Aeromagnetic Basement Complex Mapping North of Latitude 62°N, Norway

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The Geological Survey of Norway (NGU) has conducted aeromagnetic measurements over Norway since 1959, and to date approximately 90% of the country has been covered with 435,000 line kilometres of such measurements. Since 1962 NGU has also measured 183,000 kilometres of aeromagnetic profiles over Norwegian shelf areas. The entire shelf between Stad (62°N) and Bear Island (74.5°N) out to a water depth of 2000 m and as far east as 36°E has now been systematically covered with approximately 4 km line spacing. From the measurements over the shelf, magnetic isogam maps with a 20 gamma contour interval have been constructed at a scale of approximately 1 : 350,000 south of 69°N, and ca. 1 : 700,000 north of this latitude. Copies of the maps and the original records have been sold to a number of interested companies. The material is confidential, but NGU has been allowed to publish generalized small-scale maps together with a rough interpretation of the data.

An interpretation in terms of depth to magnetic basement reveals that the shelf north of 62°N is composed of great thicknesses of sediments. Outside western Norway there are maximum thicknesses exceeding 10 km, and the inner part of the Vøring Plateau is underlain by approximately 6 km of sediments. Even in Vestfjorden, a major fjord south of Lofoten, there are more than 4 km of sedimentary rocks.

In the Barents Sea some special problems arise in the interpretation due to the presence of several kilometres of non-magnetic, Late Precambrian–Eocambrian sediments. An aeromagnetic survey over the Varanger Peninsula shows up to 7 km of such sediments. The Caledonian belt of metamorphic rocks is practically non-magnetic, except for some small iron ore-bearing formations and scattered ultrabasic bodies. However, in addition to anomalies from the basement, which is probably the Precambrian Baltic Shield, it has been possible to trace anomalies from a shallow level (?Paleozoic). Contouring of these shallow depths shows that they are in fairly good agreement with acoustic (refraction) basement.

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Introduction

Aeromagnetic measurements in Norway have been conducted by the Geological Survey of Norway (NGU) since 1959, and up to the present time about 90% of the country has been systematically covered with approximately 435,000 line kilometres of such measurements (Fig. 1). Areas with relatively gentle topography were covered first, mostly with around 500 m line spacing and 150 m ground clearance. In recent years, when areas with more rugged terrain have been surveyed, it has been impossible to maintain a constant ground clearance. In these cases profiles have been flown as low as possible at constant barometric altitude within each region, and the line spacing has been adjusted accordingly.

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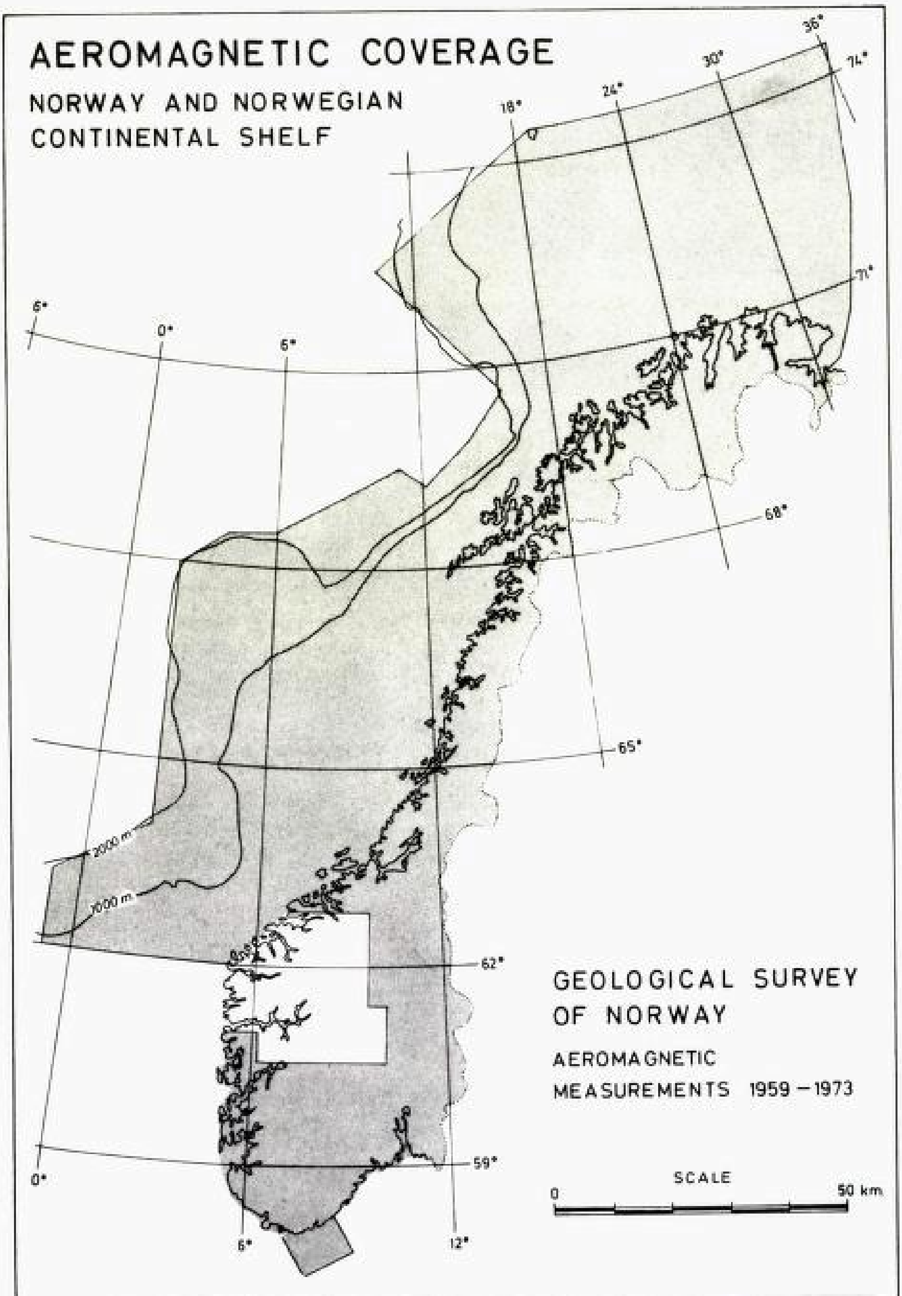


Fig. 1. Areas systematically covered with aeromagnetic measurements by NGU in the years 1959–1973.

From the measurements over land, NGU produces magnetic isogam maps with a 100 gamma contour interval at scales 1 : 50,000 and 1 : 100,000. The maps are available in the form of paper copies at a price of 12 N.kr. per sheet. These maps are further reduced to a scale of 1 : 250,000, redrawn and printed in colour.

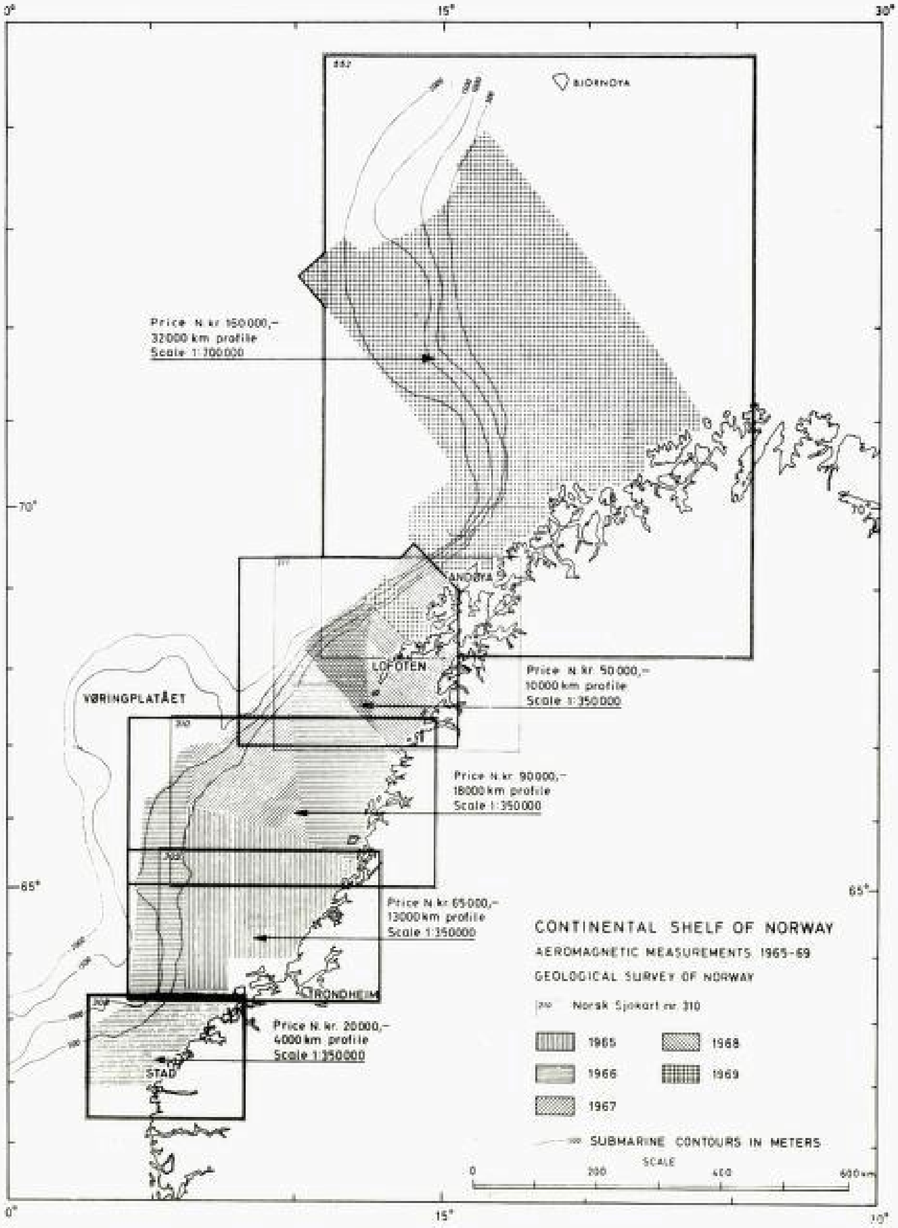


Fig. 2. Aeromagnetic maps from the continental shelf of Norway on sale at NGU, Trondheim.

Since 1962 NGU has also measured some 185,000 kilometres of aeromagnetic profiles over Norwegian shelf areas. After some reconnaissance flights in the Skagerrak in 1962–63 (Aalstad 1963, 1964a, Sellevoll & Aalstad 1971) and between Stad (62°N) and Andøya (69,5°N) in 1963–64 (Aalstad 1964b), systematic suveying started in 1965. To date, the entire shelf between Stad and Bjørnøya (Bear Island, 74,5°N) out to a water depth of around 2000 m and as far east as 36°E has been covered with approximately 4 km line spacing or a total of 160,000 line kilometres (Fig. 1). In addition, a detailed survey was flown in the Skagerrak in 1965 (Sellevoll & Aalstad 1971, Åm 1973), and in 1970 some reconnaissance profiles were measured over Svalbard and surrounding waters (Åm, in press).

Magnetic isogam maps with a 20 gamma contour interval have been constructed at a scale of 1 : 350,000 south of 69°N and 1 : 700,000 north of this latitude. The maps are largely confidential, but copies of some of the map sheets and original records are available at a price of approximately 5 N.kr. per line kilometre; this concerns the area covered up to 1969 (Fig. 2). In addition, NGU has been allowed to publish generalized small-scale maps from the shelf together with a rough interpretation of the data.

In the years to come, NGU hopes to be able to carry out detailed measurements along the coast in order to tie together the separate measurements made over land and sea. At the moment, this is a difficult task because of the wider line spacing used in the profiling of the sea areas.

A general outline of the geology of Northern Norway is presented in Fig. 3. A full account of the geology will be found in Holtedahl (1960). The old Precambrian Baltic Shield to the east is known to contain strongly magnetic rocks, but also large areas of non-magnetic material, mainly quartzites. In the north-east this metamorphic complex is overlain by several kilometres of Late Precambrian–Eocambrian sediments. This unit is completely non-magnetic except for some swarms of diabase dykes. The overlying Caledonian belt of metamorphosed Eocambrian to Silurian rocks is also practically non-magnetic except for some iron ore formations and strongly magnetic gabbro provinces. However, it should be noted that many of the Caledonian gabbros are non-magnetic. The only Mesozoic sediments known in Norway are found in a small down-faulted area on Andøya.

The purpose of this paper is to present some of the results of aeromagnetic mapping over Norway and its continental shelf conducted by NGU. The following subjects and areas will be dealt with:

1. A short section on the interpretation of magnetic measurements.
2. The shelf between Stad and Lofoten including the Vøring Plateau.
3. Lofoten–Vesterålen (granulites).
4. Andøya and Andfjorden (Mesozoic sediments).
5. Kvænangen–Finnmarksvidda (section across the Caledonides).
6. Varangerhalvøya (Late Precambrian sediments).
7. The shelf between Andøya and Bjørnøya.

Interpretation of magnetic data

Magnetic anomalies reflect variations in the content of magnetite in the bedrock, and as the distribution of magnetite is governed by geological laws a magnetic map reveals geological features. In particular, strike directions, tectonic lines and the outline and areal extent of geological provinces are often

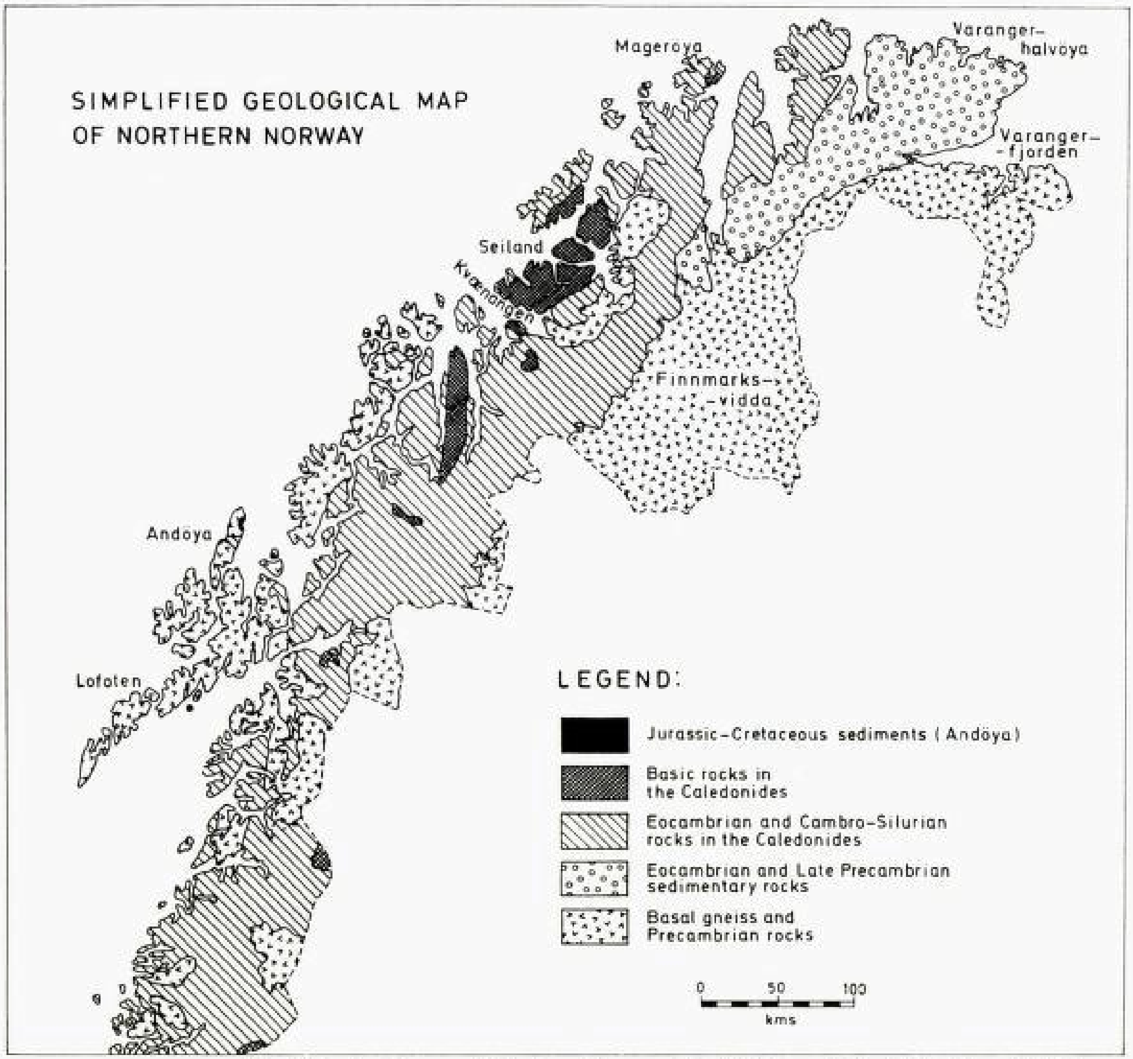


Fig. 3. Geological map of Northern Norway. Modified from Holtedahl & Dons (1960).

clearly seen. From the form of a magnetic anomaly it is also possible to determine the approximate depth to the top of its causative body (Vacquier et al. 1951). In a general way it can be stated that a rugged appearance with steep gradients and sharp anomalies indicates shallow sources, while a smooth picture with gentle slopes and usually broader and weaker anomalies is indicative of a deeper origin. This is well illustrated in Fig. 4, which shows one of the reconnaissance profiles measured over the shelf by NGU in 1963. The sharp and rugged anomalies over land are due to causes actually exposed or close to the surface, whereas it is probably 5–8 km down to the sources of the broad anomalies recognized above the shelf.

It is well known that aeromagnetic surveys over sedimentary basins are very useful for the determination of a general picture of the basement surface. Such

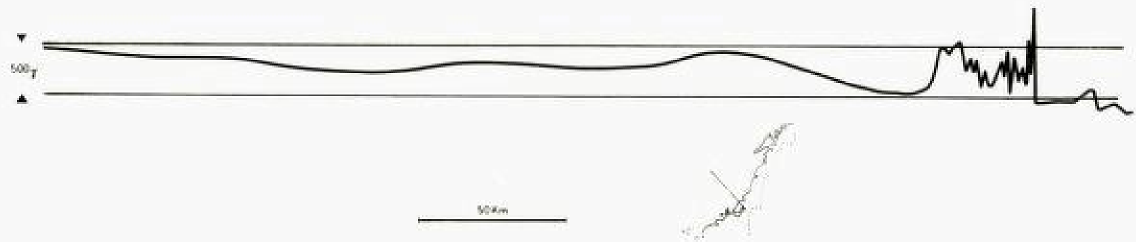


Fig. 4. Reconnaissance NW–SE magnetic profile flown across the shelf by NGU in 1963, after Aalstad (1972). The profile illustrates the difference in magnetic signature over the crystalline rocks on land and over the deep sedimentary basin on the shelf.

interpretations are generally found to be in reasonably good agreement with reality (e.g. Nettleton 1971). The depth determinations are based on two fundamental facts: 1) From the form of a magnetic anomaly it is possible to calculate the depth to the top of the body causing the anomaly. 2) Significant magnetic anomalies are almost exclusively due to magnetization contrast in the basement because the sedimentary cover is generally devoid of larger masses of magnetic material.

Consequently, if it is assumed that the magnetic bodies reach the surface of the crystalline basement, the depths to the tops of the anomalous bodies, determined from a careful study of the anomalies, will give points on the basement surface. When such depths have been determined for all magnetic anomalies in an area, the results are critically examined before a generalized contouring of the basement surface is made, giving less weight to uncertain determinations and to values differing too much from the others.

A review of the various methods for manual interpretation of magnetic data by the use of characteristic points and distances in the anomaly curves has been published by Åm (1972). Three lengths related to the inflection tangents of an anomaly are often used as depth estimators. These are the Straight Slope length, the Peters length and the Sokolov length, illustrated in Fig. 5. To yield the correct depth, the depth estimator used must in each case be divided by a certain factor depending on the form and dimensions of the causative body, which can be found with the aid of a suitable interpretation chart. However, magnetic anomalies generally fall into two classes so that as a rule the Straight Slope length has to be divided by 0.7 or 1.0, the Peters length by 1.5 or 2.0 and the Sokolov length generally by a factor around 2.0.

In the present case the interpretation has been made directly on the original magnetometer records by the use of characteristic points and distances in the anomaly curves. All the three depth estimators mentioned above have been used where possible. Since the original magnetometer records from the Kvænangen–Finnmarksvidda region are curvilinear, it was difficult to use the Straight Slope or the Peters length in that region. However, the Sokolov length, when averaged from two neighbouring profiles flown in opposite directions, yielded results close to those obtained on redrawn profiles. The Solokov length was therefore used throughout in the Kvænangen–Finnmarks-

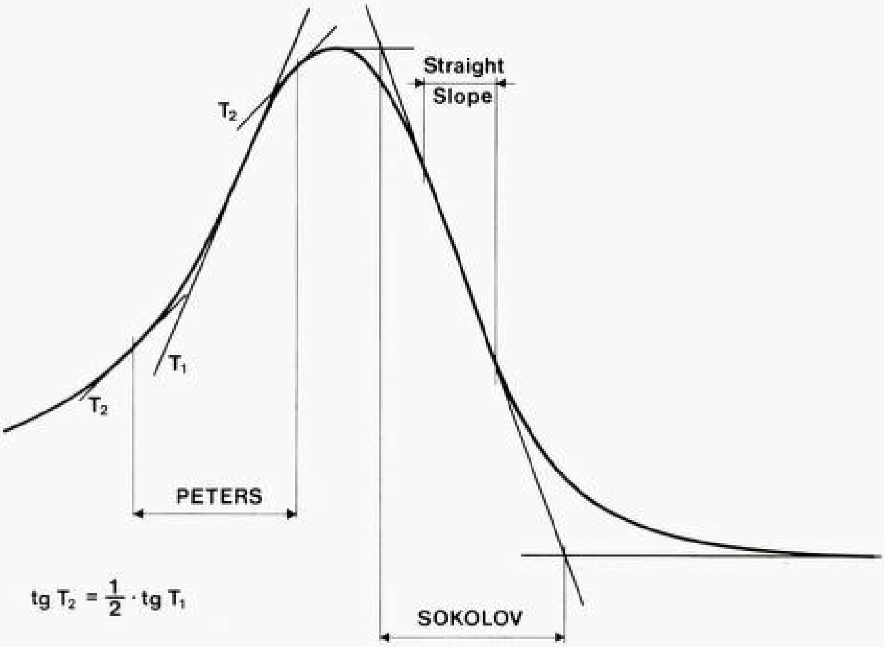


Fig. 5. Magnetic anomaly with three popular depth estimators. When divided by a certain factor, a depth estimator gives the depth to the top of the body causing the magnetic anomaly. In the Figure the vertical represents field strength and the horizontal is distance.

vidda region, together with the interpretation chart in Fig. 16 of Åm (1972). The depths thus obtained have been corrected for strike directions and strike extents where necessary.

The shelf between Stad and Lofoten (62-68°N)

A map of the residual magnetic field between Stad and Lofoten was published in 1970 together with a rough interpretation of the data, mainly in terms of depth to magnetic basement (Åm 1970). The data indicated the existence of a sedimentary basin more than 200 km wide aligned parallel to the coast with its axis 120–150 km from the coastline.

Off the coast of Nordland (65–67°N) the axis of this basin is situated not far from the middle of the shelf with maximum depths to basement exceeding 9 km. A culmination (7–8 km depths) is indicated outside Trøndelag (64°N). Off Møre (63°N) the basin deepens again, reaching depths of probably more than 13 km with the axis situated on the continental rise about 60 km off the shelf edge. There is a pronounced difference in magnetic signature north and south of the culmination (64°N), with strong and irregular anomalies to the south and a weak and featureless picture to the north. The depth to anomaly sources is approximately the same in both regions, so there must be a difference in the type of basement. The strong and irregular magnetic anomalies to the south are not unlike the anomalies observed over the Precambrian gneisses of the adjacent mainland, implying that the magnetic basement south of 64°N is probably Precambrian. The weaker anomalies to the north of 64°N might possibly be due to intrusions of Caledonian age, suggesting that the magnetic basement could be Palaeozoic in this region.

The Vøring Plateau can be divided into two parts on the basis of the magnetic picture seen in the U.S. Naval Oceanographic Office map (USNOO 1967). The inner half of the Vøring Plateau is magnetically quiet and similar in magnetic pattern to the adjacent shelf area. Some very weak magnetic anomalies indicate that the basement is 6–7 km deep in this part of the plateau. The outer part of the Vøring Plateau is characterized by shallow 'volcanic' anomalies similar to those observed over the deep ocean. These anomalies could be due either to (1) shallow oceanic basement or to (2) volcanic material in the sediments. The first possibility is supported by Talwani & Eldholm (1972) who demonstrated the existence of shallow refraction basement under the outer part of the Vøring Plateau, and the second is supported by Hinz (1972), who found that this part of the plateau is a continental fragment. There are also some magnetic indications that the second possibility might be true, e.g. magnetic anomalies continuing into the eastern part of the plateau, where they seem to originate from sources above the basement. It is hoped that an interpretation of the detailed aeromagnetic survey of the plateau carried out by NGU in 1973 will provide an answer to this problem.

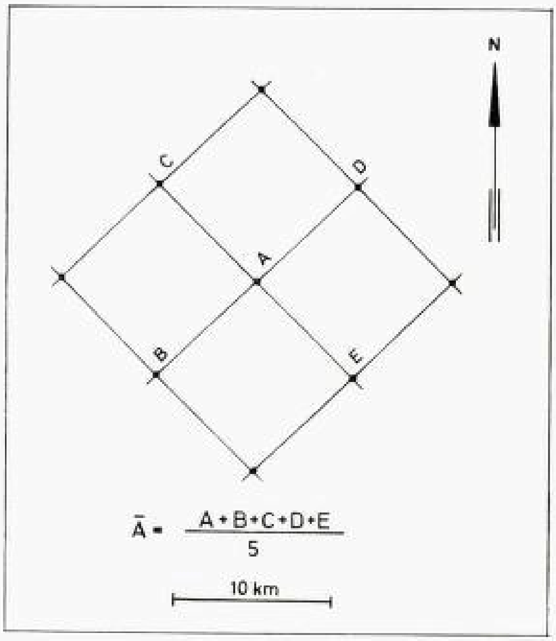
Lofoten–Vesterålen (granulites)

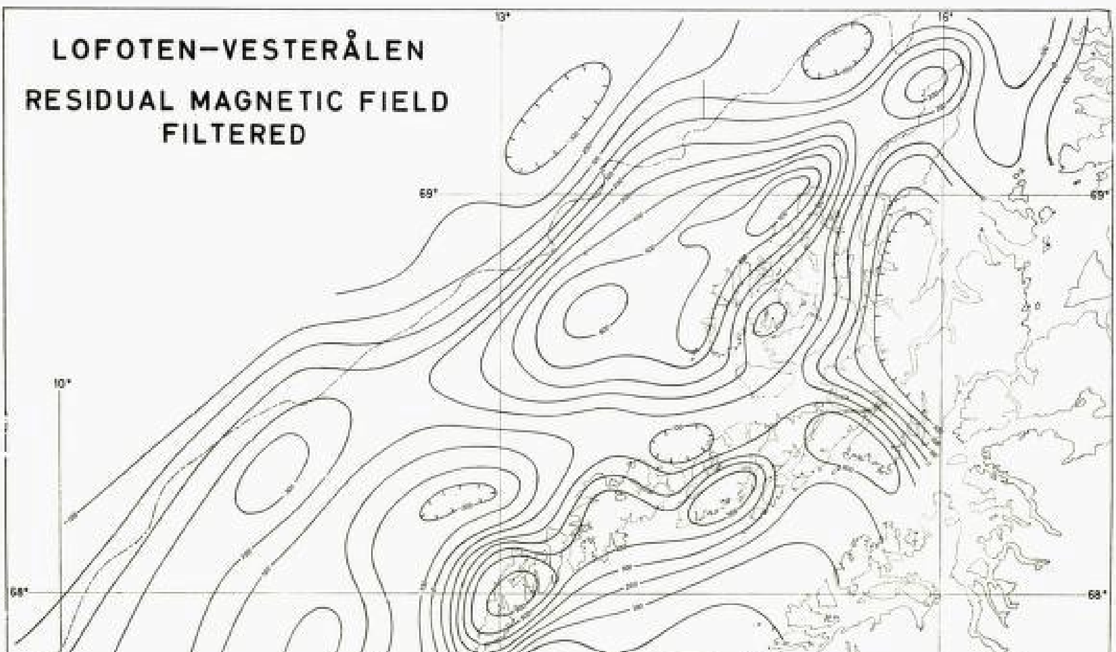
The Lofoten–Vesterålen island group (68–69°N) was covered with aeromagnetic measurements by NGU in 1965. The survey was flown N–S at 1000 m barometric altitude and with a flight-line spacing of approximately 2 km. The surrounding sea areas were flown NW–SE in 1968 and 1969 at a height of 200 m above sea level with ca. 4 km line spacing and Decca navigation. In spite of the different flight elevations over land and sea, it proved to be comparatively easy to tie the maps together. Five point moving averages in a 9 km square grid (Fig. 6) were then taken to filter the map, and the IGRF regional gradient, which is 2.6 γ/km towards NE in this area (Fabiano & Peddie 1969), was removed. The resulting residual map is presented in Fig. 7.

The Lofoten–Vesterålen island group consists mainly of granulite facies rocks (Heier 1960). From the strongly filtered aeromagnetic map (Fig. 7) it can be seen that large magnetic anomalies are associated with this granulite complex. The magnetic anomaly over Lofoten can easily be explained by the magnetic properties of the rocks occurring at the surface, if these extend down to a depth of around 20 km. The average magnetic susceptibility measured on

Fig. 7. Filtered magnetic map of Lofoten–Vesterålen with regional field removed. See Fig. 3, for geology and location.

Fig. 6. Five point moving average used to filter the aeromagnetic map from Lofoten–Vesterålen.





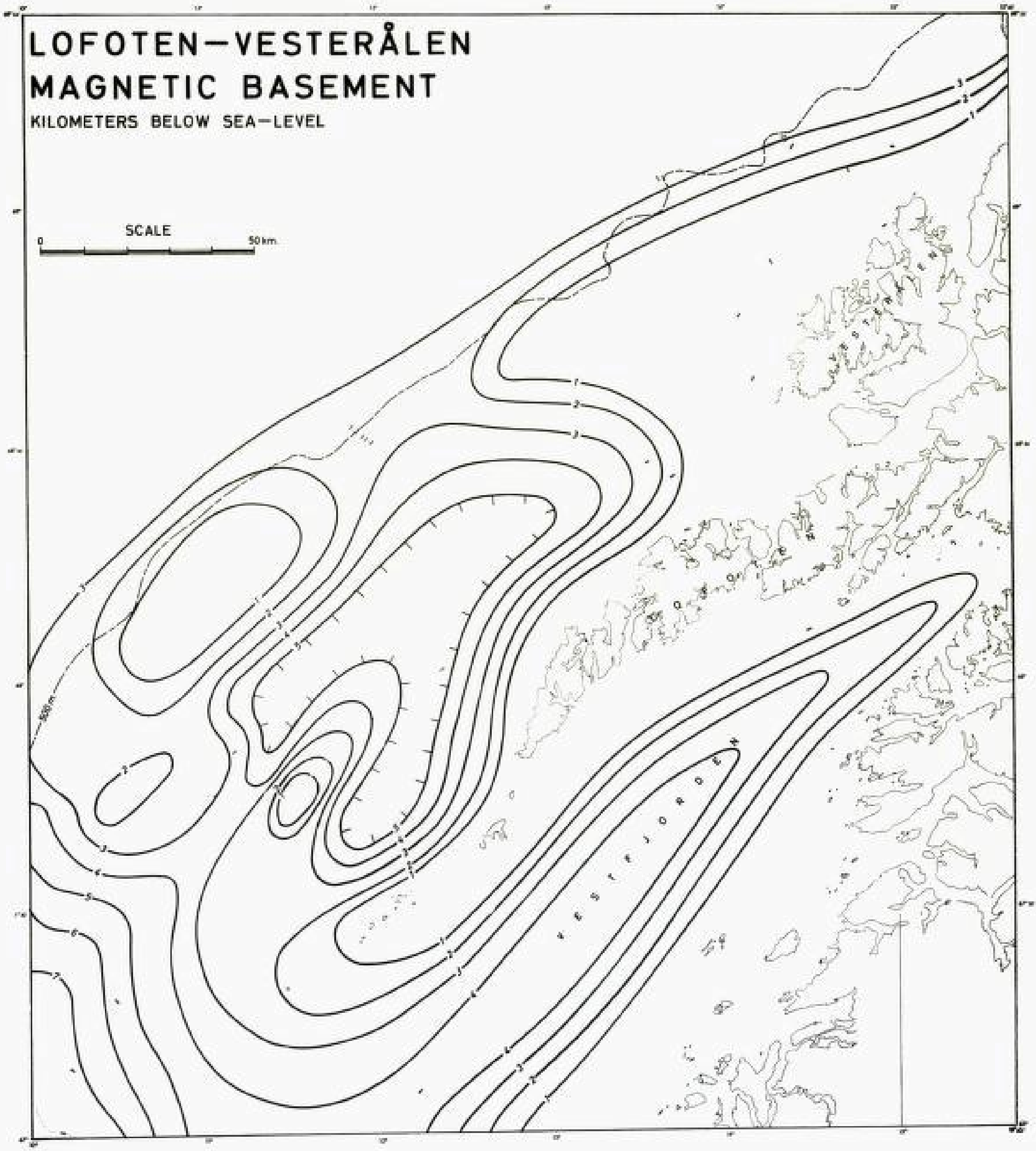


Fig. 8. Tentative magnetic basement map of Lofoten–Vesterålen.

900 rock samples is 0.003 cgs. The anomalies clearly demonstrate that the Lofoten granulites continue towards the south-west. The similar magnetic anomalies to the west show that there is another equally large mass of such rocks lying parallel to Lofoten on the shelf edge, with its top at some depth below the surface. This body is also causing the gravimetric 'shelf high' of Talwani & Eldholm (1972), and it is most likely a southward continuation of the granulites of Vesterålen. In between these two large masses of high-

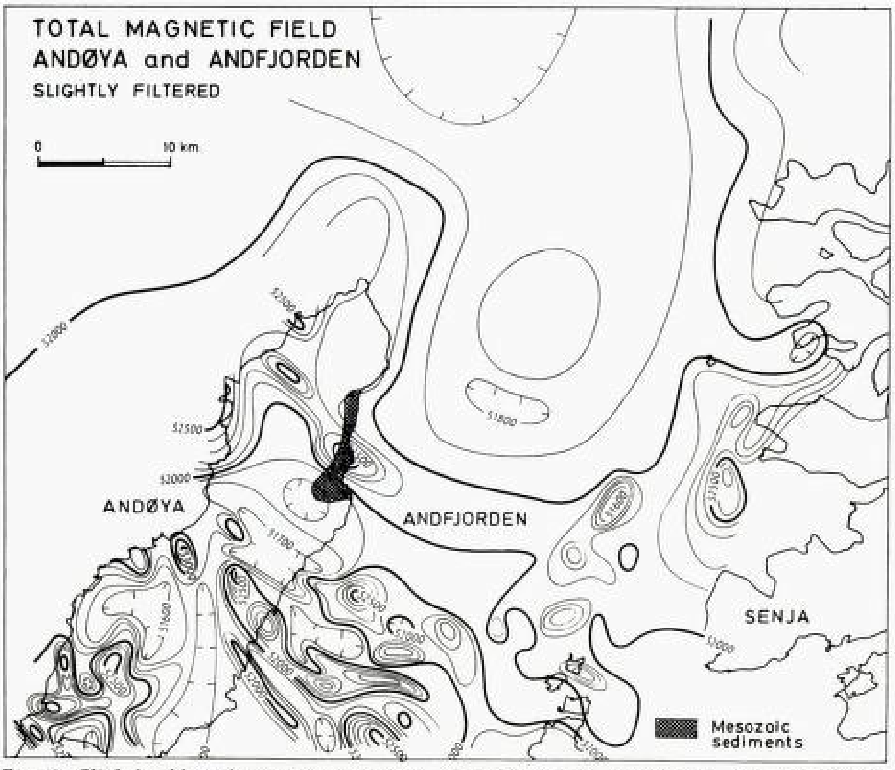


Fig. 9. Slightly filtered aeromagnetic map of Andøya and Andfjorden. See Fig. 3 for location.

grade metamorphic rocks there are indications of a much smaller body at approximately 67°45'N, 11°45'E as outlined by the 100 gamma contour.

A magnetic basement map is presented in Fig. 8. This is based on a careful study of the original records, but as the magnetic gradients seem to be, in part, associated with sources situated far below the top of the basement, the contours must be regarded as tentative. Three refraction profiles shot in the area give considerably shallower basement depth values (Sundvor & Sellevoll 1971). However, the contours in Vestfjorden are based on some good magnetic depth determinations ,and there is little doubt about the position of the 1 and 2 km contours in the rest of the area. The ridge associated with the small central granulite complex cannot therefore be questioned. It is also quite clear that the Lofoten massif and its twin to the west represent horst-like structures.

Andøya and Andfjorden (Mesozoic sediments)

Andøya is the only locality in Norway where Mesozoic sediments have been found. The occurrence has been known for more than a century, and a summary of the geology has been given by Ørvig (1960); see also Dalland (this volume). Upper Cretaceous sediments have also been dredged from the continental rise west of Andøya (Manum 1966). The area around Andøya

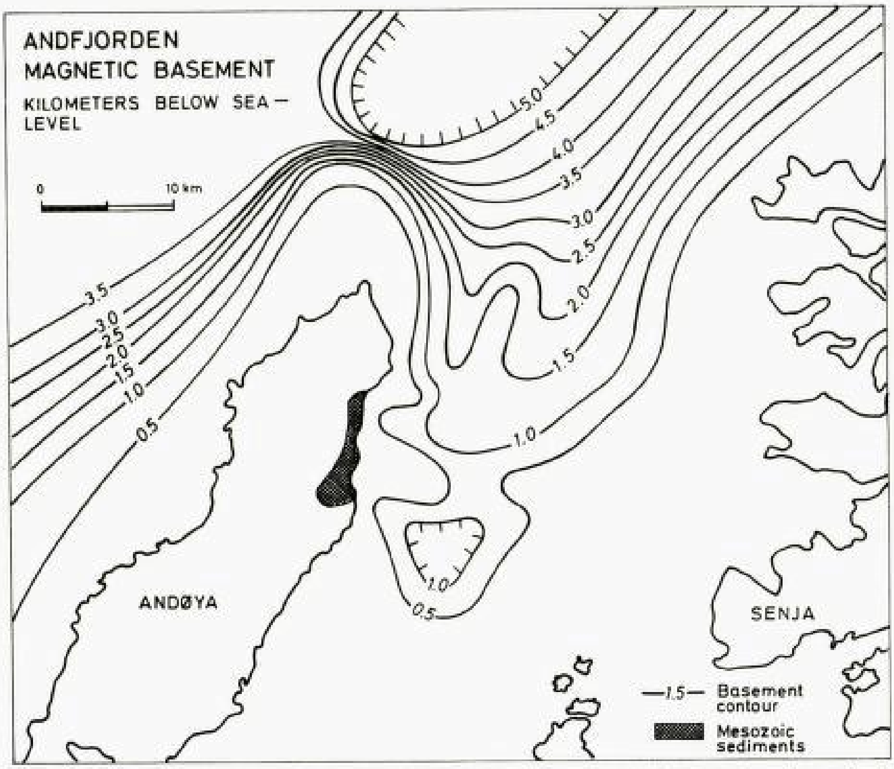


Fig. 10. Generalized contour map of the basement surface in Andfjorden based on depth determinations made on the original magnetometer records.

was therefore a natural target for an aeromagnetic survey after the first reconnaissance profiles had been flown over the shelf in 1962 and 1963.

Andøya and Andfjorden were covered with aeromagnetic measurements by NGU in 1964. The survey was flown E–W with 150 m 'ground' clearance and 1 km line spacing. A part of the resulting map has been published by NGU at a scale of 1 : 100,000 (Aeromagnetisk kart 1233). A somewhat simplified aeromagnetic map of the area is presented in Fig. 9.

One of the more important conclusions that could be drawn from the data was that the area of Mesozoic sediments is divided into two separate parts by a magnetic body with its top at or close to the surface. This ridge-forming body is probably the south-eastward continuation of the Trolltind gabbro, which is exposed to the north-east along the continuation of the anomaly in question (Dalland et al. 1973).

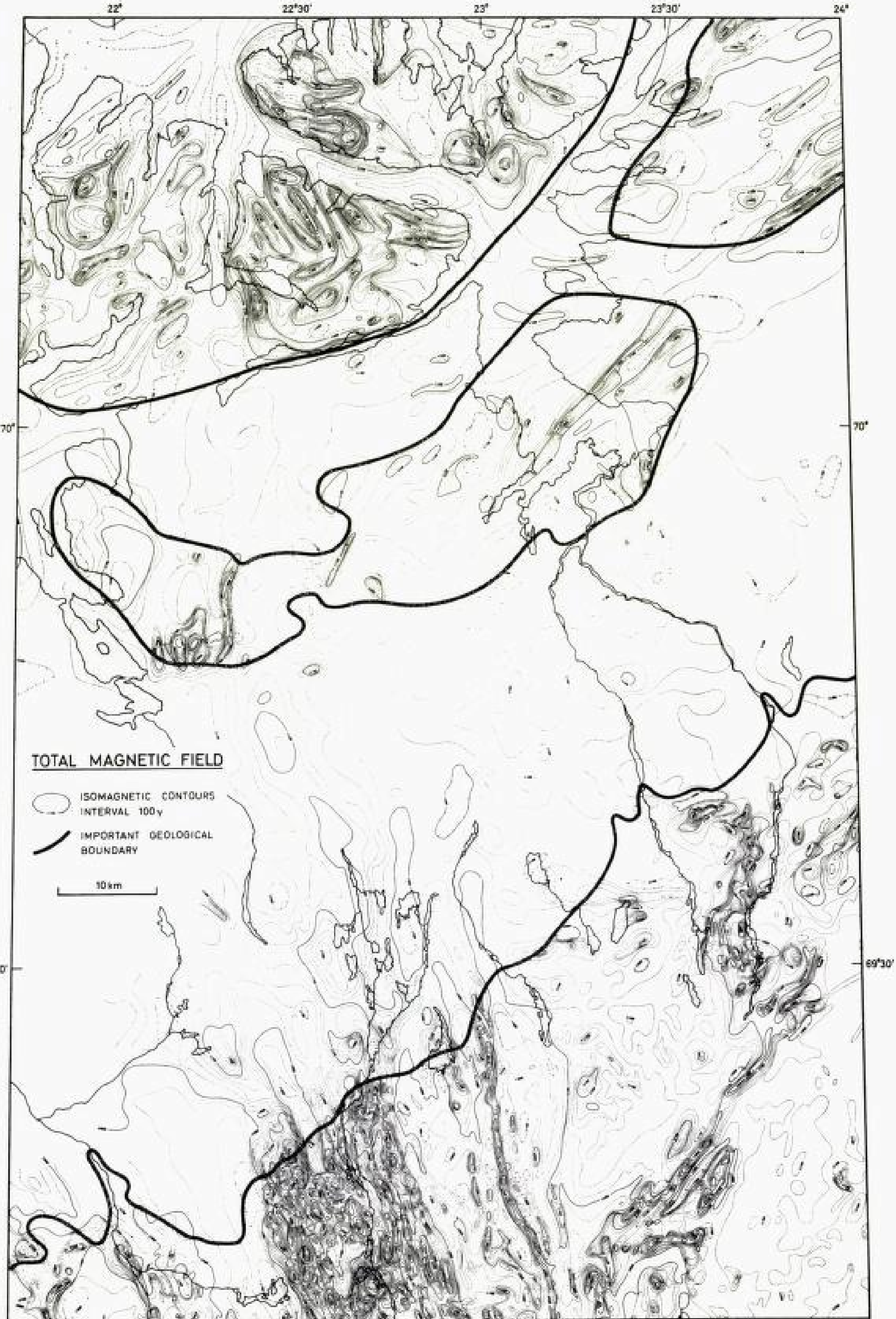
Fig. 10 shows a generalized contour map of the basement surface based on depth determinations made on the original magnetometer records. The depths to the east of Andøya were calculated by I. Aalstad in 1965, while the remainder were determined by the present author in 1970 on records from measurements made by NGU in 1969. The interpretation shows that the basement high associated with the Trolltind gabbro continues across Andfjorden. It also shows that Andfjorden is almost devoid of sediments, the water depth being around 500 m in this part of the fjord. Ten kilometres north of Andøya the depth to basement is more than 5 km. This is in good agreement with a depth of 5.1 km to seismic refraction basement as reported by Sundvor (1971, Profile R1). The rapid change in depth over such a short distance must evidently be due to the presence of a major fault.

Kvænangen–Finnmarksvidda (Caledonides)

As a part of the general aeromagnetic mapping of Norway, the area in question was covered with aeromagnetic measurements in 1959, 1962 and 1965. The survey was flown E–W with 100–150 m ground clearance and approximately 1 km flight-line spacing. The resulting isogam maps have been printed as 1 : 250,000 coloured maps (NGU 1971a & 1971b), a portion of which is reproduced in Fig. 11 at a reduced scale together with the principal geological boundaries between the Precambrian of Finnmarksvidda, the Caledonian rock complexes, the Precambrian windows of Alta–Kvænangen and Komagfjord and the Seiland gabbroic province (see Fig. 3).

The prominent magnetic anomalies to the south and south-east are associated with basic volcanics or 'greenstones' of Precambrian age. These anomalies are seen to continue into the Caledonian region in a weaker and more regular form, indicating that the greenstones continue northwards at some depth under the Caledonian nappe cover. Generally speaking these broad anomalies can be followed continuously until they join up with the sharp anomalies associated with the Precambrian greenstones of the Alta–Kvænangen window. The reason why these 'deep' anomalies can be so readily traced must be that the rocks of the Caledonian cover are practically non-magnetic. If this were not so they would give rise to sharp anomalies which would interfere with and eventually mask completely the deeper effects from the Precambrian greenstones. Over the Seiland gabbroic province there are strong and irregular magnetic anomalies due to magnetic bodies at or close to the surface. Most of this gabbro province, however, is virtually non-magnetic.

Based on this map (Fig. 11) and a study of the original magnetometer records, an interpretation of the form of the basement surface below the Caledonian nappe cover in this region has been produced (Fig. 12). Some major tectonic lines and areas showing signs of magnetic material at or close to the surface in addition to deeper material are also indicated. It should be borne in mind that each depth 'point' gives the approximate depth to the top of magnetic material, which in this case generally means Precambrian 'greenstone'. There is, of course, no guarantee against the greenstones being covered with non-magnetic Precambrian quartzites, and since the points where the Precambrian surface is known ('geologic control' in Fig. 12) sometimes refer to quartzites, the contouring is somewhat inconsistent. The question marks at 69°50′N denote that no anomalies exist so that no depths can be determined. It is therefore impossible to tell whether or not the basement deepens in this area. The maximum depth in the north-eastern part of Fig. 12 is in good



22°
22°30'
23°
23°30'
24°
70°
69°30'
TOTAL MAGNETIC FIELD
ISOMAGNETIC CONTOURS
INTERVAL 100 γ
IMPORTANT GEOLOGICAL
BOUNDARY
10 km

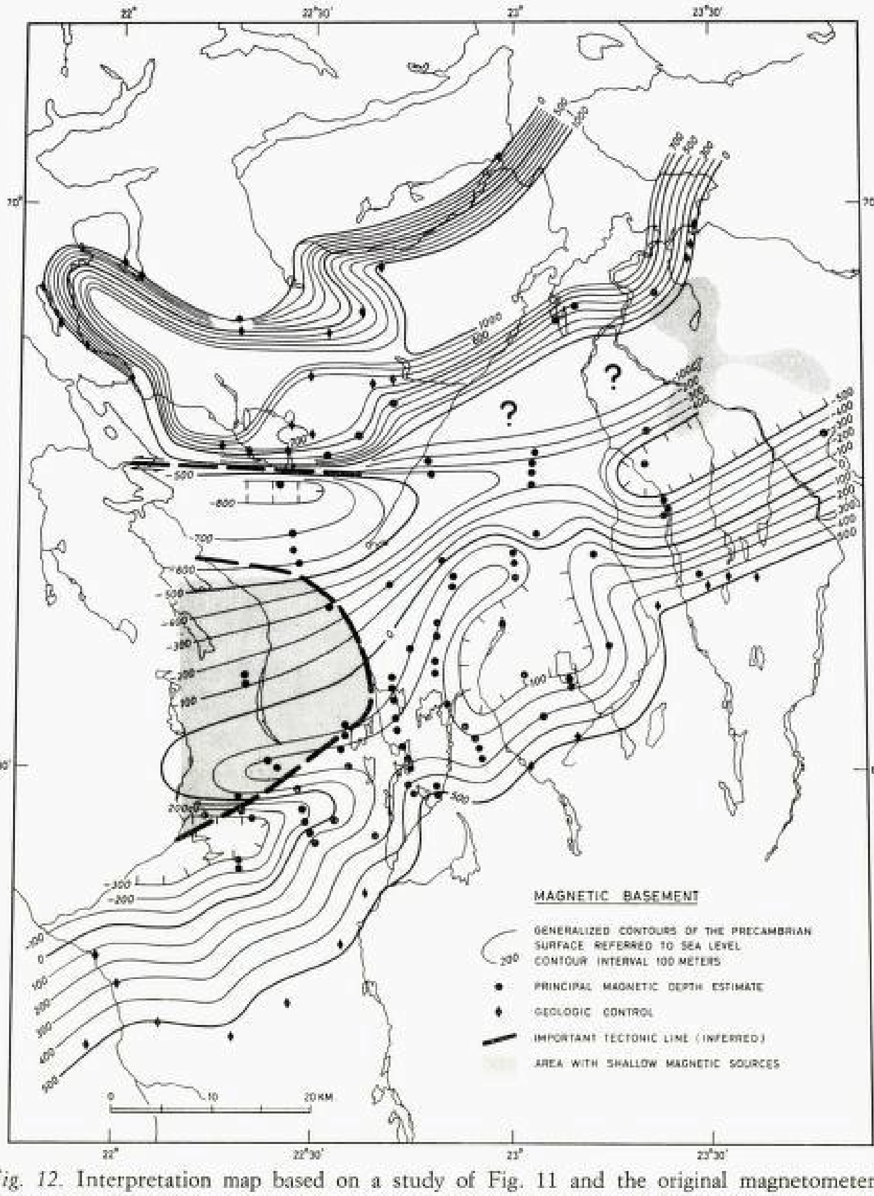


Fig. 12. Interpretation map based on a study of Fig. 11 and the original magnetometer records. The topography in the Caledonides of the region is around 500 m above sea level, meaning that the Caledonian cover is generally less than 1 km thick.

agreement with the tentative depth given for this area by Holtedahl (1918, p. 290).

The important tectonic lines indicated in Fig. 12 have been drawn after a careful inspection of the magnetic map (Fig. 11). The anomalies associated with the greenstones around 22°45'E in the southern part of the map are

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Fig. 11. Aeromagnetic map across the Caledonides in the Kvænangen–Finnmarksvidda region. See Fig. 3 for geological explanation.

seen to continue towards the NNW until they stop against an approximately NE-striking line around 69°30′N. Some weak features, however, are also seen to continue beyond this line. The anomaly at 22°35′E, 69°30′N seems to have been bent or displaced eastwards; it then curves back to resume its 'normal' shape around 22°30′E, 69°40′N. Strangely enough, this important tectonic line, which is based on the magnetic features of the Precambrian basement, has recently been found to coincide with the general tectonic trends within the Caledonian cover (Preliminary map Nabar 1834 III and K. B. Zwaan, pers. comm.).

In the area covered with Caledonian nappe rocks most of the magnetic anomalies originate from the underlying Precambrian basement. However, in some cases sharp anomalies originating from the surface rocks are also seen in addition to the anomalies from deeper sources. The anomalies can be clearly seen in the original magnetometer records, but only a few of them are visible on the contoured map (Fig. 11). These 'shallow' anomalies can generally be ascribed to small, outcropping ultrabasic bodies.

The anomaly at 22°27′E, 69°42′N is caused by a body situated approximately 800–900 m below sea level, while a little farther north the same source body is situated 700 m above sea level. This means that there is considerable vertical displacement over a comparatively short distance, indicating the existence of a large fault with at least 1.6 km of vertical throw. There is also an apparent horizontal displacement of 7–8 m, indicated with arrows in Fig. 12. The actual displacement along this fracture could in fact be explained solely by vertical movement if the greenstone plate is dipping gently westwards.

In conclusion, it can be stated that the cover of Caledonian nappe rocks is relatively thin in this area, the thickness being generally less than 1000 metres.

Varangerhalvøya (Late Precambrian sediments)

Varangerhalvøya was covered with aeromagnetic measurements in 1969. The survey was flown in an east-west direction at 750 m barometric altitude and with 2 km flight-line spacing except for the southernmost part, where the spacing was 1 km. The resulting magnetic map is represented in Fig. 13.

The anomalies are due to magnetic bodies in the Precambrian crystalline basement. The only exception seen on the map is the elongated anomaly in the north-western corner which is caused by a low-grade magnetite-bearing formation in rocks of the Caledonian nappe complex (R. Kvien & S. Siedlecki, pers. comm.). There is no sign in the map (Fig. 13) of shallow magnetic anomalies originating from the Late Precambrian–Eocambrian sediments on Varangerhalvøya. A careful inspection of the original records, however, reveals some weak features originating within 1 km of the surface. These faint anomalies can be traced from profile to profile and they are probably due to basic dykes, which are especially numerous in this area (S. Siedlecki, pers. comm.). The picture which emerges is very interesting (Fig. 14). It indicates

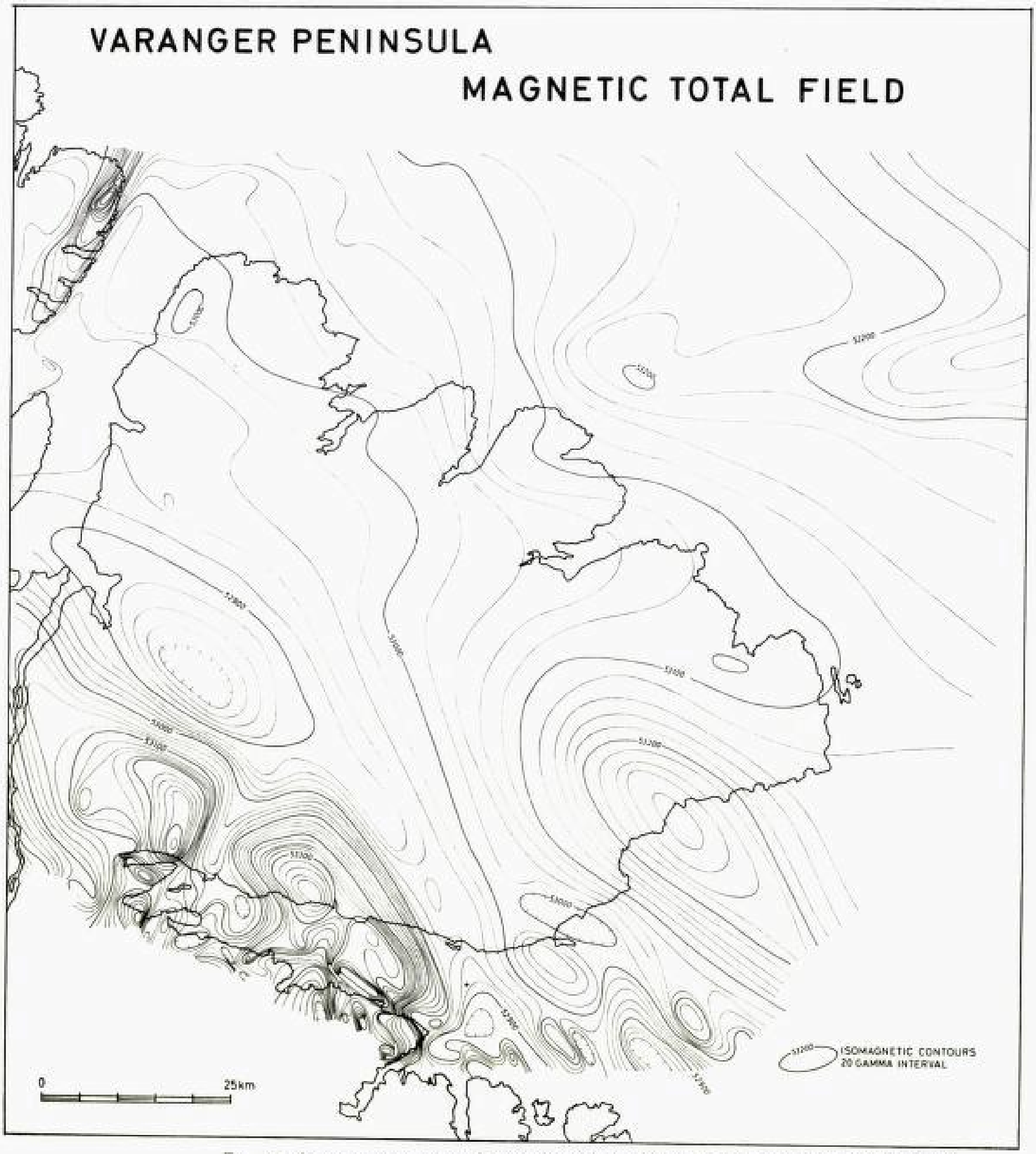

Fig. 13. Aeromagnetic map of Varangerhalvøya. See Fig. 3 for geology and location.

that there has been an eastward movement of the northern part of Varangerhalvøya. This is in good agreement with the conclusion reached by Roberts (1972, p. 37) on the basis of structural work in the area, that the complex Trollfjord–Komagelv thrust-fault mapped by Siedlecka & Siedlecki (1967) has an important dextral strike-slip or partly oblique-slip component of movement.

Since there are practically no magnetic effects from the sediments, it is

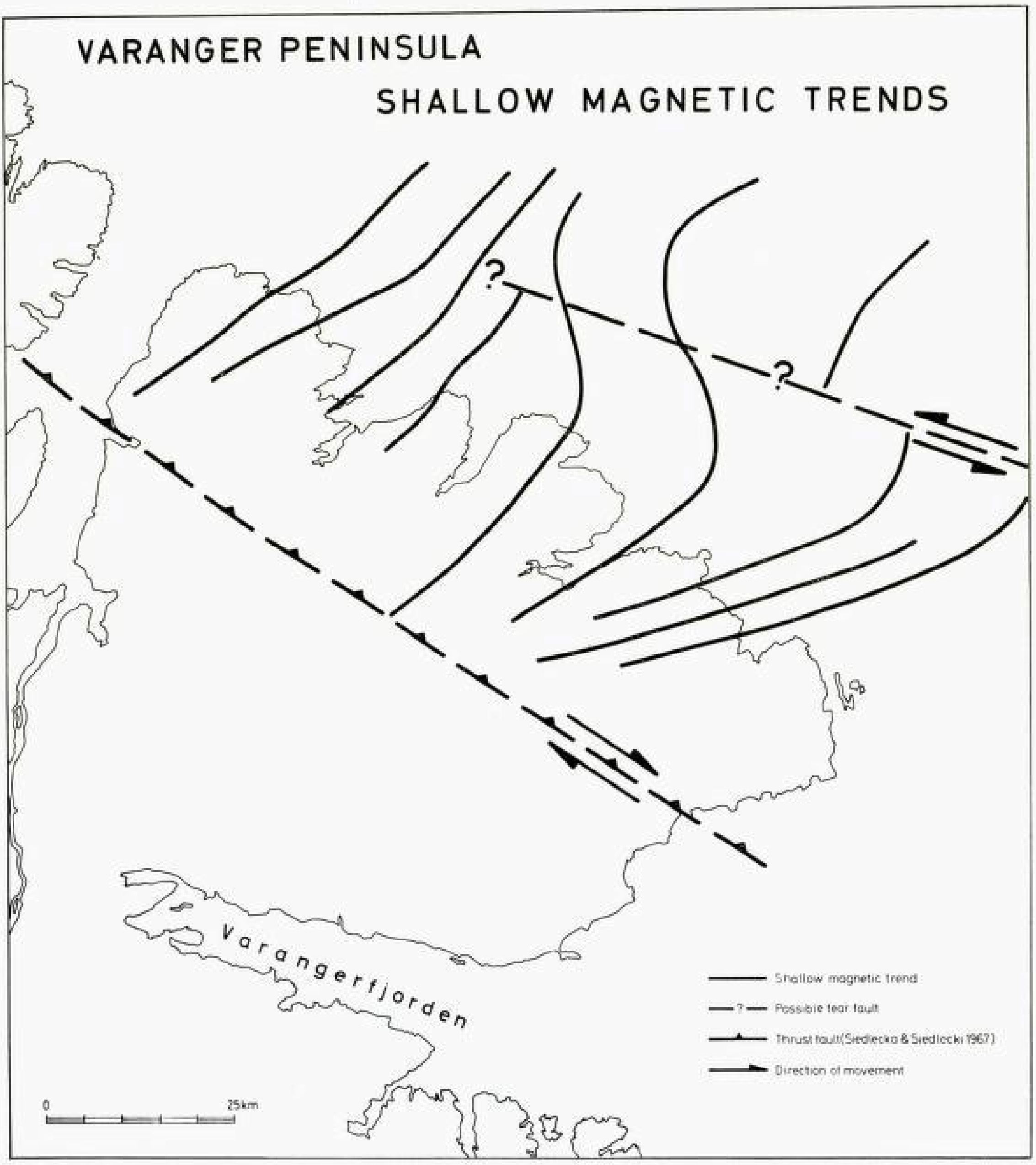

Fig. 14. Shallow magnetic trends over Varangerhalvøya (probably due to basic dykes) as seen from the original magnetometer records.

possible to trace the old Precambrian Shield beneath the sediments of Varangerhalvøya. An interpretation in terms of depth to magnetic basement (Fig. 15) shows that there are up to 7 km of non-magnetic Late Precambrian–Eocambrian sediments on Varangerhalvøya. It also shows that the shield is dipping gently below the sediments without any sign of a major vertical fault

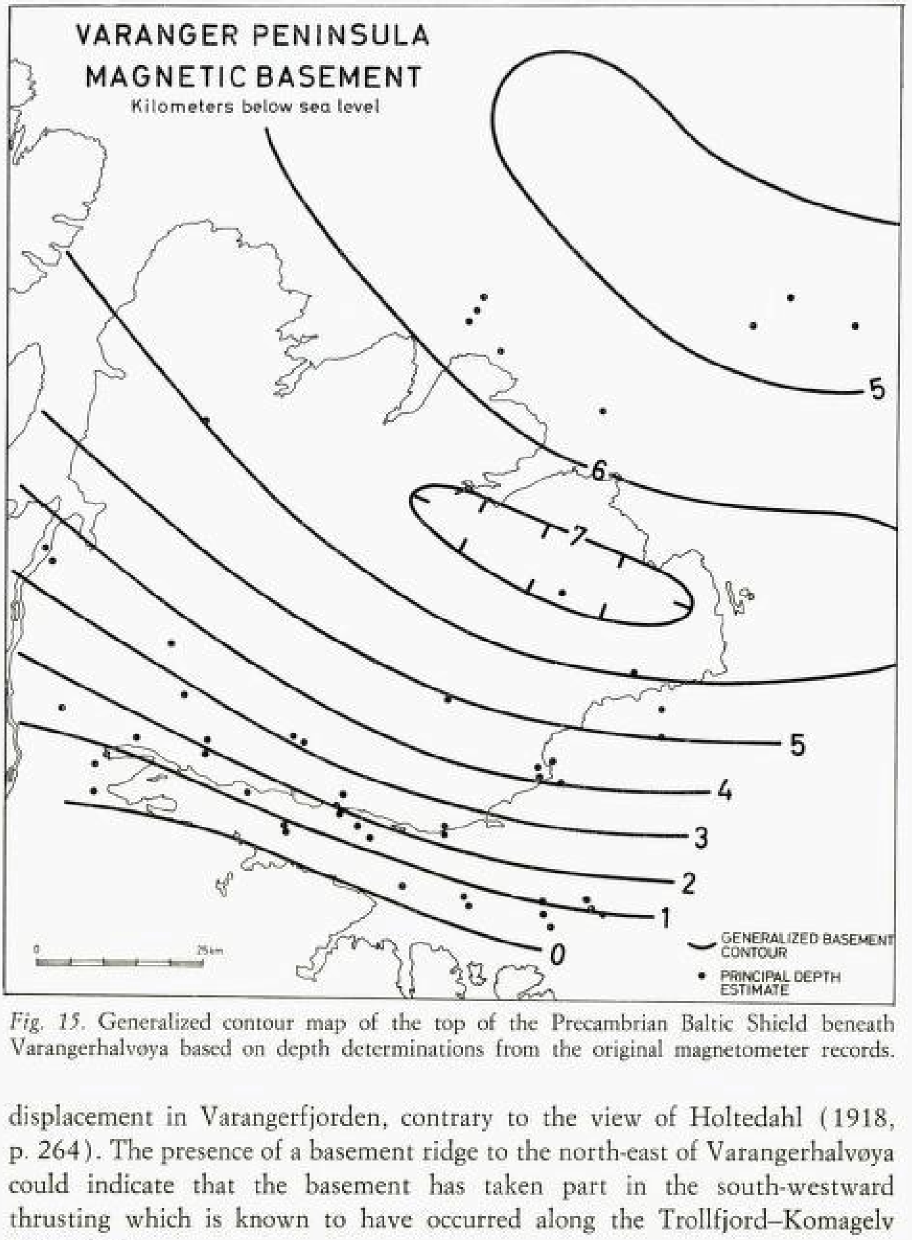

Fig. 15. Generalized contour map of the top of the Precambrian Baltic Shield beneath Varangerhalvøya based on depth determinations from the original magnetometer records.

displacement in Varangerfjorden, contrary to the view of Holtedahl (1918, p. 264). The presence of a basement ridge to the north-east of Varangerhalvøya could indicate that the basement has taken part in the south-westward thrusting which is known to have occurred along the Trollfjord–Komagelv thrust-fault.

The shelf between Andøya and Bjørnøya (69–74.5°N)

A simplified magnetic map of the region with a 100 gamma contour interval is presented in Fig. 16. The area to the west of a line running from 71°N, 24°E to 74°N, 17°E was flown in 1969 at 200 m altitude in a NW–SE direction with 4 km line spacing and Decca navigation. The area to the east of this line was flown in 1970 and 1971 at 500 m altitude. The flight path followed

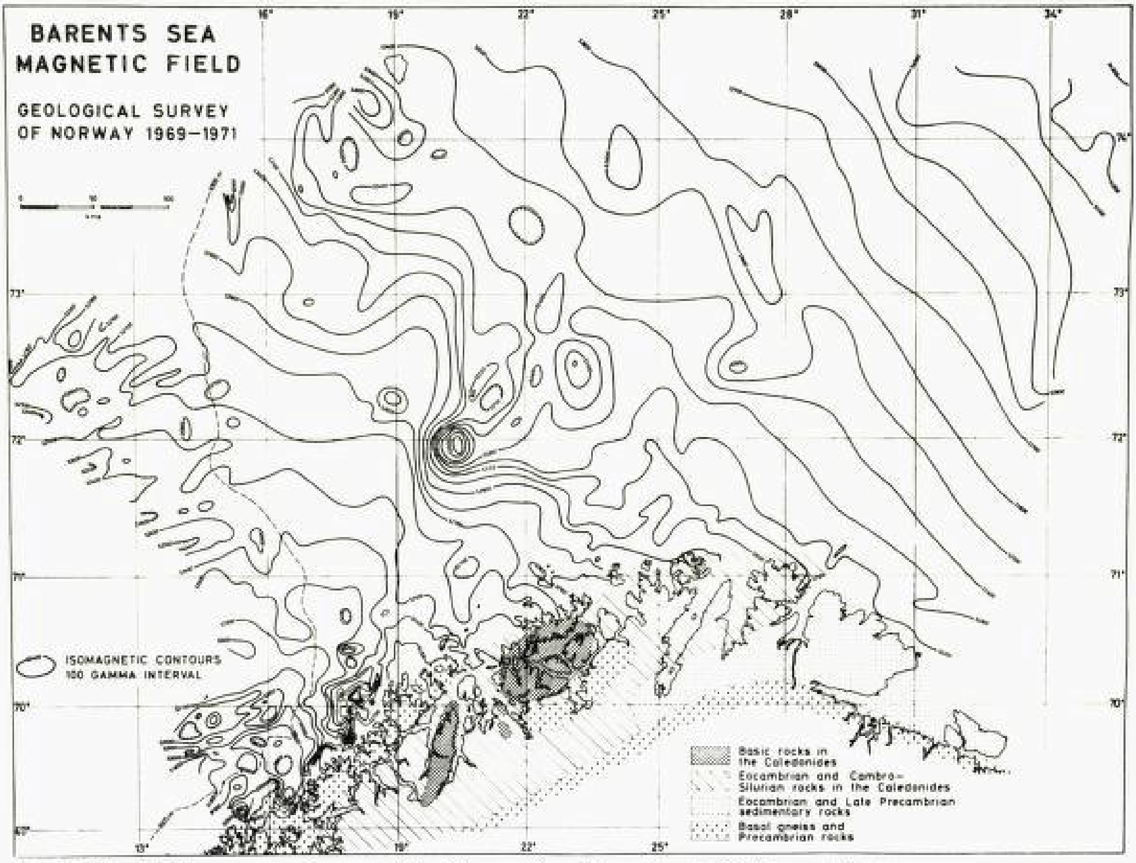

Fig. 16. Simplified aeromagnetic map of the Barents Sea. The regional field has not been removed.

Decca lanes almost perpendicular to the coast, resulting in a flight-line spacing of 3–4 km close to the coast, gradually increasing to up to 15 km at the outer end of the profiles.

The magnetic picture in Fig. 16 shows linear oceanic anomalies to the west of the 1000-metre water depth contour. The anomalies are due to semi-outcropping sources and they stop abruptly against the shelf where there is a discordant line of anomalies following approximately the shelf edge (1000-m water depth contour). This indicates the presence of a major fracture zone along the shelf edge which would coincide with the de Geer fracture zone (transcurrent fault) postulated by e.g. Wilson (1965) and Harland (1969, p. 841). To the east of this there is a magnetic quiet zone over the western part of the shelf before one gets into an irregular magnetic pattern trending in several directions and clearly demonstrating that the basement is of continental type. In the eastern part of the shelf the magnetic picture is extremely quiet, indicating large thicknesses of non-magnetic material. The NW–SE trending contours only reflect the shape of the normal magnetic field, which has not been removed in the present case.

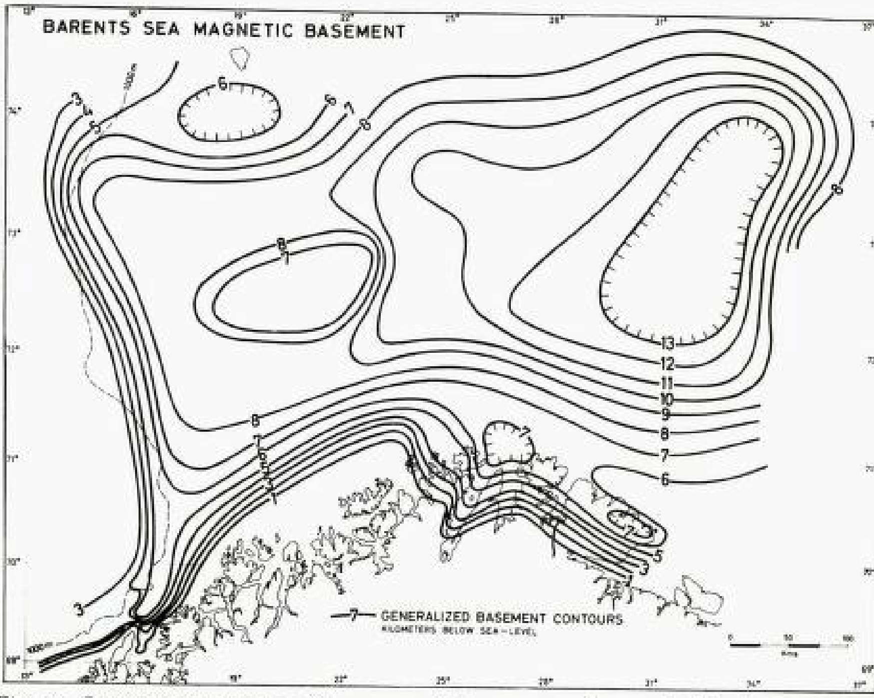

Fig. 17. Generalized contours of the magnetic basement surface, probably the top of the crystalline Precambrian Shield.

It is difficult to tell what is the actual cause of the magnetic anomalies, but from the correlations outlined in the preceding chapters it is considered that magnetic bodies in the Precambrian Shield and some Caledonian gabbros are likely to provide the most important sources of the anomalies measured over the shelf. Some weak effects can also be expected from Eocambrian and Lower Paleozoic rock complexes. In addition, Tertiary intrusions are known from Svalbard and such intrusions would of course give rise to strong anomalies if they happened to occur in the sediments of the shelf.

When trying to map the basement surface in the Barents Sea, some special problems arise in view of the presence of several kilometres of non-magnetic, Late Precambrian–Eocambrian sediments. The Caledonian belt of metamorphic rocks is also practically non-magnetic except for some ore-bearing formations and ultrabasic bodies. However, in addition to the anomalies originating from bodies within the basement, it is evident from maps and especially from the records that there are additional anomalies which must be due to shallower sources. This is also supported by spectral analysis of the data.

Fig. 17 shows the resulting contoured surface of the basement, which is probably the old Precambrian Shield. The general trend is almost east-west with prominent trends striking NNE–SSW and NNW–SSE. The greater depths to the east are based on a few depth estimates in the area of very weak anomalies. The estimates are probably on the shallow side, which would mean that they are in reasonably good agreement with the results published by

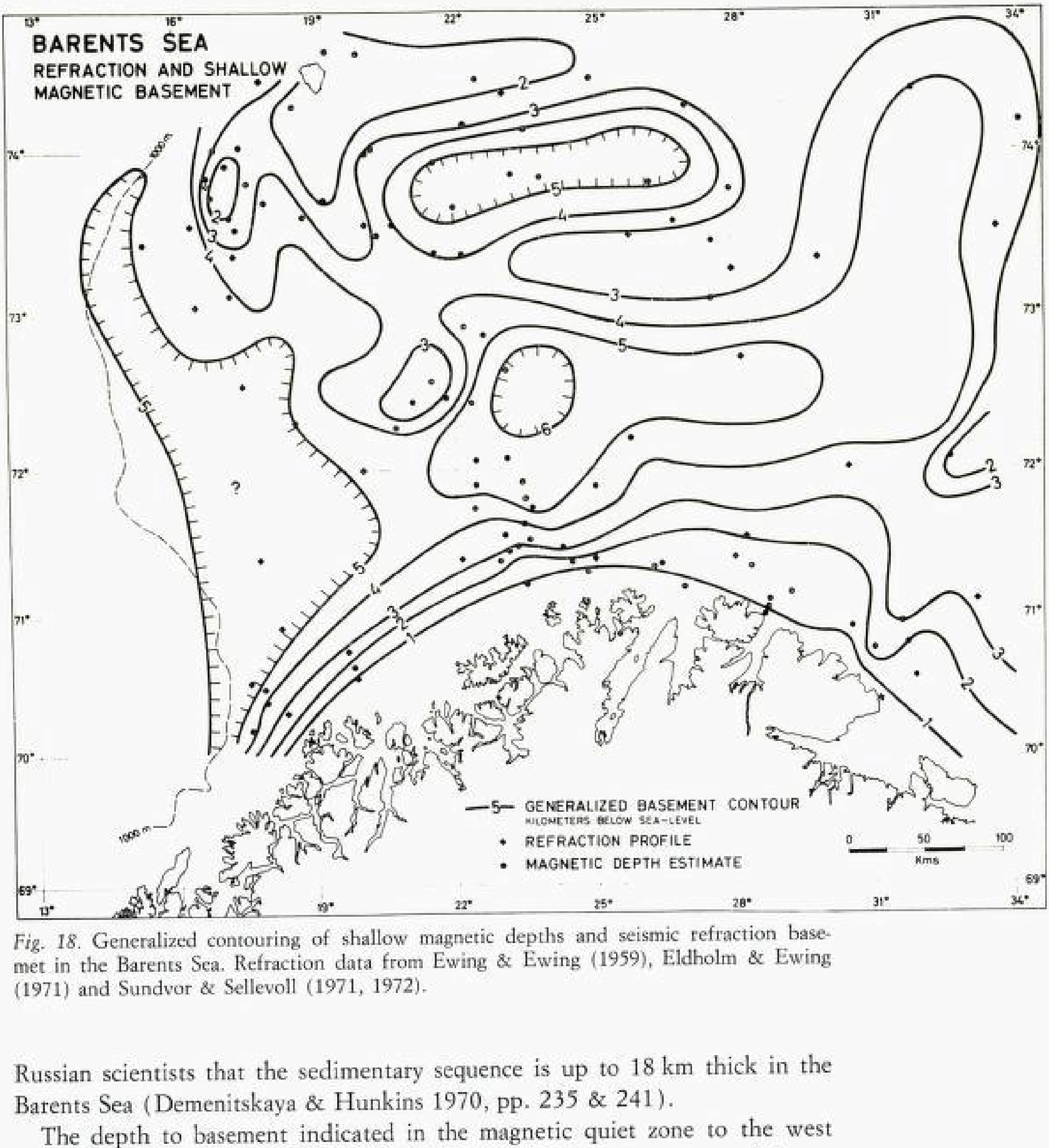

Fig. 18. Generalized contouring of shallow magnetic depths and seismic refraction basemet in the Barents Sea. Refraction data from Ewing & Ewing (1959), Eldholm & Ewing (1971) and Sundvor & Sellevoll (1971, 1972).

Russian scientists that the sedimentary sequence is up to 18 km thick in the Barents Sea (Demenitskaya & Hunkins 1970, pp. 235 & 241).

The depth to basement indicated in the magnetic quiet zone to the west (between the large basement high and the shelf edge) represents a minimum value. The depth is probably much greater than the 8 km shown in Fig. 17.

Contouring of the shallower depths shows that they are in fairly good agreement with depths to acoustic refraction basement (velocities higher than 5 km/sec.) as published by Ewing & Ewing (1959, Profile F3), Eldholm & Ewing (1971) and Sundvor & Sellevoll (1971, 1972). From work on Varangerhalvøya (e.g. NGU Rapport 227, 1959) the Late Precambrian–Eocambrian sediments are known to give velocities around 5 km/sec. It is therefore reasonable to assume that the shallow magnetic sources define a Palaeozoic basement. This basement is presented in Fig. 18, where the published refraction data have also been incorporated.

In the western part of the map (Fig. 18) there is no sign of two basements, possibly meaning that the oldest (Late Precambrian) sediments are restricted to the eastern region. The question mark to the west means that no shallow depths have been found in this region. The shallow depths around 74°N, 17°E could of course be due to Tertiary igneous material in the sediments. The deep basins around 23°E should be examined with some care since they are situated rather close to the deeper basement surface; consequently it will be difficult to differentiate between the two basements in these areas. These basins in the upper basement could, therefore, possibly represent highs in the lower basement instead.

The north-south and east-west trending ridge over Bjørnøya represent a continuation of the basement ridge (Hecla Hoek) along the western coast of Spitsbergen, which has been subject to Caledonian metamorphism (Åm, in press). This indicates a connection between the Caledonides of Spitsbergen and Norway. The NNE-SSW trending basin to the east (32°E) could also represent a continuation of the Norwegian Caledonides in that direction.

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REFERENCES

Aalstad, I. 1963: Magnetiske flymålinger i Skagerak. *NGU-Rapport 398*, 5 pp.

Aalstad, I. 1964a: Magnetiske flymålinger i Skagerak. *NGU-Rapport 519*, 5 pp.

Aalstad, I. 1964b: Magnetiske flymålinger i Norskehavet, Molde–Bodø. *NGU-Rapport 534*, 4 pp.

Aalstad, I. 1972: NGU's magnetiske flymålinger over kontinentalsokkelen. *NGU-nytt nr. 17*, 14–24.

Åm, K. 1970: Aeromagnetic investigations on the continental shelf of Norway, Stad–Lofoten (62–69°N). *Norges geol. Unders. 266*, 49–61.

Åm, K. 1972: The arbitrarily magnetized dyke. Interpretation by characteristics. *Geoexploration 10*, 63–90.

Åm, K. 1973: Geophysical indications of Permian and Tertiary igneous activity in the Skagerrak. *Norges geol. Unders. 287*, 1–25.

Åm, K. (in press): Magnetic profiling over Svalbard and surrounding shelf areas. *Norsk Polarinst. Årbok 1973.*

Dalland, A., Hansen, R. & Sellevoll, M. 1973: Geologiske og geofysiske undersøkelser av Jura–Kritt feltet på Andøya utført av Universitetet i Bergen 1969–1971. Foreløpig meddelelse. *In* Sellevoll, M. A. & Sundvor, E. (eds.) Seismic investigations of the Norwegian continental shelf. *Jordskjelvstasjonen, Universitetet i Bergen, Tekn. Rapp. 7*, 35 pp.

Demenitskaya, R. M. & Hunkins, K. L. 1970: Shape and structure of the Arctic Ocean. *In* Maxwell, A. E. (ed.) *The Sea. Volume 4, Part II*, 223–249. Wiley–Interscience.

Eldholm, O. & Ewing, J. 1971: Marine geophysical survey in the south-western Barents Sea. *J. Geophys. Res. 76*, 3832–3841.

Ewing, J. & Ewing, M. 1959: Seismic refraction measurements in the Atlantic Ocean basins, in the Mediterranean Sea, on the Mid-Atlantic Ridge, and in the Norwegian Sea. *Bull. Geol. Soc. Am. 70*, 291–318.

Fabiano, E. B. & Peddie, N. W. 1969: Grid values of total magnetic intensity IGRF–1965. *ESSA Techn. Rep. C & GS 38*, 55 pp.

Harland, W. B. 1969: Contribution of Spitsbergen to understanding of tectonic evolution of North Atlantic region. *In* Kay, M. (ed.) North Atlantic–geology and continental drift. *Am. Ass. Petrol. Geol. Mem. 12*, 817–851.

Heier, K. S. 1960: Petrology and geochemistry of high-grade metamorphic and igneous rocks on Langøy, Northern Norway. *Norges geol. Unders. 207*, 1–246.

Hinz, K. 1972: Der Krustenaufbau des Norwegischen Kontinentalrandes (Vøring Plateau) und der Norwegischen Tiefsee. *'Meteor' Forsch. – Ergebnisse C 10*, 1–16.

Holtedahl, O. 1918: Bidrag til Finmarkens geologi. *Norges geol Unders. 84*, 1–314.

Holtedahl, O. (ed.) 1960: Geology of Norway. *Norges geol. Unders. 208*, 1–540.

Holtedahl, O. & Dons, J. A. 1960: Geological map of Norway, (Bedrock). *In* Holtedahl, O. (ed.) Geology of Norway. *Norges geol. Unders. 208*.

Manum, S. 1966: Deposits of probable Upper Cretaceous age off-shore from Andøya, Northern Norway. *Norsk geol. Tidsskr. 46*, 246–247.

Nettleton, L. L. 1971: Elementary gravity and magnetics for geologists and seismologists. *SEG–Monograph 1*, 121 pp.

NGU 1971a: *Hammerfest. Magnetisk totalfelt 19650–1:250,000.* Universitetsforlaget, Oslo.

NGU 1971b: *Nordreisa. Magnetisk totalfelt 19650–1:250,000.* Universitetsforlaget, Oslo.

Ørvig, T. 1960: The Jurassic and Cretaceous of Andøya in Northern Norway. *In* Holtedahl, O. (ed.) Geology of Norway. *Norges geol. Unders. 208*, 344–350.

Roberts, D. 1972: Tectonic deformation in the Barents Sea region of Varanger Peninsula, Finnmark. *Norges geol. Unders. 282*, 1–39.

Sellevoll, M. A. & Aalstad, I. 1971: Magnetic measurements and seismic profiling in the Skagerrak. *Marine Geophys. Res. 1*, 284–302.

Siedlecka, A. & Siedlecki, S. 1967: Some new aspects of the geology of Varanger peninsula (Northern Norway). Preliminary report. *Norges geol. Unders. 247*, 288–306.

Sundvor, E. 1971: Seismic refraction measurements on the Norwegian continental shelf between Andøya and Fugløybanken. *Marine Geophys. Res. 1*, 303–313.

Sundvor, E. & Sellevoll, M. A. 1971: Seismiske undersøkelser av den norske kontinentalsokkel, Lofoten–Bjørnøya (68°–75°N). *Jordskjelvstasjonen, Universitetet i Bergen Tekn. Rapp. 5*, 20 pp.

Sundvor, E. & Sellevoll, M. A. 1972: Seismiske undersøkelser av den norske kontinentalsokkel, Barentshavet. *Jordskjelvstasjonen, Universitetet i Bergen Tekn. Rapp. 6*, 15 pp.

Talwani, M. & Eldholm, O. 1972: Continental margin off Norway. A geophysical study. *Bull. Geol. Soc. Am. 83*, 3775–3806.

USNOO 1967: *Total Magnetic Intensity Chart of the Norwegian Sea.* Washington D.C.

Vacquier, V., Steenland, N. C., Henderson, R. G. & Zietz, I. 1951: Interpretation of aeromagnetic maps. *Geol. Soc. Am. Mem. 47*, 151 pp.

Wilson, J. T. 1965: A new class of faults and their bearing on continental drift. *Nature 207*, 343–347.