gravity map series of the
earth physics branch

RESULTS OF UNDERWATER AND SURFACE REGIONAL GRAVITY SURVEYS OFF THE COAST OF LABRADOR, 1972

with maps: 156—Hamilton Inlet (Bouguer)
156—Hamilton Inlet (Free-air)

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DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA 1974

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Contents

Abstract – A geophysical survey was completed in the Labrador Sea off Hamilton Inlet in 1972 using two surface gravimeters and one underwater gravimeter. The two surface meters were operated simultaneously aboard *CSS Hudson*. The underwater meter was operated from *CFAV Sackville* in an area which overlapped the surface meter measurements. The observations from the three gravimeters were adjusted by the method of least squares and the composite data were completed in the form of free-air and Bouguer anomaly maps at a scale of 1:1,000,000. The accuracy of the computed anomalies was estimated at between one and two mgal ($\pm 1\sigma$) depending on the number of instruments which were observed at the point.

Résumé – En 1972, des levés géophysiques étaient effectués dans la mer du Labrador, au large de l'inlet Hamilton, à l'aide de deux gravimètres de surface et d'un gravimètre sous-marin. Les deux gravimètres de surface ont servi simultanément aux levés depuis le navire *Hudson,* et le gravimètre sous-marin du *Sackville* a servi au recoupement dans une zone des mesures gravimétriques de surface. Les observations obtenues des trois gravimètres ont été coordonnées par la méthode des moindres carrés, et les données combinées ont été mises sous forme de cartes des anomalies de Bouguer et des anomalies à l'air libre, à une échelle de 1:1,000,000. Les auteurs ont estimé la précision du calcul des anomalies entre un et deux milligals ($\pm 1\sigma$), selon le nombre d'instruments utilisés à ce point.

Introduction

A geophysical survey off the coast of Labrador was conducted in 1972 in the area shown in Figure 1. Although gravity, seismic, magnetic and bathymetric data were collected simultaneously, this paper deals exclusively with the gravity data and to the extent that they are related to gravity the bathymetric data. Seismic and magnetic data have been published elsewhere (Srivastava *et al.*, 1973; van der Linden *et al.*, 1973).

Surface gravity measurements were obtained aboard *CSS Hudson*; a 90.5 m, 4.4Gg (4,800 ton) ship operated by the Department of the Environment. Scientists from the Earth Physics Branch, Atlantic Geoscience Centre, and the Atlantic Oceanographic Laboratory collaborated in the collection and reduction of these data.

The offshore data presented herein were collected with three different gravimetry systems. Two surface gravimeters, one LaCoste and Romberg (Model S-39) and one Graf-Askania (Model GSS-2) were operated simultaneously aboard the *Hudson.* In addition, underwater measurements were observed from a second ship *(CFAV Sackville)* within the area to provide independent control for the surface data. On the accompanying maps, underwater measurements are indicated by dots and surface data as continuous tracks. The actual data that were contoured however were obtained by a least squares adjustment three data sets.

The Graf-Askania meter was located in the gravity laboratory which is situated as close as possible to the ship's centre of motion. This installation is part of the permanent equipment normally operated aboard the *Hudson.* The LaCoste and Romberg meter was accommodated in the geochemistry laboratory located on the centreline of the ship and approximately 35 m aft of the Graf-Askania. Because of its less advantageous location S-39 was subjected to greater accelerations.

Weather conditions were generally poor throughout the survey which took place in September and October. Swell heights reached a maximum of 8 m with a 5 m sea. Gravity data could not be collected for a large portion of day 283 (track 13–Figure 1), as the stable platform for S-39 frequently hit its stops (±30°) during violent rolls. On one other occasion from 1630 hr on day 298 to 1350 hr on day 299 (part of line 21, Figure 1) severe rolling conditions led to excessive cross-coupling errors with S-39 when the cross-coupling correction exceeded the dynamic range of the analogue cross-coupling computer. In this case the excessive cross-coupling occurs because S-39 is operated on a three-axis stable platform which orients the gravimeter beam towards the north regardless of the ship's heading. For east or west lines the beam axis lies generally athwart ships which tends to maximize the magnitude of the cross-coupling error. The GSS-2 which operates on a two axis platform was not so affected because its orientation is fixed along the ship's thrust line.

The cruise was primarily intended as a mapping mission with equal priority for the measurement of all parameters. Consequently neither the ship's course nor speed were altered to compensate for inclement weather conditions as long as overall productivity was judged satisfactory. This resulted in the loss of a small amount of gravity data as mentioned above and generally reduced accuracy in the gravity observations. On the other hand the rigid survey scheme which was followed resulted in a uniform grid pattern of ship tracks which facilitated data analysis and presentation. A slightly more flexible approach could allow speed and course alterations that would improve gravimeter performance without significantly altering the geometric structure of the survey.

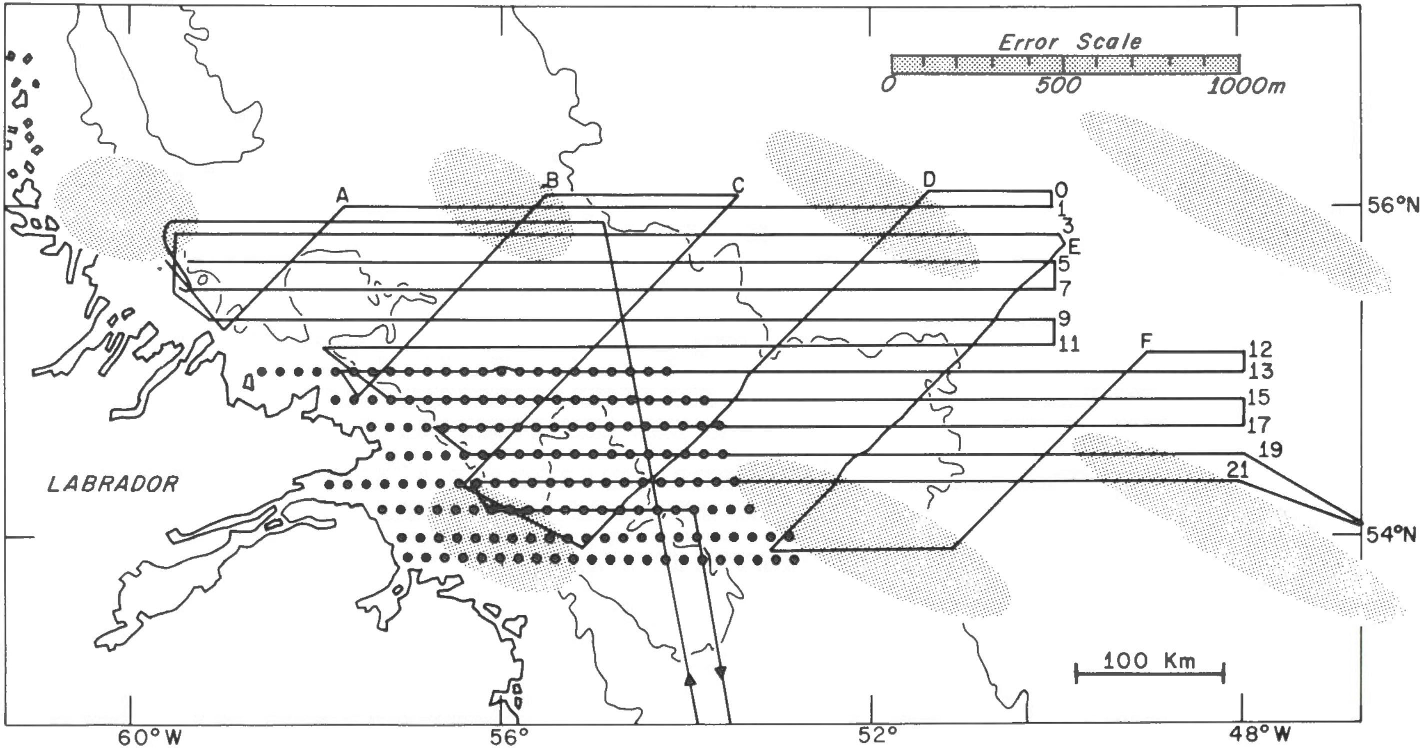

Figure 1. Plot of ship's track with navigational error ellipses superimposed. Underwater measurements are represented by dots. Also shown are the 200 and 3,000 m depth contours after map 813 of the Hydrographic Map Service.

Navigation

Surface measurements (*CSS Hudson*)

Primary positioning during survey operations was accomplished through a combination of satellite navigation and Loran-C in the two or three range mode. In the latter system, ranging information was provided by transmissions originating at: Cape Race, Newfoundland; Angissoq, Greenland and Sandur, Iceland. In practice, satellite fixes taken over periods of several hours yielded land-path and clock drift corrections which could be applied to Loran-C readings. In turn, the Loran-C data provided accurate course and speed information for satellite computations and provided intermediate positions between satellite fixes.

The clock drift correction was found to be approximately 0.30 μs per day, which was equivalent to an increase of all ranges of about 90 m per day. In addition to the clock drift correction, a correction was applied for the additional phase lag delay due to overland path from the Cape Race Station. This correction varied from about 2.5 μs (750 m) near the coast to about 0.5 μs (150 m) at the eastern end of the survey area. These corrections were determined by comparisons with satellite navigation, two buoy checks and a number of baseline crossings. As a result of these checks the accuracy in range was estimated at between 100 and 200 m. The resulting positioning accuracy is therefore estimated to be about 175 m in latitude and between 350 and 500 m in longitude depending on location. Figure 1 shows error ellipses at various points throughout the survey area based on a ranging accuracy of 175 m.

Clock drift and phase lag errors changed very slowly so that over the short term the relative accuracy of Loran-C is affected only by random fluctuation of the signals. These fluctuations depend on a number of factors such as the distance to the transmitter and its power output, atmospheric conditions and the damping characteristics of the receiver, but generally these appear to be less than about .15 to .20 μs equivalent to a ranging error of 45 m to 60 m. At 5.1 m/s (10 knots) with a logging interval of 10 min the error in course and speed introduced by this noise would be less than 1° and 0.1 m/s (0.2 knot) respectively.

At the outer ends of the survey lines the ship crossed the baseline between the master station at Angissoq, Greenland and Slave "Z" at Cape Race, Newfoundland. In order to give continuous positions a third station, Slave "W" at Sandur, Iceland is included in the fix computation. However, since the angle of cut between the Angissoq–Cape Race baseline and Sandur range circles is only about 15° there is a deterioration in the accuracy of longitude in this vicinity.

Underwater measurements (*CFA V Sackville*)

Positioning for *CFA V Sackville* was by Loran-C alone. Control to provide clock drift corrections and calibration was obtained while the ship was stationary in port. Frequent updates were available by this technique as the ship returned to port for fuel at intervals of approximately two weeks. The error ellipses as shown in Figure 1 are also representative of the positioning errors for the underwater measurements.

Data acquisition

Bathymetry

Measurements from CSS Hudson

Depth measurements were made by means of the Bedford Institute of Oceanography (Gifft-Alpine) depth sounding system. Depths were corrected according to Matthews' tables for zone 4, (Matthews, 1939) and depths less than 183 m (100 fathoms) were reduced by 1.8 m (1 fathom).

Precision of the surface bathymetric data is shown in Figure 2 in the form of a histogram of crossover differences.

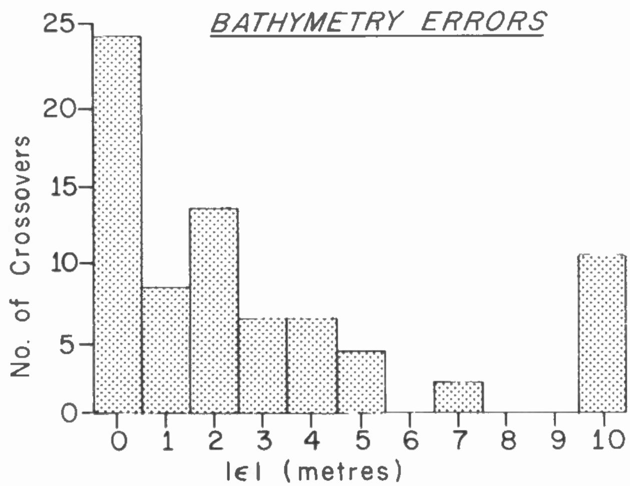

Figure 2. Histogram of absolute value of bathymetry crossover differences.

Measurements from CFAV Sackville

In addition to soundings made from the surface aboard the *Hudson* approximately 246 point measurements were obtained aboard *Sackville* while making underwater gravity measurements. These depths were obtained from a Gifft-Alpine depth sounder similar to the one used on *Hudson*. From prior experience the accuracy in these depths is estimated at ±5 m, which includes such systematic effects as errors in determining the velocity of sound.

General discussion of bathymetric data

Contours of a composite plot of depths measured from both vessels are shown in Figures 8 and 9. No data from other sources were incorporated into these diagrams as they are intended as a display of the depth data used in the computation of the Bouguer anomaly thus providing a direct comparison between the simultaneous gravity and bathymetric measurements. A new bathymetry chart of this area, incorporating this and additional data is being prepared by the Canadian Hydrographic Service for publication in the near future.

Gravimetry

LaCoste and Romberg gravimeter

In this installation meter S-39 was equipped with an on-line mini-computer to provide real time filtering of the data. An additional off-line mini-computer was employed to generate the Eötvös correction from 5 minute navigation samples and to compute free-air gravity anomalies.

Data were recorded by the data acquisition system at 10 second intervals on 7 track magnetic tape. The recorded data consisted of: raw gravimeter parameters, (spring tension, beam position, cross-coupling, etc.); the gyro rates and accelerometer outputs from the stable platform; and the computed values of gravity and cross-coupling correction. The on-line computer calculated a final gravity value (exclusive of relative calibration and Eötvös correction) which was filtered by a 60 point convolution filter supplied by the manufacturer. This filter has a frequency response as shown by curve A in Figure 3.

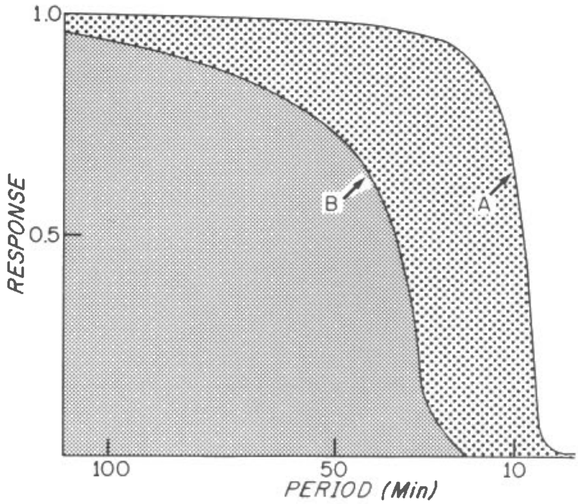

Figure 3. Frequency response of A) 60 point convolution filter, B) 21 point running average.

Random errors in navigation of 1° in heading and 0.1 m/s (0.2 knot) in speed lead to errors in the calculated Eötvös correction of approximately 1 mgal* at the latitude of the survey. It might be expected that the effect of this random error could be reduced by further smoothing the navigation data. This was tested by applying a variety of smoothing functions to the navigation data and comparing the resulting reduced gravity values with values along two signature lines established in the survey area with the underwater meter. Simple smoothing by taking running averages of 2, 4 and 14 successive five minute navigation samples was tried. No significant change in the error distribution was observed with any of these filters. We are therefore led to believe that random errors in the Eötvös correction due to navigation errors are insignificant for this case.

The effect of filtering gravity data was tested in a slightly different manner. Simulated data along a typical profile were digitized in a manner equivalent to 5 min samples gathered by a ship underway at 5.1 m/s (10 knots). These simulated data were then

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*1 mgal = 10^{-5} m/sec^2

compared with the results of filtering them with the 60 point convolution filter. Slight distortion up to about 0.5 mgal in magnitude was observed at inflection points in the profile. Further smoothing by applying a simple running average of 21 consecutive 1 min gravity samples showed distortions as large as 2 mgal at inflection points (Figure 4).

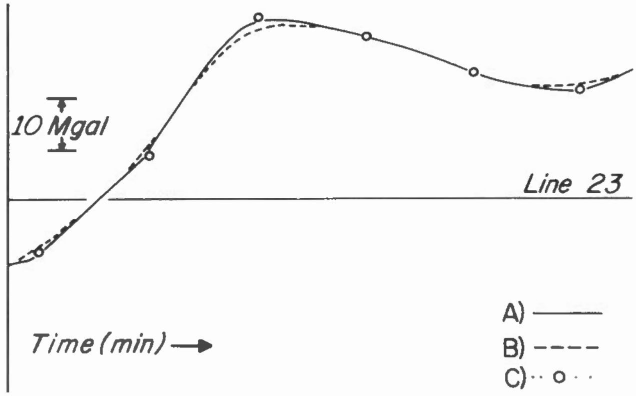

Figure 4. The effect on a typical gravity profile (C) of: (A) 60 point convolution filter and (B) 60 point convolution filter cascaded with 21 point running average.

As a further test the complete data set was smoothed by averaging the 5 min samples over 6.4 km track segments. This is equivalent to smoothing with a 21 point average mentioned above with a ship's speed of 6.2 m/s (12 knots). Both the smoothed data (60 point convolution filter cascaded with 4 mile averaging) and filtered data (60 point convolution filter alone) were plotted, contoured and compared at a scale of one to one million. Although the smoothed data led to distortion along specific profiles as mentioned previously, no significant differences in the resulting contour map were observed. Consequently, no digital smoothing in addition to the standard LaCoste 60 point convolution filter was found to be required.

Graf-Askania gravimeter

The instrumentation and data reduction procedure, employed with the GSS-2 meter have been developed and used by the Bedford Institute of Oceanography over a period of several years. The various aspects of this system are fully described elsewhere (Shih, 1973; Haworth and Loncaveric, 1974). It is pertinent to the subsequent data analysis to note however that no correction is applied to the GSS-2 data for cross-coupling effects. Instead the data is rejected when cross-coupling errors become excessive and therefore the GSS-2 data may be regarded as a smooth-weather subset of the total population.

Underwater measurements

The primary purpose for the underwater gravimeter survey was to provide control data to compare with the surface data and to provide additional coverage in areas of shallow depth. Approximately 246 gravity stations were observed using a LaCoste and Romberg (G-14) underwater gravimeter. Observed gravity values were transferred to the surface, using depths measured simultaneously with the gravity observations, and were corrected for instrument drift and tidal effects in the usual fashion (Tanner and Buck, 1964).

Error analysis

Closure errors

Repeat measurements at Dartmouth on departure and return disclosed a 3.1 mgal discrepancy for S-39. This closure error was subsequently found by direct comparison with the GSS-2 data to be a "tare" (discrete jump in the gravimeter's reading) which occurred at 1700 hr on day 284 along track "C" near the intersection of track 15 (Figure 1). A correction therefore to all S-39 data subsequent to this time has been made. The cause of the tare was later determined to be a maladjusted spring tunnel in combination with weather conditions that caused the platform to hit against its stops.

The closure with the GSS-2 was 0.3 mgal and this instrument showed no evidence of either drift or tares throughout the survey period.

Instrument calibration

It is the normal practice of the Earth Physics Branch to periodically recalibrate all its gravimeters by repeat measurements along calibration lines established for this purpose. Accurate calibration is particularly vital in the present survey because for logistic reasons, only the gravity base at Dartmouth could be employed to control surface data measurements. As there is a difference of about 900 mgal in gravity between Dartmouth and the survey area a calibration error for the surface meters of even 0.1 per cent can introduce an average offset in the data of 1 mgal.

Unfortunately S-39 was damaged before its calibration, which was scheduled to immediately follow the survey, could be completed. It was taken to the manufacturer to have the spring tunnel adjusted while en route for calibration. During the course of this adjustment, normally a trivial operation, one of the gravimeter's ligatures was broken which, although ultimately repaired, irrevocably altered its calibration.

A further check with the manufacturer revealed that the supplied calibration for S-39 was from early measurements subject to considerable inaccuracy in an absolute sense. At the factory, relative calibration over the complete range of the meter is performed by simulating gravity changes with a series of calibrated weights attached to the gravimeter beam. The resulting curve is then fixed in an absolute sense by measurements on a local calibration line. According to the manufacturer a systematic offset in the calibration curve as large as 0.3 per cent was possible for this instrument.

The GSS-2 has been calibrated only by the manufacturer over a 10 mgal range which in this case is extrapolated to 900 mgal. At this time no information regarding the linearity or accuracy of the instrument's spring constant is available.

The underwater meter was successfully calibrated at the completion of the survey over a 1,300 mgal range from Ottawa, Ontario to Austin, Texas. A scale correction factor of 1.0106 (±0.0007) was determined and applied to the underwater measurements. As gravity in the survey area differs from the base value at St. John's, Newfoundland by 635 mgal, the datum error in the underwater data should not exceed 0.5 mgal.

Statistics

The data are intercompared in several ways to provide error estimates as follows:

1. Underwater and surface measurements are compared directly.
2. The data from the two surface meters are compared directly.
3. Crossovers are analyzed individually and collectively for the surface meter data.
4. The complete data set are studied through a least squares adjustment.

We will define the intersection of any two surface meter tracks as an internal crossover. Surface measurements coincident with underwater measurements will be called external crossovers. The difference in the free-air anomaly at crossover points will be referred to as the crossover error. All internal crossover errors will be computed as the earlier measurement minus the later measurement with the resulting sign of the difference being preserved.

The exact times (±5 s) of the intersection of ship's tracks were obtained from a large scale plot of the survey. These times were then used to extract the nearest 10 second sample from the digitized S-39 observations. These times were also employed to obtain internal crossovers for the GSS-2 by interpolation from one minute samples. For external crossovers the times of closest approach of the ship's track to the underwater station was also scaled from the survey plot. Again the nearest 10 second gravity value was extracted from the S-39 data and values interpolated from 1 minute samples for the GSS-2 data. No underwater station that lay more than 370 m (0.2 nautical mile) from the survey tracks was used in the following analysis.

External crossover errors

The statistics for external crossover errors are given in Table I. An average offset between the surface and underwater data of approximately 3.2 mgal exists. This is to be expected since the surface meters are poorly calibrated, although the agreement between the two surface meters is unexpected. The only possible working hypothesis is to use the scale factor for the underwater meter to establish scale and datum for the surface data. Histograms of external crossovers are given in Figure 5.

TABLE I
Crossover Statistics

Description	Mean Difference (mgal)	Standard Deviation (mgal)
S-39 – GSS-2	−0.8	2.3
S-39 – Underwater	−3.7	2.7
GSS-2 – Underwater	−3.3	2.6

Internal crossover errors

Figure 6 shows histograms for S-39 and GSS-2 internal crossovers. In Figure 6(A) the distribution of all crossovers for S-39 is compared before and after the tare correction. Note how the bi-modal character of the original distribution (front histogram) is eliminated when a tare correction of 3.1 mgal is applied to the S-39 data (rear histogram). This change in the distribution can be used to determine the approximate time of a tare of known amplitude when no other means are available.

Figure 6(B) compares the distribution of the tare-corrected S-39 crossovers (rear histogram) with the subset (front histogram) containing only observations where simultaneous observations with GSS-2 were obtained. Similarly Figure 6(C) compares the distribution of all crossovers observed with GSS-2 (rear histogram) with the subset coincident with S-39 data (front histogram). Since the set of all GSS-2 observations may be regarded as a smooth-weather subset of the total population, the gross effect of weather conditions on S-39 is clearly evident in Figure 6(B) where the smooth-weather subset is normally distributed (χ^2 = 3.79) while the total distribution shows a large departure from normality. No correlation was found between crossover errors and the direction of sailing.

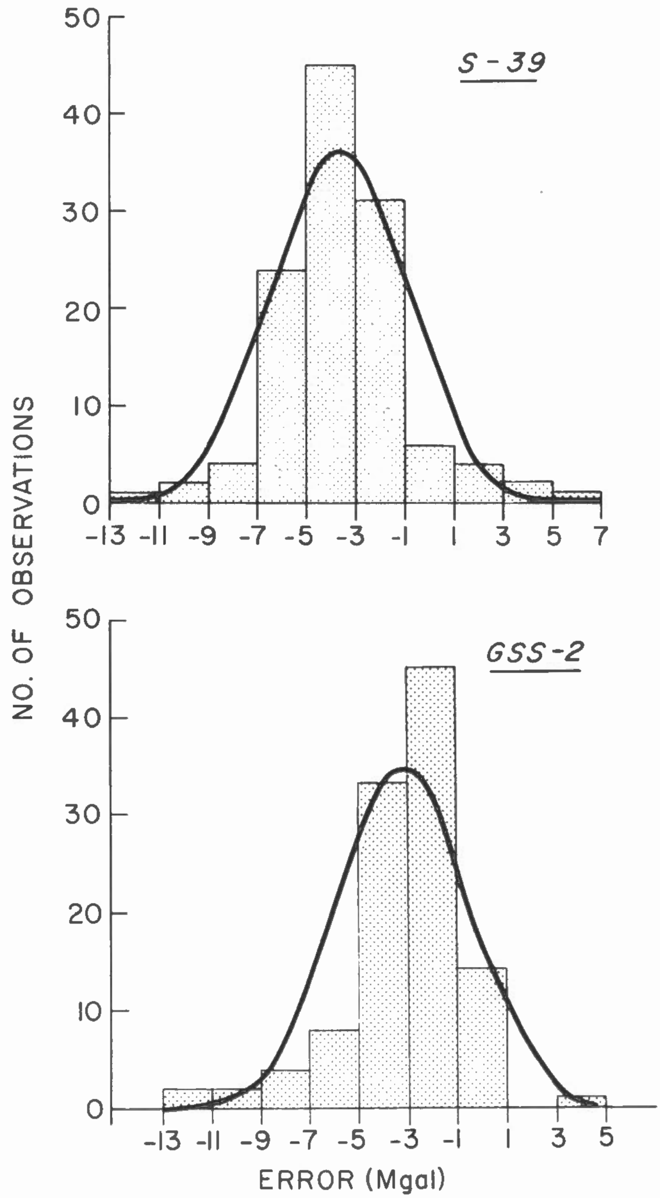

Figure 5. Histograms of external crossover errors. These errors are defined as surface minus underwater gravity values after transfer of underwater measurements to the surface.

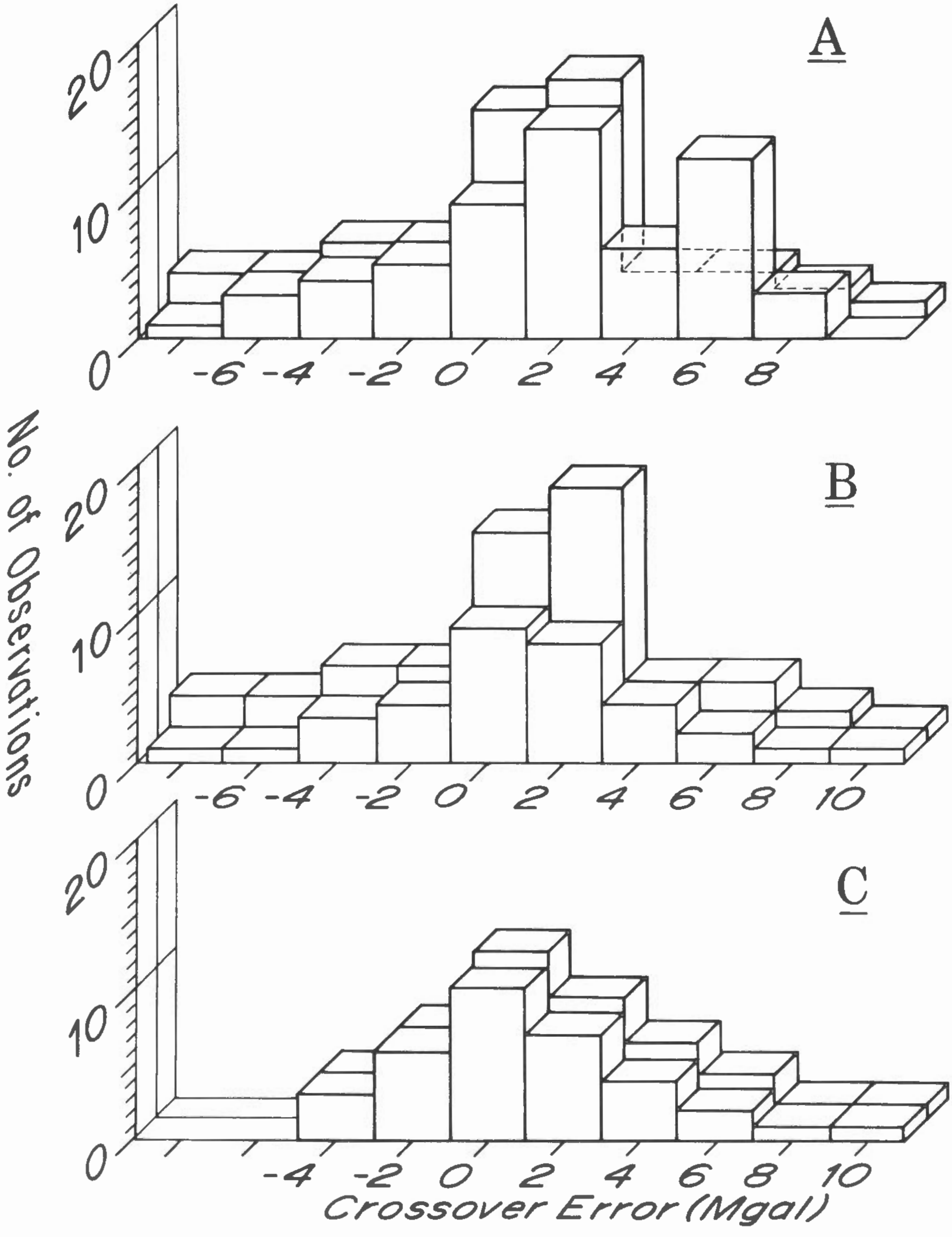

Figure 6. Histograms of internal crossovers. Errors are computed as the earlier minus later value. (A) Comparison of S-39 crossover before (front) and after (rear) application of the tare correction. (B) Comparison of all crossovers observed with S-39 (rear) with the subset containing only observations coincident with GSS-2 measurements (front). (C) Comparison of all crossovers observed with GSS-2 (rear) with the subset containing only observations coincident with S-39 measurements (front).

Comparison of the two surface meters

Average differences between unadjusted S-39 and GSS-2 measurements as well as the standard deviation of these differences are presented on a daily basis in Table II. Also included in Table II are wind speed, sea and swell. Such a tabulation implies stationary statistics over 24 hrs which is hardly true. Indeed the directions of sea and swell were so variable as to preclude tabulation of this parameter on a daily basis.

Both ship's heading and the directions of sea and swell have a large influence on the comparison of the two sets of data. For example, the large difference and standard deviation on day 299 resulted from rolling in excess of 30°, although the general sea state was moderate. Both the sea and swell directions at this time were nearly abeam and as S-39 was oriented athwart ships the cross-coupling term was sufficiently large to saturate the electronics and lead to excessive errors in the S-39 data for a period of approximately 17 hours.

TABLE II
Daily Average Surface Meter Differences
(S-39 minus GSS-2)

Day	No. of Obs.	Mean Diff. (mgal)	s.d. (mgal)	Wind Speed Knot	Sea Height m	Swell m
273	81	−0.5	2.5	17	1.2	2.4
274	72	−0.9	2.0	15	0.9	2.1
275	83	0.0	1.3	18	1.2	1.8
276	95	−1.1	2.9	17	0.9	2.1
277	78	+1.5	1.5	22	2.4	2.1
278	24	−2.6	5.5	17	0.9	2.1
279	92	−0.8	2.0	18	1.8	1.8
280	106	0.0	1.4	11	0.6	4.2
281	94	−1.3	2.6	23	2.4	2.4
282	91	−1.4	3.6	19	2.7	2.4
283	55	−3.9	5.1	25	2.4	4.5
284	76	−2.9	5.1	31	3.3	3.6
285	89	−2.1	5.3	24	2.1	3.9
286	87	+1.9	3.4	23	2.4	3.6
287	99	+1.1	1.6	15	1.8	1.8
288	53	+2.3	2.4	30	3.3	3.3
289	103	+2.1	3.0	22	1.8	2.4
290	67	+3.5	4.7	29	3.3	3.6
291	89	+0.1	2.7	34	4.5	6.0
292	40	+1.5	3.2	29	3.6	4.8
293	92	−0.4	1.9	19	1.5	2.1
294	111	−0.4	1.9	18	1.5	2.4
295	62	−0.7	2.5	33	3.0	3.6
296	95	−0.6	2.0	22	1.8	1.8
297	125	−1.4	3.1	18	1.5	2.1
298	117	−1.8	3.6	29	3.0	3.0
299	102	−4.0	5.4	22	1.8	2.1
300	67	−0.8	2.4	22	1.8	2.4
All Data	2413	−.05	3.2			

Summary of error statistics and error model

The following was adopted as a final error model:

1. A tare of 3.1 mgal in the S-39 data at 1700 hr on day 284.
2. No appreciable drift in either surface meters.
3. Calibration of surface meters unknown; calibration of underwater meter known.
4. All other errors assumed to be random although considerable departure from a normal distribution is observed for rough weather measurements.

Generally the above analysis indicates that apart from systematic offsets, an accuracy of 3 mgal ($\pm 1\sigma$) may be ascribed to the measurements with surface data. Furthermore the underwater measurements may be used to provide scale control to eliminate this systematic offset in the absence of adequate surface meter calibration.

Least squares adjustment

On the basis of the above model differences in observed gravity between all crossovers were adjusted by the method of least squares under the following constraints using standard procedures (Morelli *et al.*, 1974) for adjusting gravity control networks:

1. Base values fixed as in Table III.
2. Scale of the underwater meter fixed.
3. Rejection limit: 5 mgal.
4. Unit weight applied to all observations.
5. Unknowns: a) Scale correction factors for both surface meters.
   b) Adjusted gravity values at the crossover points.

TABLE III
Table of Base Values

Base No.	Base Name	Gravity Value (mgal)
940172	St. John's, Nfld.	980,843.17
940272	St. John's, Nfld.	980,842.62
905270	Halifax, N.S.	980,581.51
986162	Halifax, N.S.	980,578.94

Data between crossovers were then linearly corrected to match the adjusted gravity values at the crossovers. Because of inclement weather and other logistic problems several crossovers were not observed. Data along the tracks in the vicinity of the missing crossover pairs were examined to ensure consistency. Near one crossover in particular, the intersection of tracks 2 and A, (Figure 1) a misfit of 10 mgal was observed. Track 2 was linearly adjusted between adjacent crossover points to match track A at the missing crossover. This forced-fit is justified because track 2 was without control for over 12 hrs whereas track A is well controlled throughout its length.

Statistically, the results of the adjustment are as follows:

1. Standard error for an observation of unit weight: 1.8 mgal.
2. Scale correction factor of S-39 relative to G-25: 1.003 ±0.002.
3. Scale correction factor GSS-2 relative to G-25: 1.004 ±.002.

Histograms for the general population and for each gravimeter are given in Figure 7 along with the respective values of standard deviation and χ^2. This test indicates with better than 99 per cent confidence that the overall population and the Askania data were not drawn from normal populations. This departure from normality is possibly due to the rejection procedure applied to the GSS-2 data to avoid corrections for cross-coupling effects as previously discussed.

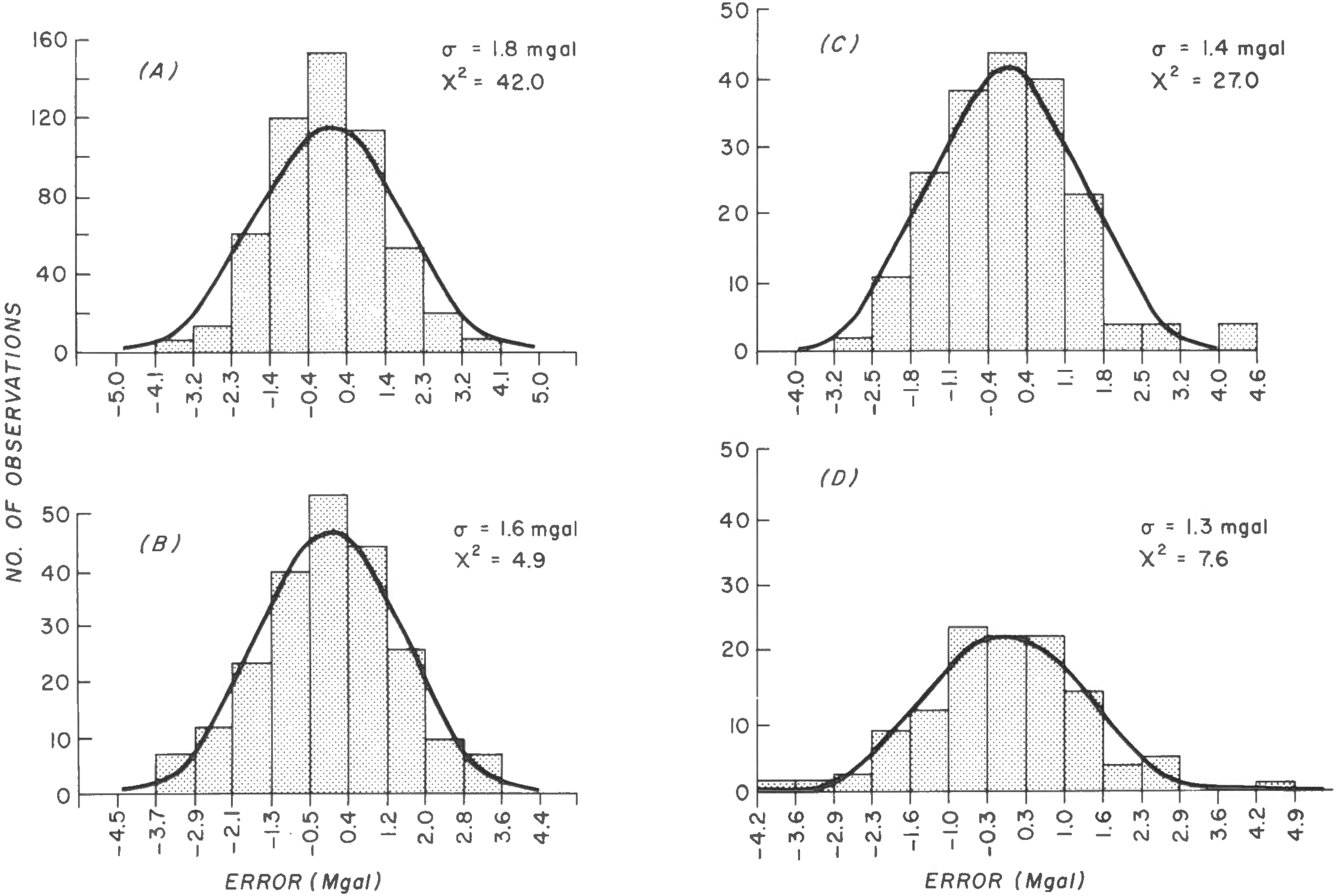

Figure 7. Histograms of crossover residuals after least squares adjustment. (A) Histogram of all residuals. (B) Histogram of residuals for S-39. (C) Histogram of residuals for GSS-2. (D) Histogram of residuals for underwater meter.

An accuracy of between approximately 1 and 2 mgal ($\pm 1\sigma$) can be ascribed to the composite adjusted gravimeter data indicated on the accompanying maps, depending on the number of instruments observed at each station. The accuracy of the final Bouguer anomaly values must also include a contribution for bathymetry errors. These however, amount to less than ±0.5 mgal and may be neglected in comparison with other errors. The effect of positioning errors depend on the horizontal gravity gradient and the magnitude of the positional error. Assuming worst case conditions (maximum product of gradient and position error) a maximum contribution of approximately ±1.6 mgal from this source is indicated. Note that this error source is already included in the crossover analysis as outlined previously.

The onshore data included on the maps has been extracted from previous work. The accuracy of the onshore Bouguer anomalies is estimated at ±2.5 mgal (Thomas, 1974). Errors in the onshore free-air anomalies are approximately ±3.3 mgal largely due to errors in altitude measurements.

Correlation with geology

The survey area is situated on the Labrador continental shelf on strike with the Grenville Front which, on land, separates rocks of the Churchill and the Grenville Provinces. The bathymetric data indicate that the Labrador Shelf deviates in its linear northward trend opposite Melville Inlet. The continental shelf consists of unconsolidated Mesozoic and Cenozoic sediments which lie nonconformably on Precambrian plutonic and metamorphic rocks. These sediments have subsequently been glaciated by the Wisconsin glaciation thereby forming marginal and transverse troughs along the Labrador Shelf (Grant, 1972 and Mayhew *et al.*, 1970). Seismic data indicate that vertical movements along large segments of the continental shelf have offset portions of the Mesozoic strata and Precambrian basement (Grant, 1972). Similar structures caused by block faulting and subsidence on other ruptured margins such as along the Red Sea have been related to tensional stresses occurring at the time of continental breakup (Hutchinson and Engels, 1972) which in the area of the Labrador Sea occurred about 82 million years ago (Laughton, 1971).

On land, the Bouguer gravity field has been described by M.D. Thomas (in press). Here the most striking feature is the linear negative Bouguer anomaly which coincides with the Grenville Front. As it is traced eastward, (Figure 8) the magnitude of this anomaly decreases significantly towards the Labrador coast and over the continental shelf there is no sign of it. The northwest trends of high gravity anomalies over the southern portion of the survey area are similar to those on land south of Hamilton Inlet where an intense gravity anomaly is interpreted as a massive gabbroic intrusion (Thomas, 1974).

Although the free-air anomaly map (Figure 9) cannot effectively be used for geological correlations on land or the continental shelf, it does emphasize the positive free-air gravity anomalies which trend along the continental margin and which are characteristic of continental shelves. Possible causes for these high free-air anomalies in addition to edge effects include:

i) a basement ridge;
ii) crustal thinning;
iii) high density belts in the basement;
iv) uncompensated Quaternary and Tertiary sediments.

As Sobczak (in press) has already discussed all these possibilities in some detail no further explanation is required here.

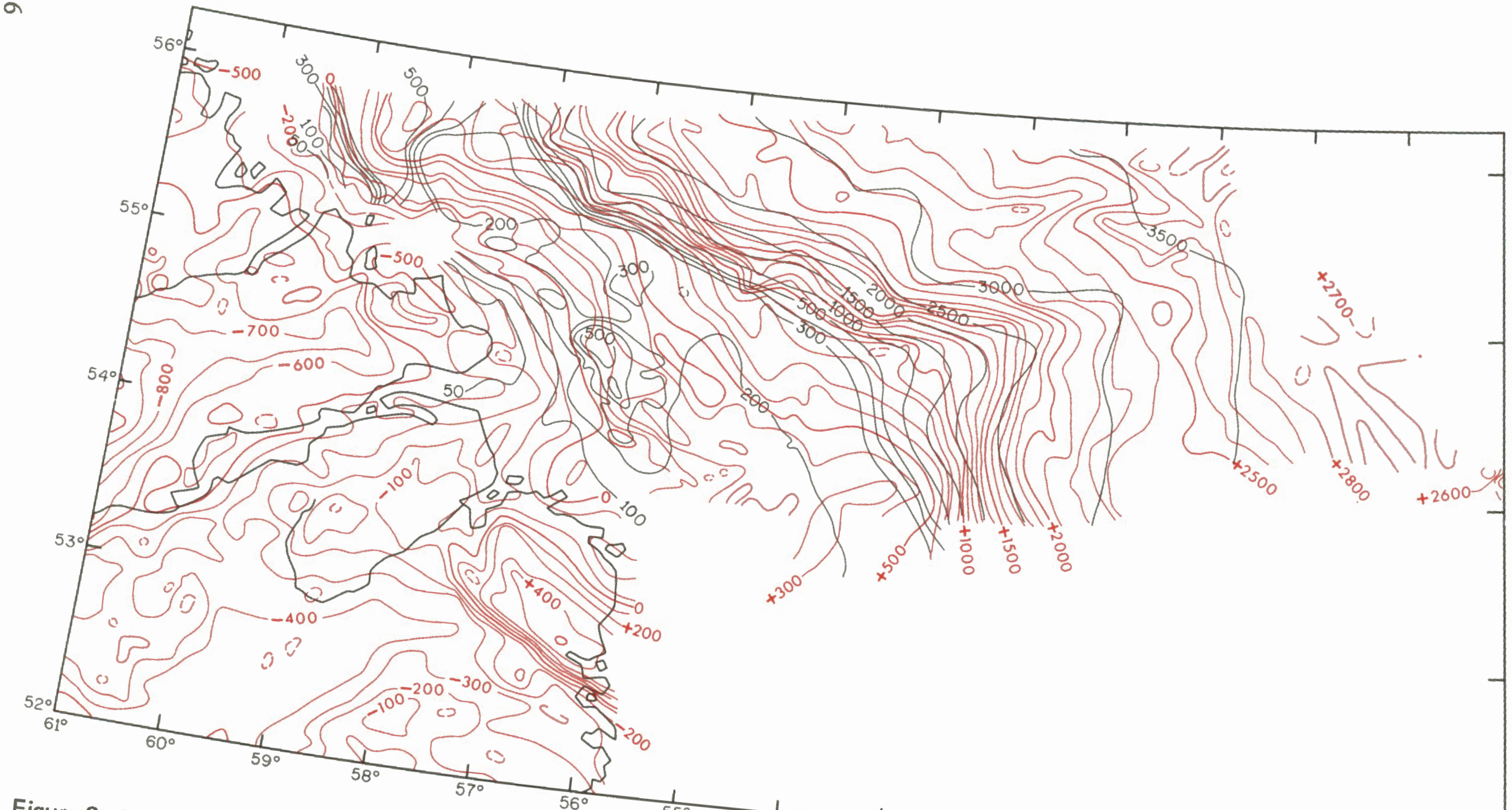

Figure 8. Bouguer anomaly map of the survey area superimposed on the bathmetry. Gravity values (red) are in tenths of mgal; water depths are in metres.

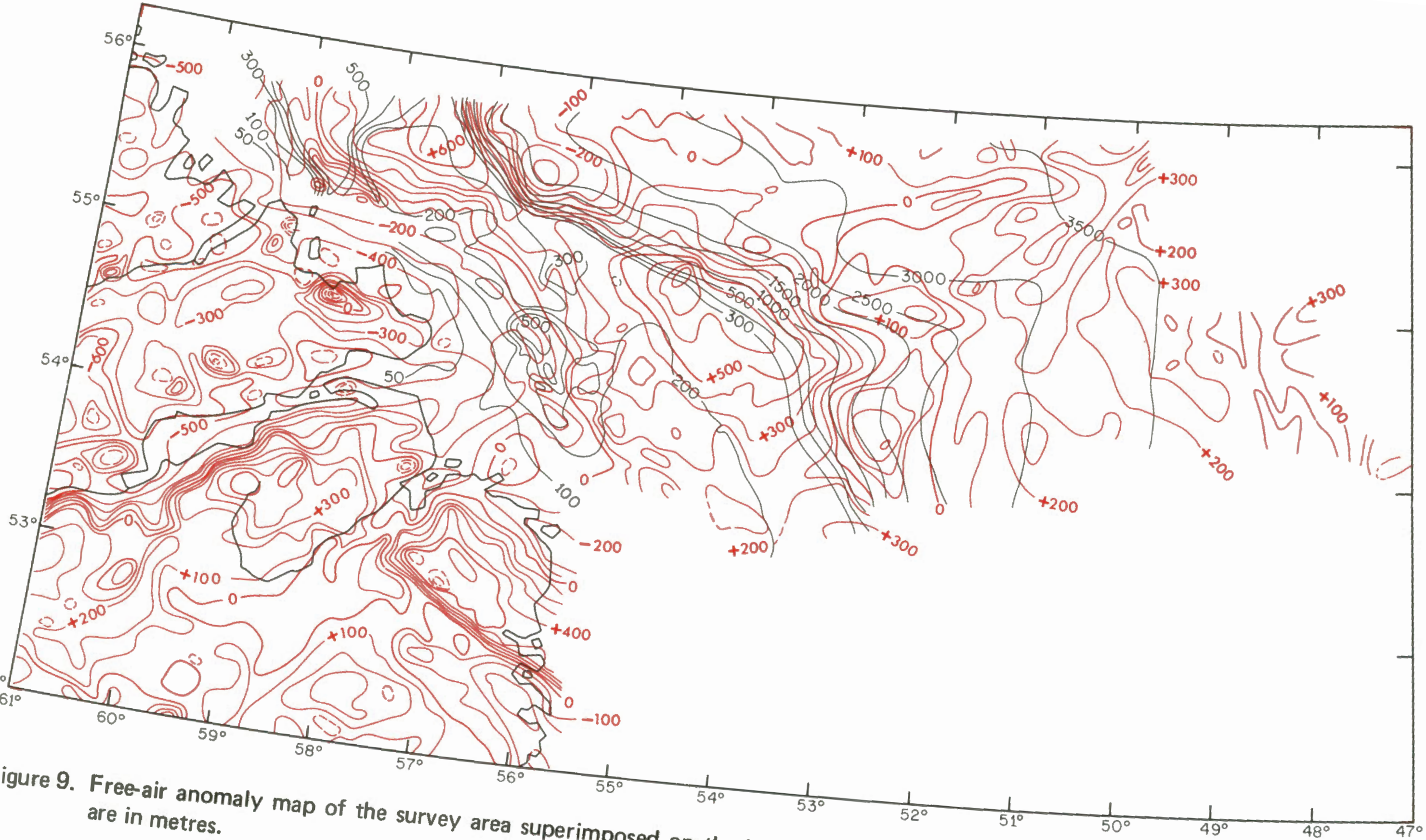

Figure 9. Free-air anomaly map of the survey area superimposed on the bathymetry. Gravity values (red) are in tenths of mgal; water depths are in metres.

In both the free-air and Bouguer anomaly maps, a southwestern trending anomaly in the northeast corner of the survey area is aligned with Hamilton Inlet and indicates a possible major discontinuity in the continental shelf. The northwest structural trends as outlined by the gravity field over the southern part of the survey area do not extend north of this proposed discontinuity which may be related to the eastward extension of the Grenville Front over the continental shelf. The negative free-air anomaly in the northeast corner of the area coincides with a transform fault which has been located by magnetics (Le Pichon *et al.*, 1971). The gravity data may indicate the trace of the ancient fault along which the oceanic transform fault developed.

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