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EMR OFFSHORE REGIONAL GRAVITY PROGRAM

BY

R.A.Gibb, R.A.Stacey, J.B.Boyd, and R.K.McConnell

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INTRODUCTION

An objective of the National Gravity Service of Earth Physics Branch (EPB) is to systematically map the gravity field of the Canadian landmass, continental shelves and inland waters. Progress is shown in Figure 1. In this report we describe an offshore regional gravity program designed to complete reconnaissance gravity coverage of the Atlantic and Pacific continental margins, the inter-island channels of the Arctic and Hudson Bay. On land, surveys are made primarily by EPB with some input from provincial agencies and industry. At sea, in addition to the surveys of EPB, a contribution is made to the collection of regional data by the more localized activities of the Atlantic Geoscience Centre (AGC), a division of the Geological Survey of Canada, and the Vancouver Office (GSC(V)) of the Geological Survey of Canada. Support for this program comes also from three agencies of the Marine Science Directorate, Department of the Environment viz. Canadian Hydrographic Service Atlantic Region (CHS(A)), Canadian Hydrographic Service Central Region (CHS(C)), and Canadian Hydrographic Service Pacific Region (AGC(P)).

In this report we list major departmental concerns in the offshore relating to gravity measurements and discuss the role of the Earth Physics Branch in co-ordinating offshore gravity surveys. The release of gravity data is discussed under two headings corresponding to multi-parameter surveys and to gravity surveys carried out by EPB on ice or underwater. Finally we present a list of priorities and a proposed program in four phases. Specifications for three types of offshore gravity surveys are given in Appendix I. General specifications for gravity surveys are summarized in Appendix II.

...2

DEPARTMENTAL CONCERNS OFFSHORE RELATED TO GRAVITY

Gravity data are but one of many inputs which provide the geoscience information base upon which government can develop national policies for management of energy and mineral resources and for management of the landmass for the benefit of all Canadians.

Geoscience Surveys are required in the offshore regions of Canada to assist the government with the formulation of policies in three major areas;

1. Ocean policy as it concerns offshore boundaries, national sovereignty, and international relations concerning the exploitation and management of non-renewable resources of the oceans and seafloor.
2. Policies concerning all aspects of offshore primary non-renewable resources.
3. Policies concerning offshore land use and land management.

More specifically, gravity surveys contribute directly to several major concerns of the Department in the offshore:

1. Knowledge of the tectonic framework and history of offshore regions.
2. Detailed knowledge of the geoid in Canada.
3. Understanding the dynamics of the landmass in relation to adjacent continental and oceanic regions.
4. Identification of the extent of the Canadian landmass beneath the seas.
5. Encouragement of exploration for natural resources.

...3

ROLE OF EPB IN COORDINATION OF OFFSHORE REGIONAL GRAVITY PROGRAM

Marine geoscience survey programs involving the collection of gravity data with various densities of coverage are presently in progress in the Arctic, Pacific and Atlantic regions. In the Arctic, EPB has a continuing program to map the gravity field over ice-covered regions. These surveys are carried out in co-operation with hydrographers of CHS(C) with logistical support from the Polar Continental Shelf Project (PCSP) of EMR. Ship surveys (usually multiparameter) of the Arctic region have been mounted from Victoria (western Arctic) and Dartmouth (eastern Arctic). Authorship of these Arctic surveys has been divided between EPB, GSC(V), CHS(P) in the west, and AGC and CHS(A) in the east.

In the Pacific region multiparameter surveys have been made by EPB, GSC(V), CHS(P) and on occasion by AGC. In the Atlantic region AGC, CHS(A) and on occasion EPB have participated in multiparameter cruises of the Resource Mapping program. AGC has also been deeply involved in surveys of a more local nature in support of marine geological problems, and in other multidisciplinary studies. EPB has also completed extensive underwater gravity measurements in the eastern region.

As the foregoing shows, a number of groups have been involved with gravity work. These groups in the past have proceeded largely in an uncoordinated way as manifested by some duplication of effort, unexplained differences in gravity datum and lack of uniformity in gravity standards. In an effort to overcome these difficulties it is strongly recommended that all Departmental agencies involved in gravity surveys consult with Gravity Division, Earth Physics Branch so that national standards may be maintained

...4

in all surveys. The Gravity Division in keeping with its mandate and within the terms of reference of the national gravity mapping program offers to coordinate all government sponsored offshore gravity surveys and to regulate standards by:

1. participating in planning stages of gravity surveys
2. offering advice on specifications for surveys and signature lines.
3. providing gravimeter calibration lines and gravity control stations.
4. participating in the assessment of gravimeter performance.
5. maintaining a national gravity library containing gravity data from various government agencies and other sources.
6. reviewing all gravity maps before publication to ensure consistency with existing data.
7. providing personnel and instrumentation to participate in multi-parameter surveys, subject to availability of resources.

Release of Gravity Data

(a) Resource Mapping Surveys (in which gravity is but one of several parameters measured)

Adjusted gravity data in digital form collected to the specifications of the Resource Mapping program will be released as soon as possible after completion of a survey. Notice of release of these data will be by GSC open file along with other geophysical data collected during the same cruise.

Release of gravity data by open file will be followed by publication of data in map form, either in the DOE-EMR Resource Chart series or in the Gravity Map Series of EPB.

(b) Gravity Surveys on Sea Ice and Underwater Gravity Surveys (in which gravity is the sole geoscience parameter measured).

Finally adjusted gravity data will initially be released by an EPB open file system. Publication in the Gravity Map Series of EPB will follow as soon as possible after completion of a survey. In some cases data may be released initially in the Gravity Map Series without going through EPB open file system.

Gravity Data File

The Earth Physics Branch presently maintains a gravity data file and retrieval system which provides digital data from EPB surveys to user specifications. Data may be obtained as a plot or listing or on cards or tape according to retrieval charges specified in the EPB Index of Publications. Data released by the Atlantic Geoscience Centre have now been incorporated into this file although AGC still continues to release combined gravity and magnetic data in digital form through the Computer Science Centre. At present EPB releases AGC gravity data only in the form of digital map plots - a service which is not available through CSC. In order to achieve some degree of uniformity, we suggest that all digital gravity data be released only by the EPB gravity data centre. If present plans for ERDS materialize this centre will function as a node of ERDS.

EPB and AGC should work toward development of uniform procedures to observe and reduce marine gravity observations and thereby ease the problems of incorporating these data into the national file. Toward this end a set of specifications for marine gravity surveys is given in the appendices.

Similar files for offshore magnetic data, CSP data and bathymetric data should be maintained by experts in appropriate agencies within government. The question of who will maintain and operate these files will undoubtedly be considered in future planning for ERDS.

PROPOSED PROGRAM FOR OFFSHORE REGIONAL GRAVITY SURVEYS

Priority Areas

1. Labrador Shelf and the inter-island channels of the Arctic

Both are areas of active exploration and high hydrocarbon potential. Regional geoscience data are required by both government and industry for planning and assessment purposes.

2. Hudson Bay and West Coast

Commercial exploration is beginning again in these areas and should be encouraged by the provision of regional geoscience data as soon as possible, again, for both planning and assessment purposes.

3. Baffin Bay, Foxe Basin, Arctic Ocean

These are frontier areas for imminent exploration and development. The requirement for regional geoscience data is important at this pre-exploration stage.

Program

This program is for completion of regional gravity surveys of the priority areas. It will be complemented by more detailed local investigations which are not specifically included here. Where coordinated or multiparameter surveys carried out by regional units contribute to the regional gravity program they are included except where the objectives of the regional gravity program may be achieved sooner without significant disruption. Other ships carrying gravity meters will contribute to the program but their contribution will be small compared with that from systematic surveys such as the Resource Mapping program, and so they are not included.

Phase I (1975)

AREA	Responsible Agency					Ship, etc.	Navigation	Comments
	OIC	MAGNETICS	GRAVITY	CSP	BATHYMETRY			
Western Arctic	PCSP	-	EPB	-	CHS	Helicopter	Decca	Ice Survey, station interval 6 km west of Banks Island and supplementary measurements 6 km spacing in Amundsen Gulf. March-April.
Hudson Bay								
(a)	EPB CHS(C)	GSC?	EPB	-	CHS(C)	Helicopter	Decca	Ice survey, station interval 6 km James Bay. February - March.
(b)	CHS(C)	AGG?	EPB	AGC?	CHS(C)	Narwhal	Satnav plus sonar doppler	Signature lines U/W meter at Mansel I., S.W. of Belcher Is., Cape Churchill. Reconnaissance survey, line spacing 45 km to be followed by interlining in subsequent years. S/meter, July - September
Labrador Shelf	CHS(A)	AGC	AGC	AGC	CHS(A)	Minna? Hudson?	Loran C	Resource Charting Program June-October. Reduce overall line spacing to 12 km
West Coast	CHS(P)	GSC(V)	EPB	GSC(V)	CHSP	Parizeau?	Hi - Fix?	Resource Charting Program May-June. Hecate Strait-Dixon Entrance?

Phase II (1976)

Area	Responsible Agency					Ship, etc	Navigation	Comments
	OIC	MAGNETICS	GRAVITY	CSP	BATHYMETRY			
Arctic	PCSP	-	EPB	-	CHS	Helicopter	Decca?	Ice survey, station interval 6 km. Viscount Melville Sound I March-May
Hudson Bay								
(a)	EPB CHS(C)	-	EPB	-	CHS(C)	Helicopter	Decca	Ice survey, station interval 6 km. James Bay - East Hudson Bay. February - March.
(b)	CHS(C)	AGC?	EPB	AGC?	CHS(C)	Narwhal	Satnav plus sonar doppler	Hudson Bay first phase of interlinir 45 km. July - September
Labrador Shelf and/or Hudson Strait	CHS(A)	AGC	AGC	AGC	CHS(A)	Minna?	Loran C	Resource Charting Program. June - October.
West Coast?	CHS(P)	GSC	EPB	GSC(V)	CHS(P)	Parizeau	Decca?	Resource Charting Program. May - June

Phase III (1977)

Area	Responsible Agency					Ship, etc.	Navigation	Comments
	OIC	MAGNETICS	GRAVITY	CSP	BATHYMETRY			
Arctic	PCSP	-	EPB	-	CHS	Helicopter	Decca?	Ice survey, station interval 6 km. Viscount Melville Sound II March - May
Hudson Bay								
(a)	EPB CHS(C)	-	EPB	-	CHS(C)	Helicopter	Decca?	Ice survey, station interval 6 km. E. Hudson Bay if not finished in Phase II. February - March.
(b)	CHS(C)	AGC?	EPB	AGC?	CHS(C)	Narwhal	Satnav plus sonar doppler	Hudson Bay second phase interlining 45 km. July-September.
Hudson Strait Davis Strait	CHS(A)	AGC	AGC	AGC	CHS(A)	Minna?	Loran C and Decca?	Resource Charting Program. July - September.
West Coast	CHS(P)	GSC	EPB	GSC(V)	CHS(P)	Parizeau	Decca or inertial	Regional survey up to 400 km off-shore. May - June.

Beyond Phase III

Plans are less firm beyond Phase III. In the Arctic, ice surveys are planned as listed below to 1980.

Area	Responsible Agency					Ship, Etc.	Navigation	Comments
	OIC	MAGNETICS	GRAVITY	CSP	BATHYMETRY			
Arctic	PCSP		EPB	-	CHS(C)	Helicopter	Decca?	Ice survey, station interval 6 km. McLintock Channel? March - April, 1978
Arctic	PCSP	-	EPB	-	CHS(C)	Helicopter	Decca?	Ice survey, station interval 6 km. Foxe Basin I. March - April, 1979.
Arctic	PCSP	-	EPB	-	CHS(C)	Helicopter	Decca?	Ice survey station interval 6 km. Foxe Basin II. March - April, 1980

As well as its coordinating role, EPB will contribute approximately two sea-ice surveys (Arctic and Hudson Bay) and two shipboard surface meter operations (West Coast and Hudson Bay) to the national program in each of the next three years. The exact level of output each year, will depend on maintaining the present level of A budget support plus additional funds for rental of navigation aids as requested. The program is divided into phases, each of which corresponds approximately to a year of operations. It is recognized that any proposed co-operative offshore program must be flexible and subject to the changing priorities within participating departments and the availability of ships, navigation aids, scientific equipment and experienced personnel.

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APPENDIX I

SPECIFICATIONS FOR OFFSHORE GRAVITY SURVEYS

1.0 Sea Surface Gravity Data

1.1 Gravity Measurements

The gravity survey must be consistent in datum and scale with the National Gravity Net. Gravimeter scale correction factors must be determined from multiple readings at two or more National Gravity Net stations separated by a gravity interval greater than the expected variation of gravity in the survey area, and lying in the same latitude range. The determination of the instrument scale correction factor and connections to the National Gravity Net must be sufficiently accurate to ensure that the survey datum error is not greater than 1 mgal with respect to the National Gravity Net.

Base station measurements should be repeated as frequently as possible during the course of the survey. The survey must include a series of tracks through a gravity test range, or along the lengths of established signature lines. Total system performance will meet minimum specifications if true errors, as defined by the difference between signature line gravity values and processed gravity values, are normally distributed about a mean value differing from zero by less than 1 mgal and have a standard deviation of less than 3 mgal.

Cross-over points should be evenly distributed in both time and area throughout the survey. Cross-over differences of free air anomaly (defined as earliest measurement minus latest measurement) should be normally distributed about a mean value of zero with a maximum standard deviation of 3 mgal for deep ocean surveys and 2 mgal for surveys carried out on the continental shelves and inland waters.

1.2 Water Depth

Calibration of the depth sounder must be performed at the commencement and completion of the survey. A report of the calibration procedure should indicate all system errors and reduction techniques used. Crossover differences in depths, expressed as a percent of depth should be normally distributed about a zero mean with a maximum standard deviation of 2 percent.

1.3 Navigation System

The operator must ensure that the navigation system used is capable of providing Eötvös corrections at the specified sample rate (usually 5-10 minutes) accurate to 1 mgal. Point locations must be determined with a maximum standard deviation of 200 m or less.

1.4 Data Collection

Gravity data must be collected and supplied at specified time intervals (usually corresponding to 1 km point spacing) on IBM compatible magnetic tape along with time, latitude, longitude, water depth, velocity components, and Eotvos correction.

2.0 Sea Ice Gravity Data

2.1 Gravity Measurements

Observations will be made using LaCoste and Romberg damped geodetic gravimeters. The gravity observations must be consistent in datum and scale with the National Gravity Net. Instrument calibrations, and connections to

the National Gravity Net must be sufficiently accurate to ensure that the survey datum is not in error by more than 0.15 mgal with respect to the National Gravity Net.

The standard deviation of a series of repeat measurements should not exceed 0.4 mgal.

2.2 Water Depth

Depth sounder calibrations must be carried out before the commencement and after completion of the survey. A report of the calibration procedure should indicate all system errors and reduction techniques used. The standard deviation of a series of repeated depth measurements expressed as a percent of depth must not exceed 1 percent for depths <600 m or 2 percent for depths >600 m.

2.3 Navigation System

The navigation system used to determine the geographical location of individual observation sites must be capable of a positioning accuracy better than ±200 m. Horizontal survey control must be linked to the national geodetic network such that positional errors do not exceed specified limits in the survey area.

2.4 Quality Control

A random repeat sampling of 5 percent of the observations is required. The standard deviation of the Bouguer anomaly for these repeat stations must not exceed 2 mgal.

3.0 Underwater Gravity Data

3.1 Gravity Measurements

The gravity observations will be made by LaCoste and Romberg underwater gravimeters. Observations must be consistent in datum and scale with the National Gravity Net. Gravimeter calibrations and connections to the National Gravity Net must be sufficiently accurate to ensure that the gravity datum in the survey area has a maximum error of 0.2 mgal.

The standard deviation of the gravity observation, determined by repeat measurements, must not exceed 0.5 mgal.

3.2 Water Depth

The depth measuring equipment must be calibrated before the commencement and after completion of the survey. Equipment calibration procedures should indicate all system errors and reduction techniques used. The standard deviation of a series of repeat depth measurements expressed as a percent of depth must not exceed 1 percent.

3.3 Navigation System

Offshore underwater gravity surveys should strive for horizontal positioning having an accuracy of ±200 m. This specification recognizes that reconnaissance surveys may be carried out at such distances from shore that currently available navigation systems are incapable of meeting this standard. In such cases this standard may be relaxed.

3.4 Quality Control

A minimum repeat sampling of 5 percent of the observed data, randomly distributed in the survey area, is required. The standard deviation of the free air anomaly for repeated stations should not exceed 1 mgal.

APPENDIX II

SUMMARY OF GENERAL SPECIFICATIONS FOR GRAVITY SURVEYS

1. Regional Reconnaissance Surveys

Gravity station spacing 6-15 km
Track spacing 1-20 km
Standard deviation of horizontal positioning 200 m
Standard deviation of elevation 8 m
Standard deviation of water depth (<600 m) 1% of depth
Standard deviation of water depth (>600 m) 2% of depth
Standard deviation of Bouguer anomaly 2 mgal (land surveys*)
Standard deviation of free air anomaly 2 mgal (offshore surveys - continental shelves
Standard deviation of free air anomaly 3 mgal (offshore surveys - deep oceans)

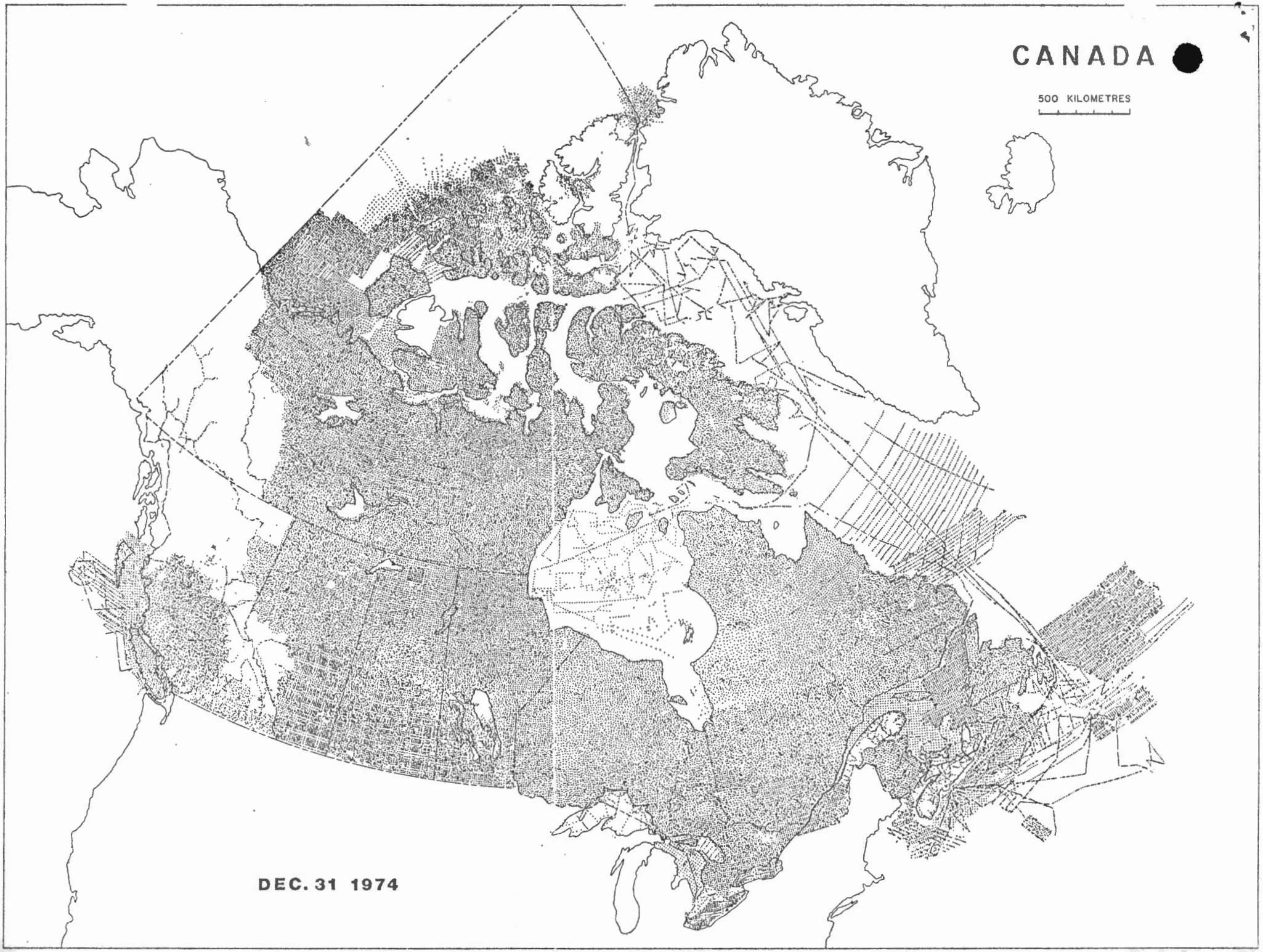
2. Regional Detailed Surveys

Gravity station spacing 1-5 km
Standard deviation of horizontal positioning 50 m
Standard deviation of elevation 3 m
Standard deviation of water depth (<600 m) 1% of depth
Standard deviation of water depth (>600 m) 2% of depth
Standard deviation of Bouguer anomaly 1 mgal (land surveys*)
Standard deviation of free air anomaly 1 mgal (offshore surveys)

3. Local Detailed Surveys

Gravity station spacing <1 km
Standard deviation of horizontal positioning 2 m
Standard deviation of elevation 15 cm
Standard deviation of water depth (<600 m) 1% of depth
Standard deviation of Bouguer anomaly 0.1 mgal (land surveys*)
Standard deviation of free air anomaly 0.4 mgal (offshore surveys)

* land surveys include ice surveys over inland lakes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