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Mapping of bioclastic sediments - data, methods and confidence

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REPORT

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Summary:
MAREANO has shown that acoustic mapping with limited ground truthing is a powerful tool for mapping biogenic mounds and associated bioclastic sediments. Standard Quaternary geology maps show the genesis of surficial sediments, i.e. the origin of the sediments and how they have been deposited. In MAREANO, maps of bottom sediment genesis (where bioclastic sediment is one of many sediment classes) are complementary to the maps of bottom sediment grain size. Bioclastic sediments (BS) is a common term used to describe all carbonate sediments resulting from dead organisms and includes a range of grain sizes and origins, from silt to gravel clasts, coral rubble and dead coral blocks. BS normally have a minerogenic component, either coming from in situ deposits, traction currents along the seabed, or deposition from suspension. Many biogenic mounds are wholly or partly covered by living corals and other organisms, but these are not considered part of the bioclastic sediment. In this report, we have defined biogenic mounds based on morphology; i.e. they are structures which can be mapped from bathymetric data. This report contains 1) a general description of BS, 2) a description of how the interpretation is done in MAREANO, 3) a comparison of predicted versus verified occurrences of BS, including an assessment of the confidence of the interpretation in different geological environments, and 4) a description of BS mapped to date, and probable occurrences of BS in other areas. BS have so far been mapped between the outlet of the Norwegian Trench at c. 62° N in the south, and as far north as Fugløybanken at 70°32' N. A total area of c. 95 000 km^2 has been mapped, and BS cover c. 1000 km^2. Areas with flat bottom and low relief structures can be mapped with high confidence while slide and bedrock areas, where biogenic mounds are less easily distinguished from the surrounding topography, confidence is low. Mapping of biogenic mounds and associated BS by use of acoustic methods is considered to be achievable, although limited confidence in some geological environments is noted. New technologies, such as underwater vehicles equipped with synthetic aperture sonar, may help to overcome challenges associated with data resolution.

Keywords: Marine geology	Multibeam bathymetry	Morphology
Bottom photo	Hugin AUV	Bioclastic sediment
Coral mound	Landform	Seabed sediment

CONTENTS

1. INTRODUCTION

Bioclastic sediments (BS) is a term term commonly used to describe all carbonate sediments resulting from dead organisms (Fig. 1). BS includes carbonate sediments found in the coastal zone, originating from shells and calcareous algae (shell sand), but this type of bioclastic deposit is not considered further here. In this report, we focus on BS found on the continental shelf, frequently occurring in association with stony coral (biogenic) mounds.

The term "bioclastic sediment" includes a range of grain sizes from silt to gravel, and both coral rubble and dead coral blocks. BS normally have a minerogenic component, coming from either in situ deposits, traction currents along the seabed or deposition from suspension.

Many biogenic mounds are wholly or partly covered by living corals and other organisms, but these are not considered part of the bioclastic sediment. In this report, we have defined biogenic mounds based on morphology; i.e. they are structures which can be mapped from bathymetric data. Backscatter data from multibeam echosounder (which gives an acoustic proxy to the nature of the sediments) has locally proved to offer a good guide to the distribution of BS, but should be used with care.

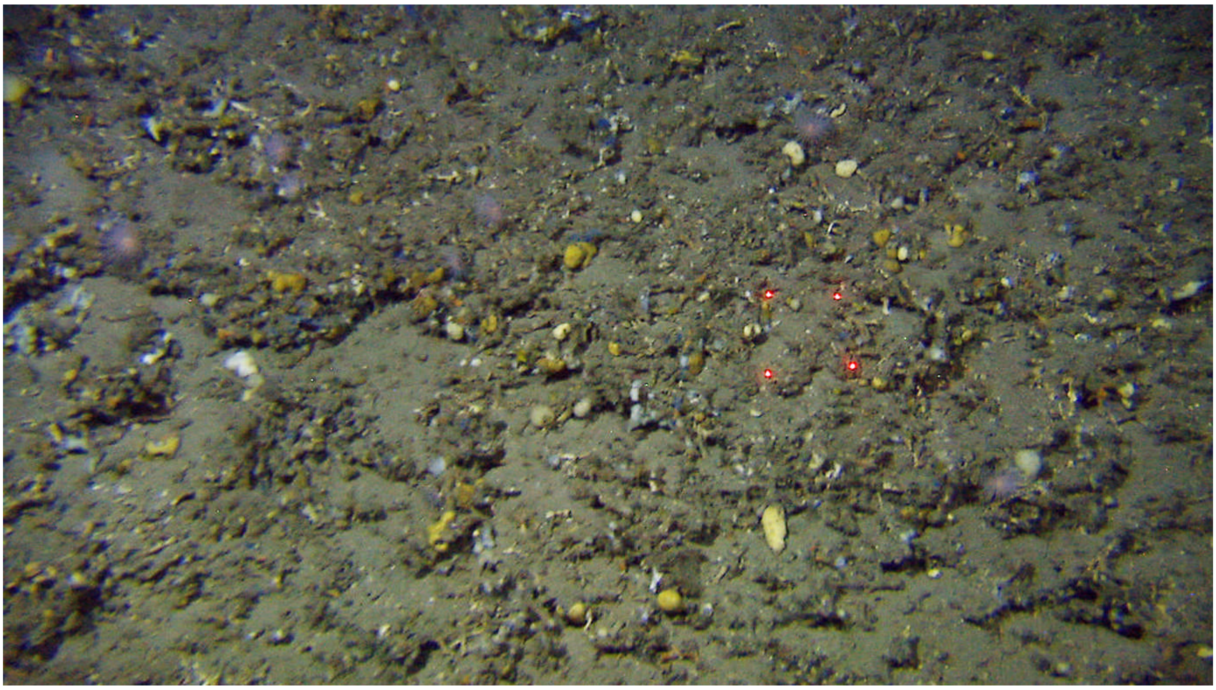

Figure 1. Bioclastic sediments comprise a mixture of minerogenic and biogenic components, covering a wide range of grain sizes. Distance between red laser dots is 10 cm.

MAREANO and other projects have shown that acoustic mapping with limited ground truthing is a powerful tool for mapping biogenic mounds and associated BS. These mounds are composite structures, commonly with a marginal zone with a mixture of minerogenic and biogenic material, and a core zone composed of dead and living corals together with varying proportions of BS (e.g., Buhl-Mortensen et al. 2010).

Standard Quaternary geology maps show the genesis of surficial sediments, i.e. the origin of the sediments and how they have been deposited. Such maps are commonly made from both land and ocean areas, e.g. ISPRA (2013). In MAREANO, maps of bottom sediment genesis (where bioclastic sediment is one of many sediment classes) are complementary to the maps of bottom sediment grain size.

Mapping of BS in MAREANO has been carried out from a geological perspective, focussing on sediment genesis, and not on the biological components of the ecosystems. The maps of BS do not include information on the proportions of dead or living organisms, or any information on which species may occur. This is similar to established standards and procedures in geological mapping onshore, where surficial sediment classes are presented in sediment maps without information about the biology.

The report contains:

- a general description of BS, based on national and international sources
- a description of how the interpretation and prediction of BS is carried out, including data sources and a case study
- a comparison of predicted versus verified occurrences of BS, including an assessment of the confidence of the interpretation in different geological environments
- a description of BS mapped up to now and probable occurrences of BS where mapping has not yet started

2. BIOCLASTIC SEDIMENTS - GENERAL DESCRIPTION

Bioclastic sediments containing scleractinian (stony) corals are reported from many stages of the stratigraphic record, from ancient to modern. Zonneveld et al. (2007) described bioclastic accumulations composed of crinoids, brachiopods, molluscs, spongiomorphs and scleractinian corals from Upper Triassic sedimentary rocks in British Columbia, Canada. Small mounds are interpreted as patch reefs composed of packstone, bioclastic floatstone/rudstone and carbonate breccia intercalated with mixed siliciclastic carbonate sediments.

Biogenic gravel comprising coral and shell fragments in the form of rubble derived locally from a number of cold-water coral mini-mounds have been described from the interfluves of the Dangeard and Explorer canyons in the South Western Approaches in UK (Stewart et al. 2013). They also report the presence of mixed substrata, with both lithic and biogenic sand and gravel, between 200 and 500 m water depth.

Cold-water coral mounds and a large number of living *Lophelia pertusa* reefs along the Galicia bank on the Atlantic NW Iberia margin have been reported by Somoza et al. (2014). Detection and mapping of living coral reefs and mounds was carried out by means of multibeam bathymetry, backscatter, ultra-high and high-resolution multichannel seismic reflection data and sampling. The authors describe mini-mounds (average heights 3-5 m, with 250 m separation) corresponding to living cold-water coral reefs. The mounds are bound upslope by an active field of sandwaves, and downslope by biogenic sands. The summit of the Galicia Bank is covered by a large field of asymmetrical m-scale sandwaves, and samples from these sandwaves yielded coarse fragments of dead Scleractinia corals and other bioclastic sands.

Acoustic mapping of cold-water coral reefs and surrounding habitats using multibeam echosounder has been reported by Roberts et al. (2005) from four areas west of Scotland. They found that *Lophelia pertusa* reefs and the associated coral rubble were best treated as one habitat class, because they could not be separated acoustically, even if they were distinct on video surveys. Their study showed that multibeam echosounders are effective for identifying cold-water coral reefs and providing a baseline to interpret distribution of other habitats. They also point out the discovery of small cold-water coral reefs in previously well-studied waters suggesting that such reefs may be far more widespread than previously thought.

BS have also been recorded on the margin west of Ireland. A 440 cm long piston core from the summit of one of the large cold-water carbonate mounds on the Southwest Rockall Trough margin consisted entirely of biogenic carbonate sand and silt with variable amount of coral debris and other coarse grained bioclastic material (Mienis et al. 2009). A box core retrieved from the same location contained living colonies of *Lophelia pertusa, Stylaster sp.* and associated fauna like anemones, crustaceans and sponges on top of a 20 cm thick layer of coral debris. On average, more than 40% of the piston core and box core sediment consists of sand sized particles.

On a typical *Lophelia pertusa* reef, three different zones were recognized by Mortensen et al. (1995), based on observations from Norway. The zones are 1) "the live *Lophelia*-zone; 2) the dead *Lophelia*-zone; and 3) the *Lophelia* rubble zone, with smaller skeletal fragments mixed with sediments, flanking the reefs. Acoustic mapping of *Lophelia pertusa* coral reefs was performed by Mortensen et al. (2001). The multibeam echosounder revealed 70 mounds presumed to be *Lophelia* reefs. Visual investigation of 15 mounds revealed 1 dead and 14 living *Lophelia* reefs.

3. INTERPRETATION METHODS

3.1 Data sources

This section gives an overview of the data sources used in production of geological seabed maps.

Bathymetry and backscatter data have been collected using multibeam echosounder according to NHS (2010) "Technical specifications Seabed Mapping - MAREANO-programme" published on www.mareano.no.

Seabed video data have been collected in 700 m long transects, using towed HD video equipment and digital storage. All data were collected according to Standard Norge (2009) "Visuelle bunnundersøkelser med fjernstyrte og tauede observasjonsfarkoster for innsamling av miljødata" (NS 9435).

Seabed sediment samples were collected using grab, box corer and multicorer according to guidance on sampling in marine sediments (Standard Norge 2004). Grabs were used to take sediment samples up to a few kilos of the uppermost c. 10 cm of the seabed. Visual description of sediment samples was done onboard according to SOSI-classification, and subsamples were preserved in plastic bags for grain size and other analyses. Box corers were used to obtain sediment samples of the uppermost c. 50 cm of the seabed. Visual description of the sediment surface was done onboard according to SOSI-classification. Box cores were sub-sampled with plastic tubes to obtain cores for grain size and other analyses. All samples and cores were carefully labelled and documented in a station journal. Post-cruise grain-size analyses on subsamples were performed by wet sieving and Laser Coulter Counter (http://www.beckmancoulter.com/coultercounter/product_LS2Series.jsp).

A TOPAS PS018 (www.kongsberg.com) parametric sub-bottom profiler was used for collecting high-resolution seismic data on R/V G.O. Sars (http://www.imr.no/om_havforskningsinstituttet/fasiliteter/fartoy/g_o_sars/en). Data are stored in TOPAS raw format for later processing.

3.2 Data processing and interpretation

This section gives an overview of the steps, from initial data processing to interpretation and digitising of the final map products.

Multibeam backscatter data were processed by NGU from raw multibeam data into raster grids of backscatter amplitude in decibels (dB). The processed data were converted to ArcGIS format and archived in NGU's Marine Geology database.

Terrain modelling was used to produce quantitative descriptors (e.g. slope) of the seabed from bathymetry data. Quantitative descriptors were used for identifying potential coral mounds and delimiting the extent of BS.

Preliminary maps for cruise planning were compiled prior to the combined geology/biology/pollution mapping cruises. Preliminary maps were based on multibeam bathymetry (including various terrain indices such as slope), backscatter data as well as existing geological information, and were used for planning the location of ground truthing stations (video, grab, boxcorer, multicorer) and shallow seismic profiles.

After completing the cruise, all data were integrated in an ArcGIS environment with datasets on bathymetry, backscatter, shaded relief, shallow seismic, seabed samples, videos and photos, and geochemistry. Geological interpretations were done according to the SOSI standard for superficial deposits (Statens kartverk 2006). Sediment genesis maps (comparable with Quaternary geology maps on land) were made according to this standard.

ArcGis 10.1 from ESRI (www.esri.com) was used for interpretation and compilation of geological maps. Fledermaus 7.3.5 (www.qps.nl) was used for visualizing bathymetric data (shaded relief).

Digitizing of geological boundaries and features was done manually at a scale of 1:20 000 to make maps suitable for presentation at 1:100 000 scale. The distance between data points for lines and geological boundaries is set to 50 m. Only objects larger than 100 m in length/diameter are digitized.

The interpretation of the spatial distribution of BS is primarily based on the recognition of biogenic mounds from multibeam bathymetry, supplemented with video footage and physical samples where these are available. Multibeam backscatter data has locally proved to be indicative of the spatial distribution of BS, but has to be interpreted with care because it has been difficult to establish a consistent and systematic relationship. The minimum dimensions for structures interpreted as biogenic mounds are 20 m diameter and 2 m height (see example in Fig. 2). This will vary according to the surrounding terrain complexity.

A buffer zone of c. 30 m has been drawn around the biogenic mounds. Due to the limitations defined by digitizing resolution, several small mounds are frequently digitised as one area. The grid size of the multibeam bathymetry used is generally 5 m, however, old multibeam bathymetry with lower resolution has had to be used in some areas. This is the case for parts of the shelf edge west of Mørebankene, and the Røst Reef area in Nordland VI. Incorporation of lower resolution data has led to more generalised maps than in areas with full, modern multibeam coverage. For further description of the methods used for geological mapping offshore, please refer to Bøe et al. (2010).

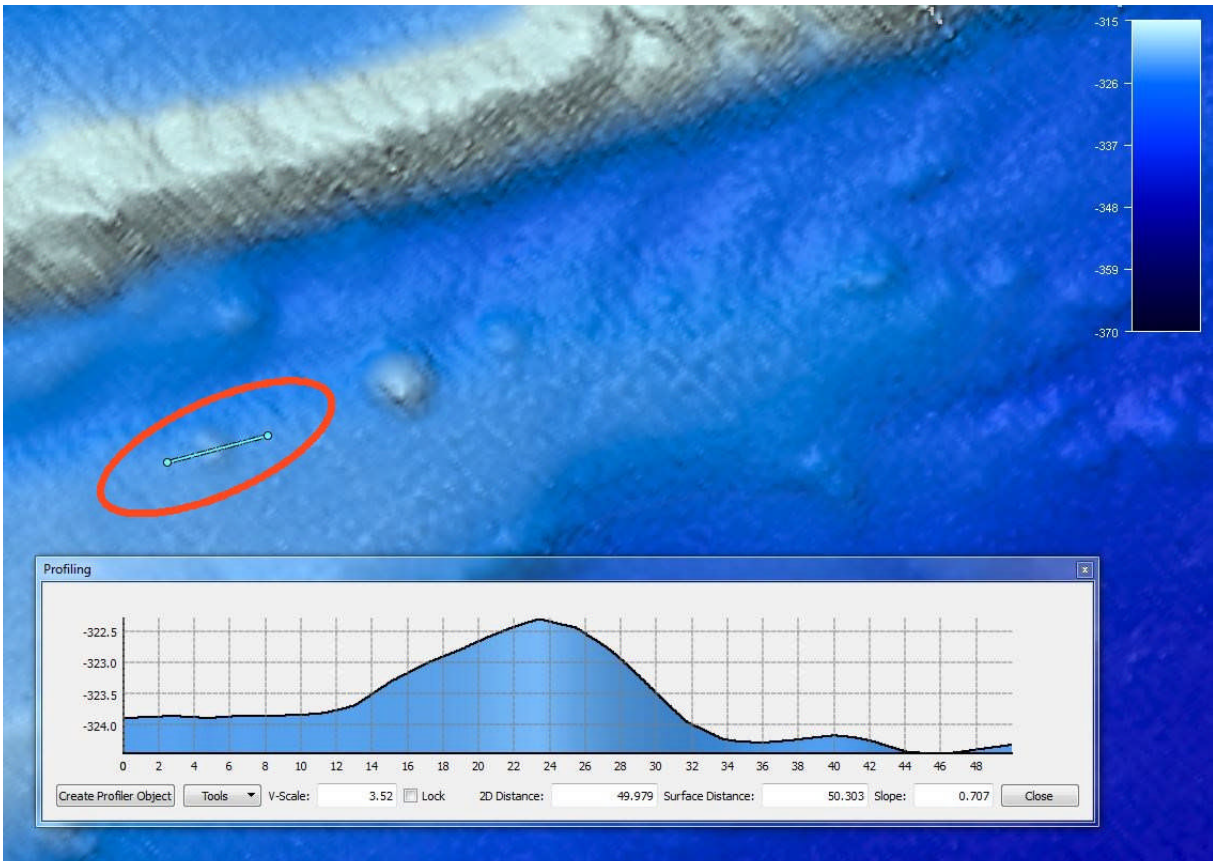

Figure 2. Screen dump from Fledermaus, showing a profile over a biogenic mound at the Sula Reef. The profile line (in the red ellipse) is 50 m long. The height of the mound is 1.5-2 m.

3.3 Examples of bioclastic sediments associated with coral mounds

The Sula Reef is one of the best documented cold-water coral reef complexes in Europe (see Hovland (2008) and references therein), and the bathymetric mapping by MAREANO in 2012 shows that there are nearly 1000 mounds in the Sula Ridge area. The number of confirmed coral reefs in the coral database of the Institute of Marine Research (IMR) (www.mareano.no) is considerably lower. The confirmed coral reefs are published by IMR as points, not polygons delineating areas (Figs. 3 and 4).

One video transect (R960) is located in the central-northern part of the reef complex, starting in gravelly muddy sand and extending ENE onto a more than 1000 m long coral ridge. The morphology of the ridge, the position of the video line, and 8 pictures from the CAMPOD video are shown in Figure 5. The first pictures (1-2) show that sediments surrounding the ridges and mounds are gravelly muddy sand. Pictures 3-5 show that a large part of the southwestern end of the ridge is covered by BS. On the central part of the ridge, live corals are common (pictures 6-8).

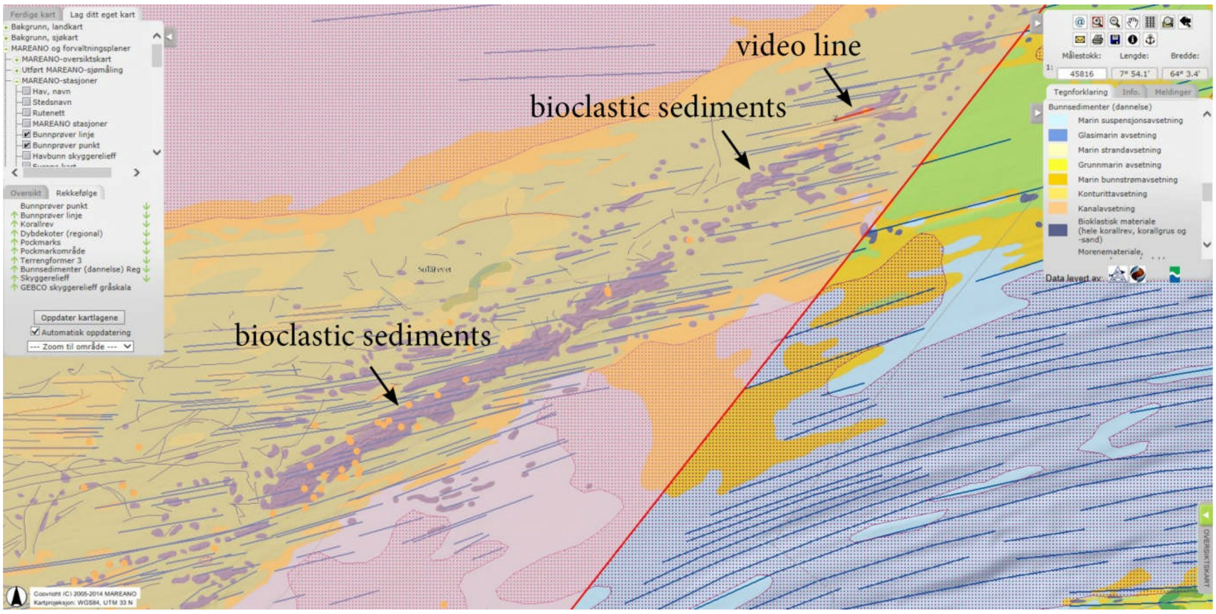

Figure 3. Screen dump from www.mareano.no, showing the Sediment genesis map including BS (violet polygons) and land forms. Also shown is the distribution of confirmed coral reefs (orange dots). The pink overlay to the left of the red line marks protected coral areas. The position of the video line in Fig. 5 is shown.

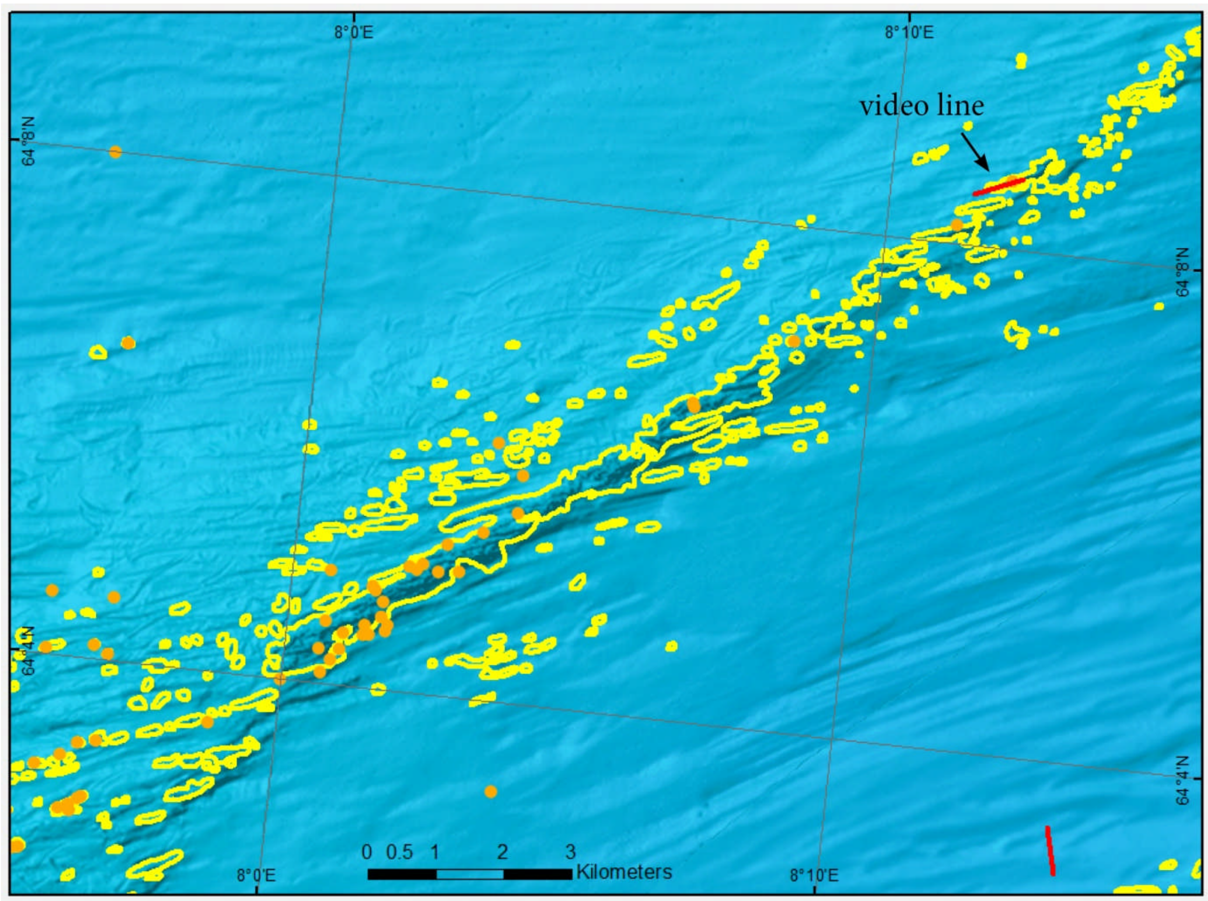

Figure 4. Map showing BS (yellow outlines) (interpreted by NGU as part of the seabed sediment genesis map) and confirmed coral reefs (IMR, www.mareano.no). The position of the video line in Fig. 5 is shown.

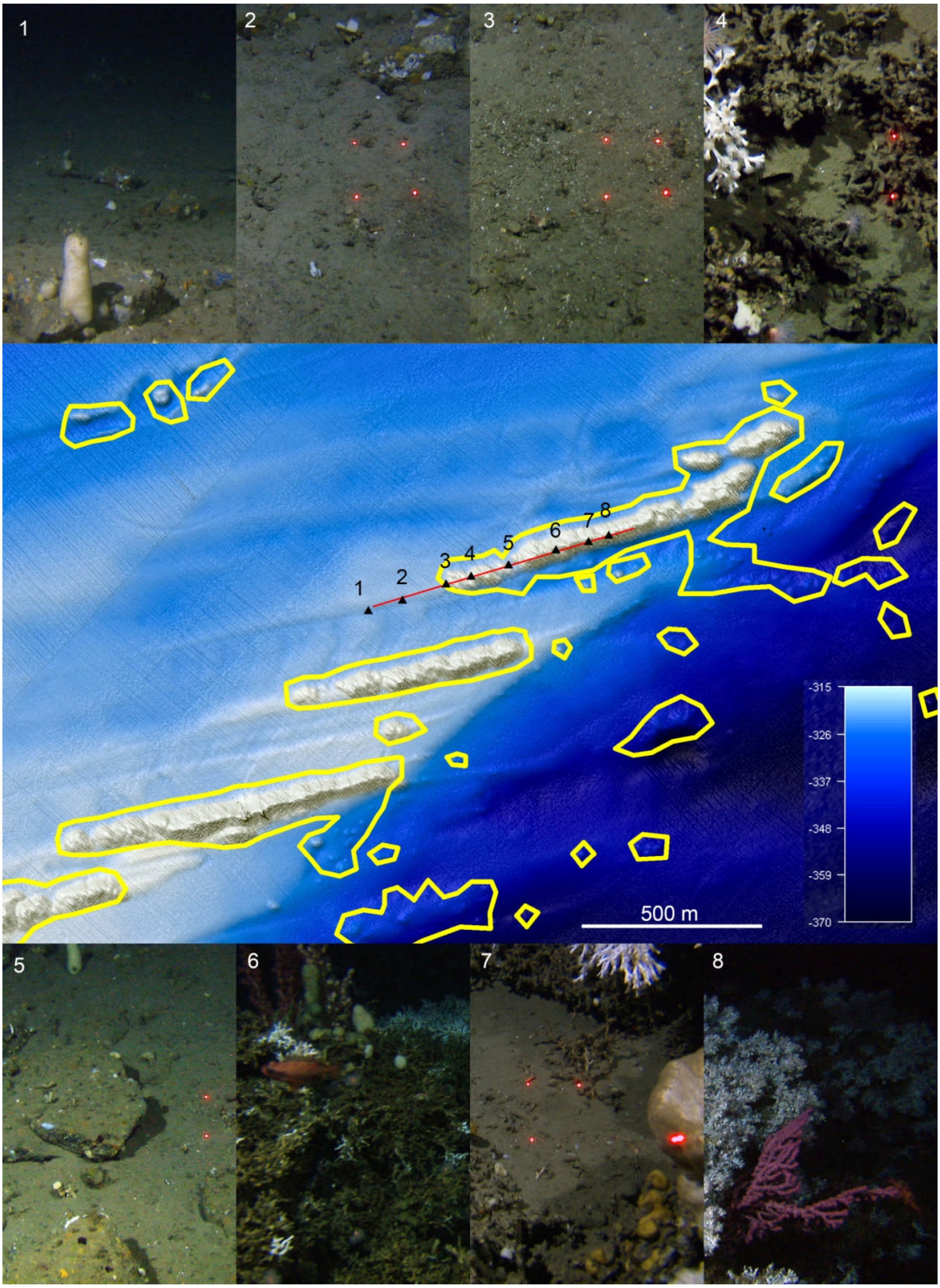

Figure 5. Central part - shaded relief map from the Sula Ridge, showing ENE-WSW trending coral ridges on top of glacial ridges, and solitary coral mounds (e.g. upper left corner). The yellow outlines show areas with BS. The CAMPOD video line is shown by a red line, and numbers refer to the pictures in the upper and lower part. 1 - gravelly muddy sand. 2 - gravelly muddy sand. 3 - gravelly sand with biogenic material. 4 - muddy sand with coral rubble. 5 - gravelly muddy sand with blocks. 6 - mainly coral rubble or dead coral framework. 7 - muddy sand with coral rubble. 8 - living corals on top of BS.

4. ASSESSMENT OF CONFIDENCE AND STRENGTH OF CORAL MOUND PREDICTIONS

4.1 Comparison of predicted and verified occurrences

This section provides quantitative documentation of the level of agreement between BS occurrences, based on NGUs interpretation of acoustic data, and observed coral mound occurrences. From the four MAREANO cruises in 2012 and 2013 in the Norwegian Sea, a total of 285 video lines were acquired. BS (various biogenic clasts of silt to gravel size, coral rubble, dead coral blocks partly covered by live corals) were identified on 60 lines (Figure 6, Table 1). The occurrences of BS including biogenic mounds have been grouped according to the bottom environment (geological landscape or landform) where they occur. BS were predicted on 44 of the lines, based on expert interpretation on multibeam data. The predictions were verified in 41 lines, while 3 predicted occurrences were not verified. Of the 41 predicted occurrences, 29 were considered to have a high certainty. All of these predictions turned out to be correct. 15 predictions (out of the 44) had medium to low certainty (MidLowC). The result here was that 12 predictions were verified, while 3 were not verified (2 in bedrock, 1 on a glacial ridge).

Table 1. Percentage of verified and non-verified coral mound occurrences versus predictions.

Bottom environment	Verified (%)	Not verified (%)
Flat, with low relief structures	52	0
Bedrock	2	5 (MidLowC, on bedrock)
Iceberg ploughmarks	18	0
Glacial lineations - ridges	11	2 (MidLowC, on ridge)
Moraine ridges	7	0
Pockmarks	0	0
Shelf edge	2	0
Slide (scar, ridges)	0	0
Sum	***93***	***7***

BS were found in 19 video lines without being predicted. Table 2 shows that unpredicted BS occur primarily in the Slide regions. Some were also found in Bedrock, Iceberg ploughmarks, Pockmarks and one on the Shelf edge, based on 15 m grid bathymetry.

Table 2. Number of non-predicted coral mound occurrences.

Bottom environment	**Not predicted**
Flat, with low relief structures	0
Bedrock	3 (1 with 50 m grid)
Iceberg ploughmarks	2
Glacial lineations - ridges	0
Moraine ridges	0
Pockmarks	3
Shelf edge	1 (15 m grid)
Slide (scar, ridges)	10 (2 with 15 m grid)

The rate of successful prediction has increased over the period 2012-2013. For example, the first 2012 cruise showed that it was difficult to predict correctly the occurrence of BS on Bedrock. This was taken into account during the subsequent interpretation in 2013. The last 2013 cruise proved that it is very difficult to identify BS with certainty in Slide areas, especially where there are many ridges and small blocks. Biogenic mounds and mounds created by sliding are difficult to distinguish.

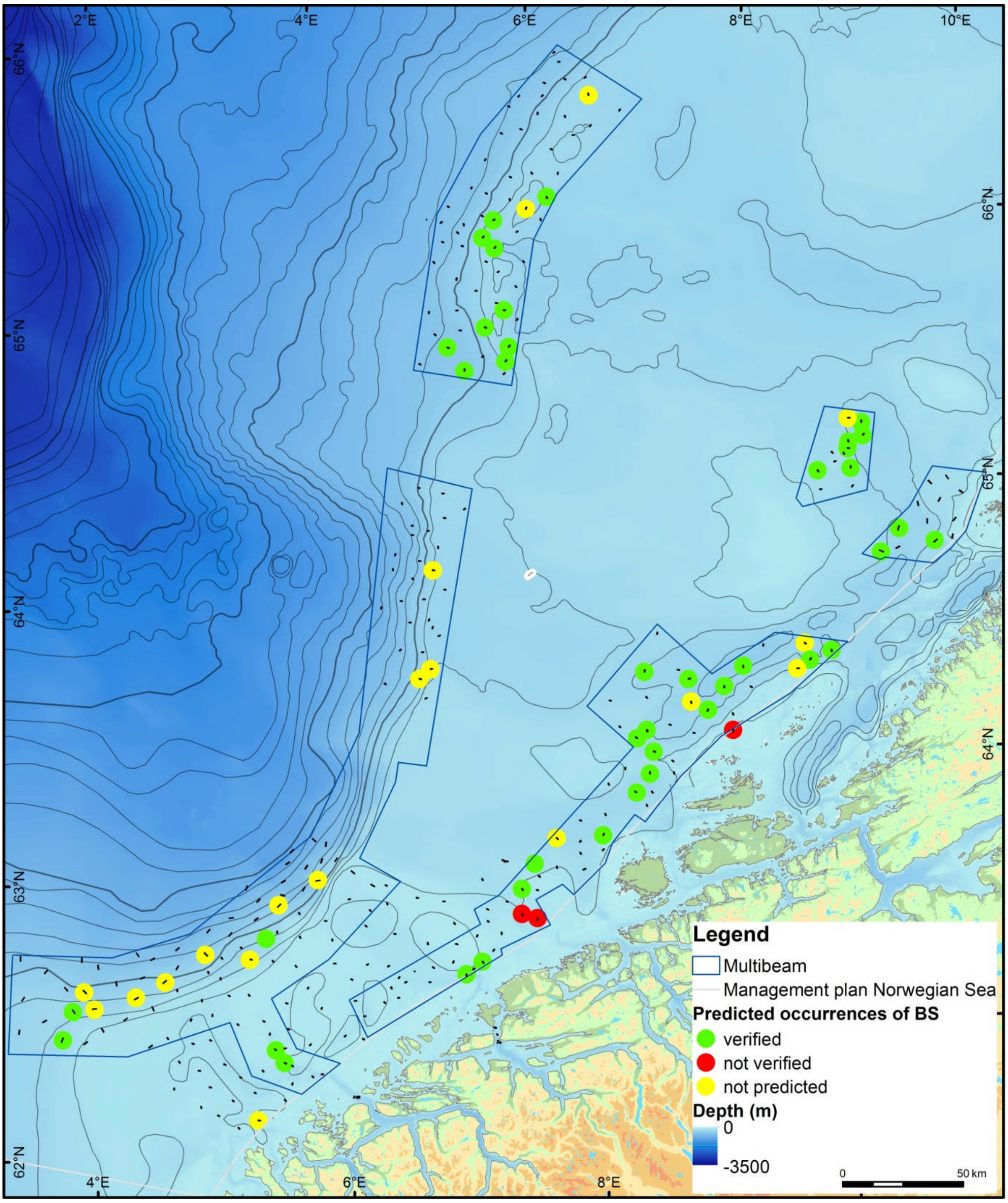

Figure 6. Spatial distribution of verified and non-verified predictions, and occurrences of BS not predicted.

4.2 Assessment of predictions in different geological environments

The experience of the work done in 2012-2013 on prediction of biogenic mounds with BS is summarised in Table 3. A qualitative ranking scale for confidence has been implemented based on the geologists ability to interpret BS from acoustic data where Poor means that there is a considerable risk for both under- and overestimation, Moderate to Good means low risk, while Very Good means that there is a very low risk for both under- and overestimation.

Very good predictions can be expected in areas of flat bottom and low relief structures (when exceeding the minimum size of 2 m height and 20 m diameter). The Sula Reef area (Fig. 4) is a good example. The biogenic mounds can be distinguished from geological structures with high confidence.

The confidence is assessed to be Good to Moderate in slightly more complex bottom environments, such as areas with iceberg ploughmarks, ridges or pockmarks (Fig. 7). In these environments, there are geological structures which may be interpreted incorrectly as biogenic mounds with BS.

The most challenging environments are Bedrock and Slides. The very high terrain complexity in these environments make the distinction between biogenic mounds and morphological features created by bedrock erosion or slide processes very difficult, with a high to medium high risk for underestimation, and a medium high to low risk for overestimation (Fig. 8).

Table 3. Assessment of predictive capability in different geological environments (classes).

Bottom environments	Confidence	Risk for underestimation	Risk for overestimation
Flat, with low relief structures	Very good	0	0
Bedrock	Poor	XX	X
Iceberg ploughmarks	Good	XX	X
Glacial lineations – Ridges - Moraines	Good	X	X
Coral in pockmarks*	Moderate	X	X
Slide (scar, ridges) – Shelf edge	Poor	XXX	XX

* Small mounds in pockmarks have proved to be easy to recognise, based on post-cruise analysis. Risk classes: 0 - very low; X - low; XX - medium high; XXX - high.

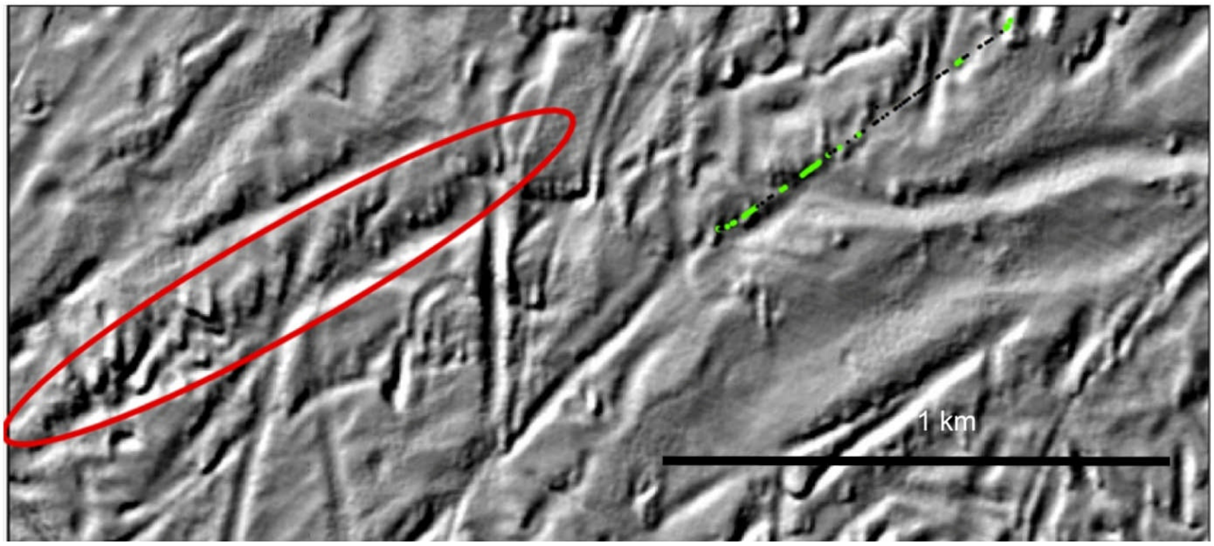

Figure 7. Shaded relief image of 5 m multibeam bathymetry data showing biogenic mounds and associated BS in an iceberg ploughmark area. The video line (right) shows identified BS (green dots along the line). The circle to the left shows similar structures which are interpreted as BS.

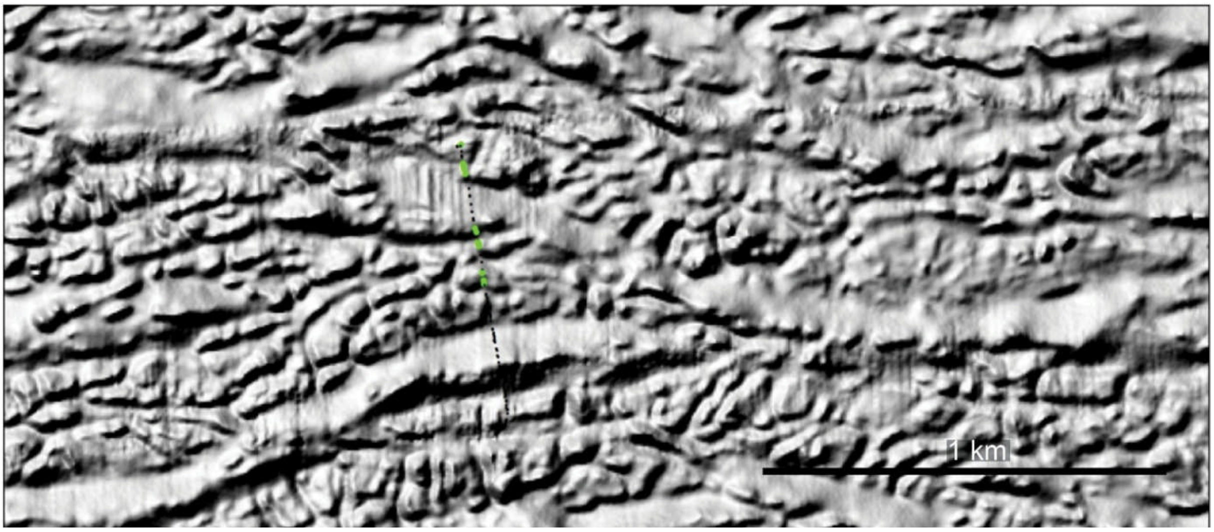

Figure 8. Shaded relief image of 5 m multibeam bathymetry data showing slide blocks and ridges in the Storegga Slide area, NW of Mørebankene. The video line (central part) shows identified BS (green dots along the line). It is difficult to interpret BS in this area because of the numerous slide blocks forming hills and mounds resembling coral mounds.

5. SPATIAL DISTRIBUTION OF BIOCLASTIC SEDIMENTS

Bioclastic sediments described in this report have been mapped between the outlet of the Norwegian Trench at c. 62º N in the south and Fugløybanken at 70º32' N in the north. The mapping is based on multibeam bathymetry and other data from an area of c. 95 000 km^2. This includes large parts of the shelf edge, Mørebankene, Sularevet, Iverryggen, parts of the coastal belt, Nordland VI, Nordland VII and Troms III. All of these areas have been given a special status in the management plans for the Norwegian Sea, and for the Lofoten - Barents Sea.

Mapped BS cover an area of c. 1000 km^2. Biogenic mounds make up 10-20% of the total area interpreted as BS, i.e. 100-200 km^2. This proportion will vary significantly by area. In places with single biogenic mounds on flat bottom with low relief, the proportion will exceed 50%. In areas where the interpretation is based on multibeam bathymetry with lower resolution, and where the bottom environment is characterised by for example ploughmarks, the proportion of biogenic mounds may be 10% or lower.

The frequency of BS and biogenic mounds is considerably higher on the mid-Norwegian shelf south of 68º N, than on the shelf north of 68º N (Figs. 9 and 10). There is full multibeam bathymetric data coverage from 4 nautical miles and outwards down to 1000-3000 water depth north of 67º N, while south of 67º N only selected areas have been mapped with multibeam bathymetry. This mirrors the apparent reduction in coral reef abundance northwards.

The area covered by BS between the 12 nautical mile boundary and the inner boundary of the ocean management plan area south of 67º N is 204 km^2, while the area covered by multibeam bathymetry is 6630 km^2. This gives an average cover of c. 3%. The area covered by BS in this zone north of 67º N is 37 km^2, while the area covered by multibeam bathymetry is 9600 km^2. This gives an average cover of 0.4%.

There are large areas still not covered by multibeam bathymetry, such as the coastal belt, parts of the shelf edge, and the shelf areas between the coastal belt and shelf edge including Haltenbanken. Some coral reefs have been identified by IMR and the petroleum industry from these areas, but it is expected that a considerable number of biogenic mounds with associated BS will be found once these areas are mapped. The two major slide areas along the shelf edge, the Storegga Slide in the south, and the Træna Deep Slide in the north can also be expected to have large areas of BS which have not yet been identified using the existing methods and technology.

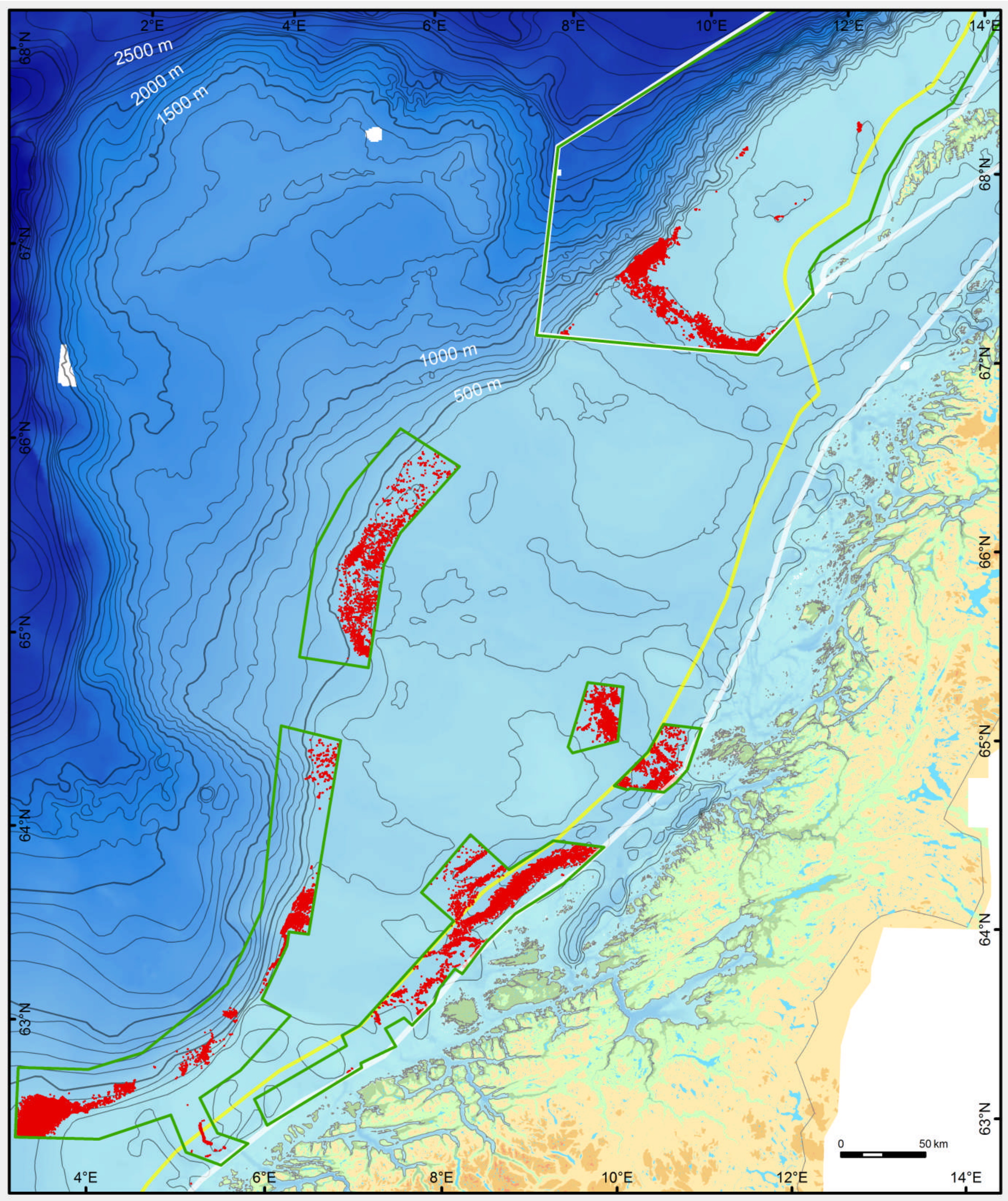

Figure 9. Spatial distribution of BS (red areas) on the continental shelf and upper slope in the Norwegian Sea between 62º N and 68º N. Dark green polygons show areas with multibeam bathymetry that have been mapped. Yellow line - 12 nautical mile boundary. Light grey line - boundary for ocean management plan areas.

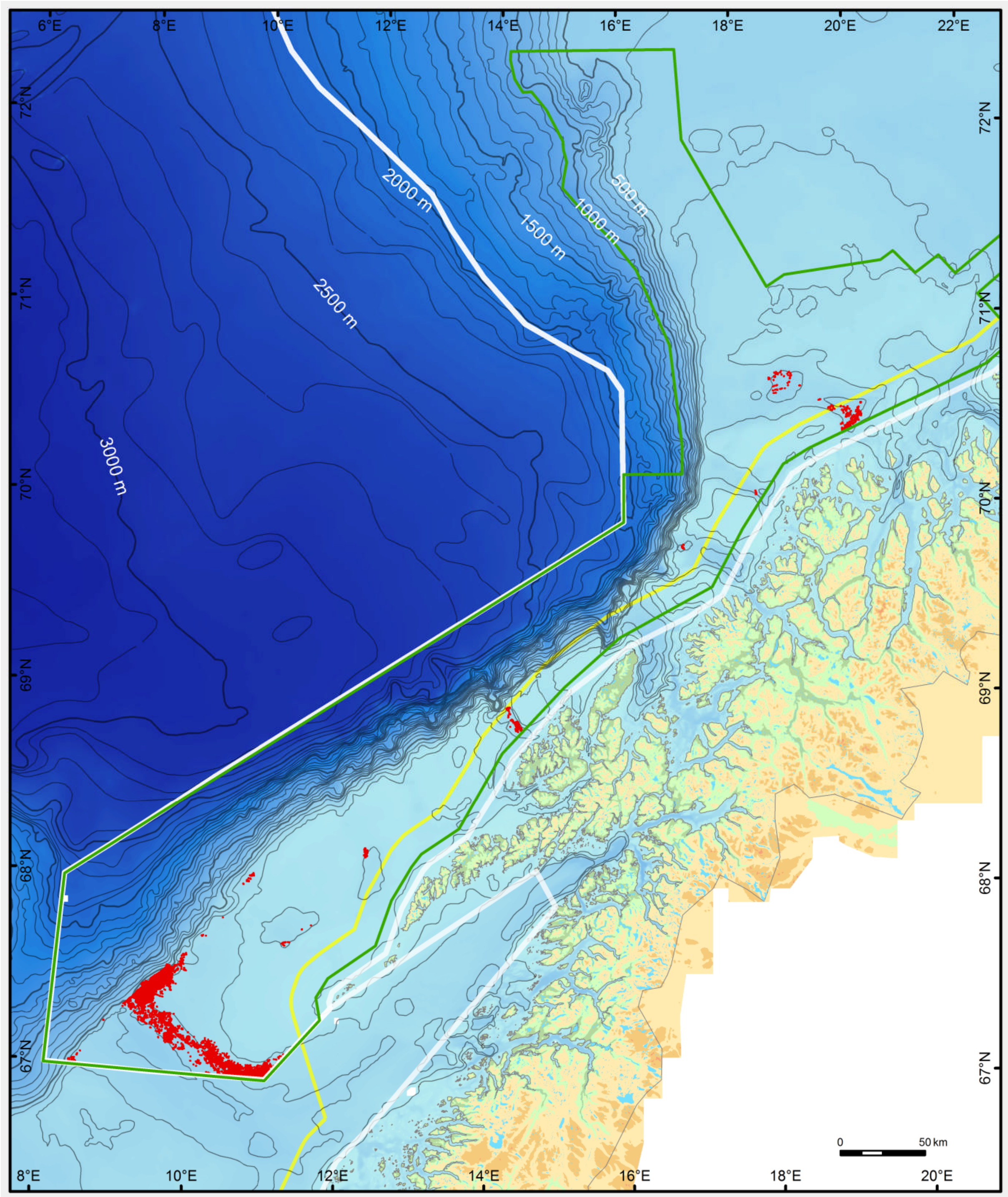

Figure 10. Spatial distribution of BS (red areas) in the Norwegian Sea-Barents Sea between 67º N and 71º N. Dark green polygon show areas with multibeam bathymetry that have been mapped. Yellow line - 12 nautical mile boundary. Light grey line - boundary for ocean management plan areas.

6. DISCUSSION

Bioclastic sediments associated with biogenic mounds are widespread in areas mapped by MAREANO south of 70º32’ N. The interpretation of spatial distribution of biogenic mounds is based mainly on multibeam bathymetry. The confidence of this mapping is considered to be high in certain environments such as flat bottom with low relief structures, while the confidence is poor in slide and bedrock areas.

Recognition of biogenic mounds has so far primarily been based on the use of terrain indices combined with expert interpretation of shaded relief maps. More automated methods such as Object-based image classification offer potential improvements for interpretation of biogenic mounds and associated BS, and would allow interpretation to become faster and less subjective. New technologies such as Autonomous Underwater Vehicles (AUVs) equipped with Synthetic Aperture Sonar (SAS) are expected to become powerful instruments for identifying biogenic mounds and associated BS. In slide and bedrock areas the increased resolution offered by these instruments will prove particularly useful in light of the limitations of existing, hull mounted multibeam data.

An example illustrating this is shown in Figure 11, from a survey conducted by Lundin Norway AS, the Norwegian Defence Research Establishment (FFI) and NGU in the Troms III area west of Lopphavet. The sonar image has a resolution of 6x6 cm, and provides detailed images of sediments and structures such as stony corals, but not soft tissue organisms. AUVs also have the capability to carry photographic equipment which can give visual ground truthing for the interpretation of biogenic mounds and BS.

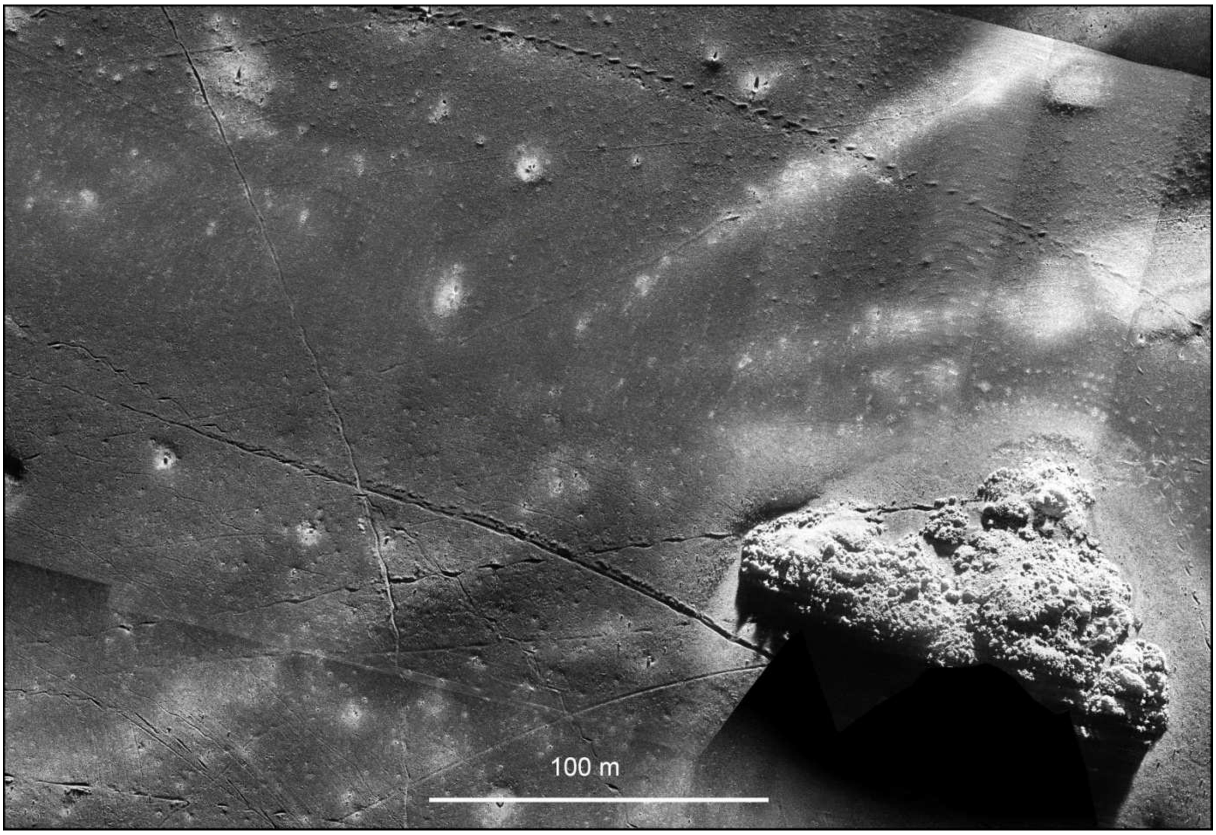

Figure 11. Sonar image (SAS, mounted on a HUGIN AUV) from Troms III, showing a biogenic mound fringed by a 30 m wide zone of BS. Note abundant small pockmarks and trawl marks. Courtesy: Lundin Norway AS and FFI.

7. CONCLUSIONS

Bioclastic sediments have been mapped between the outlet of the Norwegian Trench at c. 62º N in the south, and as far north as Fugløybanken at 70º32' N. A total area of c. 95 000 km^2 has been mapped, and BS cover c. 1000 km^2. Biogenic mounds, with possible coral reefs, constitute 100-200 km^2 of the mapped areas.

The confidence of the maps of biogenic mounds and BS vary considerably. Areas with flat bottom and low relief structures can be mapped with high confidence while in slide and bedrock areas, the confidence is low. Mapping of biogenic mounds and associated BS by use of acoustic methods is considered to be a powerful tool although limited confidence in some geological environments is noted.

New methods such as object-based image classification may help for the interpretation of biogenic mounds and BS. These methods may give quantitative classifications that can be reproduced so one does not have to rely solely on expert interpretations.

New technologies like AUV carrying SAS and other instruments may partly overcome challenges associated with hull-borne multibeam echosounders and increase mapping confidence in challenging bottom environments such as slide and bedrock areas.

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