Norway and its marine areas - a brief description of the sea floor

From the deep sea to the fjord floor

Norwegian waters comprise widely differing environments - from the deep sea via the continental slope and continental shelf to the coastal zone with its strandflat, archipelagos and fjords. This constitutes a geological diversity that is unique in a European context.

An exciting geological history lies behind this diversity - a development that has taken place over more than 400 million years. The continents consist of plates of solidified rock that float on partially molten rock, and these plates move relative to one another. Where they collide, the Earth's crust is folded and mountain chains are created. Where they drift apart, deep oceans form and new sea floor is created along rifts because molten rock (magma) streams up from below. A good example is the Mid-Atlantic Ridge, including Iceland, which is a result of Greenland and Europe drifting from each other at a rate of about 2 cm a year.

The plates on which Norway and Greenland rest collided more than 400 million years ago and formed mountain chains on either side of a shallow sea. Both Greenland and Norway are remnants of worn down mountain chains. Between these mountain chains, the shallow sea

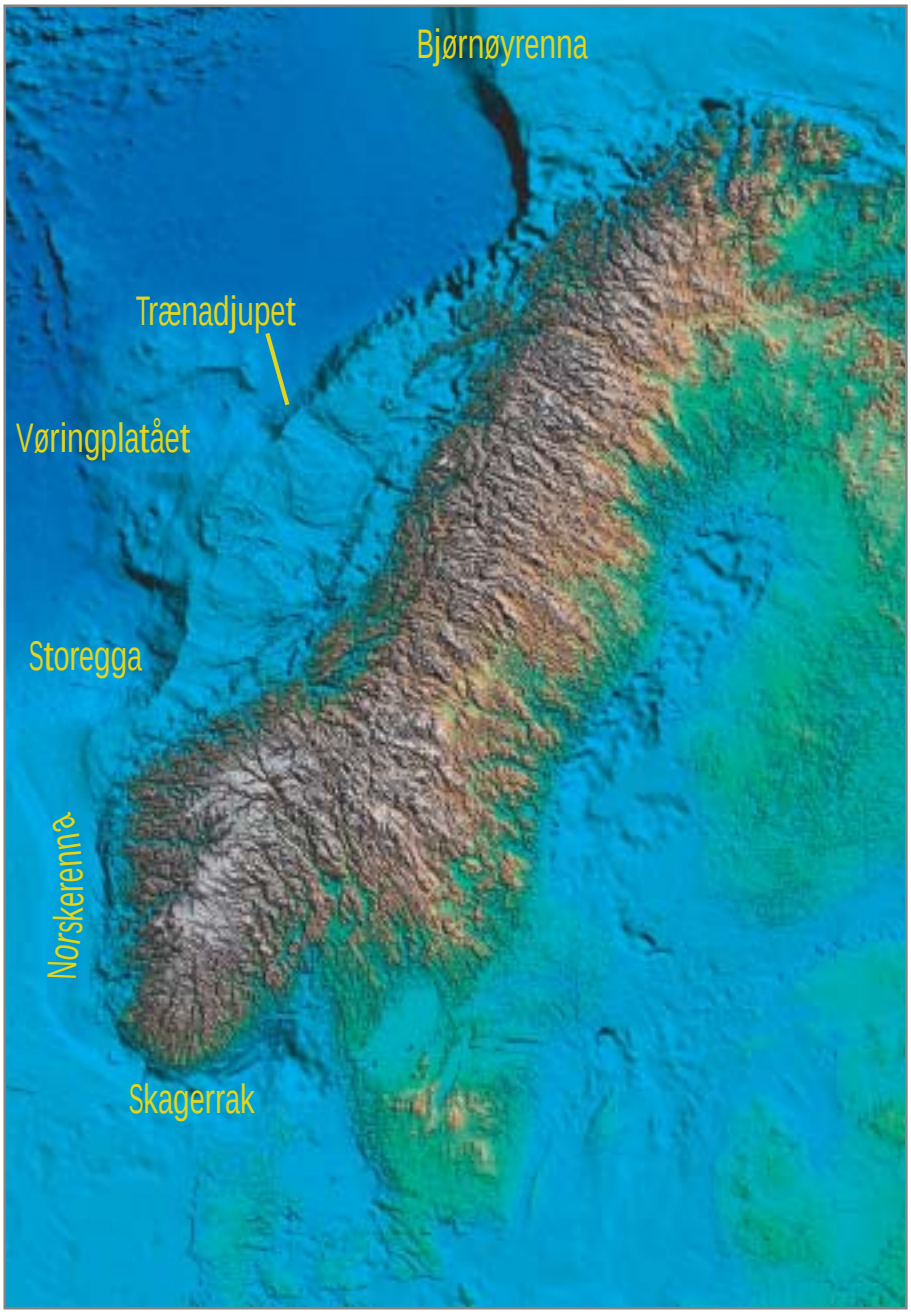

Figure 1. Norway and its neighbouring seas.

gradually filled with sediments derived from the erosion of the chains. These sediments became transformed into sandstones, shales and limestones and it is in these rocks we now find oil and gas on the Norwegian continental shelf.

The deep ocean, as we know it today, began forming some 60 million years ago. This was when the plates started drifting apart, the crust fractured and the Norwegian Sea segment of the Atlantic Ocean, with depths of more than 4000 m, took shape. Figure 2 shows how this ocean has gradually become larger.

The continental slope comprises the area from the shelf margin down into the deep ocean. It is a marked terrain feature from Great Britain, past central and northern

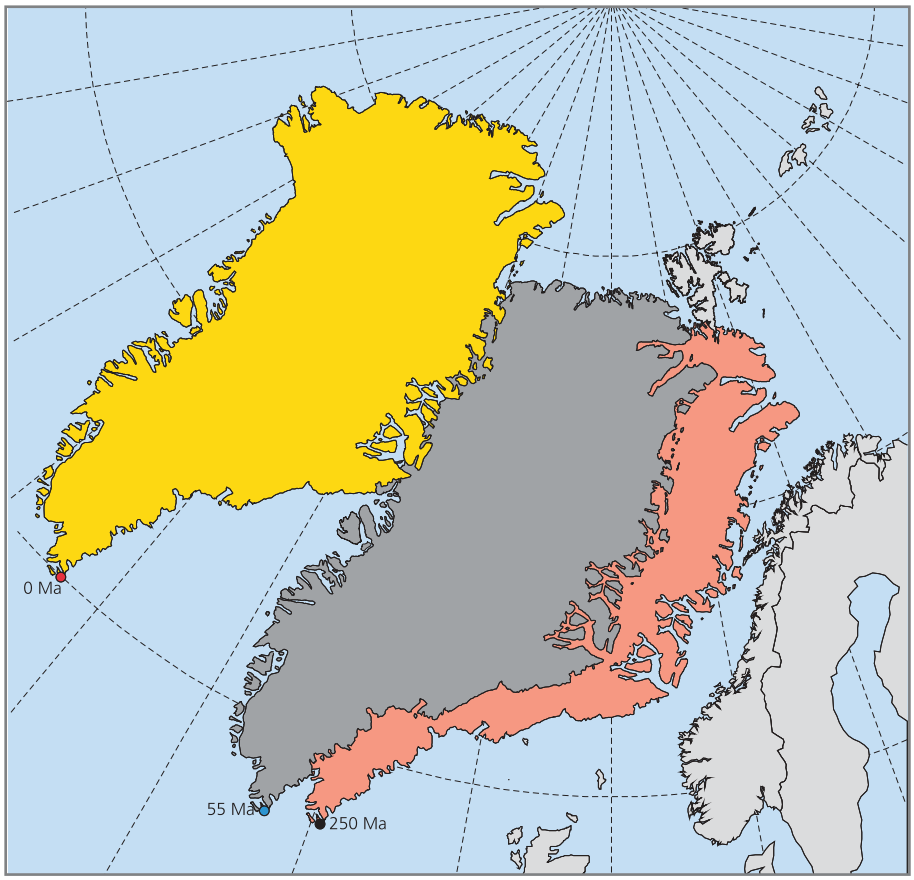

Figure 2. Greenland has drifted away from Norway. Three stages in the drift are shown, 250 mill. years ago (red), 55 mill. years ago (grey) and today (yellow).

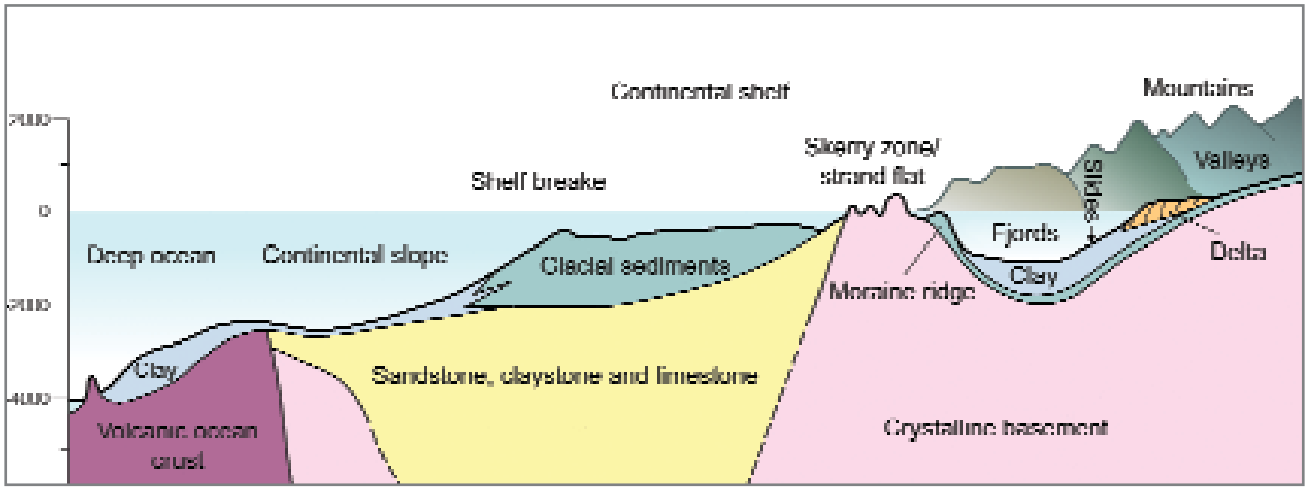

Figure 3. The stratigraphy on the Norwegian shelf is shown in a generalised section from the Vøring Plateau over the Skjold Ridge to the coast. The figure shows how the fjords were incised deeply into the bedrock and partially filled with sediments derived from the final deglaciation and afterwards (the last 10,000 years). We see how the strandflat is a level incised into the bedrock by the erosion of the sea and the ice and how the sediments which the glaciers removed from the land form the upper portion of the continental shelf.

Figure 4. The strandflat seen from the island of Dønna on the coast of Nordland. Vega, which is an inselberg on the strandflat, is seen in the background.

Photo: Turid Helle

Norway, and on past Svalbard (Fig. 1). The foot of the slope is located approximately where Norway and Greenland separated 250 million years ago. 3 million years ago, the global climate became so cold that ice ages developed. Since then, Norway has been glaciated many times and the glaciers have excavated valleys and fjords, discarding the eroded material out on the shelf. Each time, the shelf margin and the continental slope have been moved further from the coast, more so than anywhere else off central Norway, between the Halten Bank and Røst.

The continental shelf is the area stretching from the shelf margin to the coast. Off the coast of central Norway, including Nordland, Troms and Finnmark (Fig. 1), it consists of shallow banks separated by deeper channels. This submarine landscape is a product of the uneven flow of the glaciers on their passage from mainland Norway westwards to the shelf margin, with an enormous transport of ice out of Vestfjord and along the Træna Deep, for example, whereas the banks were covered with slowly moving ice. Because the glaciers in the Barents Sea and the North Sea flowed more smoothly, these areas are comparatively shallow and flat. A distinctive feature of the landscape in the North Sea is the Norwegian Channel, which extends along the coast from the Skagerrak to Stad, reaching a depth of up to 700 m (Fig. 1). This channel has been excavated by glacier streams that flowed out from south-east Norway and Sweden, coalescing to flow along the coast and calve in the Norwegian Sea off Stad.

The archipelagos and the strandflat form a brim of variable width round large parts of mainland Norway. Archipelagos, with their multitude of islands and islets, are particularly widespread on the southernmost coast and between Stavanger and Lofoten. The strandflat comprises an area of irregular terrain stretching from 40 m below to 40 m above sea level, with the exception of some deeper channels that run parallel to the coast in zones of weakness in the rock, or which are aligned transverse to the coast which they cross and continue out onto the shelf. The strandflat was formed by marine and glacial erosion. A typical feature of the strandflat is the presence of islands composed of a flat brim encircling higher ground, which is the remains of a former more elevated landscape.

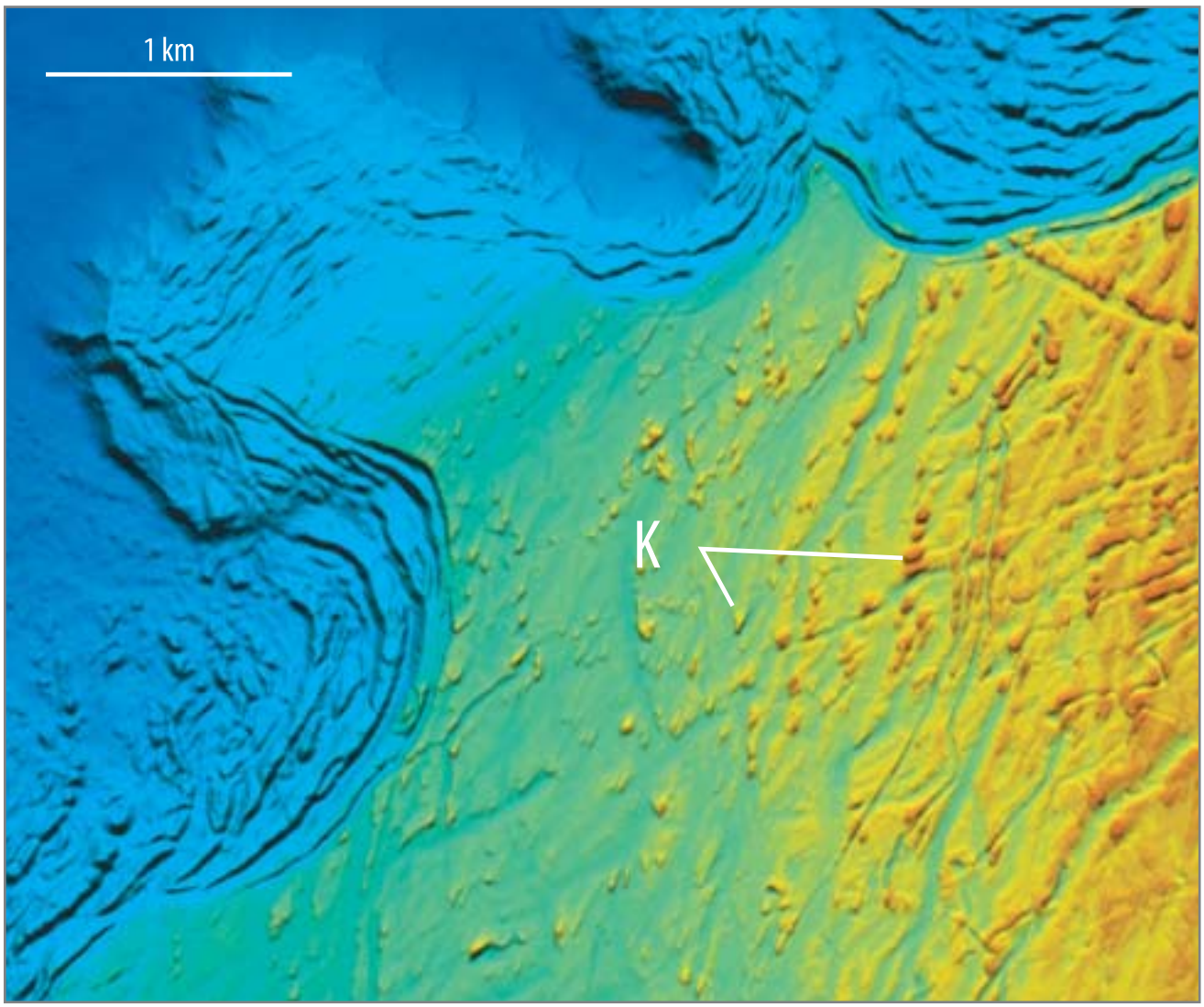

Figure 5. The shelf margin at the Træna Deep displays the avalanche brink formed by the Træna Deep avalanche that occurred 4000 years ago. The channels running towards the rim of the avalanche scar are plough marks carved by icebergs on the bottom at the end of the last Ice Age. Along the rim, on both the surface to the right and extending down into the avalanche scar are many knolls formed by coral reefs. The section to the right shows the coral reefs as knolls (K) on the seabed. This area forms one of the largest concentrations of deep-water corals so far known in the world.

The fjord mouths are located where the mountainous hinterland opens out onto the strandflat. Most fjords have a shallow threshold at their mouth and are deeper further in. The fjords were excavated by glaciers along zones of weakness in the bedrock and became deeper with each ice age.

Conditions on the floor

The floor of the deep ocean mostly alternates between plains covered with mud derived from products of the primary production - remains of plankton and algae - and volcanic seamounts. Such seamounts are clearly visible in the upper left part of Figure 1. In some places, this pattern is interrupted by avalanche debris derived from huge slides down the continental slope, as for example below Storegga, west of Møre and Trøndelag.

The continental slope generally consists of clayey sediments, but near the shelf margin, where powerful currents usually flow, the finest material is mostly washed out and the floor consists of rocks, gravel or sand. Cold water coral reefs are present along extensive stretches of the shelf margin, especially along Storegga and the Træna Deep where steep avalanche brinks occur, the reef-building animals thriving where the current is strong and the bottom offers substrates on which they can gain a foothold (Figs. 5 and 6).

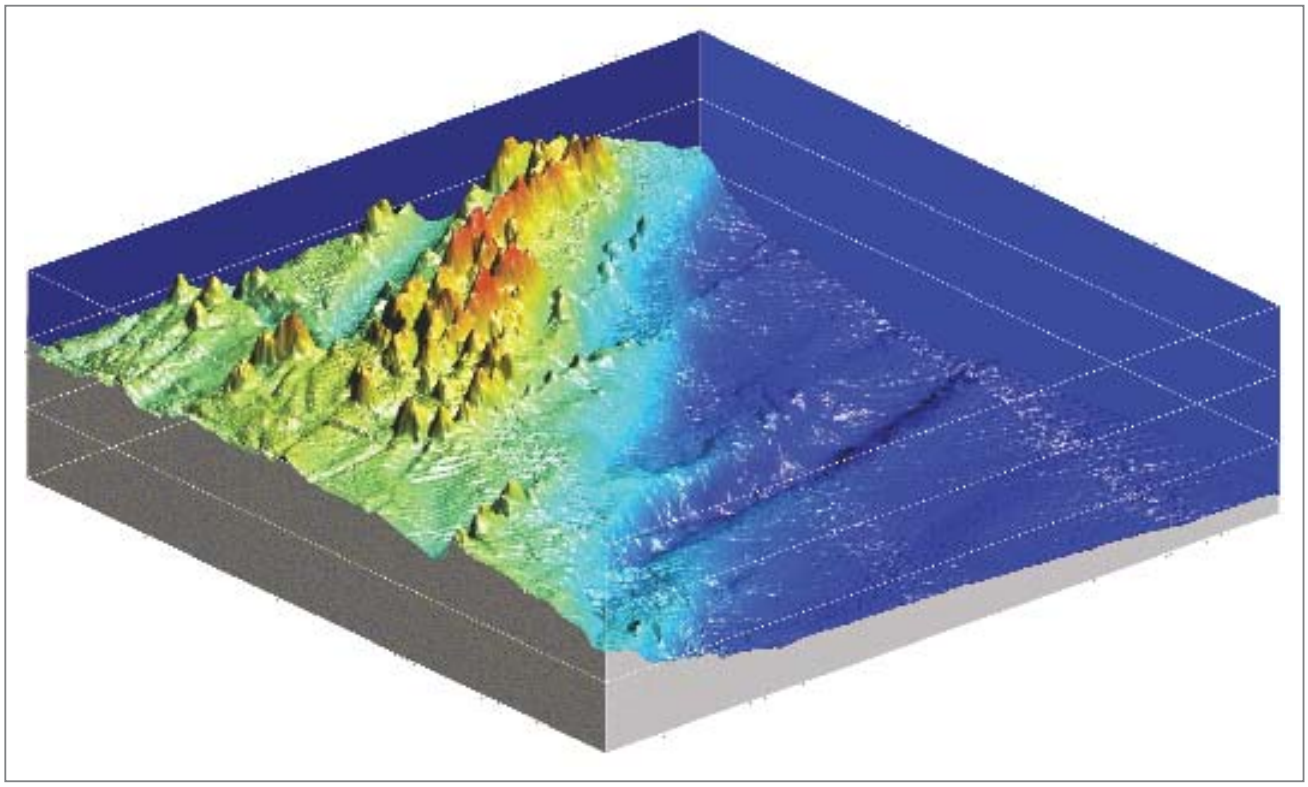

Figure 6. The Sula Reef with cones formed by the deep-water coral, Lophelia pertusa. The cones are about 100 m wide at their base and up to 30 m high, and stand on elevations on the seabed where the current is strong and carries sufficient plankton through the area to provide the corals with the food they need.

The continental shelf consists of three main areas, the North Sea, the shelf off central Norway and north to Troms and Finnmark, and the Barents Sea. Many of the banks on the continental shelf were briefly dry land after the ice melted. Consequently, they show evidence of having been washed in the shore zone when the sea flooded over it, and the floor there frequently consists of gravely and sandy areas just like we can see in the present shore zone. The clay that was washed out collected in the deep channels to form muddy bottoms, except where the current ran strongly. In such locations, sandy areas or a stony and gravely bottom can be found. The banks are important spawning areas for both demersal and pelagic species of fish.

Cold water coral reefs are also found on the shelf. The best known is the Sula Reef, 50 km north of Frøya, off the coast of Trøndelag, which is composed of up to 30 m high cones of coral situated on the crest of a 15 km long ridge of bedrock. The coral reefs have a great diversity of life and the adolescent stages of many of the species of fish that are commercially exploited in Norway grow up in these areas.

In the North Sea and the Barents Sea, the floor is flat and consists mostly of sand or more stony moraine, except in the Norwegian Channel and the Bjørnøya Channel where a clay-covered floor is found. Gas leaks from the bedrock on many parts of the shelf. It rips away sediment to form hollows in the seabed, called pockmarks. These are generally 50 - 100 m wide and 4 - 10 m deep, but in some places, such as the southern slope of the Norwegian Channel in the Skagerrak, pockmarks occur which are 1 km long and up to 30 m deep. Cultures of bacteria and also other growths occur in the pockmarks, where they live on the gas and attract fish which graze there.

In the coastal zone, the bottom consists of an alternation of rocky knolls and channels whose floor is covered with a variety of sediments, clay and mud, sand, stones and gravel. In the transitional zone from breaking waves to calmer water, or in straits with powerful currents, large quantities of shell sand often accumulate. The shallow water gives good light conditions, and bedrock and stones offer footholds for the large fronds of sea tangles which form kelp forests. This alternation of different types of bottom gives an enormous abundance of different species of fish and crustaceans.

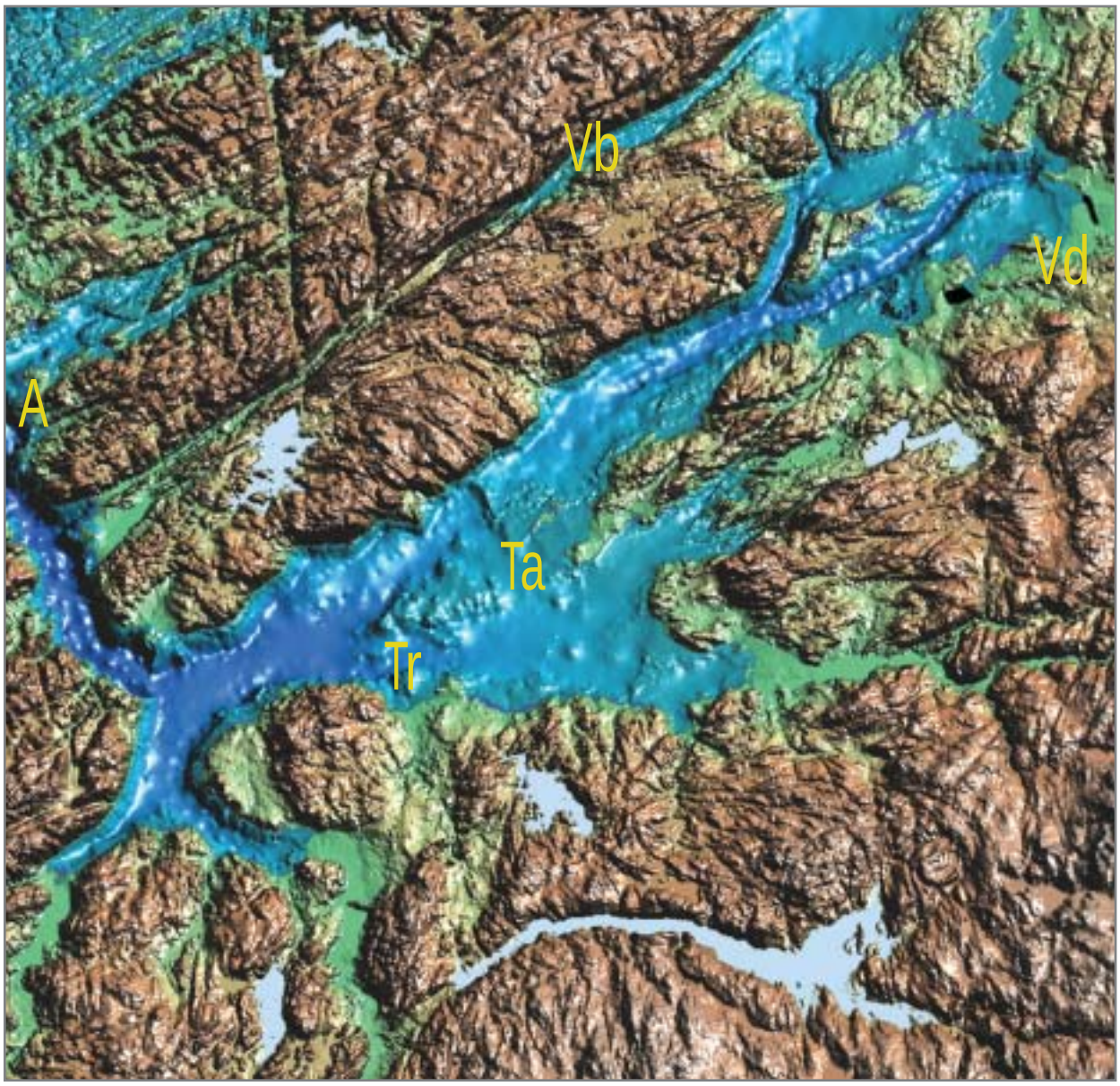

Figure 7. If Trondheimsfjord is drained of water, we can clearly see how the deep channels in the fjord are continuations of valleys on land (Vb - Verrabotn) and how ridges (Ta - Tautra Ridge with Selligrunnen and its corals, and A - Agdenes) partition the fjord into several basins. Tr - Trondheim, Vd - Verdal.

The fjords are much deeper than the coastal waters. Their sides generally form steep cliffs between which is a flat bottom covered with clay and mud. In the transition between the fjord bottom and the fjord sides there are often avalanche fans formed by rock and snow avalanches and rock falls, or gravel and sand deposits brought by rivers and streams. Where valleys enter the fjord, the rivers flowing into the fjord generally build up large deltaic deposits composed of gravel and sand (Fig. 3). Many fjords have large or small ridges of moraine with a blocky or stony surface, and these form local thresholds over the fjord. The ridges were formed during the deglaciation when the glacier had temporary advances, or halted for shorter or longer periods during its retreat. The Tautra Ridge in Trondheimsfjord (Fig. 7) is one such moraine ridge. Selligrunnen, a shallow area with numerous coral reefs, is situated on the Tautra Ridge.

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