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Comparisons Between Pogo Satellite Magnetic Data and Airborne Magnetic Data Over Canada 50°N-85°N, 100°W-140°W

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ABSTRACT

POGO satellite magnetometer data selected to minimize the effect of magnetospheric/ionospheric disturbances have been used to make a magnetic anomaly map over western Canada and Arctic regions. Residuals were calculated relative to a thirteenth degree field model. The map represents the anomaly field at an average altitude of about 500 km. Airborne magnetic data over this same area, relative to the same field model, have been upward continued to 500 km. The resulting map compares favourably with the satellite-derived map. It confirms the reality of the general features in this latter map, and points to their lithospheric origin. Satellite data have also been used to obtain an equivalent source representation. This removes the effects of varying altitude and spurious features resulting from low data density.

INTRODUCTION

NASA Goddard Space Flight Centre and the Earth Physics Branch, Ottawa, are jointly engaged in comparisons between magnetic data from OGO 2,4 and 6 (POGO) satellites and data obtained from airborne vector magnetometer surveys over Canada and Arctic regions. A primary aim of the program is the identification of magnetic anomalies arising from lithospheric sources, and the development of procedures for modelling them.

SATELLITE MAGNETIC DATA

Langel et al. (1975) presented a preliminary satellite anomaly map for latitudes 50^{o}*N to* 85^{o}*N. A refined version of a portion of this map, over Canada* *between 100°W and 140°W, is presented here (Figure 1). This map was derived from data from 131 passes at altitudes below 600 km; the mean altitude over the map area was about 500 km. The anomalies were obtained by subtracting from the total field a spherical harmonic model field of order 13, POGO 6/71, which was itself derived from a subset of OGO data (J.C. Cain; personal communication). Passes which contained residual* ΔB *anomalies greater than 20 gammas were rejected, such fields being considered due to non-lithospheric sources. Only those passes which had 30 to 40 data points near the map-area were used, Careful visual examination and selection of passes were a necessary part of the procedure.*

Nevertheless, in many cases, individual profiles over nearly the same area, and at the same elevation, agreed poorly; obvious differences in level and overall trend were present. In effect, each profile had its own 'regional', evidently an external field effect. Such profiles could be brought into good agreement simply by subtracting a least-squares best-fit linear function independently from each. An explanation of the reason for this, in terms of an external field, has been given by Mayhew and Davis (1976).

Figure 1 was contoured from averages of the data over 2° squares (2° at the equator). Figure 2 is a contoured plot of the number of points included in each average. The reliability of the anomaly map is basically higher where the data density is greater.

We emphasize that the southernmost 4° strip of the anomaly map is to be regarded with caution. Discrepancies occur between this and the map of Mayhew and Davis (1976) to the south. Different satellite passes were used for this latter map.

In order to effectively bring the satellite data to constant elevation, the anomaly field was modelled by an array of dipoles at the earth's surface, *the "equivalent source field" at 500 km being shown in Figure 3. The dipoles were spaced at 5° in latitude, and 8° in longitude at and below 65°N and 10° in longitude above 65°N. They were oriented in the direction fo the field of a tilted dipole representing the core field. The average dipole array intensity is used outside the map-area, except to the south where artificial data based on the similar map between 45°-50°N (Mayhew and Davis 1976) were included. This equivalent source result should be regarded as preliminary; however, the general agreement with the ΔB map shows that the technique is potentially a useful interpretation tool. Certain features of the equivalent source field appear to be affected by the positions of specific dipoles. Although a closer dipole spacing would provide better resolution, there is a trade-off since the solution then tends to become unstable because of noise in the data and the areas of low data density.*

AIRBORNE MAGNETIC DATA

Airborne vector magnetic data have been obtained at altitudes ranging from 3.5 to 6.8 km over western Canada and Arctic regions (Coles et al. 1976; Haines and Hannaford, 1972, 1974, 1976). Figure 4 shows the distribution of data points used here. For the purposes of this study, the data along individual flight lines have been averaged over 35 km intervals.

Residuals of the vertical component of the field were calculated, relative to the same spherical harmonic model, POGO 6/71, used for the satellite anomaly map (The vertical component was used as it was the most complete over the region, and it is strictly more valid for the upward continuation process). These residuals (5600 in number) were upward continued to 500 km altitude (Figure 5). The continuation computation assumed a spherical earth and assumed that the residual field outside the data area was zero. The finiteness of the data set and the extreme continuation height may result in broad trends or distortions on the anomaly pattern, but comparisons with continuatons to lower altitudes confirm the validity of the general features of the map.

COMPARISON OF THE ANOMALY MAPS

We see now, by comparing Figures 1 and 5, a remarkable agreement between the satellite data and the airborne data in their common spectral region. The agreement is excellent in the north, with a high anomaly north of 80°N, a low region between 71° and 80°N, and a northeasterly trending ridge of high field centred near 65°N in the west and 69°N in the east. A weak south-trending ridge is centred on 120°W (Figures 1 and 5). In the south, the agreement is less good; a large gradient is evident in the airborne-derived map. Nevertheless, the indications are of a relatively low field over the southwestern Cordilleran region in Canada.

The reason for the discrepancy in the south between the two maps is not yet clear. The method of upward continuation is considered not to be a major factor since analysis of the original data also indicates a similar discrepancy. The POGO anomaly map is determined relative to a model also derived from POGO data, and since r.m.s. errors to POGO models are of order a few gammas, one would not expect trends of order tens of gammas to be present in that map. All that can be said at present is that either the satellite data are consistently high in this region, or that the airborne data (one particular survey) are consistently low, or the secular change characteristics of the POGO 6/71 model are not entirely correct in modelling the field for the 1969.1 epoch of the airborne survey. Further independent checks are needed here.

CORRELATIONS WITH GEOLOGIC FEATURES AND LOW ALTITUDE MAGNETIC ANOMALIES

Figure 6 shows some of the major geologic and tectonic features. In the extreme north, the Alpha Ridge of the Arctic Basin underlies the high anomaly. Airborne surveys have shown the field to be complex, with a series of intense sublinear anomalies subparallel to the trend of the ridge. These anomalies extend north and south of the Ridge, southward to about 80°N where the zero contour on the POGO map occurs. The Alpha Ridge has been variously interpreted, as down-dropped continental crust, as an extinct centre of sea-floor spreading, and as a subduction zone.

In the southern Canada Basin and the northern Canadian Arctic Islands, the low altitude magnetic field is remarkably smooth. Considerable depths of sediments are present in the Sverdrup Basin, Arctic Coastal Plain, and Beaufort Shelf. At 500 km altitude, this is manifest as a region of low field.

The zero contour on the POGO anomaly map south of this region coincides with a distinct change in low altitude magnetic character and is close to the edge of the craton as interpreted geologically. The ridge of high field evident in the high altitude maps between latitudes 65° and 71°N overlies the northernmost parts of the platform deposits on the Precambrian craton and in the east extends southward over the northern parts of the exposed Shield. In the extreme west, a narrow region of intense positive short-wavelength anomalies is observed at low altitudes. This has been interpreted as an indication of an extension of the crystalline basement as far as the Alaskan border. To the east, the high over southern Victoria Island is apparently not associated with a concentration of intense short-wavelength anomalies. The long-wavelength anomaly is readily seen in the low altitude data. It may be a result of a thickened magnetic crust in the stable craton.

The weak south-trending ridge centred about 60°N 120°W overlies a region of considerable field complexity, observed at low altitudes. High relief positive and negative anomalies occur such that the superposition of their long-wavelength components tends almost to cancel out (in contrast to the region to the northwest). Most of this region is underlain by sedimentary cratonic cover rocks, reaching thicknesses of several kilometres in the west. Much of the crystalline basement here is highly magnetic.

To the southeast, similar thicknesses of sedimentary cratonic cover exist, but here the short-wavelength field is more subdued, suggesting a less magnetic basement, or less structure within it, or both. The higher altitude field is lower, also.

In the west, the low altitude field over the Cordilleran region is generally subdued, particularly near the southern border along 120°W. At high altitudes, this region is one of low field. Heat flow measurements and geomagnetic induction work indicate that the Curie isotherm here is probably much shallower than in the craton to the east.

The extreme southwestern parts of the high altitude anomaly maps, over the Pacific Ocean, are uncertain, firstly because of low satellite data densities, and secondly because of the level discrepancy between the satellite and airborne data sets. In the region, the familiar oceanic striping pattern of anomalies is found at low altitudes.

CONCLUSIONS

The results of these comparisons between satellite data and airborne data and the relation of the data to crustal features demonstrate the value of such comparisons in aiding the interpretation of the satellite anomaly maps.

The comparisons have also resulted in improved data reduction techniques in both the satellite and the airborne data sets.

The relations between anomalies observed at satellite altitudes and those observed at low altitudes are not simple, and depend on the nature and complexity of the low altitude field. This is important when considering modelling techniques for the satellite maps.

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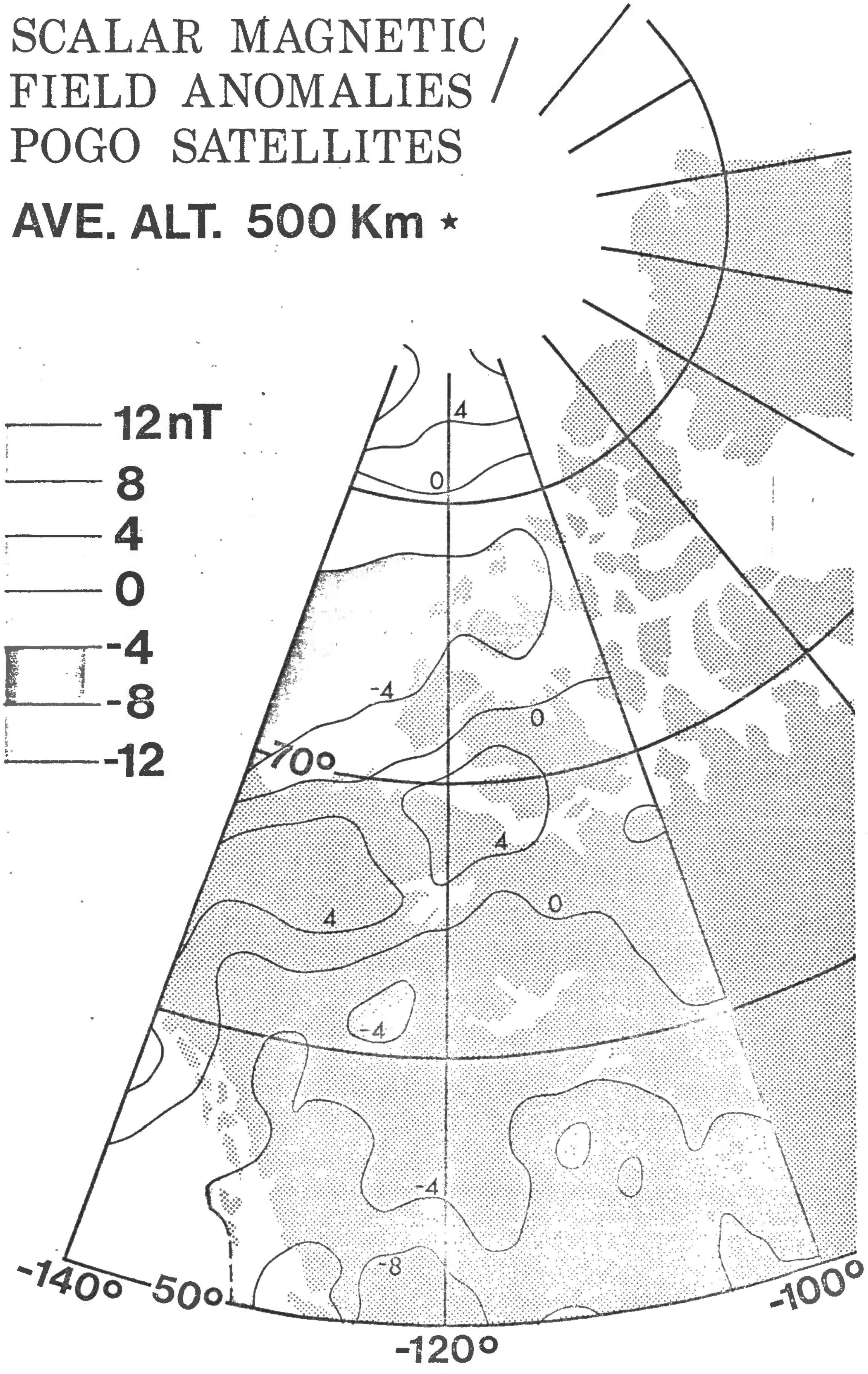
FIGURE CAPTIONS

Fig. 1	*Satellite ΔB anomaly map 2° averages*
Fig. 2	*pts/average density plot*
Fig. 3	*Equivalent source field at 500 km*
Fig. 4	*Airborne data distribution plot*
Fig. 5	*Upward continuation 500 km map*
Fig. 6	*A stylized map showing tectonic features and "magnetic provinces"; 1. areas of magnetic 'highs';2. axes of magnetic 'lows';3. boundaries of Magnetic Regions, as discussed in the text and indicated by Roman numerals;4. edge of exposed Precambrian Shield and Precambrian province boundaries; 5. eastern limit of Cordilleran deformation; 6. northern edge of stable Precambrian platform; 7. some major faults; RMTS - Richardson Mountains.*

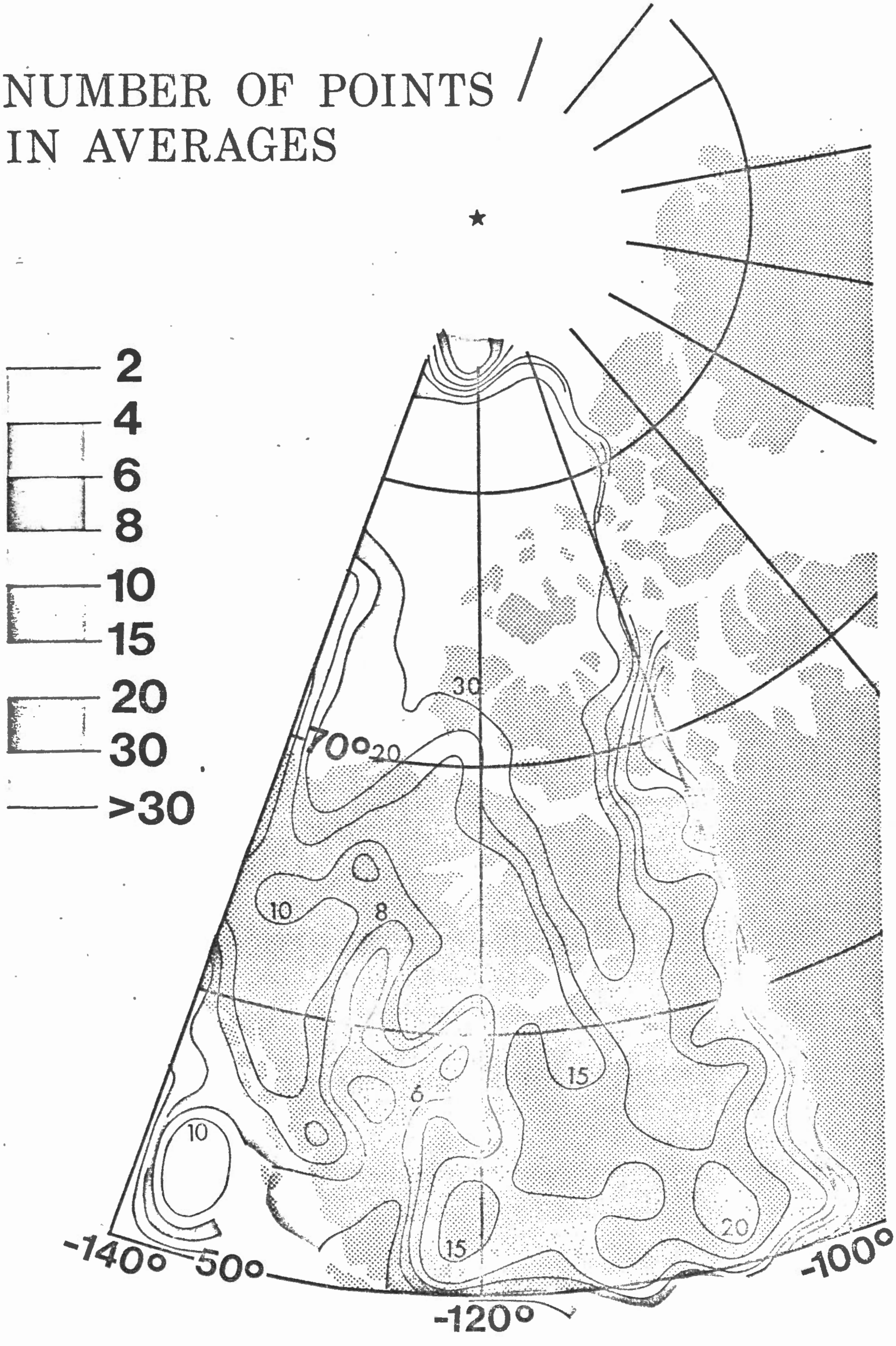
Fig. 1



SCALAR MAGNETIC FIELD ANOMALIES POGO SATELLITES

AVE. ALT. 500 Km *

Fig. 2



NUMBER OF POINTS IN AVERAGES

Fig. 3

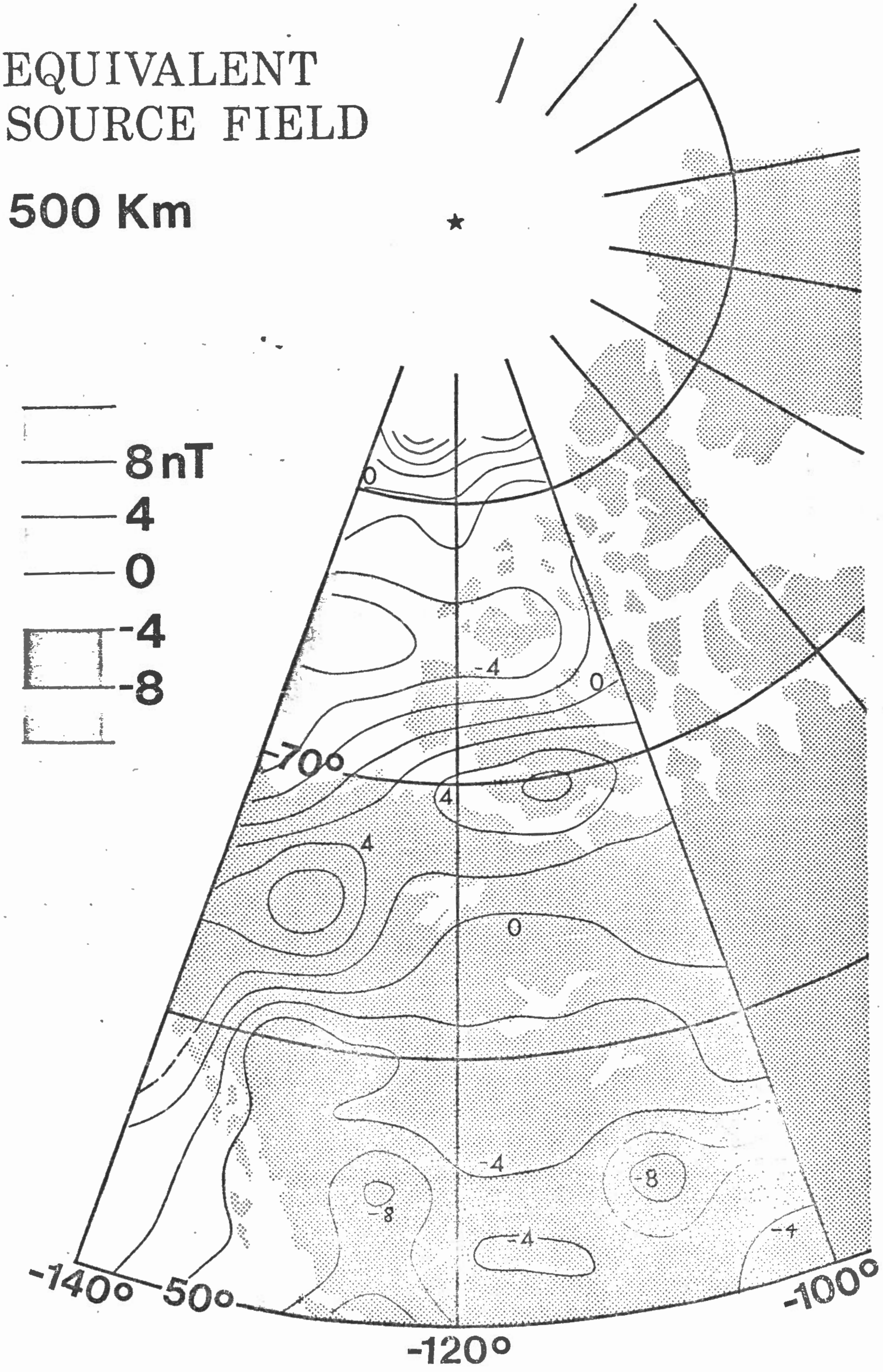

EQUIVALENT
SOURCE FIELD
500 Km
8 nT
4
0
-4
-8
0
-4
0
-70°
4
4
0
-4
-8
-8
-4
-4
-140°
-50°
-120°
-100°

Fig. 4

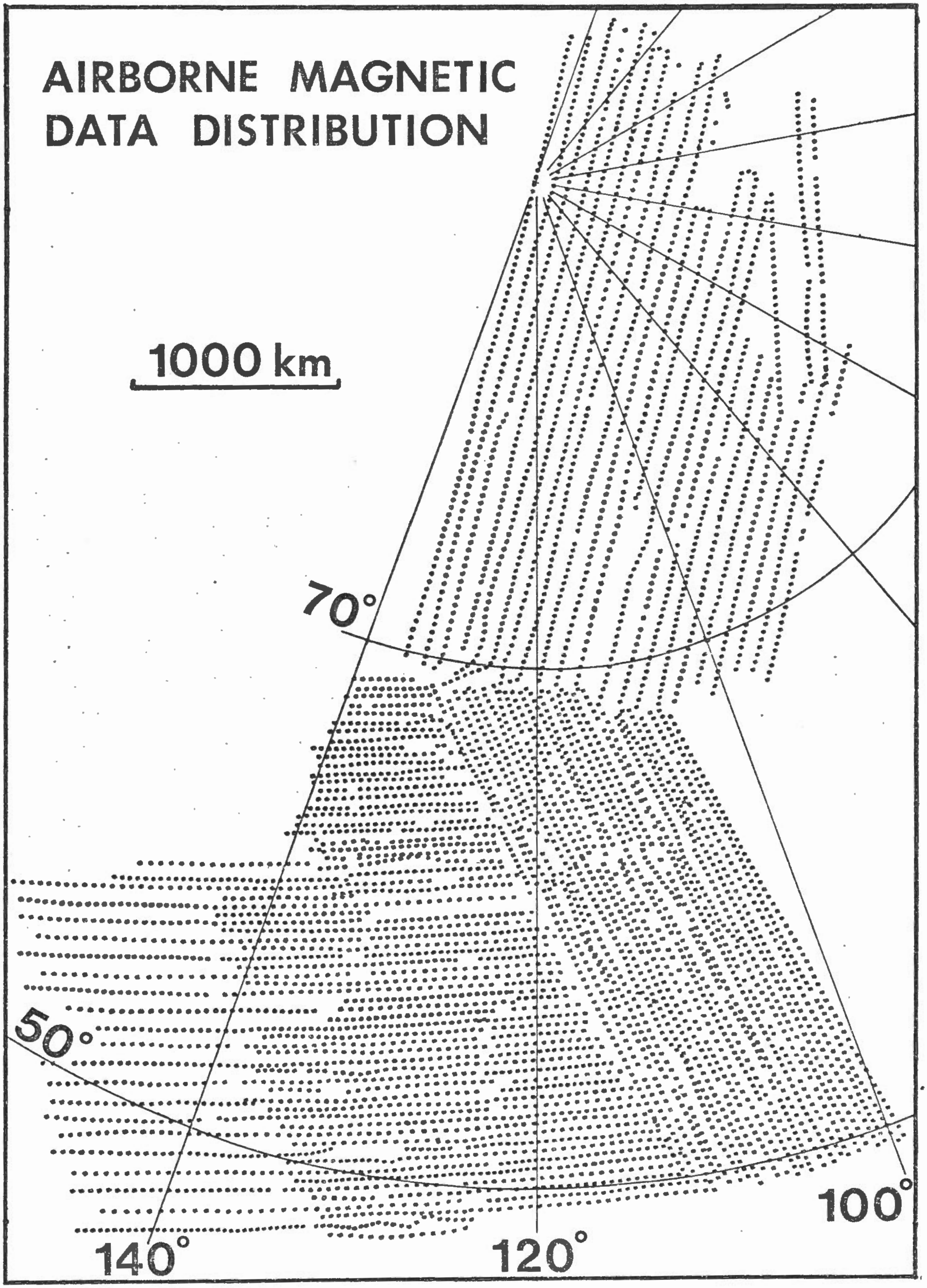

AIRBORNE MAGNETIC DATA DISTRIBUTION
1000 km
70°
50°
100°
120°
140°

Fig. 5

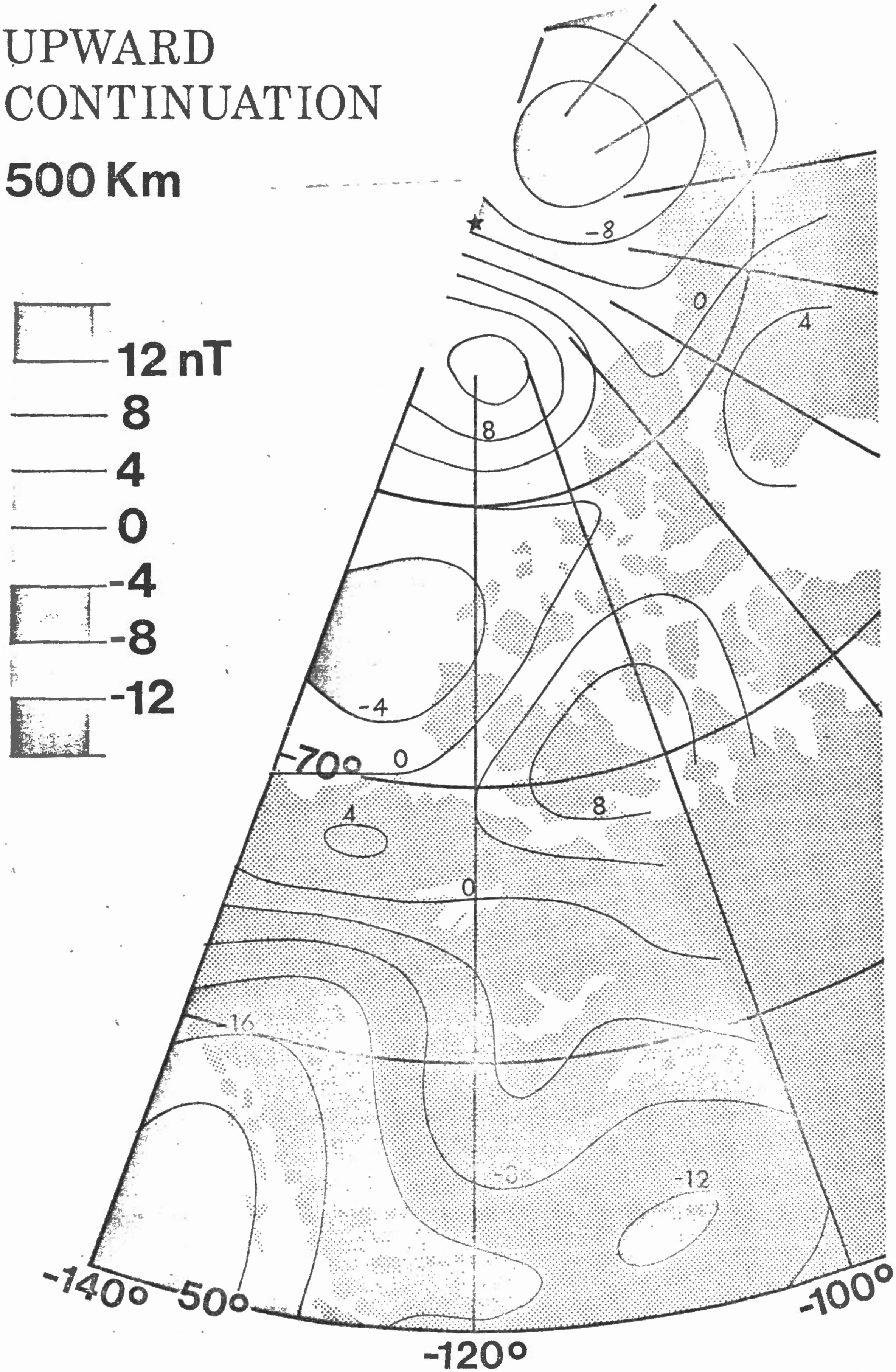
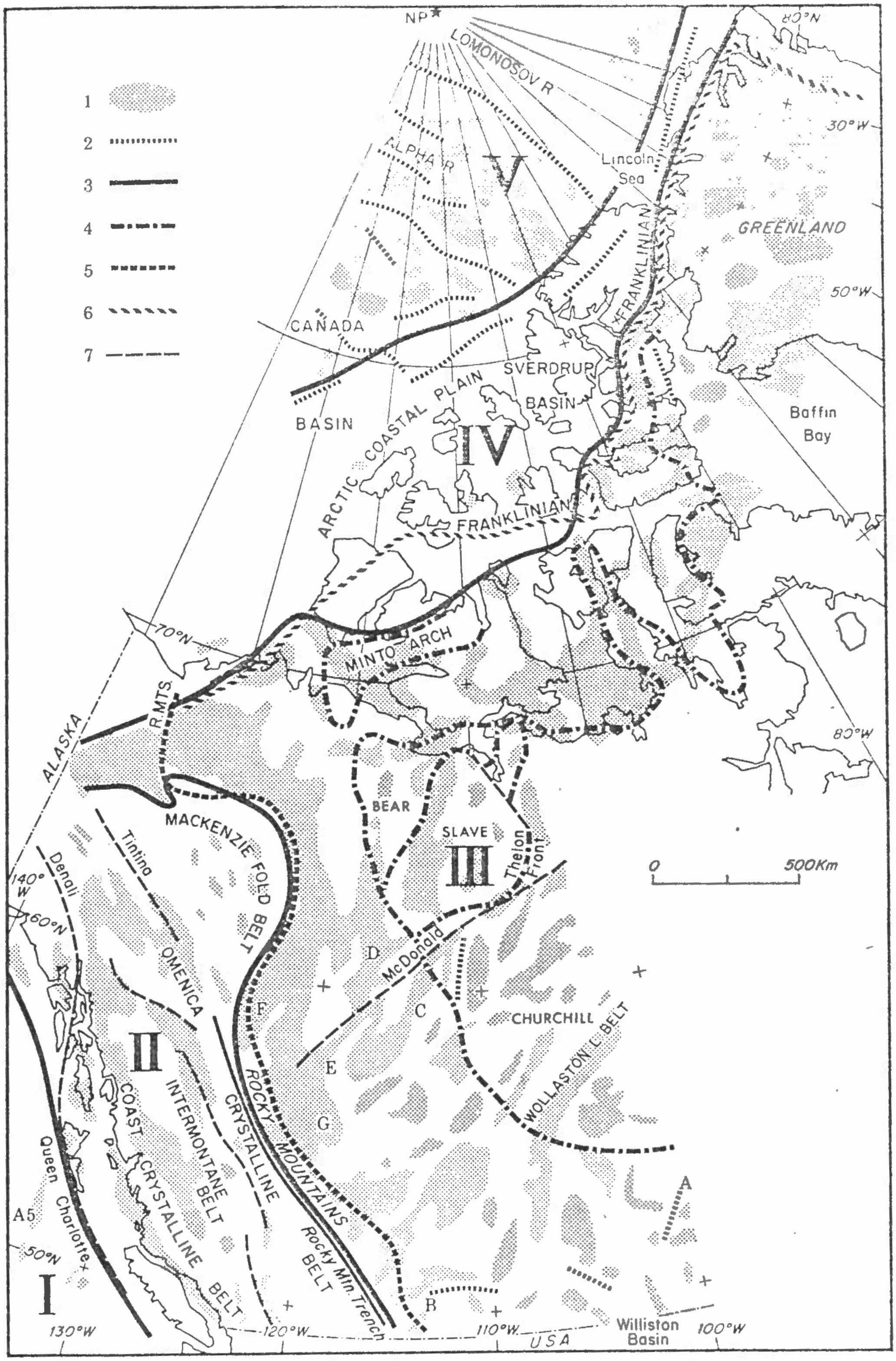

UPWARD CONTINUATION
500 Km
12 nT
8
4
0
-4
-8
-12
-8
0
4
8
-4
0
-70°
4
8
0
-16
-8
-12
-140°
-50°
-120°
-100°

Fig. 6



1
2
3
4
5
6
7
NP
LOMONOSOV R
ALPHA R
V
Lincoln Sea
80°N
30°W
GREENLAND
50°W
FRANKLINIAN
CANADA
BASIN
ARCTIC COASTAL PLAIN
SVERDRUP BASIN
IV
Baffin Bay
FRANKLINIAN
70°N
MINTO ARCH
R. MTS.
ALASKA
80°W
BEAR
SLAVE
III
Thelon Front
0
500Km
MACKENZIE FOLD BELT
Tintina
Denali
140° W
60°N
OMENICA
D
McDonald
C
F
CHURCHILL
WOLLASTON L. BELT
II
E
G
COAST CRYSTALLINE BELT
INTERMONTANE BELT
CRYSTALLINE
ROCKY MOUNTAINS
Rocky Mtn. Trench
BELT
Queen Charlotte
A5
50°N
I
A
B
130°W
120°W
110°W
USA
Williston Basin
100°W