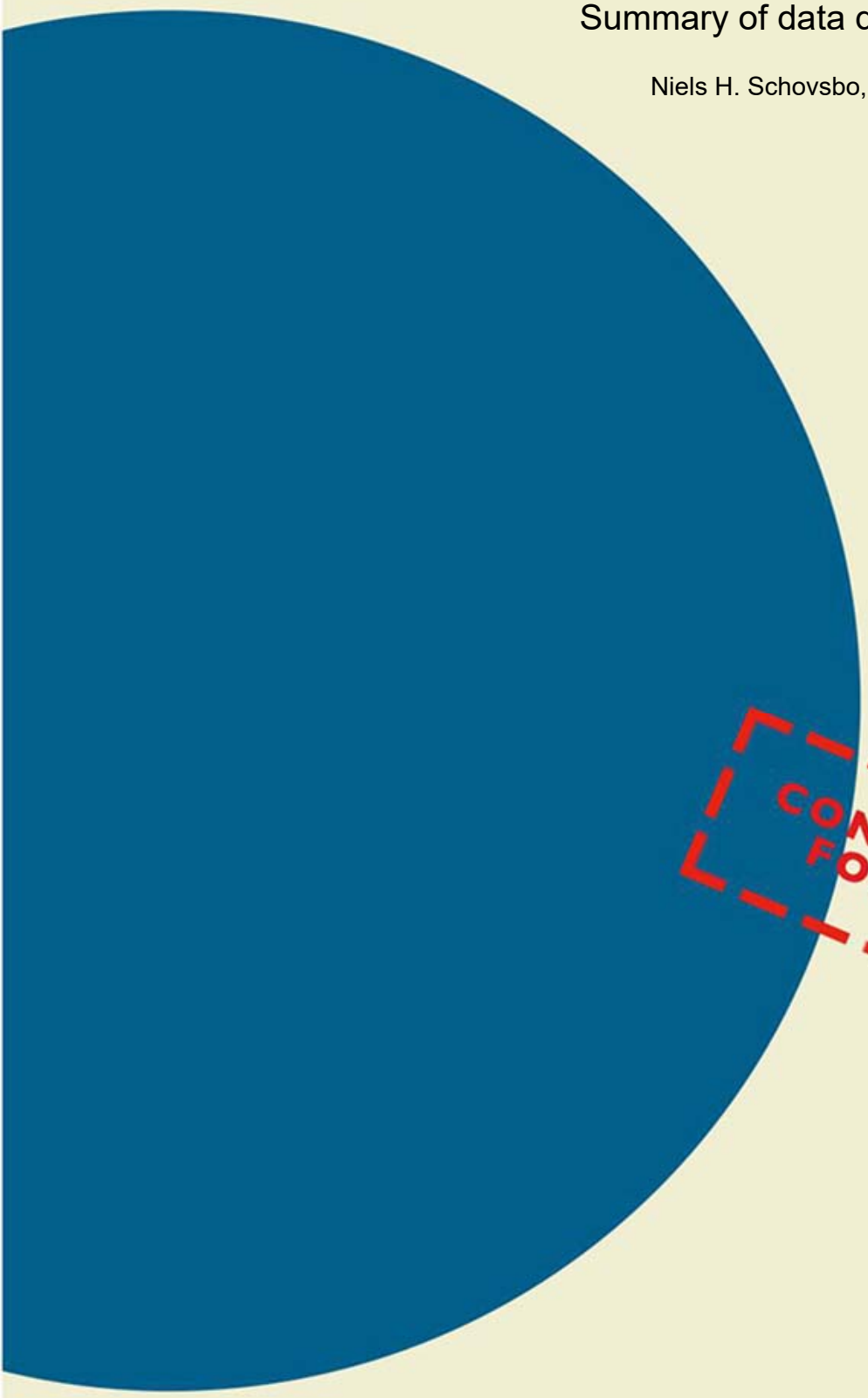
DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/125

European Black Shale Data Base: Contribution from Denmark

Summary of data delivery part 1 and 2 to TNO

Niels H. Schovsbo, Torben Bidstrup & Anders Mathiesen



GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY

GEUS

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2011/125

European Black Shale Data Base: Contribution from Denmark

Summary of data delivery part 1 and 2 to TNO

Geochemical and stratigraphical evaluation of the Lower Paleozoic shales on Bornholm

Niels H. Schovsbo, Torben Bidstrup & Anders Mathiesen

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
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GEUS

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1. Introduction

This report summarizes the data deliveries made by GEUS to TNO as part of the 'European Black Shale Data Base' (EBSD) on the 'GASH sub-project 1'.

The data was delivered in two steps. The first data was delivered in January 2011 and consisted of the result of a screening study of Denmark for organic rich shales and relevant well data and base maps for the shales.

The second data was delivered in December 2011. The data consisted of the interpretation of 4 seismic lines, digital well logs from the Skelbro-2 well and pdf of selected well logs from the Slagelse-1 and Terne-1 wells. An agreement between TNO and GEUS on the conditions of the data sale of the seismic lines was made separately to this report.

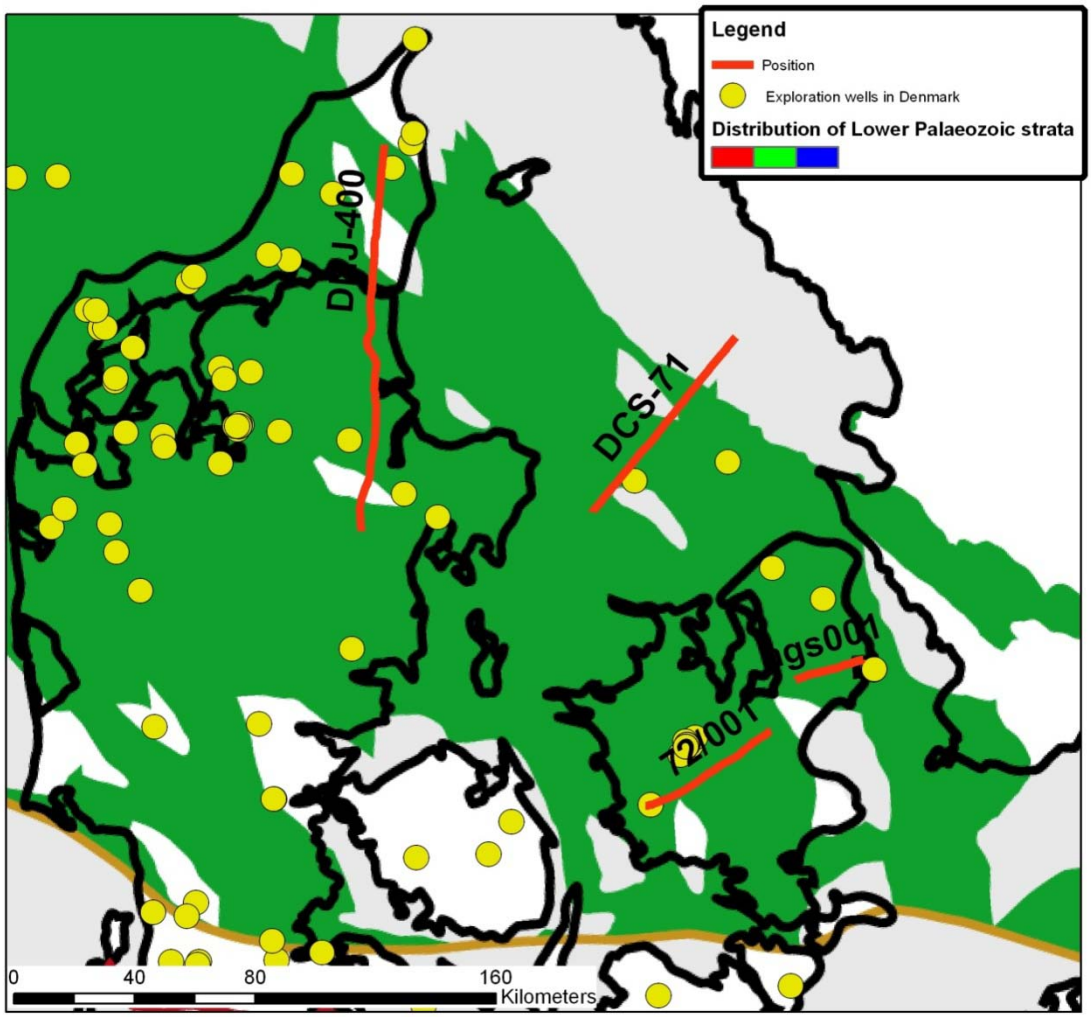


Figure 1. Distribution of Lower Palaeozoic strata in the Danish area (green fill) (Nielsen & Schovsbo 2011). Yellow circles represent exploration wells in Denmark and the red lines indicate the location of the seismic lines interpreted as part of the second data delivery (see Section 3). The lines are: DNJ-400, DCS-71, 72/001, HGS001.

2. Status for the EBSD data request 1

Data delivered to EBSD/TNO in 2011

Wells:

- Palaeozoic:
  - TOC, RE, %R for the Alum Shale in the wells:
    - Terne-1
    - Slagelse-1
    - Billegrav-1
    - Skelbro-1
  - Depth plots of well log data
  - Mesozoic:
  - Average TOC, RE, %R for black shale units in 34 well
    Depth plots of well log data

Maps:

Map request

- Palaeozoic:
  - Distribution of Lower Palaeozoic strata
  - Thickness of the Alum Shale Fm
  - Maturity of the Alum Shale Fm
  - Facies maps for the Alum Shale Fm
  - Structural outline of Danish area
  - Depth structure map of the Pre-Zechstein surface
  - Sub-crop map of the Pre-Zechstein surface

All the data is included on the attached CD in the folder ‘First data delivery’.

2.1. Well data

Uploaded data to the TNO/EBSD ftp site:

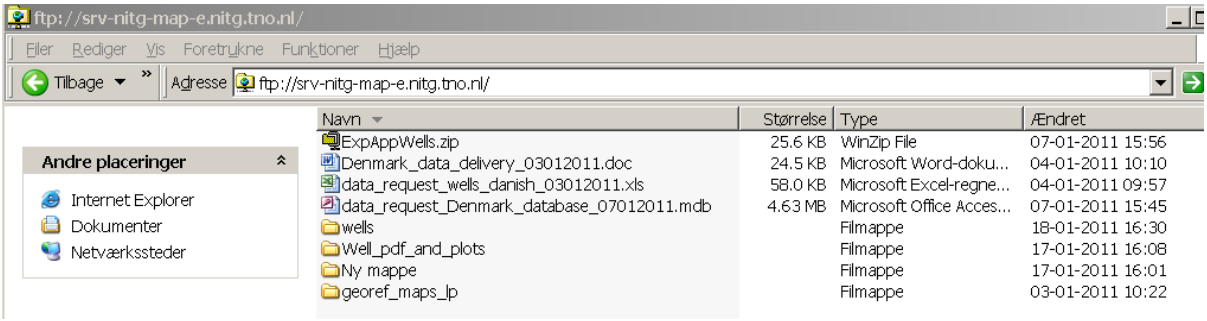


Figure 2. Screen dump of the TNO/EBSD ftp site showing the organization of the folders of the uploaded data.

	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	SHORT_NAME	WELL_NAME	OWNER_OPER	START_DATE	END_DA	TARG_S	END_S	ENDDPT_MD	ENDDPT_	RESULT	CORES	LOGS	DEVIATED	WELL_ID	LOC_ACCUR	LINK
2	SLAGELSE-1	:5511/22-01	(STANDARD) GULF	:1959-03-09	:1959-05-	Hardebe	Hardeb	2974.8	2934	Exploration	1	1	0	1	acurate	http://www.geus.c
3	TERNE-1	:5611/23-01	Amoco	:1985-05-26	:1985-08-	Hardebe	Hardeb	3361	3324	Exploration	1	1	0	2	acurate	http://www.geus.c
4	SKELBRO-1	:246.749	GEUS	:1984-01-05	:1984-01-	Læså	Læså	43	43	Scientific	1	1	0	3	acurate	http://jupiter.geus
5	SKELBRO-2	:246.817	GEUS	:2010-08-10	:2010-08-	Læså	Læså	37	37	Scientific	1	1	0	4	acurate	http://jupiter.geus
6	BILLEGRAV-1	:247.560	GEUS	:1984-01-05	:1984-01-	Komstad	Dicello	61	61	Scientific	1	1	0	5	acurate	http://jupiter.geus
7	BILLEGRAV-2	:248.61	GEUS	:2010-08-15	:2010-08-	Læså	Læså	125.2	125.2	Scientific	1	1	0	6	acurate	http://jupiter.geus
8	AARS-1	:5609/07-01	DONG	:1978-11-06	:1979-09-	0	Vinding	3401	3356	Geothermal	0	1	1	7	acurate	GEUS Well Info
9	BØRGLUM-1	:5709/20-01	(DAPCO) GULF	:1951-08-14	:1951-09-	0	Gassur	1527	1504	Exploration	1	1	0	8	acurate	GEUS Well Info
10	C-1X	:5607/15-01	Gulf	:1968-01-19	:1968-03-	0	Rotlieg	3206	3171	Exploration	1	1	0	9	acurate	GEUS Well Info
11	F-1X	:5706/32-01	Gulf	:1968-10-06	:1968-10-	0	Skager	2422	2385	Exploration	0	1	0	10	acurate	GEUS Well Info
12	FARSØ-1	:5609/06-02	DONG	:1981-10-22	:1982-01-	0	Vinding	2950	2925	Geothermal	1	1	0	11	acurate	GEUS Well Info
13	FELICIA-1	:5708/18-01	Statoil	:1987-07-04	:1987-12-	0	Skager	2543	2503	Exploration	0	1	0	12	acurate	GEUS Well Info
14	FJERRITSLEV-2	:5709/30-01	(STANDARD) DAPCO	:1958-03-13	:1958-05-	0	Skager	2345	2337	Exploration	1	1	0	13	acurate	GEUS Well Info
15	FLYVBJERG-1	:5710/21-01	(STANDARD) DAPCO	:1958-06-14	:1958-07-	0	Skager	1699	1652	Exploration	1	1	0	14	acurate	GEUS Well Info
16	FREDERIKSHA\	:5710/19-01	(DAPCO) GULF	:1950-07-03	:1950-08-	0	Precam	1317	1304	Exploration	1	1	0	15	acurate	GEUS Well Info
17	FREDERIKSHA\	:5710/19-02	(DAPCO) GULF	:1952-04-21	:1952-05-	0	Skager	963	948	Exploration	1	1	0	16	acurate	GEUS Well Info
18	GASSUM-1	:5610/13-01	(DAPCO) GULF	:1948-03-18	:1951-03-1	0	Zechst	3441	3383	Exploration	1	1	0	17	acurate	GEUS Well Info
19	HALDAGER-1	:5709/32-01	(DAPCO) GULF	:1950-10-10	:1950-12-	0	Fjerritsl	1524	1519	Exploration	0	1	0	18	acurate	GEUS Well Info
20	HANS-1	:5612/21-01	MÆRSK OLIE OG GA	:1983-08-04	:1983-10-	0	Permia	1782	1758	Exploration	1	1	0	19	acurate	GEUS Well Info
21	HOBRO-1	:5609/15-01	Gulf	:1974-06-07	:1974-07-	0	Oddesu	2589	2557	Exploration	0	1	0	20	acurate	GEUS Well Info
22	HYLLEBJERG-1	:5609/06-01	MÆRSK OLIE OG GA	:1975-12-07	:1976-01-1	0	Oddesu	2843	2815	Exploration	0	1	0	21	acurate	GEUS Well Info
23	INEZ-1	:5606/08-01	Chevron	:1977-09-11	:1977-10-	0	Skager	1984	1949	Exploration	0	1	0	22	acurate	GEUS Well Info
24	J-1X	:5708/19-01	Gulf	:1969-12-24	:1970-01-1	0	Skager	1989	1952	Exploration	0	1	0	23	acurate	GEUS Well Info
25	K-1X	:5707/25-01	Chevron	:1970-01-21	:1970-02-	0	Skager	2291	2254	Exploration	0	1	0	24	acurate	GEUS Well Info
26	KVOLS-1	:5609/14-01	MÆRSK OLIE OG GA	:1976-02-27	:1976-03-	0	Oddesu	2641	2622	Exploration	0	1	0	25	acurate	GEUS Well Info
27	LAVØ-1	:5612/29-01	(STANDARD) DAPCO	:1959-01-19	:1959-03-	0	Vinding	2441	2413	Exploration	1	1	0	26	acurate	GEUS Well Info
28	MEJRUP-1	:5608/19-01	Phillips	:1987-03-22	:1987-04-	0	Vinding	2485	0	Exploration	0	1	0	27	acurate	GEUS Well Info
29	MORS-1	:5609/04-01	Gulf	:1966-12-13	:1967-09-	0	Bunter	5321	5303	Exploration	1	1	0	28	acurate	GEUS Well Info
30	NØVLING-1	:5608/28-01	Gulf	:1966-09-13	:1966-11-2	0	Siluriar	3762	3693	Exploration	1	1	0	29	acurate	GEUS Well Info
31	RØDDING-1	:5608/12-01	MÆRSK OLIE OG GA	:1976-01-27	:1976-02-	0	Oddesu	2163	0	Exploration	0	1	0	30	acurate	GEUS Well Info
32	RØNDE-1	:5610/22-01	Gulf	:1965-10-23	:1966-08-	0	Siluriar	5300	5257	Exploration	1	1	0	31	acurate	GEUS Well Info
33	SKAGEN-2	:5710/11-02	(DAPCO) GULF	:1951-09-24	:1951-10-2	0	Skager	621	619	Exploration	1	1	0	32	acurate	GEUS Well Info
34	SKIVE-1	:5609/09-01	MÆRSK OLIE OG GA	:1976-04-04	:1976-04-	0	Vinding	2318	2290	Exploration	0	1	0	33	acurate	GEUS Well Info
35	SÆBY-1	:5710/22-01	DOPAS	:1985-08-07	:1985-08-	0	Rotlieg	1854	1790	Exploration	1	1	0	34	acurate	GEUS Well Info
36	VEDSTED-1	:5709/27-01	(STANDARD) DAPCO	:1958-05-09	:1958-06-	0	Skager	2073	2068	Exploration	1	1	0	35	acurate	GEUS Well Info
37	VINDING-1	:5608/23-01	(DAPCO) GULF	:1947-07-17	:1947-12-	0	Falster	2434	2373	Exploration	1	0	0	36	acurate	GEUS Well Info
38	VOLDUM-1	:5610/18-01	Gulf	:1974-03-04	:1974-04-	0	Oddesu	2312	2277	Exploration	1	1	0	37	acurate	GEUS Well Info

Figure 3. Screen dump showing well data sheet delivered. Hyperlinks from the exploration wells to the GEUS homepage are provided. Following the link will provide information relevant for the well i.e. availability of reports, logs, and the conditions on how to obtain these data.

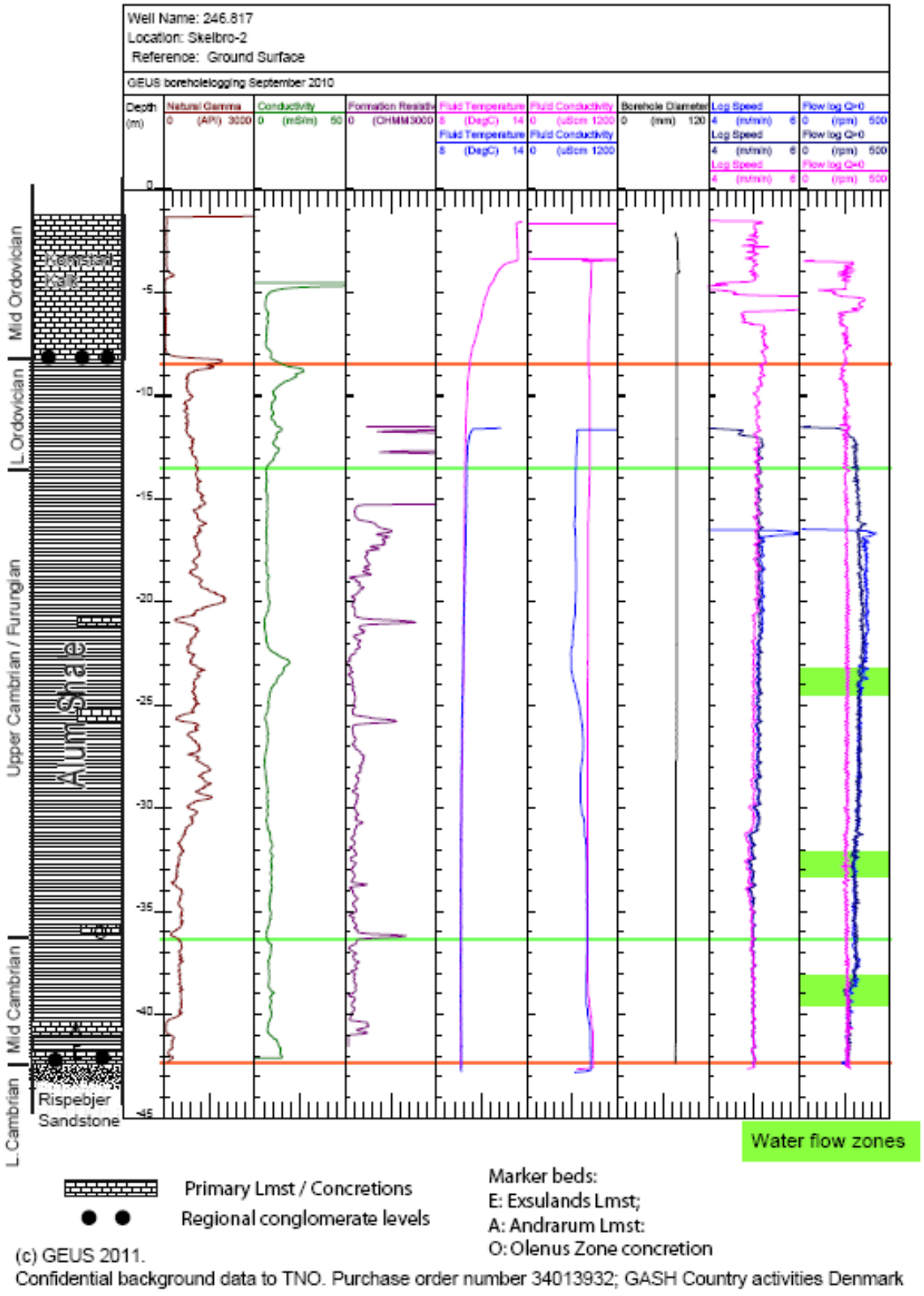
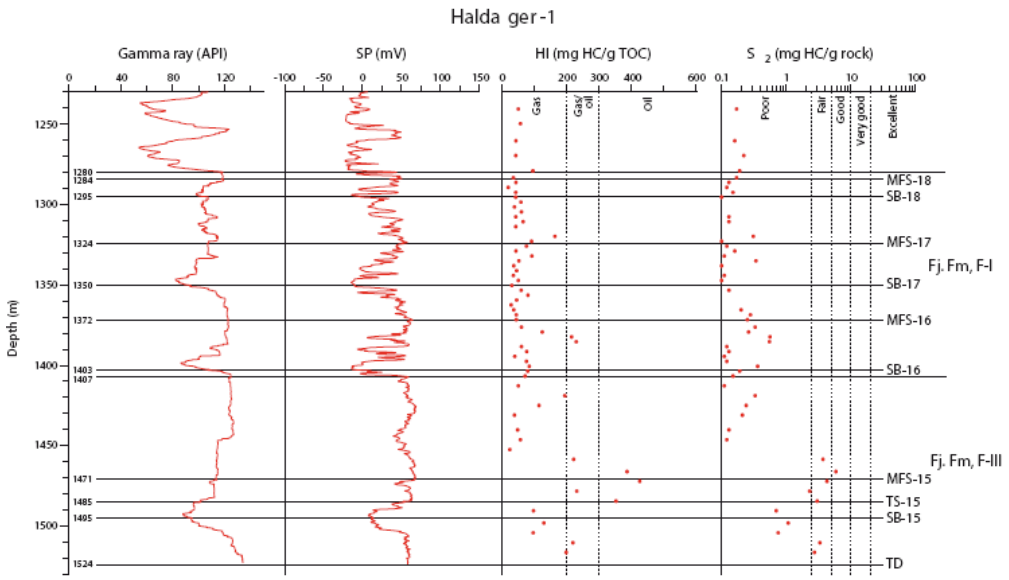


Figure 4. Example of the data delivery for the Skelbro-2 well. A digital version of the well logs is included as part of the second data delivery.



Plots showing well logs, Hydrogen Index (HI) values, S_2 yields, sequence stratigraphic key surfaces and formations DT , sonic velocity; MFS , maximum marine flooding surface; SB , sequence boundary; TS , transgressive surface. Bø., Børglum; Fj., Fjerritslev; H.S ., Haldager Sand.

Figure 5. Example of the data delivery for the Haldager-1 well.

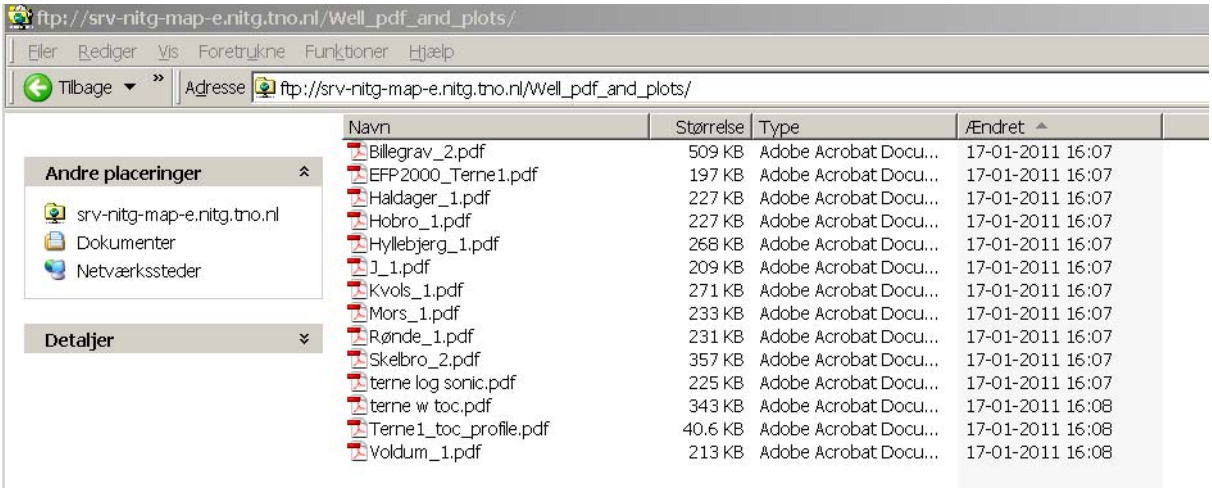


Figure 6. Screen dump showing the delivered well files.

2.2. Shape files

Uploaded data to the TNO/EBSD ftp site:

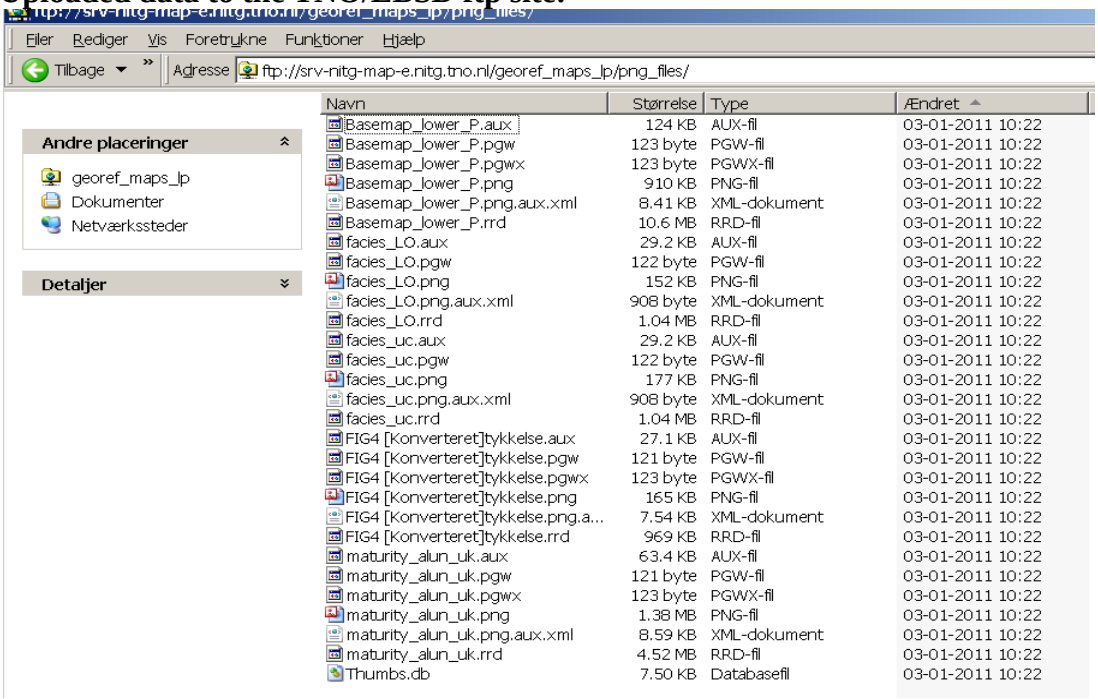


Figure 7. Screen dump showing the content of the georef_maps_lp directory.

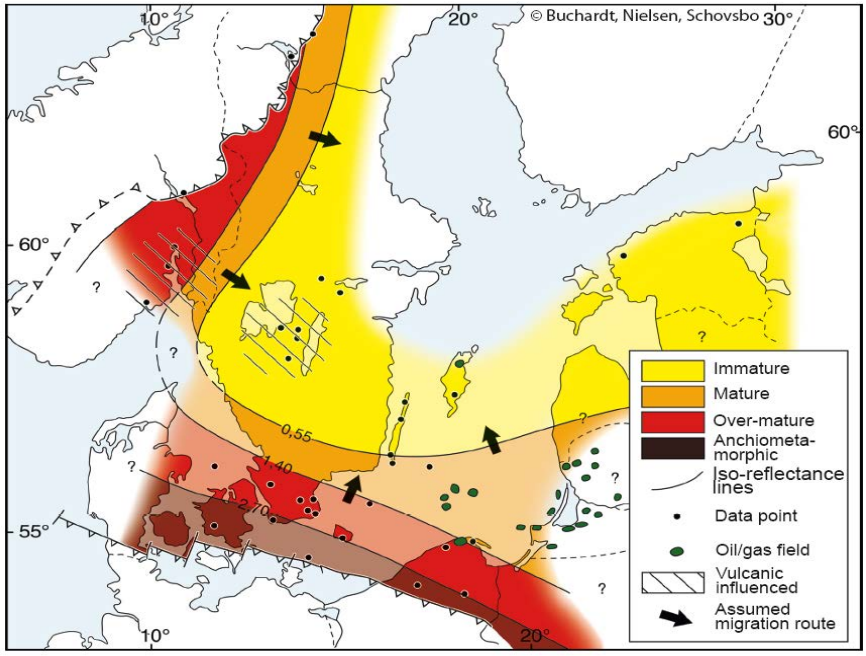


Figure 8. Example of a geo-referenced map: Maturity of Alum Shale.

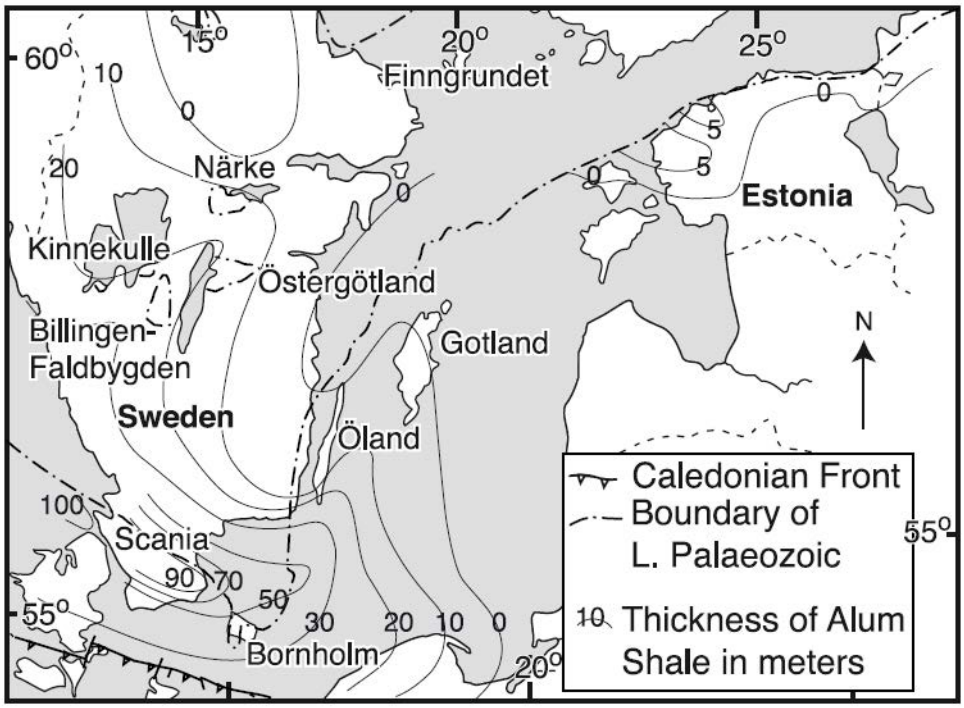


Figure 9. Example of a geo-referenced map delivered to the EBSD: Thickness of the Alum Shale Fm.

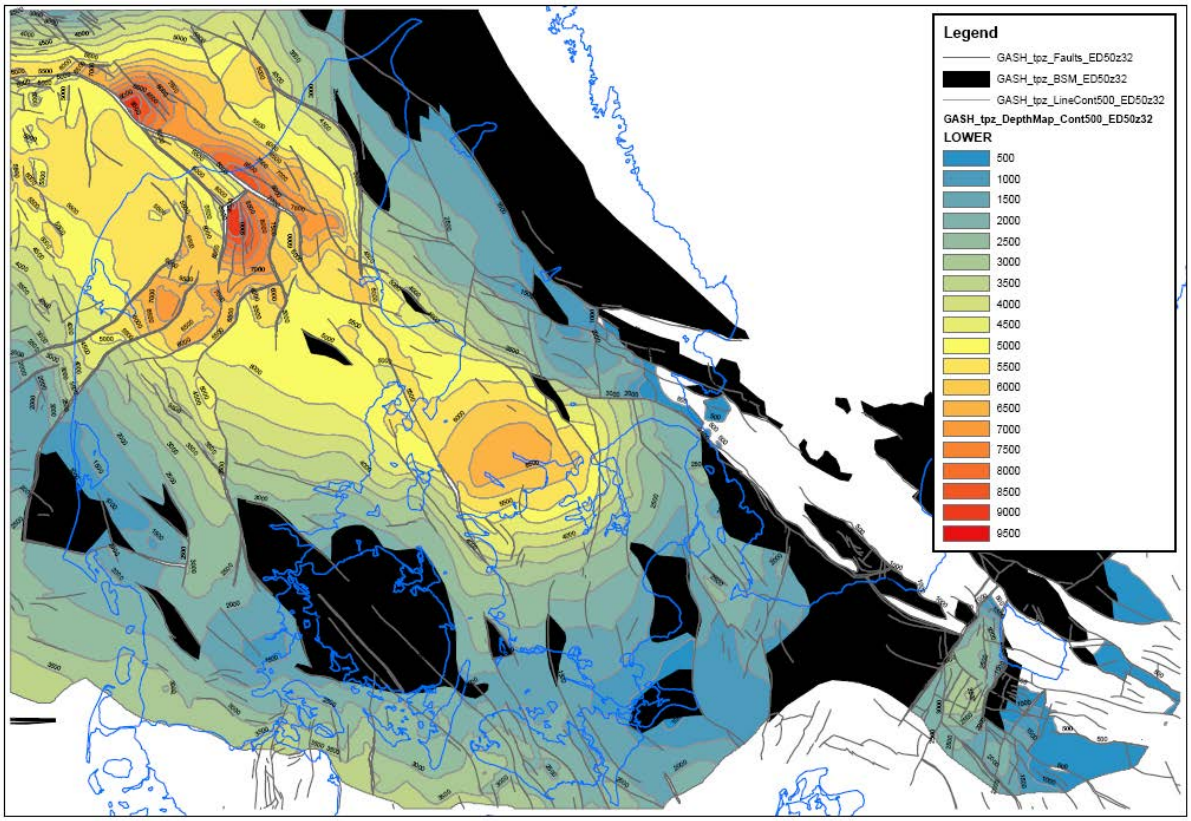


Figure 10. Example of shape file delivered to the EBSD: Depth structure map of the top pre-Zechstein surface.

3. Status for the EBSD data request 2

Delivered pr 31/12 2011:

Digital version of the Skelbro-2 well-logs
Depth plot for GR and NEUT in Slagelse-1 well (no sonic recorded) as pdf (source Michelsen & Nielsen 1991)
Depth plot for GR and sonic for the Terne-1 well as pdf (source Michelsen & Nielsen 1991)

Interpretation of the deep seismic reflectance lines (in TWT):

Seismic line DNJ-400
Seismic line DCS-71
Seismic line 72/001
Seismic line Hgs001

The interpreted horizons include: Base Upper Cretaceous, Top Jurassic, Mid-Cimmerian Unconformity (MCU), Top Gassum, Top Bunter, Top Zechstein, Top Pre-Zechstein and Top basement (Figure 11). The legend for the interpreted horizons on the seismic profiles is shown in Figure 11.

The interpretation of the seismic profiles is provided in the following formats:
1) high resolution vector map in postscripts (.ps) format
2) cgm file version
3) low resolution (downscaled to 150 dpi) in pdf format
4) low resolution (downscaled to 150 dpi) in jpg format

Interpretations are located in the directory: ‘Second data delivery/seismic profiles/’.

The following name code for the files has been used:

[line_name]_tolkning:	Contains only the interpretation
[line_name]_blank:	Contains only the seismic line
[line_name]_tolket:	Contains both the interpretation and the seismic line

Raw data for the interpretation is provided as exported horizons from the GEUS Landmark system. Coordinates are UTM Zone 31, ED50 and depth (z) is in TWT. The data is located in the directory: ‘Second data delivery/raw data on the interpreted horizons’

A position file for the seismic lines is located in the directory: ‘Second data delivery/Position of lines’.

All data is included in the folder ‘Second data delivery’ on the attached CD.

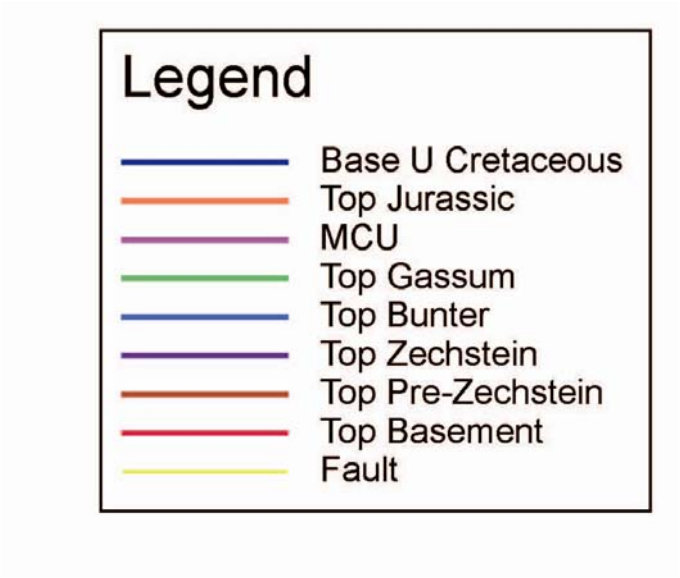


Figure 11. Legend for the seismic interpretation.

3.1. Seismic line DNJ-400

Location:

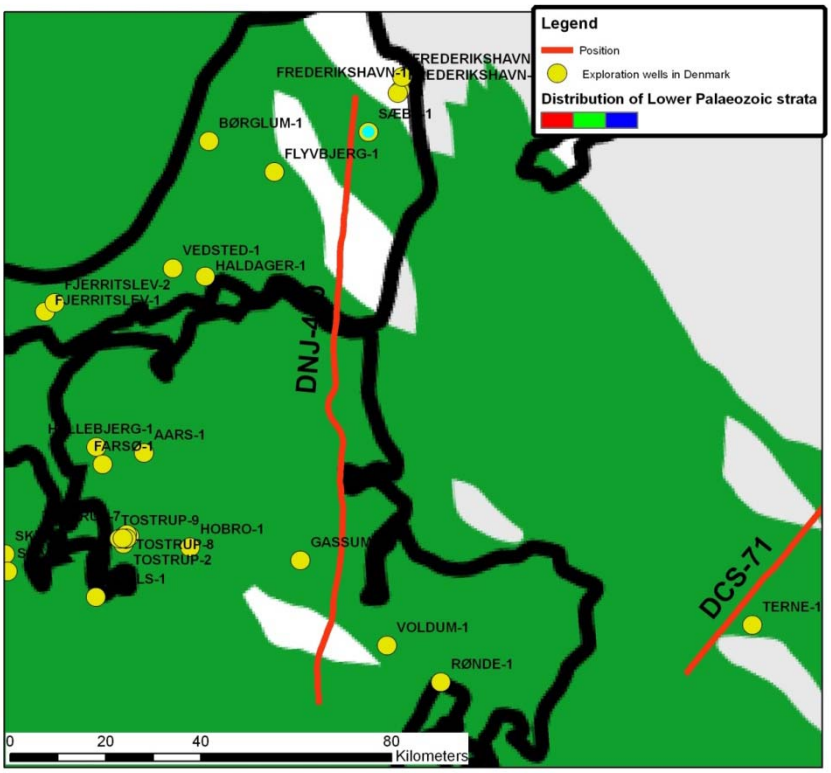


Figure 12. Location of the deep reflection line DNJ-400 in northern Jutland. The line is 131.6 km long and was recorded in 1983. Well control for the Palaeozoic interval is provided by the Sæby-1 well (highlighted with light blue colour). Yellow circles represent exploration wells and the distribution of the Lower Palaeozoic strata is shown with green (Nielsen & Schovsbo 2011). For a larger view of the map see Figure 1.

Well control:

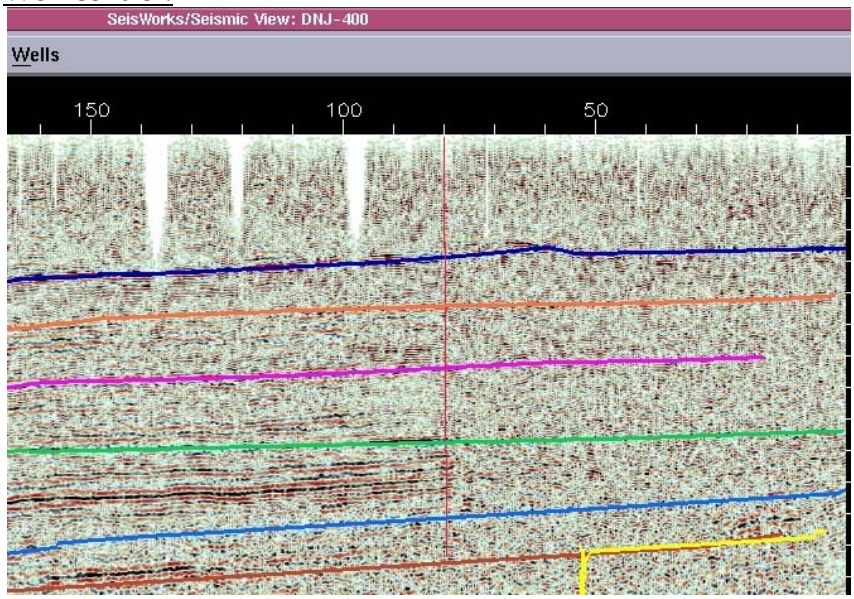


Figure 13. Projected position of the Sæby-1 well onto the line (vertical red line at pos. 80).

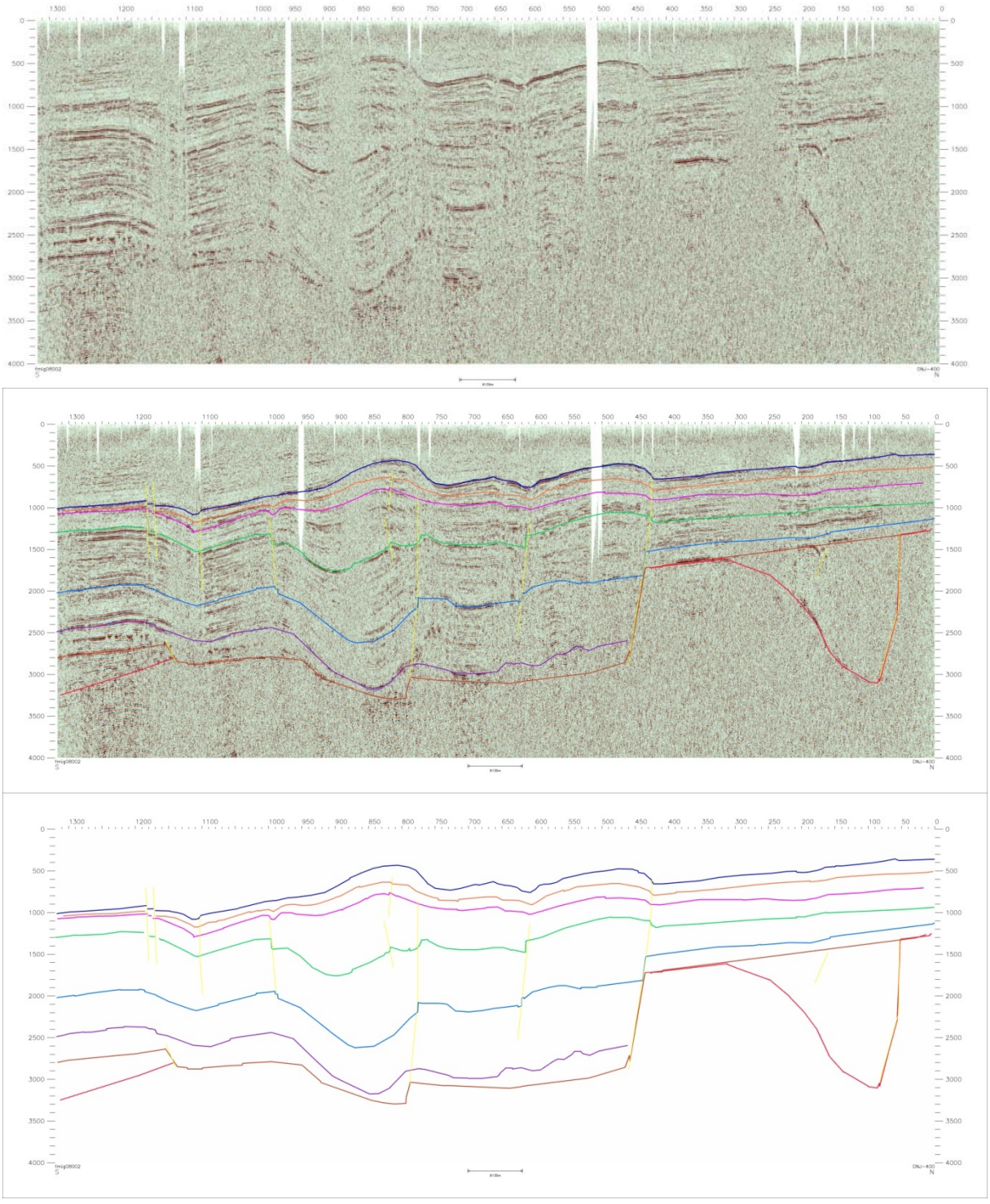


Figure 14. Data delivery for the line DNJ 400. For legend see Figure 11.

Interpretation:

Interpretation of the DNJ-400 line has previously been presented by Mogensen & Korstgård (2003). Their interpretation is shown in Figure 15. According to Mogensen & Korstgård (2003) the line show fault rotated blocks each containing a lower Palaeozoic sequence.

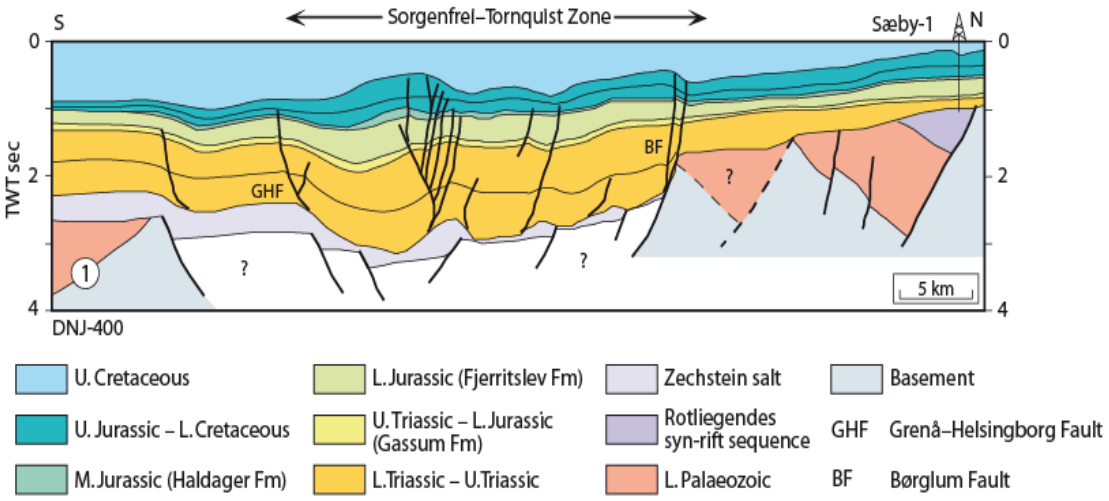


Figure 15. Interpretation of the line DNJ-400 by Mogensen & Korstgård (2003).

3.2. Seismic line DCS-71

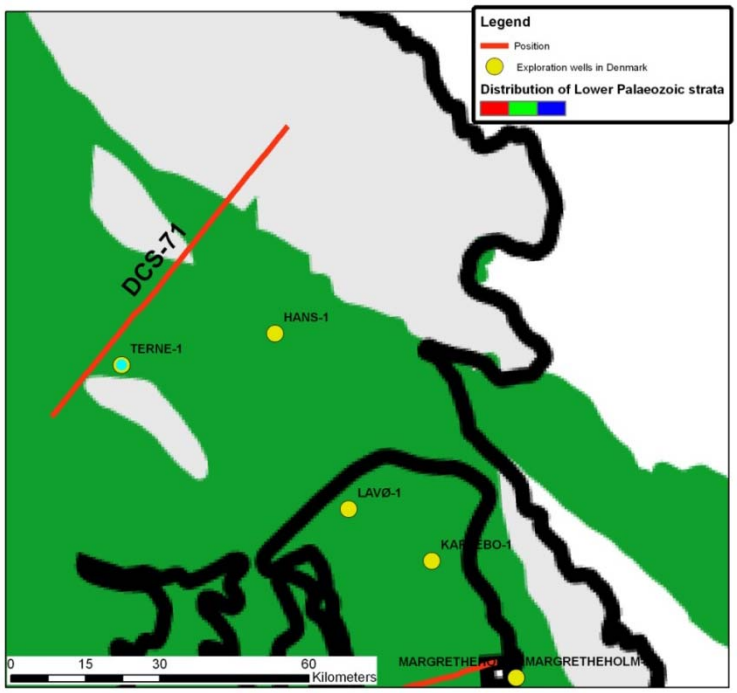


Figure 16. Location of the deep reflection line DCS-71 in the Kattegat area. The line is 75.4 km long and was recorded in 1982. Well control is provided by the Terne-1 well (highlighted with light blue colour). Yellow circles are exploration wells and the distribution of the Lower Palaeozoic strata is shown with green (Nielsen & Schovsbo 2011). For a larger view of the map see Figure 1.

Well control:

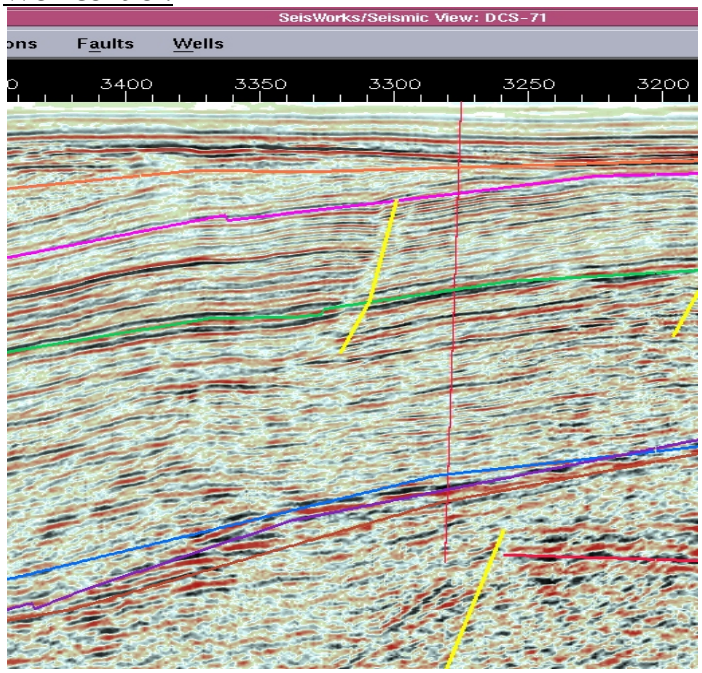


Figure 17. Projection of the Terne-1 well onto the line DCS-71 (vertical red line at pos. 3275).

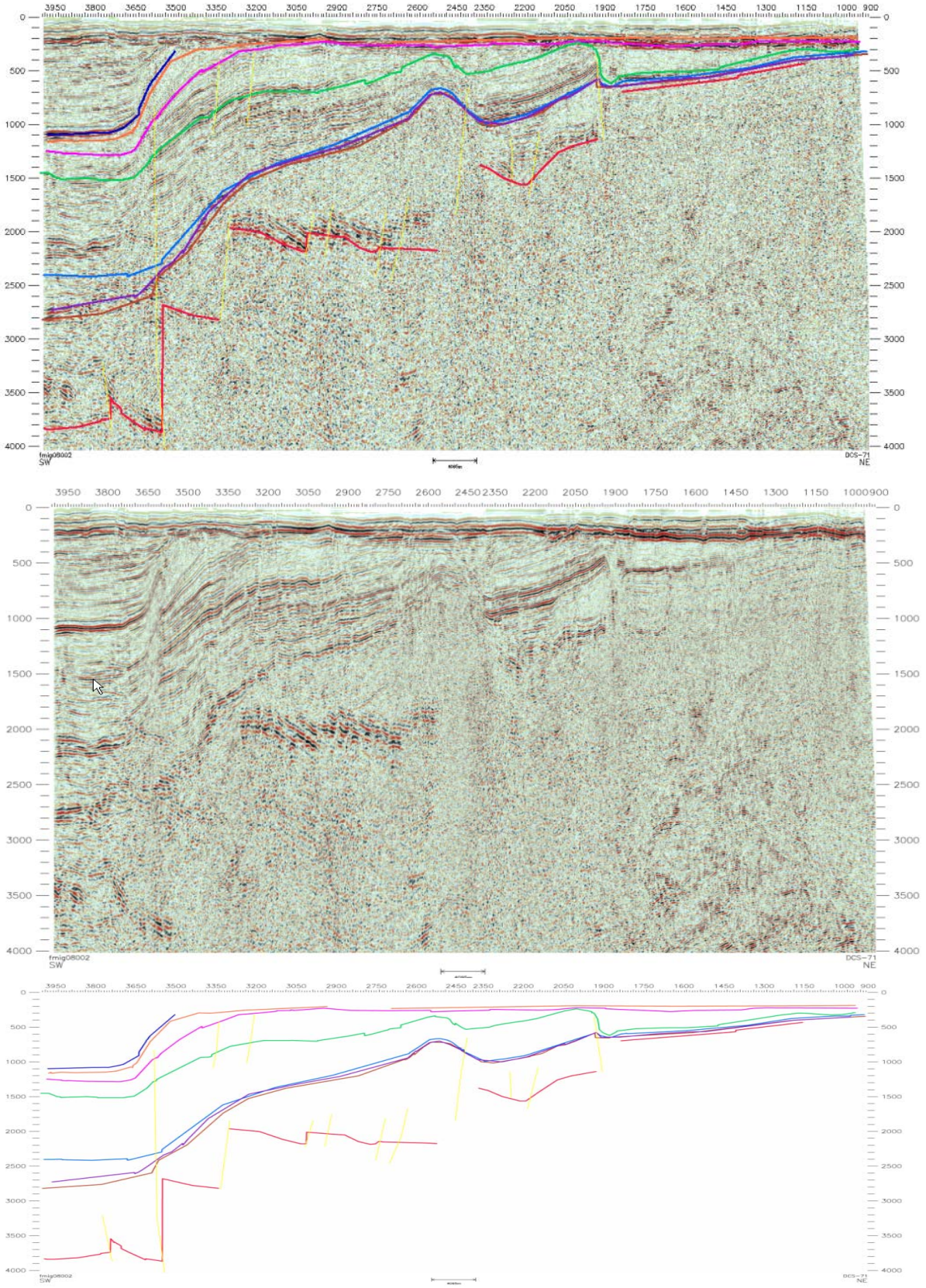


Figure 18. Data delivery for the line DCS-71. For legend see Figure 11.

Interpretation:

Interpretation of the DCS-71 line has not previous been published. Interpretations of lines in the area of the DCS-71 are shown in Figure 19.

In this part of the Sorgenfrei-Tornquist Zone internal structures in the Palaeozoic package can be seen and there is a discordant relationship between the Lower and Upper Palaeozoic sequences. Thickness of the Palaeozoic sequence is about 1.5 TWT corresponds roughly to 3 km.

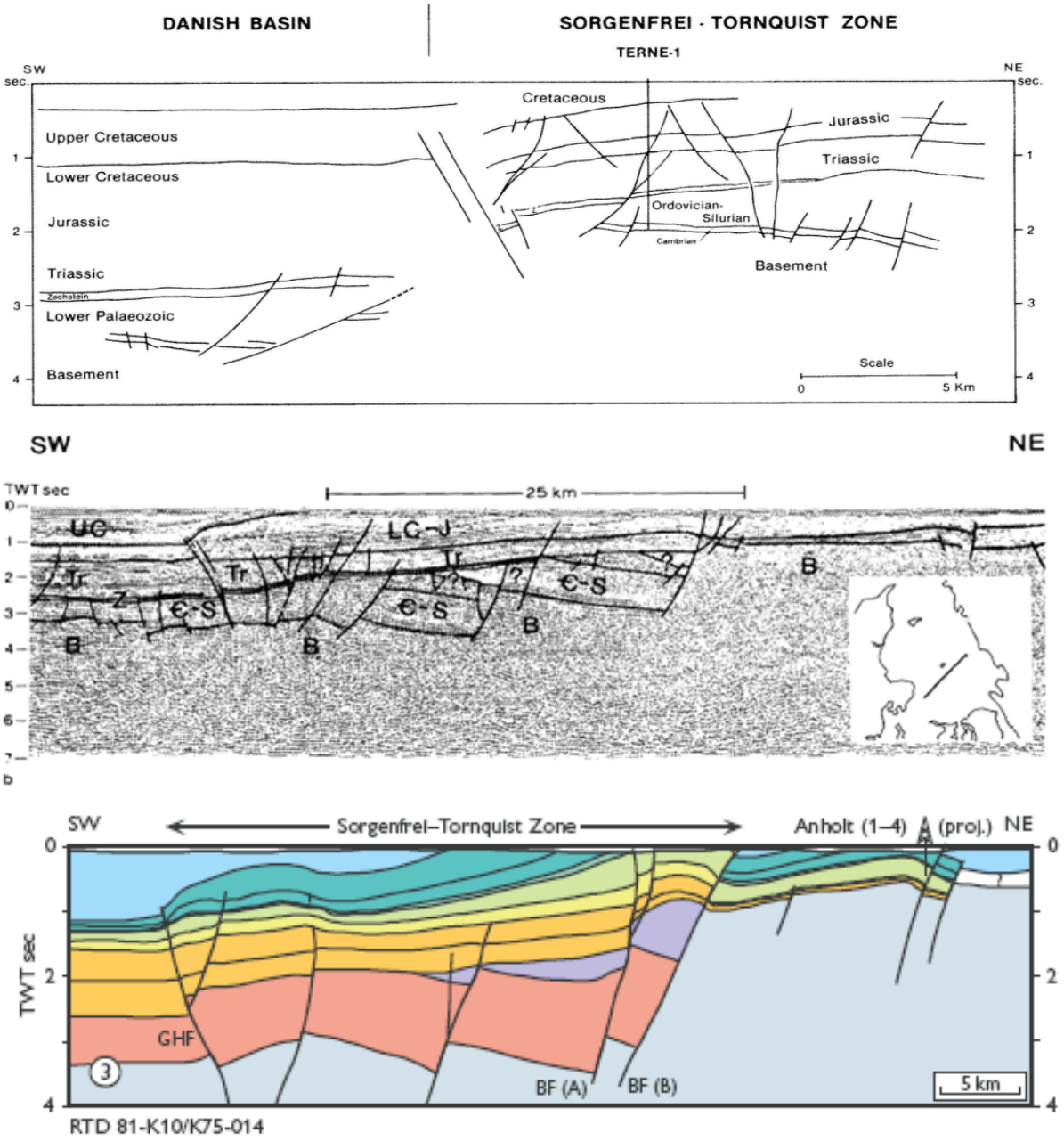


Figure 19. Interpretation of three different seismic lines in Kattegat. Top panel: the line ADK84 177/117A interpreted by Michelsen & Nielsen (1991). Middle panel: an unidentified line presented by EUGENO-S Working Group (1988). Lower panel: the lines RTD 81-K10/K75-014 interpreted by Mogensen & Korstgård (2003).

3.3. Seismic line 72/001

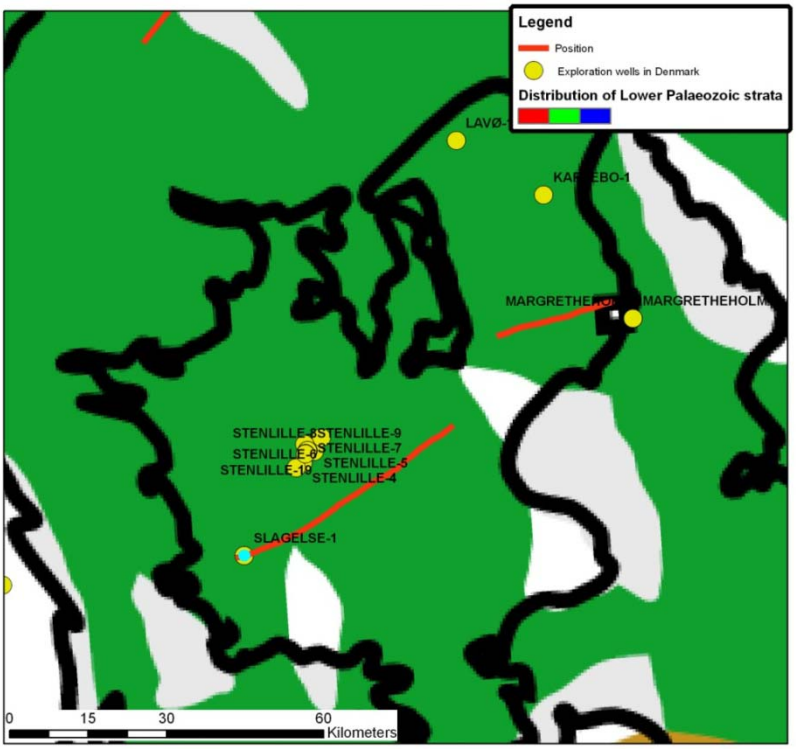


Figure 20. Location of the deep reflection line 72/001 in SW part of Zealand. The line is 49.1 km long and was recorded in 1972. Well control is from the Slagelse-1 well (highlighted with light blue colour). Yellow circles are exploration wells and the distribution of the Lower Palaeozoic strata is shown with green (Nielsen & Schovsbo 2011). For a larger view of the map see Figure 1.

Well control:

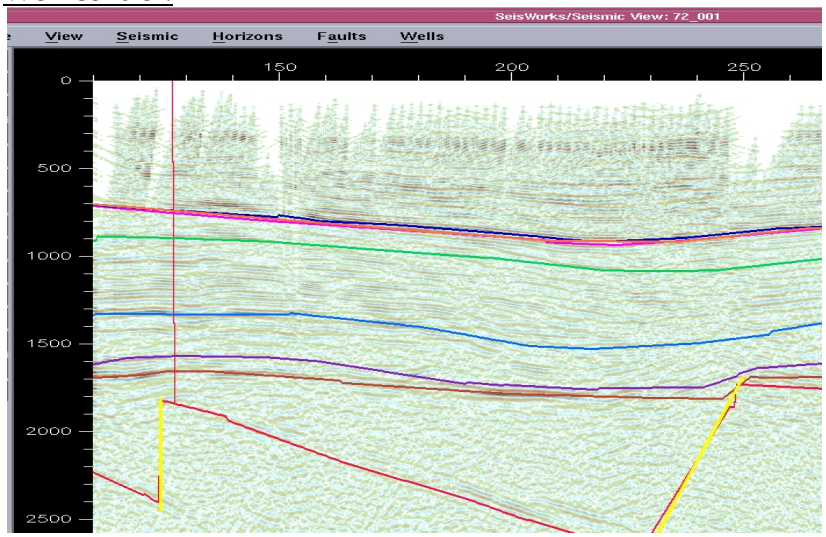


Figure 21. Position of the Slagelse-1 well on line 72-001. The position of the well is indicated with a vertical red line at position 128..

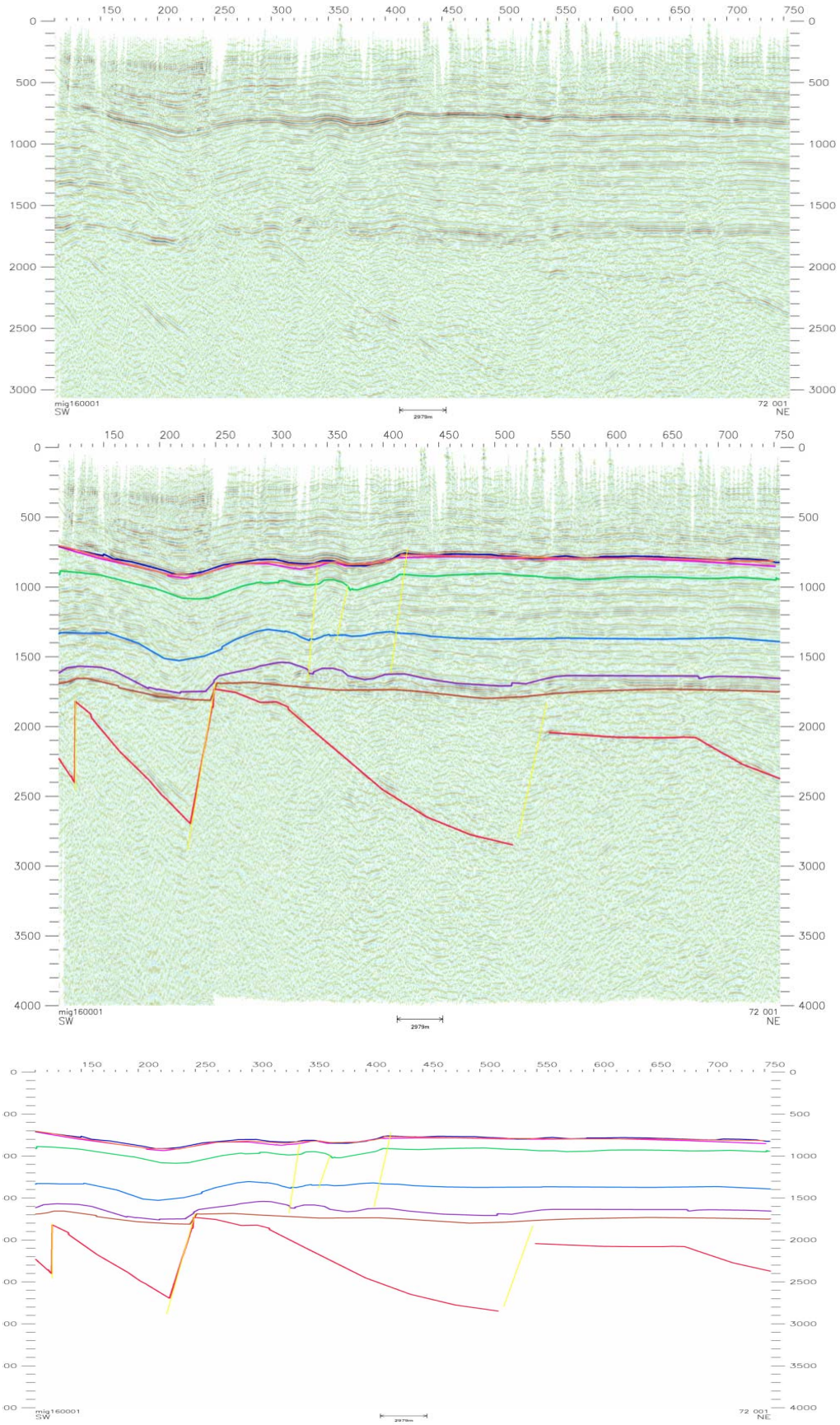


Figure 22. Data delivery for the line 72/001. For legend see Figure 11.

Interpretation:
Interpretation of the 72/001 line has not been published. The profile shows 4 fault blocks with presumed Lower Palaeozoic sediments.

3.4. Seismic line Hgs001

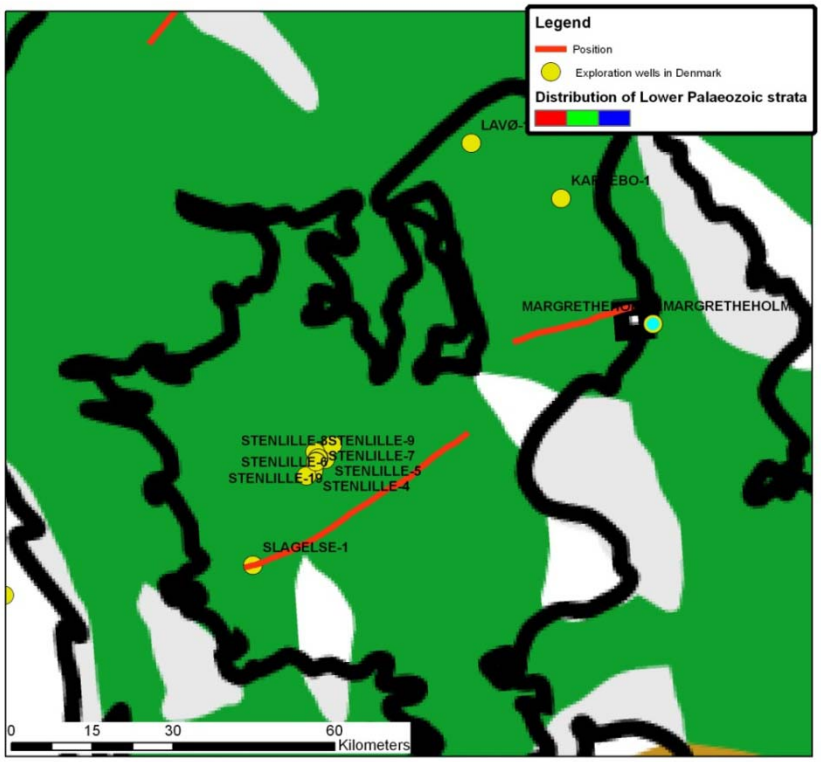


Figure 23. Location of the deep reflection line HGS001 in NE part of Zealand. The line is 23.6 km long and was recorded in 2000. Well control is from the Margreteholm-1 well (highlighted with light blue colour). Yellow circles are exploration wells and the distribution of the Lower Palaeozoic strata is shown with green (Nielsen & Schovsbo 2011). For a larger view of the map see Figure 1.

Well control:

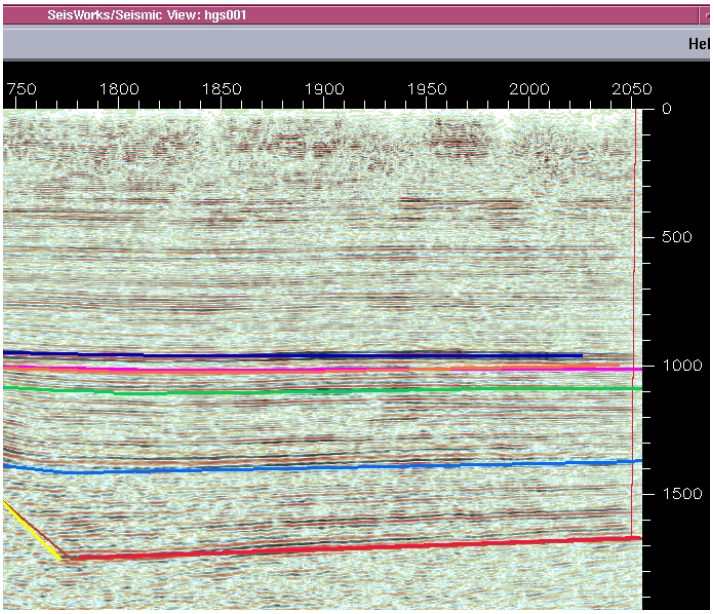


Figure 24. Projection of the Margreteholm-1 well onto the line HGS001. The position of the projected well is indicated with a vertical red line at position 2050.

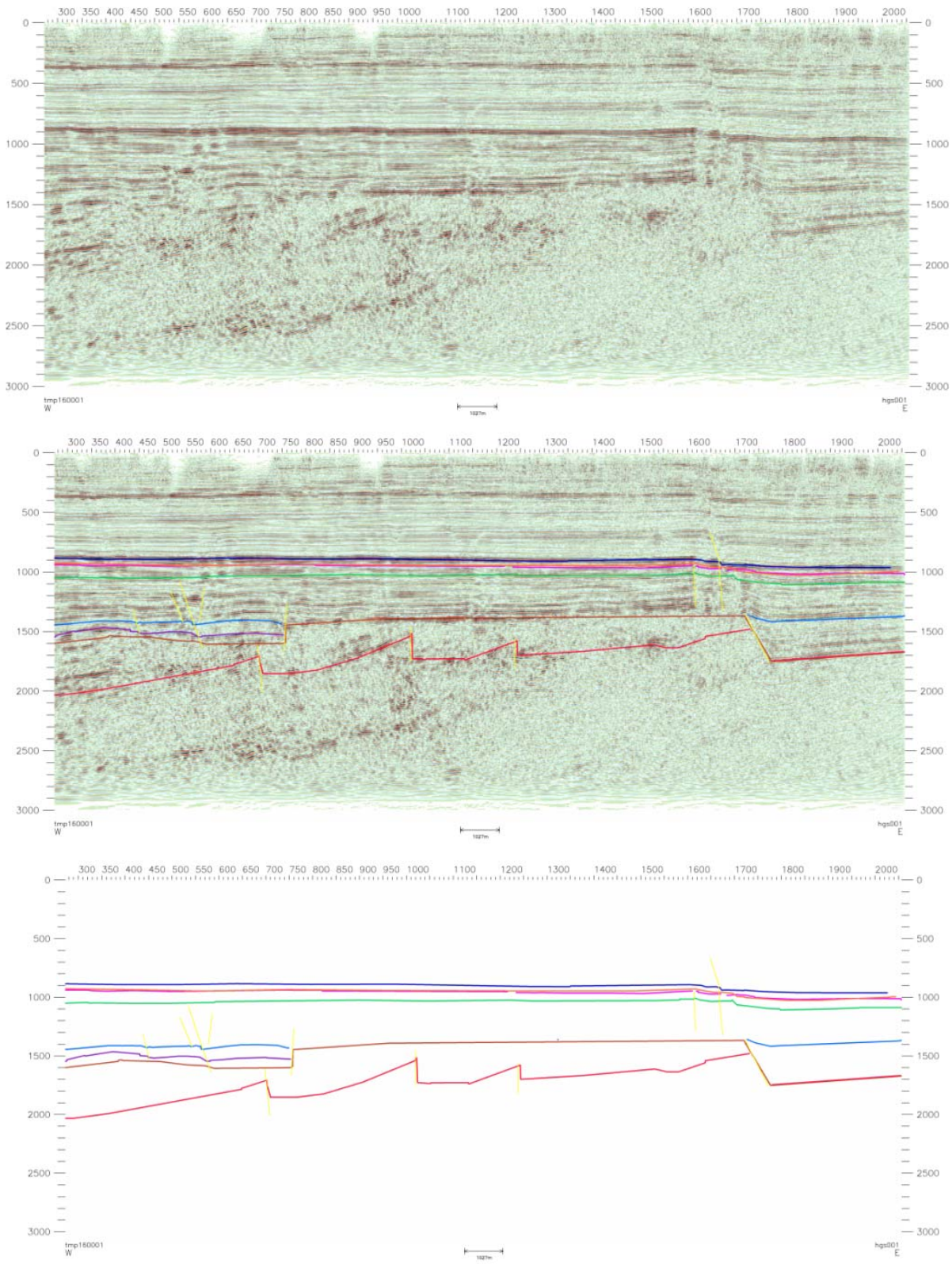


Figure 25. Data delivery for the line HGS001. For legend see Figure 11.

Interpretation:
Interpretation of the HGS001 line has not been published. The line show 4 fault blocks with presumed Lower Palaeozoic sediments.

3.5. Well logs

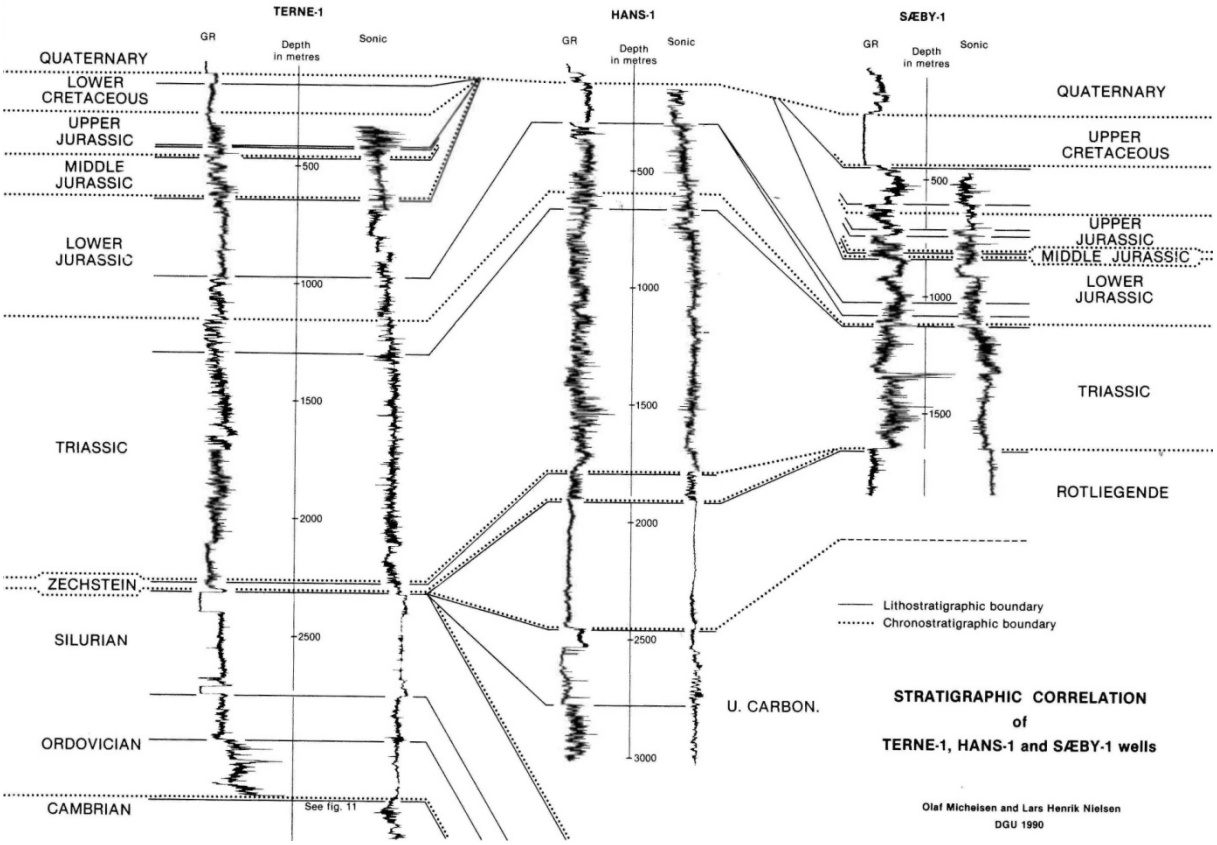


Figure 26. Well correlation profile between Terne-1, Hans-1 and Sæby-1 wells. From Michelsen & Nielsen (1991).

Only two exploration wells penetrate the Alum Shale in Denmark; the Terne-1 well located in Kattegat (near line DCS-71 on Figure 16) and the Slagelse-1 well located on the Zealand (on line 72/001 on Figure 20). Beside this, the Alum Shale in Denmark is known from the island of Bornholm where it has been drilled by several wells including the Skelbro-2 well (Figure 4).

Correlation between the wells has been presented by Michelsen & Nielsen (1991) (Figure 27).

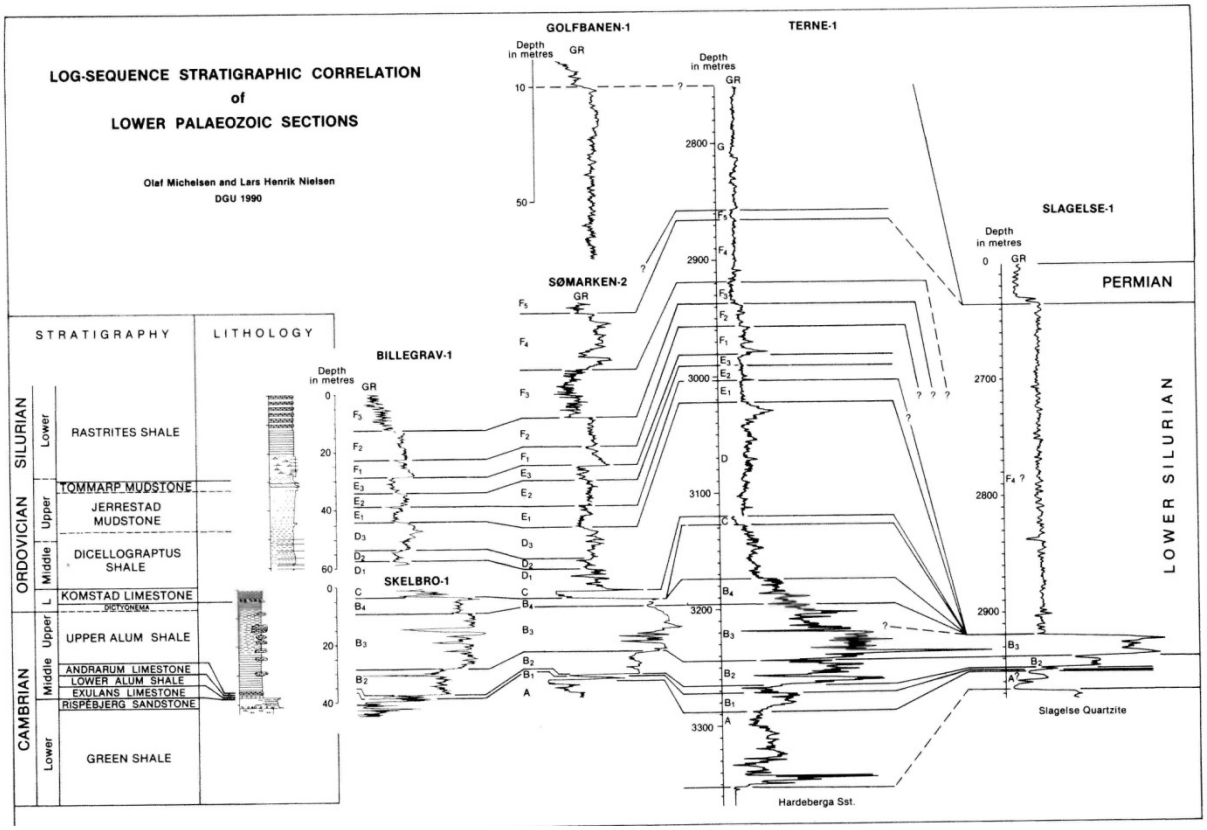


Figure 27. Example of well log correlation between Terne-1, Slagelse-1 and the scientific wells Billegrav-1 and Skelbro-1 on Bornholm. From Michelsen & Nielsen (1991).

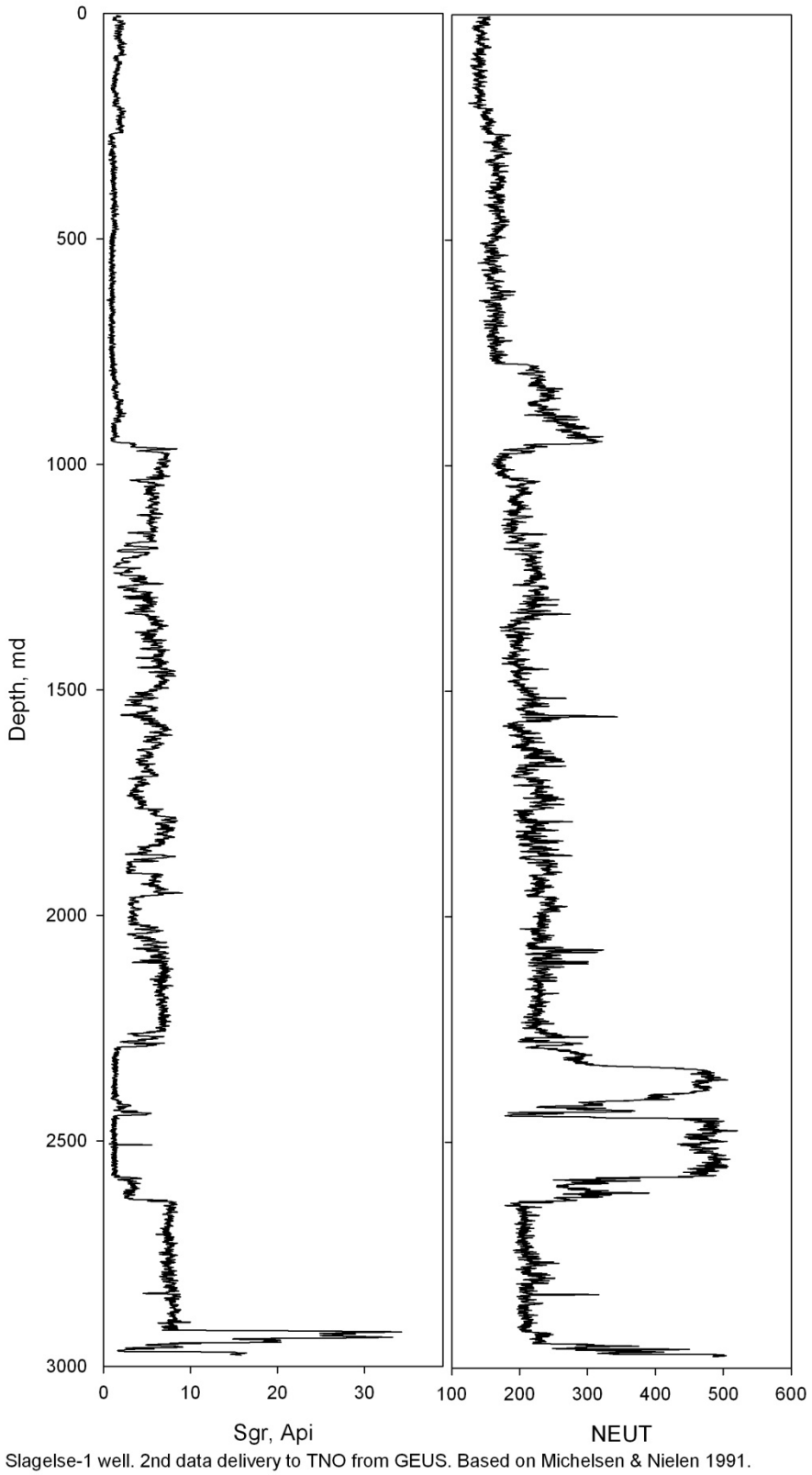


Figure 28. Well log from the Slagelse-1 well.

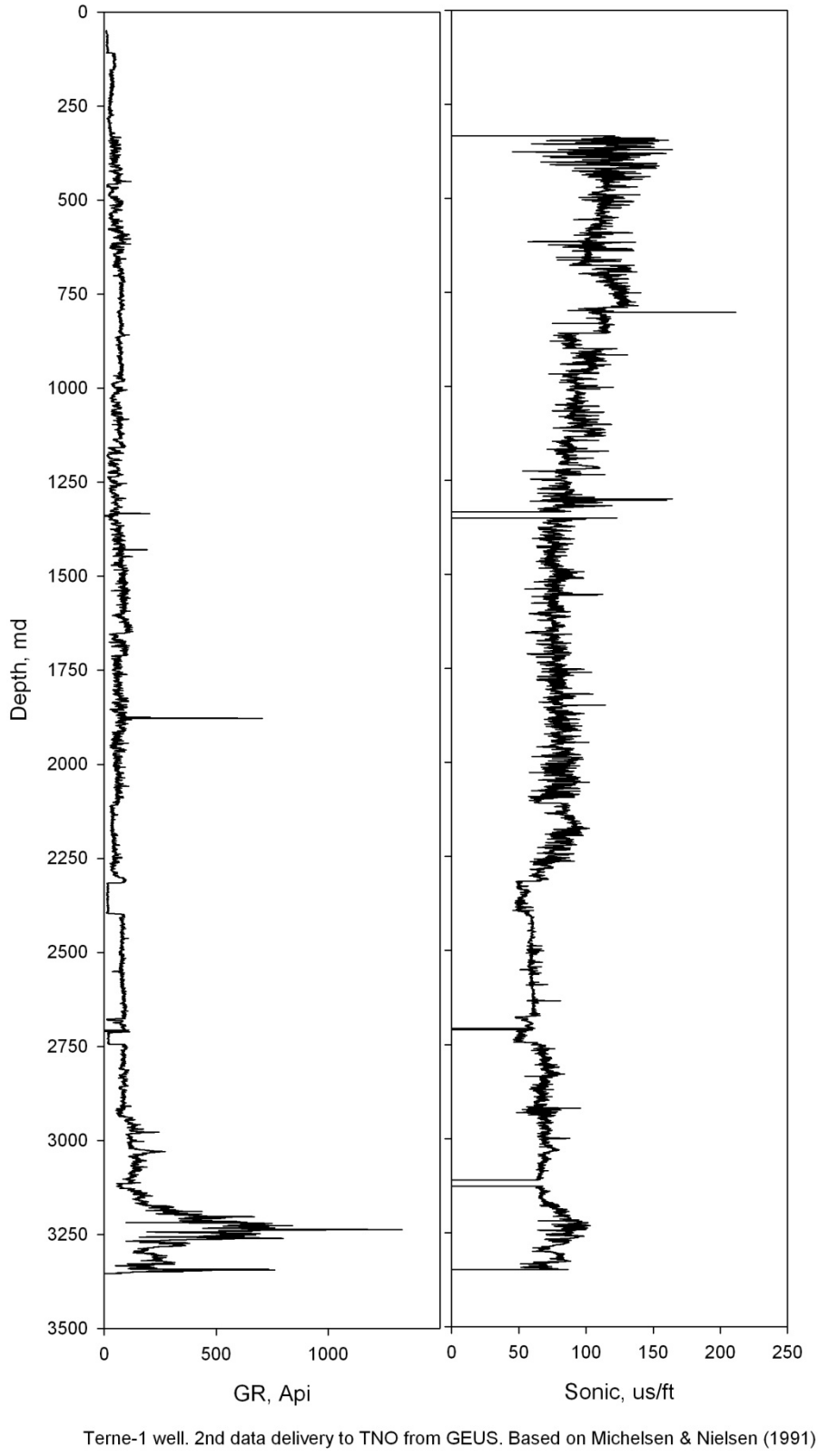


Figure 29. Well log from the Terne-1 well.

4. References

EUGENO-S Working Group, Crustal structure and tectonic evolution European of the transition between the Baltic Shield and the North German Caledonides (the EUGENO-S Project), Tectonophysics, Volume 150, Issue 3, 1 August 1988, Pages 253-348. (http://www.sciencedirect.com/science/article/pii/004019518890073X)

Michelsen, O., Nielsen, L.H., 1991. Well records on the Phanerozoic stratigraphy in the Fennoscandian Border Zone, Denmark: Sæby-1, Hans-1 and Terne-1 wells. Danmarks Geologiske Undersøgelse Serie A29, 1–37.

Mogensen, T.E., Korstgård, J.A., 2003. Triassic and Jurassic transtension along part of the Sorgenfrei-Tornquist Zone, in the Danish Kattegat. In Ineson, J.R, Surlyk, F. (eds): The Jurassic of Denmark and Greenland. Geological Survey of Denmark and Greenland Bulletin 1, 439–458.

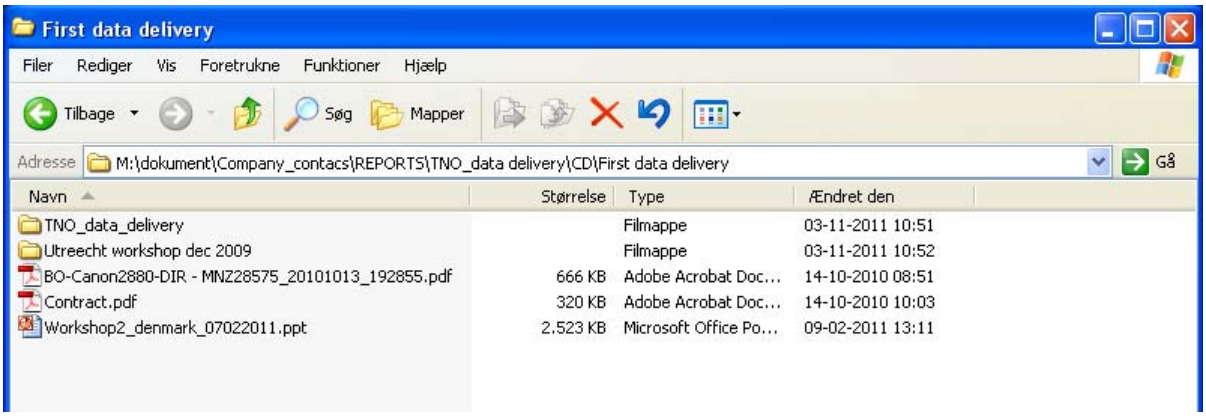
Nielsen, A.T., Schovsbo, N.H., 2011. The Lower Cambrian of Scandinavia: Depositional environment, sequence stratigraphy and palaeogeography. Earth Science Reviews 107, 207-310.

5. Data included on CD

Attached to this report is a CD that contains the following documentation:

1. Folder termed 'First data delivery' contain all data delivered

Subfolders include: 'TNO_data_Delivery'; 'Utreecht workshop dec 2009'.



2. Folder termed 'Second data delivery' contains all data delivered.

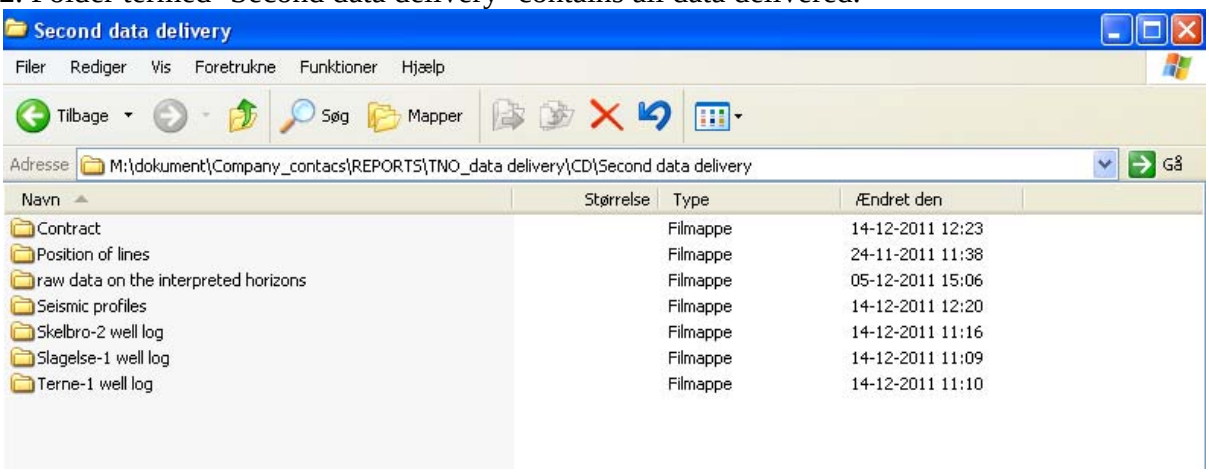


Figure 30. Top: Screen dump showing content of the directory ' First data delivery'. Base: screen dump showing content of the directory: 'Second data delivery'.

The interpretation of the seismic profiles is provided in these formats:

1) high resolution vector map in postscripts (.ps) format
2) cgm file version
3) low resolution (downscaled to 150 dpi) in pdf format
4) low resolution (downscaled to 150 dpi) in jpg format

Interpretations are located in the directory: ‘Second data delivery/seismic profiles/’.

The following name code for the files has been used:

[line_name]_tolkning:	Contains only the interpretation
[line_name]_blank:	Contains only the seismic line
[line_name]_tolket:	Contains both the interpretation and the seismic line

Raw data for the interpretation is provided as exported horizons from the GEUS Landmark system. Coordinates are UTM Zone 31, ED50 and depth (z) is in TWT. The data is located in the directory: ‘Second data delivery/raw data on the interpreted horizons’

Position file of the seismic lines is located in the directory: ‘Second data delivery/Position of lines’.