Sediments and Shallow Stratigraphy of a Portion of the Continental Shelf of Southeastern Virginia

by

Carl H. Hobbs, III

Contract Report for

U. S. Department of the Interior
Minerals Management Service
Cooperative Agreement 14-35-0001-30740

Virginia's Inner Continental Shelf:
Continued Studies Relative to the Potential for Aggregate Mining

Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

August 1997

The following document, *Sediments and Shallow Stratigraphy of a Portion of the Continental Shelf of Southeastern Virginia*, is the complete text of the author's Ph.D. dissertation at the University of Mississippi. As much of the work was performed with funds provided by the Office of International Activities and Marine Minerals of the Minerals Management Service of the U. S. Department of the Interior, the dissertation also serves as a report of work accomplished as part of Cooperative Agreement 14-35-001-30740. The work was conducted at the Virginia Institute of Marine Science of the College of William & Mary.

Portions of the dissertation have appeared in earlier reports.

ABSTRACT

SEDIMENTS AND SHALLOW STRATIGRAPHY OF A PORTION OF THE CONTINENTAL SHELF OF SOUTHEASTERN VIRGINIA

HOBBS, CARL HEYWOOD, III, B.S., Union College, 1968, M.S. University of Massachusetts, 1972. Ph.D. University of Mississippi, 1997. Dissertation directed by Dr. J. Robert Woolsey.

A network of high-resolution, seismic-reflection profiles and grab samples of the surficial sediments of the inner continental shelf of southeastern Virginia demonstrate that the Quaternary geology of the region is more complex than indicated by earlier studies. The spatial variability of the surficial sediments depicts active processes, such as outflow from Chesapeake Bay, as well as the underlying geology in outcrops of finer grained sediments near False Cape.

The complexity of the Quaternary geology results from large and small scale fluctuations in sea level. Individual, relatively large-scale, seismostratigraphic units are separated by erosional surfaces formed during the major changes in sea level that created the Cape Charles, Eastville, Belle Haven, and Exmore paleochannels in Chesapeake Bay. The low amplitude, high frequency variations in sea level that occurred during the mid-Pleistocene impacted the inner shelf forming several thin depositional strata separated by local erosional surfaces.

Substantial resources of sand exist on the inner shelf and are suitable for use in beach nourishment and construction aggregate. The deposits occur in three distinct stratigraphic settings: discrete shoals on the surface, filled channels, and laterally variable stratigraphic facies. The three types of filled paleochannels within the inner shelf have different origins: 1) riverine flow, 2) back-barrier or lagoonal channels, and 3) migration of (Holocene?) tidal inlets.

ACKNOWLEDGMENTS

Many persons have participated in the actual work of the several projects that I have herein attempted to draw together. My co-investigators and co-workers on the various projects, C. R. Berquist, Jr, S. M. Kimball, C. S. Hardaway, R. A. Gammisch, and D. A. Milligan, among others, each had a role in some aspect of the work. My graduate students Z.-Q. Chen, S. M. Dydak, and H. Ozalpasan helped with the work and helped me continue to learn.

The several projects that are included in this work were funded by the Minerals Management Service of the U. S. Department of the Interior and by the Commonwealth of Virginia. Throughout this exercise I have been a full-time faculty member of the Virginia Institute of Marine Science of the College of William & Mary. I thank the administration for its indulgence as I have pursued this effort within and around my more regular duties.

This dissertation would not have been written were it not for my major professor, J. Robert Woolsey. Without his encouragement to seek admission to the program at the

University of Mississippi it is unlikely I would have made or had the opportunity to synthesize the information into what I hope is a coherent presentation. Since entering the program he has been a continuing source of encouragement and advice.

Dr. Robin C. Buchannon of the Marine Minerals Technology Center at the University of Mississippi provided an enormous amount of help in all areas as she guided me through administrative and logistical requirements and made cogent suggestions about my work. The members of my committee, Gary Gaston, Jim Harding, and, Dave Bazard have provided advice, assistance, and encouragement.

A graduate fellowship funded by the Marine Minerals Technology Center has been a significant factor in helping this project to completion.

Finally I thank my mother, Lydia H. Hobbs and my daughter, Catherine E. Hobbs, for challenging me to continue learning and reminding me that life and work should be fun.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The inner continental shelf, herein defined as that portion of the continental shelf in water depths 30 m or less, is a geological, geomorphic, and geographic region that is the subject of new or renewed interest to the oceanographic and geologic communities. As sediments move from continental highlands to the abyss, they must cross the continental shelf. A subset of the sediments makes a relatively quick passage across the continental shelf through submarine canyons, a second subset moves more slowly under the influences of wave driven currents and other dynamic processes, and a third subset never fully crosses the shelf but remains on it, building the shelf upward or outward.

The sediment wedge forming the continental shelf on the east coast of North America began to develop during the Cretaceous and continued to grow during the Tertiary and the Quaternary. Uchupi (1970) described the geologic history of the shelf as the up- and out-building on the slope atop subsiding Triassic and Jurassic rocks. The inner continental shelf bears substantial evidence of the changes wrought by several great changes in sea level during the Pleistocene.

It is the physical story outlined by the sediments and strata that is the basis of this dissertation. The specific spatial focus of which is the inner continental shelf adjacent to southeastern Virginia (Figure 1).

As the continental shelf is the submarine portion of the larger wedge of sediment that also includes the coastal plain, any complete study of the shelf cannot ignore the latter. Much of the present coastal plain was submerged during Pleistocene high-stands of sea level during which it was part of the continental shelf. Conversely, much of the present inner shelf was emergent and part of the coastal plain during the intervening low-stands. Although the emphasis of this dissertation is the current inner continental shelf, the investigation requires reference to the coastal plain. Today the surface of the continental shelf slopes gently to the east and is marked with shoals (Figure 2).

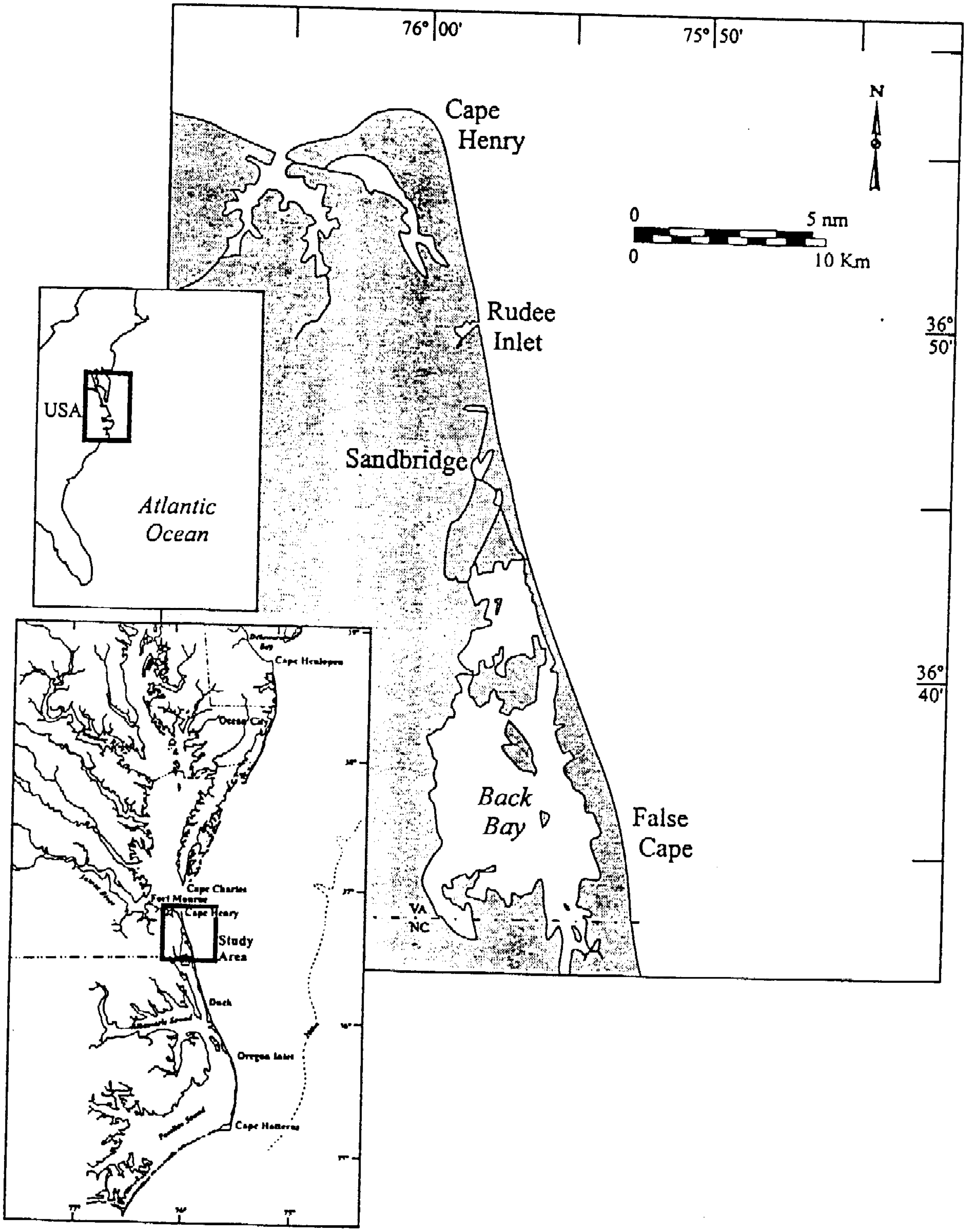


Figure 1: Location map depicting the location and extent of the study area.

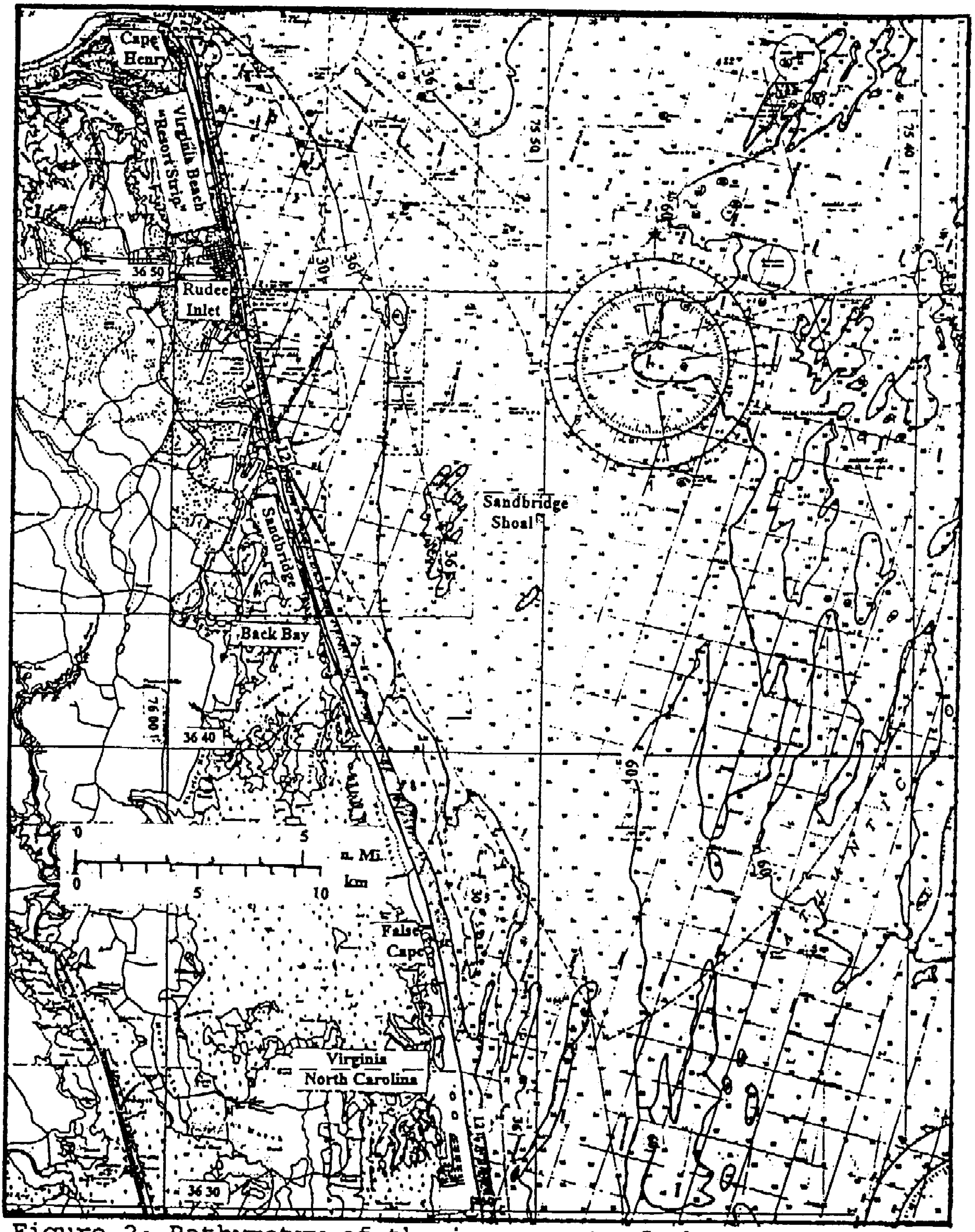


Figure 2: Bathymetry of the inner part of the continental shelf adjacent to southeastern Virginia as shown on NOS Chart 12207 (reduced). The 12, 30, 36, and 60 ft contours are shown.

GOALS AND OBJECTIVES

It is the intent of this study to review the evidence pertaining to the Pleistocene and Holocene geological history of the inner continental shelf adjacent to southern Virginia with the primary goal of developing a coherent interpretation thereof. Part of the interpretive process involves mapping the three dimensional patterns of sediment bodies. As there are many practical uses for specific types of sediment, another objective of this study is to characterize the distribution of sand potentially suitable for use in civil works such as beach nourishment or in commercial applications such as construction aggregate. A lower-level objective is a discussion of the distribution of various species of heavy minerals within the sediments.

The specific area of study is that region of the inner continental shelf between Cape Henry at the mouth of Chesapeake Bay and the boundary between Virginia and North Carolina. The study area extends offshore a variable and indefinite distance to a water depth of approximately 30 meters.

PREVIOUS WORK

The earliest modern reference to the sediments of the southern Virginia inner continental shelf was Shepard (1932), who depicted the area's sediments as being "shells, sand & gravel," "gravel," near the Virginia - North Carolina border, and "shells & sand" near the mouth of Chesapeake Bay. Shepard based the distribution on information recorded on navigation charts augmented by examination of samples collected by the United States Coast Survey but provided no indication of the number or spacing of samples.

Milliman and others (1972) and Milliman (1972), using a grid of grab samples with an 18 km (10 n mi) spacing, described the sediments of the Atlantic continental shelf of the United States. The reports mentioned a plume of very fine sand with coarse silt extending seaward from Chesapeake Bay and a band of arkosic sediments in the sand portion also extending outward from the bay. With ten or so samples within the present study area, the reports described the nearshore subarkosic to arkosic fine-grained sediments and sands as being derived from modern, nearshore, fluvial sources and the similarly-composed materials found farther offshore as relict fluvial sediments. Hollister (1973), using the same samples as Milliman and others (1972), also provided information on the sediments from New Jersey to Florida.

Amato (1994), in describing the sand and gravel resources of the Atlantic Continental Shelf, provided a summary and review of earlier works and included maps showing the distribution of sediment types. As is the nature of a compilation and review, his work basically echoes the above-referenced studies but does specifically consider the sediments as a resource.

Uchupi (1970) discussed the "shallow structure" of the shelf. However, in that his study extended from Maine to Florida and the data were acquired using a sparker system with an energy peak at around 100 Hz, the data are better attuned to answering questions relating to epochal (*series* in chronstratigraphic terminology (North American Commission on Stratigraphic Nomenclature, 1983) or longer time periods, than to the stage (age) or substage levels of this dissertation. Uchupi's seismic profiles depict two-way travel times of a full second or more, an order of magnitude longer than some of the data used in the present study. Although his study was more concerned with the outer shelf and slope, its figures portray the Quaternary section of the inner slope as a sequence of nearly parallel beds.

Richards (1967, 1974) provided further information on the structural setting of the Atlantic Coastal Plain. The present study area is near the crest of the Fort Monroe High, a structural high between the Salisbury Embayment and the Pamlico Basin or Hatteras Low. Beneath Fort Monroe, just inside the mouth of Chesapeake Bay at the entrance to the Hampton Roads harbor, crystalline rocks were encountered in a well at -681 m (-2,234 ft). At Ocean City, Maryland in the Salisbury Embayment a well bottomed in Lower Cretaceous sediments at -2,350 m (-7,710 ft). Crystalline rocks were reached at -3,041 m (-9,978 ft) beneath Cape Hatteras in the Pamlico Basin (Richards, 1967, 1974).

Swift, Shideler, and their co-workers (Shideler and others, 1972; Shideler and Swift, 1972; Swift and others, 1970; 1971; 1972a,b; 1974; 1977) performed a series of studies of the Virginia continental shelf. Shideler and others (1972) proposed a standard stratigraphic section for the area (Figure 3) which most subsequent workers have used. The standard section consists of a sequence of four

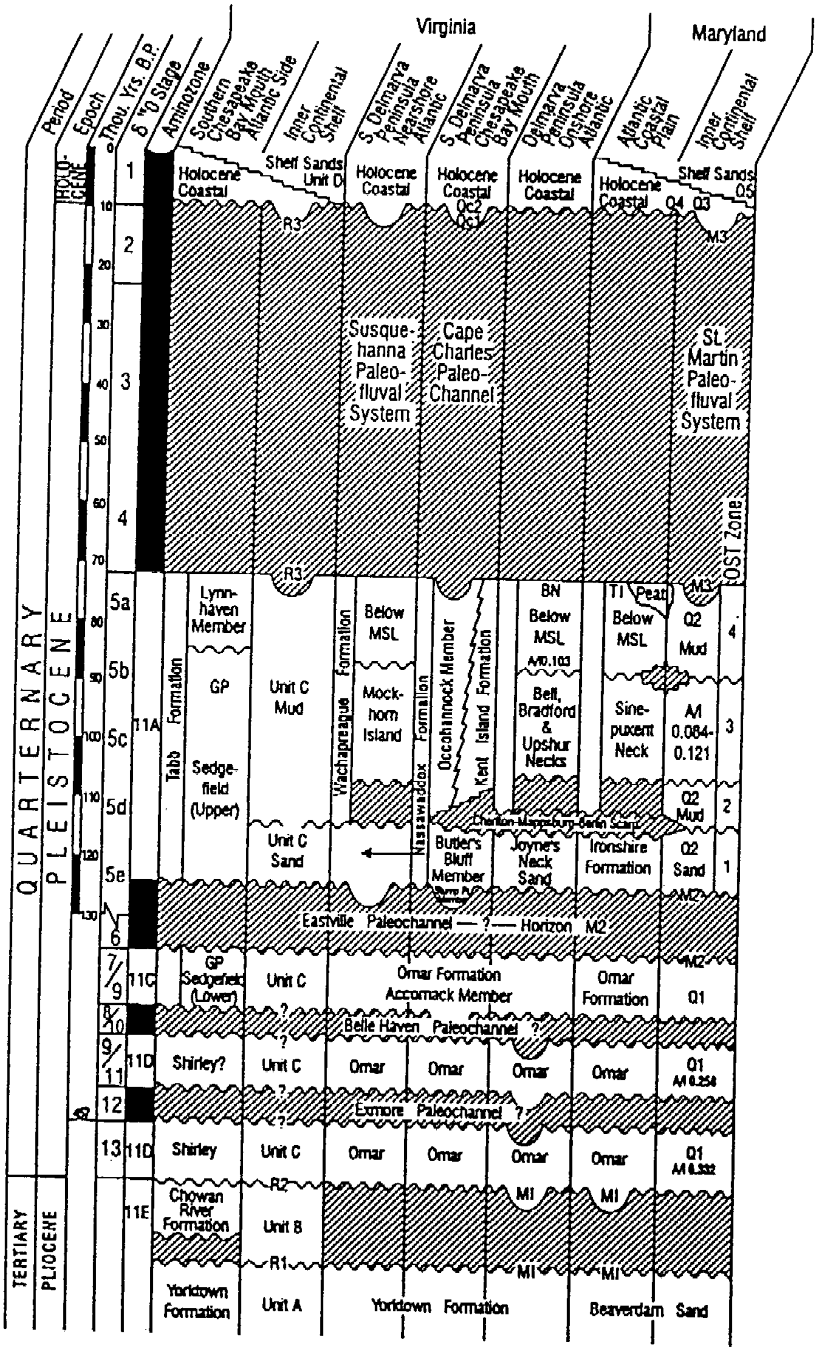


Figure 3: Correlation chart for the middle Atlantic Coastal Plain and inner continental shelf, modified from Toscano and York (1992). Chronological data from Hays and others (1976) and Toscano (1992).

stratigraphic units, termed units A, B, C, and D, separated by major reflectors.

Unit A is "the deepest and oldest sedimentary sequence detected within the study area, which can be considered a discrete stratigraphic entity ... . This unit is defined as the sequence whose upper boundary is reflector 1, the deepest prominent acoustic discontinuity observed during the study" (Shideler and others, 1972). Although several later workers have been able to identify and utilize unit A and reflector 1, the seismostratigraphic elements are somewhat problematical as they are dependent upon the geophysical equipment used, "deepest observed," and a subjective interpretation. Different equipment or different operational conditions might provide greater penetration and allow observation of deeper reflectors. Indeed, Poag and others (1994), working just inside the mouth of Chesapeake Bay, depicted reflectors down to a pre-Lower Cretaceous "basement," and work in mid-1996 by Hobbs (unpublished) revealed the stratigraphy down to 200 ms two way travel time (about 150 m) well below reflector 1. Shideler and others (1972) suggested that reflector 1 is the Miocene--post-Miocene boundary. Since publication, one of the authors (J. H. Johnson, oral communication) has suggested that unit A is the Yorktown Formation, which now is considered of Pliocene, not Miocene, age or another Pliocene formation, thus perhaps making reflector 1 the Pliocene-Pleistocene boundary. Shideler and others (1972) further described reflector 1 as a widespread, regional, angular unconformity, dipping eastward at an average apparent rate of 1 m km^{-1} and having local relief of up to 3 m. On one profile, reflector 1 dipped from 30 to 75 m below sea level, 10 to 44 m below the sea floor.

Shideler and others (1972) defined unit B as the "sequence above reflector 1, whose seismic profiles are characterized by commonly lenticular stratification and prominent local channeling. The upper boundary is generally reflector 2, ... in the absence of unit C, the upper boundary consists of reflector 3 ... ." Considering the channels, there is as much as 18 m of local relief evident in unit B. They further "surmise that fluvial, estuarine, and lagoonal tidal channels, and barrier ridges are present; ... portions of unit B occur in a coast-parallel belt which may be a barrier complex (submarine extension of Oaks (1964) sand-ridge complex) ... ." They go on to suggest an early Wisconsin age for the upper portion of unit B.

Shideler and others (1972) described unit C, the next younger stratigraphic unit as "the sequence with uniform horizontal stratification, whose basal and upper boundaries are reflectors 2 and 3 ... ." Reflector 2 occurs within the depth range of 17 to 39 m below sea level and 1 to 19 m below the seafloor. It has an eastward dip of 0.48 m km^{-1} and has local relief of up to 5 m. In the eastern portion of their study area, reflector 2 is truncated by reflector 3. Unit C itself ranges in thickness from zero to 14 m and "is characterized by relatively uniform horizontal stratifications throughout, with only occasional indications of minor local channeling."

The youngest sedimentary unit described by Shideler and others (1972) is unit D, the sequence above reflector 3. They state that reflector 3 occurs intermittently within the study area, is the shallowest prominent subsurface reflector, and variously is exposed or buried as much as 9 m below the sea floor. Unit D is composed of modern surficial sediments of the sea floor, its thickness usually being a function of surface topography.

Meisburger and Williams (1987) and Meisburger and others (1989), studying the nearshore at Duck, North

Carolina, south of the present study area, described a unit E. This unit is the modern beach and dune sediments, discrete from unit D.

Oaks and others (1974) described the terrestrial, post-Miocene geology (more recent interpretations (Johnson and others, 1985) consider the same sequence to be post Pliocene) of southeastern Virginia. Oaks and others (1974) discuss ten stratigraphic units that were formed during "6 distinct periods of submergence" and "6 important periods of emergence." According to this scheme (Table 1), the sedimentary units atop the Yorktown Formation are the Sedley, Bacons Castle, Moorings, Windsor, Great Bridge, Norfolk, Kempsville, Londonbridge, Sandbridge Formations, and modern, Holocene deposits. The major sea-level lows occurred before the Sedley, Moorings, Windsor, Great Bridge, Londonbridge, and modern units.

Johnson and Berquist (1989) summarized the stratigraphic nomenclature used since 1928 in studies of Virginia's coastal plain. Table 1 compares Johnson and Berquist's (1989) terminology, modified with the inclusion of the Chowan Formation from Johnson and others (1985), with the stratigraphy discussed by Oaks and others (1972).

Table 1

Comparison of Nomenclature for the Stratigraphy of Virginia's Coastal Plain

	Oaks and Coch (1973) Oaks and others (1974)	Johnson and Berquist (1989) (inc. Johnson and others (1985))		
HOLOCENE	Unnamed Holocene and Dismal Swamp peat	Unnamed Holocene deposits		HOLOCENE
	Sandbridge Fm.	Tabb Fm	Poquoson Mbr	
	Londonbridge Fm.		Lynnhaven Mbr	
	Kempsville Fm. Norfolk Fm.		Sedgefield Mbr	
PLEISTOCENE	Great Bridge Fm.	Shirley Fm.		PLEISTOCENE
		Chuckatuck Fm.		
	Windsor Fm.	Charles City Fm.		
		Windsor Fm. (restricted)		
PLEISTOCENE AND/OR PLIOCENE	"Moorings" unit	"Moorings" unit		
	Bacons Castle Fm.	Bacons Castle Fm.		PLIOCENE
MIOCENE	Sedley Fm	Chowan River Fm. Yorktown Fm		
	Yorktown Fm.	Eastover Fm.		MIOCENE

Toscano and others(1989) and Toscano (1992) discussed the Quaternary history of inner continental shelf offshore of Maryland and the inner shelf of the mid-Atlantic. One facet of these studies that has specific bearing to the inner shelf off southeastern Virginia is the set of small-scale fluctuations of sea level, -23 to + 6 m, during Oxygen Isotope Stage 5, roughly 75,000 to 130,000 years B.P. (Figure 4). This period corresponds to the North American Sangamon (Richmond and Fullerton, 1986). These oscillations, three highs and two intervening lows within 23 m of today's sea level, should be evident on the inner shelf. Those sections of the shelf less than 20 m in depth would have been exposed and the areas at slightly greater depth would have been subjected to shallow-water wave and current energy.

Table 2 is a listing of oxygen isotope stages and respective dates. The ratio of ^{16}O and ^{18}O in tests of planktonic foraminfera is a function of global ice volume during the time the organism was alive. Changes in the oxygen isotope ratio correlate with glacially controlled variations in sea level.

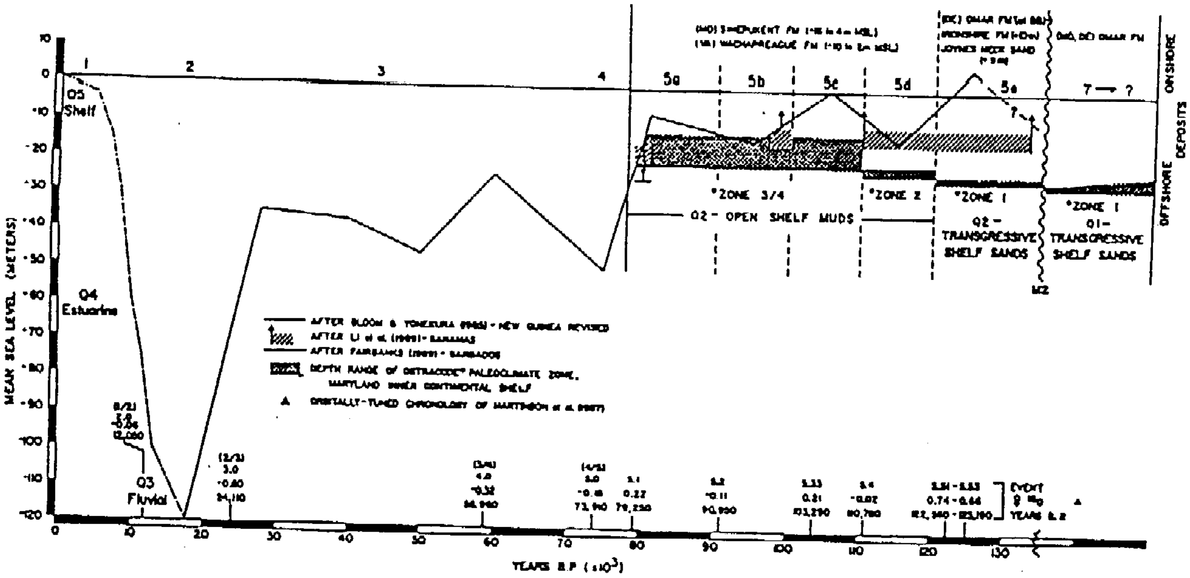


Figure 4: Late Pleistocene sea-level curve (from Toscano and York, 1992 and Toscano, 1992). The range of sea level during Oxygen Isotope Ratio Stage 5 is from -23 to +6 m.

Table 2

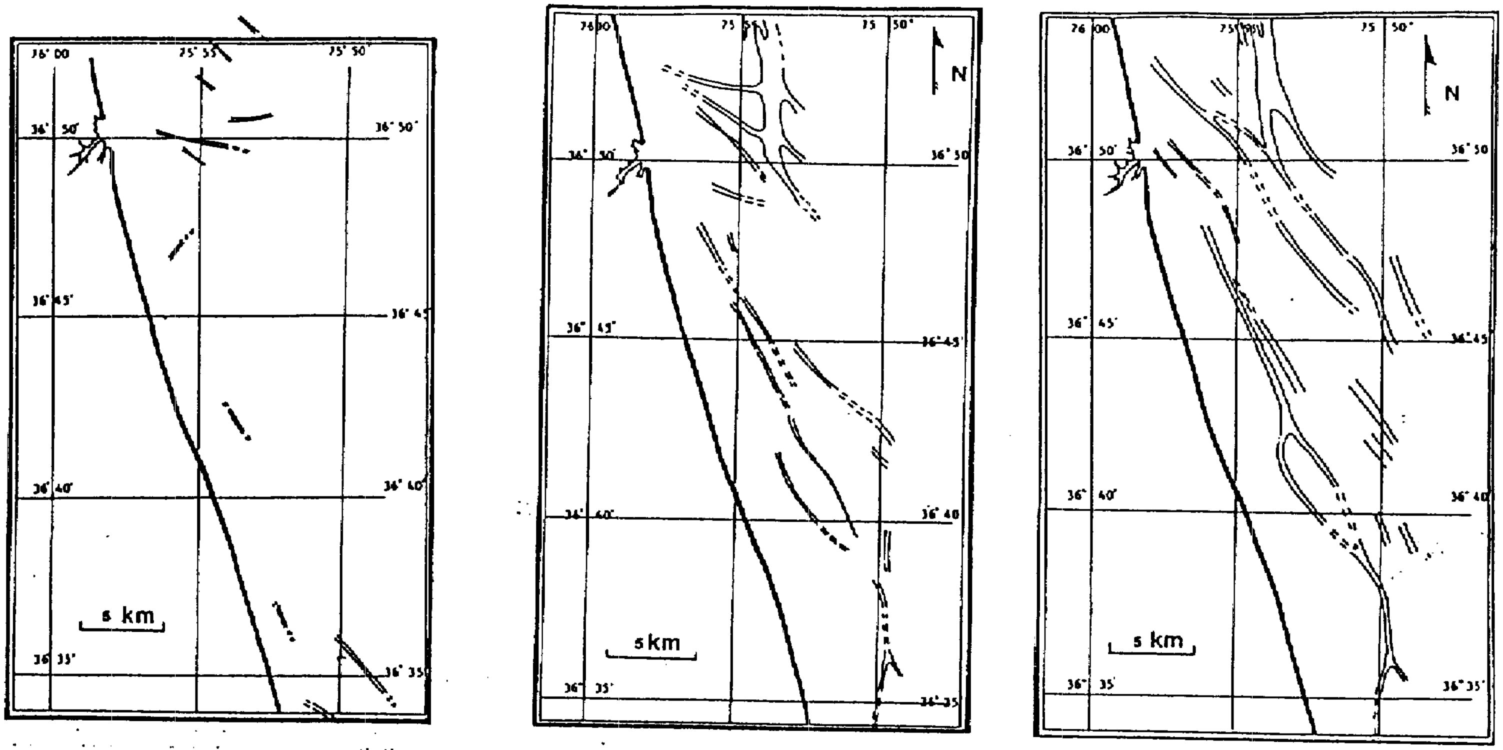
OXYGEN ISOTOPE STAGES AND DATES

from Hays, J. D., J. Imbrie & N. J. Shackelton, 1976

	BOUNDARY
STAGE	YEARS BP
1	
	10 x 10^3
2	
	29 "
3	
	61 "
4	
	73 "
5	
	127 "
6	
	190 "
7	
	247 "
8	
	276 "
9	
	336 "
10	
	356 "
11	
	~425 "
12	
	~457 "
13	

Toscano and York (1992) further developed the geologic history of the Maryland inner continental shelf and proposed correlations with adjacent areas. Their "revised correlation chart for the middle Atlantic Coastal Plain and inner continental shelf" (Figure 3), is a regional correlation which includes interpretations from other studies. The figure also suggests some of the questions or problems of interpretation and correlation. Specifically, the correlation shows the "unit C" (Shideler and others, 1972) as existing across major regressions; that is unit C continues in time through the formation of the Exmore and Eastville (and by extension, Belle Haven (Oertel and Foyle, 1995))paleochannels. This lack of differentiation in unit C possibly results from the inability of their (Shideler and others's, 1972) equipment to image or resolve some reflectors. To the north of the present study area, the terrestrial Omar Formation shows a similar continuum.

Chen (1992) and Chen and others (1995), using some of the same data used in the present study, described three sets of paleochannels buried in the Quaternary of the inner continental shelf offshore of southeastern Virginia (Figure 5). They equated the ages of the channel systems to the Cape Charles, Exmore, and Eastville paleochannels of



Cape Charles Aged Paleohannels

Eastville Aged Paleochannels

Exmore Aged Paleochannels

Figure 5: Maps of paleochannels of Cape Charles, Eastville, and Exmore ages presented by Chen (1992).

Chesapeake Bay defined by Colman and Hobbs, 1987, 1988; Colman and Mixon, 1988; and Colman and others, 1990.

Foyle (1994) and Oertel and Foyle (1995) discussed the Quaternary geology of the inner continental shelf adjacent to the lower Delmarva Peninsula, the region immediately to the north of the present study area. As would be expected, their analyses portray a geological history similar to that of the Maryland shelf. They describe a previously unidentified paleochannel system running under the Delmarva Peninsula from Chesapeake Bay. This newly recognized paleochannel, called the Belle Haven, is physically and chronologically between the more northerly and older Exmore and the more southerly and younger Eastville paleochannel as identified and described by Colman and others (Colman and Hobbs, 1987, 1988; Colman and Mixon, 1988; Colman and others, 1990). The chronology, defined by the series of channels and prograding spits that form the Delmarva Peninsula (Mixon, 1985), provides much tighter control on the sequence of Quaternary transgressions and regressions that have formed and modified the continental shelf and coastal plain in the mid-Atlantic region of the United States.

Riggs and others (1992) reviewed the Quaternary depositional patterns in northeastern North Carolina considering the transition from fluvial to estuarine systems. Snyder (1993)presented seismic data but little stratigraphic interpretation from an area offshore of North Carolina south of the present study area.

Mirecki and others (1995) addressed the Quaternary geochronology of coastal plain deposits near the study area. Using aminostratigraphic and electron spin resonance data from outcrops of Quaternary materials, they discerned two transgressive units overlying the Pliocene and cite evidence of a third. Their discussion supports the chronology of Foyle (1994) and Oertel and Foyle's (1995), with the Belle Haven channel having been formed during a lowstand between the excavation of the Exmore and Eastville Channels.

Wright (1995)described the variation in energy impacting the bottom ("excess wave-induced bed stress for fine sand transport") during the late Quaternary. By characterizing the cumulative duration of the periods during which wave energy was sufficient to resuspend bottom sediment as determined by sea-level history for conditions of different storm-waves, he indicates how dynamic the shelf has been during the last 140,000 years. The historic distribution of energy across the shelf indicates areas where the bottom sediments were more mobile and, thus, provides an indication of which portions of the shelf might have experienced erosion and which might have been sites of accumulation, perhaps in the form of bars or shoals.

According to Wright (1995) the cumulative period of "activity", increases with depth to about 45 m, where, given waves with a 1 m height and a 10 s period, there have been about 55,000 years of activity on the bottom during the past 140,000 years. There is a second peak of about 70,000 years cumulative activity between 85 and 95 m depth. For larger waves, 5-m height and 10-s period, which resuspend sea-floor sediment at a greater water depth, the cumulative duration of activity increases from a minimum at present sea level to a maximum at about 90 m depth of almost 120,000 years of the total 140,000 year interval.

The same general pattern holds true for the last 18,000 years. The cumulative period of activity increases rapidly from a minimum of a few hundred years in very shallow water to about 6,000 years of activity at 10 m depth then increasing less rapidly to a peak of 9,500 years between 40 and 50 m for the smaller waves. The cumulative period of activity falls rapidly to less than 4,000 years of activity beyond 55 m (Wright, 1995).

In a series of studies, Kimball and Dame (1989), Dame (1990), and Kimball and others (1991) investigated sand resources potentially available to Virginia Beach and described the morphology and history of Sandbridge Shoal. The two most recent of those reports discuss a two-stage formation of the shoal, the lower bed within the shoal possibly being the reworked remains of a barrier or submerged bar formed during a Pleistocene sea-level high-stand and which survived the subsequent marine transgression. The second stage in the formation of the shoal was the deposition of the upper unit during the Holocene transgression. Hardaway and others (1995) and Hobbs (1996) continued studies of the area's offshore sand resources.

The distribution of heavy minerals in the sediments of the Virginia continental shelf has been the focus of much work (Swift and others, 1971; Nichols, 1972; Goodwin and Thomas, 1973; Firek, 1975; Firek and others, 1977; Grosz and Eskowitz, 1983; Berquist, 1986, 1990; Berquist and Hobbs, 1986, 1988a, b, 1989; Ozalpasan, 1989; Berquist and others, 1990 a, b, c; Calliari and others, 1990; Dydak, 1991). Goodwin and Thomas (1973) analyzed the heavy mineral content of the sand fraction (0.062 to 1.0 mm (4 to 0 phi)) of 112 grab samples collected from the Virginia shelf north of the mouth of Chesapeake Bay. The samples ranged between 0 and 18 weight percent heavy minerals, with an average of 5.3 percent, and included garnet, magnetite-ilmenite, hornblende, and epidote with lesser proportions of kyanite, sillimanite, tourmaline, rutile, and zircon. Grosz and Eskowitz (1983) specifically addressed the potentially economic marine heavy minerals and identified some areas as having concentrations in excess of 10 weight percent heavy minerals. Their work highlighted the concentrations of the titanium minerals rutile, ilmenite, and leucoxene.

A subsequent series of studies, culminating in Berquist (1990), Berquist and others (1990), and Calliari and others (1990), characterized the heavy-mineral occurrence and distribution offshore of Virginia. The analyses also utilized the whole sample (Grosz and others, 1990) in contrast with the more common analyses of just the sand fraction or a sub-part thereof. In twenty percent of 390 samples (100 surficial grabs and 290 core segments) the heavy mineral content equaled or exceeded 5 percent and 13 percent of the samples had heavy mineral concentrations above Garnar's (1978) threshold economic values for terrestrial deposits. Ilmenite, leucoxene, rutile, zircon, and monazite were the minerals of interest.

Ozalpasan (1989), using 129 surficial grab samples from the mouth of Chesapeake Bay north along the Delmarva Peninsula, applied Q-mode factor analysis and identified 3 factors. In Q-mode factor analysis, individual factors can be likened to end-members of a suite of samples in which each end-member represents a group of samples that are more alike one-another than they are like the samples in other groups of the suite of samples. According to Ozalpasan (1989), his Factor 1 suggested that there was movement of the amphibole, pyroxene, and epidote mineral associations from the bay to the shelf. His Factor 2 suggested that Chesapeake Bay and an area off the Delmarva Peninsula were potential sources for zircon, garnet, and amphiblole. Factor 3 suggested transportation of sediments toward the bay mouth.

Calliari and others (1990) also employed Q-mode factor analysis in a larger study of the spatial distribution of heavy minerals on the continental shelf offshore of Virginia. They identified three factors or end members in the suite of samples. One factor was within the mouth of Chesapeake Bay and decreased in concentration seaward. This factor suggested a source of amphibole and pyroxenes within the Chesapeake Bay drainage basin with probable transportation toward the sea. The second factor showed two probable sources, one within the bay, the other south of the bay mouth (the area of the present study). This factor was comprised of zircon, garnet and amphibole. The third factor, a garnet, amphibole, epidote assemblage, primarily occurs north of the bay mouth along the Eastern Shore. The distribution of the concentration of this factor suggested transport into the bay-mouth and that (at least within 5 km of the shore) the sediment transport system did not carry sediments across the bay mouth.

Earlier studies discussed the transport of sediment into Chesapeake Bay from the inner shelf. Harrison and others (1967) reported on a study that used bottom-drifters deployed on the shelf and recovered within Chesapeake Bay. Meade (1969 and 1972) addressed the landward transport and deposition of suspended sediments. Hobbs and others (1992) determined that the continental shelf is the greatest individual source of sediments deposited within the bay and suggest substantial transport into the bay from the shelf.

Use of the sand resources whether in civil or coastal engineering projects requires knowledge of specific characteristics of the sand. The criteria for aggregate used in construction projects varies widely with the application. Aggregate used in concrete must meet specific standards of grain-size distribution, mineral composition, and, sometimes, grain shape. Other uses have other criteria.

In beach nourishment projects "the most important borrow material characteristic is the sediment grain size. Borrow material grain size matching the native material is considered synonymous with quality" (Committee on Beach Nourishment and Protection, 1995, page 97). Although "almost any offshore borrow source near the shore will include some suitable size materials," (Coastal Engineering Research Center, 1984, page 5-10), the likely efficiency of the nourishment project can be estimated with the use of overfill factors and renourishment ratios (James, 1975, Hobson, 1977, and Coastal Engineering Research Center, 1984). These parameters are calculated using grain-size data from both the natural beach that is to be nourished and the borrow areas. The median grain size (Md), also frequently referred to as D_{50}, is the most widely used measure of sand size (Norfolk District, 1992) in the context of beach nourishment. In addition to the median grain size, calculations of the overfill and renourishment factors use simple measures of the sorting of the native and borrow materials (Hobson, 1977). Sediments used for beach nourishment also must be free from appreciable quantities of very-fine-grained sediments and organic matter (Coastal engineering Research Center, 1984)

As part of a larger study for the Norfolk District of the U. S. Army Corps of Engineers, Waterway Surveys & Engineering, Ltd (1986) determined that the finest sand on the subaerial beach in the vicinity of Sandbridge had a D_{50} of about 0.25 mm (2 phi) and that occurred only locally on the foreshore. The study concluded that material used to nourish the beach at Sandbridge should have a D_{50} greater than 0.20 mm (2.3 phi). Wright and others (1987) reported that the D_{50} for sediment in the foreshore increased from 0.25 to 0.75 mm (2 to 0.7 phi) from Rudee Inlet north toward Cape Henry and that sediment at less than a 3 m water depth seaward of the foreshore also increased in grain size toward the north. They also reported a small seasonal variation in grain size.

Kimball and Dame (1989) and Kimball and others (1991) discussed three areas on the inner continental shelf offshore of southeastern Virginia with the potential for beach quality sand. The first area they described is a set of linear shoals near False Cape containing over 2.5 x 10^6 m^3 of clean, medium- to coarse-sand. They concluded that the shoals were too far from areas that would need to be nourished to be used in most cases. The second area they considered was a possible filled channel southeast of Rudee Inlet. They dismissed the area has having an insufficient reserve of suitable material. The third area they examined was a large shoal approximately 5 km east of Sandbridge. They concluded that this shoal contains several million cubic meters of clean sand suitable for use in beach nourishment projects.

METHODS

High-resolution, seismic-reflection profiling is the primary tool that was used in obtaining the evidence presented in this study. Side-scan sonography provided additional information about the surface of the sea floor. These sets of data were augmented by information from cores and grab samples. All of the data were collected as parts of numerous individual projects over the past several years. To date, there was not an opportunity to draw the interpretations from the projects together and view them as a coherent whole.

High-resolution, seismic-reflection profiling is an acoustic, remote-sensing technique in which a short pulse of sound is directed toward the sea floor and the reflected portions of that signal are recorded and presented in a visual display (Hobbs and Dame, 1992). Depending upon the physical properties of the sediments, especially sharp contrasts in sediment bulk-density, varying portions of that signal are reflected by the sediments and by the interfaces between different bodies of sediment. The common working assumption in the interpretation of the resultant graphic displays is that continuous reflectors represent specific stratigraphic features such as bedding planes and unconformities.

As the system measures strength of the acoustic signal versus time since transmission of the pulse, it is necessary to relate the "two way travel time" (TWTT) of the signal representing a particular feature to depth below the water surface and below the sea floor. In lieu of specific measurements of the speed of sound in the various media, standard arbitrary values can be assumed. An acoustic velocity of 1,500 m s^{-1} is widely used for sea water and shallow, saturated, unconsolidated sediments (Hobbs and Dame, 1992). Should the signal penetrate sufficiently far into the sediment column that consolidation would have increased the bulk density, various arbitrary and increasing values are assigned to specific strata (Colman and Halka, 1989). Other authors (Meisburger, 1990; Snyder, 1993) use 1,500 m s^{-1} for the water column and a greater velocity for the sediments. Throughout this study, 1,500 m s^{-1} is used for both water and sediment.

Although employing a constant value does introduce error, the errors are expected and do not compromise the stratigraphic interpretations. If the actual acoustic velocity in the sediment is 1,700 m s^{-1}, not 1,500 m s^{-1}, the error is 1 m per each 0.01 s of two-way-travel-time. Individual acoustically defined strata will be calculated as slightly thinner than they are and depths from the sea or sediment surface to individual reflectors will be slightly underestimated as will calculated volumes.

The seismic records used in the present study were obtained during the course of several independent studies on the southern Virginia inner continental shelf (Hobbs and others, 1986; Colman and Hobbs, 1987; Kimball and Dame, 1989; Dame, 1990; Hobbs, 1990; Kimball and others, 1991; Hobbs and Dame, 1992; Hardaway and others, 1995, and Hobbs, 1996). These records were developed with a Datasonics SBP-5000 system, which utilizes a signal generator-transmitter-receiver-processor-amplifier capable of producing a 3.5, 5.0, or 7.0 kHz primary signal connected to a set of four transducers. The transducers transmit and receive the acoustic signal. Most of the work was performed using 3.5 kHz except where empirical observation indicated that one of the other frequencies provided a better record. The processed signal was conveyed to either or both an EPC 3202 or EPC 4800 graphics recorder for production of the profile.

The signals were not captured for storage on either tape or disk. The system usually was operated with a sweep rate of an eighth or a sixteenth of a second (0.125 or 0.063 s) with a trigger or repetition from the sweep-rate to a fourth or a half second. These sweep rates resulted in the full scale of the graphic record being 94 or 47 m, respectively, although bottom penetration rarely exceeded 30 m.

All work was conducted aboard the Virginia Institute of Marine Science (VIMS) *R/V Bay Eagle* which was steered along track lines usually following lines of constant loran-C time delay. Positioning data were automatically recorded at time intervals never exceeding 5 minutes and frequently 2 minutes or less. Early projects relied upon conversion of loran-C coordinates to latitude and longitude by the on-board loran processor, whereas the more recent data-sets were recorded from a GPS (Global Positioning System) reporting geographic coordinates in the 1983 North American Datum (NAD 83). Differences between the datum used in the loran conversions (assumed to be NAD 27) and NAD 83 are on the order of a few tens of meters and have been ignored.

A total of 1,100 km (595 nautical miles) of track were run. Figure 6 depicts the track lines.

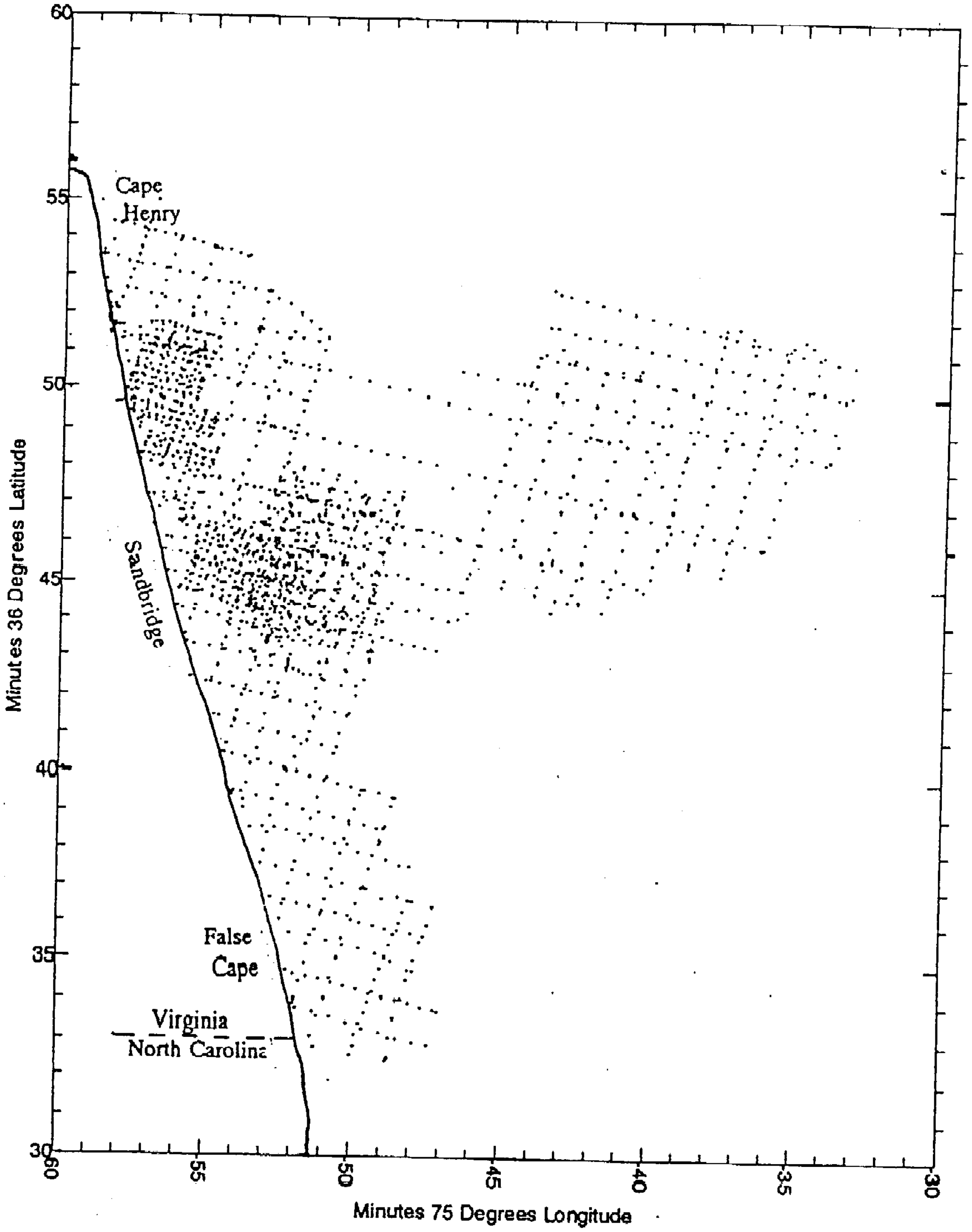


Figure 6: Track lines of seismic-reflection profiles.

As the transducer was towed at various depths (usually between 1 and 3 m), the water depths depicted on the seismic profile are inaccurate. These differences as well as tidal variations were ignored. These errors are additive with the error resulting from the assumption of a constant acoustic velocity.

The side-scan sonar used was a 105 kHz, EG&G SMS-960 set to record a 100 m swath either side of the towed transducer. Through a graphic depiction of the intensity of the back-scattered return of a shaped acoustic signal, side-scan sonar indicates the general condition or character of the bottom (Flemming, 1976; D'Olier, 1979; Williams, 1982; Duane, 1987; Duane and Stubblefield, 1988; Hobbs, 1990; Hobbs and Dame, 1992)

The seismic records were interpreted manually and the data plotted on maps of the track lines. Specific elements noted were water depth, depth to specific reflectors, and location of thalwegs of paleochannels. Thickness of sedimentary units was determined either by measurement on the profile or by subtraction of the recorded depths of the reflectors bounding the bed.

The side-scan records also were interpreted and features observed were plotted on maps of the track lines. Apparent gross changes in sediment type or surface condition were cross-checked with the sub-bottom profiles to see if the surface changes mirrored stratigraphic changes.

Grab samples were collected using a variety of samplers. The largest individual set of samples consisted of 380 grab samples obtained during the fall and spring of 1994-1995 (Figure 7). All were obtained with a Smith-McIntyre grab, most from VIMS *R/V Langley* with the remainder from the *R/V Bay Eagle*. Duplicates of the samples in this set remain available to other researchers. Samples were placed in plastic bags in the field. On return to the laboratory, splits of the samples were taken for various analyses. Location and grain-size data are presented in Appendix 1.

Two sets of cores were obtained during the course of these studies. The first were 9 cm (3.5 in) diameter vibracores up to 6 m (20 ft) in length taken in 1987 under contract by Alpine Ocean Seismic Survey aboard the *R/V Atlantic Twin*. The second group, 7.5 cm (3 in) diameter

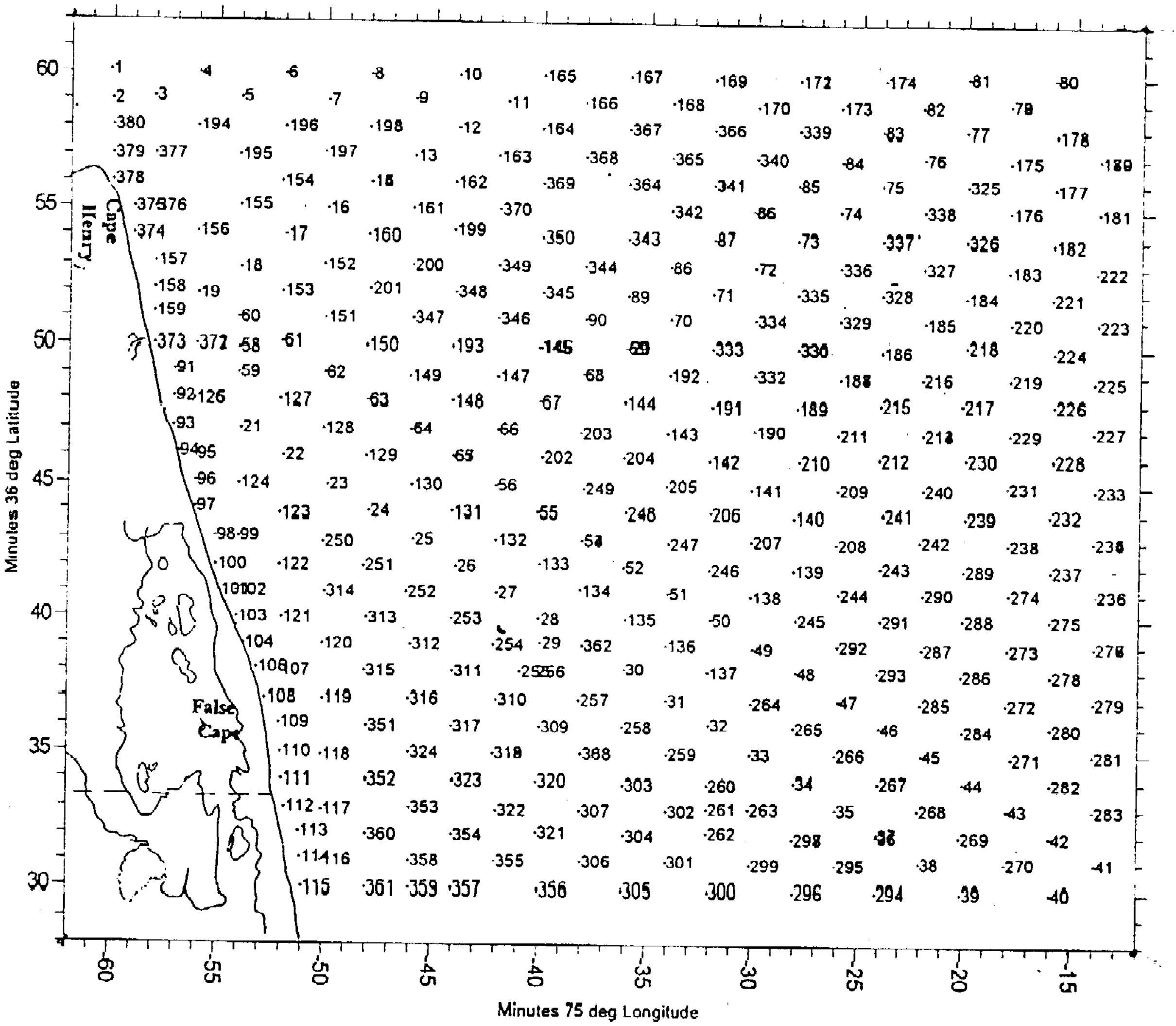


Figure 7: Locations of the grab samples collected in 1994-1995. The numbers shown by each location-dot indicate the sample number. Overprinted numbers indicate duplicate samples at the same site.

vibracores, up to 9 m (30 ft) in length, was taken in 1994 under contract with Exmar from a chartered barge. In both cases, the cores were cut into 1.5 to 2.5 m lengths aboard ship for handling and returned to the laboratory where they were split, logged, and sampled. Loran-C was the primary positioning system in both coring exercises. Copies of the logs and listing of location and grain-size data for the second set of cores are in Appendix 2.

Grab and core samples selected for grain-size analyses were wet-sieved to separate granules, sands, and fines. The coarser fractions were oven-dried at approximately 60°C to remove interstitial water and weighed on an electronic balance. The fines were pipetted following the procedures of Folk (1974) to determine the quantities of silt and clay and to allow the calculation of the sand:silt:clay ratio. Most sand samples were further processed in a Rapid Sediment Analyzer (settling tube) to determine the grain-size distribution of the sand fraction. Mineralogical analyses were performed on some samples as part of some of the preceding studies using methods generally described in Luepke and Grosz (1986) and detailed in Grosz and others (1990).

Electronic processing of the data has been an integral part of the work. Desk-top computers using standard, commercially available software have facilitated virtually all aspects of the work. Spread sheets, plotting programs, a simple Geographic Information System (GIS) (Golden Software's *Surfer)*, and coordinate and datum conversion programs purchased from NOAA *(Corpscon* version 3.01), have been most useful.

RESULTS

SURFICIAL SEDIMENTS

Figures 8 - 12 are contour plots of the weight percents of granule, sand, silt, clay, and granules plus sand. The contour lines were drawn by the computer software using an inverse distance squared algorithm. A contour plot of the mean grain size of the sand fraction of the samples and simple x-y plots of depth, latitude, or longitude vs. textural characteristics suggest no relationships. Appendix 1 contains position and grain-size data for each sample,

The region is dominated by coarser sediments, most of the area having in excess of 90 or 95 percent sand or granule. Most of the sands are medium to coarse sands (coarser than 2 phi) with finer sands occurring generally south of False Cape and in a large area adjacent to the bay mouth, roughly analogous to the bay mouth shoals or the shoal retreat massif of Swift (1975). If plotted on Shepard's (1954) ternary classification, all but five of the 380 grab samples would plot as "sands." These five include two

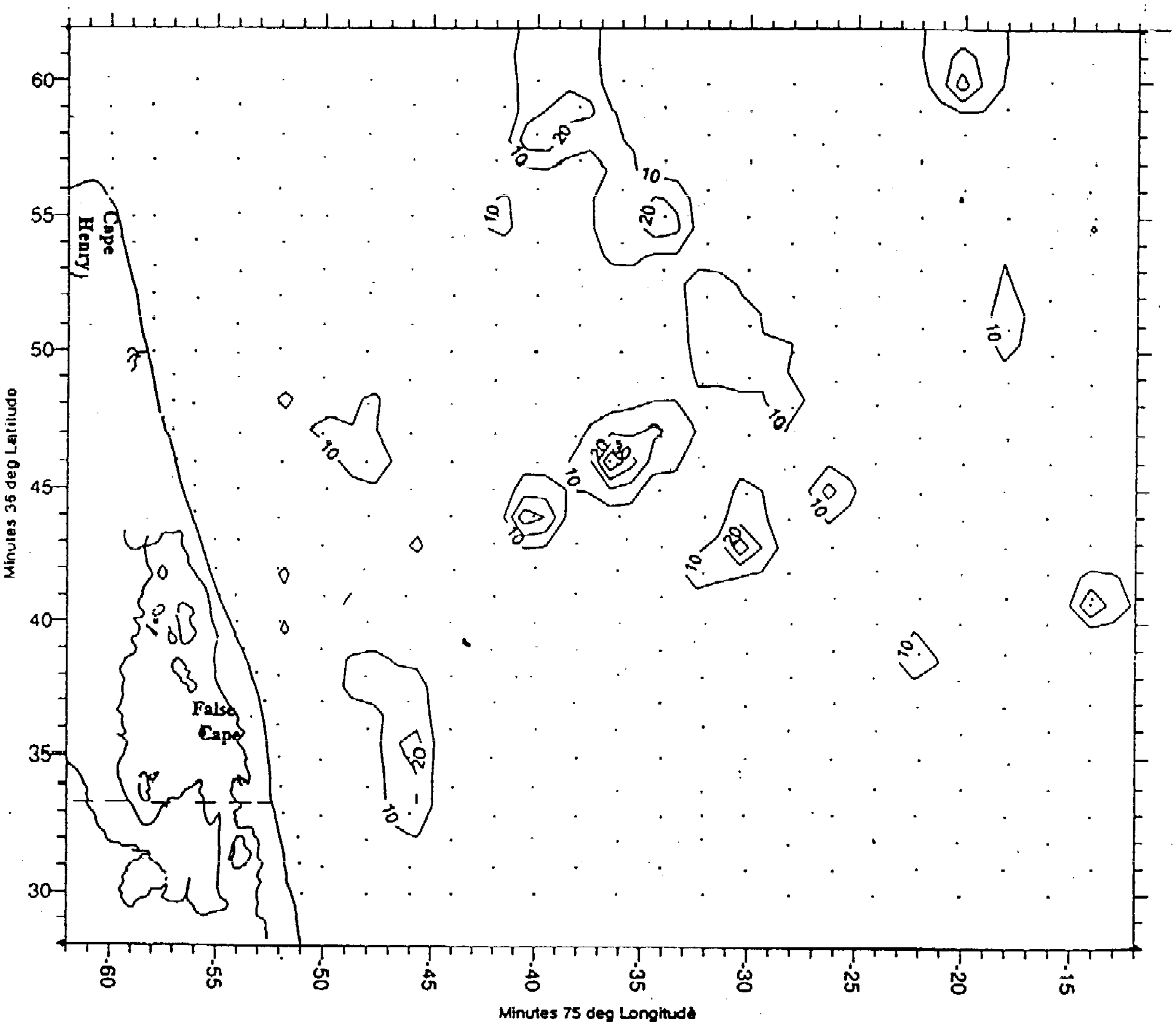


Figure 8: Contour plot of the weight percent granule of the grab samples collected in 1994-1995. The contour interval is 10 percent.

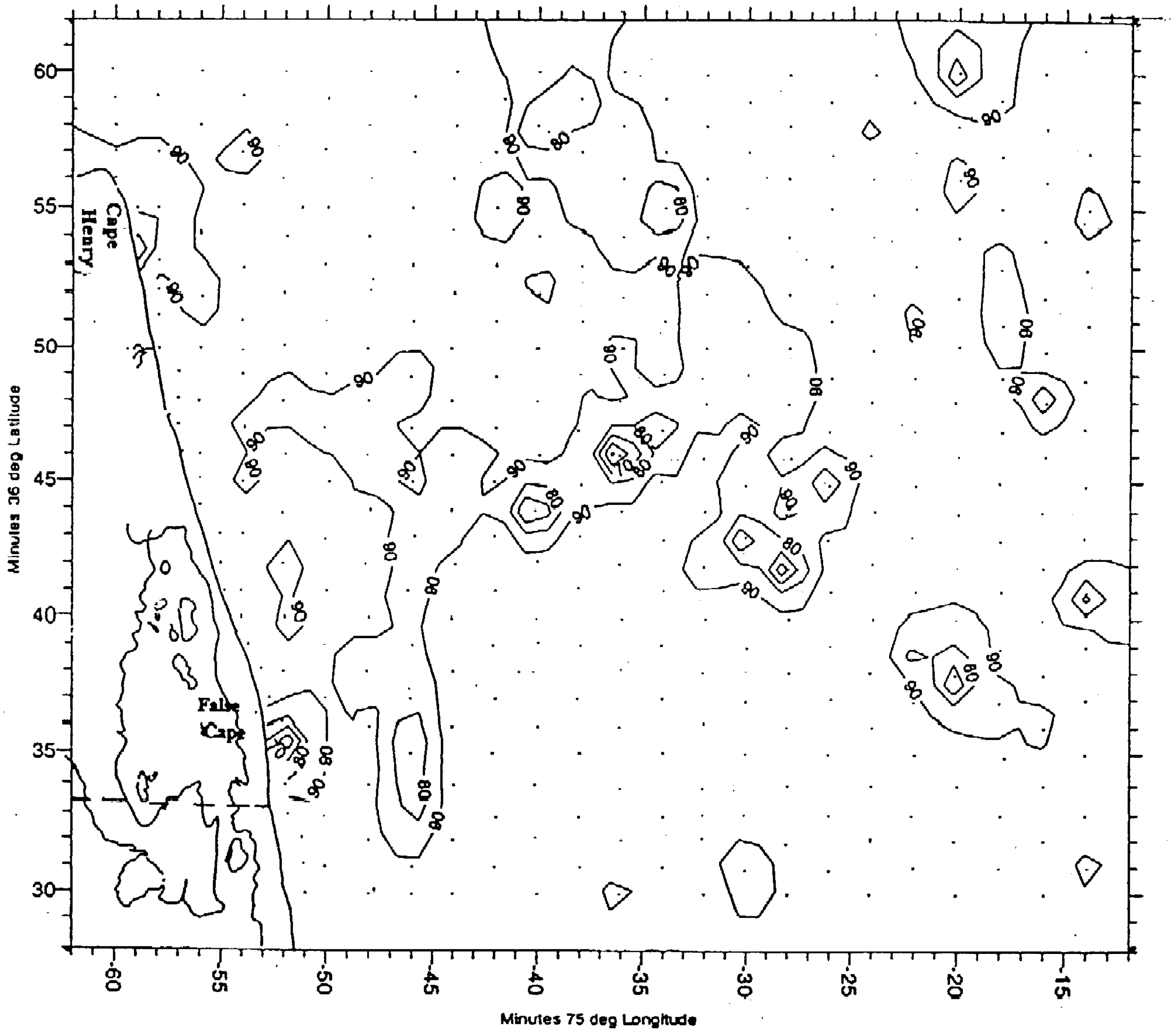


Figure 9: Contour plot of the weight percent sand of the grab samples collected in 1994-1995. The contour interval is 10 percent.

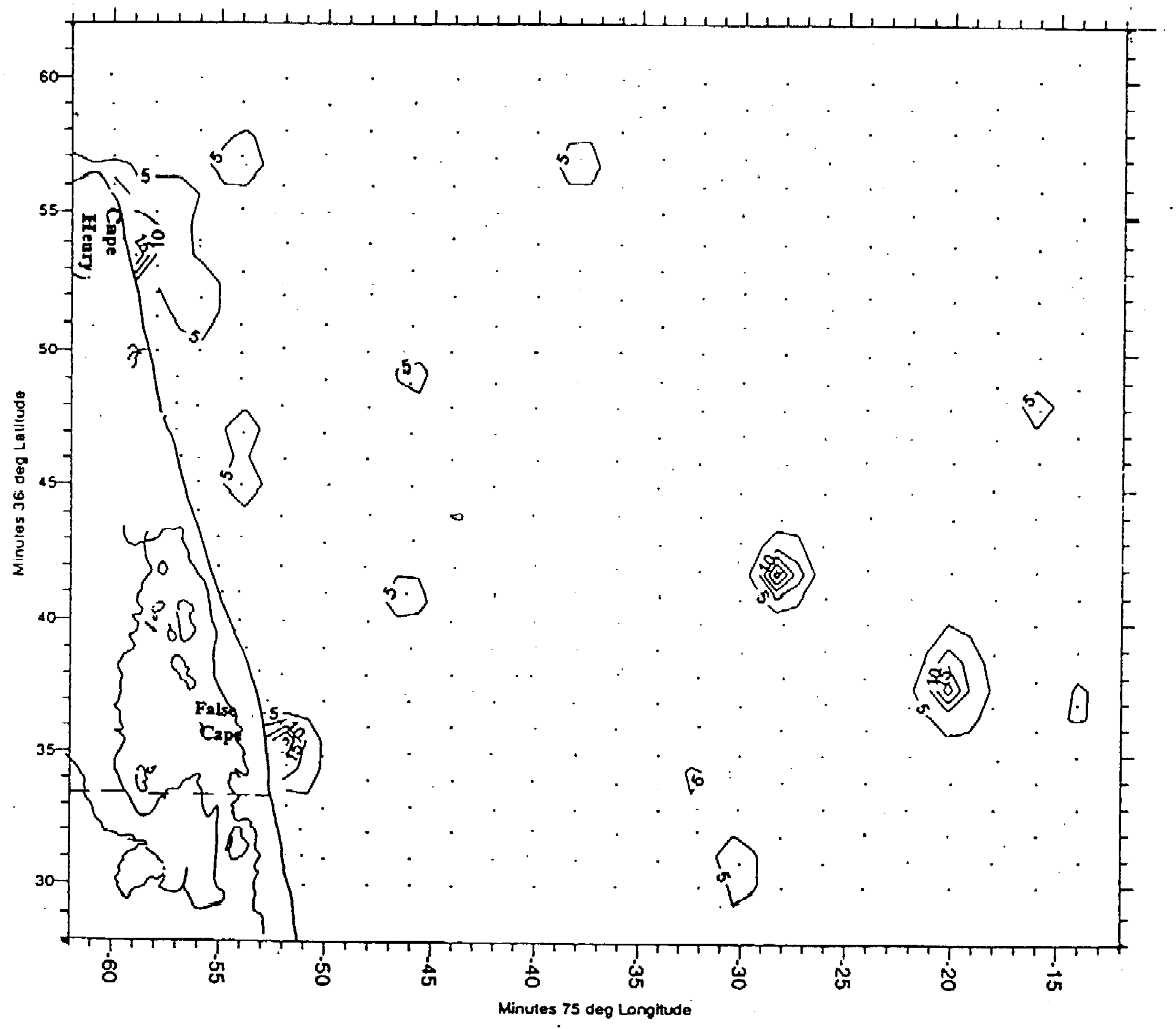


Figure 10: Contour plot of the weight percent silt of the grab samples collected in 1994-1995. The contour interval is 5 percent.

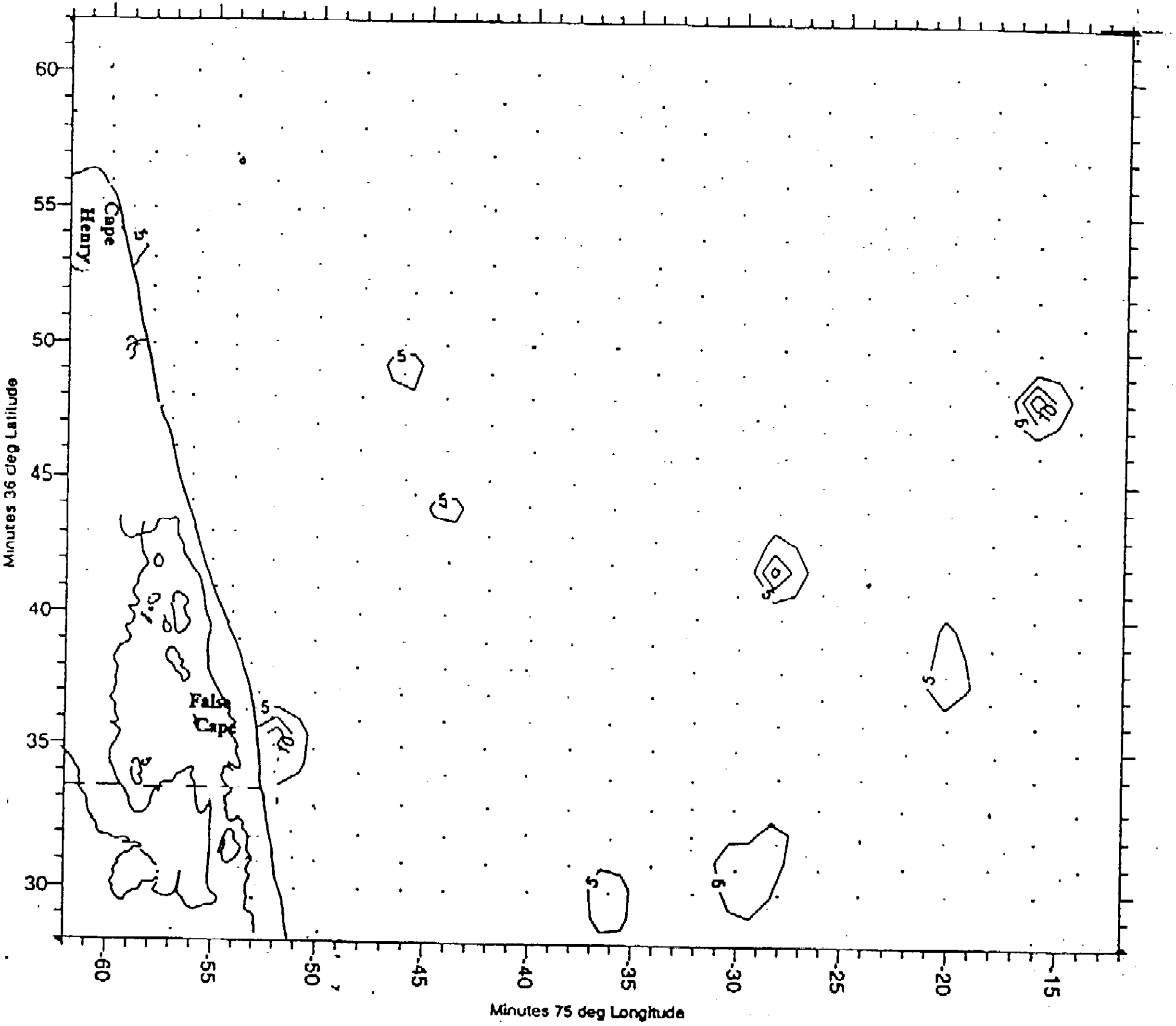


Figure 11: Contour plot of the weight percent clay of the grab samples collected in 1994-1995. The contour interval is 5 percent.

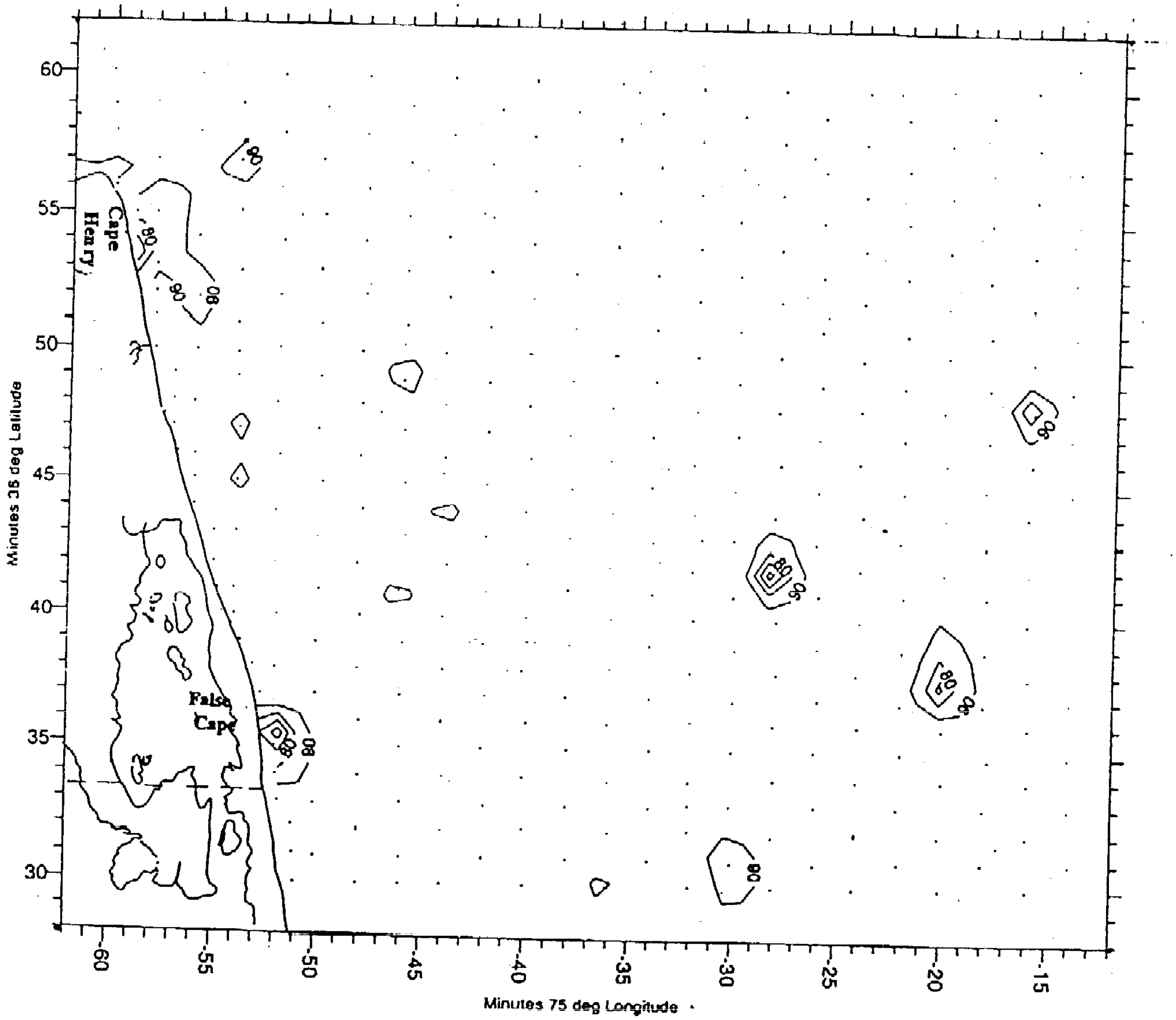


Figure 12: Contour plot of the weight percent granule plus sand of the grab samples collected in 1994-1995. The contour interval is 10 percent.

sandy-silts and one each clayey-sand, sandy silt, and clayey-silt.

SUBSURFACE GEOLOGY

The high-resolution, shallow-penetration, seismic records demonstrate a complex stratigraphy within which the many relationships are difficult to define. Data from the thirteen 3.5 kHz lines surveyed in 1988 (Figures 13 through 26) exemplify this complexity. The surficial sand shoal or sheet, unit D of Shideler and others (1972), is clearly depicted on most of the lines. Several of the lines show at least one major filled paleochannel. Additionally, two or more parallel, near-horizontal reflectors are evident near the surface on several of the lines. Figure 27 is a sketch map of the locations of three, large channels found in the 1988 survey.

Figure 14 (Line 1) depicts a thin layer at the surface that pinches out about halfway across the line and suggests a filled channel on the east end and, perhaps, another channel in the deeper subsurface near the center. Figure 15 (Line 2) presents the same features but also suggests relatively closely spaced, near horizontal reflectors very

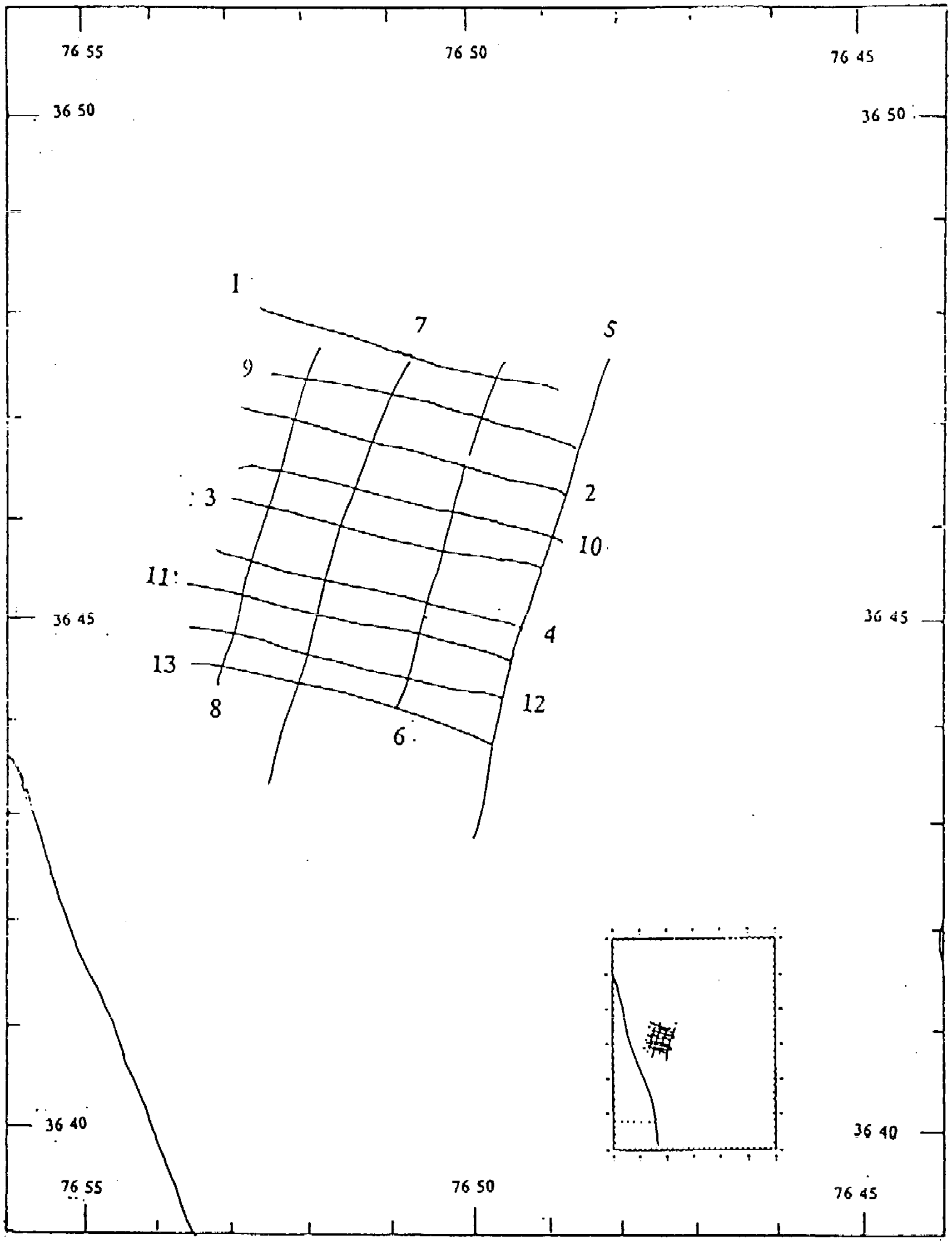


Figure 13: Map of the 13 high-resolution, seismic-reflection lines run in the summer of 1988.

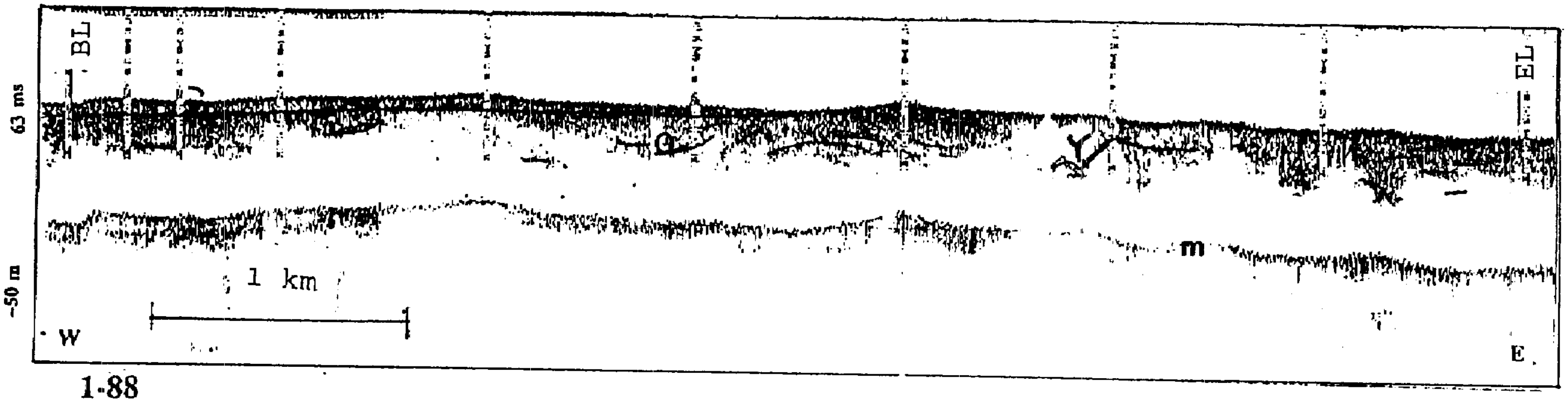


Figure 14: Reduced copy of line 1 from the 1988 survey with selected reflectors emphasized. D is the surficial sand sheet. Y and O are indications of filled paleochannels. m is a multiple of the surface reflector. BL and EL are the beginning and end of the line. Horizontal scale is approximate

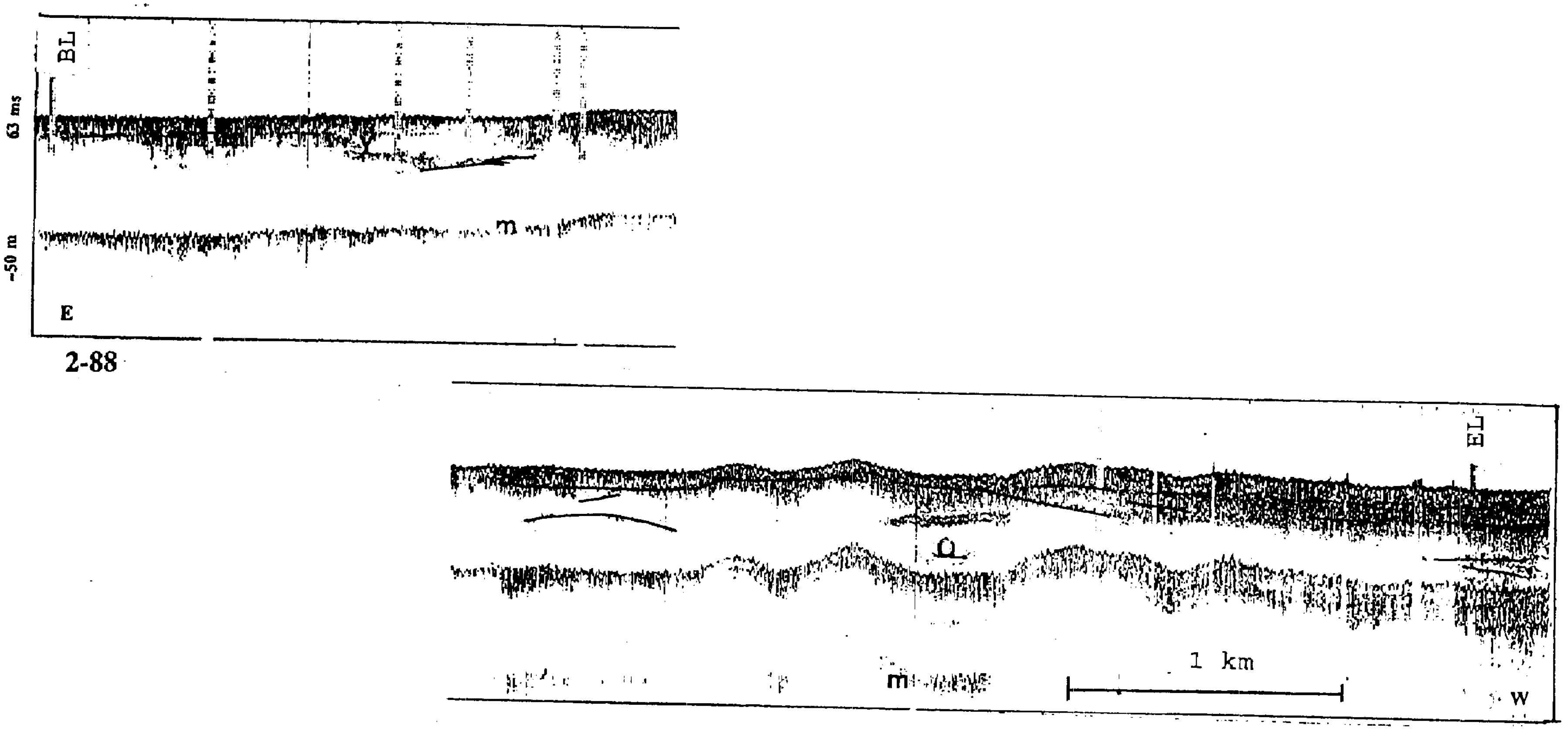


Figure 15: Reduced copy of line 2 from the 1988 survey with selected reflectors emphasized. Y, I, and O indicate the three paleochannels. Immediately under H are the closely spaced reflectors perhaps indicative of rapid oscillations in seal level. The reflectors indicated by m are multiples of the surface reflector. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

near the surface. Figure 16 (Line 3) very clearly shows the two channel sequences, one at each end of the line, and the character of the surficial sand sheet as it pinches out to the east. Although the eastern channel is not evident on Figure 17 (Line 4), the multiple, sub-parallel, near horizontal reflectors close to the surface and the surficial shoal are apparent.

Figure 18 (Line 5) shows the crosscutting relationship between the two channels on the eastern edge of the 1988 study area. One channel cuts into, and hence is younger than, the other. The profile depicts the shoal atop a specific reflector that becomes the sea floor. Figure 19 (Line 6) shows the separation of the two channels. Figure 20 (Line 7) also shows the spatial relationship between the western and more central channels and the upper parallel reflectors. Line 8 (Figure 21) runs along the course of the western channel, the "steeply" dipping cross-beds, and presents a good cross section of the shoal. The stratigraphy in Line 9 (Figure 22) is among the more complex of the lines showing all three channels and the shoal. Figure 23 (Line 10) also displays the complex stratigraphy in the relationship of the two eastern channels as well as the intermediate age western channel. The surficial shoal

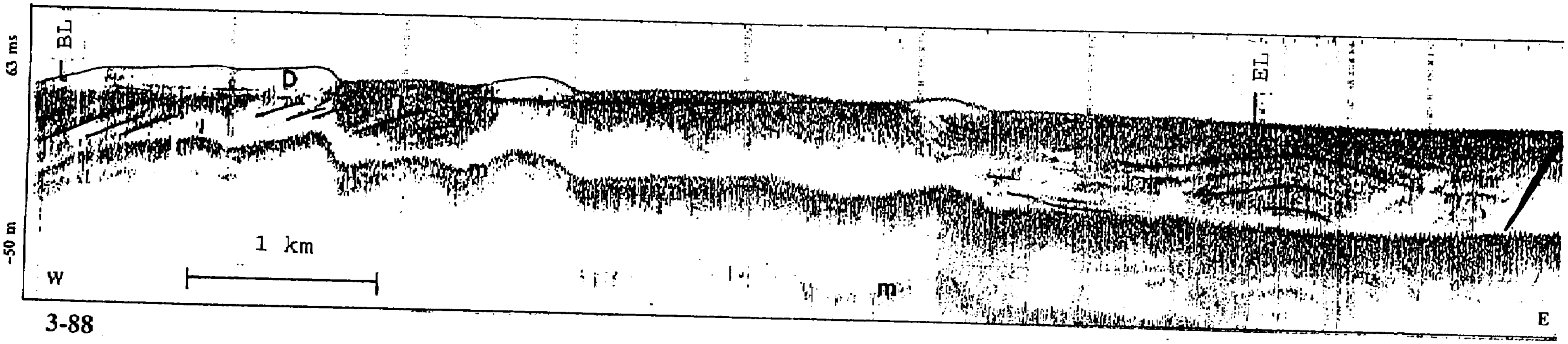


Figure 16: Reduced copy of line 3 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. Y and I indicate paleochannels. m indicates multiples of the surface reflector. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

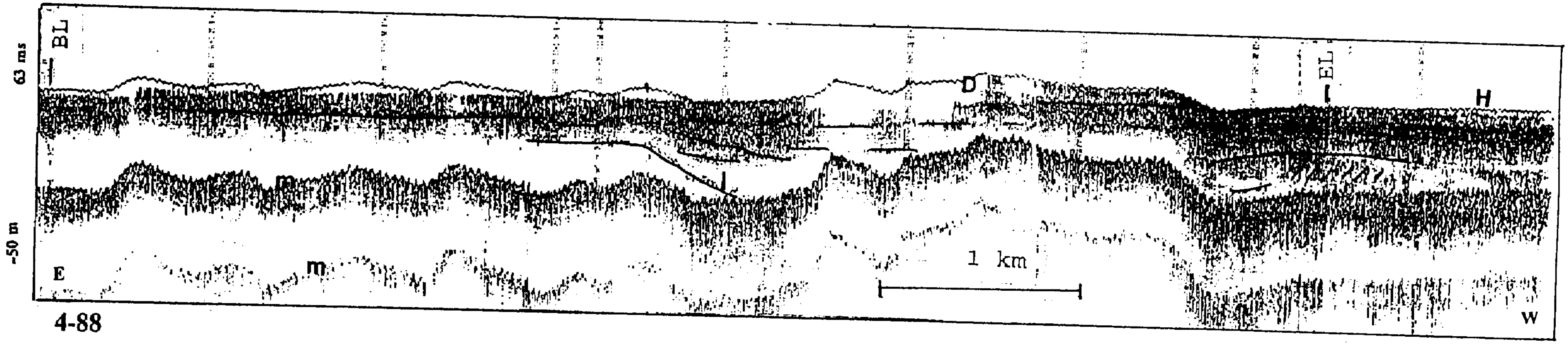


Figure 17: Reduced copy or line 4 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. I indicates a filled paleochannel. Immediately under H are closely spaced horizontal reflectors. M shows multiples of the surface reflector. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

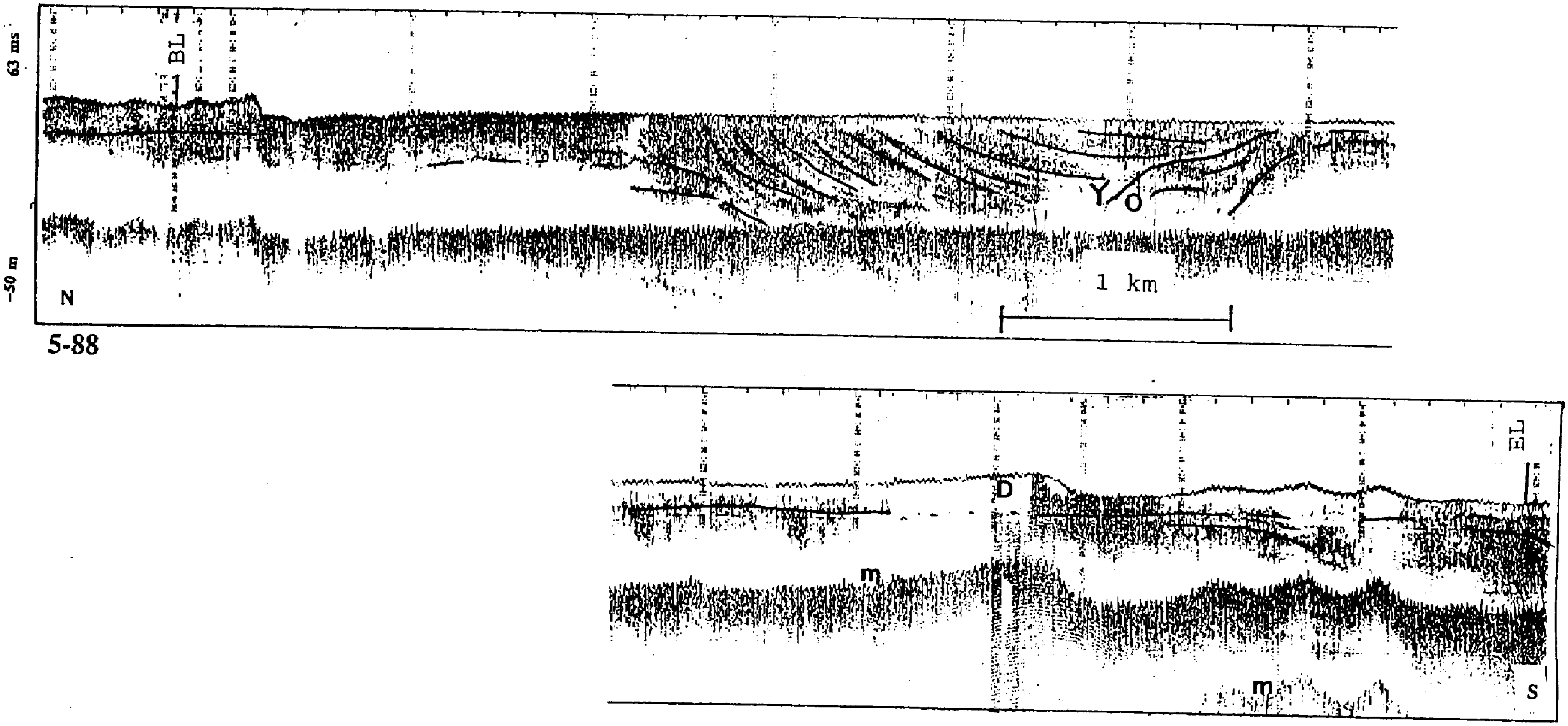


Figure 18: Reduced copy of line 5 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. Y and O show paleochannels. Multiples of the surface reflector are shown by m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

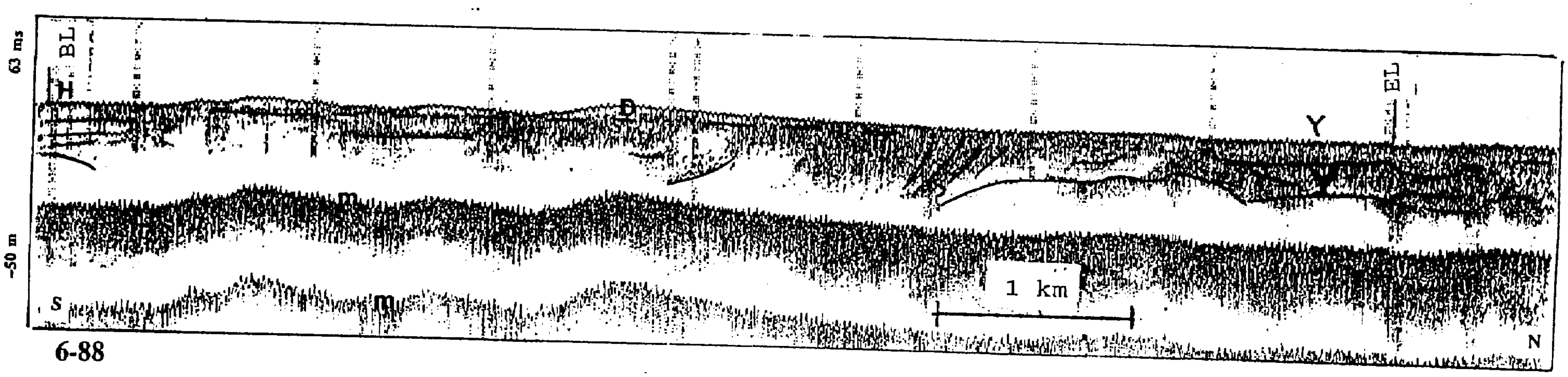


Figure 19: Reduced copy of line 6 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. Y and O show filled paleochannels. Note the closely spaced reflectors below H. m marks multiples of the surface reflector. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

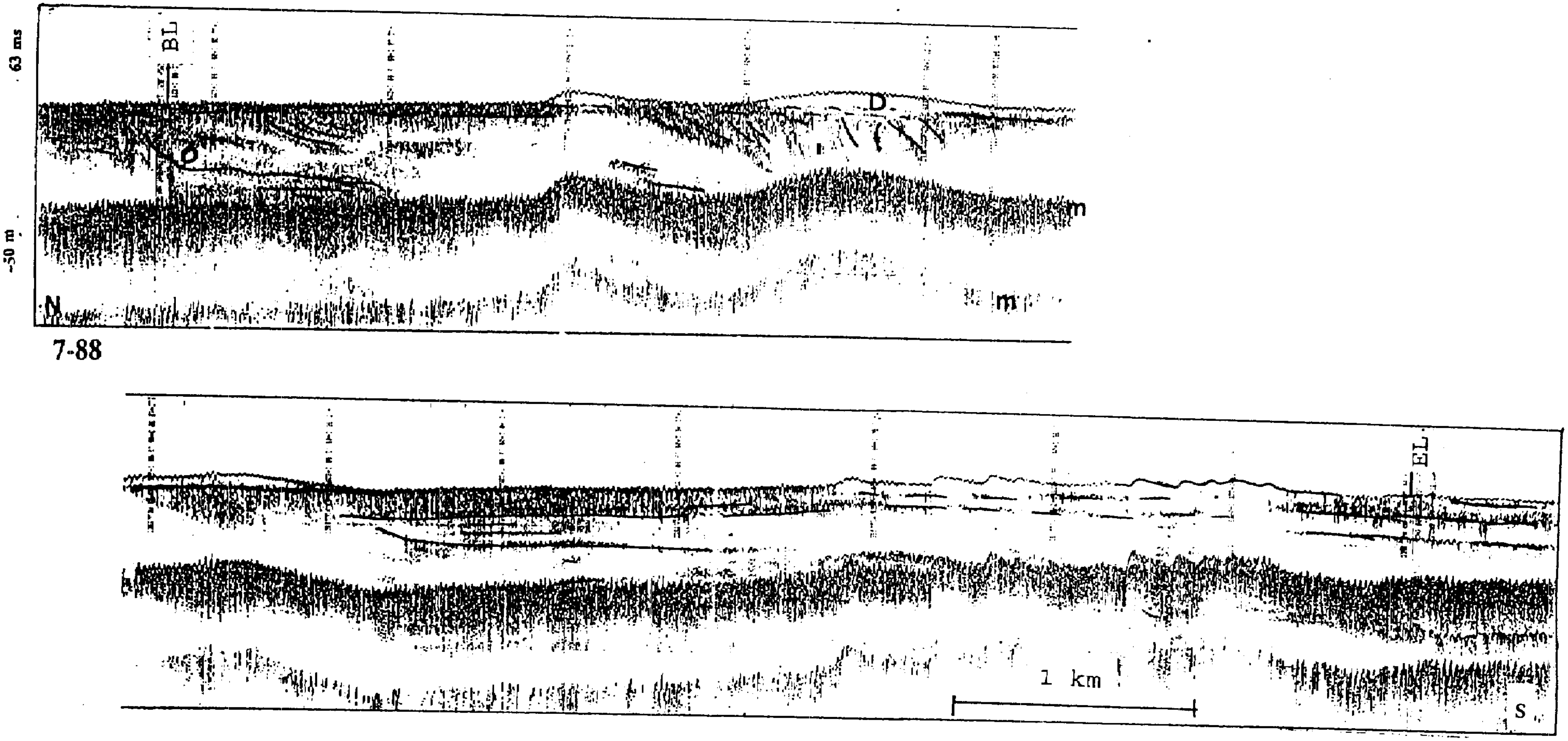


Figure 20: Reduced copy of line 7 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. O and I (below D) show filled paleochannels. Multiples of the surface reflector are shown with m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

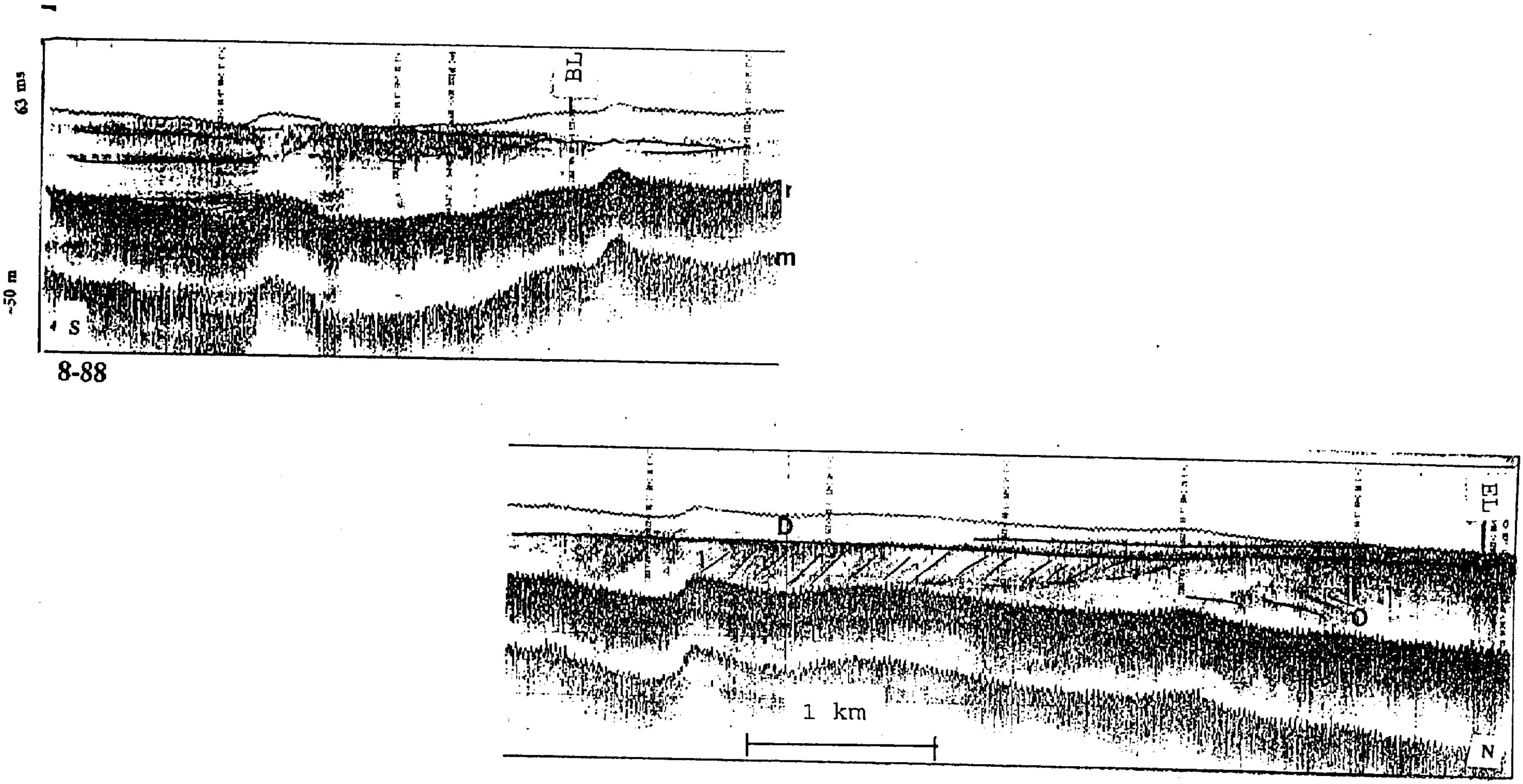


Figure 21: Reduced copy of line 8 from the 1988 survey with selected reflectors emphasized. D indicates the surficial sand sheet. I and O mark filled paleochannels. Multiples of the surface reflector are shown with m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

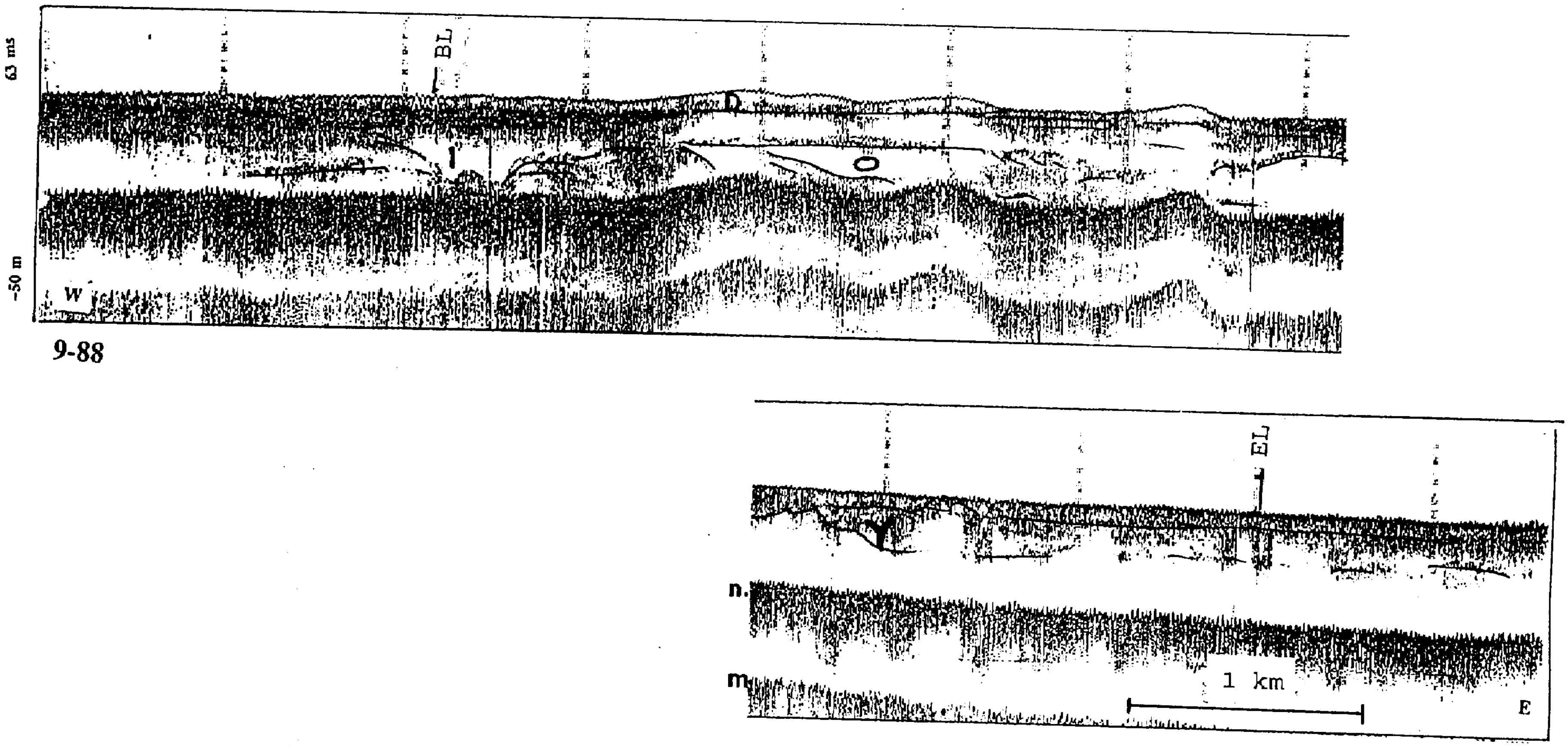


Figure 22: Reduced copy of line 9 from the 1988 survey selected reflectors emphasized. D shows the surficial sand sheet. Y, I and O mark filled paleochannels. Multiples of the surface reflector are shown with m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

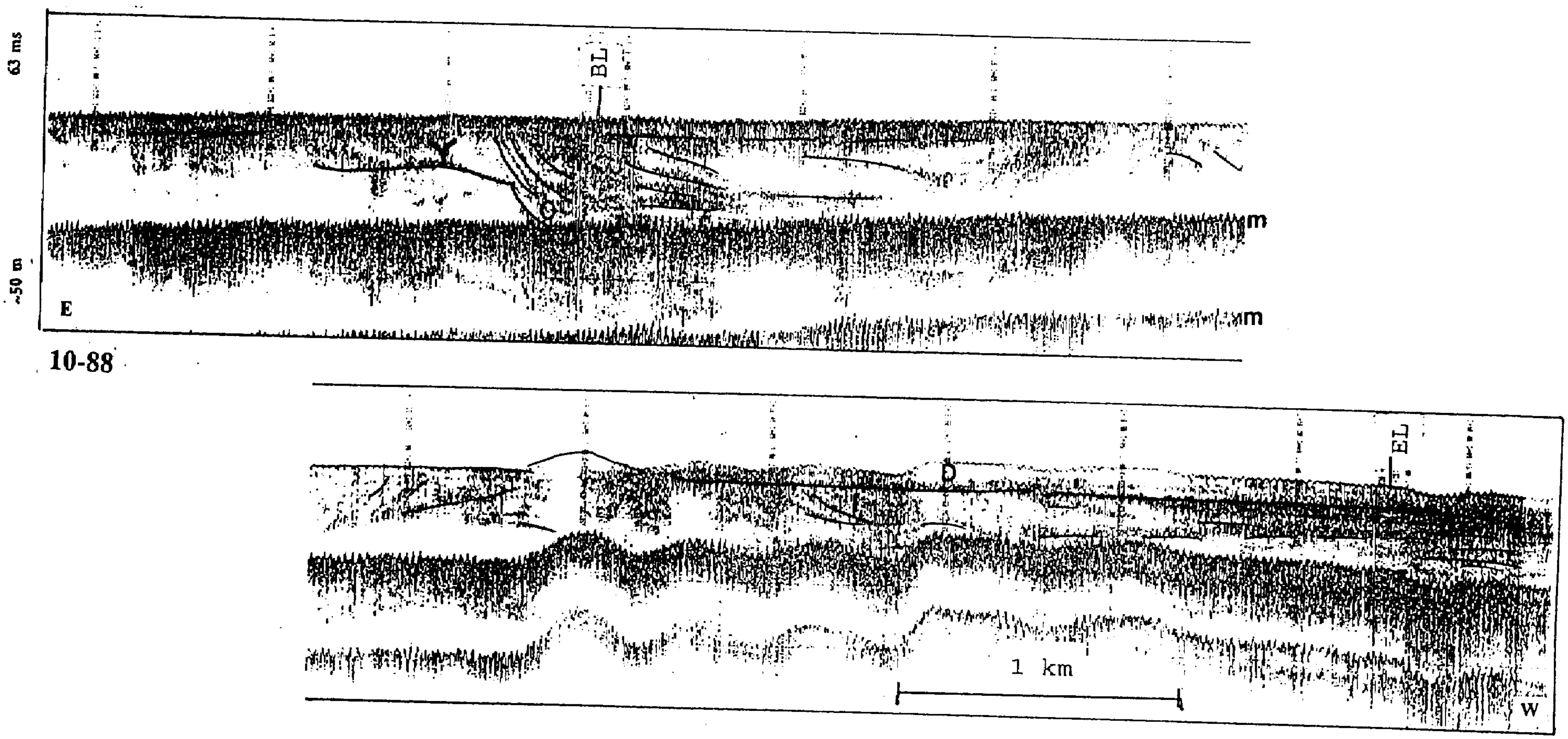


Figure 23: Reduced copy of line 10 from the 1988 survey with selected reflectors emphasized. D shows the surficial sand sheet. Y, I, and O indicate filled paleochannels. Multiples of the surface reflector are shown with m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

is present but not as strongly evident as on some other lines. Figure 24 (Line 11) shows only the eastern and western channels and the surficial sheet. The cross beds at the western end of the line are strong indicators of the direction of channel filling or migration. Data from Lines 12 and 13 (Figures 25 and 26) provide further detail.

Viewed together, these 13 seismic-reflection lines indicate the complexity of the Quaternary stratigraphy of the continental shelf adjacent to southern Virginia. Figure 27 is a sketch map indicating the approximate locations of the 3 channels and the limit of the shoal area. Hence the number of channels shown in Figure 28 and the doubt associated with the interpretations of the channels are not surprising.

Figure 29 depicts the lithologies in 18 cores offshore of the major resort area of Virginia Beach north of Rudee Inlet. As discussed in Hardaway and others (1995) the cores show substantial vertical and lateral variability within the three basic sedimentary facies. The stratigraphically deepest unit is moderately to very stiff, slightly sandy, blue-grey clay. The unit contains numerous *Rangia* and *Polynices*, especially in cores 10 and 16, and oysters in the

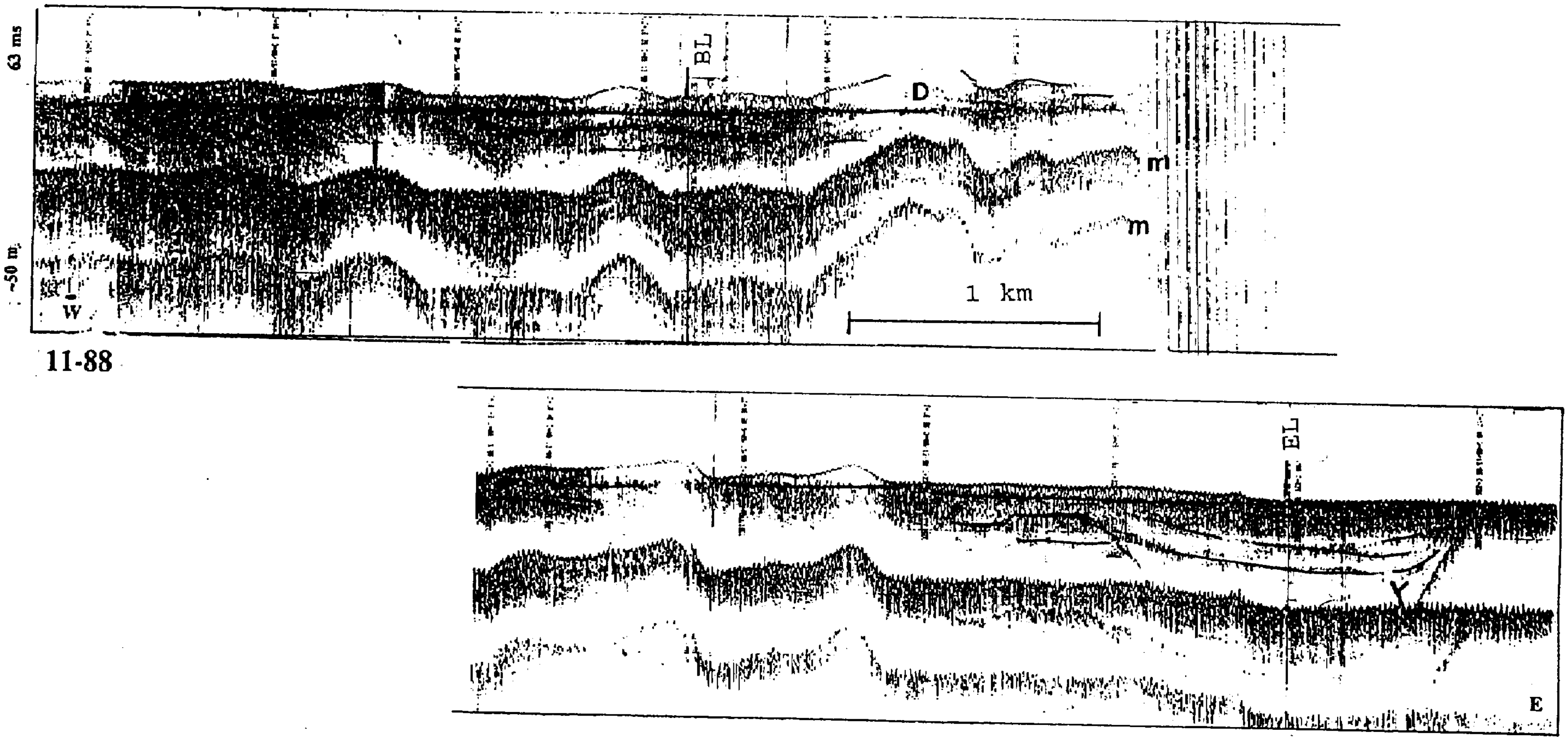


Figure 24: Reduced copy of line 11 from the 1988 survey with selected reflectors emphasized. D marks the surficial sand sheet. Y and I indicate filled paleochannels. Multiples of the surface reflector are shown with m. BL and EL are the beginning and endof the line. Horizontal scale is approximate.

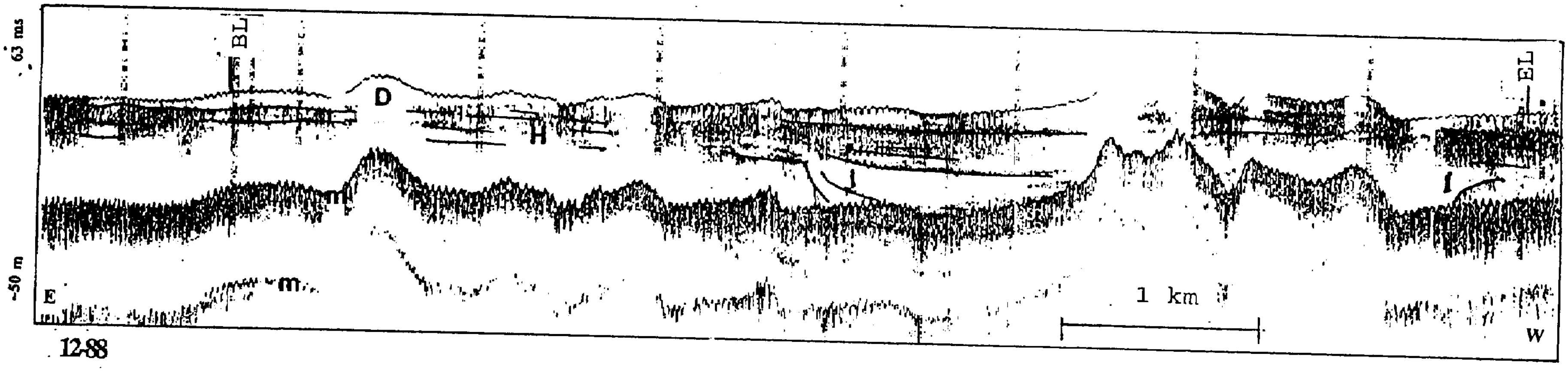


Figure 25: Reduced copy of line 12 from the 1988 survey with selected reflectors emphasized. D marks the surficial sand sheet. I indicates a filled paleochannel. The area around H contains several closely spaced reflectors. Multiples of the surface reflector are shown with m. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

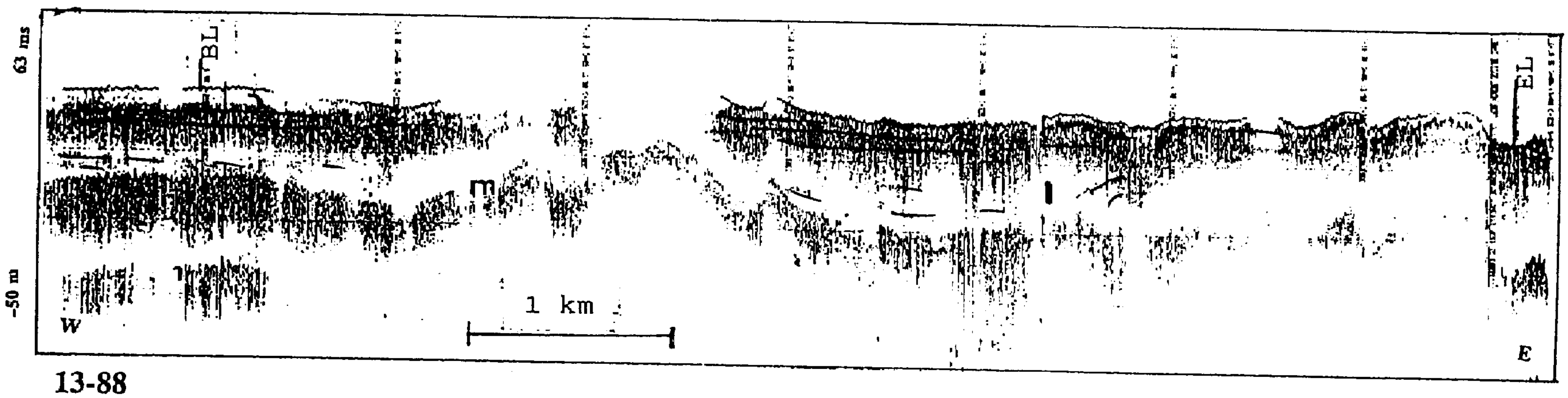


Figure 26: Reduced copy of line 13 from the 1988 survey with selected reflectors emphasized. D shows the thin, surficial sand sheet. I indicates a filled paleochannel. Multiples of the surface reflector are shown with m. Note the closely spaced reflectors in the western and central portions of the profile. BL and EL are the beginning and end of the line. Horizontal scale is approximate.

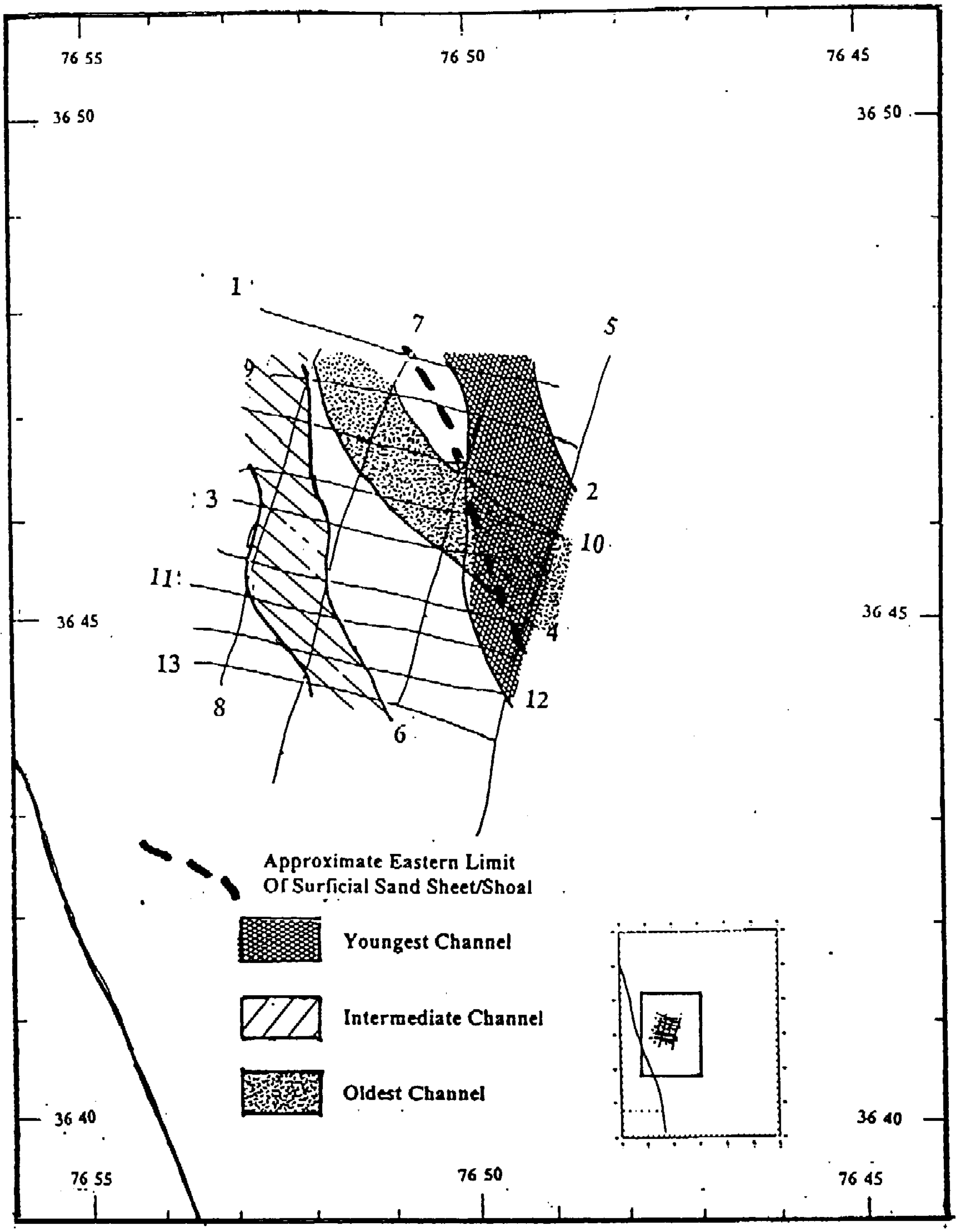


Figure 27: Sketch map depicting the 3 filled paleochannels identified in the 1988 sub-bottom profiles.

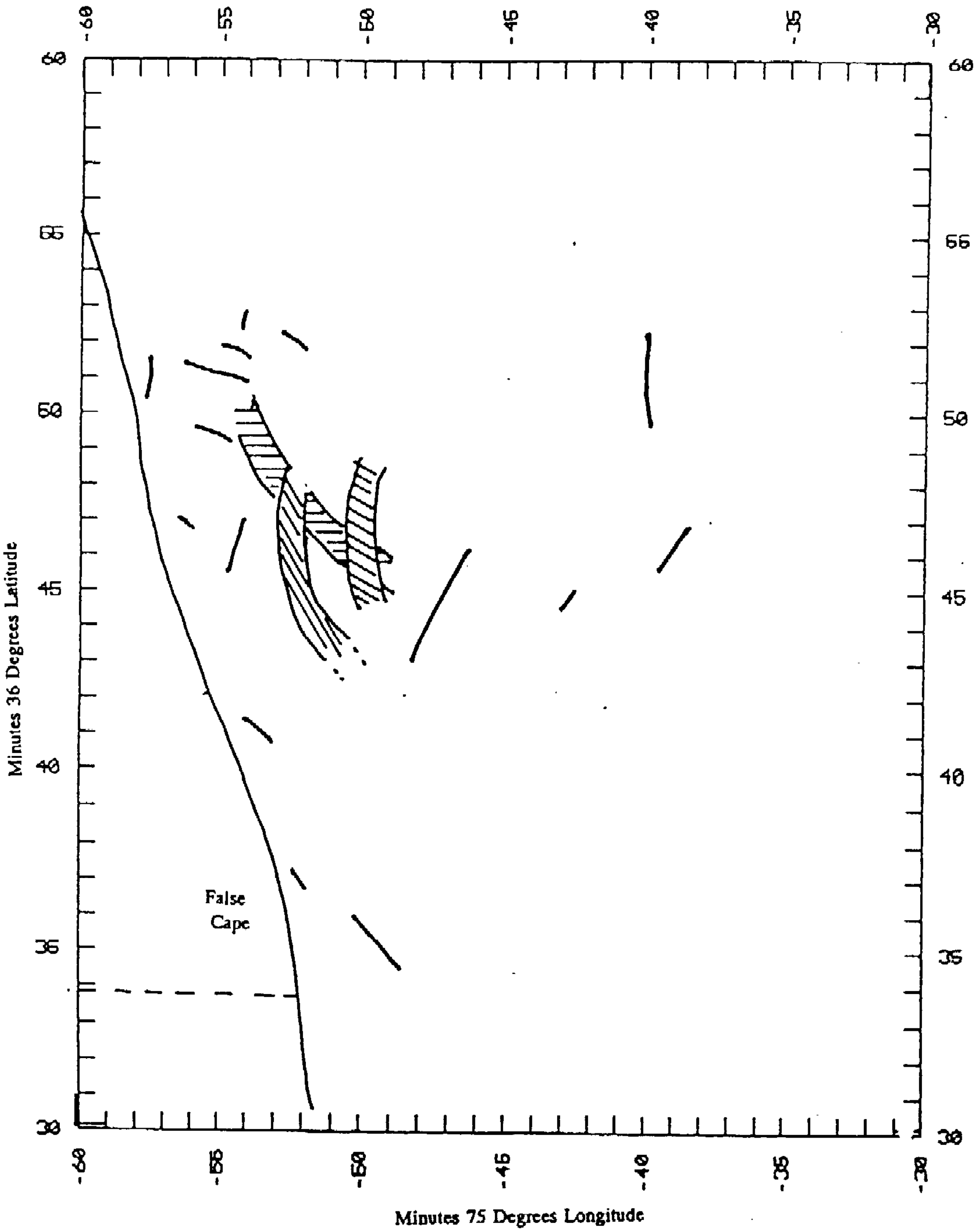


Figure 28: Sketch map indicating the many filled paleochannels throughout the study area.

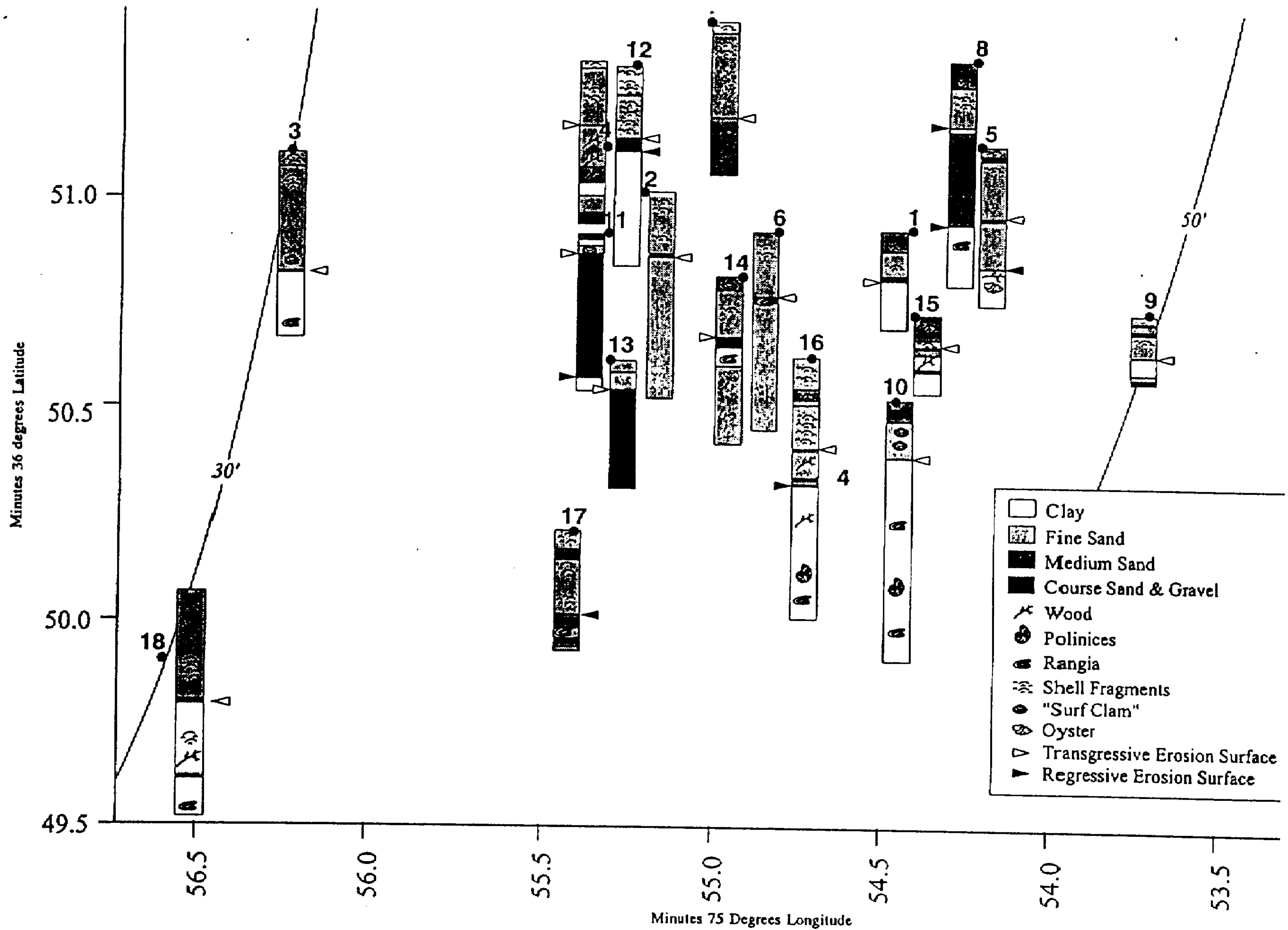


Figure 29. A schematic depiction of 18 cores offshore of the northern portion of Virginia Beach. The 30 and 50 ft. (9 and 15 m) depth contours are shown. From Hardaway and others (1995).

upper portion of core 5. In cores 1, 3, 9, 10, 15, and 18 the clay is unconformably overlain by a marine sand. Fluvial sands and gravel that contain no shells but some wood cap the clay in cores 5, 8, 11, 12, and 16. This non-marine unit is overlain by the marine sand. Cores 11 and 13 have thick lenses (3.4 and 4.3 m, respectively) of coarse sand and gravel. A large fragment of wood from 3.7 m below the seafloor (approximately 15.2 m below sea level) in core 4 had a carbon-14 date of 9,440 $^{+}/_{-}$ 50 y BP. Appendix 2 contains logs of the individual cores and grain-size analyses of sediment samples taken from the cores. The logs for the four cores taken offshore of Sandbridge all indicate that the top several feet were "jetted" and not sampled. The driller's field notes state that the upper portion of the sediment column contains "medium sands" that were very difficult to sample.

SIDE-SCAN SONAR

Hobbs (1990) presented the results of the side-scan sonar surveys of the study area (Figures 30 and 31). The northern portion of the area is characterized by a large region of "drag" marks (Figure 32), perhaps caused by

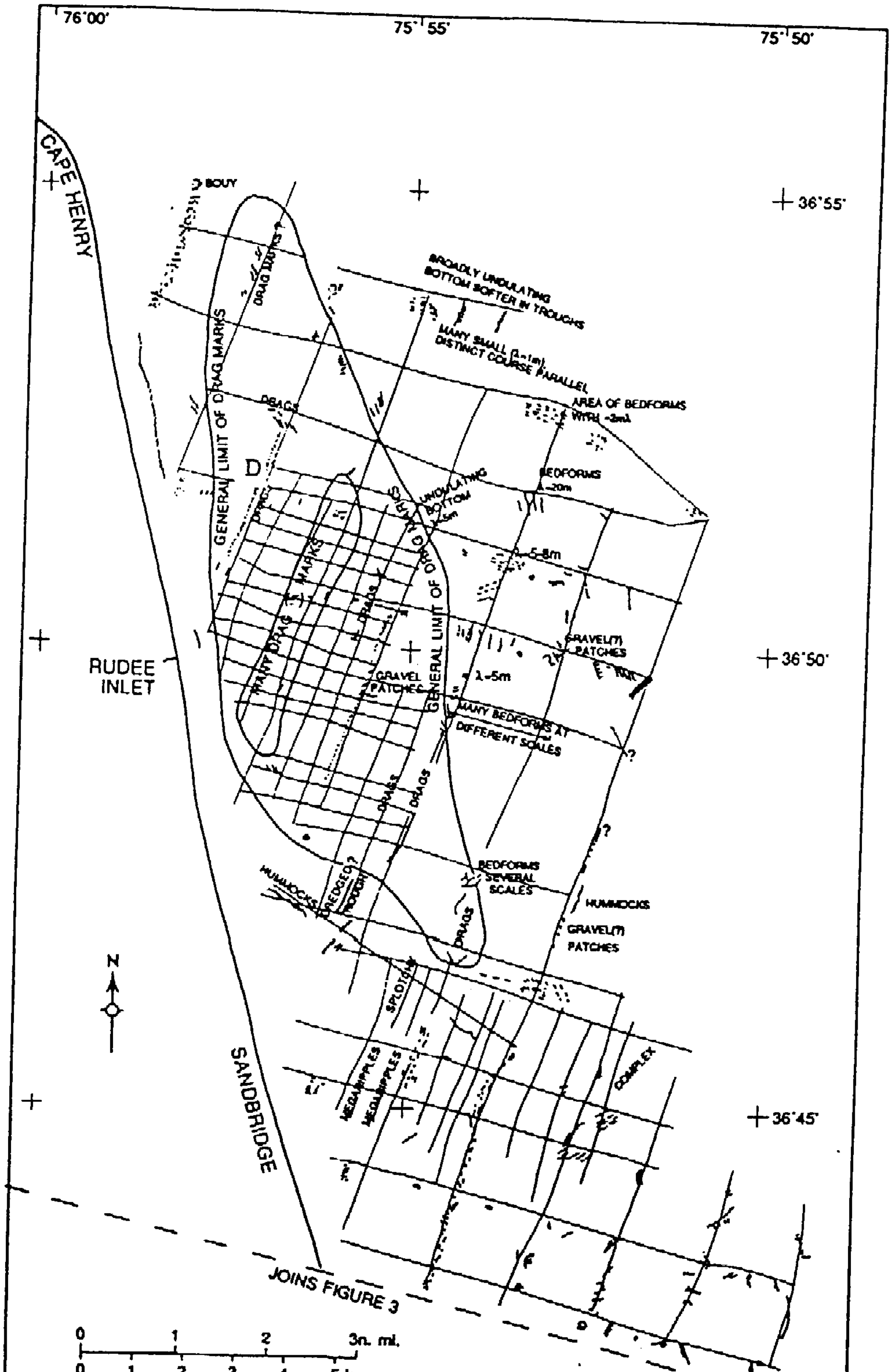
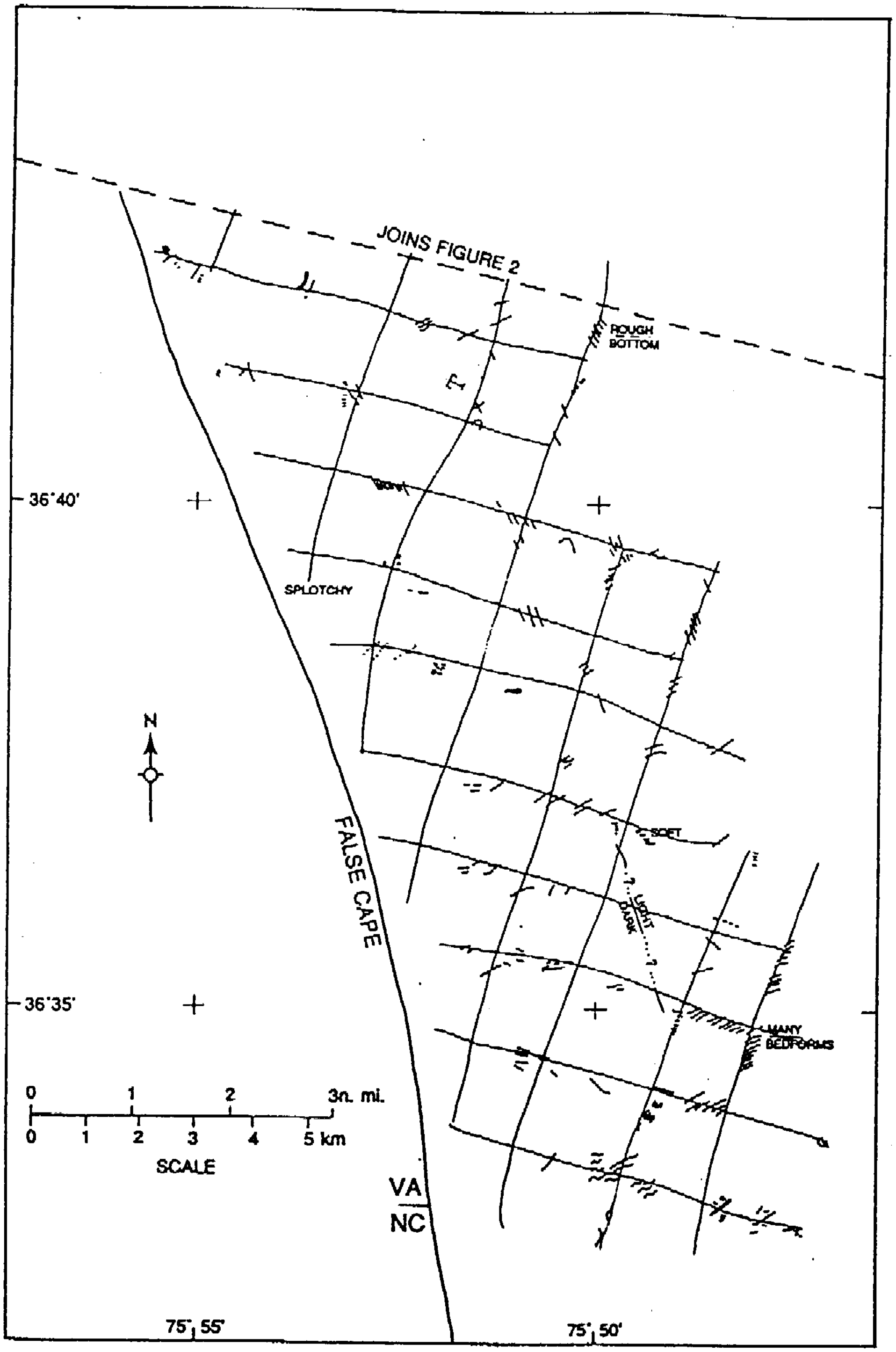


Figure 30: Interpretive map of the side-scan-sonar record of the northern portion of the study area. The areas shown in Figures 32 is indicated by (D).



31: Interpretive map of the side-scan-sonar record of the southern portion of the study area. The area shown in Figure 33 is indicated by (T).

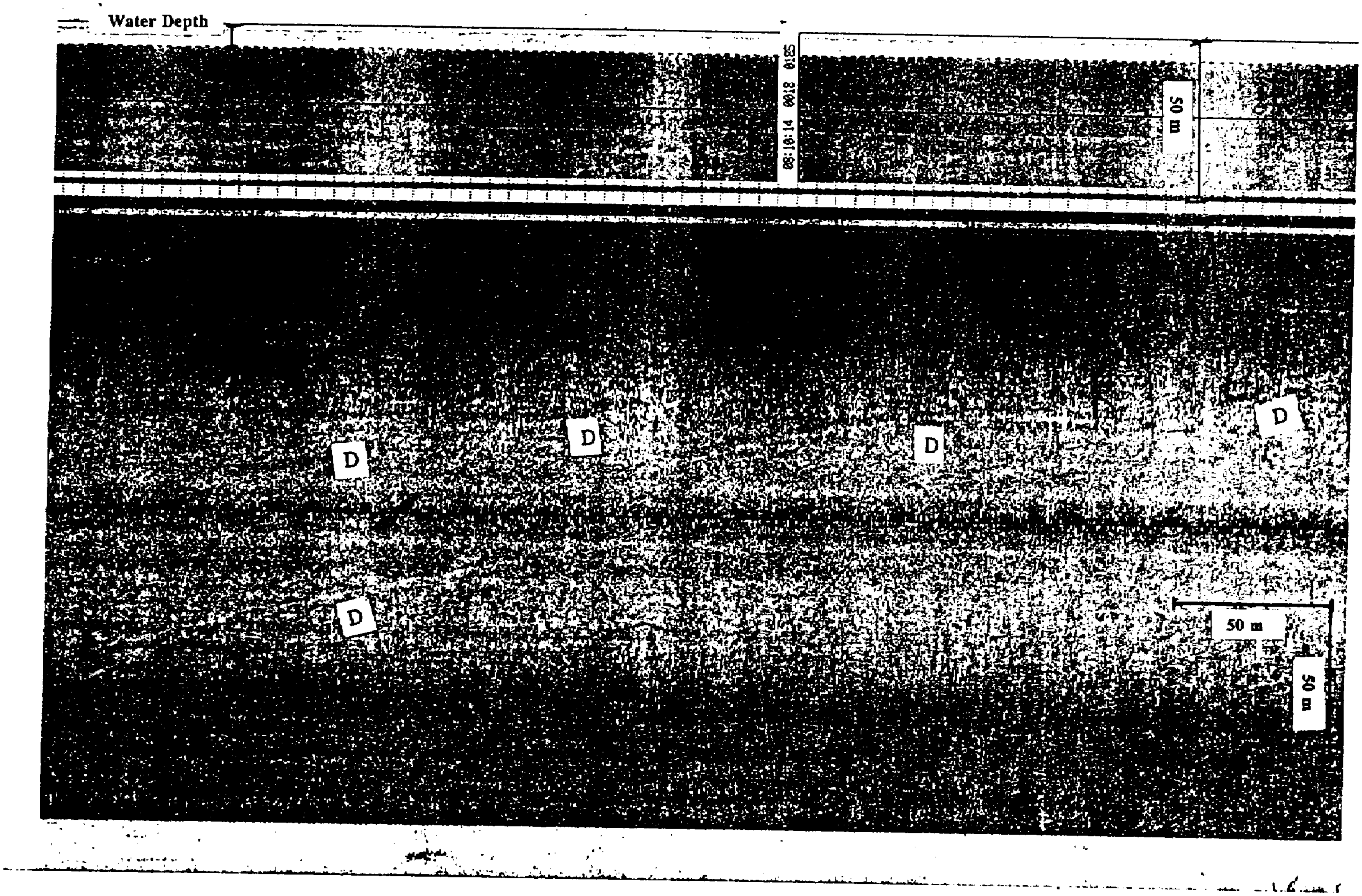


Figure 32: A side-scan sonar image showing several of the linear features thought to be drag marks indicated by (D). See Figure 30 for location.

commercial fishing gear. Throughout the study area there are dark-to-light changes in the side-scan-sonar record that appear to be related to rhythmic changes in bottom topography. Generally darker areas are related to topographic highs and lighter, less reflective areas to sides of the between-ridge troughs. Figure 33 is a section of side-scan sonar image depicting variations associated with smal scale topographic changes.

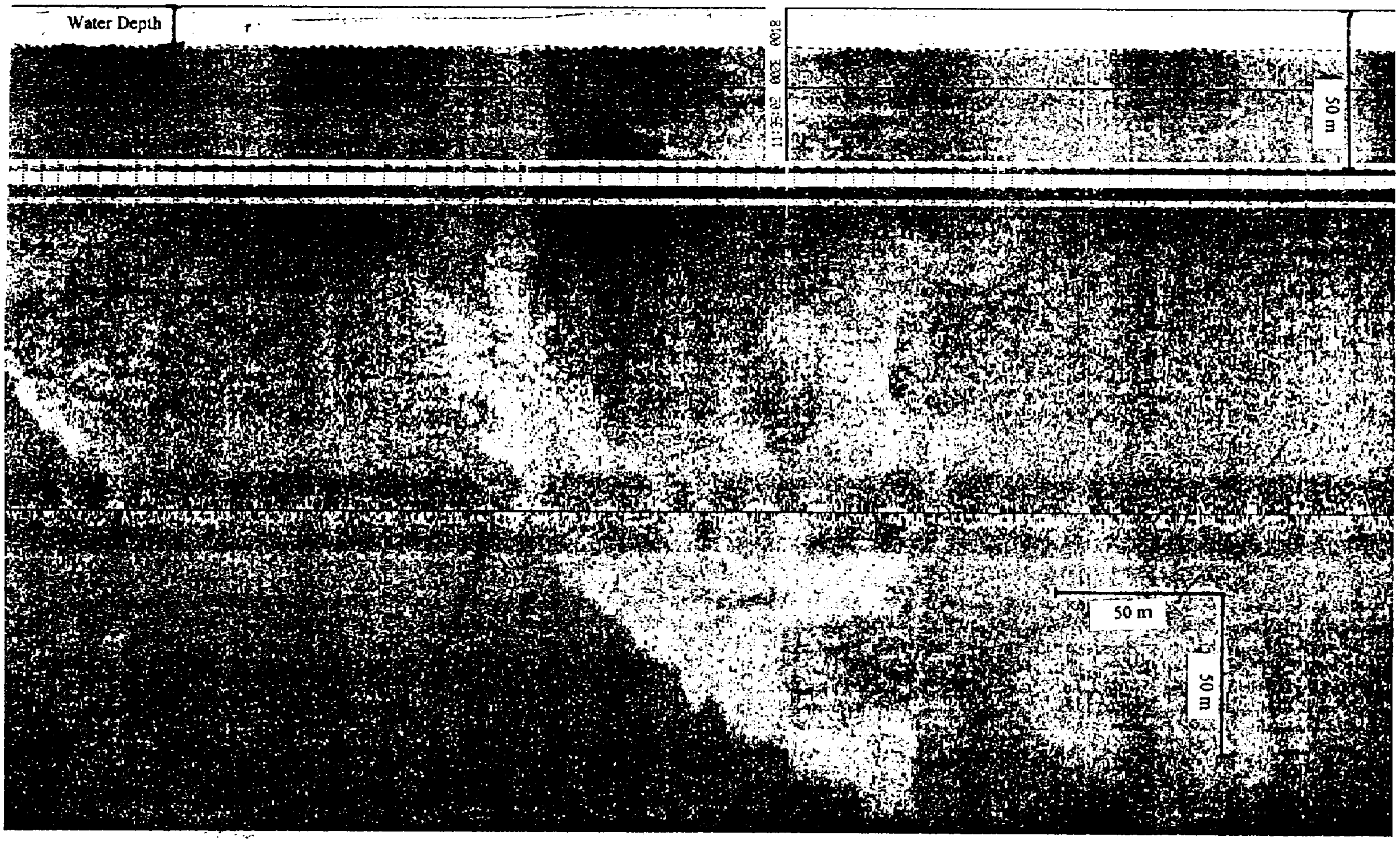


Figure 33: A side-scan sonar image depicting variations related to small scale topographic changes. The darker poritons of the image indicate finer-grained sediments associated with the lower portions of the area whereas the lighter portions indicate coarser sediments on the topographic highs. Topographic relief is approximately 1 m. See Figure 31 for location.

DISCUSSION

SURFICIAL SEDIMENTS

The surficial sediments of the study area are dominantly sands and granules. The two western (near shore) pockets of slightly elevated content of fine grained sediments (Figures 10 and 11) may result from different causes. The northern patch, identified by seven samples ranging from 5 to 51, average 18, weight percent silt plus clay (Samples SVG-1, 2, 379, 376, 19, and 374) is fine-grained sediment probably transported out of Chesapeake Bay in its "plume." Sample SVG-374, which was taken from very near shore, probably is from an outcrop of muddy sediments or a deposit of dredge spoil. Similarly, sample SVG-110, the fine-grained pocket along shore near the Virginia - North Carolina border, likely represents an outcrop of muddy (back-barrier lagoon?) sediments. Outcrops of once-buried marsh are common along the beach of the False Cape area which is immediately shoreward of the site of SVG-110.

The reasons for the three, small pockets of decreased sand and granule content in the southeastern quadrant of the study area (Figure 12) are unclear sand interpretation is hindered by their very small size, one or two samples. They may be related to subtle topographic features or they may be related to an outcrop of another facies. The northeastern-most pocket is a single sample with 22 percent clay and 11 percent silt (Sample SVG-226). The southeastern pocket consists of two samples, one with 12 percent clay and 28 percent silt, the other, 6 percent clay and 6 percent silt (Samples SVG-286 and 288, respectively). The western-most of the three pockets also is a single sample (SVG-139) of 19 percent clay and 31 percent silt.

HEAVY MINERALS

Although the present work does not add to the body of data concerning the occurrence and distribution of heavy minerals on the inner continental shelf of southeastern Virginia, it allows a better understanding of previous works. Calliari and others (1990) describe a heavy-mineral population of zircon, garnet, and amphibole, and other heavy minerals (their Factor 2) existing on the shelf south of the mouth of Chesapeake Bay and in the bay itself discrete from populations of amphibole, pyroxene, and other minerals within the bay (Factor 1) and of garnet, amphibole, epidote, and other minerals north of the bay mouth (Factor 3). The distribution of the sample groups lends itself to suggestion about possible sources and possible routes of transport.

The location of the prime concentration of Factor 2, nearshore, roughly adjacent to the Virginia - North Carolina border, with a lesser concentration in the southern portion of the bay mouth, suggests both that there is a separate source for the minerals in this set of samples and that there is little transportation of sediments across the bay mouth. Thus the sand resources of the southeastern Virginia shelf either are derived locally or have been transported through geologic time from farther offshore. The locus of the factor roughly at the state border might result from the previous existence of a major inlet, Currituck Inlet (Prow, 1977), with a drainage basin potentially extending into the Piedmont of Virginia and North Carolina.

SIDE-SCAN SONAR

The side-scan-sonar records provide information on the impacts of humans on the bottom as well as on the regional marine geology. As stated in Hobbs (1990), the bottom type in the study area fits into the classification of Wright and others (1987)as Inner-Shelf Shoreface (Type Ia) or Inner-Shelf Ridge Field (Type Ib). This classification scheme categorizes estuarine, bay, and shelf bottom types on the basis of the type and scale of bottom and bed roughness. As roughness is related to sediment type and wave, current, and biologically induced bedforms, the classification affords a comparison of estuarine and marine bottom conditions on the basis of the source and magnitude of energy affecting the sediment surface.

The area just offshore of Dam Neck, just north of Sandbridge, is the type area for the Wright and others' (1987) Inner-Shelf Shoreface environment. Type Ia (Inner-Shelf Shoreface) has very little biogenic roughness at the sediment surface as there is virtually no colonization of the sediments in the surf zone by benthic organisms. Type Ib bottoms (Inner-Shelf Ridge Field) has greater current induced roughness reflecting currents that produce bedforms. Both Type Ia and Ib have small scale (heights 1 to 10 cm, wavelength 1 to 50 cm) wave- and current-induced bottom roughness, mesoscale (height 0.1 to 2 m, wavelength 0.5 to 50 m) current-induced roughness, and little biogenetic roughness.

The presence of drag marks on the bottom in much of the study area is indicative of an active commercial fishery. The drag marks are near linear scours that most probably are caused by trawl nets or similar fishing equipment dragged along the sea floor.

SUBSURFACE GEOLOGY

The discussion by Wright (1995) of the history of bottom resuspension activity has implications for the study area whether looking at 18,000 or 140,000 year time scales. In the less than 20-m depths within the study area, the cumulative time during which the bottom would have been subject to agitation by waves is directly and strongly proportional to depth. In the very shallow portions, where the cumulative period of activity is short, one would expect little evidence of modern processes and relatively smaller active sand-bodies whereas in deeper water, where there has been more time for resuspension and transportation, dynamic sand bodies, such as unit D of Shideler and others (1972), should be more developed.

Given the present sea level and the last interglacial high about 125,000 years ago, the shallow portion of the current continental shelf has experienced about 15,000 total years of activity capable of resuspending sediments. That cumulative activity increases with depth across the shelf, suggesting that there might be more evidence of sedimentary processes, hence a more complex stratigraphic record, in deeper water. Again, as most of the study area is in less than 20-m depths, much of the activity would have been farther offshore.

The high frequency, low amplitude sea-level variations of Oxygen Isotope Stage 5 (Figure 4)(Toscano and others, 1989; Toscano, 1992; Toscano and York, 1992; and Riggs and others, 1992) should have had an appreciable effect on the inner shelf, perhaps of sufficient magnitude to compensate for the relative short cumulative time of activity. Fluctuations ranging between -23 m and +6 m of the present sea level would have moved the shoreline completely across the study area with consequence of multiple episodes of erosion that should be evident in the seismostratigraphic record of the inner shelf. The periods of subaerial exposure would have resulted in erosional surfaces which later would serve as the floor across which shoals might develop and move and as the surface upon which new deposition could occur. These erosional surfaces would have had limited vertical range and relatively small shore-normal extent. Some of the near parallel reflectors in the seismic records likely are indications of such erosional surfaces.

The three sea-level peaks (5a, 5c, and 5e)(Figure 4) and the intervening mini-lows occurred over a period of approximately 50,000 years (80,000 to 130,000 y. B.P.) within 23 m of present sea level. This set of high-frequency fluctuations is on the same order as Mitchum and Van Wagoner's (1991) fifth-order stratigraphic sequences which have a cyclicity of 0.01 to 0.02 m.y. Although they report the presence of fifth-order stratigraphic sequences in areas with very rapid deposition, the strata of slow deposition inner continental shelf of Virginia form similar sequences. The low rates of sedimentation increase the difficulty of discerning and tracing system boundaries.

Because the resolving power of more modern seismic reflection systems provides more detail than was available to Shideler and others (1972), the utility of their proposed standard stratigraphic section (Figure 3) has diminished. Unit C in particular requires reconsideration. The major sea-level low stands associated with the Exmore, Belle Haven, and Eastville channel systems in Chesapeake Bay were major global changes in sea level, comparable to the late Pleistocene regression that resulted in the Cape Charles channel. The continental shelf of the mid-Atlantic would have been exposed to sub-aerial processes and would have been scoured as the surf zone first retreated and then advanced during the following transgression of each cycle. Compared to the smaller, sea-level fluctuations of Stage 5, the much larger and longer lasting eustatic cycles would have resulted in erosion surfaces of a much broader geographic extent. The major regional non-conformities separate unit C into four depositional units which meet Mitchum and Van Wagoner's (1991) classification as fourth-order stratigraphic sequences. Fourth order sequences have cyclicity of 0.1 to 0.2 m.y., comparable to that of Pleistocene glacial episodes. Again, the low rates of deposition result in strata that are thin and difficult to trace.

The interpretation of the cores further highlights the complexity of the geologic section. The 9,440 y B.P. radiocarbon date from the wood fragment 15 m below present sea level in core 4 (Figure 29) indicates that the fragment was deposited in a fluvial setting approximately 45 m above what then was sea level. Thus there are Holocene fluvial channels cut into older estuarine or marine strata. The filled channels are overlain by recent marine sediments. Indeed it is likely that the channels experienced a transition from fluvial to marine conditions as sea level rose and flooded existing drainage systems. Analysis of the cores demonstrates the mix of fluvial, estuarine, and marine environments in strata in the continental shelf offshore southeastern Virginia.

SAND RESOURCES

As previously discussed, if the offshore sediments are to be used for beach nourishment, it is important that the offshore sands have grain-size characteristics that closely match those of the beach. As indicated in Wright and others (1987), the median grain-size of the foreshore within the study area varies between 0.25 and 0.75 mm. As the utility of borrow material for a beach nourishment project is strongly dependent upon the equality of the median grain-sizes of the native and borrow sediments, there is broad leeway in the requirements for borrow material. Many of the surficial samples have median grain-sizes coarser than 0.25 mm (2 phi). Similarly, portions of the cores in the area offshore from Rudee Inlet (Figure 29) are medium or coarse sands with acceptable medians (Appendix 2). The shoal offshore of Sandbridge contains substantial quantities of clean sand with median grain sizes coarser than 0.25 mm (Kimball and Dame, 1989; Kimball and others, 1991; and Appendix 2) that satisfies the grain-size criteria for borrow material.

Of the cores collected offshore of Rudee Inlet, numbers 7, 8, 11, and 13 (Figure 29) contain reasonable sections of medium to coarse sand. Almost two-thirds of the core 7 is coarser than 0.35 mm (1.5 phi), the section of fine sands being between 1 and 7 feet (0.3 to 2.2 m) beneath the surface. Core 8 is similar, with section between 3 and 6.5 feet (1 to 2 m) containing fine sands with a median grain size of 0.08 mm (3.5 phi) but the overlying section consisting of medium sands. The underlying section appears to be medium sands, but several feet of the section was missing, casting some doubt on the overall content. Cores 11 and 13 are dominantly medium and coarse sands with only very lenses of finer material. As the sediments are so variable, the area would have to be much more thoroughly cored before specific portions could be identified for sand mining.

The three of the four cores collected off Sandbridge contain medium sands with median grin sizes between 1.12 and 2.07 phi (0.51 and 0.24 mm). The fourth core, contains fine sands with median grain sizes dominantly coarser than 2.25 phi (0.21 mm), which should be acceptable for beach nourishment on much of the southeastern Virginia's shore.

CONCLUSIONS

The conclusions of this study fall into three topic areas: surficial sediments, geological history of the inner continental shelf, and sand resources. The conclusions address and satisfy the goals and objectives set forth in the Objectives.

SURFICIAL SEDIMENTS

The sediments on the surface of the southeastern Virginia inner continental shelf are more varied than has been indicated previously. Although the surficial sediments within the study area are dominantly sands, the density of the sample grid used in this study allows identification of a greater spatial variability in grain-size characteristics than had been possible previously. The characteristics of the surficial sediments depict both active processes (*e.g.*, the "plume" of generally finer sediments exiting the mouth of Chesapeake Bay) and the underlying geology (*e.g.*, the outcrop of siltier sediments near False Cape).

GEOLOGICAL HISTORY

The Pleistocene history of the inner continental shelf offshore of southeastern Virginia and the resulting stratigraphy are substantially more complex than have been described previously in the literature. The sedimentary structure and stratigraphy of the study area results from the previously unconsidered impact of the Pleistocene sea-level lows associated with the Exmore, Belle Haven, and Eastville channel-forming events on submarine Unit C and the several high-frequency, low-amplitude fluctuations of sea level associated with Oxygen Isotope Stage 5.

The three major sea-level lows, sufficient to carve major channels across the coastal plain would have had marked consequences across the shelf. The Exmore, Belle Haven, and Eastville lows correspond to major Pleistocene glacial maxima. Thus it is reasonable to view unit C as a composite of four fourth-order stratigraphic sequences. The low rate of deposition on the mid-Atlantic continental shelf has limited the thickness of the individual units and thus had made regional correlation of specific strata difficult.

The three Stage 5 peaks (5a, 5c, and 5d) and intervening mini-lows (5b and 5d), roughly 80,000 to 130,000 years ago, occur within 23 m of today's sea level and thus would have had little impact farther out on the shelf but should be obvious in the strata of the inner shelf.

The shallow-penetration seismic records reviewed for this study depict several reflectors bounding thin strata within the upper 10 m or so of the sediment column. Although vertical control on the original data does not allow specific correlation of these reflectors and strata from line to line, it is most likely that they are associated with the low amplitude fluctuations of the last interglacial episode. These reflectors and strata from which they result are fifth-order sequences that occur within the greater fourth-order units and further confound the correlation of individual elements.

Some of the smaller channels discernable in the seismic profiles may be related to sea-level variations during Stage 5, but larger systems, such as two of the three reported by Chen (1992) and Chen and others (1995), are more likely associated with major regressions.

There are three distinct types of filled paleochannels within the inner continental shelf. Relatively near surface, generally small, roughly shore normal channels, such as seen near Rudee Inlet, are likely the courses of tidal inlet channels, in this instance dating from the last low-stand of sea level. Small, relatively wide and relatively shallow, generally shore-parallel channels, some of which are evident in the records, may be back barrier or lagoonal channels. The third type of channel results from riverine flow.

SAND RESOURCES

There are substantial resources of sand on the inner continental shelf of Virginia which may be suitable for use in beach nourishment or as construction aggregate. As always is the case, the specific geotechnical and compositional characteristics of the resource must be reviewed for each potential application. Beach nourishment and construction uses have different criteria. As the grain size and shape and mineral composition criteria for construction aggregate vary with the specific application, further discussion of them is beyond the scope of this dissertation. Basic grain-size characteristics of sediments in cores from offshore of Sandbridge, offshore of Rudee Inlet, and elsewhere in the study area indicate that there are substantial quantities of sand suitable for use in beach nourishment projects.

The deposits occur in three distinct stratigraphic settings. The most easily discernable type of deposit is the discrete, surficial shoal as exemplified by Sandbridge Shoal. The shoals are well-defined topographic features on the surface of the inner shelf. In the seismic records they have clear bottom boundaries. After the grain-size characteristics of such deposits are verified by coring, the physical process of mining should be relatively straight forward; dredge the shoal to the depth of the bottom contact.

Filled channels, as those offshore of Rudee Inlet, are another class of deposit. The fluvial sands filling the channels can be a very clean, high quality sand suitable for use in beach restoration or nourishment and in construction aggregate. Although there is no surface expression of the deposit, the extent of the deposit is fairly clear in sub-bottom profiles. Mining the filled channels is substantially more difficult than the surficial shoals. Any overburden would have to be removed or mixed with the more desirable channel fill. The lateral extent of the deposit is small relative to its length and the boundaries sharp.

Dredging requires careful mapping of the lateral and vertical limits of the deposit through seismic profiling and coring and careful control of the dredge.

The third type of sand deposit, a lenticular facies, is the most difficult to find. A portion of a bed may grade from sediments of unacceptable quality for use to acceptable quality and back to unacceptable. There is no surface expression of the deposit, the top of which could be buried or which could be the sea floor. There are no reliable indicators in the seismic records. This class of deposit is discovered serendipitously and only by coring. However once discovered and defined, again by coring, the process of mining is relatively easy. Changes in sediment type are apt to be gradual with the result that the limits of the area to be dredged are set arbitrarily on the basis of sedimentary characteristics determined by analysis of core samples.

In conclusion, the interaction of the Quaternary history of sea-level changes and low rates of deposition on the continental shelf of southern Virginia has resulted in a complex and vertically condensed stratigraphy. The distribution of grain-size characteristics of the surficial sediments provides some clues about the regional processes and geology but little definitive evidence. There are substantial quantities of sand available for use as beach fill or construction aggregate. Exploitable deposits occur in three different settings; each setting with its own set of attributes affecting the accessibility of the resource.

Table 3

Inner Shelf Sand Bodies

	Shoal	**Filled Channel**	**Gradational**
Visibility	On Surface	Buried	Buried
Lateral Limits	*	Sharp	Undefined
Top	Sea Floor	Varied	Varied
Bottom	Sharp	Usually Sharp	Varied
Seismic Definition	Good	Good	Poor
How Found	Bathymetry	Seismics Geology	Serendipity Geology (?)
How Proved	Coring through Bottom Reflector	Coring	Coring
Dredging	'Easy' Remove Shoal to Predetermined Depth	'Difficult Stay within Channel	'Very Easy' Stay within Broad Vertical and Horizontal Limits

REFERENCES CITED

Amato, R. V., 1994. Sand and Gravel Maps of the Atlantic Continental Shelf with Explanatory Text. U. S. Department of the Interior, Minerals Management Service, Office of International Activities and Marine Minerals, OCS Monograph MMS 93-0037, 35.

Berquist, C. R., Jr., 1986. Stratigraphy and Heavy Mineral Analysis in the lower Chesapeake Bay, Virginia. Unpub. Ph.D. Dissertation, School of Marine Science, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA, 105.

Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia Division of Mineral Resources, Charlottesville, 124.

Berquist, C. R., Jr., 1990. Chemical analyses of offshore heavy-mineral samples, Virginia inner continental shelf. 109-124 in Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia Division of Mineral Resources, Charlottesville, 124.

Berquist, C. R., Jr., C. T. Fischler, L. J. Calliari, S. M. Dydak, and S. A. Skrabal, 1990. Heavy-mineral concentrations in sediments of the Virginia inner continental shelf. 31-93 in Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia Division of Mineral Resources, Charlottesville, 124.

Berquist, C. R., Jr. and C. H. Hobbs, III, 1986. Assessment of Economic Heavy Minerals of the Virginia Inner Continental Shelf. Open-File Report 86-1, Virginia Division of Mineral Resources, Charlottesville. 17.

Berquist, C. R., Jr. and C. H. Hobbs, III, 1988a. Reconnaissance of Economic Heavy Minerals of the Virginia Inner continental Shelf. Open-File Report 88-1, Virginia Division of Mineral Resources, Charlottesville, 74.

Berquist, C. R., Jr. and C. H. Hobbs, III, 1988b. Study of Economic Heavy Minerals of the Virginia Inner Continental Shelf. Open-File Report 88-4, Virginia Division of Mineral Resources, Charlottesville, 149.

Berquist, C. R., and C. H. Hobbs, III, 1989. Heavy mineral potential of offshore Virginia. Marine Geology, 90:83-86.

Bloom, A. L. and N. Yonekura, 1985. Coastal terraces generated by sea level change and tectonic uplift 139-154 in Woldenberg, M. J. (ed.) Models in Geomorphology, Allen and Unwin, Inc., Winchester, Massachusetts. (cited in Toscano, 1992)

Calliari, L. J., C. T. Fischler, and C. R. Berquist, Jr., 1990. Heavy-mineral variability and provenance of the Virginia inner shelf and lower Chesapeake Bay. 95-107 in Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia Division of Mineral Resources, Charlottesville, 124.

Chen, Z.-Q., 1992. An Investigation of the Late Pleistocene Paleochannel Systems in the Continental Shelf, South of the Chesapeake Bay Mouth. Unpublished Master's Thesis, School of Marine Science, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA. 100 p.

Chen, Z.-Q., C. H. Hobbs, III, J. F. Wehmiller, and S. M. Kimball, 1995. Late Quaternary Paleochannel Systems on the continental Shelf, south of the Chesapeake Bay entrance. Journal of Coastal Research, 11(3):605-614.

Coastal Engineering Research Center, 1984. Shore Protection Manual. Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS

Colman, S. M. and J. P. Halka, 1989. Quaternary geology of the southern Maryland part of the Chesapeake Bay. U. S. Geological Survey Miscellaneous Field Investigations Map MF-1948-C.

Colman, S. M., J. P. Halka, C. H Hobbs, III, R. B. Mixon, and D. S. Foster, 1990. Ancient channels of the Susquehanna River beneath Chesapeake Bay and the Delmarva Peninsula. Geological Society of America Bulletin, 102:1268-1279.

Colman, S. M. and C. H. Hobbs, III, 1987. Quaternary geology of the southern Virginia part of the Chesapeake Bay. U. S. Geological Survey Miscellaneous Field Investigations Map MF-1948-A.

Colman, S. M. and C. H. Hobbs, III, 1988. Quaternary Geology of the Northern Virginia Part of the Chesapeake Bay. U. S. Geological Survey Miscellaneous Field Investigations Map MF-1948-B.

Colman, S. M. and R. B. Mixon, 1988. The record of major Quaternary sea-level changes in a large Coastal Plain estuary, Chesapeake Bay, eastern United States. Palaeogeography, Palaeoclimatology, Palaeoecology, 68:99-116.

Committee on Beach Nourishment and Protection, Marine Board, Commission on Engineering and Technical Systems, National Research Council, 1995. Beach Nourishment and Protection. National Academy Press, Washington, D.C., 334.

Dame, J. K. II, 1990, Origin of a Solitary Sand Shoal Offshore of Sandbridge Beach, Virginia. Unpublished Master's Thesis, College of William & Mary, School of Marine Science, Virginia Institute of Marine Science, Gloucester Point, Virginia, 94.

D'Olier, B., 1979. Side-scan sonar ad reflection seismic profiling. <u>In</u> Dyer , K. R. (Ed.) Estuarine Hydrography and Sedimentation, Cambridge University Press. (Cited in Williams, 1982.)

Duane, D. B. 1987. Marine placers: Reconnaissance exploration technology. 71-80 <u>in</u> Teleki, P.G. and others (eds.) Marine Minerals. D. Reidel Publishing Co.

Duane D. B. and W. L. Stubblefield, 1988. Sand and gravel resources: U. S. Atlantic continental shelf. 447-495 <u>in</u> Sheridan, R. E. and J. A. Grow (eds.), The Geology of North America, I-2, The Atlantic Continental Margin. Geological Society of America.

Dydak, S. M., 1991. The Hydraulic Sorting of Light and Heavy Minerals, Heavy-Mineral Concentrations, and Grain Size. Unpublished M. A. Thesis, School of Marine Science, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia, 90.

Fairbanks, R. G., 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting on the Younger Dryas event and deep ocean circulation. Nature, 32:637-647. (cited in Toscano, 1992)

Firek, F., 1975. Heavy Mineral Distribution in Lower Chesapeake Bay, Virginia. Unpublished M. S. thesis, Old Dominion University, Norfolk, Virginia, 147.

Firek, F., G. L. Shideler, and P. Fleischer, 1977. Heavy mineral variability in bottom sediments of the lower Chesapeake Bay, Virginia. Marine Geology, 23:217-235.

Flemming, B. W., 1976, Side-scan sonar: A practical guide. International Hydrographic Review, LIII(1). (Cited in Williams, 1982)

Folk, R. L., 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin, Texas, 182.

Foyle, A. M., 1994. Quaternary Seismic Stratigraphy of the Inner Shelf and Coastal Zone, Southern Delmarva Peninsula, Virginia. unpublished Ph.D. Dissertation, Old Dominion University, Norfolk, Virginia. 492.

Garnar, T. E., 1978. Geological classification and evaluation of heavy mineral deposits. Georgia Geological Survey Information Circular 49, 25-36.

Goodwin, B. K. and J. B. Thomas, 1973. Inner Shelf Sediments off Chesapeake Bay, III, Heavy Minerals. Special Report No. 68, Virginia Institute of Marine Science, Gloucester Point, Virginia, 34.

Grosz, A. E., C. R. Berquist, and C. T. Fischler, 1990. A procedure for assessing heavy-mineral resources potential of continental shelf sediments. 13-30 in Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia division of Mineral Resources, Charlottesville, 124.

Grosz, A. E. and E. C. Eskowitz, 1983. Economic heavy minerals of the U. S. Atlantic continental shelf. 231-242 in Tanner, W. F. (ed.) Proceedings of the Sixth Symposium on Coastal Sedimentology. Florida State University, Tallahassee, Florida.

Hardaway, C. S., C. H. Hobbs, III, and D. A. Milligan, 1995. Investigations of Offshore Beach Sands: Virginia Beach and Sandbridge, Virginia. Contract Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia. 16.

Harrison, W. R., J. J. Norcross, N. A. Pore, and E. M. Stanley, 1967. Circulation of shelf waters of the Chesapeake Bight, surface and bottom drift of continental shelf waters between Cape Henlopen, Delaware, and Cape Hatteras, North Carolina, June 1963-December 1964. ESSA Professional Paper 3, 82.

Hays, J. D., J. Imbrie, and N. J. Shakelton, 1976. Variations in the earth's orbit: Pacemaker of the ice ages. Science 1944(4270):1121-1132.

Hobbs, C. H., III, 1990. Acoustic geology of a portion of Virginia's innermost continental shelf. 1-11 _in_ Berquist, C. R., Jr., (ed.) Heavy-Mineral Studies, Virginia Inner Continental Shelf. Publication 103, Virginia Division of Mineral Resources, Charlottesville, 124.

Hobbs, C. H., III, 1996. Investigations of Isolated Sand Shoals and Associated Deposits Virginia Inner Shelf. Contract Report. Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia. 10.

Hobbs, C. H., III, S. M. Colman, and C. R. Berquist, Jr., 1986. Sandy estuarine fill transported into the mouth of Chesapeake Bay. 180-198 _in_ Tanner, W. F. (ed.), Suite Statistics and Sediment History: Proceedings 7th Symposium on Coastal Sedimentation. Florida State University, Tallahassee.

Hobbs, C. H., III and J. K. Dame, II, 1992. Very-high-resolution, seismic-reflection profiling and other acoustic techniques with examples from Virginia. 192-211 _in_ Geyer, R. A. (ed.) CRC Handbook of Geophysical Exploration at Sea, 2nd Edition, Hard Minerals. CRC Press, Boca Raton, Florida. 520.

Hobbs, C. H., III, J. P. Halka, R. T. Kerhin, and M. J. Carron, 1992. Chesapeake Bay Sediment Budget. Journal of Coastal Research, 8(2):292-300.

Hobson, R. D., 1977. Review of Design Elements for Beach-fill Evaluation. U. S. Army Corps of Engineering, Coastal Engineering Research Center, Technical Paper No. 77-6. 51.

Hollister, C. D ., 1973. Atlantic Continental Shelf and Slope of the United States - Texture of Surface Sediments from New Jersey to Southern Florida. U. S. Geological Survey Professional Paper 529-M, 23.

James, W. R., 1975. Techniques in Evaluation Suitability of Borrow material for Beach Nourishment. U. S. Army Corps of Engineering, Coastal Engineering Research Center, Technical Memorandum 60.

Johnson, G. H. and C. R. Berquist, Jr., 1989. Geology and Mineral Resources of the Brandon and Norge Quadrangles, Virginia. Publication 87, Virginia Division of Mineral Resources, Charlottesville, 28.

Johnson, G. H., P. C. Peebles, L. J. Otte, and B. J. Smith, 1985. the Late Cenozoic Geology of Southeastern Virginia and the Great Dismal Swamp. American Association of Petroleum Geologists Eastern Section, Field Trip 1, Guidebook, 68.

Kimball, S. M. and J. K. Dame, 1989. Geotechnical evaluation of sand resources on the inner shelf of southern Virginia. Final Report to the City of Virginia Beach in two volumes. Virginia Institute of marine Science, College of William & Mary, Gloucester Point, Virginia.

Kimball, S. M., J. K. Dame, II, and C. H. Hobbs, III, 1991. Investigation of Isolated Sand Shoals on the Inner Shelf of Southern Virginia. Project Report, Virginia Institute of Marine Science, School of Marine Science, College of William & Mary, Gloucester Point, Virginia, 73.

Li, W.-X., J. Lundberg, A. P. Dickin, D. C. Ford, H. P. Schwarcz, R. McNutt, and D. Williams, 1989. High-precision mass spectrometric uranium-series dating of cave deposits and implications for paleoclimatic studies. Nature, 339:534-536. (cited in Toscano, 1992)

Luepke, G. and A. E. Grosz, 1986. Distribution of economic heavy minerals in sediments of Saco Bay, Maine. U. S. Geological Survey Bulletin 1681, 12.

Martinson, D. G., N. G. Pisias, J. D. Hays, J. Imbrie, T. C. Moore, and J. J. Shackleton, 1987. Age dating and orbital theory of the ice ages: Development of a high-resolution o to 300,000-year chronostratigraphy. Quaternary Research, 27:1-29. (cited in Toscano, 1992)

Meisburger, E., 1990. Exploration and Sampling Methods for Borrow Areas. Waterways Experiment Station, Coastal Engineering Research Center, Technical Report CERC-90-18, 68.

Meade, R. H., 1969. Landward transport of bottom sediments in estuaries of the Atlantic Coastal Plain. Journal of Sedimentary Petrology, 41:222-234.

Meade, R. H., 1972. Transport and deposition of sediments in estuaries. 91-120 in Nelson, B. W. (ed) Environmental framework of coastal plain estuaries. Geological Society of America Memoir 133.

Meisburger, E. P., C. Judge, and S. J. Williams, 1989. Physiographic and geological setting of the coastal engineering research center's field research facility. Miscellaneous Paper CERC-89-9, U. S. Army Corps of Engineers, Waterways Experiment Station, 28.

Meisburger, E. P. and S. J. Williams, 1987. Later Quaternary stratigraphy and geological character of coastal and inner shelf sediments of northern North Carolina. 2141-2156 in Kraus, N. C. (ed.) Coastal Sediments '87, Volume II, American Society of Civil Engineers.

Milliman, J. D., 1972. Atlantic Continental Shelf and Slope of the United States - Petrology of the Sand Fraction of Sediments, Northern New Jersey to Southern Florida. U. S. Geological Survey Professional Paper 529-J, 40.

Milliman, J. D., O. H. Pilkey, and D. A. Ross, 1972. Sediments of the continental margin off the eastern United States. Geological Society of America Bulletin, 83(5):1315-1334.

Mirecki, J. E., J. F. Wehmiller, and A. F. Skinner, 1995. Geochronology of Quaternary coastal plain deposits, southeastern Virginia, U.S.A. Journal of Coastal Research, 11(4):1135-1144.

Mitchum, R. M., Jr. and J. C. Van Wagoner, 1991. High-frequency sequences and their stacking patterns: sequence-stratigraphic evidence of high-frequency eustatic cycles. Sedimentary Geology, 70:131-160.

Mixon, R. B., 1985. Stratigraphic and geomorphic framework of uppermost Cenozoic deposits in the southern Delmarva Peninsula, virginia and Maryland. U. s. Geological Survey Professional Paper 1067-G, 53.

Nichols, N. M., 1972. Inner Shelf Sediments off Chesapeake Bay, I, General Lithology and Composition. Special Scientific Report No. 64, Virginia Institute of Marine Science, Gloucester Point, Virginia, 20.

Norfolk District, U. S. Army Corps of Engineers, 1992. Beach Erosion Control and Hurricane Protection, Sandbridge Beach, Virginia Beach, Virginia, Draft Feasibility Report and Environmental Assessment.

North American Commission on Stratigraphic Nomenclature, 1983. North American Stratigraphic code. American Association of Petroleum Geologists bulletin, 67(5):841-875.

Oaks, R., Jr., 1964. Post-Miocene stratigraphy and morphology, outer coastal plain south-eastern Virginia. U. S. Office of Naval Research Technical Report 5, 241 p.

Oaks, R. Q., Jr., N. K. Coch, J. E. Sanders, and R. F. Flint, 1974. Post-Miocene shorelines and sea levels, southeastern Virginia. 53-87 in Oaks, R. Q., Jr. and J. R. DuBar, Post-Miocene Stratigraphy Central and Southern Atlantic Coastal Plain. Utah State University Press.

Oertel, G. F. and A. M. Foyle, 1995. Drainage displacement by sea-level fluctuation at the outer margin of the Chesapeake Seaway. Journal of Coastal Research, 11(3):583-604.

Ozalpasan, H., 1989. Distribution Analysis of Heavy Minerals on the Inner Continental Shelf of Virginia. Unpublished M. A. Thesis, School of Marine Science, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia, 83.

Poag, C. W., D. S. Powars, L. J. Poppe, and R. B. Mixon, 1994. Meteoroid mayhem in Ole Virginny: Source of the North American tektite strewn field. Geology, 22(8):691-694.

Prow, W., 1977. Evolution of the Virginia, North Carolina boundary. 8-1 - 8-7 in Goldsmith, V. (ed.) Coastal Processes and Resulting Forms of Sediment Accumulations: Currituck Spit, Virginia-North Carolina. Guidebook, Eastern Section, Society of Economic Paleontologists and Mineralogists and Special Report in Applied Marine Science and Ocean Engineering No. 143, Virginia Institute of Marine Science, Gloucester Point, Virginia.

Richards, H. G., 1967, Stratigraphy of the Atlantic coastal plain between Long Island and Georgia -- review. American Association of Petroleum Geologists Bulletin, 51:2400-2429.

Richards, H. G., 1974. Structural and stratigraphic framework of the Atlantic coastal plain in Oaks, R. Q., Jr. and J. R. duBar (eds.) Post-Miocene stratigraphy - central and southern Atlantic coastal plain. Utah State University Press, Logan, Utah, 11-20.

Richmond, G. M. And D. S. Fullerton, 1986. Introduction to Quaternary glaciations in the United States of America. Quaternary Science Reviews, 5:3-10.

Riggs, S. R., L. L. York, J. F. Wehmiller, and S. W. Snyder, 1992. Depositional patterns resulting from high-frequency quaternary sea-level fluctuations in northeastern North Carolina. 141-153 in Fletcher, C. H., III and J. F. Wehmiller (eds.) Quaternary Coasts of the United States: Marine and Lacustrine Systems. SEPM Special Publication 48, 450.

Shepard, F. P., 1932. Sediments of the continental shelves. Geological Society of America Bulletin, 43(12):1017-1040.

Shepard, F. P., 1954. Nomenclature based on sand-silt-clay ratios: an interim report. Journal of Sedimentary Petrology, 24:151-158.

Shideler, G. L. and D. J. P. Swift, 1972. Seismic reconnaissance of post-Miocene deposits, middle Atlantic continental shelf -- Cape Henry, Virginia to Cape Hatteras, North Carolina. Marine Geology, 12:165-185.

Shideler, G. L., D. J. P. Swift, G. H. Johnson, and B. W. Holliday, 1972, Late Quaternary stratigraphy of the inner Virginia continental shelf; a proposed standard section. Geological Society of America Bulletin, 83(6):1787-1804.

Snyder, S. W., 1993. North Carolina Outer Banks Beach Nourishment Sand Resource Study, First Interim Report: Shallow, High-Resolution Seismic Survey, Offshore Nags Head Area. Open-File Report 93-38, North Carolina Geological Survey, Raleigh. 47.

Swift, D. J. P., 1975. Tidal sand ridges and shoal-retreat massifs. Marine Geology, 18:105-134.

Swift, D. J. P., C. E. Dill, Jr., and J. McHone. 1971. Hydraulic fractionation of heavy mineral suites on an unconsolidated retreating coast. Journal of Sedimentary Petrology, 41(3):683-690.

Swift, D. J. P., D. B. Duane, and T. McKinney. 1974. Ridge and swale topography of the middle Atlantic bight: Secular response to Holocene hydraulic regime. Marine Geology, 15:227-247.

Swift, D. J. P., B. Holliday, N. Avignone, and G. Shideler. 1972a. Anatomy of a shore face ridge system, False Cape, Virginia. Marine Geology, 12:59-84.

Swift, D. J. P., J. W. Kofoed, F. P. Saulsbury, and P. Sears. 1972b. Holocene evolution of the shelf surface, central and southern shelf of North America, in Swift, D. J. P., D. B. Duane, and O. H. Pilkey (eds.), Shelf Sediment Transport Processes and Pattern. Dation, Hutchinson and Ross. Stroudsburg, Pennsylvania. 499-574.

Swift, D. J. P., T. Nelsen, J. McHone, B. Holliday, H., Palmer, and G. Shideler. 1977. Holocene evolution of the inner shelf of southern Virginia. Journal of Sedimentary Petrology, 47(4):1454-1474.

Swift, D. J. P., G. L. Shideler, N.F. Avignone, B. W. Holliday, and C.E. Dill, Jr. 1970. Quaternary sedimentation on the inner Atlantic shelf between Cape Henry and Cape Hatteras: A preliminary report. Maritime Sediments, 6:5-11.

Toscano, M. A., 1992. Record of oxygen isotope Stage 5 on the Maryland inner shelf and Atlantic coastal plain, a post-transgressive-highstand regime. 89-99 in Fletcher, C. H., III and J. F. Wehmiller (eds.) Quaternary Coasts of the United States: Marine and Lacustrine Systems, SEPM Special Publication 48, 450.

Toscano, M. A., R. T. Kerhin, L. L. York, T. M. Cronin, and S. J. Williams, 1989. Quaternary Stratigraphy of the Inner Continental Shelf of Maryland, Report of Investigations No. 5, Maryland Geological Survey, Baltimore, Maryland. 116.

Toscano, M. A., and L. L. York, 1992. Quaternary stratigraphy and sea-level history of the U. S. Middle Atlantic Coastal Plain. Quaternary Science Reviews, 11:301-328.

Uchupi, E., 1970. Atlantic Continental Shelf and Slope of the United States - Shallow Structure. U. S. Geological Survey Professional Paper 529-I, 44.

Waterway Surveys & engineering Ltd., 1986. Engineering Study for disposal of Dredged Material from Atlantic Ocean Channel on sandbridge Beach Between Back Bay and Dam Neck. Final Report prepared for Dredging Management Branch, Norfolk District, U. S. Army Corps of Engineers, 79 p. plus appendices.

Williams, S. J., 1982. Use of High resolution Seismic reflection and Side-Scan Sonar Equipment for Offshore Surveys. U. S. Army Corps of Engineers, Coastal Engineering Research Center Tech Aid 82-05, 22.

Wright, L. D., 1995. Morphodynamics of Inner Continental Shelves. CRC Press, Inc. Boca Raton, Florida. 241

Wright, L. D., D. B. Prior, C. H. Hobbs, III, R. J. Byrne, J. D. Boon, L. C. Schaffner, and M. O. Green, 1987. Spatial variability of bottom types in the lower Chesapeake Bay and adjoining estuaries and inner shelf. Estuarine, Coastal and Shelf Science, 24:765-784.

Wright, L. D., C. S. Kim, C. S. Hardaway, S. M. Kimball, and M. O. Green, 1987. Shoreface and Beach Dynamics of the Coastal Region from Cape Henry to False Cape, Virginia. Technical Report, Virginia Institute of Marine Science, Gloucester Point, Virginia, 116

APPENDIX 1

Position and Grain Size Data of the Surficial Samples

Latitude and Longitude are in Degrees and Minutes, NAD 83, as determined by the ship's GPS.

Depth is the uncorrected depth in feet displayed by the ship's fathometer at the sample site.

% Gravel, Sand, Silt, Clay, Gravel + Sand, and Mud are weight percents.

Mud is silt + clay.

Mz is the Graphic Mean

Md is the Median

Incl Graph St Dev is the Inclusive Graphic Standard Deviation

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	1	37 0.10	76 0.17	-32	0.1	95.0	1.9
SVG	2	36 59.00	76 0.06	-46	0.2	93.0	3.2
SVG	3	36 59.10	75 58.05	-36	0.1	97.6	0.6
SVG	4	37 0.00	75 55.98	-32	6.8	91.3	0.0
SVG	5	36 59.10	75 54.00	-32	0.3	96.9	0.7
SVG	6	37 0.00	75 51.99	-37	0.1	94.3	2.0
SVG	7	36 59.00	75 49.97	-41	0.8	94.1	2.3
SVG	8	37 0.00	75 47.99	-46	0.1	92.5	3.7
SVG	9	36 59.10	75 45.95		0.2	93.2	3.0
SVG	10	37 0.00	75 43.92	-46	0.2	95.6	0.3
SVG	11	36 59.00	75 41.65	-56	0.1	94.4	2.3
SVG	12	36 58.00	75 43.91	-50	0.5	96.2	1.1
SVG	13	36 57.00	75 45.96	-47	2.8	93.2	0.9
SVG	14	36 56.00	75 47.93	-42	0.0	93.3	2.9
SVG	15	36 56.00	75 47.93	-42	0.0	93.1	2.7
SVG	16	36 55.00	75 49.97	-39	0.2	93.7	2.3
SVG	17	36 54.00	75 51.92	-33	0.0	95.6	1.5
SVG	18	36 52.90	75 53.97	-48	1.4	95.1	0.8
SVG	19	36 51.90	75 55.94	-33	0.0	82.6	10.5
SVG	20	36 50.00	75 35.95	-29	0.1	92.6	4.6
SVG	21	36 47.00	75 53.92	-39	0.2	86.8	8.7
SVG	22	36 46.00	75 51.96	-39	1.7	96.7	0.3
SVG	23	36 45.00	75 49.90	-46	0.7	98.0	0.4
SVG	24	36 44.00	75 47.98	-49	5.7	92.1	0.6
SVG	25	36 43.00	75 45.92	-46	13.0	85.3	0.0
SVG	26	36 42.00	75 43.92	-67	0.4	90.8	4.6
SVG	27	36 41.00	75 42.01	-54	1.1	97.3	0.4
SVG	28	36 40.00	75 40.04	-59	3.6	94.7	0.3
SVG	29	36 39.10	75 39.96	-55	1.3	97.2	0.2
SVG	30	36 38.10	75 36.04	-66	0.7	98.5	0.2
SVG	31	36 37.00	75 34.09	-71	0.0	98.8	0.0
SVG	32	36 36.10	75 32.07	-75	0.1	97.2	0.1
SVG	33	36 35.00	75 30.08	-77	0.0	97.5	0.7
SVG	34	36 34.00	75 27.99	-61	0.8	97.6	0.3
SVG	35	36 33.00	75 26.04	-67	0.0	98.4	0.7
SVG	36	36 32.00	75 24.05	-106	0.0	93.7	3.5
SVG	37	36 32.10	75 24.07	-106	0.3	94.5	1.4
SVG	38	36 31.00	75 22.03	-80	1.3	96.7	0.1
SVG	39	36 30.00	75 20.06	-94	2.0	95.7	0.4
SVG	40	36 30.00	75 15.95	-92	1.5	95.0	2.5
SVG	41	36 31.00	75 13.95	-87	9.8	87.4	0.1
SVG	42	36 32.00	75 15.98	-100	0.4	97.3	0.1
SVG	43	36 33.00	75 17.97	-79	0.6	97.6	0.1
SVG	44	36 34.00	75 20.01	-106	0.1	96.8	2.1
SVG	45	36 35.00	75 21.97	-86	1.4	96.3	0.0
SVG	46	36 36.00	75 24.00	-61	1.4	96.7	0.3

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	47	36 37.00	75 25.96	-72	2.2	95.8	0.3
SVG	48	36 38.00	75 27.96	-63	1.0	95.5	2.1
SVG	49	36 38.90	75 30.01	-62	0.9	96.9	0.1
SVG	50	36 40.00	75 31.99	-52	0.6	97.3	0.1
SVG	51	36 41.00	75 34.03	-59	2.5	95.4	0.2
SVG	52	36 42.00	75 36.10	-72	0.4	95.5	1.3
SVG	53	36 43.00	75 38.04	-65	1.6	95.9	0.0
SVG	54	36 43.00	75 38.04	-65	3.6	93.8	0.1
SVG	55	36 44.00	75 40.13	-66	53.0	43.7	1.9
SVG	56	36 45.00	75 42.06	-64	0.3	92.0	5.2
SVG	57	36 46.00	75 44.05	-59	3.6	92.4	3.2
SVG	58	36 49.90	75 54.03	-31	7.9	88.9	2.2
SVG	59	36 49.00	75 54.02	-34	0.7	96.1	2.0
SVG	60	36 51.00	75 54.07	-37	0.6	95.6	2.3
SVG	61	36 50.10	75 52.07	-48	0.2	92.3	4.1
SVG	62	36 49.00	75 50.07	-50	0.0	92.5	4.8
SVG	63	36 48.00	75 48.05	-57	13.7	84.2	0.7
SVG	64	36 47.00	75 46.04	-57	5.3	93.2	0.1
SVG	65	36 46.00	75 44.09	-56	18.2	80.9	0.0
SVG	66	36 47.00	75 42.00	-58	7.1	90.9	0.8
SVG	67	36 48.00	75 40.05	-44	3.6	94.6	0.3
SVG	68	36 49.00	75 38.05	-72	3.2	92.4	1.5
SVG	69	36 50.00	75 36.05	-56	12.4	85.2	0.0
SVG	70	36 51.00	75 34.00	-56	1.4	96.0	0.0
SVG	71	36 52.00	75 32.01	-76	21.8	75.1	0.1
SVG	72	36 53.00	75 30.03	-78			
SVG	73	36 54.00	75 28.03	-79	0.5	96.6	0.1
SVG	74	36 55.00	75 26.02	-88	0.0	94.7	0.5
SVG	75	36 56.00	75 24.03	-86	0.0	97.0	0.0
SVG	76	36 57.00	75 22.03	-92	3.1	93.6	0.2
SVG	77	36 58.00	75 20.02	-96	0.3	95.5	0.0
SVG	78	36 59.00	75 18.04	-96	5.2	92.1	0.5
SVG	79	36 59.00	75 18.04	-96	11.7	85.5	0.0
SVG	80	37 0.00	75 16.01	-105	0.1	94.7	0.5
SVG	81	37 0.00	75 20.01	-90	37.4	59.7	0.3
SVG	82	36 58.90	75 22.11	-100	2.9	95.3	0.4
SVG	83	36 58.00	75 24.05	-82	10.9	87.3	0.2
SVG	84	36 56.90	75 25.98	-82	5.9	92.2	0.4
SVG	85	36 56.00	75 28.03	-87	0.2	97.6	0.6
SVG	86	36 55.00	75 30.11	-74	3.1	95.1	0.6
SVG	87	36 54.00	75 31.98	-73	0.0	97.0	0.9
SVG	88	36 53.00	75 34.03	-60	2.7	95.2	0.5
SVG	89	36 51.90	75 36.01	-52	0.1	97.6	0.6
SVG	90	36 51.00	75 37.98	-62	0.2	97.7	0.5
SVG	91	36 49.10	75 57.02	-30	0.0	92.8	4.9
SVG	92	36 48.10	75 57.04	-31	1.5	91.9	4.0

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	93	36 47.10	75 57.04	-29	0.1	94.9	2.7
SVG	94	36 46.10	75 56.84	-23	0.1	95.7	2.4
SVG	95	36 46.00	75 56.02	-32	0.0	92.9	3.9
SVG	96	36 45.10	75 56.03	-32	0.0	92.5	4.5
SVG	97	36 44.10	75 56.02	-26	0.0	96.2	1.8
SVG	98	36 43.10	75 55.08	-34	0.2	92.4	4.0
SVG	99	36 43.10	75 53.99	-39	0.0	97.0	1.4
SVG	100	36 42.00	75 55.04	-30	0.2	92.7	4.2
SVG	101	36 41.00	75 54.86	-21	0.2	95.5	2.6
SVG	102	36 41.00	75 54.08	-34	0.0	91.9	5.5
SVG	103	36 40.00	75 54.05	-24	0.0	98.3	0.3
SVG	104	36 39.00	75 53.72	-16	0.0	98.3	0.5
SVG	105	36 38.10	75 53.11	-18	0.0	98.3	0.2
SVG	106	36 38.10	75 53.11	-18	0.0	98.1	0.4
SVG	107	36 38.00	75 52.07	-33	3.3	94.6	0.5
SVG	108	36 37.00	75 52.71	-19	0.0	92.9	3.5
SVG	109	36 36.10	75 52.09	-30	4.3	90.1	2.4
SVG	110	36 35.00	75 52.00	-27	1.2	11.2	53.3
SVG	111	36 34.00	75 51.94	-16	0.2	94.4	2.2
SVG	112	36 33.00	75 51.81	-12	0.1	96.0	0.9
SVG	113	36 32.10	75 51.13	-23	0.0	91.3	5.0
SVG	114	36 31.10	75 51.04	-23	0.0	91.0	5.2
SVG	115	36 30.00	75 50.97	-18	0.0	96.6	1.0
SVG	116	36 31.00	75 50.05	-33	1.3	95.8	0.7
SVG	117	36 32.90	75 50.08	-36	0.0	95.1	3.0
SVG	118	36 34.90	75 50.12	-38	0.2	97.8	0.6
SVG	119	36 37.00	75 50.07	-37	3.8	93.8	0.5
SVG	120	36 39.00	75 50.09	-47	5.8	91.2	0.6
SVG	121	36 40.00	75 52.00	-40	14.5	83.8	0.1
SVG	122	36 42.00	75 52.12	-41	14.2	83.7	0.4
SVG	123	36 43.90	75 52.10	-44	0.2	91.9	5.5
SVG	124	36 45.00	75 54.00	-37	0.0	87.4	8.8
SVG	125	36 48.00	75 56.09	-27	0.4	93.3	3.8
SVG	126	36 48.00	75 56.12	-27	1.6	92.7	3.1
SVG	127	36 48.00	75 52.10	-48	14.5	82.9	0.8
SVG	128	36 47.00	75 50.10	-38	14.9	84.1	0.2
SVG	129	36 46.00	75 48.10	-53	20.2	77.8	0.3
SVG	130	36 45.00	75 46.00	-52	6.5	91.9	0.2
SVG	131	36 44.00	75 44.10	-66	1.1	83.3	7.1
SVG	132	36 43.00	75 42.04	-57	0.4	97.3	0.6
SVG	133	36 42.10	75 40.02	-54	1.1	96.9	0.3
SVG	134	36 41.10	75 38.10	-60	0.4	97.8	0.3
SVG	135	36 40.00	75 36.00	-61	2.7	95.7	0.2
SVG	136	36 39.00	75 34.10	-61	0.5	97.9	0.4
SVG	137	36 38.00	75 32.10	-60	0.0	98.8	0.1
SVG	138	36 40.90	75 30.10	-60	0.9	97.4	0.4

Samp #	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG 139	36 41.90	75 28.10	-91	0.7	49.0	31.2
SVG 140	36 43.90	75 28.10	-90	0.5	95.2	1.4
SVG 141	36 44.90	75 30.10	-64	11.1	87.8	0.1
SVG 142	36 45.90	75 32.10	-66	1.0	97.4	0.1
SVG 143	36 46.90	75 34.10	-75	27.0	67.7	2.1
SVG 144	36 48.00	75 36.10	-71	1.4	93.7	1.5
SVG 145	36 50.00	75 40.10	-61	8.1	90.4	0.2
SVG 146	36 50.00	75 40.00	-61	0.3	98.1	0.3
SVG 147	36 48.90	75 42.00	-59	5.8	93.1	0.2
SVG 148	36 48.00	75 44.10	-65	0.6	95.6	1.3
SVG 149	36 48.90	75 46.10	-64	0.3	78.5	10.4
SVG 150	36 50.00	75 48.10	-55	0.7	96.7	0.5
SVG 151	36 51.00	75 50.04	-53	0.0	97.2	0.7
SVG 152	36 53.00	75 50.10	-44	0.2	95.7	2.1
SVG 153	36 52.00	75 52.06	-52	0.9	97.7	0.3
SVG 154	36 56.00	75 52.10	-38	0.1	96.2	1.4
SVG 155	36 55.10	75 54.00	-45	0.0	96.7	1.1
SVG 156	36 54.10	75 56.01	-41	1.5	94.1	2.0
SVG 157	36 53.10	75 57.96	-24	0.8	90.1	5.9
SVG 158	36 52.10	75 58.01	-26	0.0	93.0	3.9
SVG 159	36 51.20	75 58.01	-27	0.0	91.8	4.2
SVG 160	36 54.00	75 48.06	-48	0.0	94.4	2.3
SVG 161	36 55.00	75 46.03	-52	0.0	96.0	1.9
SVG 162	36 56.00	75 44.06	-51	0.1	97.7	0.4
SVG 163	36 57.00	75 42.04	-50	0.1	97.8	0.2
SVG 164	36 58.00	75 40.06	-56	40.4	58.0	0.2
SVG 165	37 0.00	75 40.00	-62	14.4	83.8	0.1
SVG 166	36 59.00	75 38.05	-73	29.9	68.5	0.3
SVG 167	37 0.00	75 35.97	-73	0.3	97.8	0.1
SVG 168	36 59.00	75 34.01	-79	4.1	93.9	0.3
SVG 169	36 59.90	75 32.01	-79	0.0	95.4	1.0
SVG 170	36 58.90	75 29.98	-77	8.2	89.5	0.1
SVG 171	36 59.90	75 28.01	-89	3.5	93.4	0.4
SVG 172	36 59.90	75 28.01	-89	0.2	95.3	1.1
SVG 173	36 58.90	75 26.07	-84	0.7	94.3	0.6
SVG 174	36 59.90	75 23.96	-83	0.9	96.9	0.2
SVG 175	36 56.90	75 18.01	-93	2.5	95.4	0.3
SVG 176	36 55.00	75 17.99	-84	3.0	94.8	0.1
SVG 177	36 55.90	75 15.96	-103	2.2	95.0	0.0
SVG 178	36 57.90	75 15.92	-91	1.4	96.9	0.3
SVG 179	36 57.00	75 13.96	-102	1.1	96.0	0.3
SVG 180	36 57.00	75 13.96	-122	0.4	93.7	1.2
SVG 181	36 55.00	75 13.96	-109	12.9	84.3	0.4
SVG 182	36 53.90	75 15.99	-103	1.6	96.2	0.2
SVG 183	36 52.90	75 18.03	-98	13.8	84.2	0.1
SVG 184	36 51.90	75 20.01	-90	0.0	97.3	0.3

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	185	36 50.90	75 21.93	-82	13.4	85.0	0.2
SVG	186	36 49.90	75 24.00	-88	3.4	94.3	0.4
SVG	187	36 48.90	75 25.98	-74	4.5	93.3	0.4
SVG	188	36 48.90	75 25.98	-74	9.5	88.7	0.0
SVG	189	36 47.90	75 28.00	-67	14.1	84.3	0.2
SVG	190	36 47.00	75 30.00	-67	5.3	93.2	0.1
SVG	191	36 47.90	75 31.99	-67	8.4	90.0	0.3
SVG	192	36 49.00	75 34.04	-75	2.4	97.5	0.1
SVG	193	36 50.00	75 44.13	-63	0.7	96.8	2.3
SVG	194	36 58.00	75 56.00	-28	0.1	99.2	0.5
SVG	195	36 57.00	75 54.06	-37	0.0	81.0	12.7
SVG	196	36 58.00	75 51.96	-36	0.1	98.3	1.0
SVG	197	36 57.10	75 50.10	-40	0.0	99.2	0.7
SVG	198	36 58.00	75 48.04	-45	4.5	94.2	0.8
SVG	199	36 54.20	75 44.09	-67	0.0	94.6	3.2
SVG	200	36 53.00	75 46.02	-57	0.0	99.6	0.4
SVG	201	36 52.10	75 47.96	-60	0.0	98.9	0.5
SVG	202	36 46.00	75 39.95	-74	2.2	96.2	1.6
SVG	203	36 46.90	75 38.15	-64	7.0	92.2	0.3
SVG	204	36 46.00	75 36.14	-66	64.3	35.1	0.3
SVG	205	36 45.00	75 34.15	-77	1.3	95.9	0.8
SVG	206	36 44.00	75 32.04	-67	0.5	98.3	0.3
SVG	207	36 43.00	75 30.10	-71	43.2	55.7	0.4
SVG	208	36 42.90	75 26.10	-68	6.7	92.4	0.2
SVG	209	36 44.90	75 26.05	-81	27.1	66.2	5.1
SVG	210	36 45.90	75 27.90	-76	3.2	95.6	0.5
SVG	211	36 46.90	75 26.07	-77	2.6	95.4	0.2
SVG	212	36 46.00	75 24.09	-81	0.3	98.7	0.2
SVG	213	36 46.90	75 22.01	-78	0.4	98.4	0.3
SVG	214	36 46.90	75 22.01	-78	0.7	98.8	0.3
SVG	215	36 48.00	75 24.05	-77	3.5	95.2	0.2
SVG	216	36 48.90	75 22.04	-76	5.5	93.4	0.2
SVG	217	36 48.00	75 20.14	-78	2.1	96.3	0.7
SVG	218	36 50.10	75 19.98	-81	0.0	98.8	0.3
SVG	219	36 48.90	75 17.93	-89	8.1	89.9	0.5
SVG	220	36 50.90	75 17.94	-95	21.9	77.7	0.1
SVG	221	36 51.90	75 16.04	-94	3.0	95.4	0.3
SVG	222	36 52.90	75 14.07	-94	4.3	93.8	0.1
SVG	223	36 50.90	75 13.97	-94	0.1	98.3	1.4
SVG	224	36 49.90	75 15.94	-89	1.3	97.2	0.1
SVG	225	36 48.80	75 14.10	-84	1.3	96.9	0.4
SVG	226	36 48.00	75 15.91	-95	0.0	67.4	10.7
SVG	227	36 47.00	75 14.10	-88	0.1	99.1	0.5
SVG	228	36 46.00	75 15.95	-99	0.7	97.2	1.5
SVG	229	36 46.90	75 17.93	-89	0.3	98.1	1.2
SVG	230	36 46.00	75 19.98	-89	1.7	96.8	1.3

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	231	36 45.00	75 18.06	-69	5.4	94.3	0.3
SVG	232	36 44.00	75 16.09	-97	1.4	97.3	0.1
SVG	233	36 44.90	75 14.07	-63	0.9	97.3	0.3
SVG	234	36 43.00	75 14.11	-126	0.1	96.9	2.3
SVG	235	36 43.00	75 14.11	-126	0.0	99.5	0.4
SVG	236	36 41.00	75 14.00	-111	34.9	63.4	1.0
SVG	237	36 41.90	75 16.03	-65	2.6	96.4	0.0
SVG	238	36 42.90	75 17.99	-59	4.3	94.7	0.4
SVG	239	36 43.90	75 19.97	-56	0.5	98.4	0.4
SVG	240	36 44.90	75 21.97	-69	0.1	97.8	0.6
SVG	241	36 44.00	75 23.90	-72	0.2	98.0	0.7
SVG	242	36 43.00	75 22.11	-68	5.0	92.8	1.5
SVG	243	36 42.00	75 24.00	-73	1.1	97.8	0.6
SVG	244	36 41.00	75 25.97	-68	1.2	97.3	0.7
SVG	245	36 40.00	75 27.97	-85	0.4	95.9	0.7
SVG	246	36 41.90	75 32.09	-58	16.7	82.4	0.0
SVG	247	36 42.90	75 34.03	-63	0.4	96.0	1.2
SVG	248	36 44.00	75 36.02	-76	0.2	97.1	0.6
SVG	249	36 44.90	75 38.01	-68	7.8	90.4	0.6
SVG	250	36 42.90	75 50.09	-51	0.1	93.7	3.7
SVG	251	36 42.00	75 48.19	-49	0.2	97.6	1.3
SVG	252	36 41.00	75 46.23	-64	0.1	82.9	11.9
SVG	253	36 40.00	75 44.09	-49	0.0	99.2	0.1
SVG	254	36 39.00	75 42.12	-63	0.7	98.1	0.1
SVG	255	36 38.00	75 40.90	-61	1.0	96.9	0.9
SVG	256	36 38.00	75 40.19	-61	0.3	96.6	1.8
SVG	257	36 37.00	75 38.14	-64	1.0	98.8	0.2
SVG	258	36 36.00	75 36.12	-61	0.7	94.1	2.2
SVG	259	36 35.00	75 34.03	-82	3.7	91.1	3.4
SVG	260	36 33.90	75 32.12	-81	3.7	87.4	8.5
SVG	261	36 33.00	75 32.11	-81	0.4	92.9	4.2
SVG	262	36 32.10	75 32.10	-82	4.5	90.1	5.3
SVG	263	36 33.00	75 30.14	-82	0.3	93.8	3.4
SVG	264	36 36.90	75 30.06	-69	1.6	91.7	4.4
SVG	265	36 36.00	75 28.06	-60	1.1	95.0	1.6
SVG	266	36 35.00	75 26.09	-61	2.5	92.4	2.7
SVG	267	36 34.00	75 24.03	-102	0.3	91.1	4.2
SVG	268	36 33.00	75 22.12	-87	0.2	97.5	0.8
SVG	269	36 32.00	75 20.15	-105	0.2	94.5	2.6
SVG	270	36 31.00	75 18.02	-70	0.7	96.6	0.5
SVG	271	36 34.90	75 17.79	-113	4.4	89.5	3.1
SVG	272	36 36.90	75 18.02	-113	3.7	89.1	3.9
SVG	273	36 38.90	75 17.98	-103	0.0	93.0	3.3
SVG	274	36 41.00	75 17.93	-81	1.7	96.5	0.7
SVG	275	36 40.00	75 16.06	-101	0.0	92.8	2.3

Samp #	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG 276	36 39.00	75 14.04	-83	1.1	92.6	2.8
SVG 277	36 39.00	75 14.04	-83	0.8	93.6	5.6
SVG 278	36 37.90	75 15.99	-100	0.2	94.9	0.8
SVG 279	36 37.00	75 14.04	-90	0.1	92.6	7.1
SVG 280	36 36.00	75 15.97	-83	7.9	86.0	4.5
SVG 281	36 35.00	75 14.07	-82	0.8	98.2	0.2
SVG 282	36 34.00	75 15.98	-95	0.1	94.6	5.2
SVG 283	36 33.00	75 14.03	-93	2.7	96.6	0.5
SVG 284	36 35.90	75 20.02	-107	0.0	91.6	4.8
SVG 285	36 36.90	75 22.03	-97	0.8	94.7	3.0
SVG 286	36 37.90	75 20.12	-101	7.6	52.5	28.1
SVG 287	36 38.90	75 21.98	-70	25.0	74.0	0.3
SVG 288	36 40.00	75 20.06	-107	0.6	87.4	5.7
SVG 289	36 41.90	75 20.02	-69	1.6	96.1	1.9
SVG 290	36 41.00	75 21.95	-70	0.1	95.8	0.9
SVG 291	36 40.00	75 23.97	-70	0.4	99.4	0.1
SVG 292	36 39.00	75 26.01	-69	1.0	96.4	1.7
SVG 293	36 38.00	75 24.10	-67	3.9	95.6	0.2
SVG 294	36 30.00	75 24.10	-74	0.0	98.7	0.4
SVG 295	36 30.90	75 26.02	-84	0.2	95.3	4.3
SVG 296	36 30.00	75 28.01	-93	0.5	90.5	3.9
SVG 297	36 31.90	75 28.05	-90	0.2	92.3	0.0
SVG 298	36 31.90	75 28.05	-90	0.4	90.6	2.9
SVG 299	36 30.90	75 30.05	-90	0.9	78.8	9.9
SVG 300	36 30.00	75 32.04	-68	0.2	98.2	0.6
SVG 301	36 31.00	75 34.04	-81	0.2	97.1	2.4
SVG 302	36 32.90	75 34.02	-73	0.0	98.4	0.1
SVG 303	36 33.90	75 36.05	-73	0.7	97.1	0.3
SVG 304	36 32.00	75 36.01	-82	0.2	94.6	0.8
SVG 305	36 30.00	75 36.08	-88	0.4	87.1	3.4
SVG 306	36 31.00	75 38.01	-83	0.4	92.7	6.2
SVG 307	36 32.90	75 38.05	-78	0.1	94.1	2.8
SVG 308	36 35.00	75 38.04	-72	0.2	94.9	2.5
SVG 309	36 36.00	75 39.97	-70	0.3	95.0	2.1
SVG 310	36 37.00	75 41.98	-53	0.0	96.2	2.8
SVG 311	36 38.00	75 44.03	-62	0.4	97.7	1.1
SVG 312	36 39.00	75 46.01	-65	8.2	87.7	1.2
SVG 313	36 40.00	75 48.02	-56	0.0	97.1	0.5
SVG 314	36 41.00	75 49.99	-55	0.0	96.7	1.2
SVG 315	36 38.00	75 48.10	-55	23.8	74.7	0.2
SVG 316	36 37.00	75 46.08	-66	23.6	72.9	1.2
SVG 317	36 36.00	75 44.07	-66	0.0	95.8	0.4
SVG 318	36 35.00	75 42.12	-67	0.0	94.5	1.1
SVG 319	36 35.00	75 42.12	-67	0.0	96.4	0.8
SVG 320	36 34.00	75 40.11	-71	0.0	92.5	2.3
SVG 321	36 32.10	75 40.09	-66	0.0	97.6	0.1

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	322	36 32.90	75 41.93	-61	0.0	95.5	0.5
SVG	323	36 34.00	75 43.97	-68	0.5	95.5	0.5
SVG	324	36 35.00	75 46.07	-68	0.5	95.6	0.7
SVG	325	36 56.00	75 19.98	-68	37.0	61.2	1.5
SVG	326	36 54.00	75 20.00	-96	12.8	85.1	0.1
SVG	327	36 53.00	75 22.01	-85	7.4	90.5	0.3
SVG	328	36 52.00	75 24.00	-101	0.0	93.4	0.8
SVG	329	36 51.00	75 26.01	-79	3.6	92.9	0.1
SVG	330	36 50.00	75 27.99	-76	0.0	96.9	0.0
SVG	331	36 50.00	75 27.95	-68	11.8	85.5	0.1
SVG	332	36 49.00	75 29.99	-68	11.2	86.4	0.1
SVG	333	36 50.00	75 32.00	-69	12.0	82.9	0.9
SVG	334	36 51.00	75 30.00	-87	14.9	80.1	1.0
SVG	335	36 52.00	75 27.99	-83	13.6	84.0	0.1
SVG	336	36 53.00	75 26.00	-95	0.0	96.8	0.1
SVG	337	36 54.00	75 23.99	-82	0.0	97.6	0.1
SVG	338	36 55.00	75 22.00	-95	0.0	97.1	0.1
SVG	339	36 58.00	75 27.99	-86	2.5	95.5	1.9
SVG	340	36 57.00	75 29.99	-79	0.0	98.1	0.0
SVG	341	36 56.00	75 32.00	-87	5.6	92.3	0.0
SVG	342	36 55.00	75 34.00	-69	0.0	99.3	0.0
SVG	343	36 54.00	75 36.00	-72	43.2	55.5	0.4
SVG	344	36 53.00	75 38.01	-76	18.5	79.9	0.3
SVG	345	36 52.00	75 39.98	-70	1.6	96.8	0.1
SVG	346	36 51.00	75 42.00	-67	13.8	84.5	0.2
SVG	347	36 51.00	75 46.00	-70	0.0	96.9	0.0
SVG	348	36 52.00	75 44.00	-62	0.0	97.4	0.1
SVG	349	36 53.00	75 42.00	-70	0.0	93.6	2.9
SVG	350	36 54.00	75 40.00	-69	0.0	94.4	1.4
SVG	351	36 36.00	75 47.99	-71	0.0	95.3	1.0
SVG	352	36 34.00	75 47.99	-48	0.9	97.6	0.2
SVG	353	36 33.00	75 46.00	-48	0.0	96.5	0.5
SVG	354	36 32.00	75 44.00	-62	26.5	68.8	2.3
SVG	355	36 31.00	75 41.99	-59	0.0	97.9	0.2
SVG	356	36 30.00	75 40.00	-71	0.0	96.6	0.5
SVG	357	36 30.00	75 44.00	-77	0.0	91.3	2.9
SVG	358	36 31.00	75 45.99	-59	0.0	97.9	0.2
SVG	359	36 30.00	75 45.99	-44	0.0	90.5	0.4
SVG	360	36 32.00	75 48.00	-44	0.0	98.0	0.2
SVG	361	36 30.00	75 48.00	-48	0.0	92.6	3.6
SVG	362	36 39.00	75 38.00	-50	0.0	89.4	5.5
SVG	363	36 35.00	75 38.00	-53	0.4	97.5	0.5
SVG	364	36 56.00	75 36.00	-68	0.0	93.8	1.4
SVG	365	36 57.00	75 34.00	-57	11.7	86.3	0.6
SVG	366	36 58.00	75 32.00	-79	2.2	93.7	0.5
SVG	367	36 58.00	75 36.00	-76	0.7	95.5	1.0

Samp	#	Latitude	Longitude	Depth ft	Grvl %	Sand %	Silt %
SVG	368	36 57.00	75 38.00	-66	4.4	81.3	12.4
SVG	369	36 56.00	75 40.00	-63	0.0	95.4	1.9
SVG	370	36 55.00	75 41.97	-59	20.6	77.0	0.8
SVG	371	36 50.00	75 56.00	-30	0.0	92.1	5.0
SVG	372	36 50.00	75 56.01	-30	0.0	92.4	4.8
SVG	373	36 50.00	75 57.98	-12	0.0	97.9	1.1
SVG	374	36 54.00	75 58.99	-18	0.0	39.5	40.5
SVG	375	36 55.00	75 58.99	-16	1.9	96.8	0.8
SVG	376	36 55.00	75 57.99	-34	2.1	79.0	9.7
SVG	377	36 57.00	75 57.99	-70	6.3	88.6	2.7
SVG	378	36 56.00	76 0.00	-35	9.8	84.3	2.7
SVG	379	36 57.00	75 59.99	-82	0.0	86.0	6.5
SVG	380	36 58.00	76 0.00	-63	0.0	96.6	1.1

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	Incl Graph St Dv
SVG	1	3.0	95.1	4.9	3.23	3.21	0.27
SVG	2	3.6	93.2	6.8	3.28	3.28	0.31
SVG	3	1.7	97.7	2.3	2.36	2.27	0.48
SVG	4	1.8	98.1	1.8	1.52	1.50	0.55
SVG	5	2.0	97.2	2.7	2.81	2.85	0.51
SVG	6	3.6	94.4	5.6	3.35	3.34	0.80
SVG	7	2.9	94.9	5.2	2.92	3.07	0.64
SVG	8	3.6	92.6	7.3	3.36	3.34	0.56
SVG	9	3.6	93.4	6.6	3.31	3.31	0.24
SVG	10	3.8	95.8	4.1	3.16	3.16	0.31
SVG	11	3.2	94.5	5.5	2.81	2.96	0.63
SVG	12	2.2	96.7	3.3	0.42	0.39	0.63
SVG	13	3.1	96.0	4.0	1.55	1.53	0.64
SVG	14	3.8	93.3	6.7	3.04	3.09	0.50
SVG	15	4.3	93.1	7.0	3.10	3.16	0.36
SVG	16	3.8	93.9	6.1	3.00	3.15	0.52
SVG	17	2.9	95.6	4.4	2.87	2.94	0.42
SVG	18	2.8	96.5	3.6	1.08	1.09	0.70
SVG	19	6.9	82.6	17.4	3.19	3.22	0.62
SVG	20	2.7	92.7	7.3	3.36	3.35	0.41
SVG	21	4.3	87.0	13.0	3.47	3.46	0.41
SVG	22	1.3	98.4	1.6	1.39	1.43	0.51
SVG	23	0.9	98.7	1.3	1.43	1.48	0.51
SVG	24	1.6	97.8	2.2	1.11	1.17	0.71
SVG	25	1.7	98.3	1.7	1.07	1.11	0.72
SVG	26	4.3	91.2	8.9	2.46	2.56	0.83
SVG	27	1.3	98.4	1.7	1.45	1.56	0.61
SVG	28	1.4	98.3	1.7	1.24	1.34	0.65
SVG	29	1.4	98.5	1.6	1.44	1.51	0.63
SVG	30	0.6	99.2	0.8	1.79	1.81	0.44
SVG	31	1.1	98.8	1.1	1.74	1.79	0.43
SVG	32	2.6	97.3	2.7	1.95	2.01	0.47
SVG	33	1.8	97.5	2.5	2.30	2.37	0.37
SVG	34	1.4	98.4	1.7	1.61	1.67	0.48
SVG	35	0.8	98.4	1.5	1.60	1.60	0.40
SVG	36	2.7	93.7	6.2	2.52	2.52	0.44
SVG	37	3.7	94.8	5.1	2.65	2.66	0.51
SVG	38	1.9	98.0	2.0	1.53	1.56	0.58
SVG	39	1.9	97.7	2.3	1.93	1.99	0.46
SVG	40	0.9	96.5	3.4	1.68	1.67	0.60
SVG	41	2.8	97.2	2.9	1.67	1.74	0.62
SVG	42	2.1	97.7	2.2	1.82	1.76	0.45
SVG	43	1.7	98.2	1.8	1.29	1.31	0.54
SVG	44	1.0	96.9	3.1	1.76	1.78	0.47
SVG	45	2.3	97.7	2.3	1.64	1.62	0.48

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	46	1.6	98.1	1.9	1.52	1.54	0.52
SVG	47	1.7	98.0	2.0	1.59	1.64	0.55
SVG	48	1.5	96.5	3.6	1.84	1.89	0.47
SVG	49	2.1	97.8	2.2	1.22	1.30	0.61
SVG	50	2.1	97.9	2.2	1.25	1.29	0.54
SVG	51	1.9	97.9	2.1	1.47	1.54	0.61
SVG	52	2.8	95.9	4.1	2.13	2.19	0.46
SVG	53	2.5	97.5	2.5	1.16	1.29	0.77
SVG	54	2.5	97.4	2.6	1.24	1.30	0.58
SVG	55	1.4	96.7	3.3	0.39	0.35	0.63
SVG	56	2.5	92.3	7.7	2.44	2.32	0.63
SVG	57	0.8	96.0	4.0	1.06	1.08	0.62
SVG	58	1.0	96.8	3.2	1.05	1.11	0.69
SVG	59	1.2	96.8	3.2	1.98	1.99	0.65
SVG	60	1.6	96.2	3.9	2.45	2.89	1.02
SVG	61	3.3	92.5	7.4	3.15	3.22	0.66
SVG	62	2.7	92.5	7.5	3.41	3.40	0.33
SVG	63	1.4	97.9	2.1	1.36	1.43	0.77
SVG	64	1.4	98.5	1.5	1.32	1.36	0.64
SVG	65	1.0	99.1	1.0	0.98	0.99	0.73
SVG	66	1.3	98.0	2.1	1.37	1.57	0.78
SVG	67	1.5	98.2	1.8	1.13	1.19	0.69
SVG	68	2.9	95.6	4.4	2.39	2.54	0.90
SVG	69	2.3	97.6	2.3	1.38	1.47	0.66
SVG	70	2.6	97.4	2.6	1.56	1.64	0.50
SVG	71	3.0	96.9	3.1	1.02	1.08	0.76
SVG	72						
SVG	73	2.8	97.1	2.9	1.72	1.77	0.43
SVG	74	4.8	94.7	5.3	3.13	3.13	0.30
SVG	75	3.0	97.0	3.0	1.86	2.02	0.74
SVG	76	3.0	96.7	3.2	1.77	1.82	0.78
SVG	77	4.1	95.8	4.1	2.18	2.15	0.53
SVG	78	2.2	97.3	2.7	1.34	1.30	0.65
SVG	79	2.8	97.2	2.8	0.97	0.98	0.73
SVG	80	4.7	94.8	5.2	2.85	2.94	0.45
SVG	81	2.6	97.1	2.9	1.05	1.11	0.76
SVG	82	1.4	98.2	1.8	1.65	1.65	0.48
SVG	83	1.6	98.2	1.8	1.65	1.61	0.64
SVG	84	1.5	98.1	1.9	0.98	0.92	0.65
SVG	85	1.6	97.8	2.2	1.74	1.79	0.59
SVG	86	1.2	98.2	1.8	1.66	1.75	0.98
SVG	87	2.1	97.0	3.0	2.84	2.92	0.50
SVG	88	1.6	97.9	2.1	1.86	1.87	0.57
SVG	89	1.7	97.7	2.3	1.91	1.95	0.41
SVG	90	1.6	97.9	2.1	1.56	1.59	0.53

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	91	2.3	92.8	7.2			
SVG	92	2.6	93.4	6.6			
SVG	93	2.3	95.0	5.0	3.07	3.10	0.28
SVG	94	1.8	95.8	4.2			
SVG	95	3.2	92.9	7.1	2.88	3.01	0.59
SVG	96	3.0	92.5	7.5			
SVG	97	2.0	96.2	3.8	3.35	3.34	0.46
SVG	98	3.5	92.6	7.5	2.43	2.47	0.78
SVG	99	1.5	97.0	2.9	2.31	3.40	1.42
SVG	100	2.9	92.9	7.1	2.55	2.49	0.54
SVG	101	1.7	95.7	4.3	3.37	3.35	0.30
SVG	102	2.7	91.9	8.2	3.08	3.17	0.47
SVG	103	1.4	98.3	1.7	3.37	3.37	0.31
SVG	104	1.2	98.3	1.7	1.59	1.65	0.58
SVG	105	1.5	98.3	1.7	1.71	1.29	0.99
SVG	106	1.4	98.1	1.8	1.96	1.97	0.37
SVG	107	1.6	97.9	2.1	1.86	1.84	0.44
SVG	108	3.6	92.9	7.1	1.45	1.56	0.75
SVG	109	3.1	94.4	5.5	3.27	3.26	0.29
SVG	110	34.3	12.4	87.6	2.10	1.96	0.92
SVG	111	3.3	94.6	5.5	2.73	3.48	1.42
SVG	112	3.0	96.1	3.9	3.16	3.17	0.30
SVG	113	3.7	91.3	8.7	2.91	3.00	0.59
SVG	114	3.7	91.0	8.9	3.07	3.23	0.61
SVG	115	2.4	96.6	3.4	3.42	3.40	0.26
SVG	116	2.2	97.1	2.9	2.87	3.05	0.60
SVG	117	1.9	95.1	4.9	2.12	2.16	0.54
SVG	118	1.5	98.0	2.1	2.99	2.97	0.58
SVG	119	1.9	97.6	2.4	2.12	2.15	0.63
SVG	120	2.3	97.0	2.9	1.38	1.48	0.86
SVG	121	1.6	98.3	1.7	1.21	1.33	0.78
SVG	122	1.8	97.9	2.2	1.00	1.03	0.71
SVG	123	2.5	92.1	8.0	0.91	0.85	0.74
SVG	124	3.8	87.4	12.6	3.15	3.24	0.85
SVG	125	2.5	93.7	6.3	3.50	3.45	0.29
SVG	126	2.5	94.3	5.6	3.38	3.37	0.39
SVG	127	1.8	97.4	2.6	3.30	3.29	0.58
SVG	128	0.8	99.0	1.0	1.49	1.48	0.69
SVG	129	1.7	98.0	2.0	0.95	0.89	0.80
SVG	130	1.4	98.4	1.6	1.05	1.07	0.88
SVG	131	8.6	84.4	15.7	1.41	1.50	0.83
SVG	132	1.7	97.7	2.3	2.66	2.62	0.89
SVG	133	1.6	98.0	1.9	1.51	1.68	0.93
SVG	134	1.5	98.2	1.8	1.51	1.62	0.92
SVG	135	1.4	98.4	1.6	1.17	1.22	0.80

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	137	1.1	98.8	1.2	1.76	1.81	0.50
SVG	138	1.4	98.3	1.8	1.72	1.77	0.63
SVG	139	19.1	49.7	50.3	2.46	2.34	0.74
SVG	140	2.9	95.7	4.3	2.52	2.48	0.50
SVG	141	1.0	98.9	1.1	1.46	1.51	0.66
SVG	142	1.5	98.4	1.6	1.37	1.42	0.72
SVG	143	3.2	94.7	5.3	2.40	2.50	0.90
SVG	144	3.5	95.1	5.0	2.73	2.73	0.49
SVG	145	1.3	98.5	1.5	1.76	1.77	0.72
SVG	146	1.2	98.4	1.5	2.01	2.03	0.42
SVG	147	0.9	98.9	1.1	1.36	1.43	0.72
SVG	148	2.5	96.2	3.8	2.16	2.18	0.71
SVG	149	10.8	78.8	21.2	2.98	3.07	0.68
SVG	150	2.0	97.4	2.5	2.79	2.72	0.50
SVG	151	2.1	97.2	2.8	1.25	1.17	0.95
SVG	152	2.1	95.9	4.2	3.45	3.45	0.39
SVG	153	1.0	98.6	1.3	3.31	3.30	0.48
SVG	154	2.3	96.3	3.7	3.18	3.23	0.71
SVG	155	2.2	96.7	3.3	2.14	2.20	0.78
SVG	156	2.4	95.6	4.4	1.78	1.99	1.08
SVG	157	3.3	90.9	9.2	3.33	3.31	0.31
SVG	158	3.1	93.0	7.0	1.54	1.45	1.01
SVG	159	4.0	91.8	8.2	3.14	3.16	0.76
SVG	160	3.3	94.4	5.6	3.25	3.26	0.71
SVG	161	2.1	96.0	4.0	3.27	3.28	0.41
SVG	162	1.8	97.8	2.2	2.67	2.73	0.55
SVG	163	1.9	97.9	2.1	2.38	2.39	0.84
SVG	164	1.4	98.4	1.6	0.35	0.19	0.79
SVG	165	1.6	98.2	1.7	1.23	1.15	0.96
SVG	166	1.3	98.4	1.6	0.84	0.97	1.07
SVG	167	1.7	98.1	1.8	1.04	0.64	1.21
SVG	168	1.8	98.0	2.1	1.04	0.64	1.21
SVG	169	3.6	95.4	4.6	3.04	3.06	0.53
SVG	170	2.3	97.7	2.4	0.79	0.85	0.82
SVG	171	2.7	96.9	3.1	1.57	1.58	0.62
SVG	172	3.4	95.5	4.5	2.68	2.69	0.54
SVG	173	4.4	95.0	5.0	2.95	2.97	0.41
SVG	174	2.0	97.8	2.2	2.16	2.17	0.54
SVG	175	1.8	97.9	2.1	1.36	1.39	0.72
SVG	176	2.1	97.8	2.2			
SVG	177	2.8	97.2	2.8	1.43	1.59	0.80
SVG	178	1.4	98.3	1.7	1.48	1.50	0.58
SVG	179	2.6	97.1	2.9	1.79	1.79	0.59
SVG	180	4.7	94.1	5.9	2.61	2.88	0.79
SVG	181	2.4	97.2	2.8	1.26	1.31	0.79

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	182	2.1	97.8	2.3	1.11	1.12	0.69
SVG	183	2.0	98.0	2.1	1.24	1.29	0.85
SVG	184	2.3	97.3	2.6	2.13	2.16	0.51
SVG	185	1.4	98.4	1.6	1.37	1.42	0.75
SVG	186	1.9	97.7	2.3			
SVG	187	1.8	97.8	2.2	1.30	1.25	0.65
SVG	188	1.8	98.2	1.8	1.37	1.43	0.65
SVG	189	1.5	98.4	1.7	1.34	1.34	0.66
SVG	190	1.4	98.5	1.5	1.55	1.57	0.55
SVG	191	1.3	98.4	1.6	1.26	1.43	0.76
SVG	192	0.1	99.9	0.2	2.60	2.55	0.43
SVG	193	0.2	97.5	2.5	1.51	1.53	0.65
SVG	194	0.2	99.3	0.7	2.70	2.71	0.35
SVG	195	6.3	81.0	19.0	3.29	3.29	0.44
SVG	196	0.5	98.4	1.5	3.28	3.27	0.31
SVG	197	0.0	99.2	0.7	3.17	3.18	0.51
SVG	198	0.5	98.7	1.3	1.75	1.36	1.22
SVG	199	2.2	94.6	5.4	3.37	3.36	0.50
SVG	200	0.0	99.6	0.4	3.28	3.29	0.43
SVG	201	0.6	98.9	1.1	1.82	1.79	0.61
SVG	202	0.0	98.4	1.6	1.53	1.51	0.76
SVG	203	0.5	99.2	0.8	1.47	1.49	0.79
SVG	204	0.3	99.4	0.6	0.72	0.69	0.80
SVG	205	2.1	97.2	2.9	2.30	2.30	0.86
SVG	206	0.9	98.8	1.2	1.71	1.68	0.68
SVG	207	0.8	98.9	1.2	1.50	1.58	0.87
SVG	208	0.7	99.1	0.9	1.28	1.29	0.78
SVG	209	1.5	93.3	6.6	1.97	2.19	0.77
SVG	210	0.8	98.8	1.3	1.51	1.61	0.69
SVG	211	1.8	98.0	2.0	1.43	1.50	0.70
SVG	212	0.8	99.0	1.0	1.97	2.06	0.81
SVG	213	0.9	98.8	1.2	1.42	1.50	0.74
SVG	214	0.2	99.5	0.5	1.62	1.62	0.54
SVG	215	1.1	98.7	1.3	1.40	1.42	0.70
SVG	216	1.0	98.9	1.2	1.30	1.40	1.08
SVG	217	0.9	98.4	1.6	1.50	1.50	0.70
SVG	218	0.8	98.8	1.1	1.63	1.72	0.73
SVG	219	1.5	98.0	2.0	1.54	1.55	0.60
SVG	220	0.3	99.6	0.4	1.20	1.23	0.63
SVG	221	1.2	98.4	1.5	1.42	1.46	0.81
SVG	222	1.8	98.1	1.9	1.26	1.34	0.62
SVG	223	0.2	98.4	1.6	1.91	2.00	0.67
SVG	224	1.3	98.5	1.4	1.61	1.64	0.80
SVG	225	1.4	98.2	1.8	1.66	1.70	0.75
SVG	226	21.9	67.4	32.6	2.07	2.08	0.56

Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	227	0.4	99.2	0.9	1.99	1.98	0.40
SVG	228	0.5	97.9	2.0	1.69	1.79	0.78
SVG	229	0.5	98.4	1.7	1.61	1.75	0.86
SVG	230	0.2	98.5	1.5	0.75	0.70	0.70
SVG	231	0.0	99.7	0.3	1.66	1.66	0.57
SVG	232	1.2	98.7	1.3	1.49	1.58	0.81
SVG	233	1.4	98.2	1.7	1.59	1.61	0.47
SVG	234	0.8	97.0	3.1	2.38	2.35	0.40
SVG	235	0.0	99.5	0.4	2.16	2.24	0.52
SVG	236	0.7	98.3	1.7	0.97	1.04	0.86
SVG	237	1.0	99.0	1.0	1.75	1.79	0.54
SVG	238	0.7	99.0	1.1	1.29	1.43	0.73
SVG	239	0.7	98.9	1.1	1.75	1.74	0.65
SVG	240	1.5	97.9	2.1	2.14	2.08	0.68
SVG	241	1.0	98.2	1.7	1.90	1.93	0.46
SVG	242	0.7	97.8	2.2	1.06	1.29	0.97
SVG	243	0.4	98.9	1.0	1.76	1.82	0.56
SVG	244	0.9	98.5	1.6	1.44	1.46	0.53
SVG	245	3.1	96.3	3.8	2.49	2.49	0.63
SVG	246	0.8	99.1	0.8	1.42	1.45	0.83
SVG	247	2.4	96.4	3.6	1.98	2.00	0.48
SVG	248	2.0	97.3	2.6	1.55	1.53	0.61
SVG	249	1.1	98.2	1.7	1.53	1.57	0.99
SVG	250	2.5	93.8	6.2	2.79	2.66	0.68
SVG	251	0.9	97.8	2.2	1.97	2.00	0.35
SVG	252	5.1	83.0	17.0	3.24	3.35	0.48
SVG	253	0.7	99.2	0.8	1.84	1.90	0.48
SVG	254	1.1	98.8	1.2	1.93	1.92	0.47
SVG	255	1.3	97.9	2.2	1.94	1.95	0.53
SVG	256	1.2	96.9	3.0	1.99	1.99	0.51
SVG	257	0.1	99.8	0.3	2.02	2.05	0.48
SVG	258	2.9	94.8	5.1	1.88	1.89	0.62
SVG	259	1.8	94.8	5.2	2.74	2.72	0.59
SVG	260	0.4	91.1	8.9	2.38	2.56	0.80
SVG	261	2.5	93.3	6.7	2.61	2.63	0.42
SVG	262	0.1	94.6	5.4	2.22	2.27	0.59
SVG	263	2.4	94.1	5.8	2.75	2.70	0.43
SVG	264	2.2	93.3	6.6	1.85	1.89	0.53
SVG	265	2.2	96.1	3.8	1.59	1.66	0.77
SVG	266	2.4	94.9	5.1	1.57	1.57	0.80
SVG	267	4.4	91.4	8.6	2.36	2.91	1.05
SVG	268	1.5	97.7	2.3	2.14	2.22	0.72
SVG	269	2.7	94.7	5.3	1.75	1.73	0.63
SVG	270	2.3	97.3	2.8	1.64	1.64	0.47

Samp #	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG 272	3.2	92.8	7.1	2.39	2.46	0.63
SVG 273	3.7	93.0	7.0	2.73	2.67	0.51
SVG 274	1.2	98.2	1.9	1.49	1.52	0.56
SVG 275	4.8	92.8	7.1	2.52	2.52	0.26
SVG 276	3.5	93.7	6.3	1.67	1.73	0.54
SVG 277	0.1	94.4	5.7	1.73	1.74	0.51
SVG 278	4.1	95.1	4.9	2.14	2.21	0.44
SVG 279	0.2	92.7	7.3	2.06	2.09	0.47
SVG 280	1.6	93.9	6.1	1.24	1.25	0.81
SVG 281	0.9	99.0	1.1	1.75	1.79	0.52
SVG 282	0.1	94.7	5.3	2.33	2.35	0.54
SVG 283	0.1	99.3	0.6	1.67	1.71	0.72
SVG 284	3.6	91.6	8.4	2.76	2.73	0.30
SVG 285	1.4	95.5	4.4	1.96	2.00	0.56
SVG 286	11.9	60.1	40.0	2.01	1.90	0.82
SVG 287	0.8	99.0	1.1	1.05	1.06	0.76
SVG 288	6.3	88.0	12.0	2.69	2.65	0.58
SVG 289	0.3	97.7	2.2	1.53	1.60	0.52
SVG 290	3.2	95.9	4.1	1.93	1.92	0.45
SVG 291	0.1	99.8	0.2	1.93	2.00	0.53
SVG 292	0.9	97.4	2.6	1.69	1.73	0.47
SVG 293	0.3	99.5	0.5	1.61	1.62	0.69
SVG 294	0.9	98.7	1.3	2.39	2.38	0.27
SVG 295	0.2	95.5	4.5	2.72	2.70	0.29
SVG 296	5.1	91.0	9.0	3.04	3.15	0.45
SVG 297	7.5	92.5	7.5	3.06	3.10	0.39
SVG 298	6.1	91.0	9.0	2.94	2.94	0.44
SVG 299	10.5	79.7	20.4	2.96	2.96	0.41
SVG 300	1.1	98.4	1.7	2.52	2.53	0.27
SVG 301	0.2	97.3	2.6	2.85	2.79	0.44
SVG 302	1.5	98.4	1.6	2.20	2.18	0.45
SVG 303	1.9	97.8	2.2	2.43	2.55	0.57
SVG 304	4.4	94.8	5.2	3.01	2.98	0.38
SVG 305	9.1	87.5	12.5	1.88	1.86	0.37
SVG 306	0.7	93.1	6.9	2.71	2.74	0.58
SVG 307	3.0	94.2	5.8	2.90	2.92	0.51
SVG 308	2.4	95.1	4.9	2.57	2.57	0.39
SVG 309	2.6	95.3	4.7	2.41	2.42	0.32
SVG 310	1.0	96.2	3.8	2.02	2.03	0.41
SVG 311	0.7	98.1	1.8	1.78	1.76	0.50
SVG 312	3.0	95.9	4.2	0.91	0.92	0.75
SVG 313	1.2	97.1	1.7			
SVG 314	1.0	96.7	2.2	2.36	2.32	0.59
SVG 315	0.6	98.6	0.8	1.03	0.97	0.86
SVG 316	1.1	96.6	2.3	1.46	1.33	0.83

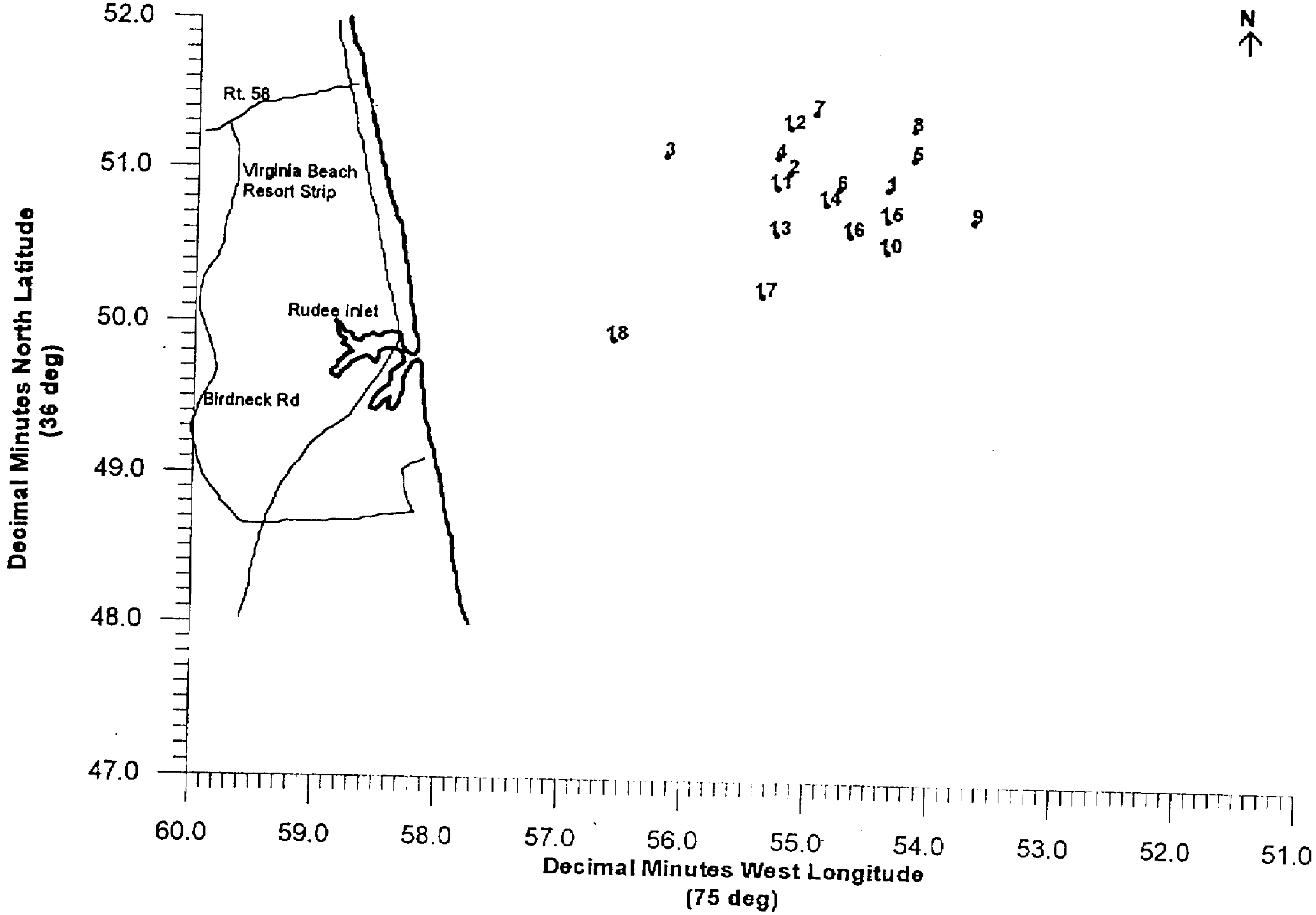
Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	317	1.9	95.8	2.3	2.28	2.32	0.35
SVG	318	2.2	94.5	3.3	2.53	2.56	0.45
SVG	319	1.4	96.4	2.2	2.50	2.56	0.47
SVG	320	2.6	92.5	4.9	2.59	2.56	0.52
SVG	321	1.2	97.6	1.2	2.16	2.20	0.39
SVG	322	2.0	95.5	2.5	2.45	2.48	0.40
SVG	323	1.6	96.1	2.3	2.43	2.45	0.42
SVG	324	0.1	98.2	1.7	0.96	0.98	0.74
SVG	325	1.0	97.9	1.1	1.33	1.35	0.66
SVG	326	0.9	97.9	1.2	0.95	1.01	0.72
SVG	327	2.9	93.4	3.7	3.20	3.23	0.31
SVG	328	1.7	96.5	1.8	1.46	1.54	0.55
SVG	329	1.5	96.9	1.5	1.77	1.82	0.48
SVG	330	1.3	97.3	1.4	1.02	1.10	0.65
SVG	331	1.2	97.6	1.2	1.05	1.07	0.63
SVG	332	2.1	94.9	3.0	1.00	1.00	0.69
SVG	333	2.0	95.1	2.9	2.63	2.52	0.53
SVG	334	1.2	97.6	1.3	1.31	1.35	0.51
SVG	335	1.6	96.8	1.6	0.81	0.87	0.75
SVG	336	1.2	97.6	1.2	1.68	1.80	0.58
SVG	337	1.4	97.1	1.5	1.72	1.78	0.47
SVG	338	0.1	98.0	2.0	1.33	1.46	0.79
SVG	339	0.9	98.1	0.9	2.53	2.53	0.49
SVG	340	1.0	97.9	1.1	1.29	0.82	1.02
SVG	341	0.3	99.3	0.4	1.89	1.96	0.65
SVG	342	0.5	98.7	0.8	1.06	0.98	1.14
SVG	343	0.6	98.5	0.9	1.33	1.44	0.86
SVG	344	0.7	98.4	0.9	1.49	1.47	0.70
SVG	345	0.8	98.3	1.0	1.07	1.08	0.81
SVG	346	1.5	96.9	1.6	1.64	1.65	0.75
SVG	347	1.3	97.4	1.3	1.82	1.89	0.67
SVG	348	1.7	93.6	4.7	3.35	3.32	0.46
SVG	349	2.1	94.4	3.5	3.18	3.22	0.48
SVG	350	1.9	95.3	2.8	3.02	3.13	0.50
SVG	351	0.7	98.5	0.8	1.78	1.86	0.71
SVG	352	1.5	96.5	2.0	2.60	2.59	0.39
SVG	353	1.2	95.2	3.5	1.49	1.17	1.35
SVG	354	0.9	97.9	1.1	2.53	2.55	0.34
SVG	355	1.5	96.6	1.9	2.64	2.63	0.63
SVG	356	2.9	91.3	5.8	2.82	2.77	0.60
SVG	357	0.9	97.9	1.1	2.25	2.33	0.71
SVG	358	4.5	90.5	5.0	1.92	1.89	0.56
SVG	359	0.9	98.0	1.1	1.81	1.82	0.39
SVG	360	1.9	92.6	5.5	3.04	2.95	0.51
SVG	361	2.6	89.4	8.1	3.46	3.44	0.33

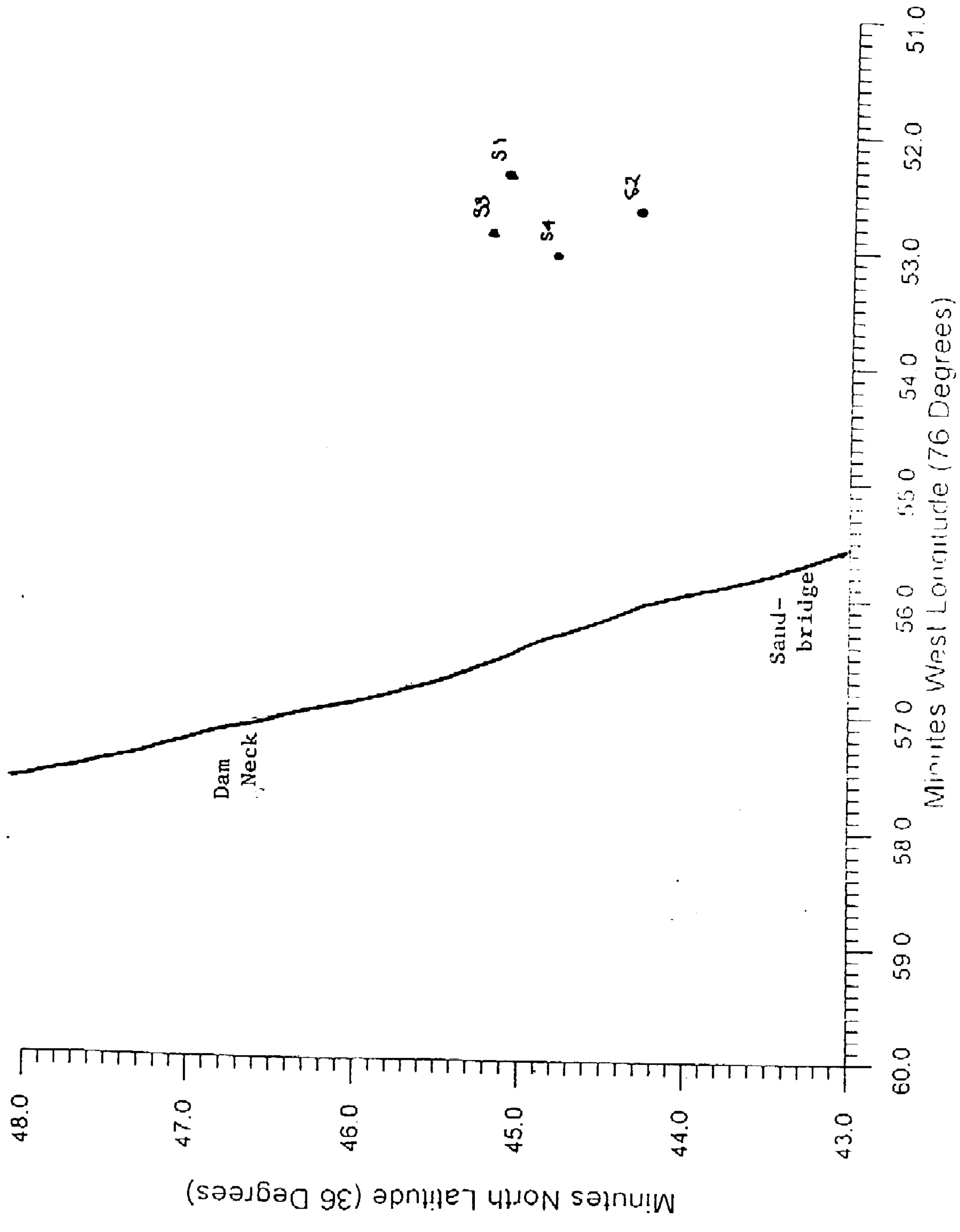
Samp	#	Clay %	Grvl+ Sand %	Mud %	Mz phi	Md phi	incl graph st dv
SVG	362	0.8	97.9	1.3	1.67	1.77	0.66
SVG	363	2.4	93.8	3.8	3.06	3.10	0.37
SVG	364	0.7	98.0	1.3	1.55	1.49	0.70
SVG	365	1.8	95.9	2.3	2.71	3.04	0.90
SVG	366	1.4	96.2	2.4	2.87	3.04	0.66
SVG	367	0.5	98.2	1.3	1.49	1.48	0.90
SVG	368	1.0	85.7	13.4	1.46	1.42	0.85
SVG	369	1.4	95.4	3.3	3.13	3.13	0.32
SVG	370	0.8	97.6	1.6	1.68	1.60	0.72
SVG	371	1.5	92.1	6.5	3.40	3.37	0.39
SVG	372	1.4	92.4	6.2	3.36	3.36	0.45
SVG	373	0.5	97.9	1.6	2.70	2.69	0.46
SVG	374	10.0	39.5	50.5	3.58	3.58	0.45
SVG	375	0.3	98.7	1.0	1.41	1.33	0.68
SVG	376	4.6	81.1	14.3	2.80	3.04	0.98
SVG	377	1.3	94.8	3.9	1.96	1.80	0.83
SVG	378	1.6	94.0	4.3	1.99	1.88	1.01
SVG	379	3.8	86.0	10.2	2.46	3.33	1.50
SVG	380	1.1	96.6	2.2	2.46	2.32	0.58

Appendix 2

1994 Cores

Location Maps
Logs
Grain-size Data


N
Rt. 58
Virginia Beach
Resort Strip
Rudee Inlet
Birdneck Rd
3
12
7
8
4
2
5
11
6
1
14
15
9
13
16
10
17
18
52.0
51.0
50.0
49.0
48.0
47.0
Decimal Minutes North Latitude
(36 deg)
60.0
59.0
58.0
57.0
56.0
55.0
54.0
53.0
52.0
51.0
Decimal Minutes West Longitude
(75 deg)


S1
S3
S4
S2
Dam Neck
Sand-bridge
Minutes West Longitude (76 Degrees)
Minutes North Latitude (36 Degrees)
60.0
59.0
58.0
57.0
56.0
55.0
54.0
53.0
52.0
51.0
48.0
47.0
46.0
45.0
44.0
43.0

CORE LOG

PAGE 1 OF 2

CORE LABEL: MHS-941

PROJECT: MHS-94

DATE OF CORE: 15 April 94

DRILLER: Elmar

FIELD LOCATION DETERMINED BY: Loran

LAT: ____ LONG: ____ LORAN: 27143.0, 41226.5

TYPE OF CORE: 3in vibracore

WATER DEPTH FT: 40'

PENETRATION: 15'

RECOVERY: 11.7'

JETTED: 0

LOGGED BY: Angela

DATE: 5.17.94

DEPTH	SAMP #	DESCRIPTION · coarsening upwards
0 ft		· coarse sand, brown, some shells some patches of medium sand present
1ft	A	~~[illegible]~~ mud.-coarse sands, gray/brown some coarse sand present ~~[illegible]~~ few shells present [illegible] saturated
2ft		· sand at top of core section appears to have changed from sands at bottom of 1st core section probably a function of drying (no [illegible])
3ft	B	· fine - v. fine sand · gray · sands along edge of core (parallel) is more brown in color - drying difference? · hardly any shells present v. small shells
4ft		
4'11"		
5ft	C	coarse sands - granules/pebbles present (some med. sand) gray : brown gray : tends to be med. brown-coarse
6ft		clay/mud. gray

CORE: MHS-94-1

PAGE 2 OF 2

6ft		clay/mud, gray ↓
7ft		
8ft		
9ft		
10ft		
11ft		11'3". plastic embedded in clay
12 ft		

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-2 PROJECT: MMS-94
DATE OF CORE: 15 April 94 DRILLER: Egemaa
FIELD LOCATION DETERMINED BY: Loran
LAT: LONG: LORAN: 27146.5, 41226.2
TYPE OF CORE: 3in Vibracore WATER DEPTH FT: 38'
PENETRATION: 13.3' RECOVERY: 13.3 JETTED: 0
LOGGED BY: ASP DATE: 17 May 94

DEPTH	SAMP #	DESCRIPTION
0 ft		coarse sand, brown no shells
7.5"		dark gray - v. black at top 5" gray - alot of it. v. fine - silty sand some small shells present, ~~[illegible]~~
1	A	
2		↓
3		
4		
5		
6		

CORE: MMS-94-2

PAGE 2 OF 3

DEPTH	SAMP #	DESCRIPTION
6		
6.1' [illegible]	B	v.fine - silty sand, some clay present pebbles present gray
7 / 7.15'	C	v. coarse - med sand gray; brown, mostly gray large pebbles v. poorly sorted
	~~D~~	v. fine - silty sand lt gray no shells
8		
9		↓
10		
11		
12		
13	[illegible]	
14		
15		

CORE: MMS-94-2

PAGE 3 OF 3

15		
16		
17		brown - 3" layers - almost like stripes
18		v fine sand lt gray no shells
19		dark gray v. fine sand - [illegible] no shells present
20		
21		
22		v. hard to cut through consolidated / hardened sand
23	D	gray fine sand

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-3 PROJECT: MMS

DATE OF CORE: 19 April 94 DRILLER: Exman

FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27151.0, 41226.2

TYPE OF CORE: 3 in vibracore WATER DEPTH FT: 30.0

PENETRATION: 21.8′ RECOVERY: 21.8′ JETTED: 0

LOGGED BY: A.S.J DATE: 18 May 94

1" of extra core w/no sed. went by measurement on tube started measuring at top of sed.

DEPTH	SAMP #	DESCRIPTION
0 ft	A	fine sand shells - small fragments v. dark gray
1-ft		layer of bigger, whole shells
	B	fine - medium sand dark gray - dark greenish gray shells - not as many as ↑ layer small fragments some whole pieces
2ft		↓
3ft		↓
4ft		
5ft		
6ft		

CORE: MMS-94-3

PAGE 2 OF 3

6ft		compaction of sediments 4" from top ↓
7ft		↓
8		↓
9		
10		
11		large muscle shells present compaction of sediments 3" from top
12		
13		
136"		clay / mud dark gray - dark greenish gray shells
14		
15		

CORE: MMS-94-3 PAGE 3 OF 5

15	C	clay/mud interbedded with med. sand dark gray-dark greenish gray black. bottom 4"
16		clay/mud dark gray - dark greenish gray (same as layer before ↑)
17		shells present - mollusks w/ crowns on shells wood fragments ↓
18		
19		
20		
21		
22		

easured
rom
op of
diment

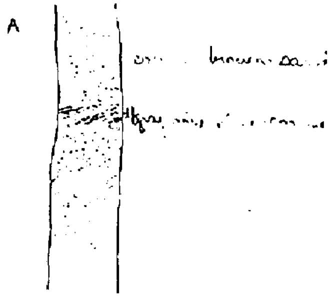
CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-4
PROJECT: MMS
DATE OF CORE: 15 April 94
DRILLER: Efman
FIELD LOCATION DETERMINED BY: Loran
LAT:
LONG:
LORAN: 27146.7, 41227.1
TYPE OF CORE: 3 in. vibracore
WATER DEPTH FT: 38.0
PENETRATION: 18.0
RECOVERY: 18.0
JETTED: 0
LOGGED BY: O.S.J.
DATE: 19 May 94

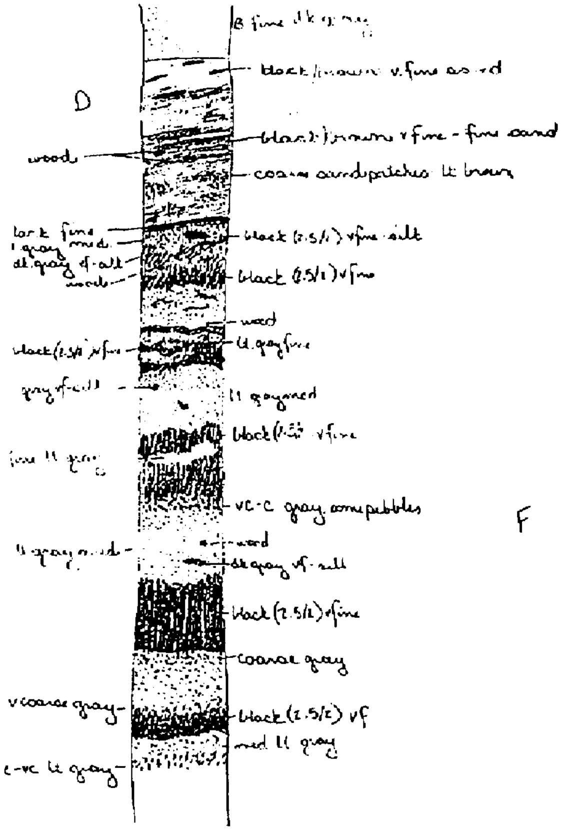
DEPTH	SAMP #	DESCRIPTION
0 ft	A	coarse sand grayish brown some organics, shell fragments
1		1" interbedded dark gray mix of v. fine sand; coarse sand 4" - ½ inch of same interbedded ↑
1'3"		
2	B	fine sand dark gray few shell framents
3		↓
4		
5		
6		

sketch →

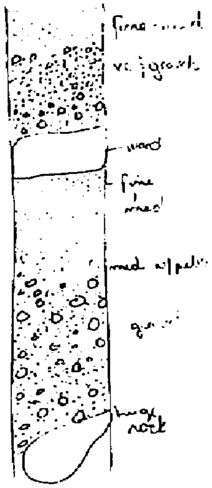


CORE: MMS-94-4 PAGE 2 OF 3

6		
7	(no CORE)	alternating sequences · coarse light brown, with blackish brown v fine - fine sand · light gray med sand · black (2.5/1) v fine - silt
8		· dark gray v fine - silt · black (2.5/1) - v fine · coarse - v coarse gray sand
9	D	· lt gray fine sand many wood fragments no shells (some 3" pieces)
10		- gravels present.
11		
12		huge wood chunk (3" & 2" at least)
		overall fining up sequences fine - med lt. gray sands fine - med v coarse ↓ gravels v.coarse lt gray sand - gravel pebbles
13	F	13' 2"-4" - huge piece of wood fine med med w/ pebbles
14		med ↓ coarse v coarse w/ gravels
15		



F



CORE: MMS-94-4 PAGE 3 OF 3

15 16	G	v fine sand dark greenish gray (5GY 4/1) some v fine-silt present in patches (towards bottom) a few small pebbles towards top
17 18	H	fine-med. sand dark greenish gray (5GY 4/1)

18'1"

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-5 PROJECT: MMS

DATE OF CORE: 17 April 94 DRILLER: Exmar

FIELD LOCATION DETERMINED BY: Loran

LAT: ______ LONG: ______ LORAN: 27142.8 , 41230.0

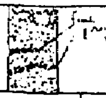
TYPE OF CORE: 3 in vibracore WATER DEPTH FT: 34.5

PENETRATION: 19.0' RECOVERY: 17.6' JETTED: 0

LOGGED BY: O.SJ DATE: 20 May 94

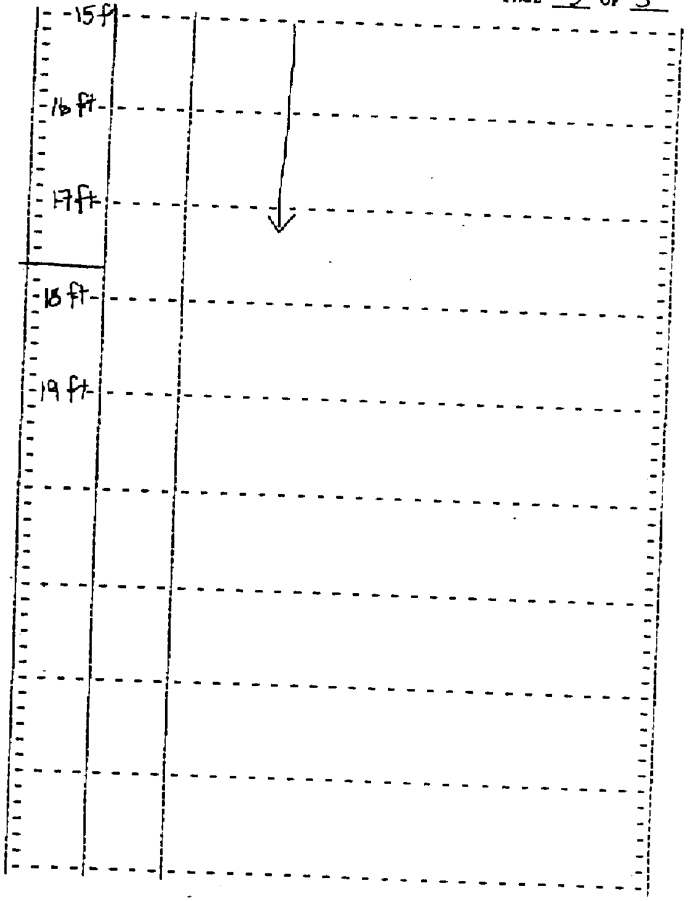
DEPTH	SAMP #	DESCRIPTION
0 ft	A	Pt 3½" of sediment are missing fine sand olive gray / grayish brown small shell fragments 9" — distinct color change — dark gray — fine sand
1'½" 1 ft		only a drying difference (vk next day gone) gray? fine sand - med. sand organics - shell fragments
2 ft	B	
3 ft		
4 ft		some interbedded med-coarse sand  ± fine gr
5 ft		
6 ft		

CORE: MMS-94-5 PAGE 2 OF 3

DEPTH	SAMP #	DESCRIPTION
6 ft		
7 ft	C	coarse sand organic - shell fragments top 2" grayish - brown  fine 1"
8 ft		dark gray med. sand some fine v. dark gray lenses
		dark gray clay with silt coarse & fine sand lenses 
9 ft	D	fine sand dark gray shell fragments - few pretty non-descript
10 ft		
11 ft		
12 ft		
13 ft		transitional - pebbles present  - sand patches - clay
		v. dark clay whole shells - oyster
14 ft		some small wood fragments shells a few small patches of fine sand
15 ft		

CORE: MMS-94-5

PAGE 3 OF 3



CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-6 PROJECT: MMS

DATE OF CORE: 17 April 94 DRILLER: Epmas

FIELD LOCATION DETERMINED BY: Loran

LAT: ______ LONG: ______ LORAN: 27145.0 , 41126.2

TYPE OF CORE: 3 in vibracore WATER DEPTH ~~FT~~ fathoms CX 35.0

PENETRATION: 22.4 RECOVERY: 22.4 JETTED: ______

LOGGED BY: ABJ DATE: 10 May 94

DEPTH	SAMP #	DESCRIPTION
0 ft	A	med- coarse sand grayish brown lots of shells & shell fragments shell- 1 ft
1		med-fine dark grayish brown shell fragments
	B	fine sand- v fine sand v dark gray shell fragments
2		
3		1.5" dark gray clay lens inch
4		
5		
adational range	C	gray fine sand- interbedded with v dark gray fine sand ~~[illegible]~~ (from above) some v dark gray silt also
6		

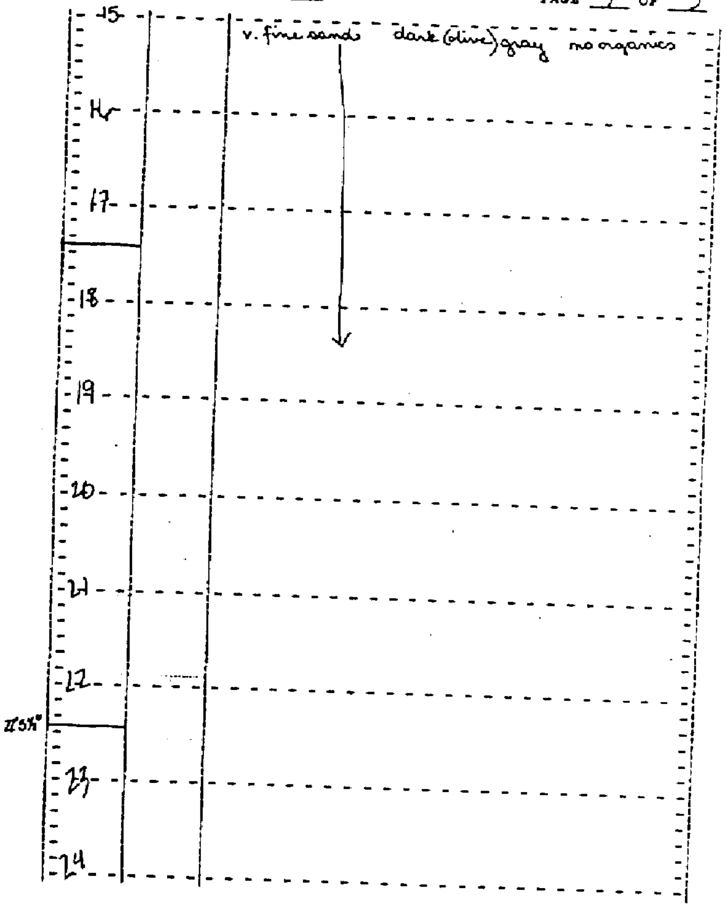
CORE: MMS-94-6

PAGE 2 OF 3

DEPTH	SAMP #	DESCRIPTION
6		6.7" coarse sand, inch thick layer shell fragments
7	D	v. poorly sorted v coarse sand - clay granules & pebbles also v shelly 1mm dark gray - v. dark gray v. dark gray shells (same as ↑ layer) clay
8	E	fine sand gray- some clay lenses, dark gray no shells, organics
9		
10		
11	F	fine sand - v fine dark (olive) gray ↑ layers interbedded no shells in patches for 10"
12		
13		v. fine sand (no more fine sand)
14		some same color clay lenses
15		

CORE: MMS-94-6

PAGE 3 OF 3



v. fine sands dark (olive) gray no organics

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-7 PROJECT: MMS

DATE OF CORE: 25 April 94 DRILLER: Esman

FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27141.5 , 41232.6

TYPE OF CORE: 3" vibracore WATER DEPTH FT: 38.0 fathometer

PENETRATION: 17.0' RECOVERY: 8'10" JETTED: to 9' gravity to 11', vibrated to 17'

LOGGED BY: ASF DATE: 26 May 94

DEPTH	SAMP #	DESCRIPTION
0 ft	A	coarse olive gray (5Y 4/2) shells; fragments
1	B	V. dk. gray (5Y 3/1) silty fine sand shells; fragments
2		interbedded layers of medium sand
3		
4		a few sparse clay lenses
5		
6		

CORE: MMS-94-7 PAGE 1 OF 3

DEPTH	SAMP #	DESCRIPTION
6		a small patch of light olive gray med. sand (5Y 6/2)
7	C	dk. gray med. sand transitions into light olive gray (5Y 6/2) medium sand some silty/sand gray (5Y 6/1) no shell fragments
8 2nd run 1st core 1st run 2nd core		
9		
10		transitions gradually to light brownish gray (2.5Y 6/2) still med. sand w/ a few patches of gray silty/sand
11		
12		
13		
14		
15		

CORE: MMS-947

PAGE 3 OF 3

15		
		pebbles present - interspersed w/ med. sands
16		
		lt. olive gray med sands
17		
18		
19		

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-8 PROJECT: MMS
DATE OF CORE: 25 April 94 DRILLER: Edman
FIELD LOCATION DETERMINED BY: Loran
LAT: LONG: LORAN: 27143.0, 41232.5
TYPE OF CORE: 3in vibracore WATER DEPTH FT: 46.3
PENETRATION: 11' / 24.5' RECOVERY: 7.5' / 11' JETTED: 0-15'
LOGGED BY: ASE DATE: 31 May 94

DEPTH	SAMP #	DESCRIPTION
0 ft	A	med. sand shells; fragments (5Y 5/2) olive gray
1		
1'3'	B	mixture with seemingly no distinct layers black v fine sands black silt some olive gray med. sand shell fragments
2		v. dark gray (5Y 3/1) med sand (2")
2'5¼'	C	silty fine sand dark gray (5Y 4/1) shell fragments inch patch of med sand
3		
4		
5		
6		

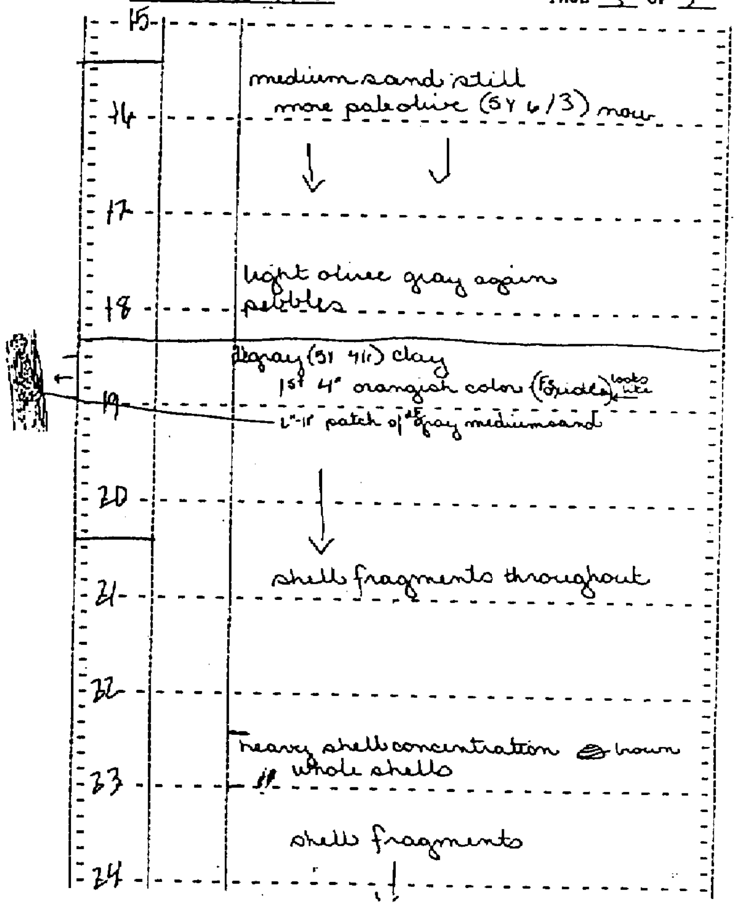
CORE: MMS-94-8

PAGE 2 OF 3

DEPTH	SAMP #	DESCRIPTION
6		
7	D	coarse-v. coarse lt. olive gray (5Y 6/2) pebbles · no shells
7'5¼"		med. gray sands also
8		
9		
10		nothing
11		
12		
13	E	medium sands. coarse sand as well some pebbles interspersed same as D ? light olive gray (5Y 6/2)
14		some silty gray (5Y 4/1) patches silt no shells
15		

CORE: MHS-94-8

PAGE 3 OF 3



medium sand still
more pale olive (5Y 6/3) now

light olive gray again
pebbles

dkgray (5Y 4/1) clay
1st 4" orangish color (Fe oxides) looks like
1"-1" patch of dk gray medium sand

shells fragments throughout

heavy shell concentration brown
// whole shells

shells fragments

CORE LOG

PAGE 1 OF 2

CORE LABEL: MMS94-9 PROJECT: MMS 1994

DATE OF CORE: 25 April 1994 DRILLER: Exmar

FIELD LOCATION DETERMINED BY: Loran

LAT: ______ LONG: ______ LORAN: 27140.1 , 41226.2

TYPE OF CORE: 3in vibracore WATER DEPTH FT: 48.6

PENETRATION: 10' RECOVERY: 6'8" JETTED: NO

LOGGED BY: Donna Milligan DATE: 23 June 1994

DEPTH	SAMP #	DESCRIPTION	
0 ft		empty	
		well sorted fine-med sized med brown sand	
		med gray silty fine sand becoming a dk gray clay layer	
1 ft		fine brown sand surrounded by dk gray silty fine sand	
		abrupt clay layer over a thin layer of brown fine sand	
	clay ball	med gray slightly silty fine sand mottled w/ dk gray clayey fine sand	abrupt contact
	A	dk brown med sand w/ small shell frags	fairly abrupt contact
2 ft		med gray silty fine-v. fine sand with small shell frags	trans. tional contact
3 ft		dk gray v. fine sandy silt mottled with a few areas of dk brown only slightly silty fine - v. fine sand	
1.0" 4 ft		a few small shell frags dk gray v. fine sandy silt	transitional contact
		dk gray v. fine sandy clay	
5 ft		amt of clay present decreases somewhat down the core	
		occasional small shell frags	
6 ft	small wood frag	pocket of lt gray slightly clayey coarse sand	

CORE: MMS-94-9 PAGE 2 OF 2

DEPTH	SAMP #	DESCRIPTION	
6 ft		dk gray med-coarse sandy clay - sand grain size increases down the core + gravel + rocks ~1 in on its longest side	transitional contact
6'8"	B	med brown well sorted coarse sand	fairly abrupt contact
		End of core	
7 ft	large shell frag		

CORE LOG

PAGE 1 OF 4

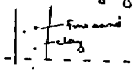
CORE LABEL: MMS- 94-10
PROJECT: MMS
DATE OF CORE: 21 April 94
DRILLER: Eymann
FIELD LOCATION DETERMINED BY: Loran
LAT:
LONG:
LORAN: 27143.0 , 41223.8
TYPE OF CORE: 3" vibracore
WATER DEPTH FT: 40 [illegible]
PENETRATION: 29.0'
RECOVERY: 29'
JETTED: 0
LOGGED BY: ASF
DATE: 2 June 94

DEPTH	SAMP #	DESCRIPTION
0 ft		medium sand olive gray (5Y 6/2) shells, fragments ~~[illegible]~~
1	A	transitions to dk. gray (5Y 4/1) med. sand
2		dark gray (5Y 4/1) silt - fine sand (mostly fine sand w/ silt present) first 2" still have some dk gray med. sand ~~[illegible]~~ shells ; shell fragments
3	B	↓ ↓
4		
5		
6		

CORE: MMS-94-10

PAGE 2 OF 4

DEPTH	SAMP #	DESCRIPTION
6		no shells dark gray (5Y 4/1) clay a few patches of fine sand at facies boundary
7		some small v. dk. gray (5Y 3/1) patches of fine sand
8		
9		
10		
11		
12		
13		
14		
15		



CORE: MMS-94-10 PAGE 3 OF 4

15

shell fragments brown on them →

16

17

18

vdk. gray (5Y 3/1) fine-med. sand

19

20

21 shell © (saved in a sample bag) 20'11"

22

23

24

CORE: MMS-94-10 PAGE 4 OF 4

24 same dk. gray clay &

whole shell © (with halves together) sample bag

25

shells -

fragments

26

whole shells

27

another whole shell (both halves) sample bag w/ (smaller of the two)

28

29

CORE LOG

PAGE 1 OF 1

CORE LABEL: MMS-94-11A PROJECT: MMS

DATE OF CORE: 21 April 94 DRILLER: Edman

FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27146.6 , 41224.2

TYPE OF CORE: 3in vibracore WATER DEPTH FT: 37.0

PENETRATION: 11.0' RECOVERY: 4.0' JETTED: 0

LOGGED BY: ASF DATE: 3 June 94

DEPTH	SAMP #	DESCRIPTION
0 ft	A	medium sand lt. olive gray (5Y 6/2) shell fragments
	B	medium sand dk. olive gray (5Y 3/2) shell fragments
1	C	v. dk. gray (5Y 4/1) shell fragments silty fine sand interspersed patches of medium sands (both v. dk. gray & dk. olive gray)
2	D	(5GY 5/1) greenish gray fine – v fine sand shell fragments
3		
[illegible]		
5		

CORE LOG

PAGE 1 OF 1

CORE LABEL: MMS-94-118

PROJECT: MMS 1994

DATE OF CORE: 21 April 1994

DRILLER: Exmar

FIELD LOCATION DETERMINED BY: Loran

LAT:

LONG:

LORAN: 27146.6, 41224.2

TYPE OF CORE: 3" vibracore

WATER DEPTH FT: 37.0

PENETRATION: 11 ft

RECOVERY: 4 ft

JETTED:

LOGGED BY: Donna Milligan

DATE: 17 June 1994

DEPTH	SAMP #	DESCRIPTION	
0 ft		empty	
	A	Brown medium sand	abrupt contact
1 ft		dk gray slightly sandy clay A few shell frags one area of clayey coarse sand	transitional contact
		med gray silty fine-v. fine sand [illegible] brownish color	
2 ft	B shell	a few shell frags + one whole shell sampled	abrupt contact
		silty fine-v. coarse sand with gravel (about 1 inch on its longest side) silt is dk brownish gray	fairly transitional contact
3 ft	C	fine-coarse sand color is lt brown mottled unevenly with med gray silty fine-coarse sand	
		area of md brownish gray silty, fine-v. coarse sand w/ gravel	
:9"		a few scattered pieces of gravel	

CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-11C PROJECT: MMS 1994

DATE OF CORE: 21 April 1994 DRILLER: Exmar

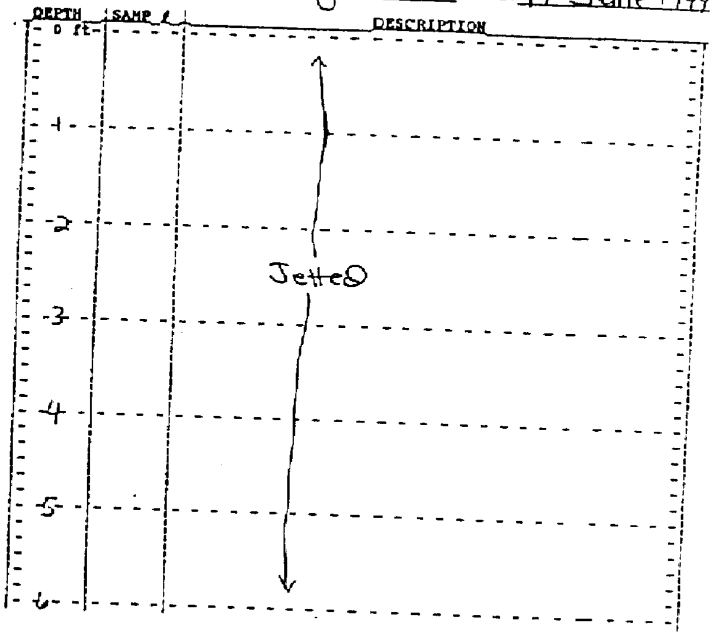
FIELD LOCATION DETERMINED BY: Loran

LAT: ______ LONG: ______ LORAN: 27146.6 . 41224.2

TYPE OF CORE: 3" Vibracore WATER DEPTH FT: 37.0

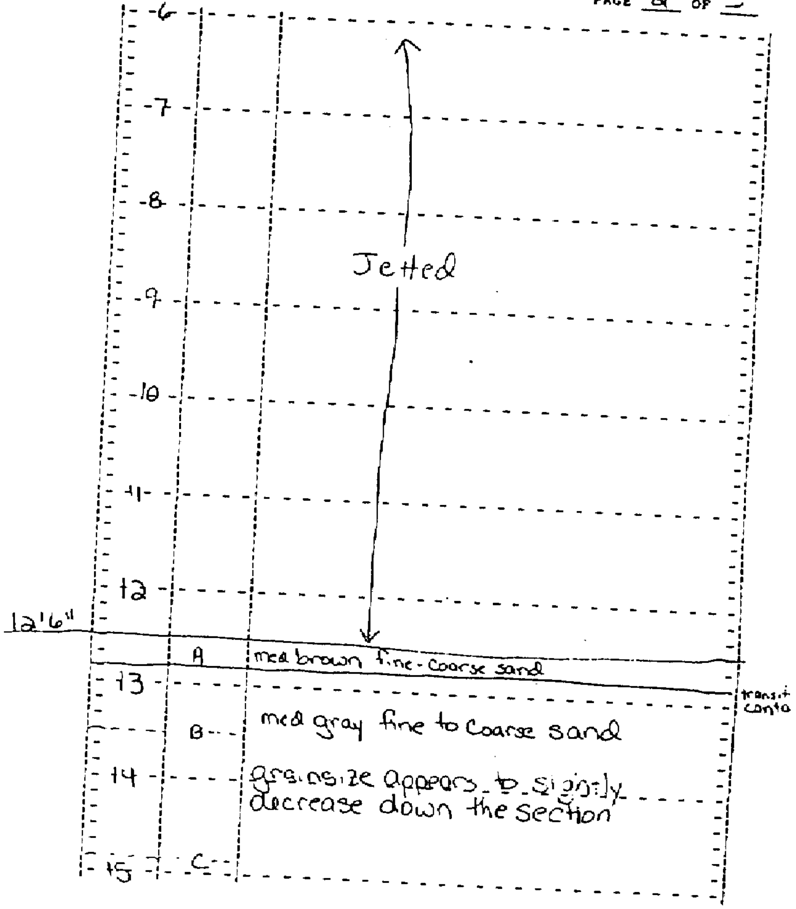
PENETRATION: 17.5 ft RECOVERY: 5 ft JETTED: 14 ft

LOGGED BY: Donna Milligan DATE: 17 June 1994

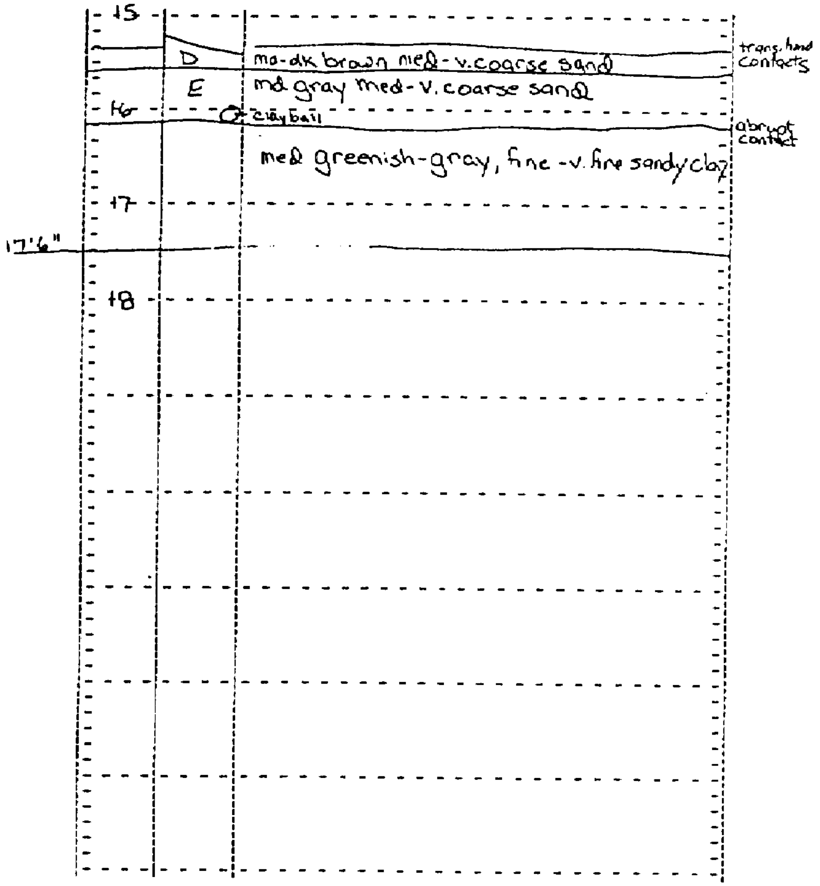


CORE: MMS-94-11C

PAGE 2 OF 3



CORE: mms-94-11c PAGE 3 OF 3



CORE LOG

PAGE 1 OF 3

CORE LABEL: MMS-94-12 PROJECT: MMS 1994

DATE OF CORE: 25 April 1994 DRILLER: Exmar

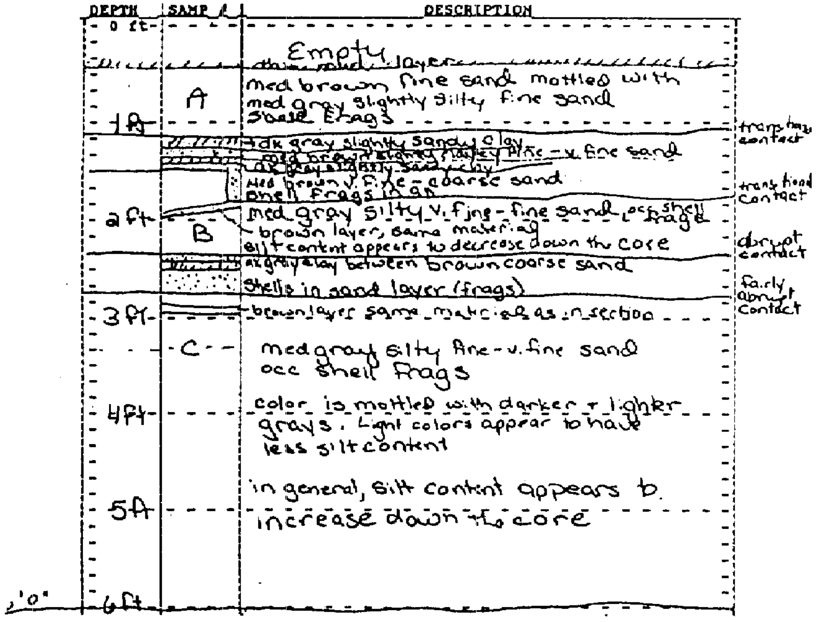
FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27147.4, 41222.9

TYPE OF CORE: 3" Vibracore WATER DEPTH FT: 32.0'

PENETRATION: 23' RECOVERY: 22'6" JETTED: NO

LOGGED BY: Donna Milligan DATE: 24 June 1994



Empty

~~thin sand layer~~

med brown fine sand mottled with med gray slightly silty fine sand shell frags

transitional contact

dk gray slightly sandy clay

~~med brown slightly clayey~~ fine – v. fine sand

~~dk gray slightly sandy clay~~

Med brown v. fine – coarse sand shell frags in ~~sa~~

transitional contact

med gray silty v. fine – fine sand, occ shell frags

brown layer, same material

silt content appears to decrease down the core

abrupt contact

dk gray clay between brown coarse sand

Shells in sand layer (frags)

fairly abrupt contact

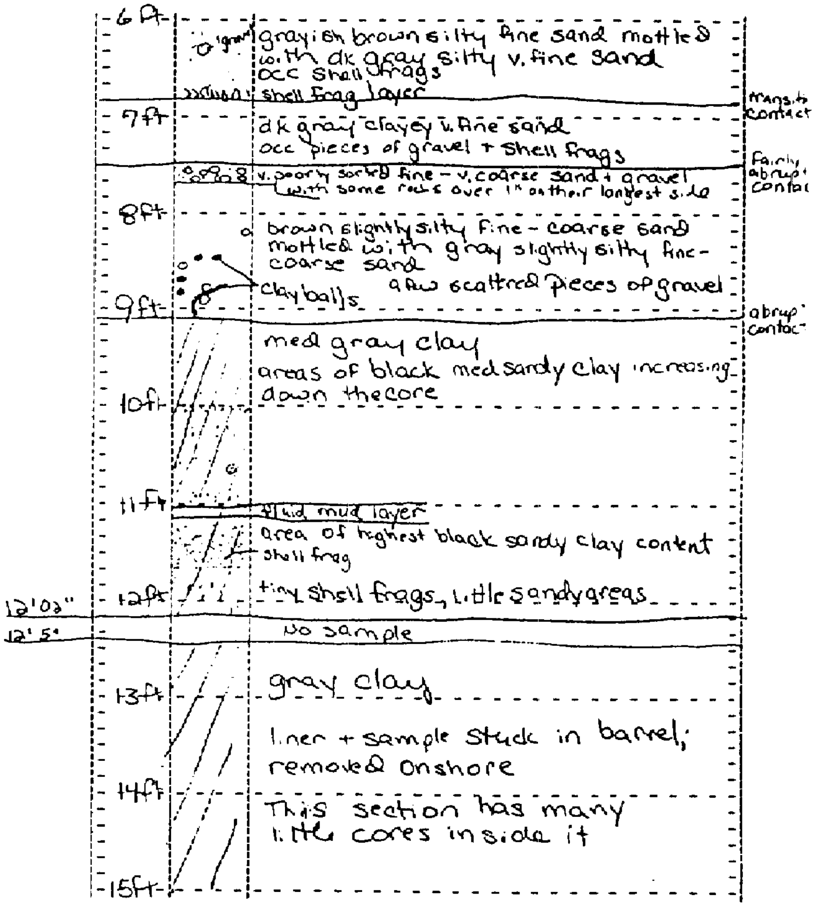
brown layer same material as in section

med gray silty fine – v. fine sand occ shell frags

color is mottled with darker + lighter grays. Light colors appear to have less silt content

in general, silt content appears to increase down the core

CORE: MMS-94-12 PAGE 2 OF 3



grayish brown silty fine sand mottled with dk gray silty v. fine sand occ shell frags

shell frag layer

transitional contact

dk gray clayey v. fine sand occ pieces of gravel + shell frags

fairly abrupt contact

v. poorly sorted fine – v. coarse sand + gravel with some rocks over 1" on their longest side

brown slightly silty fine – coarse sand mottled with gray slightly silty fine – coarse sand

a few scattered pieces of gravel

clay balls

abrupt contact

med gray clay

areas of black med sandy clay increasing down the core

fluid mud layer

area of highest black sandy clay content

shell frag

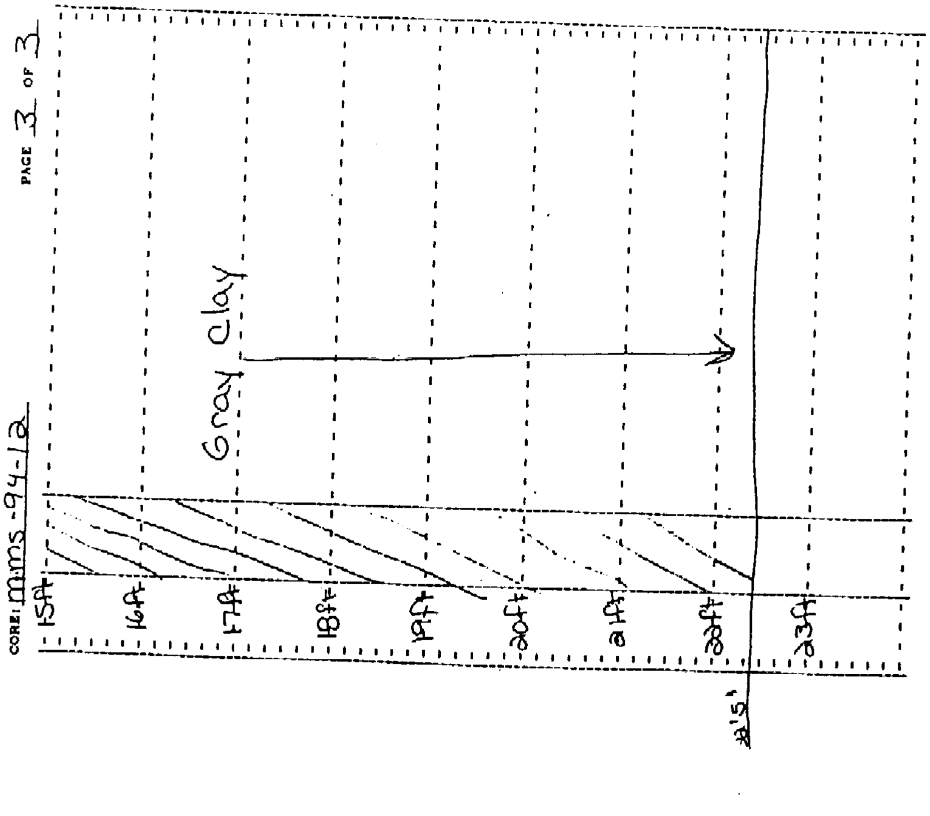
tiny shell frags, little sandy areas

No sample

gray clay

liner + sample stuck in barrel; removed onshore

This section has many little cores inside it


CORE: mims-94-12
PAGE 3 OF 3
15ft
16ft
17ft
18ft
19ft
20ft
21ft
22ft
23ft
Gray clay
22'5'

CORE LOG

PAGE 1 OF 1

CORE LABEL: MMS-94-13A

PROJECT: MMS 1994

DATE OF CORE: 25 April 1994

DRILLER: Exmar

FIELD LOCATION DETERMINED BY: Loran

LAT:

LONG:

LORAN: 27146.5, 412230

TYPE OF CORE: 3" vibracore

WATER DEPTH FT: 35

PENETRATION: 10 ft

RECOVERY: 5'6"

JETTED: No

LOGGED BY: Donna Milligan

DATE: 21 June 1994

DEPTH	SAMP #	DESCRIPTION	
0 ft		med brown slightly silty v. fine-fine sand w thin mud layer on top	
		dk gray v. fine sandy clay mottled with med brown silty v. fine sand	abrupt contact
1 ft		med Brown silty v. fine sand	abrupt contact
		Color change to dk gray mottled with md gray silty v. fine Sand	
	A	whole Shell found - a few small shell frags through section	
2 ft		slightly sandy clay ball	
		silt content appears to increase down the core	
3 ft		not well sorted fine to v. coarse brown sand with a gravel (some ~1 inch on its longest side)	abrupt contact
		slightly sandy clay ball	
4 ft		Color change to grayish brown	
	B	med gray fine-v. coarse sand mottled with dk gray silty fine-coarse sand	transitional contact
		Color: change to grayish brown	
5 ft	C	Brown med-v. coarse sand w/ gravel	fairly abrupt contact
5'6"		Brownish gray silty fine-v. coarse sand w/ gravel	transitional contact

CORE LOG

PAGE 1 OF 1

CORE LABEL: MMS-94-138 PROJECT: MMS 1994

DATE OF CORE: 25 April 1994 DRILLER: Exmar

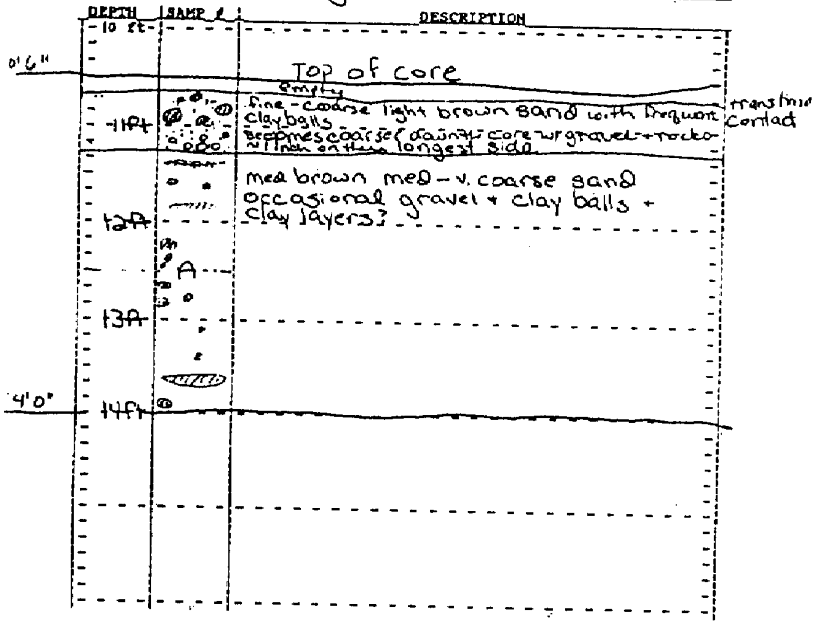
FIELD LOCATION DETERMINED BY: Loran

LAT: ____ LONG: ____ LORAN: 26146.5, 41223.0

TYPE OF CORE: 3" vibracore WATER DEPTH FT: 35 ft

PENETRATION: 14.5' RECOVERY: 3'6" JETTED: 10'6"

LOGGED BY: Donna Milligan DATE: 21 June 1994



DEPTH	SAMP #	DESCRIPTION
10 ft (0'6")		Top of core
		empty
11 ft		fine-coarse light brown sand with frequent clay balls Becomes coarser downward core w/ gravel + rocks ~1 inch on their longest side
		transitional contact
12 ft		med brown med-v. coarse sand occasional gravel + clay balls + clay layers?
	A	
13 ft		
14 ft (4'0")		

CORE LOG

PAGE 1 OF 3

CORE LABEL: mms-94-14 PROJECT: mms-94

DATE OF CORE: 25 April 1994 DRILLER: Exmar

FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27145.1, 41224.9

TYPE OF CORE: 3 in vibracore WATER DEPTH FT: 39.0

PENETRATION: 22.0 ft RECOVERY: 19.1 ft JETTED: 0

LOGGED BY: Donna Milligan DATE: 13 June 1994

DEPTH	SAMP #	DESCRIPTION
0 ft		Top 6 inches empty
		tan/Brown coarse sand - poorly sorted transitional to below
1 ft	A 1'4"	dark gray + brown silty sand poorly sorted fine - coarse sand some shells
		DK Brown silty sand / sand is fine-med shell frags
2 ft	B 2'1"	tan/br. fine sand mottled with dk gray silty material dk gray increasing down core
3 ft		gray very fine sand + dk gray silt occasional shell frags
4 ft		↓
5 ft		
6 ft		

transitional contacts

CORE: mms94-14 PAGE 2 OF 3

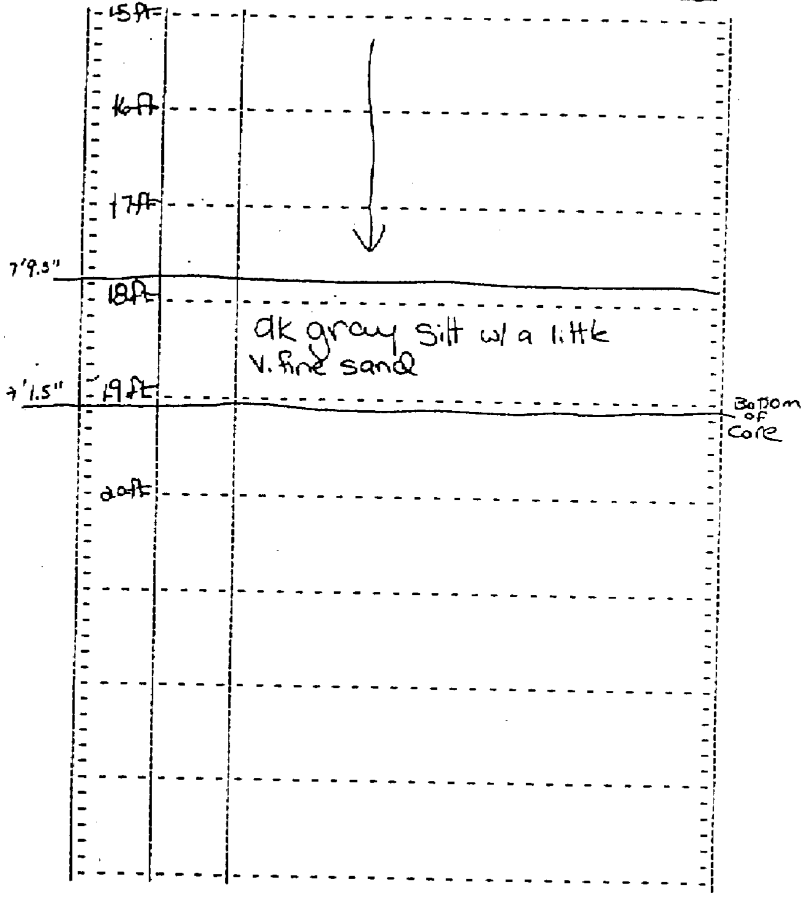
DEPTH	SAMP #	DESCRIPTION
6 ft		↓
		dk gray sandy silt
7 ft		sand is very fine
7'8.5"	C	Poorly sorted fine - v. coarse lt. gray sand + shell frags
	D	dk gray silty coarse sand whole shells + frags
8 ft		dk gray clay several shells about every 2 inches
9 ft		
		dk gray clay but many, many shells/a lot of frags
10 ft		lt to dk gray v. fine sandy silt occasionall mottled w/ brown v. fine sandy silt
11 ft		↓
12 ft	E	
12'8.5"		
13 ft		lt gray wet pattern dk grayish brown fine sandy silt a little mottling with lt. brown silty sand
14 ft	F	
15 ft		

abrupt contact

lens of very coarse gray sand

abrupt contact

CORE: mms-94-14 PAGE 3 OF 3



dk gray silt w/ a little v. fine sand

CORE LOG

PAGE 1 OF 2

CORE LABEL: MMS-94-15 PROJECT: MMS

DATE OF CORE: 27 April 94 DRILLER: Edmonds

FIELD LOCATION DETERMINED BY: Loran

LAT: LONG: LORAN: 27143.0 . 41225.5

TYPE OF CORE: 3" vibracore WATER DEPTH FT: 41.0 fathoms ft

PENETRATION: 15.5' RECOVERY: 8'6" JETTED: 0

LOGGED BY: ASF DATE: 25 May 94

not covery may be due to taking? [illegible] material rough ft clay?

DEPTH	SAMP #	DESCRIPTION
0 ft	A	medium sand shells; shell fragments olive gray (5Y 5/2)
1		
2	B	fine med. sand + a little bit of dk gray silt gray (5Y 5/1) shell fragments
2'7½"		
3	C	(5Y 4/1) dk gray + fine sand a few scattered shell fragments
	D	coarsening up sequence coarse-med sand w/ pebble concentration gray (5Y 5/1) ↑ med sand
4	E	med. sand olive gray (5Y 5/2) - a few pebbles interspersed
4'1½"		dark gray (5Y 5/1) clay / no shells poorly sorted med-coarse w/ pebbles dk gray clay woods/organic material (½ inch) clay
5		coarse - v. coarse sand w/ pebbles dk gray
6		

CORE: MMS-94-15

PAGE 2 OF 2

6		
7		
8		
9		

CORE LOG

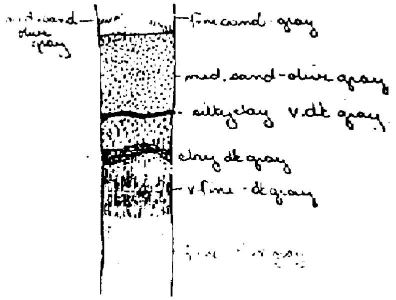
PAGE 1 OF 4

CORE LABEL: MMS-94-16
PROJECT: MMS
DATE OF CORE: 17 April 94
DRILLER: Ejmar
FIELD LOCATION DETERMINED BY: loran
LAT:
LONG:
LORAN: ?26142.0 , 41226.7
TYPE OF CORE: 3" vibracore
WATER DEPTH FT: 41.5 fathoms ft
PENETRATION: 17'
RECOVERY: 79"
JETTED:
LOGGED BY: ASF
DATE: 13 May 94

recovery may have slipped 2'

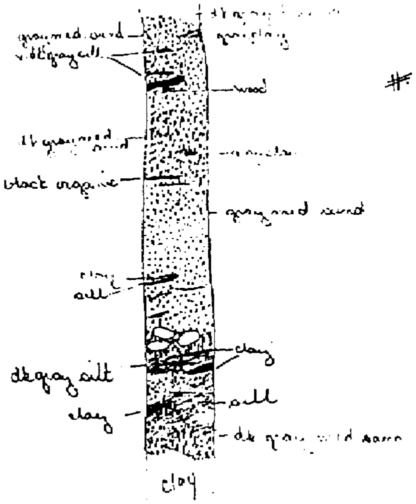
DEPTH	SAMP #	DESCRIPTION
0 ft		fine sand few (small) shell fragments light olive gray (5Y 6/ 1st foot gradually changes to gray (5Y 5/1)
1	A	
2		
3		medium sand interbedded larger shell fragments
		medium sand shell fragments olive gray (5Y 4/2)
4	B (channel sample)	flaser beds - v. dark gray (5Y 3/1) silty clay 1/2" - dark gray (5Y 4/1) clay 1/4" - v. fine dark gray (5Y 4/1) sand fine sand - olive gray (5Y 4/2)
5		shells & fragments fine sand - olive gray (5Y 5/2)
6		

→ diagra



CORE: MMS-94-16 PAGE 2 OF 4

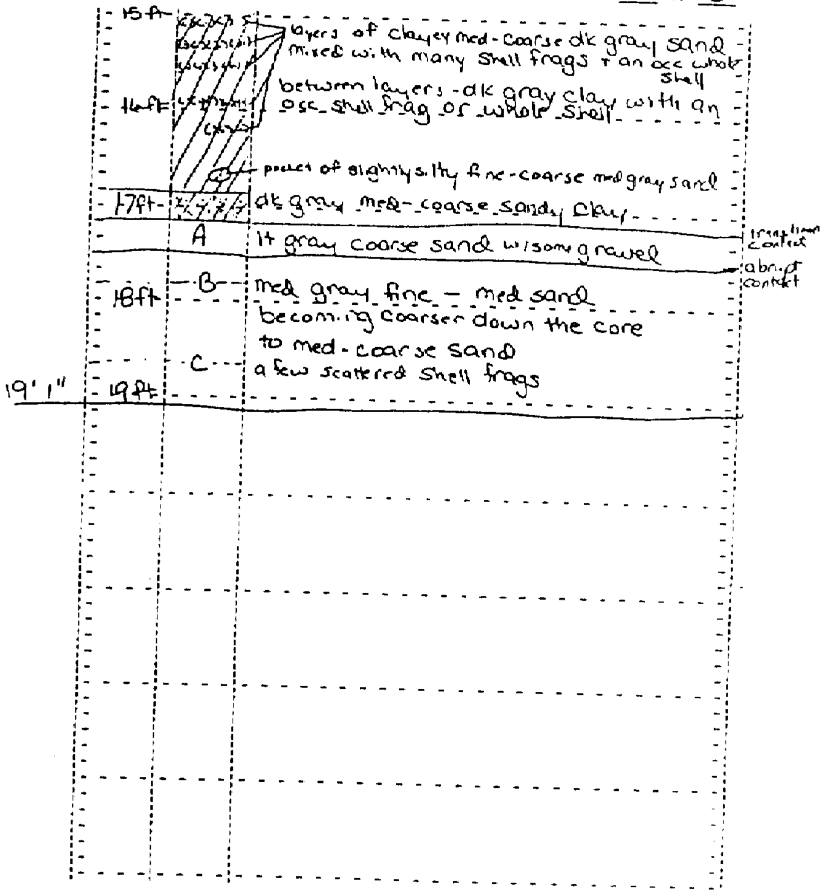
6	C	dark gray (5Y 4/1) fine sand - v fine sand some shell fragments a few silty-clay lenses (flasers)
7		
8		
9		flaser bedding - no continuous [illegible] / many different [illegible] / [illegible] / mostly med. sand/flasers only diagram →
10	D (channel sample)	* ~~dark~~ gray (5Y 5/1) clay * gray (5Y 6/1) med. sand & dk. gray (5Y 4/1) med. sand v. dk. gray (5Y 3/1) silt (v little present)
11		wood & organic material
12		
12'-12.8'		[illegible] mixed w/ med. sand dk gray (5Y 4/1) ~~[illegible]~~
13		? flasers - more clay present but still flasers same as ↑ dk. gray silt (5Y 4/1) dk. gray fine sand
14	no sample b/c all clay drill samples	dark gray (5Y 4/1) clay no shells or wood
15		



D

CORE: 5-94-3

PAGE 3 OF 3



layers of clayey med-coarse dk gray sand mixed with many shell frags + an occ whole shell

between layers - dk gray clay with an osc shell frag or whole shell

pocket of slightly silty fine-coarse med gray sand

dk gray med-coarse sandy clay

lt gray coarse sand w/some gravel

med gray fine - med sand becoming coarser down the core to med-coarse sand

a few scattered shell frags

Gravel, Sand, Silt, and Clay percents are weight percents of the entire sample.

Remaining data refer only to the sand portion of each sample as determined by Rapid Sediment Analyzer (settling tube)

M1, M2, M3, and M4 are the moment measures.

Mz is the Graphic Mean
Md is the Median
SI is the Inclusive Graphic Standaard Deviation
SKI is the Inclusive Graphic Skewness
KG is the Graphic Kurtosis

ID	GRV %	SAND %	SILT %	CLAY %
MMS-94-1-A	0.0	95.4	0.6	4.1
MMS-94-1-B	0.0	81.9	10.2	7.9
MMS-94-1-C	24.9	67.0	2.4	5.7
MMS-94-2-A	0.0	83.4	9.0	7.6
MMS-94-2-B	13.8	58.9	14.4	12.9
MMS-94-2-C	39.8	50.4	3.4	6.4
MMS-94-2-D	0.0	71.5	21.8	6.7
MMS-94-3-A	0.0	88.2	5.2	6.6
MMS-94-3-B	0.0	88.4	4.6	7.0
MMS-94-3-C	0.0	79.4	6.9	13.8
MMS-94-4-A	0.1	95.2	2.6	2.1
MMS-94-4-B	0.0	71.4	18.1	10.5
MMS-94-4-D	0.8	78.1	13.3	7.8
MMS-94-4-F	58.2	39.5	1.4	0.9
MMS-94-4-G	0.7	61.1	23.8	14.4
MMS-94-4-H	0.0	92.1	3.9	3.9
MMS-94-5-A	0.0	93.5	2.3	4.2
MMS-94-5-B	0.0	92.8	4.4	0.4
MMS-94-5-C	0.4	95.7	1.6	2.4
MMS-94-5-D	0.0	84.8	9.3	6.0
MMS-94-6-A	0.0	94.6	1.1	4.3
MMS-94-6-A				
MMS-94-6-B	0.0	84.7	8.0	7.3
MMS-94-6-B				
MMS-94-6-B				
MMS-94-6-C	0.0	75.3	15.0	9.7
MMS-94-6-C				
MMS-94-6-D	34.8	51.9	5.5	7.8
MMS-94-6-D				
MMS-94-6-E	1.0	63.1	19.9	16.1
MMS-94-6-E				
MMS-94-6-F	0.0	65.4	20.3	14.3
MMS-94-6-F				
MMS-94-7-A	0.4	95.8	1.1	2.7
MMS-94-7-B	0.0	81.1	10.5	8.4

ID	GRV %	SAND %	SILT %	CLAY %
MMS-94-7-C	1.4	90.9	7.1	0.6
MMS-94-8-A	0.0	94.6	1.1	4.3
MMS-94-8-B	0.0	78.6	9.8	11.7
MMS-94-8-C	0.0	71.5	17.3	11.2
MMS-94-8-D	0.8	93.9	0.6	4.8
MMS-94-8-E	3.4	89.7	1.6	5.2
MMS-94-9-A	0.0	96.1	1.9	2.0
MMS-94-9-B	0.2	94.3	2.4	3.1
MMS-94-10-A	0.7	93.9	2.8	2.6
MMS-94-10-B	0.0	82.2	11.7	6.1
MMS-94-11A-A	0.2	94.6	1.3	4.0
MMS-94-11A-B	0.0	88.8	4.4	6.8
MMS-94-11A-C	1.0	73.7	12.3	13.0
MMS-94-11A-D	0.2	80.2	8.9	10.7
MMS-94-11-B-A	0.0	91.5	5.9	2.6
MMS-94-11-B-B	0.0	81.0	13.4	5.6
MMS-94-11-B-C	4.9	87.7	4.4	3.0
MMS-94-11-B-D	18.5	75.3	3.4	2.8
MMS-94-11-C-A	0.1	94.6	3.1	2.2
MMS-94-11-C-B	0.0	94.2	3.8	1.9
MMS-94-11-C-C	0.0	94.4	3.1	2.5
MMS-94-11-C-D	5.0	89.8	3.7	1.5
MMS-94-11-C-E	2.4	92.6	3.3	1.7
MMS-94-12-A	0.0	93.1	3.9	3.0
MMS-94-12-B	0.4	85.6	9.2	4.8
MMS-94-12-C	0.2	89.4	5.9	4.5
MMS-94-12-D	0.0	93.5	3.5	3.0
MMS-94-13-A-A	0.0	84.1	7.2	8.7
MMS-94-13-A-B	12.8	77.0	2.9	7.3
MMS-94-13-A-C	19.8	73.6	0.8	5.8
MMS-94-13-B-A	10.3	83.5	1.0	5.2
MMS-94-14-A	0.5	89.6	4.3	5.6
MMS-94-14-B	0.0	79.3	10.6	10.0
MMS-94-14-C	3.9	87.3	2.5	6.3

ID	GRV %	SAND %	SILT %	CLAY %
MMS-94-14-D	20.6	60.0	7.3	12.1
MMS-94-14-E	0.0	68.0	17.4	14.6
MMS-94-14-F	0.1	63.1	21.6	15.1
MMS-94-15-A	0.0	97.2	0.5	2.4
MMS-94-15-B	0.0	88.9	4.5	6.6
MMS-94-15-C	0.0	86.1	6.4	7.6
MMS-94-15-D	11.6	81.7	2.5	4.2
MMS-94-15-E	4.4	88.8	2.6	4.3
MMS-94-16-A	0.0	94.2	2.6	3.2
MMS-94-16-B	0.0	91.4	3.6	5.0
MMS-94-16-C	0.0	74.0	16.2	9.8
MMS-94-16-D	0.7	79.0	10.3	10.1
MMS-94-17-A	0.0	86.4	8.5	5.1
MMS-94-17-B	0.4	92.0	3.9	3.7
MMS-94-17-C	0.2	86.8	6.7	6.4
MMS-94-17-D	0.4	87.5	7.9	4.2
MMS-94-17-E	0.0	83.2	10.5	6.3
MMS-94-17-F	0.9	81.9	9.4	7.8
MMS-94-17-G	0.6	82.0	10.1	7.3
MMS-94-17-H	1.4	95.2	2.9	0.5
MMS-94-18-A	0.0	90.3	5.6	4.1
MMS-94-18-B	0.0	89.2	7.3	3.5
MMS-94-18-C	0.0	88.1	7.3	4.6
MMS-94-18-D	3.4	91.0	2.2	3.4
MMS-94-18-E	25.0	63.3	6.9	4.8
S-94-1-A	1.5	95.5	1.2	1.8
S-94-1-B	1.1	96.1	0.9	1.9
S-94-1-C	0.0	95.8	2.0	2.3
S-94-1-D		84.6	7.7	7.3
S-94-1-E	0.2	96.7	1.3	1.8
S-94-2-A	12.5	83.1	0.8	3.6
S-94-2-B	15.5	80.2	0.9	3.3
S-94-2-C	1.0	94.3	1.1	3.6
S-94-2-D	1.6	93.6	0.9	3.9
S-94-2-E	0.4	92.6	1.9	5.1

ID	GRV %	SAND %	SILT %	CLAY %
S-94-3-A	5.0	89.0	1.5	4.5
S-94-3-B	0.1	86.7	4.9	8.2
S-94-3-C	0.7	88.6	6.0	4.7
S-94-4-A	10.5	86.6	2.1	0.7

ID	M1 PHI	M2 PHI	M3	M4	Mz PHI	Md PHI	SI PHI	SKI	KG
MMS-94-1-A	1.671	0.577	0.922	7.281	1.647	1.660	0.517	0.072	0.621
MMS-94-1-B	3.129	0.900	-2.545	9.850	3.346	3.353	0.573	-0.319	0.497
MMS-94-1-C	1.278	0.984	0.111	2.868	1.167	1.316	1.027	-0.083	0.819
MMS-94-2-A	3.366	0.697	-4.787	28.190	3.469	3.442	0.240	0.124	0.156
MMS-94-2-B	2.111	1.537	-0.366	1.664	2.062	2.252	1.502	-0.209	0.549
MMS-94-2-C	1.290	1.259	0.584	2.535	1.236	1.175	1.265	0.176	0.889
MMS-94-2-D	3.187	0.473	-2.453	19.776	3.208	3.172	0.322	0.254	0.244
MMS-94-3-A	3.086	0.918	-2.856	11.273	3.270	3.296	0.682	-0.039	0.611
MMS-94-3-B	3.294	0.833	-3.508	15.971	3.449	3.429	0.570	-0.256	0.539
MMS-94-3-C	2.471	1.050	-1.146	3.847	2.528	2.901	1.007	-0.572	0.583
MMS-94-4-A	1.393	0.733	1.132	5.993	1.305	1.385	0.661	-0.016	0.949
MMS-94-4-B	3.433	0.558	-3.711	20.522	3.520	3.489	0.314	-0.013	0.228
MMS-94-4-D	2.464	0.904	-0.956	4.024	2.486	2.653	0.899	-0.310	0.576
MMS-94-4-F	1.590	1.303	-0.170	1.770	1.588	1.875	1.319	-0.235	0.649
MMS-94-4-G	3.257	0.635	-1.872	10.407	3.309	3.299	0.529	-0.046	0.309
MMS-94-4-H	3.031	0.568	-4.260	26.613	3.094	3.105	0.289	-0.114	0.222
MMS-94-5-A	3.057	0.533	-2.763	17.063	3.104	3.151	0.377	-0.027	0.273
MMS-94-5-B	2.906	0.763	-1.838	8.246	2.959	3.064	0.644	-0.325	0.450
MMS-94-5-C	1.441	0.742	0.190	4.977	1.409	1.445	0.679	0.035	0.736
MMS-94-5-D	3.380	0.765	-4.503	26.646	3.497	3.474	0.256	0.098	0.167
MMS-94-6-A	1.435	0.740	0.492	5.368	1.383	1.468	0.675	-0.110	0.841
MMS-94-6-A	1.629	0.720	0.441	6.527	1.587	1.603	0.588	0.045	0.743
MMS-94-6-B	3.229	0.843	-2.905	11.643	3.413	3.398	0.569	-0.264	0.521
MMS-94-6-B	3.182	1.006	-3.229	13.225	3.418	3.405	0.641	-0.314	0.582
MMS-94-6-B	3.116	1.119	-2.695	9.616	3.412	3.396	0.737	-0.308	0.686
MMS-94-6-C	3.561	0.470	-4.866	36.699	3.606	3.582	0.240	0.167	0.148
MMS-94-6-C	3.462	0.814	-4.390	23.036	3.604	3.572	0.260	0.105	0.171
MMS-94-6-D	0.981	1.325	0.961	2.621	1.020	0.440	1.347	0.592	0.908
MMS-94-6-D	0.871	1.203	1.087	3.318	0.893	0.485	1.241	0.503	1.307
MMS-94-6-E	3.634	0.650	-4.901	31.921	3.717	3.709	0.276	0.007	0.170
MMS-94-6-E	3.271	1.077	-2.626	9.610	3.470	3.565	0.856	-0.506	0.686
MMS-94-6-F	3.651	0.514	-4.051	26.637	3.709	3.681	0.287	0.104	0.175
MMS-94-6-F	3.514	0.694	-3.385	17.195	3.649	3.634	0.555	-0.277	0.471
MMS-94-7-A	1.352	0.761	1.177	6.248	1.275	1.338	0.697	0.036	0.916
MMS-94-7-B	3.195	0.920	-2.951	12.237	3.407	3.386	0.586	-0.234	0.533

ID	M1 PHI	M2 PHI	M3	M4	Mz PHI	Md PHI	SI PHI	SKI	KG
MMS-94-7-C	1.562	0.882	-0.024	3.788	1.561	1.652	0.903	-0.189	0.868
MMS-94-8-A	1.762	0.844	0.066	4.685	1.733	1.731	0.767	0.090	0.746
MMS-94-8-B	2.088	1.010	-0.069	2.826	2.147	1.982	1.031	0.149	0.595
MMS-94-8-C	3.320	0.864	-3.260	14.443	3.508	3.485	0.571	0.149	0.512
MMS-94-8-D	1.543	0.912	0.200	2.828	1.537	1.514	0.858	-0.254	0.512
MMS-94-8-E	1.628	0.791	0.139	3.726	1.628	1.569	0.746	0.027	0.558
MMS-94-9-A	1.981	0.784	-0.725	4.701	1.989	2.074	0.739	-0.170	0.633
MMS-94-9-B	1.615	0.724	0.945	6.959	1.546	1.508	0.587	0.306	0.839
MMS-94-10-A	1.513	0.818	-0.247	4.221	1.512	1.577	0.800	-0.113	0.920
MMS-94-10-B	3.485	0.566	-4.694	31.279	3.551	3.527	0.261	0.151	0.163
MMS-94-11A-A	1.675	0.885	0.679	4.176	1.625	1.529	0.781	0.262	0.943
MMS-94-11A-B	2.034	0.930	0.252	3.036	2.120	1.773	0.911	0.437	0.508
MMS-94-11A-C	2.001	1.081	0.330	1.997	2.029	1.691	1.114	0.343	0.512
MMS-94-11A-D	3.400	0.702	-3.815	16.612	3.516	3.502	0.352	-0.124	0.266
MMS-94-11-B-A	1.839	0.866	0.730	4.142	1.936	1.646	0.850	0.446	0.807
MMS-94-11-B-B	3.462	0.451	-4.846	38.795	3.497	3.465	0.231	0.233	0.149
MMS-94-11-B-C	1.393	0.970	0.744	3.397	1.285	1.309	0.983	0.089	0.944
MMS-94-11-B-D	0.800	1.084	1.150	4.045	0.699	0.600	1.021	0.284	1.060
MMS-94-11-C-A	1.502	0.776	0.515	5.587	1.480	1.472	0.644	0.077	0.735
MMS-94-11-C-B	1.325	0.674	0.228	4.623	1.302	1.306	0.635	0.010	0.811
MMS-94-11-C-C	1.414	0.687	-0.516	7.704	1.434	1.429	0.536	-0.003	0.778
MMS-94-11-C-D	0.531	0.868	1.549	6.465	0.524	0.335	0.766	0.362	1.293
MMS-94-11-C-E	0.747	0.761	0.889	4.658	0.795	0.597	0.704	0.358	1.047
MMS-94-12-A	3.272	0.610	-3.614	20.144	3.353	3.329	0.325	0.017	0.262
MMS-94-12-B	3.318	0.788	-3.089	13.583	3.496	3.474	0.493	-0.221	0.429
MMS-94-12-C	3.314	0.847	-3.602	16.214	3.476	3.445	0.519	-0.241	0.481
MMS-94-12-D	2.402	0.564	-0.795	10.585	2.398	2.310	0.481	0.349	0.379
MMS-94-13-A-A	3.231	0.921	-3.315	13.550	3.439	3.433	0.592	-0.329	0.568
MMS-94-13-A-B	1.423	1.183	-0.052	1.826	1.382	1.505	1.177	-0.126	0.619
MMS-94-13-A-C	0.926	0.900	0.895	3.740	0.848	0.780	0.896	0.226	0.978
MMS-94-13-B-A	0.598	0.839	0.558	3.058	0.563	0.515	0.820	0.102	0.820
MMS-94-14-A	1.422	0.770	-0.364	6.386	1.432	1.477	0.587	-0.130	0.718
MMS-94-14-B	3.116	1.137	-2.708	9.699	3.389	3.399	0.830	-0.373	0.756
MMS-94-14-C	1.965	1.020	-0.553	3.381	0.972	2.097	0.970	-0.230	0.780

ID	M1 PHI	M2 PHI	M3	M4	Mz PHI	Md PHI	SI PHI	SKI	KG
MMS-94-14-D	1.152	0.989	0.532	2.932	1.129	0.964	0.968	0.024	0.769
MMS-94-14-E	3.132	1.193	-2.389	7.873	3.385	3.513	0.882	-0.584	0.757
MMS-94-14-F	3.508	0.739	-3.844	20.447	3.639	3.601	0.431	-0.093	0.321
MMS-94-15-A	1.602	0.626	-0.218	6.658	1.590	1.161	0.514	-0.013	0.573
MMS-94-15-B	2.148	0.762	-0.276	4.972	2.199	2.042	0.696	0.292	0.563
MMS-94-15-C	2.940	0.873	-2.442	10.214	3.047	3.152	0.674	-0.399	0.470
MMS-94-15-D	1.870	0.842	-1.106	4.754	1.906	2.054	0.753	-0.354	0.697
MMS-94-15-E	1.976	0.687	-0.795	5.843	2.011	2.080	0.569	-0.299	0.578
MMS-94-16-A	3.225	0.507	-3.618	26.257	3.268	3.252	0.324	0.038	0.217
MMS-94-16-B	2.178	0.834	0.160	2.886	2.211	2.025	0.885	0.247	0.526
MMS-94-16-C	3.430	0.710	-3.570	16.948	3.560	3.544	0.443	-0.213	0.371
MMS-94-16-D	1.988	0.896	-0.555	3.303	2.013	2.066	0.895	-0.133	0.693
MMS-94-17-A	3.166	0.680	-2.589	12.772	3.282	3.257	0.477	-0.153	0.395
MMS-94-17-B	2.127	0.724	0.230	4.823	2.257	1.904	0.654	0.686	0.579
MMS-94-17-C	3.164	0.717	-2.651	11.754	3.314	3.323	0.442	-0.253	0.360
MMS-94-17-D	3.427	0.534	-4.900	35.099	3.482	3.455	0.237	0.189	0.155
MMS-94-17-E	3.440	0.619	-4.923	30.600	3.512	3.493	0.231	0.155	0.144
MMS-94-17-F	3.335	0.805	-3.299	13.972	3.503	3.488	0.538	-0.283	0.493
MMS-94-17-G	2.628	0.910	-0.881	4.165	2.715	2.572	0.869	0.048	0.526
MMS-94-17-H	1.730	0.716	-0.431	3.306	1.713	1.852	0.708	-0.259	0.556
MMS-94-18-A	3.257	0.634	-3.525	20.025	3.352	3.324	0.385	-0.067	0.324
MMS-94-18-B	3.373	0.550	-4.418	31.167	3.430	3.411	0.296	0.078	0.185
MMS-94-18-C	3.343	0.604	-3.781	21.839	3.426	3.399	0.309	0.024	0.219
MMS-94-18-D	2.203	0.948	-1.038	4.440	2.242	2.407	0.934	-0.344	0.720
MMS-94-18-E	1.273	1.345	0.518	2.143	1.223	0.852	1.363	0.376	0.702
S-94-1-A	2.127	0.835	-1.618	7.143	2.179	2.269	0.722	-0.287	0.714
S-94-1-B	2.242	0.693	-1.578	10.698	2.279	2.302	0.494	-0.064	0.497
S-94-1-C	2.382	0.649	-1.276	10.559	2.389	2.396	0.476	0.023	0.477
S-94-1-D	2.904	0.766	-1.506	7.302	2.973	2.910	0.643	0.033	0.389
S-94-1-E	1.899	0.737	-0.320	3.364	1.881	2.017	0.718	-0.262	0.546
S-94-2-A	1.453	0.827	-0.585	4.284	1.458	1.553	0.743	-0.206	0.828
S-94-2-B									
S-94-2-C	1.817	0.556	-0.710	5.222	1.844	1.865	0.493	-0.131	0.464
S-94-2-D	1.453	0.608	-0.049	3.794	1.474	1.468	0.581	-0.021	0.592
S-94-2-E	2.082	0.558	0.363	5.828	2.076	2.091	0.515	0.016	0.503

ID	M1 PHI	M2 PHI	M3	M4	Mz PHI	Md PHI	SI PHI	SKI	KG
S-94-3-A S-94-3-B S-94-3-C	1.228	0.780	1.139	5.259	1.177	1.124	0.708	0.244	0.970
S-94-4-A	1.255	0.724	0.645	6.693	1.218	1.282	0.631	-0.049	0.756

BIOGRAPHICAL SKETCH

The author of this dissertation, Carl Heywood Hobbs, III, was born May 3, 1946 to Carl Heywood and Lydia Hewitt Hobbs in New Haven, Connecticut. Following graduation from Hopkins Grammar School in 1964 he matriculated at Union College, Schenectady, New York, graduating in 1968 with a B.S. in geology. Mr. Hobbs studied at the University of Massachusetts, Amherst, from September 1968 to August 1971 receiving a M.S. in Geology in February, 1972. His thesis, *Sedimentary Environments and Coastal Dynamics of a Segment of the Shoreline of Cape Cod Bay, Massachusetts*, was written under the supervision of Miles O. Hayes.

Mr. Hobbs was a graduate student in marine science at the School of Marine Science, Virginia Institute of Marine Science, College of William & Mary from September 1971 until July 1972 when he resigned as a student to accept the staff position which he still holds. He was appointed to the faculty as an Instructor in 1975 and as Assistant Professor in 1977. His research interests include the geological history of the continental shelf including Chesapeake Bay, the natural resources of the shallow waters, and the influence of the environment on society. He is a Certified Professional Geologist in Virginia and a member of the Board of the International Marine Minerals Society.