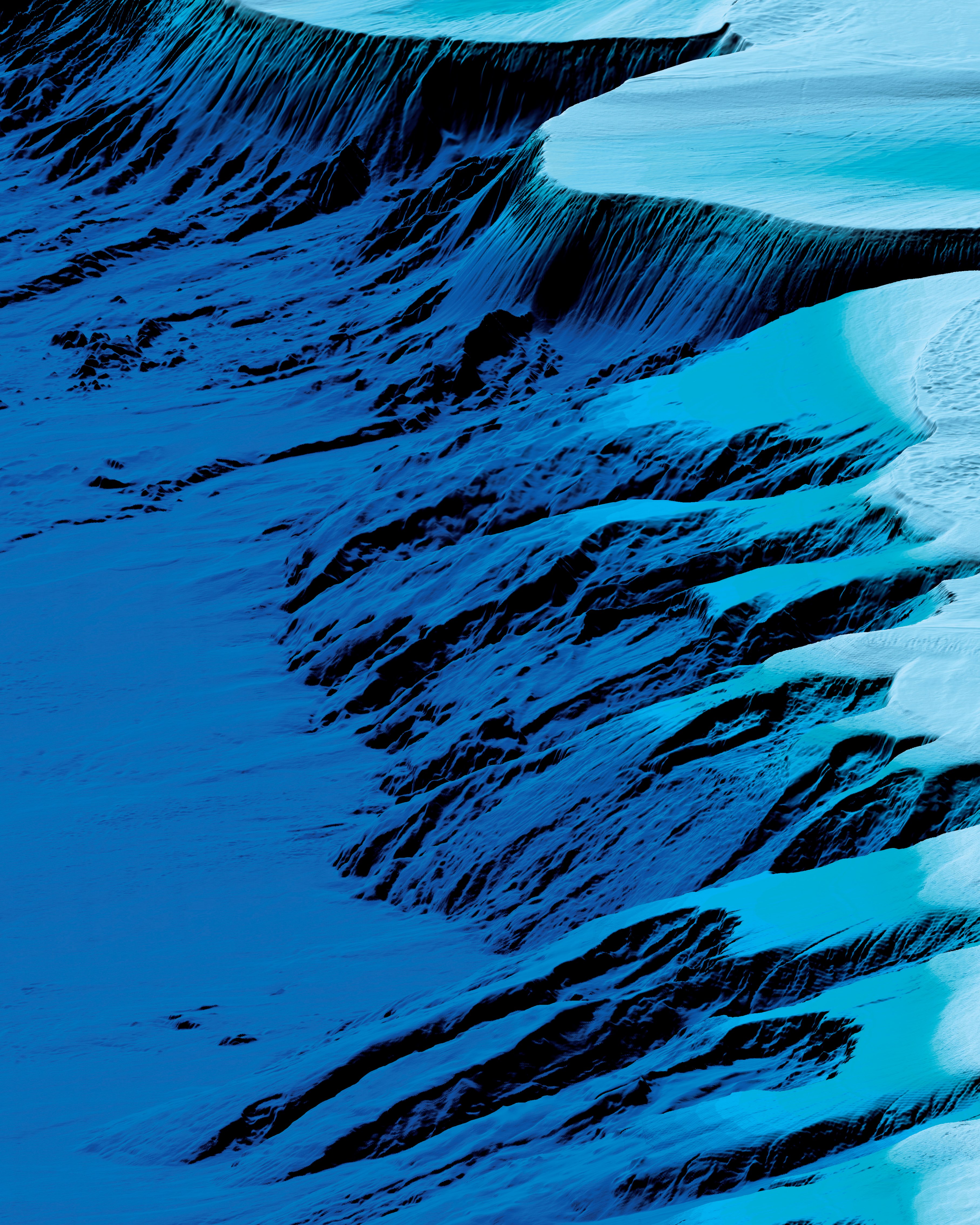


THE DEEP-SEA OFF LOFOTEN, VESTERÅLEN AND TROMS

5.1 Valérie Bellec, Terje Thorsnes, Leif Rise, Reidulv Bøe, Margaret Dolan and Odd Harald Selboskar
5.2 Lene Buhl-Mortensen, Pål Buhl-Mortensen, Børge Holte and Genoveva Gonzalez-Mirelis

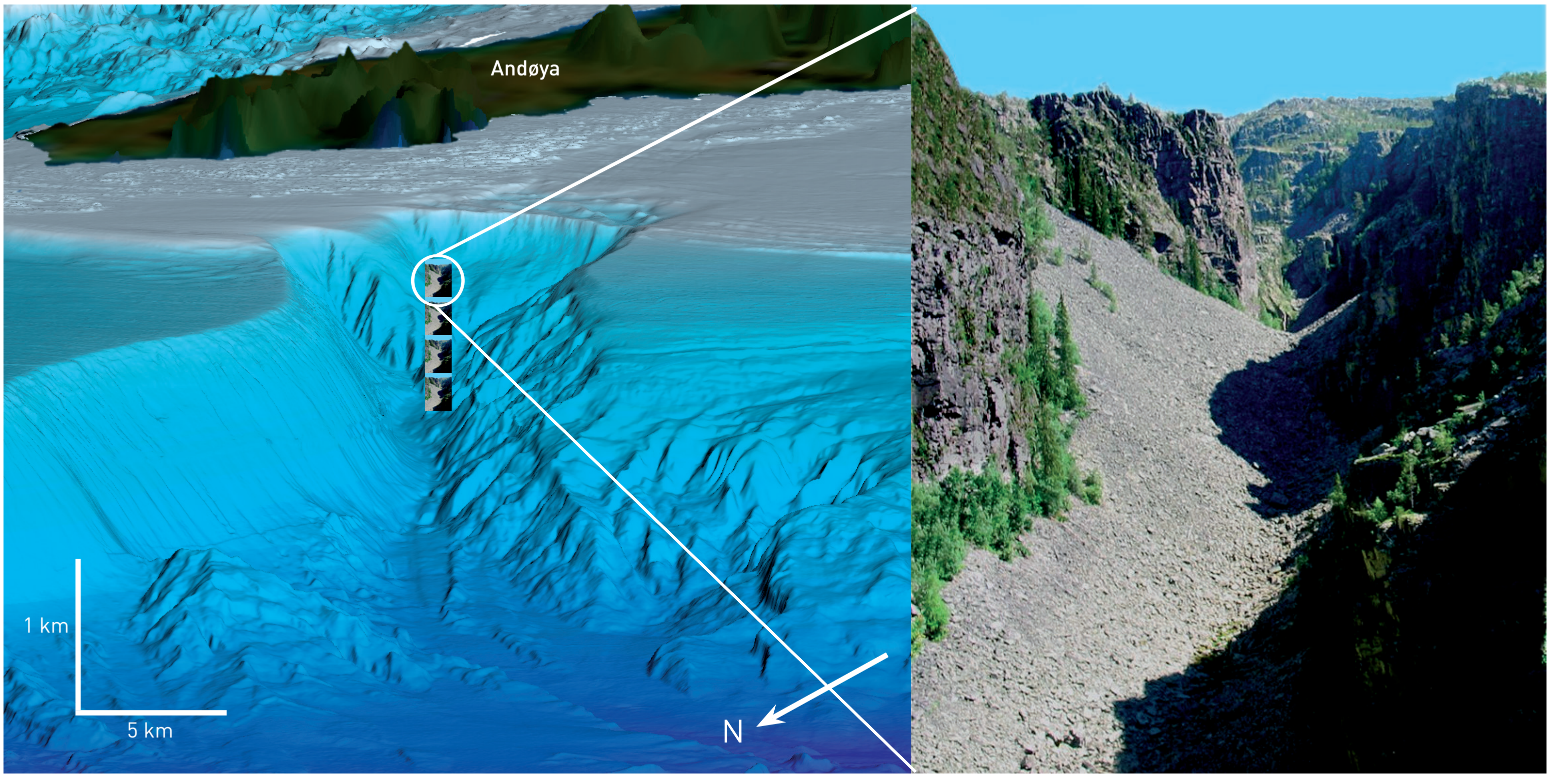


Figure 1. Many have been impressed by the dimensions of Jutulhogget (right), but in Bleiksdjupet (left), four Jutulhogget stacked on top of each other would not even reach to the top. Source Jutulhogget: Wikimedia.

5.1 THE SEABED – MARINE LANDSCAPES, GEOLOGY AND PROCESSES

5.1.1 Marine Landscapes – Deep Canyons, Large Landslides and Flat Plains

With walls reaching almost 250m high the Jutulhogget canyon in Hedmark, Norway is widely renowned as one of the largest canyons in Northern Europe. Many visitors are awestruck as they imagine the forces in play as this mighty canyon was carved out by catastrophic meltwater drainage at the end of the last Ice Age.

In fact Norway hosts many more canyons, many of which are even larger than Jutulhogget but these lie hidden under the sea on the continental slope off Lofoten, Vesterålen and Troms. The rugged underwater landscape here with more than ten large canyons is a far cry from the featureless landscape many imagine exists beneath the waves. The largest of the canyons is Bleiksdjupet off Andøya. At almost 1000 m deep it is four times the size of Jutulhogget. This means that, where the canyon is at its deepest, you could stack four Jutulhoggets on top of each other (figure 1) and still not quite reach the shelf edge. How were these massive canyons created, and why are there so many of them? If they were not made the same way as Jutulhogget what other massive forces were at play? These are just some of the questions geologists are trying to understand.

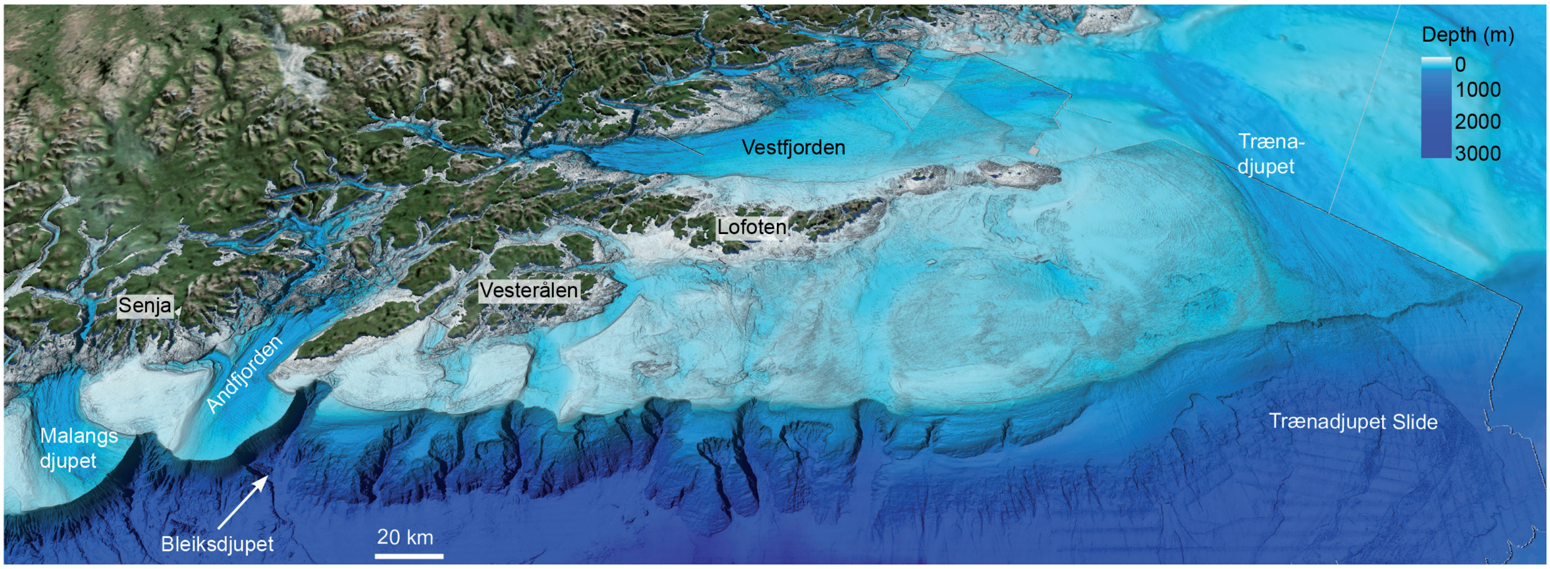


Figure 2. The continental slope off Lofoten and Vesterålen is dramatic, with numerous canyons and large landslides.

The Continental Slope – Wild and Rugged

The continental slope off Lofoten-Vesterålen-Troms is a little over 500 km long and has 10 large (figure 2) and several smaller canyons. In the southernmost part, the slope is dominated by the large Trænadjupet Slide.

Bleiksdjupet is the largest canyon – almost 10 km wide and 30 km long. The steep sides, up to 30° (figure 3), tell the story of a slow development with repeated landslides and periods of erosion. The canyon cuts into thick layers of sediment deposited throughout the Ice Ages all the way down to hard sediments and sedimentary rock dating back millions of years. From the bottom of the canyon, a channel runs far out onto the deep-sea plain.

The slope off Lofoten-Vesterålen-Troms is the only area in Norway featuring such canyons, which are among the largest on the northwest European margin. The origin and the detailed geological history of these canyons are still not fully understood, but some evidence is clear. The marine landscape map (chapter 4, figure 9) shows that several canyons are continuations of marine valleys and troughs on the shelf. Looking at the 3D model of the area between Hola and the deep sea (figure 4) we see large slide scars in the canyons and debris that has been transported through the canyons onto the deep-sea plain. At the top of the canyons, we often find headwalls of slides coinciding with the shelf edge. There are many marine valleys on the continent al shelf, like the one at Hola, and these valleys frequently end right where the canyons start. It seems that marine valleys, landslides and canyons frequently appear together but the connection is unclear. Did the canyons start where the ice streams forming the marine valleys met the shelf edge? Did the canyons develop where there had been landslides? Or did the slides occur where a canyon had formed and created steep sides? Former investigations in this area have shown that erosion by bottom currents is important for the formation and maintenance of marine canyons. It may therefore be reasonable to assume that the marine canyons on the

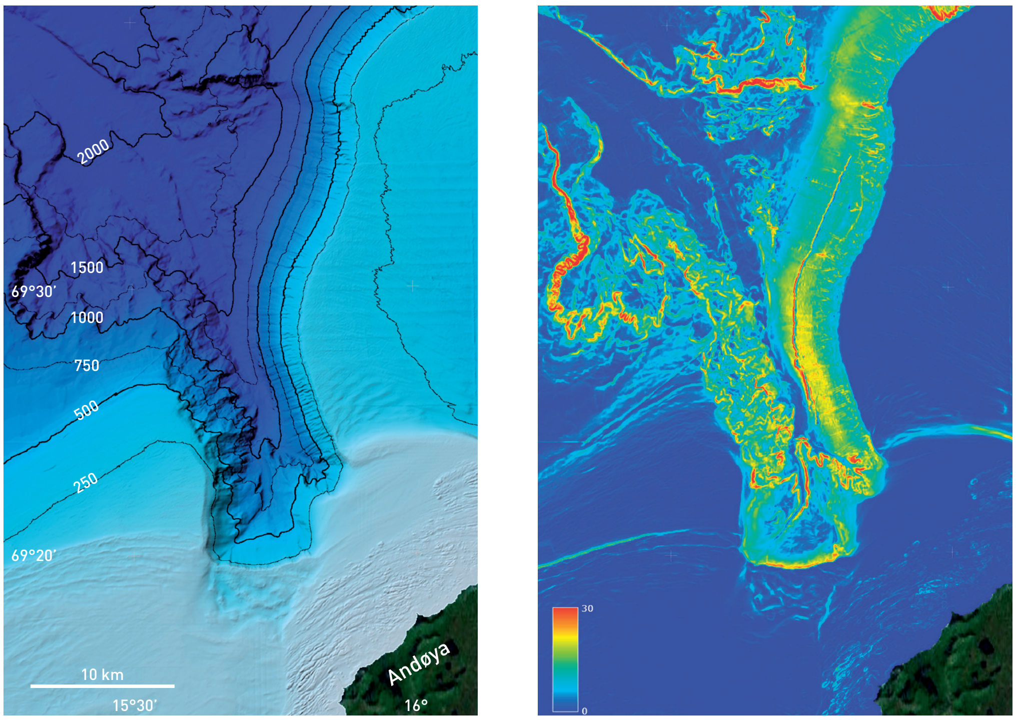


Figure 3. Depth contour chart (left) and slope chart (right) of Bleiksdjupet. The slope chart shows how steep the sides of Bleiksdjupet are – up to 30°. The depth contour chart shows how the 10km wide canyon cuts almost 30 km into the continental shelf.

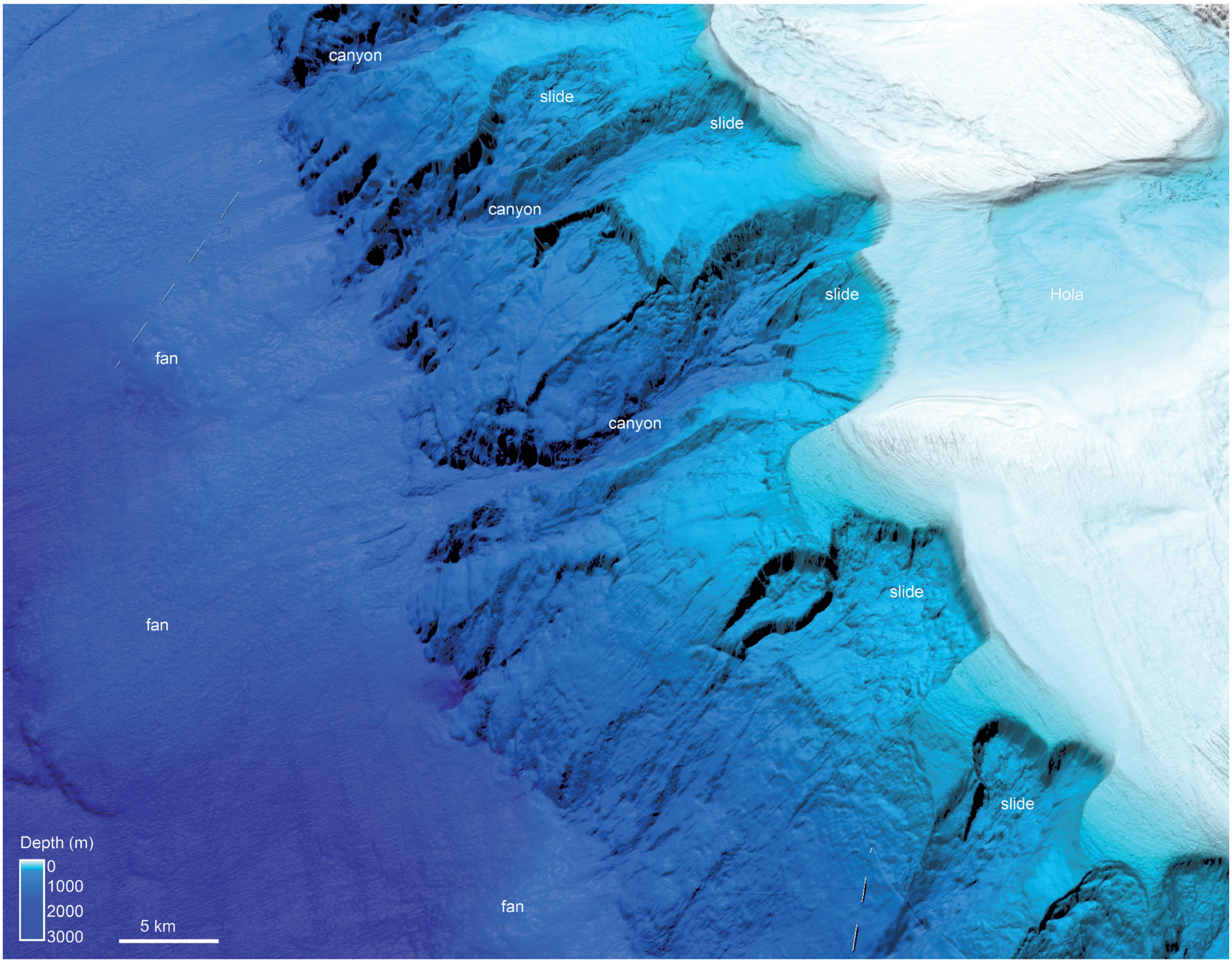


Figure 4. 3D model from Hola to the deep sea. The sediments in the alluvial fan on the deep-sea plain (left) have poured out of the canyon and the canyon is connected to the marine valley at Hola (5x vertical exaggeration).

continental slope off Lofoten, Vesterålen and Troms were formed by a combination of all these processes even if a detailed explanation is not yet clear. The canyons probably developed over several million years. At present, there appears to be little mass movement activity in the canyons.

In the southernmost part, west off Lofoten, the entire continental slope is dominated by the large Trænadjupet Slide (figure 5). This is a major submarine slide which has created a dramatic landscape with complex seabed structures, locally forming the substrate for corals and other organisms preferring a hard bottom.

The Deep-Sea Plain – Fans, Channels and Slide Debris

Below the continental slope lies the large and relatively flat deep-sea plain. Towards the south, the transition between the continental slope and the deep-sea plain is rather gradual, while there is a distinct demarcation in the area directly west of Vesterålen (figure 6). This marked shift in topography is not well understood, but it may be related to both faulting and differential uplift of the margin. There has been extensive deposition of sediments on the slope, either transported by the ice streams, or by along-slope currents. Parts of these sediments have been redistributed downslope and deposited on the deep-sea plain by mass movement processes (e.g. turbidites, slides). Some places, large blocks – up to 100 m high

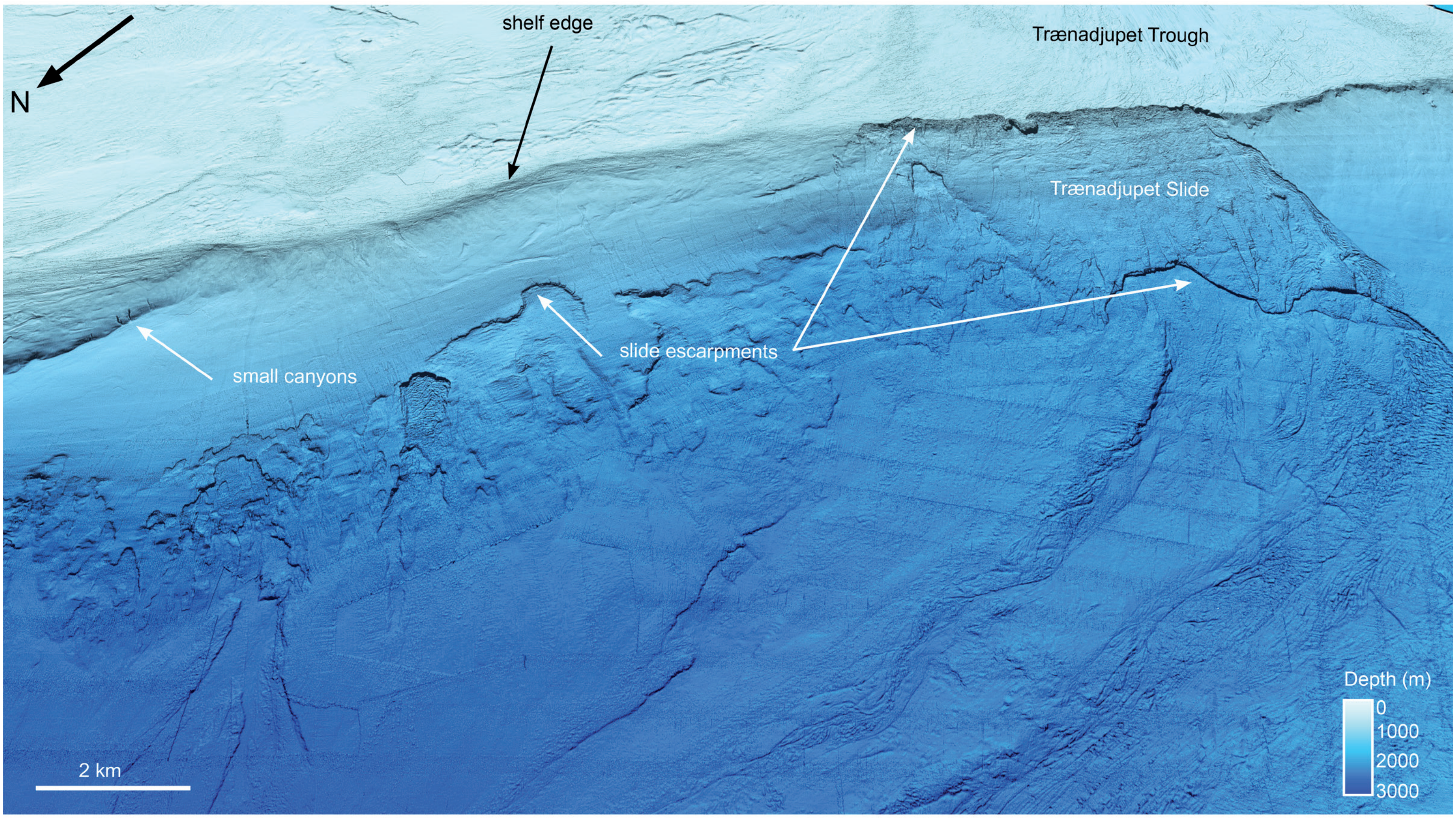


Figure 5. The c. 4000 year old Trænadjupet Slide extends from the shelf edge at c. 300 m water depth to more than 3 000 m. The slide area to the north with the upper escarpments at c. 1000-1500 m water depth is probably older, but may partly have been activated during the last event. No vertical exaggeration.

and several kilometres long – have tumbled down and formed ”mountains” on the seabed (figure 7).

On the deep-sea plain, there are numerous submarine fans, i.e. debris transported through the canyons and deposited on the plain in the shape of a fan outside the mouth of the canyons (figure 4). In some places, there are channels between the canyons and the deep-sea plain. A good example is the channel running from Bleiksdjupet into the Lofoten Basin (figure 7).

5.1.2 Sediments

The Canyons

In the canyons on the continental slope, there is a wide variety of sediments. The sediments often differ from one side of a canyon to the other as well as along its length. The upper part of the slope is generally dominated by gravelly sand and sandy gravel, with a transition to more muddy sediments down slope. At the bottom of the canyons, the sediments consist of both gravelly muddy sand and gravelly sandy mud (figure 8). In channels along the base of the canyon, the sediments are dominated by gravelly sandy mud and sandy mud.

The canyons generally have steep sides cut into firm sediments. The sides may be almost vertical, consisting of mudstone, siltstone and sandstone, possibly millions of years old. In the grain size maps, these sediments are labelled ”Very compacted sediments or sedimentary bedrock”. Broken-off boulders of hard sediments rest on ledges and at the foot of slopes. Underwater video surveys have also shown the presence of debris with boulders that probably come from till deposited higher up on the continental slope (figure 9). The boulder areas are generally too small to feature on the grain size maps.

The Continental Slope Between the Canyons

On the continental slope between the canyons, there is a gradual transition from fairly coarse sediments at the top of the slope to finer sediments further down. Sandy gravel dominates on the shelf edge and a little way down, followed by a zone of gravelly sand. This bottom type mostly appears on slope terraces in the upper part of the continental slope.

At the mid and lower part of the continental slope, we find gravelly sandy mud, but the sediment type varies according to depositional processes. From high resolution seismic data, we see sediments without structures in the slope channels, probably representing coarse sediments. Layered sediments which commonly appear between the channels, may represent shift ing layers of gravel, sand and mud. On steep slopes, we generally find compacted sediments. North of the Trænadjupet Slide, the prominent Lofoten Contourite is deposited on the mid continental slope.

Within the slides, including the Trænadjupet Slide, a wide array of sediments occur. In the upper parts, compacted sediments and sandy gravel dominate. Between 600 and 1200 m water depth, gravelly sand and gravelly muddy sand are more common. Further down the slides, we are more likely to find gravelly sandy mud, sandy mud, mud with slide blocks and mud. Bioclastic sediments derived from stony corals occur in the uppermost part of the slide area.

The Deep-Sea Plains

The continental rise (the transitional zone between the continental slope and the deep-sea plains) and the deep-sea plains exhibit a great variety of bottom types. Gravelly sandy mud is most common on the continental rise, whereas mud, with or without slide blocks and slide deposits dominates the deep-sea plains (figure 8). Coarse grained sediments often stretch far out onto the deep-sea plains from the largest canyons, but are also found on areas outside slides. Gravel, cobbles and boulders dropped from drifting icebergs at the end of the last Ice Age occur almost everywhere in the surface sediments.

Large areas with blocks, sometimes with gigantic slide blocks, occur both on the continental rise and the deep-see plains. Most of these are old and partially covered by more recent, finer sediments (chapter 5.1.1). Several of these boulder areas are situated at the mouth of a canyon, or in front of large slides.

5.1.3 A Changing Seabed – Deep Canyons and Large Plains

Steep Canyons with Rockfalls and Landslides

The most characteristic landforms on the continental slope off Lofoten, Vesterålen and Troms are the large canyons cutting into the sediments. Bleiksdjupet canyon cuts deep into the continental shelf beyond the shelf edge and which terminates only around 10 km from Andøya. The canyons have a long history, but sedimentary processes are not very active to-day. In many places, we see traces of landslides, including scars, escarpments and slide debris (figure 11). At the foot of steep slopes compo-sed of hard sediments we often find broken-off blocks. How far back these rockslides date is uncertain, but terrain forms and seismic data suggest that some may have occurred during the last few thousand years.

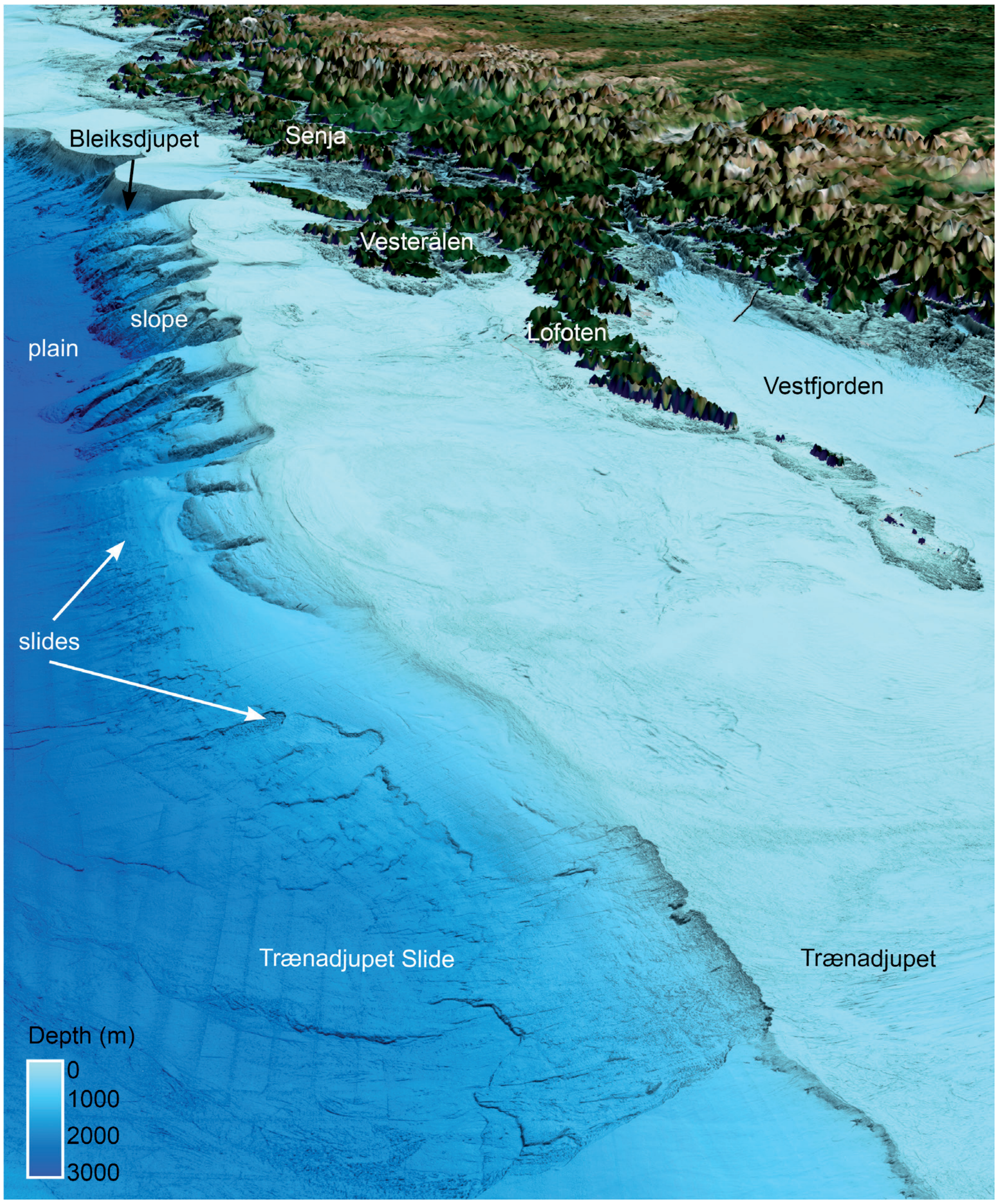


Figure 6. The boundary between the continental slope and the deep-sea plain is easily observed west of Senja and Vesterålen, but becomes more gradual southwards. 5x vertical exaggeration.

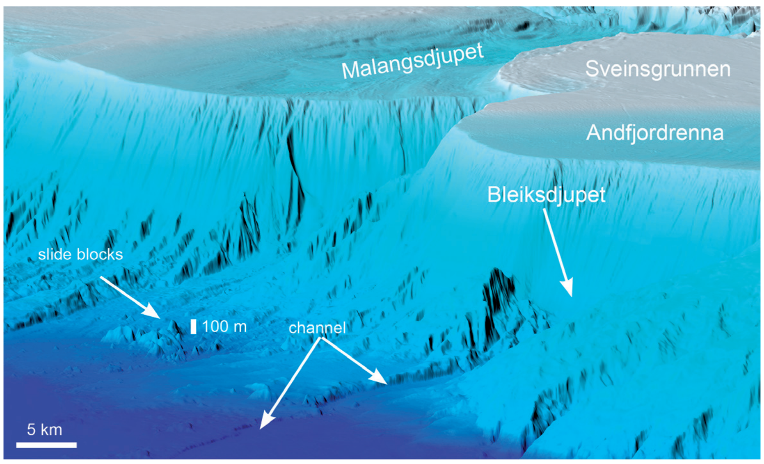


Figure 7. Large slide blocks (arrow) at the transition between the continental slope and the deep-sea plain outside Malangsdjupet and Andfjordrenna. 5x vertical exaggeration.

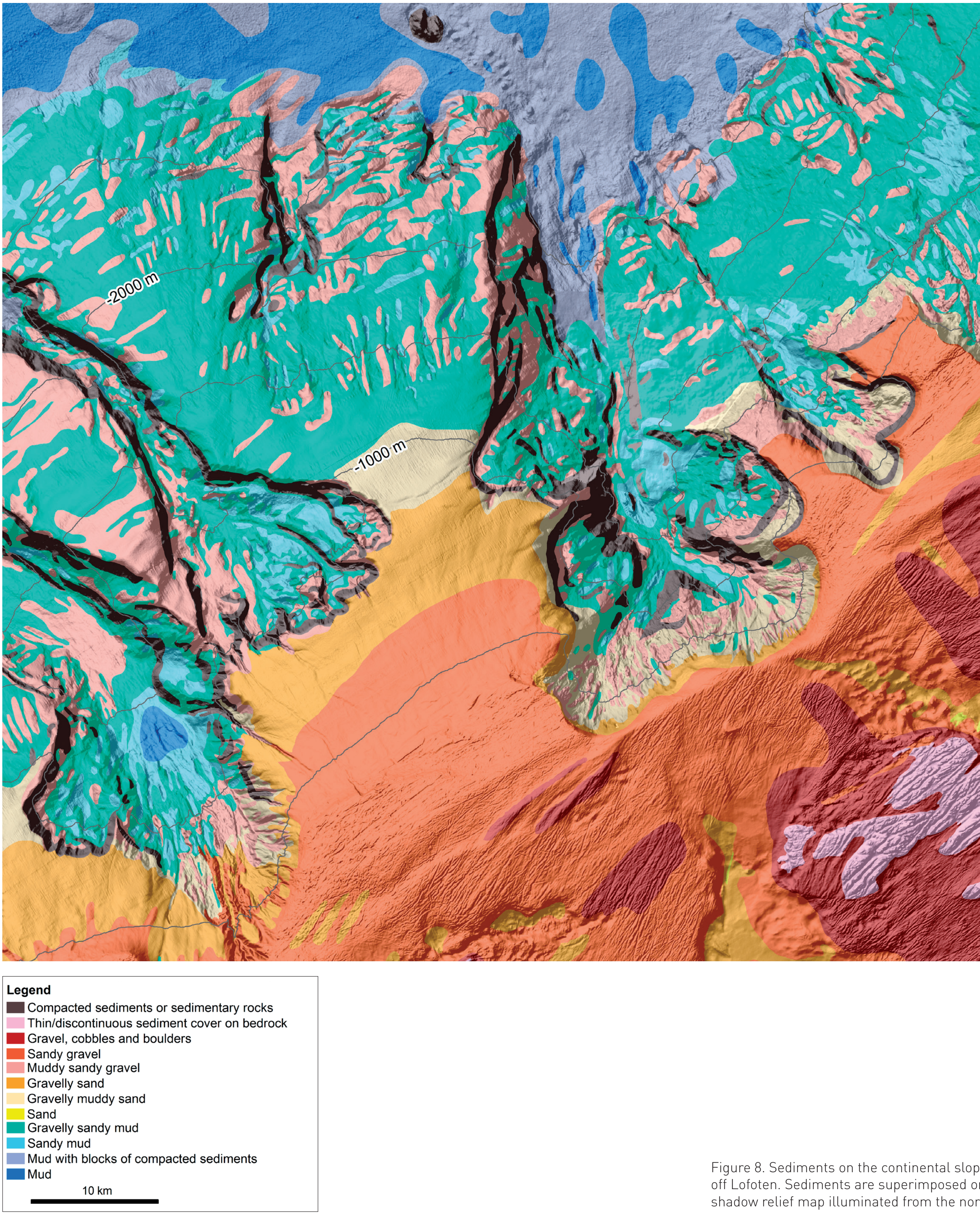


Figure 8. Sediments on the continental slope off Lofoten. Sediments are superimposed on a shadow relief map illuminated from the northeast.

Some small canyons just north of the Trænadjupet Slide show features of special interest. Video investigations have revealed that the walls of one of the canyons are covered with bacterial mats. Bacterial mats sometimes result from decomposition of organic matter, but may also be an indicator of gas leakage from below the seabed. Unusual rocks occur in the same place. These are thought to be possible carbonate crusts formed as a result of chemical reactions related to seepage from the subsurface to the seabed, where anaerobic microbial oxidation of methane-rich fluids has caused precipitation of carbonate in the sediment. Gas-charged sediments are more easily eroded and will be less resistant to sliding. It is therefore reasonable to assume that gas seepage has contributed to the formation of canyons in this area, but further investigations are needed to confirm this hypothesis.

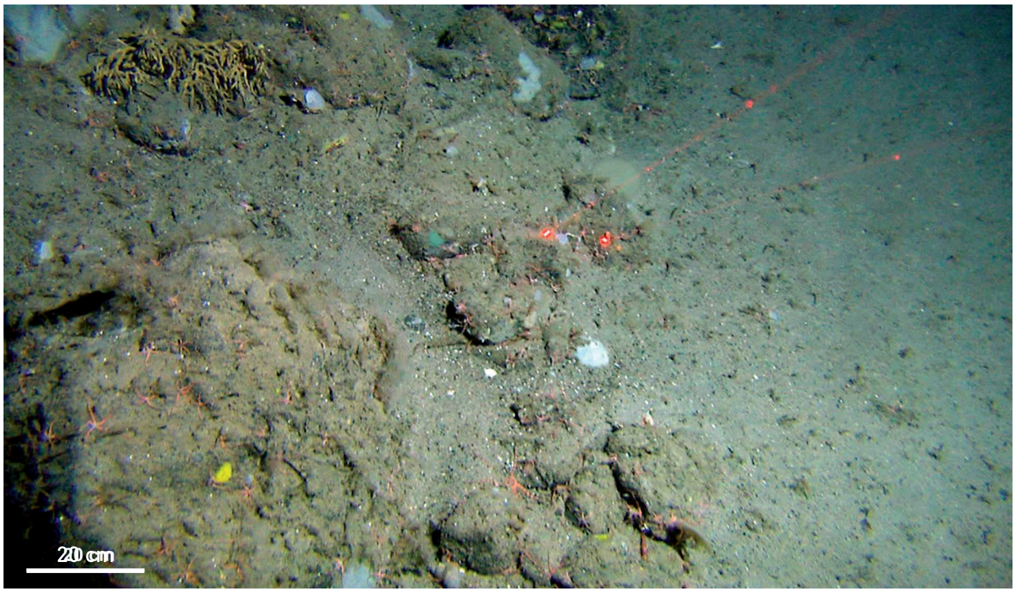


Figure 9. Slide debris containing boulders from till at the foot of a steep slope in a canyon off Lofoten.

Landslides on the Continental Shelf and the Deep-Sea Plains

Landslide scars, escarpments and debris are common in the continental slope between the canyons, for example in the upper part of the continental shelf southwest of Bleiksdjupet. Many small to medium-sized landslides have been observed in the continental slope north of the Trænadjupet Slide (figure 6). Some slides are situated in the deposit zone of the Lofoten Contourite (see below) and southwards to Trænadjupet. The largest submarine slide is the Trænadjupet Slide (figure 13), which according to investigations by scientists from the University of Tromsø extends from the shelf break to more than 3 000 m water depth in the Lofoten Basin, affecting an area of around 14 100 km^2, and which occurred about 4 000 years ago. The upper headwall of the slide scar is around 40 km long. The upper slide escarpment is up to 150 m high, and commonly very steep with slope angles above 25°, (figure 13b), locally exceeding 40°. Detached sediment ridges parallel to the shelf edge occur in a zone up to 1,000 m wide down-slope from the shelf edge escarpment (figure 13c). The detachment ridges are up to 2 km long, 200 m wide and up to 30 m high. The slopes of these ridges commonly exceed 30°. Down slope of this zone, some of the ridges become deflected and disrupted, locally forming trains of blocks. There is a gradual transition down slope into elongated to equi-dimensional blocks, with diameters up to 100 m and heights up to 20 m. Ridges oriented normal to the escarpment are also found, some of them as high as 45 m.

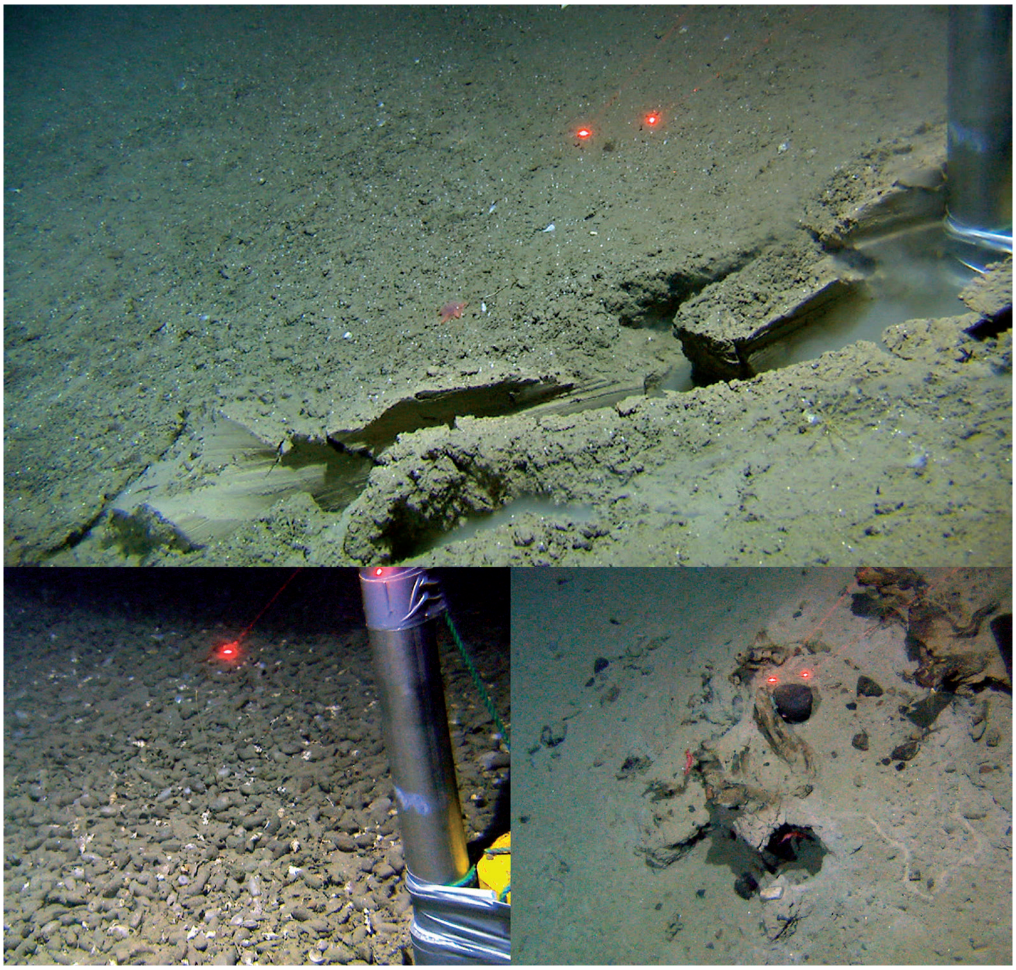


Figure 10. At the foot of the continental slope off Lofoten, submarine alluvial fans have formed at the canyon mouths. Sediments are transported down the canyons by landslides, turbidity currents and other density currents and deposited in the fans.

The detachment ridges consist of compacted sediments – till – with an unsorted grain size mixture from mud to blocks. In the depressions between the ridges, sandy gravel and gravelly sand dominate. An abundant hard-bottom fauna is present in the uppermost part of the slide scar, including stony corals (*Lophelia pertusa*), sea trees, sponges and anemones. The shelf immediately to the southeast of the slide scar is dominated by sandy gravel and bioclastic sediments mainly composed by coral mounds. Several kilometre-long iceberg ploughmarks have been revealed by multibeam bathymetry. Their widths are up to 100 m, with depths up to 8 m, and flanking berms up to 5 m high. Coral mounds are commonly found on these berms.

Landslides on the continental slope can be caused by a number of factors. Earthquakes are common triggers. They may cause unstable sediments to start moving. Another common trigger is rapid deposition of sediments, becom ing unstable due to locally increased pore pressure. After the last Ice Age, sediments have mostly been transported along the slope from the southwest by alongslope currents. Hence, sediments are mainly deposited in the southwestern parts of the canyons, leeward of the current, and these sediments are probably the most unstable.

Old landslide debris with large blocks covers large parts of the deep-sea plains off Lofoten, Vesterålen and Troms (see chapter 5.1.1). The debris is frequently found on the seabed surface, indicating that only small amounts of sediment are currently being deposited in these areas.

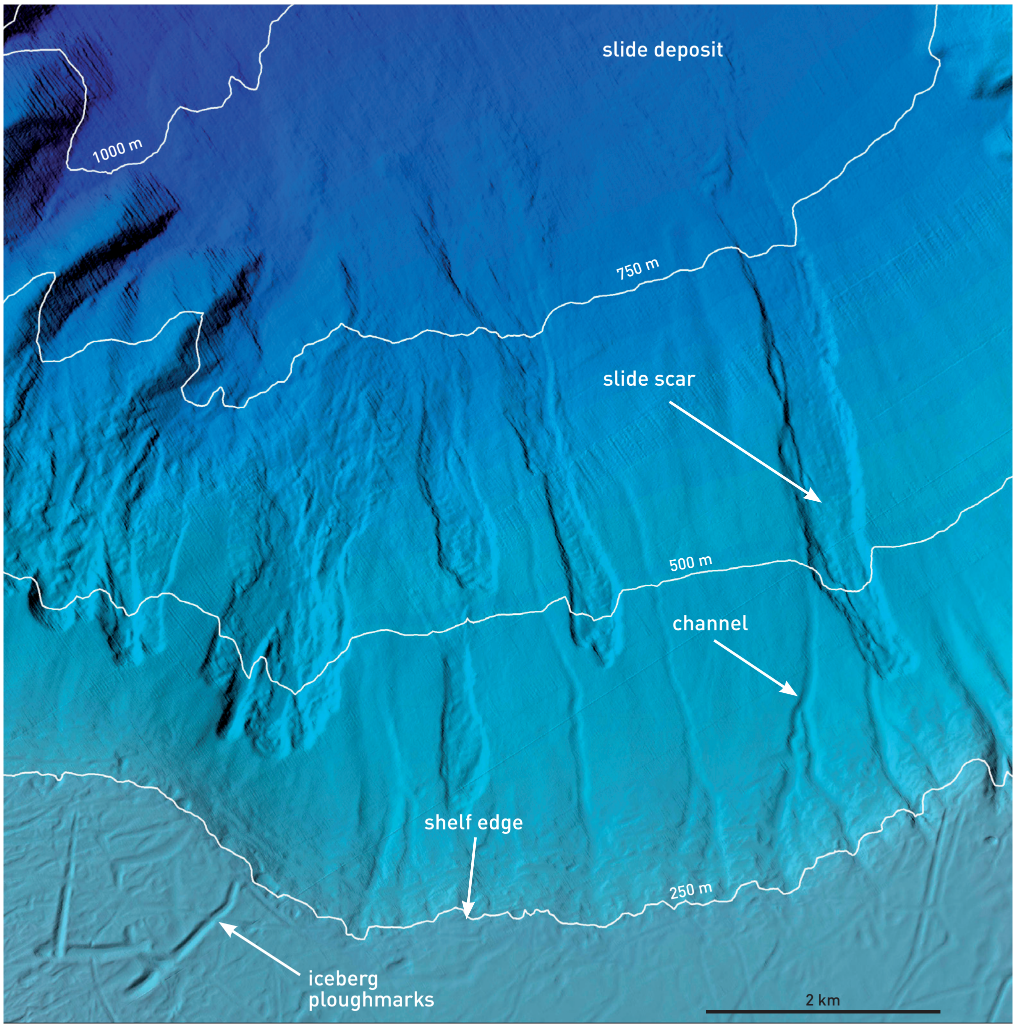


Figure 11. Landslides in one of the canyons north of Lofoten. The landslides start on the seabed just below the shelf edge. The age of the slides is unknown, but they seem to be covered by only a thin layer of sediments, which suggests that they may be relatively young.

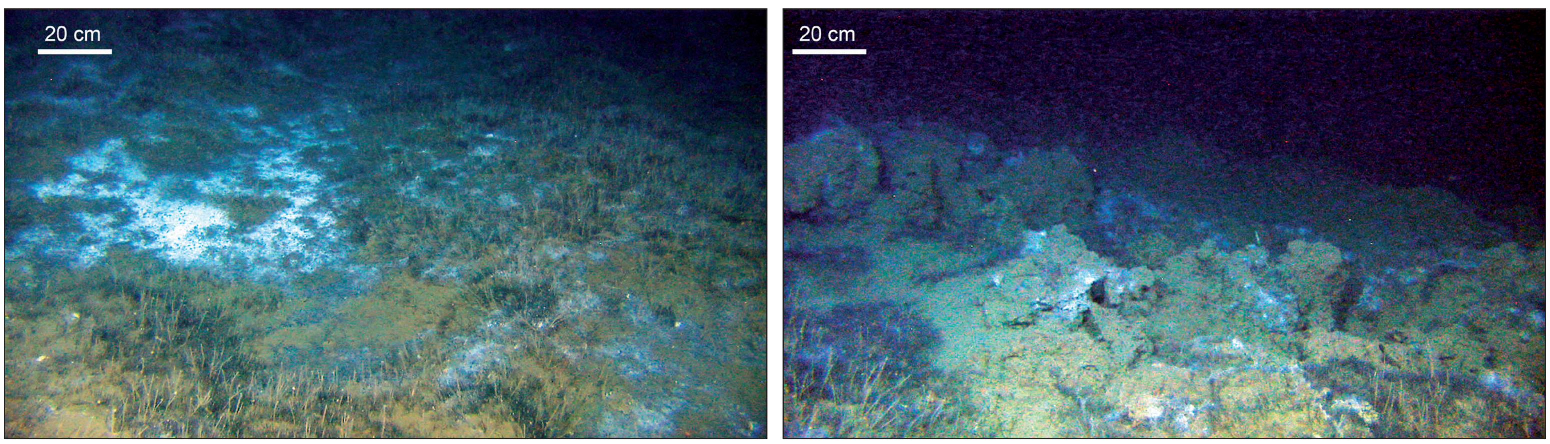
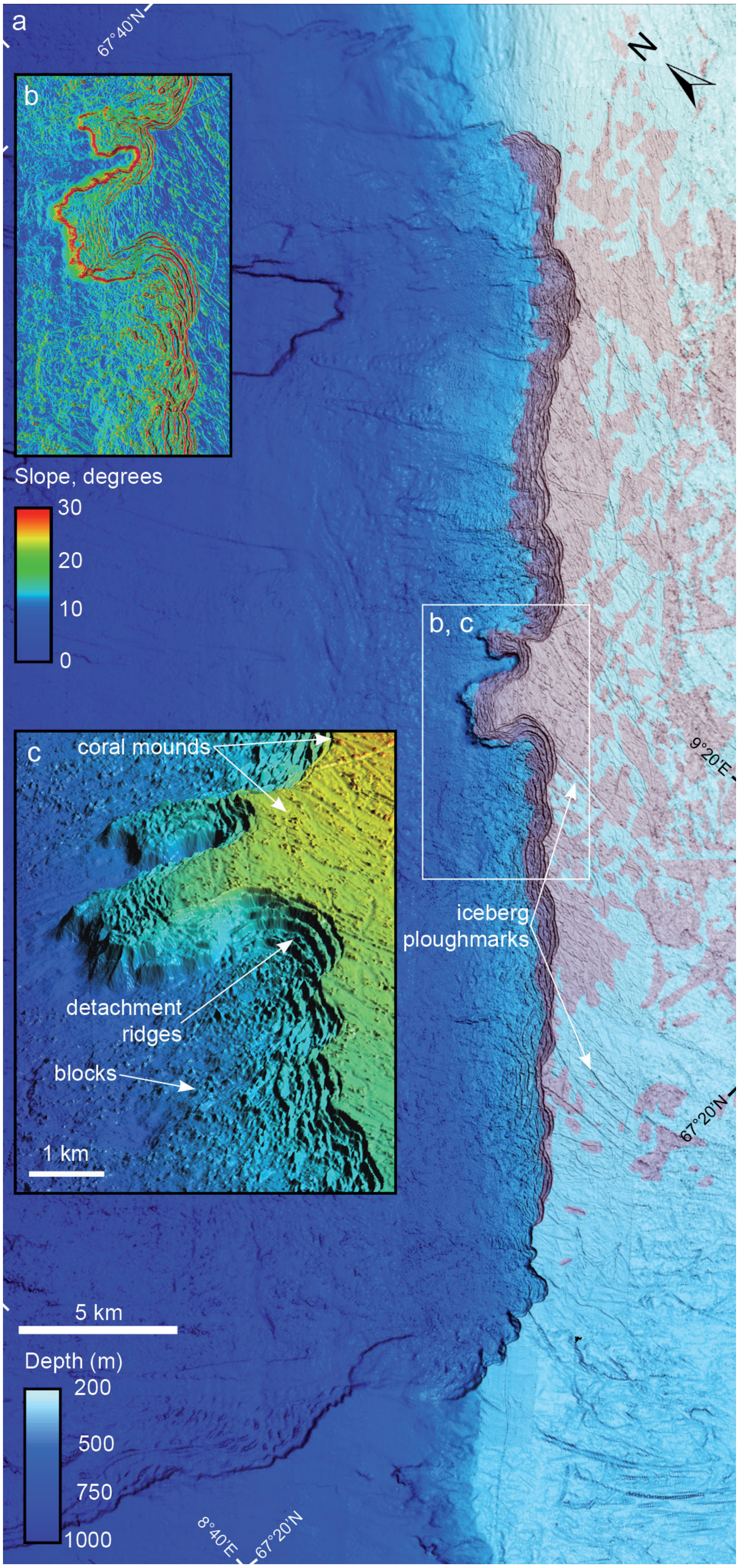


Figure 12. Photographs from one of the canyons showing large areas of white bacterial mats and possible carbonate crusts.

Figure 13. (a) Shaded relief map of the Trænadjupet Slide. Pink transparent areas show bioclastic sediments related to coral mounds. White frame shows location of (b) and (c). (b) Slope map, with slopes up to 30°. (c) 3D model of the central part of the slide.



Channels, Turbidites and Submarine Alluvial Fans

Landslide debris moving down the continental slope will gradually absorb more water and turn into turbidity currents (currents driven by the high density of the sediment-loaded water). Turbidity currents can erode the seabed. In the canyons, the currents will develop channels. The most distinctive channel in this area, the Lofoten Basin Channel, starts in the inner part of Bleiksdjupet and runs more than 1000 kilometres into the Lofoten Basin (figure 7). Studies have shown that the last big turbidity current occurred about 4000 years ago (at the same time as the Trænadjupet Slide), while transport and deposition of sediments from smaller turbidity currents probably still occurs today. Sediments in turbidity currents are deposited in thin layers (turbidites) when the current stops.

Submarine fans form where landslide debris and turbidites accumulate, generally on the deep-sea plain outside the large canyons (figure 14). Some fans are characterised by large boulders and others by turbidites. In seismic sections, turbidites appear as layered deposits while landslide debris is more chaotic. The thickness of the deposits in the fans decreases with the distance from the canyon mouths. Channels on the surface of some fans suggest that sediments are regularly transported and deposited as turbidites.

Contourites

The Lofoten Contourite occurs on the continental slope west of Lofoten, in water depths between 700 m and 1500 m. It consists of fine, layered sediments (clay, silt and sand) transported and deposited by contour currents. Contour currents are currents moving along the depth contours at specific depths. The Atlantic Current is a contour current that runs north along the continental slope off Lofoten, Vesterålen and Troms. This current

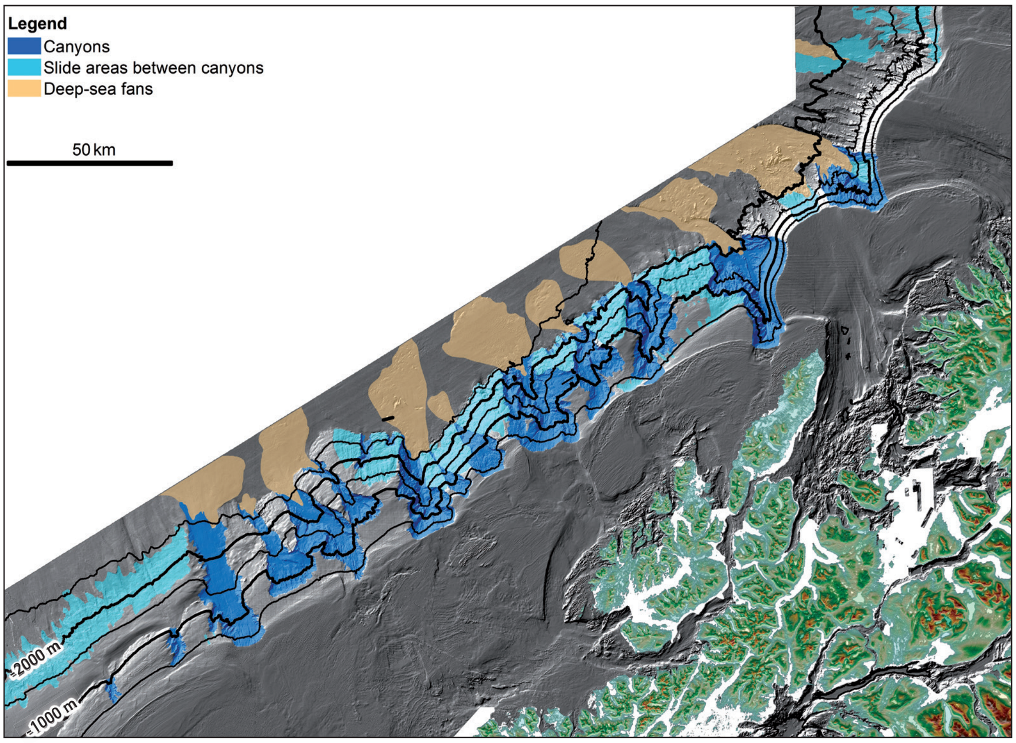


Figure 14. At the foot of the continental slope off Lofoten, Vesterålen and Troms, submarine fans have formed at the canyon mouths. Sediments are transported down the canyons by landslides, turbidity currents and other density currents and deposited in the fans.

Figure 15. Cave in hard sediments in the continental slope off Lofoten. 10 cm distance between red laser dots.

plays a significant role in the transport of sediments along the seabed in the area. According to studies, the Lofoten Contourite is up to 300 m thick, but most of the sediments are more than 10 000 years old, and only 1 metre or so has been deposited over the past 10 000 years. This suggests that the deposition rate currently is low on most of the continental slope.

Seabed Caves

During video surveys MAREANO has observed holes and caves in the seabed at around 2200 m depth off Lofoten (figure 15). One cave is formed in hard sediments in an uneven area of landslide debris consisting of compacted sediments and Quaternary slide debris. In front of the cave, there are loose boulders clearly stemming from the material the cave is eroded into.

In the sediments on the side of the cave, there are a number of smaller holes, 3–4 cm in diameter. These caves are interpreted to be catastrophic fluid escape venting-tunnels associated with large submarine slides on the continental slope. The holes are always found in connection with slide scars or slide deposits, usually in water depths deeper than 1000 m, for example at the Trænadjupet Slide (figure 16). They are often associated with small chimney structures on slide blocks. It is interpreted that these holes as caused by pore water being expelled from sediments which have been affected by sliding and have undergone compaction due to the sliding.

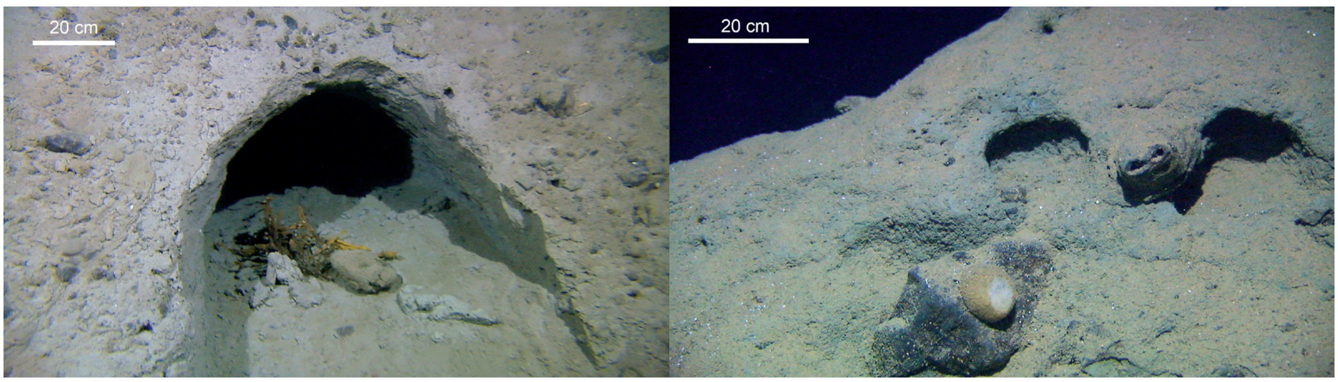


Figure 16. Left: Hole in the seabed at the Trænadjupet Slide. Right: Small chimney associated with holes in a compacted sediment slide block (Trænadjupet Slide).

5.2 BOTTOM HABITATS AND FAUNA

In this chapter, we describe habitats, biotopes and biodiversity in the deep areas off Lofoten, Vesterålen and Troms, from the shelf break and below. The seascape in this area is extremely varied and as the bathymetry map (figure 18) indicates, the terrain is dramatic, with sudden shifts in depth. In many ways, the topography defines the environment; it controls local current patterns and transport of sediments and organic matter to the deep sea where food is scarce. This transport is facilitated by a combination of the special current patterns and the funneling effect of the canyons.

Off Troms and Nordland, the slope of the continental shelf is very close to land. The shelf break in this part of the Norwegian Sea occurs at 200–500m depth and here the seabed drops away abruptly down to 3000 m depth. From the shelf break and down the continental slope, three distinct water masses occur, with properties so different that they operate like separate climate zones (figure 19)

On the upper part of the slope we find the continuation of the warm Gulf Stream, which provides Norway with a relatively mild climate for its northerly location. The most evident fauna transition appears at about 700m depth. This coincides with the boundary between the Atlantic Water with temperatures above 0.5 degrees and the Arctic Intermediate Water with temperatures between 0.5 and –0.5 degrees. In this transitional layer, the fauna is very different to that found at shallower depths. The next major transition in fauna occurs at around 1000m, where the upper range of Norwegian Sea Water is found, with temperatures between –0.5 and –1.1 degrees. Other shifts in fauna are not related to depth, i.e. water mass, but rather to the marine landscape, topographic features and bottom types. On the slope, there is a steady transport of organic matter from the productive shelf areas down to deeper and less productive areas. The deep sea is dependent upon the supply of nutrients from the production rich areas many hundred metres above. Generally for deep sea areas, only small amount of nutrients reach the bottom but on the slope, the transport is quicker and the quantities are higher; partly due to the sloping terrain, partly to currents. It appears to be mainly the landscape that influences the currents transporting nutrients, eggs and larvae. This transport tends to happen in the numerous marine canyons carved into the continental slope in the area. In these canyons, the steep walls often consist of compacted sediments resembling rock and are a preferred habitat for gorgonians and other corals.

5.2.1. Biotope Distribution

Based on quantitative analyses of video observations of dominant fauna and environment, the seabed from just below the shelf edge down to the deep-sea plain was divided into five biotopes mainly related to

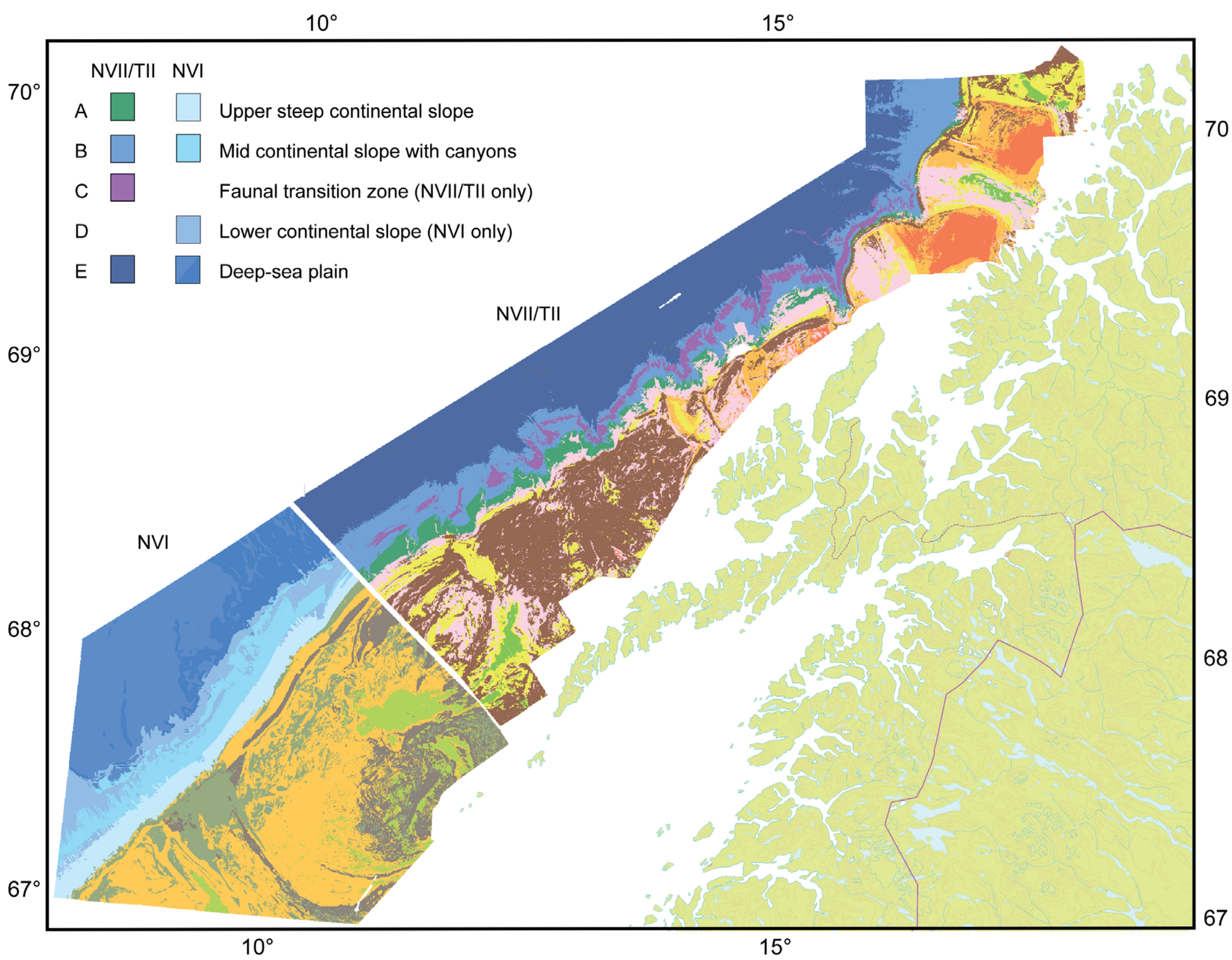


Fig 17. Map of predicted biotopes for Vesterålen/Troms (NVII and TII) and Lofoten (NVI). Legends are given for deep-sea biotopes with separate colour codes for the two areas.

depth. The areas Nordland VII and Troms II have been analysed together, providing a unified classification of biotopes for both areas (figure 17), whereas the data from Nordland VI has been analysed separately (figure 17). However, the classifications of habitats and patterns appearing on the map fit nicely together with only some smaller differences for the deepest areas. Five biotopes were predicted for the deep-sea off Lofoten (Nordland VI), while only four biotopes were predicted off Vesterålen and Troms (Nordland VII and Troms II). Below, these are listed with letters:

A) Upper steep continental slope
B) Mid continental slope with canyons
C) Faunal transition zone
D)Lower continental slope
E) Deep-sea plain

A) Upper Steep Continental Slope
The upper continental slope, at depths generally between 500 to 800 metres is an area with strong currents and a coarse bottom substrate. The fauna here is rich. On sandy gravelly bottoms, we find dense populations of broccoli corals (*Drifa glomerata*) and basket stars (*Gorgonocephalus eucnemis*) (figure 21). The Greenland halibut is common in this biotope.

B) Mid Continental Slope with Canyons
The mid-continental slope from around 800 m down to around 1300. In this biotope, around 1000m depth *Umbellula* (figure 22) has been observed in relatively high density "forests". These animals belong to the sea pens and can grow several metres high. In Stabbråa, a ravine off Hola, *Umbellula* occurred just a few metres apart which is dense in comparison

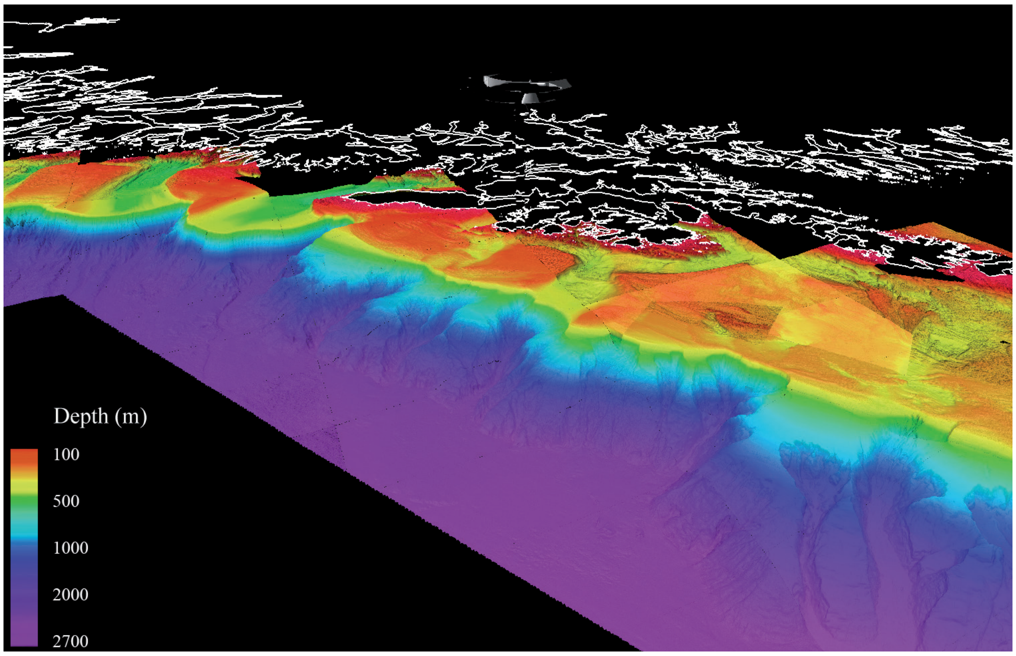


Figure 18. Depth and bottom topography off Nordland, Vesterålen and Troms. Red–orange < 100m: Banks on the shelf. Yellow 100–350m: Troughs on the shelf and shelf edge. Green 350–700m: Upper slope. Light blue 700–100m: Transitional zone between warm and cold water. Dark blue 1000–1400m: Mid-slope. Bluish purple 1400–2400m: Lower slope. Reddish purple 2400–2800m: Deep-sea plain.

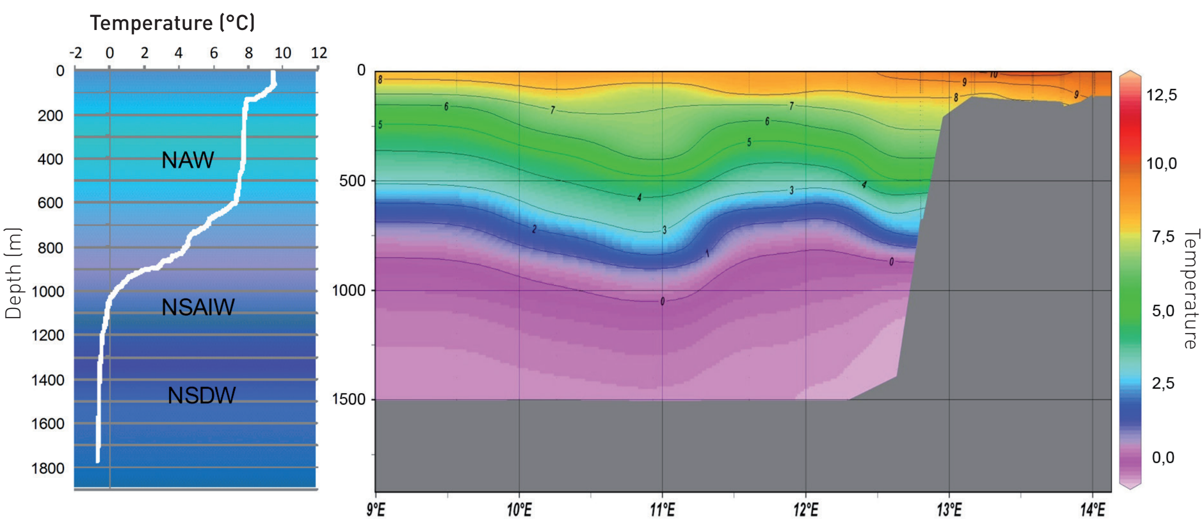
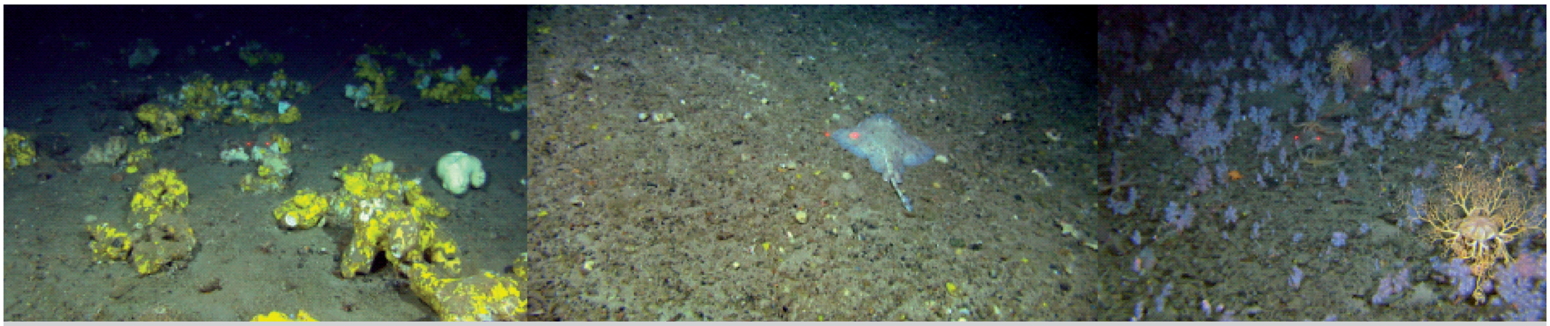
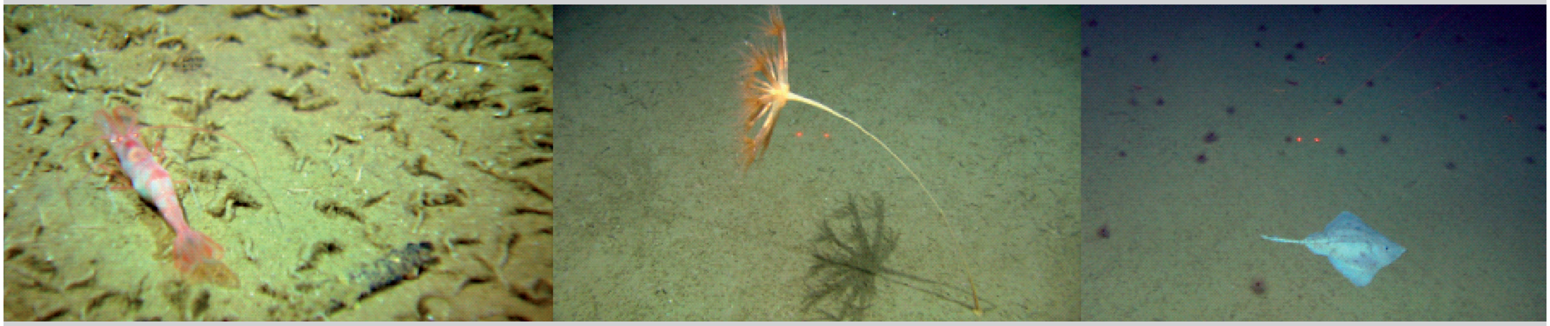


Figure 19. The figures show the strong temperature gradient with depth and water masses in the area off Lofoten-Vesterålen. The distance is short (10–25km) from the shallow banks down to the deep-sea plains where the temperature is at a constant low of –1.1 °C. We pass through three water masses: Northeastern Atlantic Water (NAW) at the surface, then a transitional layer of Norwegian Sea-Arctic Intermediate Water (NSAIW) and below 1000m we find the Norwegian Sea Deep Water (NSDW). The transition between the zones varies some during the year and long waves may form in the transitional layer. The figures show the situation during spring/summer. The temperature along with bottom type and landscape determine what benthic fauna we will find in the various depth zones.

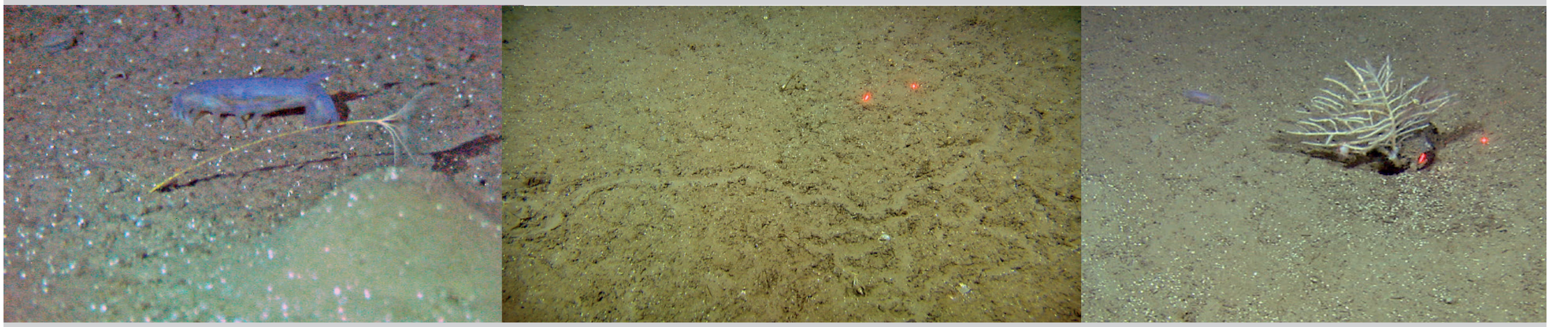


Continental shelf edge and upper slope (230–700m). Mainly gravelly-sand with occurrence of gravel. Varied and rich fauna with sponges and "fields" of broccoli coral.



Mid-slope (700–1000m): Mainly smooth sandy-mud with some rugged areas close to marine canyons and ridges. Temperatures from –0.5 °C to 0.5 °C. Transitional zone with occurrences of fauna from both deeper and shallower areas.

Lower slope (1000–2400m): Mainly smooth sandy-mud with some rugged areas close to marine canyons and ridges. Stable cold water from –0.5 °C to -1.1 °C. In this zone and below, we find "real" Arctic species such as tube anemones, the starfish *Hymenaster* and the sea cucumber *Elpidia*.



Deep-sea plain (<2400m): Smooth sandy-mud with a high concentration of foraminifers. Stable cold water from –0.5 °C to -1.1 °C. Tube anemones, glass sponges, the sea cucumber *Kolga* and the sea urchin *Pourtalesia* are common.

Figure 20. Short description and examples of four main biotopes in deep water off Nordland, Vesterålen and Troms.

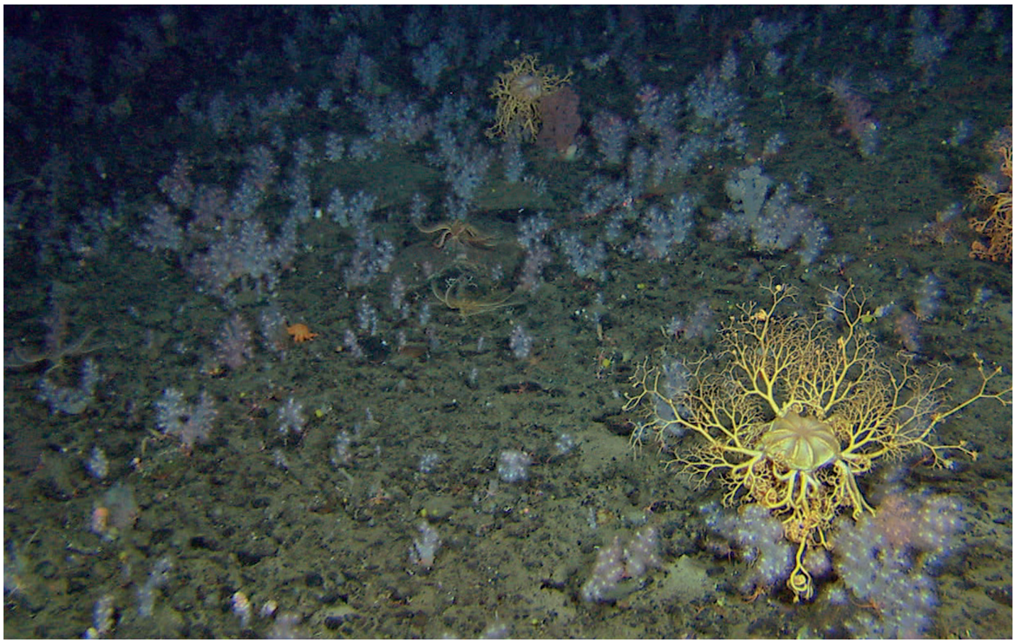


Figure 21. Gravelly bottom at the shelf edge with a "field" of broccoli coral and basket stars.

Figure 22. In the canyon off Hola, there are relatively dense populations of the deep-sea sea-pen *Umbellula encrinus*, with only a few metres between each individual.

to most other large species at these depths. One specimen we caught in the beam trawl was over 2m long. The age of individuals of that size is unknown but given that fauna in the deep-sea cold water generally grow very slowly, the age of *Umbellula* is probably similar to that of other corals (i.e. over 100 years). The bottom-dwelling jellyfish *Lucernaria bathyphilia* (figure 23) only exists in deep water. Any animal at such great depths is rarely sampled or mentioned in scientific reports. It is therefore not surprising that this peculiar organism has hardly been mentioned since it was described by a German scientist 130 years ago.

Part of the continental slope is rugged having been disturbed by landslides and canyons while other areas are undisturbed. The processes that have formed these marine landforms are described in chapter 6.1. On one of the areas of undisturbed seafloor sticking out between two canyons west of Andøya, we found an impressively large hydroid *Corymorpha regalis* (figure 33) measuring 25cm. This is big for a single polyp.

Marine Canyons

Bleiksdjupet is Norway's largest marine canyon and also one of the largest in Europe. It is situated west of the northern tip of Andøya (figure 31). Bleiksdjupet and the closest fjord on the landward side, Andfjorden have been proposed as marine protected areas. MAREANO explored Bleiksdjupet

Figure 23. A bottom-dwelling jellyfish, *Lucernaria bathyphilia*, was observed in several locations at more than 1000m depth.

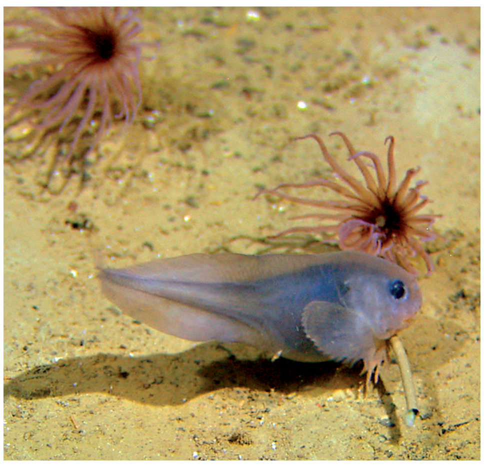


Figure 24. Threadfin seasnail was observed in areas with tube anemones.

Figure 25. Most glass sponges are found at great depths. The sponge in this photograph, *Caulophacus arcticus*, is typical for the northern deep, cold water masses. During the survey, it was quickly nicknamed "chanterelle sponge". This specimen is approx. 30cm tall.

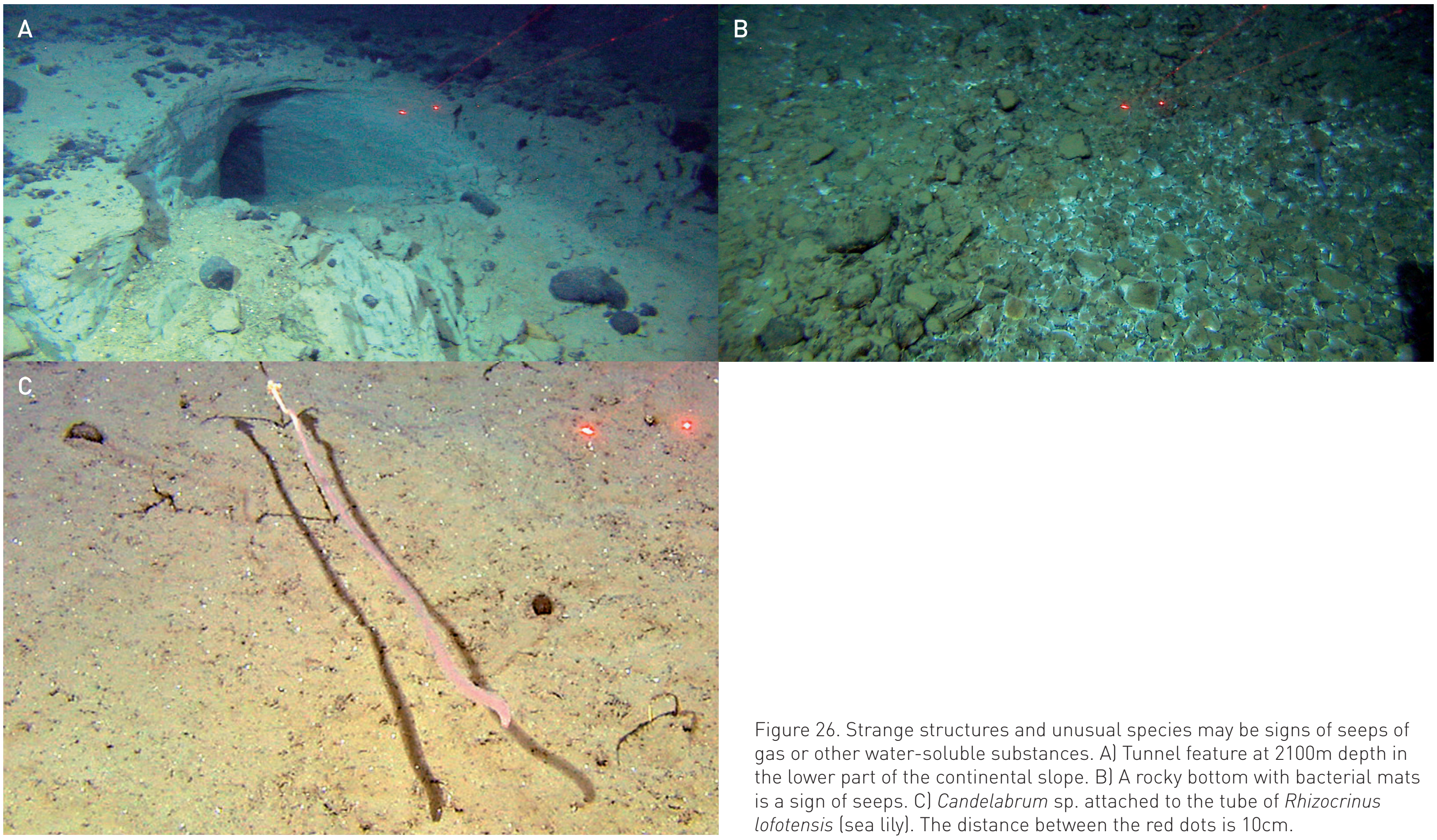


Figure 26. Strange structures and unusual species may be signs of seeps of gas or other water-soluble substances. A) Tunnel feature at 2100m depth in the lower part of the continental slope. B) A rocky bottom with bacterial mats is a sign of seeps. C) *Candelabrum* sp. attached to the tube of *Rhizocrinus lofotensis* (sea lily). The distance between the red dots is 10cm.

canyon down a depth of 1850m and found a spectacular, varied landscape with steep canyon sides covered in compact sediments (figure 25) as well as flatter, smoother areas with varying bottom types. Quite a lot of litter was observed at the bottom of the canyon. The steep walls probably act as a funnel where loose objects are transported by the current. We found few traces of fishing activity and our main impression is that the area is relatively undisturbed by human activities.

C) Faunal Transition Zone

This biotope has a narrow depth range, mainly from 700 to 1000 m, and coincides with the depth of Arctic Intermediate Water. Off Vesterålen it occurs as a narrow band in the middle of the continental slope biotope B. Here we find representatives of both shallower

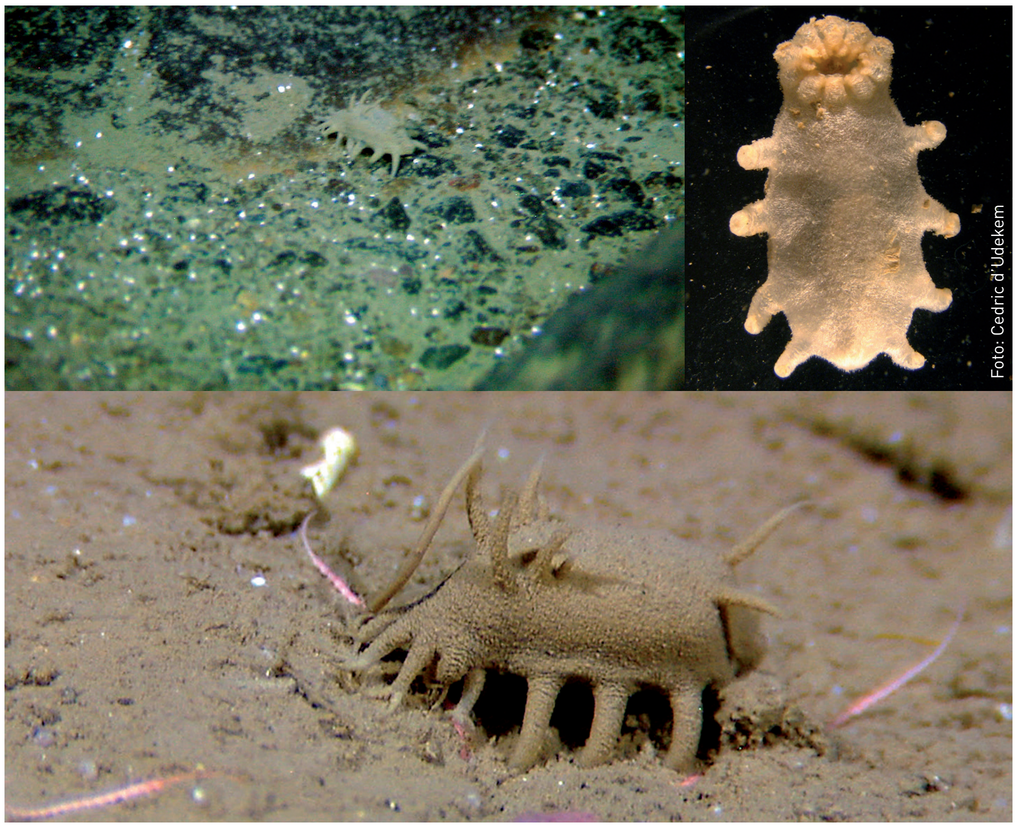


Figure 27. *Elpidia glacialis* is a deep-sea sea cucumber, here photographed at 1800m depth and in the lab. The lab photograph shows the animal's abdomen and closed mouth papilla. This specimen is only 2cm long.

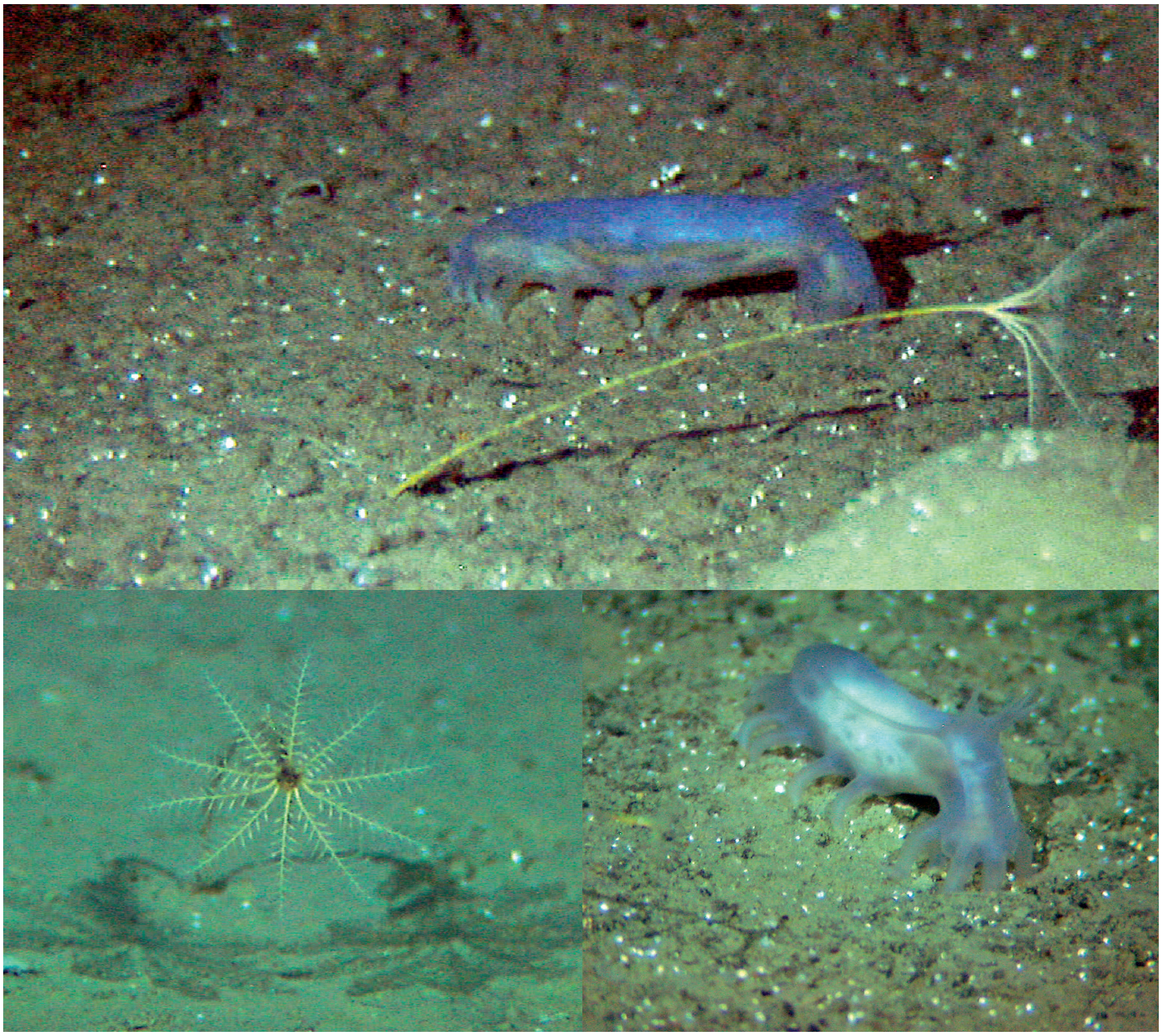


Figure 28. The fauna on the deep-sea plain, at 2700m depth, is unique but quite poor. The photograph shows a dense collection of sea lilies (*Rhizocrinus lofotensis*). Between them, small and large sea cucumbers are walking around on their short legs. Here, we see *Kolga hyalina* (approx. 5cm long). The biodiversity may diminish in deeper water but the sea cucumbers are a group of organisms that is richer in deep water. The white dots are foraminifera, single-cell organisms with a calcareous shell.

and deeper fauna, hence we recognize this biotope as a faunal transistion zone.

D)Lower Continental Slope

The lower continental slope biotope occurs generally at depths between 1300 and the foot of the continental slope where it meets the level abyssal plain (also known as the continental rise). The sediments here are more fine grained than in the upper part of the slope. At depths of more than 1300m, the bottom was densely populated by tube anemones (Ceriantharia). The threadfin seasnail (*Rhodichthys regina*) has only been observed a few times during the MAREANO mapping, but always in the same areas as these tube anemones (figure 24). The sea lily, *Rhizocrinus lofotensis* is also common at this depth. This is an echinoderm (same kind of organism as starfish, sea urchins etc.) which is attached to the bottom with a stalk. The stalks are often home to other organisms that benefit from getting off the bottom and into the stronger current to access food.

In uneven terrain, we observed relatively dense populations of glass sponges. *Caulophacus arcticus* (figure 25) is a characteristic and common species at this depth. Most other glass sponges found here were bushy, stalked or feathery.

At about 2100m, we observed peculiar holes, or tunnels about 40cm wide that are difficult to explain both biologically and geologically. These caves were observed in several locations in the lower slope. It is difficult to imagine organisms at this depth capable of digging such large holes in hard clay, and the tunnels are most likely catastrophic fluid escape venting tunnels associated with submarine landslides. Nearby areas with bacterial mats and carbonate crusts are thought to be a result of related processes. The peculiar hydroid *Candelabrum* sp. (figure 26), known from areas with gas seeps on the Mid-Atlantic Ridge, was found at the same depth.

E) The Deep-sea Plain

Beyond the foot of the continental slope the marine landscape consists of vast, flat plains with fine sediments and high densities of foraminifera (single-cell organisms with a calcareous shell). The water is cold and the

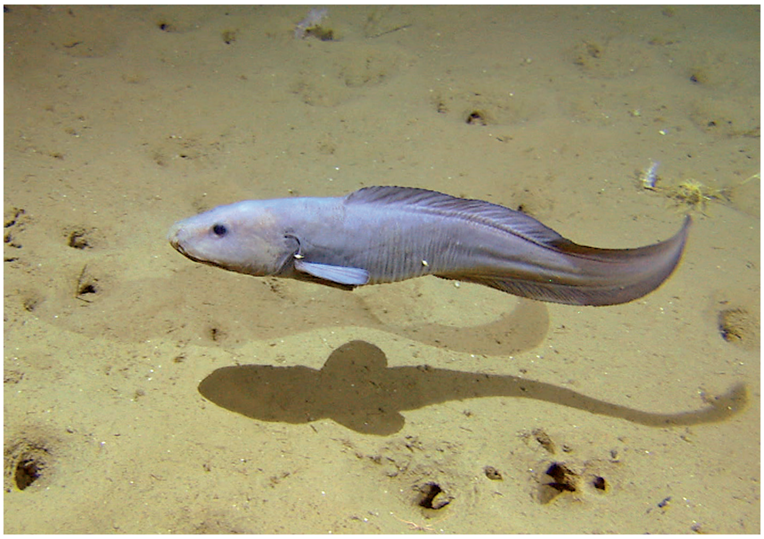


Figure 29. Glacial eelpout was one of the most common deep-water fish species. This photograph was taken at 1200m depth.

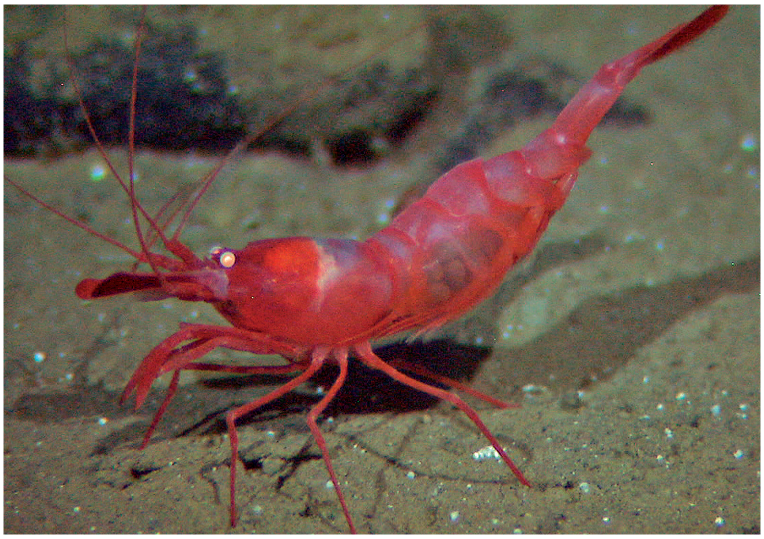


Figure 30. *Bythocaris* is a large, red shrimp thriving on the soft bottom in the deep sea.

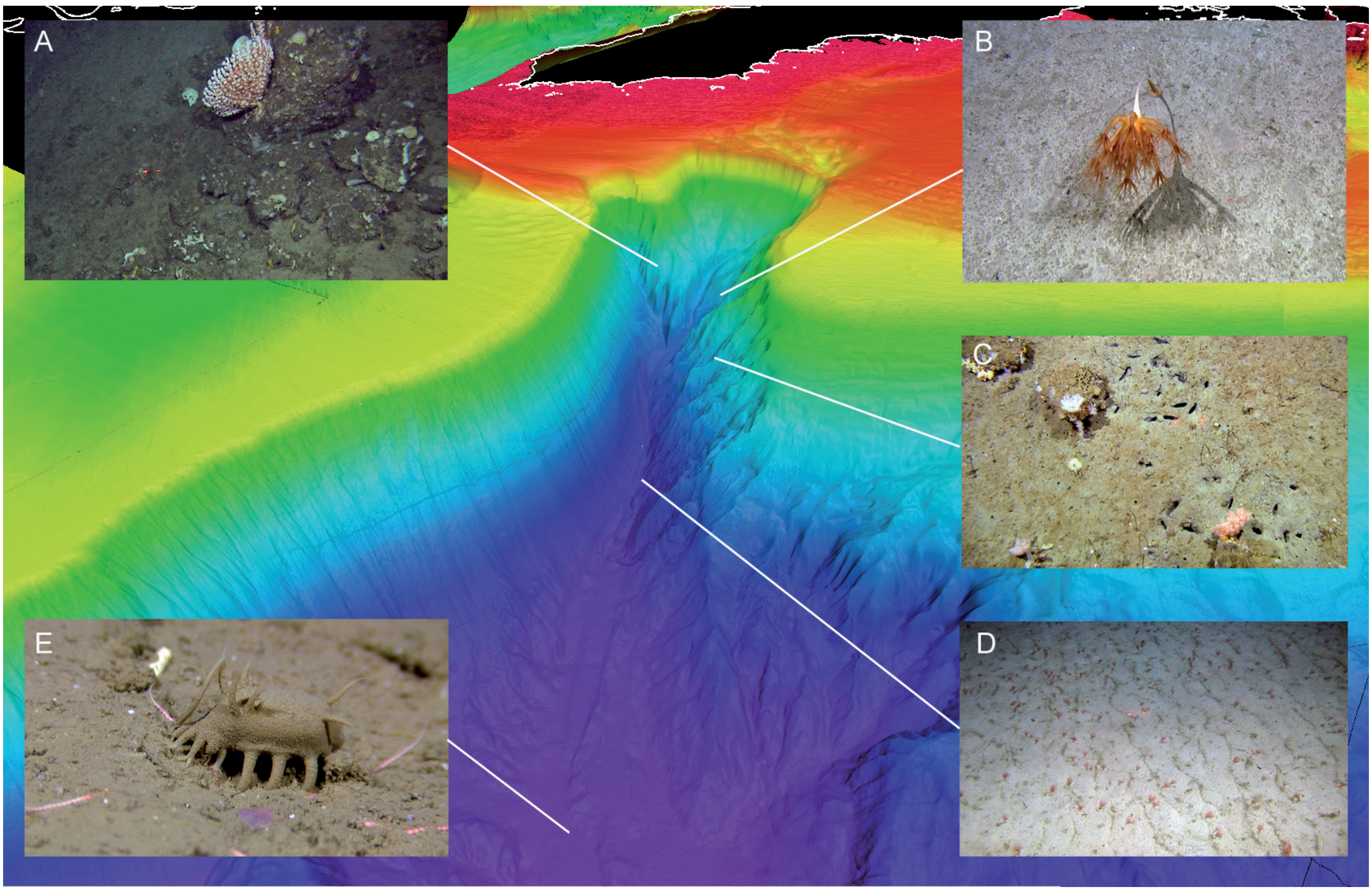


Figure 31. The Bleiksdjupet canyon off Andøya is one of Europe's largest submarine canyons. This is the part of the Norwegian coast where the distance is shortest between land and the deep sea. A: Protrusion of hard clay and rock with a bubble gum coral (*Paragorgia arborea*) at 650m depth. B: The deep-water sea-pen *Umbellula encrinus* at 850m depth. C: Holes after digging organisms, scattered cobbles and broccoli corals. D: Sandy bottom with small, red anemones at 1130m depth. E: Finely grained deep-sea mud with the sea cucumber *Elpidia glacialis* at 1890m depth.

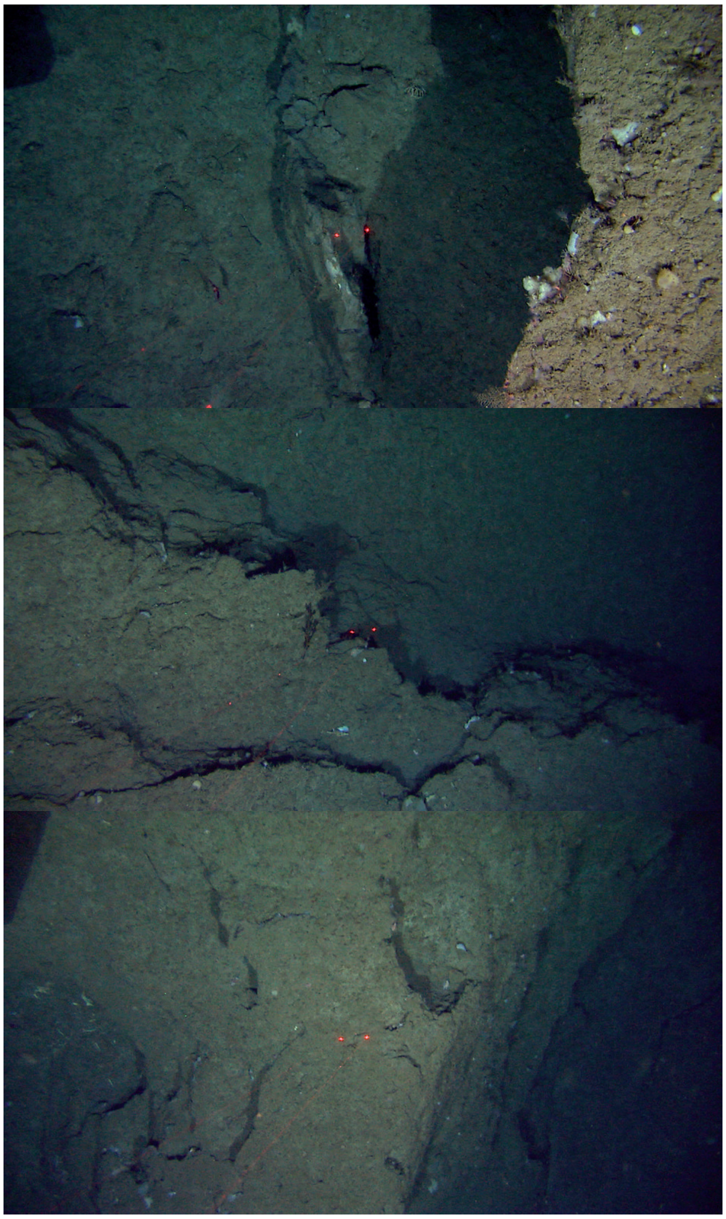


Figure 32. In Bleiksdjupet, the video rig, CAMPOD, rapidly descends along the steep walls of compact moraine clay.

Figure 33. At 1000m depth on a headland west of Andøya, we found this large (approx. 25cm tall) hydroid *Corymorpha regalis.*

fauna is Arctic, and common to the deeper parts of the North Atlantic and the Norwegian Sea Basin. Compared to the richer fauna higher up the slope this is a poor, but unique, fauna where few species lives in the bottom substrate. The megafauna consists mainly of the sea cucumbers *Elpidia glacialis* and *Kolga hyalina*, the sea lily *Bathycrinus carpenteri* along with the crustaceans *Bythocaris* and *Saduria* and the sea urchin *Pourtalesia* (figures 20, 27 and 28). These species, or close relatives of them, are also found in deep waters in the Canadian Basin and off Spitsbergen. The Norwegian Sea Basin is unique with its low temperatures and poor but old fauna. In this sub-zero water, there are no rapid movements and time seems to stand still, also in terms of evolution.

5.2.2. Vulnerable Habitats in Deep Waters

There are several habitats characterized by long-lived and fragile megafauna in this area, both on the shelf and in the deep-sea. Up until now, key or fragile species in deep waters have not been given much attention. The Oslo/Paris convention (OSPAR) has established a list of threatened and/or declining marine habitats. The OSPAR Convention is the current legal instrument to guide international cooperation on the protection of the marine environment of the North-East Atlantic. Among the OSPAR-habitats are deep-sea sponge aggregations, coral reefs, coral gardens, and sea-pen and burrowing megafauna communities. Several of these habitats are described so generally that they can be sub-divided into several categories (figure 34). This is the case for coral gardens, which in Norwegian waters include broccoli coral fields, soft bottom coral gardens and hard bottom coral gardens. Consequently, we have given separate names for the *Umbellula* population (a deep-sea sea pen), the *Radicipes* population (a coral garden we would put in a habitat named soft bottom coral garden) and the glass sponge populations.

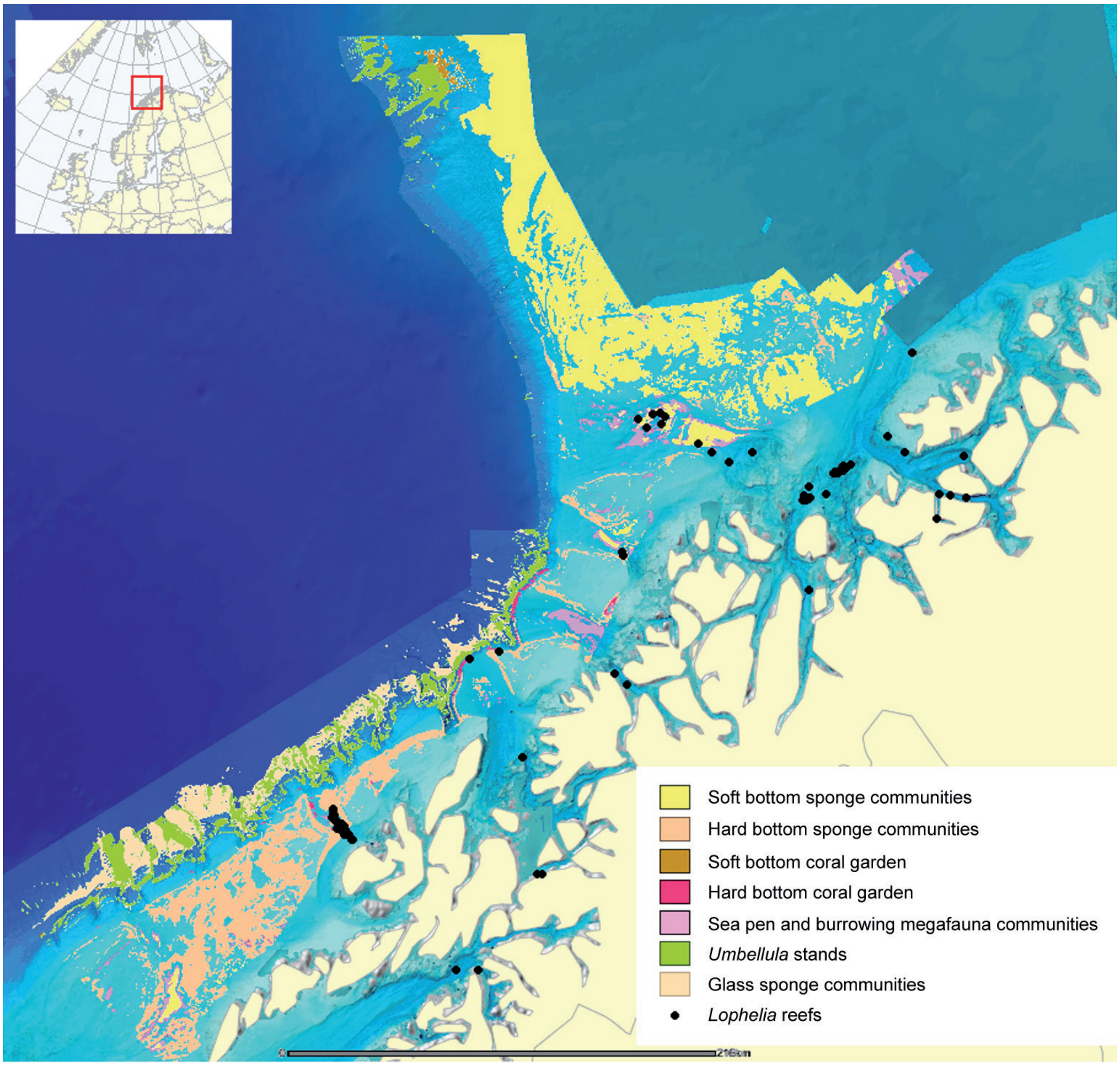


Figure 34. Distribution of vulnerable habitats within the MAREANO mapping area, indicated from predictive modeling based on abundances of species characteristic for these habitats. *Lophelia* reefs are represented as points based on observed occurrences rather than modeled areas.