ANNEX 2

Geological heritage and summary

PLATÅBERGENS GEOPARK
Layers of history

SUMMARY

Platåbergens Geopark is situated in the southwest Swedish gneiss terrane of the Fennoscandian shield, covering the Swedish table mountain landscape. Several remarkable and unique geological features are easily accessible in the geopark, together representing a time span of around 1.7 billion years. The main attractions are the 15 classic table mountains, which has been an important area for geological research since 18th century. The table mountains themselves are relicts of Palaeozoic cover of sedimentary bedrocks and stands out as prominent features in the landscape. Underlying the table mountains is the sub-Cambrian peneplain, which is well preserved and well visible in the aspiring geopark area. The region also contains landforms created during two of the most important events during the late Quaternary of Sweden; the Younger Dryas cold interval and the drainage of the Baltic Ice Lake.

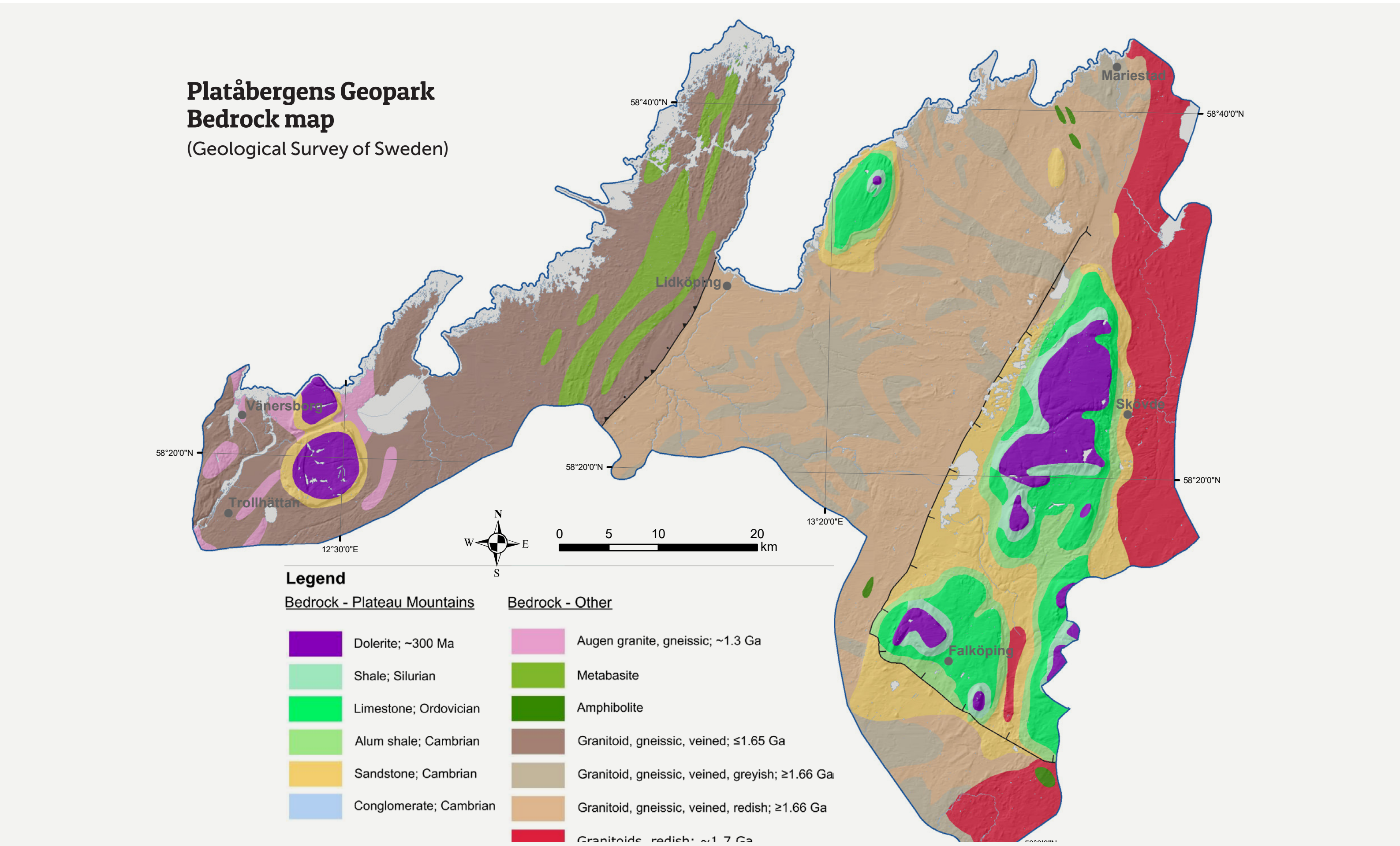
E.1.1 Geological heritage and conservation

General geological description of the aUGGp

THE PRECAMBRIAN

The Swedish Precambrian bedrock was formed over a very long time. The crustal growth started at about 2.8 billion years ago in the very north of the country and finished in the southwest at 1.5 billion years ago; that is more than 1 billion years of crust construction. The crust formation is characterised by repeated accretions forming the oldest rocks in the present northernmost Sweden to the present western part of Sweden. Several suture zones attest to subduction and continental accretion. Five to six orogenies can be sorted out which contributed to the construction and modification of the bedrock in different parts of Sweden. Finally, at 1.5 Ga ago, the craton was established although later magmatism and metamorphic overprinting occurred.

In the geopark area the principal crust was formed at 1.7 to 1.6 Ga ago, although later covered by sedimentary rocks and intruded by mafic intrusions and granitoids. Granitoid compositions characterise most of these gneissic rocks of



which some are porphyritic with aggregates of K-feldspar. Granitoids of the 1.7 Ga TransScandinavian Igneous Belt (TIB) outcrop in the very east of the park. More deformed, veined, 1.70 to 1.65 Ga gneissic granitoids are found to the west of TIB ending at a major north-south striking shear zone, the Great Mylonite Zone, in the central part of the park. To the west of this shear zone somewhat younger 1.65 to 1.60 Ga gneissic granitoids dominate that were created during the Gothian orogeny.

It is believed that Baltica was part of a supercontinent before 1.3 Ga that subsequently was rifted from Laurentia but once again collided with the same 300 Ma later (at approximately 1 Ga ago). This collisional event is named the Sveconorwegian orogeny and corresponds to the Grenvillian in North America. The effects of this is shown in zircon growth rendering Sveconorwegian U-Pb ages and also in structural fabrics resulting in foliated, banded, veined and folded gneisses and a medium to upper amphibolite facies overprint. Repeated overprinting is revealed by the difference in fabrics between younger granitoids and the oldest rocks in correspondence to the polymetamorphic overprints (Gothian, Hallandian/Dano-Polonian, Sveconorwegian orogenies) recorded in gneisses further south.

In the geopark, the Sveconorwegian tectonics is also manifested by the prominent thrust zone mentioned above. This zone, which strikes north–south across the geopark from Kedumbergen in the south to Kållandsö to the north, is named the Great Mylonite Zone (MZ). This thrust event resulted in a considerable thickening of the crust to the east of the zone by top-to-the-east sense of movements. Isostatic rebound readjusted the thickened crust to a "normal" thickness some million years later by the reverse sense of movement along the zone. It separates rocks older than ca 1.65 Ga to the east from rocks younger than this to the west; the latter considered to have been formed during the Gothian orogeny but later overprinted by younger events.

Following this long history of Precambrian crustal formation and deformation, a long period of quiescence began, characterised by extensive erosion and levelling of the mountains. This period also includes a global Ice Age, the "Snowball Earth". An extensive peneplain was created. It is this surface that was covered by Palaeozoic seas and sediment, and then exhumed during the Cenozoic. Thus, this Precambrian peneplain now characterises the surface topography in much of the geopark. The gneissic bedrock surface today corresponds to that which was exposed some 550 million years ago. In places within the geopark it forms extremely flat surfaces and is called the sub-Cambrian peneplain. The reason for this denudation must have been extreme climate conditions governing weathering and erosion that followed the global Neoproterozoic glaciation (Snowball Earth).

The present land surface is a product of peneplanation due to repeated uplift and subsidence of the crust. The sub-Cambrian peneplain covered most of the country and was subsequently buried beneath Palaeozoic sediments in a transgressive sea named the Iapetus Ocean.

THE LOWER PALAEOZOIC

During the Ediacaran the supercontinent Rodinia broke up by rifting, and the initiation of the Iapetus Ocean took place between Laurentia and Baltica. The high rate of continental drift and active mid-ocean ridges resulted in a first-order sea level rise that continued through the entire Cambrian and Ordovician. The resulting sediment successions in the geopark table mountains give the visitor a unique chance to follow the evolution of sedimentation and ecology in the shallow seas.

The onset of the closure between Laurentia, Baltica and Avalonia in the Ordovician led to the Caledonian Orogeny and final closure of the Iapetus Ocean during the Silurian. This is also reflected in the sedimentary layers of the table mountains. In the Kinnekulle table mountain a complete

Gneiss. Photo: Eva-Lena Tullborg

Sandstone. Photo: Eva-Lena Tullborg

Alum shale.

Limestone, with meteorite. Photo: Eva-Lena Tullborg

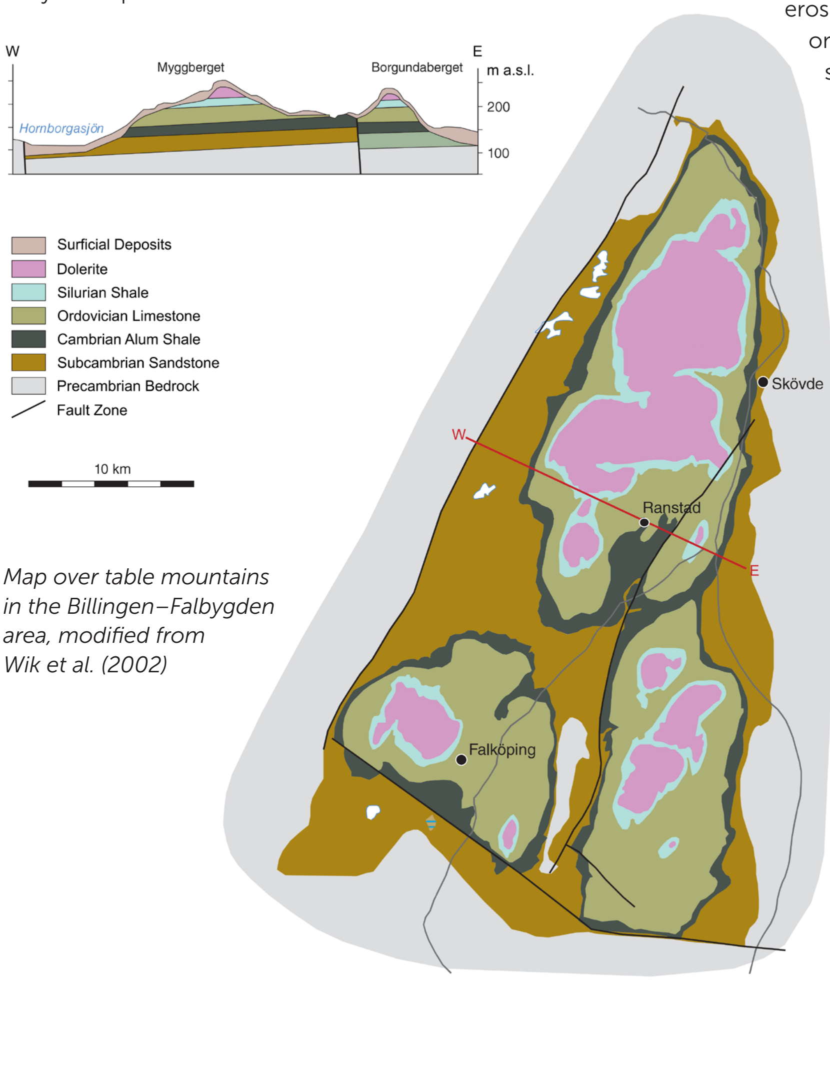
Shale. Photo: Eva-Lena Tullborg

Dolerite. Photo: Torbjörn Skogedal

Erosional remnants of the Cambrian basal conglomerate resting on Proterozoic gneiss just north of Råbäck harbour.
Photo: Mikael Calner.

succession is offered from the Proterozoic bedrock to the lower Silurian. A core drilling was carried out through this entire sequence in 2016 and can form the basis for a guide illustrating the succession for visitors in good detail.

The oldest Palaeozoic rocks in the geopark are a conglomerate with reworked clasts from the gneissic basement rocks. This conglomerate tells a unique history of an early Cambrian, windblown and desert-like landscape, and how it was reshaped by the rising sea levels. The conglomerate is overlain by quartz-rich sandstones with abundant trace fossils from inner shelf and beach deposits. The pure, whitish sandstones are abruptly overlain by the black alum shale deposited in an oxygen-deficient shallow sea. The shales include calcareous, disc-shaped concretions called Orsten (stinkstone), hosting a world-famous microscopic fauna of early arthropods.



Map over table mountains in the Billingen–Falbygden area, modified from Wik et al. (2002)

The alum shale is overlain by a spectacular suite of reddish and grey ortoceratite limestone rich in fossils. It was formed during the time of the Great Ordovician Biodiversification Event (GOBE), an unprecedented rise in marine biodiversity on the family, genera and species level. GOBE is the subject of intense research today, and mechanisms for the rise in biodiversity are debated. Several other Ordovician limestone units and shale units follow above, all more or less rich in fossils.

A particularly interesting horizon within the Ordovician limestone is found to be very rich in fossil meteorites, a witness of intense bombardment at this time, of which some have an odd and rare achondritic composition. The meteorites are a result of a collision between two asteroids in our solar system, leaving the asteroid belt between Mars and Jupiter. The geopark thus houses the largest known archive of fossil meteorites in the world. This Ordovician collision was so extensive that a large percent of meteorites falling to Earth today are from this event.

The narrowing of the epeiric Iapetus Ocean led to tectonic subsidence of western Sweden and the geopark area. The marine environments therefore became deeper, and clay became the primary deposit. Thus, the upper portions of the Kinnekulle table mountain host shale deposits rich in a deep-water pelagic fauna. The upper Ordovician and the Silurian parts of the succession also yield numerous volcanic ash (bentonite) beds from the volcanism that was related to the closing of the Iapetus Ocean, the thickest being more than one metre.

The successive collision of Baltica and Laurentia caused a stack of nappes to be thrusted onto the western margin of Baltica to form the Scandinavian Caledonides. Although these mountains were eroded already in the Silurian, erosional products were continuously deposited on the foreland, in some places reaching several kilometres in thickness but thinning to the east. This caused the Cambrian-Silurian sediments in the geopark to be covered by a considerable stack of mainly Devonian sediments, which were subsequently completely eroded away.

This pile of Palaeozoic sediments was intruded by dolerites at approximately 300 million years ago, contemporaneous with intense volcanism in Western Europe, e.g. in the nearby Oslo region, which also created dyke swarms along the Swedish west coast. The dolerites in the geopark were formed as sills. The present thicknesses show that some of them originally were more than 60 meters thick. They were intruded at different levels in the Cambrian-Silurian sediments. Later erosion of the sedimentary cover rocks exposed the dolerite sills, which can now be found as caps on the table mountains.

The table mountains are bordered by faults and the brittle deformation postdates the Carboniferous-Permian dolerites and must be Mesozoic or even younger features. In south-central Sweden, the crust was uplifted during the Jurassic–Cretaceous periods. The most elevated parts of the sub-Cambrian peneplain were eroded and weathering occurred along fractures. Late in the Cretaceous most of the weathering products were eroded, the sea level was raised and sediments were deposited.

Another uplift of the crust took place during the Paleogene and Neogene, which caused new parts of the Precambrian rocks to weather and erode. This story of uplift and weathering and erosion makes southern Sweden a fascinating landscape with several generations of peneplanation. Platåbergens Geopark is thus a preserved flat land shaped by peneplanation in the latest Precambrian and modified by later deep-weathering in warm climates and subsequently modified by the Pleistocene glaciations. That is why we today can walk on the exact same surface as was exposed 550 million years ago! On this peneplain the conformly deposited Cambrian sediments from the transgressive Iapetus Ocean are demonstrated in the table mountains of Platåbergens Geopark.

QUATERNARY

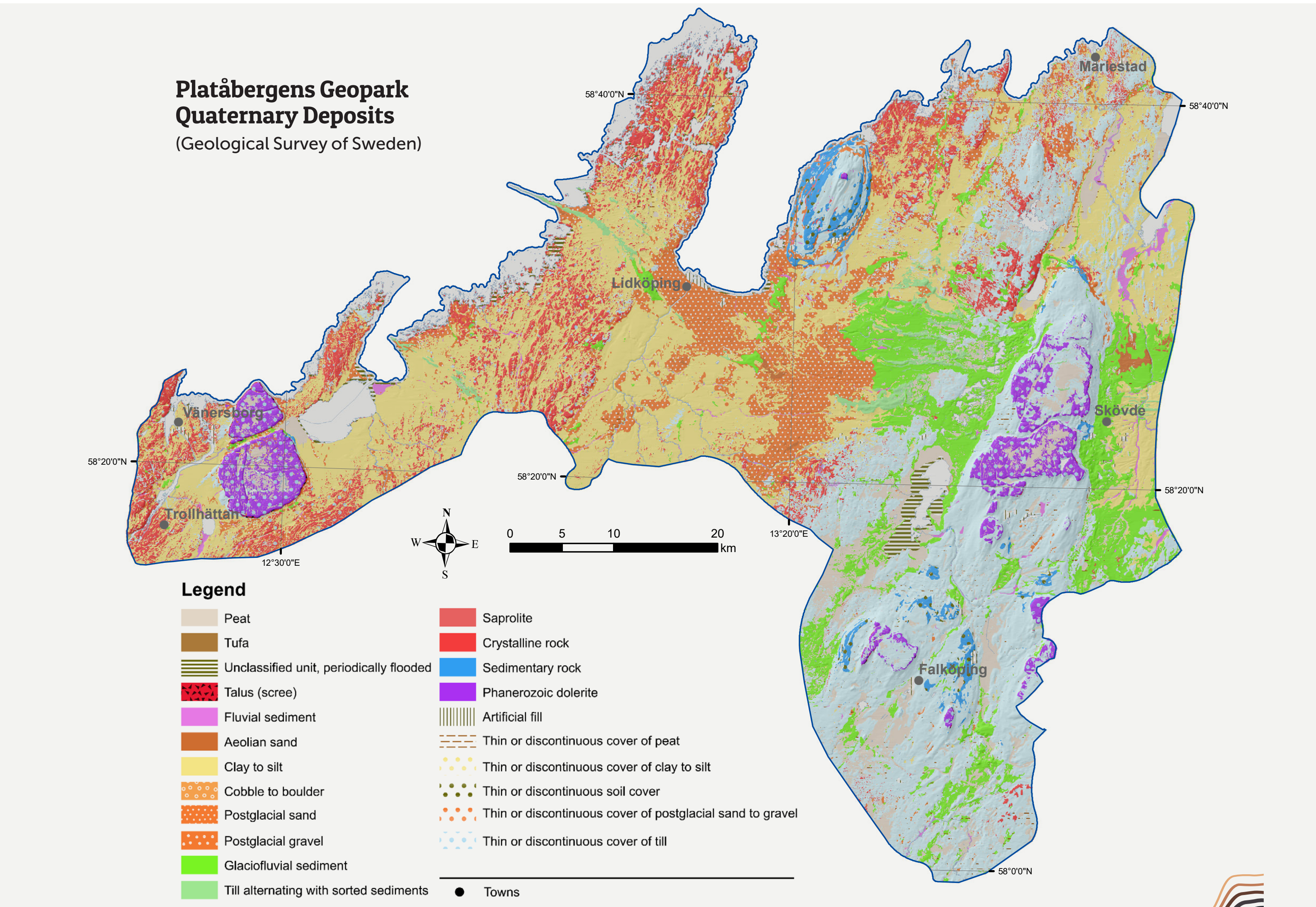
Sweden was completely covered by glacial ice during the last Ice Age, but as it melted away, two of the most dramatic and significant events that occurred during the Ice Age took place within the area of the geopark. These two are the dramatic "return to Ice Age conditions" that is referred to as the Younger Dryas (from around 13 to 11,6 ka ago) followed by the dramatic drainage of the Baltic Ice Lake at the northern end of Billingen.

Event I: the Younger Dryas and The Middle Swedish End Moraines

The Younger Dryas (YD) was a cold event in Earth history that has been recognised all over the world. As the world warmed out of the Ice Age, a dramatic and sudden (within a few years) return to an Ice Age climate occurred. This event lasted more than 1,000 years, followed by a dramatic and rapid continuance of warming until the ice sheets were gone.

When the YD occurred, the Scandinavian ice sheet had retreated so that its southern boundary was within the geopark area. But the newly frigid conditions caused the ice sheet to re-advance. This re-advance formed the prominent end moraine that forms the broad ridge just north of Skara and continues west to Hindens Rev and east to the prominent ridges at Skövde. In fact, the ridges can be traced into Norway (the Ra moraines) and into Finland (the Salpauselka moraines)–these are among the most famous, prominent and well-studied glacial features in the Nordic region. In Sweden, these moraines occur in a band of several ridges, referred to as the Middle Swedish End Moraine Zone (MSEMZ). In the geopark area, there are seven such ridges, and it is clear from studying their internal construction that the southernmost one formed first, and the successive ridges to the north were shaped by successive oscillation of the ice margin – each ridge being created when the ice, having slightly retreated, made a new small advance.

These end moraines are of interest internationally because they represent well-studied examples of what are



called "push moraines". End moraines can form in a number of ways, but these were made bulldozer like, by the ice shoving sediment in front of it into ridges. Of additional importance is that these ridges were made under water. The entire region (below 125–130 m) lay under the sea surface because the land had been depressed by the weight of the ice. Ocean sediment in the form of varved to non-varved clay accumulated on the ocean floor in front of the ice – during ice-margin oscillations, the clay was pushed into the ridges. Therefore, these end moraines are composed almost entirely of clay.

In part because of their long history of study, but in particular due to new exposures when highway E20 was extended, we have a very clear picture of how these moraines were constructed. Of additional interest has been the discovery that the clays that accumulated during ice retreat have annual layers. These are referred to as "varved clays". Varved clays are seldom reported from marine sediment because they seem to have difficulty forming in saltwater. However, excellent varved sediment has been discovered in boreholes in the geopark area and has been the subject of published research.

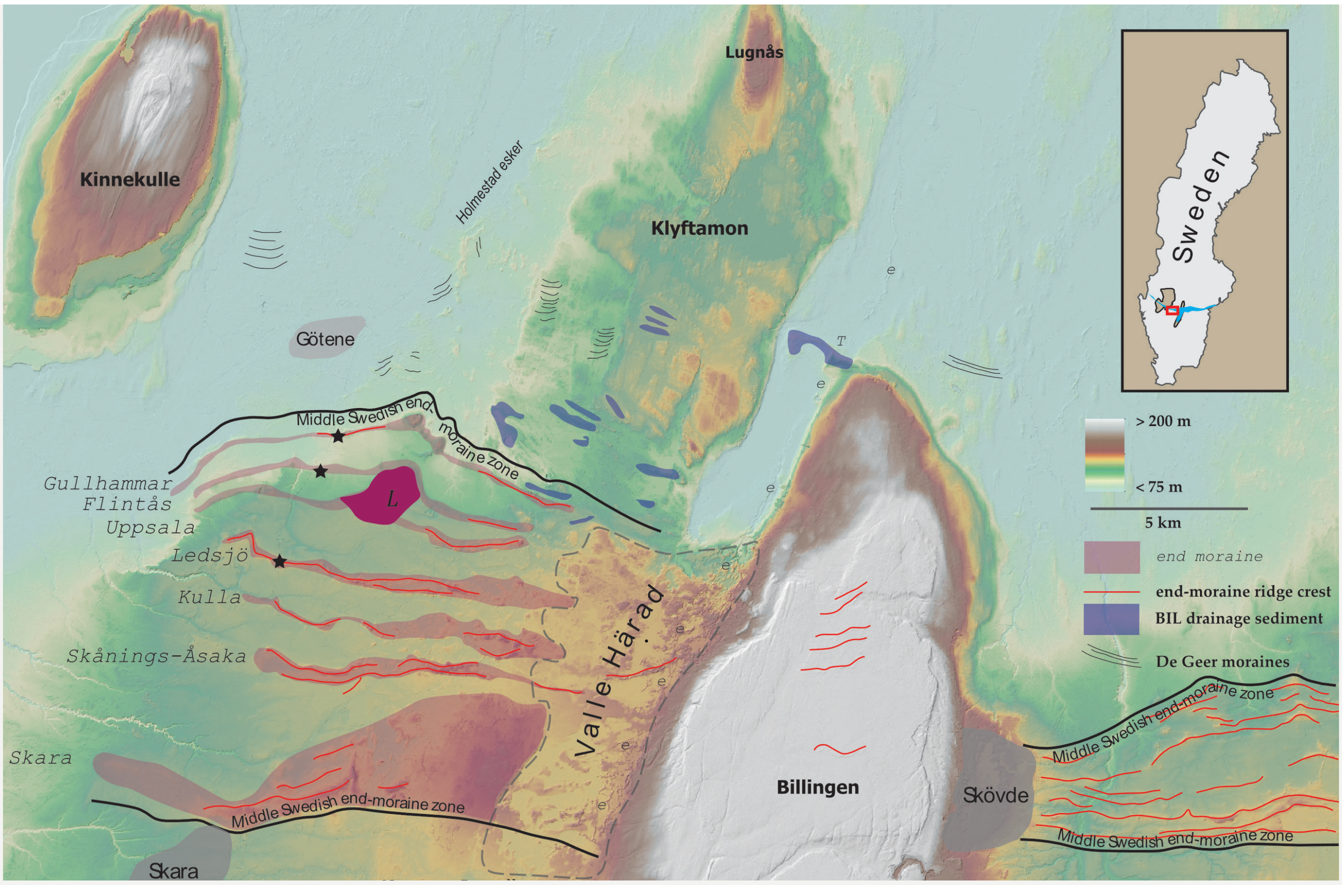
Lastly, the well-known "kame landscape" of Valle Härad was also formed during the ice-margin oscillations of the ice sheet. However, it was an area above sea level at the time, and large amounts of coarse sand and gravel were deposited in front of the ice by streams of meltwater emanating from subglacial tunnels. Because some of the ice became buried by this outwash (only to melt later), numerous "kettle" lakes occur. Valle Härad is arguably Sweden's most known kame and kettle landscape.

Event II: the drainage of the Baltic Ice Lake

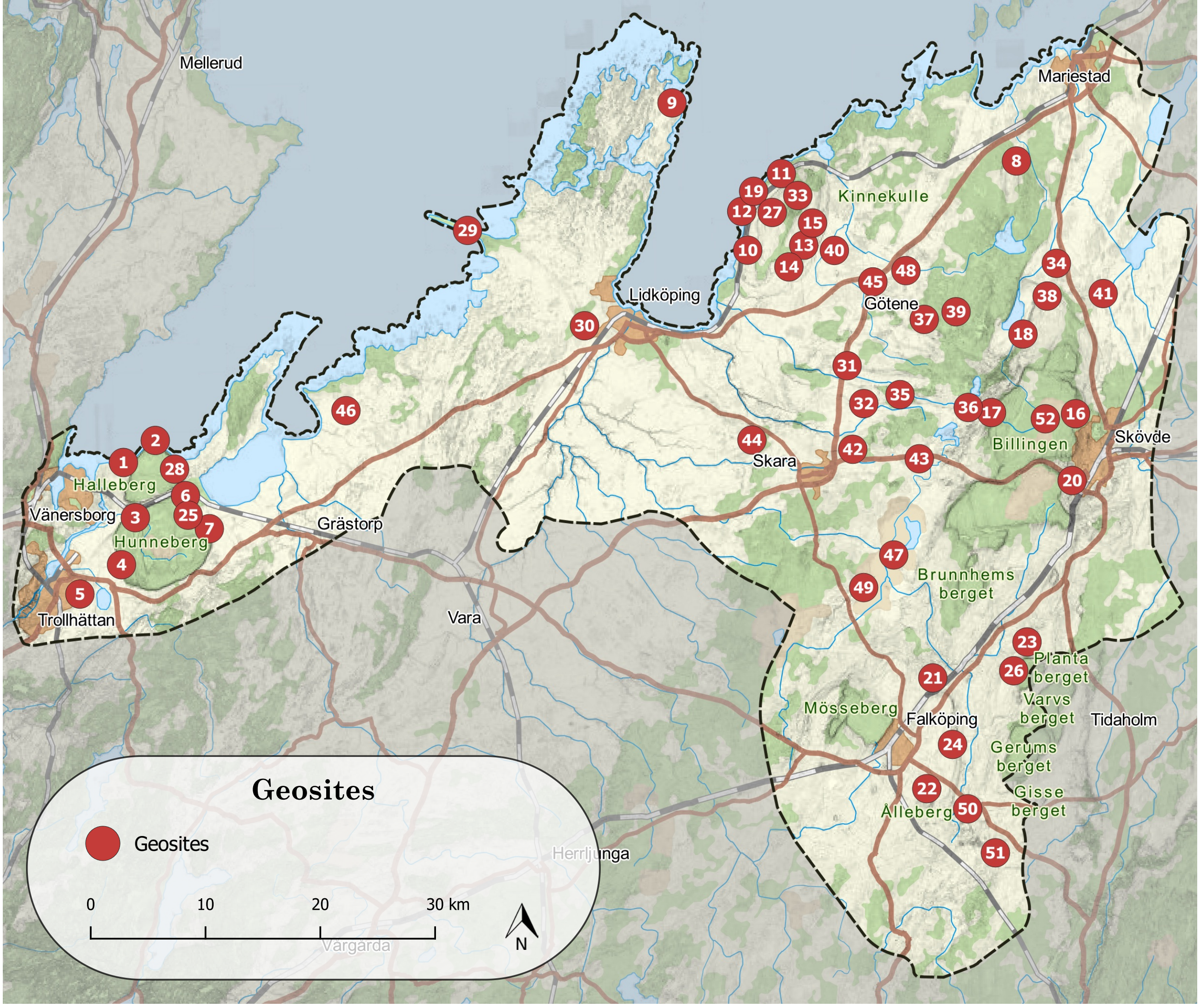
During deglaciation, the world's seas were at a much (120 m!) lower level. For Scandinavia, this meant that the sea was unable to reach into the Baltic basin. Instead, this basin was occupied by a large lake, dammed to the north by the retreating ice margin. Sweden's south east coast was covered by this ice lake, whereas the south west coast was inundated by the sea – the highlands in the centre of southern Sweden separated these two. As the ice retreated, the lake expanded to the north. However, when the ice margin retreated to the north end of the table mountain Billingen, a low-elevation passage was uncovered, which allowed the dammed Baltic Ice Lake to drain (catastrophically) to the west, into the sea. It has been calculated that 7,500 km^3 of water drained to the west because the Baltic Ice Lake was 25 m above sea level at the time. Even though rapid, it still would have taken over a year for the water to drain completely down to sea level.

The geopark hosts some of the strongest evidence for this event. Zones of washed-clean bedrock occur where the drainage started at Billingen as well as many "boulder bars" deposited on the highland called Klyftamon over which the drainage waters escaped. A ridge at Timmersdala represents the deposits of this event. It was at the west edge of Klyftamon that the drainage water entered the sea. Boreholes and exposures in the flat lands around Götene have uncovered the remains of this event, where sand and gravel had been further buried by the marine clays.

This event has been studied around the Baltic basin for over a century and is of interest not only to geologists, but also to archaeologists and biologists because these events had direct effects on the peopling of Scandinavia and the evolution of its flora and fauna.



Map showing the Middle Swedish End Moraine Zone (MSEMZ). Black stars show locations of cuts through the Ledsjö, Flintås and Gullhammar end moraines. Modified from Johnson et al. (2019).



Listing and description of geological sites within the aUGGp, with details on the interest of these sites in terms of their value and current or potential pressure on the geological sites regarding their preservation and current status in terms of protection

ID	Name of site, coordinates and municipality	Key words	Importance & interest	Legal status and potential pressure
1	Nordkroken Vänersborg 58°23′17.3″N 12°24′16.9″E	Bedrock site, sub-Cambrian peneplain, granite, conglomerate	INT Sci, Edu, Tour	Area of national interest, shore protection The area is not under direct threat today due to its spread and the fact that the bedrock is robust. However, the rock surface is so unique that it should be better recognised in physical planning, e.g. by an area protection.
2	Predikstolen, Hallesnipen Vänersborg 58°24′20.8″N 12°27′05.8″E	Bedrock site, view-point, dolerite	REG Tour	Nature reserve No threat at present. There is a footpath the whole way, some 1.5 km from the parking lot. Some trees need to be cut down to maintain the viewpoint.
3	Geology Trail Byklev Vänersborg 58°20′42.5″N 12°25′25.4″E	Bedrock site, stratigraphy, sedimentary bedrocks, geotrail	NAT Edu, Tour	Nature reserve A large number of visitors can wear down the trail. However, an increased number of visitors is not deemed a threat to the geoscientific values (exposure of rocks).
4	Västra Tunhem's caves Vänersborg 58°18′29.3″N 12°24′15.7″E	Bedrock site, alum shale, dolerite, cultural history	NAT Edu, Tour	Nature reserve Risk of natural cave-ins in the caves, but no need for action at present.

5	Slättbergen Trollhättan 58°17′04.7″N 12°20′35.8″E	Bedrock site, sub-Cambrian peneplain, granite, conglomerate	INT Sci, Edu, Tour	Nature reserve Large parts of the peneplain are protected, but since it is located in an inhabited area there is always a risk, e.g. for development, littering etc. The bedrock is considered robust.
6	Gyllene spiken Grästorp 58°21′46.6″N 12°29′52.0″E	Global boundary Stratotype Section and Point (GSSP), fossil site, Floian age, alum shale	INT Sci, Edu, Tour	Nature reserve The shale is fragile and breaks if touched. There is a need for signs and/or a barrier so that visitors cannot reach the rock wall.
7	Flo viewpoint Grästorp 58°20′52.6″N 12°31′04.4″E	Viewpoint, dolerite, Västgötaslätten plain	REG Tour, Edu	Nature reserve No threat at present.
8	Lugnås millstone quarry Mariestad 58°37′42.6″N 13°44′08.6″E	Bedrock site, gneiss, conglomerate, sandstone, millstone production	INT Sci, Edu, Tour	Nature reserve An increase in visitors may entail wear on the area. A vulnerable situation with dependence on volunteer work through the organisation that runs the business.
9	Kållandsö Lidköping 58°40′25.9″N 13°13′08.8″E	Bedrock site, gneiss, mylonite zone, large area	NAT Sci, Tour	Area of national interest, to a large part shore protection Large area, no threat at present.
10	Kakeled Götene 58°33′31.6′′N 13°19′19,8′′E	Bedrock site, alum shale, fossil site, old quarry	INT Sci, Edu	Nature management area Relatively large threat due to fossil/rock collecting as the area is visited by a significant number of geologists and students each year. A sign needs to be put up informing visitors that it is illegal to collect rocks.
11	Large quarry at Hällekis Götene 58°36′39.9″N 13°23′28.7″E	Bedrock site, limestone, old quarry, orthoceratites, fossil site	INT Sci, Edu, Tour	Nature management area Large area visited by several geology excursions each year. Risk for fossil/rock collecting. Should be prevented with signs.
12	Trolmen harbour Götene 58°35′44,5′′N 13°20′16.2′′E	Bedrock site, sandstone, sub-Cambrian peneplain, conglomerate	INT Sci, Edu, Tour	Nature management area No threat at present.
13	Österplana hed Götene 58°34′26.6″N 13°25′33.1″E	Bedrock site, alvar plain, limestone	INT Edu, Tour	Nature reserve No threat at present.
14	Kinne-Kleva Götene 58°32′44.9″N 13°23′41.7″E	Bedrock site, alum shale, limestone, old quarry	NAT Sci, Edu, Tour	Nature management area The present exposures may be destroyed if the racetrack is expanded.
15	Thorsberg's quarry Götene 58°34′44.4″N 13°25′46.9″E	Bedrock site, meteorites, limestone, quarry	INT Sci, Edu	Nature management area Active quarry, so the area is subject to constant change.
16	Ryds grottor Skövde 58°25′50.1″N 13°49′20.9″E	Bedrock site, dolerite, viewpoint	NAT Tour	Nature reserve No threat at present. Vegetation needs to be cleared at least every two years to keep the dolerite visible, as well as to maintain the viewpoint.

17	Jättadalen and Öglunda caves Skara 58°25′54.3″N 13°41′49.9″E	Bedrock site, dolerite, viewpoint	NAT Tour	Nature reserve No threat at present. Vegetation needs to be cleared at least every two years to keep the dolerite visible, as well as to maintain the viewpoint.
18	Silverfallet Skövde 58°29′35.0″N 13°44′40.4″E	Bedrock site, sandstone, alum shale, limestone, old quarry	REG Edu, Tour	Nature reserve No threat at present. Vegetation needs to be cleared so that both the geology (bedrock exposure) and the cultural-historical relics are visible.
19	Råbäck harbour Götene 58°36′22.1″N 13°20′45.5″E	Bedrock site, sand-stone, sub-Cam-brian peneplain, conglomerate	INT Sci, Edu, Tour	Nature reserve No threat at present.
20	Cementa's south quarry Skövde 58°22′41.9″N 13°49′00.8″E	Bedrock site, fossil site, limestone, old quarry	NAT Sci, Edu, Tour	Bird protection area No threat at present.
21	Tomtens lime-stone quarry Falköping 58°13′27.2″N 13°36′32.8″E	Bedrock site, fossil site, limestone, old quarry	REG Sci, Edu, Tour	No protection No threat at present.
22	Ålleberg Falköping 58°08′15.3″N 13°35′59.7″E	Viewpoint, table mountain, sedi-mentary bedrocks, dolerite, landscape	INT Edu, Tour	Nature reserve No threat at present.
23	Djupadalen, Dala Falköping 58°15′07.8″N 13°44′55.9″E	Geomorphology site, bedrock site, canyon, limestone, ice lake drainage site, alvar	NAT Edu, Tour	Nature reserve No threat at present.
24	Djupadalen, Karleby Falköping 58°10′19.8″N 13°38′17.3″E	Geomorphology site, bedrock site, canyon, stratig-raphy	REG Sci, Edu, Tour	Nature reserve No threat at present.
25	Dolerite quarry at Hunneberg Grästorp 58°21′38.2″N 12°30′07.5″E	Bedrock site, dolerite, old quarry	REG Sci, Edu,	Nature reserve No threat at present.
26	Högstena Plantaberget Falköping 58°13′46.8″N 13°43′44.3″E	Bedrock site, shale	REG Sci, Edu,	Nature reserve No threat at present.
27	Råbäck's lime-stone quarry Götene 58°35′48.1″N 13°21′34.3″E	Bedrock site, alum shale, fossil site, old quarry	NAT Edu, Tour	Nature reserve No threat at present. Vegetation needs to be cleared so that both the geology and the cultural-historical relics are visible.

28	Shingle field at Grytet Vänersborg 58°22’22.8”N 12°29’37.1”E	Geomorphology site, shoreline, rounded rocks	REG Edu, Tour	Nature reserve An increase in visitors may entail wear on the area. Vegetation has to be cleared regularly.
29	Hindens Rev Lidköping 58°34’23.1”N 12°54’50.1”E	Geomorphology site, peninsula, end moraine, MSEMZ	INT Sci, Edu, Tour	Nature reserve An increase in visitors may entail wear on the area.
30	Rådaåsen Lidköping 58°29’57.0”N 13°05’23.6”E	Geomorphology site, end moraine, MSEMZ	NAT Sci, Edu, Tour	Area of national interest, water protection area, partly nature reserve An expansion of the gravel pit may partly threaten the values of the ridge.
31	Ledsjö moraine Götene 58°28’06.7”N 13°28’55.1”E	Geomorphology site, end moraine, MSEMZ	NAT Sci	No protection No threat at present. Gravel extraction may pose a future threat.
32	Skåning-Åsaka moraine Skara 58°26’20.1”N 13°30’24.5”E	Geomorphology site, end moraine, MSEMZ	NAT Sci, Edu	Area of national interest No threat at present. Gravel extraction may pose a future threat.
33	Högkullen – Kinnekulle drumlines Götene 58°36’06.0”N 13°24’29.1”E	Geomorphology site, drumlines	NAT Sci	Nature reserve No threat at present.
34	Låstad esker Mariestad 58°32’53.9”N 13°47’41.4”E	Geomorphology site, esker	NAT Sci, Edu	Area of national interest No threat at present. Gravel extraction may pose a future threat.
35	Krogstorp esker Skara 58°26’45.4”N 13°33’39.2”E	Geomorphology site, esker, outwash fan	NAT Sci	Area of national interest No threat at present. Gravel extraction may pose a future threat.
36	Valle Härad Skara, Skövde 58°26’08.8”N 13°39’45.2”E	Geomorphology site, kame land-scape, MSEMZ	INT Sci, Edu, Tour	Nature reserve No threat at present. An increase in visitors and development may pose a future threat.
37	Store Mon Skara 58°30’17.1”N 13°35’49.7”E	Geomorphology site, sedimentary deposits, Baltic Ice Lake drainage site	INT Sci, Edu	No protection A possible re-opening of the gravel pit may pose a threat, but there are no such plans at present.
38	Stora Stolan Skövde 58°31’21.9”N 13°46’51.2”E	Geomorphology site, bedrock site, sedimentary deposits, Baltic Ice Lake drainage site, alum shale, old quarry	INT Sci, Edu, Tour	Area of national interest No threat at present. Vegetation needs to be cleared so that both the geology and the cultural-historical relics are visible.
39	Klyftamon Götene, Skövde 58°30’38.5”N 13°38’41.1”E	Geomorphology site, Baltic Ice Lake drainage site	INT Sci, Edu, Tour	Nature reserve No threat at present.

40	Kestad De Geer moraines Götene 58°33′31.5″N 13°27′46.3″E	Geomorphology site, De Geer moraines	NAT Sci, Edu	No protection No threat at present. An increase in agriculture may threaten a few of the ridges, but hardly the whole area.
41	Binneberg De Geer moraines Skövde 58°31′28.1″N 13°51′52.6″E	Geomorphology site, De Geer moraines	NAT Sci, Edu	Area of national interest. No threat at present. An increase in agriculture or development may threaten a few of the ridges, but hardly the whole area
42	Skara moraine Skara 58°24′11.3″N 13°29′25.7″E	Geomorphology site, end moraine, MSEMZ	INT Sci, Edu, Tour	Nature reserve Parts of the moraine ridge that are located outside the reserve may be threatened by agriculture or development in the future, but we see no threat at present.
43	Axevalla hed Skara 58°23′44.6″N 13°35′21.9″E	Geomorphology site, outwash fan, sedimentary deposits	REG Tour	Area of national interest, Natura 2000 No threat at present.
44	Händene sand dunes Skara 58°24′37.1″N 13°20′25.0″E	Geomorphology site, sand dunes, aeolian processes	INT Sci	No protection An increase in agriculture or development may threaten parts of the dune field.
45	Pellagården varved clay Skara 58°32′03.0″N 13°31′13.8″E	Geomorphology site, varved clay, scientific test site, Baltic Ice Lake drainage site	INT Sci	No protection No threat at present.
46	Tun moraine Lidköping 58°25′51.9″N 12°44′06.2″E	Geomorphology site, end moraine	NAT Sci, Tour	Area of national interest No threat at present.
47	Lake Hornborga Skara, Falköping 58°19′13.7″N 13°33′04.8″E	Geomorphology site, lake	NAT Edu, Tour	Nature reserve No threat at present.
48	Holmestad esker Götene 58°32′34.5″N 13°34′11.6″E	Geomorphology site, esker	NAT Sci, Edu, Tour	No protection No threat at present. An increase in agriculture or development may threaten parts of the ridge, but hardly the whole area. The E20 runs across the northern part of the ridge.
49	Ore backar Skara 58°17′41.9″N 13°30′23.9″E	Geomorphology site, esker	REG Tour	Nature reserve No threat at present. An increase in visitors may entail wear on the area.
50	Rännefalan delta Falköping 58°07′18.3″N 13°39′37.2″E	Geomorphology site, outwash plain, Åsle Ice Lake drainage site	REG Sci	No protection No threat at present.
51	Nolgården Näs Falköping 58°05′14.2″N 13°42′03.9″E	Geomorphology site, esker net	INT Sci, Edu, Tour	Nature reserve No threat at present.
52	Blängsmossen Skövde 58°25′36.2″N 13°46′38.7″E	Raised bog, mountain plateau	NAT Sci, Edu, Tour	Nature reserve No threat at present.

Geoconservation

For information on how the natural heritage of the area is valued, interpreted, promoted and maintained in Sweden, please look at section E.2.1 Natural heritage. Platåbergens Geopark has developed a Conservation plan for geological heritage in the geopark area. The conservation plan has been developed with support from the Swedish Environmental Protection Agency through their "LONA" programme for local environmental protection activities. As part of the conservation plan, Platåbergens Geopark has defined several principles for geological natural values.

Platåbergens Geopark's principles regarding geological natural values:

- Geological diversity is a fundamental part of environmental diversity and to conserve a geological variation is necessary for having resilient natural and human societies.
- Geological natural values in the table mountain region should be recognised, mapped and protected.
- Areas with high natural values should be used in such a way as to not destroy those values.
- Platåbergens Geopark will work to increase understanding and knowledge about these geological natural values and the geological processes at work in the landscape.
- Geological natural values are a necessary resource for human societies, but the resources should be used in a sustainable and long-term manner and with consideration for the needs of future generations.

We identify the following values in relation to geological diversity:

1. Intrinsic value
   Geological diversity has a value per se, i.e. as a part of planet Earth whether or not it is useful to humans.
2. Scientific values
   Our geological heritage contains sites and areas that are of scientific importance, to understand the development of our planet as well as ongoing processes and future development.
3. Value based on rarity or distinctiveness
   Several geological sites are one of a kind and should be preserved as scientific references or as important places for teaching and tourism.
4. Cultural and historical values
   Since the beginning of human history, human evolution and development have depended on geological resources. The special geological conditions in one place have created different cultural and historical societies.
5. Ecological values
   Different rocks give off different nutrients that affect flora and vegetation. Different soil types, containing sand, gravel or clay, affect the ground and plant life. Geological variation gives us different landforms and landscapes, and a variation in habitats and ecosystems.
6. Value through contribution to ecosystem services (geosystem services)
   Geological diversity strongly contributes to all four types of ecosystem services. For example, the geological cycle is regulating, soil-forming processes are supporting, access to nutrients and minerals is provisioning, and the possibilities for tourism and outdoor activities are cultural.
7. Value to outdoor activities, recreation and tourism
   Special geological conditions are the basis for several tourist attractions and outdoor activity areas. Geological sites raise curiosity and wonder while providing knowledge about planet Earth. Thus, geological values often add an extra dimension to nature experiences, recreation and outdoor activities.

Platåbergens Geopark will work to protect geological diversity in the geopark by:

1. collecting data and knowledge about the geological history of the area and about important geological sites;
2. keeping an internal database of information sheets on each geological site, including vulnerability and accessibility analyses;
3. regularly visiting the geological sites in the field to monitor wear and other threats;
4. collaborating with individuals and municipalities and other authorities to ensure that geological conservation is considered in physical planning; and
5. facilitating, collaborating with and stimulating scientific research within the geopark area.

Ramson at Kinnekulle.