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## Stratigraphical and surficial distribution of Quaternary deposits

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# Abstract

This report describes the surficial and stratigraphical distribution of regolith in the drainage area of Lake Gunnarsboträsket in Forsmark. The drainage area will be a reference site for studying natural hydrological variations during the planned building of a repository for spent nuclear fuel.

Regolith refers to all type of unconsolidated material overlying the bedrock and is also referred to as Quaternary deposits (QD). Different types of regolith have different hydrological properties and the surficial and stratigraphical distribution of regolith is therefore important when evaluating the results from hydrological investigations and for the parameterization of hydrological models.

The surficial distribution of QD is preceded on a map for the scale 1:10 000. The work started by using a detailed elevation model to update a more generalized older map of QD. The updated map was later used as a basis in the field when mapping the distribution of regolith. The field investigation also included stratigraphical investigation of the regolith distribution, focusing on Lake Gunnarsboträsket and the wetlands surrounding the lake.

The results show that glacial till is the dominating regolith type in the area. Postglacial sand and gravel occur in many of the low topographical areas. These deposits are often underlain by glacial clay. Some of the low laying areas constitute wetlands with a surficial peat layer that at many places in the following order is underlain by clay gyttja, postglacial sand, glacial clay and till. In Lake Gunnarsboträsket, and in surrounding wetlands, the clay gyttja is overlain by a partly calcareous gyttja. The general stratigraphy described above is not complete at all places. As an example, glacial clay is missing at some of the investigated places in and around Lake Gunnarsboträsket. That may have implications for the hydrology of the lake, since glacial clay is characterized by a very low hydraulic conductivity.

# Sammanfattning

I denna rapport beskrivs fördelningen av jordarter i Gunnarsboträskets avrinningsområde som ligger i Forsmark. Avrinningsområdet kommer utgöra ett referensområde för att studera naturliga hydrologiska variationer under det planerade bygget av slutförvaret för använt kärnbränsle.

Jordarterna har olika hydrologiska egenskaper och jordarternas fördelning på ytan och djupet är därför viktig för att kunna utvärdera resultat från hydrologiska undersökningar samt för att kunna parametrisera hydrologiska modeller.

Fördelningen av jordarter på ytan presenteras på en karta anpassad till skalan 1:10 000. Arbetet inleddes med att Lantmäteriets höjdmodell användes först för att uppgradera SGU:s äldre jordartskarta (skala 1:50 000) som sedan tidigare finns för det studerade området. Den uppgraderade kartan användes sedan som underlag för att i fält kartera jordarternas fördelning på ytan. Dessutom undersöktes jordarternas fördelning på djupet. Det senare främst genom borrningar i Gunnarsboträsket samt i våtmarkerna runt sjön.

Resultaten visar att morän är den i särklass vanligaste jordarten i området. I många sänkor finns postglacial sand och grus som många gånger underlagras av glaciallera. Vissa sänkor utgörs av våtmarker med ett ytligt ett torvlager som på många platser i följande ordning underlagras av lergyttja, postglacial sand, glaciallera och morän. I Gunnarsboträsket och i våtmarkerna kring sjön överlagras lergyttjan av en delvis kalkhaltig gyttja. Ovan nämnda lagerföljd är inte komplett på alla platser. Exempelvis finns inte glaciallera på flera av de undersökta platserna i och kring Gunnarsboträsket. Eftersom glaciallera har en mycket låg hydraulisk konduktivitet kan detta ha betydelse för sjöns hydrologi.

# Contents

# 1 Introduction

This report presents a geological map (that can be presented in the scale 1:10 000), which shows the superficial distribution of regolith and exposed bedrock in Gunnarsboträsket drainage area (Figure 1-1) that is situated south-west of the Forsmark nuclear powerplant. The study also includes stratigraphical data, where thicknesses and properties of the different regolith types are presented. Regolith, also called Quaternary deposits (QD), refers to all unconsolidated deposits overlying the bedrock. The mapping was performed according to the Activity Plan AP SFK-18-028, Version 1.0. The methods used are described in SKB MD 131.001, Version 1.0. The Activity Plan and Method description are SKB internal controlling documents.

**Table 1-1. Controlling documents for the performance of the activity.**

| Activity plan | Number | Version |
|---|---|---|
| Jordartsgeologiska undersökningar i Gunnarsboträskets avrinningsområde | AP SFK-18-028 | 1.0 |
| **Method description** | | |
| Metodbeskrivning för jordartskartering | SKB MD 131.001 | 1.0 |

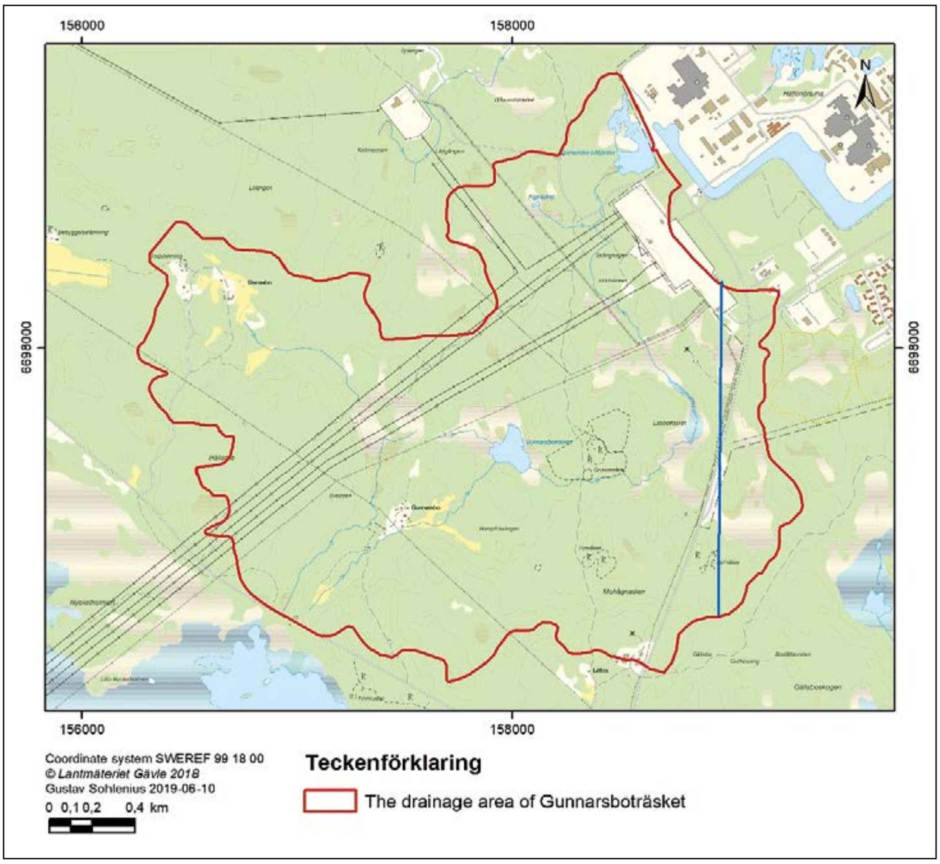


*Figure 1-1. The distribution of Quaternary deposits was mapped within the drainage area of Gunnarsboträsket. The area east of the blue line was mapped during the site investigation (Sohlenius et al. 2004). Sites mentioned in the report are shown in the map.*

# 2 Objective and scope

The hydrological conditions in drainage area of Lake Gunnarsboträskets are not expected to be affected by the planned building of the repository for spent nuclear fuel. The area will therefore be a reference area for hydrology during the construction of the repository. Information concerning properties and distribution of Quaternary deposits will then be used for evaluating hydrological data and for parametrization of the hydrological models that will be made for the area. There is an old map showing the distribution of QD in the drainage area (Person 1985, 1986). The information in that map is however not detailed enough for evaluating the hydrological properties of the area. The aim of this study was therefore to delineate the surficial distribution of different type of QD with a higher geographical accuracy and to describe the stratigraphical distribution of QD. The map shows the distribution of QD in the whole drainage area, while the stratigraphical studies focus on Lake Gunnarsboträsket and surrounding wetlands. The map also includes the distribution of artificial fill that also is referred to as regolith.

# 3 Execution

## 3.1 Preparatory work

The methods for studies and classification of Quaternary deposits (QD) used in this investigation are described in detail in SKB MD 131.001. The nomenclature and methods have changed slightly since earlier SGU investigations (Persson 1985a, b, 1986a, b). For an up to date nomenclature the readers are referred to SKB MD 131.001 and to the report describing the map of QD that was produced during SKB's site investigation (Sohlenius et al. 2004). The methodology for mapping QD has however changed slightly since the studies of QD that took place during SKB's site investigation more than 15 years ago. The mapping of QD is now to a large extent supported by Lantmäteriets digital elevation model that is based on laser scanning (Lidar). Since topography and QD correlates the digital elevation model is used to delineate different types of QD with a high geographical precision. Furthermore, the mapping of QD is nowadays done using a field computer with GPS. It is then possible to use the computer for delineating different types of QD in the field.

Before the fieldwork started the old QD map (Persson 1985a, b, 1986a, b) was reinterpreted by using Lantmäteriets digital elevation model and aerial orthophotos. The reinterpreted QD map was exported to a field computer. Other geographical data such as topographical maps, aerial photos and the height model was also stored in the field computer.

## 3.2 Equipment

The uppermost deposits were investigated using a spade and a hand driven probe. A field computer was used for orientation and for delineate different types of QD. All field data have been digitally stored in a database in accordance with the SKB method.

## 3.3 Field work

The aim of the field mapping was to produce a map that demonstrates the distribution of Quaternary deposits (QD) at a depth of 50 cm below ground surfaces. Surface layers thinner than 50 cm have also been marked in the map (e.g. peat overlying other deposits). In areas with till the surficial frequency of boulders and effects of wave-washed surface layers were also determined in the field. Furthermore, the stratigraphical distribution of QD was investigated by hand held drilling as described by Hedenström (2003).

The geographical distribution of the different QD was marked directly in the field computer. Delineations between different types of QD were, as mentioned above, interpreted before the fieldwork started. Many of these delineations were correctly interpreted already in the office when preparing for the fieldwork. In the field new delineations were only made when misinterpretations were discovered or where deposits not recognized in the office were discovered.

All QD, that could be delineated from other deposits, and have an area larger than 100 $m^2$, were marked as surfaces. Smaller outcrops were marked with a point symbol. Several classes of thin surface layers (< 50 cm) are demonstrated in the map presented in this report. These thin layers, except thin peat layers, are not shown on the earlier SGU maps from the area (Persson 1985a, b, 1986a, b).

There were certain difficulties in interpreting the Quaternary geology during the fieldwork:

- There are numerous small patches with sand and clay in the small topographical depressions that are present in the studied area, and some of these areas were most probably not found during the fieldwork.
- The glacial clay is often covered by a layer of sand, gravel and stones. It was not always possible to penetrate these layers with the probe down to a depth of 50 cm. Some of the areas mapped as sand or gravel may consequently be underlain by glacial clay.

- The superficial boulder frequency of the till varies throughout the area. The boulders are often covered by mosses and other vegetation and it was therefore sometimes difficult to determine the frequency of boulders. Furthermore, many areas are characterized by hills, a few meters across, with a high superficial boulder frequency. The areas in-between the hills are often characterized by a much lower boulder frequency. It was therefore often not possible to delineate all surfaces with a certain boulder frequency. The boulder frequency shown on the map is therefore a generalization and the map (Figure 5-2) shows the dominating boulder frequency within each till area. Small surfaces with a diverging character can consequently occur within each area.
- Large parts of the till areas that has been affected by wave-washing. These areas are characterized by a high surficial frequency of stones and boulders. It was, however, difficult to make an exact delineation of wave-washed till, and these areas are therefore not shown on the final map.

# 4 Results

### 4.1.1 General description

The investigated area is situated in a region that is characterised by a flat upper surface with small variations in altitude. When looking in a smaller scale parts of the area is characterised by shallow depressions, often only a few tens of metres across, and hills, often less than 200 metres across and with an altitude of some 10 meters. Especially the eastern area has a rough small scaled topography. Wetlands are situated in some of the depressions and there are three small lakes within the studied area (Figure 1-1). One of these lakes is Lake Gunnarsboträsket, situated in the central part of the drainage area. The vegetation in the area is dominated by forest intersected by areas with bushes where the power lines from the powerplant are situated. The wetlands around the lakes are partly open and dominated by reed. The area was completely covered by the Baltic Sea after the latest deglaciation and has successively been uplifted during the past thousands of years. The highest topographical areas are situated around 25 m above the present sea level and was uplifted almost 4 000 years ago (cf. Hedenström and Risberg 2003). Lake Gunnarsboträsket is situate 6 m above the present sea level. This is similar to the nearby located Lake Eckarfjärden that has been investigated regarding stratigraphy and isolation age was determined to 850 years ago (Hedenström and Risberg 2003).

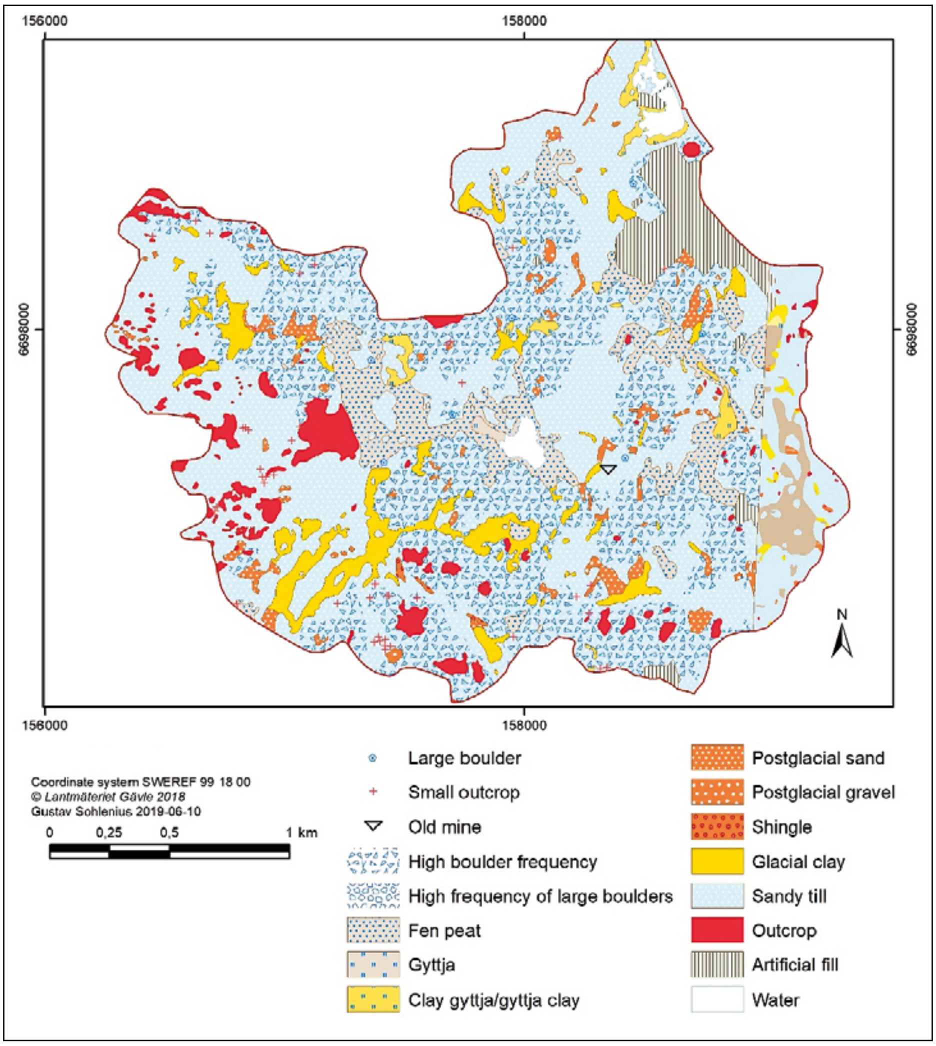


***Figure 4-1.*** *The distribution of regolith in the drainage area of Gunnarsboträsket. Thin layers of e.g. peat are not shown on this map but has been delivered to SKB's database. The easternmost part of the drainage area was mapped by Sohlenius et al. (2004). That area is recognised by a slightly different symbolisation of the different type of QD.*

### 4.1.2 Distribution of Quaternary deposits

Sandy glacial till is the most commonly occurring surficial QD in the studied area (Figure 4-1). The lowest topographical areas are characterized by water laid sediments that in many of the wetlands are covered with a layer of peat. The frequency of bedrock outcrop varies within the studied area. The till in the eastern area has a high frequency of boulders with general low frequency of bedrock outcrops. The till in the western part of the mapped area has normal boulder frequency with a higher frequency of outcrops. Earlier studies from neighbouring areas show that the matrix of the till is characterised by the occurrence of calcium carbonate (Sohlenius et al. 2004).

In the eastern area, characterised by a high boulder frequency, depressions in the terrain interpreted as traces from icebergs are visible as scars, often only ten metre across, in the till. These depressions are interpreted to have been formed during the deglaciation when the area was below the water level of the Baltic Sea and large icebergs calved from the retreating ice. One such example is shown in Figure 4-2. These iceberg traces were previously observed in the region and can be seen in the height model but are often difficult to recognise in the field (Öhrling et al. 2019).

A large part of the studied area has been exposed to wave erosion fine material has been eroded from the till and the surface is characterised by a high frequency of stones and boulders (Figure 4-3). These areas are, as mentioned above, difficult to delineate from other till areas. It is, however, obvious that sites sloping towards the Baltic Sea are characterised by a high frequency of stones and boulders, which has been interpreted as an effect of wave erosion. Furthermore, the more elevated areas are often characterised by a high frequency of boulders and stones. These hills have been exposed to waves during the time when they emerged from the sea due to the land upheaval. At some sites former shore deposits were recorded. In the southern part of the studied area a shingle field was recorded (Figure 4-4).

***Figure 4-2.*** *A depression (PFM008055) that is interpreted as the result of an iceberg that was dropped at the seafloor during the latest deglaciation (c 0.5 km west of Labboträsket in Figure 1-1).*

***Figure 4-3.*** *Boulder rich till (PFM008047) in an area situated at a relatively high altitude in the south-eastern part of the studied area (c 200 m north of Lättsa in Figure 1-1). The till has been affected by waves causing erosion of sand and finer material.*

***Figure 4-4.*** *Shingle field situated in the southernmost part of the studied area (Figure 4-1). (PFM008058). The area is situated at a relatively high altitude (c 25 m a.s.l.) where the exposure from waves have been significant.*

Sand and gravel that has been washed out from the till has been deposited in the frequently occurring, often small, topographical depressions (Figure 4-5). The sand and gravel are often underlain by glacial clay that was deposited at the floor of the Baltic Sea during the latest deglaciation. It was, however, not always possible to determine if the sand and gravel are underlain by that clay. The glacial clay is varved (Figure 4-6) where each pair of light and dark layer represent the sediment accumulation during one year. Earlier studies have shown that the glacial clay is characterised by the high occurrence of calcium carbonate, with an average content 26 % (Hedenström 2004).

***Figure 4-5.*** *The grass covered area in front constitute postglacial sand. Small areas with such sand and gravel deposits were recorded at many places in low topographical areas. The sand and gravel are often underlain by glacial clay (PFM008051). Boulder rich till is visible in the background. The photo is taken 500 m north of lake Gunnarsbotråsket close to the power line.*

***Figure 4-6.*** *Varved glacial clay sampled with the Russian peat corer. The clay was deposited during the latest deglaciation. Each pair of dark and light clay represent the sedimentation during one year. The clay was sampled in a fen 100 m south of Lake Gunnarsbotråsket (PFM008041).*

Peat is the surficial deposit in many of the wetlands. The peat layer is often thinner than one meter and never thicker than 1.2 m. In some wetlands, the peat layer is only a few decimetres thick. Stratigraphical studies show that the peat in the wetlands is underlaid by clay gyttja that in turn are underlaid by postglacial sand, glacial clay and till. The general stratigraphical distribution of QD is shown in Table 4-1. In in the wetlands around Lake Gunnarsboträsket the peat is underlain by algae gyttja that is partly calcareous with a high frequency of shells (Figure 4-7). In the present lake Gunnarsboträsket, gyttja is currently deposited. The recorded thicknesses of the sediment layers are below one metre, even though thicker layers of glacial clay might occur in the area. The sand layers are often only a few decimetres thick. The different types of QD shown in Table 4-1 are not present in all peat covered wetlands. As an example, glacial clay is missing in some of the investigated sites of Lake Gunnarsboträsket as well as in in parts of the wetlands surrounding the lake. That patchy distribution of glacial clay may have implication for the hydrology of the lake since glacial clay is characterised by a very low hydraulic conductivity.

**Table 4-1. The general stratigraphical distribution of Quaternary deposits. This stratigraphy is in accordance with the one during the site investigation (e.g. Hedenström and Sohlenius 2008) although no glaciofluvial deposits were found in the area studied here.**

| Type of deposit | Depositional environment | |
|---|---|---|
| Peat | Wetland | youngest |
| Gyttja (partly calcareous) | Lake | |
| Clay gyttja | Sheltered marine environments such as bays | |
| Sand/gravel | By streams and waves at the sea floor | |
| Glacial clay | Deposited at the Baltic floor by meltwater from the inland ice | |
| Glaciofluvial deposits (not found in the present study) | Deposited by meltwater from the inland ice | |
| Till | Deposited by the inland ice | oldest |


***Figure 4-7.*** *Calcareous gyttja sampled in the peat covered wetlands surrounding Lake Gunnarsboträsket. The gyttja contain a high frequency of shells (PFM008042). The same type of gyttja was found at the floor of the lake and have also been recorded in many other lakes in the area and a calcium carbonate content as high as 63 % has been recorded (Hedenström 2004).*

### 4.1.3 Land use

The till is in some restricted areas used as arable land, and stones and boulders from the till has been laid in piles to facilitate for cultivation. Some of the areas with glacial clay is also cultivated. In the past a larger proportion of the land was used for agriculture and remnants of agricultural activities can be seen at many sites. There are also remnants from mining activity close to the road east of Lake Gunnarsboträsket.

### 4.1.4 Comparisons with earlier investigations

Compared to the older map (Persson 1985a, b, 1986a, b) the general geological interpretation is the same, however the map presented in this report shows the distribution of QD with a higher geographical accuracy. Furthermore, several previously unrecorded outcrops and small areas with water laid sediments are shown on the map presented here. The use of Lidar data has made it possible to delineate the distribution of different types of QD with a high accuracy. Especially, the delineation between till and different types of water laid deposits can be done with a high precision.

The distribution of QD within the catchment area of Lake Gunnarsboträsket is in accordance with the observations made during the mapping of QD within the site investigations directly east of the area studied here (Sohlenius et al. 2004). No grain size or chemical analyses have been performed within this study, but samples were taken and are available for further analyses. These samples will be stored at SGU. Even though no analyses were performed it is likely that the chemical and physical properties of the deposits in the mapped area are similar to the ones in neighbouring areas. There are several SKB-reports reporting properties of QD in the Forsmark area (Hedenström and Sohlenius 2008, Grolander 2013, Sohlenius and Hedenström 2009), and the deposits around Lake Gunnarsboträsket can be assumed to have similar properties. One significant characteristic of the till and glacial clay in the area is the occurrence of calcite. The area has relatively recently been uplifted and the soils are still young. The calcite is, however, currently weathering from the soils and will disappear with time. Calcite leached from till and glacial clay is partly reprecipitated in lakes, which explains the occurrence of calcareous gyttja.

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