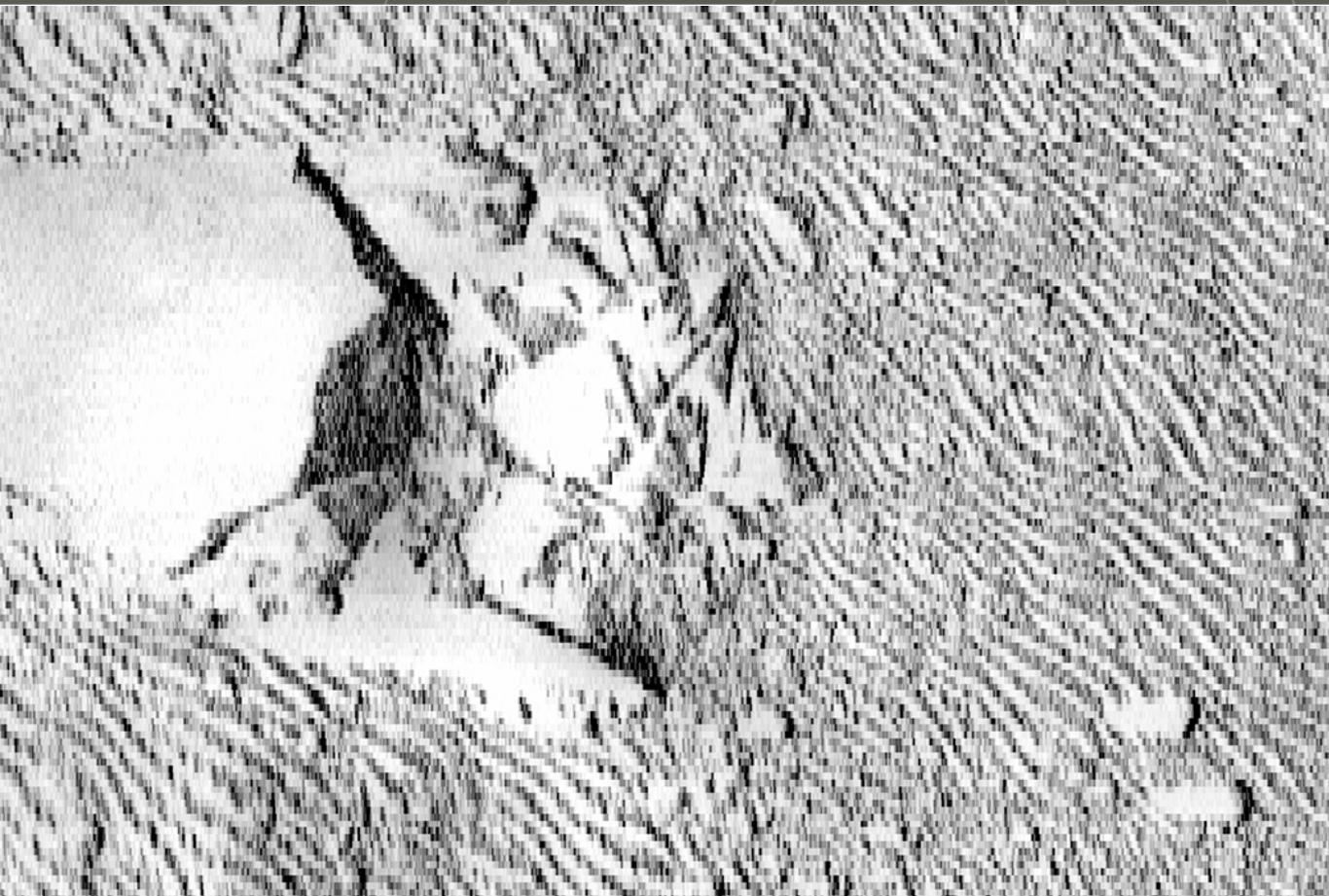


ENERGY ISLAND BORNHOLM
Geoarchaeological Analysis of Energy Island Bornholm
Export Transects

VIR 2937



John Howorth



VIKINGESKIBS
MUSEET

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July 2023

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EXPORT TRANSECTS

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Geoarchaeological Analysis of Energy Island Bornholm – Export Transects

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Abstract

Energinet has requested that the Viking Ship Museum (VIR) identify potential cultural historical objects (CHOs) located at the planned wind farm sites and related cable routes of the Energy Island Bornholm. This report covers the Export Transect between Bornholm and the windfarms, Bornholm I and Bornholm II.

The Viking Ship Museum has identified a number of possible cultural historical objects on the seabed in the geophysical data, including 3 potential wrecks and 32 mounds. Moreover, the paleo-terrain that best represents the terrain during the Late Palaeolithic and Early Mesolithic, between c. 9400 BC and 8400 BC, was analysed and a number of potential settlement 'hotspots' were highlighted.

Dansk resumé

Energinet har anmodet Vikingeskibsmuseet (VIR) om at identificere potentielle kulturhistoriske objekter i den planlagte Vindmøllepark *Bornholm Energiø* og dens kabelkorridorer i Østersøen. Nuværende rapport dækker eksporttransekter mellem Bornholm og vindmølleparkerne, Bornholm I og Bornholm II.

Vikingeskibsmuseet har identificeret et antal potentielle kulturhistoriske objekter, heraf tre potentielle vrage og 32 "mound" (bunke). Desuden er et palæo-terræn, tolket som den bedste repræsentation af terrænoverfladen i sen Palæolitikum, tidlig Mesolitikum mellem ca. 9400 BC og 8400 BC, blevet analyseret og steder udpeget for sandsynlige bosættelses-"hotspots".

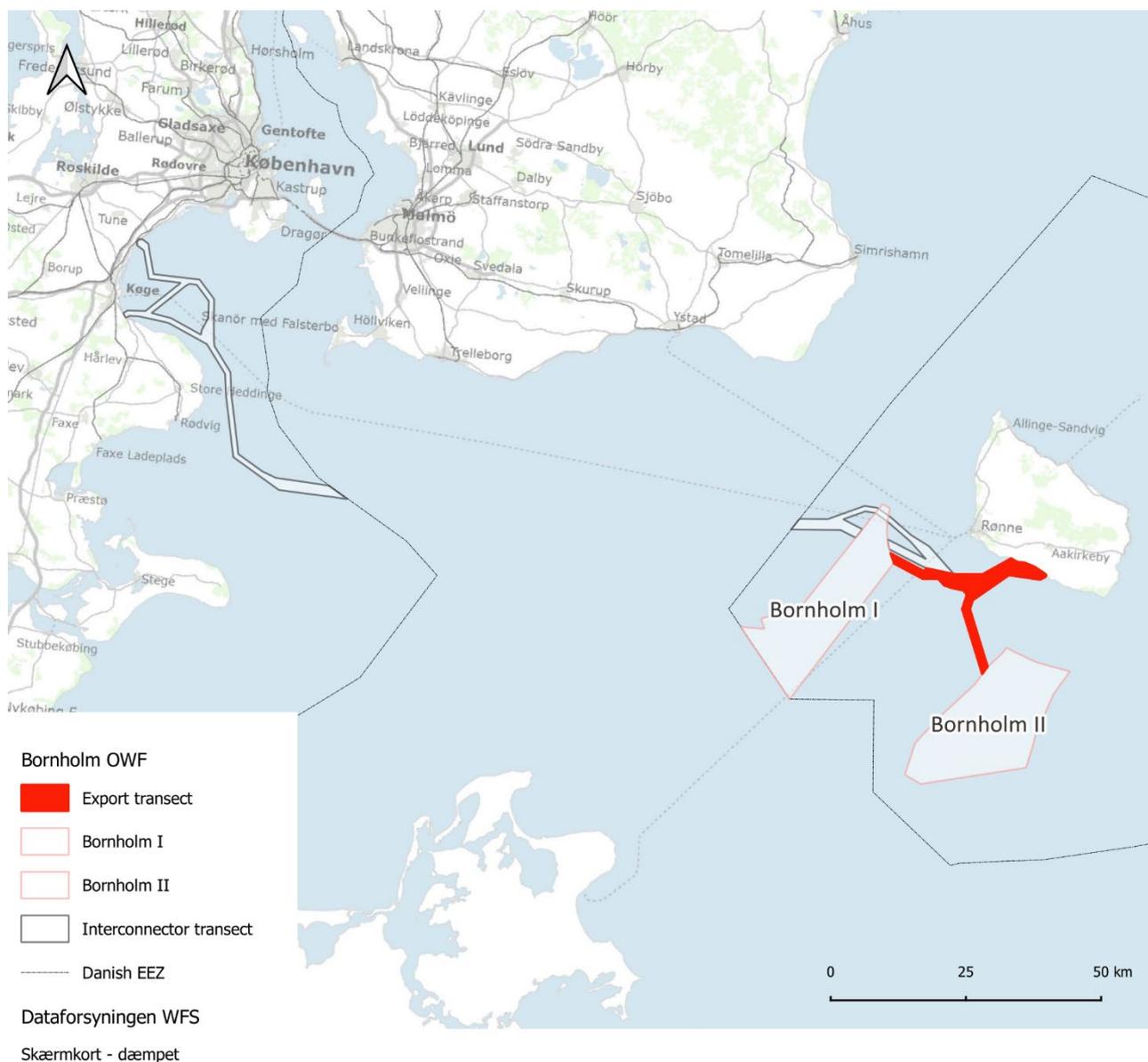


Figure 1. Map showing the areas included in the Energy Island Bornholm. The Export Transect in red. Graphics: Marie Jonsson © Vikingskibsmuseet.

Introduction

Following a decision by the Danish Parliament in June 2020, Denmark is on the path to establishing offshore energy infrastructure in the Danish North Sea and the Danish Baltic Sea to connect offshore wind energy to the Danish mainland and to neighbouring countries via offshore energy hubs called *Energy Islands*. In the Baltic Sea, the Energy island is the existing island of Bornholm.

The Export Transect overlaps considerably with the east portion of the Interconnector Transect and therefore, targets which appear in the eastern part of the Interconnector Transect are included in this report.

Table 1. Abbreviations used in the text.

CHO	Cultural history object	Kulturhistorisk objekt
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DMA	Danish Maritime Authority	Søfartsstyrelsen
EEZ	Exclusive Economic Zone	Eksklusiv økonomisk zone
GIS	Geographical information system	Geografisk informationssystem
HF	High frequency	Højfrekvent
LF	Low frequency	Lavfrekvent
MAG	Magnetometer, magnetic	Magnetometer, magnetisk
MBES	Multibeam echo sounder	Flerstråleekkolod
MMO	Man-made object	Menneskeskabt objekt
ROV	Remotely operated vehicle	Fjernstyret undervandsfartøj
SBP	Sub-bottom profile	
SSS	Sidescan Sonar	Sideseende sonar
VIR	Viking Ship Museum, Roskilde	Vikingskibsmuseet i Roskilde
WGS 84	World geodetic system 1984	

Project data

The Export Transect Sidescan Sonar (SSS) data screening was completed at the Viking Ship Museum in Roskilde, Denmark by maritime archaeologists Marie Jonsson, Torben Malm, Staffan Lundblad and John Howorth.

The entire Energy Island Bornholm project archive is filed at VIR under file no. 2937.

Topography, terrain and geology

The Export Transect runs from Bornholm in the east out to the wind farm sites, BH1 and BH2 towards west. Large portions of the Export Transect cable route lie in very shallow water on the Rønne Banke, at around 10 metres depth or less for the first 10 kilometres out from Bornholm. The water depth then remains below minus 20 metres for most of the rest of the route. For the last kilometre to the south the seabed suddenly drops away to minus 30 metres as it leaves the Rønne Banke. To the north, the seabed drops from minus 20 metres to 40 metres over the last 8 kilometres. The seabed substrate in this area is quite mixed. The north-eastern portion is mainly sedimentary rock with only the areas closest to land, i.e. the beaches, being composed of sand. Towards the centre of the area, there is an area of till/diamiction. The southern portion of the area is entirely sand, whereas, to the northwest there is a mixture of sand, till/diamiction, and quaternary clay and silt.

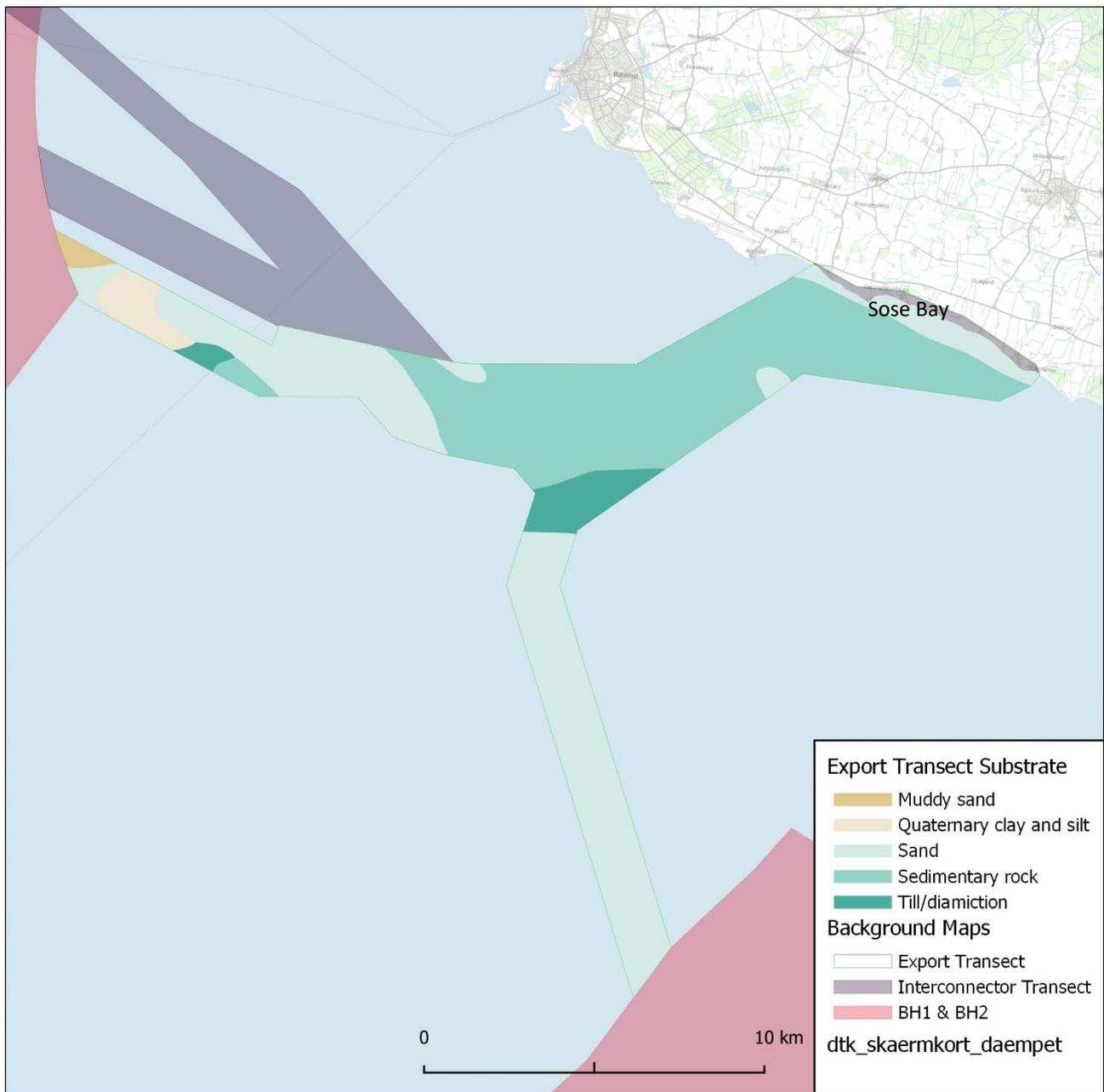


Figure 2. Map showing seabed substrate in the area for the Export Transect portion of the cable route. Data collated by GEUS, GPDN and PGI-NRI. Illustration: John Howorth ©Vikingskibsmuseet. Contains data from EMODnet © European Union, 2022, and data from Styrelsen for Dataforsyning og Effektivisering.

Sose Bay (Figure 2) was the site of the sinking of at least 15 ships in 1678 and the wrecks likely remain on the seabed although not all of them have been identified and registered. Artefacts such as musket balls, tin plates, coins, sword parts, silver goblets and spoons have been found in this area by recreational divers and fishermen. Large numbers of human bones presumably from victims of the mass foundering were also reported on the beaches in the late 19th century and there is a chance that there may still be human remains in the area.

Within 1.3 kilometres of the shore, there are four wrecks registered with *Fund og Fortidsminder*, reportedly from the mass foundering, although one, FF 150703, has not been verified.

These factors, on top of the fact that Bornholm is situated within an area that has been an important and busy shipping channel throughout history, means there is a likelihood of a high number of CHOs in this area.

The shallow water close to Bornholm also offers up the potential for prehistoric remains. An Iron Age quern-stone and a potential stone-age settlement site have both been discovered on the seabed within 500 metres from the coast and there are several known prehistoric monuments on land, along the coastline.

Large parts of the seabed in Sose Bay would have been dry land during the Mesolithic period (Jensen & Bennike, 2021). Sub-bottom profile (SBP) and multibeam echo sounder (MBES) data have been used to study the submerged terrain in order to identify likely areas for human activity and settlement. The submarine terrain close to Bornholm contains areas that would have been suitable for human habitation but there is a widespread lack of sedimentation which may inhibit preservation and thus limit the potential to find Mesolithic archaeology in the greater part of the area.

Coordinate system

The present report and associated digital files archived at VIR use the coordinate system: UTM zone 33N, WGS 84, unless otherwise specified.

Methodology

Using Sonarwiz (v.7.10) software, all High Frequency (HF) Sidescan sonar data for the Export Transect area was screened and potential archaeological targets were selected based on their shape and size, and the potential for being a Cultural Historical Object (CHO). The target was then checked for matching anomalies in other datasets:

- The surveyor's SSS targets
- The surveyor's Magnetic (MAG) anomalies
- Danish national registry of CHO finds *Fund og Fortidsminder* (FF) (<https://www.kulturarv.dk/ffreg/>).

Targets were then exported to a mapping project in QGIS (v.3.28.4 – Firenze), where further matches were made from the following records:

- Søfartsstyrelsens vragregister – The Danish Maritime Authority's Register for Wrecks.
- Holddatabasen – a database from the Agency for Culture and Palaces which contains a list of potential wrecks where the positions have not yet been further investigated.
- Vragguiden – Denmark's largest online wreck database for and by recreational divers.
- Nord Stream 1 and 2 – information from the museum's archives, VIR 2545 and VIR 2740.
- Baltic Pipe - information from the museum's archives, VIR 2813.

Furthermore, extra attention has been paid towards any targets that are found within 500 metres of a registered CHO as they may be related which means that the registration can help identify and/or date the target.

Within this report, references made to objects registered with *Fund og Fortidsminder* are preceded with FF followed by the unique *system number*.

Results

In total there are 327 targets identified in the SSS data and geolocated within the Export Transect area. Each target was assigned a category, the list of the categories used for this project can be seen below. The vast majority of these are so-called *linear objects*. There is a total of 3 potential *wrecks* and 32 *mounds* (Figure 3). All the information regarding the potential wrecks and mounds can be found in Appendices 1a and 1b respectively, a full list of the targets and their descriptions can be seen in Appendix 2, and an overview map of all targets identified in the SSS screening can be seen in Appendix 3.

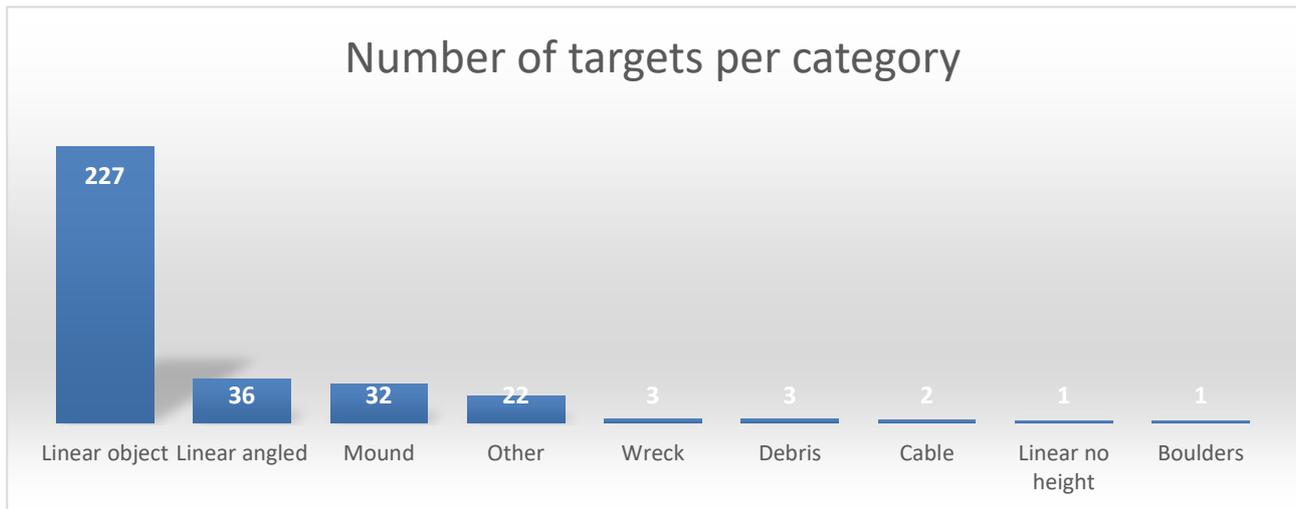


Figure 3. Target categories and number of occurrences.

All targets are potentially CHO's. The different linear objects can be remains from fish weirs, wreck parts or cargo. Debris can be remains of cargo or broken up wrecks. Cables is used collectively for cables, wires and ropes, all of which can be part of fish traps or wrecks or anchors. These categories are not presented in full below in the same manner as wrecks and mounds, as this would make a too detailed report. However, all targets are covered in Appendix 2, and should be considered as CHO's until investigated.

List of target categories

Each target category is described below:

<i>Boulders</i>	Boulders, large rocks, etc.
<i>Cable</i>	Cable, chain, etc.
<i>Debris</i>	Manmade object, debris
<i>Linear object</i>	Linear object of certain size and with shadow
<i>Linear angled</i>	Angled linear object, with or without shadow
<i>Linear no height</i>	Linear object of certain size, without shadow but still noteworthy
<i>Mound</i>	Mound, potentially ballast from broken down wreck
<i>Other</i>	Other type of object. See description
<i>Wreck</i>	Wreck/potential wreck



Figure 4. Overview of the location of possible wrecks in relation to known CHOs. Illustration: John Howorth © Vikingskibsmuseet. Contains data from Styrelsen for Dataforsyning og Effektivisering.

Wrecks

There are three targets labelled as potential wrecks in the SSS data; SSS_B1A_0046, SSS_B1A_0084, and SSS_B1A_0087 (Table 2). All of them are less than three kilometres from land but none of them are within 500 metres of any previously identified CHOs. Furthermore, one of the potential wrecks, SSS_B1A_0084, actually lies around 50 metres just outside the Interconnector Transect area (Figure 4), although, in the case that this target is identified as a significant wreck, future protection areas around the target may affect the Transect area.

Table 2. List of potential wrecks.

SSS_B1A_0046	Wreck	Poss frame elements
SSS_B1A_0084	Wreck	Mound, good size for ballast mound. A few linear objects visible in SSS image. Poss wreck
SSS_B1A_0087	Wreck	Pile of linear objects, poss wreck.

SSS_B1A_0046, is however, surrounded by potentially related objects seen in the SSS data. A cable, SSS_B1A_0090, is situated about 30 metres away. A linear object, SSS_B1A_0047, is also possibly part of the wreck and there are two further linear objects situated approximately 150 metres to the north. A *mound*, SSS_B1A_0045, described in the survey data as an “odd mound with lines running along and across” and being “either natural, or frame elements from wreck” is situated about 165 metres to the northeast. Both the mound and the potential wreck could be part of the same object, or they may be two separate wrecks. A further four linear objects have been identified approximately 260 metres to the south which have been described as potential wreck parts, SSS_B1A_0100 to SSS_B1A_0103. These linear objects lie approximately halfway between the wreck and number 3979 in Holddatabasen.

SSS_B1A_0084 is described as a good size for ballast mound with a few linear objects visible in SSS image, while SSS_B1A_0087 is described as a pile of linear objects.

Mounds

There is a total of 32 mounds and all are within 11 kilometres from the coast (Figure 5). The seabed in this area is very uneven and mainly made up of rock so it is possible that some of the mounds may be natural features.

Very few of the mounds correlate closely with previously known CHOs.

One of the most promising mounds is SSS_B1A_0060. This is described as a faint mound, possibly ballast discovered close to the Sose Bay foundering site. It correlates closely with FF 150225, a number of artefacts from the base of a wreck, found during fishing activities and possibly related to the mass sinking of Swedish ships in 1678.

Two mounds also in Sose Bay, SSS_B1A_0025 and SSS_B1A_0026, are close to two wreck sites from the mass foundering of 1678, FF 150222 and FF 150223. Both mounds are described as flat and lie approximately 70 metres apart. Both are equally distant from a prehistoric settlement site, FF 152669, that was discovered by divers in 2001. There are also two groups of linear objects, SSS_B1A_0015 and SSS_B1A_0016, which lie close to one another around 220 metres from the shore in the Sose Bay area within 400 metres of the two mounds. They are located less than 200 metres from two FF numbers, 150224 and 197346, and only 250 metres from FF 150226, which are points from where a number of artefacts relating to the Sose Bay foundering were recovered. They lie 200 metres and 275 metres from FF 150222 and 150223 respectively. Two more FF numbers within 500 metres of these groups of linear objects are 150226 and 219713, which are also linked to the mass sinking in 1678. Two linear objects, SSS_B1A_0001 and SSS_B1A_0059, as well as a possible rope or cable, SSS_B1A_0082, lie just to the east of the two shipwreck sites, FF 150222 and FF 150223. The locations of all these targets and correlating CHOs can be seen in Figure 6.

SSS_B1A_0037 is another mound within the Sose Bay area and lies within 500 metres from the site of where a ship, the *Blakgrund*, grounded in 1858, FF 151001. It also corresponds with a MAG anomaly. A nearby linear object, SSS_B1A_0012, has been described as a probable cable and could

be related if this mound is a wreck. The mound is also just over 500 metres away from the site of a ship which sank in during the mass foundering and there is the possibility that this could be related.

There are a further four mounds in the Sose Bay area, SSS_B1A_0032, SSS_B1A_0040, SSS_B1A_0049, and SSS_B1A_0065. The latter is located just outside the Export Transect area, approximately 120 metres from where a stone age artefact was recovered, FF 141402, and about 330 metres from the site of a medieval harbour, FF 151555.

Table 3. List of mounds.

SSS_B1A_0025	Mound	One of two flat mounds, visible as a darker patches with a little rise, 70 meters apart.
SSS_B1A_0026	Mound	The nuber two of two flat mounds.
SSS_B1A_0032	Mound	Poss ballast mound
SSS_B1A_0037	Mound	Corresponding MAG anomaly. Poss ballast mound
SSS_B1A_0040	Mound	Pile of small rocks. Poss ballast mound
SSS_B1A_0045	Mound	Odd mound with lines running along and across. Either natural, or frame elements from wreck.
SSS_B1A_0049	Mound	Pile of stones in an otherwise pretty empty area.
SSS_B1A_0060	Mound	Faint mound, possible ballast. Close to Sose bugt foundering site. FF system nummer 150225
SSS_B1A_0065	Mound	Poss ballast mound
SSS_B1B_0009	mound	Potential ballast mound. Interpretation based on size, shape and the fact that the rocks are found in an area without a large amount of loose rock. Although the feature could still be naturally formed.
SSS_B1B_0033	mound	Large very even looking circular mound or very large boulder.
SSS_B1B_0041	mound	Potential ballast mound. Interpretation based on size and shape of feature.
SSS_B1B_0063	mound	Possible ballast mound.
SSS_B1B_0065	mound	Pile of rocks, possible ballast mound.
SSS_B1B_0070	mound	Potential ballast mound or buried feature.
SSS_B1B_0071	mound	Potential buried feature.
SSS_B1B_0085	mound	Potential remains of a ballast mound but could just be a patch of rocks.
SSS_B1B_0086	mound	Potential buried feature or ballast mound.
SSS_B1B_0087	mound	Mound, possible buried feature.
SSS_B1B_0088	mound	Possible buried feature.
SSS_B1B_0107	mound	Possible ballast mound situated next to another possible ballast mound SSS_B1B_0108. Interpretation based on size and shape.
SSS_B1B_0108	mound	Possible ballast mound situated next to another possible ballast mound SSS_B1B_0107. Interpretation based on size and shape.
SSS_B1B_0109	mound	Possible ballast mound.
SSS_B1B_0111	mound	Possible ballast mound but could also be a natural feature. Situated close to M_DV_WPB_B1B_0522.
SSS_B1B_0112	mound	Possible ballast mound or natural feature.
SSS_B1B_0116	mound	Possible ballast mound or buried object.
SSS_B1B_0129	mound	Very circular mound.
SSS_B1B_0145	mound	Very circular mound of rocks.
SSS_B1B_0146	mound	High, circular mound.
SSS_B1B_0147	mound	Circular mound of rocks.
SSS_B1B_0148	mound	Possible ballast mound.
SSS_B1B_0184	mound	Mound of rocks in an area without many other rocks. Possible ballast mound but probably natural.

The first two, SSS_B1A_0032 and SSS_B1A_0040, are possible ballast mounds but have very few VIR targets nearby. SSS_B1A_0049 is located close to two targets that have been described as possible wrecks, SSS_B1A_0022 and SSS_B1A_0051.

Another exception is SSS_B1B_0184, which lies within 100 metres of a wreck registered as the Luna in the DMA's register for wrecks and in the Fund og Fortidsminder register as a fishing vessel lost in 1952.

The following five mounds are also located between 3 and 6 kilometres from the coast.

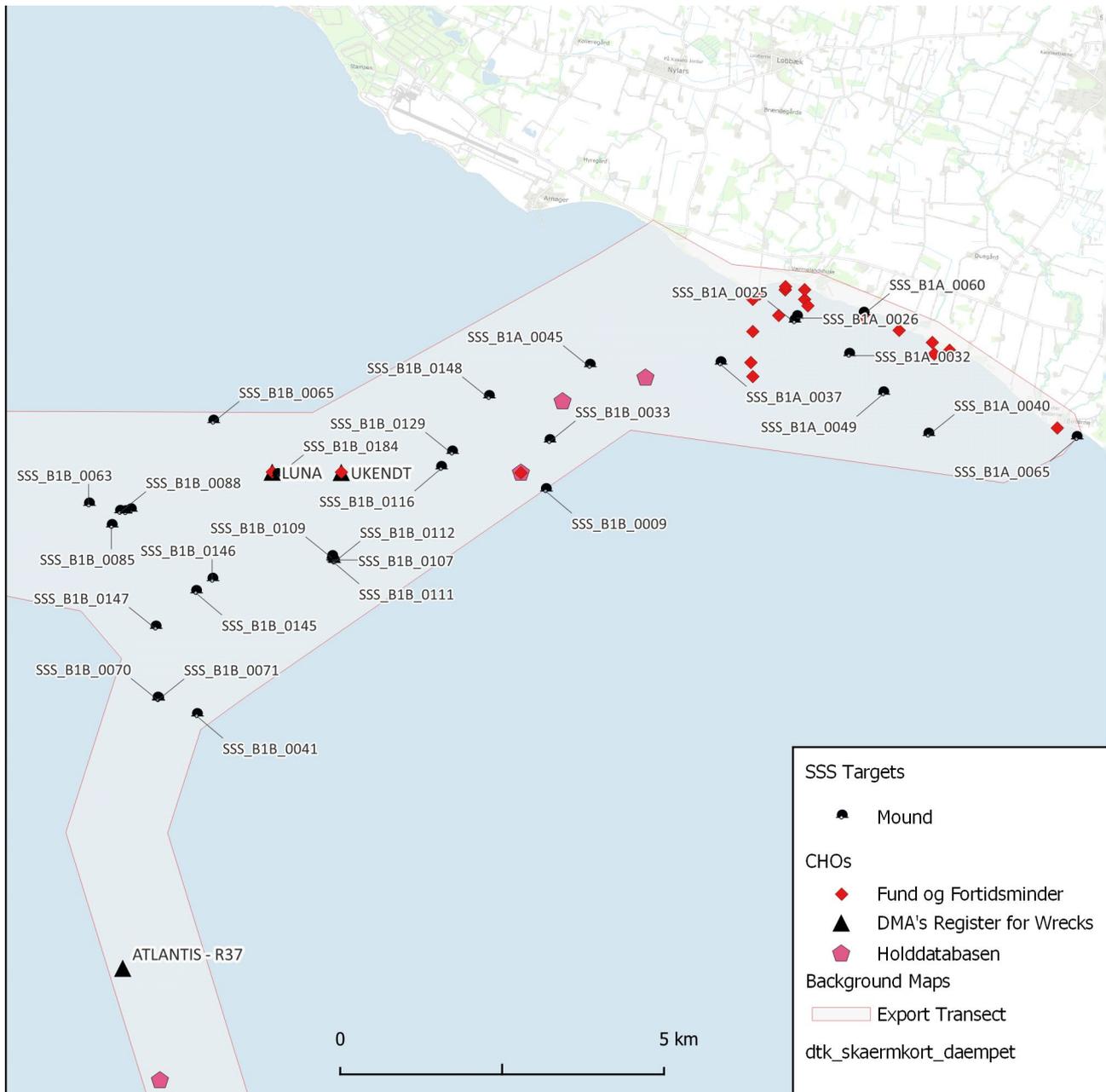


Figure 5. Overview of the location of mounds in relation to known CHOs. Illustration: John Howorth © Vikingskibsmuseet. Contains data from Styrelsen for Dataforsyning og Effektivisering.

SSS_B1B_0009 is described as a potential ballast mound and is situated about 465 metres from FF 187033, a ship which sank in 1942. The ship also corresponds to 11692 in Holddatabasen. Within 500 metres of this wreck site are six more VIR targets which could potentially be wreck debris: three linear objects with no description, SSS_B1B_0020, SSS_B1B_0034, and SSS_B1B_0038; and three “Other” objects, SSS_B1B_0044, described as a relatively square possible buried object, and SSS_B1B_0048 and SSS_B1B_0056, which are described as large oval shaped features which are potentially boulders.

The last four of these five mounds, SSS_B1B_0033, SSS_B1B_0116, SSS_B1B_0129, and SSS_B1B_0148, are not close to any previously known CHOs, the closest targets are mainly linear objects. The significance of the linear objects in this area is difficult to assess as there is such a large number and many have no description.

There is an area of debris, SSS_B1B_0166, approximately 340 metres to the west of SSS_B1B_0148, which is situated close to several other linear objects; SSS_B1B_0154, SSS_B1B_0157, SSS_B1B_0158, and SSS_B1B_0167 to SSS_B1B_0170. This grouping of linear objects could be the sign of a wreck.

The latter is approximately 350 metres from a potential debris field around the linear object, SSS_B1B_0167, although many of these objects could be geological features in the rocky sea floor.

There are three mounds at the point where the route branches towards the south, SSS_B1B_0041, SSS_B1B_0070, and SSS_B1B_0071. The first two are described as potential ballast mounds with the latter described as a potential buried object. There are no previously known CHOs close to these mounds. A number of linear objects are located within the vicinity but there is no strong indication that these are ship parts or wreckage.

The remaining mounds all have the potential to be wrecks but, due to the nature of the seabed and the fact that none match closely with previous CHOs, it is difficult to make an assessment without a visual investigation.

Sose Bay

There is a high number of finds/features registered with Fund og Fortidsminder within 1.5 kilometres of the coastline, in the Sose Bay area. Eighteen of these are found either in the water or on the shore. Of these eighteen, six are wrecks. Two of which are from the 19th century, FF 151001 and FF 154637; three are dated to the Sose Bay foundering in 1678, *Fund og Fortidsminder* entries FF 150222, FF 150223, and FF 150703; and one, FF 150699, has been given a date of 1800-1848 in the register but has been described as possibly originating from the Sose Bay foundering.

FF 219713, a device for measuring the calibre of canons was found close to FF 150699 which supports the earlier date. Within 100 metres of the wreck, there are two linear objects, SSS_B1A_0054 and SSS_B1A_0055, and a possible debris field, SSS_B1A_0099, which could also be wreck parts.

Seven of the FF points denote where single finds, or groups of finds, were discovered. Six of these are from the same time period as the Sose Bay foundering: FF 150221, FF 150224, FF 150225, FF 150226, FF 197346, and FF 219713 which has been discussed above. The seventh point, FF 214591, is an iron age quern-stone.

Within 500 metres of FF 150221 are SSS_B1A_0017 and SSS_B1A_0018, a “peanut shaped outline” and a linear object respectively. They are just over 100 metres apart and described as possible wreck parts.

There are a number of linear objects, SSS_B1A_0068 to SSS_B1A_0071, closely grouped together in a possible debris field about 100 metres from the shore within the Sose Bay and approximately 330 metres from the above-mentioned FF 150225. They are also approximately 260 metres from the iron age quern stone.

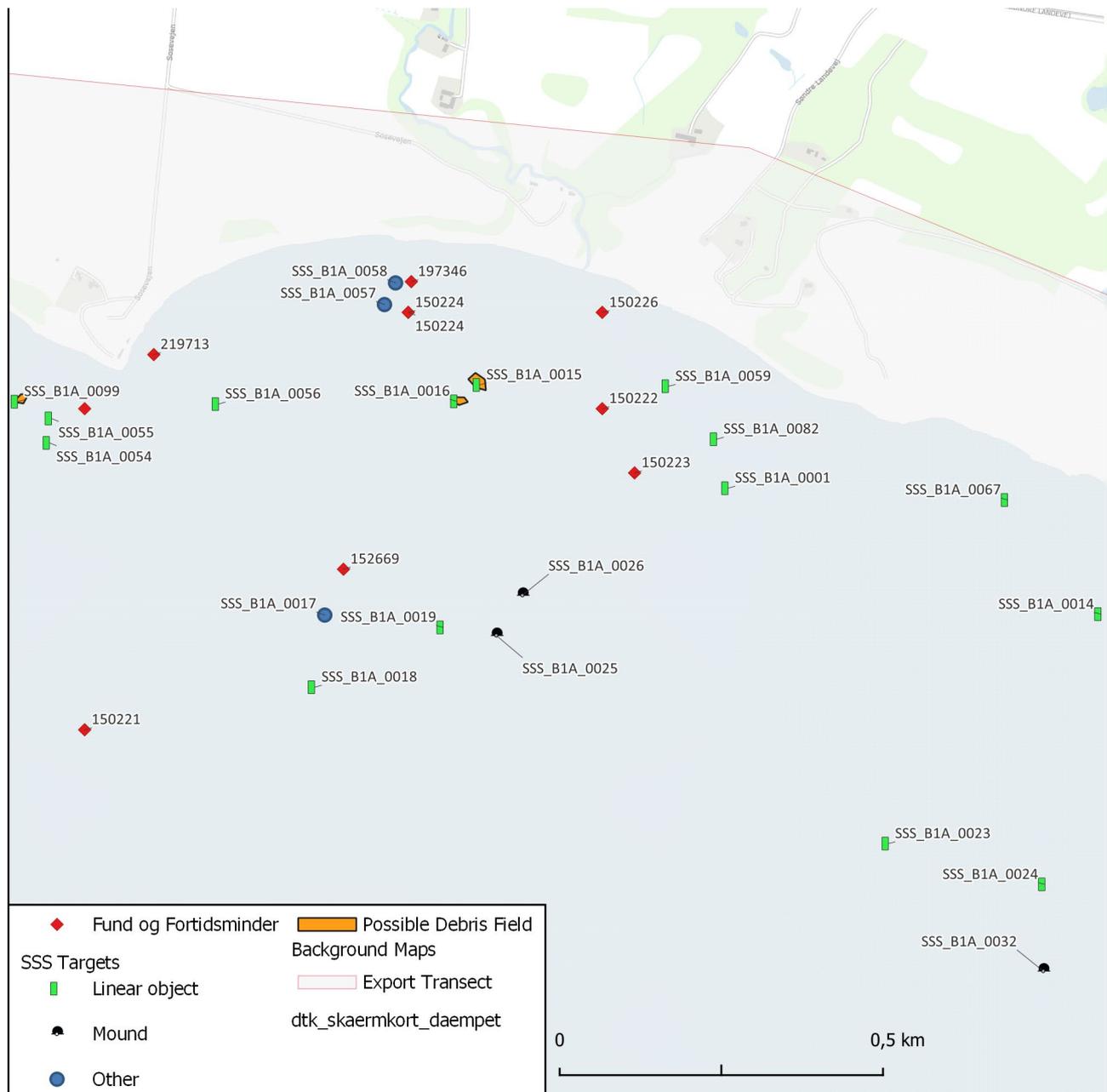


Figure 6. Close-up of Sose Bay, specifically showing SSS_B1A_0025 and SSS_B1A_0026 along with other VIR SSS targets and previously known CHOs. Graphics: John Howorth © Vikingskibsmuseet. Contains data from Styrelsen for Dataforsyning og Effektivisering.

Two FF numbers refer to hearths/fireplaces, 378 and 141273, reportedly from the pre-medieval period that were discovered along the shoreline. One number refers to evidence of a settlement found approximately 500 metres off the modern coast, FF 152669.

There is an additional FF number located on land at Sose Odde which also could have significance for any work to be carried out in the Sose Bay area. FF 123190 is a report from 1876 which describes a large number of human bones being discovered along the beach in this area and links them to the Sose Bay foundering. Although none of the targets from the SSS data match the description of bones, it remains a possibility that human remains could be found.

The final FF number, FF 151555, relates to a medieval harbour located at the very north-eastern edge of the area.

SSS_B1A_0005 is described as a group of linear objects that could be wreck parts and is located just over 500 metres from Sose Odde so there is a possibility that this could be linked to the Sose Bay foundering.

The high concentration of registered finds from the Sose Bay foundering in this area, the prehistoric finds, the two 19th century wrecks, and the presence of a medieval harbour indicate that there is a heightened probability that objects identified in the SSS data are historically significant.

Other Targets

Five linear objects, SSS_B1B_0176 and SSS_B1B_0178 to SSS_B1B_0181, are located about 400 metres from the site of a shipwreck, the identity of which is unknown. The latter is described as a possible rope or cable and it appears that there could be an anchor towards one end. The objects are fairly closely grouped together and may represent parts of a wreck that have drifted from the original site.

SSS_B1A_0053 is described as a ship-shaped anomaly and lies about 75 metres off the shore approximately 1 kilometre to the northwest of Sose Odde. Although, there are no previous CHOs in the near vicinity and very few targets identified in the SSS data.

There are a number of linear objects located between 300 and 400 metres to the northwest of an unidentified wreck in the DMA's register for wrecks also registered as FF 186848. This is an unknown vessel which sank in 1942. SSS_B1B_0176 and SSS_B1B_0178 to SSS_B1B_0181 are linear objects in close proximity to one another and described as wreck parts, with SSS_B1B_0181 described as a possible rope.

At the point where the route branches towards the south, there is a potential debris field which includes linear objects, SSS_B1B_0119 to SSS_B1B_0123 and is close to a further three linear objects, SSS_B1B_0126 to SSS_B1B_0128. These linear objects could represent the remains of a wreck.

SSS_B1A_0091 is a cable found relatively close to number 3980 in Holddatabasen, no other targets of significance are nearby, but this could be an anchor cable/rope/chain from a vessel that may have sunk in the near vicinity.

There are nine objects at the very southern end of the Export Transect, eight linear objects and one piece of debris. These objects lie in the deep water just off the eastern side of Rønne Banke and do not appear to be close to any previously known CHOs.

According to DMA’s Register for Wrecks, there is a wreck called the Atlantis R-37 within the route heading south towards the windfarm area BH2. This is recorded as sinking in 2008 and there are almost no objects identified within the SSS data in the area.

Pound Net Fishing

This is a form of stationary fishing in which rows of nets run perpendicular with the coast leading the fish into a pound or trap. The nets are held in place by a series of wooden posts and weights. The “lead” nets often extended several kilometres out from the coast.

Evidence for this fishing activity may be visible in the SSS data in Sose Bay. Towards the northeast side of the Export Transect, approximately 600 metres from the shore, there are two linear objects SSS_B1A_0028 and SSS_B1A_0029 which are joined by a polyline which is described as a row of objects with further linear objects to one side. There is a similar feature located at about 100 metres to the southeast.

Stone-Age Potential

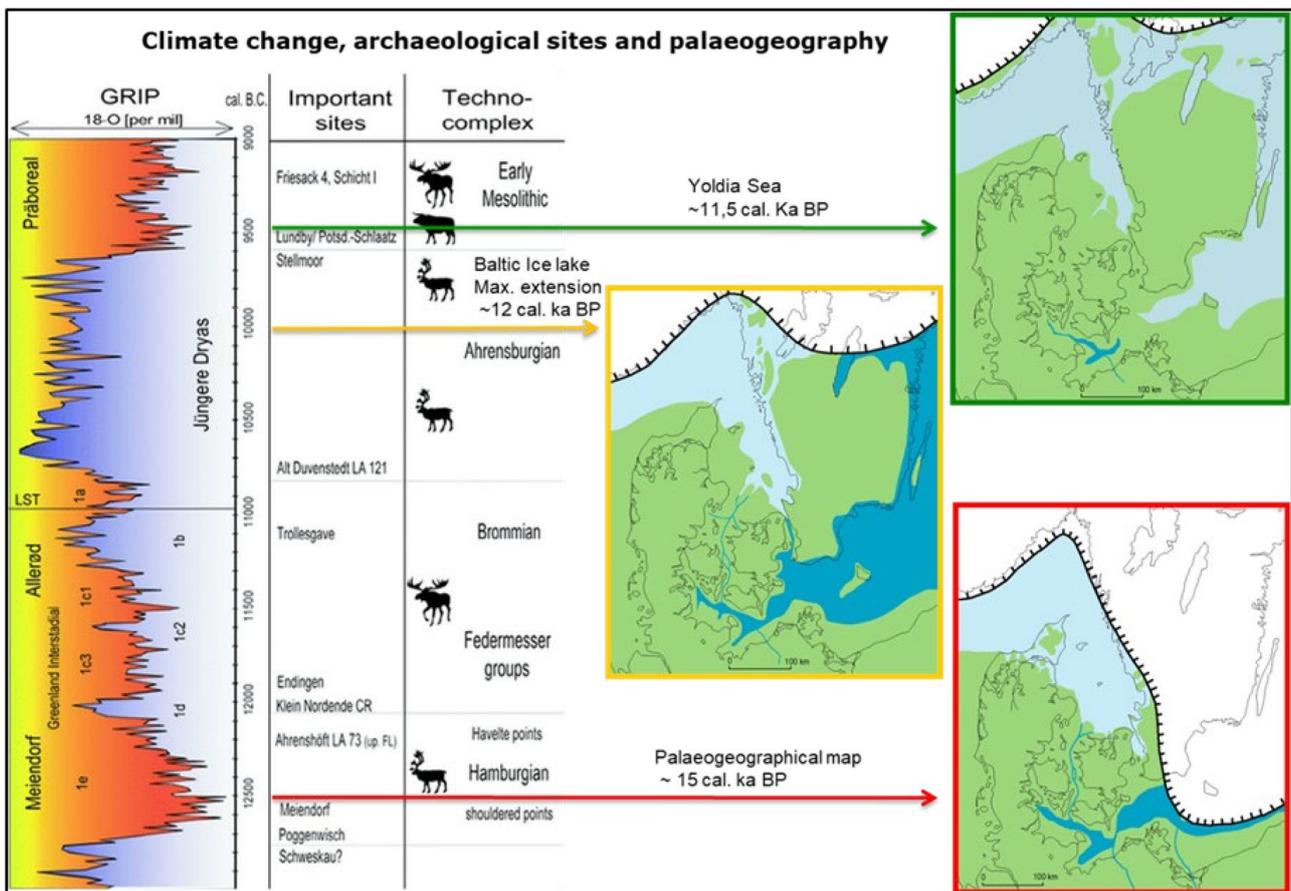


Figure 7. Late glacial and Holocene general paleogeography in the Danish area and related archeological cultures. (Jensen & Bennike, 2021, s. 58)

A geophysical survey carried out by Ocean Infinity on behalf of Energinet (Oakley & Pickworth, 2023) was used to study the sub-bottom profiles and bathymetry to analyse potential sites of Mesolithic settlement. Previous discoveries, recorded in *Fund of Fortidsminder*, have also been used to analyse the potential of the preservation of stone-age finds. Due to the fluctuating water levels throughout the post glacial period, the shorelines have changed significantly. During a period

of low-stand water level about 11700 years BP, the water was around 45 metres below present levels. The water depth then increased significantly over a relatively short period of time. According to a geological desk study of the cable routes, it is considered that evidence for archaeological sites from the early and mid-Mesolithic period are the most likely to be found in the Baltic Sea (Jensen & Bennike, 2021).

There are three entries into the *Fund og Fortidsminder* register for potential stone-age CHOs within the Export Transect, all of which lack a secure date (Figure 8).

Two of these entries are clay-lined firepits with no further evidence of settlement, FF 378 and FF 141273, both were discovered eroded out of the coastal bluff. There is a possibility that there are similar, still buried, features along this stretch of coast and potentially more substantial settlement remains buried along the coastal bluff itself.

The third entry, FF 152669, is described as a possible stone-age settlement. It is located at about 500 metres from the shore at a depth of between 1.5 and 2 metres below sea level. There are reports of flint and burnt bones within a burnt area, possible fire pit or hearth, but no finds have been collected from the site. The possible settlement site is situated within a submerged delta where there are several palaeochannels leading from extant small streams on Bornholm to the east of Sose Odde. This type of terrain could have been suitable for settlement during the Mesolithic period. However, according to the SBP data there is a lack of surviving sediment in this area which lessens the probability of finding archaeological remains. At the mouth of one of the small streams, just off the coast of Risebækken, there is an area of marine sand approximately 200 metres by 600 metres where archaeological evidence could survive (Figure 9). A similar area is found towards the very eastern extent of the Export Transect, close to Boderne Havn, at the mouth of a small river, Læså. The sediment in these areas could preserve archaeology on the seabed and could also contain objects washed down the streams from sites on the land, especially as the rivers and streams run past several prehistoric monuments.

There is a further area of marine sand lying across a submerged palaeochannel located at around 900 metres to the southwest of the coast at Julegaard. At some point during the Mesolithic period, this area would have been on the banks of a wide river and potentially a suitable area for settlement (Figure 8). The sediment could contain preserved settlement evidence such as worked flints, charcoal, butchered animal bones, or fish traps/weirs.

Approximately 1 kilometre to the south of Sose Odde, there are two submerged islands. At their highest points, these lie at just 3 and 4 metres below sea level, compared with the surrounding terrain which lies at depths of around 10 metres. The two 'islands' are over 100 metres in width and length and may have been suitable for settlement during the Mesolithic period. Unfortunately, there is a lack of surviving sediment on the 'islands' themselves, however, there is marine sand lying to the south and southeast which has the potential to hold evidence for human habitation.

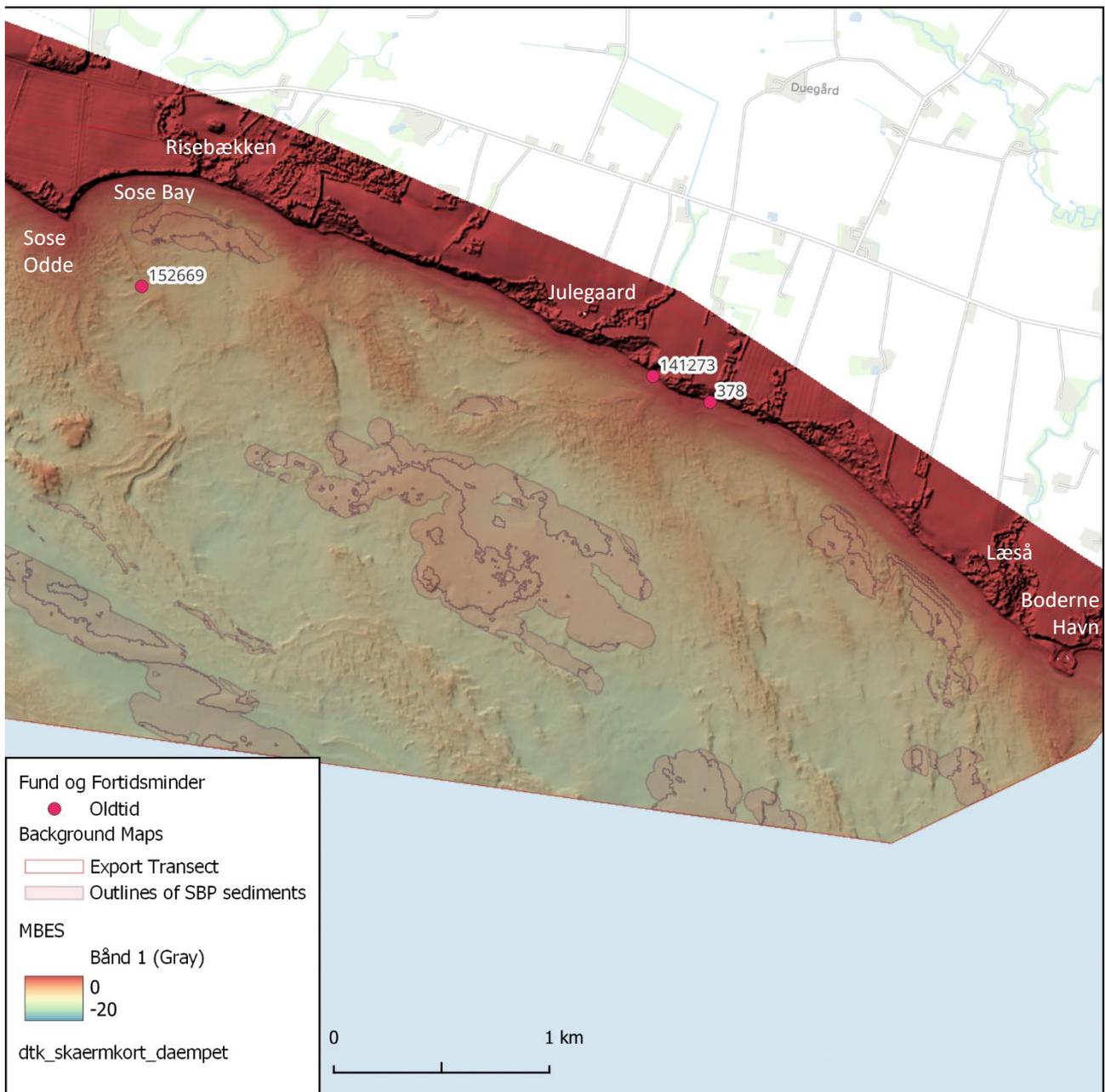


Figure 8. Location of CHO mentioned in the Fund og Fortidsminder register placed over the MBES data and sediments identified from the SBP. Data provided by Ocean Infinity on behalf of Energinet (Oakley & Pickworth, 2023). Illustration: John Howorth ©

A further 600 metres out from the ‘islands’, lies Arnager Reef, a submerged rocky peninsula which runs across the entire width of the cable route. Traditionally, this kind of terrain is well suited for prehistoric settlement, especially along the edge closest to the modern coastline. Again, there is a lack of sediment on the highest points but there are a few areas of marine sand in the deeper areas along its eastern edge. A particularly promising area is situated at the north-western extent where the submerged terrain forms a sheltered, almost harbour-like, area between two ridges (Figure 9). There is some marine sand in the deeper parts between the ridges where evidence for settlement could have been washed down from the ‘high’ points. Evidence for fish traps/weirs could also be present in this sand deposit. Just to the south of this potential ‘harbour’ area, there is a sharp drop between the reef and the lower terrain to the northeast. For a time during the Mesolithic period,

these would have been 3-metre-high cliffs. Along the top and immediately below these submerged cliffs, there is marine sand up to a metre thick in some areas, potentially containing archaeology.

A final interesting feature close to the Bornholm coast is a deep hollow in the seabed. This is a potential submerged lake and is 250 metres long, 150 metres wide, and 6 metres deeper than the surrounding seabed at its deepest. The sediment to the west and northwest of this feature is 0.4 metres thick in some places and could preserve any evidence of settlement or human activity on the shores of the lake.

Farther out from the coast, 3 kilometres from the present shoreline, lies a small submerged islet. Again, there is no SBP data for sedimentation on the top of this feature but there are areas of marine sand which could preserve archaeological layers surrounding the base of it.

The highlighted areas in Figure 9 are where there is a higher likelihood of discovering evidence for human activity in the Mesolithic period.

Farther along the cable route to the north and south there is the possibility that tree remains, rooted and unrooted, will be found among the many *linear objects* that have been identified in the SSS data across the Rønne Banke, particularly where there is sedimentation (Oakley & Pickworth, 2023). In the Baltic Pipe project, a large area of rooted tree stumps was found on the Rønne Banke at depths between 16 and 19 metres. Uprooted tree remains were identified in deeper waters, around 30 metres deep, to the west and southeast of Rønne Banke (Jonsson & H. Thomsen, 2022).

In conclusion, the submerged terrain in the shallower areas of the Export Transect, close to Bornholm, is very promising in terms of finding human activity from the Mesolithic period. There is little to no sedimentation across large parts of this terrain but there are still several areas which may contain preserved stone-age material. The sediments within the potential submerged delta area, particularly those at the mouths of extant rivers and across the large palaeochannel, may be covering stone-age layers. The sediment layers immediately to the east of the Arnager Reef, especially by the small sheltered 'bay' area at the northern end, also hold potential for preserving stone-age archaeology. Likewise, the sediments around the submerged lake are potentially covering evidence for Mesolithic settlement. The small patches of sediment to the southeast of the submerged islands would also be an area of interest, as are those sediments immediately around the base of the small submerged islet around 3 kilometres from the present shore.

As the cable route moves farther away from the island of Bornholm, the submarine terrain becomes more featureless with thicker sedimentation and it is difficult to identify possible areas for Mesolithic settlement or activity. The deeper areas have also been under water for a longer period of time and were only dry land for a relatively short time (Jensen & Bennike, 2021). However, the previous Baltic Pipe project identified areas of submerged forest in some of these slightly deeper waters. Finding similar features within the Export Transect could be seen as indirect evidence for the likelihood of the preservation for any settlement remains in the area. The sedimentation on Rønne Banke becomes gradually thicker towards the east before the seabed suddenly drops off the ridge and into deep water, over 30 metres below sea level. Rooted tree stumps may be present in this sedimentation.

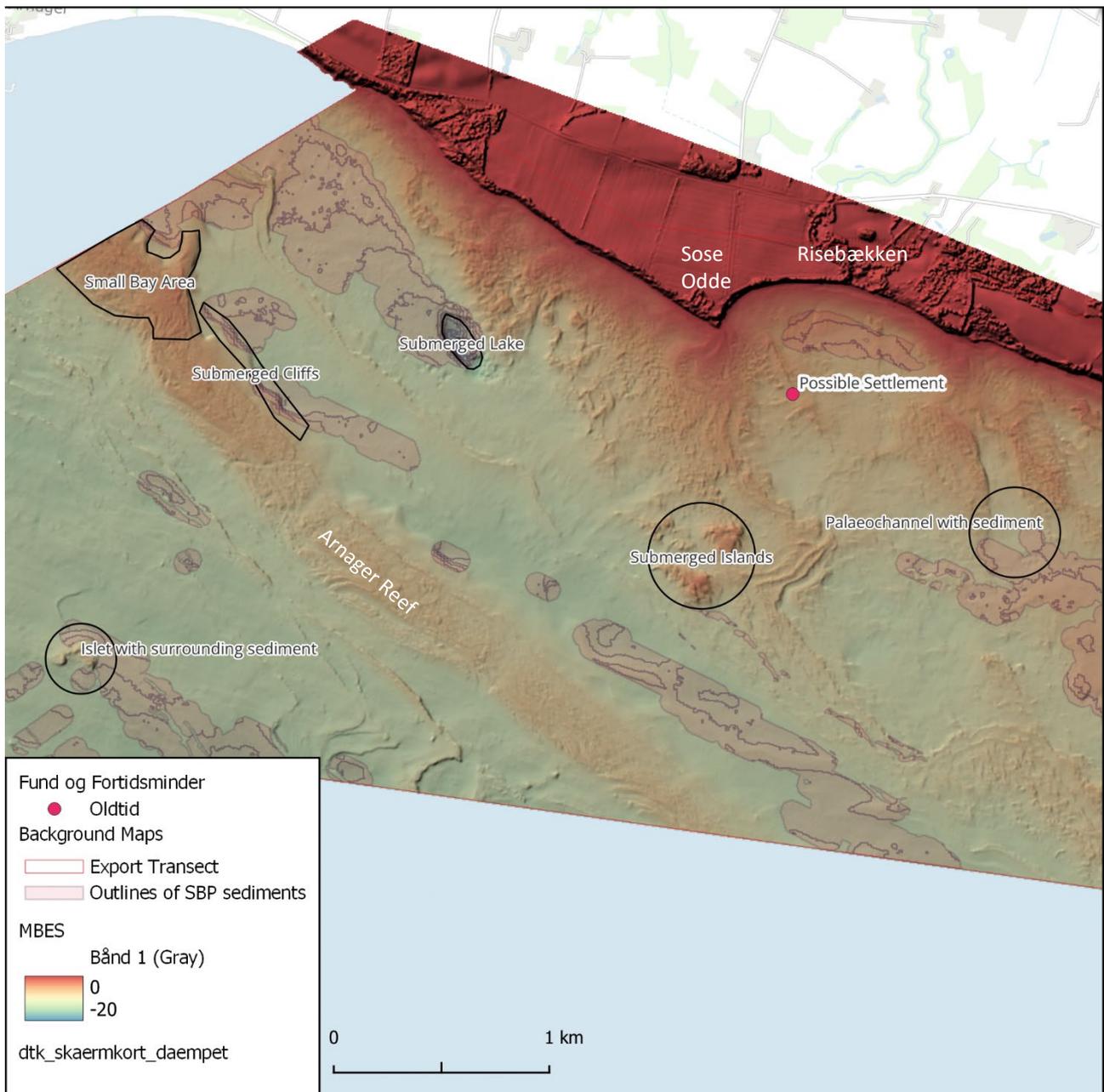


Figure 9. The eastern portion of the Export Transect showing various terrain features which have the potential for archaeological remains from the Mesolithic period. SBP and MBES data provided by Ocean Infinity on behalf of Energinet (Oakley & Pickworth, 2023). Illustration: John Howorth © Vikingskibsmuseet. Contains data from Styrelsen for Dataforsyning og Effektivisering.

The deepest parts of this cable route, the areas beyond the edge of Rønne Banke, hold the least potential for finding any preserved remains from the stone age as they were already underwater from the time humans began to settle the landscape (Jensen & Bennike, 2021).

Future Work

For the present route design (2022_04_14 MMT_Updated_Route), all the SSS targets from the separate survey blocks have been merged into a single GIS file:

VIR_SSS_Export_transect

The GIS file corresponds to Appendix 2 in this report.

In previous projects, it was common practice to create so-called first-generation exclusion zones around potential CHOs depending on the nature and size of the object. An assessment was then made on whether these zones intersected the future work areas. The targets with buffer zones which intersected the work areas were then more closely studied in the side scan and multibeam sonar and the buffer zone was reassessed based on the type, shape, and extent of object. However, more recent guidelines from the Danish Agency for Culture and Palaces urge against the use of these preliminary exclusion zones before visual inspection (Appendix 4).

All targets which are within, and in close proximity to, the proposed work areas should be visually inspected by ROV and the footage screened by archaeologists from VIR in order to further assess their significance. Targets which, through this process, are positively identified as CHOs, will be reported to the National Sites and Monuments register (*Fund og Fortidsminder*). A definitive exclusion zone can then be created around any protected archaeological objects.

The same goes for the potential stone age sites, initial potential sites have been highlighted, but in order to conclude any positively identified sites, further investigation is needed. Such investigations could include dive and/or machine test pit excavations.

If the client's work cannot be carried out due to an exclusion zone or altered to avoid it, special dispensation can be sought. This dispensation would typically state that a marine archaeological survey or excavation would need to be carried out on the site.

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