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RAPPORT

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Interpretation of geophysical data from Spitsbergen: Structure of the basement and implications for regional geology

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Sammendrag:

New Arctic aeromagnetic data from Spitsbergen, Svalbard Archipelago, have been interpreted. The depths to the top of the magnetic source rocks have been interpreted using profile data, and the interpretation shows that the magnetic basement is deeper than 3 km below sea level over large areas. A picture of basement horsts and grabens emerges from this map. A deep N-S trending trough, more than 8 km deep, exists beneath Isfjorden. It has a graben structure and is bordered to the east by a southward extension of the Billefjorden Fault Zone. Model calculations show that steep east-dipping structures in the pre-Devonian Hecla Hoek basement rocks can explain anomalies above the Billefjorden Fault Zone. The Billefjorden Fault Zone is interpreted to extend from the shelf north of Spitsbergen to south of Isfjorden and may extend southwards into the Barents Sea.

A new aeromagnetic map covering Spitsbergen and the adjacent northern Barents Sea has been compiled which shows that structures on Spitsbergen continue far into the Barents Sea.

Some of the anomalies that originate within the crystalline basement occur near the boundaries to younger sedimentary basins and suggest that basement tectonics have influenced basin formation.

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INTRODUCTION

The Spitsbergen aeromagnetic survey (SPA-88) was conducted in 1988 by Norges Geologiske Undersøkelse (NGU) in co-operation with Geco a.s. covering the southern two-thirds of Spitsbergen, the principal island of the Svalbard Archipelago (Fig. 1). This new Arctic aeromagnetic data set, in addition to recent surveys in Canada (Nelson et al., 1991), is some of the highest resolution aeromagnetic data obtained this far north. The systematic pattern of flight lines provides data along east-west (4 km spacing) and north-south lines (spacing varies; 12 and 24 km). Data sets and quality are described later.

While studies of geology and Landsat images (Ohta, 1982a) from Svalbard have provided information on surface geology and structural geology, geophysical data are needed to interpret and quantify the deep geology in terms of depth to the concealed basement, structure of the basement, and off shore extension of structural elements. In the last few years reflection seismic data have been collected from the fjords, which provide structural information along a few lines (Eiken, 1985; Eiken and Austegaard, 1987; Faleide et al., 1991). Seismic data provide some constraints on the interpretation of aeromagnetic data. Over most of Spitsbergen the new aeromagnetic data reported here provide the only geophysical information on upper crustal structure. Quantitative interpretations of these data (depth to basement) play an important role in understanding the three-dimensional geological structure.

The author has analyzed each individual profile record displaying the following information: measured anomalies, calculated first vertical derivative of the anomalies, radar altimetry, magnetic base data and surface geology. Thus, it was possible to carefully check measured anomalies for occurrences of diurnal noise, topographic effects in the data and expressions of surface geology.

GENERAL GEOLOGY AND TECTONIC SETTING

Spitsbergen is the principal island of the Svalbard Archipelago. Svalbard is covered by geological maps at a scale of 1:500,000 (Flood et al., 1971; Winsnes and Worsley, 1981; Hjelle and Lauritzen, 1982; Lauritzen and Ohta, 1984; Winsnes, 1986). The Precambrian and Early Palaeozoic basement on Spitsbergen, the so-called Hecla Hoek (HH) rocks, forms the crystalline basement to the Devonian and younger, unmetamorphosed, sedimentary rocks. HH rocks occur in Ny-Friesland (northeast Spitsbergen) and along the West Spitsbergen Tertiary Orogenic Belt (Fig. 2). The Orogenic Belt (also called the Tertiary Fold and Thrust Belt) is probably the result of transpression that accompanied dextral strike-slip plate motions between North Greenland and Svalbard during the opening of the North Atlantic Ocean (Harland, 1965,1966,1969; Talwani and Eldholm, 1977; Eldholm et al., 1987; Myhre and Eldholm, 1988). The main Tertiary deformation front follows the contact between HH rocks and post-Devonian sediments in West Spitsbergen (Fig. 2). The Old Red Sandstone is mainly preserved in the Devonian graben in central-northern Spitsbergen. The Tertiary Central Basin is elongated along a NNW-SSE trend in central-south Spitsbergen. Mesozoic sedimentary rocks occur as a belt to the west, north and east of the Central Basin/Graben.

Mid-Palaeozoic Caledonian deformation and metamorphism in

Svalbard was followed by Late Devonian faulting along a NNW-SSE trend (Harland et al., 1974; Hjelle and Lauritzen, 1982). The Hornsund Fault Zone (HFZ), the Billefjorden Fault Zone (BFZ) and the Lomfjorden Fault (LF) are important basement lineaments (e.g. Harland et al., 1974). The HFZ is close to the continent-ocean boundary offshore west of Svalbard (Sundvor and Eldholm, 1976; Myhre and Eldholm, 1988). The BFZ is the border fault between Devonian rocks (Old Red Sandstone) to the west and a basement horst comprising HH rocks on Ny Friesland (northeast of Isfjorden). South of Isfjorden, the BFZ may border the Palaeogene Central Basin where it is covered by the Tertiary sediments (Mann and Townsend, 1989). The LF is associated with an area of flexure development and differential movements in Palaeozoic, Mesozoic and Cenozoic times (Steel and Worsley, 1984; Andresen et al., 1988), and may represent an important basement fault zone. How far the BFZ and the LF extend to the south cannot be deduced from surface geology.

DATA SET AND DATA QUALITY

A total of 13,320 profile kms were acquired along a network with 4 km spacing between east-west lines and 12, 24 and 36 km between N-S tie lines. The flight altitude was 1000 m above sea level south of 77^0 N, and 1600 m to the north of this line.

Satellite navigation (GPS) was used in conjunction with a precise radio positioning system operating in the UHF range (SYLEDIS chain). The majority of the profile data were recovered using GPS (88.4%). Comparisons of GPS-SYLEDIS positional fixes revealed that the two positions generally agree to within +/- 50m. Careful checking of the acquired position data revealed a few cases of major departures from pre-plotted survey lines. Errors were corrected by applying linear interpolation assuming that the aircraft had followed a straight line.

Base station magnetometers were recorded in Longyearbyen and at Nordlysobservatoriet in Ny Ålesund (Fig. 1). The data from Longyearbyen were used by the author to choose the best periods for acquisition, and to decide which lines to re-fly because of magnetic time variation (diurnal noise).

In preparing the diurnal correction, the following considerations were made, based the experiences from the northern Barents Sea aeromagnetic survey (Skilbrei, 1988a; Skilbrei et al., 1990). Simple diurnal subtraction of low-pass filtered base magnetic data from the best base station (with respect to location and phase correlation) was superior to applying phase corrections and a weighted use of two base stations. Visual inspections of magnetic data revealed a relatively high degree of correlation between the recorded data and the high-frequency diurnal noise (Skilbrei, 1988b). Even so, to avoid introducing noise, the base data were low-pass filtered prior to diurnal subtraction of the base magnetic data. A 50-km cut-off filter applied to base data was chosen (50 km is approximately equal to the length of the shortest E-W lines).

Conditions were better in Longyearbyen than in Ny Ålesund (Skilbrei, 1988b). This is probably due to the fact that Longyearbyen is near the centre of the survey area, whereas Ny Ålesund is located in the extreme north-west.

The final map was prepared for an elevation of 1600 m. The 1000 m data were upwards continued to fit the 1600 m data.

Visual inspection showed that a profile continuation method was superior to grid continuation in the transfer zone between the two data sets; this method was therefore chosen. The final profiles, on which the depth estimates were made, display versions of these lines both at the original acquisition elevation and at the upward continued elevation. Some lines were flown at both elevations in order to enable comparison of the results of the upward continuation method with the measured field at that higher level. The agreement turned out to be good, which means that the 2-D continuation hypothesis (profile continuation method) was a good approximation for the anomalies in question.

After diurnal correction and systematic line level correction, 6.24 nT average deviations remained at line crossings. The anomalies in the survey area are of generally low amplitude (Fig. 3). This, combined with the problem of relatively poor tie-line control, caused problems in the map preparation (see later). A manual first-order correction to six of the tie-lines was therefore applied. Seven lines showing diurnal noise were not used in the map preparation. This procedure reduced the average mistie value for the diurnal corrected data (50km-filtered base data from Longyearbyen) to 4.65 nT. Line effects are visible over the eastern areas where the magnetic field is almost flat. The IGRF-85 model for May 1988 has been subtracted from the recorded data.

Contour maps 'filter out' much of the original information content of the data relating to faint features associated with geological structure and trend (Lee et al., 1990). A colour shaded relief map (Fig. 4) of the residual total field component is presented which contains information on both anomaly amplitude (colour) and anomaly trend (relief). Illumination is from the east. The shaded relief presentation emphasizes anomalies that strike at a high angle to east-west, and de-amphasize east-west striking anomalies. The map covers both the SPA-88 survey area and the adjacent northern Barents Sea area which was covered by measurements in 1987 (Skilbrei, 1988a; Skilbrei et al., 1990). The map is produced using an Applicon ink-jet plotter which utilizes a programme system developed by Kihle (1985). The Barents Sea data were upward continued to a common level (from 330 m to 1600 m above sea level) to minimize differences between the data sets at their overlap regions. The upward continuation is effectively a smoothing operator and places a lower limit on wavelength of anomaly that may be resolved. Together with the 4 km line spacing, figures 3 and 4 adequately resolve anomaly wavelengths of about 10 km and greater corresponding to geological features of similar scale. The minimum curvature method of Briggs (1974) was used to grid the data.

INTERPRETATION

General features of the aeromagnetics

Generally, the magnetic trends are NW-SE to NNW-SSE for the whole of the map area, except for the Billefjorden-Wijdefjorden area where the positive magnetic trend is N-S (Figs. 3 & 4). It is interesting that the NW-SE to NNW-SSE trend is parallel to the Tertiary Fold and Thrust Belt along western Spitsbergen.

Low- to medium-wavelength anomalies of moderate amplitudes (<200 nT) occur above the HH basement rocks within the West Spitsbergen Orogenic Belt. During interpretation, the aeromagnetic profiles were placed upon geological maps at the scale 1:500,000. In many areas it was possible to isolate anomalies caused by individual sources within the HH basement. For instance, on the western part of Prins Karls Forland

(PKF), short-wavelength magnetic anomalies occur directly above outcropping volcanic formations that are areally significant (Hjelle et al., 1979, detailed geological map in Fig. 1, p.147). The statement of Kurinin (1965), claiming that HH rocks are practically non-magnetic, is therefore not generally valid.

A belt of low magnetization level trends NNW-SSE from the outer Isfjorden area, along onshore Spitsbergen to the east of the HH rocks, and into the northern Barents Sea. The gradient that separates this low from the positive anomalies that occur farther west, trends from Kongsfjorden to Sørkapp Land, and generally delineates the eastern margin of the basement rocks (Fig. 2), which is the Tertiary deformation front. Since the sediments are non-magnetic, the character of the gradient varies along strike due to the variation in magnetization of the HH rocks to the west of the Tdf.

Inspection of profiles across Forlandssundet (Fls) and PKF shows that the magnetic field is flat and low above the sea and the Tertiary rocks on Prins Karl Forland and Oscar II Land to the east of the Fls. (See Fig 3 for geographical names). A steep gradient is associated with the fault-bounded contact between HH rocks and Tertiary rocks (Hjelle et al., 1979; Hjelle and Lauritzen, 1982). This gradient can be traced along the entire length of the PKF, separating HH rocks from the non-magnetic Tertiary clastic sediments. Also, Tertiary clastic sediments occur in grabens that have been mapped by seismic reflection data (Eiken and Austegaard, 1987), in basins down-faulted within the basement west of Spitsbergen. These grabens are delineated on the magnetic map by magnetic lows to the west of the coastline of Spitsbergen (NW Bellsund and NW Hornsund in Fig. 3). The low to the south of Hornsund is probably a negative flank effect of the prominent high on Sørkapp Land.

An anomaly in the southeastern corner of Fig. 4 (H1) originates from sources at a depth of more than 9 km in the basement, indicating the presence of thick sediments in Storfjorden. Some line effects, that are due to diurnal problems, can be seen in the northeastern part of the map area where the magnetic field is almost flat (Figs. 3 & 4). On the profiles, low-amplitude, short-wavelength anomalies are located above known occurrences of dolerites that are widespread on Spitsbergen (Parker, 1966; Flood et al., 1971; Weigand and Testa, 1982).

Tertiary volcanism?

The Hornsund Fault Zone (HFZ) lies to the west of the survey area (Fig. 2). High-amplitude anomalies occur (anomalies H2 & H3 in Fig. 4) at the western end of profiles between 77^0 N and 77^0 30' N. Depth determinations show that they originate from shallow sources. The anomalies trend roughly NNW-SSE; i.e. sub-parallel to the HFZ. Since these anomalies are close to the important HFZ and the initial plate boundary (transform) between Svalbard and Greenland, they may be caused by Tertiary intrusions.

A magnetic anomaly north of Nordfjorden (anomaly H4, Fig. 4), gives depth to magnetic source estimates around 2 km below sea level. The anomaly trends NW-SE, and is situated at the southeastern end of one of the main faults which has been mapped in northern Spitsbergen (e.g. Amundsen et al., 1988). On Sverresfjellet (south of Bockfjorden, see Fig. 3), close to the mapped fault, there are volcanic rocks which are considered to be of Quaternary age; hot springs are also present (Skjelkvåle et al., 1989). Many xenoliths of granulites and upper mantle peridotites were brought up by the volcanism (Amundsen et al., 1988). Anomaly H4 trends along the fault and may represent volcanites emplaced at subsurface levels along a zone of weakness in Tertiary time. This interpretation is highly speculative, but not impossible, in view of the proximity of northern Spitsbergen to the plate boundary between oceanic and continental crust on the Yermak Plateau just north-northwest of Svalbard.

Billefjorden Fault Zone (BFZ)

The BFZ extends from the north along Wijdefjorden and to the Isfjorden area (e.g. Harland et al., 1974), and defines the eastern margin of Devonian sediments. To the north of Billefjorden, the BFZ comprises a 2-4 km wide zone of parallel branching faults that dip to the east (Lamar et al., 1986). In Fig. 5, the location of faults interpreted by Harland et al. (1974) is compared with the magnetic anomaly pattern. Outcrops of HH rocks are shown with a dotted pattern. The Mittag-Lefflerbreen glacier covers large areas. The main fault (Balliolbreen Fault, fault B in Fig. 5) is an east-dipping reverse fault which has displaced HH metamorphic rocks in the east onto Devonian sediments in the west. The steep western flank of the magnetic anomaly (Fig. 5) correlates with fault B, along which there are slices of HH rocks. Another fault (named C in Fig. 5) runs along the axis of the main anomaly. The fault itself, with 40 m downthrow to the west (Harland et al., 1974), cannot explain the anomaly.

Measurements on amphibolite samples from the basement in northeast Spitsbergen (Ny Friesland) gave relatively high average magnetic susceptibility values of 0.01600 SI (Kurinin, 1965). Further east five samples of granite were practically non-magnetic (Hjelle, 1966). Also, to the north of Billefjorden, HH basement (the Harkerbreen Formation of Harland et al., 1974) contains many thin concordant and discordant sheet-like dykes of metagabbro-diabase, considered to be pre-Caledonian igneous rocks (Lauritzen and Ohta, 1984; Ohta et al., 1989). Thus, the basement rocks show large contrasts in magnetization.

Depth estimates performed on the profiles range from 1 km to 2 km below the observation plane (1600 m). These depths probably coincide with the depth to the top of the crystalline basement as taken from the geological cross-sections of Harland et al. (1974, Fig. 9, p.33). This indicates that the anomaly has its source within the basement.

Published geological maps show no volcanic rocks on the surface along the fault zone that could explain the anomaly. Some low-amplitude, short-wavelength anomalies occur 30 km to the east of the BFZ, over outcropping dolerites. These anomalies seem to be unrelated to the anomaly above the BFZ. Also, 10 km to the west of the south end of Wijdefjorden, in the Devonian, a few dykes (alkali lamprophyre) occur subparallel to the BFZ; these are considered to be of Carboniferous age (Gayer et al., 1966). These dykes make up too small a volume to explain anomalies measured at 1600 m flight altitude. From the above considerations, it can be concluded that the anomaly associated with the BFZ is caused by magnetic sources within the crystalline basement, and not by the fault itself.

A geological model of the BFZ has been tested for line SPA-7842 using forward modelling (Fig. 6). HH metamorphic rocks are exposed in a sliver within the fault zone. North of Billefjorden the HH consists of feldpathic and amphibolitic gneisses, with a high proportion of basic igneous rocks (Harland et al., 1974; Hjelle and Lauritzen, 1982). The latter may be highly magnetic. The modelling work showed that basement topography alone cannot explain the anomalies, since this required unrealistically high susceptibility values for the basement, or too high basement relief incompatible with the structural geology as reported by Harland et al. (1974) and Lamar et al. (1986), as well as seismic work carried out in Isfjorden (Faleide et al., 1988). In the model we have therefore used a combination of intrabasement susceptibility contrasts and basement topography. The BFZ constitutes the western margin of a basement high (Fig. 6). A small Carboniferous basin occurs to the east of the basement high, trending parallel to the BFZ (Harland et al., 1974). A reasonably good fit between observed and calculated anomalies is obtained. The aeromagnetic map shows that a large volume of highly magnetic HH rocks occurs along, and to the east of, the N-S trending BFZ.

Isfjorden area

The magnetic field over central and inner parts of Isfjorden is characterized by a positive, long-wavelength and low-amplitude anomaly (H5 in Fig. 4), with interfering positive short-wavelength anomalies of very small amplitudes possibly indicating sources at different depths. The axis along the magnetic maximum correlates with the northern part of the Central (Tertiary) Basin which is underlain by the deeper part of the NNW-SSE trending Devonian graben (Faleide et al., 1988). The western flank of the Devonian graben coincides with the western gradient of the magnetic anomaly. Sills of dolerite in the upper sediments can explain the short-wavelength anomalies. The magnetization of Tertiary sediments and of the Old Red Sandstone is low (Kurinin, 1965). Tertiary intrusions are scattered throughout the Devonian basin to the north of 78^0 30' N, but apparently make up small volumes (Winsnes, 1986). Extrusive rocks of Devonian age have also been reported further north (Murasov et al, 1983), but can hardly explain the Isfjorden anomaly.

Magnetic modelling did not contribute much towards an understanding of the anomaly source(s). It merely demonstrated the fundamental problem of ambiguity of potential field anomaly interpretation: It was possible to model the observed anomaly both by applying an intrusion within the lower part of the Devonian, and by assuming an intrabasement magnetic body with its top at the basement surface which is at c. 8 km as determined by depth-to-source estimates. The depth estimates were made independently of the modelling using several techniques that utilize only the form of the anomaly (Åm, 1972; Skilbrei, 1991). The depth estimates agree with the depth to the bottom of the Devonian Graben as depicted on a published seismic profile from Isfjorden (Faleide et al., 1988; Faleide et al., 1991).

Magnetic basement map

From the form of a magnetic anomaly it is possible to estimate the depth to the top of its causative body (Peters, 1949; Vacquier et al., 1951). An aeromagnetic survey over sedimentary basins is very useful for determining the general picture of the basement surface. However, for mapping small-scale structures in the top basement surface, the fallibility of the method has been demonstrated (e.g. Jacobsen, 1961). Basement depths are generally found to be in reasonably good agreement with seismic data (e.g. Nettleton, 1971). The magnetic basement map (Fig. 7) is based on a careful analysis of the original magnetic profiles. A manual interpretation using characteristic points and distances (straight-slope method and Peters' method) of all suitable anomalies has been performed (see e.g. Åm, 1972, for a review of methods). These methods assume that anomalies originate from intrabasement susceptibility contrasts, and that the top of the vertical causative bodies defines the basement surface. The autocorrelation method (Phillips, 1975) was also applied to find depth estimates automatically, using the Mapran3 program (Thorning, 1982), a modification of the ADEPTH-program (Phillips, 1975, 1979). This method is also described in Olesen et al. (1990) and Skilbrei (1990). For depth estimates that were considered reliable, the average of the estimates resulting from different methods was in most cases used as the 'point estimate'.

In some parts of the map area, few anomalies exist to provide depth estimates. In these areas the contours are dashed. The estimated depths agree fairly well with published depth converted seismic profiles (Eiken, 1985; Eiken and Austegaard, 1987; Faleide et al., 1988). However, the magnetic basement may not always coincide with the acoustic basement. Seismic data improved the contouring in Isfjorden. Elsewhere, the contouring is based only on the point estimates.

The most pronounced feature of the basement map is the very deep structure beneath inner Isfjorden. Strong gradients in the depth contours suggest it to be fault bounded, at least to the east, perhaps against a southerly continuation of the BFZ. The basement depths beneath central Spitsbergen become shallower (and the basin becomes narrower) to the south-southeast. This probably corresponds to a termination of the Central (Tertiary) Basin off the southeast coast of Spitsbergen. A similar situation occurs to the north of Isfjorden. Depths increase rapidly towards the centre of Storfjorden, where a N-S trending deep basin is suggested to exist.

An eastward directed slope in the basement surface in the west coincides with the Tertiary deformation front (Tdf in Fig. 3, the front/zone is discussed in Dallman et al., 1988). An en echelon arrangement of shallow troughs along the western margin of the survey area corresponds to the grabens on the

Spitsbergen shelf, and in the Forlandssundet (see Eiken and Austegaard, 1987).

Although the drawing of isolines of equal depth is subjective in some areas, the basement map suggests that the prevailing trends of the structure of the top of the magnetic basement are NW-SE to NNW-SSE. Fig. 8 depicts this pattern more clearly. The trend of the top of the magnetic basement surface is similar to tectonic trends (compare Fig. 8 with Fig. 2), and to the main aeromagnetic anomalies. Such a congruence of trends, which may indicate that the stongest gradients in the basement surface coincide with basement faults, allows speculation that the basement fault zones have been reactivated several times during basin formation.

DISCUSSIONS

Basement control of structure along the BFZ?

There is strong directional and spatial correlation between the surface trace of the BFZ and N-S trending aeromagnetic anomalies over exposed Precambrian HH rocks along the BFZ. This suggests that the BFZ existed as an important lineament in the Precambrian, and that the BFZ has been reactivated along this zone which is marked by an aeromagnetic lineament. A few reconnaissance profiles flown by NGU north of the SPA-88 survey area show strong magnetic anomalies above the HH rocks where they meet Wijdefjorden to the west (Åm, 1975), which can be related to the BFZ. The positive magnetic high can be followed from the continental shelf north of Svalbard, along the eastern coast of Wijdefjorden and to the Isfjorden area, where they become unresolvable.

Offshore extension of structures?

1. There is indirect evidence that the crystalline rocks of the Svalbard Archipelago also constitute the basement rocks to the south of Spitsbergen, in the adjacent Barents Sea. First, the geology of Bjørnøya (see inset in Fig. 1 for location south of Spitsbergen) is similar to the geology of Spitsbergen (e.g. Birkenmajer, 1975). Secondly, the lower crust in the Svalbard area is generally reflective with an abundance of diffractions, similar to that of the northern Barents Sea (Gudlaugsson et al., in prep.). Thirdly, the trends of aeromagnetic anomalies on Spitsbergen and the adjacent northern Barents Sea are very similar. If the anomalies reflect intrabasement strike trends, than the character of the basement underlying the adjacent Barents Sea can be assumed to be similar to the HH basement on Spitsbergen.

2. The BFZ and the LF may continue southwards into the Barents Sea, perhaps as far south as the pair of positive magnetic anomalies striking NNW-SSE (H6 and H7 in Fig. 4) in Storfjorden. This suggestion is speculative, because there is no direct continuation between the magnetic anomaly over the BFZ and either of the two magnetic anomalies trending from the Barents Sea onto Spitsbergen. However, thicker sediment cover south of Isfjorden (Fig. 8), and/or a non-magnetic basement here, would suppress the magnetic response of the basement rocks along the fault. Additionally, it must be mentioned that the magnetic response of the LF is very weak to non-detectable in the northeastern part of the map area where, unfortunately, evidence of diurnal noise is found. However, small steps on some of the original profiles (2-5 nT in magnitude) are observed above the surface trace of the LF, which could tentatively be associated with the fault. In Fig. 9, the most likely traces of the southern extensions of the BFZ and the LF are shown. The westernmost (stippled) line follows the

present erosional level of the eastern limit of Tertiary rock in Svalbard (Mann and Townsend, 1989). The interpretation favoured here merges the two fault zones with the pair of positive anomalies (H6 and H7 in Fig. 4) that occur over the northern Barents Sea. Ohta's (1982b) interpretation, which was based only on bathymetry, is shown for comparison.

3. The BFZ and the LF may define the margins of a basement horst on Ny Friesland (Figs. 7 & 8). The Basement horst is buried south of Isfjorden where a sub-basin is probably present, but basement depths again become shallower further to the south (around 2 km). To the east of the southern extension of the LF, the basement very is deep (in Storfjorden).

CONCLUSIONS

1. The map of estimated depth to the magnetic basement suggests a series of basement horsts and grabens/basins which trend N-S and NNW-SSE on Spitsbergen. The N-S trending Devonian graben is at least 8 km deep beneath central to inner parts of Isfjorden. This interpretation agrees with the seismic interpretation of Faleide et al. (1988). The deep basin is bordered to the east by a southerly extension of the Billefjorden Fault Zone (BFZ), which is the border fault to the Devonian graben in the north.

2. The BFZ and the Lomfjorden Fault (LF) form the borders to a basement horst on Ny Friesland which trends N-S to NNW-SSE from northern to central Spitsbergen. The estimated depths suggest this horst to be locally subdued to the southeast of Isfjorden (towards Storfjorden). The structure reappears as a buried basement horst further south and continues southwards to approximately 76^0 N. At the southern end the horst is

bordered to the west by a seaward continuation of the Tertiary Central Basin, and to the east by a deep basin in Storfjorden (see Fig. 7).

3. From structural geology it has been concluded that the BFZ is a long-lived structural feature with movements spanning the time from at least pre-Devonian to Tertiary (Harland et al., 1974). The aeromagnetic data illustrate the trend of the BFZ and suggest that this feature extends from north of Svalbard to the Barents Sea.

4. The aeromagnetic lineaments are probably a direct expression of basement lithologies beneath a non-magnetic sedimentary cover of variable thickness. The main aeromagnetic lineament system trends NW-SE to NNW-SSE which is also the trend of the main basement fracture direction. In general, geological field data, satellite data (Ohta, 1982a), seismic data (Faleide et al., 1988) and aeromagnetic data indicate a close directional, and sometimes spatial, correlation. This suggests that the main fault zones present in the crystalline basement have imposed a great deal of control during the subsequent tectonic evolution of the Svalbard area and the adjacent Barents Sea.

5. Positive magnetic anomalies to the west of Spitsbergen may reflect Tertiary volcanic intrusions along the Hornsund Fault Complex.

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LIST OF FIGURES.

FIG. 1

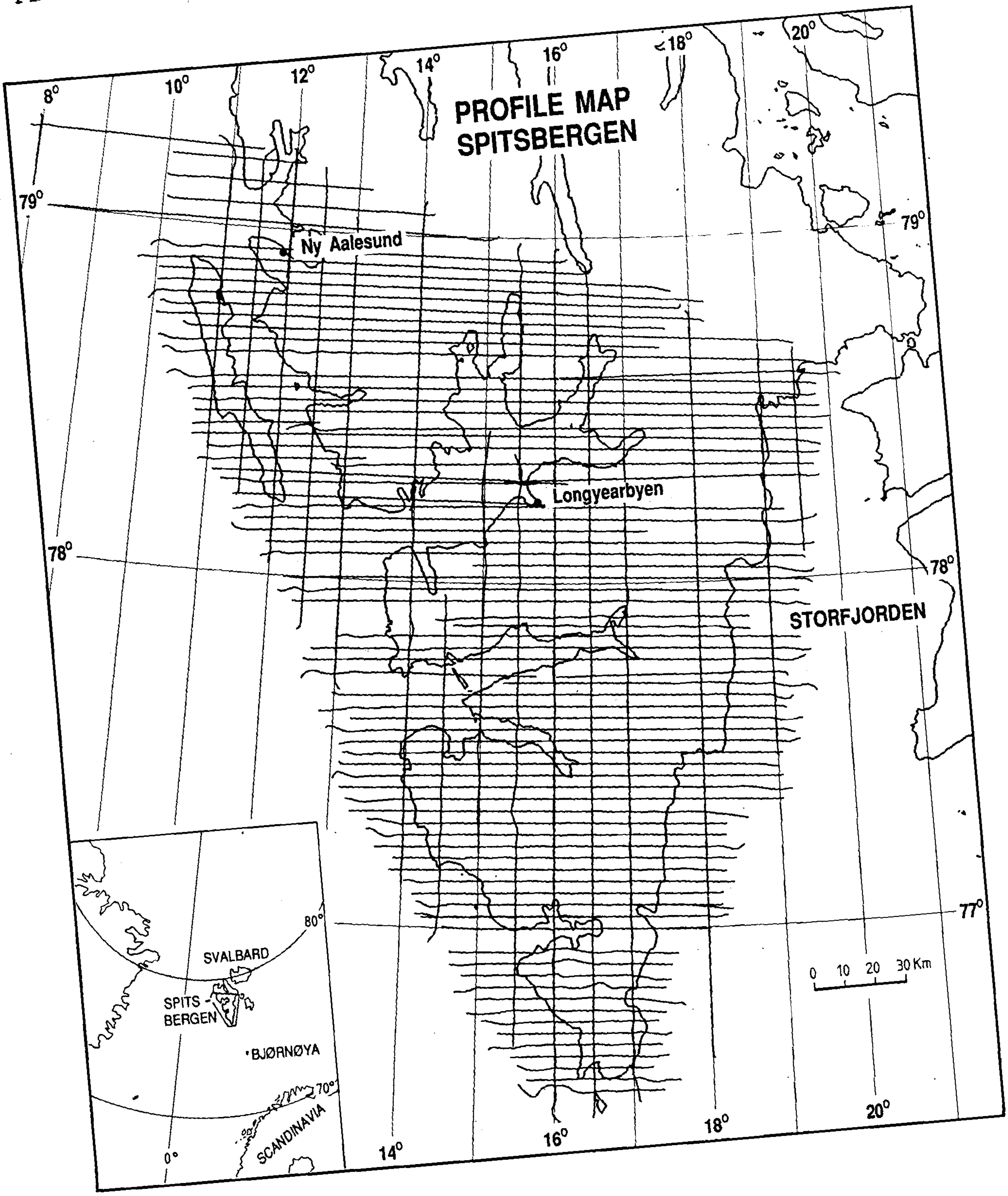
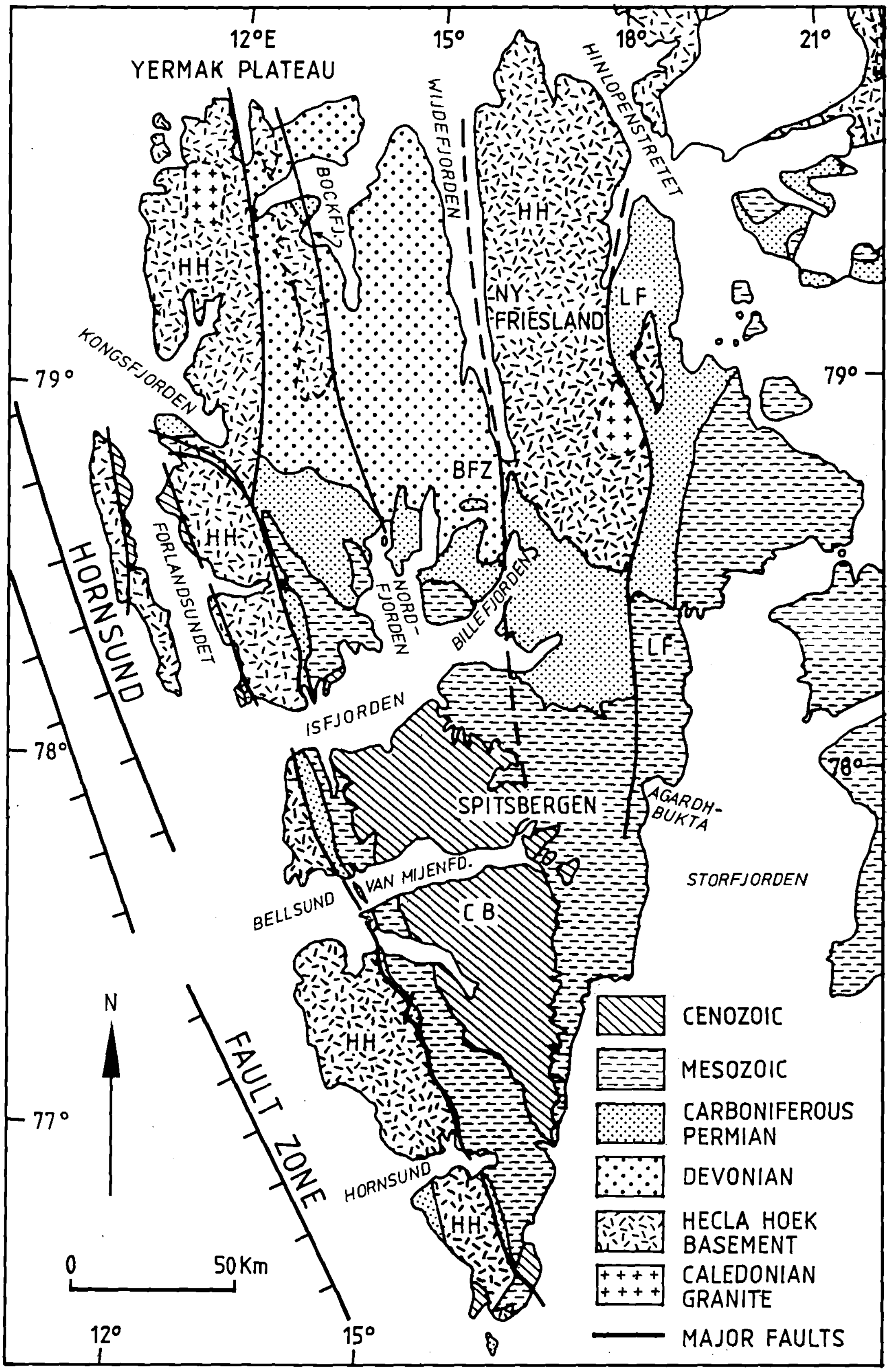

PROFILE MAP
SPITSBERGEN
8°
10°
12°
14°
16°
18°
20°
79°
78°
77°
Ny Aalesund
Longyearbyen
STORFJORDEN
0 10 20 30 Km
80°
70°
SVALBARD
SPITS-
BERGEN
BJØRNØYA
SCANDINAVIA
0°

FIG. 2



12°E
15°
18°
21°
YERMAK PLATEAU
WIJDEFJORDEN
HINLOPENSTRETET
BOCKFJ.
HH
NY FRIESLAND
LF
KONGSFJORDEN
79°
BFZ
HORNSUND
FORLANDSUNDET
NORD-FJORDEN
BILLEFJORDEN
ISFJORDEN
78°
SPITSBERGEN
AGARDH-BUKTA
STORFJORDEN
VAN MIJENFD.
BELLSUND
CB
N
FAULT ZONE
77°
HORNSUND
0
50Km
12°
15°
CENOZOIC
MESOZOIC
CARBONIFEROUS PERMIAN
DEVONIAN
HECLA HOEK BASEMENT
CALEDONIAN GRANITE
MAJOR FAULTS

FIG. 3

AEROMAGNETIC MAP

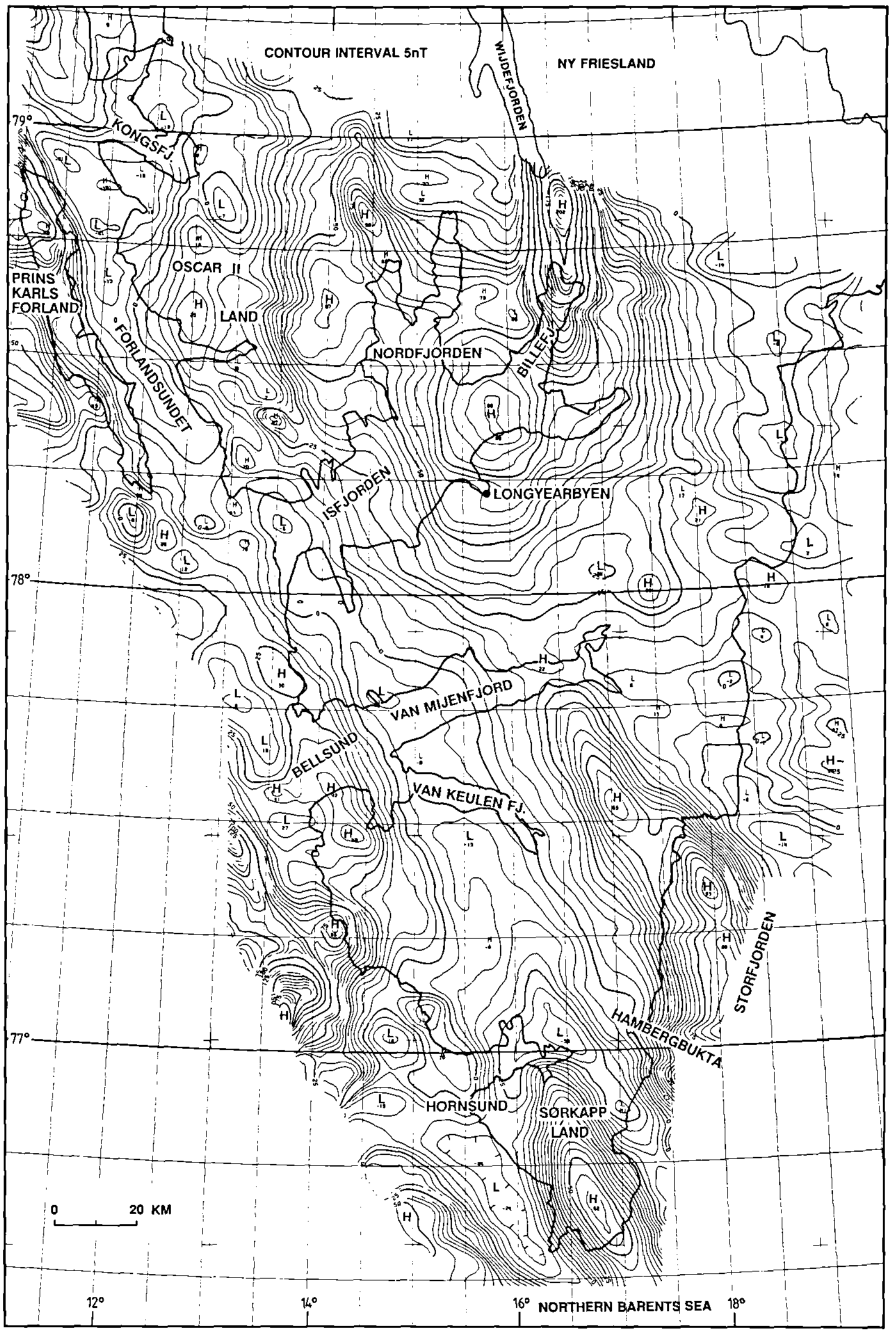
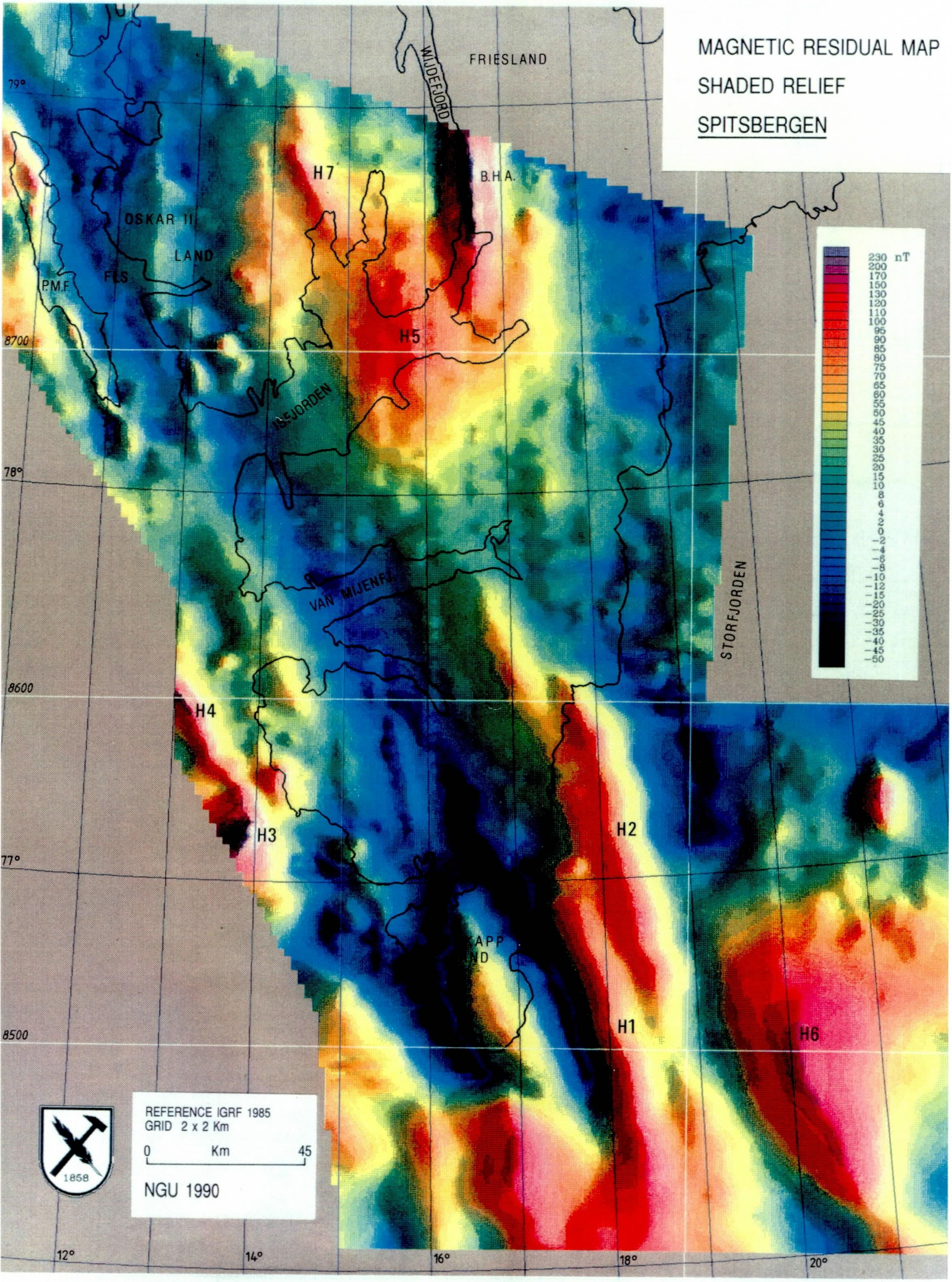


Fig. 4



MAGNETIC RESIDUAL MAP
SHADED RELIEF
SPITSBERGEN
FRIESLAND
WIJDEFJORD
B.H.A.
H7
OSKAR II
LAND
P.M.F.
F.L.S.
H5
ISFJORDEN
VAN MIJENFJ.
STORFJORDEN
H4
H3
H2
H1
H6
79°
78°
77°
8700
8600
8500
12°
14°
16°
18°
20°
230 nT
200
170
150
130
120
110
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
−15
−20
−25
−30
−35
−40
−45
−50
REFERENCE IGRF 1985
GRID 2 x 2 Km
0 Km 45
NGU 1990
1858

FIG. 5

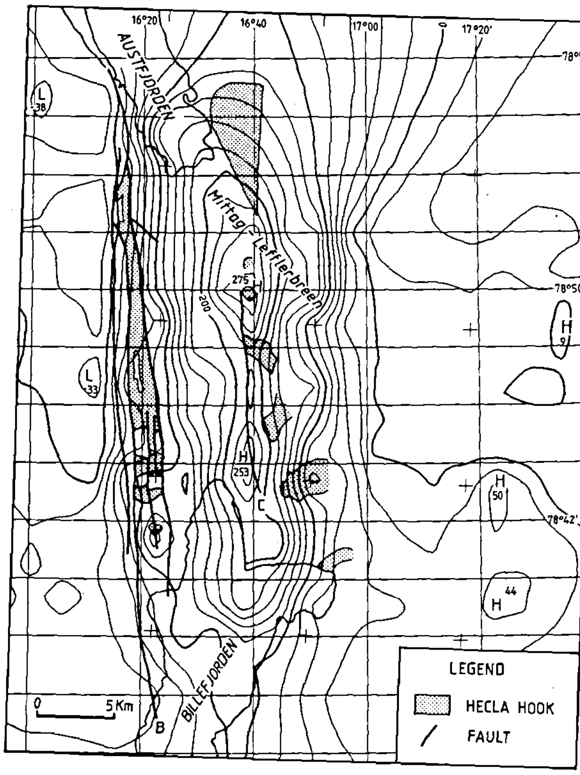

16°20'
16°40
17°00
17°20'
78°58'
78°50'
78°42'
AUSTFJORDEN
Mittag-Lefflerbreen
BILLEFJORDEN
L 38
L 33
H 253
275
200
H 9
H 50
H 44
0 5Km
B
C
LEGEND
HECLA HOOK
FAULT

FIG. 6

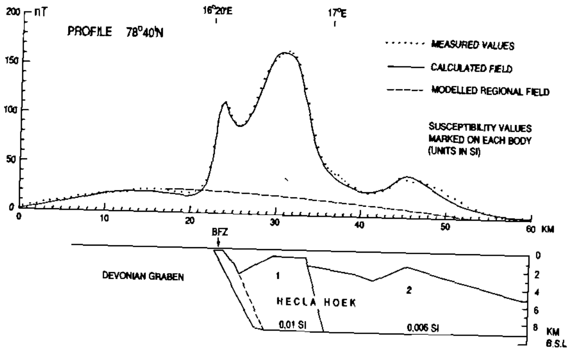

nT
PROFILE 78°40'N
16°20'E
17°E
MEASURED VALUES
CALCULATED FIELD
MODELLED REGIONAL FIELD
SUSCEPTIBILITY VALUES MARKED ON EACH BODY (UNITS IN SI)
KM
BFZ
DEVONIAN GRABEN
HECLA HOEK
0.01 SI
0.006 SI
KM B.S.L

FIG. 7

DEPTH TO THE MAGNETIC BASEMENT

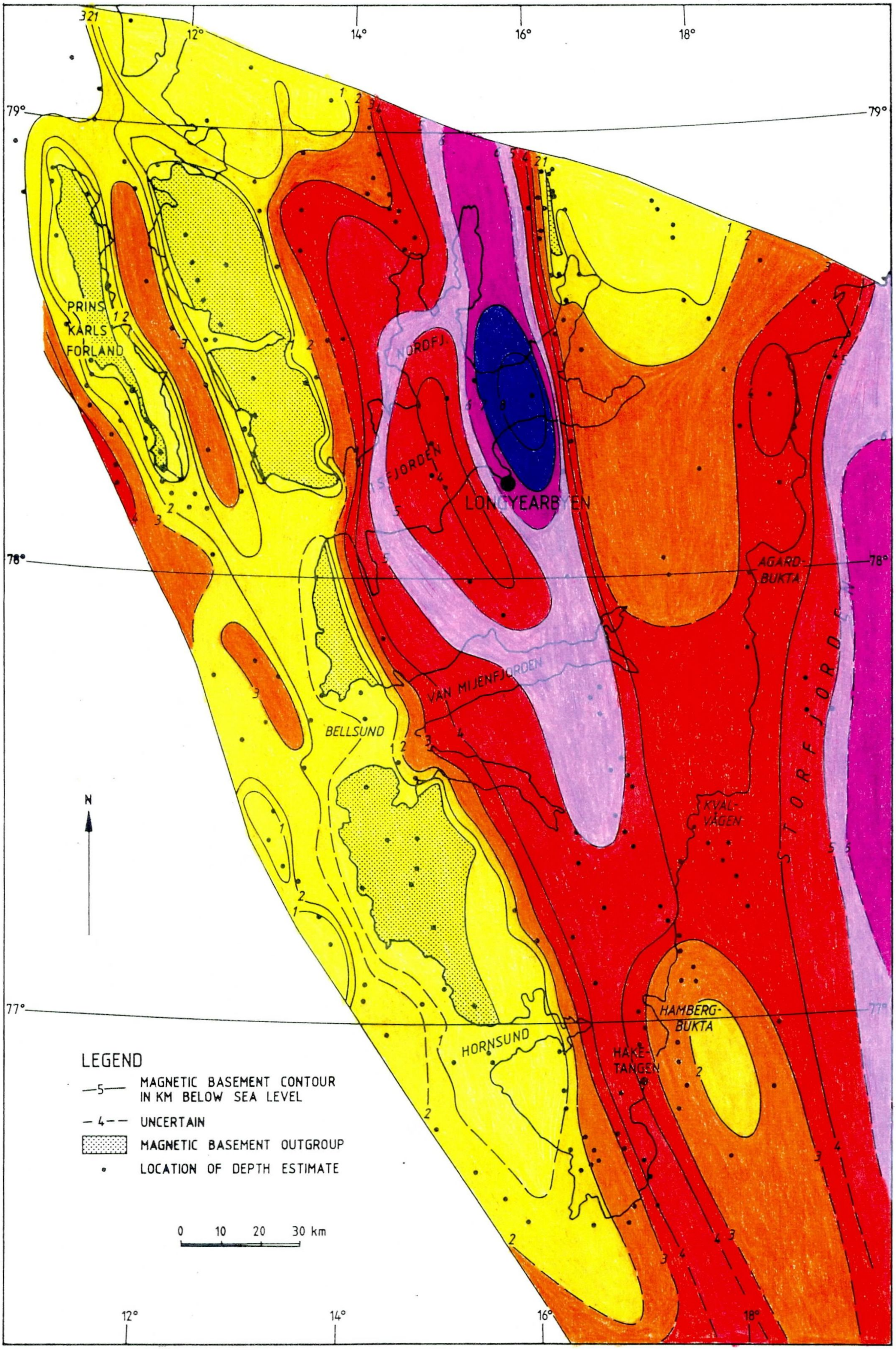


FIG. 8

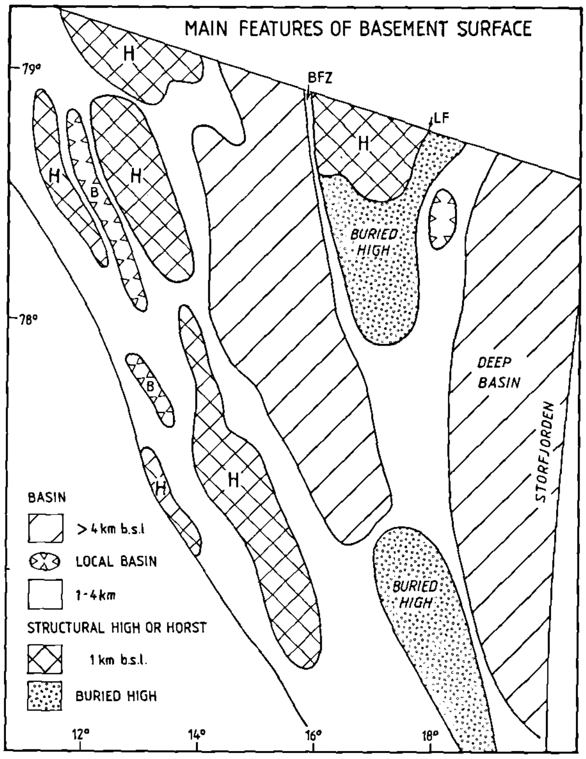
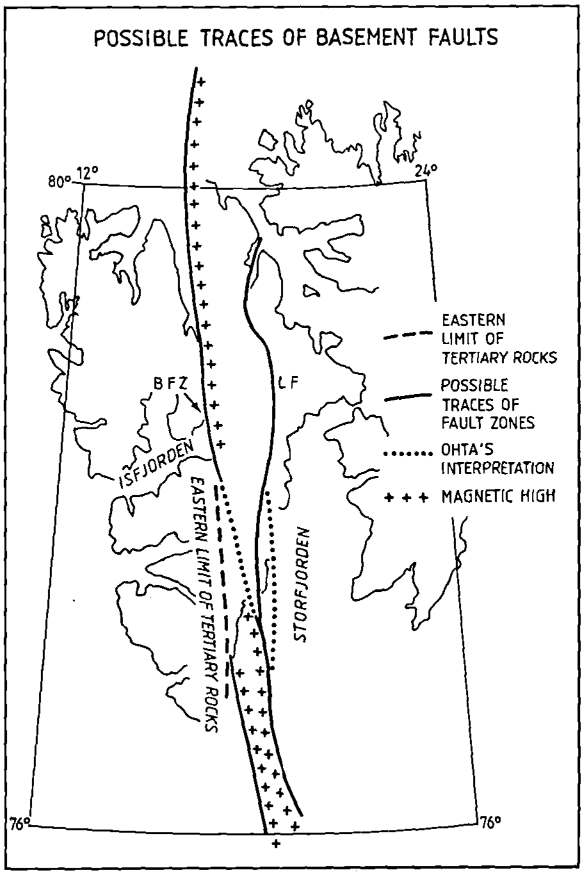

MAIN FEATURES OF BASEMENT SURFACE
79°
78°
BFZ
LF
H
H
B
H
H
B
H
H
BURIED HIGH
DEEP BASIN
STORFJORDEN
BURIED HIGH
BASIN
> 4 km b.s.l
LOCAL BASIN
1-4 km
STRUCTURAL HIGH OR HORST
1 km b.s.l.
BURIED HIGH
12°
14°
16°
18°

FIG. 9


POSSIBLE TRACES OF BASEMENT FAULTS
80°
12°
24°
BFZ
LF
ISFJORDEN
EASTERN LIMIT OF TERTIARY ROCKS
STORFJORDEN
EASTERN LIMIT OF TERTIARY ROCKS
POSSIBLE TRACES OF FAULT ZONES
OHTA'S INTERPRETATION
MAGNETIC HIGH
76°
76°