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Geochemistry and geophysical framework of the shallow sediments of Assawoman Bay and Isle of Wight Bay in Maryland

by
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Geochemistry and geophysical framework of the shallow sediments of Assawoman Bay and Isle of Wight Bay in Maryland

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ABSTRACT

For the 8th year of the Mineral Management Service's Continental Margins Program, the Maryland Geological Survey conducted a sedimentological and geochemical study of the sediments of Isle of Wight and Assawoman Bays. The objectives of the study were to delineate the shallow stratigraphic sequence of the coastal bays, relating the stratigraphy to late Quaternary sea level fluctuations, and to document the geochemical character of the shallow sediments, providing preliminary base-line data for comparison for future studies.

Thirty-three kilometers of 7 kHz seismic profile surveys and eleven sediment cores were collected. Surficial sediments grab samples were collected at three other stations. The cores were X-rayed, described and sampled at various intervals. A total of 96 sediment samples were analyzed for texture (SAND, SILT, CLAY contents), water content, total nitrogen, carbon, and sulfur concentrations, and six metals: Cr, Cu, Fe, Mn, Ni and Zn.

Seismic records feature several shallow paleochannels defined by a very strong reflector. Depths to the reflector were mapped, allowing the structure of a pre-transgression surface beneath the bays to be contoured. The surface reveals a simple paleodrainage system which is traceable to the present tributaries. Maximum depths of the paleochannels are approximately 8 meters below MSL. Thalweg depths, particularly for the St. Martin paleochannel, are much shallower than previously projected based on well log and bridge boring data.

The coastal bay sediments are predominately SILTY. SILT contents averaged 44% for all samples. Averages for SAND and CLAY contents are 31% and 25%, respectively. SAND contents generally are higher for those samples collected along the eastern margin of the bays. CLAY becomes an important component in cores collected in the tributaries.

Concentrations for nitrogen, carbon and sulfur for most of the sediments are within ranges expected for marine sediments and are comparable with those found in the Chesapeake Bay and other Atlantic coast estuaries. Nitrogen contents range from 0 to 1.39%, averaging 0.22%; carbon contents range from 0.02 to 30%, averaging 2.8%; and

sulfur contents range from 0 to 5.28%, averaging 1.05%. Nitrogen, carbon and sulfur contents are strongly related to the texture of the coastal bay sediments, with higher values associated with finer-grained sediments.

Metal concentrations are within the ranges of other coastal bays not subject to heavy industry. The behavior of the metals were determined by two methods. The first method utilized enrichment factors referenced to average continental crust (Taylor, 1964). Enrichment factor values for Cu, Mn and Ni are less than one for most of the sediments suggesting that the reference material used may not represent the coastal bay sediments. Nevertheless, enrichment factors indicate that the upper 20 to 30 cm of sediment column are enriched with Cr, Cu, Ni and Zn compared to sediments deeper than 30 cm. The metal concentrations in the deeper sediments are interpreted to represent historical or background levels.

The second technique employed to assess metal concentrations in the sediments correlated metal content with the grain size composition. Sediment deeper than 30 cm were used to obtain the relationship between texture and metal contents to determine background metal concentrations. Background levels were calculated for all samples and compared to measured levels, obtaining variation factors. Variation factors showed the same trends in the behavior of Cu and Zn as did the enrichment factors.

INTRODUCTION

During the past seven years of the Mineral Management Service-Association of American State Geologist Continental Margins Program, the Maryland Geological Survey has mapped the surficial sediments and defined the shallow geological framework of the inner continental shelf of Maryland (Kerhin and Williams, 1987; Toscano *et al.*, 1989). These continental shelf studies consisted of sedimentological, paleontological, stratigraphical and geophysical investigations. Stratigraphic horizons, identified in seismic records, were correlated to onshore stratigraphy based on data from existing well logs. Paleochannels were also mapped, reconstructing the early Holocene inner-shelf paleodrainage system.

The area of focus for the previous studies have been limited to the inner continental shelf of Maryland, and did not include the adjacent coastal bay systems. These coastal bays consist of four bays: Assawoman Bay, Isle of Wight Bay, Sinepuxent Bay and Chincoteague Bay. These coastal bays mark the leading edge boundary of the present transgression and overlie sedimentary sequences that link the onshore and offshore stratigraphy. Therefore, studies of the geologic framework of these bays would contribute to the understanding of the relationship between offshore and onshore stratigraphy and the history of the holocene transgression. However, there have been few studies investigating the shallow stratigraphy or geologic history of Maryland's coastal bays.

The coastal bays are considered very valuable resources not only from a geological viewpoint, but from an environmental perspective. During the last two decades, development pressures along the shoreline around the bays have caused concern about the "health" of the bays. Yet, there is a paucity of environmental data available to adequately assess and monitor the bays. Little is understood about the hydrodynamics and sedimentation processes. An understanding of the hydrodynamics of the bays is critical in dealing with dredging and disposal of polluted sediments. Because the bays are very shallow, bottom sediments are often resuspended, mixing with the overlying water column. Therefore, the bottom sediments play an important role in bay water quality. Sedimentological studies are important to the understanding of the relationship between bottom sediments and bay hydrodynamics as well as to the general health of the bays.

OBJECTIVES

The Maryland Geological Survey initiated this study to define the shallow geological framework and near surface geochemical character of the sediments of Maryland's two northern-most coastal bays: Assawoman Bay and Isle of Wight Bay. The objectives of this study were:

1) To delineate the shallow stratigraphic sequence beneath the coastal bays and relate the stratigraphy to late Quaternary sea level fluctuations;
2) To map the geochemical character of the near surface sediments of the bays, providing preliminary base-line data for future studies of these back-bay areas.

Presented in this report are the results of the first year study. Results include geophysical data from shallow seismic surveys, and textural and chemical data from analyses of sediments taken from a series of shallow cores.

ACKNOWLEDGEMENTS

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PREVIOUS STUDIES

The general stratigraphy of the eastern Delmarva Peninsula has been described by Owens and Denny (1976), Mixon (1985), and Sheridan *et al.* (1974) (Delaware). Chrzastowski (1986) investigated the stratigraphy and geologic history of Rehoboth and Indian River Bays in Delaware. Halsey (1978) described the shallow stratigraphy beneath Maryland's coastal bays including Isle of Wight and Assawoman Bays.

More recent work relating onshore stratigraphy to offshore stratigraphy include Kerhin and William (1987), Toscano (1992), Toscano *et al.* (1989), and Toscano and

York (1992). Toscano *et al.* (1989) also mapped a network of paleochannels on Maryland's inner continental shelf. These paleochannels are interpreted to be part of the ancestral St. Martin River System. Offshore seismic records show the main stem of the channel cutting into the top of the Beaverdam sand (Tertiary). Based on thalweg depths, widths and orientations, the main channel stem follows a depression in the top of the Beaverdam Formation. This depression extends under Fenwick Island and Isle of Wight Bay.

Very few studies have investigated the geochemical characteristics of sediments in Maryland's coastal bays. Most previous environmental studies focused on biological aspects (UM and CESI, 1993). Some studies looked at the chemistry of the water column in the bays. Early studies primarily focused on water quality monitoring in the bays (Sieling 1958, 1959, 1960; Cerco *et al.*, 1978; and Allison 1975). Water column studies conducted by Allison (1975) measured pH, salinity, water temperature, dissolved oxygen (D.O.), nutrients, chlorophyll-a, total iron, heavy metal and pesticide concentrations, turbidity, and fecal coliform bacteria. At twelve (12) sites within Isle of Wight and Assawoman Bays, Allison analyzed bottom sediments for six metals: Cu, Cr, Pb, Zn, Cd, and Hg. Allison concluded that the metals concentrations in the sediments were not significantly high.

STUDY AREA

GEOLOGIC SETTING

The study area is located on the Atlantic coast of the Delmarva Peninsula (Figure 1a). Isle of Wight and Assawoman Bays are the two northern-most coastal bays in Maryland. Fenwick Island, part of the barrier Island/southern spit unit of the Delmarva coastal compartment (Fisher, 1967), separates the coastal bays from the Atlantic Ocean. The bays are underlain by unconsolidated Coastal Plain sediments, the upper-most 60 m of which are Cenozoic in age. Sediments of the Sinepuxent Formation are exposed along much of Maryland's coastal area from Bethany Beach, Delaware, southward to the Maryland-Virginia border and directly underlie the study area (Figure 1b). The Sinepuxent Formation was described by Owens and Denny (1979) based on information from drill holes along Sinepuxent Neck, the designated type locality for the Formation. The Sinepuxent Formation is composed of dark colored, poorly sorted, silty fine to medium sand with thin beds of peaty sand and black clay. Heavy minerals are abundant and consist of both amphibole and pyroxene minerals. All of the major clay mineral groups: kaolinite, montmorillonite, illite and chlorite, are represented. The sand consists of quartz,

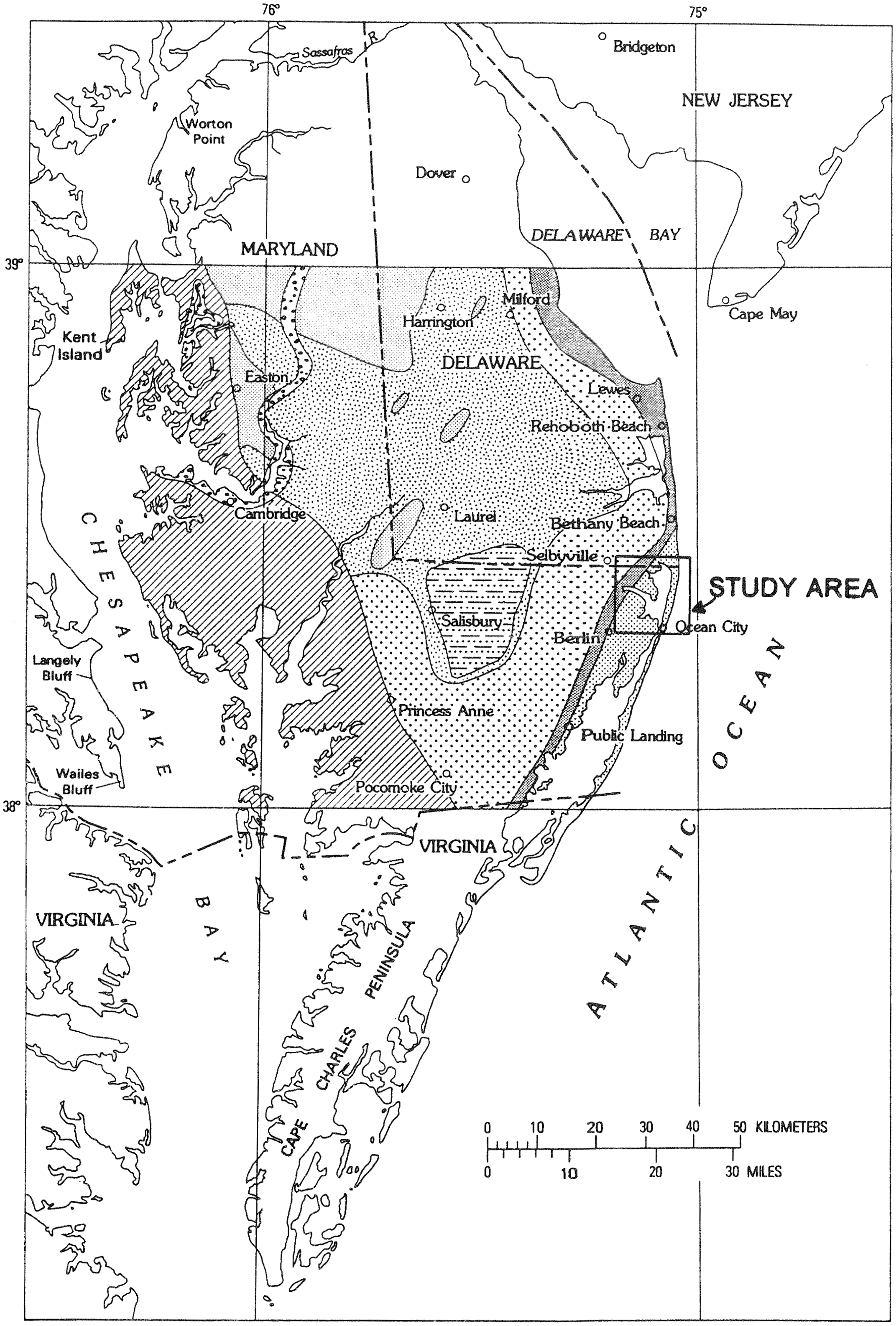

Figure 1. A) Generalized geologic map of central Delmarva Peninsula (from Owens and Denny, 1979). See Figure 1b for pattern key.

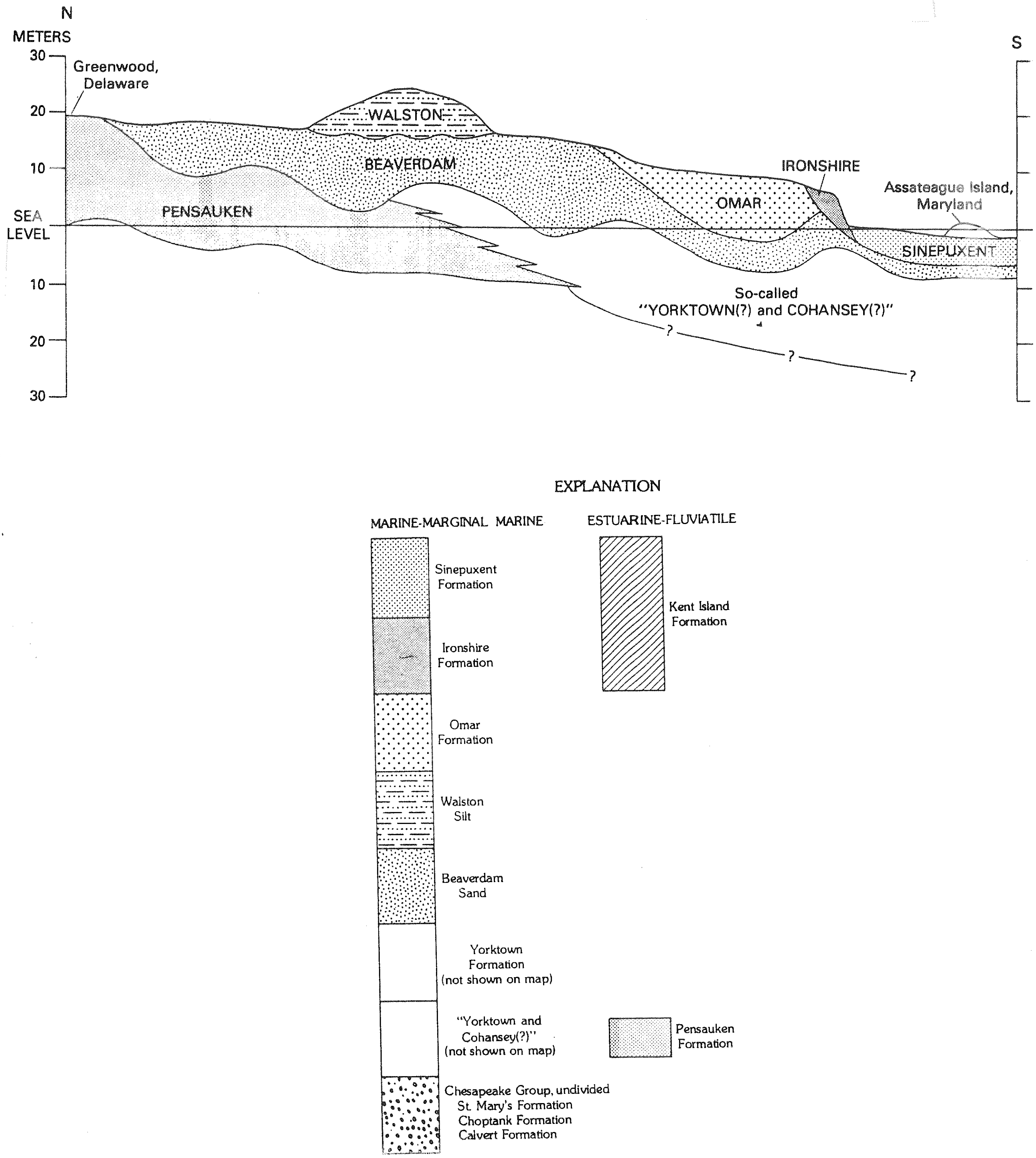

Figure 1. B) Cross-section showing stratigraphic relationship of formations shown in Figure 1a (from Owens and Denny, 1979), with pattern key.

feldspar and abundance of mica (muscovite, biotite, and chlorite). The preponderance of mica make the Sinepuxent Formation lithologically distinct from underlying older units (Owens and Denny, 1979).

The Sinepuxent Formation is interpreted to be a marginal marine deposit. The Sinepuxent Formation has been correlated to the offshore Q2 deposits which were determined to be of oxygen-isotope Stage 5 age (between 80 to 120 ka) based on amino-acid racemization (Toscano, 1992; Toscano *et al.*, 1989; Toscano and York, 1992).

Within the study area, the Sinepuxent is underlain by the Beaverdam Sand Formation which is Pliocene in age (Figure 1b). The western edge of the Sinepuxent formation lies against the Ironshire Formation which consists of pale yellow to white sand and gravelly sand. Although the Ironshire Formation sits unconformably on top of the Beaverdam, at no point does it underlie the Sinepuxent Formation (Owens and Denny, 1979).

PHYSICAL CHARACTERISTICS

Assawoman Bay and Isle of Wight Bay are microtidal (<2 m tidal range) coastal lagoons and are contiguous with each other. For this discussion, the boundary between Assawoman Bay and Isle of Wight Bay is the Rt. 90 bridge which spans Fenwick Island (Ocean City at 60th Street) and Isle of Wight. Table I lists the basic morphometric data for both bays.

Table I. Morphometric data for Isle of Wight and Assawoman Bays; area data compiled from Bartberger and Biggs (1970) and UM and CESI (1993).

	Assawoman Bay	Isle of Wight Bay	Two Bay System
Surface area	20.0 km^2	33.4 km^2	53.4 km^2
Maximum length	7.9 km	6.7 km	14.5 km
Maximum width	3.3 km	4.3 km	___
Drainage area	18.4 km^2	152.7 km^2	171.1 km^2

Assawoman Bay, the northern-most bay, has a water surface area of 20.0 km^2 (4952 acres) (UM and CESI, 1993) and is elongated in north-south direction. The length of Assawoman Bay, measured from the mouth of Roy Creek to Rt. 90 bridge, is 7.9 km. Maximum width of Assawoman Bay is 3.3 km. Isle of Wight Bay has a surface area of 33.4 km^2 (8257 acres) (UM and CESI, 1993). The length of this bay, from Rt. 90 Bridge to west end of north jetty at the inlet, is 6.7 km. Maximum width is 4.3 km, at the mouth of St. Martin River.

The two bays are connected to the Atlantic Ocean through a single outlet, Ocean City Inlet, located at the extreme south end of Isle of Wight Bay. Ocean City Inlet formed during a hurricane in 1933 and was immediately stabilized by jetties to keep it opened.

Historically, several other inlets have been documented along Fenwick Island (Truitt, 1968). These inlets also formed during storms as did the Ocean City Inlet, but were eventually filled in as a result of natural processes. During the March, 1962, storm, also known as the Ash Wednesday Storm, Fenwick Island was breached at approximately 71st street. A channel approximately 50 ft wide was cut through to the bay (U.S. Army Corps of Engineers, 1962). The Army Corps of Engineers immediately filled in the inlet with sand dredged from Assawoman Bay.

Several streams are tributaries to the two bays. Roy Creek and Greys Creek drain into Assawoman Bay. St. Martin River, Manklin Creek and Turville Creek drain into Isle of Wight Bay. St. Martin River is the major tributary, accounting for 62% of the total drainage area for the bays (Bartberger and Biggs, 1970; UM and CESI, 1993). Drainage area for Isle of Wight Bay is about 4.5 times the area of the bay itself (Table I). On the other hand, the surface area of Assawoman Bay is slightly larger (1.1 times) than its drainage area. In all, the drainage area for both bays is about 3 times as large as their open water areas. For comparison, the watershed basin for the Chesapeake Bay is 28 times its open water area. As a result of the relatively small drainage area combined with flat topography, fresh water input into the two coastal bays is small. The limited fresh water input and restricted access to open ocean contribute to poor flushing of the bays (Bartberger and Biggs, 1970: UM and CESI, 1993).

The bays are very shallow, the average depth less than 2 m. Generally, areas with greater depths (*i.e.* > 3 m) are a result of dredging. Some of the deepest areas are within the Federal Navigation Channel that is maintained at -10 m. These deep areas are located in the southern end of Isle of Wight Bay. Other artificially deep areas include numerous dredge holes in Assawoman Bay and along the east side of Isle of Wight Bay. The material dredged from these holes were used to fill in low-lying areas on Fenwick Island for development, or used as beach fill to replenish the beach in Ocean City after the

March 1962 storm. These holes vary in depth from 4.9 to 9.8 m. Another artificially deep area is along a canal known as "The Ditch", the depths of which average 4.5 m. This canal connects Assawoman Bay to Little Assawoman Bay (in Delaware).

Circulation patterns and tidal ranges in the two bays are dependent on proximity to the inlet and wind conditions. Near the inlet, currents are primarily an effect of tidal cycles. Currents over 200 cm/sec are common near the inlet and within the Federal Navigation channel. Tidal amplitudes, based on data from NOS tide stations located in southern Isle of Wight Bay, range from 0.78 to 0.55 m. Tidal influence diminishes rapidly with increasing distance from the inlet. Along the western and northern margins of the bays, wind conditions have a greater effect on water levels and current velocities.

Casey and Wesche (1981) measured tidal amplitudes and current velocities at several locations in Isle of Wight and Assawoman Bays. Nominal tidal amplitudes ranged from 0.25 m on a spring tide to 0.16 m during a neap tide at the northern most station, located at Drum Pt. north of Rt. 90 Bridge. Peak ebb and flood velocities were measured between 14 cm/sec and 26 cm/sec at this station. The canal allows some water exchange between Assawoman Bay and Little Assawoman Bay in Delaware. Tidal amplitudes in the canal range from 0.6 to 0.9 m (Allison, 1975).

Salinity in the two bays decreases slightly with increasing distance from Ocean City Inlet. Maximum salinity measured during the summer (Casey and Wesche, 1981) ranged from 30 ppt near the inlet to 26 ppt in Assawoman Bay just north of the Rt. 90 bridge. Salinity tends to be higher in the summer due to limited freshwater input and high evaporation.

Bordering the bays are wetlands and marshes, found mainly along the western margin. Much of the bay side of Fenwick has been developed, at the expense of wetlands (Dolan *et al.*, 1980). Large areas have been filled in and built up, and much of natural shoreline has been armored by bulkheads or rip-rap.

SUMMARY AND CONCLUSIONS

Based on seismic data, a pre-transgressive surface has been mapped, revealing paleodrainage network traceable to existing tidal creeks. Thalweg depths, particularly for the St. Martin paleochannel, are much shallower than the previously projected depths based on well log and bridge boring data. The nature and age of the surface defined by the reflector and the associated fill sequences seen in the seismic records remains to be resolved. Additional cores penetrating the reflector need to be collected to define and date these sediment sequences.

Overall, the shallow bay sediments are very silty. Although no textural trends are apparent in vertical sequence of the sediments, the sediments generally become coarser in an easterly direction across the bays. This trend is a result of SAND being transported into the bays from the ocean side of Fenwick Island.

Values for nitrogen, carbon and sulfur contents for most of the bay sediments are within the range expected for marine sediments. Nitrogen, carbon and sulfur contents are strongly related to the texture of the sediments, with higher values associated with finer-grained sediments. Extreme values were obtained from peat and peaty sediments which yielded carbon and sulfur contents up to 30% and 5.3%, respectively. Generally, carbon contents decrease with depth as sulfur contents increase, the relationship predicted by sulfate reduction processes that occur naturally in the sediments under anoxic conditions.

Results of metal analyses yield no excessively high metal concentrations. Enrichment factor (EF) values relative to average crustal rock were calculated to be greater than one for Zn and Cr and less than one for Cu, Mn and Ni. The low values, particularly for Mn, suggest that the reference material used to calculate the EF values probably does not adequately represent the sediments found in the study area. Although the reference material used is questionable, the calculated enrichment factors for Isle of Wight and Assawoman Bays are similar to enrichment factors for other Atlantic coast bays in non-industrial regions (Sinex and Helz, 1981).

Enrichment factor values reveal some significant trends in metal behavior within the sediment column. Plots of EF values versus depth in core reveal that the surficial sediments compared to deeper sediments are slightly enriched with all metals except Mn which showed no change in enrichment. The greatest increase in EF values are for Zn and Cu which show 2-fold increases. EF values decrease downcore, generally leveling off between 20 to 30 cm. The EF values for sediment below 20 to 30 cm are interpreted to represent historical or background levels before anthropogenic influence.

A second technique to assess and compare metal levels correlates metal concentrations to textural composition. The results of this second technique generally corroborate the observations based on enrichment factors. The second technique indicates that Zn and Cu levels in surficial and near surface sediments are twice that of background levels. On the other hand, Cr and Ni levels in the upper sediment column (< -30 cm depth) are within background levels, suggesting that there is little or no anthropogenic input of Cr and Ni in the study area. Because this second technique is based on correlation of metal concentrations with the textural composition of sediments, the results characterize the study area more realistically than enrichment factor values.

RESULTS AND DISCUSSION

SEISMIC PROFILES

Maximum penetration of the 7.0 kHz signal was between 6 to 7.5 m (-20 to 25 ft). The penetration was less in shoaling areas where bottom sediments were predominately SAND. Shallow water depths combined with hard (sandy) bay bottom resulted in strong multiples obscuring the detail in the seismic records. The better seismic records were collected in the western and central portions of the bays where finer-grained sediments predominate. Extensive sand deposits representing washover fans or tidal deltas cover a large portion of the eastern and southern margin of the two bays. The seismic records collected in these areas show little or no subsurface detail (structure).

Shallow paleochannels are seen in many of the seismic profiles. Maximum depths of the channels range from -7 to -8 m MSL. Paleochannel floors and walls are very hummocky in areas as illustrated in Line 3 (Figure 2). Paleochannel walls extend up to the sediment surface converging with the present bay bottom.

The reflector defining the geometry of the paleochannels is very prominent, marking the maximum penetration of the acoustical signal. The surface defined by this reflector is interpreted to represent a pre-transgression surface, portions of which formed directly on Pleistocene deposits (Sinepuxent Formation). The reflector is intercepted by several dredged areas on the eastern side of Assateague Bay (Figure 3). These deep areas are results of dredging for backfill to build up areas in Ocean City for development. Peat had been recovered from the bottom of these dredged holes during past benthic studies (Al Wesche, pers. comm.).

The contours which show the structure of this pre-transgression surface are presented in Figure 4. The structure details a portion of an earlier drainage system, age of which is unknown. The paleodrainage represents ancestral extensions of Greys and Roy Creeks and St. Martin River. Based on the trend of the deeper contours (-5 and -7 m), the paleochannel traced to Roy Creek extends laterally across Assawoman Bay, passing beneath Fenwick Island just south of Montego Bay. Greys Creek paleochannel extends down Assawoman Bay and into Isle of Wight Bay converging with the St. Martin River paleochannel. The St. Martin/Greys Creek paleochannel appears to extend under Fenwick Island between 50th and 55th Streets (just south of Rt. 90 bridge).

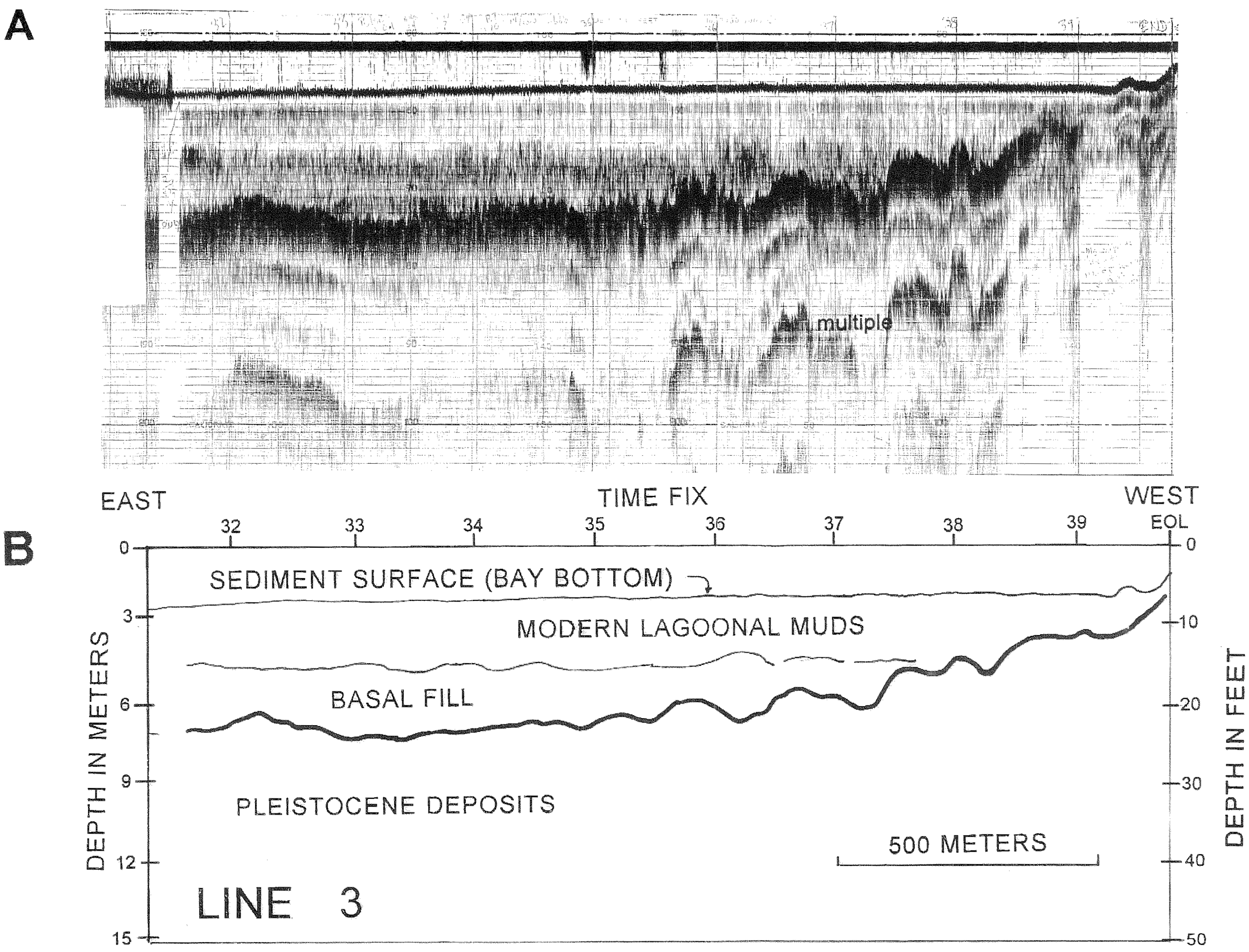

Figure 2. A) West end of record for seismic line 3 which crosses the widest part of Isle of Wight Bay. B) Interpreted section showing prominent reflector defining paleochannel and pre-transgression surface. Time of day and latitude and longitude coordinates for time fixes are listed in Appendix I.

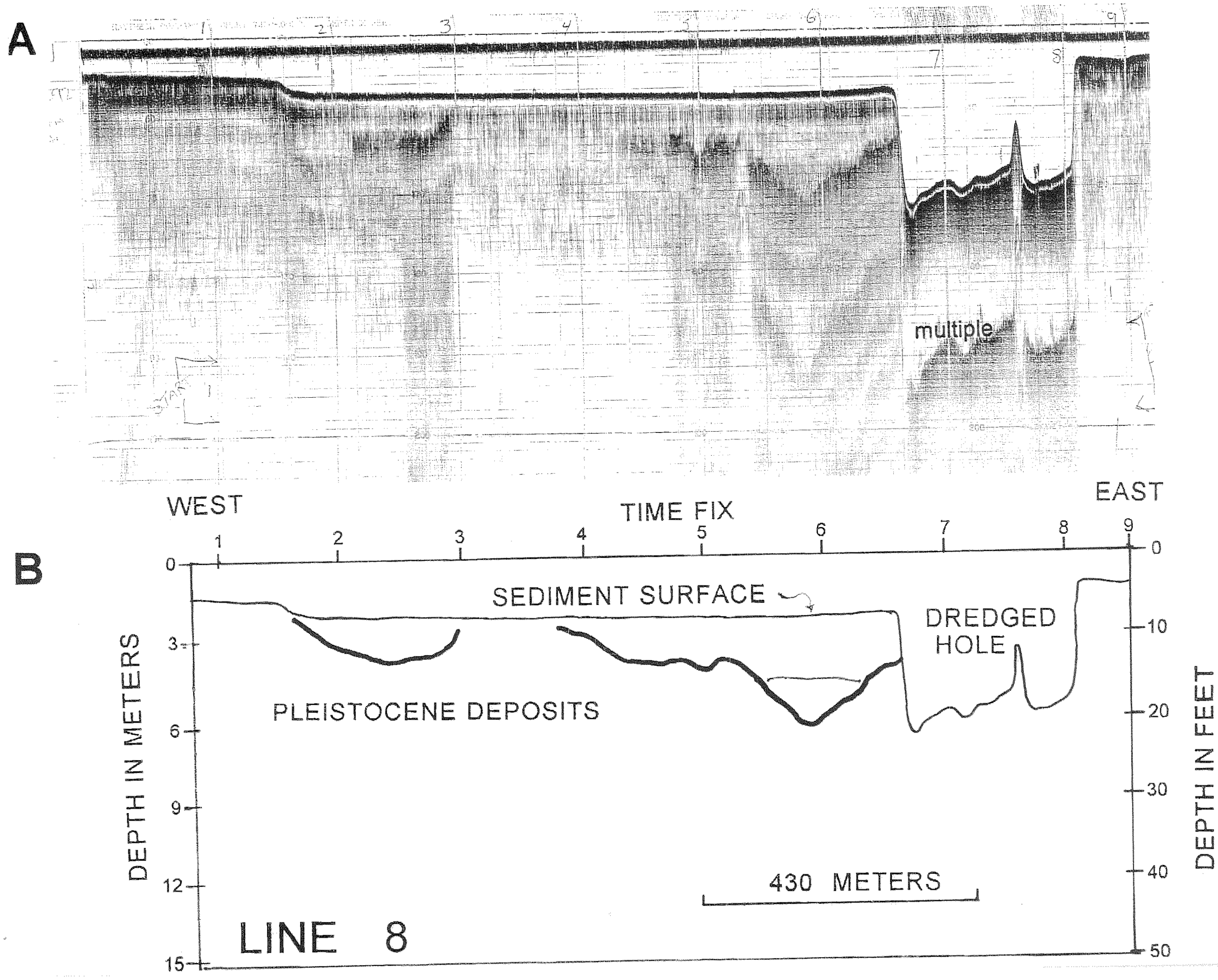

Figure 3. A) Record for seismic line 8 crossing north Assawoman Bay. B) Interpreted section featuring cross-section of a dredged hole adjacent to Montego Bay Trailer Park located on the bay side of North Ocean City, Maryland. Note that the dredged hole cuts below the reflector.

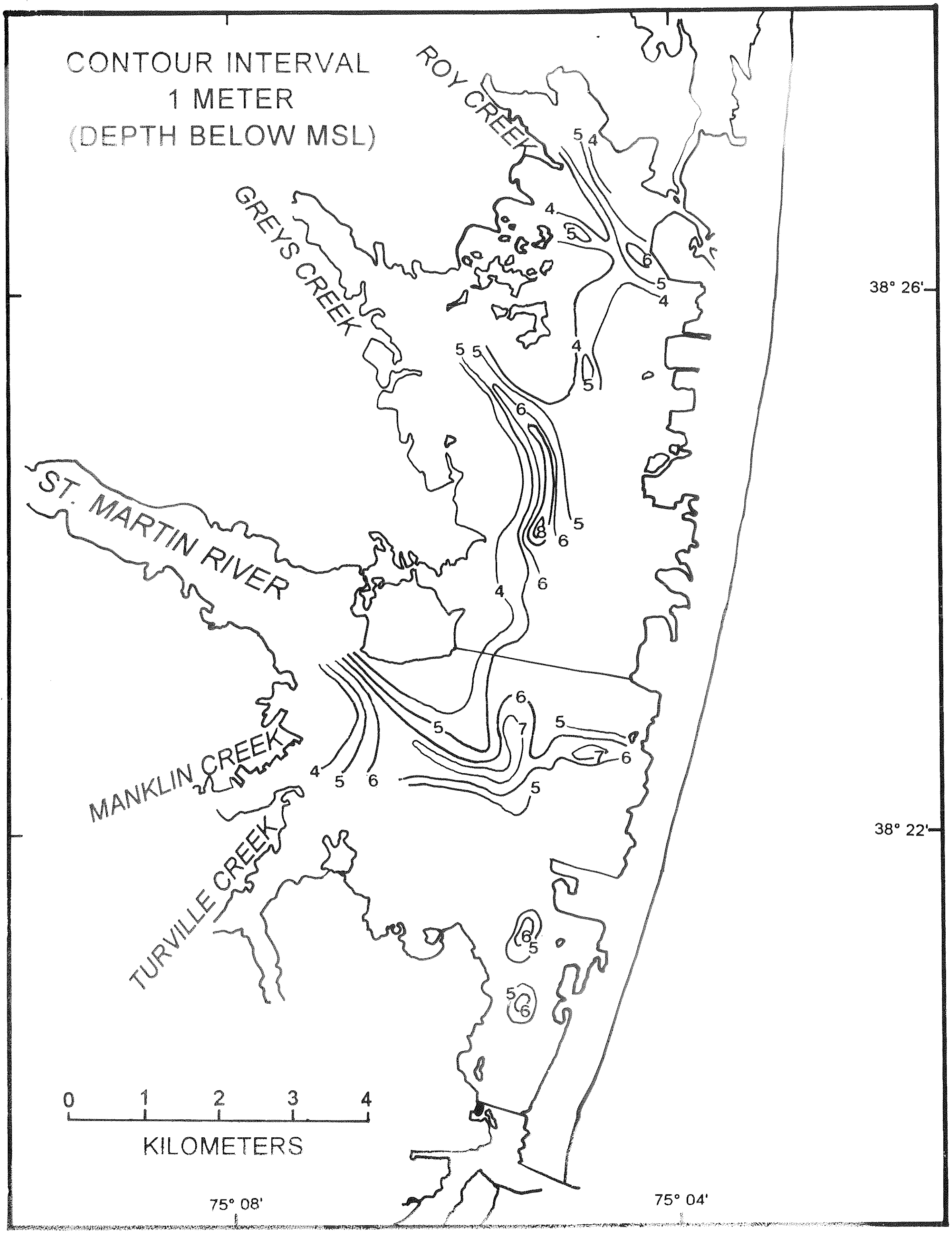

Figure 4. Contour of surface defined by the prominent reflector seen in seismic profiles. The reflector is identified in Figures 2 and 3.

Measured thalweg depths of the St. Martin paleochannel are 7.5 to 8 m below MSL, much shallower than the +30 m depth projected by Halsey (1978) and Toscano *et al.* (1989). Assuming that the base of the paleochannel is deeper, then this reflector marks the lower boundary of some intermediate Holocene channel-fill sequence.

A second very faint, planar, reflector is visible within most of the paleochannels (Figures 2 and 3). This reflector marks the boundary between a lower fill sequence (tidal creek or palustrine deposits) and the overlying modern lagoonal sediments.

Modern Holocene deposits (lagoonal muds) are thin over much of the western portion of the bays. Thicknesses range from 0 to 6 m, with maximum thicknesses corresponding to the central axes of the underlying paleochannels. Recent washover and deltaic deposits are restricted to the eastern and southern end of the study area. The thickness of these deposits could not be determined from the seismic data.

SEDIMENT TEXTURE

Sediment textures are discussed in terms of the lithosomes outlined by Chrzastowski (1986) for sediments in Rehoboth and Indian River Bays, Delaware. Chrzastowski divided the Holocene deposits into four major lithosomes: 1) flood-tidal delta/barrier sand; 2) lagoonal mud; 3) marsh mud; and 4) tidal stream mud.

Most sediment samples contained a significant percentage of SILT, averaging 44% for all samples. This reflects the silty character of the Sinepuxent Formation, a major source of sediment to the bays. Averages for SAND and CLAY contents were 31% and 25% respectively. CLAY contents were higher for the cores collected in the tributaries (Stations 7 and 12- refer to Figure 5 for core locations). SAND contents were higher in cores collected toward the eastern side of the bays. Sediments with higher SAND components are expected along the southern and eastern margins of the bays. SAND is transported into the bay either by eolian and washover processes from the ocean side of Fenwick Island or through the inlet by tidal processes. The amount of SAND transported and deposited by these processes diminishes significantly as distance from the source areas increases.

Cores collected at stations 1, 4, 6, 9 and 10 consisted entirely of modern lagoonal sediments. These cores were very similar in appearance and texture, containing dark olive grey to greenish black SAND-SILT-CLAYS and CLAYEY SILTS. SAND contents range from less than 5 to 30% SAND fractions are well to very well sorted, very fine SAND.

Xeroradiographs of the cores reveal varying levels of bioturbation (*i.e.* sediment mixing by biogenic activity). Burrows of bivalves and polychaetes are common. *Mercenaria mercenaria*, *Crassostrea virginica*, and *Nassarius sp.* were found in many the cores with *Nassarius sp.* being the most common shell encountered. Distinct laminae are evident in radiographs for station 1 (mouth of Greys Creek) and station 10 (bayward of St. Martin River) (Appendix II). Visually, the laminae were not apparent. The laminae indicate that sediment have not been disturbed or mixed by biogenic activity.

Based on the low bioturbation levels, core 1 was selected for analysis of ^{210}Pb activity to determine sedimentation rate. The analysis was done by the University of Maryland Horn Point Environmental Laboratory. Based on ^{210}Pb activity, sedimentation rate for core 1 was estimated to be 0.3 to 0.4 cm/yr (Jeffrey Cornwell, unpubl. data). This sedimentation rate is within the range determined by Chrzastowski (1986) for mid-bay, mud dominated area in Rehoboth Bay and Indian River Bay in Delaware. Based on ^{210}Pb and ^{137}Cs activity analyses, sedimentation rates were 0.26 cm/yr for Rehoboth Bay and 0.57 cm/yr for Indian River Bay. These rates agreed with those determined by bathymetric comparisons of the Delaware bays.

The 0.3 to 0.4 cm/yr sedimentation rate for Isle of Wight Bay is typical of rates for eastern U.S. coastal bays. Atlantic and Gulf coast bays usually have sediment accumulation rates ranging from 0.4 to 0.5 cm/yr (Rusnak, 1967). These sedimentation rates also match the present rate of sea level rise which is 0.33 to 0.39 cm/yr (Belknap and Kraft, 1977).

The core collected at station 2 may have penetrated the pre-transgression surface. The location of station 2 corresponds to time-fix 1036 on Seismic Line 6. The seismic record shows the pre-transgression surface to be very shallow, at -2.5 m MSL, at this location. The bottom of this core (-2.8 m MSL) contained peaty mud. A wood fragment, identified possibly as Oak (*Quercus*) rootwood (Center for Wood Anatomy Research, U.S. Forest Products Lab., written comm.) was recovered at -2.9 m.

Cores 11 and 13 were collected along the eastern edge to the bays. Core 11 contained greenish black to dark olive grey, organic SILTY SAND, representing tidal flat sediments. Core 13 was collected in a shallow shoaling area and consisted of light tan to medium olive grey, medium to fine SAND.

Cores 7 and 12 were collected in St. Martin River and Turville Creek, respectively. These cores consisted of dark grey CLAYEY SILT and SILTY CLAY. The sediments from these cores contained the least amount of SAND compared to other cores collected for this study. Based on lower SAND content and higher CLAY contents, the sediments are classified as tidal stream deposits.

Core 14 was collected in a marshy area near Horn Island located in southern Isle of Wight Bay. The sediments contained in this core consisted of interbedded layers of dark olive grey to brownish black SAND-SILT-CLAY, SILTY CLAY, and CLAYEY SILT. Peaty material was abundant, increasing with depth. Several sediment samples taken from this core consisted entirely of peat material and were not analyzed for SAND-SILT-CLAY components.

WATER CONTENT

Correlation analyses of water contents as well as SAND, SILT, CLAY, carbon, nitrogen and sulfur contents for all sediment samples were performed to detect any significant associations between variables. The correlations were done using Pearson product-moment technique (STSC, Inc., 1986). The resulting correlation matrix is presented in Table II. Samples from core 14 were not included in the correlation analysis since many of the samples contained high amount of peat and plant debris and very little inorganic material (sediment). These samples are not considered to be representative of bay sediments.

Table II. Correlation matrix for nitrogen, carbon, sulfur contents and sediment textural data based on all core samples except station 14. Values are Pearson correlation coefficients (r). Significant levels for all values are less than 0.01 (critical value of r at 99% = 0.479).

	%Carbon	%Nitrogen	%Sulfur
%Carbon	1.000	-	-
%Nitrogen	0.852	1.000	-
%Sulfur	0.677	0.629	1.000
%H_2O	0.770	0.772	0.834
%SAND	-0.611	-0.653	-0.803
%SILT	0.536	0.583	0.669
%CLAY	0.609	0.638	0.857

Water contents of the core sediments ranged from 7.98% wet weight for SAND (100% SAND) to 80.9% for SILTY-CLAY (54% CLAY). Water contents are strongly associated with the CLAY component of the sediment as reflected by the high correlation coefficient between percent water and CLAY content (r = 0.92). Associations between water content and SAND (r = -0.84) and SILT content (r = 0.66) are weaker.

Since the amount of water a sediment holds is strongly influenced by grain size, downcore variations in water content track variations in CLAY contents (refer to plots in Appendix III). Any downcore decrease in water contents due to compaction is not readily apparent.

GEOCHEMISTRY

Results of the chemical analyses are listed in Appendix III. The results versus depth in core were also plotted and are presented along with plots of the other variables (water content, SAND, SILT, CLAY components, and carbon, sulfur and nitrogen concentrations) in Appendix III.

All measured parameters were included in correlation analysis. Two correlation matrices were generated. The first matrix, correlations between sediment textural components and nitrogen, carbon and sulfur (NCS) contents, has been presented in Table II. The second matrix, correlations between metal concentrations and textural components, is presented in Table III. The correlations between carbon, nitrogen, and sulfur contents and metal contents were moderate to weak ($r < 0.7$). The poor correlations reflect the different geochemical processes that control the behavior of these chemical components. These correlation coefficients are not presented in this report.

Nitrogen Content

Nitrogen contents in sediments range from 0 to 1.39% and averaged 0.22%. The highest nitrogen values were found in sediment containing peat material (Core 14). Correlation analysis of nitrogen, carbon and sulfur contents with textural data show that nitrogen content of sediments is strongly correlated with carbon content (correlation coefficient (r) = 0.852, Table II). The correlation coefficient is higher if correlation analysis include core 14 samples (r = 0.97). The strong relationship between nitrogen and carbon reflects the fact that nitrogen comes primarily from organic geopolymers found in the sediment (Hill *et al.*, 1992). Therefore, nitrogen is expected to maintain a constant proportionality with carbon content. Ratios of nitrogen to carbon range from 0.05 to 0.23 with a mean value of 0.10 ± 0.05 which is slightly lower than the ratio of 0.113 obtained from sediment cores collected in the Chesapeake Bay (Hill *et al.*, 1992). The lower ratio is attributed to the fact that sediments having extremely low or no nitrogen contents were included in the calculation of the mean ratio.

Carbon Content

The carbon found in sediments consists of both inorganic and organic components. Studies of the Chesapeake Bay sediments have shown that inorganic carbon component is minor, contributing less that 18% to the total carbon content (Hennessee *et al.*, 1986; Hobbs, 1983). Shell fragments accounted for the bulk of inorganic carbon measured in Chesapeake Bay sediments. However, shell fragments were not as abundant in the coastal bay sediments compared to Chesapeake Bay sediments. Therefore, it is assumed that inorganic carbon contributes little to the total carbon measured in the coastal bay sediments

Total carbon contents measured in the core sediments range from 0.02 to 30.0% with a mean value of 2.8%. The highest carbon values were obtained from peaty sediments sampled from core 14. Values for the peaty samples range from 8.5 to 30.0% carbon. Carbon contents for surficial sediments range from 0.25 to 3.65% about a mean value of 1.83% which are within the range of those values reported for the Chesapeake Bay (range = 0 to 10.5%; mean = 2.1%; Hennessee *et al.*, 1986) and for other pristine estuaries (Folger, 1972). Folger observed that organic carbon contents for fine-grained sediments from estuaries not subjected to high pollution seldom exceeded 5% and were often less than 3%. He attributed anomalously high values for carbon to plant debris. For example, peat deposits from Albemarle Sound yielded carbon content values as high as 20 to 30%.

Correlation analysis reveals a moderately strong association between carbon content and % water (r = 0.73) (Table II). Correlation coefficients between carbon content and SAND, SILT, CLAY contents are moderately small (r = -0.61, 0.54 and 0.61, respectively), indicating that carbon is not associated with any particular size fraction. The poor correlations may be related to the nature of the carbon. For example, in northern Chesapeake Bay, carbon is most strongly associated with SILT, reflecting the terrigenous nature of the carbon, composed of coal particles and plant detritus (Hennessee *et al.*, 1986). In the middle Chesapeake Bay where the main source of carbon is planktonic detritus, the strongest correlation is between carbon and CLAY content (r = 0.91). The poor correlation between carbon content and size fraction in the coastal bays suggests a more complex relationship. The carbon content reflects a combination of both terrigenous and planktonic sources.

Sulfur Content

Sulfur in sediments is found primarily as inorganic metal sulfides and elemental sulfur. These sulfur species form as a result of a bacterially mediated reaction during which organic carbon is oxidized using dissolved sulfate (SO_4^{-2}) from seawater as an oxidant (Berner, 1967, 1972; Goldhaber and Kaplan, 1974). During the process that occurs under anaerobic conditions, sulfate is reduced to sulfide. The sulfide reacts with ferrous iron (Fe^{+2}) forming an iron monosulfide precipitant which further reacts with elemental sulfur to form FeS_2 (pyrite and its polymorph, marcasite) (Berner, 1970). As a result of this process, sulfur is enriched and preserved in the sediments as the amount of organic carbon is depleted.

Total sulfur contents of coastal bay sediments range from 0 to 5.28% about a mean of 1.05%. Sulfur contents of surficial sediments range from 0.04 to 1.48%, averaging 0.58%. The range and mean for surficial samples are similar to those values reported for the Chesapeake Bay (Hennessee *et al.*, 1986; Hobbs, 1983). As with nitrogen and carbon contents, core 14 samples containing peat yielded the highest sulfur contents, ranging from 1.43 to 5.28%.

The ratio of carbon to sulfur (C/S) decreases with depth in most of the cores. This decrease is expected as sediments tend to become enriched with sulfur over time (i.e. increased depth of burial) while carbon is metabolized. The C/S ratios average 2.8 for all samples. This value is identical to the C/S ratio for modern marine sediments, 2.8 ± 1.5 (Berner and Raiswell, 1984). The C/S ratios for the peaty sediment are much higher indicating that a relatively small proportion of carbon has been metabolized to produce sulfide. Most carbon in peat is plant detritus which is less susceptible to bacterial decay compared to algal debris (Goldhaber and Kaplan, 1975).

Results of correlation analysis show a strong association between sulfur and CLAY content ($r = 0.86$) and water content ($r = 0.83$). Correlation between sulfur and SILT is weaker ($r = 0.67$). The strong correlation between sulfur and CLAY content suggests that sulfur is best preserved in clayey sediments as opposed to silty sediments. The more reactive carbon, planktonic detritus, is also associated with CLAY. Clayey sediments typically have high water contents which accounts for the strong correlation between sulfur and water content. These results are consistent with those of the Chesapeake Bay (Hennessee *et al.*, 1986).

Monosulfides, measured in cores 1 and 10, decrease sharply between 15 to 20 cm below the sediment surface. This sharp decline in monosulfide indicates a change in the sedimentation rate.

Metals

Sediment samples have metal concentrations (refer to Appendix III, Table XI) of the same order of magnitude as those reported from a previous study (Allison, 1975). However, since Allison did not analyze sediments for Fe, Al or textural parameters (SAND-SILT-CLAY content), his results are difficult to interpret. Also, quantitative comparison of Allison's data to other data sets can not be done. Generally, Zn and Cu concentrations from this study are within the range of those reported by Allison. Cr concentration are overall higher than Allison's values. The differences in Cr levels between the two studies are due to the different analytical methods used.

Correlation analysis reveals that all elements are significantly correlated with one another (Table III). The highest correlations are between Fe and Cr (r = 0.99), Fe and Ni (r = 0.976) and Fe and Mn (r = 0.941), Cr and Ni (r = 0.985), and Cu and Zn (r = 0.936). There are also high correlations between CLAY content and Cr, Fe, and Ni. These metals typically are associated with clay minerals (Cantillo, 1982). These metals are either components of the mineral lattice structure or absorbed onto clay surfaces. Clay minerals comprise a significantly large portion of the fine (CLAY size) sediment fraction. In general, metal concentrations show a strong inverse relationship with SAND contents indicating that the trace metals are contained in the mud fraction (SILT and CLAY).

Table III. Correlation matrix for trace metal concentrations and sediment textural data based on all core samples except station 14. Values are Pearson correlation coefficients (r). Significant levels for all values are less than 0.01 (critical value of r at 99% = 0.479).

	Cr	Cu	Fe	Mn	Ni	Zn
Cr	1.000	-	-	-	-	-
Cu	0.689	1.000	-	-	-	-
Fe	0.993	0.639	1.000	-	-	-
Mn	0.943	0.550	0.941	1.000	-	-
Ni	0.985	0.712	0.976	0.932	1.000	-
Zn	0.807	0.936	0.765	0.704	0.817	1.000
% SAND	-0.915	-0.728	-0.908	-0.837	-0.907	-0.790
% SILT	0.785	0.701	0.772	0.717	0.790	0.732
% CLAY	0.944	0.630	0.945	0.864	0.915	0.729

Enrichment Factors

In order to reduce the effect of grain size, metal concentrations are discussed in terms of enrichment factors (EF). The use of enrichment factors also allows for comparisons of sediments from different environments and the comparisons of sediments whose trace metal contents were obtained by different analytical techniques (Cantillo, 1982; Hill *et al.*, 1990; Sinex and Helz, 1981).

Enrichment factor is defined as:

$$EF_{(X)} = \frac{(X/Fe)_{sample}}{(X/Fe)_{reference}} \qquad (1)$$

where:

$EF_{(x)}$ is the enrichment factor for the metal X;

$X/Fe_{(sample)}$ is the ratio of the concentrations of metal X to Fe in the sample; and

$X/Fe_{(reference)}$ is the ratio of the concentrations of metal X to Fe in a reference material, such as an average crustal rock.

Fe is chosen as the element for normalizing because anthropogenic sources for Fe are small compared to natural sources (Helz, 1976). Taylor's (1964) average continental crust is used as the reference material. Average crustal abundance data may not be representative of the coastal bay sediments because there is a higher proportion of SAND in the bay sediments compared to the average crustal rock. However, abundance data is useful as a relative indicator.

Enrichment factors for the five metals in the core sediments are listed in Appendix III (Table XIII). The bay sediments are enriched in Cr and Zn with respect to crustal rock. For surficial sediments, the average enrichment factor values for Cr and Zn are 1.5 and 2.6 respectively. Sediments generally are not enriched in Cu, Mn, and Ni relative to average crustal rock. EF values for these three metals are less than one. These low values do not necessarily signify the area is depleted in these metals, but instead reflect the unsuitability of the reference material.

EF values for Cr, Mn and Ni in surficial samples increase very slightly toward the eastern side of the bays. Additional sampling stations are needed to determine the significance of this trend.

Most cores show a downcore decrease in EF values for all metals except Mn (refer to plots in Appendix III). EF values are highest in the upper 20 cm of sediment column and level off downcore. This decrease in the enrichment factors suggests that metal contents in the upper sediment column reflect anthropogenic input above a background level. Metal contents in sediments deeper than 20 to 30 cm represent pristine, natural levels before human influence. The 20 to 30 cm depth represents approximately 60 to 100 years assuming that the sedimentation rate of 0.3 to 0.4 cm/yr (based on ^{210}Pb activity) represents the sediment accumulation rate in the two bays.

Relative decrease in EF values varies for the different metals. Cu and Zn show the largest downcore decrease in enrichment, with surficial sediments having twice the enrichment factor of the deeper sediments. Ni and Cr factors decrease 10% to 30% downcore. EF values for Mn, on the other hand, do not vary with depth suggesting that measured levels come entirely from natural sources with very little anthropogenic input.

Enrichment factors referenced to Taylor's average crust have been used by Sinex and Helz (1981) to compare Chesapeake Bay sediments to various east and gulf coast estuaries. The comparisons are listed in Table IV and include the average enrichment factors for surficial sediments analyzed in this study. The coastal bay sediments yielded EF values similar to other estuaries not subjected to heavy industrial activities. Enrichment factors of Cr, Cu, Mn, and Ni are near unity for these estuaries. Assawoman and Isle of Wight Bays are enriched in Zn, although not as high as some other estuaries. Sinex and Helz (1981) suggested that the large enrichment factors for Zn could be attributed to one of two possibilities. 1) Zn values for Taylor's average crustal rock are too small to be representative of eastern United States sediments. 2) Anthropogenic contamination of Zn is ubiquitous. In Maryland's coastal bays, it is likely that Zn enrichment comes from anthropogenic contamination. Zn is widely used as a sacrificial anodizing metal on boat hulls and metal crab traps (Al Wesche, pers. comm.). Similarly, Cu is also ubiquitous but not at the same level as Zn. Sources of Cu include marine paints widely used until recently, and chemical compounds used to impregnate wood for marine use.

Table IV. Comparisons of average enrichment factors in various East and Gulf Coast estuaries. Enrichment factors are relative to the average earth's crust (Taylor, 1964). *N* is the number of samples used to obtain the average factors. The table was modified from Sinex and Helz, 1981.

	Cr	Cu	Mn	Ni	Zn	*N*
Narragansett Bay (Goldberg *et al.*, 1977)	3	6	1	1	6	(1)
Hudson Estuary (Williams *et al.*, 1978)	-	2	2	-	4	(37)
Delaware Bay (Bopp and Biggs, 1973)	3	2	-	13	10	(124)
Chesapeake Bay (Sinex and Helz, 1981)	1	1	2	1	5	(177)
Baltimore Harbor (Villa and Johnson, 1974)	7	10	1	1	20	(194)
Isle of Wight/Assawoman Bays (this study*)	**1**	**1**	**1**	**1**	**3**	**(14)**
Savannah River (Goldberg *et al.*, 1978)	1	1	1	1	1	(5)
Mobile Bay (Brannon *et al.*, 1977)	-	1	1	-	4	(8)
Mississippi Delta (Trefry and Presley, 1976)	-	1	1	1	3	(72)
Galveston Bay (Hann and Slower, 1972)	4	2	3	2	6	(44)
San Antonio Bay (Trefry and Presley, 1976)	-	1	1	1	3	(51)

* Averages based on surface samples (top of cores) only.

Variation from Historical Norms

The "degree" of metal enrichment in sediments relative to a regional norm or historical levels can be assessed by correlating trace metal concentrations with grain size composition (Hennessee *et al*, 1990; Hill *et al.*, 1990). Based on the downcore decrease in enrichment factor values, metal concentrations of sediments below 30 cm in the sediment column are interpreted to represent the historical norm for the coastal bays. Metal concentration values for these sediments (*i.e.* sediments below -30 cm) were fitted to the following equation:

$$X = a(SAND) + b(SILT) + c(CLAY) \tag{2}$$

where:

X is the metal of interest;

a, b, and b are the proportionality coefficients determined for the SAND, SILT and CLAY components, respectively; and

SAND, SILT, and CLAY are grain size fractions of the sediment sample.

Using an algorithm developed by Marquardt (1963), least square coefficients were estimated. The results are presented in Table V. The correlations are excellent for all of the metals. The values for the coefficients indicate that CLAY fractions account for a significant amount of the metal concentrations.

Table V. Least squares coefficients for metal data. Metal concentration values for sediments sampled below 30 cm in cores were fitted to Equation 2. Core 14 data were not included in the data set.

	Estimates of coefficients					
	Cr	Cu	Fe	Mn	Ni	Zn
SAND	5.4905	0.97712	0.12284	37.682	3.43225	5.158017
SILT	32.8062	5.83	1.24878	166.7049	13.37438	25.15979
CLAY	173.0266	14.374	7.8523	691.4095	50.4597	127.3579
R^2	0.9505	0.9042	0.9536	0.823282	0.9006	0.92221

By substituting the least squares coefficients from Table V in equation 2, "predicted" metal concentrations were calculated for all of the sediments. These predicted metal concentration values represent the expected historical or background levels of metals based on grain size composition of the sediment. To determine variations from historical norms, the predicted metal concentrations were compared to the measured values using the following equation.

$$Variation_X = \left(\frac{Measured_X - Predicted_X}{Predicted_X}\right) \qquad (3)$$

Negative values indicate depletion and positive values indicate enrichment relative to background levels.

Variation values calculated for sediments below 30 cm in the sediment column were analyzed according to Gaussian statistics. Variation values for all metals exhibit near-normal distributions with mean values close to zero. Mean variation values and standard deviations for each metal are presented in Appendix III (Table XIV). The standard deviation (σ), a measure of dispersion of values, provides a convenient means to identify significantly high or low variation values. For example, in a normal distribution, 68% of the values fall within 1σ of the mean; 95.5% of the values fall within 2σ of the mean. Values greater than 3σ are considered significant beyond the natural population dispersion.

The variation values for each metal were calculated for all core sediments and are presented in Appendix III (Table XV). Variation values exceeding 3σ are highlighted in the table. Compared to enrichment factors, variation values reveal similar trends in Cu and Zn behavior. Variation values for Cu and Zn for surficial and near surface sediments (sample depths < 20 cm) for all cores except core 13 exceed 3σ levels. Surficial sediments contain twice the amount of Cu and Zn over background levels (historical levels). Cr, Fe, Mn and Ni do not vary appreciably from background levels in the sediment column. With the exception of core 14, variation values for Cr, Fe, Mn, and Ni for surficial sediments at all stations fall within 2σ levels. The Fe and Mn contained in the sediment are attributed almost entirely to natural sources and, therefore, are not expected to show any increase (or decrease) over historical or background levels. On the other hand, based on the results of enrichment factor analysis, higher variation values were expected for Cr and Ni. However, the calculated variation values for Cr and Ni fall within 2σ levels, suggesting that these two metals also come from natural sources and not from anthropogenic contamination.

METHODS

SEISMIC PROFILING

Shallow seismic surveys were conducted in April, 1992. Approximately 33 kilometers of seismic profile surveys were collected. Track lines for the seismic surveys are shown in Figure 5. Seismic profiles were collected using a Raytheon subbottom profiler, Model DE 719 Survey Fathometer, with a PTR 106 C-1 Transceiver, set at a frequency of 7 kHz. A Loran-C System was used for navigation. Loran time difference pairs (TD's) were recorded every two minute and referenced to time fix marks on the seismic record. Loran TD's were converted to geographic coordinates using a conversion program developed for the Chesapeake Bay (Halka, 1987). The corrected geographic coordinates were further adjusted for the study area by adding correction factors of -5.26" latitude and +1.70" longitude.

CORING TECHNIQUES

Cores and surficial sediments were collected during July, 1991. Location of the fourteen (14) sampling stations are shown in Figure 5. Positions of these stations were determined by a Loran-C Navigational System.

Most cores were collected within the central portions of the bay to insure vertical sampling of fine-grained sediments representative of modern lagoonal muds. However, other depositional environments such as fringing marsh, tidal stream and tidal shoal areas were also sampled to compare physical and chemical characteristics of sediments from the different depositional environments.

In water depths greater than 1.5 m (5 ft) sediment cores were collected using a Benthos Gravity corer, Model #2171, fitted with clear cellulose acetate butyrate (CAB) liner tubes, 6.7 cm in diameter. At three stations (#3, 5, and 8), the bottom was too hard (sandy) for the corer to penetrate. As a result, only surficial sediment samples were collected at these stations. In waters depths shallower than 1.5 m cores were collected using a portable vibracoring unit similar to the unit described in Finklestein and Prins (1981). CAB tubes were used as core liners. As soon as the cores were collected, they were cut at the sediment-water interface and capped. Once in the laboratory, the cores were refrigerated at 4°C until analyses.

LABORATORY ANALYSES

Xeroradiography and Initial Core Processing

Prior to analyses, the cores were X-rayed using a TORR-MED medical X-ray unit. Instrument settings varied depending on the composition of the cores. The most frequently used settings ranged between 80 to 90 kV at 5 mA for 30 to 50 seconds.

Latent X-ray images of the cores were developed using a dry processing technique (xeroradiography) invented by the Xerox Corporation. For the developing process, the negative mode setting was used, producing a radiograph in which denser material such as sand or shells show up as white images. Composites of the xeroradiographs are presented in Appendix II.

After X-raying was completed, each core was extruded from the plastic liner, split, photographed and visually described noting any sedimentological structures and lithological changes. Core logs are presents in Appendix II.

Sediment samples were taken at specific locations in the cores based on the visual and radiographic observations.

Textural Analyses

Sediment samples were analyzed for water content and grain size (SAND, SILT, CLAY content). Water content was calculated as the percentage of water weight to the weight of the wet sediment using equation 4.

$$\% Water = \frac{W_w}{W_t} * 100 \tag{4}$$

where: W_w is the weight of water; and

W_t is the weight of wet sediment.

Water content was determined by weighing 30 to 50 grams of sediment, drying the sediment at 65°C, and then reweighing the dried sediment. Dried sediments were saved for chemical analyses (see **Chemical Analyses** section).

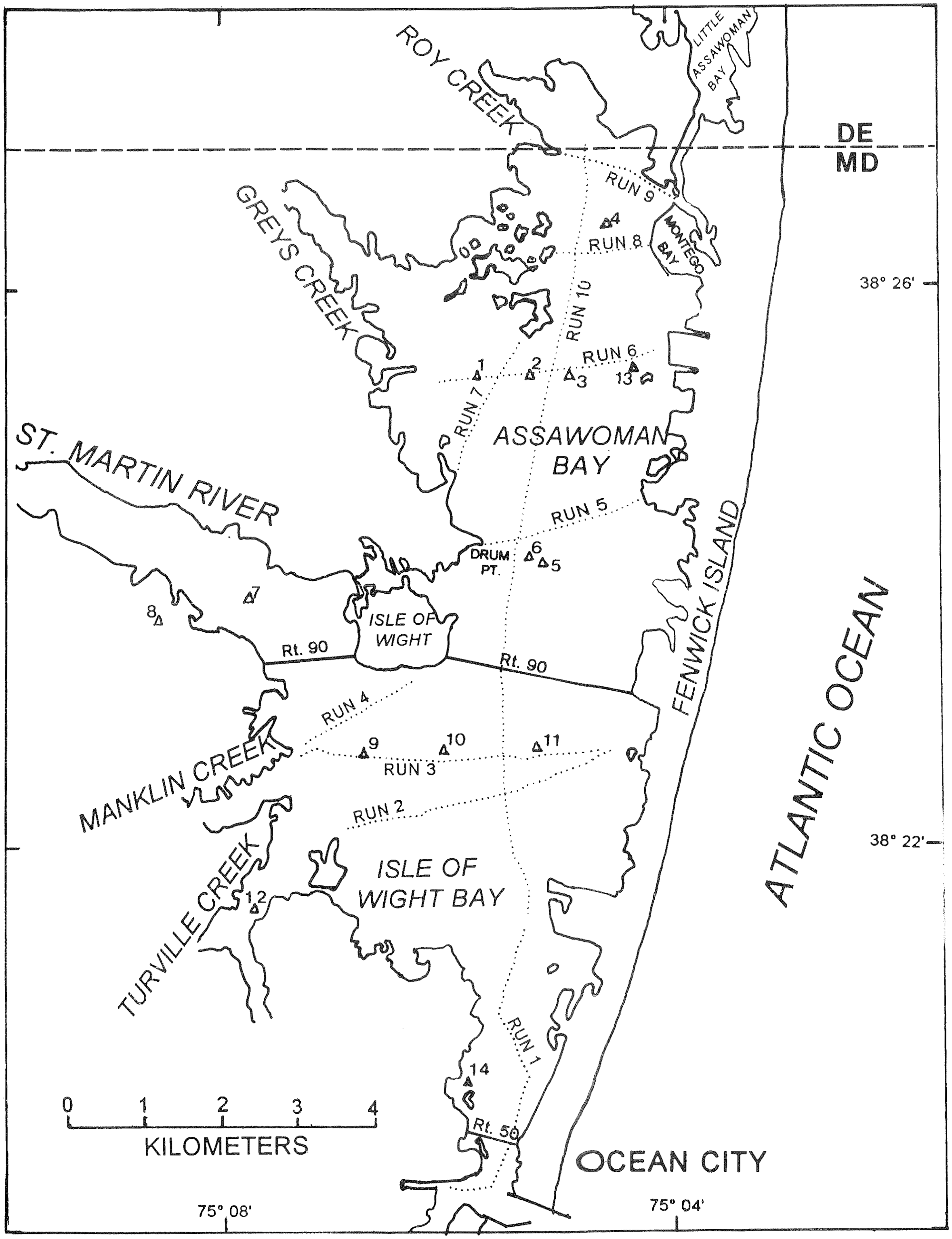

Figure 5. Map of the track lines for seismic profile surveys with locations of core and surficial sediment stations.

SAND, SILT and CLAY contents were determined using the textural analysis detailed in Kerhin *et al.* (1988). Sediment samples were first treated with 10% solution of hydrochloric acid (HCl) to remove carbonate material such as shells and then treated with a 6 to 15% solution of hydrogen peroxide (H_2O_2) to remove organic material. The sediments were then passed through a 62 micron mesh sieve separating SAND from the mud fraction.

Mud fractions were analyzed using a pipette technique to determine SILT and CLAY contents. Weights of the SAND, SILT and CLAY fractions were converted to relative proportions (weight percentages). The sediments were categorized according to Shepard's (1954) classification based on percent SAND, SILT and CLAY components.

SAND fractions were analyzed using a rapid sediment analyzer (RSA) (Halka *et al.*, 1980), obtaining graphic mean, inclusive graphic standard deviation (sorting) and inclusive graphic skewness.

The results of the textural analyses are listed in Appendix III.

Chemical Analyses

Sediments dried for water content determination were analyzed for total elemental nitrogen, carbon and sulfur (NCS) contents and six metals. The dried sediments were pulverized in tungsten-carbide vials using a ball mill, then placed in Whirl-Pak^{TM} bags and stored in a desiccator.

Nitrogen, Carbon, and Sulfur Analyses

The sediments were analyzed for total nitrogen, carbon and sulfur (NCS) content using a Carlo Erba NA1500 analyzer. Approximately 10 to 15 mg of dried sediment was weighed into a tin capsule. The exact weight (to the nearest μg) of the sample was recorded. To enhance complete combustion during the analysis, 15 to 20 mg of vanadium pentoxide (V_2O_5) was added to the sediment. For estuarine and marine sediments, the optimum ratio of vanadium to sediment is 1.5:1. The tin capsule containing the sediment and vanadium pentoxide mixture was then crimped to seal and stored until analysis.

The sediment sample, contained in a tin capsule, was dropped into a combustion chamber where the sample was oxidized in an atmosphere of pure oxygen. The resulting combustion gases, along with pure helium used as a carrier gas, were passed through a reduction furnace to remove free oxygen and then through a sorption trap to remove water. Separation of the gas components was achieved by passing the gas mixture through a chromatographic column. A thermal conductivity detector was used to measure the relative concentrations of the gases.

The NA1500 Analyzer was configured for NCS analysis using the manufacturer's recommended settings. As a primary standard, 5-chloro- 4-hydroxy- 3-methoxy-benzylisothiourea phosphate was used. Blanks (tin capsules containing only vanadium pentoxide) were run every 12 samples and standards. Replicates of every fifth sample were run. As a secondary standard, a NIST reference material (NIST SRM #1646 - Estuarine Sediment) was run every 6 to 7 samples. Table VI presents the comparisons of the MGS results and the certified values for total carbon, nitrogen and sulfur contents for the NIST standard. There is excellent agreement between the NIST values and MGS's results.

Table VI. Results of nitrogen, carbon, and sulfur analyses of NIST-SRM #1646 (Estuarine Sediment) compared to the certified or known values. MGS values were obtained by averaging the results of all SRM analyses run during this study.

Element Analyzed	Certified Values* (% by weight)	MGS Results (this study)
Nitrogen	0.211	0.21 ±0.01
Carbon	1.72	1.71 ±0.12
Sulfur	0.96	0.99 ±0.08

* The value for carbon is certified by NIST. The sulfur value is the non-certified value reported by NIST. The value of nitrogen was obtained from repeated analyses inhouse and by other laboratories (Haake Buchler Labs and U.S. Dept. of Agriculture).

Monosulfide Analyses

Monosulfides (acid volatile sulfides) were determined using a method adapted from Berner (1964, 1970). Wet sediment samples were acidified to produce hydrogen sulfide (H_2S), purged with oxygen-free nitrogen gas (N_2), and trapped in a solution of zinc sulfate-ammonium hydroxide which converted the H_2S to zinc sulfide (ZnS). The ZnS was then re-acidified, producing H_2S, the amount of which was determined by iodometric titration.

Metal Analyses

Sediments were analyzed for six metals: chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn). These metals were selected for several reasons. 1) These metals are non-volatile. As opposed to volatile metals, these metals are less likely to be lost during analytical procedures used in this study. 2) Studies have shown that these metals can be used as environmental indicators (Hennessee *et al.*, 1990; Hill, 1984; Cantillo, 1982; Sinex and Helz, 1981). 3) Comparable data for these metals are available for the Chesapeake Bay (Cantillo, 1982; Helz *et al.*, 1982; Hill *et al.*, 1985; and Sommer and Pyzik, 1974) and for other estuaries (Sinex and Helz, 1981).

Concentrations for the six metals were determined using a microwave digestion technique, followed by analyses of the digestate on an Inductively Coupled Argon Plasma unit (ICAP). The microwave digestion technique is detailed in Appendix IV.

A Thermo Jarrel-Ash Atom Scan 25 sequential ICAP was used for the metal analysis. The wavelengths and conditions selected for the metals of interest were determined using digested bottom sediments from the selected sites in the Chesapeake Bay and reference materials from the National Institute of Standards and Technology (NIST SRM #1646 - Estuarine Sediment; NIST SRM #2704 - Buffalo River Sediment) and the National Research Council of Canada (PACS-1 - Marine Sediment).

The wavelengths and conditions were optimized for the expected metal levels and the sample matrix. Quality control was maintained using the method of bracketing standards (Van Loon, 1980). Blanks were run every 12 samples. Replicates of every tenth sample were run. A set of reference materials (NIST #1646, NIST #2704, and PACS-1) was analyzed every ten to fifteen samples.

Results of the analysis of the three standard reference materials are compared to the certified values in Table VII. The MGS's results indicate better than 90% recovery for all of the metals except Mn. The lower recovery values for Mn (for NIST SRM #1646 and PACS-1) may be due to incomplete digestion during sample preparation.

Table VII. Results of metal analyses of standard reference materials compared to the certified values.

Metals	Certified Values			MGS Results					
	BR*	ES*	PAC*	BR*	% recovery	ES*	% recovery	PAC*	% recovery
Cr (μg/g)	135 ±5	76 ±3	113 ±8	128 ±2.21	94.6	77 ±2.54	94.5	107 ±2.83	94.5
Cu (μg/g)	98.6 ±5	18 ±3	452 ±16	94 ±1.11	95.3	16 ±1.00	91.2	431 ±18.87	95.3
Fe (%)	4.11 ±0.1	3.35 ±0.1	4.87 ±0.12	4.00 ±0.12	97.3	3.12 ±0.11	93.1	4.67 ±0.15	96.0
Mn (μg/g)	555 ±19	375 ±20	470 ±12	550 ±15.38	99.1	287 ±17.90	76.5	348 ±15.17	74.0
Ni (μg/g)	44.1 ±3	32 ±3	44.1 ±2	40 ±1.05	90.3	29 ±1.38	91.6	39 ±1.24	89.3
Zn (μg/g)	438 ±12	138 ±6	824 ±22	416 ±3.08	94.9	116 ±1.40	84.2	796 ±9.68	96.6

*BR = NIST-SRM #2704 - Buffalo River Sediment
*ES = NIST SRM #1646 - Estuarine Sediment
*PAC= National Research Council of Canada PACS-1 - Marine Sediment

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Appendix I

Location data for coring sites and selected seismic surveys .

Table VIII. Coordinates (latitude and longitude) of time fixes for seismic records presented in Figures 2 and 3. Coordinates are based on 1927 North American datum.

TRACK LINE	FIX #	DATE	TIME	LATITUDE			LONGITUDE			COMMENTS
				DD	MM	SS.S	DD	MM	SS.S	
RUN 3	32	May 4 1992	1429	38	22	37.7	75	6	9.8	
	33		1431	38	22	37.8	75	6	17.8	
	34		1433	38	22	38.3	75	6	27.1	
	35		1435	38	22	38.9	75	6	34.9	Core station 9
	36		1437	38	22	38.8	75	6	44.0	
	37		1439	38	22	39.8	75	6	52.9	
	38		1441	38	22	40.2	75	7	1.1	
	39		1443	38	22	42.8	75	7	9.7	
	end		1445	38	22	39.3	75	7	18.6	EOL; Cedar Island
RUN 8	1	May 5 1992	1157	38	26	14.9	75	5	1.8	SOL; Corn Hammock
	2		1159	38	26	15.6	75	4	57.7	west to east; $A_z = 85°$
	3		1201	38	26	15.4	75	4	51.6	
	4		1203	38	26	15.5	75	4	51.5	
	5		1205	38	26	14.9	75	4	37.0	
	6		1207	38	26	16.2	75	4	29.2	
	7		1209	38	26	16.9	75	4	20.2	
	8		1211	38	26	17.9	75	4	12.8	
	9		1212	38	26	18.3	75	4	9.0	EOL; Montego Bay Trailer Park

Table IX. Geographical coordinates and general information for sampling stations.

STATION #	LATITUDE			LONGITUDE			LENGTH (cm)	WATER DEPTH (M)	COMMENTS
	DD	MM	SS.S	DD	MM	SS.S			
1	38	25	23.3	75	5	41.7	-75	2.13	
2	38	25	23.6	75	5	13.0	-60	2.29	
3	38	25	23.6	75	4	52.5	SURF	1.98	
4	38	26	28.2	75	4	33.8	-68	3.05	MONTEGO BAY
5	38	24	2.7	75	5	6.5	SURF	2.44	
6	38	24	5.4	75	5	13.4	-85	2.44	
7	38	23	47.3	75	7	46.5	-88.5	1.83	ST. MARTIN RIVER
8	38	23	37.7	75	8	36.6	SURF	2.44	DEAD-END CANAL, OCEAN PINES
9	38	22	41.3	75	6	43.3	-76	1.98	
10	38	22	42.4	75	5	59.2	-76	2.13	
11	38	22	43.6	75	5	9.3	-41	2.13	
12	38	21	34.0	75	7	43.5	-89	2.44	TURVILLE CREEK
13	38	25	26.2	75	4	19.6	-73	1.07	
14	38	20	19.6	75	5	46.5	-130	1.07	

Appendix II

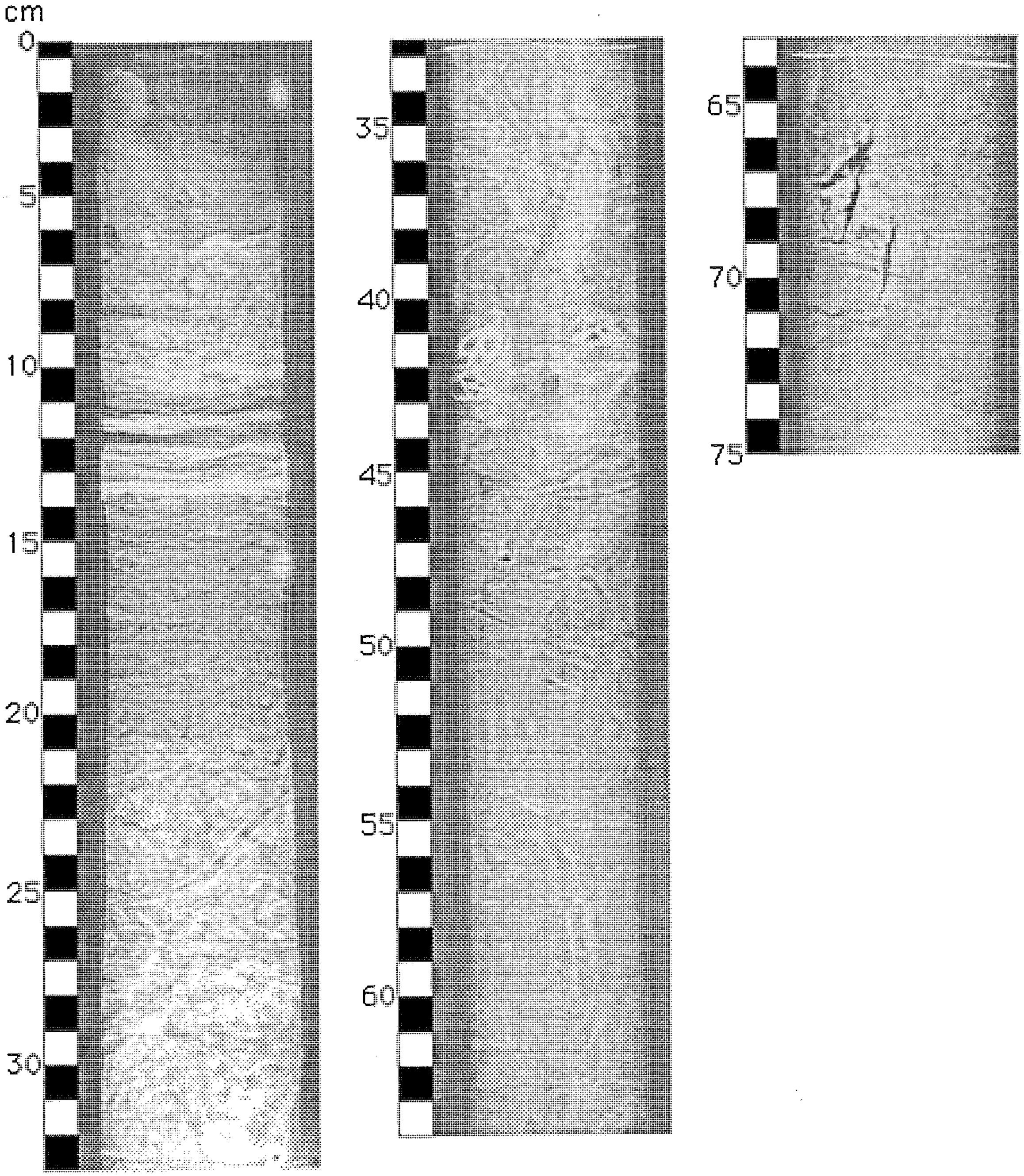
Lithologic logs and xeroradiographs for sediment cores collected in Isle of Wight and Assawoman Bays. Coordinates and descriptions for the surficial samples are also included. Refer to Table IX and Figure 5 for station locations. Sediment color descriptions are referenced to the GSA Rock-Color Chart which is based on the Munsell system of color identification (Goddard *et al.*, 1948).

STATION 1

DEPTH (cm)	DESCRIPTION
0-2	Greenish-black (5GY 2/1) soft, mud; slightly gritty texture.
10-14	Slightly lighter, greenish black (5GY 2/1), soft mud, no visible banding but laminae seen in xeroradiograph.
14-20	Greenish black (5GY 2/1) mud, slightly firmer and more gritty than above section; gradually lightens to greenish grey (5GY 4/1), decrease in silt downcore.
20-75	Uniform, firm cohesive, smooth mud, dark greenish grey (5GY 4/1), slight mottling, group of mud snails at 40-42 cm, few shell fragments throughout bottom.

Station 1

Greys Creek



STATION 2

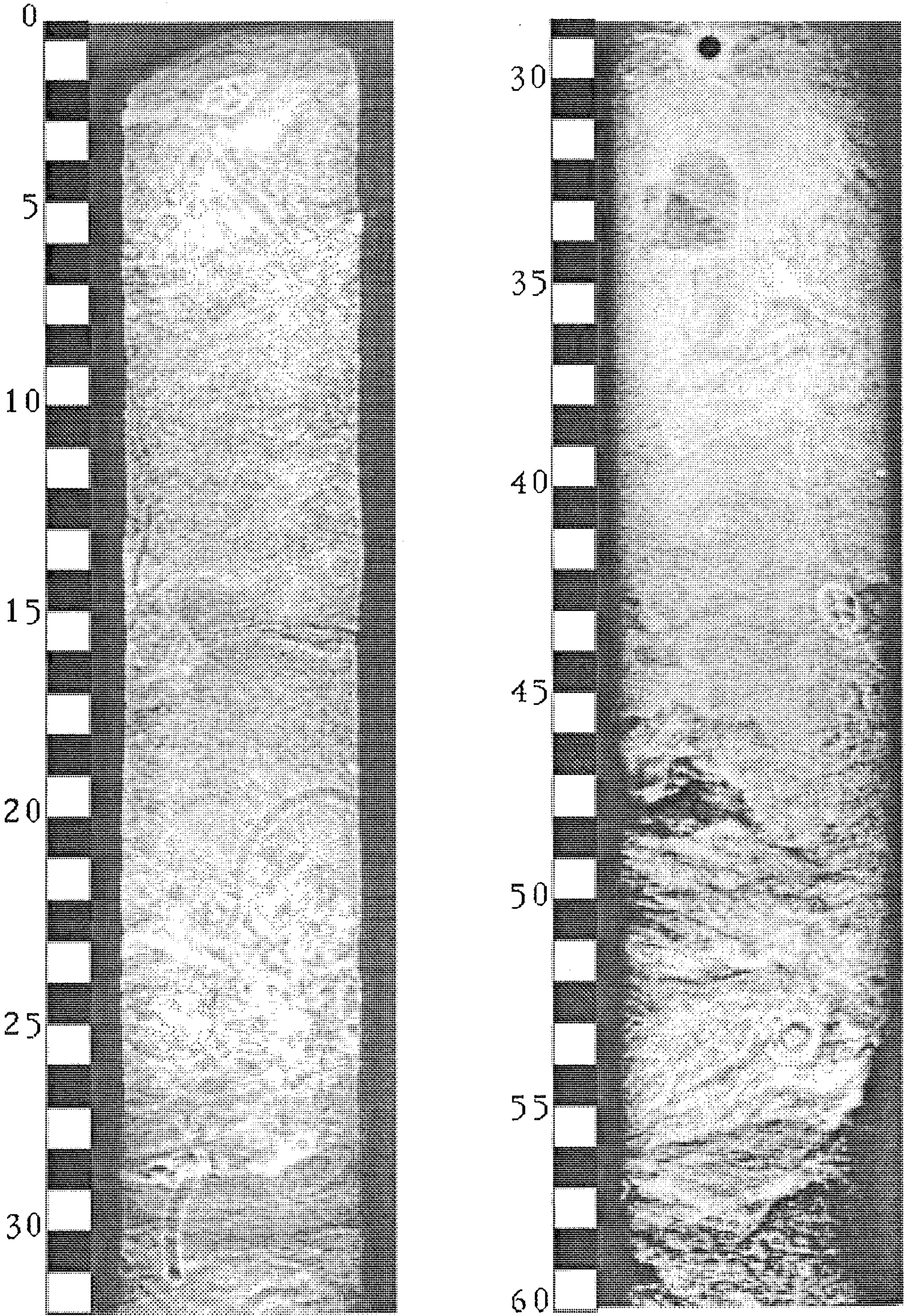
DEPTH (cm)	DESCRIPTION
0-23	Dark greenish grey, silty cohesive mud, silt decreases slightly down core, somewhat mottled appearance with darker band at 14-16 cm; snails at surface, plant material - rhizomes - found in upper 10 cm.
23-30	Lighter greenish grey mud, stiffer than overlaying mud, very little silt, no odor.
30-46	Greenish grey, slightly darker silty mud, silt increases down core; mud snail at 44 cm.
46-55	Mottled mixture of silty mud and peat material, large pocket of peat at 46 to 50 cm.
55-60	Dark brown black gritty mud, peat mixed with large piece of wood.

STATION 3

DEPTH	DESCRIPTION
Surface	Bottom too hard for gravity corer; collected a grab sample: tan to brown medium to fine sand, some silt.

Station 2

Assawoman Bay



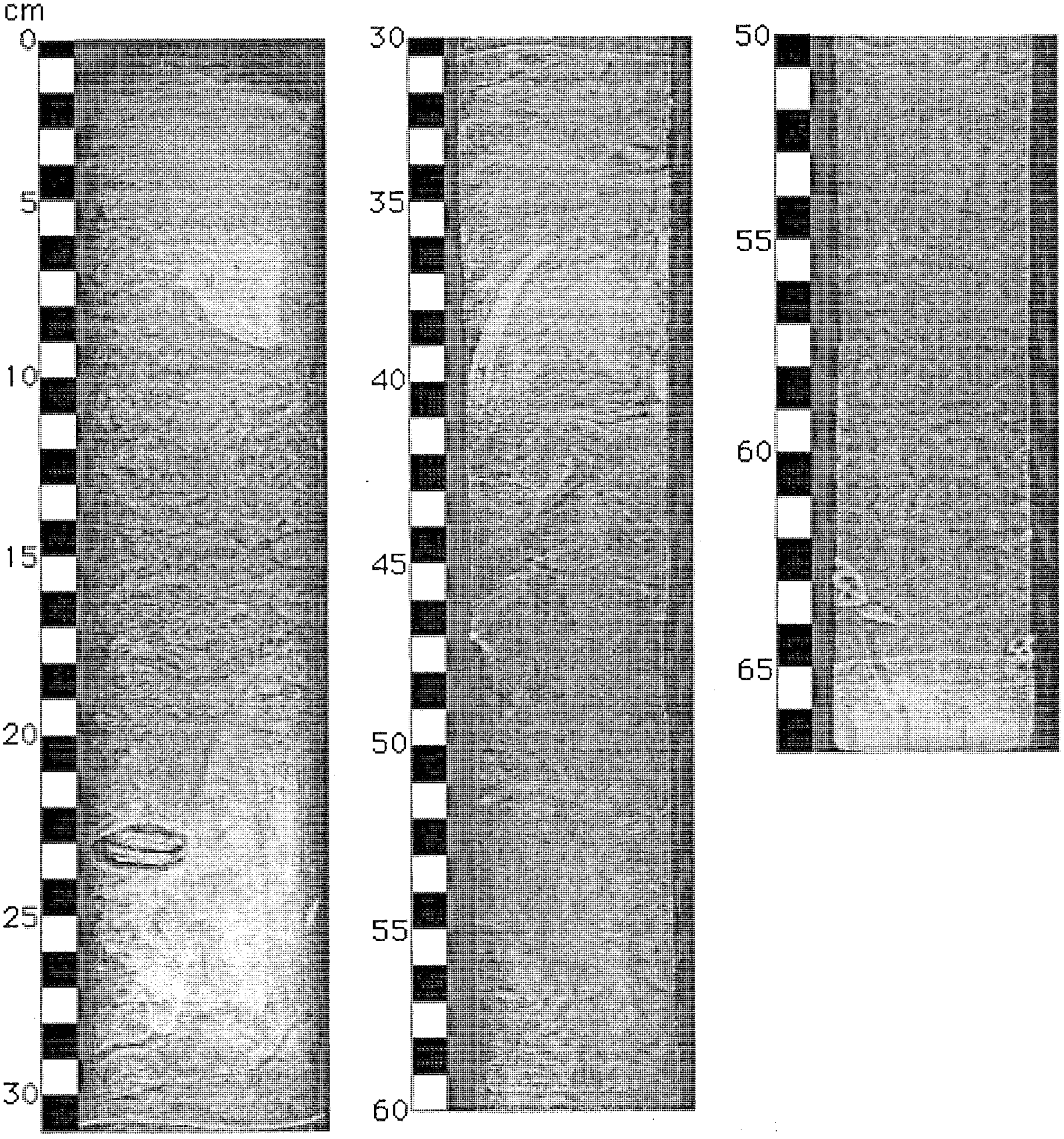
STATION 4

DEPTH (cm)	DESCRIPTION
0-17	Dark green grey (5Y 3/2), firm mud, thin 1 cm floc layer -oxidized to brown color, plant material - rhizomes.
17-40	Olive grey mud, becoming more firm (less water content) and siltier down core, fine mica flakes present; burrow filled with darker mud extends from 17 to 20 cm; very dense clay ball at bottom of burrow (25 cm), very visible in xeroradiograph; layer of shells, bivalve fragments at 34 to 35 cm.
40-67	Color change to grey sediment, slightly softer, less silt, more cohesive, no mica, sediment becomes very smooth, even texture to bottom of core, occasional shell fragment; pocket of shell hash at 42 cm; several gastropods (mud snails) at 60 to 64 cm.

STATION 5

DEPTH	DESCRIPTION
Surface	Bottom too hard for corer, collected grab sample: brown muddy sand.

Station 4
Assawoman Bay/Montego Bay



STATION 6

DEPTH (cm)	DESCRIPTION
0-28	Greenish black (5GY 2/1), cohesive gritty mud, gradually lightens with depth.
28-45	Somewhat abrupt change to dark greenish grey or olive grey (5Y 4/1 or 5GY 4/1) mud.
45-62	Medium grey, sandy mud with pockets of clay, shell fragments and pockets of sandier, very firm mud.
62-80	Medium dark grey (N4) mud, little or no silt, homogeneous, very dense, smooth, firm mud, no H_2S odor.

Station 6
Assawoman Bay

STATION 7

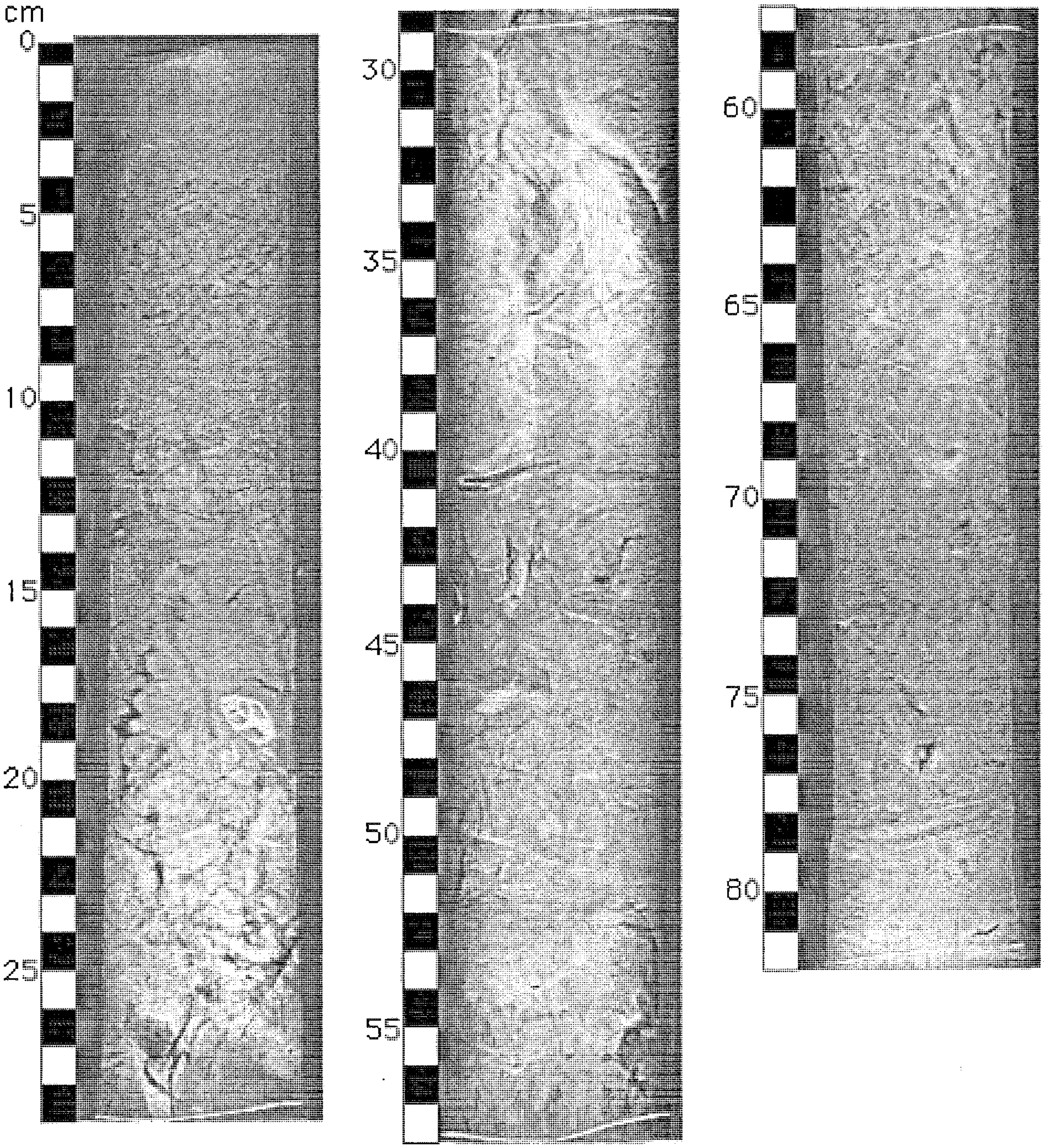
DEPTH (cm)	DESCRIPTION
0-10	Dark olive grey (5Y 2/1), somewhat watery, slightly silty mud, slight H_2S odor.
10-87	Light olive grey (5Y 4/1); very little color change down rest of core, mud becomes more firm - less water; xeroradiograph shows mud is bioturbated but distinct laminae is evident at 30, 43, & 82 cm (not seen visually), few shell fragments scattered throughout, thin shell layer at 46-48 cm.

STATION 8

DEPTH	DESCRIPTION
Surface	Bottom too hard for gravity corer, collected surficial sample: Dark brown stiff sand mud, abundant leaf and woody material.

Station 7

St. Martin River

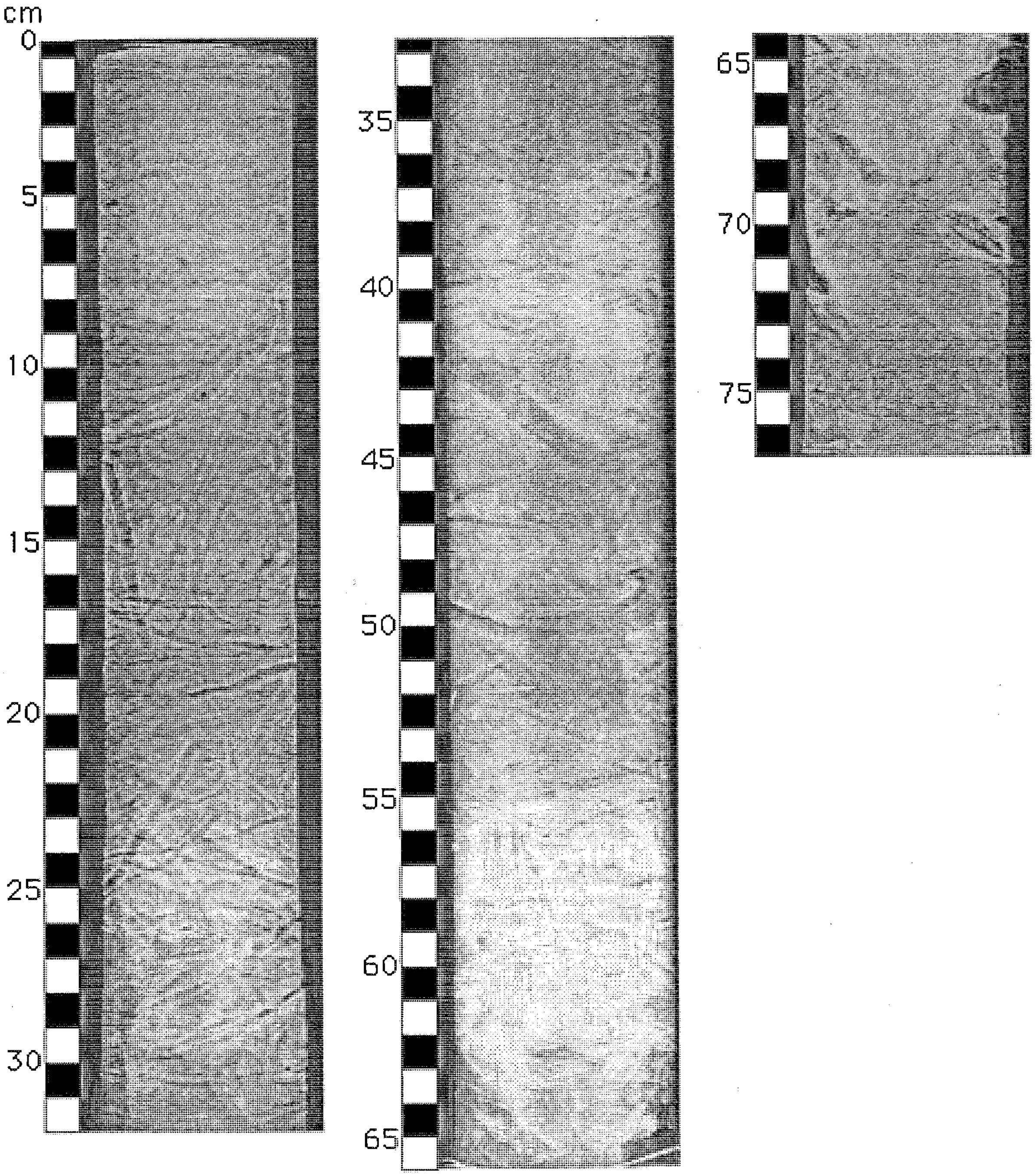


STATION 9

DEPTH (cm)	DESCRIPTION
0-26	Very thin (2 mm) floc layer on top of olive black (5Y 2/1), silty mud, somewhat watery, silt decreases downcore, no visible structures.
26-48	Very subtle change in color to olive grey mud, becomes firmer down core.
48-76	Mottled olive grey (5Y 4/1) to dark greenish grey (5GY 4/1), cohesive mud, very firm; large relic burrows filled with less firm (more watery) mud; voids (gas pockets?) which may have been worm burrows; few shell fragments, disarticulated bivalves at 68 cm, live worms (Polychaetes) throughout core.

Station 9

Isle of Wight Bay

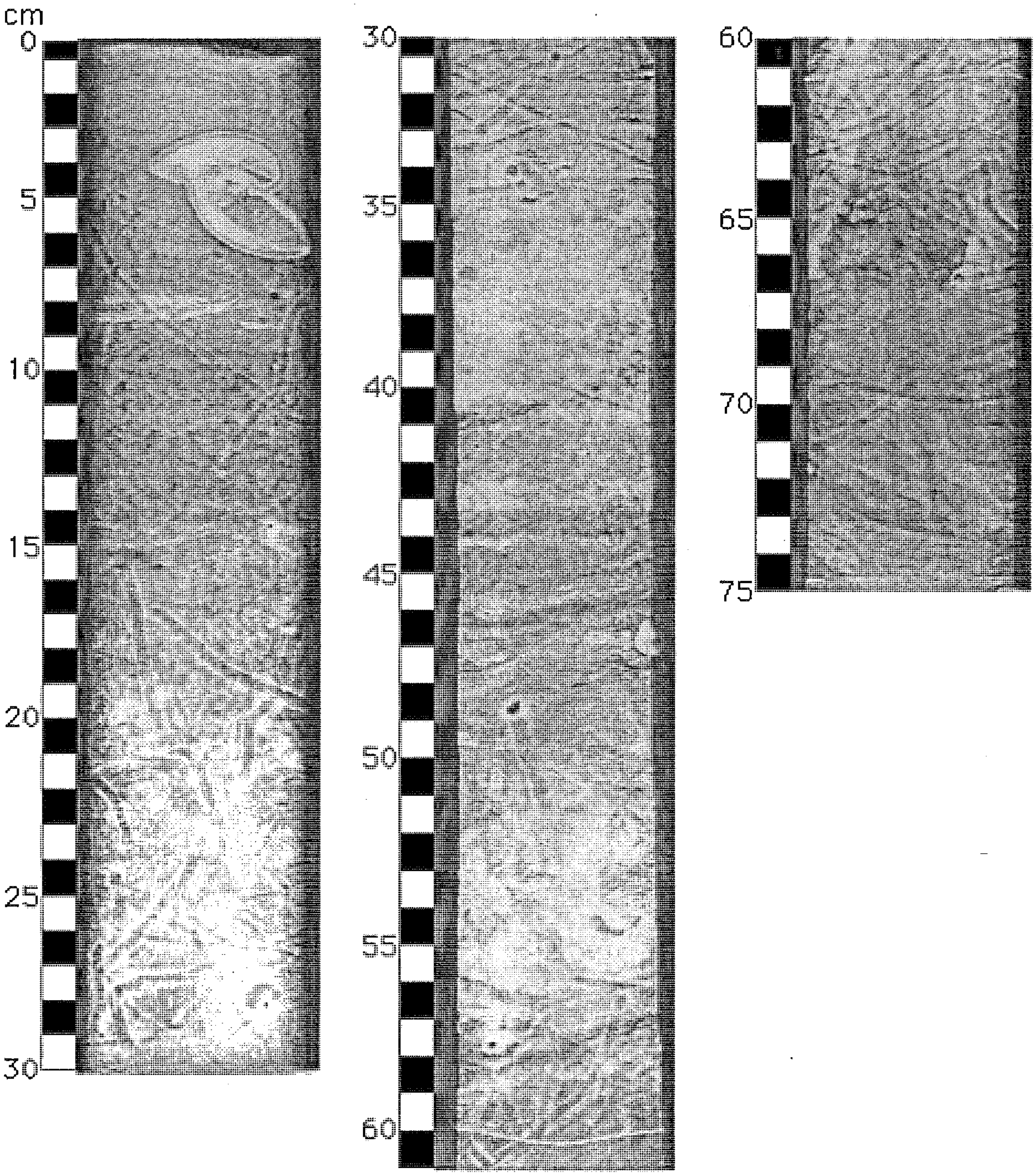


STATION 10

DEPTH (cm)	DESCRIPTION
0-10	Thin (0.5 cm) oxidized brown mud layer on top of greyish black (N2), slightly gritty, cohesive mud, gradually lightens to greenish black (5GY 2/1) mud.
10-34	Dark greenish grey (5GY 4/1) mud, silt increase with depth; subtle mottling between 14-34 cm, abundant worm burrows which appear as voids in split core.
34-76	Dark greenish-grey, cohesive, firm mud; layer distinct in xeroradiograph but not visually visible, large watery pocket of mud at 64-66 cm; few shell fragments throughout core.

Station 10

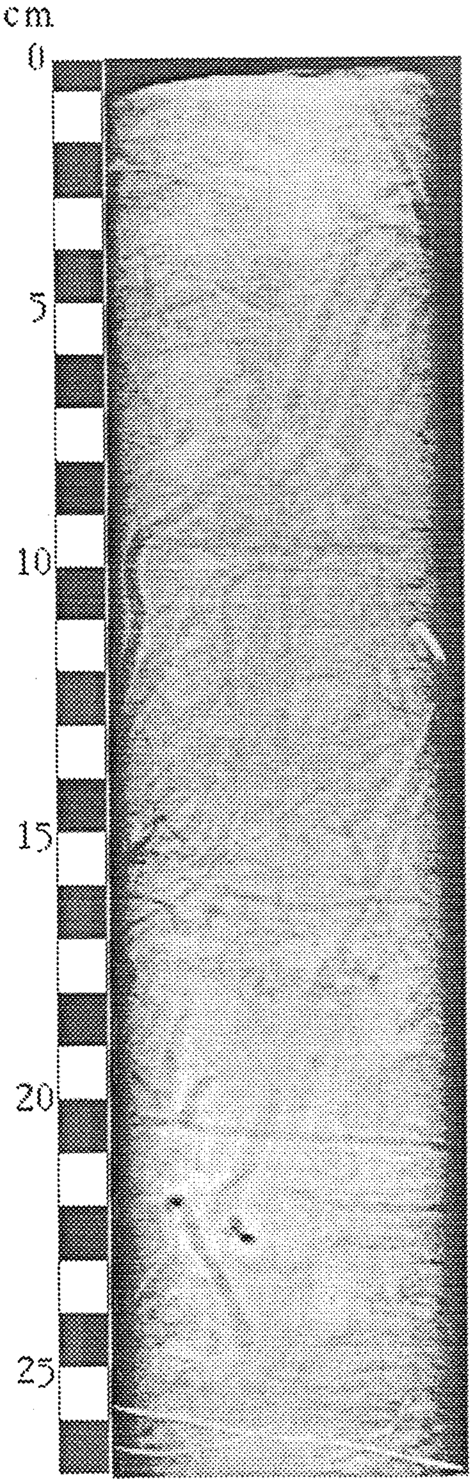
Isle of Wight Bay

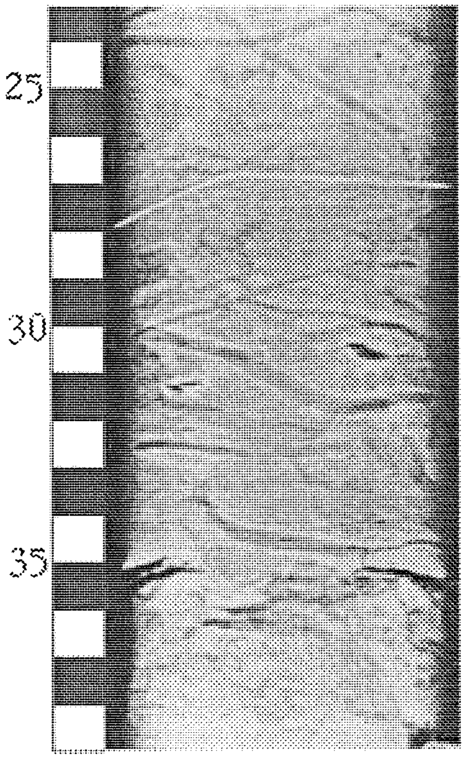


STATION 11

DEPTH (cm)	DESCRIPTION
0-37	Dark greenish-grey to brownish-grey, dry, silty mud; worm burrows throughout (visible in x-ray) suggesting sediment is fairly bioturbated; live worms (polychaetes) common; very subtle (faint) laminae at 10, 18 and 36 cm. Sediments become slightly lighter and more dense down core. Mica flakes are abundant. Shell fragments at 14-15 cm. Strong H_2S odor when first opened, but dissipated quickly; strongest H_2S odor at 26-29 cm. Mud snail (*Nassarius*) at 38 cm.

Station 11
Isle of Wight Bay/ Reedy Pt.



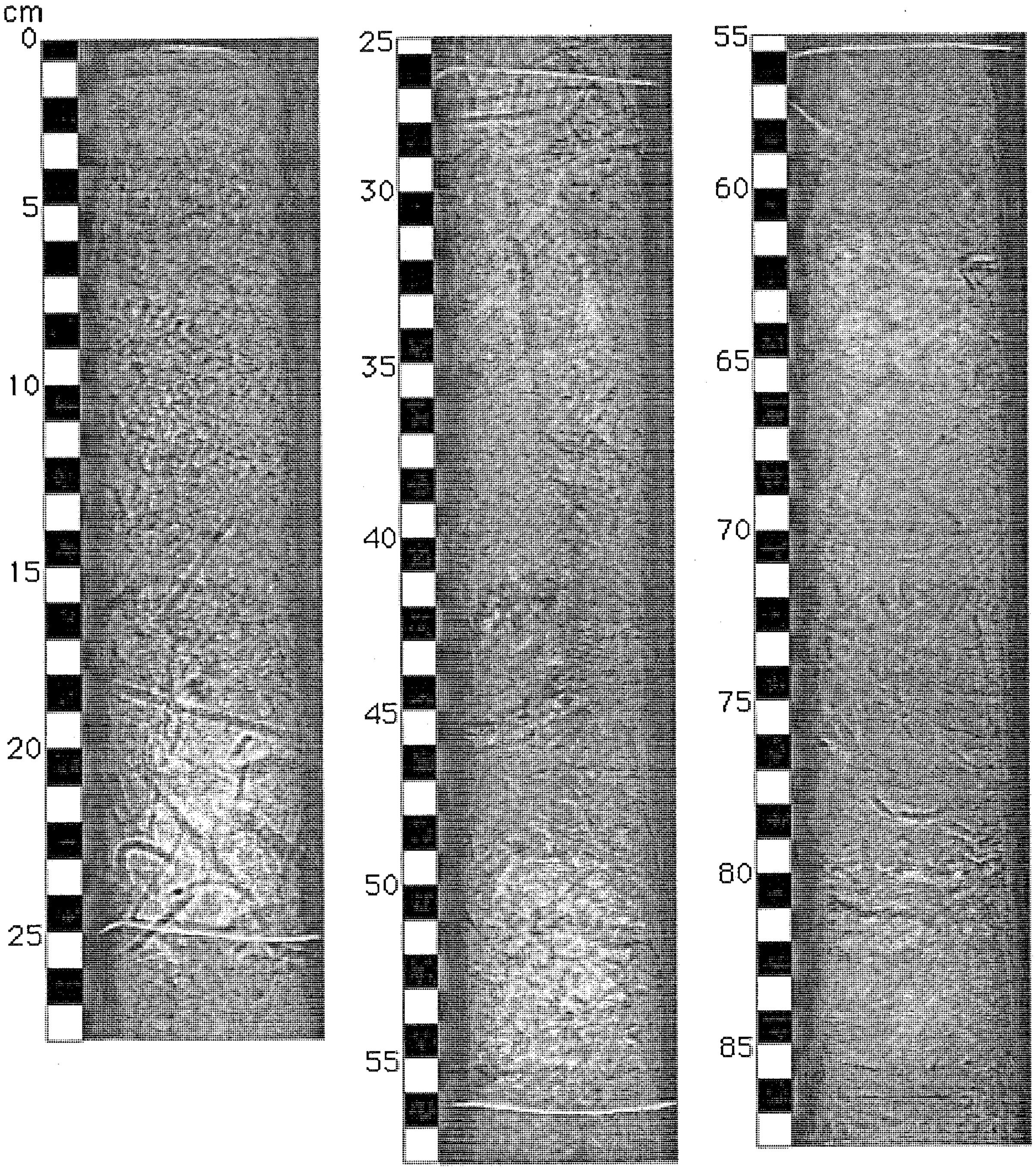


STATION 12

DEPTH (cm)	DESCRIPTION
0-6	Mottled greyish black (N2), to olive black (5Y 2/1), somewhat watery, gritty mud. Sediments gradually lighten down core to uniform olive grey (5Y 4/1). Slight H_2S odor detected when opened.
4-14	Radiograph suggested presence of gas in mud, darker sediments, and small burrows compared to what is seen between 20-30 cm.
20-25	Dryer and firmer than above intervals, no distinguishing features except for worm burrows which show up as voids.
34-36	Plant material.

Station 12

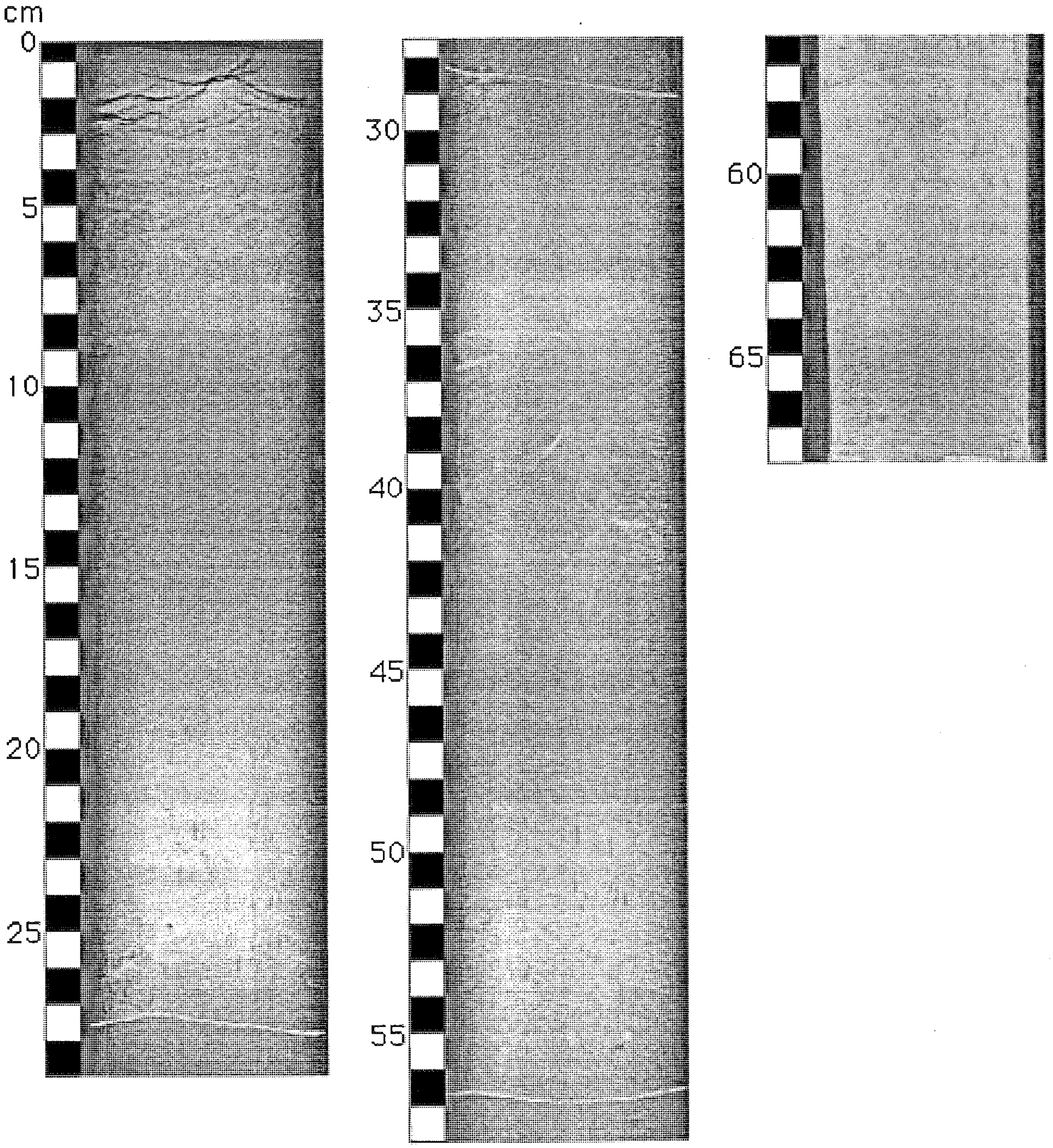
Turville Creek



STATION 13

DEPTH (cm)	DESCRIPTION
0- 4	Light tan sand; layer was lost during core processing.
4-13	Medium to fine sorted, light olive grey (5Y 7/1) sand (lighter than 5Y 6/1).
12-16	Mottled interface where sand becomes darker, olive grey (5Y 4/1).
16-36	Mottled light olive grey (5Y 6/1) to olive grey (5Y 4/1) fine sand.
36-42	Shell layer, pockets of olive black (5Y 2/1), muddy sand and shell fragments.
42-69	Mottled medium light grey (N6) to medium grey (N5) fine sand, very small inclusion of peat (approximately 1-2 mm) between 54-60 cm, below 60 cm - visible small laminae, alternating light & medium grey fine sand.

Station 13
Assawoman Bay/ Horse Island



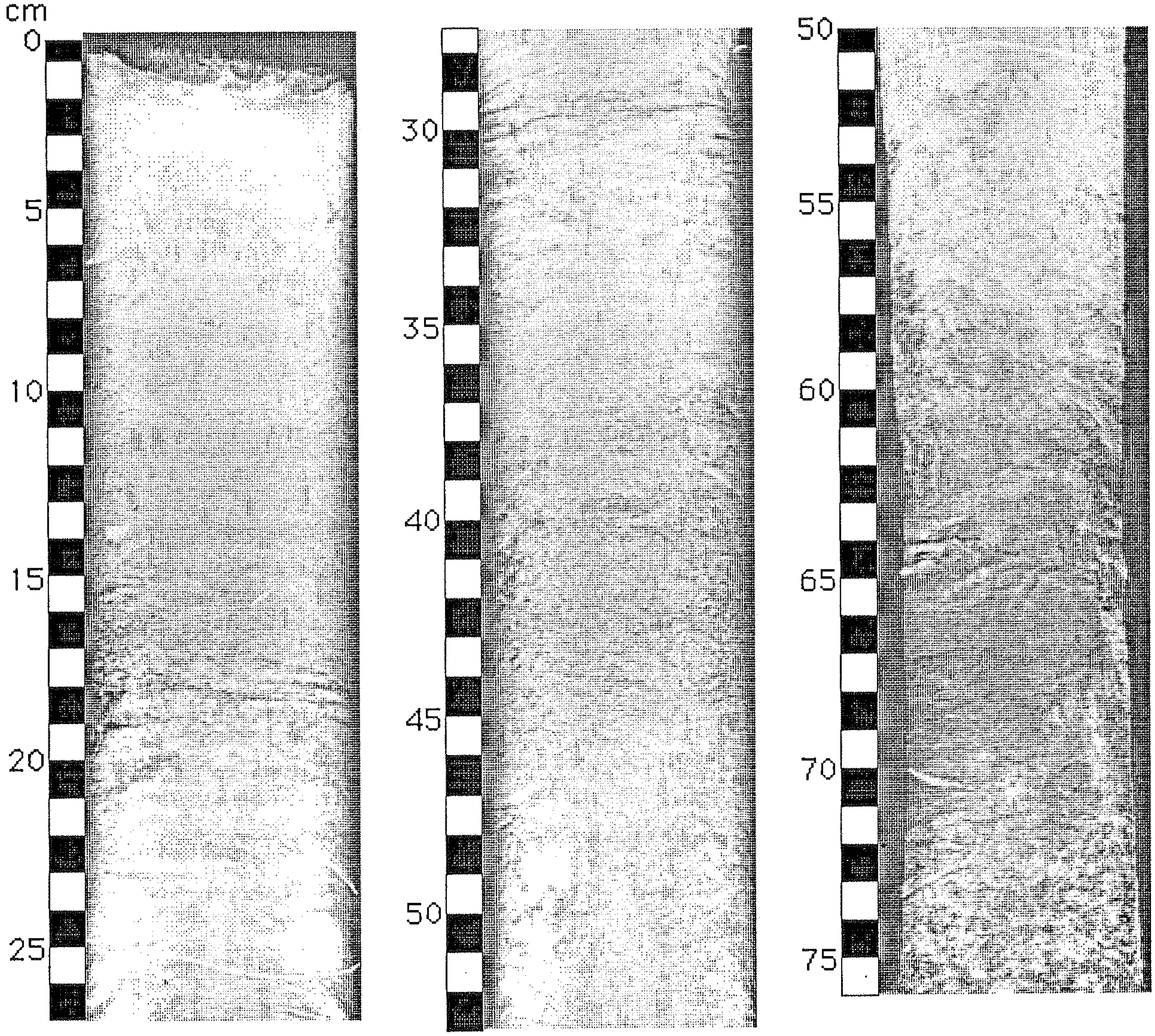
STATION 14

DEPTH (cm)	DESCRIPTION
0-50	Mottled olive grey (5Y 4/1) and greenish black (5GY 2/1), muddy sand, very firm, compact mica flakes visible, decrease in sand down core, light layer (5Y 4/1) of muddy silt at 25 cm, darker greyish black (N2), silty mud above and below layer.
50-68	Greenish black (5G 2/1), silty mud, very compact, dry, firm, mica appears to decrease downcore.
68-75	Greenish black (5G 2/1) to olive grey (5Y 4/1) mud with pockets of peat - greyish brown (5YR 3/2) to moderate brown (5YR 3/4) in color, amount of peat gradually increases down core.
75-88	Predominately peaty material inter-bedded with thin mud, laminae at 82-84 cm.
88-103	Brownish black (5YR 2/1) mud, gradual decrease in peat.
103-120	Banded inter-bedded peat and mud alternating between brownish black to light olive grey mud.
117-120	Light olive grey (5Y 6/1) mud interlaced with vertical peat stringers which may be remnants of plant roots - rhizomes.
120-128	Predominately olive black (5Y 2/1) mud with pockets of peat.

Station 14

Isle of Wight Bay/ Horn Island

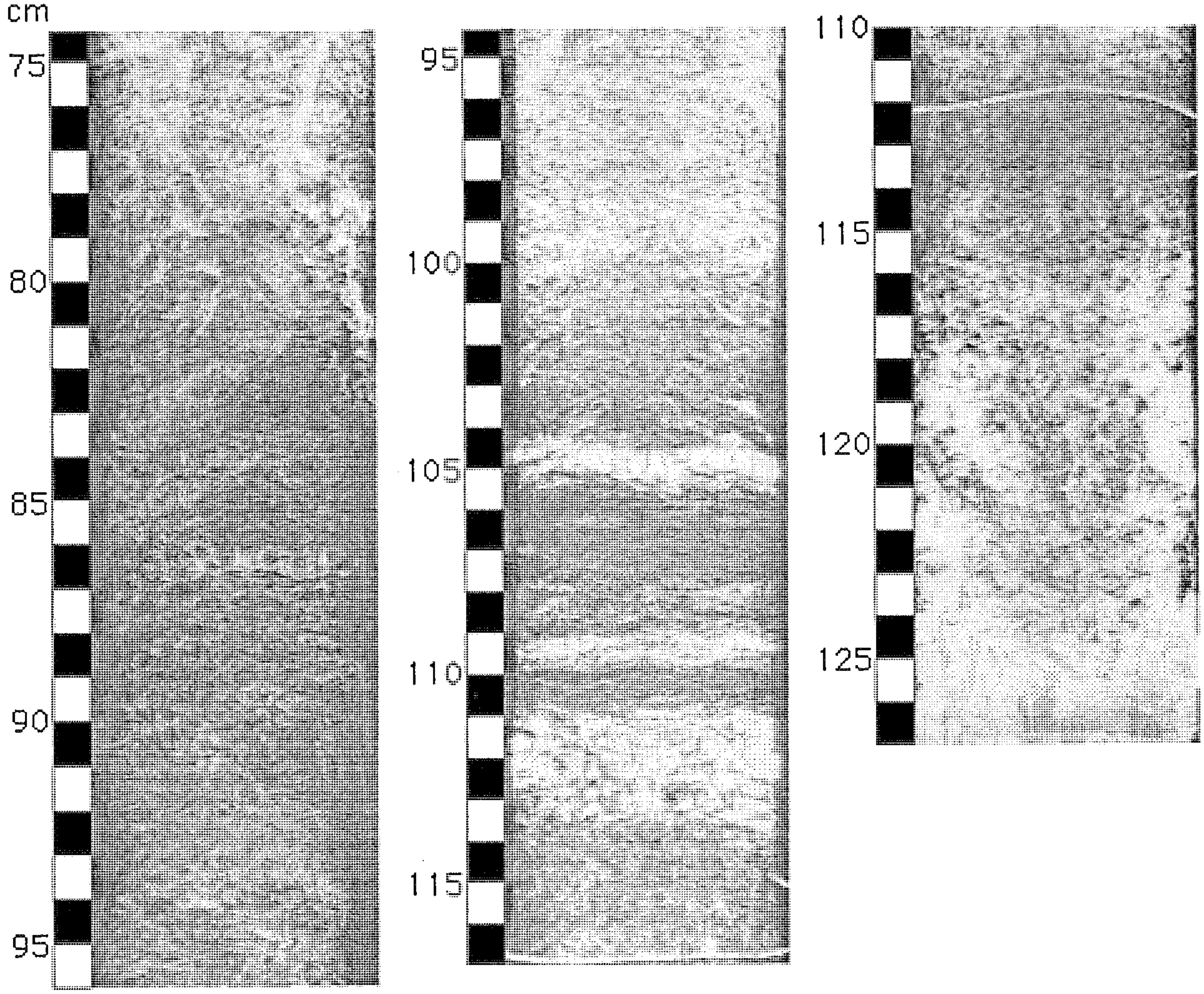
(Top 75 cm)



Station 14

Isle of Wight Bay/ Horn Island

(Bottom 50 cm)



Appendix III

Textural and geochemical data for core sediment samples.

Table X. Textural data for sediment samples taken from cores.

Station #	Sample Interval (cm)		Water content (%)	Textural Component (percent by weight)			Shepard's (1954) Class.*	Statistical Parameters (sand fraction only)	
	Upper	Lower		Sand	Silt	Clay		Mean (ϕ)	Sorting (ϕ)
1	0	-4	52.51	2.59	69.48	27.93	ClSi		
1	-10	-14	51.93	6.90	70.91	22.19	ClSi		
1	-20	-24	47.27	39.94	37.87	22.19	SaSiCl	2.92	0.58
1	-30	-34	41.26	22.19	51.77	26.05	ClSi	3.17	0.58
1	-40	-44	36.92	22.03	51.27	26.70	SaSiCl	3.33	0.41
1	-50	-53	50.63	2.67	52.48	44.85	ClSi	3.33	0.52
1	-60	-63	53.17	2.53	54.56	42.91	ClSi	2.92	0.88
1	-72	-75	52.52	1.50	55.84	42.66	ClSi	3.50	0.31
2	0	-2	31.21	56.96	30.42	12.62	SiSa	2.75	0.52
2	-2	-4	30.52	61.99	27.17	10.84	SiSa	2.58	0.55
2	-4	-6	30.85	69.85	19.85	10.29	SiSa	2.42	0.65
2	-6	-8	32.08	66.04	23.37	10.59	SiSa	2.58	0.72
2	-8	-10	31.96	62.50	25.83	11.68	SiSa	2.50	0.62
2	-18	-20	26.95	68.60	22.22	9.18	SiSa	2.42	0.65
2	-24	-26	51.39	25.84	42.45	31.72	SaSiCl	2.67	0.65
2	-32	-34	19.28	65.06	21.88	13.06	SiSa	2.50	0.72
2	-40	-42	19.77	78.86	14.78	6.37	Sa	2.42	0.78
2	-50	-52	33.98	63.30	25.09	11.61	SiSa	2.25	0.75
2	-58	-60	32.69	72.81	16.05	11.14	SiSa	2.17	0.62
3	0	0	18.65	93.40	4.53	2.07	Sa	2.58	0.34
4	0	-4	38.65	38.30	46.58	15.11	SaSi	3.25	0.28
4	-8	-12	40.04	48.59	36.97	14.44	SiSa	3.08	0.45
4	-16	-20	39.60	26.41	57.33	16.27	SaSi	3.08	0.55
4	-24	-28	33.57	18.99	64.38	16.63	SaSi	3.33	0.34
4	-32	-36	37.73	12.98	68.09	18.93	ClSi	3.25	0.28
4	-40	-44	48.17	3.88	62.13	33.99	ClSi	3.25	0.32
4	-50	-54	50.09	0.95	59.90	39.15	ClSi		
4	-60	-64	45.35	2.01	64.92	33.08	ClSi		
5	0	0	26.02	74.58	18.10	7.32	SiSa	2.83	0.41
6	0	-2	48.86	15.08	60.80	24.13	ClSi	3.33	0.30
6	-4	-6	45.76	19.71	57.10	23.19	ClSi	3.42	0.24
6	-12	-14	44.19	21.40	57.62	20.98	SaSiCl	3.25	0.28
6	-24	-26	45.96	22.85	49.35	27.80	SaSiCl	3.25	0.35
6	-34	-36	45.13	33.51	41.78	24.71	SaSiCl	3.00	0.52
6	-46	-48	28.00	28.16	51.83	20.01	SaSiCl	2.83	0.52
6	-58	-60	28.15	46.07	37.63	16.30	SiSa	3.00	0.52
6	-78	-80	46.57	8.26	50.14	41.60	ClSi	3.17	0.38

Station #	Sample Interval (cm)		Water content (%)	Textural Component (percent by weight)			Shepard's (1954) Class.*	Statistical Parameters (sand fraction only)	
	Upper	Lower		Sand	Silt	Clay		Mean (ϕ)	Sorting (ϕ)
7	0	-2	61.13	0.69	56.07	43.25	ClSi		
7	-4	-6	58.58	1.78	59.24	38.97	ClSi		
7	-8	-10	55.43	3.57	58.80	37.62	ClSi		
7	-12	-14	50.04	2.17	58.53	39.30	ClSi		
7	-24	-26	46.48	1.31	58.89	39.79	ClSi		
7	-36	-38	48.83	1.93	63.40	34.67	ClSi		
7	-48	-50	53.01	1.00	57.02	41.98	ClSi		
7	-60	-62	56.58	0.57	50.15	49.28	ClSi		
7	-72	-74	59.39	0.73	44.12	55.15	SiCl		
7	-84	-86	56.44	0.73	48.04	51.23	SiCl		
8	0	0	47.43	16.81	46.10	37.19	ClSi	2.67	0.65
9	0	-2	47.22	5.69	70.88	23.43	ClSi	3.50	0.24
9	-6	-8	46.31	5.82	69.58	24.61	ClSi	3.50	0.28
9	-14	-16	40.42	7.10	70.08	22.82	ClSi	3.50	0.28
9	-24	-26	42.40	6.88	66.83	26.29	ClSi	3.42	0.38
9	-34	-36	42.52	7.91	66.17	25.92	ClSi	3.50	0.24
9	-50	-52	32.49	15.07	68.10	16.84	ClSi	3.42	0.41
9	-72	-74	39.65	2.05	72.32	25.62	ClSi	3.42	0.41
10	0	-3	44.14	14.21	60.04	25.76	ClSi	3.50	0.28
10	-5	-8	46.52	18.13	56.09	25.79	ClSi	3.33	0.34
10	-14	-17	36.40	35.60	45.97	18.43	SaSi	3.17	0.38
10	-27	-30	35.19	44.35	36.44	19.20	SiSa	3.25	0.28
10	-45	-48	35.82	38.16	44.24	17.61	SaSi	3.25	0.28
10	-57	-60	41.12	24.19	52.31	23.49	SaSiCl	3.33	0.34
10	-72	-75	43.87	13.43	56.39	30.19	ClSi	3.42	0.41
11	0	-3	31.34	63.40	25.68	10.93	SiSa	3.17	0.28
11	-9	-12	27.77	60.03	26.40	13.57	SiSa	3.25	0.28
11	-17	-20	24.33	72.94	17.14	9.91	SiSa	3.17	0.28
11	-26	-29	29.20	70.24	20.31	9.45	SiSa	3.25	0.28
11	-34	-37	25.04	69.04	21.20	9.76	SiSa	3.00	0.28
12	0	-2	Sample not analyzed for textural parameters						
12	-6	-8	56.88	3.90	64.82	31.29	ClSi		
12	-14	-16	56.39	5.71	67.70	26.59	ClSi		
12	-24	-26	51.71	3.46	66.35	30.19	ClSi		
12	-34	-36	56.35	2.55	63.07	34.39	ClSi		
12	-50	-52	54.02	3.63	62.95	33.42	ClSi	3.50	0.24
12	-68	-70	52.49	0.60	62.74	36.65	ClSi		
12	-84	-86	56.50	0.45	57.58	41.97	ClSi		
13	-4	-6	7.98	100.00	0.00	0.000	Sa		

Station #	Sample Interval (cm)		Water content (%)	Textural Component (percent by weight)			Shepard's (1954) Class.*	Statistical Parameters (sand fraction only)	
	Upper	Lower		Sand	Silt	Clay		Mean (ϕ)	Sorting (ϕ)
13	-14	-16	16.54	99.88	0.12	0.001	Sa	2.42	0.41
13	-36	-40	16.04	94.17	3.31	5.83	Sa	2.33	0.52
13	-48	-50	17.45	98.27	1.69	0.04	Sa	2.67	0.41
13	-64	-66	18.09	97.07	2.93	0.001	Sa	2.75	0.28
14	0	-3	22.94	84.18	12.56	3.26	Sa	3.08	0.38
14	-22	-25	32.53	71.16	19.49	9.35	SiSa	3.08	0.18
14	-27	-30	22.50	92.64	6.26	1.10	Sa	3.00	0.24
14	-40	-43	25.48	84.63	11.00	4.38	Sa	3.25	0.28
14	-57	-60	41.50	20.18	50.66	29.16	SaSiCl	3.25	0.28
14	-75	-78	67.88	2.49	45.63	51.88	SiCl		
14	-80	-83	78.93	12.43	38.53	49.05	SiCl		
14	-84	-86	Sample predominately peat; not analyzed for textural parameters						
14	-94	-97	74.50	0.24	38.57	61.19	SiCl		
14	-101	-103	80.89	1.64	44.35	54.01	SiCl		
14	-105	-106	Sample entirely peat; not analyzed for textural parameters						
14	-107	-110	79.30	0.40	49.54	50.06	SiCl		
14	-117	-120	69.10	0.34	55.55	44.11	ClSi		
14	-125	-127	54.09	0.17	50.08	49.76	ClSi		

*Key for sediment classification in Table XI, based on Shepard's (1954) nomenclature:

Sa = SAND
Cl = CLAY
SiSa = SILTY SAND
SaCl = SANDY CLAY
ClSi = CLAYEY SILT
Si = SILT
SaSi = SANDY SILT
ClSa = CLAYEY SAND
SiCl = SILTY CLAY
SaSiCl = SAND-SILT-CLAY

Table XI. Chemical data for sediment samples.

Station #	Sample Interval (cm)		Carbon	Nitrogen	Sulfur	Monosulfide
	Upper	Lower	Percent by weight			
1	0	-4	2.63	0.22	1.04	0.034
1	-10	-14	2.93	0.25	1.43	0.027
1	-20	-24	2.09	0.17	1.32	0.004
1	-30	-34	1.61	0.00	1.27	0.006
1	-40	-44	1.54	0.00	1.16	0.004
1	-50	-53	1.62	0.19	1.71	0.003
1	-60	-63	1.74	0.13	1.47	0.005
1	-72	-75	2.41	0.21	1.82	0.006
2	0	-2	0.90	0.15	0.25	
2	-2	-4	0.87	0.15	0.27	
2	-4	-6	0.91	0.13	0.32	
2	-6	-8	0.00	0.00	0.00	
2	-8	-10	0.97	0.12	0.35	
2	-18	-20	0.81	0.11	0.28	
2	-24	-26	1.69	0.18	1.20	
2	-32	-34	0.45	0.04	0.26	
2	-40	-42	0.44	0.10	0.26	
2	-50	-52	1.38	0.14	0.69	
2	-58	-60	3.96	0.17	0.92	
3	0	0	1.85	0.18	0.09	
4	0	-4	1.70	0.17	0.52	
4	-8	-12	1.50	0.15	0.88	
4	-16	-20	1.45	0.13	1.02	
4	-24	-28	1.22	0.12	0.77	
4	-32	-36	1.45	0.13	1.08	
4	-40	-44	1.34	0.17	1.23	
4	-50	-54	1.64	0.15	1.52	
4	-60	-64	1.71	0.18	1.65	
5	0	0	0.74	0.00	0.22	

Station #	Sample Interval (cm)		Carbon	Nitrogen	Sulfur	Monosulfide
	Upper	Lower	Percent by weight			
6	0	-2	1.99	0.20	0.61	
6	-4	-6	1.77	0.22	0.74	
6	-12	-14	1.76	0.17	0.95	
6	-24	-26	1.68	0.19	0.95	
6	-34	-36	1.39	0.17	0.83	
6	-46	-48	0.72	0.07	0.44	
6	-58	-60	0.60	0.12	0.47	
6	-78	-80	1.29	0.13	1.11	
7	0	-2	3.62	0.31	1.48	
7	-4	-6	3.27	0.28	1.67	
7	-8	-10	2.76	0.29	1.50	
7	-12	-14	1.58	0.18	1.03	
7	-24	-26	1.55	0.20	1.21	
7	-36	-38	0.90	0.00	0.87	
7	-48	-50	1.41	0.17	1.33	
7	-60	-62	1.66	0.20	1.43	
7	-72	-74	2.49	0.28	1.68	
7	-84	-86	2.70	0.25	2.00	
8	0	0	3.15	0.24	0.89	
9	0	-2	1.66	0.17	0.62	
9	-6	-8	1.63	0.18	0.77	
9	-14	-16	1.50	0.16	0.85	
9	-24	-26	2.00	0.20	1.34	
9	-34	-36	1.21	0.14	0.90	
9	-50	-52	0.71	0.14	0.71	
9	-72	-74	0.67	0.17	0.65	
10	0	-3	2.03	0.20	0.83	0.059
10	-5	-8	2.05	0.18	1.03	0.087
10	-14	-17	1.38	0.14	0.75	0.011
10	-27	-30	1.27	0.13	1.01	0.002
10	-45	-48	1.18	0.17	0.80	0.001
10	-57	-60	1.36	0.12	1.08	0.004
10	-72	-75	1.43	0.15	1.25	0.003
11	0	-3	0.90	0.10	0.24	
11	-9	-12	0.72	0.09	0.59	

Station #	Sample Interval (cm)		Carbon	Nitrogen	Sulfur	Monosulfide
	Upper	Lower	Percent by weight			
11	-17	-20	0.90	0.08	0.36	
11	-26	-29	0.96	0.11	0.44	
11	-34	-37	0.63	0.08	0.30	
12	0	-2	3.65	0.32	1.13	
12	-6	-8	3.46	0.29	0.13	
12	-14	-16	3.52	0.29	1.48	
12	-24	-26	3.00	0.30	1.34	
12	-34	-36	3.46	0.27	1.72	
12	-50	-52	3.35	0.27	1.30	
12	-68	-70	2.61	0.28	1.32	
12	-84	-86	3.41	0.31	1.90	
13	-4	-6	0.25	0.04	0.04	
13	-14	-16	0.19	0.00	0.02	
13	-36	-40	0.32	0.07	0.11	
13	-48	-50	0.02	0.00	0.09	
13	-64	-66	0.08	0.00	0.05	
14	0	-3	0.61	0.08	0.17	
14	-22	-25	1.14	0.13	0.55	
14	-27	-30	0.27	0.00	0.15	
14	-40	-43	0.83	0.08	0.26	
14	-57	-60	2.49	0.17	1.07	
14	-75	-78	9.58	0.71	1.87	
14	-80	-83	16.79	0.94	2.44	
14	-84	-86	15.54	0.79	2.30	
14	-94	-97	11.68	0.77	3.00	
14	-101	-103	20.22	1.21	3.69	
14	-105	-106	30.01	1.39	5.28	
14	-107	-110	17.61	1.04	2.51	
14	-117	-120	8.52	0.46	1.43	
14	-125	-127	3.91	0.28	2.82	

Table XI (cont.). Chemical data for sediment samples.

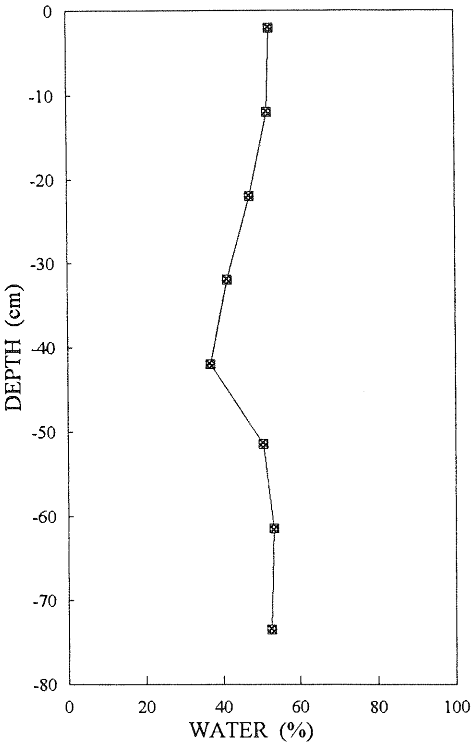
Station #	Sample Interval (cm)		Metal Concentrations					
	Upper	Lower	Cr (ug/g)	Cu (ug/g)	Fe (%)	Mn (ug/g)	Ni (ug/g)	Zn (ug/g)
1	0	-4	72.66	15.67	2.80	315.48	26.33	101.36
1	-10	-14	75.66	13.66	3.13	328.70	26.32	99.80
1	-20	-24	49.94	5.65	2.21	199.24	15.61	40.67
1	-30	-34	69.86	7.46	2.90	317.41	22.75	50.87
1	-40	-44	67.35	7.46	2.77	303.72	22.63	50.44
1	-50	-53	94.89	9.04	3.91	430.59	28.85	70.36
1	-60	-63	95.70	9.44	4.04	468.70	29.60	71.41
1	-72	-75	89.72	10.64	3.90	382.80	29.24	68.98
2	0	-2	29.13	6.20	1.09	116.69	10.95	37.16
2	-2	-4	31.57	5.85	1.18	140.80	9.97	40.81
2	-4	-6	31.29	6.25	1.19	127.62	9.51	43.16
2	-6	-8	34.94	6.44	1.25	145.42	12.63	43.73
2	-8	-10	34.96	6.58	1.32	153.21	11.51	43.07
2	-18	-20	28.89	4.98	1.08	113.76	9.60	37.11
2	-24	-26	88.48	11.42	3.32	343.73	29.43	69.05
2	-32	-34	24.76	3.61	0.90	112.34	9.05	19.80
2	-40	-42	24.70	3.37	0.92	120.70	9.44	18.20
2	-50	-52	46.25	5.67	1.74	220.27	15.72	35.39
2	-58	-60	15.76	1.59	0.78	45.36	2.61	5.41
3	0	0	12.74	2.36	0.46	70.89	5.87	16.06
4	0	-4	43.41	12.37	1.64	166.41	12.93	54.68
4	-8	-12	43.33	6.06	1.70	179.90	16.00	40.76
4	-16	-20	54.70	6.35	2.38	277.82	19.54	41.45
4	-24	-28	50.30	5.77	2.12	229.65	17.39	36.88
4	-32	-36	62.30	7.18	2.73	282.45	23.38	47.32
4	-40	-44	86.04	8.44	3.66	419.27	28.84	65.89
4	-50	-54	87.81	8.28	3.94	428.14	27.74	66.36
4	-60	-64	80.09	8.34	3.73	383.51	26.02	59.58
5	0	0	30.63	6.57	1.13	149.90	10.22	33.40

Station #	Sample Interval (cm)		Metal Concentrations					
	Upper	Lower	Cr (ug/g)	Cu (ug/g)	Fe (%)	Mn (ug/g)	Ni (ug/g)	Zn (ug/g)
6	0	-2	64.79	11.94	2.67	249.60	22.12	83.56
6	-4	-6	65.68	12.11	2.63	261.67	21.81	80.89
6	-12	-14	60.99	8.36	2.54	263.41	18.86	61.72
6	-24	-26	63.86	7.82	2.58	241.25	18.49	55.45
6	-34	-36	70.46	8.46	2.89	278.69	23.43	53.81
6	-46	-48	35.39	4.14	1.38	139.68	11.85	27.11
6	-58	-60	38.11	4.20	1.60	203.64	12.55	30.47
6	-78	-80	90.08	8.36	3.91	500.98	26.79	68.49
7	0	-2	90.80	18.72	3.60	313.33	28.92	128.93
7	-4	-6	87.73	15.03	3.69	294.78	26.84	105.40
7	-8	-10	85.99	12.54	3.56	288.81	26.80	86.52
7	-12	-14	63.31	8.59	2.48	277.00	18.67	61.93
7	-24	-26	88.29	8.53	3.83	300.80	25.61	65.58
7	-36	-38	85.62	8.79	3.90	339.49	26.77	63.62
7	-48	-50	92.62	8.68	4.18	385.91	30.59	70.37
7	-60	-62	103.63	9.87	4.67	391.61	33.62	78.21
7	-72	-74	107.14	10.19	4.80	422.29	34.52	80.44
7	-84	-86	106.06	10.17	4.81	416.55	32.95	75.93
8	0	0	51.02	14.32	1.99	139.30	20.12	55.11
9	0	-2	62.69	12.49	2.55	242.01	20.75	84.23
9	-6	-8	66.20	13.25	2.67	250.81	22.39	89.44
9	-14	-16	59.38	10.39	2.38	211.28	20.85	64.90
9	-24	-26	84.81	9.65	3.67	305.29	26.67	67.37
9	-34	-36	64.74	7.66	2.70	274.46	20.88	50.28
9	-50	-52	51.74	6.19	2.31	234.49	17.96	41.47
9	-72	-74	64.44	6.52	2.73	309.59	23.50	46.03
10	0	-3	69.18	17.03	2.77	273.40	24.40	87.18
10	-5	-8	70.74	15.45	2.88	293.04	22.86	93.49
10	-14	-17	50.55	10.32	2.08	207.99	17.16	68.14
10	-27	-30	51.20	7.81	2.20	247.62	17.62	45.23
10	-45	-48	49.92	5.83	2.06	206.63	16.61	38.19
10	-57	-60	65.23	7.96	2.71	273.60	21.79	49.19
10	-72	-75	76.51	8.71	3.21	342.76	24.06	57.95
11	0	-3	37.16	7.59	1.32	162.93	14.38	44.40

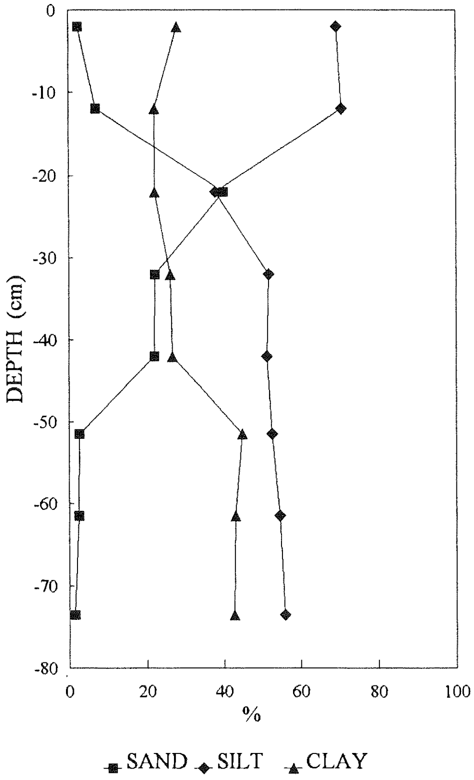
Station #	Sample Interval (cm)		Metal Concentrations					
	Upper	Lower	Cr (ug/g)	Cu (ug/g)	Fe (%)	Mn (ug/g)	Ni (ug/g)	Zn (ug/g)
11	-9	-12	35.27	7.09	1.27	155.21	11.61	44.96
11	-17	-20	29.99	5.39	1.16	141.83	11.18	34.48
11	-26	-29	36.55	6.68	1.51	204.39	13.43	33.49
11	-34	-37	29.39	4.19	1.20	136.75	10.68	23.48
12	0	-2	73.50	17.30	3.07	242.12	24.18	110.10
12	-6	-8	72.84	17.30	3.03	256.98	25.72	107.00
12	-14	-16	62.81	14.99	2.74	199.26	21.64	63.79
12	-24	-26	65.21	7.71	2.75	253.58	20.66	50.21
12	-34	-36	76.62	8.66	3.43	289.43	21.49	53.91
12	-50	-52	63.71	8.60	2.72	213.67	20.04	41.21
12	-68	-70	85.57	9.64	3.65	287.08	26.52	61.32
12	-84	-86	86.12	9.43	3.88	287.13	27.19	62.77
13	-4	-6	4.07	0.74	0.15	27.18	5.15	5.58
13	-14	-16	4.61	0.96	0.19	38.55	3.87	4.74
13	-36	-40	12.86	1.74	0.53	91.93	5.33	13.40
13	-48	-50	7.40	0.52	0.32	36.84	3.54	7.72
13	-64	-66	8.15	0.34	0.30	39.85	8.13	5.92
14	0	-3	20.61	3.84	0.80	89.57	8.10	24.60
14	-22	-25	53.05	10.19	2.03	208.29	19.25	66.55
14	-27	-30	20.07	5.48	0.76	84.78	9.27	25.22
14	-40	-43	31.17	5.86	1.16	134.19	11.87	34.39
14	-57	-60	70.62	16.37	2.68	276.69	24.70	85.64
14	-75	-78	76.73	10.82	2.84	233.06	27.36	55.96
14	-80	-83	63.08	10.45	2.14	136.43	25.06	71.74
14	-84	-86	60.16	9.16	1.81	135.47	24.12	44.29
14	-94	-97	85.25	11.92	3.51	188.70	32.60	79.14
14	-101	-103	58.11	9.31	2.51	145.16	23.49	48.31
14	-105	-106	42.30	12.62	2.41	112.52	24.70	57.79
14	-107	-110	46.03	8.27	1.58	104.03	14.51	26.79
14	-117	-120	61.06	5.89	1.73	119.39	17.07	28.46
14	-125	-127	107.19	12.42	4.77	294.04	42.67	91.26

Plots of textural and chemical parameters versus depth in core for each sediment core.

Station 1

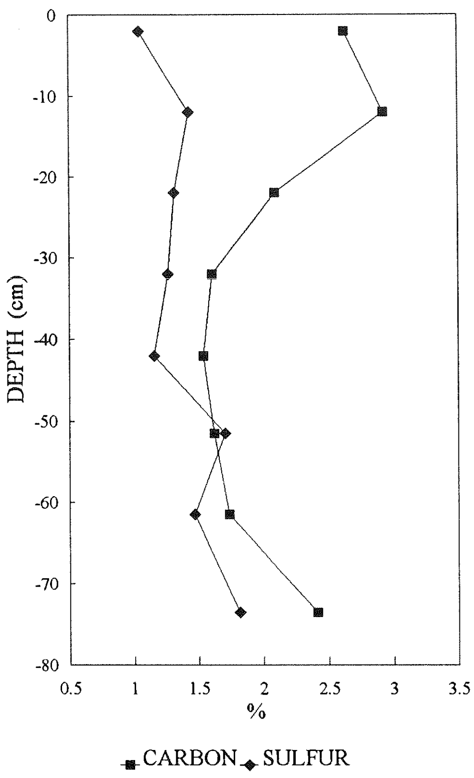


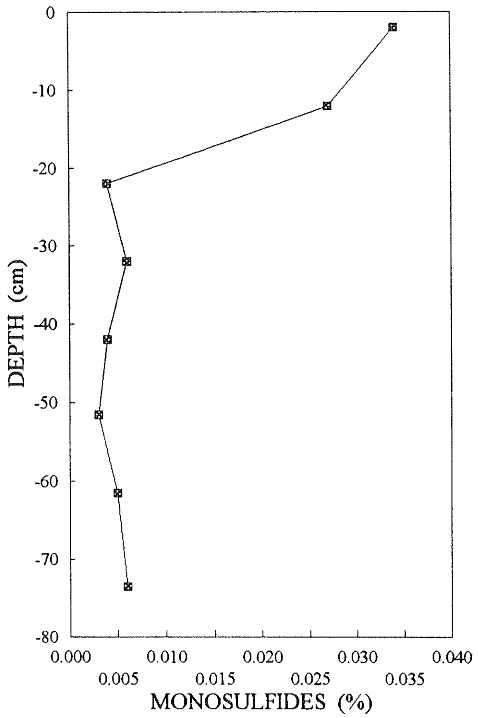
0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
20
40
60
80
100
WATER (%)

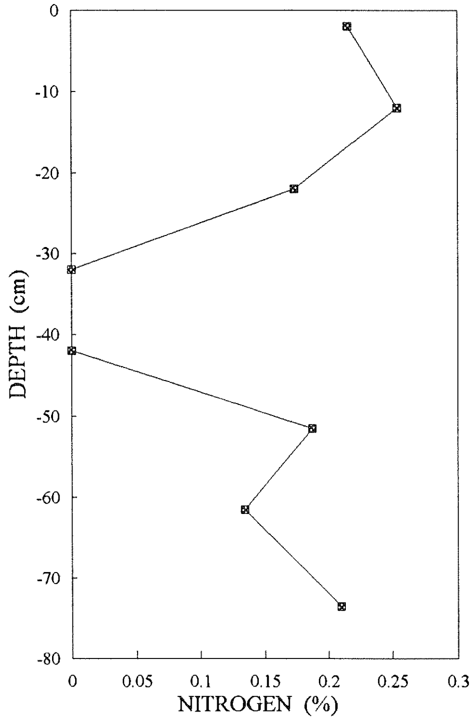


0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
20
40
60
80
100
%
SAND
SILT
CLAY

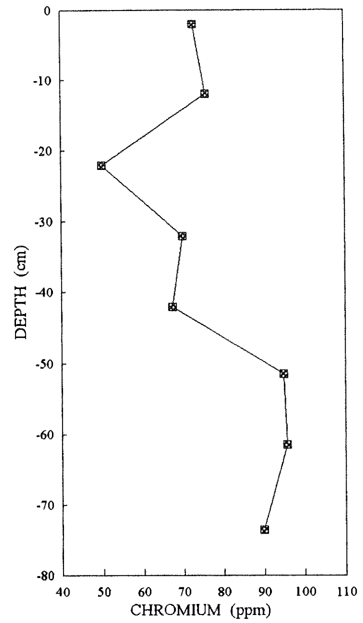
Station 1

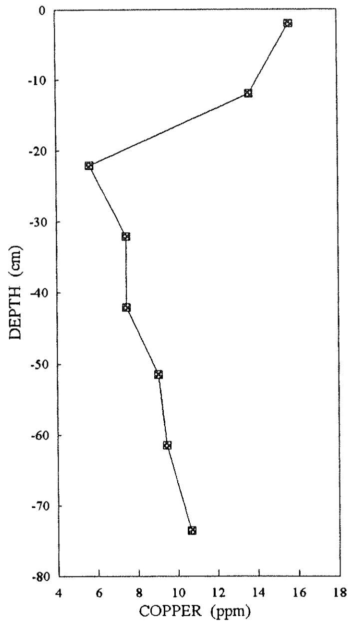

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0.5
1
1.5
2
2.5
3
3.5
%
CARBON
SULFUR

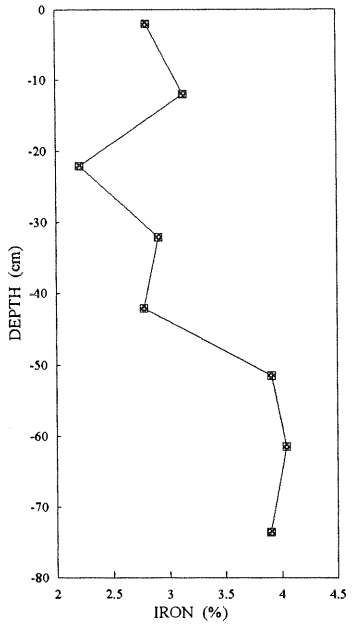

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0.000
0.010
0.020
0.030
0.040
0.005
0.015
0.025
0.035
MONOSULFIDES (%)

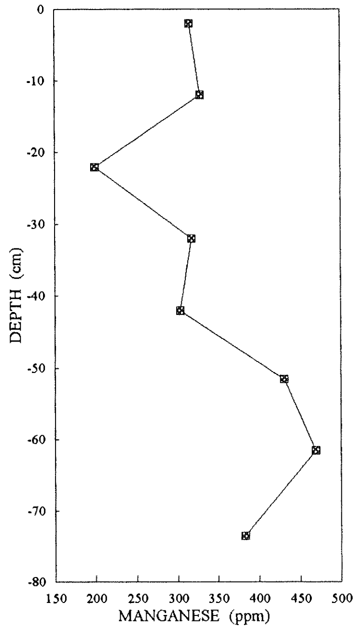

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
0.05
0.1
0.15
0.2
0.25
0.3
NITROGEN (%)

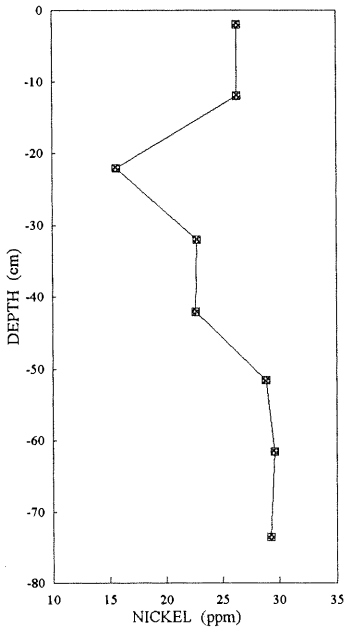
Station 1

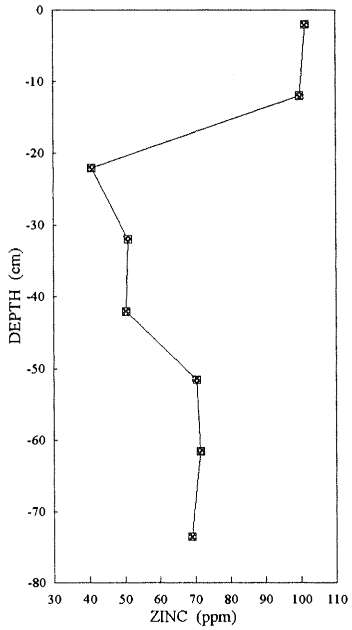

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
40 50 60 70 80 90 100 110
CHROMIUM (ppm)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
4 6 8 10 12 14 16 18
COPPER (ppm)

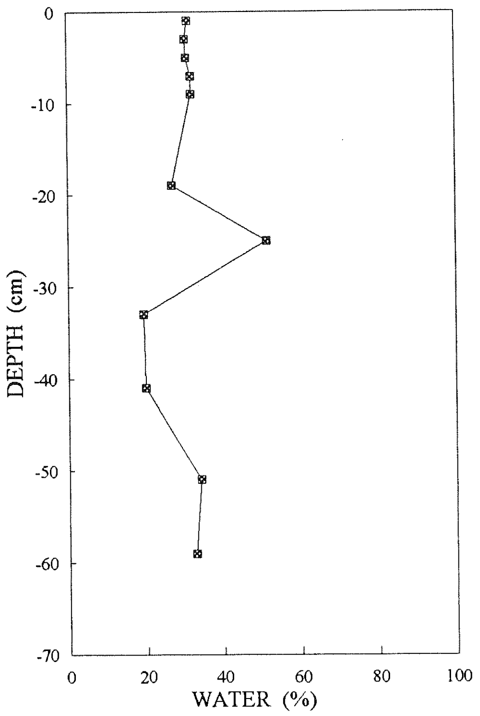

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
2 2.5 3 3.5 4 4.5
IRON (%)

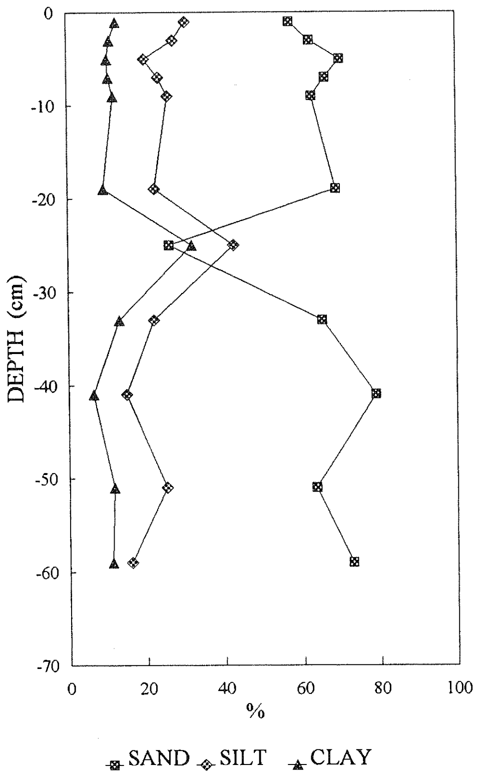

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
150 200 250 300 350 400 450 500
MANGANESE (ppm)

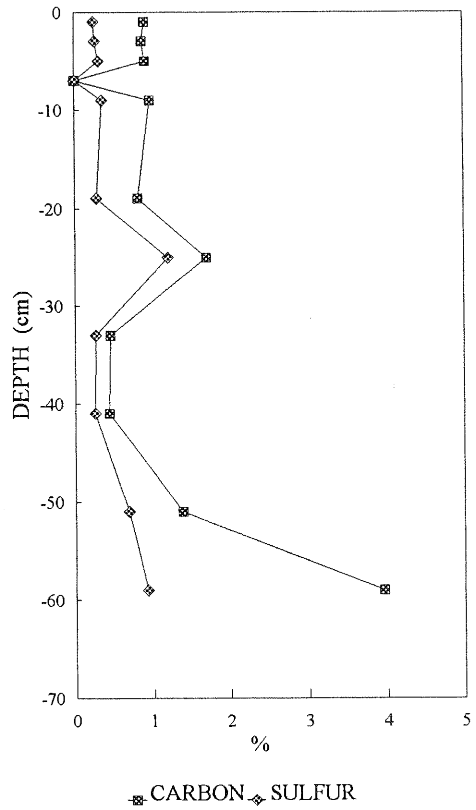

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
10 15 20 25 30 35
NICKEL (ppm)

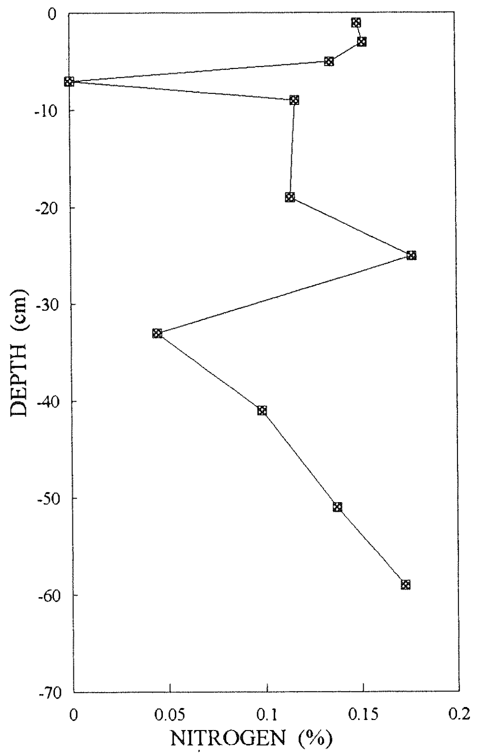

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
30 40 50 60 70 80 90 100 110
ZINC (ppm)

Station 2

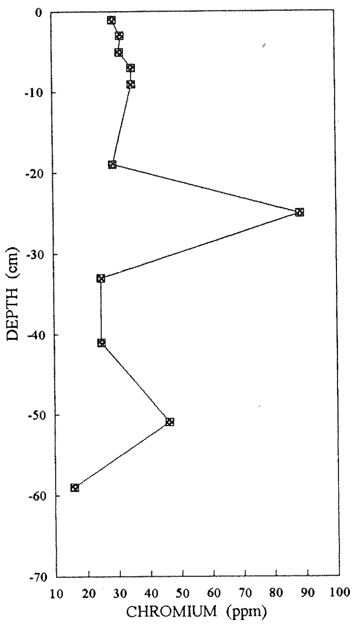

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
20
40
60
80
100
WATER (%)

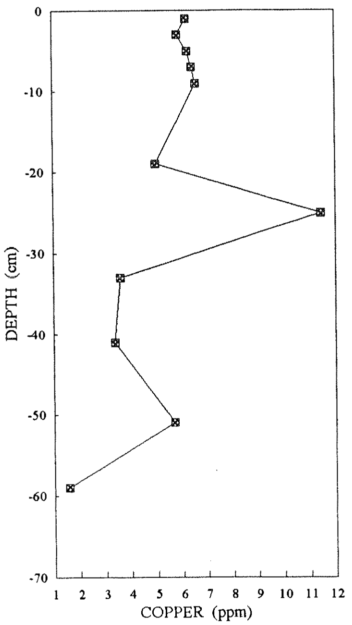

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
20
40
60
80
100
%
SAND
SILT
CLAY

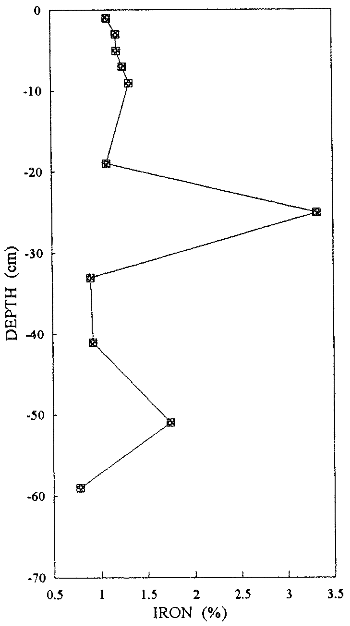

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
1
2
3
4
5
%
CARBON
SULFUR

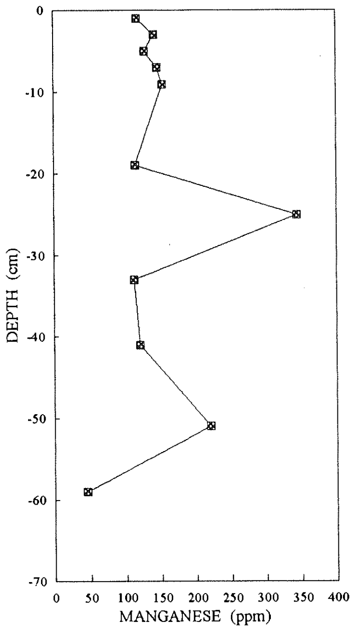

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
0.05
0.1
0.15
0.2
NITROGEN (%)

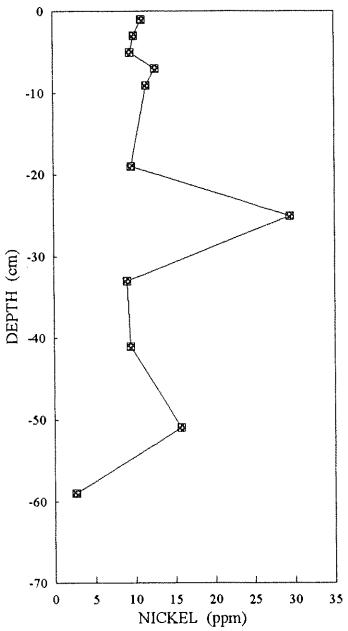
Station 2

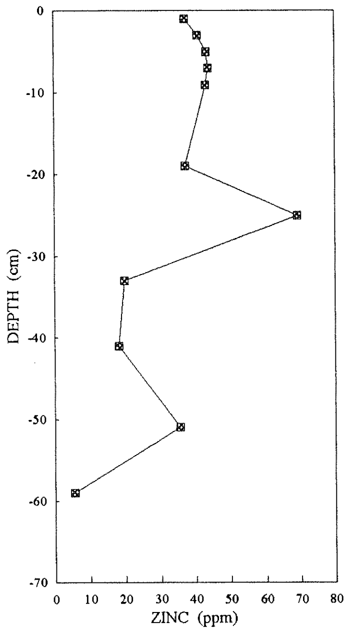

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
10 20 30 40 50 60 70 80 90 100
CHROMIUM (ppm)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
1 2 3 4 5 6 7 8 9 10 11 12
COPPER (ppm)

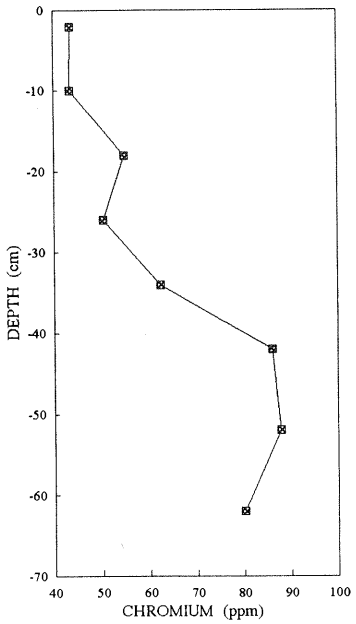

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0.5 1 1.5 2 2.5 3 3.5
IRON (%)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0 50 100 150 200 250 300 350 400
MANGANESE (ppm)

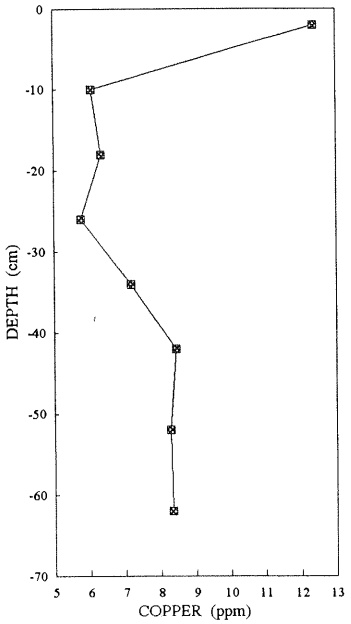

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0 5 10 15 20 25 30 35
NICKEL (ppm)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0 10 20 30 40 50 60 70 80
ZINC (ppm)

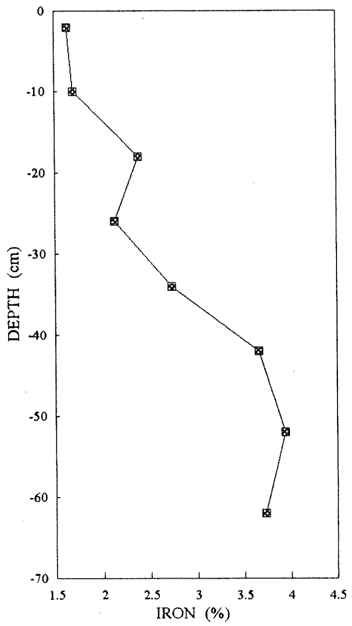
Station 4



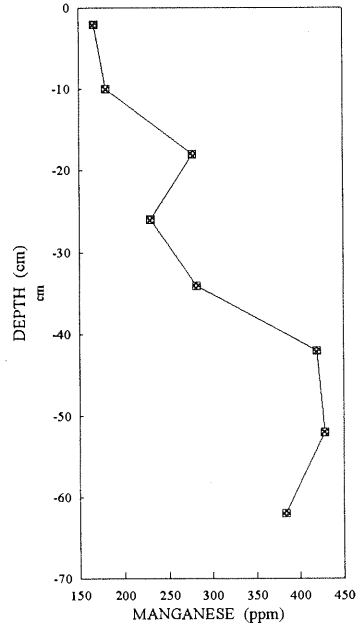
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
40
50
60
70
80
90
100
CHROMIUM (ppm)



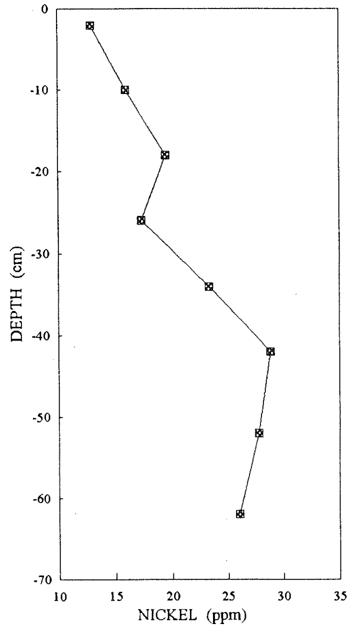
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
5
6
7
8
9
10
11
12
13
COPPER (ppm)



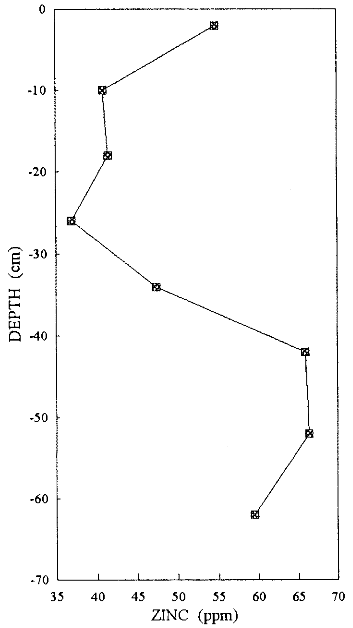
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
1.5
2
2.5
3
3.5
4
4.5
IRON (%)



DEPTH (cm)
cm
0
-10
-20
-30
-40
-50
-60
-70
150
200
250
300
350
400
450
MANGANESE (ppm)

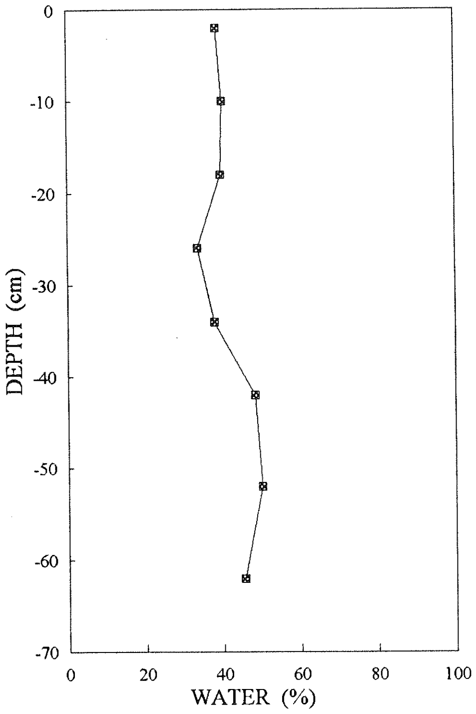


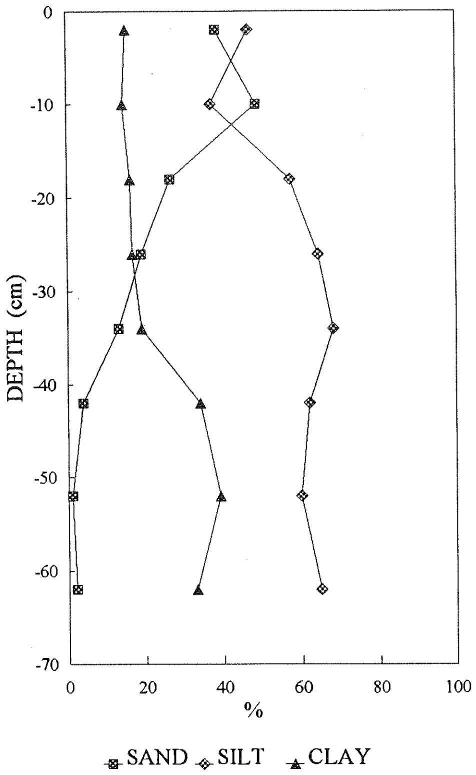
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
10
15
20
25
30
35
NICKEL (ppm)

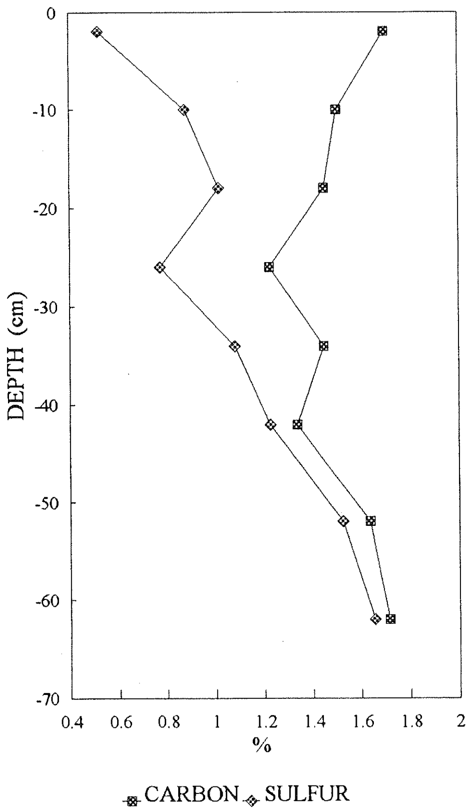


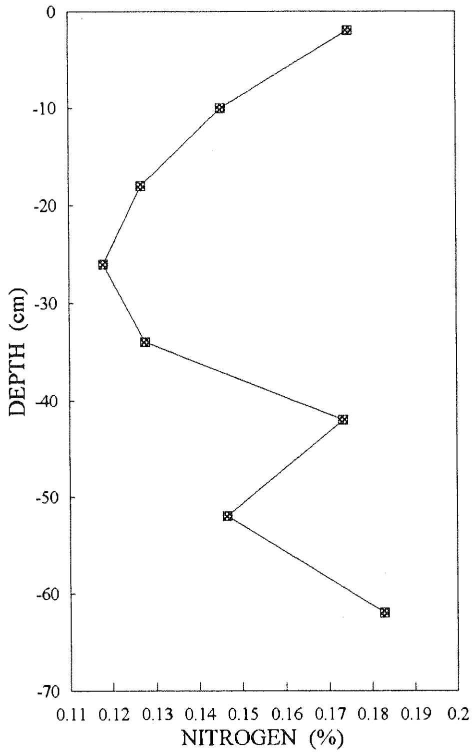
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
35
40
45
50
55
60
65
70
ZINC (ppm)

Station 4

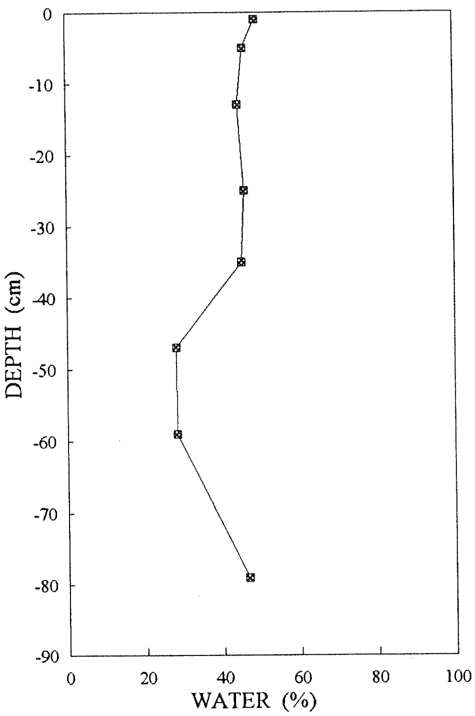

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
20
40
60
80
100
WATER (%)

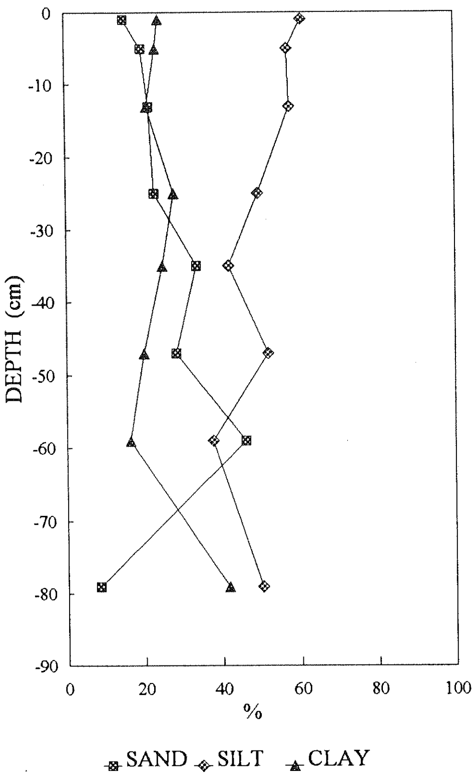

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0
20
40
60
80
100
%
SAND
SILT
CLAY

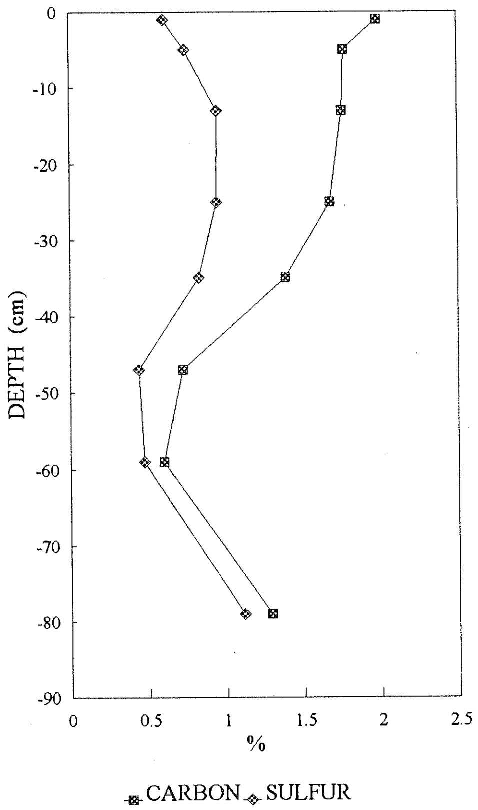

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
%
CARBON
SULFUR

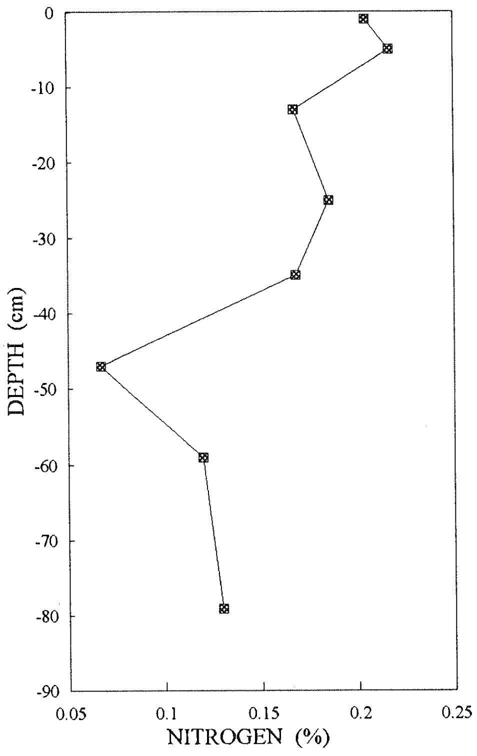

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.2
NITROGEN (%)

Station 6

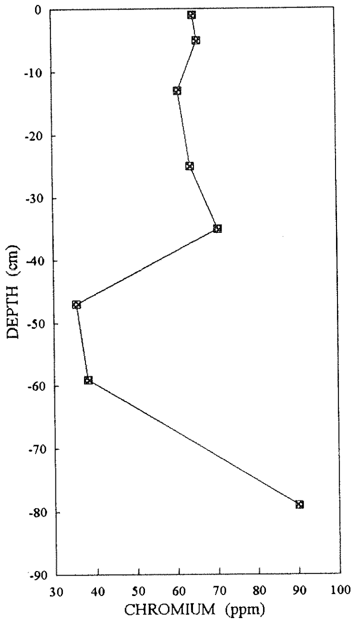

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
0
20
40
60
80
100
WATER (%)

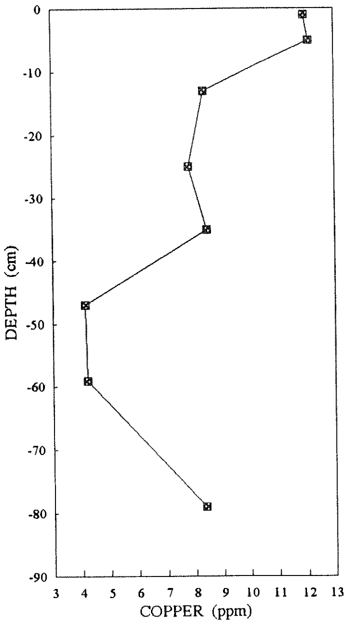

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
0
20
40
60
80
100
%
SAND
SILT
CLAY

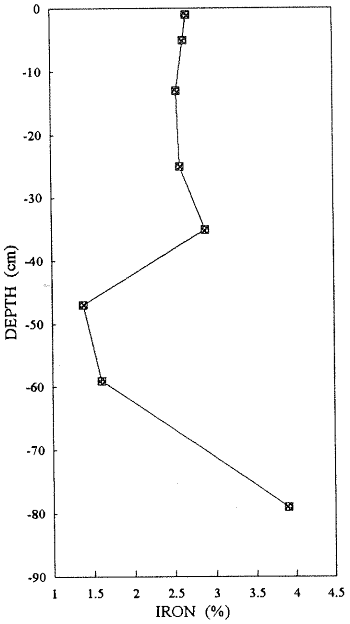

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
0
0.5
1
1.5
2
2.5
%
CARBON
SULFUR

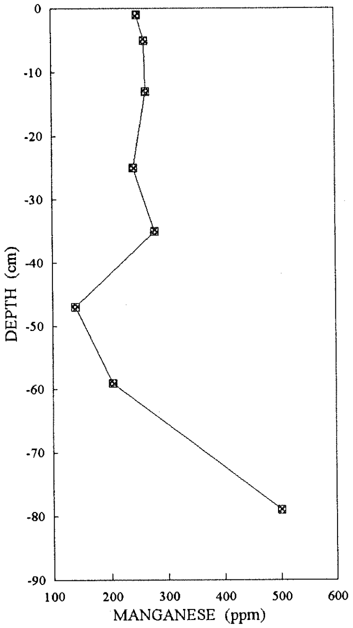

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
0.05
0.1
0.15
0.2
0.25
NITROGEN (%)

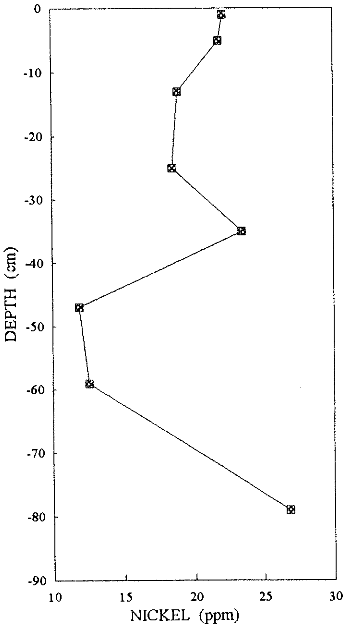
Station 6

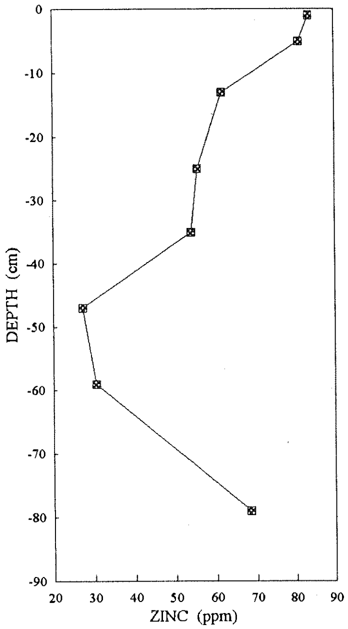

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
30
40
50
60
70
80
90
100
CHROMIUM (ppm)


0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
3
4
5
6
7
8
9
10
11
12
13
COPPER (ppm)

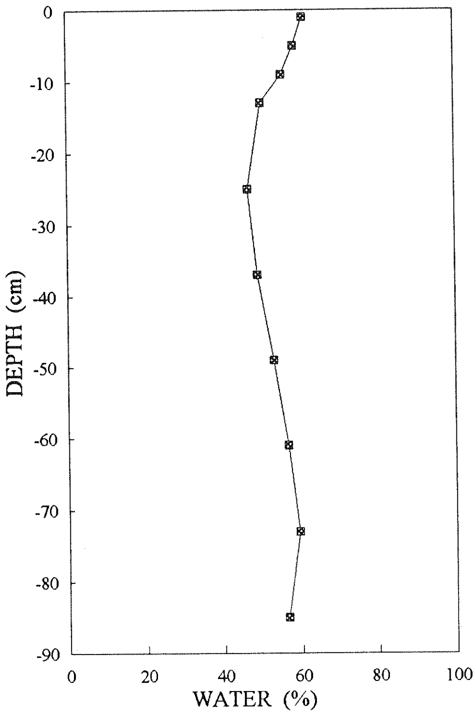

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
1
1.5
2
2.5
3
3.5
4
4.5
IRON (%)

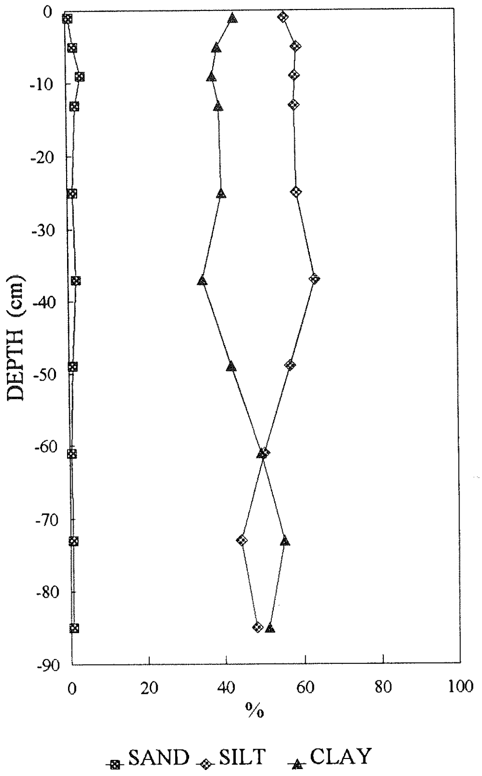

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
100
200
300
400
500
600
MANGANESE (ppm)

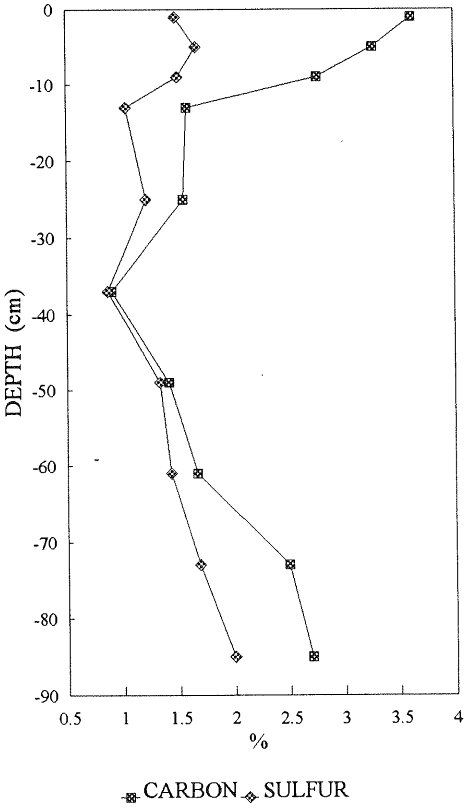

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
10
15
20
25
30
NICKEL (ppm)

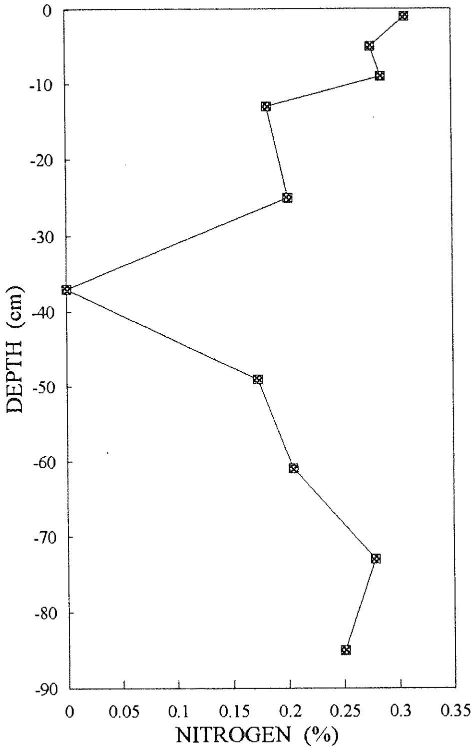

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
DEPTH (cm)
20
30
40
50
60
70
80
90
ZINC (ppm)

Station 7

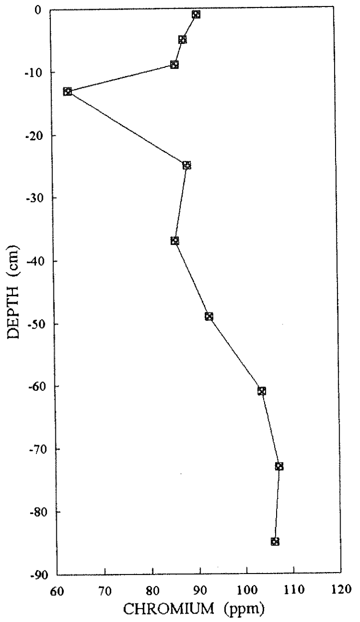

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
20
40
60
80
100
WATER (%)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
20
40
60
80
100
%
SAND
SILT
CLAY

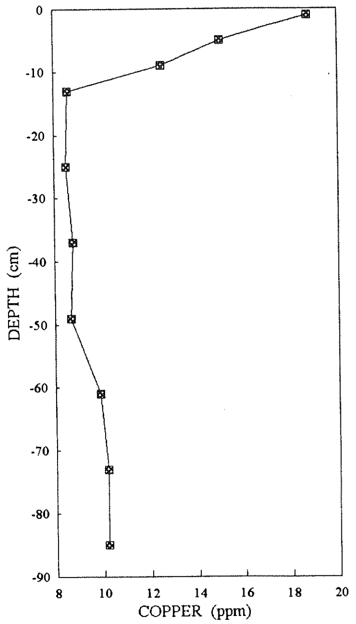

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0.5
1
1.5
2
2.5
3
3.5
4
%
CARBON
SULFUR


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
NITROGEN (%)

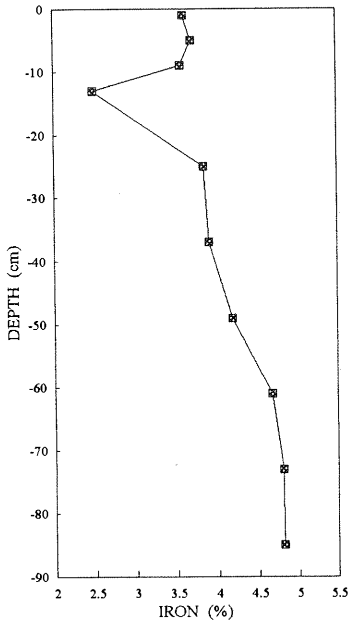
Station 7



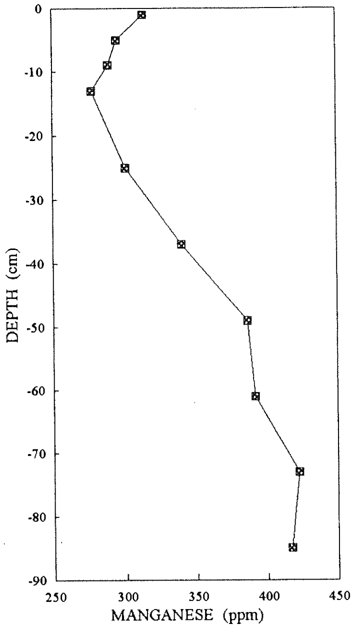
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
60
70
80
90
100
110
120
CHROMIUM (ppm)



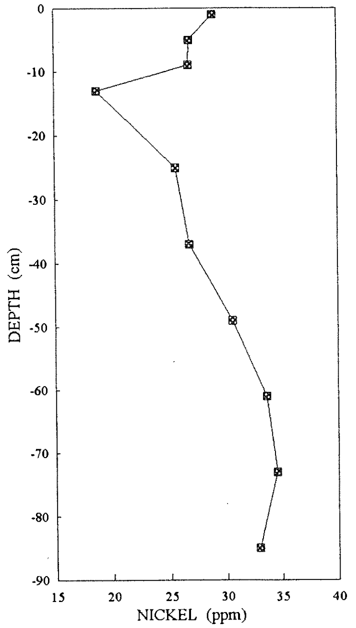
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
8
10
12
14
16
18
20
COPPER (ppm)



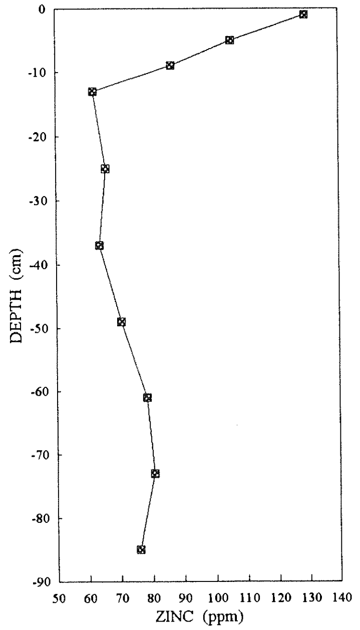
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
2
2.5
3
3.5
4
4.5
5
5.5
IRON (%)



DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
250
300
350
400
450
MANGANESE (ppm)

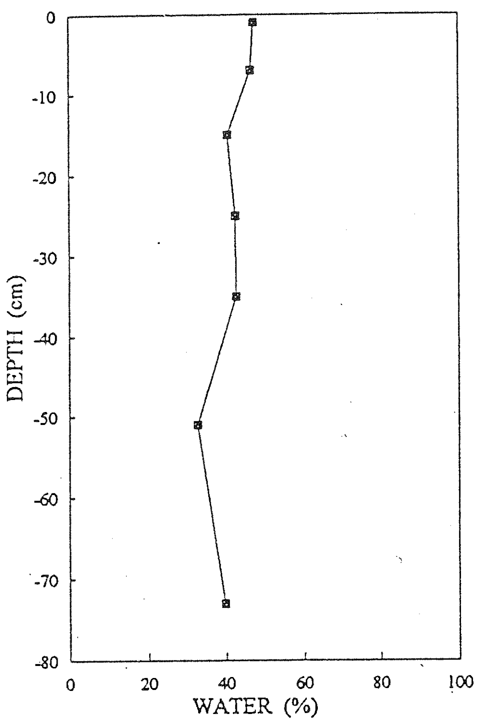


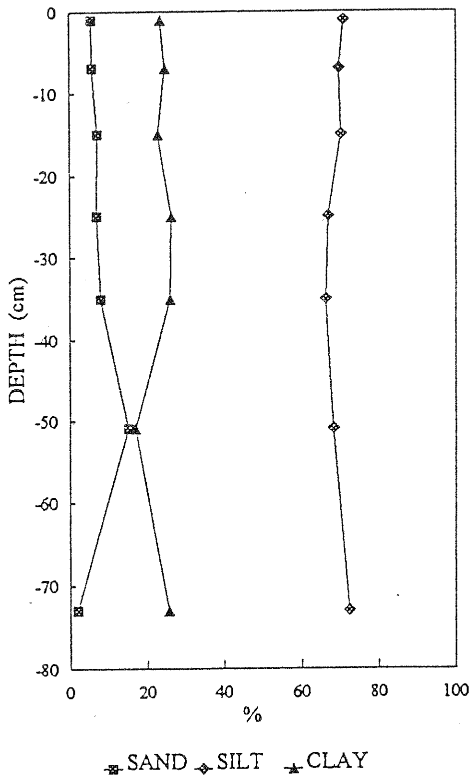
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
15
20
25
30
35
40
NICKEL (ppm)

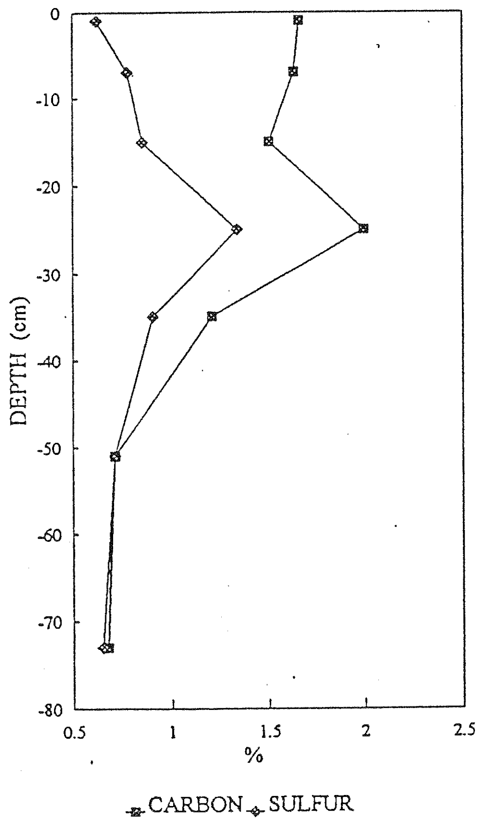


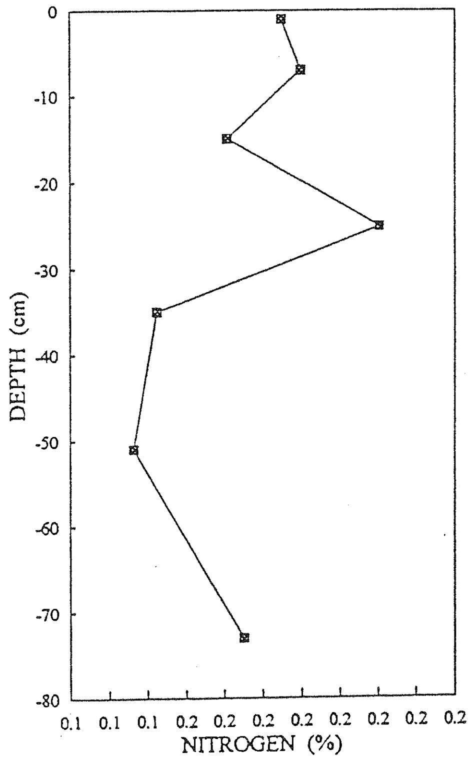
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
50
60
70
80
90
100
110
120
130
140
ZINC (ppm)

Station 9

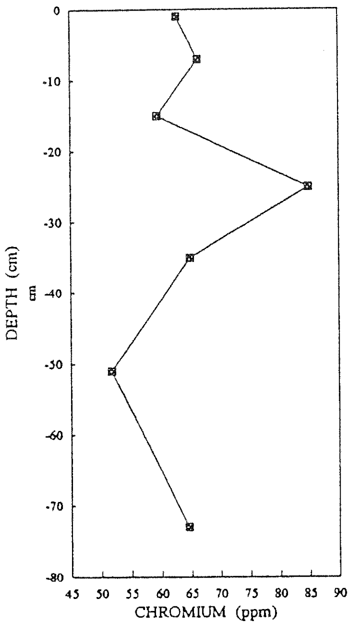

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
0
20
40
60
80
100
WATER (%)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
0
20
40
60
80
100
%
SAND
SILT
CLAY

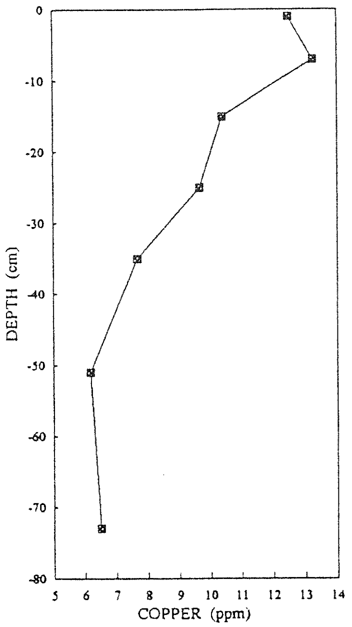

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
0.5
1
1.5
2
2.5
%
CARBON
SULFUR


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
0.1
0.1
0.1
0.2
0.2
0.2
0.2
0.2
0.2
0.2
0.2
NITROGEN (%)

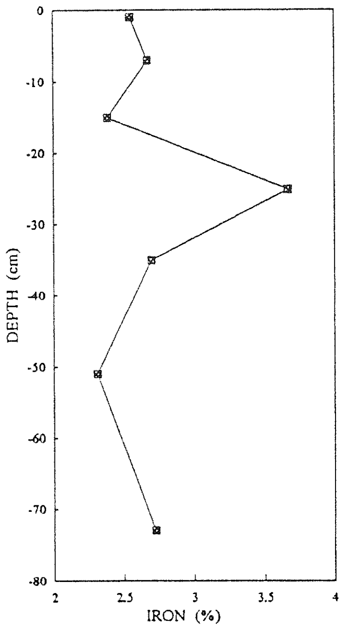
Station 9



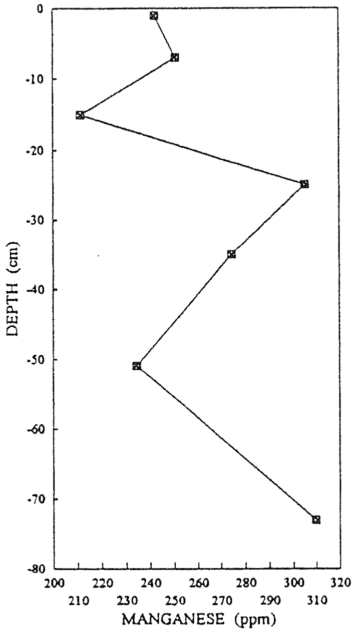
DEPTH (cm)
cm
0
-10
-20
-30
-40
-50
-60
-70
-80
45 50 55 60 65 70 75 80 85 90
CHROMIUM (ppm)



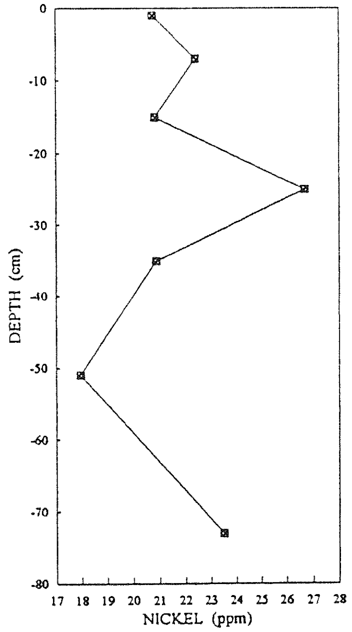
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
5 6 7 8 9 10 11 12 13 14
COPPER (ppm)



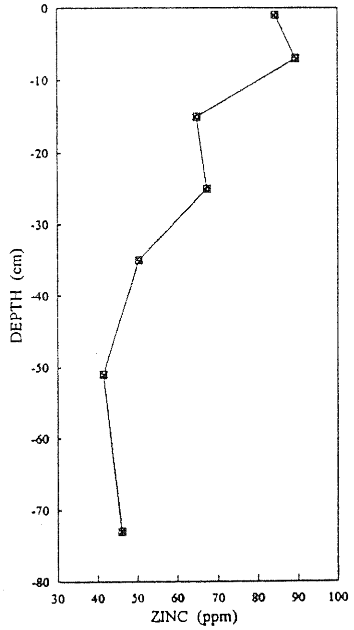
DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
2 2.5 3 3.5 4
IRON (%)



DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
200 220 240 260 280 300 320
210 230 250 270 290 310
MANGANESE (ppm)

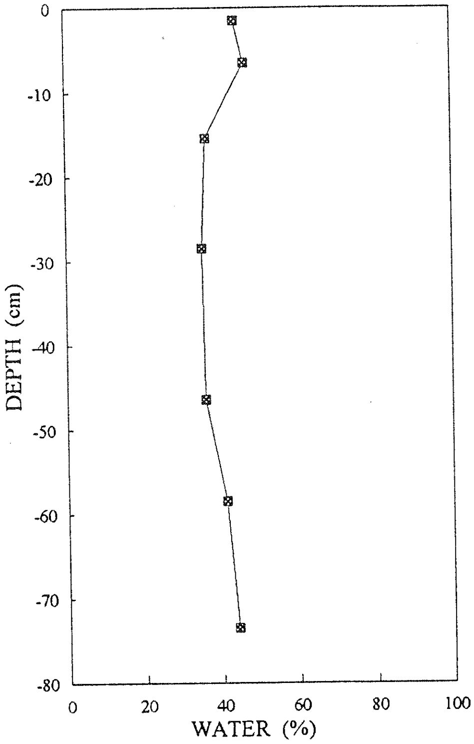


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
17 18 19 20 21 22 23 24 25 26 27 28
NICKEL (ppm)

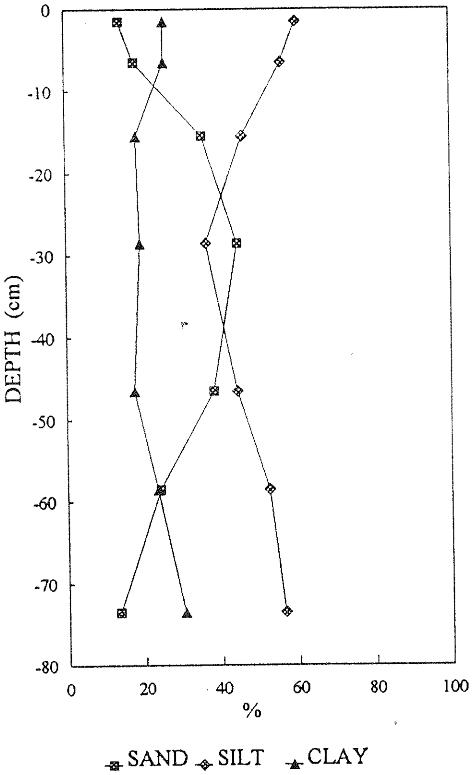


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
30 40 50 60 70 80 90 100
ZINC (ppm)

Station 10

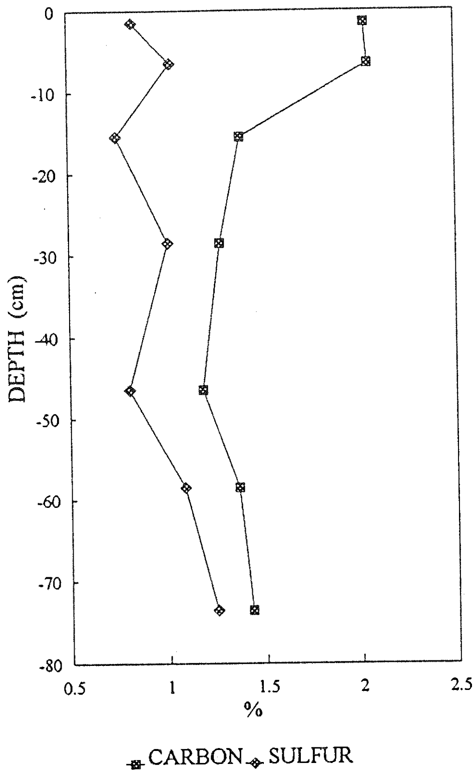


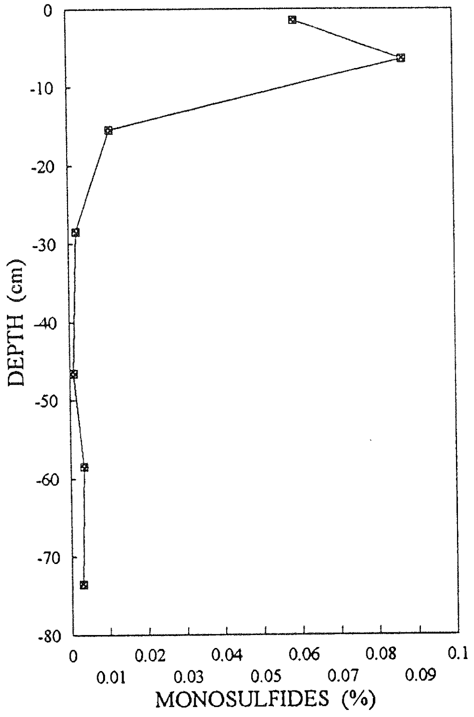
0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
20
40
60
80
100
WATER (%)

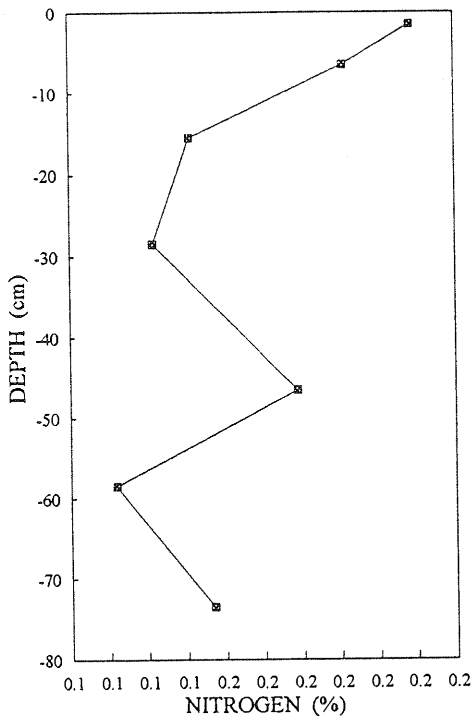


0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
20
40
60
80
100
%
SAND
SILT
CLAY

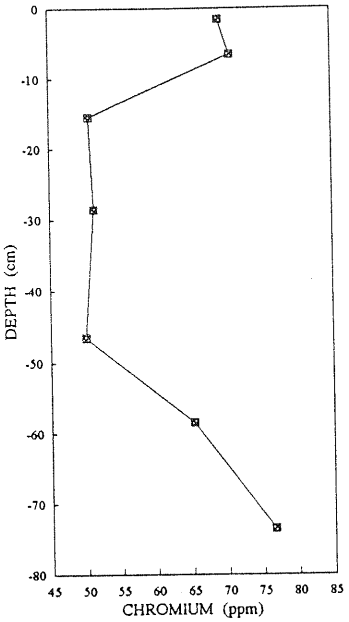
Station 10

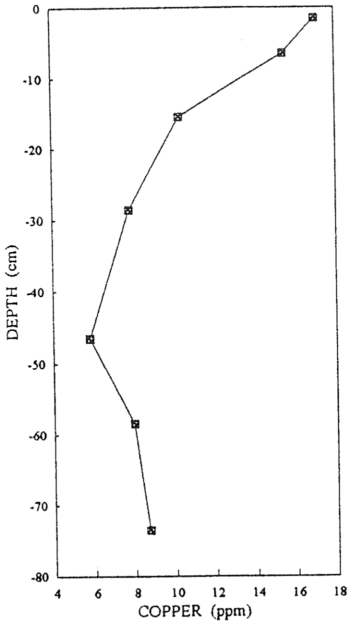

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0.5
1
1.5
2
2.5
%
CARBON
SULFUR

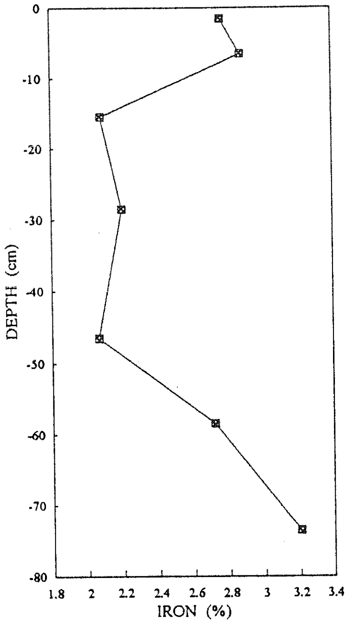

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
MONOSULFIDES (%)

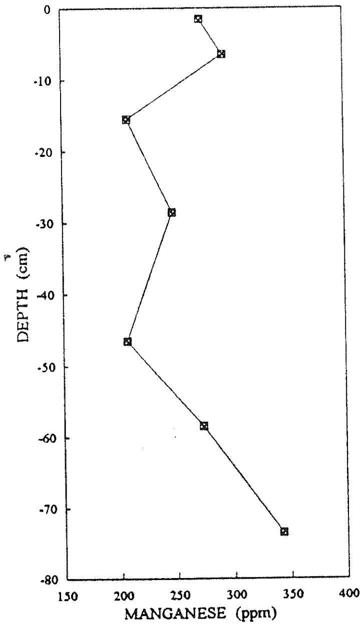

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
0.1
0.1
0.1
0.1
0.2
0.2
0.2
0.2
0.2
0.2
0.2
NITROGEN (%)

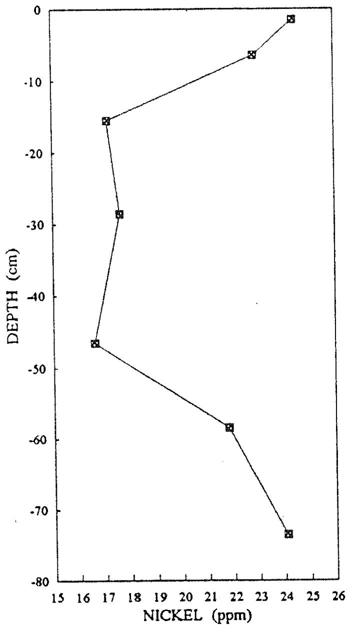
Station 10

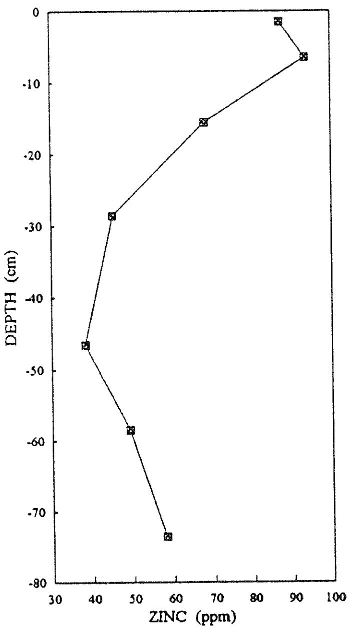

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
45 50 55 60 65 70 75 80 85
CHROMIUM (ppm)


0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
4 6 8 10 12 14 16 18
COPPER (ppm)

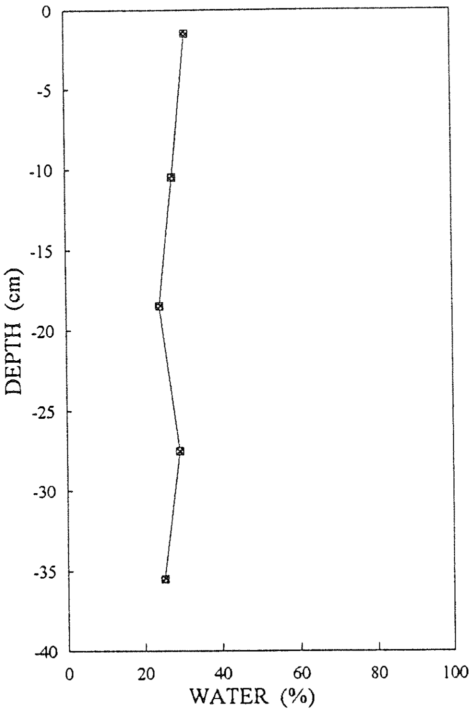

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4
IRON (%)


0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
150 200 250 300 350 400
MANGANESE (ppm)

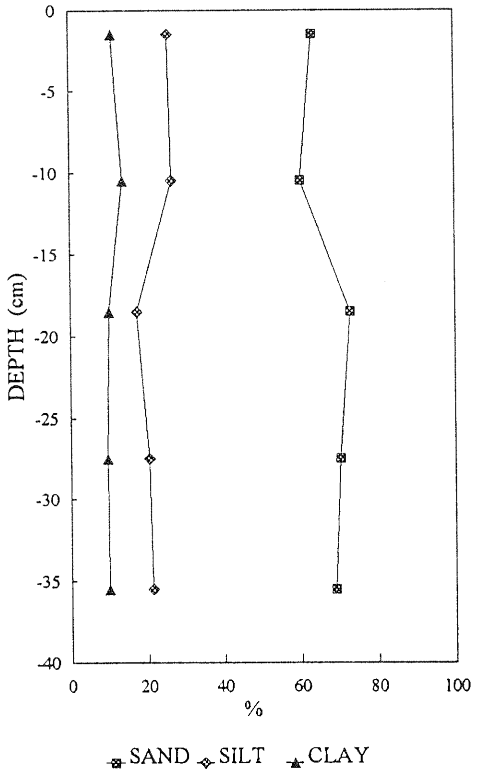

0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
15 16 17 18 19 20 21 22 23 24 25 26
NICKEL (ppm)


0
-10
-20
-30
-40
-50
-60
-70
-80
DEPTH (cm)
30 40 50 60 70 80 90 100
ZINC (ppm)

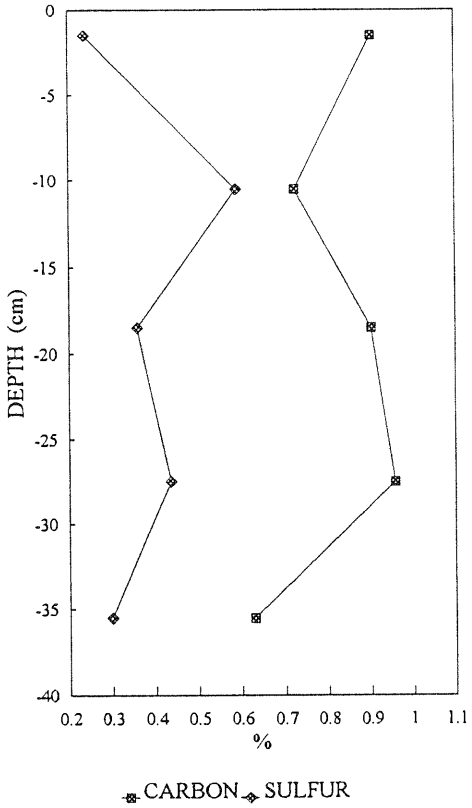
Station 11



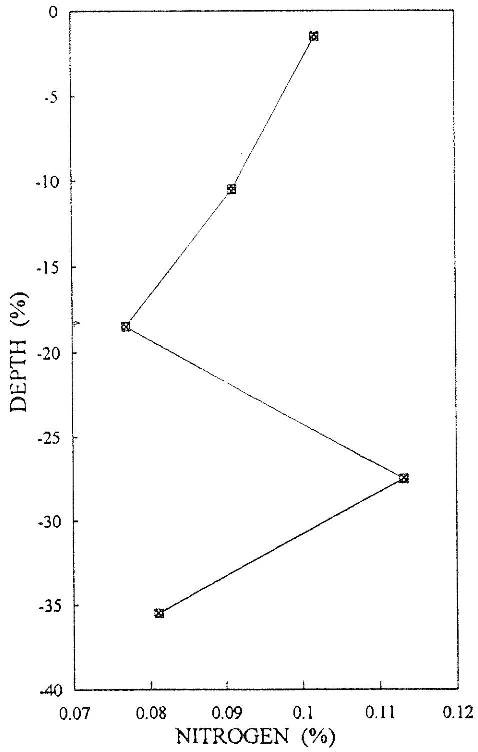
DEPTH (cm)
0
-5
-10
-15
-20
-25
-30
-35
-40
0
20
40
60
80
100
WATER (%)



DEPTH (cm)
0
-5
-10
-15
-20
-25
-30
-35
-40
0
20
40
60
80
100
%
SAND
SILT
CLAY

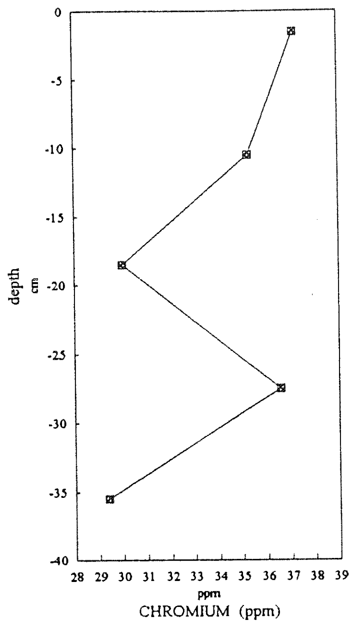


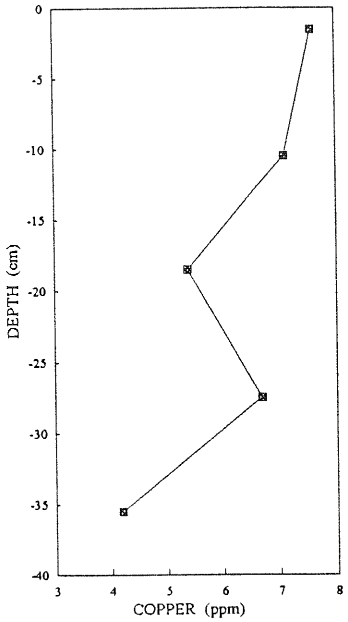
DEPTH (cm)
0
-5
-10
-15
-20
-25
-30
-35
-40
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
%
CARBON
SULFUR

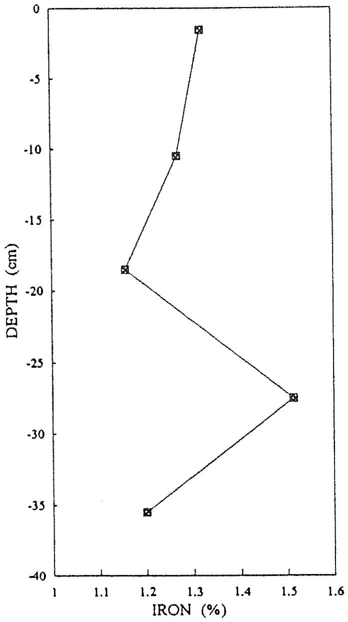


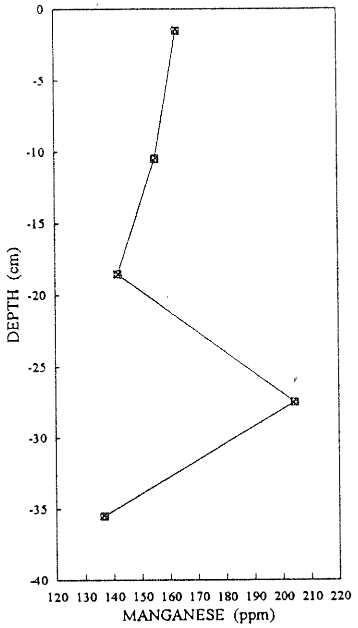
DEPTH (%)
0
-5
-10
-15
-20
-25
-30
-35
-40
0.07
0.08
0.09
0.1
0.11
0.12
NITROGEN (%)

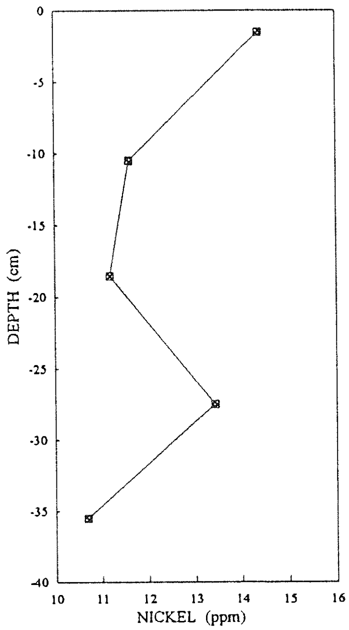
Station 11

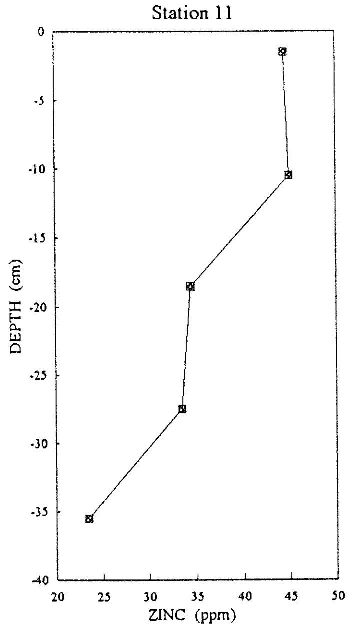

0
-5
-10
-15
-20
-25
-30
-35
-40
depth
cm
28 29 30 31 32 33 34 35 36 37 38 39
ppm
CHROMIUM (ppm)


0
-5
-10
-15
-20
-25
-30
-35
-40
DEPTH (cm)
3 4 5 6 7 8
COPPER (ppm)

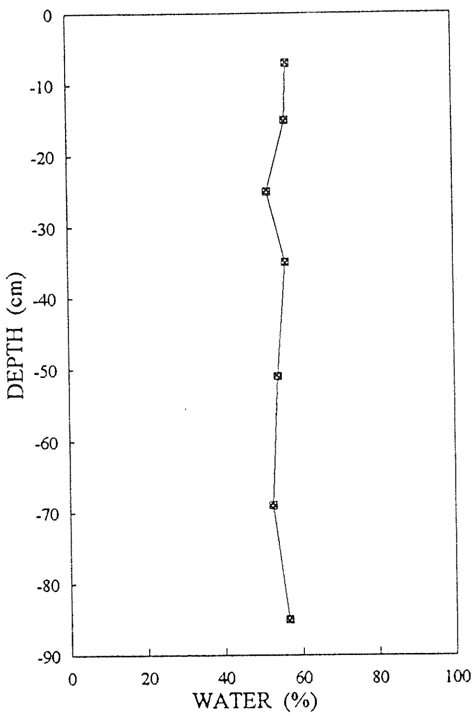

0
-5
-10
-15
-20
-25
-30
-35
-40
DEPTH (cm)
1 1.1 1.2 1.3 1.4 1.5 1.6
IRON (%)

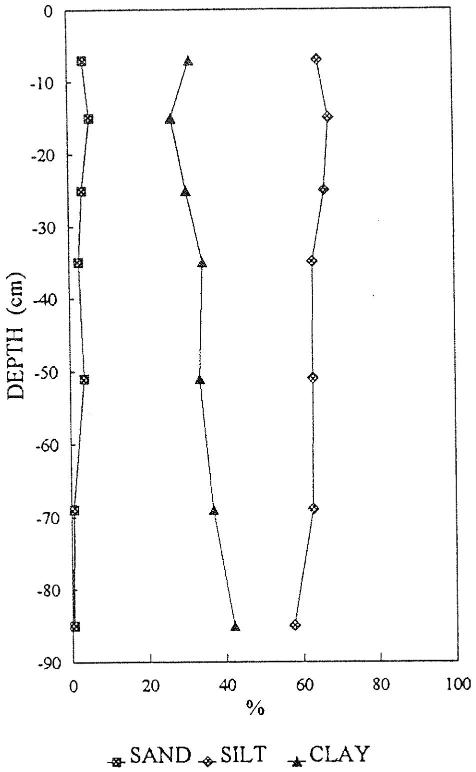

0
-5
-10
-15
-20
-25
-30
-35
-40
DEPTH (cm)
120 130 140 150 160 170 180 190 200 210 220
MANGANESE (ppm)

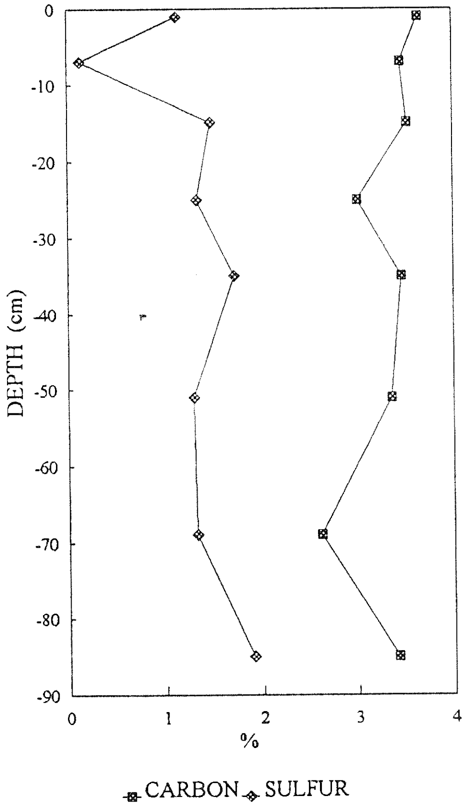

0
-5
-10
-15
-20
-25
-30
-35
-40
DEPTH (cm)
10 11 12 13 14 15 16
NICKEL (ppm)

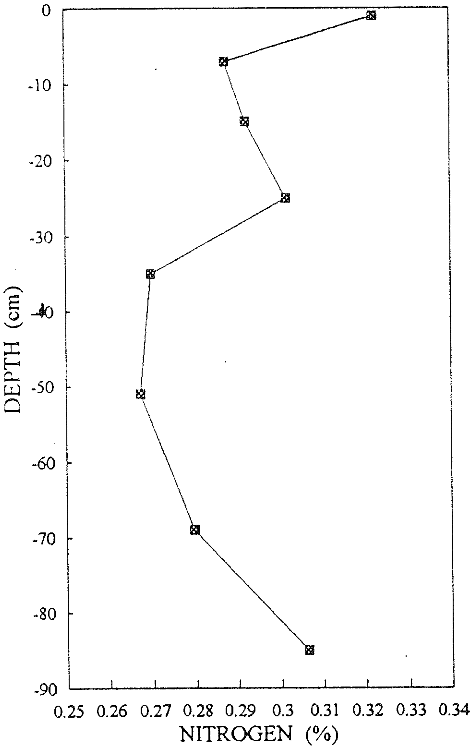

Station 11
0
-5
-10
-15
-20
-25
-30
-35
-40
DEPTH (cm)
20 25 30 35 40 45 50
ZINC (ppm)

Station 12

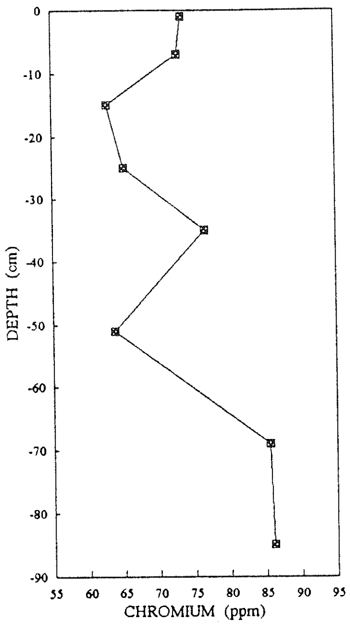

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
20
40
60
80
100
WATER (%)

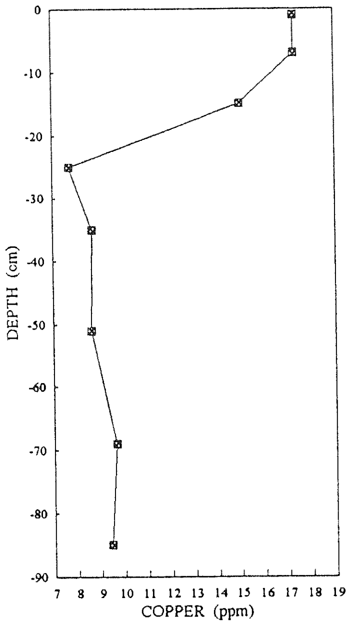

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
20
40
60
80
100
%
SAND
SILT
CLAY

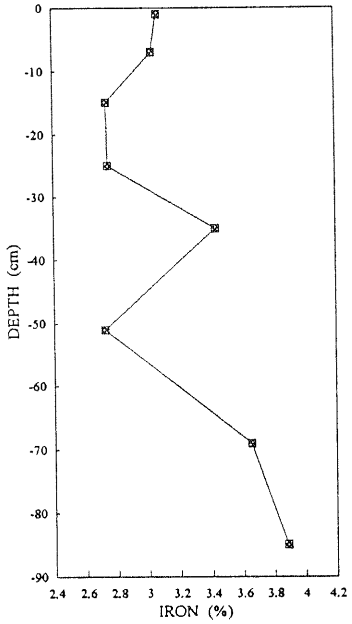

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
1
2
3
4
%
CARBON
SULFUR

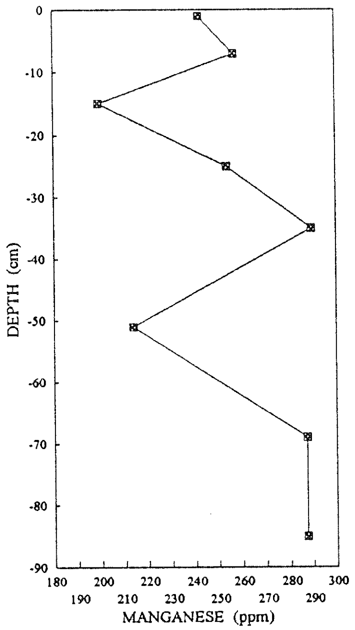

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0.25
0.26
0.27
0.28
0.29
0.3
0.31
0.32
0.33
0.34
NITROGEN (%)

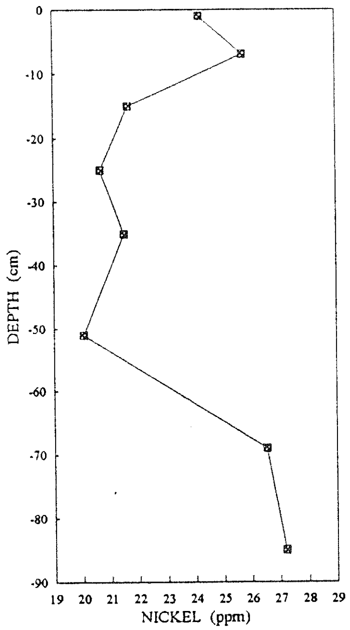
Station 12

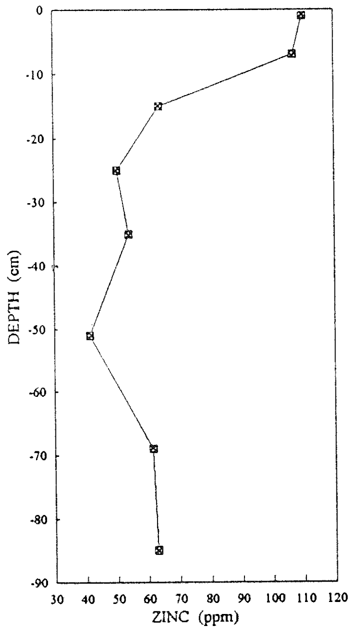

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
55 60 65 70 75 80 85 90 95
CHROMIUM (ppm)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7 8 9 10 11 12 13 14 15 16 17 18 19
COPPER (ppm)

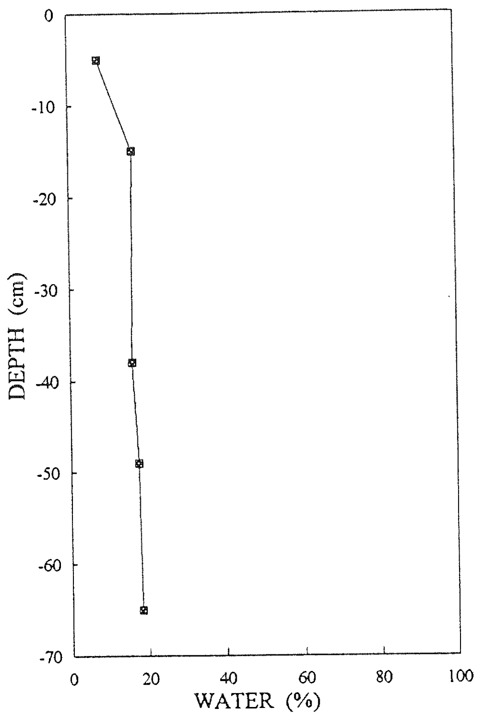

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2
IRON (%)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
180 200 220 240 260 280 300
190 210 230 250 270 290
MANGANESE (ppm)

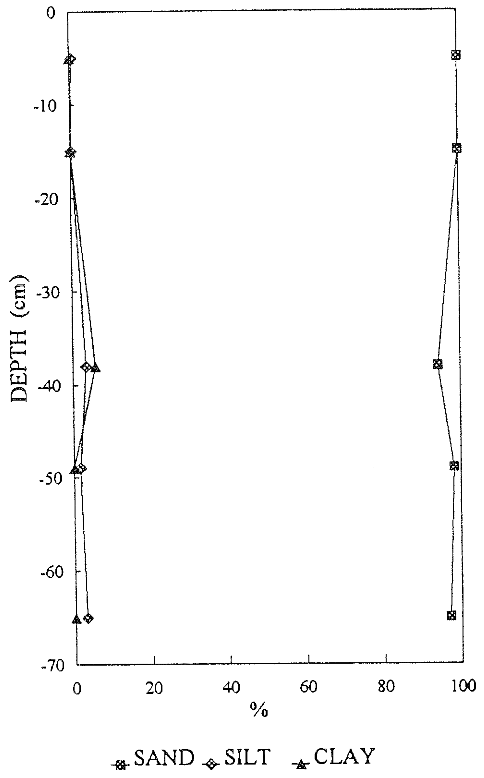

DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
19 20 21 22 23 24 25 26 27 28 29
NICKEL (ppm)


DEPTH (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
30 40 50 60 70 80 90 100 110 120
ZINC (ppm)

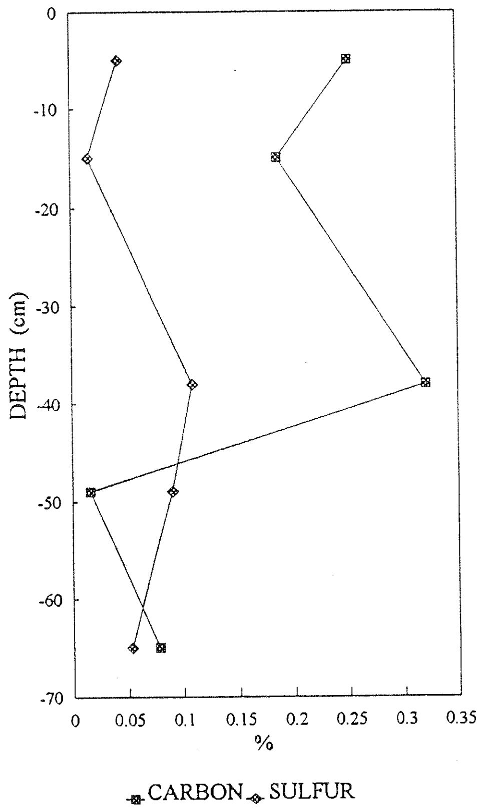
Station 13



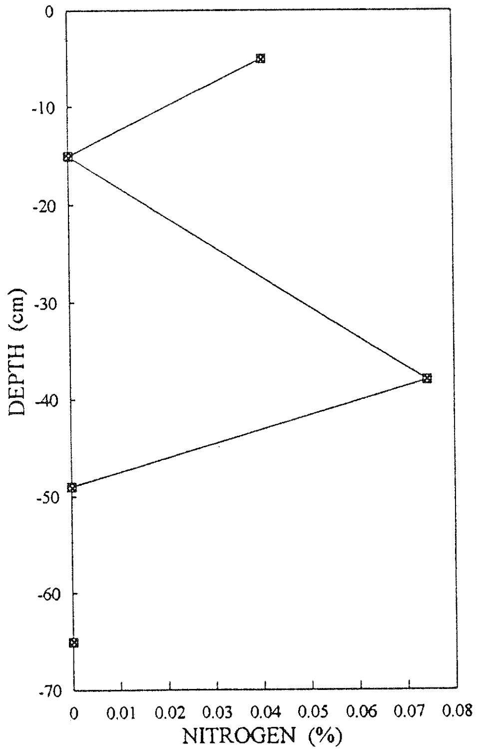
0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0
20
40
60
80
100
WATER (%)



0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0
20
40
60
80
100
%
SAND
SILT
CLAY

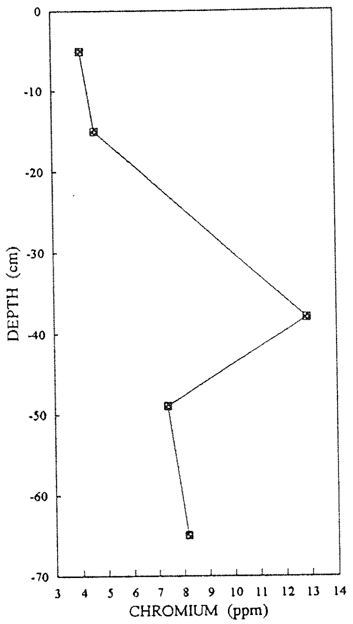


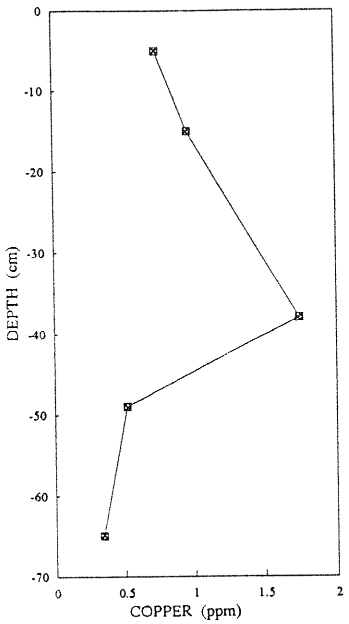
0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
%
CARBON
SULFUR

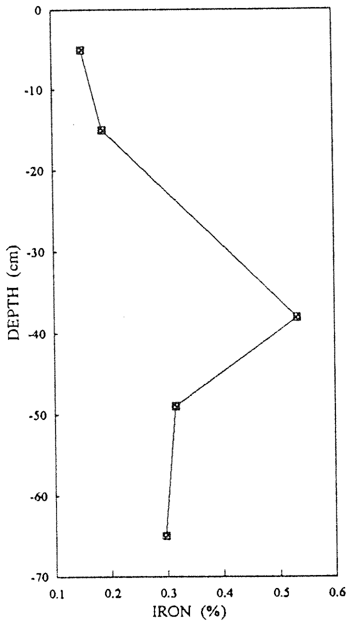


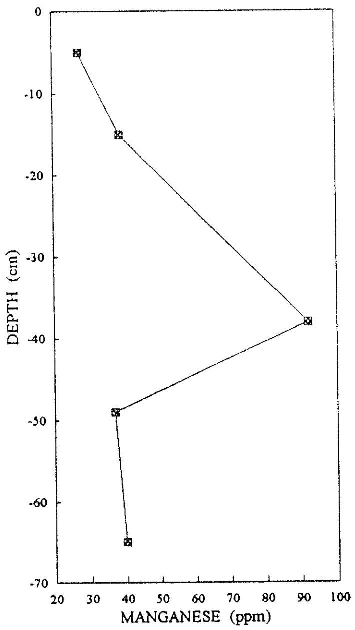
0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
NITROGEN (%)

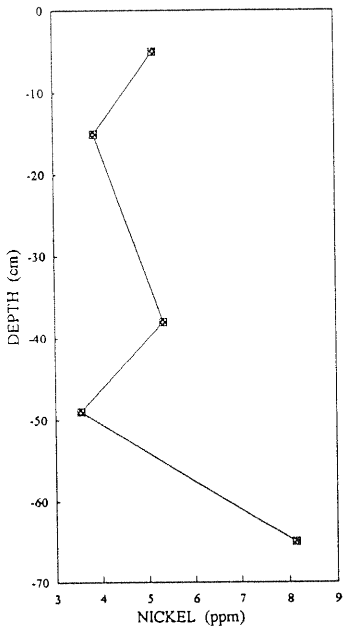
Station 13

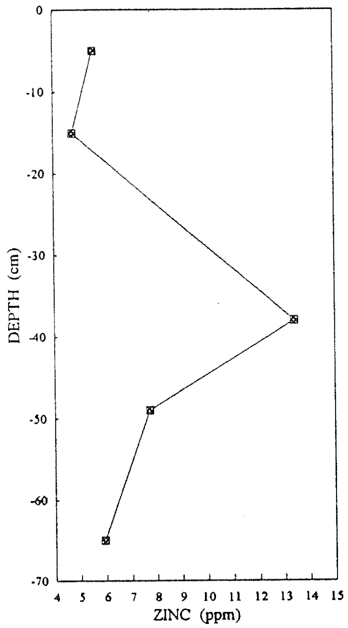

0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
3 4 5 6 7 8 9 10 11 12 13 14
CHROMIUM (ppm)


0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0 0.5 1 1.5 2
COPPER (ppm)

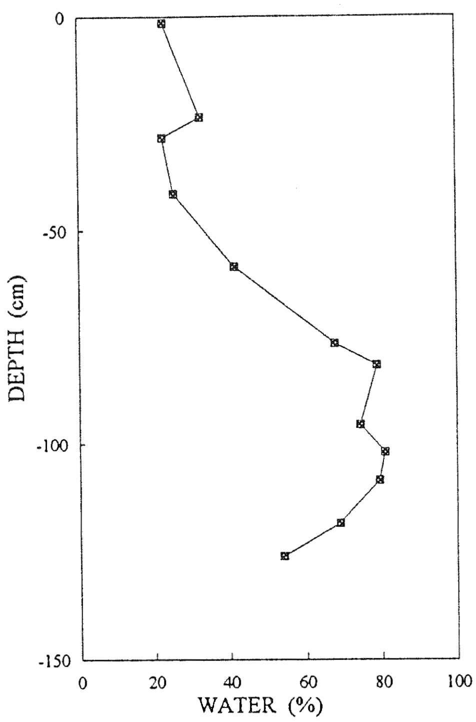

0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
0.1 0.2 0.3 0.4 0.5 0.6
IRON (%)

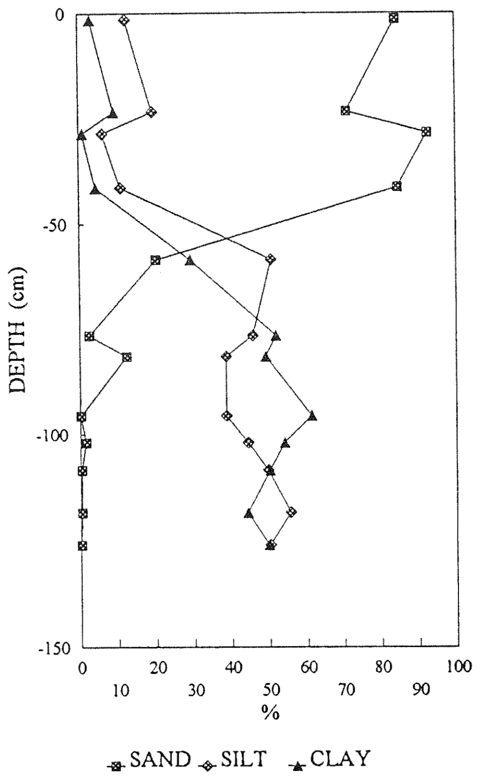

0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
20 30 40 50 60 70 80 90 100
MANGANESE (ppm)

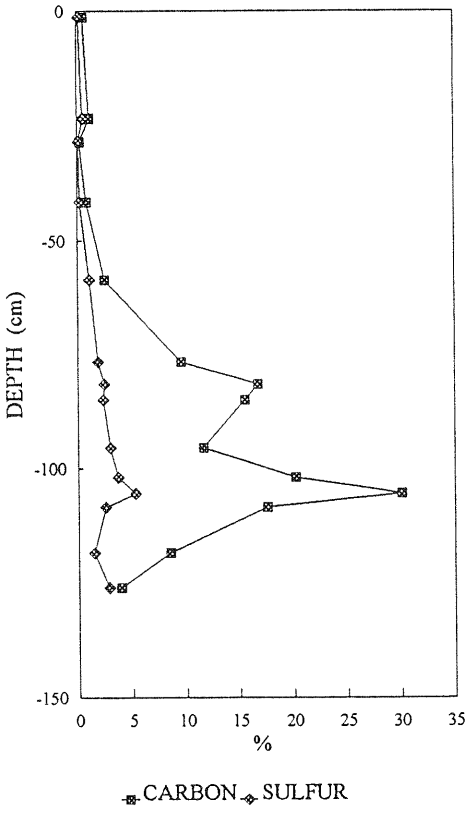

0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
3 4 5 6 7 8 9
NICKEL (ppm)

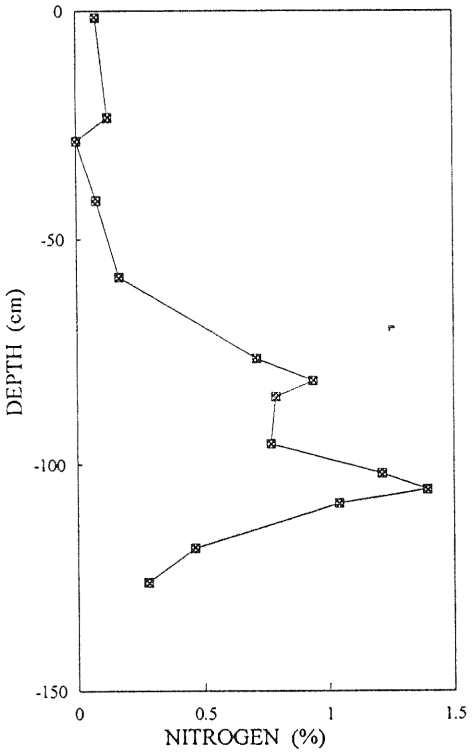

0
-10
-20
-30
-40
-50
-60
-70
DEPTH (cm)
4 5 6 7 8 9 10 11 12 13 14 15
ZINC (ppm)

Station 14

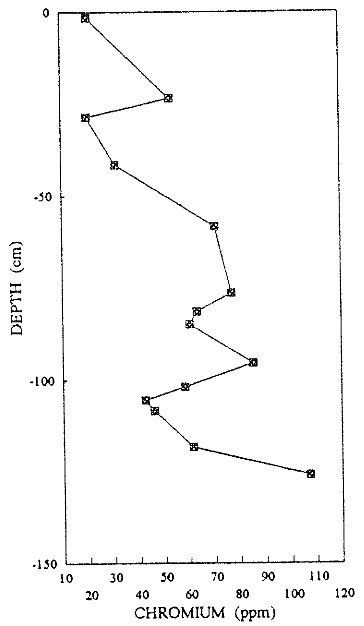

DEPTH (cm)
0
-50
-100
-150
0
20
40
60
80
100
WATER (%)

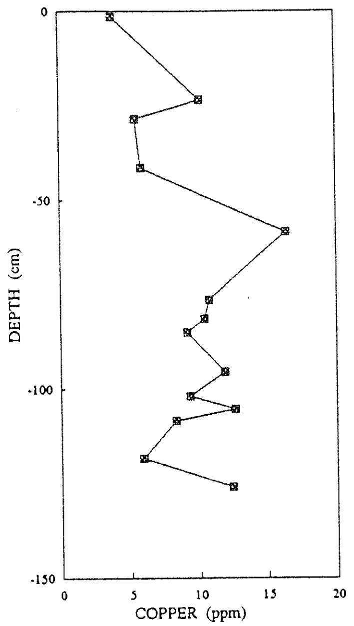

DEPTH (cm)
0
-50
-100
-150
0
20
40
60
80
100
10
30
50
70
90
%
SAND
SILT
CLAY

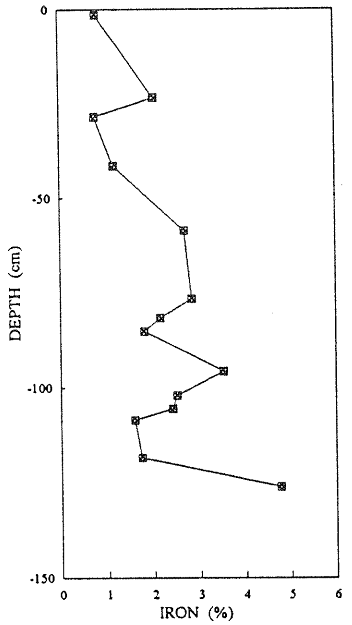

DEPTH (cm)
0
-50
-100
-150
0
5
10
15
20
25
30
35
%
CARBON
SULFUR

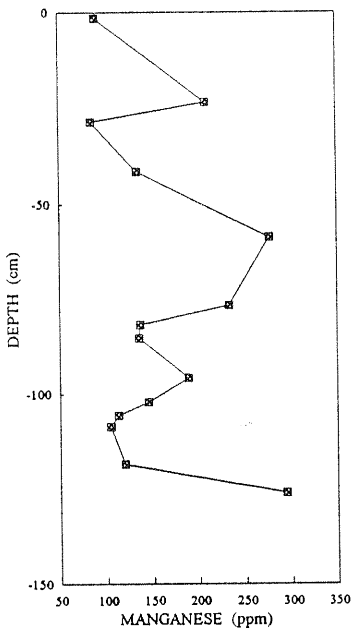

DEPTH (cm)
0
-50
-100
-150
0
0.5
1
1.5
NITROGEN (%)

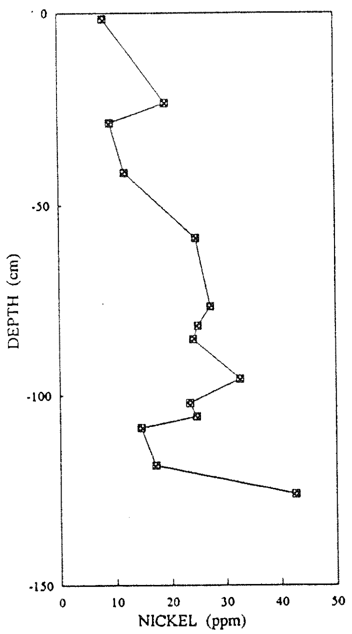
Station 14


0
-50
-100
-150
DEPTH (cm)
10
30
50
70
90
110
20
40
60
80
100
120
CHROMIUM (ppm)


0
-50
-100
-150
DEPTH (cm)
0
5
10
15
20
COPPER (ppm)


0
-50
-100
-150
DEPTH (cm)
0
1
2
3
4
5
6
IRON (%)


0
-50
-100
-150
DEPTH (cm)
50
100
150
200
250
300
350
MANGANESE (ppm)


0
-50
-100
-150
DEPTH (cm)
0
10
20
30
40
50
NICKEL (ppm)

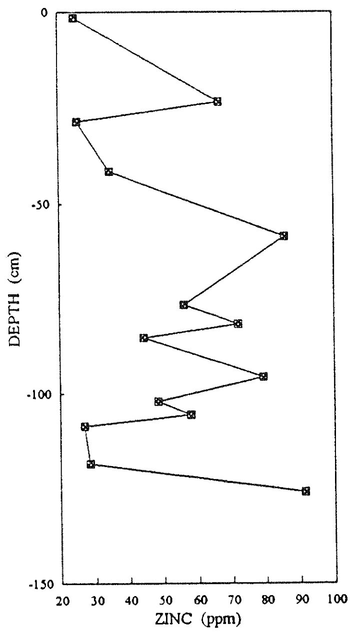

0
-50
-100
-150
DEPTH (cm)
20
30
40
50
60
70
80
90
100
ZINC (ppm)

Table XII. Enrichment factors for metals analyzed in core sediments.

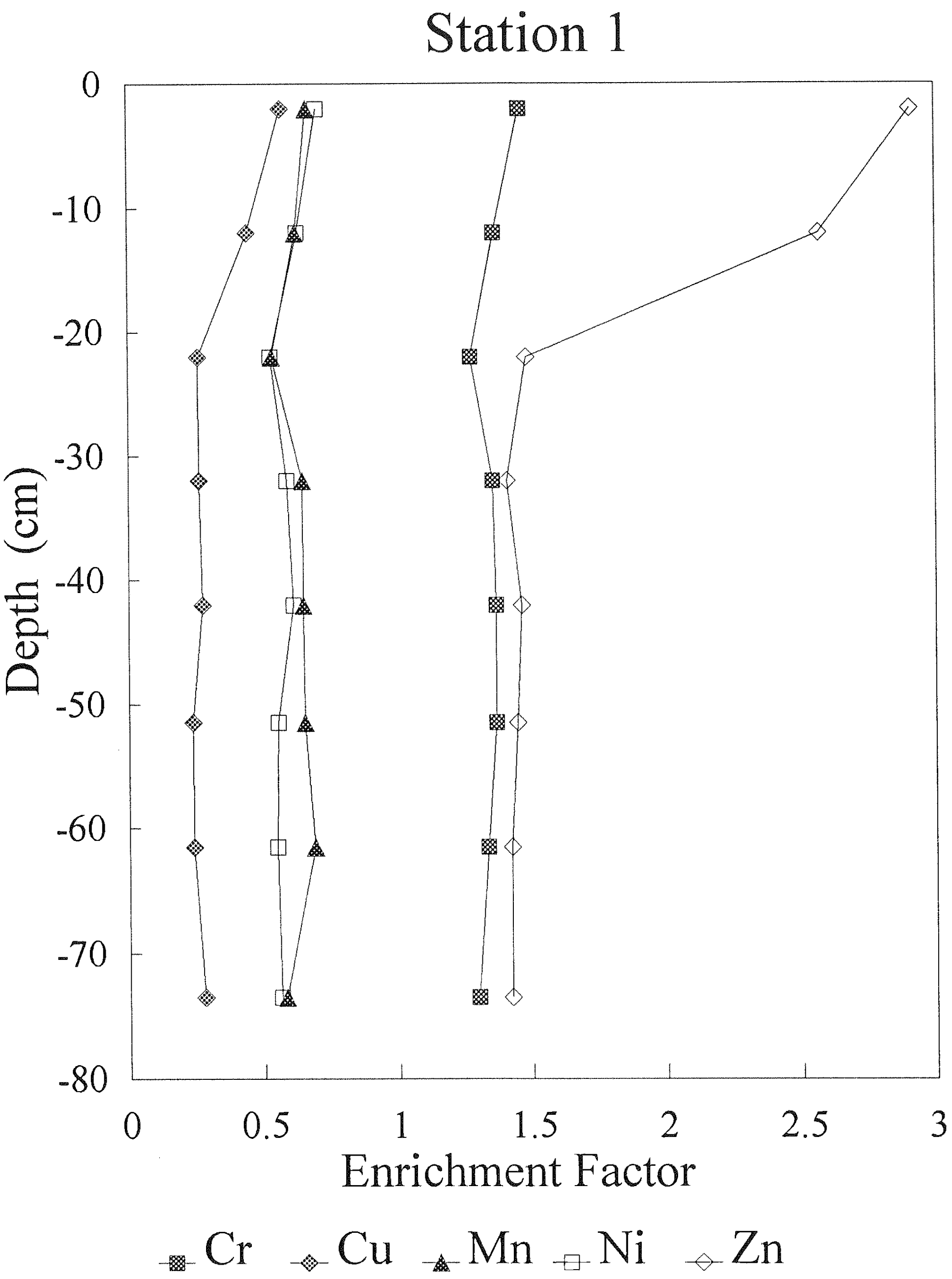
Station #	Sample interval (cm)		Enrichment factor relative to average continental crust (Taylor, 1964)				
	Upper	Lower	Cr	Cu	Mn	Ni	Zn
1	0	-4	1.46	0.57	0.67	0.71	2.91
1	-10	-14	1.36	0.45	0.62	0.63	2.56
1	-20	-24	1.27	0.26	0.53	0.53	1.48
1	-30	-34	1.35	0.26	0.65	0.59	1.41
1	-40	-44	1.37	0.28	0.65	0.61	1.46
1	-50	-53	1.37	0.24	0.65	0.55	1.45
1	-60	-63	1.33	0.24	0.69	0.55	1.42
1	-72	-75	1.29	0.28	0.58	0.56	1.42
2	0	-2	1.50	0.58	0.63	0.75	2.74
2	-2	-4	1.50	0.51	0.70	0.63	2.77
2	-4	-6	1.48	0.54	0.63	0.60	2.91
2	-6	-8	1.57	0.53	0.69	0.76	2.81
2	-8	-10	1.49	0.51	0.69	0.65	2.62
2	-18	-20	1.51	0.47	0.63	0.67	2.77
2	-24	-26	1.50	0.35	0.61	0.66	1.67
2	-32	-34	1.55	0.41	0.74	0.75	1.77
2	-40	-42	1.51	0.38	0.78	0.77	1.59
2	-50	-52	1.49	0.33	0.75	0.68	1.63
2	-58	-60	1.14	0.21	0.35	0.25	0.56
3	0	0	1.57	0.53	0.92	0.96	2.83
4	0	-4	1.49	0.77	0.60	0.59	2.68
4	-8	-12	1.44	0.37	0.63	0.71	1.93
4	-16	-20	1.30	0.27	0.69	0.62	1.40

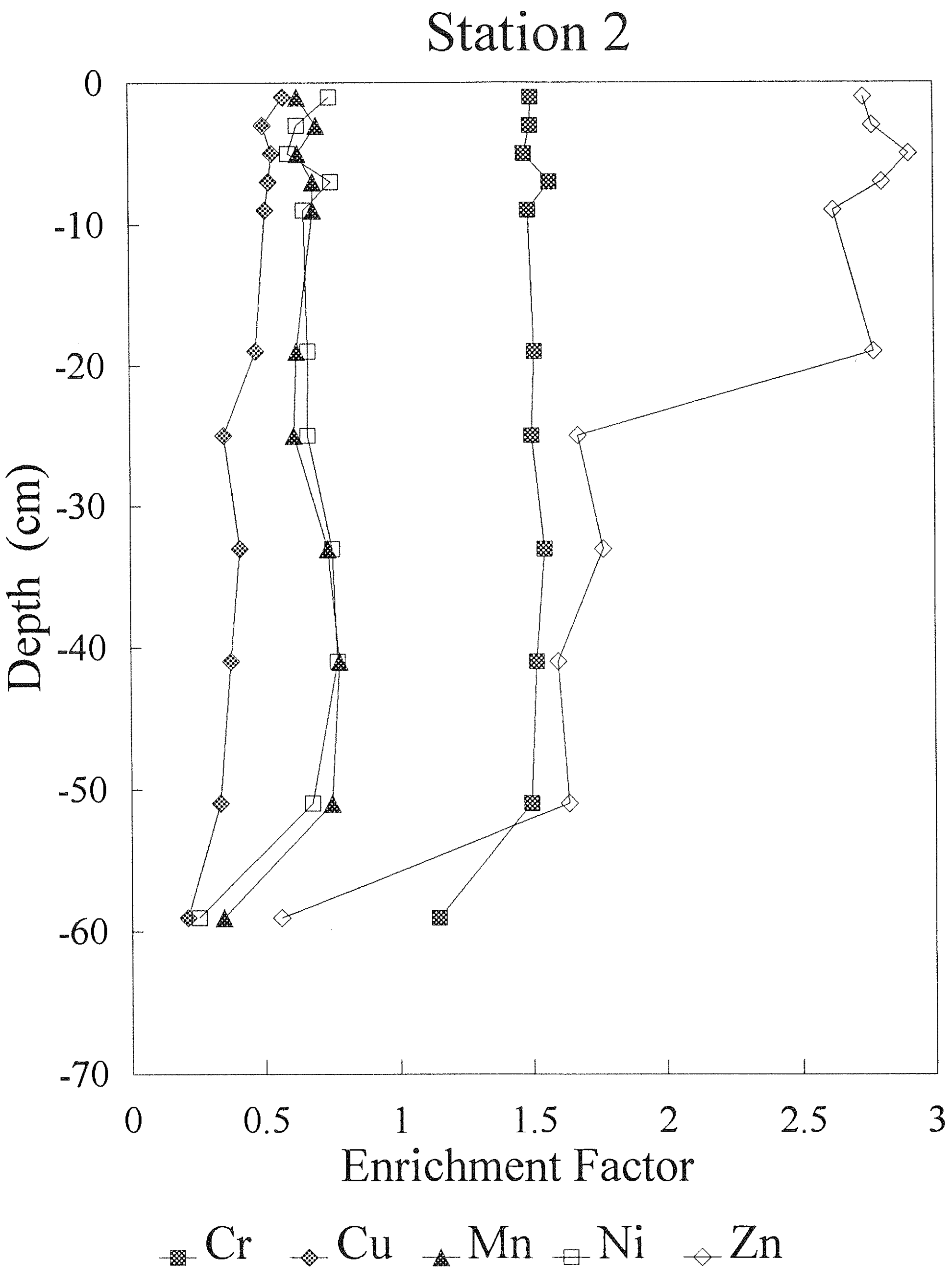
Station #	Sample interval (cm)		Enrichment factor relative to average continental crust (Taylor, 1964)				
	Upper	Lower	Cr	Cu	Mn	Ni	Zn
4	-24	-28	1.33	0.28	0.64	0.61	1.40
4	-32	-36	1.29	0.27	0.61	0.64	1.39
4	-40	-44	1.32	0.24	0.68	0.59	1.45
4	-50	-54	1.26	0.22	0.64	0.53	1.36
4	-60	-64	1.21	0.23	0.61	0.52	1.29
5	0	0	1.52	0.59	0.78	0.68	2.37
6	0	-2	1.36	0.46	0.55	0.62	2.51
6	-4	-6	1.40	0.47	0.59	0.62	2.47
6	-12	-14	1.35	0.34	0.61	0.56	1.95
6	-24	-26	1.39	0.31	0.55	0.54	1.73
6	-34	-36	1.37	0.30	0.57	0.61	1.50
6	-46	-48	1.44	0.31	0.60	0.64	1.57
6	-58	-60	1.34	0.27	0.75	0.59	1.53
6	-78	-80	1.30	0.22	0.76	0.52	1.41
7	0	-2	1.42	0.53	0.52	0.60	2.88
7	-4	-6	1.34	0.42	0.47	0.55	2.30
7	-8	-10	1.36	0.36	0.48	0.56	1.95
7	-12	-14	1.43	0.35	0.66	0.56	2.01
7	-24	-26	1.30	0.23	0.46	0.50	1.38
7	-36	-38	1.24	0.23	0.52	0.52	1.31
7	-48	-50	1.25	0.21	0.55	0.55	1.35
7	-60	-62	1.25	0.22	0.50	0.54	1.35
7	-72	-74	1.26	0.22	0.52	0.54	1.35
7	-84	-86	1.24	0.22	0.51	0.51	1.27
8	0	0	1.44	0.74	0.41	0.76	2.22
9	0	-2	1.39	0.50	0.56	0.61	2.66
9	-6	-8	1.40	0.51	0.56	0.63	2.70
9	-14	-16	1.40	0.45	0.53	0.66	2.19

Station #	Sample interval (cm)		Enrichment factor relative to average continental crust (Taylor, 1964)				
	Upper	Lower	Cr	Cu	Mn	Ni	Zn
9	-24	-26	1.30	0.27	0.49	0.55	1.48
9	-34	-36	1.35	0.29	0.60	0.58	1.50
9	-50	-52	1.26	0.27	0.60	0.58	1.45
9	-72	-74	1.33	0.24	0.67	0.65	1.36
10	0	-3	1.41	0.63	0.59	0.66	2.53
10	-5	-8	1.38	0.55	0.60	0.60	2.61
10	-14	-17	1.37	0.51	0.59	0.62	2.63
10	-27	-30	1.31	0.36	0.67	0.60	1.65
10	-45	-48	1.36	0.29	0.59	0.60	1.49
10	-57	-60	1.35	0.30	0.60	0.60	1.46
10	-72	-75	1.34	0.28	0.63	0.56	1.45
11	0	-3	1.58	0.59	0.73	0.82	2.70
11	-9	-12	1.56	0.57	0.72	0.69	2.85
11	-17	-20	1.46	0.48	0.73	0.73	2.40
11	-26	-29	1.36	0.45	0.80	0.67	1.78
11	-34	-37	1.38	0.36	0.68	0.67	1.57
12	0	-2	1.35	0.58	0.47	0.59	2.89
12	-6	-8	1.35	0.58	0.50	0.64	2.84
12	-14	-16	1.29	0.56	0.43	0.59	1.87
12	-24	-26	1.34	0.29	0.55	0.56	1.47
12	-34	-36	1.26	0.26	0.50	0.47	1.26
12	-50	-52	1.32	0.32	0.47	0.55	1.22
12	-68	-70	1.32	0.27	0.47	0.55	1.35
12	-84	-86	1.25	0.25	0.44	0.53	1.30
13	-4	-6	1.50	0.49	1.05	2.53	2.93
13	-14	-16	1.37	0.52	1.20	1.53	2.01
13	-36	-40	1.36	0.33	1.02	0.75	2.02
13	-48	-50	1.32	0.17	0.69	0.84	1.97

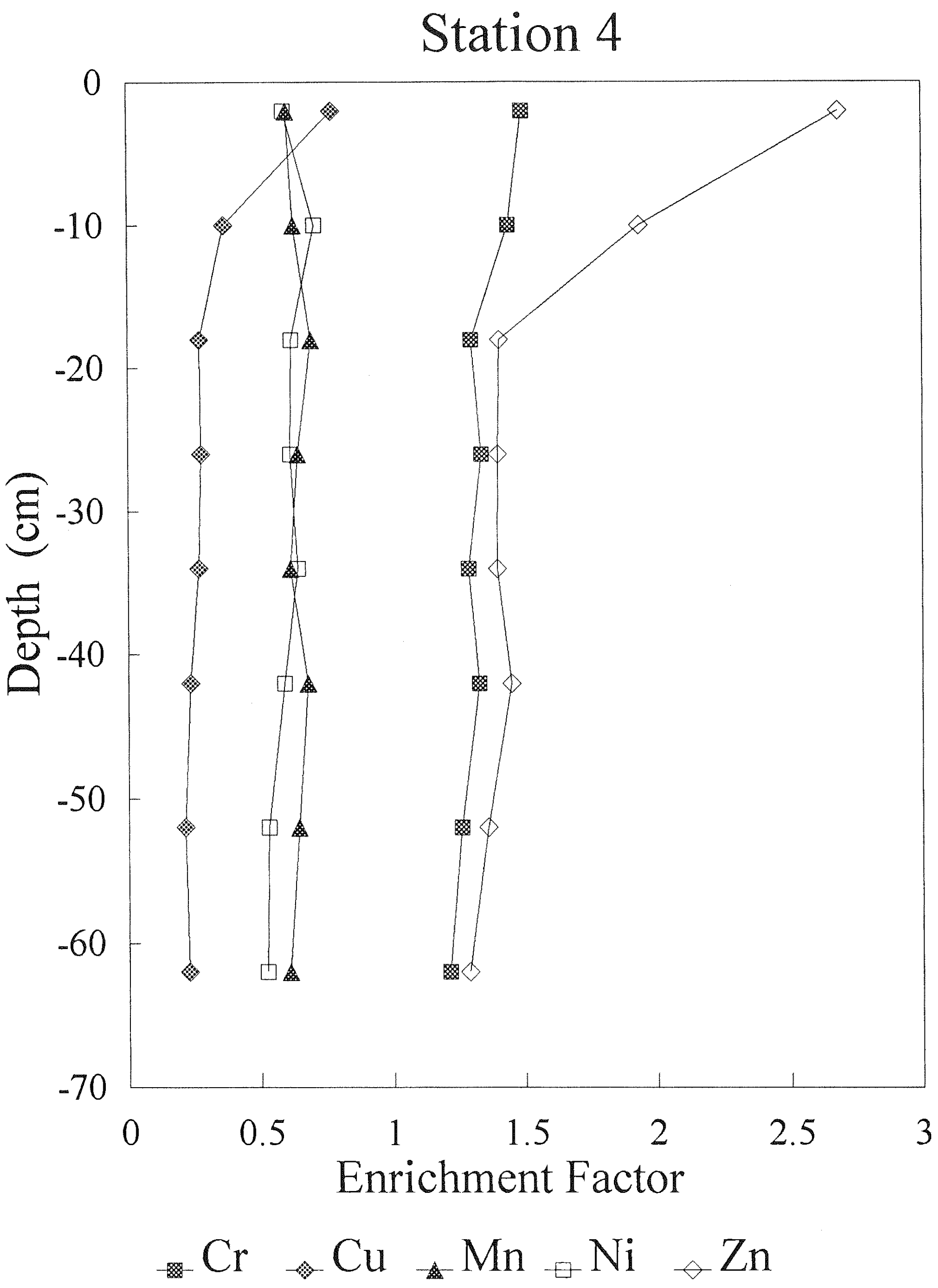
Station #	Sample interval (cm)		Enrichment factor relative to average continental crust (Taylor, 1964)				
	Upper	Lower	Cr	Cu	Mn	Ni	Zn
13	-64	-66	1.55	0.12	0.80	2.06	1.61
14	0	-3	1.45	0.49	0.67	0.76	2.48
14	-22	-25	1.47	0.51	0.61	0.71	2.63
14	-27	-30	1.49	0.74	0.66	0.92	2.67
14	-40	-43	1.51	0.52	0.69	0.77	2.39
14	-57	-60	1.48	0.63	0.61	0.69	2.57
14	-75	-78	1.52	0.39	0.49	0.72	1.58
14	-80	-83	1.66	0.50	0.38	0.88	2.69
14	-84	-86	1.87	0.52	0.44	1.00	1.97
14	-94	-97	1.37	0.35	0.32	0.70	1.81
14	-101	-103	1.31	0.38	0.34	0.70	1.55
14	-105	-106	0.99	0.54	0.28	0.77	1.93
14	-107	-110	1.64	0.54	0.39	0.69	1.36
14	-117	-120	1.98	0.35	0.41	0.74	1.32
14	-125	-127	1.26	0.27	0.37	0.67	1.54

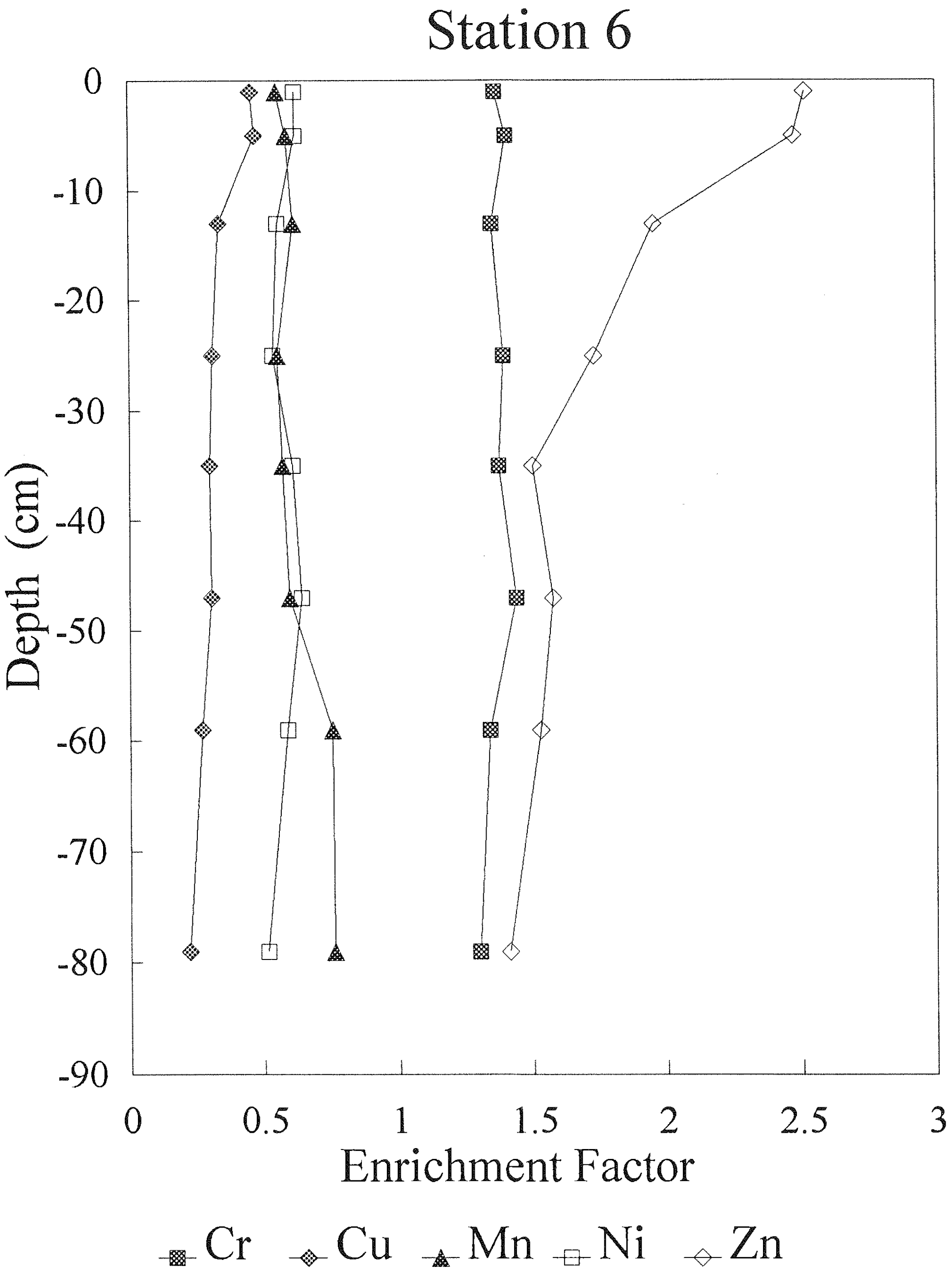
Plots of enrichment factors versus depth in cores.

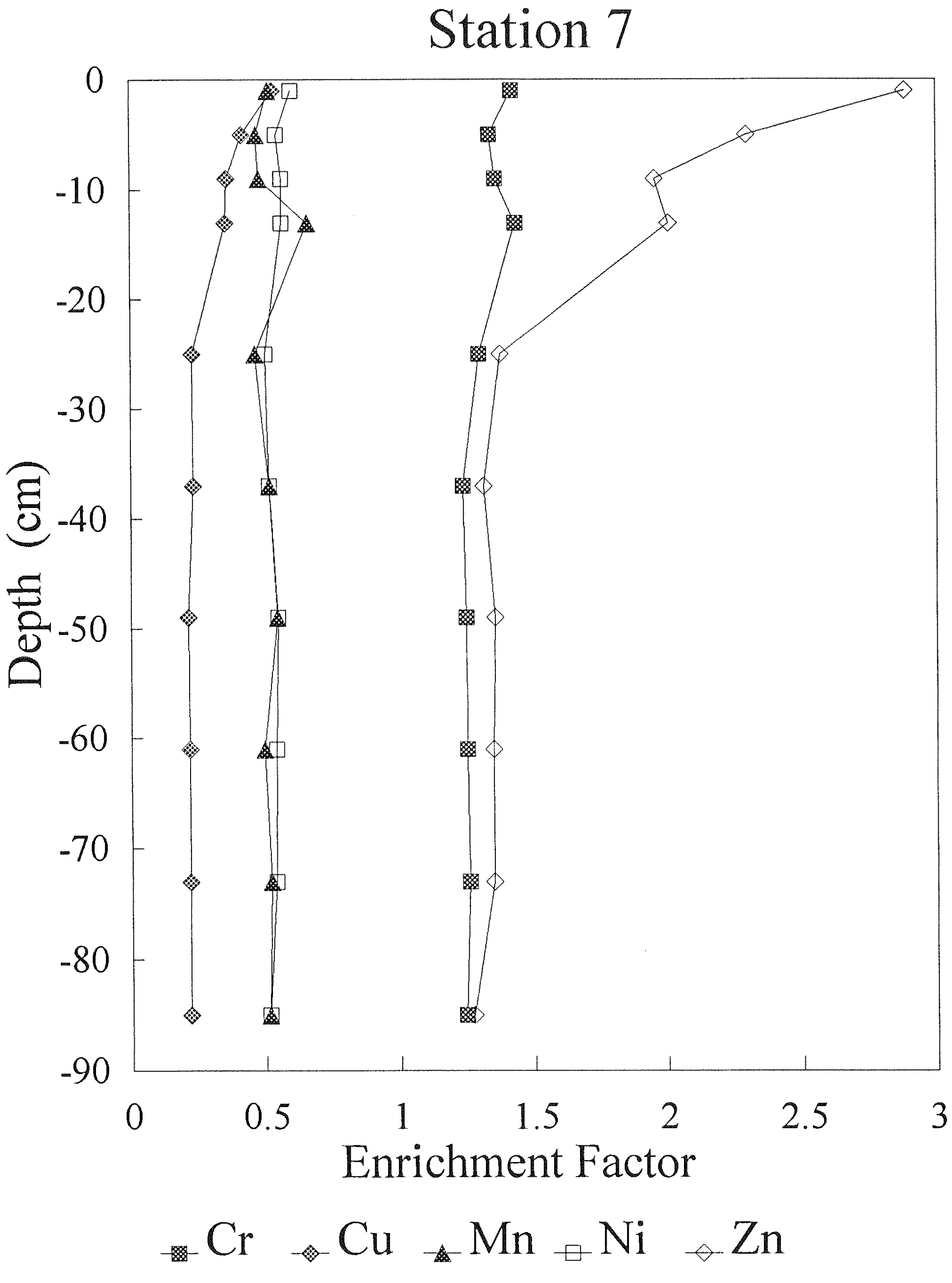

Station 1
0
-10
-20
-30
-40
-50
-60
-70
-80
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

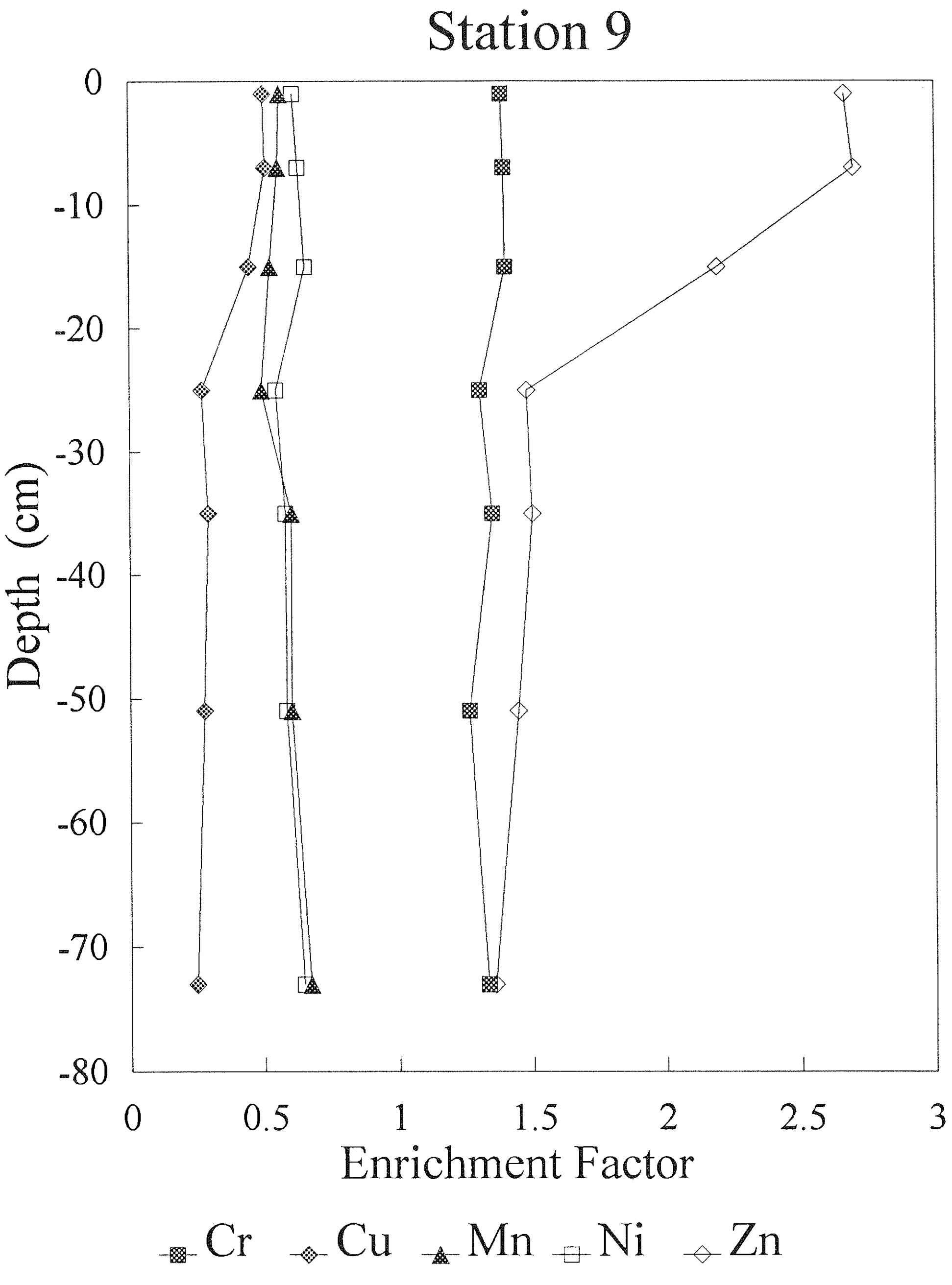


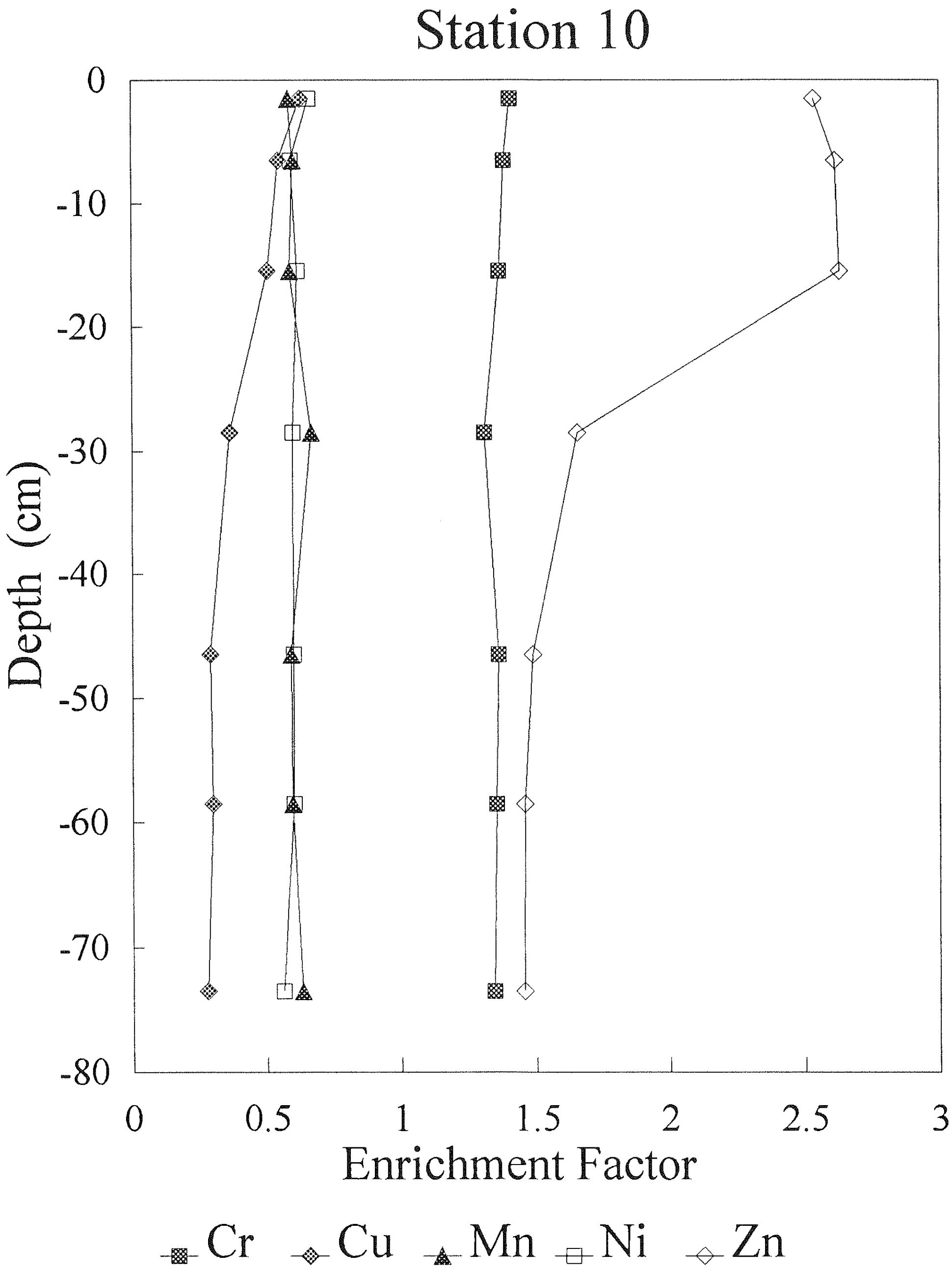
Station 2
0
-10
-20
-30
-40
-50
-60
-70
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

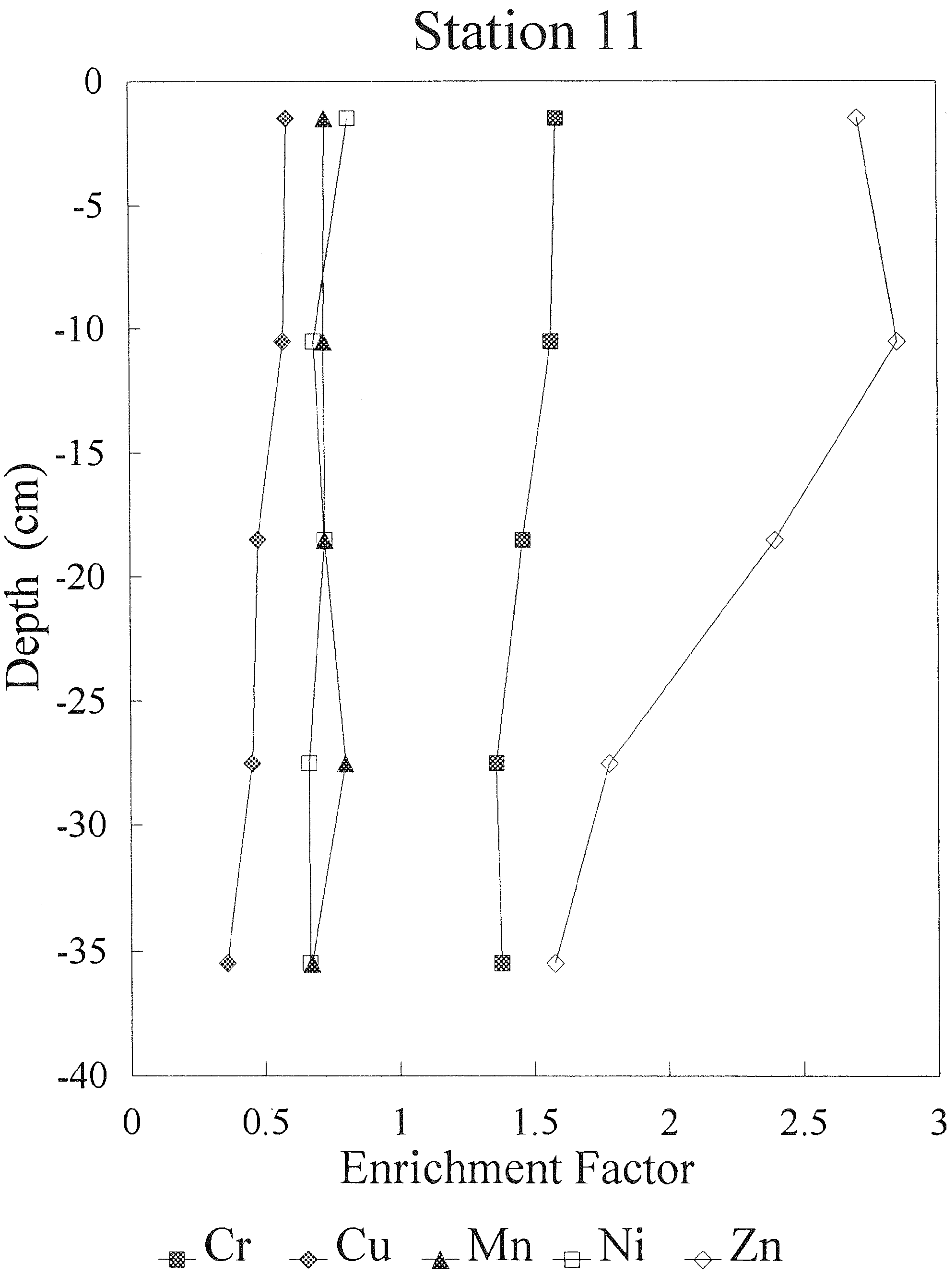

Station 4
0
-10
-20
-30
-40
-50
-60
-70
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

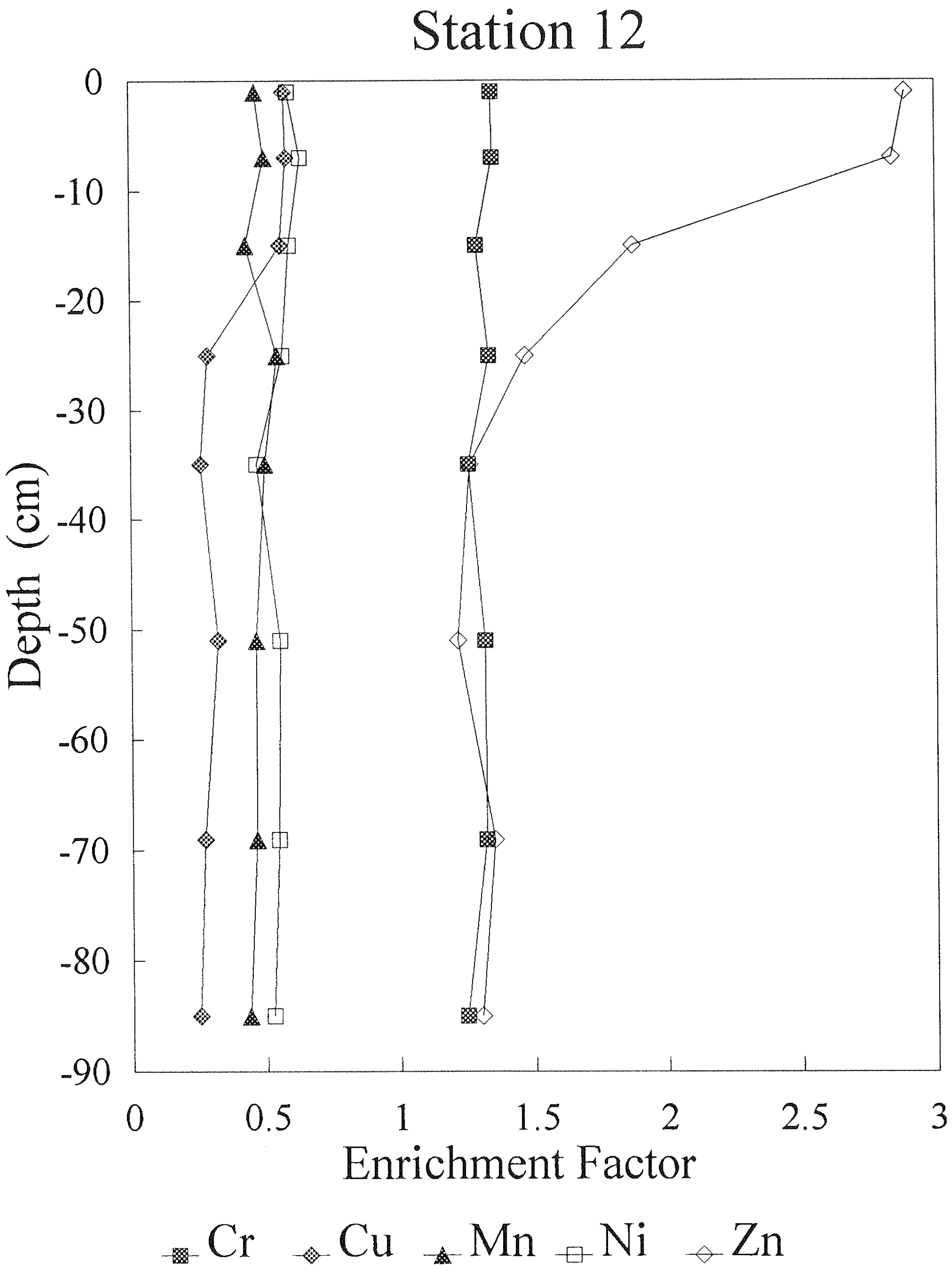

Station 6
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

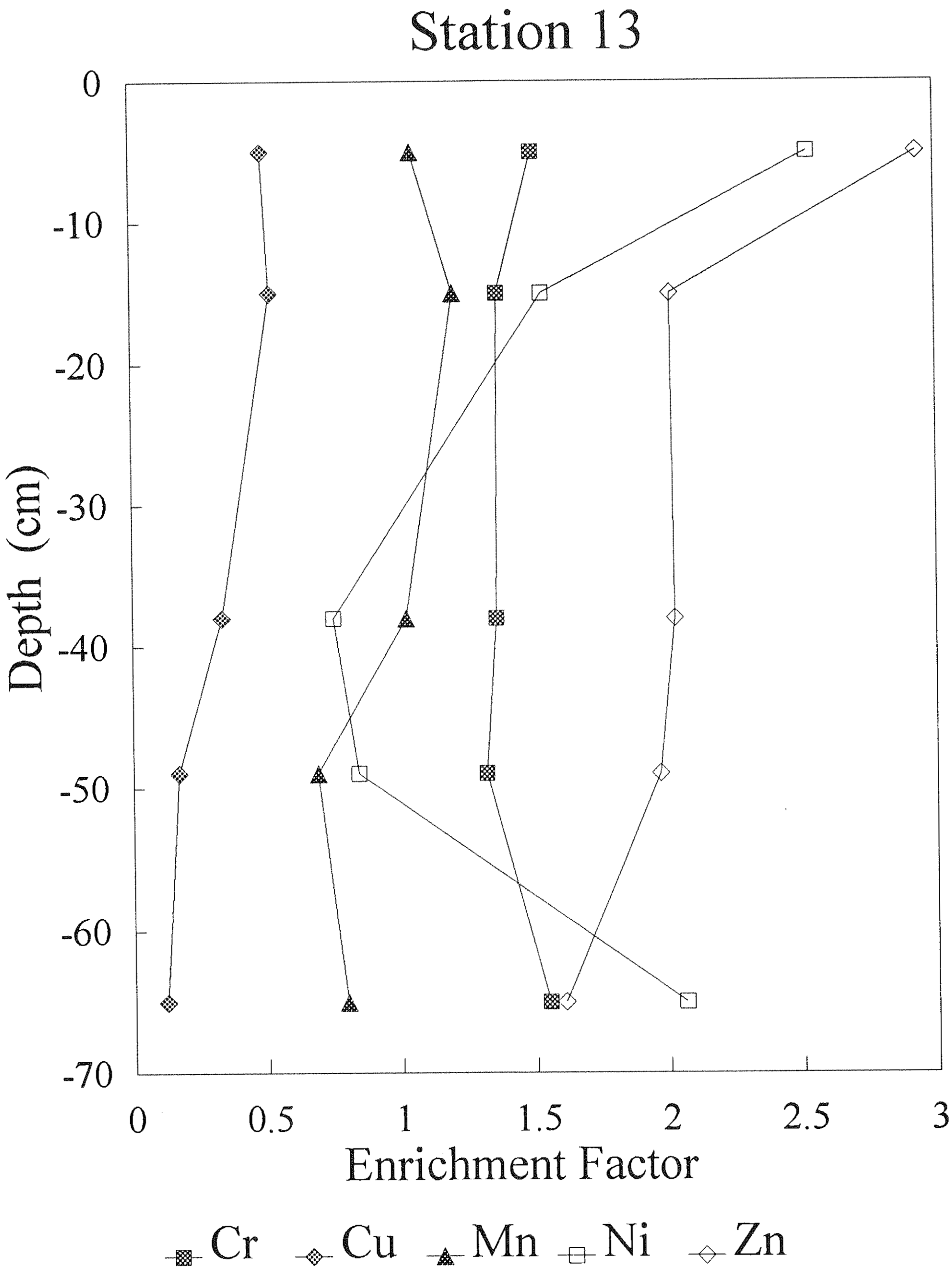

Station 7
Depth (cm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn


Station 9
0
-10
-20
-30
-40
-50
-60
-70
-80
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn


Station 10
0
-10
-20
-30
-40
-50
-60
-70
-80
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn


Station 11
0
-5
-10
-15
-20
-25
-30
-35
-40
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn


Station 12
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn


Station 13
0
-10
-20
-30
-40
-50
-60
-70
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

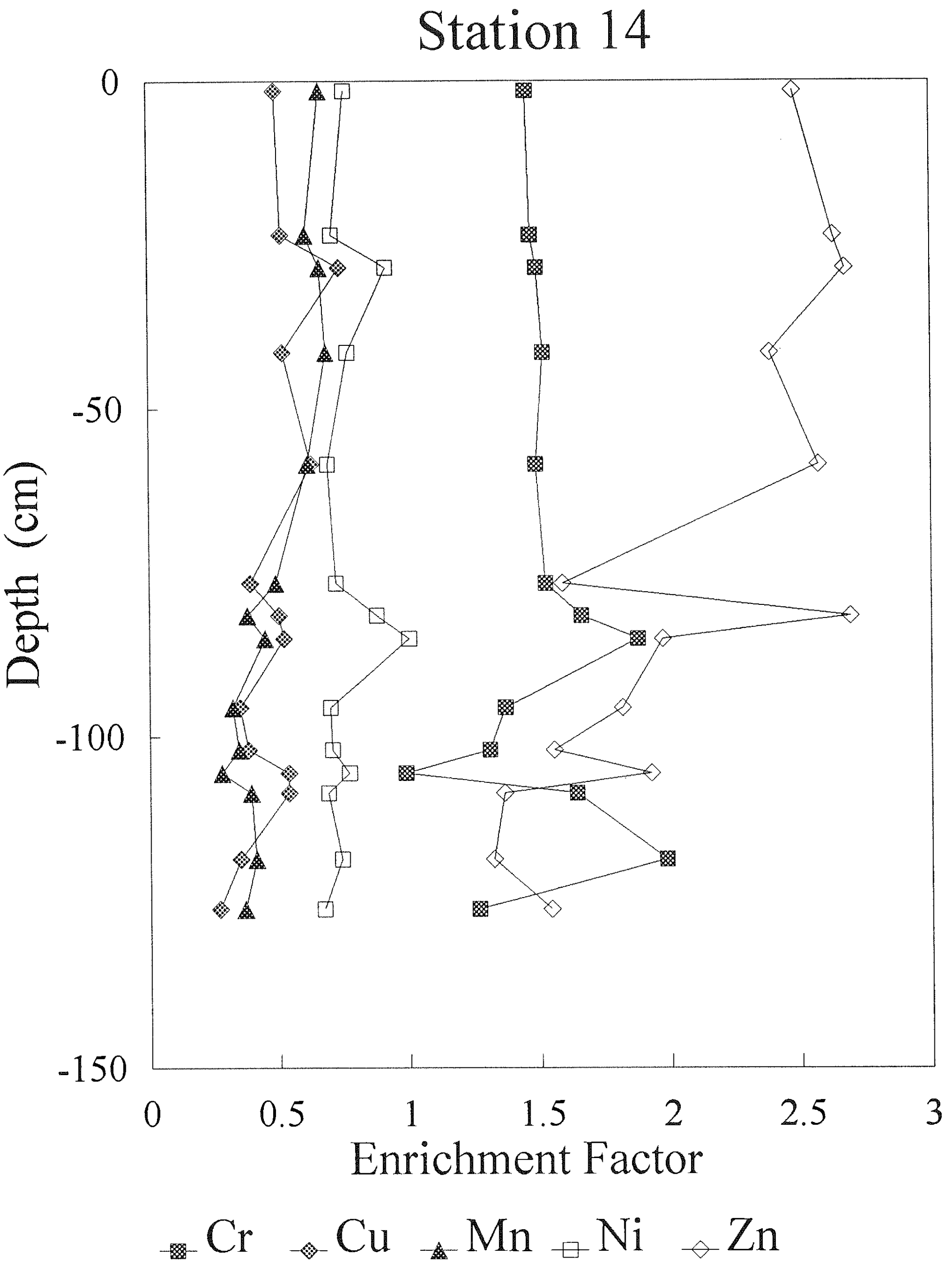

Station 14
0
-50
-100
-150
Depth (cm)
0
0.5
1
1.5
2
2.5
3
Enrichment Factor
Cr
Cu
Mn
Ni
Zn

Table XIII. Mean and standard deviation (σ) of the variation values calculated for sediments below 30 cm in the sediment column. The mean and 3σ values are used to identify significantly low or high variation values (see Table XIV).

Metal	Mean	σ	2σ	3σ
Cr	0.01	± 0.17	± 0.34	± 0.50
Cu	-0.02	± 0.23	± 0.46	± 0.69
Fe	0.05	± 0.28	± 0.57	± 0.85
Mn	0.00	± 0.21	± 0.43	± 0.65
Ni	0.02	± 0.27	± 0.54	± 0.82
Zn	0.01	± 0.20	± 0.39	± 0.60

Table XIV. Variation values for metal concentration relative to background levels. Variation values were calculated using equations 2 and 3 (see explanation in text). Values exceeding 3σ (refer to Table XIII) are **bolded**.

Station #	Sample interval (cm)		Variation from background levels (calculated using equations 2 and 3- see text for explanation)					
	Upper	Lower	Cr	Cu	Fe	Mn	Ni	Zn
1	0	-4	0.02	**0.94**	-0.09	0.02	0.12	**0.91**
1	-10	-14	0.22	**0.85**	0.19	0.20	0.26	**1.15**
1	-20	-24	-0.06	-0.02	-0.02	-0.14	-0.11	0.02
1	-30	-34	0.10	0.07	0.07	0.16	0.09	0.07
1	-40	-44	0.05	0.06	0.00	0.09	0.07	0.05
1	-50	-53	0.00	-0.05	-0.06	0.08	-0.03	0.00
1	-60	-63	0.04	0.01	0.00	0.21	0.02	0.04
1	-72	-75	-0.03	0.13	-0.04	-0.01	0.01	0.01
2	0	-2	-0.17	0.50	-0.24	-0.27	-0.12	0.39
2	-2	-4	0.02	0.56	-0.06	-0.02	-0.11	**0.71**
2	-4	-6	0.11	**0.88**	0.05	-0.02	-0.07	**0.99**
2	-6	-8	0.18	**0.82**	0.04	0.06	0.18	**0.92**
2	-8	-10	0.09	**0.73**	0.00	0.04	0.00	**0.75**
2	-18	-20	0.07	0.52	-0.01	-0.10	-0.04	**0.78**
2	-24	-26	0.26	0.57	0.09	0.15	0.30	0.32
2	-32	-34	-0.26	-0.05	-0.35	-0.26	-0.23	-0.22
2	-40	-42	0.22	0.32	0.17	0.23	0.20	0.14
2	-50	-52	0.45	0.51	0.34	0.51	0.38	0.45
2	-58	-60	-0.45	-0.51	-0.33	**-0.65**	-0.75	**-0.75**
3	0	0	0.25	0.60	0.37	0.24	0.21	**0.87**
4	0	-4	0.00	**1.35**	-0.10	-0.15	-0.15	**0.66**
4	-8	-12	0.09	0.29	0.02	0.00	0.15	0.35
4	-16	-20	0.13	0.07	0.17	0.27	0.16	0.14
4	-24	-28	-0.01	-0.09	0.00	0.00	-0.02	-0.04

Station #	Sample interval (cm)		Variation from background levels (calculated using equations 2 and 3- see text for explanation)					
	Upper	Lower	Cr	Cu	Fe	Mn	Ni	Zn
4	-32	-36	0.12	0.05	0.16	0.13	0.22	0.13
4	-40	-44	0.08	-0.01	0.06	0.23	0.13	0.11
4	-50	-54	0.00	-0.09	0.03	0.15	0.00	0.02
4	-60	-64	0.02	-0.03	0.09	0.14	0.02	0.02
5	0	0	0.35	**1.32**	0.27	0.38	0.18	**0.88**
6	0	-2	0.04	0.67	0.00	-0.09	0.06	**0.79**
6	-4	-6	0.10	**0.77**	0.03	0.00	0.09	**0.80**
6	-12	-14	0.08	0.27	0.06	0.06	-0.01	0.46
6	-24	-26	-0.03	0.10	-0.09	-0.15	-0.14	0.13
6	-34	-36	0.21	0.34	0.15	0.10	0.22	0.23
6	-46	-48	-0.33	-0.33	-0.39	-0.41	-0.34	-0.32
6	-58	-60	-0.12	-0.16	-0.11	0.06	-0.15	-0.07
6	-78	-80	0.01	-0.07	0.00	0.34	-0.04	0.04
7	0	-2	-0.03	**0.97**	-0.12	-0.20	-0.01	**0.86**
7	-4	-6	0.01	0.66	-0.03	-0.20	-0.03	**0.63**
7	-8	-10	0.02	0.41	-0.04	-0.20	-0.01	0.38
7	-12	-14	-0.27	-0.05	-0.35	-0.25	-0.33	-0.05
7	-24	-26	0.00	-0.07	-0.01	-0.20	-0.09	0.00
7	-36	-38	0.06	0.01	0.11	-0.02	0.03	0.06
7	-48	-50	0.01	-0.07	0.04	0.00	0.06	0.04
7	-60	-62	0.02	-0.01	0.04	-0.08	0.06	0.04
7	-72	-74	-0.03	-0.03	-0.02	-0.07	0.02	-0.01
7	-84	-86	0.02	0.00	0.04	-0.04	0.02	-0.02
8	0	0	-0.37	**0.75**	-0.43	-0.59	-0.21	-0.08
9	0	-2	-0.02	0.65	-0.07	-0.14	-0.03	**0.76**
9	-6	-8	0.01	**0.73**	-0.05	-0.13	0.02	**0.82**
9	-14	-16	-0.06	0.40	-0.11	-0.24	-0.01	0.38

Station #	Sample interval (cm)		Variation from background levels (calculated using equations 2 and 3- see text for explanation)					
	Upper	Lower	Cr	Cu	Fe	Mn	Ni	Zn
9	-24	-26	0.25	0.25	0.26	0.03	0.19	0.33
9	-34	-36	-0.03	0.00	-0.06	-0.06	-0.06	0.00
9	-50	-52	-0.01	-0.05	0.05	0.00	-0.01	0.05
9	-72	-74	-0.05	-0.18	-0.07	0.04	0.04	-0.10
10	0	-3	0.06	1.32	-0.01	-0.04	0.13	**0.79**
10	-5	-8	0.10	1.16	0.05	0.05	0.08	**0.95**
10	-14	-17	0.03	0.82	0.01	-0.04	0.03	**0.85**
10	-27	-30	0.08	0.47	0.09	0.18	0.10	0.26
10	-45	-48	0.06	0.06	0.04	-0.02	0.03	0.07
10	-57	-60	0.10	0.19	0.07	0.06	0.11	0.11
10	-72	-75	0.07	0.12	0.04	0.11	0.04	0.09
11	0	-3	0.21	**1.06**	0.05	0.15	0.29	**0.88**
11	-9	-12	0.00	**0.74**	-0.14	-0.03	-0.07	**0.66**
11	-17	-20	0.12	**0.72**	0.07	0.14	0.14	**0.67**
11	-26	-29	0.36	**1.07**	0.40	0.63	0.36	**0.61**
11	-34	-37	0.06	0.26	0.08	0.06	0.05	0.10
12	0	-2						
12	-6	-8	-0.04	**1.08**	-0.07	-0.21	0.05	**0.90**
12	-14	-16	-0.08	**0.92**	-0.07	-0.33	-0.05	0.25
12	-24	-26	-0.12	-0.06	-0.14	-0.21	-0.15	-0.09
12	-34	-36	-0.05	0.00	-0.02	-0.16	-0.17	-0.10
12	-50	-52	-0.19	0.01	-0.20	-0.37	-0.21	-0.30
12	-68	-70	0.02	0.08	0.00	-0.20	-0.01	-0.02
12	-84	-86	-0.06	0.00	-0.03	-0.26	-0.06	-0.08
13	-4	-6	-0.26	-0.25	0.25	-0.28	0.50	0.08
13	-14	-16	-0.17	-0.02	0.53	0.02	0.12	-0.08
13	-36	-40	-0.21	-0.11	-0.13	0.13	-0.19	0.02

Station #	Sample interval (cm)		Variation from background levels (calculated using equations 2 and 3- see text for explanation)					
	Upper	Lower	Cr	Cu	Fe	Mn	Ni	Zn
13	-48	-50	0.23	-0.51	**1.18**	-0.08	-0.02	0.39
13	-64	-66	0.30	-0.69	**0.90**	-0.04	**1.18**	0.03
14	0	-3	0.43	**0.90**	0.55	0.19	0.30	**1.11**
14	-22	-25	**1.00**	**2.21**	**0.91**	**0.68**	**0.97**	**2.25**
14	-27	-30	**1.22**	**2.83**	**1.73**	0.60	**1.03**	**2.25**
14	-40	-43	**0.97**	**1.80**	**0.98**	**0.67**	0.80	**1.71**
14	-57	-60	0.04	**1.23**	-0.09	-0.06	0.11	**0.68**
14	-75	-78	-0.27	0.07	-0.39	-0.47	-0.15	-0.28
14	-80	-83	-0.36	0.11	-0.51	**-0.67**	-0.17	-0.01
14	-84	-86						
14	-94	-97	-0.28	0.08	-0.34	-0.61	-0.10	-0.10
14	-101	-103	-0.46	-0.10	-0.48	**-0.68**	-0.29	-0.40
14	-105	-106						
14	-107	-110	**-0.55**	-0.18	-0.65	**-0.76**	-0.55	**-0.65**
14	-117	-120	-0.35	-0.39	-0.58	**-0.70**	-0.43	**-0.59**
14	-125	-127	0.05	0.23	0.05	-0.31	0.34	0.20

APPENDIX IV

MICROWAVE DIGESTION TECHNIQUE

The steps in microwave digestion, modified from EPA Method #3051 (Soil Sample Digestion Procedure for Floyd Digestion Vessels), are as follows:

1. Approximately 0.5 g of dried, ground sediment was placed in the teflon digestion vessel.

2. 2.5 ml concentrated HNO_3 (trace metal grade) and 7.5 ml concentrated HCl (trace metal grade) was added to the teflon vessel. (Preparation of blanks were made by using 0.5 ml of high purity water plus the acids used in this step.)

3. Digestion vessel was capped and placed in microwave carousel. A minimum of four vessels were processed in the microwave at a time.

4. Sediment and acid mixture was digested by irradiating the vessel according to the programmed steps recommended for the number of vessels in the microwave. The sample was brought to a temperature of 175° C in 5.5 minutes, then maintained between 175-180° C for 10 minutes. (The pressure during this time peaks at approximately 6 atm. for most samples.)

5. The vessel was allowed to cool to room temperature before opening. The contents of the vessel was transferred to 50 ml volumetric flask and diluted with high purity water to 50 ml. (For Fe and Mn analyses, samples were diluted three times or to 150 ml.)

6. The dissolved samples are transferred to polyethylene bottles and stored for analysis.

All surfaces that came into contact with the samples were acid washed (3 days 1:1 HNO_3; 3 days 1:1 HCl), rinsed six times in high purity water (less than 5 mega-ohms), and stored in high-purity water until use.