Excursion guide NW Skåne, NGEA 01, 2017
PART 1. Introduction

by

Associate Prof. Jonas Åkerman

Cover photo; The NW exposed coastline at Josefinelust with coarse beach boulders (Sw. “malar”), gneiss is the mother rock intersected by various intrusive rocks in dykes. (Photo J. Åkerman)

Excursion guide to NW - Skåne, NGEA 01 Ht. 2017

Part 1

INTRODUCTION

This excursion guide has been compiled from material prepared and processed for different introductory courses during several years. A number of teachers and assistants have contributed to its design. This year's version has been edited by **Associate Prof. Jonas Åkerman** who, (together with the ordinary teachers at your course – may be, time permitting), will be your instructor in the field **Sept. 14th 2016**. The material to the guide has been collected from various sources. In order to make the guide easier to read and use in the field only very few references are indicated in the running text! A lot of material, maps and map descriptions has been taken from SGU's (Swedish Geological Survey) material from papers by Prof. Sven Behrens, L. Carserud guides "Geological Attractions in Skåne" and from the periodical "Skånes Natur". Details and information about logistics for the excursion are given during the preparation and previous lectures. Is there anything you want/need to know before then you may contact Cecilia Axelsson or Ulrik Mårtensson or me on; ***Jonas.Akerman@nateko.lu.se*** or in "emergency" 070 69 70 520 (use SMS)

During this excursion to northwest Skåne, we have ***rocks, soils, morphology, endogenous and exogenous processes*** as the overall theme but we should also try to observe as much as possible of the landscape and its processes, the overall scenery and land use, agricultural actions and other things we come across or drive past.
Some of the stops we make and the objects we see and observe may not have been treated in literature and lectures yet!! You will have to see each of the three excursions as one of three pieces of a jigsaw puzzle and put your observations into their proper places of the course. For example, during this excursion, we will experience a lot of coastal features that add to what we have as the main theme during **excursion No3** ("The Coasts of Skåne").
To put all this information in place will be your own work, but your lecturers and I will assist and give plenty of notifications to help you. '
NB!!! Note that the excursion is carried out regardless of weather conditions (in principle!). This requires some planning regarding clothing, etc. (Waterproof clothing, rubber boots or hiking boots is a must). During this excursion we will stop at numerous places and have lunch outdoors so packed lunch and sufficient to drink is appropriate "equipment". Field Toilet (bushes) can be used in most cases - but a couple of the stops have simple toilet facilities. **Bring notebook, this guide** (and binoculars, camera, etc. if you like).

NB - no shopping stops!!!!

Departure from Sölvegatan 12, **September 14th 0800 Sharp !!!. We do not wait !!!!!** (Return at approximately 1700 (no guaranties!). Absence Report on SMS 070 69 70 520 !! Note that the excursions are compulsory during the course and an attendance list will be circulated for our record. You might of course be sick but then give me a note on SMS so I have it in my records.

Pre text.
Mastering methods to observe and to collect data in the field is an extraordinary important part of our professional skills in our multidisciplinary and multifaceted work as geographers and ecologists. Very often the information we encounter and collect in a work situation is not readily found in a digital package in or from a logger but the individual observer must collect and edit it all or part of the observation. Today we very often use a combination of digital data (i.e. GPS coordinates) and analog observations. We must learn how to record and combine these different observations and data sets so that they may be processed and analyzed according to modern standards.

Equally important is to be able to plan and lead an excursion for students or colleagues regarding a particular theme or in a particular site or region (i.e. to present your fieldwork area for your examination work and thesis). This is something that a future job situation very often is requires of you.
Of great importance to us geographers, ecologists and ecosystem scientists is also the skill to "read the landscape". By this we mean being able to interpret the general appearance of the landscape, its combination of geology, morphology, hydrography, vegetation and anthropogenic elements like farming in a systematic way. It also means the skill of observation and interpretation of individual specific objects or events and in a relevant way, recording it or documenting it.
Such observations should help us to interpret what is happening in the landscape, what has happened, and thus led to an understanding of the current status and/or what might happen in the landscape under different circumstances (climate change, environmental changes, etc.).
Increasingly important is that our observations require quantification in a way that our field data properly can be linked to other data in GIS and modeling applications. This increases the demands on our measurement and observation methods. Nonetheless, often still quite simple observation and measurement techniques and instruments are used to supplement for example GPS positioning.
During this excursion in northwest Skåne, we have rocks, morphology endogenous and exogenous processes as the theme but we should also try to observe as much as possible of the scenery and other things we come across or drive past.

EXCURSION TO NW SKÅNE

Our excursion to NW Scania has the aim to visualize and exemplify:

- Relations between rocks/soils and landforms.
- The postglacial landscape development
- Some aspects of the anthropogenic components of the landscape in Skåne
- That Skåne may be developed into sub regions based upon the geomorphology
- That Skåne is divided in three natural morphotectonic areas based upon NW/SE lineaments
- These lineaments are tectonic lines of old age (more than 60 milj.)
- That the hydrography of Skåne show a typical these NW/SE tectonic lineaments
- That Kullaberg and the Söderåsen horst are forms of this NW/SE tectonic lineaments
- That the soils of Skåne is a mirror of the underlying bedrock
- That Kullaberg and the Söderåsen horst are dissected by a set of valleys with a N/S direction
- That the caves of Kullaberg primarily are localized through three structural systems in the bedrock

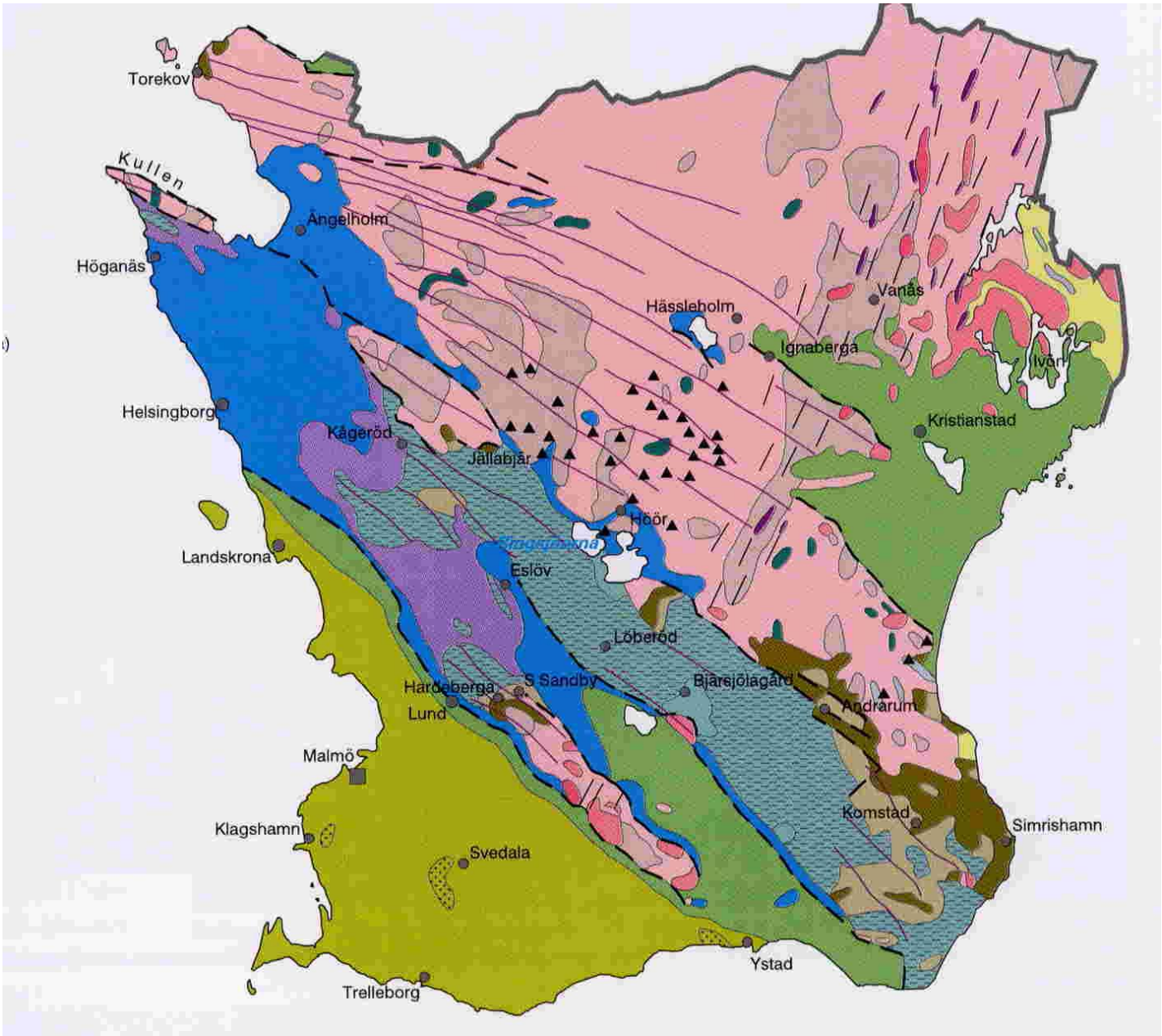


Figure.1. Basic bedrock map over Skåne. (For legend - see below) (*from SGU.*)

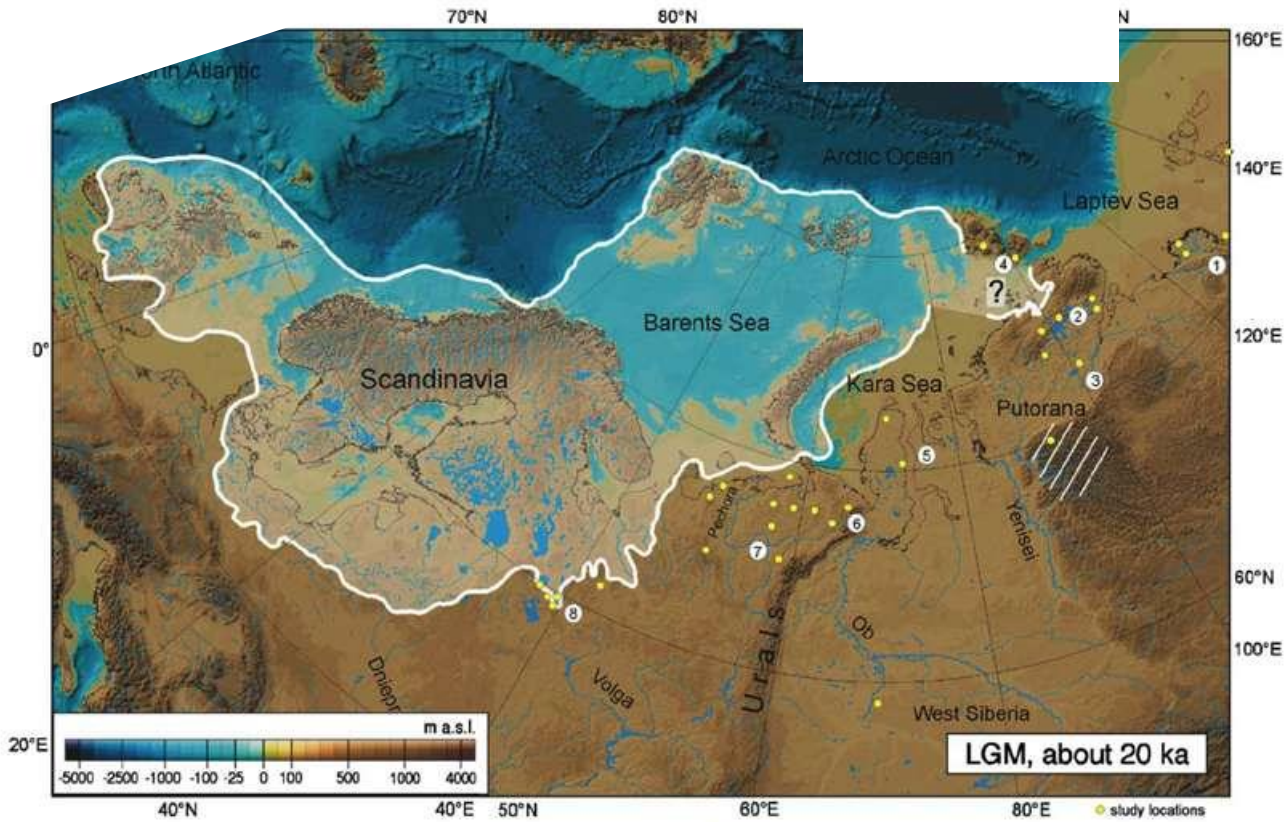
Pink and red are volcanic gneiss and granite.
Blue/bluish and lilac are shales and schists.
Green is limestone
Black triangles are fossil volcanoes
Brown is quartzites

Figure.2. Generalized route of the route for the NW-Skåne excursion, NGEA 01 - 2017

1. Background

Without using too much time on the subject still we must go back to the glacial and postglacial history and landscape development. For you who come from parts of the world with no glacial history it might be difficult to understand our landscape if we do not give you a short background.

All of northwest Europe was covered by a more than 3 km thick inland ice between approximately 110 000 and 14 000 years BP. (Take out your “mental picture” of Antarctica or Greenland and put it over Northern Europe!)



Map showing the LGM Eurasian Ice Sheet according to Svendsen et al. (2004b), with the numbered working areas described in the text. (1) Laptev Sea Coast and Bykovsky Peninsula, (2) Central Taymyr Peninsula, (3) SE Taymyr Peninsula, Labaz Lake Region, (4) Severnaya Zemlya Archipelago, (5) West Siberia and Yamal Peninsula, (6) Ural Mountains, (7) Pechora Lowland, and (8) NW Russian Plain.

Figure 3. Modern opinion about the distribution of the inland ice over Northern Europe and Russia at the Last Glacial Maximum (LGM)

This **last glacial period** was the most recent glacial period occurring in the Pleistocene epoch. It began about 110,000 years ago and ended between 10,000 and 15,000 BP. During this period, there were several changes between glacier advance and retreat. The end of the last glacial period was about 14,000 years ago in south Sweden. **(Fig. 3 & 4)**

The **Last Glacial Maximum (LGM)** refers to the time of maximum extent of the ice sheets during the last glaciation (the Würm or Wisconsin glaciation), approximately 20,000 years ago. This extreme persisted for several thousand years. At this time, ice sheets covered the whole of Iceland and all but the southern extremity of the British Isles. Northern Europe was largely covered. The southern boundary passed through Germany and Poland, and joined to the British ice sheet, which had its own centre over Scotland. This ice extended northward to cover Svalbard and eastward to occupy the northern half of the West Siberian Plain, ending at the Taymyr Peninsula **(Fig. 1)**. In North America, the ice covered essentially all of Canada and extended roughly to the Missouri and Ohio Rivers, and eastward to New York City.
The glacial and postglacial history vegetation history and colonization by man follow a simple pattern from a; 1. Glacial, 2. Periglacial, 3. Boreal forest to a, 4. Temperate forest environment. **(cf. Fig 4)**

- **Glacial period** - inland ice cap, more than 3 km thick over Scania at maximum. Ended in southernmost parts of Scania approximately 14 000 years ago. (The distribution of the inland ice – see **Figure 4**)
- **Periglacial climate –** open tundra ecosystem. 14 000 to10 000 years ago.
- **A postglacial climate optimum –** stone age period 8 000 –7 000 years ago

- **Boreal forests –** coniferous forest ecosystems, taiga
- **Temperate forest -** deciduous forest ecosystems

The pattern of surface water in the landscape up to its present status as well as the hydrography in general is of course a result of this environmental change from the glacial up to the present climate. Still the old patterns governed by the bedrock are clearly visible.

Today the region of Scania is one of the most densely populated regions of Scandinavia and completely in the hands and under influence of man and her activities. This means that urban centres, agriculture and intense forestry dominate, leaving no virgin ecosystems that are remaining "intact". Scania is hence also the most densely populated areas of Sweden and the area, has the highest % area under highly mechanized agriculture.
The main crops are cereals (wheat, barley, and oats), oilseed, sugar beet, and intensive dairy and meat production is important.
The surface water and the hydrography have become highly influenced also by man's agricultural activities in this process of transformation. Processes of change are still going on.
The history of transformation of the hydrography has many connections with present day environmental problems, i.e. the nutrient leaching from agricultural lands to rivers, lakes and coastal waters, loss of biodiversity, increased water and wind erosion etc.

.

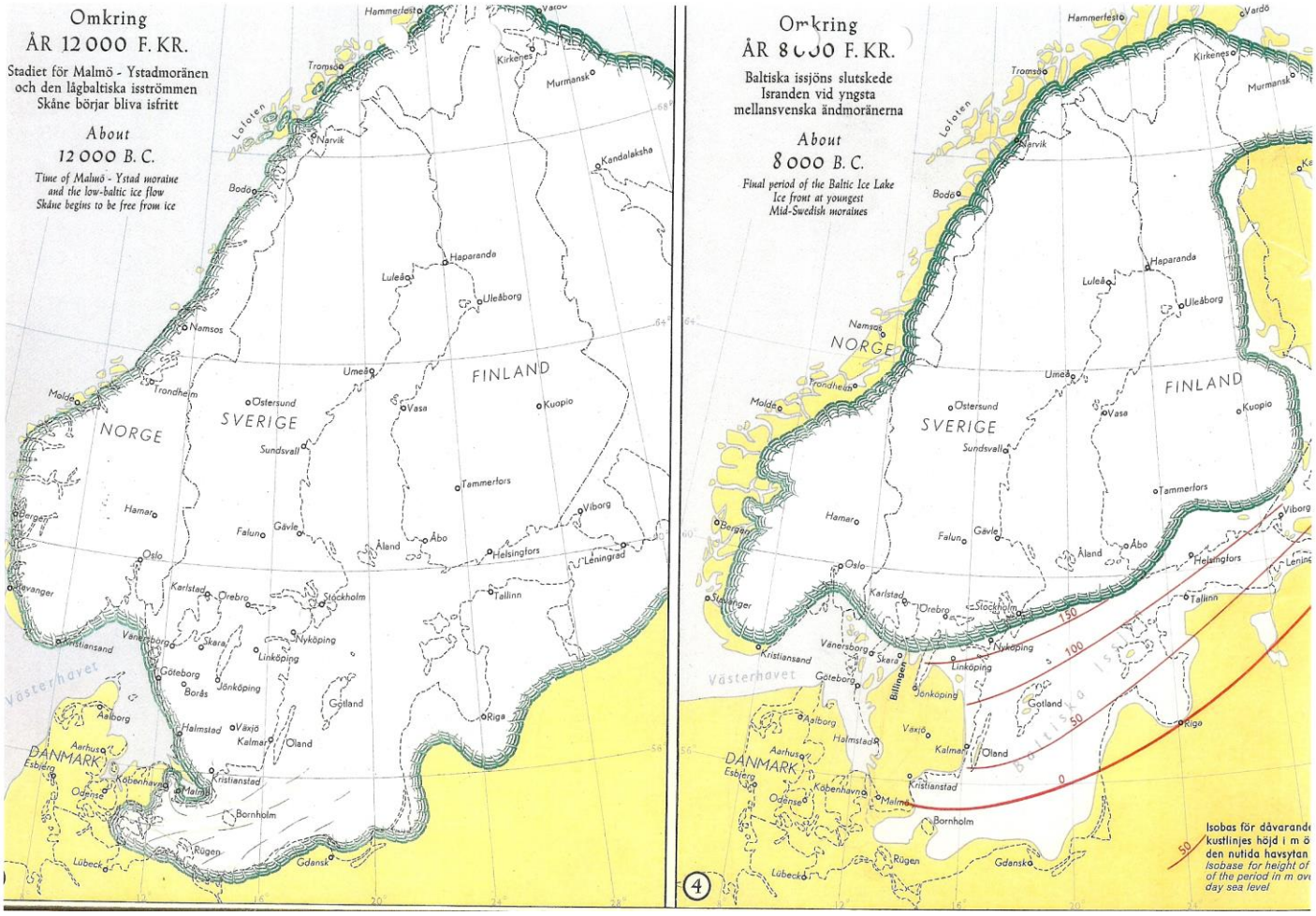


Figure 4. Distribution of the inland ice at 14 000 BP and 10 000 BP

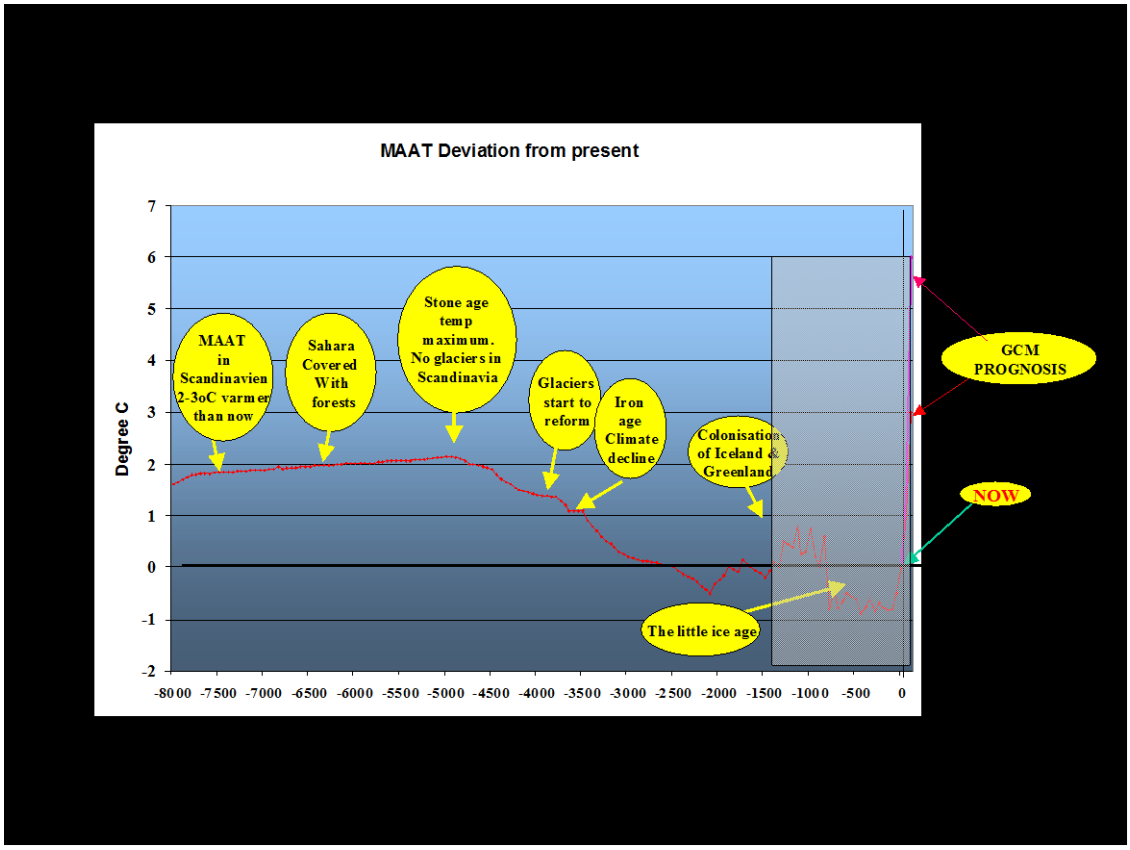


Figure 5. The relative climate development in southern Sweden during the last 8 000 years.

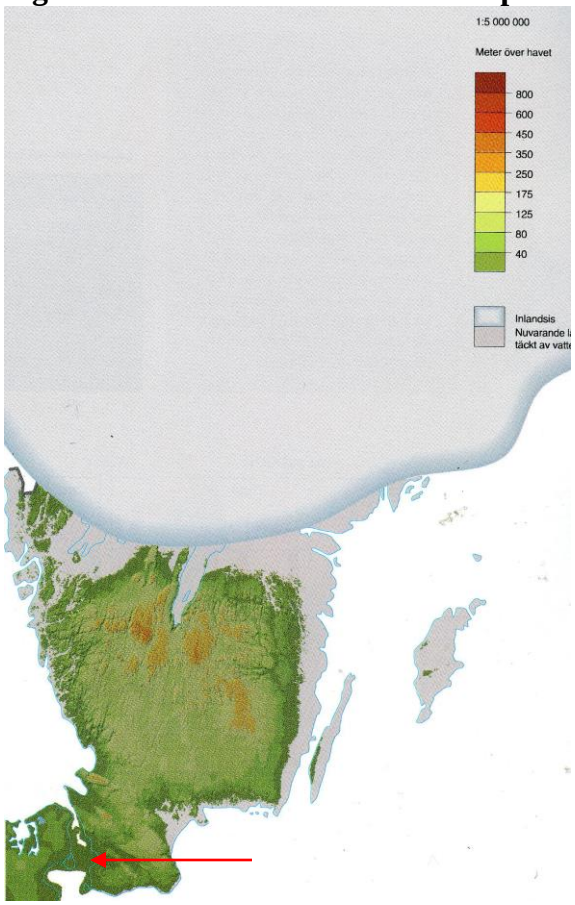


Figure 6. The deglaciation situation in south Sweden about 10 000 BP. Note the land bridge between Denmark and Sweden.

Endo - and exogenic processes during the geological history

Old endogenic processes create the background and set the scene for both large scale and small-scale landform features of the landscape in Scania. Scania is situated on the southern fringe of the Baltic shield and this fringe has been a zone of disturbances throughout geological history. The disturbances have occurred along a SE-NW stretching zone – the Törnquist zone **(Fig. 7).** This zone gives character to all of the major components the landscape of Scania, geology, topography, and hydrography. During later stages, the detail geomorphology of the landscape has then been reformed and reshaped. Especially important is the Quaternary glaciations and especially during its later deglaciation phases 14 000 –10 000 years BP.

Despite its very old age, the Törnquist zone is still active and in fact, 16th December 2008 we hand a quite significant earthquake here along this fault zone **(Fig 8)**.

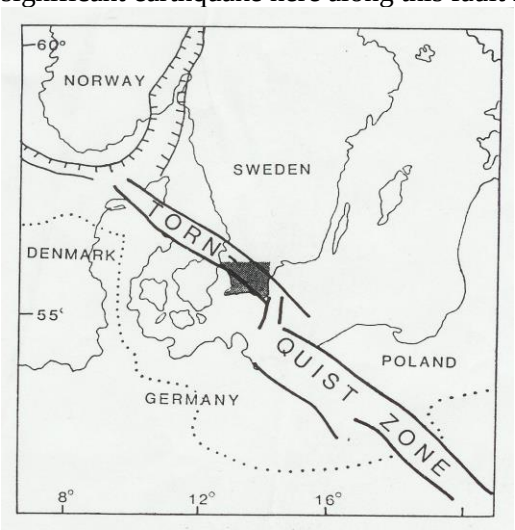


Figure. 7. The Törnquist zone.

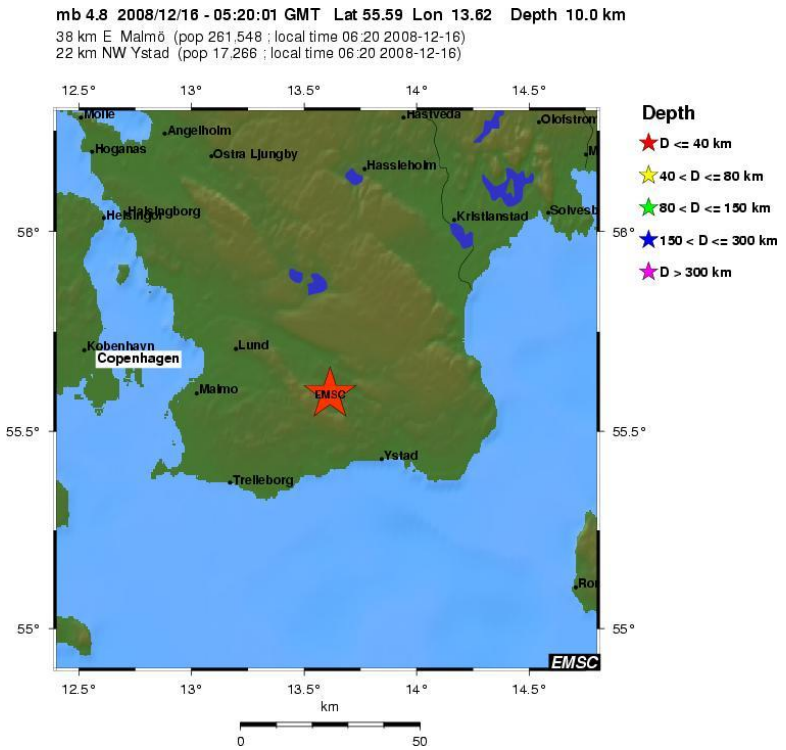


Figure 8. Epicentre of the earthquake 16th December 2008

2. The excursion area

The area to the North and Northwest of Lund

We are initially leaving Lund going in a northerly direction. From a morphological point of view, we are passing through a landscape that is rather flat – an almost 100% cultivated agricultural plain. The area has been under the highest level of the sea and most of soils are a mixture of marine sediments and tills coming from the **southwest**. The ice that left these tills came from the southwest through the large lobes of ice that flow south in the Baltic Sea depression and then turned west and then north again!!! **(See also fig. 29).** To the north we soon see a smooth rise or "long ridge" this is the southernmost parts of the SÖDERÅSEN mountain ridge. This ridge is the last remains of a very old bedrock feature – a horst - that today only raise less than 200 m above the surrounding plain. **(Fig. 9).**

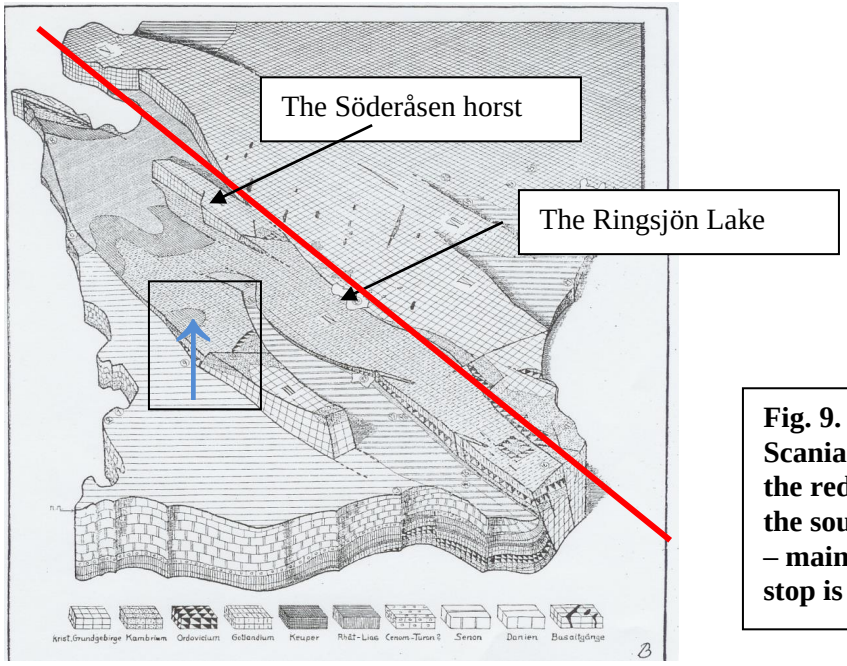


Fig. 9. Schematic picture of the Scanian geology. To the north of the red line is the Baltic Shield, in the southwest sedimentary rocks – mainly limestones. The first stop is by the blue arrow.

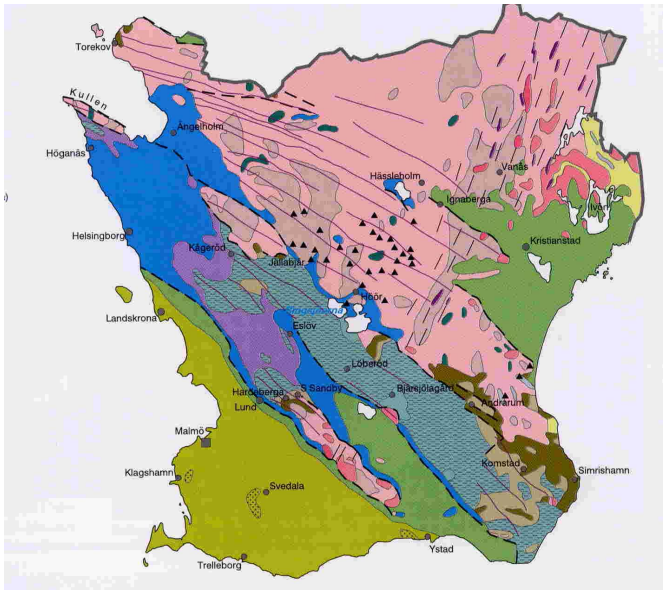


Figure. 10. Geological overview of Scania. ***For better details - see the Map at the end of Part 2.***

Pink and red are volcanic gneiss and granite.
Blue/bluish and lilac are shales and schists.
Green is limestone
Black triangles are fossil volcanoes
Brown is quartzites

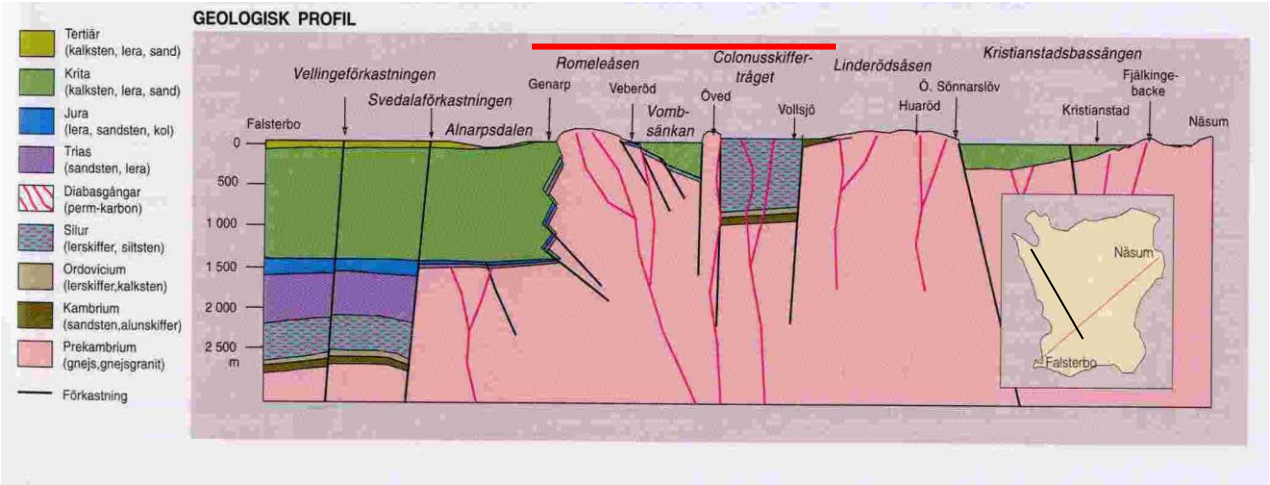


Figure. 11. Geological profile across Scania. We will cross the landscape and the "geology" along the black line, (which geology partly is like the red one).

Originally, the ridge was very much higher and the actual tectonic uplift of the horst is estimated to 1500 m but erosion has kept even pace with the uplift and it is not a very high mountain ridge today. We will follow the southern slope for some few km and then cross the crest over to its northern side. To the south, we have soils that are highly calcareous. These soils are formed by the ice that came from the south grinding down the limestone and from marine sediments that were deposited during the later stages of the glaciation when this area was below sea level.

North of this zone the bedrock in this part of Scania consists of long-stretching belts of sedimentary rocks (lime stones, shale, schist's, quartzite's and sandstones) from the Mesozoic time. These sedimentary rocks, which tend to have the same general alignment in the landscape i.e. from the northwest to the southeast **(see Figs. 8-11).**

Geomorphology and endogenic and exogenic processes in central and NW Skåne

Exogenic processes during the geological development

The major features of the geomorphology of central Skåne developed by tectonic movements along the Tornquist Zone during the Mesozoic - Triassic, Jurassic, and Cretaceous 225 – 65 milj years ago (e.g. the Söderåsen, the Romeleåsen and the Kullaberg horsts). Besides the endogenous processes, the following exogenous processes (weathering and erosion) had a great influence on the geomorphological and geological development. The nature and intensity of the processes were affected by an interaction between the rocks, climate, tectonics and sea level changes (erosion base position). During certain periods, chemical weathering of the land surface dominated, while other periods were characterized by widespread erosion (eg, river erosion or sheet erosion by rainfall runoff), and the following deposition and sedimentation. The degradation products are then deposited as sediment over time and then transformed into sedimentary rocks. These can later again be have eroded away. During the Quaternary (last 2 million. Years) cold climate affected land area by glacial and periglacial processes. Most of the modern, young forms are thus glacially developed. The result is that the contemporary landscape thus contains landforms that vary widely in age.

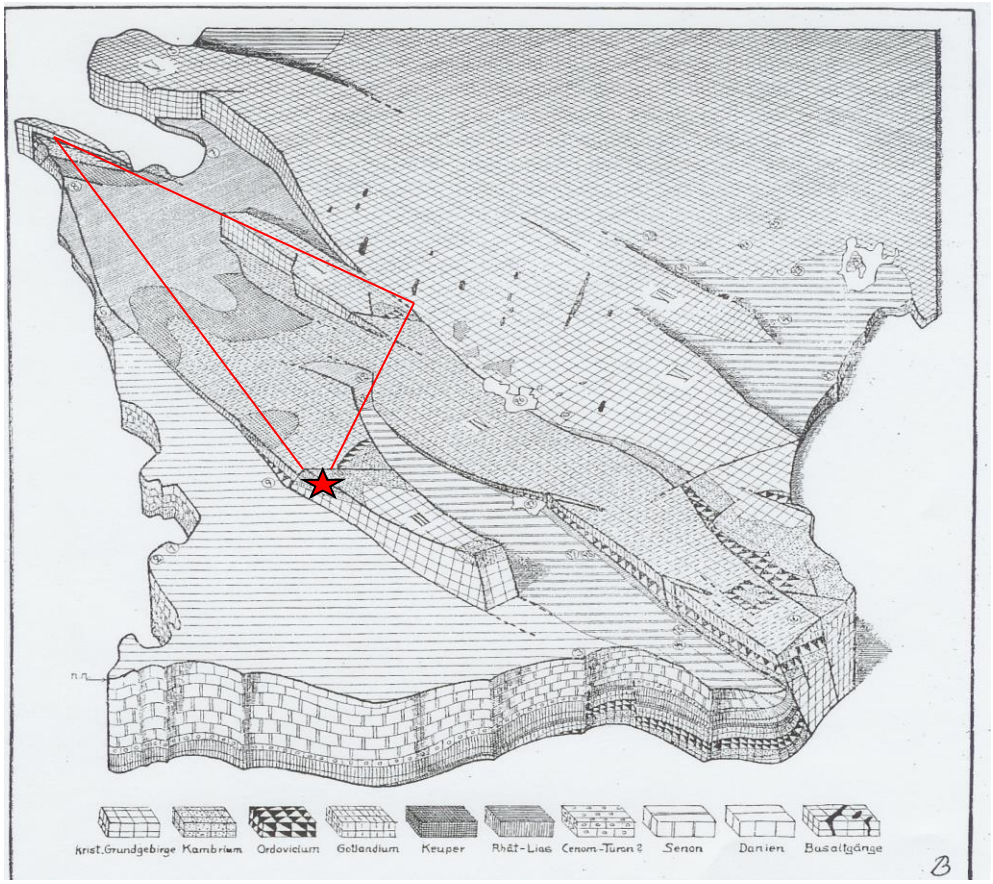


Figure. 12. 3-dimentional geological block diagram of Skåne. Lund is by the star.

The bedrock-related forms can be hundreds of millions of years old, while the forms of the loose material largely emanate from the last glaciation (about 10 000 -100 000yr). Contemporary exogenous processes changes the landscape only slowly – the most visible and obvious activity is the aeolian and costal processes. During the excursion, we will pass across the Skåne NW-SE fault zone, in the southern marginal area represented by the Ringsjön Fault. Southwest of this fault dominates Silurian shale bedrock (also some Silurian sandstone bedrock) and further south the limestones. The morphology is smooth undulating plains called the Skåne shale plains of south Skåne. North east of this fault lines the shield bedrock (gneiss and granite) and a higher hilly relief dominates. To explain the complex geomorphology of the area, we need to include considerations of periods of weathering under very different climate than today.

Weathering in different climates

In today's climate both chemical and mechanical weathering are of relatively low intensity. Examples of active processes are frost weathering, biological weathering and in places “grus” weathering. It is perhaps difficult to imagine that the slow-acting weathering processes could have a decisive influence on the terrain shape development of today. Despite that, the importance of weathering in previous different climate is remarkably large for the geomorphology of Central Skåne. Deep chemical weathering in a hot, humid climate of the Mesozoic period has formed many of the bedrock forms we see today. Bedrock of granites and gneisses were during this period exposed to kaolin weathering (chemical weathering of feldspar).

Of much younger origin are the faint traces of weathering in a cold climate that we can find. Periglacial conditions with strong mechanical weathering prevailed later in late glacial time. Rock out crops then were subject to superficial frost weathering with formation of angular weathering material. What remains to be seen are **talus and tors**, especially where bedrock has been closely fractured and "an easy victim" of frost weathering, e.g. the gneiss of Söderåsen.

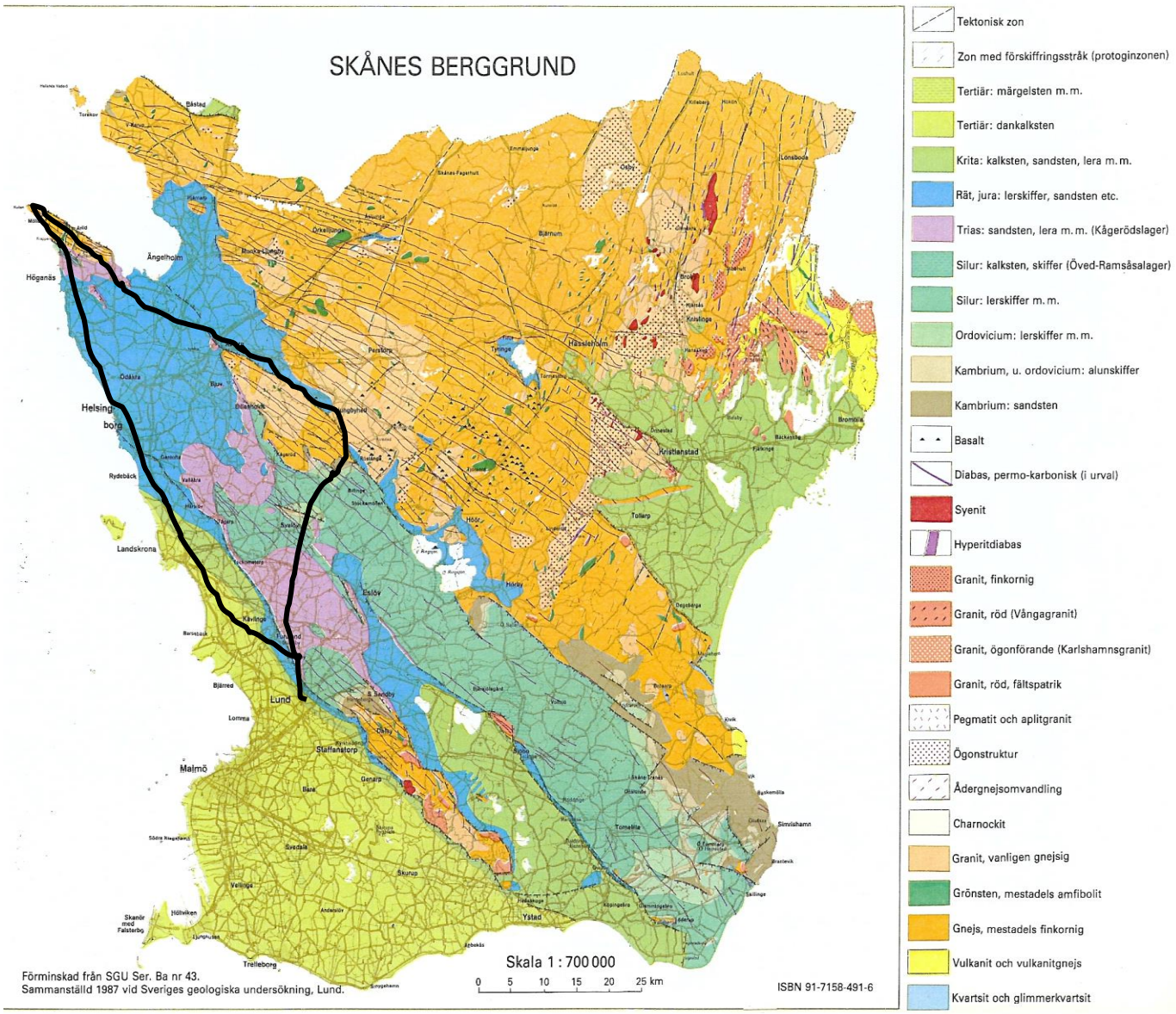


Figure. 13. Geological map of the bedrock of Skåne. (*from SGU.)*

Mesozoic weathering and land forms

Drilling has shown that the crystalline bedrock in central Skåne (granite and gneiss) is often kaolinized several meters down. Kaolin weathering took place during a period from the end of Triassic and a bit into the Jura. The border between weathered and unweathered rock (the so-called weathering front) was inconsistent with resistant rock bodies embedded in the weathering material. This means that potential, even partially buried landforms were

created. During tectonic movements in the beginning of Jura started an erosion of the weathered material and the sediments from it were transported and deposited in depressions on the marginal parts of the shield rock or in the bordering marine environment.

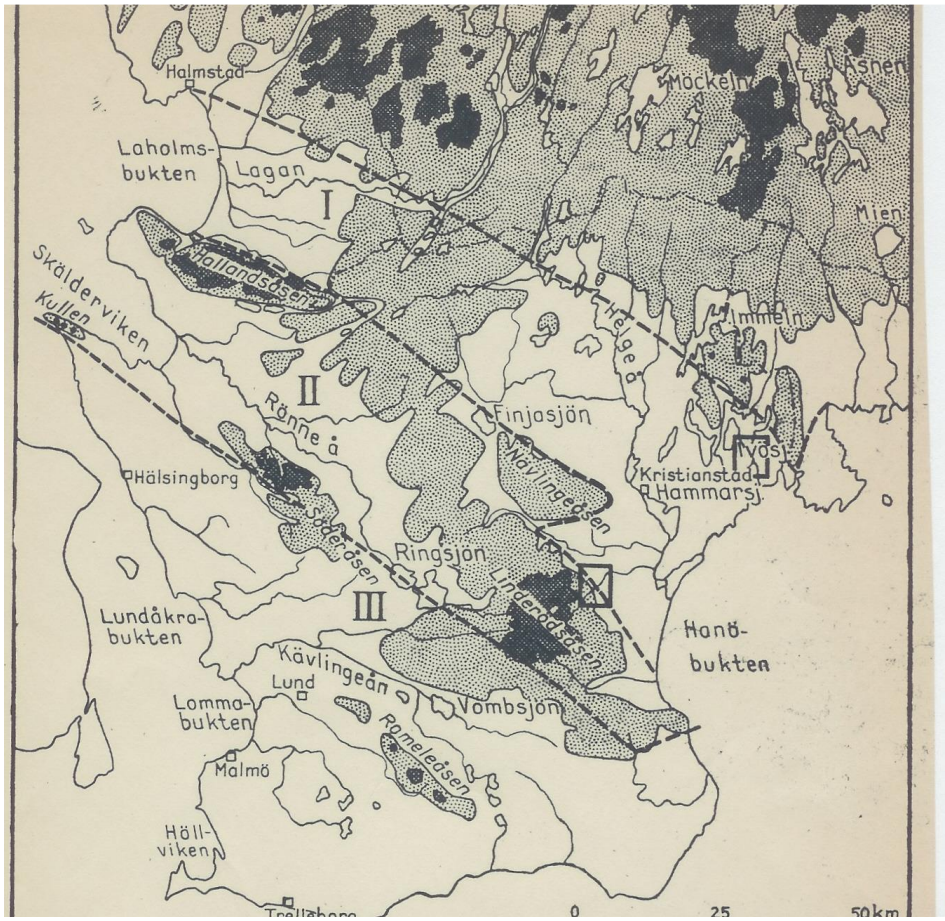


Figure 14. Schematic figure of the major landform units of Skåne.

The so-called Höör sandstone was formed during this period and has been mined and used as building material – for example for the Lund Cathedral. The sediments were long lying as a protective blanket that hid crystalline bedrock forms. Through renewed erosion during the Tertiary and Quaternary, the Mesozoic weathering front again was exposed. Scattered remnants of Jurassic sediments persist immediately north of the Ringsjön fault. All limestone rocks that may have existed are gone. The shield bedrock surface here form the most southerly occurring hilly terrain in our country. In north-eastern Skåne, the result of Mesozoic deep weathering is seen even clearer than in Central Skåne and is dominating the landscape. Today's bedrock surface is a surface - prepared and shaped by old forms characterized by subtropical and tropical weathering and the protective sediments on top of bedrock was formed here during the Cretaceous period. Some of these protective sediments may still be found in NE Skåne but most of it is gone in higher terrain.

.

Mountain hills in central Scania

Low hills and even minor tors, characterize hills in the crystalline bedrock of central Skåne as upstanding remains of an ancient weathering front. Core blocks dislodged from the weathered bedrock can also be found on the

ground, probably more or less moved by the ice. They are often considerably larger and more rounded than the "usual" moraine blocks in the till. During the Quaternary glaciations, the hills were transformed to some extent by glacial erosion and made into **drumlins** and **kames** (check the concept **drumlin & kame** in your text book and also in excursion guide III).

Figure 15. Granite Rock in central Swaziland with core blocks embedded in the surrounding kaolinite material. *(foto. J. Åkerman)*

As mentioned earlier, there are also more than a hundred hills as remnants of the volcanic episode that began in the Jurassic (195-140milj BP). These hills consist of basalt and are called volcanic necks - **Basaltkupper** (in Swedish). Basalt necks are the clearest geomorphological traces of the volcanic episode that began in the Jurassic. The necks are often covered by till (drumlinized) by the ice sheet in an elongated form. It is very rare that the volcanic ash (basalt tuff) is intact, but it can be found in protected sites, like at Djupadal (see locality 4).

Present exogenic processes

In a geological perspective, the period after the last glaciation is short. The current landscape is still in a phase where the temperate climate and its exogenous processes affect the "legacy" of forms and sediments. It is however not only a glacial landscape in transformation. Bedrock forms, as described above, of very old and diverse origins, weathering products and forms from periglacial climate episodes are also available at many places. The glacial events and processes can still easily be seen on many sites. Of the contemporary processes, mainly coastal and river erosion are dominant and easily observed.

The major valleys of Skåne, eroded into the bedrock are likely to be of prequarternary age, or when developed only in loose material, eroded by strong flows during the melting of the ice sheets during the finiglacial stages. Wind erosion is not important in this part of Scania today but was significant during the tundra times with the absence of higher vegetation. This can be observed in the presence of wind-polished rock out crops and blocks. Such tracks are found almost everywhere in Skåne.

Weathering and slope processes are also slow in the current climate. One factor limiting the intensity of the present day exogenous process is the well-developed vegetation cover. Erosion by wind and water may generally only be seen where the vegetation is lacking, as in arable fields where the soil is a naked at least part time of the year.

The horsts of Skåne

The mountain ridges of Skåne (horsts) and their geomorphological terminology, has always been problematic. The word "*ås"* - in Swedish has two completely different meanings in geology and geomorphology. In the first case, it is the glacifluvial gravel ridge **or eskers** deposited and formed at the edge of the ice sheet when it melted and "retreated" over Skåne between 14,000 to 10,000 years ago. The second case, it is a **tectonic bedrock feature**, formed in Skåne for more than 70 million years ago. These mountain ridges (**horsts**) are thus at least 7000 times older than the eskers. Both types occur frequently in Skåne. The fact that both phenomena have the same name is due to linguistic heritage from old Nordic languages. If we concentrate on horsts of Skåne they form mountain ridges that usually extend in the northwest - southeast direction. This applies to the Hallandsås, Kullaberg, Söderåsen, Matterödsåsen, Nävlingeåsen, Linderödsåsen and Romeleåsen (see Figure 10-14 and below).

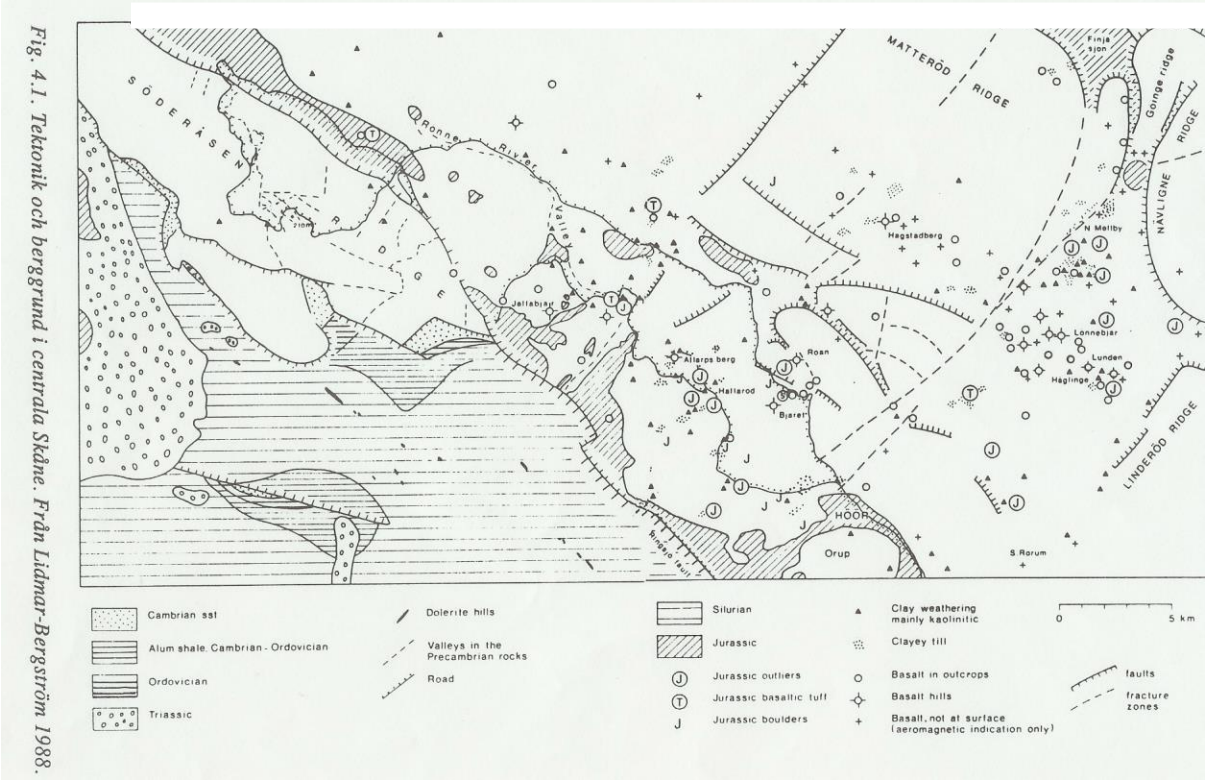


FIGURE 16. Tectonics and bedrock in central Skåne

The directions of the horsts are not accidental but are due to the forces that created them. The bedrock, of which the horsts are composed, is 1,000 to 1,700 million years old. The landscape forms, however, has changed many times since the crystalline bedrock formation. 750 million years ago the Cambrian sea inundated (transgression) the bedrock fundament that as we know, was very flat - the sub-Cambrian peneplain. The sandy sediments have covered and preserved the flat peneplain surface. 160 million years later strong tectonic activity on the continent south of Skåne folded bedrock. The forces were propagated to Skåne, where tectonic uplift and subsidence formed **hosts and grabens**. About 280 million years ago (Perm) the entire area of central Skåne was affected by volcanic activity. Lava welled up in the cracks and out over the land surface. During late Permian time, some 250 million years ago, the crust returned to peace. The country had then again been smoothened out by the weathering and

erosion forces to a flat surface a **peneplain**. This forms the basis for the transformation of land surface in modern times.

We know that the Earth's crust began to subside in south-western Skåne during the Triassic - 225 million years ago. During the Jurassic, the instability again increased over the whole county. Volcanoes formed in an area between the Söderåsen, Ringsjön and Hässleholm. What happened was linked to movements in the so-called Tornqvist zone (see above), a zone of weakness in the Earth's crust that extends from the North Sea in the northwest by Scania and Poland to the Black Sea in the southeast. The zone is named after the discoverer, a German geologist. The boundaries between the moving blocks often follow the direction of the Tornqvist zone. The horsts formed during this period are not directly visible in today's landscape, but are only visible in the geological layered structures. In Österlen the bedrock subsided, and hundreds of meters of sand and clay were deposited. A similar process took place in many parts of northwest Skåne.
During the Late Cretaceous of about 70-90 million years ago, something happened that is known as inversion, a reversal of the movement's direction. Basically, it meant that areas that were previously submerged came to be lifted up, and vice versa. No absolute rule of course. In any case, it was then that today's mountain ridges began to form. The rise of the horsts can be dated by determining the age of the deposits in the adjacent depressions formed simultaneously. On the southwest side of Romeleåsen the Malmö plain fell about 2 km over the course of 20 million years, a short time in a geological context. At times, during this process rivers flowed over the young Romeleåsen from north the south and deposed sandy deltas along the southern edge.

In the same way, one can determine the age of several other ridges, and it is found that Hallandsåsen, Nävlingeåsen and Linderödsåsen were formed at exactly the same time as Romeleåsen. Presumably this also applies to Kullaberg, Söderåsen and Matterödsåsen.
A glance at the map shows that the ridges generally have one steep and one less steep or flat side. The map indicated that the variations in the constraining lines' thickness. (fig. 17.)
After the original formation of the horsts there is again a calm period in the bedrock of Skåne. The landscape was during this period further developed (eroded and lowered) through nature's destructive forces – weathering and transport of the material. The horsts during this phase started to break down and become lower and more rounded, but it has been shown that they occasionally have increased in height as the less resistant bedrock in the surrounding area has eroded faster.

Weathering during the Tertiary period, (from 65 to 2 million years BP), have transformed parts of the shield bedrock -including the horsts- into weathering soils (**kaolinite**), which then could be washed away by runoff from rainfall. Additional weathering soils was swept away by ice sheets during quaternary (the last two million years), and the ice has also picked up and redistributed blocks and loose material and scratched and polished outcrops elsewhere. Where the rock is crushed in fracture zones valleys and canyons have been formed. The most beautiful example is perhaps Skäralid on Söderåsen, where frost and other periglacial processes extended and widened a valley which must have begun to form already during the Tertiary period. The degradation continues to this day, but the process is of course so slow that we do not have time to see much result during our short time on earth.

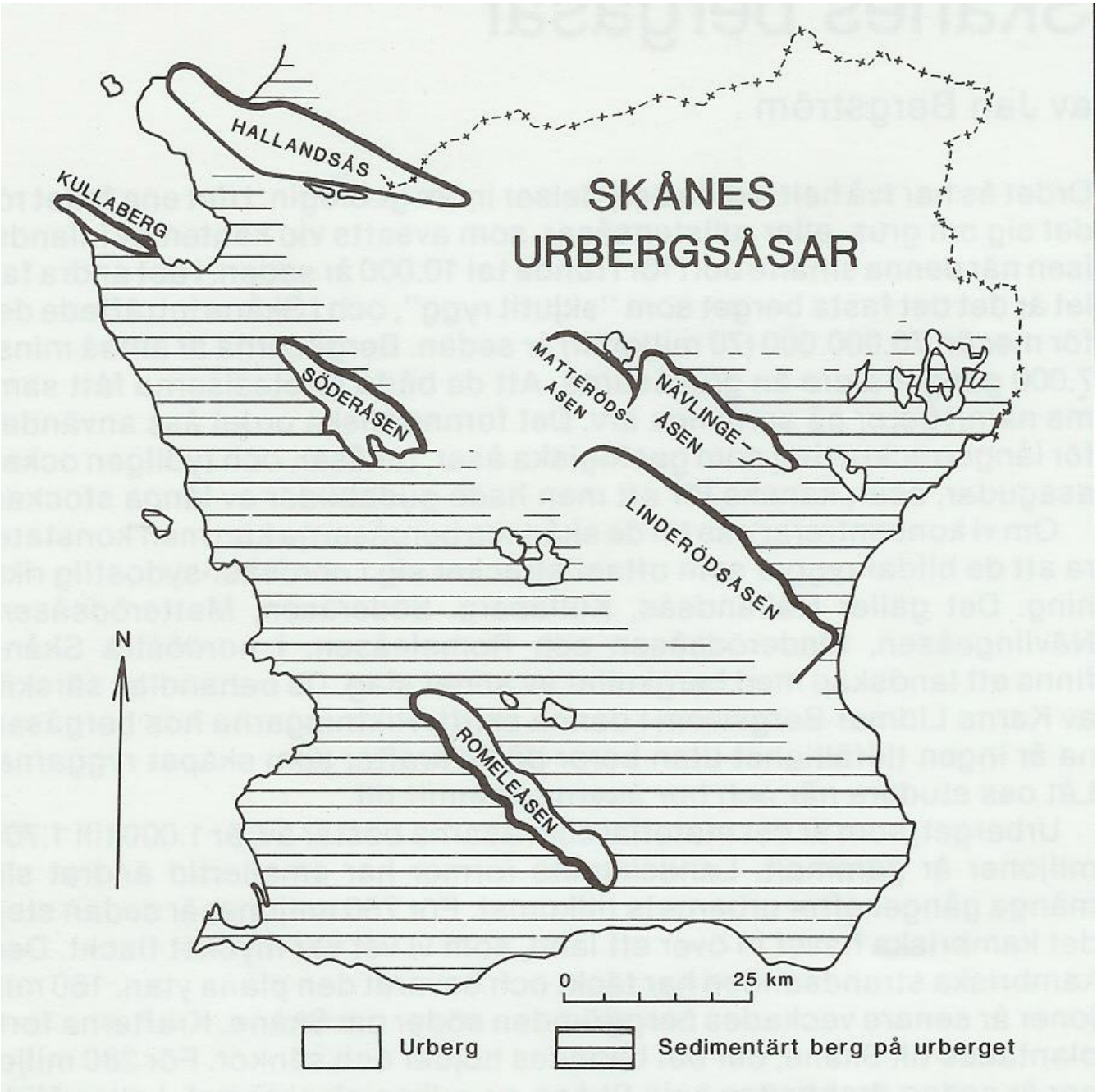


FIGURE 17. The horsts of Skåne. The thicker line indicates a steeper and higher edge. Note that it is only Romeleåsen that have a steeper south facing side. Kullaberg has two steep sides.

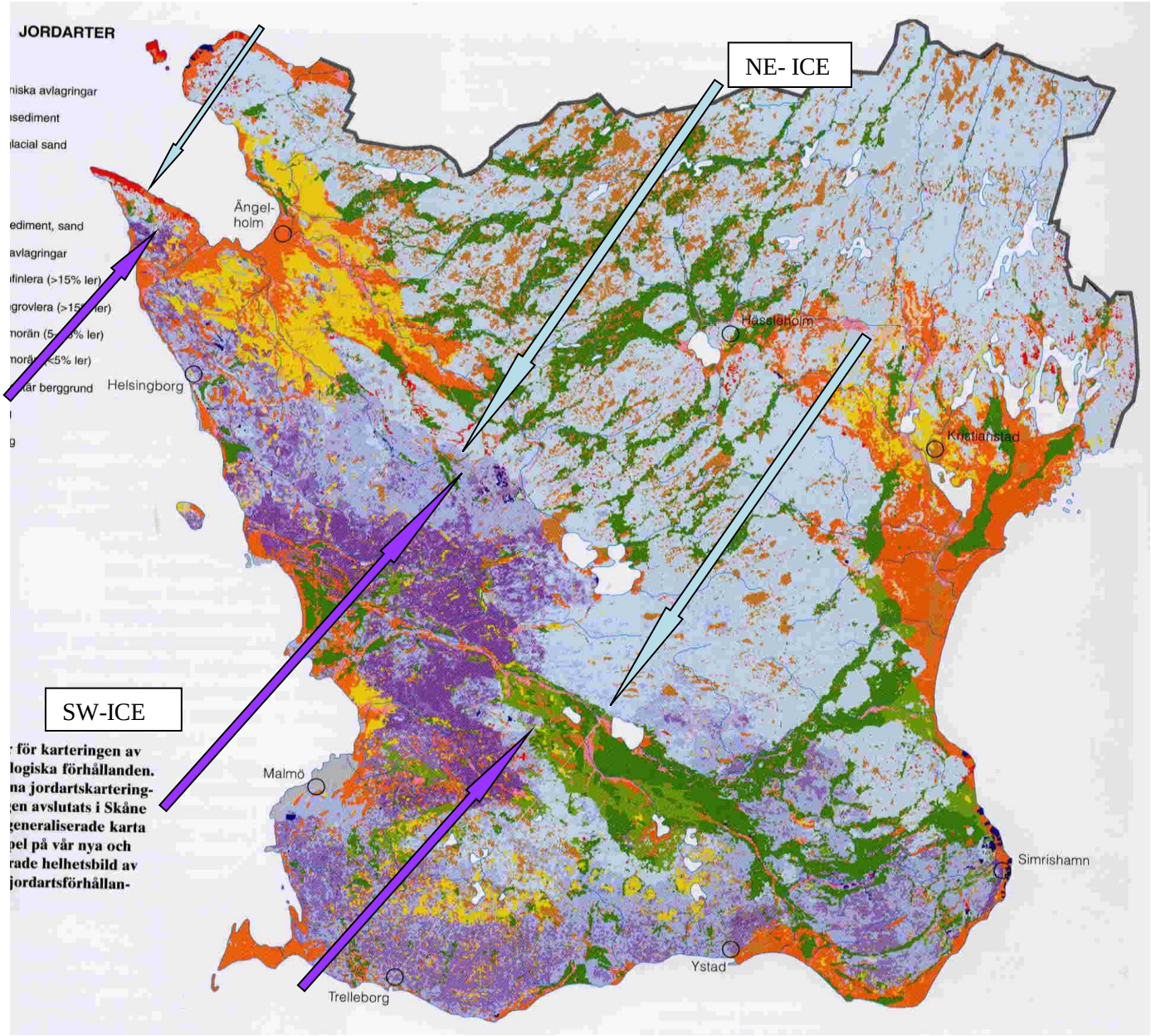


FIGURE 18. The Scanian soil map. Violet colours; Clay rich moraines from SW, light blue; Rocky gravelly moraines from the N-NE, yellow and orange; marine sediments and sand deposits, Green; glacifluvium ; (eskers, deltas, etc.)

Kullaberg.

Kullaberg is the long, narrow and relatively high ridge which forms the tip of the peninsula between the Skälderviken bay and the northern part of the Öresund which in a north-westerly direction is pointing into the Kattegatt Sea. Kullaberg is one of Scania's most prominent landscape features. From a geological point of view extends from the tip of Kullaberg ESE out to Svanshall and reaches a length of about 15 km and a maximum width of about 2 km. Kullaberg is a horst, i.e. a portion of the rock that had been lifted or in this case been left when the surrounding rocks have been lowered along generally parallel and vertical fault lines. The time for the emergence of the horst cannot yet definitively be established, but indications show that the horst formation is related to the mountain formation in Perm (280–225 milj. BP). Movements along these fault lines have occurred during repeated periods of instability of the crust. The zone of horsts that runs diagonally through Skåne shows that these basement rock elements are a part of the border belt between the Fennoscandian bedrock region and the Central European sedimentation area. This zone has been the buffer zone for several movements in the crust.

The bedrock of Kullaberg predominantly consists of gneisses with a slightly varying composition eg, biotite gneiss, hornblende gneiss and banded gneiss. The banded gneiss exhibits some primary structures suggesting that the source material for the partially or fully metamorphosed gneiss is formed from clayey -sandy sediments with thin basic layers of volcanic ash. At a later stage, these sediments were converted at great depths under high pressure and high temperature by intensive tectonic movements. The mineral composition is now completely changed, but the original sedimentological structure is preserved at some places. 300 m west Ransvik exceptionally well-preserved folds of this sediment gneiss may be studied. The dark amphibolite occurs as bands, veins or intrusions (sills and dykes) in the gneiss.

Amphibolites exist in different varieties of which the elderly occurs in conformity with the gneiss and is possibly related the same age. These oldest amphibolite dykes are often garnet -bearing e.g. the Diamond Cliffs (Stop 12). Together with amphibolite, which most often extends parallel with the NS (the S-layers) of the gneisses, a younger diabase rock with an extent in SSE -ESE, i.e. parallel to the main direction of the rocks and the horst? Many such dykes of varying width cut through the gneiss and amphibolite and are accordingly younger than these. Kullait is one type of diabase closely related to the normal black one, but is reddish due to a high content of potassium feldspar. These dykes are originally molten magmas and lavas from the deeper parts of the Earth's crust pushed up in cracks in the bedrock and solidified in them. In age, these dykes differ only slightly from one another and are all likely from post Silurian time. Both to the N and S of Kullaberg the plains are built up of considerably younger rocks. On the south side, they consist of the so called Kågeröd formation (Triassic - Mesozoic) which at Mölle reaches the surface in sandstone outcrops. On the north side, we find the pre-Jurassic formation on the bottom of Skälderviken. At Rekekroken (We will visit this site) the Cambrian sandstones are found directly on the old surface of the gneiss. In the contact zone between the gneiss and the sandstone it can be clearly seen that the gneiss is heavily weathered. Directly on the weathered gneiss rests rocks belonging to the pre-Cambrian series. These basic components consist of an arkose - a conglomeratic sandstone.

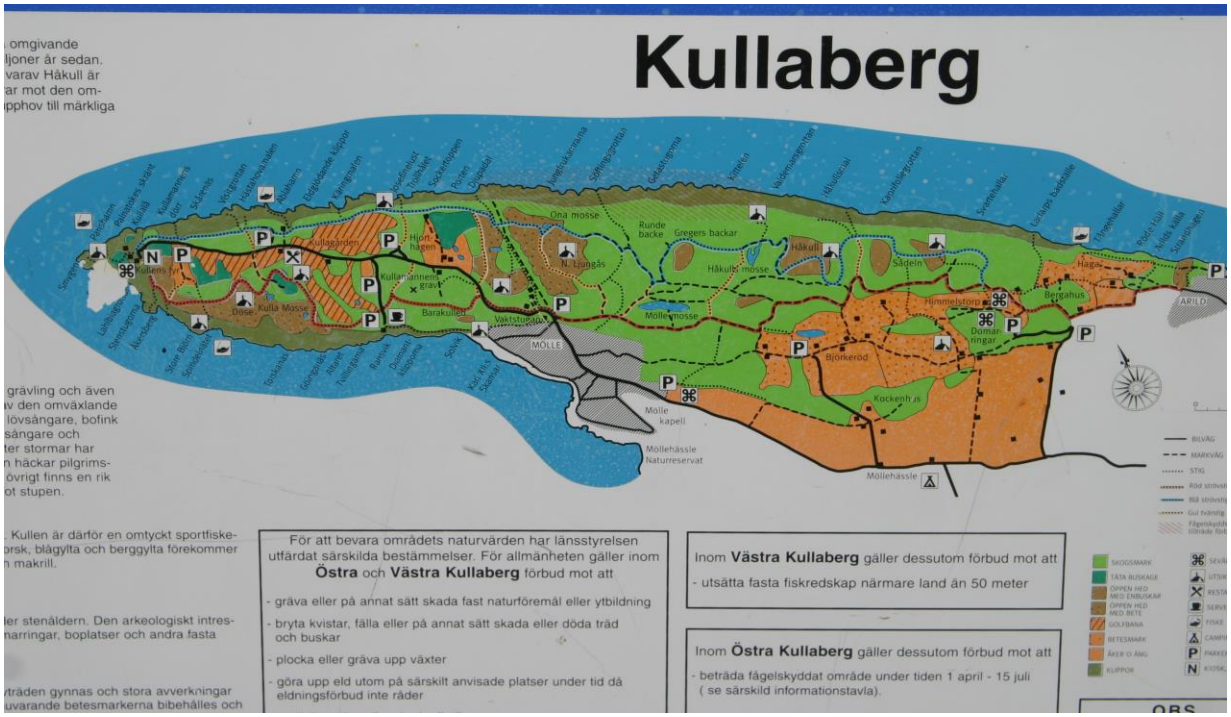
The morphology of Kullaberg is something of a sensation. Its steep bare sides and high peaks are in stark contrast to the surrounding low plain. On the south side of the horst it is clearly seen that the surrounding has subsided. As the actual reference surfaces are lacking, one cannot determine the height of the movement but it is estimated to be several hundred meters. Also along the north side the boundary is strongly pronounced along fracture zones and surfaces.

The detail land forms of Kullaberg are determined by the fracture processes and the structure of the gneisses (S-surfaces). The former is more often in the longitudinal direction of the mountain than in the north-south direction. By and large, the mountain is through these two lines of weakness divided into ranges, separated by transverse valleys and longitudinal valleys. Weathering and wave-erosion activity has greatly benefited from the sharp tectonization of the bedrock and its schistosity and lithological variation.

The detail morphology of Kullaberg is determined by the tectonic fracture processes and the layered structure of the gneisses ("*skiffrighetsplan*" Eng. S-surfaces). The former is mainly in the longitudinal direction of the mountain and the later are in the north-south direction. In general, this can easily be seen in the bedrock as these two lines of weakness are seen in the landscape as transverse valleys and length valleys.

Weathering and wave erosion activity has attacked these zones of weakness in the bedrock and its schistosity and lithological variation is clearly visible in the outline of the rocky coastline. The coastal zone is therefore determined by the "strengths and weaknesses" of the bedrock. The marine coastline features can be found in the area between the existing waterline and the highest coastline (about 50 m a.s.l). As the variations in the coastal zone is determined by the relative strength of the different "strengths and weaknesses" of the bedrock there is a clear systematic pattern. If the cracks in the NW-SE dominate the coastal zone will be steep and straight (cliff coast). If the layered structure of the gneisses ("*skiffrighetsplan*" Eng. S-surfaces) is more pronounced the coastline is developed with alternating bays and rocky headlands (**serrated coast**). (see cover photo!)
The detailed design of the coastal zone also includes caves that occur quite plentiful around Kullberg's coast. Most of the caves are situated with the floor at, 5-10 m.a.s.l suggesting that they were formed by the Tape Sea, the equivalent of the Baltic Sea level the Litorina Sea, about 5000 BC. The location of the caves and their detail forms can usually be traced to features in the bedrock.
According to the dominant form factor, they can be divided into gneiss structure caves, skiffrighetsgrottor, ('s-caves ") where the structure of the gneiss played a crucial role in the occurrence and crack caves " sprickgrottor "where the strong tectonization of the bedrock is the main cause (eg Josefinelust Cave).

Another typical geomorphological form is talus features. They are found all around the horsts of Skåne and are common on Kullaberg. The highly fractured bedrock proved material mainly through freeze and thaw action producing material that fall in the slopes. This material form heaps of sharp jagged rocks and boulders. The larger blocks are located at the bottom and finer material higher up in the slope.
If the talus material reaches down to sea level wave action transform then material to rounded beach boulders. Grinding the stones against each other gradually producing rounded and polished boulders of both local and rocks and erratic's. Such rubble is found for example at Josefinelust which we will visit.



För att bevara områdets naturvärden har länsstyrelsen utfärdat särskilda bestämmelser. För allmänheten gäller inom **Östra** och **Västra Kullaberg** förbud mot att

- gräva eller på annat sätt skada fast naturföremål eller ytbildning
- bryta kvistar, fälla eller på annat sätt skada eller döda träd och buskar
- plocka eller gräva upp växter
- göra upp eld utom på särskilt anvisade platser under tid då eldningsförbud inte råder

Inom **Västra Kullaberg** gäller dessutom förbud mot att

- utsätta fasta fiskredskap närmare land än 50 meter

Inom **Östra Kullaberg** gäller dessutom förbud mot att

- beträda fågelskyddat område under tiden 1 april - 15 juli (se särskild informationstavla).

Figure 19. Land use and vegetation history on Kullaberg

The environmental development at Kullaberg.

The environmental development at Kullaberg follows the same general sequences as has been described earlier;

- **Preglacial period -** horst formation that occurred about 250 million years ago (Permian period)
- **Glacial period** - inland ice cap, more than 3 km thick over Scania at maximum. Ended in the southernmost parts of Scania approximately 14 000years ago. (The distribution of the inland ice **Figure 4**)
- **Periglacial climate –** open tundra ecosystem. 14 000 to10 000 years ago.
- **A postglacial climate optimum –** stone age period 8 000 –7 000 years ago
- **Boreal forests –** coniferous forest ecosystems, taiga
- **Temperate forest -** deciduous forest ecosystems

Pre-glacial period

Kullaberg is one of Skåne’s smallest bedrock ridges - horsts. These ridges are the result of faults in the earth's crust formed during pressure from the south forming NW-SE fracture lines. See earlier text. The Kullaberg horst stretches in the WNW-ESE direction and have a length of approximately 15 km between the lighthouse and Svanshals site and the largest width is only about 2 km. Between the two sites Djupadal and Himmelstorp the height above sea level exceeds 100 meters and the highest peaks are N. Ljungås (174 m a s l) and Håkull (187.5 m a.s.l). The bedrock consists of gneisses with transverse dykes of intrusives (amphibolite) and the gneisses are assumed to have an age of at least two billion years, while the horst formation occurred about 250 million years ago (Permian period). In connection with the horst formation longitudinal cracks been filled with diabase. The amphibolite and diabase creates through its basic weathering products a nutritious soil and contributes to a rich and varied flora.

Glacial period

A lot of Kullberg is bare rock but there is still an extensive soil cover. When the different events of inland ice lobes swept over Skåne till and glacifluvium were deposited in depressions and burrows. Tills may have different nutrient content depending on the origin of the material. The younger ice sheet from the SW apparently at times has reached or passed over Kullaberg. As it came from the south and brought material from, among other limestone (with Flintstone), schists and sandstone areas but also from the Baltic seabed. We find both the grey and the black flint from the chalk bedrock in SW Skåne. The higher areas contain thin layers of NE tills which are sandy, gravelly, blocky and unfertile.
When the inland ice retreated and left the mountain about 12 to 15,000 years ago, the land was pressed down at least 50m below the current level (isotactic subsistence). We should remember that the sea level at that time was far below the current as large volumes of water were tied up in the ice sheets. As the ice left the scene the land started an up lift (isotactic uplift) which still continues.
After the retreat of the inland ice followed a period of dynamic environmental variability due to the rapidly changing climate. The **older Dryas period** 12,000 years ago had an arctic to subarctic climate with tundra and permafrost. The flora was sparse with a birch, dwarf birch, and Arctic willow species. The field layer contained grass and sagebrush species. Following the **older Dryas period,** the climate shifted between warmer and colder periods. From that old-time period until the 1600s, we have poor or no knowledge of the vegetation changes on Kullaberg, as the peat layer in all the swamps and bogs are dug away. It is from these layers and the record of pollen in it that we get most of the environmental records. The peat has been used as energy during long tree-poor periods. This lack of historical data is set back because we thereby lack continuous strata, which could verify the vegetation changes. Of greatest interest would be to know the changes of and during human influence, since the first farmers took possession of the area.
Despite the lack of some data we still know parts of the story. The forest eventually took over when the climate became milder. The oak has been an important feature of the forest on Kullaberg as it has been from other coastal areas as well as other deciduous trees. There are numerous animal fossils from the area. "The reindeer and other animals from the tundra had gone north in the ice track they were followed by the later extinct species of wild horse, European bison, saiga-antelope and giant deer. Among the large carnivores were bear, wolf, fox, lynx, moose and beaver. From the time of about 12 700 years ago, a femur from the polar bear found in a peat bog.
Clearly there were also human beings here at this time. As the climate warmed, melting ice sheets and oceans water level raised while uplift subsided. The ancient land surfaces were drowned and the low lands became a water landscape. Later, for about 5000-6000 years ago, the temperature rose further, which meant that the sea level around the mountain rose by at least 3 m above the present level? The Kullaberg horst became an elongated rocky island.

Man, on the mountain

It is clear from countless findings from the western side of Kullaberg that it has been a popular area for the early Stone Age fishermen. The area has ten large settlements located here and there are also findings from the older Neolithic. The localization suggests that fishing has been an important source of livelihood. Fishing grounds, for example, existed at Ransvik, near the lighthouse, and on both sides of fishing village Arild.
In three of rock's caves have been found traces of ancient human activity. The lesser Josefinelust cave was already inhabited in the Palaeolithic period (i.e. more than 6000 years ago). South of Kullaberg from Möllehässle-Björkered to Arild is a string of burial mounds and other ancient remains from the Bronze and Iron Ages. The most remarkable of these lies north of Kockenhus. These are low mounds, with four-sided stone formations and outcrops and boulders with carvings, and stone circles.

The Landnam period

The time of the first forest clearing is usually referred to as “the landnam period” (Landnam means seizure – you take land- and come from Icelandic and refers to the time when Norwegians settled in Iceland) and is a short phase, beginning about 4200 BC in southern Sweden. As pastoralists and farmers increasingly were taking over

the country, they were starting a new era, which subsequently reshaped the entire landscape. The current landscape of Skåne as well as the rest of the Swedish cultural landscape is almost entirely influenced by the farmer's activities. Ever since the first farmers began raising livestock and cleared up suitable land for barley and wheat cultivation the landscape has changed. The forest thinned out or was opened for grazing, mowing and cultivation. Slash and burning, “Primitive” forestry may also have occurred as well as pollarding appropriate tree species and shrubs. The forest on the slopes is probably the most original natural forest on the mountain as these were unlikely used by early man.

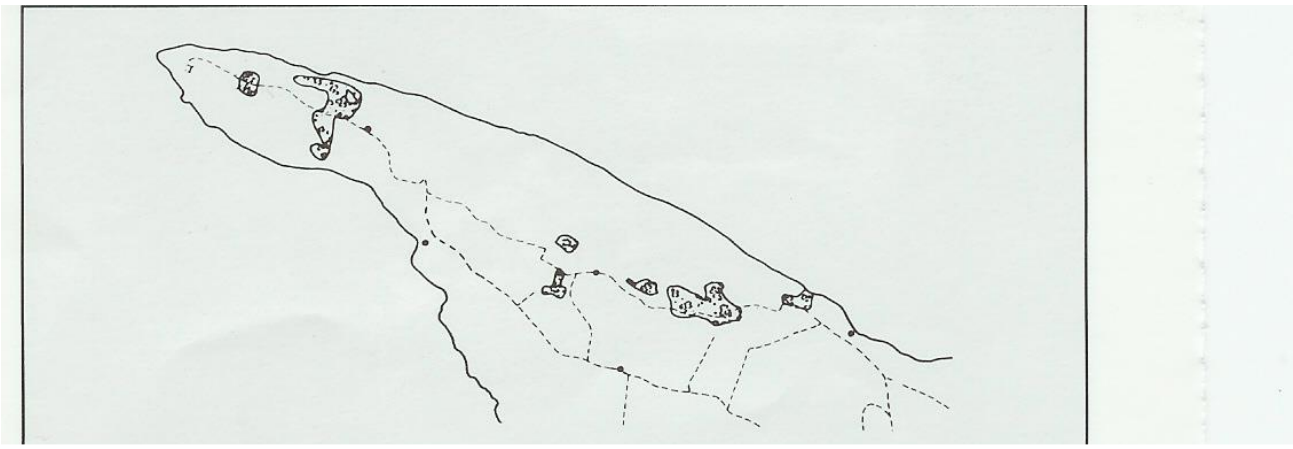


Figure 20a. Distribution of forests 1600-1800

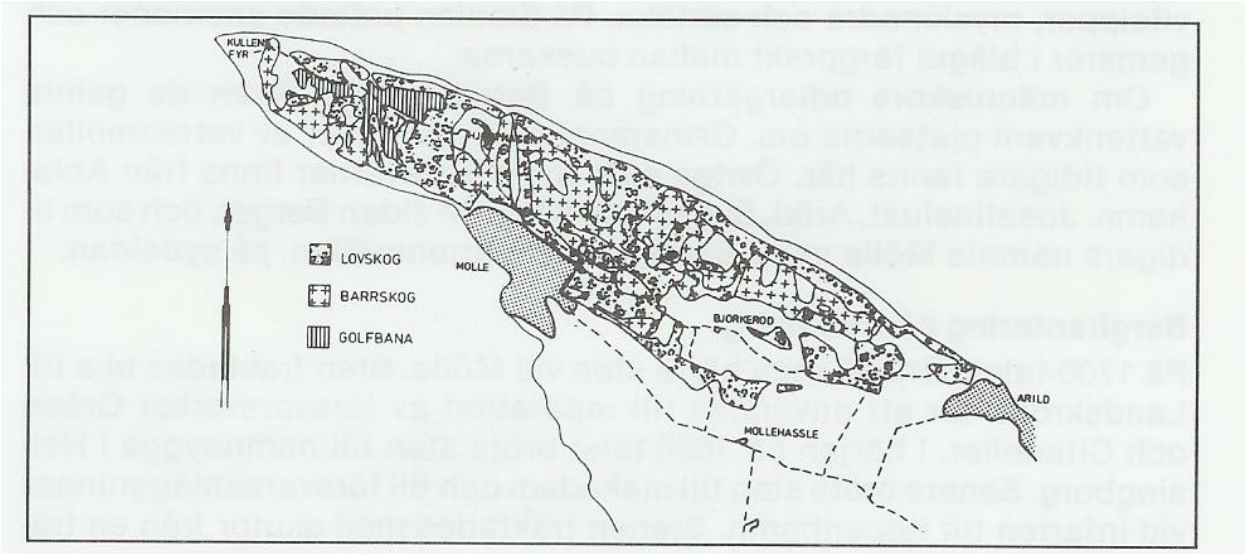


Figure 20b. Distribution of forests 1974

Land use after 1600

Maps from the 1600s and 1700s (Fig. 20) occupy only small woodlots, probably beech, partly at Kullagården and partly at Himmelstorp and between Haga and Arild. The maps from the 1700s show the area as being covered

mainly with bushes and heather. Linnaeus visited the area in the late 1700 and describes an open landscape with visible remains of cultivations. Here and there one can still see rows of rough stone that may have acted as a fence, while the stones gathered to facilitate mowing or chopping operation
Overgrown stone fenced fields and small agricultural pieces "lyckor" can be found here and there.

We know that the forest on all available surfaces gradually disappeared. The same happened in other places of Skåne and in the rest of Europe, there are ample evidences of that. The disappearance of forests exposed the previously fertile soil for leaching and heathlands with heather formed. Many place names include “Ljung” (heather) deriving from the older times when the heather was a character growth on the mountain.
Kullaberg was virtually treeless is seen in a map from about 1715 (fig. 20). It shows only minor woodland, beech forest on the east and north sides

During inventory works on the north side of Kullaberg geologists in 1978 found an interesting rock shelf in the north facing slope. Extensive talus scree material with a slope angle of about 45° composed of coarse angular rock covered the slope and it was largely overgrown with dwarf forms of oak and hazel. The area showed clearly a well-developed human use of the vegetation. This area is well preserved with a high biodiversity of plants and rare insects. Other signs of early settlements are numerous old water mills some of which still easily may be seen and some are only left in place names. The place name Mölle is a good example of this as it referrers to a water mill that was previously here. Other traces of water mills are found in Ablahamn, Josefinelust, Arild, Svanshals on the north side of the mountain, and as mentioned before Mölle and Bärekull and Vattenmöllan, on the south side.

Mining and quarrying on Kullaberg

In the 1700s stone quarrying began at Mölle. Stone was and still is a rare and expensive commodity in South Skåne and Denmark. The stone products were transported along the coast and initially to Landskrona to be used to construct and repair the defense castle there. In the early 1800s the gneiss was quarried to build the port in Helsingborg. At the same time, much stone was quarried to be used for the harbor and the defense installations at the entrance to Copenhagen. The stone was transported by barges from a wooden pier at Solvik.
Late 1860th the work was terminated as the land owner the Baron on Krapperup castle prohibited further excavation. The discovery of a couple of very rare local plants was the reason. The rare plant was “vårvialen” *Lathyrus sphaericus*, which still can be found on a rock shelf above the beach. *Lathyrus sphaericus* was found in 1869 and has since been regarded as Kullaberg’s greatest rarity and despite annual visits of scrupulous collecting botanists managed to stay on this rock shelf.

Modern forestry

The castle of Krapperup, which since long ago been owners of large parts of the Kulla peninsula including Kullaberg began afforestation on a large scale in the 1860s. The proper horst area was planted mainly with black pine - *Pinus nigra*, which is considered to be better against the sea winds than our native pine *Pinus sylvestris*. Later other coniferous such as other pines, fir, white fir, Douglas fir, larch and other species have been introduced. Figure 20 shows the forest coverage in 1974. With the reforestation followed a dramatic change in the landscape. From being an open heather covered or bare and barren land type, Kullaberg is today a wooded ridge.

Recent changes during the 1900th and early 2000th.

Krapperup castle offered the property western Kullaberg for sale in 1913. Interested buyers came from many directions, among others from Germany which potentially meant large scale quarrying on the mountain. To prevent a widespread exploitation of the valuable nature a protection area was established, mainly by people from the University of Lund and a foundation the “Kullabergs Natur”, who decided to buy as much as possible of the property. The purchase was completed in 1915 and since then the area has been managed as a nature reserve. The

golf course on the western Kullaberg started in 1945 on the croplands of the Kullagården farm. The area is leased by Mölle Golf Club and the income from this is used to manage the nature reserve. The construction of the golf course in a sensitive natural area therefore attracted less resistance.

Autumn storms in the early 1980, 1990s and 2000s fell much of the pine forest on the mountain. But the trees, which mainly were ready for harvesting, were expected to be harvested in the near future anyhow. After the clean-up has been done according to modern methods oak and other deciduous species has been planted instead. The idea is trying to restore the area into how it is thought have been before landnam. In some area with invasive bushes and trees there is introduced an intensive new sheep grazing program to possibly stop the bush encroachment.

The caves of Kullaberg

Weathering and erosion

The caves of Kullaberg belong to the type beach caves, even if this bedrock coast is not a real beach. All the caves have been formed in a similar way, if we exclude the Silver Cave, which is artificial, (i.e. carved into the pegmatite dyke by human hand). It is mainly wave action and erosion activity that has been the active force during the caves genesis, although other natural processes are involved in their design (frost action).

The location of the caves relative to sea level shows that it is not the current ocean waves that created them. Most are situated with the floor at an average of 7-8 m a.s.l -That means that they are out of reach for even the highest storm waves attack. It was the so-called Littorina Sea and its higher level that gave rise to most of the caves. Another interesting question regarding the caves of Kullaberg is their location along the steep coastline.
The localization is determined by weak points in the bedrock!

Three types of caves

The first group of caves have been created at sites with numerous fractures in the gneiss which also are cutting each other under a favourable angle. Many caves clearly show this situation, the local crack arrangement, as the determining factor of its occurrence and localization. The most spectacular example is Major Josefinelust Cave - also the most-visited and accessible cave Kullaberg - where in the inner wall and the ceiling you can see that the prism-shaped blocks are easily removable. Other famous caves of the same type but with very different design are eg. Visitgrottan, Lahebiagrottan, Getastugorna, Valdemar cave, cave Munthe and Kaprifoliegrottan.
The second set of caves depends upon the orientation, location and shape of the characteristics of the foliation or s-surfaces of the gneiss and amphibolite. It is easy to see how some areas are dominated by westward orientated oblique gneiss surfaces, for example at the beach at the Röde Hall near Arild. Examples include the Fiskargrottan, Söftingsgrottan, Retzius and Wallgrens caves

The third type of caves, whose location and form factor is quite easy to observe, are the caves that are tied to the intrusive volcanic dykes, and especially dykes of amphibolite, diabase and kullaite. At the boundary between two different rock types, e.g. amphibolite and its side rock gneiss, is a weak attack point for the waves. In this way the caves, for example, the Frederick VII's cave and the Small Josefinelust cave have been formed.