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TR-133

TECHNICAL REPORT

A MARINE MAGNETIC SURVEY OFF THE EAST COAST OF THE UNITED STATES

PROJECT N-20

Geomagnetics Branch
Marine Surveys Division

SEPTEMBER 1962

U. S. NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C.
Price 40 cents

ABSTRACT

In July 1961, a survey of the total intensity of the geomagnetic field of an irregularly shaped area lying between latitudes 35°N and 40°N and longitudes 70°W and 76°W was conducted. The survey operations were conducted aboard the USS PREVAIL (AGS-20) utilizing a nuclear resonance magnetometer. This report describes the geomagnetic character of an extensive offshore area and its relation to bathymetric and available seismic data. The geological significance of some of the data, particularly an elongate anomaly occurring along the continental slope, is discussed.

FOREWORD

The results of the survey described in this report are considered to be of significance to both the Navy and the scientific community. The region investigated is a transition zone between a continental mass and a true oceanic basin. Geophysical investigations of such regions may lead to a better understanding of the earth's major crustal features and their origin. The use of geophysical exploration techniques such as described here provide a means of deducing information about the earth's deeper structures lying beyond the limits of direct measurement.

E. C. STEPHAN
Rear Admiral, U. S. Navy
Commander

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FIGURES

I. INTRODUCTION

A. Purpose

In July 1961, the USS PREVAIL (AGS-20) conducted total magnetic intensity, bathymetric, and bathythermal survey operations for the U. S. Naval Oceanographic Office.* The purpose of the magnetics phase of this survey was to define more precisely the characteristics of the earth's magnetic field over the continental shelf, slope, and adjacent deep-water area off the east coast of the United States.

Coincident with the geomagnetic and bathymetric measurements, bathythermograph observations and continuous recordings of sea surface and injection temperatures were taken. These observations were part of a project to develop a method for predicting the ocean's thermal structure. Thermal structure data are reported in U. S. Naval Oceanographic Office Technical Report 113 (in preparation) and are not included in this report.

B. Background

Several airborne magnetometer survey tracks had been flown by Oceanographic Office Project MAGNET survey aircraft over the east coast of the United States and the adjacent ocean area. Analysis of the data recorded along these tracks indicated that a magnetic anomaly is characteristically present at or near the location of the continental slope. Distinct magnetic anomalies of about twenty miles in horizontal extent and with various shapes and amplitudes

*In accordance with Public Law 87-533 effective 10 July 1962, the U. S. Navy Hydrographic Office was redesignated as the U. S. Naval Oceanographic Office.

always appeared on magnetic profiles flown transverse to the slope. In this area, seismic investigations by others indicated the presence of a ridge in the crystalline basement rocks. However, it was not known whether this seismic ridge was the source of the magnetic anomalies. Likewise, neither the detailed configuration of the magnetic anomalies nor the exact positional relationship of the anomalies and the continental slope were known.

C. Survey Area

The survey was conducted in an irregularly shaped area lying between latitudes 35°N and 40°N and longitudes 70°W and 76°W. The survey track lines were run approximately perpendicular to the continental slope. Specific survey tracks are shown in Figure 1.

II. SURVEY OPERATIONS

A. Conduct of Survey

The PREVAIL departed New York on 17 July and arrived in Washington, D. C., on 25 July after completing almost 2500 miles of survey track. As shown in Figure 1, average track spacing was approximately 30 miles with the tracks trending northwest and southeast. This particular survey track configuration was established to best meet both magnetic and bathythermal survey requirements. The average speed of advance over the survey track was 12.5 knots.

B. Control

Survey control was by Loran-A with additional position determinations by radar where possible. The position of the ship was determined every fifteen minutes and then plotted on Mercator Plotting Sheets (H.O. 3000 series). On the shoreward side of the survey area, both Loran-A and radar were used. Here, the probable position accuracy is estimated as being within ± 1 mile. On the seaward side of the survey area, radar fixes were not available, and only Loran-A fixes were taken. Here, the probable position accuracy is estimated as being within ± 2 miles.

C. Instrumentation

A Varian nuclear resonance magnetometer, Model XN-4901, was used to measure the earth's total magnetic field intensity. With this instrument, the total field intensity can be measured to an accuracy of about ± 1 gamma (0.00001 oersted). Magnetometer equipment consisted of a power supply, preamplifier, counting circuits, analog recorder, and towed sensing unit. The sensing unit, a Varian Model X-49-813 using 700 feet of Simplex #310 two-conductor cable, was towed 400 feet astern. This sensing unit was streamed and recovered manually. Console electronic equipment was installed in the drafting room on the after part of the ship. Data were recorded in analog form on a Varian G-11 recorder in units of "magnetometer counts". These units, an inherent property of the magnetometer design, are an inverse function of the total magnetic field intensity. In the survey area, one magnetometer count is equal to approximately 1.3 gammas.

Bathymetric instrumentation aboard the PREVAIL consisted of an Edo AN-UQN-1B sonar receiver-transmitter, the output of which was recorded directly in fathoms on a Mark V Precision Depth Recorder (PDR). This type of recorder can be read to the nearest one fathom. The bathymetric recording instrumentation was located in the ship's drafting room.

D. Personnel

Two geophysicists from the Geomagnetics Branch, U. S. Naval Oceanographic Office installed and operated the magnetometer system. PREVAIL personnel operated the bathymetric instrumentation.

III. DATA PROCESSING

A. Preliminary Data Processing

The magnetometer recorder traces were scaled at time intervals of fifteen minutes and also wherever maximum and minimum magnetic intensity values were recorded. These values were converted from magnetometer counts to gammas and plotted on the smooth plot of the survey track. The Precision Depth Recorder traces were scaled in a similar manner.

B. Magnetic Temporal Variations

No attempt was made to remove temporal variations of the earth's magnetic field from the data. Records of the Fredericksburg, Virginia, Magnetic Observatory indicate that no severe disturbances occurred during the time of the survey. Magnetograms and calibration data are reproduced in the Appendix.

The Fredericksburg observatory is approximately 150 miles from the shoreward side of the survey area and about 500 miles from the seaward side. Because of these distances, it is not possible to determine accurately the magnitude of the errors introduced by the temporal variations. Nevertheless, the magnetograms should indicate times when the data cannot be considered completely reliable. Variations that occurred will introduce small errors in the location of contour lines, particularly in the areas of shallow magnetic relief. However, it is considered that they had little effect on the magnitude and position of the most significant anomalies.

C. Total Magnetic Intensity Contour Chart (Figure 2)

The total intensity values plotted on the Smooth Track Chart were contoured at 50-gamma intervals. The contours are shown in Figure 2. Dashed contours represent extrapolated data.

D. Residual Magnetic Intensity Contour Chart (Figure 3)

In order to more clearly define the anomalies, the regional gradient of the total magnetic intensity was removed from the original values. To accomplish this, the total intensity contours from H. O. Chart No. 1703, The Total Intensity of the Earth's Magnetic Force (for the year 1955) were corrected to the year 1961 and then interpolated at 50-gamma intervals. These interpolated contours were then reproduced on the total intensity contour sheet of the survey area. At each point on the sheet where survey plot contour lines intersected charted contour lines taken from H. O. 1703, the difference was computed. If the survey contour value was greater than the charted contour value, a plus (+) value was assigned to the difference; if smaller, a minus (-) value was assigned. An overlay was placed over these two contour representations, and the differences at contour intersections were plotted and contoured at 50-gamma intervals. The Residual Magnetic Intensity Contour Chart for the survey area is shown in Figure 3.

E. Profiles

Profiles of the total magnetic intensity and the measured bathymetric depth along each track are presented in Figures 4 through 12. These profiles were constructed using the smooth-plotted survey tracks as base lines. An index to the geographical location of each profile is shown in Figure 1.

IV. SURVEY RESULTS

A. General

A significant advantage of a shipborne magnetic survey is that bathymetric measurements can be taken simultaneously with the magnetic measurements. Direct comparison of magnetic and bathymetric data relative to each other is thus possible, irrespective of the certainty of the ship's true position.

The data contained in this report provide useful information relating to the geologic structure pattern in this area. These data can be correlated with similar information from adjacent regions. Such correlation may yield clues leading to a better understanding of the relationship between continents and ocean basins.

B. Discussion of Data

The magnetic field contour pattern in the survey area (see Figure 2) contains a large, elongate, magnetic anomaly on the western side. This anomaly has lineations corresponding closely to those of the continental slope. On the eastern side, the increasing complexity of the contour pattern suggests the existence of a magnetic feature lying just outside the survey area. Between these two features is a broad area void of magnetic anomalies.

In the survey area, the bathymetric data indicate that the sea bottom has no topographic features capable of accounting for the observed magnetic anomalies. Figure 1 shows that a portion of the survey track connecting points C and D passed directly over Baltimore Canyon. Similarly, the track connecting points E and F passed directly over Norfolk Canyon. In neither case was there any magnetic field change to correspond with these prominent topographic features.

Using the data shown on Profiles G-G', H-H', and I-I', depths to the source of the large magnetic anomalies that were found near the continental slope were estimated. These depth estimates were made in accordance with empirical slope methods of Vacquier et al (1951). The average depth estimates to magnetic sources for these profiles are as follows:

Profile G-G'	19000 feet
Profile H-H'	18900 feet
Profile I-I'	19980 feet

Depth estimates made from magnetic data from a single survey track are at best only approximate. It was found, however, that the "magnetic depths" estimated above are in reasonable agreement with the depth to the crystalline basement complex, as determined from seismic and drilling data by Ewing et al (1950). It appears that the top of the magnetic source is probably closely coincident with the basement surface.

North of this survey area, seismic data (Ewing et al, 1950) indicate the existence of a ridge on the surface of the crystalline basement. The possibility has been considered that this ridge may extend into the survey area and may be the source of the magnetic anomalies found in the vicinity of the continental slope. However, King et al (1961) computed values of the magnetic polarization intensity that this ridge would be required to have in order to produce the magnetic anomalies observed over it. These computed values were too large to be plausible.

In the southern part of the survey area, the magnetic anomalies peak more sharply. This phenomenon may indicate a shallowing of the basement in that region.

It appears that the most probable general explanation for the continental slope magnetic anomaly is that advanced by King et al (1961). These investigators suggest that although basement topography probably contributes to the magnetic profile, the continental slope magnetic anomaly may be partly the expression of a large mass or series of masses of more highly magnetic rocks within the basement.

Another significant feature is the relative position of the peak of the magnetic anomaly. Profiles H-H' and I-I' (Figures 11 and 12) are representative of the southern part of the survey area. These profiles show the peak of the anomaly to lie seaward from the break between the continental shelf and the continental slope. In the northern part, profiles A-A' and B-B' do not show any peak lying seaward but indicate that the peak lies shoreward from this break. This difference in trend suggests that the lineation of the magnetic anomaly is not directly related to that of the continental slope. Instead, the lineations of both are probably related to a subsurface structural trend.

The small, broad anomalies occurring about 60-80 miles seaward from the continental shelf have been reported previously by Keller et al (1954). They were noted as occurring in approximately the same location as an increase in isostatic gravity anomalies. Bathymetric data revealed no topographic features to account for the anomalies. Consequently, they may be reflections of some type of deep-seated lithologic contrast. In profile view, these anomalies are best seen on Profiles A-A', D-D', and F-F' on Figures 4, 7, and 9 respectively.

V. SUMMARY OF FINDINGS

Magnetic measurements across the continental slope and adjacent deepwater area off the east coast of the United States revealed the presence of an elongate anomaly of a few hundred gammas amplitude. This anomaly has a lineation corresponding closely, but not exactly, with that of the continental slope. Depth estimates made on this anomaly are in reasonable agreement with seismic depths to crystalline rocks. This agreement suggests that the anomaly is caused by contrasts in intensity of magnetic polarization within the basement.

The center of the survey area is void of magnetic features. However, small, broad anomalies occur about 60-80 miles east of the continental slope. Bathymetric data revealed no topographic features capable of accounting for these anomalies. Consequently, these anomalies may be reflections of some type of deep-seated lithologic contrast.

U. S. NAVY HYDROGRAPHIC OFFICE

PROJECT N-20

MARINE MAGNETIC SURVEY

TRACK CHART AND PROFILE INDEX

1961

Mercator Projection

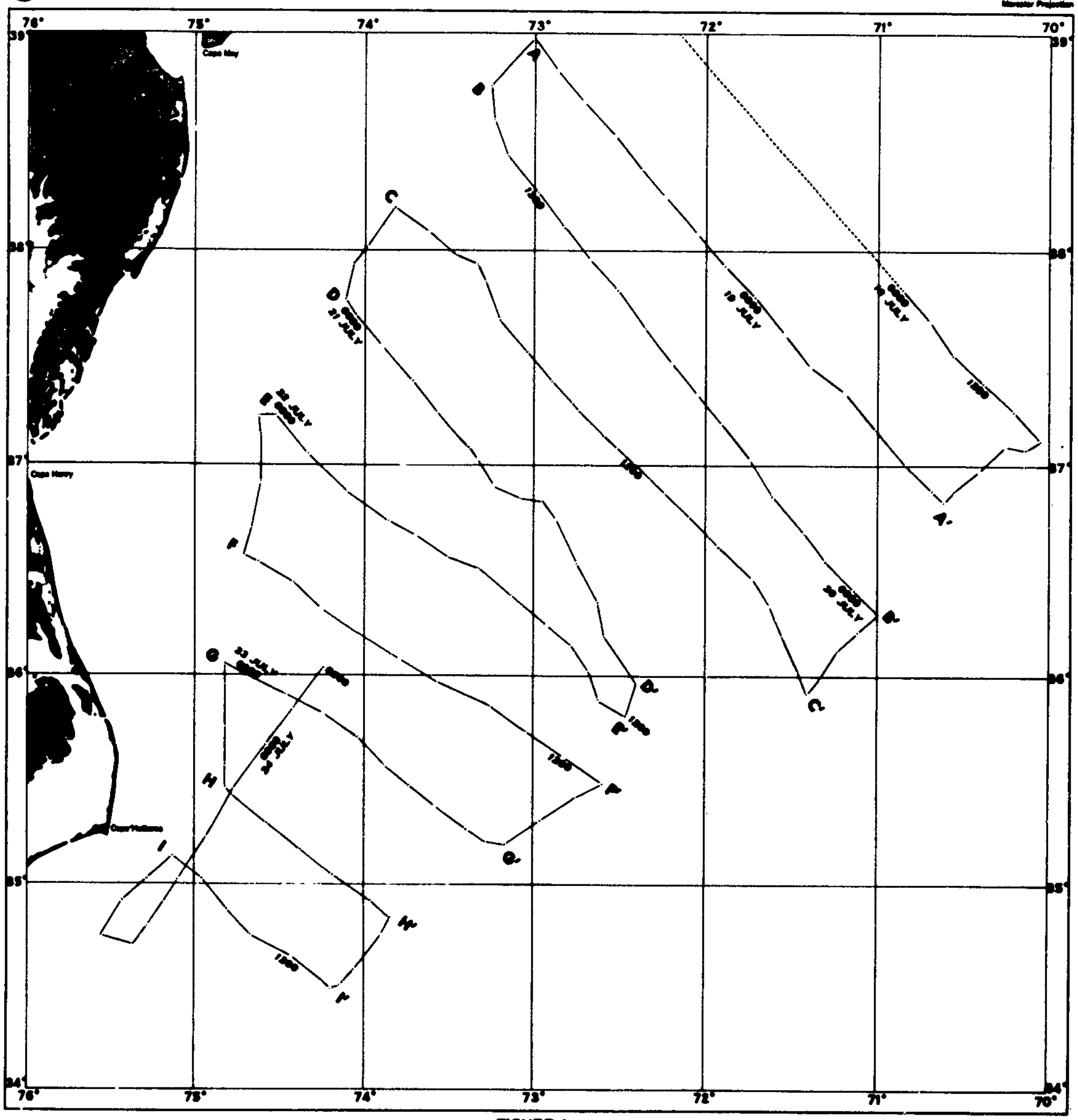

FIGURE 1

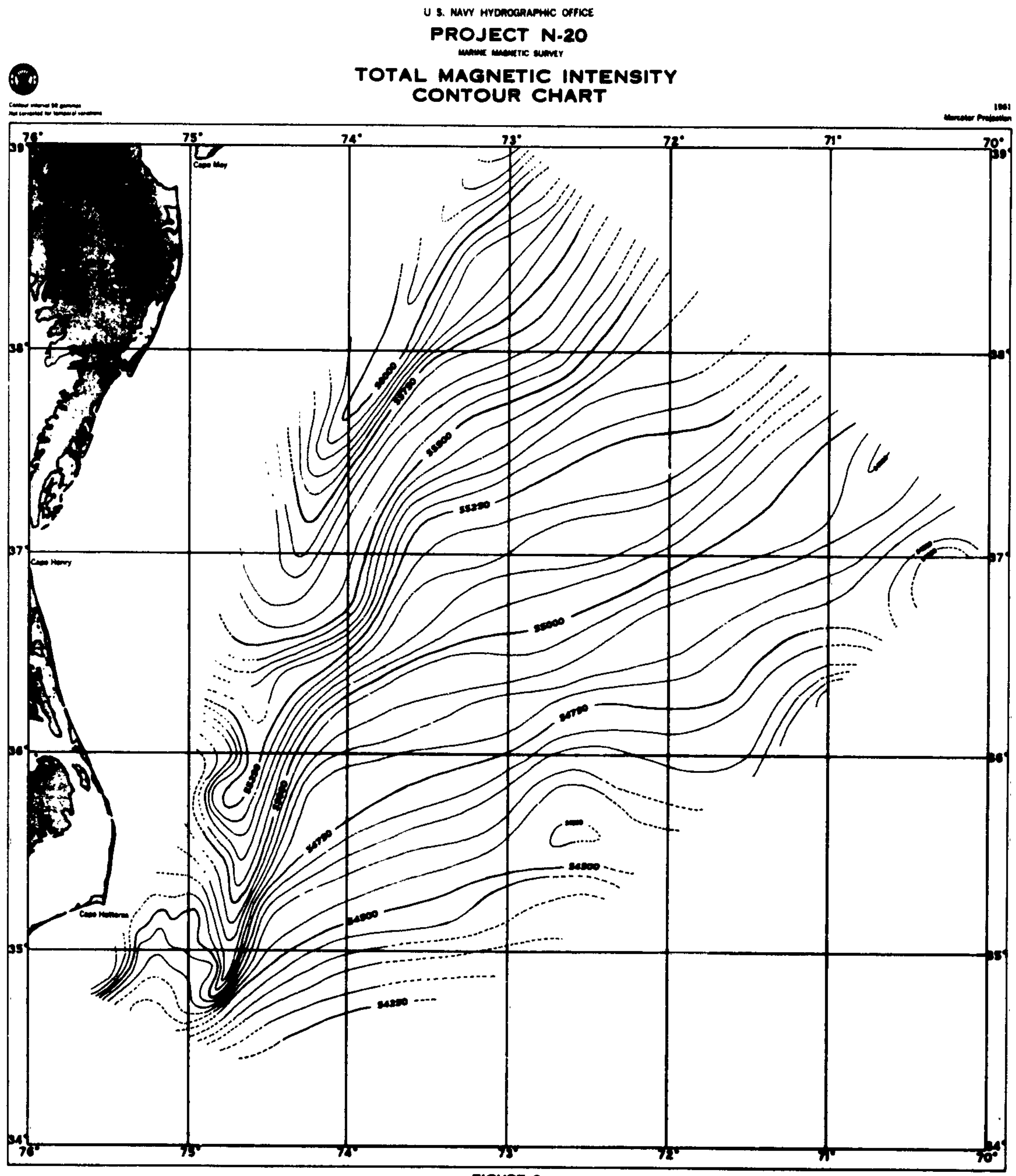
U S. NAVY HYDROGRAPHIC OFFICE
PROJECT N-20
MARINE MAGNETIC SURVEY
TOTAL MAGNETIC INTENSITY
CONTOUR CHART
1961
Mercator Projection
76°
75°
74°
73°
72°
71°
70°
39°
38°
37°
36°
35°
34°
Cape May
Cape Henry
Cape Hatteras
35250
35000
34750
34500
34250

FIGURE 2

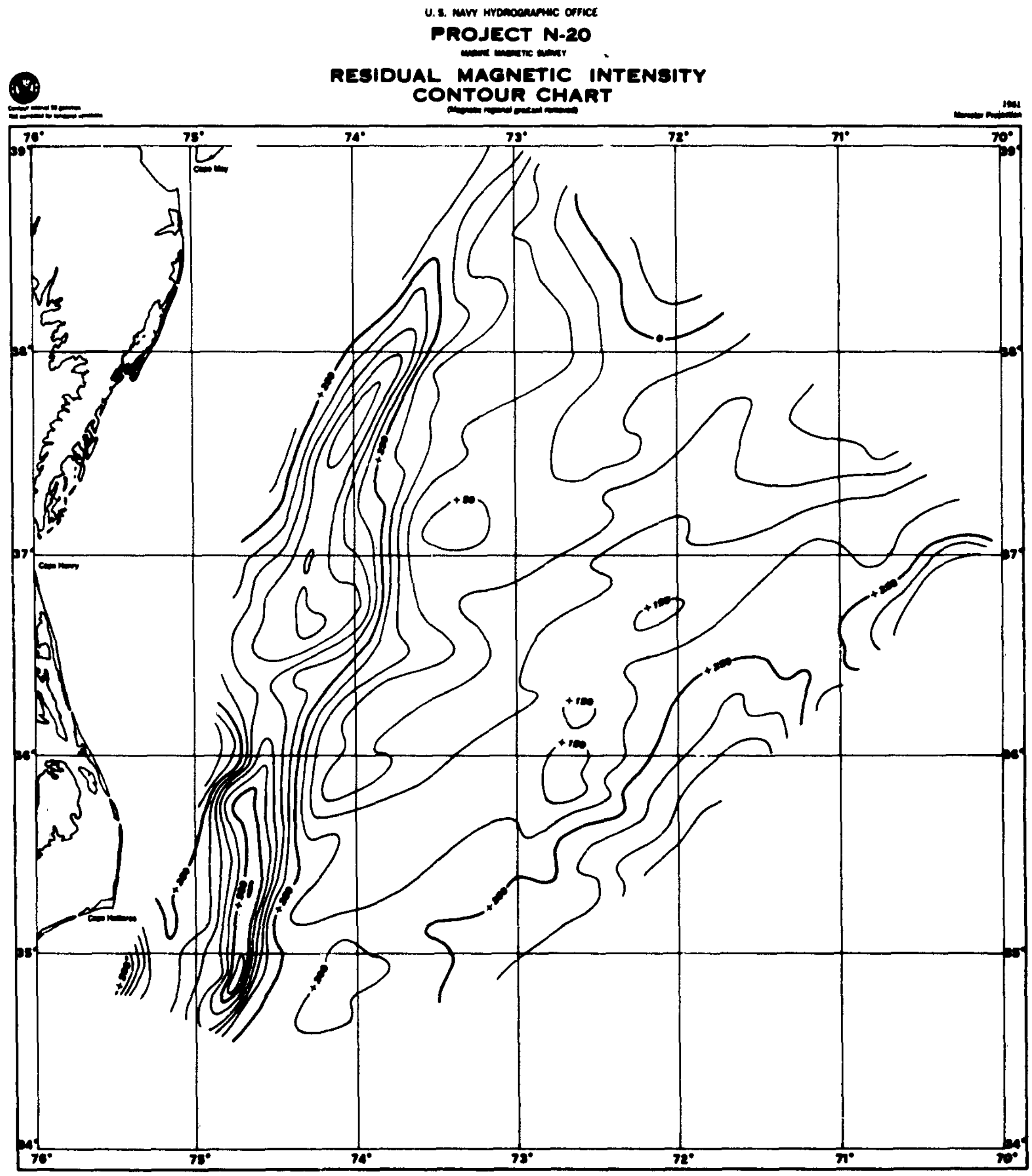
U. S. NAVY HYDROGRAPHIC OFFICE
PROJECT N-20
MARINE MAGNETIC SURVEY
RESIDUAL MAGNETIC INTENSITY
CONTOUR CHART
(Magnetic regional gradient removed)
1961
Mercator Projection
76°
75°
74°
73°
72°
71°
70°
39°
38°
37°
36°
35°
34°
Cape May
Cape Henry
Cape Hatteras

FIGURE 3

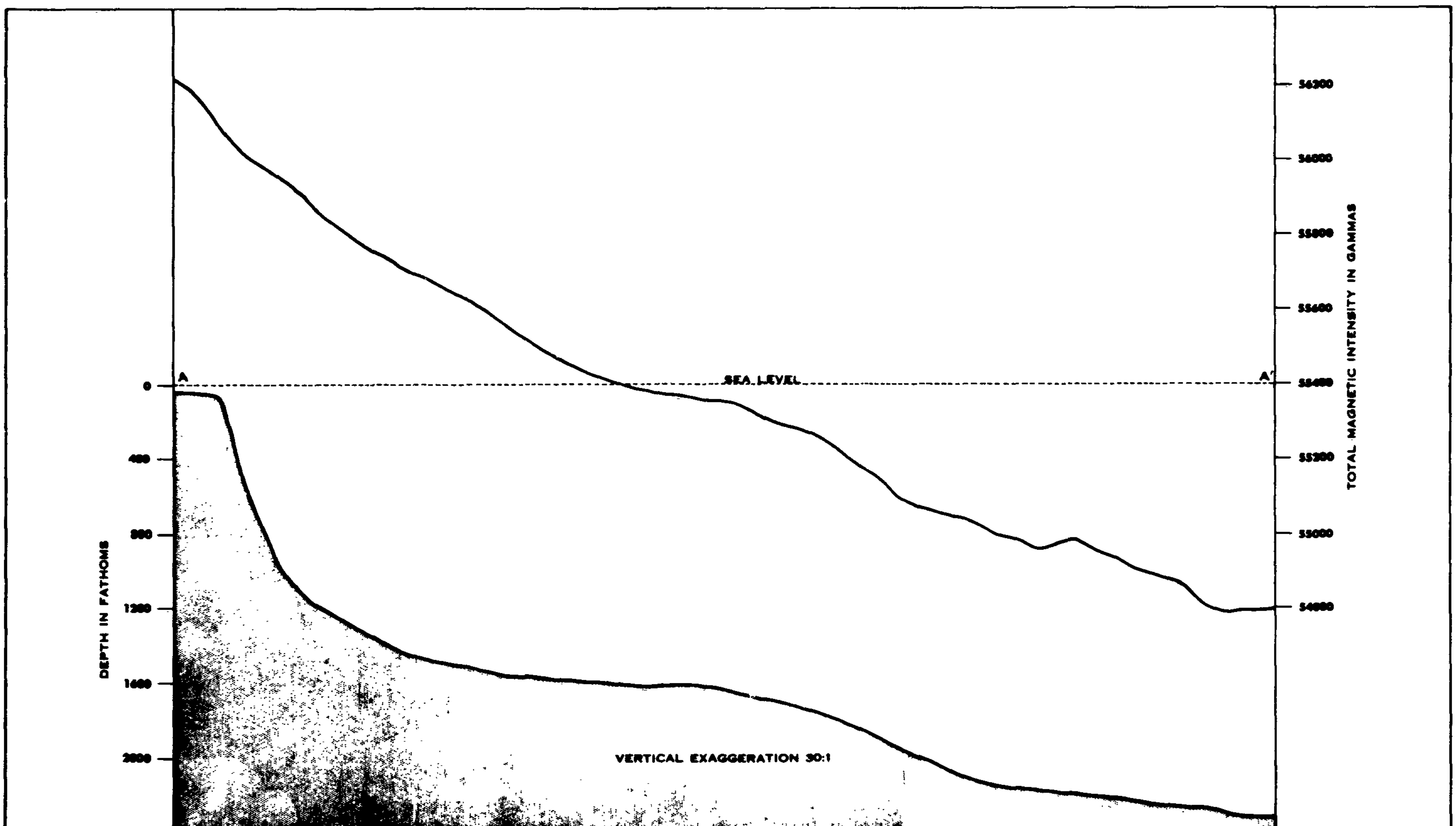

FIGURE 4

MAGNETIC AND BATHYMETRIC PROFILES A-A'

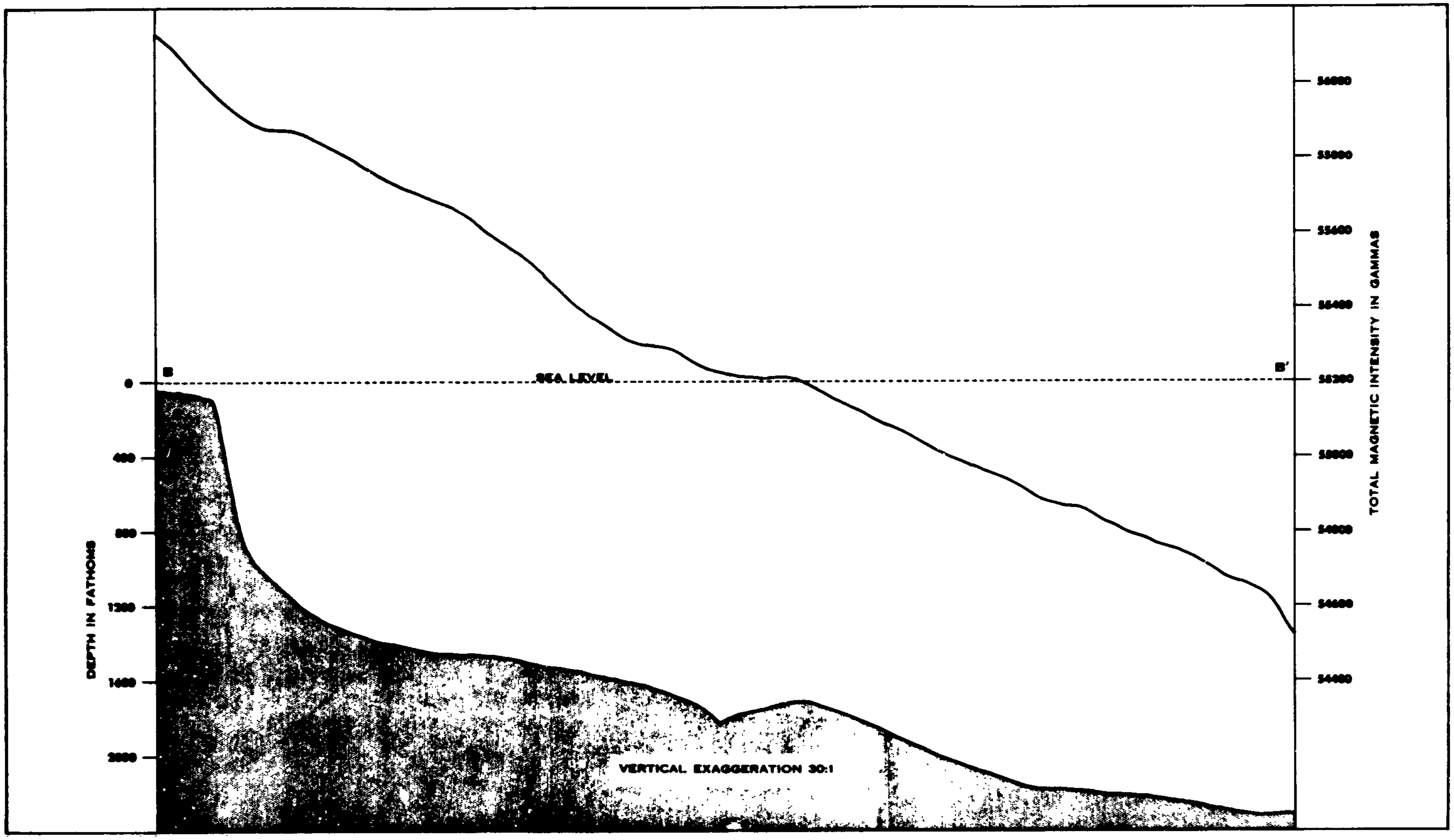

FIGURE 5

MAGNETIC AND BATHYMETRIC PROFILES B-B′

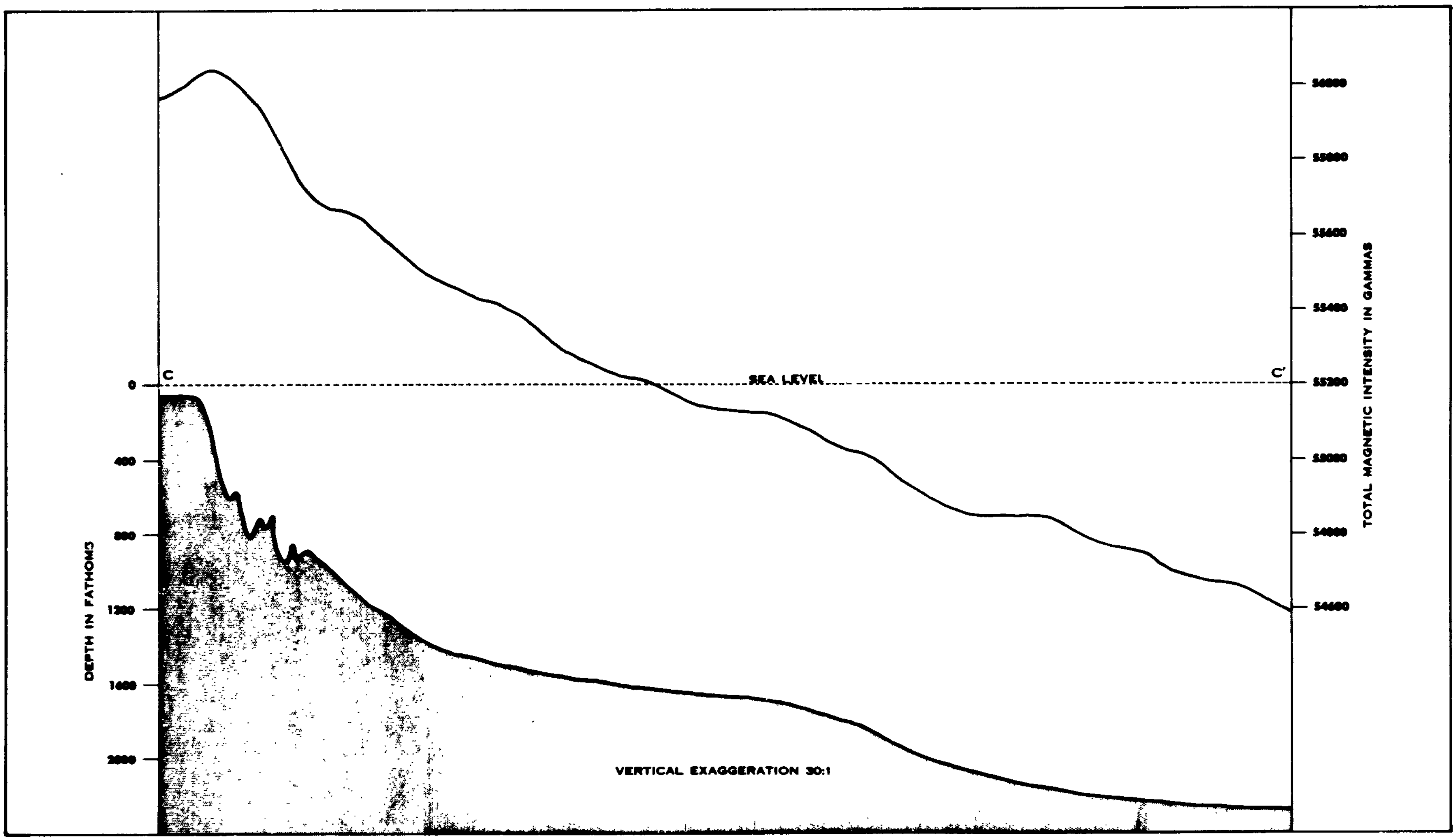

FIGURE 6

MAGNETIC AND BATHYMETRIC PROFILES C-C′

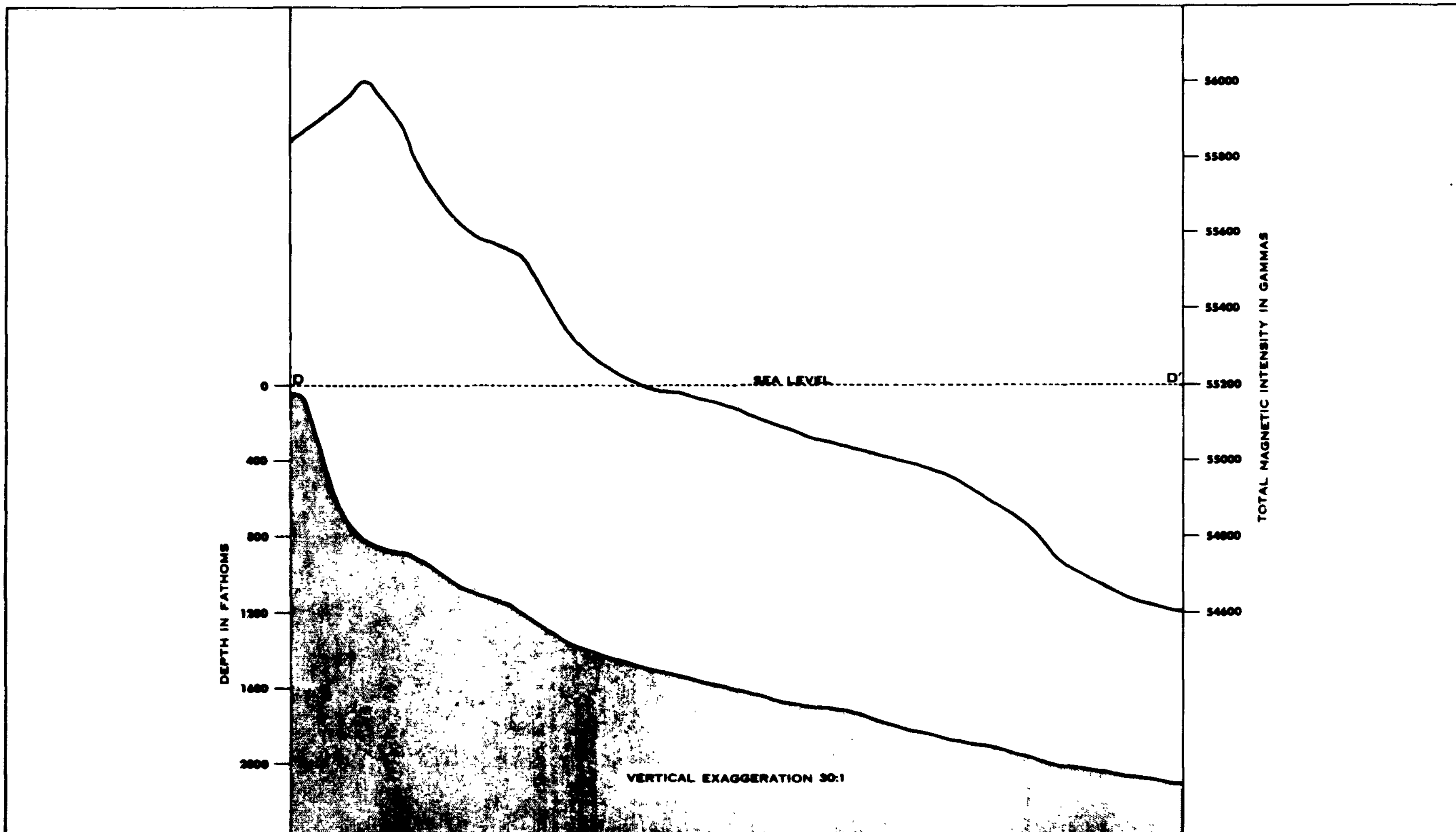

FIGURE 7

MAGNETIC AND BATHYMETRIC PROFILES D-D′

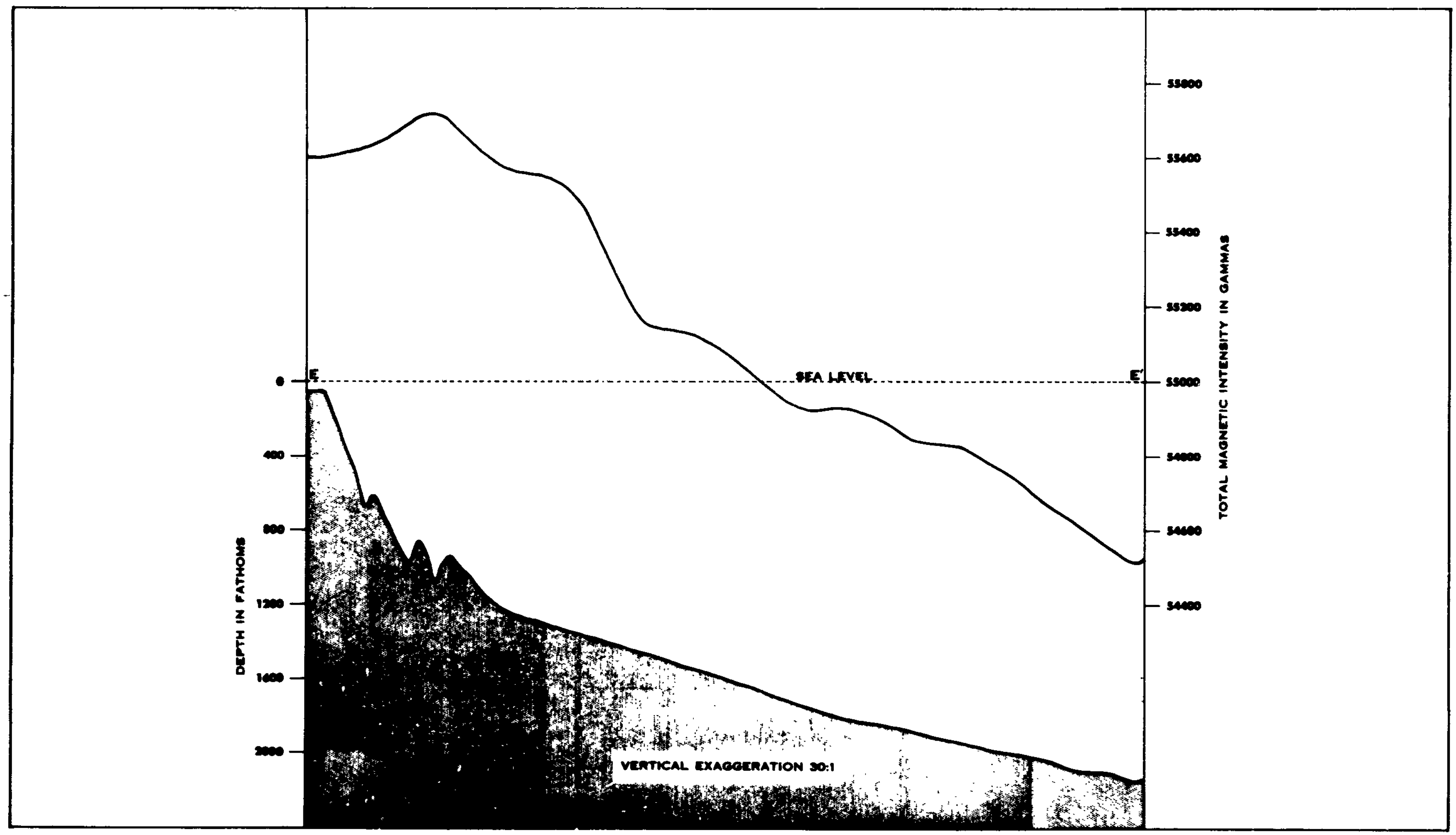

FIGURE 8

MAGNETIC AND BATHYMETRIC PROFILES E-E'

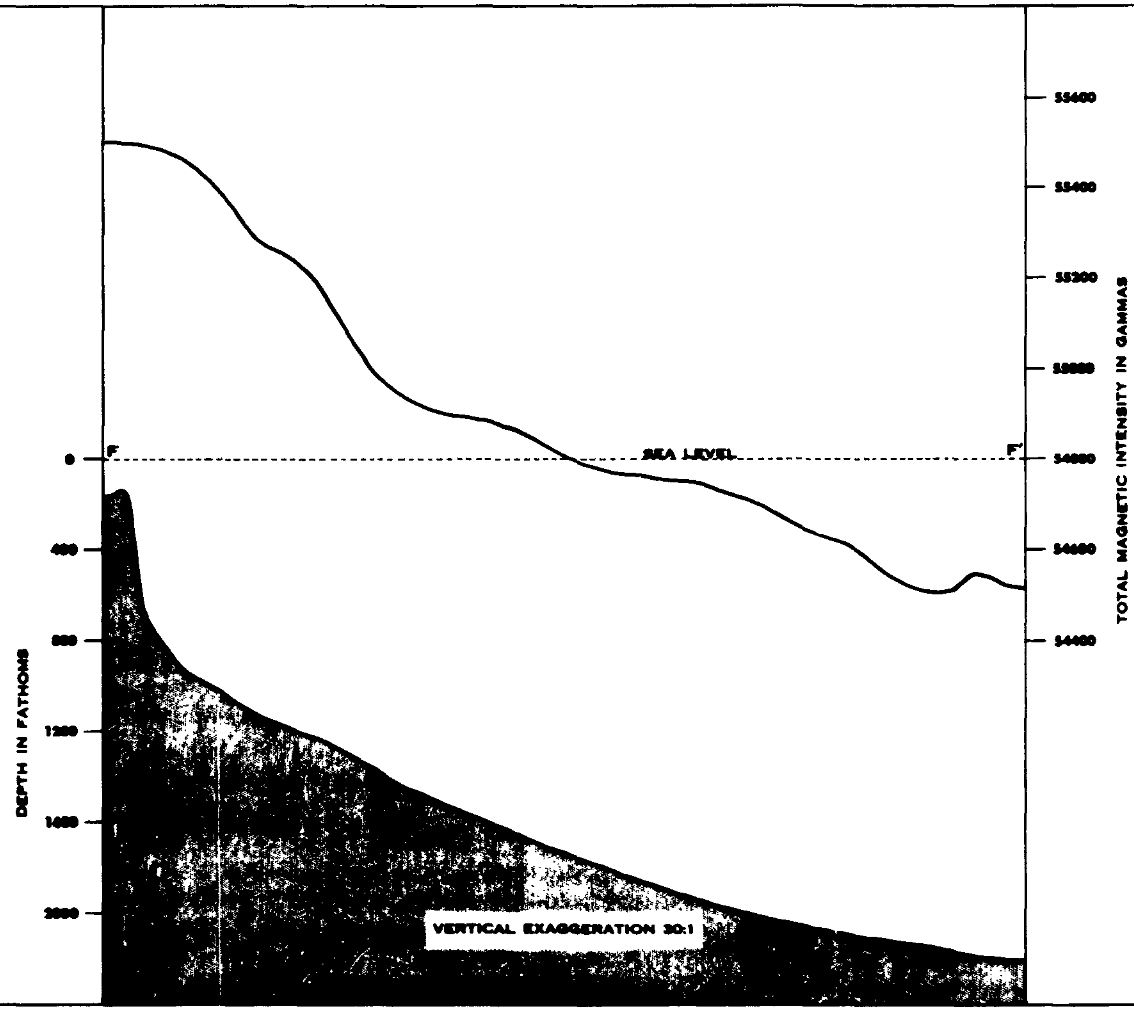

FIGURE 9

MAGNETIC AND BATHYMETRIC PROFILES F-F'

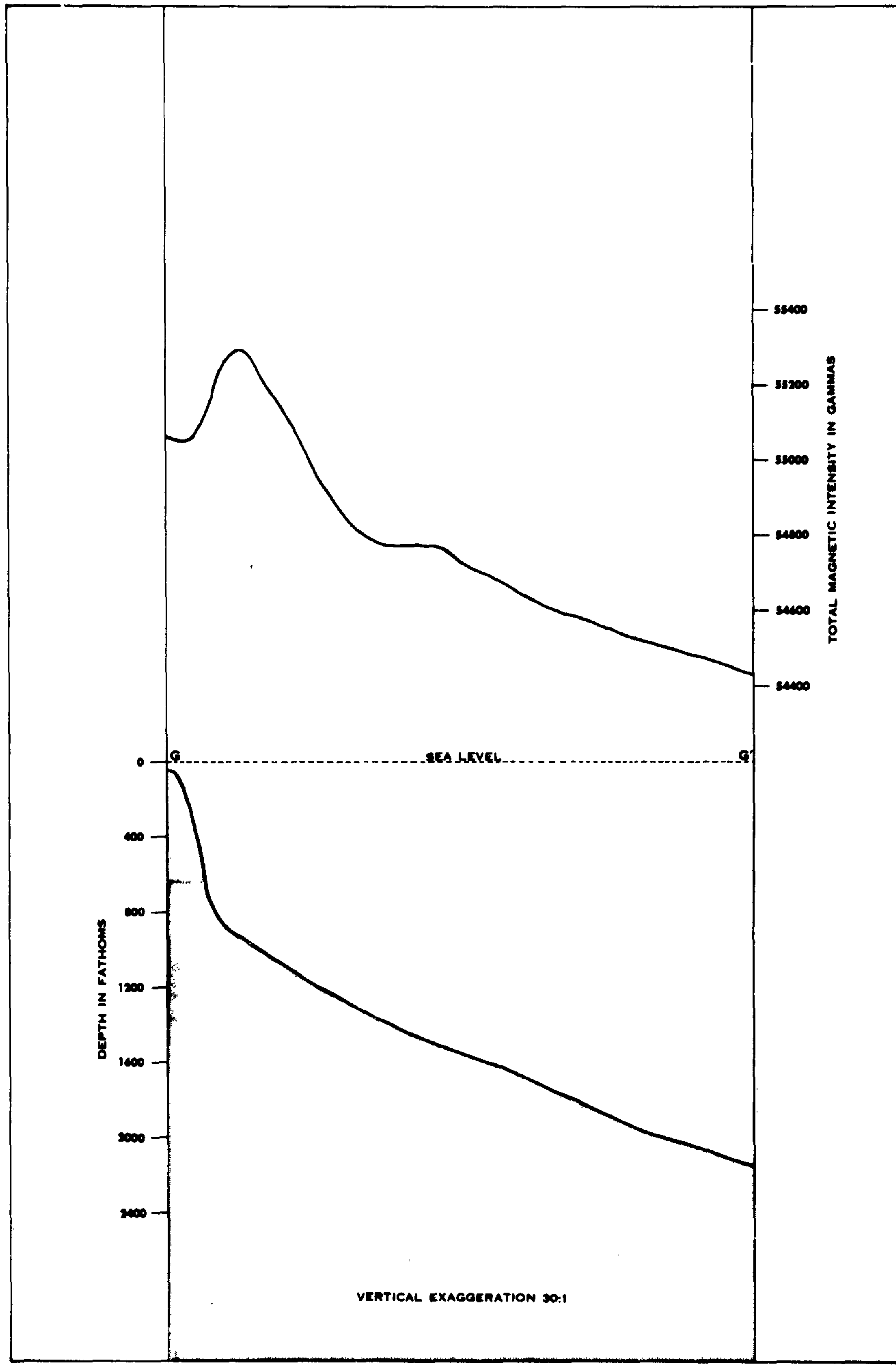

FIGURE 10

MAGNETIC AND BATHYMETRIC PROFILES G-G′

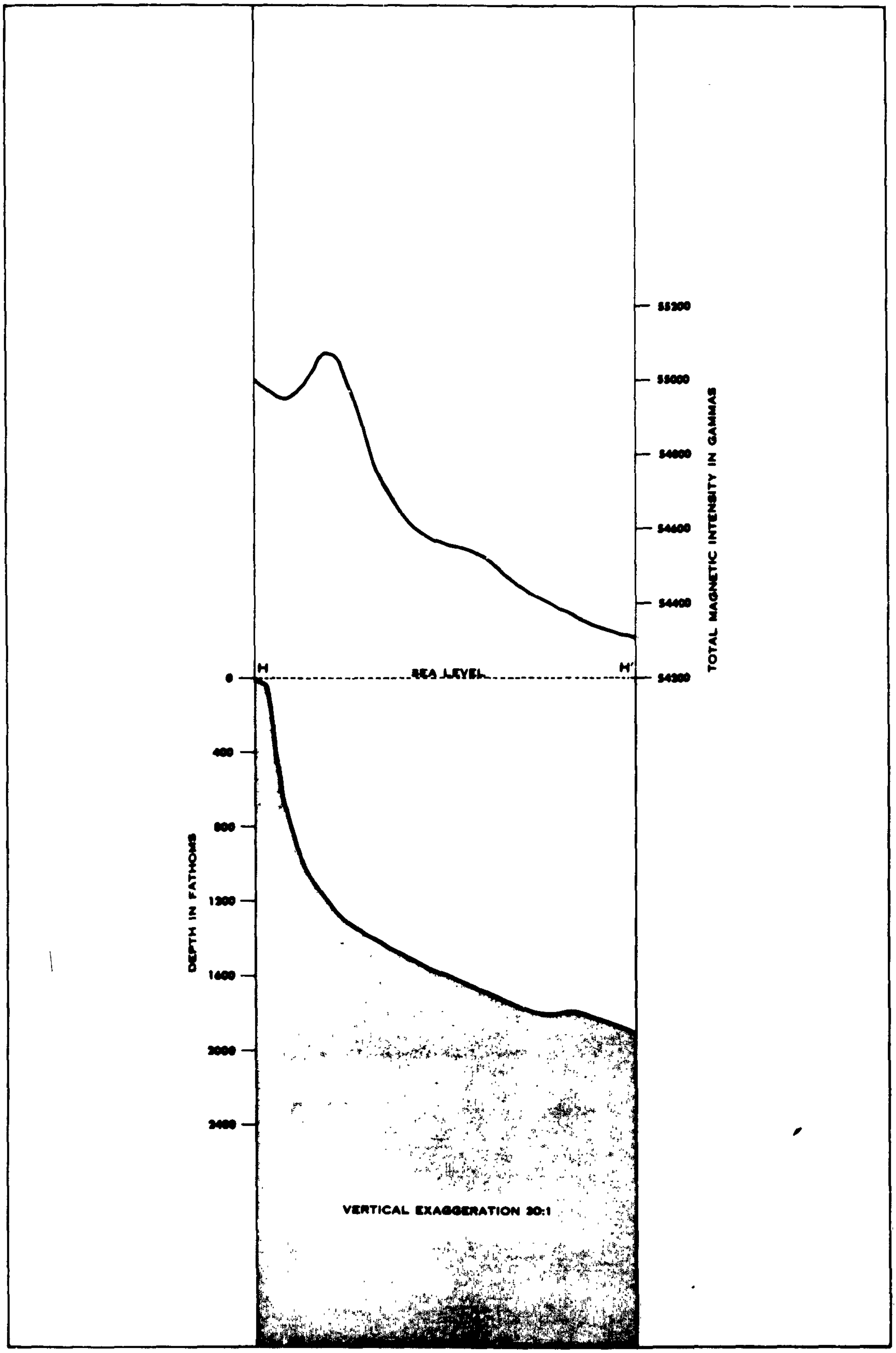

FIGURE 11

MAGNETIC AND BATHYMETRIC PROFILES H-H'

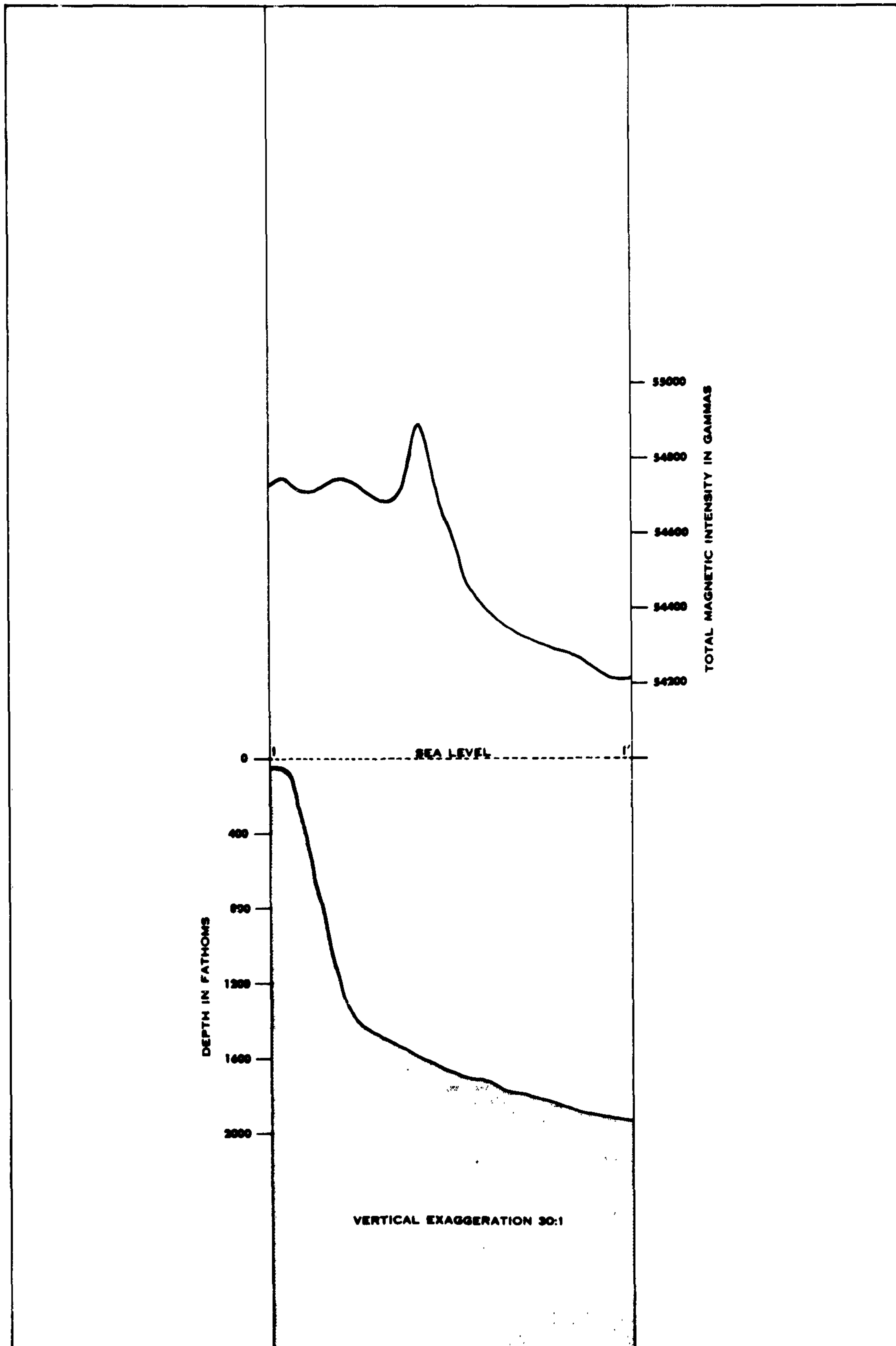

FIGURE 12

MAGNETIC AND BATHYMETRIC PROFILES I-I'

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Ewing, M., Worzel, J. L., Steenland, N. C., and Press, F., "Geophysical Investigations in the Emerged and Submerged Atlantic Coastal Plain, Part V, Woods Hole, New York, and Cape May Sections." Bulletin of the Geological Society of America, Vol. 61, No. 9 (Sept. 1950), pp. 877-892.

Keller, F., Meuschke, J. L., and Alldredge, L. R., "Aeromagnetic Surveys in the Aleutian, Marshall, and Bermuda Islands." Transactions of the American Geophysical Union, Vol. 35, No. 4 (Aug. 1954), pp. 558-572.

King, E. R., Zietz, I., and Dempsey, W. J., The Significance of a Group of Aeromagnetic Profiles Off the Eastern Coast of North America. U. S. Geological Survey, Professional Paper 424-D. 1961.

Vacquier, V., Steenland, N. C., Henderson, R. G., and Zietz, I., "Interpretation of Aeromagnetic Maps." The Geological Society of America Memoir 47. 1951.

APPENDIX

FREDERICKSBURG MAGNETOGRAMS, JULY 18-24, 1961

Table of Base-line and Scale Values
for Full-size Magnetograms

Fredericksburg Magnetic Observatory

Standard Magnetograph

PRELIMINARY VALUES

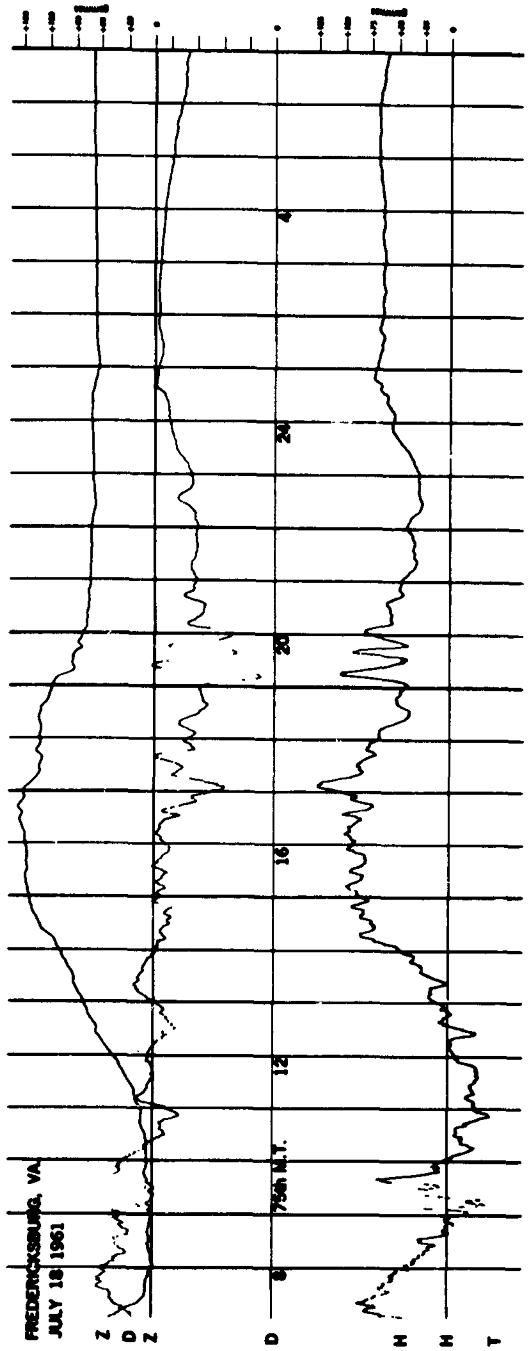
	Declination (D)		Horizontal Intensity (H)		Vertical Intensity (Z)	
Interval	Base-line value ° '	Scale value '/mm	Base-line value γ	Scale value γ/mm	Base-line value γ	Scale value γ/mm
Jul 18-24 1961	6 22	0.49	19165	2.5	53055	3.0

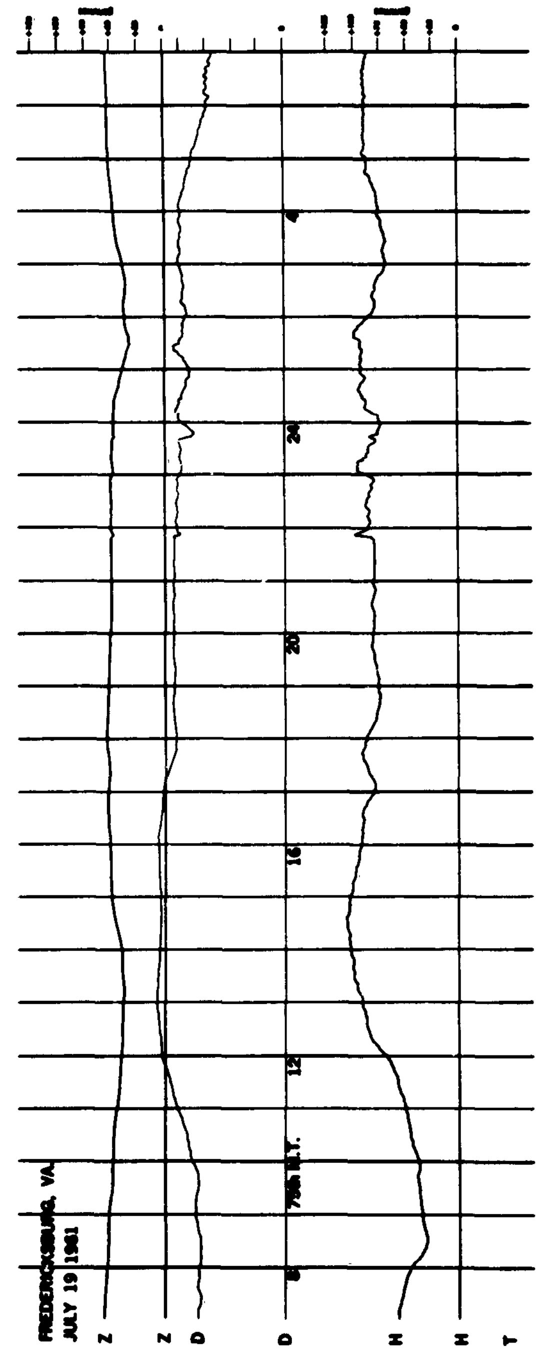
Base-line separation distance on original magnetograms Z-H 111 mm.

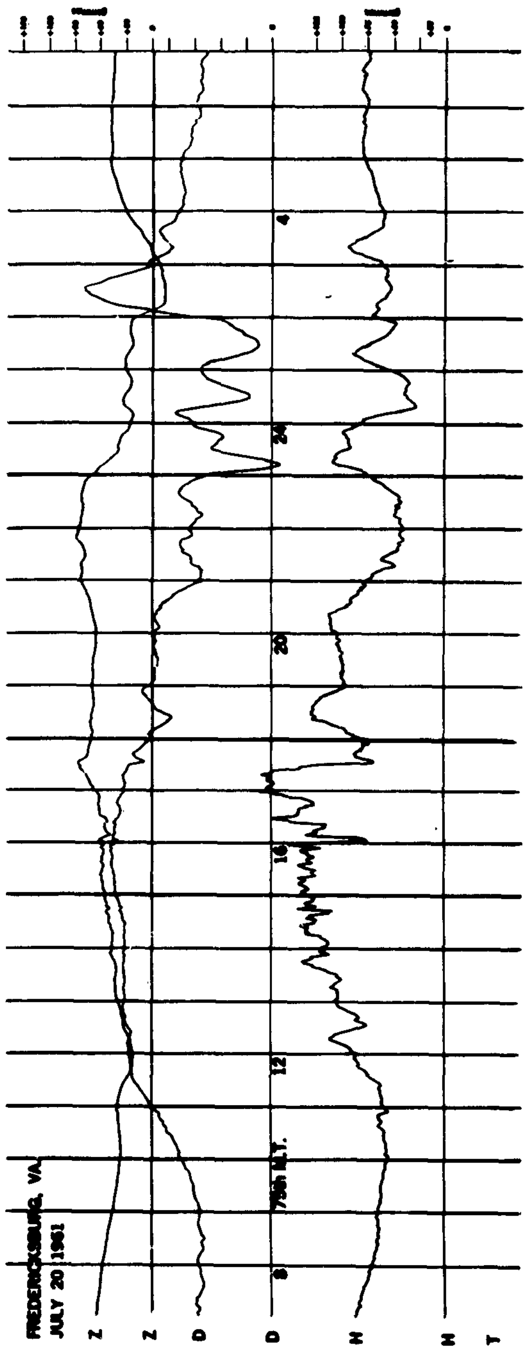
$D = B_D + S_D d_{mm}$ $H = B_H + S_H h_{mm}$ $Z = B_Z + S_Z z_{mm}$

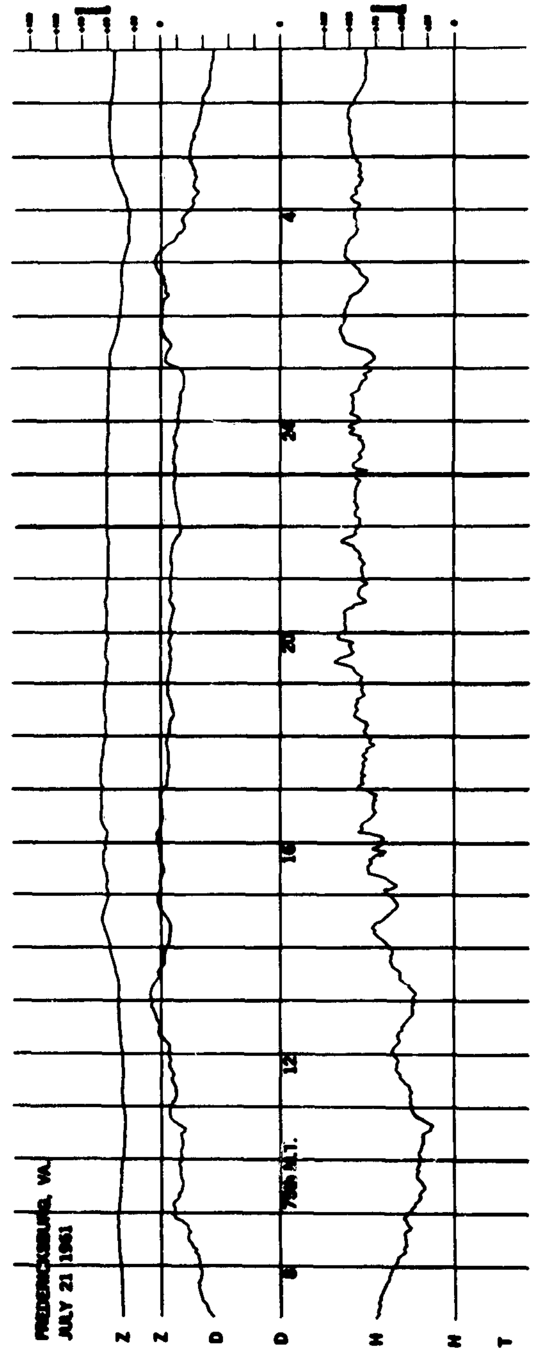
D (gamma) scale value = 2.7 γ/mm

Directions of increase on magnetograms: D (W) up: H up: Z up


FREDERICKSBURG, VA.
JULY 18 1961
75th M.T.
Z
D
Z
D
H
H
T


FREDERICKSBURG, VA.
JULY 19 1961
75th M.T.
Z
Z
D
D
H
H
T


FREDERICKSBURG, VA.
JULY 20 1961
75th M.T.
8
12
16
20
24
4
Z
Z
D
D
H
H
T


FREDERICKSBURG, VA.
JULY 21 1961
75th M.T.
8
12
16
20
24
4
Z
Z
D
D
H
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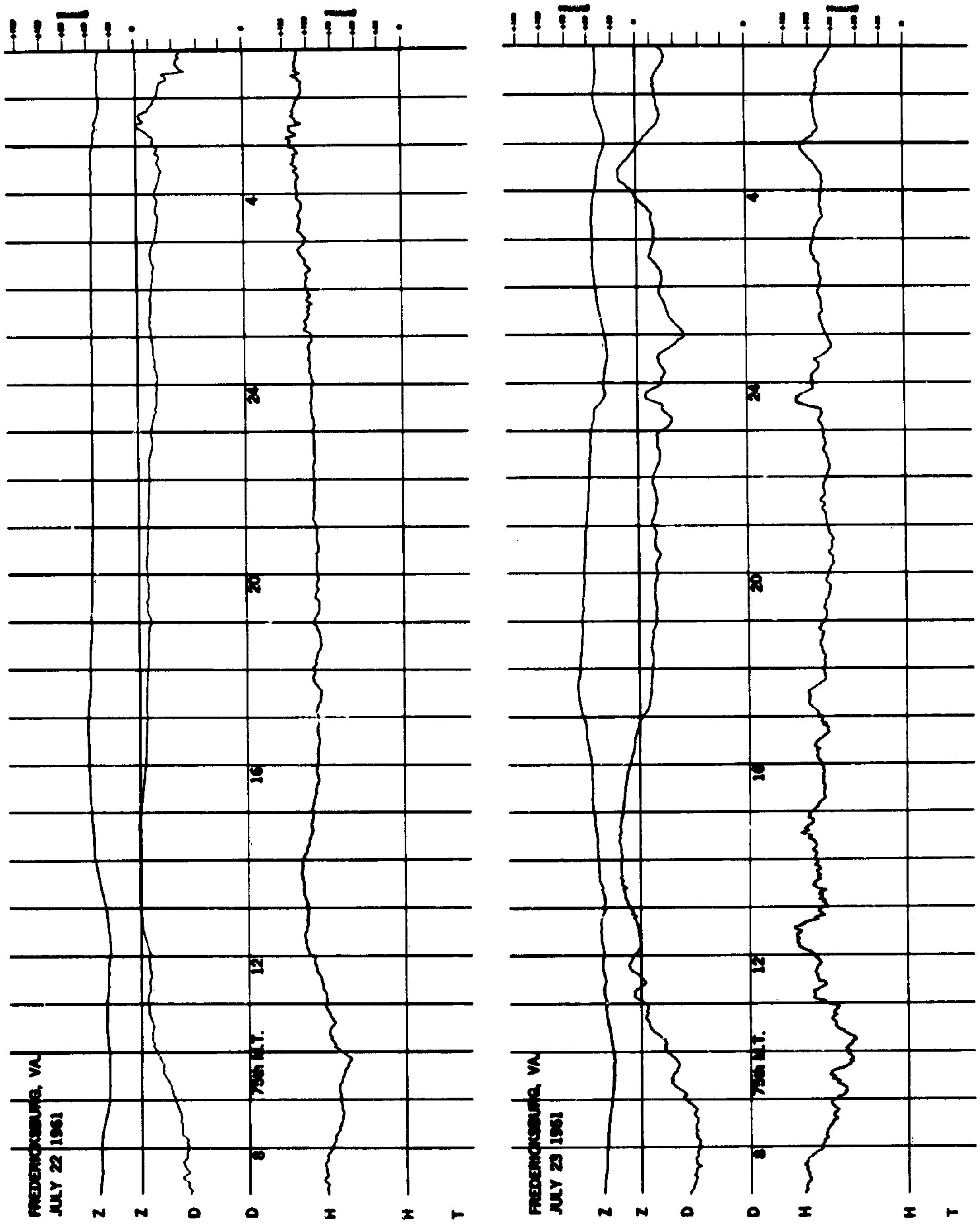
T


FREDERICKSBURG, VA.
JULY 22 1961
75th M.T.
8
12
16
20
24
4
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FREDERICKSBURG, VA.
JULY 23 1961
75th M.T.
8
12
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T

U. S. Naval Oceanographic Office.
A MARINE MAGNETIC SURVEY OFF THE EAST COAST OF THE UNITED STATES, September 1962. 29 p. including 12 figs. (TR-133).

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i. title: A Marine Magnetic Survey Off the East Coast of the United States

ii. TR-133

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