NGU Report 2001.111

Final Report: Sedimentation, tectonics and uplift in Vesterålen. Phase 1 – Localizing near-shore faults and Mesozoic sediment basins.

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REPORT

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Title:
Final Report: Sedimentation, tectonics and uplift in Vesterålen. Phase 1 – Localizing near-shore faults and Mesozoic sediment basins.

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Client:
NGU, Statoil, Norsk Hydro, Enterprise

County:
Nordland, Troms

Commune:
Hadsel, Bø i Vesterålen, Vågan, Sortland, Øksnes, Andøy, Kvæfjord, Harstad, Ibestad, Bjarkøy, Tranøy

Map-sheet name (M=1:250.000)
Svolvær, Andøya, Tromsø

Map-sheet no. and -name (M=1:50.000)
1131 I Austvågøya, 1131 IV Kvalnes, 1231 IV Raftsundet, 1132 II Stokmarknes, 1132 III Skårvågen, 1232 I Kvæfjorden, 1232 II Gullesfjorden, 1232 III Sortland, 1232 IV Myre, 1233 II Dverberg, 1233 III Langenes, 1332 I Andørja, 1332 II Harstad, 1333 II Stonglandet, 1333 III Bjarkøy

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Summary:
This report describes the final results from the project: *Sedimentation, tectonics and uplift in Vesterålen. Phase 1 – Localizing near-shore faults and Mesozoic sediment basins,* run by the Geological Survey of Norway (NGU) as a joint project with Statoil, Norsk Hydro and Enterprise Oil Norge Ltd.

The interpreted was acquired during two shallow seismic surveys in 2001 (NGU reports 2001.059 and 2001.096) in data set Vesterålen and adjoining areas in Troms County (Kvæfjorden and Vågsfjorden).

Sedimentary rocks of probable Mesozoic age exist in very near-shore positions in Gavlfjorden, between Andøya and Langøya, in addition to the previously known location at Sortlandsundet. Also, sedimentary strata in Vesterålsfjorden (west of Hadseløya), are confirmed. In all these areas the sedimentary successions display both unconformable and faulted basement contacts.

No sedimentary rocks are found in other areas examined; i.e. Hadselfjorden, outer part of Eidsfjorden, Kvæfjorden/Godfjorden/Gullesfjorden, southern part of Andfjorden, and Vågsfjorden.

The occurrences of sedimentary rocks in Sortlandsundet and Gavlfjorden are considered suitable for sampling by diamond drilling to shallow depths.

Keywords: Reflection seismics	Vesterålen	Near-shore basins
Magnetometry	Sortlandsundet basin	Faults
Seisma	Gavlfjorden	Vågsfjorden

CONTENTS

APPENDIXES

1. INTRODUCTION

This report describes the final results from the project: *Sedimentation, tectonics and uplift in Vesterålen. Phase 1 – Localizing near-shore faults and Mesozoic sediment basins,* run by the Geological Survey of Norway (NGU) as a joint project with Statoil, Norsk Hydro and Enterprise Oil Norge Ltd.

The purpose of this project has been to:

- Identify sedimentary basins in near-shore settings in Vesterålen, if any
- Localise near-shore faults
- Establish the outline of known Mesozoic occurrences in near-shore settings
- Document and preserve scientifically valuable erratics in Sortlandsundet

Shallow seismic data sets were collected in two surveys earlier this year; 30th April – 9th May and 29th August – 1st September 2001. Results from the two surveys have previously been submitted to the partners; NGU reports 2001.059 and 2001.096.

According to the contract, reporting of the project shall consist of:

- Survey reports
- Maps localizing sedimentary basins and possible faults, including descriptions
- Map on possible locations for sampling site(s) by drilling

This report covers the last two points.

Trondheim, November 21st, 2001

Børre Davidsen
Project leader

2. DATA ACQUISITION

During the spring and summer of 2001, 85 shallow seismic lines have been profiled in Vesterålen and adjoining areas in Troms County, giving a total of 880 km (*Figure 1*).
In Vesterålen, the investigated area comprises Vesterålsfjorden, the outer part of Eidsfjorden, Hadselfjorden, Sortlandsundet, Gavlfjorden and southern part of Andfjorden, while Vågsfjorden and Kvæfjorden/Godfjorden/Gullesfjorden represent Troms County. Profiling is relatively dense in the inner part of Hadselfjorden/southern part of Sortlandsundet and parts of Gavlfjorden, while other areas are more scarcely covered.

During profiling, data were collected simultaneously by 15 or 40 cubic inch sleeve gun, boomer, magnetometer, and echo sounding.
Technical details and data on the surveys are given in the NGU reports 2001.059 and 2001.096.

In addition to the two surveys, 3 days were spent sampling the known occurrences of Mesozoic erratics on the shores close to Sortland, in cooperation with Elsebeth Thomsen from the Museum of Tromsø. Some 680 kg of sample material were returned to the museum, of which several larger blocks were chosen for future exhibition purposes. The main reason for collecting the material was to conserve of the most valuable samples and enable a proper description of the macro-fauna. The Museum of Tromsø no longer sees any need for keeping the location a secret for the public.

Though not a contained part of this project, another two days were spent looking for erratics south of the discovered basins in Sortlandsundet/Hadselfjorden. Specifically, we made an attempt to find the boulder at Brottøya, described by Ravn & Vogt (1916), but without success. The whole boulder (apx. 125 kg) may possibly have been removed by Vogt in 1914. On the other hand, we did succeed in finding another small Mesozoic erratic on Holdøya (close to Fiskebøl, where the ferry crosses between Lofoten and Vesterålen), a bit further to the west. The lithology closely resembles the sandstones found close to Sortland.

As for the material collected in cooperation with the University Museum of Tromsø, this has been prepared for speciation of mussels and other fossils. A total of 34 mussels have been identified, of which some are said to be age-diagnostic. During October, Dr. Franz Fürsich of the University of Würsburg, who is a specialist on Jurassic mussels, visited the Museum of Tromsø and will contribute in species determination. His first statement on these samples was highly surprising; a possible Portlandian age! This does not accord with the micro fauna, which indicate Bathonian – Callovian age, and sets the scene for an interesting discussion in the near future.

3. BASIS OF INTERPRETATION

Data collected during the surveys form the basis for the interpretation here reported, combined with bathymetry purchased/acquired as a part of the project. In addition, a magnetometry grid (filtered to 8 km), topographic data and trajectories of NPD lines have been included on the map presentations (*Figures 2 and 3*). These additional pieces of information have, however, not been extensively used as a basis for the interpretation, as this goes beyond the agreed frame of the project.

4. FAULTS

Fault trajectories are interpreted based on seismic sections, acquired magnetometry profiles, and bathymetric data. In particular, possible anomalous contacts on the magnetometry profiles are indicated on the map (*Figure 3*). These may, or may not, represent faults. In some areas (e.g. Vesterålsfjorden and outer part of Gavlfjorden), the regional grid helps in tracing faults, but in general, the displayed data set is of too low resolution to be of significant help. Faults, definite as well as probable, are given on the map.
Nevertheless, various data sets (of which some are not included here) could provide more information on the faults, but this interpretation goes beyond the agreed project.

5. RESULTS FROM SEISMIC INTERPRETATION

Of the areas examined, sedimentary rocks of probable Mesozoic age exist in very near-shore positions in Gavlfjorden, between Andøya and Langøya, in addition to the previously known location at Sortlandsundet. Also, sedimentary strata in Vesterålsfjorden (west of Hadseløya), are confirmed. In all of these areas the sedimentary successions display both unconformable and faulted contacts to the basement. Identified Mesozoic(?) strata on the seismic sections are indicated by coloured lines along the survey trajectories (*Figures 2, 3 and 4*).

No sedimentary rocks are found in other areas examined; i.e. Hadselfjorden, the outer parts of Eidsfjorden, Kvæfjorden/Godfjorden/Gullesfjorden, southern part of Andfjorden, Vågsfjorden.

Following the two seismic surveys, it is clear that structures originally thought to represent possible sedimentary rocks in Hadselfjorden and Vågsfjorden are caused by diffraction artefacts (Hadselfjorden) or thick Quaternary deposits (Vågsfjorden).

5.1 Sortlandsundet

The Sortlandsundet basin is located in the southern part of Sortlandsundet, 10 km south of the town of Sortland. The basin is 5 km long and 3.5 km wide, and has a spoon-shaped geometry. The extension of the basin is well constrained by a closed and regular grid of seismic lines and the boundaries can be traced with confidence (*Figure 4*). The northwestern boundary has a rounded shape, whereas the southeastern boundary is defined by a normal fault, dipping to the

NW towards the basin. This main fault, which controls the basin, is oriented NE-SW in the northern part and swings to E-W toward the SW. The northern boundary is an on lap surface. The sedimentary succession in the basin comprises Quaternary sediments on top of sedimentary rocks of Mesozoic age, which rest on a Precambrian crystalline basement. The boundary between the Quaternary deposits and the substratum is generally well displayed. The thickest Quaternary cover is located in the centre of the basin, measuring about 20 m (assuming a compressional wave velocity of 1700 m/s). The boundary between the Mesozoic strata and the basement rocks is well expressed along the boundaries of the basin. The base of the sedimentary rocks within the basin is, however, more difficult to define, due to the presence of multiples and restricted penetration of the seismic energy. Sedimentary Mesozoic strata are well identified on the dip seismic lines. They display sub-parallel reflectors dipping a few degrees to the SE. The rocks are well bedded and highlighted regularly by strong continuous reflectors, which represent contrasts in lithology. Between these major reflectors, some units presents more discontinuous reflectors and also internal discordances have been observed, but are very difficult to trace. On strike lines, Mesozoic reflectors show either flat or wavy strata. Basement appears as a transparent rather seismic unit. The contact between the Mesozoic rocks and basement substratum is abrupt and well defined on seismic lines. In a few lines it appears to be more of a transition zone and this can be explained either by the quality of the data or the nature of the contact. Assuming an average compressional wave velocity of 3.5 km/s, the vertical thickness of the Mesozoic rocks within the basin can be estimated to be more than 400 m. The subcrop map of the Sortlandsundet basin *(Figure 4)* also shows synclines, anticlines and small faults. Along the main fault, one syncline and further to the NE, an anticline, appear to be related to the motion on the fault, developing as associated folds. Parallel to the main fault, a secondary fault is recognized on a few lines. The extension of this fault is uncertain, but towards the south it possibly merges into the main fault. Synclines have also been observed on strike lines and their orientation is almost perpendicular to the main fault. On the map, dip data (exact values have not been calculated) appear to swing, defining the spoon shape of the basin. Seismic data suggest that the main fault in Sortlandsundet was active during the deposition of the sediments as well as afterward. Seismic lines do not show a thickening of the layers toward the faults.

As described in Davidsen et al. (2001), glacier-transported boulders and erratic blocks are found on the shorelines from 3 to 10 km north of the basin. Their location often corresponds to moraine ridges seen on the bathymetry. These erratics must be eroded from the basin, and dinoflagellates give a middle Jurassic age; Bathonian to Callovian (apx. 165 – 170 Ma). The age distribution of detrial zircons from one sample has also been determined, indicating both local and presently unknown sediment sources (Mansfeld & Davidsen 2001). Lastly, ongoing work on detrial apatites from the same sandstone gives a preliminary fission track age of 176 ± 13 Ma (1 sigma) (B. Hendriks, pers. comm.).

5.2 Gavlfjorden (west of Andøya)

Gavlfjorden is located between the northern part of Langøya and the south-western part of Andøya, grading into the open sea to the northwest (*Figure 1*). The outer part of this area has previously been investigated by NPD during their seismic surveys, though without establishing accurate limits and nature of the contact between Mesozoic sediments and basement. This survey therefore contributes with significant new data on the area. Compared to the Sortlandsundet basin, however, the outline of the Mesozoic strata in Gavlfjorden is much more complicated. The southern boarder of this basin appears to be an unconformable contact against the Precambrian basement, even if the precise limit is somewhat difficult to define on the seismic sections. The eastern boarder, against the western side of the island of Andøya, the limit of the Mesozoic rocks is hard to define on the seismic sections, due to shallow water depth (< 50 m) and multiples present on seismic sections. However, based on the magnetic profile along NGU line 0108011, the eastward contact against the Precambrian basement is believed to be quite close to the shore, and faulted. The trajectory of this eventual fault is uncertain, but supposed to follow the western coast of Andøy. At the western margin of the Gavfjorden basin, basement rocks crop out at the seabed. These highs are surrounded by Mesozoic rocks and the contact is either faulted or unconformable. In this area, a major N-S trending and eastward dipping, normal fault is located just east of Anda lighthouse (*Figure 2*), forming the western limitation of the local basin in Gavlfjorden. Northwest of Anda lighthouse, another important fault is oriented NE-SW and dips toward E. This fault defines a contact between basement rocks and Mesozoic sediments.

Apparent dips in the Mesozoic units (from seismic lines) are shown where the quality of the data is good. They vary across the studied area and the steepest dips are generally observed closest to the faults. A few low amplitude anticlines and synclines have been recognized, mainly on NGU line 0108014, but they can not be correlated to other lines, as no equivalent structures have been found. Concerning the stratigraphy, thick Quaternary sediments cover the Mesozoic rocks, except on line 01080011, where the Quaternary cover is very thin between the two basement highs in the western part. In general, the thickness of the Quaternary units can reach more than 60 m, assuming a compressional wave velocity of 1700 m/s. Strata in the Mesozoic units are well bedded in the centre of the studied area, with strong and continuous reflectors. On the western side, seismic signatures on the lines become less clear and discontinuous, and weak reflections are more common. The basement appears transparent on seismic sections. Assuming an average compressional wave velocity of 3.5 km/s, the vertical thickness of the Mesozoic rocks, within the small basin illustrated on line 0108011 northwest of Anda lighthouse (shot points 108-120), can be estimated to be maximum 300 m.

As shown on the map (*Figure 2*), the area west of Andøya presents a complex pattern of structures. Tracing faults from one line to another is difficult and the open grid does not allow us to present a precise model.

5.3 Vesterålsfjorden (west of Hadseløya)

This area is relatively well described in IKU reports, and this survey does not add substantial, new information. Three seismic lines of the NGU survey cross the Mesozoic basin, which is fault bounded to the south and east. The northern contact, on the other hand, appears unconform. The main structure of this basin is a pronounced east-west trending syncline in the southern part.

6. POSSIBLE SAMPLING LOCATIONS

This study has highlighted two areas where subsurface Mesozoic rocks are present and overburden scarce, the Sortlandsundet basin and Gavlfjorden west of Andøy (*Figure 2*). In both areas, sampling by diamond drilling using BGS' Rockdrill should be possible, even if cores are limited to 5 m.

Data from Boomer seismics is used for estimating cover thickness (*Figures 5 and 6*). For each location, a primary and a subsidiary drilling site are indicated.

6.1 Sortlandsundet basin

In Sortlandsundet, the proposed drilling location is on line 0009007 at shot point 16.8 (*Figure 4*). The Quaternary cover is estimated to be less than 2 meters (*Figure 5*). The water depth at this point is about 115 m.

6.2 Gavlfjorden

In Gavlfjorden, or more precisely immediately northwest of Anda lighthouse, the location is on line 01080011 at shot point 112.5 (*Figure 2*). This is the only location encountered on the seismic sections in this area where Quaternary cover is sufficiently thin to allow a possible sampling of Mesozoic rocks, and is here estimated to be 2-3 meters (*Figure 6*). The cover is probably composed of moraine and/or boulders. At this location, Mesozoic rocks are deposited in a small basin surrounded by basement highs, probably with faulted contact to the northwest and unconformable contact to the southeast. The basin seems to open towards the southwest, but additional seismic lines will be required to confirm this. If correct, the site then has potential of providing samples of strata that might be traced into the shelf succession. The water depth is 133 m.

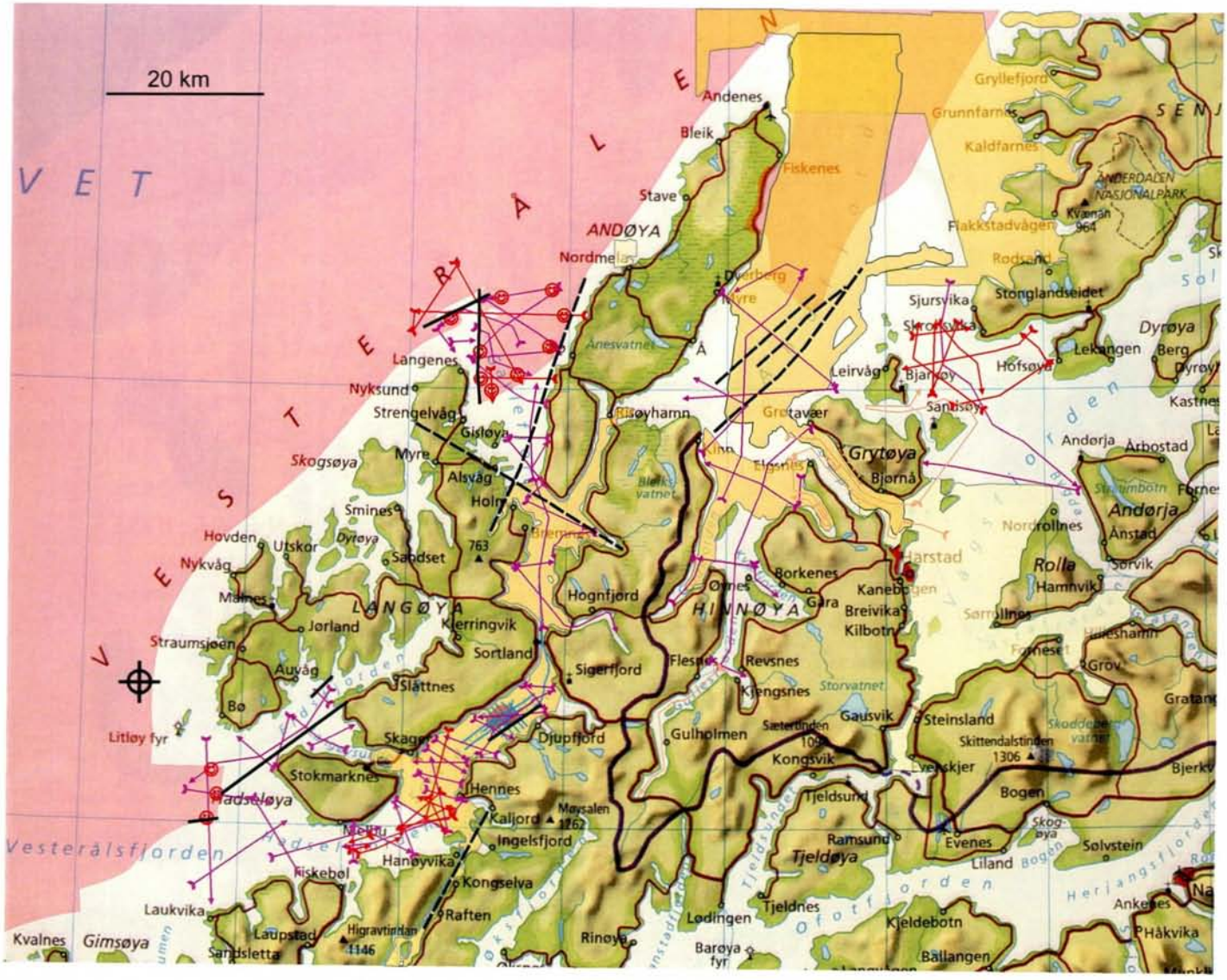
7. REFERENCES

Davidsen, B., Smelror, M. & Ottesen, D. 2001: Et nyoppdaget mesozoisk basseng i Sortlandsundet, Vesterålen. Abst. Norsk Geologisk Forenings XVII. Vinterkonferanse, Oslo, 8.-10. januar 2001. Geonytt 2001, 42-43.

Ravn, J. P. J. & Vogt, T. 1916: Om en blok av neocom fra Hanø i Vesteraalen. *Norsk Geologisk Tidsskrift*, Vol. 3, 2-31.

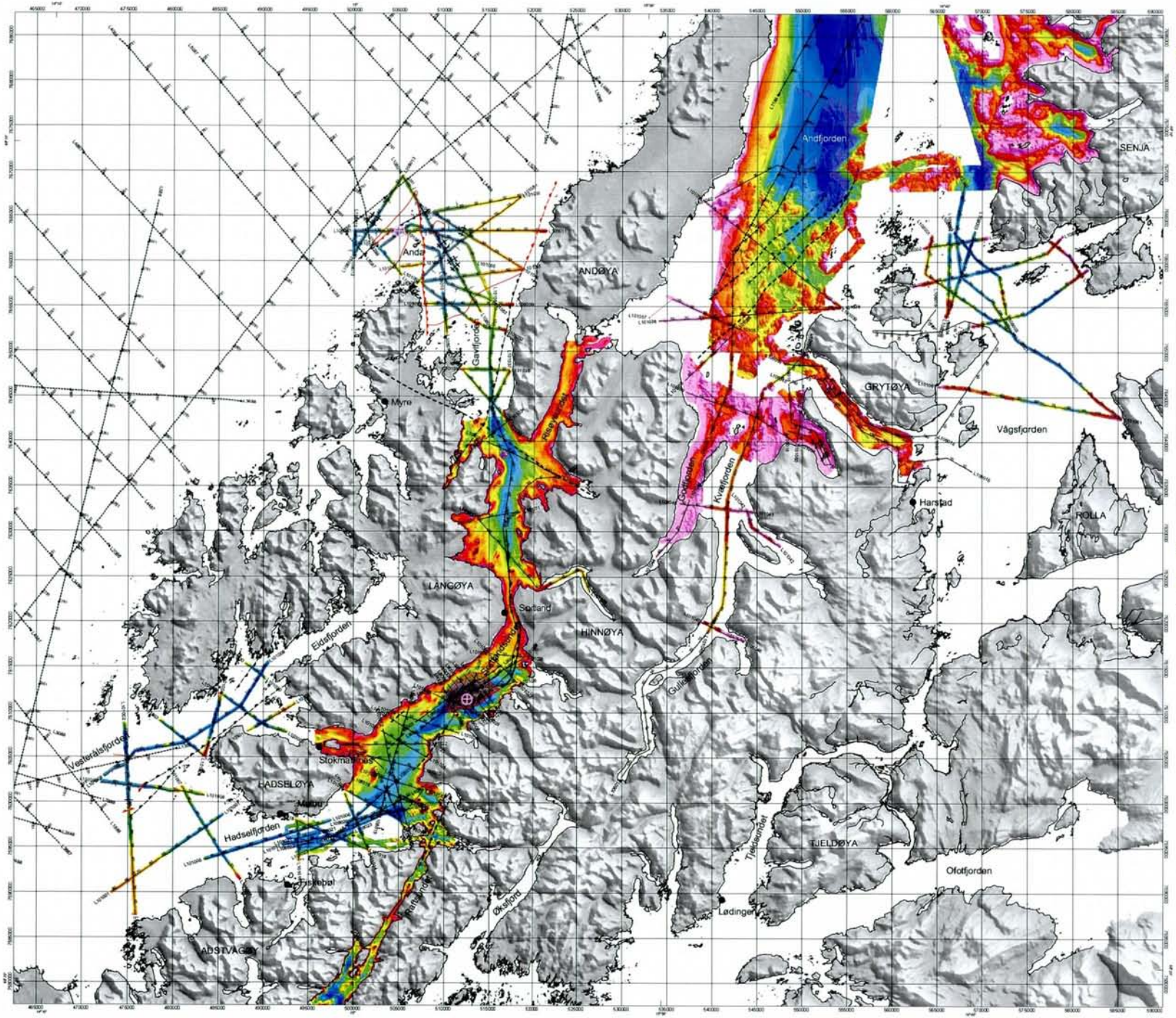
Mansfeld, J. & Davidsen, B. 2001: Surprisingly young zircon populations from the newly discovered Mesozoic basin an Sortlandsundet, Vesterålen, determined by laser ablation ICP-MS at NGU. Abst. Norsk Geologisk Forenings XVII. Vinterkonferanse, Oslo, 8.-10. januar 2001. Geonytt 2001, 79.

Figure 1. VESTERÅLEN; NGU 2001 shallow seismic survey



Tegnforklaring

	Mesozoiske bergarter
	Nye områder med mesozoiske bergarter
	Forkastninger, sikre & mulige
6814/04-U-01	Grunn boring (IKU)
	Seismikk innsamlet 2000 (tokt 0009)
	Seismikk innsamlet våren 2001 (tokt 0101), med profileringsretning
	Seismikk innsamlet høsten 2001 (tokt 0108), med profileringsretning
	Seismikk innsamlet under tokt 0106 (NGU), med profileringsretning
	Bathymetri: tilgjengelig / anskaffet



VESTERÅLEN

NGU 2001 shallow seismic survey

Projected on bathymetry

Legend

- NGU survey
- NPD survey
- Mesozoic? reflectors
- Limitation of Mesozoic rocks
- Faulted Mesozoic contact
- Area of Mesozoic rocks
- Fault
- Possible faults
- Syncline
- Anticline
- Apparent dip of strata
- Possible drilling site

Water depths in metres

Hadselfjorden, Sortlandsundet & Eidfjorden

Andfjorden

Confidential

Bathymetry must not be published, unless written permission is given by Norwegian defense authorities

Bathymetric grid is based on 50 m cell size

NGU

Enterprise Oil

NORSK HYDRO

STATOIL

N

Scale 1:100000

NGU

Vesterålen and Vågsfjorden
Figure 2
NGU survey with interpretation; projected on bathymetry

Data collected by: B. Davidsen, O. Olsen
Data processed by: F. Mauring, O. Olsen, B. Davidsen
Map produced by: H.A. Olsen, E. Mauring, B. Davidsen
Interpreted by: A. Sommaruga, R. Bøe, B. Davidsen

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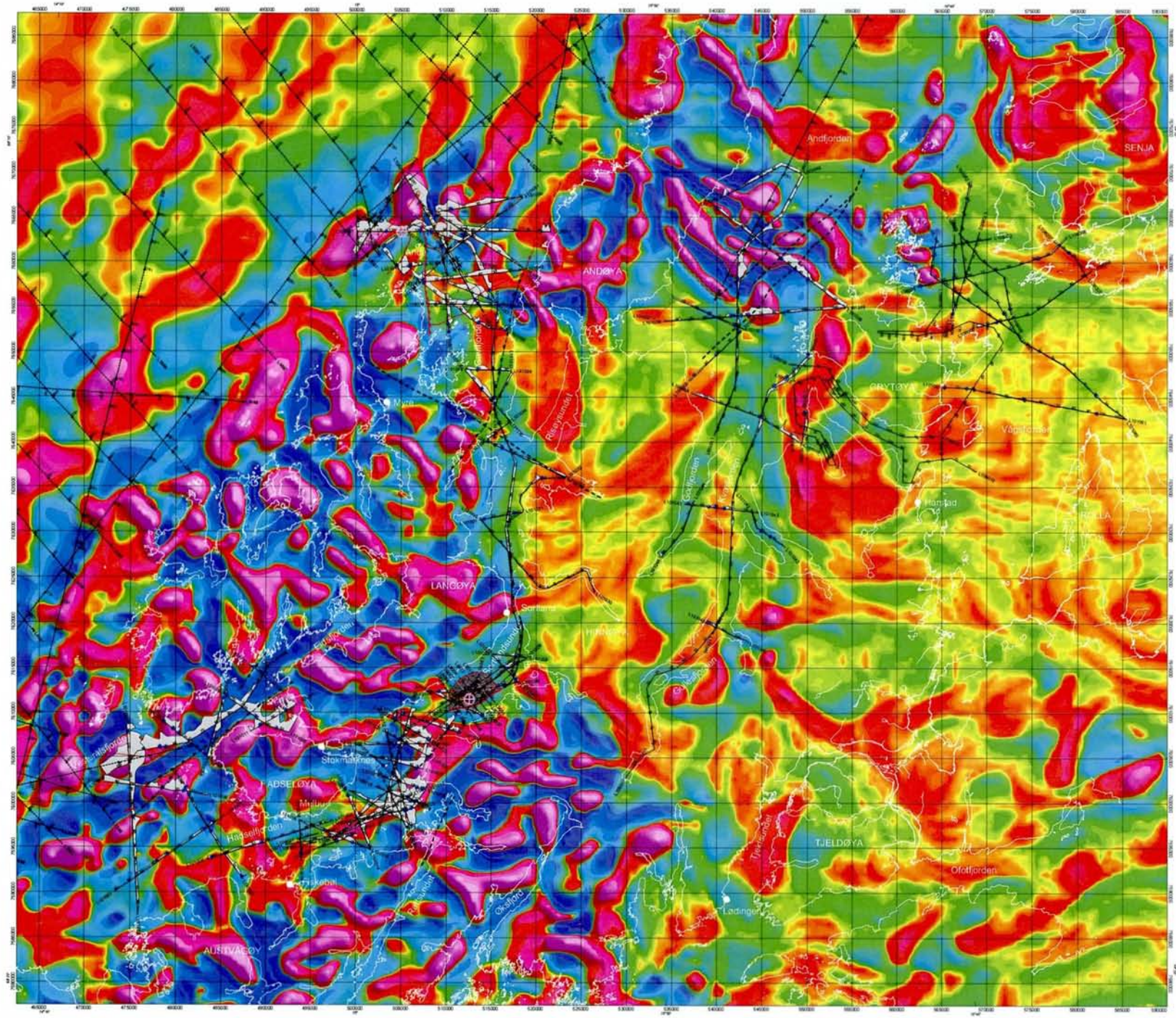


VESTERÅLEN

NGU 2001 shallow seismic survey

Projected on magnetometry

Legend

- NGU survey
- NPD survey
- Mesozoic? reflectors
- Limitation of Mesozoic rocks
- Faulted Mesozoic contact
- Area of Mesozoic rocks
- Fault
- Possible faults
- Syncline
- Anticline
- Apparent dip of strata
- Possible drilling site
- Mag profile
- Mag anomaly (fault?)

Magnetometry scale

NGU

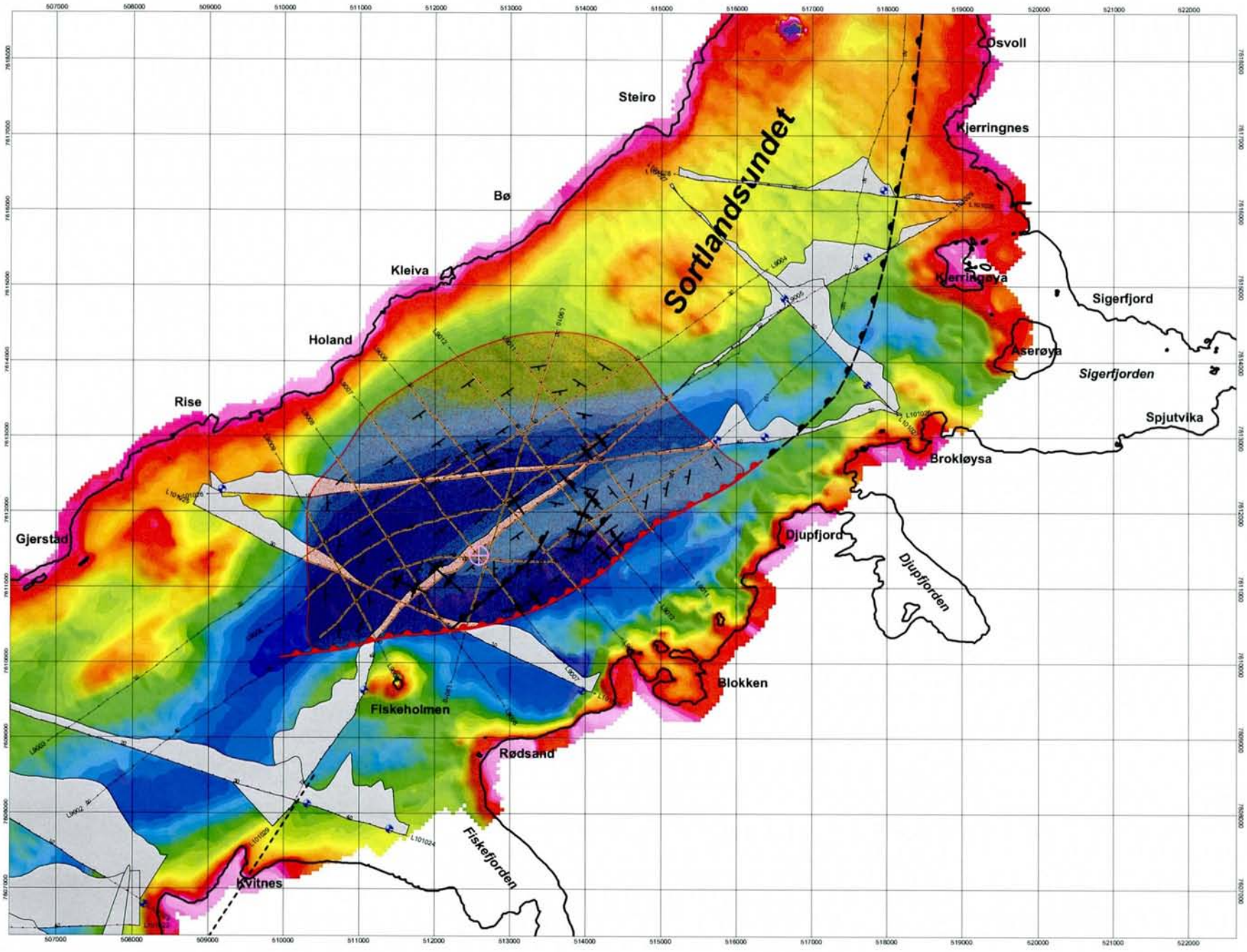
Enterprise Oil

STATOIL

Vesterålen and Vågsfjorden
Figure 3
NGU survey with interpretation; mag projection

Data collected by: E. Davidson, O. Olesen
Data processed by: F. Maurring, O. Olesen, E. Davidson
Map produced by: H.A. Olsen, F. Maurring, E. Davidson
Interpreted by: A. Sommaruga, E. Rea, S. Davidson

2001.111



VESTERÅLEN

NGU 2001 shallow seismic survey

Sortlandsundet basin

Legend

- L101014 — NGU survey
- Mesozoic? reflectors
- Limitation of Mesozoic rocks
- Faulted Mesozoic contact
- Area of Mesozoic rocks
- Fault
- Possible faults
- Syncline
- Anticline
- Apparent dip of strata
- Possible drilling site
- Mag profile
- Mag anomaly (fault?)

Water depth in metres

Confidential

Bathymetry must not be published, unless written permission is given by Norwegian defense authorities

Bathymetric grid is based on 50 m cell size

Scale 1:25000

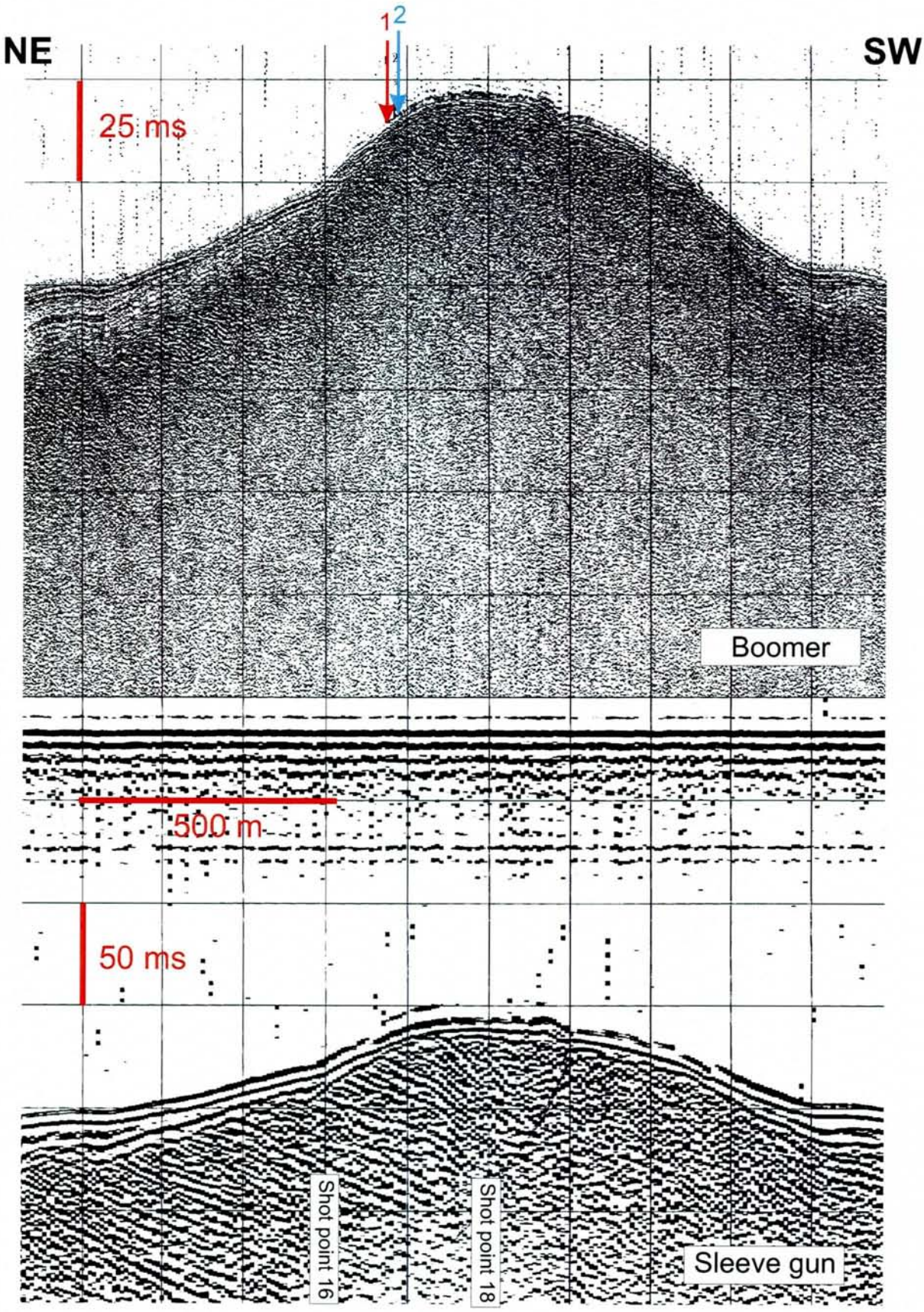
NGU

Sortland basin; detail map
Figure 4
Shot points, Mag + Bathymetri; with interpretation

Data collected by: B. Davidsen, D. Ottesen
Data processed by: E. Mauring, D. Ottesen
Map produced by: H.A. Olsen, E. Mauring, B. Davidsen
Interpreted by: A. Sommaruga, R. Bee, B. Davidsen

2001.111

Figure 5. Possible sampling site at Sortlandsundet

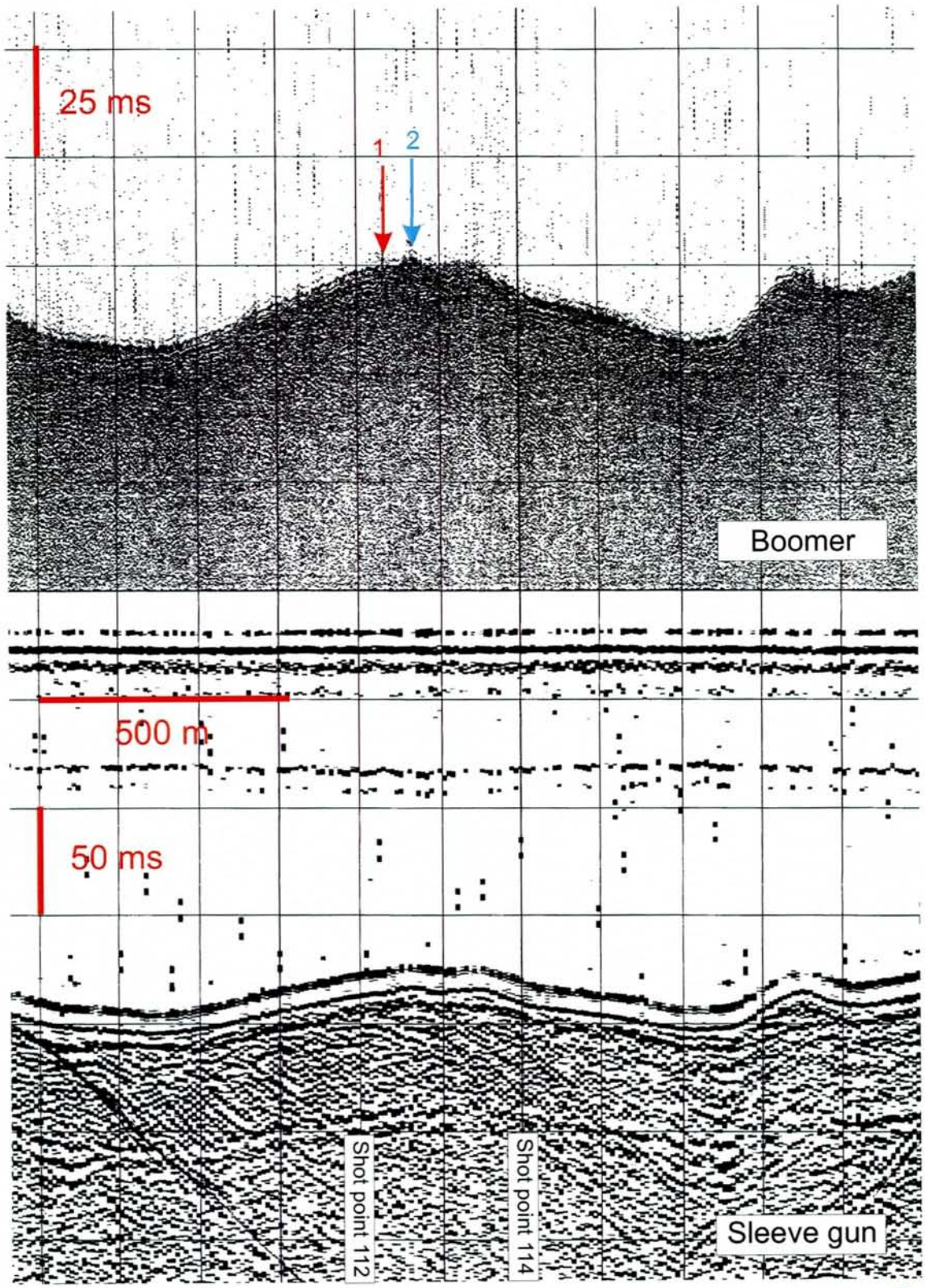


Line 0009007

NGU
Norges geologiske undersøkelse

Figure 6. Possible sampling site at Gavlfjorden

E W



Line 0008011

NGU
Norges geologiske undersøkelse