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SEISMICITY OF THE BEAUFORT SEA

Very clear - not an earthquake risk or hazards report.

by

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INTRODUCTION

This brief report on the seismicity of the Beaufort Sea is prepared in reponse to a request for information from Dr. R.G. Skinner, E.M.R. Coordinator, Beaufort Sea Project. The information and data for this report has been extracted from a paper by the present authors entitled "Seismicity of Northern Canada", which is nearing completion and will be submitted for publication in the Canadian Journal of Earth Sciences. The larger paper is being prepared as one of a trilogy - Northern, Western and Eastern - of review papers as part of the ongoing National Program.

The following two sections will present discussion of the earthquake data available for the Beaufort Sea and discussion of some of the geological and geophysical information that has been assembled to make a start on investigations that will eventually lead to a better understanding of the earthquake processes that are active in the region. Neither the review paper nor this report will cover the general field of seismic risk and earthquake hazards. The closest region to the Beaufort Sea that has been assessed by the Earth Physics Branch for earthquake hazards is the Yukon-Mackenzie Valley region for which special projects were undertaken for the Environmental-Social Program, Northern Pipelines.

Earthquake Data

The Earth Physics Branch maintains a computer file of all known earthquakes in Canada and adjacent regions. This file has been searched for all earthquakes in the region of the Beaufort Sea, latitute 69.0 to 74.0 N, longitude 124.0 to 145.0 west, and the earthquakes are listed in Table 1. The table indicates that we have knowledge of three earthquakes occurring in the Beaufort Sea region prior to 1962; the vast majority of the earthquakes (77) have been detected and located by data from the Canadian Seismograph Network during the past 14 years, a time period considered too short to clearly define seismicity patterns.

The earthquake of 1920 is from the Gutenburg and Richter catalogue of global earthquakes. The assigned position of this earthquake is off the west coast of Banks Island. The data used by Gutenburg and Richter to determine this position is not available to us, so it is difficult to assess the accuracy of this location. If this earthquake actually occurred in its assigned location it would be a very significant event. It is quite possible, however, that the epicentre is inaccurate by as much as a few hundred kilometers, and the earthquake may actually have occurred in the northern Yukon or some other region.

Data are available for the 1937 and 1943 Beaufort Sea earthquakes from the International Seismological Summary, and have been used to recompute locations for these earthquakes. From the originally assigned location given in Table 1, the 1937 earthquake is moved about 50 km to the northeast, nearer to the recent cluster of Beaufort

Sea activity (see Figures 2 and 3). The 1943 earthquake is relocated about 220 km to the south, into the northern edge of the cluster of activity in the northeastern Yukon. Both recalculated epicentres have uncertainties of about 100 km.

A capability to detect and locate smaller magnitude earthquakes in the Beaufort Sea was provided by development of the northern stations of the Canadian Seismograph Network which commenced in the early 1960's (see Figure 1). The station at Resolute (RES) has been operational since 1950, but it was not until 1957 that instrumentation was added that could detect the lower magnitude Arctic earthquakes. Between 1961 and 1971 nine stations important to the monitoring of northern seismicity were installed: SCH, CMC, FRB, YKC, BLC, PBQ, FCC, INK and WHC (see Figure 1).

For the years 1962 to 1975, all but the last earthquake in Table 1 have magnitudes in the range 2.2 to 4.5. The magnitude 5.3 earthquake of 14 June 1975 is the only known Beaufort Sea earthquake of magntiude greater than 5 since 1937 (note that the 1943 earthquake has been moved into the northern Yukon). It is quite difficult to make a general statement about the accuracy of the epicentres of these earthquakes. The larger earthquakes, detected by more stations in the latter part of this time period, are generally more accurately located. The smaller earthquakes in the early 1960's could be mislocated by as much as 100 km; the larger earthquakes since the late 1960's are unlikely to be mislocated by more than 50 km.

Relationship of Seismicity to Geophysical and Geological Features

The size of these possible location errors precludes any spatial correlation of the earthquakes with other features on a scale of a few kilometers. However, the 1962-1975 data is sufficiently accurate to identify with features on the scale of a few tens of kilometers, i.e. the larger scale features in the geological record. The larger review paper presents a search for such correlations for the entire Canadian north. The two figures that pertain to the Beaufort Sea are included here as Figures 2 and 3.

Figure 2 shows the earthquake epicentres of the Yukon-Beaufort Sea region superimposed on a map of the principal geologic structures. Some models for Cenozoic plate motions in the Arctic suggest that during one phase there was a right-lateral shear zone extending from the Richardson Mountains, through the Mackenzie Delta and the Beaufort Sea and along the northern shore of the Arctic archipelago. It is supposed that structural features due to this Cenozoic motion are the most recently produced gross structures that may be reactivated by the comtemporary stress field acting in the region. It can be seen in Figure 2 that:

a) the seismicity of the Yukon-Mackenzie Valley region is characteristic of the areas most severely faulted;

b) there is scattered seismicity along the Arctic Coastal Plain east of the Mackenzie Delta that bears no clear relationship with the structures presently identified in the area;

c) the immediate offshore area of the Beaufort Sea, north of the Mackenzie Delta and west of Banks Island appears relatively aseismic, the exception being a confined cluster of epicentres offshore from Martin Point, Alaska;

d) the Beaufort Sea seismicity appears in a relatively confined cluster directly north of the Mackenzie Delta, with most epicentres appearing between the 200 and 2500 meter bathymetric contours.

It is concluded from these observations that the Cenozoic shear zone noted above does not clearly correlate with recent seismicity along its full assumed length. The explanation for the seismicity cluster and the regions that appear aseismic with the available earthquake data must, therefore, be found in some other combination of potentially active structures and contemporary stresses.

In Figure 3 the Beaufort Sea seismicity cluster is shown superimposed on both the bathymetry and the Free Air gravity anomaly contours. Studies by Sobczak at the Earth Physics Branch indicate that elliptically shaped Free Air anomalies along the continental slope may indicate the presence of large volumes of sediments. In the case of the anomaly on the Scotian Shelf, eighty percent of the observed anomaly may be accounted for in terms of a sedimentary load which has yet to reach isostatic equilibrium. Such areas are therefore sites of inherent crustal adjustment. The Scotian Shelf example is apparently aseismic, but a similar anomaly correlates with the seismicity cluster in the Beaufort Sea. Some of these anomalies may be aseismic because the local crustal structure and stress field allow an aseismic isostatic compensation. The seismicity in the Beaufort Sea may result from the sedimentary load triggering earthquakes on underlying basement structures; the seismic pattern would then depend upon the particular relationship of the load to the underlying structures. The detailed fault structures on the Beaufort Shelf inferred by Yorath and Norris suggests that similar features are the most likely candidate for the earthquake loci.

Additional earthquake information with more accurate epicentres and focal depths is required to further deliniate the seismicity of the Beaufort Sea. The relationship between sedimentary loads, Free Air gravity anomalies and seismicity requires further investigation. The question of whether the seismicity occurs only where deeper crustal structures exist and may be reactivated is an important one. The Beaufort Sea earthquake of 14 June 1975 provides the first opportunity to determine an earthquake mechanism solution for this region. Studies of this earthquake are being pursued and may provide information on the direction of maximum horizontal stress and inferred directions of fault movement.

TABLE 1. EARTHQUAKES OF THE BEAUFORT SEA AND ADJACENT REGIONS

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE
1920	11	16	8	30	57.0	72.500	128.000	6.5
1937	7	5	1	41	0.0	71.000	138.000	5.5
1943	9	7	19	26	12.0	70.000	138.000	5.0
1962	2	26	9	19	57.0	70.900	133.000	4.4
1962	6	11	1	7	41.0	71.000	135.000	4.1
1965	3	20	19	25	43.0	72.420	129.330	3.8
1965	7	15	19	54	55.0	69.830	130.500	4.3
1966	3	2	15	12	3.0	69.420	130.000	3.6
1966	4	17	13	18	42.0	71.170	133.670	4.4
1966	5	18	17	51	1.0	72.580	138.500	3.4
1966	8	17	10	26	30.0	71.250	126.500	3.4
1966	10	20	23	44	35.0	69.750	124.750	3.6
1966	12	6	23	32	17.0	71.500	132.500	3.5
1966	12	8	16	22	26.0	69.170	144.830	4.1
1966	12	8	16	24	52.0	69.170	144.330	4.0
1966	12	8	17	13	32.0	69.170	144.670	4.3
1967	2	12	10	28	58.0	71.670	137.000	4.2
1967	3	31	20	48	28.0	71.000	131.830	4.4
1967	4	15	22	21	4.0	71.000	136.330	4.0
1967	8	25	11	7	28.0	69.580	130.500	3.7
1967	10	27	22	34	52.0	69.830	136.500	3.4
1968	1	22	9	51	24.0	70.200	144.280	3.8
1968	1	22	14	4	52.0	70.350	143.880	4.3
1968	1	23	0	13	25.0	70.230	143.800	3.2
1968	1	23	0	31	28.0	70.570	143.380	3.3
1968	1	23	2	23	10.0	70.200	144.210	3.2
1968	1	23	2	35	26.0	70.370	143.800	3.6
1968	1	23	2	36	52.0	70.060	144.380	3.6
1968	1	23	8	0	54.0	70.310	144.190	3.6
1968	1	23	8	30	45.0	70.400	144.240	4.1
1968	1	23	20	57	52.0	70.360	144.290	4.3
1968	1	26	4	56	16.0	70.480	143.660	3.6
1968	1	30	9	28	33.0	70.250	144.320	3.8
1968	1	30	9	30	18.0	70.250	144.350	3.5
1968	2	1	20	47	28.0	70.320	144.290	3.4
1968	2	5	4	7	21.0	70.320	144.240	3.9
1968	2	6	16	36	22.0	70.360	143.910	4.5
1968	2	10	17	29	0.0	70.340	143.890	4.3
1968	2	10	17	39	50.0	70.540	142.650	3.9
1968	2	12	21	5	9.0	70.270	144.790	3.6
1968	2	13	0	59	2.0	70.420	143.270	4.1
1968	2	21	23	6	39.0	70.330	143.530	3.3
1968	2	28	6	19	32.0	70.100	143.990	3.3
1968	2	28	8	36	16.0	70.410	143.160	4.1
1968	2	28	22	57	56.0	70.130	143.840	3.3
1968	3	9	13	55	37.0	70.270	144.100	4.2
1968	3	24	16	25	21.0	69.210	144.750	3.5
1968	4	25	10	33	50.0	70.210	144.460	4.4
1968	5	17	5	5	15.0	72.480	131.530	3.2
1968	8	6	9	9	54.0	72.390	136.330	4.4

YEAR	M	D	H	M	S	LAT(N)	LON(W)	FILE MAGNITUDE
1968	11	24	22	9	53.0	70.270	144.130	3.7
1968	12	7	11	7	18.0	72.010	133.220	3.2
1968	12	29	14	23	34.0	72.400	134.520	3.2
1968	12	29	19	37	25.0	71.290	130.990	3.5
1969	2	3	7	28	30.0	71.700	136.370	3.1
1969	7	5	13	25	9.0	69.910	130.250	2.2
1969	11	19	7	17	19.0	69.510	128.310	2.4
1970	5	19	11	32	53.0	69.240	130.590	4.0
1970	5	21	11	35	24.0	69.160	127.820	2.7
1970	7	10	3	35	21.0	70.360	144.420	2.9
1970	8	25	3	19	25.0	69.160	144.540	3.2
1970	10	10	4	36	43.0	71.930	135.590	3.1
1971	1	24	11	9	13.0	71.940	134.350	3.2
1971	3	2	0	32	5.0	70.230	144.070	4.3
1971	4	30	7	25	26.0	71.490	134.950	2.5
1971	5	25	3	17	5.0	71.420	135.860	3.3
1971	6	1	8	34	47.0	69.670	144.420	2.9
1971	6	25	15	16	0.0	71.810	130.220	2.9
1971	7	18	21	16	35.0	71.450	132.600	3.1
1971	9	27	21	49	27.0	70.950	131.960	4.3
1971	10	15	0	2	13.0	71.650	135.210	3.4
1971	12	2	8	42	10.0	71.380	132.810	2.7
* 1972	12	15	9	8	34.0	71.640	135.090	4.5
1973	2	15	21	30	49.0	69.300	133.140	2.4
1973	4	6	17	54	34.0	69.430	144.480	3.7
1973	12	31	17	38	40.0	69.730	128.880	2.1
1974	5	21	1	37	45.0	70.420	143.180	2.9
1974	9	11	2	6	34.0	70.460	126.610	2.4
+1975	4	6	19	25	36.0	71.56	133.12	4.3
+1975	6	14	20	50	26.	71.97	131.81	5.3

* final earthquake data reduction has not been completed for the 1972 calendar year.

\+ preliminary determinations for the first half of the 1975 calendar year.

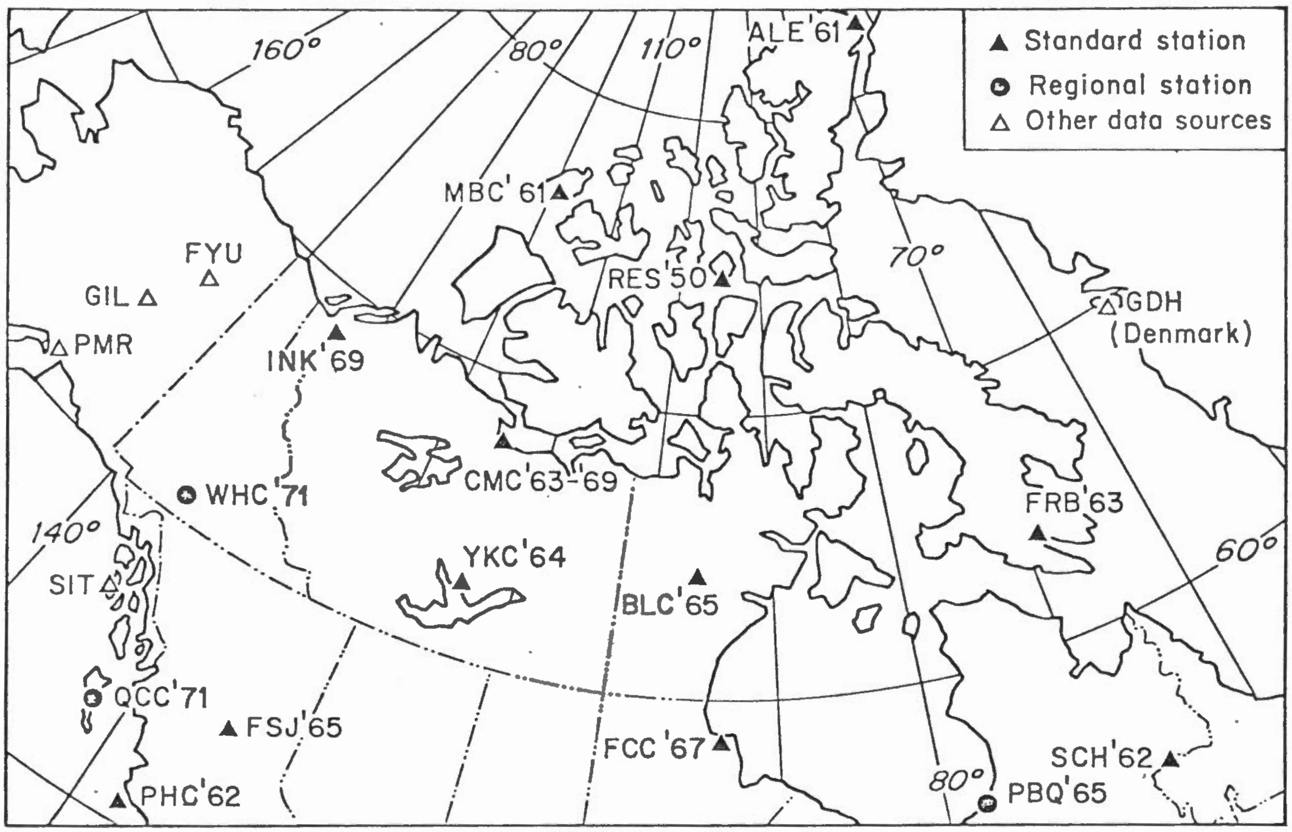
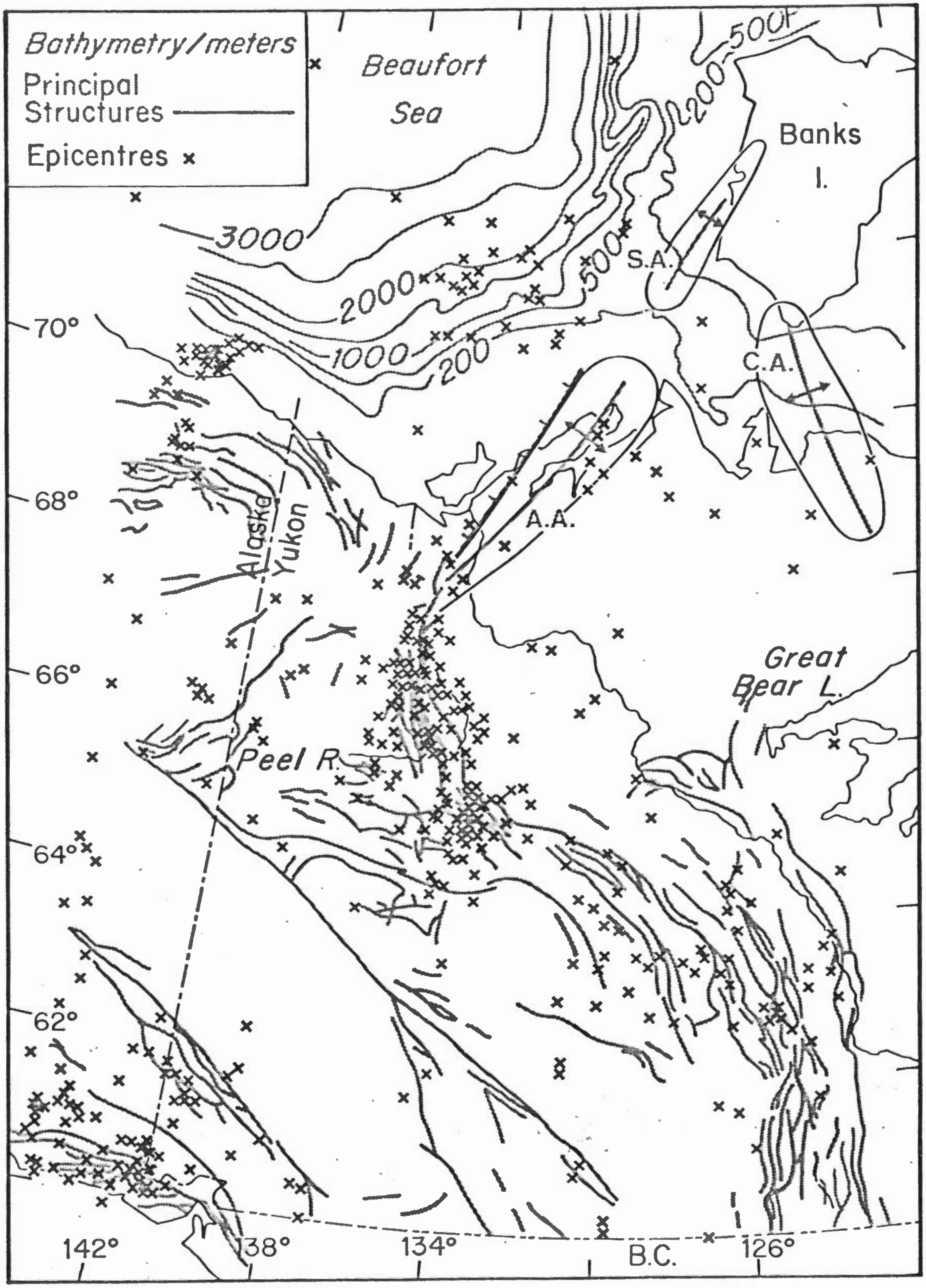


FIG. 1. SEISMOGRAPH STATIONS OF THE CANADIAN NETWORK IN NORTHERN CANADA SHOWING YEAR OF INSTALLATION.



52 THE RELATIONSHIP BETWEEN SEISMICITY AND THE PRINCIPAL STRUCTURAL FEATURES OF THE YUKON-BEAUFORT SHELF.

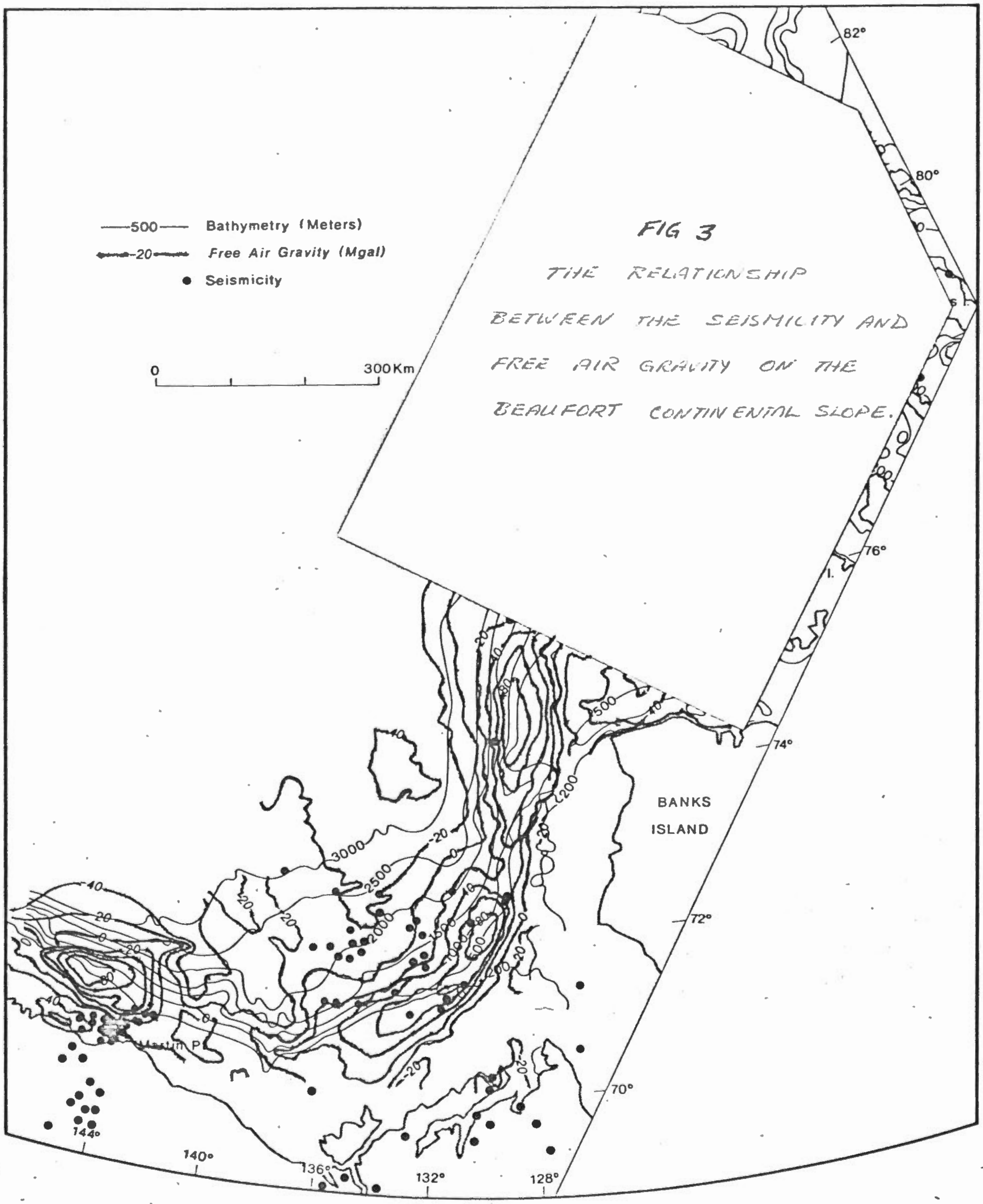


FIG 3

THE RELATIONSHIP BETWEEN THE SEISMICITY AND FREE AIR GRAVITY ON THE BEAUFORT CONTINENTAL SLOPE.