NGU Rapport 91.269

# Shaded relief Aeromagnetic colour map of Norway and the Norwegian-Greenland and Barents seas: Data compilation and examples of interpretation

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# RAPPORT

| Rapport nr. 91.269 | ISSN 0800-3416 | Åpen/~~Fortrolig~~ |
|---|---|---|

**Tittel:**
Shaded relief Aeromagnetic colour map of Norway and the Norwegian-Greenland and Barents seas: Data compilation and examples of interpretation

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| Fylke: | Kommune: |
| Kartbladnavn (M. 1:250 000) | Kartbladnr. og -navn (M. 1:50 000) |
| Forekomstens navn og koordinater: | Sidetall: 15 Pris: kr 100,- <br> Kartbilag: |

| Feltarbeid utført: | Rapportdato: | Prosjektnr.: | Seksjonssjef: |
|---|---|---|---|
| | 29.11.1991 | 61.1568.00 | |

**Sammendrag:**

The report is a summary of a poster that was presented at the 20. IUGG (International Union of Geodesy and Geophysics) meeting in Vienna, August, 1991.

The Geological Survey of Norway (NGU) has covered the whole of Norway and its continental shelves with aeromagnetic surveys between 1965 and 1975. These data were complemented recently by significant acquisitions of new data from the northern Barents Sea.

The combined NGU data sets have been merged with offshore magnetic observations assembled in the past two years by the Geological Survey of Canada (GSC). The bulk of these data sets were collected and provided to the GSC by the US Naval Research Laboratory and the US Naval Oceanographic Office. They are complemented by public domain data distributed by the US National Geophysical Data Center on behalf of a variety of organizations.

Displayed in preliminary shaded relief colour map of the magnetic anomaly east of $0^0$ longitude, the combined NGU and GSC compilations illustrate effectively the major tectonic framework of the region. For example: The continent-ocean boundary is precisely delineated along the Spitsbergen Fracture Zone. Major basement faults, structural highs and sedimentary basins are interpreted from the data. In the northern Barents Sea, the continuity of concealed orogenic elements (Caledonian?) can be appraised. Numerous anomalies on the contiental shelf intersect the coastline and provide convincing corroboration of the continuity of regional structures between offshore and onshore domains. When analyzed in conjunction with other forms of data, the new compilation promises to be an extremely useful resource for local and regional investigations.



| Emneord | Magnetometri | |
|---|---|---|
| Geofysikk | Gravimetri | |
| Fjernmåling | | |

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## INTRODUCTION

The Geological Survey of Norway (NGU) has covered the whole of Norway and its continental shelves with aeromagnetic surveys between 1965 and 1975. These data were complemented recently by significant acquisitions of new data from the northern Barents Sea and Svalbard.

The combined NGU data sets have been merged with offshore magnetic observations assembled in the past two years by the Geological Survey of Canada (GSC). The bulk of these data sets were collected and provided to the GSC by the US Naval Research Laboratory and the US Naval Oceanographic Office. They are complemented by public domain data distributed by the US National Geophysical Data Centre on behalf of a variety of organizations.

The new aeromagnetic data set can be analyzed at a variety of scales. We show interpretation examples from the northern Barents Sea, where information on the topography of the basement surface is important in exploration work. The data set illustrates effectively the major tectonic framework of the North-Atlantic region.

Other forms of digital data are also presented. On land, much promise lies in the integrated study of data that encode surface geologic information and geophysical data that also reflect deep, concealed, geological structures.

## ANOMALY MAP

Displayed in preliminary shaded relief colour map of the magnetic anomaly east of $0^0$ longitude (Fig. 1), the combined

NGU and GSC compilations effectively illustrate the major tectonic framework of the region. For example, numerous anomalies on the Norwegian continental shelf intersect the coastline and provide convincing corroboration of the continuity of regional structures between offshore and onshore domains. The continent-ocean boundary is precisely delineated along the Vøring Plateau escarpment and along the Senja Fracture Zone (see overlay on magnetic anomaly map). Seasat-gravity data (Fig. 4) show many of the features depicted on the magnetic map.

## IMAGE ANALYSIS AND EXAMPLES OF INTERPRETATIONS

A colour map of the depth to top of the magnetic basement for the northern Barents Sea ($74^0$-$78^0$ N), has been produced (Fig. 5). This information is extremely useful when planning high-cost seismic exploration work. Fig. 6 is a grey-tone, shaded-relief aeromagnetic image covering the same area as Fig. 5. Digital image processing techniques, performed on a PC, have been used to generate the image given in Fig. 6. We see that the processing has enhanced subtle trends and regional variations in the data set. Contrasting 'magnetic textures' in different parts of the image reflect different, concealed, basement complexes/terranes (Caledonian in the west?, Precambrian in the east).

The processed geophysical data have been used to delineate the boundary between the oceanic and the continental crust on the western margin (Fig. 6). Distinctive anomalies in the northern Barents Sea are continuous with basement faults and horsts on Spitsbergen (Fig. 1). From this, we infer that the basement in the northwestern Barents Sea is similar to the basement that is exposed in Spitsbergen (Svalbard). Major basement fault zones can be traced on the images: The Billefjorden Fault Zone and the Lomfjorden Fault which are exposed on northern-central Spitsbergen (e.g. Harland et al., 1974), probably trend N-S across Spitsbergen and extend far southwards into the Barents Sea (see interpretation on Figs 1 & 6).

Storfjorden (between Spitsbergen and Edgeøya in Fig. 6) stand out clearly as a separate magnetic province due to the presence of volcanic intrusions of Late Jurassic/Early Cretaceous age at shallow depths. Some of the intrusions are dykes that may have intruded along faults created during extension (rifting?) in Storfjorden.

## INTEGRATION WITH OTHER FORMS OF DIGITAL DATA

When analyzed in conjunction with other forms of data, our new compilation promises to be a useful resource for local and regional tectonic investigations. On land, much promise lies in the integrated study of data that encode surface geologic information (digital elevation, satellite data) and geophysical data that also reflect deep, concealed, geological structures. Digital elevation data is extremely useful in surface lineament mapping. The whole of Norway is covered with digital elevation data on a 100m by 100m grid. Fig. 7 is a photo of a PC-screen showing elevation data from the Møre-Trøndelag Fault Complex (MTFC, see location on the geological map in Fig. 2). We have interpreted main faults to be present further to the south of the well-known Hitra-Snåsa and Verran Faults (e.g. Grønlie and Roberts, 1989). Another example is taken from the eastern part of the MTFC, the Grong area, where a shaded-relief image of topography (Fig. 8), shows the pattern of faults where Caledonoid rocks are juxtaposed against the Precambrian Grong-Culmination (see Fig. 2 for location).

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# FIGURE CAPTIONS

FIG. 1 AEROMAGNETIC MAP

FIG. 2 GEOLOGY MAP OF NORWAY

FIG. 3: DATA TRACKS USED TO PRODUCE AEROMAGNETIC DATA ON GRID (SEA AREAS). ON LAND, DATA HAS BEEN EXTRACTED FROM AN AEROMAGNETIC DATA BASE THAT HOLDS DATA ON A 500 M BY 500 M GRID.

FIG. 4 SEASAT-GRAVITY

FIG. 5: DEPTH TO THE MAGNETIC BASEMENT, REFERRED TO SEA LEVEL. THIS MAP OUTLINES STRUCTURAL HIGHS AND SEDIMENTARY BASINS. IT IS THEREFORE EXTREMELY USEFUL WHEN PLANNING THE HIGH-COST REFLECTION SEISMIC EXPLORATION WORK IN THIS 'FRONTIER REGION'.

FIG. 6: SHADED RELIEF IMAGE OF AEROMAGNETICS COVERING THE NORTHWESTERN BARENTS SEA, ILLUMINATED FROM THE EAST. FROM THE DATA WE HAVE INTERPRETED THE DISTRIBUTION OF VARIOUS TYPES OF BASEMENT, AND DEDUCED SEAWARD EXTENSIONS OF THE BILLEFJORDEN FAULT ZONE AND THE LOMFJORDEN FAULT FROM SPITSBERGEN INTO THE BARENTS SEA.

FIG. 7 DIGITAL TOPOGRAPHIC DATA FROM THE MØRE-TRØNDELAG AREA. THE HITRA-SNÅSA AND THE VERRAN FAULTS OF THE MØRE-TRØNDELAG FAULT COMPLEX IS SHOWN ON OVERLAY. WE HAVE INTERPRETED MAIN FAULTS TO BE PRESENT FURTHER TO THE SOUTH OF THE WELL-KNOWN HITRA-SNÅSA FAULT.

FIG. 8 SHADED RELIEF IMAGE OF TOPOGRAPHY THAT MIMICS A CLOUD-FREE MONOCHROME AERIAL PHOTOGRAPH TAKEN AT LOW SUN. IMAGE IS CENTRED ON THE GRONG AREA, WHICH IS THE EASTERN PART OF THE MØRE-TRØNDELAG FAULT COMPLEX. THE IMAGE SHOWS THAT THE MAIN FAULT BRANCHES OUT WHERE CALEDONOID ROCKS ARE JUXTAPOSED AGAINST THE PRECAMBRIAN GRONG-OLDEN CULMINATION.

FIG. 1 MAGNETIC ANOMALY MAP

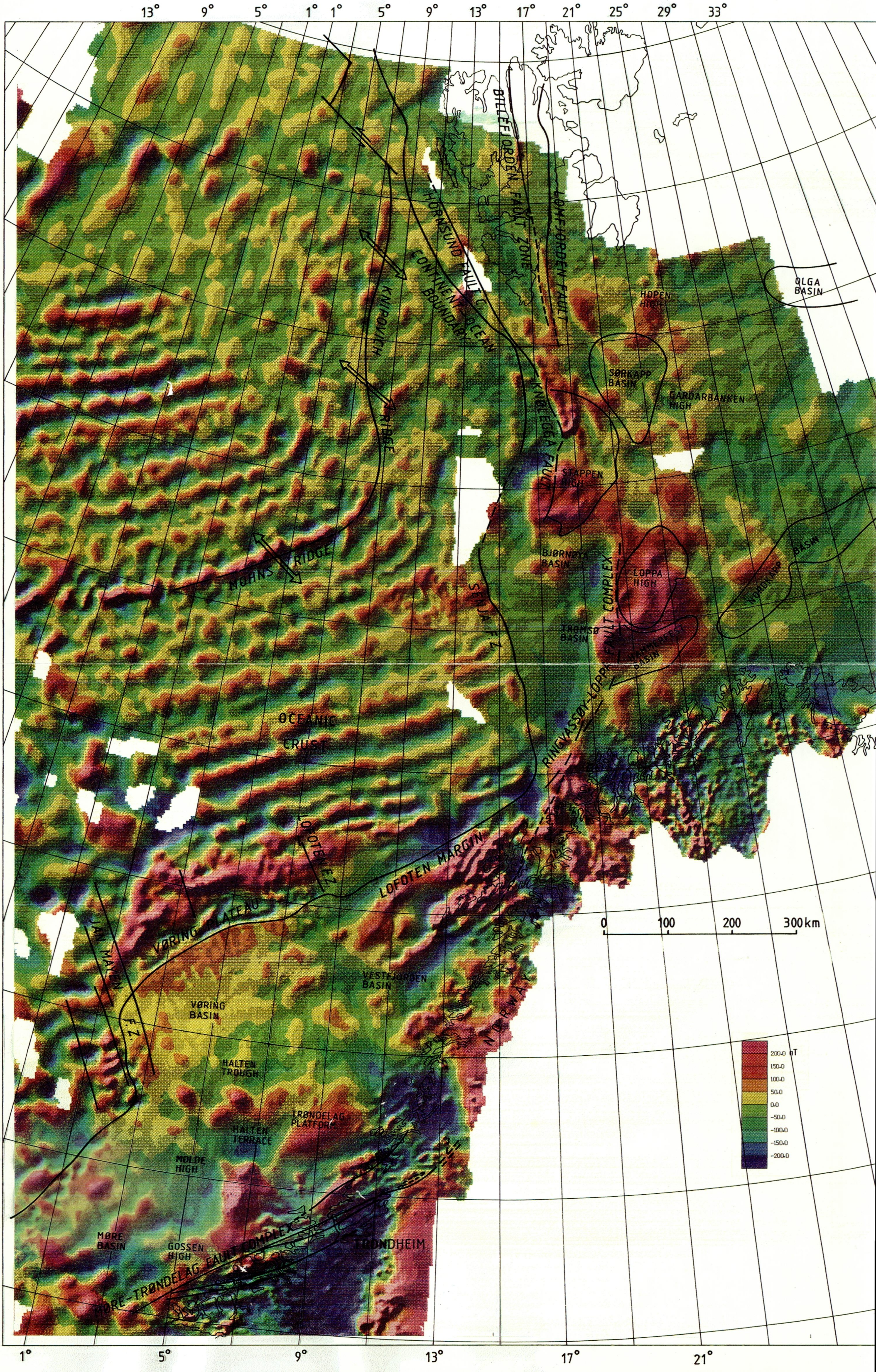
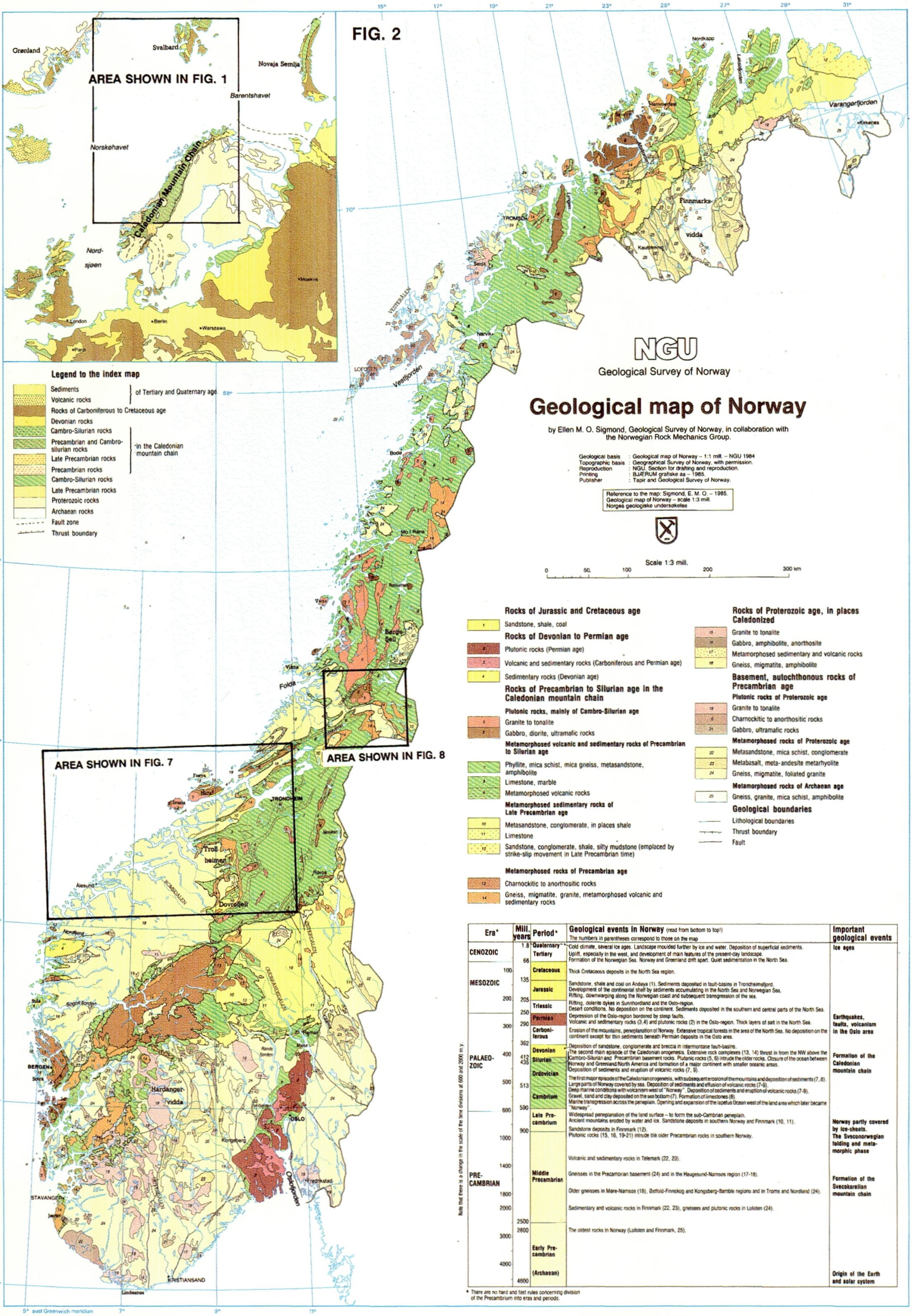


FIG. 2




NGU

Geological Survey of Norway

# Geological map of Norway

by Ellen M. O. Sigmond, Geological Survey of Norway, in collaboration with the Norwegian Rock Mechanics Group.


Geological basis : Geological map of Norway – 1:1 mill. – NGU 1984
Topographic basis : Geographical Survey of Norway, with permission.
Reproduction : NGU. Section for drafting and reproduction.
Printing : BJÆRUM grafiske as – 1985.
Publisher : Tapir and Geological Survey of Norway.

Reference to the map: Sigmond, E. M. O. – 1985.
Geological map of Norway – scale 1:3 mill.
Norges geologiske undersøkelse


Scale 1:3 mill.

0 50 100 200 300 km

**Rocks of Jurassic and Cretaceous age**

1 Sandstone, shale, coal

**Rocks of Devonian to Permian age**

2 Plutonic rocks (Permian age)
3 Volcanic and sedimentary rocks (Carboniferous and Permian age)
4 Sedimentary rocks (Devonian age)

**Rocks of Precambrian to Silurian age in the Caledonian mountain chain**

**Plutonic rocks, mainly of Cambro-Silurian age**

5 Granite to tonalite
6 Gabbro, diorite, ultramafic rocks

**Metamorphosed volcanic and sedimentary rocks of Precambrian to Silurian age**

7 Phyllite, mica schist, mica gneiss, metasandstone, amphibolite
8 Limestone, marble
9 Metamorphosed volcanic rocks

**Metamorphosed sedimentary rocks of Late Precambrian age**

10 Metasandstone, conglomerate, in places shale
11 Limestone
12 Sandstone, conglomerate, shale, silty mudstone (emplaced by strike-slip movement in Late Precambrian time)

**Metamorphosed rocks of Precambrian age**

13 Charnockitic to anorthositic rocks
14 Gneiss, migmatite, granite, metamorphosed volcanic and sedimentary rocks

**Rocks of Proterozoic age, in places Caledonized**

15 Granite to tonalite
16 Gabbro, amphibolite, anorthosite
17 Metamorphosed sedimentary and volcanic rocks
18 Gneiss, migmatite, amphibolite

**Basement, autochthonous rocks of Precambrian age**

**Plutonic rocks of Proterozoic age**

19 Granite to tonalite
20 Charnockitic to anorthositic rocks
21 Gabbro, ultramafic rocks

**Metamorphosed rocks of Proterozoic age**

22 Metasandstone, mica schist, conglomerate
23 Metabasalt, meta-andesite metarhyolite
24 Gneiss, migmatite, foliated granite

**Metamorphosed rocks of Archaean age**

25 Gneiss, granite, mica schist, amphibolite

**Geological boundaries**

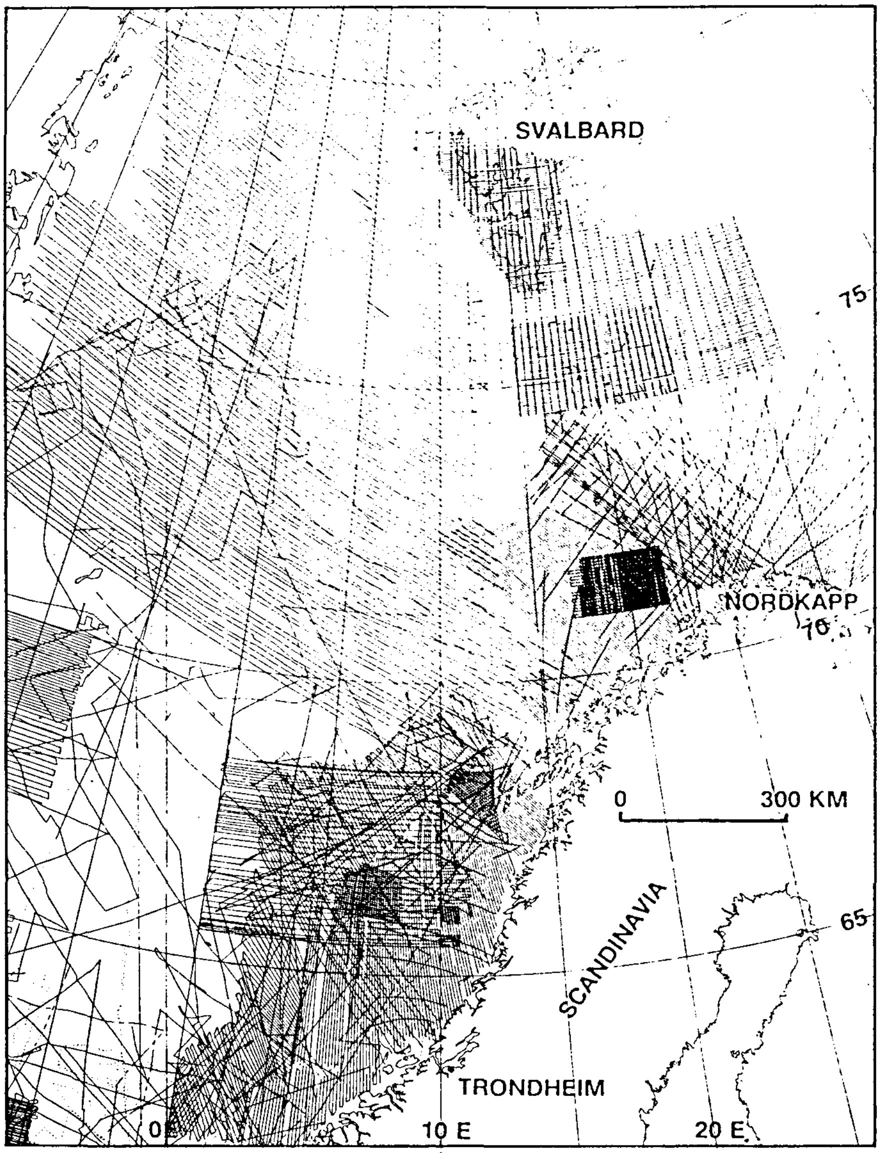
Lithological boundaries
Thrust boundary
Fault

| Era* | Mill. years | Period* | Geological events in Norway (read from bottom to top!) The numbers in parentheses correspond to those on the map | Important geological events |
|---|---|---|---|---|
| CENOZOIC | 1.8 | Quaternary** | Cold climate, several ice ages. Landscape moulded further by ice and water. Deposition of superficial sediments. | Ice ages |
| | | Tertiary | Uplift, especially in the west, and development of main features of the present-day landscape. Formation of the Norwegian Sea. Norway and Greenland drift apart. Quiet sedimentation in the North Sea. | |
| MESOZOIC | 66 / 100 | Cretaceous | Thick Cretaceous deposits in the North Sea region. | |
| | 135 | Jurassic | Sandstone, shale and coal on Andøya (1). Sediments deposited in fault-basins in Trondheimsfjord. Development of the continental shelf by sediments accumulating in the North Sea and Norwegian Sea. Rifting, downwarping along the Norwegian coast and subsequent transgression of the sea. | |
| | 200 / 205 | Triassic | Rifting, dolerite dykes in Sunnhordland and the Oslo-region. Desert conditions. No deposition on the continent. Sediments deposited in the southern and central parts of the North Sea. | |
| PALAEOZOIC | 250 | Permian | Depression of the Oslo-region bordered by steep faults. Volcanic and sedimentary rocks (3,4) and plutonic rocks (2) in the Oslo-region. Thick layers of salt in the North Sea. | Earthquakes, faults, volcanism in the Oslo area |
| | 290 / 300 | Carboniferous | Erosion of the mountains, peneplanation of Norway. Extensive tropical forests in the area of the North Sea. No deposition on the continent except for thin sediments beneath Permian deposits in the Oslo area. | |
| | 362 | Devonian | Deposition of sandstone, conglomerate and breccia in intermontane fault-basins. | |
| | 400 / 412 | Silurian | The second main episode of the Caledonian orogenesis. Extensive rock complexes (13, 14) thrust in from the NW above the Cambro-Silurian and Precambrian basement rocks. Plutonic rocks (5, 6) intrude the older rocks. Closure of the ocean between Norway and Greenland/North America and formation of a major continent with smaller oceanic areas. Deposition of sediments and eruption of volcanic rocks (7, 9). | Formation of the Caledonian mountain chain |
| | 435 | Ordovician | The first major episode of the Caledonian orogenesis, with subsequent erosion of the mountains and deposition of sediments (7, 8). Large parts of Norway covered by sea. Deposition of sediments and effusion of volcanic rocks (7-9). | |
| | 500 / 513 | Cambrium | Deep marine conditions with volcanism west of "Norway". Deposition of sediments and eruption of volcanic rocks (7-9). Gravel, sand and clay deposited on the sea bottom (7). Formation of limestones (8). Marine transgression across the peneplain. Opening and expansion of the Iapetus Ocean west of the land area which later became "Norway". | |
| PRE-CAMBRIAN | 590 / 600 | Late Precambrium | Widespread peneplanation of the land surface – to form the sub-Cambrian peneplain. Ancient mountains eroded by water and ice. Sandstone deposits in southern Norway and Finnmark (10, 11). | Norway partly covered by ice-sheets. |
| | 900 / 1000 | Middle Precambrian | Sandstone deposits in Finnmark (12). Plutonic rocks (15, 16, 19-21) intrude the older Precambrian rocks in southern Norway. | The Sveconorwegian folding and metamorphic phase |
| | 1400 | | Volcanic and sedimentary rocks in Telemark (22, 23). | |
| | | | Gneisses in the Precambrian basement (24) and in the Haugesund-Namsos region (17-18). | Formation of the Svecokarelian mountain chain |
| | 1800 | | Older gneisses in Møre-Namsos (18), Østfold-Finnskog and Kongsberg-Bamble regions and in Troms and Nordland (24). | |
| | 2000 | | Sedimentary and volcanic rocks in Finnmark (22, 23), gneisses and plutonic rocks in Lofoten (24). | |
| | 2500 / 2800 | Early Precambrian | The oldest rocks in Norway (Lofoten and Finnmark, 25). | |
| | 3000 / 4000 | | | |
| | 4600 | (Archaean) | | Origin of the Earth and solar system |

Note that there is a change in the scale of the time divisions at 600 and 2000 m.y.

* There are no hard and fast rules concerning division of the Precambrium into eras and periods.

FIG. 3 DATA TRACKS

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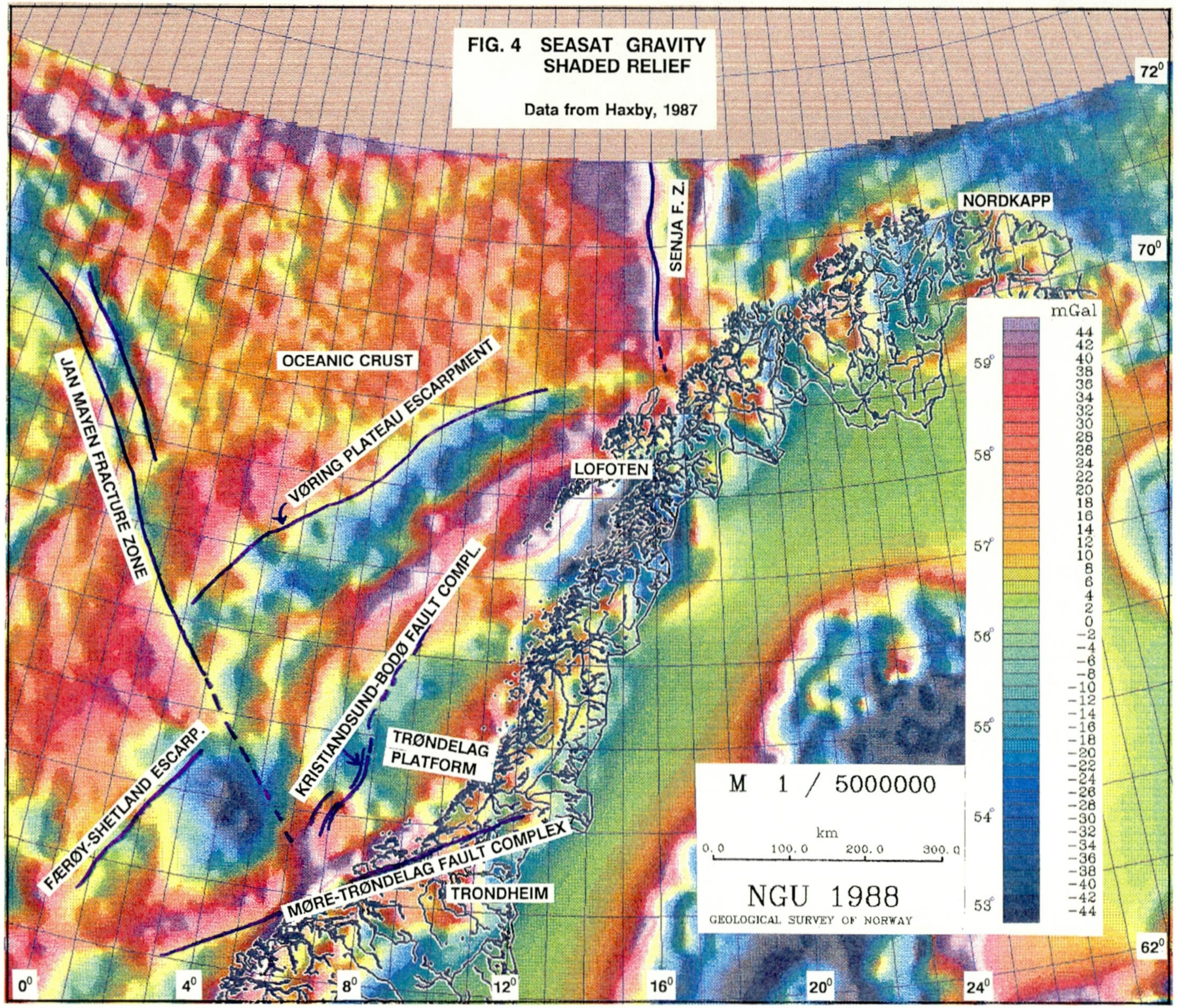
FIG. 4 SEASAT GRAVITY
SHADED RELIEF
Data from Haxby, 1987
SENJA F. Z.
NORDKAPP
OCEANIC CRUST
JAN MAYEN FRACTURE ZONE
VØRING PLATEAU ESCARPMENT
LOFOTEN
KRISTIANDSUND-BODØ FAULT COMPL.
TRØNDELAG
PLATFORM
FÆRØY-SHETLAND ESCARP.
MØRE-TRØNDELAG FAULT COMPLEX
TRONDHEIM
M 1 / 5000000
km
0.0
100.0
200.0
300.0
NGU 1988
GEOLOGICAL SURVEY OF NORWAY
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40
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16
14
12
10
8
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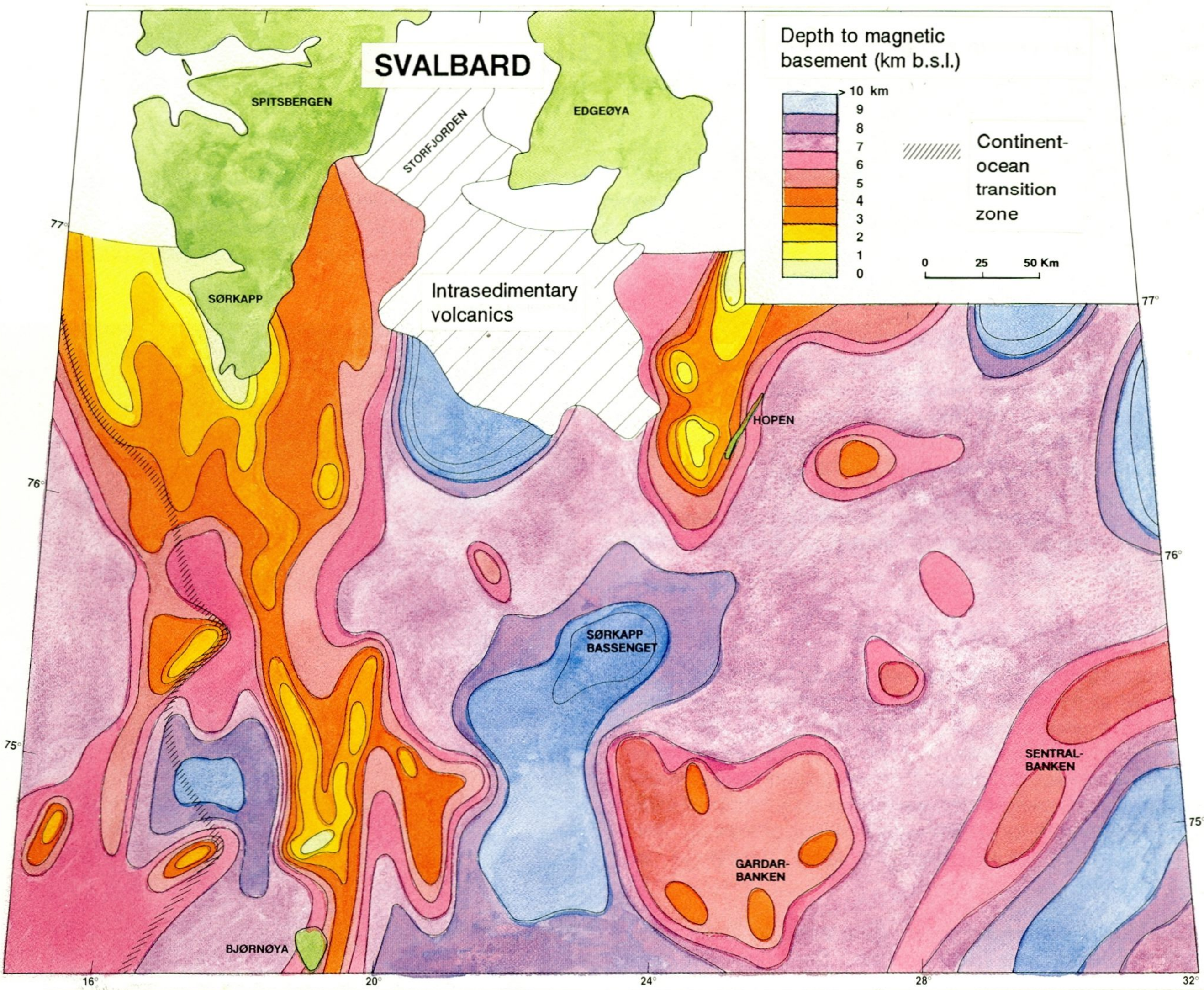
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
-32
-34
-36
-38
-40
-42
-44
72°
70°
62°
0°
4°
8°
12°
16°
20°
24°

## FIG. 5 DEPTH TO THE MAGNETIC BASEMENT

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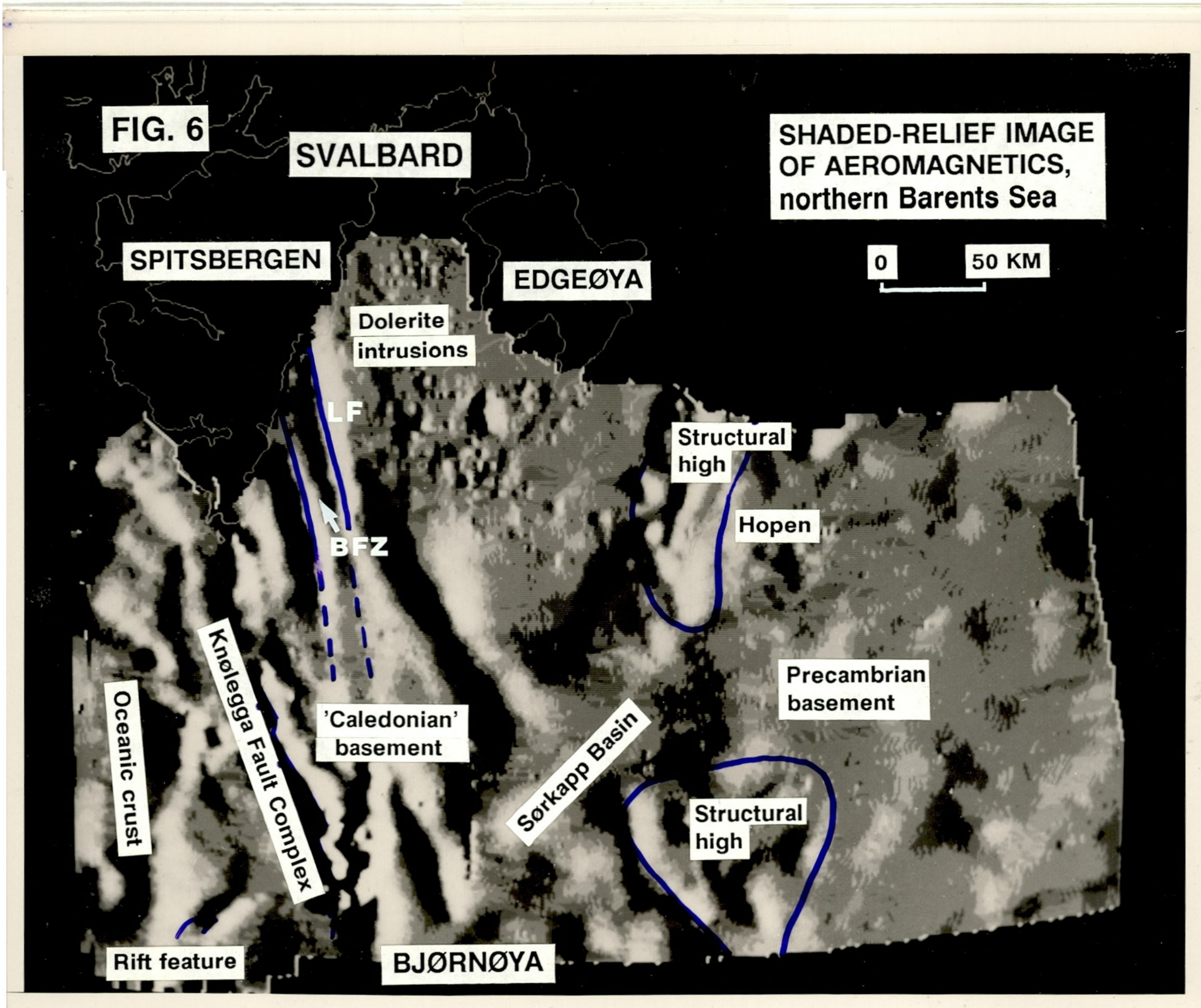


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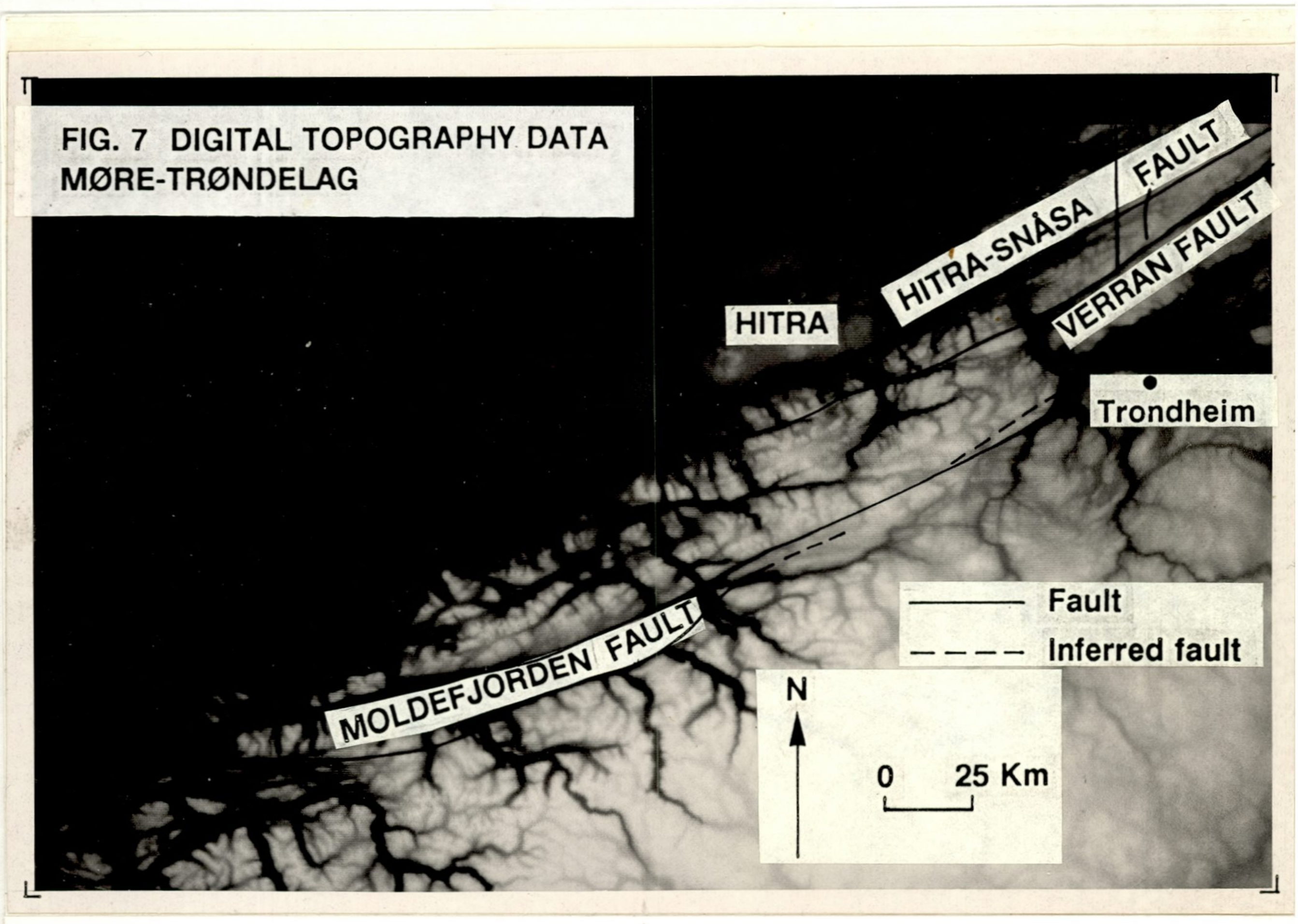


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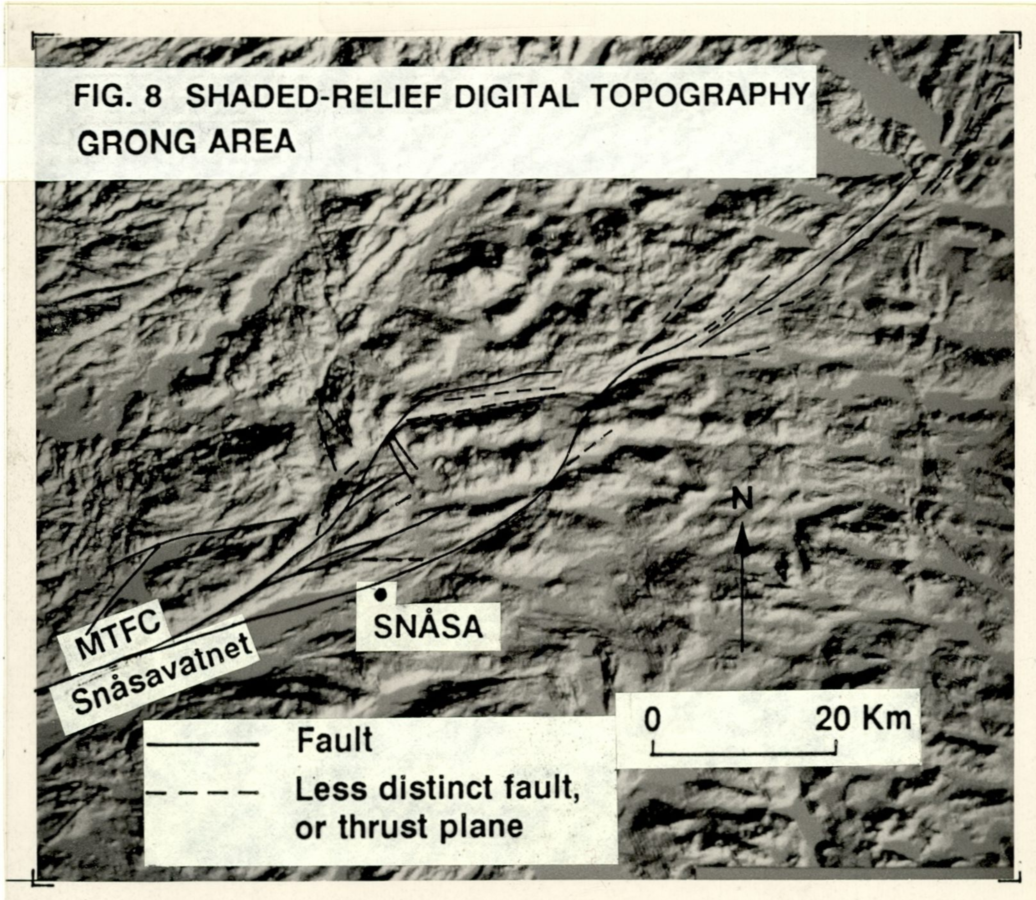


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