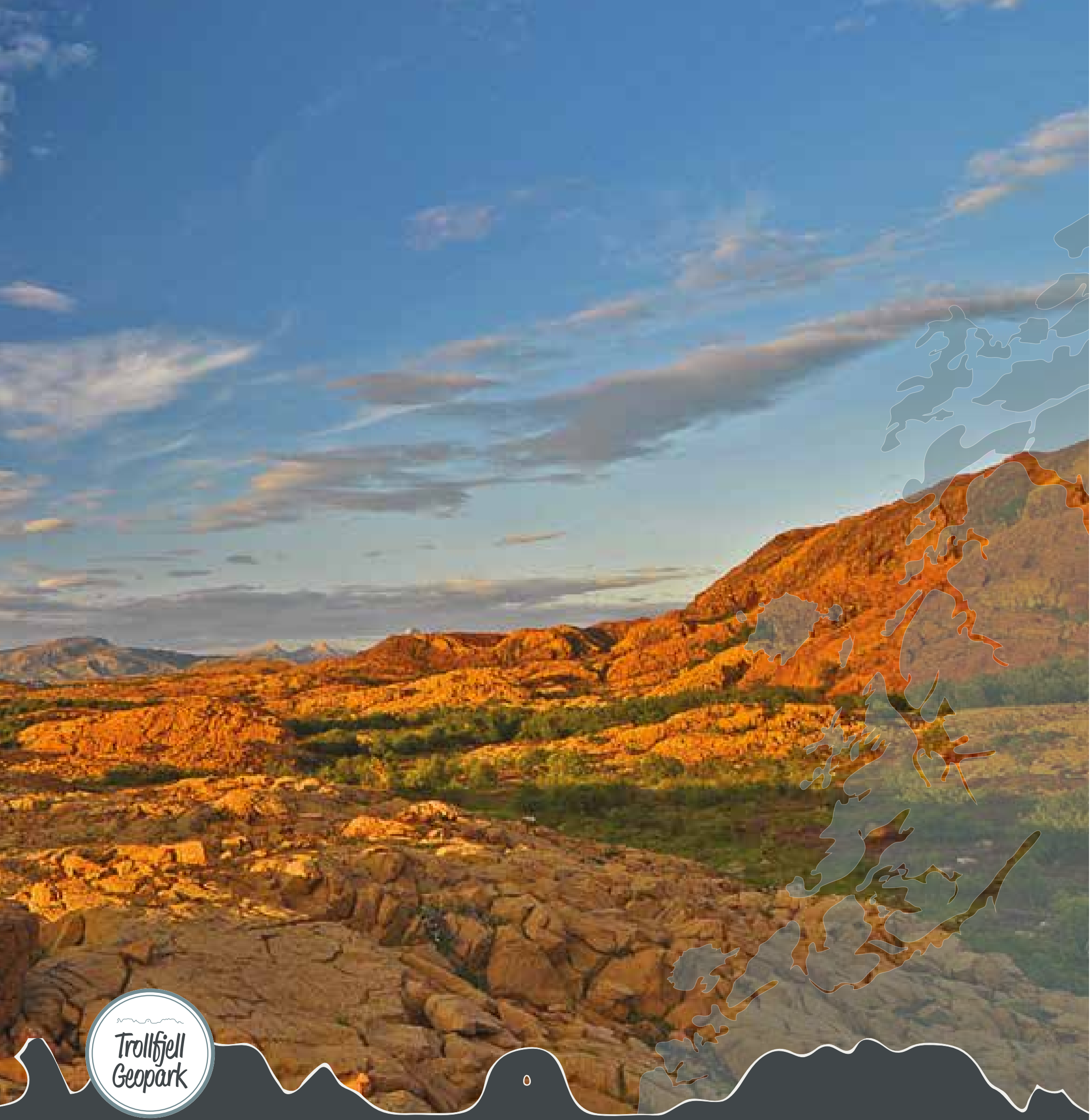
Trollfjell Geopark

GEOLOGICAL HERITAGE AND GEOSITES



Trollfjell Geopark

GEOLOGICAL HERITAGE AND GEOSITES

Brønnøysund 2016

EDITOR: Anna Bergengren, anna.bergengren@trollfjellgeopark.no TEXTS: Tom Heldal, NGU. Øystein Nordgulen, NGU. Fredrik Høgaas, NGU. Rolv Dahl, NGU. Rolf-Birger Pedersen, University of Bergen (UiB). Stein-Erik Lauritzen, UiB. SPECIAL THANKS TO: Tore Prestvik, NTNU, Calvin Barnes and Aaron Yoshinobu, Texas Tech University for helpful comments. COVER PHOTO: Leif Rune Jensen.
LAYOUT: Gaute Hauglid-Formo. PRINT: Konsis Grafisk.

MILJØMERKET 241 Trykksak 785

Trollfjell Geopark

Northern Periphery and Arctic Programme 2014–2020

EUROPEAN UNION
Investing in your future
European Regional Development Fund

DRIFTINGAPART

CONTENTS

INTRODUCTORY REMARKS 6

GEOLOGICAL DESCRIPTION 9

Connected landscapes in time and space 9
The Cambro-Silurian landscape 11
The Pleistocene and Holocene landscape: glaciations and isostatic rebound 23
Landforms and geodiversity 32

Discoveries and research history 32
Arguing for global significance: five geological areas in Trollfjell Geopark 38

LISTS OF GEOLOGICAL SITES 41

Selection of geosites 41

GEOSITES FACT SHEETS 45

REFERENCE LIST 158

INTRODUCTORY REMARKS

The large archipelago with thousands of islands along the coast in south Helgeland has entranced visitors for thousands of years. The Norwegian explorer and scientist Fridtjof Nansen wrote in 1897, “this is a fairytale world in itself, a dreamland”. Today, this is the landscape in which Trollfjell Geopark is situated. The area has been inhabited for more than 11,000 years. The unique geology is the foundation for a landscape that is rich in resources, where early humans settled around the rising mountains and found food in the shallow sea. A more obvious link between geology, landscape and cultural history can hardly be found anywhere.

EXPERIENCES AND NEW KNOWLEDGE ABOUT UNIQUE GEOLOGY

Trollfjell Geopark

In Trollfjell Geopark, the landscape is dominated by the broad area of shallow sea with the archipelago of small islands and skerries fringing the mainland and stretching far out to the open sea – the strandflat. Steep coastal mountains form a boundary to a hinterland pierced by fjords, and out on the strandflat isolated peaks stand in stark contrast to the enveloping open, flat archipelagic landscape. In northern parts of the area, the islands form long chains oriented in a pattern that reflects the folding of the bedrock in the Caledonian mountain chain. The strandflat landscape is a characteristic feature of the Norwegian coast from Rogaland in the south to Finnmark in the north, but nowhere is it better developed than in Helgeland.

This is a magnificent, weather-torn, coastal landscape with huge contrasts. The landscape experience is intensified by the great variations from one season to another, ranging from light summer nights with virtual midnight sun to dark winter months with short days and frequent displays of the northern lights, Aurora Borealis.

The municipalities of Brønnøy, Vega, Vevelstad, Sømna, Bindal and Leka are cooperating on the Trollfjell Geopark project. The vision of a geopark originates from a tourism strategy in southern Helgeland and the selection of Leka as the Geological Monument of Norway. But the initiative is also based on the world heritage status of the Vega Archipelago. The aim is to raise our sights beyond the national sphere and view geological heritage and natural and cultural assets as a single entity in a region that has much in common. A regional perspective on geological heritage and natural and cultural assets entails automatic comprehensive thinking and connection with natural resources.

Photo: A. Bergengren

The myth

Trollfjell Geopark has its name from the famous myth about the Troll Mountains in the north of Norway. Legend has it that the troll king Suliskongen had eight beautiful daughters. As the sisters bathed in the sea one summer night, the Horseman passed by and fell in love with the youngest sister, Lekamøya. He decided to steal her, and rode after the sisters, who started to flee. Seven of the sisters stopped to hide outside Alstahaug, but the eighth, Lekamøya, continued her flight south. As the Horseman realised he would not catch up with her, he got angry and decided to kill her rather than let her escape. As he lifted his bow and arrow, the king of the Sømna mountains saw what was going to happen. Just as the Horseman put an arrow to his bow, the King threw his hat in its path and saved Lekamøya, who continued south to Leka. The King's hat sank in the sea with a hole in the middle left by the arrow. As the sun rose, the trolls turned into stone and still reside here as the mountains we can see today.

Of the mountains in the myth, Torghatten, Lekamøya and the Sømnes mountains are in Trollfjell Geopark.

TROLLFJELL GEOPARK is intended to help make the area more attractive and to create values by paving the way for world-class activities and experiences based on the unique geological history and features in southern Helgeland and Leka.

TROLLFJELL GEOPARK wants to present the unique geology in a new and thrilling way, help to enhance knowledge about the attractions in the park and tie them together.

TROLLFJELL GEOPARK will help to enhance pride and strengthen local identity.

TROLLFJELL GEOPARK is seeking approval as a UNESCO Global Geopark. Such an approval will encourage safeguarding the area for generations, is a stamp of quality and opens doors to new international markets.

The seven sisters (De syv søstre), the Horseman (Hestmannen) and Suliskongen are further north. The name Trollfjell Geopark reflects the long history of kinship between humankind and the surrounding mountains. The tradition of relating stories and giving names to each mountain enabled safer navigation in the challenging archipelago full of shallows, and in the forests and mountains where lack of roads and unpredictable weather made knowledge of the landscape essential for survival.

Geological summary

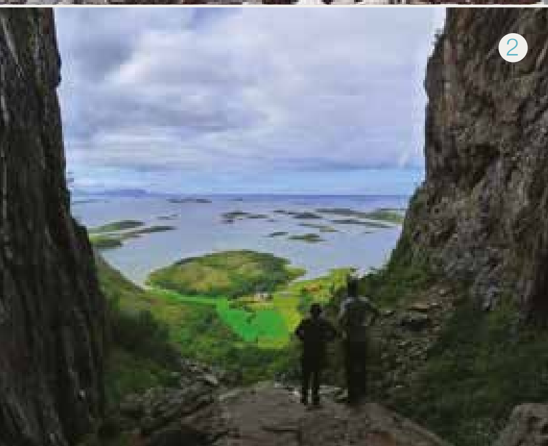
The Trollfjell Geopark displays a 500 million year long geological macro-cycle, from ocean to ocean. The bedrock is composed of rocks that once were formed beneath, in and along an ancient ocean - The Iapetus. They display the architecture of an oceanic crust and the transition to continental settings, as well as the final closing of this ocean resulting in the continent-continent collision forming the Caledonian mountain chain 400 million years ago. The present landscape forms the margin of a 'new' ocean, the Atlantic. Glacial erosion has uncovered the rocks from the past, and shaped a unique coastal landscape of monumental mountains rising from the strandflat with its numerous islands. The land has been lifted several hundred meters by isostatic rebound since the last Ice Age, and the relative sea level has fallen more than 100 meters. Ancient shorelines can be seen up to this level, where traces from the first settlers arriving 11,000 years ago are found.

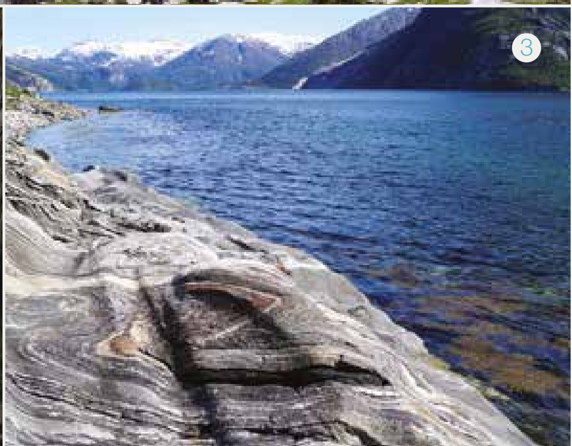
❶ *University excursion at Leknesøyan. Vega at the horizon.*

❷ *View from the Torghatten hole.*

❸ *Beautifully banded and folded bedrock at the coastal outcrops by the restingplace in Tosenfjorden.*

Photos: A. Bergengren





GEOLOGICAL DESCRIPTION

CONNECTED LANDSCAPES IN TIME AND SPACE

The Trollfjell Geopark is established upon the knowledge and impression of a rich and unique geological heritage. From ancient times, settlers and travelers along the coast have used and depended on this landscape, the rocks and processes that formed it, and processes that still are actively changing it. The Trollfjell Geopark conveys many stories about connected landscapes: the geological landscapes linking 500 million years of evolution of the Earth's crust; the evolution of the post-Ice Age landscape and the living conditions for the people settling in it; the resources in the bedrock and the daily life of the people; the geological diversity as a base for the biosphere; the geological landscape as foundation for rich mythology and deep stories.

Bedrock map of Trollfjell Geopark. Map NGU 2015.

The Trollfjell Geopark displays a 500 million years long geological macro-cycle, from ocean to ocean. The bedrock is composed of rocks that once were formed beneath, in and along an ancient ocean – the Iapetus Ocean. They display the architecture of an oceanic crust and the transition to continental settings, as well as the final closing of this ocean resulting in the continent-continent collision forming the Caledonian mountain chain 400 million years ago. The present landscape forms the margin of a 'new' ocean, the Atlantic. The rocks that once were formed by the deposition of sand and gravel along the margin of the Iapetus Ocean almost 500 million years ago are now forming the bedrock beneath modern beaches and riverbanks.

Before and during the Ice Ages, the modern bedrock was gradually carved by erosion, leaving a sculptured landscape reflecting the diversity of rocks. The hard, resistant ones as monumental mountains, the softer carved down to a sub-horizontal plateau, forming the strandflat with its numerous islands, shallow seas and dangerous skerries. A distinctive feature of the area is the utilisation of the geological landmarks as tools for safe navigation. Such

Granitic to gabbroic rocks, 465–425 mill. years

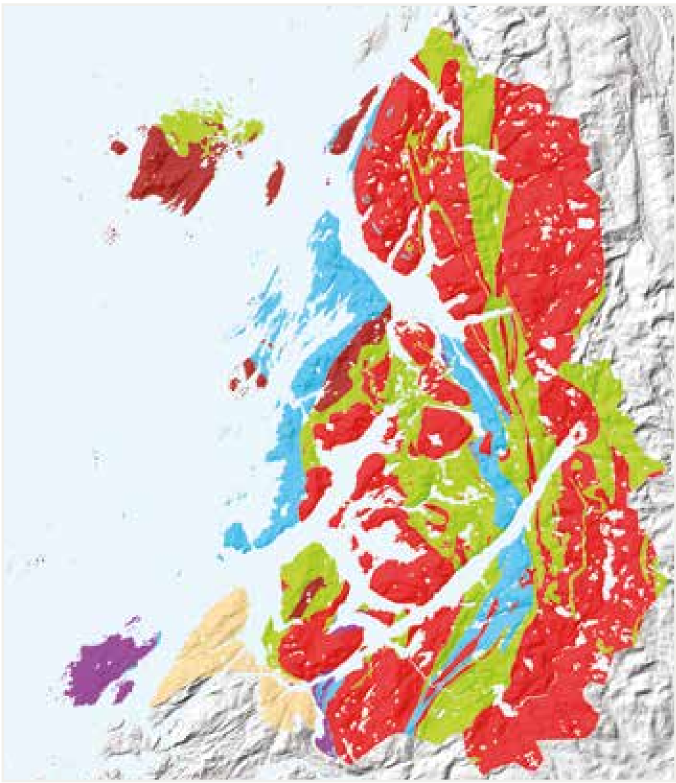
Granitic to dioritic rocks, >465 mill. years

Conglomerate, schist, sandstone, marble, 480. mill years

Peridotite, gabbro, lava (oceanic crust), 497 mill. years

Mica schist, mica gneiss, marble, older than 550 mill. years

Precambrian gneiss & Caledonian nappes, Baltica



Age map of Trollfjell Geopark. Map NGU 2015.

Vollvika in Vevelstad.
Photo: Ø. Nordgulen

ancient knowledge created deep stories and rich mythology; the monumental landmarks as representations of spectacular struggles among the Trolls.

The area covered by the geopark is increasingly acknowledged as one of the most beautiful stretches along the Norwegian coastline. Visitors have through hundreds of years been amazed by this landscape, wondering about its formation. The beauty is in the diversity: of landscape forms, ecosystems, rocks and cultural heritage. All these are connected, with the geology as the driving force. Trollfjell Geopark seeks to combine insight with nature experience, promoting a rich geological heritage and the interdependency between man, geosphere and biosphere.

THE CAMBRO-SILURIAN LANDSCAPE

The Late Proterozoic and Cambro-Silurian rocks of the Trollfjell Geopark display magmatic, sedimentary and tectonic processes related to the plate tectonic events that eventually lead to the closure of the Iapetus Ocean and the collision between the Baltica and Laurentia continents. The rocks display evidence of oceanic spreading, subduction zones, magmatic arcs and orogenic episodes.

The Trollfjell Geopark forms the westernmost parts of the Norwegian Caledonides, which extends along western Scandinavia from southernmost Norway to the Barents Sea. These rock units are the remains of the Caledonian Mountain Belt, which formed a Himalaya-scale mountain range in Silurian-Devonian times (430 to 380 million years ago). The Caledonides resulted from the collision between the ancient continents Baltica (Scandinavia) and Laurentia (North America and Greenland). Remaining parts of the mountain belt preserved in North America and Greenland, mirror their counterparts in Scandinavia and provide strong evidence that the continents were once firmly merged prior to their separation following the opening and growth of the modern Atlantic Ocean.

The two ancient continents were once separated by an older ocean (the Iapetus), which was slowly shrinking as the two continents approached each other. In the geopark area, the rock units tell us the story about the rise and fall of the ancient ocean, from being an 'Atlantic-type' ocean until the continental drift finally

Table 1:
EVENTS, ROCK TYPES AND AREAS

Time/ Period	Event	Rocks	Areas
1) Neoproterozoicum	Sedimentation on the Laurentian margin	Marble, schist, metasandstone	Along Tosenfjord, in Velfjord and on the westernmost islands
2) Early Cambrium	Rifting of the Laurentian margin		
3) 497 Ma	Formation of oceanic crust in a marginal basin	Peridotite, gabbro, mafic dykes and lava	The Leka Ophiolite and other ophiolite fragments i.e. at Kollstraumen-Sørfjorden, Nevernes in Velfjord, Bolvær in Brønnøy and Esøya in Vevelstad.
4) 497 - 480 Ma	Uplift and erosion of the ophiolite	Palaeo-terrain surface, regolith	Leka and Bolvær
5) c. 480 Ma	Deposition of a transgressive sedimentary sequence on top of the ophiolite	Conglomerate, metasandstone, schist, marble	Leka, the Brønnøysund area, western Vevelstad, Kollstraumen-Sørfjorden, and as a continuous belt between Bindal in the south, across Tosenfjord and into Velfjord.
6) c. 480-470 Ma	Burial, deformation and metamorphism; emplacement of fold-thrust nappes (Taconian Orogeny)	Medium- to High-grade metamorphism	Supracrustal rocks in the area
7) 475 Ma	Partial melting of the supracrustal rocks and batholith intrusion	Granite, granodiorite, diorite	Vega Intrusive Complex, Hamn granite, Torghatten Pluton
8) 445 - 430	Intrusion of large batholiths formed in a continental arc	Granite, granodiorite, diorite, gabbro	Andalshatten Batholith, Heilhornet Pluton
9) 430-380	Closing of the Iapetus ocean, Scandian phase of the Caledonian Orogeny	Low-grade metamorphism, folding and thrusting	

SKEI GROUP
(Early Ordovician)

- Metasandstone & conglomerate

LEKA OPHIOLITE
(Late Cambrian)

Crustal rocks

- Pillow lava
- Sheeted-dyke complex
- Quartz keratophyre & plagiogranite
- Gabbro
- Dunite

Mantle rocks

- Harzburgite
- Other Caledonian nappes
- Authochtonous Precambrian gneisses

Geological map of Leka. From NGU 2015

closed it. Each of the rock units in the geopark gives us fragments of this story, as shown in Table 1.

All the bedrock sites in the geopark display one or several of these stages. The geopark outstandingly displays steps 3 to 8, giving a unique insight in the plate tectonic processes governing the last 80 million years of the ancient Iapetus Ocean. Hence, four core areas have been selected: The Leka Ophiolite (step 3, 4 and 5), the Bolvær archipelago (step 4, 5 and 6), Vega (step 7) and Vevelstad (step 8). The core areas are also outstanding in a global context, in providing text-book examples of ocean crust formation, metamorphism and ductile deformation, and batholith formation and emplacement; a view into the deep processes of plate tectonics in the earth's crust.

The Leka Ophiolite: Late Cambrian spreading ridge

Ophiolite complexes are remnants of ancient oceanic crust that once formed in the deep sea. Understanding of such deep-sea areas is central to science as these cover more than 60% of Earth's surface. They are the most dynamic parts of the planet, and the volcanic crust that forms the present deep-seafloor has developed within the last 200 million years of Earth's 4.6 billion years long history.

Ophiolite complexes were first recognized as remnants of oceanic lithosphere in 1968. In Northwest Europe, a number of Caledonian ophiolite complexes have been distinguished as remnants of the ancient Iapetus Ocean. Dating of these complexes has

Bright red bedrock at Leka. Photo: A. Bergengren

revealed that most of them formed within a 10-million-year period in the Late Cambrian and Early Ordovician (around 490 million years ago). The volcanic rocks from these complexes show compositional signatures that point towards their formation in back-arc basins close to subduction zones. The Mariana Arc system, in the Western Pacific, has been proposed as a modern example of the geotectonic environment within which these Caledonian ophiolite complexes formed.

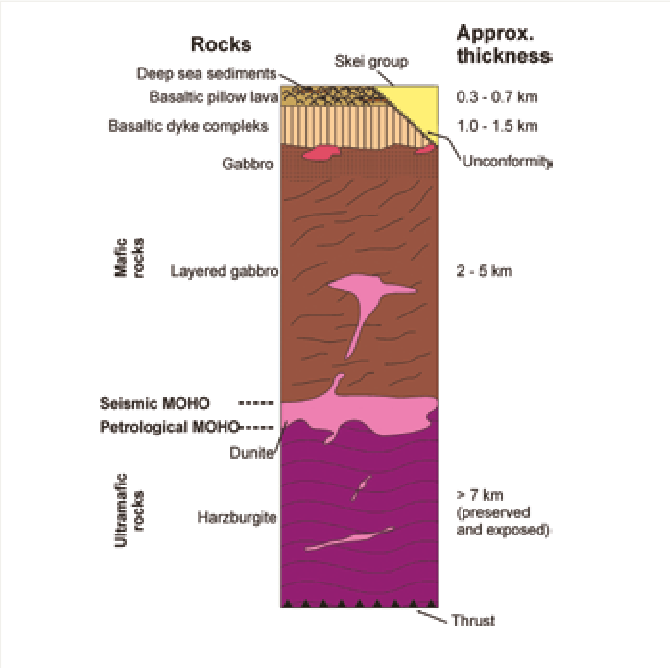
Of all the Caledonian ophiolite complexes, the Leka ophiolite is outstanding. The exposures of upper mantle and lower crustal lithologies are spectacular and among the best observed anywhere. Here, mantle peridotites - sometimes referred to as mantle tectonites because of their strong high-temperature tectonic fabric - are 100% exposed along glacially eroded and polished surfaces. On such exposures, relationships between different rock types and structures can be studied in detail. This provides knowledge about the geologic processes that take place in the mantle below spreading ridges. Deformation structures and crosscutting igneous bodies give insights into the ductile flow of mantle and the upward migration of melt from the mantle to the crust - and eventually to seafloor volcanoes. From these mantle tectonites one can cross the mantle-crust boundary on foot. When passing across this boundary, the rocks change their character. Above the mantle-crust boundary, the rocks are layered. Several tens to hundred-meter-thick units of olivine-rich rocks (dunite) are here interlayered with pyroxene rich units. This layered peridotite sequence demonstrates that the influx of magma from the mantle to the lower crust is episodic – in a similar way as volcanic eruptions occur as discrete events.

This layered series also provide insights into the nature of crustal magma reservoirs and the crystallization of magma within the lower crust. Within this layered sequence there are numerous thin horizons that are enriched chromite and nickel sulphides. These layers also contain platinum group elements (Ru, Rh, Pd, Os, Ir, Pt) that are present in rare minerals and in alloys. Although these deposits are sub-economic, they illustrate how metals important to modern society become enriched in layered ultramafic and mafic magmatic complexes.

Further up-section the peridotites grades into gabbro. Here, plagioclase appears, the amount of olivine decreases and the density of the rocks drops as a result of this change in mineralogy. In ocean basins, this up-section density decrease is observed by a distinct decrease in seismic velocities. This velocity decrease, which is named the Mohorovicic Discontinuity (Moho), typically occurs at 5 to 7 km depth below the seafloor. The Moho below the oceanic basins is generally regarded to reflect the thickness of the oceanic crust.

However, as seen on Leka and many other ophiolite complexes, the true crust-mantle transition (termed the petrologic Moho) is sometimes present at a deeper level where the layered peridotites grade into mantle tectonites.

At Leka, the mid-crustal part of the ophiolite is not as well exposed as the lower crustal and mantle sections. However, high-level gabbros and sheeted dykes, which represent tabular feeder channels to the above volcanic sequence, can be seen along some shore sections, for example at Madsøya. Further up-section, the volcanic part is again remarkably well exposed. At Leknesøyan, islands just north of Leka, “text-book” examples of different types of submarine volcanic deposits can be seen along the shores of the island. Pillow flows, sheet flows and volcanic breccia demonstrate the range of volcanic products that may form on the seafloor. This range in volcanic features reflects the seafloor topography, magma properties and eruption rates.



Simplified section through the Leka Ophiolite. Drawing: Trond Slagstad, NGU (2015)

Between such lava flows, thin layers of carbonate-rich, deep-sea sediments can locally be seen. These accumulations of sediments document shorter or longer pauses between eruptive events. In the deep-sea, sediment accumulates at very slow rates (typically less than 5 cm/1000 years), and the sediment layers present between some of the volcanic units at Leknesøyan provide insights into the temporal dimension that is fundamental for understanding geology.

Locally, pink-coloured, manganese-rich layers can also be seen between volcanic units. They were formed during episodes of seafloor hydrothermal activity and signal that black smokers were discharging metal-rich fluids into the water column somewhere nearby. At Leka – as in all other ophiolite complexes - smaller and larger sulphide deposits witness to the extent of seafloor hydrothermal activity. Ophiolite-hosted, massive sulphide deposits have been an important source of base metals such as Cu and Zn. Although only small, sub-economic deposits have been identified at Leka, they still demonstrate how hydrothermal activity has affected the rocks, and how massive sulphide deposits form at the seafloor as a result of water-rock interactions.

Leka is voted the Geological Monument of Norway, and the Leka Ophiolite Complex is outstanding among the world's ophiolite complexes. In addition to being well studied, the continuous, unweathered sections make it possible for the visitors to grasp the complexity of the oceanic crust, or just to embrace the excitement of a walk into the earth's interior.

The Bolvær archipelago

Back-arc basins are among the most unstable geological terrains on earth, characterized by rapid uplift and burial, earthquakes and volcanism. This was also the case along the Laurentian margin in the Late Cambrian and Early Ordovician. Not long after its formation, the oceanic crust was uplifted and eroded. An irregular landscape formed, with mountains and valleys. Sediments were deposited by rivers in the valleys and as talus below fault escarpments. Aluminium enrichment in weathered rock indicates a dry and warm climate. The landscape may be compared with Cyprus today, where the Late Cretaceous Troodos Ophiolite has been uplifted as a consequence of the African plate subducting ("diving") beneath the Anatolian.

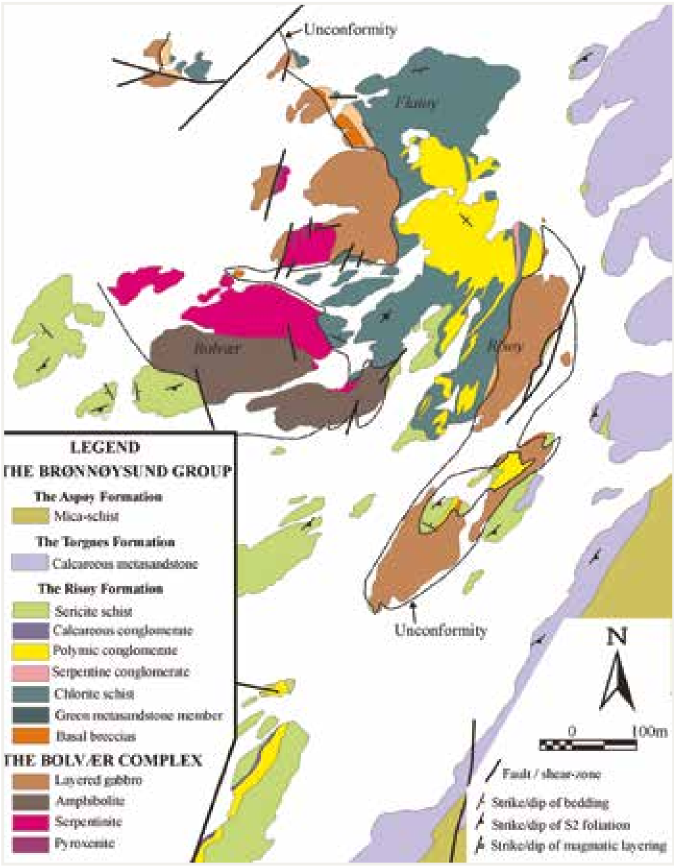
Sea level started raising again, and the Early Ordovician landscape was gradually filled with sediments, first beach and shoreface conglomerate and sandstone, later marine turbidites, carbonates and clay. The lowermost sediments were derived exclusively from the ophiolitic subsurface. Upwards in the succession, continentally derived material become more and more dominant, reflecting a close, continental source corresponding with the lithologies (and zircon composition) of the Laurentian continent.

The ancient terrain surface (unconformity) can be followed over large areas in the geopark.

At northeast Leka, the unconformity and the overlying sedimantary rocks of the Skei Group is rotated almost vertically. This is particularly visible along the well-marked geotrail, where one may literally walk back and forth crossing the Early Ordovician terrain surface.

The best exposures are, however, at the Bolvær archipelago, west of Brønnøysund. The area is accessible only by boat, but when you finally get there, the reward is unique exposures of ophiolite rocks, the ancient terrain surface and weathering profile beneath, all the sedimentary rocks filling the terrain and finally covering it as the land drowned in the sea. Although the rocks in the area are metamorphosed and folded, the sheltering effect of the ophiolite fragment to the nearest sedimentary rocks makes it possible to recognize sedimentary structures, and even to reconstruct the landscape evolution at this particular place. This unique preservation of rocks in such a high-grade metamorphic terrain makes the site a key area for understanding the Early Ordovician landscape.

The supracrustal rocks of the Trollfjell Geopark have suffered upper greenschist facies metamorphism or higher, meaning that the rocks were exposed to more than 8 kb pressure and temperature higher than 500°C, i.e. at least 20 kilometres beneath the Earth's surface. The peak of metamorphism took place around 475 Ma, simultaneous to the most intensive ductile deformation and emplacement of fold-thrust nappes onto the Laurentian margin. In most of the area, the rocks are so altered that primary features related to their formation are rarely observed.



Geological map of Bolvær Area. From Heldal 2001.

The Bolvær archipelago is hence an exception. Here, one may study metamorphic mineral growth in the sheltered metasedimentary rocks, and also early deformation episodes that have been overprinted by later ones at other places in the region. As a text book example of metamorphic mineral growth in various lithologies and structural geology (folding, axial plane cleavage formation, etc.) the site has a great value also beyond its role as a key site for understanding the regional geology.

The Bindal Batholith

Batholiths represent large volumes of igneous rocks, formed from crystallizing magmas deep in the Earth's crust. They are composed of multiple igneous bodies, or plutons, of igneous rock of irregular dimensions. Individual plutons are crystallized from magma that moved upward from a zone of partial melting in the lower to middle parts of the Earth's crust. Large batholiths commonly form the core of magmatic arcs that are present above subduction zones and are often a result of crustal thickening, transfer of magma and heat from below due to colliding island arc systems.

The Bindal Batholith is the largest Caledonian batholith in Norway, and consists of a mosaic of more than 50 major intrusions spanning ages from ca. 480 to 425 Ma. The amalgamation of nappes within the Helgeland Nappe Complex and Bindal magmatism are the result of collision of arc terranes within the shrinking Iapetus Ocean. The earliest phase of batholith formation took place near the Laurentian margin, whilst the late phases are believed to be related to subduction and the initial collision between the continents, just prior to the "grand finale" of the Caledonian Orogeny.

Two of the intrusive complexes within the greater Bindal Batholith have been selected as core sites in Trollfjell Geopark; the Vega Intrusive Complex (early phase) and the Andalshatten Batholith (late phase). Both are well studied and documented and collectively display world-class outcrops of a range of features of importance for the understanding of batholith formation.

The Vega Intrusive Complex

The same tectonometamorphic event that is so beautifully exposed on the Bolvær archipelago, led to partial melting of the sandstones and schists.

This resulted in the formation of large, granitic intrusions forming the major part of the Vega island and the adjacent archipelago. The emplacement and crystallization of the granite is dated to about 475 million years.

The Vega intrusive complex is a fairly homogeneous body ca. 350 km^2 in extent, and consists mainly of granitic and granodioritic rocks. Due to westward tilting of the intrusive complex after its formation, subsequent erosion has actually revealed a 7 to 17 kilometre thick crustal section, exposing asymmetrical internal zoning of the intrusive complex. Northeast Vega and the western half of the island Ylvingen consists of biotite granite and garnet-biotite granite with a weak magmatic foliation defined by biotite. Locally the rocks are porphyritic with up to 2 cm long K-feldspar phenocrysts. On Vega, Søla and islands southwest of Vega, we find medium-grained garnet-bearing muscovite biotite granite and granodiorite with local magmatic layering and/or foliation. The western part of this unit contains cordierite and sillimanite. The Fugleværet granodiorite occupies a zone along the western contact of the Vega intrusive complex. Cordierite is present as cm-scale phenocrysts; in places, cordierite form large nodules or exhibit spectacular dendritic shapes.

The mineral composition of the granite shows that it crystallised from a melt that was formed by partial melting of rocks similar to the sedimentary rocks occurring to the north of the granite. Compositional variation within the Vega complex is mainly due to unmixing of evolved melt fractions from residual minerals/phases. Migmatitic rocks are commonly present along intrusive contacts, and also occur as dykes that intrude the host rocks, e.g. on northern Ylvingen and northwest Vega. Varieties of migmatite (partially melted rock) are present on the nortwestern part of Vega: here, it is possible to envisage the entire process from melting of sedimentary rocks to the formation of a huge batholith. Some of the rocks that resisted melting are present as dark clots and irregular inclusions unevenly distributed in the granite, trapped by the migrating melt. Metasedimentary and mafic enclaves are locally very abundant.

Dioritic rocks occurring on Vega are considered coeval with the granitic rocks. The diorites were probably derived from a deeper mafic source and have isotope composition that differs markedly from the Vega granites. There is no geochemical evidence suggesting mixing between dioritic magmas and the Vega granite magmas. However, emplacement of mafic magmas in the lower crust was probably important in transferring heat to the zone of partial melting. This type of granite is rare in mountain belts, the Vega granite being a world-class example and by far the largest occurrence of its kind in the Caledonian mountain belt in Norway.

The Andalshatten Batholith

The Andalshatten batholith represents a very large volume of granitoid magma that crystallized in the middle crust ca. 442 million years ago. The batholith intruded several thrust nappes, each with distinctive lithologies, and pre-emplacement metamorphic and structural histories. Thus, the pluton provides remarkable and important evidence of the timing of the Caledonian Orogeny in the area: it cuts and stitches the already established internal nappe tectonostratigraphy, but pre-dates the final (Scandian) orogeny that culminated during eastward thrusting of the rock units onto the margin of the Baltic Shield.

The Vega granite, here seen with oriented swarms of inclusions found in the rocks along the trail at Sundsvoll. Photo: Ø. Nordgulen

The Andalshatten batholith covers an area of 322 km^2 and is more than 700 km^3 in volume. It is composed of at least five distinctive rock types; strongly foliated to gneissic granodiorite with mafic schlieren, coarse-grained to K-feldpar megacrystic granodiorite, diorite, and minor granite and tonalite.

One of the most remarkable and spectacular aspects of the batholith, is the abundant screens and xenoliths ranging in size from kilometer to millimeter, being superbly exposed in glacially shaped three-dimensional outcrops and vertical cliff faces. The screens were incorporated during emplacement of magma batches and form a ghost stratigraphy that preserves the gross host rock lithological and structural framework prior to batholith emplacement, i.e., the nappe stratigraphy. Among the screens are also ultramafic rocks derived from ophiolite fragments, thus creating an indirect, but important link between the batholith and the Leka Ophiolite.

Panorama views over Andalshatten pluton.

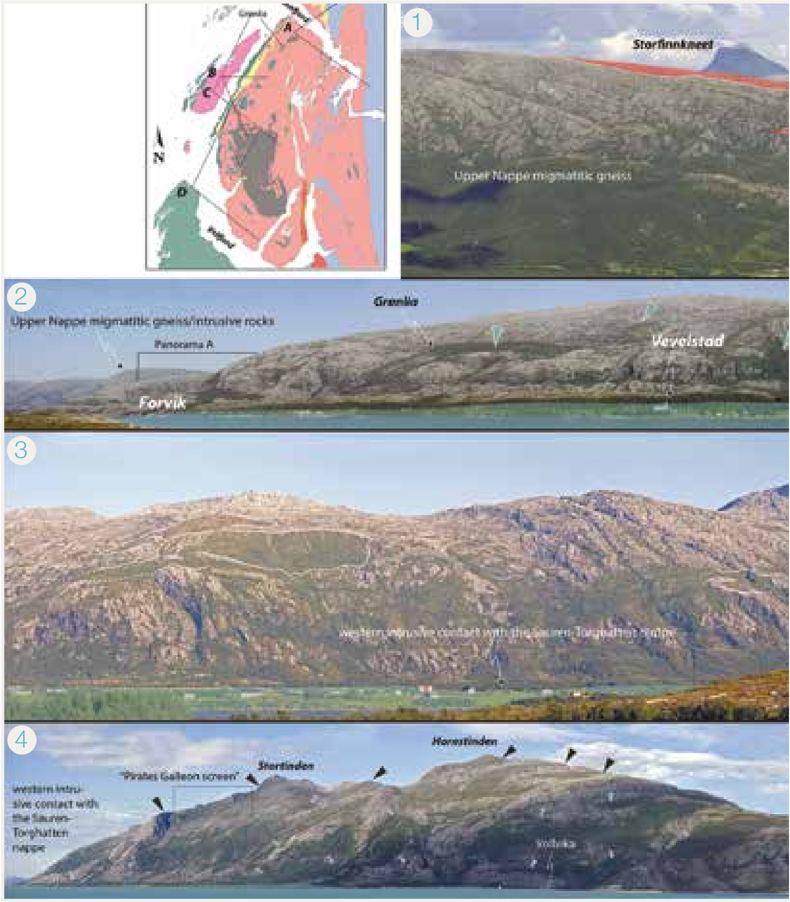
❶ Panorama view to northeast of northern intrusive shape of the Andalshatten pluton.

❷ Panorama view to east from Hamnøya.

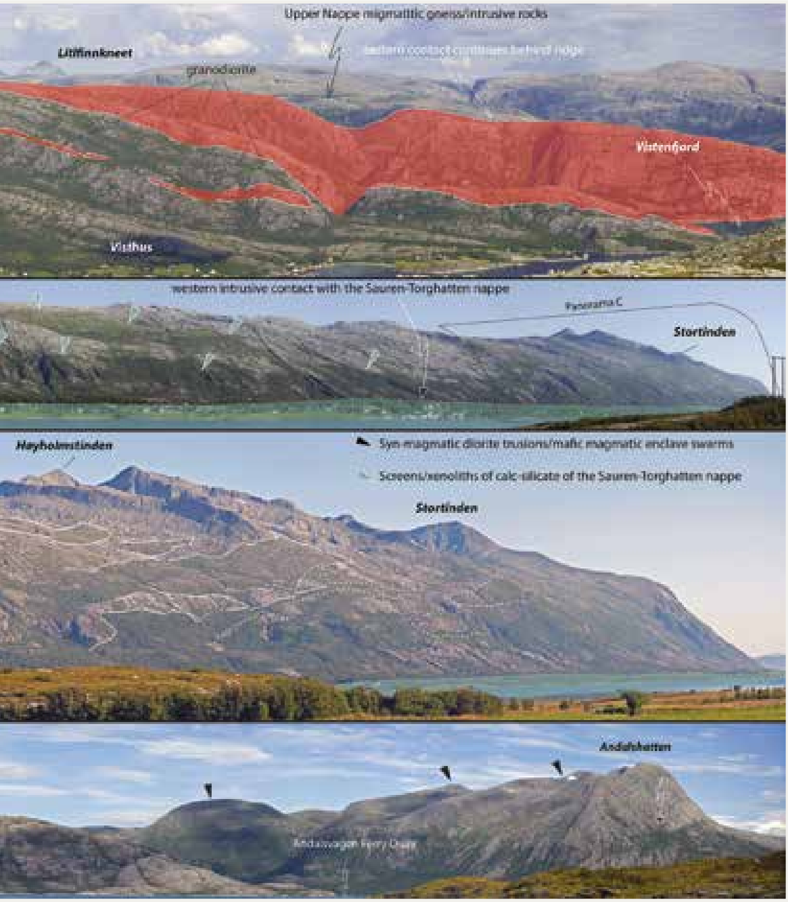
❸ Panorama view to southeast of the central portion of the western Høyholmstinden massif from Hamnøya.

❹ Panorama view to east – northeast from Horn quay.

Modified from Nordgulen et al. 2011.



The superb exposures, with easy access to ice-sculptured and wave-polished rocks along the fjords, as well as vast areas of 100 % outcrop in the high mountains, provide an unprecedented range of scales of observation of the processes that attended batholith assembly. The igneous rocks and the trapped screens and xenoliths are consistent with multiple events of magma recharge over a period of at least 0.6 to 1.7 million years. The Andalshatten Batholith is a world-class example of a continental arc pluton showing emplacement of magma pulses, the duration of magma crystallization, the processes by which xenoliths and screens are incorporated into the batholith, and the spatial scales of potential magma batches and magmatic flow. It is a unique and rare display of the beauty and force of magmatic processes in the middle crust.



THE PLEISTOCENE AND HOLOCENE LANDSCAPE: GLACIATIONS AND ISOSTATIC REBOUND

20.000 years ago - near the end of the last glacial maximum (LGM) - Norway was fully covered by a vast Fennoscandian ice sheet stretching as far south on the continent as northern Germany. The maximum western distribution was limited by the edge of the Norwegian shelf, where the glacier terminated with calving and break-up of shelf-ice, much like we see in Antarctica today. The ice sheet expanded far off today's coastline west of Trollfjell Geopark and the region was thus heavily weighted down by a dense cover of ice - in areas as thick as 1 to 2 km.

Governed by a warming climate and a rising sea-level, the ice sheet began to recede towards the coast. By 14 –13.000 years ago, the ice margin is thought to have redrawn to the outer islands on the Nordland coast, as interpreted by a radiocarbon dated ice-marginal deposit on the Vega lowland. After this temporary halt, the ice sheet receded further inland, before we got a severe worsening of the climate during the Younger Dryas chronozone (12.800 to 11.500 years ago). This cold, late-glacial period led to an expansion of the Fennoscandian ice sheet and the physical imprints of this event are easily detectable within and around Trollfjell Geopark.

The large Lysfjordmana end moraine east of Leka constitutes the terminal position of the ice sheet during Younger Dryas. Here, prominent ice-marginal moraines are traceable over a large area and indicate an ice sheet advance from a more easterly position. Radiocarbon datings correlate the moraine ridges to the nearby Tautra substage of the Trondheimsfjord region and the corresponding Tjøtta event from outer parts of Vefsnfjorden. By 11.000 to 10.000 years ago, the coastal area of Nordland was fully deglaciated.

The Trollfjell Geopark displays a variety of features related to glaciations and deglaciation phases, as well as other Quaternary features such as a significant karstic landscape formed in carbonate rocks. However, there are four features in which the geopark provides unique and outstanding sites: the raised shorelines from the isostatic rebound, the strandflat, the giant sea caves symbolized by the iconic mountain Torghatten and the karstic landscape of Velfjord with its marble caves.

Raised shorelines

As the glaciers receded, the land immediately started to rise as a response to the offloading of the thick ice cover. As this isostatic rebound generally occurred faster than the global sea level rise, we have a range of ancient, raised sea levels preserved within Trollfjell Geopark. Due to the large isostatic depression during the Ice Age in this area, these levels are often located at high altitudes. The marine limit – the highest relative sea level after the last Ice Age - within Trollfjell Geopark, ranges from 95 to 100 metres above present day sea level at Vega, to around 135 metres in the inner parts of Tosenfjorden east of Leka.

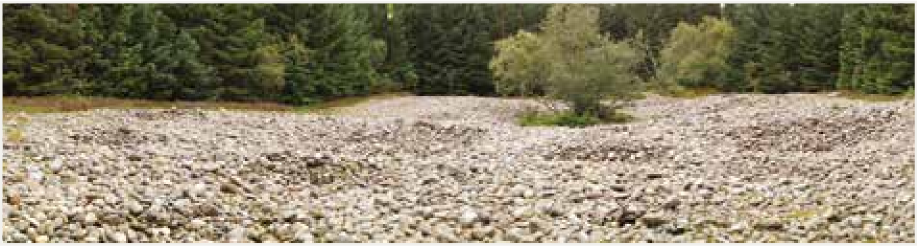
The raised sea levels can generally be identified in several ways, but within Trollfjell Geopark large beach ridges are common. These landforms are formed as wave-action erodes, redeposits and sorts existing surficial material as till. Beach ridges dominated of perfectly rounded football-sized boulders are widespread in the region and stand as a direct proof of the erosive power

Overview showing marine limit observations, isolines and drowned land in Trollfjell Geopark and adjacent areas. Map NGU 2015.

from countless storm waves. Remains of Mesolithic and Neolithic settlements are found in the upper level beach ridges, witnessing how the first settlers met a drowned land. As the land rose, new settlements were established closer to the new, lower sea level. Hence, when we move upwards in the terrain towards maximum sea-level, we also go backwards in the history of human occupation of the area.

Due to the rapid isostatic rebound in the period after the area became ice-free, the timing of the marine limit sea level often coincided with the timing of the deglaciation. In general, the relative sea level has fallen exponentially ever since, albeit with two exceptions; the Younger Dryas and the Tapes sea levels.

A temporary halt in the relative shoreline displacement during the cold Younger Dryas made the sea level fluctuate around the same level during several hundred years, and led to the formation of unique erosive bedrock imprints in the region. Conspicuous shore platforms are found several places within Trollfjell Geopark, but are perhaps most impressive on the eastern side of Leka. Here, leveled and often continuous platforms, sometimes 30 to 40 m



The raised shorline at Triborgen, Sømna. Photo: A. Bergengren

wide, are located 106 to 112 metres above present day sea level. The large amount of material stripped during shoreline formation indicates the extensive erosion performed by sea-ice, icebergs and freeze-thaw mechanisms in the littoral zone during a cold climate regime, around 12.500 years ago.

The Tapes level (9.000 to 6,000 years ago) represents a phase where the eustatic sea level rise in a small period exceeded the ongoing isostatic uplift in many parts of Norway. In Trollfjell Geopark one does not have sufficient data to conclude whether the phase inundated dry land or if the shoreline displacement stagnated just briefly. Thick shore deposits in assumed Tapes level do however indicate extensive sediment accumulation during this phase. After the Tapes phase, there has been a steady regression of the relative sea level towards the present level. Today, the isostatic uplift within the region is approximately 4-5 mm per year.

The Strandflat: a unique topographic feature of coastal Norway

The strandflat is a geomorpological feature that has left its characteristic mark on the Norwegian coastline. Some of the best examples of this geomorphological event are found within the proposed Trollfjell Geopark area.

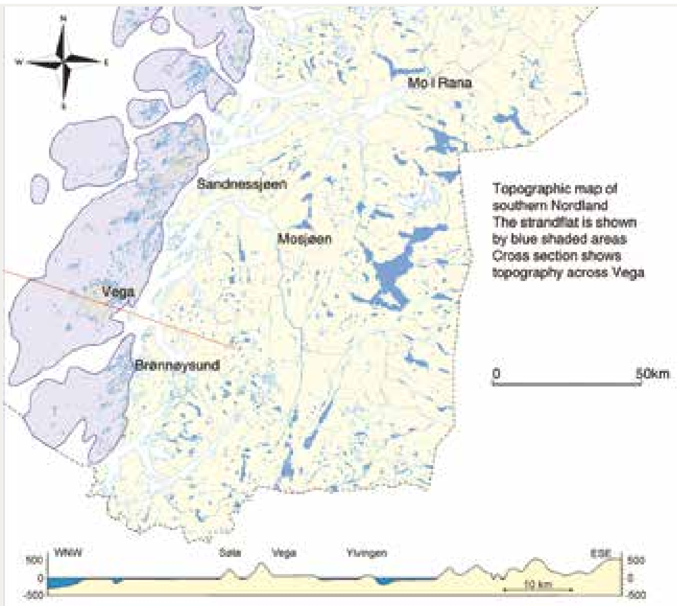
The strandflat is as a low, flat and wide platform, supporting thousands of stacks, skerries and other small islands, as well as shallow sea areas. Even though it is also evident on other Arctic coastlines, the strandflat is primarily found in Norway. This also has etymological implications. The expression has its origin from the Norwegian word strandflate, “beach flat”.

In Norway, the strandflat is visible between Stavanger and Magerøy in Finnmark. However, it is unevenly distributed. In some coastal areas there is no strandflat, while in other places, it can be a nearly 60 km wide rim of low islands and peninsulas surrounded by shallow waters. The boundary between the strandflat and the inner landscape is usually defined by a knickpoint, where the edge of slope changes dramatically into a steep headwall.

The strandflat has played a fundamental part in the human history of Norway. These areas provide excellent habitats for fish and marine mammals, thus making excellent hunting and fishing ground available for the first dwellers. Despite high latitudes, some of the islands also provided shelter and relatively lush pastures. The combination of fishing, hunting and agricultural opportunities provided by geological forces attracted human dwellers from an early stage after deglaciation.

The origin and formation of the strandflat landscape has puzzled scientists for centuries. Several hypotheses have been suggested, from mainly preglacial abrasion, to glacial abrasion as well as frost weathering. One interpretation, currently debated, is that the strandflat is a result of several processes: First, deep tropical weathering in the Mesozoic period, followed by preservation of the weathered rocks and finally Neogene uplift and corresponding erosion by a combination of coastal abrasion, frost weathering and glaciations.

The strandflat is by far the dominant landscape feature in the geopark. In Vega, the platform stretches up to 60 kilometers, making this area one of the widest on the Norwegian strandflat. The inselbergs with residual islands and steep edges, caused by frost weathering, are also visible. The island Søla, with its characteristic brim and steep cliffs is a prominent example of a residual rock. Other examples of residual islands include Torghatten (see



Map (somewhat modified) from NGU, from Vega World Heritage Convention (2003)

Strandflat islands with the residual mountans at Vega in the background. Photo: I. O. Tysnes

chapter below). Both are key localities for the understanding of the strandflat as a phenomenon.

Archipelagos such as Sklinna and Hortavær in Vega, as well as Bremstein, Lånan and Skjærvær in Vega also demonstrate low islands surrounded by shallow sea levels.

Torghatten: an iconic mountain

Torghatten, the iconic feature of Trollfjell Geopark, is an integral part of the strandflat. Torghatten has an altitude of 258 m.a.s.l., and may be regarded as the type locality for marine-abrasion tunnel (through) caves, displaying one fully developed tunnel and numerous incipient and half-finished ones.

Caves occur in several levels, of which the 112 to 120 metres contain the largest ones and also a prominent notch in the bedrock, corresponding to the Younger Dryas and possibly older, equivalent seastands. Here, the various stages of platform- and cave-forming morphology can be studied in detail. In particular, smaller caves that have almost experienced a breakthrough also contain appreciable amounts of clays, which from their mineral-ogy, may stem from pre-glacial deep-weathering. This testifies that their guiding fractures (weakness zones where erosion has attacked) do have an ancient origin and that the caves and throughs in the landscape might have been pre-mediated by a

View from Torghatten hole.
Photo: A. Bergengren

Engavatnet with and without water. Photos: A. Bergengren

template created by pre-quaternary deep weathering, a process that is also proposed for the paleic surface in general.

In all, Torghatten may be regarded as a key and type locality for quaternary marine abrasion caves and for processes that created the strandflat. Moreover, it remains one of the world's most iconic landmarks, astonishing visitors through hundreds of years.

The karst landscape

The majority of karst landforms within the Scandes mountains occur in Caledonian metacarbonates (marbles) within a belt stretching from approximately 60° to 70° N latitude. In marbles, (endo) karstification is restricted to tectonic fractures and joints; the rock mass is essentially impermeable, unlike non-metamorphic limestones where bedding plane partings and syngenetic porosity are preserved. Formation of caves and exokarst development took place during all phases of the glacial-interglacial cycles of the Pleistocene, where the glacial impact was both stimulating (speleogenesis) and destructive (erosion). Karstification was however most intensive during interglacials, with a strong overprinting of glacier ice-contact processes.

The greatest density of karst phenomena (largest and longest caves, dolines) occur north of the Arctic Circle, where Trollfjell Geopark comprise a southern province (Bindal-Tosen-Velfjord), displaying smaller, but very well-developed caves and exokarst. The area also displays a variety of carbonate rocks, ranging from pure calcite, through impure variants and to dolomite and brucite

marbles, which reveals a corresponding response to karstification. In Velfjord, the glacial overprinting on karst development is very well displayed by tunnel-shaped, phreatic passages that are often widened above sediment fills and are often exposed in a truncated fashion in cliff walls. Where detectable, water flow in the now relict caves was in accordance with local ice-sheet movements, as revealed by current marks (scallops) within the caves and surface erosion features (striae and P-forms).

A characteristic feature of the Velfjord caves are numerous examples of effluent passages situated below the upper marine limit which acted as subglacial springs during late-glacial time. These caves hosted a very rich, cold-water marine fauna, as revealed by proliferent bio-erosion from the entrance areas and quite deep into the caves, accompanied by proliferent deposits of mollusc shells, many still in growth position, proving that they actually lived deep inside the caves. Together with the antigravitative galleries - developed as a response to glacial sediment fills - the rich biology renders the caves as unique examples of a late-glacial stage where a thriving pro-glacial fauna invaded the caves. This is not commonly seen elsewhere in the country.

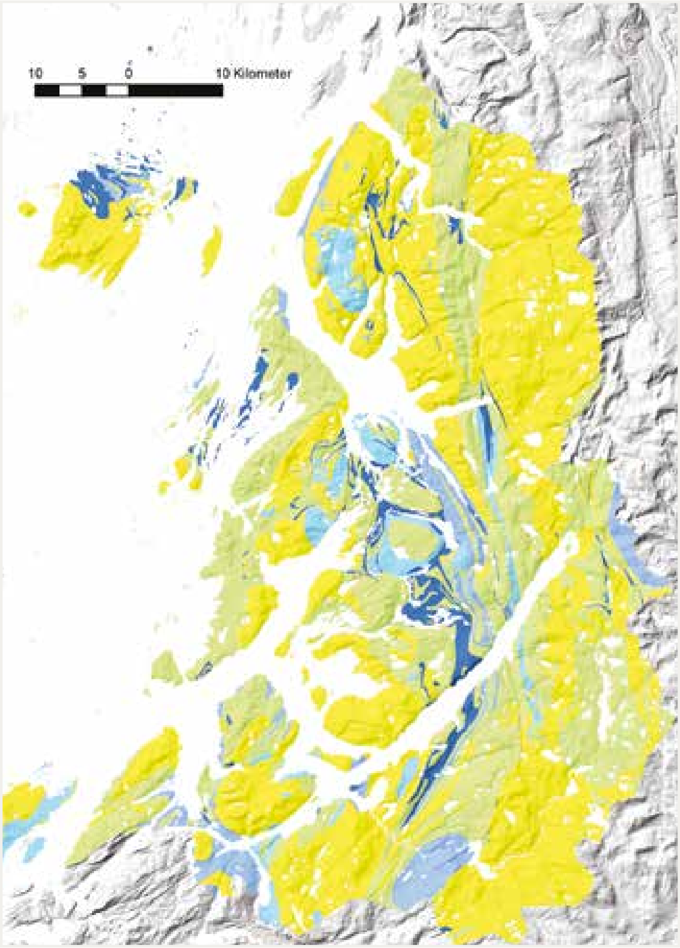
Exokarst phenomena are everywhere blended in with the glacially sculptured landscape, comprising lapies (on bare marble surfaces), dolines, streamsinks and springs. Velfjord contains the possibly largest turlough (Irish for "dry" lake) in the country, Engavatnet. The "mysterious" lake suddenly drains at erratic intervals through a cave opening in the bottom mud sediments. The drainage is closely linked with periods of prolonged draught, when the groundwater level around the lake is expected to drop. Lake level is maintained by the impervious mud bed, until it suddenly burst so that the draining of the lake is accelerated, leaving dead fish in the wet mud in the completely dry lake. After rain, the lake slowly regenerates and, surprisingly enough, the fish reappears.

LANDFORMS AND GEODIVERSITY

Cycles of glacial erosion and isostatic rebound, and even pre-glacial weathering, have created a unique landscape. Monumental and barren mountains of hard granite contrast wirth the strandflat carved into the softer, supracrustal rocks. As we have seen previously, littoral prosesses created giant caves along former sea levels, including the tunnel cave through the Torghatten mountain, and a karstic landscape of caves, highly valued by speleologists, developed in the huge marble occurrences in Velfjord. The geomorphological diversity, driven by the bedrock and shaped by the glaciers and the sea, created numerous characteristic landmarks that became important for the sea-faring people along the coast. This, in turn, became the root for a rich mythology and deep stories related to such landmarks. The strandflat is a dangerous place for sailing, but the characteristic mountains rising above it made good visual landmarks for safe navigation. The stories linked them geographically together.

From a biodiversity perspective, the landscape is young and recently populated by fauna and flora. The diversity of rocks within the geopark gave rise to a significant biodiversity, changing within short distances. From the barren granite to the rich flora of the marble areas, from the highly specialized and unique flora of the ultramafic rocks to even more unique examples on calc-silicate rocks.

The geodiversity is a key to why people visit the area again and again, discovering new aspects of the landscape each time.



Lime content in bedrock.
Map from NGU 2015

- Very low lime
- Low lime
- Intermediate
- Calcareous
- Calcite marble

View over Solsem, Leka.
Photo: A. Bergengren

DISCOVERIES AND RESEARCH HISTORY

The southern part of the Helgeland Coast has long been known and appreciated as an area displaying a unique geological diversity. Visitors and travelers have been impressed by this beautiful coastal area for centuries, and in particular by Torghatten and other landmarks. The first geological observations were probably made by Erich Pontoppidan, a Danish bishop and historian, who took great interest in geology and how rocks and landscapes were formed. He described the sea and karst caves of Helgeland (including Torghatten) already in 1752, in his "First attempt of Norway's Natural History" (Pontoppidan 1752). Later, the German geologist Leopold von Buch followed up with some observations and brief descriptions during his travels to Norway in 1807-09 (von Buch 1810), and the area is also mentioned in Keilhau's Gaea Norvegica (Keilhau 1844).

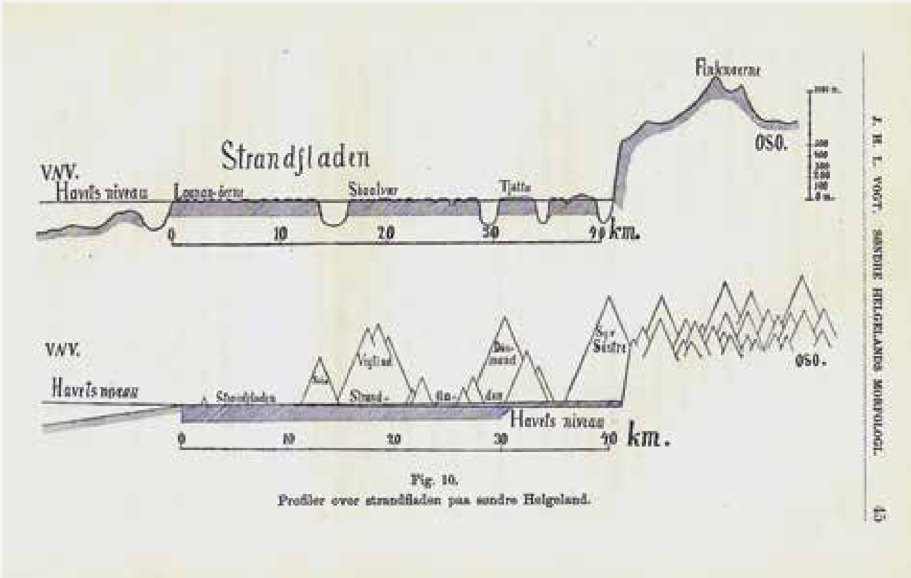
The Norwegian geologist Hans H. Reusch, who was a director of the Geological Survey of Norway 1888-1921, presented Trollfjell as one of several case studies when he launched the strandflat as a particular geomorphological feature (Reusch 1894). He was also the first to recognize ancient shorelines. More morphological and quaternary geology studies were followed up by Rekstad & Vogt (1900) and Rekstad (1915, 1916). Rekstad also made the first geological maps covering large parts of the area (Rekstad 1902, 1910). Renewed geological mapping (1:100 000 scale) took place by the Geological Survey of Norway much later (Myrland 1972, Myrland 1974), and these combined with other geological maps and investigations (Gustavson 1975a,b, 1978, Gustavson and Prestvik 1979) resulted in compilation of 1:250 000 bedrock maps (Gustavson 1982, Gustavson & Bugge 1995).

Geological map of Leka and Bindalsfjorden, from Rekstad 1909.

However, it was Prestvik (1972, 1980, 1985), and Prestvik & Roaldset (1978) who first saw the significance of the mafic and ultramafic rocks at Leka. In the light of the late 1960s new paradigm in geology of plate tectonics, Prestvik defined the Leka Ophiolite Complex, recognizing its ancient formation in a spreading ridge beneath the sea floor. This lead to several years of research at Leka. Furnes et al. (1988) added more knowledge, revealing the Leka Ophiolite as a uniquely preserved and displayed ophiolite complex containing all the diagnostic features from the mantle to the ocean floor. Moreover, they also identified the Leka Ophiolite as a supra-subduction type formed in a marginal basin setting, thus giving the first piece of the interpretation of the plate tectonics behind the formation of the rocks. Dunning & Pedersen (1988) provided a radiometric age of the ophiolite formation at 497 Ma. Several later studies have revealed new and exciting aspects of the Leka Ophiolite Complex (Pedersen, 1986, Pedersen et al. 1988, 1993, Furnes et al. 1992, Tveit et al. 1993, Maaløe 2005, Austrheim & Prestvik 2008, Daae et al. 2013).

The evidence for the Early Ordovician uplift and erosion of the Leka Ophiolite Complex were found at the base of sedimentary rocks (the Skei Group) deposited on top of the eroded ophiolite (Prestvik 1974, Sturt & Ramsay 1994).

In the 1980s, the University of Bergen carried out several student theses in the northern parts of the area, resulting in the identification of several ophiolite fragments and sedimentary cover sequences correlative to the Skei Group (Thorsnes & Løseth 1991, Heldal 2001). At the same time, research on the plutons of the Bindal Batholith was initiated (Nordgulen 1984, Nordgulen & Schouenborg 1990, Nordgulen & Sundvoll 1992, Nordgulen et al.



Drawing of the strandflat made by Vogt, from Rekstad & Vogt 1900

1993), and rocks previously believed to be “basement windows” were re-interpreted to actually represent plutons belonging to the Bindal Batholith (Hjelmeland 1987).

During the last 15 to 20 years, a research group from the Texas Tech University and University of Wyoming has provided significant new knowledge related to the granitoid magmatism and crustal evolution in the Trollfjell area. Several studies undertaken in the Velfjord area have significantly improved our understanding of middle crustal magmatism (Barnes et al. 1992, 2002, 2004, 2007, 2011, Dumond 2002, Dumond et al. 2005). To the north of Velfjord, Anderson et al. (2013) summarized the emplacement and evolution of the Andalshatten pluton.

Further petrological insights followed from the studies of the Hortavær intrusive complex, west of Leka (Barnes et al. 2003, 2005, 2009). A number of detailed studies were also carried out on the S-type granites and associated migmatites of the Vega Pluton (Oalmann 2010, Oalmann et al. 2011, Marko 2012, Marko et al. 2013).

The structural work and studies of magmatism have been combined with detailed work on selected units of meta-supracrustal rocks, providing important contributions to the tectonomagmatic and plate tectonic framework of the Trollfjell area (Barnes et al. 2007, 2011, Nordgulen et al. 2011, McArthur et al. 2013).

A major step forward in the interpretation of the geological history of the area came with the understanding of the link from the bedrock of Trollfjell to the Taconian Orogeny on the Laurentian side of the Iapetus Ocean. This was first proposed by Roberts et al. (2002), followed by Yoshinobu et al. (2002). Later, research has indeed supported that the supracrustal rocks of the Trollfjell area carry isotopic signatures from the Laurentian continent (McArthur et al. 2013).

The complex Late Cambrian and Ordovician evolution described above took place along the Laurentian margin. During the Scandian collisional phase of the Caledonian orogeny, around 400 million years ago, the earlier assembled rock complexes were thrust eastwards as a large, composite unit across subjacent nappes, and then finally onto the edge of the Baltoscandian margin (Roberts et al. 2007). Late to post-orogenic extensional collapse of the Scandian nappe pile is also evident in Trollfjell area and was documented in studies from the late 90s and onwards (Braathen et al. 2000, 2002, Nordgulen et al. 2002).

Although most of the recent research has concentrated on the bedrock geology, there are new and exciting contributions regarding the formation of sea caves (including Torghatten) (Lauritzen 2010, Lauritzen et al. 2011) and the ancient shorelines (Høgaas & Sveian 2015). New theories about the strandflat formation in Northern Norway was presented as recently as two years ago (Olesen et al. 2013).

Mining and prospecting activities have been caried out since the Late 19th century, and a full review of reports and scientific papers will demand too much space to include in this overview. However, good overviews are found in Vokes et al. (1990; gabbro-hosted metal ore, Leka), Ihlen (1993; Bindal gold deposits), Pedersen et al. (1993; platinum-group elements at Leka), Müller and Furuhaug (2008; tungsten deposits, Brønnøy) and Lindahl (2011; natural stone occurrences).

Of the 104 literature references given in the reference list, 71 are published in peer-reviewed scientific journals, of which 43 are in 18 different international scientific journals with high ranking. The SJR index for these journals in 2014 average 1.88, well within the top 20 geology journals.

The Trollfjell Geopark is still an arena of active research, with contributions from research groups from Norway and abroad. Several international conferences have, in recent years, arranged field trips to the area, and two Norwegian universities arrange annual field courses for the students at Leka.

ARGUING FOR GLOBAL SIGNIFICANCE: FIVE GEOLOGICAL AREAS IN TROLLFJELL GEOPARK

A key word for evaluating global significance in the Trollfjell Geopark is “visibility”. The bedrock is exposed and polished by glaciers so we are able to view features that remain hidden by weathering and soil cover in many other locations. We do not know if the Andalshatten Batholith is truly unique in the world, but we do know that the Trollfjell Geopark is the ideal place one can view and study these features.

Global significance should be judged on the value a site can offer to geoscience, either by providing type areas for global earth evolution models, or areas in which fundamental geological processes and features are displayed particularly well. The latter applies for Trollfjell Geopark.

- Leka provides an exposed slice through the oceanic lithosphere, where one can literally walk across the petrological and petrophysical Moho. It is possible to closely study the complexity of the mantle rocks and the transformation to ultramafic cumulates. The geology of the Leka Ophiolite is well published internationally and it is one of the key areas for identifying and understanding surpa-subduction zones ophiolites.

- The Bolvær archipelago is less well published, but we will argue that the site displays a wealth of geological information, where one can study both the depositional history of the metasedimentary rocks as well as their metamorphic and tectonic history. The site remains a treasure chest of information for specialists, and non-specialists alike.

- The Vega Intrusive Complex displays a range of magmatic rocks formed by partial melting of sedimentary rocks. The rarity of such an exposure may in itself be an argument for global significance. Furthermore, the excellent visibility of features, the occurrence of rare mineralogical compositions and features within the complex, such as layers and inclusions of non-assimilated remains of the sedimentary succession, makes it unique on a global scale. The site is also well published in international science journals.

- The Andalshatten Batholith provides an insight into deep crustal magmatism. Here you can see the preserved magmatic fabrics and contact between batholith and host rocks, as well as “ghost stratigraphy” and xenoliths of intruded host rocks. It provides a unique three dimensional display of features ideal for studying granitoid batholiths and deep crustal magmatism, and therefore is well documented and published in international science journals. These features are also clearly visible to the general public and the site may be one of the best in the world.

- The Torghatten mountain is an iconic landmark. An impressive hole, the most prominent evidence of the sea caves carved out during multiple Ice Ages, passes directly through the mountain. This has been a key tourist site for hundreds of years. But its iconic value is even greater than just a landmark and tourist site. It is enveloped in deep mythology connected to the mountains in the region. Kings have carved their names on the walls of the cave, and artists have depicted this site for centuries. Although there is only one recent international publication about its origin, the iconic and aesthetic values are indisputably global.

Several other features within the Trollfjell Geopark may prove to gain global value in the future, for example the raised shorelines carved in solid rock. Recent research also indicates that the strandflat in the area has a more complex history than previously assumed. The ongoing research in the area is significant, and it will reveal more secrets in the years to come.

Pillow lava at Leknesøyan.
Photo: A. Bergengren

LISTS OF GEOLOGICAL SITES

SELECTION OF GEOSITES

We have mapped 130 geosites, currently described in a geopark database. We see the database as something that should be updated continuously as new geosites appear and the status of the old ones changes. However, since the total number of sites in the database is high, a primary selection of the geosites that best represent our geological history and have the highest scientific, touristic or educational values was necessary. In this primary selection, 55 geosites were chosen. These are the ones we present here in this publication and the fact sheets, and they are the foundation for touristic and educational activities in the geopark today. The other 75 in the database work for example as a foundation for geoconservation activities in the area, and might be used more actively in the future.

Map over all geosites in Trollfjell Geopark.

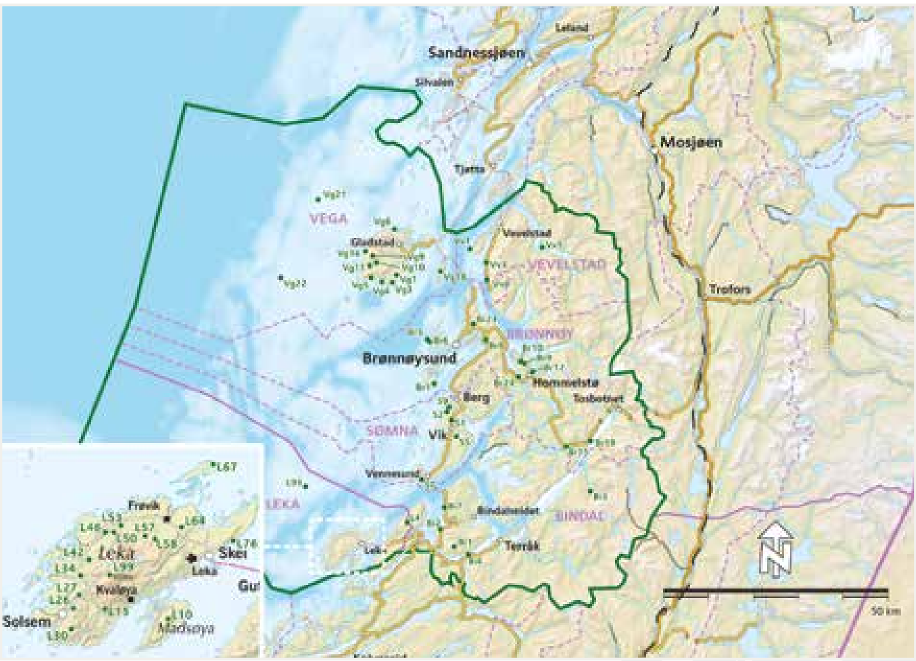


Table 2: **LISTING OF GEOSITES** (1/3)

No.	ID	Name	Type	Key words	Importance	Value
1	L4	Romsskåla and Sønndalslia	Viewpoint	Viewpoint, hiking destination, boundary western gneiss region and calc silicates, nature reserve.	REG	Educational, Touristic
2	L10	Madsøya	Complex Area	Leka Ophiolite Complex, basaltic dykes, pillow lava.	NAT	Scientific
3	L15	Hårfjellet Raised Shoreline	Section	Well extended raised shorelines, terrace in mountain side, sea level changes, quaternary geology.	NAT	Scientific, Educational, Touristic
4	L26	Emaomn	Point	Serpentine conglomerate, hiking destination.	NAT	Scientific, Educational, Touristic
5	L27	Løva	Point	Mountain formation, hiking destination, asbestos.	LOC	Touristic
6	L30	Lekamøya	Point	Mountain formation, hiking destination, mythology.	REG	Touristic
7	L34	Raudstein	Area	Leka Ophiolite Complex, layering, gabbro in dunite, folding structures.	INT	Scientific, Educational
9	L46	Steinstind Area	Complex Area	Leka Ophiolite Complex, Viewpoint, Scientific test site, geobiology, dunite massive.	NAT	Scientific, Educational, Touristic
10	L50	Støypet	Area	Raised shoreline, raised beach ridges, well-rounded stones, rock formations, quaternary geology.	REG	Scientific, Educational, Touristic
11	L53	Chromite	Area	Leka Ophiolite Complex, Chromite, Platinum group elements.	NAT	Scientific, Educational
12	L57	Layered red mountains	Area	Leka Ophiolite Complex, layered ultramafic bedrock, strong colours.	INT	Scientific, Educational, Touristic
13	L58	MOHO	Area	Leka Ophiolite Complex, MOHO, boundary harzburgite / dunite, hiking destination.	INT	Scientific, Educational, Touristic
14	L64	Nordlauvhatten	Area	Leka Ophiolite Complex, Harzburgite, foliation.	INT	Scientific, Educational, Touristic
15	L67	Leknesøyan	Area	Leka Ophiolite Complex, well-preserved pillow lava, deep sea vulcanic activity.	INT	Scientific, Educational, Touristic
16	L76	Skeisnesset Geology Trail	Complex Area	Skei Group, sedimentary bedrocks, geology trail.	NAT	Scientific, Educational, Touristic
17	L93	Hortavær	Complex Area	Hortavær complex, layered magmatic intrusion, Horta Nappe.	NAT	Scientific
18	L99	Leka mountains	Complex Area	Leka Ophiolite Complex, Hiking destinations, View-points, Mountain formations, highest peak, cairn.	REG	Touristic
19	Br1	Torghatten	Point	Cave tunnel through the mountain, tourist attraction, granite.	INT	Scientific, Educational, Touristic
20	Br5	Bolvær	Complex Are	Metamorphosed sedimentary bedrock, ophiolite frag-ment, Bolvær complex.	INT	Scientific, Touristic
21	Br6	Stor-Esjeøya	Point	Historical soapstone quarry, Bolvær complex.	REG	Scientific, Educational, Touristic
22	Br8	Skomo-Kverntind	Point	Millstone production, garnet mica-schist.	NAT	Scientific, Educational, Touristic
23	Br9	Engavatnet	Point	Karst system, disappearing lake, turlough.	INT	Scientific, Educational, Touristic
24	Br10	Aunhola	Point	Cave, karst system, ice age processes, blue marble.	REG	Scientific, Educational, Touristic

INT= International. NAT=National. REG=Regional. LOC=Local. (microscope) = Scientific. (graduation cap) = Educational. (hiker) = Touristic.

Table 2: **LISTING OF GEOSITES** (2/3)

No.	ID	Name	Type	Key words	Importance & Value	
25	Br12	Rugåsnesodden	Point	Old marble quarry, cubic block, linear sawing, karst.	NAT	Educational, Touristic
26	Br15	Aunlia road cuts	Point	Road cuts, semipelitic and calc-silicate schist.	REG	Scientific
27	Br19	Tosenfjord resting place	Point	Deformed rocks, folding, migmatites, tonalites.	REG	Scientific, Touristic
28	Br23	Tilremshatten	Viewpoint	Hiking destination, viewpoint, pot holes, mica-garnet schist.	LOC	Educational, Touristic
29	Br24	Oterhola	Point	Karst cave.	LOC	Scientific, Touristic
30	Vg1	Kjulsveten	Viewpoint	Viewpoint, hiking destination, cairn.	REG	Touristic
31	Vg3	Hestvika	Section	Raised beach ridges, marine limits, sea level changes.	LOC	Educational, Touristic
32	Vg4	Vikavågen	Area	Calc-silicate xenolith, granodiorite, folding structures.	NAT	Scientific
33	Vg5	Levika	Point	Vega granite, diversity of enclaves, magmatic fabrics.	INT	Scientific, Educational, Touristic
34	Vg6	Guristraumen	Area	Sedimentary bedrock, rich flora, hiking destination.	REG	Educational, Touristic
35	Vg9	Gullsvågfjellet	Viewpoint	Hiking destination, viewpoint.	REG	Educational, Touristic
36	Vg10	Moen 2	Area	Aeolian processes, active sand dunes.	LOC	Educational, Touristic
37	Vg11	Vegdalsskaret 1	Point	Younger Dryas local cirque moraine.	LOC	Scientific, Educational, Touristic
38	Vg16	Sundsvoll coast-line and Søla	Complex Area	Island, granite mountain, coastline, rounded boulders, enclaves.	INT	Scientific, Educational, Touristic
39	Vg18	Ylvingen Island	Complex Area	Biotite granite, metasedimentay rocks, metavolcanic rocks.	INT	Scientific, Touristic
40	Vg21	Lånan-Skjærvær	Area	Strandflat Islands, World Heritage Area.	INT	Touristic
41	Vg22	Bremstein	Point	Breakwater, granite, local stone production.	LOC	Touristic
42	Vv1	Esøya	Complex Area	Contact gabbro conglomerate, thrusting, Soapstone quarry, runic inscription.	NAT	Scientific, Touristic
43	Vv3	Høyholm	Point	Grey porphyry granite, building stone, quarry.	LOC	Touristic
44	Vv4	Vollvika	Point	Folded metasedimentary rocks, Igneous rocks, granite, xenoliths.	INT	Scientific, Educational, Touristic
45	Vv5	Vistenfjorden	Area	Fjord, quaternary geology, pot holes, caves.	REG	Touristic
46	Bi1	Heilhornet	Viewpoint	Viewpoint, hiking destination, iconic mountain.	NAT	Scientific, Touristic
47	Bi2	Lysfjordmana	Section	Terminal moraine, Younger Dryas ice-sheet readvance.	REG	Scientific, Educational
48	Bi3	Kolsvikbogen Gold Mines	Point	Gold mines, mineral extraction.	REG	Scientific, Touristic
49	Bi4	Sandvika Quarry	Point	Marble quarry, marble conglomerate.	LOC	Scientific

INT= International. NAT=National. REG=Regional. LOC=Local. (Scientific icon) = Scientific. (Educational icon) = Educational. (Touristic icon) = Touristic.

Table 2: **LISTING OF GEOSITES** (3/3)

No.	ID	Name	Type	Key words	Importance & Value	
50	Bi7	Guldvikhaugen granite dykes	Point	Granite dykes.	REG	Scientific
51	S1	Rødbergan	Point	Soapstone quarry, serpentinite.	LOC	Scientific, Touristic
52	S2	Triborgen	Point	Raised shoreline, quternary geology, local mythology.	LOC	Educational, Touristic
53	S5	Stein Potholes	Point	Potholes, hiking destination.	LOC	Touristic
54	S7	Kvennvika minerals	Point	Beach, minerals, recreational area.	LOC	Educational, Touristic
55	S9	Sømnesfjellet	Viewpoint	Viewpoint, hiking destination.	LOC	Touristic

INT= International. NAT=National. REG=Regional. LOC=Local. (Scientific icon) = Scientific. (Educational icon) = Educational. (Touristic icon) = Touristic.

GEOSITES FACT SHEETS

The fact sheets provide information about each geosite, including its type, importance, value, protection, vulnerability and accessibility.

1. Type

A geosite can be of five different types after Fuertes-Gutierrez & Fernandez-Martinez (2012, pp. 61–62), somewhat abbreviated:

Point: Small, isolated features (In this document, not larger than 1 ha.)
Section: Chronological sequences and/or features having a linear spatial development (In this document, this includes different features along a trail, e.g. Leka geology trail.)
Area: Larger sites including just one type of interest.
Complex area: Larger geosites with a physiographic homogeneity. They are composed of several points, sections, areas and/or viewpoints.
Viewpoint: A viewpoint includes two different elements: a large area of geological interest and an observatory from where this area may be viewed.

2. Importance

The importance of sites is divided into four categories, International (INT), National (NAT), Regional (REG), or Local (LOC).

An international (national, regional, local) geosite is:
A geosite that displays geological features unique on an international (national, regional, local) level in terms of its scientific, educational or aesthetic values AND/OR the geosite shows geological features important for understanding the creation of the Earth on an international (national, regional, local) scale.

In addition, whether the geosite or the features seen at the site are described in an internationally published scientific paper might be the determining factor for a site to be judged as internationally important.

3. Value

As far as value is concerned, geosites are divided into three groups, Scientific (SCI), Educational (EDU), or Touristic (TOUR). Some sites may only have one value, while others may have two or three values.

Value:

= Scientific.
= Educational.
= Touristic.

Scientific value (SCI): the site shows scientific features important to geological science, is mentioned in scientific reports, or is visited during scientific excursions.
Educational value (EDU): the site shows features in a clear and educational way, so that people with no previous or limited knowledge of geology can learn from visiting the site. This could be a regular venue for tourists or schoolchildren.
Touristic value (TOUR): the site has a high aesthetic value and can offer a wide range of experiences besides the geological features. This is a place that attracts tourists even though they have no specific interest in geology.

Please note: Educational and Touristic values depend a lot on facilities at the place. Good information signs, footbridges, good paths, etc. can easily increase these values.

4. Protection

Protection status says whether the geosite, at the moment, has any form of protection. The types of protected areas existing in Norway today are:

- Biosfærereservater (Biosphere Reserve)
- Nasjonalparker (National Park)
- Landskapsvernområder (Landscape Protection Area)
- Naturreservat (Nature Reserve)
- Dyre-, fugle- eller plantefredningsområder (Animal, Bird, or Plant Sanctuary)
- Naturminner (Natural heritage)
- Biotopvern (Biotope protection)
- Geotopvern (Geotope protection)

5. Vulnerability

The vulnerability of a site defines the extent to which the site is exposed to human or natural threats. This might be at the present day or in a scenario where the number of visitors increases. Divided into three categories, High, Medium and Low.

High: The geosite is, or might be, severely exposed to threats.
Medium: The geosite is, or might be, moderately exposed to threats.
Low: Robust site where there is no risk of exposure either at the moment or if the number of visitors increase.

At Støypet, Leka.
Photo: A. Holand

6. Accessibility
Accessibility determines how easy or difficult it is for visitors to reach the site. This is judged after Norwegian hiking standards, and each geosite is marked as green●, blue●, red● or black●. For the exact criteria for each colour, the manual can be downloaded from this site (in Norwegian only):
http://www.innovasjonnorge.no/no/Reiseliv/Nyheter/ny-merke-handbok-viser-vei-i-norsk-natur/#.Uuga4mTsS2x

Some of our sites are situated on islands only accessible by boat. For them, we mark the accessibility as BOAT.

All geosites described as points
Even for the geosites described as areas, we have decided to describe them with one GPS point, and as one point on the map. That is the point where we believe a visitor can best experience the geology, even if it is seen in a larger area. All geosites are therefore visualised as points on the map, rather than polygons.

At Solsem, Leka.
Photo: A. Holand

FACT SHEETS INDEX:

L4 Romsskåla and Sønndalslia	50
L10 Madsøya	52
L15 Hårfjellet Raised Shoreline	54
L26 Emaomn	56
L27 Løva	58
L30 Lekamøya	60
L34 Raudstein	62
L46 Steinstind area	64
L50 Støypet	66
L53 Chromite	68
L57 Layered red mountains	70
L58 MOHO	72
L64 Nordlauvhatten	74
L67 Leknesøyan	76
L76 Skeisnesset Geology trail	78
L93 Hortavær	80
L99 Herlaugsløypa (Leka mountains)	82

Br1 Torghatten 84
Br5 Bolvær 86
Br6 Stor-Esjøya 88
Br8 Skomo-Kverntind 90
Br9 Engavatnet 92
Br10 Aunhola 94
Br12 Rugåsnesodden 96
Br15 Aunlia road cuts 98
Br19 Tosenfjord resting place 100
Br23 Tilremshatten 102
Br24 Oterhola 104
Vg1 Kjulsveten 106
Vg3 Hestvika 108
Vg4 Vikavågen 110
Vg5 Levika 112
Vg6 Guristraumen 114
Vg9 Gullsvågfjellet 116
Vg10 Moen 2 118
Vg11 Vegdalsskaret 1 120
Vg16 Sundsvoll Coastline and Søla 122
Vg18 Ylvingen island 124
Vg21 Lånan-skjærvær 126
Vg22 Bremstein 128
Vv1 Esøya 130
Vv3 Høyholm 132
Vv4 Vollvika 134
Vv5 Vistenfjorden 136
Bi1 Heilhornet 138
Bi2 Lysfjordmana 140
Bi3 Kolsvikbogen gold mines 142
Bi4 Sandvika quarry 144
Bi7 Guldvikhaugen granite dykes 146
S1 Rødbergan 148
S2 Triborgen 150
S5 Stein potholes 152
S7 Kvennvika minerals 154
S9 Sømnesfjellet 156

L4
ROMSSKÅLA AND SØNNDALSLIA

To the east of Leka municipality - on the island Austra - the bedrock is completely different from the Leka ophiolite complex. Austra forms the northernmost part of the Western Gneiss Region and consists mainly of Paleo-proterozoic orthogneisses (1800-1850 million years old) with in-folded thrust sheets of mica schist, calc-silicate schist, marble and amphibolite. The orthogneisses are correlated with the Svecofennian province in Sweden, weheras the metamorphic rocks in the thrust sheets have been assigned to the Skjøtingen Nappe (a local equivalent of the Seve Nappe). The metamorphic rocks in the thrust sheets probably formed along the outer margin of Baltica. Thus, in contrast to the situation in Helgeland and Leka, where the rocks formed along the Laurentian margin, the rocks on Austra have their origin in Baltica. These contrasting rocks units were juxtaposed as a result of the Laurentia-Baltica collision during the final phase of the Caledonian orogeny around 400 million years ago. Local, early Silurian migmatitization of the orthogneisses was a response to the stacking of rock units during the collision.

A marked hiking trail leads to the top of Romsskåla, which is the highest peak in the municipality, 588 m.a.s.l. The hiking trail passes close to Sønndalslia, an area underlain by the Baltican metamorphic rocks; i.e. lime-rich meta-sedimentary bedrock such as calc-silicate schist and gneiss, marble and calcareous schist as well as biotite-rich sandstone and micaceous schist. This area has a high biodiversity with a boreal rainforest, and is protected as a natural reserve.

Tourists use this site as a hiking destination. The difference between the different bedrock and vegetation make this site suitable for education purposes.

KEY WORDS: Viewpoint, hiking destination, boundary western gneiss region and calc silicates, nature reserve.

THREATS: There are currently no threats to this site, since the area with more vulnerable bedrock has legal protection as a nature reserve.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geobiosphere, Metamorphic.

VALUE:

PROTECTION: Nature Reserve.

VULNERABILITY: Low.

ACCESSIBILITY: Red

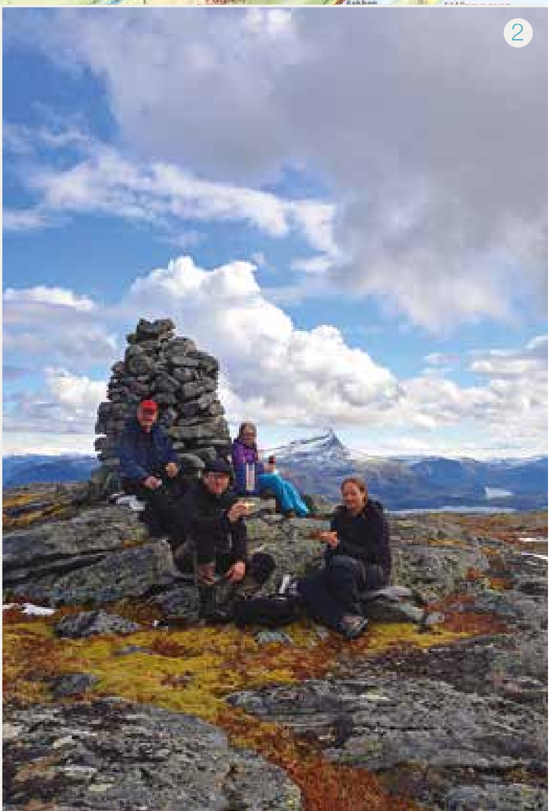
GPS POSITION:
UTM 32W 0637754 7225777
65°7'36.0"N 11°56'9,4"E

❶ *View from the trail up to Romsskåla.*

❷ *View from the top of Romsskåla.*

Photos: K. Floa


Vattafjellet
Romsskåla
L4
Sundsvika
Nord-Gutvika
Holdar
fjellet
Romsgården
Melkartuva
Nordhorsfjord
Hornfjellet
Stongfjellet
Horsfjordøya
Mølleroya
Søhorsfjord
Skjevelneset
Med-Gutvika
Fuglen

1

2

L10
MADSØYA

The eastern part of the island Madsøya east of Leka consists of different varieties of basaltic dykes. The dyke complex, being about two kilometres thick, represents a high stratigraphic level of the Leka ophiolite. To recognize the dyke complex is perhaps not straightforward for non-geologists. However, the best place for a stop would be a walk along the hiking trail at Tanganodden, where outcrops of basaltic dykes are seen close to the sea.

Pillow lava can be observed at the outcrops near Madsøygalten lighthouse, but are more easily studied on geosite L67, Leknesøyan.

Madsøya is mainly a scientific site.

KEY WORDS: Leka Ophiolite Complex, basaltic dykes, pillow lava.

THREATS: There are currently no threats to this large area.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0626360 7217565
65°3'27.4"N 11°41'9.6"E

READ MORE:
Prestvik 1980.

❶ From Haliberget, the highest peak on Madsøya.

❷ From Madsøygalten, pillow lava on the east coast of Madsøya.

Photos: A. Holand

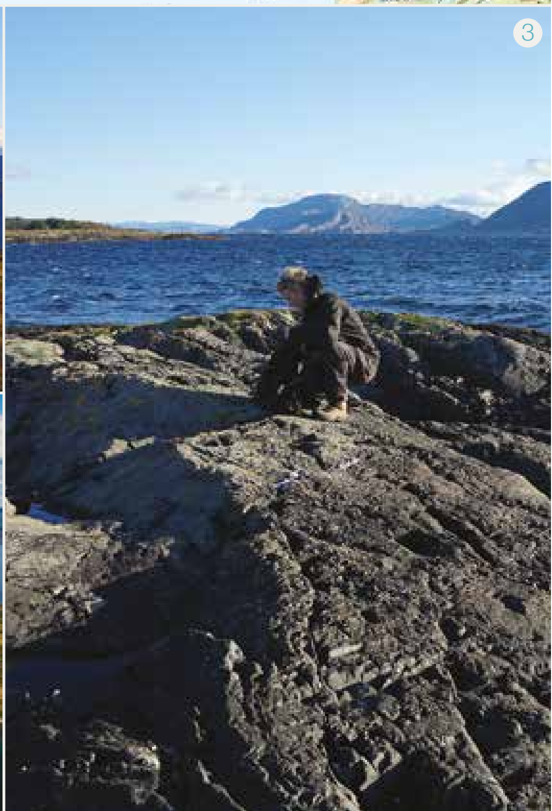
❸ Arial photo of Madsøya.

Photo: News on Request

Madsøygrenda
Madsøya
Halgeberget
L10
Frøviksundet
Frøvikøya
Frøvika
Gongstøa
Dalavika
Juvika
Kobbskjærbukta
Ovden
Madsøygalten
Tangan
Haugvik
Enneskson
Åsheim
Hogmo
Fjellset
Sjøstrand
Hårfjellet
Over-Kvervika
Brekka
Haug
Nordheim
Moen
Utheim
Stortinden
Trollfjellet
Solstad
Kukleppen
Haravollan
Bjørkly
Haugstranda
Storvarden
Ardalssanden
Halen
Haugsflesa
Leiskjæran
Lekatinden
Vattinden
L99
L27
L15
L26
L30
Steinsvatnet
Vestgård
Kleiva
Solheim
Husby
Husbysjøen
Havneholmen
Stortinden
Høgbakken
Solli
Solbakken
Nyrommet
Vikamoen
Klungvika
Knerten
Øya
Kattvika
Reppafjellet
Snåget
Heller
Lakshammaren
Hestvika
Småholman
Hestvikodden
Skotnesmyra
LEKAFJORDEN
1 km

1

2



3

L15
HÅRFJELLET RAISED SHORELINE

At Leka a shoreline level of ca 110 m.a.s.l. is easily recognized in many places, but is probably most spectacular at Hårfjellet, where it is developed as a wide terrace 108-110 m.a.s.l.. In some parts the terrace is 30–40 meters wide.

Out of several shorelines formed after the last Ice Age, the noteworthy main shoreline is a unique phenomenon in the Quaternary geology of Norway, and it is especially well developed in northern Norway. As the land rose relatively fast after as the ice had melted, falling sea levels left few traces in the landscape. However, occasionally the sea level remained constant long enough for visible shorelines to be eroded in solid rock or loose material. The main shoreline here was probably formed during Younger Dryas (12.800 - 11.500 years ago), when the rim of the ice sheet was at Lysfjordmana (geosite Bi2), about 20 km east of Leka.

The main shoreline can be observed at several sites in the geopark, but the terraces near Hårfjellet, and on Leka in general, are remarkable features and a great way of observing and illustrating the sea level changes.

The geosite has been used for science, but there is a potential for tourism and education. A trail on the terrace would be easy to arrange.

KEY WORDS: Well extended raised shorelines, terrace in mountain side, sea level changes, quaternary geology.

THREATS: Unless the numbers of visitors increase by large numbers, there are no threats to this site.

TYPE: Section.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0622701 7217776
65°3’39.2”N 11°36’30.6”E

READ MORE:
Høgaas & Sveian (2015).

Hårfjellet raised shoreline, a wide terrace 108–110 m.a.s.l.

❶❷ Photo: A.Holand
❸ Photo A. Bergengren


fjellet
Neivatnet
Storvet
Leka
Husby
Gjerde
Fagertun
Vollan
L42
Sørålva
Aunkollen
Gjerdevatnet
Steinsvatnet
Storfinden
Aunet
Kolsetsava
L99
Vattinden
Lomtjønna
Vikamoen
Buøya
Vågan
L34
Lekatinden
Vågøya
Engan
Ovden
Frøvikmyra
Klungvika
Knerten
Solheim
Steinsøya
Vestengan
Frøvika
Raudberget
Madsøyvågen
Vågsundet
Strønda
L27
Hårfjellet
Madsøygrenda
Kalvøya
Brekka
Øver-Kvernvika
Frøvik
Lamholman
Vollan
L15
Fjellset
Halgeberget
L26
Liss-
leka
Storsellivågen
Langhalsberget
Utheim
Sjøstrand
L10
Madsøya
Gongsto
Solsem
Stortinden
Haug
Nordheim
Frøviksundet
Moen
Enneåsen
Lekamøya
L30
Haug
Haugvik
Åsheim
Raudøya
Middags-
aksla
Haravollen
Bjørkly
Ovden
Visholmen
Jåholmen
Haugstranda
Madsøygalten
Battan
Brørn
Oterholmen
Solsemvågen
Gjertrud-
vika
Storvarden
Årdalssanden
Tangan
Haugsflesa
Halen
Leiskjæran
Surnholmen
Breivika
Solsemvika
Solsemholmen
N
1 km
LEKAFJORDEN

1

2

3

L26
EMAOMN

Along the trail towards Solshemhula, one passes a serpentine conglomerate named Emaomn, which has been claimed to be Norway's youngest bedrock feature. The deposit is very loosely consolidated and covers only a small area.

This site is used for science, education, and tourism. Since located on the way to Solsemhula, many visitors come this way, mainly on guided tours.

KEY WORDS: Serpentine conglomerate, hiking destination.

THREATS: This site is considered very vulnerable. Actions to prevent damage are needed, and there are plans to build a fence around the area to protect it from increasing tourism.

TYPE: Point.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: High.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0620889 7217632
65°3'37.0"N 11°34'11.7"E

READ MORE:
Bøe & Prestvik (1974).

❶❷❸ Emaomn, serpentine conglomarate. The extension of the conglomerate shown by the black circle on photo no. 3.

Photos: A. Bergengren


Skipsflesin
Gjerdet
Fagertun
fjellet
Neivatnet
Støyvet
L42
Aunkollen
Gjerdevatnet
Steinsvatnet
Johalmen
Auhet
Kolsettsiva
Buøya
L99
Vattinden
Lomtjønna
Vestgard
Raudsteinfjellet
L34
Vågan
Vågøya
Engan
Lekatinden
Oyden
Vestengan
Steinsøya
Raudberget
Kleiva
Frøvika
L27
Hårfjellet
Brekka
Kalvøya
Vågsundet
Over-Kvernvika
Frøvikøya
Lamholman
L26
Vollan
L15
Fjellet
Havholman
Storsellivågen
Austaker
Utheim
Sjøstrand
Sendingan
Langhalsberget
Frøviksundet
Solsem
Haug
Nordheim
Stortinden
Storhusberget
Lekmøy
Moen
hammaren
Trollfjellet
Solstad
Kukleppen
Haug
Haugvik
Lekamøya
L30
Raudøya
Middagsaksla
Haravollan
Bjørkly
flesa
Visholmen
Jåholmen
Ardalsmoen
Storvarden
Haugstranda
Flatskjeret
Bøttan
Oterholmen
Gjertrudvika
Ardalssanden
Brem
Tangan
Halen
Haugsflesa
Surnholmen
Breivika
Leiskjæran
Solsemvika
Solsemholmen
Kalven
N
1 km
LEKAF


1


2


3

L27

LØVA

A common feature for the whole geopark area is the local names on mountain formations given by the native people. Some have their names from stories, such as the one about Torghatten and Lekamøya. Others are named after their appearance, such as Løva. Løva means lion in Norwegian, and – from a distance – the shape of this mountain resembles a lion. A short hiking trail leads the way up from the main road. Close to the trail, natural asbestos can be found in the bedrock.

Solsemløva was formed by frost shattering and sea-ice abrasion during the cold Younger Dryas chronozone. The platform on which it stands coincides with the altitude of the raised shoreline around Hårfjellet (geosite L15).

The local population uses this site as a hiking destination with a marked trail. It is possible to to develop it into a site for tourists.

KEY WORDS: Mountain formation, hiking destination, asbestos.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geoculture, Mineralogical.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION
UTM 32W 0621143 7218437
65°4’2.6”N 11°34’33.6”E

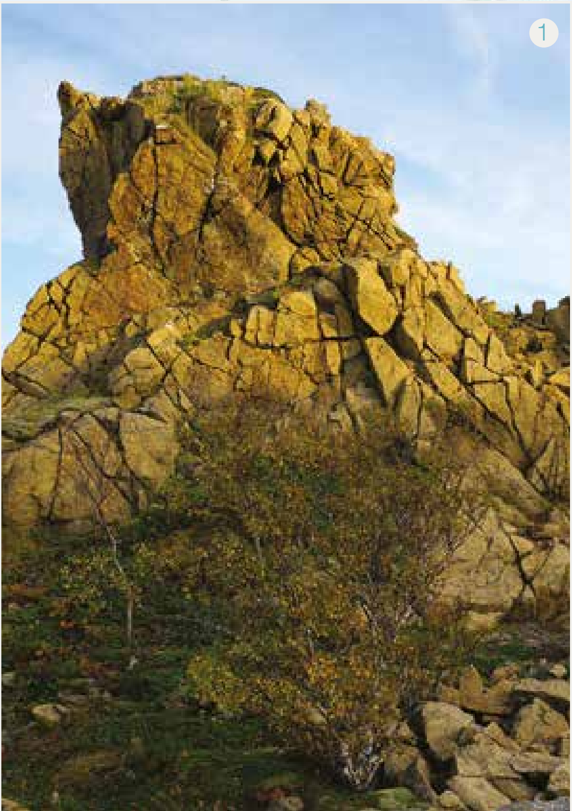
READ MORE: Høgaas (2015).

❶ The mountain Løva is a popular hiking destination.

❷ Asbestos seen along the trail to the top.

Photos: A. Bergengren


Steinsøya
Haga- fjellet
Stein
Leknes-
fjellet
Hundorar
Skipsflesin
Vollan
Gjerdet
Fagertun
Nesvatnet
Stervet
L42
Aunkollen
Gjerdevatnet
Steinsvatnet
Aunet
Kolsettuva
Vestgård
Joholmen
Raudstein-
L34
fjellet
L99
Vattinden
Lomtjønna
Buøya
Vågan
Vågøya
Lekatinden
Frøvikmyra
Engan
Ovden
Kleiva
Frøvika
Steinsøya
Vestengan
Raudberget
L27
Hårfjellet
Kalvøya
Vågsundet
Over-Kvernvika
Frøvik-
øya
Lamholman
L15
Fjellet
Vollan
L26
Lissleka
Havs-
holman
Sendingan
Storsellvågen
Langhalsberget
Utheim
Sjøstrand
Frøviksundet
Solsem
Stortinden
Nordheim
Storhus-
berget
Lekmar-
hammaren
Moen
Trollfjellet
Solstad
Haug
Lekamøya
L30
Kukleppen
Haugvik
Raudøya
Middags-
aksla
Haravollan
Bjørkly
Vaholmen
Jåholmen
Årdals-
moen
Storvarden
Haugsstranda
Flatskjeret
Bøttan
Oterholmen
Gjertrud-
vika
Årdalssanden
Tangan
Brørn
Halen
Haugeflesa
Leiskjæran
1 km
Surnholmen
Breivika
Solsemvika
Solsemholmen


1


2

L30
LEKAMØYA

The most famous named mountain formation on Leka is Lekamøya, a vertical rock formation named from the famous saga about the mountains at the Helgeland coast. Lekamøya was the beautiful maiden escaping from Hestmannen and turned to stone as the sun rose. Lekamøya is a popular local hiking destination with a marked hiking trail. Lekamøya and the surrounding bedrock is gabbro. Along the trail one passes several examples of the old sea levels: wave abraded rocks, kettle holes and raised shorelines.

Lekamøya is a raised sea-stack formed by frost shattering and sea-ice abrasion during a relative sea level standstill in Younger Dryas. The cold period resulted in extensive bedrock erosion on the entire island and this led to the formation of peculiar sea-stacks, like Lekamøya and Solsemløva.

This is a touristic site, used both by the locals and foreigners.

KEY WORDS: Mountain formation, hiking destination, mythology.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geoculture, geomorphology.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION
UTM 32W 0620892 7216453
65°2'58.9"N 11°34'8.2"E

READ MORE: Høgaas (2015).

1 Lekamøya is a popular hiking destination, with a trail going either from Haug or from Solsem.

Photo: A. Holand


Vågan
Engan
Vestengan
Raudberget
L34
L99
Vattinden
Lekatinden
L27
Brekka
Hårfjellet
Vågøya
Steinsøya
Kalvøya
Vågsundet
Lamholman
Havs-
holman
Sendingan
Storsellvågen
Langhalsberget
Vollan
L26
Liss
Auståker
leka
L15
Utheim
Stortinden
Frøviksundet
Frøvik-
øya
Nordheim
Solsem
Storhus-
berget
Lekmøy-
Trollfjellet
Solstad
Kukloppen
Haug
Moen
L30
Haugvik
Raudøya
Visholmen
Jåholmen
Flatskjeret
Bøttan
Otterholmen
Brøm
Bjørkly
Haravollan
Årdals-
moen
Storvarden
Årdalssanden
Haugstranda
Gjertrud-
vika
Halen
Haugsflesa
Tangen
Leiskjæran
Breivika
Solsemvika
Solsemholmen
Surnholmen
Kalven
LEKAF
Vattavika
Storkvitholmen
Dolmøya
1 km


1

L34
RAUDSTEIN

Raudstein is a common stop on geological excursions to Leka, a short walk from the main road. The main feature being gabbro sheets in layered ultramafic rocks (serpentinized dunite and pyroxenites). This indicates we are at a high stratigraphic level in the ultramafic part of the ophiolite, close to the transition between ultramafic rocks and gabbro. This level coincides with the geophysical MOHO, i.e. where there is an abrupt change in seismic velocity.

This is a scientific site, but also used for education at university level.

KEY WORDS: Leka Ophiolite Complex, layering, gabbro in dunite, folding structures.

THREATS: There are currently no threats to this site.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0621133 7219564
65°4'39.0"N 11°34'36.3"E

READ MORE: Prestvik (1980). Pedersen (1986).

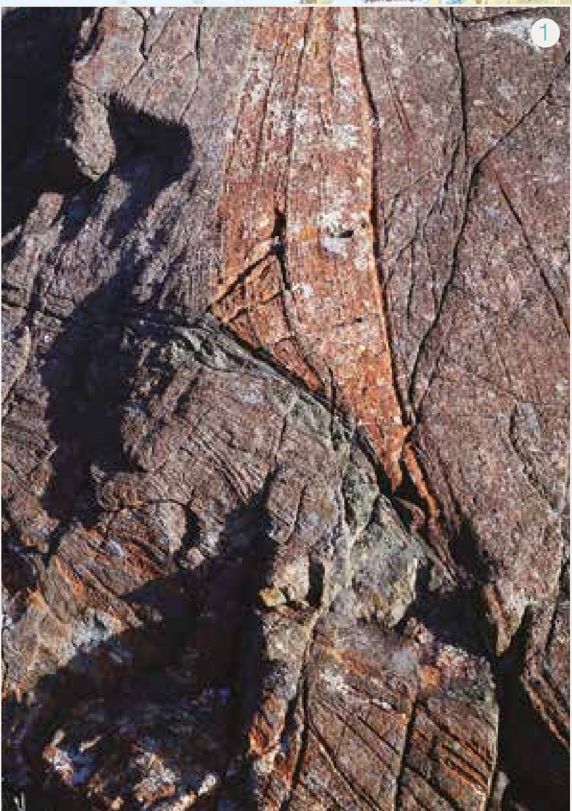
❶ Layered pyroxenite.

❷ The first layer of gabbro in the ultramafic rocks marks the tranistion to the high plutonic level og the Leka Ophiolite.

❸ Geologists on field trip to Raudstein.

Photos: A. Holand


LEKA
Nerskardfjellet
Steins-
tinden
Mannatinden
L53
L46
L50
L57
L58
Haga-
fjellet
Stein
Leknes-
fjellet
Steinsøya
Steins
sjøen
Vollan
Fagertun
Skipsflesin
Gjerdet
Gjerdevatnet
L42
Søråelva
Aunkollen
Steinsvatnet
Nesvatnet
Storvet
Hunderan
Aunet
Kolsetlauva
Vestgård
Joholmen
Buøya
Vågøya
Vågan
Raudste
L34
fjellet
Engan
L99
Vattinden
Lomtjønna
Lekatinden
Frøvikmyra
Ovden
Kleiva
Frøvika
Steinsøya
Vestengan
Raudberget
L27
Brekka
Hårfjellet
Kalvøya
Vågsundet
Lamholman
Over-Kvernvika
Frøvik-
øya
Vollan
L26
L15
Fjelhet
Havs-
holman
Storselivågen
Lissleka
Utheim
Sjøstrand
Frøviksundet
Sandingan
Langhalliberget
Austeket
Stortinden
Haug
Nordheim
Sølsem
Storhus-
berget
Lekmo
hammaren
Moen
Teplitjellet
Soltad
Kuldeppen
Haug
Haugvik
Lekamøya
L30
Middags-
aksla
Haravollan
Bjørkly
Raudøya
Visholmen
Jåholmen
Haugstranda
1 km


1


2


3

L46
STEINSTIND AREA

Together with Lekamøya, Steinstind is the most symbolic mountain on Leka. Rising as a high peak in bright yellow color, it is the best representative of the dunite massif in the ophiolite sequence. The top can be climbed from geosite L50, Støypet, and although the climb is somewhat steep, the view from the top is worth the effort. From here, one can see the layered ophiolite complex and the arid, lunar-like landscape coloured in bright yellow and red, together with the strandflat archipelago extending towards the horizon. On the north side of Steinstind, just by the road, there is a scientific test site where UiB has collected samples for geobiology studies. There is an on-going project to study microbial communities in ultramafic rocks, and the dunite at Leka provides a good model system.

At the top of Steinstind and the neighbouring peak of Mannatind there are archeological remains of fortresses from pre-historic ages. These are protected as a cultural heritage.

This site is used for science, education and tourism.

KEY WORDS: Leka Ophiolite Complex, viewpoint, scientific test site, geobiology, dunite massive.

THREATS: There are currently no threats to this site.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA:
Igneous, Geobiology, Geoculture.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: Low.

ACCESSIBILITY: Red.

GPS POSITION:
UTM 32W 0622297 7222163
65°6'1.3"N 11°36'13.6"E

READ MORE:
Albrektsen et al. (1991).
Daae et al. (2013).

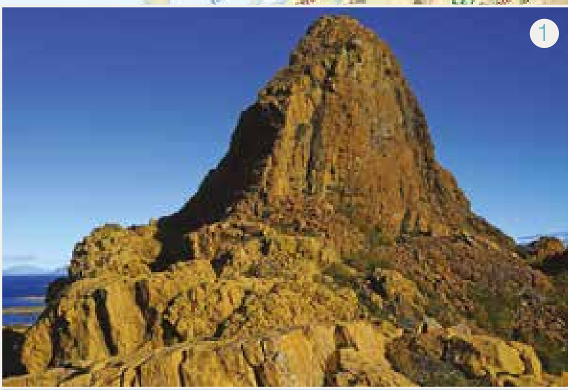
❶ *Steinstind is one of the most known landmarks on Leka.*

❷ *Scientific test site for the Univesity in Bergen (UiB).*

❸ *Remains of the fortress on Mannatind top.*

Photos: A. Bergengren


Havøydrenkern
Oterholman
Hestøya
Kvaløysteinen
Skrosen
Kvaløya
Semningan
Stonghaugen
Skråmoen
Røyrskjæret
Lottholmen
Klintholmen
Kvaløy-
moen
Skråen
Sørå
Kvaløya
Lauhatten
L64
L53
LEKA
Nerskardfjellet
L46
Stein-
tinden
L50
L57
L58
Sørlauhatten
Mannatinden
Leknes
Steinsøya
Haga- fjellet
Stein
Hundøran
Vollan
Leknes-
fjellet
Skipsflesin
Fagertun
Gjerdet
Neswatnet
Størvet
Storlinden
L42
Sørelva
Aunkollen
Gjerdevatnet
Steinsvatnet
Haugbakken
Nyrommet
Johnolmen
Auneet
Kolsettuva
Vestgård
Ramtindmoen
Raudstein-
fjellet
L99
Vattinden
Lomtjønna
Vikamoen
Buøya
L34
Vågan
Lekatinden
Frovikmyra
Klungvika
Vågøya
Engan
Ovden
Klerna
Solheim
1 km
Vestengan
Frøvika
Steinsøya
Brikdalselva
Raudberget
L27
Hårfjellet
Øya


1


2


3

L50
STØYPET

Earlier the old road on Leka went over Støypet, a large area with rounded stones in several raised shorelines.

Today there is a hiking path along the old road, and the rounded stones in bright colors leave a strong impression on any visitor. The mountain Steinstind rises in one side of the area, and the particular mountain formation with the local name Lisstind rises on the other (eastern) side. The surrounding bedrock is mainly dunite with some pyroxenite. In some parts the bedrock is layered at a quite large scale, giving an impression of striped mountains.

On the way from Støypet to Stein, one pass by several distinct beach ridges, clear indicators of a much higher sea level in the past. Here, countless fierce storm-waves have contributed to sorting and depositing pre-existing deposits into continuous covers of raised beach deposits.

This site is used for science, tourism and education, for example in the geology programme for the local school at Leka.

KEY WORDS: Raised shoreline, raised beach ridges, well-rounded stones, rock formations, quaternary geology.

THREATS: The main threat to this site is the quite new habit among visitors and tourists to build piles of rocks as a memorial of their visit. This is something the geopark strongly oppose, since it destroys the natural shape of the raised shoreline, as well as the experience of the landscape. To prevent this, we will put up signposts in the area.

TYPE: Area.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: High.

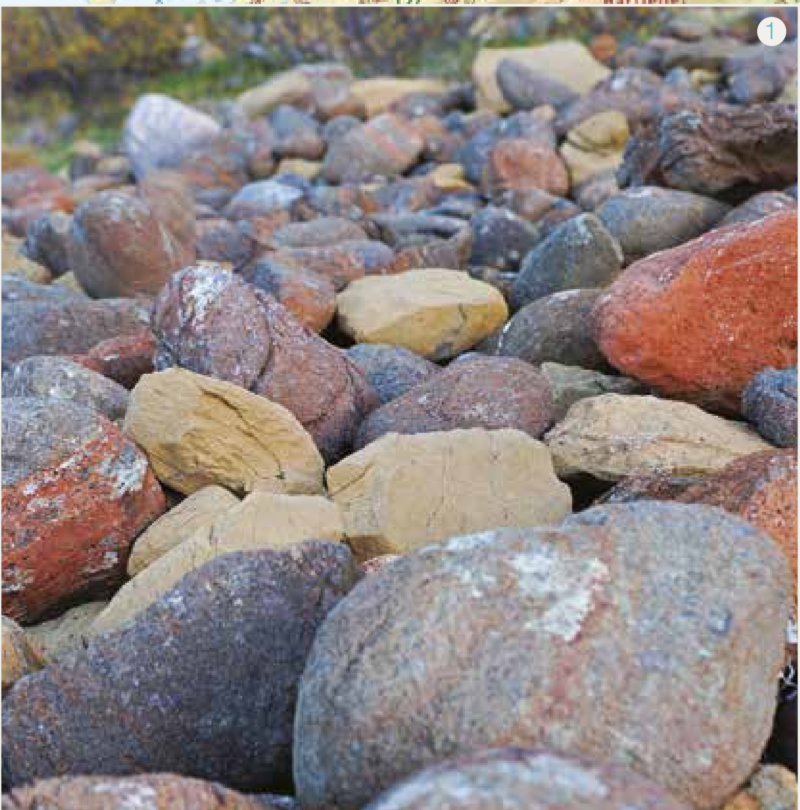
ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0622806 7222194
65°6'1.6"N 11°36'52.6"E

❶❷ The old road on Leka went over Støypet: Today it is one of Leka's most visited hiking trails.

Photos: A. Holand


Havøydrenkern
Oterholman
Hestøya
Kvaløysteinen
Kvaløya
Skrosen
Senningan
Lottholmen
Røyrskjæret
Klintholmen
Stonghaugen
Skråmoen
Skråen
Kvaløy-moen
Sjotun
Serå
Kvaløya
Lauhatten
L53
L64
Nerskardfjellet
L46
L50
LEKA
L57
L58
Sørlauhatten
Mannatinden
Lekner
Steinsøya
Haga fjellet
Stein
Leknes-fjellet
Hundoran
Vollan
Leka
Skipsflesin
Gjerdet
Fagertun
Nesvatnet
Storvet
Husby
L42
Sørelva
Stortinden
Gjerdevatnet
Aunkollen
Steinsvatnet
Høgbakka
Auhet
Kolsettuva
Vestgård
Nyrommet
Joholmen
Ramtindmoen
Raudstein-fjellet
L99
Vattinden
Vikamoen
Buøya
L34
Vågan
Vågøya
Lekatinden
Klungvika
Knerten
Engan
Ovden
Kleiva
Solheim
Frøvika
1 km
Steinsøya
Vestengan
Raudberget
Kaldalen
Hårfjellet
Øya


1


2

L53
CHROMITE

Over a large area, chromite layers are found in the dunite massif. The area with chromite can be traced for more than three kilometres, but one good spot to see the chromite layers is in the beginning of the hiking trail leading up to Støypet area. The layers are quite thin, from 0.5 to 5 cm, but some thicker layers up to 15 cm can be found.

Chromite is always associated with dunite or serpentinite (which is metamorphosed dunite). Some of the chromite layers are enriched in noble metals, especially platinum group (Pt – Pd) elements.

This is a site used for science and education.

KEY WORDS: Leka Ophiolite Complex, chromite, platinum group elements.

THREATS: There are currently no threats to this site.

TYPE: Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Igneous, Mineralogical, Georesources.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

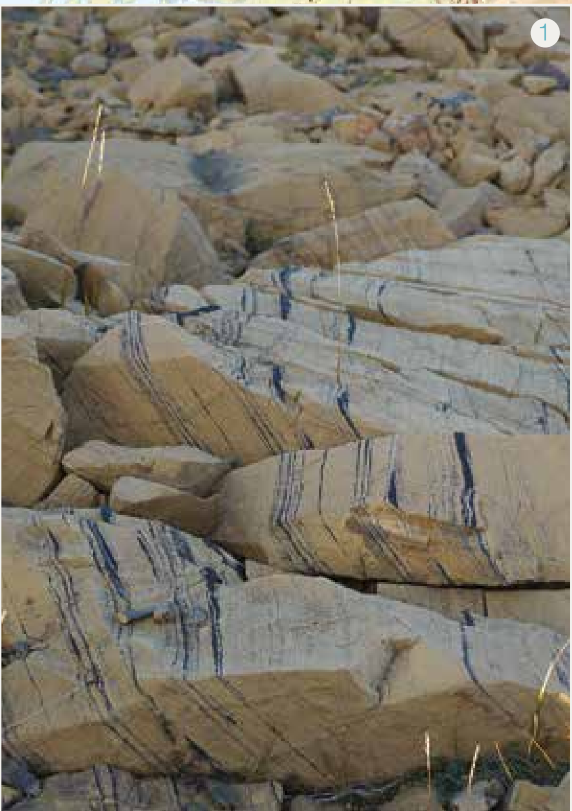
GPS POSITION:
UTM 32W 0623159 7222646
65°6'15.7"N 11°37'21.1"E

READ MORE: Boyd et al. (1990).
Pedersen et al. (1993).
Nordgulen et al. (2011).

❶❷❸ Chromite layers in the dunite massive are found over a large area at Leka.

Photos: A Bergengren

Jørnflesa
Havøydrenkem
Buraya
Hestøya
Oterholman
Kvaløysteinen
Skroren
Kvaløya
Lorttholmen
Røyrskjæret
Klinholmen
Stonghaugen
Skråmoen
Skråen
Senningan
Storsjø-
holmen
Sjøtun
Kvaløy-
moen
Sørå
Kvaløya
Lauhatten
L64
Erikvegen
L53
Nerikardfjellet
Steins-
tinden
L46
LEKA
L57
L58
Sørlauhatten
Leknes-
moen
Leknes
Mannatinden
Steinsøya
Haga-
fjellet
Stein
Steins-
sjøen
Vollan
Leknes-
fjellet
Hundoran
Leka
Skipsflesin
Gjerdet
Fagertun
Neswatnet
Størvet
Husby
Storfinden
L42
Gjerdevatnet
Aunkolien
Høgbakken
Steinsvatnet
Solli
Joholm
Aunet
Kolsettuva
Vestgård
Nyrommet
Ramtindmoen
Solbakken
Gongstaa
Raudstein-
fjellet
L99
Vattinden
Lombanna
Vikamoen
Buøya
L34
Vågan
Vågøya
Lekatinden
Klungvika
Frovikmyra
Knerten
Ovden
Engan
Kleiva
Solheim



1

2

3

L57
LAYERED RED MOUNTAINS

This geosite is an area with layered ultramafic rocks above the petrological MOHO in the Leka ophiolite complex. Layered bedrock is found at different scales in the Leka ophiolite, ranging from a few centimetres to several hundred meters in thickness. The layers at this site are mainly small-scale (0.5-2 meters). The layers are wehrlite, which gives the black/grey colour, yellow dunite, and orthopyroxenite rich in enstatite with a more reddish weathering colour.

The geosite is located in the so-called Skråa block of the layered sequence of the ophiolite complex, described in several publications (e.g. Furnes et al. (1992)).

This area with striped bedrock with bright black, red and yellow colours has a high aesthetic appeal even for non-geologists, and also offers a nice view towards the north coast with Torghatten and Vega in the distant horizon.

This geological feature at this site is described in scientific publications and the site is so far only used for science. However, the site may have potential for both tourism and education. Today, there is no marked trail here, and the site is only available through guided tours.

KEY WORDS: Leka Ophiolite Complex, Layered ultramafic bedrock, strong colour.

THREATS: There are currently no threats to this site.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0624601 7222174
65°05'58,5"N 11°39'10,0"E

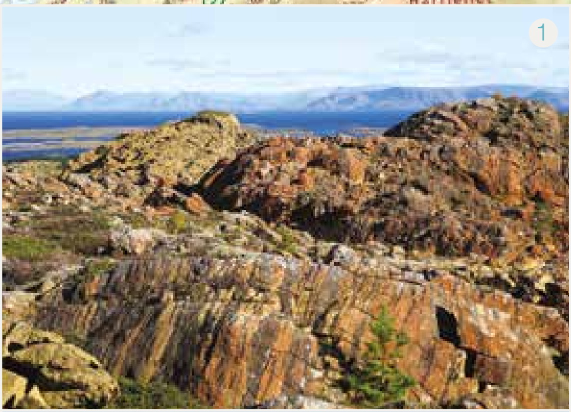
READ MORE: Furnes et al. (1988). Pedersen (1986). Furnes et al. (1992). Maaløe (2005). Nordgulen et al. (2011).

A visit to the area with layered red mountains offers a strong experience to the visitor.

❶❷ *Photo: A. Bergengren*

❸ *Photo: A. Holand*


LEKA
L57
L58
L53
L50
L46
L64
L42
L34
L99
Kvaløya
Stonghaugen
Skråmoen
Lauhatten
Sørlauhatten
Leknes
Leka
Husby
Storlinden
Botnet
Steinstinden
Haga- fjellet
Leknes- fjellet
Hunderan
Størvet
Nesvatnet
Steinsvatnet
Stein
Gjerdet
Gjerdevatnet
Aunet
Kolsettava
Vattinden
Lekatinden
Engan
Vestengan
Raudberget
Ovden
Hårfjellet
Kvaløysteinen
Otterholman
Nestøya
Burøya
Burøydraget
Steinsøya
Ønholmen
Skrosen
Senningan
Røyrskjæret
Lotsholmen
Klintholmen
Nerskardfjellet
Mannatinden
Steinsøya
Volten
Fagerlun
Aunkollen
Sørdelva
Raudsteinfjellet
Vestgård
Vikamoen
Frøvikmyra
Frøvika
Kleiva
Solheim
Klungvika
Knerten
Gongstoa
Solbakken
Solli
Heggbakkan
Nyrommet
Ramtinden
Lekneselva
Leknesvika
Lekneshamn
Hyssikjeret
Stranda
Nyheim
Myrvoll
Østby
Husby-sjøen
Erikvegen
Valan
1 km


1


2


3

L58
MOHO

In the complete ophiolite sequence found at Leka one can also experience to walk on MOHO (Mohorovicic discontinuity), the transition between the oceanic crust and the mantle. At northwest Leka there is a hiking trail leading up to MOHO, here seen as a border between dunite and harzburgite. The transition is gradual over 10-20 cm.

There is a resting place and an existing information sign at this site today. Other types of ultramafic rocks to be seen in the area are lherzolite and layers and dykes of websterite and orthopyroxenite.

This site is used for science, education and tourism.

KEY WORDS: Leka Ophiolite Complex, MOHO, boundary harzburgite / dunite, hiking destination.

THREATS: There are currently no threats to this site.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0625184 7222039
65°5’53.4”N 11°39’54.2”E

READ MORE: Maaløe (2005).

1 MOHO is a popular hiking destination.

Photo: O. Hamnes


LEKA
Kvaløya
Kvaløysteinen
Otterholman
Havøydrenkern
Skrosen
Stonghaugen
Skråmoen
Skråen
Kvaløy-moen
Sorå
Lotthalmen
Klintholmen
Røyrskjæret
Senningan
Lauhatten
Sørlauhatten
Lekneshatten
Erikvegen
Leknes
Leknesfjellet
Hagafjellet
Hundoran
Steinstinden
Manntinden
Nerskardfjellet
Stein
Vollan
Fagertun
Gjerdet
Gjerdevatnet
Aunkollen
Auhet
Kolsettuva
Raudsteinfjellet
Vågan
Lekatinden
Vattinden
Steinsvatnet
Nesvatnet
Storvet
Vestgård
Storfinden
Hagbakkan
Husby
Leka
Husbysjøen
Botnet
Nyheim
Myrvoll
Østby
Halonda
Valan
Storhjønna
Leknesfjøen
Lekneset
Leknesvika
Stonjeholmen
Hysjkjeret
Klakken
Ornholmen
Altskjeret
Steinøya
Buraya
Burøydraget
Sølbakken
Gongstøa
Klungvika
Knerten
Solheim
Kleiva
Frøvika
Havneholmen
Hårfjellet
Brekka
Vellengan
Raudberget
L27
L34
L42
L46
L50
L53
L57
L58
L64
L99

1

L64
NORDLAUVHATTEN

This hiking site and viewpoint displays the mantle section of the Leka Ophiolite, metaharzburgite. The harzburgite is the most common rock from the mantle section, and its typically weathered chocolate-colored knobbed surface is easily observed at Lauvhatten due to little vegetation. Parallel structure and planar foliation is seen in the bedrock at several places, structures formed during ductile flow in the mantle beneath the moving, crustal plates. Pockets of yellow dunite are found sporadically, reflecting patches of partial melting in the mantle rocks.

Bunkers and remains from WW II are found at the top of Nordlauvhatten, protected as a cultural heritage site. The top is a viewpoint, with a particularly good view towards Lekafjorden, Skeisnesset, the mainland and the northern coast.

This site is used for science and as a hiking destination for tourists.

KEY WORDS: Leka Ophiolite Complex, harzburgite, foliation.

THREATS: There are currently no threats to this site.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION
UTM 32W 0626629 7222875
65°6'18.4"N 11°41'47.5"E

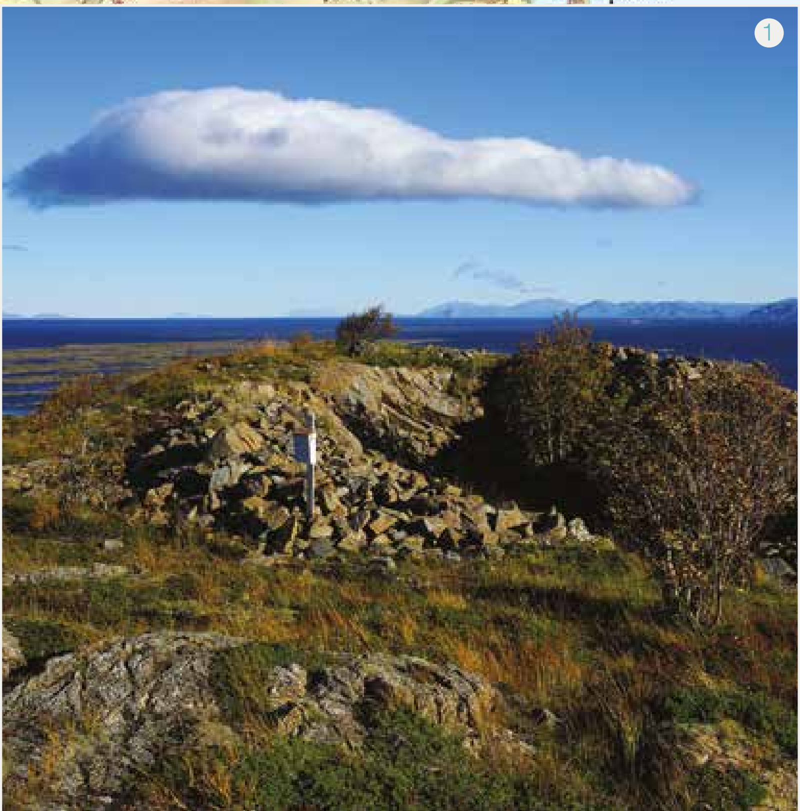
READ MORE: Prestvik (1980).
Nordgulen et al. (2011).

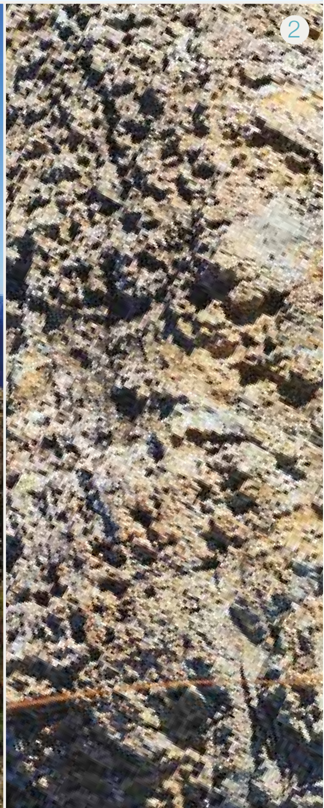
❶ Remains of the bunker from WWII on top of Nordlauvhatten.

❷ Harzburgite and its typically weathered chocolate-colored knobbed surface.

Photos: A. Holand


Leknesøyan
Jømfleia
Havøydrenkem
Steinsøya
Altskjæret
Lekaskagen
Buraøya
Burøydraget
Otterholman
Heitøya
Kvaløysteinen
Onholmen
Leknesvika
Skrosen
Klakken
Kvaløya
Hysskjæret
Senningan
Storsjøholmen
Leknesvika
Skeisneset
Stegga
Lottholmen
Klintholmen
Stonghaugen
Skråmoen
Skråen
Kvaløymoen
Sørå
Kvaløya
Sjøtun
Leknessjøen
Valan
Storsjøenna
Lauhatten
L64
Enkvegen
Nordkv
L53
Nerskardfjellet
L46
Steinstinden
L50
LEKA
L57
L58
Sørlauhatten
Stranda
Botnet
Nyheim
Vattvika
L76
Mannatinden
Haga
fjellet
Leknes
Myrvoll
Hålonda
Stein
Leknes-
fjellet
Hundoran
Nord-
Ottby
Østby
Leka
Husby-
sjøen
Havneholmen
Nesvatnet
Størvet
Husby
Storfinden
L42
Sørdelva
Aurkollen
Steinsvatnet
Høgbekken
Solli
Auhet
Kolset
Vestgard
Nyrommet
Solbakken
Gongstad
Ramtindmoen
L99
Vattinden
Lomtjønna
Vikamoen
L34
1 km
Lekatinden
Frøvikmyra
Klungvika
Knerten


1


2

L67
LEKNESØYAN

Pillow lava from the uppermost rocks in the ophiolite complex, representing volcanic eruptions on the sea floor at a spreading ridge in the Late Cambrian. The section is remarkably well preserved, displaying patches and layers of deep-sea sedimentary rocks in between the pillows. However, iron and manganese rich sedimentary layers are found between some of the lava flows, providing evidence of hydrothermal vent systems on the sea floor, such as those feeding black smokers on the present ocean floor.

This site is used for science and education.This site has a great potential for tourism, either through guided tours by boat or by kayak.

KEY WORDS: Leka Ophiolite Complex, well-preserved pillow lava, deep sea vulcanic activity.

THREATS: There are currently no threats to this site. However, sampling for scientific use should in the future be done in a more sustainable manner.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous, Paleonvironmental, Georesource.

VALUE:

PROTECTION: Bird Protection Area.

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 32W 0628099 7226650
65°8'18.1"N 11°43'52.5"E

READ MORE: Prestvik (1974).
Prestvik & Roaldset (1978).
Prestvik (1985).
Tveit, Furnes & Pedersen (1993).

❶❷❸ *Pillow lava at Leknesøyan, here investigated by master students from the University in Bergen at fieldwork.*

Photos: A. Bergengren


Ytterjørenflesin
Kjeldværøy
L67
Storøya
Leknesøyan
Vaktjønna
Jarnflesa
Havøydrenkern
Steinsøya
Altskjæret
Lekaskagen
Buraøya
Hestøya
Burøydraget
Otterholman
Skeispynten
Jakobsteinvika
Kvaløysteinen
Onholmen
Leknesvika
Skeisneset
Klakken
Skrosen
Kvaløya
Hyssklæret
Senningan
Storsjø-holmen
Lekneś-vika
Stonghaugen
Skråmoen
Stegga
Kvaløy-moen
Skråen
Valan
Storrtjønna
Haugan
Sjøtun
Leknessjøen
Kvaløya
Lauhatten
Nordkvalbaken


1


2


3

L76

SKEISNESSET GEOLOGY TRAIL

The Skei Group is composed of metamorphic sedimentary rocks including conglomerate, conglomeratic sandstone, sandstone, greywacke, marble and schist. This succession was deposited on top of the eroded Leka Ophiolite in Early Ordovician times (around 470-480 million years). The contact between the ophiolite and the Skei Group defines an irregular surface, reflecting an undulating landscape by the time of deposition. Since the ophiolite is 497 million years old, the uplift and erosion must have occurred rather shortly after the ophiolite formation.

Today there is an existing geology trail at Skei, consisting of several geosites, with separate information signs. The Skei area is a protected area and nature reserve, with several prepared walking paths. It is a nationally selected cultural landscape due to its high biological diversity, both flora and fauna, with a unique grassed heater moorland.

In addition, there are several protected archaeological findings in the area, the earliest being Stone Age settlements.

The Skei area is used for science, tourism and education.

KEY WORDS: Skei Group, sedimentary bedrocks, geology trail.

THREATS: Since the area has legal protection and there are well marked hiking trails, we believe that there are no current threats to this site.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Igneous, Metamorphic, Geomorphological, Sedimentology, Paleoenvironmental.

VALUE:

PROTECTION: Nature Reserve, Cultural Heritage, Bird Protection Area.

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32 W 0629664 7222371
65°5’57.9”N 11°45’38.1”E

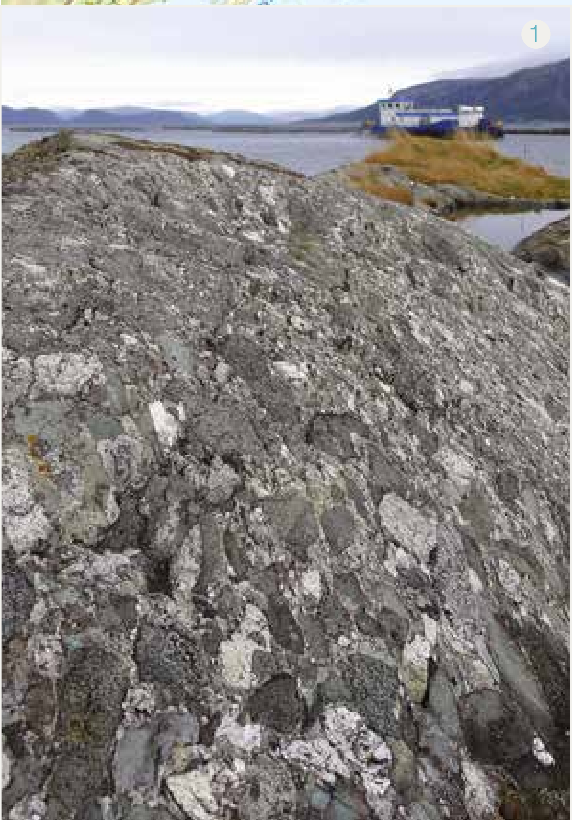
READ MORE: Prestvik (1974).
Sturt et al. (1985). Sturt et al. (1994).
Nordgulen et al. (2011).
McArthur et al. (2013).

1 Conglomerate at Skeisnesset.

2 Information posts along the geology trail at Skeisnesset.

3 Conglomeratic sandstone, basaltic rock and sandstone along the geology trail.

Photos: A. Bergengren


Jørnflesa
Steinøya
Burøya
Hestøya
Burøydraget
Altskjeret
Lekaskagen
Skeispynten
Jakobsteinvika
Store Stonghol
Ørnholmen
Leknesvika
Klakken
Skrosen
Hyskjeret
Senningan
Storøy-holmen
Leknes-vika
Stonghaugen
Skråmoen
Skeisneset
Stegga-fjellet
Valan
Storjenna
Leknessjøen
Nordkvalbaken
LEKAFJORDEN
Kvaløya
Lauhatten
L64
Erikvegen
Ivarshallaren
Tørrisengvika
Strande
Botnet
Vattvika
L76
EKA
L57
L58
Sørlauhatten
Leknes-moen
Nyheim
Leknes
Hålonda
Vedvika
Vedvik-haugen
Myrvoll
Bjørknes-odden
Hundøran
Nord-gård
Ortby
Skei
Galtvika
Leka
Husby-sjøen
Havneholmen
Daudmannsvika
Gutvikvågen
Størvet
Husby
Storfinden
Søre Gutvik
Sør-Gutvika
Høgbakken
Solli
Vestgård
Nyrommet
Solbakken
Kiubben
Ramtindmoen
Gongstaa
Vikamoen
Klungvika
Knerten
Rossvikvågen
Rossvikfjellet
Rossvika
Solheim
Frøvika
Stordalstjønn

1

2

3

L93

HORTAVÆR

The series of small islands around Hortavær north-west of Leka has given name to a layered igneous complex, the Hortavær intrusive complex. The layers in the intrusion came from multiple pulses with magma that range from gabbroic to granitic in composition. The Hortavær complex is part of a series of intrusions in the Helgaland Nappe Complex in Ordovician and Silurian times, and emplacement of the complex is dated to about 466 Ma. The Hortavær complex belongs to the Bindal batholith and is one of few plutons in the area that is partly alkalic. The complex intruded in a part of the Helgeland Nappe Complex called the Horta Nappe that consists mainly of calc-silicate rocks with some quartzite and marble.

It is difficult to access the island by boat, and therefore this site should be used for scientific purposes only.

KEY WORDS: Hortavær complex, layered magmatic intrusion, Horta Nappe.

THREATS: There are currently no threats to this site.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Igneous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 32 W 0615280 7233664
65°12'21.5"N 11°27'50.8"E

READ MORE: Gustavson & Prestvik (1979). Barnes et al. (2003). Barnes et al. (2005). Barnes et al. (2009).

1 The Kleppan sheets illustrates the overall nature of the main Horta intrusive complex: it consists of alternating dark (dioritic) and white (syenitic) sheets. These sheets were originally horizontal but have been rotated so that they are overturned. As seen in the photo, the tops of sheets are toward the right (east) and bottoms toward the left.

2 Migmatite that underlies Måsøya. This rock type is common in the northwestern islands.

3 Close-up of one type of hortitt, the rock name applied to the rocks around Vågøya. The orange mineral is garnet, the large black minerals are amphibole, and the rest of the rock consists of potassium feldspar, clinopyroxene, and plagioclase feldspar.

Photos: C. Barnes


Horsvær
Mardalsfjellet
Mardal
S1
SØMNA
17
Rossvika
Sund
Kvaløya
Vennesund
S7
Bindalsfj
L93
Horta
Holm
Røingen
Hortafjorden
Otervika
Bi7
LEKA
L67
Nord-Gutvika
L4
Kjella
Austra
Frøvik
L53
L64
Lysfjord
L46
L57
Sørhorsfjord
L50
L58
L76
Bi2
L42
Leka
Skei
171
L34
L99
Leka
Kjell-
eidet
L27
Kvaløya
Gutvik
802
Bogen
Heilhorn
L26
Bi1
L15
L10
Solsem
Madsøya
L30
5 km
Årsand
Kvaløya
Lekafjorden
Årsetfjorden
Blåfjellet
Dolma
Skotnes


L99

HERLAUGSLØYPA (LEKA MOUNTAINS)

The hiking trail at the Leka mountains, called Herlaugsløypa, provides a good introduction to the landscape and geology of Leka, and offers a stunning view in all directions. The highest peak of Leka, Vattind, is part of the trail and has an old cairn from the 13th century, part of the same system as geosite V1 Kjulsveten (Vega). The trail goes from gabbroic bedrock to the yellow dunite massif, and into the harzburgite. Several viewpoints are passed on the trail, as well as an area at Hundøyrån, where holes from talc drilling is seen. Test drilling to find talc and magnesite was carried out here in 1990.

This site is used daily by the local population, and since it has such a good network of marked trails, it could be promoted more for foreign tourists.

KEY WORDS: Leka Ophiolite Complex, Hiking destination, Viewpoints, highest peak, cairn.

THREATS: A large area with well marked hiking trails, we believe there are no current threats.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Igneous, Geomorphological, Georesource.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0622782 7219752
65°4’42.8”N 11°36’43.1”E

READ MORE: Olerud (1990).

❶❸ A beautiful scenery and a strong experience of Leka’s colorful bedrock is seen from Helraugsløypa, the hiking trail at the Leka mountains.

❷ Test drilling to find talc and magnesite are seen along the trail.

Photos: A. Bergengren

LEKA
Kvaløya
Lauhatten
L64
L53
Nerskardfjellet
L46
Steins-
tinden
L50
L57
L58
Sørlauhatten
Leknes
Mannatinden
Steinsøya
Haga
fjellet
Stein
Leknes
fjellet
Hundoran
Leka
Skipsflesin
Vollan
Gjerdet
Fagertun
Nesvatnet
Storvet
Husby
Storfinden
L42
Gjerdevatnet
Aunkollen
Steinsvatnet
Høgbakkan
Auhet
Kolsettuva
Vestgård
Johalmen
L99
Vattinden
Raudstein-
Lomtjønna
Buøya
L34
Vågan
Vågøya
Lekatinden
Engan
Knerten
Ovden
Frøvika
Vestengan
Steinsøya
Raudberget
L27
Øya
Hårfjellet
Madsøygrenda
Brekka
Kalvøya
Øver Kvernvika
Frøvik
Lamholman
Fjellet
L35
Vollan
Frøviksundet
L26
Halgeberget
Storfjellvågen
L10
Langhalsberget
Madsøya
Gongstoa
Solsem
Stortinden
Moen
Lekmo-
hammaren
Trollfjellet
Kukleppen
Haugvik
Lekamøya
L30
Haug
Middags-
Raudøya
Visholmen
Haravollan
Bjørkly
Ovden
Kobbskjærbukta
1 km

1

2

3

BR1
TORGHATTEN

The famous "hole in the mountain" is a national tourist attraction with international reputation. The Torghatten mountain is a residual mountain developed in basement granites and nappe gneisses as a part of the strandflat. The spectacular "hole" is a marine abrasion cave that has broken through the mountain, permitting a view through it from certain positions on-shore and off-shore. The hole, together with numerous raised shorelines and smaller caves were formed at high sea levels during the Pleistocene.

Several of the younger, post-glacial shorelines and beach gravel and boulder deposits host Stone-Age archaeological sites.

Torghatten is an example of Quaternary landscape evolution. The site displays very well the processes that created the standflat and the numerous inselbergs on it. The effects of glacio-isostatic reboundare very well illustrated through bedrock notches and gravel/boulder beach deposits at various levels (and ages). The Torghatten hole itself evidence the extreme efficiency of near-sealevel frost-action combined with marine abrasion.

This site is used for tourism, education and science. The area around Torghatten has great value since it combines several perspectives, both historical and geological, as well as the mythology about the mountains at Helgeland. Posts with QR-qodes giving information about geology are placed along the trail to the hole. The site has considerate potential, as one may construct "via ferrata"-type trails over the mountain summit without much environmental impact.

KEY WORDS: Cave tunnel through the mountain, tourist attraction, granite.

THREATS: This site is already as touristic as it possible can be, and the visitors follow marked trails all around the area. The granite is not considerate to be vulnerable. The raised shorelines with rounded stones are more vulnerable if the number of visitors walking here increase, and this has to be evaluated continuously. The same with the archaeological Stone Age findings in the area, even if they are protected as Cultural Heritage. Also the sediments and other loose material in the caves around the mountains might be vulnerable, and this has to be evaluated continuously if the number of visitors to these caves increase.

TYPE: Point.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous, Geomorphological, Geoculture.

VALUE:

PROTECTION: Partly Cultural Heritage.

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0365083 7255985
65°23'54.7"N 12°5'41.3"E

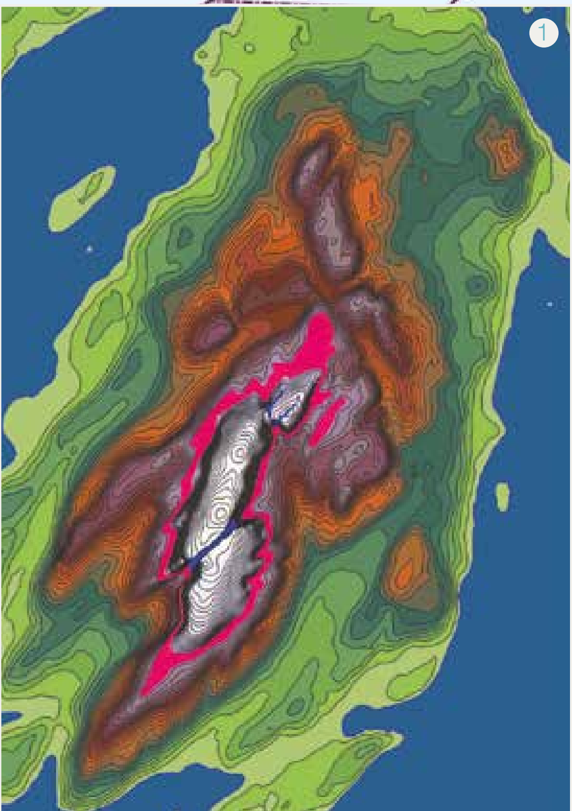
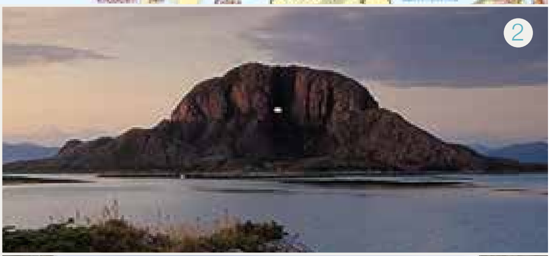
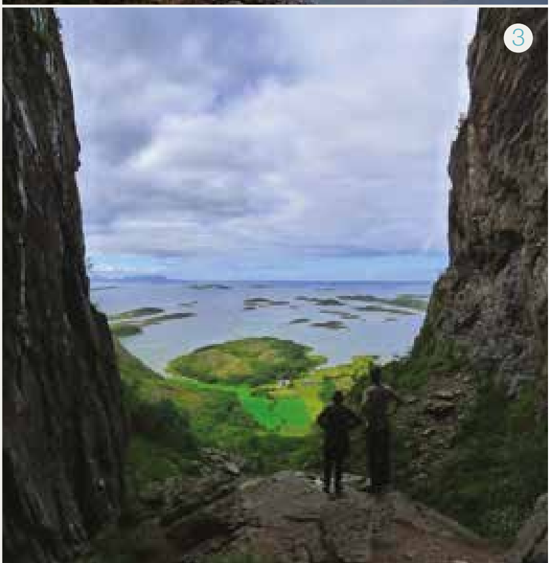
READ MORE: Lauritzen et al. (2011).

❶ *The Torghatten mountain with surveyed caves (dark blue), red filled contour: 112–125 m asl. from Lauritzen et al 2011.*

❷ *Torghatten.*

❸ *View from the Torghatten hole.*

Photos: A. Bergengren


Torget
Ytter-Torget
Inner-Torget
Vikerfjellet
Torghatten
Br1
TORGFJORDEN
Torgværet
Brurøya
Heløya
Sandøya
Husøya
Ormøya
Sømnesøya
Berg
1 km

1

2

3

BR5
BOLVÆR

Group of islands with high geological diversity. The main island Bolvær displays Early Ordovician metamorphosed sediments deposited on a small ophiolite fragment, called the Bolvær complex. Within a small area, it is possible to view the Ordovician palaeoterrain surface on which the sediments were deposited on, a range of metasedimentary rocks displaying various depositional environments and schooolbook examples of metamorphic mineral growth and structural geology. The area defines a key locality for understanding the plate tectonic processes and depositional environment in the Early Ordovician. This geosite is equivalent to the Skei group on Leka, seen at geosite L76, Skeisnesset Geology Trail. In the Helgeland Nappe Complex there are several cover sequences above ophiolites, probably deposited in Early to Middle Ordovician time.

This site is only in use for scientific purposes today, but there is a potential to use the geosite for tourism and education. This island is important in the on-going project to increase kayak tourism in the area. Bolvær is, together with other geosites and non-geological sites on islands in the area, part of a suggested geosite tour reached by kayak. Today, this site is only reachable by boat through a private arrangement.

KEY WORDS: Metamorphosed sedimentary bedrock, ophiolite fragment, Bolvær complex.

THREATS: Since the area is somewhat difficult to access, we judge that even with an increase in the number of visitors in the future the number will be low, and this will be no threat to the geological features.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Stratigraphical, Metamorphic, Tectonic, Sedimentological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 33W 0364477 7265842
65°29'11.7"N 12°4'18.9"E

READ MORE: Heldal (2001).

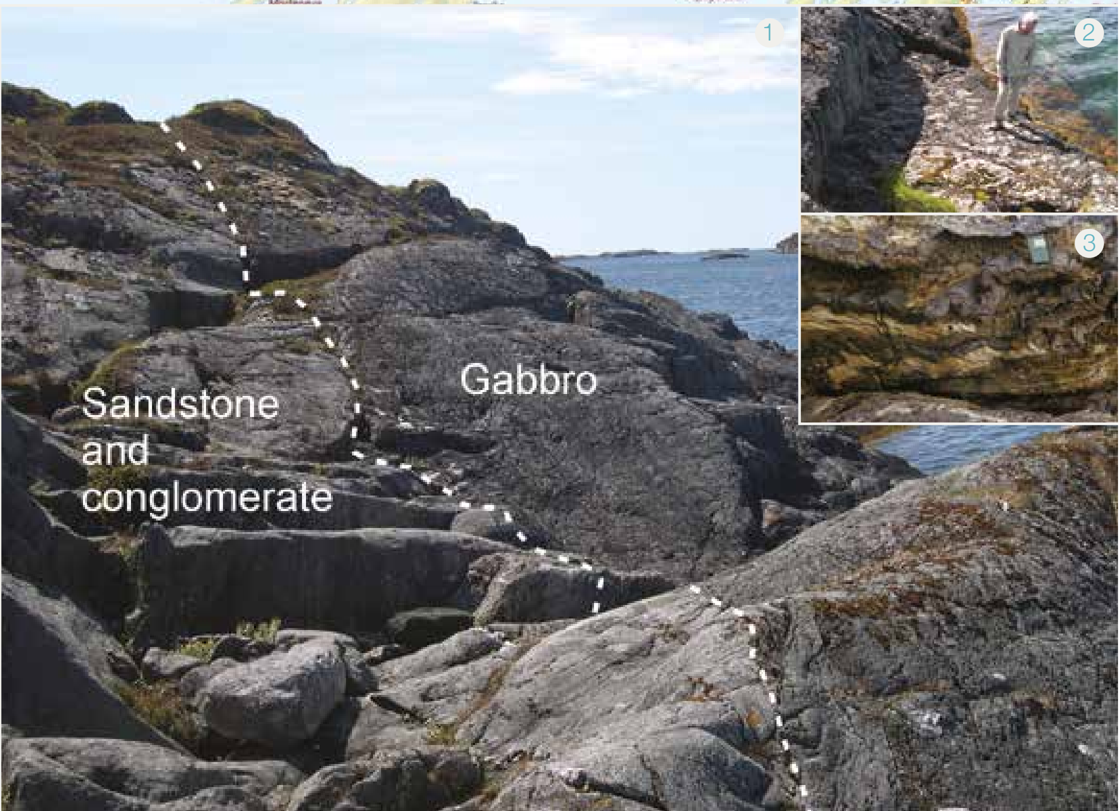
❶ Photo showing the Ordovician terrain surface, now vertical, separating the ancient bedrock exposures (gabbro; right side) from sand and gravel deposited on top (left side).

❷ Basal breccias filling depressions in the ancient terrain.

❸ Folded schist and marble.

Photos: T. Heldal


Stortorgnes
Torgnes
Bolværet
Br5
Br6
Saurheian
Sauren
Selvåg
Storøya
Uttorgværet
1 km


1
2
3
Gabbro
Sandstone and conglomerate

BR6
STOR-ESJØYA

Soapstone quarry at the island Stor-Esjøya, neighbour to Bolvær. The soapstone is a result from transformation of Ordovician metagabbro from the Bolvær complex. The layer with soapstone is about three meters thick and well visible from the sea for a length of about 50 meters. This quarry has been in use from the Viking Age until the Middle Ages. It is believed that stone from this quarry was used to build the medieval church at Tilrem.

This site is only in use for scientific purposes today, but there is a potential to use the geosite for tourism and education. This island is important in the on-going project to increase kayak tourism in the area. Esøya is, together with other geosites and non-geological sites on islands in the area, part of a purposed geosite tour reached by kayak. Today, this site is only reachable by boat through a private arrangement.

KEY WORDS: Historical soapstone quarry, Bolvær complex.

THREATS: There is already a lot of inscriptions and grafiti on some of the quarry faces (historical and from present time), and the site is considered to be vulnerable, due to the soft soapstone. The quarry is protected as a Cultural Heritage, but there is a need for a signpost informing about this at the site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Georesource, Geoculture, metamorphic.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: High.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 33W 0364990 7265271
65°28’54.1”N 12°5’0.8”E

READ MORE: Berglund (1999). Heldal (2001). Lindal (2011).

❶❷ Soapstone quarry, Medieval period, at Stor-Esjeøya, displaying unfinished soapstone pots on the quarry face and inscriptions.

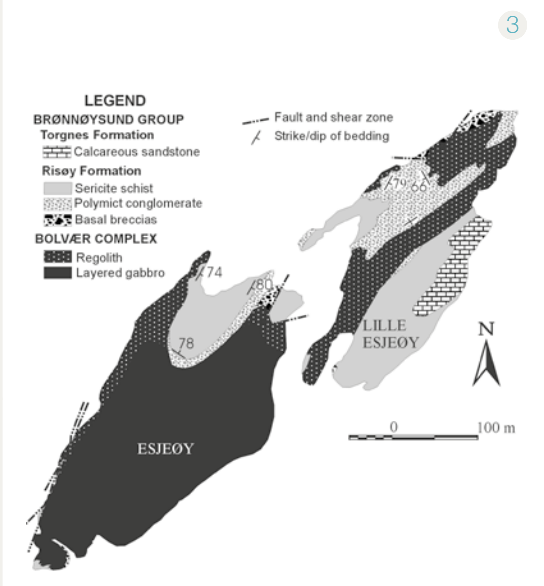
Photo: T. Heldal

❸ Geological map of Esøya from Heldal 2001).

Stortorgnes
Torgnes
Bolværet
Br5
Br6
Sauren
Lilltorgnes
Saurheian
Selvåg-heia
Storøya
Uttorgværet
Burøya
Toftøya
Toft
Lyngøya
1 km

1

2



3
LEGEND
BRØNNØYSUND GROUP
Torgnes Formation
Calcareous sandstone
Risøy Formation
Sericite schist
Polymict conglomerate
Basal breccias
BOLVÆR COMPLEX
Regolith
Layered gabbro
Fault and shear zone
Strike/dip of bedding
79
66
74
80
78
LILLE ESJEØY
ESJEØY
N
0
100 m

BR8
SKOMO-KVERNTIND

Millstone quarry with garnet mica-schist. The millstone production utilised the loose boulders at the mountainside in an area of 200 meters. There are several larger production places here, seen as depressions in the ground up to 20 meters in diameter. Piles of quarry debris are found around the depressions, as well as unfinished millstones that have been left behind. From the main production area traces of an old road can be followed down to the sea, where the millstones were loaded onto boats and shipped. Millstones that for some reasons were left behind can be seen at the beach. Brønnøy was an important area for millstone production from at least the 17th to the Early 18th century, and the millstones were traded as far south as the city of Bergen. There are several millstone quarries in the municipality, and Skomo-Kverntind is the largest. In all the quarries, the millstones were made of garnet mica-schist occurring as loose boulders in scree deposits along the mountainsides.

This site has until today only been used for science. We believe there is a large tourist potential at this site, by clearing the old road up by the mountainside. Since this is the largest and most easy accessible millstone quarry in Brønnøy area, this should become an important site for education, to tell about the historical importance of millstone production.

KEY WORDS: Millstone production, garnet mica-schist.

THREATS: Today, there are very few visitors at this site. However, since the rest material from the millstone production and the unfinished millstones are limited, we consider this site to be somewhat vulnerable. This site needs to be evaluated constantly if the number of visitors increases.

TYPE: Point.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Metamorphic, Georesource.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Blue.

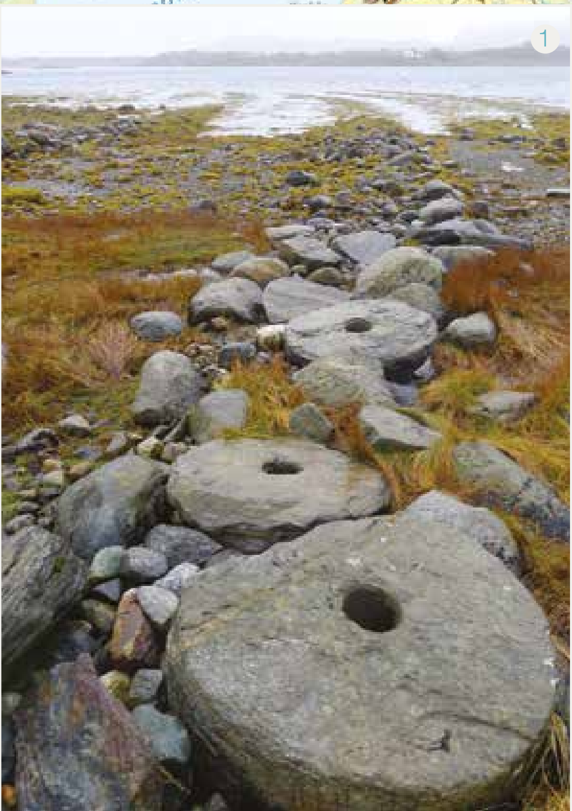
GPS POSITION:
UTM 33W 0377359 7264529
65°28’47.8”N 12°21’3.8”E

READ MORE: Krokvik (1999). Lindal (2011).

❶❷ Large millstones that for some reason were left behind are seen both down by the sea and up by the mountainside.

Photos: A. Bergengren


Ramntinden
Syltren
Skille
Salhus
Kista
Kverntinden
Br8
Moen
Skomo
Ytreskomo
Hytter
Tinden
Staulan
Liafjellet
Kjølsfjellet
Lislidalsfjellet
Skillebotnet
Kjølsøya
Horsøya
1 km


1


2

BR9
ENGAVATNET

Engavatnet is a Turlough lake in a kastic terrain. At irregular intervals, the lake drains through its bed in a spectacular way, leaving a muddy plain with dead fish and open dolines into which the water disappeared. After some time, generally after rain, the lake may start filling up again, returning to its “normal state”, when the fish also returns.

The lake is situated on karstified marbles and thus is undermined with a (unknown) cave system. During periods of severe drought (no rain), the surrounding water-table will drop, creating a pressure on the muddy lake bed, which in turn may burst and let water drain into the underlying karst. The water probably emerges in springs around Aunhola (see geosite B10). At the end of the emptying process, the drainpipe clogs up with mud, and after rain, a raised watertable permits the lake to re-fill.

Engavatnet is a “Turlough”, a karst phenomenon well-known from western Ireland, but almost unknown in Scandinavia. The site has easy access, and the process is very spectacular when it occurs.

The site is ideal for demonstrating processes and rapid changes in karst systems and their underground drainage. Also, the sensitivity of water-table balance with respect to precipitation is well explained, as well as the probable syphon-effects that operate during the emptying process. Due to the unpredictability and rate occasions of the process, the site must be well prepared and illustrated with time-lapse photos, as well as showing past- and real-time data curves of precipitation and lake level.

Tourists visit this site mainly during the years the water disappears. Otherwise, the majority of the visitors come as part of a guided tour. A simple footpath along the lake shore to a platform and display installation that should be erected at the northern end, where the emptying process is most spectacular and where lake level loggers could be installed.

KEY WORDS: Karst system, disappearing lake, turlough.

THREATS: With the number of visitors today, the only threats to this site would be construction or habitation nearby that might change the ground water level, but this is not a current problem.

TYPE: Point.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0385337 7258543
65°25’45.2”N 12°31’41.7”E

READ MORE: Lauritzen (2010).

❶ Lake Engavatnet - filled with water in the July 2013,
❷ and empty in July/ August 2014.

Photos: A. Bergengren


Seterlandet
SØRFJORDEN
Buksvågen
Dymes-
odden
Dymesvågen
Mortenøya
Nevernes
Liåsen
Åsen
Br10
Br9
Br12
Br24
Hegg-
fjorden
Høglia
Brattåsfjellet
Hilstadfjellet
Hallaraun-
fjellet
Dyrhaia
Velfjord
Hommelstø
Grendalen
1 km


1


2

BR10
AUNHOLA

Karst cave where the water is in connection with underground drainage from Engavatnet. The cave has a large portal with cross-sections showing how water and sediments underneath the quaternary ice sheets eroded the cave roof. The phenomenon is called "paragenesis" and is exceptionally well displayed in the cave. Aunhola ends in a water-filled syphon from where a cave stream continues to a spring at the foot of the cliff.

The site might also have archaeological potential, as there is a considerable earth talus in the portal and the walls bear marks of human, possibly pre-historic modification.

The site has great scientific significance as it displays the erosion of a cave ceiling underneath glacial ice. The portal itself is scenic.

The geosite is today available for everyone, but the majority of the visitors come as part of a guided tour. The trail leading to the cave could be better marked.

KEY WORDS: Cave, karst system, ice age processes, blue marble.

THREATS: Even if the site is considered vulnerable, is it the karst cave in the area that is considered to be best suitable for tourists. Remedies are a wooden platform and ladder covering the earth talus. Monitoring and evaluation is needed to protect the site from damage. By now, the site is accessible both for tourists on their own and by guide, and if the site becomes damaged, we can consider to only have it open for visits together with a guide.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: High.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 33W 0384527 7259084
65°26'1.6"N 12°30'37.2"E

READ MORE: Lauritzen (2010).

❶ A natural spring outside the cave is beleived to be connected to the water stream inside the cave.

❷ Exceptionally well displayed cross-sections showing how water and sediments underneath the quaternary ice sheets eroded the cave roof.

❸ Beautiful blue marble inside the cave.

Photos: A. Bergengren


Br10
Br9
Br12
Br24
SØRFJORDEN
Brattåsfjellet
Liåsen
Hegg-
fjorden
Nevernes
Hommelstø
Velfjord
Seterlandet
Åsen
1 km


1


2


3

BR12
RUGÅSNESODDEN

This old marble quarry with cubic stone blocks and sawed walls is part of an area with marble stretching from Tosenfjorden to Velfjord. In 1897, the geologist J.H.L Vogt described the marble of good quality. Production commenced the same year and terminated in the 1930s. The creamy white and coarse-grained marble was used as building material. The quarry is, moreover, a rare display of early 20th century wire sawing quarrying methods.

Karst landscape with karren and dolines can be seen surrounding the old quarry. The marble occurrences provide a rich ground for biodiversity, and a boreal rainforest displaying a high biological diversity surrounds the quarry. The local authorities discuss protection of this forest as this text is written.

A trail leads from Hommelstø out to the quarry, but this is old and needs to be cleared. This site is visited by tourists today, but only as part of a guided tour, and then by boat from the fjord. If the path, leading through the boreal forest with karst caves, could be cleared, we belive this site would have a high tourist potential.

KEY WORDS: Old marble quarry, cubic block, linear sawing, karst.

THREATS: The site is not protected, and mining rights are hold by the company Norwegian Holding AS, that investigated the possibilities industrial use of the marble in the 1990s. The surrounding forest, karst systems and the close location to houses does not make it suitable for production today, but legal protection to establish this is needed.

TYPE: Point.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Georesource, Metamorphic, Geobiosphere.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 33W 0387004 7256583
65°24’44.0”N 12°33’56.8”E

READ MORE: Vogt (1897). Karlsen (1991). Heldal (1994). Hoholm (1998). Lindal (2011).

➊➋➌ The old marble quarry with cubic stone blocks and sawed walls is surrounded by a karst landscape with carren and dolines.

Photos: A. Bergengren


Br10
Br9
Br12
Br24
Nevernes
Liåsen
Hegg-
fjorden
Brattåsfjellet
Hilstadfjellet
Hallaraun-
fjellet
Hogla
Råkhatten
Hommelstø
Velfjord
Storhaugen NR
Grav-
høgda
1 km


1


2


3

BR15

AUNLIA ROAD CUTS

Road cuts in various fine-grained semipelitic and calc-silicate schists of the Middle Nappe of the Helgeland Nappe Complex, cut by fine- to medium grained leucogranitic dikes. Both the schists and the dikes are strongly folded, caused by crustal deformation during the Caledonian Orogeny. Dating of similar dikes further to the north yielded an age of 431 million years. Being a key locality for the rocks of the Middle Nappe, the site is also visually impressive.

Today this site is only in use for scientific purposes, These road cuts expose a beautiful pattern that draws the attention to anyone passing by. However, the high speeds at the road and the limited possibilities for parking at the moment makes this site somewhat difficult to access for a general public.

KEY WORDS: Road cuts, semipelitic schist, calc-silicate schist.

THREATS: The only threat would be if the road was rebuilt, but this is not a current issue.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Tectonic, Metamorphic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

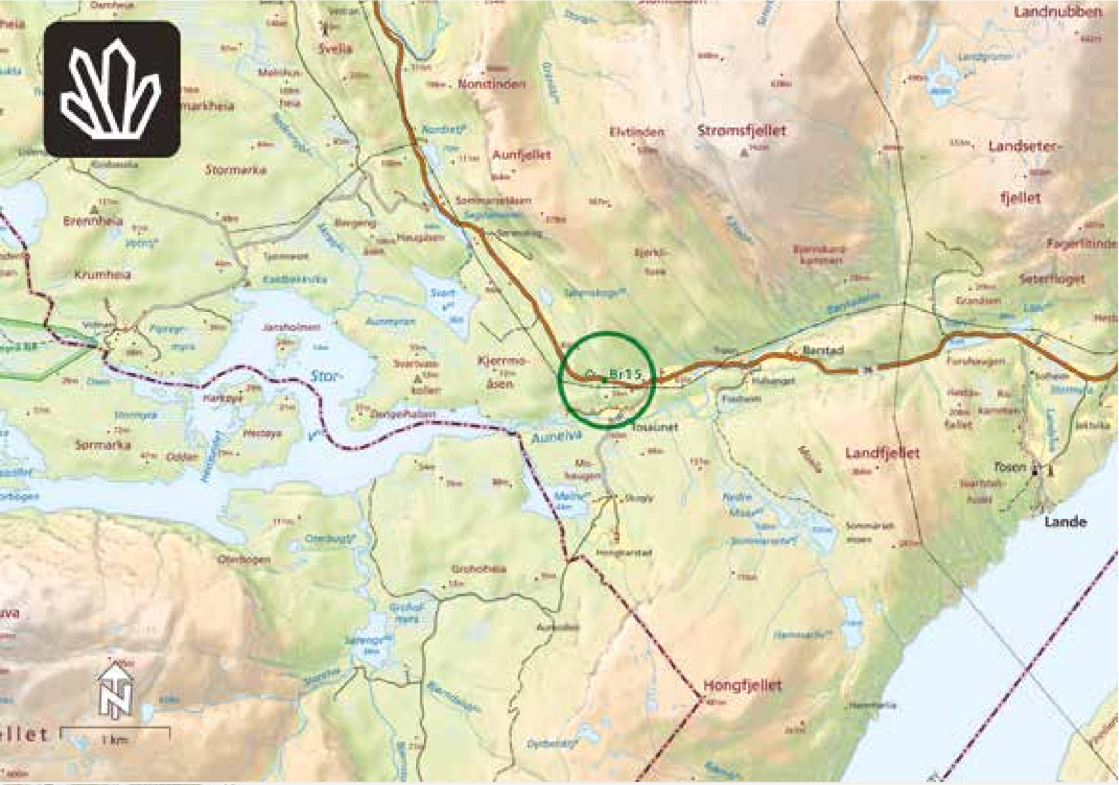
ACCESSIBILITY: Green.

GPS POSITION
UTM 33W 0392796 7239406
65°15'36.7"N 12°42'14.0"E

READ MORE: Nordgulen et al. (2011).

1 *The road cuts at Aunlia along road 76 southwest of Hommelstø.*

Photos: A. Bergengen


Landnubben
Svella
Nonstinden
Stromsfjellet
Elvtinden
Aunfjellet
Landseter-
fjellet
Stormarka
Brennheia
Krumheia
Stor-
Kjørmo-
åsen
Br15
Barstad
Aunelva
Landfjellet
Lande
Hongfjellet
1 km


1

BR19
TOSENFJORD RESTING PLACE

By the resting place at Tosenfjorden, coastal outcrops expose banded and folded migmatites (rocks that have suffered partial melting) and calc-silicate rocks. These rocks belong to the Upper Nappe of the Helgeland nappe Complex. The dark bands of the migmatites composed of biotite (mica), feldspar, garnet and quartz. The light colored bands are mostly quartz and feldspar. Cross cutting dikes of leuco-granite. Research has revealed that the migmatite formed 480 million years ago at temperatures greater than 500°C and depths in excess of 20 km. This provides a link of the Upper Nappe with the Hortavær Nappe far to the west. At low tide, tonalities, including the minerals feldspar and quartz, can be observed to have intruded the migmatites. These tonalities contain dark gray inclusions of irregularly-shaped diorite, another igneous rock that is composed of feldspar, quartz, biotite and amphibole. These distinctive igneous rocks form part of a suite of rocks studied along well-exposed road cuts along highway 76 a few kilometers to the southwest that have an age of 432 million years. They share affinity with rocks presently exposed in east Greenland and were subsequently rifted apart during the opening of the Atlantic ocean beginning about 60 million years ago. Thus, the site display important evidence of having suffered deep burial and partial melting.

This site is just by the resting place at Tosenfjorden, and is the starting point for Trollfjell Geopark if entering by road 76 through Tosen tunnel. This site is in use for scientific purposes and visited by tourists today.

KEY WORDS: Deformed rocks, folding, migmatites, tonalites.

THREATS: This site is considered robust and there are no threats with the numbers of visitors today. This has to be evaluated if the number of visitors increases.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Tectonic, Metamorphic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION
UTM 33W 0398230 7240093
65°16'5.1"N 12°49'10.8"E

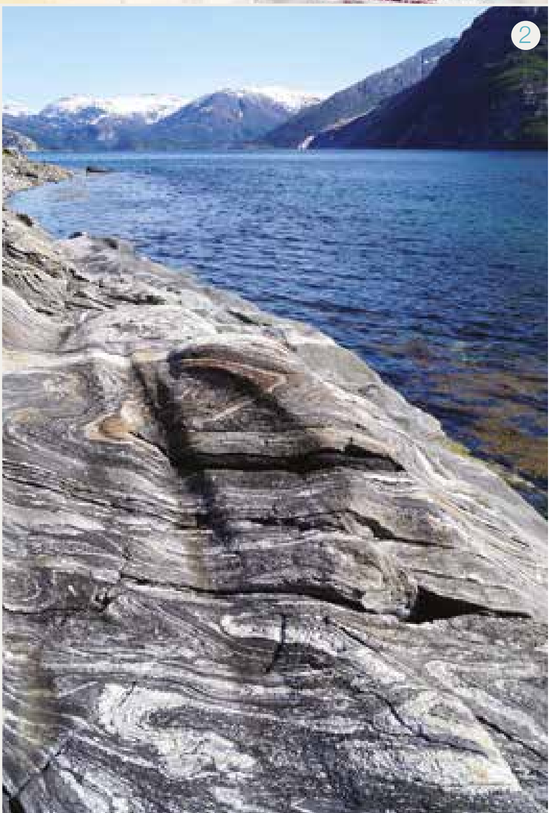
READ MORE: Yoshinobu et al (2002). Barnes et al (2011).

❶❷❸ Beautifully banded and folded bedrock at the coastal outcrops by the restingplace in Tosenfjorden.

Photos: A. Bergengren


Falkfjellet
Landnubben
Elvtinden
Strømsfjellet
Landseter-
fjellet
Fagerlitinden
Seterfloget
Granåsen
Barstad
Br15
Br19
Elvika
TOSEN
DÅASA
Kaldklavti
Bollen
Landfjellet
Tosen
Lande
Finnlifjellet
Kvitdalstinden
Hongfjellet
1 km


1


2


3

BR23
TILREMSHATTEN

Hiking destination, starting at the same parking place as non-geological site B2-1, Skarsåsen. This hike goes on a mountain ridge with a stunning view on both sides, towards the coastal strandflat land-scape in the west and the forests and mountains of Velfjord and the national park Lomsdal-Visten in the east. Along the trail is an exposure of garnet mica schists of the Sauren-Torghatten Nappe of the Hel-geland Nappe Complex. Large garnets with perfect crystal form are seen at some places along the trail, for some parts lying loose like gravel. A mountain formation has the free name “HavLars”, from a local story about a sea troll. Close to this site are a hole through the mountain, and several pot holes.

Tourists use this site today, mainly because it is close to the bunkers from WWII at Skarsåsen. This is a popular hike for the local people, and occa-sionly visited by schools, but there is a potential to further increase the educational use, to inform about geology.

KEY WORDS: Hiking destination, viewpoint, pot holes, mica-garnet schist.

THREATS: Visitors follow the already marked trail, and therefore we believe that there are few threats to this site today.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Mineralogical, Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 33W 0374906 7268263
65°30’44.9”N 12°17’40.8”E

❶❷ Garnets are seen along the trail to the top of Tilremshatten, which offers a stunning view over the costal landscape.

Photos: A. Bergengren


Mosaksla
Mosfjell
Mosaksla
Tilrem
Tilrems-
hatten
B: 23
TILREMFJORDEN
Salhus
Salhus-
rognan
Lyngøya
Prestøyan
Syltren
Skille
Eidhatten
Eidsodden
Ramntinden
Gåsheituva
Kverntinden
1 km


1


2

BR24
OTERHOLA

This is a small karst cave situated a few meter above sea level. It is a phreatic (sub-watertable) tube, with antigravitative modification in the form of multiple half-tube roof incisions and wall ledges. The cave was effluent when active and functioned as a glacimarine spring beneath the ice-sheet. Together with two larger caves (Akselberg I & II), the three caves formed a linear endokarst drainage route beneath the late-glacial ice-sheet, towards the fjord. The two other caves are now consumed by the nearby marble quarry. Oterhola was modified through multiple sediment fills and corresponding roof retreats, leaving the antigravitative features similar to Aunhola.

Oterhola bears ample evidence of being a past habitat for pro-glacial, marine organisms when active, as seen by traces of boring organisms (molluscs, sponges) and numerous mollusc shells, fish bones, etc. in the floor sediments. This can be traced quite far into the cave. The biogenic invasion is a characteristic of most low altitude caves in the Velfjord area, where Oterhola is an easily accessible and illustrating example.

Marine karren and iron precipitates is well displayed at the marble shoreline in front of the cave.

This site lay close to the road and is reached by a short walk. To make this site open for tourist, measures to protect future damage as well as an agreement with the landowner to prepare a trail has to be made.

KEY WORDS: Karst Cave.

THREATS: This site is considered highly vulnerable, since it has been some resent vandalism inside the cave, where parts of the cave wall has been removed. This demands strict management when in use. Protection and information is needed and for the moment this site is only available for visits together with a guide.

In order to preserve information on the cave development, a stratigraphic excavation of its contents must be performed before the cave is used by the public.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: High.

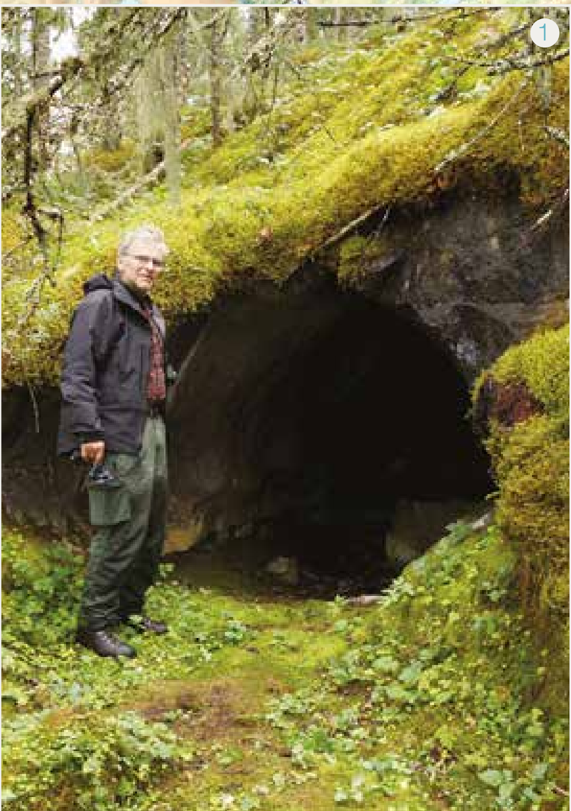
ACCESSIBILITY: Blue.

GPS POSITION:
UTM 33W 0383771 7255726
65°24'12.3"N 12°29'49.0"E

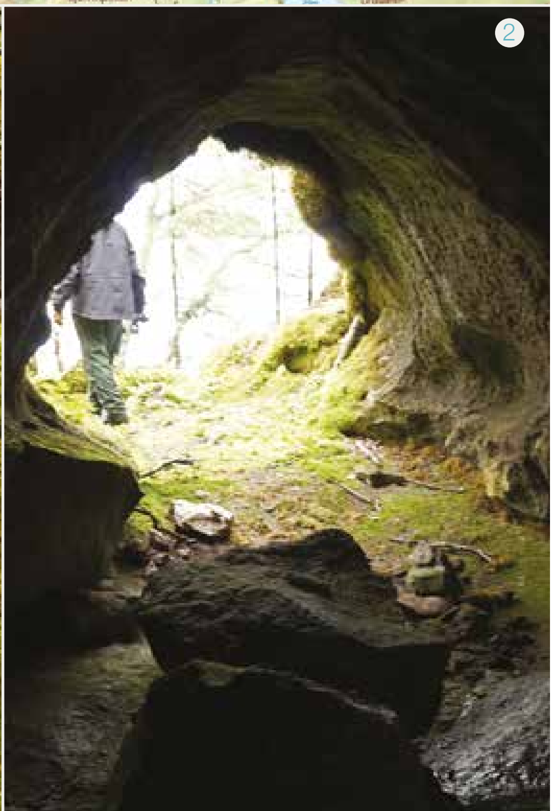
❶❷ Oterhola is one of the best examples of the Velfjord caves. However, the site is considered to be vulnerable.

Photos: A. Bergengren

Br10
Liåsen
Åsen
Br9
Hegg-
fjorden
Langnes-
odden
Brattåsfjellet
Hilstadfjellet
Ris-
kammen
Osodden
Hallaraun-
fjellet
Br12
Dyrheia
Hommelstø
Br24
Velfjord
Grøndalen
Holåsen
rondals-
fjellet
Storhaugen NR
Finnvikv.
Bordvik-
fjellet
Navafjellet
1 km
Rølihela



1



2

VG1
KJULSVETEN

Viewpoint and popular hiking destination with a good view towards northeast of Vega and the mainland. Even though the mountain consists of the typical Vega granite with a diversity of enclaves and xenolithes, the main attraction from this site is the landscape seen in the surroundings. Looking west, there is the high peak of Trollvasstinden, with plenty of talus, boulders and loose material from mechanical erosion. Towards the north is the fertile, flat agricultural landscape on meta-sedimentary bedrock. The difference in vegetation between the barren granite and the fertile sedimentary rocks of the north can easily be seen as a sharp boundary. Towards the east, there is the flat strandflat landscape, stretching towards the high mountains of the mainland. Given the ideal position close to the waterway and the mainland, Kjulsveten has been an important viewpoint for ages. At the top, there are remains of an old cairn from the 13th century. This was part of a system of landmarks along the coast, established by Manus Lagabøte, and is protected as a cultural heritage. Similar cairns that belong to the same system are found at other peaks in the geopark (e.g L99, Vattind (Herlaugsløypa), Leka)

This site is used by the locals and by tourists. We believe this site could be used for education, to learn about the landscape. Particularly suitable in combination with geosite Vg2, Hestvika.

KEY WORDS: Viewpoint, hiking destination, cairn.

THREATS: There are currently no threats to this site, and the cairn is protected as a cultural heritage.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Magmatic, Geoculture, Geomorphological.

VALUE:

PROTECTION: Cutural Heritage.

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

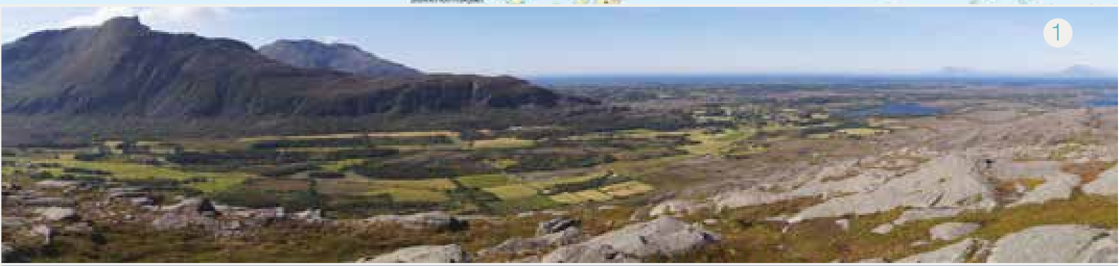
GPS POSITION:
UTM 32W 0635415 7280390
65°37’1.2”N 11°56’25.5”E

❶❷ View from the top of Kjulsveten, where the typical Vega landscape is seen with sharp contrasts between the flat, fertile areas with sedimentary bedrock and the granite mountains.

Photos: A. Bergengren

Skjeggemoen
Stordalen
Floa
Vikatinden
Hestbakken
Vegtindan
Kammen
Nordre Vika
Søre Vika
Vg1
Eidem
Tårnet
Trollrevheian
Vikasågen
Åkvika
Vg3
Hestvikfjellet
Langstranda
Nordre Kjul
Aunholmen
Norddypingan
1 km

1



2

VG3
HESTVIKA

When the ice melted after the last ice age, the sea level was situtated about 100 m above the present day sea level. The land slowly lifted due to isostatic rebound, and the traces of the the Younger Dryas Main Shoreline in the Vega area can be found between 90 and 96 m.a.s.l., mostly eroded in the bedrock. In the scar between the Hestvikfjellet and Tårnet mountains in the southern part of Vega, the raised shoreline can be seen as three separate fields with well-rounded stones, present between 92 and 96 m.a.s.l. The trail up to viewpoint Kjulsveten passes through fields of well-rounded beach sediments. At 99 m.a.s.l. the marine limit is found as a beach ridge with angular boulders. The sediments were probably heaved up by storm waves shortly after deglaciation.

Tourists and locals taking the hike up to Kjulsveten walk by the site today. In addition, we believe this site has a good educational potential. Standing on the raised shoreline, there is a good view towards the beach and the present sea level. This makes the site exceptionally good for educational purposes, for example explaining the effects of isostacy and sea level changes in the area.

KEY WORDS: Raised beach ridges, marine limits, sea level changes.

THREATS: The stone fields are so large that even if the hiking trail passes over them, the likelihood of damage is negligible, at least with the current number of visitors.

TYPE: Section.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0634452 7278761
65°36'10.1"N 11°55'4.9"E

READ MORE:
World Heritage Convention (2003).

1 *The raised shoreline at Hestvikskaret, along the trail up to Kjulsveten.*

Photo: A. Bergengren.


Vegtindan
Hestbakan
Vikatinden
Kommen
Nordre Vika
Søre Vika
Eidem
Kjulsveten
Vg1
Vg3
Vg4
Vg5
Nordre Kjul
Tårnet
Hestklubben
Hestvik
Trollrevheian
Vikasågen
Åkvika
Naustneset
Langholmen
Bærsneset
Korsholmen
Holman
Vikakråka
Hestvikodden
Norddypingan
Sørholman
Umaken
1 km

1

VG4

VIKAVÅGEN

At Vikavågen there is folded and deformed calc-silicate/ marble bedrock, exposed between the small road and the shoreline. Parking is available at the small turnaround between the houses. From here, there is only a short walk to well-exposed outcrops exhibiting strongly folded alternating layers of marble and calc-silicate rocks. The entire outcrop is a large xenolith in the Vega granite intrusion. It extends about one km northwards from Vikavågen (mostly covered by vegetation) and is surrounded by granite. The contact between the granitic host and the xenolith is clearly exposed at some places and makes this location a good pedagogical example for telling the story of the Vega granite intrusion and the partially melted sedimentary rocks found within it. The xenolith has in some parts well-preserved preserved layered structure, whereas other parts are heavily deformed.

This site is only described and used by scientists today.

KEY WORDS: Calc-silicate xenolith, granodiorite, folding structures.

THREATS: The only possible threat to this site would be the construction of houses (boat houses) along the shoreline, but this is not a current issue.

TYPE: Area.

GEOLOGICAL IMPORTANCE: NAT

GEOLOGICAL PHENOMENA: Magmatic, tectonic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

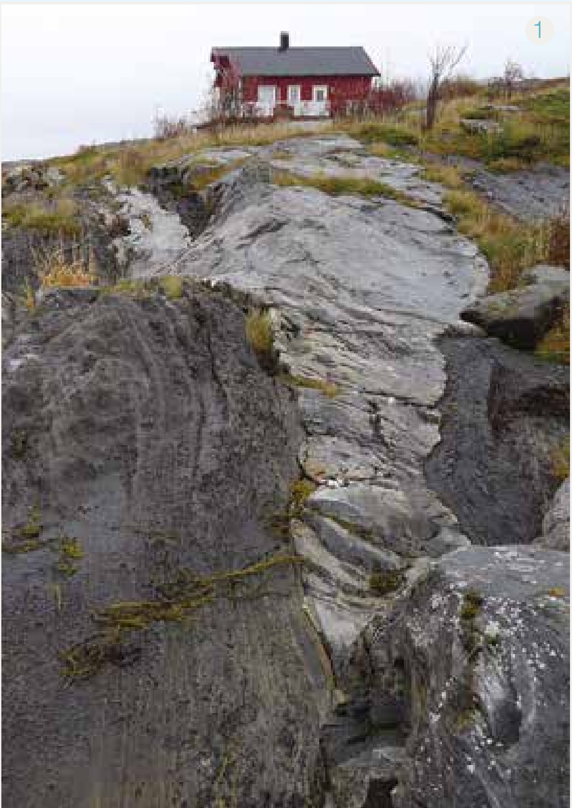
GPS POSITION:
UTM 32W 0632171 7278858
65°36’16.6”N 11°52’6.9”N

READ MORE: Nordgulen et al. (2011). Marko et al. (2013).

❶❷❸ Folded and deformed calc-silicate/ marble bedrock and xenoliths.

Photos: A. Bergengren


Trollvass
tinden
Hestbaken
Vikatinden
Vegtindan
Nordre Vika
Søre Vika
Kjulsveten
Vg1
Vg5
Eidem
Vg4
Trollrevhesan
Tårnet
Vg3
Hestvik
fjellet
Norddypingan
1 km


1


2


3

VG5
LEVIKA

At Levika you find examples of magmatic fabrics and the diverse enclave population on the south-eastern side of Vega. This is seen in the granitic rocks that extend seawards from the parking place and the football field. The Vega granite crystallized from a melt made up by partially melted sedimentary rocks (similar to those present on northern Vega today). Rocks having compositions that resisted melting are present in the granite as enclaves. Levika is situated close to the Eidem recreational area, and is a popular spot for school trips and family picnics. The enclaves are commonly shaped in a variety of ways that might resemble fantasy figures. These features will catch the attention of children, and make them interested in the different types of bedrock.

Enclaves at Levika include an assortment of schist, gneiss and mineral aggregates.

The site is described and visited by scientists today, but since there are many visitors in the recreational area, both families and school classes, this would be a good touristic and educational site. It is easily accessible and the geological features are well seen.

KEY WORDS: Vega granite, diversity of enclaves, magmatic fabrics.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Magmatic, tectonic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0629816 7279747
65°36'48.7N 11°49'6.3"E

READ MORE: Nordgulen et al. (2011). Marko et al. (2013).

1 2 4 3 Partially melted sedimentary rocks seen as enclaves in the granitic rocks at Levika.

Photos: A. Bergengren


Vg10
Vg11
Trollvass-
tinden
Hestbakken
Vikatinden
Vegtindan
Nordre Vika
Kammen
Vg5
Søre Vika
Eidem
Vg6
Trollrevheian
Vikavågen
Åkvika
Håbrannen
Erviktaren
Langholmen
Korsholmen
Vikakråka
Holmen
Hestvikodden
Lyngholmen


1
2
3
4

VG6

GURISTRAUMEN

Metamorphosed sedimentary bedrock, a walking trail on lime-rich bedrock with rich flora. Metamorphic rocks containing garnet.

This is a popular hiking trail on a peninsula close to Guristraumen, an area with strong tidal currents and exciting local stories of the lady Guri who allegedly drowned here. This is the typical landscape of northern Vega, with lime-rich, sedimentary bedrock giving a high biodiversity with many orchids. The sedimentary bedrock is highly metamorphosed, and crystals of garnets are commonly observed. Outcrops of granite are also present along the trail, providing an excellent example of the contrast in vegetation between the fertile sedimentary bedrock and the barren granite.

Trollfjell Geopark has placed signposts for a geology-biology trail here, and offers guided tours in the area.

This site is one of the areas most commonly visited by tourists on Vega today. There is a marked trail with information about geology and biology. The site has a good educational potential and should be used more frequently by the local school.

KEY WORDS: Sedimentary bedrock, rich flora, hiking destination.

THREATS: Some part of the trail with lime-rich sediments may be more vulnerable, but since visitors follow a marked trail, this is not a current problem.

TYPE: Area.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Metamorphic, Geobiosphere.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

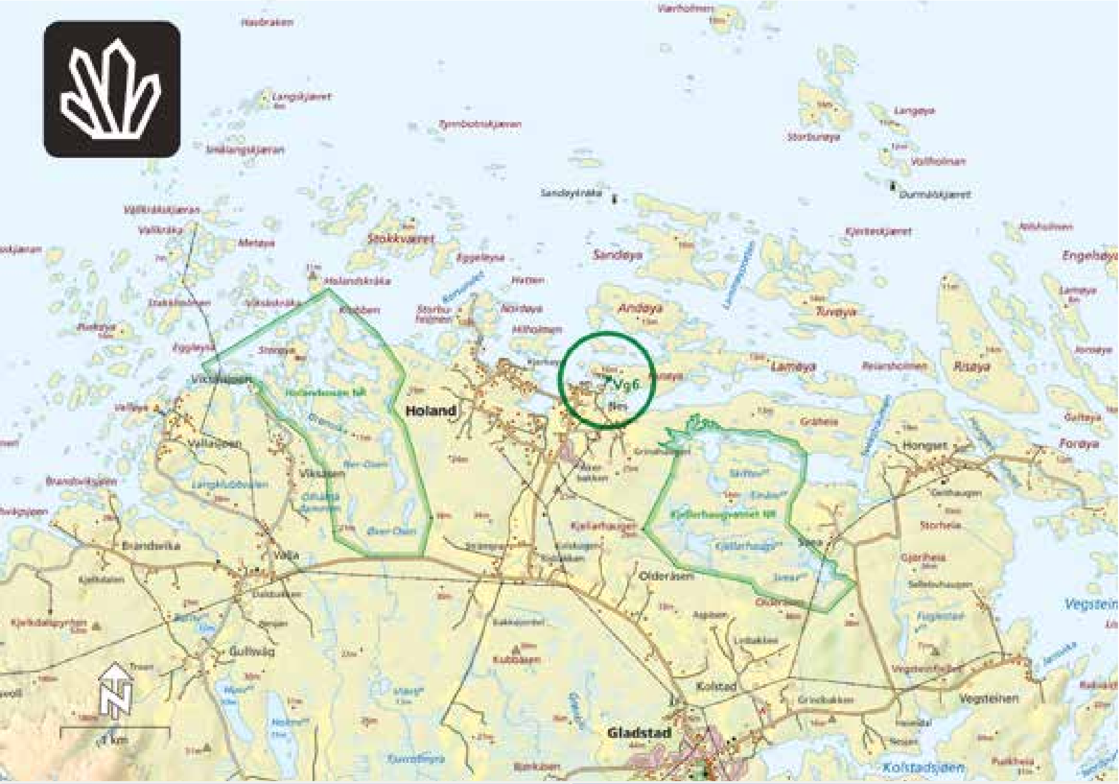
ACCESSIBILITY: Green.

GPS POSITION
UTM 32W 0634890 7290491
65°42'27.8"N 11°56'21.5"E

❶ The landscape at Vega have sharp contrasts, with the sedimentary rocks at Guristraumen in contrast to the high granite mountains in the south.

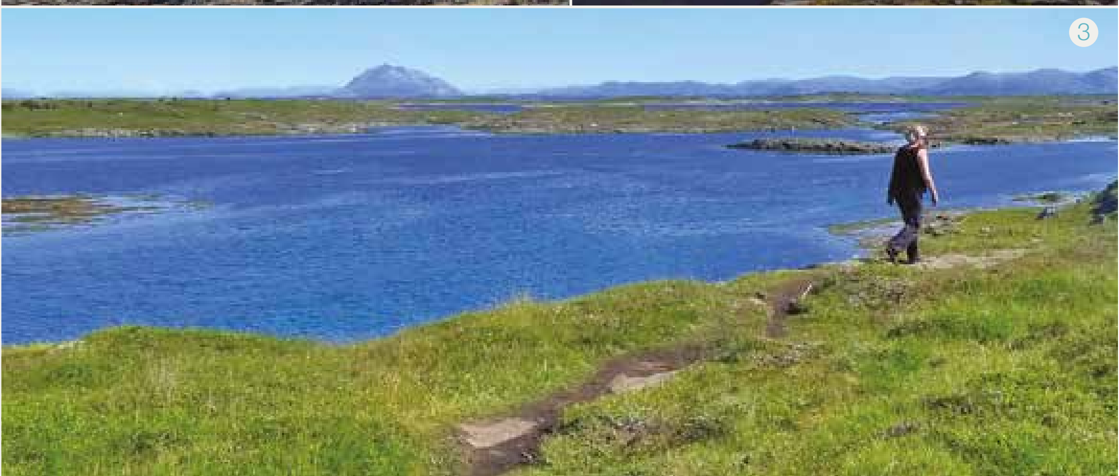
❷❸ The trail along Guristraumen is marked with information signs about the geology and biology of the area. For example, the trail passes over the breakwater made of local stone, and garnets are found for some parts along the trail.

Photos: A. Bergengren


Stokkværet
Sandøya
Andøya
Tuvøya
Lamøya
Risøya
Holand
Vg6
Hongset
Brandwika
Valla
Gullvåg
Olderåsen
Kolstad
Gladstad
Vegsteinen
Kolstadsjøen
Kjellerhaugvatnet NR
1 km


1


2


3

VG9
GULLSVÅGFJELLET

From this viewpoint, 725 m a.s.l., there is an amazing view where the typical Vega landscape, including the archipelago and the strandflat, can be seen. The radio tower at the top is a landmark for Vega, and there are remains of an old car lift to the top. This is a popular hiking destination with a marked trail. Gullsvågfjellet is the result of the about 475 million years old intrusion of the Vega granite, leaving the erosion-resistant granite mountains in the south, perfectly positioned to protect the human settlements in the northeast from the prevailing southwesterly winds. Gullsvågfjellet, as well as Trollvasstinden and Søla, are defined as a monadnock, and this type of high and steep mountains are common along the coast.

Erratic boulders have been observed on the Gullsvågfjellet plateau and we can thus conclude that the regional ice-sheet at some time, and probably also during the last Ice Age, has covered the entire island.

The extension of the strandflat is maybe best experienced from viewpoints like this, and there are thousand small islands and skerries extending towards the horizon. It is only from this highly elevated position that one can fully appreciate the wide and shallow sea areas, having a light blue-turquoise colour.

This site is used by tourists today, and could be used for education to learn about the strandflat and the landscape of Vega.

KEY WORDS: Viewpoint, hiking destination.

THREATS: There are currently no threats to this site.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Igneous, Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Red.

GPS POSITION:
UTM 32W 0631363 7284233
65°39'11.2"N 11°51'22.9"E

READ MORE: Marko et al. (2013). World Heritage Convention (2003).

❶❷The view from the top of the granite mountain Gullsvågfjellet is spectacular.

❸ Gullsvågfjellet from a distance.

Photos: A. Bergengren


Søla
Oksneset
Selneset
SØLIFJORDEN
Sundvoll
Gullvåg
Vg16
Sundsvoll-
hamran
V E G A
Aksla
Gullsvågfjellet
Vg9
Røsttinden
Røsttindlan
Vg10
Skjeggemoen
Vg11
Markaelva
Marka
Floaksla
Trollvass-
tinden
Vikatinden
1 km


1


2


3

VG10
MOEN 2

Along the trail leading towards Vegdalen, there is a small area with active sand dunes, where one can experience aeolian processes still at work. It is quite an experience for visitors to walk through the forest and suddenly arrive at this small "desert".

This site is close to the hiking trail to Vegdalen and visited by tourists. More information should be available.

KEY WORDS: Aeolian processes, active sand dunes.

THREATS: Threats to this site could be increase in vegetation or damage by rising numbers of visitors. The latter is no threat with the current number of visitors, for assessing the former, monitoring is needed.

TYPE: Area.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geomorphological, Sedimentological.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0630954 7283117
65°38'35.8"N 11°50'47.0"E

❶ *The "sand desert" at Moen, along the trail over Vegdalsskaret.*

Photo A. Bergengren

❷ *The "sand desert" at Moen, along the trail over Vegdalsskaret.*

Photo F. Høgaas


V E G A
Gullsvågfjellet
Vg9
Vg10
Vg11
Vg16
Vg1
Rosstinden
Sjeggemoen
Trollvass-
tinden
Hestbakken
Vikatinden
Vegtindan
Kammen
Nordre Vika
Søre Vika
Kjulsveten
Eidem
Markaelva
Floaksla
Floa
Marka
SØLFJORDEN
1 km
1


1


2

VG11
VEGDALSSKARET 1

Traces of a larger terminal moraine on Vega occurs on the topographically smooth northeast part of the island. In addition, two smaller local moraines are present in the mountains in the southern parts of the island. One of them, a small W-E-oriented local moraine, is situated on the east side of Vegdalsskaret. The moraine stand apart as a long ridge easily visible from the hiking trail leading from Moen towards Vegdalen. The material in the moraine derives from a local cirque glacier not connected to the regional ice sheet. The age of the moraine is unknown, but the material was most likely deposited during the colder climate in the Younger Dryas period, about 12.500 years ago. The other local moraine occurs at 500 m.a.s.l. in the mountain west of Trollvasstinden.

This site is seen from the hiking trail used by tourists, but we believe that the main value of this moraine is educational, i.e. it is a suitable site to learn about the local ice sheet movement.

KEY WORDS: Younger Dryas local cirque moraine.

THREATS: Since of its fairly remote location in the mountains, there are no current threats to this site (in comparison to the larger terminal moraine situated on the northern arable land, which has almost disappeared).

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA:
Geomorphological, Sedimentological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue.

GPS POSITION:
UTM 32W 0629456 7282410
65°38’15.2”N 11°48’47.5”E

READ MORE:
World Heritage Convention, (2003).
Bargel et al (2007).

❶❷ *The local moraine at Vegdals-skaret.*

Photo: A. Bergengren


VEGA
SØLFJORDEN
Vg16
Sundsvoll-flauran
Gullsvågfjellet
Vg9
Røstinden
Akala
Røstindtan
Vg10
Skjeggemoen
Markaelva
Vg11
Krokkavlen
Trollvass-tinden
Hestbaken
Vikatinden
Vegtindan
Kammen
Nepsundet
Dyrholmen
Båtvikholmen
Vg5
Eiden
Nordre Vika
Søre Vika
Eirvikodden
Håbrannen
1 km

1
2

VG16
SUNDSVOLL COASTLINE AND SØLA

The area at Sundsvoll is a popular resort area, with tables and a barbecue place. Along the beach, unusually large rounded boulders and cobbles can be seen. These large boulders are not just spectacular, but also good representatives for the Vega granite, with enclaves seen in the bedrock. The Vega granite with enclaves can also be seen at geosite V5, Levika. This includes superior examples of nodular and dendritic cordierite that crystallized from the melt forming the Vega granite. The various intriguing shapes of the inclusions will trigger your fantasy, and it is a popular activity for children to look for odd-looking shapes in the rocks.

The scenic trail southward along the coast from Sundsvoll towards Vegdalen offers an excellent view of the island Søla situated a couple of km west of Vega. Søla is defined as a monadnock and is an excellent example of the granite's resistance towards erosion, as the small island rises high above the sea with steep cliffs. This type of resistant granite, forming small islands with steep cliffs that rise high above sea level, is typical for this part of the Norwegian coast. Landforms such as talus are seen along the steep mountains cliffs and are good example of mechanical erosion. A raised shoreline eroded into the bedrock can be seen on the southern side of Søla.

Further south, the outcrops surrounding the bay at Vegdalen is of particular interest, providing unprecedented examples of the interaction of granite magma with metasedimentary host rocks. In this area, the granite is in many places a diatexite, e.g. a migmatite composed of partially melted metasedimentary rocks and granite. Oriented swarms of inclusions, in places deviating around large, intact xenoliths, are evidence of flow in the migmatite (see photos).

This site is visited both by scientists, tourists and school classes. However, the information about geology at the site could be improved.

KEY WORDS: Island, granite mountain, coastline, rounded boulders, enclaves.

THREATS: There are currently no threats to this site.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous, Metamorphic, Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 32W 0628534 7285642
65°40'0.7"N 11°47'46.7"E

READ MORE: Nordgulen et al. (2011).

❶ The rounded boulders at Sundsvoll coastline, with Søla in the background.

Photo: A. Bergengren

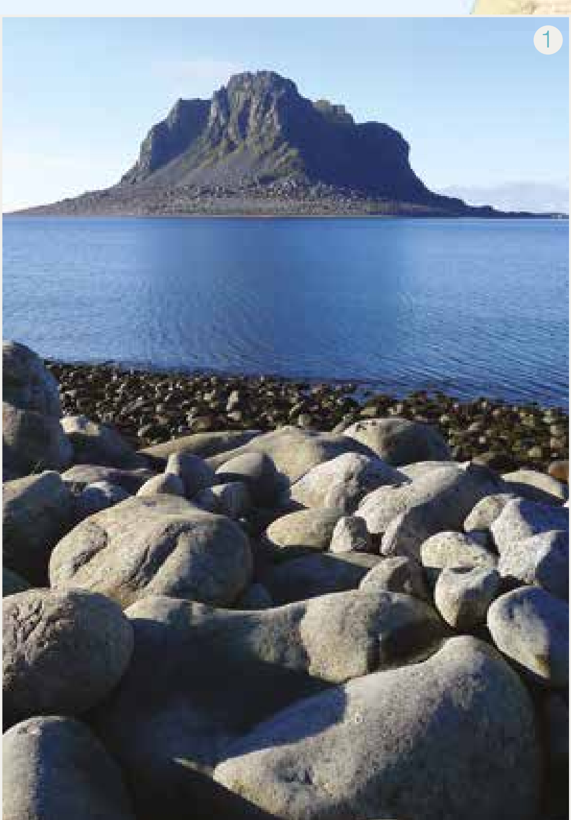
❷ Oriented swarms of inclusions found in the rocks along the trail.

Photo: Ø. Nordgulen

❸ Sundsvoll is a popular recreational area.

Photo: G. Hauglid-Formo


Sundsvoll
Fjellsøya
Slettøya
Grasskjærleia
Skarvøyskjæran
Skarvøya
Sølaværet
Søla
Harphaugen
Lisshelløya
Storhelløya
Okseneset
Selneset
Beisholmen
SØLIFJORDEN
Brandvika
Vega
Gullvåg
Kvalholmen
Vg16
Sundsvoll-
hamran
Mårneset
Gullsvågfjellet
Vg9
Røstinden
Røstindan
Aksla
V E G A
Vg10
Skjeggemoen
Vg11
1 km


1


2


3

VG18

YLVINGEN ISLAND

The island of Ylvingen has an interesting geology. Most of the island to the west consists of medium-grained biotite granite, locally with K-feldspar phenocrysts. The granite is well exposed around the WWII German artillery post (non-geological site V2-9). In general, the granites are massive, however, strong fabrics are locally present, especially close to the contacts with the metasedimantary host rocks. Garnet is present in the biotite granite in the northern parts of Ylvingen. In the same area, a small body of dark grey diatexitic migmatite crops out.

A 0.5 km wide zone along the east coast is underlain by metasedimentary rocks that are part of the S-T Nappe (Helgeland Nappe Complex): metapelite, metagreywacke, metaconglomerate, calc-silicate rocks, and marble. The metasedimenatry rocks are strongly foliated and the foliation is parallel to isoclinal folds. Despite strong deformation, sedimentary structures such as graded bedding and channel fill deposits are common in this rock unit.

The granitic rock, which is part of the Bindal batholith (or Vega granite), intruded the metasedimentary rocks around 475 Ma. This is typical for the Vega archipelago, where the many of the islands are underlain by granodiorite and biotite granite that intruded into clastic and carbonate metasedimentary rocks.

The island is a tourist destination, but scientists mostly use the geological sites today. Information and new signposts could easily inform the tourists about the geology.

KEY WORDS: Biotite granite, clastic and carbonate metasedimentary metavolcanic rocks.

THREATS: There are currently no threats to this site.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous, Metamorphic, Geomorphological.

VALUE:

PROTECTION: Natural Reserve, Bird Protection Area.

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
65°37'12.6"N 12°9'2.9"E
UTM 33W 0368800 7280550

READ MORE: Oalmann et al (2011).

❶ *Metasedimentary rocks along the east coast.*

❷ *The biotite-granite at Ylvingen.*

Photos: A. Bergengren

❸ *Gelogical map of Ylvingen from Oalmann et al 2011.*

1

2

3

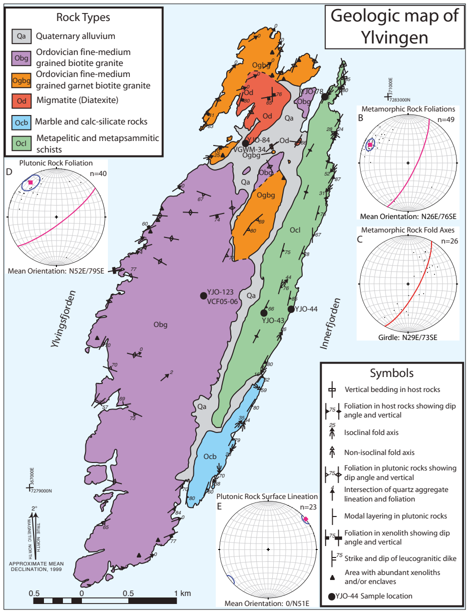


Figure 3: A) Geologic map of the island of Ylvingen. B–E) Stereographic projections of structures measured on Ylvingen. Squares and great circles on B, D, & E represent mean orientations. B) Poles to metamorphic rock foliation. C) Metamorphic rock fold axes. Red great circle represents girdle, which is a cylindrical best fit to poles. D) Poles to hypersolidus and subsolidus plutonic rock foliations. E) Intersection of quartz aggregate lineation and foliation visible on pavement surfaces in plutonic rocks.

VG21
LÅNAN-SKJÆRVÆR

Among of the numerous small islands and skerries in the strandflat archipelago, Lånan-Skjærvær is one of the best examples. This is part of the World Heritage Area, with semi-domestic eiders and eider down harvesting. During the season there are frequent boat tours for tourists out to the islands.

This site is used by tourists.

KEY WORDS: Strandflat Islands, World Heritage Area.

THREATS: The islands are protected as a Natural Reserve and as a Bird Protection area and only a limited number of visitors are allowed.

TYPE: Area.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Geomorphological, Geoculture.

VALUE:

PROTECTION: Natural Reserve, Bird Protection Area.

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 32W 0618063 7297003
65°46'21.8"N 11°34'44.2"E

READ MORE:
World Heritage Convention (2003).

❶ *Lånan-Skjærvær is one of the most visited strandflat islands in the area.*

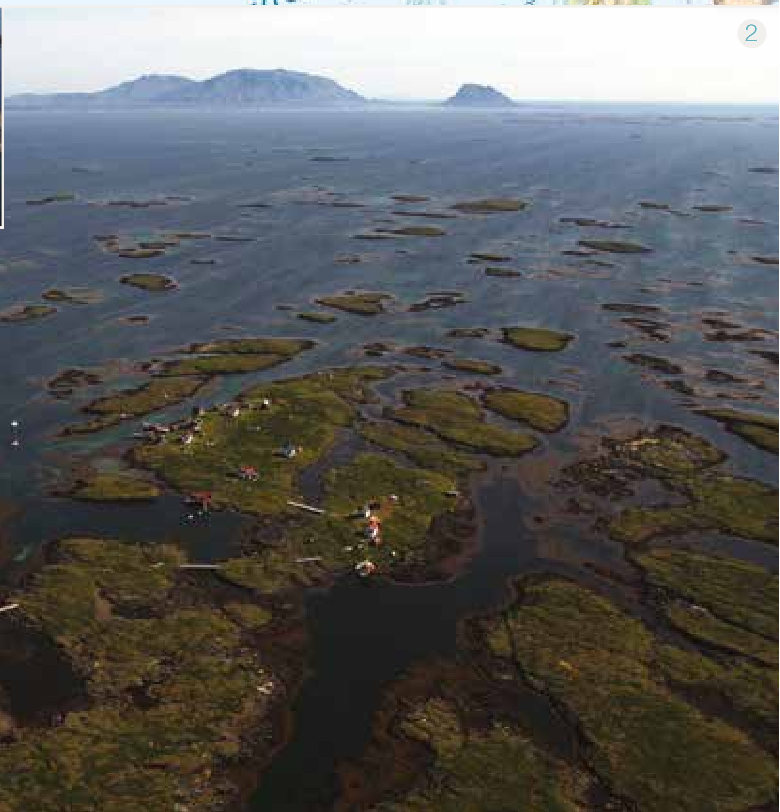
Photo: Vega World Heritage Area

❷ *Lånan-Skjærvær.*

Photo: I.O. Tysnes

ALSTAHAUG
Hestøysund
Kilværfjorden
Skogsholmen
Kilværet
Tjøtta
Tjøttfjorden
Vg21
Skjervær
Hysværet
Mykkelbo
VEGA
Kirkøy
Nes
Vg6
Hongset
Valla
Holand
Gladstad
Vegstein
Igerøy
Vågsodd
Mindvær-
Sundsvoll
Søla
Hestun
Hamnøya
839
Vg16
Åsen
Rørøy
Vv1
Hamn
Vg9
Vega
Vg10
Vg11
Floa
Vg22
Trollvasstinden
Ylvingsfjorden
Ylvingen
Høyholm
Vv3
Vika
Vg5
Vg1
Vg18
17
Eidem
Vg4
Vg3
Laukenes
Vv4
Horn
Andalsvåg
5 km
Muddværet


1


2

VG22
BREMSTEIN

An impressive breakwater is present at the strandflat island Bremstein. The breakwater is constructed by local pink granite mainly from a quarry at the neighbour island Heimøya. The granite consists of pink feldspar, biotite and some quartz and is probably from Cambrian- Silurian time. The granite is used as a building material for other houses and constructions in the island group, maybe not so much for its good quality, but rather because of the difficulty of transporting stone the long distance (15 km) from Vega. The breakwater was constructed between 1910 and 1916, and a temporary railway track was built to transport the stone. A stone monument is placed by the breakwater as a memorial.

This geosite is only reachable by boat, and even if visited by tourists today, the long distance makes this tour very weather dependent and the tourist potential is somewhat limited.

KEY WORDS: Breakwater, granite, local stone production.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geoculture, Georesource.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Boat

GPS POSITION:
UTM 32W 0609850 7279750
65°37’15.5”N 11°23’7.6”E

READ MORE: Lindahl (2011). Bremstein & Andersen (1992).

1 *The impressive breakwater at Bremstein.*

Photo: R. Johansen


Skogsholmen
Kilværet
Tjøttfjo
Vg21
Skjervær
Hysværet
VEGA
Kirkøy
Nes
Vg6
Hongset
Valla
Holand
Gladstad
Vegstein
Igerøy
Søla
Sundsvoll
839
Vg16
Åsen
Vg9
Vega
Rørøy
Vg10
Vg11
Floa
Trollvasstinden
Vika
Vg5
Vg1
Eidem
Vg4
Vg3
Ylvingsfjorden
Ylvingen
Vg18
Vg22
Bremstein
Hamnøya
Vv1
Høyholm
Horn
Muddværet
Vegafjorden
Tilremfjorden
Tilrem
Br23
Sauren
5 km


1

W1
ESØYA

The island of Esøya displays, like Skei at Leka, contact relations between ophiolitic rocks and metamorphic sedimentary rocks deposited on top of the eroded ophiolite in Early Ordovician times. Unlike Leka, the contact on Esøya is strongly disturbed by folding and thrusting, and on the southern part of the island one may walk across two thrust faults.

The ophiolitic rocks are predominantly gabbro, and on the northern part of the island they have been altered to soapstone. The soapstone deposits have been quarried in the medieval period, both for ashlar blocks for building medieval churches in the region, and for cooking pots and other utensils, such as fishing weights. Remains from the ancient quarrying are partly well preserved and spectacular, and one may even see how the land has rizen almost one meter after the quarrying ended. A 12th century runic inscription, probably made by one of the quarrymen, are found on the rock face. The site also contains a deposit of emerald green actinolite.

The metamorphic sedimentary rocks consist of flattened conglomerate and schist, in which perfect, large crystals of staurolite and garnet may be seen, a particularly good site for viewing metamorphic mineral growth.

This site is only reachable by boat, and is today mainly in use as recreation area for local people during the summer. Temporary harbour facilities are installed in the spring and removed before the winter season. The site has good potential for organized boat tours.

KEY WORDS: Contact gabbro conglomerate, thrusting, soapstone quarry, runic inscription.

THREATS: The soapstone quarry with runic inscriptions is considered vulnerable, but has legal protection as a cultural heritage. Due to the limited access there will be low numbers of visitors.

TYPE: Complex Area.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA:
Metamorphic, Tectonic, Georesource, Geoculture.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: High.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 33W 0375776 7284867
65°39'41.8"N 12°17'53.0"E

READ MORE: Berglund (1999). Grenne & Heldal (2006). Lindal (2011).

❶ The different bedrock at the southern part of the island.

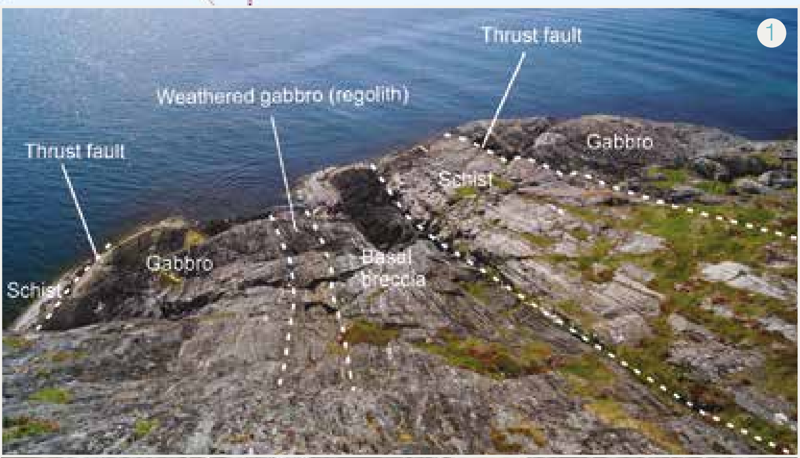
Photo: T. Heldal

❷ The runic inscriptions at the soapstone quarry.

Photo: T. Haugann

❸ Geological map of Esøya from NGU 2015.


Slåttøya
H a m n ø y a
Veten
Hamn-
fjellet
Bullfjellet
Vv1
Vv3
VEVELSTADSUNDET
Småværan
Nordgården
Midt-
Høyholmen
Nær-Høyholm
1 km


1
Thrust fault
Weathered gabbro (regolith)
Thrust fault
Gabbro
Schist
Gabbro
Basal
breccia
Schist


2


200 100 0 200 Meters
3
Fault/shearzone
Soapstone quarry
Quarry debris
Soil cover
Mica schist
Basal breccia
Gabbro
Soapstone
Actinolite rock

W3
HØYHOLM

Quarry with extraction of building stone from huge blocks of porphyritic granite produced by landslides and rock fall. The granite is a typical variety within the Andalshatten Batholith. Granite from this site was extracted between 1993-1995, and has, for example, been used in the floor of the municipality house in Vevelstad, at the Geological Survey of Norway, and for a war memorial in Mosjøen. The quarry is not in operation today, but is situated right beside the trail leading up to Oddvar I. N. Darren's art installation "Opus for Heaven and Earth", a large circle on the rock face where the granite has been polished.

The site is close to the trail to the art installation, and is visited by tourists. However, better information about the granite and the use of the stone as building material could be added.

KEY WORDS: Grey porphyry granite, building stone, quarry.

THREATS: Since the granite is situated so close to the art installation, quarrying will most likely not be carried out in the future. Threats to this site are considered to be low.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Igneous, Georesource.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

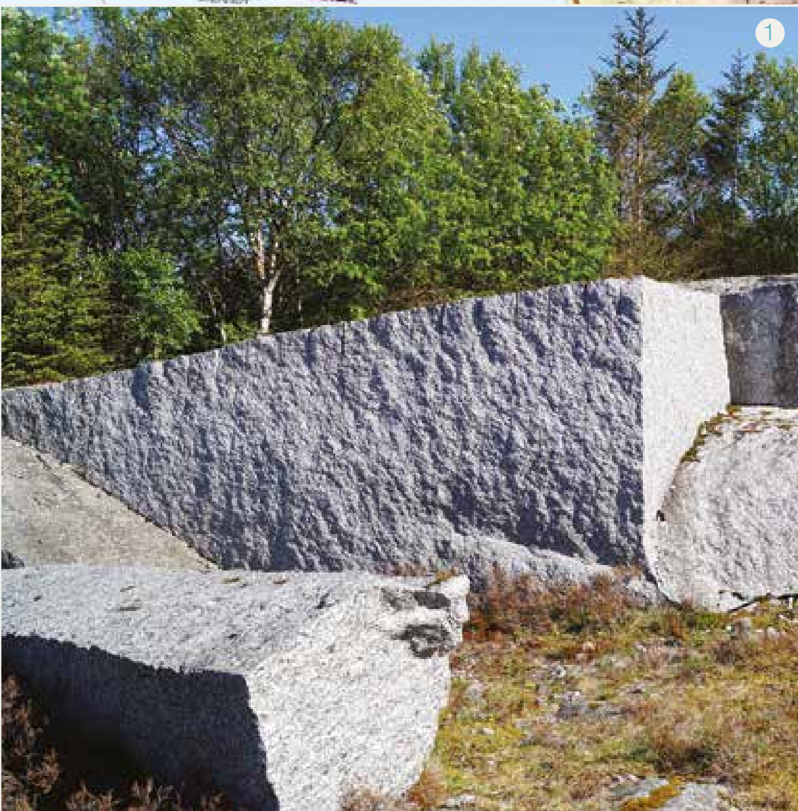
GPS POSITION:
UTM 33W 0379046 7281549
65°37'59.3"N 12°22'19.6"E

READ MORE: Lindal (2011).

❶❷ *Blocks with porphyritic granite at Høyholm.*

Photos: A. Bergengren


Vv1
fjellet
Bullfjellet
Esøya
Kongshågen
Musholmen
Nordgården
Nør-Høyholm
Midt-Høyholmen
Vv3
Nesodden
Leira
Kjertan
Fjordholman
Buøya
Brenndals-tinden
Høyholmstindan
Langdalen
Saltkar-tinden
Stortinden
Svanvasstinden
Liåa
Hansli-kammen
Hornstinden
Småvatnan
1 km
VEVELSTAD
BRØNNØY


1


2

W4

VOLLVIKA

The Andalshatten Batholith is particularly significant due to the display of large km-scale screens and small xenoliths of metamorphic sedimentary rocks that were split away from the host rock and included in the granodioritic intrusion. The large screens form a ghost stratigraphy reflecting the host rocks prior to intrusion. At Vollvika, the contact relations between the batholith and the rocks it intruded are readily observed along wave-polished coastal outcrops. Large and small wall rock xenoliths were broken apart and and injection of magma occurred along weak zones in the metasediments (i.e. contacts between layers) and brittle fractures. In places, xenoliths were partly assimilated by the granodiorite. It is also clear that the metasediments were folded before intrusion of the granite. After being included in the granodiorite, new ductile structures developed in the xenoliths. The Vollvika locality displays spectacular "schoolbook" examples of the mechanism of folding and cleavage development. Different types of dykes cut across the granodiorite and inclusions. Thus, the locality represents a frozen picture, 440 million years ago, of the relative timing of events that took place at an early stage of the Caledonian orogenesis.

This site has so far only been of interest to geologists, but we see a great potential for tourists here. The site is close to the road, and it is a nice walk close to the sea. The geological features are well visible.

KEY WORDS: Folded metasedimentary rocks, igneous rocks, granite, xenoliths.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: INT.

GEOLOGICAL PHENOMENA: Igneous, Tectonic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0378841 7277713
65°35'55.2"N 12°22'16.1"E

READ MORE: Barnes et al. (2007). Nordgulen et al. (2011).

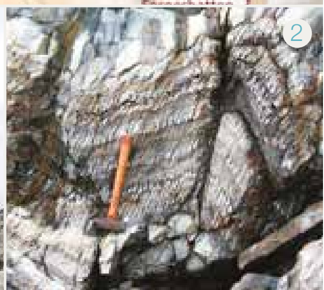
❶ *Metamorphic sedimentary rocks that were split away from the host rock and included in the granodioritic intrusion.*

❷ *Example of cleavage development in layered calc-silicate xenolith.*

Photos: Ø. Nordgulen


Stortinden
Svanvasstinden
Hansli-kammen
Hornstinden
Småvatnan
VEVELSTAD
BRØNNØY
Vv4
Fagerlia
Høyvik-fjellet
VELFJORDEN
Skutfjellet
Horn
Manndauden
Storhorn
Nesheia
1 km
Anddals-vågen
Anddalsvågen
Rundfjellet
Botn-vatnan


1


2

W5
VISTENFJORDEN

The 22 kilometre long Vistenfjorden is the most prominent fjord in the Trollfjell Geopark. Many large-scale and small-scale geolomorphological features related to the glacial periods are found along the fjord, including pot holes and raised shorelines. The latter are seen both as stone fields and terraces in the mountain side. There are also karst caves and raised sea caves in the area, but these are not easy to access and remain quite unexplored. The National Park Lomsdal-Visten encloses large parts of the fjord. An express boat is operating the fjord, and the route ends in Bønå. Here there are accommodation facilities, and the place is a good starting point for hikes in the large and wild national park.

The fjord is already a touristic site, but tourism here has large potential to grow.

KEY WORDS: Fjord, quaternary geology, pot holes, caves.

THREATS: There are no threats to the fjord today and The National Park Lomsdal-Visten surrounds the fjord for large parts.

TYPE: Area.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: National Park.

VULNERABILITY: Low.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 33W 0391686 7283695
65°39’24.7N 12°38’40.9”E

❶ *Vistenfjorden.*

Photo: A. Bergengren

❷ *Giant potholes along the fjord.*

Photo: C. Nordberg


Tjøttfjorden
Mindland
Tro
Stokkafjorden
Grytåga
Elvdalsfjellet
Mindlandet
Mykkelbostad
Stokkasjøen
Sørfjorden
Storfinnkneet
Mindvær-fjorden
Vistenfjorden
Vågsodden
Vistnes
Visthus
Grovfjellet
Forvik
Finnknefjellan
Vegstein
Igerøy
Hestun
Vevelstad
Kilvågen
839
Hamnøya
Brøløs
Kvalvågen
Vv1
Hamn
Vv5
Høyholmstindan
Visten
Bønå
Vistfjellan
Høyholm
Ylvingen
Vv3
VEVELSTAD
Vg18
Aursletta
17
Laukneset
Vv4
Snøfjelltinden
Horn
Andalsvåg
Innerhatten
Lomsdal-Visten nasjonalpark
Vistkjerringa
Tilremsfjorden
Tilrem
Br23
5 km
Austerdalsfjellet
Velfjorden
Salhus


1


2

BI1

HEILHORNET

Heilhornet is one of the most iconic mountains at Helgeland, reaching 1058 m.a.s.l. The summit is accessible in a popular, but demanding hike from the parking lot along the road south of Heilhornet. From the top there is an extraordinary view over the coast, and on a clear day one can see all the way to Træna.

The Heilhornet granite stands high above the surrounding meta-sedimentary rocks, forming three prominent peaks (Heilhornet, Kula and Lillehornet) that have the the are shaped like threeshark fins. This is a fairly common feature in glacially eroded granite terrains. The glaciers eroded on both sides of the peak, leaving a steeper and narrower "nunatak" for each glacial period.

The Heilhornet Pluton is a biotite hornblende graniteintrusion, of about 50 km^2 within the Helgeland Nappe Complex. It has been dated to 444 million years and was emplaced prior to the final collision between the Laurentia and Baltica continents, resulting in the Caledonian mountain chain.

This site is a popular hike for locals and tourists. Panorama sign at the top or information about the geology could be added.

KEY WORDS: Viewpoint, hiking destination, iconic mountain.

THREATS: Mainly being a viewpoint, there are no threats to this site.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: NAT.

GEOLOGICAL PHENOMENA: Geomorpholigical, Tectonic, Igenous.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Red.

GPS POSITION:
UTM 33W 0363170 7220899
65°4'60.0"N 12°5'18.6"E

READ MORE:
Nordgulen & Schouenborg (1990).

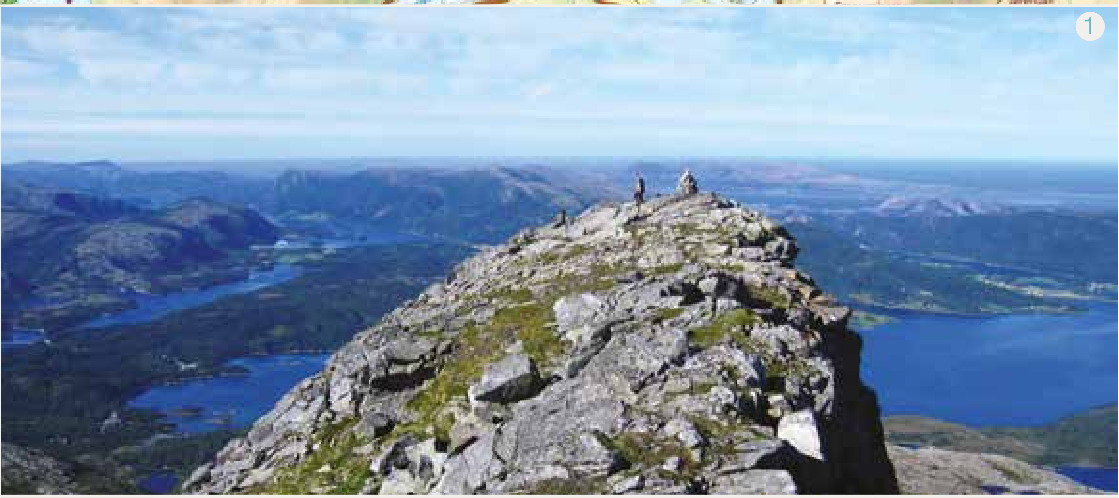
❶ *View from the top.*

Photo: Ø. Nordgulen

❷ *Heilhornet is an iconic mountain along the coast.*

Photo: A. Bergengren

Kveinfjellet
Litlhornet
Tjønnan
Kula
Horndalen
Lysfjord
myran
Husfjellet
Skjåholmen
Bi-1
Heilhornet
Hornfjellet
Markahornet
Horsbergv.
Sagvika
Svaberget
Sagfjellet
Oldervik-
fjellet
1 km
Høyklubben
Åmandøya
Sandvikholmen
Bi4
Sandvik-
fjellet


1


2

BI2
LYSFJORDMANA

The road 17 goes over, and partially through, a large moraine ridge at Lysfjordmana. This is a terminal moraine from an ice-sheet readvance during the early Younger Dryas, approximately 12.500 years ago. The Younger Dryas was a short climatic deterioration that interrupted the general temperature rise that ended the last glacial period - in other words, a final "spasm" of the Ice Age. The terminal moraine is bended and embanks the lake Lysfjordvatnet. At the mountain side 300-500 m.a.s.l. are several lateral moraines of which one can be followed for almost 5 km.

The Lysfjordmana terminal moraine is correlated to several lateral moraines east of Heilhornet. These are continuous push moraines stretching for several kilometres, indicating an ice-sheet readvance from a more easterly position. The moraine system coincides with the Tautra and Tjøtta events of the Trondheimsfjord and southern Helgeland regions, respectively.

This site has only been used by Quaternary geologists, but there is a potential to use this site for education, since the moraine is so large and the landform so visible and easy to access.

KEY WORDS: Terminal moraine, Younger Dryas ice-sheet readvance.

THREATS: The moraine is already cut by road 17, and there are several small gravel pits in the area. Further extraction of gravel and buildings of roads or houses could damage this site.

TYPE: Section.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Green.

GPS POSITION:
UTM33W 0363332 7223825
65°6'34.6"N 12°5'21.0"E

READ MORE: Bargel et al (2007). Olsen et al (2015).

123 The road 17 goes over, and partially through, a large moraine ridge at Lysfjordmana.

Photo: A. Bergengrenn


KJELLA
Heggbærneset
Heggbærnesfjellet
Lys-
fjorden
Botnafjellet
Bursvikbotn
Lysfjord
BI2
Kveinsjøaksla
Kveinfjellet
Litlhornet
Tjønnan
Kula
Lysfjord
myran
Nordhorsfjord
Horsfjordøya
Mølleraya
Sørhorsfjord
Skjeveinesodden
Skjeveineset
Hålopneset
Husfjellet
Fuglen
Valen
Bryggodden
Raymeset
BI1


1


2


3

BI3

KOLSVIKBOGEN GOLD MINES

Mineral exploration and exploratory gold mining have a long history at Buadalen, about 5 km from Kolsvikbogen at Tosenfjorden. The gold mineralization was first discovered in 1910 by a local farmer (Konrad Kolsvik). In the following years, sporadic investigations took place. In the 1930s the mineralized area was mapped in detail, drilling and geophysical investigations were carried out, and several adits up to 40 m in lenght were driven through prospective rock units. In the early 1940s an assessment of alluvial gold along the river downstream was undertaken. Extensive new mapping, more than 3,4 km of diamond drilling, and tunnelling through the ore zones took place in the 1980's (AS Sulfidmalm 1980-82 and Terra Mining A/S 1985-86), but ended due to low ore grade and volume. During this period a new road was constructed extending ca 5 km southwards from the fjord. Due to the currently high gold prices, the company Bindal Gruver AS are now activively prospecting the site again.

The main ore is native gold associated with arsenopyrite, with some galena and pyrite, occurring in quartz veins that cut granite as well as schist, marble and amphibolite. The gold is generally fine-grained, but locally visible grains are present. Highly variable contents of gold are common, and locally very high grades were recorded with consentrations ranging up to several tens of gram/ ton). A number of similar gold occurrences are known in the nearby region, e.g. at Reppen ca 6 km west of Buadalen, and at Oksfjellet and Finnlifjellet east and northeast of Buadalen.

This site is only reachable by boat from Tosenfjorden. From there, it is a hike for about 5 km to reach the site. If the mining company arranges visits, this could, together with the astonishing boat trip to get there, be a high-class tourist attraction. However, more arrangements are needed.

KEY WORDS: Gold mines, mineral extraction.

THREATS: This site has no protection and there is mining activity today by the company Bindal Gruver AS.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG

GEOLOGICAL PHENOMENA: Mineralogical, Georesource, Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: High.

ACCESSIBILITY: Boat.

GPS POSITION:
UTM 33W 0397159   7229079
65°10'8.4"N 12°48'17.8"E

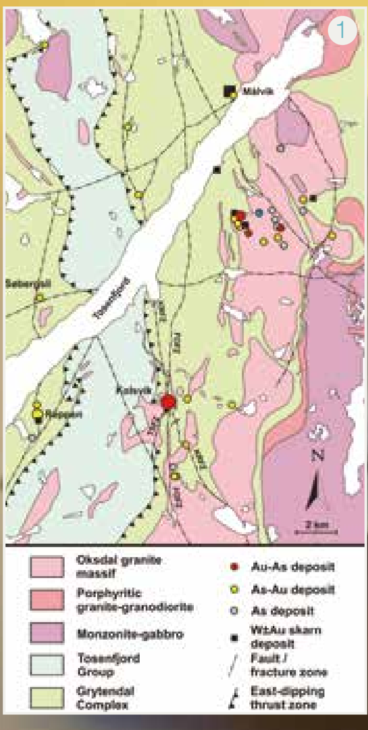
READ MORE: Bjørlykke (1943). Bjørlykke & Vogt (1944). Ihlen (1993).

❶ Geological map of Kolsvikbogen area from NGU.

❷ Gold in quartz (about 3 x1,5 cm), from Kolsvikbogen.

Photo: A. Bergengren

Vik
Ursfjorden
Kjøssvika
Nordfjellmarka
Vassbygda
Hardangen
Barstad
Br19
Br15
Lande
Rossvika
Sund
Tuvfjellet
Vennesund
S7
S5
17
Bindalsfjorden
BINDAL
Kalklavtind
Røingen
Holm
Røytvoll
Skjelsviksjøen
Otervika
Seternesfjellet
Tosen
Bi3
Bi7
Kjella
Oksen
Bindalseidet
Lysfjord
Sørhorsfjord
Bi2
71
Vassås
Terråk
802
Kjell-
eidet
Heilhornet
Bi1
Granbostadfjellet
Årsand
Bi4
Aunet
Kollfjellet
Terråkfjellet
Aelva
Åbjørvatnet
Selkie
5 km
Kollbotnet



1
Målvik
Tosenfjord
Røsgen
N
2 km
Oksdal granite massif
Porphyritic granite-granodiorite
Monzonite-gabbro
Tosenfjord Group
Grytendal Complex
Au-As deposit
As-Au deposit
As deposit
W±Au skarn deposit
Fault / fracture zone
East-dipping thrust zone

2

BI4
SANDVIKA QUARRY

In the Sandvika area, several rock units are stacked on top of each other, inclined gently towards the east. The lowermost rock unit is a gabbro derived from an ophiolite complex. The gabbro is well exposed along the fjord south of Sandvika. The gabbro is overlain by a succession of conglomerates and sandstones, deposited on top of the gabbro during the Early Ordovician. The contact is exposed along the road to the west of Sandvika.

Another unit of gabbro, also covered by conglomerates and sanstones has been thrust on top of the sandstones. This tectonically repeated nappe stack has been cut be the 444 million-year-old Heilhornet granite, showing that the thrust repetition of the rock units occurred before the main phase of the Caledonian orogeny.

The marble conglomerate at Sandvika has been strongly deformed, and the originally rounded pebbles in the conglomerate have been flattened to thin discs. The rocks contain some serpentine and other calc-silicate minerals in addition to calcite, and the combination of colour and structure made it attractive as ornamental stone. The old quarry faces and many squared blocks can still be seen in the quarry area. Quarrying took place over a few decades until it stopped in the early 1990s. Polished tiles of the marble conglomerate can still be seen at the Oslo Central Train Station.

This site is easily reached from the road, and could be used for tourism, if information about the geology was added.

KEY WORDS: Marble quarry, marble conglomerate.

THREATS: The only threat to this site would be if production continued or if the road was broadened.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Georesource, Tectonic.

VALUE:

PROTECTION: -

VULNERABILITY: Medium.

ACCESSIBILITY: Green.

GPS POSITION.
UTM 33W 0368986 7217656
65°3'23.8"N 12°12'54.4"E

READ MORE: Lindal (2011).

❶❷ *The marble conglomerate at Sandvika.*

Photo: A. Bergengren


Bl3
Hellhornet
Markahornet
Aspnesfjellet
Sørfjorden
Bogaodden
Nordodden
Valvikodden
Saltbunes-
odden
Myra
Stormyrlia
Bl4
Sandvik-
fjellet
Åsandøya
Straumhatten
Risaksla
Svartåsfjellet
Middagstuva
Middagsfjellet
Kollfjellet
Litlgrønlandet
1 km


1


2

BI7
GULDVIKHAUGEN GRANITE DYKES

The outcrops along the shoreline below Guldvikhaugen are composed of two types of rocks: dark greyish calcareous schist displaying folding and ductile shearing, and white granite, partly tourmaline bearing. The latter has intruded as hot magmas into cracks in the schist, forming thin and thick "stripes" on the outcrops. Such plate-shaped bodies of igneous rocks are called dykes.

The granite dykes are the offspring from a larger intrusion to the east and north. We may count several "generations" of dykes. The earliest have been strongly deformed, whilst the latest cut through all ductile structures, but are displaced by brittle faults. Late dykes can also be seen cutting through the older ones.

Being 100% exposed, the locality provides a unique insight in the mechanism of ductile and brittle deformation, the formation of intrusive dykes. It is a superb example of how relative timing of events seen on an outcrop scale can reveal a fragment of the geological history in the region.

This site is not in use today, is situated next to the road 17 and easy to access.

KEY WORDS: Granite dykes.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: REG.

GEOLOGICAL PHENOMENA: Igneous, Tectonic, Metamorphic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0364679 7228543
65°9'8.8"N 12°6'47.3"E

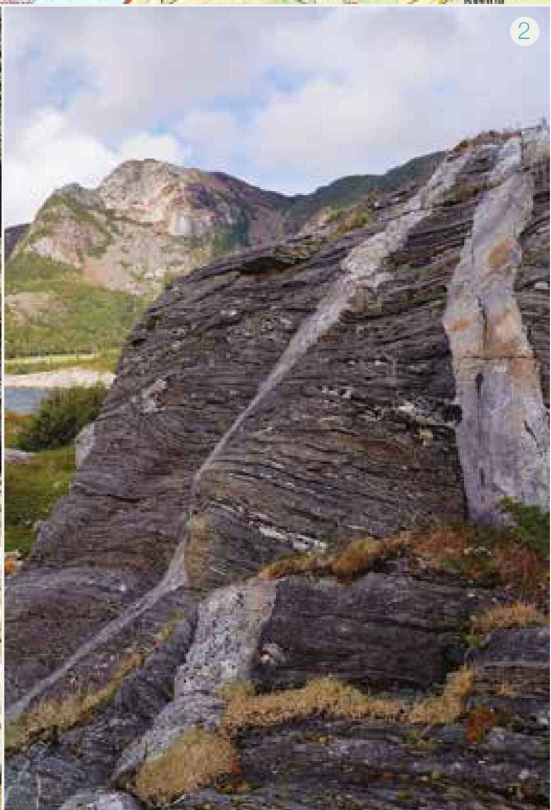
Light coloured granitic dykes cutting calcsilicate schist at Guldvikhaugen.

❶ *Photo: Ø. Nordgulen*

❷ *Photo: T. Heldal*

Holm
Holmsvågen
Rugifjellet
Halifjellet
Middagstinden
Holms-
Holmshatten
fjellet
Mefjellet
Nordfjellet
Kjellsand
Myre
Fjellenget
Bjørnlia
Middagsaksla
Bruneset
Brokengfjellet
Øvre
Markavatnet
Nedre
Vassfjellet
Heilsfjellet
Heilsvika
Storheil
Oppdalsvika
Storvika
KJELLA
Heggbærneset
Botnafjellet
Langåsen
Lys-
fjorden
Heggbærnes-
fjellet
Bursvikbotn
Røyrneset
Kveinå
1 km

1



2

S1
RØDBERGAN

North of the community Vik, to the west of road 17, a lens shaped body of serpentinite is located within mica schist. The body measures 60 times 30 metres, but is clearly visible from distance due to its reddish brown colour (from oxidation of iron in the serpentinite). The serpentinite also stands up from the surrounding mica schist, being harder and more resistant to weathering.

The serpentinite represents a mantle fragment from the ophiolite complexes, and was probably tectonically juxtaposed with the mica schists.

Along the margins of the serpentinite, soft talc schist (soapstone) is formed. Soapstone is an extremely soft but yet durable rock, and has unique heat storing capacities. This has been exploited in ancient times, probably during the Viking Period or slightly later. Soapstone was used for various utensils and cooking pots, and in the small quarry faces around the serpentinite it is possible to see circular depressions in the rock from carving, representing negative imprints from the extraction of cooking vessel roughouts.

The outcrop is well visible from the road, but there is no marked trail today. If a path and information were arranged, this has the potential to be a good touristic site.

KEY WORDS: Soapstone quarry, serpentinite.

THREATS: This soapstone quarry has legal protection as a cultural heritage site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Metemorphic, Georesource, Geoculture.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: Low.

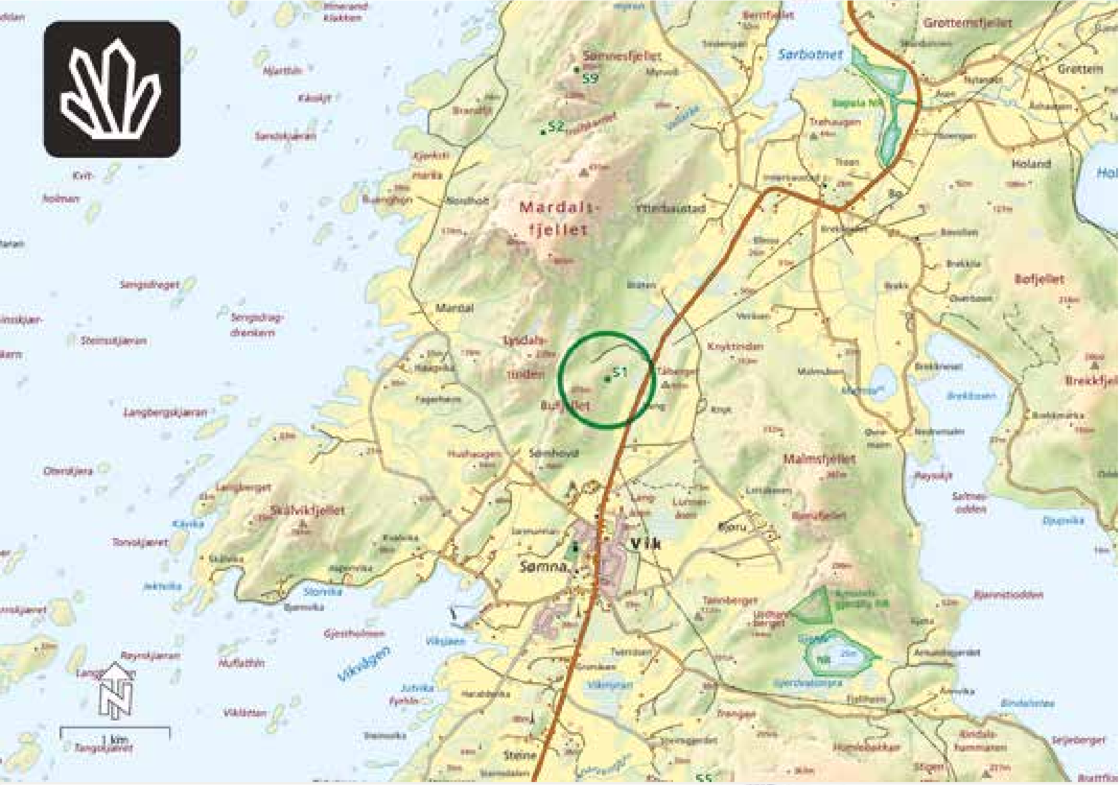
ACCESSIBILITY: Blue.

GPS POSITION:
UTM 33W 0368098 7247628
65°19'30.0"N 12°10'3.8"E

READ MORE: Lindal (2011).

❶❷ *The seprentinite body is clearly visible from distance due to its reddish brown colour. The soapstone along the margins of the sperpentinite was exploited in the Viking Age.*

Photo: A. Bergengren


Mardals-
fjellet
Sørbotnet
Grottemsfjellet
Grøttem
Holand
Bøfjellet
Malmsfjellet
Skålvikfjellet
Vik
Sømna
Vikvågen
S1
S2
S9
1 km


1


2

S2
TRIBORGEN

A raised shoreline seen as a large field with rounded stones 40-50 m.a.s.l. A marked path leads the way through a dark forest, that suddenly opens up for this area with rounded stones. As if the fairy-tale atmosphere was not there already, there are old legends about a treasure buried under the stones at Triborgen. A large delegation came to Sømna in 1887 to dig for the treasure. However, it was never found. Today the area is protected as a Cultural Heritage and no digging is allowed.

This site is one of the most well known attractions in Sømna. It is visited both by local people and by tourists, and there is a marked trail. Additional information about geology is needed.

KEY WORDS: Raised shoreline, quaternary geology, local mythology.

THREATS:
Triborgen is protected as a Cultural Heritage, but there is a risk that visitors might move rocks to dig holes or build piles, in spite of the protection.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA:
Geomorphological.

VALUE:

PROTECTION: Cultural Heritage.

VULNERABILITY: Medium.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0367507 7249908
65°20’42.2”N 12°9’10.2”E

1 Triborgen is one of the most well known attractions in Sømna.

Photos: A. Bergengren


Torgværet
Berg
Øyfjellet
Sømnesåsen
Sømnesfjellet
S9
S2
S1
Sørbotnet
Grottemsfjellet
Mardals-
fjellet
Lysdals-
tinden
Bufjellet
Malmsfjellet
Skålvikfjellet
Holand
Bø
1 km


1

S5
STEIN POTHOLES

A large pothole in the area around Stein. This is a popular hiking destination for families, and regularly visited by local people. The pothole is about five meters in diameter and at about seven meters deep.

Potholes are formed by boulder erosion into the bedrock caused by strong and turbulent water flows. Many of the potholes found in the Norwegian landscape, were formed during the later episodes of the last ice age, when high pressure melting water along the edges of glaciers created favourable environments for the formation of potholes. In folkloric tales, potholes were explained as the troll's cooking pots.

This site is in use as a touristic site with a marked trail and is popular as a hiking destination for families. Additional information about the geological process forming the pothole could be added.

KEY WORDS: Pot holes, hiking destination.

THREATS: There are currently no threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0368867 7243899
65°17'30.3"N 12°11'16.0"E

1 The large pothole in the area around Stein is a popular hiking destination for families.

Photos: A. Bergengren


Skålvikfjellet
Sømhovd
Malmsfjellet
Vik
Sømna
Vikvågen
Steine
55
Steinsfjellet
Arnesfjellet
Sande
Sandvågen
Kjøsvika
Kjøsvik-
fjellet
Kamtinden
Enge
Vig
Brokhaugen
1 km


1

S7
KVENNVIKA MINERALS

Kvennvika area is a popular recreational area, with a beautiful sandy beach and a stunning view towards Leka. In the schist outcrops on and near the beach, one can see crystals of metamorphic minerals that have grown in the schist almost 480 million years ago. Garnet, staurolite and kyanite are common. The latter makes the site scientifically important since the occurrence of kyanite shows that the rocks were exposed to high temperature and pressure when the mineral grew in the schist.

This is a popular area frequently visited by local people and tourists. Additional information about geology is needed.

KEY WORDS: Beach, minerals, recreational area.

THREATS: Since this is registered as a recreational area in the district, there are no current threats to this site.

TYPE: Point.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Mineralogical, Metamorphic.

VALUE:

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Green.

GPS POSITION:
UTM 33W 0360338 7235145
65°12’35.2”N 12°0’50.5”E

❶ *Kvennvika area is a popular recreational area.*

❷ *In the schist outcrops on and near the beach, one can see crystals of metamorphic minerals, such as kyanite.*

Photos: T. Heldal


Langøya
Kvaløya
Kvaløyfjellet
Jotulen
Vennesund
Skårfjellet
57
Sørfjellet
Søre Vennesund
Gimlinga
Gimlingsundet
Storgeitungen
Lillgeitungen
Brennholman
Kvennvikneset
Brunvikneset
Gimlingholman
Ljøstaren
Storskolten
Langdjupflua
RØINGEN
1 km


1
2

S9
SØMNESFJELLET

The top at Sømnesfjellet lays at 306 m.a.s.l and can be reached after a 1,3 km hike. It offers a good viewpoint to experience the agricultural strandflat landscape of Sømna and the archipelago with multiple islands. From the top there is a fantastic view in all directions, with Leka in the south, and Torghatten and Vega in the north.

Sømnesfjellet is a popular hiking route, often used by the local population.

KEY WORDS: Viewpoint, hiking destination.

THREATS: There are currently no threats to this site.

TYPE: Viewpoint.

GEOLOGICAL IMPORTANCE: LOC.

GEOLOGICAL PHENOMENA: Geomorphological.

VALUE: 🚶

PROTECTION: -

VULNERABILITY: Low.

ACCESSIBILITY: Blue. 🔵

GPS POSITION
UTM33 0367815 7250481
65°21'1.3"N 12°9'32.0"E

❶ ❷ ❸ The top of Sømnesfjellet is a good viewpoint to experience the agricultural landsape of Sømna, and the strandflat area along the coast.

Photos: A. Bergengren


Børg
Sømnesfjellet
59
52
51
Mardals-
fjellet
Sørbotnet
Sømnesåsen
Øyfjellet
Dyngeseterfjellet
Grottemsfjellet
Holand
Bøfjellet
Mardal
Ytterhalstad
Lysdals-
tinden
Bufjellet
Malmsfjellet
Sømnes-
øya
1 km


1


2


3

REFERENCE LIST

Albrektsen, B.A., Gurnes, H., Pedersen, R.-B. (1991): Formation of dunites in mantle tectonites, Leka Ophiolite Complex, Norway. Journal of Geodynamics, 13: 205-220

Anderson, H. S., Yoshinobu, A. S., Nordgulen, Ø. & Chamberlain, K. (2013): Batholith tectonics: Formation and deformation of ghost stratigraphy during assembly of the mid-crustal Andalshatten batholith, central Norway. Geosphere, 9 (3), 667–690.

Austrheim, H., Prestvik, T. (2008): Rodingitization and hydration of the oceanic lithosphere as developed in the Leka ophiolite, north-central Norway. Lithos 104: 177-198

Bargel, T. H, Sveian H., Bergstrøm, B., Olsen L. & Reite A. J.. (2007): Norges Kystområder, from Beskrivelse til kvartærgeologiske kart over Midt-Norden, ed. Bargel, T. H, NGU rapport 2007.024, p. 35-42.

Barnes, C.G., Dumond, G, Yoshinobu, A.S. & Prestvik, T. (2004): Assimilation and crystal accumulation in a mid-crustal magma chamber: the Sausfjellet pluton, north-central Norway. Lithos 75, 389-412.

Barnes, C.G., Frost, C.D., Yoshinobu, A.S., McArthur, K., Barnes, M.A. Allen, C.M., Nordgulen, Ø. & Prestvik, T., (2007): Timing of sedimentation, metamorphism, and plutonism in the Helgeland Nappe Complex, north-central Norwegian Caledonides. Geosphere 3, 683–703.

Barnes, C.G. & Prestvik, T. (2000): Conditons of pluton emplcament and anatexis in the Caledonian Bindal Batholith, north-central Norway. Norwegian Journal of Geology, 80, 259-274.

Barnes, C.G., Prestvik, T., Barnes, M.A. & Anthony, E.Y. (2003): Geology of a magma transfer zone: the Hortavær Igneous Complex, north-central Norway. Norsk Geologisk Tidsskrift 83:187-208.

Barnes,C.G., Prestvik, T., Li, Y. (2009): Growth and zoning of the Hortavær intrusive complex, a layered alkaline pluton in the Norwegian Caledonides. Geosphere vol. 5 no. 3: 286-301.

Barnes, C.G., Prestvik, T., Nordgulen, Ø. & Barnes, M.A. (1992): Geology of three dioritic plutons in Velfjord, Nordland. Norges geologiske undersøkelse, 423, 41-54.

Barnes, C.G., Reid, K., Frost, C.D., Barnes, M.A., Allen, C., & Yoshinobu, A.S. (2011): Ordovician and Silurian magmatism in the Upper Nappe, Uppermost Allochthon, Helgeland Nappe Complex, north central Norway. Norwegian Journal of Geology, v. 91, 121-136.

Barnes, C.G., Prestvik, T., Sundvoll, B., Surratt, D. (2005): Prevasive assimilation of carbonate and silicate rocks in the Hortavær igneous complex, north-central Norway. Lithos vol. 80:1-4, pp. 179-199.

Barnes, C.G. Yoshinobu, A., Prestvik, T., Nordgulen, Ø., Karlsson, H. & Sundvoll, B. (2002): Mafic magma intraplating: Anatexis and hybridization in arc crust, Bindal Batholith, Norway. Journal of Petrology 43, 2171-2190.

Berglund, B. (1999): Middelaldersk klebersteinsindustri på Helgelandskysten. Ottar Nr. 225, 13-24.

Birkeland, A., Ihlen, P. M., Bjørlykke, A. (1993): The sources of metals in sulfide deposits in the Helgeland Nappe Complex, North-Central Norway: Pb isotope evidence. Economic Geology, 88, 1810-1829.

Birkeland, A., Nordgulen, Ø., Cumming, G.L. & Bjørlykke, A. (1993): Pb-Nd-Sr isotopic constraints on the origin of the Caledonian Bindal Batholith, central Norway. Lithos 29, 257-271.

Bjørlykke, H. (1943): Foreløbig rapport om undersøkelse av gullgehalten i elveavsetningene i Buadalen (Kolsvikdalen), Kolsvik, Bindalen. Rapport BA 3080, Bergarkivet, Norges geologiske undersøkelse.

Bjørlykke, H & Vogt, Th (1944): Rapport om befaring av A/S Kolsvik malmfelters gullforekomster i Buadalen, Bindal. Rapport BA 3088, Bergarkivet, Norges geologiske undersøkelse.

Boyd, R., Nilsson. L.P., Pedersen, R.B., Bakke, S., Boassen, T., Grenne, T., Grønli, A., Johannesen, G.M. (1990): Geochemistry of platinum metals in ophiolites in Norway, NTNF Project no. MB10.20346, Pedersen, R.-B., Final Report no. 90.065, Norges geologiske undersøkelse

Braathen, A., Nordgulen, Ø., Osmundsen, P.T., Andersen, T.B., Solli, A. & Roberts, D. (2000): Devonian, bi-directional, opposed extension in the Central Norwegian Caledonides. Geology 28, 615-618.

Braathen, A., Osmundsen, P.T., Nordgulen, Ø., Roberts, D. & Meyer, G. (2002): Orogen-parallel extension in the Caledonides in Central Norway: an overview. Norwegian Journal of Geology, Vol. 82, 225-241.

Bremstein, K. & Andersen, I. (1992): Bremstein. Vega kulturkontors historieskrifter, hefte 1., 46 sider.
Bøe, P. & Prestvik, T. (1974): A serpentinite conglomerate on the island of Leka, Nord-Trøndelag. Norsk geologisk tidsskrift 54: 117-121.

Daae, F.L., Økland, I., Dahle, H., Jørgensen, S.L., Thorseth, I.H., Pedersen, R.-B. (2013): Microbial life associated with low-temperature alteration of ultramafic rocks in the Leka ophiolite complex. Geobiology 11: 318-339.

Dumond, G. (2002): Magma chamber construction in the middle crust: Insights from the Sausfjellet Pluton, Bindal Batholith, Norway. MS Thesis, Texas Tech University, Lubbock.

Dumond, G, Yoshinobu, A.S. & Barnes, C.G. (2005): Mid-crustal emplacement of the Sausfjellet Pluton, central Norway: Ductile flow, stoping, and in situ assimilation. Geological Society of America, Bulletin, 117, 383-395.

Dunning, G.R. & Pederesen, R,-B. (1988): U/Pb ages of ophiolites and arc-related plutons of the Norwegian Caledonides; implications for the development of iaåpetus. Contibutions to Mineralogy and Petrology, 98, 13-23.

Furnes, H., Pedersen, R.B., Hertogen, J., & Albrektsen, B.A. (1992): Magma development of the Leka Ohiolite Complex, central Norwedian Caledonides, Lithos, 27: 259-277.

Furnes, H., Pedersen, R.B., & Stillman, C.J. (1988): The Leka Ophiolite Complex, central Norwegian Caledonides: field characteristics and geotectonic significance, Journal of Geological Society, London 145: 401-412.

Fuertes-Gutierrez, I. & Fernandez–Martinez, E. (2012): Geosites Inventory in the Leon Province (Northwestern Spain): A Tool to Introduce Geoheritage into Regional Environmental Management. Geoheritage 2:57-75

Gustavson, M. (1975a):. The low-grade rocks of the Skålvær area, S. Helgeland, and their relationship to high-grade rocks of the Helgeland Nappe Complex. Norges geologiske undersøkelse, 322, 13-33.

Gustavson, M. (1975b): Vega. Berggrunnskart H18, M 1:100000. Norges geologiske undersøkelse.

Gustavson, M. (1977): Flovær. Berggrunnskart H17, M 1:100000. Norges geologiske undersøkelse.

Gustavson, M. (1978): Geochemistry of the Skålvær greenstone, and a geotectonic model for the Caledonides of Helgeland, north Norway. Norsk geologisk tidsskrift, 58 (3), 161-174

Gustavson, M. (1982): Mosjøen. Berggrunnskart 1:250 000. Norges geologiske undersøkelse.

Gustavson, M. & Bugge, T. (1995): Vega. Berggrunnskart 1:250 000. Norges geologiske undersøkelse.

Grenne, T. & Heldal, T. (2006): Soapstone deposits of the southern Helgeland region, Nordland County, Norway. PNASTINA report, Norges Geologiske undersøkelse.

Gustavson, M. & Prestvik, T. (1979): The igneous complex of Hortavær, Nord-Trøndelag, central Norway. Norges geologiske undersøkelse 348, 73-92.

Heldal, T. (1994): Naturstein i Nordland: Sydlige Helgeland. NGU rapport 94.055

Heldal, T. (2001): Ordovician stratigraphy in the western Helgeland Nappe Complex in the Brønnøysund area, North-central Norway, Norges geologiske undersøkelse Bulletin 438, 47-61.

Heldal, T., Hjelmeland, H. (2004) Brønnøysund. Berggrunnskart 17251 1:50 000. Norges geologiske undersøkelse

Hembre, O. S. (1983): Leka- kvartærgeologiske verneverdige objekter, Fylkesmannen i Nord-Trøndelag

Hjelmeland, H. (1987): Tektonostratigrafi og strukturell utvikling i området Torgøy-Brønnøysund, sørvestlige Nordland. Unpublished Cand.Scient thesis, University of Bergen

Hoholm, T. (1998): Hva fjellet skjulte – glimt fra Velfjords bergverkshistorie gjennom 190 år. Årbok Velfjord historielag, 27-35

Høgaas, F. & Sveian, H. (2015): The Younger Dryas Main Line on Leka, Norway, as determined from a high resolution digital elevation model derived from airborne LiDAR data. Geomorphology 231, 63–71

Høgaas, F. (2015). Beskrivelse til LEKA - 1725 III - kvartærgeologisk kart M 1:50 000. Landformer, løsmasser og landskapsutvikling på Leka. Norges geologiske undersøkelse, rapport nr. 2015.044

Ihlen, P. M. (1993): The Kolsvik Au-As-deposit, Bindal, North-Central Norway, I: Corelogs. Norges geologiske undersøkelse report 93.003, 322 pp.

James, D. W., Mitchell, J. G., Ineson, R., Nordgulen, Ø. (1993): Geology and K/Ar chronology of the Målvika scheelite skarns, Central Norwegian Caledonides. Norges geologiske undersøkelse Bulletin, 424, 65-74.

Karlsen, T.A. (1991): Natursteinsundersøkelser, kysten av Sør-Helgeland. NGU rapport 91.004, 44 sider + vedlegg.

Keilhau, B. M. (1844): Ueber den Bau der Felsenmasse Norwegens. In: Keilhau, B. M. Gaea Norvegica, Zweite Lieferung, Johan Dahl Pub., Christiania, pp. 218-313

Kollung, S. & Myrland, R. (1970): Velfjord, Berggrunnskart H17, M 1:100000. Norges geologiske undersøkelse.

Krokvik, O. (1999): Kvernsteinsdrift. Blad av Brønnøy historie 1999, 26-30.

Lauritzen, S. E. (2010): Grotter. Norges ukjente underverden, Tun Forlag, Oslo.

Lauritzen, S. E., Nielsen, J.O., Stav, B.A. (2011): Kartlegging i Torghatten, Brønnøy kommune: Torghatthullet og Svartholene, Acta Spelæologica Norvegica – Norsk Speologisk Årsbok 3, p. 77-96

Lindal, I. (2011): Bygningsstein i Nordland. Beskrivelse av de enkelte forekomster og undersøkte lokaliteter I Nordland. Norges geologiske undersøkelse, to be downloaded at http://www.ngu.no/upload/Georessurser/Naturstein/niba.pdf

Maaløe, S. (2005): The dunite bodies, websterite and orthopyroxenite dikes of the Leka ophiolite complex, Norway. Mineralogy and Petrology 85: 163-204.

Maaløe, S. & Prestvik, T. (2000): Dannelse av Lekas bergarter, Exkursjonsguide, Leka Motel & Camping.

Marko, W.T. (2012): The petrology, emplacement history and tectonic setting of the Vega Intrusive Complex, southern Nordland, Norway. PhD Thesis, Texas Tech University, Lubbocck.

Marko, W.T., Barnes, C.G., Yoshinobu, A.S., Frost, C.D., Nordgulen, Ø. (2013): Geology, geochemistry and emplacement conditions of the Vega intrusive complex: an example of large-scale crustal anatexis in north-central Norway, from Corfu, F., Gasser, D. & Chew, D. M. (eds) New Perspectives on the Caledonides of Scandinavia and Related Areas. Geological Society, London, Special Publications, 390.

McArthur, K.L. (2007): Tectonic reconstruction and sediment provenance of a far-travelled nappe, West-Central Norway. MS thesis, University of Wyoming. Laramie.

McArthur, K.L, Frost C.D., Barnes, C.G., Prestvik, T. & Nordgulen, Ø. (2013): Tectonic reconstruction and sediment provenance of a far travelled oceanic nappe, Helgeland Nappe Complex, west-central Norway, From Corfu, F., Gasser, D. & Chew, D.M. (eds.) new Perspective on the Caledonides of Scandinavia and Related Areas, Geological Society of London Special Publication 390, 21 pp.

McCulloch, L. (2007): Evidence for upward growth of a layered pluton in the Bindal Batholith, north-central Norway. MS Thesis, Texas Tech University, Lubbock.

Müller, A., Furuhaug, L. (2008): Resource evaluation of the Målvika tungsten deposit, Nordland. Norges geologiske undersøkelse report, 2008.008, 49 pp.

Myrland, R.(1972): Velfjord. Beskrivelse til det berggrunnsgeologiske gradteigskart I 18 - 1:100 000. Norges geologiske undersøkelse 274.

Myrland, R. (1974): Bindal Berggrunnskart I19, M 1:100 000. Norges geologiske undersøkelse

Nordgulen, Ø. (1984): The geology and emplacement of the Kråkfjellet pluton, Bindal, Central Norway. Unpublished Cand. real. thesis, University of Bergen

Nordgulen, Ø., Barnes, CG., Yoshinobu, AS., Frost, C., Prestvik, T., Austrheim, H., Anderson, HS., Marko, WT., McArthur, K. (2011): Eurogranites 2011: Pre-Scandian tectonic and magmatic evolution of the Helgeland Nappe Complex, Uppermost Allechthon, 33 IGC excursion No 35.

Nordgulen, Ø. & Bering, D. (1987): Austra, berggrunnskart 17252, 1:50000. Norges geologiske undersøkelse.

Nordgulen, Ø., Bickford, M.E., Nissen, A.L. & Wortman, G.L. (1993): U-Pb zircon ages from the Bindal Batholith, and the tectonic history of the Helgeland Nappe Complex, Scandinavian Caledonides. Journal of the Geological Society, London, 150, 771-783.

Nordgulen, Ø., Braathen, A., Corfu, F., Osmundsen, P.T. & Husmo, T. (2002): Polyphase kinematics and geochronology of the Kollstraumen detachment, central Norway. Norwegian Journal of Geology 82, 299-316.

Nordgulen, Ø., Fjeldheim, T., Ihlen, P. M., Nissen, A. L., Solli, A. (1992): Vevelstad. Berggrunnskart 18263; 1:50 000. Norges geologiske undersøkelse.

Nordgulen, Ø. & Schouenborg, B. (1990): The Caledonian Heilhornet Pluton, north-central Norway: geological setting, radiometric age and implications for the Scandinavian Caledonides, Journal of the Geological Society, London, 147, 439-450.

Nordgulen, Ø. Solli, A. & Thorsnes, T. (1990): Majafjellet, berggrunnskart 18252, 1:50000. Norges geologiske undersøkelse.

Nordgulen, Ø., Sundvoll, B. (1992): Strontium isotope composition of the Bindal Batholith, Central Norwegian Caledonides. Norges geologiske undersøkelse Bulletin, 423, 19-39.

Nordgulen, Ø., Thorsnes, T., Husmo, T. (1989): Terråk. Berggrunnskart 18253; 1:50 000.
Norges geologiske undersøkelse.

Oalmann, J.A.G. (2010): Geology, plutonism and metamorphism at the island of Ylvingen, Nordland, Norway. MS Thesis, Texas Tech University, Lubbock.

Oalmann, J.A.G., Barnes, C.G., & Hetherington, C.J. (2011): Geology of the island of Ylvingen, Nordland, Norway: Evidence for pre-Scandian (~475 Ma) exhumation in the Helgeland Nappe Complex. Norsk Geologisk Tidsskrift, Vol 91, pp. 77-99

Olesen, O., Kierulf, H. P., Brönner, M., Dalsegg, E., Fredin, O., Solbakk, T. (2013): Deep weathering, neotectonics and strandflat formation in Nordland, northern Norway. Norwegian Journal of Geology, 93, 189–213.

Olerud, S. (1990): Undersøkelse av talk-magnesitt forekomster ved Hundøyrån på Leka, Norges Geologiske Undersøkelse report

Olsen, L., Høgaas, F. & Sveian, H. (2015): Age of the Younger Dryas ice-marginal substages in Mid-Norway - Tautra and Hoklingen, based on a compilation of 14C-dates. Norges Geologiske Undersøkelse bulletin 454, 1-13.

Pedersen, R.B. (1986): The nature and significance of magma chamber margins in ophiolites: examples from the Norwegain Caledonides. Earth and Planetary Science Letters 77, 100-112.

Pedersen, R.-B, Furnes, H. & Dunning, G.R. (1988): Some Norwegian ophiolite complexes reconsidered. Norges geologiske undersøkelse, Special Publication 3, 80-85.

Pedersen, R.B., Johannesen, G.M., Boyd, R. (1993): Stratiform platinum-group element mineralizations in the ultramafic cumulates of the Leka ophiolite complex, central Norway, Economic Geology and the Bullentin of the Society of Economic Geologists, vol. 88:4, pp.782-803, ISSN: 0361-0128.

Prestvik, T. (1972): Alpine-type mafic and ultramafic rocks of Leka, Nord-Trøndelag. Norges geologiske undersøkelse, 273, 23-34.

Prestvik, T.(1974): Supracrustal rocks of Leka, Nord-Trøndelag. Norges Geologiske Undersøkelse 311: 65-87.

Prestvik, T. (1980): The Caledonian ophiolite complex of Leka, north-central Norway. In Panayotiu, A. (ed.): Proceedings international ophiolite symposium Cyprus 1979, pp 555-566. Cyprus Geological Survey Department.

Prestvik, T. (1985): Origin of the Storøya Group, Leka. Results from new geochemical investigations. Norsk Geologisk Tidsskrift 65: 237-239.

Prestvik, T. & Roaldset, E. (1978): Rare earth element abundances in Caledonian metavolcanics from the island of Leka, Norway. Geochemical Journal 12: 89-100.

Rekstad, J. (1902): Geologisk kartskisse over trakterne omkring Velfjorden med beskrivelse. Norges geologiske undersøkelse, Aarbog for 1901, 34, 42 pp.

Rekstad, J. (1910): Beskrivelse til det geologiske kart over Bindalen og Leka. Norges geologiske undersøkelse. Norges geologiske undersøkelse, Aarbog for 1909, 53, 37 pp.

Rekstad, J. (1915): Helgelands ytre kystrand. Norges geologiske undersøkelse Aarbok for 1915, 75, 53 pp.

Rekstad, J. (1916): Strandflaten ved kysten av Søndre Helgeland. Norsk geologisk tidsskrift, 4, 34-35.

Rekstad, J. & Vogt, J. H.L. (1900): Søndre Helgeland. Søndre Helgelands kvartær-geologi.
Norges geologiske undersøkelse, 29, 50 pp.

Reusch, H. (1894): Strandfladen, et nyt træk i Norges geografi. Norges geologiske undersøkelse Aarbog for 1892 og 93, 14, 1-14.

Roberts, D., Melezhik, V. M., Heldal, T. (2002): Carbonate formations and early NW-directed thrusting in the highest allochthons of the Norwegian Caledonides: evidence of a Laurentian ancestry. Journal of the Geological Society, London, 159, 117–120.

Roberts, D., Nordgulen, Ø. & Melezhik, V.M. (2007): The Uppermost Allochthon in the Scandinavian Caledonides: from Laurentian ancestry through Taconian orogeny to Scandian crustal growth on Baltica. In: Hatcher, R.D., Jr., Carlson, M.P., McBride, J.H., and Martínez Catalán, J.R., eds., 4-D Framework of Continental Crust: Geological Society of America Memoir 200, p. 357–377, doi: 10.1130/2007.1200(18).

Sturt, B.A., Andersen, T.B. & Furnes, H. (1985): The Skei Group, Leka: an unconformable clastic sequence overlying the Leka Ophiolite. In: Gee, D.G. & Sturt, B.A. (eds.). The Caledonian Orogen – Scandinavia and related areas, pp. 395-406.

Sturt, B. & Ramsay, D. (1994): The structure and regional setting of the Skei Group, Leka, north-central Norway. Norges geologiske undersøkelse 426: 31-46.

Thorsnes, T & Løseth, H. (1991): Tectonotratigraphy in the Velfjord-Tosen region, southwestern part of the Helgeland Nappe Complex, Central Norwegian Caledonides. Norges geologiske undersøkelse Bulletin, 421, 1-18.

Tveit, R., Furnes, H. & Pedersen, R.B. (1993): Geological and geochemical development of the submarine volcanic sequence on Storøya, Leka Ophiolite Complex, Nord-Trøndelag. Norsk Geologisk Tidsskrift 73: 81-94.

Vogt, J.H.L. (1897): Norsk Marmor. NGU 22, 364 sider.

Vokes, F.M.; Constatinous, G.; Panayiotou, A.; Prestvik, T. (1990): Gabbro hosted mineralization in ophiolites; examples from Troodos, Cyprus and Leka, Norway. In: Ophiolites; oceanic crustal analogues. Proceedings of a Symposium; "TROODOS 1987", pp. 627-637.

von Buch, L. (1810): Reise durch Norwegen und Lappland, erster Teil. Ordentlichen Mitgliede der Königlichen Academie der Wissenschaften zu Berlin

World Heritage Convention, (2003): Norwegian Nomination: Vegaøyan- The Vega Archipelago, Norwegian Ministry of the Environment. To be found at http://whc.unesco.org/uploads/nominations/1143.pdf

Yoshinobu, A.S., Barnes, G.H., Nordgulen, Ø., Prestvik, T., Fanning, M., Pedersen, R.B. (2002): Ordovician magmatism, deformation, and exhumation in the Caledonides of central Norway: An orphan of the Taconic orogeny?, Geology, v. 30, p. 883-886.

A geopark is an area with an exceptional geological heritage of international significance, where geotourism, sustainable development and education are at the forefront. The relationship between geological diversity and landscape, biological diversity and human settlement is presented in a geopark. Geopark status does not imply protection, and an important task of a geopark is to promote tourist attractions and sustainable economic activity to the advantage of tourists and local people.

Trollfjell Geopark is a cooperative project between the municipal boroughs of Brønnøy, Vega, Vevelstad, Sømna, Bindal and Leka, and is part of the regional tourism strategy. The geopark aims to provide worldclass activities and thrills based on the unique geological history and localities in the area.