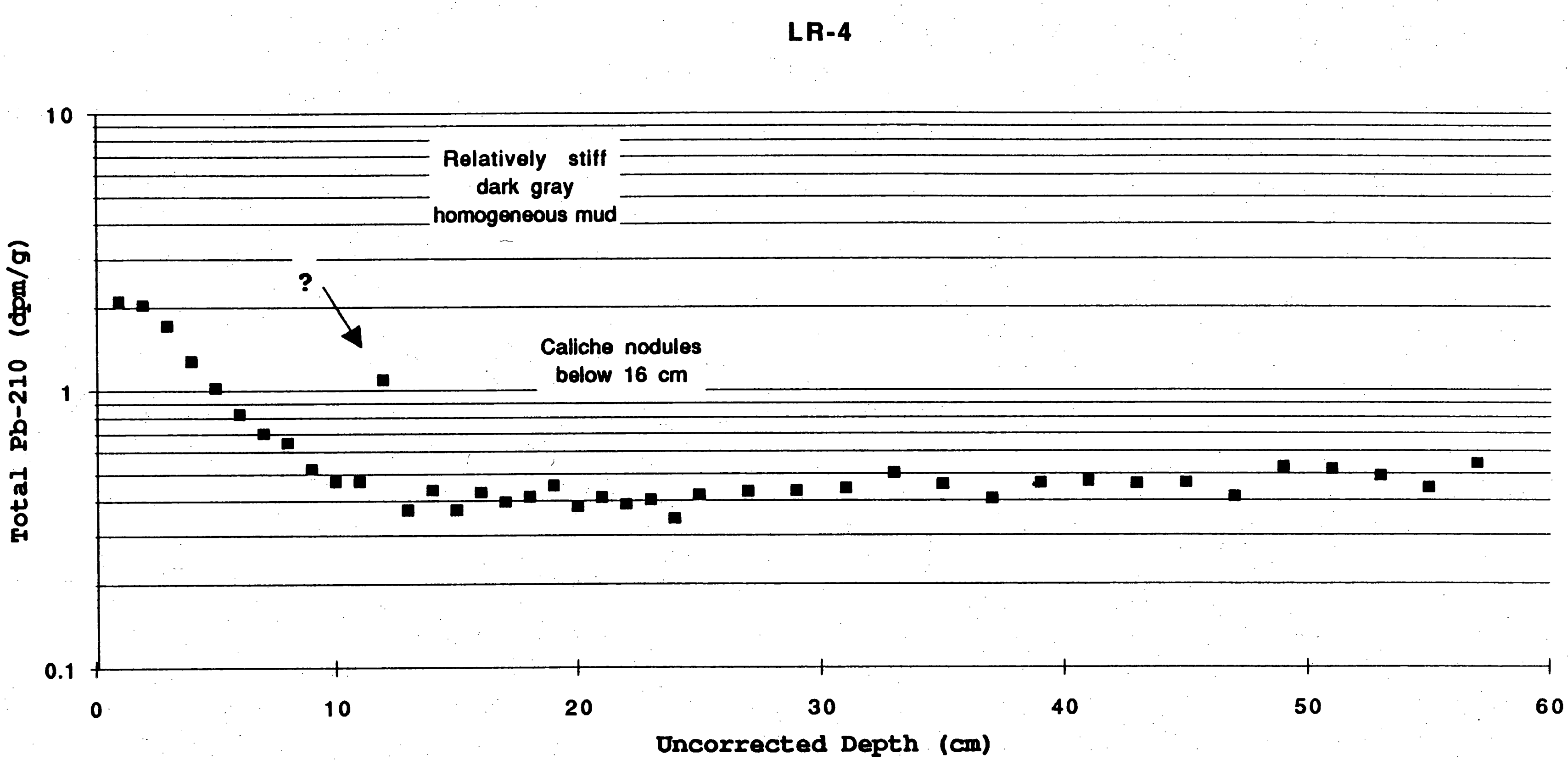


Figure 27. Core LR-4 annotated profile.

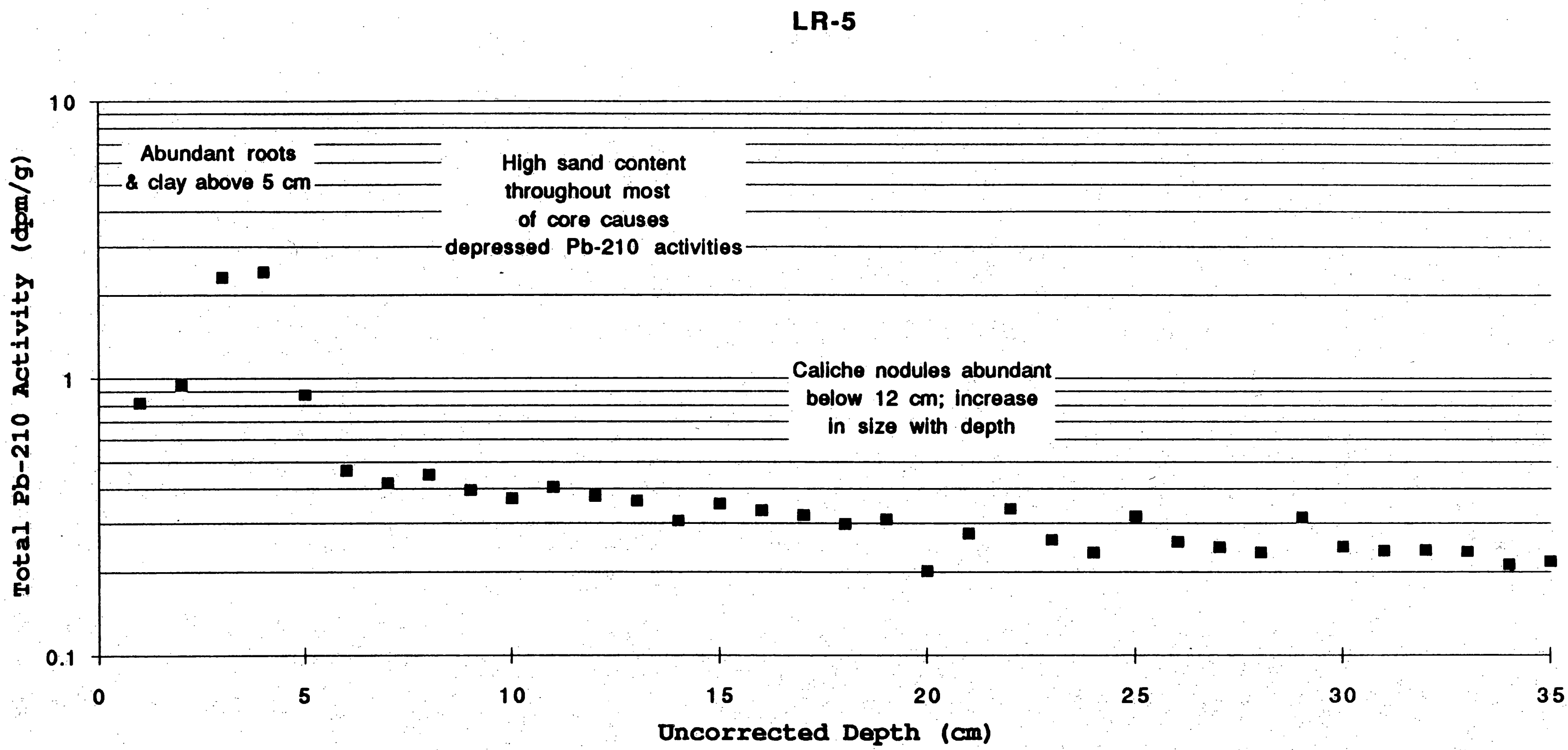


Figure 28. Core LR-5 annotated profile.

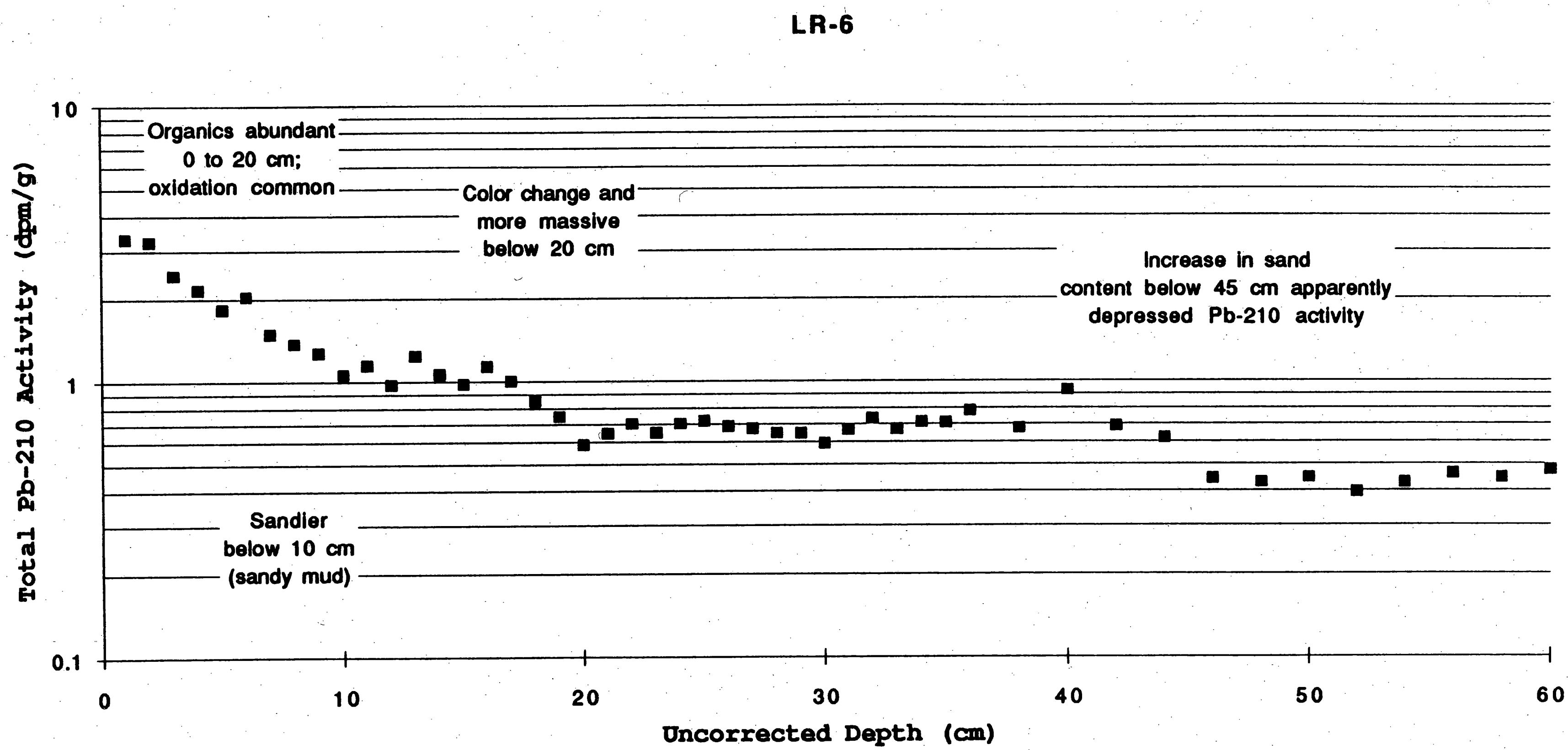


Figure 29. Core LR-6 annotated profile.

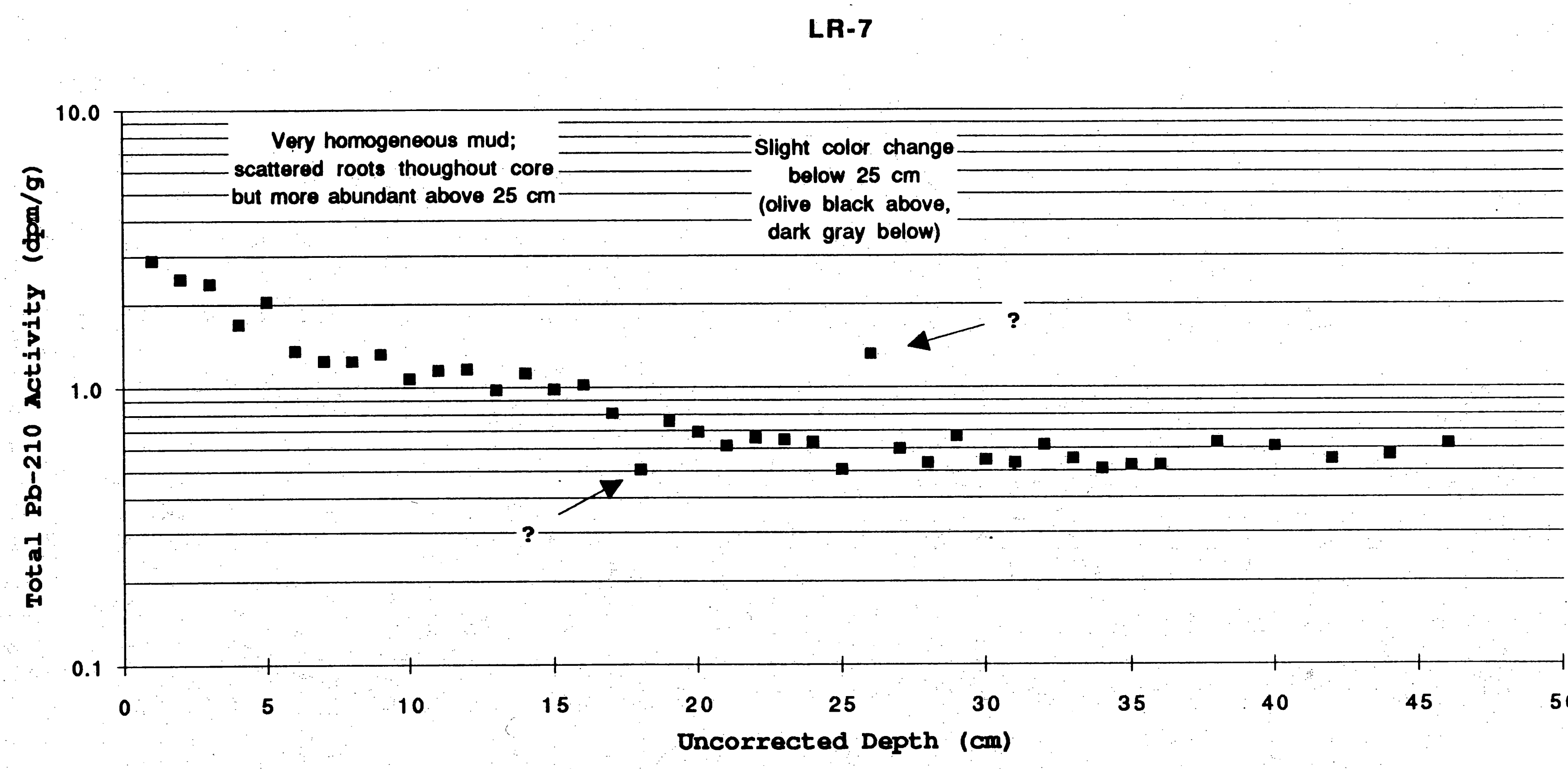


Figure 30. Core LR-7 annotated profile.

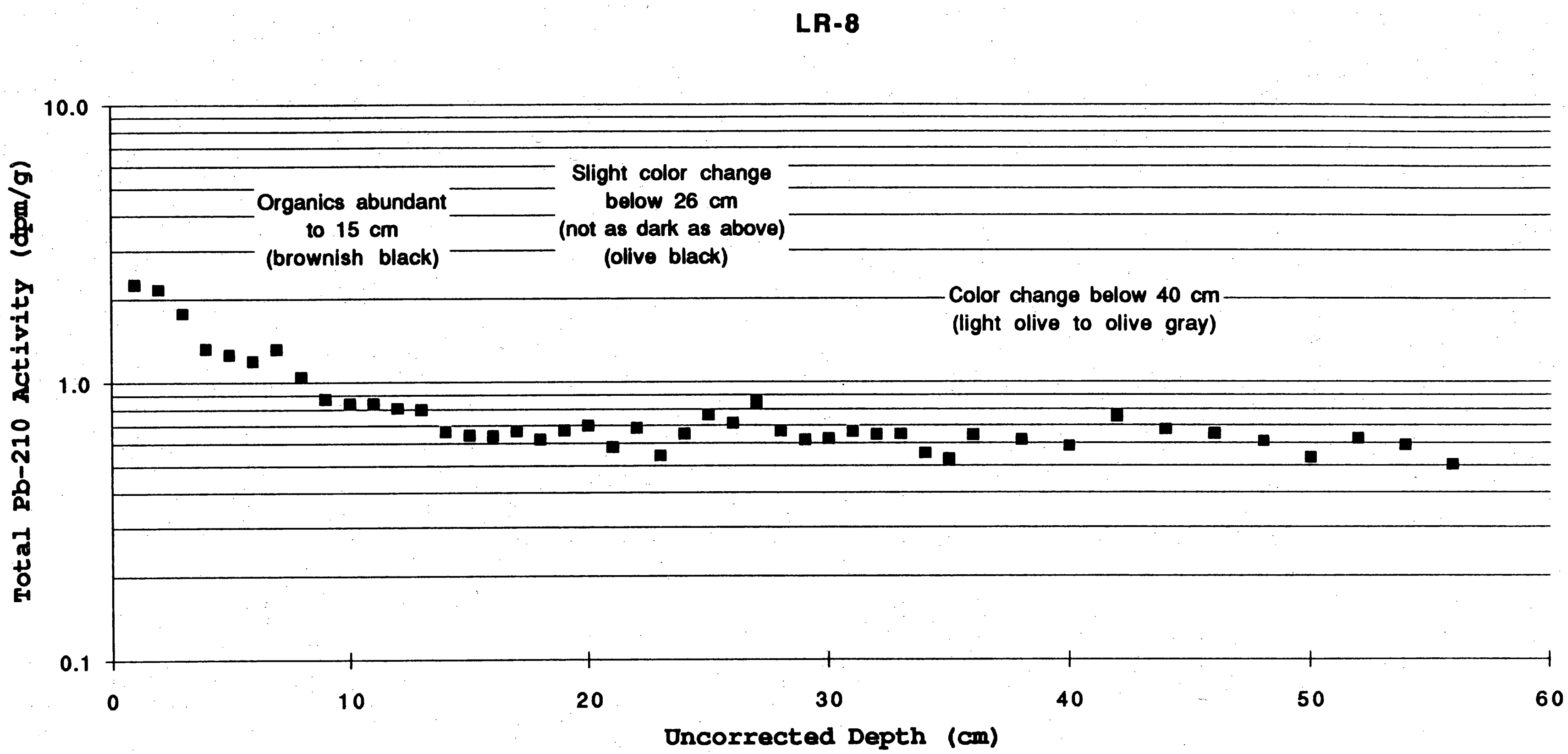


Figure 31. Core LR-8 annotated profile.

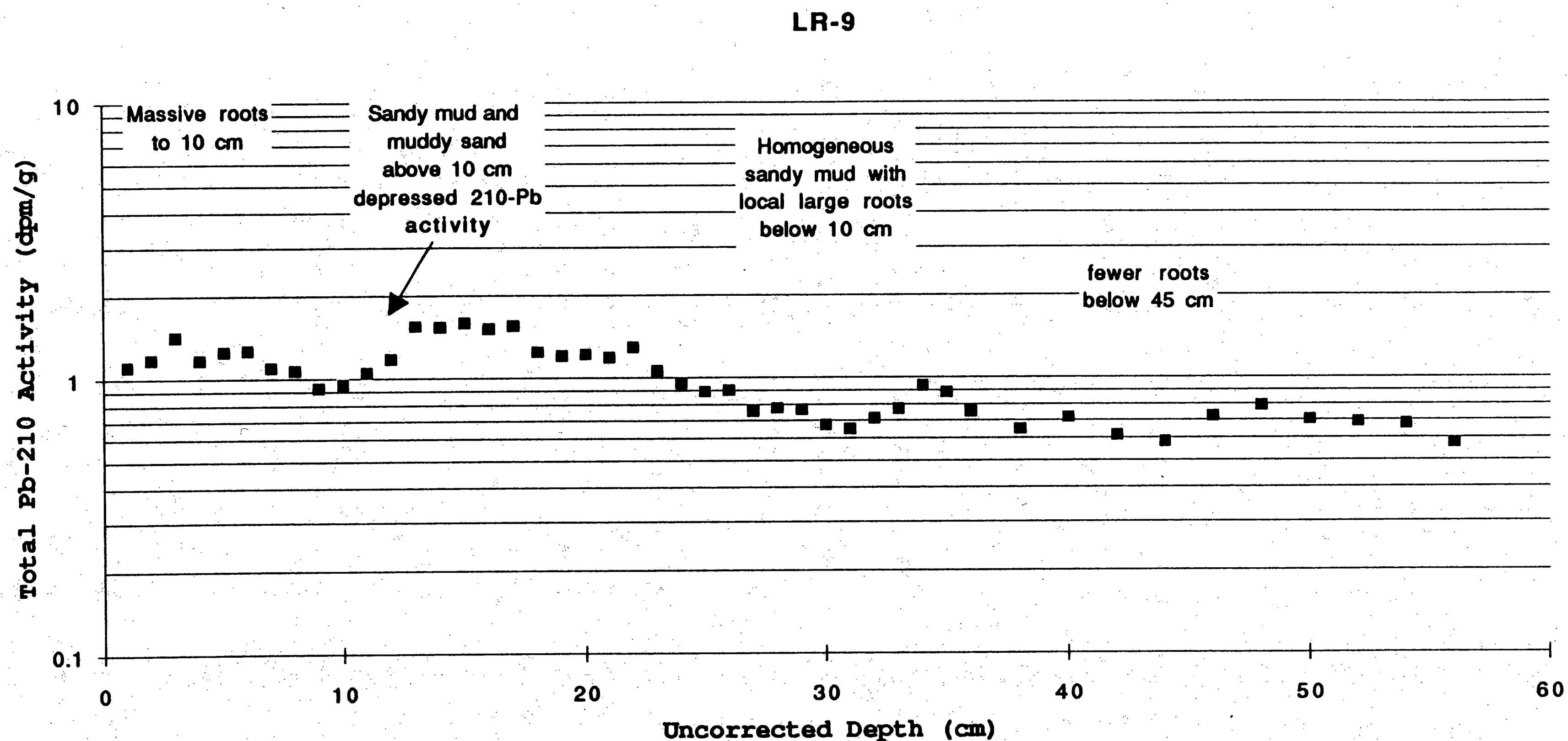


Figure 32. Core LR-9 annotated profile.

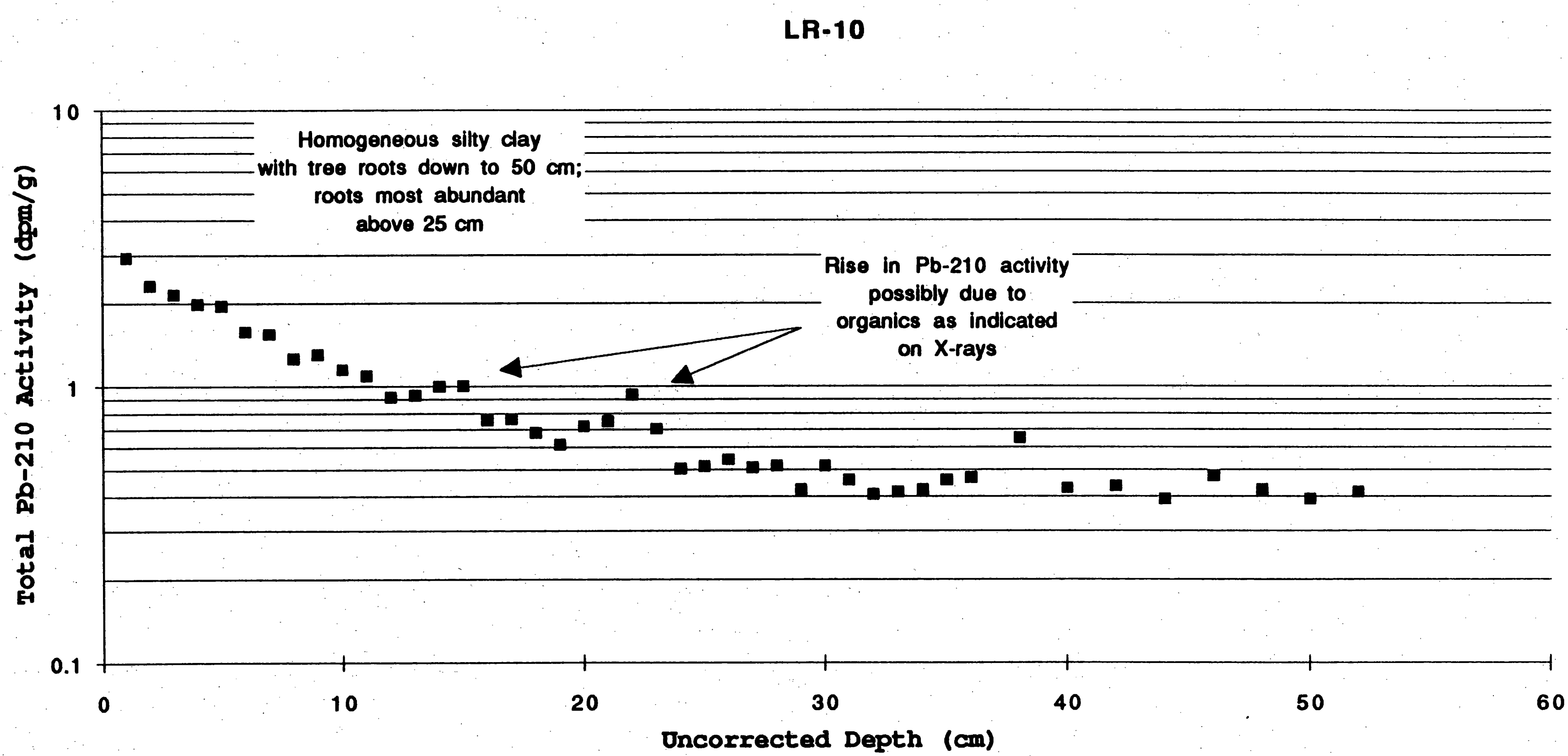


Figure 33. Core LR-10 annotated profile.

Relative Sea-Level Rise in the Study Area

More than 30 cm of subsidence has occurred in parts of the Lavaca River valley as determined by benchmark releveling surveys along FM 616 (Ratzlaff, 1980). Tide gauge records and benchmark releveling surveys from the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) provide data for determining rates of relative sea-level rise in the Lavaca River valley near Lolita. Paine (1993) compiled data on vertical movement using regional first-order levelings conducted by NGS in the 1950s, late 1970s and early 1980s. Vertical movement at each benchmark in the network was determined with reference to an arbitrarily chosen benchmark, F46 at Sinton (Paine, 1993). The geodetic network was referenced to sea level through leveling lines to tide gauge stations at Galveston, Rockport, and Port Isabel (fig. 34). These data provide relative sea-rise rates at benchmarks along the main leveling line that crosses the Lavaca River valley west of Lolita (fig. 35).

Rates of relative sea-level rise in mm/yr for the period 1951-1982 were determined for 8 benchmarks along or near State Highway FM 616, which crosses the Lavaca River valley west of Lolita (table 9). Rates of relative sea-level rise were estimated relative to the tide gauge at Port Isabel because dates of leveling surveys between Algoa and Harlingen and Harlingen and Port Isabel were in close agreement, and use of the Port Isabel gauge did not require extrapolation from a benchmark several kilometers away as was necessary for the Rockport gauge (Paine, 1993). Rates of relative sea-level rise are also relative to the reference benchmark F46. Movement of tide gauges relative to F46 are shown in table 10.

For the period of 1951 to 1982, the rate of relative sea-level rise at a benchmark in the Lavaca River valley along the Missouri-Pacific Railroad on the west side of the Lavaca River was about 9 mm/yr. Rates decreased to the west to less than 7 mm/yr but increased to the east toward Lolita to approximately 13 mm/yr (table 11 and fig. 36). These rates exceed the Gulf of Mexico mean sea-level rise rate (Gornitz and Lebedeff, 1987) by factors of about 3 to 5. The accelerated rates of sea-level rise appear to be related to oil and gas production in the area. The rate of rise is highest near the Lolita oil and gas field.

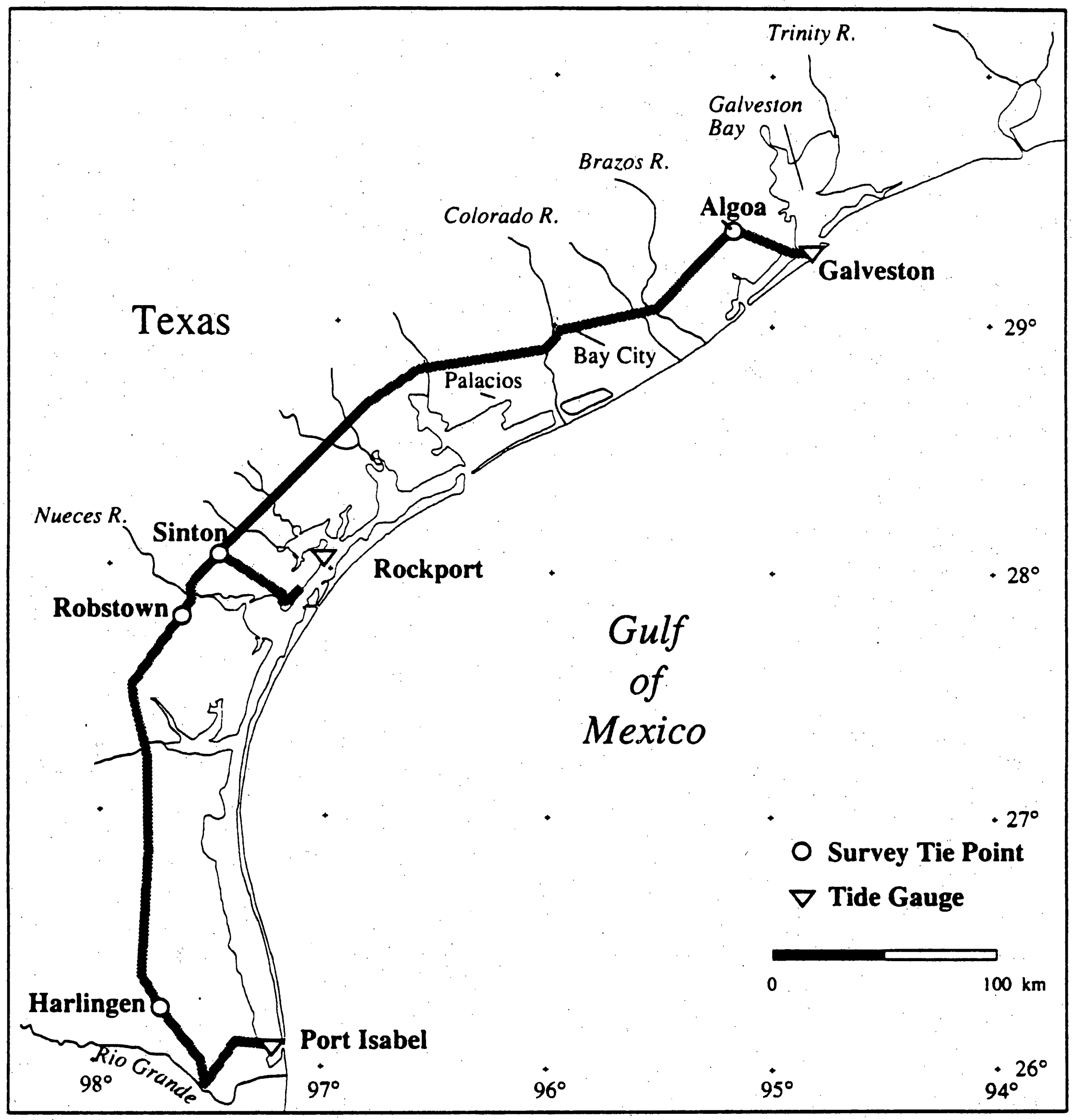


Figure 34. Location of National Geodetic Survey leveling lines and National Ocean Survey tide gages. From Paine (1993).

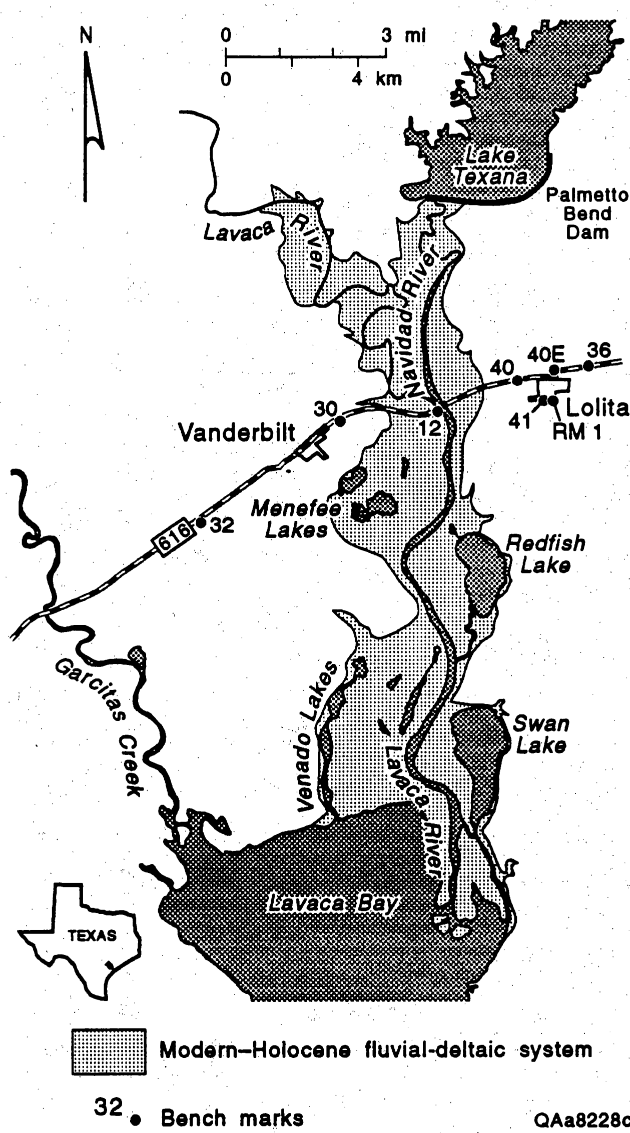


Figure 35. Location of benchmarks along leveling line across the Lavaca River near Lolita.

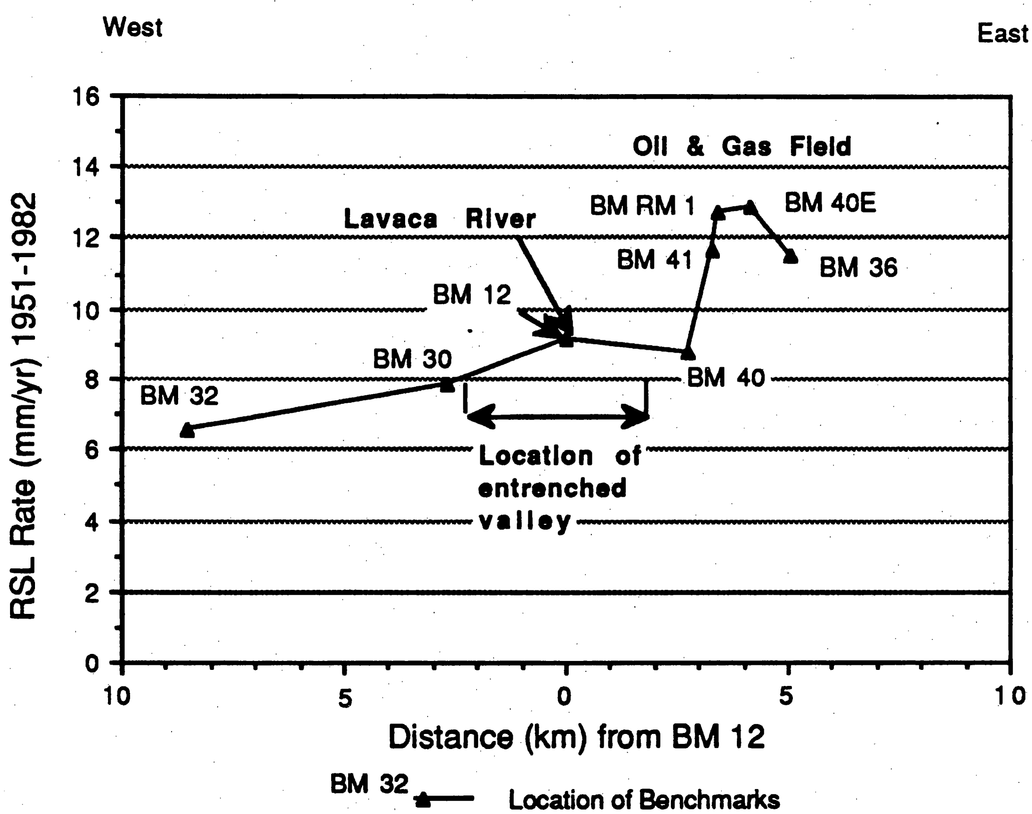


Figure 36. Rates of relative sea level rise between 1951 and 1978 to 1982 along a line crossing the Lavaca River valley southwest of Lolita. Based on data from Paine (1993).

Table 9. Rate of vertical movement for selected benchmarks along a leveling line that crosses the Lavaca River Valley near State Highway FM 616 west of Lolita. Negative change is down. Data from National Geodetic Survey as compiled by Paine (1993).

NGS Benchmark	USGS Benchmark (Lolita Quad)	Rate of vertical movement of BM (mm/yr) 1951-1978
K41	BM 32 (La Salle Quad)	+0.77
W762	BM 30	-0.58
O41	BM 12	-1.81
E456	BM 40	-1.46
Lolita	BM 41	-4.39
Lolita RM 1	(not shown)	-5.43
Z762	BM 40E	-5.54
P41	BM 36	-4.18

Table 10. Rates of vertical movement relative to NGS benchmark F46 and rates of relative sea-level rise at the Port Isabel, Rockport, and Galveston Pier 21 gauges. From Paine (1993).

Tide Gauge	Vertical movement relative to F46 mm/yr)	Relative sea-level rise rate 1951 to 1982 (mm/yr)	Relative sea-level rise rate relative to F46 (mm/yr)
Port Isabel	+2.7	4.6	7.3
Rockport	+2.2	5.4	7.6
Galveston Pier 21	-2.3	8.2	5.9

Table 11. Relative sea-level rise rates for selected benchmarks along State Highway FM 616 in the vicinity of the study area. Rates are relative to the Port Isabel tide gauge and benchmark F46 (Sinton), and were determined by adding the relative sea level rise rate at the Port Isabel gauge (table 10) with the vertical movement of benchmarks shown in table 9. These data are from Paine (1993). See figure 35 for location of benchmarks and figure 36 for plot of rates of relative sea-level rise.

NGS Benchmark	USGS Benchmark (Lolita Quad)	RSL Rate (mm/yr) 1951-1982
K41	BM 32 (La Salle Quad)	6.53
W762	BM 30	7.88
O41	BM 12	9.11
E456	BM 40	8.76
Lolita	BM 41	11.69
Lolita RM 1	(not shown)	12.73
Z762	BM 40E	12.84
P41	BM 36	11.48

Relative Sea-Level Rise at Coring Sites

Because rates of relative sea-level rise appear to be locally affected by subsidence associated with oil and gas production, it is difficult to determine with certainty the rates at locations away from the benchmark releveling line. Historically, wetland loss has been most extensive in the Menefee Flats area and downstream near Venado Lakes on the western side of the Lavaca River valley (White and Calnan, 1990). These areas are within a large oil and gas field, and subsidence has likely been a factor in the wetland loss. Low initial elevations at these sites near Lavaca Bay undoubtedly contributed to the loss of wetlands. In contrast, coring sites LR-9 and LR-10, which are the most inland sites, also overlie a large oil and gas reservoir and may have undergone subsidence, but wetland and land loss have not occurred. Even though the area may have subsided, the relatively high elevation at these inland sites has apparently been sufficient to maintain the area above a rising sea level.

Large volumes of hydrocarbons have been produced from Frio sandstone reservoirs, which have a coast parallel trend that crosses the Lavaca-Navidad River valley near State Highway FM 616. Most of the production affecting the Lavaca River project area was begun in the 1950s. Lolita oil and gas field since its discovery in 1940, has produced more than 57 million barrels of oil and 2 billion cubic-ft (bcf) of gas (Railroad Commission of Texas, 1993). Production of oil and gas in a larger area encompassing Menefee Flats has exceeded 370 million barrels of oil and more than 174 bcf gas since the discovery date of 1938. Upstream, along the Navidad, oil production, since discovery in 1941, has exceeded 26 million barrels and gas production 19 bcf (most of which has been produced from La Ward oil and gas field). Reservoir depths generally range between 1,500 and 1,800 m.

Although hydrocarbon production can produce subsidence (Pratt and Johnson, 1926; Yerkes and Castle, 1969; Gustavson and Kreitler, 1976; Verbeek and Clanton, 1981; Holzer and Bluntzer, 1984; Germiat and Sharp, 1990; Paine 1993; White and Tremblay, in press), the relationship is not as well defined as it is with ground-water withdrawal. It has been documented, for example, that reductions in pumpage of ground water can arrest subsidence over a short period of time (Gabrysch and Coplin, 1990). However, the temporal and spatial relationships between hydrocarbon production and subsidence are more complicated, and translation of subsidence to the surface from depressurization of deeper seated hydrocarbon reservoirs is not well understood. Because of a potential time lag between pressure depletion of reservoirs and surface subsidence, it is not clear if rates of subsidence are continuing to accelerate or are declining in conjunction with declining volumes of produced hydrocarbons.

Our best information on rates of relative sea-level rise are provided by the benchmark releveling surveys and tide gauges, which indicate that rates are about 9 mm/yr in the Lavaca River valley near FM 616. The closest tide gauge station with a sufficient period of record is at Rockport, where the relative sea-level rise rate for the period 1951-1982 is 5.4 mm/yr, and for the period 1948 to 1986, 4.1 mm/yr (Paine, 1993). Because possible subsidence associated with oil and gas production may continue, and because of the uncertainty in determining the exact amount of decline in subsidence in the study area due to declining production, we suggest that a relative sea-level rise rate of 9 mm/yr be used for all sites in the study area.

CONCLUSIONS

Excess ^{210}Pb activity decreases exponentially with depth. Most of the profiles of log normal activity versus depth exhibit few departures from linear relationships. A "flattening" of the ^{210}Pb profile occurs in most cores where background activities (supported ^{210}Pb) are reached at depths typically below 20 cm. Some variations in excess ^{210}Pb activity appear to correspond to physical or chemical variations in the sediments such as changes in organic and textural content. Isolated samples that plot considerably outside linear trends of other samples (possibly as a result of counting errors) should be examined individually for possible exclusion from calculations. However, in correlating river discharge with excess ^{210}Pb activity, subtle variations may signify a relationship between flooding and sedimentation, which hopefully can be defined by the Texas Water Board's model (Longley, 1992b). Because most cores from the Lavaca River underwent some compression during coring, corrected depths should be used in determining sedimentation rates unless rates are based on cumulative inorganic mass.

Preliminary analysis of excess ^{210}Pb activities, including cumulative inventories, indicates that these data should provide useable dates and sedimentation rates for comparison with river discharge information. Caution must be used, however, in interpreting ^{210}Pb data in several cores, including LR-1 and LR-4, where diagenesis associated with $CaCO^3$ may have affected activities, LR-5, where high sand content has depressed activities, and LR-9, which has a nonlinear ^{210}Pb activity profile. Preliminary estimates of dates and sedimentation rates in several cores indicate some interesting trends. For example, in core LR-10 different models (CRS and CIC) yield equivalent sedimentation rates. In cores LR-2 and LR-8, which are located along the Lavaca River, sedimentation rates appear to have decreased between 30 and 35 years ago (figs. 37 and 38). This decline in sedimentation is possibly related to decreasing suspended sediment concentrations in the Lavaca River after 1965 (fig. 39). In contrast to this trend, the age-depth relationships of sediment in cores LR-3, LR-6, and LR-9 located along the Navidad River, indicate that sedimentation rates have increased during the past 10 to 12 years, possibly in response to river channel degradation (Williams and Wolman, 1984) downstream from Lake Texana, which was completed about 14 years ago.

Supported ^{210}Pb levels vary from core to core and in a single core depending on whether average activities of ^{214}Bi or constant activities of ^{210}Pb at depth are used to determine the level of supported ^{210}Pb. The supported ^{210}Pb levels determined by both methods should be considered. The best results in core LR-10, however, were achieved when supported ^{210}Pb was based on the average ^{214}Bi activity.

There is evidence from benchmark releveling lines that subsidence is occurring in the study area. Although there is a chance that subsidence is declining with declining rates of hydrocarbon production, which means that relative sea-level rise rates are also declining, for the purpose of determining offsetting sedimentation rates, it is recommended that a relative sea-level rise rate of at least 9 mm/yr be used for all coring sites.

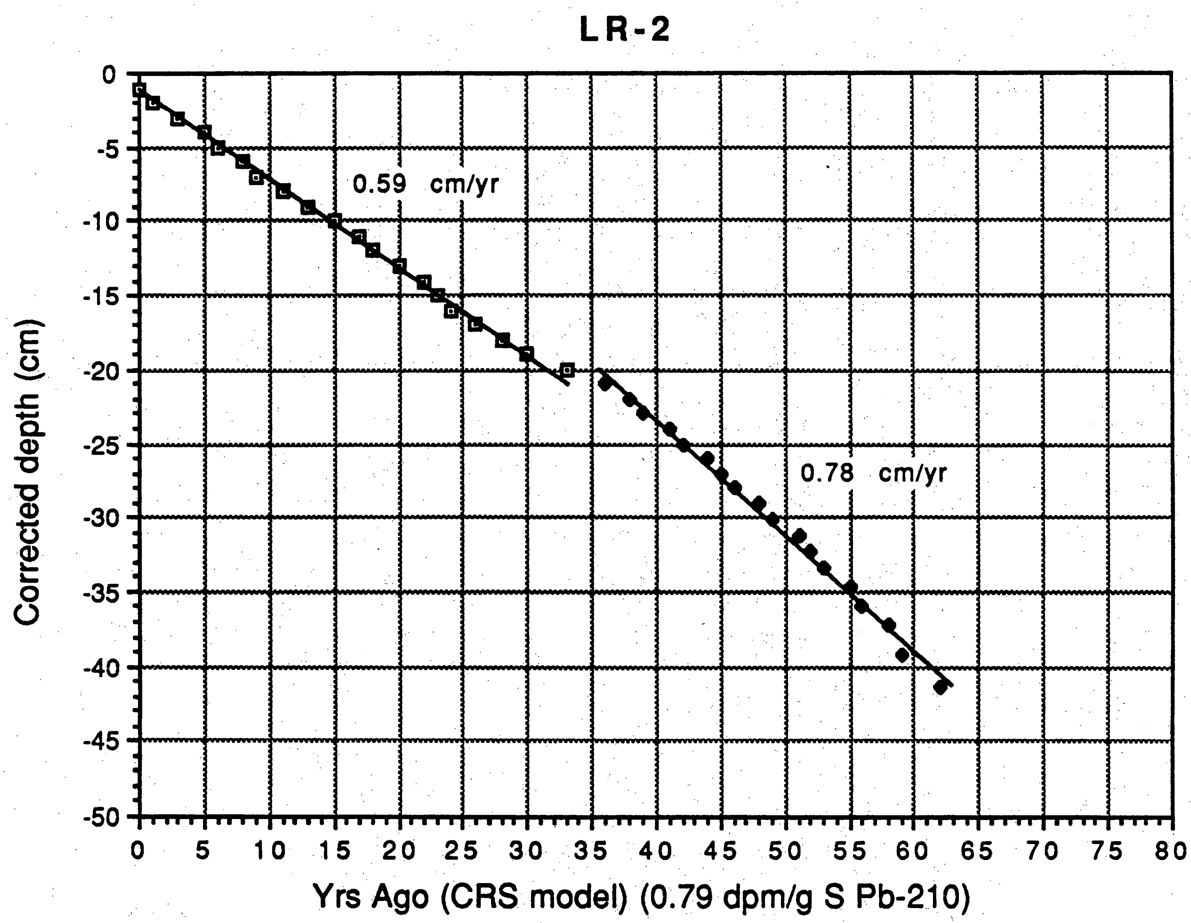


Figure 37. Estimated rates of sedimentation in core LR-2.

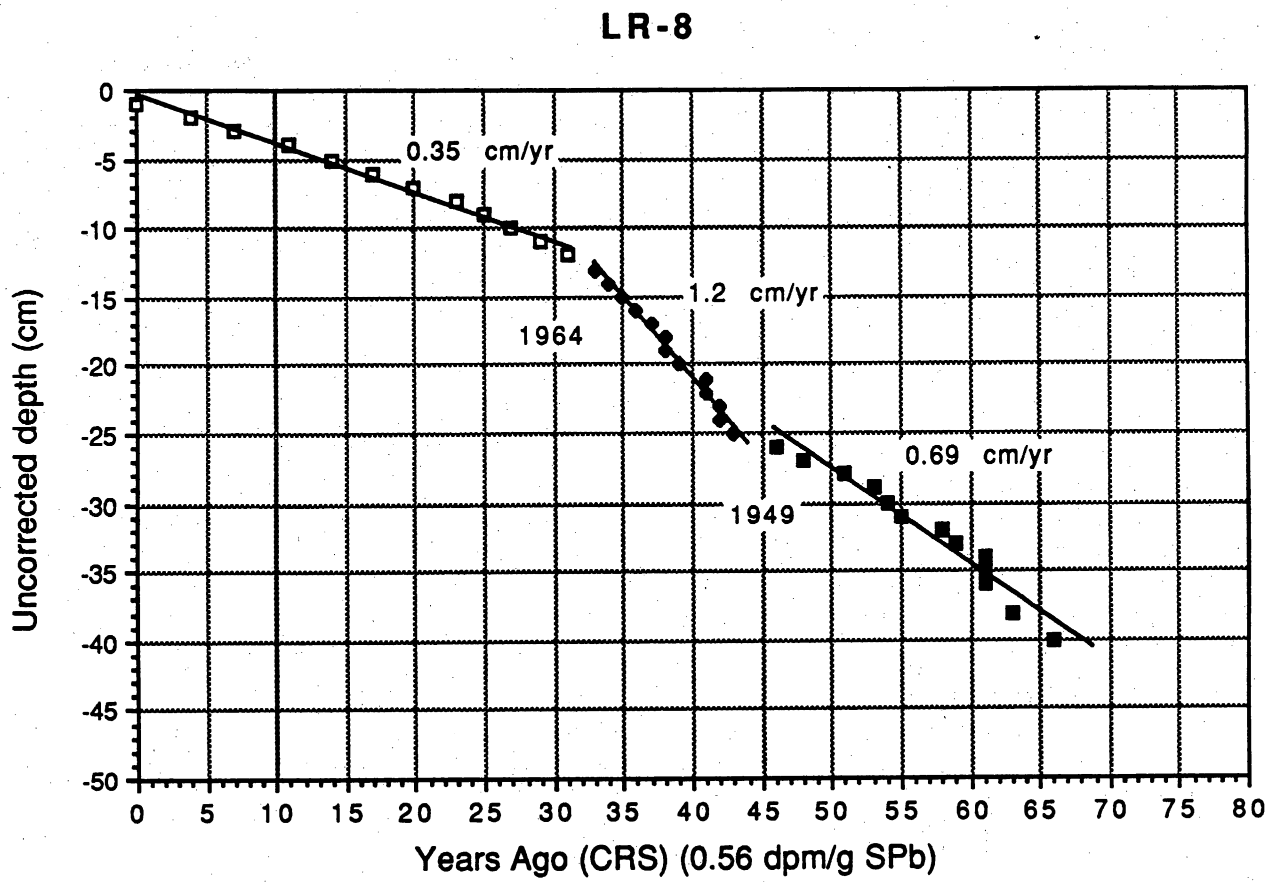


Figure 38. Estimated rates of sedimentation in core LR-8.

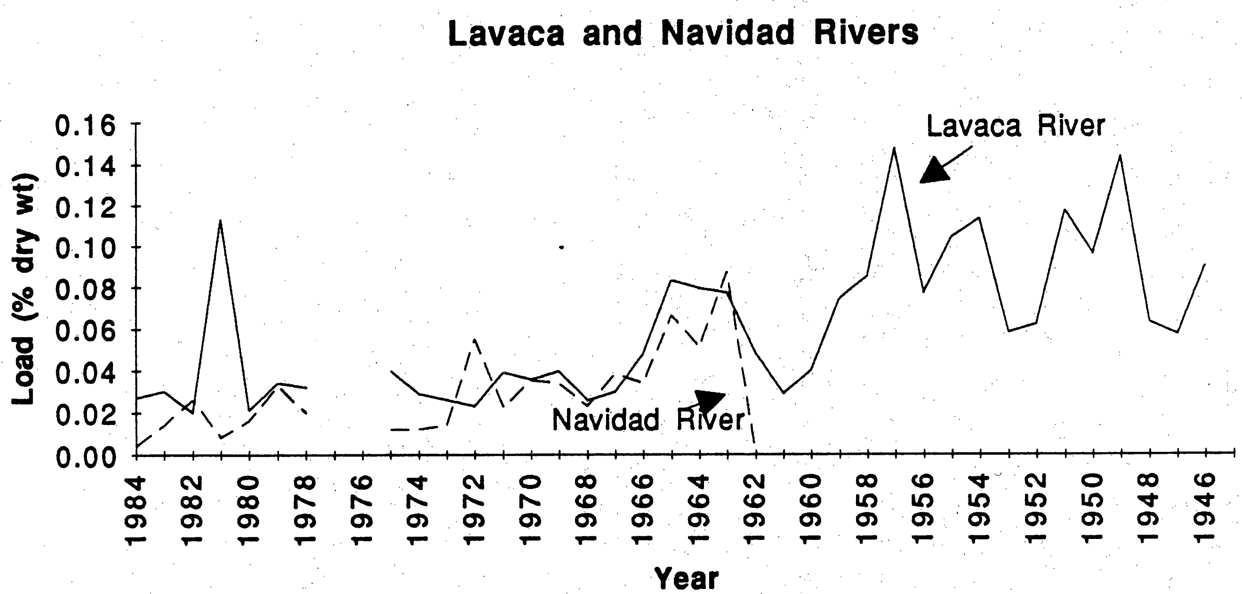


Figure 39. Suspended sediment load (percent by weight) of the Lavaca and Navidad Rivers near Edna and at Hallettsville, respectively. Data are from Stout and others (1961), Adey and Cook (1964), Cook (1967), Cook (1970), Mirabal (1974), Dougherty (1979), and unpublished records from Texas Water Development Board.

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REFERENCES

Adey, E. A., and Cook, H. M., 1964, Suspended-sediment load of Texas streams: compilation report, October 1959 - September 1961: Texas Water Commission, Bulletin 6410, 49 p.

Appleby, P. G., Nolan, P. J., Oldfield, F., Richardson, N., and Higgitt, S. R., 1988, ^{210}Pb dating of lake sediments and ombrotrophic peats by gamma essay: The science of the total environment, special issue, v. 69, p. 157–177.

Allen, J. R. L., Ray, J. E., Longworth, G., Hasler, S. E., and Ivanovich, M., 1993, A comparison of the ^{210}Pb dating technique with three other independent dating methods in an oxic estuarine salt-marsh sequence: Estuaries, v. 16, no. 3B, p. 670–677.

Brenner, M., Peplow, A. J., and Schelske, C. L., 1994, Disequilibrium between ^{226}Ra and supported ^{210}Pb in a sediment core from a shallow Florida Lake: Limnology and Oceanography, p. 1222–1227.

Bruland, K. W., Bertine, Kathe, Koide, Minoru, and Goldberg, E. D., 1974, History of metal pollution in Southern California Coastal Zone: Environmental Science and Technology, v. 8, no. 5, p. 425–432.

Callender, Edward, and Robbins, J. A., 1993, Transport and accumulation of radionuclides and stable elements in a Missouri River reservoir: Water Resources Research, v. 29, no. 6, p. 1787–1804.

Church, T. M., Lord, C. J., III, and Somayajulu, B. L. K., 1981, Uranium, thorium, lead nuclides in a Delaware salt marsh sediment: Estuarine, Coastal and Shelf Science, v. 13, p. 267–275.

Cook, H. M., 1967, Suspended-sediment load of Texas streams: compilation report, October 1961—September 1963: Texas Water Development Board, Report 45, 61 p.

Cook, H. M., 1970, Suspended-sediment load of Texas streams: compilation report, October 1963—September 1965: Texas Water Development Board, Report 106, 61 p.

Dougherty, J. P., 1979, Suspended-sediment load of Texas streams, compilation report October 1971—September 1975: Texas Department of Water Resources Report 233, 82 p.

Duxbury, A. C., 1971, The earth and its oceans: Reading, Massachusetts, Addison-Wesley Publishing Company, 381 p.

Flynn, W. W., 1968, The determination of low levels of polonium-210 in environmental materials: Analytica Chimica Acta, v. 43, p. 221–227.

Gabrysch, R. K., 1969, Land-surface subsidence in the Houston-Galveston region, Texas: United Nations Educational, Scientific and Cultural Organization (UNESCO), Studies and Reports in Hydrology, Land Subsidence Symposium, v. 1, p. 43–54.

__________ 1984, Ground-water withdrawals and land-surface subsidence in the Houston-Galveston region, Texas, 1906–1980: Texas Department of Water Resources Report 287, 64 p.

Gabrysch, R. K., and Bonnet, C. W., 1975, Land-surface subsidence in the Houston-Galveston region, Texas: Texas Water Development Board, Report 188, 19 p.

Gabrysch, R. K., and Coplin, L. S., 1990, Land-surface subsidence resulting from ground-water withdrawals in the Houston-Galveston region, Texas, through 1987: U.S. Geological Survey Report of Investigations No. 90-01, 53 p.

Gee, G. W., and Bauder, J. W., 1986, Particle-size analysis, *in* Methods of soil analysis, Part 1. Physical and mineralogical methods, Agronomy Monograph No. 9, 2d ed.: Madison, Wisconsin, American Society of Agronomy—Soil Science of America, p. 383–410.

Germiat, S. J., and Sharp, J. M., Jr., 1990, Assessment of future coastal land loss along the upper Texas Coast to the year 2050: Bulletin of the Association of Engineering Geologists, v. 27, p. 263–280.

Gornitz, V., Lebedeff, S., and Hansen, J., 1982, Global sea level trend in the past century: Science, v. 215, p. 1611–1614.

Gornitz, V., and Lebedeff, S., 1987, Global sea-level changes during the past century: Society of Economic Paleontologists and Mineralogists, Special Publication No. 41, p. 3–16.

Gustavson, T. C., and Kreitler, C. W., 1976, Geothermal resources of the Texas Gulf coast—environmental concerns arising from the production and disposal of geothermal waters: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 76-7, 35 p.

Holmes, C. W., and Martin, E. A., 1976, Rates of sedimentation, *in* Holmes, C. W., and others, Environmental studies, South Texas Outer Continental Shelf, 1976, Geology report for the Bureau of Land Management prepared by the U.S. Geological Survey, 626 p.

Holzer, T. L., and Bluntzer, R. L., 1984, Land subsidence near oil and gas fields, Houston, Texas: Ground Water, v. 22, p. 450–459.

Kadlec, R. H., and Robbins, J. A., 1984, Sedimentation and sediment accretion in Michigan coastal wetlands (U.S.A.): Chemical Geology, v. 44, p. 119–150.

Kreitler, C. W., 1977, Faulting and land subsidence from ground-water and hydrocarbon production, Houston-Galveston, Texas: The University of Texas at Austin, Bureau of Economic Geology Research Note 8, 22 p.

Kreitler, C. W., White, W. A., and Akhter, M. S., 1988, Land subsidence associated with hydrocarbon production, Texas Gulf Coast (abs.): American Association of Petroleum Geologists Bulletin, v. 72, no. 2, p. 208.

Longley, W. L., 1992a, Freshwater inflow to Texas bays and estuaries: ecological relationships and methods for determining needs: Texas Water Development Board and Texas Parks and Wildlife Department, 366 p.

__________ 1992b, Analytical approach to determine sediment requirements for maintenance of the Trinity River delta: Texas Water Development Board proposal document, 5 p.

Mackin, J. G., 1971, A study of the effect of oil field brine effluents on biotic communities in Texas estuaries: Texas A&M University Research Foundation Report, Project 735, 72 p.

Martin, E. A., and Rice, C. A., 1981, ^{210}Pb geochronology and trace metal concentrations of sediments from Upper Klamath Lake and Lake Euwana, Oregon: Northwest Science, v. 55, no. 4, p. 269–280.

Mirabal, J., 1974, Suspended sediment load of Texas Streams: Compilation report, October 1965—September 1971: Texas Water Development Board Report 184, 119 p.

Nittrouer, C. A., Sternberg, R. W., Carpenter, R., and Bennett, J. T., 1979, The use of Pb-210 geochronology as a sedimentological tool: application to the Washington continental shelf: Marine Geology, v. 31, p. 297–316.

Oldfield, F., and Appleby, P. G., 1984, Empirical testing of ^{210}Pb-dating models for lake sediments, *in* Haworth, E. Y., and Lund, J. W. G., eds., Lake sediments and environmental history: Minneapolis, Minnesota, University of Minnesota Press, p. 93–124.

Paine, J. G., 1993, Subsidence in the Texas coast: inferences from historical and late Pleistocene sea levels: Tectonophysics, v. 222, p. 445–458.

Penland, Shea, Ramsey, K. E., McBride, R. A., Mestayer, J. T., and Westphal, K. A., 1988, Relative sea level rise and delta-plain development in the Terrebone Parish region: Baton Rouge, Louisiana Geological Survey, Coastal Geology Technical Report No. 4, 121 p.

Pratt, W. E., and Johnson, D. W., 1926, Local subsidence of the Goose Creek oil field: Journal of Geology, v. 34, p. 577–590.

Railroad Commission of Texas, 1993, Oil and Gas Division Annual Report, 1992, Volumes I and II: Austin, Texas, Railroad Commission of Texas.

Ratzlaff, K. W., 1980, Land-surface subsidence in the Texas coastal region: U.S. Geological Survey Open-File Report 80-969, 19 p.

Robbins, J. A., 1978, Geochemical and geophysical applications of radioactive lead, *in* Nriagu, J. O., ed., The biogeochemistry of lead in the environment, Part A. Ecological cycles: New York, Elsevier/North-Holland Biomedical Press, chap. 9, p. 285–393.

Stout, I. M., Bentz, L. C., and Ingram, H. W., 1961, Silt load of Texas streams: a compilation report, June 1889—September 1959: Texas Board of Water Engineers, Bulletin 6108, 236 p.

Swanson, R. L., and Thurlow, C. I., 1973, Recent subsidence rates along the Texas and Louisiana coasts as determined from tide measurements: Journal of Geophysical Research, v. 78, no. 5, p. 2665–2671.

Verbeek, E. R., and Clanton, U. S., 1981, Historically active faults in the Houston metropolitan area, Texas, *in* Etter, E. M., ed., Houston area environmental geology: surface faulting, ground subsidence, hazard liability: Houston Geological Society, p. 28–68.

White, W. A., Calnan, T. R., Morton, R. A., Kimble, R. S., Littleton, T. G., McGowen, J. H., and Nance, H. S., 1989, Submerged lands of Texas, Port Lavaca area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands: The University of Texas at Austin, Bureau of Economic Geology, Special Publication, 165 p.

White, W. A., and Calnan, T. C., 1990, Sedimentation and historical changes in fluvial-deltaic wetlands along the Texas Gulf Coast with emphasis on the Colorado and Trinity River deltas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Parks and Wildlife Department under interagency contract (88-89) 1423, 124 p., 6 appendices.

White, W. A., and Morton, R. A., 1993, Determining recent sedimentation rates of the Trinity River, Texas: The University of Texas at Austin, Bureau of Economic Geology, report prepared for the Texas Water Development Board under interagency contract no. 93-483-356, 50 p., 3 appendices.

White, W. A., and Tremblay, T. A., in press, Submergence of wetlands as a result of human-induced subsidence and faulting along the upper Texas Gulf Coast: Journal of Coastal Research.

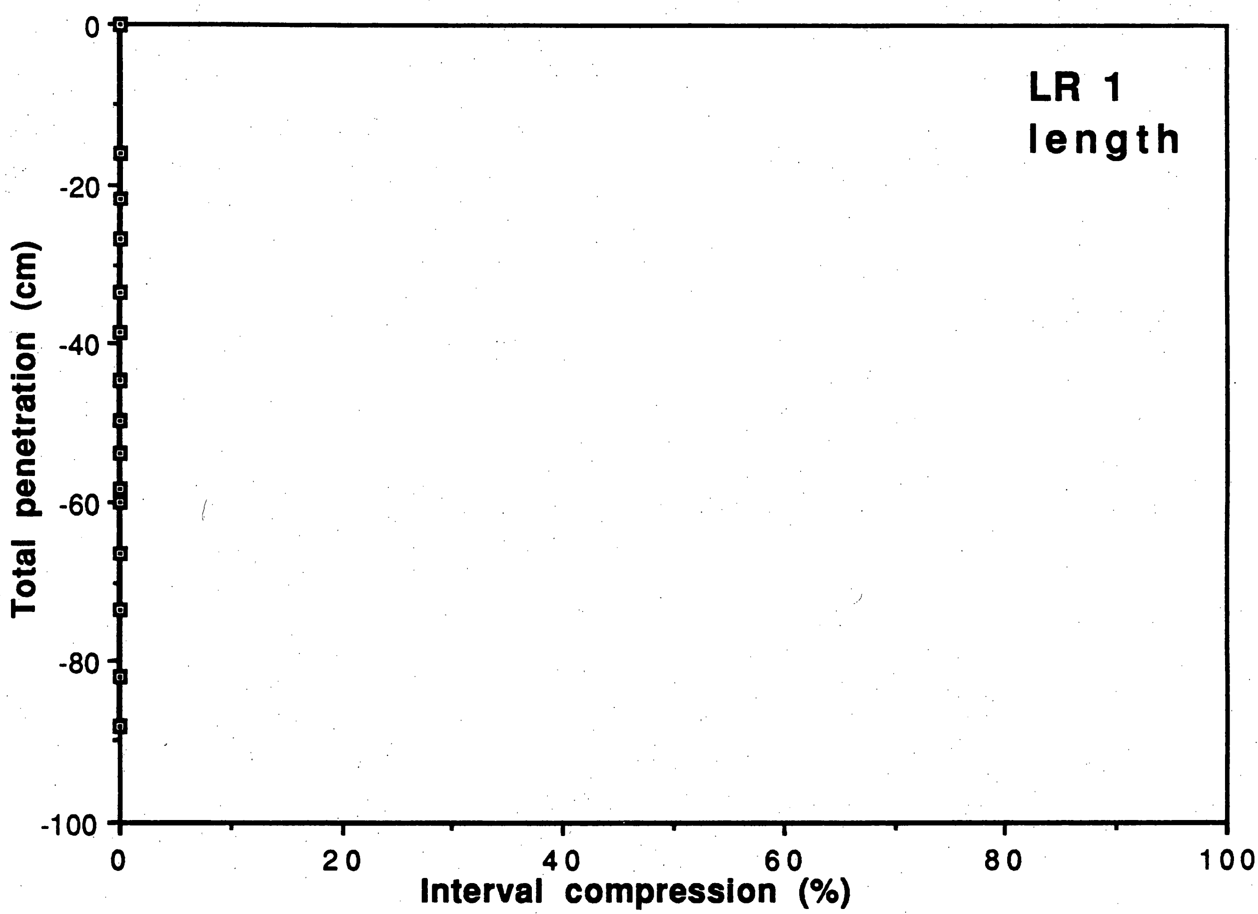
Williams, G. P., and Wolman, M. G., 1984, Downstream effects of dams on alluvial rivers: U.S. Geological Survey, Washington D.C., Professional Paper 1286, 83 p.

Winslow, A. G., and Doyel, W. W., 1954, Land-surface subsidence and its relation to the withdrawal of ground water in the Houston-Galveston region, Texas: Economic Geology, v. 49, no. 4, p. 413–422.

Yerkes, R. F., and Castle, R. O., 1969, Surface deformation associated with oil and gas field operations in the United States: Tokyo, Japan, Proceedings, International Symposium on Land Subsidence, Publication No. 88, AIHS, 1, p. 55–66.

APPENDIX A

Core Compression Analysis



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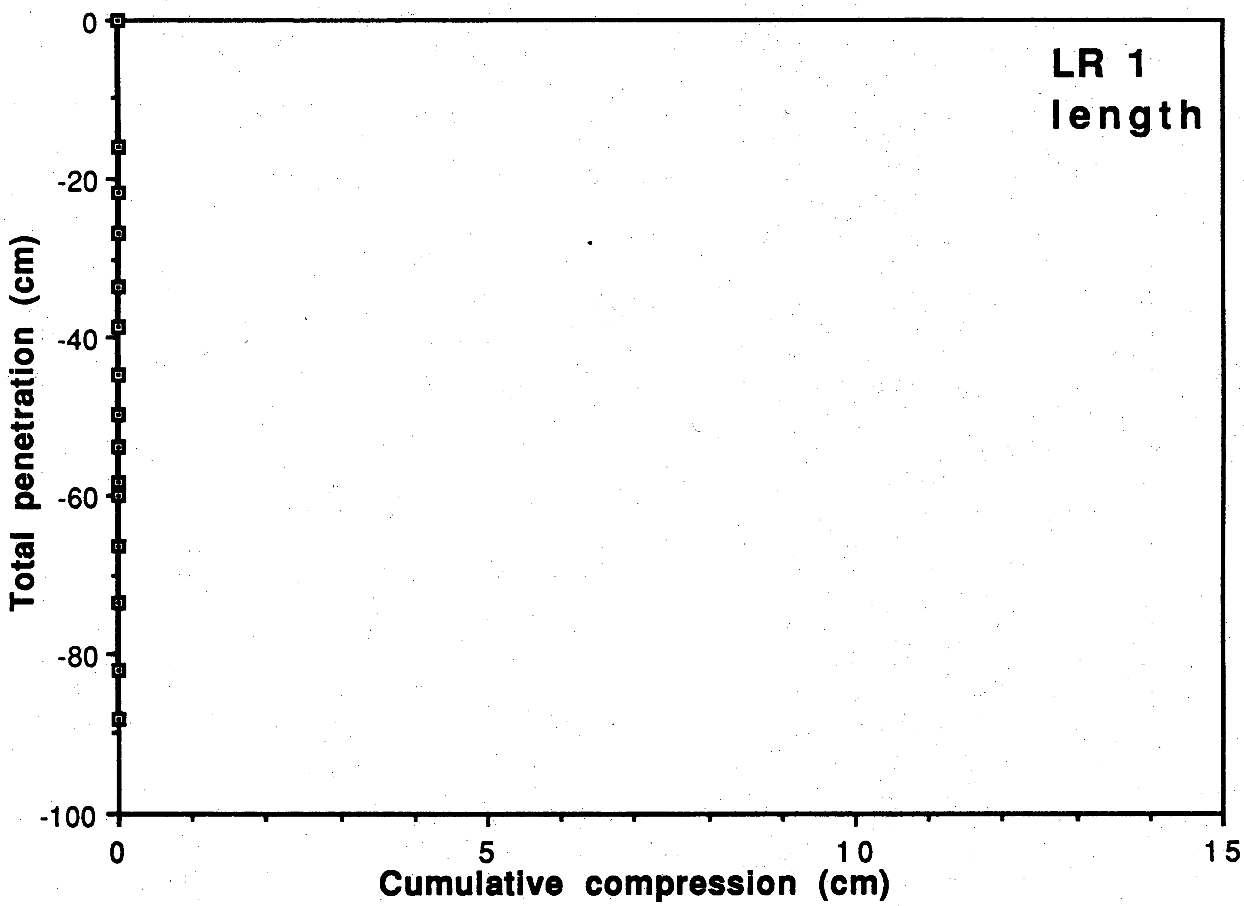
-60
-80
-100
0
20
40
60
80
100
Interval compression (%)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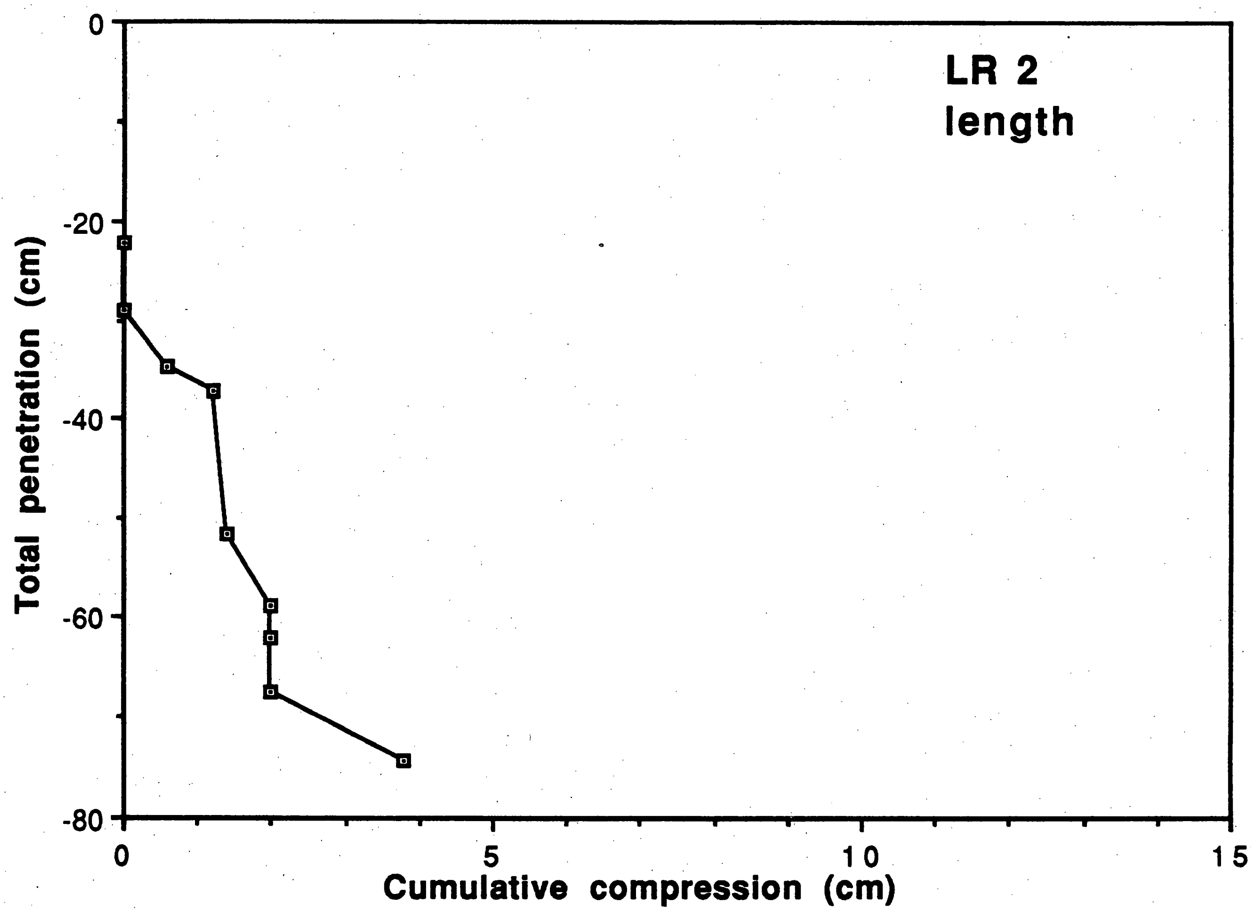
-60
-80
-100
0
5
10
15
Cumulative compression (cm)



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10
15
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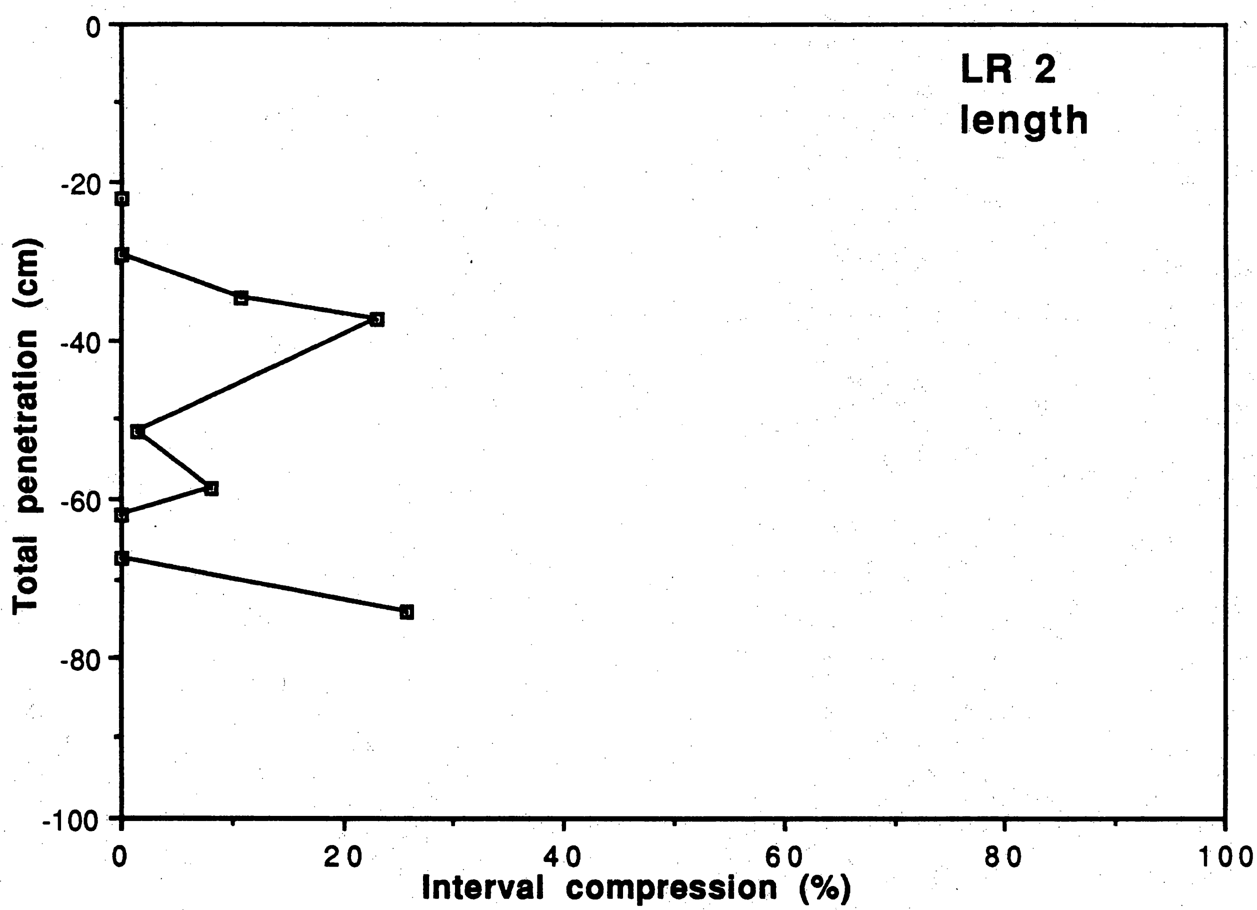

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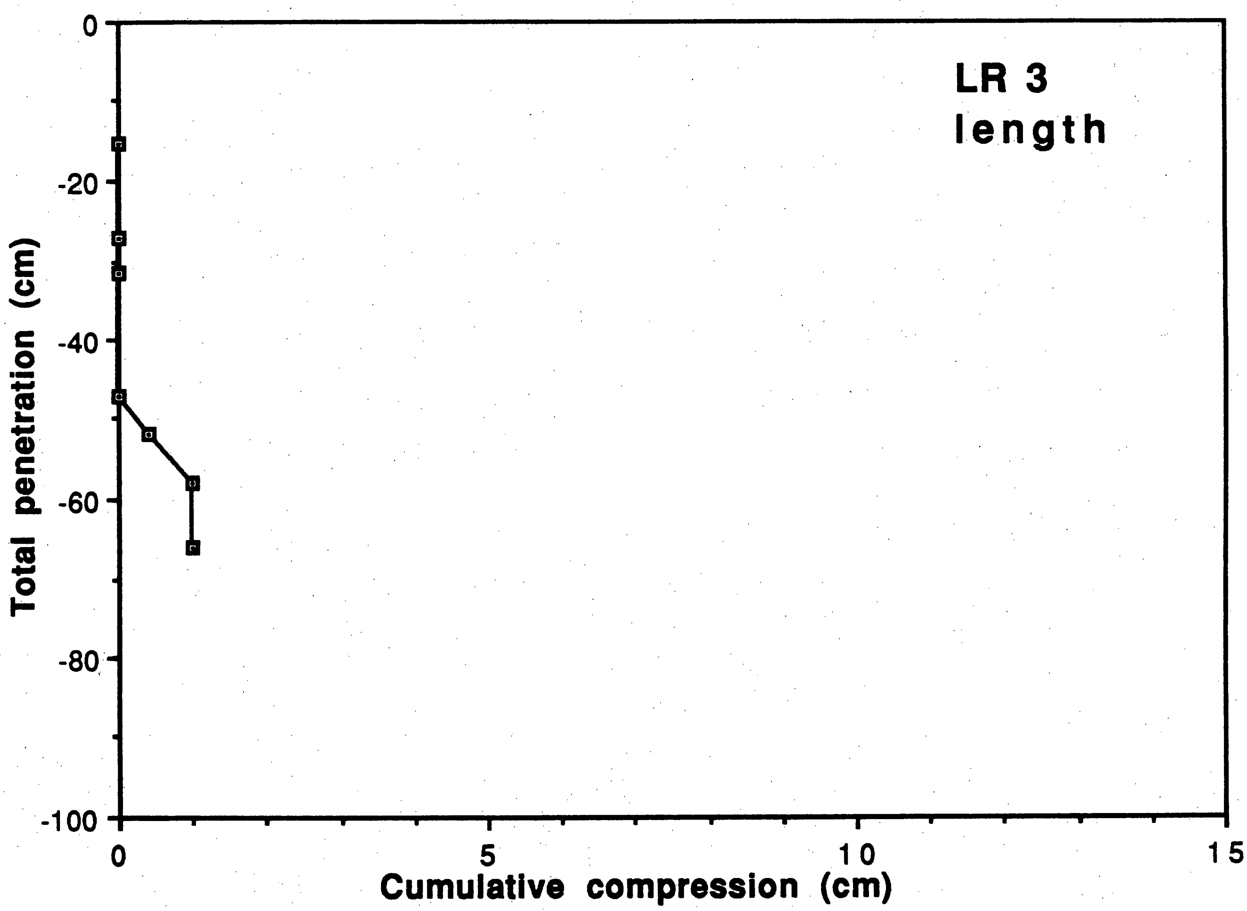
Interval compression (%)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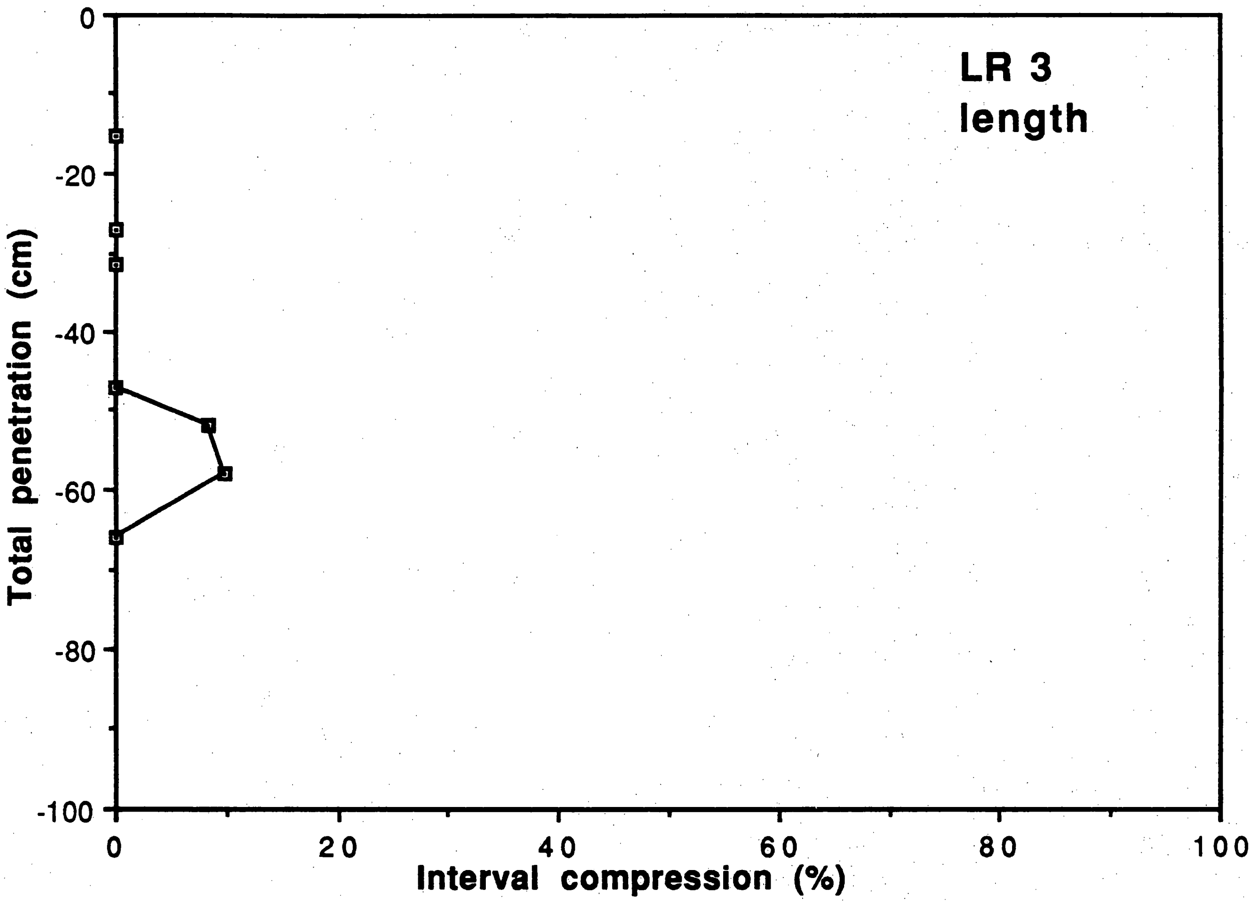
Cumulative compression (cm)



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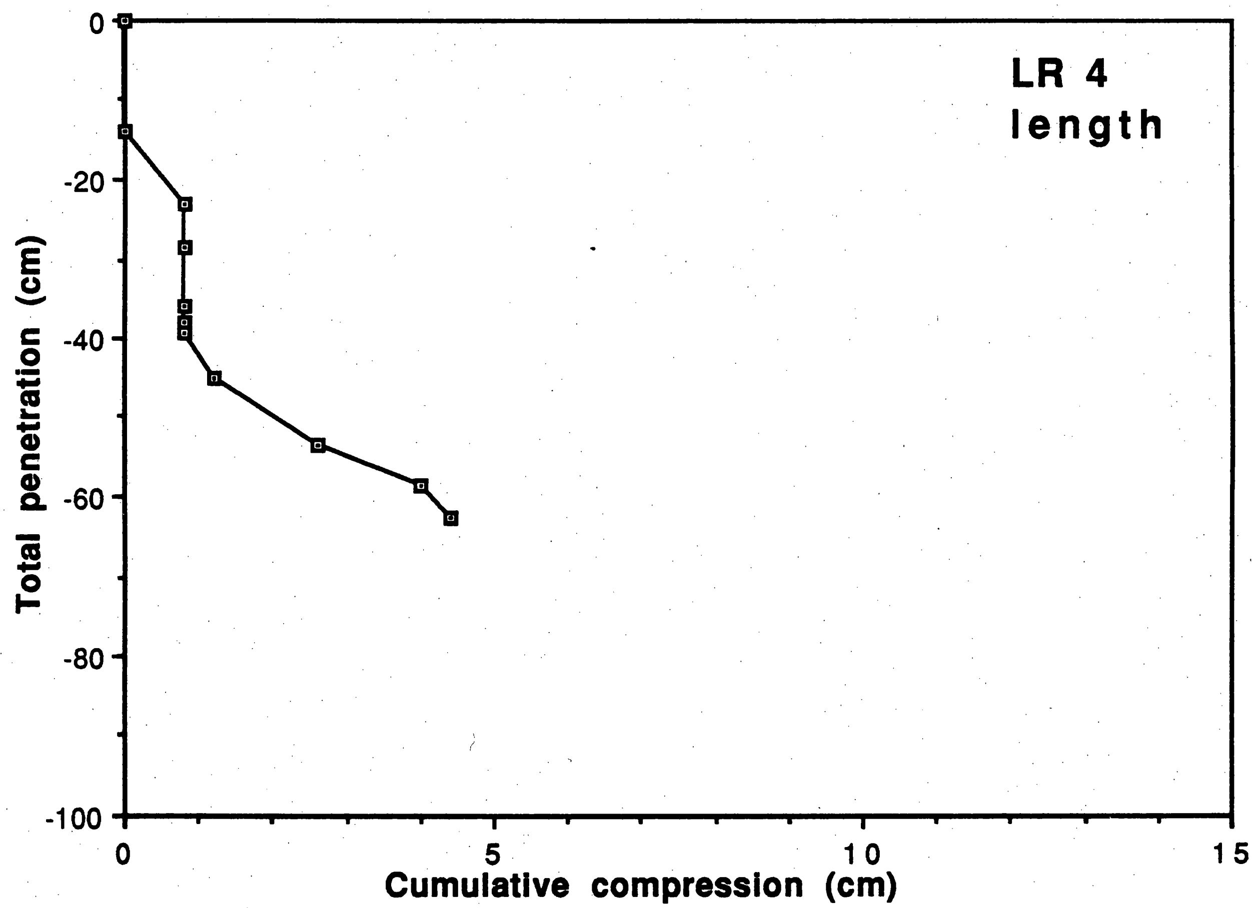
Interval compression (%)



LR 4
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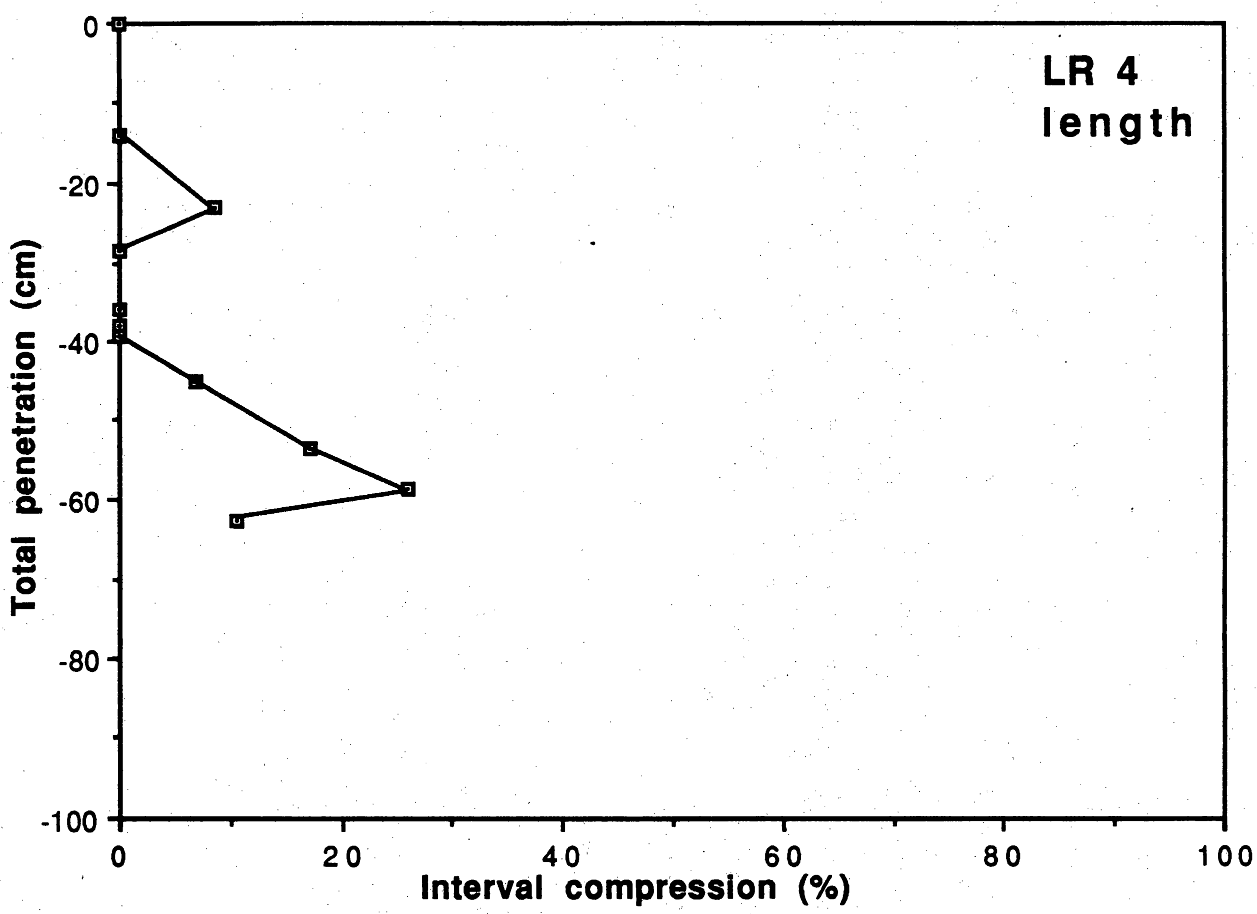
10
15
Cumulative compression (cm)



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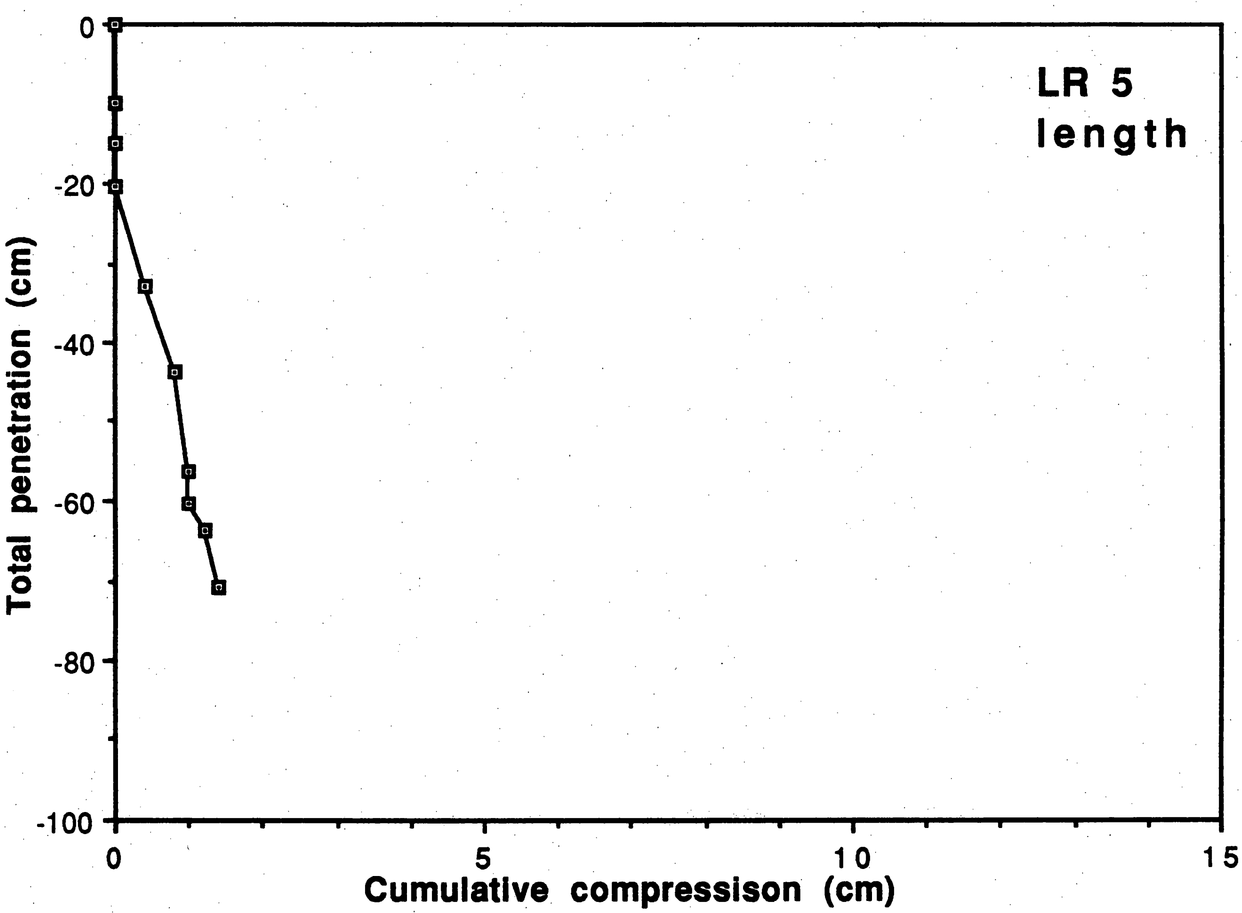
Interval compression (%)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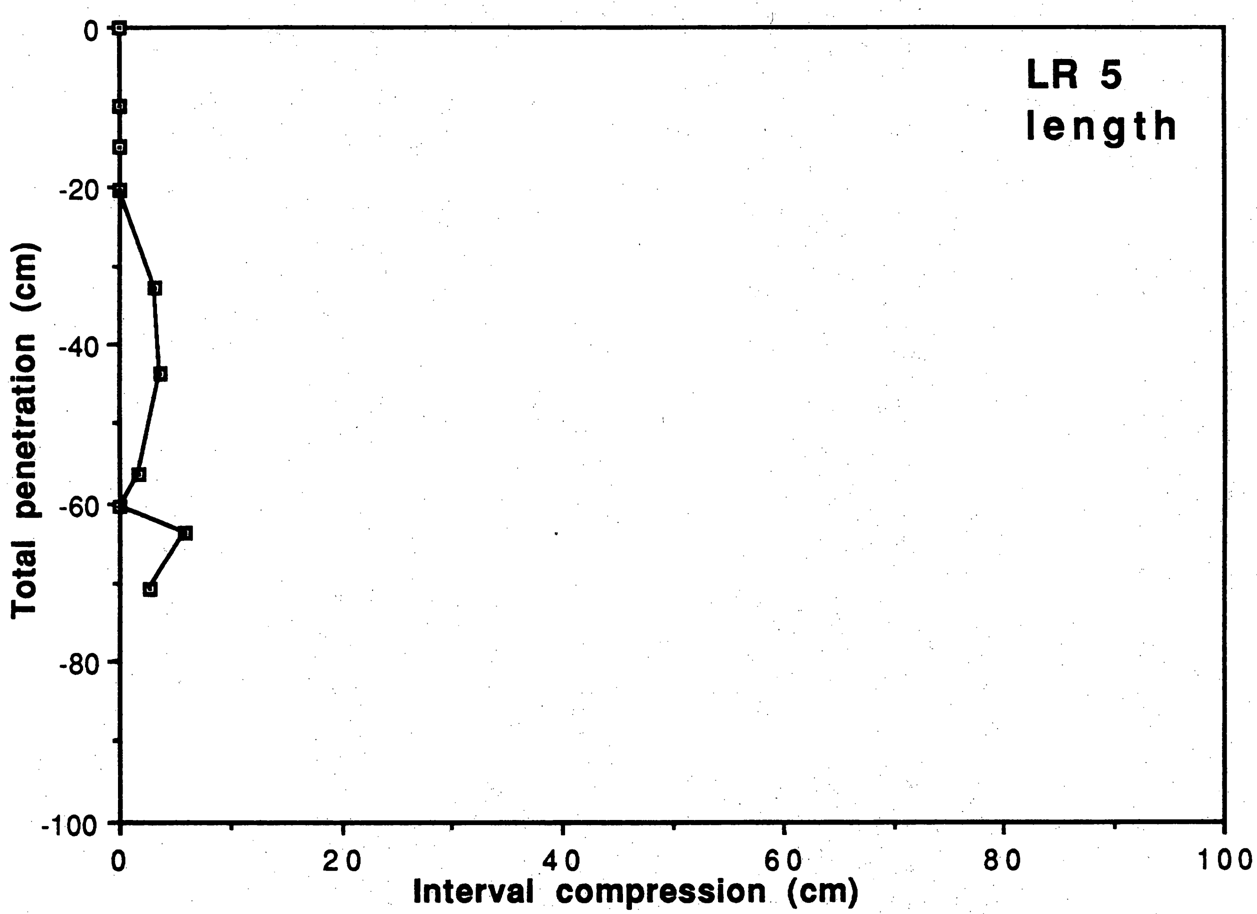
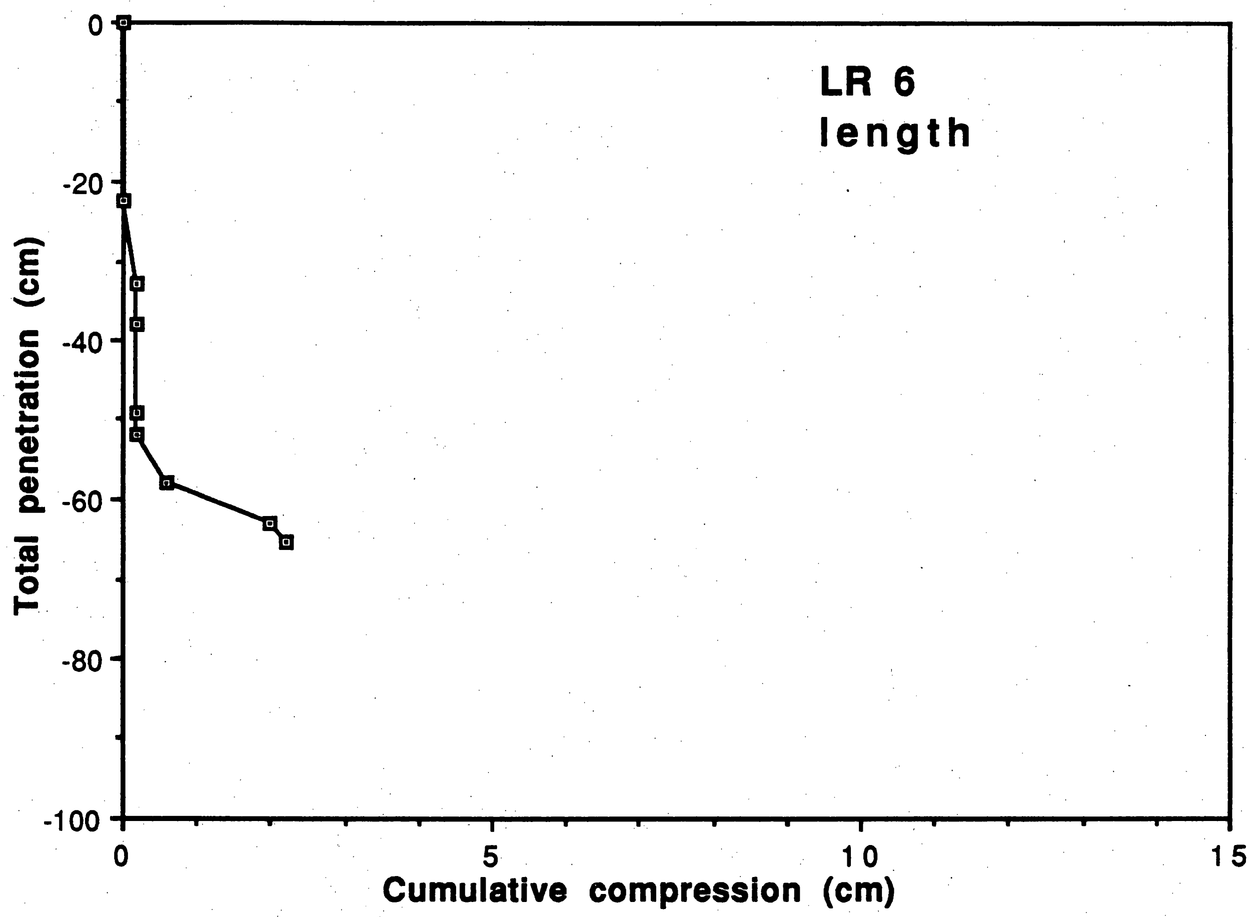
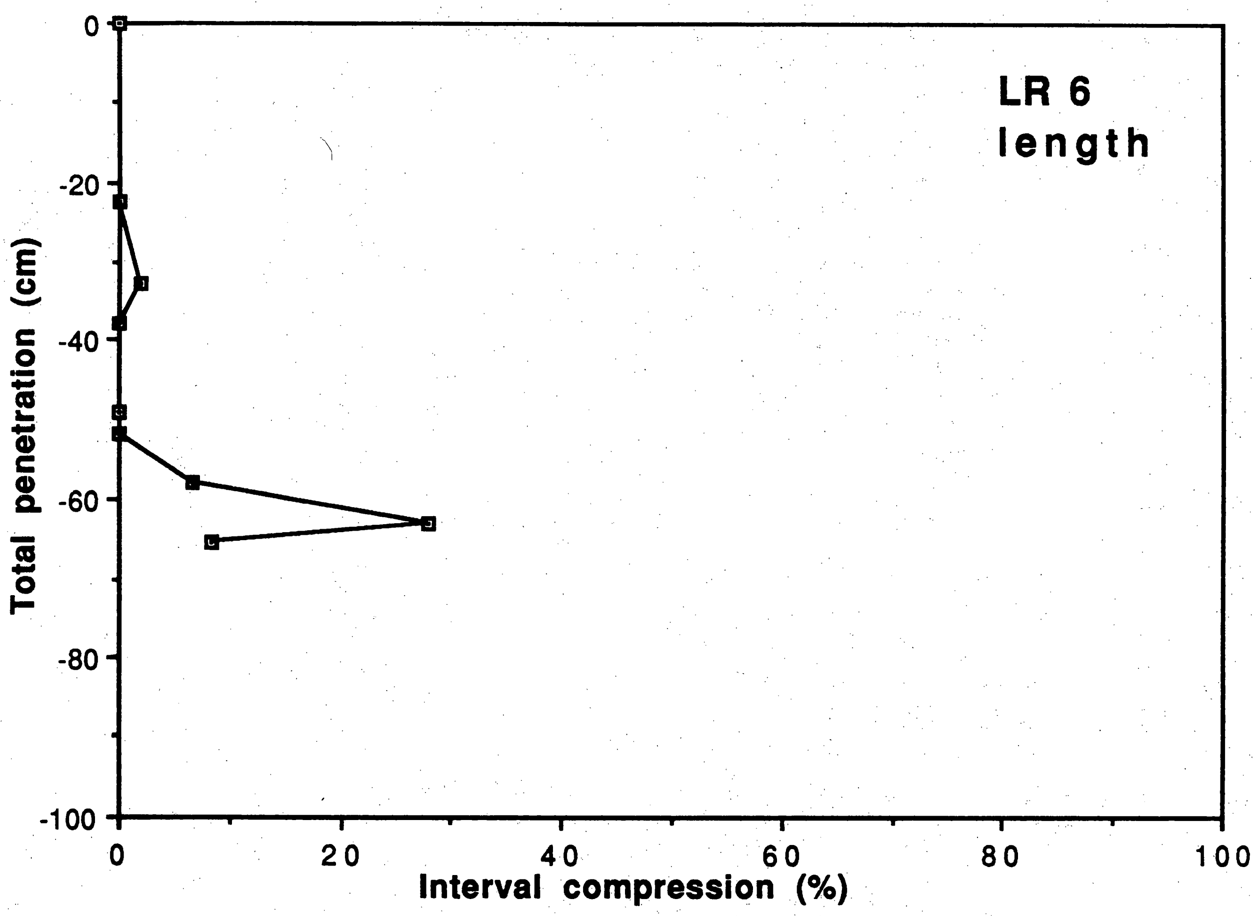
5
10
15
Cumulative compressison (cm)

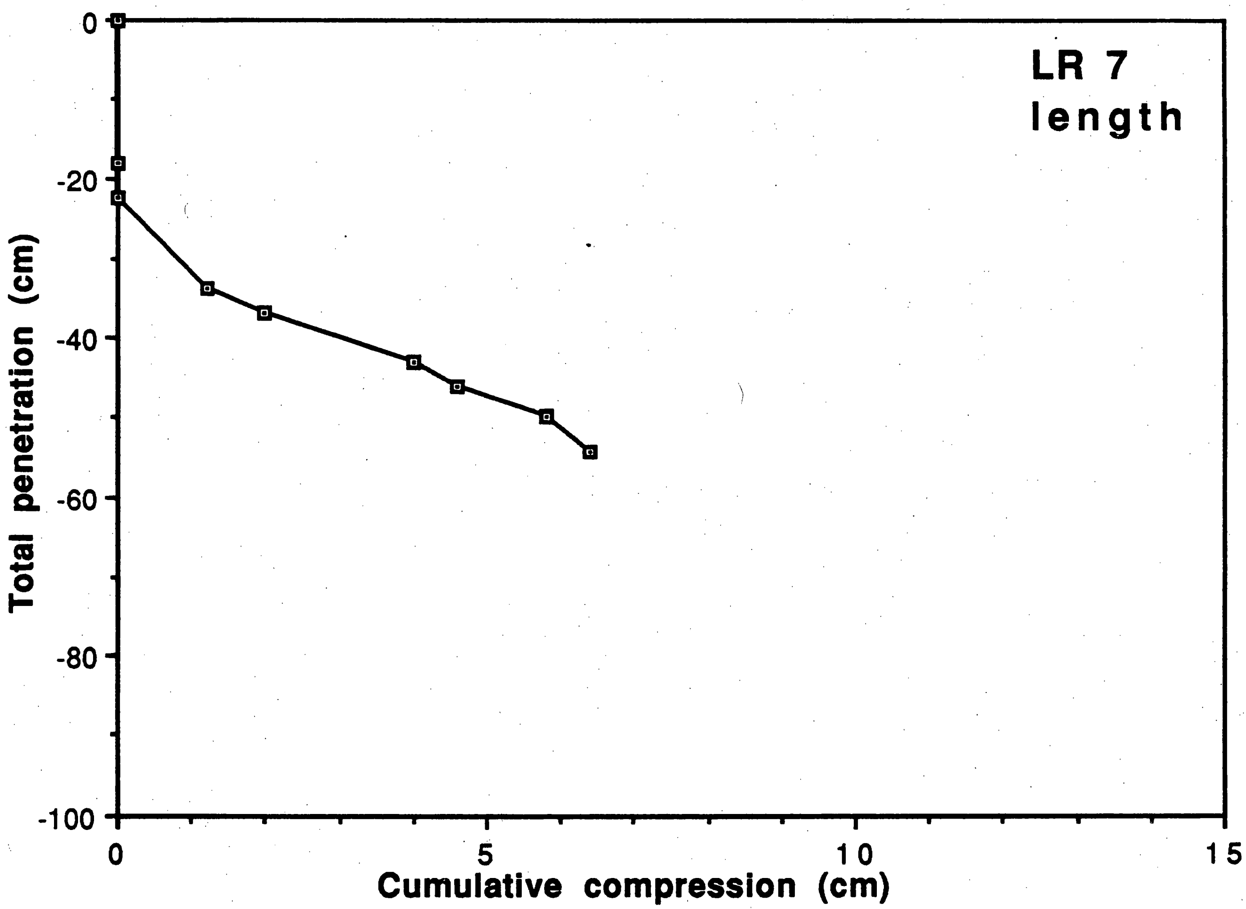

LR 5
length
Total penetration (cm)
Interval compression (cm)
0
-20
-40
-60
-80
-100
0
20
40
60
80
100

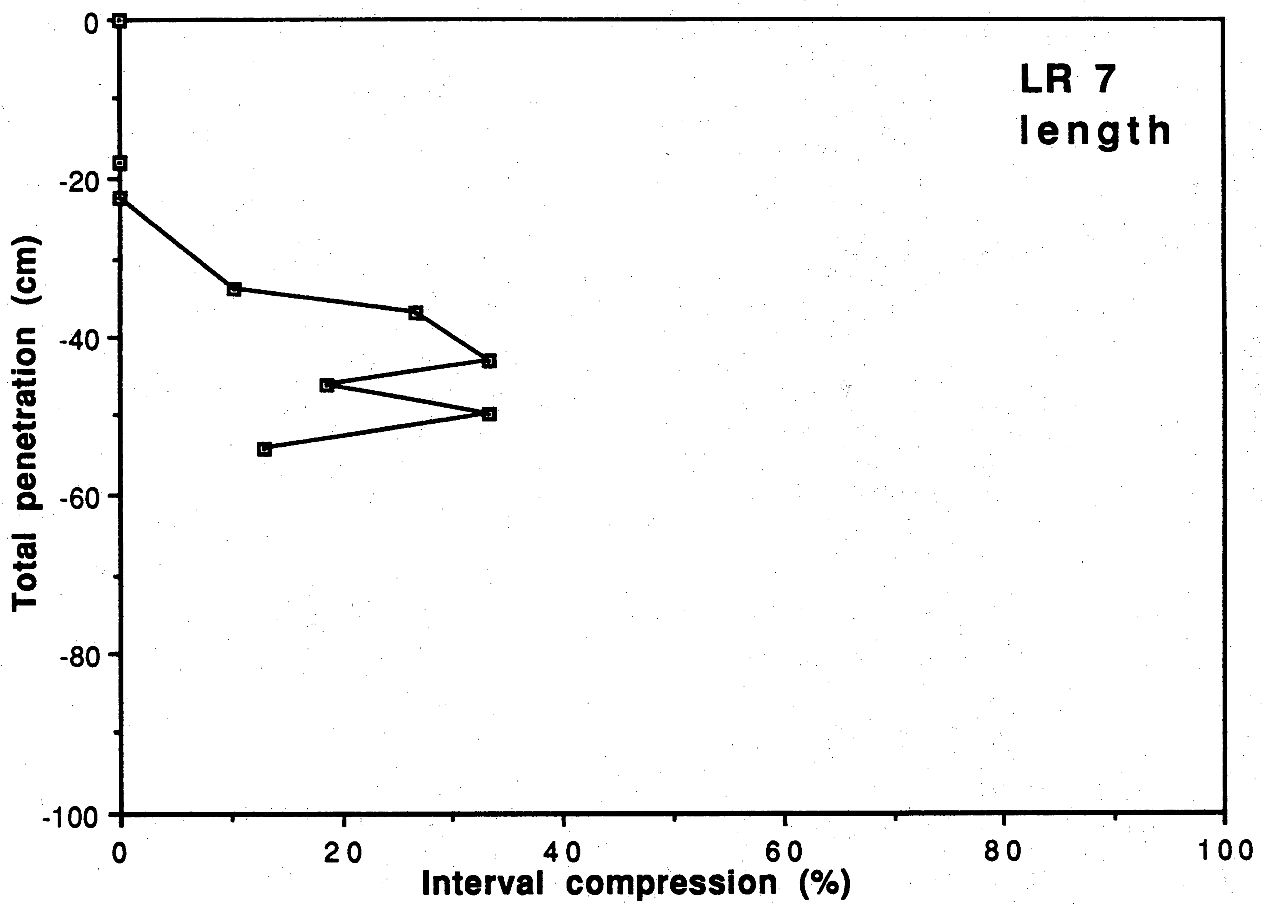


LR 6
length
Total penetration (cm)
0
-20
-40
-60
-80
-100
0
5
10
15
Cumulative compression (cm)

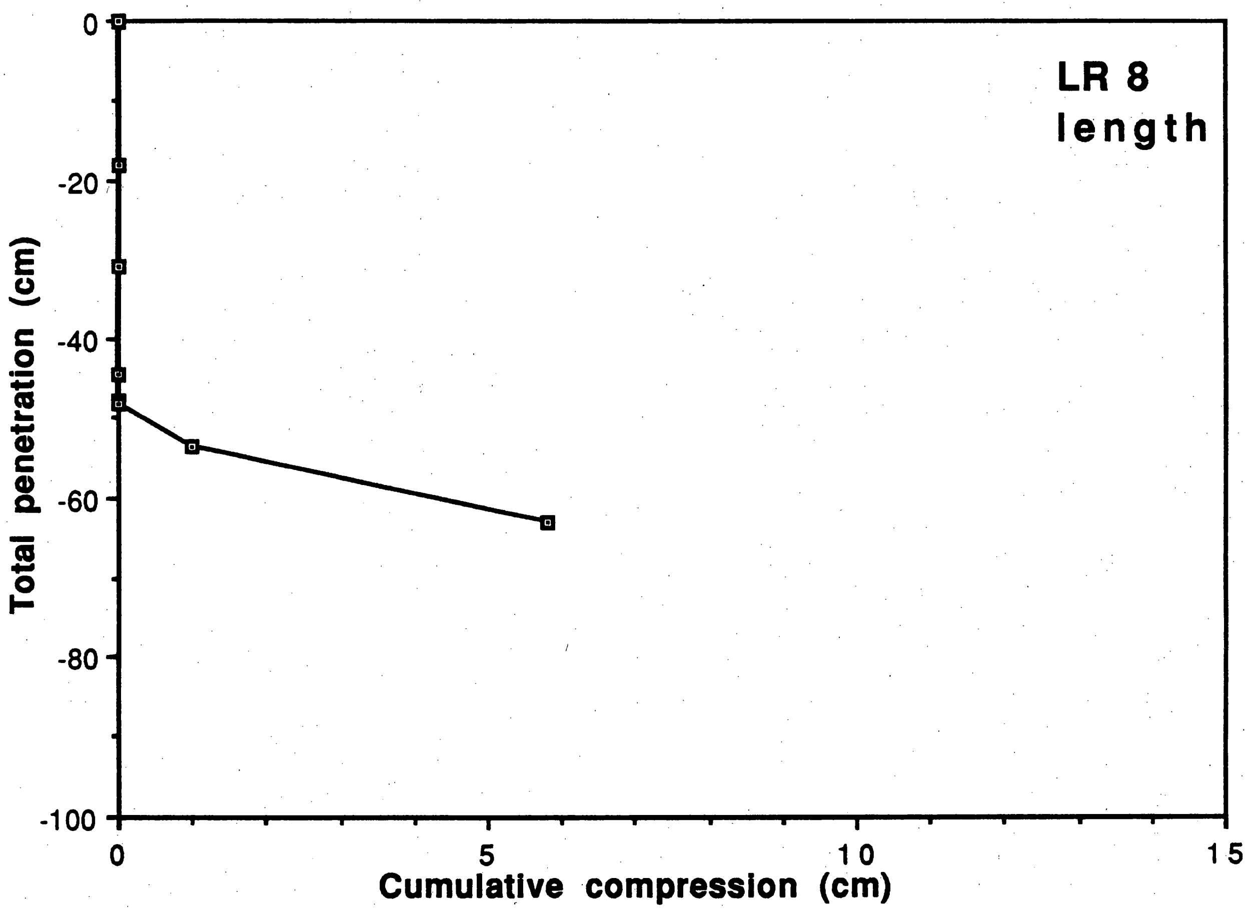


LR 6
length
0
-20
-40
-60
-80
-100
Total penetration (cm)
0
20
40
60
80
100
Interval compression (%)

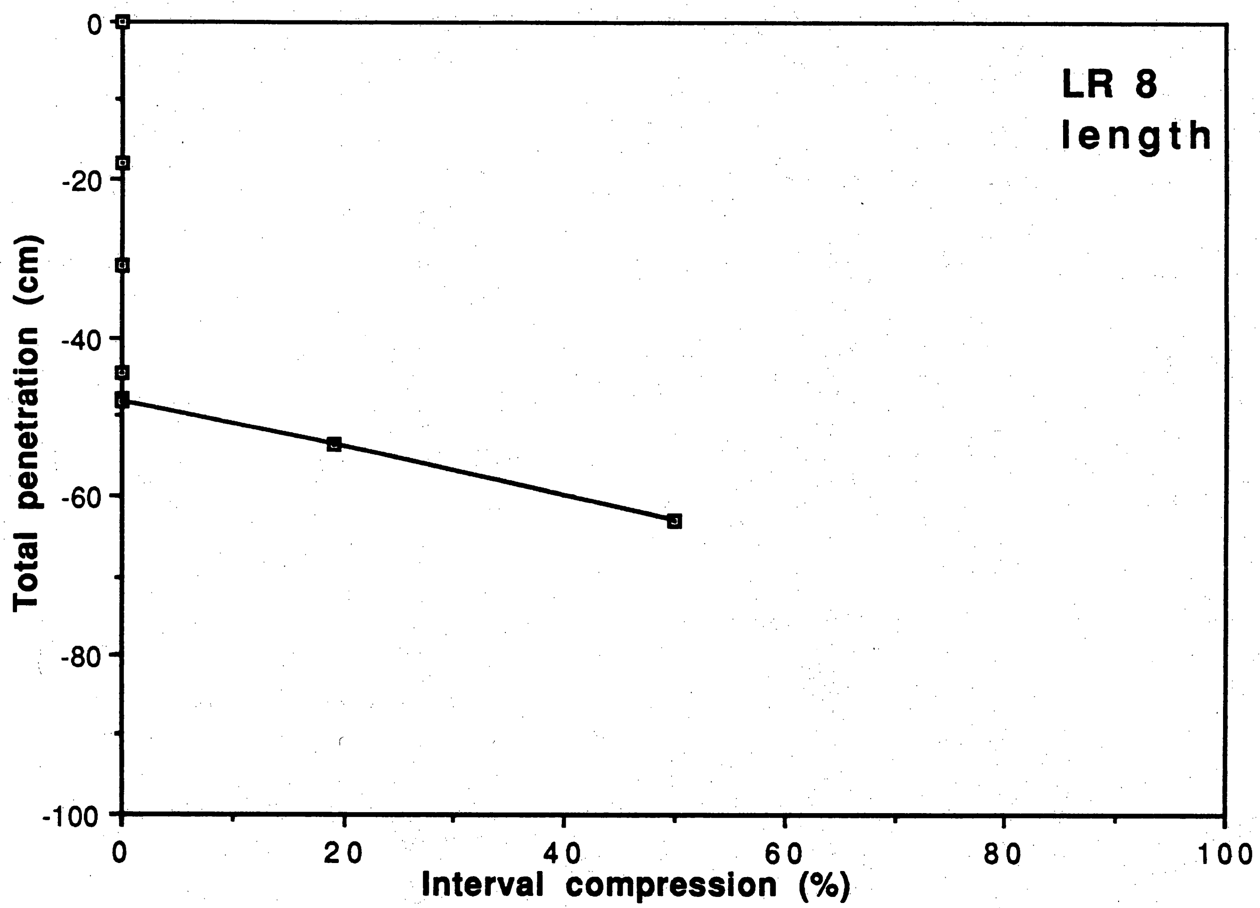

LR 7
length
0
-20
-40
-60
-80
-100
Total penetration (cm)
0
5
10
15
Cumulative compression (cm)



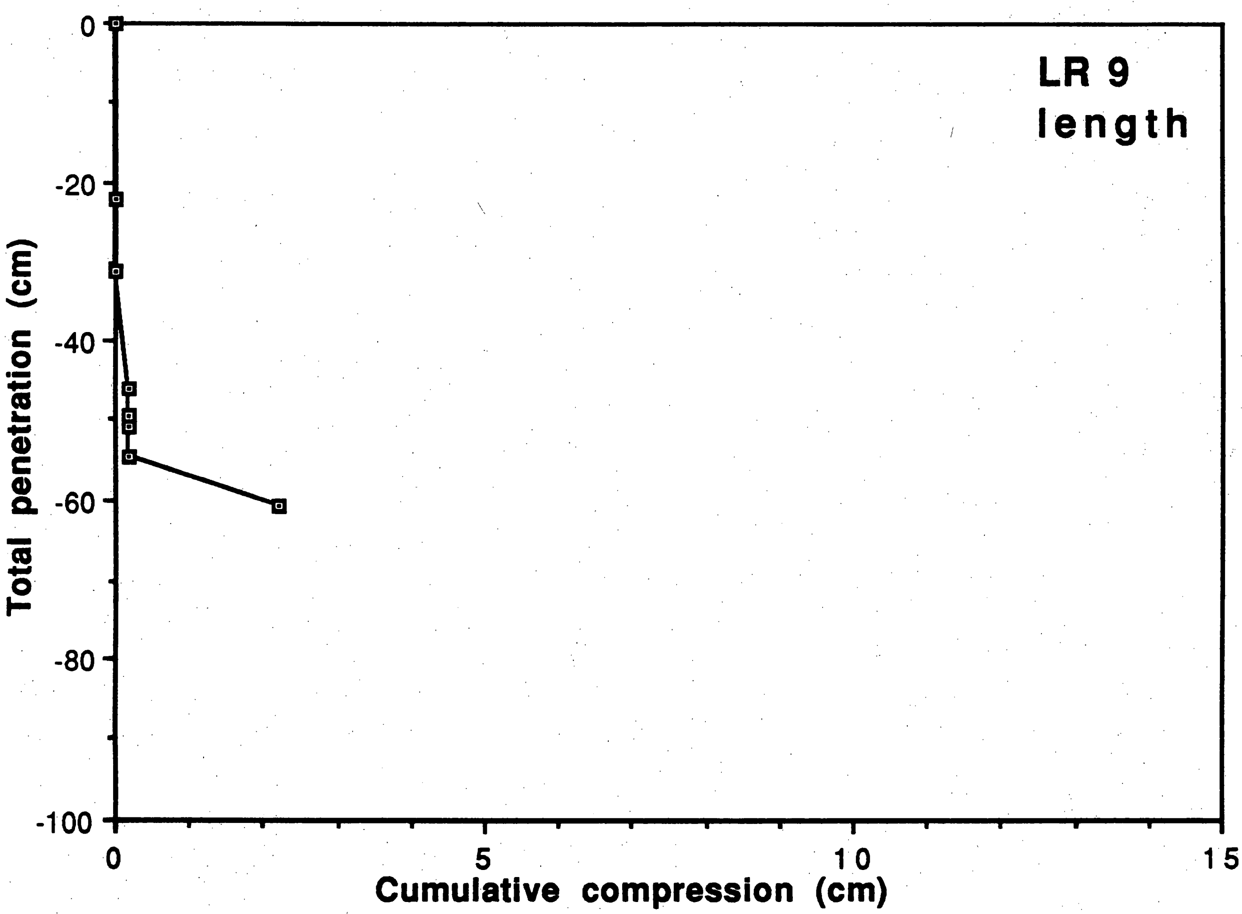
LR 7
length
Total penetration (cm)
0
-20
-40
-60
-80
-100
0
20
40
60
80
100
Interval compression (%)

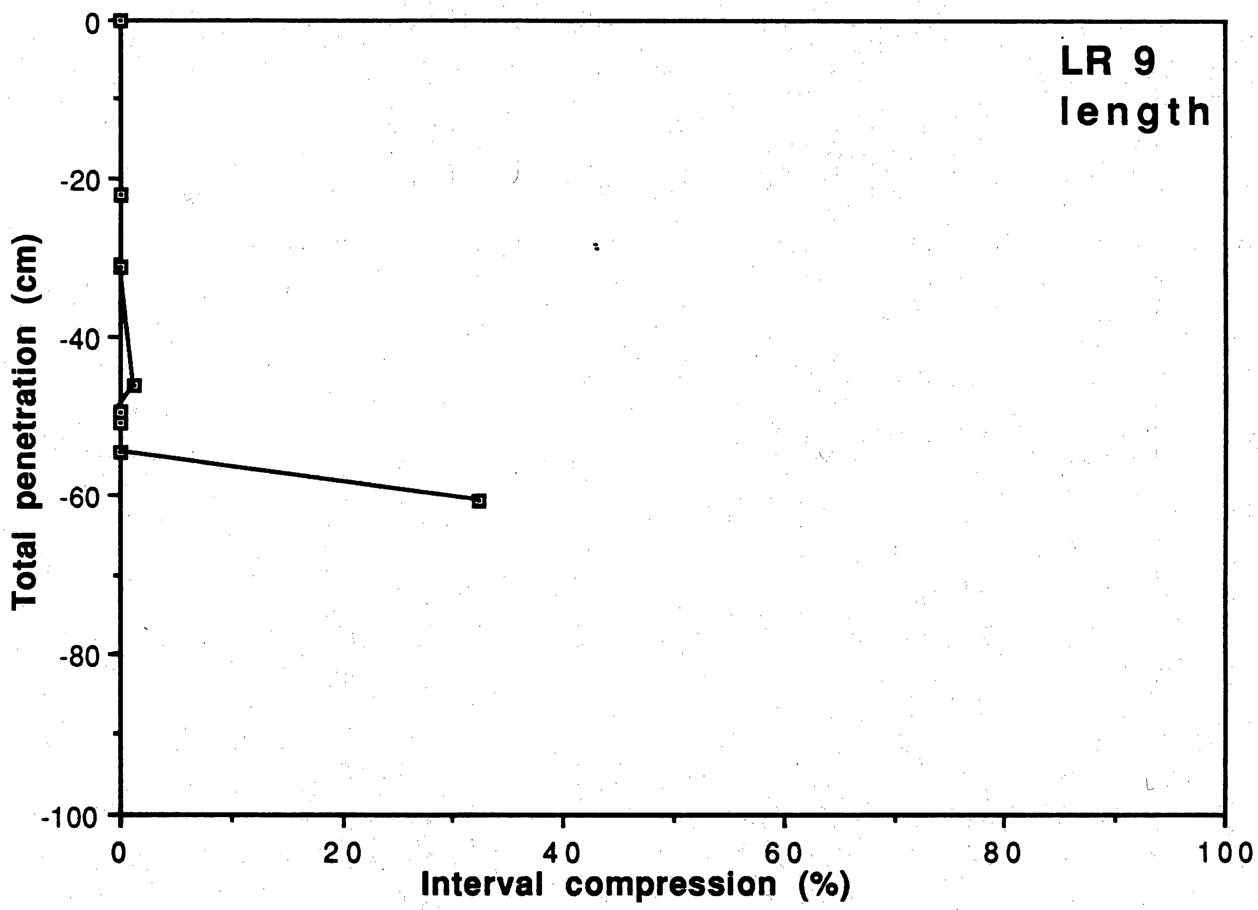


LR 8
length
Total penetration (cm)
Cumulative compression (cm)
0
-20
-40
-60
-80
-100
0
5
10
15

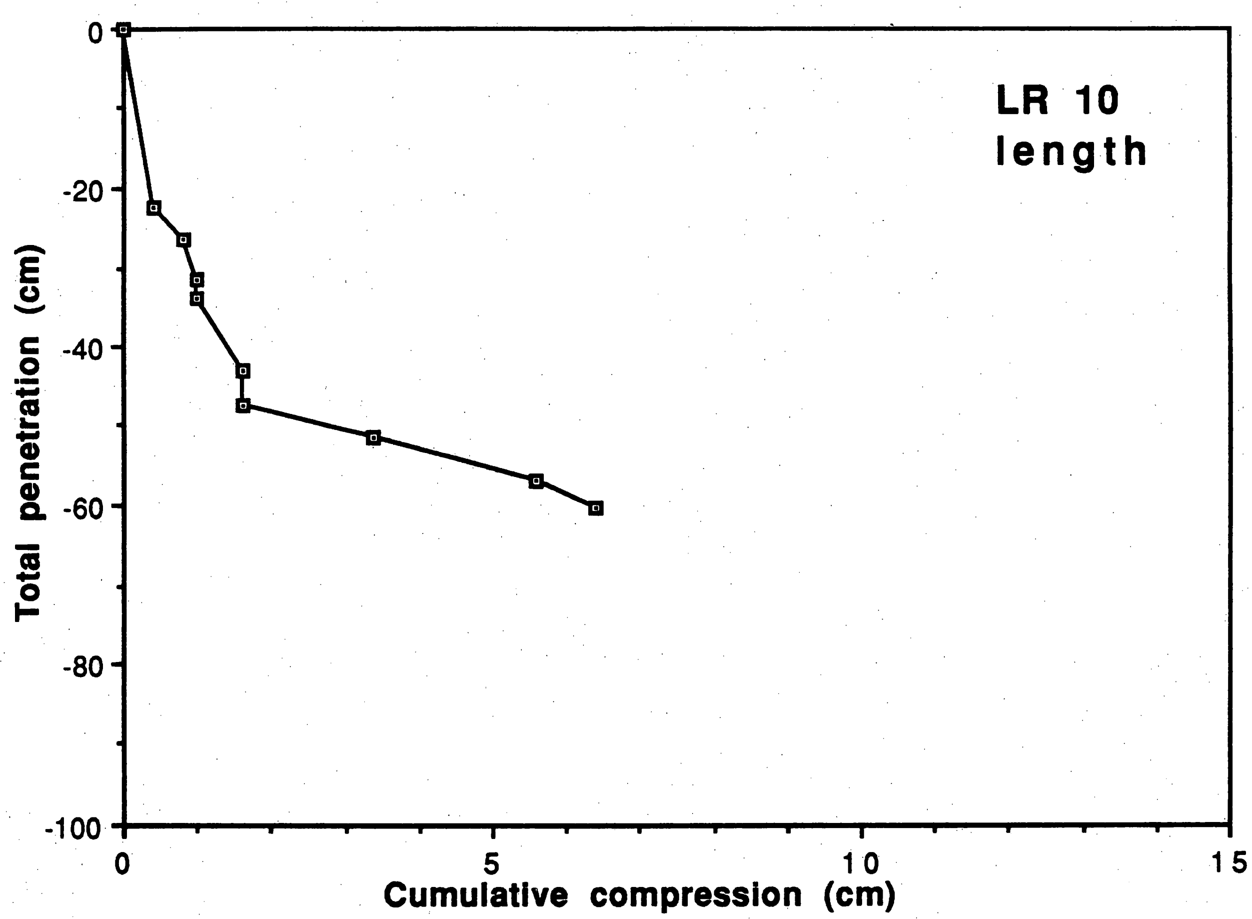


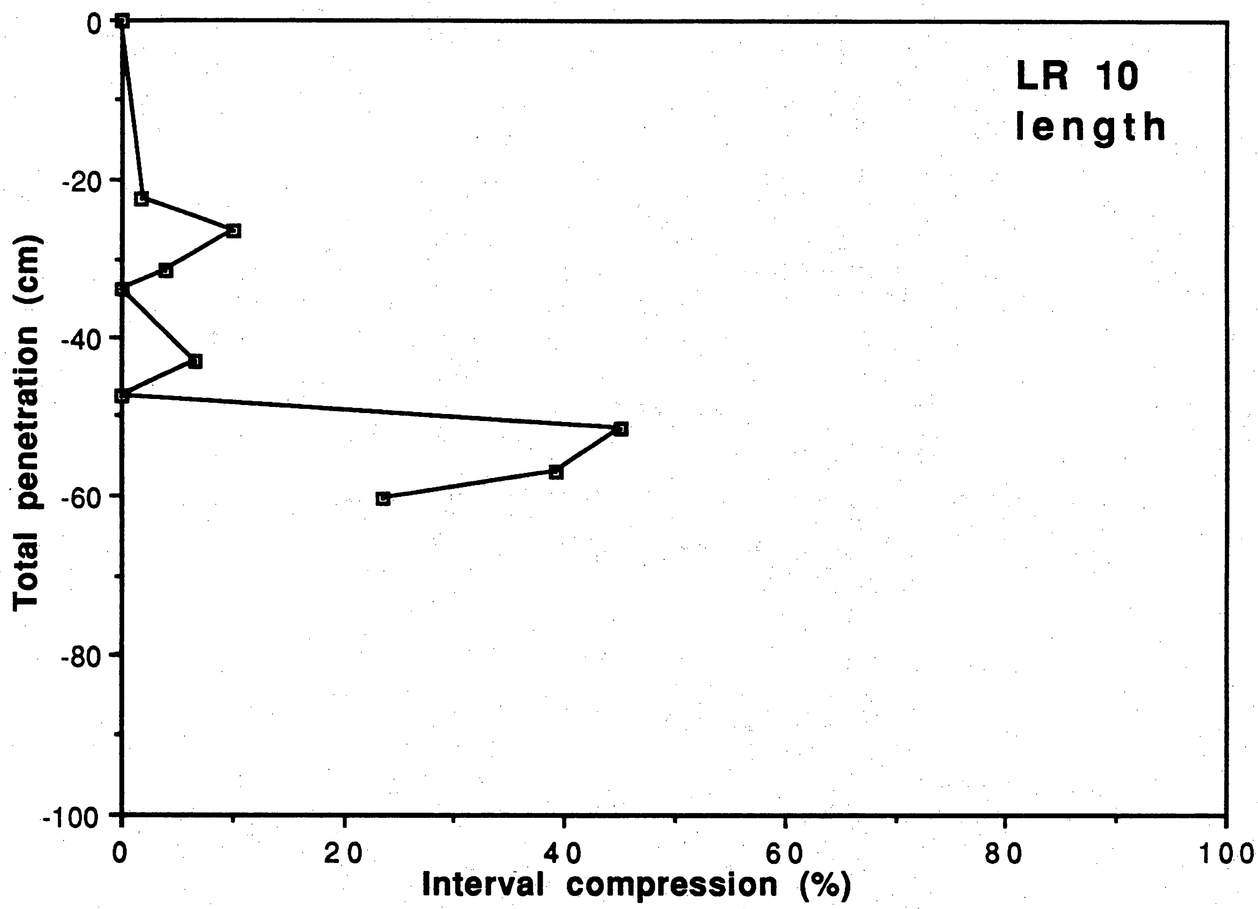
LR 8
length
Total penetration (cm)
0
-20
-40
-60
-80
-100
0
20
40
60
80
100
Interval compression (%)


LR 9
length
0
-20
-40
-60
-80
-100
Total penetration (cm)
0
5
10
15
Cumulative compression (cm)



LR 9
length
0
-20
-40
-60
-80
-100
Total penetration (cm)
0
20
40
60
80
100
Interval compression (%)


LR 10
length
Total penetration (cm)
0
-20
-40
-60
-80
-100
0
5
10
15
Cumulative compression (cm)



LR 10
length
Total penetration (cm)
Interval compression (%)
0
-20
-40
-60
-80
-100
0
20
40
60
80
100

APPENDIX B

Excess ^{210}Pb, Water Content, LOI, Bulk Density and Depth Corrections from Compression

Core No.	Sample No.	Uncorr Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-1	1	2.00	2.00	64.45	25.44	60.53	33.99	5.48	0.65	0.26	6.0226	07/19/94
LR-1	2	4.00	4.00	60.13	27.43	54.38	25.35	20.27	0.61	0.28	5.3671	07/19/94
LR-1	3	6.00	6.00	103.95	58.85	43.39	14.65	41.96	1.06	0.60	3.7317	07/19/94
LR-1	4	8.00	8.00	100.09	61.39	38.67	11.64	49.69	1.02	0.62	2.7748	07/20/94
LR-1	5	10.00	10.00	99.60	65.83	33.91	8.37	57.72	1.01	0.67	1.8496	07/21/94
LR-1	6	12.00	12.00	155.75	112.18	27.97	6.35	65.68	1.58	1.14	0.6731	07/20/94
LR-1	7	14.00	14.00	141.87	104.70	26.20	5.95	67.85	1.44	1.06	1.1539	07/20/94
LR-1	8	16.00	16.00	175.04	129.40	26.07	5.53	68.40	1.78	1.31	0.5663	07/20/94
LR-1	9	18.00	18.00	131.68	97.29	26.12	4.75	69.13	1.34	0.99	0.3552	07/21/94
LR-1	10	20.00	20.00	165.83	122.98	25.84	5.34	68.82	1.68	1.25	0.4461	07/21/94
LR-1	11	22.00	22.00	155.63	115.48	25.80	5.12	69.08	1.58	1.17	0.4207	07/21/94
LR-1	12	24.00	24.00	161.27	120.08	25.54	4.93	69.53	1.64	1.22	0.4590	07/20/94
LR-1	13	26.00	26.00	154.12	116.17	24.62	4.93	70.45	1.56	1.18	0.4275	07/21/94
LR-1	14	28.00	28.00	165.24	125.63	23.97	4.76	71.27	1.68	1.28	0.3988	07/20/94
LR-1	15	30.00	30.00	165.87	127.37	23.21	4.34	72.45	1.68	1.29	0.4068	07/21/94
LR-1	16	32.00	32.00	177.61	137.76	22.44	3.77	73.79	1.80	1.40	0.4924	07/21/94
LR-1	17	34.00	34.00	165.73	129.07	22.12	4.13	73.75	1.68	1.31	0.3804	07/21/94
LR-1	18	36.00	36.00	184.23	144.73	21.44	3.94	74.62	1.87	1.47	0.3926	07/20/94
LR-1	19	38.00	38.00	184.34	144.05	21.86	3.59	74.55	1.87	1.46	0.4149	07/25/94
LR-1	20	40.00	40.00	155.49	121.60	21.80	4.36	73.84	1.58	1.23	0.4081	07/21/94
LR-1	21	42.00	42.00	159.81	125.05	21.75	4.36	73.89	1.62	1.27	0.3678	07/21/94
LR-1	22	44.00	44.00	183.54	144.64	21.19	3.75	75.06	1.86	1.47	0.3796	07/25/94
LR-1	23	46.00	46.00	170.20	134.81	20.79	3.56	75.65	1.73	1.37	0.5119	07/21/94
LR-1	24	48.00	48.00	163.13	130.56	19.97	3.17	76.86	1.66	1.33	0.3071	07/25/94
LR-1	25	50.00	50.00	168.07	136.11	19.02	3.60	77.38	1.71	1.38	0.4151	07/22/94
LR-1	26	52.00	52.00	174.27	140.65	19.29	3.00	77.71	1.77	1.43	0.4616	07/25/94
LR-1	27	54.00	54.00	171.78	137.33	20.05	3.00	76.95	1.74	1.39	0.7396	07/22/94
LR-1	28	56.00	56.00	180.96	143.47	20.72	2.40	76.88	1.84	1.46	0.6734	07/22/94
LR-1	29	58.00	58.00	202.45	162.79	19.59	2.35	78.06	2.05	1.65	0.4735	07/22/94
LR-1	30	60.00	60.00	199.10	161.61	18.83	3.57	77.60	2.02	1.64	0.4423	07/22/94
LR-1	31	62.00	62.00	187.29	149.08	20.40	3.57	76.03	1.90	1.51	0.4007	07/22/94
LR-1	32	64.00	64.00	181.69	138.28	23.89	3.17	72.94	1.84	1.40	0.4063	07/25/94
LR-1	33	66.00	66.00	194.27	152.75	21.37	2.97	75.66	1.97	1.55	0.3844	07/25/94
LR-1	34	68.00	68.00	193.72	153.66	20.68	2.77	76.55	1.97	1.56	0.3832	07/25/94
LR-1	35	70.00	70.00	175.23	139.78	20.23	3.17	76.60	1.78	1.42	0.4604	07/22/94
LR-1	36	72.00	72.00	173.94	138.92	20.13	2.20	77.67	1.77	1.41	0.5919	07/25/94
LR-1	37	74.00	74.00	179.06	143.41	19.91	1.80	78.29	1.82	1.46	0.5034	07/25/94
LR-1	38	76.00	76.00	191.24	154.92	18.99	1.80	79.21	1.94	1.57	0.4376	07/25/94
LR-1	39	78.00	78.00	195.24	157.65	19.25	0.99	79.76	1.98	1.60	0.2995	07/25/94
LR-1	40	80.00	80.00	177.07	144.53	18.38	1.18	80.44	1.80	1.47	0.2786	07/25/94
LR-1	41	82.00	82.00	152.26	119.23	21.69	1.58	76.73	1.55	1.21	0.3868	07/25/94
LR-1	42	84.00	84.00	156.75	124.53	20.56	1.80	77.64	1.59	1.26	0.4218	07/25/94

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-2	1	1.00	1.00	46.43	23.97	48.37	17.33	34.30	1.09	0.56	3.6048	05/20/94
LR-2	2	2.00	2.00	36.90	19.58	46.94	16.97	36.10	0.87	0.46	3.8552	05/20/94
LR-2	3	3.00	3.00	55.83	29.43	47.29	16.00	36.71	1.31	0.69	3.6575	05/20/94
LR-2	4	4.00	4.00	45.45	23.71	47.83	14.96	37.21	1.07	0.56	3.4974	05/20/94
LR-2	5	5.00	5.00	52.92	28.54	46.07	12.77	41.16	1.25	0.67	3.1791	05/20/94
LR-2	6	6.00	6.00	43.30	23.00	46.88	12.90	40.22	1.02	0.54	3.3046	05/20/94
LR-2	7	7.00	7.00	47.59	25.23	46.98	13.17	39.84	1.12	0.59	3.1375	05/21/94
LR-2	8	8.00	8.00	43.55	22.35	48.68	14.48	36.84	1.03	0.53	3.1956	05/21/94
LR-2	9	9.00	9.00	49.91	25.02	49.87	14.65	35.48	1.18	0.59	3.5688	05/21/94
LR-2	10	10.00	10.00	46.34	22.26	51.96	16.37	31.67	1.09	0.52	3.4127	05/21/94
LR-2	11	11.00	11.00	50.21	24.47	51.26	16.44	32.30	1.18	0.58	2.7865	05/21/94
LR-2	12	12.00	12.00	46.26	22.68	50.97	16.96	32.06	1.09	0.53	2.7452	05/21/94
LR-2	13	13.00	13.00	63.53	29.13	54.15	15.25	30.60	1.50	0.69	2.6523	05/21/94
LR-2	14	14.00	14.00	48.69	22.74	53.30	16.77	29.94	1.15	0.54	2.2534	05/21/94
LR-2	15	15.00	15.00	43.03	13.66	68.25	13.24	18.50	1.01	0.32	2.1928	05/21/94
LR-2	16	16.00	16.00	69.75	39.36	43.57	11.75	44.68	1.64	0.93	2.1713	05/21/94
LR-2	17	17.00	17.00	50.91	28.83	43.37	11.11	45.52	1.20	0.68	2.1105	05/21/94
LR-2	18	18.00	18.00	60.73	34.37	43.41	10.34	46.26	1.43	0.81	1.8753	05/23/94
LR-2	19	19.00	19.00	69.96	39.94	42.91	10.93	46.16	1.65	0.94	2.1507	05/23/94
LR-2	20	20.00	20.00	64.47	38.42	40.41	9.09	50.50	1.52	0.90	1.7262	05/23/94
LR-2	21	21.00	21.00	80.32	50.26	37.43	8.32	54.26	1.89	1.18	1.4070	05/23/94
LR-2	22	22.00	22.00	59.36	37.54	36.76	8.04	55.20	1.40	0.88	1.2481	05/23/94
LR-2	23	23.00	23.00	75.87	47.81	36.98	7.72	55.29	1.79	1.13	1.2289	05/23/94
LR-2	24	24.00	24.00	76.10	47.90	37.06	8.45	54.50	1.79	1.13	1.2386	05/23/94
LR-2	25	25.00	25.00	60.12	38.40	36.13	6.93	56.94	1.42	0.90	1.1421	05/23/94
LR-2	26	26.00	26.00	97.83	63.69	34.90	6.14	58.96	2.30	1.50	1.0661	05/23/94
LR-2	27	27.00	27.00	48.47	31.88	34.23	6.75	59.03	1.14	0.75	1.0703	05/23/94
LR-2	28	28.00	28.00	66.37	43.82	33.98	5.53	60.49	1.56	1.03	1.1299	05/23/94
LR-2	29	29.00	29.00	89.82	59.28	34.00	4.94	61.06	2.11	1.40	1.0483	05/24/94
LR-2	30	30.00	30.12	81.48	53.38	34.49	5.35	60.17	1.92	1.26	1.0591	05/24/94
LR-2	31	31.00	31.24	62.01	40.66	34.43	5.33	60.24	1.46	0.96	1.0598	05/24/94
LR-2	32	32.00	32.36	63.05	41.95	33.47	6.19	60.35	1.48	0.99	1.0658	05/24/94
LR-2	33	33.00	33.48	79.62	52.69	33.82	5.94	60.24	1.87	1.24	1.0511	05/24/94
LR-2	34	34.00	34.60	73.23	48.29	34.06	6.13	59.82	1.72	1.14	0.9951	05/24/94
LR-2	35	35.00	35.90	72.33	47.59	34.20	6.18	59.62	1.70	1.12	1.0216	05/24/94
LR-2	36	36.00	37.20	88.56	58.83	33.57	5.58	60.85	2.09	1.39	0.9670	05/24/94
LR-2	36-38	38.00	39.23	167.40	110.02	34.28	5.96	59.76	1.97	1.30	0.9590	05/24/94
LR-2	38-40	40.00	41.26	130.95	86.29	34.10	5.98	59.92	1.54	1.02	1.0281	05/24/94
LR-2	40-42	42.00	43.29	162.54	106.79	34.30	5.77	59.94	1.91	1.26	0.9088	05/25/94
LR-2	42-44	44.00	45.31	139.49	91.66	34.29	6.13	59.58	1.64	1.08	0.8684	05/25/94
LR-2	44-46	46.00	47.34	154.96	99.99	35.47	5.74	58.78	1.82	1.18	0.9254	05/25/94
LR-2	46-48	48.00	49.37	148.01	94.03	36.47	5.33	58.20	1.74	1.11	0.8944	05/25/94
LR-2	48-50	50.00	51.40	144.20	90.37	37.33	5.77	56.90	1.70	1.06	0.9962	05/25/94
LR-2	50-52	52.00	53.58	128.71	76.32	40.70	6.13	53.17	1.52	0.90	0.9968	05/25/94
LR-2	52-54	54.00	55.75	132.66	74.85	43.58	5.98	50.45	1.56	0.88	1.0575	05/25/94
LR-2	54-56	56.00	57.93	137.76	81.47	40.86	5.38	53.76	1.62	0.96	0.9243	05/25/94
LR-2	56-58	58.00	60.00	136.67	83.44	38.95	5.36	55.70	1.61	0.98	0.9685	05/25/94
LR-2	58-60	60.00	62.00	140.22	88.35	36.99	5.73	57.28	1.65	1.04	0.9304	05/25/94
LR-2	60-62	62.00	64.00	168.33	104.16	38.12	5.99	55.89	1.98	1.23	0.9769	05/25/94
LR-2	62-64	64.00	66.00	142.61	89.14	37.49	5.58	56.93	1.68	1.05	0.9383	05/27/94
LR-2	64-66	66.00	68.21	142.97	88.84	37.86	5.78	56.36	1.68	1.05	0.7931	05/27/94
LR-2	66-68	68.00	70.90	138.98	86.52	37.75	5.34	56.92	1.64	1.02	1.0450	05/27/94
LR-2	68-70	70.00	73.59	143.12	88.87	37.91	5.56	56.54	1.68	1.05	0.7267	05/26/94

LR-3

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-3	1	1.00	1.00	16.29	7.37	54.76	28.29	16.96	0.37	0.17	7.7866	05/06/94
LR-3	2	2.00	2.00	21.90	10.91	50.18	20.32	29.50	0.50	0.25	5.7178	05/06/94
LR-3	3	3.00	3.00	22.68	11.25	50.40	22.77	26.83	0.51	0.25	5.5100	05/06/94
LR-3	4	4.00	4.00	19.97	9.38	53.03	19.68	27.29	0.45	0.21	4.3128	05/06/94
LR-3	5	5.00	5.00	18.69	8.77	53.08	18.13	28.80	0.42	0.20	3.8328	05/06/94
LR-3	6	6.00	6.00	47.15	22.41	52.47	16.44	31.09	1.07	0.51	3.1656	05/06/94
LR-3	7	7.00	7.00	52.20	24.69	52.70	17.55	29.74	1.18	0.56	3.2020	05/06/94
LR-3	8	8.00	8.00	64.74	32.83	49.29	16.60	34.11	1.47	0.74	3.1740	05/06/94
LR-3	9	9.00	9.00	78.20	41.92	46.39	15.71	37.90	1.77	0.95	3.0069	05/09/94
LR-3	10	10.00	10.00	55.06	30.29	44.99	14.91	40.10	1.25	0.69	3.0696	05/06/94
LR-3	11	11.00	11.00	74.10	43.50	41.30	11.98	46.73	1.68	0.99	2.0780	05/06/94
LR-3	12	12.00	12.00	77.90	48.42	37.84	9.86	52.29	1.77	1.10	1.4989	05/06/94
LR-3	13	13.00	13.00	56.48	35.42	37.29	8.07	54.64	1.28	0.80	1.3810	05/09/94
LR-3	14	14.00	14.00	82.58	52.61	36.29	8.70	55.01	1.87	1.19	1.3336	05/09/94
LR-3	15	15.00	15.00	76.56	49.38	35.50	7.51	56.99	1.74	1.12	1.2555	05/09/94
LR-3	16	16.00	16.00	78.19	50.91	34.89	7.72	57.39	1.77	1.15	1.2465	05/09/94
LR-3	17	17.00	17.00	82.39	53.23	35.39	7.37	57.24	1.87	1.21	1.2143	05/09/94
LR-3	18	18.00	18.00	54.50	34.95	35.87	8.17	55.96	1.24	0.79	1.3382	05/09/94
LR-3	18	19.00	19.00	50.49	32.54	35.55	8.30	56.15	1.14	0.74	1.1505	05/09/94
LR-3	20	20.00	20.00	88.28	57.56	34.80	6.69	58.51	2.00	1.30	0.9610	05/10/94
LR-3	21	21.00	21.00	83.80	55.21	34.12	6.15	59.73	1.90	1.25	0.9635	05/09/94
LR-3	22	22.00	22.00	89.83	59.80	33.43	6.18	60.39	2.04	1.36	0.9095	05/09/94
LR-3	23	23.00	23.00	100.25	66.89	33.28	5.14	61.58	2.27	1.52	0.9239	05/09/94
LR-3	24	24.00	24.00	81.93	54.59	33.37	9.34	57.29	1.86	1.24	0.8523	05/10/94
LR-3	25	25.00	25.00	65.57	43.68	33.38	4.38	62.23	1.49	0.99	0.9224	05/10/94
LR-3	25-27	27.00	27.00	174.58	116.07	33.51	5.59	60.90	1.98	1.32	0.9291	05/10/94
LR-3	27-29	29.00	29.00	143.47	95.86	33.18	5.46	61.36	1.63	1.09	0.8419	05/10/94
LR-3	29-31	31.00	31.00	135.07	88.40	34.55	4.58	60.87	1.53	1.00	0.9610	05/10/94
LR-3	31-33	33.00	33.00	177.52	119.76	32.54	5.57	61.90	2.01	1.36	0.8049	05/10/94
LR-3	33-35	35.00	35.00	153.77	97.60	36.53	6.35	57.12	1.74	1.11	0.8403	05/12/94
LR-3	35-37	37.00	37.00	143.14	90.13	37.03	5.53	57.43	1.62	1.02	0.9475	05/10/94
LR-3	37-39	39.00	39.00	134.78	84.48	37.32	3.80	58.88	1.53	0.96	0.8713	05/10/94
LR-3	39-41	41.00	41.00	168.79	104.96	37.82	4.55	57.63	1.91	1.19	0.8073	05/12/94
LR-3	41-43	43.00	43.00	139.66	86.97	37.73	5.19	57.08	1.58	0.99	0.8700	05/12/94
LR-3	43-45	45.00	45.00	164.33	101.45	38.26	7.57	54.17	1.86	1.15	0.7533	05/12/94
LR-3	45-47	47.00	47.00	153.03	92.81	39.35	6.37	54.27	1.73	1.05	0.7979	05/12/94
LR-3	47-49	49.00	49.18	132.33	80.95	38.83	5.58	55.60	1.50	0.92	0.6690	05/12/94
LR-3	49-51	51.00	51.36	165.05	104.02	36.98	6.75	56.28	1.87	1.18	0.6534	05/12/94
LR-3	51-53	53.00	53.57	159.39	100.26	37.10	4.77	58.13	1.81	1.14	0.7570	05/12/94
LR-3	53-55	55.00	55.79	142.92	89.00	37.73	3.96	58.31	1.62	1.01	0.7692	05/16/94
LR-3	55-57	57.00	58.00	166.08	104.44	37.11	3.56	59.33	1.88	1.18	0.7001	05/12/94
LR-3	57-59	59.00	60.00	150.92	96.37	36.14	4.57	59.28	1.71	1.09	0.7393	05/12/94
LR-3	59-61	61.00	62.00	156.45	100.21	35.95	4.38	59.67	1.77	1.14	0.8025	05/16/94
LR-3	61-63	63.00	64.00	164.66	105.37	36.01	4.35	59.64	1.87	1.19	0.7469	05/16/94

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-4	1	1.00	1.00	42.58	28.46	33.16	12.08	54.76	0.86	0.58	2.1170	05/16/94
LR-4	2	2.00	2.00	74.14	52.06	29.78	10.34	59.88	1.51	1.06	2.0490	05/13/94
LR-4	3	3.00	3.00	79.03	57.68	27.02	8.20	64.78	1.60	1.17	1.7261	05/13/94
LR-4	4	4.00	4.00	77.69	57.02	26.61	7.16	66.24	1.58	1.16	1.2873	05/13/94
LR-4	5	5.00	5.00	82.77	60.87	26.46	6.77	66.77	1.68	1.24	1.0291	05/13/94
LR-4	6	6.00	6.00	87.45	64.20	26.59	6.76	66.65	1.78	1.30	0.8266	05/16/94
LR-4	7	7.00	7.00	84.69	63.15	25.43	6.55	68.02	1.72	1.28	0.7050	05/13/94
LR-4	8	8.00	8.00	95.23	71.16	25.28	6.32	68.40	1.93	1.44	0.6507	05/13/94
LR-4	9	9.00	9.00	80.53	60.71	24.61	5.16	70.23	1.63	1.23	0.5227	05/13/94
LR-4	10	10.00	10.00	82.52	62.46	24.31	4.58	71.11	1.68	1.27	0.4712	05/16/94
LR-4	11	11.00	11.00	106.45	81.28	23.64	5.58	70.78	2.16	1.65	0.4709	05/16/94
LR-4	12	12.00	12.00	81.61	62.53	23.38	5.17	71.45	1.66	1.27	1.0988	05/16/94
LR-4	13	13.00	13.00	75.06	57.37	23.57	4.54	71.90	1.52	1.16	0.3706	05/18/94
LR-4	14	14.00	14.02	93.94	72.18	23.16	4.57	72.26	1.91	1.47	0.4385	05/16/94
LR-4	15	15.00	15.11	72.20	55.39	23.28	4.57	72.14	1.47	1.12	0.3709	05/16/94
LR-4	16	16.00	16.20	92.32	71.21	22.87	4.35	72.79	1.87	1.45	0.4301	05/16/94
LR-4	17	17.00	17.30	105.72	81.57	22.84	4.55	72.61	2.15	1.66	0.3967	05/18/94
LR-4	18	18.00	18.39	93.63	72.37	22.71	4.17	73.12	1.90	1.47	0.4144	05/18/94
LR-4	19	19.00	19.48	77.09	59.97	22.21	6.79	71.01	1.56	1.22	0.4536	05/18/94
LR-4	20	20.00	20.58	106.88	83.31	22.05	6.13	71.82	2.17	1.69	0.3823	05/18/94
LR-4	21	21.00	21.67	87.13	68.11	21.83	3.99	74.18	1.77	1.38	0.4110	05/18/94
LR-4	22	22.00	22.76	80.03	62.59	21.79	3.75	74.45	1.62	1.27	0.3895	05/18/94
LR-4	23	23.00	23.20	107.24	84.06	21.62	3.19	75.20	2.18	1.71	0.4036	05/18/94
LR-4	24	24.00	23.80	95.00	74.09	22.01	2.98	75.01	1.93	1.50	0.3460	05/19/94
LR-4	25	25.00	24.80	80.95	63.27	21.84	3.97	74.19	1.64	1.28	0.4187	05/18/94
LR-4	25-27	27.00	27.80	145.95	114.75	21.38	4.40	74.22	1.48	1.16	0.4320	05/18/94
LR-4	27-29	29.00	29.80	162.53	126.75	22.01	3.18	74.80	1.65	1.29	0.4347	05/18/94
LR-4	29-31	31.00	31.80	198.39	154.41	22.17	2.97	74.86	2.01	1.57	0.4427	05/19/94
LR-4	31-33	33.00	33.80	172.86	135.85	21.41	2.57	76.02	1.75	1.38	0.5057	05/19/94
LR-4	33-35	35.00	35.80	204.81	163.32	20.26	3.97	75.77	2.08	1.66	0.4594	05/19/94
LR-4	35-37	37.00	37.80	163.99	130.78	20.25	3.18	76.57	1.66	1.33	0.4085	05/19/94
LR-4	37-39	39.00	39.83	213.56	169.86	20.46	2.98	76.56	2.17	1.72	0.4635	05/19/94
LR-4	39-41	41.00	41.98	170.64	136.94	19.75	2.19	78.06	1.73	1.39	0.4702	05/19/94
LR-4	41-43	43.00	44.13	214.85	173.88	19.07	2.96	77.97	2.18	1.76	0.4609	05/20/94
LR-4	43-45	45.00	46.41	193.49	157.10	18.81	3.17	78.02	1.96	1.59	0.4645	05/19/94
LR-4	45-47	47.00	48.82	183.07	148.71	18.77	2.96	78.27	1.86	1.51	0.4143	05/19/94
LR-4	47-49	49.00	51.23	184.28	149.30	18.98	2.38	78.64	1.87	1.52	0.5290	05/19/94
LR-4	49-51	51.00	53.67	186.03	151.19	18.73	3.54	77.74	1.89	1.53	0.5201	05/20/94
LR-4	51-53	53.00	56.37	190.47	155.40	18.41	3.17	78.41	1.93	1.58	0.4912	05/20/94
LR-4	53-55	55.00	59.02	196.38	161.78	17.62	3.16	79.22	1.99	1.64	0.4456	05/20/94
LR-4	55-57	57.00	61.26	182.63	149.55	18.11	2.96	78.93	1.85	1.52	0.5433	05/20/94

LR-5

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-5	1	1.00	1.00	80.59	60.99	24.32	5.95	69.73	1.70	1.28	0.8187	06/09/94
LR-5	2	2.00	2.00	80.39	61.43	23.59	5.54	70.87	1.69	1.29	0.9490	06/09/94
LR-5	3	3.00	3.00	73.30	53.85	26.53	8.53	64.93	1.54	1.13	2.3228	06/09/94
LR-5	4	4.00	4.00	83.41	61.36	26.44	7.91	65.66	1.76	1.29	2.4264	06/09/94
LR-5	5	5.00	5.00	101.74	80.79	20.59	4.37	75.04	2.14	1.70	0.8740	06/09/94
LR-5	6	6.00	6.00	90.72	75.14	17.17	3.16	79.66	1.91	1.58	0.4663	06/09/94
LR-5	7	7.00	7.00	93.80	78.43	16.39	2.58	81.03	1.97	1.65	0.4186	06/09/94
LR-5	8	8.00	8.00	97.93	81.61	16.66	2.79	80.55	2.06	1.72	0.4501	06/09/94
LR-5	9	9.00	9.00	88.13	72.74	17.46	2.96	79.58	1.85	1.53	0.3958	06/09/94
LR-5	10	10.00	10.00	82.21	67.43	17.98	2.99	79.03	1.73	1.42	0.3693	06/09/94
LR-5	11	11.00	11.00	101.43	82.52	18.64	2.98	78.37	2.13	1.74	0.4063	06/09/94
LR-5	12	12.00	12.00	96.20	78.05	18.87	3.38	77.75	2.02	1.64	0.3765	06/09/94
LR-5	13	13.00	13.00	90.77	73.63	18.88	3.18	77.94	1.91	1.55	0.3620	06/13/94
LR-5	14	14.00	14.00	91.10	74.19	18.56	2.95	78.49	1.92	1.56	0.3071	06/13/94
LR-5	15	15.00	15.00	85.83	70.32	18.07	3.55	78.38	1.81	1.48	0.3534	06/13/94
LR-5	16	16.00	16.00	83.13	68.32	17.82	3.19	78.99	1.75	1.44	0.3349	06/13/94
LR-5	17	17.00	17.00	96.09	79.01	17.78	3.19	79.04	2.02	1.66	0.3215	06/13/94
LR-5	18	18.00	18.00	98.34	81.39	17.24	3.39	79.38	2.07	1.71	0.2987	06/13/94
LR-5	19	19.00	19.00	102.37	84.96	17.01	3.38	79.61	2.15	1.79	0.3107	06/13/94
LR-5	20	20.00	20.00	68.56	57.37	16.32	3.19	80.49	1.44	1.21	0.2014	06/13/94
LR-5	21	21.00	21.02	101.93	85.38	16.24	3.36	80.40	2.15	1.80	0.2758	06/13/94
LR-5	22	22.00	22.05	92.43	77.30	16.37	2.76	80.87	1.95	1.63	0.3382	06/13/94
LR-5	23	23.00	23.09	93.32	77.98	16.44	2.95	80.61	1.96	1.64	0.2614	06/13/94
LR-5	24	24.00	24.12	86.25	72.02	16.50	2.59	80.91	1.82	1.52	0.2350	06/16/94
LR-5	25	25.00	25.15	99.59	83.63	16.03	2.60	81.37	2.10	1.76	0.3191	06/16/94
LR-5	26	26.00	26.19	86.87	72.97	16.00	2.77	81.23	1.83	1.54	0.2572	06/16/94
LR-5	27	27.00	27.22	85.64	72.06	15.86	1.99	82.15	1.80	1.52	0.2462	06/16/94
LR-5	28	28.00	28.25	95.07	79.86	16.00	1.98	82.02	2.00	1.68	0.2357	06/16/94
LR-5	29	29.00	29.29	85.42	71.82	15.92	21.76	62.31	1.80	1.51	0.3150	06/16/94
LR-5	30	30.00	30.32	60.53	51.14	15.51	1.99	82.50	1.27	1.08	0.2473	06/16/94
LR-5	31	31.00	31.35	110.13	93.39	15.20	1.59	83.21	2.32	1.97	0.2392	06/16/94
LR-5	32	32.00	32.39	104.27	88.36	15.26	1.39	83.36	2.19	1.86	0.2399	06/16/94
LR-5	33	33.00	33.42	107.94	91.81	14.94	1.59	83.46	2.27	1.93	0.2368	06/16/94
LR-5	34	34.00	34.46	84.39	71.90	14.80	1.59	83.61	1.78	1.51	0.2130	06/16/94
LR-5	35	35.00	35.50	99.46	84.08	15.46	1.79	82.75	2.09	1.77	0.2182	06/16/94
LR-5	36	36.00	36.54	79.40	67.51	14.97	1.80	83.23	1.67	1.42		
LR-5	36-38	38.00	38.61	194.26	164.94	15.09	1.96	82.95	2.04	1.74		
LR-5	38-40	40.00	40.69	176.13	147.92	16.02	1.66	82.32	1.85	1.56		
LR-5	40-42	42.00	42.76	204.89	170.18	16.94	2.18	80.88	2.16	1.79		
LR-5	42-44	44.00	44.82	173.54	142.63	17.81	2.56	79.63	1.83	1.50		
LR-5	44-46	46.00	46.85	209.23	151.30	27.69	1.78	70.53	2.20	1.59		
LR-5	46-48	48.00	48.88	187.62	174.90	6.78	1.79	91.43	1.97	1.84		
LR-5	48-50	50.00	50.91	183.04	148.61	18.81	1.78	79.41	1.93	1.56		
LR-5	50-52	52.00	52.95	196.25	157.39	19.80	1.58	78.62	2.07	1.66		
LR-5	52-54	54.00	54.98	193.24	155.36	19.60	2.40	78.00	2.03	1.63		
LR-5	54-56	56.00	57.00	203.47	164.04	19.38	2.16	78.46	2.14	1.73		
LR-5	56-58	58.00	59.00	196.73	155.89	20.76	2.19	77.05	2.07	1.64		
LR-5	58-60	60.00	61.04	148.16	115.03	22.36	1.78	75.86	1.56	1.21		
LR-5	60-62	62.00	63.16	204.78	161.16	21.30	2.19	76.51	2.15	1.70		
LR-5	62-64	64.00	65.24	205.21	159.93	22.07	2.18	75.75	2.16	1.68		
LR-5	64-66	66.00	67.30	178.21	138.93	22.04	2.17	75.79	1.88	1.46		
LR-5	66-68	68.00	69.35	179.35	141.44	21.14	2.58	76.28	1.89	1.49		

Core No	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-6	1	1.00	1.00	25.51	13.99	45.16	16.00	38.84	0.52	0.28	3.3222	06/17/94
LR-6	2	2.00	2.00	32.21	16.51	48.74	15.55	35.71	0.65	0.34	3.2433	06/17/94
LR-6	3	3.00	3.00	40.06	22.30	44.33	12.65	43.02	0.81	0.45	2.4478	06/17/94
LR-6	4	4.00	4.00	57.89	34.80	39.89	9.78	50.33	1.18	0.71	2.1681	06/17/94
LR-6	5	5.00	5.00	51.95	32.66	37.13	8.53	54.34	1.05	0.66	1.8452	06/17/94
LR-6	6	6.00	6.00	75.65	49.05	35.16	7.95	56.89	1.54	1.00	2.0510	06/17/94
LR-6	7	7.00	7.00	75.35	50.73	32.67	7.13	60.20	1.53	1.03	1.5016	06/17/94
LR-6	8	8.00	8.00	60.84	41.84	31.23	7.34	61.43	1.24	0.85	1.3782	06/17/94
LR-6	9	9.00	9.00	69.97	49.33	29.50	6.97	63.53	1.42	1.00	1.2787	06/17/94
LR-6	10	10.00	10.00	64.39	46.57	27.68	6.50	65.83	1.31	0.95	1.0667	06/17/94
LR-6	11	11.00	11.00	84.14	61.25	27.20	6.93	65.86	1.71	1.24	1.1483	06/17/94
LR-6	12	12.00	12.00	70.25	50.98	27.43	6.56	66.01	1.43	1.03	0.9779	06/17/94
LR-6	13	13.00	13.00	92.81	66.44	28.41	7.14	64.44	1.88	1.35	1.2449	06/20/94
LR-6	14	14.00	14.00	68.37	48.91	28.46	6.53	65.00	1.39	0.99	1.0712	06/20/94
LR-6	15	15.00	15.00	94.74	67.69	28.55	6.75	64.70	1.92	1.37	0.9809	06/20/94
LR-6	16	16.00	16.00	65.97	46.55	29.44	6.56	64.00	1.34	0.94	1.1412	06/20/94
LR-6	17	17.00	17.00	81.72	58.19	28.79	7.27	63.94	1.66	1.18	1.0110	06/20/94
LR-6	18	18.00	18.00	93.53	67.25	28.10	6.90	65.00	1.90	1.37	0.8529	06/20/94
LR-6	19	19.00	19.00	78.02	56.05	28.16	6.94	64.90	1.58	1.14	0.7477	06/21/94
LR-6	20	20.00	20.00	80.48	58.41	27.42	6.34	66.24	1.63	1.19	0.5925	06/20/94
LR-6	21	21.00	21.00	73.27	53.29	27.27	6.13	66.60	1.49	1.08	0.6477	06/20/94
LR-6	22	22.00	22.00	98.54	71.96	26.97	6.14	66.89	2.00	1.46	0.7046	06/20/94
LR-6	23	23.00	23.01	76.19	55.85	26.70	5.20	68.10	1.55	1.13	0.6538	06/20/94
LR-6	24	24.00	24.03	94.01	68.75	26.87	5.36	67.77	1.91	1.40	0.7040	06/21/94
LR-6	25	25.00	25.05	61.58	45.10	26.76	7.14	66.10	1.25	0.92	0.7212	06/21/94
LR-6	26	26.00	26.07	98.25	72.26	26.45	7.28	66.26	1.99	1.47	0.6884	06/21/94
LR-6	27	27.00	27.09	80.46	59.62	25.90	7.28	66.82	1.63	1.21	0.6740	06/21/94
LR-6	28	28.00	28.11	76.74	56.41	26.49	6.53	66.97	1.56	1.15	0.6509	06/21/94
LR-6	29	29.00	29.13	83.23	58.73	29.44	6.14	64.42	1.69	1.19	0.6482	06/23/94
LR-6	30	30.00	30.15	94.72	71.21	24.82	5.34	69.84	1.92	1.45	0.5958	06/21/94
LR-6	31	31.00	31.17	84.64	63.94	24.46	6.36	69.18	1.72	1.30	0.6692	06/21/94
LR-6	32	32.00	32.18	81.20	61.00	24.88	6.77	68.35	1.65	1.24	0.7358	06/21/94
LR-6	33	33.00	33.20	74.48	56.06	24.73	6.09	69.18	1.51	1.14	0.6720	06/21/94
LR-6	34	34.00	34.20	93.35	57.65	38.24	5.98	55.78	1.90	1.17	0.7140	06/21/94
LR-6	35	35.00	35.20	82.41	57.62	30.08	5.94	63.98	1.67	1.17	0.7085	06/23/94
LR-6	36	36.00	36.20	71.50	53.19	25.61	6.15	68.24	1.45	1.08	0.7844	06/23/94
LR-6	36-38	38.00	38.20	183.58	133.39	27.34	5.14	67.52	1.86	1.35	0.6777	06/23/94
LR-6	38-40	40.00	40.20	168.13	122.81	26.96	6.94	66.10	1.71	1.25	0.9267	06/23/94
LR-6	40-42	42.00	42.20	169.75	125.98	25.78	5.71	68.51	1.72	1.28	0.6886	06/23/94
LR-6	42-44	44.00	44.20	145.19	106.02	26.98	5.69	67.34	1.47	1.08	0.6237	06/23/94
LR-6	44-46	46.00	46.20	197.28	142.82	27.61	5.31	67.08	2.00	1.45	0.4438	06/23/94
LR-6	46-48	48.00	48.20	183.34	138.95	24.21	4.90	70.89	1.86	1.41	0.4288	06/23/94
LR-6	48-50	50.00	50.20	166.26	128.41	22.77	5.19	72.05	1.69	1.30	0.4465	06/23/94
LR-6	50-52	52.00	52.21	168.00	129.90	22.68	4.38	72.94	1.71	1.32	0.3949	06/23/94
LR-6	52-54	54.00	54.36	188.63	147.70	21.70	4.74	73.56	1.91	1.50	0.4270	06/23/94
LR-6	54-56	56.00	56.50	186.22	145.79	21.71	4.72	73.56	1.89	1.48	0.4617	06/24/94
LR-6	56-58	58.00	58.83	182.24	141.51	22.35	4.31	73.34	1.85	1.44	0.4445	06/24/94
LR-6	58-60	60.00	61.61	202.68	156.98	22.55	4.37	73.09	2.06	1.59	0.4758	06/23/94

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-7	1	1.00	1.00	60.11	43.03	28.41	13.47	58.12	1.36	0.98	2.8952	06/22/94
LR-7	2	2.00	2.00	60.05	42.19	29.74	11.53	58.73	1.36	0.96	2.4829	06/23/94
LR-7	3	3.00	3.00	71.04	50.46	28.97	11.09	59.94	1.61	1.14	2.3821	06/23/94
LR-7	4	4.00	4.00	68.13	48.63	28.62	10.93	60.44	1.54	1.10	1.7004	06/23/94
LR-7	5	5.00	5.00	75.14	53.90	28.27	12.06	59.68	1.70	1.22	2.0593	06/23/94
LR-7	6	6.00	6.00	61.14	43.90	28.20	10.52	61.29	1.39	0.99	1.3645	06/23/94
LR-7	7	7.00	7.00	90.70	65.65	27.62	10.24	62.15	2.06	1.49	1.2563	06/23/94
LR-7	8	8.00	8.00	69.16	50.46	27.04	10.34	62.62	1.57	1.14	1.2518	06/27/94
LR-7	9	9.00	9.00	73.05	53.69	26.50	9.88	63.62	1.66	1.22	1.3248	06/23/94
LR-7	10	10.00	10.00	66.42	48.44	27.07	9.41	63.52	1.51	1.10	1.0797	06/23/94
LR-7	11	11.00	11.00	73.63	53.17	27.79	9.72	62.49	1.67	1.21	1.1587	06/23/94
LR-7	12	12.00	12.00	67.25	48.26	28.24	9.50	62.26	1.52	1.09	1.1698	06/23/94
LR-7	13	13.00	13.00	77.80	55.91	28.14	9.31	62.56	1.76	1.27	0.9832	06/23/94
LR-7	14	14.00	14.00	70.24	50.78	27.71	9.70	62.59	1.59	1.15	1.1268	06/23/94
LR-7	15	15.00	15.00	76.42	55.00	28.03	9.72	62.25	1.73	1.25	0.9906	06/24/93
LR-7	16	16.00	16.00	65.78	47.36	28.00	8.91	63.09	1.49	1.07	1.0241	06/24/93
LR-7	17	17.00	17.00	74.84	54.12	27.69	9.70	62.61	1.70	1.23	0.8071	06/24/93
LR-7	18	18.00	18.00	73.13	52.77	27.84	9.50	62.65	1.66	1.20	0.5078	06/24/93
LR-7	19	19.00	19.00	64.00	46.24	27.75	9.74	62.51	1.45	1.05	0.7565	06/24/93
LR-7	20	20.00	20.00	75.36	54.53	27.64	9.66	62.69	1.71	1.24	0.6925	06/24/93
LR-7	21	21.00	21.00	70.10	50.43	28.06	9.11	62.83	1.59	1.14	0.6184	06/24/93
LR-7	22	22.00	22.00	60.61	47.70	21.30	8.43	70.27	1.37	1.08	0.6593	06/24/93
LR-7	23	23.00	23.07	73.58	52.52	28.62	8.30	63.08	1.67	1.19	0.6489	06/24/93
LR-7	24	24.00	24.18	81.61	59.06	27.63	9.13	63.24	1.85	1.34	0.6355	06/24/93
LR-7	25	25.00	25.30	68.04	49.36	27.45	6.39	66.16	1.54	1.12	0.5063	06/24/93
LR-7	26	26.00	26.42	78.10	56.30	27.91	6.16	65.92	1.77	1.28	1.3264	06/28/94
LR-7	27	27.00	27.53	60.17	43.90	27.04	6.20	66.76	1.36	0.99	0.6035	06/24/93
LR-7	28	28.00	28.65	85.22	61.25	28.13	5.20	66.67	1.93	1.39	0.5360	06/24/93
LR-7	29	29.00	29.76	72.28	53.17	26.44	5.39	68.17	1.64	1.21	0.6689	06/27/94
LR-7	30	30.00	30.88	93.57	68.50	26.79	4.60	68.61	2.12	1.55	0.5495	06/27/94
LR-7	31	31.00	31.99	84.23	60.89	27.71	3.98	68.31	1.91	1.38	0.5356	06/27/94
LR-7	32	32.00	33.11	55.10	41.38	24.90	4.75	70.35	1.25	0.94	0.6207	06/27/94
LR-7	33	33.00	34.27	80.50	58.66	27.13	4.72	68.15	1.82	1.33	0.5532	06/27/94
LR-7	34	34.00	35.64	76.21	56.09	26.40	4.60	69.00	1.73	1.27	0.5089	06/27/94
LR-7	35	35.00	37.00	80.79	58.83	27.18	4.74	68.08	1.83	1.33	0.5255	06/27/94
LR-7	36	36.00	38.50	94.51	67.90	28.16	4.20	67.64	2.14	1.54	0.5255	06/28/94
LR-7	36-38	38.00	41.50	158.50	116.90	26.25	4.59	69.16	1.80	1.32	0.6321	06/28/94
LR-7	38-40	40.00	44.23	183.53	138.80	24.37	4.39	71.24	2.08	1.57	0.6141	06/27/94
LR-7	40-42	42.00	46.80	172.56	131.55	23.77	4.37	71.86	1.96	1.49	0.5500	06/27/94
LR-7	42-44	44.00	49.80	144.98	109.95	24.16	4.18	71.65	1.64	1.25	0.5703	06/28/94
LR-7	44-46	46.00	52.10	169.17	127.18	24.82	4.15	71.03	1.92	1.44	0.6286	06/27/94

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-8	1	1	1.0000	64.64	42.65	34.02	11.51	54.47	1.31	0.87	2.2677	06/27/94
LR-8	2	2	2.0000	54.12	37.17	31.32	11.71	56.97	1.10	0.75	2.1733	06/28/94
LR-8	3	3	3.0000	63.29	44.63	29.48	10.85	59.67	1.28	0.91	1.7819	06/28/94
LR-8	4	4	4.0000	66.42	46.63	29.80	9.52	60.68	1.35	0.95	1.3307	06/28/94
LR-8	5	5	5.0000	68.81	46.72	32.10	7.97	59.93	1.40	0.95	1.2625	06/28/94
LR-8	6	6	6.0000	74.11	52.96	28.54	8.33	63.13	1.50	1.08	1.1963	06/30/94
LR-8	7	7	7.0000	63.54	44.05	30.67	7.98	61.34	1.29	0.89	1.3228	06/28/94
LR-8	8	8	8.0000	65.25	47.35	27.43	8.55	64.02	1.32	0.96	1.0480	06/28/94
LR-8	9	9	9.0000	73.55	51.68	29.73	8.12	62.15	1.49	1.05	0.8705	07/01/94
LR-8	10	10	10.0000	62.29	44.42	28.69	7.77	63.54	1.26	0.90	0.8372	06/30/94
LR-8	11	11	11.0000	65.17	47.47	27.16	8.06	64.79	1.32	0.96	0.8390	06/30/94
LR-8	12	12	12.0000	77.11	55.40	28.15	7.34	64.50	1.57	1.12	0.8088	06/30/94
LR-8	13	13	13.0000	69.93	50.08	28.39	6.77	64.84	1.42	1.02	0.7977	06/28/94
LR-8	14	14	14.0000	75.74	54.40	28.18	6.76	65.07	1.54	1.10	0.6662	06/30/94
LR-8	15	15	15.0000	73.91	52.71	28.68	7.36	63.96	1.50	1.07	0.6459	06/30/94
LR-8	16	16	16.0000	84.32	56.52	32.97	6.88	60.15	1.71	1.15	0.6426	07/01/94
LR-8	17	17	17.0000	76.80	54.84	28.59	6.93	64.48	1.56	1.11	0.6681	06/30/94
LR-8	18	18	18.0000	63.62	46.02	27.66	7.13	65.21	1.29	0.93	0.6226	06/30/94
LR-8	19	19	19.0000	89.64	58.72	34.49	6.89	58.62	1.82	1.19	0.6707	06/30/94
LR-8	20	20	20.0000	87.57	56.70	35.25	6.76	57.99	1.78	1.15	0.6979	06/30/94
LR-8	21	21	21.0000	78.95	56.53	28.40	7.09	64.52	1.60	1.15	0.5851	06/30/94
LR-8	22	22	22.0000	88.92	57.37	35.48	6.57	57.94	1.81	1.16	0.6863	06/30/94
LR-8	23	23	23.0000	79.59	57.09	28.27	6.53	65.20	1.62	1.16	0.5448	07/05/94
LR-8	24	24	24.0000	88.39	57.93	34.46	9.29	56.25	1.79	1.18	0.6521	07/05/94
LR-8	25	25	25.0000	75.26	54.26	27.90	9.61	62.49	1.53	1.10	0.7663	07/05/94
LR-8	26	26	26.0000	82.81	58.97	28.79	9.36	61.85	1.68	1.20	0.7127	07/05/94
LR-8	27	27	27.0000	76.43	54.18	29.11	6.39	64.50	1.55	1.10	0.8488	07/05/94
LR-8	28	28	28.0000	87.78	63.41	27.76	5.44	66.79	1.78	1.29	0.6686	07/05/94
LR-8	29	29	29.0000	68.12	49.85	26.82	5.15	68.03	1.38	1.01	0.6200	07/05/94
LR-8	30	30	30.0000	87.14	63.93	26.64	5.00	68.36	1.77	1.30	0.6289	07/05/94
LR-8	31	31	31.0000	98.06	70.52	28.08	4.34	67.58	1.99	1.43	0.6654	07/05/94
LR-8	32	32	32.0000	75.26	52.96	29.63	4.17	66.19	1.53	1.08	0.6481	07/05/94
LR-8	33	33	33.0000	95.09	68.73	27.72	3.92	68.36	1.93	1.40	0.6496	07/06/94
LR-8	34	34	34.0000	78.06	56.30	27.88	4.99	67.13	1.58	1.14	0.5559	07/06/94
LR-8	35	35	35.0000	73.90	53.40	27.74	8.68	63.58	1.50	1.08	0.5295	07/06/94
LR-8	36	36	36.0000	93.31	66.94	28.26	3.39	68.35	1.89	1.36	0.6458	07/06/94
LR-8	36-38	38	38.0000	177.81	126.90	28.63	8.15	63.22	1.80	1.29	0.6204	07/06/94
LR-8	38-40	40	40.0000	152.81	108.80	28.80	8.13	63.06	1.55	1.10	0.5895	07/06/94
LR-8	40-42	42	42.0000	184.69	133.27	27.84	8.13	64.02	1.87	1.35	0.7535	07/06/94
LR-8	42-44	44	44.0000	163.88	118.62	27.62	7.75	64.63	1.66	1.20	0.6763	07/08/94
LR-8	44-46	46	46.0000	209.75	149.59	28.68	7.68	63.64	2.13	1.52	0.6531	07/07/94
LR-8	46-48	48	48.0000	172.89	125.11	27.64	6.93	65.43	1.75	1.27	0.6140	07/06/94
LR-8	48-50	50	50.4286	156.14	114.40	26.73	7.13	66.14	1.58	1.16	0.5363	07/06/94
LR-8	50-52	52	52.9048	206.34	153.23	25.74	6.55	67.71	2.09	1.56	0.6277	07/06/94
LR-8	52-54	54	56.6000	169.14	125.65	25.71	6.50	67.79	1.72	1.28	0.5940	07/06/94
LR-8	54-56	56	60.6000	183.63	137.12	25.33	5.52	69.15	1.86	1.39	0.5041	07/06/94

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-9	1	1.00	1.00	42.92	30.87	28.08	11.05	60.88	0.87	0.63	1.1131	07/08/94
LR-9	2	2.00	2.00	46.37	31.81	31.40	10.47	58.13	0.94	0.65	1.1809	07/07/94
LR-9	3	3.00	3.00	73.41	51.45	29.91	9.11	60.98	1.49	1.04	1.4216	07/07/94
LR-9	4	4.00	4.00	62.32	44.53	28.55	7.55	63.90	1.27	0.90	1.1740	07/07/94
LR-9	5	5.00	5.00	61.45	43.39	29.39	8.70	61.91	1.25	0.88	1.2619	07/08/94
LR-9	6	6.00	6.00	61.99	44.45	28.29	7.92	63.78	1.26	0.90	1.2707	07/07/94
LR-9	7	7.00	7.00	60.92	45.09	25.98	6.48	67.53	1.24	0.92	1.0999	07/08/94
LR-9	8	8.00	8.00	64.37	47.94	25.52	6.31	68.16	1.31	0.97	1.0766	07/07/94
LR-9	9	9.00	9.00	79.43	60.26	24.13	5.94	69.92	1.61	1.22	0.9265	07/07/94
LR-9	10	10.00	10.00	70.64	53.24	24.63	5.93	69.44	1.43	1.08	0.9543	07/07/94
LR-9	11	11.00	11.00	56.74	42.39	25.29	6.11	68.59	1.15	0.86	1.0556	07/07/94
LR-9	12	12.00	12.00	64.44	49.69	22.89	6.85	70.26	1.31	1.01	1.1826	07/07/94
LR-9	13	13.00	13.00	80.41	61.67	23.31	7.28	69.41	1.63	1.25	1.5558	07/08/94
LR-9	14	14.00	14.00	68.74	52.14	24.15	8.53	67.32	1.40	1.06	1.5402	07/08/94
LR-9	15	15.00	15.00	62.27	46.67	25.05	8.91	66.04	1.26	0.95	1.5992	07/08/94
LR-9	16	16.00	16.00	72.00	55.02	23.58	8.75	67.67	1.46	1.12	1.5191	07/08/94
LR-9	17	17.00	17.00	66.82	49.59	25.79	8.10	66.11	1.36	1.01	1.5562	07/11/94
LR-9	18	18.00	18.00	71.99	53.85	25.20	7.92	66.88	1.46	1.09	1.2480	07/08/94
LR-9	19	19.00	19.00	61.59	45.79	25.65	7.94	66.41	1.25	0.93	1.2099	07/08/94
LR-9	20	20.00	20.00	93.61	70.20	25.01	8.09	66.91	1.90	1.43	1.2270	07/08/94
LR-9	21	21.00	21.00	71.79	54.00	24.78	7.92	67.30	1.46	1.10	1.1920	07/11/94
LR-9	22	22.00	22.00	81.52	61.79	24.20	8.09	67.71	1.65	1.25	1.2934	07/08/94
LR-9	23	23.00	23.00	76.34	57.55	24.61	7.33	68.06	1.55	1.17	1.0623	07/08/94
LR-9	24	24.00	24.00	75.12	56.06	25.37	7.95	66.67	1.52	1.14	0.9572	07/08/94
LR-9	25	25.00	25.00	87.92	65.96	24.98	9.00	66.02	1.78	1.34	0.8936	07/08/94
LR-9	26	26.00	26.00	71.03	53.15	25.17	8.80	66.03	1.44	1.08	0.9029	07/08/94
LR-9	27	27.00	27.00	89.51	65.89	26.39	7.74	65.87	1.82	1.34	0.7554	07/08/94
LR-9	28	28.00	28.00	77.34	57.57	25.56	7.50	66.94	1.57	1.17	0.7776	07/12/94
LR-9	29	29.00	29.00	76.00	58.29	23.30	6.40	70.30	1.54	1.18	0.7681	07/08/94
LR-9	30	30.00	30.00	75.76	58.69	22.53	6.00	71.47	1.54	1.19	0.6745	07/08/94
LR-9	31	31.00	31.00	95.44	73.52	22.97	5.40	71.63	1.94	1.49	0.6540	07/08/94
LR-9	32	32.00	32.01	90.95	69.31	23.79	6.20	70.01	1.85	1.41	0.7117	07/08/94
LR-9	33	33.00	33.02	81.57	62.89	22.90	5.74	71.36	1.66	1.28	0.7728	07/08/94
LR-9	34	34.00	34.04	72.19	55.70	22.84	6.00	71.16	1.47	1.13	0.9360	07/12/94
LR-9	35	35.00	35.05	94.27	72.02	23.60	6.60	69.80	1.91	1.46	0.8877	07/12/94
LR-9	36	36.00	36.06	83.90	62.96	24.96	6.00	69.04	1.70	1.28	0.7522	07/12/94
LR-9	36-38	38.00	38.09	161.75	119.41	26.18	6.45	67.37	1.64	1.21	0.6508	07/12/94
LR-9	38-40	40.00	40.12	191.54	144.11	24.76	7.40	67.84	1.94	1.46	0.7189	07/12/94
LR-9	40-42	42.00	42.15	160.66	122.24	23.91	8.40	67.69	1.63	1.24	0.6192	07/13/94
LR-9	42-44	44.00	44.17	162.76	121.68	25.24	9.00	65.76	1.65	1.24	0.5845	07/13/94
LR-9	44-46	46.00	46.20	161.61	118.10	26.92	7.40	65.68	1.64	1.20	0.7250	07/13/94
LR-9	46-48	48.00	48.20	185.95	139.20	25.14	8.20	66.66	1.89	1.41	0.7905	07/13/94
LR-9	48-50	50.00	50.20	159.24	118.49	25.59	7.40	67.01	1.62	1.20	0.7027	07/12/94
LR-9	50-52	52.00	52.20	182.05	139.68	23.27	8.00	68.73	1.85	1.42	0.6912	07/12/94
LR-9	52-54	54.00	54.20	175.51	134.33	23.46	7.98	68.55	1.78	1.36	0.6792	07/15/94
LR-9	54-56	56.00	56.96	161.08	123.21	23.51	7.00	69.49	1.63	1.25	0.5766	07/13/94

Core No.	Sample No.	Uncorr Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Wet Bulk Dens. (g/cc)	Dry Bulk Dens. (g/cc)	Total Pb-210 (dpm/g)	Date Counted
LR-10	1	1.00	1.02	103.38	74.09	28.33	11.91	59.75	2.18	1.56	2.9351	07/12/94
LR-10	2	2.00	2.04	67.00	48.87	27.06	11.93	61.01	1.41	1.03	2.3267	07/13/94
LR-10	3	3.00	3.05	72.74	53.78	26.07	11.13	62.80	1.53	1.13	2.1576	07/13/94
LR-10	4	4.00	4.07	67.78	49.77	26.57	10.98	62.45	1.43	1.05	1.9934	07/13/94
LR-10	5	5.00	5.09	88.90	64.91	26.99	10.28	62.74	1.87	1.37	1.9598	07/13/94
LR-10	6	6.00	6.11	86.49	63.67	26.38	10.81	62.81	1.82	1.34	1.5861	07/13/94
LR-10	7	7.00	7.13	75.42	54.93	27.17	10.67	62.16	1.59	1.16	1.5521	07/13/94
LR-10	8	8.00	8.15	71.05	51.11	28.06	10.89	61.04	1.50	1.08	1.2650	07/13/94
LR-10	9	9.00	9.16	70.08	51.32	26.77	10.78	62.45	1.47	1.08	1.3100	07/13/94
LR-10	10	10.00	10.18	82.38	60.20	26.92	10.04	63.04	1.73	1.27	1.1563	07/13/94
LR-10	11	11.00	11.20	79.67	57.71	27.56	10.45	61.98	1.68	1.21	1.0980	07/14/94
LR-10	12	12.00	12.22	79.03	57.48	27.27	10.32	62.41	1.66	1.21	0.9184	07/15/94
LR-10	13	13.00	13.24	73.25	53.12	27.48	10.10	62.42	1.54	1.12	0.9322	07/14/94
LR-10	14	14.00	14.25	87.72	63.47	27.64	10.14	62.22	1.85	1.34	1.0019	07/14/94
LR-10	15	15.00	15.27	78.76	56.33	28.48	11.39	60.13	1.66	1.19	1.0091	07/15/94
LR-10	16	16.00	16.29	73.71	53.78	27.04	10.10	62.86	1.55	1.13	0.7554	07/15/94
LR-10	17	17.00	17.31	59.03	42.76	27.56	9.68	62.75	1.24	0.90	0.7655	07/15/94
LR-10	18	18.00	18.33	85.30	62.43	26.81	9.36	63.83	1.80	1.31	0.6812	07/15/94
LR-10	19	19.00	19.35	76.84	56.24	26.81	9.58	63.61	1.62	1.18	0.6173	07/14/94
LR-10	20	20.00	20.36	61.91	45.32	26.80	9.86	63.34	1.30	0.95	0.7201	07/14/94
LR-10	21	21.00	21.38	71.11	51.71	27.28	9.50	63.21	1.50	1.09	0.7509	07/15/94
LR-10	22	22.00	22.40	97.00	70.14	27.69	9.29	63.02	2.04	1.48	0.9367	07/15/94
LR-10	23	23.00	23.51	75.37	54.41	27.81	8.82	63.37	1.59	1.15	0.7027	07/18/94
LR-10	24	24.00	24.62	70.94	50.42	28.93	10.41	60.66	1.49	1.06	0.5043	07/15/94
LR-10	25	25.00	25.73	69.71	49.46	29.05	10.81	60.15	1.47	1.04	0.5156	07/15/94
LR-10	26	26.00	26.82	90.69	64.89	28.45	10.85	60.70	1.91	1.37	0.5439	07/15/94
LR-10	27	27.00	27.86	91.29	65.33	28.44	10.02	61.54	1.92	1.37	0.5085	07/15/94
LR-10	28	28.00	28.90	79.71	57.87	27.40	9.88	62.72	1.68	1.22	0.5175	07/18/94
LR-10	29	29.00	29.94	72.07	52.77	26.78	9.72	63.50	1.52	1.11	0.4245	07/18/94
LR-10	30	30.00	30.98	73.11	53.06	27.42	10.02	62.56	1.54	1.12	0.5166	07/15/94
LR-10	31	31.00	32.00	103.22	72.23	30.02	9.65	60.33	2.17	1.52	0.4586	07/18/94
LR-10	32	32.00	33.00	68.15	49.82	26.90	9.47	63.64	1.43	1.05	0.4073	07/18/94
LR-10	33	33.00	34.00	90.00	66.83	25.74	9.23	65.02	1.89	1.41	0.4159	07/18/94
LR-10	34	34.00	35.07	70.97	52.18	26.48	9.11	64.42	1.49	1.10	0.4237	07/18/94
LR-10	35	35.00	36.14	97.47	69.80	28.39	9.16	62.45	2.05	1.47	0.4594	07/18/94
LR-10	36	36.00	37.21	90.27	66.29	26.56	9.70	63.73	1.90	1.40	0.4680	07/18/94
LR-10	37	38.00	39.35	165.78	125.47	24.32	9.90	65.78	1.74	1.32	0.6526	07/18/94
LR-10	38	40.00	41.49	164.41	124.30	24.40	9.50	66.10	1.73	1.31	0.4288	07/18/94
LR-10	39	42.00	43.60	176.62	129.10	26.91	8.68	64.42	1.86	1.36	0.4357	07/18/94
LR-10	40	44.00	45.60	169.22	128.09	24.31	9.09	66.60	1.78	1.35	0.3926	07/18/94
LR-10	41	46.00	47.76	181.70	138.84	23.59	9.60	66.81	1.91	1.46	0.4766	07/18/94
LR-10	42	48.00	51.40	166.74	128.80	22.75	9.90	67.35	1.75	1.36	0.4238	07/18/94
LR-10	43	50.00	54.69	165.70	127.17	23.25	8.89	67.85	1.74	1.34	0.3923	07/18/94
LR-10	44	52.00	57.78	165.66	125.58	24.19	8.41	67.39	1.74	1.32	0.4168	07/22/94

APPENDIX C

Laboratory Procedures for Determining ^{210}Pb Activities

USGS Laboratory Procedures for Determining ^{210}Pb Activities

The U.S. Geological Survey's Analytical Laboratory at Denver analyzed ^{210}Pb activity in the cores. Analyses were completed under the direction of Dr. Charles W. Holmes. Other USGS personnel involved in the analyses were James D. Cathcart and Margaret Marot. The cores were sampled at either 1 cm or 2 cm intervals from the center of each core from top to bottom. Analyzed samples were prepared using the following 14 steps modified from Flynn (1968) and Martin and Rice (1981).

1. Wet samples are placed into clean, preweighed procelain evaporating dishes, weighed, dried at 40°C, and reweighed to determine water loss.

2. Dried samples are ground to a fine powder (75-100 mesh) in a grinding mill to obtain an homogeneous sample for analysis.

3. Sample splits of approximately 5 g are made and weighed, placed into precleaned, preweighed crucibles and heated in a muffle furnace at 450°C for 6 hrs until a stable weight is obtained. The samples are allowed to cool to room temperature and reweighed.

4. Each sample is transferred to a 100-ml Teflon beaker using 5-10 m. of reagent grade 16N nitric acid (HNO_3). A known amount of calibrated ^{209}Po spike is added and the sample swirled to mix the spike. The beaker is covered with a watchglass and allowed to stand overnight.

5. The solution is evaporated under heat lamps at 109°C. The dried sample is washed from the sides of the beaker using 8N hydrochloric acid (HCL) and swirled again to insure proper mixing. The solution is evaporated to dryness and allowed to cool.

6. One-milliliter aliquots of 30 percent hydrogen peroxide (H_2O_2) are added to the sample until it is completely wet, and the resulting solution is again evaporated to dryness. The sample is placed under heat lamps only after the peroxide reaction has subsided. The cooling and peroxide steps are repeated twice more.

7. The sample is then washed twice with 8N HCL and evaporated to dryness between each washing. This step is to remove all traces of the nitric acid which interferes with the autoplating onto the silver planchet.

8. Five milliliters of 8N HCL are added to the dried sample, which is then transferred to a 100-ml glass beaker using additional amounts of HCL and deionized water.

9. To minimize the interference of Fe^{+3}, Cr^{+6}, and other oxidants, 5 ml of hydroxylamine hydrochloride and 2 ml of 25% sodium citrate are added to each sample. Additionally, 1 ml of holdback carrier, bismuth nitrate ($BiN0_3$), is added to prevent deposition of ^{212}Bi. A plastic coated magnetic stir bar is added to each beaker for stirring during the autoplating.

10. The pH of the solution is adjusted to between 1.85 and 1.95 using ammonium hydoxide (NH_4OH) and HCL to inhibit any tellurium and selenium whose presence decreases the plating efficiency.

11. The beaker is placed on a stirring hot plate and heated between 85°C and 90°C for 5 minutes to reduce any $Fe^{+}3$, Cr^{+6}, or other oxidants that might be present.

12. A Teflon plating device holding the silver foil disc is placed in the solution. This allows plating on one side of the disc only. The plating device covers the beaker and therefore minimal evaporation occurs during the plating procedure.

13. The heating and stirring proceeds for a minimum of 90 minutes.

14. The plating device is disassembled, the silver disc washed with deionized water, dried and then counted on a alpha counting system.

Counting Procedure

1. The sample is positioned beneath an alpha detector in a counting chamber and put under vacuum.

2. The sample is counted for 24-48 hrs or until enough counts are obtained for each spectra.

3. Counts for each spectrum are routed to the proper channel in the Pulse Height Analyzer (PHA) and stored by a computer.

4. The PHA supports form 1-16 counting chambers at any given time.

5. The raw spectrum is transferred from the computer via a 5 1/4 inch floppy disk for later data reduction.

APPENDIX D

BEG Data on Bulk Density and TOC

ANALYSIS REPORT

UNIVERSITY STATION, BOX X
AUSTIN, TEXAS 78713-7508
(512) 471-7721 (ext 426)

MINERAL STUDIES LABORATORY
BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

STEVEN W. TWEEDY
CHIEF CHEMIST

INVESTIGATOR:	PROJECT/ACCOUNT:	DATE:	REPORT #:
B. White	Lavaca River (TWDB)	June 1, 1994	R-027-94

MSL ID# 94-267 to 94-301

SAMPLE PREPARATION / TREATMENT
These samples were obtained using a cork borer of known diameter to extract a cylindrical specimen from one-half of a sediment core. Three specimens were taken from each core (near the bottom, middle, near the top). During sampling, the length of each sample was determined by measuring the depth of the hole left after sampling. This was to eliminate error due to known compaction during sub-sampling.

The samples were placed in pre-weighed containers and weighed to determine the total weight. The samples were then dried in a drying oven to constant weight at 105 deg.C. The loss of weight was then attributed to loss of moisture and calculated to represent a percent of the original mass (% moisture).

The resulting solids were pulverized in a diamonite mortar and pestle and analyzed for total carbon content via the coulometric carbon analyser. Conditions: 950 deg.C, pure oxygen atmosphere, standard scrubbers, approx. 50 mg. sample size, blank corrected. This recovered carbon is assumed to be the organic carbon of each sample in the absence of mineral carbon (see COMMENTS, below).

SAMPLE ANALYSIS METHODS

Constituents	Technique	MSL Procedure
Moisture content	Gravimetric	---------
Bulk density	Gravimetric, calculation	---------
Total Carbon	Coulometric carbon analyser	ref: SWI 1.7, ASTM D 4129-82

RESULTS
Sample analysis results are presented in Table 1. The associated QA/QC analysis results are presented in Table 2 and Table 3.

COMMENTS
Previous samples (Trinity River) were tested for the presence of mineral carbon, all tests found no measureable quantity of mineral carbon. If any calcite were to be present, the recovered carbon would represent the combined mineral and organic forms.

This completes the requested analyses for these samples.

SAMPLE DISPOSITION:
The remains of these samples are being archived at the MSL.

ANALYST:
Tweedy

< less than indicated value
* reported value near detection limit

nd - not determined
ins - insufficient sample

ANALYSIS REPORT

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STEVEN W. TWEEDY
CHIEF CHEMIST

TABLE 1
SAMPLE ANALYSIS RESULTS

MSL ID#	LOCATION ID#	MOISTURE (wt%)	BULK DENSITY (g/cc)	TOTAL CARBON (wt %, oven dried)
94-267	LR1/top-12cm.	35.0	1.01	4.04
94-268	LR1/top-20	26.5	0.98	1.17
94-269	LR1/top-30	24.2	0.73	1.39
94-270	LR1/top-40	22.0	0.90	1.06
94-271	LR1/top-51	20.6	1.12	1.32
94-272	LR1/top-55	21.9	0.87	0.85
94-273	LR1/top-70	22.2	1.43	0.52
94-274	LR1/top-80	19.1	1.19	0.58
94-275	LR2/top-5	63.2	0.19	10.21
94-276	LR2/top-35.5	34.8	0.56	2.38
94-277	LR2/top-65.5	45.9	0.41	2.41
	LR2/top - 20	37.3	0.42	
	LR2/top - 27	35.5	0.75	
	LR2/top - 45	36.5	0.69	
94-278	LR3/top-7	48.8	0.52	6.17
94-279	LR3/top-32	36.0	0.60	1.99
94-280	LR3/top-62	36.9	0.67	1.58
	LR3/top - 9	44.0	0.61	
	LR3/top - 22.5	34.3	0.80	
	LR3/top - 41	38.9	0.43	
	LR3/top - 60.5	37.7	0.92	
	LR3/top - 62	37.9	1.04	
	LR3/top - 64	37.8	1.23	
94-281	LR4/top-4	28.2	0.73	2.15
94-282	LR4/top-30	20.4	0.63	1.77
94-283	LR4/top-56	19.4	1.07	1.47
94-284	LR5/top-4	26.2	0.78	2.61
94-285	LR5/top-35	16.2	1.30	0.69
94-286	LR5/top-69	24.3	1.49	0.30
94-287	LR6/top-6	40.1	0.34	2.75
94-288	LR6/top-32	25.1	0.63	0.85
94-289	LR6/top-62	25.6	0.98	0.49
94-290	LR7/top-3	37.1	0.48	3.85
94-291	LR7/top-24	29.8	0.54	1.50
94-292	LR7/top-45.5	28.1	0.87	1.68
94-293	LR8/top-4	35.7	0.59	2.82
94-294	LR8/top-27.5	32.7	0.64	1.80
94-295	LR8/top-55.5	27.6	0.86	1.76

< less than indicated value
* reported value near detection limit
nd - not determined
ins - insufficient sample

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TABLE 1 (cont.)
SAMPLE ANALYSIS RESULTS

MSL ID#	LOCATION ID#	MOISTURE (wt%)	BULK DENSITY (g/cc)	TOTAL CARBON (wt %, oven dried)
94-296	LR9/top-8cm.	25.5	0.74	0.96
94-297	LR9/top-25	28.6	0.61	0.92
94-298	LR9/top-58.5	27.1	0.78	1.29
94-299	LR10/top-3	30.5	0.61	2.05
94-300	LR10/top-27.5	30.2	0.71	1.11
94-301	LR10/top-51.5	28.4	0.89	1.15

TABLE 2
REFERENCE MATERIAL RESULTS
(WT % TOTAL CARBON)

MSL ID#	FOUND	TRUE VALUE	BIAS	%BIAS
NBS-1a	9.69	9.76	-0.08	-0.81
	9.71			
	9.65			
	9.68			
	9.68			
	9.66			

TABLE 3
REPLICATE SAMPLE ANALYSIS

MSL ID#	%CARBON	MSL ID#	%CARBON	MSL ID#	%CARBON
94-268-1	1.17	94-279-1	2.00	94-296-1	0.97
94-268-2	1.17	94-279-2	1.99	94-296-2	0.96
94-268-3	1.18	94-279-3	1.99	94-296-3	0.96
MEAN	1.17		1.99		0.96

< less than indicated value
* reported value near detection limit

nd - not determined
ins - insufficient sample

APPENDIX E

Percent Sand, Silt, and Clay

Core #	Uncorrected depth (cm)	Sand (%)	Silt (%)	Clay (%)
LR-1	8	26	29	45
	12	37	28	35
	14	35	31	34
	18	29	32	39
	24	30	31	39
	32	33	29	38
	42	32	30	38
	46	30	34	36
	54	30	36	34
	66	30	33	37
	72	36	31	33
	82	48	27	25
LR-2	2	5	19	76
	5	3	18	79
	9	2	16	82
	12	1	18	81
	14	1	13	86
	17	2	17	81
	22	4	21	75
	26	3	21	76
	31	2	22	76
	40	2	20	78
	44	3	22	75
	54	7	20	73
	60	8	19	73
	68	7	20	73
	70	7	20	73
LR-3	3	4	20	76
	6	4	17	79
	9	4	24	73
	11	3	22	75
	14	4	25	71
	17	5	25	70
	20	5	22	73
	29	13	32	55
	39	11	17	72
	51	8	22	70
	56	5	18	77

Core #	Uncorrected depth (cm)	Sand (%)	Silt (%)	Clay (%)
LR-4	2	16	35	49
	6	16	34	50
	9	15	37	48
	11	14	37	49
	12	16	36	48
	15	15	35	50
	18	14	35	51
	23	16	34	50
	25	19	32	49
	31	22	33	45
	35	27	33	40
	41	28	34	38
	45	28	34	38
	49	28	34	38
	55	28	35	37
	57	27	35	38
LR-5	2	42	36	22
	4	35	36	29
	7	45	41	14
	10	40	39	21
	14	34	30	36
	18	48	31	21
	22	58	24	18
	24	57	23	20
	27	54	18	28
	29	64	21	15
	34	60	25	15
LR-6	5	12	28	60
	10	28	23	49
	13	36	21	43
	15	37	21	42
	20	29	22	49
	25	31	20	49
	30	32	20	48
	32	38	20	42
	40	40	19	41
	44	44	19	37
	54	46	24	30
	56	40	24	36
	60	39	24	37

Core #	Uncorrected depth (cm)	Sand (%)	Silt (%)	Clay (%)
LR-7	2	9	30	61
	5	10	29	61
	7	10	27	63
	10	7	24	69
	13	7	25	68
	18	8	19	73
	22	8	22	70
	25	7	11	82
	26	9	14	77
	29	6	16	78
	34	10	23	67
	38	11	24	65
	42	12	27	61
	46	13	28	59
LR-8	4	9	22	69
	7	9	22	69
	9	11	14	75
	13	12	22	66
	15	11	23	66
	20	10	23	67
	23	13	25	62
	27	10	23	67
	29	14	23	63
	33	16	24	60
	35	13	27	60
	37	12	25	63
	42	9	28	63
	50	12	30	58
	52	14	30	56
	55	12	34	54
LR-9	3	56	21	23
	7	44	25	31
	10	32	33	35
	15	18	29	53
	20	20	30	50
	25	20	26	54
	30	21	26	53
	35	18	30	52
	38	21	27	52
	44	23	26	51
	48	20	28	52
	52	16	28	56
	56	15	28	57

Core #	Uncorrected depth (cm)	Sand (%)	Silt (%)	Clay (%)
LR-10	2	2	31	67
	8	4	24	72
	12	4	17	79
	15	8	25	67
	18	7	24	69
	22	8	21	71
	24	5	24	71
	27	4	26	70
	29	5	24	71
	34	5	24	71
	38	8	25	67
	40	9	25	66
	44	8	23	69
	46	10	22	68
	50	6	26	68