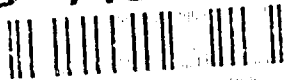


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# WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reference No. 60-35

A study of the bathymetry and sediments of  
the U. S. Navy Torpedo Range in  
Cape Cod Bay

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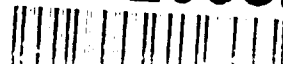
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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

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Reference No. 60-35

A study of the bathymetry and sediments of  
the U. S. Navy Torpedo Range in  
Cape Cod Bay

by

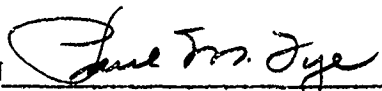
John M. Zeigler and Bernard Oostdam  
with underwater photographs by David M. Owen

Final Report

UNANNOUNCED

Submitted to the U. S. Naval Underwater Ordnance  
Station, Newport, Rhode Island  
Under Contract N298(122)16639 and  
Reqn. No. 122/5271/60  
July, 1960

APPROVED FOR DISTRIBUTION

  
Paul M. Fye, Director

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## CONTENTS

|                                      | Page |
|--------------------------------------|------|
| Introduction. . . . .                | 1    |
| Bathymetry. . . . .                  | 1    |
| Sediment Distribution. . . . .       | 3    |
| Character of the Sub-Bottom. . . . . | 7    |
| Clarity of Water. . . . .            | 8    |
| Bottom Photographs. . . . .          | 8    |
| References Cited. . . . .            | 10   |

## ILLUSTRATIONS

|                                                                                                 |   |
|-------------------------------------------------------------------------------------------------|---|
| Figure 1 - Index Map (following). . . . .                                                       | 1 |
| Figure 2 - Station chart showing location of sample and<br>camera stations (following). . . . . | 1 |
| Figure 3 - Contour Map of the sea bottom (following). . .                                       | 2 |
| Figure 4 - Sediment distribution map (following). . . . .                                       | 3 |
| Figure 5 - Nature of sub-bottom (following). . . . .                                            | 7 |
| Figure 6 - Bottom photograph - Station 43 (following). .                                        | 8 |
| Figure 7 - Bottom photograph - Station 52 (following). . .                                      | 8 |

(Appendix I - 30 Bottom Photographs Bound Separately)

|                                                                                 |     |
|---------------------------------------------------------------------------------|-----|
| Table I - Analysis of Sediment Samples. . . . .                                 | 4-5 |
| Table II - Distribution of Sand Sizes on a Traverse<br>Across the Area. . . . . | 6   |

## INTRODUCTION

The Woods Hole Oceanographic Institution contracted to make a survey of the bathymetry and sediments at the Navy Torpedo Testing Range in Cape Cod Bay (Figure 1) at the request of the Project Engineer at the U. S. Naval Underwater Ordnance Station, Newport, Rhode Island - Contract Number N298(122)16639. The area studies is approximately 35 miles SE from Boston and 15 miles NW from Provincetown in the southern part of Massachusetts Bay.

Two trips were made to the area in the Research Vessel BEAR. The first trip, May 31 to June 2, 1960 (BEAR Cruise No. 241) collected enough data to satisfy the terms of the contract, but a second trip, June 16 and 17, 1960 (BEAR Cruise No. 247) was made to confirm some rather interesting relationships between bottom sediment type and submarine photographs taken on BEAR Cruise No. 241.

The following work was completed and the results herein presented:

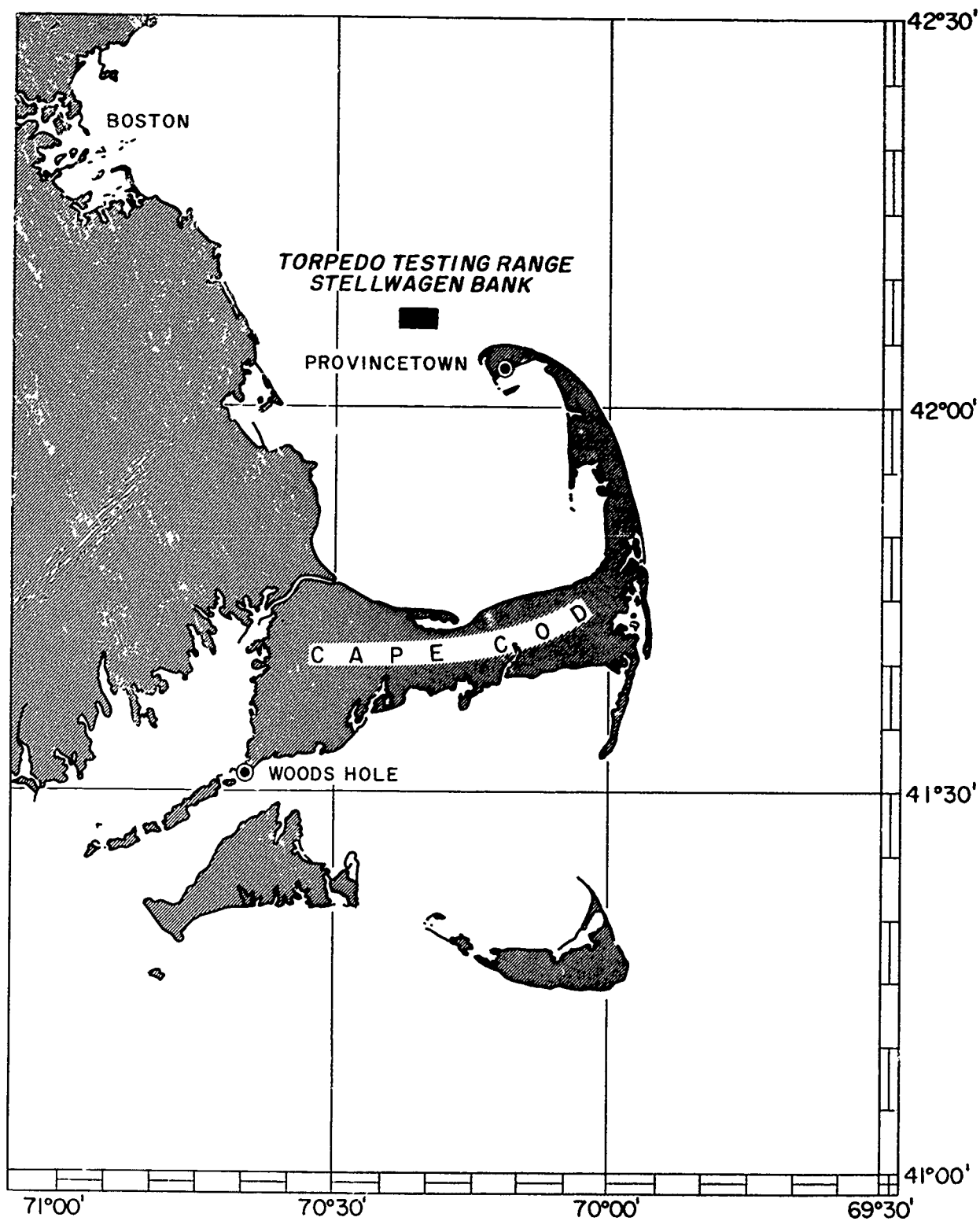
1. A bathymetric chart of the area. (Fig. 3)
2. A sediment distribution chart. (Fig. 4)
3. Nature of the sub-bottom. (Fig. 5)
4. Secchi disk readings.
5. Bottom photographs. (Fig. 6 and Appendix I)

Appendix I, bound separately, includes 30 enlargements of bottom photographs taken at various stations during the cruise. One copy of Appendix I was furnished to the U. S. Naval Underwater Ordnance Station, Newport, Rhode Island.

## BATHYMETRY

The area is located about a mile south of Stellwagen Bank, hence outside the boundaries of the range one moves into shallower water rapidly on a traverse to the north. (Fig. 1).

Inside the target range the bottom is virtually flat. Figure 3 shows the detailed configuration of the bottom using a contour interval of three feet or one-half fathom. For all



Index Map

FIG. 1

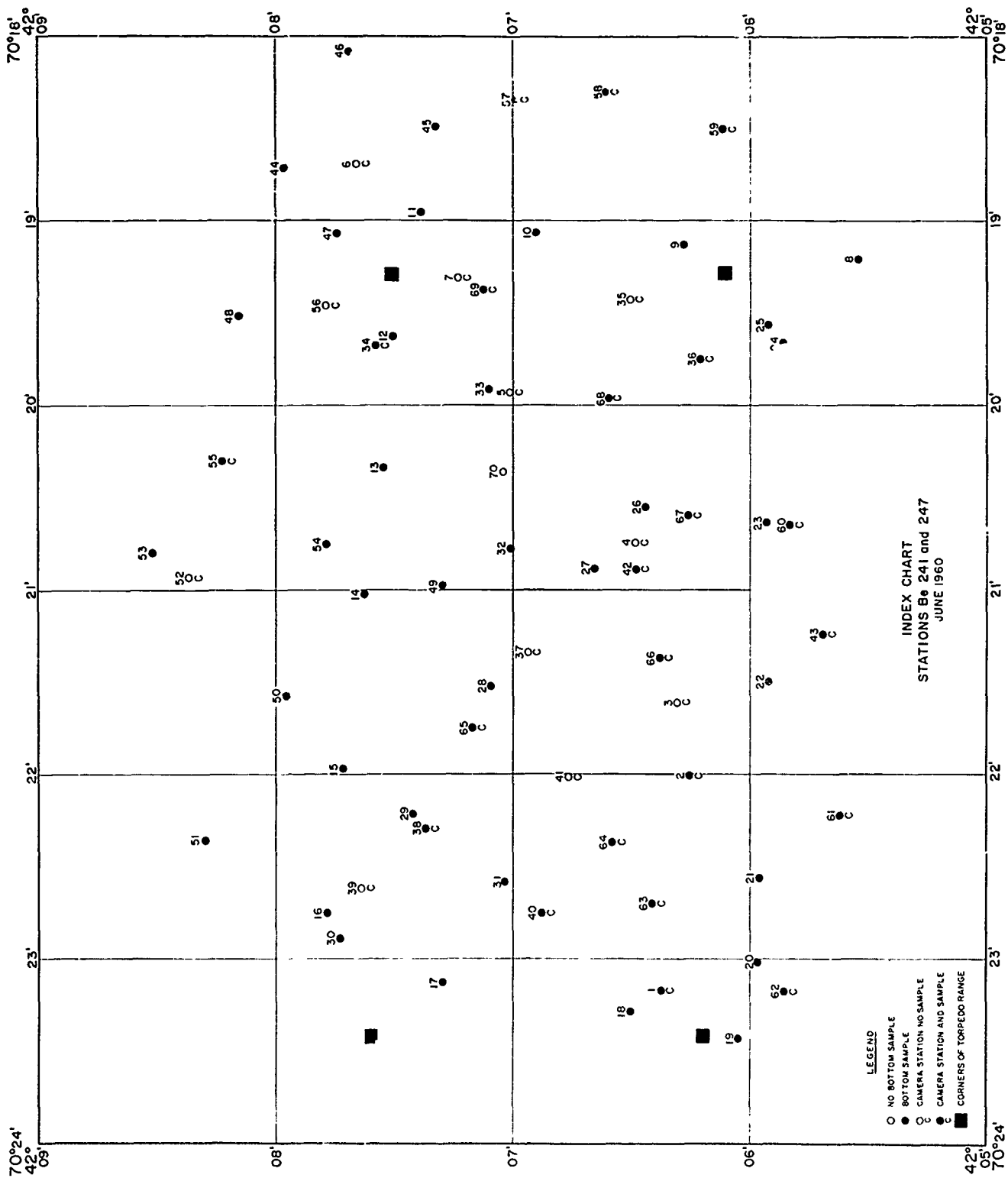


FIG. 2

practical purposes one may say that the maximum relief, the vertical distance between the highest and lowest points, inside the whole area is only about 12 feet and if one moves along the slope rather than across it the local relief is only a foot or two. The natural slope changes are so gradual that a large object such as a submarine or anything else big enough to be recorded by an echo sounder would show up as a sharp hump on a smooth bottom. There is a shallow depression near the northeast corner of the area on the northern boundary. This depression is the deepest part, but even there the bottom slopes only 13 feet in 0.4 mile. The writers found nothing unusual or diagnostic about the topography of the topographic changes observed.

Figure 3 was constructed by first plotting the depth of water at each station from the continuous recording echo sounder. Station locations were plotted and the contours drawn.

An appreciation of possible errors is useful for background information and should be considered if soundings at a specific spot become important. In general, it seems reasonable to say that the contoured appearance would not change very much from that presented on Figure 3 even if all errors were known and corrected.

In effect, there are three main sources of uncertainty which will concern any one sounding; they are listed in order of their influence for this particular area:

1. Changes in sea level over a tidal cycle.
2. Uncertainty in position (navigation)
3. Operator and instrument errors.

The tidal range at Race Point, five miles away, is about nine feet, (C&GS, 1960). We found a decided influence on soundings with respect to the tide level within the torpedo range. All of the soundings on Figure 3 are reduced to mean low water as if the full nine foot range were effective. The effect in the target area probably is not so great as 9 feet, but this reduction does not introduce an absolute error greater than the desired precision. Computations for the theoretical rise of the sea surface were not attempted. Failure to apply the

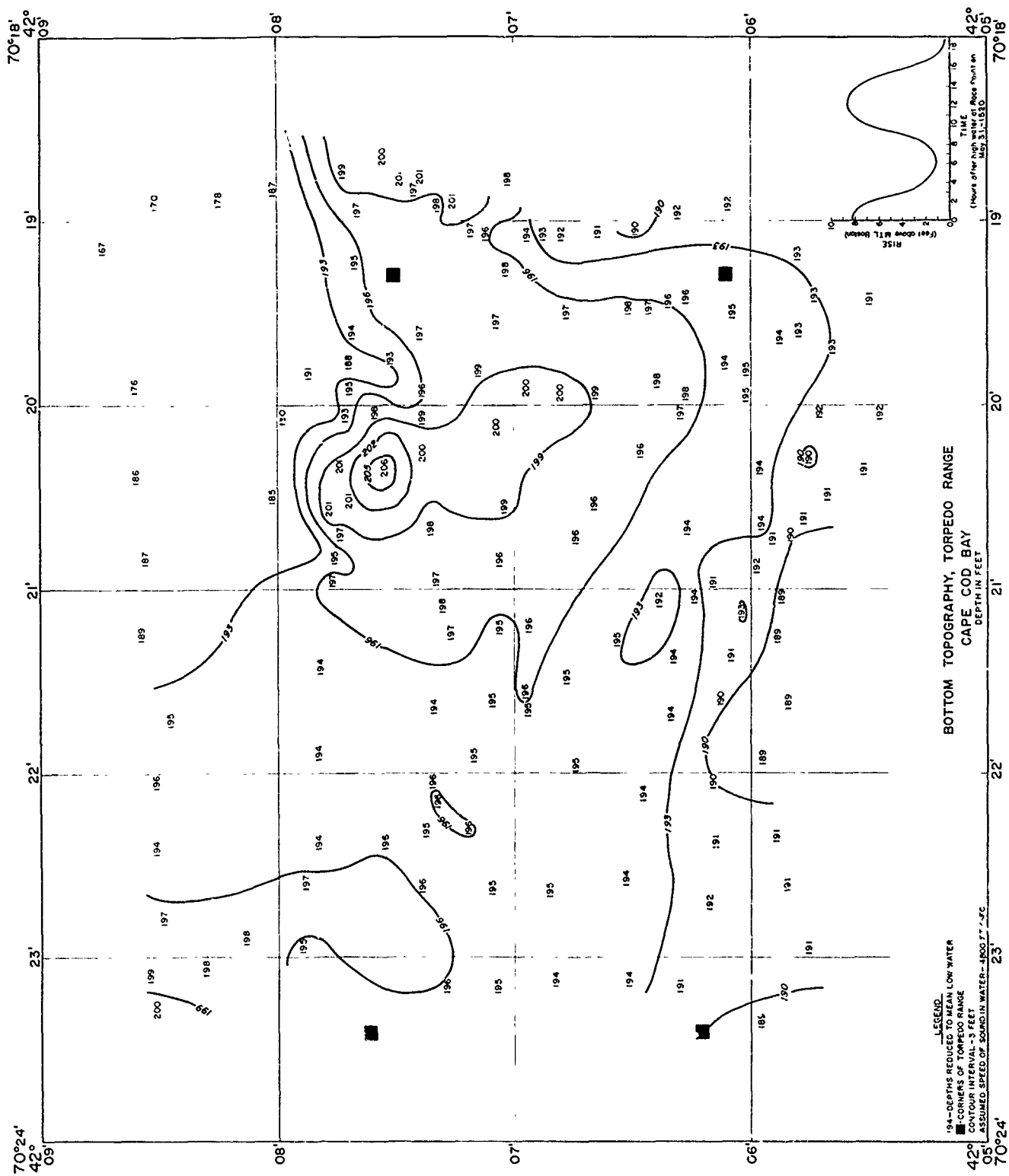


FIG. 3

reduction makes it difficult to adjust depths where the track of the sounding ship crosses itself.

Navigation was controlled by radar bearings on four buoys placed by us. Checks made on positions from all four buoys showed that uncertainty in position was approximately 0.1 mile with respect to the buoys. The marker buoys, themselves, were located by bearings on shore control points. (Provincetown Monument and various lights.)

Operator and instrument errors are not evaluated but are probably small. No efforts were made to correct the speed of sound in water for temperature. Speed of sound was assumed to be 4800 feet per second. Extremes of this correction could differ by only a few per cent in the shallow depths present at the torpedo range.

#### SEDIMENT DISTRIBUTION

Sediment samples were taken in and around the torpedo range (Fig. 2). Samples were collected by a Van Veen snapper dredge, by a coring device mounted on the underwater camera and by coring devices alone. The samples were analyzed for sand, silt, and clay (Table I). These terms indicate sediment size, not necessarily composition. Sand as used here is sediment larger than 0.062 mm. (held by No. 230 U. S. Standard sieve), silt is composed of particles between 0.062 mm and 0.0039 mm, while clay is material smaller than 0.0039 mm. The silt and clay percentages were determined by pipette analyses. The ratio of sand to silt-clay is also indicated in Table I.

The writers present the data in terms of the sand content (Figure 4) because: (1) This variable clearly shows the overall pattern of distribution, and (2) The bearing strength of the bottom material is related to sand content.

The sediments in the torpedo testing area can be classified as ranging from silty sands to sandy silts (Shepard and Moore, 1955). Such sediments have less than 20 per cent clay sized particles, from 75 to 25 per cent sand particles and 25 to 75 per cent silt sized particles. The distribution (Figure 4) clearly reflects the nearness of Stellwagen Bank, which is covered by sand and swept by strong currents.

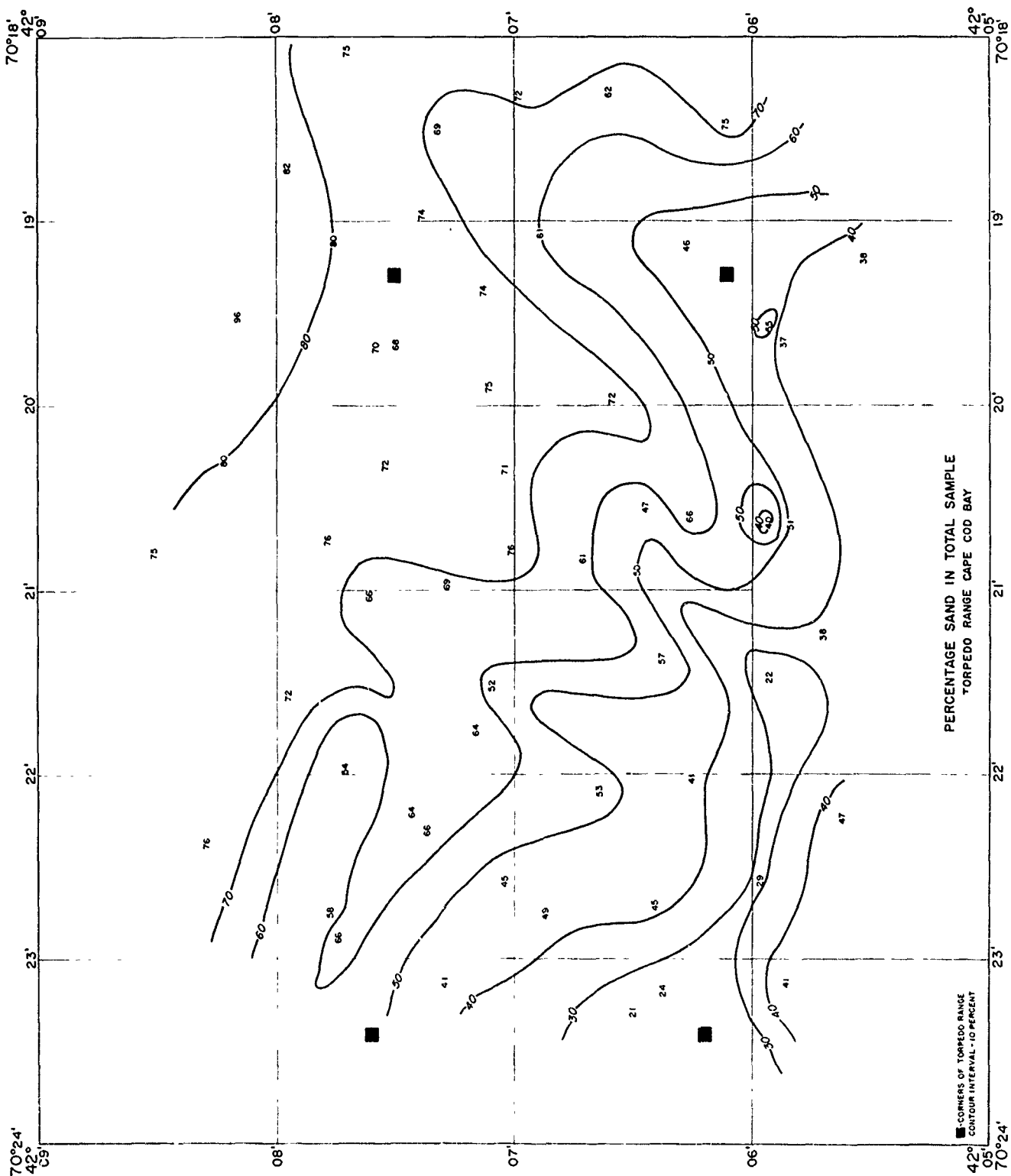


FIG. 4

TABLE I

Analysis of sediment samples collected in the Naval Torpedo  
Range - Cape Cod Bay, Massachusetts - June 1960 - BEAR  
Cruises 241 and 247

| Station<br># | % Sand | % Silt | % Clay | Sand/Silt-Clay<br>Ratio |
|--------------|--------|--------|--------|-------------------------|
| 1            | 24     | 57     | 19     | 0.32                    |
| 2            | 41     | 45     | 14     | 0.69                    |
| 8            | 38     | 48     | 14     | 0.61                    |
| 9            | 46     | 38     | 16     | 0.85                    |
| 10           | 61     | 25     | 14     | 1.56                    |
| 11           | 74     | 17     | 9      | 2.85                    |
| 12           | 68     | 20     | 12     | 2.13                    |
| 13           | 72     | 18     | 10     | 2.57                    |
| 14           | 69     | 21     | 10     | 2.23                    |
| 15           | 54     | 32     | 14     | 1.17                    |
| 16           | 58     | 32     | 10     | 1.38                    |
| 17           | 41     | 46     | 13     | 0.69                    |
| 18           | 21     | 64     | 15     | 0.27                    |
| 19           | 11     | 69     | 20     | 0.12                    |
| 20           | 34     | 49     | 17     | 0.52                    |
| 21           | 29     | 58     | 13     | 0.41                    |
| 22           | 22     | 63     | 15     | 0.28                    |
| 23           | 38     | 47     | 15     | 0.61                    |
| 24           | 37     | 50     | 13     | 0.59                    |
| 25           | 55     | 32     | 13     | 1.22                    |
| 26           | 47     | 41     | 12     | 0.89                    |
| 27           | 61     | 29     | 10     | 1.56                    |
| 28           | 51     | 36     | 13     | 1.04                    |
| 29           | 64     | 26     | 10     | 1.78                    |
| 30           | 66     | 26     | 8      | 1.94                    |
| 34           | 70     | 18     | 12     | 2.33                    |
| 36           | 50     | 39     | 11     | 1.00                    |
| 38           | 66     | 24     | 10     | 1.94                    |
| 40           | 49     | 38     | 13     | 0.96                    |
| 42           | 50     | 37     | 13     | 1.00                    |
| 43           | 38     | 47     | 15     | 0.61                    |
| 44           | 82     | 12     | 6      | 4.55                    |
| 45           | 69     | 19     | 12     | 2.33                    |
| 46           | 76     | 14     | 10     | 3.17                    |
| 47           | 80     | 11     | 9      | 4.00                    |

TABLE I - Cont.

| Station<br># | % Sand | % Silt | % Clay | Sand/Silt-Clay<br>Ratio |
|--------------|--------|--------|--------|-------------------------|
| 48           | 96     | 1      | 3      | 24.00                   |
| 49           | 69     | 20     | 11     | 2.23                    |
| 50           | 72     | 18     | 10     | 2.57                    |
| 51           | 76     | 15     | 9      | 3.17                    |
| 53           | 75     | 15     | 10     | 3.00                    |
| 54           | 76     | 15     | 9      | 3.17                    |
| 55           | 80     | 11     | 9      | 4.00                    |
| 57           | 72     | 18     | 10     | 2.56                    |
| 58           | 62     | 25     | 13     | 1.63                    |
| 59           | 71     | 18     | 11     | 2.45                    |
| 60           | 51     | 38     | 11     | 1.04                    |
| 61           | 47     | 41     | 12     | 0.89                    |
| 62           | 41     | 45     | 14     | 0.69                    |
| 63           | 45     | 44     | 11     | 0.82                    |
| 64           | 53     | 31     | 16     | 1.13                    |
| 65           | 65     | 25     | 10     | 1.86                    |
| 66           | 59     | 31     | 19     | 1.44                    |
| 67           | 68     | 23     | 9      | 2.13                    |
| 68           | 72     | 21     | 7      | 2.56                    |
| 69           | 74     | 18     | 8      | 2.85                    |
| 70           | 71     | 21     | 8      | 2.45                    |

The values presented here for sand, silt, and clay are considered reliable to  $\pm 4$  per cent. This percentage uncertainty was determined by analyzing several splits of the same sample and noting the scatter of values.

TABLE II

Distribution of sand sizes on a traverse from low quantity of sand (southwest) to high quantity of sand (northeast).

| Station<br># | Median diameter<br>Total sample<br>mm | Coarsest<br>Particle<br>mm | % Sand | Median diameter<br>Sand size fraction<br>mm |
|--------------|---------------------------------------|----------------------------|--------|---------------------------------------------|
| 61           | 0.06                                  | 0.5                        | 47     | 0.17                                        |
| 21           | 0.04                                  | 0.5                        | 29     | 0.27                                        |
| 22           | 0.04                                  | 0.6                        | 22     | 0.12                                        |
| 66           | 0.14                                  | 0.5                        | 59     | 0.15                                        |
| 42           | 0.06                                  | 0.6                        | 50     | 0.13                                        |
| 65           | 0.20                                  | 0.9                        | 65     | 0.27                                        |
| 32 *         | 0.15                                  | 0.4                        | 76     | 0.17                                        |
| 70           | 0.18                                  | 1.0                        | 71     | 0.23                                        |
| 57           | 0.23                                  | 0.9                        | 72     | 0.31                                        |
| 50           | 0.16                                  | 1.3                        | 72     | 0.22                                        |
| 13           | 0.12                                  | 0.5                        | 72     | 0.15                                        |
| 53           | 0.17                                  | 0.8                        | 75     | 0.19                                        |
| 48           | 0.22                                  | 0.5                        | 96     | 0.22                                        |

\* core

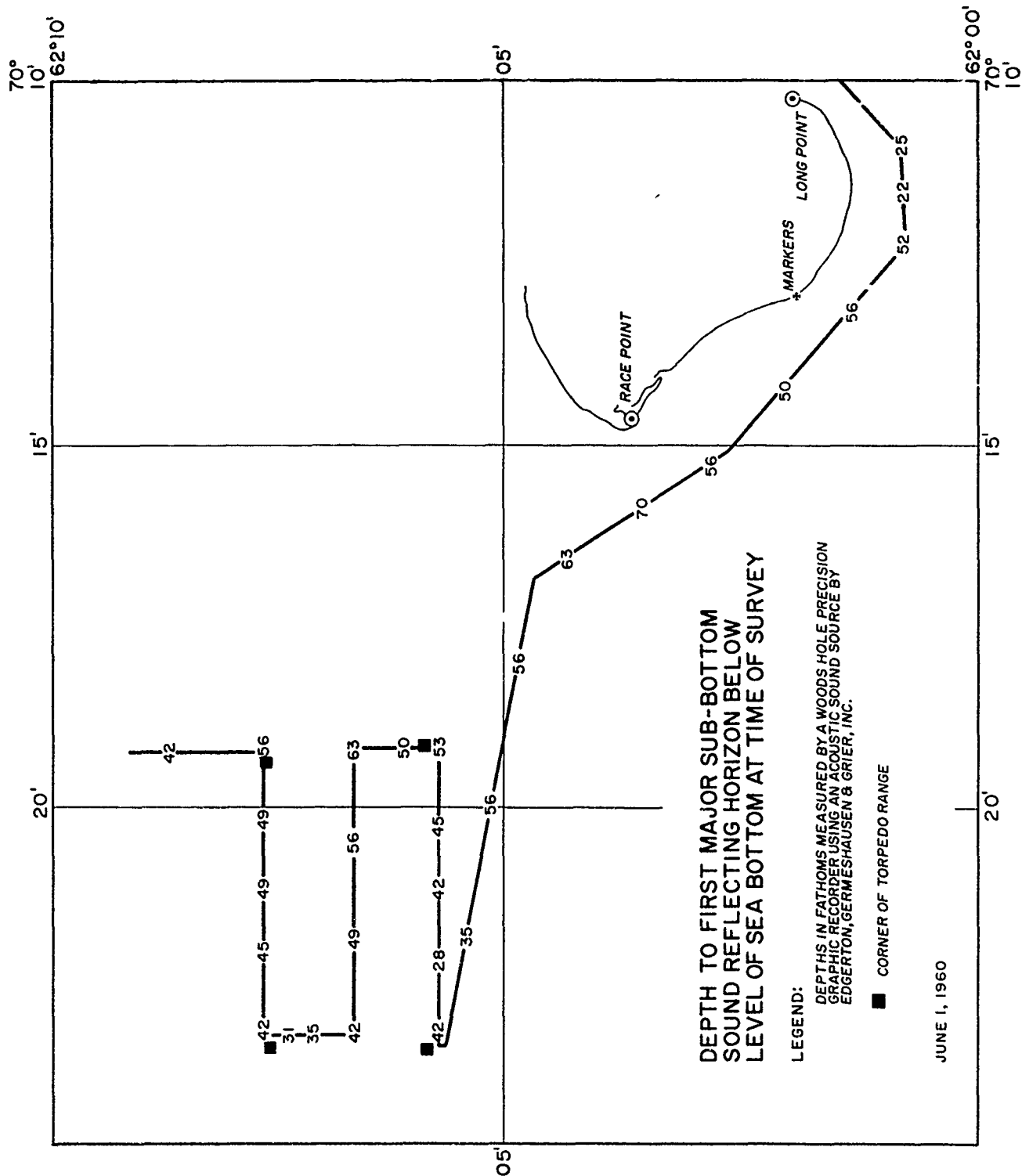
Presumably the fine sands in the study area were washed down from Stellwagen Bank.

The per cent sand in the sediment increases with surprising regularity from about 20 per cent in the southwest to 80 per cent in the northeast. Table II gives information regarding the size of the sand fraction along a traverse from southwest to northeast (from low sand content to high.) There is not apparent increase in median diameter or coarseness as sand content increases.

The increase in sand content was translated into bottom resistance when attempts were made to collect cores. It was very difficult to get significant bottom penetration with the light gravity corer; when more weight was added to the core barrel mounted on the camera, the core samples increased only slightly in length. Samples were repeatedly lost from all cores when the fine sands simply ran out of the core barrel. Penetration into the bottom increased slightly towards the southwest corner of the area. We deduce that the bottom, in general, is a good "bearing" bottom insofar as supporting an object is concerned. This is deduction only. No studied effort was made to measure penetrability or bearing strength. However, Taylor (1948, p. 72 and Fig. 4-12) indicated that, in general, the bearing strength of an undisturbed sediment increases as the sand content increases. Therefore, one assumes that bearing strength of the bottom would increase in the direction of increasing sand, southwest to northeast.

#### CHARACTER OF THE SUB-BOTTOM

Though it was not possible to examine the sub-bottom by collecting long cores we did use a sonic probe with the results given on Fig. 5. The numbers refer to the depth in feet to the first major reflecting horizon below the sea bottom probably crystalline basement (Hartley Hoskins, unpublished manuscript). Wells drilled near Provincetown penetrated both fluvio-glacial material (Woodworth and Wigglesworth, 1934) and Eocene sediments (Zeigler, Hoffmeister, Geise and Tasha, 1960). A reasonable guess based on this work is that the sea floor near the torpedo range is covered by 15 to 20 feet of marine sands and mud, 100 to 200 feet of glacial material and 100 (?) feet of Tertiary sediment overlying the crystalline basement.



**FIG. 5**

## CLARITY OF WATER

Secchi disk readings taken at the request of the Navy on cruise 241 showed the disk visible to 31 feet at all points where readings were taken.

Hardly two weeks later the same disk could be seen to a depth of only 24 feet. This change is attributed to increased production of plankton. Turbidity of the water, being largely a function of the concentration of organisms, is therefore quite sensitive to the season of the year.

## BOTTOM PHOTOGRAPHY

Bottom photographs were taken at stations marked "C" on Figure 2. These photographs and a discussion of them appear in Appendix I of this report. Much of the discussion is repeated here for the benefit of those who do not have access to the actual photographs.

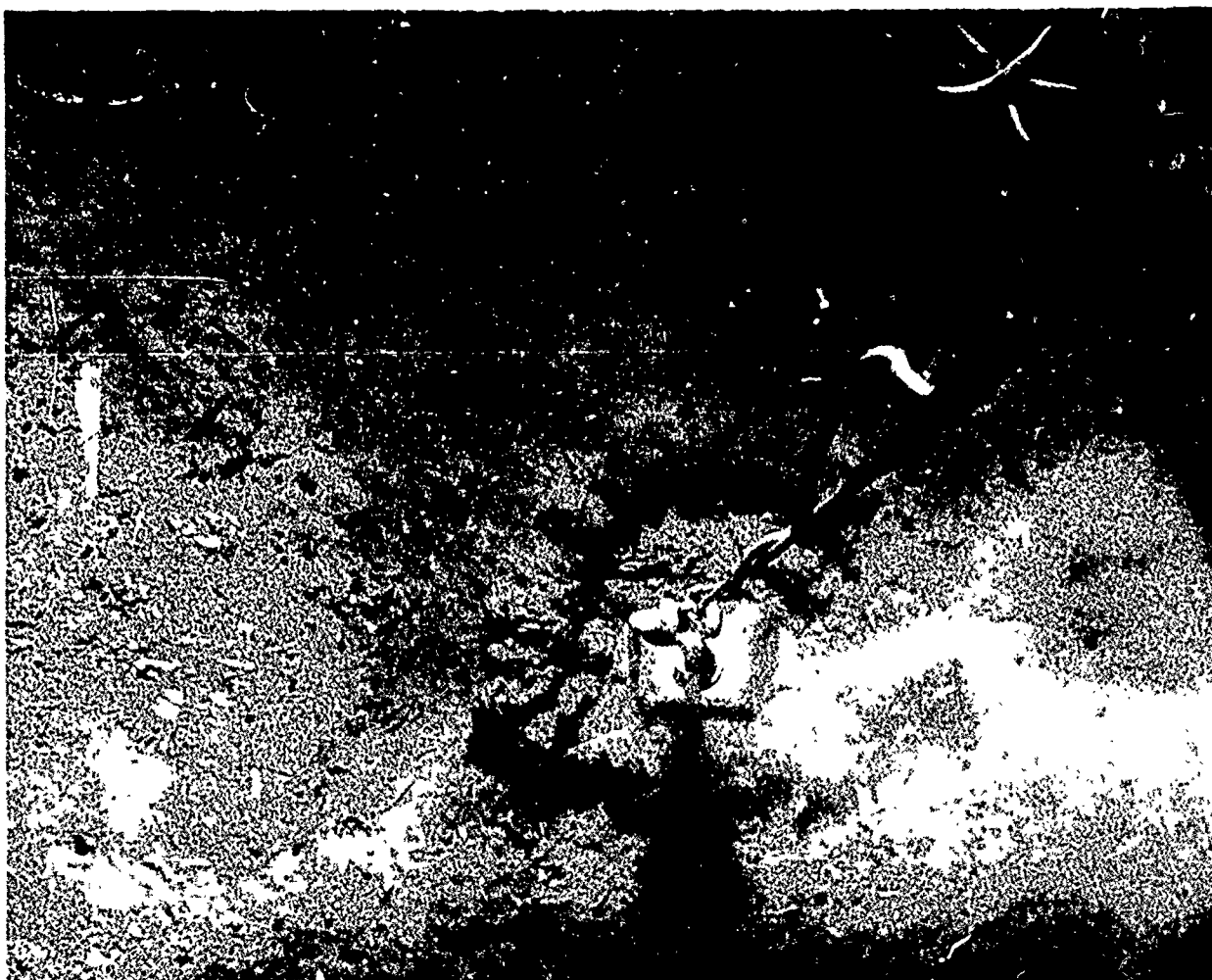
These pictures were made by Mr. D. M. Owen of Woods Hole with a camera mount and light source designed by himself. The lead weight seen in the pictures is the tripping weight. The pictures show a square of bottom about 2 feet per side (23 inches). The weight measures approximately 3" on each side. Mr. Owen attached a short core barrel on the camera frame and thereby obtained bottom samples from each camera station.

Several guides might be mentioned to assist the reader in the examination of these photographs.

1. Examine the photos from all orientations (In the first one, station 3, for example, note how the appearance of the large hole or burrow opening just to the right of center changes appearances as the photo is rotated.)



Bottom Photograph - Station 43



Bottom Photograph - Station 52

2. The appearance and density of the impact cloud thrown up by the tripping weight. Sandy areas have lighter and thinner clouds. Shepard and Emory (1948) suggested that the mud content of a sediment as seen in a photograph is indicated by the incipient mud cloud which is raised by the weights hitting the bottom. Also, mud surfaces usually show small depressions presumably due to burrowing organisms. They further noted that many sand surfaces do not show ripple marks.

These photographs give a visual impression of the flatness of the bottom and the nature of the sand and mud making it up. Based on our experience with these photographs and the sediment analysis of the bottom, we feel that a good observer could quickly train himself to make rule of thumb determinations of the sand-mud ratios of bottom sediments. If a person has a few pictures of the bottom from spots where sedimentary analyses have been made, they can be used as controls for comparison with unknowns. We asked several people, only casually familiar with sediments, to try to estimate the sand percentages of the bottom shown in the photographs taken for this report. Using eight photos with known sand percentages as standards they visually compared bottom photos with unknown amounts of sand. About nine times out of ten they were quickly able to separate the photos of sandy area from the photos of muddy area.

Copies of two representative bottom photographs (Figure 6 & 7) taken at stations 43 and 52 illustrate the difference between a sandy bottom and a muddy one. Station 43 is in an area where there was only 38 per cent sand. Station 52 has about 80 per cent sand. The difference discussed above can be seen here.

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**WOODS HOLE OCEANOGRAPHIC INSTITUTION**

**Woods Hole, Massachusetts**

**Reference No.**

**A study of the bathymetry and sediments  
of the U. S. Navy Torpedo Range  
in Cape Cod Bay**

**Appendix I**

**by**

**John M. Zeigler and Bernard Oostdam  
with underwater photographs by David M. Owen**

**Final Report**

**Submitted to the U. S. Naval Underwater Ordnance  
Station, Newport, Rhode Island  
Under Contract N298(122)16639 and  
Reqn. No. 122/5271/60  
July, 1960**

## Appendix I

The bottom photographs included here were taken in the U. S. Naval Torpedo Range in Cape Cod Bay from the W.H.O.I. Research Vessel BEAR. The first trip was made May 31 to June 2, 1960 (BEAR Cruise No. 241) and the second on June 16 and 17, 1960 (BEAR Cruise No. 247). For location of the photos, see Station Map, Plate III of the main report.

These pictures were made by Mr. David M. Owen of the Woods Hole Oceanographic Institution, with a camera mount and light source designed by himself. The lead weight seen in the pictures is the tripping weight. Slackening of the line tied to the weight blinks the light and trips the camera. After each shot the camera automatically winds the film and cocks its shutter.

The pictures show a square of bottom about 2 feet per side (23 inches). The weight measures approximately 3" on a side. These photographs show fairly small areas in considerable detail.

Some feel for the topography and sediment characteristics of the area can be developed by scanning the pictures. Examine each one from several sides. The light and shadows change with orientation and certain features are easier to see from one side than from another. The impact cloud sent up by the tripping weight hitting the bottom differs from picture to picture. Since all the photographs were made

with the same camera and in the same manner the variable nature of the "mud" cloud is caused by the variations in the amount of mud present in the sediment.

It appears from our examination of the photos that as the percentage of sand increases the "mud" cloud is thinner and smaller. Also, the cloud is not as dense in sandy areas. The areas higher in sand appear somewhat rougher in comparison with areas high in mud. The tracks, trails, etc. of the bottom dwelling and burrowing organisms also show up quite well. In general, there will be more of these visible in the high mud-low sand areas since the soft bottoms show these tracks better.

The smoothness and general flatness of the bottom is readily apparent from a quick examination of the pictures.

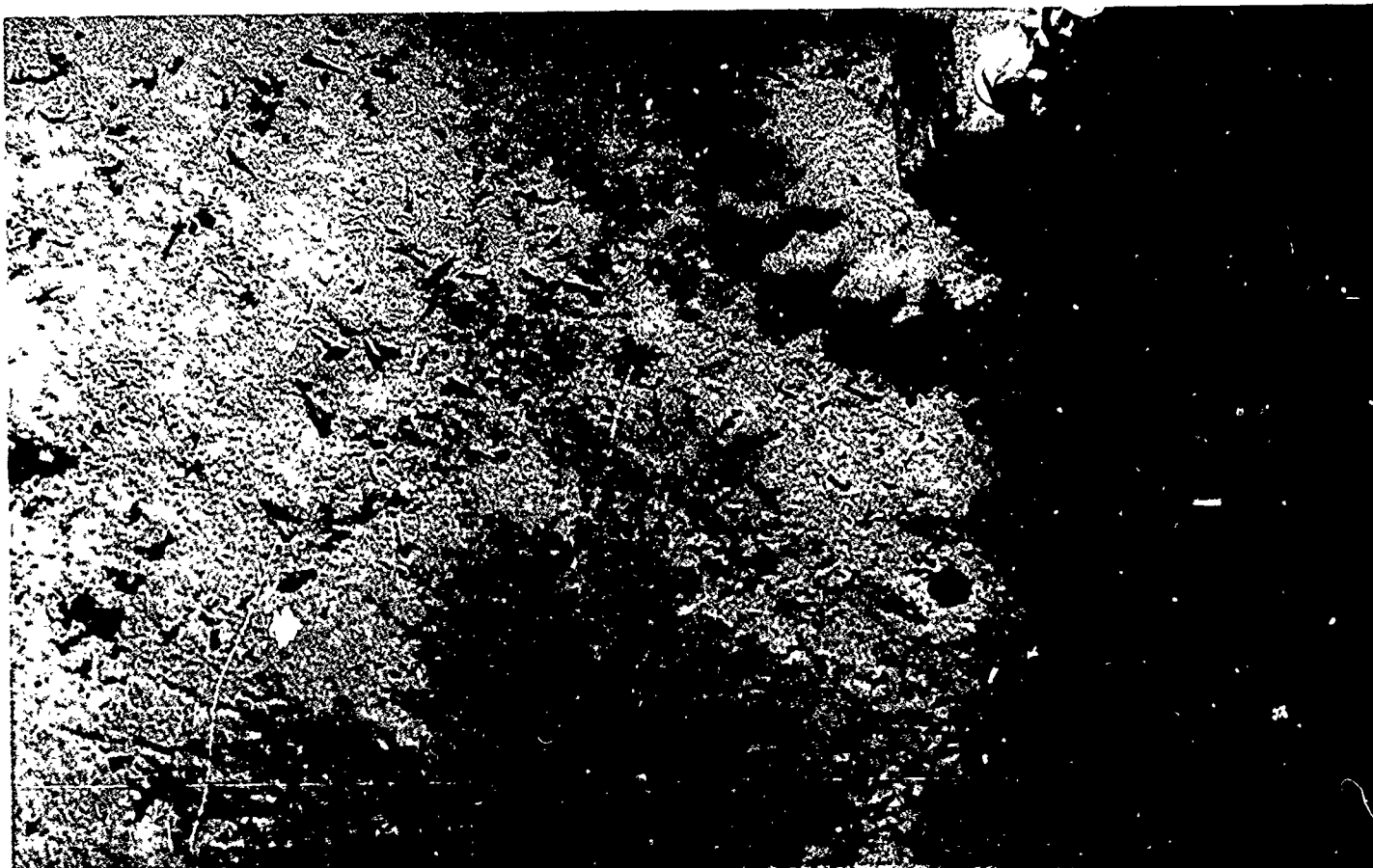


— 23" —

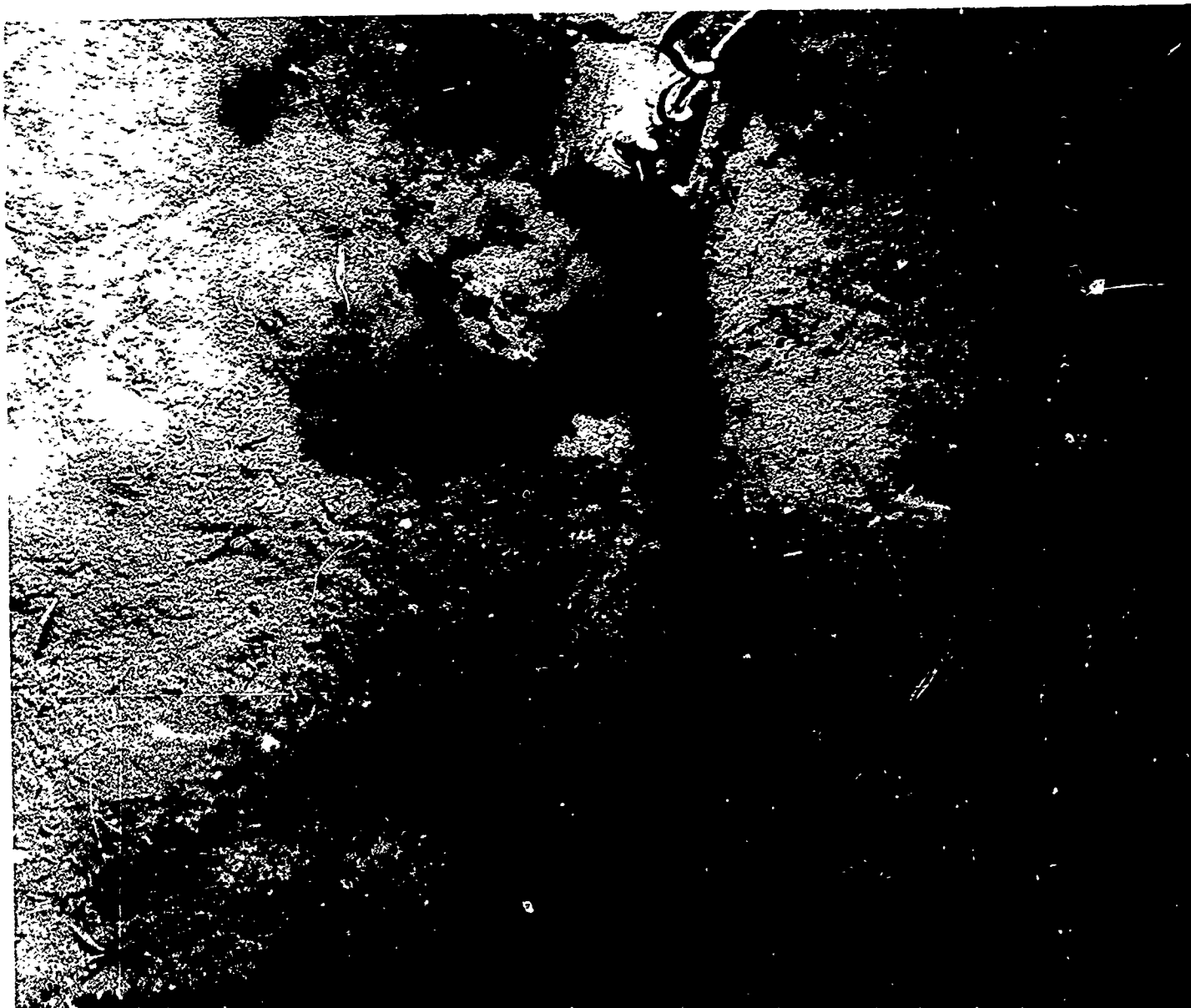
STATION 3 - no sample



STATION 5 - no sample



STATION 6 - no sample

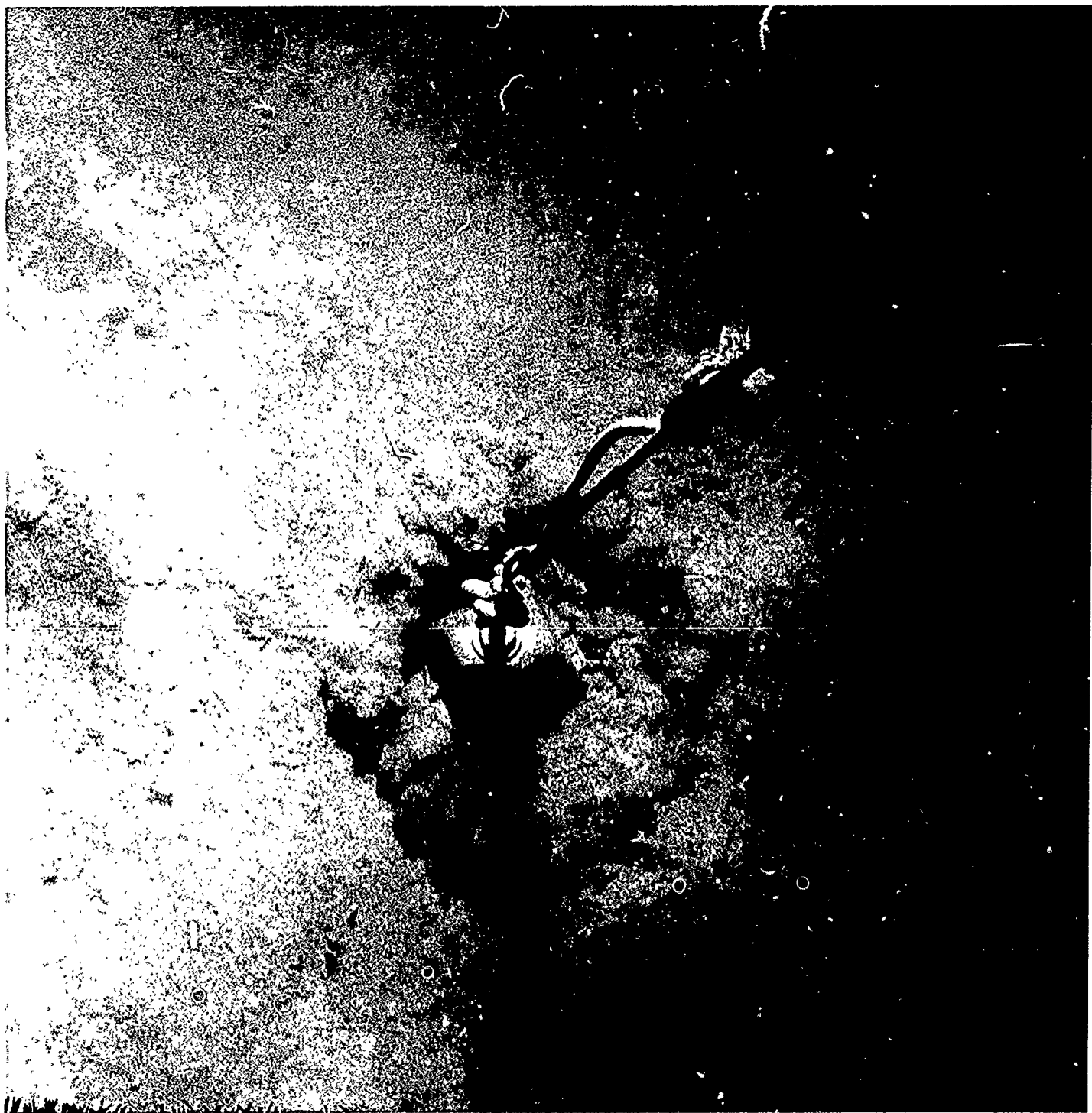


STATION 7 - no sample



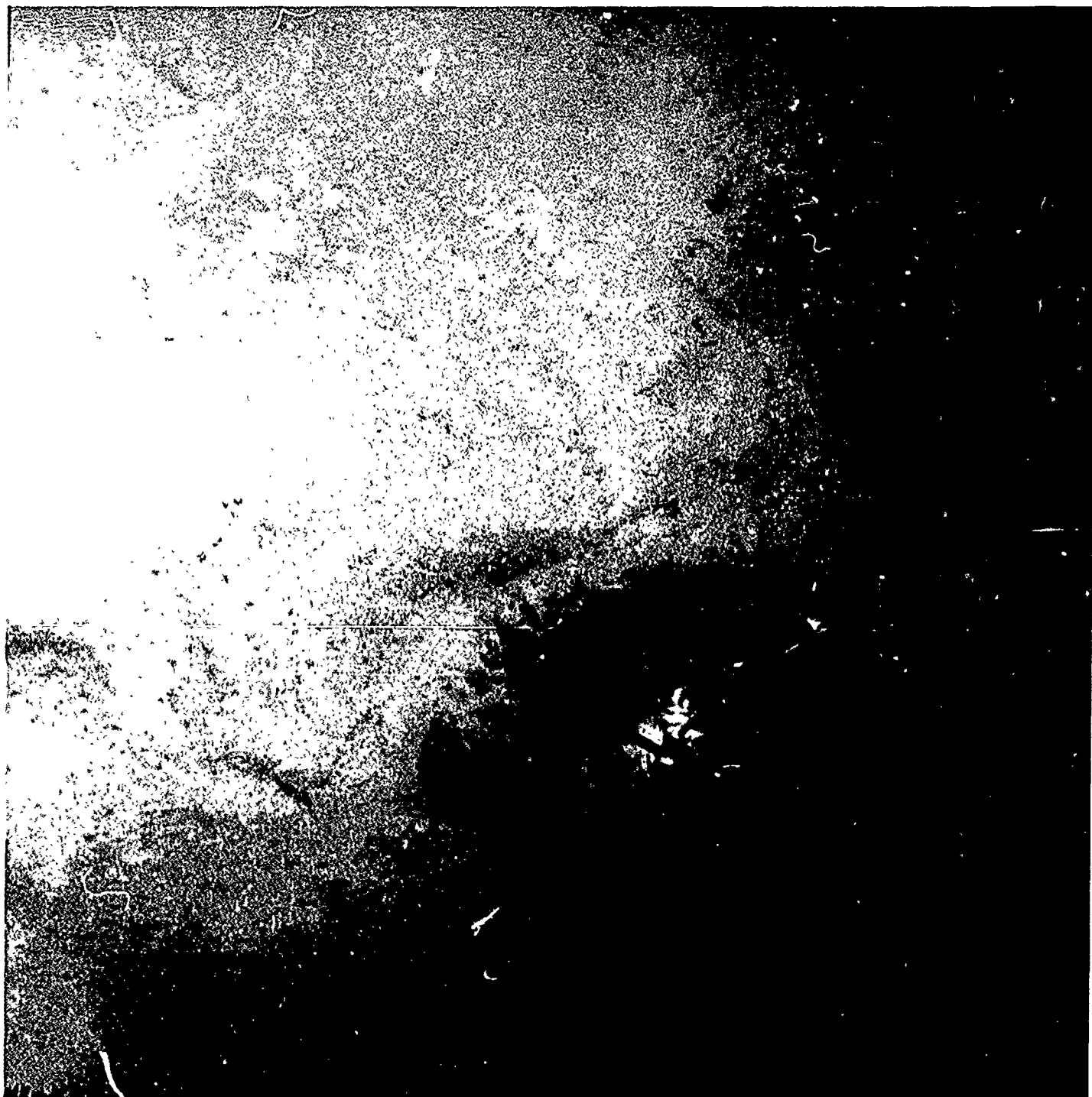
STATION 34 - Sand - 50%, Silt - 18%, Clay - 12%

Sand/Silt-Clay Ratio - 2.33



st 35

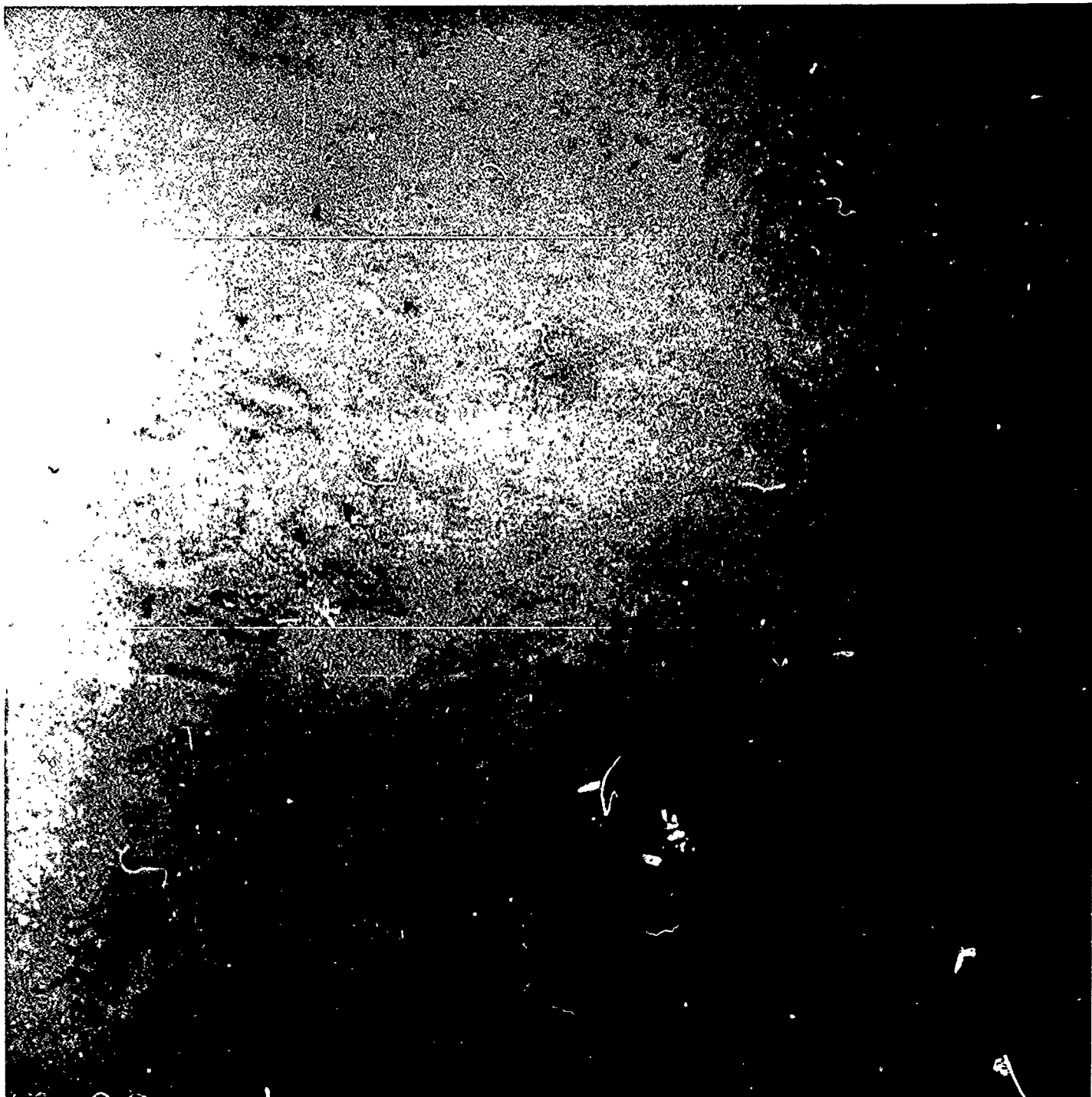
STATION 35 - no sample



St 36

STATION 36 - Sand - 50%, Silt - 39%, Clay - 11%

Sand/Silt-Clay Ratio - ~~3.73~~ /



St 37

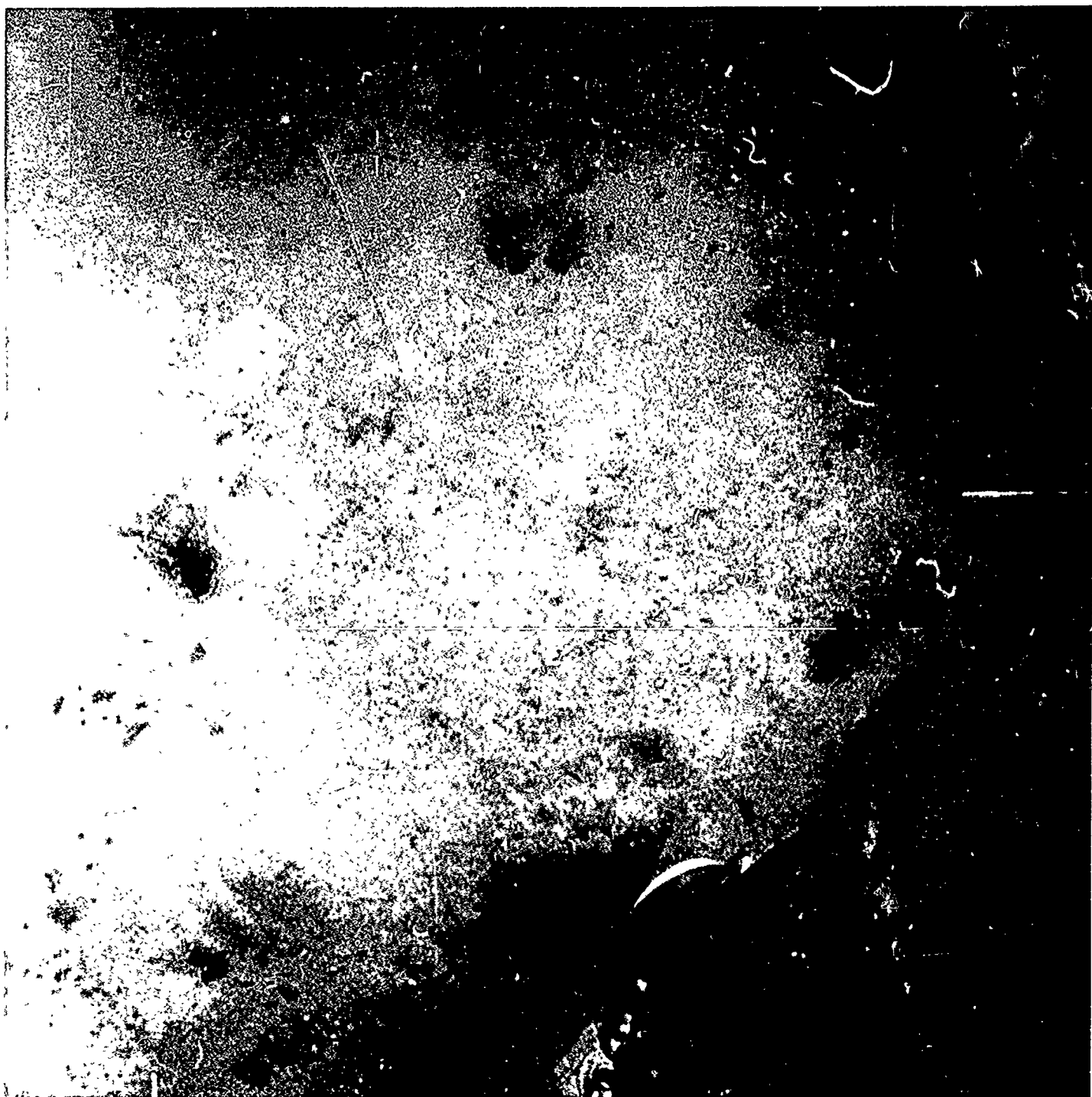
STATION 37 - no sample



Sf 38

STATION 38 - Sand 66%, Silt - 24%, Clay - 10%

Sand/Silt-Clay Ratio - 1.94



St 39

STATION 39 - no sample



57 40

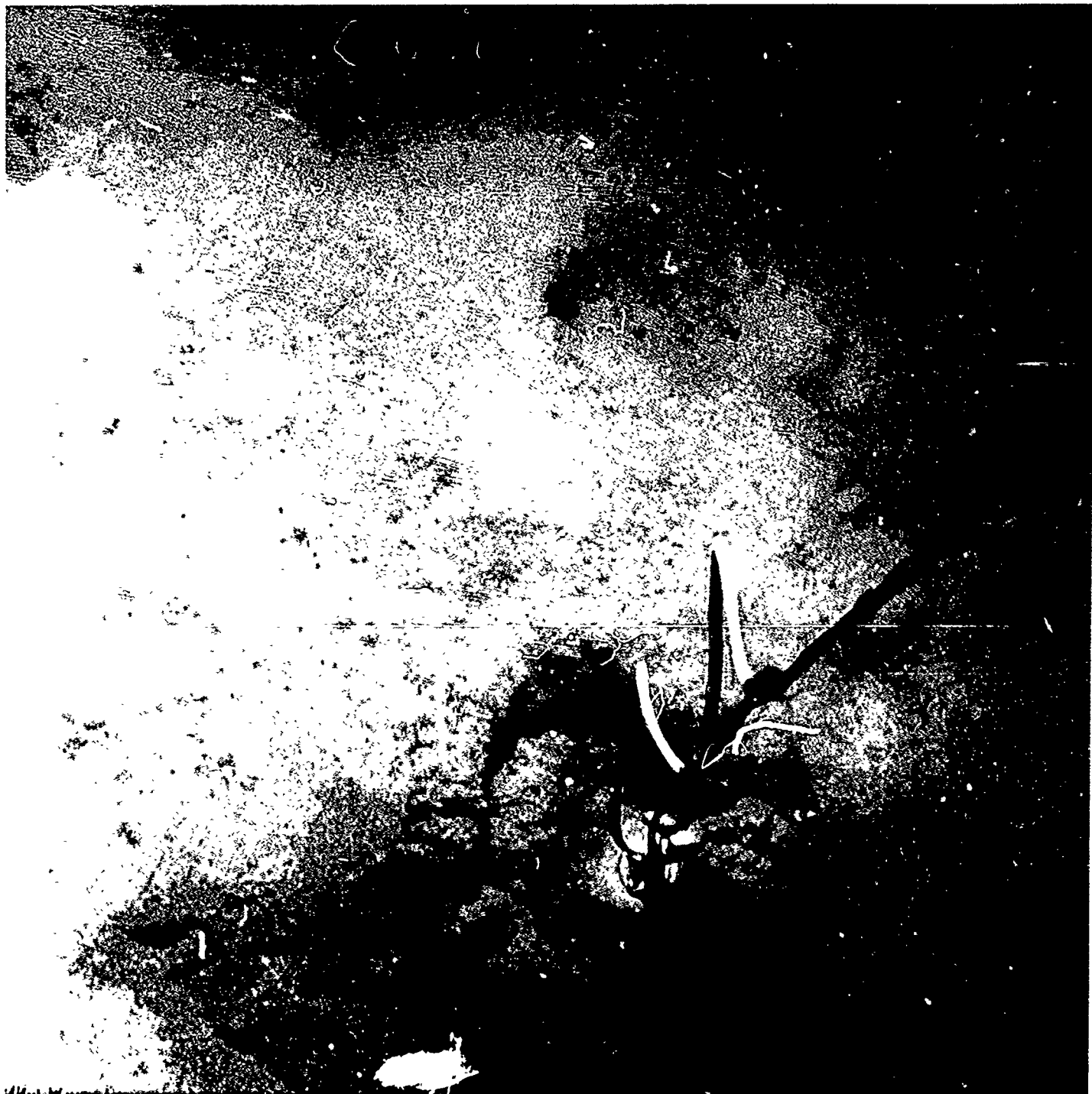
STATION 40 - Sand - 49%, Silt - 38%, Clay - 13%

Sand/Silt+Clay Ratio - 0.96



St 41

STATION 41 - no sample



St 42

STATION 42 - Sand - 50%, Silt - 37%, Clay .6

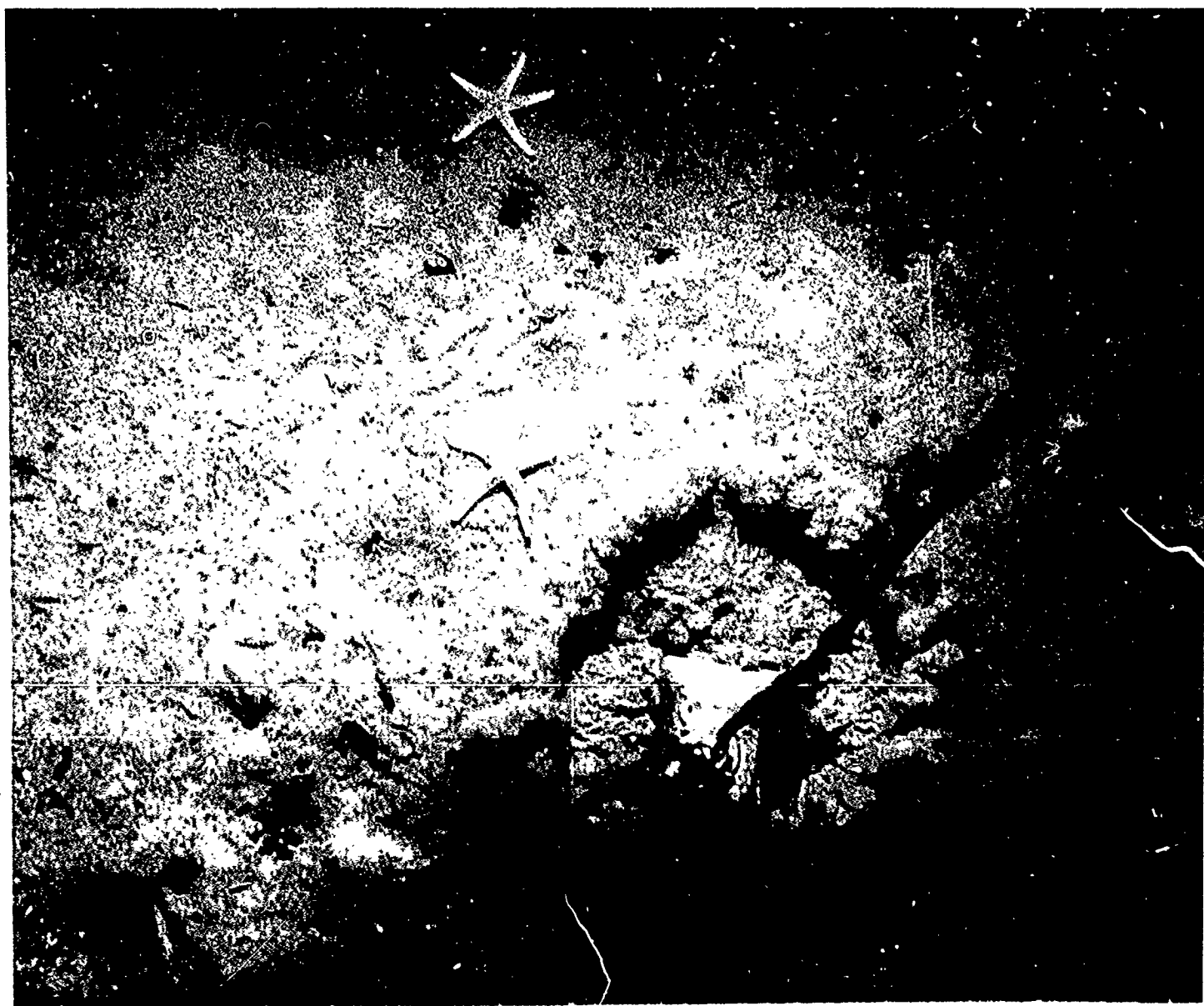
Sand/Silt-Clay Ratio - 1.00



JT 43

STATION 43 - Sand - 38%, Silt - 47%, Clay - 15%

Sand/Silt-Clay Ratio - 0.61



S+ 52

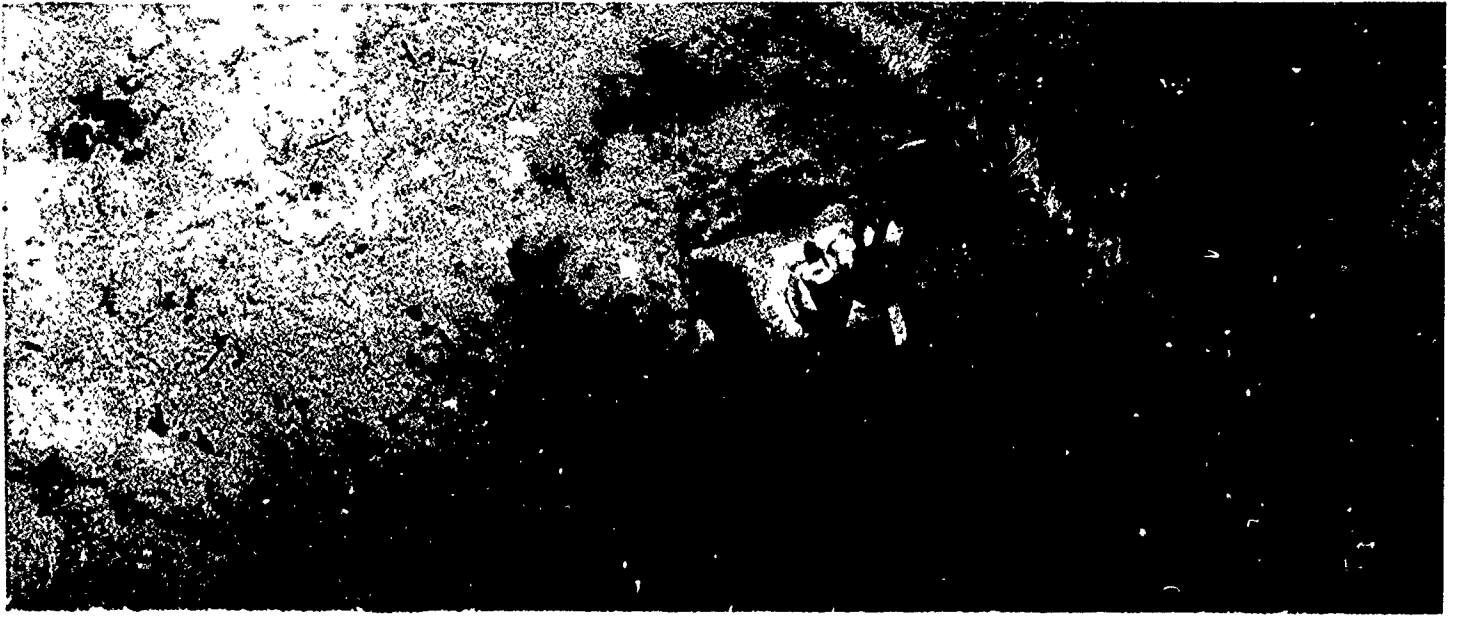
STATION 52 - no sample



St 55

STATION 55 - Sand - 80%, Silt - 11%, Clay - 9%

Sand/Silt-Clay Ratio - 4.00



St 56

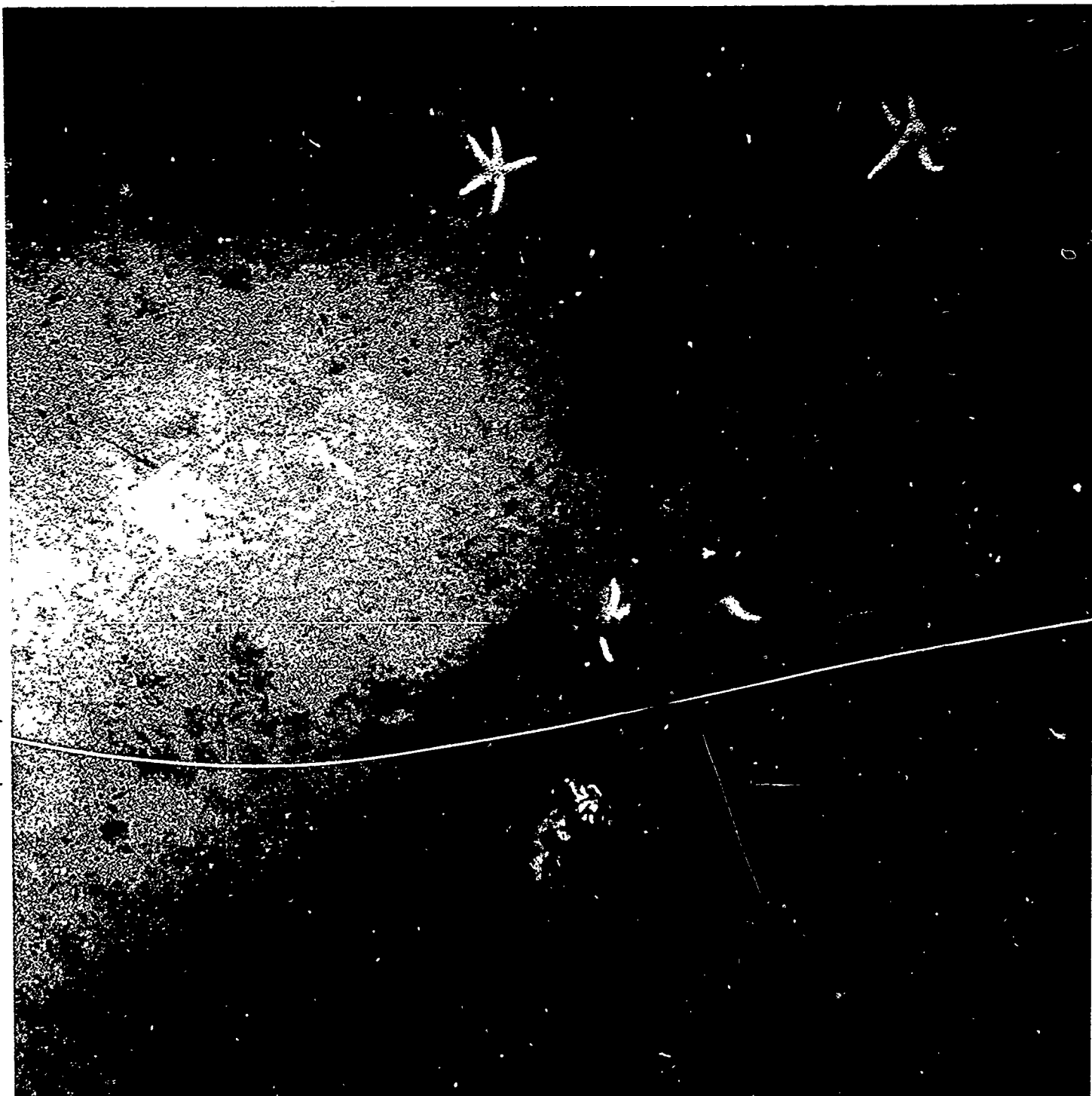
STATION 56 - no sample



St 57

STATION 57 • Sand • 72%, Silt • 18%, Clay • 10%

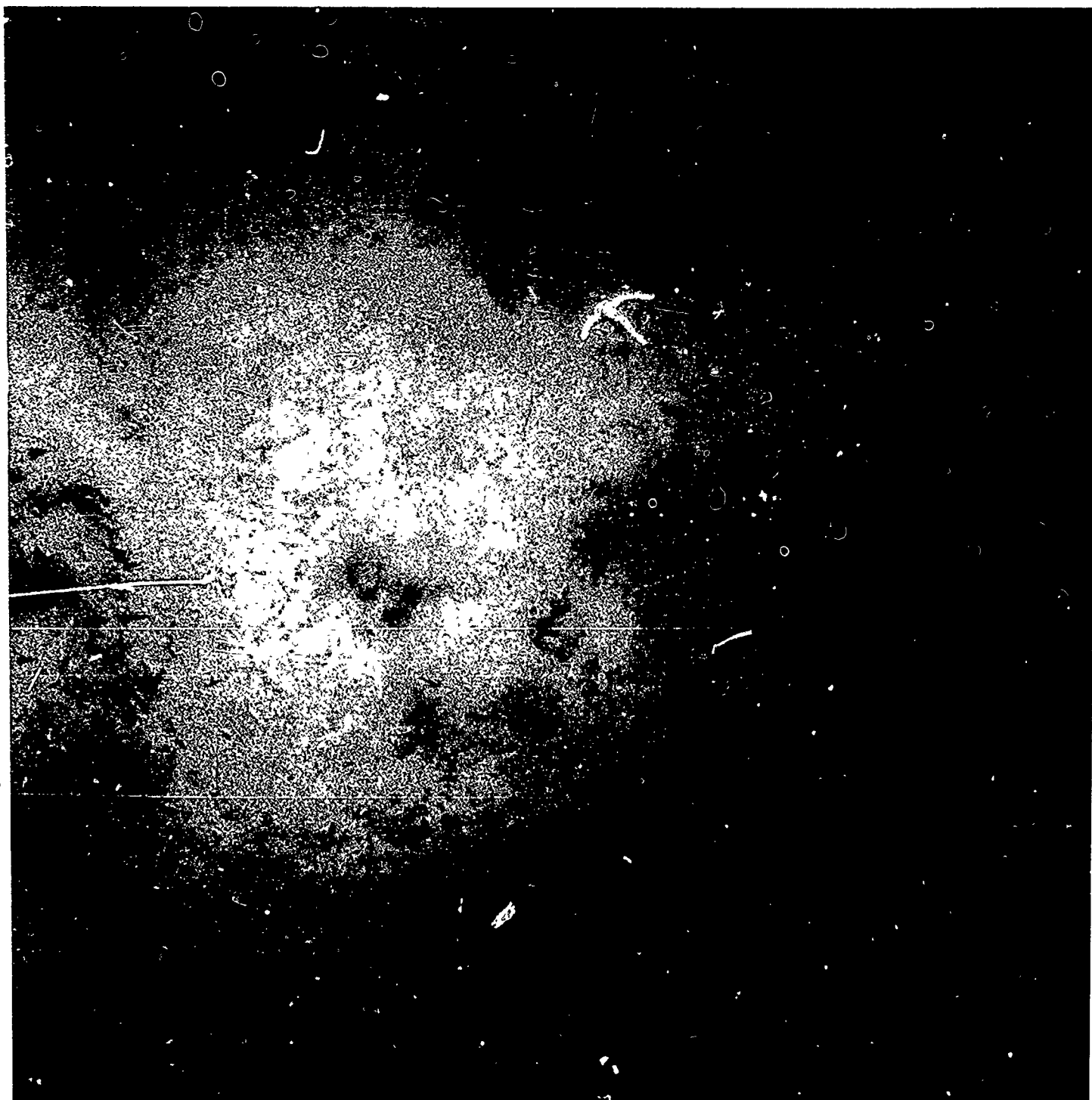
Sand/Silt-Clay Ratio • 2.56



St 58

STATION 58 - Sand - 62%, Silt - 25%, Clay - 13%

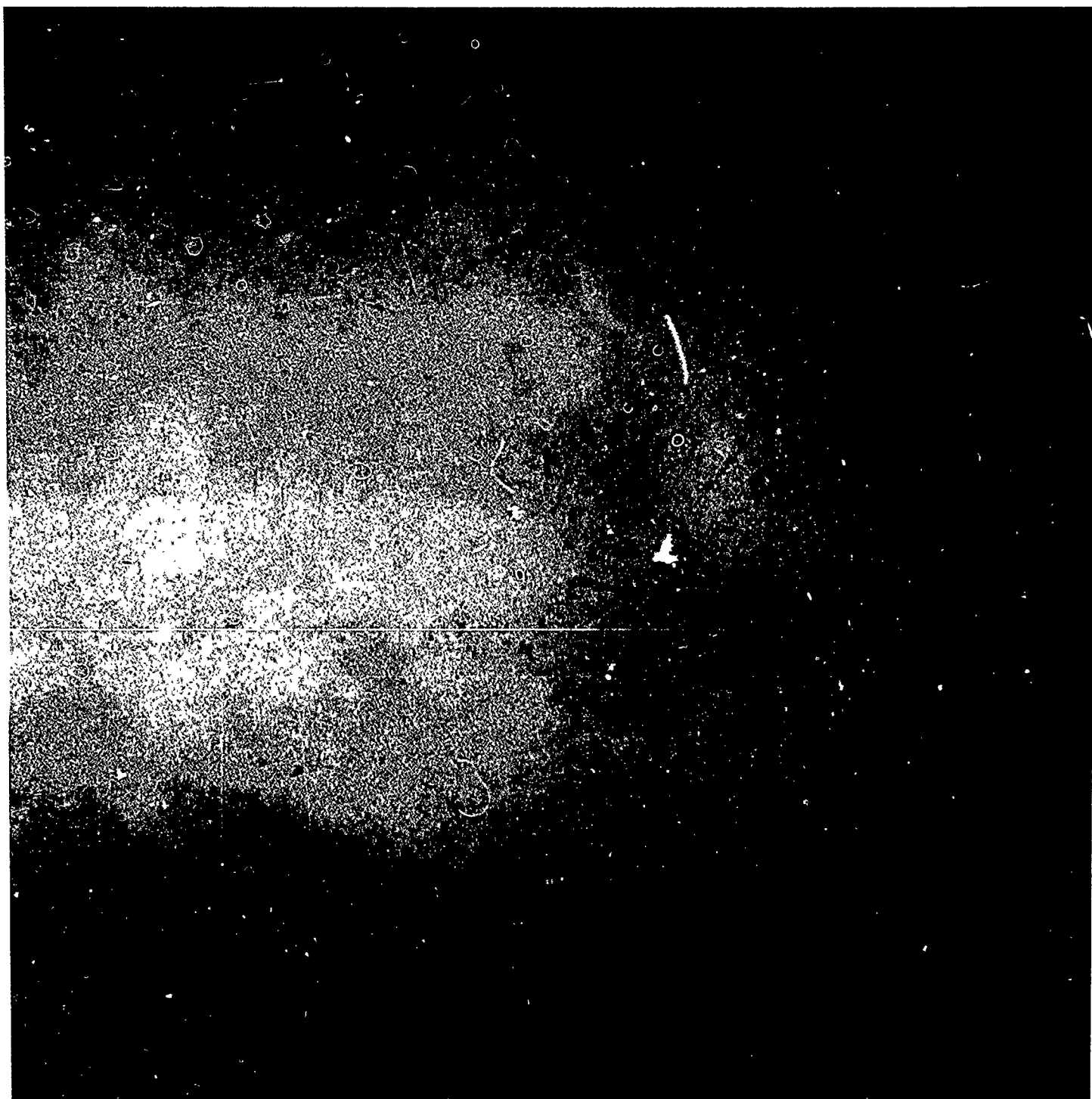
Sand/Silt-Clay Ratio = 1.63



St 59

STATION 59 - Sand - 71%, Silt - 18%, Clay - 11%

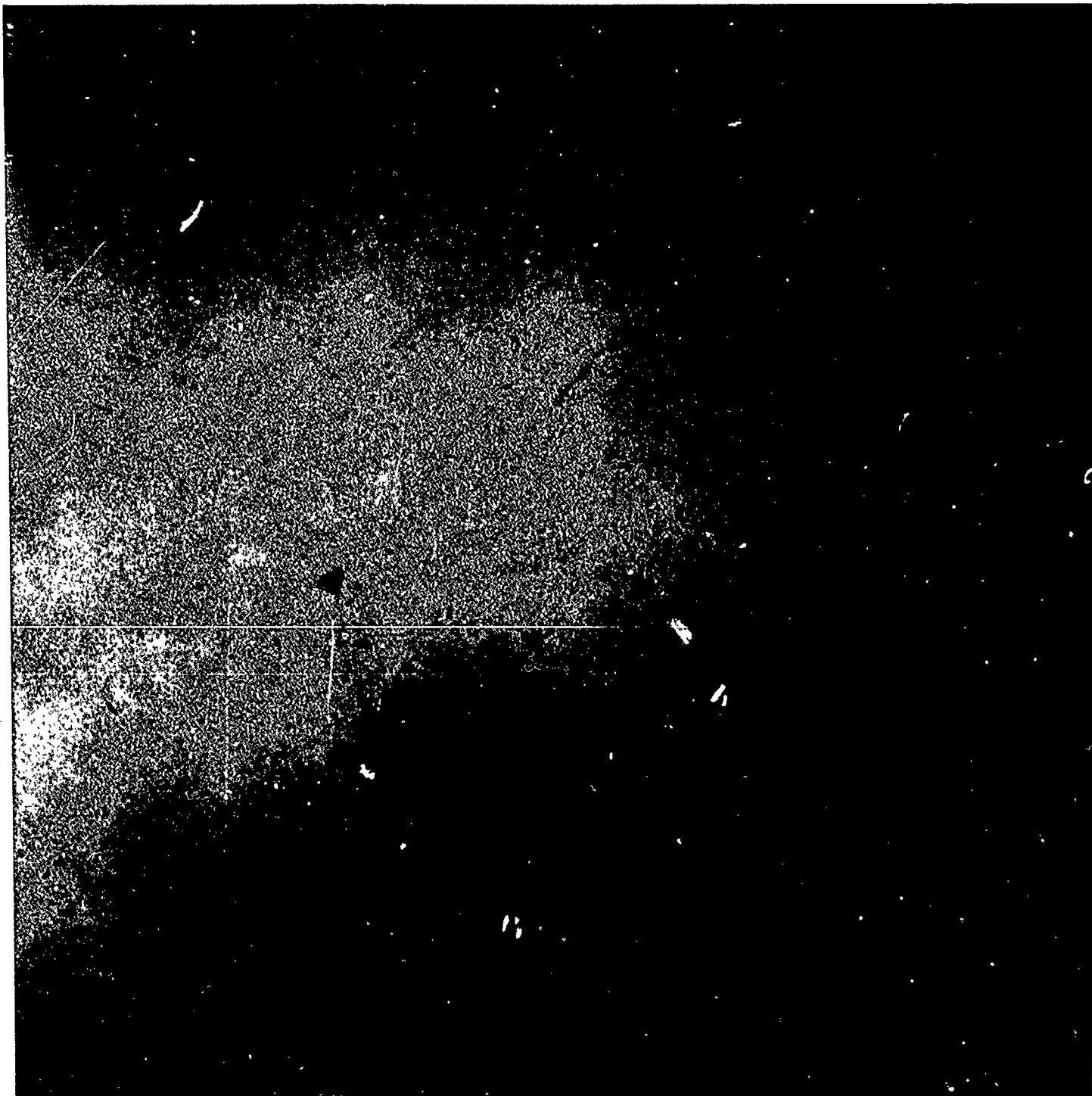
Sand/Silt-Clay Ratio - 2.45



St 60

STATION 60 - Sand - 51%, Silt - 38%, Clay - 14%

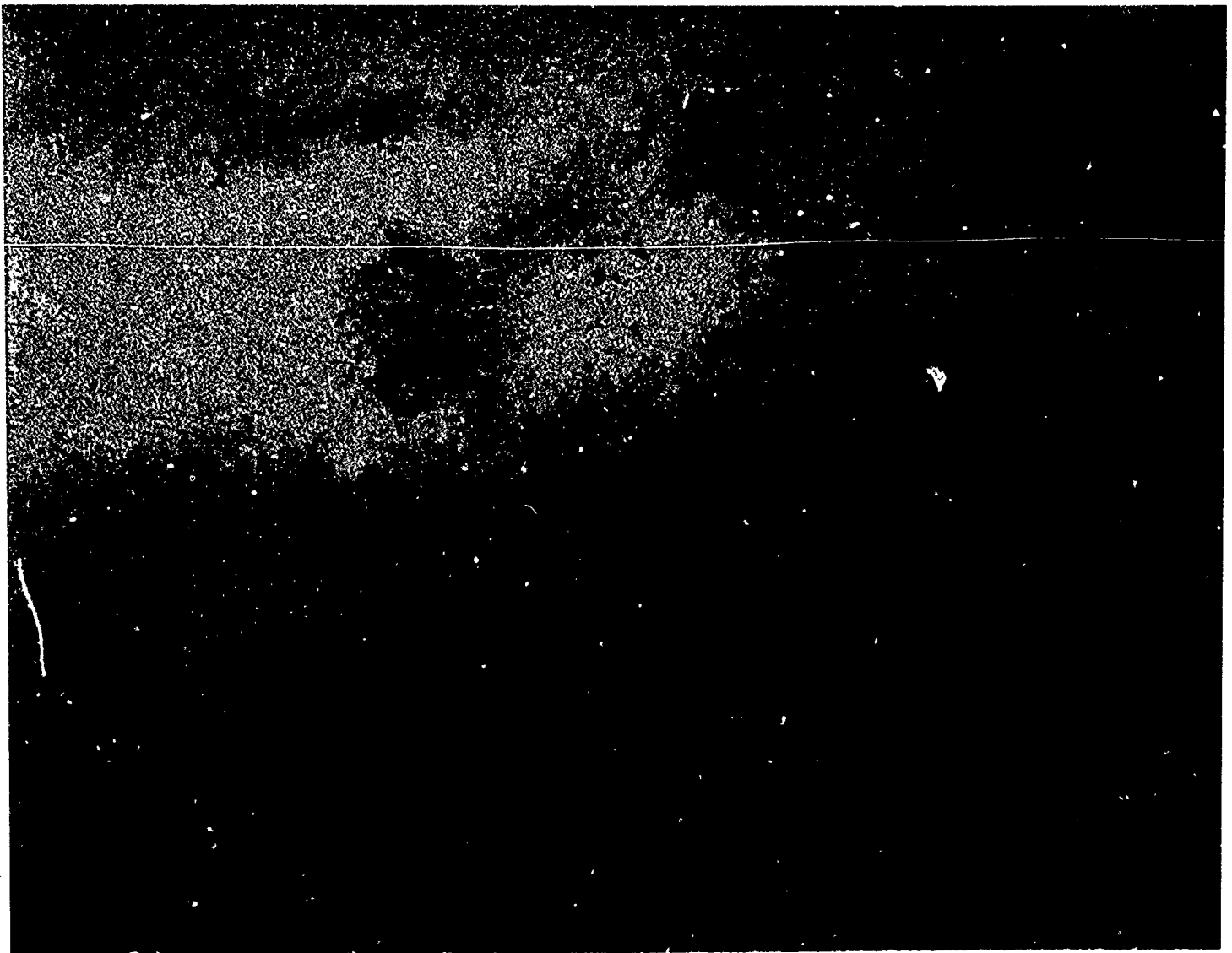
Sand/Silt-Clay Ratio - 1.04



St 61

STATION 61 - Sand - 47%, Silt - 41%, Clay - 12%

Sand/Silt+Clay Ratio - 0.89



St 62

STATION 62 - Sand - 41%, Silt - 45%, Clay - 14%

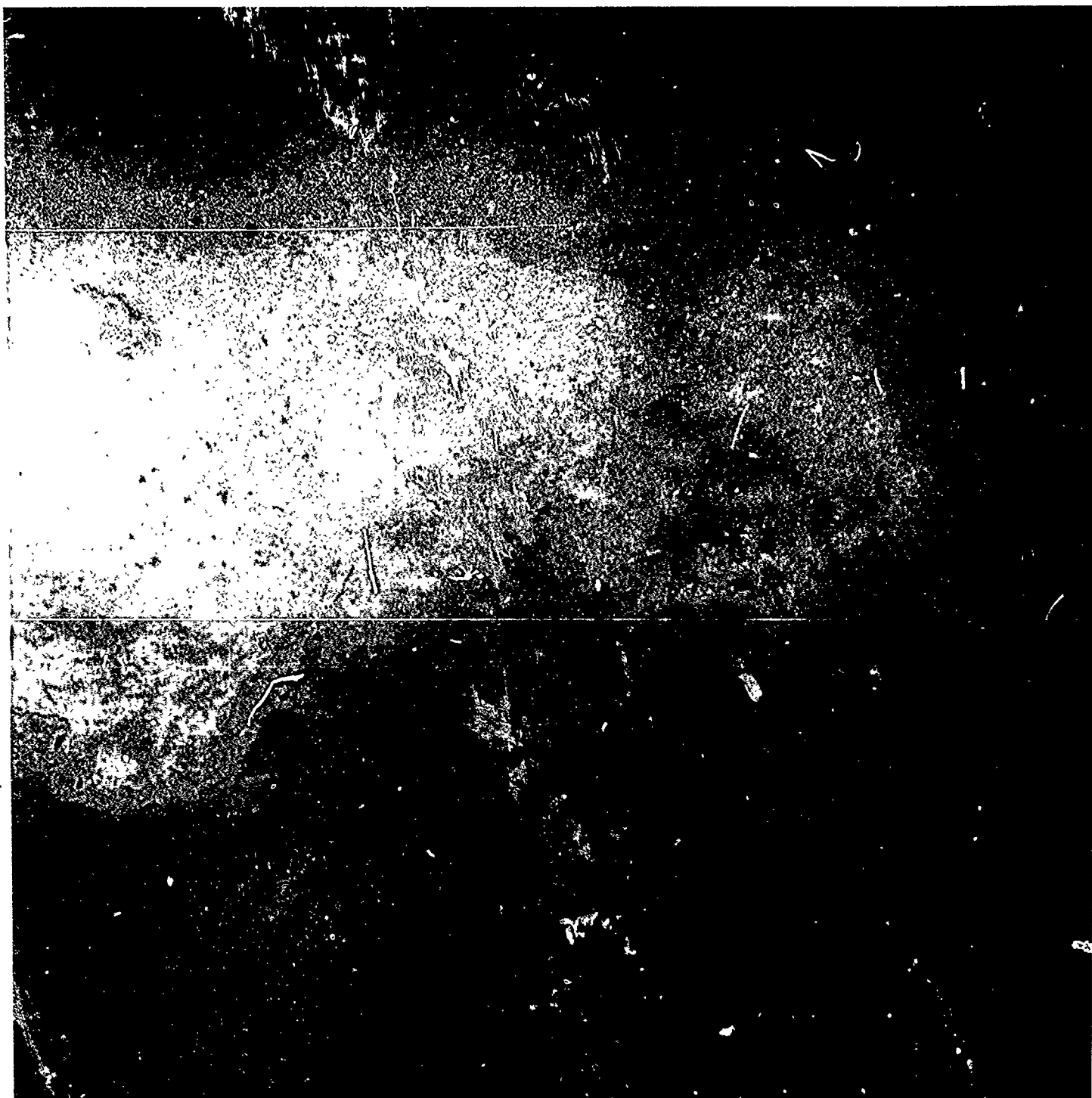
Sand/Silt-Clay Ratio - 0.69



ST 63

STATION 63 - Sand - 45%, Silt - 44%, Clay - 11%

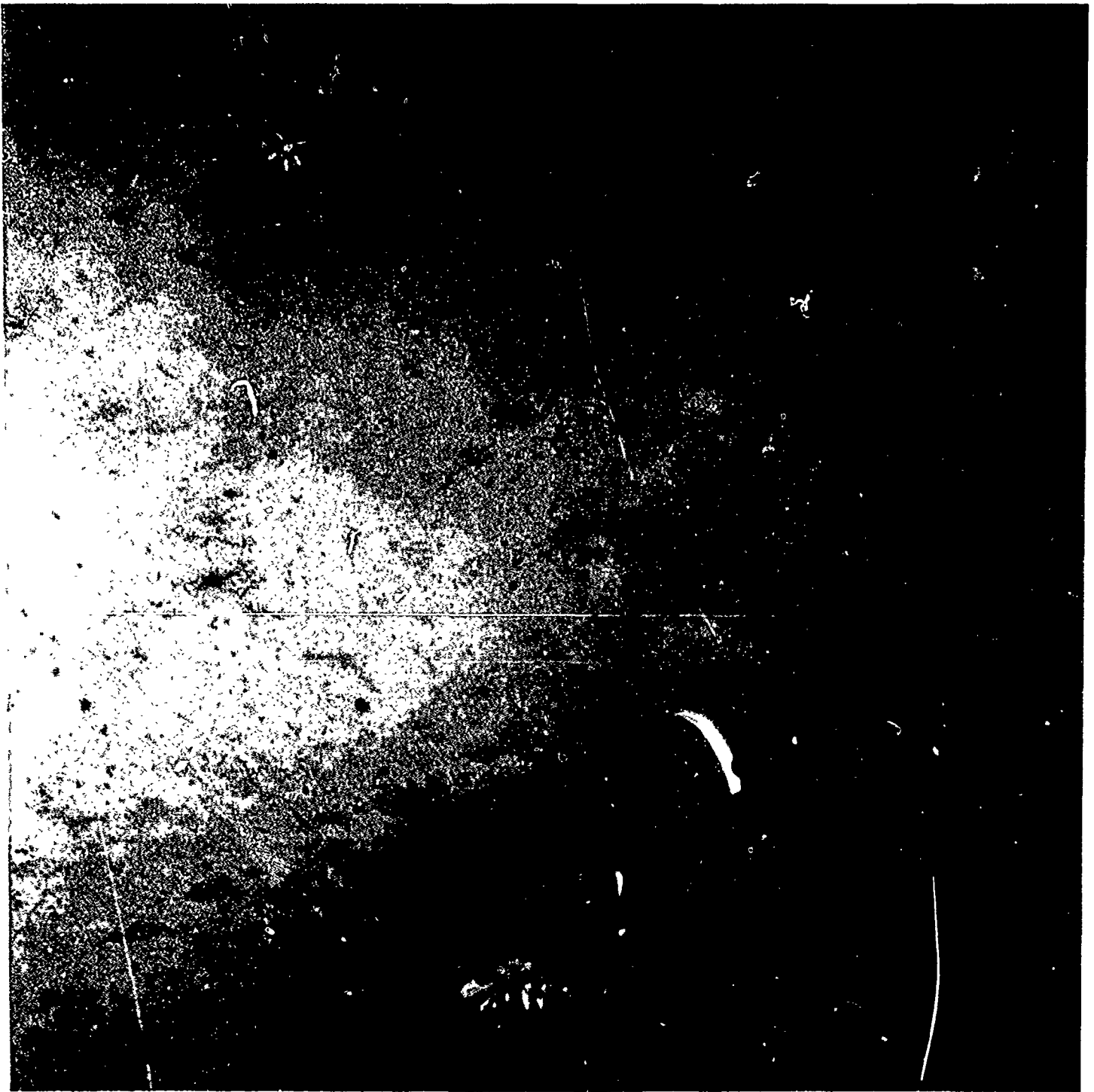
Sand/Silt-Clay Ratio - 0.82



St 64

STATION 64 - Sand - 53%, Silt - 31%, Clay - 16%

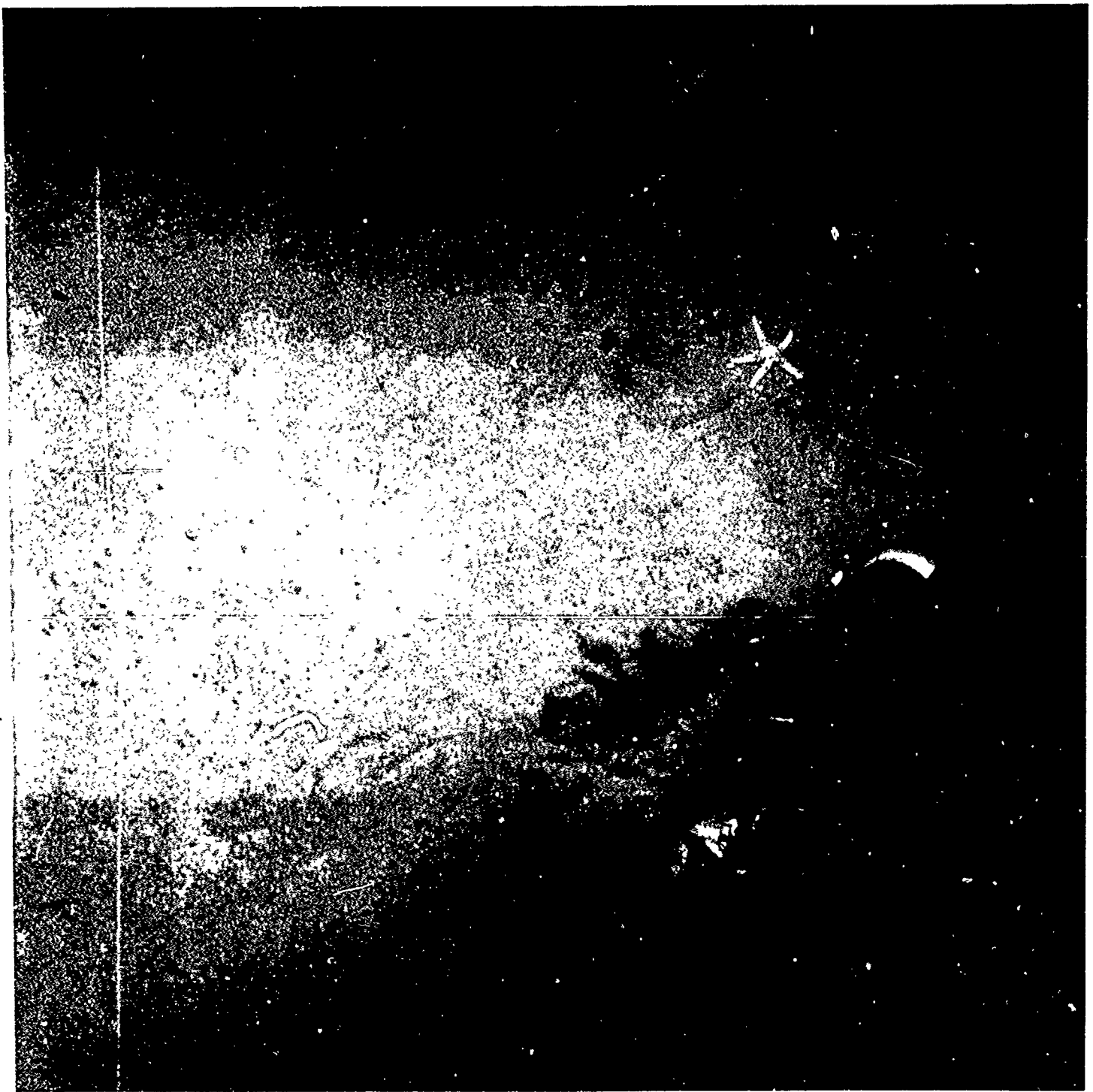
Sand/Silt-Clay Ratio - 1.13



St-65

STATION 65 - Sand - 65%, Silt - 25%, Clay - 10%

Sand/Silt-Clay Ratio - 1.86



St 66

STATION 66 - Sand - 59%, Silt - 31%, Clay - <sup>10%</sup>~~29%~~

Sand/Silt-Clay Ratio - 1.44



St 67

STATION 67 - Sand - 68%, Silt - 23%, Clay - 9%

Sand/Silt-Clay Ratio - 2.13



St 68

STATION 68 - Sand - 72%, Silt - 21%, Clay - 7%

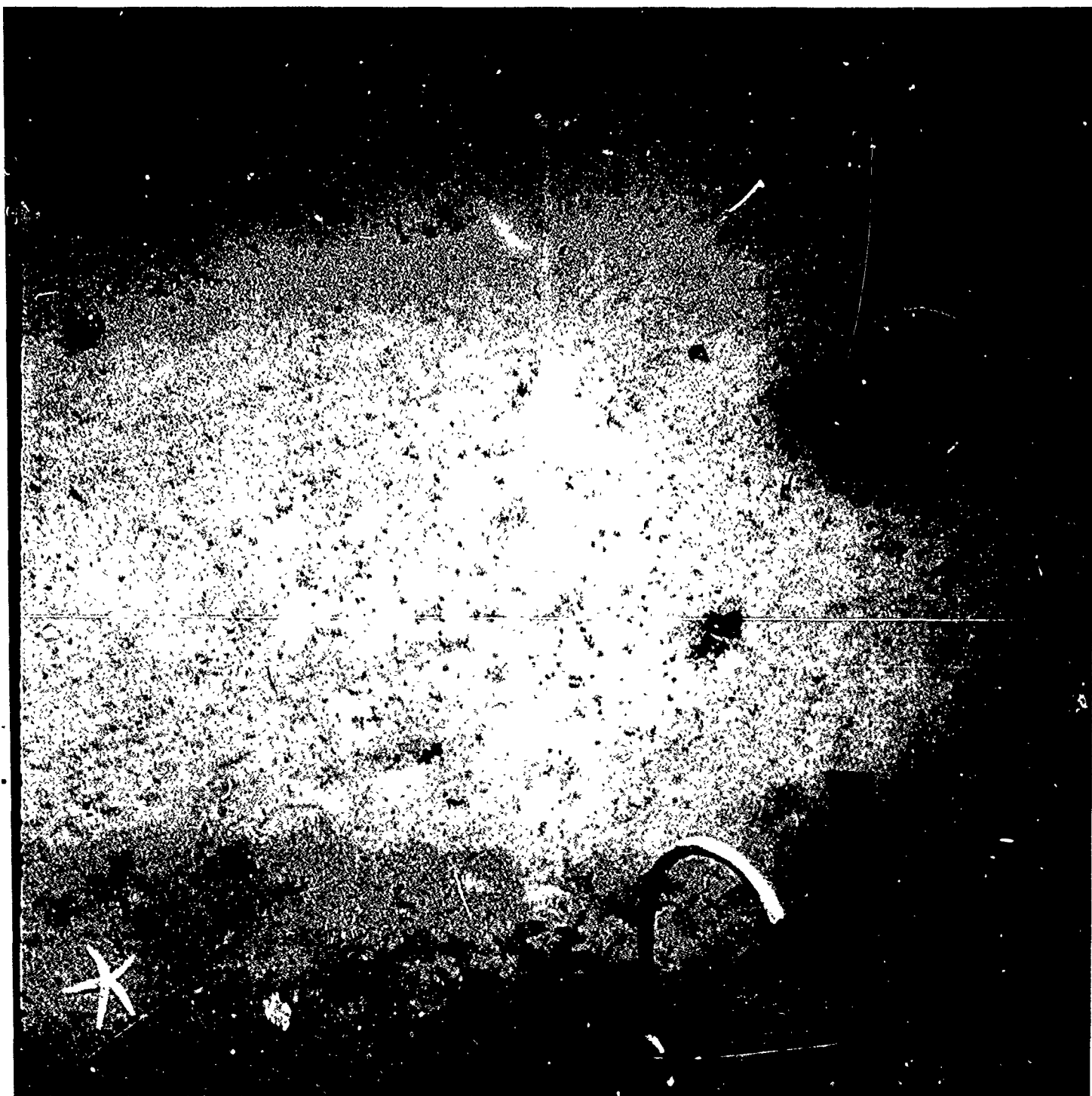
Sand/Silt-Clay Ratio - 2.56



St 69

STATION 69 - Sand - 74%, Silt - 18%, Clay - 8%

Sand/Silt-Clay Ratio - 2.85



37 70

STATION 70 - Sand - 71%, Silt - 21%, Clay - 8%

Sand/Silt-Clay Ratio - 2.45