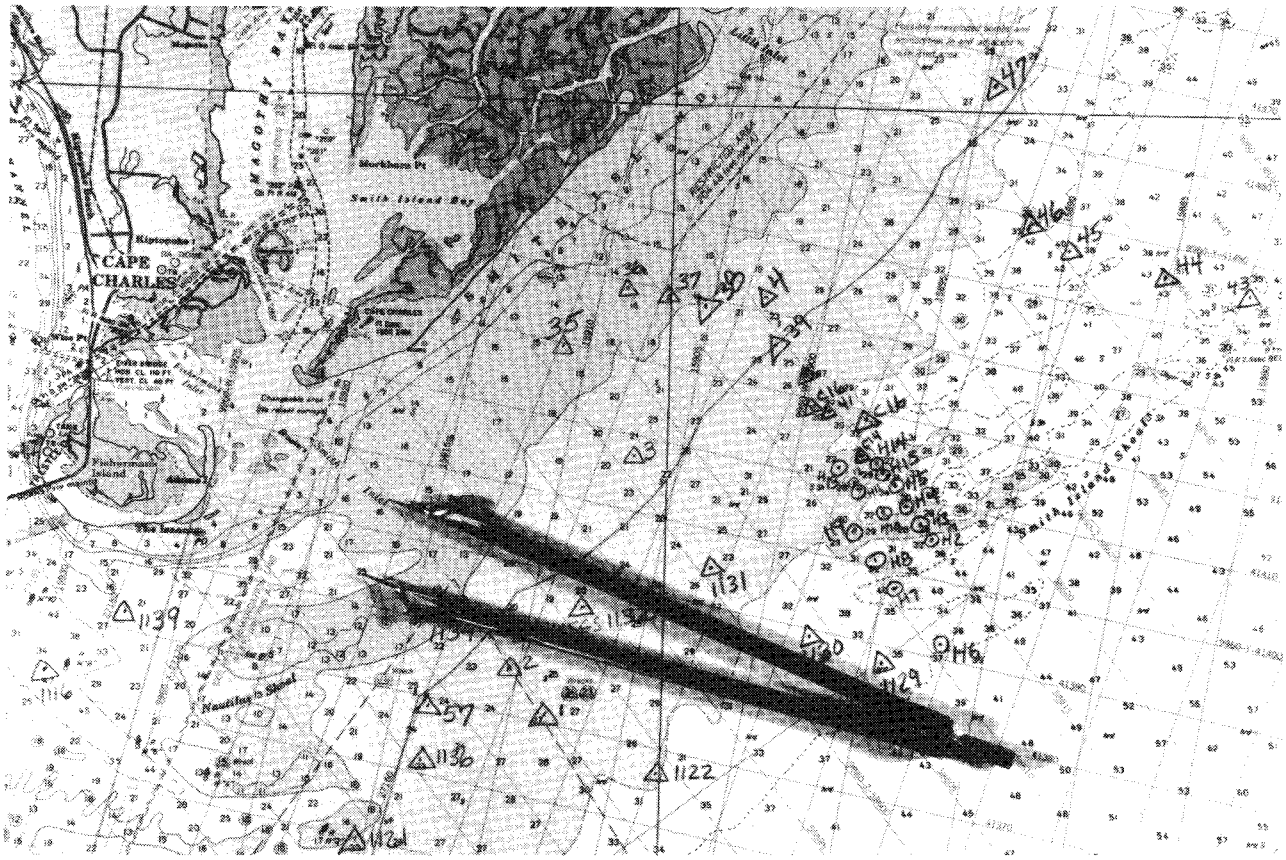
VIRGINIA DIVISION OF MINERAL RESOURCES

PUBLICATION 103

HEAVY-MINERAL STUDIES — VIRGINIA INNER CONTINENTAL SHELF

C.R. Berquist, Jr., Editor



COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
Robert C. Milici, State Geologist

CHARLOTTESVILLE, VIRGINIA
1990

FRONT COVER: Part of NOS Chart 12221 showing the location of several grab and core samples.

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DEPARTMENT OF MINES, MINERALS AND ENERGY
RICHMOND, VIRGINIA
O. Gene Dishner, Director

COMMONWEALTH OF VIRGINIA
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PREFACE

The five papers presented in this volume report on the results of heavy-mineral investigations in the inner continental shelf of Virginia. The investigations were conducted by the Virginia Division of Mineral Resources (VDMR) and the Virginia Institute of Marine Science (VIMS) for the period January, 1985 through December, 1989. The investigations were accomplished in cooperation with the U.S. Department of Interior, Minerals Management Service (MMS) who provided partial funding for the projects.

The cooperative efforts of VDMR/VIMS and MMS was accomplished through the Association of American State Geologists (AASG). Through a cooperative agreement between the Continental Margins Committee of the AASG and participating state geological surveys, the states have conducted investigations related to petroleum resources and/or strategic/critical mineral resources. The program is coordinated by the Texas Bureau of Economic Geology, The University of Texas at Austin by subagreements with each of the participating states.

The Continental Margins Program has given the states the opportunity to study resources in their coastal areas, both onshore and in the nearshore and offshore areas. The investigations reported on in this volume represents the research conducted for Years 2, 3, and 5 of the cooperative agreement under agreements 14-12-0001-30115, 14-12-0001-30296, and 14-12-0001-30387.

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ACOUSTIC GEOLOGY OF A PORTION OF VIRGINIA'S INNERMOST CONTINENTAL SHELF

Carl H. Hobbs, III [1]

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ABSTRACT

Side-scan sonography of the innermost continental shelf between Cape Henry and the Virginia-North Carolina border depicts a relatively typical inner shelf bottom generally characterized by medium density, meso-scale roughness. Sub-bottom acoustic profiles depict the stratigraphy as a Tertiary-age basement separated from Quaternary-age deposits by a regional, angular(?) unconformity. Holocene-age sediments form a discontinuous layer above another unconformity. The area's topography appears to be a function of the presence of the modern sediments.

INTRODUCTION

We collected approximately 534 km (276 n mi) of acoustic-survey line over the innermost continental shelf between the mouth of Chesapeake Bay and the Virginia-North Carolina boundary during July and August 1987 (Figure 1). This paper presents a discussion of a portion of the sub-bottom profiles as well as a qualitative report on the side-scan sonography obtained during that survey. Additionally, the paper includes a discussion of the occurrence of heavy minerals in relation to seismic stratigraphy.

The field work was a collaborative effort of two projects: one a joint Virginia Institute of Marine Science (VIMS) and Virginia Division of Mineral Resources (VDMR) study of the distribution of heavy minerals (Berquist and Hobbs, 1986, 1988a, 1988b), the other, a study by VIMS for the City of Virginia Beach of offshore reserves of sand potentially available for nourishment of the city's public beaches (Kimball and Dame, 1989). As part of the overall combined study, we also collected approximately two dozen vibracores across the survey area (Figure 1).

The area of geophysical investigation generally is inshore of that discussed by Shideler and others (1972) and Swift and others (1977) but does include the shoreface ridge system at False Cape (Swift and others, 1972). The shallow, sub-bottom profiles presented in this study add shallow detail

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to, and confirm, the earlier interpretations. Additionally, the present work provides a shoreward extension of the existing data.

As well as the work of Swift and others (1972, 1977), Shideler and others (1972), and Kimball and Dame (1989), there have been several other studies of the submarine geology of the area. Meisburger (1972) reported on the sediments and geomorphology in the immediate vicinity of the entrance of Chesapeake Bay. Hobbs and others (1984) and Kimball and others (1989) discussed resources of sand within the southernmost portion of Chesapeake Bay. Berquist (1986), Hobbs and others (1986), Colman and Hobbs (1987), and Colman and others (1988) refined the understanding of the geology of the bay mouth. Williams (1987) presented seismic and core data for the area adjacent to, and northeast of, the area of this present study. Bowen and Swean (1985) presented data on the subsurface of a portion of the area associated with the Cape Henry navigation channel.

Terrestrial studies beginning with Oaks and Coch (1973), proceeding through the various works of Johnson and others (1982, 1985), and summarized by Peebles (1984) provide further background data that can be extended offshore to enhance the interpretations.

GEOPHYSICAL SURVEYS

The surveys were performed from the VIMS's R/V Bay Eagle using a Datasonics SBP-5000 sub-bottom profiling system and an EG&G SMS-960 side-scan sonar system. (The use of trade names is for descriptive purposes only and does not imply endorsement of the products by either agency.) The primary navigation system was the ship's loran-c supplemented, at times, by a locally configured Del Norte system. Location fixes were recorded at five minute intervals except in some areas off Sandbridge and Rudee Inlet where the interval was two minutes. The sub-bottom survey was designed in two phases, one before and the other after coring. This was done in order to provide guidance for placement of the cores and then to derive the maximum information in those areas suggested by preliminary interpretation of the combined core and early seismic data.

The sub-bottom profiling system consisted of a Datasonics SBT-220 transceiver, a TTV-120 transducer vehicle, and either or both an EPC-3200 or EPC-4800 graphics recorder. The transceiver-transducer system is a dual frequency arrangement with one frequency selectable at 3.5, 5, or 7 kHz, the other preset at 200 kHz. Most of the profiling was done using a recorder sweep rate of one-eighth of a second (125 ms) yielding a potential full-scale record of approximately 90 m, assuming an acoustic velocity of 1500 ms^{-1}; the actual record seldom exceeded 30 m. Most of the profiles were recorded simultaneously on the two graphics recorders.

The near planimetrically correct sonographs were recorded in real time on electrostatic paper. The data were not recorded on magnetic media. The sea-floor mapping system uses a 105 kHz EG&G Model 272 tow fish. Sea-floor mapping was done at a 100 m half width (200 m full swath).

Side-scan sonography provides a suite of information concerning the character of the bottom surface. By graphically depicting the return strength of a "fan-shaped", acoustic signal transmitted perpendicular to the ship's track, the sonographs provide a general indication of the condition of the bottom (Williams, 1982; Duane, 1987; Duane and Stubblefield, 1988). The system relies more upon energy reflected by grain faces (backscattered) than directly reflected from the broad surface of the sea floor. A strong (return) signal suggests a relatively hard, coarse-grained bottom and a weak signal suggests a softer, finer-grained, muddy bottom (Hobbs, 1986; Wright and others, 1987). The sonographs also depict large-scale elements of bottom roughness: bedforms, as a function of variations in backscattered and reflected energy; and the occurrence of acoustic shadow zones caused by topographic highs. Side-scan sonographs also depict man-made bottom features and artifacts. The side-scan survey was a reconnaissance survey, a secondary objective to be run coincidentally with the sub-bottom profiling and not as a site specific, detailed study; thus the track lines were not spaced to allow overlapping (really side-lapping) images. Thus it usually is not possible to trace specific features from track line to track line; it is possible, however, to correlate or trace trends or groups of features.

Analysis of the sonographs is qualitative and subjective. The analyst sketches observations and interpretations of the images recorded on the sonographs onto a basemap containing the track lines and navigation fixes. The analyst looks for correlation of features and observations on adjacent and crossing lines as well as for broader patterns or trends. The end products are an interpretative map of the bottom and a discussion of general and, where possible, specific elements depicted by the imagery. Although quantitative analysis of some aspects, for example, height of some features above a level sea floor, is possible, it neither was seen as necessary nor undertaken for this project. No attempt was made to estimate the sediment type as suggested by the sonographs on a broad areal basis.

The cores were taken with a 9 cm (3.5 in) inside diameter Vibracorer operated from the R/V Atlantic Twin. The maximum length of the cores is 6.1 m (20 ft); although in some instances it was possible to approach that maximum only by jetting and obtaining multiple sections. In the laboratory, the split cores were analyzed only as to gross lithology (Berquist and Hobbs, 1988b).

RESULTS AND DISCUSSION

Side-scan sonography: Side-scan sonography is of interest in two aspects of the study of offshore heavy-minerals. Knowledge of the bottom grain-size characteristics and presence or absence of bedforms can provide information concerning the occurrence of heavy minerals. The minerals might be concentrated in sediments of a particular texture or the processes that created and maintain the bedforms might be responsible for concentrating particular suites of minerals. Knowledge of bedforms as indicators of a potentially active bottom would be important to those parties concerned with dredging or otherwise working the bottom should heavy minerals of economic interest be present. Additionally, should there be evidence of use of the bottom by man, it would

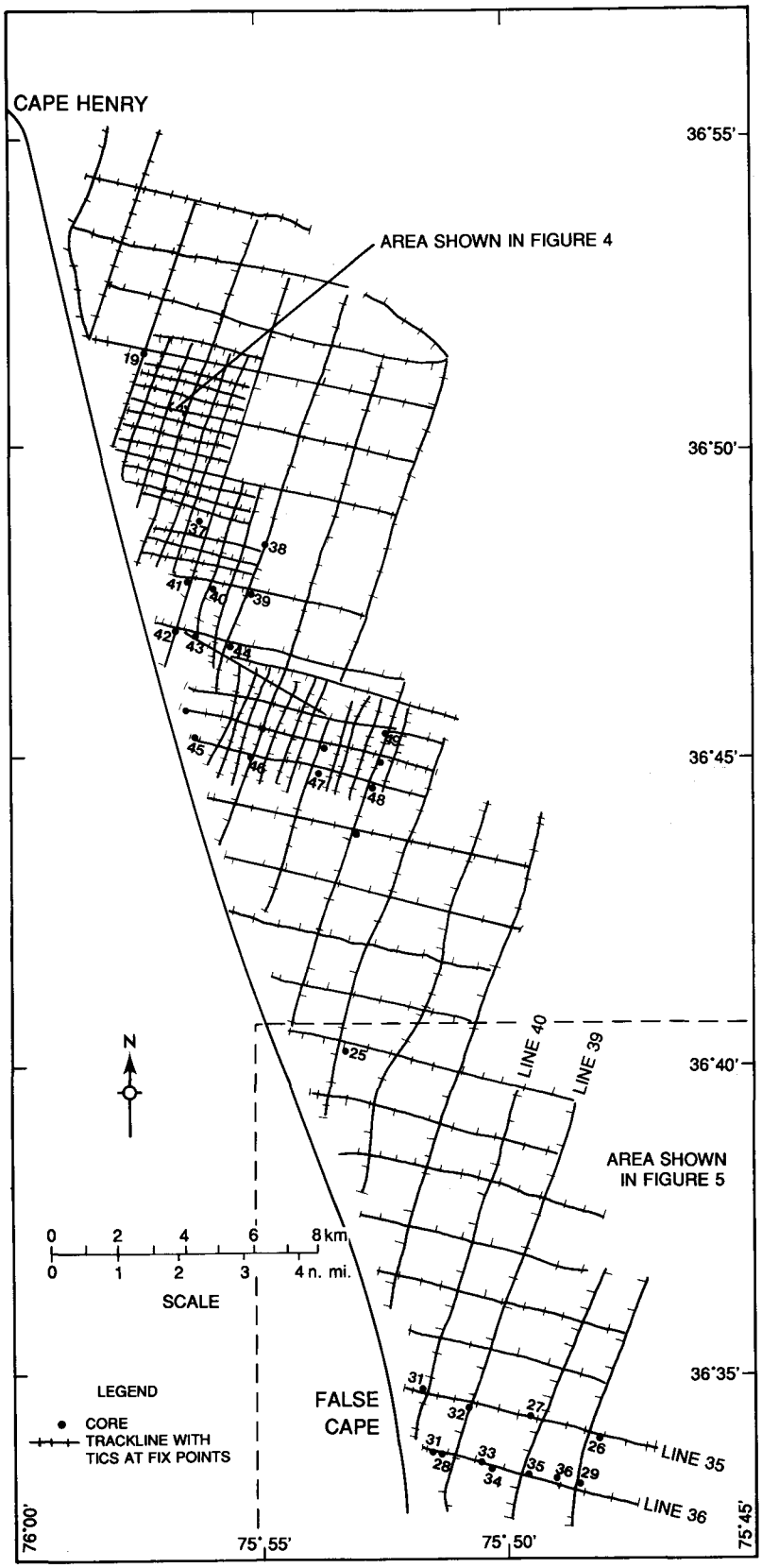


Figure 1. Location map indicating the general location of the study area and specific location of the geophysical track lines and core holes. Highlighted lines are depicted in other figures. The geological interpretation primarily is concerned with the area south of 36°55'.

have to be considered in any plans for dredging or mining.

Figures 2 and 3 are interpretive sketch maps depicting the features on the sonographs of the study area. Because of the greater line-density in the northern portion of the area (Figure 2) and the generally subjective nature of the analysis, it is difficult to assess the differences between the two regions. It appears that there may be a greater density of bottom features in the northern portion of the area, and definitely a greater number of anthropogenic features. Paramount among these is an elongate area of drag marks (Figure 4). If these are drags caused by commercial fishing gear, this would be a strong indication of a relatively intense use of the bottom, which in turn might necessitate an assessment of both the area's benthic resources and the potential impacts of dredging on other uses of the area. Alternatively the drag marks could result from anchor drags indicating another use of the bottom.

Throughout the study area there are rhythmic, light to dark changes in the base tone of the sonographs. These alternations are related to the bottom topography and might indicate changes in grain size or packing across the ridges. Generally the darker areas are associated with the sides of the troughs or between-ridge swales. The tonal variations probably are actual evidence of changes in the sediment and are not artifacts of the sea-floor mapping system as it operates over a nonplanar bottom (S. Kimball, oral communication, 1989; D. Swift, oral communication, 1989).

Whether or not the apparent decrease in bottom features toward the south is real, a function of the less closely spaced track lines, or variation in the analyst's interpretations, or a combination of the three is difficult to assess. If this is a real phenomenon, it probably is the result of increasing distance from the mouth of Chesapeake Bay and its more dynamic current regime (Ludwick, 1978).

The study area fits into Wright and other's (1987) classification as Inner Shelf Shoreface (Type Ia) or Inner Shelf Ridge Field (Type Ib) bottom types. The type section for the Inner Shelf Shoreface environment is adjacent to Dam Neck, Virginia and is within the present study area. Both the shoreface and ridge field environments are characterized by: low biogenic roughness at any scale, the presence of small-scale (heights 1 to 10 cm, wavelengths 1 to 50 cm) wave- and current-induced roughness, and usually, the presence of meso-scale (heights of 0.1 to 2.0 m, wavelengths of 0.5 to 50 m), current-induced roughness.

Sub-bottom profiles: This paper is concerned primarily with the sub-bottom profiles in the southern third of the study area (Figure 1). The remaining portions being the subjects of other studies (Williams, 1987; Kimball and Dame, 1989). Part of this area was discussed by Swift and others (1972, 1977), Shideler and others (1972), and others, whose data and interpretations are significant to the understanding of the historical geology of the area.

Consistent with the interpretation of Shideler and others (1972) and ensuing papers, there are three or four major (acoustic) units separated by two or three unconformities. The lowest unit (unit A) was considered to be of Miocene age in the 1972 work and is most probably the same as the Pliocene-age nearshore, marine deposits discussed by Colman and others (1988). Some of the later Tertiary-age deposits have been reassigned from Miocene to Pliocene on the basis of new data obtained since the publication of the earlier work. This widespread unit, the Yorktown and/or the Chowan River Formations, constitutes local "basement". Cores 32 and 34 (Berquist and Hobbs, 1988b) appear to penetrate unit A, which is discernable by a substantially higher proportion of silt, 53 percent in core 32, 26 percent in core 34, than the overlying units wherein the silt usually accounts for less than 20 percent and frequently less than 10 percent of the sediment.

Unit A is separated from the next younger unit by reflector 1, an easily traceable, wide-spread, regional reflector (Figure 5). Although Shideler and others (1972) and Colman and Hobbs (1987) agree that reflector 1 represents an erosional surface, they differ as to the age of that surface. Colman and Hobbs (1987) suggest a late Wisconsin age but agree that it could be as old as late Pliocene. Within the present study area, reflector 1 ranges from 12 to 20 m below sea level and generally dips gently to the southeast (Figure 5).

Local relief within the study area on reflector 1 is low. One of the few anomalies in reflector 1 is in the southwestern-most corner of the study area (the ends of lines 39 and 40, Figures 1 and 6) where a portion of a filled channel is visible. Although there is insufficient evidence to demonstrate whether this channel is a Pleistocene-age feature or the filled remnant of the Holocene-age Currituck Inlet channel, the magnitude of the channel and the apparent absence of unit D (see discussion below) suggests the older.

Unit B occurs immediately above reflector 1 and, according to Shideler and others (1972), is separated from unit C by reflector 2. In the present work, reflector 2 is not widely identifiable thus separation of units B and C is not always possible. The differentiation is more easily seen in the area just north of the present study (J.K. Dame, personal communication). Reflector 2 and unit C are suggested in at least some of the present study's profiles. Shideler and others (1972) refer to the discontinuous character of unit C, in which circumstance reflector 3 is the upper boundary of unit B.

According to Shideler and others (1972), reflector 2 is the basal boundary of unit C. In the western portion of their study area, which would embrace the study area of the present report, reflector 2 "appears to be truncated by overlying reflector 3." They also describe unit C as pinching out in the western portion of the study area. Thus differentiation of units B and C in the areas closer to shore is problematical. Shideler and others (1972) tentatively correlated unit B with Oak's (1964) Great Bridge Formation - Sandbridge Formation sequence. More recent work (Johnson and others, 1982, 1985) indicates that these two formations now would be mapped as the Pleistocene-age Shirley and Tabb formations. This would indicate that unit B is a pre-Wisconsin-to early Wisconsin-age series of deposits. Johnson and others (1982, 1985) describe these formations as ranging from fluvial to shallow marine, strand complexes.

Shideler and other's (1972) unit D is represented in the present study area. Unit D overlies reflector 2, or where present, reflector 3, is discontinuous, and consists of recent sea-floor sediments. Shideler and others (1972) document a ^{14}C date of approximately 4220 years BP (Figure 5) for unit D. This unit apparently has formed or is forming, during the ongoing transgression. Much of the present variation in sea-

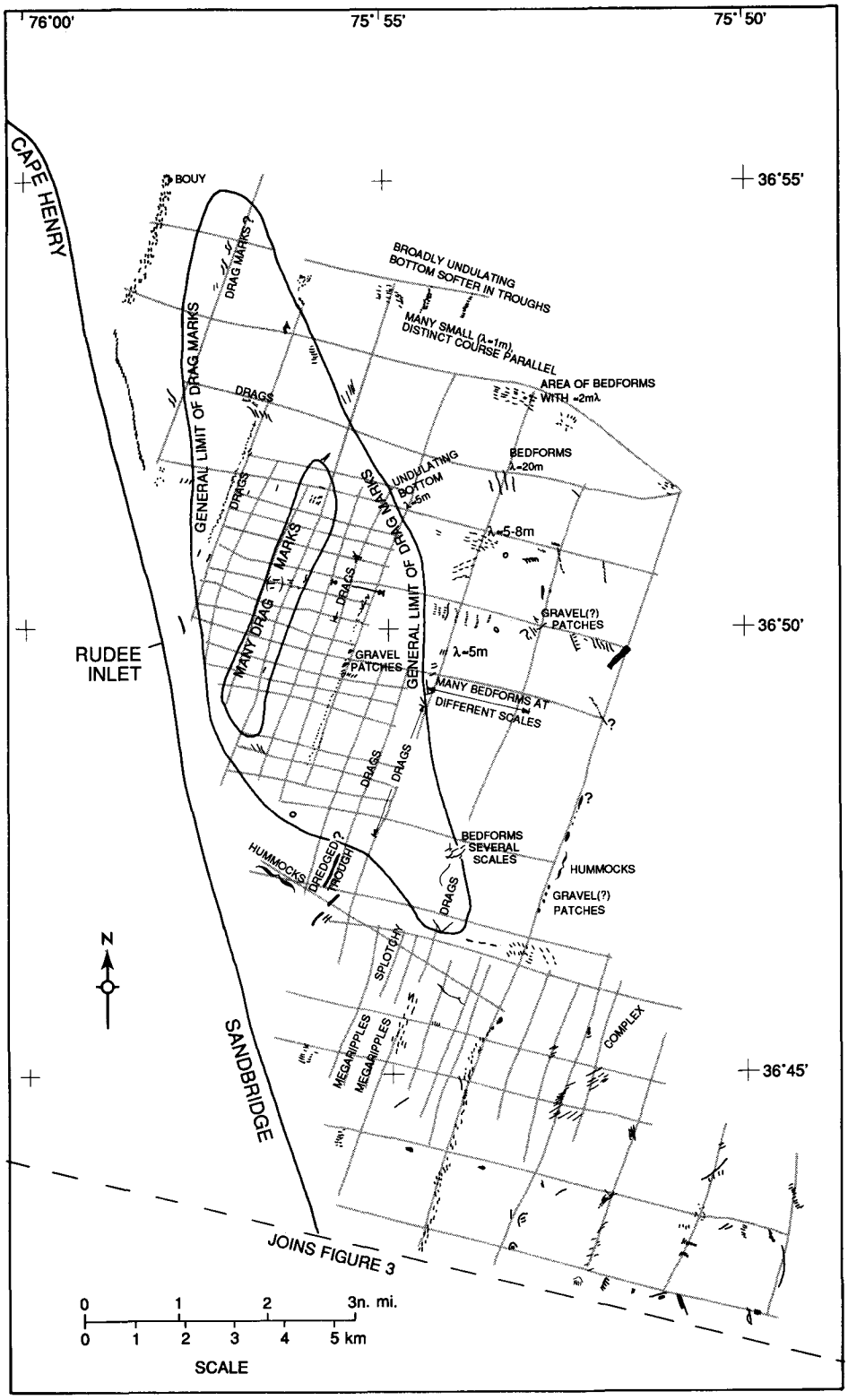


Figure 2. Interpretive map of information from side-scan sonography in the northern portion of the study area.

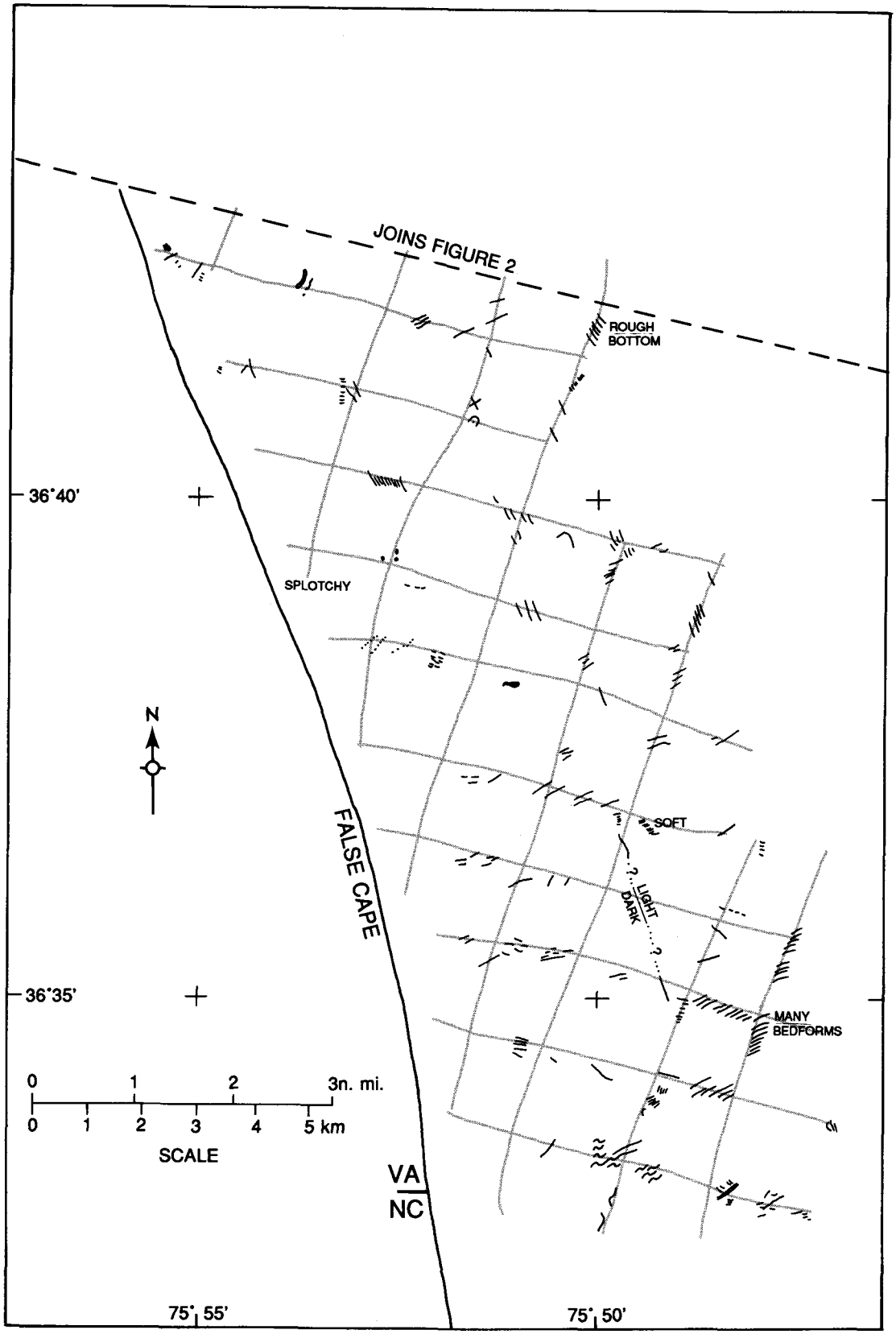


Figure 3. Interpretive map of information from side-scan sonography in the southern portion of the study area.

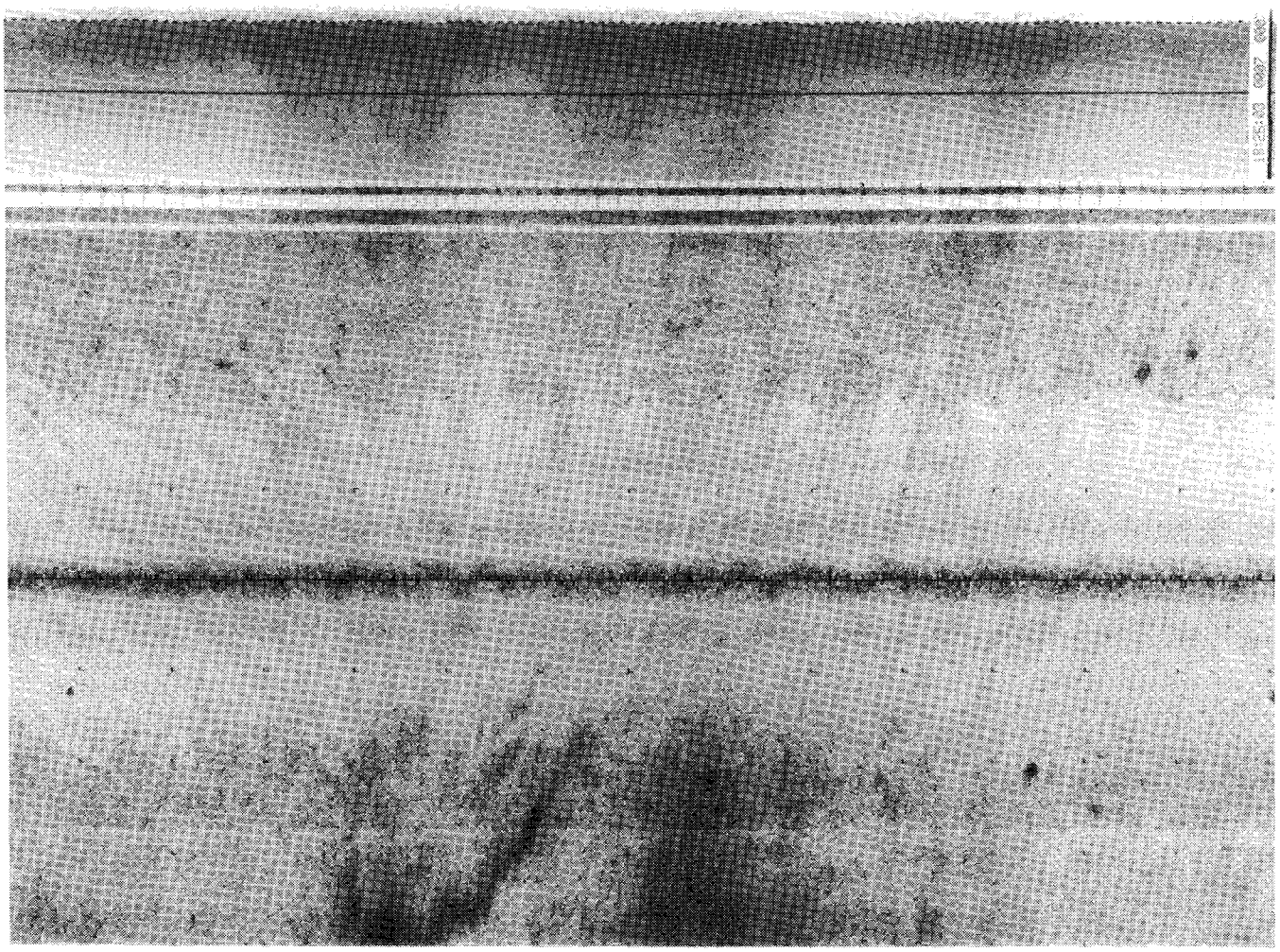


Figure 4. A portion of a side-scan sonograph depicting "drag marks."

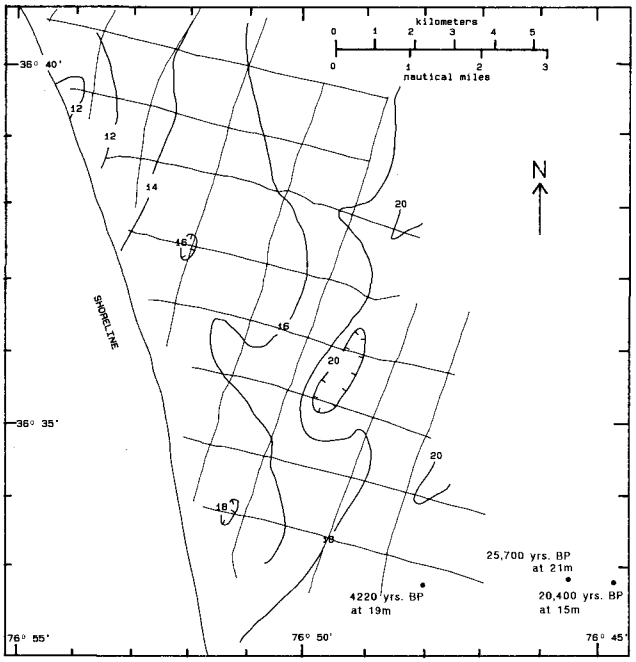
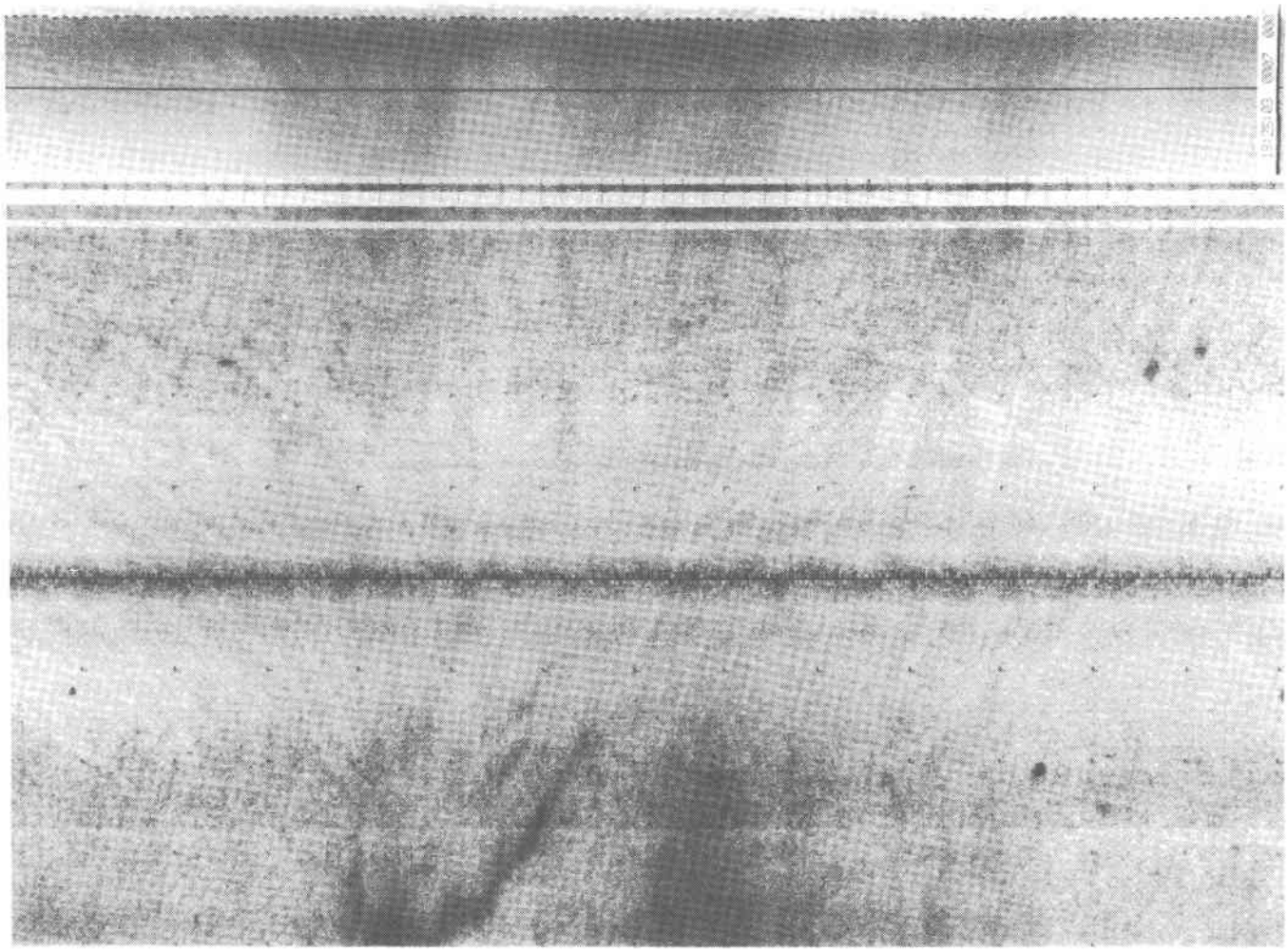


Figure 5. A contour map on reflector 1, the upper surface of unit A. This represents the top of Tertiary deposits. ^{14}C dates are from Shideler and others (1972).

floor topography, such as the False Cape Ridge System (Swift and others, 1972), reflects the distribution of this unit. The intermittent character of unit C is evident in the sub-bottom profiles (Figures 6 and 7).

Heavy minerals: The sediments in the nearshore area of southern Virginia Beach are not as abundant in total heavy minerals or in the titanium-bearing minerals as the sediments in the area north of the mouth of Chesapeake Bay (Berquist and Hobbs, 1988b). This mineralogical difference indicates that the area south of the bay's mouth may have a different source area than the northern area and that the present and past deep baymouth channels (Colman and Hobbs, 1987; Colman and others, 1988) may be an effective barrier for nearshore transportation. For a further discussion of regional mineralogical differences see Ozalpasan (1989) and Calliari and others (1990). The False Cape suite of heavy minerals appears to be more abundant in zircon and monazite (Berquist and Hobbs, 1988b, cores 26, 29, and 32) than other areas although the total concentrations are relatively low. The highest concentration of zircon and monazite occur in the cores taken at sites where unit D is thin or absent, indicating that the minerals occur either as a lag in the troughs between ridges or in older deposits, such as units B or C.



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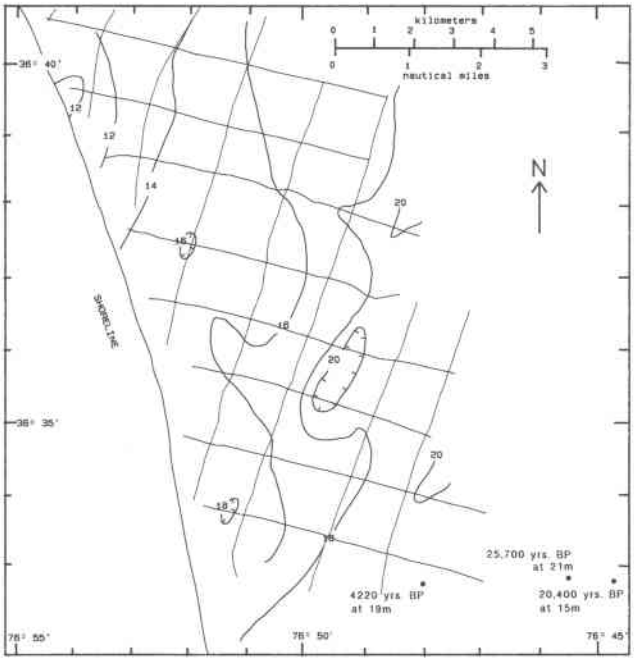

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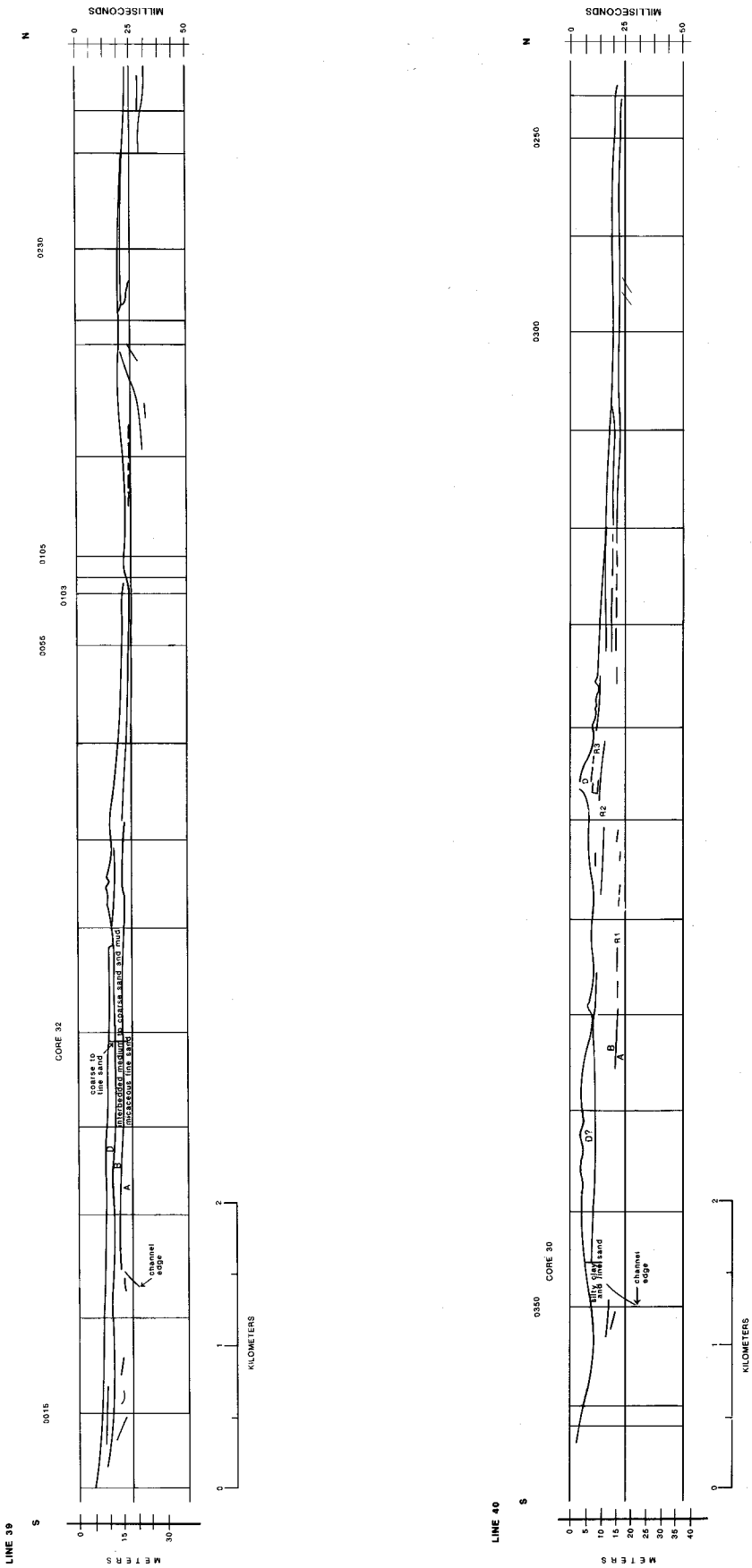

Figure 6. Interpretation of sub-bottom profiles 39 and 40, see Figure 1 for location. The upper portion of a Pleistocene-age channel is evident in the southern portion of profiles 39 and 40. The channel appears to have been eroded in both reflectors 1 and 2 suggesting that the channel fill is at least as young as unit C. The discontinuous nature of unit D, Holocene material, is best displayed in the center portion of Line 40.

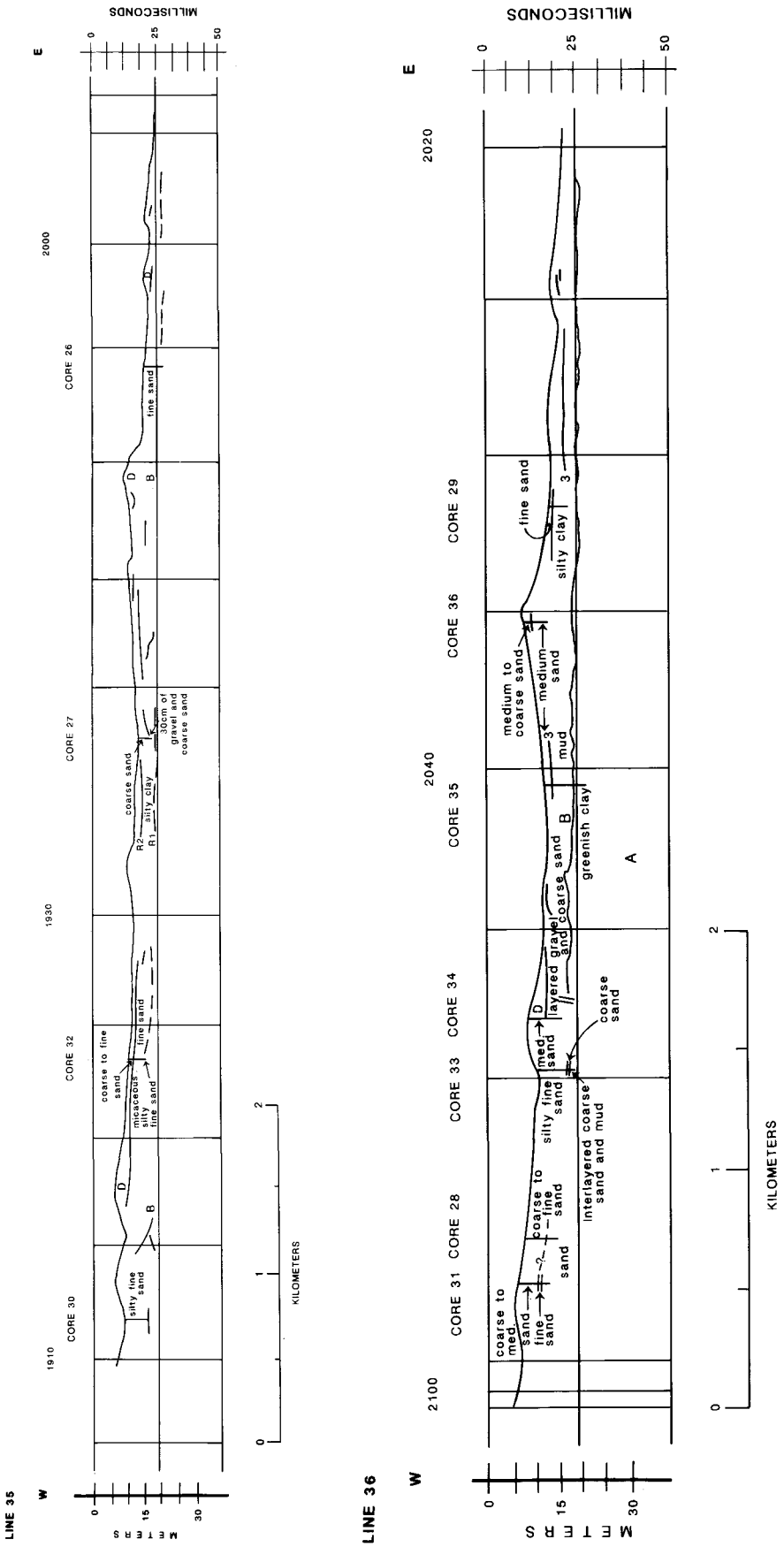

Figure 7. Interpretation of sub-bottom profiles 35 and 36, see Figure 1 for location. These profiles cross the False Cape ridge system at the southern limit of the study area. Reflectors 1 and 3 and units A, B, and D are clearly evident.

Swift and others (1972), in discussing the shoreface ridge system at False Cape, described a complex relationship between grain size and bottom topography. They described the crests as generally covered with fine- to medium-grained sand, the flanks and the margins of some troughs as floored by fine- to very-fine-grained sand, and the axes of the troughs as floored with pebbly, medium- to coarse-grains sands. They surmised that the coarser sediments formed a thin, discontinuous layer over an older substrate. This is consistent with the interpretation of later studies (Shideler and others, 1972; Swift and others, 1977) that the topography is a function of the presence of an active, recent, discontinuous deposit, unit D. This spatial variation in sediment type is reflected in the tonal variations on the side-scan sonographs as discussed above.

Samples of sediment from the most recent set of cores (Berquist and Hobbs, 1988b; Kimball and Dame, 1989) indicate that the sediments of the ridge system, and by analogy with unit D, are somewhat coarser than the sediments of units B or C. The uppermost sediment samples in cores 31, 34, and 36, which were taken at or near the crests of the ridges, have mean grain sizes of 1.56, 1.7, and 1.1 phi, respectively. By contrast, sediments from units B or C generally have mean grain sizes between 2 and 3 phi, although there are some, usually thin, lenses of coarser material. As noted above, sediments of unit A have a greatly increased proportion of silt.

CONCLUSIONS

Side-scan sonography of the inner continental shelf adjacent to Virginia Beach, Virginia, between the mouth of Chesapeake Bay and the Virginia-North Carolina border indicates that the bottom meets the criteria of an inner shelf - shoreface or an inner shelf - ridge field when classified by roughness characteristics (Wright and others, 1987). The present study area includes the type area for the inner shelf - shoreface classification. The sonographs also depict a region containing what are interpreted as "drag marks", that, if correctly interpreted, would be indicative of at least a moderate scale, bottom-fishing industry.

Sub-bottom profiles of the southern third of the area demonstrate a shoreward extension of the acoustic geology described by Shideler and others (1972) and Swift and others (1972, 1977) who worked in the immediate seaward and adjacent areas. Their interpretations proposed a Tertiary-age (Pliocene) "basement", unit A, separated from the overlying Quaternary-age deposits by a strong, regional (angular?) unconformity, reflector 1.

The next younger stratum, unit B, is a Pleistocene-age deposit, separated from still younger deposits by another unconformity. In the northern and eastern portion of the study area, there is another Pleistocene-age deposit, unit C, that is absent to the west and south. The uppermost stratigraphic layer, unit D, is separated from the older units by an unconformity, reflector 3, and is discontinuous. Three of the units appear to have a characteristic sediment type: A having a high silt content, B usually consisting of fine sands with some silt, and D generally being the coarsest unit. There are insufficient data to characterize unit C.

The heavy-mineral suite of the area is dissimilar to that north of Chesapeake Bay. The assemblage here is richer in zircon whereas the northern area has more ilmenite.

ACKNOWLEDGMENTS

C. R. Berquist, Jr., S. M. Kimball, and J. K. Dame were most generous with their advice and assistance as I attempted to decipher the data; I thank them. S. S. Johnson suggested several improvements to the paper. This is contribution 1620 of the Virginia Institute of Marine Science.

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A PROCEDURE FOR ASSESSING HEAVY-MINERAL RESOURCES POTENTIAL OF CONTINENTAL SHELF SEDIMENTS*

Andrew E. Grosz[1], C.R. Berquist, Jr.[2], and C.T. Fischler[3]

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* Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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ABSTRACT

Supplies of placer heavy minerals, such as ilmenite, rutile, zircon, and monazite, are anticipated to be in short supply by early in the next century. The depletion of conventional onshore deposits coupled with the declaration of the Exclusive Economic Zone in 1983 have provided the impetus to assess the resource potential of heavy-mineral concentrations in U.S. Continental Shelf sediments as future sources for these mineral commodities.

Mineralogically imprecise assessments of placer resources result from analyses of concentrates derived from small-volume samples because of the particle-sparsity effect. The overall low grade of heavy minerals in Atlantic Continental Shelf sediments require the analysis of mineral concentrates from large volumes of bulk sample.

A set of procedures to extract and analyze heavy minerals from large-volume samples is presented. These procedures were designed for general application to reconnaissance surveys; the Virginia study is given as an example. Resulting data are appropriate for both basic research needs and for industry's requirements for information on offshore mineral grades and distribution.

The recovery of heavy minerals was a two-stage process using a modified spiral concentrator followed by heavy-liquid separation procedures. The mineral concentrate derived from heavy-liquid separation was magnetically fractionated to reduce the number of mineral species so that mineral identification and quantification could be facilitated. Reflected and transmitted light microscopes were used for mineral identification and quantification. The overall heavy-mineral composition of samples was determined by combining the percentages of heavy-mineral species distributed across the magnetic fractions by use of a computerized database.

BACKGROUND

The United States is dependent on imports from Australia, South Africa, and a number of other countries for about 80 percent of its ilmenite, about 60 percent of its rutile, and virtually all its zircon and monazite (Lynd, 1985). These minerals are commonly mined from heavy-mineral deposits that are subaerially exposed in modern and ancient beach-complex sediments (including beach, dune, inlet, washover fan, and barrier environments). A global-class beach-complex placer deposit of the titanium minerals ilmenite, altered ilmenite, and rutile (including monazite, zircon, and others) may be up to tens of kilometers in length, up to 2 km in width, and 10 or more m in thickness. Ore grades are variable, averaging 3 to 6 percent total heavy minerals, which typically has about a 50 percent economically valuable (ilmenite, altered ilmenite, rutile, zircon, and monazite) component.

Uses for heavy minerals and the elements they contain are being developed at a faster rate than new deposits are being discovered, and, consequently, it is not known how demand will continue to be met at current costs (Fantel and others, 1986; Shepherd, 1986). According to Fantel and others (1986), the production of rutile concentrates will likely decline significantly after 2000 as many mines, particularly those in Australia, deplete their demonstrated reserves. They concluded that within the coming decade, there could be a shortage of high-grade, low-cost rutile. Inactive mines that could come into production might act as a temporary replacement source for a limited time, but this would be at substantially higher costs. Production of rutile might be maintained longer if new resources were found at operating mine sites or if inferred reserves became demonstrated. Because of limited rutile availability over the long term, the production of synthetic rutile from ilmenite deposits is seen as the likely source for future high-grade titanium concentrates.

In many chemical plants, where about 95 percent of the world's annual production of titanium minerals is used for pigment manufacturing (Lynd, 1985), both synthetic rutile and high-titanium slags are suitable alternatives to rutile. Because placer reserves are being depleted and the demand is high, the titanium industry is in a state of flux and could use any of the following sources of TiO_2: lateritic anatase from Brazil, eclogitic rutile from Italy, high-TiO_2 slag from Canada and South Africa, fine-grained placers from Western Tennessee, perovskite from Colorado, synthetic rutile from magmatic ilmenites, and offshore placers.

The declaration of the U.S. Exclusive Economic Zone (EEZ) in 1983 provided an impetus to define the mineral resources contained within ocean-floor sediments and rocks. The declaration amplified the potential importance of placer deposits of heavy minerals in continental shelf sediments as future sources for strategic and critical mineral commodities.

The Atlantic Continental Shelf (ACS) of the United States has an area of about 3.9×10^{11} m^2 and contains an estimated 8.3×10^{11} m^3 of sand and gravel, assuming a 5-m average thickness (U.S. Department of the Interior, 1979). Most sand and gravel deposits, however, are 10 m or more thick. Heavy-mineral sand of variable composition and grade on the ACS is estimated to have a volume of about 1.3×10^9 m^3, which is 0.16 percent of the estimated sand and gravel volume. Recent studies by Grosz (1987), however, showed that this value may be underestimated.

Until recently, published reports on the economic importance of detrital heavy-mineral concentrations within sediments of the ACS were often speculative and provided inadequate data for a rigorous assessment of resources. In most of the literature heavy-mineral data is only used to clarify geologic or stratigraphic problems. The analyses commonly discuss "opaques" as a component forming 20 to 60 percent of the heavy-mineral assemblage. Because most of the heavy minerals of economic value are opaque (ilmenite, altered ilmenite, and frequently rutile), an assessment of the economic potential on this previously published literature cannot be mineralogically precise. Another factor that precludes the usefulness of most published heavy-mineral analyses for resource estimation is the bias caused by analysis of a narrow size-fraction (commonly a 2-to 3-phi, 0.250-to 0.125-mm, size interval) that commonly contains comparatively high heavy-mineral values, and reporting those elevated values as representative of the heavy-mineral grades (Arthur and others, 1986). A few published studies on the economic aspects of heavy minerals in ACS sediments are known (Drucker, 1983; Goodwin and Thomas, 1973), but inconsistencies within these reports limit their usefulness. None of the data from

offshore industrial exploration programs on the ACS have been published.

A larger effort is being undertaken jointly by the U.S. Geological Survey (USGS), the Atlantic coastal state geological surveys, the universities, and industry to assess the hard-mineral resources potential (including sand, gravel, phosphate, and heavy minerals) of the ACS. The Virginia Division of Mineral Resources and the Virginia Institute of Marine Science (VIMS) of the College of William and Mary collected and analyzed vibracore and grab samples from 1986 (Berquist and Hobbs, 1986) through 1988 (Berquist and Hobbs, 1988a, 1988b) on the inner ACS (<40-m isobath) offshore of Virginia.

The studies were initiated in response to high values of heavy-mineral concentrations reported by Nichols (1972), Goodwin and Thomas (1973), and Grosz and Escowitz (1983). Additional samples from the mouth of the Chesapeake Bay area were made available when the USGS acquired approximately 1300 vibracores from the U.S. Army Corps of Engineers. In addition, about 23,000 km of high-resolution seismic reflection profiles were acquired from the Corps of Engineers on the inner ACS from Maine to Florida. These cores and profiles were originally collected to identify potential borrow areas for beach nourishment and reclamation projects. From this collection, 36 vibracores were used in addition to the 77 vibracores and 106 grab samples that were collected and analyzed for the study detailed in other sections of this publication.

SAMPLE PREPARATION

RATIONALE

The rationale for the sample processing scheme presented here is based on a number of factors, some are specific to the samples obtained from the Corps of Engineers, and others are specific to the objective of characterization of the resource potential of a large area in a timely manner. The methods and procedures used here were designed to insure uniformity of resultant databases produced by all users of core samples, to offset particle-sparsity biases, to produce rapid reconnaissance-level information without sacrificing the detail necessary for follow-up detailed studies, and to provide economic geologic information for industry.

The type and the size of the sample to be used for mineral separation depends largely on the analytical goals of the study. Heavy minerals commonly constitute less than 1 percent by weight of sediments; therefore, it may take a sample of up to several tens of kilograms, depending on the amount of heavy-mineral concentrate needed. Preliminary microscopic examination to determine the approximate heavy-mineral percentage and to establish the approximate grain sizes of the minerals will help in establishing the appropriate procedures for maximizing the efficiency of mineral recovery. The end-product of separation processes in terms of mass of sample required for complete analysis is a function of the types of analyses anticipated (textural, mineralogic, wet chemical, geophysical, microprobe, X-ray fluorescence, and so forth) and the accuracy being sought from each analytical procedure.

The heavy-mineral processing scheme for the analysis of samples from the ACS (specifically for the samples contained within the Corps of Engineers vibracores) was designed to be flexible enough to accomodate a variety of current and anticipated analytical needs and to act as a guide for studies on other continental shelves where grades and compositions of heavy-mineral assemblages differ from those found in ACS sediments. The principal objective is to assemble a regional reconnaissance database that shall show grades, compositions, and areal/vertical distribution patterns of heavy minerals in ACS sediments. Studies of the economic geology of surficial sediments based on grab samples (Grosz and Escowitz, 1983; Grosz and others, 1986; Grosz and Nelson, 1989) show high regional and local variability; studies of vibracore samples also show high variability in grade and composition with depth in the sedimentary column (Grosz and others, 1989a, 1989b). In the past, most of the advances in laboratory-scale detrital mineral separation and identification have been made by sedimentary petrologists who sought to resolve stratigraphic and sedimentologic problems. For these purposes, relatively small amounts (usually on the order of tens of grams) of bulk sample were considered appropriate. Because the initial sample size was small and most studies sought to analyze a narrow size fraction (usually the 2-to 3-phi, 0.250- to 0.125-mm, less often the 3- to 4-phi, 0.125 to 0.0625-mm, size interval as well) for their heavy-mineral content, particle-sparsity biases (Clifton and others, 1969) precluded an accurate characterization of the full heavy-mineral assemblage present in sediment samples. Methods of separation utilized in such studies relied on initial screening to isolate the size fraction of interest and subsequently processing the recovered size fraction by sink-float methods (generally by use of bromoform having a specific gravity of 2.85) to recover the heavy-mineral component. Volume percentages of individual mineral species were then determined by methods utilizing 300 to 500 point-counted grains from slide mounts. This (and modifications of this) method appears to have worked satisfactorily for the resolution of stratigraphic and sedimentologic problems; however, the problems confronting the economic geologist in assessing the resource potential of heavy-mineral concentrations in continental shelf sediments necessitated a series of modifications in sample processing and analytical methods.

The freshly collected vibracores contain wet sediment in which the sedimentary structures are usually retained intact or are only slightly disturbed. During the 10- to 20-year period over which the Corps of Engineers' vibracores were processed for information, stored first at Fort Belvoir, Virginia, then shipped to the University of Texas at Arlington for storage, and finally shipped to the USGS in Virginia, they have dried completely. The dry nature of the contained sediments, the repeated shipping, and the removal of samples either by splitting the cores lengthwise or by drilling through the core liner, have, in many instances, disrupted the vibracores to the extent where sedimentary structures are not recognizable. Furthermore, most of the sediment contained within these vibracores is unconsolidated sand. These characteristics made the vibracores of little use to small-scale studies of sedimentary textures and mineral distribution pat-

terns. However, because of the large volumes of sediment in these vibracores, infrequently occurring heavy-mineral species within the heavy-mineral assemblages were identified. Although large-volume samples for these studies are considered to be critically important, particularly in reconnaissance phases, retention of intact portions of fresh (wet) vibracores is equally important.

The sample processing and analysis procedure discussed in the following sections is shown schematically in Figure 1. Processing of vibracore samples begins with lengthwise splitting of the plastic core liner (7.6- to 10.2-cm inner diameter; 0.64-cm wall thickness) either by use of a router (Figure 2) or by other suitable means, such as a static blade cutter (Figure 3). Care should be taken not to introduce plastic shards into the sediment because they are soluble in the heavy liquids used and in acetone. The top half of the split core is removed, and the bottom half is scraped clean by using a spatula to expose a flat surface for examination. Sedimentary structures, color (if wet), texture, composition, and fauna are noted. The opened core is photographed (Figure 4) in 30-cm increments that have approximately 3-cm overlaps between sequential photographs.

Samples from the vibracores were selected on the basis of textural criteria; from vibracores that have one sedimentary texture, they averaged about 1.5 m in length, and, from those that have more than one sedimentary texture, they varied in length. After removal of materials used in age dating (shells and peat), the sediment was weighed. All vibracores used in this study were channel sampled along the length of each sample; 300 to 500 g of bulk sediment were removed for archival and grain-size analysis purposes. The balance of the sediment from the Corps of Engineers' vibracores was processed for heavy-mineral content as described in following sections. Half of each core collected between 1986 and 1988 was processed for heavy minerals, and the other half was archived.

Because the cores ranged up to 6.5 m in length, sample identification numbers consisted of the unique core number followed by "-1", "-2", and so forth, where "-1" refers to the sample from the upper portion of the core (that is, from the water-sediment interface to some specified depth), "-2" refers to the next interval down, and so on to account for the entire length of the core. Each sample was placed in a 20-liter plastic bucket to determine the net sediment weight on a dry basis. For wet sediments, the dry-weight was based on weighing, drying, and reweighing 50 to 10- to 100-g aliquots of homogenized sediment. All weight calculations referred to in this report are on a dry-weight basis.

SAMPLE CONCENTRATION

Dividing the vibracores into discrete samples yielded an average of about 7 kg of sediment and ranged from 1 to 20 kg. To determine the gravel fraction, the sample was wet-sieved through a 10-mesh (2.00-mm opening) U.S. Standard stainless steel sieve. An undetermined, but generally small, amount of predominantly clay- and a lesser amount of silt-sized material was lost from the samples during this procedure. Modifications to the process can be made to recover these fine-grained fractions if future studies require their analysis. The mass of sediment available for the recovery of heavy minerals after this step averaged 4.9 kg and ranged from 0.8 to 19.7 kg.

Efficiency and consistency of heavy-mineral recovery, ease of operation, clean-up time between sample runs, and cost resulted in the selection of a Humphreys three-turn spiral concentrator with molded rubber lining (Figure 5) for preconcentration. The selection of this equipment does not imply that others would not have performed satisfactorily. The sediments obtained from the vibracores (predominantly sand) made the spiral concentrator best suited for the task.

The operation of the spiral concentrator requires a constant water flow of about 20 L/min which carries approximately 20 percent solids (sediment). The sample is introduced into the hopper at the top of the spiral concentrator and carried down the spiral trough by the flowing water. The light minerals (predominantly quartz, feldspar, and shell fragments) are centrifugally thrown to the outside edge of the trough whereas the heavy minerals lag within a few centimeters of the inner edge of the spiral trough because of their higher density (Figure 6). An adjustable splitter placed at the lower end of the spiral concentrator separates the light minerals from the heavy minerals and routes them into separate containers. The light fraction was passed through the spiral concentrator several times to assure maximum recovery of heavy minerals. The heavy-mineral concentrate (spiral heavies) was also passed through the spiral as many as three times to remove as much of the light-mineral fraction as possible. For the Virginia study, this procedure recovered an average of 55 percent of the heavy minerals from the bulk sample (the range was between 5 and 95 percent) and resulted in a concentrate averaging 320 g, which represented approximately 5 percent of the bulk sample weight. Similar procedures on samples from offshore of Cape May, New Jersey, resulted in an average of 87 percent recovery; from offshore of central Florida, in an average of 75 percent recovery; and from Long Island Sound, New York, in an average of 82 percent recovery. Poor recovery is usually associated with muddy samples, poorly sorted samples, or samples containing significant carbonate (shell fragment) components. Because the size, the shape, and the composition of clastic grains impart different hydrodynamic properties to individual samples that affect their susceptibility to recovery by differing methods of separation, a 250- to 350-g aliquot of homogenized sediment was grab sampled from the material rejected by the spiral (spiral lights) for control purposes. The spiral concentrator was thoroughly washed between samples to reduce cross-sample contamination. The heavy-mineral concentrate and the aliquot of rejected material were dried, weighed, and then processed by heavy-liquid separation techniques.

HEAVY-LIQUID SEPARATION

As pointed out by Krumbein and Pettijohn (1938), a heavy liquid should have the following attributes to be effective: inexpensive, easily prepared or purchased, transparent, liquid at ordinary temperature, noncorrosive, chemically inert towards most minerals, odorless, fluid rather than viscous, to

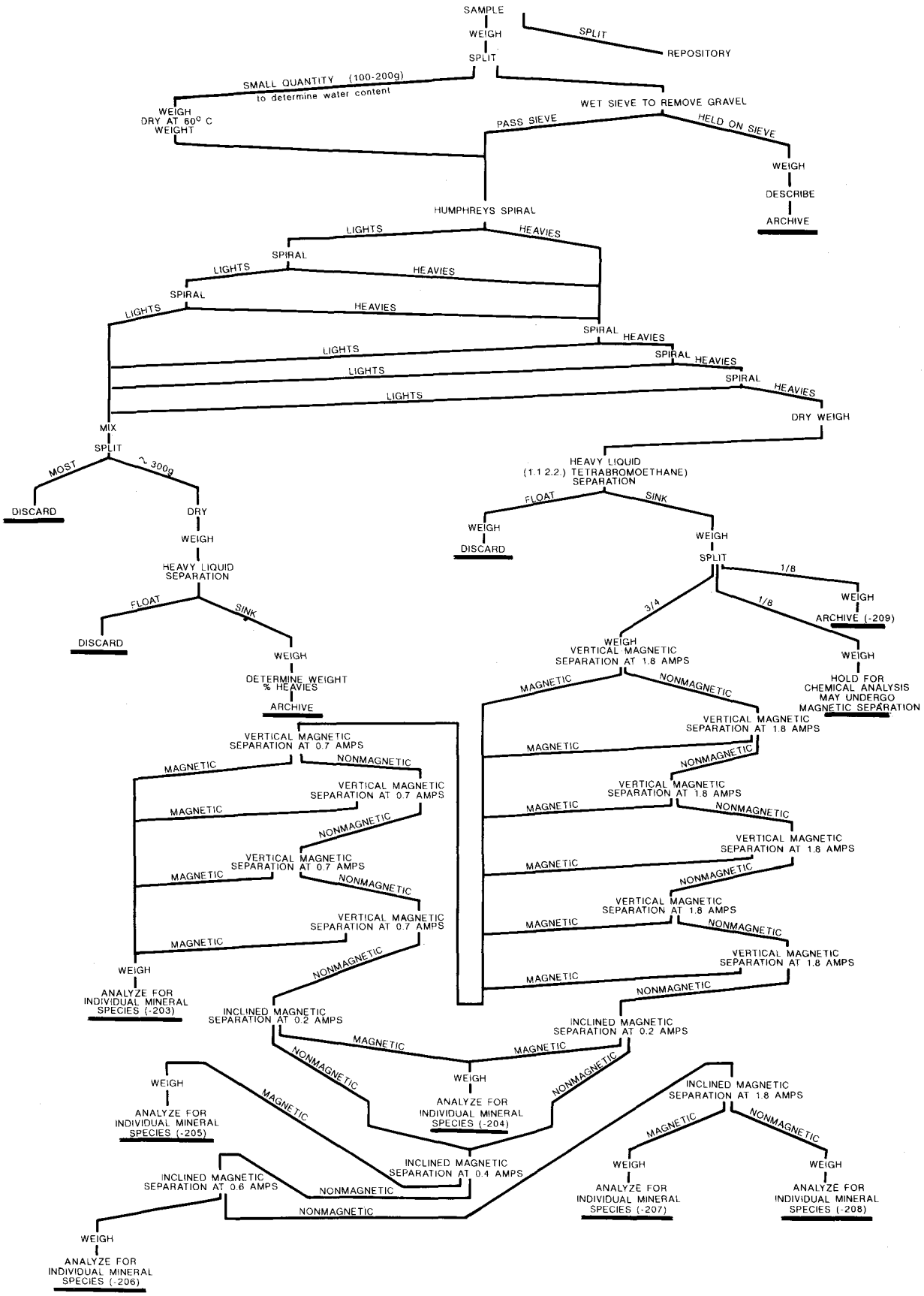

Figure 1. Flowchart showing the scheme of sample processing and analysis.

Figure 2. Photograph showing router apparatus utilized to split vibracores lengthwise.

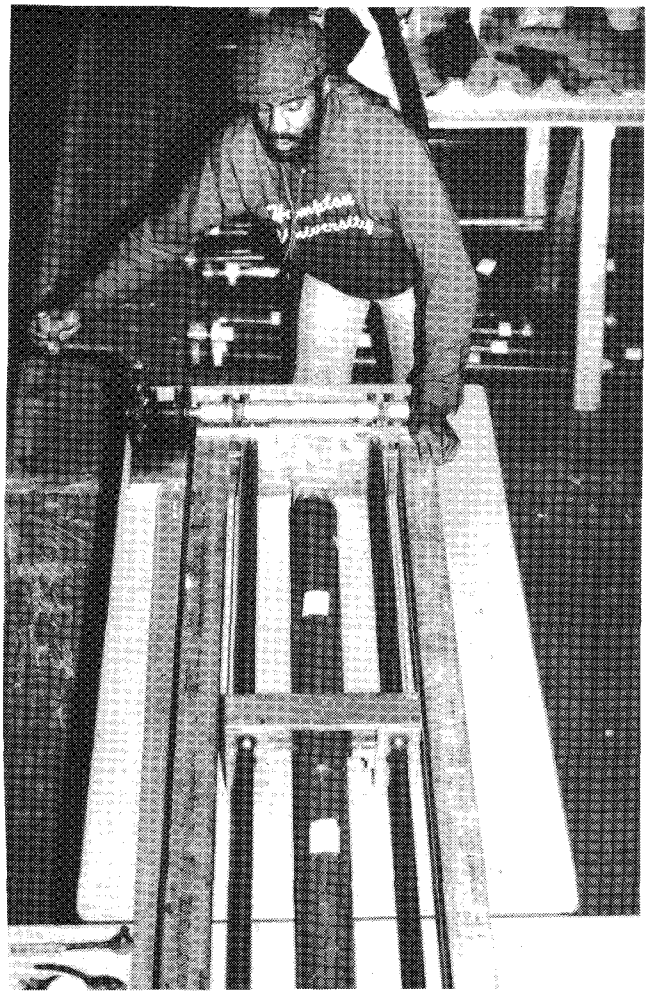

Figure 3. Photograph showing static blade cutter apparatus utilized to split vibracores lengthwise.

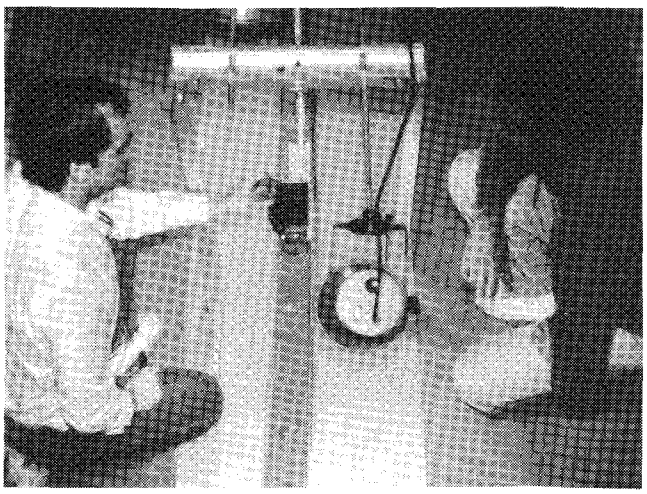

Figure 4. Photograph showing setup of equipment utilized to photograph split vibracores.

and easily diluted and recovered. None of the heavy liquids now in use have all these qualities; however, some have been proven to be better than others. For the purposes of this, and other parallel studies on the ACS, acetylene tetrabromide ($C_2H_2Br_4$), which has a specific gravity of 2.96, was used. In laboratories where heavy liquids are used extensively it is necessary to standardize procedures as much as possible. Because the original investment in large quantities of heavy liquids is comparatively high and they are toxic, efforts should be made to recover the maximum amount of the liquid.

Complete recovery is very seldom realized. However, it is possible to keep the loss of most liquids under about 1 percent on any one separation. When using the volatile liquids in large volumes, all operations should be carried out under well-ventilated hoods. The transfer of liquids from stock bottles to separatory funnels should be done in comparatively small volumes so that loss by dropping or spilling can be kept to a minimum.

The simplest and most widely used method for heavy-mineral separation is the use of liquids in separatory funnels (Figure 7). The heavy liquid and the mineral grains are introduced into the funnel and agitated by using a glass stirring rod. The mixture is allowed to stand until the light minerals float, the heavy minerals sink, and the two fractions are completely separated. The light minerals should be agitated several times to allow all the trapped heavy minerals

Figure 2. Photograph showing router apparatus utilized to split vibracores lengthwise.

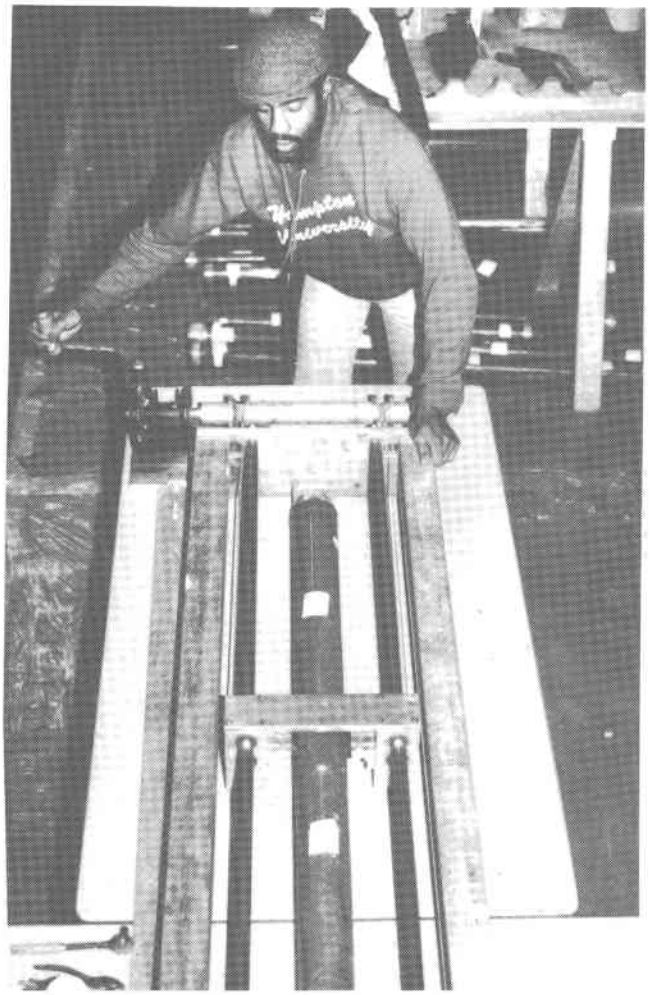

Figure 3. Photograph showing static blade cutter apparatus utilized to split vibracores lengthwise.

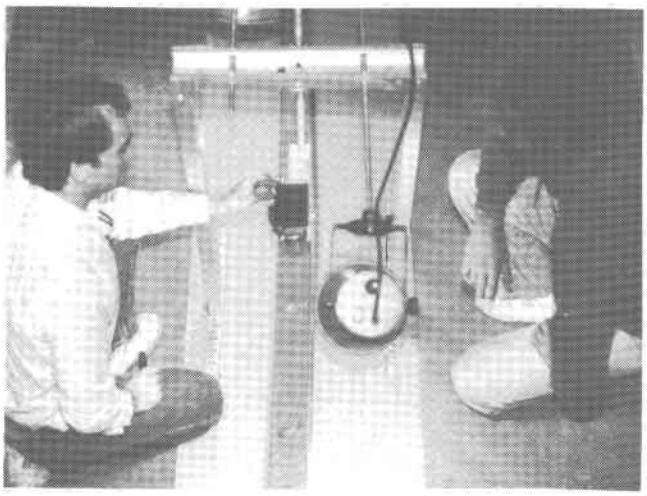

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Figure 5. Photograph of three-turn spiral concentrator.

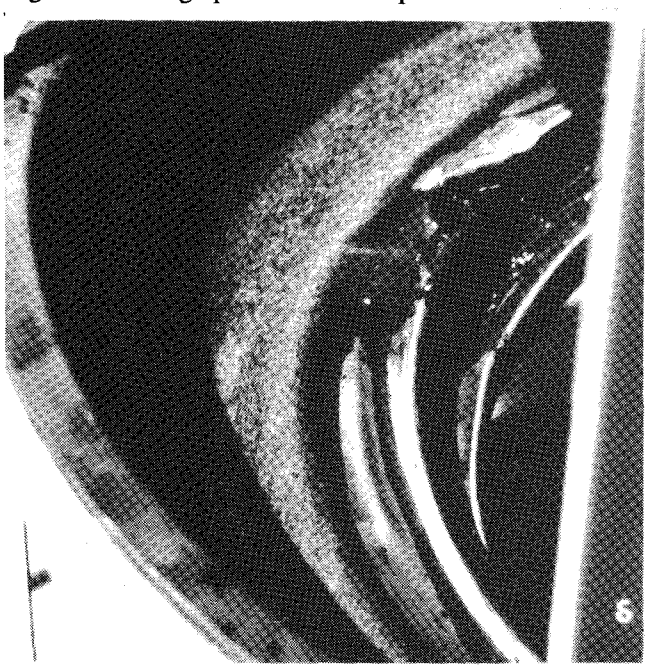


Figure 6. Close-up photograph showing separation of heavy (right) from light (left) minerals in the spiral trough.

sink. The heavy fractions are tapped by turning the stopcock and are allowed to pass through to a filter setup. Fine-grained material has a tendency to clot because the heavy minerals drag down some of the light minerals. A slow introduction of the sample into the separatory funnel along with frequent gentle agitation reduces, but does not completely eliminate, the clotting problem. After all the heavy minerals are tapped and the grains are filtered from the liquid, a new filter setup is made, and the remaining liquid and light minerals are tapped. A filtering process done under vacuum saves time and recovers a greater volume of the heavy liquid. The filters containing the light and the heavy minerals are washed liberally with acetone. The heavy liquid is recovered from the acetone washings by either using a water-wash process or by bubbling air through the washings until the specific gravity is determined to be acceptable.

The methods described above are not completely satisfactory for producing pure heavy-mineral separates, particularly if fine-grained material is present. Furthermore, the large volumes of heavy liquid that are needed for these samples result in a loss of more heavy liquid with each separation. Centrifuging overcomes both of these problems, but the use of the centrifuge precludes the rapid processing of large-volume samples.

The spiral heavies and the spiral lights were processed to obtain their "pure" heavy-mineral content by the method described above. Weights of all fractions were recorded. The heavy minerals recovered from the spiral heavies comprise the recovered heavy-mineral (RHM) fraction. The total heavy-mineral (THM) content of the bulk samples was approximated by methods described in the section "Mineral Database." The RHM fraction averaged approximately 100 g and ranged from 8.8 to 1227 g; the THM content averaged 229 g for the Virginia samples.

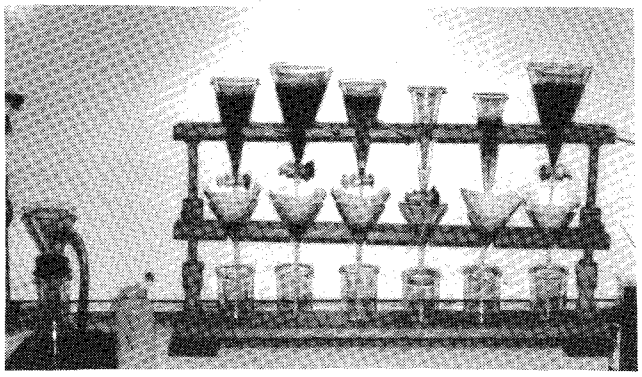


Figure 7. Photograph showing apparatus utilized for sink-float separation of heavy from light minerals in heavy liquid.

MAGNETIC MINERAL SEPARATION

The volumes of heavy minerals recovered by the (Humphreys) spiral and the heavy-liquid processing were large enough for archival and mineralogic determinations and chemical analysis. Archived samples are necessary for grain size distribution, magnetic susceptibility, gamma-ray suscep-

Figure 5. Photograph of three-turn spiral concentrator.

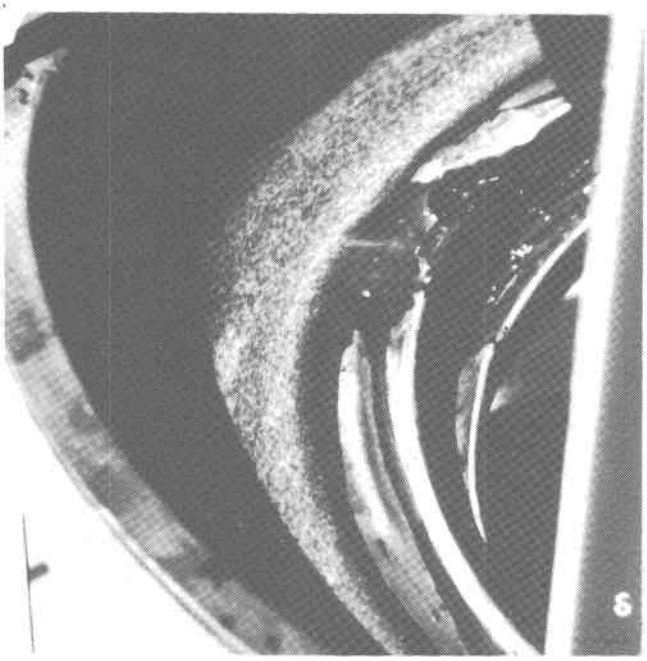


Figure 6. Close-up photograph showing separation of heavy (right) from light (left) minerals in the spiral trough.

sink. The heavy fractions are tapped by turning the stopcock and are allowed to pass through to a filter setup. Fine-grained material has a tendency to clot because the heavy minerals drag down some of the light minerals. A slow introduction of the sample into the separatory funnel along with frequent gentle agitation reduces, but does not completely eliminate, the clotting problem. After all the heavy minerals are tapped and the grains are filtered from the liquid, a new filter setup is made, and the remaining liquid and light minerals are tapped. A filtering process done under vacuum saves time and recovers a greater volume of the heavy liquid. The filters containing the light and the heavy minerals are washed liberally with acetone. The heavy liquid is recovered from the acetone washings by either using a water-wash process or by bubbling air through the washings until the specific gravity is determined to be acceptable.

The methods described above are not completely satisfactory for producing pure heavy-mineral separates, particularly if fine-grained material is present. Furthermore, the large volumes of heavy liquid that are needed for these samples result in a loss of more heavy liquid with each separation. Centrifuging overcomes both of these problems, but the use of the centrifuge precludes the rapid processing of large-volume samples.

The spiral heavies and the spiral lights were processed to obtain their "pure" heavy-mineral content by the method described above. Weights of all fractions were recorded. The heavy minerals recovered from the spiral heavies comprise the recovered heavy-mineral (RHM) fraction. The total heavy-mineral (THM) content of the bulk samples was approximated by methods described in the section "Mineral Database." The RHM fraction averaged approximately 100 g and ranged from 8.8 to 1227 g; the THM content averaged 229 g for the Virginia samples.

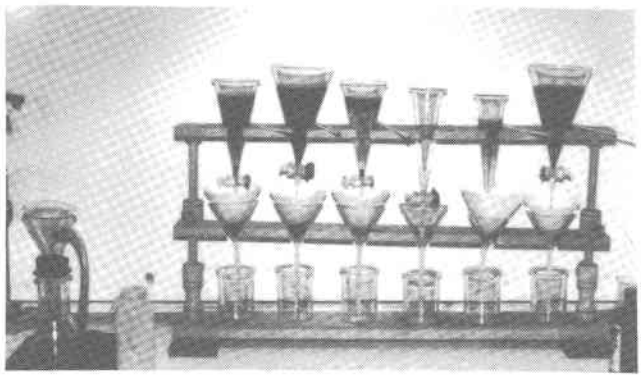


Figure 7. Photograph showing apparatus utilized for sink-float separation of heavy from light minerals in heavy liquid.

MAGNETIC MINERAL SEPARATION

The volumes of heavy minerals recovered by the (Humphreys) spiral and the heavy-liquid processing were large enough for archival and mineralogic determinations and chemical analysis. Archived samples are necessary for grain size distribution, magnetic susceptibility, gamma-ray suscep-

tibility, density, and induced polarization susceptibility measurements. A Jones splitter was used to obtain the three portions consisting of 12.5 volume percent for archiving, 12.5 volume percent for chemical analysis, and 75.0 volume percent for optical mineralogy. As the immediate objective of these studies is to reconnoiter heavy-mineral concentrations, detailed mineralogy on a large number of samples is too time consuming. Multi-element chemical analyses of the magnetic fractions from one portion of the RHM assemblage were planned to help identify mineral species that are difficult to resolve by the mineral identification methods discussed in the next section. Another portion of the RHM assemblage was retained for mineralogic analyses by optical methods. This was done to ensure that high-value, low-frequency mineral species, such as monazite, rutile, xenotime, cassiterite, and gold, had a significant chance to be identified and quantified in this reconnaissance study.

The splits retained for mineralogic determinations were separated into magnetic fractions by using a Frantz Magnetic Barrier Laboratory Separator (MBLS). This fractionation was done to reduce the number of mineral species in each magnetic fraction and to facilitate mineral identification and quantification. This procedure also should be followed with the split for chemical analyses to reduce inter-elemental interferences associated with polymineralic assemblages; this was not followed for the Virginia samples.

The Frantz Isodynamic Magnetic Separator (FIMS) is a versatile instrument and can produce excellent concentrates of many minerals. Substantial literature has been published on the subject of mineral separations performed with the FIMS (McAndrew, 1957; Gaudin and Spedden, 1943; Flinter, 1959; Hess, 1966; Nesset and Finch, 1980).

The MBLS has a significant advantage over the FIMS in the ratio of magnetic force to field intensity. Material is visible as it enters the field and undergoes separation at the magnetic barrier. These conditions result in better control, superior sensitivity, and greatly reduced processing time. A FIMS can be converted to an MBLS by using retrofit equipment. Much of the information in the literature about the FIMS is useful for operating the MBLS.

As the result of differences in design, the direction of magnetic force in the working space of the MBLS is the reverse of that in the FIMS, and the side slopes used in separating minerals according to their magnetic susceptibilities, therefore, also are reversed. For the FIMS, the magnetic force moves particles against a component of gravitational force, whereas, for the MBLS, gravitational force is used to move particles against a magnetic force. The range of field intensity provided by the two separators is substantially the same (0 to 20,000 Gauss). At any field intensity selected, however, the effective force provided by the MBLS is about 3 times greater than the effective force provided by the FIMS. A small adjustment of current to the MBLS results in a substantially greater change in the effective force than does the adjustment of current to the FIMS. Separation of materials that differ slightly in magnetic susceptibility is improved when the MBLS is used. The number of minerals that respond to magnetic force sufficiently for separation also is extended. At high magnetic force field intensities, the barrier field of the MBLS is sufficient to separate paramagnetic and weakly diamagnetic materials that cannot be separated by using the FIMS.

A sample consisting of minerals that differ in magnetic susceptibility is usually processed by separating the most strongly magnetic component first, and then separating of the other components in order of declining susceptibility. Separation of mineral mixtures that have susceptibilities ranging from ferromagnetic to diamagnetic is expedited by the initial removal of ferromagnetic minerals. Otherwise, the most magnetic minerals tend to be held by the pole pieces or on the chute surface inside the gap and thus divert other minerals from their normal paths.

The methods of removing ferromagnetic particles from heavy-mineral assemblages before paramagnetic separation include the use of hand-held magnets passed over the concentrate, the use of low current settings (10 to 20 mA) on the MBLS, and various configurations of the electromagnet that offer large surface areas over which the concentrates can be passed. These three methods offer individual advantages; however, in processing large-volume samples, a more rapid, replicable, and consistent method is necessary. For our processing, the magnetic poles of the MBLS were rotated into a vertical position and then the tops of the poles were inclined toward the operator. A 1.125-in. diameter, 0.225-in.-thick wall, glass tube was fastened to the pole pieces straddling the gap to provide a conduit for a flowing stream of concentrate containing ferromagnetic minerals. Then the magnetic field strength is set at the maximum (about 2.0 A; at this current setting, the magnetic field strength tends to decay as the magnet's coils heat up), the sample is introduced into the glass tube. As the grains fall through the tube, the more magnetic minerals are preferentially pulled against the inner side of the tube near the pole pieces (Figure 8); the minerals that are less magnetic fall through the length of the tube into a container. After the initial pass, an empty container is placed at the bottom of the glass tube, the current is turned off, and the magnetic minerals are collected. This procedure is rapid, and repeated passes through this setup are recommended for the nonmagnetic minerals, especially for the fine-grained mineral assemblages.

The ferromagnetic minerals were processed through the same setup by using a lower current setting (0.5 to 0.7 A, depending on the mineral assemblage) to concentrate those minerals that have paramagnetic properties and those minerals that have magnetic inclusions, such as zircon, staurolite, aluminosilicates, garnet, amphibole group, and others. This process was effective in removing ferromagnetic minerals in about 10 minutes for 300 g of bulk concentrate sample.

The nonmagnetic-mineral fraction derived from the free-fall separation was processed through the MBLS in sequential passes at increasing current strengths. The factory-provided ammeter on the MBLS was shunted to a digital ammeter for increased accuracy (a digital ammeter-equipped power controller is highly recommended for maintenance of current settings). Five mineral groups were thus generated at current settings of 0.2, 0.4, 0.6, 1.8 A, and nonmagnetic at 1.8 A. Each mineral group was weighed, bottled, and labeled.

General procedures for the determination of current and slope settings for the MBLS are provided by the manufacturer; optimal settings for any mineral assemblage must be

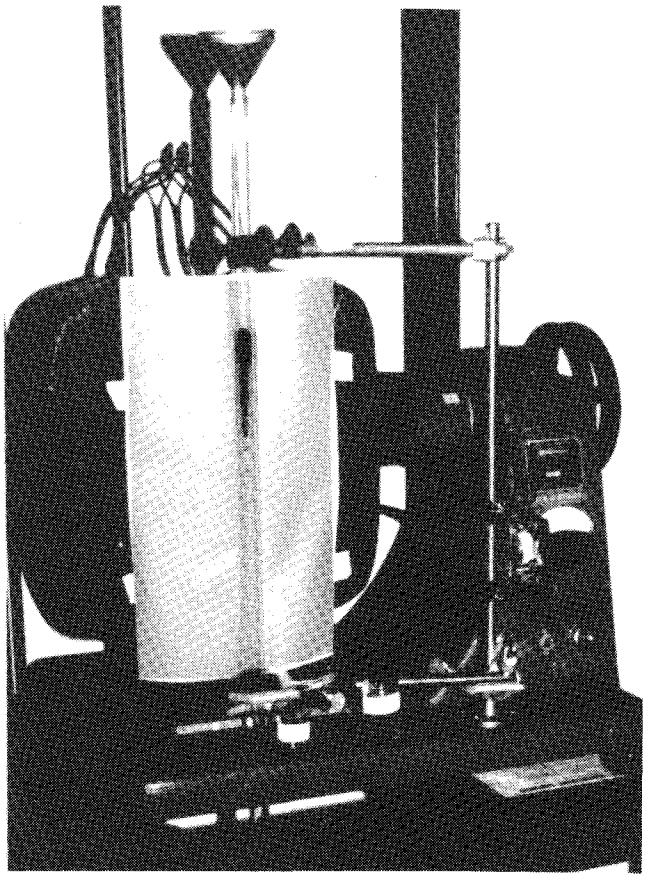


Figure 8. Photograph of magnet configuration utilized to separate ferromagnetic minerals from bulk heavy-mineral concentrates.

determined by the user. Forward and side slopes of the MBLS ranged from 15° to 20° and 15° to 25°, respectively. The current and the slope settings defined above were appropriate for the heavy-mineral assemblages found offshore of Virginia; however, for heavy-mineral assemblages elsewhere on the ACS higher current settings and steeper side slopes (up to 35° to 45°) provide cleaner and more rapidly processed separates. For our reconnaissance work, the emphasis was on processing many large samples in a short period of time.

A consequence of the time constraint is less-than-pure concentrates that have a scatter of given mineral species across a number of magnetic fractions because of variations in mineral composition and the presence of polymineralic grains. Because many heavy minerals have a wide range of possible compositions that results in a wide range of possible magnetic susceptibilities for a particular mineral, optimal current settings for extraction must be determined empirically for each suite. The mineralogy of the resultant magnetic fractions is discussed in the section "Mineral Identification and Quantification."

Geochemical data can be used to indicate the presence of potentially economic mineral species not distinguishable by rapid optical mineralogic analyses. The 12.5 volume percent split of the RHM fraction generated for chemical analyses also can be magnetically separated into three fractions. The first magnetic fraction should be derived in a manner identical to that utilized for the ferromagnetic-mineral fraction. The second magnetic fraction should be generated at a current setting of 0.6 A, and the third magnetic fraction is the nonmagnetic minerals at 0.6 A. The geochemical data from these three magnetic fractions can then be used to indicate the presence of mineral species not easily identified by petrographic procedures; for example, high tin (Sn) values in the nonmagnetic mineral fraction may signal the presence of cassiterite.

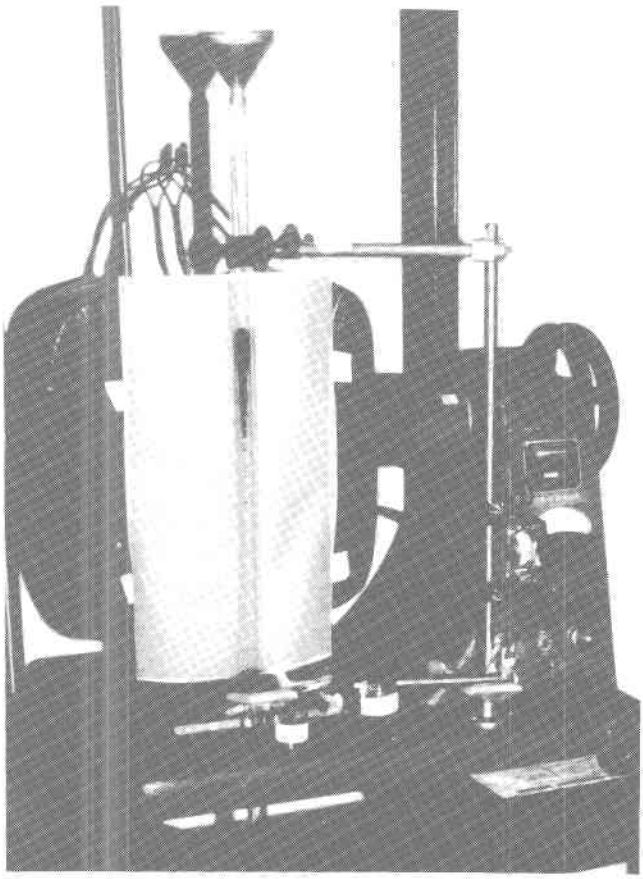
MINERAL IDENTIFICATION AND QUANTIFICATION

To estimate mineral abundances, each magnetic-mineral fraction was examined by using reflected and transmitted light microscopes. Estimation was easy because only a few mineral species were present in each fraction. Comparison charts for visual estimation of percentage composition (Folk, 1951; Terry and Chillingar, 1955; Reid, 1985) and point-counting were used for this purpose. In addition to petrographic methods, X-ray diffraction analyses were used to identify some minerals; however, because of the reconnaissance nature of the work, all the mineral species were not identified. An "Others" category was estimated and included quartz, unidentified opaques, unidentified non-opaques, polymineralic grains, and clay balls. The identification of zircon and monazite was aided by the use of ultraviolet light. The principal criteria for identification were magnetic susceptibility, grain shape, color, physical properties (that is, cleavage), streak, fluorescence, solubility in acids, and optical properties.

The estimated percentage abundances of each mineral species was multiplied by the weight of each fraction. The total percentage for each mineral was calculated by summing their weights across the magnetic fractions in which the mineral occurred. Because the average of specific gravities of all species in each magnetic fraction are generally similar, differences in specific gravities of the mineral species were ignored in the calculations. Although the calculated percentages are not true weight percentages, the differences are probably small. An example of the observations and calculations used to determine the weight percentages of minerals for a sample are given in Appendix I.

Because silt- and clay-rich sediments are difficult to separate and identify, the amounts of ferromagnesian micas and lighter heavy minerals (specific gravity <3.50) are probably underestimated in the analytical table, and higher density minerals such as garnet and zircon may be overestimated.

The ferromagnetic-mineral fraction commonly is comprised of minerals containing magnetite mineral inclusions that should be in fractions separated by low magnetic field strength. X-ray fluorescence analyses of this fraction in two samples from offshore Virginia indicated titanium values in excess of what one would expect of magnetite. The excess could be explained by the presence of approximately 40 percent titanomagnetite (Oliver Fordham, Virginia Division of Mineral Resources, oral communication, 1988). This combination of magnetite and ilmenite is confirmed by geochemical analyses given elsewhere in this publication. Because optical identification of different opaque minerals in the



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ferromagnetic-mineral fraction is difficult without the use of polished grain mounts and the mass is small, the entire fraction is labeled "magnetite."

In addition to petrographic techniques, the paramagnetic-mineral fractions were examined using ultraviolet illumination. This technique aided the identification of monazite which had green fluorescence, and zircon which had yellow to orange fluorescence. Not all zircons fluoresce, for example, metamict zircons. Because quartz was often found in the non-magnetic at 1.8 A magnetic fraction, its weight was included in the heavy-mineral fraction. For the Virginia samples, a correction was made to the weight percentage of the total heavy minerals by subtracting the weight of quartz and is included in the calculation of data under column 151 in Appendix I. The decrease in the weight of the heavy minerals ranged from 2 to 18 percent of the uncorrected value and averaged about 3 percent for Virginia samples.

DATABASE

Ideally, an offshore mineral-resource database should contain all the variables generated by direct measurements as well as those derived by calculation. Because the formulae for calculating a number of derivative variables are discussed in detail later in this section, only the directly measured variables are discussed here. The variables that should be entered into a database and their units of measure are as follows:

VARIABLE	UNIT OF MEASURE
Sample number	
Latitude	Degrees and fractions of a degree
Longitude	Degrees and fractions of a degree
Water depth	Meters
Section length (vibracore)	Centimeters
Bulk sample weight	Grams
Weight of:	
Gravel fraction	Grams
Sand-size fraction	Grams
Clay-size fraction	Grams
$CaCO_3$ component	Grams
Mean grain size on a:	
$+CaCO_3$ basis	Grams
$-CaCO_3$ basis	Millimeters
Sorting on a:	
$+CaCO_3$ basis	Millimeters
$-CaCO_3$ basis	Millimeters
Skewness on a:	
$+CaCO_3$ basis	Millimeters
$-CaCO_3$ basis	Millimeters
Kurtosis on a:	
$+CaCO_3$ basis	Millimeters
$-CaCO_3$ basis	Millimeters
Weight of:	
spiral derived HM conc	Grams
spiral gangue subsample	Grams
HM in spiral gangue	Grams
Composition of:	
gravel fraction	Percentage of shell, rock, quartz, and so forth
HM fraction	Percentage of minerals

For the samples from Virginia, several databases were used. One of these contains location data and core (sample) length, and two others hold measured weights, observed mineral compositions, and calculated or derived values.

The original concept and the outline for the database presented here were the efforts of the senior author; modifications of calculation formulae for the *20/20* spreadsheet program available on the VIMS Prime computer were made by C.R. Berquist and C.T. Fischler. Other collaborating institutions on the Atlantic seaboard utilized the *Lotus 1-2-3* spreadsheet program. The database (Appendix I) that has values for two samples is shown as an example. Each row contains the data for one sample. The column headers (variables) are generally self-explanatory; however, they are discussed briefly in the following section. Column data originates from observation, measurement, or calculation. The calculation formulae (Appendix II) follow the database (Appendix I).

DISCUSSION OF COLUMN HEADERS

Values in column 11 were calculated by determining the amount of water in a 50- to 100-g subsample and correcting the initial bulk sample weight. Because not all samples were wet (USGS vibracores were dry when received), some columns in the final database contain 0 or "ERR" (where, in fact, there is no error). The weight of sediment greater than 2.00 mm in diameter after wet sieving is given in column 12. Column 13 gives the weight of a subsample from the spiral light (SL) fraction; column 14 gives the weight of the portion which sank in heavy liquid (spiral lights tetrabromoethane sink). Column 15 is the final spiral concentrate; column 16 gives the weight of the spiral heavy, tetrabromoethane sink fraction. Column 17 is a check for gross errors in weighing sample fractions (see formulae in Appendix II). Column 18 is the percentage of heavy minerals in the spiral light fraction and approximates the amount of heavy minerals lost during the spiral concentration procedure to the spiral lights fraction (column 19). Column 20 gives the percentage of the heavy minerals recovered by the spiral concentration procedure from the calculated total amount of heavy minerals in the sample and is a measure of the efficiency of the spiral concentrator in recovering heavy minerals from a given sample. Column 21 is the calculated total amount of heavy minerals in the sample based on the recovered and the lost heavy minerals during the spiral concentrating procedure. Column 22 is the weight percentage of the heavy minerals recovered in the spiral concentrate and subsequent heavy-liquid procedure.

The mud (silt and clay), gravel (>2.00 mm), and sand size distributions were determined for some samples by using a split of the repository sample; columns 23 to 28 give these data. The mean size of the sand fraction of some samples (column 30) were determined by using a Rapid Sediment Analyzer.

The weights of the magnetic fractions derived by use of the free-fall and MBLS magnetic separators are shown in columns 31 to 36; "203" is the most magnetic fraction, and "208" is the least magnetic fraction. The sum of these weights are given in column 37. Columns 38 to 40 show the weights

of the splits of the RHM reserved for archive (-209; 12.5 volume percent of the RHM fraction), geochemical analyses (-200, -201, and -202; 12.5 volume percent of the RHM fraction), and optical analyses (-203, -204, -205, -206, -207, and -208; 75.0 volume percent of the RHM fraction). For the Virginia samples, no magnetic separation of the geochemical split was made, and the entire weight is reported in column 39. Gross weighing errors are checked in column 41. Observed amounts of individual heavy-minerals in each magnetic fraction (203 to 208) are shown in columns 42 to 116; summation columns insure that the compositions add up to 100 percent.

Columns 117 to 131 show the gram-equivalent weight of an observed mineral for an entire sample (fractions 203 to 208) calculated by summing the gram equivalent of the visually estimated frequency of the mineral in each magnetic fraction. By using these data, the weight percentage of the observed minerals in the RHM fraction is calculated and shown in columns 132 to 147. Column 147 is the sum of ilmenite + leucoxene + rutile + zircon + monazite + aluminosilicates (sillimanite, kyanite, and andalusite).

Columns 148 and 150 are copied from columns 22 and 21, respectively. "CORR" in columns 149 and 151 correct columns 148 and 150 by removing the amount of quartz observed in the 208 fraction from the mass of RHM and THM. Column 152 is a check where THM should be always greater than RHM. In column 153 the weight percentages of the observed minerals are added and checked to be certain that they total to 100 percent.

With respect to the entire bulk sample (as opposed to the concentrate), the concentrations of heavy minerals are shown in columns 154 to 169; the sum is shown in column 170. These values were calculated by multiplying the mineral abundance in the concentrate by column 151. Column 171 is a check that the sum of the mineral percentages (columns 154 to 168) and the corrected THM are the same.

APPROXIMATE TIME REQUIREMENTS FOR ANALYSIS OF AN OFFSHORE VIRGINIA SAMPLE

The sample analysis procedure that we have described requires numerous labor-intensive tasks. Based on the experience that we have gained during this study, the average times required to perform the various tasks are as follows:

TASK	TIME PER SAMPLE (in minutes)
Cut, describe, and photograph core	45
Wet sieve gravel fraction	15
Spiral concentrate sand-sized fraction	30
Dry and weigh spiral fractions	15
Heavy-liquid separation	45
Remove ferromagnetics (-203 fraction)	10
Magnetic fractionation (-204 to -208 fractions)	120
Mineral identification/quantification	180
Data entry	30
Total	490 (about 8 hr 20 min)

The volume, texture, heavy-mineral content and composition, heavy-liquid separation funnel capacity, balance capacities, and other variables have significant and highly variable effects on the time required to analyze each sample.

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Appendix I.

Example of the observations and calculations used to determine the weight percentages of heavy minerals in a sample.

This Appendix shows column titles and data for two core samples in one of the Virginia spreadsheet files. Column 0 contains the sample number; columns numbered 1 to 171 contain measured or observed values and derived values (by use of formulae; see Appendix II) for each sample. Each row represents an individual sample.

The original database allowed for observed concentrations of amphibole and pyroxene group minerals but was converted later so that pyroboles (undifferentiated pyroxene and amphibole group minerals) assumed the positions of the amphiboles columns. The columns (55, 64, 77, 92, 107, 123, 138, 160) ordinarily used for pyroxenes, therefore, are not used.

Abbreviations, and their explanations are: WT, weight; g, grams; SP, spiral; SLTBS, spiral lights, tetrabromoethane sink fraction; SHTBS, spiral heavies tetrabromoethane sink fraction; arc, 12.5 percent volumetric split of the SHTBS for archival purposes; anal, 12.5 percent volumetric split of the SHTBS for chemical analyses; THM, total heavy minerals; RHM, recovered heavy minerals; EHM, economic heavy minerals; SIK, undifferentiated aluminosilicates (sillimanite, kyanite, andalusite); ND, not determined.

0	1	2	3	4	5	6	7	8	9	10	11
SAMPLE NUMBER	BUCKET WT (g)	WT BUCKET & SAMPLE (g)	NET WT SAMPLE (g)	BEAKER WT (g)	WET WT & BEAKER (g)	DRY WT & BEAKER (g)	WET WT SAMPLE (g)	DRY WT SAMPLE (g)	WATER WT IN SAMPLE (g)	WT % WATER	DRY WT SAMPLE (g)
1-1	950	8300	7350	66.15	188.91	177.41	122.76	111.26	11.50	9.37	6661
1-2	951	8300	7349	62.77	188.54	171.14	125.77	108.37	17.40	13.83	6332

12	13	14	15	16	17	18	19	20	21	22	23
WT. > -1.0 PHI (g)	SP LIGHTS SUBSAMPLE (g)	SLTBS (g)	SPIRAL HEAVIES (g)	WT SHTBS (g)	WT SHTBS- (arc+anal+ 75% split)	% HM IN SPIRAL LIGHTS	WT HM (g) IN SPIRAL LIGHTS	% RECOVERY BY SPIRAL	WT % THM	WT % RHM	WT MUD (g)
205.83	373.04	1.81	330.92	115.16	-0.06	0.49	30.72	78.94	2.19	1.73	0.90
48.30	298.70	2.51	575.85	155.06	0.11	0.84	48.37	76.22	3.21	2.45	2.22

24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
WT SAND (g)	WT GRAVEL (g)	WT % SAND	WT % MUD	WT % GRAVEL	SUM WT % GRAVEL+SAND +MUD	MEAN SAND SIZE (PHI)	WT 203 (g)	WT 204 (g)	WT 205 (g)	WT 206 (g)	WT 207 (g)	WT 208 (g)	SUM WT 203-208 (g)	WT 12.5% ARCHIVE (g)
39.71	1.42	94.50	2.10	3.40	100.00	ND	0.25	16.95	48.55	1.77	10.32	7.21	85.05	14.76
33.48	0.28	93.00	6.20	0.80	100.00	2.31	0.83	39.10	59.73	2.86	5.49	8.04	116.05	19.10

39	40	41	42	43	44	45	46	47	48	49	50
WT 12.5 % ANALYTIC (g)	WT 75.0 % MINERALOGY (g)	DIFF 75.0% -SUM WT (g)	203 % MAGNETITE	203 % ILMENITE	203 % GARNET	203 % EPIDOTE	203 % PYROBOLES	203 % OTHERS	SUM % 203	204 % ILMENITE	204 % GARNET
15.21	85.25	0.20	97	0	3	0	0	0	100	86	6
19.57	116.28	0.23	94	0	2	1	1	2	100	38	22

51	52	53	54	55	56	57	58	59	60	61	62
204 % EPIDOTE	204 % STAUROLITE	204 % PYROBOLES	204 % TOURMALINE	COLUMN NOT USED	204 % LEUCOXENE	204 % OTHERS	SUM % 204	205 % ILMENITE	205 % GARNET	205 % EPIDOTE	205 % STAUROLITE
1	0	5	0		2	0	100	21	35	7	1
1	0	35	0		1	3	100	9	15	10	15

63	64	65	66	67	68	69	70	71	72	73	74	75
205 % PYROBOLES	COLUMN NOT USED	205 % SIK	205 % SPHENE	205 % TOURMALINE	205 % LEUCOXENE	205 % ZIRCON	205 % OTHERS	SUM % 205	206 % ILMENITE	206 % GARNET	206 % EPIDOTE	206 % STAUROLITE
16		0	0	8	4	0	8	100	10	20	5	25
40		0	0	7	1	0	3	100	0	5	2	0

76	77	78	79	80	81	82	83	84	85	86	87	88	89
206 % PYROBOLES	COLUMN NOT USED	206 % RUTILE	206 % SIK	206 % SPHENE	206 % TOURMALINE	206 % LEUCOXENE	206 % MONAZITE	206 % ZIRCON	206 % OTHERS	SUM % 206	207 % ILMENITE	207 % GARNET	207 % EPIDOTE
30		0	0	1	0	0	1	0	8	100	5	8	8
45		0	0	2	14	12	0	0	20	100	0	4	0

90	91	92	93	94	95	96	97	98	99	100	101	102	103
207 % STAUROLITE	207 % PYROBOLES	COLUMN NOT USED	207 % RUTILE	207 % SIK	207 % SPHENE	207 % TOURMALINE	207 % LEUCOXENE	207 % MONAZITE	207 % ZIRCON	207 % OTHERS	SUM % 207	208 % ILMENITE	208 % GARNET
20	0		0	5	0	0	10	0	0	44	100	0	0
0	1		18	36	3	1	5	0	7	25	100	0	0

104	105	106	107	108	109	110	111	112	113	114	115	116	117
208 % EPIDOTE	208 % STAUROLITE	208 % PYROBOLES	COLUMN NOT USED	208 % RUTILE	208 % SIK	208 % SPHENE	208 % TOURMALINE	208 % LEUCOXENE	208 % MONAZITE	208 % ZIRCON	208 % OTHERS	SUM % 208	SUM WT (g) MAGNETITE
1	0	0		8	30	0	0	1	0	50	10	100	0.24
0	0	0		9	24	0	0	1	0	37	29	100	0.78

118	119	120	121	122	123	124	125	126	127	128	129	130	131
SUM WT (g) ILMENITE	SUM WT (g) GARNET	SUM WT (g) EPIDOTE	SUM WT (g) STAUROLITE	SUM WT (g) PYROBOLES	COLUMN NOT USED	SUM WT (g) RUTILE	SUM WT (g) SIK	SUM WT (g) SPHENE	SUM WT (g) TOURMALINE	SUM WT (g) LEUCOXENE	SUM WT (g) MONAZITE	SUM WT (g) ZIRCON	SUM WT (g) OTHERS
25.47	19.20	4.55	2.99	9.15		0.58	2.68	0.02	3.88	3.39	0.02	3.60	9.29
20.23	17.94	6.43	8.96	38.93		1.71	3.91	0.22	4.64	1.69	0.00	3.36	7.26

132	133	134	135	136	137	138	139	140	141	142	143	144	145
WT % MAGNETITE	WT % ILMENITE	WT % GARNET	WT % EPIDOTE	WT % STAUROLITE	WT % PYROBOLES	COLUMN NOT USED	WT % RUTILE	WT % SIK	WT % SPHENE	WT % TOURMALINE	WT % LEUCOXENE	WT % MONAZITE	WT % ZIRCON
0.29	29.94	22.57	5.35	3.52	10.75		0.68	3.15	0.02	4.57	3.98	0.02	4.24
0.67	17.44	15.46	5.54	7.72	33.54		1.48	3.37	0.19	4.00	1.45	0.00	2.89

146	147	148	149	150	151	152	153	154	155	156	157	158	159
WT % OTHERS	WT % EHM	WT % RHM	CORR WT % RHM	WT % THM	CORR WT % THM	DIFFERENCE THM % - RHM %	SUM OF MINERAL PERCENTAGES	MAGNETITE % IN BULK SAMPLE	ILMENITE % IN BULK SAMPLE	GARNET % IN BULK SAMPLE	EPIDOTE % IN BULK SAMPLE	STAUROLITE % IN BULK SAMPLE	PYROBOLES % IN BULK SAMPLE
10.92	42.01	1.73	1.72	2.19	2.18	0.00	100	0.01	0.65	0.49	0.12	0.08	0.23
6.25	26.62	2.45	2.42	3.21	3.18	0.01	100	0.02	0.55	0.49	0.18	0.25	1.07

160	161	162	163	164	165	166	167	168	169	170	171
COLUMN NOT USED	RUTILE % IN BULK SAMPLE	SIK % IN BULK SAMPLE	SPHENE % IN BULK SAMPLE	TOURMALINE % IN BULK SAMPLE	LEUCOXENE % IN BULK SAMPLE	MONAZITE % IN BULK SAMPLE	ZIRCON % IN BULK SAMPLE	OTHER % IN BULK SAMPLE	EHM % IN BULK SAMPLE	SUM % HM % IN BULK SAMPLE	CORR WT THM -SUM % HM OF BULK
	0.01	0.07	0.00	0.10	0.09	0.00	0.09	0.24	0.92	2.18	0.00
	0.05	0.11	0.01	0.13	0.05	0.00	0.09	0.20	0.85	3.18	0.00

Appendix II.

The formulae used in calculating the described variables are based on the column numbers in Appendix I.

COLUMN NUMBER	DESCRIPTION	FORMULA IN TERMS OF COLUMN NUMBER [IN BRACKETS]
3	NET WEIGHT OF SAMPLE	[2]-[1]
7	WET WEIGHT OF SAMPLE	[5]-[4]
8	DRY WEIGHT OF SAMPLE	[6]-[4]
9	WATER WEIGHT IN SAMPLE	[7]-[8]
10	WEIGHT PERCENT WATER	[9]/[7]*100
11	DRY WEIGHT OF BULK SAMPLE	[3]-[3]*([10]/100)
17	WEIGHT LOSS DUE TO SPLITTING	[16]-([38]+[39]+[40])
18	WEIGHT % HM IN SPIRAL LIGHTS	([14]/[13])*100
19	WEIGHT HM IN SPIRAL LIGHTS	([18]/100)*([11]-[15])
20	% OF HM RECOVERED BY THE SPIRAL	100*[16]/([16]+[19])
21	WEIGHT % TOTAL HM IN SAMPLE	([19]+[16])*100/[11]
22	WEIGHT % RECOVERED HM	100*[16]/[11]
26	WEIGHT % SAND	([24]/([23]+[24]+[25]))*100
27	WEIGHT % MUD	([23]/([23]+[24]+[25]))*100
28	WEIGHT PERCENT GRAVEL	([25]/([23]+[24]+[25]))*100
29	SUM OF SAND, MUD AND GRAVEL %	SUM([26..28])
37	SUM OF MAGNETIC FRACTIONS	SUM([31..36])
41	WEIGHT LOSS DUE TO MAGNETIC FRACTIONATION	[40]-[37]
48	SUM OF % MINERAL SPECIES IN 203 FRACTION	SUM([42..47])
58	SUM OF % MINERAL SPECIES IN 204 FRACTION	SUM([49..57])
71	SUM OF % MINERAL SPECIES IN 205 FRACTION	SUM([59..70])
86	SUM OF % MINERAL SPECIES IN 206 FRACTION	SUM([72..85])
101	SUM OF % MINERAL SPECIES IN 207 FRACTION	SUM([87..100])
116	SUM OF % MINERAL SPECIES IN 208 FRACTION	SUM([102..115])
117	MAGNETITE (g) IN ALL MAGNETIC FRACTIONS	[31]*[42]
118	ILMENITE (g) IN ALL MAGNETIC FRACTIONS	[31]*[43]+[32]*[49]+[33]*[59] +[34]*[72]+[35]*[87]+[36]*[102]
119	GARNET (g) IN ALL MAGNETIC FRACTIONS	[44]*[31]+[50]*[32]+[60]*[33] +[73]*[34]+[88]*[35]+[103]*[36]
120	EPIDOTE (g) IN ALL MAGNETIC FRACTIONS	[51]*[32]+[61]*[33]+[74]*[34] +[45]*[31]+[35]*[89]+[36]*[104]
121	STAUROLITE (g) IN ALL MAGNETIC FRACTIONS	[52]*[32]+[62]*[33]+[75]*[34] +[90]*[35]+[105]*[36]
122	PYROBOLES (g) IN ALL MAGNETIC FRACTIONS	[53]*[32]+[63]*[33]+[76]*[34] +[91]*[35]+[106]*[36]+[46]*[31]
123	COLUMN NOT USED IN VIRGINIA STUDY	[55]*[32]+[64]*[33]+[77]*[34] +[92,8]*[35,8]+[107,8]*[36,8]
124	RUTILE (g) IN ALL MAGNETIC FRACTIONS	[78]*[34]+[93]*[35]+[108]*[36]
125	ALUMINOSILICATES (g) IN ALL MAGNETIC FRACTIONS	[79]*[34]+[94]*[35]+[109]*[36]+[65]*[33]
126	SPHENE (g) IN ALL MAGNETIC FRACTIONS	[66]*[33]+[80]*[34]+[95]*[35]+[110]*[36]
127	TOURMALINE (g) IN ALL MAGNETIC FRACTIONS	[67]*[33]+[81]*[34]+[96]*[35] +[111]*[36]+[54]*[32]
128	LEUCOXENE (g) IN ALL MAGNETIC FRACTIONS	[82]*[34]+[97]*[35]+[112]*[36]+[68]*[33]+[56]*[32]
129	MONAZITE (g) IN ALL MAGNETIC FRACTIONS	[83]*[34]+[98]*[35]+[36]*[113]
130	ZIRCON (g) IN ALL MAGNETIC FRACTIONS	[99]*[35]+[114]*[36]+[69]*[33]+[84]*[34]
131	OTHERS (g) IN ALL MAGNETIC FRACTIONS	[47]*[31]+[57]*[32]+[70]*[33]+ [85]*[34]+[100]*[35]+[115]*[36]

132	WEIGHT PERCENT MAGNETITE IN HM FRACTION	[117]/[37]
133	WEIGHT PERCENT ILMENITE IN HM FRACTION	[118]/[37]
134	WEIGHT PERCENT GARNET IN HM FRACTION	[119]/[37]
135	WEIGHT PERCENT EPIDOTE IN HM FRACTION	[120]/[37]
136	WEIGHT PERCENT STAUROLITE IN HM FRACTION	[121]/[37]
137	WEIGHT PERCENT PYROBOLES IN HM FRACTION	[122]/[37]
138	COLUMN NOT USED IN VIRGINIA STUDY	[123]/[37]
139	WEIGHT PERCENT RUTILE IN HM FRACTION	[124]/[37]
140	WEIGHT PERCENT ALUMINOSILICATES IN HM FRACTION	[125]/[37]
141	WEIGHT PERCENT SPHENE IN HM FRACTION	[126]/[37]
142	WEIGHT PERCENT TOURMALINE IN HM FRACTION	[127]/[37]
143	WEIGHT PERCENT LEUCOXENE IN HM FRACTION	[128]/[37]
144	WEIGHT PERCENT MONAZITE IN HM FRACTION	[129]/[37]
145	WEIGHT PERCENT ZIRCON IN HM FRACTION	[130]/[37]
146	WEIGHT PERCENT OTHERS IN HM FRACTION	[131]/[37]
147	WEIGHT PERCENT EHM	SUM([133],[139],[140],[143..145])
148	WEIGHT PERCENT RHM	100*[16]/[11]
149	CORRECTED WEIGHT PERCENT RHM	([16]-[36]*([115]*0.9))/[11]
150	WEIGHT PERCENT THM	([19]+[16])*100/[11]
151	CORRECTED WEIGHT PERCENT THM	([16]+[19]-([36]*[115]*0.9))/[11]
152	THM % - RHM %	[151]-[149]
153	SUM OF MINERAL PERCENTAGES	SUM([132..146])
154	MAGNETITE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[132]*[151]
155	ILMENITE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[133]*[151]
156	GARNET AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[134]*[151]
157	EPIDOTE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[135]*[151]
158	STAUROLITE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[136]*[151]
159	PYROBOLES AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[137]*[151]
160	COLUMN NOT USED IN VIRGINIA STUDY	[138]*[151]
161	RUTILE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[139]*[151]
162	ALUMINOSILICATES AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[140]*[151]
163	SPHENE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[141]*[151]
164	TOURMALINE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[142]*[151]
165	LEUCOXENE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[143]*[151]
166	MONAZITE AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[144]*[151]
167	ZIRCON AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[145]*[151]
168	OTHERS AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[146]*[151]
169	EHM AS A WEIGHT PERCENTAGE OF THE BULK SAMPLE	[147]*[151]
170	SUM WEIGHT PERCENTAGE OF HEAVY MINERALS IN THE BULK SAMPLE	SUM([154..168])
171	CORRECTED WT % THM - SUM % HM OF BULK SAMPLE	[151]-[170]

HEAVY-MINERAL CONCENTRATIONS IN SEDIMENTS OF THE VIRGINIA INNER CONTINENTAL SHELF

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ABSTRACT

The Virginia Division of Mineral Resources and the Virginia Institute of Marine Science investigated the occurrence of heavy minerals in the offshore sediments of Virginia. We began the project because earlier reconnaissance studies reported high heavy-mineral concentrations from several samples collected off the Eastern Shore of Virginia. Our work confirms the previously reported mineral values and locates additional high concentrations up to 20 nautical miles offshore. Furthermore, we show that potentially economic mineral values are not restricted to surficial sediments, but also are found in the upper 15 to 20 feet of inner continental shelf sediments.

Several core samples indicate that potential economic values of heavy minerals are clustered offshore of Hog Island, Smith Island, Virginia Beach, and False Cape. These areas are likely targets for resource assessment studies of heavy minerals and construction or beach nourishment sand. The high heavy-mineral concentrations suggest that further investigations are warranted. The current effort to investigate resources offshore has only begun, because our area of study comprises only 3 percent of the Exclusive Economic Zone off Virginia.

Sample sites are located along the entire Atlantic coastline of Virginia and nearly all are within 5 nautical miles of land. Three-hundred and ninety large-volume samples were analyzed, 290 of which came from vibracores; over three tons of sediment were processed. The total heavy-mineral concentration of 78 samples is equal to or exceeds 5 percent. Fifty-two samples have concentrations of one or more economic minerals equal to or greater than threshold values for land-based deposits (ilmenite 45%, leucoxene 5%, rutile 2%, zircon 5%, monazite 1%, and total heavy mineral concentration 5%; Garnar, 1978). The total heavy mineral concentration for all samples averaged 3.3 percent and the highest value was 14.7 percent.

Offshore sediments sampled by vibracores average about 5 meters in thickness and are probably Holocene in age. Core penetration into underlying Pleistocene or Tertiary sediments is suspected based on oxidized sediment at depth in cores. Microfauna were not studied.

The U.S. Minerals Management Service and the Subaqueous Minerals and Materials Study Commission, Commonwealth of Virginia also provided funding for the study. This report describes the mineral compositions and other characteristics we derived from offshore sediments from 1986 through 1988.

INTRODUCTION

The Virginia Division of Mineral Resources (VDMR) and the Virginia Institute of Marine Science (VIMS) collected and analyzed core and grab samples, and made side-scan sonar and subbottom profile surveys from April 1986 through September 1988 on the inner continental shelf of Virginia. The project was funded in part by the U.S. Minerals Management Service (MMS) and the Commonwealth of Virginia. Work performed with funding from the U.S. Minerals Management Service emphasized research in the Exclusive Economic Zone (EEZ) seaward of 3 miles from land; work done with funding from the Commonwealth of Virginia's Subaqueous Minerals and Materials Study Commission emphasized evaluation of resources within the Commonwealth's territorial waters. This report combines the results obtained over the past few years in describing the heavy-mineral occurrences offshore of Virginia.

A limited study by Berquist and Hobbs (1986) verified earlier reports of high concentrations of heavy minerals in surficial shelf sediments (Nichols, 1972; Goodwin and Thomas, 1973; Grosz and Escowitz, 1983). We acquired cores in April 1986 at Smith Island Shoal, within the Chesapeake Bay mouth, and east of Virginia Beach. In July 1986, sediments were analyzed from existing cores and from 100 new grab and box-core samples taken off the Virginia coast. The U.S Geological Survey contributed 35 cores that were located at the Chesapeake Bay entrance. A report described the results of our efforts completed through the summer of 1987 (Berquist and Hobbs, 1988a). Fifty new vibracores were taken during the summer of 1987 from offshore Assateague Island to North Carolina. The selection of core sites was guided by the results of the previous years' efforts. We also made geophysical surveys (side-scan sonar and high-resolution shallow seismic) during these projects and some of the results are described elsewhere in this publication. Berquist and Hobbs (1988b) reported on work completed from 1986 through 1988. Figures 1 and 2 show the locations of samples used in this study. Appendix I gives location coordinates for all vibracores and grab samples.

MINERAL ANALYSIS

We used a box corer and a Smith-MacIntyre sampler to take grab samples and a 4-inch diameter vibracorer to take core samples. In most sandy areas of the ocean floor, penetration by these devices, including the vibracorer, was limited greatly because of very compact sands. Grab sampling rarely exceeded 6 to 8 inches of depth in sediments. We acquired vibracores up to 20 feet in length by jetting and coring (Appendix VII). Without multiple attempts, vibracores usually penetrated about nine feet before refusal. Appendix II gives general characteristics of core and grab samples; core descriptions are found in Appendix VII.

The procedures for sample preparation and determination of mineral abundance are intricate and have been described by A. E. Grosz of the U.S. Geological Survey. Although a complete discussion of the process is found elsewhere in this publication, a brief explanation follows: The average weight of samples was large (20 pounds). Samples from the vibracores were derived by processing 6-foot (average) sections. Heavy minerals were concentrated from the samples with a three-turn spiral followed by use of tetrabromoethane. The heavy-mineral concentrate is magnetically subdivided into six fractions (labeled "203" through "208", from most magnetic to non-magnetic). The mineral composition of each fraction is estimated by using transmitted- and reflected-light microscopes. The heavy-mineral composition of the sample is determined by combining the compositions of

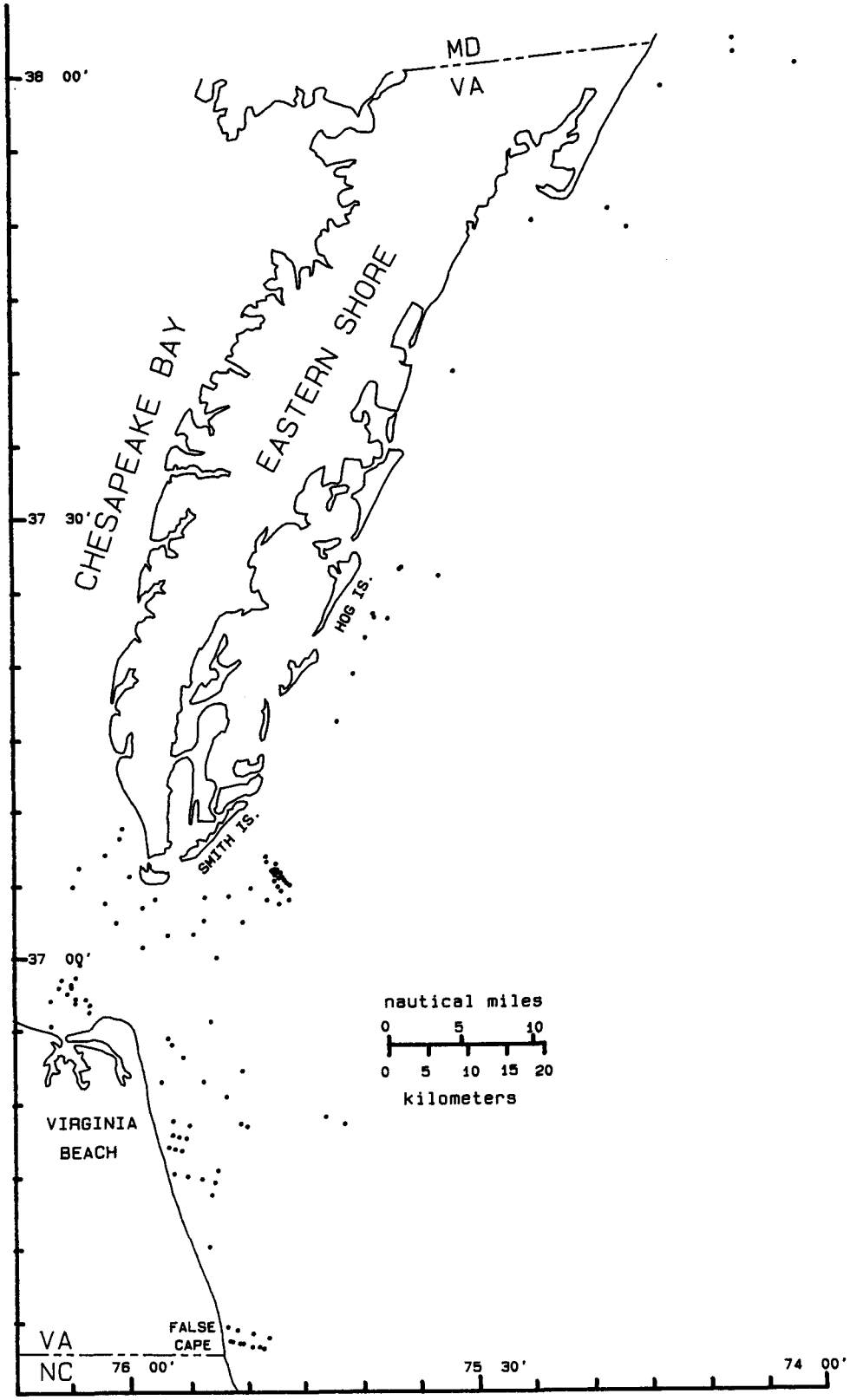

Figure 1. Map showing the location of cores.

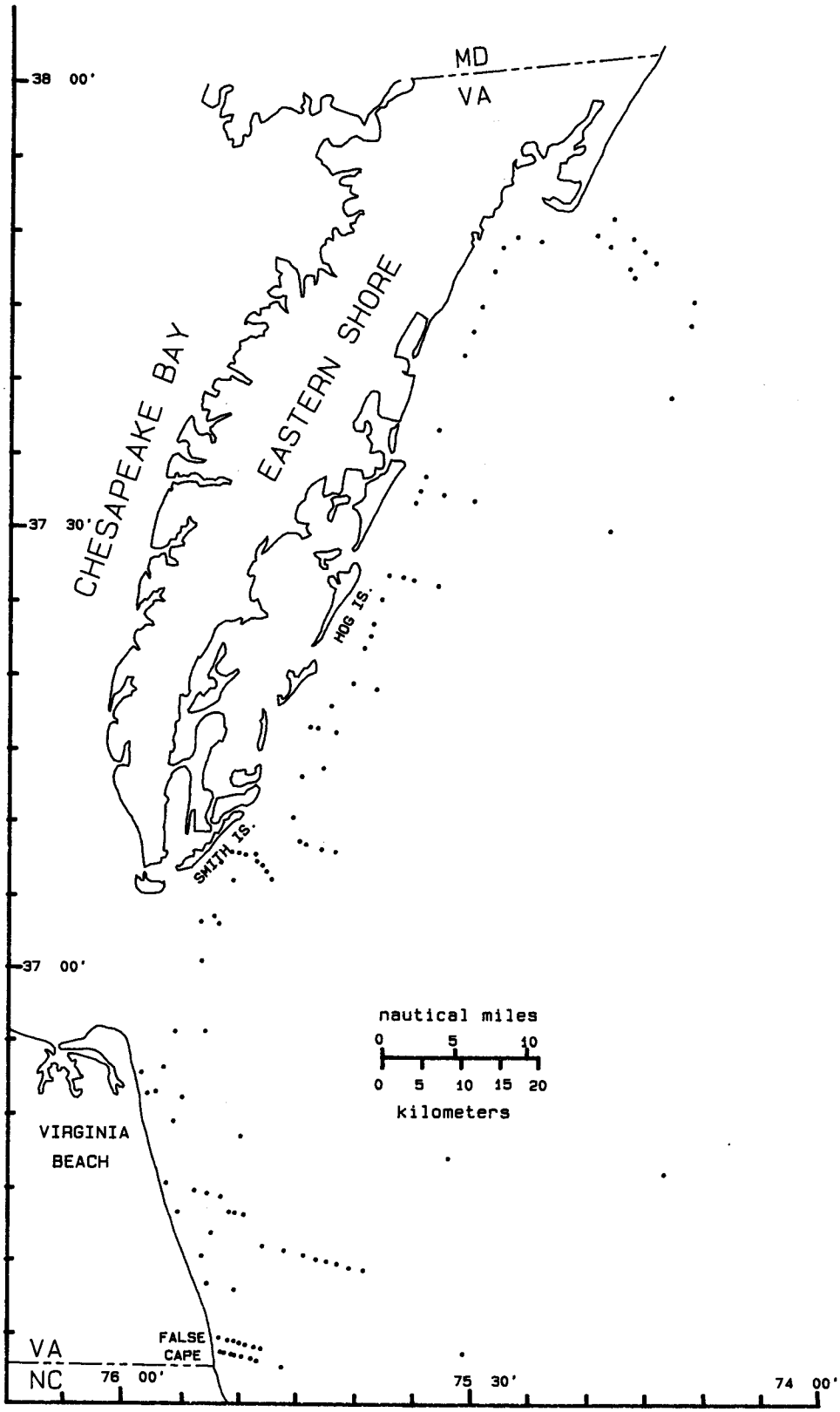

Figure 2. Map showing the location of grab samples.

the six fractions by using a computer spread-sheet program. Out of approximately 436 samples, 390 were examined for heavy-mineral content. Of the remaining 46 samples, one was lost by contamination and the others did not contain enough heavy minerals to allow for satisfactory processing.

Without the complete discussion of the analysis procedures, some additional explanation is needed to interpret the compiled mineral data. Because this is a reconnaissance study, only commonly occurring and selected economic minerals are identified. The economic minerals found in abundance offshore of Virginia are those containing titanium (ilmenite, leucoxene, and rutile) and rare-earth elements (monazite and zircon). The sum of these minerals plus the sillimanite/ kyanite (refractory minerals) fraction forms the "ECON" (economic interest) group of heavy minerals. The amphibole and pyroxene groups minerals together are more common than any other minerals. Their abundance is grouped under the name "pyrobole." Recovered heavy minerals (RHM) is the amount of heavy minerals recovered from the sample and available for analysis. Total heavy minerals (THM) is an abundance determined by adding to RHM the calculated amount of heavy minerals lost during the spiral concentration.

Minerals identified as "magnetite" in the most magnetic (labeled "203") fraction are not all solely magnetite. X-ray fluorescence of the most magnetic (203) fraction of two samples indicated excessive titanium for magnetite; this excess could be explained if approximately 40 percent of the sample was titanomagnetite (O. Fordham, personal communication). Because optical identification of different opaque minerals in the 203 fraction is difficult and inconsistent among observers, the entire fraction is labeled "magnetite"; users of the data should remember this factor when interpreting the compositional data.

The three least magnetic (206, 207, and 208) fractions were also examined under high-intensity short-wave length ultraviolet light enabling identification of monazite, by its green "fluorescence" or internal reflectance, zircon (yellow to orange fluorescence), and quartz contamination in the non-magnetic (208) fraction. Pink and light-brown (metamict) zircons are commonly observed, and although they are not fluorescent, their abundance is included in the reported zircon concentrations.

Because quartz is commonly found in the 208 fraction, its weight is included in the heavy-mineral fraction rather than the light fraction. It is commonly observed that quartz makes up at least 90 percent of the 208 "other" fraction. A correction is made to the weight percent of the total heavy minerals by subtracting the weight of quartz contamination. The correction is used in the calculation of data under column headings "WT % THM" in the appendices. The decrease ranged from 2 percent to 18 percent of the uncorrected value and averaged 2.6 percent.

DATABASE

All data entry and calculations were made on the Virginia Institute of Marine Science PRIME computer, using the *20/20* spreadsheet modeling program. For each step in the preparation of samples for mineral identification, the sample and its many fractions are weighed. We used the spreadsheet program to store and calculate weights and other characteristics throughout the analysis.

The completed database contains about 70,000 cells of information. Copies of the database are not included in this report but are available for inspection at the Virginia Division of Mineral Resources and at the Virginia Institute of Marine Science; Appendices III through VI contain the resultant sample compositions.

RESULTS

SAMPLE COMPOSITION

Mineral composition data are subdivided into two groups: cores and grab samples (Appendix III). Because the usefulness of relying upon surface grab samples in predicting economic mineral potential is questioned (A. E. Grosz, personal communication), the grab sample data are separated from core data. Appendix III includes separate statistics for each group. Appendix IV shows statistics for all samples combined.

Another way of characterizing mineral abundance is to calculate mineral composition relative to the entire sample rather than to the heavy-mineral fraction. This is shown in Appendix V. The data is "weighted" by the total heavy-mineral concentration so that mineral abundance per ton of bulk sediment, for example, may be estimated.

Tables 1 and 2 show average and highest values for certain economic minerals by core, grab, and all samples. The total heavy-mineral (THM) concentration (average and highest value) of "grabs" is approximately 50 percent greater than for cores, and these differences between the THM averages are significant at the 99.9 percent level of confidence. Average mineral concentrations, however, were nearly the same for cores and grab samples, with the exception of zircon and monazite. Therefore, based on the data, grab samples may be useful in predicting mineral composition at depth in offshore sediments, but the grab samples do not appear to be good indicators of total heavy-mineral concentration. At this time, the economic potential of sediments can only be established reliably by core analysis.

As an aid to further assessment of the economic potential of the area, Appendix V presents the weight percent of selected minerals with respect to the total sample. Garnar's values (or any other standard) can likewise be converted by multiplying by an economic threshold THM concentration (5 percent), resulting in the following mineral concentrations: ilmenite 2.25 percent, leucoxene and zircon 0.25 percent, rutile 0.1 percent, monazite 0.05 percent. Data presented in this way gives absolute (composition with respect to the bulk sample) rather than relative abundance and comparisons between samples or to an industrial standard are meaningful.

ECONOMIC POTENTIAL

The average values for the mineral concentrations shown of these and other samples are summarized in Table 3. The

TABLE 1. Average concentrations of selected minerals as a percentage by weight of the heavy-mineral fraction; 100 grab samples, 290 core samples = 390 total.

	WT % THM	WT % ILMENITE	WT % LEUCOXENE	WT % RUTILE	WT % ZIRCON	WT % MONAZITE
cores	2.9	24.0	1.7	1.4	3.8	0.1
grabs	4.4	28.6	1.8	1.2	2.8	0.3
all samples	3.3	25.2	1.8	1.3	3.6	0.1

TABLE 2. Maximum concentrations of selected minerals as a percentage by weight of the heavy-mineral fraction.

	WT % THM	WT % ILMENITE	WT % LEUCOXENE	WT % RUTILE	WT % ZIRCON	WT % MONAZITE
cores	9.1	60.3	7.9	3.2	9.2	2.5
grabs	14.7	58.8	8.2	2.8	5.4	1.8

TABLE 3. Several samples indicating economic potential are selected from Appendix III. Composition is relative to the heavy mineral fraction. See Appendix III for additional explanation of tabulated data.

Sample	WT % THM	WT % ILMENITE	WT % RUTILE	WT % LEUCOXENE	WT % MONAZITE	WT % ZIRCON	WT % ECON
H01-3	5.5	17.4	2.7	0.3	1.4	7.6	32.2
V1-4	0.8	56.2	1.7	3.3	0.3	3.8	66.1
4	9.3	21.4	1.4	3.0	0.2	3.3	30.8
33	5.1	58.8	0.8	0.6	0.1	4.1	65.8
54	14.7	29.0	1.1	0.2	0.4	4.9	35.9
59	11.0	34.9	1.5	0.6	0.1	4.3	42.4
85	10.8	54.9	2.4	1.8	0.1	3.8	63.1
1134-1	8.8	34.0	1.8	0.3	0.2	4.6	41.1
1136-1	9.0	28.7	1.1	1.0	P	3.5	34.7
C27-3	2.7	44.4	2.0	3.0	P	3.9	56.1
C42-4	3.2	49.4	2.0	2.0	0.2	6.7	62.2

in this study are lower than industry standards for mining on land (Table 1). The maximum values in Table 2 are in excess of those standards. Although market conditions may alter the following values, the concentrations of the heavy-mineral fraction of a hypothetical economic land deposit may be: ilmenite 45 percent, leucoxene 5 percent, rutile 2 percent, zircon 5 percent, staurolite 20 percent, monazite 1 percent, garnet/epidote 15 percent, kyanite/sillimanite 7 percent, and a total heavy mineral concentration of 4 or 5 percent (Garnar, 1978). Because there is no offshore production of a similar suite of heavy minerals within U.S. waters, an economic comparison to Virginia's offshore mineral potential cannot be made. Offshore concentrations may need to have twice the value of economic land deposits in order for development to proceed (U.S. Congress, 1987). Additionally, several factors make it difficult to assess the commercial potential of marine minerals; the erratic performance of domestic and global mineral economies and changing technologies affecting both demand and production being but two factors (U.S. Congress, 1987). There is also a lack of a detailed geologic analysis of an offshore site, an environmental and resource assessment, and a feasibility study. The economic potential of the heavy minerals offshore of Virginia may also depend on the volume of other co-existing marketable material (including sand and gravel) present in the deposit.

We have identified over 52 samples with concentrations of one or more of the "ECON" minerals equal to or greater than Garnar's threshold values, assuming a THM of 5 percent. These samples are marked by underlining in Appendix V and their offshore location is shown on Figure 3. Eleven

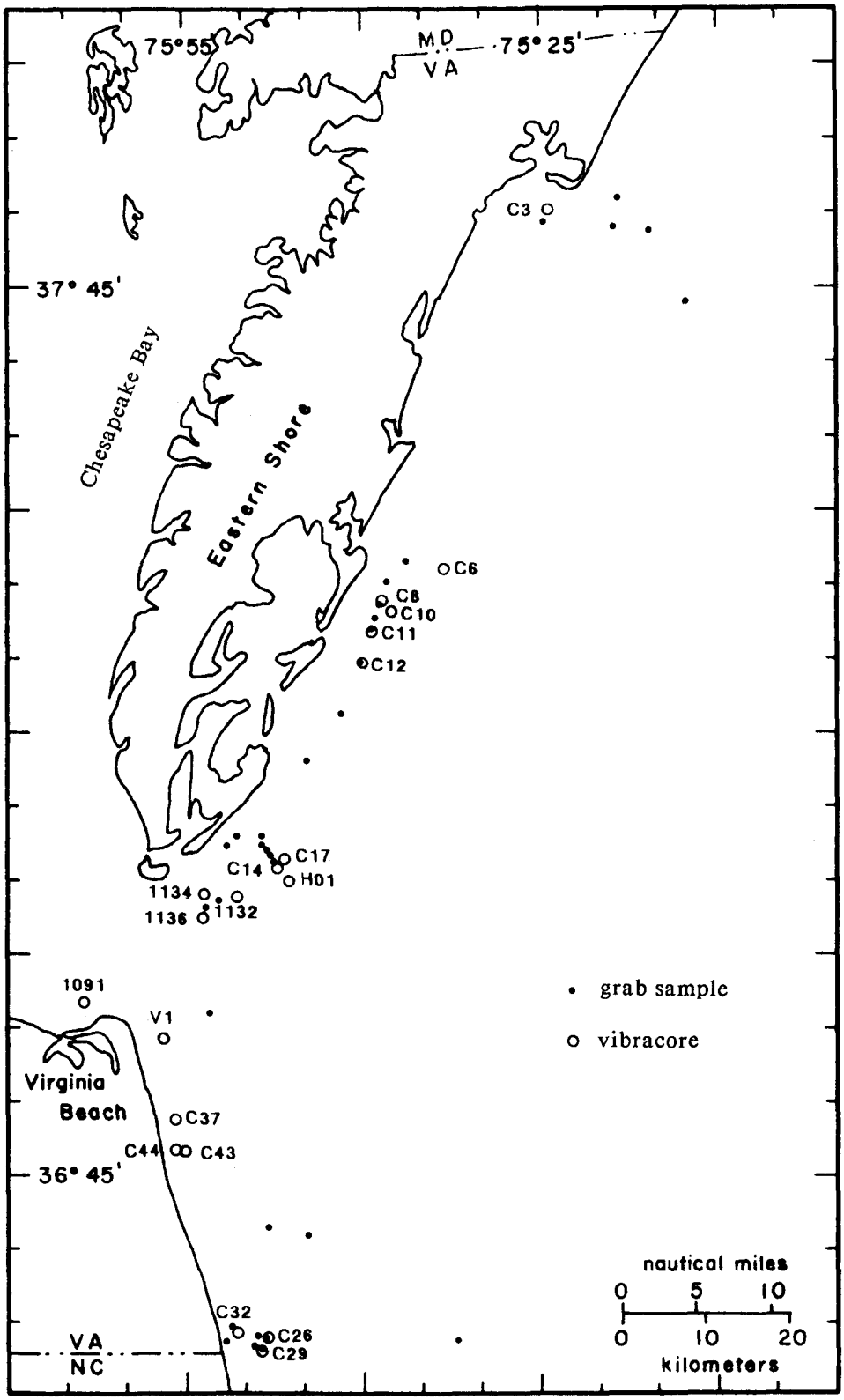

Figure 3. Map showing the location of samples with economic potential.

of these and other samples are summarized in Table 3. The compositions of two samples are graphically described in Figure 4. Although total heavy-mineral concentration may be low in some samples, an exceptional abundance of an individual mineral, or minerals may encourage further investigation.

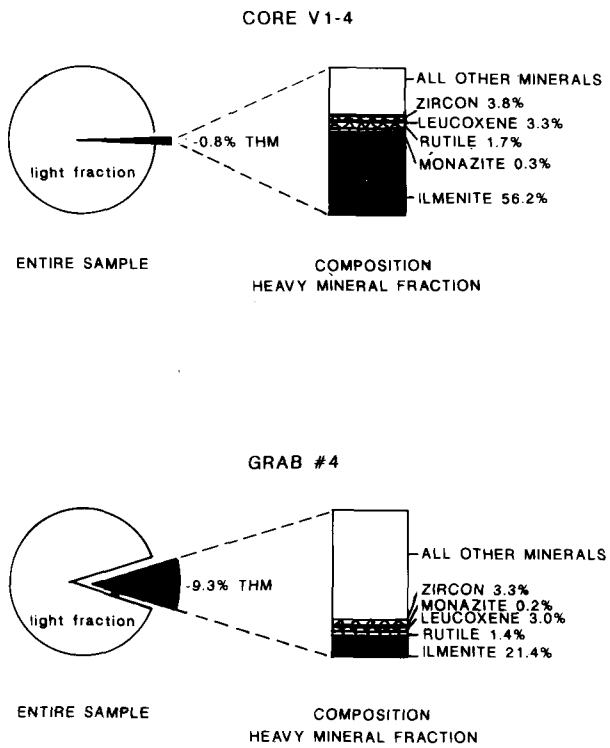

Figure 4. Graphic presentation of selected samples.

The decision of which samples to include in Table 3 is based on several criteria. For economic land deposits, the average THM concentration should be at least 3 percent. THM exceeds this in several samples, even though the individual mineral abundance may be less than the threshold values suggested by Garnar (1978). These are included because the same volume of a mineral may be present at twice the THM concentration but half the abundance of the heavy-mineral fraction (THM of 5 percent and ilmenite of 60 percent would yield a THM of 10 percent and ilmenite of 30 percent). Also included in Table 3 are samples with THM values less than 4 percent where certain ECON minerals are in great abundance, because these samples may have been deposited in an environment indicating selective enrichment and nearby higher-grade sediments.

CONCLUSIONS

Analyses indicate that sediments offshore of Virginia contain occurrences of potentially economic heavy minerals. High total heavy-mineral (THM) concentrations coupled with high concentrations of ilmenite, zircon, and to a lesser extent monazite and rutile, are encouraging and justify further investigation.

Economic potential is currently determined by acquiring mineral concentrations from cores. Mineral data from surface grab samples were used as a guide for locating nearly all vibracore sites. Surficial mineral data may be misleading because the relationship between surface and subsurface concentrations is not clear. This means that areas characterized by low surficial mineral concentrations remain as potential sites for coring.

Mineral concentrations are only part of the information needed to plan for economic recovery of the resource. National need, market conditions, advanced technological requirements, and mining costs are other factors to be considered. Evaluation of offshore mining potential should assess all materials; it may be possible to dredge sand for construction or beach nourishment and extract heavy minerals as a part of the same operation.

We planned this study as a reconnaissance survey and therefore did not attempt to precisely define economic mineral deposits. An appropriate exploration program would require many closely spaced seismic lines and deep cores. Most of our samples are located within 5 miles of the shoreline and the most wide-spread coverage of the offshore is based only on grab samples. Although ridge-fields may be the locus of high mineral concentrations, too little is known to ignore other regions of the continental shelf. The shelf seaward of Commonwealth jurisdiction is largely unexplored. Based on the high concentrations of minerals revealed in this report (STA054 and STA094, Appendix III), we recommend additional surveys further offshore in the Exclusive Economic Zone.

Finally, more work could be done within 5 miles of the coast. From a research perspective, a natural process responsible for concentrating the offshore heavy minerals has not been identified. With a greater understanding of the processes concentrating heavy minerals, areas of high mineral content could be located more readily. New geophysical techniques, such as induced polarization, are available and their use may diminish the need for numerous deep cores. The effects of dredging on biological resources must also be determined. If sediments are removed from offshore, the effect of the changed bathymetry on waves reaching the shoreline must be evaluated. To date, no government heavy-mineral economic resource assessment (tonnage and grade) or feasibility study has been made for the Exclusive Economic Zone offshore of Virginia. There are several sites off Virginia (Smith Island Shoal, Hog Island, Virginia Beach, and False Cape) each with a number of cores having high concentrations of minerals; those sites are candidates for more detailed analysis.

ACKNOWLEDGMENTS

Timely completion of the combined projects required the cooperation and effort of many individuals. Dr. A. E. Grosz (USGS) loaned equipment and guided us in establishing analytical procedures; he also assisted in mineral identification procedures and in the design of the database. With some modifications, we used many of his suggestions and methods. W. J. Swean of the U.S. Army Corps of Engineers loaned equipment and provided access to vibracores.

From the Virginia Institute of Marine Science, H.D. Evans helped cut and log cores and process samples; J. K. Dame and C. H. Hobbs helped process cores; C. H. Hobbs and R. A. Gammisch assisted in sample collection and participated in relevant discussions throughout the projects; Captains C. E. Machen and L. D. Ward, and Mate S. H. George from vessel operations provided expertise in data collection aboard the R/V Langley, R/V Bay Eagle, and R/V Captain John Smith. Many of the surface grab samples were collected from the chartered vessel Anthony Anne with the help of Captain J. A. Penello. Vibracoring was accomplished on the R/V Atlantic Twin by contract with Alpine Ocean Seismic Survey, Inc. Dr. G. P. Burbank of Hampton University performed the heavy-liquid separations and some magnetic separations under contract from the Virginia Institute of Marine Science.

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APPENDIX I

LOCATION OF SAMPLES

Loran coordinates are slaves of the 9960 chain. Latitude and longitude were obtained from automatic conversion of loran coordinates by the shipboard loran receiver-processor. Data not available are noted by "*". Locations shown on Figures 5, 6, 7, 8, 9, and 10.

VIBRACORE SAMPLES

CORE ID	WATER DEPTH (FT)	LORAN C COORDINATES Y	X	LATITUDE deg min	LONGITUDE deg min
H01	38	41405.1	27132.7	37 05.00	75 45.99
H02	38	41406.1	27133.8	37 05.12	75 46.19
H03	37	41408.0	27134.9	37 05.31	75 46.37
H04	38	41409.8	27136.1	37 05.50	75 46.58
H05	34	41412.2	27137.2	37 05.74	75 46.74
H06	37	41392.9	27131.0	37 03.94	75 46.03
H07	36	41398.8	27134.9	37 04.56	75 46.70
H08	30	41402.0	27136.7	37 04.89	75 46.98
H09	32	41405.3	27138.6	37 05.22	75 47.29
H010	35	41408.5	27137.4	37 05.44	75 46.90
H011	30	41410.7	27139.3	37 05.69	75 47.25
H012	29	41411.5	27139.7	37 05.77	75 47.31
H013	38	41412.8	27140.9	37 05.92	75 47.54
H014	38	41414.6	27138.8	37 05.99	75 47.01
H015	30	41413.6	27138.3	37 05.89	75 46.93
B01	25	41399.5	27202.9	37 07.03	76 01.97
B02	22	41415.2	27200.0	37 08.20	76 00.74
B03	15	41423.1	27200.1	37 08.84	76 00.47
B04	35	41385.3	27210.2	37 06.13	76 04.17
B05	25	41369.8	27210.1	37 04.87	76 04.71
V1	48	*	*	36 54.53	75 56.56
V2	46	*	*	36 53.15	75 55.29
V3	49	*	*	36 51.80	75 53.84
V4	52	*	*	36 50.51	75 51.55
V5	*	*	*	36 54.04	75 56.39
V6	47	*	*	36 52.41	75 50.41
1090	*	*	*	36 56.25	76 03.32
1091	*	*	*	36 56.76	76 03.27
1092	*	*	*	36 57.20	76 03.60
1093	*	*	*	36 56.88	76 04.45
1094	*	*	*	36 57.20	76 04.40
1095	*	*	*	36 57.55	76 05.20
1096	*	*	*	36 57.98	76 05.92
1097	*	*	*	36 58.50	76 05.60
1098	*	*	*	36 57.98	76 04.80
1099	*	*	*	36 58.18	76 04.80
1100	*	*	*	36 58.63	76 04.42
1103	*	*	*	37 00.55	76 03.35
1106	*	*	*	37 00.72	75 58.70
1107	*	*	*	37 02.34	76 01.00
1109	*	*	*	37 03.75	76 02.00
1111	*	*	*	37 05.62	75 59.80

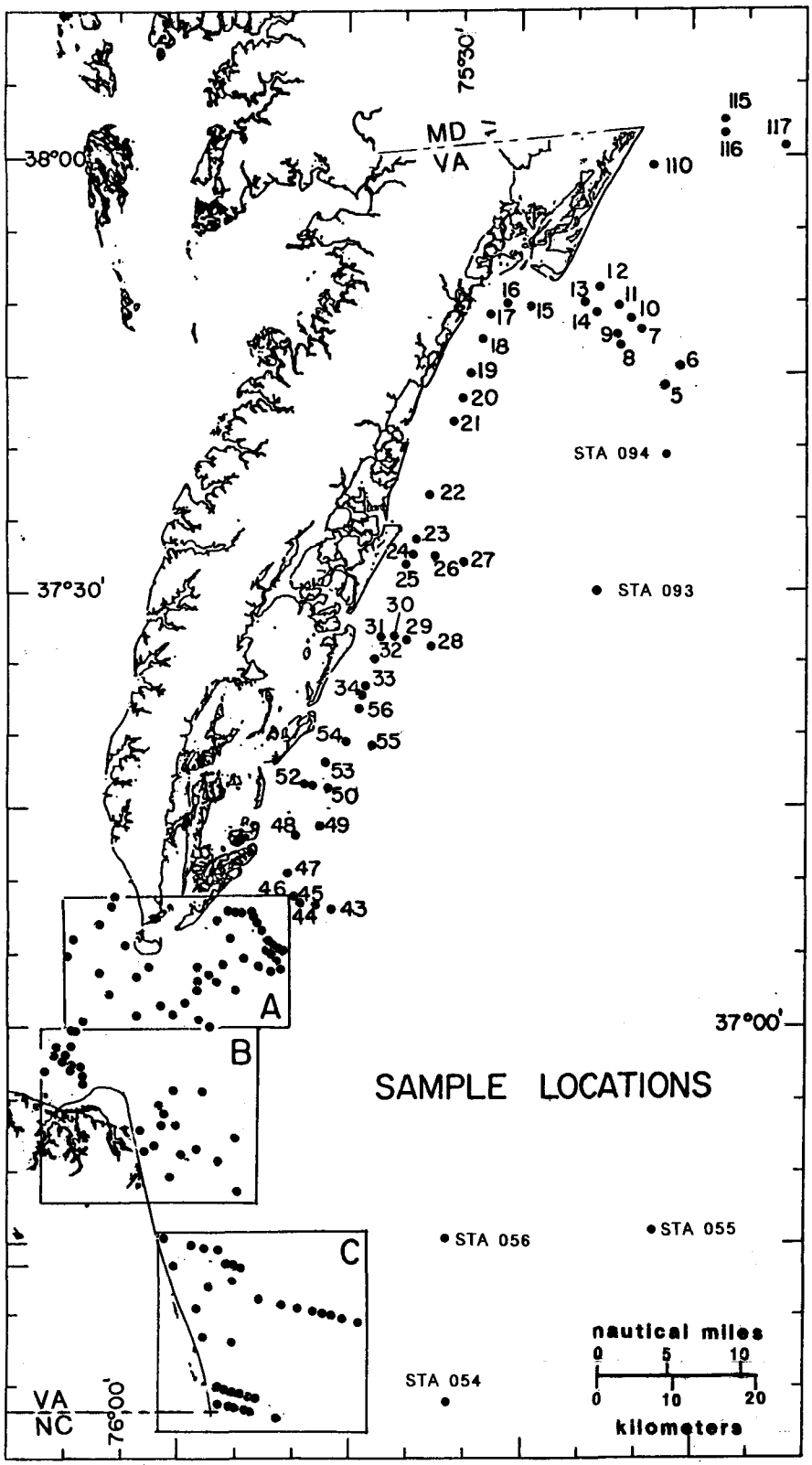

Figure 5. Map showing the location of cores and grab samples off Eastern Shore and index map of sample locations south of the Eastern Shore.

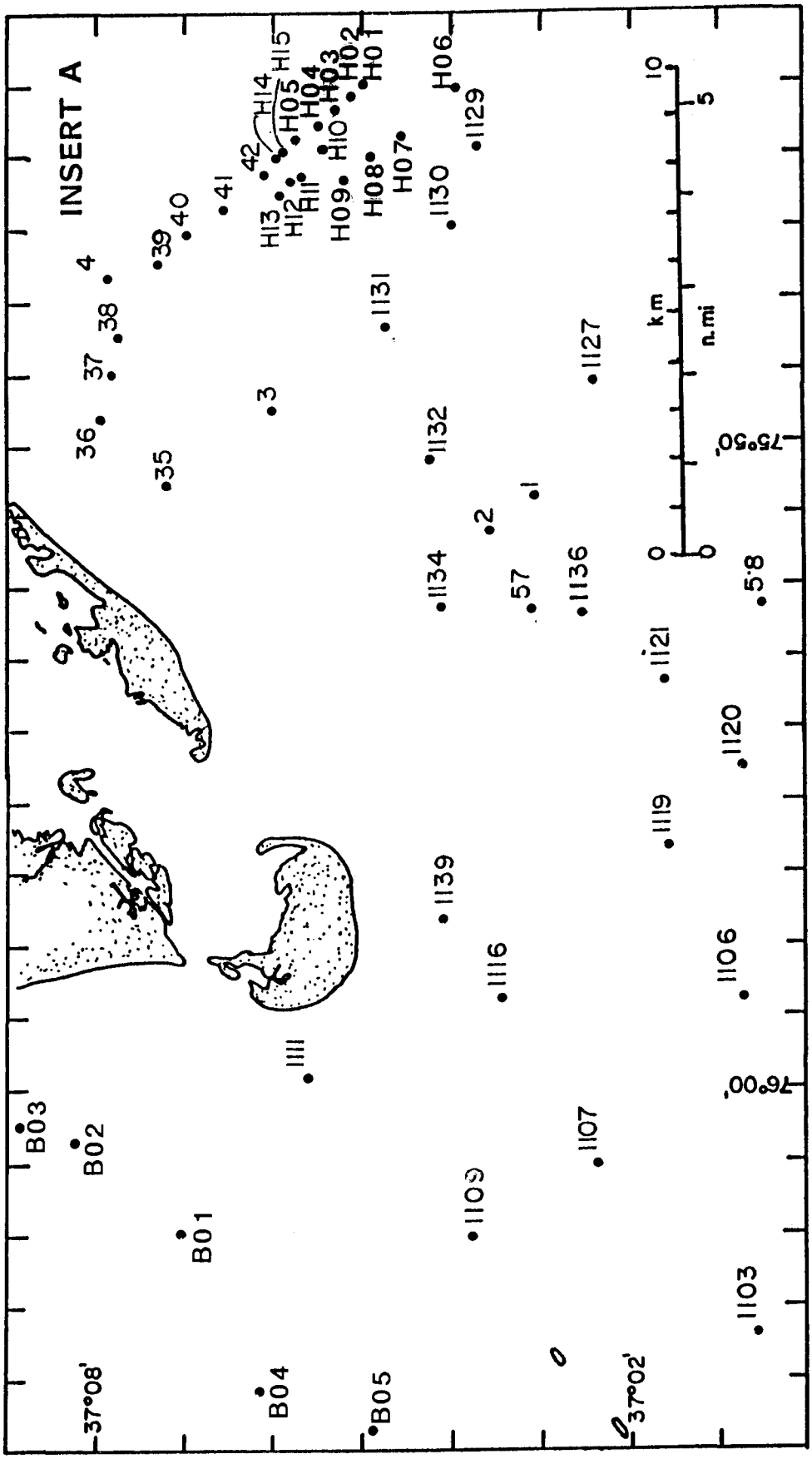

Figure 6. Insert A: map showing the location of samples at northern part of entrance to Chesapeake Bay.

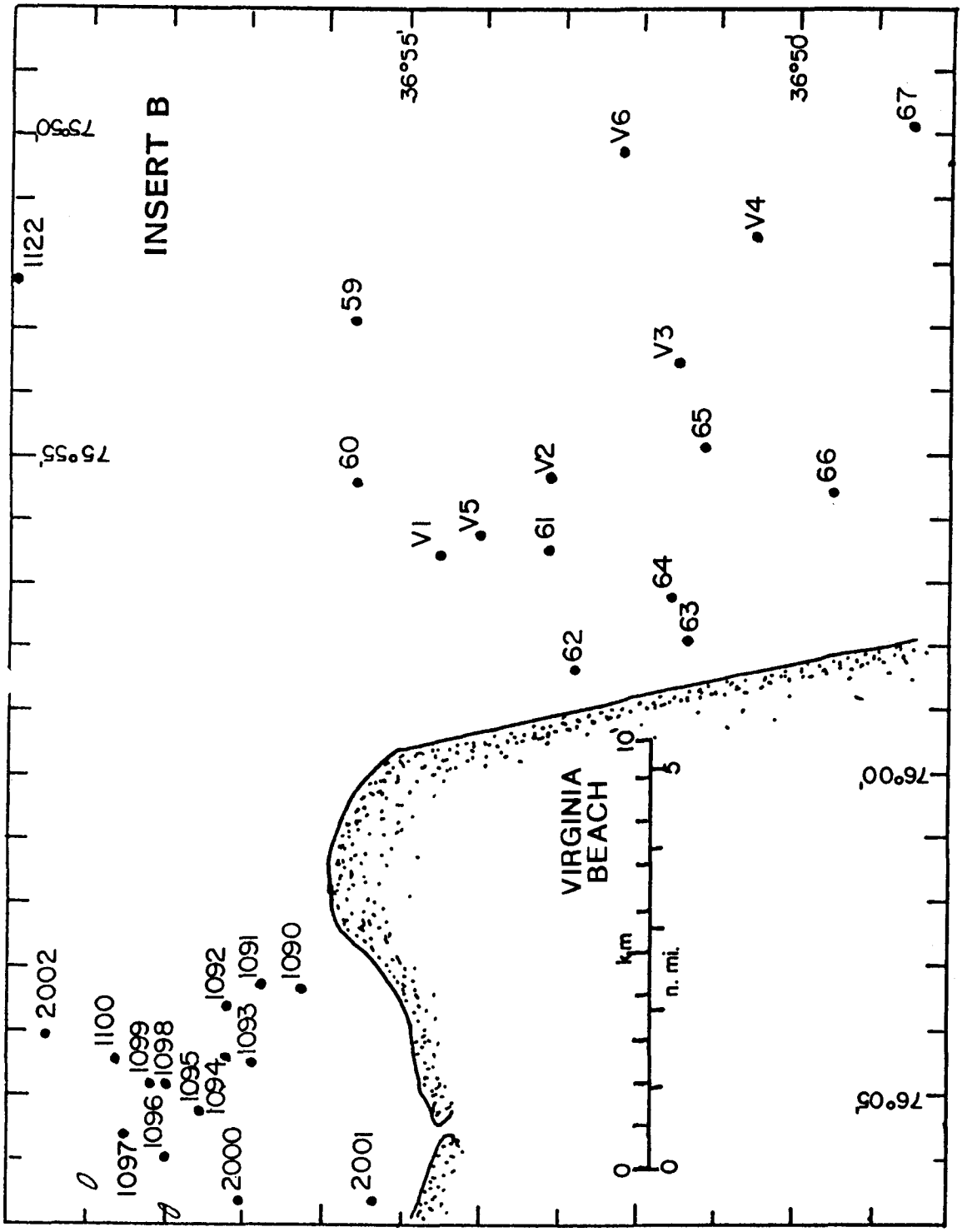

Figure 7. Insert B: map showing the location of samples at the southern part of entrance to Chesapeake Bay and off Virginia Beach.

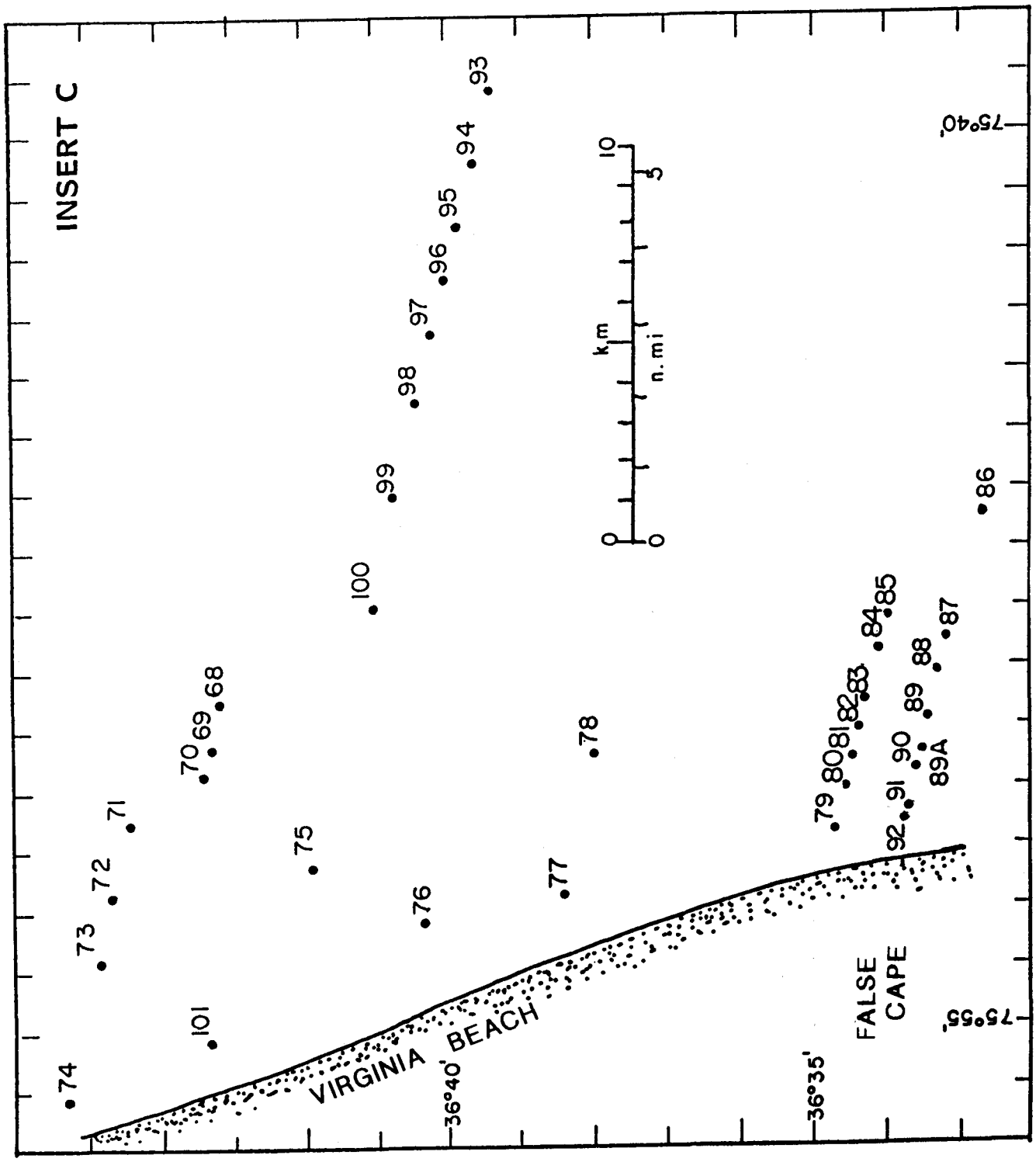

Figure 8. Insert C: map showing the location of samples off Virginia Beach to North Carolina.

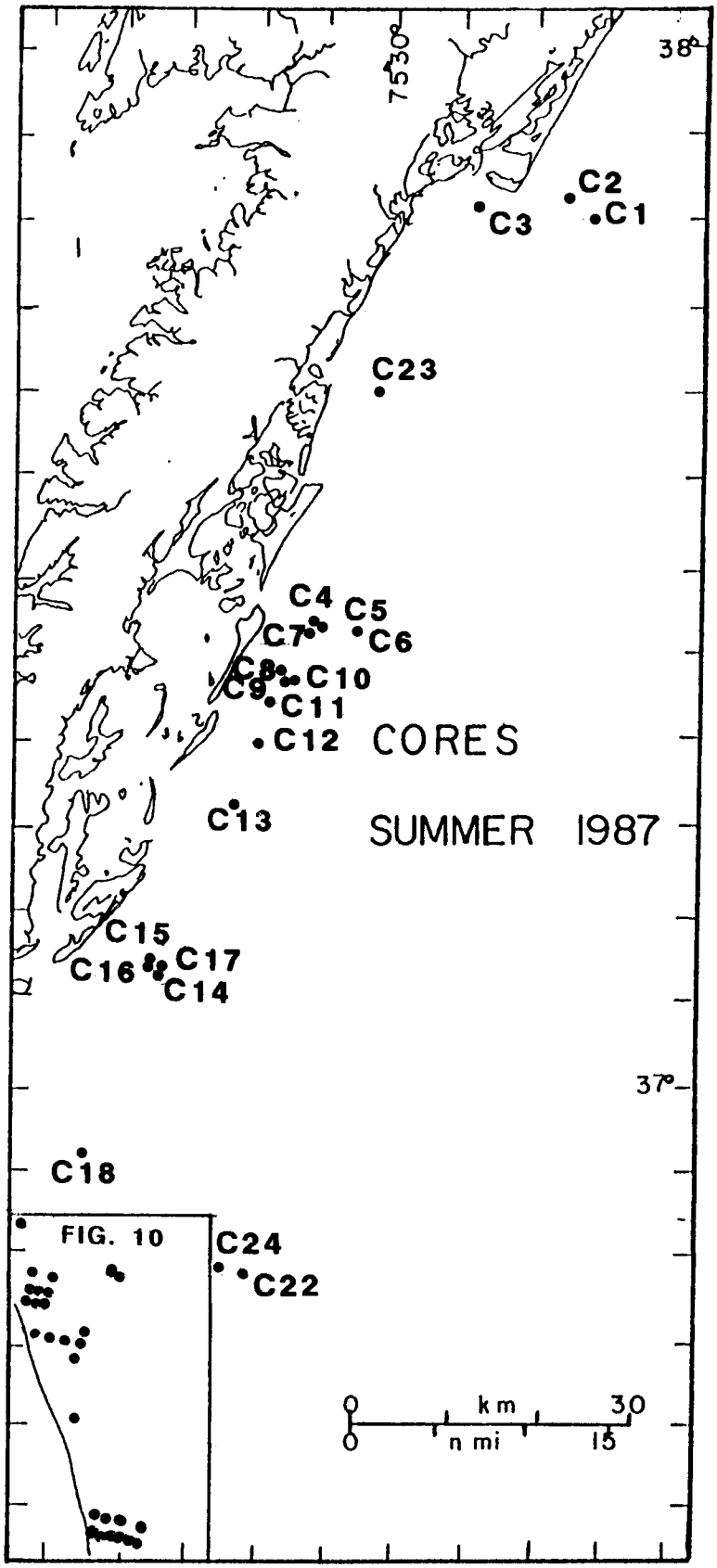

Figure 9. Map showing the location of cores taken during the summer of 1987, northern area.

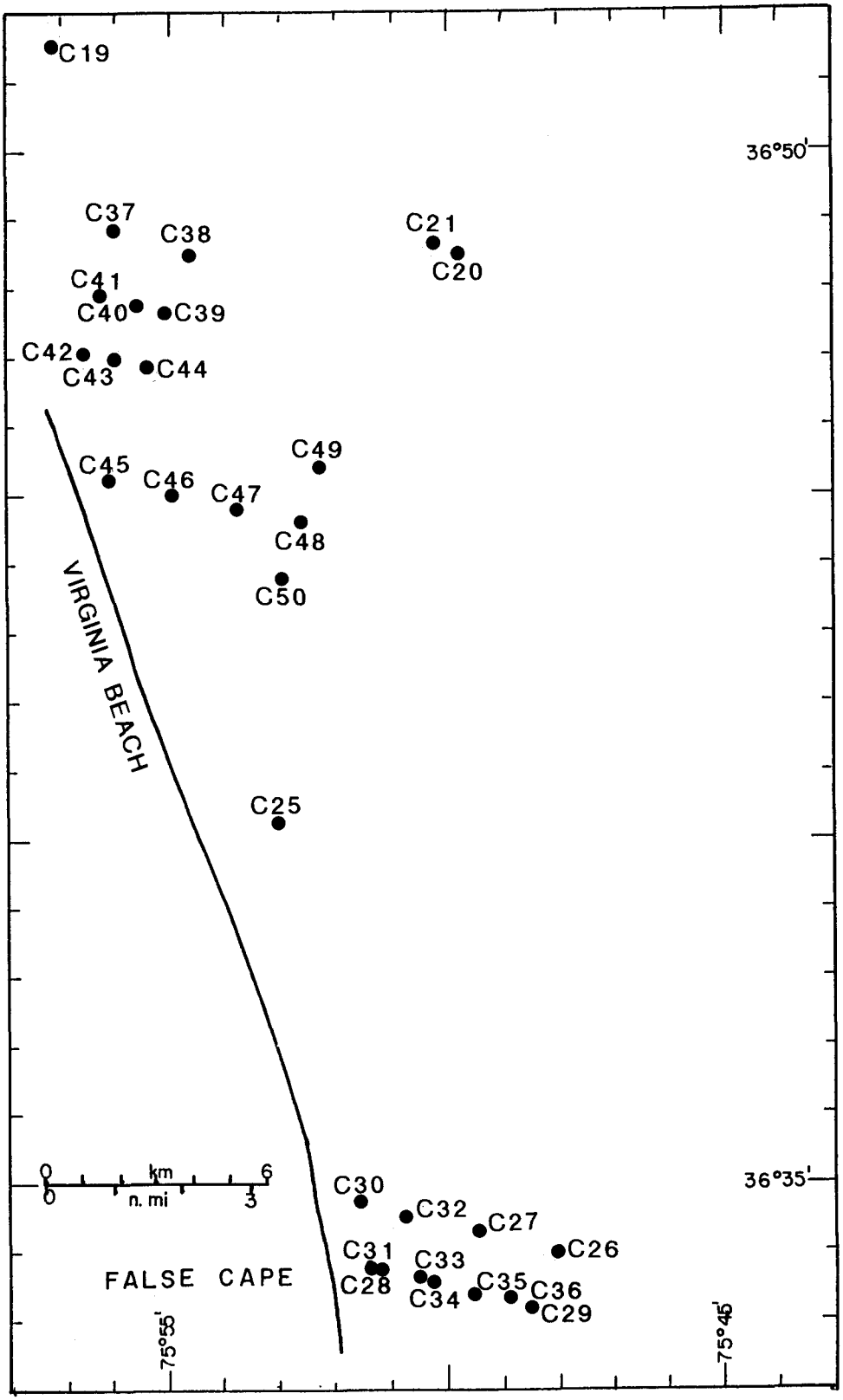

Figure 10. Map showing the location of cores taken during the summer of 1987, southern area.

CORE ID	WATER DEPTH (FT)	LORAN C COORDINATES Y	X	LATITUDE deg min	LONGITUDE deg min
1116	*	*	*	37 03.42	75 58.69
1119	*	*	*	37 01.55	75 56.58
1120	*	*	*	37 00.70	75 55.48
1121	*	*	*	37 01.60	75 54.30
1122	*	*	*	36 59.95	75 52.25
1127	*	*	*	37 02.40	75 50.05
1129	*	*	*	37 03.70	75 46.85
1130	*	*	*	37 04.00	75 47.91
1131	*	*	*	37 04.75	75 49.32
1132	*	*	*	37 04.24	75 51.18
1134	*	*	*	37 04.12	75 53.28
1136	*	*	*	37 02.50	75 53.40
1139	*	*	*	37 04.10	75 57.60
2000	*	*	*	36 57.05	76 06.62
2001	*	*	*	36 55.35	76 06.62
2002	*	*	*	36 59.52	76 04.02
110	*	*	*	37 59.25	75 13.34
115	*	*	*	38 02.38	75 07.15
116	*	*	*	38 01.44	75 07.08
117	*	*	*	38 00.59	75 01.80
C1	50	27082.8	41961.6	37 49.72	75 16.37
C2	45	27093.2	41974.0	37 51.00	75 18.02
C3	35	27047.9	41974.9	37 50.02	75 09.01
C4	36	27129.7	41669.5	37 26.61	75 36.08
C5	36	27130.0	41670.0	37 26.68	75 36.12
C6	36	27130.0	41668.0	37 26.51	75 36.19
C7	56	27114.8	41668.1	37 26.07	75 32.97
C8	32	27134.5	41629.2	37 23.45	75 68.51
C9	34	27133.5	41626.6	37 23.21	75 38.39
C10	32	27128.6	41628.0	37 23.17	75 37.29
C11	32	27134.9	41610.0	37 21.88	75 39.27
C12	28	27134.9	41580.1	37 19.43	75 40.32
C13	31	27134.8	41539.8	37 16.11	75 41.72
C14	32	27139.9	41415.1	37 06.06	75 47.21
C15	28	27144.9	41423.9	37 06.96	75 48.01
C16	29	27144.0	41420.0	37 06.61	75 47.95
C17	33	27140.5	41420.0	37 06.48	76 47.17
C18	37	27144.7	41284.9	36 55.61	75 52.85
C19	27	27155.0	41229.9	36 51.53	75 57.15
C20	53	27120.0	41210.0	36 48.50	75 49.81
C21	50	27122.0	41210.9	36 48.66	75 50.24
C22	60	27088.0	41229.9	36 48.61	75 41.26
C23	44	27135.0	41830.0	37 40.03	75 31.52
C24	60	27092.5	41230.6	36 49.07	75 42.85
C25	33	27119.8	41109.6	36 40.26	75 53.18
C26	47	27089.6	41049.9	36 33.97	75 48.14
C27	45	27095.7	41050.0	36 34.26	75 49.56
C28	8	27102.2	41039.9	36 33.73	75 51.41
C29	37	27090.3	41040.0	36 33.18	75 48.62
C30	33	27105.0	41050.1	36 34.70	75 51.73
C31	25	27102.7	41040.0	36 33.76	75 51.52
C32	35	27101.4	41049.9	36 34.52	75 50.89
C33	37	27099.0	41040.0	36 33.59	75 50.66
C34	31	27098.0	41039.8	36 33.52	75 50.43
C35	41	27094.8	41039.9	36 33.38	75 49.68
C36	25	27092.2	41040.5	36 33.31	75 49.05
C37	29	27146.0	41201.1	36 48.83	75 56.09
C38	34	27140.0	41200.0	36 48.50	75 54.74
C39	34	27140.0	41189.8	36 47.67	75 55.10
C40	30	27142.5	41190.0	36 47.78	75 55.67
C41	29	27145.1	41190.2	36 47.91	75 56.26
C42	30	27145.0	41179.9	36 47.06	75 56.60
C43	32	27142.6	41180.0	36 46.97	75 56.04
C44	33	27140.0	41180.0	36 46.87	75 55.44
C45	32	27140.0	41160.0	36 45.24	75 56.13
C46	36	27135.1	41159.9	36 45.03	75 55.00
C47	41	27130.0	41159.9	36 44.81	75 53.82
C48	29	27125.0	41160.0	36 44.61	75 52.66
C49	35	27125.1	41170.0	36 45.43	75 52.35
C50	39	27125.0	41150.0	36 43.79	75 53.01
WB063	12	27248.9	41305.6	37 01.10	76 16.02

113 core samples

GRAB SAMPLES

GRAB ID	DEPTH (FEET)	LORAN C COORDINATES Y	X	LATITUDE deg min	LONGITUDE deg min
1	33.0	41372.0	27153.0	37 03.03	75 51.69
2	27.0	41377.0	27156.0	37 03.55	75 52.19
3	27.0	41408.2	27153.4	37 05.99	75 50.49
4	24.0	41432.9	27149.1	37 07.85	75 48.65
5	78.0	41901.9	27048.0	37 43.78	75 11.51
6	82.2	41920.7	27049.7	37 45.43	75 11.25
7	75.0	41945.3	27070.3	37 48.03	75 14.54
8	60.0	41931.1	27076.8	37 47.00	75 16.32
9	57.6	41937.5	27079.9	37 47.62	75 16.72
10	59.4	41953.0	27076.4	37 48.83	75 15.50
11	51.6	41961.6	27082.8	37 49.71	75 16.48
12	46.2	41974.0	27093.2	37 51.01	75 18.14
13	44.4	41959.5	27097.8	37 49.90	75 19.54
14	36.0	41952.5	27090.9	37 49.15	75 18.41
15	36.0	41947.9	27119.8	37 49.49	75 24.33
16	30.0	41949.0	27130.0	37 49.82	75 26.35
17	30.0	41939.2	27135.0	37 49.12	75 27.71
18	36.0	41918.9	27134.8	37 47.43	75 28.40
19	44.4	41890.6	27135.0	37 45.08	75 29.44
20	48.0	41869.5	27134.9	37 43.33	75 30.17
21	47.4	41850.0	27135.1	37 41.72	75 30.91
22	30.0	41789.2	27135.1	37 36.69	75 33.05
23	36.0	41751.2	27134.0	37 33.52	75 34.17
24	36.0	41739.4	27134.2	37 32.55	75 34.63
25	30.0	41729.8	27134.6	37 31.77	75 35.06
26	52.2	41740.0	27124.6	37 32.32	75 32.59
27	24.0	41739.6	27112.0	37 31.92	75 29.97
28	58.2	41668.1	27114.8	37 26.07	75 33.01
29	36.0	41669.3	27125.2	37 26.49	75 35.19

GRAB ID	DEPTH (FEET)	LORAN C COORDINATES Y	X	LATITUDE deg min	LONGITUDE deg min
30	36.0	41669.5	27129.7	37 26.64	75 36.13
31	30.0	41669.4	27135.1	37 26.80	75 37.28
32	30.0	41650.1	27134.7	37 25.19	75 37.88
33	30.0	41629.2	27134.5	37 23.45	75 38.55
34	30.0	41619.5	27134.3	37 22.64	75 38.84
35	*	41420.4	27160.1	37 07.22	75 51.55
36	*	41429.9	27157.5	37 07.90	75 50.64
37	*	41430.2	27154.9	37 07.83	75 50.04
38	*	41430.0	27152.4	37 07.73	75 49.49
39	*	41426.9	27147.4	37 07.30	75 48.49
40	*	41423.9	27144.9	37 06.97	75 48.04
41	*	41419.8	27142.7	37 06.56	75.47.70
42	*	41415.1	27139.9	37 06.07	75 47.23
43	*	41446.8	27120.0	37 07.97	75 41.73
44	*	41447.0	27125.5	37 08.18	75 42.94
45	*	41447.7	27131.9	37 08.46	75 44.32
46	*	41449.6	27134.9	37 08.71	75 44.91
47	*	41466.8	27140.0	37 10.31	75 45.44
48	*	41500.0	27142.0	37 13.09	75 44.71
49	*	41510.1	27134.9	37 13.68	75 42.81
50	*	41539.9	27134.9	37 16.12	75 41.76
51	*	41540.1	27142.0	37 16.37	75 43.30
52	*	41540.1	27145.0	37 16.47	75 43.96
53	*	41560.1	27139.9	37 17.95	75 42.15
54	*	41580.1	27134.9	37 19.42	75 40.35
55	*	41579.9	27125.0	37 19.09	75 38.23
56	*	41610.0	27134.9	37 21.88	75 39.30
57	*	41369.8	27159.9	37 03.10	75 53.31
58	*	41339.9	27154.8	37 00.49	75 53.23
59	*	41284.9	27144.7	36 55.63	75 52.89
60	*	41279.7	27154.9	36 55.60	75 55.39
61	*	41249.6	27154.9	36 53.16	75 56.46
62	*	41241.9	27162.0	36 52.81	75 58.36
63	*	41226.7	27157.4	36 51.40	75 57.84
64	*	41229.9	27155.0	36 51.56	75 57.18
65	*	41229.9	27144.9	36 51.15	75 54.85
66	*	41209.8	27144.9	36 49.52	75 55.56
67	*	41209.9	27120.0	36 48.51	75 49.83
68	*	41149.9	27109.9	36 43.16	75 49.55
69	*	41149.7	27113.0	36 43.28	75 50.27
70	*	41149.9	27115.1	36 43.38	75 50.74
71	*	41159.9	27119.9	36 44.41	75 51.51
72	*	41159.9	27125.1	36 44.64	75 52.72
73	*	41159.7	27129.9	36 44.82	75 53.83
74	*	41160.0	27140.0	36 45.26	75 56.16
75	*	41129.5	27119.0	36 41.88	75 52.33
76	*	41109.9	27119.9	36 40.31	75 53.22
77	*	41089.5	27115.0	36 38.42	75 52.75
78	*	41089.8	27104.9	36 37.99	75 50.39
79	*	41050.1	27105.0	36 34.72	75 51.73
80	*	41049.9	27101.8	36 34.55	75 50.99
81	*	41049.9	27099.8	36 34.46	75 50.52
82	*	41049.8	27097.8	36 34.36	75 50.05
83	*	41050.0	27095.6	36 34.27	75 49.53
84	*	41049.9	27092.3	36 34.10	75 48.76
85	*	41049.9	27089.9	36 33.99	75 48.20
86	*	41039.6	27080.7	36 32.70	75 46.39
87	*	41039.9	27090.0	36 33.17	75 48.56
88	*	41039.9	27092.3	36 33.28	75 49.10
89	*	41039.9	27095.5	36 33.42	75 49.84
89A	*	41039.7	27098.0	36 33.53	75 50.44
90	*	41039.9	27099.0	36 33.59	75 50.66
91	*	41039.8	27102.0	36 33.72	75 51.37
92	*	41039.8	27103.0	36 33.78	75 51.60
93	*	41129.9	27067.5	36 39.38	75 39.29
94	*	41129.7	27067.6	36 39.59	75 40.48
95	*	41129.9	27072.3	36 39.82	75 41.54
96	*	41129.9	27076.1	36 40.00	75 42.42
97	*	41129.9	27080.0	36 40.18	75 43.32
98	*	41129.9	27085.0	36 40.41	75 44.47
99	*	41130.0	27092.1	36 40.73	75 46.10
100	*	41129.6	27100.0	36 41.05	75 47.94
101	*	41139.8	27132.9	36 43.32	75 55.21
51-1	*	*	*	36 23.00	75 49.36
51-2	*	*	*	36 22.00	75 49.30
51-3	*	*	*	36 10.55	75 45.52
51-4	*	*	*	35 50.21	75 33.38
STA054	*	*	*	36 33.70	75 30.80
STA055	*	*	*	36 46.00	75 13.50
STA056	*	*	*	36 47.10	75 32.00
STA093	*	*	*	37 29.90	75 18.30
STA094	*	*	*	37 38.90	75 13.20

111 grab samples

APPENDIX II

A. GENERAL CHARACTERISTICS OF SAMPLES

Data not available are noted by "*"; total heavy minerals = "THM"; gravel (particle size >2mm) = "GRAV". Dry sample weight is in grams. The sum of sample core lengths may be less than described length (Appendix VII) because not all core samples provided enough heavy minerals for analysis. Abbreviations: AVG - average, STD - standard deviation, MAX - maximum value, MIN - minimum value.

CORE SAMPLES

SAMPLE NAME	SAMPLED CORE LENGTH (CM)	DRY SAMPLE WT	% SAND	% MUD	% GRAV	SAND PHI MEAN	WT% THM
B01-1	140	5530	94	6	0	*	3.91
B01-2	130	6247	93	7	0	*	2.88
B02-1	137	5447	98	2	0	*	2.42
B02-2	131	6222	97	3	0	*	3.88
B03-1	122	5036	97	3	0	*	3.20
B03-2	122	6038	96	3	0	*	3.33
B03-3	113	5147	95	5	0	*	3.26

SAMPLE NAME	SAMPLED CORE LENGTH (CM)	DRY SAMPLE WT	% SAND	% MUD	% GRAV	SAND PHI MEAN	WT% THM
B04-1	289	7882	94	6	0	*	2.53
B05-1	261	7522	94	6	0	*	1.86
B05-2	146	6888	95	5	0	*	1.82
H01-1	128	6329	98	0	2	*	3.86
H01-2	137	8475	96	1	3	*	5.10
H01-3	111	6371	89	3	8	*	5.48
H02-1	86	3000	96	3	1	*	2.32
H02-2	154	5826	59	41	0	*	1.09
H02-3	142	9853	73	27	0	*	1.34
H03-1	130	6272	95	1	4	*	2.14
H04-1	133	6099	84	16	0	*	3.06
H04-2	158	7882	70	30	0	*	1.37
H04-3	151	4773	80	19	1	*	1.57
H05-1	185	7031	92	5	3	*	3.67
H06-1	167	6525	85	15	0	*	3.13
H06-2	145	6569	81	19	0	*	1.70
H06-3	152	6278	75	25	0	*	1.49
H06-4	140	5228	66	34	0	*	0.74
H07-1	112	3607	78	22	1	*	3.75
H07-2	128	4222	54	27	19	*	1.87
H07-3	132	5433	79	21	0	*	1.54
H08-1	134	5799	97	2	1	*	5.52
H08-2	144	7567	88	12	0	*	2.85
H09-1	131	5675	82	18	0	*	3.62
H10-1	165	6524	87	13	0	*	2.74
H10-2	174	7300	83	17	0	*	3.21
H11-1	189	8912	91	6	3	*	4.00
H12-1	107	5749	98	1	1	*	6.88
H12-2	121	5809	95	2	3	*	5.34
H13-1	204	8324	93	5	3	*	2.23
H14-1	148	5771	*	*	*	*	0.52
H14-2	142	5942	81	16	4	*	1.49
V1-1	149	7513	*	*	*	*	1.17
V1-2	151	7267	*	*	*	*	0.82
V1-3	152	4400	*	*	*	*	0.61
V1-4	148	5245	*	*	*	*	0.83
V2-1	113	4272	*	*	*	*	2.72
V2-2	152	5530	*	*	*	*	1.67
V2-3	156	6910	*	*	*	*	3.90
V2-4	139	6593	*	*	*	*	2.12
V4-1	190	4721	*	*	*	*	1.77
V4-2	134	7979	*	*	*	*	1.06
V4-3	163	4606	*	*	*	*	1.39
V4-4	153	3766	*	*	*	*	1.35
V3-1	152	7305	93	5	2	*	1.42
V3-2	143	6432	64	34	2	*	0.50
V5-1	108	2317	88	12	0	*	1.95
V5-3	155	5565	95	5	0	*	1.26
V5-4	110	3610	94	5	1	*	1.20
V5-5	128	6424	90	3	7	*	1.44
V6-1	147	5843	94	6	0	*	2.48
V6-2	148	7051	91	7	2	*	1.71
1090-1	165	8649	83	17	0	*	2.46
1090-2	189	15448	86	14	0	*	1.91
1091-1	150	10348	85	15	0	*	2.36
1091-2	150	11148	85	15	0	*	1.71
1091-3	170	13447	78	22	0	*	1.61
1092-1	236	14850	91	2	7	*	1.70
1092-2	242	10450	89	2	9	*	1.03
1094-1	158	14049	92	8	0	*	1.15
1094-2	179	13151	76	24	0	*	1.01
1095-1	160	12648	87	13	0	*	2.51
1095-2	150	12949	91	9	0	*	2.30
1096-1	150	11850	87	12	0	*	1.84
1096-2	150	13049	73	26	1	*	2.23
1097-1	200	17950	93	7	0	*	2.60
1097-2	180	16951	76	19	6	*	1.39
1097-3	146	13450	75	22	3	*	1.26
1098-1	191	14849	75	0	25	*	1.78
1098-2	190	14051	65	33	2	*	0.58
1099-1	257	15550	73	24	3	*	1.18
1099-2	200	15849	78	5	17	*	1.78
1100-1	162	12651	94	6	0	*	2.64
1100-2	180	16249	88	11	1	*	2.51
1103-1	160	7851	84	12	5	*	1.80
1103-2	125	4651	69	22	8	*	1.62
1103-3	215	12851	93	6	2	*	1.74
1106-1	145	13450	99	1	0	*	3.59
1106-2	151	14148	99	1	0	*	2.63
1107-1	165	15450	99	1	0	*	4.35
1107-2	167	15048	98	2	1	*	1.83
1109-1	238	11050	91	9	0	*	3.08
1111-1	148	11450	92	8	0	*	2.76
1111-2	186	15110	90	10	0	*	3.20
1116-1	193	10850	88	12	0	*	4.39
1116-2	217	15751	83	14	2	*	4.00
1119-1	205	19051	99	1	0	*	2.43
1119-2	123	19666	96	4	0	*	2.39
1120-1	160	12650	98	2	0	*	1.95
1120-2	175	15449	95	4	0	*	3.05
1121-1	236	19649	96	4	0	*	3.44
1122-1	145	12251	92	7	1	*	5.67
1127-1	140	11348	92	8	0	*	5.51
1127-2	138	11850	82	18	0	*	2.70
1129-1	145	1648	95	5	0	*	7.65
1129-2	145	12849	86	14	0	*	6.11
1130-1	125	10848	91	6	3	*	7.17
1130-2	128	9448	66	34	0	*	1.96
1131-1	182	15648	85	11	4	*	5.92
1132-1	164	14450	93	6	1	*	6.32
1134-1	181	16649	97	3	0	*	8.79
1134-2	169	15997	94	6	0	*	6.82
1136-1	150	12650	95	4	0	*	9.01
1136-2	150	12448	94	5	0	*	6.42
1136-3	185	15850	91	8	0	*	3.34
1139-1	184	13950	99	1	0	*	2.44
2000-1	160	6050	78	22	0	*	2.00
2000-2	160	9748	64	36	0	*	2.39

SAMPLE NAME	SAMPLED CORE LENGTH (CM)	DRY SAMPLE WT	% SAND	% MUD	% GRAV	SAND PHI MEAN	WT% THM
2001-1	164	10048	73	27	0	*	2.02
2002-1	177	9750	95	5	0	*	3.75
2002-2	162	11051	88	12	0	*	3.01
110-1	215	7850	84	16	0	*	2.60
110-2	161	3950	88	11	1	*	2.21
110-3	156	3950	73	26	2	*	1.41
115-1	184	5348	58	42	0	*	0.74
116-1	85	3450	97	0	3	*	0.58
116-2	275	9251	61	38	1	*	0.54
116-3	190	6848	96	2	2	*	2.17
116-4	176	6450	97	1	2	*	0.92
116-5	94	1948	99	1	0	*	1.66
117-1	150	5649	92	3	6	*	1.26
117-2	140	6351	79	3	18	*	3.87
117-3	145	5050	89	2	9	*	3.95
117-4	150	5251	98	1	1	*	2.84
C1-1	154	6661	94.5	2.1	3.4	*	2.18
C1-2	155	6332	93.0	6.2	0.8	2.31	3.18
C1-3	155	6516	93.9	5.8	0.2	*	2.09
C1-4	157	7682	81.3	18.7	0.0	*	1.95
C2-1	145	6579	67.0	32.1	0.9	2.69	4.12
C2-2	155	6186	34.9	65.1	0.0	*	1.80
C2-3	145	5802	49.8	50.1	0.1	*	2.65
C2-4	115	3712	64.9	34.3	0.8	*	1.41
C3-1	154	4543	55.3	44.5	0.3	3.25	3.99
C3-2	129	4244	76.3	23.6	0.1	3.14	4.21
C3-3	155	5087	54.6	45.2	0.2	3.24	3.54
C3-4	189	7341	53.4	46.4	0.1	3.09	3.36
C4-1	156	4863	50.4	47.9	1.7	*	2.65
C4-2	154	5783	78.3	21.3	0.4	*	2.40
C4-3	142	7339	94.0	6.0	0.0	*	2.66
C5-1	151	6692	87.3	7.6	5.1	*	2.03
C5-2	155	7526	74.4	25.3	0.4	*	2.91
C5-3	155	7033	75.8	23.9	0.3	2.61	3.51
C5-4	149	6290	65.5	30.6	4.0	2.77	3.31
C6-1	155	4727	51.5	46.8	1.7	2.76	4.38
C6-2	154	3391	18.1	81.9	0.0	*	2.55
C6-3	176	5643	58.7	40.8	0.5	3.19	5.78
C7-1	152	5787	73.1	24.5	2.4	3.05	3.14
C7-2	110	4759	65.2	32.5	2.3	*	1.45
C7-3	111	4291	60.2	39.4	0.4	*	2.35
C8-1	72	2669	83.0	5.3	11.6	2.08	3.45
C8-2	177	6820	88.8	11.2	0.0	3.02	6.75
C8-3	153	5747	45.9	54.0	0.1	2.99	3.65
C8-4	131	5615	71.3	28.3	0.4	3.13	3.56
C9-1	155	6388	80.2	14.2	5.6	2.76	4.63
C9-2	152	6099	85.8	14.2	0.0	2.92	3.84
C9-3	173	5206	75.1	24.6	0.3	2.74	3.16
C10-1	147	4808	57.9	40.6	1.5	2.47	3.22
C10-2	160	8318	69.8	29.4	0.8	3.06	4.07
C10-3	139	6195	79.7	19.6	0.7	3.08	4.98
C10-4	143	5815	58.9	40.6	0.5	3.18	4.53
C11-1	118	5641	88.4	5.5	6.2	*	1.88
C11-2	114	4900	94.5	4.7	0.9	*	1.81
C11-3	159	5919	37.9	62.0	0.0	3.20	3.53
C11-4	157	4455	56.3	43.7	0.0	3.20	3.08
C12-1	155	6746	89.5	10.2	0.3	2.93	5.62
C12-2	142	5474	60.7	39.3	0.0	3.15	5.32
C12-3	126	2801	76.0	24.0	0.0	3.19	9.12
C12-4	123	5713	83.3	14.9	1.8	3.15	7.40
C13-1	223	10455	89.5	7.3	3.3	2.35	3.21
C13-2	191	9619	86.8	13.2	0.0	*	2.64
C13-3	171	7196	89.0	11.0	0.0	*	1.73
C14-1	143	6350	81.2	18.4	0.4	3.04	4.47
C14-2	131	4084	33.2	66.8	0.0	*	1.99
C14-3	220	8595	56.7	43.3	0.0	3.35	5.95
C14-4	185	6625	61.3	38.7	0.0	3.40	5.61
C15-1	188	6711	78.0	22.0	0.0	3.06	5.70
C15-2	210	9208	77.8	22.2	0.0	3.27	6.57
C16-1	169	7624	85.7	13.2	1.1	3.02	6.91
C16-2	96	3937	70.1	29.9	0.0	3.19	5.36
C17-1	155	6583	88.1	11.9	0.0	2.97	3.80
C17-2	130	5722	70.1	29.8	0.1	3.21	4.26
C17-3	89	3211	50.8	49.0	0.2	3.25	4.03
C17-4	100	3223	79.5	20.5	0.0	3.20	5.27
C17-5	150	5281	58.1	41.9	0.0	3.36	5.72
C18-1	209	8689	90.3	9.6	0.1	2.67	2.92
C18-2	50	5757	87.4	12.2	0.4	2.84	3.50
C19-1	190	7996	79.8	12.9	7.3	2.97	4.06
C19-2	155	6435	87.0	12.3	0.7	*	2.05
C19-3	208	8423	90.0	9.8	0.2	*	2.08
C20-1	258	12131	41.9	56.3	1.7	*	1.29
C20-2	150	5957	57.5	25.2	17.3	*	1.75
C20-3	151	6511	18.9	81.1	0.0	*	0.97
C20-4	210	7489	28.9	71.1	0.0	*	1.93
C21-1	220	8954	31.7	60.4	8.0	*	1.11
C22-1	150	6886	93.5	4.4	2.2	*	1.54
C22-2	155	6157	93.9	5.4	0.7	*	1.76
C22-3	115	4660	84.5	15.2	0.3	*	2.38
C22-4	125	5913	87.8	10.4	1.8	*	1.22
C23-2	151	7368	47.8	52.2	0.0	*	1.43
C23-3	155	7505	76.4	19.0	4.6	*	1.59
C23-4	155	8563	86.9	5.8	7.3	*	0.95
C24-1	160	5552	89.2	3.9	6.9	*	1.05
C24-2	155	7354	93.3	6.4	0.4	*	1.49
C25-1	155	7111	57.7	34.5	7.8	*	0.41
C25-2	136	6072	80.8	16.5	2.7	*	1.39
C25-3	137	7887	70.7	20.4	8.9	*	1.77
C26-1	171	8910	92.4	7.1	0.5	2.39	3.53
C26-2	173	6898	57.0	41.3	1.8	*	2.60
C26-3	164	7093	24.3	72.8	2.9	3.25	5.11
C27-1	173	5973	44.7	52.8	2.5	*	2.28
C27-3	183	7626	46.2	41.2	12.6	*	2.66
C28-1	159	5817	98.7	1.3	0.0	1.98	1.88
C28-2	151	7552	93.6	6.4	0.1	2.44	3.27
C28-3	154	6419	90.3	9.2	0.6	2.56	3.08
C28-4	149	6537	79.3	20.6	0.1	*	2.40
C29-1	193	8102	93.9	3.7	2.4	2.26	4.53

SAMPLE NAME	SAMPLED CORE LENGTH (CM)	DRY SAMPLE WT	% SAND	% MUD	% GRAV	SAND PHI MEAN	WT% THM
C29-2	170	6691	27.0	72.9	0.2	*	1.29
C30-1	177	5162	52.1	47.5	0.5	*	2.96
C31-1	140	5757	97.8	1.9	0.3	1.56	0.72
C31-2	165	6361	97.1	2.5	0.5	2.07	1.52
C31-3	135	5290	85.6	14.1	0.3	2.86	3.14
C31-4	150	5327	71.4	28.0	0.5	2.93	3.99
C32-1	156	6304	86.7	12.3	1.0	*	2.71
C32-2	154	5486	56.0	42.8	1.1	*	2.73
C32-3	144	11583	62.1	36.9	1.0	2.80	3.39
C33-1	154	6265	77.5	22.4	0.0	*	1.95
C33-2	155	7031	62.2	32.5	5.3	*	2.50
C33-3	154	5604	54.0	45.5	0.5	*	2.42
C33-4	156	5610	21.3	29.3	49.4	*	1.24
C34-1	171	6675	97.7	2.0	0.3	1.72	1.08
C34-2	153	8136	93.8	5.9	0.3	2.24	3.77
C34-3	153	7062	81.1	16.5	2.4	*	2.14
C35-1	156	6198	16.6	83.4	0.1	*	1.78
C35-4	142	6189	61.0	38.9	0.0	*	1.31
C36-1	125	7861	93.2	1.9	4.9	1.11	0.62
C36-2	138	6703	96.7	2.0	1.3	1.51	0.73
C36-3	136	3207	95.8	3.7	0.5	*	0.86
C36-4	100	5024	96.5	2.2	1.3	2.06	0.80
C37-1	173	9625	88.6	11.0	0.4	3.05	4.40
C37-2	173	9367	86.6	11.8	1.6	*	2.22
C37-3	150	7881	84.6	15.3	0.1	2.42	2.16
C38-1	156	7625	84.7	14.9	0.5	*	1.99
C38-2	154	5232	39.5	50.3	10.2	*	2.32
C39-1	181	8642	91.7	8.2	0.1	3.09	4.40
C39-2	182	11016	87.3	10.1	2.6	2.45	4.13
C39-3	180	6805	88.3	9.8	1.9	2.51	2.60
C40-1	145	5965	91.4	8.4	0.1	3.13	4.56
C40-2	153	5942	83.9	15.2	0.9	2.82	4.18
C40-3	148	4916	89.0	10.9	0.1	2.67	2.75
C41-1	136	5733	91.0	8.5	0.6	3.07	3.86
C41-2	127	4435	62.0	34.8	3.2	*	1.83
C41-3	139	6148	96.6	3.4	0.0	2.07	2.65
C42-1	157	6202	71.2	22.1	6.7	2.29	3.56
C42-2	154	7423	78.7	20.9	0.5	2.29	4.35
C42-3	152	6223	59.4	40.6	0.0	2.88	*
C42-4	149	5803	48.6	51.2	0.2	*	3.17
C43-1	177	7165	89.1	8.5	2.4	2.79	6.38
C43-2	173	4961	90.8	8.7	0.4	2.50	3.55
C43-3	167	6385	78.1	21.9	0.0	3.07	6.72
C44-1	177	7886	86.6	13.3	0.1	3.09	6.49
C44-2	175	5891	93.8	6.2	0.0	2.44	3.50
C44-3	172	4742	84.2	15.4	0.4	*	1.74
C45-1	145	4886	28.9	70.0	1.0	2.08	3.01
C45-2	145	5272	86.0	11.0	3.1	*	2.63
C45-3	131	8007	83.5	5.4	11.1	*	2.85
C46-1	155	7107	77.2	21.6	1.2	2.43	3.36
C46-2	155	7049	72.4	26.3	1.3	*	2.20
C46-3	152	5843	47.1	52.5	0.4	2.01	2.19
C46-4	151	7186	83.6	16.0	0.4	1.95	3.04
C47-1	195	8006	37.9	61.3	0.8	2.43	4.47
C47-2	160	6466	64.4	24.4	11.1	*	1.62
C48-1	188	8141	96.5	1.5	2.0	*	0.89
C48-2	202	7573	97.9	1.9	0.3	1.64	0.91
C48-3	195	9661	96.2	2.5	1.4	1.48	0.74
C48-4	118	3750	93.8	2.4	3.8	*	1.79
C49-1	161	8588	98.8	1.2	0.0	1.46	1.00
C49-2	154	8152	92.3	4.5	3.2	1.57	0.82
C49-3	142	6892	89.7	6.3	4.0	*	1.66
C49-4	117	4366	70.5	22.6	6.9	1.99	4.14
C50-1	154	4832	36.8	63.2	0.0	*	2.66
WB063-1	105	4867	92.0	7.9	0.1	*	2.07
WB063-2	152	5720	87.3	12.7	0.0	*	2.13
WB063-3	153	5667	78.8	21.1	0.1	*	2.53
SUM	45430	2232476					
AVG	157	7698.19	79.07	18.99	1.94	2.67	2.87
STD	31	3407.28	18.30	17.96	4.43	0.54	1.66
MAX	289	19666.46	99.13	83.36	49.36	3.40	9.12
MIN	50	1948.00	16.58	0.30	0.00	1.11	0.41

B. GRAB SAMPLES

SAMPLE NAME	DRY SAMPLE WT	WT% THM
1	5139	7.28
2	8707	6.08
3	3681	5.29
4	4224	9.30
5	5219	7.62
6	5754	2.29
7	4819	2.10
8	7372	1.67
9	6865	1.74
10	4550	7.68
11	7128	1.53
12	2436	8.13
13	2323	3.01
14	5399	5.51
15	3551	5.94
22	1760	4.53
23	1892	1.99
24	2226	3.78
25	3025	5.64
27	3369	0.73
28	915	2.69
29	2016	4.33
30	3967	7.00
31	1986	3.03
32	3291	8.06

SAMPLE NAME	DRY SAMPLE WT	WT% THM
33	2160	5.12
34	2135	7.70
35	2443	7.12
36	7242	9.07
39	4873	8.35
40	4037	5.25
41	4940	8.62
42	4807	11.06
43	6902	2.94
44	4871	4.12
45	3058	2.35
46	5008	6.80
47	5440	6.18
48	7457	9.39
49	4147	6.32
50	5221	6.30
51	7310	6.49
52	6758	5.90
53	4421	7.79
54	8332	14.66
55	5705	7.87
56	4445	7.95
57	5197	7.79
58	4521	5.44
59	4225	11.02
60	3268	4.51
61	4354	6.08
62	6037	2.93
63	5352	3.65
64	4969	5.32
65	7957	1.53
66	4451	6.79
67	9247	2.55
68	7737	1.14
69	3984	0.83
70	8017	0.65
71	5209	1.19
72	5858	1.94
73	3682	4.92
74	3265	4.40
75	6309	0.55
76	9407	0.48
77	3685	1.51
78	10006	1.04
79	9230	0.14
80	5224	4.74
81	3607	4.39
82	7652	1.31
83	7693	0.70
84	6450	0.51
85	5742	10.75
86	5499	1.31
87	4884	4.16
88	4114	0.44
89	4047	5.22
89A	7306	4.38
90	11051	0.80
91	6650	4.52

SAMPLE NAME	DRY SAMPLE WT	WT% THM
93	6291	0.97
94	8021	0.82
95	7902	0.42
96	6542	0.79
97	6502	1.12
98	7250	6.25
100	5395	4.48
101	4760	3.47

SAMPLE NAME	DRY SAMPLE WT	% SAND	% MUD	% GRAV	SAND PHI MEAN	WT% THM
STA054	5074	97.1	2.8	0.1	2.20	5.12
STA055	5806	98.0	1.4	0.6	*	0.50
STA056	6034	98.3	1.4	0.3	*	0.83
STA093	6635	94.1	5.9	0.0	2.80	5.64
STA094	6323	96.8	3.0	0.2	2.47	7.45
51-1	19715	*	*	*	*	0.79
51-2	14692	*	*	*	*	0.09
51-3	19892	*	*	*	*	0.08
51-4	17330	*	*	*	*	9.99
SUM	583373					
AVG	5833	96.8	2.9	0.3	2.49	4.43
STD	3210	1.7	1.8	0.2	0.30	3.14
MAX	19892	98.3	5.9	0.6	2.80	14.66
MIN	915	94.1	1.4	0.0	2.20	0.08

EXPLANATION OF MINERAL COMPOSITION DATA for Appendices III, IV, and V

"P" means several grains of the mineral were observed, that is, the mineral was present in the sample.
Mineral names not spelled completely in column headings have been abbreviated as follows: IL = ilmenite, MAG = magnetite and an undetermined amount of titanomagnetite, GAR = garnet, EP = epidote, STAUR = staurolite, PYROBOLE = pyroxene and amphibole minerals combined, SILL/KY = sillimanite and kyanite, TOURM = tourmaline, LEUC = leucoxene, MONA = monazite.
"ECON" is the sum of the weight percents of ilmenite, rutile, leucoxene, sillimanite/kyanite, monazite, and zircon.
"RHM" indicates recovered heavy minerals.
"THM" indicates total heavy minerals.
"*" indicates data not available.
"<0.01" indicates less than 0.01%.
"STD" is the standard deviation.
"AVG" is the average.

APPENDIX III

MINERAL COMPOSITION OF SAMPLES

CORE SAMPLES

SAMPLE NAME	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
B01-1	9.36	14.30	15.01	9.42	0.28	27.57
B01-2	7.06	14.70	20.42	8.84	4.33	24.67
B02-1	5.44	19.96	25.41	5.87	3.37	19.36
B02-2	5.40	20.09	15.99	8.14	0.21	30.10
B03-1	4.70	16.71	11.37	11.91	0.10	34.23
B03-2	7.01	13.69	18.71	9.06	0.25	30.45
B03-3	4.95	15.23	14.38	7.08	0.39	22.14
B04-1	5.25	12.60	14.80	8.10	0.56	30.74
B05-1	4.83	21.03	17.06	8.37	6.14	21.62
B05-2	5.05	25.54	12.42	7.51	4.86	18.66
H01-1	3.15	29.89	22.02	8.10	2.77	11.70
H01-2	9.26	17.22	17.52	4.73	0.06	26.12
H01-3	11.00	17.39	9.32	3.80	2.54	9.65
H02-1	3.96	15.86	12.14	6.39	0.37	26.30
H02-2	9.28	20.44	8.89	7.50	P	27.77
H02-3	4.00	13.39	11.76	4.63	0.27	23.92
H03-1	4.37	17.15	12.49	5.46	0.73	31.75
H04-1	7.74	15.32	16.07	8.58	0.07	26.94
H04-2	10.82	13.24	8.52	3.91	6.72	34.81
H04-3	13.11	14.84	11.60	7.62	0.71	23.98
H05-1	8.67	15.89	5.02	6.43	0.34	27.76
H06-1	6.45	14.35	9.44	6.91	0.06	31.64
H06-2	3.36	20.23	19.09	7.82	4.52	18.63
H06-3	2.40	15.31	14.20	6.65	0.03	27.99
H06-4	5.25	10.02	11.81	7.45	0.29	28.39
H07-1	8.04	19.23	17.29	7.60	0.35	27.12
H07-2	3.33	13.19	18.54	4.33	2.94	32.81
H07-3	12.80	9.92	12.22	6.93	0.03	32.10
H08-1	7.28	20.72	14.97	6.47	0.07	29.19
H08-2	9.09	14.52	16.64	7.80	0.07	28.64
H09-1	17.07	7.65	14.76	5.20	0.31	20.35
H10-1	17.56	9.36	12.73	7.74	0.11	22.97
H10-2	18.03	8.76	15.05	6.24	0.44	19.17
H11-1	10.78	15.48	19.57	7.61	0.01	28.73
H12-1	6.68	20.71	15.84	5.41	0.27	24.34
H12-2	8.09	12.69	11.58	4.88	0.22	20.59
H13-1	9.35	20.24	6.75	2.22	2.30	20.94
H14-1	4.20	14.59	20.26	8.96	3.27	22.22
H14-2	12.36	9.25	11.34	4.83	2.82	17.86
V1-1	2.69	19.44	17.81	8.49	0.19	33.27
V1-2	1.42	50.71	6.69	12.80	2.34	11.45
V1-3	1.44	45.72	2.54	12.81	3.81	17.42
V1-4	1.68	56.22	6.29	6.12	1.86	9.13
V2-1	4.07	23.85	15.24	7.40	0.95	28.45
V2-2	3.09	45.22	9.76	9.11	0.63	10.55
V2-3	0.51	37.16	14.73	15.08	1.95	13.53
V2-4	1.68	50.09	4.82	7.51	0.85	11.62
V4-1	5.72	23.83	12.95	4.96	1.23	31.79
V4-2	0.85	38.30	9.62	9.92	2.48	22.49
V4-3	2.21	32.38	10.96	17.14	1.35	18.03
V4-4	2.21	45.16	8.87	13.37	1.17	11.21
V3-1	2.34	32.51	12.71	7.18	2.52	19.32
V3-2	0.81	36.21	3.37	15.10	2.59	22.50
V5-1	3.03	18.17	15.98	8.77	2.19	23.85
V5-3	1.55	42.75	6.65	12.18	2.97	17.57
V5-4	3.10	44.27	5.72	13.65	1.81	13.28
V5-5	8.86	45.79	9.50	3.69	2.81	10.54
V6-1	6.92	24.09	18.17	4.01	0.35	22.81
V6-2	4.28	24.97	14.86	7.81	1.44	22.39
1090-1	8.30	26.15	14.81	9.05	0.39	23.17
1090-2	5.13	25.84	16.38	9.67	0.79	22.06
1091-1	3.67	24.11	15.31	8.10	0.52	25.00
1091-2	2.57	30.41	14.36	8.63	0.38	17.26
1091-3	6.14	37.86	10.46	6.19	0.90	15.72
1092-1	0.85	45.28	9.81	13.01	1.48	13.12
1092-2	0.76	46.82	3.69	14.91	1.23	11.84
1094-1	3.24	36.10	13.20	7.20	1.13	19.94
1094-2	1.36	47.67	9.06	10.53	0.62	11.02
1095-1	10.29	23.13	18.31	6.16	0.81	20.61
1095-2	1.15	46.39	4.67	16.89	2.29	9.85
1096-1	5.82	25.74	13.69	10.06	0.77	26.12
1096-2	2.83	39.03	8.67	18.06	1.25	14.07
1097-1	5.62	30.25	14.61	9.00	0.80	21.33
1097-2	1.15	46.66	5.15	17.61	1.41	10.96
1097-3	1.25	53.25	8.56	4.52	0.76	14.22
1098-1	0.75	49.89	5.39	15.01	2.63	12.70
1098-2	1.43	60.33	2.01	6.96	1.34	12.44
1099-1	6.62	34.19	12.61	8.61	0.76	17.69
1099-2	1.40	51.02	6.31	11.53	1.48	10.79
1100-1	10.58	24.72	13.15	5.16	0.58	27.44
1100-2	2.78	45.03	7.06	10.58	1.64	16.47
1103-1	2.55	38.64	14.57	6.16	0.77	23.49
1103-2	1.37	40.50	12.30	7.54	0.51	17.34
1103-3	12.07	21.50	18.01	7.39	0.66	22.52

SAMPLE NAME	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
1106-1	3.78	37.70	22.82	7.69	0.05	16.22
1106-2	4.67	29.36	20.27	7.10	1.19	24.50
1107-1	4.00	30.76	17.18	6.55	1.03	24.53
1107-2	5.07	19.67	19.91	6.98	0.60	31.65
1109-1	7.27	22.70	15.94	10.86	0.88	25.25
1111-1	12.52	24.43	17.48	6.26	0.13	22.92
1111-2	10.98	29.74	19.42	6.08	0.25	16.84
1116-1	13.45	25.36	15.21	5.66	0.46	21.73
1116-2	9.73	27.64	17.18	6.12	0.51	18.44
1119-1	4.89	21.87	20.14	7.07	0.84	27.59
1119-2	6.97	28.19	19.36	4.85	0.34	22.53
1120-1	4.41	24.62	16.08	8.01	0.85	27.70
1120-2	8.29	32.17	20.13	5.62	0.42	16.72
1121-1	15.07	21.04	21.66	1.60	1.00	17.90
1122-1	13.18	27.39	13.92	7.39	0.62	21.18
1127-1	13.28	24.63	17.10	5.51	0.76	22.21
1127-2	7.22	28.96	15.72	9.49	0.04	20.32
1129-1	12.25	23.13	16.71	8.69	0.34	22.35
1129-2	13.83	18.66	15.93	7.88	0.48	25.12
1130-1	18.35	21.58	21.30	6.54	0.16	16.67
1130-2	10.01	23.01	14.21	9.11	0.13	23.44
1131-1	27.58	26.69	10.79	6.68	0.33	9.78
1132-1	20.71	21.69	18.36	5.14	0.32	16.23
1134-1	12.12	33.99	21.54	3.57	0.52	11.35
1134-2	15.29	30.93	19.10	3.51	0.20	14.38
1136-1	11.98	28.72	19.54	3.18	0.50	15.71
1136-2	11.98	28.09	15.74	7.23	0.21	16.48
1136-3	8.19	29.35	19.01	8.10	0.65	19.26
1139-1	4.98	26.64	22.64	4.65	0.81	25.01
2000-1	3.28	26.55	16.97	9.61	0.22	26.11
2000-2	2.54	21.59	17.11	8.66	0.06	30.57
2001-1	3.77	20.24	18.92	8.61	0.33	29.24
2002-1	5.07	29.15	17.49	9.24	0.29	15.74
2002-2	4.72	29.41	13.72	10.77	0.39	23.09
110-1	3.54	32.48	12.77	8.34	1.46	19.94
110-2	7.16	18.77	17.97	9.98	0.46	28.35
110-3	1.60	20.25	15.16	9.40	2.78	33.65
115-1	1.21	28.03	16.83	6.19	2.74	26.20
116-1	0.90	31.50	14.06	7.52	3.28	28.20
116-2	0.75	31.64	14.78	6.13	2.50	23.09
116-3	1.38	35.92	13.50	10.10	2.70	19.21
116-4	0.37	36.39	13.97	6.34	2.37	20.77
116-5	0.23	31.24	15.21	7.60	2.04	24.26
117-1	0.29	29.86	15.12	5.09	3.17	30.09
117-2	0.07	27.72	30.70	4.54	3.13	19.30
117-3	0.09	28.32	27.00	5.09	2.68	24.08
117-4	0.14	22.80	23.07	6.55	3.76	32.50
C1-1	0.29	29.94	22.57	5.35	3.52	10.75
C1-2	0.67	17.44	15.46	5.54	7.72	33.54
C1-3	0.65	17.08	20.91	5.94	1.80	30.95
C1-4	0.70	15.87	15.13	4.82	1.86	39.82
C2-1	4.21	27.13	23.98	4.91	1.27	18.11
C2-2	3.71	19.63	21.77	6.09	0.69	20.84
C2-3	3.67	20.60	15.93	4.97	3.67	31.30
C2-4	1.58	25.01	18.05	6.50	3.86	17.79
C3-1	4.72	10.67	19.11	9.62	0.59	20.49
C3-2	5.16	20.91	17.98	5.35	0.12	12.76
C3-3	7.56	19.59	17.74	7.80	0.81	10.55
C3-4	2.48	29.90	16.26	5.51	0.19	13.63
C4-1	5.00	17.34	23.45	4.99	2.07	29.73
C4-2	2.11	14.76	14.73	8.89	1.84	38.22
C4-3	1.66	18.43	20.78	6.01	0.15	23.40
C5-1	1.64	29.47	18.19	7.81	4.87	19.83
C5-2	2.98	11.95	14.24	5.06	1.00	38.42
C5-3	4.18	11.15	15.86	8.85	4.57	35.23
C5-4	9.25	10.91	16.66	8.48	5.73	24.74
C6-1	5.13	20.48	17.27	9.67	5.36	22.73
C6-2	6.31	17.09	21.36	3.53	1.10	27.13
C6-3	12.64	8.91	22.72	4.26	4.89	24.40
C7-1	9.96	19.80	24.24	5.75	0.88	22.84
C7-2	1.84	32.86	31.94	4.90	5.76	8.76
C7-3	13.01	24.62	21.77	6.38	0.80	17.61
C8-1	4.78	30.41	16.95	5.04	0.16	22.26
C8-2	15.33	10.70	19.11	7.17	4.34	25.32
C8-3	10.01	8.95	23.21	4.65	0.90	35.93
C8-4	17.87	7.97	21.15	6.23	0.90	28.65
C9-1	8.47	21.17	9.81	9.05	2.99	29.10
C9-2	4.31	21.91	17.45	5.68	1.23	33.58
C9-3	6.23	20.63	11.03	12.61	2.79	19.35
C10-1	5.88	26.28	25.34	6.85	1.10	17.29
C10-2	15.78	9.89	13.03	10.29	2.07	29.13
C10-3	14.35	9.50	16.26	7.36	4.13	16.68
C10-4	14.36	6.70	12.14	5.85	1.39	24.97
C11-1	1.49	17.79	14.14	5.10	3.64	35.86
C11-2	0.80	15.44	7.87	3.61	4.78	45.26
C11-3	8.49	14.90	20.00	2.62	0.26	19.48
C11-4	7.37	19.73	14.55	6.59	0.22	17.91
C12-1	11.20	15.53	26.46	15.50	1.45	17.67
C12-2	20.32	9.63	13.37	11.55	1.85	19.86
C12-3	23.36	14.76	16.84	5.82	1.34	15.49
C12-4	25.36	8.14	19.82	9.50	3.33	12.12
C13-1	6.03	15.26	19.26	10.77	7.79	21.77
C13-2	7.00	11.44	17.04	9.57	1.15	28.93
C13-3	7.07	12.58	15.32	4.28	0.52	27.47
C14-1	13.45	9.36	15.85	7.04	1.65	37.40
C14-2	15.33	6.47	12.70	5.19	0.36	31.01
C14-3	14.16	9.07	11.25	11.56	4.24	19.86
C14-4	22.23	3.28	18.36	6.22	0.56	27.10
C15-1	13.16	12.47	9.99	11.23	3.03	30.55
C15-2	23.12	7.32	14.71	9.34	6.39	21.93
C16-1	13.02	13.61	19.59	13.96	8.84	11.52
C16-2	13.67	3.31	14.30	8.23	6.21	33.05
C17-1	9.64	15.47	16.53	14.36	3.61	20.59
C17-2	16.24	8.30	17.37	7.13	P	22.88
C17-3	16.05	5.16	13.63	7.13	1.17	30.96
C17-4	17.79	6.81	16.05	11.66	1.22	29.02
C17-5	22.83	4.03	17.06	6.22	1.19	24.82
C18-1	3.89	10.79	11.02	7.69	1.91	39.39
C18-2	5.13	8.86	20.23	14.00	4.61	24.61
C19-1	13.42	13.38	11.22	7.31	3.07	29.52
C19-2	5.72	13.82	14.45	12.86	5.78	28.16
C19-3	1.26	17.83	14.77	12.04	6.17	29.31
C20-1	2.75	26.49	10.05	4.93	3.62	30.00
C20-2	4.12	23.58	13.71	8.09	3.69	18.92

SAMPLE NAME	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
C20-3	6.47	18.61	4.54	15.75	9.43	15.36
C20-4	13.17	21.74	4.15	12.78	1.98	18.54
C21-1	5.29	22.12	14.20	13.09	3.37	16.54
C22-1	2.81	25.96	9.17	7.55	2.82	28.80
C22-2	3.23	24.30	12.64	5.13	1.66	31.32
C22-3	9.41	20.86	14.05	8.19	3.78	22.63
C22-4	5.55	24.99	11.50	4.46	4.20	29.44
C23-2	5.02	21.24	15.83	8.50	2.22	29.93
C23-3	1.91	24.34	14.14	5.74	2.54	33.14
C23-4	0.49	24.03	11.68	4.58	2.91	27.96
C24-1	1.70	28.92	13.41	7.11	2.17	25.15
C24-2	4.68	24.97	12.04	8.41	6.90	19.96
C25-1	0.43	35.22	7.85	9.90	3.30	19.44
C25-2	0.84	35.87	8.30	8.09	2.84	16.51
C25-3	0.53	27.61	13.34	8.57	2.84	18.55
C26-1	4.37	33.39	6.59	12.52	2.60	18.97
C26-2	6.95	19.76	10.47	7.67	2.11	24.98
C26-3	17.17	8.47	13.41	6.82	2.75	25.90
C27-1	5.07	18.69	8.71	10.83	1.76	31.11
C27-3	0.69	44.43	10.58	5.97	2.02	13.76
C28-1	0.35	34.13	10.80	9.48	3.87	20.96
C28-2	5.82	26.08	9.51	7.06	3.10	25.47
C28-3	5.26	18.20	16.89	7.98	1.93	21.39
C28-4	4.12	28.67	6.53	9.12	1.98	21.76
C29-1	2.65	39.62	10.20	6.68	2.75	16.99
C29-2	1.43	31.61	7.00	8.92	1.56	26.50
C30-1	2.26	24.22	11.24	8.59	4.75	22.09
C31-1	0.51	34.59	9.53	6.88	3.28	26.81
C31-2	1.20	36.77	4.77	10.96	3.36	19.05
C31-3	5.53	30.61	14.27	7.66	4.15	13.96
C31-4	9.62	13.02	12.23	12.92	5.14	22.57
C32-1	4.79	27.79	8.15	7.34	0.42	29.83
C32-2	7.66	16.24	13.54	8.92	3.98	24.26
C32-3	9.98	24.02	10.40	10.35	1.30	20.08
C33-1	7.52	13.39	10.45	9.23	2.65	27.56
C33-2	7.92	13.07	12.36	8.88	1.06	26.97
C33-3	9.04	13.20	12.26	10.87	2.24	21.20
C33-4	5.24	24.95	10.96	7.91	1.62	20.18
C34-1	0.42	32.91	10.70	5.88	1.96	31.74
C34-2	3.14	32.86	12.34	7.40	3.54	19.73
C34-3	6.44	17.64	10.05	9.08	1.43	31.16
C35-1	3.02	20.55	10.40	6.32	1.00	22.95
C35-4	1.95	29.82	8.66	9.02	3.34	18.33
C36-1	0.90	41.83	18.96	6.44	5.01	11.08
C36-2	0.48	34.89	11.83	5.39	5.05	22.53
C36-3	1.10	40.04	10.63	6.73	2.40	19.16
C36-4	2.03	26.01	11.89	5.89	4.79	23.76
C37-1	11.57	13.50	18.23	8.99	2.93	21.83
C37-2	0.69	26.93	16.73	8.68	2.79	22.79
C37-3	1.88	30.55	11.43	3.80	3.87	25.74
C38-1	6.98	14.17	12.68	6.71	2.53	35.29
C38-2	0.92	19.75	16.99	9.74	3.31	15.77
C39-1	9.77	18.74	16.53	4.00	0.81	31.43
C39-2	1.37	21.36	15.72	8.91	0.13	37.79
C39-3	1.30	29.26	18.63	4.06	2.18	29.39
C40-1	10.55	19.23	16.07	10.10	4.66	19.00
C40-2	3.84	22.96	11.15	4.80	1.84	34.39
C40-3	1.20	25.74	14.87	6.61	1.56	31.43
C41-1	8.96	19.92	19.92	13.25	3.47	14.19
C41-2	2.70	20.79	11.98	10.89	3.82	16.53
C41-3	2.53	25.50	14.00	4.10	2.21	32.40
C42-1	1.62	34.40	11.50	10.21	3.59	18.08
C42-2	3.07	31.44	13.40	7.75	1.85	21.65
C42-3	3.33	31.18	20.43	9.26	4.88	10.48
C42-4	1.90	49.40	5.45	7.45	2.66	13.35
C43-1	10.23	5.11	21.39	24.35	8.86	11.63
C43-2	1.51	28.84	14.77	7.69	2.49	21.97
C43-3	4.44	18.49	18.21	3.40	2.22	33.12
C44-1	9.05	14.45	14.17	7.09	2.93	32.46
C44-2	0.40	27.87	17.28	10.48	4.74	20.12
C44-3	3.07	24.32	11.47	6.16	7.00	23.30
C45-1	4.00	13.30	19.27	11.75	6.53	24.63
C45-2	1.20	16.99	13.92	12.37	5.72	26.76
C45-3	0.84	22.21	13.95	5.28	2.90	22.70
C46-1	3.69	19.62	17.64	10.04	3.71	22.37
C46-2	1.14	22.84	14.30	8.07	4.44	27.48
C46-3	2.81	17.80	12.99	5.76	4.84	26.92
C46-4	1.11	29.17	14.15	8.14	3.23	21.86
C47-1	6.49	18.15	14.37	8.80	2.67	27.94
C47-2	0.43	33.49	10.83	8.53	5.08	18.71
C48-1	0.49	29.11	14.09	14.36	6.38	15.22
C48-2	0.77	16.89	15.21	10.54	4.60	22.29
C48-3	1.07	27.71	13.83	8.50	5.70	17.69
C48-4	0.85	29.65	16.92	5.73	5.91	18.64
C49-1	0.69	28.89	10.56	10.32	6.48	17.97
C49-2	0.50	30.27	9.58	12.44	8.55	16.16
C49-3	0.83	25.11	9.53	7.99	3.47	33.40
C49-4	0.62	21.71	14.72	11.86	4.63	23.87
C50-1	2.03	20.40	4.28	4.46	2.94	6.43
WB-						
063-1	0.24	39.20	4.74	17.24	3.73	18.50
063-2	0.67	40.78	4.70	10.52	2.61	16.21
063-3	2.01	35.64	2.64	15.71	2.26	15.29
AVG	6.03	24.01	14.42	8.10	2.28	22.79
STD	5.37	10.71	4.95	3.14	1.95	6.96
MAX	27.58	60.33	31.94	24.35	9.43	45.26
MIN	0.07	3.28	2.01	1.60	0.00	6.43

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
B01-1	0.97	0.85	0.57	0.57	0.78	P
B01-2	0.59	1.01	1.75	0.25	0.58	0.12
B02-1	1.04	1.66	1.54	0.19	0.25	0.46
B02-2	0.64	0.55	0.57	0.28	1.86	0.15
B03-1	0.56	0.73	0.59	1.09	0.86	0.05
B03-2	0.70	1.20	0.40	0.72	0.70	0.04
B03-3	1.68	1.06	0.72	1.29	1.70	P
B04-1	0.94	0.50	0.00	0.33	0.74	P
B05-1	0.65	3.31	0.92	0.18	0.54	0.51
B05-2	1.81	3.01	1.85	0.40	0.70	0.99

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
H01-1	0.75	3.12	1.14	0.27	1.80	1.15
H01-2	1.25	0.24	0.14	1.16	0.43	0.06
H01-3	2.66	2.83	1.44	0.12	0.30	1.44
H02-1	0.86	1.68	0.26	0.19	1.52	0.14
H02-2	P	1.75	0.63	0.23	0.12	0.45
H02-3	1.05	3.93	0.46	1.16	0.85	P
H03-1	0.78	1.31	1.08	0.67	1.98	0.33
H04-1	1.50	0.67	0.29	1.48	0.81	P
H04-2	0.70	3.91	0.70	0.05	0.05	P
H04-3	0.97	0.57	0.45	0.95	1.53	P
H05-1	1.27	1.15	0.61	0.10	1.23	0.12
H06-1	0.53	0.59	0.44	0.26	0.23	P
H06-2	1.77	3.69	1.17	0.18	0.57	0.15
H06-3	0.60	0.81	0.00	1.35	0.50	P
H06-4	0.96	0.90	0.38	0.56	1.55	P
H07-1	0.71	0.57	0.50	0.66	1.15	0.06
H07-2	1.11	1.57	0.56	1.32	0.23	P
H07-3	0.97	0.32	0.03	0.58	0.37	0.03
H08-1	0.58	0.18	0.32	0.21	0.71	0.14
H08-2	0.88	0.70	0.15	0.83	0.29	0.02
H09-1	0.20	1.57	0.47	1.83	0.45	0.05
H10-1	0.26	1.50	0.47	0.79	0.68	0.01
H10-2	0.61	0.53	0.46	0.79	0.99	0.06
H11-1	1.08	0.14	0.14	0.50	0.58	P
H12-1	0.42	0.49	0.72	0.05	0.68	0.09
H12-2	0.20	0.86	0.60	0.50	0.55	P
H13-1	0.84	3.24	0.98	1.38	1.80	0.37
H14-1	0.98	1.15	1.03	1.96	0.93	0.59
H14-2	1.71	5.19	2.04	0.41	0.33	1.09
V1-1	1.58	0.59	0.05	0.51	0.71	0.05
V1-2	1.93	2.20	0.32	0.73	1.90	0.36
V1-3	1.37	3.02	0.17	0.06	2.17	0.33
V1-4	1.69	0.76	0.05	0.98	3.31	0.29
V2-1	0.69	1.58	0.41	0.52	1.18	0.15
V2-2	2.25	0.75	0.18	0.28	1.77	0.04
V2-3	1.25	3.81	0.21	0.34	1.80	0.29
V2-4	1.62	0.84	0.59	0.16	1.42	0.05
V4-1	0.50	0.80	0.39	0.62	1.70	0.08
V4-2	2.09	1.43	0.77	0.10	1.86	0.04
V4-3	1.59	1.89	0.22	0.85	2.61	0.11
V4-4	2.08	1.43	0.25	0.35	3.02	0.09
V3-1	1.37	1.85	0.18	0.46	5.39	0.10
V3-2	1.89	3.83	0.28	P	1.06	0.04
V5-1	0.91	0.62	0.56	1.31	1.73	0.03
V5-3	1.61	2.93	0.43	0.36	2.24	0.30
V5-4	1.99	1.17	0.29	1.12	1.40	0.03
V5-5	1.37	1.50	0.13	0.88	3.50	0.16
V6-1	1.38	0.14	0.17	0.44	0.39	0.04
V6-2	1.59	0.06	0.03	1.79	0.45	0.03
1090-1	0.94	0.31	0.23	0.32	0.44	P
1090-2	1.23	1.04	0.52	0.57	1.33	0.07
1091-1	0.56	0.81	0.88	0.73	1.43	2.47
1091-2	1.63	1.02	0.32	0.09	1.98	0.15
1091-3	2.31	0.92	0.21	0.79	1.16	P
1092-1	1.71	1.61	0.00	0.16	1.37	0.13
1092-2	1.93	1.32	0.11	0.79	3.15	0.05
1094-1	1.26	0.60	0.44	0.65	1.33	0.01
1094-2	1.56	1.48	0.27	0.56	1.71	0.01
1095-1	0.68	0.46	0.39	0.61	1.02	P
1095-2	1.95	1.40	0.48	0.55	1.47	P
1096-1	0.36	0.98	0.26	0.66	0.86	0.05
1096-2	1.63	1.27	0.16	0.18	1.35	0.03
1097-1	0.67	0.99	0.22	0.34	1.08	P
1097-2	1.23	1.36	0.44	0.99	2.13	0.09
1097-3	2.12	0.82	0.28	0.45	1.95	P
1098-1	1.34	2.25	0.45	0.05	2.20	0.13
1098-2	1.51	2.22	0.36	0.02	2.01	0.16
1099-1	1.52	0.63	0.30	0.67	2.10	0.01
1099-2	1.66	2.08	0.32	0.47	1.31	0.25
1100-1	0.66	0.93	0.65	0.33	1.00	P
1100-2	1.25	1.85	0.10	0.09	0.83	0.01
1103-1	0.64	0.61	0.27	0.30	1.23	0.01
1103-2	1.36	1.18	0.24	0.44	3.12	P
1103-3	1.21	0.85	0.04	0.55	1.31	0.11
1106-1	0.81	0.68	0.28	0.32	0.77	0.09
1106-2	0.85	0.36	0.24	0.20	0.43	P
1107-1	0.66	0.77	0.47	0.55	0.79	0.12
1107-2	1.43	0.75	0.49	0.35	1.17	0.19
1109-1	0.47	0.22	0.37	0.74	0.96	P
1111-1	1.19	0.46	0.23	0.23	0.82	0.03
1111-2	0.91	0.00	0.32	0.97	0.71	0.03
1116-1	0.96	0.50	0.62	0.11	0.75	0.10
1116-2	2.10	0.39	0.13	0.48	0.36	0.11
1119-1	1.35	0.20	0.27	0.91	0.93	0.22
1119-2	1.35	0.40	0.28	0.90	0.35	0.05
1120-1	1.09	0.98	0.13	1.27	0.55	0.23
1120-2	1.05	0.23	0.17	0.06	1.07	0.03
1121-1	0.94	0.36	0.13	P	0.80	0.04
1122-1	0.90	0.55	0.34	0.71	0.84	0.09
1127-1	0.89	0.25	0.27	P	0.90	P
1127-2	0.55	0.67	0.17	0.54	1.23	0.07
1129-1	0.86	0.64	0.79	0.22	1.01	0.08
1129-2	0.79	0.68	0.86	0.32	0.79	P
1130-1	0.59	0.51	0.49	0.29	0.58	0.08
1130-2	0.45	0.47	0.28	0.35	0.91	0.03
1131-1	1.06	0.48	0.34	0.30	0.70	0.37
1132-1	0.68	0.52	0.63	0.44	0.84	0.01
1134-1	1.79	0.20	0.39	0.24	0.30	0.17
1134-2	0.95	0.55	0.36	0.06	0.57	P
1136-1	1.13	0.43	0.27	0.59	0.99	P
1136-2	0.61	0.21	0.55	0.31	0.73	0.30
1136-3	1.09	0.28	0.21	0.51	0.48	0.03
1139-1	1.23	0.91	0.63	0.48	1.62	0.26
2000-1	1.34	0.96	0.48	0.29	1.88	0.07
2000-2	1.45	1.03	0.25	0.39	1.42	P
2001-1	1.23	0.59	1.00	0.30	1.75	0.05
2002-1	0.49	0.44	0.21	0.45	0.21	P
2002-2	0.31	0.44	0.47	0.80	0.89	0.01
110-1	1.58	0.72	0.05	0.49	0.52	P
110-2	1.21	0.81	0.09	0.46	1.10	P
110-3	1.15	1.45	0.93	0.47	1.21	0.10
115-1	1.52	1.19	0.91	1.00	1.03	0.11
116-1	1.69	2.37	0.56	0.08	2.16	0.15
116-2	2.05	1.78	0.35	0.54	2.66	0.10

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
116-3	1.44	2.05	0.53	0.54	1.98	P
116-4	1.95	1.65	1.45	0.17	1.55	0.14
116-5	3.15	1.95	0.62	0.31	2.52	0.23
117-1	1.38	1.25	0.56	0.61	1.76	0.06
117-2	1.70	1.65	0.88	1.34	1.08	0.10
117-3	1.06	1.46	1.06	P	0.92	0.16
117-4	1.26	1.57	0.69	P	1.35	0.06
C1-1	0.68	3.15	0.02	4.57	3.98	0.02
C1-2	1.48	3.37	0.19	4.00	1.45	P
C1-3	0.00	2.82	0.23	0.62	2.91	0.08
C1-4	1.60	2.75	0.53	1.20	2.69	P
C2-1	1.32	0.89	0.40	2.05	1.07	0.03
C2-2	1.16	2.12	0.56	2.65	2.00	P
C2-3	1.03	2.42	0.49	1.15	3.39	P
C2-4	1.34	1.46	0.30	2.65	4.02	0.10
C3-1	1.73	2.75	0.03	1.17	0.91	P
C3-2	1.08	4.18	0.02	1.33	0.52	P
C3-3	1.77	3.86	0.08	3.32	1.21	P
C3-4	1.86	2.26	0.12	1.57	1.02	P
C4-1	1.55	1.42	0.18	1.55	1.09	0.03
C4-2	1.55	3.04	0.47	0.77	1.13	P
C4-3	0.87	2.56	P	4.45	1.34	P
C5-1	1.25	3.28	0.33	3.00	2.11	0.05
C5-2	1.89	5.10	0.42	0.51	1.93	P
C5-3	1.57	3.49	0.21	2.80	0.71	P
C5-4	1.39	4.62	0.26	1.31	1.62	P
C6-1	1.52	2.37	0.32	1.35	1.27	0.03
C6-2	1.37	1.65	0.05	0.41	1.15	P
C6-3	2.14	3.52	0.40	0.12	1.16	P
C7-1	0.79	0.88	0.29	0.61	0.00	P
C7-2	0.70	1.03	0.14	1.58	2.21	0.32
C7-3	0.26	1.75	0.44	0.56	1.17	P
C8-1	1.16	2.50	0.40	0.59	0.50	0.06
C8-2	1.23	2.67	0.20	1.94	0.99	P
C8-3	1.89	2.40	0.64	0.66	0.49	0.00
C8-4	1.41	1.33	0.34	1.97	0.51	P
C9-1	1.73	2.45	0.12	2.80	1.99	P
C9-2	1.33	2.53	0.15	1.87	1.15	0.00
C9-3	1.96	2.44	0.09	2.57	1.16	0.03
C10-1	1.92	2.05	0.38	1.91	0.89	0.04
C10-2	1.43	3.27	0.27	2.27	0.71	P
C10-3	1.53	4.52	0.39	1.30	1.34	0.00
C10-4	1.87	3.64	0.42	0.70	1.86	0.00
C11-1	1.07	3.08	0.26	1.02	2.81	0.07
C11-2	2.01	5.83	0.81	0.53	3.14	P
C11-3	0.70	2.91	0.00	2.13	0.60	P
C11-4	1.34	5.56	P	1.15	0.62	0.02
C12-1	0.45	1.44	0.10	2.05	1.25	P
C12-2	1.53	2.89	0.08	0.36	0.68	P
C12-3	1.17	3.72	0.20	0.74	1.17	0.00
C12-4	1.36	3.15	0.08	0.63	0.51	0.00
C13-1	1.95	1.63	0.31	1.42	2.13	P
C13-2	1.63	3.09	2.52	2.15	3.01	P
C13-3	2.15	3.79	0.21	1.11	0.96	P
C14-1	1.41	0.81	0.12	0.78	0.78	P
C14-2	1.68	3.47	0.67	1.63	0.31	0.00
C14-3	2.10	4.58	0.06	2.05	2.70	P
C14-4	1.75	2.91	0.30	0.59	1.41	P
C15-1	1.20	2.47	0.13	1.55	1.17	0.00
C15-2	1.34	2.23	0.10	0.19	1.40	0.00
C16-1	1.19	2.09	0.10	0.17	0.28	0.00
C16-2	1.69	2.21	0.25	0.22	0.31	P
C17-1	1.45	2.80	0.17	1.34	2.19	P
C17-2	1.38	3.26	0.20	1.04	0.64	P
C17-3	2.18	3.63	0.20	1.89	0.51	P
C17-4	2.09	1.68	0.42	1.07	0.96	0.00
C17-5	2.09	2.02	0.12	1.07	0.46	0.00
C18-1	0.74	4.58	0.43	1.28	1.66	P
C18-2	1.23	2.80	0.17	3.56	1.49	P
C19-1	1.98	1.77	0.73	0.60	1.05	P
C19-2	1.55	3.51	0.20	0.83	0.71	P
C19-3	0.84	2.80	0.29	1.55	2.06	0.04
C20-1	1.83	2.14	0.83	0.55	4.09	P
C20-2	1.22	3.01	0.00	1.75	6.93	P
C20-3	1.87	2.48	0.19	1.17	2.24	P
C20-4	1.59	2.52	0.61	1.08	3.51	0.00
C21-1	1.57	1.72	0.10	1.32	5.82	P
C22-1	1.73	3.16	0.13	0.67	7.87	P
C22-2	2.04	2.93	0.28	0.59	5.59	P
C22-3	1.24	2.91	0.17	1.74	4.04	P
C22-4	1.37	4.24	0.36	0.84	3.06	0.05
C23-2	0.71	1.63	P	0.63	2.61	P
C23-3	1.36	1.83	0.10	1.04	1.81	0.06
C23-4	1.06	1.79	0.98	1.09	3.23	P
C24-1	2.30	3.43	0.05	0.79	4.04	0.05
C24-2	2.03	4.10	0.41	2.18	4.08	P
C25-1	2.67	3.73	0.52	1.81	3.84	P
C25-2	1.72	2.47	P	0.64	3.41	P
C25-3	1.13	3.18	0.61	0.38	2.12	P
C26-1	1.83	2.25	0.15	2.37	3.59	0.03
C26-2	2.55	3.58	0.00	1.32	2.03	P
C26-3	2.68	2.76	0.37	1.76	1.36	P
C27-1	0.94	2.70	0.07	0.26	1.44	P
C27-3	2.05	2.63	0.52	0.89	3.03	P
C28-1	1.93	3.06	0.74	1.27	4.28	0.13
C28-2	1.86	2.13	0.00	1.20	2.55	0.02
C28-3	1.72	2.13	0.47	3.92	2.15	P
C28-4	1.57	3.27	0.13	3.31	3.37	0.04
C29-1	1.47	3.13	0.03	1.78	2.04	0.07
C29-2	1.81	2.35	0.34	0.87	2.09	0.09
C30-1	2.16	3.46	0.24	1.34	2.42	P
C31-1	2.07	3.53	1.61	0.39	3.15	0.05
C31-2	2.25	4.25	0.86	2.01	4.86	0.05
C31-3	2.30	3.12	0.21	1.33	2.09	0.03
C31-4	1.60	2.47	0.82	0.30	3.00	P
C32-1	2.55	3.03	0.35	1.27	3.00	P
C32-2	1.38	2.65	0.04	1.61	3.18	0.02
C32-3	1.75	3.06	P	1.48	2.60	P
C33-1	3.03	5.59	0.22	0.86	1.92	P
C33-2	1.91	2.63	0.13	1.68	1.40	P
C33-3	1.69	1.81	0.69	2.21	2.34	P
C33-4	1.49	3.42	0.15	0.50	2.63	0.06
C34-1	2.04	3.31	0.64	0.87	1.84	0.10
C34-2	1.14	3.16	0.04	1.95	2.52	P

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
C34-3	1.55	3.68	0.31	0.87	1.90	P
C35-1	1.46	2.80	0.65	2.20	3.88	P
C35-4	2.01	2.17	0.91	1.03	4.57	P
C36-1	1.73	4.08	P	0.77	2.37	0.37
C36-2	1.48	4.69	1.48	0.45	2.03	0.05
C36-3	1.79	3.20	0.97	0.71	1.56	0.12
C36-4	1.57	4.47	0.00	4.13	3.20	P
C37-1	1.18	3.23	0.05	0.69	2.54	P
C37-2	1.80	2.50	0.16	1.88	1.28	P
C37-3	2.46	2.36	1.40	0.32	2.64	0.04
C38-1	1.44	2.27	0.64	0.72	1.23	0.05
C38-2	1.40	4.20	0.25	1.67	1.59	P
C39-1	1.75	1.66	P	0.72	1.23	P
C39-2	1.33	2.24	0.31	0.99	0.54	P
C39-3	2.05	2.89	0.82	0.34	1.03	0.04
C40-1	1.27	2.57	0.11	1.80	1.56	P
C40-2	2.12	3.08	0.60	0.56	3.25	0.02
C40-3	1.52	2.41	0.41	1.64	2.81	P
C41-1	1.60	3.85	0.11	1.09	1.17	0.00
C41-2	2.05	6.15	0.16	1.55	2.87	P
C41-3	2.02	2.32	1.06	1.21	2.53	P
C42-1	1.64	2.06	0.07	2.86	2.88	P
C42-2	1.83	2.49	P	0.71	2.11	0.03
C42-3	2.50	2.59	0.00	0.46	0.93	0.06
C42-4	1.95	2.09	0.17	0.37	2.00	0.15
C43-1	1.72	1.97	0.18	1.23	2.48	P
C43-2	1.44	3.05	0.12	4.68	1.34	0.04
C43-3	1.28	2.31	0.06	0.98	0.77	P
C44-1	1.41	2.48	0.07	0.33	1.55	0.00
C44-2	1.25	2.89	0.22	3.21	0.60	P
C44-3	1.10	2.31	0.12	3.87	2.45	P
C45-1	1.35	2.09	0.06	0.78	2.70	0.00
C45-2	1.03	4.50	0.23	3.28	2.27	P
C45-3	2.15	4.03	0.18	2.18	2.68	P
C46-1	1.37	2.63	0.07	1.38	1.43	P
C46-2	0.85	2.94	0.13	4.47	1.30	P
C46-3	1.09	3.35	P	3.72	1.93	P
C46-4	1.99	3.34	0.16	3.08	1.16	0.04
C47-1	1.73	2.67	P	0.25	2.63	P
C47-2	1.23	4.90	P	0.88	3.06	0.04
C48-1	2.13	3.79	P	1.63	3.41	P
C48-2	1.68	3.72	0.06	2.49	3.85	P
C48-3	2.28	5.64	0.38	2.59	2.31	P
C48-4	1.74	3.16	0.12	2.11	3.03	P
C49-1	1.62	4.04	2.38	0.20	3.61	0.05
C49-2	1.44	4.62	0.25	2.02	4.20	P
C49-3	1.62	3.93	0.71	0.58	1.04	P
C49-4	1.33	3.05	0.03	2.36	1.38	P
C50-1	0.87	4.02	0.39	0.75	1.63	P
WB-						
063-1	1.81	3.67	0.12	P	1.34	P
063-2	0.59	2.75	0.29	1.55	4.15	P
063-3	1.10	2.65	1.13	1.80	5.71	0.04
AVG	1.40	2.17	0.39	1.05	1.73	0.08
STD	0.55	1.32	0.39	0.93	1.21	0.21
MAX	3.15	6.15	2.52	4.68	7.87	2.47
MIN	0.00	0.00	0.00	0.00	0.00	0.00

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
B01-1	1.46	18.86	18.36	2.95	3.91
B01-2	2.36	13.32	19.35	2.17	2.88
B02-1	3.93	11.52	27.30	2.31	2.42
B02-2	1.58	14.41	24.88	3.73	3.88
B03-1	1.56	15.55	20.46	2.85	3.20
B03-2	3.66	13.41	19.99	2.59	3.33
B03-3	3.31	26.08	22.98	2.52	3.26
B04-1	1.63	23.81	16.41	1.87	2.53
B05-1	3.96	10.88	30.00	1.48	1.86
B05-2	4.77	12.43	36.82	1.12	1.82
H01-1	3.10	11.04	39.81	3.57	3.86
H01-2	2.73	19.09	21.91	4.22	5.10
H01-3	7.60	29.91	32.23	5.13	5.48
H02-1	2.46	27.88	22.51	1.53	2.32
H02-2	2.32	20.61	25.08	0.23	1.09
H02-3	7.61	26.96	26.84	0.68	1.34
H03-1	3.13	18.78	24.68	1.85	2.14
H04-1	3.03	17.50	21.34	2.46	3.06
H04-2	4.19	12.38	22.09	0.63	1.37
H04-3	2.27	21.40	20.18	1.15	1.57
H05-1	3.33	18.07	22.98	3.28	3.67
H06-1	1.67	17.43	17.37	2.68	3.13
H06-2	4.47	14.35	30.88	1.46	1.70
H06-3	3.52	26.66	20.74	1.23	1.49
H06-4	3.81	28.65	17.24	0.59	0.74
H07-1	2.07	14.66	23.77	3.08	3.75
H07-2	3.53	16.55	19.63	1.46	1.87
H07-3	2.46	21.25	14.06	1.32	1.54
H08-1	2.25	16.91	24.58	5.21	5.52
H08-2	3.15	17.22	19.56	2.25	2.85
H09-1	6.59	23.50	16.53	2.44	3.62
H10-1	1.79	24.03	13.61	1.71	2.74
H10-2	3.48	25.40	14.42	1.45	3.21
H11-1	1.02	14.37	18.30	3.11	4.00
H12-1	2.17	22.14	24.55	5.51	6.88
H12-2	1.50	37.73	15.81	4.23	5.34
H13-1	0.78	28.80	27.27	1.22	2.23
H14-1	3.93	15.92	22.18	0.31	0.52
H14-2	3.42	27.36	20.99	0.41	1.49
V1-1	3.13	11.50	25.50	0.39	1.17
V1-2	2.82	4.32	59.92	0.59	0.82
V1-3	2.74	6.41	55.34	0.34	0.61
V1-4	3.80	7.81	66.08	0.43	0.83
V2-1	2.21	13.31	29.64	0.93	2.72
V2-2	6.16	10.22	56.19	0.36	1.67
V2-3	2.97	6.38	47.27	0.47	3.90
V2-4	3.66	15.10	57.68	0.79	2.12
V4-1	3.06	12.36	29.98	0.71	1.77
V4-2	2.01	8.04	45.73	0.73	1.06
V4-3	2.40	8.25	40.98	0.57	1.39
V4-4	3.09	7.71	54.87	0.72	1.35
V3-1	3.63	10.43	44.86	0.59	1.42
V3-2	3.11	9.20	46.15	0.27	0.50
V5-1	4.26	18.60	25.71	0.88	1.95
V5-3	3.60	4.87	53.42	0.85	1.26
V5-4	5.04	7.09	53.91	1.01	1.20
V5-5	4.30	6.99	56.61	0.84	1.44

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
V6-1	4.51	16.55	30.56	1.06	2.48
V6-2	6.62	13.67	33.73	0.75	1.71
1090-1	3.05	12.85	30.89	0.74	2.46
1090-2	3.69	11.68	33.20	0.61	1.91
1091-1	9.22	7.19	38.61	0.60	2.36
1091-2	4.05	17.15	39.24	0.64	1.71
1091-3	4.64	12.70	46.89	0.43	1.61
1092-1	3.19	8.28	53.29	0.60	1.70
1092-2	4.90	8.50	58.18	0.56	1.03
1094-1	2.93	11.98	42.23	0.32	1.15
1094-2	4.19	9.96	56.62	0.55	1.01
1095-1	3.62	13.90	28.92	0.64	2.51
1095-2	3.26	9.67	54.46	0.80	2.30
1096-1	2.04	12.59	30.03	0.72	1.84
1096-2	2.84	8.62	46.15	0.74	2.23
1097-1	4.42	10.68	37.40	0.60	2.60
1097-2	3.82	6.99	55.30	0.34	1.39
1097-3	3.17	8.65	61.31	0.47	1.26
1098-1	1.36	5.85	57.16	0.54	1.78
1098-2	3.08	6.14	69.30	0.22	0.58
1099-1	4.21	10.08	42.66	0.32	1.18
1099-2	3.00	8.38	59.32	0.52	1.78
1100-1	3.20	11.60	30.51	0.65	2.64
1100-2	3.99	8.31	52.97	0.73	2.51
1103-1	1.90	8.87	43.02	1.22	1.80
1103-2	2.74	11.35	48.90	0.31	1.62
1103-3	4.44	9.34	29.41	0.38	1.74
1106-1	2.32	6.48	42.37	1.41	3.59
1106-2	1.70	9.14	32.69	0.86	2.63
1107-1	2.59	9.99	35.70	0.68	4.35
1107-2	2.01	9.74	25.22	0.60	1.83
1109-1	1.27	13.07	25.62	0.97	3.08
1111-1	3.88	9.42	30.81	0.58	2.76
1111-2	2.72	11.03	34.11	0.60	3.20
1116-1	2.69	12.40	30.36	1.19	4.39
1116-2	3.93	12.89	34.52	1.11	4.00
1119-1	2.17	11.53	26.75	1.23	2.43
1119-2	3.71	10.73	34.04	1.12	2.39
1120-1	2.08	11.99	29.55	0.96	1.95
1120-2	2.69	11.36	37.24	1.18	3.05
1121-1	4.23	15.23	27.41	1.01	3.44
1122-1	2.23	10.66	32.00	1.31	5.67
1127-1	3.03	11.17	29.70	1.04	5.51
1127-2	3.15	11.86	34.64	0.72	2.70
1129-1	2.21	10.73	27.92	2.88	7.65
1129-2	2.20	12.46	23.11	0.78	6.11
1130-1	2.94	9.93	26.28	2.62	7.17
1130-2	0.99	16.60	25.87	0.24	1.96
1131-1	2.82	12.08	32.12	1.02	5.92
1132-1	5.57	8.85	29.32	1.21	6.32
1134-1	4.64	9.17	41.09	1.50	8.79
1134-2	3.60	10.51	36.60	1.38	6.82
1136-1	3.46	13.51	34.72	1.96	9.01
1136-2	3.68	13.87	33.63	1.74	6.42
1136-3	3.56	9.27	34.79	0.83	3.34
1139-1	2.79	7.35	33.45	1.08	2.44
2000-1	2.52	9.73	33.32	0.30	2.00
2000-2	3.37	11.54	28.86	0.14	2.39
2001-1	2.18	11.79	26.04	0.42	2.02
2002-1	3.15	18.08	33.44	0.56	3.75
2002-2	2.45	12.53	33.51	0.60	3.01
110-1	5.49	12.62	40.79	1.09	2.60
110-2	2.19	11.46	24.07	1.19	2.21
110-3	1.35	10.49	25.51	1.07	1.41
115-1	2.10	10.94	33.97	0.25	0.74
116-1	4.01	3.52	41.87	0.45	0.58
116-2	2.73	10.89	40.97	0.19	0.54
116-3	3.46	7.20	44.85	1.55	2.17
116-4	4.02	8.86	45.70	0.71	0.92
116-5	3.31	7.31	42.41	1.36	1.66
117-1	2.50	8.26	36.81	1.15	1.26
117-2	2.04	5.75	34.29	1.37	3.87
117-3	1.86	6.22	33.77	2.62	3.95
117-4	1.76	4.48	28.81	1.91	2.84
C1-1	4.24	10.92	42.01	1.72	2.19
C1-2	2.89	6.25	26.62	2.42	3.21
C1-3	0.41	15.58	23.31	1.43	2.14
C1-4	3.85	9.17	26.77	0.68	1.97
C2-1	5.34	9.26	35.80	1.63	4.17
C2-2	4.85	13.92	29.76	0.39	1.81
C2-3	4.84	6.54	32.28	1.14	2.67
C2-4	2.75	14.60	34.68	0.71	1.43
C3-1	3.67	24.53	19.73	0.64	4.07
C3-2	5.79	24.79	32.48	0.92	4.35
C3-3	7.03	18.70	33.46	0.61	3.59
C3-4	4.03	21.18	39.06	0.68	3.44
C4-1	4.78	6.81	26.21	0.87	2.67
C4-2	3.46	9.04	23.93	0.91	2.41
C4-3	3.84	16.52	27.04	1.24	2.72
C5-1	3.09	5.07	39.26	1.62	2.04
C5-2	4.51	11.99	25.38	1.53	2.98
C5-3	3.30	8.09	20.21	1.56	3.55
C5-4	7.02	8.00	25.56	1.23	3.36
C6-1	5.54	6.96	31.21	2.02	4.45
C6-2	7.33	11.52	28.59	0.26	2.56
C6-3	3.85	10.99	19.57	0.49	5.79
C7-1	2.93	11.05	24.39	0.61	3.17
C7-2	1.93	6.04	39.05	1.07	1.48
C7-3	1.44	10.18	29.24	1.41	2.41
C8-1	5.13	10.06	39.76	1.85	3.52
C8-2	4.06	6.92	19.65	2.54	6.81
C8-3	3.48	6.79	17.21	0.83	3.66
C8-4	3.67	8.00	14.89	0.67	3.58
C9-1	3.74	6.58	31.07	2.02	4.67
C9-2	2.93	5.89	29.84	1.50	3.87
C9-3	5.17	13.95	31.38	1.56	3.27
C10-1	4.80	5.28	35.98	0.76	3.23
C10-2	4.10	7.78	19.40	1.07	4.10
C10-3	6.47	16.20	23.35	1.14	5.07
C10-4	7.85	18.26	21.91	0.75	4.61
C11-1	4.61	9.06	29.42	1.51	1.92
C11-2	2.45	7.46	28.88	1.64	1.82
C11-3	6.64	21.27	25.74	0.73	3.63
C11-4	8.55	16.40	35.82	0.87	3.16

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
C12-1	2.05	4.84	20.72	3.05	5.68
C12-2	4.21	13.69	18.93	1.75	5.43
C12-3	7.33	8.08	28.15	3.28	9.21
C12-4	5.61	10.39	18.77	2.59	7.54
C13-1	3.39	8.28	24.36	1.64	3.25
C13-2	3.82	8.65	22.98	1.62	2.69
C13-3	6.93	17.61	26.41	0.95	1.83
C14-1	2.28	9.07	14.64	2.11	4.57
C14-2	5.49	15.69	17.42	0.72	2.04
C14-3	4.46	13.90	22.92	1.26	6.02
C14-4	4.52	10.78	13.87	0.64	5.63
C15-1	3.60	9.44	20.91	1.94	5.76
C15-2	3.38	8.53	15.68	1.14	6.61
C16-1	2.77	12.85	19.95	2.53	7.00
C16-2	4.49	12.05	12.02	1.82	5.43
C17-1	4.31	7.53	26.23	2.20	3.85
C17-2	6.41	15.15	19.99	1.24	4.37
C17-3	3.88	13.62	15.36	0.98	4.08
C17-4	2.98	8.24	14.53	1.42	5.31
C17-5	4.07	14.02	12.66	0.89	5.76
C18-1	2.43	14.18	20.20	2.07	3.00
C18-2	3.41	9.90	17.79	2.43	3.58
C19-1	4.62	11.34	22.79	1.20	4.10
C19-2	3.68	8.74	23.26	0.94	2.08
C19-3	1.42	9.63	24.98	1.73	2.15
C20-1	2.94	9.76	37.50	0.56	1.30
C20-2	2.58	12.39	37.32	1.29	1.78
C20-3	4.05	17.86	29.24	0.20	0.97
C20-4	5.51	12.83	34.86	0.33	1.94
C21-1	7.14	7.72	38.37	0.38	1.11
C22-1	3.93	5.38	42.66	1.36	1.55
C22-2	4.10	6.20	38.95	1.50	1.78
C22-3	3.51	7.46	32.56	1.85	2.42
C22-4	2.61	7.33	36.32	0.87	1.23
C23-2	4.09	7.59	30.28	0.89	1.45
C23-3	3.82	8.17	33.22	1.47	1.63
C23-4	3.42	16.77	33.54	0.84	0.96
C24-1	3.08	7.83	41.80	0.83	1.07
C24-2	2.86	7.37	38.05	1.16	1.51
C25-1	7.42	3.86	52.88	0.23	0.42
C25-2	4.01	15.30	47.48	0.38	1.40
C25-3	2.39	18.75	36.43	0.57	1.79
C26-1	4.29	7.03	45.39	1.87	3.58
C26-2	6.35	12.22	34.27	0.95	2.64
C26-3	5.65	10.91	20.92	0.49	5.13
C27-1	4.44	13.97	28.21	0.40	2.29
C27-3	3.94	9.49	56.08	0.34	2.67
C28-1	3.89	5.10	47.42	1.39	1.91
C28-2	7.17	8.04	39.80	1.42	3.31
C28-3	5.18	12.78	29.39	1.32	3.13
C28-4	5.14	10.99	42.06	0.98	2.43
C29-1	5.93	6.67	52.25	4.32	4.58
C29-2	4.87	10.57	42.80	0.38	1.30
C30-1	4.92	12.31	37.18	0.67	2.98
C31-1	3.53	4.08	46.91	0.59	0.73
C31-2	6.00	3.61	54.17	1.36	1.52
C31-3	5.10	9.65	43.24	1.48	3.18
C31-4	5.36	10.96	25.46	0.84	4.03
C32-1	4.86	6.62	41.24	1.59	2.75
C32-2	5.01	11.49	28.49	0.79	2.75
C32-3	7.54	7.45	38.96	0.90	3.41
C33-1	5.68	11.91	29.61	0.80	1.98
C33-2	6.63	15.36	25.64	0.65	2.53
C33-3	6.03	16.41	25.07	0.15	2.42
C33-4	5.82	15.05	38.38	0.16	1.24
C34-1	3.04	4.57	43.23	0.96	1.09
C34-2	4.56	7.62	44.24	2.42	3.83
C34-3	3.99	11.91	28.76	0.87	2.17
C35-1	6.40	18.38	35.09	0.13	1.78
C35-4	5.83	12.37	44.40	0.46	1.33
C36-1	4.75	1.70	55.13	0.48	0.62
C36-2	4.64	5.01	47.78	0.59	0.73
C36-3	7.07	4.52	53.78	0.73	0.86
C36-4	4.72	7.54	39.97	0.72	0.81
C37-1	5.62	9.66	26.06	0.91	4.43
C37-2	3.54	10.23	36.05	1.52	2.25
C37-3	3.78	9.72	41.83	1.34	2.19
C38-1	4.87	10.42	24.03	0.46	2.00
C38-2	3.16	21.26	30.09	0.29	2.33
C39-1	5.36	7.99	28.75	0.90	4.42
C39-2	3.46	5.87	28.92	1.09	4.15
C39-3	3.12	4.90	38.38	1.09	2.62
C40-1	4.32	8.74	28.95	0.79	4.58
C40-2	4.43	6.97	35.85	1.19	4.20
C40-3	4.48	5.33	36.96	1.42	2.77
C41-1	4.70	7.76	31.24	0.95	3.80
C41-2	4.51	16.01	36.37	0.63	1.89
C41-3	4.66	5.46	37.04	1.27	2.68
C42-1	3.86	7.23	44.84	1.13	3.61
C42-2	5.07	8.59	42.98	0.86	4.37
C42-3	4.33	9.59	41.58	0.60	*
C42-4	6.65	6.44	62.22	0.85	3.19
C43-1	2.72	8.13	14.00	1.17	6.40
C43-2	3.63	8.45	38.33	1.46	3.58
C43-3	3.96	10.77	26.81	1.09	6.76
C44-1	4.53	9.47	24.42	0.90	6.51
C44-2	3.55	7.38	36.17	1.59	3.53
C44-3	3.81	11.03	33.99	0.68	1.76
C45-1	4.49	9.05	23.92	0.31	3.02
C45-2	2.71	9.02	27.49	1.76	2.65
C45-3	5.74	15.18	36.80	1.57	2.93
C46-1	3.16	12.88	28.21	1.08	3.39
C46-2	2.24	9.81	30.17	0.86	2.22
C46-3	2.78	16.01	26.95	0.70	2.22
C46-4	4.74	7.83	40.45	2.28	3.10
C47-1	3.02	11.29	28.19	0.66	4.49
C47-2	4.27	8.55	46.99	1.33	1.65
C48-1	3.54	5.85	41.99	0.55	0.90
C48-2	1.67	16.24	27.81	0.63	0.96
C48-3	3.78	8.55	41.71	0.50	0.75
C48-4	3.09	9.04	40.67	1.27	1.83
C49-1	2.95	10.25	41.16	0.78	1.02
C49-2	3.73	6.26	44.25	0.61	0.82
C49-3	2.70	9.10	34.39	0.86	1.67

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
C49-4	3.38	11.06	30.85	0.81	4.16
C50-1	3.70	48.10	30.63	0.32	2.67
WB-					
063-1	4.22	5.19	50.25	1.49	2.10
063-2	5.30	9.88	53.56	1.18	2.19
063-3	5.11	8.90	50.25	2.58	2.53
AVG	3.84	11.72	33.22	1.19	2.87
STD	1.50	5.78	11.38	0.87	1.66
MAX	9.22	48.10	69.30	5.51	9.12
MIN	0.41	1.70	12.02	0.13	0.41

290 core samples

GRAB SAMPLES

SAMPLE NAME	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
1	10.20	16.71	21.25	5.73	0.53	30.33
2	6.42	31.94	19.89	6.49	1.43	12.05
3	17.05	19.04	29.79	3.43	2.90	12.95
4	9.42	21.44	16.29	2.11	1.81	21.35
5	1.13	24.10	21.92	8.28	0.17	25.81
6	0.19	22.81	37.36	2.70	9.04	15.34
7	4.65	18.90	16.35	6.97	1.30	34.04
8	0.23	34.42	22.65	1.59	7.49	21.27
9	0.51	25.56	20.05	2.00	5.24	29.72
10	0.50	25.10	26.23	7.31	P	31.44
11	0.08	31.43	34.83	0.47	2.98	16.48
12	3.00	25.02	21.19	6.51	0.91	19.58
13	2.60	20.21	22.31	5.13	0.49	26.47
14	0.74	28.72	20.74	2.84	3.19	27.11
15	5.74	35.07	15.00	4.59	0.72	13.15
22	1.31	23.73	16.21	5.43	1.57	31.65
23	3.72	21.75	17.99	4.06	2.96	30.32
24	0.53	19.35	13.76	5.25	2.35	37.66
25	2.95	17.71	19.40	3.38	2.28	34.76
27	0.12	17.65	13.53	2.27	3.26	45.74
28	2.36	30.73	18.80	8.33	0.30	22.52
29	4.28	14.80	20.18	5.98	1.26	28.62
30	2.97	30.01	17.44	5.61	1.45	23.86
31	3.48	19.49	22.37	8.27	0.21	30.70
32	2.75	27.99	25.94	1.57	4.02	22.89
33	6.35	58.85	8.75	2.24	0.49	3.84
34	6.67	18.18	17.81	4.49	0.85	32.98
35	8.39	35.58	15.13	4.92	3.31	9.74
36	10.90	24.41	17.44	4.35	2.99	19.82
39	7.61	34.58	16.82	3.79	0.88	14.12
40	6.83	44.26	6.14	3.40	1.15	12.92
41	10.34	24.88	5.75	3.79	2.52	24.18
42	7.83	21.44	20.02	2.09	0.26	18.60
43	4.56	16.65	19.40	6.26	0.17	33.41
44	5.93	19.86	27.48	3.99	0.51	20.47
45	7.85	19.48	19.30	6.55	0.75	29.97
46	4.95	24.83	16.17	3.29	2.58	23.99
47	6.38	27.94	18.07	4.80	1.05	20.53
48	7.09	30.79	15.13	1.35	1.67	16.93
49	6.78	23.31	13.88	1.20	1.17	29.56
50	3.64	18.98	19.46	7.24	0.94	31.94
51	10.66	21.39	17.07	3.82	0.93	26.44
52	11.65	25.39	18.99	3.49	0.09	20.04
53	12.08	19.39	17.17	4.74	1.82	25.22
54	11.08	28.98	20.44	3.05	0.05	19.45
55	12.97	13.08	21.56	5.07	0.02	28.26
56	10.59	22.44	13.15	4.20	2.59	29.69
57	16.18	24.98	17.69	3.36	0.46	17.27
58	11.05	22.60	20.13	1.57	1.57	23.52
59	4.48	34.94	19.55	3.93	P	19.66
60	6.55	24.63	19.89	3.11	1.34	20.78
61	6.85	23.86	16.81	0.72	0.40	25.03
62	8.81	23.09	16.97	4.38	0.85	24.32
63	12.94	13.58	16.86	3.98	1.87	27.93
64	13.56	10.17	20.68	7.98	0.02	30.08
65	0.87	27.44	10.54	13.90	2.91	24.19
66	10.13	22.23	15.69	5.61	0.04	20.71
67	3.40	50.28	12.42	2.13	5.68	6.16
68	1.08	35.93	11.78	9.41	2.73	15.42
69	0.28	20.47	8.56	14.31	2.96	32.24
70	0.42	34.69	10.78	10.73	5.95	16.03
71	3.19	28.81	15.16	8.96	0.91	26.45
72	0.34	41.63	16.84	8.20	2.96	9.12
73	5.91	21.11	16.93	3.98	1.15	19.40
74	2.63	21.08	21.89	5.08	0.06	28.44
75	0.52	29.78	19.75	5.51	3.77	19.77
76	0.33	31.24	9.29	12.76	5.07	19.75
77	2.25	31.18	9.58	9.91	0.44	26.99
78	0.44	37.19	14.50	4.70	3.06	19.22
79	0.26	22.13	8.67	8.17	11.78	10.37
80	1.47	38.22	8.14	4.19	0.80	19.73
81	6.17	24.58	17.49	9.06	0.40	22.32
82	0.31	47.30	13.36	4.85	1.67	12.74
83	0.36	44.71	15.00	7.52	5.31	10.64
84	0.26	37.74	13.52	7.73	1.96	17.46
85	3.48	54.88	8.40	3.96	1.24	8.43
86	1.32	33.13	12.26	9.94	1.82	22.55
87	1.65	42.77	11.69	7.77	0.55	6.70
88	0.34	32.51	10.81	9.46	5.44	22.87
89	7.18	19.35	18.72	4.08	0.78	23.72
89A	1.24	47.00	13.81	5.70	1.35	16.57
90	0.43	41.73	20.64	8.09	6.35	4.60
91	0.85	49.52	9.56	7.00	1.10	13.68
93	0.59	30.42	18.24	10.33	3.44	20.84
94	0.49	36.00	11.52	9.56	5.71	20.08
95	0.52	18.87	14.11	14.01	4.65	31.14
96	0.35	43.05	12.75	10.15	7.44	10.28
97	0.89	39.35	11.84	5.81	2.43	13.46
98	0.27	41.34	11.82	8.88	2.19	13.34
100	2.17	42.04	12.75	9.37	0.80	11.87
101	5.87	23.50	15.44	7.95	0.25	27.20

SAMPLE NAME	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
STA-						
054	1.51	32.88	15.39	7.07	4.27	16.24
055	1.12	23.90	17.64	8.38	6.84	16.07
056	0.35	30.97	16.62	10.16	5.74	12.61
093	6.00	23.71	15.33	10.72	3.89	16.72
094	3.57	22.86	17.39	7.22	2.64	24.15
51-1	2.80	21.72	13.21	9.04	4.42	17.69
51-2	2.27	27.76	8.94	7.53	4.06	18.20
51-3	0.65	24.53	15.43	9.21	2.85	17.12
51-4	0.37	42.81	16.88	7.76	3.20	9.94
AVG	4.35	28.51	16.66	5.99	2.34	21.30
STD	4.18	9.74	5.35	3.06	2.21	7.79
MAX	17.05	58.85	37.36	14.31	11.78	45.74
MIN	0.08	10.17	5.75	0.47	0.00	3.84

B. GRAB SAMPLES

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
1	0.27	0.32	0.20	0.01	0.43	0.07
2	0.77	1.14	0.38	0.80	1.03	0.42
3	0.77	0.37	0.34	0.04	0.94	0.05
4	1.41	1.40	1.16	0.65	2.99	0.22
5	0.92	0.10	0.26	0.22	1.73	0.13
6	0.55	0.76	0.72	P	1.15	0.57
7	0.52	0.39	0.40	0.48	0.79	0.04
8	0.82	0.86	1.03	P	1.53	0.41
9	0.59	0.94	0.52	1.09	0.97	0.28
10	0.36	0.18	0.15	0.17	0.89	0.11
11	1.62	0.39	0.31	0.26	1.96	1.70
12	0.88	0.19	0.47	0.91	1.61	0.04
13	0.79	0.28	0.92	0.55	0.97	0.19
14	0.94	1.91	1.12	P	2.89	0.82
15	1.43	1.39	1.08	0.02	1.34	0.11
22	0.44	0.85	0.53	0.72	3.08	0.58
23	1.51	0.60	0.77	1.02	0.89	0.14
24	0.82	1.17	0.45	0.09	2.18	0.29
25	1.13	0.46	0.42	1.48	1.70	0.27
27	1.16	3.36	1.51	0.47	1.56	0.56
28	0.38	0.84	0.67	0.60	1.06	0.20
29	1.22	0.92	0.33	0.21	0.71	P
30	0.86	0.86	0.99	1.15	0.88	0.39
31	1.13	0.23	0.26	0.19	1.02	0.46
32	0.91	1.00	0.59	0.09	0.90	0.41
33	0.83	1.22	0.47	0.10	0.65	0.14
34	1.01	0.46	0.50	1.24	1.95	0.44
35	0.80	2.51	0.19	P	0.19	0.99
36	0.14	0.74	0.20	0.21	1.38	0.81
39	0.75	1.07	0.80	0.91	1.84	0.02
40	0.00	0.77	0.63	0.40	0.00	0.74
41	0.12	0.33	0.21	0.66	2.97	0.17
42	0.64	0.05	0.05	0.17	0.57	0.36
43	0.73	0.37	0.27	0.41	1.17	0.17
44	1.03	1.17	0.79	0.07	0.73	0.15
45	0.82	0.42	0.21	0.05	0.62	0.10
46	0.55	0.79	0.64	0.21	1.79	0.16
47	0.83	0.72	0.57	1.33	0.52	0.15
48	0.81	0.36	0.61	1.35	2.17	P
49	0.75	0.55	0.30	0.67	1.01	0.12
50	1.09	1.41	1.04	0.63	1.17	0.67
51	1.30	0.34	0.16	1.01	1.32	0.23
52	0.66	0.18	0.25	1.49	1.32	0.28
53	0.76	1.12	0.89	0.55	0.80	0.11
54	1.07	0.36	0.28	0.01	0.19	0.37
55	1.04	0.96	0.34	0.64	1.08	0.05
56	1.39	0.36	0.36	1.73	0.91	0.39
57	0.75	0.22	0.25	1.09	1.33	0.05
58	1.01	0.18	0.08	0.38	0.44	0.08
59	1.53	0.87	0.05	0.14	0.63	0.08
60	0.54	0.81	1.26	1.00	1.14	0.01
61	1.32	0.13	0.42	0.81	0.99	P
62	1.09	0.54	0.21	0.85	1.25	P
63	1.26	0.56	0.16	0.37	1.71	0.05
64	0.90	0.64	0.27	0.17	0.83	P
65	1.12	1.20	0.46	1.64	1.46	0.15
66	1.41	0.21	0.14	0.54	0.80	P
67	1.01	1.93	0.10	0.41	3.03	0.57
68	0.57	2.20	0.38	0.63	2.79	0.51
69	1.50	1.85	0.28	1.73	4.41	0.33
70	2.13	2.20	0.35	0.79	4.25	0.5
71	0.97	0.88	0.59	0.54	1.70	0.02
72	1.40	1.87	0.45	1.18	4.05	0.44
73	0.69	0.54	0.48	0.37	0.59	0.08
74	1.07	0.12	0.24	0.72	1.10	P
75	1.60	1.14	0.00	1.59	2.39	0.43
76	2.20	1.69	0.00	1.40	1.99	0.59
77	1.06	1.10	0.09	0.82	2.72	0.12
78	1.50	1.43	0.20	0.60	2.65	0.44
79	2.55	4.80	1.26	3.94	4.80	1.17
80	0.93	0.26	0.16	0.17	1.80	0.31
81	1.65	0.79	0.40	0.52	1.47	P
82	2.77	1.40	0.53	0.59	3.26	0.49
83	2.33	1.30	0.57	0.79	1.54	0.67
84	1.02	2.03	0.14	2.73	3.18	0.29
85	2.44	0.15	0.38	0.24	1.77	0.08
86	2.07	0.64	0.37	0.35	3.04	0.19
87	2.33	0.72	0.39	0.31	2.52	0.26
88	2.04	2.20	0.11	0.68	3.59	0.91
89	1.41	0.26	0.30	0.85	2.17	0.13
89A	1.73	0.88	0.26	0.10	1.89	0.15
90	1.30	2.39	0.18	0.44	3.27	0.62
91	0.93	1.15	0.12	0.39	2.60	0.22
93	1.50	1.19	0.00	0.52	2.93	0.73
94	1.88	2.32	0.00	1.08	1.87	0.56
95	0.87	3.51	0.04	1.41	2.14	0.67
96	1.59	2.07	0.26	0.55	1.65	1.80
97	1.57	0.83	0.04	0.31	1.35	0.10
98	1.69	1.65	0.00	0.09	1.95	0.67
100	2.02	0.71	0.04	0.07	0.99	0.04
101	0.88	0.55	0.18	0.61	1.24	0.03

SAMPLE NAME	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
STA054	2.48	3.47	0.24	1.54	2.68	P
STA055	2.14	6.13	0.42	2.95	2.46	P
STA056	1.98	4.47	0.31	3.01	1.23	P
STA093	1.24	4.26	0.04	1.34	1.92	P
STA094	1.58	4.05	0.09	2.77	1.33	0.02
51-1	1.80	6.15	0.70	3.83	5.64	P
51-2	1.20	8.01	0.13	2.65	8.20	0.09
51-3	1.18	7.67	0.00	2.97	5.98	P
51-4	2.32	4.22	0.00	1.05	3.02	0.10
AVG	1.19	1.40	0.39	0.82	1.85	0.30
STD	0.58	1.56	0.33	0.83	1.31	0.34
MAX	2.77	8.01	1.51	3.94	8.20	1.80
MIN	0.00	0.05	0.00	0.00	0.00	0.00

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
1	1.56	12.39	19.36	6.86	7.28
2	2.62	14.62	37.92	4.25	6.08
3	1.30	11.03	22.47	4.21	5.29
4	3.31	16.44	30.76	5.18	9.30
5	4.24	11.00	31.21	5.53	7.62
6	1.29	7.52	27.13	1.72	2.29
7	3.00	12.18	23.64	0.41	2.10
8	2.12	5.58	40.16	1.02	1.67
9	1.49	11.04	29.83	1.66	1.74
10	0.62	6.94	27.26	6.53	7.68
11	2.45	5.04	39.55	1.31	1.53
12	3.16	16.52	30.91	4.35	8.13
13	1.91	17.18	24.35	1.31	3.01
14	1.62	7.36	36.90	4.17	5.51
15	5.37	15.00	44.70	0.34	5.94
22	1.87	12.04	30.55	3.03	4.53
23	2.54	11.73	27.43	0.65	1.99
24	2.06	14.04	25.86	3.05	3.78
25	1.76	12.30	23.04	4.14	5.64
27	2.30	6.49	26.60	0.62	0.73
28	1.90	11.29	35.12	1.06	2.69
29	2.44	19.05	20.10	3.24	4.33
30	2.88	10.63	35.88	4.83	7.00
31	2.07	10.12	24.41	2.43	3.03
32	1.63	9.30	32.84	5.33	8.06
33	4.10	11.96	65.80	3.13	5.12
34	1.97	11.43	24.02	3.57	7.70
35	1.64	16.61	41.71	3.44	7.12
36	2.06	14.56	29.54	4.22	9.07
39	1.46	15.35	39.71	4.64	8.35
40	4.29	18.46	50.06	2.48	5.25
41	3.00	21.09	31.47	3.42	8.62
42	5.07	22.85	28.13	5.61	11.06
43	3.28	13.15	22.37	2.08	2.94
44	3.21	14.60	26.16	2.94	4.12
45	1.80	12.08	23.24	1.42	2.35

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
46	3.69	16.35	31.81	4.64	6.80
47	1.46	15.63	31.62	4.27	6.18
48	3.67	18.07	37.80	4.65	9.39
49	2.73	17.97	28.47	3.72	6.32
50	1.79	9.99	25.12	4.97	6.30
51	3.49	11.85	28.06	2.65	6.49
52	3.86	12.31	31.68	1.92	5.90
53	1.15	14.20	23.32	4.30	7.79
54	4.92	9.74	35.89	7.02	14.66
55	3.09	11.84	19.31	4.14	7.87
56	3.83	8.36	29.33	4.04	7.95
57	3.34	13.04	30.67	3.48	7.79
58	2.01	15.38	26.33	2.18	5.44
59	4.30	9.83	42.36	6.74	11.02
60	1.87	17.07	29.00	1.12	4.51
61	3.48	19.16	29.79	0.87	6.08
62	1.35	16.28	27.33	1.34	2.93
63	3.33	15.40	20.49	1.78	3.65
64	3.44	11.25	15.98	2.84	5.32
65	2.15	11.95	33.52	1.22	1.53
66	3.56	18.93	28.21	4.67	6.79
67	2.10	10.81	58.92	1.58	2.55
68	3.42	13.15	45.42	0.66	1.14
69	1.29	9.81	29.83	0.72	0.83
70	2.09	9.06	45.90	0.58	0.65
71	2.43	9.39	34.81	0.58	1.19
72	2.66	8.87	52.04	1.62	1.94
73	1.19	27.59	24.20	1.60	4.92
74	2.39	15.19	25.75	2.91	4.40
75	2.79	10.97	38.12	0.47	0.55
76	3.68	10.02	41.39	0.32	0.48
77	2.58	11.16	38.75	0.46	1.51
78	2.91	11.17	46.12	0.89	1.04
79	2.72	17.38	38.18	0.12	0.14
80	3.82	20.00	45.35	3.10	4.74
81	3.42	11.73	31.92	0.76	4.39
82	3.15	7.57	58.37	0.92	1.31
83	2.05	7.20	52.61	0.58	0.70
84	2.62	9.32	46.88	0.37	0.51
85	3.82	10.73	63.14	9.63	10.75
86	3.24	9.08	42.31	0.76	1.31
87	3.31	9.03	51.90	2.96	4.16
88	2.23	6.83	43.47	0.38	0.44
89	2.79	18.25	26.11	1.76	5.22
89A	2.54	6.77	54.20	3.76	4.38
90	3.36	6.58	52.68	0.76	0.80
91	3.39	9.49	57.82	3.93	4.52
93	2.90	6.38	39.66	0.81	0.97
94	1.63	7.29	44.25	0.68	0.82
95	1.58	6.47	27.64	0.38	0.42
96	3.95	4.13	54.11	0.46	0.79
97	3.07	18.95	46.26	0.37	1.12
98	3.51	12.60	50.82	0.51	6.25
100	3.68	13.46	49.47	2.23	4.48
101	2.04	14.24	28.24	0.20	3.47
STA054	4.80	7.43	46.31	4.41	5.21
STA055	1.85	10.08	36.49	0.39	0.51

SAMPLE NAME	WT % ZIRCON	WT % OTHER	WT % ECON	WT% RHM	WT% THM
STA056	2.98	9.58	41.63	0.58	0.84
STA093	4.07	10.76	35.20	3.23	5.74
STA094	3.26	9.06	33.11	5.23	7.57
51-1	2.89	10.10	38.20	0.68	0.80
51-2	3.17	7.79	48.43	0.07	0.09
51-3	3.99	8.42	43.35	0.05	0.08
51-4	4.05	4.27	56.53	7.06	10.01
AVG	2.77	12.12	36.02	2.56	4.43
STD	0.98	4.33	11.07	2.04	3.14
MAX	5.37	27.59	65.80	9.63	14.66
MIN	0.62	4.13	15.98	0.05	0.08

100 grab samples

APPENDIX IV

SUMMARY COMPOSITION STATISTICS (WITH RESPECT TO HEAVY MINERAL CONCENTRATE) FOR ALL SAMPLES

	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR	WT % PYROBOLE
AVG	5.60	25.17	14.99	7.56	2.29	22.41
STD	5.14	10.64	5.15	3.25	2.02	7.21
MAX	27.58	60.33	37.36	24.35	11.78	45.74
MIN	0.07	3.28	2.01	0.47	0.00	3.84
GARNAR'S VALUES	NONE GIVEN	45.00	15.00	15.00	20.00	NONE GIVEN

	WT % RUTILE	WT % SIL/KY	WT % SPHENE	WT % TOURM	WT % LEUC	WT % MONA
AVG	1.34	1.97	0.39	0.99	1.76	0.13
STD	0.56	1.42	0.37	0.91	1.24	0.27
MAX	3.15	8.01	2.52	4.68	8.20	2.47
MIN	0.00	0.00	0.00	0.00	0.00	0.00
GARNAR'S VALUES	2.00	7.00	NONE GIVEN	NONE GIVEN	5.00	1.00

	WT % ZIRCON	WT % OTHER	WT % ECON	CORR WT% RHM	CORR WT% THM
AVG	3.57	11.82	33.94	1.55	3.27
STD	1.46	5.44	11.35	1.40	2.24
MAX	9.22	48.10	69.30	9.63	14.66
MIN	0.41	1.70	12.02	0.05	0.08
GARNAR'S VALUES	5.00	NONE GIVEN	NONE GIVEN	NONE GIVEN	5.00

390 samples (100 grab, 290 core)

APPENDIX V

SELECTED MINERAL COMPOSITION WITH RESPECT TO THE ENTIRE SAMPLE

Underlined samples have concentrations of one or more ECON minerals equal to or greater than Garnar's values (using THM = 5%). See text for explanation.

SAMPLE NAME	WT% THM	WT% IL	WT% RUTILE	WT% LEUC	WT% MONA	WT% ZIRCON
B01-1	3.91	0.56	0.04	0.03	<0.01	0.06
B01-2	2.88	0.42	0.02	0.02	<0.01	0.07
B02-1	2.42	0.48	0.03	0.01	0.01	0.10
B02-2	3.88	0.78	0.03	0.07	0.01	0.06
B03-1	3.20	0.53	0.02	0.03	<0.01	0.05
B03-2	3.33	0.46	0.02	0.02	<0.01	0.12
B03-3	3.26	0.50	0.05	0.06	<0.01	0.11
B04-1	2.53	0.32	0.02	0.02	<0.01	0.04
B05-1	1.86	0.39	0.01	0.01	0.01	0.07
B05-2	1.82	0.46	0.03	0.01	0.02	0.09
H01-1	3.86	1.15	0.03	0.07	0.04	0.12
H01-2	5.10	0.88	0.06	0.02	<0.01	0.14
H01-3	5.48	0.95	0.15	0.02	0.08	0.42
H02-1	2.32	0.37	0.02	0.04	<0.01	0.06
H02-2	1.09	0.22	<0.01	<0.01	<0.01	0.03
H02-3	1.34	0.18	0.01	0.01	<0.01	0.10
H03-1	2.14	0.37	0.02	0.04	0.01	0.07
H04-1	3.06	0.47	0.05	0.02	<0.01	0.09
H04-2	1.37	0.18	0.01	<0.01	<0.01	0.06
H04-3	1.57	0.23	0.02	0.02	<0.01	0.04
H05-1	3.67	0.58	0.05	0.05	<0.01	0.12
H06-1	3.13	0.45	0.02	0.01	<0.01	0.05
H06-2	1.70	0.34	0.03	0.01	<0.01	0.08
H06-3	1.49	0.23	0.01	0.01	<0.01	0.05
H06-4	0.74	0.07	0.01	0.01	<0.01	0.03
H07-1	3.75	0.72	0.03	0.04	<0.01	0.08
H07-2	1.87	0.25	0.02	<0.01	<0.01	0.07
H07-3	1.54	0.15	0.01	0.01	<0.01	0.04
H08-1	5.52	1.14	0.03	0.04	0.01	0.12
H08-2	2.85	0.41	0.03	0.01	<0.01	0.09
H09-1	3.62	0.28	0.01	0.02	<0.01	0.24
H10-1	2.74	0.26	0.01	0.02	<0.01	0.05
H10-2	3.21	0.28	0.02	0.03	<0.01	0.11
H11-1	4.00	0.62	0.04	0.02	<0.01	0.04
H12-1	6.88	1.43	0.03	0.05	0.01	0.15
H12-2	5.34	0.68	0.01	0.03	<0.01	0.08
H13-1	2.23	0.45	0.02	0.04	0.01	0.02
H14-1	0.52	0.08	0.01	<0.01	<0.01	0.02
H14-2	1.49	0.14	0.03	<0.01	0.02	0.05
V1-1	1.17	0.23	0.02	0.01	<0.01	0.04
V1-2	0.82	0.42	0.02	0.02	<0.01	0.02
V1-3	0.61	0.28	0.01	0.01	<0.01	0.02
V1-4	0.83	0.46	0.01	0.03	<0.01	0.03
V2-1	2.72	0.65	0.02	0.03	<0.01	0.06
V2-2	1.67	0.76	0.04	0.03	<0.01	0.10
V2-3	3.90	1.45	0.05	0.07	0.01	0.12
V2-4	2.12	1.06	0.03	0.03	<0.01	0.08
V4-1	1.77	0.42	0.01	0.03	<0.01	0.05
V4-2	1.06	0.41	0.02	0.02	<0.01	0.02
V4-3	1.39	0.45	0.02	0.04	<0.01	0.03
V4-4	1.35	0.61	0.03	0.04	<0.01	0.04
V3-1	1.42	0.46	0.02	0.08	<0.01	0.05
V3-2	0.50	0.18	0.01	0.01	<0.01	0.02
V5-1	1.95	0.35	0.02	0.03	<0.01	0.08
V5-3	1.26	0.54	0.02	0.03	<0.01	0.05
V5-4	1.20	0.53	0.02	0.02	<0.01	0.06
V5-5	1.44	0.66	0.02	0.05	<0.01	0.06
V6-1	2.48	0.60	0.03	0.01	<0.01	0.11
V6-2	1.71	0.43	0.03	0.01	<0.01	0.11
1	7.28	1.22	0.02	0.03	<0.01	0.11
2	6.08	1.94	0.05	0.06	0.03	0.16
3	5.29	1.01	0.04	0.05	<0.01	0.07
4	9.30	1.99	0.13	0.28	0.02	0.31
5	7.62	1.84	0.07	0.13	0.01	0.32
6	2.29	0.52	0.01	0.03	0.01	0.03
7	2.10	0.40	0.01	0.02	<0.01	0.06
8	1.67	0.58	0.01	0.03	0.01	0.04
9	1.74	0.44	0.01	0.02	<0.01	0.03
10	7.68	1.93	0.03	0.07	0.01	0.05
11	1.53	0.48	0.02	0.03	0.03	0.04
12	8.13	2.03	0.07	0.13	<0.01	0.26
13	3.01	0.61	0.02	0.03	0.01	0.06
14	5.51	1.58	0.05	0.16	0.05	0.09
15	5.94	2.08	0.08	0.08	0.01	0.32
22	4.53	1.08	0.02	0.14	0.03	0.08
23	1.99	0.43	0.03	0.02	<0.01	0.05
24	3.78	0.73	0.03	0.08	0.01	0.08
25	5.64	1.00	0.06	0.10	0.02	0.10
27	0.73	0.13	0.01	0.01	<0.01	0.02
28	2.69	0.83	0.01	0.03	0.01	0.05
29	4.33	0.64	0.05	0.03	<0.01	0.11
30	7.00	2.10	0.06	0.06	0.03	0.20
31	3.03	0.59	0.03	0.03	0.01	0.06
32	8.06	2.26	0.07	0.07	0.03	0.13
33	5.12	3.01	0.04	0.03	0.01	0.21
34	7.70	1.40	0.08	0.15	0.03	0.15
35	7.12	2.53	0.06	0.01	0.07	0.12
36	9.07	2.21	0.01	0.12	0.07	0.19
39	8.35	2.89	0.06	0.15	<0.01	0.12
40	5.25	2.33	0.00	0.00	0.04	0.23
41	8.62	2.14	0.01	0.26	0.01	0.26
42	11.06	2.37	0.07	0.06	0.04	0.56
43	2.94	0.49	0.02	0.03	0.01	0.10
44	4.12	0.82	0.04	0.03	0.01	0.13
45	2.35	0.46	0.02	0.01	<0.00	0.04
46	6.80	1.69	0.04	0.12	0.01	0.25
47	6.18	1.73	0.05	0.03	0.01	0.09
48	9.39	2.89	0.08	0.20	<0.01	0.34
49	6.32	1.47	0.05	0.06	0.01	0.17
50	6.30	1.20	0.07	0.07	0.04	0.11
51	6.49	1.39	0.08	0.09	0.01	0.23
52	5.90	1.50	0.04	0.08	0.02	0.23
53	7.79	1.51	0.06	0.06	0.01	0.09
54	14.66	4.25	0.16	0.03	0.05	0.72
55	7.87	1.03	0.08	0.09	<0.01	0.24

SAMPLE NAME	WT% THM	WT% IL	WT% RUTILE	WT% LEUC	WT% MONA	WT% ZIRCON
56	7.95	1.78	0.11	0.07	0.03	0.30
57	7.79	1.95	0.06	0.10	<0.01	0.26
58	5.44	1.23	0.05	0.02	<0.01	0.11
59	11.02	3.85	0.17	0.07	0.01	0.47
60	4.51	1.11	0.02	0.05	0.00	0.08
61	6.08	1.45	0.08	0.06	<0.01	0.21
62	2.93	0.68	0.03	0.04	<0.01	0.04
63	3.65	0.50	0.05	0.06	<0.01	0.12
64	5.32	0.54	0.05	0.04	<0.01	0.18
65	1.53	0.42	0.02	0.02	<0.01	0.03
66	6.79	1.51	0.10	0.05	<0.01	0.24
67	2.55	1.28	0.03	0.08	0.01	0.05
68	1.14	0.41	0.01	0.03	0.01	0.04
69	0.83	0.17	0.01	0.04	<0.01	0.01
70	0.65	0.23	0.01	0.03	<0.01	0.01
71	1.19	0.34	0.01	0.02	<0.01	0.03
72	1.94	0.81	0.03	0.08	0.01	0.05
73	4.92	1.04	0.03	0.03	<0.01	0.06
74	4.40	0.93	0.05	0.05	<0.01	0.11
75	0.55	0.16	0.01	0.01	<0.01	0.02
76	0.48	0.15	0.01	0.01	<0.00	0.02
77	1.51	0.47	0.02	0.04	<0.01	0.04
78	1.04	0.39	0.02	0.03	<0.01	0.03
79	0.14	0.03	<0.01	0.01	<0.01	<0.01
80	4.74	1.81	0.04	0.09	0.01	0.18
81	4.39	1.08	0.07	0.06	<0.01	0.15
82	1.31	0.62	0.04	0.04	0.01	0.04
83	0.70	0.31	0.02	0.01	<0.01	0.01
84	0.51	0.19	0.01	0.02	<0.01	0.01
85	10.75	5.90	0.26	0.19	0.01	0.41
86	1.31	0.43	0.03	0.04	<0.01	0.04
87	4.16	1.78	0.10	0.10	0.01	0.14
88	0.44	0.14	0.01	0.02	<0.01	0.01
89	5.22	1.01	0.07	0.11	0.01	0.15
89A	4.38	2.06	0.08	0.08	0.01	0.11
90	0.80	0.34	0.01	0.03	0.01	0.03
91	4.52	2.24	0.04	0.12	0.01	0.15
93	0.97	0.29	0.01	0.03	0.01	0.03
94	0.82	0.29	0.02	0.02	<0.01	0.01
95	0.42	0.08	<0.01	0.01	<0.01	0.01
96	0.79	0.34	0.01	0.01	0.01	0.03
97	1.12	0.44	0.02	0.02	<0.01	0.03
98	6.25	2.59	0.11	0.12	0.04	0.22
100	4.48	1.88	0.09	0.04	<0.01	0.16
101	3.47	0.82	0.03	0.04	<0.01	0.07
1090-1	2.46	0.64	0.02	0.01	<0.01	0.08
1090-2	1.91	0.49	0.02	0.03	<0.01	0.07
1091-1	2.36	0.57	0.01	0.03	0.06	0.22
1091-2	1.71	0.52	0.03	0.03	<0.01	0.07
1091-3	1.61	0.61	0.04	0.02	<0.01	0.07
1092-1	1.70	0.77	0.03	0.02	<0.01	0.05
1092-2	1.03	0.48	0.02	0.03	<0.01	0.05
1094-1	1.15	0.42	0.01	0.02	<0.01	0.03
1094-2	1.01	0.48	0.02	0.02	<0.01	0.04
1095-1	2.51	0.58	0.02	0.03	<0.01	0.09
1095-2	2.30	1.07	0.04	0.03	<0.01	0.07
1096-1	1.84	0.47	0.01	0.02	<0.01	0.04
1096-2	2.23	0.87	0.04	0.03	<0.01	0.06
1097-1	2.60	0.79	0.02	0.03	<0.01	0.11
1097-2	1.39	0.65	0.02	0.03	<0.01	0.05
1097-3	1.26	0.67	0.03	0.02	<0.01	0.04
1098-1	1.78	0.89	0.02	0.04	<0.01	0.02
1098-2	0.58	0.35	0.01	0.01	<0.01	0.02
1099-1	1.18	0.40	0.02	0.02	<0.01	0.05
1099-2	1.78	0.91	0.03	0.02	<0.01	0.05
1100-1	2.64	0.65	0.02	0.03	<0.01	0.08
1100-2	2.51	1.13	0.03	0.02	<0.01	0.10
1103-1	1.80	0.70	0.01	0.02	<0.01	0.03
1103-2	1.62	0.65	0.02	0.05	<0.01	0.04
1103-3	1.74	0.37	0.02	0.02	<0.01	0.08
1106-1	3.59	1.35	0.03	0.03	<0.01	0.08
1106-2	2.63	0.77	0.02	0.01	<0.01	0.04
1107-1	4.35	1.34	0.03	0.03	0.01	0.11
1107-2	1.83	0.36	0.03	0.02	<0.01	0.04
1109-1	3.08	0.70	0.01	0.03	<0.01	0.04
1111-1	2.76	0.67	0.03	0.02	<0.01	0.11
1111-2	3.20	0.95	0.03	0.02	<0.01	0.09
1116-1	4.39	1.11	0.04	0.03	<0.01	0.12
1116-2	4.00	1.11	0.08	0.01	<0.01	0.16
1119-1	2.43	0.53	0.03	0.02	0.01	0.05
1119-2	2.39	0.67	0.03	0.01	<0.01	0.09
1120-1	1.95	0.48	0.02	0.01	<0.01	0.04
1120-2	3.05	0.98	0.03	0.03	<0.01	0.08
1121-1	3.44	0.72	0.03	0.03	<0.01	0.15
1122-1	5.67	1.55	0.05	0.05	<0.01	0.13
1127-1	5.51	1.36	0.05	0.05	<0.01	0.17
1127-2	2.70	0.78	0.01	0.03	<0.01	0.09
1129-1	7.65	1.77	0.07	0.08	0.01	0.17
1129-2	6.11	1.14	0.05	0.05	<0.01	0.13
1130-1	7.17	1.55	0.04	0.04	0.01	0.21
1130-2	1.96	0.45	0.01	0.02	<0.01	0.02
1131-1	5.92	1.58	0.06	0.04	0.02	0.17
1132-1	6.32	1.37	0.04	0.05	<0.01	0.35
1134-1	8.79	2.99	0.16	0.03	0.01	0.41
1134-2	6.82	2.11	0.06	0.04	<0.01	0.25
1136-1	9.01	2.59	0.10	0.09	<0.01	0.31
1136-2	6.42	1.80	0.04	0.05	0.02	0.24
1136-3	3.34	0.98	0.04	0.02	<0.01	0.12
1139-1	2.44	0.65	0.03	0.04	0.01	0.07
2000-1	2.00	0.53	0.03	0.04	<0.01	0.05
2000-2	2.39	0.52	0.03	0.03	<0.01	0.08
2001-1	2.02	0.41	0.02	0.04	<0.01	0.04
2002-1	3.75	1.09	0.02	0.01	<0.01	0.12
2002-2	3.01	0.89	0.01	0.03	<0.01	0.07
110-1	2.60	0.84	0.04	0.01	<0.01	0.14
110-2	2.21	0.41	0.03	0.02	<0.01	0.05
110-3	1.41	0.29	0.02	0.02	<0.01	0.02
115-1	0.74	0.21	0.01	0.01	<0.01	0.02
116-1	0.58	0.18	0.01	0.01	<0.01	0.02
116-2	0.54	0.17	0.01	0.01	<0.01	0.01
116-3	2.17	0.78	0.03	0.04	<0.01	0.08
116-4	0.92	0.33	0.02	0.01	<0.01	0.04
116-5	1.66	0.52	0.05	0.04	<0.01	0.05
117-1	1.26	0.38	0.02	0.02	<0.01	0.03

SAMPLE NAME	WT% THM	WT% IL	WT% RUTILE	WT% LEUC	WT% MONA	WT% ZIRCON
117-2	3.87	1.07	0.07	0.04	<0.01	0.08
117-3	3.95	1.12	0.04	0.04	0.01	0.07
117-4	2.84	0.65	0.04	0.04	<0.01	0.05
C1-1	2.18	0.65	0.01	0.09	<0.01	0.09
C1-2	3.18	0.55	0.05	0.05	<0.01	0.09
C1-3	2.09	0.36	<0.01	0.06	<0.01	0.01
C1-4	1.95	0.31	0.03	0.05	<0.01	0.08
C2-1	4.12	1.12	0.05	0.04	<0.01	0.22
C2-2	1.80	0.35	0.02	0.04	<0.01	0.09
C2-3	2.65	0.55	0.03	0.09	<0.01	0.13
C2-4	1.41	0.35	0.02	0.06	<0.01	0.04
C3-1	3.99	0.43	0.07	0.04	<0.01	0.15
C3-2	4.21	0.88	0.05	0.02	<0.01	0.24
C3-3	3.54	0.69	0.06	0.04	<0.01	0.25
C3-4	3.36	1.01	0.06	0.03	<0.01	0.14
C4-1	2.65	0.46	0.04	0.03	<0.01	0.13
C4-2	2.40	0.35	0.04	0.03	<0.01	0.08
C4-3	2.66	0.49	0.02	0.04	<0.01	0.10
C5-1	2.03	0.60	0.03	0.04	<0.01	0.06
C5-2	2.91	0.35	0.05	0.06	<0.01	0.13
C5-3	3.51	0.39	0.06	0.02	<0.01	0.12
C5-4	3.31	0.36	0.05	0.05	<0.01	0.23
C6-1	4.38	0.90	0.07	0.06	<0.01	0.24
C6-2	2.55	0.44	0.04	0.03	<0.01	0.19
C6-3	5.78	0.51	0.12	0.07	<0.01	0.22
C7-1	3.14	0.62	0.02	0.00	<0.01	0.09
C7-2	1.45	0.48	0.01	0.03	<0.01	0.03
C7-3	2.35	0.58	0.01	0.03	<0.01	0.03
C8-1	3.45	1.05	0.04	0.02	<0.01	0.18
C8-2	6.75	0.72	0.08	0.07	<0.01	0.27
C8-3	3.65	0.33	0.07	0.02	0.00	0.13
C8-4	3.56	0.28	0.05	0.02	<0.01	0.13
C9-1	4.63	0.98	0.08	0.09	<0.01	0.17
C9-2	3.84	0.84	0.05	0.04	0.00	0.11
C9-3	3.16	0.65	0.06	0.04	<0.01	0.16
C10-1	3.22	0.85	0.06	0.03	<0.01	0.15
C10-2	4.07	0.40	0.06	0.03	<0.01	0.17
C10-3	4.98	0.47	0.08	0.07	0.00	0.32
C10-4	4.53	0.30	0.08	0.08	0.00	0.36
C11-1	1.88	0.33	0.02	0.05	<0.01	0.09
C11-2	1.81	0.28	0.04	0.06	<0.01	0.04
C11-3	3.53	0.53	0.02	0.02	<0.01	0.23
C11-4	3.08	0.61	0.04	0.02	<0.01	0.26
C12-1	5.62	0.87	0.03	0.07	<0.01	0.12
C12-2	5.32	0.51	0.08	0.04	<0.01	0.22
C12-3	9.12	1.35	0.11	0.11	0.00	0.67
C12-4	7.40	0.60	0.10	0.04	0.00	0.42
C13-1	3.21	0.49	0.06	0.07	<0.01	0.11
C13-2	2.64	0.30	0.04	0.08	<0.01	0.10
C13-3	1.73	0.22	0.04	0.02	<0.01	0.12
C14-1	4.47	0.42	0.06	0.03	<0.01	0.10
C14-2	1.99	0.13	0.03	0.01	0.00	0.11
C14-3	5.95	0.54	0.13	0.16	<0.01	0.27
C14-4	5.61	0.18	0.10	0.08	<0.01	0.25
C15-1	5.70	0.71	0.07	0.07	0.00	0.21
C15-2	6.57	0.48	0.09	0.09	0.00	0.22
C16-1	6.91	0.94	0.08	0.02	0.00	0.19
C16-2	5.36	0.18	0.09	0.02	<0.01	0.24
C17-1	3.80	0.59	0.06	0.08	<0.01	0.16
C17-2	4.26	0.35	0.06	0.03	<0.01	0.27
C17-3	4.03	0.21	0.09	0.02	<0.01	0.16
C17-4	5.27	0.36	0.11	0.05	0.00	0.16
C17-5	5.72	0.23	0.12	0.03	0.00	0.23
C18-1	2.92	0.31	0.02	0.05	<0.01	0.07
C18-2	3.50	0.31	0.04	0.05	<0.01	0.12
C19-1	4.06	0.54	0.08	0.04	<0.01	0.19
C19-2	2.05	0.28	0.03	0.01	<0.01	0.08
C19-3	2.08	0.37	0.02	0.04	<0.01	0.03
C20-1	1.29	0.34	0.02	0.05	<0.01	0.04
C20-2	1.75	0.41	0.02	0.12	<0.01	0.05
C20-3	0.97	0.18	0.02	0.02	<0.01	0.04
C20-4	1.93	0.42	0.03	0.07	0.00	0.11
C21-1	1.11	0.25	0.02	0.06	<0.01	0.08
C22-1	1.54	0.40	0.03	0.12	<0.01	0.06
C22-2	1.76	0.43	0.04	0.10	<0.01	0.07
C22-3	2.38	0.50	0.03	0.10	<0.01	0.08
C22-4	1.22	0.31	0.02	0.04	<0.01	0.03
C23-2	1.43	0.30	0.01	0.04	<0.01	0.06
C23-3	1.59	0.39	0.02	0.03	<0.01	0.06
C23-4	0.95	0.23	0.01	0.03	<0.01	0.03
C24-1	1.05	0.30	0.02	0.04	<0.01	0.03
C24-2	1.49	0.37	0.03	0.06	<0.01	0.04
C25-1	0.41	0.15	0.01	0.02	<0.01	0.03
C25-2	1.39	0.50	0.02	0.05	<0.01	0.06
C25-3	1.77	0.49	0.02	0.04	<0.01	0.04
C26-1	3.53	1.18	0.06	0.13	<0.01	0.15
C26-2	2.60	0.51	0.07	0.05	<0.01	0.17
C26-3	5.11	0.43	0.14	0.07	<0.01	0.29
C27-1	2.28	0.43	0.02	0.03	<0.01	0.10
C27-3	2.66	1.18	0.05	0.08	<0.01	0.10
C28-1	1.88	0.64	0.04	0.08	<0.01	0.07
C28-2	3.27	0.85	0.06	0.08	<0.01	0.23
C28-3	3.08	0.56	0.05	0.07	<0.01	0.16
C28-4	2.40	0.69	0.04	0.08	<0.01	0.12
C29-1	4.53	1.79	0.07	0.09	<0.01	0.27
C29-2	1.29	0.41	0.02	0.03	<0.01	0.06
C30-1	2.96	0.72	0.06	0.07	<0.01	0.15
C31-1	0.72	0.25	0.01	0.02	<0.01	0.03
C31-2	1.52	0.56	0.03	0.07	<0.01	0.09
C31-3	3.14	0.96	0.07	0.07	<0.01	0.16
C31-4	3.99	0.52	0.06	0.12	<0.01	0.21
C32-1	2.71	0.75	0.07	0.08	<0.01	0.13
C32-2	2.73	0.44	0.04	0.09	<0.01	0.14
C32-3	3.39	0.81	0.06	0.09	<0.01	0.26
C33-1	1.95	0.26	0.06	0.04	<0.01	0.11
C33-2	2.50	0.33	0.05	0.04	<0.01	0.17
C33-3	2.42	0.32	0.04	0.06	<0.01	0.15
C33-4	1.24	0.31	0.02	0.03	<0.01	0.07
C34-1	1.08	0.35	0.02	0.02	<0.01	0.03
C34-2	3.77	1.24	0.04	0.10	<0.01	0.17
C34-3	2.14	0.38	0.03	0.04	<0.01	0.09
C35-1	1.78	0.37	0.03	0.07	<0.01	0.11
C35-4	1.31	0.39	0.03	0.06	<0.01	0.08
C36-1	0.62	0.26	0.01	0.01	<0.01	0.03

SAMPLE NAME	WT% THM	WT% IL	WT% RUTILE	WT% LEUC	WT% MONA	WT% ZIRCON
C36-2	0.73	0.25	0.01	0.01	<0.01	0.03
C36-3	0.86	0.34	0.02	0.01	<0.01	0.06
C36-4	0.80	0.21	0.01	0.03	<0.01	0.04
C37-1	4.40	0.59	0.05	0.11	<0.01	0.25
C37-2	2.22	0.60	0.04	0.03	<0.01	0.08
C37-3	2.16	0.66	0.05	0.06	<0.01	0.08
C38-1	1.99	0.28	0.03	0.02	<0.01	0.10
C38-2	2.32	0.46	0.03	0.04	<0.01	0.07
C39-1	4.40	0.83	0.08	0.05	<0.01	0.24
C39-2	4.13	0.88	0.05	0.02	<0.01	0.14
C39-3	2.60	0.76	0.05	0.03	<0.01	0.08
C40-1	4.56	0.88	0.06	0.07	<0.01	0.20
C40-2	4.18	0.96	0.09	0.14	<0.01	0.19
C40-3	2.75	0.71	0.04	0.08	<0.01	0.12
C41-1	3.86	0.77	0.06	0.04	0.00	0.18
C41-2	1.83	0.38	0.04	0.05	<0.01	0.08
C41-3	2.65	0.68	0.05	0.07	<0.01	0.12
C42-1	3.56	1.23	0.06	0.10	<0.01	0.14
C42-2	4.35	1.37	0.08	0.09	<0.01	0.22
C42-3	*	*	*	*	*	*
C42-4	3.17	1.56	0.06	0.06	<0.01	0.21
C43-1	6.38	0.33	0.11	0.16	<0.01	0.17
C43-2	3.55	1.02	0.05	0.05	<0.01	0.13
C43-3	6.72	1.24	0.09	0.05	<0.01	0.27
C44-1	6.49	0.94	0.09	0.10	0.00	0.29
C44-2	3.50	0.97	0.04	0.02	<0.01	0.12
C44-3	1.74	0.42	0.02	0.04	<0.01	0.07
C45-1	3.01	0.40	0.04	0.08	0.00	0.14
C45-2	2.63	0.45	0.03	0.06	<0.01	0.07
C45-3	2.85	0.63	0.06	0.08	<0.01	0.16
C46-1	3.36	0.66	0.05	0.05	<0.01	0.11
C46-2	2.20	0.50	0.02	0.03	<0.01	0.05
C46-3	2.19	0.39	0.02	0.04	<0.01	0.06
C46-4	3.04	0.89	0.06	0.04	<0.01	0.14
C47-1	4.47	0.81	0.08	0.12	<0.01	0.13
C47-2	1.62	0.54	0.02	0.05	<0.01	0.07
C48-1	0.89	0.26	0.02	0.03	<0.01	0.03
C48-2	0.91	0.15	0.02	0.04	<0.01	0.02
C48-3	0.74	0.21	0.02	0.02	<0.01	0.03
C48-4	1.79	0.53	0.03	0.05	<0.01	0.06
C49-1	1.00	0.29	0.02	0.04	<0.01	0.03
C49-2	0.82	0.25	0.01	0.03	<0.01	0.03
C49-3	1.66	0.42	0.03	0.02	<0.01	0.04
C49-4	4.14	0.90	0.06	0.06	<0.01	0.14
C50-1	2.66	0.54	0.02	0.04	<0.01	0.10
WB063-1	2.07	0.81	0.04	0.03	<0.01	0.09
WB063-2	2.13	0.87	0.01	0.09	<0.01	0.11
WB063-3	2.53	0.90	0.03	0.14	<0.01	0.13
STA054	5.12	1.69	0.13	0.14	<0.01	0.25
STA055	0.50	0.12	0.01	0.01	<0.01	0.01
STA056	0.83	0.26	0.02	0.01	<0.01	0.02
STA093	5.64	1.34	0.07	0.11	<0.01	0.23
STA094	7.45	1.70	0.12	0.10	<0.01	0.24
51-1	0.79	0.17	0.01	0.04	<0.01	0.02
51-2	0.09	0.03	<0.01	0.01	<0.01	<0.01
51-3	0.08	0.02	<0.01	<0.01	<0.01	<0.01
51-4	9.99	4.28	0.23	0.30	0.01	0.40
AVG	3.27	0.78	0.04	0.05	0.00	0.12
STD	2.24	0.68	0.03	0.04	0.01	0.10
MAX	14.66	5.90	0.26	0.30	0.08	0.72
MIN	0.08	0.02	0.00	0.00	0.00	0.00
GARNAR'S VALUES	5.0	2.25	0.10	0.25	0.05	0.25

Grab samples 51-1, 51-2, 51-3, and 51-4 were taken from North Carolina barrier island beaches.

APPENDIX VI

SAMPLES SORTED BY DECREASING ABUNDANCE OF SELECTED MINERALS

Samples are sorted by decreasing abundance (with respect to the total sample) of selected minerals. Only those samples with values equal to or greater than Garnar's values (ilmenite, 2.25%; leucoxene, 0.25%; rutile, 0.1%; monazite, 0.05%; zircon, 0.25%; based on THM = 5%) are listed.

sample	% ILMENITE
85	5.90
51-4	4.28
54	4.25
59	3.85
33	3.01
1134-1	2.99
48	2.89
39	2.89
1136-1	2.59
98	2.59
35	2.53
42	2.37
40	2.33
32	2.26

sample	% LEUCOXENE
51-4	0.30
4	0.28
41	0.26

sample	% RUTILE
85	0.26
51-4	0.23
59	0.17
1134-1	0.16
54	0.16
H01-3	0.15
C26-3	0.14
4	0.13
STA054	0.13
C14-3	0.13
6-3	0.12
C17-5	0.12
STA094	0.12
56	0.11
C17-4	0.11
C43-1	0.11
12-3	0.11
98	0.11
1136-1	0.10
C12-4	0.10
C14-4	0.10
87	0.10
66	0.10

sample	% MONAZITE
H01-3	0.08
36	0.07
35	0.07
1091-1	0.06
54	0.05
14	0.05

sample	% ZIRCON
54	0.72
C12-3	0.67
42	0.56
59	0.47
H01-3	0.42
C12-4	0.42
85	0.41
1134-1	0.41
51-4	0.40
C10-4	0.36
1132-1	0.35
48	0.34
5	0.32
C10-3	0.32
15	0.32
1136-1	0.31
4	0.31
56	0.30
C44-1	0.29
C26-3	0.29
C8-2	0.27
C17-2	0.27
C29-1	0.27
C43-3	0.27
C14-3	0.27
C11-4	0.26
57	0.26
41	0.26
12	0.26
C32-3	0.26
C14-4	0.25
46	0.25
C3-3	0.25
C37-1	0.25
STA054	0.25
1134-2	0.25

APPENDIX VII

CORE DESCRIPTIONS

The following 39 cores were provided by A.E. Grosz of the U.S. Geological Survey. They were taken by the U.S. Army Corps of Engineers Coastal Engineering Research Center (CERC) and used by Meisburger, 1972. They are arranged by the CERC numbers, so a cross-reference to the USGS-assigned number is provided. Colors are from the Munsell Soil Color charts.

USGS NO.	CERC NO.	USGS NO.	CERC NO.
110	70	1111	12
115	59	1116	9
116	58	1119	54
117	D73	1120	39
1090	5	1121	40
1091	43	1122	20
1092	33	1127	29
1093	4	1129	25
1094	46	1130	26
1095	47	1131	19
1096	48	1132	28
1097	49	1134	56
1098	34	1136	41
1099	35	1139	16
1100	30	2000	2
1103	36A	2001	3
1106	53	2002	31
1107	52	2003	58
1109	11B	2004	60
2005	61		

Thickness (meters)

USGS NUMBER 2000 (CERC #2)

Silt, gray (5Y 6/1), clayey; some sand, very-fine-grained; oyster shell at top of core 6.30

USGS NUMBER 2001 (CERC #3)

NOTE: Empty plastic liner labeled 3A.....2.00

Silt, light olive gray (5Y 6/2); sandy, very-fine-grained; massively bedded; scattered shell fragments at top and bottom of core; sand, fine-to medium-grained, laminae throughout core (1-3cm thick);labeled 3B.....1.34

USGS NUMBER 1093 (CERC #4)

Silt, light-olive-gray (5Y 6/2); clayey; sandy, fine-grained; massively bedded.....3.01

Thickness (meters)

USGS NUMBER 1090 (CERC #5)

Sand, grayish-brown (2.5Y 5/2), fine-grained; silty; massively bedded; shell fragments common; many shell fragment at approxmately 0.95m 2.45

Sand, grayish-brown (2.5Y 5/2), fine- to medium-grained; massively bedded; grading into sand, medium- to coarse-grained; some gravel; massively bedded.....1.09

USGS NUMBER 1116 (CERC #9)

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; silty; massively bedded; *Ensis* fragments common.....2.50

Sand, coarse-grained; and gravel; and shell fragments; including coral (4cm long) 0.25

Sand, light -brownish-gray (2.5Y 6/2), fine-grained; silty; massively bedded; *Ensis* fragments common.....1.35

USGS NUMBER 1109 (CERC #11B)

NOTE: Top of section B, not the top of the core

Sand, light-olive-gray (5Y 6/2), fine-grained, micaceous; massively bedded; shell fragments common.....2.38

USGS NUMBER 1111 (CERC #12)

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; massively bedded; scattered shell fragments common ...2.00

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; massively bedded; shell fragments common; a small sandy mud pod; from 0.8 to 1.10m in this interval is a higher concentration of shell fragments 1.34

USGS NUMBER 1139 (CERC #16)

Sand, light-gray (2.5Y 7/2), fine- to medium-grained; massively bedded; with small shell fragments (a few mm.).....0.45

Sand, light-brownish-gray (2.5Y 6/2), very-fine- to fine-grained; massively bedded 1.39

USGS 1131 (CERC #19)

Sand, light-brownish-gray (2.5Y 6/2),fine-grained; massively bedded; abundant shell fragments in this interval at 0.3 to 0.65 m.....0.98

Thickness (meters)

Sand, pale-yellow (2.5Y 7/4), fine-grained; massively bedded; in this interval at 0.27m Callianassa? tubes (up to 5cm) 0.84

USGS NUMBER 1122 (CERC #20)

Sand, light-brownish-gray (2.5Y 6/2) fine-grained; massively bedded; abundant shell fragments; shell layer-(.5-.65m) shells up to 6cm.....0.65

Sand, light-olive-gray (5Y 6/2), fine-grained; massively bedded; shell fragments common.....0.80

USGS NUMBER 1129 (CERC #25)

Sand, light-brownish-gray (2.5Y 6/2), fine grained; massively bedded; sparse shell fragments 1.93

Sand, coarse-grained; with shell fragments.....0.18

Sand, grayish-brown (2.5Y 5/2), fine-grained; massively bedded.....0.24

Clay and silt, light-yellow-brown (2.5Y 6/4).....0.12

Sand, grayish-brown (2.5Y 5/2) fine-grained; massively bedded.....0.43

USGS NUMBER 1130 (CERC #26)

Sand, light-olive-gray (5Y 6/2), micaceous, fine-grained; massively bedded; with shell fragments.....1.45

Silt, light-brownish-gray (2.5Y 6/2), slightly clayey; lenses of sand, fine-grained.....1.08

USGS NUMBER 1132 (CERC #28)

Sand, light-olive-gray (5Y 6/2), fine- to medium-grained; with shell fragments; *Ensis* clam at top; oyster shell at 0.45m 1.64

USGS 1127 (CERC #29)(Cape Charles)

Sand, light-olive-gray (5Y 6/2), micaceous, fine-grained 2.78

USGS NUMBER 1100 (CERC #30)

Sand, light-olive-gray (5Y 6/2), micaceous, coarse- to fine-grained.....0.53

Thickness (meters)

Sand, coarse-grained; and gravel; iron stained 0.07

Sand, micaceous, fine- to medium-grained; shell fragments 0.10

Sand and silt and clay, olive gray (5Y 5/2), massively bedded 0.83

Silt, light-olive-gray (5Y 6/2) sandy, fine-grained; massively bedded 0.70

Sand, light-olive-gray (5Y 6/2), medium- to coarse-grained; and gravel 0.27

USGS NUMBER 2002 (CERC #31)

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; massively bedded; shell layer at 0.26-0.30m, shells up to 3cm diameter 0.30

Sand, gray (5Y 6/1), fine- to very-fine-grained; shell fragments common; *Ensis* fragment in this interval at 0.63m 1.47

Silt and sand, gray (5Y 6/1), very-fine-grained; massively bedded shell fragments rare 1.62

USGS NUMBER 1092 (CERC #33)(#33a,33b Cape Henry 8/21/68)

Sand, light-yellowish-brown (2.5Y 6/4), coarse-grained; and gravel; massively bedded; local concentrations of clay 0.75

Sand and gravel, olive-yellow (2.5Y 6/6), coarse-grained; (increased amounts of gravel).....1.05

Sand, light-yellowish-brown (2.5Y 6/4), medium- to fine-grained; some coarse-grained sand; massively bedded 0.56

Sand, pale-yellow (2.5Y 7/4), medium- to coarse-grained; and gravel massively bedded 1.49

Sand, light-gray (2.5Y 7/2), fine-grained; and gravel; plant roots in this interval at 0-0.15m 0.45

Sand, pale-yellow (2.5Y 7/4), medium- to coarse-grained; and gravel massively bedded 0.48

NOTE: Bottom of last core liner is threaded

Thickness (meters)

USGS NUMBER 1098 (CERC #34)

Sand, light-yellowish-brown (2.5Y 6/4), coarse-grained; and gravel; massively bedded; high concentration of pebbles at .45-.60m 0.70

Sand, yellowish-brown (10YR 5/8), coarse-grained; and gravel; massively bedded; high concentration of gravel in this interval at .10-.25m and again at .65-.95m 1.21

Sand, yellowish-brown (10YR 5/8), coarse-grained; and gravel; and pebbles; iron staining; micaceous; grades into below 0.68

Sand, light-olive-gray (5Y 6/2), medium-grained; grades into below 0.16

Silt, light-yellowish-brown (10YR 6/4); sandy, fine-grained; clayey; micaceous 1.06

Silt, light-yellowish-brown (10YR 6/4); clayey; sandy, fine grained; shell fragments; micaceous 1.89

USGS NUMBER 1099 (CERC #35)

Sand, light-brownish-gray (2.5Y 6/2), fine- to medium-grained; shell fragments; massively bedded; grades into below 0.50

Sand, fine-grained; muddy; micaceous; grades into below 1.55

Sand, fine- to medium-grained; muddy; scattered gravel at bottom of interval 0.52

Sand, fine- to medium-grained; muddy; scattered shell fragments.....0.38

Sand, pale yellow (5Y 7/3), coarse- to medium-grained; gravelly; micaceous 0.25

Sand, light-yellowish-brown (2.5Y 6/4), coarse- to medium-grained gravelly; micaceous 0.25

Sand, light-brownish-gray (2.5Y 6/2), coarse- to medium-grained; gravelly; micaceous.....0.70

Sand, light-yellowish-brown (2.5Y 6/4), coarse-grained; pebbly; gravelly; iron stained 0.41

USGS NUMBER 1103 (CERC #36A)

Shell fragments; silt; and clay; light-olive-gray (5Y 6/2); core highly disturbed.....0.25

Thickness (meters)

Sand, olive-gray (5Y 5/2), fine-grained; silt; and clay; shell fragments; core highly disturbed 0.95

Sand, olive-gray (5Y 5/2), coarse-grained; silt; and gravel; few shell fragments; core highly disturbed 0.60

Sand, gray (5Y 5/1), fine- to medium-grained; gravel; small amount of silt and clay; scattered shell fragments 1.05

Sand, gray (5Y 5/1), fine- to very-fine-grained; sparse shell fragments 1.80

Sand, gray (5Y 5/1), fine- and medium-grained; gravel 0.35

USGS NUMBER 1120 (CERC #39)

Sand, light-gray (2.5Y 7/2), medium- to coarse-grained; abundant shell fragments (up to 2cm) including *Ensis*, various other bivalves, and a sand dollar fragment; massively bedded 0.62

Sand, light-olive-gray (5Y 6/2), medium- to fine-grained; massively bedded 0.70

Sand, light-gray (2.5Y 7/2), medium- to coarse-grained; abundant shell fragments, some large (up to 6cm); massively bedded 0.18

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; massively bedded 0.10

Sand, light-brownish-gray (2.5Y 6/2), fine- to very -fine-grained, massively bedded 1.75

USGS NUMBER 1121 (CERC #40)

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous; massively bedded; widely scattered shells 2.36

USGS NUMBER 1136 (CERC #41)

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous; massively bedded; widely scattered shells 1.50

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous; massively bedded; shelly layer in this interval at 1.02-1.08m 3.15

Clay, silty 0.20

NOTE: Iron stain at bottom of core due to rusted core-catcher

Thickness (meters)

USGS NUMBER 1091 (CERC #43)

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; silty; micaceous; massively bedded 4.70

USGS NUMBER 1094 (CERC #46) CAPE HENRY

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous massively bedded; shell fragments rare; well-formed worm tubes at 0.25m.; some unidentified fragments, coal? 1.58

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous; massively bedded; rare shell fragments 0.91

Clay, light-olive-gray (5Y 6/2); silty; massively bedded; iron staining in the surface along the core.....0.88

USGS NUMBER 1095 (CERC #47) CAPE HENRY

Sand, light-olive-gray (5Y 6/2); silty; massively bedded; shell fragments rare; big piece of coal this interval at 0.25m 1.61

Sand, light-yellowish-brown (2.5Y 6/4), fine- to very-fine-grained; silty; massively bedded; iron stained; coarse quartz grains rare.....0.44

Sand, light-gray (5Y 7/2), (gray color), fine-grained; silty; clay; massively bedded 0.15

Sand, pale-yellow (2.5Y 7/3), mixture of fine-, medium- and coarse-grained; (poor sorting).....1.08

USGS NUMBER 1096 (CERC #48)

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; silty; micaceous; massively bedded; worm tubes in the surface (10cm); some coal fragments in the first 20 cm; layer of shell fragments this interval at 1.50-1.55m ...1.80

Clay, light-gray (5Y 7/1); silty; with some laminations 0.55

Sand, light-olive-gray (5Y 6/2), fine-, medium-, and coarse-grained; poorly sorted.....0.55

Cobbles (6x3 cm); gravel; coarse sand; poorly sorted 0.17

Silt, olive-yellow (2.5Y 6/6); sand; with clay; iron-colored 1.68

Thickness (meters)

USGS NUMBER 1097 (CERC #49)

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; massively bedded; few scattered shell fragments; grading to sand, medium-grained; micaceous; massively bedded; grading to sand, medium- with some coarse-grained; micaceous; massively bedded; grading to sand, pale yellow (2.5Y 7/4), medium- to coarse-grained; micaceous massively bedded 2.78

Sand, coarse-grained; and gravel up to 2cm 0.07

Silt, brownish-yellow (10YR 6/6), fine-grained sand, and silty, fine- grained sand; iron stained; clam shells common up to 6 or more cm partially dissolved, casts and molds; micaceous; massively bedded; grades to below 1.65

Sand, yellowish-brown (10YR 5/4), fine-grained; silty; shells and shell fragments (0.5 cm to several cm); massively bedded 0.76

USGS NUMBER 1107 (CERC #52)

Sand, pale-yellow (5Y 7/3), medium-grained; micaceous; shell fragments; massively bedded 0.15

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; massively bedded shell fragments; grading into below 0.85

Sand, pale-yellow (5Y 7/3), medium-grained; micaceous; scattered shell fragments; massively bedded; grading into below 0.40

Sand, light-olive-gray (5Y 6/2), fine- with some medium-grained; scattered shell fragments; massively bedded; micaceous 1.91

USGS NUMBER 1106 (CERC #53)

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; scattered shell fragments including *Ensis*; massively bedded 2.96

USGS NUMBER 1119 (CERC #54)

Sand, light-olive-gray (5Y 6/2), medium-grained; micaceous; scattered shell fragments; massively bedded; grading into below 0.70

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; scattered shell fragments; concentrated shell fragments up to 1.5cm and some gravel in this interval at 0.72-0.82m; massively bedded; grades to below 2.70

Thickness (meters)

Sand, medium-grained; micaceous; scattered shell fragments; massively bedded; grading into below 0.50

Sand, medium- to fine-grained; micaceous; scattered shell fragments; massively bedded 0.28

USGS NUMBER 1134 (CERC #56)

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; widely scattered shell fragments; massively bedded; medium- to fine- grained sand this interval at 0.25-0.35m 3.50

USGS NUMBER 2003 (CERC #58)

Sand, light-olive-gray (5Y 6/2), fine-grained; micaceous; scattered shell fragments; massively bedded 0.25

Sand, light-gray (2.5Y 7/2), coarse-grained; shelly; and gravel; (shells to 6 cm) including sand dollar; massively bedded 0.25

Sand, light-gray (2.5Y 7/2), medium- to coarse-grained; abundant shell fragments (somewhat smaller); massively bedded; grading into below 0.80

Sand, light-gray (2.5Y 7/2), coarse-grained; with gravel; abundant shell fragments (to 6cm); gravel is iron stained; massively bedded 0.50

Silt, light-olive-gray (5Y 6/2); sandy, fine-grained; possibly Pliocene (Yorktown?) in age; massively bedded 0.21

Silt, light-brownish-gray (2.5Y 6/2); slightly clayey; some sand, fine-grained; small amount of gravel; massively bedded 0.39

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; silty; massively bedded; grading into below 0.85

Sand, fine-grained; micaceous; massively bedded; grading into below 0.13

Sand, light-brownish-gray (2.5Y 6/2), medium-grained; massively bedded 0.33

USGS NUMBER 2004 (CERC #60)

Silt, pale-brown (10YR 6/3); clayey; massively bedded; grading into below 0.60

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; silty; massively bedded; grading into below 0.25

Thickness (meters)

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; micaceous; massively bedded; grading into below 0.80

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; silty; massively bedded; grading into below 0.65

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; massively bedded 0.17

USGS NUMBER 2005 (CERC #61)

Sand, light-gray (5Y 7/2), medium-grained; rare shell fragments; massively bedded 1.40

Sand, light-gray (5Y 7/2), fine- to medium-grained; abundant shell fragments; massively bedded; increased amount of shell fragments in this interval at 0.8-0.93m 0.93

USGS NUMBER 116 (CERC #58 and #D58) Delmarva sand

Sand, pale-yellow (5Y 7/3), fine- to medium-grained; micaceous; shell fragments 0.55

Sand, pale-yellow (2.5Y 7/4), coarse -grained; and gravel; shelly 0.30

Clay, gray (5Y 5/1); silty; massively bedded; scattered shell fragments (well-preserved, mostly bivalves, some gastropods and sand dollars up to 1-2cm) 2.76

Sand, light-olive-gray (5Y 6/2), fine- to very-fine-grained; micaceous; massively bedded; scattered shell fragments (clam and oyster shells to 2cm); numerous shell fragments in this interval at 1.16-1.32m; plant roots at bottom of core - possibly modern contamination 1.90

(CERC #D58B) Note: No markings to show top or bottom of core.

Sand, light-gray (5Y 7/2), fine- to medium-sand; massively bedded; shell fragments 0.80

Sand, light-olive-gray (5Y 6/2), fine-grained matrix with medium- to coarse-grains; numerous shell fragments (to 2cm) 0.20

Sand, light-gray (5Y 7/2), fine- to medium-grained, coarsening toward bottom; shell fragments rare; massively bedded 0.76

Thickness (meters)

USGS NUMBER 116-5 D58 A 2/2

NOTE: Core was broken. Most of the material was absent.

Sand, fine-grained; micaceous; same sand as the other two sections 0.94

USGS NUMBER 117 (CERC #D73)

Sand, pale-olive (5Y 6/3), medium- to coarse-grained; gravel; shells 0.30

Sand, light-olive-gray (5Y 6/2), medium-grained; micaceous; scattered shell fragments; massively bedded; grading into below 0.30

Sand, fine-grained; micaceous; massively bedded 0.60

Mud, and sand,fine- to coarse-grained; and gravel, gray (5Y 5/1); abundant shell fragments 0.95

Sand, light-olive-gray (5Y 6/2); fine- to medium-grained; scattered shell fragments 0.75

Sand, light-olive-gray (5Y 6/2); medium-grained; micaceous; abundant shell fragments; massively bedded 0.65

Sand, fine-grained; micaceous; abundant shell fragments; massively bedded.....0.15

Sand, medium-grained; micaceous; abundant shell fragments; massively bedded.....0.25

Sand, coarse-grained; and gravel; poorly sorted shells 0.10

Sand, pale-yellow (5Y 7/3), fine- to medium-grained; silty; micaceous; massively bedded; shell fragments, well-preserved gastropods 0.75

Sand, gray (5Y 6/1), medium grained; abundant shell fragments; scattered quartz gravel; massively bedded ...1.05

USGS NUMBER 110 (CERC #70)

Silt, pale-yellow (5Y 7/3); clayey; massively bedded 0.70

Sand, pale-yellow (5Y 6/3), very-fine-grained; micaceous; massively bedded.....1.65

Sand, gray (5Y 6/1), very-fine-grained; silty; micaceous; massively bedded.....0.95

Silt, grayish-brown (2.5Y 5/2); sandy, very-fine-grained; shelly 0.55

Silt, clayey 0.15

Thickness (meters)

Sand, very-fine-grained; silty; micaceous 0.20

Silt, clayey.....0.20

Silt, light-brownish-gray (2.5Y 6/2); sandy, fine-grained; shelly; clayey silt layers in this interval at 0.30-0.35m and 0.48-0.51m 0.60

Silt; clayey; shelly.....0.32

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NOTE: possible missing core section listed below

Silt, coarse-grained 0.05

Silt, light-olive-gray (5Y 6/2); clayey; shell fragments rare (a few mm); massively bedded 3.30

Silt, gray (5Y 6/1); clayey; shell fragments rare (up to 2cm); massively bedded.....1.80

The following 25 cores were acquired during the summer of 1986.

CORE H01

Sand, light-brownish-gray (2.5Y 6/2), fine- to medium-grained; massive; shell fragments up to 1.5cm; oyster shell fragment 2cm; *Spisula*? 1.5cm 1.80

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; slightly silty; massive; shell fragments; in this interval shell fragments up to 1.5cm beginning at 1.20m; well preserved shell *Spisula*? 3cm at 1.65m; gastropods 1cm long below 1.70m 1.96

CORE H02

Sand, coarse- to medium-grained; with clay balls; shells-oysters, clam, *Ensis* - up to 5.5cm 0.17

Sand, fine- to very-fine-grained; massive; grading into below 0.11

Sand, coarse-grained; massive; shell fragments up to 1cm 0.14

Sand, fine- to very-fine-grained; massive 0.44

Silt, (5Y 2/1), clayey; small amount of very-fine-sand; massive; interspersed with clayey, silty, very-fine-grained sand this interval at 0.89m 2.96

Thickness (meters)

CORE H03

Sand, fine- to very-fine-grained; massive; shell fragments up to 1-2mm grading into below 0.22

Sand, coarse- to fine-grained; massive; shell fragments up to 2cm; well-preserved clams, *Ensis* ; grading into below 0.18

Sand, fine- to very-fine-grained; massive; grading into below 0.13

Sand, coarse-grained; massive; shell fragments up to 1.5cm; grading into below 0.09

Sand, medium- grained; massive; shell fragments several mm; grading into below 0.08

Sand, fine- to coarse-grained; shell fragments several mm; grading into below.....0.08

Sand, fine- to very-fine-grained; massive; micaceous.....0.51

CORE H04

Sand, olive-gray (5Y 4/2), fine- to very-fine-grained; massive 1.09

Clay, plastic; massive; very wet.....0.09

Sand, very-fine-grained; silty; massive 0.15

Clay, plastic; massive.....0.24

Sand, olive-gray (5Y 4/2), fine- to very-fine-grained; silty; massive; in this interval: shell fragments up to .8cm some well-preserved at 1.12-1.16m; abundant shell fragments up to 1.5cm at 1.37-1.57m 2.08

Shelly layer shell up to 1cm.....0.05

Clay, dark-gray (5Y 4/1), silty; with stringers of silty fine- to very-fine-grained sand.....0.41

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; silty; micaceous 0.30

CORE H05

Sand, olive-gray (5Y 4/2), fine- to very-fine-grained; massive; micaceous; locally slightly silty, fine- to very-fine-grained sand; in this interval: shell fragments in upper 0.75m (up to 6cm long); and layer of medium- to fine-grained sand, abundant shell fragments up to .5cm (clams, *Ensis*, oyster shell 6cm long; color changes several time throughout core as follows: very-dark-gray (5Y 3/1) at

Thickness (meters)

0.16m; olive-gray (5Y 5/2) at 0.39m, dark-gray (5Y 4/1) at 0.72m 1.85

CORE H06

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; massive; scattered shell fragments up to 3cm 0.72

Oyster shell and clam shell fragments up to 7cm long.....0.10

Silt, clayey; slightly sandy; massive; slightly plastic; 3cm long bone? fragment this interval at 0.67m 0.84

Sand, very-dark-gray (5Y 3/1), fine-grained; silty; clayey; micaceous; massive; grading into slightly muddy fine-grained sand 1.46

Sand, very-dark-gray (5Y 3/1), fine-grained; muddy; micaceous; massive; with clay pods interspersed 1.52

Silt, very-dark-gray (5Y 3/1), clayey; sandy; micaceous; massive; slightly plastic; grading to clayey, silty, fine-grained sand; with sparse clay pods 1cm 1.40

CORE H07

Sand, very-dark-gray (5Y 3/1), fine-grained; massive; scattered shell fragments of several mm 0.48

Sand, fine- to course-grained; poorly sorted; abundant shell fragments of several mm; some well-preserved oyster, scallop, and clam shells up to 5cm (which continue into mud layer, abundant to 0.12m depth); nonhomogenous color this interval at 0.00-0.05m 0.12

Clay, dark-olive-gray (5Y 3/2), silty; plastic; with pods of muddy fine-grained sand; micaceous; color changes to very-dark-gray (5Y 3/1) 1.17

Mud, fine-grained sand; plastic; abundant shell fragments 3-4cm; well-preserved oyster shell 7cm 0.05

Clay, silty; fine-grained sand; plastic; scattered shell fragments 0.28

Shell layer; plastic fine-grained sand, silty clay; well-preserved oyster shell (7cm); abundant oyster shells; grading into below 0.10

Clay, silty; micaceous; plastic; some sandy pods, scattered shell fragments; grading into below 0.02

Sand, dark-gray (5Y 4/1)to olive-gray (5Y 4/2), fine- to very-fine-grained; massive; micaceous; intercalations of silty clay this interval at 0.63-0.76m 1.22

Clay, silty; with firm clay balls 0.10

CORE H08

Sand, grayish-brown (2.5Y 5/2), fine-grained; micaceous; massive; shell fragments 0.17

Sand, medium- to fine-grained; shell fragments up to 0.5cm 0.08

Sand, dark-gray (2.5Y 4/0), fine-grained; micaceous; massive; shell fragments up to 4cm; in this interval: oyster shell fragment 4cm at 0.75m; coarse-grained sand with shell fragments up to 2cm at 0.93-0.97m; 2.5 cm scallop shell; grading into below 1.09

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; silty; micaceous; massive; several interspersed discontinuous clay pods 0.5cm 1.11

Shell hash.....0.05

Sand, fine- to very-fine-grained; silty.....0.07

Silt, olive (5Y 5/4), fine-grained sand; with clay pods 0.21

CORE H09

Sand, fine- to very-fine-grained; micaceous 0.28

Sand, dark-reddish-gray (10YR 4/1), fine-grained; sparse shell fragments up to 4cm 1.03

CORE H10

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; massive; scattered shell fragments up to 1mm; possible plant stems this interval at 0.55m 0.95

Sand, coarse-grained; shell fragments up to 6cm 0.08

Sand, dark-gray (5Y 4/1), fine-grained 0.04

Sand, fine-grained; with silty clay pods (highly indurated); grading into below 0.16

Sand, olive (5Y 4/3), fine- to very-fine-grained; micaceous; massive; somewhat silty??; color changes to olive-gray (5Y 5/2) and olive (5Y 5/3); grading into below 1.61

Silt, clayey; grading into below.....0.18

Clay, silty; grading into below.....0.15

Thickness (meters)

Silt, fine-grained sand; slightly micaceous 0.22

CORE H11

Sand, fine- to very- fine-grained; micaceous; massive; scattered *Ensis* fragments at top, other shell fragments throughout; in this interval: 4cm oyster shell fragment at 0.41m; poorly sorted coarse-grained sand, abundant shell fragments well-preserved clams, etc. up to 3cm at 0.33-0.36m, and 0.40-0.45m 1.89

CORE H12

Sand, medium- to coarse-grained; abundant shell fragments 0.19

Sand, dark-gray (5Y 4/1) to very-dark-gray (5Y 3/1), medium-grained; abundant shell fragments up to 1cm; grading into below 0.81

Sand, very-fine- to fine-grained; micaceous; shell fragments 0.23

Sand, fine-grained; rare shell fragments up to 2cm; shell layer, well-preserved 2cm clam this interval; at 0.52m color changes dark-gray (5Y 4/1) to very-dark-gray (5Y 3/1) 1.05

CORE H13

Sand, coarse-grained; poorly sorted; abundant shell fragments up to 3.5cm, *Ensis*, oyster and clam fragments; grading into below 0.27

Sand, light-brownish-gray (2.5Y 6/2), fine-grained; abundant shell fragments up to 5cm (oyster shell) 0.28

Sand, dark-gray (10YR 4/1), fine-grained; micaceous; sparse shell fragments 1.49

CORE H14

Sand, coarse- to medium-grained; poorly sorted; with oyster shells, well-preserved gastropod (5cm) 0.30

Clay, very-dark-gray (5Y 3/1), silty; plastic; intercalated with layers of fine-grained, micaceous sand; sand 1-2cm thick 0.28

Sand, dark-gray (5Y 4/1), fine-grained; massive; micaceous 0.59

Thickness (meters)

Clay, silty; plastic; intercalated with layers of fine-grained, micaceous sand (up to 9cm thick); piece of wood removed for dating this interval at 0.11m 0.31

Clay, very-dark-gray (5Y 3/1), silty; plastic; intercalated with fine-grained micaceous fine sand; well-preserved oyster shell 7.5cm this interval at 0.35m 0.75

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous; abundant shell fragments; in this interval: Ensis at 0.05m; well-preserved *Ensis*, oyster shells, clam shells at 0.28m; fewer shell fragments at bottom of core 0.67

CORE H15 — One-foot length of core, not processed.

CORE B01

Sand, olive-gray (5Y 5/2), fine- to very-fine-grained; massive; locally very micaceous; vertical stringer of very-dark- gray (2.5Y 3/0) sand at 0.46-0.85m; color changes to gray (5Y 5/1) and then to very-dark-gray (2.5Y 3/0); well-preserved clam shell 1cm at 2.33m; few shell fragments about 1mm from 2.33m and down 2.69

CORE B02

Sand, olive-gray (5Y 5/2), fine- to very-fine-grained; micaceous; massive; scattered shell fragments about 1mm; color changes throughout as follows: very-dark-gray (5Y 3/1) at 0.51m; olive-gray (5Y 5/2) at 1.37m; dark-gray (5Y 4/1) at 1.62m 2.68

CORE B03

Sand, olive-gray (5Y 5/2), fine- to very-fine-grained; micaceous; massive; scattered shell fragments, well-preserved articulated *Ensis* 2cm; color changes throughout as follows: very-dark-gray (5Y 3/1) at 0.55m; olive-gray (5Y 5/2) then very-dark-gray (5Y 3/1); 1.5cm long piece of wood at 1.83m; gastropod 0.7cm long at 2.20m...2.44

Sand, very-dark-gray (2.5Y 3/0), fine- to very-fine-grained; micaceous; massive; scattered shell fragments 1.13

CORE B04

Sand, olive-gray (5Y 5/2), fine- to very-fine-grained; micaceous; massive; scattered shell fragments up to 2cm long, *Ensis*, clam; clayey silt pod at 0.88-0.94m; color changes to dark gray (5Y 4/1) at 1.00m 1.89

Thickness (meters)

CORE B05

Sand, very-dark-gray (2.5Y 3/0), fine- to very-fine-grained; micaceous; massive; sparse shell fragments of 1- 2mm 2.00

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; massive; sparse shell fragments of 1-2mm 1.07

CORE V1

Sand, fine-grained; with clay pods....0.49

Sand, medium-grained; with clay pods....0.83

Sand, coarse-grained....0.17

Sand, coarse-grained; coarsening toward bottom....1.51

Sand, coarse-grained; and gravel; iron oxide stain....1.52

Sand, medium- and fine-grained....0.48

Sand, coarse-grained; and gravel....0.40

Sand, medium-grained; heavy iron-oxide staining this interval at 0.06-0.14m....0.60

CORE V2

Sand, fine-grained; small amount of mud....1.18

Sand, medium-grained; shell fragment 3-4cm this interval at 0.21m....0.25

Sand, fine- to medium-grained; laminations of silt and clay 1.11

Mud layer....0.03

Sand, fine-grained....0.17

Mud, compact; with rock fragments (5cm)....0.16

Mud, compact; with scattered shells....0.31

Shell layer with mud....0.06

Sand, mixed; plastic mud....0.58

CORE V3

Sand, olive-gray (5y 4/2), coarse- to medium-grained; rare shell fragments up to 1.5cm....0.39

Thickness (meters)

Sand, dark-olive-gray (5Y 3/2), fine-grained; silty; massive; some mud balls near bottom; rare gravel; grading into below....0.91

Sand, dark-olive-gray (5Y 3/2), medium- to coarse-grained; rare shell fragments (oyster shells to 5cm); some mud near bottom....0.60

Clay, greenish-gray (5GY 5/1), plastic; interrupted by layers of coarse sand 2cm thick this interval at 0.32-0.70m; some iron staining....0.90

Sand, greenish-gray (5GY 5/1), coarse-grained; and mud 0.24

Sand, olive-gray (5Y 5/2), coarse-grained....0.20

Clay, greenish-gray (5GY 5/1), plastic....0.13

Sand, light-olive-brown (2.6Y 5/6), coarse-grained; and gravel massive; iron stained (in part)....0.85

Clay, olive-gray (5Y 4/2), plastic....0.13

CORE V4

Sand, fine- to medium-grained; rare shell fragment; whole skate or ray egg case....0.40

Sand, fine-grained; interbedded with medium- to coarse-grained sand and large clay pods; 2.5cm clam shell and other shell fragments....0.50

Sand, fine-grained; bottom 10cm includes some coarse-grained sand....0.35

Sand, medium- to fine-grained; small clay pods; grading into below....0.09

Sand, coarse-grained....0.29

Sand, medium- to coarse-grained; and gravel....0.22

Sand, medium-grained....0.09

Sand, medium-grained; occasional pebbles up to 2cm; becoming coarser and more pebbly....0.53

Sand, medium-grained....0.18

Sand, medium-grained; grading to coarse-grained sand, and gravel; clay pods....0.39

Sand, coarse grained....0.12

Thickness (meters)

Sand, fine- to medium-grained; with clast of pebbles and medium-grained sand; grading into medium- to coarse-grained sand with pebbles up to 1cm 0.59

Sand, fine-grained 0.09

Mud layer; pebbly fine sand below.....0.06

Sand, fine-grained 0.43

Mud, plastic 0.03

Sand, medium-grained.....0.22

Sand, medium- to coarse-grained 0.53

Sand, fine-grained; silt; wood fragment.....0..07

Sand, fine-grained.....0.52

Sand, fine-grained; mixed with gravel up to 4cm thick 0.07

Gravel, well-rounded; in sand-silt matrix; gravel up to 2cm thick.....0.24

CORE V5

Sand, gray (5Y 5/1), fine-grained; silty; massive; rare shell fragments; dry 1.08

Sand, olive-gray (5Y 4/2), medium- to coarse-grained; rare shell fragments; some clay balls 1cm; grading into below 0.73

Sand, olive-gray ((5Y 4/2) medium-grained; massive; rare shell fragments and clay balls; grading into below 1.55

Sand, olive-gray (5Y 4/2), fine-grained; massive; grading into below 1.10

Sand, light-olive-brown (2.5Y 5/4), medium- to coarse-grained; rare gravel 1.28

The following 50 cores were acquired during the summer of 1988. For this project, deep penetration was attempted at 16 sites. When vibracoring refused to penetrate the offshore sediments, the core was removed and labeled "RUN-1". The vibracorer was placed again on the sea floor and water was pumped through the empty core liner, thus "jetting" down to about the same depth where refusal was previously encountered. Vibracoring began again at this new depth below the sea floor; this core section was labeled "RUN-2". This procedure was repeated to attain a total penetration of up to 20 feet.

Thickness (meters)

CORE C1

Sand, olive-gray (5Y 5/2), medium- to coarse-grained; shell fragments (up to 3cm, bivalves); coarse-grained sand abundant in this interval at 0.40-0.75m; color grading downwards 0.85

Sand, medium- to coarse-grained; scattered shell fragments (a few mm) 0.35

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous; scattered shell fragments (a few mm) 0.34

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; shell fragments (up to 2cm); 6cm clam fragment this interval at 0.26m 0.31

Silt, sandy, very-fine-grained; scattered shell fragments ..0.05

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; scattered shell fragments; silty laminae; micaceous 0.30

Sand, olive-gray (5Y 5/2), fine-grained; micaceous; shell fragments rare(a few mm); scattered silty lamina 0.84

Sand, gray (5Y 6/1) dry; fine-grained; micaceous; very few shell fragment 0.91

Sand, dark-gray (5Y 4/1), medium- to fine-grained; scattered shell fragments (up to 1cm); scattered mud pods; grading into below 0.50

Sand, gray (5Y 5/1), fine-grained; micaceous; scattered shell fragments; grading into sand, medium to fine grained 0.25

Sand, dark-greenish-gray (5GY 4/1) fine- to very-fine-grained; silty; micaceous; abundant pods of clayey silt; scattered shell fragments (a few mm) 1.45

CORE C2

Sand, very-dark-gray (2.5Y 3/0), fine-grained; micaceous; H_2S smell;abundant mud pods; shell fragments at top up to 5cm; shell fragments at the bottom 0.37

Sand, dark-gray (5Y 4/1), coarse-grained; quartzose; shelly 0.10

Sand, dark-gray (5Y 4/1), fine grained; micaceous; mud pods; shell fragments 0.78

Silt, dark-gray (5Y 4/1), clayey; with sand pods, fine-grained; few shell fragments 0.20

Silt, dark-gray (5Y 4/1), clayey; with sand pods, fine-grained 0.30

Thickness (meters)

Silt, dark-gray (5Y 4/1), clayey; with scattered pods; gastropod in this interval at 0.75m 1.22

Sand, very-dark-gray (5Y 3/1), fine-grained; and clayey silt; interlayered - layers about 1cm; micaceous 0.93

Sand, very-dark-gray (5Y 3/1), medium-grained; shelly; mud pods of silty clay and clayey silt 1cm thick 0.50

Sand, very-dark-gray (5Y 3/1), medium-grained; shelly ..0.05

Sand, dark-gray (5Y 4/1), medium-grained; shelly; pods of silty clay 0.45

Sand and clayey silt, shelly, interlayered.....0.10

Sand, medium-grained; shelly.....0.20

Sand, shelly, and clayey silt; interlayered 0.30

Sand, medium-grained; very shelly 0.10

CORE C3 RUN-1, RUN-2

Run-1

Silt, black (2.5Y 2/0); clayey; fluid mud; strong sulfur smell 0.10

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous 0.45

Sand, fine- to very-fine-grained; and silty clay; interlayered, (1-4cm); micaceous; slightly shelly this interval at 0.55m 0.68

Clay, silty 0.12

Sand, fine- to very-fine-grained; micaceous; some shell hash; gastropod this interval at 0.09m 0.19

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; some mud; scattered shell fragments 0.36

Sand, fine- to very-fine-grained; clay and silt; interlayered 0.12

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; shell fragments 0.81

Run-2 penetration-6.03m, recovery-3.05m

Silt, black (2.5Y 2/0); clayey; (fluid mud) 0.10

Sand, fine-grained; micaceous; scattered shell fragments 0.25

Thickness (meters)

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous scattered shell fragments; interlayered with silty clay; 1cm shell layer in this interval at 0.92m 0.95

Silt, clayey 0.15

Sand, fine-grained; micaceous; scattered shell fragments 0.10

Sand, fine-grained; clayey silt; interlayered; micaceous; scattered shell fragments.....0.23

Shell fragments, 10cm long 0.04

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; very few mud pods; shell hash 0.48

Sand, fine- to very-fine-grained; micaceous; interlayered with silty clay and clayey silt; slightly mottled 1.14

CORE C4

Sand, very-dark-gray (5Y 3/1), medium- to fine-grained; micaceous; shelly; shell fragments 0.60

Sand, medium- to fine-grained; shelly; interlayered with silty clay; pieces of wood this interval at 0.28m 0.35

Clay, silty; with sand laminations (shelly and medium-grained sand, 1cm thick) 0.61

Clay, silty 0.32

Sand, fine- to medium-grained; micaceous; few shell fragments; grading to medium-grained sand 0.32

Sand, medium-grained; micaceous; piece of wood 6cm long this interval at 0.77m 1.14

Sand, fine-grained; micaceous; few shell fragments 0.28

CORE C5

Shells and shell hash, quartzose sand, fine-grained; (bivalves) 0.42

Sand, fine-grained; micaceous; with laminations of shell hash and clayey silt (less than 1cm thickness); scattered shell hash 0.78

Sand, very-dark-gray (5Y 3/1), very-fine-grained; muddy; grading into very-fine-grainrd sandy mud 0.31

Thickness (meters)

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; muddy; micaceous; with pods of very-fine-grained sandy clayey silt 1.55

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; muddy; micaceous; with pods of very-fine-grained sandy, clayey silt; some scattered shell hash; shelly layer this interval at 0.34-0.39m 1.55

Sand, fine- to very-fine-grained; muddy; shelly 0.39

Sand, fine- to very-fine-grained; muddy; micaceous; with pods of fine-grained sandy clayey silt 0.95

Sand, fine- to very-fine-grained; micaceous; small amount of silt 0.15

CORE C6

Sand, fine-grained; micaceous; scattered shell fragments 0.10

Sand, fine-grained; muddy; shelly.....0.10

Sand, fine-grained; micaceous; scattered shell fragments 0.10

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; pods of silty clay up to 15cm thick; scattered shell fragments, 1cm thick shell layer in this interval at 0.03m 1.25

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; alternating layers with scattered shell fragments and silty clay; lamination thickness ranges from less than 1cm to 10cm; micaceous 1.54

Clay, very-dark-gray (2.5Y 3/0); silty; some very-fine-grained sand; massive 0.47

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; shell fragments (including gastropod, *Ensis*, up to 2cm almost a shell hash; silt and clay layer this interval at 0.14-0.20m 0.28

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; massive 1.01

CORE C7

Sand, black (2.5Y 2/0), fine- to very-fine-grained; massive; small mud pods; abundant small shell fragments (a few mm); sandy shell layer (*Ensis*, oyster shell, to 4cm) this interval at 0.25-0.34m 0.34

Thickness (meters)

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; scattered shell fragments (a few mm).....0.51

Shell layer, bivalves (1cm) and fragments up to 3cm 0.04

Sand, dark gray (5Y 4/1), fine- to very-fine-grained; scattered shell fragments; increase in mud content at bottom (slightly muddy sand) 0.65

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; shell fragments (bivalve, to 4cm) 0.26

Sand, medium- to coarse-grained; quartzose; abundant shell fragments (up to 10cm clam shell, also gastropods)...0.25

Sand, olive-gray (5Y 5/2), medium- to coarse-grained; shell fragments rare (a few mm) 0.26

Clay, dark-gray (5Y 4/1), silty; plastic.....0.11

Mud, medium-grained, sandy; shell fragments rare 0.20

Sand, gray (5Y 5/1), medium- to coarse-grained; shell hash; and fragments up to 3cm 0.43

Clay, very-dark-gray (5Y 3/1), silty; with shelly medium sand pods or lenses (up to 3cm thick); plastic mud 0.68

CORE C8 RUN-1, RUN-2, RUN-3

Run-1

Sand, olive-gray (5Y 4/2), fine- to medium-grained; abundant shell fragments (1cm bivalves and smaller fragments); grades into below 0.26

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous; scattered shell fragments 0.36

Shell hash, (1cm bivalve and fragments to 4cm); with sand, coarse-grained 0.10

Sand, olive (5Y 4/4), fine-grained; some fine parallel laminations; scattered shell fragments; micaceous 0.32

Run-2 jetted-2.07m, penetration-3.08m; recovery-1.46m
Sample 8-2 continues into core 8 Run-2

Sand, olive (5Y 4/4), fine-grained; some parallel laminations; micaceous; scattered shell fragments, (1cm bivalves and smaller fragments) 1.45

Run-3 jetted-3.05m; penetration-6.04m; recovery-2.90m

Clay, olive-gray (5Y 4/2), plastic; with lenses of fine-grained sand; up to 2cm thick 0.42

Sand, dark-gray (5Y 4/1), fine-grained; abundant shell in top half of layer (1cm bivalves and smaller fragments); micaceous 0.25

Thickness (meters)

Mud, dark-gray (5Y 4/1), plastic; sandy; shell fragments 0.13

Sand, olive-gray (5Y 4/2), fine-grained; micaceous; scattered shell fragments; and mud lenses this interval at 0.00-0.03m and 0.05-0.07m 0.73

Sand, olive-gray (5Y 4/2), fine-grained; micaceous; scattered shell fragments.....0.65

Mud and fine-grained sand pods; gradual color change...0.15

Sand, very-dark-gray (5Y 3/1), fine-grained; with mud lenses to 2cm thick; micaceous; scattered shell fragments 0.44

Shell hash, mostly bivalves of <1cm 0.07

CORE C9

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous; shell fragments; (mostly 1mm, also one *Ensis* 6cm long, gastropod of 2cm); layer of silty clay and shell (10cm thick) this interval at 0.52-0.62m; a few lenses of muddy sand (1cm thick) 1.55

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous; widely scattered shell fragments (1mm) 0.72

Sand, very-dark-gray (5Y 3/1), fine-grained; silty; micaceous; pods of clayey silt and very-fine-grained sandy silt; few scattered shell fragments (1mm) 0.80

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; muddy; micaceous; abundant shell fragments (1 to several mm); pods of clayey silt and very-fine-grained sandy silt; in this interval shell fragment 3cm at 0.88m; piece of wood (saved for dating) at 1.05m 1.73

CORE C10 RUN-1, RUN-2, RUN-3

Run-1

Sand, very-dark-gray (5Y 3/1), fine-grained; shelly; micaceous; (shells to 1cm, bivalve) 0.09

Sand, fine-grained, micaceous; interlayered with plastic silty clay and micaceous shelly fine-grained sand; layers of <1 to 10cm thick; concentration of shells (a few mm) this interval at 0.34-0.46m 0.62

Clay, very-dark-gray (5Y 3/1); silty; plastic 0.46

Sand, fine- to very-fine-grained; muddy; micaceous 0.04

Shell hash, very-dark-gray (5Y 3/1), fragments up to 6cm oyster shell and many 1cm whole bivalves 0.19

Thickness (meters)

Clay, silty; shell hash; 7cm oyster shell 0.06

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; with pods of silty clay (scattered, less than or equal to 1cm thickness) and scattered concentrations of shell fragments (a few mm) shelly layer this interval at 1.45-1.47m (<1cm whole bivalves) 1.59

Run-2 jetted-2.68m, penetration-4.97m, recovery-1.46m

Sand, fine-grained; micaceous; few pods of silty clay (<1cm thick) scattered shell fragments (1mm) concentration of shell this interval at 0.54m (1cm bivalves) 1.39

Run-3 jetted-3.72m, penetration-6.04m, recovery-1.52m

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; scattered shell fragment (1cm bivalve); pods of silty clay (1-3cm) 1.16

Shell hash (<1cm fragments and whole bivalves) 0.05

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; scattered shell fragment (1cm bivalve); pods of silty clay (1-3cm) 0.22

CORE C11 RUN-1, RUN-2

Run-1

Sand, dark-gray (5Y 4/1), medium- to coarse-grained; shelly, (fragments to 5cm).....0.75

Shell hash, dark-gray (5Y 4/1); sandy, medium- to coarse-grained (fragments up to 5cm) 0.20

Sand, dark-gray (5Y 4/1), medium-grained; scattered shell fragments 0.23

Sand, olive-gray (5Y 5/2), medium-grained; scattered shell fragments (<1cm); shell layer this interval at 0.54-0.57m; layer of shelly muddy sand, very-dark-gray (5Y 3/1) this interval at 0.93-0.97m 1.14

Run-2 jetted-3.51m, penetration-6.04m, recovery-3.20m

Clay, very-dark-gray (5Y 3/1); silty; top 1-2cm (whole and fragments of oyster shell up to 4cm long) 0.92

Sand, very-dark-gray (5Y 3/1), very-fine-grained; silty; clayey; few scattered shell fragments.....0.67

Sand, very-dark-gray (5Y 3/1), very-fine-grained; clayey; silty; few pods of silty clay (2cm thick); mud content increases toward bottom 1.57

Thickness (meters)

CORE C12 RUN-1, RUN-2

Run-1

Sand, very-dark-gray (2.5Y 3/0), fine- to very-fine-grained; micaceous; few scattered shell fragments; concentration of shell and shell fragments this interval at 0.30-0.35m (1cm long) 1.55

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; scattered shell fragments; layer of fine, sandy shell hash fragments up to 5cm; whole gastropods this interval at 0.45-0.47m 0.47

Sand, very-fine-grained; clayey; silty....0.08

Clay, very-dark-gray (5Y 3/1); silty; highly plastic; with 2cm thick fine-grained sand lamination 0.15

Sand, very-dark-gray (5Y 3/1), very-fine; micaceous....0.72

Run-2 jetted-2.62m, penetration-4.82m, recovery-2.44m
NOTE: Top of core totally disrupted
Sand, dark-gray (5Y4/1), fine-grained; micaceous 0.10

Clay, dark-gray (5Y 4/1); silty; plastic....0.15

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous 0.53

Clay, silty (layer)....0.03

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous 0.45

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; shell fragments up to 5cm....0.34

Sand, shelly; with bivalves and gastropods 0.09

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; fine-grained sand with shell fragments this interval at 0.49-0.54m 0.80

CORE C13 RUN-1, RUN-2, RUN-3

Run-1

Sand, dark-gray (5Y 4/1), medium- to fine-grained; scattered shell fragments up to 5cm 0.60

Shell layer with medium-grained sand; shell fragments up to 5cm long 0.27

Sand, fine-grained; micaceous; shell fragments up to 5cm long 0.15

Sand, fine-grained; shelly; shell fragments up to 2cm mostly bivalves and gastropods 0.21

Thickness (meters)

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; silty clay layer this interval at 0.33-0.36m 1.00

Run-2 jetted-2.29m, penetration-5.00m, recovery 1.98m
Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; fine, silty clay laminations this interval at 1.16-1.19m 1.92

Run-3 jetted-4.21m; penetration-6.04m; 1.74m
Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous 1.71

CORE C14 RUN-1, RUN-2, RUN-3

Run-1

Sand, fine-grained; micaceous; shell fragments (to 1cm)..0.13

Sand, coarse-grained; shell fragments (gastropods to 2cm, etc.) 0.03

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; shell fragments rare; color change to olive-gray (5Y 4/2) this interval at 0.79m 0.91

Sand, fine-grained; micaceous; abundant shell fragments 0.06

Shell hash with matrix of micaceous, fine-grained sand, (bivalves 1-2cm) 0.04

Sand, fine-grained; micaceous; shell fragments rare; shell fragments becoming more abundant toward bottom 0.24

Clay, olive-gray (5Y 4/2); silty....0.02

Clay, olive-gray (5Y 4/2); silty; layers of fine-grained sand (1-2cm thick); sand layer this interval at 0.07-0.10m 0.32

Sand, dark-grayish-brown (2.5Y 4/2), fine-grained; micaceous 0.19

Clay, silty; sand laminations (up to 1cm thick) 0.09

Sand, olive (5Y 4/3), fine- to very-fine-grained; micaceous; no shell fragments 0.48

Clay, silty; with fine-grained sand laminations (up to 1cm) 0.17

Sand, fine- to very-fine-grained; micaceous 0.06

Run-2 jetted-2.41m, penetration-4.18m, recovery-2.20m
Sand, dark-gray (5Y 4/1), fine-grained; micaceous 0.15

Shell layer (fragments of up to a few mm) 0.01

Thickness (meters)

Clay, silty 0.04

Sand, fine-grained; micaceous 0.05

Clay, silty; pockets of micaceous fine-grained sand 0.25

Sand, dark-grayish-brown (2.5Y 4/2), fine-grained; micaceous; silty clay laminations this interval at 0.20-0.25m; shell fragments (1mm or less) and silty clay laminations at 1.10-1.2; mud ball at 1.41-1.44m 1.70

Run-3 jetted-4.42m, penetration-6.04m, recovery-1.83m
Sand, fine-grained; micaceous; shell fragments rare; sediments disturbed by water in core liner 0.33

Clay, gray (5Y 5/1), silty; sand laminations (up to 1cm thick) 0.21

Sand, olive-gray (5Y 4/2), fine-grained; shell fragments rare this interval at 0.96-1.01m.....1.31

Core C15 RUN-1, RUN-2

Run-1
Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; top 12cm has scattered shell fragments (up to 1cm) 0.80

Clay, silty; with fine-grained sand laminations (0.5 cm thick) 0.20

Sand, dark- gray (5Y 4/1), fine- to very-fine-grained; micaceous; color changes to olive gray (5Y 4/2) this interval at 0.30m 0.88

Run-2 jetted-1.83m, penetration-6.04m, recovery-2.14m
Sand, olive-gray (5Y 4/2), fine-grained; micaceous; (no shell); silty clay laminations this interval at 1.01-1.03m and 1.33-1.36m; color changes to olive brown (2.5Y 4/4) this interval at 1.00m 2.10

CORE C16 RUN-1, RUN-2

Run-1
Sand, very-dark-gray (2.5Y 3/0), fine-grained; micaceous; rare shell fragments (abundant only from 0.15-0.20m); color changes to dark gray (5Y 4/1) this interval at 0.94m EXCEPT for silty clay lamination this interval at 1.21-1.22m with color of very dark gray (2.5Y 3/0) 1.69

Run-2 jetted-1.98m, penetration-3.36m, recovery-0.92m
Sand, dark-gray (2.5Y 4/0), fine- to very-fine-grained; micaceous; few scattered shell fragments (1mm); silty clay laminations this interval at 0.22-0.23m and 0.30-0.33m; color changes to dark-grayish-brown (2.5Y 4/2) this interval at 0.30m 0.96

Thickness (meters)

CORE C17 RUN-1, RUN-2, RUN-3, RUN-4

Run-1
Sand, dark-gray (2.5Y 4/0), fine- to very-fine-grained; micaceous; shell fragments (1mm) rare; silty clay lamination this interval at 1.28m 1.64

Dark gray (2.5Y 4/0); silty clay and micaceous fine-grained sand, alternating layers; (layers up to 7cm thick); scattered shell fragments in sand; color changes to dark-gray (5Y 4/1) this interval at 0.19m 0.36

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; scattered shell fragments 1mm (mostly below .35); silty clay laminations with shell fragments (a few mm) this interval at 0.72-0.73m and 0.75-0.76m 0.85

Run-2 jetted-2.29m, penetration-3.66m, recovery-0.76m
Clay, dark-gray (2.5Y 4/0), silty; laminations of micaceous, silty, fine-grained sand; (up to 3cm thick); widely scattered shell fragments a few mm; color changes to very-dark-gray (5Y 3/1) in this interval at 0.10m 0.36

Sand, fine-grained; micaceous; (no shells); layer of abundant shell fragments (bivalves, a few mm) this interval at 0.34-0.39m 0.53

Run-3 jetted-3.29m, penetration-4.06m, recovery-1.07m
Clay, dark-gray (5Y 4/1), silty; laminations of silty fine-grained sand (to 1 cm thick) 0.21

Sand, very-dark-gray (5Y 3/1), fine-grained; micaceous 0.23

Clay, silty; fine-grained sand lamination this interval at 0.04-0.05m 0.20

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; few scattered shell fragments (about a mm) 0.36

Run-4 jetted-4.03m, penetration-6.04m, recovery-1.52m
Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; scattered shell fragments (to 1cm); in this interval: silty clay layer at 0.45-0.50m; widely scattered shells between 0.42-0.90m (1mm); silty clay layer with shell fragments at 0.91-0.96m; abundant shell fragments (bivalves, a few mm) silty sand at 1.04-1.06m; abundant shell fragments silty clay with sand at 1.28-1.32m 1.50

CORE C18 RUN-1, RUN-2

Run-1
Sand, dark- gray (5Y 4/1), fine- to very-fine-grained; micaceous; abundant to widely scattered shell fragments (<1mm-1.5cm); shell fragments up to 4cm this interval at 2.00-2.09m 2.09

Thickness (meters)

Run-2 jetted-1.98m, penetration-2.59m, recovery-0.55m
Sand, dark-gray (5Y 4/1), fine-grained; micaceous; scattered shell fragments (mostly 1-2mm, also a bivalve of 2cm) .....

CORE C19 RUN-1, RUN-2, RUN-3

Run-1
Sand, dark-gray (2.5Y 4/0), fine- to very-fine-grained; lightly scattered shell fragments, 1-2mm; grades into silty fine-grained sand 1.80

Sand, fine- to coarse- grained; silty; and gravel; micaceous; shell fragments up to 3cm 0.10

Run-2 jetted-1.83m, penetration-4.88m, recovery-1.62m
Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; scattered shell fragments up to 6cm; shell fragments up to 1cm common this interval at 0.98-1.09m 1.09

Sand, light-gray (5Y 6/1), medium- with some fine-grained; shell fragments up to 6cm (bivalve); this interval at 0.00-0.06m; pod of fine- to medium-grained sand, slightly silty this interval at 0.39-0.43m 0.46

Run-3 jetted-3.38m, penetration-5.89m, recovery-2.10m
Sand, medium- with fine-grained; widely scattered gravel and shell fragments; gravel up to 5cm; shell fragments up to 4cm; scattered pods of mud (1cm size); cobble this interval at 1.85m 1.70

Sand, fine-grained; pod of silty fine sand this interval at 0.03-0.07m 0.38

CORE C20 RUN-1, RUN-2

Run-1
Sand, dark-olive-gray (5Y 3/2), coarse- with some fine-grained; scattered shell fragments up to 3cm 0.27

Cobble; sandy siltstone, in fine- to medium-grained sand; rounded gravel; shell fragments 0.18

Sand, dark-gray (5Y 4/1), fine-grained; shelly; pods of silty sand and gravelly shell hash, shell up to 1-2mm.....0.37

Shell fragments in silty clay matrix with fine- to medium-grained sand and gravel; shell fragments up to 3cm 0.10

Clay, silty; lenses of fine- to medium-grained sand; also gravel; lenses less than 1cm thick; some mica.....0.30

Thickness (meters)

Clay, dark-gray (5Y 4/1), slightly silty; lenses of medium- to fine-grained sand; micaceous; lenses <1cm; thin parting of clayey silt <1mm, black this interval at 0.43m and 0.72m 1.27

Sand, fine-grained; micaceous; with silty clay layers up to .5cm thick 0.09

Run-2 penetration-6.04m; recovery-5.09m
Sand, dark-grayish-brown (2.5Y 4/2), coarse- to medium-grained; shell fragments (up to 6cm) and rounded gravel (up to 2cm) increasing in abundance downward 0.50

Cobble, showing alternating layers of sandstone and siltstone; pebbles and shells common 0.06

Sand, dark-gray (5Y 4/1), fine-grained; abundant shell fragments (up to 2mm) and some rounded gravel (<1cm); shelly layer this layer at 0.83-0.84m 0.44

Shell hash, sandy; fragments up to 3cm, some gravel; silty clay pods 0.08

Sand, fine-grained; some silt.....0.03

Clay, dark-gray (5Y 4/1), silty; micaceous; fine-grained sand laminations (up to 1mm); crossbed of silty fine-grained sand and gravel <3cm thick this interval at 0.26m 0.39

Clay, dark-gray (5Y 4/1), micaceous and silty, alternating with beds of micaceous silty fine-grained sand; layering ranges from <1mm to 1cm for sandy layers and <1mm to 5cm for clayey layers; sporadic pods of silty medium- and fine-grained sand; sandy layers begin to range in thickness from <1mm to 8cm; this interval at 2.1 to 2.55m 3.16

CORE C21

Sand, olive-gray (5Y 5/2), coarse-grained; few scattered shell fragments 0.40

Sand, olive-gray (5Y 5/2), course-grained; and gravel; abundant biodetritus, bivalves up to 10cm (quratz shelly sand) 0.46

Clay, gray (5Y 4/1), silty; plastic; with coarse-sand pockets this interval between 0.04-0.09m 1.34

CORE C22

Sand, olive-gray (5Y 4/2), coarse-grained; lot of shell fragments up to 6cm long) 0.40

Thickness (meters)

Sand, olive-gray (5Y 4/2), coarse- to medium-grained; scattered shell frgaments 0.45

Sand, olive-gray (5Y 4/2), medium-grained; shell fragments 0.65

Sand, medium-grained....0.15

Sand, olive-gray (5Y 4/2), coarse-grained; shell fragments up to 4cm long 0.06

Sand, medium-grained 0.09

Sand, coarse-grained; shell fragments up to 4cm long 0.03

Sand, medium-grained 0.07

Sand, medium-grained; abundant shell fragments 0.15

Sand, gray (5Y 4/1), medium-grained 0.40

Sand, medium-grained; abundant shell fragments 0.05

Sand, medium-grained; big oyster shell this interval at 0.30m 0.40

Sand, medium- to fine-grained; scattered shell fragments 0.15

Sand, very-dark-gray (5Y 3/1), fine-grained; scattered shell fragments; small silty clay pod this interval at 0.87m 1.09

Sand, coarse-grained 0.04

Sand, very-dark-gray (5Y 3/1), fine- to medium-grained; small amounts of silt; scattered shell fragments 0.08

Sand, olive-gray (5Y 4/2), medium- to coarse-grained; gravel (quartz) up to 2cm 0.10

Sand, olive-gray (5Y 4/2), medium- to coarse-grained ...0.69

Sand, olive-gray (5Y 4/2), medium- to fine-grained; scattered shell fragments; scattered gravel (quartz and rock) up to 2cm 0.40

CORE C23

Clay, very-dark-gray (2.5Y 3/0), silty; smelly; small silty sand pocket this interval at 0.17-0.19m; shelly layer this interval at 0.96m 1.55

Sand, silty; possibly washed in 0.06

Clay, black (5Y 2.5/1), silty....0.31

Thickness (meters)

Sand, dark-gray (2.5Y 4/0), silty; laminations of coarse- to medium-grained sand up to 2cm thick; very micaceous; no shell fragments 0.78

Sand, very-fine-grained; micaceous 0.36

Sand, dark-gray (5Y 4/1), very-fine-grained; micaceous 0.70

Sand, coarse-grained 0.05

Sand, very-fine-grained; micaceous; silty clay this interval at 0.00-0.02m 0.10

Sand, gray (5Y 5/1), coarse-grained; grading into below 0.55

Sand, medium-grained....0.16

Sand, dark-gray (5Y 4/1), medium- to coarse-grained 0.59

Sand, coarse-grained; gravel and pebbles up to 2cm 0.20

Sand, medium- to coarse- grained 0.55

Sand, fine- to very-fine-grained; micaceous; shelly layer with fine-grained sand shell (biodetritus) to 5cm long, this interval at 0.07-0.15m 0.21

CORE C24

Sand, dark-gray (5Y 4/1), coarse- to medium-grained 0.91

Sand, dark-gray (5Y 4/1), coarse-grained; and gravel; scattered shell fragments up to 8cm 0.30

Sand, dark-gray (5Y 4/1), medium- to fine-grained; higher concentration of finer grained material at bottom; some well-preserved bivalves 3-4cm long this interval at 0.35m 0.40

Sand, coarse- to medium-grained; scattered shell fragments 0.13

Sand, dark-gray (2.5Y 4/1), medium- to fine-grained; scattered shell fragments 1.16

Clay, silty; interlaminated with medium- to fine-grained sand up to 1cm thick 0.06

Sand, fine-grained; shell fragments up to 7cm long 0.20

CORE C25

Clay, dark-gray (5Y 4/1), silty; very silty, medium-grained

Thickness (meters)

sand pods in this interval at: 0.03-0.12m (with scattered shell fragments), and 0.16-0.22m, and 0.50-0.52m (with shell fragments up to 2cm), and 0.70-1.03m, and 1.19-1.21m (with scattered shell fragments), and 1.31-1.33m (with medium- to fine-grained sand) 1.35

Sand, gray (5Y 5/1), coarse-grained; shell fragments; becomes silty towards bottom; silty clay pod this interval at 0.20m 0.50

Sand, dark-gray (5Y 4/1), fine-grained; silty 0.10

Sand, gray (5Y 5/1), medium-grained; grading into below 0.15

Sand, coarse-grained 0.45
Clay, silty 0.04

Sand, coarse-grained; cobble (5cm) 0.06

Clay, dark-gray (5Y 4/1), silty; and fine- to very-fine-grained sand laminations up to 3cm thick 0.65

Sand, dark-gray (5Y 4/1), very-coarse-grained; and gravel; large shell fragments up to 8cm; silty clay lens this interval at 0.44-0.45m 0.45

Sand, gray (5Y 5/1), coarse- to medium-grained 0.53

CORE C26

Sand, olive-gray (5Y 5/2), fine- to very-fine-grained; micaceous; fine-grained sand with shell hash; fragments up to 1cm this interval at 1.10-1.14m and at 1.26-1.28m; silty, fine-grained sand laminations 1cm thick at 1.20-1.25m; silty clay layer at 1.60-1.64m; color changes to dark-gray (5Y 4/1) at 1.24m 1.71

Sand, fine- to very-fine-grained; micaceous; some scattered shell fragments; shell fragments up to 8cm long this interval at 0.20-0.25m concentration of shell fragments at 0.33-0.36m 0.69

Sand, medium-grained; shell fragments up to 2cm and clay balls 2cm dia 0.13

Sand, fine-grained; silty; silty clay pod this interval at 0.16-0.32m; silty clay layers at 0.72-0.75m and 0.84-0.87m 0.90

Clay, very-dark-gray (5Y 3/1), silty; laminations of silty fine-grained sand; sand laminations up to 1cm thick; color changes to dark gray (5Y 4/1) this interval at 0.16m 0.63

Sand, fine-grained; silty; with silty clay laminations; clay laminations vary between 1cm and 10cm thick; concentration of bivalve shells up to 1cm long fine sand matrix this interval at 0.04-0.13m; shell fragments up to 4cm long at 0.54-0.56m; crossbedded (?) clay layer at 0.56-0.62m; concentration of bivalve and gastropod shells up to 1.5cm, in fine sand matrix at 0.62-0.69m 1.02

CORE C27

Sand, dark-gray (5Y 4/1), coarse- to very-coarse-grained; scattered shell fragments 0.12

Sand, dark-gray (5Y 4/1), fine-grained; micaceous; silty clay lamination this interval at 0.11m. 0.13

Sand, coarse- to medium-grained; sandy shell hash (shell fragments up to 3cm long) this interval at 0.07-0.13m 0.20

Sand, very-fine-grained; micaceous; scattered shell fragments 0.08

Clay, dark-gray (2.5Y 4/1), silty; shelly medium- to coarse-grained sand this interval at 0.08-0.11m; silty sand pods at 0.12-0.17m and 0.0.43-0.45m 1.20

Clay, dark-gray (2.5Y 4/1), silty; small well compacted sand pod this interval at 0.03-0.05m 2.95

Silt, sandy; various amounts of fine sand 0.32

Cobbles to coarse-grained sand; (quartz); small mud pod this interval at 0.10-0.15m 0.30

CORE C28

Sand, medium- to fine-grained; colors as follows: light-olive-gray (5Y 6/2) up to 0.28m, dark-gray (5Y 4/1) up to 1.30m, light-olive-gray (5Y 6/2)up to 1.59; shell fragment 2cm long this interval at 0.44m; exhibits planer bedding at 0.50-0.60m; silty clay layer thins from 3cm to <0.05cm at 1.99-2.02m 2.12

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; scattered shell fragments <0.05cm; concentration of shell fragments some medium-grained sand this interval at 1.62-1.72m; grading into below 2.08

Sand, medium- to coarse- grained 0.15

Sand, dark-gray (5Y 4/1), fine- to medium-grained with interlaminations silty clay; silty clay 3mm-1cm thick; sand 1-3cm thick 0.67

Sand, dark-gray (5Y 4/1), medium-grained; scattered shell fragments up to 1cm 0.26

Thickness (meters)

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; silty; widely scattered shell fragments; becomes slightly coarser this interval at 5.75m 1.00

CORE C29

Sand, olive-gray (5Y 5/2), medium- to fine-grained; some silt; scattered shell fragments up to 2mm; concentration of fragments this interval at 0.98-1.02m; and at 0.95-1.45m (these up to 3cm); color changes to dark gray (5Y 4/1) at 1.50m 2.33

Clay, dark-gray (5Y 4/1), silty; well-compacted; less compacted mud pods this interval at 0.18m and 0.32m and 0.57m; fine-grained sand pod at 2.27m (2mm thick) 2.89

CORE C30

Clay, dark-gray (5Y 4/1), silty; scattered shell fragments <1mm; fine-grained sandy silt layer 3cm thick at a 45 degree angle this interval at 0.20m 0.34

Sand, fine-grained; silty; shell fragments up to 3cm; peice of wood 2cm long this interval at 0.08m 0.44

Clay, dark-gray (5Y 4/1), silty with interlayers and silty fine-grained sand; with scattered shell fragments up to 1mm; clay layers 4-5cm; sand layers 15-20cm 0.56

Clay, dark-gray (5Y 4/1), silty 0.14

Sand, fine-grained; silty; scattered shell fragments to 1mm 0.29

Clay, dark-gray (5Y 4/1), silty; widely scattered shell fragments <1mm well compacted; shell fragment 2cm long this interval at 0.74m 1.69

Clay, dark-gray (5Y 4/1), silty; shell fragments absent; air pockets in center of core this interval at 0.13-0.17m and 0.46-0.64m 1.64

CORE C31 RUN-1, RUN-2

Run-1

Sand, pale-yellow (5Y 7/4), medium-grained; scattered shell fragments up to 1mm; clam shell 3cm this interval at 0.31m; color changes to very-dark-gray (5Y 3/1) at 0.15-1.20m (bioturbation), pale-yellow (5Y 7/4) at 1.20-1.40m, dark-gray (5Y 4/1) at 1.45-2.00m (bioturbation); medium- to coarse- grained sand with higher concentration of shell fragments at 2.40-2.54m, and at 2.87-2.92m 3.05

Thickness (meters)

Run-2 penetration-3.11m, recovery-2.99m

Sand, dark-gray (5Y 4/1), fine-grained; some silt; shell fragments up to 2mm; plastic plug this interval at 0.35-0.45m 0.45

Sand, dark-gray (5Y 4/1), fine-grained; silty; scattered shell fragments <1mm; very moist to wet (high water content) 1.51

Silt; sandy, fine-grained; scattered shell fragments <1mm 0.27

Sand, coarse-grained; silty; shell fragments <2mm; upper contact at 45 degree angle 0.16

Silt; sandy, fine-grained; shell fragments <1mm 0.06

Sand, coarse-grained; silty; upper contact at 45 degree angle 0.09

Sand, dark-gray (5Y 4/1), fine-grained; silty; scattered shell fragments up to 4cm 0.26

CORE C32

Sand, dark-gray (5Y 4/1), fine-grained; silty; scattered shell fragments up to 2mm; large shell fragment (3cm long) this interval at 0.70m; becomes coarser at 0.85-1.05m 1.17

Silt; fine-grained, sandy; scattered shell fragments <1mm 0.11

Sand, dark-gray (5Y 4/1), coarse-grained; silty; grading into fine-grained sand this interval at 0.04m; scattered shell fragments up to 3mm 0.28

Sand, fine-grained; scattered shell fragments 0.49

Clay, silty 0.05

Sand, fine-grained; scattered shell fragments 0.14

Clay, dark-gray (5Y 4/1); several <1mm, silty -and laminations; silty, fine-grained sand layer this interval at 0.17-0.18m; concentration of shell at bottom contact 0.25

Sand, dark-grayish-brown (2.5Y 4/2), fine-grained; micaceous; silty; silty-clay lamination (1mm thick) this interval at 0.14m; horizontal bedding visible; color changes to light-olive-brown (2.5Y 5/4) at 0.11m 0.16

Clay, light-olive-brown (2.5Y 5/4), silty; becomes coarser from 0.30m and down; color changes several times in this interval to gray (5Y 5/1) at 0.04m; and dark-gray (5Y 4/1) at 0.05m; and dark-grayish-brown (2.5Y 4/2) at 0.30m 0.45

Thickness (meters)

Sand, dark-gray (5Y 4/1), very-fine-grained; silty; micaceous; color changes several times in the interval from 0.13m to bottom alternating colors of olive gray (5Y 4/2) and yellowish- brown (10YR 5/8) with fine material related to darker color and coarser material related to lighter colors 0.40

Sand, laminations of silty, fine-grained and medium-grained; laminations range from 1mm to 0.5cm thick 0.15

Sand, medium- to coarse-grained; and gravel; (rounded) 0.06

Sand, fine-grained; micaceous; mud lens <1mm this interval at 0.04m 0.04

Sand, medium- to coarse-grained; and gravel 0.03

Sand, medium-grained 0.08

Sand, medium-grained; and gravel 0.04

Clay, fine-grained sand lenses....0.08

Sand, olive-gray (5Y 4/2), fine-grained; some silt; micaceous 0.54

Sand, dark-gray (2.5Y 4/0), fine-grained; some silt; micaceous; begin to have shell fragments with increasing concentration with depth 0.20

Shell hash; some fine-grained sand; mostly bivalves up to 1cm with trace gravel 0.26

Sand, dark-gray (2.5Y 4/0), very-fine-grained; silty; micaceous; widely scattered shell fragments; shelly layer this interval at 0.10-0.12m 0.57

CORE C33

Sand, black (2.5Y 6/0), fine-grained; silty; widely scattered shell fragments; interlayers of silty clay ranging from 0.5-6.0cm thick this interval from 0.0-0.95m; silty-clay layers at 0.32-0.38m, and 0.45-0.48m (with .5cm layer of coarse-grained sand below), and 0.64-0.67m; silty, fine- to medium-grained sand layer at 0.50-0.57m; medium-grained sand with shell fragments up to 4cm some silt at 0.68-0.73m; color changes to dark-gray (2.5Y 4/0) at 0.48m 1.54

Sand, fine-grained; silty 0.34

Clay, silty 0.03

Sand, fine-grained; silty 0.04

Clay, silty; with several fine-grained sand lenses 0.05

Thickness (meters)

Sand, dark-olive-gray (5Y 3/2), coarse-grained; and gravel; abundant shell fragments up to 5cm long; pod of mud this interval at 0.06m 0.31

Sand, dark-gray (2.5Y 4/0), fine-grained; very silty; mud pods; scattered shell fragments 0.53

Silt, clayey; interlayered with silty clay, layers range 1-2cm; shell absent 0.13

Clay, very-dark-gray (2.5Y 3/0), silty; grading into below 0.15

Sand, dark-gray (5Y 4/1), fine-grained; silty; becomes less silty with depth; pod of mud this interval at 0.91m 1.34

Sand, dark-gray (5Y 4/1), fine-grained; gravelly 0.17

Gravel, black (2.5Y 2/0); with silty fine-sand; scattered shell fragments 0.32

Silt, clayey; more clayey at top; some gravel at bottom 0.16

Gravel, with silty fine-grained sand; scattered shell fragments; gravelly silt layer this interval at 0.14-0.15m; higher concentration of shell fragments with some medium-grained sand toward bottom 0.26

Silt, black (2.5Y 2/0), clayey 0.06

Gravel and shell fragments, with silty fine-grained sand and some medium-grained sand 0.25

Clay, silty; interlayered with clayey silt; with gravel; shows horizontal bedding 0.07

Gravel and scattered shell fragments; with medium- to coarse-grained sand and silt 0.17

Sand, gray (5Y 5/1), interbedding of silty, fine- and medium-grained; clay ball this interval at 0.09m 0.10

Sand, gray (5Y 5/1), medium- to fine-grained; and gravel; trace clay; abundant shell fragments 0.17

CORE C34

Sand, olive-gray (5Y 5/2), medium-grained; trace of coarse- and fine-grained sand; widely scattered shell fragments 2.20

Sand, fine- to medium-grained; widely scattered shell fragments; mud lamination up to 2mm thick this interval at 0.15m; higher percent of medium sand at 0.20-0.27m 0.27

Thickness (meters)

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; widely scattered shell fragments; layer of abundant shell fragments 2cm thick this interval at 0.43m 1.05

Sand, medium-grained; shell fragments 0.02

Sand, dark-gray (5Y 4/1), very-fine-grained; silty; with layers of medium-grained sand and shell fragments this interval at 0.13-0.14m, and 0.23-0.26m; pod of coarse-grained sand at 0.33-0.38m; 0.5cm thick layer of silty clay at 0.39m 0.39

Sand, olive-gray (5Y 5/2), coarse-grained; shell fragments; several mud pods 0.17

Sand, fine-grained; and shell fragments 0.06

Sand, olive-gray (5Y 5/2), coarse-grained; abundant shell fragments 0.11

Sand, dark-gray (f5Y 4/1) very-fine-grained; silty 0.52

CORE C35

Sand, medium-grained; in mud matrix; shell fragments up to 4cm 0.08

Clay, very-dark-gray (5Y 3/1); pods and discontinuous laminations of fine-grained sand common; pods toward surface contain medium-grained sand and mud; scattered fragments of wood this interval at: 1.15-1.20m, and 1.35-1.56m, and 1.80-1.95m; color changes to dark-gray (5Y 4/1) at 0.80m; abundant fine-grained sand laminations at 4.15-4.60m; sand laminations increase in thickness and interlayers of clay become more silty and thinner at 5.25-5.42m 5.42

Sand, gray (5Y 5/1), medium- to fine-grained; grading to very-fine-grained sand at bottom; interlayered mud and fine-grained sand this interval at 0.35-0.38m, and 0.42-0.46m; trace of gravel at bottom contact this interval at 0.48m 0.48

Clay, silt matrix; pods of green, compacted clay; scattered shell fragments; colors: clay, dark-greenish-gray (5GY4/1); silt, dark-gray (5Y 4/1) 0.12

CORE C36 RUN-1, RUN-2, RUN-3, RUN-4

Run-1

Sand, olive (5Y 5/3), medium- to coarse-grained; abundant shell fragments up to 5cm; abundant fine- to medium-grained sand, coarse-grained sand common this interval at 0.72m 1.25

Thickness (meters)

Run-2 jetted-1.13m, penetration-2.41m, recovery-1.37m

Sand, pale-olive (5Y 6/3), medium-grained; scattered shell fragments; plastic plug this interval at 0.22-0.32m; color changes to olive-gray (5Y 5/2) this interval at 0.15m; silty-clay pod with color of dark-gray (5Y 4/1) this interval at 1.02m; grades into below 1.15

Sand, fine- to medium-grained; scattered shell fragments 0.23

Run-3 jetted-2.35m, penetration-3.08, recovery-1.07m

NOTE: top 0.4m of tube empty; measurements not exact; core disturbed

Sand, olive (5Y 5/3), medium-grained; abundant shell fragments; color changes to gray (5Y 5/1) this interval at 0.55m 1.03

Sand, dark-gray (5Y 4/1), fine-grained; abundant shell fragments 0.33

Run-4 jetted-2.99m, penetration-3.96m, recovery-1.01

Sand, gray (5Y 5/1), fine- to medium-grained; abundant shell fragments; darker colored parting this interval at 0.33m; plastic plug this interval at 0.77-0.87m 1.00

CORE C37

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; scattered shell fragments; concentration of shell fragments mostly *Ensis* this interval at 0.12-0.14m; laminations of silty clay up to 2cm thick at 0.53-0.65m and 1.29-1.30m grading into below 2.00

Sand, dark-gray (5Y 4/1), medium- to fine-grained; shelly layer in sand matrix, fragments up to 3cm this interval at 0.45-0.53m; shell layer in sand matrix, gastropods and bivalves up to 8cm at 0.75-0.80m 0.82

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; silty sand layer this interval at 0.31-0.33m; silty clay layers at 0.46 and 0.56 (1cm) 2.14

CORE C38

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous; *Ensis* shell fragment 4cm long this interval at 0.81-0.84m 1.03

Sand, dark-olive-gray (5Y 3/2), coarse-grained; some gravel 0.08

Sand, medium-grained; silty.....0.03

Sand, medium- to coarse-grained; shell fragments up to 4cm 0.06

Thickness (meters)

Sand, very-dark-gray (5Y 3/1), medium- to fine-grained; silty clay this interval at 0.00-0.01m 0.22

Sand, very-dark-gray (5Y 3/1), medium-grained 0.11

Sand, very-dark-gray (5Y 3/1), fine- to very-fine-grained; micaceous 0.30

Clay, silty; some fine-grained sand; micaceous 0.15

Sand, coarse-grained; silty; and gravel; shell fragments up to 7cm 0.21

Clay, dark-gray (5Y 4/1), slighty silty; high degree of compaction; small pods of coarse-grained sand this interval at 1.64-1.74m; 0.5cm thick layer of shell fragments this interval at 3.20m 3.96

CORE C39

Sand, dark-gray (5Y 4/1), very-fine-grained; massive; scattered shell fragments up to 4cm *Ensis*; dark band this interval at 0.10-0.12m 1.54

Sand, medium-grained; and gravel; shell fragments 0.05

Sand, fine- to very-fine-grained; some medium-grained sand; micaceous 0.22

Sand, coarse- to medium-grained; trace of gravel 0.03

Sand, dark- gray (5Y 4/1), fine- to very-fine-grained; micaceous; scattered shell fragments; trace of subrounded gravel; concentration of gravel and shell fragments up to 4cm this interval at 0.46-0.56m; piece of wood 4cm long at 1.28m; concentration of bivalve shells at 2.05-2.08m; layer of silty, fine-grained sand at 2.79-2.84m; layer of silty clay at 2.89-2.95m; shell hash with fragments up to 3cm with coarse-grained sand at 3.29-3.34m; laminations of silty clay and silty, fine-grained sand up to 1cm thick at 3.42-3.46m 3.59

CORE C40

Sand, dark-gray (5Y 4/1), very-fine-grained; micaceous; massive; widely scattered shell fragments 1.45

Sand, dark-gray (5Y 4/1), very-fine-grained; micaceous; massive; scattered shell fragments up to 1cm; several pods of silty, fine-grained sand this interval at 0.55-0.70m; 1cm wide shell layer (clams 1cm at an angle) at 0.80m 1.53

Sand, dark-gray (5Y 4/1), very-fine-grained; micaceous; massive; widely scattered shell fragments; 1cm thick lenses of silty fine-grained sand common 1.49

Thickness (meters)

CORE C41

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; silty; micaceous; widely scattered shell fragments; in this interval: 1cm wide layer abundant shell fragments <1cm oriented at 45 degree angle at 0.30-0.35m, horizontal layer of abundant shell fragments 1cm at 0.42-0.44m, abundance of *Ensis* at 0.20m 1.31

Sand, dark-greenish-gray (5GY 4/1), fine- to very-fine-grained; micaceous; silty; widely scattered shell fragments up to 1cm; in this interval: decrease in sand and increase in clay content at 0.37m; silty clay with scattered occurrences of very-fine-grained sand at 0.55m; scattered coarse grains of sand below 0.54m 0.74

Clay; some silt 0.17

Sand, gray (5Y 5/1), medium- to coarse-grained; and gravel, scattered shell fragments <1cm 0.36

Sand, medium- to coarse- grained 0.03

Sand, gray (5Y 5/1), fine- to very-fine-grained; widely scattered shell fragments up to 1cm; gathering of shell fragments including 3cm *Ensis* this interval at 1.14m 1.36

CORE C42

Sand, very-dark-gray (2.5Y 3/1), very-fine- grained; micaceous 0.13

Sand, coarse-grained; and gravel; shell fragments up to 1cm 0.02

Sand, medium- to fine-grained 0.05

Clay, dark-gray (2.5Y 4/1); laminations of medium- to fine-grained sand and silty-clay up to 2cm thick 0.28

Sand, coarse-grained; shelly; shell fragments up to 2cm 0.09

Sand, dark-gray (2.5Y 4/1), fine-grained; micaceous; scattered shell fragments; silty sand layer this interval at 0.15m 1.00

Sand, medium- to fine-grained; micaceous 0.48

Sand, dark-gray (5Y 4/1), medium- to fine-grained; micaceous; shell fragments up to 2cm 0.25

Sand, dark-gray (5Y 4/1), very-fine -grained; micaceous; variable amounts of silt and clay along core; in this interval: silty sand at 0.00-0.40m, clayey sand at 0.40-0.70m; silty sand at 0.70-0.81m 0.81

Thickness (meters)

Sand, very-fine-grained; silty; clayey; variable amounts of silty clay along the core, no lamination pattern, looks like disrupted lenses of sand, silt and clay; in this layer: silty clay layer at 0.05-0.07m; gastropod at 0.27m 1.52

Clay, dark-gray (5Y 4/1), silty; pods and stringers of silty fine-grained sand; scattered shell fragments 1mm along clay/sand boundary; in this interval: 3cm pebble at 0.92m; becoming more sandy at 1.17m 1.38

Sand, gray (5Y5/1), medium- to fine-grained; micaceous 0.11

CORE C43

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; mud pod this interval at 0.78-0.80m; layer of coarse shelly sand, shell fragments up to 6cm at 1.24-1.30m 1.77

Sand, fine-grained; widely scattered shell fragments; shell fragments up to 3cm this interval at 1.48m 1.48

Sand, fine-grained; interlaminated with silty clay; laminations up to 2cm thick 0.25

Sand, dark-gray (2.5Y 4/1), very-fine-grained; micaceous; with silty sand and clay laminations up to 3cm long 1.67

CORE C44

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; shelly layer 2cm thick this interval at 0.23m 1.56

Sand, coarse-grained; shelly; fragments up to 8cm 0.09

Sand, dark-gray (5Y 4/1), medium- to fine-grained; micaceous; abundant shell fragments;shell fragments up to 5cm throughout; shelly sand layers this interval at 0.13-0.17m, 1.48-1.52m, and 1.73-1.79m; abundance of bivalve shells this interval at 1.87-2.05m 2.35

Sand, coarse-grained; interlaminated with silty clay; laminations up to 10cm thick; coarse-grained sand - color gray (5Y 6/1); silty sand - color gray (2.5Y 5/1); piece of wood (sample taken) 6cm long this interval at 0.80m 1.15

Sand, dark-gray (5Y 4/1), medium- to fine-grained; widely scattered shell fragments 0.09

Thickness (meters)

CORE C45

Sand, fine- to very-fine-grained; micaceous 0.02

Sand, coarse- to medium-grained; scattered shell fragments up to 1mm 0.08

Sand, fine- to very-fine-grained; micaceous; scattered shell fragments 0.05

Sand, very-dark-gray (2.5Y 7/0), muddy; some shell fragments 0.10

Clay, dark-gray (5Y 4/1), silty; with laminations of shell hash and silty sand up to 2cm thick 1.20

Clay, silty; laminations of muddy sand up to 3cm 0.15

Sand, dark-gray (5Y 4/1), medium-grained; scattered shell fragments 0.61

Sand, coarse-grained; shell fragments up to 7cm, gastropod and bivalve 0.15

Sand, dark-gray (5Y 4/1), medium- to fine-grained; scattered shell fragments; silty clay lense up to 2mm this interval at 0.59m 1.14

Sand, coarse-grained; abundant shell fragments up to 5cm, bivalves 0.22

Sand, gray (5Y 5/1), medium-grained; silty fine-grained sand layer showing more compaction this interval at 0.30-0.38m 0.49

CORE C46

Sand, dark--gray (5Y 4/1), fine-grained; micaceous; scattered shell fragments; in this interval: concentration of shell fragments at 0.30-0.40m, silty clay with very fine-grained sand at 0.40-0.44m 0.76

Sand, coarse-grained; shelly; silty clay; shell fragments up to 4cm 0.19

Clay, silty; scattered shell fragments....0.10

Sand, silty; scattered shell fragments....0.10

Sand, silty; with laminations of silty clay up to 2cm 0.16

Sand, dark-gray (5Y 4/1), medium-grained; scattered shell fragments 0.24

Sand, gray (5Y 5/1), medium-grained; small amount of silt and clay; scattered shell fragments; shell hash this interval at 0.05-0.11m 0.34

Thickness (meters)

Sand, gray (5Y 5/1), fine-grained; laminated with silty clay; laminations range from 2-10cm; shell hash with fine-grained sand this interval at 0.32-0.36m 1.21

Clay, gray (5Y 5/1), silty; laminations of fine-grained sand; laminations range from 1-5cm; in this interval: coarse-grained sand layer at 0.36-0.42m; pod of coarse-grained shelly sand at 1.38-1.42m; shell fragment 5cm at 1.60m 1.68

Sand, coarse-grained; shelly; fragments up to 4cm 0.06

Sand, dark-gray (5Y 4/1), medium-grained; scattered shell fragments <1mm 0.48

Sand, medium- to fine-grained; with silty clay laminations up to 2cm 0.16

Sand, coarse-grained; abundant shell fragments; silty clay layer this interval at 0.03-0.05m 0.28

Sand, medium- to fine-grained; scattered shell fragments about 1mm 0.36

CORE C47

Sand, dark-gray (5Y 4/1), fine- to very-fine-grained; micaceous; silty-clay lamination this interval at 0.40-0.43m 0.56

Clay, dark-gray (5Y 4/1), slightly silty; with laminations of coarse- and fine-grained sand; laminations range from 1-5cm; several large shell fragments up to 8cm this interval at 0.99m 1.84

Sand, coarse-grained; shelly; scattered shell fragments up to 5cm; silty-clay layer this interval at 0.20-0.30m 0.45

Sand, gray (5Y 5/1), medium- to coarse-grained; widely scattered shell fragments up to 1mm; trace of subangular gravel 0.70

CORE C48 RUN-1, RUN-2, RUN-3

Run-1

Sand, light-olive-brown (2.5Y 4/4), medium- to coarse-grained; scattered shell fragments up to 2cm 0.82

Sand, olive-gray (5Y 4/2), fine- to coarse-grained; fewer scattered shell fragments than above 1.06

Run-2 jetted-1.92m, penetration-4.39m, recovery-3.99m

Sand, light-olive-gray (5Y 6/2), coarse- to medium-grained; with pods of darker colored coarse- to medium-grained sand; trace of shell fragments up to 2mm; in this interval: plastic plug at 0.47-0.57m; large shell fragment 5cm at 1.42m; layer of dark gray coarse to medium-grained sand, olive gray (5Y 4/2) at 1.50-1.66m; and 1.70-2.02m 2.02

Sand, dark-gray (5Y 4/1), coarse- to medium-grained; scattered shell fragments; pods of light brownish gray (2.5Y 6/2) 1.00

Sand, fine- to medium-grained 0.13

Sand, dark-gray (5Y 4/1), coarse- to mediun-grained; pods of light-brownish-gray (2.5Y 6/2); layer of medium- to fine-grained sand this interval at 0.25-0.27m; fine sandy silt at 0.71-0.74m 0.80

Run-3 jetted-4.24m, penetration-6.04m, recovery-1.22m

Sand, olive-gray (5Y 4/2), medium- to fine-grained; widely scattered shell fragments in this interval, becoming coarse- to medium-grained at 1.40m; becomes very shelly, fragments up to 1.5cm grayish brown (2.5Y 5/2) at 1.60m 1.91

Sand, dark-gray (5Y 4/1), medium- to fine-grained; plastic plug this interval at 0.11-0.19m 0.27

CORE C49

Sand, light-olive-gray (5Y 6/2), medium- to coarse-grained; widely scattered shell fragments 0.50

Sand, olive-gray (5Y 5/2), medium- to coarse-grained; widely scattered shell fragments in this interval; color mottle of light-olive-gray (5Y 6/2) at 0.20-0.25m; larger percentage of coarse-grained sand near bottom 1.11

Sand, dark-gray (5Y 4/1), coarse- to medium-grained; scattered shell fragments up to 1cm 1.52

Silt, very clayey 0.02

Sand, olive-gray (5Y 5/2), fine- to medium-grained; scattered shell fragments; becomes finer toward bottom; shell fragments to 2.5cm 0.86

Sand layers, dark-gray (5Y 4/1), fine-grained and silty, fine-grained 0.13

Clay, silty; pods of medium- to coarse-grained shelly sand; shell fragments up to 3cm 0.21

Clay, gray (5Y 5/1), silty; pods of silty fine shelly sand 0.22

Clay, silty; and shelly medium- to fine-grained sand in patches; gravel in medium- to fine-grained sand ; shells up to 3cm 0.56

Thickness
(meters)

Sand, fine- to very-fine-grained; micaceous; widely scattered shell fragments up to 0.5cm 0.61

CORE C50

Silt, dark-gray (5Y 4/1); micaceous; with very-fine-grained sand and clay; pod of fine-grained sand this interval at 0.42m; grading into below 0.54

Clay, silty; micaceous 0.30

Sand, very-dark-gray (5Y 3/1), mottles of fine-grained sand and clay; more sandy and less silty toward bottom 0.29

Clay, gray (5Y 5/1) 0.41

Clay, dark-gray (2.5Y 4/1), silty; well compacted 0.46

Clay 1.07

Clay, dark-gray (2.5Y 4/1), silty; well compacted; scattered shell fragments this interval at 0.18m and 0.53m 1.53

Clay, silty; compacted; shell concentrations this interval at 0.54m and 0.70m 1.11

Clay, very-dark-gray (5Y 3/1), silty; fine-grained sandy 0.06

Shell hash, dark-gray (5Y 4/1), in clay matrix 0.39

HEAVY-MINERAL VARIABILITY AND PROVENANCE OF THE VIRGINIA INNER SHELF AND LOWER CHESAPEAKE BAY

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ABSTRACT

The mineral composition of the 3- to 4-phi (0.125 to 0.063 mm) size fraction of 49 surficial grab samples, located north and south of the entrance to Chesapeake Bay and of 38 surficial samples, located in the bay mouth, was determined during this study. Although up to 17 minerals were identified, principal components analysis indicated that seven minerals accounted for 96 percent of the composition variance in the bay samples. By using Q-mode factor analysis, three mineral composition end-members (factors) were selected from the sample data and provided an adequate description of the spatial variation in heavy-mineral composition. The end-members suggest possible mineral sources.

One end-member (amphibole, pyroxene, and epidote), shows that the interior of the bay is a possible source for the amphibole and pyroxene in the samples. A second end-member, comprised of zircon, garnet, and amphibole, suggests two different sources for the sediment, (one source is in the lower bay and the other is south of the bay mouth). The sample composition gradient of a third end-member, comprised of garnet, amphibole, and epidote, suggests sediment transport into the bay resulting from southerly littoral drift along the Delmarva Peninsula. This sediment flux from the north does not appear to bypass the bay mouth and move south, at least not in the sampled area extending up to 5 km offshore.

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INTRODUCTION

FACTOR ANALYSIS

When dealing with a large number of samples and many columns of observed measurements, such as heavy-mineral data, it is commonly difficult to determine meaningful trends related to geologic processes by merely inspecting the data. Q-mode factor analysis, a mathematical procedure, can be used in an attempt to simplify such multi-variable data. Because this study relies on Q-mode factor analysis, definition of terms and a brief explanation of the method is given here; however, references and a more complete discussion is given by Berquist (1986).

Successful use of Q-mode factor analysis can result in a reduction of the number of variables in a large array of data to a few new variables, called factors. The factors, just like samples, have a defined composition in terms of the original variables; the compositions of all samples are then redefined in terms of a few factors instead of the many, original variables. For the analysis of mineral-composition data in this study (the minerals are the variables), we required that the composition of each of the factors (new variables) should approximate the composition of actual samples. For example, if three actual samples are mathematically chosen from the data, the result is called a 3-factor solution and the composition of each of the three chosen samples becomes the composition of a respective factor. The original compositions of all the samples are then redefined, and instead of being comprised of garnet, staurolite, zircon, etc., the samples may be comprised of, say, 80 percent factor I, 10 percent factor II, and 10 percent factor III. During the computation, the composition of each factor may be adjusted and then may only approximate the composition of its corresponding actual sample. The "approximated" compositions are called "end-members".

At the completion of the method when applied to heavy-mineral data, an important relationship exists between the factor composition and original variables. The two or three minerals commonly making up the bulk of the composition of each factor define a mineral suite, or mineral assemblage. In other words, the use of Q-mode factor analysis defines mineral suites (factors) and redefines the composition of all samples in terms of these mineral suites.

Successful use of factor analysis on mineral-composition data is followed by more common approaches of explanation and interpretation. Much the same as making a contour map of zircon concentration over a study area, we can make a contour map of factor concentrations. A mineral suite defining a particular factor may be the mineral assemblage that represents a geologic province. The factor composition gradient in the study area should point to the local (as opposed to ultimate) origin (area of highest concentration) of that mineral assemblage. Also, the down-gradient direction should reflect the direction of transport, or dilution, of the mineral suite away from its source. Thus, sediment transport pathways are defined by the gradient patterns. An analogy is the case where a small amount of dye is introduced into a larger amount of water; concentration of the dye will be highest at its source of entry and decrease away from its source. In summary, two reasons, or applications, for using factor analysis on heavy minerals are, one, a geologic province may be identified and, two, a local source and sediment transport directions may be suggested.

HEAVY MINERALS AND SEDIMENT TRANSPORT

Heavy minerals can be used as natural tracers to define provenance or to assist with studies of sediment transport. The relationship of bottom sediment movement between Chesapeake Bay and the inner continental shelf has been discussed by Firek (1975), Firek and others (1977), Berquist (1986), Colman and others (1988), and Hobbs and others (1986). In these studies provenance and transport direction of sediment were identified, but more data were needed from the inner shelf. The recognition of sedimentary provinces in the lower Chesapeake Bay and inner continental shelf is complicated by the existence of multiple sediment sources. Little knowledge about the sediment transport processes make it difficult to separate the effects of the natural estuarine processes from anthropogenic influences in the sediment source areas.

Previous studies (Firek, 1975; Firek and others, 1977; Berquist, 1986) show that the spatial distribution of selected heavy-mineral suites helps to identify the sedimentary provenance of the complex mineral assemblages. Firek and others (1977), using the mineral distribution patterns in conjunction with analysis of variance, were able to identify characteristic mineral suites for arbitrary geographic areas within the lower bay. Firek and others (1977) also subjected seven major heavy minerals to an R-mode factor analysis, using a 2-factor solution, and proposed that sediment maturity and sediment provenance may have contributed to the observed mineral suites. Based on the relationships of the minerals in each factor and on the way the minerals of the predefined areas compared with one another, Firek and others (1977) found evidence of a bayward influx of littoral and inner shelf sediments.

Berquist (1986) combined Firek's (1975) data with new data from near the bay-mouth area. Q-mode factor analysis defined three suites or end-members. Concentration gradients of one of the factors (a mineral assemblage) were not easily explained in terms of provenance. Of the other two factors, one showed sediment transport into the bay, whereas the concentration gradient of the other factor suggested a source within the bay. These findings are in agreement with Firek and others (1977). Firek's (1975) and Berquist's (1986) heavy-mineral trends were based on data from the northern inner shelf and the bay mouth.

The primary objective of the present study is to project

the sediment transport pathways defined by Berquist (1986) and Firek (1975) using the heavy-mineral variability in the Chesapeake Bay mouth into the inner continental shelf of Virginia. A second purpose is to provide more information on particular mineral assemblages along the inner shelf, especially south of the bay. This study includes part of the data previously analysed by Firek (1975) and Berquist (1986) as well as 49 new grab samples from the Virginia inner shelf (Figure 1). The study relies upon heavy-mineral composition gradients obtained through Q-mode factor analysis. Figure 1 defines the study area and shows the location of the samples used.

METHODS

The 49 grab samples used in this study were obtained while conducting a project funded by the Virginia Subaqueous Mineral and Materials Study Commission (Berquist and Hobbs, 1988). Approximately 0.75 grams of the archived heavy mineral samples were sieved to remove the 3- to 4-phi (0.125 to 0.063mm) size fraction. A portion of this fraction was mounted on a glass slide with Caedax. The heavy minerals were point-counted using a petrographic microscope. Seventeen minerals, including opaques, were identified. Based on their apparent variability in the samples only seven transparent minerals were selected for this study. Point counts continued until at least 200 transparent grains were counted on each slide. This resulted in a total count of 300 to 600 grains per slide. This wide range is due to the variable concentrations of the opaques in the samples. To check reproducibility between individual observations, minerals on two slides were identified and counted by two of us, and the results compared. The results showed replication to within 3 percent in each mineral species.

The complete data set included the 49 grab samples and 38 additional samples analyzed with similar methodology from Firek (1975) and Berquist (1986). The final data matrix consisted of seven minerals (zircon, sphene, amphibole, epidote, staurolite, pyroxene, and garnet) from 87 samples (Table 1). These seven minerals (Table 1) were chosen because principal components analysis performed previously by Berquist (1986) showed them to account for 96 percent of the mineral variability among samples, in the lower Chesapeake Bay area. In order that the composition of all samples added up to 100 percent, the composition of samples characterized by more than the seven minerals were normalized.

These data were analyzed by Q-mode factor analysis. The analysis and conclusions are based on the assumption that high concentrations of heavy minerals are found at or near the source (or end-member) and that these concentrations decrease away from the source by dilution with other materials. It is the concentration gradients that make the use of factor analysis particularly suitable. For each factor, the concentrations of the factor in the samples were plotted on a map and values were contoured. The final results are shown in Figures 2, 3, and 4 and in Table 2.

RESULTS AND DISCUSSION

We attempted 2-, 3-, and 4-factor solutions, but the 3-factor solution was chosen as the most appropriate for the problem at hand. The 2-factor solution showed high communality values for each factor used to describe the samples, but large negative end-member compositions made this solution unrealistic. The 4-factor solution showed high communalities and no negative values of end-member compositions, but two end-members were redundant as they had nearly the same composition. The 4-factor solution was rejected.

The best practical description was achieved with the 3-factor solution because it accounted for 98.3 percent of the variance, had positive composition loadings, high communalities for each sample, and provided good reproduction of the raw-data matrix. Most importantly, the locations of the end-members (Figure 1) represented by the 3-factor solution provide a reasonable geologic explanation. The first end-member (composed entirely of factor I material) is located inside the bay midway between the mouth of the James River and Cape Henry. The second end-member (composed entirely of factor II) is located on the inner shelf south of the bay's mouth. The third end-member (composed entirely of factor III) is located in the vicinity of Fishermans Island. The compositions of the end-members are listed in Table 3. Figures 2, 3, and 4 are contoured plots of the factor abundance (listed in Table 2) in each sample from the 3-factor solution.

Factor I is comprised, in order of decreasing abundance, primarily of amphibole, pyroxene, and some epidote (Table 3), and is an immature mineral assemblage. The plot (Figure 2) of factor I shows a trend of decreasing concentration offshore suggesting sediment transport out of the bay and to the south. This interpretation differs from what we should expect from the circulation studies done in the inner shelf adjacent to the bay mouth (Boicourt, 1981; Harrison and others, 1967) and modern shelf and bay sedimentation (Swift and others, 1971; Hobbs and others, 1986; Colman and others, 1988). However, relevant studies regarding sediment transport and bottom types in this area were conducted by Ludwick (1970, 1974) and others, who estimated bottom shear stress and found net sediment transport near the bed can be ebb-dominated around Cape Henry. His studies support our interpretation of offshore transport in this area. Furthermore, Ludwick's (1978) study of coastal currents from the entrance of Chesapeake Bay to south of Virginia Beach found that tidal currents are rotary, with major elliptical axis nearly parallel to the shoreline. These tidal currents produce a net southerly current at depths of 8 to 15 meters. Ludwick postulates that wave motion superimposed on this net southerly tidal current produces a southerly flowing stream of sand about 5 km wide off Virginia Beach (Inman and Dolan, 1989).

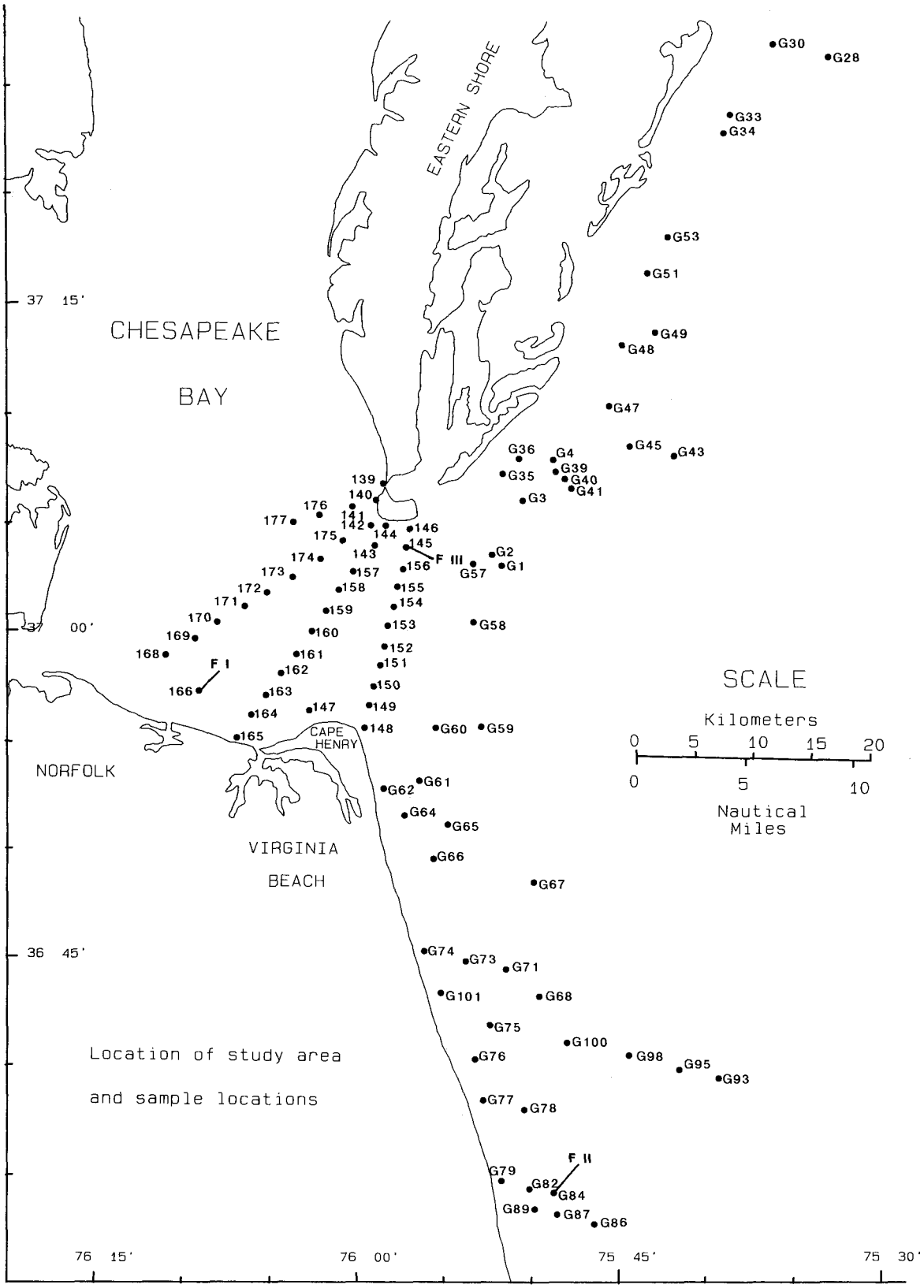

Figure 1. Location of study area, sample sites, and factors (F I, F II, F III).

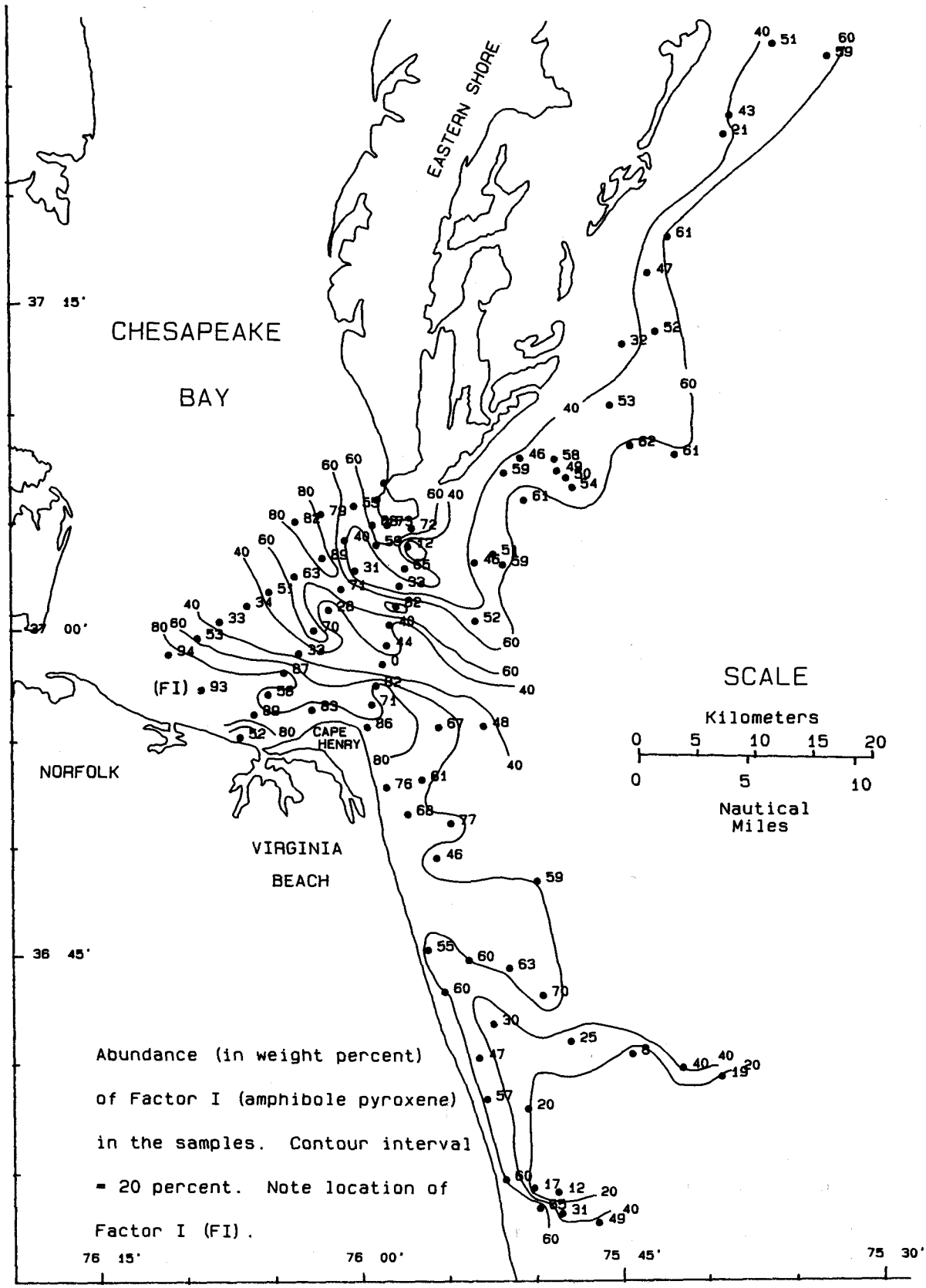

Figure 2. Abundance of Factor I (amphibole, pyroxene) in samples.

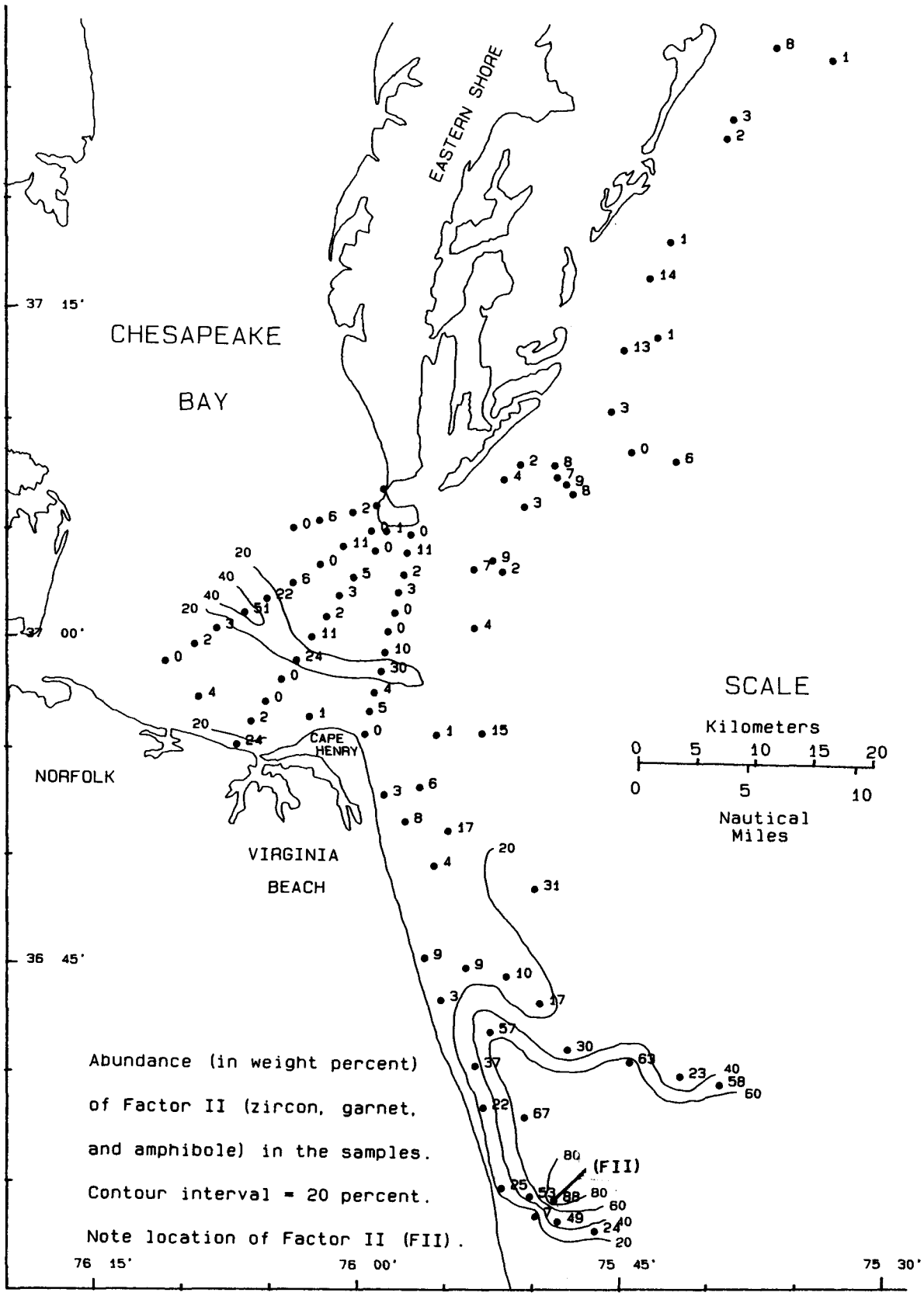

Figure 3. Abundance of Factor II (zircon, garnet and amphibole) in samples.

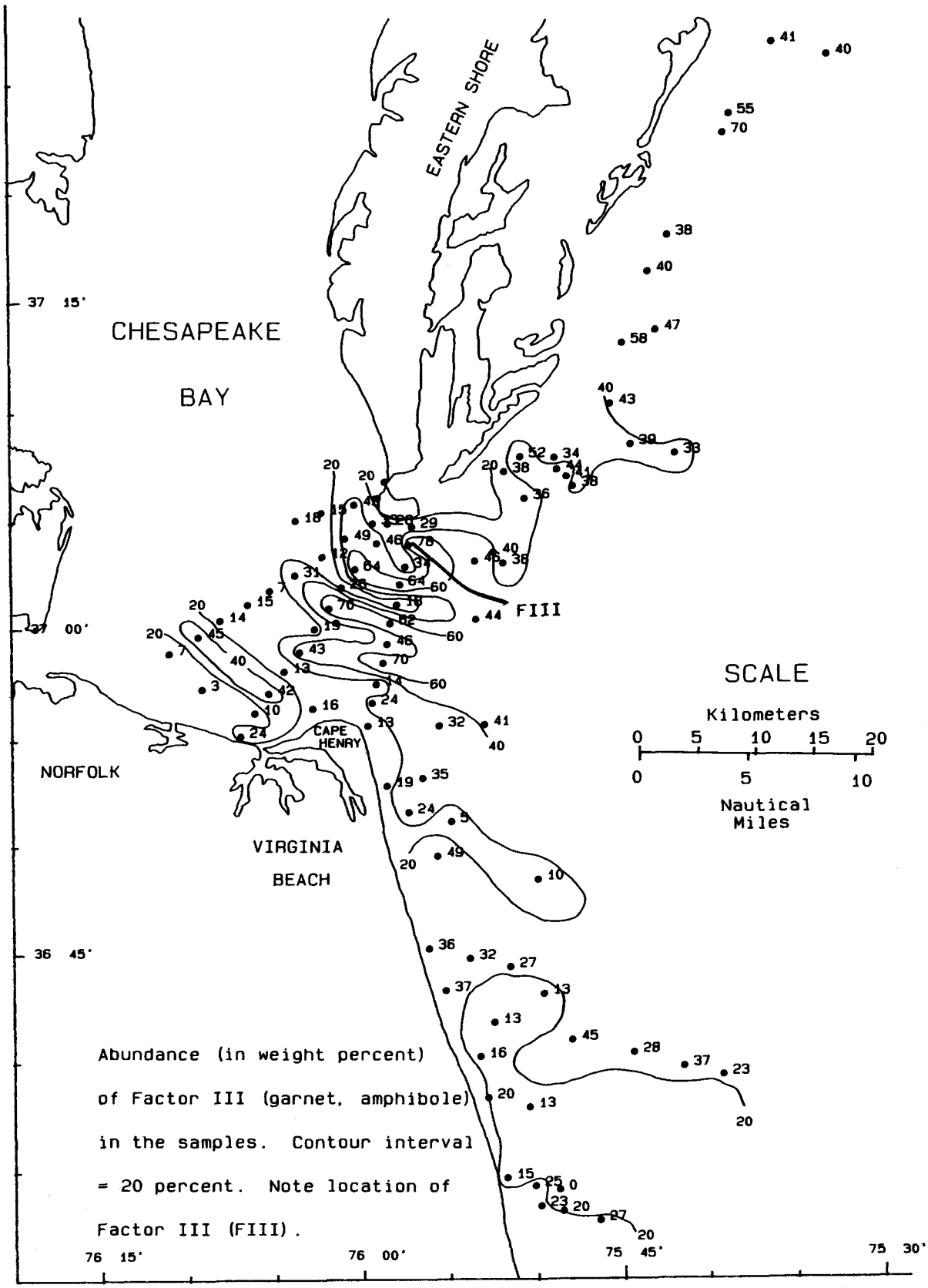

Figure 4. Abundance of Factor III (garnet, amphibole) in samples.

Table 1. Raw-data matrix percentages.

SAMPLE	ZIRCON	SPHENE	AMPHIBOLE	EPIDOTE	STAUROLITE	PYROXENE	GARNET
139	0.00	2.90	60.14	7.25	0.00	13.77	15.94
140	4.14	4.14	47.93	5.92	4.73	12.43	20.71
141	3.27	1.96	47.06	4.58	0.65	14.38	28.10
142	0.60	1.80	56.29	5.99	3.59	10.78	20.96
143	0.00	2.65	48.34	3.97	0.00	17.22	27.81
144	1.72	3.45	55.75	5.17	2.87	13.79	17.24
145	6.94	7.55	24.24	4.48	8.22	5.71	43.57
146	1.16	1.16	56.98	4.65	2.91	13.95	19.19
147	1.39	1.39	61.11	6.25	2.08	15.97	11.81
148	0.56	0.56	56.50	4.52	4.52	22.60	10.73
149	3.52	4.93	58.45	5.63	2.82	7.75	16.90
150	2.40	3.59	55.09	2.40	5.99	19.16	11.38
151	14.86	16.57	17.71	5.14	4.00	1.14	40.57
152	6.67	2.78	36.67	2.22	4.44	17.22	30.00
153	1.40	4.90	42.66	4.90	3.50	6.29	36.36
154	0.58	3.47	53.76	4.05	3.47	21.97	12.72
155	4.03	6.71	36.24	3.36	5.37	7.38	36.91
156	2.35	1.76	51.76	4.71	2.35	14.71	22.35
157	5.00	6.88	35.62	6.25	2.50	6.25	37.50
158	2.21	4.42	52.49	4.97	4.42	14.36	17.13
159	3.57	5.36	36.31	6.55	2.98	4.17	41.07
160	5.26	4.68	48.54	7.02	5.26	14.62	14.62
161	11.80	4.35	32.30	12.42	4.35	6.21	28.57
162	0.58	2.31	59.54	8.67	0.58	18.50	9.83
163	1.35	0.68	52.03	6.76	5.41	7.43	26.35
164	1.16	3.47	47.40	4.62	4.05	30.64	8.67
165	11.26	11.26	41.06	7.95	4.64	5.96	17.88
166	1.69	2.81	56.18	5.62	4.49	23.60	5.62
168	0.00	3.64	55.15	5.45	3.64	25.45	6.67
169	2.60	2.60	49.35	9.09	2.60	5.84	27.92
170	1.73	4.05	50.87	5.78	2.31	24.28	10.98
171	18.07	9.04	24.70	9.04	17.47	5.42	16.27
172	7.82	8.38	35.20	7.82	6.15	25.14	9.50
173	2.70	3.38	47.97	13.51	4.05	9.46	18.92
174	0.56	1.13	62.71	2.26	2.26	20.90	10.17
175	5.77	5.13	35.90	9.62	7.05	7.69	28.85
176	3.77	1.89	54.09	3.77	1.89	21.38	13.21
177	0.67	1.33	61.33	7.33	2.67	14.00	12.67
G30	6.66	0.61	48.48	3.03	0.61	10.91	29.70
G34	4.12	1.03	31.96	9.28	0.00	7.22	46.39
G41	4.55	1.51	42.05	12.50	0.00	15.15	24.24
G45	0.47	0.00	42.72	14.55	0.00	19.72	22.54
G49	2.69	1.61	43.01	6.99	0.00	16.67	29.03
G58	3.77	2.15	41.93	9.14	0.00	15.59	27.42
G59	9.50	1.60	37.40	7.40	0.50	14.70	28.90
G65	8.20	1.09	54.64	10.93	2.19	14.21	8.74
G71	4.95	1.10	44.51	12.64	0.55	17.57	18.68
G84	41.94	1.61	17.20	10.22	3.22	4.84	20.97
G100	13.61	1.18	26.63	17.16	4.14	7.10	30.18
G1	2.87	1.64	47.13	7.38	0.00	16.39	24.59
G2	6.30	1.00	40.80	6.80	0.00	18.00	27.20

Table 1. (continued).

SAMPLE	ZIRCON	SPHENE	AMPHIBOLE	EPIDOTE	STAUROLITE	PYROXENE	GARNET
G3	2.30	0.90	45.60	11.20	0.00	17.20	22.80
G4	4.90	1.00	43.80	9.40	0.00	17.70	23.20
G35	3.44	2.59	49.57	7.76	0.43	11.64	24.57
G36	3.00	2.63	42.10	8.27	0.00	12.42	31.58
G39	5.00	0.50	43.30	10.90	0.50	11.40	28.40
G40	5.70	0.50	42.40	10.90	1.00	12.90	26.70
G57	5.90	1.00	43.30	6.90	0.00	11.80	31.00
G60	1.69	0.42	50.21	8.01	0.00	18.57	21.10
G61	2.60	2.16	45.89	11.25	0.43	15.59	22.08
G62	3.49	0.50	60.70	8.95	0.99	11.44	13.93
G64	5.00	2.00	52.00	8.50	0.50	14.50	17.50
G66	3.85	1.92	38.46	7.69	0.96	16.83	30.29
G67	17.10	0.37	48.33	3.72	0.74	13.38	16.36
G73	4.90	2.86	43.26	9.39	0.41	17.96	21.22
G74	6.50	0.44	48.92	6.06	0.86	11.25	25.97
G75	29.71	0.85	30.12	5.44	2.09	8.79	23.00
G76	17.30	2.00	34.20	11.40	0.00	16.30	18.80
G78	33.47	0.42	23.73	7.20	4.24	6.36	24.58
G28	2.20	0.90	52.60	9.20	0.90	8.80	25.40
G33	3.20	0.90	42.30	11.70	0.40	8.10	33.30
G43	3.50	0.40	43.50	13.00	0.90	17.80	20.90
G47	3.40	1.40	45.70	8.60	0.50	13.00	27.40
G48	8.60	0.00	34.40	8.10	0.50	9.60	37.80
G51	9.04	1.13	46.89	7.34	1.13	5.66	28.81
G53	1.50	0.00	49.50	12.60	0.50	12.10	23.80
G68	8.50	1.00	58.50	15.00	0.00	4.50	12.50
G77	11.34	2.57	50.00	12.37	3.10	3.10	17.52
G79	13.10	1.40	50.50	10.20	1.00	7.80	16.00
G82	30.60	1.60	25.90	6.70	1.60	3.60	30.00
G86	12.30	1.90	41.50	9.40	2.40	10.40	22.20
G87	25.83	1.10	34.07	8.24	2.20	3.84	24.72
G89	4.28	2.14	51.70	8.11	2.56	11.97	19.24
G93	31.60	0.00	27.70	3.03	3.03	4.74	29.90
G95	12.74	1.12	41.20	7.49	4.12	4.87	28.46
G98	31.60	1.00	18.10	9.80	1.00	6.70	31.60
G101	1.80	0.00	46.10	16.00	0.50	13.20	22.30

Table 2. Location and sample composition in terms of factors for the 3-factor solution; negative values were converted to zero before contouring. Factor composition sums may not equal 100 because of rounding.

SAMPLE	LATITUDE	LONGITUDE	FACTOR I	FACTOR II	FACTOR III
139	37.06.8	75.58.5	78	-2	25
140	37.06.0	75.58.8	62	7	32
141	37.05.7	76.00.2	55	2	43
142	37.04.9	75.59.2	68	-1	33
143	37.04.0	75.58.9	59	-4	46
144	37.05.0	75.58.2	73	1	26
145	37.03.9	75.57.1	12	11	78
146	37.04.7	75.56.9	72	0	29
147	36.56.4	76.02.6	83	1	16
148	36.55.6	75.59.5	86	0	13
149	36.56.6	75.59.3	71	5	24
150	36.57.4	75.59.0	82	4	14
151	36.58.5	75.58.6	0	30	70
152	36.59.4	75.58.4	44	10	46
153	37.00.3	75.58.2	40	-2	62
154	37.01.2	75.57.8	82	0	18
155	37.02.0	75.57.6	33	3	64
156	37.02.9	75.57.3	65	2	34
157	37.02.8	76.00.1	31	5	64
158	37.01.9	76.00.9	71	3	26
159	37.01.0	76.01.8	28	2	70
160	37.00.0	76.02.6	70	11	19
161	36.59.0	76.03.4	33	24	43
162	36.58.1	76.04.2	87	0	13
163	36.57.1	76.05.1	58	0	42
164	36.56.2	76.06.0	89	2	10
165	36.55.2	76.06.8	52	24	24
166	36.57.2	76.09.0	93	4	3
168	36.59.0	76.10.8	94	0	7
169	36.59.7	76.09.2	53	2	45
170	37.00.4	76.07.9	83	3	14
171	37.01.2	76.06.4	34	51	15
172	37.01.8	76.05.1	71	22	7
173	37.02.5	76.03.7	63	6	31
174	37.03.4	76.02.1	89	0	12
175	37.04.2	76.00.7	40	11	49
176	37.05.3	76.02.2	79	6	15
177	37.05.0	76.03.6	82	0	18
G30	37.26.64	75.36.13	51	8	41
G34	37.22.64	75.38.84	21	2	77
G41	37.06.56	75.47.70	54	8	38
G45	37.08.46	75.44.32	62	0	39
G49	37.13.68	75.42.81	52	1	47
G58	37.00.49	75.53.23	52	4	44
G59	36.55.63	75.52.89	43	16	41
G65	36.51.15	75.54.85	77	17	5
G71	36.44.41	75.51.51	63	10	27
G84	36.34.10	75.48.76	12	88	0
G100	36.41.05	75.47.94	25	30	45
G1	37.03.03	75.51.69	59	2	38

Table 2. (continued).

SAMPLE	LATITUDE	LONGITUDE	FACTOR I	FACTOR II	FACTOR III
G2	37.03.55	75.52.19	51	9	40
G3	37.05.99	75.50.49	61	3	36
G4	37.07.85	75.48.65	58	8	34
G35	37.07.22	75.51.55	59	4	38
G36	37.07.90	75.50.64	46	2	52
G39	37.07.30	75.48.49	49	7	44
G40	37.06.97	75.48.04	50	9	41
G57	37.03.10	75.53.31	46	7	46
G60	36.55.60	75.55.39	67	1	32
G61	36.53.16	75.56.46	61	3	35
G62	36.52.81	75.58.36	76	6	18
G64	36.51.56	75.57.18	68	8	24
G66	36.49.52	75.55.56	46	4	49
G67	36.48.51	75.49.83	59	31	10
G73	36.44.82	75.53.83	60	8	32
G74	36.45.26	75.56.16	55	9	36
G75	36.41.88	75.52.33	30	57	13
G76	36.40.31	75.53.22	47	37	16
G78	36.37.99	75.50.39	20	67	13
G28	37.26.07	75.33.01	59	1	40
G33	37.23.45	75.38.55	43	3	55
G43	37.07.97	75.41.73	61	6	33
G47	37.10.31	75.45.44	53	3	43
G48	37.13.09	75.44.71	30	13	58
G51	37.16.37	75.43.30	47	14	40
G53	37.17.95	75.42.15	61	1	38
G68	36.43.16	75.49.55	70	17	13
G77	36.38.42	75.52.75	57	22	20
G79	36.34.72	75.51.73	60	25	15
G82	36.34.36	75.50.05	17	58	25
G86	36.32.70	75.46.39	49	24	27
G87	36.33.17	75.48.56	31	49	20
G89	36.33.42	75.49.84	65	7	28
G93	36.39.38	75.39.29	19	58	23
G95	36.39.82	75.41.54	40	23	37
G98	36.40.41	75.44.47	08	63	28
G101	36.43.32	75.55.21	60	3	37

Table 3. Composition of end-members (factors) from the 3-factor solution

FACTOR I sample 166	FACTOR II sample G84	FACTOR III sample 145
64% amphibole	47% zircon	57% garnet
22% pyroxene	23% garnet	24% amphibole
8% epidote	11% amphibole	8% epidote
3% garnet	9% epidote	5% sphene
2% staurolite	6% staurolite	4% zircon
1% sphene	3% sphene	2% staurolite
-.1% zircon	1% pyroxene	1% pyroxene

Factor II is comprised primarily of zircon, garnet, and amphibole and is a more stable mineral assemblage. It is important to visualize the extreme differences in gradients along the inner shelf as well as the middle bay (Figure 3). The highest composition loading values are found south of the bay's mouth with a small area of slightly lower values located in the lower bay. Factor II probably represents reworked deposits of Pleistocene age.

Results of other studies compiled by Berquist (1986) showed that zircon is abundant in ancient coastal plain sediments. Swift and others (1977) have shown through seismic data and vibratory coring that older sediments are exposed on the inner shelf commonly in the troughs of the sand ridges. Recent seismic data provided by Hobbs (this volume) and side-scan sonar results obtained by Green (1986) shows that south of the bay mouth older sediments crop out in the troughs of sand ridges and at other places.

Some of our samples with high concentration of factor II are located in the vicinity of older (Pleistocene?) sediments. The high concentrations of zircon found in Firek's and Berquist's data in samples from the lower bay can be explained by the reworking of the older sediments and erosion of the nearby shoreline. Colman and others (1988) showed that, south and west of the Chesapeake channel, a thin layer of modern sediment covers an irregular Tertiary surface. We believe the two areas of high concentration are related only in that they involve reworking of the older sediments. Gradients do not indicate sediment transport between the two areas.

Factor III is comprised primarily of garnet, amphibole, and some epidote and is also an unstable mineral assemblage. Factor III concentration gradients show trends similar to those shown by previous studies (Figure 4). Firek and others (1977) reasoned that erosion of the east side of Delmarva Peninsula (a source of garnet) was a source of sediment to the bay mouth province. Berquist's (1986) factor III was comprised of the same components (garnet, amphibole, and epidote) as our factor III. Goodwin and Thomas (1973) studied the 0- to-4 phi (1.00 to 0.0625mm) fraction and found high concentrations of garnet, hornblende, and epidote on the shelf between Assateague Island and the Chesapeake Bay mouth. Studies done by Swift and others (1971) also support the idea of the shelf as a source of garnet. Our plot of factor III (Figure 4) suggests an influx of sediment into the bay from the inner shelf off the Eastern Shore, the concentrations decreasing towards the bay.

CONCLUSIONS

The results of this study in the northern section of the bay mouth are consistent with those of Berquist (1986) and Firek (1975). However, the influx of sediment into the bay from the inner shelf is not evident in the southern part of the bay mouth especially around Cape Henry. Three end-members define three sediment sources around the Chesapeake Bay mouth and nearby inner continental shelf. Factor I represents a source from inside the bay where the percent composition decreases towards the bay mouth. Factor II shows the influence of two older sediment sources (possibly Pleistocene), one inside the bay and the other south of the bay mouth on the inner shelf. The gradient patterns do not suggest sediment transport between the inside and outside of the bay. Factor III represents a source located to the north, along the Eastern Shore, and is in agreement with other studies in the northern part of the bay mouth.

The gross sediment transport patterns based on the mineral compositions shown in our work are not entirely consistent with the general model of sediment transport for estuaries. If our defined transport pathways reflect active movement of sand-sized materials, then the generalized models of sediment transport based solely on current studies are insufficient to explain our observations. This suggests a need for more detailed studies in sediment transport that consider spatial variability of bottom types (roughness and sediment composition) and flow regimes. Wright and others (1987) showed that the lower bay and inner shelf are characterized by appreciable spatial variability in both bottom types and benthic flow regimes, which are key factors in controlling the shear stress on the bottom and consequently sediment transport processes.

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CHEMICAL ANALYSES OF OFFSHORE HEAVY-MINERAL SAMPLES, VIRGINIA INNER CONTINENTAL SHELF

C.R. Berquist, Jr.[1]

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ABSTRACT

Major oxide, multi-element and electron-probe point-count analyses were made on the magnetic fractions of eight samples and on 34 bulk samples from 390 offshore heavy-mineral samples. The results of the analyses were tabulated without interpretation.

INTRODUCTION

Gross mineralogic compositions of heavy minerals were determined by optical examination of 390 samples acquired from the continental shelf off Virginia and the entrance to the Chesapeake Bay (Berquist and others, 1990). From these samples geochemical analyses were made on the magnetic fractions of eight samples and on 34 bulk samples (Figures 1 and 2) to enhance the description of offshore minerals. Location coordinates and optically determined compositions of the samples are found in Berquist and others (1990). Anomalously high concentrations of certain elements may indicate optically overlooked, rare, and economically important minerals; for example, anomalously high concentrations of the rare-earth element yttrium could indicate the presence of the mineral xenotime.

The analytic scheme developed not only provides chemical data but also permits comparison of element concentration with mineralogic composition. Although the opportunities for finding composition-chemical relationships in the data by statistical or mathematical methods is recognized, the chemical results are presented without interpretation.

Two analytical methods were both used on two groups of samples. Bulk samples and magnetically separated fractions of bulk samples were selected to be analyzed by "standard"

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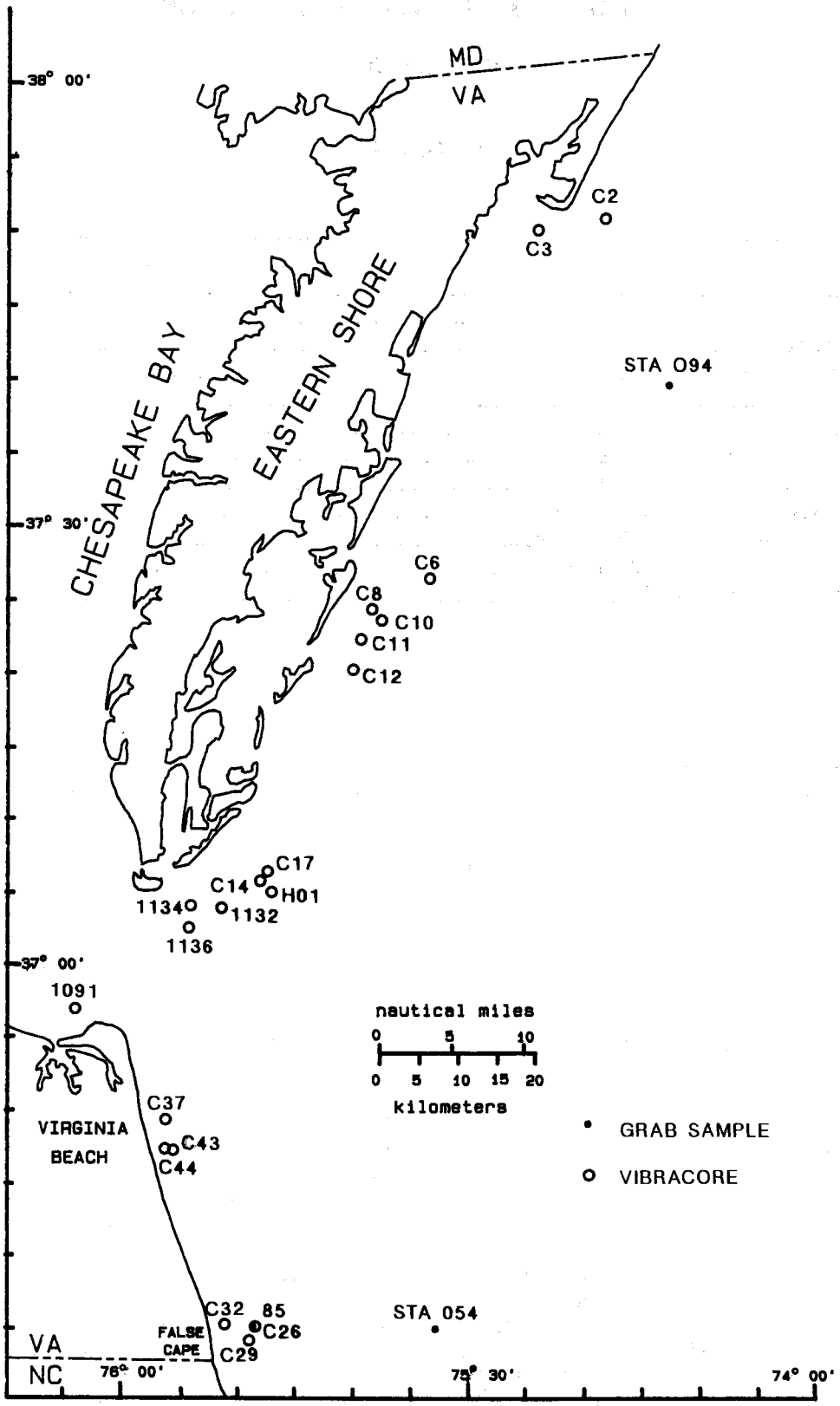

Figure 1. Location of offshore samples.

multi-element (and major-oxide composition) methods and by point-counting with an electron probe. Table 1 shows the selected samples and the applied procedures.

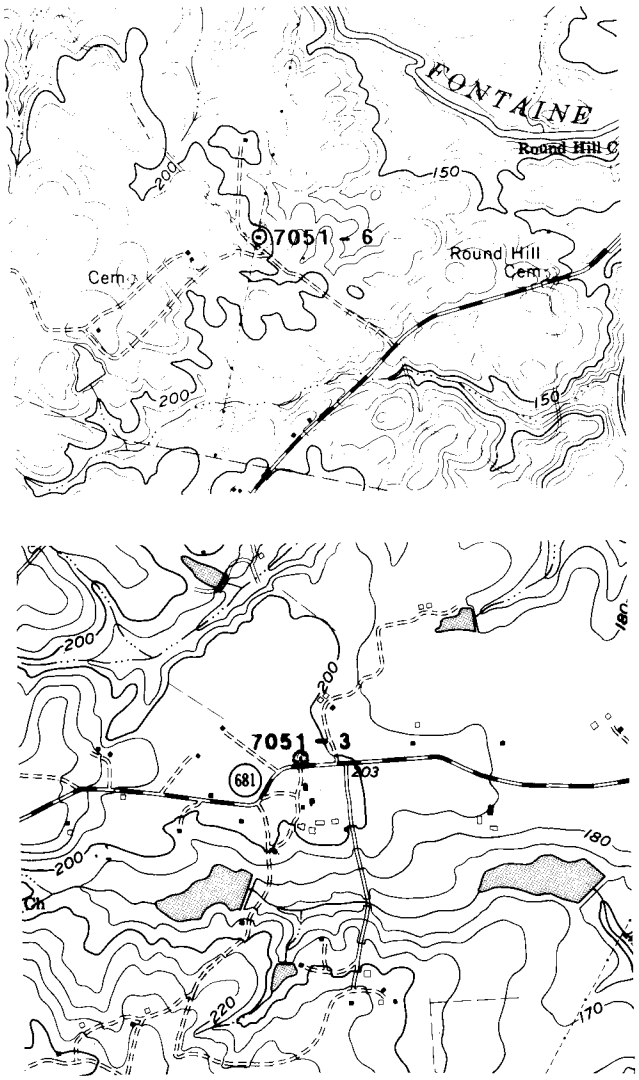

Figure 2. Location of land samples; top map - Emporia 7.5-minute quadrangle; bottom map - Cherry Hill 7.5-minute quadrangle.

Table 1. Selected samples and applied procedures. The "7051" series samples are from an economic mineral deposit on land (Berquist, 1987). Samples "85" "STA-54" and "STA-94" are offshore grab samples. **1** = multi-element and major oxides, **2** = probe point-count.

	BULK SAMPLE		MAGNETIC FRACTIONS OF SAMPLE	
SAMPLE	1	2	1	2
C2-1		X		
C3-2	X			
C3-3	X			
C6-3	X			
C8-2	X	X		X
C10-3	X			
C10-4	X			
C11-4	X			
C12-3	X			
C12-4	X			
C14-3	X			
C14-4	X			
C17-2	X			
C17-4	X			
C17-5	X			
C26-3	X			
C29-1	X	X	X	X
C32-3	X			
C37-1	X			
C43-3	X			
C44-1	X	X		
H01-1		X		
H01-2	X	X	X	X
H01-3	X	X	X	X
1091-1	X	X		
1132-1	X			
1134-1	X	X		X
1134-2	X			
1136-1	X			
7051-3	X	X		
7051-6	X	X		
STA-54	X	X		
STA-94	X			
85	X	X	X	X

SAMPLE SELECTION

A brief explanation of the method used to (label) different bulk and magnetic fractions of samples is given here although the method is described in detail by Grosz and others (1990). The heavy minerals recovered from the processing of sediment samples were divided into three portions. A 12.5 percent portion designated for analytical analysis had the sample identification number suffixed by "-AA". Another 12.5 percent portion was archived and labeled with the suffix "-209"; this means the" -AA" and "-209" identify replicates of the same sample, as listed in the Appendices. The remaining 75 percent of the recovered heavy minerals were split into six magnetic fractions based on mineral magnetic susceptibility; sample (label) suffixes ranged from" -203" for the most magnetic fraction to" -208" for the least magnetic fraction.

Several criteria guided the selection of samples for analysis. Representative coverage over the entire inner continental shelf was desired. Because economic potential is normally based on core data, most of the selected samples are from vibracores identified as containing economic concentrations of minerals (Berquist and others, 1990, Appendix V). Another requirement was that there be enough material to analyze (20 grams of sample was needed for multi-element analysis). Many samples could not be tested because we recovered less than 20 grams of heavy minerals. Three grab samples were chosen as well as sections comprising one entire

core ("H01" series). Finally, samples ("7051" series) representative of heavy minerals from deposits on land (Berquist, 1987) were included for comparison.

ANALYTICAL ANALYSES

MULTI-ELEMENT METHOD

Chemical analyses for 50 elements was done by Nuclear Activation Services, Inc. Four analytical techniques were used: direct current plasma emission spectrometry, X-ray fluorescence spectrometry, atomic absorption, and neutron activation. Certain rare-earth and actinide elements were detected by neutron activation. An intermediate or "exploration" grade was specified for detection limits. Resulting concentrations were on the order of percentages for major oxides and parts per million for minor elements.

Appendices I and II show results of major-oxide and multi-element analysis methods of bulk samples. Appendices III and IV show results of the analysis of the magnetic fractions of samples.

PROBE POINT-COUNT METHOD

Three-hundred grain point-counts were made with an electron probe by CARPCO, Inc. Minerals were identified by computer analysis of probe data through the use of proprietary software. An advantage of this method is the subdivision of ilmenite and leucoxene on the basis of TiO_2 concentration. Furthermore, the rare mineral xenotime and monazite were found in several samples. Appendices V and VI show results of this method on the bulk and magnetic fractions, respectively.

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APPENDIX I

MAJOR OXIDE ANALYSIS OF BULK SAMPLES (weight percent)

Abbreviations for all appendices: AVG = average; STD = standard deviation; MAX = maximun value; MIN = minimum value; LOI = loss on ignition.

SAMPLE	% SiO_2	% Al_2O_3	% CaO	% MgO	% Na_2O	% K_2O	% Fe_2O_3	% MnO	% Cr_2O_3	% TiO_2	% P_2O_4	% LOI	% SUM
C 2-1-AA	29.40	9.26	6.71	4.36	0.74	0.37	24.50	0.76	0.10	16.10	0.87	-0.46	92.71
C 3-2-AA	41.10	8.53	5.45	2.26	1.05	0.47	19.30	0.79	0.08	13.50	0.67	-0.01	93.19
C 3-3-AA	34.60	8.73	6.23	3.47	0.89	0.46	22.40	0.72	0.19	14.50	0.88	-0.69	92.38
C 6-3-AA	28.70	8.59	9.13	3.79	0.74	0.37	27.30	1.01	0.06	11.10	1.38	1.54	93.71
C 8-2-AA	28.20	8.71	8.15	3.48	0.79	0.36	29.90	1.14	0.07	11.80	1.16	-0.46	93.30
C 8-2-209	28.20	8.80	7.75	4.33	0.64	0.42	29.70	0.65	0.06	11.70	1.23	-0.46	93.02
C 10-3-AA	37.50	8.11	7.95	3.27	0.86	0.46	24.50	0.84	0.06	9.17	1.03	0.62	94.37
C 10-4-AA	38.50	8.02	7.96	3.26	0.90	0.49	23.70	0.78	0.05	8.77	0.98	1.69	95.10
C 11-4-AA	40.70	8.88	7.07	2.96	0.93	0.41	22.00	0.87	0.07	12.30	0.89	-0.01	97.07
C 12-3-AA	29.80	7.71	6.65	2.76	0.72	0.24	35.50	1.40	0.09	12.60	0.95	-0.46	97.96
C 12-4-AA	29.00	7.26	6.37	2.48	0.76	0.27	35.50	1.36	0.09	12.80	0.94	-0.46	96.37
C 14-3-AA	33.80	8.56	10.10	4.11	0.80	0.46	24.00	0.78	0.07	8.47	1.33	1.69	94.17
C 14-4-AA	30.00	8.40	9.75	3.70	0.75	0.38	27.70	0.93	0.08	9.80	1.44	0.62	93.55
C 17-2-AA	36.20	8.00	8.06	3.13	1.00	0.44	25.70	0.86	0.08	9.19	1.10	0.62	94.38
C 17-4-AA	29.60	8.70	9.97	4.11	0.63	0.36	27.60	0.97	0.08	9.49	1.46	0.46	93.43
C 17-5-AA	29.00	8.05	9.89	4.01	0.73	0.36	27.70	0.94	0.08	9.76	1.36	1.69	93.57
C 26-3-AA	27.10	7.95	8.15	3.44	0.64	0.32	29.60	1.07	0.07	12.70	1.25	1.38	93.67
C 29-1-AA	18.40	7.32	4.08	2.07	0.53	0.17	31.30	1.39	0.13	29.20	0.35	-0.46	94.48
C 32-3-AA	21.20	7.85	5.28	2.04	0.69	0.23	28.70	1.14	0.11	23.30	0.85	-0.15	91.24
C 37-1-AA	31.00	8.77	8.27	3.50	0.81	0.40	24.70	0.98	0.08	13.00	1.18	0.31	93.00
C 43-3-AA	26.30	8.57	7.04	4.55	0.66	0.39	25.70	0.81	0.11	17.60	1.14	-0.30	92.57
C 44-1-AA	29.40	9.48	8.63	4.76	0.61	0.43	25.50	0.67	0.10	12.90	1.36	-0.30	93.54
85-AA	17.80	5.50	2.35	2.00	0.76	0.17	31.00	0.96	0.09	31.50	0.26	-0.84	91.55
1091-1-AA	31.20	9.16	7.74	4.45	0.66	0.47	23.70	0.68	0.11	14.40	1.11	-0.15	93.53
1132-1-AA	22.10	6.91	4.87	3.29	0.62	0.26	34.60	0.78	0.08	17.60	0.72	-1.07	90.76
1134-1-AA	21.10	6.85	4.36	3.05	0.66	0.24	35.60	0.82	0.08	18.90	0.65	-1.38	90.93
1134-2-AA	21.40	6.53	4.66	2.99	0.64	0.24	36.70	0.79	0.08	17.40	0.78	-1.07	91.14
1136-1-AA	25.70	7.25	5.39	3.32	0.75	0.33	33.10	0.74	0.07	15.70	0.83	-0.92	92.26
7051-3-AA	10.90	4.77	0.07	0.78	1.14	0.03	18.50	0.69	0.05	46.20	0.13	1.31	84.57
7051-6-AA	12.70	7.84	0.09	0.88	1.05	0.03	17.80	0.76	0.06	43.00	0.16	0.85	85.22
H01-1-AA	32.30	9.57	6.10	4.55	0.71	0.45	24.50	0.69	0.07	14.80	0.50	-0.53	93.71
H01-2-209	35.00	9.27	7.36	4.52	0.78	0.50	24.40	0.63	0.09	11.50	0.88	-0.30	94.63
H01-2-AA	32.70	8.78	6.93	4.27	0.73	0.47	26.00	0.65	0.06	12.20	0.88	-0.38	93.29
H01-3-209	46.90	7.65	5.61	3.24	0.96	0.66	20.40	0.50	0.09	9.31	0.67	0.23	96.22
H01-3-AA	46.90	7.72	5.65	3.26	1.00	0.66	20.30	0.50	0.05	9.28	0.68	0.23	96.23
STA-54-209	24.80	9.40	4.87	3.92	0.59	0.27	25.40	0.84	0.08	21.50	0.31	-0.61	91.37
STA-54-AA	24.80	9.47	5.01	3.04	0.58	0.23	27.40	1.21	1.10	21.50	0.27	-0.01	94.60
STA-94-AA	30.60	9.66	7.26	4.20	0.85	0.39	23.80	1.04	0.00	14.50	0.65	-0.15	92.80
AVG	29.42	8.10	6.52	3.32	0.78	0.36	26.79	0.86	0.08	15.92	0.90	0.05	93.12
STD	8.21	1.06	2.41	1.03	0.15	0.14	5.04	0.22	0.03	8.85	0.36	0.85	2.64
MAX	46.90	9.57	10.10	4.76	1.14	0.66	36.70	1.40	0.19	46.20	1.46	1.69	97.96
MIN	10.90	4.77	0.07	0.08	0.53	0.03	17.80	0.50	0.05	8.47	0.13	-1.38	84.57

APPENDIX II

MULTI-ELEMENT ANALYSIS OF BULK SAMPLES

Concentrations are in PPM (parts per million) except for Au and Ir values in PPB (parts per billion). The symbol "*" indicates no summary statistics were calculated because data was undefined (concentration preceded with "<" symbol). "INTFR" means that detection of an element was not possible because of interference, or masking, of spectral data by another element(s) during the analysis.

SAMPLE	Ag	As	Au	B	Ba	Be	Br	Cd	Co	Cs	Cu	Ge	Hf	Mn	Mo	Nb	Ni	Pb	Rb	Sb	Sc	Se
C 2-1-AA	<0.5	6	<20	290	100	5	180	3	35	<3.2	13.0	40	490	6100	<5	220	58	22	10	1.1	60.0	<10
C 3-2-AA	<0.5	4	<10	180	<10	5	250	<1	29	INTFR	6.5	40	670	4400	<5	700	29	18	40	0.7	47.9	<5
C 3-3-AA	<0.5	6	<20	160	100	4	170	3	26	<3.2	22.0	40	540	5900	<5	190	79	28	<10	1.0	52.1	<10
C 6-3-AA	<0.5	31	<10	340	<10	9	93	<1	34	INTFR	12.0	20	360	4300	7	700	41	8	20	0.7	52.8	<5
C 8-2-AA	<0.5	6	<10	260	<10	7	250	<1	32	INTFR	18.0	40	450	4500	<5	700	32	6	20	0.4	53.1	<5
C 8-2-209	<0.5	5	<20	280	50	5	240	3	37	<3.1	18.0	20	380	5300	<5	170	48	0	30	0.4	54.5	<10
C 10-3-AA	<0.5	10	<10	240	<10	8	130	<1	31	INTFR	4.0	30	290	3700	<5	700	25	6	30	0.6	46.8	<5
C 10-4-AA	<0.5	13	<10	260	<10	7	120	<1	29	INTFR	7.0	40	270	3600	<5	630	33	8	30	0.6	42.3	<5
C 11-4-AA	<0.5	5	<10	260	<10	6	160	1	29	INTFR	5.5	40	490	4100	<5	700	27	6	30	0.6	48.5	<5
C 12-3-AA	<0.5	2	<10	320	<10	9	170	<1	31	INTFR	5.0	40	600	4700	<5	630	26	8	10	0.5	47.7	<5
C 12-4-AA	<0.5	4	<10	170	<10	9	140	<1	30	INTFR	5.5	50	630	4700	<5	630	34	8	30	0.3	47.0	<5
C 14-3-AA	<0.5	5	<10	20	<20	<1	180	<1	33	INTFR	4.0	<10	290	3500	16	630	31	8	30	0.6	51.0	<5
C 14-4-AA	<0.5	6	<10	170	<10	10	140	<1	32	INTFR	5.0	60	360	3800	9	630	31	10	30	0.8	52.1	<5
C 17-2-AA	<0.5	10	<10	200	<10	6	120	<1	31	INTFR	4.0	30	360	3400	<5	630	26	2	20	0.4	46.1	<5
C 17-4-AA	<0.5	8	<10	340	<10	8	110	<1	36	INTFR	3.5	20	310	3800	10	630	33	2	30	0.8	54.6	<5
C 17-5-AA	<0.5	7	<10	270	<10	7	66	<1	31	INTFR	5.0	30	330	3800	<5	630	30	8	30	0.6	49.1	<5
C 26-3-AA	<0.5	37	<10	380	<10	8	150	<1	31	INTFR	7.5	40	490	4100	7	700	36	10	20	1.1	48.8	<5
C 29-1-AA	<0.5	7	<10	390	<10	8	640	1	41	INTFR	18.0	120	790	6500	<5	840	45	30	20	1.2	53.6	<5
C 32-3-AA	<0.5	9	<10	380	<10	6	510	<1	32	INTFR	15.0	90	940	5600	<5	770	41	30	20	1.1	50.4	<5
C 37-1-AA	<0.5	3	<10	320	<10	7	260	<1	30	INTFR	6.0	40	440	4600	9	700	31	6	30	0.7	52.6	<5
C 43-3-AA	<0.5	6	<20	170	70	5	380	2	36	<3.2	15.0	30	400	6800	<5	250	65	12	<10	0.7	63.2	<10
C 44-1-AA	<0.5	6	<20	260	70	5	270	2	35	<3.0	14.0	20	300	5300	<5	200	60	12	<10	1.0	59.0	<10
85-AA	<0.5	5	<20	250	120	5	84	3	27	4	24.0	60	1000	7700	6	350	58	40	20	1.3	47.0	<10
1091-1-AA	>0.5	4	<20	320	80	6	75	3	33	5	16.0	50	470	5300	<5	200	53	12	10	0.9	57.0	<10
1132-1-AA	<0.5	7	<20	160	120	6	74	<1	26	<3.1	16.0	60	750	5800	<5	200	40	12	<10	0.8	48.4	<10
1134-1-AA	<0.5	<3	<20	150	90	6	47	<1	29	6	12.0	60	910	5800	<5	230	36	14	<10	<0.5	45.7	<10
1134-2-AA	<0.5	7	<30	140	120	6	55	<1	28	<3.3	10.0	50	870	5800	<5	220	32	4	<10	0.8	45.1	<10
1136-1-AA	<0.5	<3	<20	190	130	6	70	<1	27	<2.9	12.0	40	640	5500	<5	190	35	8	<10	<0.4	46.1	<10
7051-3-AA	<0.5	18	<30	160	80	3	770	4	19	5	26.0	110	2400	4500	<5	400	46	100	<10	3.9	49.5	<10
7051-6-AA	<0.5	17	<20	330	30	5	280	2	18	<2.9	25.0	100	2300	4700	<5	380	48	110	<10	4.3	46.5	<10
H01-1-AA	<0.5	<3	<20	250	90	4	440	1	34	<3.0	12.0	20	400	5100	<5	210	47	16	10	0.7	51.0	<10
H01-2-209	<0.5	4	<20	260	90	5	95	1	31	4	10.0	20	440	4400	<5	180	46	4	20	<0.4	51.0	<10
H01-2-AA	<0.5	<3	<20	220	110	5	90	<1	29	<3.0	8.0	20	500	4500	<5	170	48	10	20	1.0	49.2	<10
H01-3-209	<0.5	4	<20	160	180	5	78	<1	24	<2.6	9.0	20	390	3300	<5	130	32	4	30	0.6	37.5	<10
H01-3-AA	<0.5	<3	<20	200	140	4	80	<1	26	4	7.0	<10	420	3300	<5	130	31	6	30	0.5	37.1	<10
STA-54-209	<0.5	5	<20	470	70	5	450	2	33	<3.2	17.0	40	570	6400	<5	280	50	24	30	1.0	61.0	<10
STA-54-AA	<0.5	7	<10	430	<10	6	460	<1	37	INTFR	12.0	50	590	5900	<5	770	34	30	30	0.8	59.3	<5
STA-94-AA	<0.5	5	<10	200	<10	6	140	<1	37	INTFR	7.5	60	460	4900	5	700	39	18	20	0.8	59.1	<5
AVG	*	*	*	251	*	*	211	*	31	*	11.5	*	613	4879	*	456	40	17	*	*	50.6	*
STD	*	*	*	93	*	*	171	*	5	*	6.3	*	457	1071	*	242	12	23	*	*	5.9	*
MAX	*	37	*	470	180	10	770	4	41	*	26.0	120	2400	7700	16	840	79	110	<10	4.3	63.2	*
MIN	*	<3	*	20	<10	<1	47	<1	18	*	3.5	<10	270	3300	<5	130	25	0	40	<0.4	37.1	*

Appendix II, (continued).

SAMPLE	Sr	Ta	Th	U	V	W	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Ir
C 2-1-AA	90	15	74	32.9	460	10	300	230	26000	376	662	255	54.2	10.6	7.8	39.9	7.17	<20
C 3-2-AA	160	14	86	38.7	310	9	400	150	27000	411	734	393	54.3	10.1	8.9	39.3	6.97	<20
C 3-3-AA	130	16	80	35.5	370	0	340	210	29000	404	709	309	55.2	11.6	10.5	41.1	7.35	<20
C 6-3-AA	130	10	44	22.1	450	0	280	190	12000	242	495	230	40.9	8.6	7.8	30.9	5.44	<20
C 8-2-AA	110	11	55	24.9	470	5	290	210	16000	267	515	248	42.1	7.5	7.6	32.3	5.66	<20
C 8-2-209	80	11	58	23.0	430	8	240	240	16000	273	523	250	45.2	10.2	8.4	32.6	5.91	<30
C 10-3-AA	120	9	39	17.9	350	7	220	180	9800	200	405	202	33.9	7.5	5.7	27.0	4.46	<20
C 10-4-AA	130	8	36	18.1	350	7	250	160	10000	187	362	185	30.9	6.2	5.7	23.7	3.94	<20
C 11-4-AA	150	11	58	26.7	310	10	310	170	19000	278	521	243	41.2	8.3	7.8	33.5	5.76	<20
C 12-3-AA	100	12	69	31.1	450	8	310	190	19000	315	581	266	44.4	8.2	7.7	37.3	6.39	<20
C 12-4-AA	90	12	75	34.8	470	0	310	180	21000	345	616	280	48.6	7.0	9.0	39.2	6.87	<20
C 14-3-AA	180	9	32	16.7	56	5	240	180	9700	207	408	207	34.7	7.9	6.1	25.9	4.40	<20
C 14-4-AA	160	9	38	19.9	520	7	290	170	12000	240	455	232	38.0	8.0	7.9	30.4	5.07	<20
C 17-2-AA	140	8	39	19.8	390	7	240	160	12000	222	438	206	34.2	6.7	5.3	27.5	4.99	<20
C 17-4-AA	150	9	36	18.3	470	9	250	190	10000	224	435	226	37.0	8.4	5.6	28.4	4.99	<20
C 17-5-AA	160	8	38	20.4	410	6	250	160	11000	220	415	214	34.6	6.4	6.4	28.1	5.03	<20
C 26-3-AA	110	12	68	30.3	420	9	320	190	18000	329	631	308	48.3	9.7	8.5	35.8	6.23	<20
C 29-1-AA	80	24	76	28.7	700	13	220	280	32000	269	493	201	34.3	5.2	5.7	26.4	4.92	<20
C 32-3-AA	110	21	130	48.7	470	13	460	240	40000	602	1090	475	75.7	11.4	11.4	48.8	9.37	<20
C 37-1-AA	150	12	60	25.5	440	10	320	190	17000	294	557	284	43.6	8.0	7.8	32.2	5.73	<20
C 43-3-AA	100	16	62	22.3	410	9	230	260	22000	308	569	282	47.0	8.5	7.3	31.3	5.90	<40
C 44-1-AA	110	11	44	20.1	360	11	200	250	14000	253	495	208	45.3	10.2	11.6	33.2	5.58	<20
85-AA	30	28	190	43.1	630	17	210	430	46000	699	1140	424	77.3	9.5	8.8	37.4	7.27	<50
1091-1-AA	110	14	68	27.5	410	<6	260	250	18000	322	568	204	49.5	10.0	8.8	37.5	6.76	<30
1132-1-AA	50	15	110	42.7	490	12	230	220	35000	469	778	295	60.0	9.2	11.3	45.0	8.81	<20
1134-1-AA	40	17	140	51.0	490	10	210	200	34000	578	976	412	72.1	10.1	11.4	52.0	9.86	<40
1134-2-AA	40	17	120	46.6	460	10	250	190	32000	526	889	355	67.3	11.0	10.9	51.1	10.00	<20
1136-1-AA	60	12	83	39.8	460	<6	220	200	29000	344	630	258	50.2	8.2	7.9	41.7	8.19	<20
7051-3-AA	<10	45	94	42.0	790	19	280	190	120000	108	259	52	13.2	1.8	2.7	38.1	8.13	<20
7051-6-AA	<10	46	150	51.9	630	13	310	250	110000	252	458	99	26.2	2.0	3.8	41.2	9.20	<20
H01-1-AA	80	12	70	21.5	390	15	200	230	18000	283	497	211	40.1	6.6	5.1	26.9	4.96	<30
H01-2-209	110	13	70	24.8	390	<6	230	220	16000	316	550	231	44.9	8.4	7.0	33.1	5.73	<40
H01-2-AA	90	13	77	29.6	360	<6	230	190	19000	320	596	277	47.9	7.7	7.8	36.2	6.60	<20
H01-3-209	100	12	70	23.0	310	<6	210	150	15000	300	514	235	41.7	8.2	6.3	27.6	5.02	<20
H01-3-AA	100	9	71	22.5	260	<6	210	150	15000	298	509	230	41.1	5.4	6.2	28.2	5.30	<20
STA-54-209	70	21	75	26.7	600	<8	170	340	23000	277	485	217	36.9	5.7	5.8	31.9	5.53	<20
STA-54-AA	90	19	64	23.9	490	15	220	240	24000	234	440	190	30.9	4.8	5.2	26.6	4.80	<20
STA-94-AA	120	13	66	24.5	370	7	290	210	18000	298	565	232	43.5	8.1	6.7	29.6	5.36	<20
AVG	*	15	74	29.4	437	*	263	212	25645	318	578	253	44.9	8.0	7.5	34.4	6.3	*
STD	*	9	34	10.1	126	*	58	54	23131	120	188	81	13.2	2.2	2.1	7.1	1.6	*
MAX	180	46	190	51.9	790	19	460	430	120000	699	1140	475	77.3	11.6	11.6	52.0	10.0	*
MIN	<10	8	32	16.7	56	0	170	150	9700	108	259	52	13.2	1.8	2.7	23.7	3.9	*

APPENDIX III

MAJOR OXIDE ANALYSIS OF MAGNETIC FRACTIONS

SAMPLE	% SiO_2	% Al_2O_3	% CaO	% MgO	% Na_2O	% K_2O	% Fe_2O_3	% MnO	% Cr_2O_3	% TiO_2	% P_2O_5	% LOI	% SUM
29-1-203	2.17	0.83	0.40	0.96	0.16	0.05	60.20	0.83	0.40	34.00	0.05	-2.92	97.13
-204	4.38	1.95	0.89	1.30	0.16	0.09	45.50	1.31	0.06	44.30	0.06	-2.38	97.62
-205	29.30	12.90	7.48	5.36	0.51	0.43	22.90	0.75	0.16	14.40	0.18	0.47	94.84
-206	32.90	18.80	10.90	4.27	0.47	0.29	11.50	0.25	0.14	11.20	0.61	2.16	93.49
-207	27.90	10.80	8.91	3.64	0.52	0.45	2.78	0.13	0.05	33.30	0.82	2.93	92.23
-208	31.30	7.97	3.29	1.78	2.72	0.10	0.25	0.54	0.03	12.10	2.08	1.39	63.55
85-203	0.74	0.43	0.12	0.87	0.13	0.03	54.00	0.96	0.34	45.10	0.04	-3.30	99.46
-204	3.29	1.46	0.48	1.07	0.20	0.05	46.60	1.35	0.04	47.10	0.08	-2.61	99.11
-205	24.40	11.10	5.50	4.13	0.47	0.31	26.00	0.95	0.16	21.20	0.29	0.31	94.82
-206	31.20	19.50	11.20	3.53	0.43	0.21	10.30	0.19	0.09	9.33	1.64	1.93	89.55
-207	26.00	9.78	6.22	2.41	0.61	0.38	3.17	0.16	0.06	39.30	0.80	1.47	90.36
-208	49.00	5.09	0.71	1.02	2.58	0.17	0.20	0.53	0.03	9.35	0.38	0.31	69.37
H01-2-203	1.83	0.52	0.36	0.81	0.17	0.05	75.40	0.58	0.12	23.40	0.05	-2.84	100.45
-204	11.60	4.45	1.96	2.23	0.23	0.20	44.50	1.25	0.05	32.90	0.06	-2.46	96.97
-205	39.10	13.30	9.64	7.25	0.73	0.62	21.20	0.63	0.07	4.28	0.19	0.31	97.32
-206	38.60	14.90	14.50	5.89	0.52	0.33	8.07	0.17	0.09	8.03	0.76	1.54	93.40
-207	35.00	8.22	14.90	4.02	0.56	0.47	2.49	0.12	0.03	23.50	1.05	1.70	92.06
-208	54.30	6.41	7.54	1.15	2.22	0.55	0.23	0.35	0.02	5.28	4.37	0.77	83.19
H01-3-203	1.96	0.68	0.35	0.84	0.17	0.06	70.10	0.67	0.09	26.70	0.04	-2.84	98.82
-204	11.80	4.37	1.84	2.11	0.22	0.20	44.80	1.32	0.05	33.60	0.05	-2.46	97.90
-205	38.40	12.90	8.48	7.02	0.72	0.69	23.80	0.74	0.08	4.26	0.12	-0.07	97.14
-206	40.70	14.10	12.90	6.96	0.74	0.58	13.80	0.28	0.07	3.85	0.37	1.31	95.66
-207	45.10	10.40	12.00	4.36	0.87	0.87	4.16	0.12	0.02	12.20	0.79	3.08	93.97
-208	72.50	5.70	4.48	0.92	2.13	0.92	0.37	0.18	0.03	2.28	1.60	1.39	92.50
AVG	27.23	8.19	6.04	3.08	0.76	0.34	24.68	0.60	0.10	20.87	0.69	-0.03	92.54
STD	19.20	5.81	5.01	2.19	0.79	0.26	24.23	0.42	0.09	14.73	0.97	2.09	8.93
MAX	72.50	19.50	14.90	7.25	2.72	0.92	75.40	1.35	0.40	47.10	4.37	3.08	100.45
MIN	0.74	0.43	0.12	0.81	0.13	0.03	0.20	0.12	0.02	2.28	0.04	-3.30	63.55

APPENDIX IV

MULTI-ELEMENT ANALYSIS OF MAGNETIC FRACTIONS

Concentrations are in PPM (parts per million) unless noted in column headings as PPB (parts per billion). The symbol "*" indicates no summary statistics were calculated because data was undefined (concentrations preceded with "<" symbol). "INTFR" means that detection of an element was not possible because of interference, or masking, of spectral data by another element(s) during the analysis. Au and Ir values in PPB.

SAMPLE	Ag	As	Au	B	Ba	Be	Br	C	Co	Cs	Cu	Ge	Hf	Mn	Mo	Nb	Ni	Pb	Rb
29-1																			
-203	<0.5	5	<10	50	130	6	410	<1	54	<2.9	25	50	31	7000	13	400	94	12	<10
-204	<0.5	5	<10	40	100	6	580	3	45	<3.0	29	60	23	12000	7	510	54	20	<10
-205	<0.5	9	<20	560	60	5	710	2	40	5.9	15	30	21	6000	9	220	71	30	20
-206	<0.5	<10	<30	2500	80	6	900	2	46	<4.0	10	20	62	1100	<5	190	45	56	10
-207	<0.5	22	<30	1100	100	5	950	5	16	<4.1	22	60	490	530	<5	600	59	60	10
-208	<0.5	7	<20	80	160	2	220	1	3	<2.4	7.5	70	4900	88	<5	100	14	8	20
85-203	<0.5	8	<10	40	140	7	64	<1	55	<2.6	25	60	18	7800	10	470	68	14	<10
-204	<0.5	8	<10	40	120	7	83	2	40	2.7	28	50	140	12000	5	520	47	30	<10
-205	<0.5	10	<30	370	90	5	110	3	31	<4.1	19	30	310	7300	<5	280	52	56	<10
-206	<0.5	<19	<100	2300	80	6	110	2	37	<16.3	14	40	49	1400	<5	10	74	120	<10
-207	<0.5	23	<30	980	130	5	150	4	18	<4.6	23	80	630	390	<5	690	50	84	<10
-208	<0.5	<3	<20	40	270	2	27	<1	2	<2.0	6.5	50	5100	46	<5	90	14	6	10
H01-2																			
-203	<0.5	<2	<5	<10	150	8	71	<1	37	<1.0	10	30	22	4100	18	270	44	<2	<10
-204	<0.5	4	<5	20	120	7	86	<1	38	<1.0	16	30	27	10000	21	400	33	<2	<10
-205	<0.5	5	<20	320	80	5	100	<1	37	<3.3	3.5	10	86	4300	<5	80	73	12	30
-206	<0.5	<10	<20	2100	50	6	140	<1	35	<11.6	11	20	66	1100	<5	110	80	38	<10
-207	<0.5	12	<20	640	40	4	170	3	7	<3.2	18	40	380	600	<5	450	39	26	20
-208	<0.5	7	<20	40	190	2	50	<1	3	1.0	4.5	10	2800	100	<5	60	9	8	20
H01-3																			
-203	<0.5	2	<7	20	160	8	69	<1	39	<1.4	12	30	28	5700	15	280	52	<2	<10
-204	<0.5	3	<8	20	100	6	79	<1	37	<1.5	19	40	31	11000	<5	410	41	6	<10
-205	<0.5	<4	<20	160	120	5	85	2	45	<3.1	3.5	<10	53	5800	9	80	45	4	20
-206	<0.5	7	<5	790	80	5	120	<1	32	<3.9	4.5	10	33	2000	<5	50	65	20	<10
-207	<0.5	9	<20	880	100	3	130	2	15	<4.0	12	10	190	740	<5	240	43	20	10
-208	<0.5	4	<20	40	360	<1	45	<1	2	<0.8	3.5	<10	1100	72	<5	40	6	4	40
AVG	*	*	*	*	125.4	*	227.5	*	29.7	*	14.2	*	691.2	4215.2	*	272.9	48.8	*	*
STD	*	*	*	*	70.0	*	272.8	*	16.9	*	8.2	*	1453.1	4132.9	*	199.2	*	*	*
MAX	*	23	*	2500	360	8	950	5	*	29	80	5100	12000	21	690	55	94	120	40
MIN	*	<2	*	<10	40	<1	27	<1	2	*	3.5	<10	18	46	<5	10	6	<2	<10

Appendix IV, continued

SAMPLE	Sb	Sc	Se	Sr	Ta	Th	U	V	W	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Ir
29-1																					
-203	0.9	33.9	<10	<10	20	6.5	4.0	1000	5	<10	450	1200	24	48	23	3.3	1.2	<0.7	3.2	0.68	<20
-204	0.9	48.3	<10	<10	32	8.5	4.3	890	10	<10	520	750	26.2	52	<5	4.5	1.5	<1.8	6.6	1.18	<20
-205	1.0	67.7	<10	160	21	130	18.0	410	8	170	310	950	536	870	361	66.4	8.2	8.8	23.3	3.71	<40
-206	3.1	56.2	<10	390	22	520	38.3	380	26	260	500	2500	1850	2820	1010	191	23.7	14.2	16.9	2.03	<20
-207	6.0	42.1	<10	320	56	220	64.1	510	48	530	150	31000	836	1350	585	100	24.6	15.7	59.4	11	<50
-208	1.0	29.7	<10	<10	18	45	117.0	340	24	1100	20	270000	53.0	262	90	14.7	3.5	6.3	109	23	<20
85-203	0.9	40.6	<10	<10	30	5.4	<1.2	1200	8	<10	520	930	9.5	22	17	1.1	1.0	<0.5	1.2	0.26	<20
-204	1.1	43.4	<10	<10	38	34	10.8	800	11	<10	580	5000	114	195	83	13.0	1.9	<1.7	6.7	1.35	<20
-205	0.9	58.8	<10	120	30	290	35.3	440	10	260	320	11000	1070	1730	773	129	15.5	16.4	40.5	6.40	<30
-206	7.8	56.9	<10	430	26	1100	80.9	410	43	590	460	2900	4070	6370	2320	432	68.4	48.9	16.7	4.51	INTFR
-207	5.2	43.5	<10	300	62	450	81.6	570	61	640	180	51000	1640	2490	969	156	24.1	15.5	65.4	11	<20
-208	0.9	30.2	<10	<10	15	50	140.0	250	18	1100	19	230000	17.1	179	8	6.9	2.1	5.5	114	26	<20
H01-2																					
-203	0.4	18.7	<5	<10	13	4.0	2.2	860	4	<10	240	370	11.3	28	13	2.0	0.5	<0.5	1.9	0.35	<20
-204	0.5	51.8	<5	<10	26	8.3	4.1	620	6	<10	280	400	33	96	32	9.8	2.1	3.8	18.3	2.86	<20
-205	<0.5	73.6	<10	160	7	96	15.0	290	<8	240	240	2700	443	738	367	60.4	11.2	8.6	30.3	4.70	<20
-206	2.9	50.8	<20	410	15	460	41.7	380	<27	410	190	2000	1860	2910	1180	208	32.8	22.4	16.8	3.71	<20
-207	3.4	35.4	<10	230	37	150	62.7	400	30	760	83	19000	579	1100	586	119	34.4	20.7	82.3	14	<20
-208	0.6	18.4	<10	110	9	40	97.1	120	10	880	17	120000	107	314	121	29.0	7.9	8.9	83.8	18	INTFR
H01-3																					
-203	0.5	24.3	<5	<10	16	5.4	2.2	860	3	<10	270	410	16.6	37	14	3.1	1.0	0.5	2.8	0.48	<20
-204	0.5	50.2	<6	<10	28	11	8.3	570	13	40	370	480	43.3	104	36	10.6	2.0	3.0	18.9	2.93	<20
-205	0.6	75.4	<10	100	6	70	12.9	260	<8	240	260	1100	350	606	311	51.6	9.2	10.0	35.8	5.73	<20
-206	<0.6	65.6	<10	380	7	230	22.8	350	14	310	200	1400	1080	1730	804	135	19.8	15.0	23.6	3.22	<20
-207	2.0	32.0	<30	290	22	330	52.5	290	18	550	99	8200	1430	2300	1090	179	34.5	22.9	48.8	7.44	<20
-208	0.4	8.2	<10	160	4	24	43.6	58	7	480	16	57000	53.7	150	85	14.5	3.5	4.1	40.2	7.53	<20
AVG	*	44.0	*	*	23.3	178.7	*	510.7	*	*	262.2	34179	677.2	1104.2	*	80.8	13.9	*	36.1	6.8	*
STD	22.7	17.8	*	*	14.6	254.0	*	288.7	*	*	175.6	72106	959.2	1477.4	*	101.6	16.5	*	33.5	7.2	*
MAX	7.8	75.4	*	430	62	1100	140	1200	61	1100	580	270000	4070	6370	2320	432	68.4	48.9	114	26.1	*
MIN	<0.5	8.2	*	<10	4	4.0	<1.2	58	<8	<10	16	370	9.5	22	<5	1.1	0.5	<0.5	1.2	0.3	*

APPENDIX V

ELECTRON PROBE POINT-COUNT ANALYSIS OF BULK SAMPLES

The definition of mineral abbreviations are: LCX = leucoxene; SCND IL = secondary ilmenite; MAGNTITE = magnetite; AL SILCATE = alumino-silicate minerals (kyanite, sillimanite...); STAUR = staurolite; TOURM = tourmaline; PYROX = pyroxene; AMPHBOL = amphibole; KSPAR = potassium feldspar; PLAG = plagioclase feldspar; DOLMITE = dolomite; CROMITE = chromite. Mineral concentrations are in weight percent.

SAMPLE	RUTILE	HI LCX 85-99% TiO_2	LO LCX 65-85% TiO_2	PRI IL 57-65% TiO_2	SCND IL <57% TiO_2	Ti MAGNTITE <5%TiO_2	FE OXIDE	QUARTZ
C- 2-1	1.8	2.8	1.4	6.4	21.1	0.0	0.4	2.1
C- 8-2	1.5	1.1	0.7	2.1	17.4	1.8	8.2	2.4
C-29-1	1.8	0.7	3.1	30.3	17.6	0.8	0.8	2.2
C-44-1	3.4	0.7	2.2	8.7	11.7	0.5	4.1	1.2
85	2.4	2.3	3.3	29.6	24.4	0.4	1.2	4.7
1091-1	3.0	0.7	0.4	13.2	15.7	0.9	2.7	3.8
1134-1	2.3	0.3	2.0	8.7	27.7	1.2	13.7	1.0
7051-3	4.9	16.4	27.6	21.2	2.2	0.0	0.0	1.0
7051-6	9.5	14.7	12.1	27.8	3.2	0.0	0.0	0.4
H01-1	1.5	0.4	3.2	10.4	18.8	0.0	5.3	6.0
H01-2	3.7	0.0	0.7	5.7	17.5	0.5	5.0	6.1
H01-3	2.5	0.0	0.8	4.5	12.1	0.5	7.0	23.3
STA-54	2.1	1.7	1.4	19.6	18.5	0.0	0.4	2.4
AVG	3.1	3.2	4.5	14.5	16.0	0.5	3.8	4.4
STD	2.2	5.5	7.6	10.0	7.3	0.6	4.1	6.0
MAX	9.5	16.4	27.6	30.3	27.7	1.8	13.7	23.3
MIN	1.5	0.0	0.4	2.1	2.2	0.0	0.0	0.4

Appendix V, (continued)

SAMPLE	ZIRCON	MONAZITE	Al SILCATE	SPINEL	GARNET	STAUR	TOURM	PYROX + AMPHBOL
C-2-1	7.4	1.3	1.4	0.4	13.1	1.6	0.5	28.4
C-8-2	4.0	0.0	1.1	0.0	14.0	0.3	0.8	33.5
C- 29-1	4.9	0.0	0.8	0.0	7.9	1.5	1.0	19.6
C-44-1	2.0	0.9	1.1	0.0	13.0	0.3	1.4	36.3
85	8.0	0.8	1.0	0.0	6.9	1.5	0.2	8.3
1091-1	1.6	0.4	1.1	0.0	12.2	1.0	2.2	30.9
1134-1	9.6	0.0	0.2	0.0	13.0	1.7	0.0	12.6
7051-3	22.1	0.0	1.0	0.0	0.0	3.7	0.0	0.0
7051-6	23.0	0.4	1.9	0.0	0.0	6.7	0.2	0.0
H01-1	6.7	0.0	0.3	0.0	13.2	1.3	1.1	25.1
H01-2	5.6	0.0	0.8	0.0	14.2	0.6	0.3	30.0
H01-3	3.5	0.0	0.3	0.0	7.6	0.7	0.3	24.5
STA-54	9.0	0.4	1.0	0.0	15.8	1.5	1.3	17.0
AVG	8.3	0.3	0.9	0.0	10.1	1.7	0.7	20.5
STD	6.8	0.4	0.5	0.1	5.2	1.7	0.7	12.2
MAX	23.0	1.3	1.9	0.4	15.8	6.7	2.2	36.3
MIN	1.6	0.0	0.2	0.0	0.0	0.3	0.0	0.0

Appendix V, (continued)

SAMPLE	KSPAR	PLAG	DOLMITE	APATITE	EPIDOTE	SPHENE	CROMITE	SUM
C-2-1	0.2	0.2	0.0	1.9	5.2	1.7	0.0	99.3
C-8-2	0.0	1.0	0.2	1.4	5.1	3.0	0.0	99.6
C-29-1	0.0	0.4	0.4	2.1	3.3	0.3	0.4	99.9
C-44-1	0.0	0.7	0.0	3.4	6.0	2.1	0.0	99.7
85	0.4	0.4	0.0	0.0	2.7	1.1	0.4	100.0
1091-1	0.2	0.9	0.6	2.5	4.2	1.5	0.0	99.7
1134-1	0.0	0.4	0.0	0.2	3.7	0.8	0.4	99.5
7051-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.1
7051-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.9
H01-1	0.2	1.2	0.6	1.4	2.9	0.3	0.0	99.9
H01-2	0.2	1.4	0.2	2.2	3.8	1.5	0.0	100.0
H01-3	1.0	7.0	1.1	0.3	2.6	0.3	0.0	99.9
STA-54	0.2	0.7	0.2	0.8	5.0	0.8	0.0	99.8
AVG	0.2	1.1	0.3	1.2	3.4	1.0	0.1	99.8
STD	0.3	1.8	0.3	1.1	1.8	0.9	0.2	0.2
MAX	1.0	7.0	1.1	3.4	6.0	3.0	0.4	100.1
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.3

Appendix V, (continued)

SAMPLE	OTHER MINERALS
C-2-1	.4% XENOTIME, .2% MUSCOVITE
C-8-2	.3% BIOTITE
C-29-1	.2% MUSCOVITE
C-44-1	
85	
1091-1	
1134-1	.3% OLIVENE
7051-3	
7051-6	
H01-1	.2% MUSCOVITE
H01-2	
H01-3	
STA-54	

APPENDIX VI

ELECTRON PROBE POINT-COUNT ANALYSIS OF MAGNETIC FRACTIONS

Mineral abbreviations are explained in Appendix V.

SAMPLE	RUTILE	HI LCX 85-99% TiO_2	LO LCX 65-85% TiO_2	PRI IL 57-65% TiO_2	SCND IL <57% TiO_2	Ti MAGNTITE <5%TiO_2	FE OXIDE	QUARTZ
8-2-203	0.0	0.3	0.0	6.9	32.7	1.1	49.3	0.0
-204	0.0	0.4	0.7	14.9	26.1	1.8	5.3	0.2
-205	0.0	0.9	0.4	1.4	0.0	0.0	0.0	1.1
-206	9.7	6.2	0.8	0.0	0.0	0.0	0.0	5.8
-207	22.9	2.0	0.0	0.0	0.0	0.0	0.0	4.3
-208	7.0	0.4	0.0	0.0	0.0	0.0	0.0	10.3
29-1-203	0.0	0.0	0.8	20.3	44.4	2.4	27.3	0.0
-204	0.0	0.0	2.7	39.1	40.8	2.6	0.0	0.4
-205	0.0	1.1	7.9	11.4	4.7	0.0	0.0	0.7
-206	5.3	5.2	3.6	1.8	0.9	0.0	0.0	2.0
-207	29.4	5.1	0.0	0.0	0.0	0.0	0.0	7.0
-208	13.2	0.0	0.0	0.0	0.0	0.0	0.0	8.1
85-203	0.0	0.0	0.3	42.2	48.1	0.0	8.7	0.2
-204	0.0	0.6	0.9	53.2	39.1	0.4	0.0	0.4
-205	1.1	1.4	3.2	30.4	5.6	0.0	0.0	0.7
-206	3.2	6.7	2.4	0.9	0.0	0.0	0.0	1.5
-207	44.4	2.2	0.0	0.4	0.0	0.0	0.0	7.7
-208	0.0	10.7	0.0	0.0	0.0	0.0	0.0	22.0
1134-1-203	0.0	0.0	0.0	2.7	18.9	6.8	69.9	0.2
-204	0.0	0.7	2.3	14.9	38.7	4.9	2.1	0.2
-205	1.6	2.0	2.0	0.4	0.0	0.0	0.5	0.8
-206	7.5	6.9	0.8	0.0	0.4	0.0	0.0	4.7
-207	25.1	1.5	0.0	0.0	0.0	0.0	0.0	4.5
-208	8.9	0.0	0.0	0.0	0.0	0.0	0.0	2.7
H01-2-203	0.0	0.0	0.6	8.6	41.6	2.5	44.3	0.0
-204	0.0	0.7	1.0	17.3	46.1	3.3	2.4	0.6
-205	0.8	0.8	1.7	0.9	0.0	0.0	0.5	0.0
-206	3.8	3.3	0.8	0.0	0.0	0.0	0.0	4.5
-207	19.9	4.0	0.0	0.0	0.0	0.0	0.0	9.9
-208	4.8	0.0	0.0	0.0	0.0	0.0	0.0	36.0
H01-3-203	0.0	0.3	0.3	11.0	46.7	2.4	37.1	0.4
-204	0.0	0.3	1.7	17.4	45.8	0.8	2.1	1.3
-205	0.0	0.0	2.3	5.2	1.3	0.0	0.5	0.7
-206	1.3	0.9	1.7	0.5	0.0	0.0	0.0	1.9
-207	7.1	3.9	0.4	0.5	0.0	0.0	0.0	23.8
-208	1.0	0.0	0.0	0.0	0.0	0.0	0.0	54.4
AVG	6.1	1.9	1.1	8.4	13.4	0.8	6.9	6.1
STD	10.2	2.6	1.6	13.5	19.1	1.6	16.7	11.3
MAX	44.4	10.7	7.9	53.2	48.1	6.8	69.9	54.4
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix VI, (continued)

SAMPLE	ZIRCON	MONAZITE	Al SILCATE	SPINEL	GARNET	STAUR	TOURM	PYROX + AMPHBOL
8-2-203	0.3	0.0	0.0	0.3	1.8	0.0	0.0	6.9
-204	0.0	0.0	0.0	0.0	6.8	0.0	0.0	42.5
-205	0.5	1.0	0.3	0.0	0.0	0.8	2.2	77.4
-206	1.4	1.0	0.6	0.0	0.0	0.0	2.4	41.1
-207	6.0	0.0	3.0	0.7	0.0	0.0	0.0	15.8
-208	39.9	0.0	4.9	0.0	0.0	0.0	0.0	2.6
29-1-203	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.6
-204	1.0	0.0	0.0	0.0	4.2	0.0	0.0	9.0
-205	0.4	0.0	0.0	0.0	7.6	4.7	2.0	44.9
-206	2.6	1.9	0.0	0.4	2.0	7.4	10.3	26.7
-207	4.4	0.9	4.2	0.0	0.0	0.0	2.9	18.3
-208	58.4	0.0	8.8	0.0	0.3	0.0	0.0	1.3
85-203	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
-204	1.3	0.0	0.2	0.0	0.6	0.0	0.0	3.0
-205	3.1	1.7	0.3	0.0	12.9	2.8	0.3	31.3
-206	2.2	8.1	0.0	0.0	0.8	11.1	6.1	33.9
-207	11.0	1.4	6.3	0.3	0.0	0.0	1.1	12.8
-208	54.4	0.0	8.4	0.0	0.0	0.0	0.3	1.1
1134-1-203	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4
-204	0.0	0.0	0.0	0.0	9.3	0.3	0.0	25.6
-205	4.8	3.4	0.3	0.0	4.8	4.9	2.7	58.5
-206	2.5	2.8	0.9	0.0	0.4	0.7	1.4	39.1
-207	14.6	0.5	2.3	0.4	0.0	0.0	0.5	16.7
-208	72.2	0.0	2.7	0.0	0.0	0.0	0.0	0.2
H01-2-203	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.5
-204	0.0	0.0	0.3	0.0	7.9	0.0	0.7	19.1
-205	1.4	1.0	0.0	0.0	9.5	1.5	1.5	73.7
-206	0.9	4.0	0.0	0.0	0.4	3.6	3.7	42.2
-207	3.0	0.0	1.8	0.0	0.0	0.0	1.5	21.5
-208	27.9	0.0	4.8	0.0	0.0	0.0	0.0	0.3
H01-3-203	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.9
-204	0.0	0.0	0.0	0.0	4.7	0.6	0.2	24.2
-205	0.4	0.0	0.0	0.0	12.8	2.4	0.0	70.7
-206	0.0	1.0	0.0	0.0	1.7	3.0	1.6	67.0
-207	2.9	1.1	0.0	0.0	0.0	0.8	1.9	22.6
-208	11.7	0.0	1.1	0.0	0.0	0.0	0.0	0.7
AVG	9.2	0.8	1.4	0.1	2.5	1.2	1.2	23.8
STD	18.2	1.6	2.4	0.2	3.9	2.4	2.1	23.5
MAX	72.2	8.1	8.8	0.7	12.9	11.1	10.3	77.4
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Appendix VI, (continued)

SAMPLE	KSPAR	PLAG	DOLMITE	APATITE	EPIDOTE	SPHENE	CROMITE	SUM
8-2-203	0.0	0.0	0.0	0.0	0.0	0.5	0.0	100.1
-204	0.0	0.0	0.0	0.3	0.0	0.6	0.4	100.0
-205	0.0	1.1	0.0	0.3	11.1	1.4	0.0	99.9
-206	0.0	3.4	0.7	1.6	6.0	18.0	0.0	98.7
-207	0.0	0.3	1.6	10.2	0.3	30.1	0.0	97.2
-208	0.0	2.4	0.7	26.9	0.0	4.9	0.0	100.0
29-1-203	0.0	0.2	0.0	0.0	0.2	0.0	1.5	100.0
-204	0.0	0.0	0.0	0.0	0.2	0.0	0.0	100.0
-205	0.0	0.5	0.0	0.0	13.5	0.6	0.0	100.0
-206	0.0	0.5	0.0	0.0	28.4	0.6	0.4	100.0
-207	0.9	0.9	2.1	1.9	7.4	14.7	0.0	100.1
-208	0.4	0.7	2.8	4.3	0.0	1.7	0.0	100.0
85-203	0.0	0.0	0.0	0.0	0.0	0.0	0.3	100.0
-204	0.0	0.0	0.0	0.0	0.0	0.0	0.3	100.0
-205	0.0	0.0	0.0	0.0	5.2	0.0	0.0	100.0
-206	0.2	0.5	0.0	0.0	21.7	0.6	0.0	99.9
-207	0.7	1.7	0.0	0.3	3.0	6.0	0.0	99.3
-208	1.6	0.2	0.4	0.0	0.0	0.9	0.0	100.0
1134-1-203	0.0	0.0	0.0	0.0	0.2	0.0	0.3	99.7
-204	0.0	0.0	0.0	0.0	0.3	0.0	0.7	100.0
-205	0.2	0.0	0.0	0.0	12.0	0.6	0.4	99.9
-206	0.2	0.7	0.2	0.9	15.9	13.8	0.0	99.8
-207	0.5	1.0	0.2	2.8	3.3	26.1	0.0	100.0
-208	0.6	0.4	0.4	9.3	0.3	2.3	0.0	100.0
H01-2-203	0.0	0.2	0.0	0.0	0.0	0.5	0.0	100.1
-204	0.0	0.0	0.0	0.0	0.3	0.3	0.0	100.0
-205	0.0	0.0	0.0	0.6	6.0	0.0	0.0	99.9
-206	0.0	1.3	0.0	0.3	26.8	3.7	0.0	99.3
-207	0.0	2.3	0.5	2.4	9.0	23.4	0.0	99.2
-208	4.2	8.2	1.5	9.7	0.0	2.4	0.0	99.8
H01-3-203	0.0	0.2	0.0	0.0	0.0	0.2	0.0	100.1
-204	0.2	0.2	0.0	0.0	0.3	0.0	0.0	99.8
-205	0.0	0.0	0.2	0.0	3.1	0.3	0.0	99.9
-206	0.8	2.2	0.0	0.0	15.5	0.3	0.0	99.4
-207	1.1	6.7	1.2	1.7	7.1	14.1	0.0	96.9
-208	4.8	17.8	2.8	3.3	0.0	2.4	0.0	100.0
AVG	0.5	1.5	0.4	2.1	5.5	4.7	0.1	99.7
STD	1.1	3.3	0.8	5.1	7.9	8.2	0.3	0.7
MAX	4.8	17.8	2.8	26.9	28.4	30.1	1.5	100.1
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.9

Appendix VI, (continued)

SAMPLE	OTHER MINERALS
8-2-203	
-204	
-205	
-206	.3% OLIVENE, 1% PYRITE
-207	.6% OLIVENE, 2.3% PYRITE
-208	
29-1-203	
-204	
-205	
-206	
-207	
-208	
85-203	
-204	
-205	
-206	
-207	.4% CORUNDUM, .3% OLIVENE
-208	
1134-1-203	.3% XENOTIME
-204	
-205	
-206	
-207	
-208	
H01-2-203	
-204	
-205	
-206	.3% OLIVENE, .3% CALCITE
-207	.5% MUSCOVITE, .3% CALCITE
-208	.3% CALCITE
H01-3-203	
-204	
-205	
-206	.3% MUSCOVITE, .3% CALCITE
-207	1.8% MUSCOVITE, 1.4% CALCITE
-208	