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THE BOUGUER ANOMALY FIELD OF THE NOTRE DAME BAY AREA, NEWFOUNDLAND

with map: No. 163 — Notre Dame Bay

H.G. Miller and E.R. Deutsch

Gravity Map Series
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ABSTRACT

Gravity observations at 705 locations in the Notre Dame Bay area of Newfoundland delineate an arcuate belt in which closely spaced gravity anomaly contours tend to follow the coastline. This belt marks the surface contact between mafic volcanics and ophiolite sequences within the Notre Dame tectono-stratigraphic zone and (1) sedimentary and volcanic rocks in the Exploits zone to the south and east and (2) predominantly metasedimentary and metavolcanic rocks in the Fleur de Lys zone to the west. Positive Bouguer anomalies over the Fleur de Lys zone to the east of the Baie Verte lineament indicate a westerly subsurface extension of the oceanic rocks found in the Notre Dame zone. Sedimentary rocks in the Exploits zone have no perceptible effect on the gravity anomaly field.

RÉSUMÉ

Des observations gravimétriques effectuées à 705 stations dans la région de la baie Notre-Dame (Terre-Neuve) ont délimité une zone en arc de cercle dans laquelle les courbes des anomalies gravimétriques, très rapprochées, tendent à suivre la littoral. Cette zone marque la ligne de jonction, en surface, des roches volcaniques ferro-magnésiennes et de séries de roches ophiolitiques dans la zone tectono-stratigraphique de Notre-Dame et (1) des roches sédimentaires et volcaniques dans la zone Expoits au sud et à l'est, et (2) la zone Fleur de Lys à prédominance de roches sédimentaires et volcaniques métamorphisées à l'ouest. Les anomalies positives de Bouguer au-dessus de la zone Fleur de Lys, jusqu'à l'est de l'alignement structural de la Baie Verte, révèlent un prolongement en profondeur vers l'ouest des roches océaniques que l'on a trouvées dans la zone Notre-Dame. Les roches sédimentaires de la zone Exploits n'exercent aucune influence perceptible sur le champs des anomalies gravimétriques.

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THE BOUGUER ANOMALY FIELD OF THE NOTRE DAME BAY AREA, NEWFOUNDLAND

H.G. Miller and E.R. Deutsch

INTRODUCTION

In this report we present a Bouguer anomaly map (scale 1:250,000) of the region adjacent to Notre Dame Bay, Newfoundland and a discussion of the main features of the gravity field. The map area and its relationship to Newfoundland geology are shown in Fig. 1. The gravity data presented here were calculated from observations made by personnel of Memorial University of Newfoundland during 1968, 1969, 1974 and 1975. The data are based on a total of 705 gravity stations.

Transportation in the area was by car along available roads, by boat in the Bay of Exploits and along the coast from Point Leamington to Nipper's Harbour, and by aeroplane for the purpose of establishing a base tie between Fogo and New World Islands. The mean station spacing was approximately 2.5 km along the roads; this spacing was maintained along the coast and on islands where possible.

The only gravity data available prior to the present work for the immediate area were those presented by Weaver (1967), who published the results of an island-wide gravity survey of Newfoundland at 10 - 13 km spacing. Weaver's survey contained approximately 40 gravity stations in the present survey area, the results of his work being a major incentive for the present study.

In 1975 the Atlantic Geoscience Centre, Bedford Institute, conducted a near-shore survey off the northeast coast of Newfoundland under the direction of R.T. Haworth. Although the data from that survey

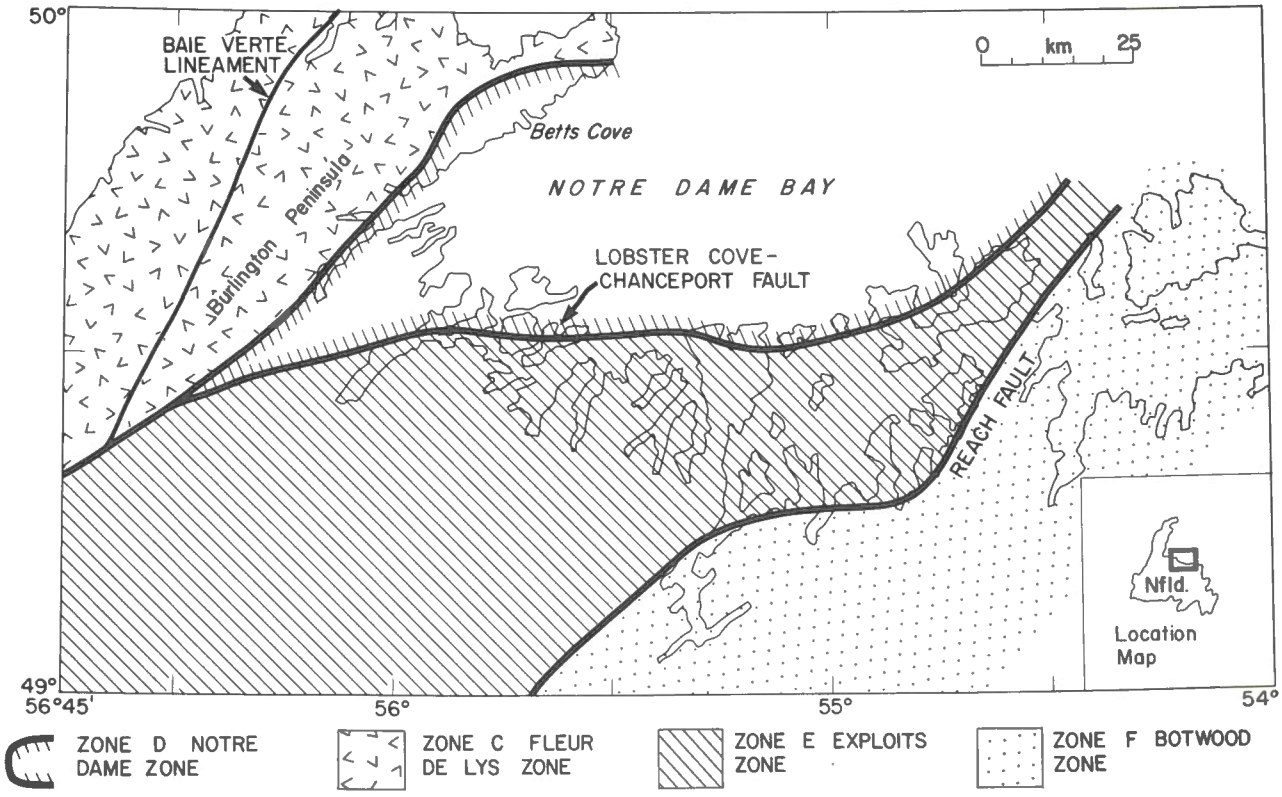

Figure 1 Location map and generalized geology. Geology from Williams et al. (1974).

have not been released yet, one of us (H.G.M.) is collaborating in their interpretation. Lamont-Doherty Geological Observatory also collected ship-borne data in Notre Dame Bay along a single loop in the central portion of the bay (Jacobi and Kristoffersen, 1976).

OBSERVATION AND REDUCTION OF DATA

Initially all readings for both control (base) and gravity stations were obtained using Sharpe Instruments CG2 gravimeter, serial number 192. To provide a calibration check on that instrument several of the control stations were reoccupied using an Earth Physics Branch Lacoste and Romberg meter, G88.

Control station ties using the Sharpe instrument were of the ABABABA type with the number of ABA legs varying from 3 to 5. The combined Sharpe and Lacoste and Romberg control ties were processed at the Gravity and Geodynamics Division and adjusted to the National Gravity Net. Error estimates on the adjusted gravity values varied from ± 0.03 to ±0.30 mgal with a mean of ± 0.15 mgal.

The gravity readings are subject to random errors in the drift of the meter and in the reading of the instrument. These two errors combined are estimated to be about ± 0.05 mgal. On the basis of this error and that in the control stations, the observed gravity values have an estimated accuracy of ± 0.16 mgal.

The major factor determining the accuracy of the computed Bouguer anomalies is the measurement of elevation. For the data presented in this report the elevations have been measured by direct levelling and by altimetry. In the case of the directly levelled stations, of which there are 269, the elevation was shot directly from the water line and corrections for tidal height were applied. The elevation uncertainty for these stations is estimated to be ± 0.1 m corresponding to an error of about ± 0.02 mgal in Bouguer anomaly.

For the 436 barometrically determined elevations, several techniques were employed utilising two sets of paired Wallace and Tiernan altimeters, one set being maintained at a fixed reference point and the other set employed as a "roving" set. A complete description of the methods used for barometric determinations of elevations on these surveys is given in Miller (1970) and Miller and Deutsch (1976). The uncertainty for barometrically determined station elevations is about ± 2 m corresponding to an uncertainty of ± 0.4 mgal in Bouguer anomaly.

A third factor which influences the accuracy of the Bouguer anomalies is the determination of latitude. All station locations were scaled from 1:50,000 NTS sheets and are estimated to be accurate to ± 100 m corresponding to an uncertainty of ± 0.08 mgal. On the basis of the above error analysis the average error in the Bouguer anomalies is estimated to be ± 0.02 mgal for the directly levelled stations and ± 0.4 mgal for the barometric stations.

In addition to the above random errors there may be systematic errors in the Bouguer anomalies arising from the neglect of terrain effects. It is estimated that the terrain effect is always less than 0.5 mgal and that for the vast majority of stations it is less than 0.1 mgal.

The Bouguer anomalies were reduced on the International Gravity Standardization Net 1971 (IGSN71) datum using a crustal density of 2.67 g/cm^3. Theoretical gravity was based on the Geodetic Reference System 1967 (GRS67). As a result, these anomalies are systematically lower by about 6 mgal than those given by Weaver (1967) and Miller and Deutsch (1973, 1976) for the Notre Dame Bay area, but the basic interpretation presented by these authors is unaffected by this shift.

GEOLOGICAL SETTING

The map area is in the northeastern extremity of the Appalachian system as exposed on land. Specifically, the area is in the central Paleozoic Mobile Belt of Newfoundland (Williams, 1964). Williams et al. (1972, 1974) have subdivided the Island of Newfoundland into eight tectono-stratigraphic zones based upon Ordovician and older stratigraphy and deformation. Under this classification scheme the Notre Dame Bay area traverses all or parts of four tectono-stratigraphic zones (Fig. 1). From west to east these zones are the Fleur de Lys, Notre Dame, Exploits, and Botwood zones.

The Fleur de Lys zone, found on the Burlington Peninsula, is characterized by a mixed assemblage of Late Precambrian to Early Paleozoic rocks that have experienced polyphase deformations in the Late Cambrian or Early Ordovician (Williams et al., 1974). There is also evidence, albeit the subject of controversy, that the area was affected by a Silurian or younger deformation (Neale et al., 1975; de Grace et al., 1976). On the west, the zone contains metasediments and metavolcanics which, upon crossing the Baie Verte lineament, give way to the Mings Bight ophiolite. East of this occur the Pacquet Harbour Group of mafic-felsic volcanics, the

Cape Brulé porphyry, and the Cape St. John Group composed of calc-alkaline volcanics. Unconformably underlying the Cape St. John Group is the Snook's Arm Group with its classic ophiolite sequences, with the boundary between the Cape St. John and the Snook's Arm Groups marking the boundary between the Fleur de Lys and Notre Dame zones. The Fleur de Lys zone on the southern Burlington Peninsula is intruded by the Burlington Granodiorite. The boundary between the Notre Dame and Fleur de Lys zones is not exposed along the east coast of the southern part of the Burlington Peninsula but is inferred by Williams et al. (1972, 1974).

The Notre Dame zone, which stretches eastward along the headlands of Notre Dame Bay from Green Bay to east of New World Island, contains not only the Snook's Arm Group but also the mafic volcanic rocks of the Lush's Bight Terrane in eastern Notre Dame Bay (Horne and Helwig, 1969). The rocks are fault-bounded, being separated from the rocks of the Exploits zone to the south by the Lobster Cove Fault in the west and the Chanceport Fault in the east. Strong and Payne (1973) have interpreted the rocks of the Lush's Bight Terrane as being the lower part of an ancient island arc.

The Exploits zone is typified by Ordovician sediments and mostly acidic volcanic rocks. These are represented in the west by the Robert's Arm Group and in the east by numerous groups in the Bay of Exploits having local names (Heyl, 1936). On New World Island the arrangement of the various formations has been altered by numerous faults. To the southeast, the Reach Fault (Eastler, 1971) separates the Bay of Exploits portion of the Exploits zone from the Botwood zone. There is no fault marking the boundary in the western portion of the zone. The eastern boundary in the vicinity of the Reach Fault has been interpreted as the site of an ancient subduction zone (Williams et al., 1974). Several granitic and granodioritic bodies ranging in age from Ordovician to Devonian are found in the zone.

Finally, the Botwood zone is typified by Ordovician slates overlain by Silurian conglomerates, terrestrial volcanics, and fluviatile red beds. There has been some deformation along the western boundary of this zone. The eastern boundary is not traversed by the data reported here.

INTERPRETATION OF THE BOUGUER ANOMALY FIELD

The Bouguer anomalies for the 705 gravity stations and sub-bases are presented in the form of a map (Fig. 2 and GMS No. 163 in the envelope). The most striking feature of the map is the large gravity gradient found along the coastline of Notre Dame Bay. Comparison with Fig. 1 suggests that this major gradient is intimately associated with the boundary

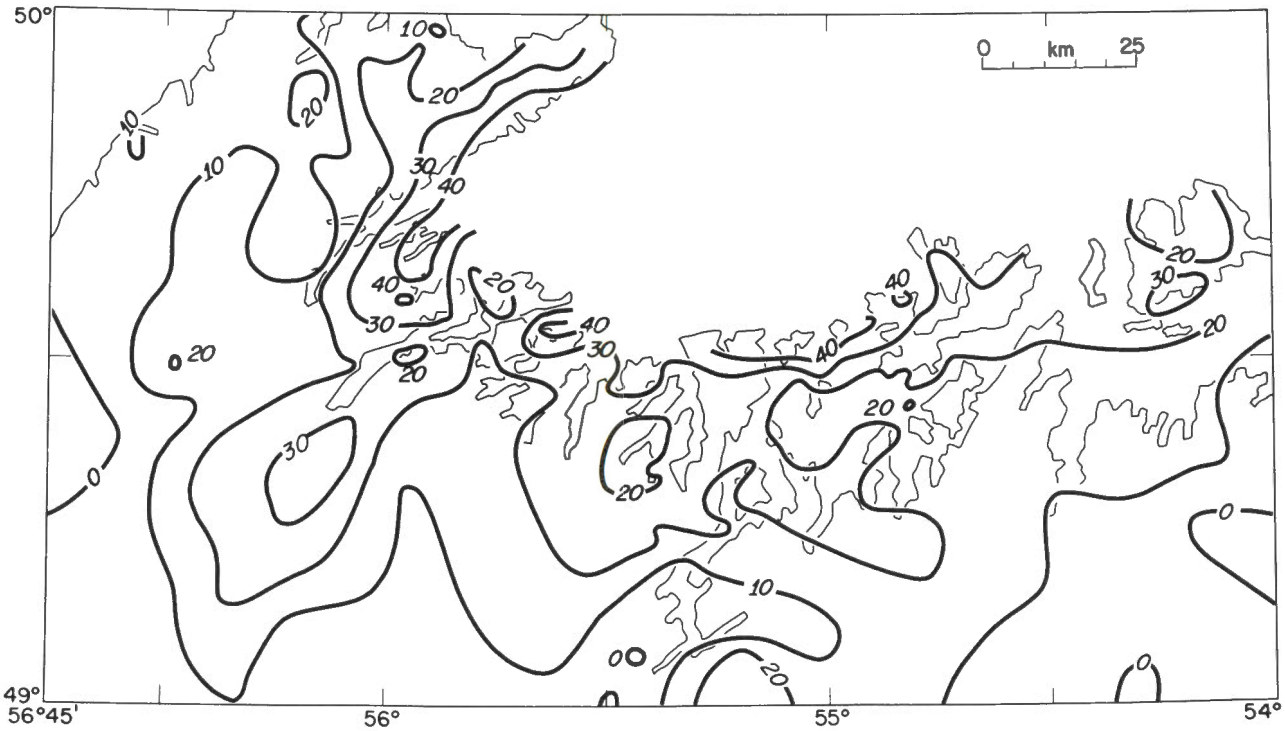

Figure 2 Generalized Bouguer anomaly map of Notre Dame Bay area. Contour interval is 10 mgal.

between the Notre Dame zone and the Fleur de Lys zone in the west and between the Notre Dame zone and the Exploits zone in the south and east (as delineated by the Lobster Cove - Chanceport Fault). The location of this gravity gradient, which is compatible with the geology, is substantiated when one examines the change in rock density across the boundaries (Table 1). These data show that there is a 0.10 g/cm^3 density contrast between the Exploits and Notre Dame zones and a 0.06 g/cm^3 contrast between the Fleur de Lys and Notre Dame zones.

The second feature which is immediately noticed is that all anomaly values are positive east of the Baie Verte lineament and north of the Reach Fault. This is the case even in the presence of material having lower than average density, for example granites, implying the existence at depth of a layer having a positive density contrast with the overlying crustal rocks.

The presence of known oceanic crustal rocks on the east side of the Burlington peninsula coincides, as would be expected from the density of the rocks involved, with the gravity high in that area.

In eastern Notre Dame Bay the areas of sedimentary rocks in the Exploits zone have no noticeable perturbing effects on the gravity field. The mean density of the sediments in these areas is 2.71 g/cm^3 (Miller, 1970), which is close to the average for the whole island (Weaver, 1967), hence these rocks would be expected to have little or no effect on the gravity field.

In order to examine the effects of alternative geological structures, detailed three-dimensional modelling was conducted for the gravity data from eastern Notre Dame Bay where the coverage was sufficiently dense to warrant such an approach. This modelling has been reported in detail (Miller, 1970; Miller and Deutsch, 1973); for the present report it is sufficient to summarize our conclusions.

This area is situated mainly in the Exploits zone, but those portions which define the major gradient or which are located to the north of the major gradient lie within the Notre Dame zone. The Botwood zone is represented approximately by the data south of a line running from 49°N; 55°30'W to 49°20'N; 55°25'W and data east of 55°25'W. The major conclusions for the densely covered area are:

(i) the overall positive aspect of the field is caused by the presence of a layer having a positive density contrast of 0.20 g/cm^3 whose top is 5 km below the surface.

(ii) the difference in gravity anomaly of approximately 20 mgal between the Notre Dame zone and the Exploits zone can be explained by the presence of the Lush's Bight Terrane north of the Chanceport Fault. Based upon the density of the rocks of the Lush's Bight Terrane, the sequence must be about 5 km thick to explain the anomalies.

TABLE 1

ROCK DENSITY DATA
FOR NOTRE DAME BAY AREA

Zone*	No. Samples	Mean g/cm^3	Standard deviation g/cm^3	Density contrast relative to 2.70 g/cm^3 **
C Fleur de Lys	47	2.79	0.16	0.09
D Notre Dame	38	2.85	0.12	0.15
E Exploits	202	2.75	0.10	0.05
F Botwood	13	2.72	0.08	0.02

* Zonation designation - alphabetic after Williams et al. (1972)
- local nomenclature after Williams et al. (1974)

** Mean density of rocks from Newfoundland is 2.70 g/cm^3 (Weaver, 1967; Weir, 1971)

(iii) sedimentary rocks have little or no perturbing effect on the gravity field.

(iv) there is a second major break in structure across Change Islands as shown by the north-south trend of the gravity field in the area.

(v) the proposed high-density layer at 5 km depth may be a landward continuation of the intermediate layer of Sheridan and Drake (1968).

These considerations suggest that the Exploits zone contains oceanic crust, but the data are insufficient to conclude that there is oceanic crust in the Botwood zone.

The models derived by Miller and Deutsch (1976) for the Fleur de Lys/Notre Dame boundary show that there must be high density material lying at depth further to the west. This indicates that Notre Dame zone type material must extend beneath that part of the Fleur de Lys zone on the east side of the Baie Verte lineament, and on the basis of this model and its supporting data a change in the zoning of the Burlington peninsula has been suggested (Miller and Deutsch, 1976).

SUMMARY AND CONCLUSIONS

The gravity data show a striking correlation with the boundary between oceanic crustal material present in the Notre Dame zone and the material of adjoining zones. Crustal models derived from the gravity data show that material similar to the exposed oceanic crustal material of the Notre Dame zone may be present at depth beneath the Fleur de Lys zone as far west as the Baie Verte lineament and to the south and east beneath the Exploits zone. On the basis of the gravity derived models a revision in the tectono-stratigraphic zonation was proposed (Miller and Deutsch, 1976).

More detailed modelling of the possible causative bodies in the Notre Dame zone awaits the interpretation of the Bedford Institute gravity and magnetic data from the seaward portion of the bay. A joint interpretation of offshore and onshore data is now in progress and preliminary results indicate the presence of alternating bands of high and low gravity values striking northeastward from the anomalies described in this report.

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BIBLIOGRAPHY

DeGrace, J.R., Kean, B.F., Hsu, E., and Green, T., 1976. Geology of the Nippers Harbour Map area (2E/13), Newfoundland. Mineral Development Division, Dept. Mines & Energy, Report 76-3, 73 p.

Eastler, T.E., 1971. Geology of Silurian rocks, Change Island and easternmost Notre Dame Bay, Newfoundland. Unpubl. Ph. D. Thesis, Columbia University, New York City, New York.

Heyl, G.R., 1936. Geology and mineral deposits of the Bay of Exploits area, Newfoundland. Dept. Natur. Resour., Geol. Sect., Bull. 8, 42 p.

Horne, G.S. and Helwig, J., 1969. Ordovician stratigraphy of Notre Dame Bay, Newfoundland. In: North Atlantic-Geology and Continental Drift (M. Kay, Ed.). Am. Assoc. Pet. Geol., Memoir 12, 388-407.

Jacobi, R. and Kristoffersen, Y., 1976. Geophysical and geological trends on the continental shelf off northeastern Newfoundland. Can. J. Earth Sci., 13, 1079-1051.

Miller, H.G., 1970. A gravity survey of eastern Notre Dame Bay, Newfoundland. Unpubl. M.Sc. Thesis, Memorial University, St. John's, Newfoundland.

Miller, H.G. and Deutsch, E.R. 1973. A gravity survey of eastern Notre Dame Bay, Newfoundland. In: Earth Science symposium on Offshore Eastern Canada. (P.J. Hood, Ed.), Geol. Surv. Can. Paper 71-23, 389-406.

Miller, H.G. and Deutsch, E.R., 1976. New gravitational evidence for the subsurface extent of oceanic crust in north-central Newfoundland. Can. J. Earth Sci., 13, 459-469.

Neale, E.R.W., Kean, B.F., and Upadhyay, H.D., 1975. Post-ophiolite unconformity, Tilt Cove - Betts Cove area, Newfoundland. Can. J. Earth Sci., 12, 880-886.

Sheridan, R.E. and Drake, C.L., 1968. Seaward extension of the Canadian Appalachians. Can. J. Earth Sci., 5, 337-373.

Strong, D.F. and Payne, J.G., 1973. Early Paleozoic volcanism and metamorphism of the Moreton's Harbour-Twillingate area, Newfoundland. Can. J. Earth Sci., 10, 1363-1379.

Weaver, D.F., 1967. A geologic interpretation of the Bouguer anomaly field of Newfoundland. Publ. Dom. Obs. 35(5), 223-251.

Weir, H.C., 1971. A gravity profile across Newfoundland. Unpubl. M. Sc. Thesis, Memorial University, St. John's, Newfoundland.

Williams, H., 1964. The Appalachians in northeastern Newfoundland - a two-sided symmetry. Am. J. Sci., 262, 1137-1158.

Williams, H., Kennedy, M.J. and Neale, E.R.W. 1972. The Appalachian structural province. In: Tectonic Styles in Canada (R.A. Price & R.J.W. Douglas, Eds.) Geol. Assoc. Can. Special Paper, 11, 181-262.

Williams, H., Kennedy, M.J. and Neale, E.R.W., 1974. The northeastward termination of the Appalachian Orogen. In: The Ocean Basins and Margins, vol. 2 (A.E. Nairn & F.G. Stehli, Eds.) Plenum Publ., New York, pp. 77-123.