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Seabed sedimentary environments and sediments (genesis) in the Nordland VI area off northern Norway

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REPORT

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Summary:

This report presents maps of sedimentary environments and seabed sediments (genesis) in the Nordland VI management area off northern Norway. The maps, which cover about 25 000 km² and water depths from 60 m to 2700 m, are based on multibeam echosounder data (bathymetry and backscatter), 215 video lines each 700 m long, seabed sediment samples from 40 stations (grab, boxcore and multicore) and 5500 km of sub-bottom profiler data. The sedimentary environment map has 6 classes, focussing on present depositional environments (erosion and deposition). Large parts of the Nordland VI continental shelf are dominated by erosion processes, but some deposition occurs in topographic depressions and glacial troughs like Trænadjupet and Vesterdjupet. Hemipelagic sediments are deposited in deep water areas on the continental slope and abyssal plain. The seabed sediments (genesis) map comprises a geological interpretation of the uppermost few metres of the seabed, and has 10 classes. On the continental shelf, we find marine suspension deposits, bedload (traction) deposits, bioclastic sediments, till and bedrock with thin or discontinuous sediment cover. The continental slope is dominated by mass movement deposits and a major contourite deposit with the following classes: contourite, debris flow deposit, mass movement deposits and hemipelagic sediments, mass movement deposit (locally covered by younger sediments), debris flow deposits and laminated sediments (>1m) underlain by debris flow deposits.

Keywords: MAREANO	Seabed sediments	Sediment genesis
Depositional environment	Continental shelf	Multibeam
Mass movement	Continental slope	Quaternary geology

CONTENTS

APPENDICES

1. INTRODUCTION

The seabed sediment maps from the Nordland VI area are products from the Norwegian seabed mapping programme MAREANO (www.mareano.no), which was launched in 2006 in order to improve the knowledge of the Norwegian seafloor. The programme produces detailed maps of bathymetry and topography, seabed sediments, contaminants, biodiversity and biotopes (Bellec et al., in press). The Institute of Marine Research (IMR), the Geological Survey of Norway (NGU) and the Norwegian Mapping Authority (Norwegian Hydrographic Service, NHS) are the executing partners responsible for field sampling, mapping and scientific studies. The knowledge gained from MAREANO provides basis for ecosystem-based management, organised through integrated management plans covering the Norwegian offshore areas.

More than 175 000 km^2 of the Norwegian continental shelf and slope, down to 3000 m depth, have been mapped since 2005. All results from the mapping programme are published on http://www.mareano.no/en/maps/mareano_en.html, including the following geological map products: Seabed sediments (grain size), seabed sediments (genesis), sedimentary environment, and landscapes and landforms. The maps are based on data sets such as multibeam bathymetry and backscatter, seabed sediment samples and cores, videos of the seafloor and high resolution sub-bottom profiler data (TOPAS).

This report presents two maps, the sedimentary environment and the seabed sediments (genesis) maps, made by NGU for presentation at scales of 1:100 000 to 1:250 000. The sedimentary environment map focuses on the present depositional environment and shows areas of sediment erosion and deposition, thus providing information of how bottom currents influence the seabed. In most cases sediment grain size reflects the strength of bottom currents: mud suggests weak bottom currents and sediment deposition, while coarser sediments may suggest stronger currents with sediment transport and/or erosion. The map is to a large degree based on multibeam backscatter and ground-truthing. The seabed sediments (genesis) map comprises an interpretation of the sedimentary processes that have formed the sediments in the upper few metres of the seabed. Landforms, sediment grain-size and TOPAS lines are among the tools used to make this map.

The Nordland VI management area described in this report is defined by the Norwegian authorities for evaluation of exploitation of oil and gas. It is located southwest of the Lofoten islands, north Norway. One of the largest known live cold-water coral reefs in the world (Røstrevet; Fosså et al., 2005) is located here along the shelf edge. On the shelf, very important fishing grounds occur. This area has been prioritised in the integrated management plan for the Barents Sea and the sea areas off the Lofoten Islands (Anon., 2006) because of possible conflicts between human activities (fishing and oil industry), and vulnerable marine ecosystems (Bellec et al., in press).

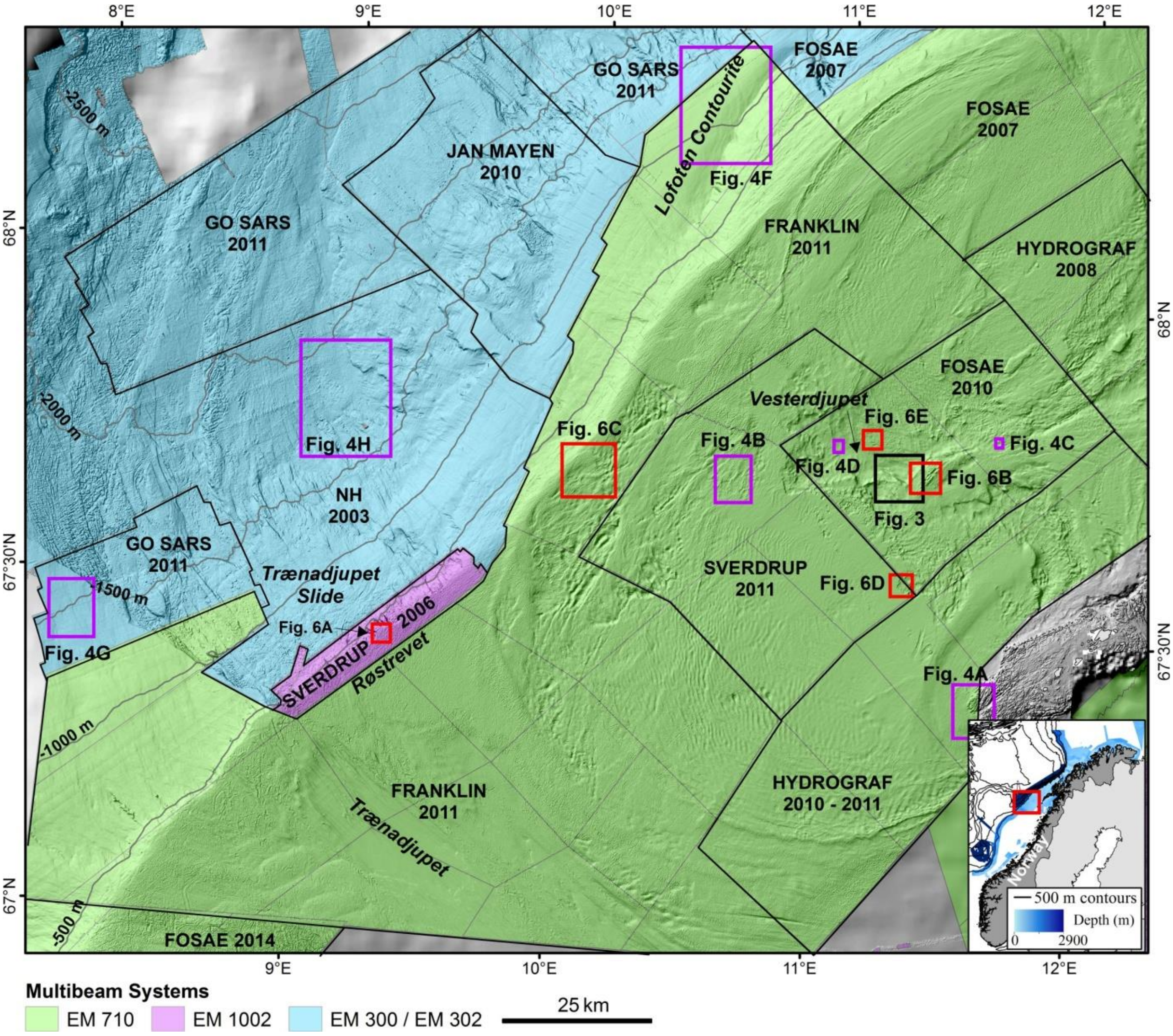


Figure 1. Map from the Nordland VI management area showing extent of multibeam echosounder surveys (black polygons), research vessels (in capital letters) and year of surveys. Also shown are figure locations referred to in the text. Inset map shows MAREANO multibeam data with depth contours labelled every 500 m.

The Nordland VI area covers about 25 000 km² of the Norwegian continental shelf and slope, from 60 m to 2700 m water depth (Fig. 1). Its morphology shows that the continental shelf (from the coast to about 300 m depth) was shaped by the Scandinavian ice sheet during the last glaciations. The most prominent glacial landscape feature is the 40-80 km wide and up to 500 m deep Trænadjupet Trough which is a continuation of the Vestfjorden basin southeast of Lofoten. The Trænadjupet Trough was strongly eroded during the last glaciation, and more than 100 m thick glacial debris flow deposits were deposited beyond the shelf edge (Rise et al., 2005). Another characteristic topographic feature is the Vesterdjupet Trough (about 290 m deep), probably formed by glaciotectonic erosion of the shelf west of Lofoten. The continental slope is incised by the large Trænadjupet Slide, which occurred ca. 4000 years ago due to failure of contourite deposits below the debris flow deposits (Laberg and Vorren, 2000; Laberg et al., 2002). North of the Trænadjupet Slide, several older slides have transported huge quantities of sediments towards deeper areas (Baeten et al., 2013, 2014). Sediments are also transported along the continental slope by contour (parallel) currents. Sand and gravel waves locally occur on the upper slope, while finer-grained sediments accumulate between 600 and 1000 m water depth as a contourite deposit (Lofoten Contourite; Laberg et al., 1999). The upper slope south of the Trænadjupet Slide and the area between the Trænadjupet Slide in the southwest and the Lofoten Contourite in the northeast are characterized by glacigenic debris flows deposits (Lindberg et al., 2004; Baeten et al. 2013, 2014).

2. METHODS

2.1 Data

The study area is the same as presented in Bellec et al. (2017) with focus on seabed sediments (grain size). It was mapped between 2003 and 2014 with multibeam echosounders (MBES) on seven different research vessels operated by five contractors (Figure 1 and Table 1). Two different MBES were used for less than 1000 m depth (EM1002 – 95 kHz and EM710 – 70-100 kHz range) and two for depths greater than 1000 m depth (EM300 and EM302, both 30 kHz). The specifications of the various MBES are listed in Table 2.

Table 1. Research vessel, operator, year of survey and multibeam echosounder system used during surveys (from Bellec et al., in press).

Research Vessel	Operator	Year	Multibeam echosounder
Unknown	Norsk Hydro	2003	EM300
Sverdrup	FFI	2006	EM1002
Sverdrup	FFI	2011	EM710
FOSAE	FUGRO	2007/2014	EM710 / EM300
Jan Mayen	University of Tromsø	2010	EM300
Hydrograf	Norwegian Mapping Authority	2010/2011	EM710
G.O. Sars	MAREANO	2011	EM302

Table 2. Technical specification of the different multibeam echosounder systems used during surveys. NA: not applicable (from Bellec et al., in press).

Multibeam echosounder	Frequency	Beamwidth	Beam numbers	Maximum ping rate	Swath coverage sector
EM710	70-100 kHz	0.5x1° to 2x2°	400/800	30 Hz	140°
EM1002	95 kHz	2x2°	111	>10 Hz	150°
EM300	30 kHz	1x1° to 2x4°	135	NA	150°
EM302	30 kHz	0.5x1° to 4x4°	144/288	NA	5.5xdepth

Both bathymetry and backscatter data were recorded during the surveys (Figure 2). The bathymetry data were processed by NHS with CARIS and then regridded with QPS DMagic software. The backscatter data were processed by NGU with two different softwares: Most of the FOSAE 2007 (multibeam data acquired by Fugro in 2007) and Hydrograf 2008 (multibeam data acquired by the Norwegian Mapping Authority in 2008) backscatter data (Figure 1) were processed with the Atlantic Geoscience Center (Geological Survey of Canada) Grass 5 software. The remaining backscatter data were processed by QPS FMGT software. An angle varying gain has been applied to the data to correct the angular dependence. The data density allowed gridding at 5 m for depths <1000 m and 10-25 m for depths >1000 m, permitting detailed analysis of seabed features, especially on the continental shelf and the upper slope.

About 5500 km of high resolution seismic data (Kongsberg TOPAS PS 018 parametric sub-bottom profiler, Chirp modus, secondary beam frequency 0.5-6 kHz) were acquired on transit between video stations. TOPAS vertical resolution is better than 1 m. TOPAS lines were processed by TOPAS software and then converted to JPEG2000 by SegJp2 software (software courtesy of Geological Survey of Canada). Navigation shape files were extracted by SegJp2Viewer (software courtesy of Geological Survey of Canada) to be displayed in ArcGIS. SegJp2Viewer was also used to display and interpret the lines.

Forty stations for biological, environmental and sedimentological studies were sampled by grab, boxcorer and multicorer and used to make the seabed sediments (grain size) map (Bellec et al., in press). Video surveys were performed using IMR's towed video platform CAMPOD (Buhl-Mortensen et al., 2009). A total of 215 video lines of 700 m length were acquired in an area of about 25 000 km² (Figure 2).

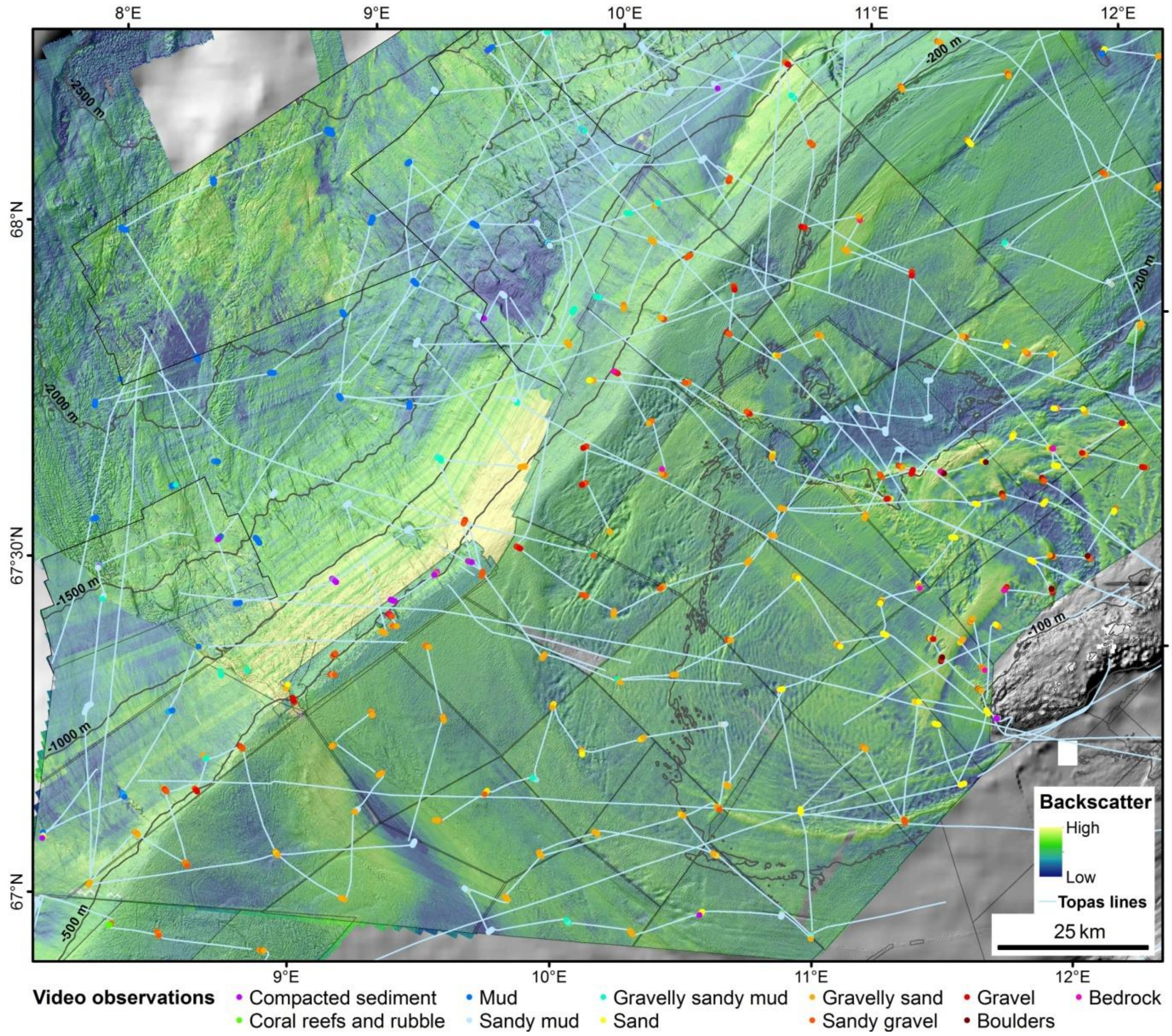


Figure 2. Backscatter data from the study area draped on a shaded relief image with depth contours labelled every 500 m (100 m and 200 m depth contours are also labelled). Coloured dots represent seabed sediment grain-size observations from video (only few observations are displayed along the video lines due to the compressed scale of the figure).

Classes used for compilation of sedimentary environment maps in MAREANO have been developed by NGU and will be included in the SOSI standard (v. 5) (a Norwegian national standard for geographical data). The seabed sediments (genesis) map was compiled according to the SOSI standard: http://www.kartverket.no/globalassets/standard/sosi-standarden-del-1-og-2/sosi-standarden/losmasse.pdf.

2.2 Sedimentary environment map

The sedimentary environment map (Main Map 1) is based on multibeam backscatter data and ground-truthing. Backscatter is one of the most important datasets for both the seabed sediments (grain size) and the sedimentary environment maps as both use backscatter classified in different classes. A detailed description of how backscatter is classified can be found in Bellec et al. (in press); here follows only a short summary. The backscatter data are visually classified based on ground-truthing information (video, grab, boxcore, multicore, TOPAS) and the assumption that backscatter values increase with sediment grain size. This assumption was checked with Kernel Density Estimation from Parzen (1962) (Bellec et al., in press).

Backscatter intensity intervals were defined based on ground-truthing information, which are assumed to broadly correspond to different sediment types, and by using the Symbology options in ArcGIS (Figure 4). However, we observed an overlap of the sediment classes, so this classified backscatter needs to be interpreted in terms of sediment grain size. Multibeam bathymetry and its derivatives (e.g. slope and bottom position index) and landforms (e.g. moraines, pockmarks and sand waves) were also used for the interpretation. As different surveys can show different backscatter values, each survey was visually classified (Bellec et al., in press). This classified backscatter then needs to be interpreted in terms of sedimentary environment classes which are digitized manually (Figure 3). Six sedimentary environment classes were defined and are summarized in Table 3.

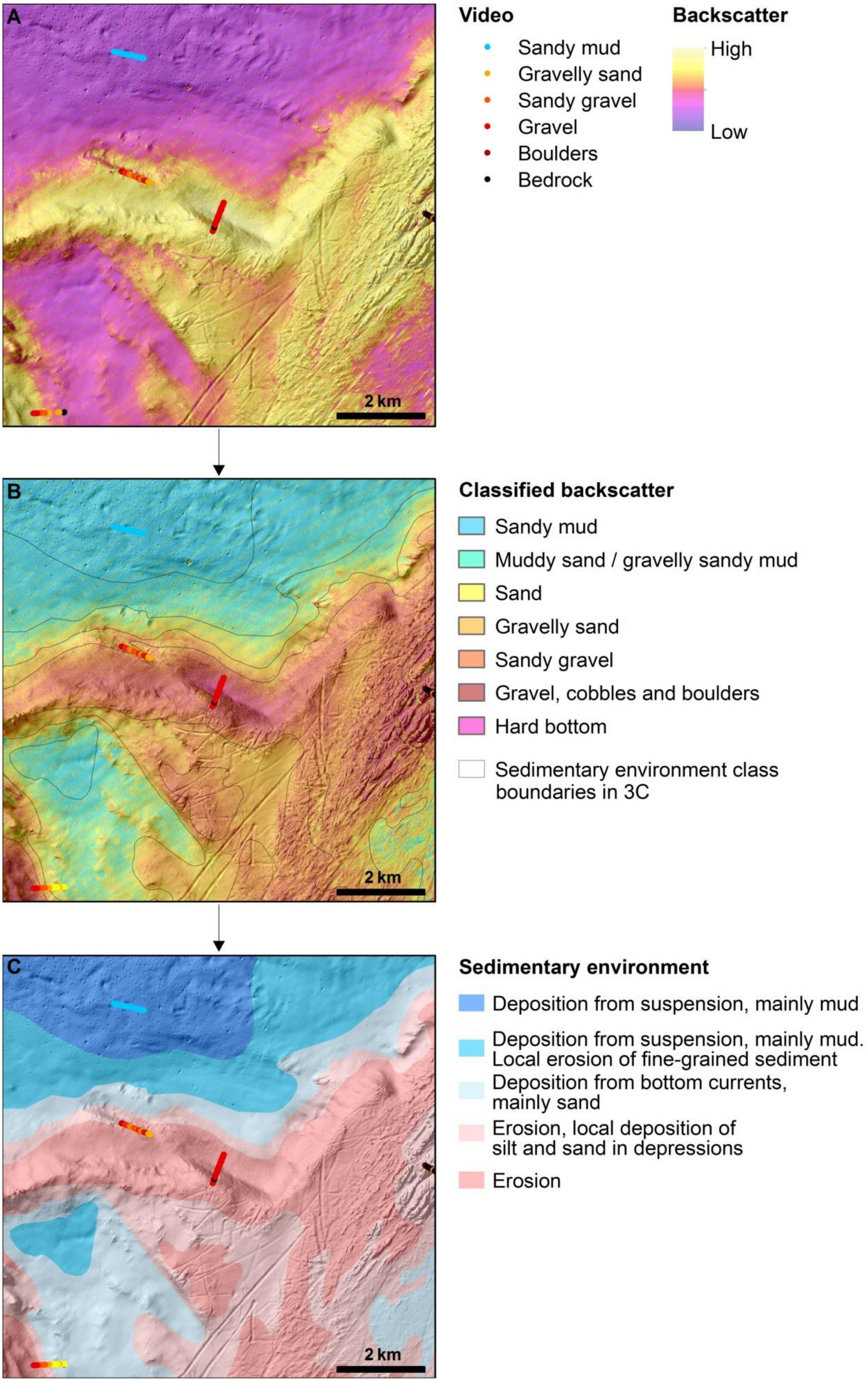
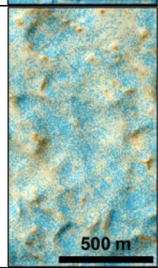
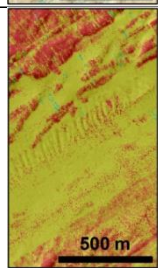
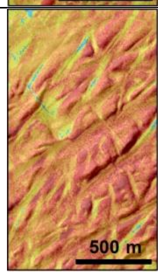


Figure 3. From individual data sets to final map of sedimentary environment. Classified video observations are represented by coloured dots. A) Backscatter. B) Backscatter classified based on sediment grain-size information from video observations. C) Sedimentary environment. See Figure 1 for location.

Table 3. Sedimentary environment classes, backscatter and interpreted classified backscatter facies associated.

Sedimentary environment class	Description	Backscatter signature	Classified backscatter	Example of classified facies
Deposition from suspension, mainly mud.	Areas of fine-grained sediments (mud and sandy mud), primarily found in troughs and topographic depressions.	Low backscatter.	Mud, sandy mud.	
Deposition from suspension, mainly mud. Local erosion of fine-grained sediments.	Areas of fine-grained sediments, including muddy sand, local erosion on topographic highs.	Low to medium backscatter, small areas with higher backscatter.	Sandy mud, muddy sand. Spots of sand and gravelly sediments.	
No or very slow deposition. Mainly sand.	Sandy areas without bedforms.	Medium to high backscatter.	Muddy sand, gravelly muddy sand.	
Deposition from bottom currents, mainly sand.	Sandy areas with bedforms such as ripples and sandwaves.	Medium backscatter.	Sand, gravelly sand.	
Erosion, local deposition of silt and sand in depressions.	Areas with coarse-grained sediments (gravelly sand and coarser sediments, and bedrock) with finer-grained sediments in depressions.	High backscatter with smaller areas of lower backscatter in depressions.	Gravelly/ coarse sediments. Spots of soft sediments (sandy mud, muddy sand and sand).	

Erosion.	Areas with coarse sediments and bedrock.	High backscatter.	Gravelly sand, sandy gravel, gravel, cobbles and boulders, bedrock.	

Classified backscatter

- Sandy mud
- Muddy sand
- Sand
- Gravelly muddy sand
- Gravelly sand
- Sandy gravel
- Gravel
- Cobbles, boulders and bedrock

2.3 Seabed sediments (genesis) map

The seabed sediments (genesis) map (Main Map 2) is based on the seabed sediments (grain size) map (Bellec et al., in press), landscapes and landforms and TOPAS sub-bottom profiler data. On the continental shelf, the map is basically a translation/re-interpretation of the sediment grain-size map, supported by interpretation of landforms and TOPAS lines. Due to the nature of the seabed sediments, TOPAS data have larger penetration on the continental slope and the deep-sea plain than on the continental shelf. Thus, TOPAS data were important for interpretation in these areas. For example, debris flows and stratified sediment could be recognized and interpreted in terms of sedimentary processes, aided by interpretation of landforms. Ten seabed sediments (genesis) classes have been mapped in our study area (Table 4, Figure 4).

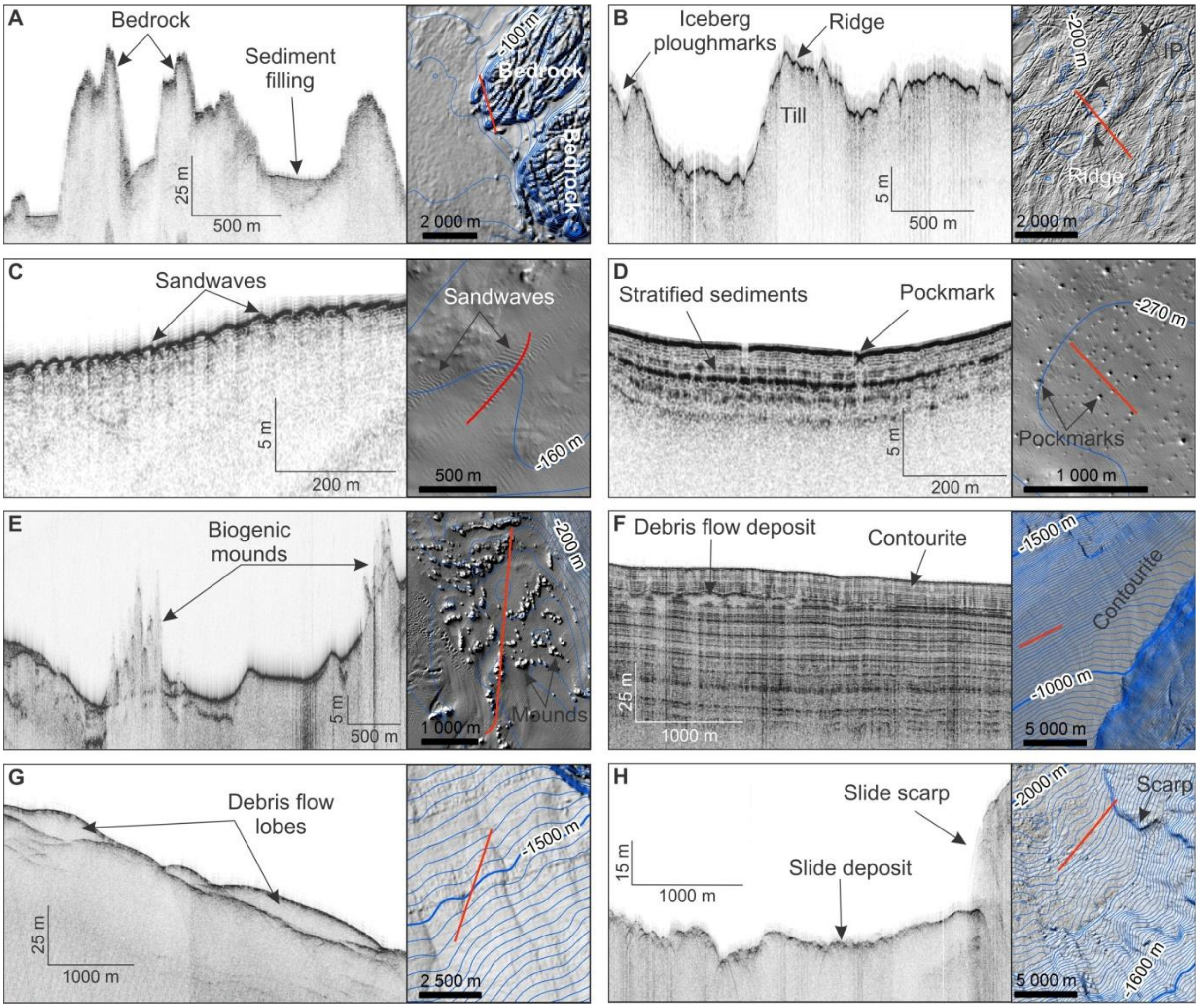


Figure 4. TOPAS seismic lines showing different facies (left panels) and location (red lines on shaded reliefs with blue depth contours in right panels). Sound velocity used for TOPAS depth conversion was 1800 m/s. A) Crystalline bedrock with small sediment basins southwest of Røst, B) Till with iceberg ploughmarks (IP) and ridges between Vesterdjupet and Trænadjupet, C) Sandwaves at the eastern side of Vesterdjupet, D) Stratified sediments in Vesterdjupet, E) Biogenic mounds (cold-water coral reefs) in the Hola Trough, north of the study area, F) Lofoten Contourite, G) Glacigenic debris flow lobes southwest of the Trænadjupet Slide, H) Trænadjupet Slide scarps and deposits. See Figure 1 for location. Example E is from the Hola Trough north of the study area (Bøe et al., 2016).

Table 4. Seabed sediments (genesis) classes and their relationships with the seabed sediments (grain size) map, landforms and TOPAS facies.

Seabed sediments (genesis) class	Description	Seabed sediments (grain size)	Common landforms	TOPAS facies
Marine suspension deposit.	Fine grained sediments (mainly clay and silt) transported by and deposited from suspension.	Mud, sandy mud, muddy sand.	Pockmarks.	Stratified facies.
Bedload (traction) deposit.	Sediment transported by and deposited from bottom currents. Consists of sand, gravelly sand or occasionally sandy gravel. Bedload deposits may occur in channels and shallow marine areas, and often display characteristic sandwaves and current ripples.	Sand, gravelly sand.	Sandwaves and current ripples.	Transparent facies. Seabed can reflect sandwaves or be irregular / chaotic.
Contourite.	Sediment body deposited by a permanent ocean current (contour current) along the continental margin. Consists of fine grained, well sorted material (mainly clay and silt, but also sand).	Mud, sandy mud and gravelly sandy mud.	Mound and channel	Stratified facies.
Bioclastic sediment.	Carbonate rich sediment consisting of fragments/shells of dead organisms mixed with clastic sediments.	Poorly sorted mixture of mud, sand and gravel.	Biogenic mounds.	Transparent mounds.
Till, unspecified.	Unsorted glacial sediment consisting of material ranging in size from clay to boulders.	Poorly sorted mixture of material ranging in size from clay to boulders.	Moraine ridges, iceberg ploughmarks.	High amplitude seabed reflection.

Debris flow deposit.	Sediment deposited by a fast moving, liquefied landslide of unconsolidated, saturated debris. Consists of material ranging in size from clay to boulders.	Poorly sorted mixture of material ranging in size from clay to boulders.	Elongated lobes.	Transparent lobes.
Laminated sediments (>1m) underlain by debris flow deposits.	Laminated sediments (>1m) underlain by debris flow deposits.	Mostly mud, sandy mud and muddy sand.	Elongated lobes and channels with smooth surface layer.	Stratified facies covering transparent lobes.
Mass movement deposits and hemipelagic sediments.	Alternating units of mass-movement deposits and hemipelagic sediments that are too thin/ discontinuous to be separated and mapped individually.	Various, often mud, sandy mud.	Smooth slide scars/scarps and slide deposits.	Alternating chaotic and stratified facies.
Mass movement deposit, locally covered by younger sediments.	Mass-movement deposit locally covered by a layer of younger sediments that is too thin/ discontinuous to be mapped as a separate unit	Various.	Slide scars/scarps and slide deposits.	Mostly chaotic facies.
Bedrock with thin or discontinuous sedimentary cover.	Lateral variation of small basins with sediments, exposed bedrock and/or bedrock with thin/ discontinuous sediment cover. Sediments in small basins may be of varying grain size.	Bedrock, locally covered by sediments of various grain sizes.	Rugged topography.	High amplitude seabed reflector.

3. RESULTS

3.1 Sedimentary environment map

On the continental shelf, deposition from suspension only occurs in glacial troughs (e.g. Trænadjupet) and depressions deep enough to protect the seabed from eroding currents (e.g. Vesterdjupet). The class "Erosion, local deposition of silt and sand in depressions" is mostly utilized in the southernmost area. Over most of the shelf, currents are strong enough to create bedforms (Deposition from bottom currents, mainly sand) or to erode the finest grain sizes (Figure 5C and 5D). According to the Sedimentary environment map, strong currents especially occur on the outer shelf and the uppermost slope to create bedforms like ripples and sandwaves (e.g. Figure 5B). This is due to the Norwegian Atlantic Current which is particularly strong along the shelf edge west of Lofoten (Heathershaw et al., 1998; Andersson et al., 2011).

Erosion decreases with depth, and below 600-700 m, areas with no or very slow deposition occur. Even deeper, deposition occurs from suspension, with still some erosion until 1100-1200 m depth (Figure 5A). Some of the steepest slopes (>10º) along slide scarps are interpreted to belong to the class "Erosion, with local deposition of silt and sand".

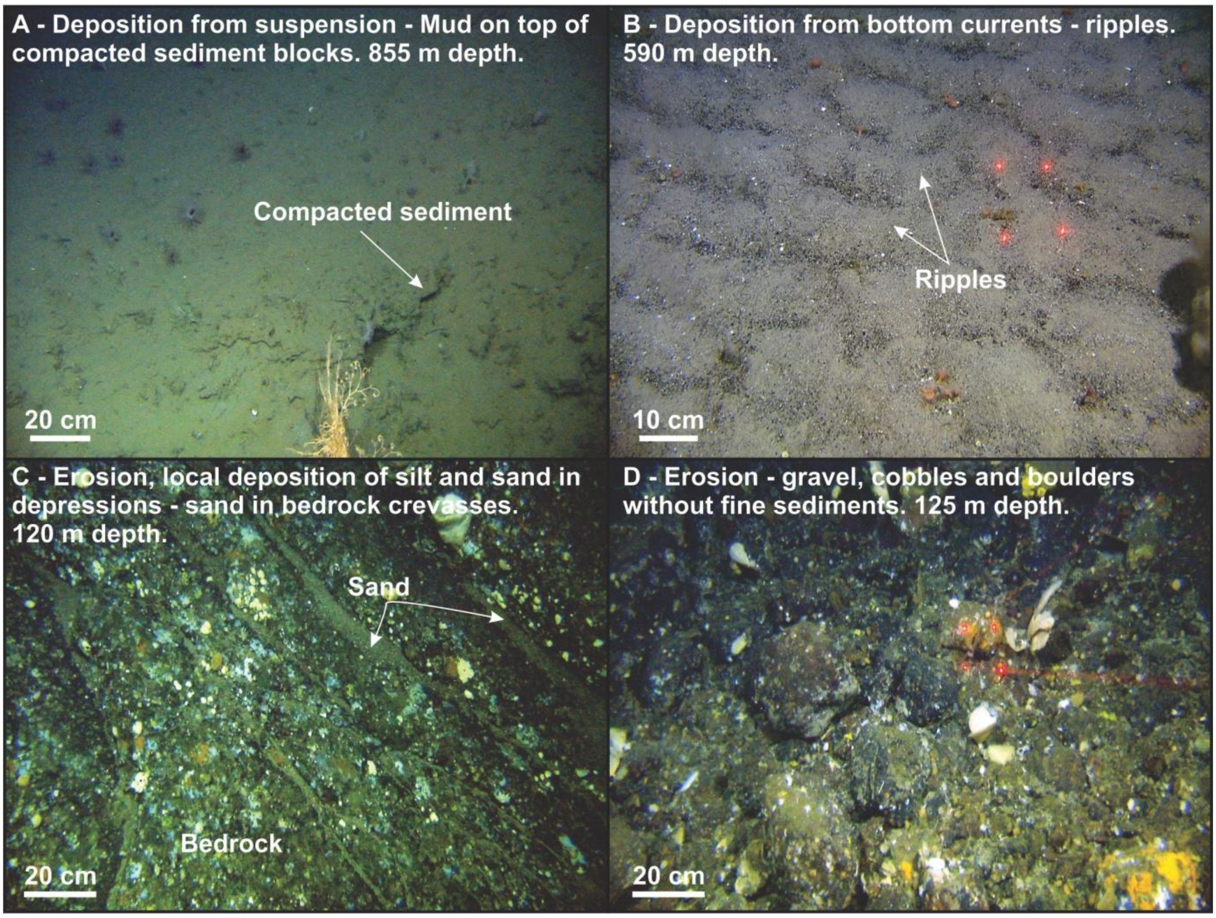


Figure 5. Pictures showing different sedimentary environments.

3.2 Seabed sediments (genesis) map

The continental shelf is characterized by five main classes (Figure 6). Marine suspension deposits generally occur in Trænadjupet, Vesterdjupet and a few deep depressions east of the study area. Bedload (traction) deposits are mostly found in shallow depressions and areas with stronger currents. Till is the dominating class on the continental shelf. It has frequently experienced erosion so that it is covered by coarse-grained lag deposits. Till occurs from the inner to the outer shelf. Bedrock with a thin or discontinuous sediment cover occurs in three main areas; crystalline bedrock close to the coastline, on the southern border of Vesterdjupet, and north of Vesterdjupet. Bioclastic sediments occur primarily at Røstrevet (the Røst Reef, Thorsnes et al., 2016) and along the northern side of Trænadjupet. Smaller areas of bioclastic sediments are found around Vesterdjupet and along the outer continental shelf.

Contourite occurs along the upper continental slope (Lofoten Contourite, Laberg et al., 1999; Figure 4F), northeast of the 4000 years old Trænadjupet Slide (Laberg and Vorren, 2000; Laberg et al., 2002), while debris flow deposits are found on the slope both northeast and southwest of the slide (Figure 4G). Glacigenic debris flow deposits cover the older Nyk Slide (Lindberg et al., 2004) on the southern side of the Trænadjupet Slide. In some areas, these debris flow deposits are covered by more than 1 m of stratified sediments. The rest of the slope is covered by mass movement deposits, locally covered by younger sediments, and mass movement deposits and hemipelagic sediments in alternation (Figure 4H). Low backscatter on the lower slope indicates a larger proportion of hemipelagic deposits.

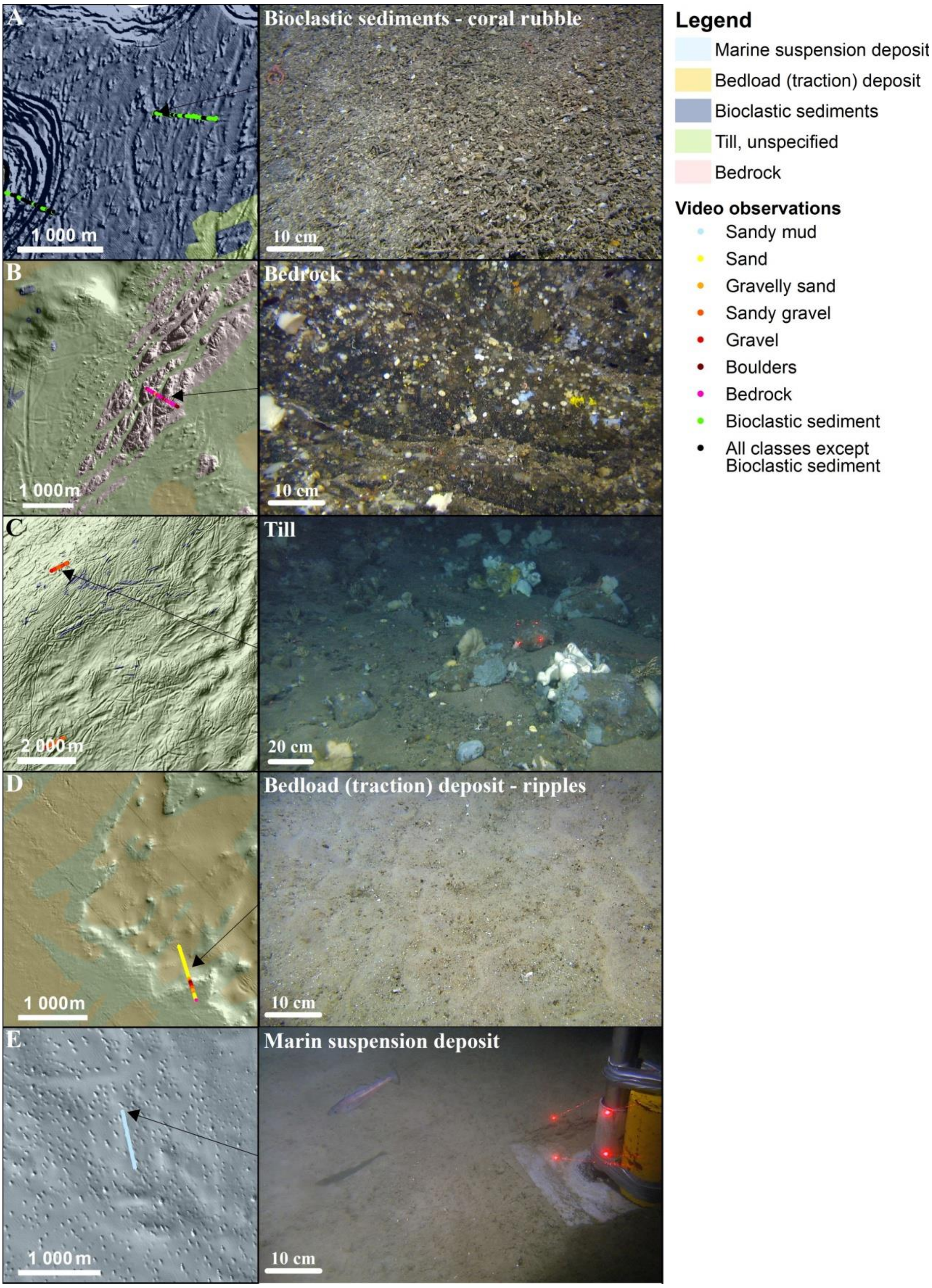


Figure 6. The five main seabed sediments (genesis) classes used for the continental shelf. Left panel: bathymetry, shaded relief; right panel: pictures from videos. A) Bioclastic sediments at Røstrevet, with an example of coral rubble, B) Bedrock outcropping south of Vesterdjupet, C) Till, covered by a thin layer of sand, gravel and cobbles, strong bottom currents indicated by comet marks behind cobbles, D) Bedload (traction) deposit showing small sandwaves and ripples, E) Marine suspension deposit (sandy mud). Note that colours along video lines do not always match the bottom type in the picture because of the low resolution along the lines. See Figure 1 for location.

4. CONCLUSIONS

This report presents maps of sedimentary environment and seabed sediments (genesis) for the Nordland VI management area west of the Lofoten-Vesterålen islands, north Norway. The area covered is about 25 000 km^2, with water depths ranging from 60 m to 2700 m. The report details methods used for data collection and interpretation for both maps.

Six classes were utilized for the sedimentary environment map, which focuses on areas of erosion and deposition. Currents erode large parts of the continental shelf (100-300 m water depth), especially the outer shelf, but deposition from bottom currents is common, especially in low-lying areas of the shelf. Deposition from suspension is mostly observed in the deepest troughs and depressions.

The upper continental slope (300-500 m depth) is characterized by erosion. Current strength decreases down slope, and below 700 m, very little erosion occurs. The deeper areas are characterized by deposition from suspension with no erosion.

Ten classes were used for the seabed sediments (genesis) map. This map is a Quaternary geology map with interpretation of the geological processes that have formed the sediments in the upper part of the seabed, as well as the bioclastic sediments around biogenic mounds. The continental shelf is transected by the Trænadjupet Trough and the Vesterdjupet Trough, the deepest parts of which are dominated by marine suspension deposits. The main part of the shelf is covered by till. In topographic depressions, currents are locally strong enough to create bedforms (deposition from bottom currents and bedload (traction) deposition). Bedrock occurs in three main areas of the shelf. Bioclastic sediments, mostly comprising remains of cold-water corals, are particularly abundant along the northern margin of Trænadjupet and at Røstrevet.

The continental slope is marked by the huge Trænadjupet Slide scar and numerous glacigenic debris flows. In the northeast, between 500 m and 1500 m depth, the slope is covered by contourite deposits alternating with debris flow deposits. The strength of the currents decreases down slope, and below 1000 m depth, the seabed is mostly characterized by hemipelagic sediments covering slide or glacigenic debris flow deposits.

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APPENDIX 1

Software

The bathymetry data were processed in CARIS HIPS and SIPS hydrographic software by NHS and gridded in QPS DMagic software. The backscatter data were processed by NGU with two different softwares: AGC (Grass 5) software from the Geological Survey of Canada and QPS FMGT software. Sediments and geological features were identified and digitised on-screen using ESRI ArcGIS. TOPAS data were processed with TOPAS software from Kongsberg. Processed TOPAS files were converted to JPG2000 with SegyJp2 software and displayed with SegyJp2viewer, both from the Geological Survey of Canada.

Data

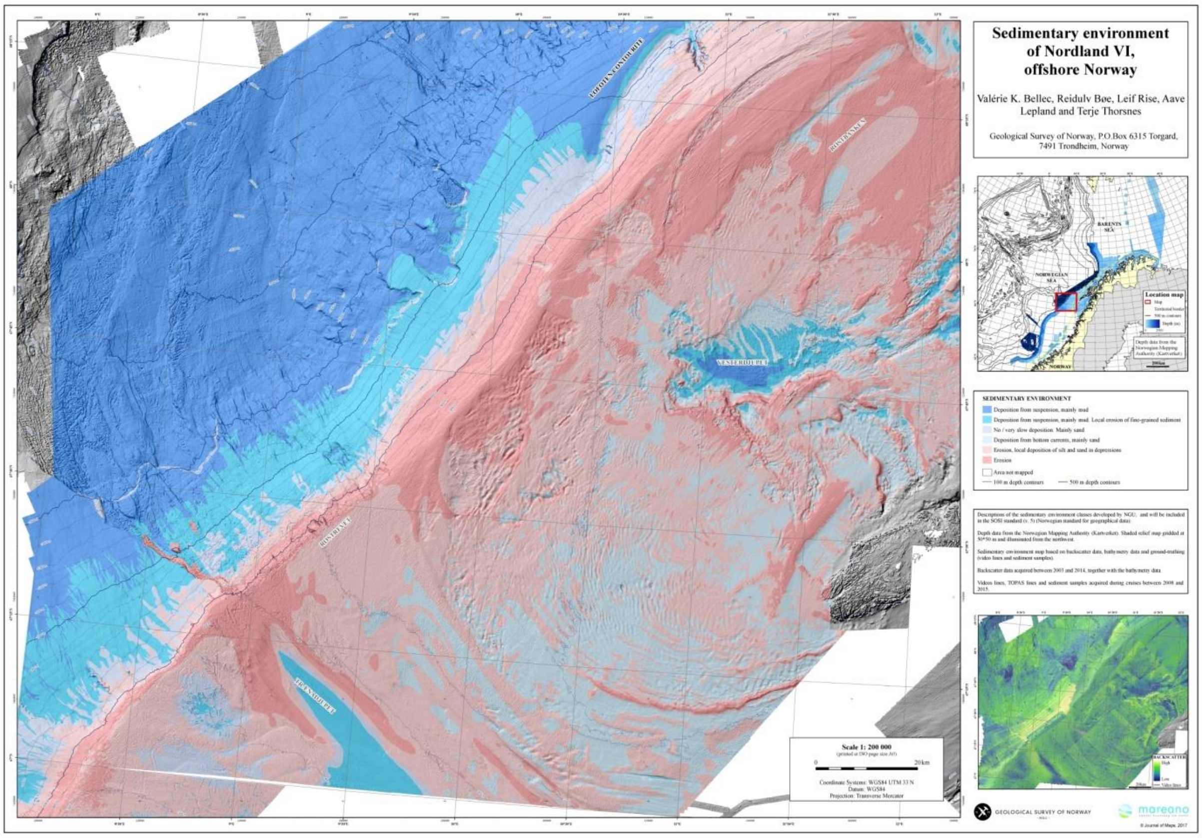
Sedimentary environment and seabed sediments (genesis) interpretations are stored in NGU's Marine Geological Database (Oracle). Formatted PDF maps have been created for printouts and illustrations. Data and maps are available for viewing at http://www.mareano.no/en/maps/mareano_en.html and downloading http://www.mareano.no/en/download-data/the-geological-survey-of-norway-ngu (digital data, WMS-layer, pdf).

Map design

Sedimentary Environment: The Norwegian standard for marine sedimentary environments comprises seven classes. The graded colour scheme from blue to dark pink that is used for symbolizing the sedimentary environments on the map, expresses the different hydrological conditions (increasing bottom current velocities), which in combination with sediment supply define sedimentation patterns, from quiet continuous deposition of fine-grained sediments (blue colour) to erosion and formation of lag deposit (pink).

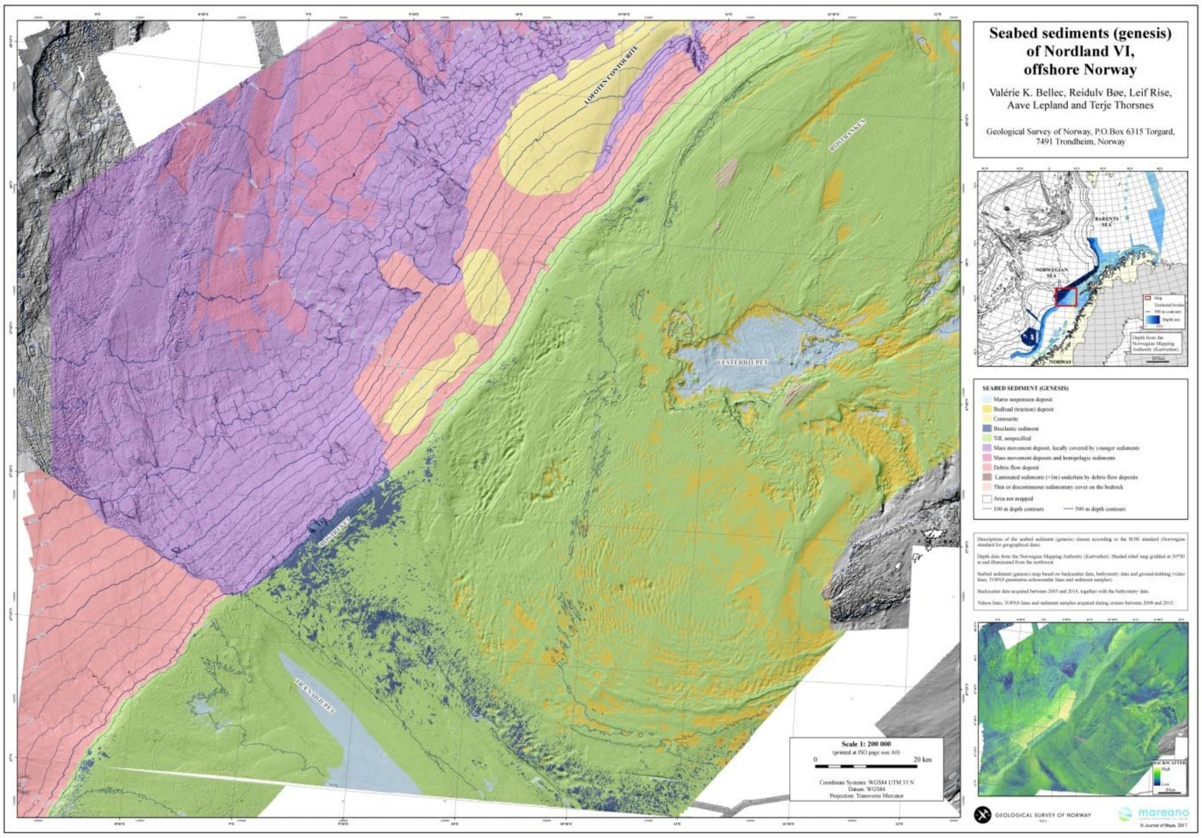
Seabed sediments (genesis): Only a fraction of classes defined in the Norwegian standard for sediment genesis, is so far used on marine geological maps. However, the sediment distribution can still exhibit rather complex patterns and significant variations over short distances. To allow the user to obtain a quick overview and easy understanding of prevailing sediments and geological processes in specific areas, shades of the same basis color are used for sediments of similar genesis. Shades of green are used for glacial sediments (tills, moraines). Pink and lilac colors depict slides, mass movement and debris flow deposits (caused by gravity). Yellow colors represent sediments reworked, transported and deposited by currents and waves, whereas blue colors show quiet water column sedimentation (suspension deposit). Bioclastic sediments, that typically have limited areal extent, are emphasized with dark purple color, making them easily recognizable within a scheme dominated by pastel colors.

APPENDIX 2



Map of Sedimentary environments (www.mareano.no).

APPENDIX 3



Map of Seabed sediments (genesis) (www.mareano.no).

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