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SEA MAGNETOMETER SURVEYS OF THE GRAND BANKS OF NEWFOUNDLAND, BURGEO BANK, AND ST. PIERRE BANK

(Report and 6 figures)

Margaret E. Bower

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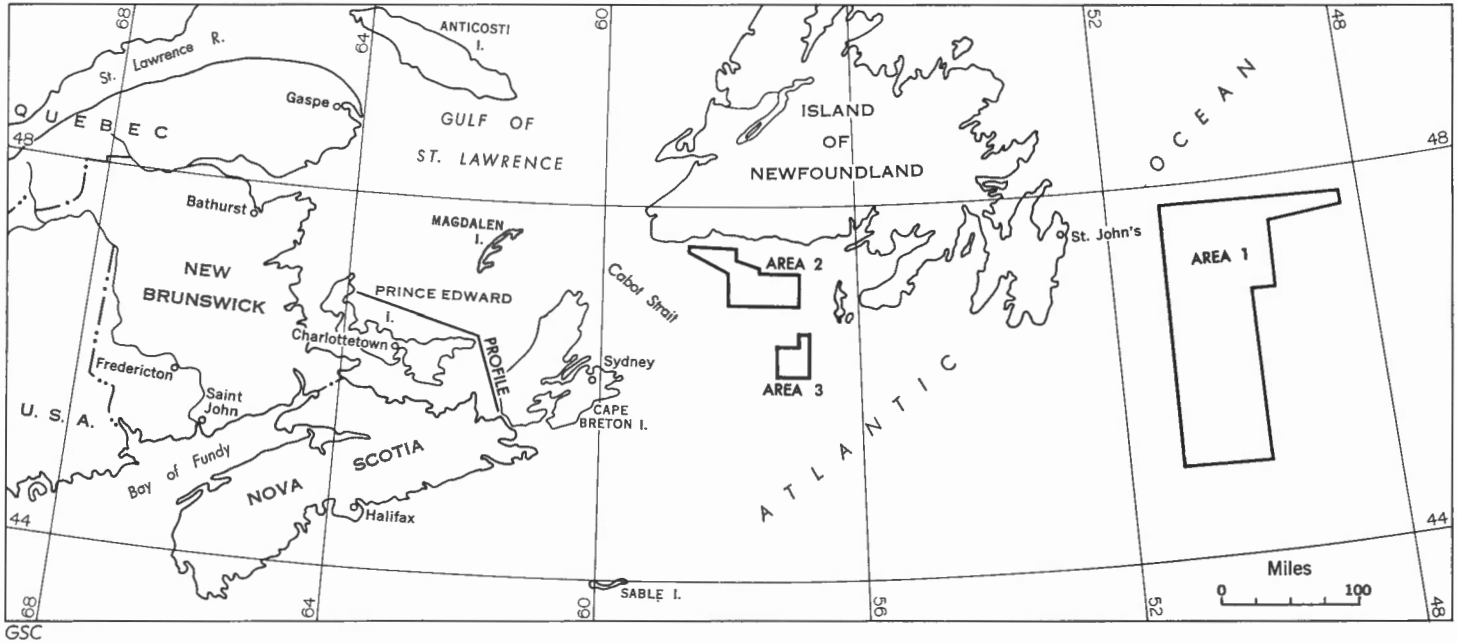

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Figure 1. Areas surveyed with sea magnetometer

SEA MAGNETOMETER SURVEYS OF THE GRAND BANKS OF NEWFOUNDLAND, BURGEO BANK, AND ST. PIERRE BANK

In 1959 the Geological Survey of Canada and the Canadian Hydrographic Service carried out the first of a series of magnetometer surveys in the coastal waters of the Maritime Provinces. A magnetometer was installed on the Canadian Hydrographic ship "Kapuskasing". This ship was making depth soundings and taking bottom samples in various areas to the south and east of Newfoundland. The magnetometer equipment was installed and operated by personnel of the Geological Survey of Canada. Areas for which magnetic data have been compiled are shown in Figure 1.

Field Work

The field work was in progress from June 18 to the end of October, 1959, although not all of this time was actually spent on the survey. Time lost—a total of 40 days—was due to the ship being in port or inoperative at sea.

The "Kapuskasing" traversed the survey areas on a series of parallel paths, in much the same manner as an aircraft doing aeromagnetic work. However, the line spacing varied greatly, ranging from less than 1/4 mile over shoals to 3 miles in deeper water. Some single profiles were also made.

The ship's position was determined by the Decca navigation system, using the established Decca chain (see Fig. 2). The Decca fixes were recorded automatically on the magnetometer tapes and the fix numbers and times were written in by the operator.

A Varian station magnetometer was used to measure the magnetic field strength. This is a proton precession magnetometer that records the reciprocal of the absolute total magnetic field. A reading was taken every 6 seconds. At the ship's normal operating speed of 10 or 11 knots the readings were made at approximately 110-foot intervals. The detecting unit was towed in a 'fish' about 400 feet behind the ship. At this distance magnetic effects from the ship are negligible. The "Kapuskasing" has a displacement of 1,085 tons. A heading effect of about 10 gammas was observed on traverses repeated in opposite directions.

Compilation

A plot of the ship's course was supplied to the Geological Survey by the Hydrographic Service staff on the ship, with corrections having already been made for known position errors. The accuracy of the Decca fixes varies with the distance of the ship from the Decca

transmitters. Near the coast the possible position error may be as little as 50 yards; out on the Grand Banks it may be greater than 1,000 yards. In addition to this known error, it has been observed that both magnetic and ionospheric storms may cause distortion of the Decca lanes and result in large position errors.

No drift corrections have been made on these magnetometer records. The precession magnetometer is assumed to have no instrumental drift, and, as no ground station was in operation, there could be no correction for diurnal drift. However the Agincourt records of the Dominion Observatory were checked for all times during which the ship was in operation, and the magnetic conditions classified as "quiet", "rough" or "magnetic storm". Sea magnetometer records taken during magnetic storms were not used; those taken during periods of some magnetic activity were used with caution. An attempt was made to put control lines on the records using the values from cross traverses, as is done in aeromagnetic work. This was unsuccessful because of inaccuracy in the positions of the traverse intersections.

The Varian magnetometer records counts-per-second of a counting frequency. These values must be converted into gammas of magnetic field strength. The conversion factor included the precession constant, the number of cycles of the precession frequency, and the number of cycles of the standard counting frequency. The problem of converting the counts to gammas was programmed for the IBM 650 computer. From these results scales were made for the range of magnetic values encountered in the areas surveyed. Intercept values were taken on the magnetometer records at 50-gamma intervals, and these values reduced to the scale of the plotted charts. Contour maps compiled from these values are shown in Figures 3 to 6.

Some difficulty was encountered in contouring the magnetic data. Most of this was due to position errors and lack of magnetic control, as discussed above. On the contoured maps, certain parts have been left blank; although these areas were surveyed it was not possible to compile the data for the following reasons:

1. Magnetic storms. There were many in 1959.
2. Traverses too far apart in magnetically active areas. In several places many small sharp anomalies were recorded—as many as three or four within a mile. The line spacing, however, was from 2 to 3 miles. To have contoured such data would have been to give a completely false picture.
3. Shallow water and shoals. Although the line spacing was as little as 1/4 mile, the relative positions of adjacent lines was rather uncertain. In addition, the lack of a continuous magnetic record could give ambiguous results, for, where the water was very shallow and the rocks somewhat magnetic, readings taken at 110-foot intervals may not give an accurate profile of the magnetic variation.

Results and Interpretation

Included in this report are four maps (Figs. 3 to 6); three are contoured maps and the fourth is a single profile. The values on the contours are in gammas, absolute total magnetic field. No correction has been made for regional gradient, which is different for each area, but in general it increases toward the west or northwest at a rate of 7 to 10 gammas per mile.

Not all of the maps are on the same scale. A larger scale is used in magnetically active areas than in less active areas.

Area 1 (Fig. 3)

This area, to the east of Newfoundland on the Grand Banks, was the largest surveyed in 1959. Most of the traverses were made in a north-south direction, but those in the northeast corner run east-west. The standard line spacing was about 2 1/2 miles, except that over shoals it was as little as 1/4 mile.

Most of the gaps in the map are due to magnetic storms that occurred during the survey. On 8 days there were disturbances of more than 200 gammas, plus numerous rapid fluctuations of small amplitude. On many other days there were small variations—some were the short-burst type, others were a gradual drift up or down over a period of several hours. Allowance had to be made for these disturbances in contouring most of the map.

The average depth of the ocean varies from 70 fathoms at the north end of the area to 30 fathoms at the south end. There are shoals between 46° 20'N and 46° 30'N, and 50° 25'W and 50° 50'W. There the depths range from 3 to 45 fathoms. Depths of greater than 100 fathoms were recorded in only a few small patches toward the north end of the area. The ocean floor is mainly sand, gravel, and shell debris; rock was found at a few widely scattered locations. The revised hydrographic charts for this area have not yet been published.

Little can be said about the geology of this area. The nearest land is the Avalon Peninsula of Newfoundland, 70 miles from the western boundary of the area. There the rocks are mainly Precambrian volcanic and sedimentary rocks with some Palaeozoic intrusions (Weeks, 1955)[1]. Aeromagnetic anomalies in eastern Newfoundland are mostly caused by the volcanic rocks.

In 1951 the Lamont Geological Observatory made a series of seismic-refraction measurements in the North Atlantic Ocean (Press and Beckmann, 1954). By measuring the velocities of the seismic waves in the different strata they could distinguish between unconsolidated sediments, semi-consolidated sediments, consolidated

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[1]Names and dates in parentheses refer to publications listed in the References.

sediments and basement—(the term 'basement' is usually defined as crystalline rock, probably of Precambrian age). One of the profiles was run at approximately 45°15'N between 50°40'W and 51°10'W, which is in the southern part of Area 1. It was found that at the west end of the profile the basement is overlain by 2,300 feet of sedimentary rock and unconsolidated sediments. At the east end of the profile these have thickened to 5,000 feet. Two other seismic profiles were made on the Grand Banks, one 140 miles to the south and the other 110 miles to the west. On the southern profile the sediments were found to be from 5,000 to 12,000 feet thick, and on the western profile, about 5,000 feet thick. These results indicate that there is a topographic 'high' in the basement near the southwest corner of Area 1. No seismic work was done farther north.

The gradient of the magnetic field can often be used to determine the distance from the plane of observation to the rock causing the anomaly. There are various methods of doing this, but the one used here is the Peters' "half-slope" formula (Peters, 1949). Although depths calculated on the sea magnetometer data are not very accurate, they should at least give the correct order of magnitude of the depths to the source rocks. For convenience, the source of anomalies will be described as "shallow" (less than 1,000 feet), "intermediate", or "deep"(greater than 5,000 feet). This classification is quite arbitrary and is intended to refer only to the areas included in this report. The rock causing an anomaly is generally within the crystalline basement, but may be an intrusion or lava flow above the basement.

On Figure 3, three distinctly different kinds of magnetic patterns are depicted. North of 47° the anomalies are of the type that indicate a deep source. The shallowest depth calculated was 7,500 feet, and in most of the northern part the magnetic gradients are so small that no calculation could be made. There is no indication of near-surface magnetic rocks. Therefore it seems reasonable to conclude that the anomalies are due entirely to the basement rock, and that the basement is overlain by at least 7,000 feet of sedimentary material.

In the southern part of Area 1 the anomalies have somewhat shallower sources; their depths could be described as intermediate. Calculations give depths of 2,100 to 2,700 feet, which are in good agreement with the depths to basement found in the seismic surveys.

A third type of magnetic pattern is that which occurs over and around the shoals. As previously explained, the data from these could not be contoured. However, to illustrate the kind of anomalies that occur, four profiles are shown on Figure 3, together with profiles of the ocean bottom made from depth soundings.

Profiles 1 and 2 are of adjacent traverses; they are near the shoals but not over them. The small anomalies at the south end of these profiles have a very shallow source, indeed the depth calculated for some was only 400 feet. Furthermore, the rock causing any particular anomaly must have a very limited extent, as, from one profile to the next, there is no continuity in either the positions of the

anomaly peaks or of the magnetic intensities. In contrast, the larger anomaly immediately to the north gives a calculated depth of 4,000 feet.

Profiles 3 and 4 are across the Eastern Shoals. Calculations show that some of the magnetic material is within 250 feet of the surface of the water, and anything much closer than this would not be recorded as an anomaly on the magnetometer record. Since the maximum depth of the water in this vicinity is about 270 feet, the anomalies must be caused by the rocks in the shoals. No direct correlation can, however, be made between the magnetic profile and the depth to the rocks. Profile 3 shows several anomalies and a flat ocean bottom, whereas Profile 4 shows that the rocks rise almost to the surface of the water but cause practically no magnetic variation. There are three possible reasons for this lack of magnetic expression:

1. Not all the rocks are magnetic.

2. All may be magnetic, but some may be flat-lying so that no anomalous magnetic field is produced.

3. As the readings were taken more than 100 feet apart, small anomalies present may not have been recorded. Judging by the appearance of the magnetometer record this is, however, improbable.

The first of these possibilities seems the most reasonable. If the shoals were the surface expression of a large mass of magnetic rock there would be an increase in the magnetic intensity over the whole area. This is not the case.

Another interesting feature is the presence of negative anomalies whose values are 300 to 400 gammas lower than the average magnetic intensity. These may be caused by remanent magnetization in a direction different from that of the present earth's field.

Other than what may be inferred from geophysical evidence, nothing is known about the rocks in Area 1. Although the hydrographic charts show the presence of rock in a few places, no samples were kept or records made to indicate the kind of rock present. The geophysical evidence indicates that:

1. At the south end of Area 1 the basement rock is less than 2,500 feet below sea-level. From there it slopes in a northerly direction to more than 7,500 feet below sea-level.

2. The magnetic anomalies in the vicinity of the shoals are not associated with the basement rocks. They are shallow, local features and are probably of volcanic or intrusive origin.

Area 2 (Fig. 4)

Area 2 covers the Burgeo Bank and extends north almost to the southern coast of Newfoundland. Traverses were made

in a north-south direction and the line spacing ranged from 1/2 mile to 1 1/2 miles.

Magnetic storms were not a serious problem on this project, occurring on only 2 days during the survey. The relatively quiet magnetic conditions and the proximity of the Decca transmitters greatly decreased the probability of large position errors. Consequently, this map-sheet was much simpler to compile than Figure 3, and the results should be more accurate.

In the vicinity of the Burgeo Bank the average depth of the water is about 40 fathoms, with a minimum of 28 fathoms. Beyond the bank the depth increases to more than 100 fathoms in all directions and to more than 200 fathoms in the southwest. There are no shoals in the area. Not many bottom samples were taken, but those recovered from the Burgeo Bank were mainly sand, gravel, and shell fragments, and occasionally rock.

Detailed geological maps are available for most of the coastal regions north of Area 2 (Cooper, 1954; Riley, 1959). Metamorphosed sedimentary and volcanic rocks are present, as are many intrusive rocks, mainly of Palaeozoic age. No aeromagnetic work has been done in this area, but the volcanic and intrusive rocks are the most likely to cause magnetic anomalies. No seismic work has been done in the immediate area, and the nearest profile made by the Lamont Observatory is more than 100 miles to the south. There the depth to basement rock was found to be from 8,000 to 10,000 feet.

Except for those at the extreme northern boundary, the magnetic anomalies over this area are from deep or intermediate sources. South of 47° 15'N the magnetic gradients are so small that depths cannot be calculated. Three anomalies at about 47° 20'N lat. give depths of 4,200 to 5,900 feet below sea-level; one at 47° 28'N gives a 3,500-foot depth.

North of 47° 30'N the source of the anomalies rapidly becomes shallower, with depths of 1,000 feet calculated close to the northern edge of the area. The magnetic pattern also indicates that the line spacing there is greater than the wavelengths of the anomalies, so that this part of the map is probably not very accurate. As the traverses were made in a north-south direction, the ship sailed a bit north of the area boundary on turns at the north end. The magnetometer was running continuously and it was noted that on the turns many small, sharp anomalies were recorded, similar to those near the shoals at Area 1. These do not occur on the turns at the south end of the lines, so the anomalies were not caused by the 'fish' coming closer to the ship on the turns. At the north end of the lines the ship was probably within 5 miles of the shore and the water there is less than 50 fathoms deep, with many shoals.

The rocks along the southern coast of Newfoundland are crystalline and therefore considered to be part of the basement. Figure 4 indicates that this type of rock is at or near the surface for at least 5 miles out to the sea. Beyond this the basement rock dips down rather steeply, and 35 miless offshore it is at least 6,000 feet

below sea-level, possibly much more. Where the basement is deep there is no evidence of near-surface magnetic material.

Area 3 (Fig. 5)

Area 3 is a composite of two of the smaller areas surveyed in 1959. It is located on the St. Pierre Bank about 30 miles south of Area 2. The traverse direction and line spacing are the same as for Area 2.

For this area there is little data with which to work, but the wide spacing of the contours does suggest that the basement is deep. As no complete anomalies lie within the area, depth calculations are not very reliable. Nonetheless, the anomaly at the western edge of the area seems to lie at a depth of at least 8,000 feet. An interesting feature of this anomaly is the direction in which it trends. The small area of steeper gradient at the northeast corner of Figure 5 seems to represent a continuation of the anomaly. About 5 miles farther east a broad anomaly was recorded during a ferry trip out of St. Pierre. The peak of this anomaly was 54,920 gammas, which is a bit higher than any value over Area 3. If these are actually peaks on a single continuous anomaly, they are almost directly in line with St. Pierre Island (see Fig. 2). This island consists almost entirely of volcanic rock in which some iron occurrences have been found (De la Rüe, 1951). At the north end of the island they produce a magnetic effect strong enough to be observed by navigators on passing ships. Still farther northeast are the volcanic rocks of the Burin Peninsula (Weeks, 1955). No aeromagnetic work has been donethere, but a survey was made of a similar rock type in the Conception Bay area (McCartney, 1954). There the volcanic rocks of the Harbour Main Group gave anomalies of up to 800 gammas.

It is therefore possible that the anomalies over Area 3 are caused by a continuation of the volcanic rocks of St. Pierre, which in turn may be related to those of the Burin Peninsula. However, more field work is necessary before any definite conclusion can be reached.

Profile (Fig. 6)

This profile was recorded during a ferry trip from Alberton, Prince Edward Island, to Canso, Nova Scotia. No other sea magnetometer work was done there, but the whole area has been flown with the airborne magnetometer. The Decca positions indicating the ship's course are shown on the map. The base map used was Hydrographic Chart No. 1651 which has a scale of about 1 inch to 11.4 miles.

Four profiles are shown on Figure 6: the sea magnetometer data, the aeromagnetic data, diurnal variation, and depth of water. The aeromagnetic profile was made from published Geophysics Papers (Geol. Surv., Canada). The diurnal variation was obtained from the Agincourt records of the Dominion Observatory.

The vertical component only is shown, but at this latitude it is about 85 per cent of the total field. A more serious problem is the great distance—more than 800 miles—between the Agincourt station and the survey area. No other ground station was, however, closer, and at least the main features of the diurnal variation should be similar at the two locations.

As would be expected the sea magnetometer and aeromagnetic profiles are fairly similar in appearance. In this area the basement is overlain by several thousand feet of sediment so that the difference of 1,000 feet in the height of the surveys should cause little difference in the magnetic effects. On the sea magnetometer profile the anomalies do, however, tend to have slightly steeper sides. On the sea magnetometer profile the difference between the highest and lowest points is 920 gammas; on the aeromagnetic profile it is 1,140 gammas. This is unusual, because the aeromagnetic profile should normally show the smaller variation. Most of this discrepancy seems to be due to diurnal variation. For example, the anomaly peak 'A' on the sea magnetometer profile appears only as a shoulder on the aeromagnetic profile. This may be caused by the difference in elevations of the two surveys or by the diurnal variation, but is probably a combination of the two. The same is true of the small anomalies near the right end of the profiles.

A comparison of these profiles indicates the necessity of having a ground-station control as close as possible to the area being surveyed to avoid the possibility of false anomalies appearing in the magnetic maps. Although a distant station may serve to detect large magnetic disturbances, it cannot be used to correct the sea magnetometer records for diurnal variation.

Conclusions

The compilation of the sea magnetometer data was greatly hampered by the uncertainty of the ship's position and the lack of any means of magnetic control. The maps must be used with some caution, as they do not have the relatively high degree of accuracy of aeromagnetic maps. However the data is useful in areas such as these, where practically no previous work has been done. The depth to basement can be estimated and the presence of intrusive rocks in the sediments can be detected.

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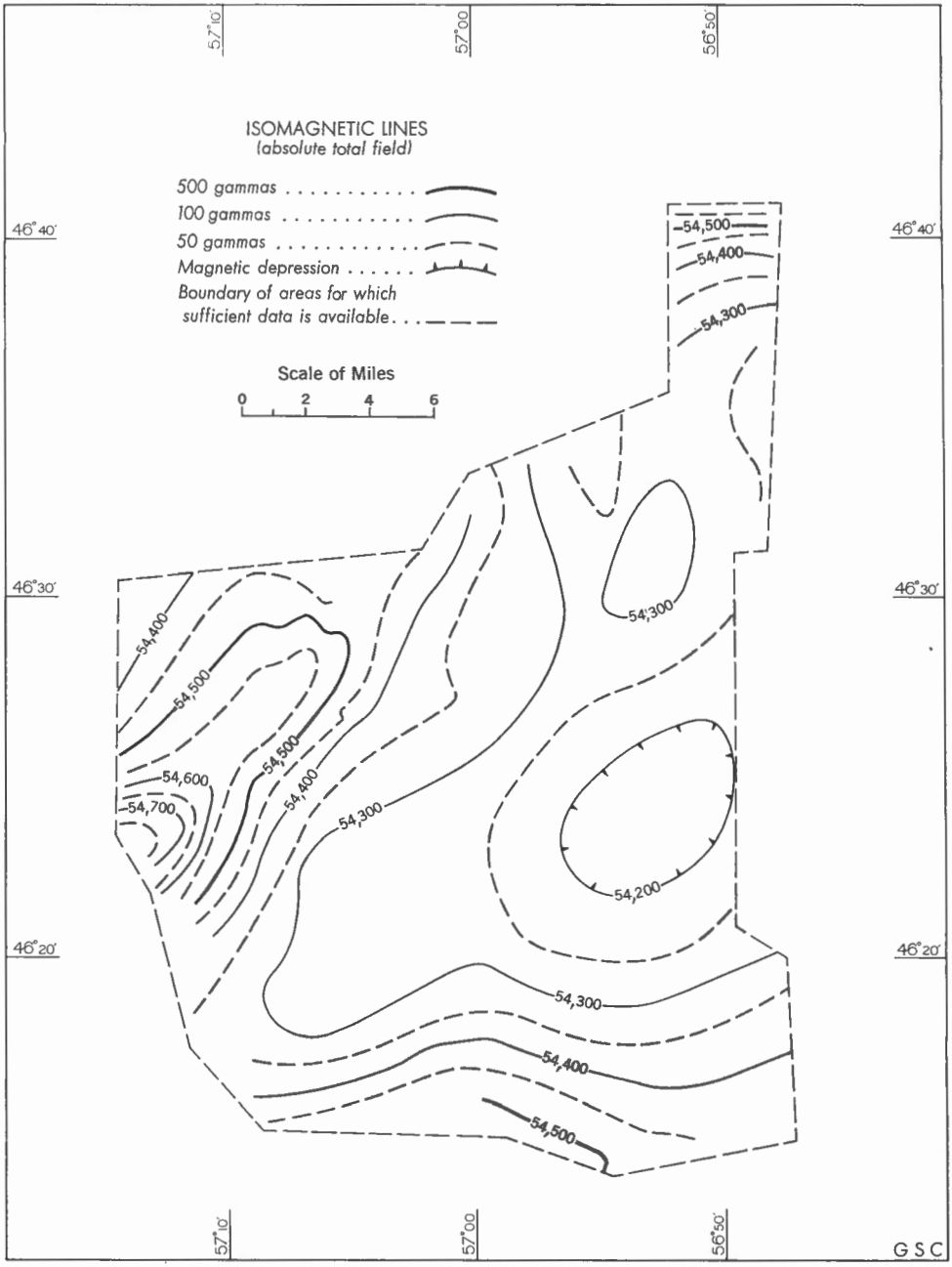

Figure 5. Sea magnetometer survey of St. Pierre Bank (Area 3)

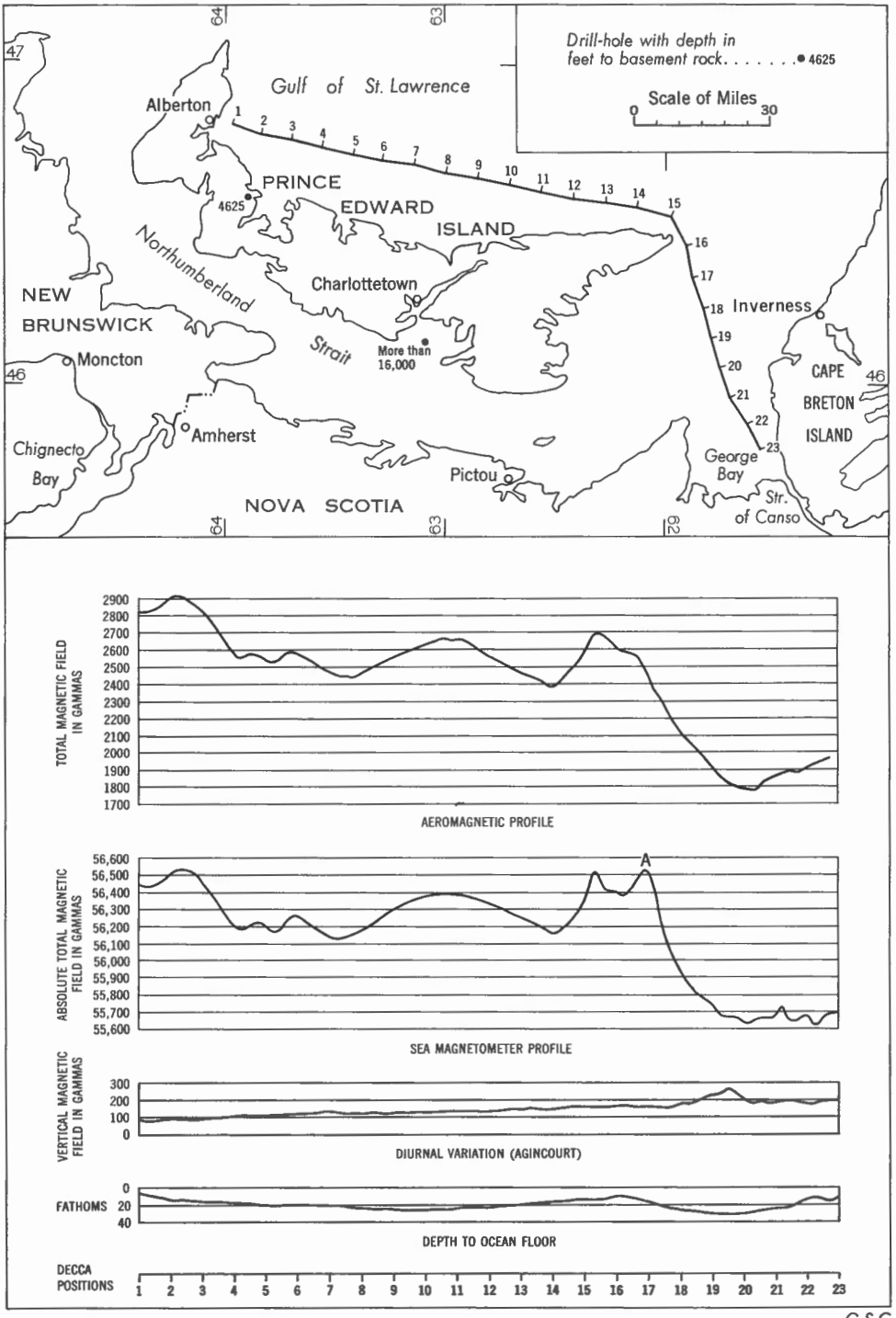

Figure 6. Profile from sea magnetometer survey from Alberton, Prince Edward Island to Strait of Canso, Nova Scotia

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