Gravity and bathymetry taken along seismic refraction lines from the Canadian Ice Island during 1985 and 1986[1]

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Abstract

As part of the Frontier Geoscience Program a combined gravity – bathymetry survey along four seismic refraction lines was carried out during the spring of 1985 and 1986 from the Canadian Ice Island base camp located on the Arctic Ocean about 30 to 40 km northwest of Axel Heiberg Island, N.W.T. A total of 140 gravity observations and 124 water depth measurements were made along two lines parallel, and two lines perpendicular to the coastline of the Queen Elizabeth Islands.

Water depth measurements from these surveys combined with previous data indicate two hitherto unmapped ridges and valleys striking perpendicular to the trend of the Queen Elizabeth Shelf.

Gravity measurements indicate an elongated coastal Bouguer anomaly "high", subparallel to the coastline, with accompanying landward trending spurs. These anomalies overlie the northeastern end of the Sverdrup Rim at the northwestern end of Ellesmere Island where the Bourne Complex and Unnamed Formation, consisting of volcanic basalt flows with dense mafic intrusions, are exposed.

Résumé

Au printemps de 1985 et de 1986, dans le cadre du Programme géoscientifique des régions pionnières, un relevé combiné de gravité-bathymétrie a été effectué le long de quatre lignes de sismique réfraction à partir du camp de base de la Canadian Ice Island située dans l'océan Arctique à environ 30 ou 40 km au nord-ouest de l'île Axel-Heiberg (T.N.-O.). Au total, 140 observations gravimétriques et 124 mesures de bathymétrie ont été recueillies le long de 2 lignes parallèles et de 2 lignes perpendiculaires à la côte des îles Reine Elizabeth.

Les relevés bathymétriques annexés aux données antérieures montrent l'existence de deux crêtes et de deux vallées jusqu'ici inconnues, d'orientation perpendiculaire à la direction générale du plateau continental Reine Elizabeth.

Les mesures gravimétriques indiquent l'existence d'une anomalie de Bouguer positive subparallèle à la côte et avec des ramifications dans la direction de cette dernière. Cette anomalie coïncide avec l'extrémité nord-est du bassin de Sverdrup et l'extrémité nord-ouest de l'île Ellesmere où sont exposés le complexe de Bourne et la formation Sans Nom constitués de coulées volcaniques de basalte et d'intrusions mafiques denses.

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INTRODUCTION

During April, 1985 and April to May, 1986, 140 gravity and 124 water depth measurements were made along seismic refraction lines (Fig. 28.1) in support of the seismic refraction program (The Refraction Team, 1986). The Polar Continental Shelf Project (PCSP) camp on the Canadian Ice Island (CII) was used as a base.

Gravity observations were made with Lacoste-Romberg G gravimeters on the ice surface at about 5 km intervals at the locations of the seismic recording sites and shot points. Water depths were determined at the same sites using seismic water depth sounders.

This report discusses primarily the new gravity and bathymetry data obtained in 1985 and 1986. Field procedures

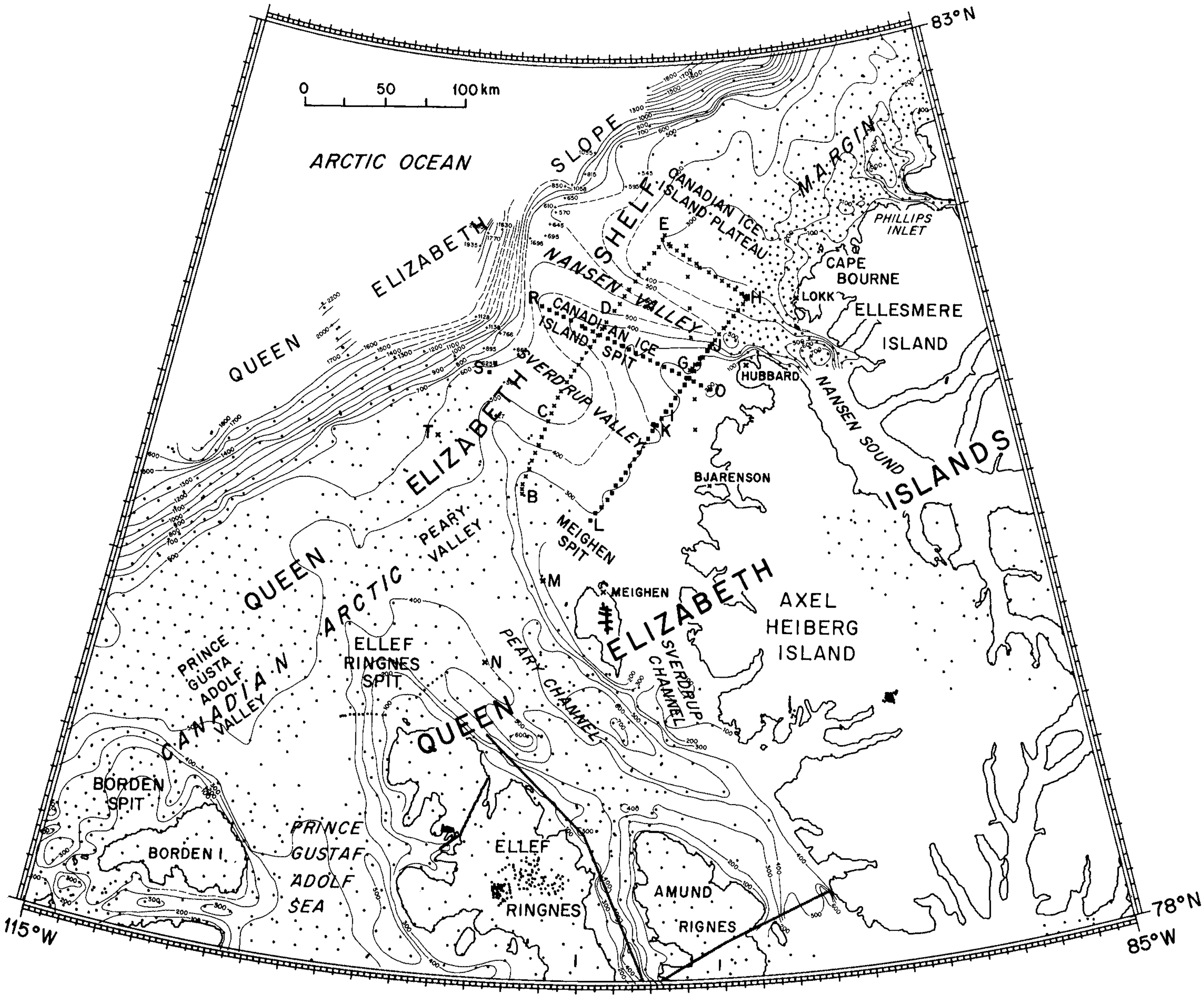

Figure 28.1. Location of gravity and water depth measurements are shown by dots prior to 1985, crosses for 1985 and squares for 1986. The shot points are lettered. Water depths are in metres corrected for temperature and salinity using Matthews' velocity – depth relationship (Matthews, 1939). Depth contours are at 100 m intervals (dashed contours show regions of poor control). The Syledis transmitters are located at Lokk, Hubbard, Bjarenson, Meighen and the Ice Island (I).

and instrumentation have been discussed elsewhere by Sobczak and Schmidt (1985), Sobczak and Weber (1986) and Weber and Sobczak (1986).

THE SURVEY

Navigation was provided by a Syledis UHF positioning system, loaned and operated by the Canadian Hydrographic Survey, Department of Fisheries and Oceans at the Bedford Institute of Oceangraphy. Five unmanned transmitter stations were situated at Lokk, Hubbard, Bjarnason, Meighen and on the CII, which was located near shot point H in 1985 and near point I in 1986 (Fig. 28.1). The stations were positioned by means of a model T14100 Global Positioning System (GPS) to an accuracy of ±40 m absolute (J. Popelar, personal communication, 1986). The helicopters used for the survey were equipped with Syledis UHF as well as Omega VLF receivers. The positioning accuracy of the Syledis system depends on the distance from the transmitters, on the geometrical configuration of transmitters and on the accuracy of the transmitter antennae locations. Comparison of the Syledis and GPS positions on the CII indicated a difference of less than 20 m.

Water depths were determined by a seismic reflection method using 0.5 to 1 kg charges of geogel (Weber and Sobczak, 1986). The seismic recorder determined two-way travel time to an accuracy of ± 0.5 ms, corresponding to a ± 0.7 m of water depth. Travel time was converted to water depth using Mathew's velocity – depth relationship (Sobczak et al., 1973).

The gravity difference between the CII and the gravity control station in Resolute Bay was determined with the two LaCoste-Romberg gravimeters, G75 and G498, during deployment and again at evacuation. During the survey period G75 was used as a base monitor housed in a temperature-controlled environment while G498 was used on traverse. The CII did not move significantly between deployment and evacuation. The accuracy of individual gravity measurements are estimated at ± 0.1 mGal (1 mGal = 10 $\mu m/s^2$). Gravity measurements were reduced to free-air and Bouguer anomalies by the method described by Tanner and Buck (1964) using the International Gravity Standardization Net, 1971 (1974) and the Geodetic Reference System, 1967 (1971).

RESULTS

Bathymetry, including new names proposed for undersea features, free-air and Bouguer anomalies are discussed below and shown in Figures 28.1 to 28.3. The new names have been submitted for approval to the Advisory Committee on Undersea Feature Names.

Bathymetry

Water depths taken along the seismic refraction lines during 1985 and 1986 combined with data from earlier surveys (Sobczak et al., 1963; Weber, 1963; Weber and Sweeney, 1985) and the twenty-six water depths taken from the Arctic Geophysical Review (Sobczak and Sweeney, 1978) although sparse, show a corrugated morphology in the area of the refraction lines. There is evidence for two, previously unmapped, valleys striking northwest from the mouth of Nansen Sound and the Sverdrup Channel across the Queen Elizabeth Shelf. These valleys will be referred to in this discussion as *Nansen Valley* and *Sverdrup Valley* respectively. Nansen Valley is flanked to the northeast by a prominent plateau which is about 250 to 400 m higher than the valley floor and about 100 m higher than the adjacent shelf to the northeast. During the winter months of 1985 the Canadian Ice Island was stationary over this plateau, and thus it will be referred to here as the *Canadian Ice Island Plateau*. Between the valleys there is evidence for an underwater spit that plunges seaward and, because the Canadian Ice Island was stationary over this feature in 1986, it is referred to here as the *Canadian Ice Island Spit*. Similar spit features are observed trending northwest from the islands of the Queen Elizabeth Islands and are named after the adjacent islands as *Meighen Spit, Ellef Ringnes Spit* and *Borden Spit*.

Based on the limited data, it seems that Nansen Valley differs in shape and depth from Sverdrup Valley, but has characteristics similar to Peary Channel. It is deeper than Sverdrup Valley, more V-shaped with deep pockets right into the mouth of Nansen Sound (maximum depth of 730 m). The 300 m contour of the Sverdrup Valley meanders along the southern refraction line, whereas in Nansen Valley it is located on steep valley walls that extend landward into Nansen Sound.

The Canadian Ice Island Spit protrudes from the northwestern part of Axel Heiberg Island as a narrow crest that plunges seaward from a depth of 144 m along the southern seismic refraction line to possibly 700 m, where it merges with the Queen Elizabeth Slope. Similarly Meighen Spit extends seaward from Meighen Island, is a little wider, and is not as pronounced as the Canadian Ice Island Spit in intercepting the slope.

Free-air anomalies

Gravity anomalies observed prior to 1985 within the area of Figure 28.2 have been discussed previously by Sobczak (1963), Weber (1963), Sobczak et al. (1963), Sobczak and Weber (1970, 1973), Sobczak and Overton (1984), Sweeney et al. (1984), Sweeney et al. (1987), and Sobczak et al. (1987). The discussion of free-air anomalies in this report is restricted to anomalies shown along the seismic refraction lines completed in 1985 and 1986.

Generally, higher gravity values are noted over the plateau and spits and lower values over the valleys, but not in a one to one relationship. Differences between the gravity – bathymetry relationship indicate an anomalous behavior of the gravity field. The free-air gravity high over the Canadian Ice Island Plateau (maximum value +36 mGal) is localized over the southeastern end of the plateau, trends parallel to the coastline and extends over the eastern flank of Nansen Valley.

To the east, an east-west low centered on Phillips Inlet (minimum value −52 mGal) crosses the seaward end of the Canadian Ice Island Plateau and appears to merge with a northwestward trending belt of lows along Nansen Valley.

Gravity lows along Nansen Valley are normal in some places and anomalous in others. At the eastern end of Nansen Valley, a low is localized over an area with greatest water depths, whereas the low to northeast of Hubbard, although centred over Nansen Channel, does not overlie the deepest portion which lies about 20 km to the west. This low trends northwards across the southeastern end of the Canadian Ice Island Plateau and also extends seaward along Nansen Channel but disappears between points D and E, where Nansen Valley is quite prominent.

The gravity high over the Canadian Ice Island Spit is not centred over the crest but is shifted to the west about 16 km over its western flank.

A very broad low overlies the seaward end of Sverdrup Valley and does not appear to go much farther southeastward than the most southern refraction line. A minor relative gravity high overlies Meighen Spit.

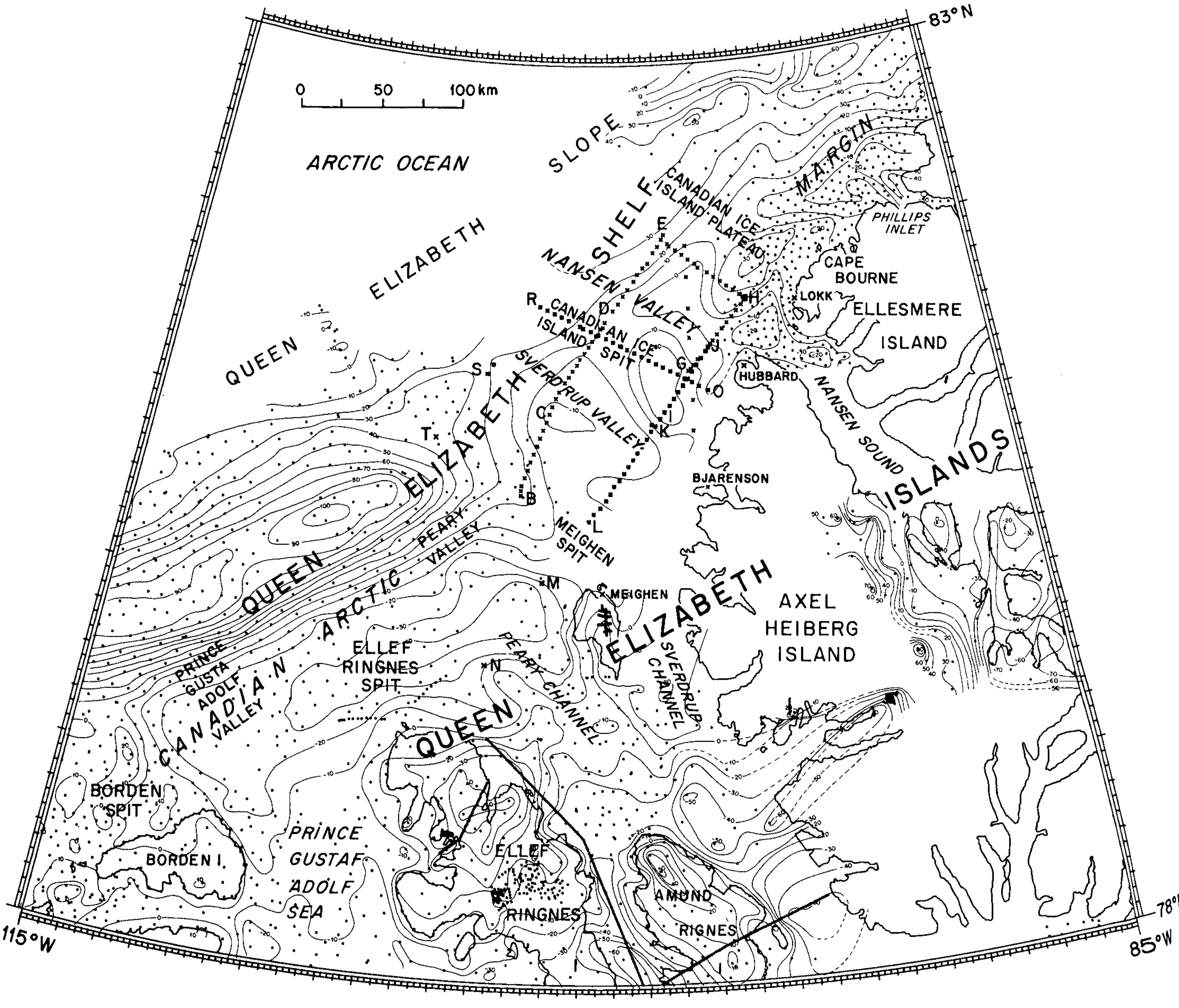

Figure 28.2. Free-air anomalies are shown in contours at 10 mGal intervals.

Bouguer anomalies

Bouguer anomalies (Fig. 28.3) within the vicinity of the seismic refraction lines indicate a large elliptical anomaly overlying the Canadian Ice Island Plateau and Canadian Ice Island Spit. The strike of this anomaly is parallel to the coast. Above the 30 mGal contour the anomaly is not well defined as there are no gravity observations across Nansen Valley. From the southern flank of this elliptical anomaly, a spur of positive values extends across Nansen Valley towards Hubbard. Also, on the southern side of the eastern end of this anomaly, a spur of positive anomalies crosses Cape Bourne and overlies the eastern end of Nansen Valley. Between these spurs lies a relative low which overlies and crosses Nansen Valley from the Hubbard area towards Lokk. No prominent high overlies Meighen Spit.

To the east of the elliptical high lies an extensive low that curves around the northern flank of the high and crosses the northern sides of the Canadian Ice Island Plateau and the Canadian Ice Island Spit. Normally, gravity lows occur along or just seaward of the coastline, often reflecting a seaward thickening of low density sediments (Fig. 4, Sobczak et al., 1986).

The high over the Canadian Ice Island plateau and spit, with accompanying landward trending spurs, is anomalous to the shelf area. It has a steep gravity gradient, which probably indicates a shallow dense mafic rock complex, similar to the multi-layered intrusions drilled and modelled in the vicinity of northern Ellef Ringnes Island (Sobczak, 1963; Sobczak and Overton, 1984, Sweeney et al., 1984; Sobczak et al., 1986). In addition, the adjoining north-south trending high, which crosses Cape Bourne and overlies the mouth of Nansen

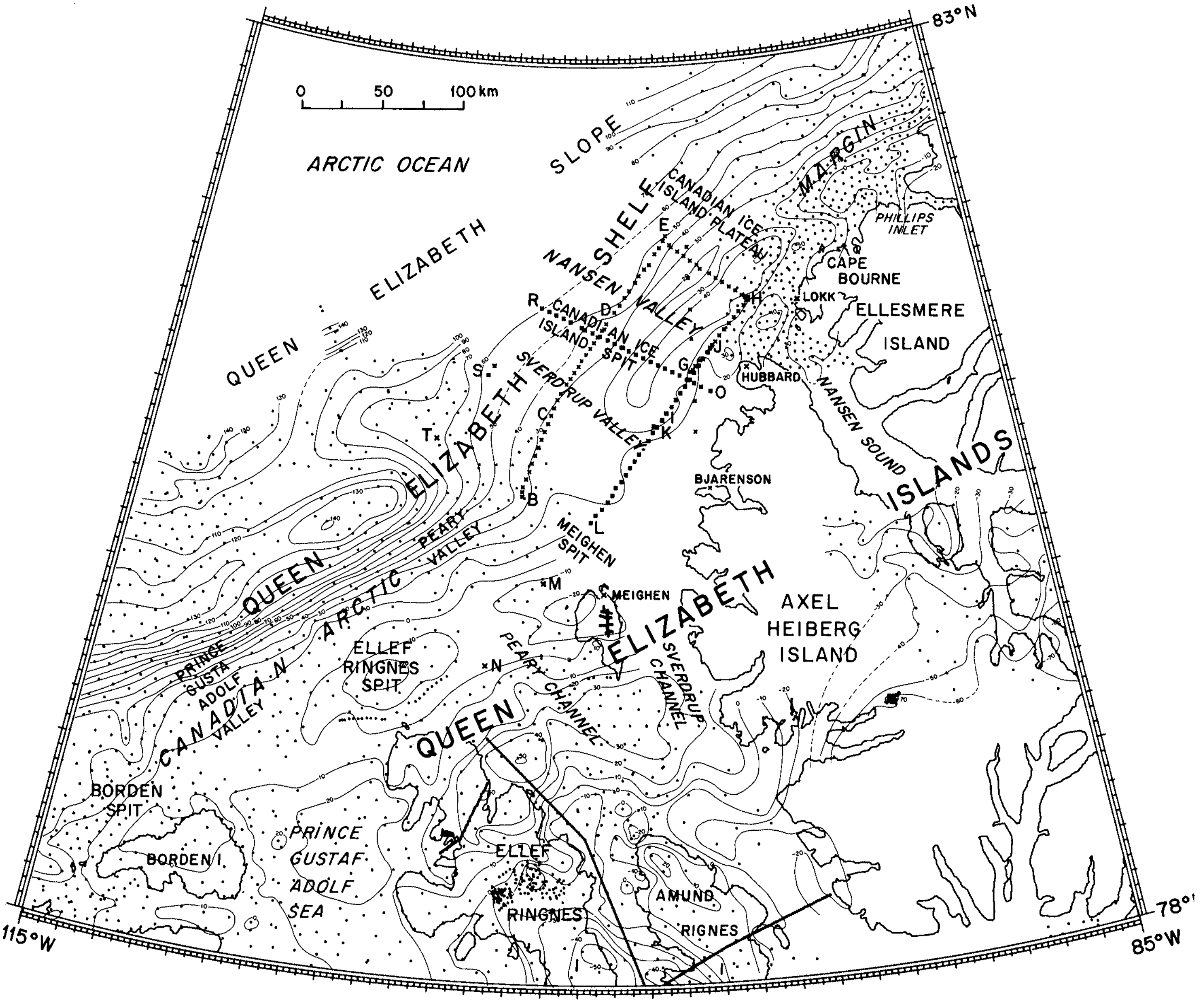

Figure 28.3. Bouguer anomalies are shown in contours at 10 mGal intervals and the density used in data reduction is $\rho = 2.67$ Mg/m^3.

Sound, may be related to the exposed rocks of the Bourne Complex along the northwestern coast of Ellesmere Island and the Unnamed Formation exposed on the peninsula southeast of Lokk (Thornsteinsson and Trettin, 1972). The Bourne Complex, a hybrid terrane, includes volcanic flows with abundant diabase intrusions of unknown age and the Unnamed Formation includes volcanic basalt flows also of unknown age. Mafic intrusions and flows are usually dense (greater than 3.00 Mg/m^3) and are generally distributed within low-density sedimentary rocks. These probable zones of mafic rocks, as depicted by the gravity highs, lie at the northeastern extension of the Sverdrup Rim and northwestern edge of the Sverdrup Basin (Sobczak et al., 1986, Fig. 1).

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