GEOPARK
SUNNHORDLAND

**APPLICANT UNESCO GLOBAL GEOPARK**

# Building Continents and Societies

NORSKE
GEO
PARKER

## TABLE OF CONTENT

# A. GENERAL INFORMATION

*Bondhusdalen. The Bondhus glacier in the back and our National flower Saxifraga cotyledon. Photo: Jan Rabben*

## A1

The name is Geopark Sunnhordland.

## A2

The Geopark is located on the south-west coast of Norway within the borders of the Sunnhordland region in Vestland county (Fig. page 7). It includes 8 municipalities by the large Hardangerfjord that forms an east-west axis through the park.

The point of the head quarter is located at Moster Amfi; (EU89): 59.7009348N 5.3815155E

## A3

Total area of the Geopark is 4764 km$^2$, incl. 1769 km$^2$ of sea (37%). Land area is 2995 km$^2$.

## A4

The 8 municipalities that make up the Sunnhordland region have a population of 64.000 people. The landscape offers a wide range of different sights appealing to various interests. The western part, facing the North Sea, consist of an archipelago at the mouth of the 183 km long Hardanger fjord. Many of the low islets that are exposed to the open sea barely have any vegetation. In contrast, larger islands in more sheltered waters are often overgrown with pine, deciduous forests and heather. At the eastern part of Sunnhordland alpine mountains are overlooking the fjord with the outer coast facing the North Sea. The largest mountain rises 1565 m.a.s.l. and is embraced by the Folgefonna Ice Cap, the 3rd largest glacier in Norway. The glacier is part of a national park and covers an area of 214 km$^2$. From the steep mountain sides waterfalls dive into the fjord, waterfalls and glaciers that have attracted tourists since early

1800's. Geologists took a special interest in the region when pyrite became a valuable resource in the 1850's, and exploitations of geo-resourses have long traditions. The island municipality of Bømlo, located right out in the ocean gap, became a pioneer area for the Norwegian Stone Age archaeology. Extensive excavations started her in 1901 when some startling sites were discovered. The findings showed that these were workshop sites where pre-historic humans through 6000 yrs were engaged in large-scale production of greenstone axes. The quarry where the raw material for the axe production was later found in a small islet at the rim of the North Sea, still present as the Stone Age pioneers left it. Further east in the geopark some of the earliest agriculture in western Norway took place at the easily cultivable moraine terraces.

The Hardanger fjord and the straits divide the mainland and the islands, but also bind the population together. The need for crossing fjords and straits triggered inventions of boat technologies since long before Viking Age. Later, freight vessels, ferries, modern fishing boats, huge tankers and oil rigs were constructed in this region. Now gigantic windmills for open seas are made here. But the slim and quick rowing boat 'færing' – more or less unchanged through the centuries – are still not uncommon to see in these waters. The Oseberg ship from 820 AD, considered to be among the most precious cultural treasures of Norway, was built in this region. Gjøa, the ship used by Roald Amundsen on his exploration of the North West Passage in 1903-1905 was also built in Sunnhordland, a region rich on pine and oak for ship building, energy from waterfalls and a population owning maritime experience and craftsmanship.

The Atlantic current, a branch of the Gulf Stream, gives cool summers and mild winters. The proximity to the sea and the westerly wind belt provide plenty of precipitation. Average temperatures in Jan-Feb is 5°C, in July 18°C.

The region is easily accesible by air, boat, bus or car. The highways E39 and E134 runs through the geopark crossing fjords on bridges or ferries. Most areas can be reached in 2-3 hours from the cities of Bergen and Stavanger.

Within the Geopark, most of the inhabitants live in villages and small towns, leaving large areas sparsely inhabited. The town of Leirvik in Stord municipality is the regional centre and a hub for infrastructure where the biggest shipyard and a University branch are situated.

Sunnhordland has a rich cultural heritage stemming from ever since the first humans came here more than 11000 yrs ago. In addition to the oldest and longest-used quarry (Hespriholmen) from the Stone Age known in Northern Europe, here is some of the oldest stone churches in Norway. Sunnhordland was a central arena for historic persons and happenings during the Viking Age, for e.g. the sagas refer to the bay beneath the mountain of Siggjo (Moster) as the place where the baptized Viking king Olav Haraldson (Saint Olav) implemented Christianity by law in 1024 AD. A national jubilee remembering this essential happening for Norway will be arranged in 2024. This will take place on marble bedrock at Moster, at the historical centre and visitor centre of Geopark Sunnhordland.

Even if the populations in this area have been oriented towards marine resources, agriculture has been practized most places since Bronze Age, even on the barren soils on the outer islands. However, the most important agricultural settlements are located on fertile soils found on moraines and marine terraces. Mining has been an important industry and a number of raw materials have been extracted, including pyrite, copper, gold, soapstone, greenstone, rhyolite, jasper, chlorite shale, granite and marble.

An innovative spirit prevails in the small villages and over the years a number of technical companies have emerged. The first Norwegian internal combustion engine was constructed here in 1902 by the 18 year old son of a blacksmith. The Wichmann engine played a major role in the Norwegian fisheries during the 20th century when herring was the main economical resource. Fishermen from open decked herring boats in the rough North Sea later became the chosen crew on the anchor-handler ships when the first oil rigs should be anchored up in the same tough waters from early 1970's. An onshore oil industry developed; some of the biggest oil rigs for the

North Sea have been built in Sunnhordland since 1970's. Now the same industry is demolitting condemned rigs and building the new giant windmills for open seas.

Melting water from the glacier of Folgefonna and rain produced above these mountains has been our source for electricity since 1952, for households but also for energy-demanding aluminium production with the lowest carbon footprint world-wide. The biggest windmill park in Norway was built onshore here in 2010, and now a total of 55 mills produces 443 GWh annually. Together water and wind makes Sunnhordland a netto exporter of sustainable energy. Industry, fisheries and fish farming (salmon and halibut) are today the most important sources of income, thereafter farming, service business, tourism and public service. Much is in place to further development of tourism. Together with the recent approval of our region as a Sustainable Destination the UNESCO-geopark will be a tool for increasing knowledge on our geoheritage and developing a sustainable tourism. This shall be done by utilization of existing and traditional facilities, facilitation of our geoheritage and awareness of the values of a clean nature, modest inhabitance and concious visitors.

## A5

Geopark Sunnhordland is organized as a joint stock company owned by The Region Council of Sunnhordland. The management structure is organised in a board of 7 members involving professionals as well as politicians.

## A6

Contact person is Tora Haslum Myklebust, post@geoparksunnhordland.no

## A7

www.geoparksunnhordland.no

## A8

Facebook
#geoparksunnhordland

*Folgefonna glacier, delivering sustainable energy to Sunnhordland. Photo: Jan Rabben*

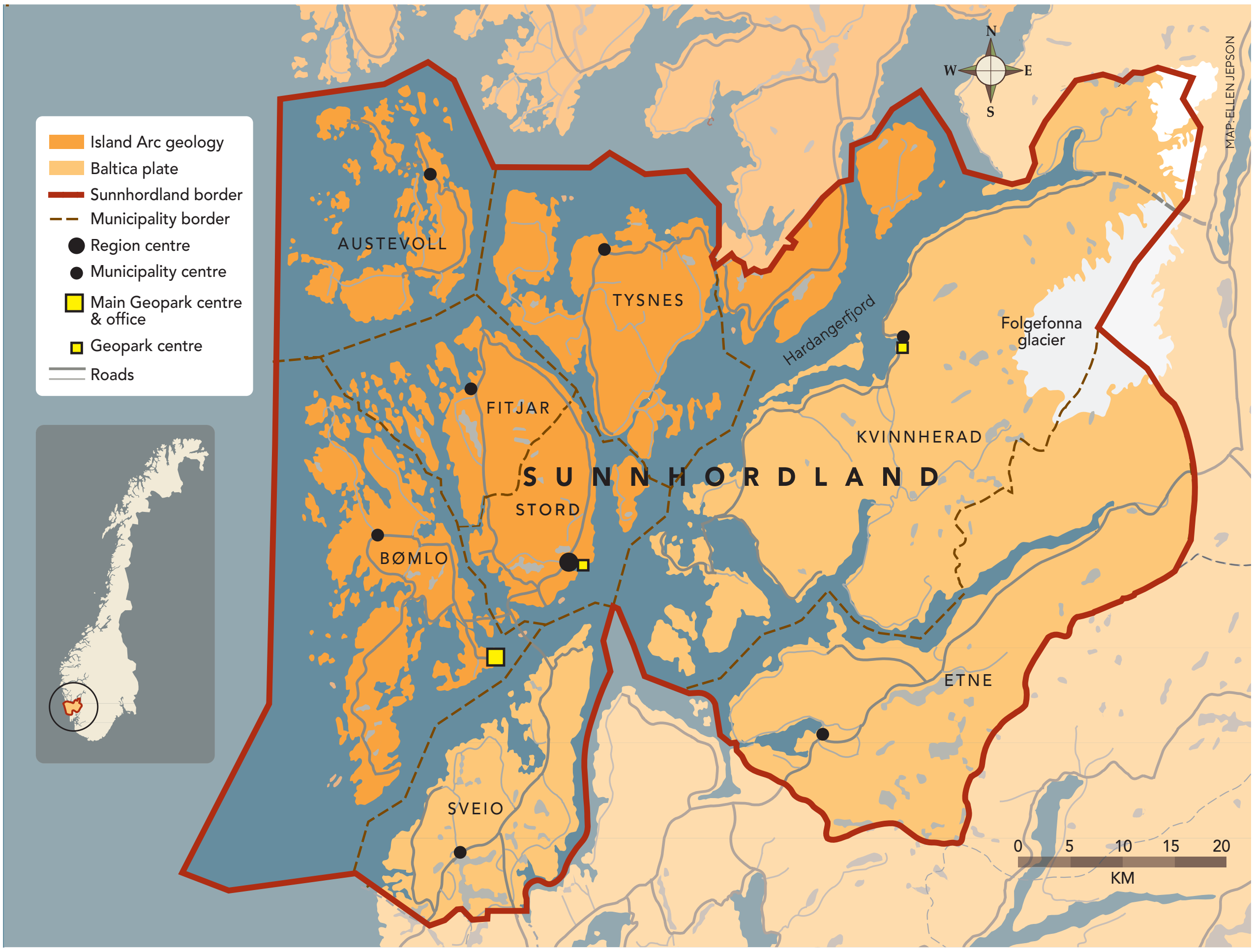
# B. DOCUMENTS CHECKLIST

| | | | |
|---|---|---|---|
| Expression of interest | | | ✓ |
| Application dossier (Main document) | | | ✓ |
| Self evaluation | | | ✓ |
| Annexes to the application dossier: | | | |
| | Annex 1 | Self evaluation form (Excel) | ✓ |
| | Annex 2 | Geological description (E1) | ✓ |
| | Annex 3 | Endorsements | ✓ |
| | Annex 4 | Geotourism Map | ✓ |
| | Annex 5 | One page geological and geographic summary | ✓ |
| | Annex 6 | Complete bibliography of the area | ✓ |

*Precambrian granittic mountains on this side of the Hardangerfjord. Island arc geology at the far side. Photo: Jan Rabben*

# C. LOCATION OF THE AREA


EU89: North: 59.7009348 East: 5.3815155




*The region of Sunnhordland, containing 8 communities, 64 000 people and 4764 km2*

# D. MAIN GEOLOGICAL HIGHLIGHTS AND OTHER ELEMENTS

## Building Continents and Societies

Most of the current growth of continents is related to magmatism associated with island arcs and continental arcs [1] . Today, this growth takes mainly place along subduction zones within and along the margins of the Pacific Ocean. Old mountain ranges represent ancient growth zones, and within Sunnhordland Geopark two of the major ancient growth zones on Earth are juxtaposed. Whereas the oldest zone formed by continental arc magmatism, the younger formed by island-arc magmatism and by arc-continent and continent-continent collision. The variety of plutonic and volcanic rock complexes that are exposed within these contrasting terrains display the rock types that make up the crust. The geology of the geopark is unusually varied. Within a geographically small area a wide range of magmatic, metamorphic, and sedimentary rocks give also insight into the deep crustal and surface processes that build continents.

This geology is exceptionally well exposed in spectacular and contrasting landscapes that have been shaped by glaciers. The eastern part the territory is composed of an alpine and partly glaciated terrain that is crosscut by deep fjords. Westwards the landscape transforms into a low-relief archipelago composed of several thousand smaller and larger islands. A wide diversity of rock types, landscapes and climate zones result in habitats that range from the harsh environments of the glaciated mountains and the wave-washed skerries - to the rich boreal rain forests. A national park covers the glacier and the surrounding mountainous areas, and more than 50 natural reserves have been established within the archipelago.

This landscape became exposed as the ice rapidly retreated at around 11.000 years ago. The territory then became colonized by life and inhabited by humans. Stone age settlements started the mining of the raw materials, and greenstone from the area became a valued commodity that was spread widely in Europe. Numerous mines were later established as the demands for building materials, industrial minerals, and metals developed. Today the landscape continuous to sustain the society. The archipelago harbours fish farming, the glaciated mountainous areas support hydroelectric power production and aluminium production plants, and the sheltered deep fjords enable the construction of large platforms for offshore petroleum industry and for the harvesting of wind energy.

The diversity and quality of the exposures in the territory was recognized as a gift for teaching and training almost hundred years ago: *The landscape is so distinct in its form, and so varied in display, that in many ways it can be viewed as a lecture book in geology* [2]. Since then, the area has been extensively used as a training-ground for students. Several thousand geology students enrolled at University of Bergen have had their first eye-opening field experiences in this area. The territory continues to be a key area both for elementary and more advanced training, as well as for research in geology, archaeology, and botany.

The 8 municipalities of the region of Sunnhordland are Austevoll, Bømlo, Etne, Fitjar, Kvinnherad, Sveio, Stord and Tysnes. Area, population, landscape and main occupation are as follows:

*PhD-students studying deep-marine siltstones and black shales overlain by radiolarian cherts and more coarse-grained debris deposits*

*1 Stern, R. J., & Scholl, D. W. (2010). Yin and yang of continental crust creation and destruction by plate tectonic processes. International Geology Review, 52(1), 1-31.*

*2 Prof. Niels-Henrik Kolderup*

| MUNICIPALITIES | POPULATION | LANDSCAPE | LAND-AREA km2 |
|---|---|---|---|
| **Austevoll** | 4924 | archipelago, strandflat | 117 |
| **Bømlo** | 12001 | island, archipelago, strandflat | 247 |
| **Etne** | 4062 | mainland, mountains, morenas | 753 |
| **Fitjar** | 3009 | island, mount.,archip, morenas | 142 |
| **Kvinnherad** | 13232 | mainland, mount., strandflat | 1091 |
| **Sveio** | 5463 | mainland, strandflat | 246 |
| **Stord (region ctr)** | 18425 | island, mountain, strandflat | 144 |
| **Tysnes** | 2745 | island, mountain, strandflat | 255 |
| **SUM** | **63861** | | **2995** |

*This gives a average of 22 human beings pr. km²*

## Why visit Geopark Sunnhordland?

Sunnhordland offers a variety of landscapes; Alpine glaciers and mountains, one of the worlds longest fjords, internationally top ten ranked waterfalls and an archipelago of islands at the outlet of a fjord and the brim of the North Sea. The geology spans over 1,6 billion years, including Precambrian and Caledonian bedrock, both continental arc magmatism, island arc magmatism, arc-continent and continent-continent collision. In addition comes the extreme impact of the Quaternary glaciations on our landscape. The first traces of humans found in the Geopark is 11300 years old. The oldest mine in Northern Europe is available just as it was left 5000 years ago, after being utilized for 6000 years. Our geosites provide explanations to the landscape we live in, stories of miners and quarry-men, awe over natural wonders and past volcanoes and seafloors. Some of them can be easily reached by everyone, others are hidden gems that demands efforts by boat or over land to visit. Our sites display in large the interaction and interdependence between humans and the geology, being cultural heritage initiated from geological resources, biodiversity and agriculture caused by geology. We are rich on history, and we create values. The geopark is well equipped with three visitor centres, Moster Amfi being the main centre, built in a exausted marble mine and close to the oldest stone church in Norway. The Folgefonn Centre focusing on the cycle of water and climate is the second, our regional museum the third. Geopark Sunnhordland was in 2018 accepted as Norwegian Geopark by the Norwegian Committe for Geoparks and geo-heritage, as the first Geopark in Norway.

*Moster Amfi, the main visitor centre in Geopark Sunnhordland.*

# E. VERIFICATION OF UNESCO GG-CRITERIA

## TERRITORY

The presentation of the territory is separated in three issues;

**1)** The bedrock of the territory - and the making of Continents
**2)** The Emergence of today's Landscape
**3)** Geological Resources through deep time.

## 1 THE BEDROCKS OF THE TERRITORY - AND THE MAKING OF CONTINENTS

Two of the largest orogenic belts on Earth comes together and are exposed within the Territory. South of the Hardanger Fjord the area is composed of large granitic to gabbroic plutons that formed in the Mesoproterozoic Era (1600-1000 Ma). This represents a part of the Scandinavian branch of the Grenville orogenic belt that extends across the globe from Antarctica, through America, to Western Europe and Scandinavia. The Grenville orogeny was a long-lived mountain-building event associated with the assembly of an ancient supercontinent called Rodinia. It represents a major continent crust building phase that largely took place along volcanic arcs that developed at convergent plate margins [1] . The Pacific margin of South America and the Andes Mountain range represent a modern example of such a continent forming environment. Whereas the modern examples display the surface and the shallow crustal parts of this crust-building environment, the ancient examples typically display the deeper parts, and the territory of the Geopark is a prime example of this. Here, a gneissic terrain show how the oldest part of the Territory was built around 1500 Ma, and how a belt of granitic plutons that formed during the Grenville orogeny continued to build the deep crustal parts of the continent by protracted formation of igneous rocks [112].

The Territory north of the Hardanger Fjord is composed of rock complexes that formed during the Caledonian orogeny that occurred approximately 500-600 million years after the Grenville orogeny ended. This younger part of the territory is composed of remnants of oceanic crust, submarine and sub-aerial volcanic sequences, and a large granitic intrusive complex. Whereas the older terrain appears to have developed within a continental volcanic arc, this younger terrain formed at an island arc setting within the ancient Iapetus Ocean [88]. These remnants of island arc crust are a part of a 5000 km long belt of arc-ophiolites that stretches throughout the Caledonian-Appalachian orogen from Northern Norway, through Britain and Ireland, to the eastern North America [87]. It has been well documented how this ancient island arc system started to develop in the late Cambrian for then to collide with the Laurentian continental margin after approximately twenty million years of arc-crust formation [87,90]. The accretion of this extensive arc system to the continental margin represents an important example of growth by arc-continent collision. This varied geology and the quality of many of the exposures in this extraordinary landscape, do indeed make this Geopark into a lecture book about the making of continents.

### The Geology of the Proterozoic Continental Terrain

South of the Hardangerfjord the Territory consist predominantly of crystalline basement rocks of Precambrian age. The terrain formed during two major crust forming events. The oldest of these events occurred early in the Mesoproterozoic

*1 Rivers, T. (1997). Lithotectonic elements of the Grenville Province: review and tectonic implications. Precambrian Research, 86(3-4), 117-154.*

Era, and the rock complexes that formed at this time have partly the character of a gneissic terrain that locally exhibits recognizable volcanic rocks and sedimentary rocks, and partly of large gabbroic and granitic intrusions [101,129]. U–Pb zircon geochronology and isotope data show that the magmatism and crust formation in the area occurred over a time span of 40 million years (1521 to 1485 Ma) and that the Mesoproterozoic crust formed from mantle-derived magmas that interacted with altered oceanic crust and continent-derived sediments. The oldest rock complex of the Territory accordingly formed from a phase of Mesoproterozoic continental arc magmatism (the Suldal arc magmatism) that resulted in significant crustal growth along the margin of the Baltic shield at this time [101].

In the late Proterozoic a phase of renewed continental growth occurred along the Baltic margin. This growth zone, known as the Sirdal Magmatic Belt, forms a ~50 km wide and more than 150 km long belt that extends from the southern tip of Norway to the Hardangerfjord - where it disappears under the Caledonian Nappes. The Sirdal Magmatic Belt is composed of ca. 1070–1020 Ma calc-alkaline granite batholiths that have been interpreted to have formed in a continental arc setting [29,111]. Magmatism in the Sirdal Magmatic Belt ceased ca. 1020 Ma, and was succeeded by widespread, long-lived granitic and bimodal magmatism between ca. 990 and 920 Ma [111].

In the Territory these two crust forming phases gave rise to gneisses and plutonic complexes that are excellently exposed along the fjords and in the mountainous areas of the Territory. The variation in rock types, the size and architecture of individual plutons, the number of plutonic bodies, and the age range of the rocks that make up this terrain, provide insight into how continental crust gradually form by intermittent intrusion and crystallization of magmas.

### The Geology of the Early Palaeozoic Oceanic Terrain

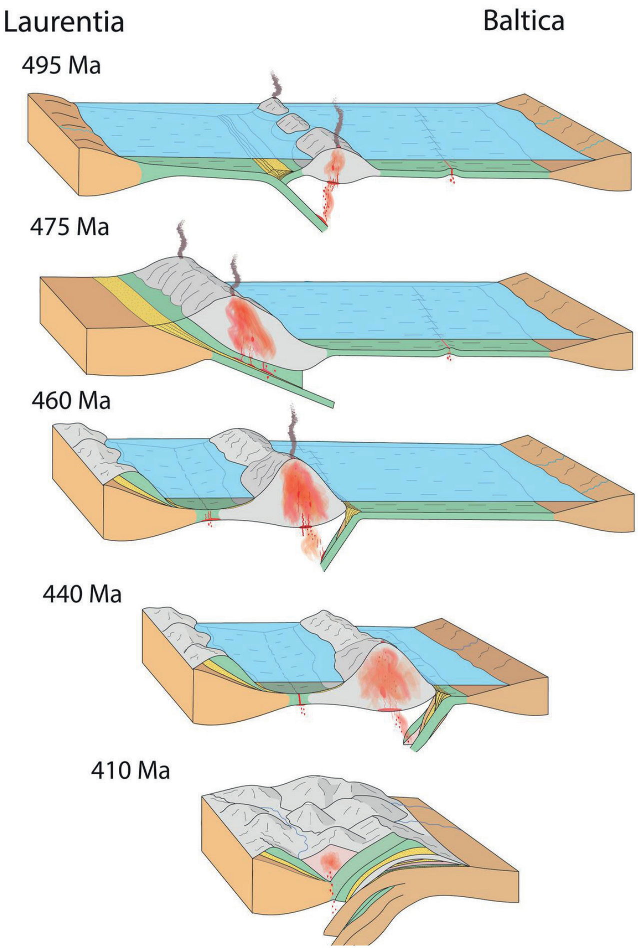
The territory to the north of the Hardanger Fjord is made up of a range of volcanic, intrusive, and sedimentary rocks that formed by a series of crust building events that lasted 50 million years from the late Cambrian to the early Silurian. The geology of the terrain records five major crust building events: 1) the formation of juvenile oceanic arc crust by island arc magmatism; 2) the collision of this island arc with continental margin; 3) a phase of renewed volcanism and magmatism at an active continental margin; 4) marginal basin development; 5) continent-continent-collision and the final development of the Caledonian orogen.

### Development of Oceanic Crust in an ancient Island Arc Environment

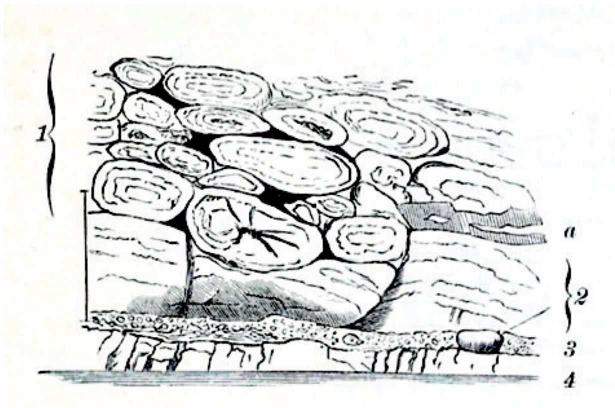
Ophiolite complexes make up the oldest part of the oceanic terrain. A coherent section of mantle peridotites is missing, but mantle lithologies are present in numerous lentoid bodies that crop out along tectonic boundaries. In general, these bodies are serpentinised and carbonatised and have partly been transformed to soapstone that has been quarried since the Middle Ages. At some outcrops, the primary tectonic mantle fabric is still well preserved, and together with cross cutting dunite bodies and chromite pods they visualize the interplay between tectonic and magmatic processes that occurs in the mantle below spreading centres.

The lower crustal section is well exposed along the western coastline of Bømlo. Here gabbro and peridotite are interlayered, and rhythmically layered gabbro grades up section into isotropic gabbro and plagiogranite, and then into a dyke complex that represent the tabular feeder channels to the volcanic sequence. Pillow flows, sheet flows and volcanic breccia demonstrate the range of volcanic products that form at the seafloor when 1200 $^{0}$C magma meets cold seawater.

Associated with this ophiolite complex is a mixed extrusive and sedimentary sequence with volcanic rocks ranging from basaltic to dacitic compositions [23,82]. The volcanic sequence has a U-Pb zircon age of 494 Ma [30], and this late Cambrian age overlaps with the age of other Caledonian ophiolite complexes. The sequence has a distinct immature island arc geochemical signature [82,87], implying that the formation of oceanic crust somehow was related to an oceanic arc environment. Similar arc-ophiolites have been documented throughout the Caledonian-Appalachian orogenic belt. At the westernmost islets of the territory this type of geology is well exposed and preserved.




1. *495 Ma: Formation of an immature island arc (Geitung Unit) on top of volcanic seafloor (Lykling Ophiolite)*
2. *475 Ma: The oceanic terrane collides with the Laurentian margin forming a small orogenic belt. Melting of sediments form S-type granites and migmatites (Bremnes Migmatite Complex)*
3. *460 Ma: The orogenic belt has collapsed and lead to rifting and formation of a marginal basin. Formation of rift-related sub-aerial volcanic rocks (Siggjo Complex) and deposition of marine sediments (Vikafjord Group).*
4. *440 Ma: Further closing of the Iapetus Ocean while depositing sediments in various basins. Last pre-collision magmatism.*
5. *410 Ma: Continent-continent collision between Laurentia and Baltica forming the Caledonian Orogeny. Stacking of nappes onto Baltica while the leading edge of the continent is subducted beneath Laurentia*




*Pillow lava at Helgeneset, Reusch 1888.*

*495 Ma old pillow lava from Iapetus Sea, now on Helgeneset, Sunnhordland.*

Several aspects of arc-ophiolites have been enigmatic. The Izu-Bonin-Mariana arc in the Western Pacific represent a modern analogue to the environment that formed many arc-ophiolites - including the ophiolitic terrain of the territory [88]. Deep drilling into the Mariana fore-arc has recently documented that there was an initial phase of seafloor spreading just after the subduction zone was established [2] . This led to formation of juvenile oceanic crust on which island arc volcanic centres developed, and into which granitic plutons intruded. The same relationships are well displayed in the ophiolitic terrain exposed in territory. But here, this first stage of arc-crust development can be studied without a drill ship - just simply by using a pair of hiking boots, or a small boat that will take visitors to coastal exposures that truly are windows into the initial stages in the forming of island arcs and continents.

Numerous sulphide mineralisations are associated with this ophiolite complex. Historical records from 1856 show that 306 sulphide findings were registered on the islands of Bømlo and Stord in a single year. The mining boom in the second half of the 19th century also led to the first comprehensive mapping and description of the geology of the area [96]. At that time there were no knowledge as to where and how these and other volcanic massive sulphide deposits formed. Today we know that they formed by hydrothermal activity in the deep of the ancient Iapetus Ocean, and that similar deposits today form at oceanic spreading centres and within island arcs systems. Both the ancient volcanic massive sulphide deposits of the Geopark, and their modern counterparts in the Norwegian Sea have been studied extensively by University of Bergen. By using the modern hydrothermal systems to cast light on the ancient mineral deposits.

### Arc-continent collision and the melting of continental margin sediments

Twenty million years after the immature arc crust started to form at an intra-oceanic island arc, the oceanic terrain had become uplifted, deformed and eroded [23,90]. The uplift and deformation coincides with the amalgamation of the oceanic terrain with continental shelf sediments and S-type granitic complexes. Together this signals a mountain building event that was caused by the collision of the island arc with a continental margin, and a 475-million-year age of the S-type granites [87,113] is presently our best age estimate of this arc-continent collision event.

The S-type granites have a composition like an average shale, and they are also loaded with a range of sedimentary xenolith that have undergone variably degree of melting [113]. The S-type granitoids therefore illustrate how sediments that formed by the weathering of older igneous rocks were re-melted to form new igneous rocks, and they tell the story of large-scale recycling of rocks on Earth.

These granites tell also another fascinating story: Whereas the rims of the zircons grew when the granites crystalized (475 Ma), the cores yield the age of the detrital zircons of the sedimentary source rocks. The dating of several thousand zircons from this rock complex show that cores of these crystals are unusually old [34,113]. A large fraction of them is of Archean age (older than 2.5 billion years), and some are almost 4 billion years and their age approach that of the oldest rocks on Earth. Crustal rocks of this age are not present within the Baltic Shield where these rocks are resting today. But in Scotland, 500 km to the west of the territory, the Cambrian-Ordovician marine sequences that formed the shelf of the North American Shield, show the same zircon provenance signatures [90,113]. Together with fossil faunal evidence, this demonstrates that the arc-ophiolite was accreted to the margin of the North American Shield in the Early Ordovician 90. This arc-continent event is recorded throughout most of the length of the Caledonian-Appalachian orogenic belt, and this event represents a remarkable example of how continents grow by the collision of young island arcs to continental margins.

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*2 Reagan, M. K., Pearce, J. A., Petronotis, K., Almeev, R. R., Avery, A. J., Carvallo, C., ... & Whattam, S. A. (2017). Subduction initiation and ophiolite crust: new insights from IODP drilling. International Geology Review, 59(11), 1439-1450*

## Renewed formation of crust by continental margin volcanism

A series of crust-building events took place within ten million years after the oceanic terrain had been accreted to the continental margin: A thick sequence of sub-aerial volcanic rocks was deposited on the uplifted and eroded ophiolite complex[23,81]; a large intrusive complex crystallised to form the deeper parts of the new crust[9,10]; and a sedimentary sequence was deposited as the terrain subsided and probably developed into a marginal basin [119,126].

The sub-aerial volcanic activity resulted in the formation of a km-thick succession of basaltic, andesitic, and rhyolitic lavas and pyroclastic deposits [23,81]. Like the immature island arc sequence that formed twenty million years in advance, this volcanic succession is well exposed along shorelines and islets where a range of rock types and volcanic processes can be seen. Here visitors can study a km-thick stack of massive and auto-brecciated lava flows, intercalated ash layers, ignimbrites, and other types of pyroclastic deposits.

A quality of the Geopark territory is that both the volcanic and the plutonic parts of this magmatic complex are well preserved and exposed. At the same time as lavas, ash and pyroclastic erupted at the surface at around 473 Ma, a large gabbroic intrusive complex crystallized at mid-crustal levels [87]. This was followed by the formation of granitic batholiths composed by numerous plutons and smaller rock bodies. This major crust-building phase lasted at least five million years. Large syn-magmatic shear zones formed at the same time 9, and these structures may reflect a phase of regional extension that led to subsidence and the formation of a marginal basin.

These intrusive complexes cover an area of more than 1000 km$^2$ of the archipelago, and are displayed at many world-class exposures. For a non-geologist, granitic dyke swarms can easily be distinguished. Numerous granite pegmatites with huge crystals represent an almost self-explaining introduction into the world of minerals. For elementary geology training, the area is used to demonstrate a variety of igneous rocks, and to exemplify how relative ages are established. At a more advanced level this part of the Territory is used as an introduction to magmatic and metamorphic processes: like the differentiation of magma, migmatisation, assimilation, and magma transport. The wide range of crust building processes and events that are displayed do also introduce students and visitors to the frontiers of these geosciences.

The rocks that formed during this stage have been widely used by society. Andesitic and rhyolitic volcanic rocks, as well as the deep marine cherts, were quarried in the Stone Age. The carbonates and marbles of the sedimentary sequence have been utilised for lime mortar and building blocks since the Middle Ages. Also, the deeper crustal rocks have been exploited. At many localities, the granitic complexes have been quarried for building blocks, and gold-bearing epithermal quartz veins were mined during a local goldrush in the late nineteenth century.

## The closing of the Iapetus Ocean

The sub-aerial volcanic succession is overlain by a marine sedimentary sequence that grades from shallow marine conglomerates, sandstones, and carbonates, to deep marine shales/phyllites and radiolarian chert. Submarine lavas and volcaniclastic deposits occur together with this sedimentary sequence. Overall, this stage reveals that arc-continent collision and continental margin volcanism were followed by subsidence and the formation of a marginal basin during the closing stage of the Iapetus Ocean.

A tectonic disturbance in the Late Ordovician signals the final closure of the Iapetus Ocean and the imminent continent-continent collision. A sequence of a shallow marine fossiliferous limestone and graptolitic shales was then deposited unconformably on the deformed rock complexes of the oceanic terrain [123]. The fossiliferous beds are overlain by 1000 m thick sequence of conglomerates with boulders of cherts, greywackes, greenstones, and granitic rocks [51]. Similar sedimentary sequences overlay the deformed and uplifted oceanic terrain at several areas in the Scandian Caledonides [121,123]. Together, these define a regional Late Ordovician unconformity that marks the onset of the final collision.

An interesting side-track is the fact that these fossiliferous limestones formed during the Hirnantian stage that marks the end of the Ordovician. The stage lasted for 1.4 million years during which the second largest mass extinction occurred. The Hirnantian extinction seems to have been caused by glaciation and lowering of sea-level, and by a global oceanic anoxic event that extended into the Early Silurian, when the graptolitic black shales that overly the limestones were deposited [3] . The composition of Hirnantian sedimentary sequences also signals that the extinction may have been triggered by volcanic activity [4] . This ad a wider perspective to fossiliferous units that were studied more than hundred years ago to clarify the stratigraphy of the area. Although it is unlikely that these metamorphosed strata can add significantly to the current knowledge about the Hirnantian extinction, they do set a stage for outreach about Earth-Life interactions, and how volcanism, mountain building, glaciations, oceans and climates are linked in a complex system that effect life on Earth.

**Collision of continents and mountain building**

The geology of the territory is also shaped by large-scale tectonic events connected to the closing of the Iapetus Ocean and the collision of continents. The continent-continent collision resulted in the subduction of the Baltic margin deep below the leading edge of Laurentia [11], and eastward thrusting of a thick nappe stack onto the Baltic margin that contained fragments of Baltica and remnants of the Oceanic Terrain and the Laurentian margin [13]. This Mid to Late Silurian contractional phase was followed by orogenic collapse, gravitational backsliding, and the development of large-scale extensional shear zones in the Devonian [38,40].

Also, this last stage resulted in the formation of rocks that have been, and still are, a resource for the society. A thick sequence of mica schists that formed along has for centuries been used for shist roofing. Today the associated mylonites are extensively quarried for stone blocks for retaining- and building walls.

Both the contractional and the extensional phases have made marked imprints on the geology of the Territory. The lower part of the Caledonian nappe stack is exposed in the mountainous areas of the Etne municipality located south of the Hardangerfjord. Here nappes composed of Precambrian crystalline basement rocks overly Cambro-Ordovician shaly shelf deposits that acted as a gliding plane for the eastward thrusting of the Nappes during the contractional phase [13.]

The orogenic collapse also resulted in the formation of large shear zones. The Hardangervidda Shear Zone represents a more than 600 km long low-angle extensional structure with a total maximum displacement in the order of 10-15 km 40. This structure divides the geology of the Territory in two. North of the shear-zone and the fjord, the nappe-stack and the Precambrian basement were down-faulted several kilometres, and the oceanic terrain that form the upper nappe thereby became shielded from erosion. South of the fjord, however, the upper nappe was gradually eroded away, and after the last glaciation the erosion reached the level of the lower nappes, the shelf deposits and the Precambrian crystalline basement.

As a result of this orogenic collapse, the oceanic terrain that nucleated within an island arc environments 500 million years ago, was juxtaposed against a Precambrian terrain that formed by continental arc type magmatism during two major crust building periods. Within a relative small area, the Territory therefore display the main crust-forming processes and crustal rock complexes that form continents.

*3 Brenchley, P. J., Carden, G. A., Hints, L., Kaljo, D., Marshall, J. D., Martma, T., ... & Nõlvak, J. (2003). High-resolution stable isotope stratigraphy of Upper Ordovician sequences: constraints on the timing of bioevents and environmental*

*4 Jones, D. S., Martini, A. M., Fike, D. A., & Kaiho, K. (2017). A volcanic trigger for the Late Ordovician mass extinction? Mercury data from south China and Laurentia. Geology, 45(7), 631-634.*

# THE EMERGENCE OF TODAY'S LANDSCAPE – A LONG PROCESS THAT HAS TAKEN 400 MILLION YEARS

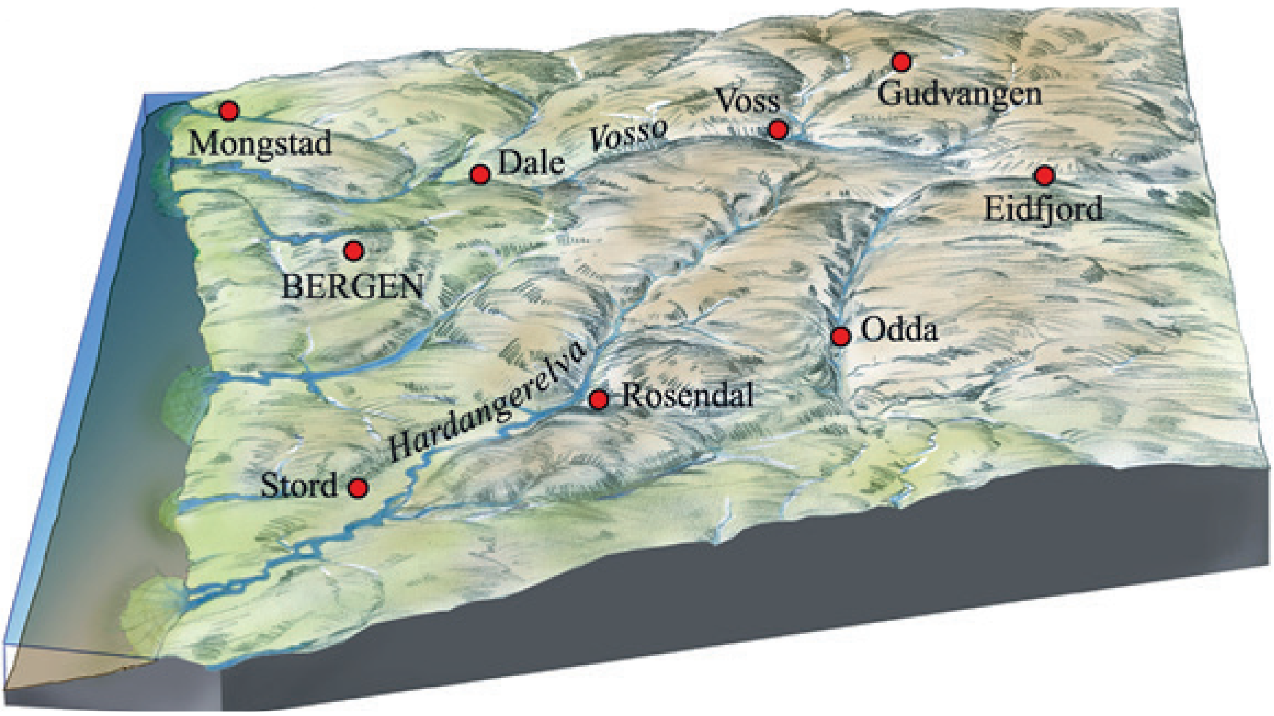
The landscape in the Geopark region was formed during the Quaternary period and is largely a result of repeated glaciations [5, 128]. Typical glacial landforms such as deeply incised cirques and u-shaped valleys, and many deepened bedrock basins that are today lakes or bogs are present throughout the park. The Scandinavian Ice Sheet and more localized glaciers have eroded deep into the bedrock and reshaped the pre-glacial landscape [59,60]. The low-lying area around the mouth of the Hardangerfjord, is part of the Norwegian strandflat [94,61] with a rugged and uneven coastline. A myriad of islands and inlets form a scenic archipelago. Farther inland, around the present-day ice cap Folgefonna, is a spectacular alpine mountain landscape. Throughout the Geopark area there is only a thin and patchy veneer of sediments, mostly glacial tills and at places some marine sediments. However, during the retreat of the last ice sheet, some pockets of thicker deposits were formed, including prominent moraines and glaciomarine deltas in the inner fjords[135,75]. These are green oases that have provided a better basis for agriculture than in an otherwise barren rocky landscape.

**The Caledonian mountain range erodes and becomes a lowland area.**

The Geopark is located in the root zone of the former Caledonian mountain range that was formed when the plates of the ancient North American and Baltic continents collided some 400 million years ago. This mighty mountain range was similar in size to the present Himalaya Mountain range and is believed to have been more than 8-10,000 meters high. There is nothing left of the original mountain landscape from this era today, but peneplanation and younger uplift episodes gave the landscape in this area its

*The Halsnøy moraine. Folgefonna glacier behind. Photo: Jan Rabben* current design long before the Quaternary Ice ages set in. Erosion products from over 400 million years are deeply buried in the sediment formations that accumulated in the North Sea. These can be studied in offshore sediment cores and seismic profiles. Finds of ancient weathering horizons on the strandflat [44,27] and fragments of Jurassic sediments in a narrow fault zone just west of Bergen [43] suggest that a lowland in the present coastal areas developed in an early phase of the Mezosoic Era. As a result of these new surveys on Bømlo it has been proposed that the coastal areas formed a flat and deeply weathered landscape that from the Jurassic and onwards became flooded and covered by Mesozoic sediments which have since been eroded away [44,25].

Wide mountain plateaus in Norway are traditionally referred to as the Paleic land surface, a term introduced by the geologist Hans Reusch in 1901[95]. This includes the Hardangervidda plateau located further inland to the east of the Geopark. He thought that this surface must have existed before a late upheaval of the land, as it is distinct from the deeply incised valleys. This view has since been accepted by most geologists. The classical model is that tthese land masses reached their current elevations through several episodes of land uplift, perhaps related to the opening of the Norwegian Sea that started some 50-60 million years ago[14]. The highest mountain summits along the fjord possibly mark the former level of an ancient more coherent land surface that today is falling gently towards the North Sea. This classical understanding of landscape development, which is also supported by more recent synthesis of geological as and geochronological data [68], is hotly debated today. A research group that bases its results on modelling and exposure dating of rock surfaces is skeptical about this hypothesis and finds it more likely that at least a large part of the Paleic surfaces was formed by widespread glacial erosion during the Quaternary glaciations [31,6]. Along with the discoveries of deep preglacial weathering on the strandflat area these recent studies have once more placed the geology within the Geopark in the center of a scientific debate.




*The landscape before Quaternary Ice Ages. There was a river where the Hardangerfjorden is today (Aarseth 2005).*

**Hardangerfjorden – carved by ice sheets in the ruins of a mountain range.**

Hardangerfjorden is deeply cut into the older surrounding low-relief landscape[60]. It is 183 km long and up to 850 m deep and is Norway's second longest fjord after the Sognefjord to the north. It is located along a more than 600 km long shear zone that separates Precambrian granitic gneisses and gabbros in the south from the much younger Cambro-Silurian rocks on the opposite side of the fjord. A thick slab of the crust was here downfaulted when the overlying nappe complex that were pushed inland during the Caledonian plate collision started to slide back when the mountain chain began to collapse during the Devonian period [42]. A river incised a valley along this zone of weakness in the crust and it eventually grew deeper in response to the subsequent Cenozoic uplift events. During the Quaternary, outlet glaciers of the Scandinavian Ice Sheet eventually made the former valley into a fjord that became deeper and longer for each glaciation. The vertical linear erosion along the main fjord amounts to 1500–2000 m [134].

**Folgefonna National Park – a showcase for the formation of alpine landforms**

Folgefonna National Park, established in 2005, is located on the eastern side of Hardangerfjord and it hosts a large ice cap after which the park is named. At 214 square kilometers, it is the third largest ice cap in Norway[65]. Its highest point is 1,662 meters above sea level, and this is one of the wettest places in Norway, receiving an estimated annual precipitation of around 5,500 millimeters. This area is known for its dramatic and beautiful nature with fjords, mountains, rivers, lakes, and glaciers and is an important tourist destination in Norway.

**The Norwegian strandflat – a low-lying coastal landscape flanking the mountains**

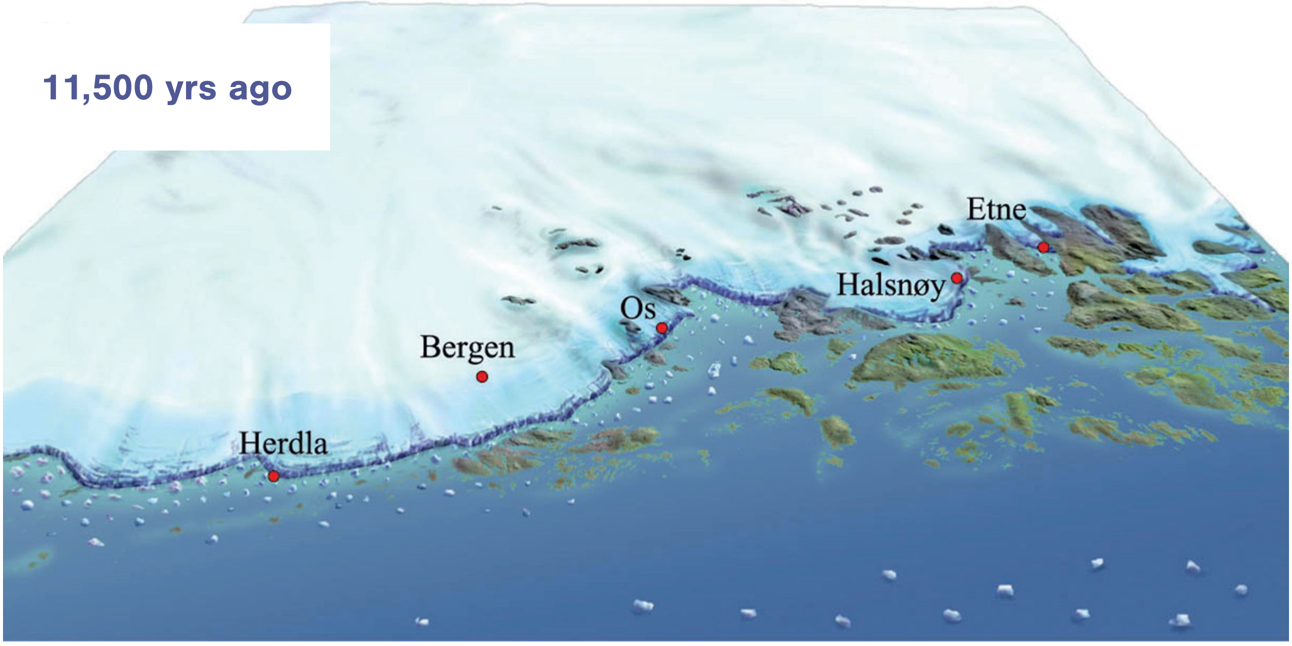
The Norwegian strandflat is the geomorphological term for the low-lying rim of land that is developed in solid rock along the west coast61. This is an uneven and fragmented bedrock surface that encompasses much of the archipelago. Its top surface defines a rather smooth plane that is gently dipping from about 50-60 m a.s.l. at the inner edge of the strandflat to about 30-40 m a.s.l. at the outer islands. Southwest of Bømlo, this surface slopes slightly into the sea and is recognized as skerries and small islets. The prevailing view is that this platform in solid rock is mainly the result of intense frost weathering with subsequent wave erosion along the seashore. It is not a continuous surface as it has been further modified and dissected by glacial erosion. This landscape element probably formed in a rather cold climate during the Ice Ages when the outer coast was ice-free and relative sea level was higher than today due to glacioisostatic depression of the crust[79].

**The whole area has repeatedly been covered by the Scandinavian Ice Sheet**

The ice sheets that expanded beyond the present coastline has removed older sediments and stripped away segments of the bedrock which were redeposited on the seafloor off the coast. The Quaternary sediments in the North Sea basin consists of a series of thick prograding wedges of glacially derived sediments which are related to several ice sheet advances that reached the continental shelf. It is estimated that the pre-Quaternary land surface over southern Norway is worn down by several hundred meters on average. These high estimates for how much rock have been removed by glacial erosion are also supported by $^{10}$Be and $^{26}$Al measurements on bedrock surfaces suggesting that there has been a lot of erosion also over the land areas between the fjords[6]. There is some evidence to suggest that the forerunners of today's fjords were eroded by ice sheets during an early phase of the Quaternary (between 2.6–1.1 Ma ago)[73]. The oldest identified till in the North Sea off the west coast of Norway has been dated to about 1.1. Ma, but it seems clear that the ice sheet was far out on the continental shelf long before that. It is unclear how many times the Scandinavian Ice Sheet has grown into the sea, but it must have happened dozens of times. Only since the last interglacial (128-115,000 yrs ago) this has happened at least 5 times[73].

**The ice sheet extent during the Last Glacial Maximum (LGM) 20,000 years ago**

During the last ice age, the ice sheet attained its maximum extent shortly before 20,000 yrs ago when it covered the highest mountains and merged with the British Ice Sheet across the North Sea[63]. Glacial striae and lineation show that ice was then flowing almost due west across




*A reconstruction of the ice sheet extent during the end of the Younger Dryas. Notice that relative sealevel was higher at the time (Aarseth 2005)*

Hardangerfjorden, but it turned north just off the coast as it became confluent with a giant ice stream in the Norwegian Channel that follows the coastal contours around southern Norway. This fast-flowing ice stream subsequently broke up c. 19-18 ka after which an ice-free corridor opened in the North Sea that lay parallel with the coast[110,122]. The western margin of the ice sheet stabilized a few km to the west of Bømlo and remained in this position for a period that lasted 4000 years or so[75.] Exposure dating, by measuring the $^{10}$Be content in quartz in ice-transported boulders above the marine limit on land, reveal how long the widely scattered erratics have been exposed to cosmic radiation and in principle provide a basis for determining when they came out of the ice. Recently performed $^{10}$Be dating from the mountain massifs Ulvanosi and Melderskinn suggest that the highest mountain peaks along the fjord emerged from the ice surface and became nunataks as early as 20-19, 000 yrs ago[93], perhaps reflecting an initial thinning of the ice sheet after the LGM.

**The initial deglaciation of the outer coast**

Exposure dates show that the summit of the 474 m high coastal mountain Siggjo on Bømlo came out of the ice at around 14,500 yrs ago[93]. The oldest radiocarbon dates of marine molluscs as well terrestrial plant remain collected from investigated postglacial strata from the adjacent lowland have given similar ages. There is thus no doubt that the outer coast and probably the entire strandflat area became permanently ice free at around this time. This ice sheet retreat occurred in response to a climatic warming that goes by the name Bølling interstadial. A rich and varied marine mollusc fauna as well as frequent finds of whalebones (mostly Bowheads) testifies to a productive marine environment with influx of Atlantic water masses. This in many ways resembled the environment along the west coast of Spitsbergen before the whaling started74.

**The last climatic spasms of the Ice Age left clear marks in the landscape**

TThe ice sheet retreated more than 60 km into the fjord in the centuries after 14,000 yrs ago during the relatively mild interlude called the Allerød interstadial. At about 12,800 yrs ago, the climate suddenly became much colder again. This marks the start of the Younger Dryas, an extreme cold spell with arctic conditions that was to last for 1200 years and left its clear marks on the landscape. The maximum extend of this ice sheet advance is delimited by a prominent end moraine across the mouth of Hardagerfjorden, termed the Halsnøy Moraine. Moraine ridges stemming from this ice sheet advance can be seen on the islands of Halsnøy and Tysnes[135,77]. Corresponding lateral moraines belonging to this outlet glacier are located along the slopes on the south side of the fjord where they can be traced up to 1000 m above sea level[33,75]. This moraine system has been mapped all around Scandinavia and the outline defines an ice sheet the size of Greenland that existed during the Younger Dryas at the very end of the last Ice Age[63]. During this cold spell, a local ice cap formed over the mountain massif Ulvanosi where an ice tongue left beautiful moraine ridges (Dyrrinda) along the hiking trail that leads up to the summit from the settlement at Utåker on the southern slopes[93]. In Etne, a large glaciomarine delta along with other glacial sediments was deposited and was the basis for the rich agriculture land and from which large sand and gravel resources are extracted

**The ice sheet collapsed in response to the Holocene warming.**

At the beginning of the Holocene period in which we now live, an abrupt and dramatic climate warming occurred which eventually completely changed the landscape and the environment in the Geopark region. The melting of the entire ice sheet increased and the front of the large outlet glacier that terminated at the mouth of Hardangerfjorden started to calve inwards the fjords[75,133]. The results of geological surveys show that it took only 400 years before the fjord was completely ice free. This implies a withdrawal rate of 300 m pr. year on average for this period. As a result of a warmer climate, the light-demanding herbaceous vegetation that prevailed during the late glacial gave way to birch forests established soon after the transition to the Holocene. Later came the pine trees before the deciduous trees took their place in the landscape. The first humans made their entrance to the outer coast in this deglaciation phase after the cold Younger Dryas period was over. This was a time when an armada of iceberg sluggishly drifted out the fjord as a farewell to the ice age. The last remnants of the Scandinavian Ice Sheet that for a while still covered the mountain areas further inland had melted away soon after 10,000 years ago[63].

**Sea-level changes have been decisive for where people have lived.**

The proximity to the sea and the resources here has been decisive for where people have settled since the first immigrants arrived on the outer coast more than 11,000 years ago. The sea-level changes have been a governing factor for the location of the settlements through time. The relative sea level changes over the last ice-free period are primarily the result of the interaction between glacioisostatic crustal movements

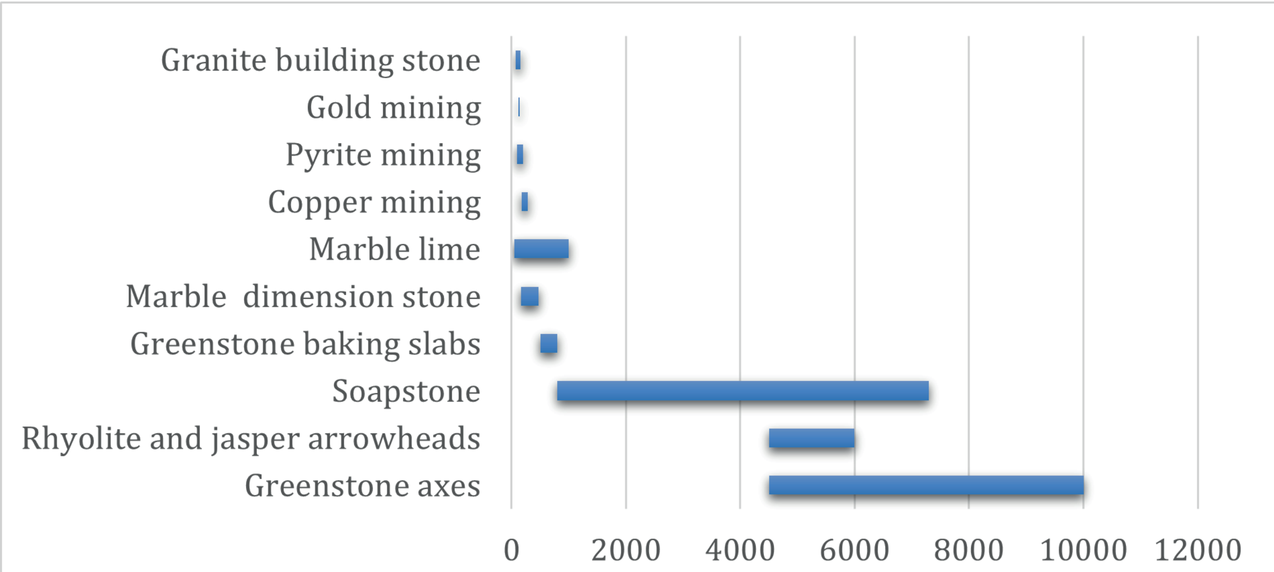
*Guided glacier climbing. Photo: Visit Sunnhordland* caused by the ice sheet loading and global eustatic changes. This interaction has caused sea level on the outer coast to have moved up and down twice, first in the final stage of the ice age (Younger Dryas) and later in the Holocene period. This second sea level rise is called the Tapes transgression[69,71]. The shorelines are all tilted and rises inwards towards the fjords where the uplift has been the greatest, but with decreasing gradients through time. The marine limit at Bømlo on the outer coast is 30-40 m a.s.l. whereas in the innermost part of the fjord that became ice free 3,500 years later, it is as much 110 m a.s.l. [75]. In an area on the strandflat on Bømlo (Halleråker) the marine limit (32 m a.s.l.) can be seen by prominent beach ridges at the site Kjøl that were deposited during the culmination phase of the late-glacial transgression which is put in connection with the large ice sheet advance that reached the mouth of Hardangefjorden at the end of the cold Younger Dryas cold spell 11,700 years ago[72].

In research historical perspective a good knowledge of the course of past sea-level changes has been crucial for archaeologists in dating, interpreting and understanding human occupation history in this region especially for the stone age settlements. An important goal for the researchers involved in this work was to reconstruct the sea-level changes and how these related to the stone age sites and their age. In the wake of the discovery of the famous Stone Age quarry on the islet Hespriholmen on Bømlo with its many workshop sites that are up to 10,000 years old, a close interdisciplinary collaboration with geologist and botanists was established at an early stage. As a methodological groundbreaking work, the sediment stratigraphy in several lake basins that had previously related to the sea was examined in order to reconstruct and date the sea level changes[49,69]. Using such archives have since become a classic method in sea-level research.

*Kayaking in the archipelago. Photo: Finn Bakke*

## GEOLOGICAL RESOURCES THROUGH DEEP TIME

Volcanic arcs around the globe are excellent factories for geological resources. The spreading- and subduction related volcanism, combined with the exhumation of mantle rocks and deep to shallow marine sedimentation, creates a range of geological resources useful to humans. The island arc system of the Sunnhordland Geopark makes no exception. Throughout almost 11.500 years of human occupation in the area since the last glaciation, the island arc has provided a range of geological resources, each reflecting the needs of periods of human and societal development. Although such reflections can be made for a range of similar geological environments, we will claim that the Sunnhordland Geopark has unique qualities in that the remains and traces of human exploitation are so excellently preserved and highly available for visitors that they collectively provide an unbroken path along the evolution of human geological resource acquisition through deep time.




*Known resource exploitation through deep time since the Mesolithic.*

As was the case with geology, Sunnhordland caught the interest of early archaeologists. Haakon Shetelig was employed curator of archaeology at Bergens Museum in 1901, and the same year he went to Bømlo to excavate the Stone Age site Sokkamyro. This site was soon published [108, 23], and he returned to Bømlo to excavate further this and other sites. Shetelig noticed that most of the lithic tools at the Stone Age sites were made from other raw materials than flint. The most important were greenstone and rhyolite, and he suggested that these were quarried and manufactured into tools locally. The greenstone quarry a Hespriholmen was found in 1923 by the archaeologist Johs. Bøe, the geologist Nils-Henrik Kolderup, and the local farmer Arnt Hovland [63]. The rhyolite quarry at Siggjo was found in 1980 by the archaeologist Sigmund Alsaker, who also analyzed and published the results of the raw material studies from Bømlo [86, 2]. Several new Stone Age quarries have been located since then, and during later years, and material from this region has contributed important data to Ph.D. dissertations and scientific articles in archaeology, and the results are of international importance 1[6, 83, 84]. Furthermore, recent excavations at several sites at Bømlo related to cultural heritage management have generated new data with great research potential for future cross-disciplinary studies on Stone Age tool-production [70]. During the last few years significant progress have also been made on the scientific treatment of the medieval chlorite schist quarries at Ølve and Hatlestrand, and the Viking Age/medieval soapstone quarries within the geopark [14, 15], and provenance studies for soapstone vessels [58].

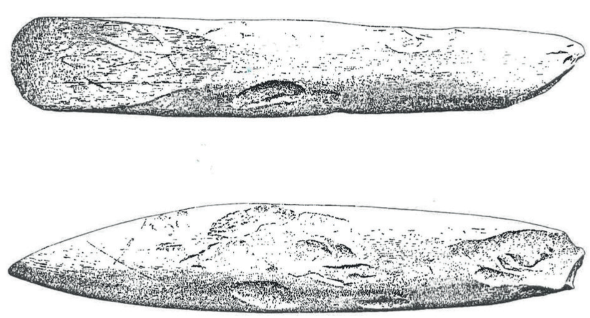
## Lava rocks and their resources

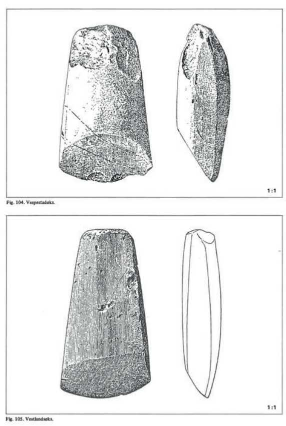
The earliest human populations in Sunnhordland were mobile hunters who used flint for their stone tools. However, already around 8000 BC the exploitation of suitable geological resources began, and it continued throughout the Stone Age. Particularly important were the low-grade metamorphic basalt flows (greenstone) and rhyolite flows related to the subaeric volcanism, dating from around 474–480 million years. To a more limited extent, jasper (related to supra-subduction spreading) was also applied.

### The stone axe quarries at Hespriholmen and Stegahaugen

The most important of these is the Hespriholmen greenstone quarry, which is situated at a small islet c. 3 km off the mainland of southern Bømlo. The quarry is characterized by artificial and easily spotted, deep stuffs in the rock surface. The two largest stuffs are located just beside each other on the western side of the islet. The total area of the quarry is c. 250 $m^2$ and the quarried volume is calculated to c. 400 $m^3$. Archaeological test excavations at Hespriholmen have uncovered large heaps of quarried waste material, consisting of flakes and big gabbro hammerstones. The quarrying started during the early Stone Age c. 8000 BC, and continued until c. 2300 BC, for altogether for 5700 years. This is a remarkably long period of axe production, also in an international context. On average, c. 1$m^3$ was quarried each year, to which c. 9$m^3$ of firewood – preferably oak – was applied. Firewood must have been transported from the mainland, because Hespriholmen is too small to provide wood. The quarrying took place just at the water's edge and was affected by sea-level changes. It was probably moved to the top of the islet during the transgression after a swift regression during the early part of the Stone Age.

The greenstone at Hespriholmen is dense, tough, and very homogenous, making it very well suited as raw material for stone axes. The production was probably carried out by a combination of heating and hammering. A tension in the rock was first created by the lighting of fires on the surface, which was thereafter hammered with the hammerstones, producing blocks and rough outs. This process took place on Hespriholmen itself, and rough outs were thereafter taken by boats to workshops on the mainland for further manufacturing. Many such axe workshops have been surveyed and excavated at Southern Bømlo, and they have not found outside this local area, which means that it must have been an "axe production center" there. The workshops are characterized by large amounts of greenstone flakes, and occasional blanks. Very few complete, ground axes are found at these sites. This indicates the main purpose of the workshops was to produce blanks, and as such they were distributed further from the production center. The final shaping the axes, by grinding





*Drawings of Stone adze-types made from Hespriholmen greenstone. The adze to the left is a "Chubby adze" from the early Stone Age (Mesolithic 8000-4000 BC). The adzes to the right are from late Stone Age (Neolithic 4000-2300 BC). The one at the top right is a "Vespestad adze", named from the find spot at Bømlo, and the one below right is a so-called "Vestland adze".*

and surface pecking, took place at the residential sites throughout the distribution area.

Another greenstone axe quarry – geochemically identical to that of Hespriholmen – is located further north at Bømlo, at Stegahaugen c. 52 m.a.s.l. on the western slope of the mountain Siggjo. This is much smaller, and the quarried volume is estimated to be only 6m$^3$. Like Hespriholmen, reduction of blocks took place at the quarry itself.

Several different axe-types were made from the greenstone and the shapes changed over time. Axes – or more precisely adzes – were probably used for a variety of purposes connected to woodwork.

Dugout canoes, and smaller items such as wooden bowls would have been important products. Geochemical analyses show that greenstone from these sites were important in networks for trade and exchange during most of the Stone Age in western Norway. Several thousand axes of greenstone have been found and some up to 300 km away. Within a 100 km radius from the quarry, in the area between the Sognefjord and Jæren, archaeological and geological studies show that greenstone made up almost 90% of the total amount of axes [86, 84].

**The stone quarry for projectile points**

The Siggjo quarry lies on the northern side of the top of the mountain Siggjo (474 m.a.s.l.). The quarried material is rhyolite (subaerial lava flows). The area covers c. 600 m$^2$ and around 100m$^3$ has been extracted. It is characterized by easily recognizable concave and convex surfaces and other artificial depressions and bulbs in the rock. Large heaps of refuse material are found in the quarry area. Radiocarbon dates show that main period of rhyolite-use in western Norway is c. 4000-2300 BC.

Rhyolite possesses the qualities necessary for production of sharp stone tool edges, as it is fine, dense, and homogenous. The extraction and first preparation of the stone were done in a similar fashion as greenstone. The quarried blocks were carried down to the sea for further distribution by boats. At residential sites within the main distribution area, these blocks were then further reduced by a particular “cylindrical core technique”, which was very effective in terms of lithic raw material utilization. Most likely, this technique was originally developed to suit the Siggjo rhyolite, thus making Bømlo an important area for technological innovation as well as stone production and distribution in this period. It is very likely that people living between the Sognefjord in the north and the Boknafjord in the south had direct access to the quarry at Siggjo and took out material there themselves for their own consumption. Populations who lived further away acquired it through trade and exchange. Such a pattern is indicated by the presence of a marked fall-off in the use of rhyolite from c. 70% to c. 5% in the area just to the south of the Sognefjord, which is supported by archaeological and geochemical investigations [2, 16].

*Arrowhead made from Siggjo-rhyolite found at the site Stokkset in Sande, Møre og Romsdal county. It is an example of the extensive trade between Bømlo and districts to the north during the Stone Age (Photo: University Museum of Bergen)*

**Jasper/chert quarries**

Two jasper/chert quarries are known from the geopark area, one Skjervika bay at southeast Bømlo, the other at Nautøya, a small island between Bømlo and Stord. The jasper is dark red in color, and it has clearly visible negative scars and crush marks on the rock surfaces at the quarries attesting to the use of hammer stones, possibly in combination with the use of wedges. There were no clear traces of the use of fire.

C. 3 m$^3$ of waste layers lie just in the front of both quarries, containing flakes and fragments of brittle and impure jasper. Jasper was used to make knives (blades) and possibly arrowheads. The use-period of jasper span c.4500-3300 BC [83]. The use of jasper was partly contemporary to that of rhyolite but was minimally used and had only local significance. .

## Resources from pyroclastic rocks

Metamorphic tuffite deposits occurs several places on the northwestern side of the Hardangerfjord. These are mostly chlorite-rich green schists, also containing small amounts of talc. The mafic mineral composition together with the schistosity make the rocks suited for extracting thin slabs of rock that are fire resistant.

**The bakestone and building stone quarries**

The quarries are situated at Ølve and Hatlestrand in Kvinnherad on the western side of the Hardanger fjord. The quarried material is chlorite rich talc-bearing green schist. Altogether 71 quarries are known from this area, most of which lie on the eastern side of the Kvitberg lake. Some of the quarries are open, others are under rock overhangs, and some underground quarries resulted in up to 30 m deep artificial caves. The first archaeological investigations took place during the 1930s and several surveys and test excavations have been performed since then [129, 15]. The investigations uncovered marked traces of quarrying in the rock surfaces (furrows, circles, depression marks, hewed channels), and large spoil heaps of refuse material in front of quarries as well as at local workshop sites. Several samples of charcoal from the test excavations have been radiocarbon dated, and the results span the early and high Middle Ages, c. 1025-1250 AD. The production probably also continued during the fourteenth century with an extension into the early modern period. The chlorite shist is dense, homogenous, and provide regular cleavage planes with ample opportunities for controlled splitting. It was therefore highly valued and extensively utilized for several purposes. The quarries were carved directly from the bedrock. Using an iron pickaxe, they cut the shape of the products into the rock, and the products were thereafter broken loose by following the cleavage plane, horizontally. Baking stones (for baking flat bread) was one of the main products. Building stones, and roofing tiles were also manufactured.

The standard finished baking stones were c. 1 cm thick, rounded and 25-50 cm in diameter. The surfaces on both sides were finished by carving long, parallel lines in all directions. This took place in the quarries themselves or at workshops close to the quarries.

While building stones and tiles were primarily used for construction of local stone buildings, such as churches, the baking stones were distributed more widely. During the Middle Ages, baking stones were standard implements in everyday cuisine in Norway including the North Atlantic region. They were therefore extensively traded within this area in bulk on ships via medieval towns like Bergen. The quarries and the quarrying were owned and run by the medieval elite, but the practical work in them was probably carried out by local people or itinerant workers.

## Resources from exhumed mantle rocks

Within several of the geological units in the area, there are small bodies of periodotite, most likely remains of the lower parts of ophiolites and fragments of exhumed mantle blocks on the sea floor, later emplaced within the stacks of Caledonian nappes. Most of the ultramafic bodies have been altered to soapstone (talc-carbonate rocks). Soapstone was used throughout the prehistory and early history of western Norway.

During the early part of the Stone Age (Mesolithic), it was used to make line sinkers and animal figures [17]. In the Bronze Age, casting moulds to produce bronze tools were made of soapstone, and it was also an important raw material for cooking vessels during the last centuries BC [92]. Due to the high heat capacity, such pots could stay hot long after removing the heat source. During the early Iron Age, soapstone was also used as temper during the production of pottery, and as raw material for net sinkers, loom weights and spinning whorls [114]. In the Viking period, large-scale production of soapstone cooking vessels took place, and this continued into the medieval period [58]. Finally, when the construction of clerical buildings (churches and monasteries) commenced in the early Middle Ages around 1100 AD soapstone was a preferred for material, such as ashlars and decorative elements. It is very likely that the many outcrops of soapstone within the geopark area were quarried throughout the prehistory of western Norway, however, geological provenance studies have only been performed for Viking Age/ medieval cooking vessels and medieval building stones. The Urda quarry was one of the most important building-stone quarry in southwestern

Norway during the Middle Ages. Provenance studies have revealed that it was used for the Moster church, perhaps the oldest stone church in Norway, and numerous medieval churches in the city of Bergen, until c. 1160 when the quarry was exhausted and abandoned.

At the small islet of Russøy, another soapstone quarry is found, also exhausted and probably abandoned around 1180. Today, the quarry remains partly water filled, and the surrounding bedrock defines a lens-shaped cavity delineating the exploited soapstone resource. Provenance studies show that the quarry was almost solely exploited for stone to the Munkeliv Monastery in Bergen [67].

## Resources linked to sea-floor hydrothermal events

In the Late Cambrian/Early Ordovician hydrothermal events along a spreading ridge predating the main phase of the island arc, massive sulphide deposits were formed, in a similar way as we see at present time around volcanic spreading ridges. These resources initiated several mines in the area, most of them post-reformation (after 1537 AD). However, we do not yet know if there were earlier mining. A range of different VMS sulphide mineralization types are found in the area, including copper-zinc dominated and massive pyrite. The sulphide mines near Ølve are among the oldest in Norway, and also the first place in Norway to apply explosives in mining in the late 17th century. Several historical mines are available for visits, displaying both old mining technology and the actual resource the old miners were hunting. During the 19th century, sulphuric acid became a valuable resource, making the massive pyrite resources valuable. The Litlabø mine at Stord provides an excellent example, displaying a well-preserved mine, visible exposures of metallic ore and a small museum.

## Resources from deep seated magma chambers

The island arc-related magma chambers, varying from gabbroic to granitic composition, were formed between 475 and 460 million years ago. At present time, these rocks outcrop in the Northwestern part of the Geopark. The utilization of granitoid rocks began during the industrial revolution, when needs for paving and building stones increased. Numerous quarries were established in the last half of the 19th century and first part of the 20th century, predominantly for export to the city of Bergen, but also for local construction. Although there were some large quarries, most of them were small and located on islets. Several of these have been left undisturbed since the early 19th century where one may study the extraction methods from bedrock, sites for fine splitting and carving, and quays for shipping blocks to Bergen.

## Resources from sedimentary rocks

During Ordovician and early Silurian times, limestone, and other sedimentary rocks, such as sandstone and mudstone, were deposited in the marine shelfs and basin surrounding the island arc. From a resource perspective, the limestone units (later metamorphosed to marble) are the most important.

The first application of marble in the Geopark was for lime mortar. There are several Medieval stone buildings within the Geopark, and it is likely that local marble resources were applied. There are also remains of lime kilns from that period. In modern periods, the lime production reached its peak around 1900 when construction of hydro power plants further in the fjords made marble the valuable raw material for industrial carbide and cyanamide. This trade ended in the 1960's. In the 18th century, several of the marble resources in the Geopark were exploited for ornamental stone. The Baroque Danish-Norwegian king launched a campaign for finding "beautiful stones" for embellishing the royal constructions in Copenhagen, and Sunnhordland became one of the most important sources for such. Thus, varieties of marble from Sunnhordland can be seen in several 18th century castles and churches in Copenhagen. It is also a sad fact that the marble from Sunnhordland found its way to St. Croix in the Caribbean, as a part of the Triangular Trade of humans and goods.

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## Orogenic gold resources

Although not directly formed during the Ordovicium Silurian island arc system, orogenic gold is found in the Lykling area at Bømlo. The gold was deposited in quartz veins, related to an episode of hydrothermal activity in ophiolitic rocks at a later stage in the Caledonian orogeny, most likely during the extensional faulting following the culmination of the orogeny. Gold mining was initiated around 1880. The gold is unevenly distributed in the veins, from barren to extremely rich. The Bømlo gold rush in the late 19$^{th}$ century made the small village of Lykling into a buzzling klondyke. Some got wealthy, others lost all. Around 1910 it was all over, and the mines were abandoned. 200 kilos of gold was extracted. The hydrothermal resource system and some of the mines are well preserved and easy accessible.

*Pines & ponds sheltered from the open sea. Photo: Jan Rabben*

## Geological heritage and conservation

## Listing and description of geological sites

We present 47 unique geosites in the application, out of a total of 110 in our database. The geosites are classified as Bedrock, Landscape or Geo-resource. Some of the sites are listed in two categories. In addition we have listed 13 sites of Cultural significance (see E2), most of them with a connection to geo-heritage.

| Type | Total | Int. Value | Nat.Value | Reg. Value |
|---|---|---|---|---|
| Bedrock | 22 | 9 | 8 | 5 |
| Landscape | 18 | 12 | 6 | 2 |
| Geo-resource | 13 | 4 | 4 | 4 |
| **TOTAL** | | **25** (22 unique) | **18** (16 unique) | **11** (9 unique) |

## Bedrock: 22 sites

| Nr. | Issue | Name | Value | Protection | Subject | Key words |
|---|---|---|---|---|---|---|
| 19 | Bedrock Cambro-ordov./Landscape | **Goddo fault** | INT | Municipal protection | Edu, Sci, | Fault & clay revealing secrets |
| 9 | Bedrock Caledonian | **Grutlebrekka** | INT | Mun. protect. | Edu, Sci, | Volcanic breccia |
| 15 | Bedrock Caledonian | **Helgeneset** | INT | Mun. protect. | Edu, Sci, Tour | Pillow lava with jasper |
| 37 | Bedrock Caledonian | **Røyrvikeskaget** | INT | Mun. protect. | Edu, Sci, Tour | Sediments with granite |
| 38 | Bedrock Caledonian | **Bårdhaugen** | INT | Mun. protect. | Edu, Sci, Tour | Granite-gabbro border |
| 10 | Bedrock Caledonian | **Holsøyane** | INT | Mun. protect. | Edu, Sci, Tour | Slanted lava layers Ingimbrittic breccia |
| 35 | Bedrock Caledonian & Landscape | **Fitjar islands** | INT | Cult.landsc. of Nat. Interest (KULA) | Tour, Edu | Granite archipelago in strandflat-area. |
| 17 | Bedrock Caled. | **Tverråno** | INT | none | Edu/Sci | S-type granite, migmatite |
| 29 | Bedrock Cambro-ordov./Landscape | **Digerneskluben** | NAT | Mun. protect. | Edu, Tour | Chert |
| 11 | Bedrock Caledonian | **Søre Lyklingholmen** | NAT | Mun. protect. | Edu, Tour, Sci | Deep sea sediments |
| 58 | Bedrock Caledonian | **Møsevatnet** | NAT | National park. Nat. protect. | Edu, Tour | Lake terminating glacier |
| 20 | Bedrock Caledonian | **Utslåttøy** | NAT | Mun. protect. | Edu, Tour | Granite, pegmatite |
| 47 | Bedrock Caledonian | **Ulvanosa** | NAT | Mun. protect. | Edu, Sci, Tour | Ice sculptured mountain, blockfield, moraines, erratics |
| 32 | Bedrock Caledonian | **Kattnakken** | NAT | Mun. protect. | Edu, Tour, Sci | Volcanites, rhyolite |
| 7 | Bedrock Caledonian & Landscape | **Bergesfjell** | NAT | Mun. protect. | Edu, Sci, Tour | Nappe |
| 21 | Landscape & Bedrock, Caledon. | **Ørnavikhaugen** | NAT | Mun. protect. | Tour | Granite/pegmatite/ archipelago |
| 33 | Bedrock Caledonian | **Dalskarvatnet** | NAT | Mun.prot. | Edu, Sci, Tour | Stratigraphic, fossils |
| 8 | Bedrock Caledon & Georesource | **Skjervika** | REG | Nat. protect. | Edu, Sci, Tour | Stone Age jasper quarry |
| 1 | Landscape & Bedrock Precamb. | **Ryvarden** | REG | Mun. protect. | Tour | Lighthouse, proteozoic rock, fjord mouth. |
| 30 | Bedrock Caledonian | **Sagvåg skule** | REG | Mun. protect. | Edu/ Tour | Conglomerate |
| 46 | Bedrock Precambrian | **Vannes** | REG | Mun. protect. | Edu/Sci | Volcanic and plutonic bergrock (Andes-type) |
| 36 | Bedrock Precambrian | **Rauholmen** | REG | Mun. protect. | Edu, Sci, Tour | Peridotite |

## Landscape: 18 sites

| Nr. | Issue | Name | Value | Protection | Subject | Key words |
|---|---|---|---|---|---|---|
| 26 | Landscape & Georesource | **Siggjo** | INT | National protection | Edu, Sci, Tour | Glacial erratics, rhyolite quarry. Landscape |
| 60 | Landscape | **Rullestad** | INT | Mun. protect. | Edu, Sci, Tour | Glacial potholes |
| 54 | Landscape | **Melderskin** | INT | National park Nat. protect. | Edu, Tour | Geomorphologic process,remaining paleiclandscape. View to glacier |
| 48 | Landscape | **Skorpo** | INT | Mun. protect. | Edu, Tour, Sci | Ice sculptured formation |
| 52 | Landscape | **Nordli Moraine** | INT | National park Nat. protect. | Edu, Tour, Sci | Lateral moraine, Younger Dryas |
| 57 | Landscape | **Bondhusdalen** | INT | National park Nat. protect. | Edu, Tour, Sci | Glacier, moraines, landslides, landscape. |
| 16 | Landscape | **Kjøl** | INT | Mun. protect. | Edu, Tour, Sci | Raised beach ridge, strandflat |
| 43 | Landscape | **Halsnøy Moraine** | INT | Mun. protect. | Science | End moraine, Ice Age, Monastery ruins |
| 59 | Landscape | **Langfoss** | INT | Mun. protect. | Tour | Exeptional waterfall, 612 m |
| 5 | Landscape | **Sætrehillaren** | INT | Nat. protect. | Tour, Sci, Edu | Fault, archeological site for important bone comb w/early rune message (600 AC). |
| 19 | Landscape & Bedrock Caledonian | **Goddo fault** | INT | Municipal protection | Edu, Sci, | Fault & clay revealing secrets |
| 24 | Landscape & Bedrock Caledonian | **Idledalen** | INT | Municipal prot | Edu, Sci, | Deep weathering, saprolite |
| 35 | Landscape & Bedrock Precambrian | **Fitjar islands** | INT | Cult.landsc. of Nat. Interest (KULA) | Tour, Edu | Granite archipelago in strandflat-area. |
| 20 | Landscape & Georesource | **Utslåttøy** | NAT | Mun. protect. | Edu, Tour | Granite, pegmatite |
| 52 | Landscape | **Nordli Moraine** | NAT | National park Nat. protect. | Edu, Tour, Sci | Lateral moraine, Younger Dryas |
| 47 | Landscape & Bedrock Caledonian | **Ulvanosa** | NAT | Mun. protect. | Edu, Sci, Tour | Ice sculptured mount., blockfield, moraines, erratics |
| 44 | Landscape | **Etne terrace** | NAT | Nat. protect. | Edu, Tour, Sci | Moraine, Bronze Age petroglyphs & Medieval stone church |
| 21 | Landscape & Bedrock Precambrian | **Ørnavikhaugen** | NAT | Mun. protect. | Tour | Granite/pegmatite/ archipelago |
| 18 | Landscape | **Steganeset** | NAT | Mun. protect. | Edu, Sci, | Deep weathering/saprolite |
| 1 | Landscape & Bedrock Precambrian, | **Ryvarden** | REG | Mun. protect. | Tour, Edu | Pegmatites, glacial forms, |
| 45 | Landscape | **Skånevik** | REG | Mun. protect. | Edu, Tour | Moraine, raised marineterrace |

## Geo-resource: 13 sites

| 'Nr. | Issue | Name | Value | Protection | Subject | Key words |
|---|---|---|---|---|---|---|
| **26** | Georesource & Landscape | **Siggjo** | INT | National protection | Edu, Sci, Tour | Glacial erratics, rhyolite quarry. Landscape |
| **6** | Georesource | **Hespriholmen** | INT | Nat. protect. | Edu, Sci, Tour | Stone Age quarry (greenstone) |
| **49** | Georesource | **Fuglebergåsen** | INT | Nat. protect. | Edu, Sci, Tour | Chlorite schist, medieval quarry for bakingstones |
| **13** | Georesource | **Lykling goldmine** | INT | Mun. protect. | Edu, Sci, Tour | Gold mines, quartz veinsw/ orogenic gold,very exposed geology. |
| **31** | Georesource | **Stordø Mines** | NAT | Mun. protect. | Edu, Tour | Pyrite mines, 90 km of tunnels |
| **27** | Georesource | **Moster Amfi** | NAT | Mun. protect. | Edu, Sci, Tour | Marble quarry 1100-1960 |
| **12** | Georesource | **Urda** | NAT | Nat. protect. | Edu, Tour, Sci | Medieval soapstone quarry |
| **50** | Georesource | **Attramadal** | NAT | Mun. protect. | Edu, Tour | Copper mine |
| **44** | Georesource & Landscape | **Etne terrace** | NAT | Nat. protect. | Edu, Tour, Sci | Glaciomoraine delta, ancient monuments, rock carvings |
| **39** | Georesource | **Russøy** | REG | Nat. protect. | Edu, Sci, Tour | Soapstone quarry |
| **42** | Georesource | **Seløy** | REG | Mun. protect. | Edu, Sci, Tour | Marble quarry |
| **23** | Georesource | **Ospholmbleika** | REG | Mun. protect. | Edu, Tour | Granite quarry |
| **51** | Georesource | **Bergspytt** | REG | Nat. protect. | Edu, Tour | Soapstone quarry for two churches |
| **8** | Georesurce | **Skjervika** | REG | Nat protect | Edu, Sci | Jasper quarry, Stone Age |

*Attramadal copper mine. Photo: Jan Rabben*

## Pressure on geological sites

At present time, none of the sites in Geopark Sunnhordland are experiencing area conflicts or pressure from other use. Nine of our sites are protected based on cultural heritage legislations (all sites older than 1537 AD are automatically protected), three are protected as being part of the National Park and eighteen are in areas not allowed for any intervention due to municipality regulations.

The governments of sites of National and International importance will adapt to a recent legislation in Norway. In collaboration with the Geological Survey of Norway, value assessment of such sites according to new national guidelines has been carried out. This will create a basic protection in the form of right of objection (in the case of other land use) from the environmental heritage authorities. This will form the backbone of a site management strategy within the Geopark.

## Boundaries

The boundaries of Geopark Sunnhordland strictly follows the exterior boundaries of the municipalities of Sunnhordland region in Vestland county. All of the municipalities are represented in The Region Council of Sunnhordland by their mayors. The council collaborates both internal and with the county or national authorities when it comes to issues of common concern.

The Folgefonna National Park is situated mainly in Sunnhordland, but also stretching eastwards into our neighbour region of Hardanger.

# VISIBILITY

Profiling of the Geopark is in continous progress and is done balancing the needs for visibility at vulnerable locations. Our visitor centres are profoundly profiled as Geopark Sunnhordland. Portals, main roads and developed geosites have designed information panels. Digital information is mainly used in the terrain, via QR-code as a start, continuously considering suitable GPS-apps wich is practical, reliable and sustainable. SoMe's are important channels for information.

Panels are arranged along E39 (Digernes) and E134 (Langfoss) late 2021. Directional signage (national "worth seeing-signs") located appr. 600 meters along the road in both directions before the site. On these locations there is general information on Geopark Sunnhordland. A tourist map for Geopark Sunnhordland is showing main geological features and sites, general infrastructure, member hotels and -restaurants and our visitor centres. Geological legend included. Information is given in Norwegian, English and German. Profiling is in continuously progress.

## Facilities and infrastructure

Our three visitor centres are strategically located in our region, being sufficient distributors of our geoheritage to a varyed audience. .

**Moster Amfi** was built in 1984 in an exausted marble mine as a theatre for our medieval national history. Now it is a profiled cultural arena and the main Geopark visitor centre with geological- and cultural exhibitions, restaurant, showcase, library, and a outdoor amfi with 1100 seats. The medieval stone church at Moster is part of the Moster Amfi geosite, as well as the lime oven situated there. The architecture in Moster Amfi is influenced by medieval style, as well as the immediate vicinity to the old stone church gives the arena a solemnly atmosphere. In 2024 Moster Amfi will be the arena for the national jubilee celebrating the Christian law introduced to Norway at this spot in 1024. With it's several issues Moster Amfi introduces our geo-heritage and the UGGp network to a regional, national and international audience.

**The Folgefonn Centre** was built in 2018 by the municipalities surrounding the glacier of Folgefonna, in cooperation with The University of Bergen, The National Park of Folgefonna Glacier and The Bjerknes Centre for Climate Research. It is a centre for scientific based dissemination on issues connected to the glacier of Folgefonna, the landscape and the fjord systems surrounding the glacier. 'The cycle of water' is the concept of the exhibitions and interactive installations in the centre. Folgefonn Centre is a well equipped centre for visitors, students and scientists, and brings the interpretation of our issues to a highly qualified level.

**Sunnhordland Museum** is owned by the 8 municipalities of Sunnhordland, responsible for conserving and promoting our regional history. The museum provides both permanent collections and temporary exhibitions on architecture, tools, clothes, photographs, litterature and intangible culture. The museum serves knowledge and support, and is a channel for information on geo-heritage to their audience, especially via the Halsnøy Monastery. Appr. 4000 pupils visit the museum annually.

## Information, education and research

An agreement with The University of Bergen and the Norwegian Geological Survey (NGU) was established in 2018 to support Geopark Sunnhordland and the UGGp-application scientifically. The members are:

- Professor in geology John Inge Svendsen, University of Bergen,
- Professor in archeology Knut Andreas Bergsvik, University of Bergen
- Professor in geology Rolf Birger Pedersen, University of Bergen
- Geoscientist Tom Heldal, Norwegian Geological Survey
- PhD-candidate in geology, Håvard Stubseid, University of Bergen

This team also bring information about ongoing and planned scientific research in the Geopark area, and promotes issues in the Geopark to their students looking for relevant issues for their degrees. In addition to support from academia we promote the geo-heritage via our visitor centres, SoMe's and members of our network. Our staff run courses for teachers and guides, and are frequently hired to present our geo-heritage as introductions to business events in the region. This gives Geopark Sunnhordland a good infrastructure on information, education and research. Geopark Sunnhordland also participated in the panel of the Climate Conference arranged by Folgefonnsenteret and Bjerknes Centre for Climate Research both in 2020 and 2021.

Sunnhordland has since 1860's been one of the areas in Norway most interesting to geologists and archeologists, as Annex 6 shows. And it still is, as this list of contemporary scientific research shows;

Lateglacial and early Holocene palaeoclimatic reconstruction based on glacier fluctuations and equilibrium-line altitudes at northern Folgefonna, Hardanger, western Norway.

Sirdal: 1 Ga granite belt formation (NGU and University of Bergen)

Ordovician island arc formation and evolution of the Caledonian orogeny (University of Bergen)

Stone Age transformations in coastal western Norway

«Basement weathering and fracturing on- and offshore Norway»

University of Bergen; "Metallogenic model of the Lykling ophiolite-hosted Au deposit, Scandinavian Caledonides: Insight from fluid inclusions, mineral chemistry and stable isotope geochemistry." Authors: Sabina Strmic Palinkas, Frida Riple Forsberg, Rolf B. Pedersen, Håvard H. Stubseid, Sean Mc Clenaghan, Jorge E. Spangenberg.

# OTHER HERITAGE

Sunnhordland owns a wide variety of other natural, cultural and tangible/intangible sites, practices and values.

## NATURAL HERITAGE

When natural heritage of the area is regarded, and how it is valued, interpreted, promoted and maintained, there are managements on several levels.  Prior are the national laws, managed by the Norwegian environment Agency and the County Governor of Vestland. Norway is also committed to the European Landscape Convention.  There are 70 protected areas in Sunnhordland, with Folgefonna National Park as the biggest covering 545 km2. Our Geopark is closely interferred with the National Park and the Folgefonnsenteret being one of our portals. The rest of the protected areas are in the following municipalities p.t

| | National reservate | National park | Protected landscape | Nesting area for seabirds | Reefs |
|---|---|---|---|---|---|
| **Austevoll** | 3 | | | 5 | 1 |
| **Bømlo** | 3 | | | 12 | |
| **Fitjar** | 2 | | | 2 | |
| **Kv.herad** | 12 | 1 | 5 | 6 | |
| **Etne** | 1 | 1 | | | |
| **Tysnes** | 2 | | | 2 | 1 |
| **Stord** | 4 | | 1 | 1 | |
| **Sveio** | 7 | | | | |

Nesting area for seabirds are protected level 1, from 15.april-31.july.
Subsea reefs: Bottom trawling prohibited in these areas.

### Terrestrial flora

Sunnhordland is an oasis of rare nature-types and species.  The south-western part of Norway ischaracterized by a mild climate and relatively high precipitation the whole year through. Even in winter, the temperature seldom falls below zero. Due to this, a characteristic and dominant nature-type in the area is the semi-natural coastal heathlands. This landscape has characterized the west coast of Europe from Portugal to Lofoten in Norway for several thousand years, and is an interaction between man, plants and domestic animals. The nature-type is dominated by the heathers *Calluna vulagaris*, and in the most oceanic parts *Erica cinerea.* In Sunnhordland this nature-type is especially dominant in Bømlo municipality where it is often grazed by old Norwegian sheep, which due to the mild climate are grazing the whole year through.

The mild climate combined with rich geology also favours a lot of plants which have their main distribution in this area. Sunnhordland therefore is a “meeting place” for different plant-geographic elements. Many seldom species, like Baldellia repens, Dwarf eelgrass *(Zoosteri noltii)* and Pillwort *(Calamistrum globuliferum)* have their global southernly boarder in Sunnhordland. They are all categorized as endangered on the Norwegian red list. Here they meet the typical coastal plants like the Prime rose *(Primula vulgaris)* and the very rare Hart`s tongue fern *(Asplenium scolopendrium)*.

Even special mountain plants like the Pyramidal saxifrage *(Saxifraga cotyledon)* and the Purple saxifrage *(Saxifraga oppositifolia)* are found here just above the intertidal zone. Some plants which were more common in the post glacial warm period are also found in Sunnhordland. These plants have survived here in areas with favourable local climate. These are the Royal fern *(Osmunda regalis)* and the Swamp sawgrass *(Cladium mariscus)*, which are both very rare in Norway and limited to the south-western part of the country.

**Seminatural grasslands.** The South-western part of Norway still has a great variety of old grassland with long continuity grazed by domestic animals and with little or no use of fertilizers. Some locations like Hovaneset, a peninsula in the south-eastern part of Stord municipality, has human traces like burial mounds made of stone going back to the Bronze Age. At that time it was an island, since the former icecap had pressed the land down and the sea-level was about 4 meters higher than today. The local inhabitants placed burial mounds on the islands outside the coast to tell people sailing by that this area was already occupied. The peninsula therefore has a long continuity as grassland for domestic animals and has not been fertilized to any extent. Such locations with long continuity contain special grasslandfungi which are normally restricted to such landscapes. Hovaneset is the most species-rich grassland in Norway known today (Fadnes 2013, Fadnes 2021). About 90 different species of characteristic grasslandfungi has been found here where about 40 are on the Norwegian redlist (Artsdatabanken 2015). However, this is only one of many species-rich semi-natural grasslands, occurring in most of the municipalities in Sunnhordland.

**Boreonemoral rainforests.** The forests in the western part of Norway is dominated by coastal pine forests. The relatively mild winter temperature and the high precipitation in the area favours a wide number of special adapted oceanic lichens and mosses, which have a very narrowly world distribution. These special pine forests are today called boreonemoral rainforests due to their occurrence in the boreonemoral climatic vegetation zone. The lichens are normally epiphytes on deciduous trees like Roe *(Sorbus)* and Hazel *(Corylus)* growing in the pine forests. The special climatic factors of the rainforests are difficult to sense, so the they are characterized by the occurrence of those special lichens and mosses called exclusive taxa based on their fidelity to a certain nature type. In these forests we find between 15 and 20 redlisted species, especially lichens like different species in the genera Arthonia, Thelotrema, Coniocarpon and Pyrenula. The south-western part of Sunnhordland, especially the municipalities Stord and Bømlo, are “hot spots” for these kinds of forests in Norway and also worldwide. One of the most characteristic rainforests in Sunnhordland is Digernes in the south-western part of Stord municipality.

*Red deer. Photo: Jan Rabben*

## Fauna

**Animals.** Red deer *(Cervus elaphus)* is the biggest common wild animal in Sunnhordland as for the rest of the South western Norwegian coast. Red deer immigrated to this landscape 9000 years ago, and became a main source for humans for pelt, meat, tendons (thread), bone- and antler tools. It also became a central value in religion and mythology shown in the Bronze Age petroglyphs, issues wich survived into the viking religion and myths (ex. the stag Eiktyrne with antlers delivering water to the world).

In our language the general word for animal is *'dyr'*, wich is just a minor auditive twist of the word deer. During hunting the word *'dyr'* categorically is used by the hunters for seen or hunted deer.

A successfull management of this resource combined with abscense of predators and a reduced number of livestock grazing the pastries has led to the renaissance of the Red deer in our fauna after a long period (1700-1900) when deer was almost extinguished by wolves, bears and humans. The population of deer now is as far as we know at an all time high level. Kvinnherad is the municipality in Norway with the highest amount of hunting permits (1197 deers in 2019). In 2019 a total of 3217 animals was shot in Sunnhordland, wich was all time high. This represents a solid hunting tradition between the locals, and gives local produced meat with a low carbon footprint. Also the small antilope Roe deer *(Capreolus capreolus)* has increased to a depletable stock in the mainland parts of Sunnhordland during the last 30 years. Moose *(Alces alces)* is represented but sparcely depleted (zero in 2019). The existence and increase of Red deer in an area seems to displace moose. Of other wild viable mammals in our fauna is Fox *(Vulpes vulpes)*, Stout *(Mustela erminea)*, Red squirrel *(Sciurus vulgaris)*, European pine marten (Martes martes), Hedgehog *(Erinaceus europaeus)*, Hare *(Lepus timidus)* and Eurasian utter *(Lutra lutra)*. American mink *(Neovison vison)* was imported to the Norwegian coast as farmed fur-animal in the 1950's. Escaped animals from the farms quickly established viable stocks and are today hunted as a threat to our original fauna, especially to seabirds in the nesting season.

Other marine mammals are seals and whales, where the small Harbour seal *(Phoca vitulina)* and far bigger Grey seal *(Halichoerus grypus)* are the most common seals, both marginally hunted on special licences. Of whales Porpoise *(Phocoena phocoena)*, Long Finned Pilot whale *(Globicephala melas)*, Orcas *(Orcinus orca)* and Common minke whale *(Balaenoptera acutorostrata)* are common. Only Common minke whale is hunted in Norway, 429 whales in 2019 wich represents a decreasing trend due to lower prices. There is none registered whaleboats in Sunnhordland.

Of bigger predators on shore (mainland) there are stray animals of Eurasian lynx *(Lynx lynx)* and yet more seldom Wolverine ***(Gulo gulo)***. Wolf *(Canis lupus)* and Brown bear *(Ursus arctos)* was common in the mainland parts of Sunnhordland until early 1900, but was eradicated by state fundings due to the threat to the already marginal livestock. Today viable stocks of these animals is as strictly managed as possible and only present in northern and eastern parts of Norway.

When reptiles are concerned, Common European Viper *(Vipera berus)* is the snake commonly found here as in the rest of southern Norway. Of lizzards we have Slow worm *(Anguis fragilis)* and North lizzard ***(Zootoca vivipara)***. Of amphibiums here are frogs common to the west coast of Norway, and also Great Crested Newt *(Triturus cristatus)*. Reptiles and amphibiums are all protected by Norwegian law, and in Sveio municipality known to its wetlands, one area (The Salamander Park) is locally protected for the red listed Northern crested newt.

**Birdlife.** One of the municipalities in the Geopark, Bømlo, have 255 registered bird species wich is among the highest number of registered bird species in Vestland County, and the maximum number of species in Sunnhordland. One of our geosites, Kjøl, is also regarded as the best site for ornithologists in Vestland County. The ornithology of Sunnhordland is in general similar to the West Coast of Norway, but since our Geopark spans from alpine mountains till open sea, birdlife is ditto varied from seabirds till mountain birds. Of seabirds the Common gull *(Larus canus)* is now a threatened specie in Europe, and the

White tail eagle. Photo: Øystein Gjerde

Geopark will take a certain responsibility for contributing to the conservation of this specie. During summer the amount of birds in the Geopark rises due to migration from both from south and north. Most migratory birds travels inside Europe and mostly northern Europe, but Common tern *(Sterna hirundo)* and Arctic tern *(Sterna paradisaea)* are long distance migraters breeding in Arctic and Sub-arctic regions and returning to the Antarctic during our winter. Arctic tern is breeding as far north as Svalbard. Mute swan *(Cygnus olor)*, a specie originally imported to Europe, is increasing from zero 20 years ago till becoming a challenge now. Swans own a rich cultural and estethic value and was never hunted for food. When it comes to birds of prey here are several species of owls, hawks and eagles, where the big Eagle owl *(Bubo bubo)* is a red-listed specie and listed as such. All birds of prey are protected by law in Norway, eagles since 1968, and now the biggest White tailed eagle is a common sight and probably back at the natural level after having been so to say eradicated, supported by national bountys. Golden eagle *(Haliaeetus albicilla)* is found in the inner parts of Sunnhordland, but far from the high level as for White tail eagles. Typical forest birds are the big Western Capercaillie *(Tetrao urogallus)* and the smaller Black Grouse *(Lyrurus tetrix Linnaeus).*

Nesting areas for seabirds are protected by law in Sunnhordland between 15.04-31.07 and counts 43 locations, mostly being minor islands.

**Fish, shells, corals and crustaceans**

Sunnhordland is a region heavily funded on fish and marine resources due to the terms given by our fjord and archipelago facing the North Sea. Herring *(Clupea harengus)* was the resource wich the modern Norway developed from during the 19. century, with Sunnhordland being a centre for both the annual spawning and the developing industry. When bigger nets, instruments and hydraulic tools replaced manpower on shipping vessels after the 2.WW, herring was almost eradicated by norwegian and icelandic fishermen supported by state administrations who denied the risk of extinction. Thanks to a total protection introduced by the new generation of marine scientists in 1971, the herring is now back as a viable and economically important resource together with mackerel, tobis, cod, pollock, haddock, cusk, monkfish, common ling, catfish, halibut and several sorts of flounder. Eel was earlier a important catch for export, but is now protected due to the general decline of this mysterious catadrome fish. Of crustaceans and shells here are European flat Oyster *(Ostrea edulis)*, scallop, Cromer crab *(Cancer pagurus)* and lobster (Homarus gammarus) wich all are part of local food traditions. The lobster is though at a historic low level and now strictly regulated. Pacific oyster *(Crassostrea gigas)* is increasing in our waters, probably due to a higher sea temperature. Mussels are experiencing a profound decline in our waters, for the time being without a finally proved reason. Rising temperature could play a role, but the parasite *(Marteilia pararefringens)* is found in mussels in Sunnhordland and could be part of a hopefully temporary reason.

In the fjords of Sunnhordland there are several reefs of the coral Lophelia pertusa, one of the reefs over 1 km long. These are several thousand years of age, and of the biggest on the West Coast of Norway. Reefs are of great importance to the eco system in the fjord, especially as habitats for Roe fish *(Sebastes norvegicus)* and Cusk *(Brosme brosme)* and vulnerable for human activity as bottom trawling. Two out of eight reefs in Sunnhordland are protected by law.

Geopark Sunnhordland is in a position to initiate a protection of lobsters in designated areas in Sunnhordland, as a part of a sustainable influence on the administration of our marine areas and -resources.

Finally; No other area in Sunnhordland is recognized under UNESCO-programmes.

## Cultural Heritage

Sunnhordland is rich on cultural heritage. We have chosen the following 13 objects as cultural heritage of special interest, all of them having a relation to our geo-heritage.
NB! Moster church, Halsnøy Monastery and the petroglyphs in Etne are cultural sites of high national value, but parts of geosites and not included here.

| Nr. | Name | Protection | Key words |
|---|---|---|---|
| 55 | **Barony Rosendal** | Nat. protect. | Castle from 1665, lime and local stone |
| 34 | **Fitjar centre** | Mun. protect. | Buildings with granite walls (local) |
| 41 | **Årbakka** | Nat. protect. | Bautas/menhirs |
| 28 | **Einstapevoll** | Nat. protect. | Stone roofs, shale quarry |
| 53 | **Kvinnherad church** | Nat. protect. | Stone church 1250, local soapstone |
| 2 | **Hummerparken** | Nat. protect. | Lobster park 1887, Europa Nostra Diploma |
| 14 | **Kulleseid canal** | Mun. protect. | Canal built 1854-'56 for the herring fisheries |
| 25 | **Wichmann-smithy** | Mun. protect. | Smithy for the Wichmann engine (1902) |
| 4 | **Sokkamyro** | Nat. protect. | Stone age workshop- and residential site |
| 22 | **Slåtterøy lighthouse** | Nat. protect. | The strongest beacon in Norway, on granite. |
| 3 | **Espevær village** | Mun. prot | Pittoresque village of historic interest |
| 40 | **Flakkavåg** | Mun. prot. | Lime ovens for local marble |
| 56 | **Ænes kyrkje** | Nat.prot | Medieval stone church |

*Photo: Roar Bakke*

**Baroniet Rosendal,** a manor from 1665 built of money earned on trading timber with Scotland and Shetland. The barony offers concerts, exhibitions, a beautiful rose garden, accomodation and a fine restaurant. Appr. 70.000 visitors annually.

**Årbakka**, trading centre and prehistoric burial site with 4 bautas. Originally, there were 6-7 menhirs and at least 35 mounds, cairns and stone rings. Grave goods such as pottery and weaponry have been found in the mounds, but most of it is lost today.

**Kvinnherad church**, built 1250 of soapstone from local quarry. In the church there are two marble sarcophagus of marble from Moster (1749) .

**Hummarparken** (the Lobster Park), built 1887 was assigned the UNESCO-related Europa Nostra-Diploma in 1993. Fascinating architecture, open to tourists in season.

**The Kulleseid canal** was built between 1854 and 1856 to make a safe seaway for the fishermen and their small boats between the inside of the archipelago and the spawning waters for herring west of Bømlo. Sunnhordland was a central area for herring fishery from 1800-1970. The canal is 2,5 km long and partly blasted out through solid rock with black powder and power from 200 men.

**The Wichmann smithy**. In 1902 the 19 year old son of the smith made the first norwegian combustion engine (2hp) wich survived the prototype-stadium. This two-stroke engine dominated the motorization of the norwegian fishing fleet through the 20-century. Early 1990 the engine was conquered by international brands, and now the smithy is a museum at the factory for Wartsila Propulsion. Here is a solid link to geology. In 1860's some hardy swedes came to this remote village to chisel out granite blocks for the quays in Bergen. A local 16 year old boy learned from these granite masons how to smith proper steel. Later he built the best smithy in this area. Yet 40 years later this mans son built the first norwegian engine in his father smithy at the age of 19. It shows how geology has both cultural and industrial repercussions.

**Sokkamyro** is a archeological site of national value, situated at southern Bømlo. During the Stone Age it was a dwelling site and a workshop connected to the quarry at Hespriholmen. It has thick deposits of stone refuse from these activities. The lowermost level of the Stone Age site at Sokkamyro is only 4,80 m.a.s.l. The site was found by a local farmer in 1897 and was excavated in 1901 (as the second Stone Age excavation carried out in Norway), and later during several campaigns until 1939. The excavations showed that Sokkamyro was used for the first time during the early Stone Age, around 8000 BC. From this period, archeologists found flint artifacts and large amounts of coarse greenstone flakes from the production of stone axes, as well as many axe blanks. These artifacts lay in a deep gravel layer over the bedrock in the excavated units. Above this layer was a thick clayish marine deposit without any tools or flakes – indicating temporary flooding of the site – and above this again a cultural layer with charcoal, arrowheads made of rhyolite, flint, and slate, and large amounts of flakes. There were also axe blanks, and complete axes from the late Stone Age. The complex stratigraphy at Sokkamyro clearly show that the site was used as a stone axe workshop site twice, at an interval of more than 3000 years, but both connected to the Hespriholmen quarry. It was a good harbor, easily accessible by boat from two directions, and therefore well suited for this purpose. Quite as important was the observation that the oldest Stone Age gravel layer had been covered by marine deposits. This showed that site – after first being on dry land – again was covered by sea water. This indicated complex sea-level changes connected to the Tapes transgression and led to extensive collaborations between the archaeologist Shetelig and the botanist Knut Fægri to establish a shoreline displacement curve for south Bømlo, a work that was continued by the botanist Peter Emil Kaland and the geologist John-Inge Svendsen in recent years. Sokkamyro is an important site by virtue of the rich and interesting archaeological material, which shows two phases of stone axe production, both connected to the quarry at Hespriholmen, but chronologically separated by 3000 years. The site is also important because one of the first scholarly archaeological excavations in Norway took place here. It also central because it led to interdisciplinary ground-breaking work to solve problems connected to the significant changes in sea-levels at the coast during the Holocene.

**Slåtterøy lighthouse** (1859) built of cast iron, 25 meters high and with the strongest rays of light in a Norwegian lighthouse (5,180,000 candela). The island of Slåtterøy is an island of polished white granite, with the red lighthouse on top.

**Espevær village** was a centre for the herring fisheries during the 1800's. Appr. 50 people lives there today. All transportation by boat (no cars). The Lobster park is in Espevær, and it is a good start for visiting Hespriholmen.

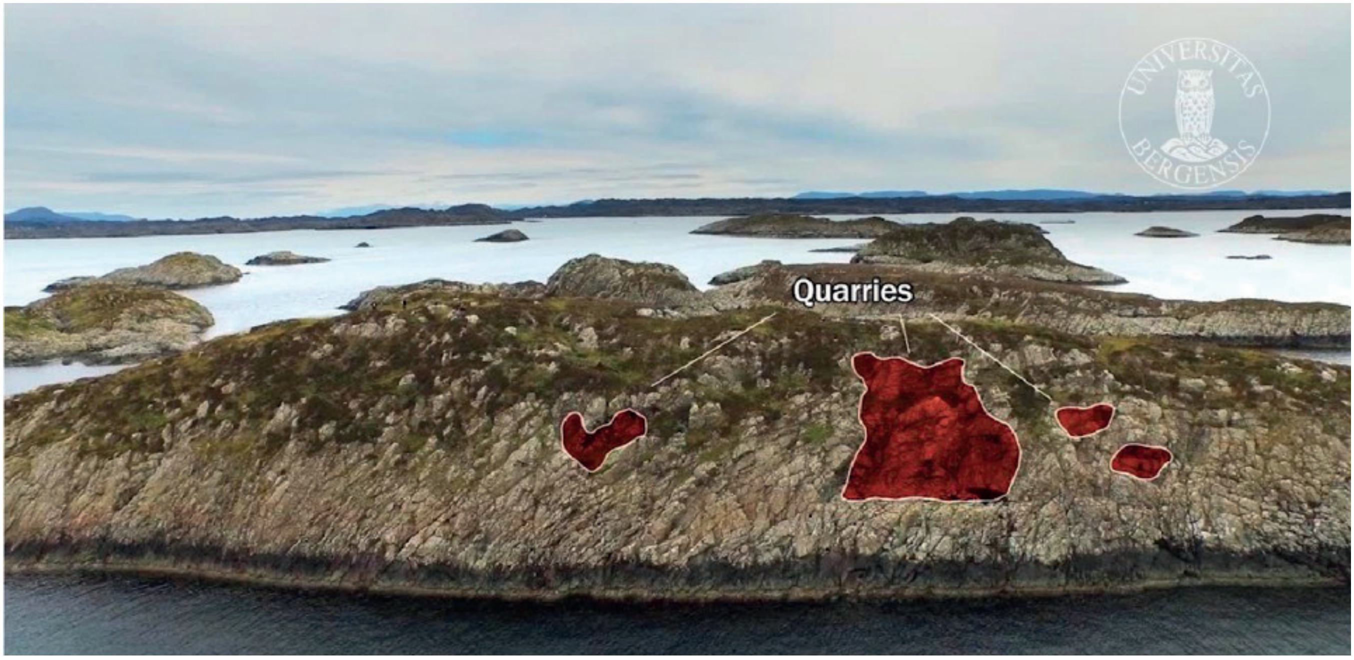
**Einstapevoll** (1816) is a farm characterized with extensive use of shale (bonded gneiss) as building material. The farm is nationally protected, but in daily use as a private farm.

**Ænes church** , a medieval stone church (1190-1200) made of local soapstone (Bergspytt). Ænes is a pittoresque U-valley leading up to the glacier.

**Fitjar centrum** have buildings of local granite.

## Visual art

When it comes to visual art, we will claim that the greenstone axes from Hespriholmen have visual values in addition to practical- and probably symbolic values.




*The stone axe quarries during 6000 years. Photo: University of Bergen*

*Early Stone Age " Chubby stone adze", 18,3 cm long. Photo: University of Bergen*

*The adze is a functional tool with a completed form. Photo: Brynjar Stautland*

Explicit expressions of visual art from the Bronze Age are the rock carvings in Etne which contain depictions of spirals, cupmarks, rings, trees and boats, which probably refer to common religious beliefs and world views in Scandinavia during this time. Another example of artistic work from prehistory is the bone comb dated to 600 AD found in Sætrehelleren with a inscription being the first love poem known in Norway. During the last 300 years the landscape of Sunnhordland has been portrayed by several artists. The paintings of Fredrik Kolstø (1860-1945) gives a unique impression of the life, colours and atmosphere in our region just before our society transformed into modernity.

Of contemporary painters Jan Terje Rafdal is a major force focusing on the mountains of Sunnhordland, his rough style giving a long lasting expression.

*Fredrik Kolstø, 1860-1945*

*Jan Terje Rafdal (1974 - )*

When earlier painters (1800-1900) is regarded, Lars Hertervig, Hans Gude, Hans Sager, Katarina Kølle and Lul Krag are some of the most relevant artists with motifs from our region. The life of the inhabitants working in the landscape, but also the Barony beneath the majestic mountains was a popular motive for many of the early painters. These artistic works are elements in the interpretation of our landscape, and will be further interpreted by the Geopark. Of contemporary art exept paintings is Siggjo-pila, a silver metal casting of a ryolite arrowhead from Sunnhordland, made and sold by a local goldsmith from 2020 in Moster Amfi and promoted by the Geopark. This item is the first effort to use our neolithic culture as contemporary art, and a result of the Geopark focusing on the artefacts from the Stone Age.

**Intangible heritage.** When it comes to intangible heritage of the area, our regional cultural beacon is the annual play Mostraspelet wich since 1984 has told our medieval story of relevance to establishing the nation of Norway. Based on the focus on this history given by the theatre, a national jubilee was arranged here in 1995 and now the national jubilee in 2024. Appr. 180 000 people have seen this annual play by now.

Production of lime from marble, and slating for masonry is an intangible skill brought here by foreign masons when the Moster church was built 1000 years ago. This tradition is still alive and interpreted at Moster both as geoheritage but also for production of lime till the regional medieval churches.

## Involvement in topics related to climate change and natural hazards

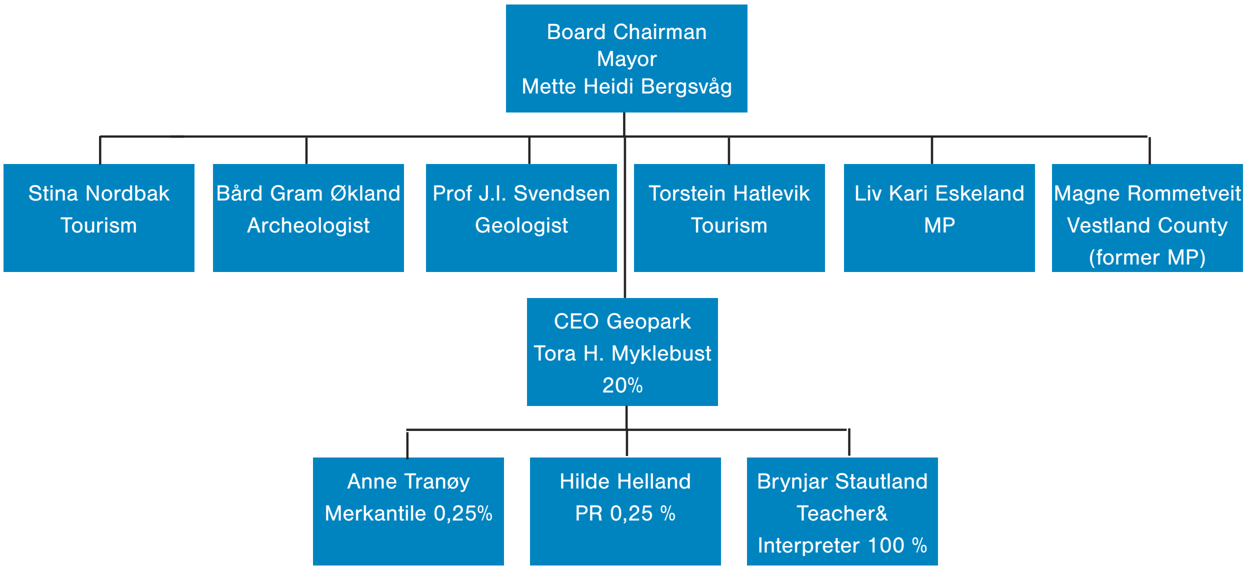
Folgefonnsenteret has climate change and natural hasards as a primary subject. The centre offers interactive exhibitions on issues in the National Park, the aquatic life in the Hardangerfjord, the worlds water cycle, sustainable natural resources and climate change. The Bjerknes Centre for Climate Research is one of the owners of the centre having substantial support from The Norwegian Institute of Marine Research.

Folgefonn Centre also arranges the annual climate conference "Rosendalsveka", where scientists, entrepreneurs, students and tourism operators attends. The Geopark repr. by the CEO was attending the panel both in 2020 and 2021. The general rise of temperature is influencing the marine ecosystem in our fjords, reducing the glacier and influencing the weather. The Bondhus glacier, an arm of Folgefonna glacier and a popular geosite has been reduced dramatically the last 20 years and is now hardly visible from the trail.

*Fonnabu at Folgefonna, cabin owned by DNT and open to the public. (The Norwegian Tourist Association)*

# MANAGEMENT

Geopark Sunnhordland is registered as a Norwegian joint stock company. Shares are owned 100% by the Region Council of Sunnhordland and the company is registered as a ideal institution, not allowing dividend to owners. The Region Council (the 8 mayors of Sunnhordland) decides who should be represented in the Board for periods of one or two years at a time. The board has 7 members. The CEO of the Geopark is Secretary of the Board.




**The Board of Geopark Sunnhordland 2021-2022**

*Upper left; Mette Heidi Bergsvåg, mayor of Etne municipality, Board Chairman of The Region Council and Boars Chairman of Geopark Sunnhordland.*
*Second left: Liv Kari Eskeland, MP. Third left: Archeologist Bård Gram Økland. Upper right: Magne Rommetveit, former MP and repr. Vestland County.*
*Lower left: Stina Nordbak, tourism developer. Second left; prof geology John Inge Svenden. Right; Hotel entrepreneur Torstein Hatlevik*

## Management Plan

Management plan was approved by the Board in 2021 (see Self Evaluation page 46).

## Operational Budget for 2022

All numbers in NOK

| COST | | FINANCING | |
|---|---|---|---|
| **Type** | **BUDGET** | **Source** | **BUDGET** |
| Payment CEO 100% inkl. soc.cost | 910 000 | Municipalities (8) | 810 000 |
| PR | 150 000 | Vestland County – annual op.grants | 500 000 |
| Administr.resource | 150 000 | Region Council subst own effort | 50 000 |
| Geoscientist resource | 150 000 | Visit Sunnhordland subst own effort | 50 000 |
| Meetings and travels | 100 000 | Subst. own effort University of Bergen and NGU | 150 000 |
| Office expences | 50 000 | | |
| Diverse | 50 000 | | |
| **Sum** | **1 560 000** | | **1 560 000** |

## Operational Budget for 2023 – 2026

| COST | | FINANCING | |
|---|---|---|---|
| **Type** | **BUDGET** | **Source** | **BUDGET** |
| Payment CEO 100% inkl. soc.cost | 950 000 | Municipalities (8) incl. gen. adjustment | 830 000 |
| Payment geoscientist 100%, incl. soc.cost | 950 000 | State Budget annual op.grants | 1 000 000 |
| PR | 100 000 | Vestland County – annual op.grants | 500 000 |
| Administr. resource | 100 000 | | |
| Meetings, travels, seminars | 130 000 | | |
| Office exp. | 50 000 | | |
| UGGp annual fee | 15 000 | | |
| Diverse | 35 000 | | |
| **Sum** | **2 330 000** | **Sum** | **2 330 000** |

## Investments:

All investments comes in addition. Basic promotion in 2021 has a budget of NOK 1,2 mill. By september 2021 NOK 950.000,- is received after applications to banks, funds, regional energy suppliers, our regional waste disposal company etc. Annual investments will be financed by similar schemes, but always to funds and companies who do have a regional connection and a sustainable policy.

## Operating budget financing

**2022: NOK 1.320.000,-:**

| | | |
|---|---|---|
| Bømlo | NOK | 80.000,- + 6,50,- pr inhabitant |
| Stord | NOK | 65.000,- + 6,50,- pr inhabitant |
| Kvinnherad | NOK | 65.000,- + 6,50,- prinhabitant |
| Fitjar | NOK | 38.000,- + 6,50,- pr inhabitant |
| Austevoll | NOK | 38.000,- + 6,50,- pr inhabitant |
| Tysnes | NOK | 38.000,- + 6,50,- pr inhabitant |
| Etne | NOK | 38.000,- + 6,50,- pr inhabitant |
| Sveio: | NOK | 38.000,- + 6,50,- pr inhabitant |
| Vestland County | NOK | 500.000,- |
| **TOTAL 2022** | **NOK 1.320.000,-** | |

**2023-2026: NOK 2.320.000,-** (when UNESCO GGN-status)

| | |
|---|---|
| 8 municipalities and 1 County | NOK 1.320.000,- |
| State Budget | NOK 1.000.000,- |
| **TOTAL** | **NOK 2.320.000,-** |

## Explisit and associated staff

The staff of Geopark Sunnhordland is p.t a CEO in 100% position, supported by mercantile- and PR-resources from The Region Council of Sunnhordland (2x20%). When UNESCO-status is achieved a geoscientist will be employed directly in a 100% position. In addition comes associated staff employed with our partners, and highly skilled volounteers in academia or relevant organisations (as ornithology) being at service on request. Women are generally well represented in relevant roles associated to the geopark. A precise overwiew of the explisit and associated staff, and also volounteers, is given in Annex 1b.

## OVERLAPPING

Sunnhordland is not overlapping with any other UNESCO-designated area. But further north in Vestland County there is Nordhordland UNESCO Biosphere and the UNESCO Protected Nærøyfjord. There is also an aspiring UGGp in the northern end of Vestland, named Fjordkysten Regional- and Geopark.

# EDUCATIONAL ACTIVITIES

Groups of different ages visites our centres where the origin of our bedrock, the transformation of the landscape and use of island arc geology are interpreted. In one of the tunnels in Moster Amfi there are an exhibition on the types of rock being utilized by humans in Sunnhordland. Samples of the different rocks are presented to see and touch. Pedagogics are developed and tried in cooperation with teachers at The University of Western Norway. The Geopark is regularly visited by kindergartens and classes attending geo-games as bow and arrow, making food in cooking pits, visiting the old stone church and the marble tunnels. Tunnels (secured) are adventourous when visited with helmets and lamps. During the visit they make a small memory-stone by grinding a small piece of marble on grinding boards made of re-designed classroom-desks. During summer we regularly have guideid boat trips waters of Sunnhordland, interpreting the geo-heritage.

Folgefonnsenteret is equipped with the most modern and interactive exhibition dedicated to The Circulation of Water, Climate and Climate changes. There is an extensive use of this exhibition by classes, pupils and tourists.

Courses for teachers and guides on our geoheritage was suspended in 2020 due to covid, but will be re-scheduled when the situation allows. Most of the headmasters at schools in the municipalities have been visited by us for orientation (before covid). Sunnhordland Museum interpretes the medieval masonry techniques used in our medieval buildings, in addition to our general cultural heritage. The museum have a programmes on interpreting local culture for different ages, e.g. “Legends from Sunnhordland”, “Stone Age-activities”, “The miner”, and “The Bronze Sword”. “I am building myself a boat” learn 5. grade kids the names and principles of the wooden boat Faering built here since before Viking age. By putting together the parts in a half scale model they learn names, then making their own key ring by whittle and grinding a half fabricated shaft.

Guide courses has been suspended by covid, but will be developed in cooperation with Norske Parker. Candidates will be widely recruited from our partners, as well as for other with an ambition to become a Partner.

*Originally a mine tunnel for marble in Moster Amfi, now a established exhibition of our geoheritage.*

## GEOTOURISM

In the Geopark we interprets geo-tourism based on the UNESCO GGN and EGN-s definition of Geoparks as single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. We also know Thomas Hose and Ross Dowlings interpretations of geotourism, as well as the ideas of Freeman Tilden and John Muir on interpretation. The Norwegian eco-philosopher Arne Næss is also an inspiration to our view on human relation to nature. To us communicating the goals of geotourism is to emphasize the fundament in the geological issues of our area, and how bedrock, landscape and georesources has formed our culture. To hotels, guides, restaurants in our network this is done by a educational programme interpreted by our CEO where the general idea of the Geopark is shared, and then what geosites is available close to the entrepreneur. Our goal is that every entrepreneur in our network is familiar with the issues in the relevant geosites, and is able to promote them in a enthusiastic way to their guests, in terms understandable to a general audience. The Geopark is cooperating with the Norwegian tourist operator Fotefar temareiser, and has planned a 3 day tour programme in the geo-heritage and history of Sunnhordland from the season of 2022. Fotefar positively chooses UNESCO-areas if possible when producing tours around the world. To our visitors the Code of Conduct is printed on signs saying *Take nothing but memories, Leave nothing but footprints.*

## SUSTAINABLE DEVELOPMENT AND PARTNERSHIPS

### Sustainable development policy

The Region Councils office, also housing Visit Sunnhordland, is sertified as Eco Lighthouse, the most known Norwegian sustainability certificate and also acknowledged by EU. Two of our visitor centres is sertified as Eco Lighthouse or in process of being so. Visit Sunnhordland was also sertified as Sustainable Destination in june 2021, a certificate based on UNWTO and the programme of Global Sustainable Tourism Council. Brynjar Stautland in the Geopark ran this certification from 2019-2021, giving inhouse knowledge in the Geopark of the regional quality and challenges on sustainablity. There is a relevant synergi between the sertificate of Visit Sunnhordland as Sustainable Destination and the Geopark. We believe that the UNESCO GGN recognition and -logo will give a higher level of attention to our region, and specially to a public concerned striving to leave a minimum carbon footprint. More visitors, staying longer due to the geo-heritage prepared for both students, inhabitants and tourists, will improve the economic development of our region as a sustainable destination.

Geopark Sunnhordland is a new major factor for Visit Sunnhordland, wich make the strategy for tourism in our area towards 2024. Having a UGGp in our region, giving partners and ambassadors the opportunity to use the UGGp-logo, is a profound motivation for our tourism companies to qualify for geopark cooperation.

**Projects of the aUGGp related to sustainable development:**

Our visitor centres are frequently providing lectures, information and tours in the geopark for audiences at different levels, promoting the idea of UGGP's. The cooperation agreement with the Western Norway University of Applied Science is an example of projects related to sustainable development.

## Partners

First; our ambition is that all inhabitants of Sunnhordland identifies with the geopark and promotes the geo-heritage earning the GGN-status. Second we have two levels of official cooperation;

1. Main Partner
2. Partner

Partners are major interpretors and promoters of the geopark, having dedicated exhibitions, facilities, skilled interpreters and a sustainable approval/certificate. The Main Partner-contract commits both the partner and the geopark in a standard agreement based on the principles of the EGN Charter and The UN Agenda 2030. Partnerships are free of charge, but requires a profound knowledge of the issues of our geopark. By 2021 we have four Partners, all of them having been part of the preliminary board for the geopark project since 2015:

- Visit Sunnhordland
- Moster Amfi og Kyrkjehistoriske Senter AS
- Stiftinga Folgefonnsenteret
- Sunnhordland Museum

When Partners are regarded, these are candidates inside the Geopark area with skills and practice compatible with the geopark and of mutual interest. Being a Partner also requires a course in the contents of our Geopark and the geosites relevant to the Partner. Partners could be hotels, pensions, food producers, farmers, restaurants specialized in local food, teachers in science, ornitologists, botanists, artists, craftsmen, wooden boatbuilders etc. By now we have five Partners:

- Bømlo Hotel
- Stord Hotel
- Bekkjarvik Gjestgiveri
- Haaheim Gaard
- Galleri G Guddal

Partners must pay a annual fee equivalent to membership in Visit Sunnhordland, and thereby also becomes a member of Visit Sunnhordland. If already member of Visit Shld there is no additional fee. But; a member of Visit Sunnhordland will not automatically be Partner of the geopark. Single persons (teachers, ornithologists etc) will not be charged for being an Partner. When number of Partners are regarded, we follow the advice from Odsherred UNESCO Geopark that quality is more important than amount, and that a maximum number of appr. 20 is reasonable. Partners are promoted in all relevant foras.

There is an existing brand for local food from smaller producers (REKO). When our geopark is accepted as UGGp we will promote the established UGGN-brand GEOfood to relevant food producers. There is so far established a intentional agreement with the farm Snill Bonde and their products from bees, sheeps and cows. 'Snill Bonde' is an obvious candidate for GEOfood, keeping Brown Bees (*Apis mellifera mellifera)* and Norwegian Short Tail Land Race sheep originating from the first domestized sheep in Norway (turf sheep). Their cattle is the old race 'Vestland Fjord Cattle', small and light animals skilled to climb rough terrains and also utilizing the pastures well without perforating the turf. Snill Bie is situated inside the geopark and produces all raw materials here. The honey is made on the local heather *(Erica cinerea, Erica tetralix, Calluna vulgaris)* and processed at the farm. The meat is processed by Jan Sigve and Marianne at a approved slaughterhouse in the bufferzone.

## Participation of local municipalities and indigenous people

Geopark Sunnhordland is initiated by all the mayors in The Region Council of Sunnhordland, the Council also being the owner of the Geopark company. The municipalities and the County of Vestland are financing the geopark, with support from the State budget after UGGp-status is achieved. Here are no indigenous people.

## NETWORKING

The Norwegian Geoparks Gea Norvegica UGGp by former CEO Pål Tjømøe and Magma UGGp by CEO Kristin Rangnes are and has been our exellent supporters for any question during the process of developing our geopark towards the UGGp-application. We visited Toscana Mining UGGp in 2016, Odsherred UGGp in 2017 and assisted to the 15th European Geopark Conference in Sierra Norte de Sevilla UGGp in 2019. In 2021 we have had several digital meetings discussing issues on partnerships etc. with Dr. Sandra Teuber in UGGp Schwäbische Alb.  We will strive to establish further international connections and cooperation during 2022.

By 2021 we have formal appointments with the following international, regional and national institutions;

**University of Bergen (UiB),**
Department of Earth Sciences, Department of Cultural History.

**Western Norway University of Applied Sciences (HVL)**
Agreement on cooperation on education of teachers on our geoheritage, by prof. Dag Olav Larsen and prof. Leif Inge Trædal.

**Norwegian Geological Survey (NGU)**, by geo-scientist Tom Heldal.

**Folgefonna National Park**
Brynjar Stautland is representing Geopark Sunnhordland in The Advising Council in the board of Folgefonna National Park.

**Norske Parker**. In 2020 there was established a network between Norske Parker (member of Europarc) and the Norwegian geoparks. This network is cooperating on issues concerning common interests and strategies.

**Joyce Country and Western Lakes Geopark, Ireland.** A Cooperation Intent is made between our two aspiring UNESCO Global Geoparks. Both are based on the island arc geology of the Iapetus Ocean, the Caledonian orogeny, the Quaternary impact on the landscape and the exploitation and conservation of the geology. Our ambition is to exchange ideas on pedagogics and interpretation, as well as developing projects together.

### Facilities available for the public, affecting sustainable tourism and economic develop-ment.

Our visitor centres and all geosites are available for the public. Our visitor centres are well equipped when it comes to general service and facilities. Geosites in the terrain is free of charge, and the priored sites are presented on website and maps. General information in our visitor centres are free of charge, but visitor centres do charge a ticket for entrance to specific exhibitions.

## SELLING OF GEOLOGICAL MATERIAL

We confirm that Geopark Sunnhordland is not involved in explisit selling of geological material.

# F. INTEREST AND ARGUMENTS FOR BECOMING A UNESCO GLOBAL GEOPARK

Our ambition of UGGP-membership is based on the following aspects;

a. The region has geoheritage of International Significance
b. The region is a defined region suitable for a UGGp
c. The strategy of regional tourism is to promote low carbon footprint tourism
d. Visit Sunnhordland is sertified as Sustainable Destination.
e. Sunnhordland has potential for increasing values in sustainable tourism
f. The UGGp-brand will be highly valuable for us promoting our region
g. The geopark emphazises the relation between geology and culture in a way that strengthens our identity, pride and affection to our region
h. To UGGN the Geopark Sunnhordland will contribute with a nordic landscape with geological- and cultural heritage of international significance
i. Geopark Sunnhordland is equipped with 3 visitor centres
j. Geopark Sunnhordland is certified as a Norwegian Geopark
k. Geopark Sunnhordland is registered as a company, with annual operational financing from municipalities, county and State Budget (2023)

*Armeria maritima facing the ocean. Photo: Jan Rabben*