

Fehmarnbelt Fixed Link

Geophysical investigations in the Fehmarnbelt area for archaeological purposes

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF CLIMATE AND ENERGY



G E U S

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Client: DHI Water • Environment • Health

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Introduction

This project was conducted under a contract with DHI Water, Environment, Health. It is part of a larger project for investigating the area where the proposed bridge is to be constructed. The bridge will link Denmark (Rødbyhavn) with Germany (Puttgarden in Fehmarn Island), Fig.(1).

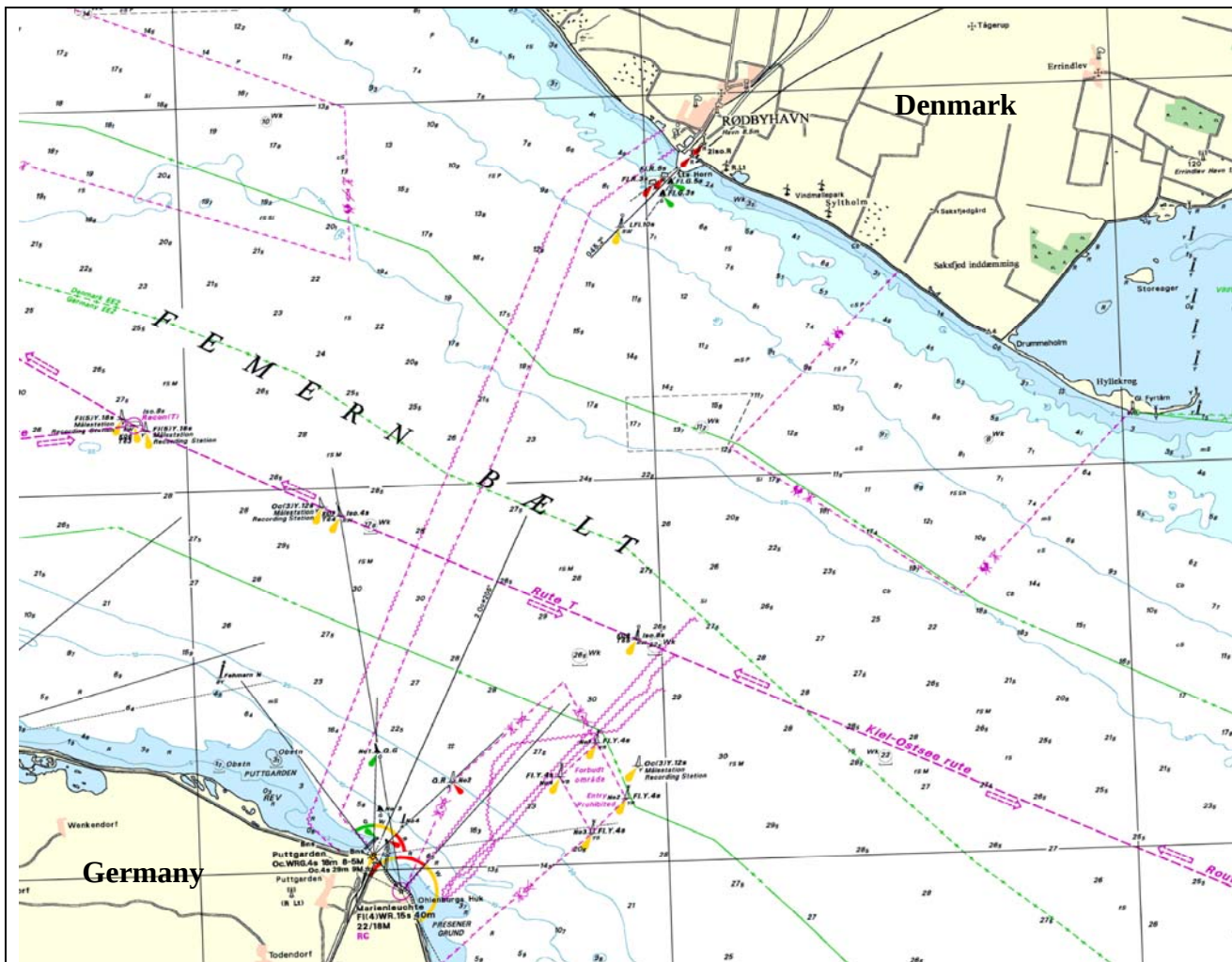


Figure 1. The Femern Bælt project geographic location.

GEUS has been contracted to perform several types of geological and geophysical investigations in the Femern Bælt project. This report will present the results of the geophysical survey and processing that will be used by the marine archaeologists in the Vikingskibsmuseet and the Landesamt S-H to locate historically significant objects as well as drowned coastlines that can help in identifying submerged stone age settlements in the area.

The report includes the survey procedure, the instruments used in the survey, the processing, the results and their interpretation. It's a common procedure in marine archaeology projects that a discussion is to be held between GEUS and the marine archaeologists after the first draft of the results has been submitted. Raw data for the most prominent sites can be presented on the screen and elaborated; this will help the archaeologists to decide on the positions that look promising and require further investigations.

Some examples of the magnetic anomalies profiles are given in the appendices together with their corresponding sidescan images. All results are included in the DVD that accompanies this report.

Planning

Two main regions have been investigated in this project, the Danish side (offshore Rødby harbour) and the German side (offshore Puttgarden harbour). The required survey areas are ~ 5-6km of coastline from 6m depth contour up to shoreline. The survey area for both the Danish and the German sides is shown in Fig. (2).

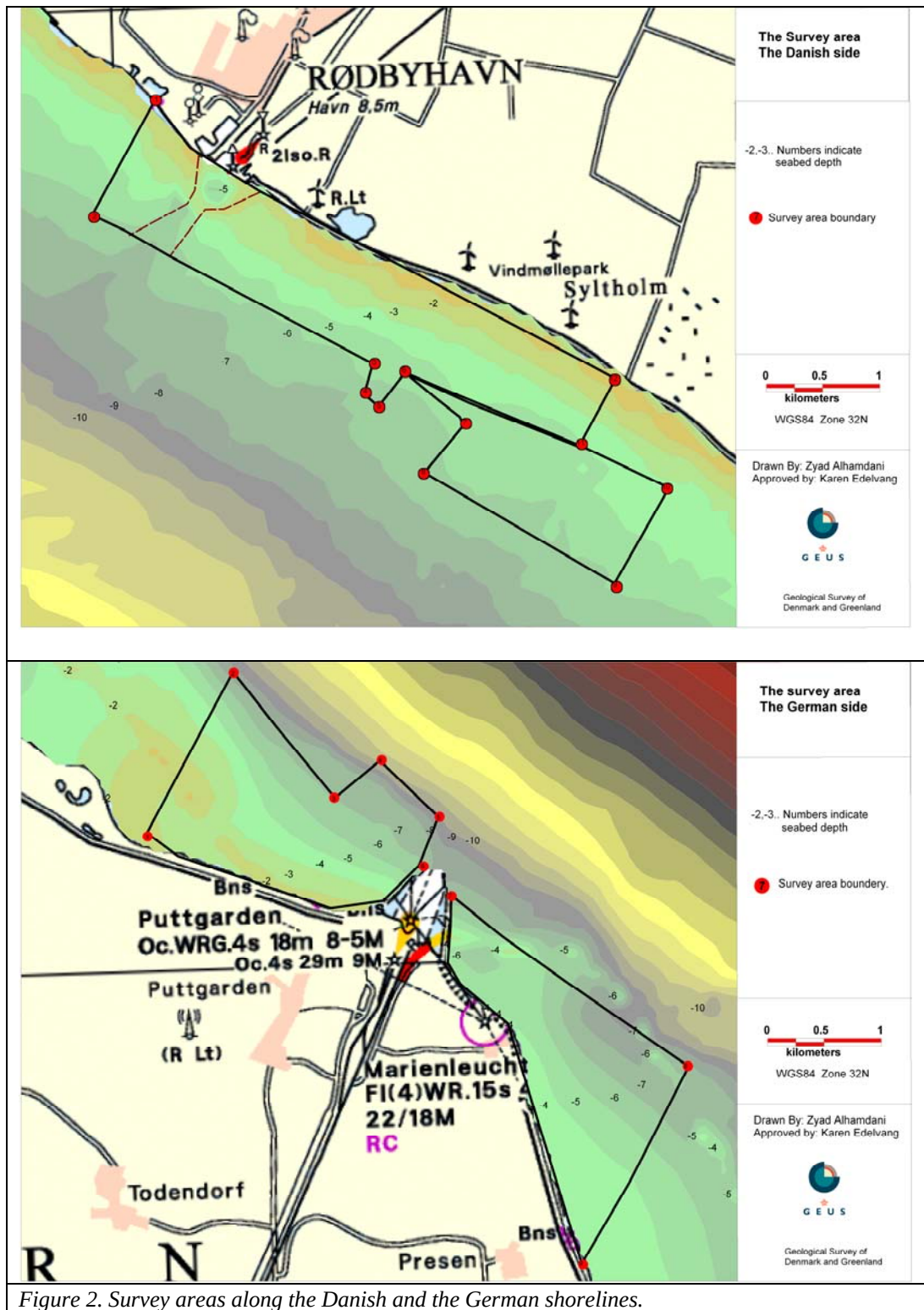


Figure 2. Survey areas along the Danish and the German shorelines.

To fulfil the archaeological requirements, two types of remote sensing instruments were used in the survey, the magnetometer and the Chirp sub-bottom/sidescan system.

The results of these two instruments can be used to identify big metal objects from ship wrecks and to visually scan the seabed for any interesting feature as well as mapping the near seabed layers.

The survey area coordinates were provided by the client and were plotted in the GIS software (MapInfo) together with a digitised sea-chart map in order to see the survey areas boundaries and extent as well as the bathymetry of the areas which is useful for survey lines planning.

The field work

The actual field work operation for this project started at the 25th April 2009 and lasted until the 4th May 2009. The survey party from GEUS was: Ziyad Alhamdani (Senior researcher), Peter Rasmussen (Senior researcher) and Lars Rödel (Senior surveyor).

The survey ship

The ship that was used as a platform for conducting the geophysical survey is Føniks Miljø, Fig. (3), this ship has been used by GEUS in previous projects conducting similar surveys in the Danish inner waters. The ship has the following specifications:

Ship name	Føniks Miljø
Owner	Føniks A/S
Size	Length, 18m. Width, 4m.
Max Draft	1.8m.
Crane	1200kg/m
Speed	11knots
Machine	Detroit (GM) Marine Diesel and 2 Skania support machines (2x22kW).
Crew	2

The ship was mobilised in Copenhagen and Rødby harbours where the primary test was conducted to insure all systems readability. The ship sailed then to Rødbyhavn where *in situ* tests were performed on the geophysical systems as well as the navigation systems. The electrical connections were tested and the current stability was investigated.



Figure 3. The survey ship Føniks Miljø.

The instruments and acquisition software

A suite of instruments were deployed on board Føniks Miljø:

1. The G882 magnetometer.
2. The SIS-1620 sidescan/sub-bottom profiler.
3. The DC202 Adnav positioning system.
4. The Navipac navigation software.
5. MagLog magnetic logging software.
6. ISIS software for sidescan and sub-bottom profiler data acquisition.

The specification sheet of these instruments is shown in Appendix IV.

The survey

The survey planning was made prior to the survey using the provided coordinates of the survey area and the GIS software. The survey lines were decided to go parallel to the coast line and at 25m spacing between them, to ensure a complete magnetic and sidescan coverage of the survey areas. The sidescan/sub-bottom profiler was attached to the ship crane and positioned at the starboard side of the ship at about 1.5m below water level, Fig. (4A). The penetration depth of the sub-bottom profiler is a function of the operation frequency and seabed sediment type. The sidescan system was

put to 50m swath width for high resolution results; the swath width is a function of depth in shallow waters.

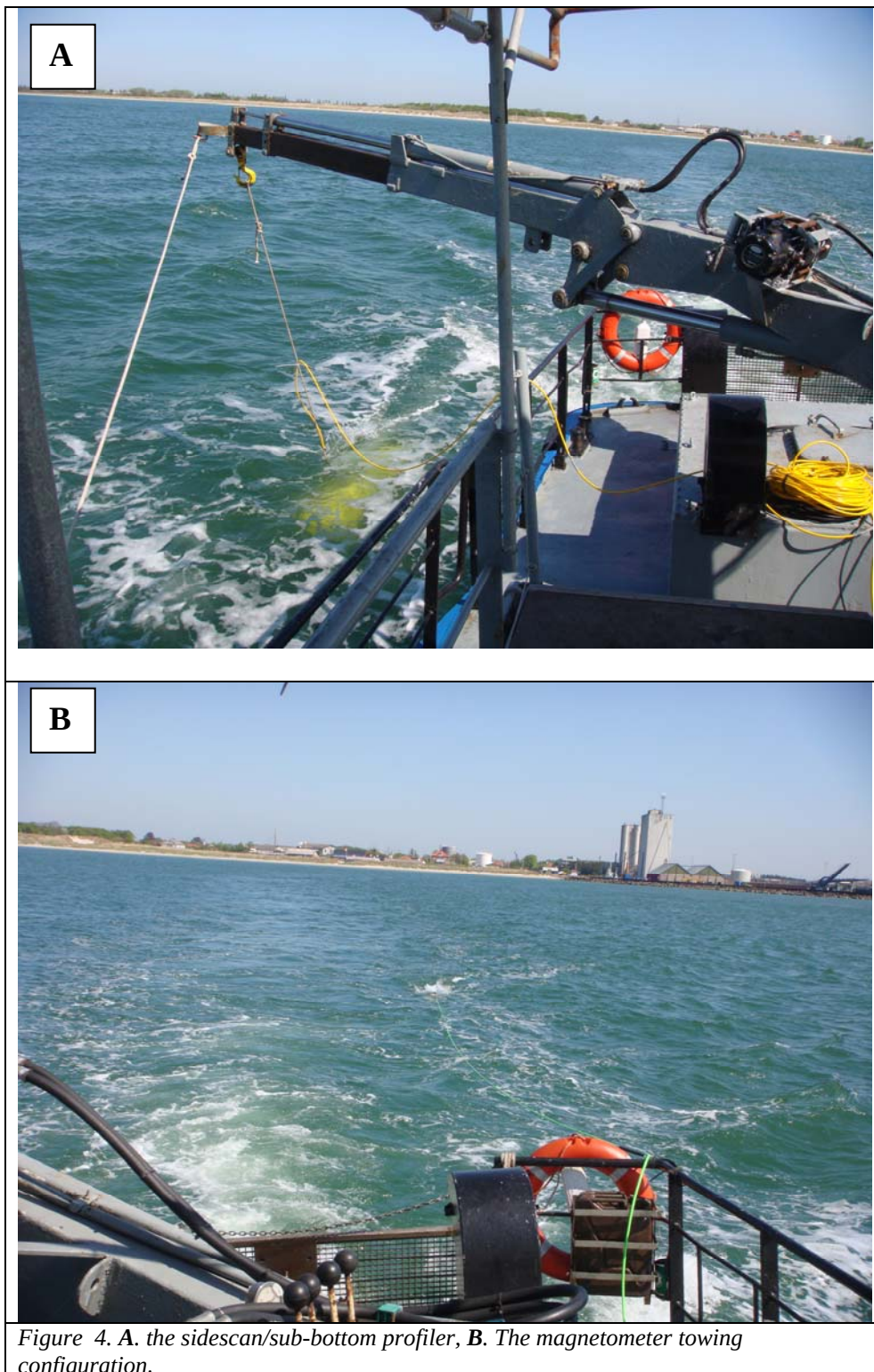


Figure 4. A. the sidescan/sub-bottom profiler, B. The magnetometer towing configuration.

The magnetometer was towed behind the ship at a ~37m distance. A buoy was attached to the towing rope to maintain the fixed height of the magnetometer fish above the seabed. The magnetometer height was ~2m above the seabed. During acquisition, the height of the

magnetometer was continuously checked on screen (which is part of the acquisition program MagLog) and compared to the bathymetry which was also monitored via the ships echo-sounder.

The survey plan was altered after the first day reconnaissance/survey and equipment testing routine, which took place in the Danish side of the survey area. The survey group and the ship crew had encountered a series of fishing nets on poles (bundgarn) along the Danish coast line, Fig. (5).



Figure 5. The fishing net poles along the Danish coast line inside the survey area.

These obstacles prevented the originally planned surveying in parallel lines, therefore all the lines had to be altered and new survey strategy was established.

On the German side, the survey group and the ship crew discovered a lot of large boulders along the coast line, which made it impossible for the ship to sail over them. Therefore, the survey in that area was maintained according to the sailing possibility to cover as much as possible of the survey area without damaging the equipments or the survey vessel.

The two designated survey areas were covered by survey lines and data was stored in two different external discs for further processing. A daily check was made on the acquired sidescan and magnetometer data to ensure its reliability and accuracy.

Data processing and interpretation

To process the acquired geophysical data, the following programs were used in data handling, cleaning, processing and presentation:

- The Triton ISIS program from Triton Imaging, Inc. was utilised for visual sidescan data and sub-bottom profile inspection, for sidescan data processing, mosaicing and the final mosaic export into geotiff format readable by GIS software.
- The Geographix from Landmark. This software was used to process the seismic data obtained from the sub-bottom profiler. The horizon of the top layer surface and its bottom was digitised with this program utility. The resulting dataset was exported as ASCII data files for further processing.
- MagMap2000 from Geometrics Inc. It's post-acquisition software used in this project to check navigation and to transfer the magnetic field data to an XYZ data that can be readily used in the processing software. The program was also used to clean the large spikes in the datasets.
- Oasis montaj software from GeoSoft Inc., this program utilises the data exported from MagMap2000 in data processing. By this software the magnetic data was filtered from high frequency noise that was introduced to the data during acquisition. It was also used to produce the magnetic survey lines profile where magnetic anomalies were picked and plotted. Data quarrying and algebraic calculations were performed using this software. The final processed and cleaned data was then exported as ASCII files for GIS presentation.
- MapInfo from Pitney and Bowes software Inc., it's a GIS program used in this project for data gridding, map algebra and presentation.

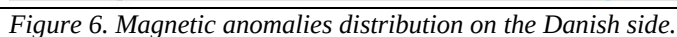
The raw magnetic data was processed and each survey line was inspected visually for prominent magnetic variation. Each magnetic anomaly was registered and its profile was plotted in a separate database. The background magnetic value in the vicinity of that anomaly was also noted and then the residual magnetic anomaly value was calculated and documented in a spread sheet together with the anomaly geographic location and the survey line number and the shape of that anomaly. Different types of filters were applied to the raw data such as low, high or band pass filters to clean the raw magnetic data from all small scale/high frequency spikes and signals that were embedded in the raw data during data acquisition from different sources.

The final spread sheet of the residual magnetic anomalies was imported to the MapInfo GIS program and projected over the map of the survey area. The magnetic anomalies can then be clearly seen together with anomaly values and positions. This visual inspection enables the interpretation of the possible sources of some anomalies as will be shown in the results.

The sidescan data was played back using the ISIS software. The survey lines were visually inspected line by line with both the low and high frequency channels open to look for any peculiar feature on the seabed that might resembles an artefact which could be of archaeological significance like a boat or an anchor...etc. If so the position of this feature was noted and reported to the marine archaeologists for further investigations.

The positions of the magnetic anomalies were visually located on the sidescan playback data of the same survey line; an image of the seabed at the anomaly position is taken and stored in the database.

1. The residual magnetic anomaly distribution for the Danish and German sides is presented in Fig. (6, 7) respectively. Magnetic anomalies above 10nT and below -10nT were drawn in the figures. The overall area surveyed on the Danish and the German sides is characterised by a high level of magnetic values. Over 90 anomalies (>10nT) were located in the Danish side and 160 anomalies were located on the German side.



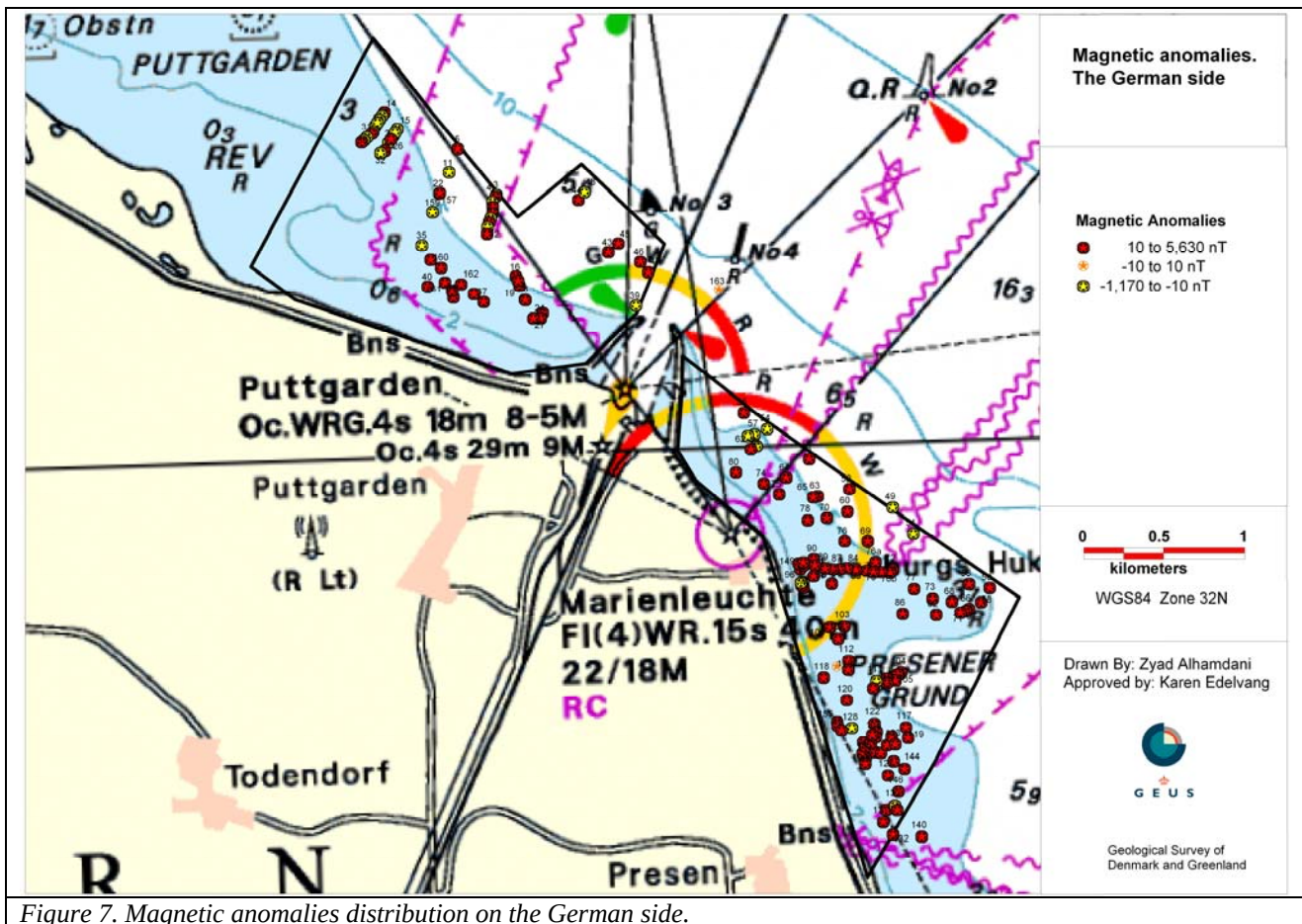


Figure 7. Magnetic anomalies distribution on the German side.

The amplitude and shape of some anomalies is a typical manifestation of magnetic behaviour over a metal pipe or electric cables. Others are caused by magnetic objects that litter the seabed in the area of investigation.

2. The sidescan images reveal considerable information about the seabed and its constituents. Using a high transmission frequency channel (380kHz) with a very narrow horizontal beam angle enables a detailed scan of the sea bottom and the low grazing angle (angle between the seabed and the acoustic axis) enhance the shadowing effect which in-turn make objects look much clearer. This makes the visual inspection of the sidescan record an interesting and important part of the work in such projects. Because of the dense survey lines (25m spacing) the survey swath of the sidescan instrument was put to 50m and that gives a very high overlap which was exploited to look at different objects from different aspect angles or to compensate for bad signal in one of the channels. Figures (8 & 9) show two examples of the sidescan images, the red box in the figures indicates the exact location of the magnetic anomaly which correspond to that survey line. The images reveal clearly the resolution power of the sidescan survey. An elongated feature is shown in Fig.(8) which could indicate a pipe and an accumulation of aggregates can be noticed in both Fig.8 and Fig.9 which is a clear indication of a seabed full with stones and mixed sediments.

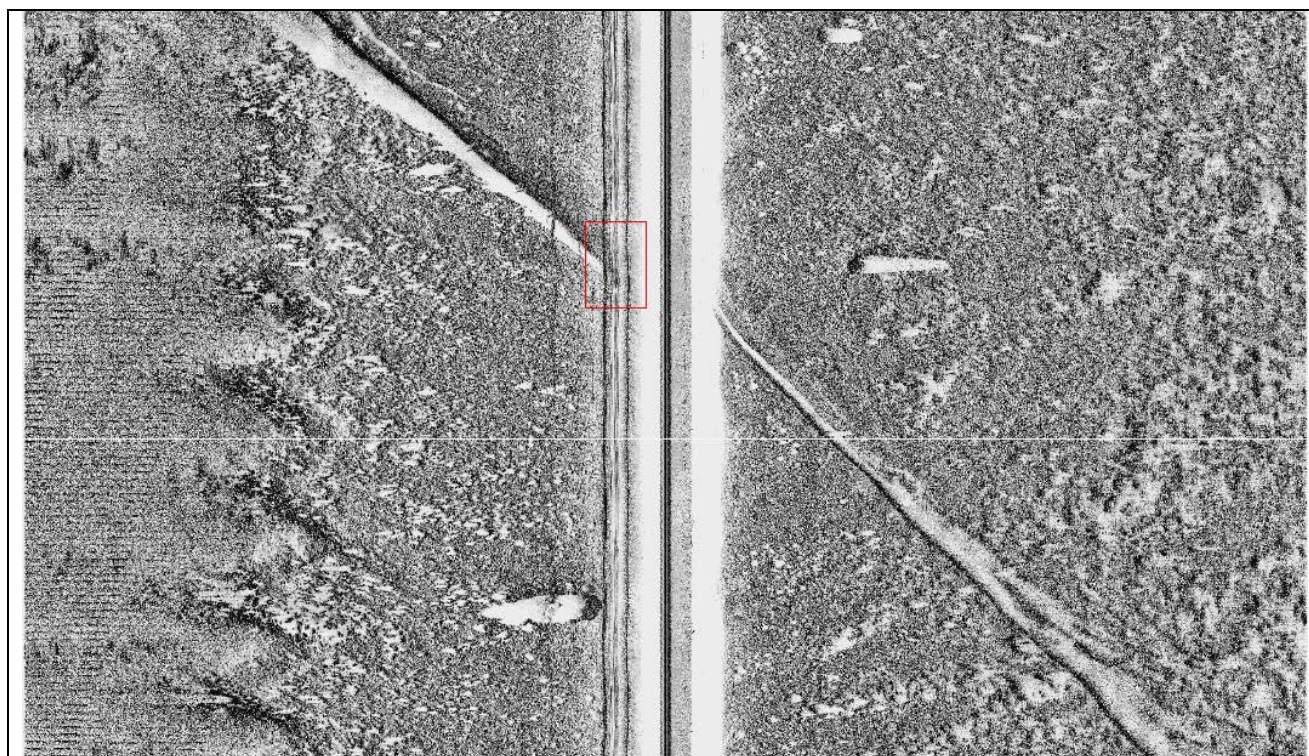


Figure 8. Sidescan image of line GR15E. The red box represents the position of anomaly 79.

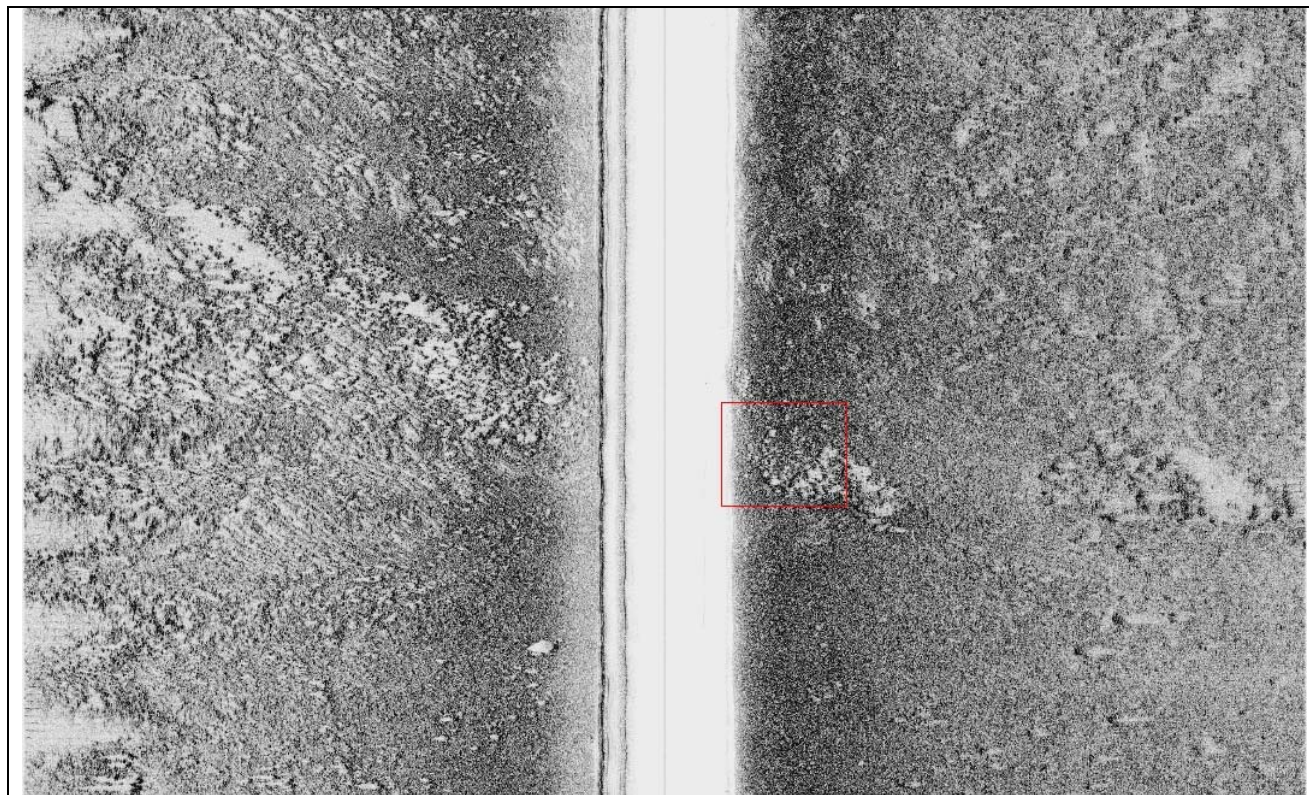


Figure 9. Sidescan image of line DK60. The red box represents the position of anomaly 1.

3. The sub-bottom profiler seismic cross sections show the succession of sediment layers in the seabed. The top layer surface and bottom were manually digitised and an example of the seismic section with and without digitised lines in Geographix software is shown in Fig. (10 & 11).

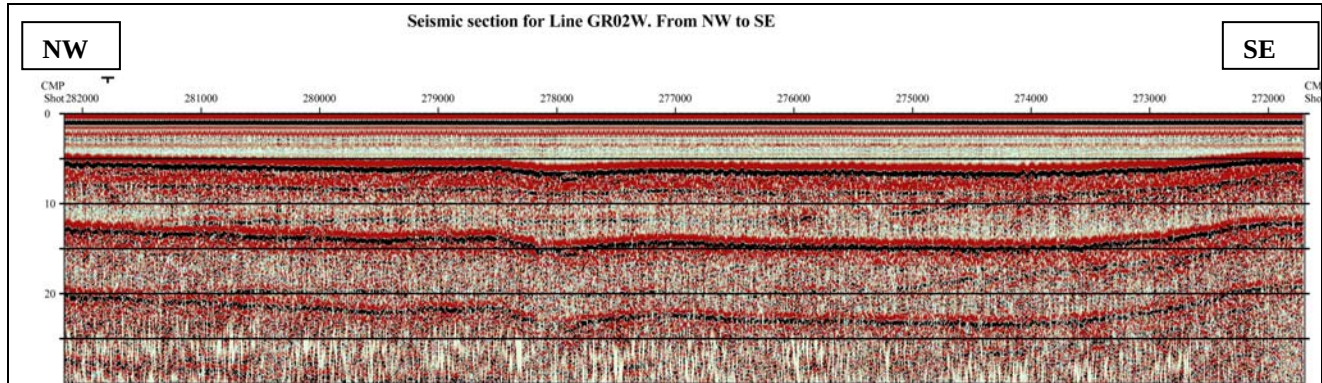


Figure 10. Seismic cross section of line GR02. The original section before picking.

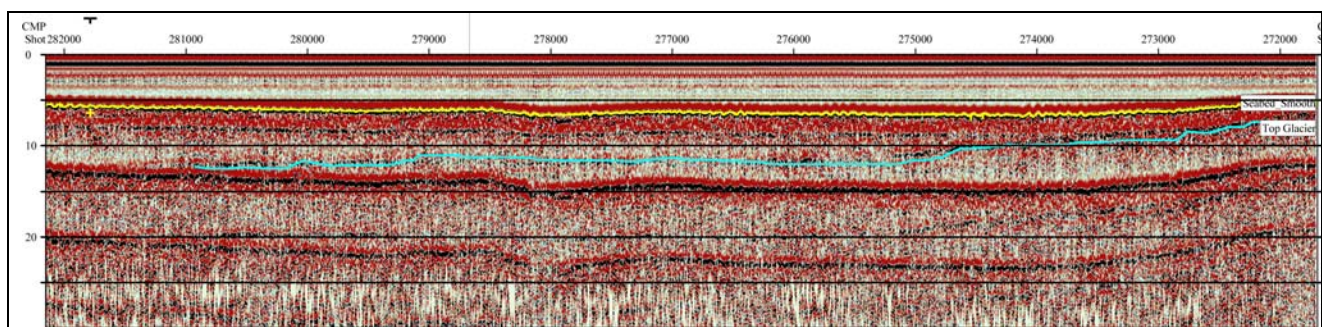


Figure 11. Seismic cross section of line GR02. The yellow line represents the seabed horizon, and the blue line is the bottom of the first layer.

The section shows the variation in the first layer thickness which seems to be reduced from NW to SE until it diminishes at the end of the section.

The procedure was applied to all seismic lines and the digitized horizons were plotted on the MapInfo GIS program where it was gridded and presented.

Three maps were produced from this endeavour; the seabed surface maps which are shown in Fig. (12 & 13) for the Danish and the German side respectively. The maps show a gently sloping near-shore area on the Danish side while a steep sloping is observed on the German side. A feature is present to the west of the survey area on the German side.

The other set of maps include the depth to the bottom of the first layer which is shown in Fig.(14 & 15) for the Danish and the German sides, respectively. They represent the grid of the blue horizon in Fig.(11).

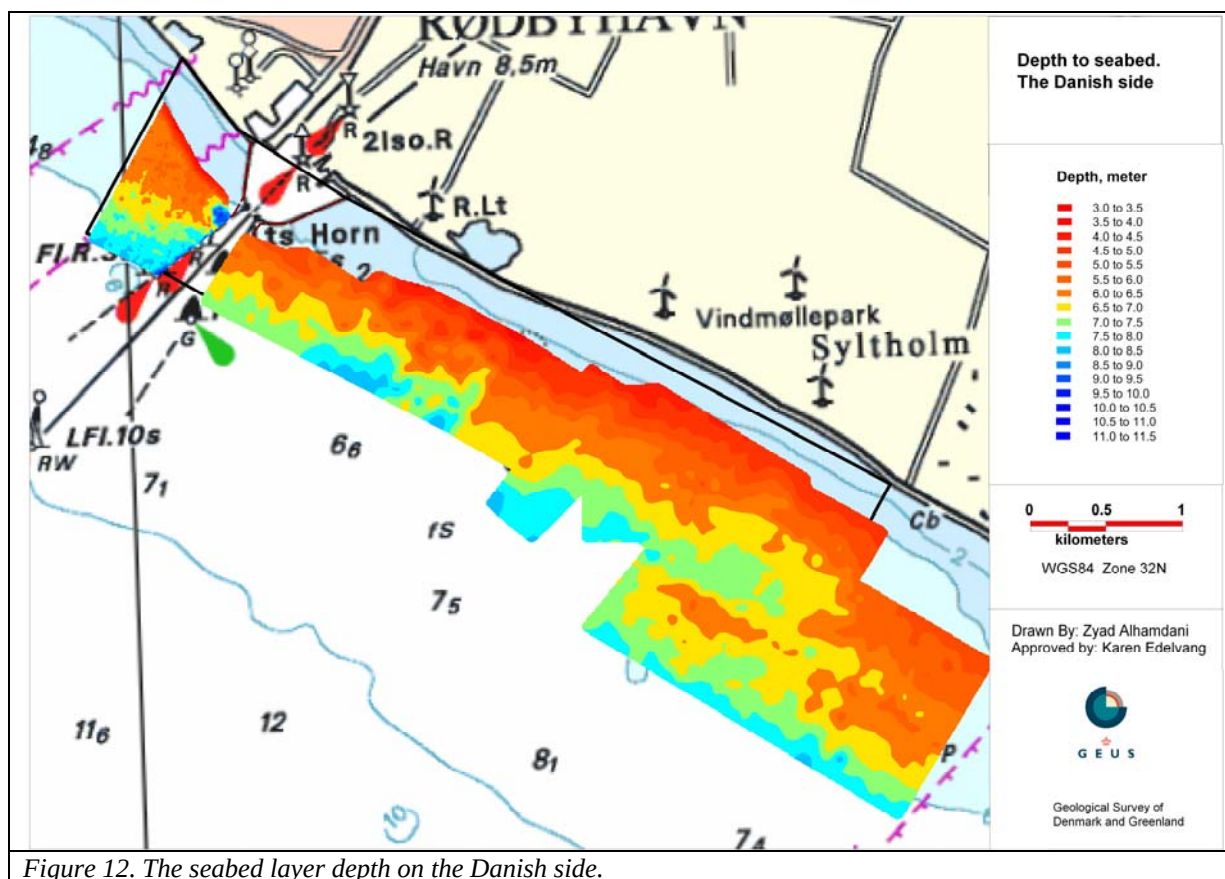


Figure 12. The seabed layer depth on the Danish side.

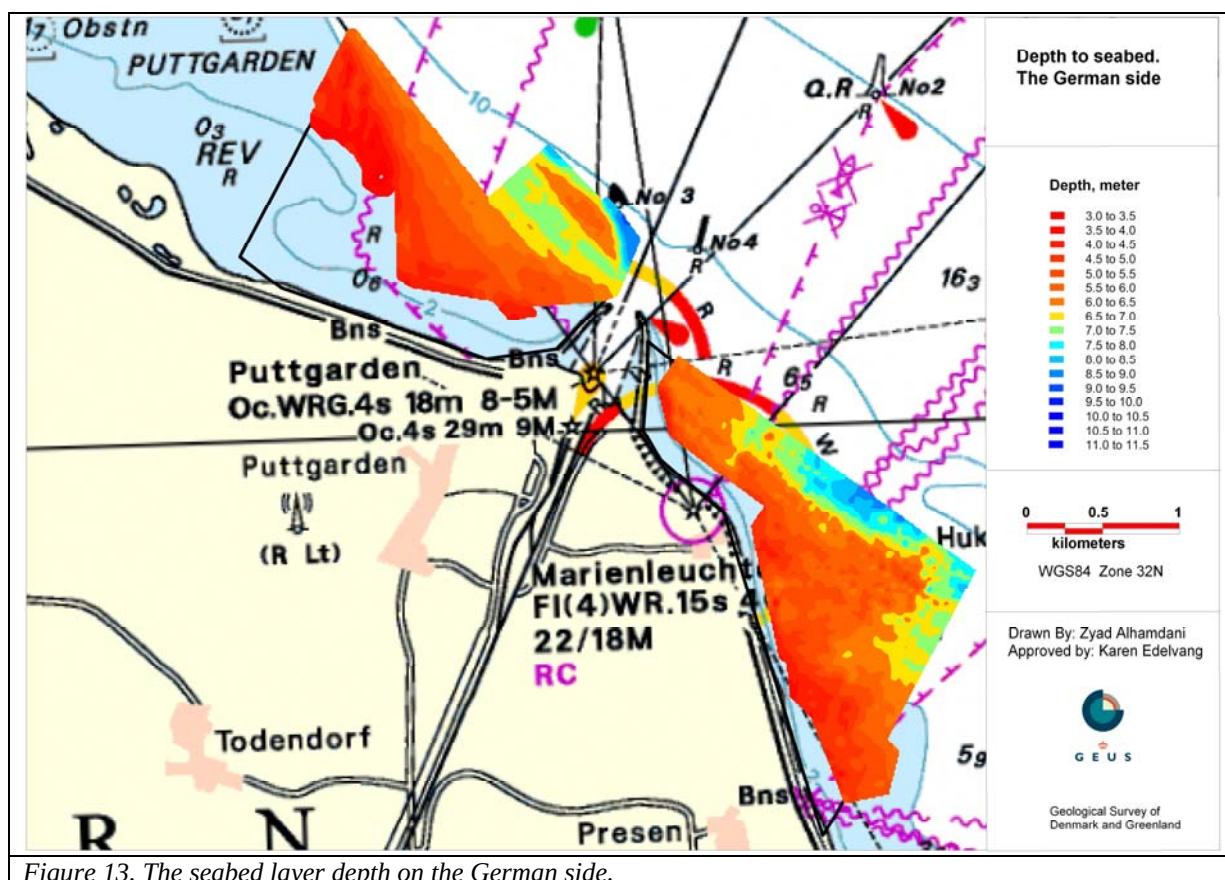
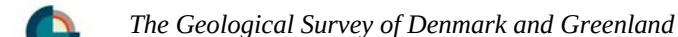
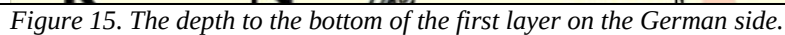


Figure 13. The seabed layer depth on the German side.



The third set of maps show the thickness of the top layer Fig.(16 & 17) which was deduced by subtracting algebraically (in GIS) the depth to the surface from the depth to the bottom of the first layer.

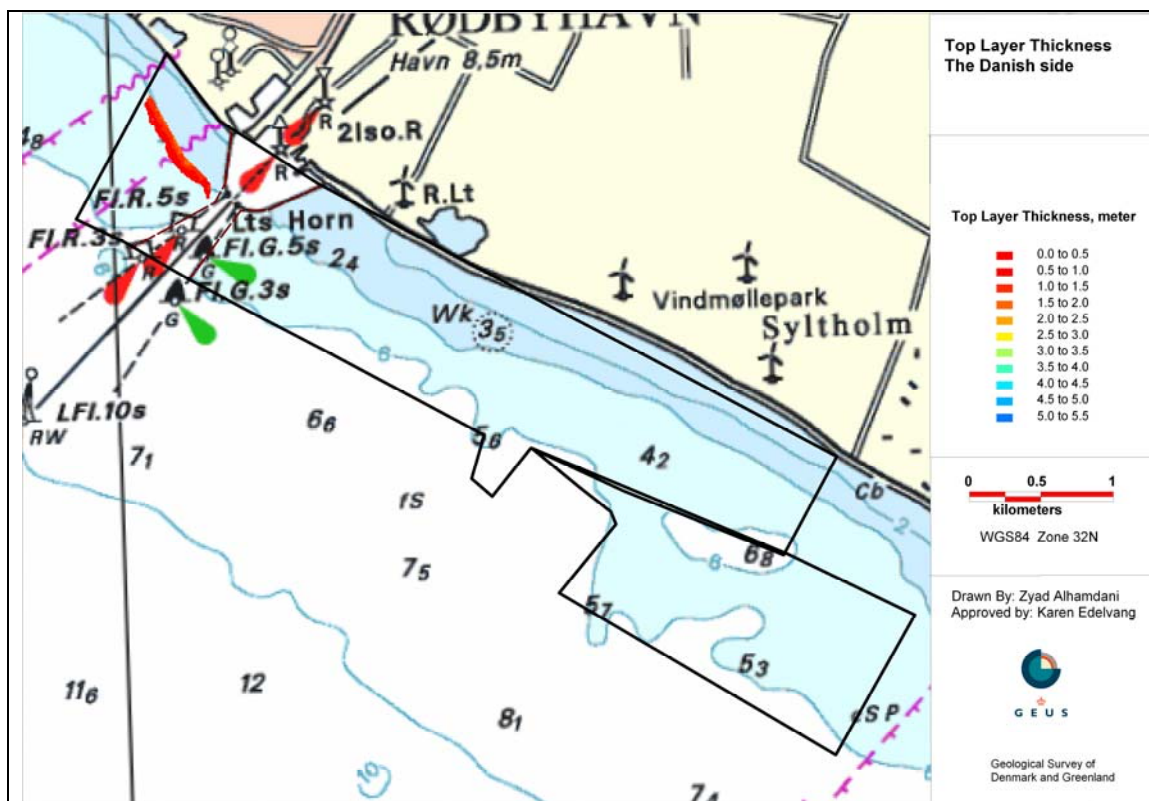


Figure 16. The thickness map of the first layer on the Danish side.

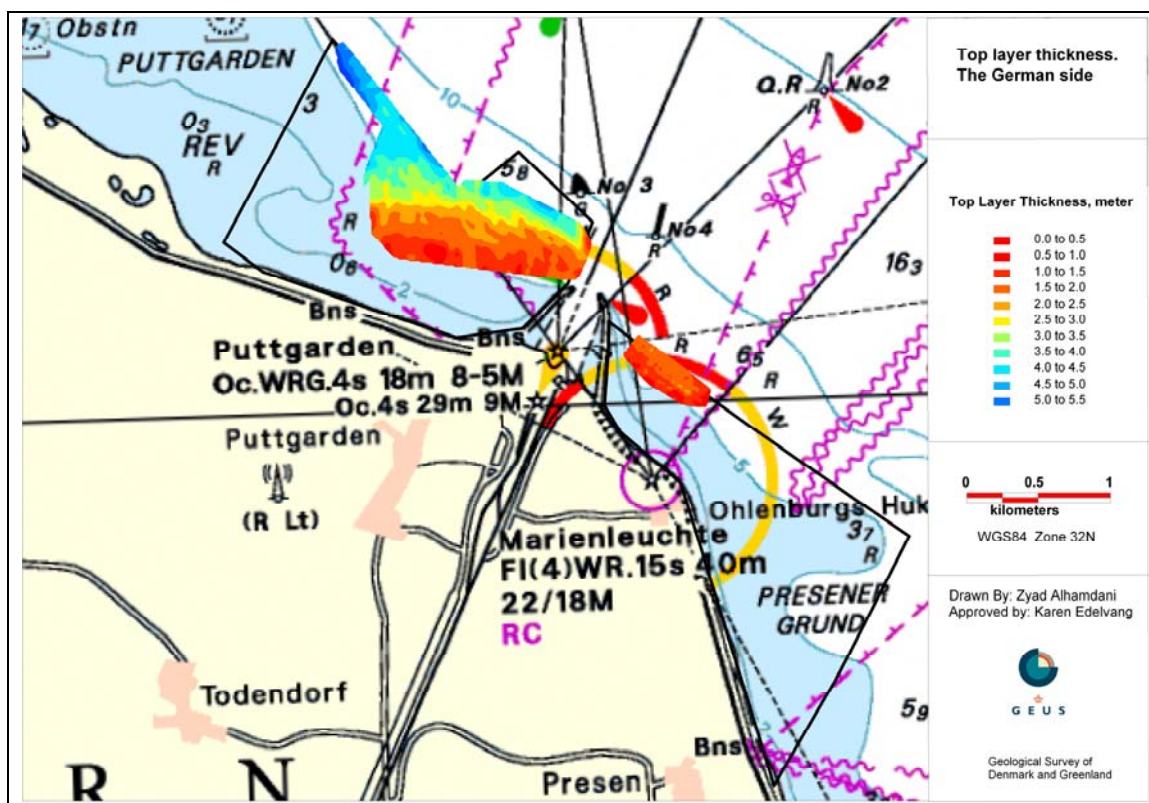


Figure 17. The thickness map of the first layer on the German side.

Discussion and conclusion

In this report there are two main results which need discussion, the first is the magnetic survey and its corresponding sidescan mosaicing; and the second is the sub-bottom profiling and sub-surface information obtained from the seismic section.

The magnetic survey

Observing Fig. (6 and 7) for the magnetic anomalies distribution on the Danish and the German sides shows that the anomalies follow a distinct pattern which is elongated and extends from NE to SW in the western part of the Danish survey area. When the sidescan record is played back and a mosaic is made out of the survey lines that run in that area the image shows an elongated object on the seabed which may be an elongated metal object like a pipe, Fig.(18).

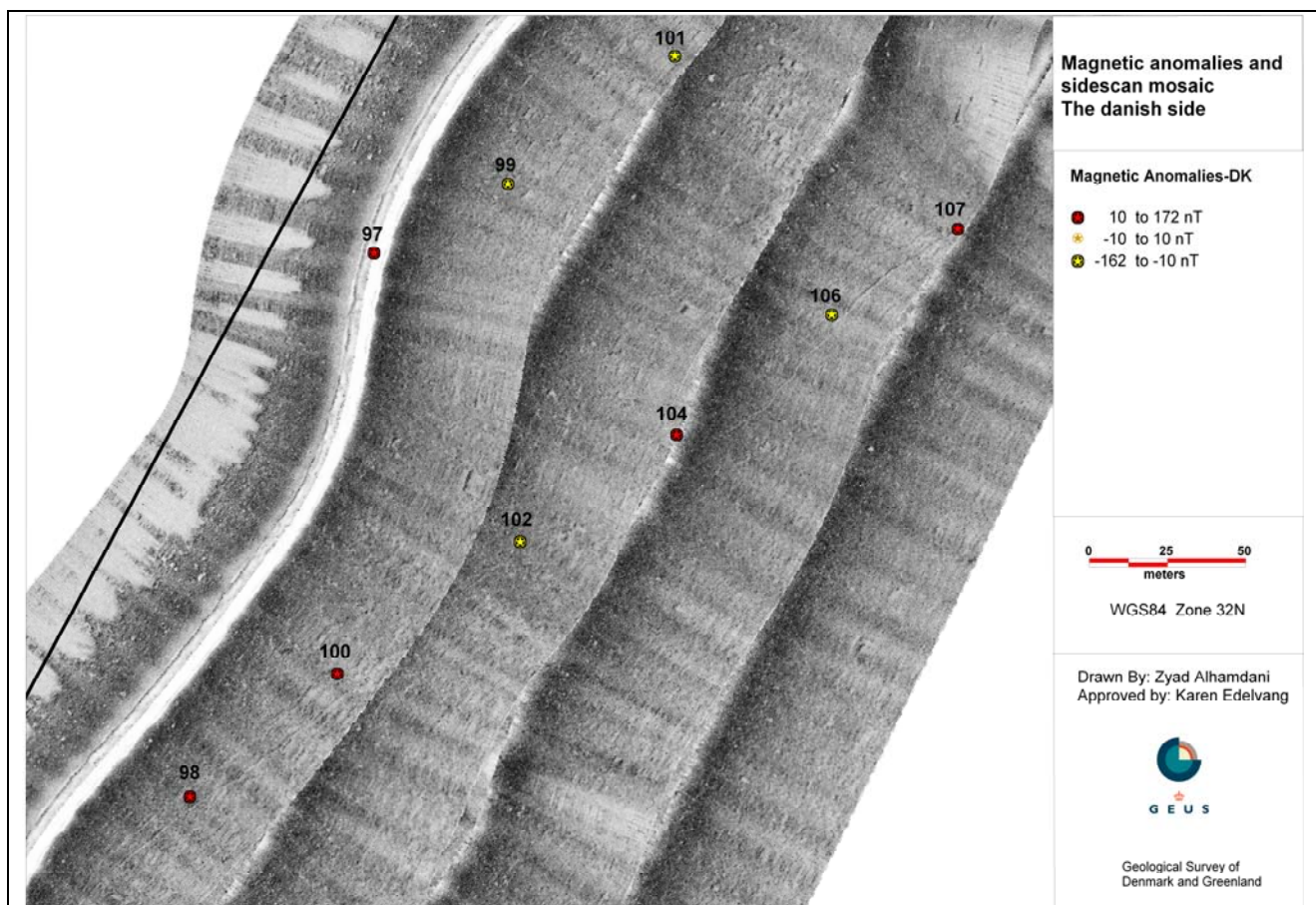


Figure 18. Magnetic anomalies and sidescan image on the Danish side. Observe the elongated shape on the seabed and the pattern of the magnetic anomalies distribution.

A similar elongated pattern is noticed on the German Eastern side with a direction NE to SW as well, but it is much more pronounced on the German side. It could also be related to an elongated metal object like a pipe, Fig. (19). On the western part of Puttgarden on the German side a similar pattern is observed by the magnetic anomalies but the sidescan mosaic shows a sandy area and no feature can be observed on the seabed. However, it could be related to an elongated metal object, like a pipe which is buried under the sand, Fig (20).

On both sides the magnetic anomalies are randomly distributed over the surveyed area. It's worth mentioning here that the two areas are subjected to considerable amount of human activities Such as harbour building, fishing or ship traffic.

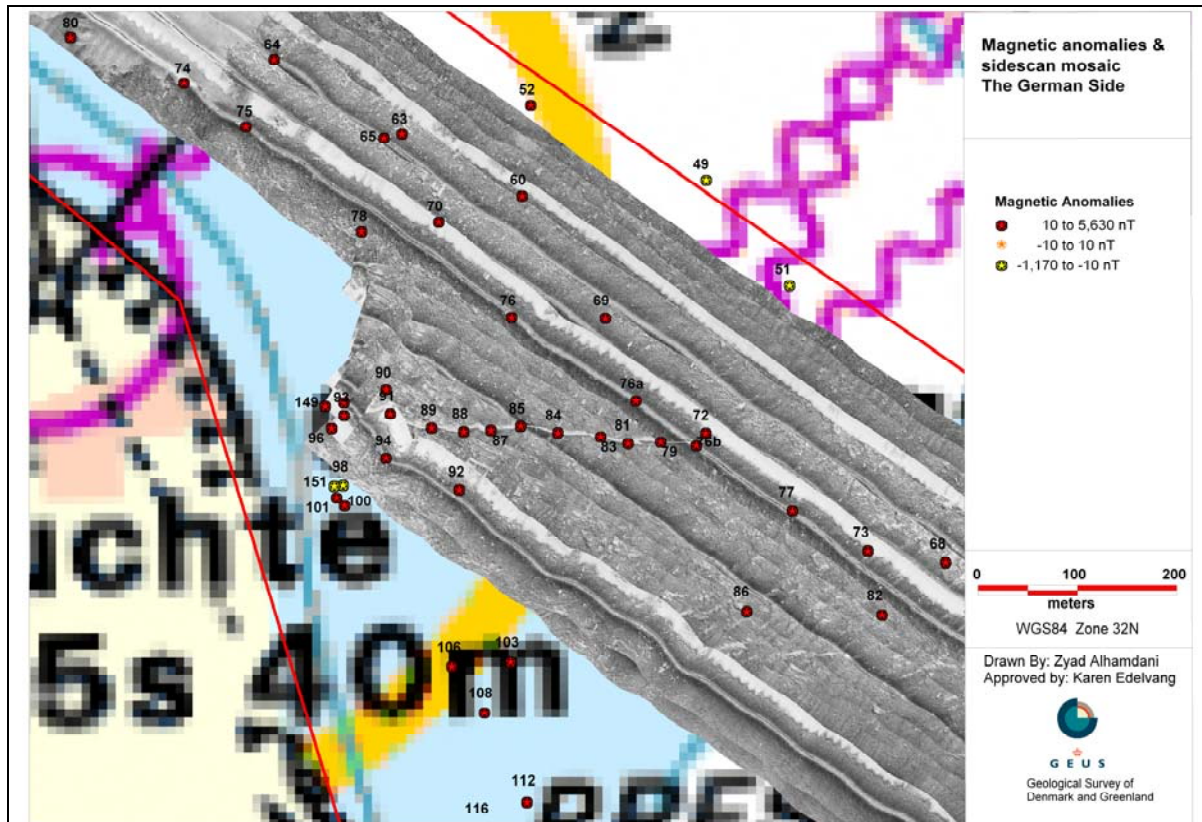


Figure 19. Magnetic anomalies and sidescan image on the Eastern German side. Observe the elongated shape on the seabed and the pattern of the magnetic anomalies distribution.

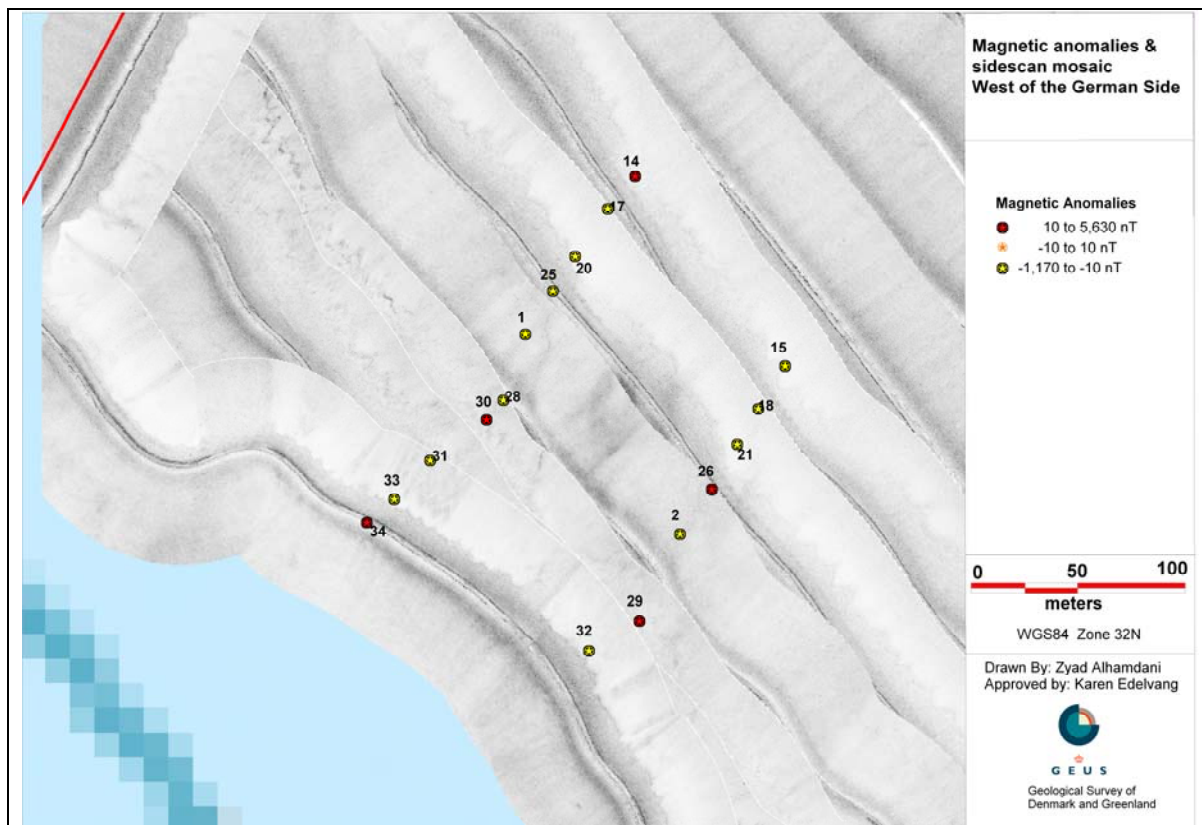


Figure 20. Magnetic anomalies and sidescan image on the Western German side. Observe the pattern of the magnetic anomalies distribution on sandy seabed.

The sub-bottom profiler survey

- In the Danish side the thickness of the top layer is very thin and exists only on the Western part of Rødby harbour as shown in Fig.(16). The rest of the area is covered with mixed sediment with lots of stones (till).
- On the German side the picture is different, the thickness of the top layer is significant as shown in Fig.(17). Till is also observed on the surface but a thick sand cover is noticed as well especially on the Western side of Puttgarden.

An interesting morphological feature is observed on the Western part of Puttgarden. If one looks at Fig.(13) and zoom on to the Western part as shown in Fig.(21), an elongated feature is clearly observed in the resulting seabed depth map, it's a ridge formation and identified to be a drowned spit. It's a typical coastal feature found in this part of the survey area.

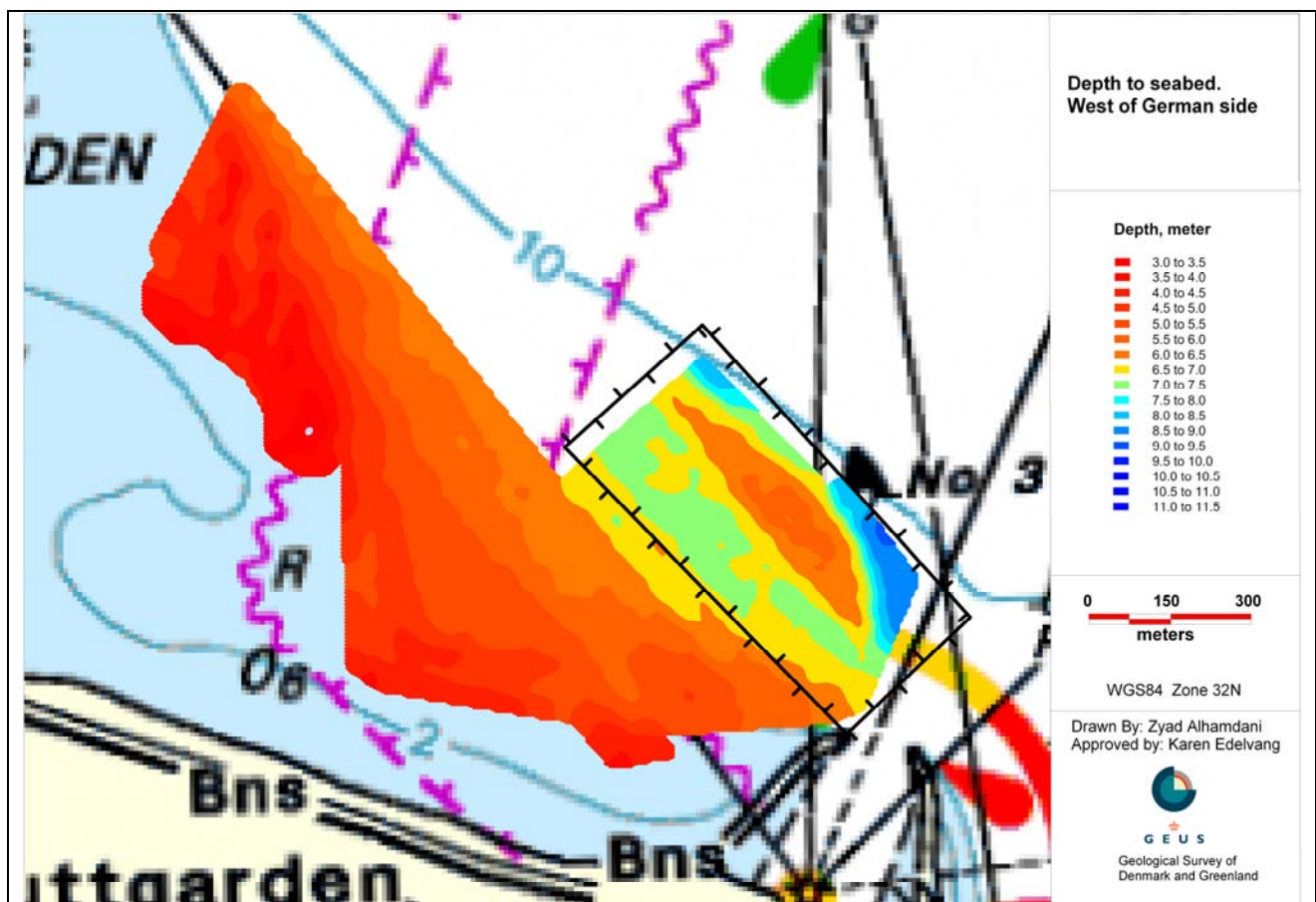


Figure 21. Seabed depth map for the Western side of Puttgarden. The structure striking NW-SE which is surrounded by a box is believed to be a spit.

A previous study in the Femern Bælt (Novak, 2002) shows that the area is influenced by highly varying sedimentary processes and dynamic environment since the latest glacial retreat around 14.0 ka BP ^{14}C . As the glacial melted back from the area, till and glacialfluvial material was deposited. At the Danish coast offshore Rødby, stone pavement and boulders are found on the seafloor. At the German coast, West of Puttgarden, the till deposits are covered by meters of sand platform deposits. Fossil spit/platform systems have been observed in this area. The accumulation is believed to be a product of the so called Littornia transgression and of the subsiding sub-ground. As the transgression submerged Femern Bælt, the wave energy eroded the Western headland of the island of Fehmarn. The mobilised erosion products were deposited at the lee side east of the headland.

West of Puttgarden harbour, the water is shallow and a well known spit/platform has been developed in modern time. The extension of this system is from the Western tip of Fehmarn Island to the port area. The study of seismic sections across Femern Bælt (Novak, 2002) shows similar spit features in the deeper water Fig. (22).

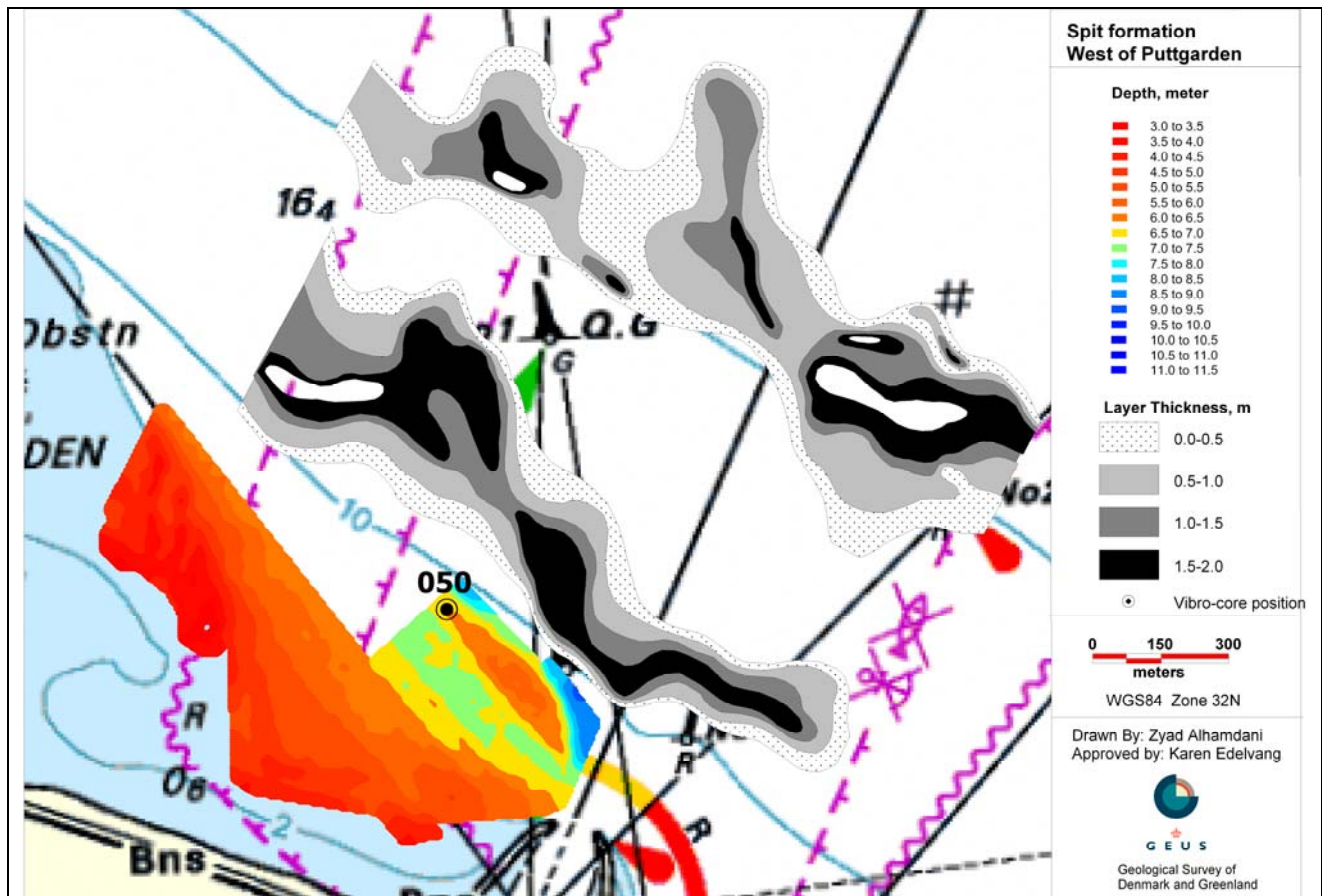


Figure 22. The seabed depth on the Western part of Puttgarden. The gray features represent finding of buried fossil spits at water depth below 10m. Core site 50 is also shown in the figure (Novak2002).

Vibrocore data was acquired by (Novak, 2002) for the study area and vibrocore site 50 which penetrates the spit structure is shown in Fig.(22).. The vibrocore (4.5 meter) shows that the base of the spit contains till penetrated by roots and topped by a 0.1 meter gravel lag. On top of that, one meter of clay with thin silt lamina and findings of seeds, shell fragments. The clay is eroded and above the erosion surface, 3 meters of sand is deposited. The sequence in core VC 50 strongly suggests that a lagoon developed above the till basement and later, as rising sea level submerged the Northern part of the lagoon was buried under a spit. The backstepping and onlapping of lagoon sediments took place in the shallower Southern and protected inner lagoon basin, where there is a relatively high chance of finding areas of archaeological interests.

Conclusion

1. Two areas in Femern Bælt were surveyed with magnetometer and chirp sidescan/sub-bottom profiler where maps of the magnetic anomalies distribution and its corresponding seabed images were presented as well as maps for the first layer depth and thickness.
2. Sidescan swath was made to cover the entire area with 150% overlap.
3. The magnetic anomalies were linked in some places to the existence of buried metal objects like a pipe. There was no obvious artifact in the area observed by the sidescan image.

4. The sub-bottom profiler reveals the existence of a spit on the Western part of Puttgarden harbour. This spit is part of a system that has been developed in the area after the last glacial regression. Similar features were observed at deeper waters.

References

Novak B. 2002. Early Holocene brackish and marine facies in the Fehmarn Belt, southwestern Baltic Sea: depositional processes revealed by high-resolution seismic and core analysis. *Marine Geology* 189, 307-321.

Appendices

1. Appendix I. Magnetic anomalies spread sheet and examples of magnetic profiles.
2. Appendix II. Examples of Sidescan images.
3. Appendix III. Examples of Sub-bottom profiles.
4. Appendix IV. Instrument specifications and software.

Appendix I: Magnetic anomalies spread sheet and magnetic anomalies profiles

Magnetic anomalies in the Femern Bælt archaeology project

The Danish Side OVER
±10nT

WGS84 32N projection

Anom #	Line number	Amplitude, nT	BG value, nT	Anomaly, nT	Easting UTM	Northing UTM
8	DK55	49690.08	49679.5	10.58	655186.71	6055093.38
11	DK53	49720.78	49704.96	15.82	654751.5	6055411.38
12	DK52	49704.06	49688.26	15.8	654669.06	6055496.63
14	DK51	49712.93	49700.46	12.47	654769.38	6055460.38
15	DK50	49706.33	49691.23	15.1	653567.96	6056220.23
16	DK49	49712.66	49700.59	12.07	655329.07	6055181.86
23	DK39	49698.32	49685.33	12.99	655437.28	6055407.91
25	DK33	49675.05	49664.47	10.58	655280.1	6055684.01
27	DK29	49678.4	49666.34	12.06	654482.35	6056275.93
28	DK27	49691.23	49679.08	12.15	655035.27	6056003.31
29	DK27	49689.05	49679.08	10	655177.12	6055913.93
31	DK21	49710.5	49697.42	13.08	654847.4	6056284.14
32	DK15	49705.66	49693.57	12.09	654808.23	6056489.93
39	DK-F2WPAR1	49663.34	49675.29	-11.95	653385.88	6057369.84
42	DK-Fence4Eparal1	49730.26	49711.96	18.3	652286.51	6057868.53
45	DK11B	49749.84	49720.53	29.31	653013.06	6057481.99
46	DK11C	49713.45	49703.4	10.05	652561.68	6057552.31
48	DK14C	49730.03	49684.09	45.94	652728.35	6057768.37
49	DK14C	49714.55	49684.75	29.8	652673.76	6057794.59
50	DK14C	49717.65	49684.75	32.9	652649.2	6057809.2
51	DK14C	49746.28	49686.39	59.89	652599.02	6057837.72
52	DK14C	49800.61	49687.11	113.5	652515.49	6057887.93
53	DK15A	49695.21	49684.16	11.05	653943.41	6056998.82
54	DK15D	49641.63	49692.54	-50.91	651942.63	6058185.93
55	DK15D	49754.32	49694.11	60.21	651826.71	6058211.75
56	DK15D	49724.33	49694.11	30.22	651802.08	6058213.67
57	DK15D	49721.57	49694.61	26.96	651739.45	6058216.09
58	DK19A2	49598.5	49674.53	-76.03	653633.92	6057080.9
63	DK8A	49705.47	49690.56	14.91	654113.5	6057114.97
64	DK8A/9A	49752.52	49690.26	62.26	653704.11	6057335.03
65	DK9A	49733.59	49703.52	30.07	653752.56	6057295.44
66	DK9A,10A	49717.52	49705.36	12.16	653970.87	6057157.82
67	DK9C	49723.97	49704.64	19.33	652661.53	6057595.12
68	DK-Fenc4DzonE	49709.57	49689.95	19.62	652147.98	6057908
69	DK01D	49702.61	49689.97	12.64	652227.21	6057757.98
70	DK03D	49709.14	49688.69	20.45	652155.02	6057741.05
71	DK04C	49730.03	49701.33	28.7	652601.65	6057287.6
72	DK04C	49715.42	49701.33	14.09	652651.85	6057360.35
73	DK05C	49733.95	49702.98	30.97	652706.86	6057488.98
74	DK07C	49781.3	49704.24	77.06	652632.35	6057464.82
75	DK09D	49707.98	49685.92	22.06	652094.55	6057923.76
76	DK11D	49739.33	49713.33	26	651977.43	6057842.42
77	DK14D	49706.47	49684.93	21.54	651932.03	6057903.32
78	DK16C1	49726.18	49697.6	28.58	652518.21	6057701.52

79	DK20D	49703.32	49686.28	17.04	651716.04	6057864.3
80	DK20D	49707.01	49685.6	21.41	651840.79	6058027.28
81	DK22C	49711.57	49691.46	20.11	652402.18	6057787.65
82	DK23C	49751.37	49719.66	31.71	652229.87	6057587.13
83	DK23D	49705.97	49688.84	17.13	651765.46	6058053.39
84	DK25C	49705.23	49693.77	11.46	652334.17	6057816.93
85	DK27D	49754	49696.18	57.82	651452.31	6057776.45
86	DK28D	49656.53	49699.02	-42.49	651434.9	6057803.71
88	DK33D	49717.79	49706.89	10.9	651321.13	6057855.5
89	DK35D	49697.94	49707.62	-9.68	651371.71	6058008.61
90	DK36D	49724.83	49710.95	13.88	651285.66	6057931.07
91	DK37D	49687.45	49708.65	-21.2	651243.15	6057942.63
93	DK38D	49722.87	49711.78	11.09	651300.62	6058037.52
95	DK43Dext	49653.51	49710.92	-57.41	651143.28	6058072.66
96	DK1E-test	49687.45	49712.07	-24.62	650502.78	6058589.36
97	DK1E-test	49737.89	49712.07	25.82	650628.73	6058821.12
98	DK2E	49763.05	49705.68	57.37	650574.89	6058662.6
99	DK2E	49666.62	49705.68	-39.06	650667.96	6058841.43
100	DK3E	49784.07	49700.79	83.28	650617.98	6058698.43
101	DK3E	49675.93	49700.79	-24.86	650716.8	6058878.62
102	DK4E	49620.2	49699.81	-79.61	650671.5	6058737.01
103	DK4E	49736.67	49699.81	36.86	650771.15	6058914.11
104	DK5E	49776.93	49696.5	80.43	650717.3	6058768.26
105	DK5E	49661.81	49696.5	-34.69	650806.42	6058928.8
106	DK6E	49642.35	49693.32	-50.97	650762.69	6058803.2
107	DK7E	49768.49	49689.5	78.99	650799.61	6058828.21
108	DK8E	49731.79	49695.32	36.47	650858.9	6058873.36
109	DK9E	49712.72	49691.07	21.65	650609.27	6058356.06
111	DK13E	49674.6	49707.75	-33.15	650677.94	6058270.43
112	DK13E	49757.71	49707.75	49.96	650777.09	6058455.41
113	DK15ZonC	49870.47	49697.73	172.74	652829.29	6057676.07
115	DK15E	49677.19	49700.35	-23.16	650724.92	6058249.64
116	DK15E	49614.78	49700.35	-85.57	650826.09	6058441.98
117	DK16ZonC1	49796.04	49686.95	109.09	652812.88	6057648.52
118	DK16ZonC1	49746.17	49686.95	59.22	652801.46	6057652.59
119	DK16E	49708.83	49696.86	11.97	650724.86	6058190.23
120	DK16E	49708.4	49696.86	11.54	650948.13	6058616.38
121	DK17ZonC	49663.52	49698.68	-35.16	652795.22	6057626.98
122	DK17ZonC	49717.07	49698.68	18.39	652376.16	6057888.64
123	DK17E	49715.92	49698.29	17.63	650747.11	6058184.72
126	DK22E1	49705.86	49687.27	18.59	650936.09	6058288.44
127	DK22E1	49700.82	49687.27	13.55	650968.63	6058351.67
128	DK23E	49534.2	49690.38	-156.18	650990.7	6058324.34
130	DK25E,FeryRutE	49699.45	49684.7	14.75	651038.45	6058289.93
131	DK-FeryRutE	49712.97	49691.28	21.69	650857.15	6058906.5
132	DK-FeryRutE	49741.01	49691.28	49.73	650817.95	6058976.58
133	DK-FeryX1	49726.59	49710.32	16.27	650879.01	6058098.9
134	DK-FeryX2	49549.37	49711.62	-162.25	650954.6	6058252.22
135	DK-FeryX3	49700.05	49722.65	-22.6	651126.02	6058313.85

Magnetic anomalies in the Femern Bælt archaeology project

The German Side OVER $\pm 10\text{nT}$

WGS84 32N projection

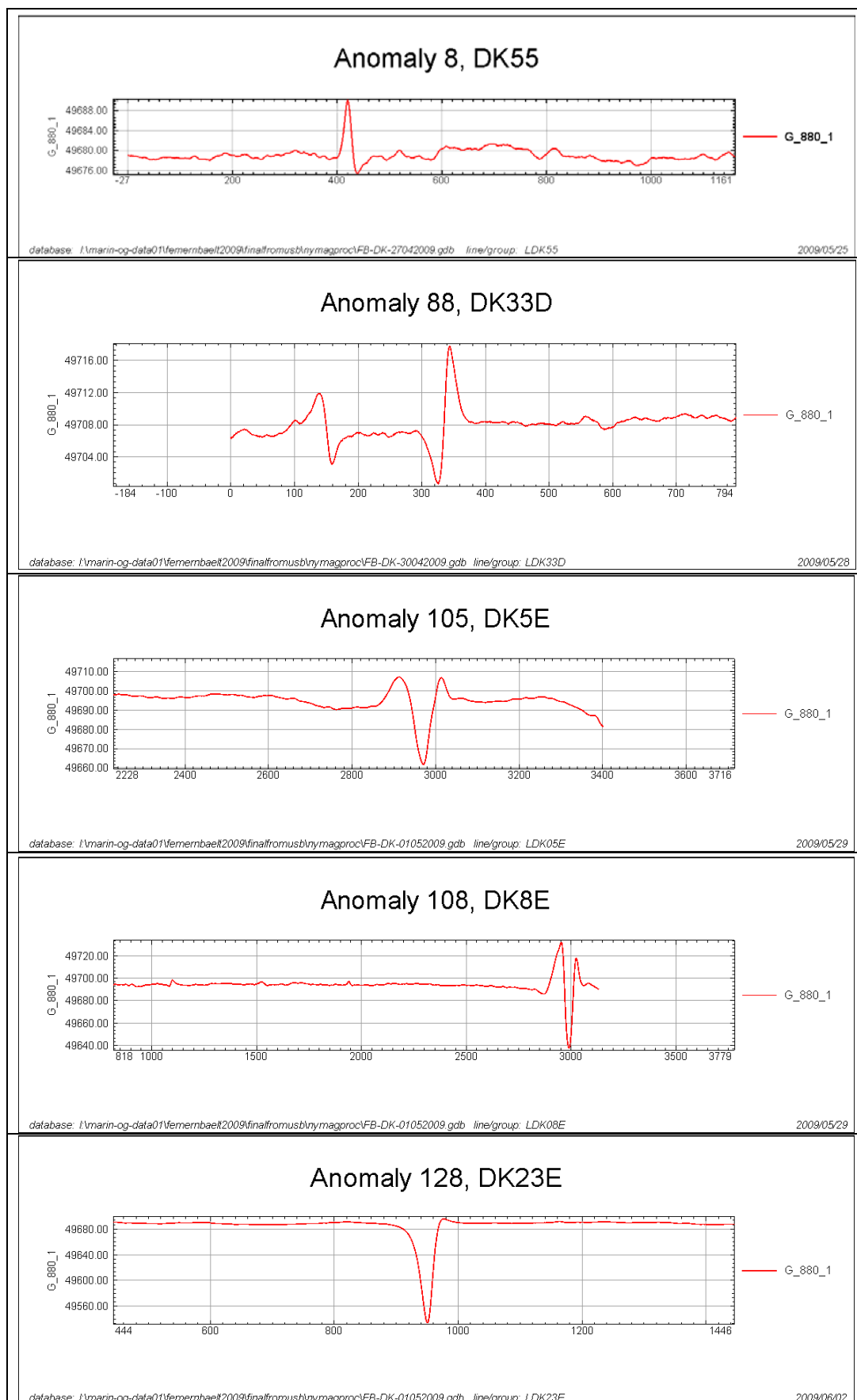
Anom #	Line number	Amplit, nT	BG value, nT	Anomaly, nT	Easting UTM	Northing UTM
1	GR14W	49608.99	49654.57	-45.58	642797.74	6043400.49
2	GR14W	49529.18	49649.9	-120.72	642877.44	6043297.65
3	GR01W	49604.73	49637.37	-32.64	643529.17	6042986.87
4	GR02W	49668.03	49633.59	34.44	643524.60	6042975.84
5	GR02W	49646.51	49632.31	14.2	643295.79	6043264.20
6	GR03W	49604.39	49661.34	-56.95	643505.81	6042944.22
7	GR04W	49680.95	49648.6	32.35	643507.30	6042914.99
8	GR05W	49636.42	49623.78	12.64	643506.86	6042876.56
9	GR06W	49592.31	49625.83	-33.52	643495.05	6042844.19
10	GR07W	49712.03	49627.97	84.06	643484.61	6042820.72
11	GR07W	49606.15	49628.6	-22.45	643243.99	6043123.96
12	GR08W	49597.09	49631.32	-34.23	643475.28	6042790.68
13	GR09W	49687.65	49634.15	53.5	643472.34	6042750.67
14	GR10W	50133.01	49646.62	486.39	642854.36	6043482.01
15	GR10W	49539.56	49642.25	-102.69	642931.66	6043384.35
16	GR10W	49767.55	49643.63	123.92	643646.16	6042494.32
17	GR11W	49270.06	49646.1	-376.04	642840.25	6043465.07
18	GR11W	49466.5	49646.17	-179.67	642917.86	6043362.23
19	GR11W	49691.16	49647.18	43.98	643668.83	6042436.18
20	GR12W	49577.21	49652.16	-74.95	642823.39	6043440.88
21	GR12W	49424.23	49652.16	-227.93	642906.99	6043343.72
22	GR12W	49678.04	49647.26	30.78	643186.04	6042994.70
23	GR12W	49783.82	49644.35	139.47	643701.05	6042354.66
24	GR12W	49692.33	49644.35	47.98	643794.58	6042240.53
25	GR13W	49569.8	49651.93	-82.13	642811.96	6043422.95
26	GR13W	49762.33	49651.93	110.4	642893.95	6043320.73
27	GR13W	49823.95	49641.46	182.49	643751.39	6042241.57
28	GR15W	49608.65	49628.78	-20.13	642786.39	6043366.76
29	GR16W	49701.06	49626.66	74.4	642856.57	6043252.92
30	GR16W	49703.34	49626.66	76.68	642777.75	6043356.60
31	GR17W	49521.28	49645.48	-124.2	642748.66	6043335.46
32	GR17W	49564.18	49645.48	-81.3	642830.52	6043237.56
33	GR18W	49552.34	49645.23	-92.89	642730.13	6043315.80
34	GRshallowW	49745.94	49654.07	91.87	642716.02	6043303.59
35	GRshallowW	49596.71	49671.83	-75.12	643079.33	6042680.23
36	GRshallowW	49735.05	49646.74	88.31	643269.09	6042368.01
37	GRshallowW	49751.48	49641.54	109.94	643452.97	6042341.28
38	GRshallowW	49854.45	49634.09	220.36	643807.94	6042273.47
39	GRshallowW	49555.35	49626.3	-70.95	644370.41	6042318.57
40	GRshallowW	49739.26	49646.91	92.35	643114.71	6042432.06
43	GR43W	49751.75	49662.24	89.51	644203.11	6042641.20
44	GR45W	49714.16	49669.55	44.61	644023.27	6042955.25
45	GR46W	49762.69	49667.24	95.45	644263.35	6042693.40

46	GR47W	49685.24	49645.75	39.49	644395.77	6042582.15
47	GR48W1-rpt	49687.54	49645.6	41.94	644443.80	6042519.52
48	GR48W1-rpt	49608.72	49650.77	-42.05	644059.06	6043002.97
49	GR01E	49660.33	49671.2	-10.87	645918.05	6041099.81
50	GR03E	49666.34	49653.2	13.14	646502.04	6040613.80
51	GR03E	49639.69	49654.68	-14.99	646042.06	6040942.45
52	GR03E	49664.92	49647.91	17.01	645656.86	6041210.83
53	GR03E	49661.97	49648.58	13.39	645413.71	6041391.68
54	GR03E	49622.45	49637.84	-15.39	645161.26	6041572.92
55	GR03E	49662.63	49643.29	19.34	645020.33	6041671.93
56	GR05E	49668.86	49645.32	23.54	646378.13	6040637.95
57	GR06E	48474.68	49635.25	-1160.57	645084.74	6041539.71
58	GR07E	49697.15	49642.24	54.91	646450.63	6040527.94
59	GR07E	49624.36	49641.29	-16.93	645045.66	6041530.31
60	GR08E	49669.54	49640.93	28.61	645644.20	6041076.41
61	GR08E	49612.05	49640.18	-28.13	645097.56	6041470.28
62	GR09E	49693.07	49654.86	38.21	645063.15	6041451.47
63	GR09E	49677.37	49656.88	20.49	645465.57	6041167.85
64	GR10E	49679.42	49654.66	24.76	645275.25	6041278.99
65	GR10E	49673.83	49658.08	15.75	645438.58	6041161.84
66	GR10E	49683.37	49661.23	22.14	646376.85	6040486.89
67	GR11E	49680.47	49654.52	25.95	646359.00	6040474.04
68	GR11E	49686.14	49654.52	31.62	646274.30	6040530.97
69	GR11E	49715.92	49653.47	62.45	645767.96	6040894.91
70	GR12E	49687.52	49664.65	22.87	645520.06	6041037.05
71	GR12E	49690.55	49667.26	23.29	646325.72	6040464.75
72	GR13E	49674.6	49657.13	17.47	645917.45	6040723.34
73	GR13E	49676.33	49657.04	19.29	646158.65	6040548.20
74	GR14E	49698.27	49650.4	47.87	645141.32	6041243.80
75	GR14E	49717.5	49650.4	67.1	645233.38	6041179.00
76	GR14E	49705.75	49649.7	56.05	645628.61	6040896.09
76a	GR14E	49681.08	49649.7	31.38	645813.49	6040771.03
76b	GR14E	49678.65	49653.17	25.48	645903.40	6040704.92
77	GR14E	49676.33	49654.21	22.12	646046.25	6040607.41
78	GR15E	49677.05	49650.29	26.76	645405.18	6041022.93
79	GR15E	49708.49	49658.03	50.46	645850.29	6040710.10
80	GR16E	49677.61	49650.7	26.91	644972.30	6041311.40
81	GR16E	49699	49659.45	39.55	645801.82	6040707.87
82	GR16E	49683.49	49655.36	28.13	646179.58	6040453.03
83	GR17E	49709.84	49645.09	64.75	645761.07	6040718.19
84	GR18E	50688.64	49641.99	1046.65	645697.23	6040723.76
85	GR19E	49706.78	49642.42	64.36	645642.02	6040733.60
86	GR20E	49740.65	49645.92	94.73	645978.23	6040457.93
87	GR20E	49689.39	49643.16	46.23	645597.61	6040727.43
88	GR21E	49768.92	49648.84	120.08	645557.31	6040725.43
89	GR22E	49708.31	49646.96	61.35	645509.42	6040731.27
90	GR22E	49691.7	49636.05	55.65	645441.74	6040788.05
91	GR23E	49872.93	49649.96	222.97	645447.90	6040751.66
92	GR24E	49682.63	49656.35	26.28	645550.40	6040639.13
93	GR25E1	49700.64	49656.37	44.27	645379.22	6040749.61
94	GR25E1	49709.15	49654.84	54.31	645441.74	6040685.73
96	GR26E	49773.67	49647.79	125.88	645360.78	6040730.48
98	GR28E	49538.97	49665.33	-126.36	645378.00	6040645.57
100	GR29E	49709.71	49659.22	50.49	645380.10	6040615.65

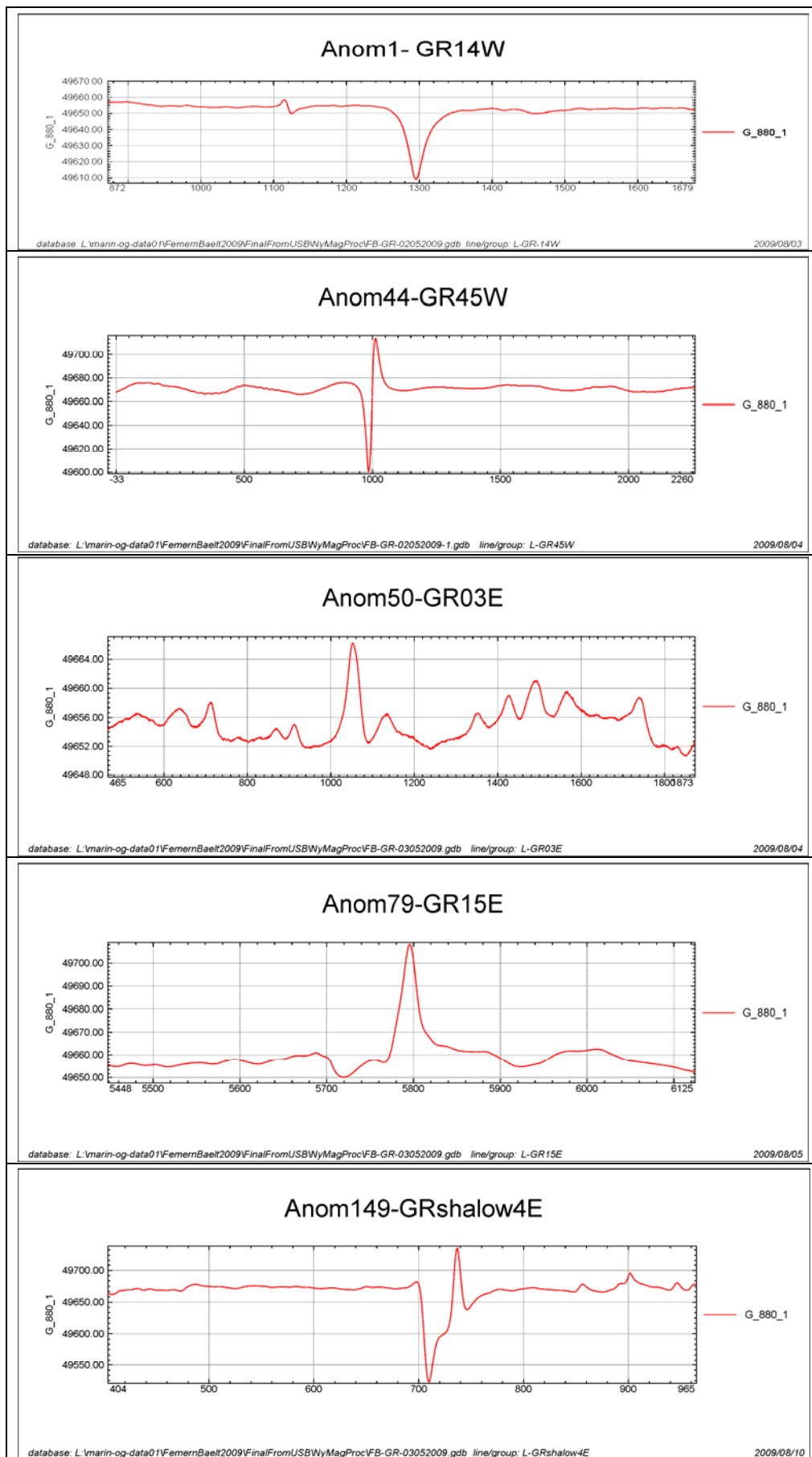
101	GR30E	49733.65	49662.51	71.14	645,368.15	6,040,627.09
103	GR31E	49713.6	49666.14	47.46	645627.10	6040382.49
104	GR32E	49694.65	49656.93	37.72	645968.50	6040103.65
105	GR33E	49704.4	49661.95	42.45	645947.75	6040091.32
106	GR33E	49690.62	49661.41	29.21	645539.70	6040376.04
107	GR34E	49697.71	49652.2	45.51	645934.46	6040056.37
108	GR34E	49671.45	49653.89	17.56	645588.09	6040307.14
109	GR35E	49699.47	49654.99	44.48	645880.65	6040066.56
110	GR36E	49695.53	49657.38	38.15	645883.70	6040041.33
111	GR37E	49647.38	49663.28	-15.9	645820.18	6040051.67
112	GR37E	49709.48	49665.21	44.27	645651.43	6040174.25
113	GR39E	49690.44	49667.98	22.46	645650.03	6040119.43
114	GR39E	49709.77	49663.66	46.11	645800.20	6040009.13
116	GR40E	49683.01	49674.46	8.55	645581.79	6040133.41
117	GR42E	49787.47	49669.91	117.56	645997.61	6039768.92
118	GR44E	49701.83	49681.51	20.32	645501.19	6040072.67
119	GR44E	49706.13	49683.11	23.02	646011.41	6039703.81
120	GR45E	49714.16	49683.67	30.49	645640.91	6039937.05
121	GR46E	49704.17	49666.32	37.85	645911.46	6039713.01
122	GR46E	49702.46	49664.11	38.35	645807.34	6039791.33
123	GR47E	49731.54	49666.52	65.02	645932.42	6039664.81
124	GR47E	49723.53	49661.75	61.78	645820.84	6039741.43
126	GR54E	49712.57	49682.18	30.39	645756	6039586.94
127	GR54E	49688.44	49657.99	30.45	645889.01	6039477.81
128	GRfinal1E	49615.25	49683.26	-68.01	645672.31	6039764.03
129	GRfinal1E	49792.26	49678.17	114.09	645735.91	6039608.73
130	GRfinal1E	49718.55	49683.8	34.75	645753.19	6039548.13
131	GRfinal1E	49945.57	49675.16	270.41	645860.56	6039194.83
132	GRfinal1E	49820.82	49680	140.82	645919.66	6039120.06
133	GRfinal7E1	50100.92	49653.94	446.98	645931.31	6039292.04
134	GrfinalrundE	49706.94	49652.16	54.78	645883.98	6039659.76
135	GrfinalrundE	49832.28	49652.25	180.03	645816.09	6039708.69
136	GrfinalrundE	49717.97	49658.76	59.21	645794.74	6039721.44
137	GrfinalrundE	49761.63	49673.61	88.02	645740.72	6039675.31
138	GrfinalrundE	49743.35	49679.59	63.76	645755.76	6039648.94
139	GrfinalrundE	49737.17	49684.08	53.09	645878.81	6039268.39
140	GrfinalrundE	49687.86	49661.25	26.61	646093.17	6039107.61
141	GrfinalrundE	49724.38	49688.26	36.12	645813.14	6039616.61
142	GrfinalrundE	49626.01	49669.17	-43.16	645931.15	6039294.96
143	GrfinalrundE	49753.39	49644.23	109.16	645945.87	6039268.65
144	GrfinalrundE	49682.3	49657.94	24.36	645989.61	6039516.81
145	GrfinalrundE	49681.46	49639.76	41.7	645922.78	6039562.02
146	GrfinalrundE	49724.72	49685.37	39.35	645952.01	6039379.39
147	GrfinalrundE	49682.32	49654.72	27.6	645847.19	6039612.18
148	GrfinalrundE	49974.18	49657.36	316.82	645785.67	6039670.94
149	GRshallow4E	49735.91	49670.77	65.14	645351.19	6040763.01
150	GRshallow5E	55188.21	49563.15	5625.06	645378.97	6040767.97
151	GRshallow5E	49647.32	49679.26	-31.94	645364.72	6040644.19
153	GRshallow8E	49743.74	49679.21	64.53	654559.51	603901.80
154	GRshallow8E	49856.65	49681.91	174.74	645583.26	6039801.00
155	GRshallow8E	49784.41	49675.7	108.71	645586.50	6039776.20
156	GRshallow8E	49754.16	49684.63	69.53	645609.60	6039749.50
157	GRshallowW-fil1	49699.35	49671.4	27.95	643187.06	6042997.42
158	GRshallowW-fil1	49776.28	49651.04	125.24	643659.56	6042467.15

159	GRshallowW1	49656.95	49682.56	-25.61	643144.30	6042881.50
160	GRshallowW1	49711.51	49652.09	59.42	643195.90	6042545.50
161	GRshallowW1	49752.76	49632.7	120.06	643218.47	6042457.27
162	GRshallowW1	49670.21	49638.86	31.35	643315.64	6042446.01
163	GRXferry	49652.85	49662.63	-9.78	644870.21	6042409.31
164	GRshallowW-fil	49718.53	49674.49	44.04	643133.25	6042595.21
165	GRshallowW-fil	49732.33	49655.49	76.84	643261.83	6042408.11
166	GRshallowW-fil	49709.19	49648.29	60.9	643392.95	6042388.97
167	GRshallowW-fil	49785.04	49647.82	137.22	643703.11	6042352.11

Examples of few magnetic anomalies profiles from the Danish side.



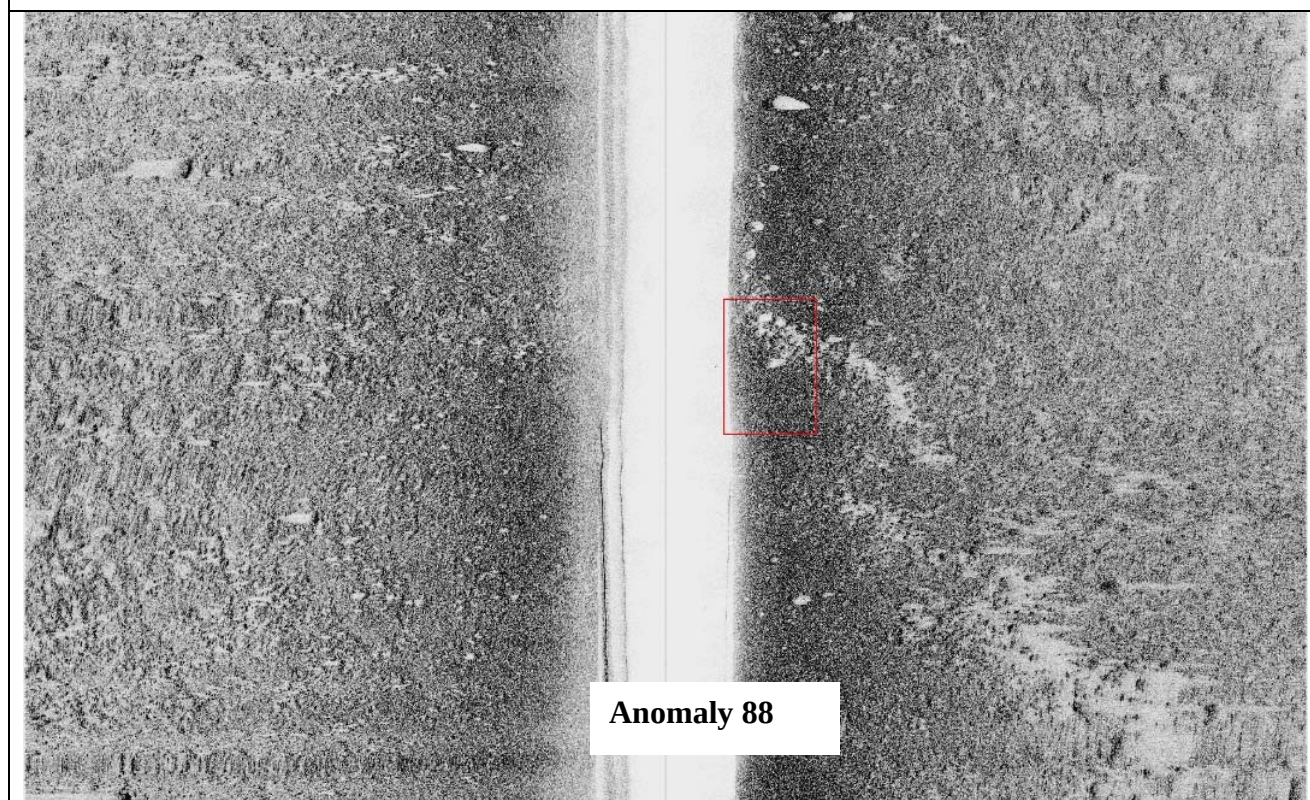
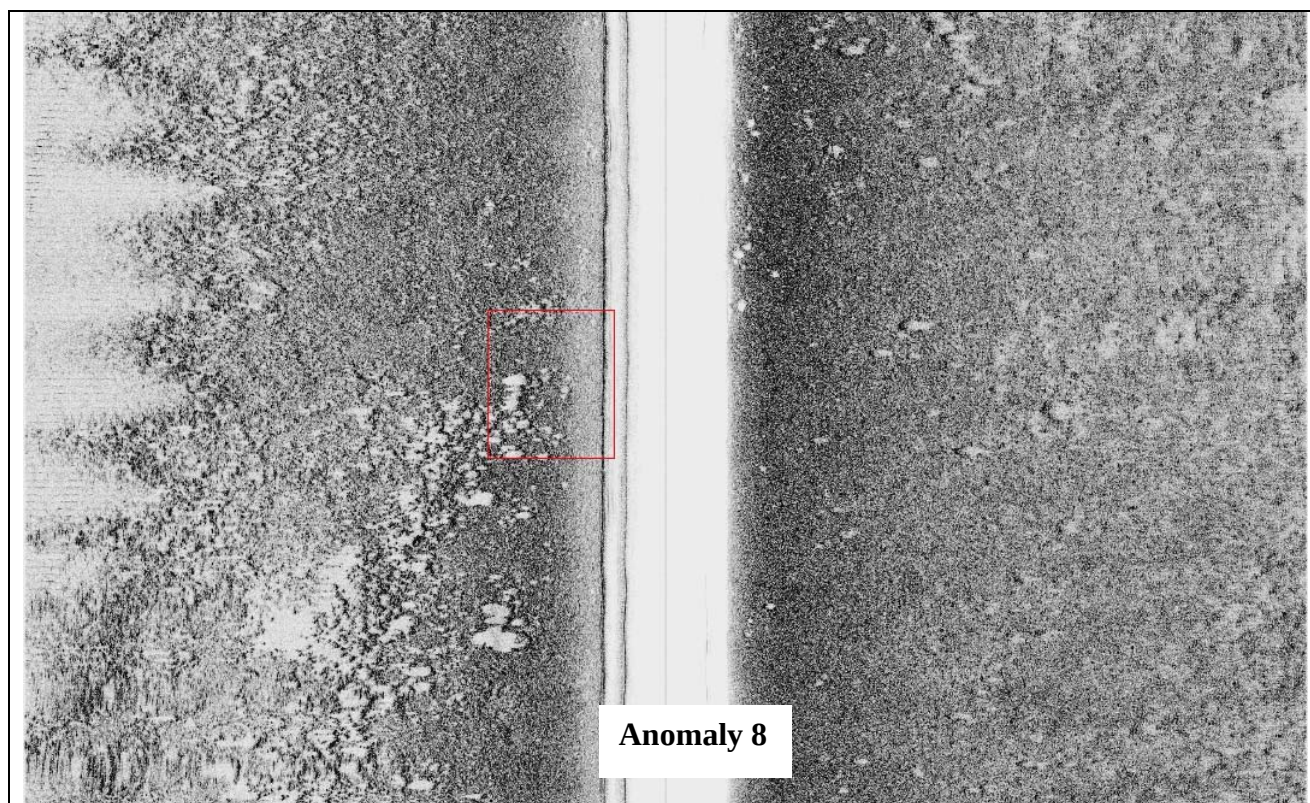
Examples of few magnetic anomalies profiles from the German side.

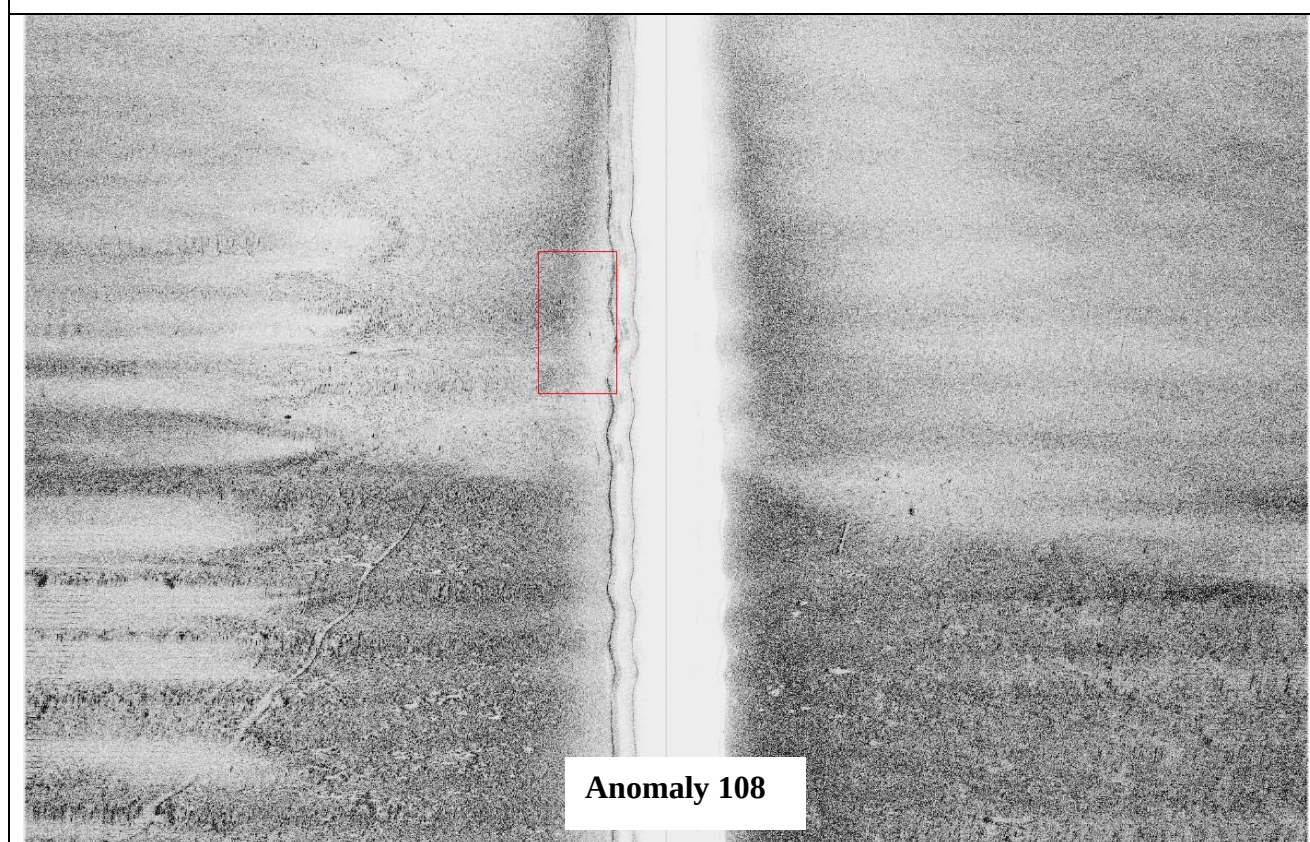
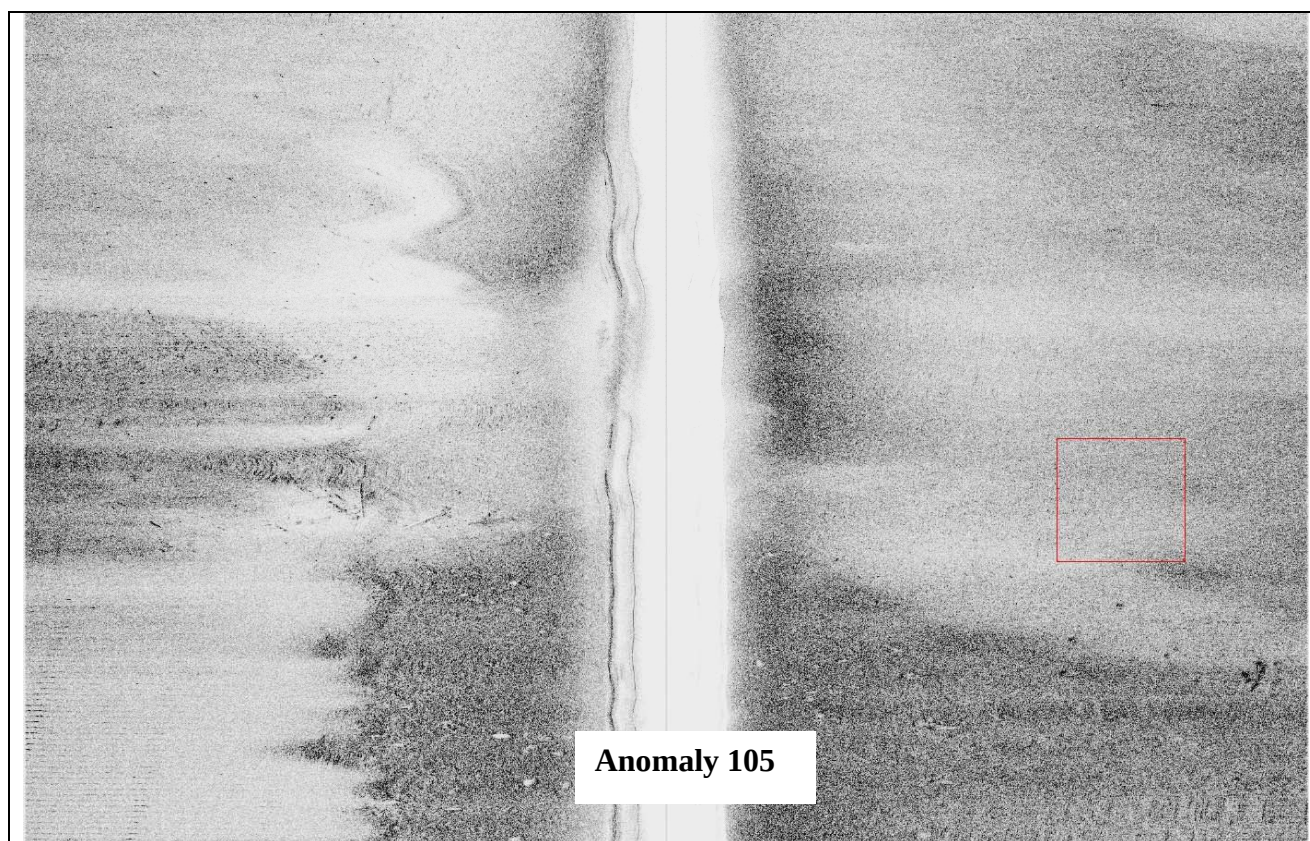


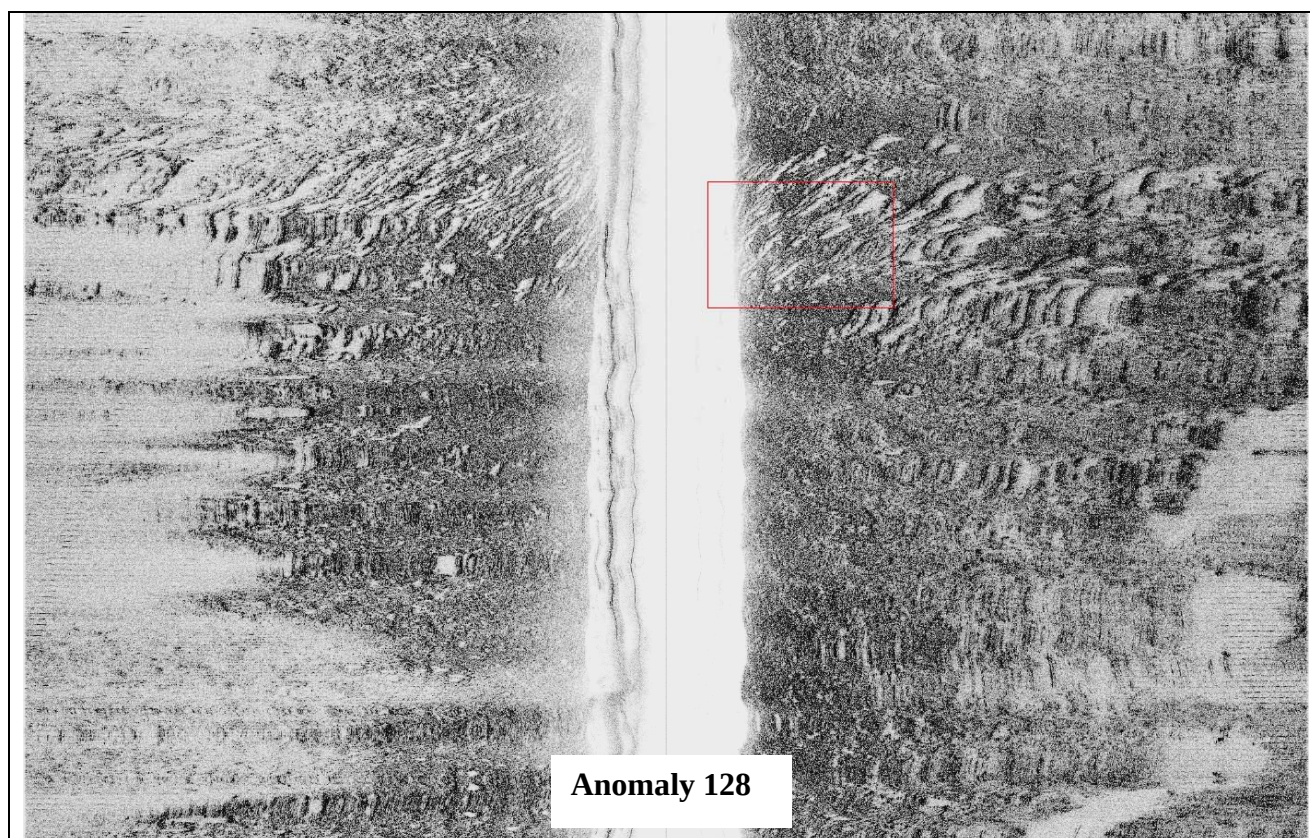
Appendix II. Sidescan images

Few examples will be given here the rest is in the accompanied DVD.

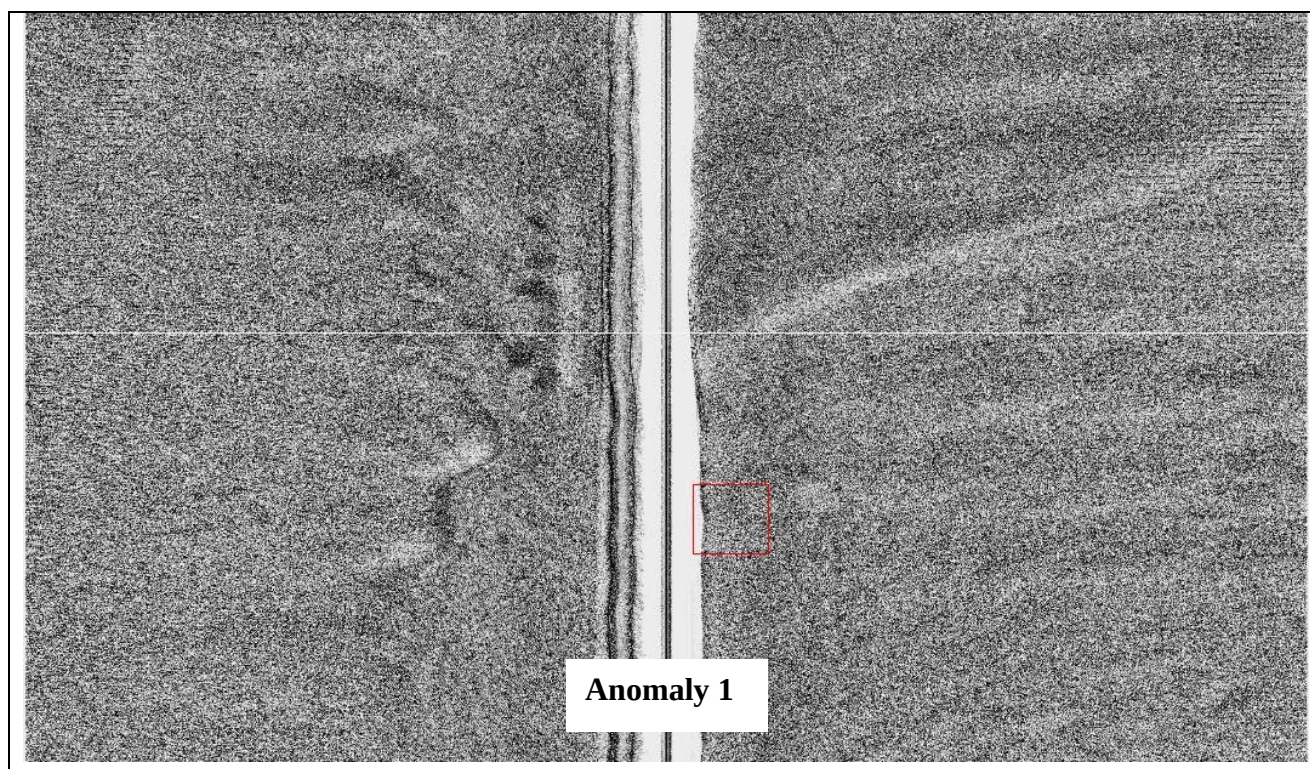
Examples from the Danish side.

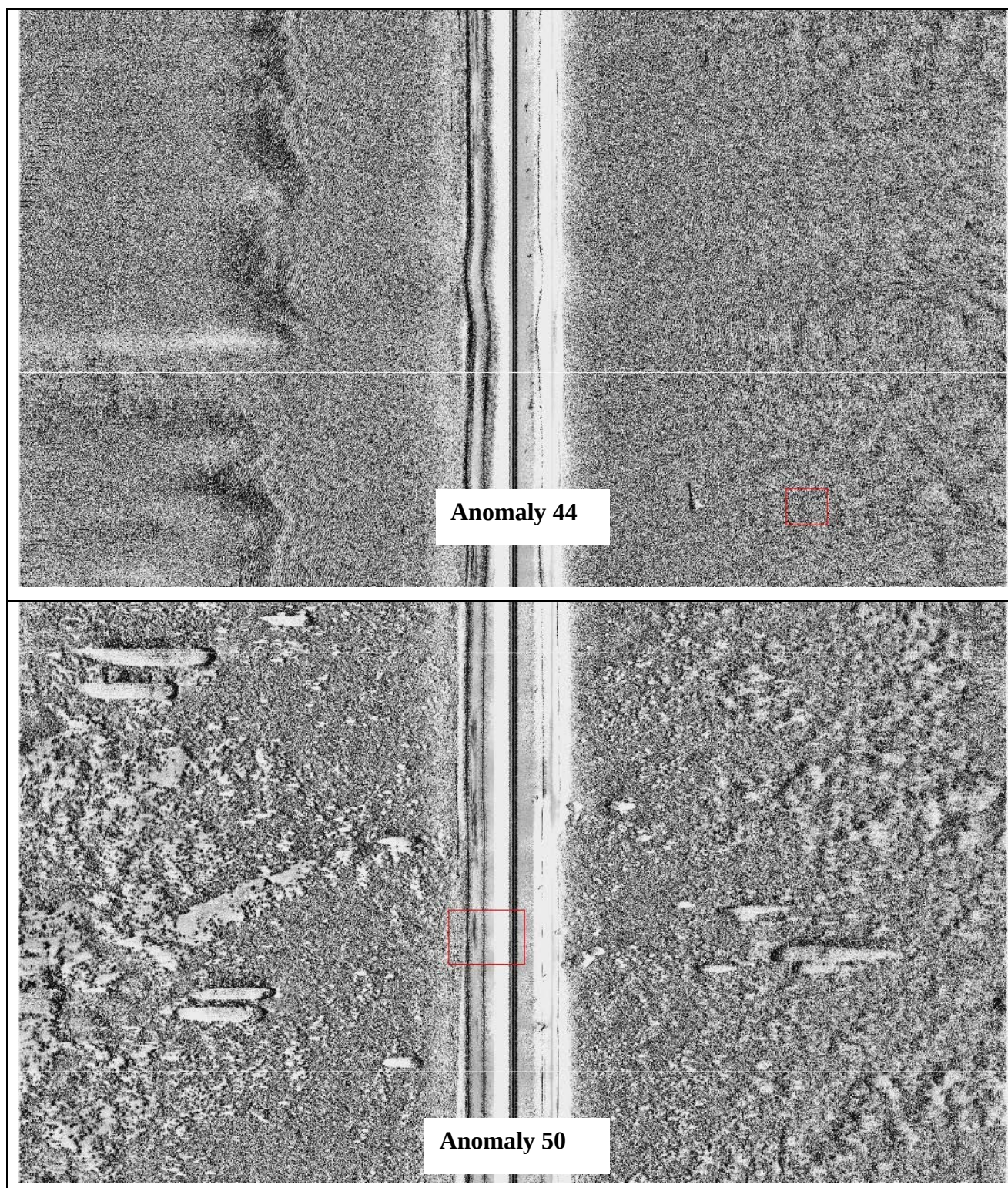


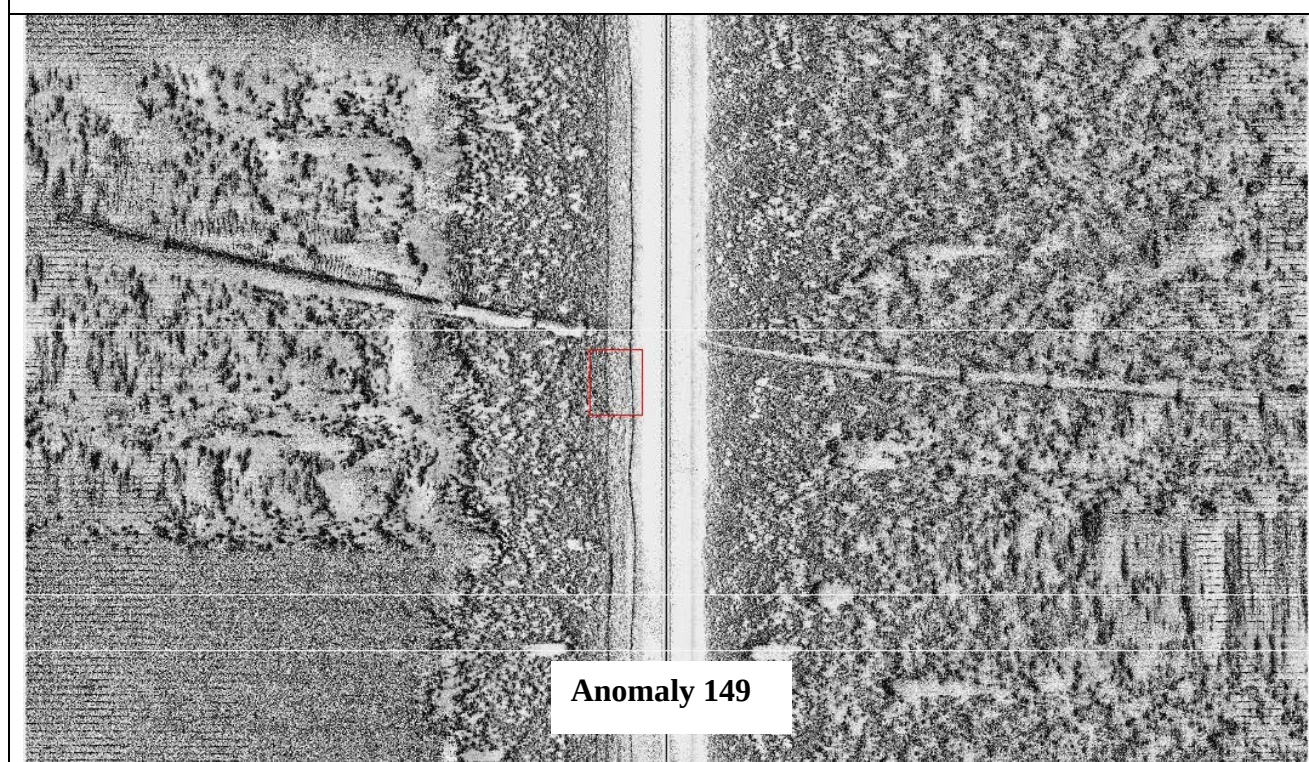
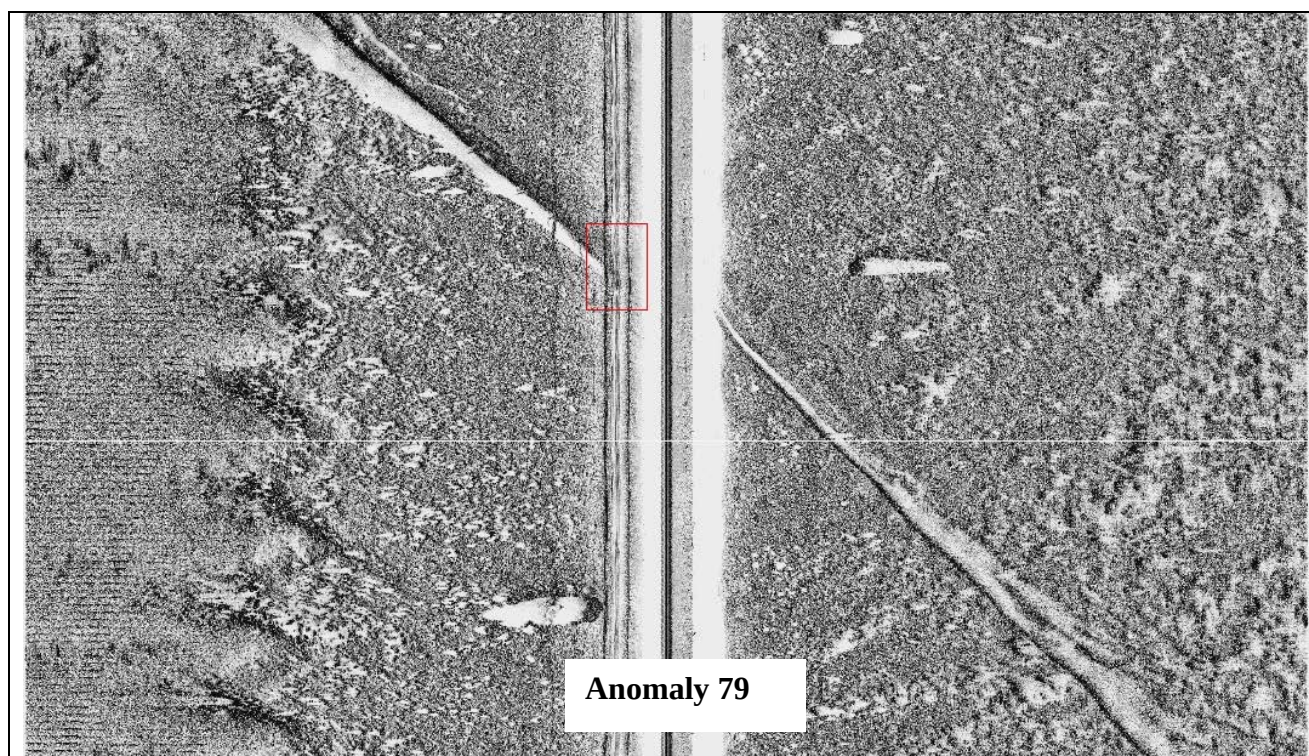




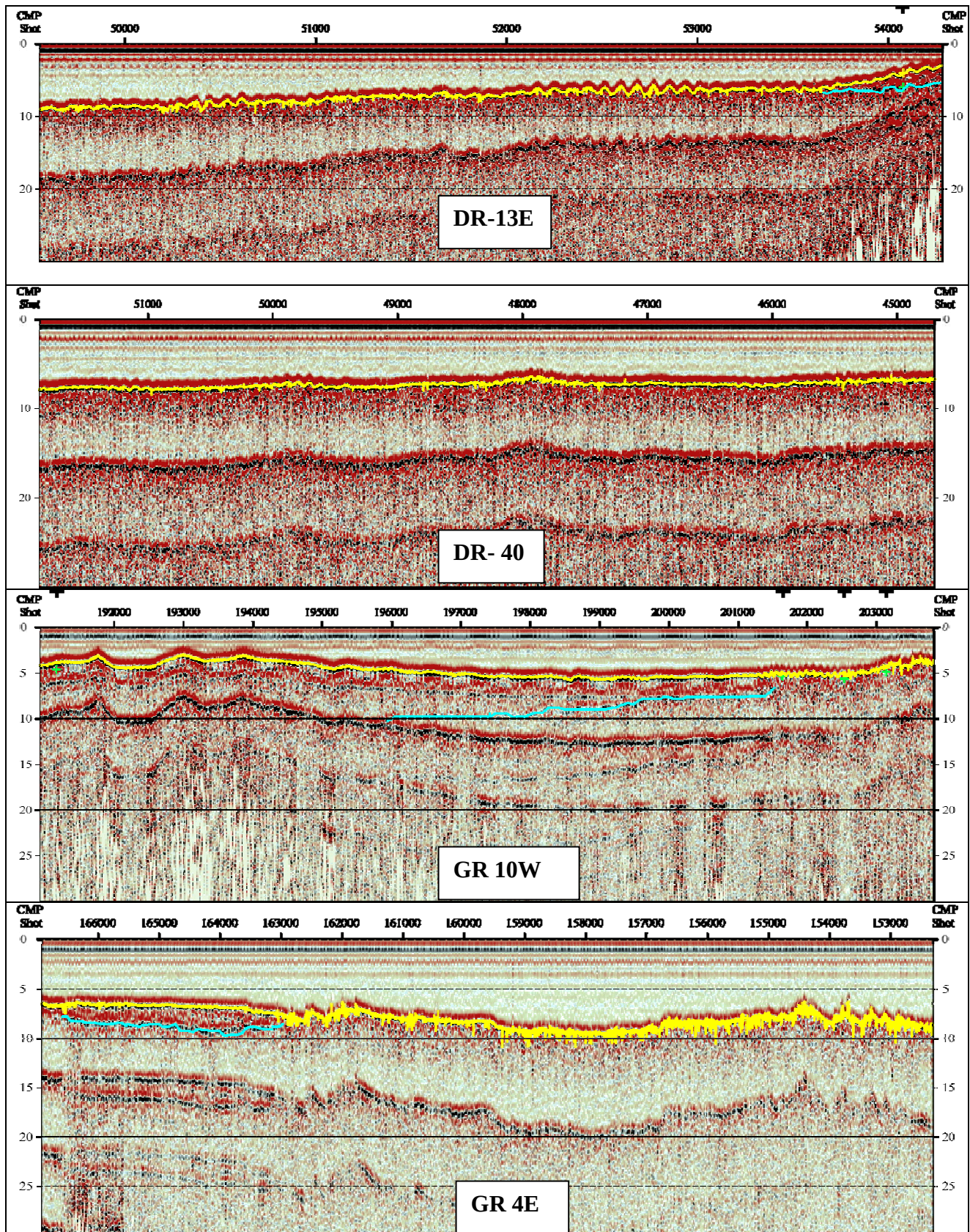
Examples from the German side.

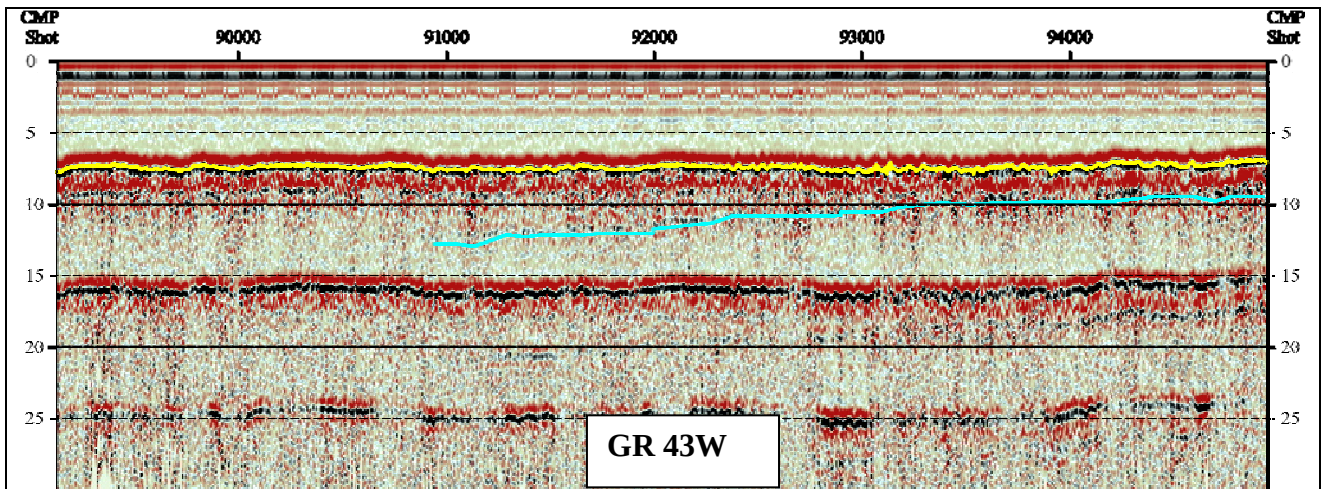






Appendix III. Examples from the sub-bottom profiler





These sections were shown to display the existence of a top layer in some areas and its absence in others. Most of the Danish side does not have the top layer or it is of a very small thicknesses. In the German side a thick sand top layer is noticed especially in the Western part of Puttgarden.

Appendix IV: Instrument specifications and software

The instruments used in this project are:

1. The G882 marine magnetometer.
2. The SIS-1625 Chirp sidescan/sub-bottom profiler.
3. The DC202 Adnav positioning system.
4. The acquisition and processing software.

G-882 Marine Magnetometer

Very high resolution Cesium Vapor performance is now available in a low cost, small size system for professional surveys in shallow or deep water. High sensitivity and sample rates are maintained for all applications. The well proven Cesium sensor is combined with a unique new CM-221 Larmor counter and ruggedly packaged for small or large boat operation. Use your computer and standard printer with our MagLog Lite™ software to log, display and print GPS position and magnetic field data. The G-882 is the lowest priced high performance full range marine magnetometer system ever offered.



The G-882 is flexible for operation in small boat, shallow water surveys as well as deep tow applications (4,000 psi rating, telemetry over steel coax available to 10Km). Being small and lightweight (40 lbs net, no extra weights) it is easily deployed and operated by one person. But add several streamlined weight collars and the system can quickly weigh more than 100 lbs. Power may be supplied from a 24 to 30 VDC battery power or the included 110/220 VAC power supply. The tow cable employs high strength Kevlar with a standard length of 200 ft (61 m) and optional cable length up to 500m (no telemetry required). A rugged fiber-wound fiberglass housing provides selectable orientation of the sensor and therefore maintains operations throughout the world with only small limitations as to direction of survey in equatorial regions. The shipboard end of the tow cable is attached to an included junction box or optional on-board cable for quick and simple hookup to power and output of data into any Windows 98, ME, NT, 2000 or XP computer equipped with RS-232 serial ports.

The G-882 Cesium magnetometer provides the same operating sensitivity and sample rates as the larger deep tow model G-880. MagLogLite™ Logging Software is offered with each magnetometer and allows recording and display of data and position with Automatic Anomaly Detection! Additional options include: MagMap2000 plotting and contouring software and post acquisition processing software MagPick™ (free from our website.)



Shown is a unique application for multiple mag G-882 array for UXO detection. Photos courtesy of Sky Research.

The G-882 system is particularly well suited for the detection and mapping of all sizes of ferrous objects. This includes anchors, chains, cables, pipelines, ballast stone and other scattered shipwreck debris, munitions of all sizes (UXO), aircraft, engines and any other object with magnetic expression. Objects as small as a 5 inch screwdriver are readily detected provided that the sensor is close to the seafloor and within practical detection range.

The following YouTube clip has some footage of the G-882 and a good introductory treatment of marine surveying for shipwrecks.

Typical Detection Range For Common Objects

Ship 1000 tons: 0.5 to 1 nT at 800 ft (244 m)
Anchor 20 tons: 0.8 to 1.25 nT at 400 ft (120 m)
Automobile: 1 to 2 nT at 100 ft (30 m)
Light Aircraft: 0.5 to 2 nT at 40 ft (12 m)
Pipeline (12 inch): 1 to 2 nT at 200 ft (60 m)
Pipeline (6 inch): 1 to 2 nT at 100 ft (30 m)
100 kg of iron: 1 to 2 nT at 50 ft (15 m)
100 lbs of iron: 0.5 to 1 nT at 30 ft (9 m)
10 lbs of iron: 0.5 to 1 nT at 20 ft (6 m)
1 lb of iron: 0.5 to 1 nT at 10 ft (3 m)
Screwdriver 5 inch: 0.5 to 2 nT at 12 ft (4 m)
1000 lb bomb: 1 to 5 nT at 100 ft (30 m)
500 lb bomb: 0.5 to 5 nT at 50 ft (16 m)
Grenade: 0.5 to 2 nT at 10 ft (3 m)
20 mm shell: 0.5 to 2 nT at 5 ft (1.8 m)

The design of this high sensitivity G-882 marine unit is directed toward the largest number of user needs. It is intended to meet all marine requirements such as shallow survey, deep tow through long cables, integration with Side Scan Sonar systems and monitoring of fish depth and altitude.

- Fastest sampling at high sensitivity means even small targets can be detected

- Cesium vapor technology provides furthest detection range. highest sensitivity at 0.004 nT/ÖHz
- New streamlined design improves safety, less chance of snagging on rocks or debris
- Convertable nose or CG tow mechanism, lets you choose survey style, gets fish deeper.
- Flash memory stores all parameters, eliminates need for oh-board reprogramming
- New echo sounder and altimeter shows height above sea bottom and depth in water column in real time
2700 m (9000') depth rating lets you use one mag for all surveys
- Easy portability and handling - no winch required- single man operation, 44 lbs with 200 ft cable (without weights or depressor wing), new carrying handle
- Combine two systems for increased coverage– Internal CM-221 Mini-Counter provides multi-sensor data concatenation allowing side by side coverage which maximizes detection of small targets and reduced noise
- Two Year Warranty

Specifications

- **Operating Principle:** Self-oscillating split-beam Cesium Vapor (non-radioactive)
- **Operating Range:** 20,000 to 100,000 nT
- **Operating Zones:** The earth's field vector should be at an angle greater than 60 from the sensor's equator and greater than 60 away from the sensor's long axis. Automatic hemisphere switching.
- **CM-221 Counter Sensitivity:*** <0.004 nT/ pHz rms. Typically 0.02 nT P-P at a 0.1 second sample rate or 0.002 nT at 1 second sample rate. Up to 10 samples per second
- **Heading Error:** <1 nT (over entire 360o spin and tumble)
- **Absolute Accuracy:** <3 nT throughout range
- **Output:** RS-232 at 1,200 to 19,200 Baud

Mechanical

- **Sensor Fish:** Body 2.75 in. (7 cm) diameter, 4.5 ft (1.37 m) long with fin assembly (11 in. cross width), 40 lbs. (18 kg) Includes Sensor and Electronics and 1 main weight. Additional collar weights are 14lbs (6.4kg) each, total of 5 capable
- **Tow Cable:** Kevlar Reinforced multiconductor tow cable. Breaking strength 3,600 lbs, 0.48 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
- **Operating Temperature:** -30oF to +122oF (-35oC to +50oC)
- **Storage Temperature:** -48oF to +158oF (-45oC to +70oC)
- **Altitude:** Up to 30,000 ft (9,000 m)
- **Water Tight:** O-Ring sealed for up to 9000 ft (2750 m) depth operation
- **Power:** 24 to 32 VDC, 1.0 amp at turn-on and 0.5 amp thereafter

Standard Accessories:

View201 Utility Software, operation manual and ship kit

Optional:

Telemetry to 10Km coax, gradiometer (longitudinal or transverse), reusable shipping case

MagLog Lite™ Software:

Logs, displays and prints Mag and GPS data at 10 Hz sample rate. Automatic anomaly detection and single sheet Windows printer support

SIS-1625 Seafloor Imaging System

SIDE SCAN SONAR / PROFILER



ACOUSTICS

FLOTATION

GEOPHYSICAL

HYDROPHONES

MODEMS

LOCATOR

ROBOTICS

Combined Chirp/CW Side Scan Sonar/ Sub-bottom Profiling System

The SIS-1625 Seafloor Imaging System has quickly become the industry standard for shallow water (<2000M) seafloor survey operations. This field proven, highly versatile survey tool offers a fully digital platform capable of collecting high resolution chirp side scan/sub-bottom data, as well as a full suite of customer selected sensor data. The high resolution, extended range chirp data and multiple data sensor capability provide the surveyor with a significant savings in instrument cost and survey time.



One Workstation

Topside system consists of:

- Chirp DSP based side scan sonar, operating at 100/400 kHz simultaneously, allows a full 1000 meter swath, with resolution equivalent to much higher frequency systems.
- Chirp DSP/CW based sub-bottom profiling, operating in the 1 to 10 kHz region, allows maximum sediment penetration with greatly improved resolution.
- Gain, TVG, image correction, color palette, and other programmable parameters are under trackball control.
- Digital interface provided for thermal graphic recorders.

One Tow Vehicle—TTV-290

The TTV-290 is a fully digital platform with standard Chirp side scan/sub-bottom transducer arrays, digital multiplexor, subsea electronics, and RS-232 ports for optional sensors.

- Hydrodynamically stable tow vehicle includes pitch, roll and heading sensors, optional position responder/transponder, and other customer selected sensors.
- 0.5° side scan sonar horizontal radiation pattern, combined with broad band Chirp DSP match filter processing, provides optimal cross-track and along track resolution.
- Tow vehicle operates in depths up to 2000 meters.



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www.benthos.com

SIS-1625 Seafloor Imaging System



One Cable—CL-160 Communications Link

The comm link was designed through a program to develop a full ocean depth telemetry module for a multisensor seafloor mapping system.

- Two-way communication with tow vehicle over single coax with digital high speed multiplexor. Standard cable length—up to 10,000 meters.
- Digital multiplexor for single coaxial tow cables. Communication rates: sonar data—up to 5 megabit/sec; uplink status—9600 bits/sec; downlink command—9600 bits/sec.

SPECIFICATIONS

CL-160 Shipboard Sub-System

Chirp Processing:	Sonar/status control PC based workstation; 5-DSP based sonar matched filter processing channels.
Display:	High resolution video display.
Recording:	Large capacity hard drive, DVD writable, other..
Status Display:	Vehicle pitch, roll, heading (standard); speed, altitude, and depth (optional). Customer input ship position, vehicle position, event marks; all status data recorded.
Sonar Display:	Side scan port, starb; dual channel sub-bottom; all sonar data recorded.
Corrections:	Slant range and speed; beam angle/grazing angle.
Multiplexor:	Digital MUX for coaxial cables (ADSL).
Sonar Data:	up to 5 megabit/sec.
Uplink Status:	9600 bit/sec.
Downlink Command:	9600 bits/sec.
Power Supply:	110/220 VAC autosensing.

Side Scan

Side Scan Transducers:	Multi-element array, dual channel 100/400 kHz 0.5° horizontal beam; 60° vertical beam.
Frequency:	100/400 kHz band swept FM; 4.5 cm resolution.
Processing:	Calibrated transmit waveform stored in ROM; match filter FFT digital signal processing.
Swath Selection:	25 meters to ±500 meters.

Sub-Bottom

Transducer:	Transmit projector array; line array receiving hydrophone; 30° conical radiation pattern.
Frequency:	1 kHz to 10 kHz swept FM (4 KW output), synchronous with side scan.
Resolution:	5 cm.
Processing:	Calibrated transmit waveform stored in ROM; matched filter FFT digital signal processing.
Scale Selection:	25 meters to 500 meters full scale.

TTV-290 Tow Vehicle Sub-System

Depth rating:	2000 meters.
Vehicle Dimensions:	18 inches (45 cm) OD x 64 inches (162.6 cm) long.
Weight:	In air: 300 lbs (136 Kg); in water: 170 lbs (77 Kg).



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SERIES
DC 200
GPS/GLONASS L1/L2 RTK RECEIVER



One Button. Millions of Signals.



AD Navigation DC200-series GPS/GLONASS L1/L2 RTK Receiver

With a 19" rack form factor, the new DC-200 series RTK receivers from AD Navigation provide real time positioning data at the 1 cm level while attaining the highest reliability and stability possible. The DC-200 series RTK receivers are specifically designed to meet the most demanding requirements from the hydrographic and dredging industries.

Unique Advantage of Seamless Combination GPS and GLONASS

The heart of the AD Navigation DC-200 RTK receivers is built around the world's most advanced GPS/GLONASS L1/L2 technology. By seamlessly combining the GPS and GLONASS system, the DC-200 series RTK receivers access the total of 40 positioning satellites. During normal operation, the DC-200 series RTK receivers track 30-50% more satellites than does a GPS-only system.

Integrated High Quality UHF Receiver

The DC-200 series RTK receivers integrate a UHF receiver. By using diversity receiver techniques (dual antenna system), reception of the UHF signal is significantly improved, even under difficult radio conditions. The base station sends CMR corrections at up to 5Hz. The diversity receiver technique, in combination with high update rate of CMR correction broadcasts, results in operational RTK up to 80 kilometres from the RTK base station!

Optional Heading

As an attractive option, the DC-200 series can offer precise heading. With two GPS/GLONASS antennas installed, accuracies of 0.01 deg are achieved at 10 times per second. The unit contains no moving parts, and neither calibration nor maintenance is needed.

User Friendly 19" Rack System

This state-of-the-art technology is available in a 19" rack form factor, making your installation very easy. GPS/GLONASS, UHF radio, and PPS TTL device, are all built into one box. User configuration is minimal; the receiver installation is plug and play.

RTK Reference Station

For RTK Operation, AD Navigation supplies the compact DC201B as GPS/GLONASS L1/L2 Reference Station.



Let the waves rock your boat ... not your GPS



User Experiences

For some time now, the Survey and Dredging Departments of the Port of Rotterdam Authority have been using this technology from AD Navigation on all of their hydrographic vessels.

“We have been using various RTK positioning systems for almost a decade, and up until now, have seen inconsistent GPS performance. With the DC-200 series RTK receivers from AD Navigation, our down time as a result of poor GPS/RTK performance and satellite drop-outs is now reduced to zero, even under the most difficult satellite tracking conditions close to large vessels, buildings, bridges and container cranes.”

Jeroen van Reenen
Head of the Hydrographic Department
Port of Rotterdam

Highlighted Features

- GPS/GLONASS L1/L2 Tracking
- 5 Hz Update Rate (20 Hz optional)
- Precise Heading Option
- Integrated UHF with Diversity Reception
- WAAS/EGNOS Capability
- Integrated PPS with TTL Pulse, RS232
- 4x DB9 Com Ports
- 19" Mounting Rack System

One Button. Millions of Signals.

Technical specifications

Tracking:

20 Channel Dual Constellation (DC) GPS/GLONASS L1/L2

Cold start: < 60 seconds

Warm start: < 10 seconds

Reacquisition: < 1 second

Processing: Co-op Tracking and Advanced Multipath Reduction

DC200 Series RTK Positioning¹ and Heading Accuracies²:

Horizontal: 1 cm + 0.15 ppm RMS (DC201/202)

Vertical: 1.5 cm + 0.15 ppm RMS (DC201/202)

Heading: 0.01 degrees RMS (DC202 only)

Update Rate:

Positioning: 5Hz (DC201/202) 20Hz Optional

Heading: 10Hz (DC202 Only) 20Hz Optional

RTK Initialisation¹: Typically 10-30 seconds

Operating Range³: Up to 80 km

Built-in UHF Radio Modem:

Frequency Range: 380-470 MHz

25 KHz Channel Separation

19,200 bps on Air Transmission

Diversity Reception (Dual Antenna System)

Timing:

External PPS Output

PPS to TTL converted to RS232 Interrupt Signal

Output formats:

GPS based NMEA-0183 Messages

Proprietary ASCII and Binary Output Formats

CMR/RTCM, Differential Corrections

Input Formats:

CMR/RTCM, Differential Corrections

Accessories:

GPS/GLONASS L1/L2 Marine Antenna

AC and DC Power Cables

DB 9 Serial Cables

Physical specifications

Power input: 12-28 VDC or 110-230 AC

Size: 2U 19" rack unit, 254 mm (d), 89 mm (h)

Weight: 4.8 kg

Environmental: Vibration, EMI: EN 60945

Temperature:

Operation: -20 to 55°C

Storage: -40 to 70°C

Communications:

4 x RS232 com ports, DB9, 115,200 bps

1 x RS232 TTL, DB9

1 x PPS output, BNC-F

1 x GPS antenna input, TNC-F (N optional)

2 x UHF antenna input, TNC-F (N optional)

¹ Performance is dependent on GPS/GLONASS satellite geometry, environment, ionospheric conditions and distance to the base station

² Antenna separation > 10 meter

³ Operating range is depending on availability of differential correction data

Note: Specifications subject to change without notice.

www.adnav.com



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GROUP OF COMPANIES

Client: **GEUS**
Lars Rödel

Femern campaign. RTK: Reference stations. Positioning Systems

Ref: Femern
Date:19-06-2009
Ver: final_ver1

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1. INTRODUCTION

EON operates one RTK reference station at Rødsand-2HR2. The RTK reference signal are broadcasted to all vessels via UHF, at frequency 449.100Mhz
This reference station is intended to be used initially throughout the area.

The base line is 10-28 km for the reference station at Rødbyhavn. The worst case accuracy is 5.5cm (XYZ, Equipment spec: 1.5cm+1.5ppm)

Starting with in-survey and geological investigations in 2006, this reference station has been used for the entire work.

The reference station coordinates has been verified by a chartered surveyor, using GPSnet-DK. Survey report can be requested.

For additional information, report malfunctioning etc.
Please contact Dansurvey.
Phone +45 45354585.
Mail jd@dansurvey.dk

2. GEODETIC PARAMETERS.

Geodetic Parameters:

**UTM-EUREF-89. Zone 32N
Vertical reference, DVR90**

As there is no official transformation between WGS84 and EUREF89 at Rødsand 2, a 7 parameter transformation cannot be provided.
Presently work concerning a transformation between WGS84 and EUREF89 is in progress by officials. (KMS)

3. HEIGHT REDUCTION TO VERTICAL REFERENCE DVR-90.

The geoids model DVR-90 is an attempt to be MSL in 1990±10y. The model is accurate for the in-ways Danish water, and may not be absolute accurate to MSL at the Femern area

In 2004, officials decided at all surveys, charts, C-maps and construction work shall use DVR-90 as vertical reference.

The height reduction to DVR90 can be carried out in one of three ways.

- a.) The official geoids model, filename 'dvr90g2002.01'
This is a binary data file, which can only be handled by GPS manufactures and acquisition software,, which equipment are custom designed to import this file format.
- b.) Fixed separation. A fixed separation can be calculated by use of the official program KMSTrans2007.
- c.) Use interpolation model in sub-contractors acquisition software.

Link to Transformation software.:

<http://www.kms.dk/English/Geodesy+and+Surveying/Transformation/>

Download the program KMSTrans2008, and the responding geoids model dvr90g2202.01

4. PRIMARY POSITIONING SYSTEM. (ROVER)

The primary positioning system shall be RTK using GPS L1/L2. The GNSS receiver shall be capable of operating at long baselines
The accuracy archived all depends on the rover supplied by the subcontractor.

Please pay notice to the installation of the rover antenna. The GNSS antenna should have best possible free view to the horizontal above 12 degrees.
Alternative there's a risk that the rover measurements gets unstable, running on multi path signals."

The elevation mask on the rover should be set to 12'. Our experiences indicates that - using not too low elevating mask when working on long baselines with different GNSS antennas.

The UHF antennas must be mounted in sufficient height to receive the reference at Rødbyhavn, (Line of sight) and further the antennas must have free horizontal view to avoid obstructions to block out the signal.

The UHF radio shall have 1-way connection only on the serial connection. This to insure the vessels rover can't cause the UHF radio to transmit, and by this interfere/jam the signals from the reference stations.

A positioning verification shall be carried out and demonstrated prior to the contractual work is initiated.

All systems and software used for navigation and transformation to DVR-90, shall be included in the verification.

(GNSS receiver, Acquisition software, Vessel reference unit, Vessel local reference measurement, etc.).

5. RØDBYHAVN RTK. REFERENCE, SPECIFICATION.

ID1: Reference Station: Rodbyhavn	
Station Name	Station ID No: 1 Short ID: Rodbyhavn Long ID: Rødsand2
Reference Station co-ordinates. Geo_EUref 89 (WGS84) (WGS84)	Lat 54 39'18,81503 N Lon 11 20'57,32698 E Ellipsoid h = 90,314 m (Ant. APM to APC = 0.054+0.002m) Base-station h. 90.370 m (Entered value)
Reference Station co-ordinates. EUref 89 UTM Zone 32N	N 6058961.349 m. E 651550.376 m. DVR 90 h = 51.865 m. Geoide sep. 38.449 m (DVR90)
GNSS RTK receiver.	AD-Navigation model DC201B. L1/L2 GPS/GLONASS RTK receiver.
Measurements sent.	CMR format. (Reference coordinates = Antenna APC) GPS CA/L1,+P/L2, GLONASS L1 Update rate 5 hz. Time slot. 0.5 Period 0.25sec TX delay, 0.0s,
TX UHF radio specifications.	Telemetry: Satel 3AS Epic Frequency 449.100 Mhz , No addressing. TX power 10watt. Baud rate (Air) 19200. Omni directional antenna. (5db)
Rover telemetry: RX UHF Radio. (Recommended)	Telemetry: Satel 3AS Epic. Space diversity (Two antennas) Frequency 449.100 Mhz , . No addressing. Baudrate (RS232) 19200. Programmable. RS232 Connector DB9-F. RXd pin2.GND pin5. Pin 3 (TX) must not be terminated due to risk of interference.
Additional Information.	a.) DC-UPS, 30hours back up at 24volt. b.) Internet connection, fixed IP c.) GSM alarm & control. (SMS)

Figure 1: Rødbyhavn
GNSS antenna (LH) & UHF.

Coming up soon



6. PUMPESTATION: RTK. REFERENCE, SPECIFICATION.

ID2 Reference Station: Pumpestation	
Station Name	Station ID No: 2 Short ID: PumpeStation Long ID: Rødsand2
Reference Station co-ordinates. Geo_EUref 89 (WGS84) (WGS84)	Lat 54 04.65043N Lon 11 28 18.00532 E Ellipsoid h = 45.5157m (Ant. APM to APC = 0.054m) Base-station h. 45.5697 m (Entered value)
Reference Station co-ordinates. EUref 89 UTM Zone 32N	N 6055086.8232 m. E 659591.4277 m. DVR 90 h = 7.154 m. Geoid sep. 38.3615 m (DVR90)
GNSS RTK receiver.	AD-Navigation model DC201B. L1/L2 GPS/GLONASS RTK receiver.
Measurements sent.	CMR format. (Reference coordinates = Antenna APC) GPS CA/L1,+P/L2, GLONASS L1 Update rate 2 hz. TX delay, 0.25s, 0.25 time slot. Period 0.5sec
TX UHF radio specifications.	Telemetry: Satel 3AS Epic Frequency 449.100 Mhz , No addressing. TX power 10watt. Baud rate (Air) 19200. Omni directional antenna. (3db)
Rover telemetry: RX UHF Radio. (Recommended)	Telemetry: Satel 3AS Epic. Space diversity (Two antennas) Frequency 449.100 Mhz , . No addressing. Baudrate (RS232) 19200. Programmable. RS232 Connector DB9-F. RXd pin2.GND pin5. Pin 3 (TX) must not be terminated due to risk of interference.
Additional Information.	a.) Internet connection, fixed IP b.) Not 24 hours accessible



Software for Earth Science Mapping and Processing

"The raw power that Oasis montaj provides for quickly and easily creating and recreating grids, tweaking colour bars, recontouring, and doing real time sun shading with different orientations of lineaments, is not available in any other software program..."

Bill Pearson, Pearson Technologies Interactive Visualization



Why Oasis montaj?

A leading exploration technology solution, Oasis montaj provides a scalable environment for efficiently importing, processing, viewing, analyzing and sharing large volume geophysical, geochemical and geological data, all within one integrated environment.

This powerful mapping and processing software is designed to support and streamline your daily problem solving needs, with a rich set of easy to use features that meet and exceed rising global standards.

Join the global leaders in earth exploration and geosciences currently using Geosoft® Oasis montaj™ technology, to increase productivity and profitability.

Use Oasis montaj for:

Oasis montaj provides a complete data experience, including data access, processing, interpretation, data sharing and decision making.

Industries that use Oasis montaj:

- Mineral exploration
- Government Geological Surveys
- Oil and Gas Exploration
- UXO (Unexploded Ordnance) detection
- Environmental
- Education

"We remain focused on usability and productivity advances within the Geosoft environment, allowing us to put more power, flexibility and control into the hands of our clients. This focus is the foundation of our vision to help geoscientists recapture time lost to handling and working with data, so they are free to explore."

Louis Racic, Geosoft Product Management Director



Proven ROI

A proven industry standard technology, Oasis montaj achieves long term savings in both time and money. Integrated productivity tools maximize your ability to make strategic use of large volumes of geoscience data within today's compressed project time lines.

- Access all available data for a complete investigation and informed decision making.
- Collect and view data for quick site assessment in the field, or use Oasis montaj for in depth processing and analysis.
- Create sophisticated visualizations to guide subsurface exploration.
- Construct professional quality maps of complex 3D earth models for sharing your information with colleagues and investors.

Key Features

Professional map-making

Whether you're a geologist, geochemist or geophysicist, easily create maps to share, integrate data and use in presentations. Quickly access standard map templates from the template library or customize your own. Templates are fully scriptable for power users.

Subsurface 3D visualization simplifies viewing and analysis

3D capabilities in Oasis montaj software responds to the growing emergence of 3D visualization as the standard for integration and analysis of interdisciplinary data. Its stability, usability, axis display and voxel manipulation enable you to quickly integrate all your data, from surfaces, drill data and geophysical models.

Seamless interoperability

Oasis montaj supports a large range of data formats, including point data, grids and images, vectors and 3D data, through native format support or import/export. We support a large variety of instrument data formats, GIS layer formats, ODBC links to databases as well as to wire frame and block model formats. We support most commonly used data formats to ensure seamless interoperability within our environment.

Pinpoint map data, through dynamic linking

Oasis montaj includes built-in dynamic linking between, and among, imagery, maps, profiles, graphs, data and metadata, in one, two and three dimensions. Click on a point on a map and immediately see the exact data point within the appropriate profile, graph or data view. Ideal for QA/QC, it provides a quick, yet powerful way to visually link common features or areas of interest. It makes anomaly location and target selection quicker and more efficient. It also adds value throughout your project lifecycle, by enabling you to interact with data and immediately evaluate results.

Advanced gridding capabilities saves you time

Gridding algorithms with Oasis montaj are fast, efficient and optimized for large-volume geoscientific data. This enables you to interpolate data and to produce grids, using minimum curvature, bi-directional, trended, gradient, tinning and kriging gridding routines. Grid processing and enhancement tools include interactive shading display, grid windowing, the ability to create shaded relief grids and display grid outlines. An array of advanced grid utilities include: grid filters, locating grid peaks, boolean operators to merge overlapping grids, grid math functions, calculating grid volume and grid masking.

High-performance database

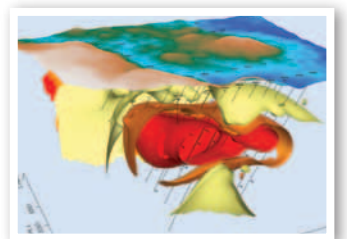
The built-in, high-performance database provides efficient storage for very large geoscientific data sets. Direct access to data contained in the database is provided through a spreadsheet and an integrated profile display window. The database is the key advantage for working with large datasets at each stage of the project lifecycle, from acquisition, storage, processing and analysis through to visualization and integration with other data and information.

ESRI Integration

ESRI technology is built into Oasis montaj ensuring the seamless creation, viewing and sharing of ArcGIS MXD and Geosoft Map files between Geosoft and ArcGIS users.

Built-in data access technology

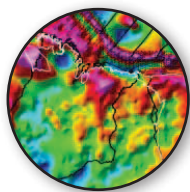
For complete investigation and informed decision making, use Dapple Globe Viewer to find, display and extract more data from a variety of data servers. You can search internal as well as public servers, including DAP, ArclIMS, and Tile servers, without leaving the Geosoft environment.



Advanced geophysical, geological and geochemical analysis

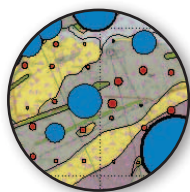
Geosoft montaj extensions and montaj plus extensions make Oasis montaj one of the world's most robust and comprehensive geoscience mapping and processing systems. Extensions are available for advanced geophysics and geochemical data processing, analysis and quality control, 3D drillhole plotting, gravity and magnetic filtering, levelling, interpretation and other functionality.

montaj extensions



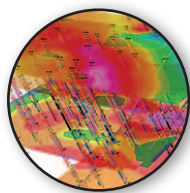
Geophysics

Provides a range of filters and statistical tools for working with large volume geophysical data. Spatial 1D filters enable field geophysicists to process data by applying a variety of space-domain filters (linear and non-linear). The 1D FFT filter enables you to apply a variety of Fourier domain filters to one-dimensional (line) potential field and other data. A variety of geostatistical tools provide the ability for summary and advanced statistics, including histogram, scatter and triplot analysis, and the ability to subset data based on rock code or map group classification.



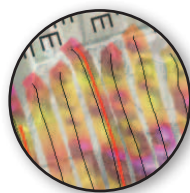
Geochemistry

Provides QA/QC tools, analytical tools and advanced mapping techniques for surface and subsurface geochemistry. Easy to use Standards and Duplicates handling simplifies the quality control process. Multi-element geochemistry analysis is made simpler with interactive histograms, scatter plots, probability and ternary plots to identify outliers and populations. This extension also includes SEMPlot, a simple to use workflow for analyzing indicator mineral grain geochemistry in diamond exploration.



Drillhole Plotting

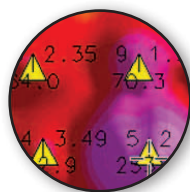
Allows quick, easy and accurate production of presentation quality drillhole section and plan maps. It enables geologists to set up drill projects, manage results dynamically, and interpret results for follow-up drilling and



decision making. The extension includes plan, section, stacked section, strip logs, fence diagrams and 3D visualization. Other capabilities include anisotropic 3D gridding, iso-surface and lithology surface creation and compositing of drillhole data.

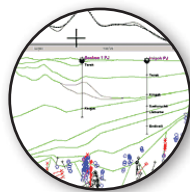
Airborne Quality Control

Provides essential tools for planning an airborne survey, and meeting basic tender specifications. Includes flight path planning tools, the ability to monitor the survey progress, and streamlined quality control (QC) tools. A built-in mapping wizard automatically displays QC results. Quality control functions provide the ability to perform tests for altitude deviation, flight path deviation, flight line separation, sample spacing, diurnal drift and magnetic noise.



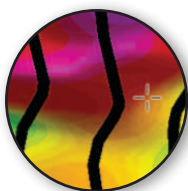
UX-Detect

Provides unique capabilities for locating and analyzing UXO targets, based on magnetic (total field and gradiometer) and electromagnetic data. Use UX-Detect to quickly locate the ground position of potential UXO targets in large volumes of data and narrow these selections to a final target list. Geophysical correction tools identify and remove noise in data from sources such as background geology or instrument inherent sources.



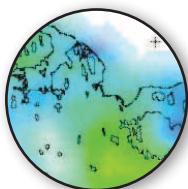
Depth to Basement

Provides an automated method for determining the position, dip and intensity of magnetic source bodies for a magnetic profile. The depths are determined using Werner Deconvolution, Analytic Signal and Extended Euler Deconvolution. With large, distinct density contrasts, the extension can also be used on gravity profiles to determine the position of gravity source bodies.



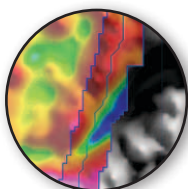
Geophysics Levelling

Incorporates advanced tools for processing and enhancing airborne magnetic and other geophysical data. A step-by-step methodology for accomplishing a variety of levelling and correction tasks. The microlevelling toolkit enables you to perform microlevelling corrections on line-based data.



Gravity and Terrain Correction

A complete system for processing and reducing gravity data from conventional surveys. Apply terrain corrections from digital elevation models or gridded elevation data. With the streamlined menu system, perform all the standard gravity processing steps quickly and easily. And the uniquely optimized terrain reduction algorithm delivers accurate corrections quickly, even for very large data sets.



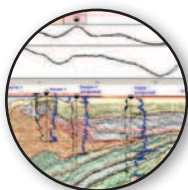
Gridknit

Delivers two advanced methods for rapidly and accurately merging virtually any pair of geophysical grids. The blending method quickly merges grids via standard smoothing functions. The suturing method enables you to automatically or manually define a join path, then applies a proprietary multi-frequency correction to eliminate differences between the grids along the path. "Postage stamp" stitching allows easy insertion of high resolution grids into regional backgrounds.



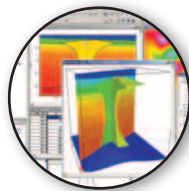
Grav/Mag Interpretation

Automatically locates and determines depth for gridded magnetic and gravity data with Euler 3D Deconvolution processing routines. Euler 3D automates 3D geologic interpretation by delineating magnetic and gravimetric boundaries, and calculating source depths. Also includes the Keating Magnetic Correlation Coefficients tool for kimberlite exploration. This tool uses a simple pattern recognition technique to locate magnetic anomalies that resemble the response of modeled kimberlite pipes. A Source Edge Detection tool locates edges (e.g. geological contacts) or peaks from potential field data by analyzing the local gradients. The Source Parameter Imaging tool quickly and easily calculates the depth of magnetic sources.



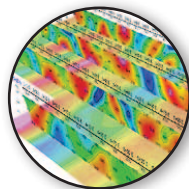
GM-SYS Profile Modeling

Using a user-friendly and interactive interface, create a geologic model and compare its gravity and magnetic response to observed measurements. Basic, Intermediate and Advanced profile modeling are available based on your requirements.



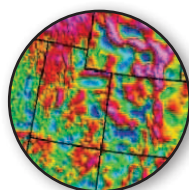
GMSYS-3D Modeling

Design three dimensional models that depict the variation and irregularity of subsurface structures within this interactive layer based gravity and magnetic modeling extension. The user-friendly interface provides easy model creation, visualization and manipulation. The inversion module and the ability to import constraints from other sources simplifies the creation of a well-constrained model.



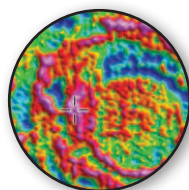
Induced Polarization

Designed for both contractors and in-house geophysicists, this extension performs a variety of tasks on your IP data including: import, quality control, processing, gridding, and plotting. Import, perform basic quality control, process, and present data from both time and frequency domain surveys. Import time-domain or frequency-domain data in Zonge, Iris, Scintrex, Phoenix and Geosoft formats. Process data from dipole-dipole, pole-dipole, pole-pole, or gradient surveys. Automatically calculate apparent resistivity, metal factor, IP, self potential and individual time slices. Evaluate duplicate samples with the unique quality control tool. Filter your data using standard pant-leg filters. Produce pseudo-section presentations, including stacked sections, and instantly convert your stacked sections to display in three dimensions.



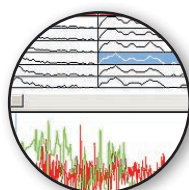
Isostatic Residual

Calculate a depth to the Moho (the "root") using the topographic grid, terrain density, Moho density contrast and depth of sea level compensation. It then calculates the 3D gravity response of that root at sea level, out to 166.7 km. We use a modified version of the USGS algorithm to calculate the Airy isostatic regional and residual gravity from a topographic grid.



MAGMAP Filtering

Utilizes a 2D-FFT filter library to allow the application of common Fourier domain filters to gridded data in Oasis montaj. MAGMAP rapidly processes and enhances gridded datasets by applying a wide range of robust geophysical and mathematical filters. Easily apply multiple filters together, modify selected filter parameters, and define and apply your own filters.



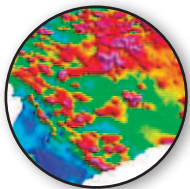
256-Channel Radiometrics Processing

Provides the capability to visualize and process 256 channel spectrometer data. From a data handling and processing perspective, there are three main phases in airborne spectrometer surveying: acquisition, processing and presentation. This extension is designed specifically for processing raw data collected from airborne surveys.

Expand your capabilities with **montaj plus** partner extensions

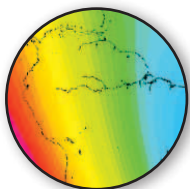
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montaj plus extensions



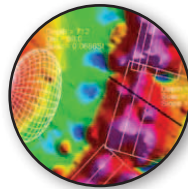
Compudrape

Drapes any potential field profile or gridded data to any reference surface. The Compudrape extension performs height continuation on aeromagnetic profile data, to transform it from the original magnetic field on an arbitrary observation surface to the magnetic field on a new surface of specified height. The primary uses are to drape barometric or loose drape surveys to a tight drape, drape over the basement surface, transform drape-flown surveys to barometric and apply height corrections to minimize line-to-line effects.



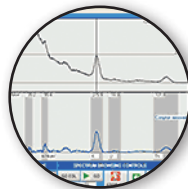
Grav/Mag Filtering

Create a grid that is reduced to the pole everywhere with a Continuous Reduction to the Pole function. It also enables you to calculate Total Magnetic Field from Measured Horizontal Gradients.



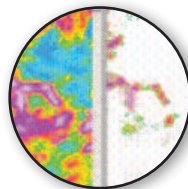
PotentQ Modeling Lite

Provides rapid semi-automatic modeling of a single magnetic and/or gravity anomaly. A specially formulated inversion scheme generally requires no user intervention. PotentQ is a simplified and streamlined version of Potent, GSS's mainstream potential field modeling tool. The model consists of a single body chosen from one of seven possible geometries.



Praga3

Provides an advanced solution for processing of whole spectrum gamma-ray spectrometry data, acquired by modern spectrometers using NaI(Tl) detectors. This extension includes a spectrum browser with tools for peak identification, advanced full spectrum processing using least-squares fitting techniques, principal component (NASVD or MNF) analysis, spectrum restoration and complete solutions for radon background removal.



Predictive Targeting with Neural Networks

Highlight new exploration targets using neural network simulation. Predictive Targeting is a two step process. First, apply neural network training to your known targets to generate a target signature, then apply neural network simulation to locate similar signatures. This extension allows you to integrate a wide variety of gridded data types (e.g. geology, geophysics, geochemistry, remote sensing, topography) for robust and unbiased target generation.



SHARE DATA WITH ANYONE

Download your **free** Oasis montaj Viewer

Use the Oasis montaj viewer to share all your maps, grids and interpretations created in Oasis montaj. As an added bonus, the viewer can complete a wide variety of grid conversions and print capabilities.

>> Visit www.geosoft.com for your copy.

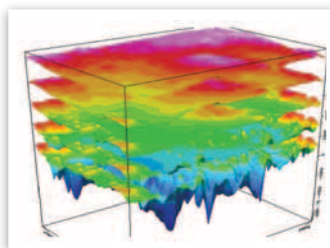


ABOUT GEOSOFT

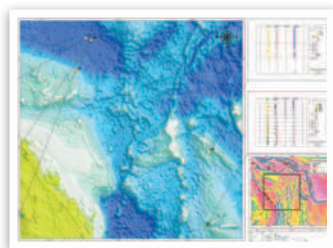
For more than 20 years, Geosoft has pushed the boundaries of earth science exploration, by providing software tools that maximize workflow efficiency, accuracy and integration. With offices in North America, South America, Europe, South Africa, United States and Australia, Geosoft is a global leader in delivering next-generation software solutions and services to progressive exploration companies around the world.



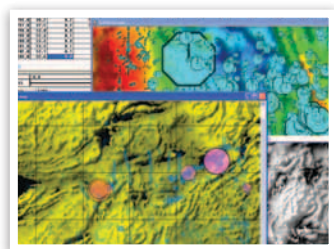
Easily produce multiple map sheets.



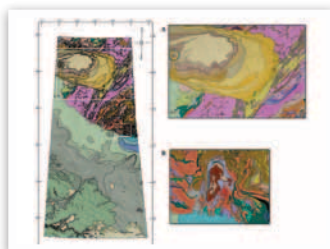
Complete 3D interpretations.



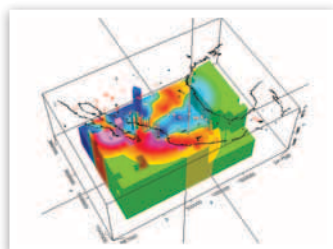
Produce professional quality maps.



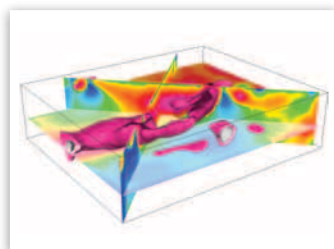
View multiple symbol plots.



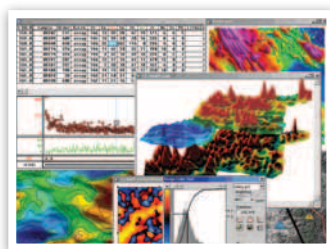
Access all data with Dapple globe technology.



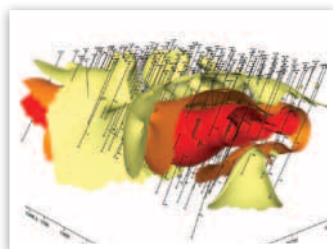
Integrate vectors with 3D grids .



Slice 3D voxels.



Integrate all your data in one environment.



Generate isosurfaces from voxel data.



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www.geosoft.com



Magnetometer Data Processing

MagMap 2000

■ **Powerful Windows Program for Processing Land-Marine Mag, OhmMapper MetalMapper EM61 Data**

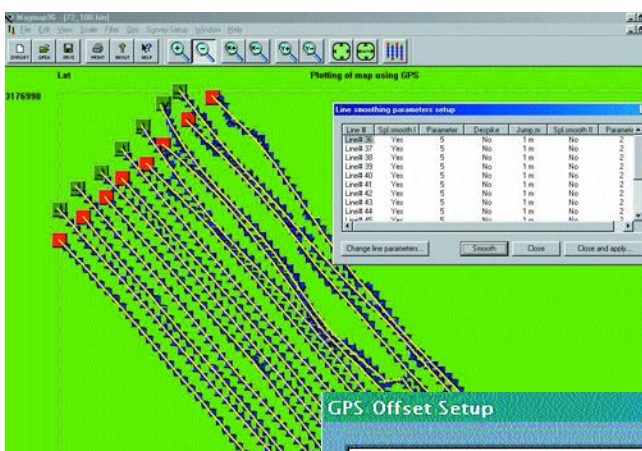
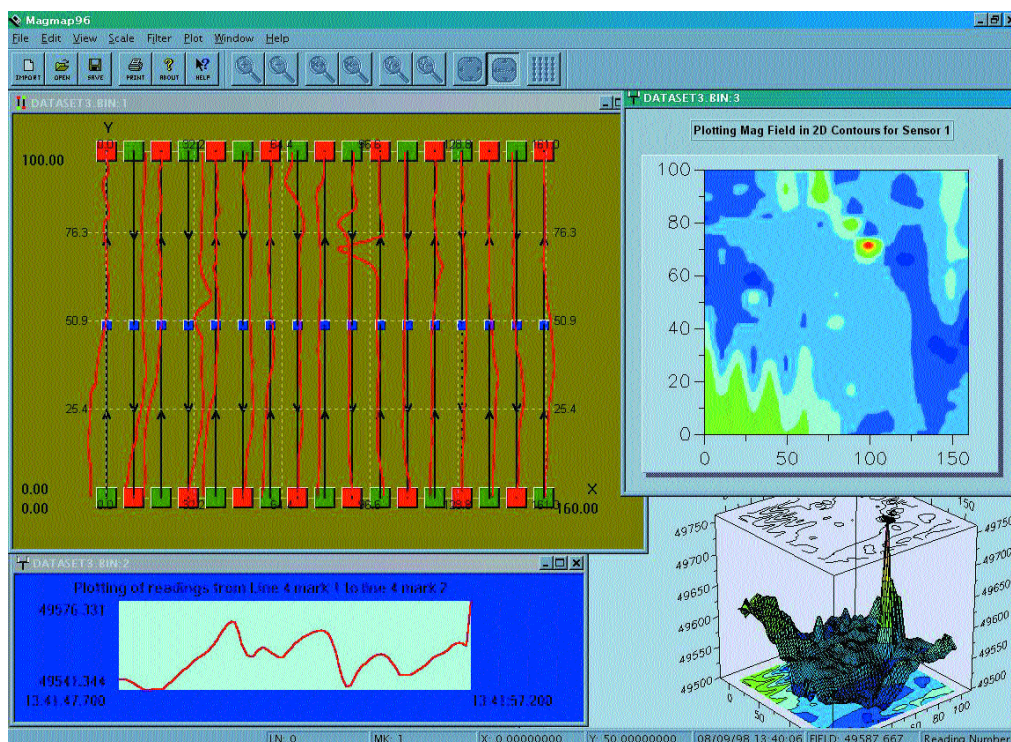
■ **Provides Download, Diurnal Correction, Repositioning and Profile Plots**

■ **Full GPS Support with UTM Conversion AND Sensor-GPS Antenna Offset Computation**

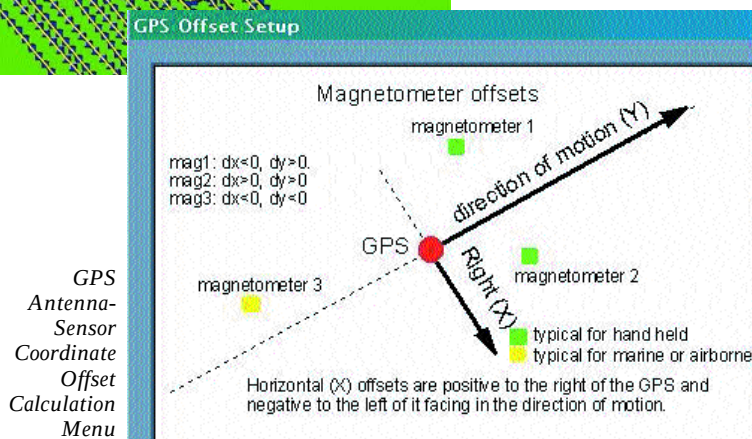
■ **Performs Sensor Data AND GPS Position Filtering, Despiking, Smoothing**

■ **Plots Profile Data Right on Track or Position!**

■ **Generates 2D/3D Color Contour Plots and Shaded Relief Maps**



GPS
Position
Trackplot
Smoothing
Feature



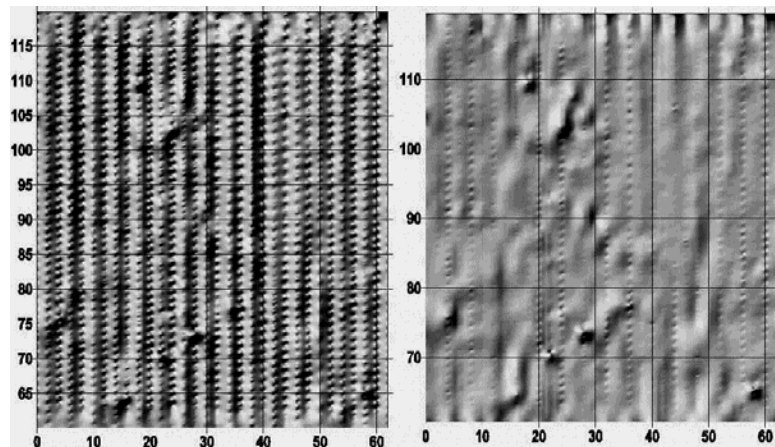
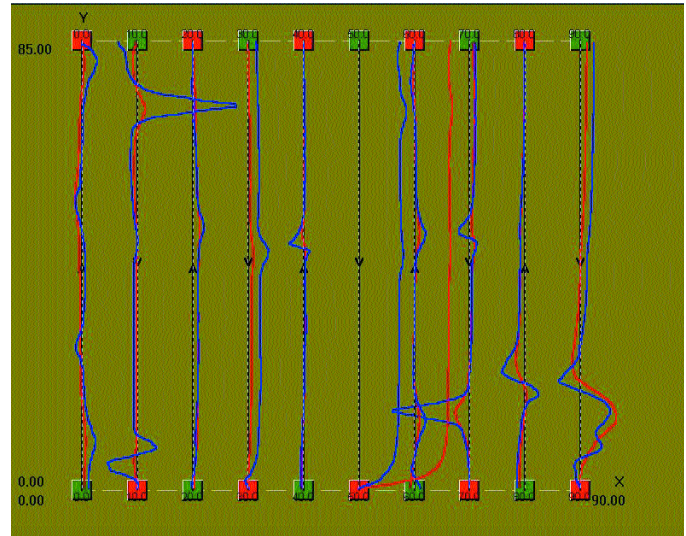
Geometrics legendary “**free**” magnetometer support software just became more powerful and feature rich. As the new name symbolizes, we have added more facility for correcting, filtering, repositioning and plotting magnetometer data as well as OhmMapper, MetalMapper and EM61 data to support our customers in 2000 and beyond. In addition, we now offer a new feature that provides easy-to-use destriping (removal of heading error) and period filtering along the line (stride noise removal). These algorithms provide unparalleled control and automation in processing high sensitivity land and marine magnetometer data.

Recent improvements include one-button color contour equalization for more representative contour maps and a shaded relief map feature which heightens detection of small anomalies while suppressing long wavelength geologic features.

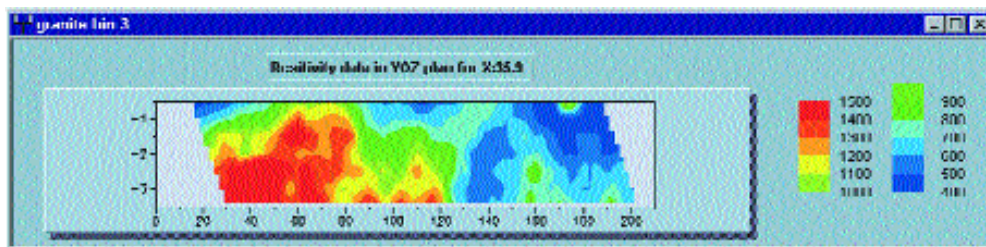
MagMap2000 provides data handling capabilities for the entire suite of Geometrics man-portable magnetic and electromagnetic equipment including the OhmMapper Resistivity system and new GTEM Metal-Mapper which uses time-domain metal-detector technology. In addition, its unique features may be used with other instruments such as the Geonics EM61 and GSSI GEM300 or almost any ASCII columnar data in x, y (Lat-Long), z format using the new data import routine. Powerful GPS support allows the user to smooth the GPS path, remove position spikes, transform the data into UTM coordinates using various ellipsoid datum **and add offsets between the GPS antenna and magnetometer or other sensors!** This provides data sets which are free of positional “tears” and less linear feature distortion in the final map. The program exports in Surfer, Geosoft, RES2D/3DINV and as standard ASCII x, y, z file formats.

MagMap Software is available for immediate download from our website — www.geometrics.com. If you are using a Geometrics G-856, G-858, OhmMapper, MagSea, MagLogNT or MagLogLite hardware or software product, please obtain the latest version now. You will be pleased that Geometrics continues to support our large customer base with the very latest in application support **at no charge**.

Dual
Magnetometer
Vertical
Gradiometer
Profiles



Results of
Destriping
and
Periodic
Noise
Removal
Feature



MagMap2000 display of resistivity pseudosection from OhmMapper TR1 data

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Isis Sidescan Acquisition Software

This complete software suite has the options of logging the sidescan and the sub-bottom profiler data, process the data and produce a mosaic image of the seabed as shown in the figure. It has the ability to export these images in a geotiff format which can be read directly by any GIS software, like MapInfo.



ISIS online mosaic screenshot.

ISIS continues to be the most advanced sidescan sonar acquisition system available today. Isis® Sonar™ is the tool of choice for a variety of applications including: mine-hunting, hydrography, archaeology, environmental studies, oilfield engineering, civil engineering, oceanography, and law enforcement.

Real-time Sensor Quality Control

ISIS offers a wealth of display options to ensure high data quality. Typical windows for monitoring raw sensor information include a waterfall display for the sonar imagery, a signal voltage display for each incoming ping, and a parameter display for navigation, motion sensor, etc., and file storage. A real-time link with TEI TritonMap™ provides for on-line mosaic production, an invaluable tool for assessing seabed coverage and the quality of geo-referencing between adjacent lines (figure 6).

Reliable, Precise Sonar Data Acquisition

ISIS systems are active throughout the world, incorporating over 20 years of field experience in hardware and software design. Incoming sidescan sonar and ancillary sensor data are time-stamped to

millisecond accuracy, thereby ensuring the final data products can be properly corrected during processing. Wide Compatibility,

Compatible with All Sidescan Sonars

ISIS interfaces with any sidescan sonar available today. Analogue or digital, regardless of the manufacturer -- we offer a custom interface that is intuitive to set up and is designed around the sonar's communication requirements. All data are stored in TEI's open XTF (eXtended Triton Format), an industry-standard, non-proprietary format.

Comprehensive Data Correction & Analysis

Numerous tools exist within ISIS for correcting and analyzing data and generating reports. Bottom-tracking, time-varying gain, slant range correction, and layback may all be applied to the imagery on-screen without affecting the raw data being logged. Events, scale lines, and notes can be associated with the imagery. A powerful ASCII report tool allows practically any information stored in the XTF file to be extracted in user-defined formats.

GIS Mosaicing

A mosaicing link exists between Isis® Sonar™ and TEI's TritonMap™ GIS product. These mosaics may be overlain on navigation charts or other background information. Contours, navigation hazards, or contacts may be overlain on the mosaics as they are being built.



Integrated GeoscienceSuites

By tightly integrating our best-in-class geophysical and geologic technologies with powerful data management and mapping tools we have created the ultimate geoscience solution suites that increase asset understanding and provide the highest quality products.

Discovery™

The Discovery™ suite is a Windows®-based geologic and geophysical interpretation system that combines industry-leading technologies supported by a common data and project architecture. Geoscientists use this tightly integrated system to easily interpret reservoirs, support field development and exploit mature assets. The Discovery suite is the ultimate integrated collaborative environment for geologists and geophysicists to develop highly accurate interpretations of their assets or exploration plays.

Discovery™ on OpenWorks®

GeoGraphix Discovery™ technology now directly accesses OpenWorks® and SeisWorks® data and projects without data transfer or replication. Discovery on OpenWorks technology directly links to Landmark's OpenWorks system, the most widely used project data-management application in the exploration and production (E&P) industry. For geoscience professionals, this means that they can choose between any Landmark or Discovery application to support their interpretation process without complicating their project environment.



Utilities

Efficient data management is critical to any oil and gas company, providing an environment where your technical staff is interpreting and not searching for or validating data. Our data management utilities reduce effort and streamline data sharing.

SDE Connect

GeoGraphix's SDE Connect utility enables a direct connection to Oracle® spatial data engines so that you can display lease and cultural information on our mapping tools without exporting, importing and duplicating data. Because this connection is live, you can be confident that your maps are always current with the latest data available. Even create SDE layers as virtual snapshots of your data for when connections to the SDE server are not available or when you take your projects on the road.

SeisXchange™

We realize that many of our customers operate their geoscience IT technologies in a hybrid Unix/PC environment. SeisXchange™ technology reduces the effort to transfer geophysical 2-D and 3-D horizon picks, faults and seismic attributes between Discovery™ and Landmark's Unix-based interpretation tools.

WellXchange™

Want to use both GeoGraphix and Landmark geoscience environments yet are tired of manipulating data between these systems? GeoGraphix's WellXchange™ utility allows you to manually transfer or set up scheduled synchronizations between the Discovery™ GXDB and OpenWorks® databases. Well header, formations, log curves, fault data and production data are a few of the data types handled by this efficient data-transfer utility.



Engineering

GeoGraphix's engineering technologies help reservoir and production engineers maximize your asset's financial performance. Proactively and easily analyze and identify opportunities to optimize production and reservoir recovery.

Dynamic Surveillance System™ (DSS™)

Integrates all the information necessary for engineers to manage their assets. Monitoring all well and operations data enables engineers to proactively identify opportunities to increase production across an asset, while at the same time reducing downtime. By replacing spreadsheets with a dedicated surveillance tool, one engineer can easily manage an asset with more than 500 wells.



Economics Technologies

Designed for companies around the globe, our economic solutions accurately support your wide range of financial decisions, assess and report your company's reserves and help you manage a portfolio of projects all within one integrated system.

Economics Evaluation

ARIES™ System

ARIES™ System combines superior well and project management, sophisticated graphical analysis, and a robust economics engine to forecast production, economics, and reserves for all types of properties and assets. Designed to accurately support financial decisions across your company and forms the foundation for the reserve management and decision support tools described below.

ARIES™ International

Extends the power of ARIES™ technology so you can accurately model complex international fiscal contracts. Easily combines domestic and international results into the reserves and portfolio management systems, saving time and preserving accuracy.

Reserve Management

ARIES™ Reserves Management System (RMS)

Improves evaluation, approval, reconciliation and reporting of reserve values. Increases the accuracy, speed and your control of the results. Built-in government and corporate reports save additional time and effort. With the extra time, companies can easily update and report reserves throughout the fiscal year.

Decision Support

ARIES™ Decision Suite™

Enhances the risk analysis of ARIES™ software through graphical decision-tree analyses that support evaluations of individual economic cases and expected value summaries. Also enables Monte Carlo simulations through links from economic data to Crystal Ball® technology.

ARIES™ Portfolio

Supports capital allocation decisions. It aggregates all the inputs – property type, cash flows, capital expenditure, time frames and more – that managers consider when allocating capital for a project. With all the relevant data in one place, managers can easily create reports that help evaluate the impact a particular project will have on the company's bottom line.

ARIES™ Optimizer

Automates rigorous economic and financial analysis that is cumbersome to do manually. It quickly identifies the most effective combinations in the portfolio data set within the context of your corporate objectives. It helps produce insights which, when combined with your judgment, can produce better strategic decisions and value for your company.



Land Solutions

Because land management is such an integral part of exploration and exploitation of your assets, GeoGraphix has tightly integrated mineral interest and leasehold technology into our mapping system providing the complete picture.

LeaseMap®

GeoGraphix's LeaseMap® application is a powerful yet easy to use land-management tool that provides a complete understanding of any region's mineral interest and leasehold situation. Using industry standard reports and interactive maps, LeaseMap software helps you identify the details and status of mineral and lease holdings across your assets or in an area of interest. The lease information can be integrated with our mapping tools displaying geologic, geophysical and engineering data.



Our Strategy

Our vision is to help our customers optimize production and maximize their return on investment by providing the most comprehensive software solutions on a windows-based platform.



Geology Solutions

GeoGraphix's high-performance geology solutions are tightly integrated into either one of the two bundled mapping systems or geologic interpretation systems – four systems total, all designed to support basic and advanced geologic workflows.

Advanced Well Log Correlation

Whether you are trying to understand a regional trend or identify subtle unconformities in a complex reservoir across hundreds of wells, our advanced well log interpretation tools provide powerful interpretation workflows.

smartSECTION®

smartSECTION® technology specializes in high-performance well log correlation and advanced geologic interpretation by working with digital or raster logs and simulating paper-based log correlation workflows. Unique fault gapping tools are used to interpret structural relationships plus sequence stratigraphy tools allow geologists to accurately correlate large volumes of wells, interpret reservoir facies, build maps and identify drilling opportunities more efficiently than ever before.

Geologic Interpretation Systems

By combining our industry-leading geologic interpretation technologies into systems, we've made it easier for you to purchase the right components to support your most common interpretation workflows.

Basic Geologic Interpretation System

The Basic Geologic Interpretation System is composed of all of the basic geological interpretation applications that the petroleum geologist needs to interpret and map subsurface data. It combines our Mapping System with the Xsection™ application to extend the subsurface interpretation functionality. It is designed for the geoscientist who works primarily with well data and does not have the need to incorporate geophysics or well log analysis into the interpretation.

Geologic Interpretation System

The Geologic Interpretation System is our high-performance geologic application encompassing everything from gridding, contouring, cross sectioning and log analysis to production mapping, basemapping and well data management. Advancing beyond the Basic Interpretation System, we added PRIZM™ to include petrophysical analysis functionality to create the industry's leading product of its kind. Companies around the world use GeoGraphix's Geologic Interpretation System to improve the quality of their interpretations.

Mapping Systems

Whether you are creating base maps or need to display reservoir characteristics, our integrated mapping systems include the right combination of technologies to support your demanding mapping needs.

Base Map System

The Base Map System gives you everything you need to create powerful, informative base maps that derive maximum value from your data. It combines the DataManager™, GeoAtlas™ and LandNet components to deliver comprehensive base map and data management functionality plus basic gridding and contouring for a quick look at regional structure and trends.

Mapping System

The Mapping System takes the components of the Base Map System and adds more sophisticated gridding and contouring capabilities with the IsoMap® module. This system gives geologists a range of tools to address every possible geologic mapping challenge for a solid understanding of the subsurface structural, stratigraphic and reservoir configurations. From more efficient data management to presentation-quality output the first time around, this package delivers everything you need to put your data into context and communicate it effectively.



Geophysical Solutions

From comprehensive seismic interpretation to seismic modeling, GeoGraphix offers the geoscientist all the geophysical tools needed to gain true insight into reservoir opportunities and make the most of the information at hand.

Seismic Interpretation Systems

By combining our advanced data management and mapping systems with our full-featured seismic interpretation and analysis tools, we have created the ultimate environment for the geophysicist to produce high-quality prospects in a fraction of the time.

Seismic Interpretation System

Whether your play involves complex structural problems or subtle stratigraphic traps, having an integrated seismic tool that is sophisticated provides you with the power to accurately interpret your seismic data with confidence. GeoGraphix's Seismic Interpretation System combines the power of DataManager™ with the seismic interpretation capabilities of SeisVision™ 2D/3D to meet your mainstream geophysical needs.

Seismic Interpretation System with Advanced Mapping

The Advanced Mapping version of the Seismic Interpretation System adds the powerful gridding and contouring capabilities of IsoMap®, as well as the superior display capabilities of GeoAtlas™, to provide the ultimate geophysical tool set. Empower geoscientists to work on the same project with GeoGraphix's unique data management tools and common database.

Seismic Modeling

Interpreting seismic data sometimes is not enough to accurately pick well locations. Building seismic models to create synthetic traces correlated to well data is essential to increasing the quality of complex depositional environments.

LogM™ Advanced Synthetics

LogM™ Advanced Synthetics, running on either UNIX or Windows® desktops, allows you to tie the trace data with synthetics in real time. For added accuracy, the wavelet of the seismic can be extracted, and applied to the synthetic using WavX. 1-D modeling can be accomplished with AVO/AVA synthetics or fluid substitution. The result? More confidence in your interpretation accuracy.

LogM™ Modeling

LogM™ Modeling is an interactive add-on to the LogM Advanced Synthetics application and is available for both UNIX and Windows® desktops. It includes the industry standard for 2-D stratigraphic or structural modeling to predict seismic responses for stratigraphic changes or in highly structured areas where steeply dipping reflectors and complex velocity problems mask true bed geometry. As with LogM Advanced Synthetics, you can display the models directly in SeisVision™ to enhance the accuracy and confidence of your geophysical interpretation.

Seismic Processing

Are you dissatisfied with your seismic data? Instead of sending seismic data back to the processor for reprocessing, GeoGraphix provides you with the tools to perform post-stack processing right from your desktop.

SCAN™

SCAN™ technology is an add-on to the processing module, pSTaX®. With SCAN, the geoscientist can readily identify subtle discontinuities in the seismic data that may be related to geologic features. Based on Landmark's PostStack ESP™ technology, this tool provides a cost-effective alternative to outsourcing these types of projects.

pSTaX

pSTaX technology eliminates the need to send seismic data back to the processor for reprocessing. Instead, your geoscientists can perform post-stack processing flows directly from the desktop. Integrated with the SeisVision™ interpretation application, we've included all the mainstream post-stack processing functions, such as amplitude scaling, correlations, convolution, filtering, phase rotation and more, to create the ultimate desktop environment for evaluating the effects of new processing flows quickly and easily.



GeoGraphix is built upon these main objectives:

1. Price/Performance	To provide industry leading performance at a cost-effective price point.
2. Integration	Offer a complete integrated and flexible solution where all G&G workflows and project teams can access/leverage the same data.
3. Portability	Ability to access and interpret data anywhere.