GRAVITY MAP SERIES

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Ottawa

A Regional Gravity Survey of Devon and Southern Ellesmere Islands

Canadian Arctic Archipelago with map

No. 87 - Devon Island and Southern Ellesmere Island

Donald D. Picklyk

CANADA

Department of Energy, Mines and Resources

OBSERVATORIES BRANCH

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INTRODUCTION

During the summer of 1967, a Dominion Observatory field party in co-operation with the Polar Continental Shelf Project made a regional gravity survey of Devon Island east of longitude 89° W and southern Ellesmere Island east of longitude 88° W (Figure 1). Baumann Fiord in the west and Makinson Inlet in the east mark the northern limits of the survey of Ellesmere Island. Stations were also established on Coburg Island and Philpotts Island. Some 463 stations were occupied during the survey which was part of the Observatory's continuing program to map the Arctic Islands.

The results of the survey are presented as a Bouguer anomaly map (in pocket) at a scale of 1:500,000. Some earlier results obtained by the Observatory in 1961 and 1962 (Sobczak, et al., 1963) are incorporated in the map.

Prior to the gravity surveys little geophysical work had been done in this area. Hyndman (1965) has published the results of gravity measurements over the Devon Ice Cap which were tied to the Observatory base network. The results of some aeromagnetic and radiometric flight lines across the area have been reported by Gregory, et al. (1961). Barrett (1966) made a shipborne magnetometer survey of Lancaster Sound between Devon Island and Baffin Island.

Physiography

Most of the area surveyed on Devon Island is a plateau of flat-lying, clastic and carbonate sediments bounded at the coast by cliffs reaching as high as 1000 feet. In the interior the plateau is dissected by deeply gouged river valleys. The eastern part of the island is mountainous and has a central ice cap which has an average elevation of about 4500 feet.

Much of the Bjorne Peninsula, Ellesmere Island, forms part of the Norwegian Bay Lowlands. South of these lowlands and separated from them by a transitional belt of ridged uplands is a central plateau which is an extension of the Devon Island Plateau. Ice caps occur on this plateau northwest of Heim Peninsula and in the highlands to the east of the plateau.

GEOLOGY

The rocks of the survey area range from Precambrian to Recent and generally increase in age easterly to Baffin Bay. As will be shown, the gravity anomaly field can be related to several structural provinces which have been recognized within the area (Figure 2). These provinces are: (i) the Canadian Shield, (ii) the Central Stable Region, (iii) the Franklinian Miogeosyncline, and (iv) the Sverdrup Basin.

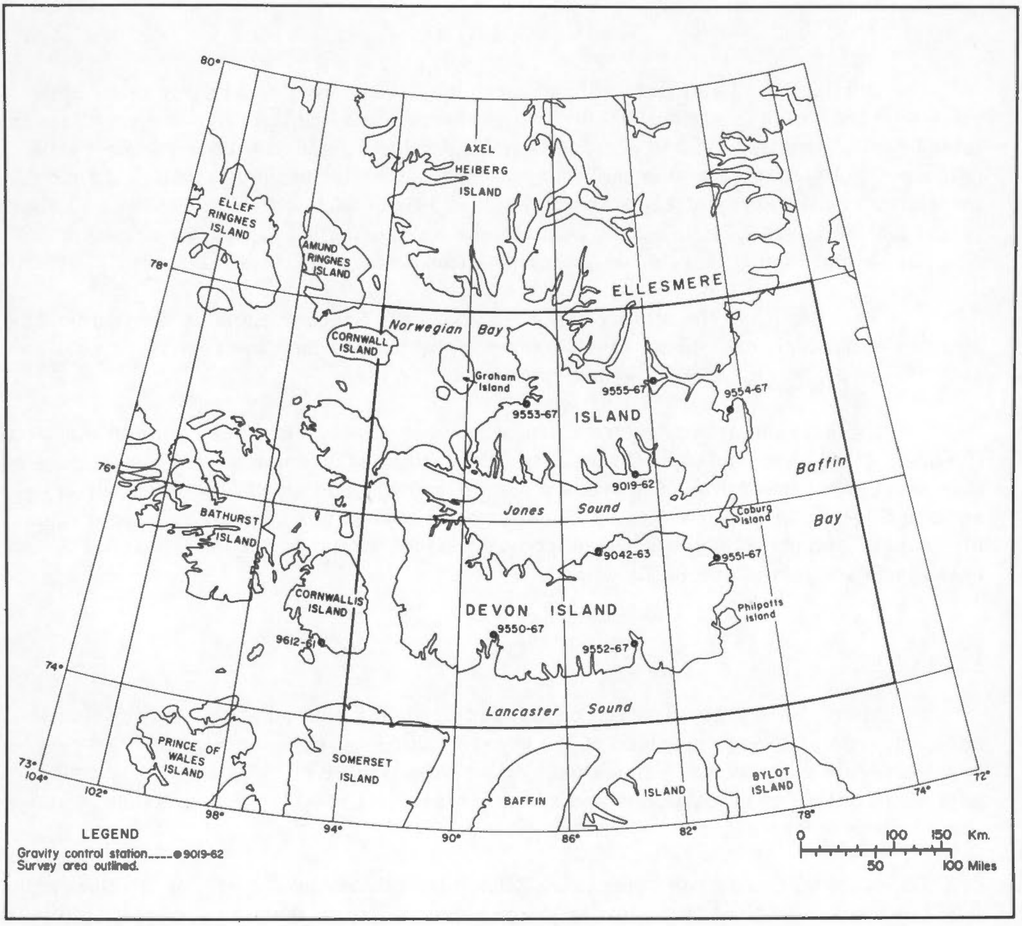

Figure 1. Location map.

(i) The Canadian Shield

Christie (1962) described the rocks of the Canadian Shield on Ellesmere Island as gneiss, granite, migmatite and related rocks. These rocks include metasediments, crystalline limestone, lime-silicate rocks, gneiss intruded by pegmatite and granite and granitic gneiss. Similar rocks of the same age were described by Roots in Fortier, et al. (1963) in the Cape Sparbo region of Devon Island. Notable differences are the absence of crystalline limestone and lime-silicate rocks and the presence of granulite. Further east, samples similar to the Precambrian rocks of eastern Ellesmere Island were collected.

(ii) The Central Stable Region

With the exception of Recent beach deposits and two areas of the Eureka Sound Formation (Cretaceous), the Central Stable Region is underlain by sedimentary rocks ranging in age from Cambrian (or older) to Ordovician. The rocks are mainly limestone, dolomitic limestone, gypsum, argillaceous limestone, sandstone and shale. In general the sequence is from older carbonates to younger clastic rocks. The gypsum is found in the Middle Ordovician Cornwallis Group*.

(iii) The Franklinian Miogeosyncline

The rocks of the Franklinian Miogeosyncline in the map area are mainly Devonian. The Lower and Middle Devonian beds are composed primarily of limestone with argillaceous limestone, silty limestone, dolomitic limestone, silty dolomite and a few shale members. The Upper Devonian beds are mainly non-marine sandstones, shales and some coal seams.

(iv) The Sverdrup Basin

The Sverdrup Basin contains both marine and non-marine rocks which range from Pennsylvanian to Tertiary. The rocks are of variable composition and include chert and cherty limestone, shale, siltstone, sandstone and pebbly sandstone. Coal and peaty lignite are found in some of the non-marine members. Recent emergent beaches are widespread in some areas, especially on Graham Island.

GRAVITY SURVEY

A local network of gravity control stations (Figure 1) tied to the Arctic Gravity Control Network was established using a LaCoste and Romberg gravimeter, G-139.

*Kerr (1967a) has proposed that the Cornwallis Formation, as it appears on maps 1099A and 100A in Fortier, et al. (1963) be raised to Group status retaining the original stratigraphic boundaries.

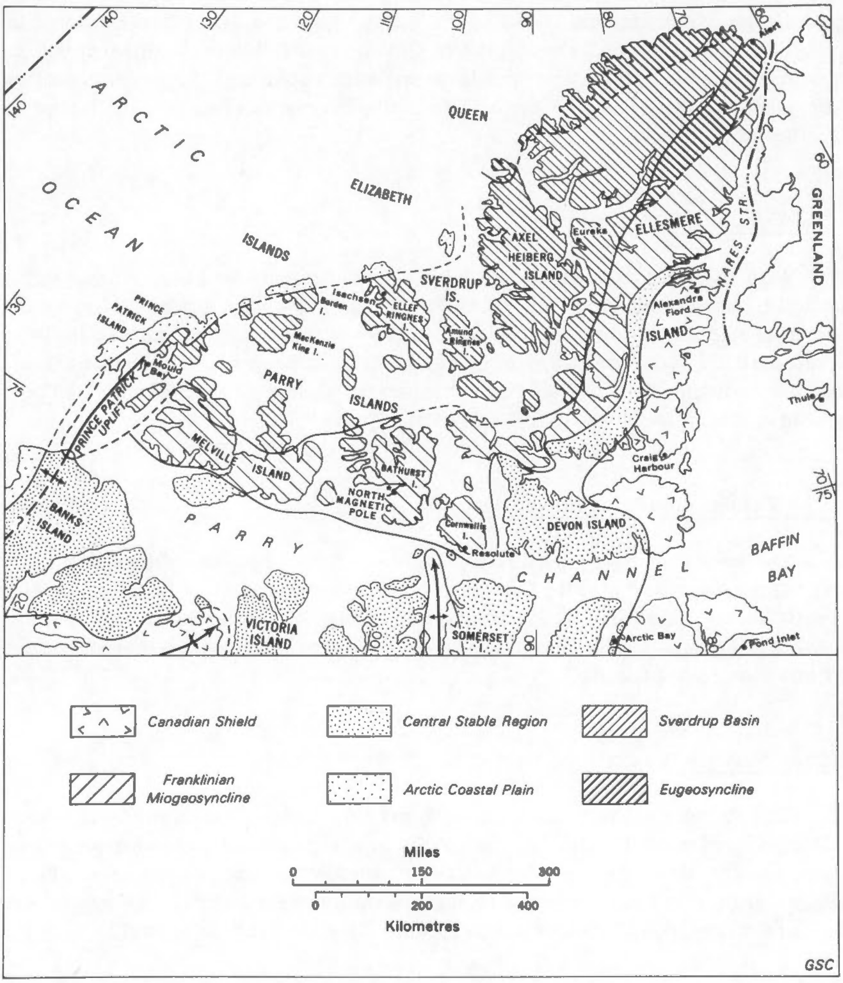

Figure 2. Stratigraphic-structural provinces in the Queen Elizabeth Islands (after Kerr, 1967a).

This instrument is thermostatically controlled and was operated at a temperature of 40.5°C. The base network was tied to known values at Resolute Bay (9612-61), Cape Newman Smith (9042-63) and Grise Fiord (9019-62). Secondary stations were occupied with a thermostatically controlled Worden gravimeter W-573 operated at a temperature of 20°C. A total of 463 stations were occupied during 48 traverses in a Bell 47G4A helicopter; 229 stations were established on Devon, Philpotts and Coburg Islands and 234 stations were occupied on Ellesmere Island. The mountainous terrain and the widespread icefields prevented a regular 8-mile grid of stations; the actual spacing varies from 4 to 10 miles.

Horizontal control was obtained by plotting station positions on 1:125,000 maps, which were preliminary prints of the 1:250,000 topographic maps of the area. The latitude and longitude of each station were scaled from these prints to within one tenth of a mile.

Elevations were obtained using a pair of Wallace and Tiernan altimeters. Points of known elevation (for example, Topographic Survey markers, sea level and barometrically established control points) were visited as often as possible during the traverses. About 20 per cent of the stations were established at these control elevations.

Data Reduction

Preliminary results were reduced in the field as the survey progressed. Final results were processed using the method of Tanner and Buck (1964). A density of 2.67 g/cm^3 was used in the Bouguer correction. Terrain corrections were applied to 30 stations on Devon Island; these included all base stations, all stations where changes in relief were extreme and some stations in area of lower relief. Normally the terrain corrections were in the range of 0.5 to 2.9 mgal with a mean of 2.0 mgal. However in cases of extreme relief the corrections varied between 3.4 and 13.1 mgal with a mean of 6.5 mgal. Principal facts and base station locations are available on request from the Gravity Division, Dominion Observatory, Ottawa 3, Ontario.

Accuracy of the Results

The simple Bouguer anomalies are accurate to within 2 mgal. This value includes errors of up to 1.8 mgal caused by elevation errors of up to 30 feet and errors of up to 0.05 and 0.15 mgal in observed gravity values and in scaling latitudes, respectively.

Those stations without terrain corrections may have errors of up to 3 mgal on Devon Island and a much higher error of about 6 to 10 mgal on Ellesmere Island where no terrain effects were considered as detailed topographic maps were not available. The omission of terrain corrections in this preliminary report will not severely affect the preliminary correlation of the regional anomalies of very large amplitude with geology.

ROCK DENSITIES

Rock samples were collected at 109 stations for density determinations. Extreme weathering of many outcrops at station locations hampered the collection of a representative suite of rocks. However, the samples were divided into three broad groups to determine whether a regional variation in density could be related to the gravity field. These groups are as follows: (i) igneous and metamorphic rocks of dominantly sialic composition including granite, granitic gneiss and granulite; (ii) igneous and metamorphic rocks of dominantly mafic composition including gabbro, metagabbro and diorite; (iii) sedimentary rocks including dolomite, dolomitic limestone and limestone. The results of the density measurements are listed in the table. The average density of both the sialic rocks and the sedimentary rocks is 2.67 g/cm^3. This result would suggest that there is no direct relationship between the anomaly variations and surface densities on a regional scale because the sialic and sedimentary rocks which underly most of the area have the same average density and the denser mafic rocks are of limited, more local occurrence.

The large ranges in density seen in the table are the result of a few singular samples. In particular areas, rocks of abnormal density, if present in large enough quantities, could explain some of the local anomalies.

ROCK DENSITIES FROM SURFACE SAMPLING

Rock Type	Number of Samples	Range (g/cm^3)	Average Density (g/cm^3)
Igneous and metamorphic rocks of sialic composition	62	2.57 - 3.01	2.67
Sedimentary rocks	36	2.06 - 2.81	2.67
Igneous and metamorphic rocks of mafic composition	11	2.66 - 3.08	2.83

PRELIMINARY CORRELATION OF BOUGUER ANOMALIES WITH GEOLOGY

In this report only a brief description of the anomalies and their probable relations with the geology of the area is made. Inspection of the regional geological and Bouguer anomaly maps reveals that each of the major structural units already described has a distinctive gravity pattern. Each unit will be described in turn.

Canadian Shield

The gravity pattern over the Shield areas is characterized, in both Devon and Ellesmere Islands, by steep gravity gradients up to 6 mgal/mile and large variations in amplitude of up to 90 mgal. In Devon Island the easterly gravity trends are in sharp contrast to the northerly trends in Ellesmere Island. Steep gradients rise to the southeast coast of Devon Island where the maximum anomaly is 100 mgal at Cape Sherard and parallel the east coast of Ellesmere Island where the maximum anomaly attained is 40 mgal south of Clarence Head. In both areas the high anomalies are underlain by granitic gneiss and although some mafic dykes occur at Cape Sherard and some andesite and basalt have been reported at Clarence Head and Cape Combermere (Christie, 1962) there are no exposures of large bodies of dense rock in either area which could cause the high gravity anomalies. The anomaly must therefore be explained by the presence of high-density intra-crustal intrusive rocks or local crustal thinning which would bring high-density mantle material closer to the surface. Kerr (1967b, c) has presented arguments for the translational and rotational separation of Greenland from Ellesmere Island. As a result of this movement Baffin Bay is believed to be underlain by a down-faulted remanent of continental crust. In the light of Kerr's theories, large faults which parallel the east coast of Ellesmere Island and the south coast of Devon Island (Barrett, 1966), may penetrate the entire crust, and may be tectonically related to the basic masses necessary to explain the gravity anomalies which trend parallel to the faults. Further gravity surveys, particularly of Lancaster Sound and Baffin Bay, are required before a quantitative study of these interesting anomalies can be undertaken. Similar positive gravity anomalies along the east coast of Bylot Island (Berkhout, 1968) may be related to the anomalies of Ellesmere and Devon Islands.

Central Stable Region

On Devon Island the anomalies of the Central Stable Region generally range from about 10 to -20 mgal. The surface rocks are mainly Lower Paleozoic sediments which thicken to the west over the Devon homocline (Fortier, et al., 1963). There is no obvious correlation between the anomalies and geology apart from a local minimum of -10 mgal which is underlain by the Haughton dome located in a belt of Cornwallis Group sediments of Middle Ordovician age which stretches north-south across the island from Thomas Lee Inlet to Maxwell Bay. Only five gravity stations define this low and more work would be required for quantitative interpretation. A belt of negative anomalies which parallels the southwestern coast from Burnett Inlet to Beechey Island perpendicular to the geological strike offers no obvious correlation with the surface geology.

On central Ellesmere Island between Grise Fiord and Swinnerton Peninsula there is a large, regional, north-trending low over Lower Paleozoic rocks. This low extends southward as far as the north coast of Devon Island where it terminates in the vicinity of the fault or faults which parallel the north Devon coast (Gregory, et al., 1961). The low is bounded to the west by a steep gravity gradient which again may mark a fault zone in basement rocks. The magnitude of the low (35 to 50 mgal) requires 10,000 to 15,000 feet of low-density sandstone or gypsum (density contrast of 0.3

g/cm^3), or an intrusion of granitic rocks (density contrast of 0.15 g/cm^3) in the basement 15,000 to 25,000 feet thick. As the sediments between Grise Fiord and Makinson Inlet are generally believed to be gently dipping thin beds on the edge of the Franklinian Miogeosyncline the anomaly probably represents a lighter rock type within the basement.

The Franklinian Miogeosyncline and Sverdrup Basin

The gravity field over the Franklinian Miogeosyncline is generally flat and does not indicate the known great thickness of the sediments of the area. This is not unexpected as much of the miogeosyncline is composed of limestone and dolomite beds with densities similar to those of rocks of the Precambrian basement.

There is a large gravity low over Bjorne Peninsula and Graham Island which can be related to the low-density clastic sediments of the Shei syncline (Fortier, et al., 1963) and the Sverdrup Basin. A thickness of 10,000 feet or more is suggested by the gravity anomaly if the density contrast is -0.3 g/cm^3.

CONCLUSIONS

Although detailed interpretation of the gravity field in the map area must await further geological and geophysical studies certain correlations are clear.

1. Large gravity anomalies on the coast of Ellesmere, Devon and Bylot Islands can be correlated with postulated fault movements in the Baffin Bay area which may have allowed dense rocks to move nearer the surface.

2. A large gravity low over the Central Stable Region on Ellesmere Island is probably related to basement structure.

3. A large gravity low over Bjorne Peninsula and Graham Island is related to low-density sediments of the Sverdrup Basin and Shei syncline.

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