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RECONNAISSANCE OF ECONOMIC HEAVY MINERALS OF THE VIRGINIA INNER CONTINENTAL SHELF

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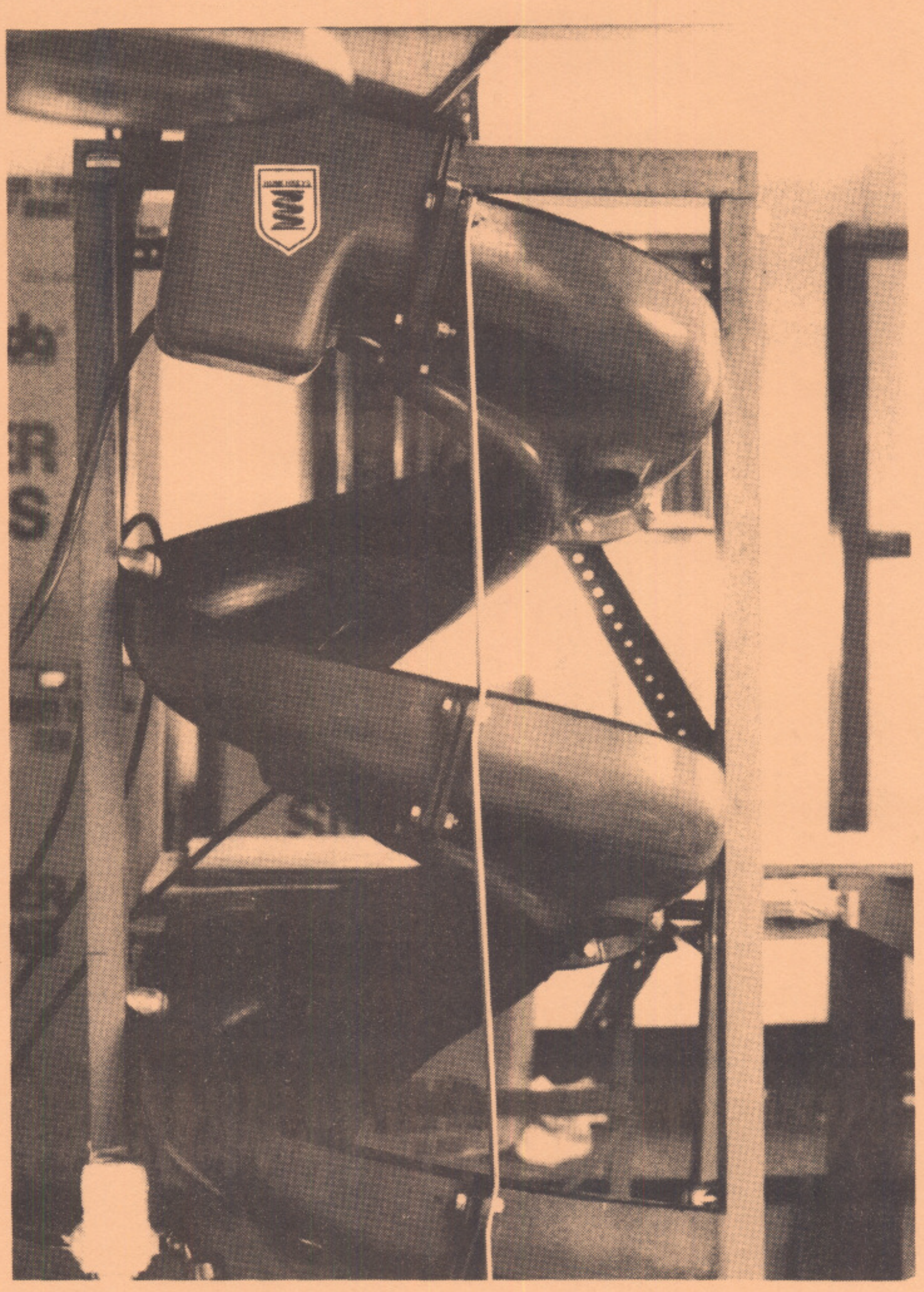

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U. S. Minerals Management Services, and
Virginia Subaqueous Minerals and Materials Study Commission

FRONT COVER: Humphrey's Spiral used for first stage heavy mineral concentration.

Reconnaissance of Economic Heavy Minerals of the Virginia Inner Continental Shelf

by

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Contribution No. 1425, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, Virginia.

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ABSTRACT

The Virginia Division of Mineral Resources and the Virginia Institute of Marine Science acquired and analyzed records of 88 nautical miles of seismic and sidescan surveys and 222 grab and core samples from the Virginia inner continental shelf. The project was supported through combined funding from the U.S. Minerals Management Service and the Commonwealth of Virginia (Subaqueous Minerals and Materials Study Commission) to investigate economic heavy minerals offshore of Virginia.

Procedures used to determine heavy mineral concentrations were designed to provide information helpful to mineral industries. The average weight of a sample was 20 pounds. Some samples were derived from processing 5-foot (average) vibracore sections. Concentration of heavy minerals was done with a three-turn spiral and tetrabromoethane. The sand-size fraction of the heavy minerals was estimated from six magnetically separated subfractions by using transmitted- and reflected-light microscopes.

Concentrations of one or more minerals from 33 samples surpassed typical values for economic land-based deposits. The threshold values of the heavy mineral fraction that were used are: ilmenite, 45 percent; leucoxene, 5 percent; rutile, 2 percent; zircon, 5 percent; staurolite, 20 percent; monazite, 1 percent; and a total heavy mineral (THM) concentration of 4 percent. The THM concentration for all samples averaged 3.5 percent and the highest value was 14.7 percent. Offshore sediments sampled by vibracoring are probably Holocene in age and average about 30 feet in thickness. Core penetration into underlying Pleistocene or Tertiary sediments was not attained. High concentrations of THM, ilmenite, zircon, and, to a lesser extent, rutile and monazite support the conclusion that economic mineral occurrences exist on the inner continental shelf of Virginia and suggest that further exploration is justified.

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 sidescan sonar and subbottom profile surveys from April 1986 through September 1987 on the inner continental shelf of Virginia. The project was funded by the U. S. Minerals Management Service and the Commonwealth of Virginia. Work performed with funding from the U. S. Minerals Management Service (MMS) 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 of the total effort during the past 20 months in describing the heavy mineral occurrences offshore of Virginia. It is both a final report to the Minerals Management Service for year-three funding and an interim report to the Subaqueous Minerals and Materials Study Commission following their first year of funding.

The Virginia Division of Mineral Resources and the Virginia Institute of Marine Science entered into a cooperative agreement with the Bureau of Economic Geology, University of Texas at Austin, (the Bureau was acting as agent for the Minerals Management Service) and began the project in January 1985. During this project geophysical surveys (sidescan sonar and high-resolution shallow seismic) were made and sediment samples were taken from offshore areas with reported high concentrations of heavy minerals (Nichols, 1972; Goodwin and Thomas, 1973; Grosz and Escowitz, 1983). The project was supported by the Minerals Management Service year-two program with funds from Virginia Division of Mineral Resources and Virginia Institute of Marine Science. A report was delivered to Minerals Management Service in early 1986, and the results were published by the Virginia Division of Mineral Resources (Berquist and Hobbs, 1986).

Based on the previous data and surveys, the Subaqueous Minerals and Materials Study Commission solicited and received proposals from the Virginia Institute of Marine Science and the Virginia Division of Mineral Resources to expand the work initiated by the Minerals Management Service project. The Commission recommended a research program to the General Assembly and the Governor (Subaqueous Minerals and Materials Study Commission, 1987). The program to assess the heavy-mineral potential offshore of Virginia was funded for the period July 1986 through June 30, 1988.

In January 1986, the Virginia Division of Mineral Resources and the Virginia Institute of Marine Science began, with Minerals Management Service year-three funding, vibracoring at several sites, analyzing the cores for heavy minerals, and making geophysical surveys of these and additional sites. In April 1986, cores were aquired at Smith Island Shoals, within the Chesapeake Bay mouth, and east of Virginia Beach.

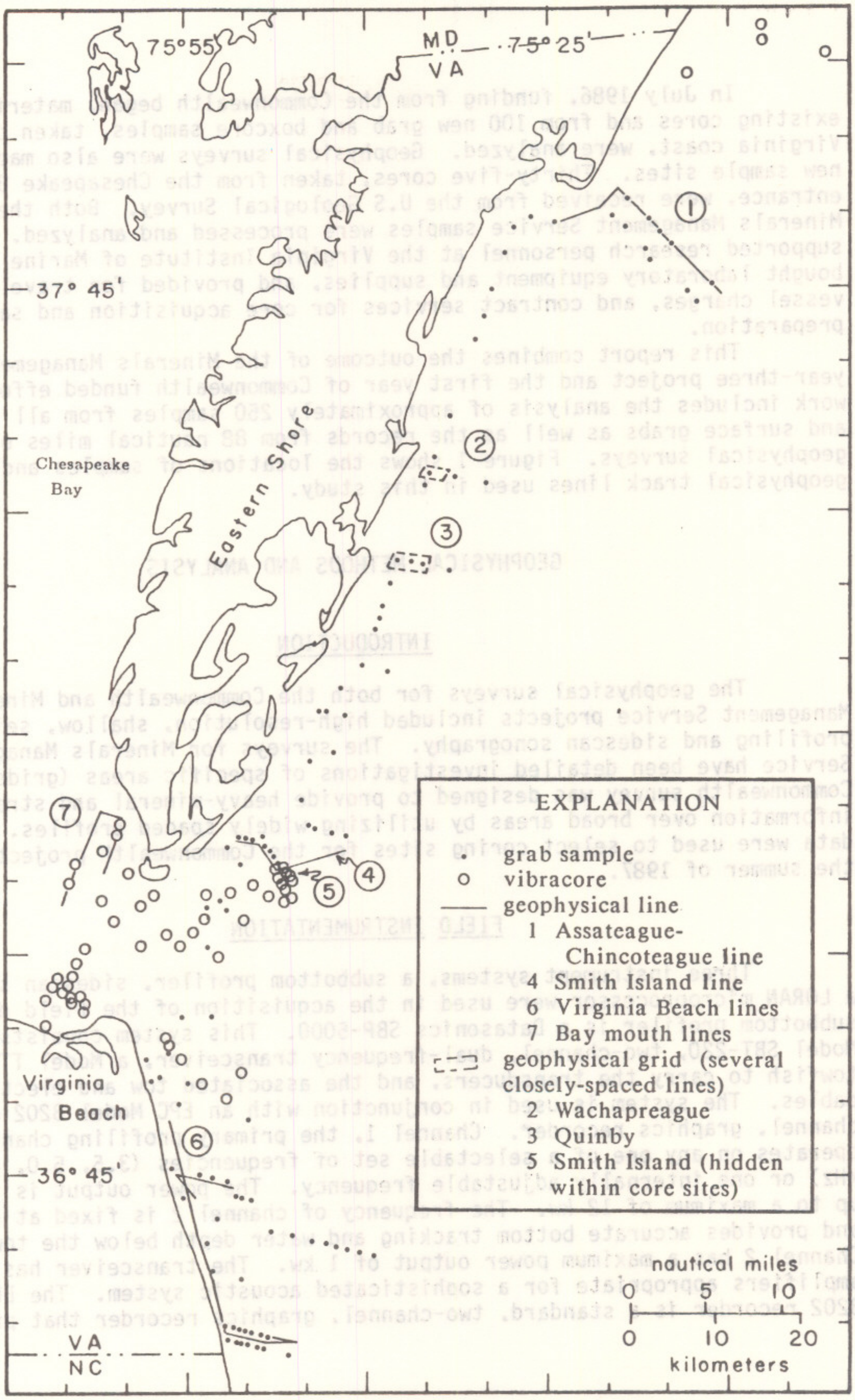

Figure 1. Location of samples and geophysical tracklines.

In July 1986, funding from the Commonwealth began, materials from existing cores and from 100 new grab and boxcore samples, taken off the Virginia coast, were analyzed. Geophysical surveys were also made at the new sample sites. Thirty-five cores, taken from the Chesapeake Bay entrance, were received from the U.S Geological Survey. Both these and the Minerals Management Service samples were processed and analyzed. Funding supported research personnel at the Virginia Institute of Marine Science, bought laboratory equipment and supplies, and provided for travel, research vessel charges, and contract services for core acquisition and sample preparation.

This report combines the outcome of the Minerals Management Service year-three project and the first year of Commonwealth funded efforts. The work includes the analysis of approximately 250 samples from all the cores and surface grabs as well as the records from 88 nautical miles of geophysical surveys. Figure 1 shows the locations of samples and geophysical track lines used in this study.

GEOPHYSICAL METHODS AND ANALYSIS

INTRODUCTION

The geophysical surveys for both the Commonwealth and Minerals Management Service projects included high-resolution, shallow, seismic profiling and sidescan sonography. The surveys for Minerals Management Service have been detailed investigations of specific areas (grids). The Commonwealth survey was designed to provide heavy-mineral and stratigraphic information over broad areas by utilizing widely spaced profiles. These data were used to select coring sites for the Commonwealth project during the summer of 1987.

FIELD INSTRUMENTATION

Three instrument systems, a subbottom profiler, sidescan sonar, and a LORAN microprocessor were used in the acquisition of the field data. The subbottom profiler is a Datasonics SBP-5000. This system consists of a Model SBT-220, two-channel, dual-frequency transceiver, a Model TTV-220 towfish to carry the transducers, and the associated tow and electronics cables. The system is used in conjunction with an EPC Model 3202 dual-channel, graphics recorder. Channel 1, the primary profiling channel, operates on any one of a selectable set of frequencies (3.5, 5.0, and 7.0 kHz) or one internally adjustable frequency. The power output is variable up to a maximum of 12 kw. The frequency of channel 2 is fixed at 200 kHz and provides accurate bottom tracking and water depth below the tow vehicle. Channel 2 has a maximum power output of 1 kw. The transceiver has amplifiers appropriate for a sophisticated acoustic system. The EPC Model 3202 recorder is a standard, two-channel, graphics recorder that produces a hard copy of the seismic data on electrostatic paper. The adjustable sweep rate of the recorder sets both the repetition rate of the transceiver and the scale of the hard copy.

The sidescan sonar, an EG&G Model SMS 960, is an advanced system sonar that produces nearly planimetrically correct images of the sea floor. The system uses a Model 272 towfish that transmits and receives a 105 kHz acoustic signal in an arc that is normal to the trackline. During the work for this project, the system was set to scan 100 meters (approximately 330 ft) to each side of the towfish. The system's chart-paper rate of advance is adjustable and is automatically scaled to the speed of the vessel. When operating in the 100-m half-width, the image is set at a scale of 1:10,000.

As noted elsewhere in this report, the strength of the reflected signal is indicative of the character of the bottom. Strong reflections, dark areas on the record, result from solid objects, indurated sediments, or bedforms oriented so as to reflect the acoustic signal directly toward the transducer. Light areas on the record result from poor reflection caused by absorption of the acoustic signal by fine-grained soft sediments, scattering of the returned signal, or shadow zones behind raised areas.

To create mosaics of the sidescan images, to determine the speed of the ship over the bottom (to set the sidescan's chart speed), and to be able to return to specific sites, it is necessary to have an accurate and precise navigational system that functions in real time. The R/V Langley is equipped with a Northstar 6500 LORAN-C receiver-processor. LORAN-C is the standard, general-service navigational system for coastal waters. The microprocessor and peripheral additions allow real-time calculations of latitude and longitude (by proprietary software within the microprocessor), speed over the bottom, heading, and other information. The LORAN-C coordinates (time delays) and the other data may be printed automatically on associated equipment.

INDIVIDUAL SITES

The Smith Island Grid (Figure 1) was the subject of an earlier report (Berquist and Hobbs, 1986) and will not be discussed in detail. The sidescan mosaic of the Quinby Grid (Figure 2) is nearly featureless. The only significant variation on the otherwise uniform sonographs is caused by a topographically generated increase in reflection along the eastern portion of the grid. There are one or two minor variations in reflection that are apparently caused by minor changes in bottom topography. The seismic profiles (Figures 3a and 3b) indicate a relatively hard bottom, because there is little penetration of the acoustic signal. In some sections, there are indications that the surface layer of Holocene material over older sediments is approximately 5 meters thick.

The Wachapreague Grid (Figure 1) is somewhat more informative. The interpretation of the sidescan data (Figure 4) shows a number of features that generally follow the changes in bottom topography. The seismic profiles (Figure 5) also depict the bottom topography. These data indicate the relationship between the sidescan imagery and the bottom morphology.

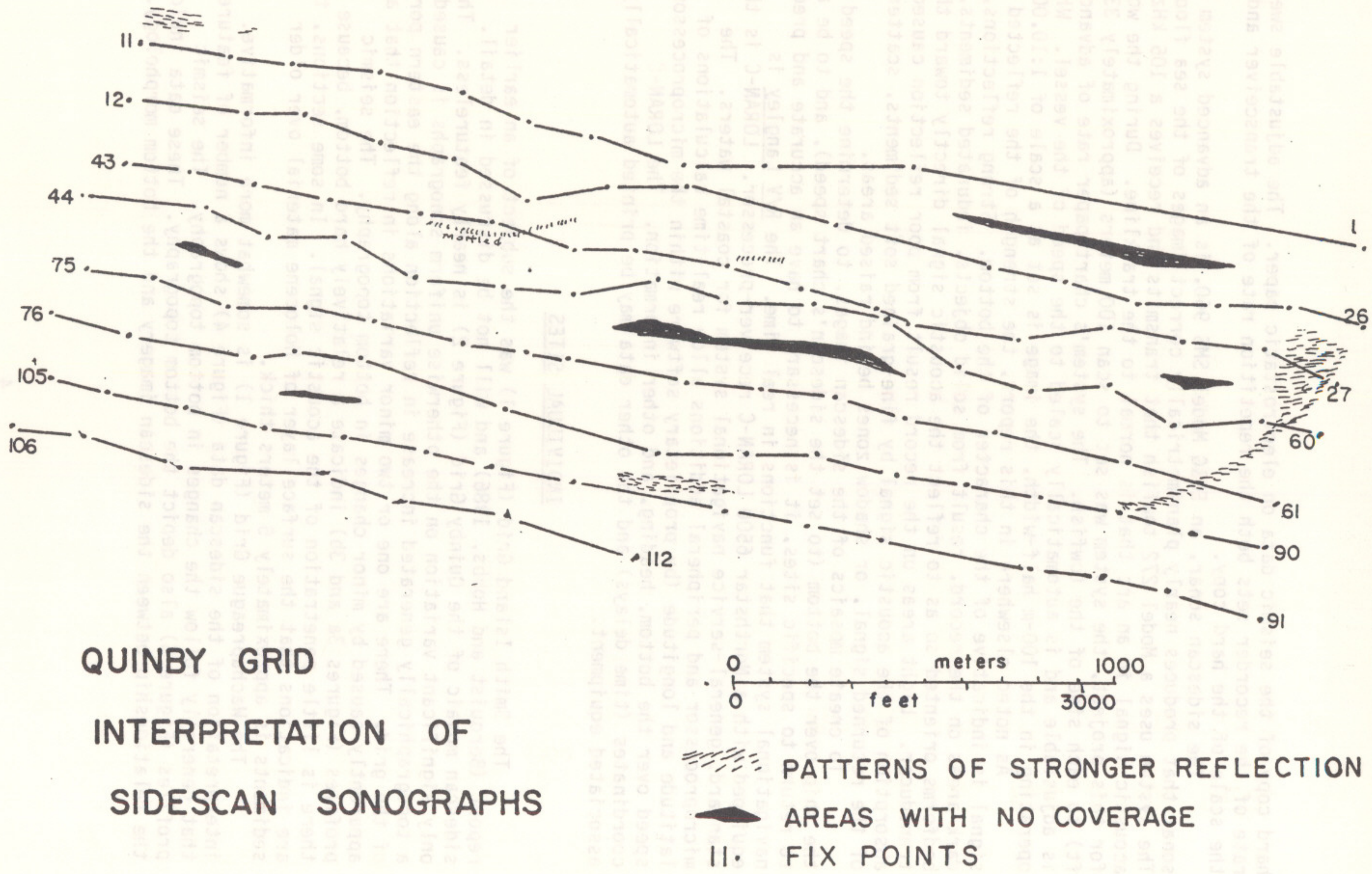

Figure 2. Interpretation of Quinby grid sidescan mosaic.

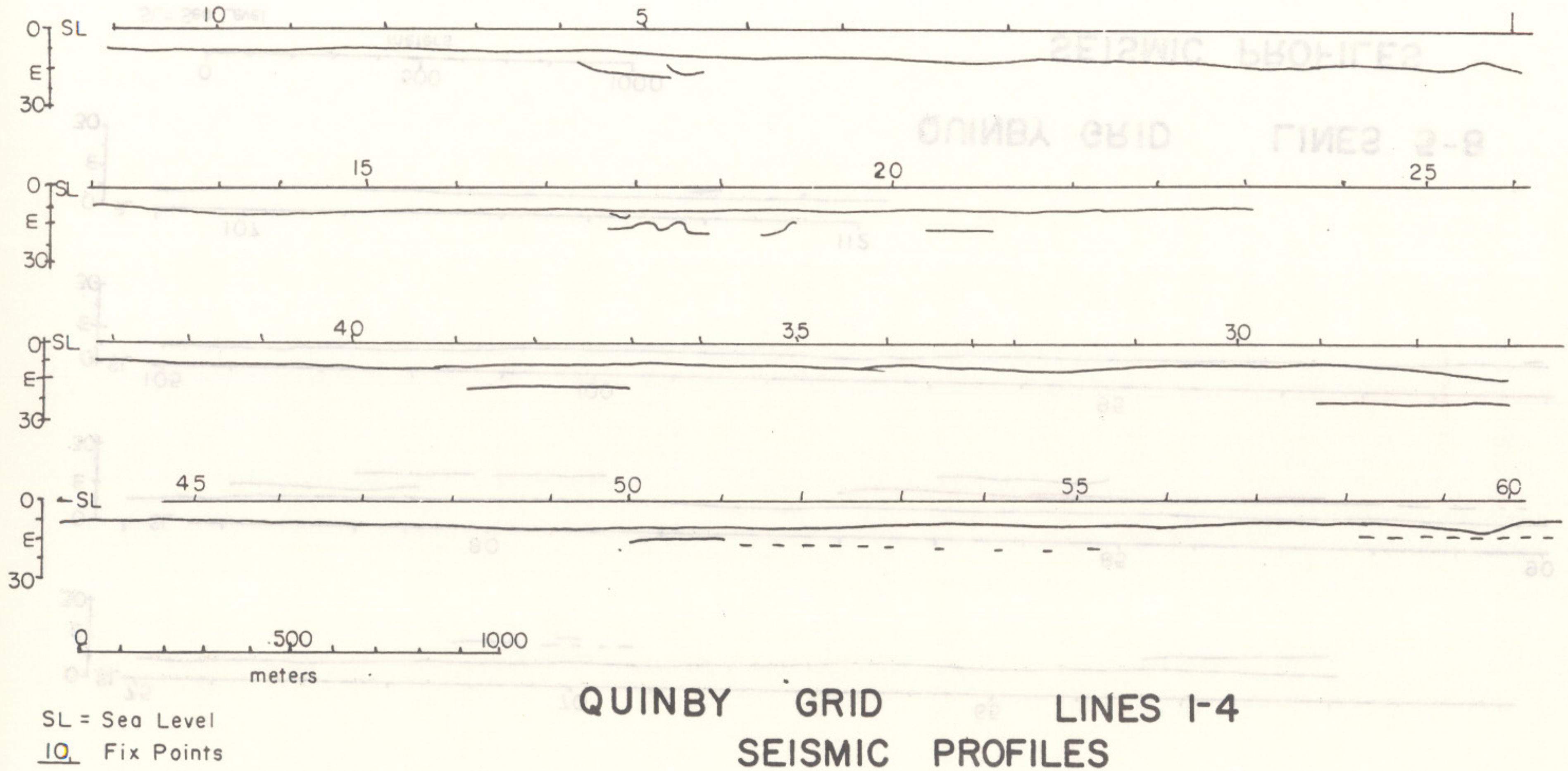

Figure 3a. Interpreted subbottom profiles from the Quinby grid.

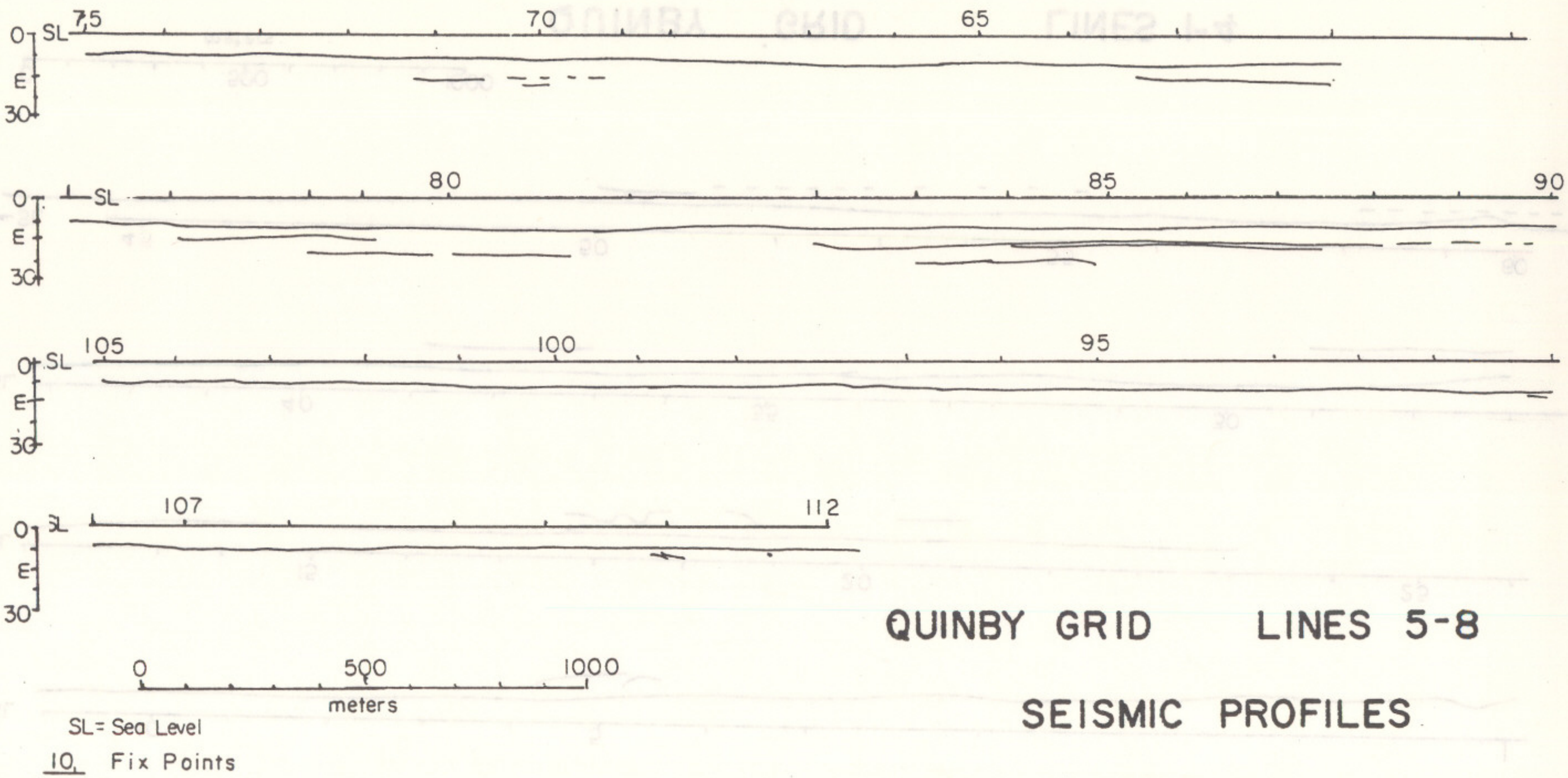

Figure 3b. Interpreted subbottom profiles from the Quinby grid.

Some of the sidescan features, particularly those in the northwestern corner of the mosaic, however, do not appear to have a direct relation to the topography. They may be related to the hardness of the bottom or the roughness of the bottom sediment.

The bottom topography at the Wachapreague site exposes underlying stratigraphy. As determined from seismic data in the northernmost line of the grid between fixes 11 and 12, a separate stratigraphic unit appears at the abrupt 2- to 3-meter rise. Similar relationships are evident throughout the area where profiles were obtained. Heavy-mineral concentrations in surficial samples from this site could be representative of different subsurface strata.

A single track line offshore of Assateague and Chincoteague shows that similarly complex patterns exist in the subbottom profiles and sidescan sonographs (Figure 6). The ridgelike features in the bottom topography in this area appear to be composed of discrete sedimentary units.

The reconnaissance seismic survey off Virginia Beach (Figures 7 and 8) shows several acoustic layers between 2 and 5 meters thick. Individual topographic features appear to be confined to specific strata; however, the relationships among elevation (altitude), bottom form, and stratigraphy appear to be better defined than in other locations. Thus, surficial samples may be useful when taken in the specific context of their bathymetric and stratigraphic setting.

The single seismic line off Smith Island (Figure 9) is relatively uninformative. The bottom sediments are hard and so tightly packed that very little of the acoustic signal was able to penetrate the bottom.

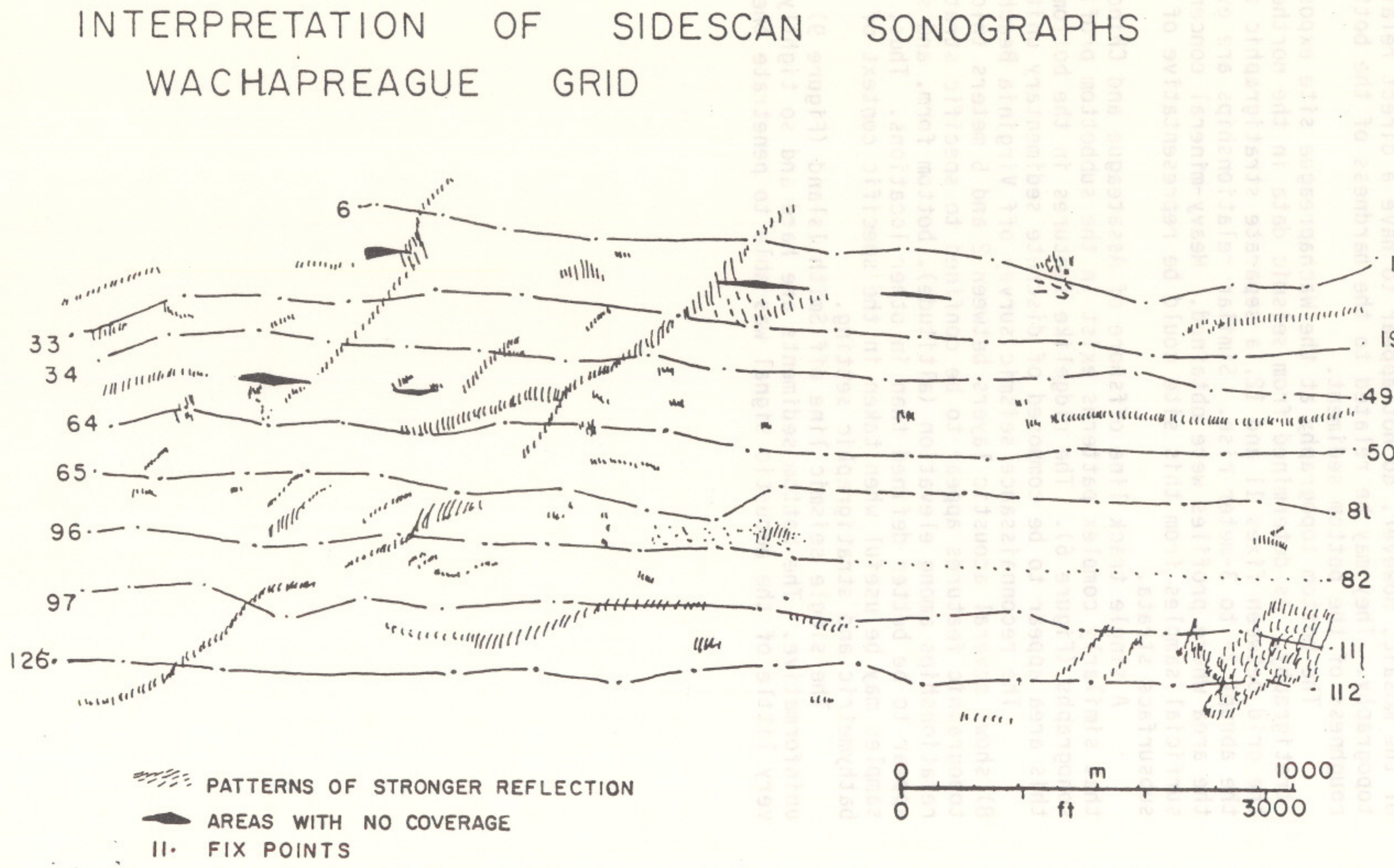

Figure 4. Interpretation of the Wachapreague grid sidescan mosaic.

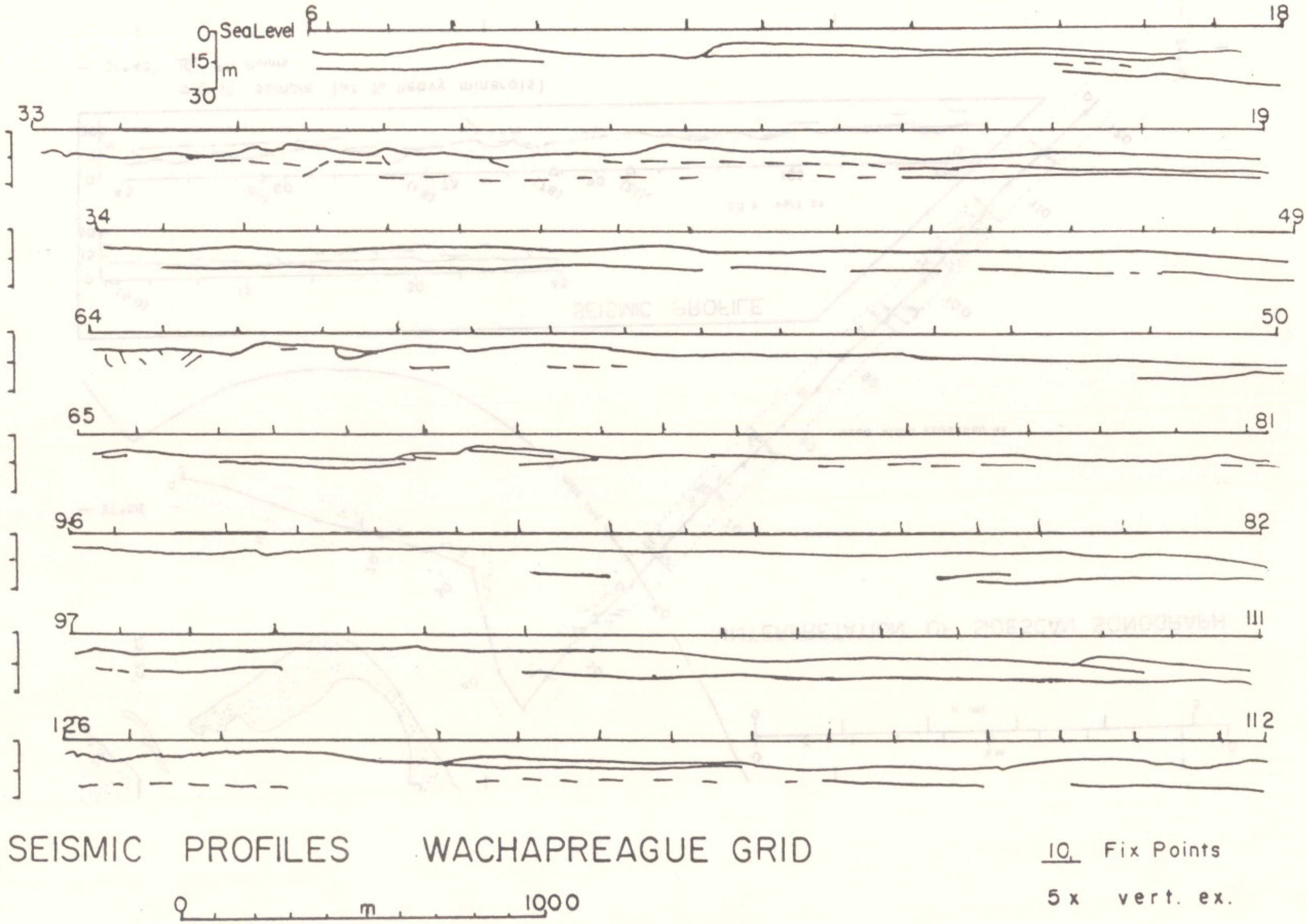

Figure 5. Interpretation of the Wachapreague grid subbottom profiles.

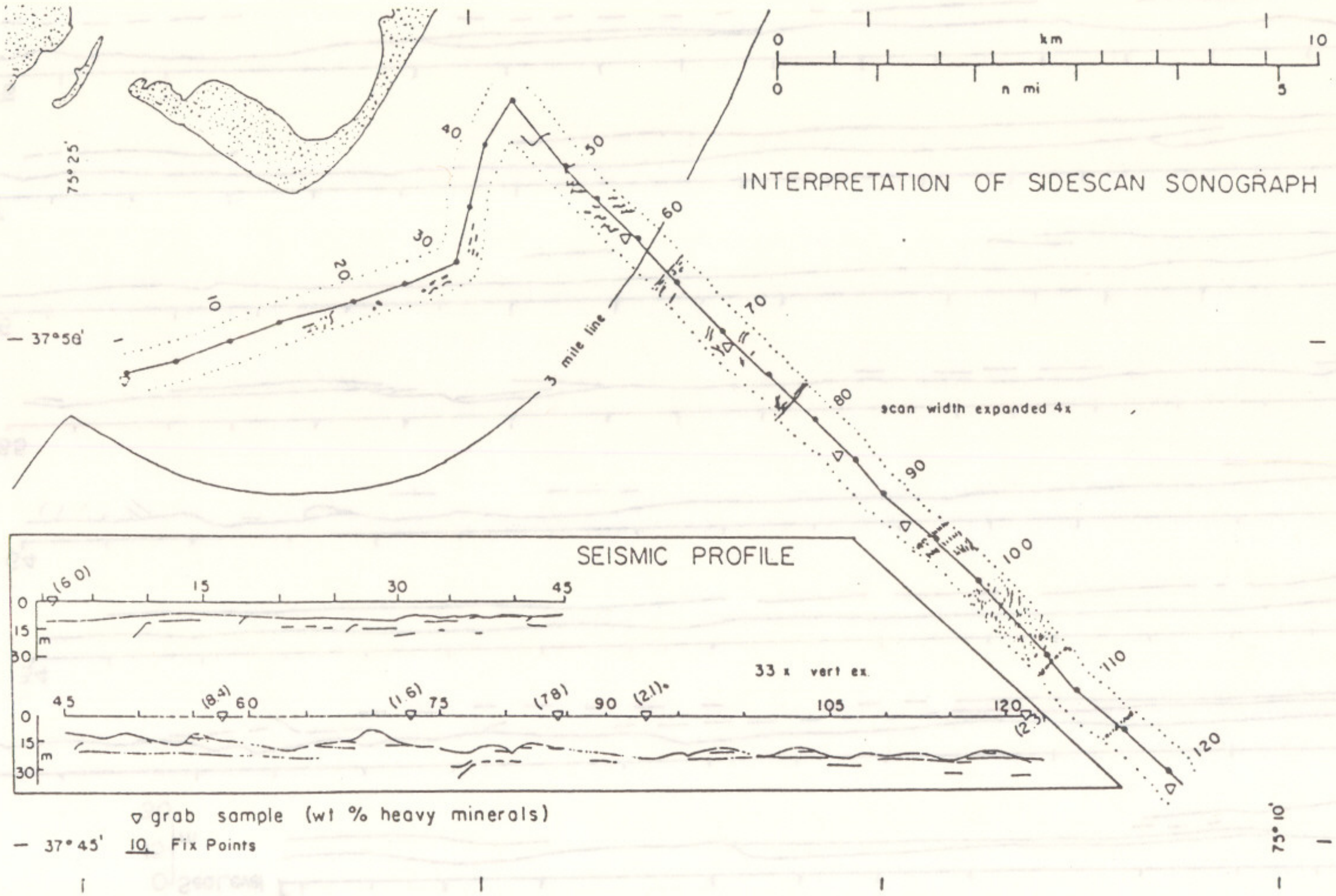

Figure 6. Interpretation of subbottom profiles and sidescan sonographs from the Assateague - Chincoteague area.

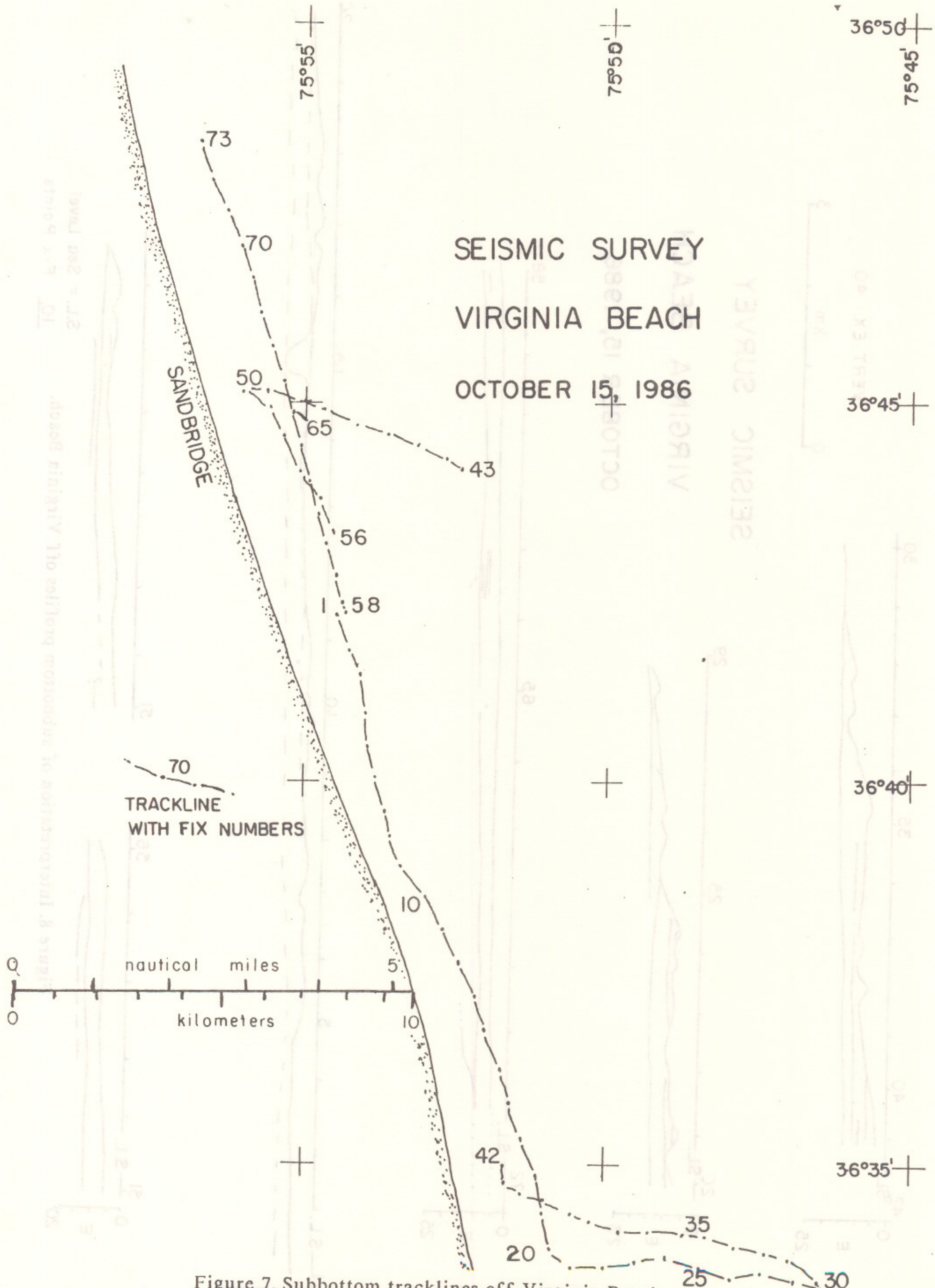

Figure 7. Subbottom tracklines off Virginia Beach.

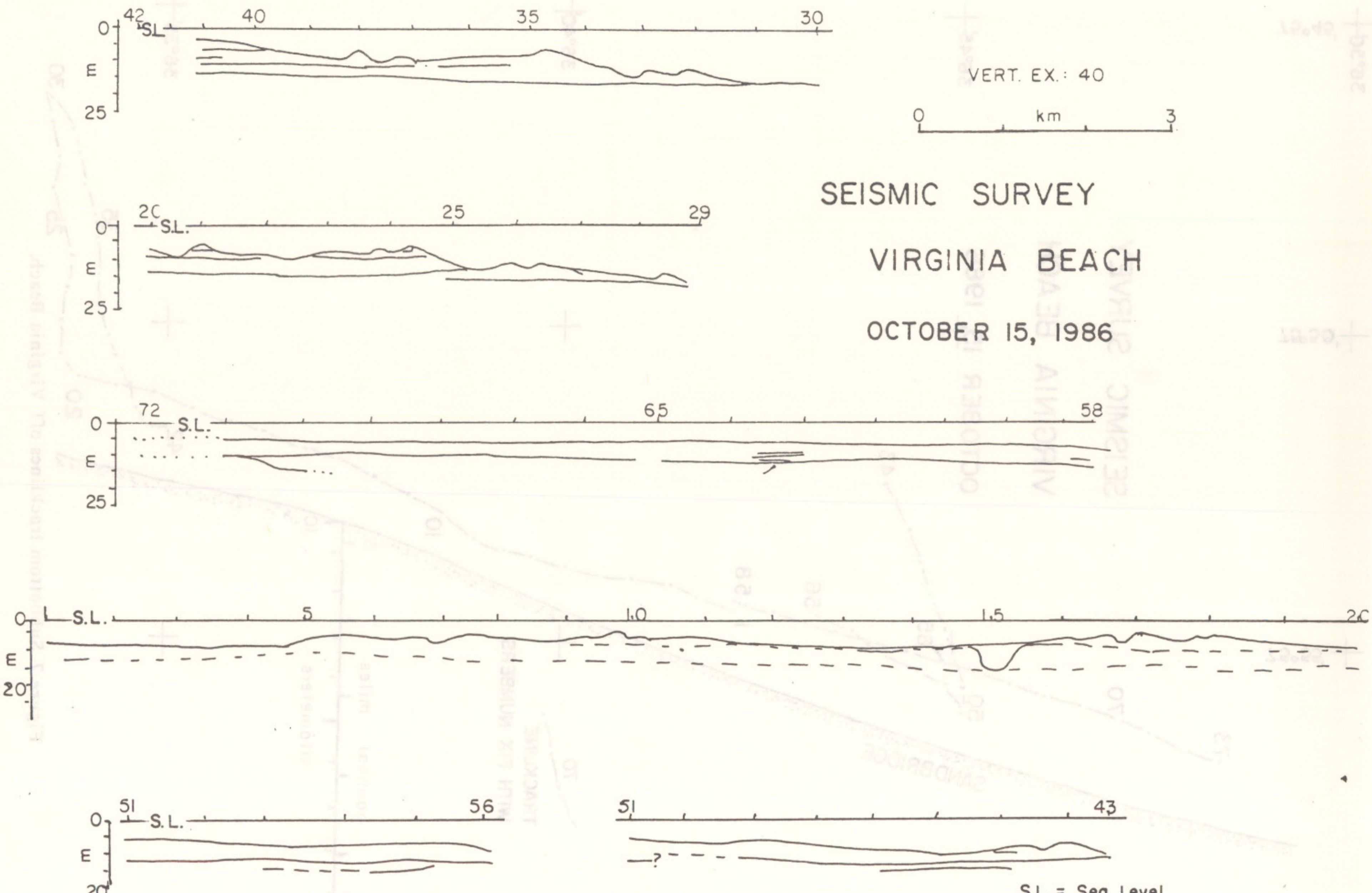

Figure 8. Interpretation of subbottom profiles off Virginia Beach.

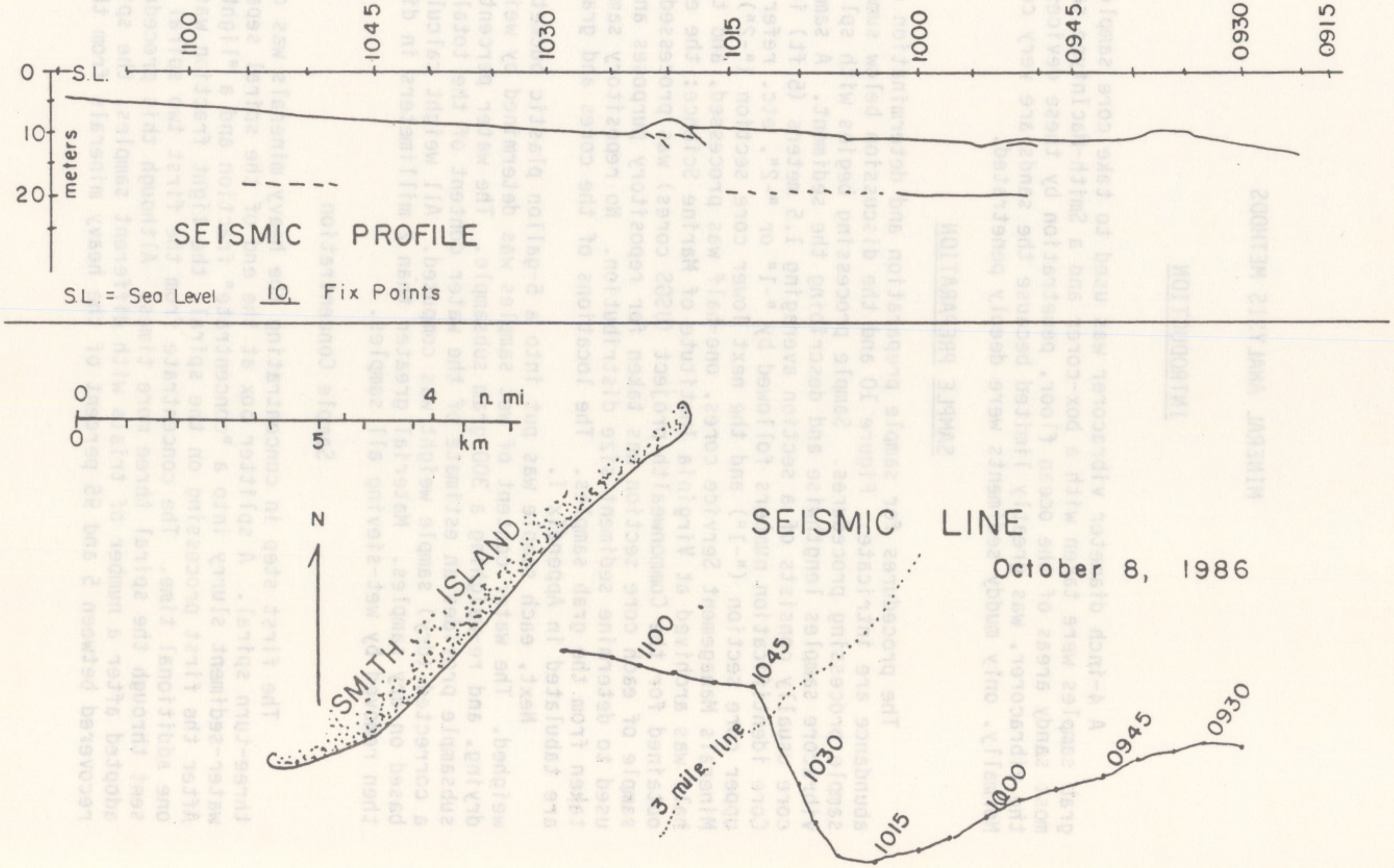

Figure 9. Interpretation of new seismic line off Smith Island.

MINERAL ANALYSIS METHODS

INTRODUCTION

A 4-inch diameter vibracorer was used to take core samples. The grab samples were taken with a box-corer and a Smith-MacIntyre sampler. In most sandy areas of the ocean floor, penetration by these devices, including the vibracorer, was greatly limited because the sands are very compact. Normally, only muddy sediments were deeply penetrated.

SAMPLE PREPARATION

The procedures for sample preparation and determination of mineral abundance are intricate. Figure 10 and the discussion below summarize the sample processing procedures. Sample processing begins with splitting the vibracore samples lengthwise and describing the sediment. A sample from a core usually consists of a section averaging 1.5 meters (5 ft) in length. Core identification numbers followed by "-1" or "-2", etc. refer to the upper core section ("-1") and the next lower core section ("-2"). For the Minerals Management Service cores, one-half was processed, and the other half was archived at Virginia Institute of Marine Science; the entire core obtained for the Commonwealth project (USGS cores) was processed. A channel sample of each core section was taken for repository purposes and was also used to determine sediment size distribution. No repository samples were taken from the grab samples. The locations of the cores and grab samples are tabulated in Appendix I.

Next, each sample was put into a 5-gallon plastic bucket and weighed. The water content of wet samples was determined by weighing, drying, and re-weighing a 300 gram subsample. The water percent of the subsample provides an estimate of the water content of the total sample, and a corrected (dry) sample weight was computed. All weight calculations are based on dry samples. Material greater than 2 millimeters in diameter was then removed by wet-sieving all samples.

Sample Concentration

The first step in concentrating the heavy minerals was done on a three-turn spiral. A splitter box at the end of the spiral separated the water-sediment slurry into a "concentrate" fraction and a "light" fraction. After the first processing on the spiral, the light fraction was processed one additional time. The concentrate from the first two spiral runs was sent through the spiral three more times. Although this procedure was adopted after a number of trials with different samples, the spiral recovered between 5 and 95 percent of the heavy minerals from the bulk

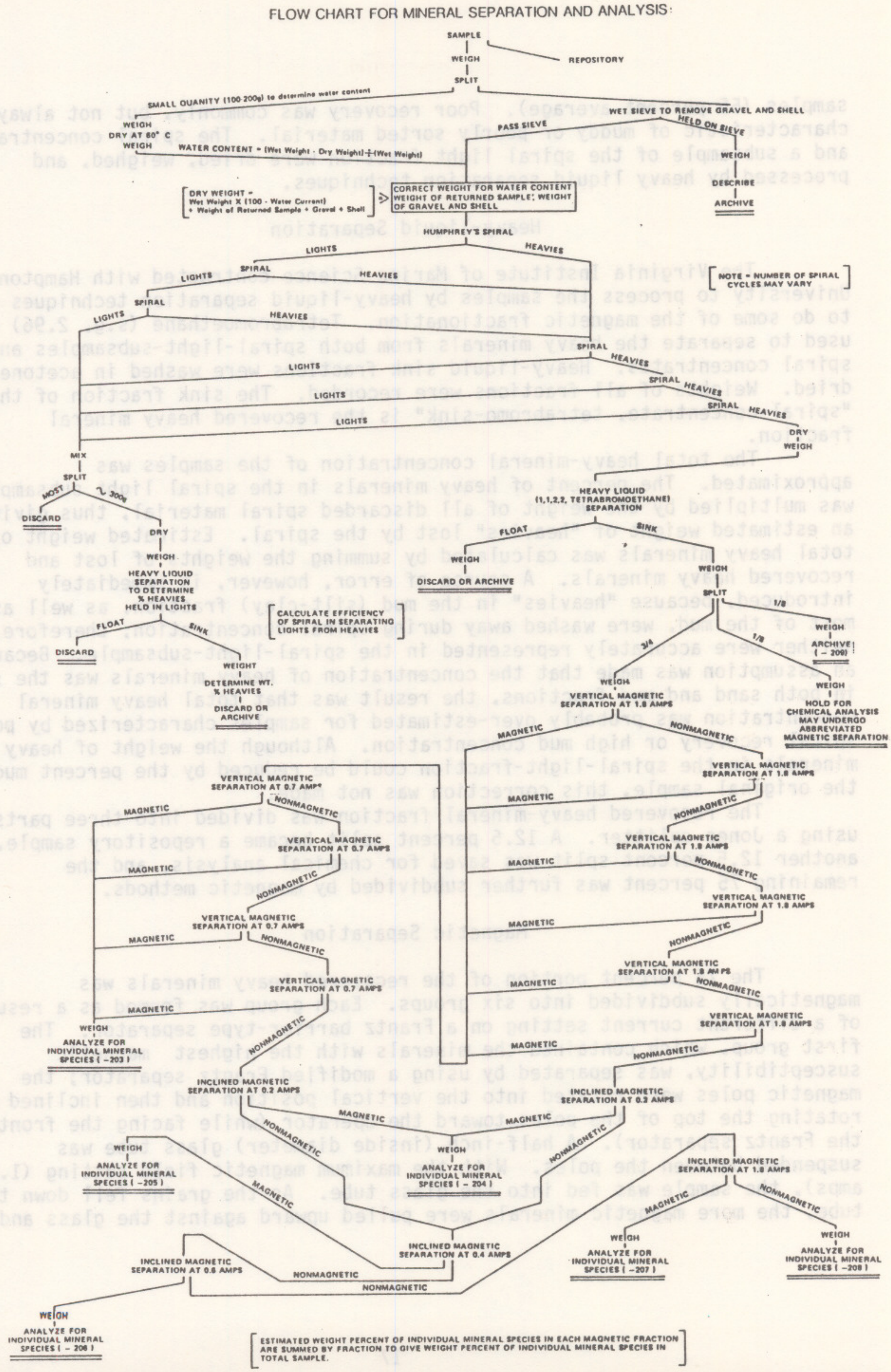

Figure 10. Flow chart showing the scheme of sample analysis.

samples (55 percent average). Poor recovery was commonly, but not always, characteristic of muddy or poorly sorted material. The spiral concentrate and a subsample of the spiral light fraction were dried, weighed, and processed by heavy liquid separation techniques.

Heavy-liquid Separation

The Virginia Institute of Marine Science contracted with Hampton University to process the samples by heavy-liquid separation techniques and to do some of the magnetic fractionation. Tetrabromoethane (s.g. 2.96) was used to separate the heavy minerals from both spiral-light-subsamples and spiral concentrates. Heavy-liquid sink fractions were washed in acetone and dried. Weights of all fractions were recorded. The sink fraction of the "spiral-concentrate, tetrabromo-sink" is the recovered heavy mineral fraction.

The total heavy-mineral concentration of the samples was approximated. The percent of heavy minerals in the spiral light subsample was multiplied by the weight of all discarded spiral material, thus giving an estimated weight of "heavies" lost by the spiral. Estimated weight of total heavy minerals was calculated by summing the weights of lost and recovered heavy minerals. A source of error, however, is immediately introduced, because "heavies" in the mud (silt-clay) fraction, as well as most of the mud, were washed away during spiral concentration; therefore, neither were accurately represented in the spiral-light-subsample. Because an assumption was made that the concentration of heavy minerals was the same in both sand and mud fractions, the result was that total heavy mineral concentration was probably over-estimated for samples characterized by poor spiral recovery or high mud concentration. Although the weight of heavy minerals in the spiral-light-fraction could be reduced by the percent mud in the original sample, this correction was not made.

The recovered heavy-mineral fraction was divided into three parts using a Jones splitter. A 12.5 percent split became a repository sample, another 12.5 percent split was saved for chemical analysis, and the remaining 75 percent was further subdivided by magnetic methods.

Magnetic Separation

The 75 percent portion of the recovered heavy minerals was magnetically subdivided into six groups. Each group was formed as a result of a different current setting on a Frantz barrier-type separator. The first group, which contained the minerals with the highest magnetic susceptibility, was separated by using a modified Frantz separator; the magnetic poles were rotated into the vertical position and then inclined by rotating the top of the poles toward the operator (while facing the front of the Frantz separator). A half-inch (inside diameter) glass tube was suspended between the poles. With the maximum magnetic field setting (1.8 amps), the sample was fed into the glass tube. As the grains fell down the tube, the more magnetic minerals were pulled upward against the glass and toward the poles of the separator. The portion of the sample held by the magnet was again run through the vertical Frantz separator but at a setting of 0.7 ampere. The retained fraction (labeled 203) is commonly known as the "hand-magnetic" portion. Minerals not attracted to the magnet were processed through the barrier-type separator. Successive mineral groups were derived from the magnetic fractions of the Frantz separator at 0.2 (labeled "204"), 0.4 (labeled "205"), 0.6 (labeled "206"), and 1.8 amperes (labeled "207"). The last group, the nonmagnetic fraction at 1.8 amperes, and was labeled "208". Each of the six groups was weighed and stored in a glass vial.

MINERAL IDENTIFICATION

Each of the six magnetic fractions (203 to 208) was examined under reflected- and transmitted-light (dissecting and petrographic) microscopes. The minerals in each fraction were identified and their abundances were estimated or counted. The weight of a mineral in each fraction was calculated by multiplying its observed abundance by the weight of the fraction. Because some minerals were present in more than one magnetic fraction, their total abundance was determined by summing their weights in each fraction. Figure 11 is an example of the observations and calculations used to determine the weight percent for the entire sample. Minerals observed, but not listed on Figure 11, were grouped into the "other" category.

The magnetite fraction may contain minerals common to subsequent magnetic fractions. X-ray fluorescence of the 203 fraction of two samples indicated excessive titanium; the excess could be explained by approximately 40 percent titano-magnetite (O. Fordham, personal communication). Because optical identification of different opaque minerals in the 203 fraction was difficult and inconsistent among observers, the entire fraction was labeled "magnetite."

The 206, 207, and 208 fractions were also examined under high-intensity short-wave ultraviolet light. This technique identified monazite (green fluorescence) and zircon (yellow to orange fluorescence) as well as helped to estimate quartz contamination in the 208 fraction.

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

SAMPLE 54 heavy mineral wt of sample 453.3g

fraction wt=	51.26g	163.92	165.55	2.75	14.93	54.89	
MINERAL	203	204	205	206	207	208	sum wt/ hm wt
MAGNETITE	98%						50.23
wt	50.23g						453.3 =11.08%
ILMENITE		73%	7%	4%			131.3
wt		119.7	11.6	0.1			453.3 = 28.9
GARNET	1%	19%	36%	8%	8%		92.6
wt	0.5	31.1	59.6	0.2	1.2		453.3 = 20.4

Figure 11. Partial record of observed mineral abundances in each magnetic fraction. Calculations to determine sample composition were computed in the spreadsheet program and are shown here as an example.

DATA BASE

All calculations and data entry 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 were weighed. The spreadsheet program stored and calculated weights and other characteristics throughout the analysis. Of approximately 268 samples, 222 were completed through mineral identification. The remaining 46 samples, one was lost by contamination, did not contain enough heavy minerals to allow for satisfactory processing.

The completed data base contains about 26,000 cells of information. Copies of the data base are not included in this report but are available for inspection at Virginia Division of Mineral Resources and Virginia Institute of Marine Science; Appendices II through V contain the resultant sample compositions.

RESULTS

SAMPLE COMPOSITION

Appendix III shows the mineral composition for the heavy mineral fractions of all samples. The data is subdivided into three groups: Commonwealth cores, Commonwealth grab samples, and Minerals Management Service cores. Because the usefulness of relying upon surface grab samples in predicting economic mineral potential is questioned (A. E. Grosz, personal communication), grab sample data were separated from core data for the Commonwealth project. Appendix III includes separate statistics for each of the three groups. Appendix IV shows statistics for all samples treated as one group.

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 have been "weighted" by the total heavy-mineral concentration so that mineral abundance per ton, for example, may readily be estimated.

Tables 1 and 2 show average and highest values for the more economic minerals both by group and by all samples. The total heavy-mineral (THM) concentration (average and highest value) of "CW grabs" (Commonwealth acquired grab samples) departed more from "all samples" than did the values for cores. However, mineral concentrations were nearly the same for cores and grab samples. Therefore, grab samples appear to be useful in predicting offshore mineralogy, but they may not be good indicators of total concentration. This hypothesis was only apparent by inspection and has not been statistically tested.

TABLE 1. Average concentrations of selected minerals as a percentage of the heavy-mineral fraction. CW = Commonwealth data, MMS = Minerals Management Service data.

	WT % THM	WT % ILMENITE	WT % LEUCOXENE	WT % RUTILE	WT % ZIRCON	WT % MONAZITE
MMS cores	2.4	23.0	1.2	1.1	3.3	0.2
CW grabs	4.5	28.6	1.7	1.1	2.7	0.3
CW cores	2.9	30.8	1.2	1.2	3.1	0.1
all samples	3.5	27.8	1.4	1.2	3.1	0.2

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

	WT % THM	WT % ILMENITE	WT % LEUCOXENE	WT % RUTILE	WT % ZIRCON	WT % MONAZITE
MMS cores	6.9	56.2	5.4	2.7	7.6	1.4
CW grabs	14.7	58.8	4.8	2.8	5.4	1.8
CW cores	9.0	60.3	3.2	3.2	9.2	2.5
all samples	14.7	60.3	5.4	3.2	9.2	2.5

ECONOMIC POTENTIAL

The average values for the minerals in Table 1 are lower than industry standards for mining on land but the maximum values in Table 2 are in excess of that minimum. Although market conditions may alter the following values, the concentrations of the heavy-mineral fraction of a hypothetically economic land deposit are: ilmenite, 45 percent; leucoxene, 5 percent; rutile, 2 percent; zircon, 5 percent; staurolite, 20 percent; monazite, 1 percent; garnet/epidote, 15 percent; and kyanite/sillimanite, 7 percent (Garner, 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. It has been suggested that 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 are two of the factors (U.S. Congress, 1987). The economic potential of the offshore heavy-minerals may also depend on the volume of other marketable material (including sand and gravel) present.

The economic minerals found in abundance offshore of Virginia are those containing titanium (ilmenite, leucoxene, and rutile) and minerals containing rare-earth elements (monazite and zircon). The sum of these minerals plus the sillimanite/kyanite fraction forms the "ECON" (economic interest) group of heavy minerals.

Over 35 samples with high concentrations of one or more of the "ECON" minerals have been identified. These samples are marked by underlining in Appendices III and V and are indicated on Figure 12. Nine of these samples are summarized in Table 3 and two are shown graphically in Figure 13. Although total heavy-mineral concentration may be low, an exceptional abundance of an individual mineral(s) may encourage further investigation.

Determinations of the "best" samples were based on several criteria. For land deposits, the average THM concentration should be at least 3 to 4 percent. Several samples were noted where THM exceeds this, even though the individual mineral abundance may be less than the threshold values suggested by Garner (1978). These were included because the same volume of a mineral may be available at twice the THM concentration but half the abundance of the heavy-mineral fraction, e.g., a THM of 5 percent and ilmenite of 60 percent is equivalent to a THM of 10 percent and ilmenite of 30 percent. Also marked were samples with THM values less than 4 percent where certain ECON minerals were in great abundance because these samples may suggest a depositional environment with selective enrichment leading to nearby higher-grade sediments.

As an aid to further assessment of the economic potential of the samples, Appendix V presents the weight percent of selected minerals with respect to the total sample. Garner's values can likewise be converted by multiplying each of the following mineral concentrations by 5 percent: ilmenite= 2.25 percent, leucoxene and zircon = 0.25 percent, rutile = 0.1 percent, and monazite = 0.05 percent. As previously mentioned, this procedure partially eliminates the concern for THM concentration while searching for high-grade samples.

TABLE 3. Several samples with economic potential selected from Appendix III. Composition is relative to the heavy-mineral fraction.
P = present; see Appendix III for additional explanation of tabulated data.

Sample	WT % THM	WT % IL	WT % RUT	WT % LEUCX	WT % MON	WT % ZR	WT % ECON
H01-3	5.4	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	4.5	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

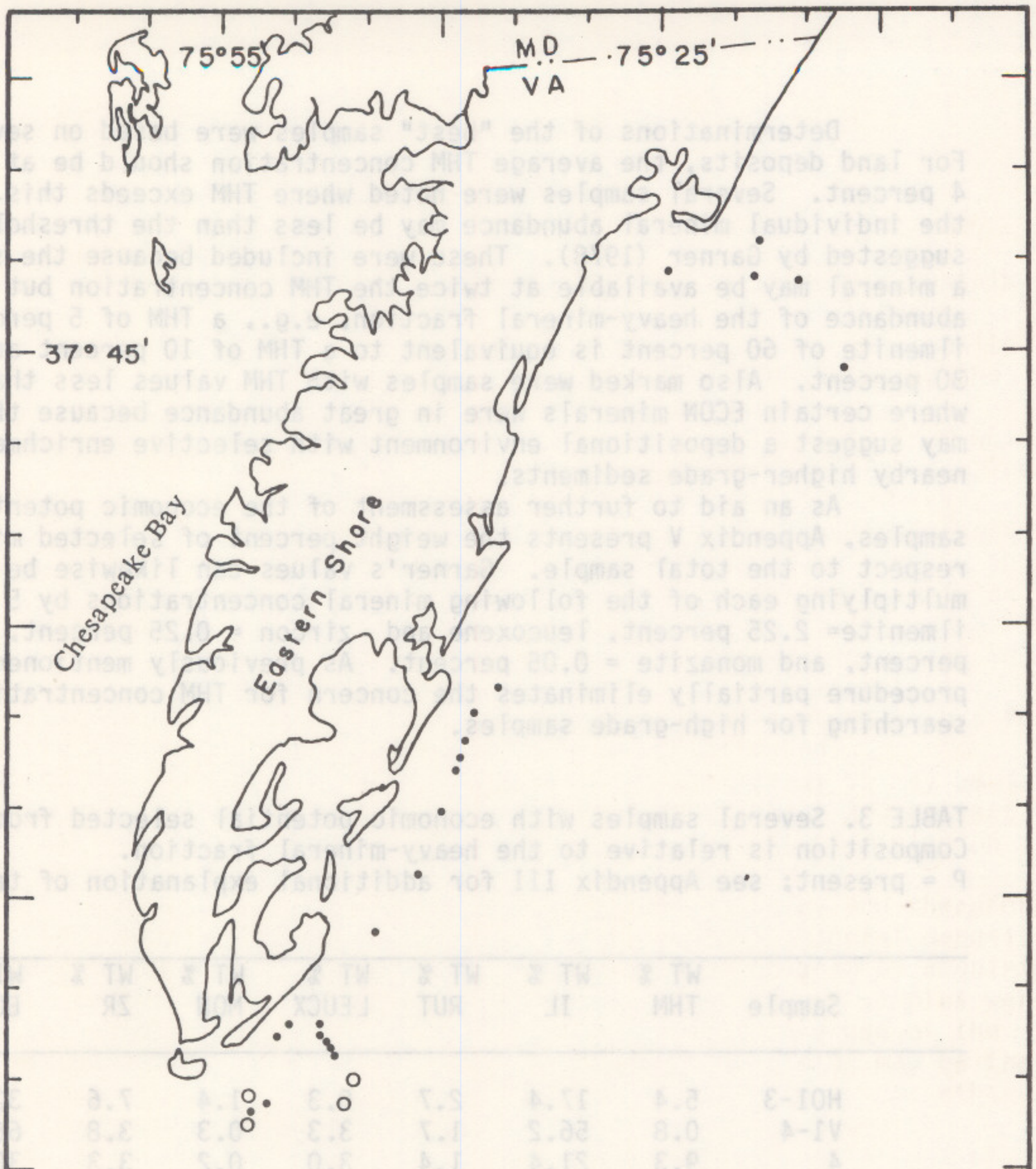

Figure 12. Map showing the location of samples with apparant economic interest.

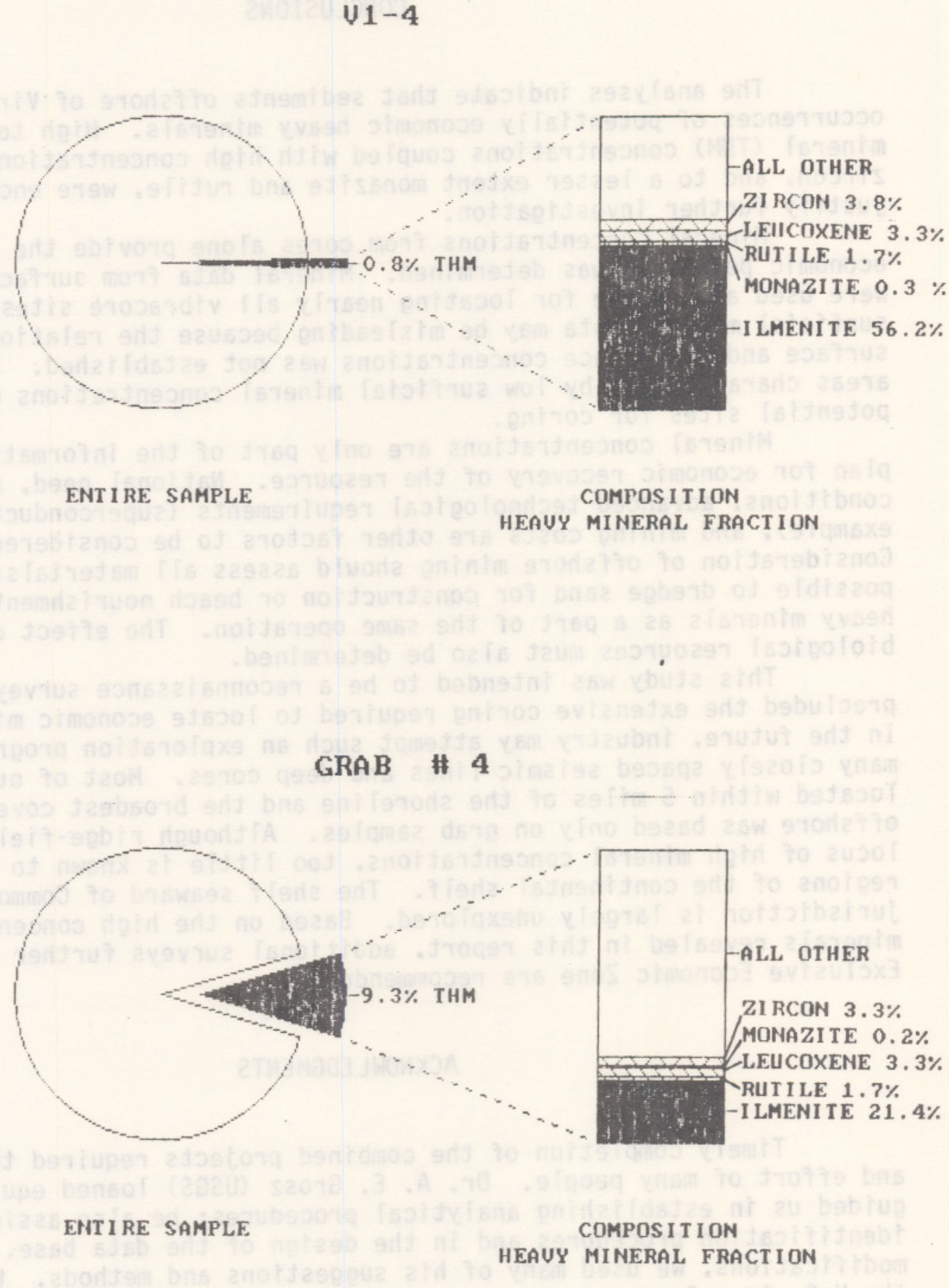

Figure 13. Graphic presentation of selected samples.

CONCLUSIONS

The 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, were encouraging and justify further investigation.

Mineral concentrations from cores alone provide the data from which economic potential was determined. Mineral data from surface grab samples were used as a guide for locating nearly all vibracore sites. However, surficial mineral data may be misleading because the relationship between surface and subsurface concentrations was not established. This means that areas characterized by low surficial mineral concentrations may 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 (superconducting alloys for example), and mining costs are other factors to be considered. Consideration of offshore mining 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. The effect of mining on biological resources must also be determined.

This study was intended to be a reconnaissance survey and therefore precluded the extensive coring required to locate economic mineral deposits. In the future, industry may attempt such an exploration program by acquiring many closely spaced seismic lines and deep cores. Most of our samples were located within 5 miles of the shoreline and the broadest coverage of the offshore was 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, additional surveys further offshore in the Exclusive Economic Zone are recommended.

ACKNOWLEDGMENTS

Timely completion of the combined projects required the cooperation and effort of many people. 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 data base. 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 samples.

From Virginia Institute of Marine Science, S. A. Skrabal, L. J. Calliari, S. M. Dydak, and C. T. Fischler cut and logged cores, processed samples, and identified and estimated mineral abundance. C. T. Fischler was responsible for managing the sediment laboratory; her responsibility extended to daily attention to equipment and supply orders, work schedule coordination, and computerized data compilation. R. A. Gammish 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 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. Dr. G. P. Burbank of Hampton University performed the heavy-liquid and some magnetic separations under contract from the Virginia Institute of Marine Science.

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GLOSSARY

Box-corer: A device to collect a sample of uniform depth across an area approximately 6 by 9 inches. The sampler is driven into the bottom by its own weight and ballast; depending upon the hardness of the bottom, penetration ranges up to 18 inches.

Core, core sample: A sample collected with an aim to acquire information over depth. See box-corer, vibracorer.

Exclusive Economic Zone (EEZ): A zone extending offshore from 3 nautical miles (separating state from federal jurisdiction) to 200 nautical miles in which the federal government has jurisdiction. (Reference Presidential Proclamation No. 5030, 1983)

Frantz magnetic separator: A commercially marketed device used for separating minerals according to their magnetic susceptibility. It is used to aid in the identification of individual mineral species.

Grab sample: A sample taken from the surface of the bottom sediment without concern for the penetration depth or uniformity. Usually grab samples are the most easily obtained samples of the bottom; however, their value is limited to information on the sea bottom only.

Heavy-liquid separation: A laboratory procedure for separating minerals based on their specific gravities (density). Minerals with a density greater than the liquid will sink and minerals with a density less than the liquid will float. "Heavy" liquids used in this process are usually toxic.

Heavy mineral: A detrital mineral having a specific gravity greater than an arbitrary standard (usually around 2.85). Most of the detrital minerals of economic interest are heavy minerals. Note: Heavy minerals should not be confused with heavy metals. When these metals are found in the marine environment in higher than normal concentrations, they are usually anthropogenically introduced pollutants.

Humphrey Spiral: A commercially marketed device for making a rough separation of the heavy minerals from bulk sediment samples.

Magnetic susceptibility: The ratio of induced magnetization to the strength of the magnetic field causing the magnetization. Material that shows no magnetic properties while it is not in a magnetic field may show magnetic properties if placed in a magnetic field.

Mineral: A naturally occurring, inorganic substance with a characteristic chemical composition and usually possessing a definite crystalline structure, which is sometimes expressed in external geometric forms.

Sand: A size classification of sediments. Sand grains are rock fragments or detrital particles with diameters between 0.0025 and 0.08 inch (1/16 to 2 mm).

Sidescan sonar: An acoustic device which produces an image or depiction of the surface and texture of a subaqueous bottom on each side of the ship's track. The image provides information on the roughness of the bottom and the nature of the bottom surface sediment.

Subbottom or seismic profile: A depiction of the layering of sediments underlying the sea floor. The data are acquired from the reflection of acoustic signals back to the surface from sediment layers of differing degrees of compaction.

Surface or surficial sample: A sample with very limited penetration of the sediments of the bottom surface. See grab sample.

Vibracorer: A device which obtains relatively long or deep, usually continuous samples of the bottom sediment. The samples generally are less than 4 inches in diameter but may be many feet long. The name derives from the vibrating action used to drive the core tube into the bottom. See core.

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 "*".

MMS VIBRACORES

CORE NUMBER	WATER DEPTH (FT)	LORAN C COORDINATES Y	X	LATITUDE deg	min	LONGITUDE deg	min	RECOVERED CORE LENGTH (FEET)
H1	38	41405.1	27132.7	37	05.00	75	45.99	13.5
H2	38	41406.1	27133.8	37	05.12	75	46.19	15.0
H3	37	41408.0	27134.9	37	05.31	75	46.37	4.5
H4	38	41409.8	27136.1	37	05.50	75	46.58	15.5
H5	34	41412.2	27137.2	37	05.74	75	46.74	6.2
H6	37	41392.9	27131.0	37	03.94	75	46.03	20.4
H7	36	41398.8	27134.9	37	04.56	75	46.70	12.8
H8	30	41402.0	27136.7	37	04.89	75	46.98	9.5
H9	32	41405.3	27138.6	37	05.22	75	47.29	6.0
H10	35	41408.5	27137.4	37	05.44	75	46.90	12.1
H11	30	41410.7	27139.3	37	05.69	75	47.25	7.0
H12	29	41411.5	27139.7	37	05.77	75	47.31	7.0
H13	38	41412.8	27140.9	37	05.92	75	47.54	6.8
H14	38	41414.6	27138.8	37	05.99	75	47.01	10.0
H15	30	41413.6	27138.3	37	05.89	75	46.93	2.0
B1	25	41399.5	27202.9	37	07.03	76	01.97	9.5
B2	22	41415.2	27200.0	37	08.20	76	00.74	9.0
B3	15	41423.1	27200.1	37	08.84	76	00.47	12.5
B4	35	41385.3	27210.2	37	06.13	76	04.17	6.5
B5	25	41369.8	27210.1	37	04.87	76	04.71	10.5
V1	48	*	*	36	54.53	75	56.56	19.7
V2	46	*	*	36	53.15	75	55.29	18.6
V3	49	*	*	36	51.80	75	53.84	14.3
V4	52	*	*	36	50.51	75	51.55	20.0
V5	*	*	*	36	54.04	75	56.39	18.8
V6	47	*	*	36	52.41	75	50.41	6.4

COMMONWEALTH GRAB SAMPLES

GRAB NUMBER	DEPTH (FATHOMS)	LORAN C COORDINATES Y	X	LATITUDE deg	min	LONGITUDE deg	min
1	5.5	41372.0	27153.0	37	03.03	75	51.69
2	4.5	41377.0	27156.0	37	03.55	75	52.19
3	4.5	41408.2	27153.4	37	05.99	75	50.49
4	4.0	41432.9	27149.1	37	07.85	75	48.65
5	13.0	41901.9	27048.0	37	43.78	75	11.51
6	13.7	41920.7	27049.7	37	45.43	75	11.25
7	12.5	41945.3	27070.3	37	48.03	75	14.54
8	10.0	41931.1	27076.8	37	47.00	75	16.32
9	9.6	41937.5	27079.9	37	47.62	75	16.72
10	9.9	41953.0	27076.4	37	48.83	75	15.50
11	8.6	41961.6	27082.8	37	49.71	75	16.48
12	7.7	41974.0	27093.2	37	51.01	75	18.14
13	7.4	41959.5	27097.8	37	49.90	75	19.54
14	6.0	41952.5	27090.9	37	49.15	75	18.41
15	6.0	41947.9	27119.8	37	49.49	75	24.33
16	5.0	41949.0	27130.0	37	49.82	75	26.35
17	5.0	41939.2	27135.0	37	49.12	75	27.71
18	6.0	41918.9	27134.8	37	47.43	75	28.40
19	7.4	41890.6	27135.0	37	45.08	75	29.44
20	8.0	41869.5	27134.9	37	43.33	75	30.17
21	7.9	41850.0	27135.1	37	41.72	75	30.91
22	5.0	41789.2	27135.1	37	36.69	75	33.05
23	6.0	41751.2	27134.0	37	33.52	75	34.17
24	6.0	41739.4	27134.2	37	32.55	75	34.63
25	5.0	41729.8	27134.6	37	31.77	75	35.06
26	8.7	41740.0	27124.6	37	32.32	75	32.59
27	4.0	41739.6	27112.0	37	31.92	75	29.97
28	9.7	41668.1	27114.8	37	26.07	75	33.01
29	6.0	41669.3	27125.2	37	26.49	75	35.19
30	6.0	41669.5	27129.7	37	26.64	75	36.13
31	5.0	41669.4	27135.1	37	26.80	75	37.28
32	5.0	41650.1	27134.7	37	25.19	75	37.88
33	5.0	41629.2	27134.5	37	23.45	75	38.55
34	5.0	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

COMMONWEALTH GRAB SAMPLES, continued

GRAB NUMBER	DEPTH (FATHOMS)	LORAN C COORDINATES Y	X	LATITUDE deg	min	LONGITUDE deg	min
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

COMMONWEALTH GRAB SAMPLES, continued

GRAB NUMBER	DEPTH (FATHOMS)	LORAN C COORDINATES Y	X	LATITUDE deg	min	LONGITUDE deg	min
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

COMMONWEALTH CORES (USGS)

SAMPLE NUMBER	LATITUDE deg	min	LONGITUDE deg	min
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

COMMONWEALTH CORES (USGS), continued

CORE NUMBER	LATITUDE deg min	LONGITUDE deg min
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
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

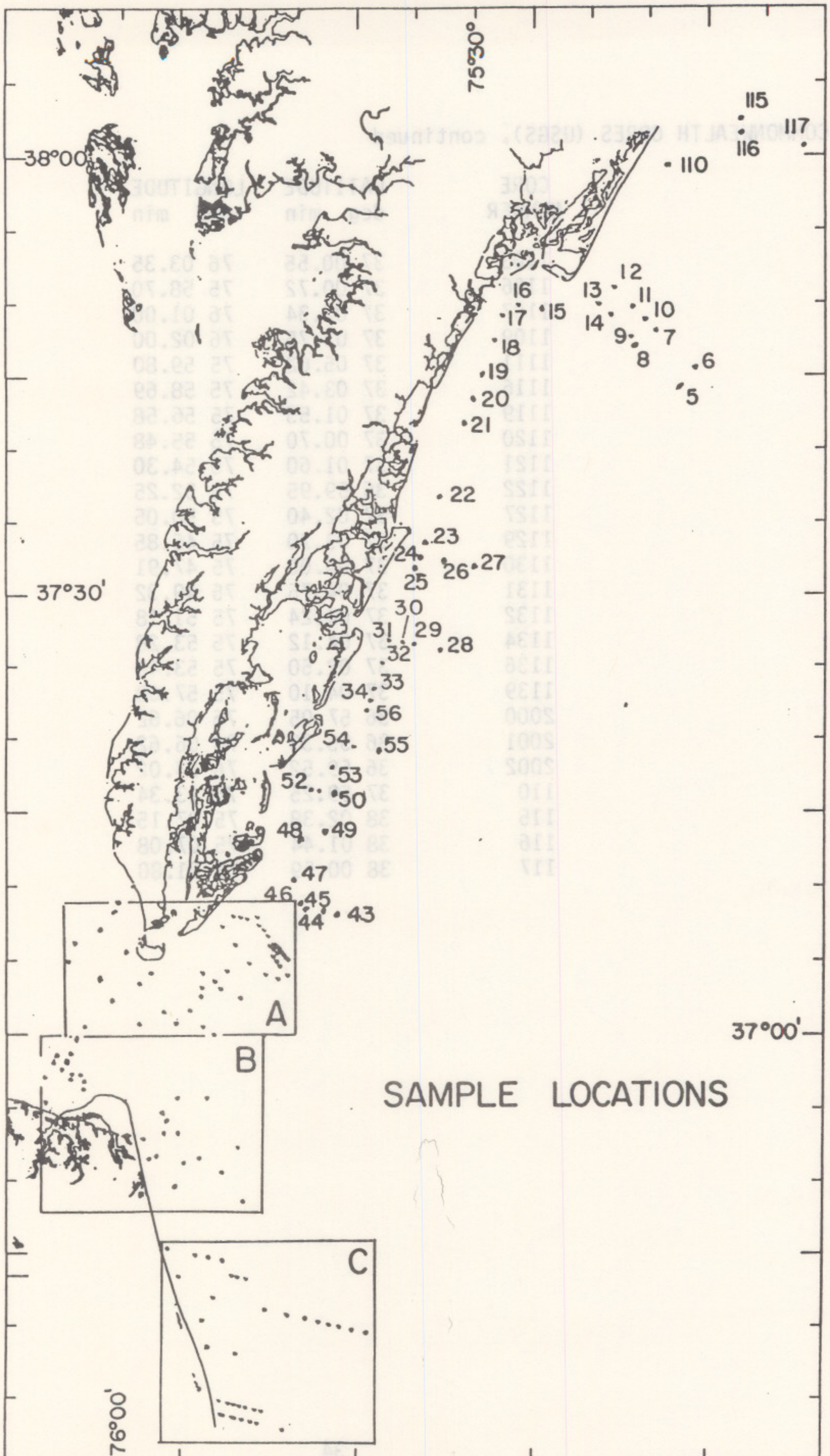

Figure 14. Location of samples off the Eastern Shore and index map of sample locations south of the Eastern Shore.

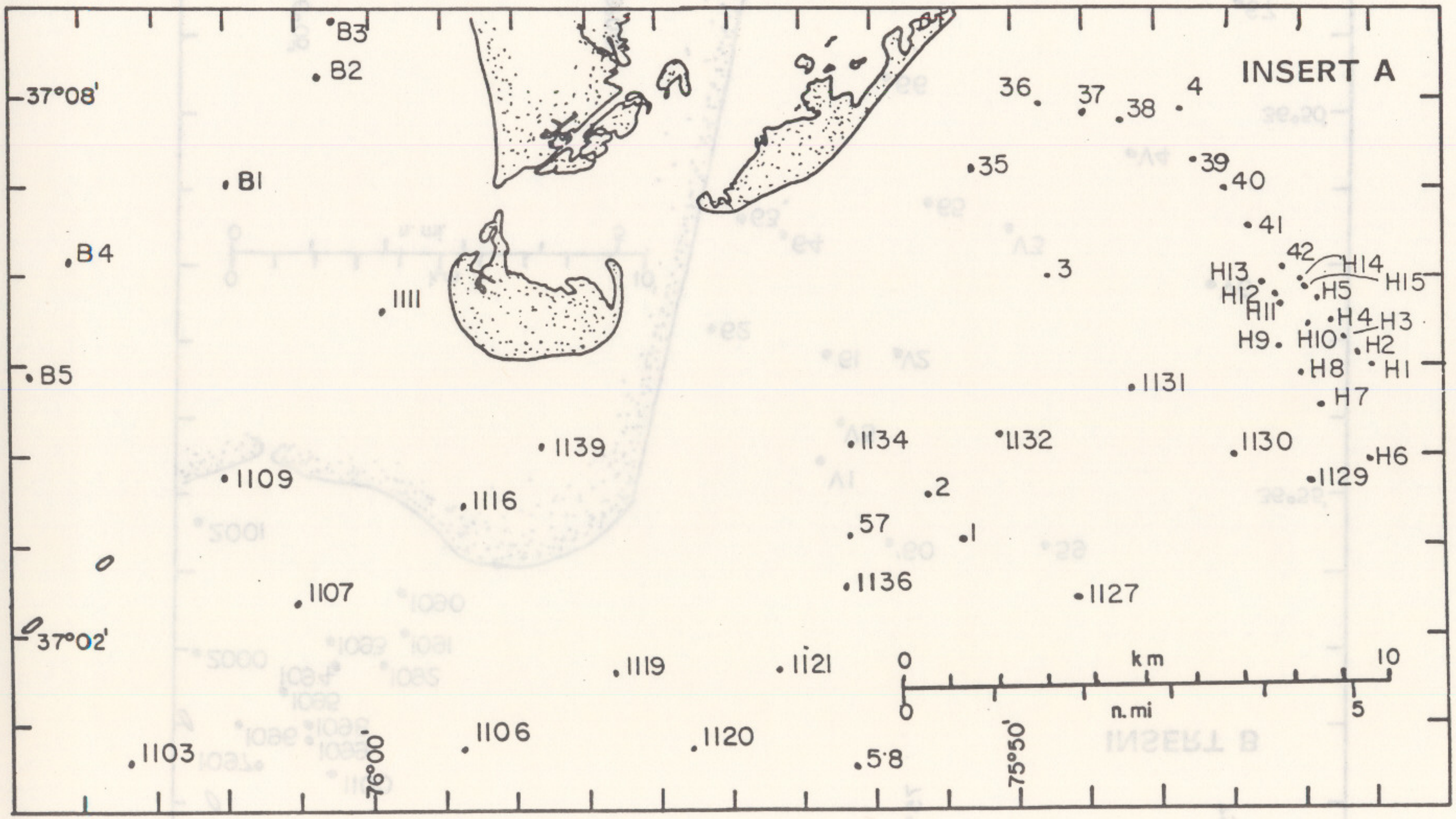

Figure 15. Location of samples at northern entrance to Chesapeake Bay.

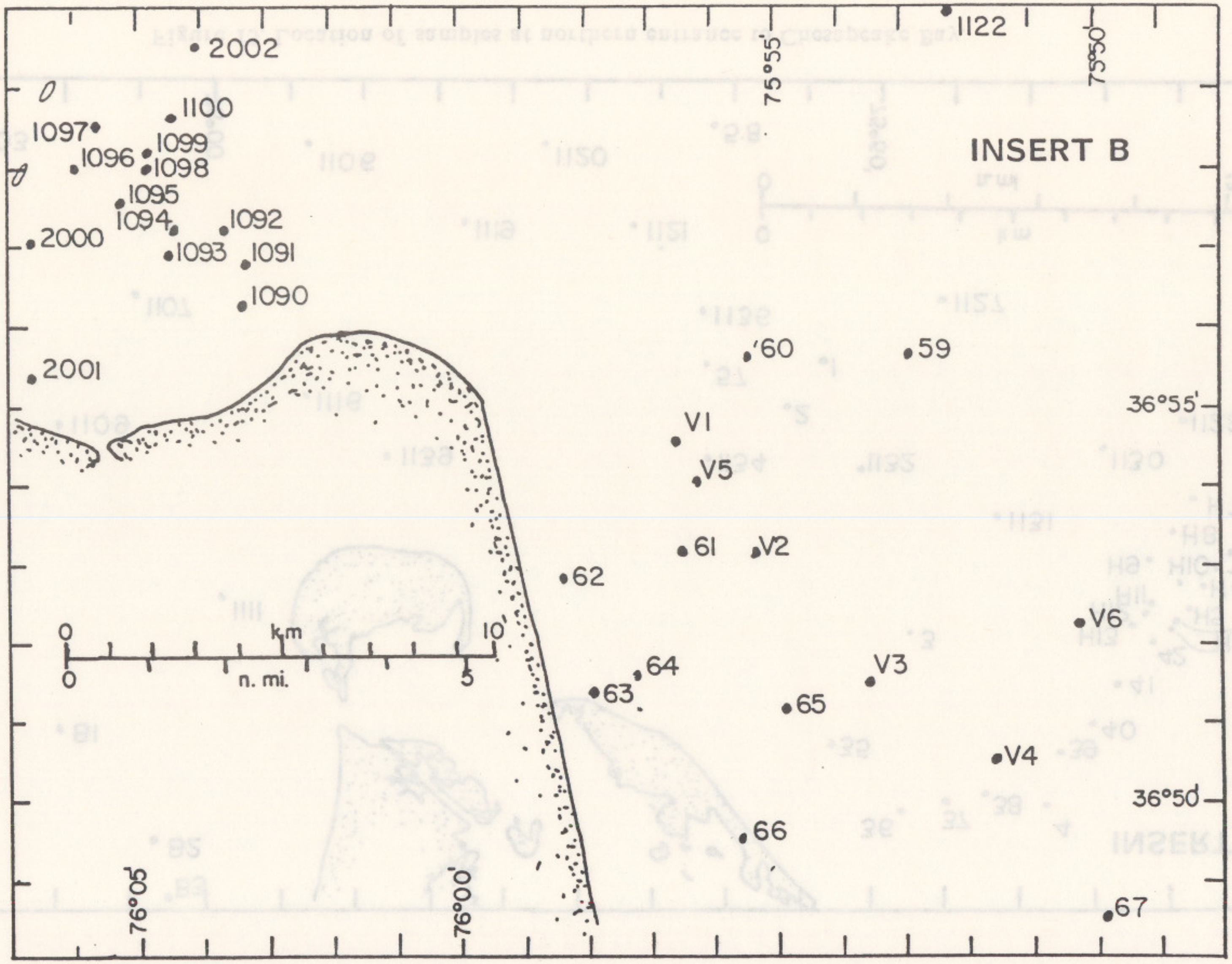

Figure 16. Location of samples at southern entrance to Chesapeake Bay and off Virginia Beach.

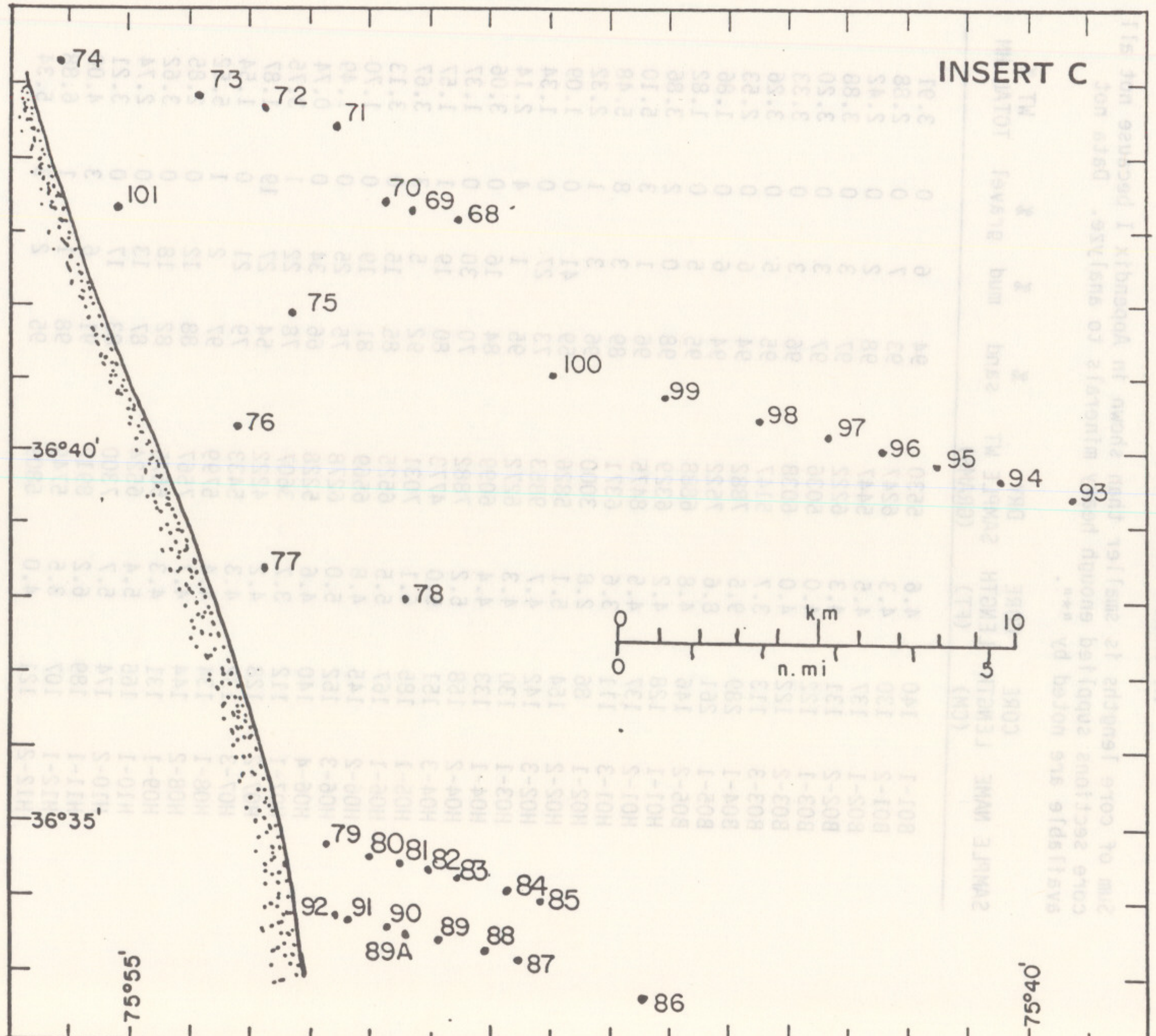

Figure 17. Location of samples off Virginia Beach to North Carolina.

APPENDIX II
A. CHARACTERISTICS OF MMS CORES

Sum of core lengths is smaller than shown in Appendix I because not all core sections supplied enough heavy minerals to analyze. Data not available are noted by "*".

SAMPLE NAME	CORE LENGTH (CM)	CORE LENGTH (FT)	DRY SAMPLE WT (GRAMS)	% sand	% mud	% gravel	WT % TOTAL HM
B01-1	140	4.6	5530	94	6	0	3.91
B01-2	130	4.3	6247	93	7	0	2.88
B02-1	137	4.5	5447	98	2	0	2.42
B02-2	131	4.3	6222	97	3	0	3.88
B03-1	122	4.0	5036	97	3	0	3.20
B03-2	122	4.0	6038	96	3	0	3.33
B03-3	113	3.7	5147	95	5	0	3.26
B04-1	289	9.5	7882	94	6	0	2.53
B05-1	261	8.6	7522	94	6	0	1.86
B05-2	146	4.8	6888	95	5	0	1.82
H01-1	128	4.2	6329	98	0	2	3.86
H01-2	137	4.5	8475	96	1	3	5.10
H01-3	111	3.6	6371	89	3	8	5.48
H02-1	86	2.8	3000	96	3	1	2.32
H02-2	154	5.1	5826	59	41	0	1.09
H02-3	142	4.7	9853	73	27	0	1.34
H03-1	130	4.3	6272	95	1	4	2.14
H04-1	133	4.4	6099	84	16	0	3.06
H04-2	158	5.2	7882	70	30	0	1.37
H04-3	151	5.0	4773	80	19	1	1.57
H05-1	185	6.1	7031	92	5	3	3.67
H06-1	167	5.5	6525	85	15	0	3.13
H06-2	145	4.8	6569	81	19	0	1.70
H06-3	152	5.0	6278	75	25	0	1.49
H06-4	140	4.6	5228	66	34	0	0.74
H07-1	112	3.7	3607	78	22	1	3.75
H07-2	128	4.2	4222	54	27	19	1.87
H07-3	132	4.3	5433	79	21	0	1.54
H08-1	134	4.4	5799	97	2	1	5.52
H08-2	144	4.7	7567	88	12	0	2.85
H09-1	131	4.3	5675	82	18	0	3.62
H10-1	165	5.4	6524	87	13	0	2.74
H10-2	174	5.7	7300	83	17	0	3.21
H11-1	189	6.2	8912	91	6	3	4.00
H12-1	107	3.5	5749	98	1	1	6.88
H12-2	121	4.0	5809	95	2	3	5.34

CHARACTERISTICS OF MMS CORES, continued

SAMPLE NAME	CORE LENGTH (CM)	CORE LENGTH (FT)	DRY SAMPLE WT (GRAMS)	% sand	% mud	% gravel	WT % TOTAL HM
H13-1	204	6.7	8324	93	5	3	2.23
H14-1	148	4.9	5771	*	*	*	0.52
H14-2	142	4.7	5942	81	16	4	1.49
V1-1	149	4.9	7513	*	*	*	1.17
V1-2	151	5.0	7267	*	*	*	0.82
V1-3	152	5.0	4400	*	*	*	0.61
V1-4	148	4.9	5245	*	*	*	0.83
V2-1	113	3.7	4272	*	*	*	2.72
V2-2	152	5.0	5530	*	*	*	1.67
V2-3	156	5.1	6910	*	*	*	3.90
V2-4	139	4.6	6593	*	*	*	2.12
V4-1	190	6.2	4721	*	*	*	1.77
V4-2	134	4.4	7979	*	*	*	1.06
V4-3	163	5.3	4606	*	*	*	1.39
V4-4	153	5.0	3766	*	*	*	1.35
V3-1	152	5.0	7305	93	5	2	1.42
V3-2	143	4.7	6432	64	34	2	0.50
V5-1	108	3.5	2317	88	12	0	1.95
V5-3	155	5.1	5565	95	5	0	1.26
V5-4	110	3.6	3610	94	5	1	1.20
V5-5	128	4.2	6424	90	3	7	1.44
V6-1	147	4.8	5843	94	6	0	2.48
V6-2	148	4.9	7051	91	7	2	1.71
AVERAGE	146	4.8	6075.4	87.1	11.4	1.5	2.44
STD DEV	33	1.1	1442.5	11.0	10.5	3.2	1.40
MIN VALUE	86	2.8	2317.0	54.0	0.0	0.0	0.50
MAX VALUE	289	9.5	9853.0	98.0	41.0	19.0	6.88
SUM	8632	283.2	358453.				

number of samples = 59

B. CHARACTERISTICS OF COMMONWEALTH GRAB SAMPLES

SAMPLE NAME	DRY SAMPLE WT (GRAMS)	WT % TOTAL HM
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
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

CHARACTERISTICS OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	DRY SAMPLE WT (GRAMS)	WT % TOTAL HM
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

CHARACTERISTICS OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	DRY SAMPLE WT (GRAMS)	WT % TOTAL HM
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
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
AVERAGE	5295.3	4.53
STD. DEV.	2086.5	3.09
MIN VALUE	915	0.14
MAX VALUE	11051	14.66
SUM	481874	

number of grab samples = 91

C. CHARACTERISTICS OF COMMONWEALTH (USGS) CORES

SAMPLE NAME	CORE LENGTH (cm)	CORE LENGTH (ft)	DRY SAMPLE WT (grams)	% SAND	% MUD	% GRAVEL	% TOTAL HM
1090-1	165	5.41	8649	83	17	0	2.46
1090-2	189	6.20	15448	86	14	0	1.91
1091-1	150	4.92	10348	85	15	0	2.36
1091-2	150	4.92	11148	85	15	0	1.71
1091-3	170	5.58	13447	78	22	0	1.61
1092-1	236	7.74	14850	91	2	7	1.70
1092-2	242	7.94	10450	89	2	9	1.03
1094-1	158	5.18	14049	92	8	0	1.15
1094-2	179	5.87	13151	76	24	0	1.01
1095-1	160	5.25	12648	87	13	0	2.51
1095-2	150	4.92	12949	91	9	0	2.30
1096-1	150	4.92	11850	87	12	0	1.84
1096-2	150	4.92	13049	73	26	1	2.23
1097-1	200	6.56	17950	93	7	0	2.60
1097-2	180	5.91	16951	76	19	6	1.39
1097-3	146	4.79	13450	75	22	3	1.26
1098-1	191	6.27	14849	75	0	25	1.78
1098-2	190	6.23	14051	65	33	2	0.58
1099-1	257	8.43	15550	73	24	3	1.18
1099-2	200	6.56	15849	78	5	17	1.78
1100-1	162	5.32	12651	94	6	0	2.64
1100-2	180	5.91	16249	88	11	1	2.51
1103-1	160	5.25	7851	84	12	5	1.80
1103-2	125	4.10	4651	69	22	8	1.62
1103-3	215	7.05	12851	93	6	2	1.74
1106-1	145	4.76	13450	99	1	0	3.59
1106-2	151	4.95	14148	99	1	0	2.63
1107-1	165	5.41	15450	99	1	0	4.35
1107-2	167	5.48	15048	98	2	1	1.83
1109-1	238	7.81	11050	91	9	0	3.08
1111-1	148	4.86	11450	92	8	0	2.76
1111-2	186	6.10	15110	90	10	0	3.20
1116-1	193	6.33	10850	88	12	0	4.39
1116-2	217	7.12	15751	83	14	2	4.00
1119-1	205	6.73	19051	99	1	0	2.43
1119-2	123	4.04	19666	96	4	0	2.39
1120-1	160	5.25	12650	98	2	0	1.95
1120-2	175	5.74	15449	95	4	0	3.05

CHARACTERISTICS OF COMMONWEALTH (USGS) CORES, continued

SAMPLE NAME	CORE LENGTH (cm)	CORE LENGTH (ft)	DRY SAMPLE WT (grams)	% SAND	% MUD	% GRAVEL	% TOTAL HM
1121-1	236	7.74	19649	96	4	0	3.44
1122-1	145	4.76	12251	92	7	1	5.67
1127-1	140	4.59	11348	92	8	0	5.51
1127-2	138	4.53	11850	82	18	0	2.70
1129-1	145	4.76	11648	95	5	0	7.65
1129-2	145	4.76	12849	86	14	0	6.11
1130-1	125	4.10	10848	91	6	3	7.17
1130-2	128	4.20	9448	66	34	0	1.96
1131-1	182	5.97	15648	85	11	4	5.92
1132-1	164	5.38	14450	93	6	1	6.32
1134-1	181	5.94	16649	97	3	0	8.79
1134-2	169	5.54	15997	94	6	0	6.82
1136-1	150	4.92	12650	95	4	0	9.01
1136-2	150	4.92	12448	94	5	0	6.42
1136-3	185	6.07	15850	91	8	0	3.34
1139-1	184	6.04	13950	99	1	0	2.44
2000-1	160	5.25	6050	78	22	0	2.00
2000-2	160	5.25	9748	64	36	0	2.39
2001-1	164	5.38	10048	73	27	0	2.02
2002-1	177	5.81	9750	95	5	0	3.75
2002-2	162	5.32	11051	88	12	0	3.01
110-1	215	7.05	7850	84	16	0	2.60
110-2	161	5.28	3950	88	11	1	2.21
110-3	156	5.12	3950	73	26	2	1.41
115-1	184	6.04	5348	58	42	0	0.74
116-1	85	2.79	3450	97	0	3	0.58
116-2	275	9.02	9251	61	38	1	0.54
116-3	190	6.23	6848	96	2	2	2.17
116-4	176	5.77	6450	97	1	2	0.92
116-5	94	3.08	1948	99	1	0	1.66
117-1	150	4.92	5649	92	3	6	1.26
117-2	140	4.59	6351	79	3	18	3.87
117-3	145	4.76	5050	89	2	9	3.95
117-4	150	4.92	5251	98	1	1	2.84
AVERAGE	170	5.58	11799.8	86.8	11.2	2.0	2.94
STD. DEV.	34	1.12	4114.2	10.3	10.2	4.4	1.94
MIN VALUE	85	2.79	1948	58	0	0	0.54
MAX VALUE	275	9.02	19666	99	42	25	9.01
SUM	12239	401.56	849589				

number of samples from cores = 72

APPENDIX III

MINERAL COMPOSITION OF SAMPLES

Explanation of Tabulated Data

"P" means several grains of the mineral were observed in the entire sample; that is, it was present.

"T" means the mineral was observed to be between 0.5 percent and 1 percent in abundance or in trace quantity.

"ECON" is the sum of the weight percents of ilmenite, rutile, leucoxene, sillimanite/kyanite, monazite, and zircon.

"MAG" (magnetite) contains an undetermined amount of titanomagnetite.

Samples with high concentrations of one or more ECON minerals are underlined

Mineral names not spelled completely in column headings have been abbreviated as follows: IL = ilmenite, MAG = magnetite, GAR = garnet, EP = epidote, STAUR = staurolite, AMPHIB = amphiboles, PYROX = pyroxenes, SILL/KY = sillimanite and kyanite, TOURM = tourmaline, LEUCOX = leucoxene

APPENDIX III

A. COMPOSITION OF MMS CORES

SAMPLE NAME	WT% TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
B01-1	3.91	9.36	14.30	15.01	9.42	0.28
B01-2	2.88	7.06	14.70	20.42	8.84	4.33
B02-1	2.42	5.44	19.96	25.41	5.87	3.37
B02-2	3.88	5.40	20.09	15.99	8.14	0.21
B03-1	3.20	4.70	16.71	16.37	11.91	0.10
B03-2	3.33	7.01	13.69	18.71	9.06	0.25
B03-3	3.26	4.95	15.23	14.38	7.08	0.39
B04-1	2.53	5.25	12.60	14.80	8.10	0.56
B05-1	1.86	4.83	21.03	17.06	8.37	6.14
B05-2	1.82	5.05	25.54	12.42	7.51	4.86
H01-1	3.86	3.15	29.89	22.02	8.10	2.77
H01-2	5.10	9.26	17.22	17.52	4.73	0.06
H01-3	5.48	11.00	17.39	9.32	3.80	2.54
H02-1	2.32	3.96	15.86	12.14	6.39	0.37
H02-2	1.09	9.28	20.44	8.89	7.50	P
H02-3	1.34	4.00	13.39	11.76	4.63	0.27
H03-1	2.14	4.37	17.15	12.49	5.46	0.73
H04-1	3.06	7.74	15.32	16.07	8.58	0.07
H04-2	1.37	10.82	13.24	8.52	3.91	6.72
H04-3	1.57	13.11	14.84	11.60	7.62	0.71
H05-1	3.67	8.67	15.89	15.02	6.43	0.34
H06-1	3.13	6.45	14.35	19.44	6.91	0.06
H06-2	1.70	3.36	20.23	19.09	7.82	4.52
H06-3	1.49	2.40	15.31	14.20	6.65	0.03
H06-4	0.74	5.25	10.02	11.81	7.45	0.29
H07-1	1.75	8.04	19.23	17.29	7.60	0.35
H07-2	1.87	3.33	13.19	18.54	4.33	2.94
H07-3	1.54	12.80	9.92	12.22	6.93	0.03
H08-1	5.52	7.28	20.72	14.97	6.47	0.07
H08-2	2.85	9.09	14.52	16.64	7.80	0.07
H09-1	3.62	17.07	7.65	14.76	5.20	0.31
H10-1	2.74	17.56	9.36	12.73	7.74	0.11
H10-2	3.21	18.03	8.76	15.05	6.24	0.44
H11-1	4.00	10.78	15.48	19.57	7.61	0.01
H12-1	6.88	6.68	20.71	15.84	5.41	0.27
H12-2	5.34	8.09	12.69	11.58	4.88	0.22
H13-1	2.23	9.35	20.24	6.75	2.22	2.30
H14-1	0.52	4.20	14.59	20.26	8.96	3.27
H14-2	1.49	12.36	9.25	11.34	4.83	2.82

COMPOSITION OF MMS CORES, continued

SAMPLE NAME	WT % TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
V1-1	1.17	2.69	19.44	17.81	8.49	0.19
V1-2	0.82	1.42	50.71	6.69	12.80	2.34
V1-3	0.61	1.44	45.72	2.54	12.81	3.81
V1-4	0.83	1.68	56.22	6.29	6.12	1.86
V2-1	2.72	4.07	23.85	15.24	7.40	0.95
V2-2	1.67	3.09	45.22	9.76	9.11	0.63
V2-3	3.90	0.51	37.16	14.73	15.08	1.95
V2-4	2.12	1.68	50.09	4.82	7.51	0.85
V4-1	1.77	5.72	23.83	12.95	4.96	1.23
V4-2	1.06	0.85	38.30	9.62	9.92	2.48
V4-3	1.39	2.21	32.38	10.96	17.14	1.35
V4-4	1.35	2.21	45.16	8.87	13.37	1.17
V3-1	1.42	2.34	32.51	12.71	7.18	2.52
V3-2	0.50	0.81	36.21	3.37	15.10	2.59
V5-1	1.95	3.03	18.17	15.98	8.77	2.19
V5-3	1.26	1.55	42.75	6.65	12.18	2.97
V5-4	1.20	3.10	44.27	5.72	13.65	1.81
V5-5	1.44	8.86	45.79	9.50	3.69	2.81
V6-1	2.48	6.92	24.09	18.17	4.01	0.35
V6-2	1.71	4.28	24.97	14.86	7.81	1.44
AVERAGE	2.44	6.19	23.01	13.39	7.86	1.50
STD. DEV	1.40	4.19	12.50	4.76	3.07	1.63
MIN VALUE	0.50	0.51	7.65	2.54	2.22	0.00
MAX VALUE	6.88	18.03	56.22	25.41	17.14	6.72

COMPOSITION OF MMS CORES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
B01-1	22.30	5.27	0.97	0.85	0.57	0.57
B01-2	13.94	10.74	0.59	1.01	1.75	0.25
B02-1	10.99	8.37	1.04	1.66	1.54	0.19
B02-2	23.09	7.01	0.64	0.55	0.57	0.28
B03-1	26.76	7.47	0.56	0.73	0.59	1.09
B03-2	23.70	6.75	0.70	1.20	0.40	0.72
B03-3	17.12	5.01	1.68	1.06	0.72	1.29
B04-1	25.59	5.15	0.94	0.50	0.00	0.33
B05-1	11.95	9.66	0.65	3.31	0.92	0.18
B05-2	12.12	6.54	1.81	3.01	1.85	0.40
H01-1	7.06	4.64	0.75	3.12	1.14	0.27
H01-2	20.04	6.09	1.25	0.24	0.14	1.16
H01-3	5.24	4.40	2.66	2.83	1.44	0.12
H02-1	19.72	6.58	0.86	1.68	0.26	0.19
H02-2	14.68	13.09	T	1.75	0.63	0.23
H02-3	21.09	2.82	1.05	3.93	0.46	1.16
H03-1	23.28	8.47	0.78	1.31	1.08	0.67
H04-1	20.00	6.94	1.50	0.67	0.29	1.48
H04-2	12.98	21.82	0.70	3.91	0.70	0.05
H04-3	14.31	9.67	0.97	0.57	0.45	0.95
H05-1	21.81	5.95	1.27	1.15	0.61	0.10
H06-1	25.52	6.13	0.53	0.59	0.44	0.26
H06-2	9.80	8.83	1.77	3.69	1.17	0.18
H06-3	20.57	7.43	0.60	0.81	0.00	1.35
H06-4	20.72	7.67	0.96	0.90	0.38	0.56
H07-1	20.60	6.52	0.71	0.57	0.50	0.66
H07-2	15.92	16.89	1.11	1.57	0.56	1.32
H07-3	26.15	5.95	0.97	0.32	0.03	0.58
H08-1	22.95	6.24	0.58	0.18	0.32	0.21
H08-2	24.28	4.36	0.88	0.70	0.15	0.83
H09-1	14.63	5.72	0.20	1.57	0.47	1.83
H10-1	15.47	7.50	0.26	1.50	0.47	0.79
H10-2	14.52	4.64	0.61	0.53	0.46	0.79
H11-1	22.28	6.45	1.08	0.14	0.14	0.50
H12-1	19.50	4.84	0.42	0.49	0.72	0.05
H12-2	16.58	4.01	0.20	0.86	0.60	0.50
H13-1	12.70	8.24	0.84	3.24	0.98	1.38
H14-1	13.99	8.23	0.98	1.15	1.03	1.96
H14-2	9.34	8.52	1.71	5.19	2.04	0.41

COMPOSITION OF MMS CORES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
V1-1	26.52	6.75	1.58	0.59	0.05	0.51
V1-2	9.07	2.39	1.93	2.20	0.32	0.73
V1-3	15.01	2.41	1.37	3.02	0.17	0.06
V1-4	7.82	1.31	1.69	0.76	0.05	0.98
V2-1	22.27	6.19	0.69	1.58	0.41	0.52
V2-2	9.26	1.29	2.25	0.75	0.18	0.28
V2-3	12.29	1.24	1.25	3.81	0.21	0.34
V2-4	9.17	2.45	1.62	0.84	0.59	0.16
V4-1	23.27	8.52	0.50	0.80	0.39	0.62
V4-2	17.60	4.89	2.09	1.43	0.77	0.10
V4-3	15.63	2.40	1.59	1.89	0.22	0.85
V4-4	9.07	2.14	2.08	1.43	0.25	0.35
V3-1	13.35	5.97	1.37	1.85	0.18	0.46
V3-2	21.53	0.98	1.89	3.83	0.28	T
V5-1	15.78	8.07	0.91	0.62	0.56	1.31
V5-3	13.33	4.25	1.61	2.93	0.43	0.36
V5-4	11.18	2.11	1.99	1.17	0.29	1.12
V5-5	6.99	3.55	1.37	1.50	0.13	0.88
V6-1	18.18	4.64	1.38	0.14	0.17	0.44
V6-2	20.05	2.34	1.59	0.06	0.03	1.79
AVERAGE	16.79	6.18	1.13	1.53	0.55	0.64
STD. DEV	5.76	3.60	0.57	1.20	0.47	0.49
MIN VALUE	5.24	0.98	0.00	0.06	0.00	0.00
MAX VALUE	26.76	21.82	2.66	5.19	2.04	1.96

COMPOSITION OF MMS CORES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
B01-1	0.78	P	1.46	18.86	18.36
B01-2	0.58	0.12	2.36	13.32	19.35
B02-1	0.25	0.46	3.93	11.52	27.30
B02-2	1.86	0.15	1.58	14.41	24.88
B03-1	0.86	0.05	1.56	15.55	20.46
B03-2	0.70	0.04	3.66	13.41	19.99
B03-3	1.70	T	3.31	26.08	22.98
B04-1	0.74	P	1.63	23.81	16.41
B05-1	0.54	0.51	3.96	10.88	30.00
B05-2	0.70	0.99	4.77	12.43	36.82
H01-1	1.80	1.15	3.10	11.04	39.81
H01-2	0.43	0.06	2.73	19.09	21.91
H01-3	0.30	1.44	7.60	29.91	32.23
H02-1	1.52	0.14	2.46	27.88	22.51
H02-2	0.12	0.45	2.32	20.61	25.08
H02-3	0.85	T	7.61	26.96	26.84
H03-1	1.98	0.33	3.13	18.78	24.68
H04-1	0.81	T	3.03	17.50	21.34
H04-2	0.05	T	4.19	12.38	22.09
H04-3	1.53	T	2.27	21.40	20.18
H05-1	1.23	0.12	3.33	18.07	22.98
H06-1	0.23	T	1.67	17.43	17.37
H06-2	0.57	0.15	4.47	14.35	30.88
H06-3	0.50	T	3.52	26.66	20.74
H06-4	1.55	T	3.81	28.65	17.24
H07-1	1.15	0.06	2.07	14.66	23.77
H07-2	0.23	0.00	3.53	16.55	19.63
H07-3	0.37	0.03	2.46	21.25	14.06
H08-1	0.71	0.14	2.25	16.91	24.58
H08-2	0.29	0.02	3.15	17.22	19.56
H09-1	0.45	0.05	6.59	23.50	16.53
H10-1	0.68	0.01	1.79	24.03	13.61
H10-2	0.99	0.06	3.48	25.40	14.42
H11-1	0.58	T	1.02	14.37	18.30
H12-1	0.68	0.09	2.17	22.14	24.55
H12-2	0.55	P	1.50	37.73	15.81
H13-1	1.80	0.37	0.78	28.80	27.27
H14-1	0.93	0.59	3.93	15.92	22.18
H14-2	0.33	1.09	3.42	27.36	20.99

COMPOSITION OF MMS CORES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
V1-1	0.71	0.05	3.13	11.50	25.50
V1-2	1.90	0.36	2.82	4.32	59.92
V1-3	2.17	0.33	2.74	6.41	55.34
V1-4	3.31	0.29	3.80	7.81	66.08
V2-1	1.18	0.15	2.21	13.31	29.64
V2-2	1.77	0.04	6.16	10.22	56.19
V2-3	1.80	0.29	2.97	6.38	47.27
V2-4	1.42	0.05	3.66	15.10	57.68
V4-1	1.70	0.08	3.06	12.36	29.98
V4-2	1.86	0.04	2.01	8.04	45.73
V4-3	2.61	0.11	2.40	8.25	40.98
V4-4	3.02	0.09	3.09	7.71	54.87
V3-1	5.39	0.10	3.63	10.43	44.86
V3-2	1.06	0.04	3.11	9.20	46.15
V5-1	1.73	0.03	4.26	18.60	25.71
V5-3	2.24	0.30	3.60	4.87	53.42
V5-4	1.40	0.03	5.04	7.09	53.91
V5-5	3.50	0.16	4.30	6.99	56.61
V6-1	0.39	0.04	4.51	16.55	30.56
V6-2	0.45	0.03	6.62	13.67	33.73
AVERAGE	1.21	0.19	3.30	16.54	30.37
STD. DEV	0.97	0.31	1.47	7.37	14.03
MIN VALUE	0.05	0.00	0.78	4.32	13.61
MAX VALUE	5.39	1.44	7.61	37.73	66.08

B. COMPOSITION OF COMMONWEALTH GRAB SAMPLES

SAMPLE NAME	WT% TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
1	7.28	10.20	16.71	21.25	5.73	0.53
2	6.08	6.42	31.94	19.89	6.49	1.43
3	5.29	17.05	19.04	29.79	3.43	2.90
4	9.30	9.42	21.44	16.29	2.11	1.81
5	7.62	1.13	24.10	21.92	8.28	0.17
6	2.29	0.19	22.81	37.36	2.70	9.04
7	2.10	4.65	18.90	16.35	6.97	1.30
8	1.67	0.23	34.42	22.65	1.59	7.49
9	1.74	0.51	25.56	20.05	2.00	5.24
10	7.68	0.50	25.10	26.23	7.31	T
11	1.53	0.08	31.43	34.83	0.47	2.98
12	8.13	3.00	25.02	21.19	6.51	0.91
13	3.01	2.60	20.21	22.31	5.13	0.49
14	5.51	0.74	28.72	20.74	2.84	3.19
15	5.94	5.74	35.07	15.00	4.59	0.72
22	4.53	1.31	23.73	16.21	5.43	1.57
23	1.99	3.72	21.75	17.99	4.06	2.96
24	3.78	0.53	19.35	13.76	5.25	2.35
25	5.64	2.95	17.71	19.40	3.38	2.28
27	0.73	0.12	17.65	13.53	2.27	3.26
28	2.69	2.36	30.73	18.80	8.33	0.30
29	4.33	4.28	14.80	20.18	5.98	1.26
30	7.00	2.97	30.01	17.44	5.61	1.45
31	3.03	3.48	19.49	22.37	8.27	0.21
32	8.06	2.75	27.99	25.94	1.57	4.02
33	5.12	6.35	58.85	8.75	2.24	0.49
34	7.70	6.67	18.18	17.81	4.49	0.85
35	7.12	8.39	35.58	15.13	4.92	3.31
36	9.07	10.90	24.41	17.44	4.35	2.99
39	8.35	7.61	34.58	16.82	3.79	0.88
40	5.25	6.83	44.26	6.14	3.40	1.15
41	8.62	10.34	24.88	5.75	3.79	2.52
42	11.06	7.83	21.44	20.02	2.09	0.26
43	2.94	4.56	16.65	19.40	6.26	0.17
44	4.12	5.93	19.86	27.48	3.99	0.51
45	2.35	7.85	19.48	19.30	6.55	0.75
46	6.80	4.95	24.83	16.17	3.29	2.58

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
47	6.18	6.38	27.94	18.07	4.80	1.05
48	9.39	7.09	30.79	15.13	1.35	1.67
49	6.32	6.78	23.31	13.88	1.20	1.17
50	6.30	3.64	18.98	19.46	7.24	0.94
51	6.49	10.66	21.39	17.07	3.82	0.93
52	5.90	11.65	25.39	18.99	3.49	0.09
53	7.79	12.08	19.39	17.17	4.74	1.82
54	14.66	11.08	28.98	20.44	3.05	0.05
55	7.87	12.97	13.08	21.56	5.07	0.02
56	7.95	10.59	22.44	13.15	4.20	2.59
57	7.79	16.18	24.98	17.69	3.36	0.46
58	5.44	11.05	22.60	20.13	1.57	1.57
59	11.02	4.48	34.94	19.55	3.93	P
60	4.51	6.55	24.63	19.89	3.11	1.34
61	6.08	6.85	23.86	16.81	0.72	0.40
62	2.93	8.81	23.09	16.97	4.38	0.85
63	3.65	12.94	13.58	16.86	3.98	1.87
64	5.32	13.56	10.17	20.68	7.98	0.02
65	1.53	0.87	27.44	10.54	13.90	2.91
66	6.79	10.13	22.23	15.69	5.61	0.04
67	2.55	3.40	50.28	12.42	2.13	5.68
68	1.14	1.08	35.93	11.78	9.41	2.73
69	0.83	0.28	20.47	8.56	14.31	2.96
70	0.65	0.42	34.69	10.78	10.73	5.95
71	1.19	3.19	28.81	15.16	8.96	0.91
72	1.94	0.34	41.63	16.84	8.20	2.96
73	4.92	5.91	21.11	16.93	3.98	1.15
74	4.40	2.63	21.08	21.89	5.08	0.06
75	0.55	0.52	29.78	19.75	5.51	3.77
76	0.48	0.33	31.24	9.29	12.76	5.07
77	1.51	2.25	31.18	9.58	9.91	0.44
78	1.04	0.44	37.19	14.50	4.70	3.06
79	0.14	0.26	22.13	8.67	8.17	11.78
80	4.74	1.47	38.22	8.14	4.19	0.80
81	4.39	6.17	24.58	17.49	9.06	0.40
82	1.31	0.31	47.30	13.36	4.85	1.67
83	0.70	0.36	44.71	15.00	7.52	5.31
84	0.51	0.26	37.74	13.52	7.73	1.96
85	10.75	3.48	54.88	8.40	3.96	1.24
86	1.31	1.32	33.13	12.26	9.94	1.82

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
87	4.16	1.65	42.77	11.69	7.77	0.55
88	0.44	0.34	32.51	10.81	9.46	5.44
89	5.22	7.18	19.35	18.72	4.08	0.78
89A	4.38	1.24	47.00	13.81	5.70	1.35
90	0.80	0.43	41.73	20.64	8.09	6.35
91	4.52	0.85	49.52	9.56	7.00	1.10
93	0.97	0.59	30.42	18.24	10.33	3.44
94	0.82	0.49	36.00	11.52	9.56	5.71
95	0.42	0.52	18.87	14.11	14.01	4.65
96	0.79	0.35	43.05	12.75	10.15	7.44
97	1.12	0.89	39.35	11.84	5.81	2.43
98	6.25	0.27	41.34	11.82	8.88	2.19
100	4.48	2.17	42.04	12.75	9.37	0.80
101	3.47	5.87	23.50	15.44	7.95	0.25
AVERAGE	4.53	4.58	28.56	16.81	5.74	2.16
STD. DEV	3.09	4.29	10.01	5.53	3.07	2.19
MIN VALUE	0.14	0.08	10.17	5.75	0.47	0.00
MAX VALUE	14.66	17.05	58.85	37.36	14.31	11.78

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
1	23.83	6.50	0.27	0.32	0.20	0.01
2	7.39	4.66	0.77	1.14	0.38	0.80
3	8.42	4.52	0.77	0.37	0.34	0.04
4	14.27	7.07	1.41	1.40	1.16	0.65
5	21.81	4.01	0.92	0.10	0.26	0.22
6	11.69	3.65	0.55	0.76	0.72	P
7	26.94	7.09	0.52	0.39	0.40	0.48
8	14.26	7.01	0.82	0.86	1.03	T
9	24.83	4.89	0.59	0.94	0.52	1.09
10	27.28	4.16	0.36	0.18	0.15	0.17
11	11.88	4.60	1.62	0.39	0.31	0.26
12	17.92	1.66	0.88	0.19	0.47	0.91
13	21.76	4.71	0.79	0.28	0.92	0.55
14	23.20	3.90	0.94	1.91	1.12	P
15	10.67	2.47	1.43	1.39	1.08	0.02
22	27.49	4.16	0.44	0.85	0.53	0.72
23	20.94	9.37	1.51	0.60	0.77	1.02
24	34.18	3.48	0.82	1.17	0.45	0.09
25	28.57	6.20	1.13	0.46	0.42	1.48
27	34.71	11.04	1.16	3.36	1.51	0.47
28	10.49	12.04	0.38	0.84	0.67	0.60
29	21.86	6.75	1.22	0.92	0.33	0.21
30	10.04	13.82	0.86	0.86	0.99	1.15
31	25.57	5.13	1.13	0.23	0.26	0.19
32	9.83	13.05	0.91	1.00	0.59	0.09
33	0.00	3.84	0.83	1.22	0.47	0.10
34	25.72	7.25	1.01	0.46	0.50	1.24
35	5.54	4.19	0.80	2.51	0.19	P
36	14.08	5.73	0.14	0.74	0.20	0.21
39	6.64	7.49	0.75	1.07	0.80	0.91
40	5.45	7.47	0.00	0.77	0.63	0.40
41	15.44	8.74	0.12	0.33	0.21	0.66
42	12.96	5.64	0.64	0.05	0.05	0.17
43	24.93	8.48	0.73	0.37	0.27	0.41
44	6.33	14.15	1.03	1.17	0.79	0.07
45	23.78	6.19	0.82	0.42	0.21	0.05
46	13.04	10.95	0.55	0.79	0.64	0.21

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
47	10.60	9.94	0.83	0.72	0.57	1.33
48	7.82	9.11	0.81	0.36	0.61	1.35
49	15.63	13.93	0.75	0.55	0.30	0.67
50	22.90	9.04	1.09	1.41	1.04	0.63
51	20.15	6.29	1.30	0.34	0.16	1.01
52	15.93	4.11	0.66	0.18	0.25	1.49
53	6.12	19.10	0.76	1.12	0.89	0.55
54	15.68	3.77	1.07	0.36	0.28	0.01
55	22.13	6.12	1.04	0.96	0.34	0.64
56	15.34	14.35	1.39	0.36	0.36	1.73
57	5.99	11.28	0.75	0.22	0.25	1.09
58	16.04	7.48	1.01	0.18	0.08	0.38
59	15.19	4.48	1.53	0.87	0.05	0.14
60	6.75	14.04	0.54	0.81	1.26	1.00
61	8.20	16.83	1.32	0.13	0.42	0.81
62	13.72	10.60	1.09	0.54	0.21	0.85
63	17.97	9.96	1.26	0.56	0.16	0.37
64	24.66	5.42	0.90	0.64	0.27	0.17
65	19.25	4.94	1.12	1.20	0.46	1.64
66	15.61	5.10	1.41	0.21	0.14	0.54
67	5.75	0.41	1.01	1.93	0.10	0.41
68	10.82	4.59	0.57	2.20	0.38	0.63
69	27.67	4.57	1.50	1.85	0.28	1.73
70	12.42	3.61	2.13	2.20	0.35	0.79
71	20.74	5.71	0.97	0.88	0.59	0.54
72	4.92	4.19	1.40	1.87	0.45	1.18
73	11.28	8.12	0.69	0.54	0.48	0.37
74	20.31	8.12	1.07	0.12	0.24	0.72
75	14.78	4.99	1.60	1.14	0.00	1.59
76	15.80	3.95	2.20	1.69	0.00	1.40
77	19.02	7.97	1.06	1.10	0.09	0.82
78	15.94	3.28	1.50	1.43	0.20	0.60
79	7.24	3.13	2.55	4.80	1.26	3.94
80	12.86	6.87	0.93	0.26	0.16	0.17
81	18.47	3.85	1.65	0.79	0.40	0.52
82	9.84	2.90	2.77	1.40	0.53	0.59
83	8.18	2.45	2.33	1.30	0.57	0.79
84	13.23	4.23	1.02	2.03	0.14	2.73
85	5.86	2.57	2.44	0.15	0.38	0.24

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
86	14.39	8.16	2.07	0.64	0.37	0.35
87	12.18	4.53	2.33	0.72	0.39	0.31
88	19.64	3.22	2.04	2.20	0.11	0.68
89	18.78	4.94	1.41	0.26	0.30	0.85
89A	14.84	1.73	1.73	0.88	0.26	0.10
90	3.91	0.69	1.30	2.39	0.18	0.44
91	11.66	2.02	0.93	1.15	0.12	0.39
93	15.15	5.69	1.50	1.19	0.00	0.52
94	13.82	6.26	1.88	2.32	0.00	1.08
95	23.51	7.64	0.87	3.51	0.04	1.41
96	7.55	2.72	1.59	2.07	0.26	0.55
97	6.72	6.75	1.57	0.83	0.04	0.31
98	9.30	4.04	1.69	1.65	0.00	0.09
100	9.48	2.39	2.02	0.71	0.04	0.07
101	16.52	10.69	0.88	0.55	0.18	0.61
AVERAGE	15.30	6.47	1.14	1.00	0.41	0.66
STD. DEV	7.25	3.66	0.56	0.83	0.33	0.62
MIN VALUE	0.00	0.41	0.00	0.05	0.00	0.00
MAX VALUE	34.71	19.10	2.77	4.80	1.51	3.94

COMPOSITION OF COMMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
1	0.43	0.07	1.56	12.39	19.36
2	1.03	0.42	2.62	14.62	37.92
3	0.94	0.05	1.30	11.03	22.47
4	2.99	0.22	3.31	16.44	30.76
5	1.73	0.13	4.24	11.00	31.21
6	1.15	0.57	1.29	7.52	27.13
7	0.79	0.04	3.00	12.18	23.64
8	1.53	0.41	2.12	5.58	40.16
9	0.97	0.28	1.49	11.04	29.83
10	0.89	0.11	0.62	6.94	27.26
11	1.96	1.70	2.45	5.04	39.55
12	1.61	0.04	3.16	16.52	30.91
13	0.97	0.19	1.91	17.18	24.35
14	2.89	0.82	1.62	7.36	36.90
15	1.34	0.11	5.37	15.00	44.70
22	3.08	0.58	1.87	12.04	30.55
23	0.89	0.14	2.54	11.73	27.43
24	2.18	0.29	2.06	14.04	25.86
25	1.70	0.27	1.76	12.30	23.04
27	1.56	0.56	2.30	6.49	26.60
28	1.06	0.20	1.90	11.29	35.12
29	0.71	T	2.44	19.05	20.10
30	0.88	0.39	2.88	10.63	35.88
31	1.02	0.46	2.07	10.12	24.41
32	0.90	0.41	1.63	9.30	32.84
33	0.65	0.14	4.10	11.96	65.80
34	1.95	0.44	1.97	11.43	24.02
35	0.19	0.99	1.64	16.61	41.71
36	1.38	0.81	2.06	14.56	29.54
39	1.84	0.02	1.46	15.35	39.71
40	0.00	0.74	4.29	18.46	50.06
41	2.97	0.17	3.00	21.09	31.47
42	0.57	0.36	5.07	22.85	28.13
43	1.17	0.17	3.28	13.15	22.37
44	0.73	0.15	3.21	14.60	26.16
45	0.62	0.10	1.80	12.08	23.24
46	1.79	0.16	3.69	16.35	31.81

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
47	0.52	0.15	1.46	15.63	31.62
48	2.17	T	3.67	18.07	37.80
49	1.01	0.12	2.73	17.97	28.47
50	1.17	0.67	1.79	9.99	25.12
51	1.32	0.23	3.49	11.85	28.06
52	1.32	0.28	3.86	12.31	31.68
53	0.80	0.11	1.15	14.20	23.32
54	0.19	0.37	4.92	9.74	35.89
55	1.08	0.05	3.09	11.84	19.31
56	0.91	0.39	3.83	8.36	29.33
57	1.33	0.05	3.34	13.04	30.67
58	0.44	0.08	2.01	15.38	26.33
59	0.63	0.08	4.30	9.83	42.36
60	1.14	0.01	1.87	17.07	29.00
61	0.99	T	3.48	19.16	29.79
62	1.25	T	1.35	16.28	27.33
63	1.71	0.05	3.33	15.40	20.49
64	0.83	P	3.44	11.25	15.98
65	1.46	0.15	2.15	11.95	33.52
66	0.80	P	3.56	18.93	28.21
67	3.03	0.57	2.10	10.81	58.92
68	2.79	0.51	3.42	13.15	45.42
69	4.41	0.33	1.29	9.81	29.83
70	4.25	0.54	2.09	9.06	45.90
71	1.70	0.02	2.43	9.39	34.81
72	4.05	0.44	2.66	9.05	52.04
73	0.59	0.08	1.19	27.59	24.20
74	1.10	T	2.39	15.19	25.75
75	2.39	0.43	2.79	10.97	38.12
76	1.99	0.59	3.68	10.02	41.39
77	2.72	0.12	2.58	11.16	38.75
78	2.65	0.44	2.91	11.17	46.12
79	4.80	1.17	2.72	17.38	38.18
80	1.80	0.31	3.82	20.00	45.35
81	1.47	T	3.42	11.73	31.92
82	3.26	0.49	3.15	7.57	58.37
83	1.54	0.67	2.05	7.20	52.61
84	3.18	0.29	2.62	9.32	46.88
85	1.77	0.08	3.82	10.73	63.14

COMPOSITION OF COMMONWEALTH GRAB SAMPLES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
86	3.04	0.19	3.24	9.08	42.31
87	2.52	0.26	3.31	9.03	51.90
88	3.59	0.91	2.23	6.83	43.47
89	2.17	0.13	2.79	18.25	26.11
89A	1.89	0.15	2.54	6.77	54.20
90	3.27	0.62	3.36	6.58	52.68
91	2.60	0.22	3.39	9.49	57.82
93	2.93	0.73	2.90	6.38	39.66
94	1.87	0.56	1.63	7.29	44.25
95	2.14	0.67	1.58	6.47	27.64
96	1.65	1.80	3.95	4.13	54.11
97	1.35	0.10	3.07	18.95	46.26
98	1.95	0.67	3.51	12.60	50.82
100	0.99	0.04	3.68	13.46	49.47
101	1.24	0.03	2.04	14.24	28.24
AVERAGE	1.68	0.33	2.71	12.47	35.42
STD. DEV	1.01	0.34	0.97	4.34	11.22
MIN VALUE	0.00	0.00	0.62	4.13	15.98
MAX VALUE	4.80	1.80	5.37	27.59	65.80

C. COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES

SAMPLE NAME	WT% TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
1090-1	2.46	8.30	26.15	14.81	9.05	0.39
1090-2	1.91	5.13	25.84	16.38	9.67	0.79
1091-1	2.36	3.67	24.11	15.31	8.10	0.52
1091-2	1.71	2.57	30.41	14.36	8.63	0.38
1091-3	1.61	6.14	37.86	10.46	6.19	0.90
1092-1	1.70	0.85	45.28	9.81	13.01	1.48
1092-2	1.03	0.76	46.82	3.69	14.91	1.23
1094-1	1.15	3.24	36.10	13.20	7.20	1.13
1094-2	1.01	1.36	47.67	9.06	10.53	0.62
1095-1	2.51	10.29	23.13	18.31	6.16	0.81
1095-2	2.30	1.15	46.39	4.67	16.89	2.29
1096-1	1.84	5.82	25.74	13.69	10.06	0.77
1096-2	2.23	2.83	39.03	8.67	18.06	1.25
1097-1	2.60	5.62	30.25	14.61	9.00	0.80
1097-2	1.39	1.15	46.66	5.15	17.61	1.41
1097-3	1.26	1.25	53.25	8.56	4.52	0.76
1098-1	1.78	0.75	49.89	5.39	15.01	2.63
1098-2	0.58	1.43	60.33	2.01	6.96	1.34
1099-1	1.18	6.62	34.19	12.61	8.61	0.76
1099-2	1.78	1.40	51.02	6.31	11.53	1.48
1100-1	2.64	10.58	24.72	13.15	5.16	0.58
1100-2	2.51	2.78	45.03	7.06	10.58	1.64
1103-1	1.80	2.55	38.64	14.57	6.16	0.77
1103-2	1.62	1.37	40.50	12.30	7.54	0.51
1103-3	1.74	12.07	21.50	18.01	7.39	0.66
1106-1	3.59	3.78	37.70	22.82	7.69	0.05
1106-2	2.63	4.67	29.36	20.27	7.10	1.19
1107-1	4.35	4.00	30.76	17.18	6.55	1.03
1107-2	1.83	5.07	19.67	19.91	6.98	0.60
1109-1	3.08	7.27	22.70	15.94	10.86	0.88
1111-1	2.76	12.52	24.43	17.48	6.26	0.13
1111-2	3.20	10.98	29.74	19.42	6.08	0.25
1116-1	4.39	13.45	25.36	15.21	5.66	0.46
1116-2	4.00	9.73	27.64	17.18	6.12	0.51
1119-1	2.43	4.89	21.87	20.14	7.07	0.84
1119-2	2.39	6.97	28.19	19.36	4.85	0.34
1120-1	1.95	4.41	24.62	16.08	8.01	0.85

COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES, continued

SAMPLE NAME	WT % TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
1120-2	3.05	8.29	32.17	20.13	5.62	0.42
1121-1	3.44	15.07	21.04	21.66	1.60	1.00
1122-1	5.67	13.18	27.39	13.92	7.39	0.62
1127-1	5.51	13.28	24.63	17.10	5.51	0.76
1127-2	2.70	7.22	28.96	15.72	9.49	0.04
1129-1	7.65	12.25	23.13	16.71	8.69	0.34
1129-2	6.11	13.83	18.66	15.93	7.88	0.48
1130-1	7.17	18.35	21.58	21.30	6.54	0.16
1130-2	1.96	10.01	23.01	14.21	9.11	0.13
1131-1	5.92	27.58	26.69	10.79	6.68	0.33
1132-1	6.32	20.71	21.69	18.36	5.14	0.32
1134-1	8.79	12.12	33.99	21.54	3.57	0.52
1134-2	6.82	15.29	30.93	19.10	3.51	0.20
1136-1	9.01	11.98	28.72	19.54	3.18	0.50
1136-2	6.42	11.98	28.09	15.74	7.23	0.21
1136-3	3.34	8.19	29.35	19.01	8.10	0.65
1139-1	2.44	4.98	26.64	22.64	4.65	0.81
2000-1	2.00	3.28	26.55	16.97	9.61	0.22
2000-2	2.39	2.54	21.59	17.11	8.66	0.06
2001-1	2.02	3.77	20.24	18.92	8.61	0.33
2002-1	3.75	5.07	29.15	17.49	9.24	0.29
2002-2	3.01	4.72	29.41	13.72	10.77	0.39
110-1	2.60	3.54	32.48	12.77	8.34	1.46
110-2	2.21	7.16	18.77	17.97	9.98	0.46
110-3	1.41	1.60	20.25	15.16	9.40	2.78
115-1	0.74	1.21	28.03	16.83	6.19	2.74
116-1	0.58	0.90	31.50	14.06	7.52	3.28
116-2	0.54	0.75	31.64	14.78	6.13	2.50
116-3	2.17	1.38	35.92	13.50	10.10	2.70
116-4	0.92	0.37	36.39	13.97	6.34	2.37
116-5	1.66	0.23	31.24	15.21	7.60	2.04
117-1	1.26	0.29	29.86	15.12	5.09	3.17
117-2	3.87	0.07	27.72	30.70	4.54	3.13
117-3	3.95	0.09	28.32	27.00	5.09	2.68
117-4	2.84	0.14	22.80	23.07	6.55	3.76
AVERAGE	2.94	6.23	30.85	15.43	7.99	1.04
STD. DEV.	1.94	5.60	9.13	5.22	3.16	0.92
MIN VALUE	0.54	0.07	18.66	2.01	1.60	0.04
MAX VALUE	9.01	27.58	60.33	30.70	18.06	3.76

COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
1090-1	13.82	9.35	0.94	0.31	0.23	0.32
1090-2	13.37	8.68	1.23	1.04	0.52	0.57
1091-1	18.00	7.00	0.56	0.81	0.88	0.73
1091-2	12.07	5.18	1.63	1.02	0.32	0.09
1091-3	12.40	3.32	2.31	0.92	0.21	0.79
1092-1	9.00	4.12	1.71	1.61	0.00	0.16
1092-2	7.60	4.24	1.93	1.32	0.11	0.79
1094-1	14.83	5.11	1.26	0.60	0.44	0.65
1094-2	8.39	2.63	1.56	1.48	0.27	0.56
1095-1	14.39	6.22	0.68	0.46	0.39	0.61
1095-2	6.98	2.86	1.95	1.40	0.48	0.55
1096-1	21.12	4.99	0.36	0.98	0.26	0.66
1096-2	9.57	4.50	1.63	1.27	0.16	0.18
1097-1	11.31	10.02	0.67	0.99	0.22	0.34
1097-2	9.00	1.96	1.23	1.36	0.44	0.99
1097-3	10.76	3.46	2.12	0.82	0.28	0.45
1098-1	9.30	3.40	1.34	2.25	0.45	0.05
1098-2	10.87	1.56	1.51	2.22	0.36	0.02
1099-1	13.75	3.94	1.52	0.63	0.30	0.67
1099-2	9.82	0.97	1.66	2.08	0.32	0.47
1100-1	18.46	8.98	0.66	0.93	0.65	0.33
1100-2	10.22	6.25	1.25	1.85	0.10	0.09
1103-1	15.44	8.05	0.64	0.61	0.27	0.30
1103-2	12.49	4.85	1.36	1.18	0.24	0.44
1103-3	13.60	8.92	1.21	0.85	0.04	0.55
1106-1	11.86	4.36	0.81	0.68	0.28	0.32
1106-2	13.48	11.02	0.85	0.36	0.24	0.20
1107-1	14.89	9.64	0.66	0.77	0.47	0.55
1107-2	22.10	9.55	1.43	0.75	0.49	0.35
1109-1	15.29	9.97	0.47	0.22	0.37	0.74
1111-1	15.17	7.75	1.19	0.46	0.23	0.23
1111-2	11.02	5.82	0.91	0.00	0.32	0.97
1116-1	16.48	5.25	0.96	0.50	0.62	0.11
1116-2	14.70	3.74	2.10	0.39	0.13	0.48
1119-1	22.89	4.70	1.35	0.20	0.27	0.91
1119-2	17.10	5.43	1.35	0.40	0.28	0.90
1120-1	19.70	8.00	1.09	0.98	0.13	1.27
1120-2	10.63	6.09	1.05	0.23	0.17	0.06

COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES, continued

SAMPLE NAME	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
1121-1	12.06	5.84	0.94	0.36	0.13	P
1122-1	15.07	6.10	0.90	0.55	0.34	0.71
1127-1	17.06	5.15	0.89	0.25	0.27	0.00
1127-2	12.84	7.48	0.55	0.67	0.17	0.54
1129-1	16.77	5.58	0.86	0.64	0.79	0.22
1129-2	15.03	10.09	0.79	0.68	0.86	0.32
1130-1	13.25	3.41	0.59	0.51	0.49	0.29
1130-2	5.17	18.27	0.45	0.47	0.28	0.35
1131-1	6.37	3.41	1.06	0.48	0.34	0.30
1132-1	12.30	3.93	0.68	0.52	0.63	0.44
1134-1	8.37	2.99	1.79	0.20	0.39	0.24
1134-2	7.57	6.80	0.95	0.55	0.36	0.06
1136-1	11.63	4.07	1.13	0.43	0.27	0.59
1136-2	12.60	3.89	0.61	0.21	0.55	0.31
1136-3	13.20	6.06	1.09	0.28	0.21	0.51
1139-1	18.54	6.47	1.23	0.91	0.63	0.48
2000-1	19.05	7.05	1.34	0.96	0.48	0.29
2000-2	18.84	11.73	1.45	1.03	0.25	0.39
2001-1	20.64	8.60	1.23	0.59	1.00	0.30
2002-1	9.52	6.22	0.49	0.44	0.21	0.45
2002-2	12.04	11.05	0.31	0.44	0.47	0.80
110-1	16.89	3.05	1.58	0.72	0.05	0.49
110-2	20.78	7.57	1.21	0.81	0.09	0.46
110-3	26.97	6.68	1.15	1.45	0.93	0.47
115-1	21.61	4.59	1.52	1.19	0.91	1.00
116-1	22.86	5.34	1.69	2.37	0.56	0.08
116-2	20.41	2.67	2.05	1.78	0.35	0.54
116-3	17.10	2.11	1.44	2.05	0.53	0.54
116-4	16.76	4.01	1.95	1.65	1.45	0.17
116-5	20.40	3.86	3.15	1.95	0.62	0.31
117-1	24.34	5.75	1.38	1.25	0.56	0.61
117-2	14.80	4.50	1.70	1.65	0.88	1.34
117-3	20.71	3.38	1.06	1.46	1.06	P
117-4	29.22	3.28	1.26	1.57	0.69	T
AVERAGE	14.76	5.87	1.22	0.92	0.41	0.45
STD. DEV.	5.00	2.90	0.52	0.58	0.27	0.30
MIN VALUE	5.17	0.97	0.31	0.00	0.00	0.00
MAX VALUE	29.22	18.27	3.15	2.37	1.45	1.34

COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
1090-1	0.44	T	3.05	12.85	30.89
1090-2	1.33	0.07	3.69	11.68	33.20
1091-1	1.43	2.47	9.22	7.19	38.61
1091-2	1.98	0.15	4.05	17.15	39.24
1091-3	1.16	T	4.64	12.70	46.89
1092-1	1.37	0.13	3.19	8.28	53.29
1092-2	3.15	0.05	4.90	8.50	58.18
1094-1	1.33	0.01	2.93	11.98	42.23
1094-2	1.71	0.01	4.19	9.96	56.62
1095-1	1.02	T	3.62	13.90	28.92
1095-2	1.47	P	3.26	9.67	54.46
1096-1	0.86	0.05	2.04	12.59	30.03
1096-2	1.35	0.03	2.84	8.62	46.15
1097-1	1.08	T	4.42	10.68	37.40
1097-2	2.13	0.09	3.82	6.99	55.30
1097-3	1.95	T	3.17	8.65	61.31
1098-1	2.20	0.13	1.36	5.85	57.16
1098-2	2.01	0.16	3.08	6.14	69.30
1099-1	2.10	0.01	4.21	10.08	42.66
1099-2	1.31	0.25	3.00	8.38	59.32
1100-1	1.00	T	3.20	11.60	30.51
1100-2	0.83	0.01	3.99	8.31	52.97
1103-1	1.23	0.01	1.90	8.87	43.02
1103-2	3.12	T	2.74	11.35	48.90
1103-3	1.31	0.11	4.44	9.34	29.41
1106-1	0.77	0.09	2.32	6.48	42.37
1106-2	0.43	T	1.70	9.14	32.69
1107-1	0.79	0.12	2.59	9.99	35.70
1107-2	1.17	0.19	2.01	9.74	25.22
1109-1	0.96	T	1.27	13.07	25.62
1111-1	0.82	0.03	3.88	9.42	30.81
1111-2	0.71	0.03	2.72	11.03	34.11
1116-1	0.75	0.10	2.69	12.40	30.36
1116-2	0.36	0.11	3.93	12.89	34.52
1119-1	0.93	0.22	2.17	11.53	26.75
1119-2	0.35	0.05	3.71	10.73	34.04
1120-1	0.55	0.23	2.08	11.99	29.55
1120-2	1.07	0.03	2.69	11.36	37.24

COMPOSITION OF COMMONWEALTH (USGS) CORE SAMPLES, continued

SAMPLE NAME	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
1121-1	0.80	0.04	4.23	15.23	27.41
1122-1	0.84	0.09	2.23	10.66	32.00
1127-1	0.90	P	3.03	11.17	29.70
1127-2	1.23	0.07	3.15	11.86	34.64
1129-1	1.01	0.08	2.21	10.73	27.92
1129-2	0.79	T	2.20	12.46	23.11
1130-1	0.58	0.08	2.94	9.93	26.28
1130-2	0.91	0.03	0.99	16.60	25.87
1131-1	0.70	0.37	2.82	12.08	32.12
1132-1	0.84	0.01	5.57	8.85	29.32
1134-1	0.30	0.17	4.64	9.17	41.09
1134-2	0.57	T	3.60	10.51	36.60
1136-1	0.99	P	3.46	13.51	34.72
1136-2	0.73	0.30	3.68	13.87	33.63
1136-3	0.48	0.03	3.56	9.27	34.79
1139-1	1.62	0.26	2.79	7.35	33.45
2000-1	1.88	0.07	2.52	9.73	33.32
2000-2	1.42	T	3.37	11.54	28.86
2001-1	1.75	0.05	2.18	11.79	26.04
2002-1	0.21	P	3.15	18.08	33.44
2002-2	0.89	0.01	2.45	12.53	33.51
110-1	0.52	T	5.49	12.62	40.79
110-2	1.10	T	2.19	11.46	24.07
110-3	1.21	0.10	1.35	10.49	25.51
115-1	1.03	0.11	2.10	10.94	33.97
116-1	2.16	0.15	4.01	3.52	41.87
116-2	2.66	0.10	2.73	10.89	40.97
116-3	1.98	T	3.46	7.20	44.85
116-4	1.55	0.14	4.02	8.86	45.70
116-5	2.52	0.23	3.31	7.31	42.41
117-1	1.76	0.06	2.50	8.26	36.81
117-2	1.08	0.10	2.04	5.75	34.29
117-3	0.92	0.16	1.86	6.22	33.77
117-4	1.35	0.06	1.76	4.48	28.81
AVERAGE	1.22	0.11	3.14	10.36	37.45
STD. DEV.	0.64	0.29	1.22	2.76	10.25
MIN VALUE	0.21	0.00	0.99	3.52	23.11
MAX VALUE	3.15	2.47	9.22	18.08	69.30

APPENDIX IV

SUMMARY COMPOSITION STATISTICS FOR ALL SAMPLES

	WT% TOTAL HM	WT % MAG	WT % IL	WT % GAR	WT % EP	WT % STAUR
average	3.46	5.54	27.83	15.45	7.03	1.62
std. dev.	2.54	4.77	10.86	5.39	3.27	1.78
min value	0.14	0.07	7.65	2.01	0.47	0.00
max value	14.66	27.58	60.33	37.36	18.06	11.78

	WT % AMPHIB	WT % PYROX	WT % RUTILE	WT % SILL/KY	WT % SPHENE	WT % TOURM
average	15.52	6.20	1.16	1.12	0.45	0.58
std. dev.	6.23	3.41	0.55	0.91	0.36	0.51
min value	0.00	0.41	0.00	0.00	0.00	0.00
max value	34.71	21.82	3.15	5.19	2.04	3.94

	WT % LEUCOX	WT % MONAZITE	WT % ZIRCON	WT % OTHER	WT % ECON
average	1.41	0.22	3.01	12.87	34.74
std. dev.	0.92	0.33	1.22	5.48	12.01
min value	0.00	0.00	0.62	3.52	13.61
max value	5.39	2.47	9.22	37.73	69.30

APPENDIX V

SELECTED MINERAL COMPOSITION WITH RESPECT TO THE ENTIRE SAMPLE

Underlined samples have high concentrations of one or more ECON minerals.
T = trace, P = present.

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
B01-1	0.56	0.04	0.03	P	0.06	0.72
B01-2	0.42	0.02	0.02	0.00	0.07	0.56
B02-1	0.48	0.03	0.01	0.01	0.10	0.66
B02-2	0.78	0.03	0.07	0.01	0.06	0.97
B03-1	0.53	0.02	0.03	0.00	0.05	0.65
B03-2	0.46	0.02	0.02	0.00	0.12	0.66
B03-3	0.50	0.05	0.06	T	0.11	0.75
B04-1	0.32	0.02	0.02	P	0.04	0.42
B05-1	0.39	0.01	0.01	0.01	0.07	0.56
B05-2	0.46	0.03	0.01	0.02	0.09	0.67
H01-1	1.15	0.03	0.07	0.04	0.12	1.53
H01-2	0.88	0.06	0.02	0.00	0.14	1.12
H01-3	0.95	0.15	0.02	0.08	0.42	1.77
H02-1	0.37	0.02	0.04	0.00	0.06	0.52
H02-2	0.22	T	0.00	0.00	0.03	0.27
H02-3	0.18	0.01	0.01	T	0.10	0.36
H03-1	0.37	0.02	0.04	0.01	0.07	0.53
H04-1	0.47	0.05	0.02	T	0.09	0.65
H04-2	0.18	0.01	0.00	T	0.06	0.30
H04-3	0.23	0.02	0.02	T	0.04	0.32
H05-1	0.58	0.05	0.05	0.00	0.12	0.84
H06-1	0.45	0.02	0.01	T	0.05	0.54
H06-2	0.34	0.03	0.01	0.00	0.08	0.52
H06-3	0.23	0.01	0.01	T	0.05	0.31
H06-4	0.07	0.01	0.01	T	0.03	0.13
H07-1	0.72	0.03	0.04	0.00	0.08	0.89
H07-2	0.25	0.02	0.00	0.00	0.07	0.37
H07-3	0.15	0.01	0.01	0.00	0.04	0.22
H08-1	1.14	0.03	0.04	0.01	0.12	1.36
H08-2	0.41	0.03	0.01	0.00	0.09	0.56
H09-1	0.28	0.01	0.02	0.00	0.24	0.60
H10-1	0.26	0.01	0.02	0.00	0.05	0.37
H10-2	0.28	0.02	0.03	0.00	0.11	0.46
H11-1	0.62	0.04	0.02	T	0.04	0.73
H12-1	1.43	0.03	0.05	0.01	0.15	1.69
H12-2	0.68	0.01	0.03	P	0.08	0.84
H13-1	0.45	0.02	0.04	0.01	0.02	0.61
H14-1	0.08	0.01	0.00	0.00	0.02	0.11
H14-2	0.14	0.03	0.00	0.02	0.05	0.31

APPENDIX V, continued

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
V1-1	0.23	0.02	0.01	0.00	0.04	0.30
V1-2	0.42	0.02	0.02	0.00	0.02	0.49
V1-3	0.28	0.01	0.01	0.00	0.02	0.34
V1-4	0.46	0.01	0.03	0.00	0.03	0.55
V2-1	0.65	0.02	0.03	0.00	0.06	0.81
V2-2	0.76	0.04	0.03	0.00	0.10	0.94
V2-3	1.45	0.05	0.07	0.01	0.12	1.84
V2-4	1.06	0.03	0.03	0.00	0.08	1.23
V4-1	0.42	0.01	0.03	0.00	0.05	0.53
V4-2	0.41	0.02	0.02	0.00	0.02	0.49
V4-3	0.45	0.02	0.04	0.00	0.03	0.57
V4-4	0.61	0.03	0.04	0.00	0.04	0.74
V3-1	0.46	0.02	0.08	0.00	0.05	0.64
V3-2	0.18	0.01	0.01	0.00	0.02	0.23
V5-1	0.35	0.02	0.03	0.00	0.08	0.50
V5-3	0.54	0.02	0.03	0.00	0.05	0.67
V5-4	0.53	0.02	0.02	0.00	0.06	0.65
V5-5	0.66	0.02	0.05	0.00	0.06	0.82
V6-1	0.60	0.03	0.01	0.00	0.11	0.76
V6-2	0.43	0.03	0.01	0.00	0.11	0.58
1	1.22	0.02	0.03	0.00	0.11	1.41
2	1.94	0.05	0.06	0.03	0.16	2.31
3	1.01	0.04	0.05	0.00	0.07	1.19
4	1.99	0.13	0.28	0.02	0.31	2.86
5	1.84	0.07	0.13	0.01	0.32	2.38
6	0.52	0.01	0.03	0.01	0.03	0.62
7	0.40	0.01	0.02	0.00	0.06	0.50
8	0.58	0.01	0.03	0.01	0.04	0.67
9	0.44	0.01	0.02	0.00	0.03	0.52
10	1.93	0.03	0.07	0.01	0.05	2.09
11	0.48	0.02	0.03	0.03	0.04	0.60
12	2.03	0.07	0.13	0.00	0.26	2.51
13	0.61	0.02	0.03	0.01	0.06	0.73
14	1.58	0.05	0.16	0.05	0.09	2.03
15	2.08	0.08	0.08	0.01	0.32	2.65
22	1.08	0.02	0.14	0.03	0.08	1.38
23	0.43	0.03	0.02	0.00	0.05	0.55
24	0.73	0.03	0.08	0.01	0.08	0.98
25	1.00	0.06	0.10	0.02	0.10	1.30
27	0.13	0.01	0.01	0.00	0.02	0.19
28	0.83	0.01	0.03	0.01	0.05	0.94
29	0.64	0.05	0.03	T	0.11	0.87

APPENDIX V, continued

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
30	2.10	0.06	0.06	0.03	0.20	2.51
31	0.59	0.03	0.03	0.01	0.06	0.74
32	2.26	0.07	0.07	0.03	0.13	2.65
33	3.01	0.04	0.03	0.01	0.21	3.37
34	1.40	0.08	0.15	0.03	0.15	1.85
35	2.53	0.06	0.01	0.07	0.12	2.97
36	2.21	0.01	0.12	0.07	0.19	2.68
39	2.89	0.06	0.15	0.00	0.12	3.31
40	2.33	0.00	0.00	0.04	0.23	2.63
41	2.14	0.01	0.26	0.01	0.26	2.71
42	2.37	0.07	0.06	0.04	0.56	3.11
43	0.49	0.02	0.03	0.01	0.10	0.66
44	0.82	0.04	0.03	0.01	0.13	1.08
45	0.46	0.02	0.01	0.00	0.04	0.55
46	1.69	0.04	0.12	0.01	0.25	2.16
47	1.73	0.05	0.03	0.01	0.09	1.95
48	2.89	0.08	0.20	T	0.34	3.55
49	1.47	0.05	0.06	0.01	0.17	1.80
50	1.20	0.07	0.07	0.04	0.11	1.58
51	1.39	0.08	0.09	0.01	0.23	1.82
52	1.50	0.04	0.08	0.02	0.23	1.87
53	1.51	0.06	0.06	0.01	0.09	1.82
54	4.25	0.16	0.03	0.05	0.72	5.26
55	1.03	0.08	0.09	0.00	0.24	1.52
56	1.78	0.11	0.07	0.03	0.30	2.33
57	1.95	0.06	0.10	0.00	0.26	2.39
58	1.23	0.05	0.02	0.00	0.11	1.43
59	3.85	0.17	0.07	0.01	0.47	4.67
60	1.11	0.02	0.05	0.00	0.08	1.31
61	1.45	0.08	0.06	T	0.21	1.81
62	0.68	0.03	0.04	T	0.04	0.80
63	0.50	0.05	0.06	0.00	0.12	0.75
64	0.54	0.05	0.04	P	0.18	0.85
65	0.42	0.02	0.02	0.00	0.03	0.51
66	1.51	0.10	0.05	P	0.24	1.92
67	1.28	0.03	0.08	0.01	0.05	1.50
68	0.41	0.01	0.03	0.01	0.04	0.52
69	0.17	0.01	0.04	0.00	0.01	0.25
70	0.23	0.01	0.03	0.00	0.01	0.30
71	0.34	0.01	0.02	0.00	0.03	0.41
72	0.81	0.03	0.08	0.01	0.05	1.01
73	1.04	0.03	0.03	0.00	0.06	1.19

APPENDIX V. continued

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
74	0.93	0.05	0.05	T	0.11	1.13
75	0.16	0.01	0.01	0.00	0.02	0.21
76	0.15	0.01	0.01	0.00	0.02	0.20
77	0.47	0.02	0.04	0.00	0.04	0.59
78	0.39	0.02	0.03	0.00	0.03	0.48
79	0.03	0.00	0.01	0.00	0.00	0.05
80	1.81	0.04	0.09	0.01	0.18	2.15
81	1.08	0.07	0.06	T	0.15	1.40
82	0.62	0.04	0.04	0.01	0.04	0.76
83	0.31	0.02	0.01	0.00	0.01	0.37
84	0.19	0.01	0.02	0.00	0.01	0.24
85	5.90	0.26	0.19	0.01	0.41	6.79
86	0.43	0.03	0.04	0.00	0.04	0.55
87	1.78	0.10	0.10	0.01	0.14	2.16
88	0.14	0.01	0.02	0.00	0.01	0.19
89	1.01	0.07	0.11	0.01	0.15	1.36
89A	2.06	0.08	0.08	0.01	0.11	2.37
90	0.34	0.01	0.03	0.01	0.03	0.42
91	2.24	0.04	0.12	0.01	0.15	2.61
93	0.29	0.01	0.03	0.01	0.03	0.38
94	0.29	0.02	0.02	0.00	0.01	0.36
95	0.08	0.00	0.01	0.00	0.01	0.12
96	0.34	0.01	0.01	0.01	0.03	0.43
97	0.44	0.02	0.02	0.00	0.03	0.52
98	2.59	0.11	0.12	0.04	0.22	3.18
100	1.88	0.09	0.04	0.00	0.16	2.22
101	0.82	0.03	0.04	0.00	0.07	0.98
1090-1	0.64	0.02	0.01	T	0.08	0.76
1090-2	0.49	0.02	0.03	0.00	0.07	0.63
1091-1	0.57	0.01	0.03	0.06	0.22	0.91
1091-2	0.52	0.03	0.03	0.00	0.07	0.67
1091-3	0.61	0.04	0.02	T	0.07	0.75
1092-1	0.77	0.03	0.02	0.00	0.05	0.90
1092-2	0.48	0.02	0.03	0.00	0.05	0.60
1094-1	0.42	0.01	0.02	0.00	0.03	0.49
1094-2	0.48	0.02	0.02	0.00	0.04	0.57
1095-1	0.58	0.02	0.03	T	0.09	0.72
1095-2	1.07	0.04	0.03	P	0.07	1.25
1096-1	0.47	0.01	0.02	0.00	0.04	0.55
1096-2	0.87	0.04	0.03	0.00	0.06	1.03
1097-1	0.79	0.02	0.03	T	0.11	0.97
1097-2	0.65	0.02	0.03	0.00	0.05	0.77

APPENDIX V. continued

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
1097-3	0.67	0.03	0.02	T	0.04	0.77
1098-1	0.89	0.02	0.04	0.00	0.02	1.02
1098-2	0.35	0.01	0.01	0.00	0.02	0.40
1099-1	0.40	0.02	0.02	0.00	0.05	0.50
1099-2	0.91	0.03	0.02	0.00	0.05	1.05
1100-1	0.65	0.02	0.03	T	0.08	0.80
1100-2	1.13	0.03	0.02	0.00	0.10	1.33
1103-1	0.70	0.01	0.02	0.00	0.03	0.78
1103-2	0.65	0.02	0.05	T	0.04	0.79
1103-3	0.37	0.02	0.02	0.00	0.08	0.51
1106-1	1.35	0.03	0.03	0.00	0.08	1.52
1106-2	0.77	0.02	0.01	T	0.04	0.86
1107-1	1.34	0.03	0.03	0.01	0.11	1.55
1107-2	0.36	0.03	0.02	0.00	0.04	0.46
1109-1	0.70	0.01	0.03	T	0.04	0.79
1111-1	0.67	0.03	0.02	0.00	0.11	0.85
1111-2	0.95	0.03	0.02	0.00	0.09	1.09
1116-1	1.11	0.04	0.03	0.00	0.12	1.33
1116-2	1.11	0.08	0.01	0.00	0.16	1.38
1119-1	0.53	0.03	0.02	0.01	0.05	0.65
1119-2	0.67	0.03	0.01	0.00	0.09	0.81
1120-1	0.48	0.02	0.01	0.00	0.04	0.58
1120-2	0.98	0.03	0.03	0.00	0.08	1.14
1121-1	0.72	0.03	0.03	0.00	0.15	0.94
1122-1	1.55	0.05	0.05	0.00	0.13	1.82
1127-1	1.36	0.05	0.05	P	0.17	1.64
1127-2	0.78	0.01	0.03	0.00	0.09	0.94
1129-1	1.77	0.07	0.08	0.01	0.17	2.14
1129-2	1.14	0.05	0.05	T	0.13	1.41
1130-1	1.55	0.04	0.04	0.01	0.21	1.88
1130-2	0.45	0.01	0.02	0.00	0.02	0.51
1131-1	1.58	0.06	0.04	0.02	0.17	1.90
1132-1	1.37	0.04	0.05	0.00	0.35	1.85
1134-1	2.99	0.16	0.03	0.01	0.41	3.61
1134-2	2.11	0.06	0.04	T	0.25	2.50
1136-1	2.59	0.10	0.09	P	0.31	3.13
1136-2	1.80	0.04	0.05	0.02	0.24	2.16
1136-3	0.98	0.04	0.02	0.00	0.12	1.16
1139-1	0.65	0.03	0.04	0.01	0.07	0.82
2000-1	0.53	0.03	0.04	0.00	0.05	0.67
2000-2	0.52	0.03	0.03	T	0.08	0.69

APPENDIX V, continued

SAMPLE NAME	wt% IL of TOTAL	wt% RUT of TOTAL	wt% LEUCX of TOTAL	wt% MON of TOTAL	wt% ZR of TOTAL	wt% ECON of TOTAL
2001-1	0.41	0.02	0.04	0.00	0.04	0.52
2002-1	1.09	0.02	0.01	P	0.12	1.25
2002-2	0.89	0.01	0.03	0.00	0.07	1.01
110-1	0.84	0.04	0.01	T	0.14	1.06
110-2	0.41	0.03	0.02	T	0.05	0.53
110-3	0.29	0.02	0.02	0.00	0.02	0.36
115-1	0.21	0.01	0.01	0.00	0.02	0.25
116-1	0.18	0.01	0.01	0.00	0.02	0.24
116-2	0.17	0.01	0.01	0.00	0.01	0.22
116-3	0.78	0.03	0.04	T	0.08	0.97
116-4	0.33	0.02	0.01	0.00	0.04	0.42
116-5	0.52	0.05	0.04	0.00	0.05	0.70
117-1	0.38	0.02	0.02	0.00	0.03	0.46
117-2	1.07	0.07	0.04	0.00	0.08	1.33
117-3	1.12	0.04	0.04	0.01	0.07	1.33
117-4	0.65	0.04	0.04	0.00	0.05	0.82
average	0.92	0.04	0.04	0.01	0.10	1.14
std. dev.	0.79	0.03	0.04	0.01	0.10	0.94
min value	0.03	0.00	0.00	0.00	0.00	0.05
max value	5.90	0.26	0.28	0.08	0.72	6.79
Garner's values (see text)	2.25	0.10	0.25	0.05	0.25	