P-06-88

Forsmark site investigation

Mapping of Quaternary deposits on the bottom of shallow bays outside Forsmark

Jonas Ising, Geological Survey of Sweden

February 2005

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Abstract

The distribution of Quaternary deposits on the bottom of the shallow bays outside Forsmark has been mapped. The present map fills the gap between the map of Quaternary deposits on land and the marine geological map, of which the latter covers areas with a water depth greater than 3 metres. The mapping has been performed by coring and probing from the sea ice and from a small boat. The resulting map with 140 stratigraphic descriptions shows that the western part of the investigated area is dominated by till with thin patches of sand and clay. Eastwards, close to the Börstilåsen esker, the amount of sand and clay increases and in the bays Kallrigafjärden and Tixelfjärden great quantities of gyttja and clay are found.

Sammanfattning

Utbredningen av jordarter på botten av de grunda havsvikarna utanför Forsmark har karterats. Karteringen fyller det tomrum i kartbilden som fanns mellan området som täcktes av jordartskartan på land och områden inom den maringeologiska kartan. Den senare inkluderar områden med vattendjup på > 3 meter. Karteringen har utförts med borrningar och sonderingar dels från isen och dels från en liten båt. En jordartskarta med 140 lager-följdsbeskrivningar visar att västra delen av området domineras av morän med tunna fläckar av sand och lera. Österut, när man närmar sig Börstilåsen ökar mängden sand och lera. Framför allt i Kallrigafjärden och Tixelfjärden finns stora arealer med gyttja och lera av betydande mäktighet.

Contents

1 Introduction

This document reports the results gained during the mapping of Quaternary sediments on the bottom of shallow bays outside Forsmark, which is one of the activities performed within the site investigation at Forsmark. The work was carried out during the winter and summer 2005 in accordance with activity plan AP PF 400-04-117. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method description are SKB's internal controlling documents.

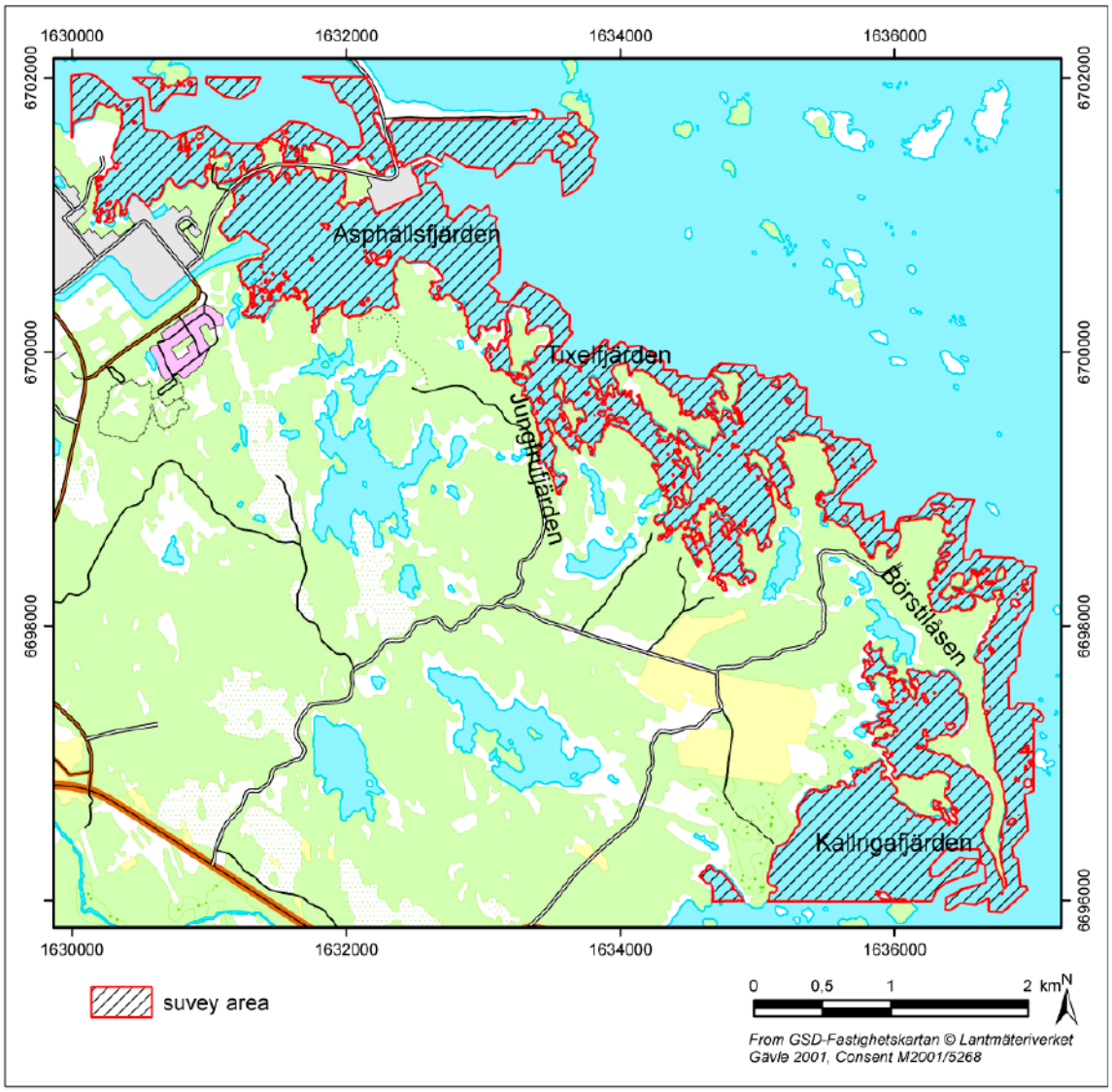


Figure 1-1. *Map showing the survey area and sites referred to in the text. The distribution of Quaternary deposits at sea bottom with water depths less than 3 metres has been investigated.*

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

Activity plan	Number	Version
Kartering av jordarter på botten av grunda havsvikar	AP PF 400-04-117	1.0
Method description	**Number**	**Version**
Metodbeskrivning för jordartskartering	SKB MD 131.001	1.0

2 Objective and scope

The aim of this study is to:

- Describe the distribution of Quaternary deposits at the shallow sea bottoms outside Forsmark. The result will fill the gap between the geological map covering land areas /Sohlenius et al. 2003, 2004/ and the marine geological map /Elhammer and Sandkvist 2005/.
- Describe the stratigraphy of each cored or probed point.
- Collect samples and perform analysis of the sediments.

3 Equipment

3.1 Description of equipment

The stratigraphy of the sediments was investigated from the ice during winter using a Russian peat corer, length 1 metres and width 5 cm. For a further description and pictures of the equipment, see /Hedenström 2003/. Mapping of the spatial distribution of the sediments was performed using a probe with extension rods (Figure 3-1) from a small boat during summer (Figure 3-2).

Figure 3-1. *The probe with extension rods.*

Figure 3-2. *Probing from a small boat during summer 2005.*

4 Execution

4.1 General

The area is investigated along lines or profiles, approximately 200 metres apart. The distance between the coring or probing points in these lines varies between 100 and 200 metres. This method makes the precision of the map adapted to a presentation scale of 1:50,000 and no area less than 50×50 metres will be displayed.

During winter, in February 2005, the corings were made from the ice in all areas where it was possible due to ice quality. In August 2005, the remaining parts were investigated using a probe from a small boat. A GPS navigator (Garmin 12/Garmin 60) was used for orientation, as well as copies of the field maps used by /Sohlenius et al. 2004/. In the map in Figure 4-1 all the coring and probing points are displayed.

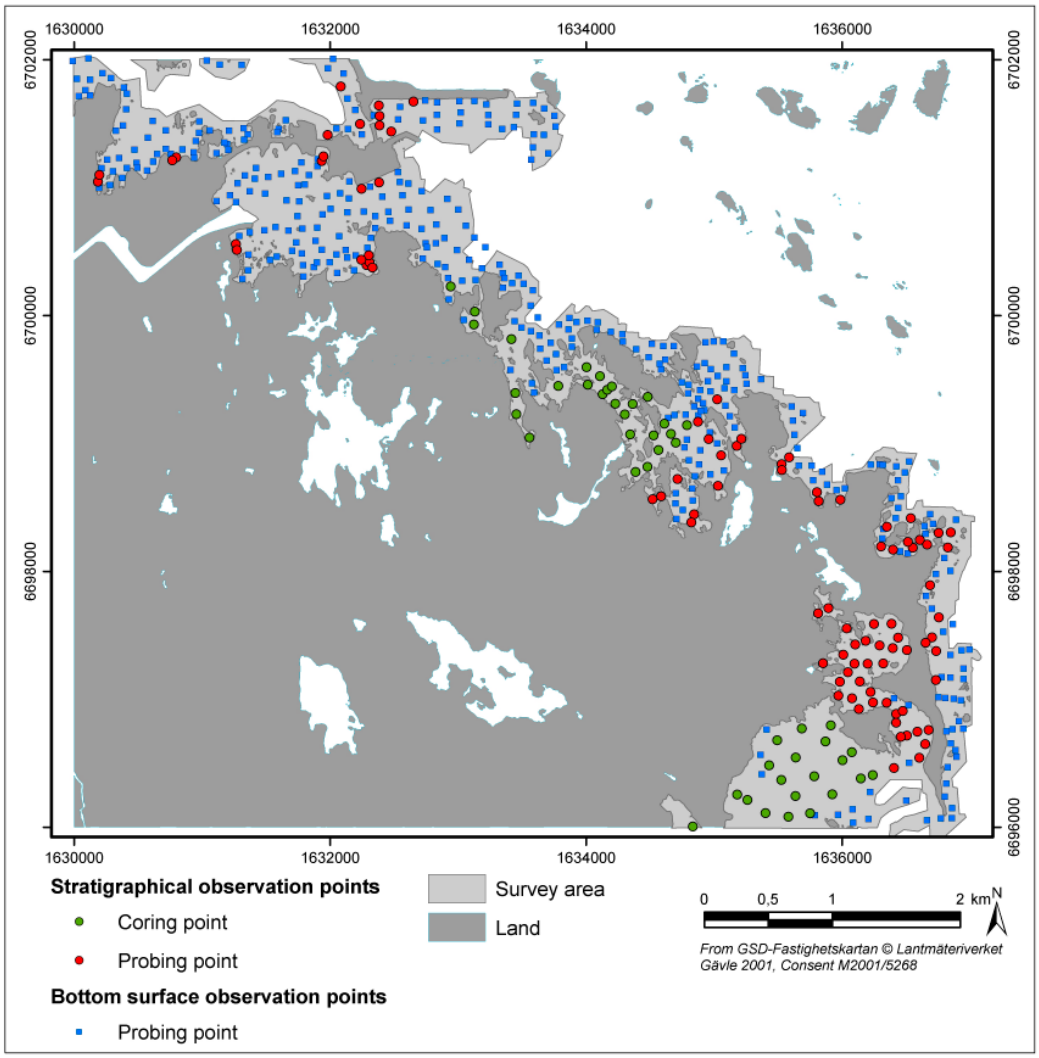


Figure 4-1. *Map showing the survey area with the coring and probing sites. The coring points were investigated with a Russian peat corer, hence the sediment was inspected. At the probing points a probe was used and the stratigraphy or bottom surface is based on interpretation without ocular inspection. Blue squares are sites where the bottom substrate was hard.*

The methods applied are described in SKB MD 131.001 (SKB internal document) but modified to be used in (sub)marine conditions. The main discrepancy is that the mapping is mainly based on a number of point observations.

At the coring points the water depth was first checked with a plummet, see /Hedenström 2003/. At the probed points it was possible to measure the water depth with the probe with sufficient accuracy. Each point observation was given an individual PFM number and the position was measured with the GPS navigator. The stratigraphy from each coring and probing point has been described and exported to the SKB SICADA database.

Seven samples from four coring sites were analysed with respect to grain size distribution and $CaCO_3$-content. Three of these sites are located at Kallrigafjärden and one at Jungfrufjärden.

The construction of the map of Quaternary deposits has been based mainly on the corings and probings in this survey. To extend the contour lines, support has been obtained from the mapping of benthic vegetation in shallow bays /Borgiel 2005/, where the bottom substrate was mapped along profiles, and the digital elevation model for the area /Brydsten and Strömgren 2004ab/. Additionally, the final map was matched to correspond to the map of Quaternary deposits on land /Sohlenius et al. 2004/ and to the marine geological map /Elhammer and Sandkvist 2005/.

4.2 Preparations

The GPS was checked repeatedly at a reference site (PP0012). This control defined a precision better than ±5 metres.

4.3 Data handling/post processing

The observation points were given separate PFM numbers, which were stored in the GPS navigator as waypoints. These values were imported to the computer and entered together with the observations and stratigraphic descriptions into a database. Data were exported to the SKB SICADA database where they are traceable by the activity plan number. The map was delivered as a shape-file to SKB GIS and displayed in Figure 5-1.

4.4 Analyses and interpretations

The grain size analyses were carried out at SWECO GEOLAB according to Standardiseri ngskommisionen i Sverige /SIS Swedish Standards Institute 1992ab/. The results from the analyses were delivered to the SKB SICADA database.

4.5 Nonconformities

The activity was conducted according to the activity plan without any nonconformities.

5 Results

The main result of the present survey is the map of Quaternary deposits on the bottom of bays with a water depth of less than 3 metres, outside Forsmark. The map is displayed in Figure 5-1. In the western area, outside the power plant and Asphällsfjärden, the major parts of the bottom is covered by till, partly rich in boulders, and the extent and thickness of sorted sediments is very limited. Along the shore between Asphällsfjärden and Tixelfjärden the extent of sand and clay increases clearly, possibly due to the proximity to the Börstilåsen esker. At Tixelfjärden and Kallrigafjärden the basins contain large quantities of gyttja and clay. The surface coverage of the different deposit types is summarised in Table 5-1.

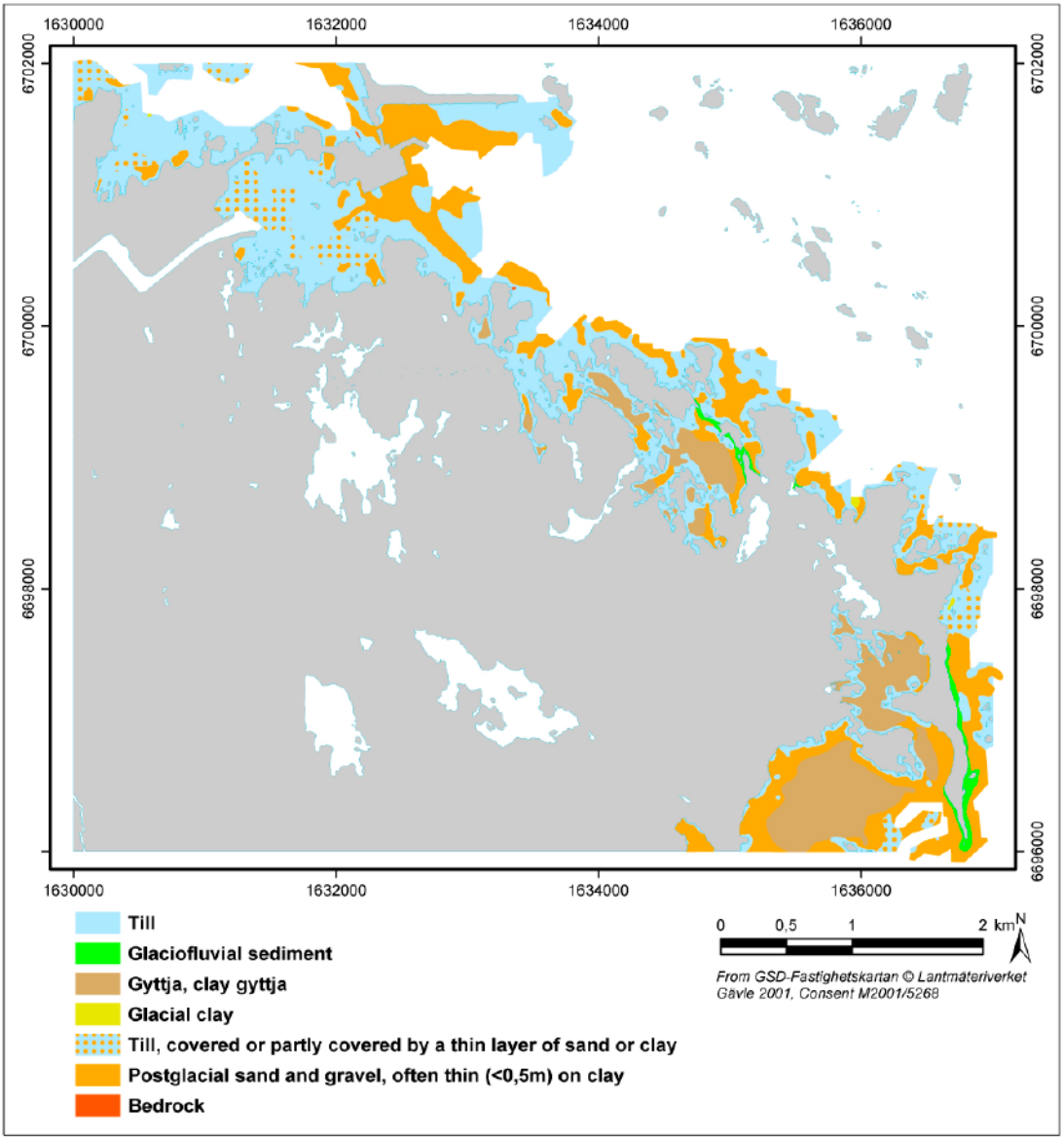


Figure 5-1. *The map of Quaternary deposits on the bottom of bays.*

Table 5-1. Surface coverage of the different deposits in the shallow bays outside Forsmark.

	km²	%
Gyttja – clay gyttja	1.07	15.2
Postglacial sand and gravel	2.05	29.0
Clay-silt	0.01	0.1
Till, partly covered by a thin layer of sand or clay	0.55	7.9
Glaciofluvial sediment	0.09	1.3
Till	3.28	46.5
Bedrock	0.00	0.0
Sum	7.05	100.0

Stratigraphic columns for 47 coring points and 93 probing points have been described, and at additionally 356 points the bottom has been probed for observation of the bottom surface. All these point observations are delivered into the SICADA database. The observations and stratigraphies are displayed in Figure 5-2 and some typical sediment stratigraphies are summarised in Table 5-2. The succession of the sediment column in the area is from the bottom: till – glaciofluvial sediments – silt and varved clay – non-varved clay – postglacial gravel to sand – clay gyttja – algae gyttja. This succession is similar to that in the lakes in the vicinity, described by /Hedenström 2004/, except from the calcareous gyttja present on the top of the lake sediment succession. The sedimentation of postglacial gravel and sand is probably due to bottom currents associated with erosion and hence various quantities of sediment are missing beneath that layer.

Table 5-2. Summary of some of the more complete sediment stratigraphies from different areas.

	Kallrigafjärden PFM006074	PFM006076	Tixelfjärden PFM006054	PFM006062	Jungfrufjärden PFM006046	Asphällsfjärden PFM006111
Algae gyttja	1.75–1.97	3.77–4.36	2.12–3.24	1.15–2.05	1.80–2.30	missing
Clay gyttja	missing	missing	Missing	2.05–2.24	Missing	missing
Sand-gravel	1.97–2.20	4.36–4.70	3.24–3.43	2.24–2.31	2.30–2.40	1.30–1.60
Non-varved clay	2.20–5.57	4.70–5.90	3.43–3.80	2.31–2.70	2.40–4.00	1.60–2.50
Varved clay – silt	5.57–6.31	5.90–>6.60	3.80–4.95	2.70–>5.09	4.00–4.20	

Seven samples from four cores were analysed with respect to grain size distribution and $CaCO_3$-content. The results from the analyses are summarised in Table 5-3 and graphs of the grain size distribution from the laboratory are attached in Appendix 1. Additionally one core collected in Tixelfjärden was submitted for chemical analyses (administrated in another project, AP PF 400-05-061).

Table 5-3. Results from the grain size and $CaCO_3$ analyses together with calculated hydraulic conductivity (Fair & Hatch). [1]) The permeability could not be correctly calculated for this type of material.

Id code	Depth (m)	Deposit (Swedish)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	CaCO3 (%)	Hydraulic cond (m/s)
PFM006073	4.13–4.18	Heavy clay (styv lera)	0	10.9	42.7	46.4	20	(2.7E–6)[1]
PFM006073	4.18–4.31	Clayey sandy till (Lerig sandig morän)	17.7	42.5	26.3	13.5	8	2.7E–8
PFM006094	1.55–1.87	Sand	13.6	80.7	3.1	2.6	0.4	3.0E–5
PFM006095	0.29–0.59	Sand	0	94.9	2.0	3.1	0.3	4.2E–5
PFM006095	2.20–2.50	Heavy clay (styv lera)	0	1.5	32.7	65.8	29	(2.0E–6)[1]
PFM006095	2.76–3.00	Boulder clay (Moränlera)	9.2	37.6	37.5	15.7	25	1.7E–8
PFM006097	3.55–3.67	Clayey sandy till (Lerig sandig morän)	17.7	42.4	26.7	13.2	10	2.6E–08

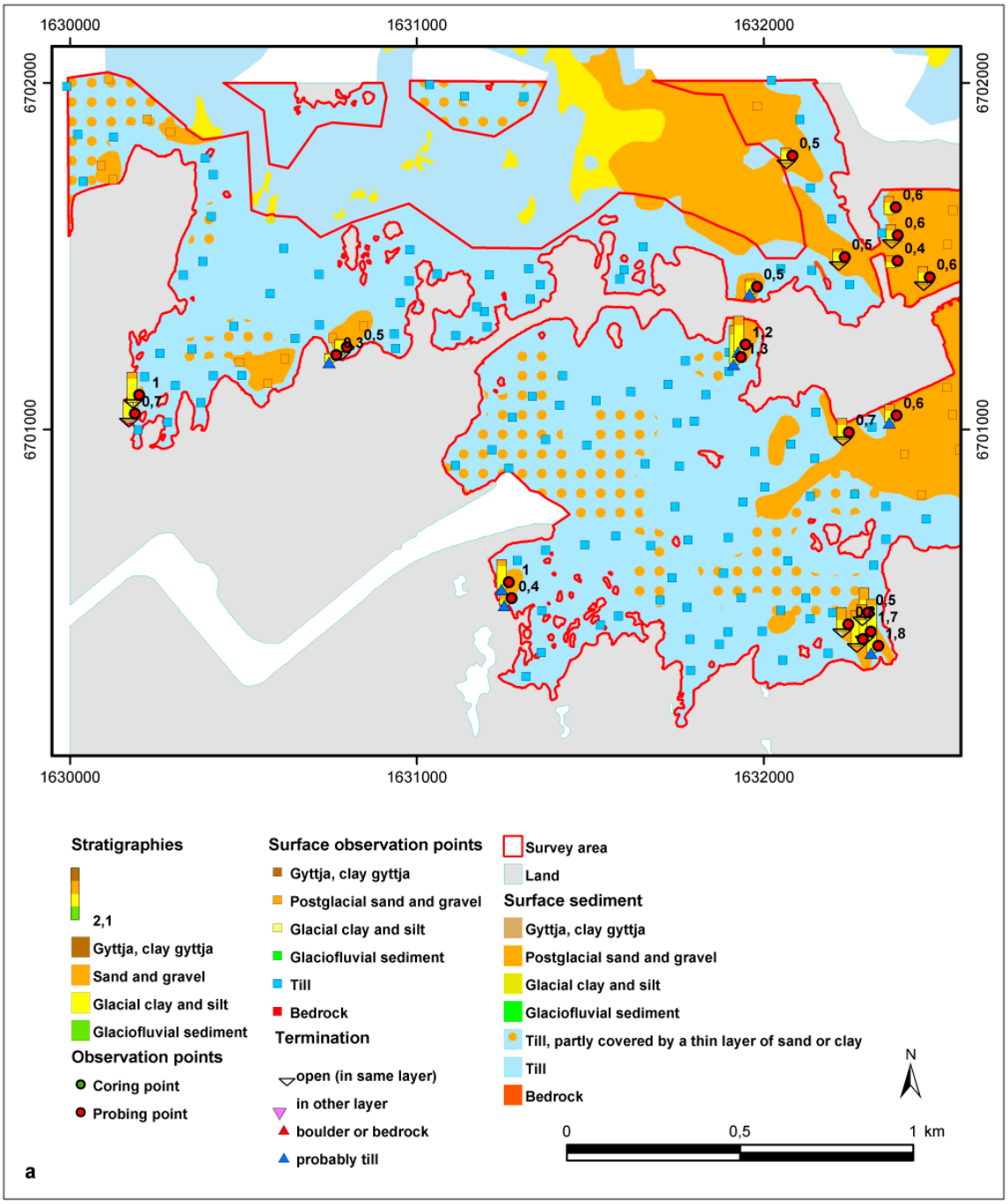
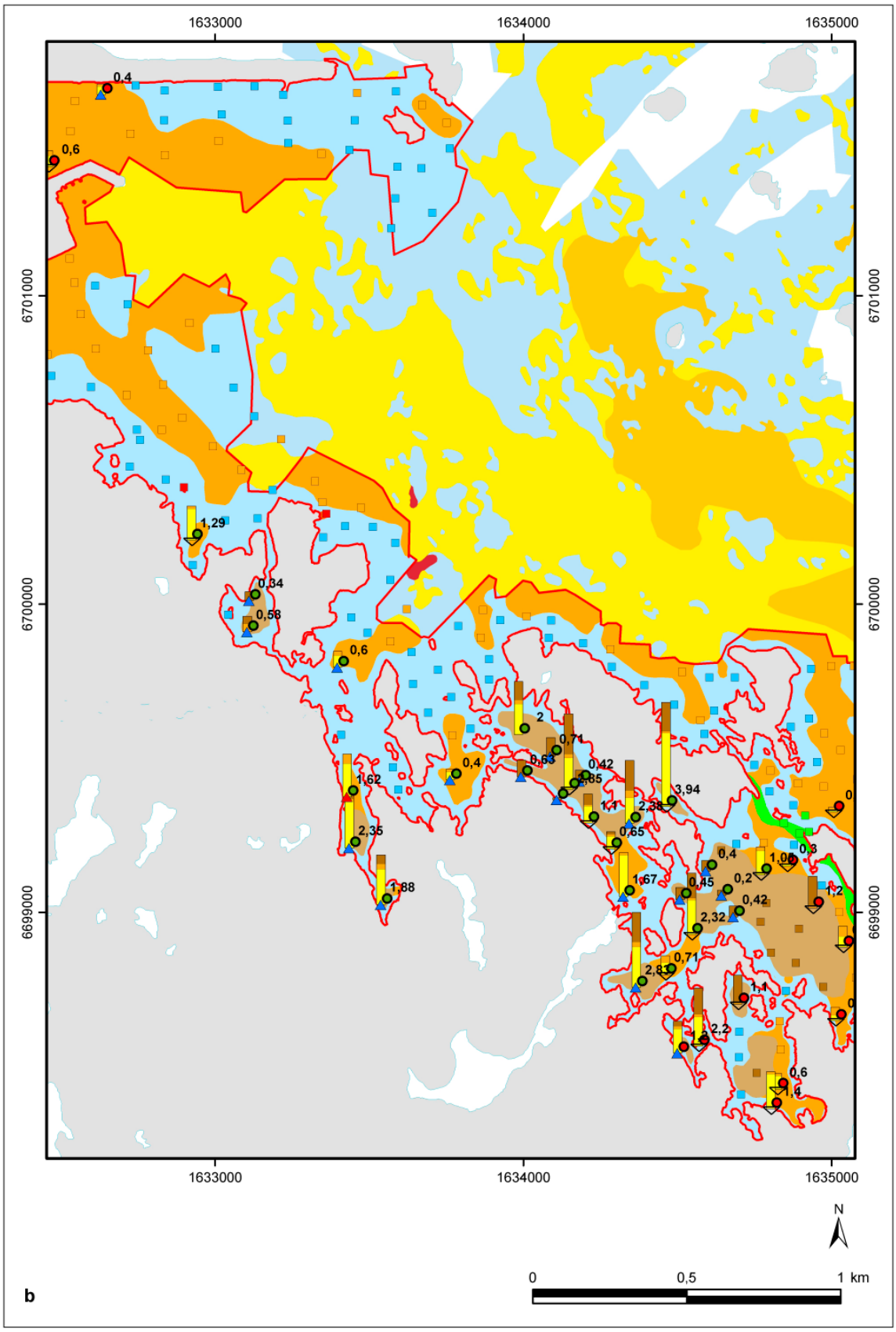


Figure 5-2a–c. *Map showing the observation points and stratigraphic columns. The label at the stratigraphic column displays the penetrated sediment depth. The figures include the inner part of the marine geological map.* ***a****) The western part of the area, dominated by till.* ***b****) The middle part of the area characterised by sand in the outer parts and gyttja in the bays Jungfrufjärden and Tixelfjärden.* ***c****) The south-eastern part of the area with sand and gravel around the Börstilåsen esker and great quantities of clay and gyttja in the bays Tixelfjärden and Kallrigafjärden.*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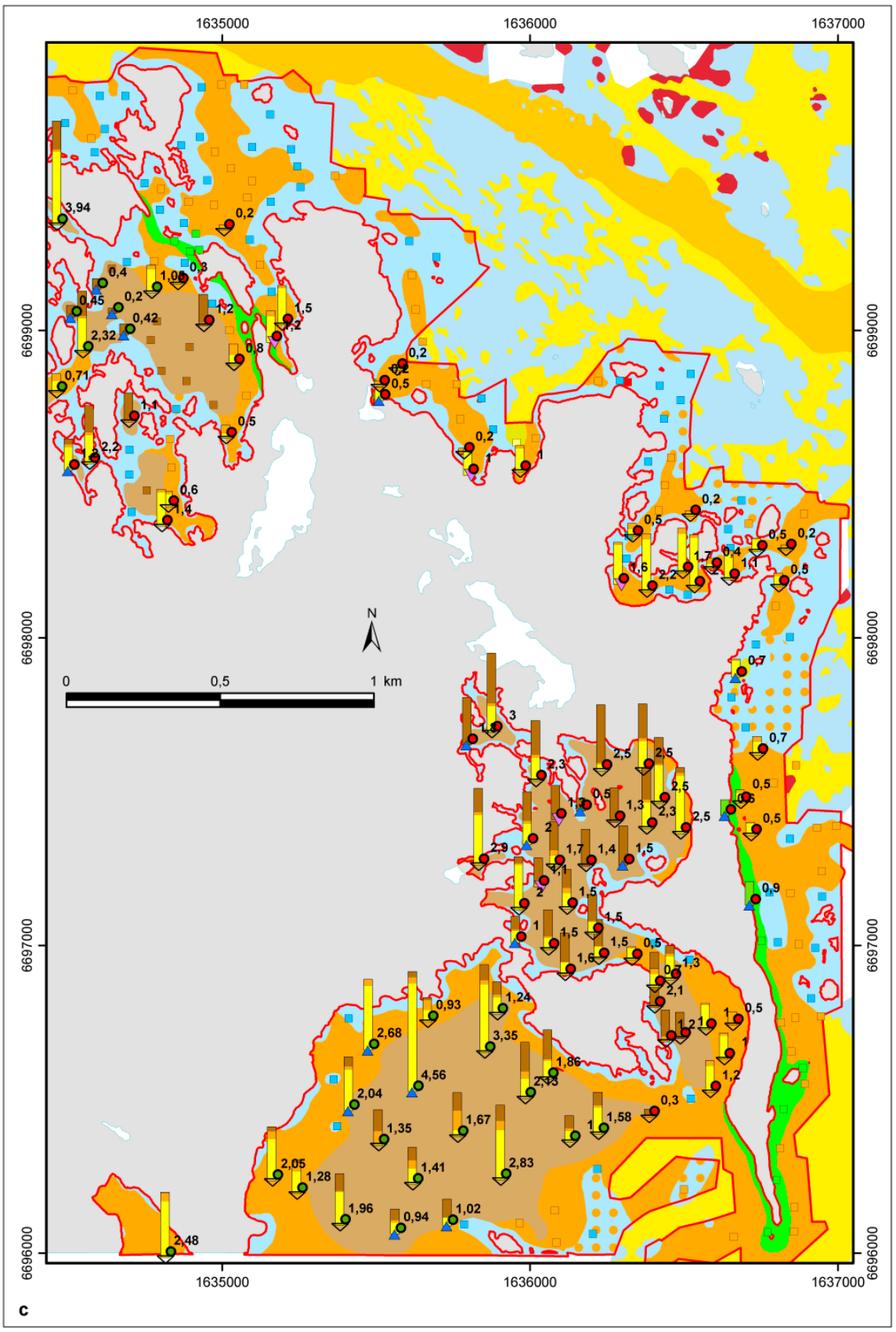
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0,5
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Svensk Kärnbränslehantering AB.

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Grain size distribution curves

Kornfördelning
enl. SS027123 och SS027124

SWECO GEOLAB

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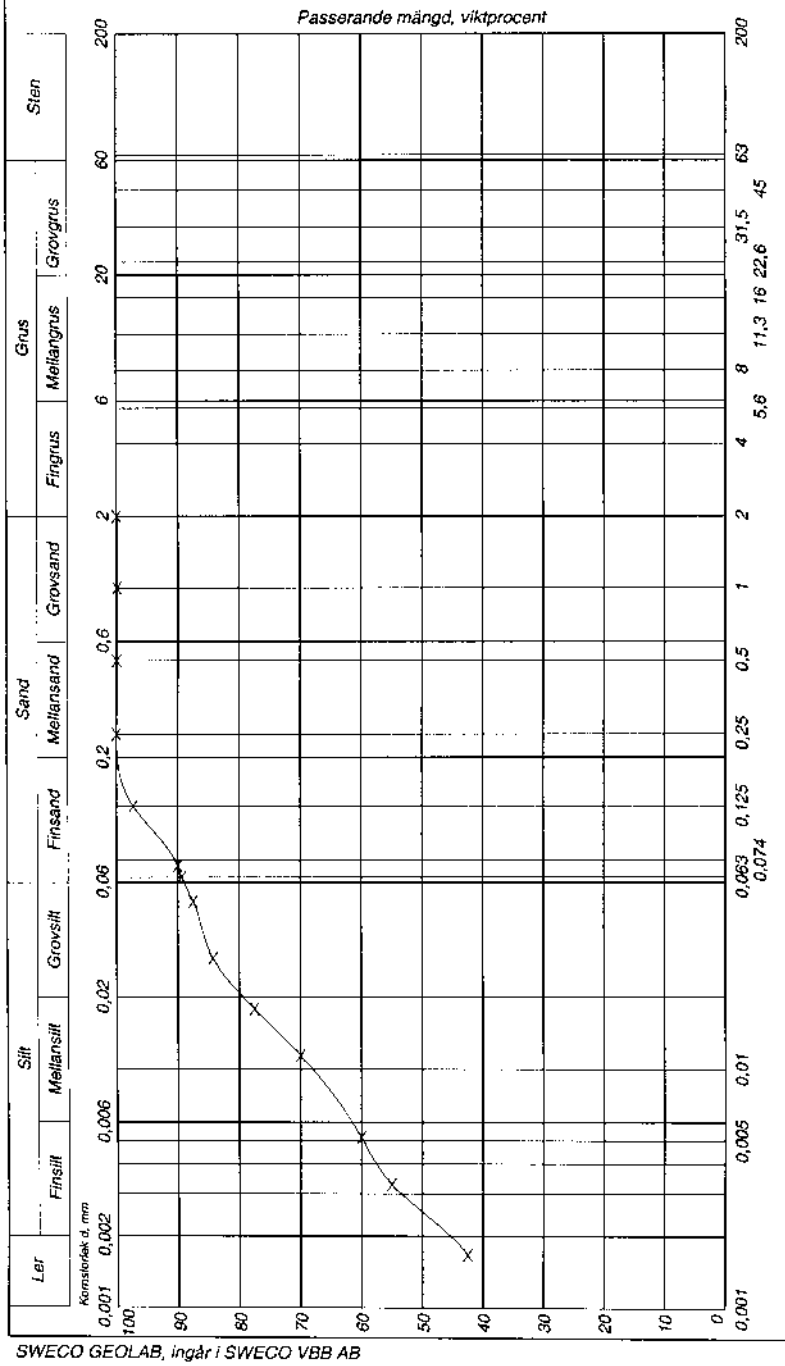

* = Anläggnings AMA 98

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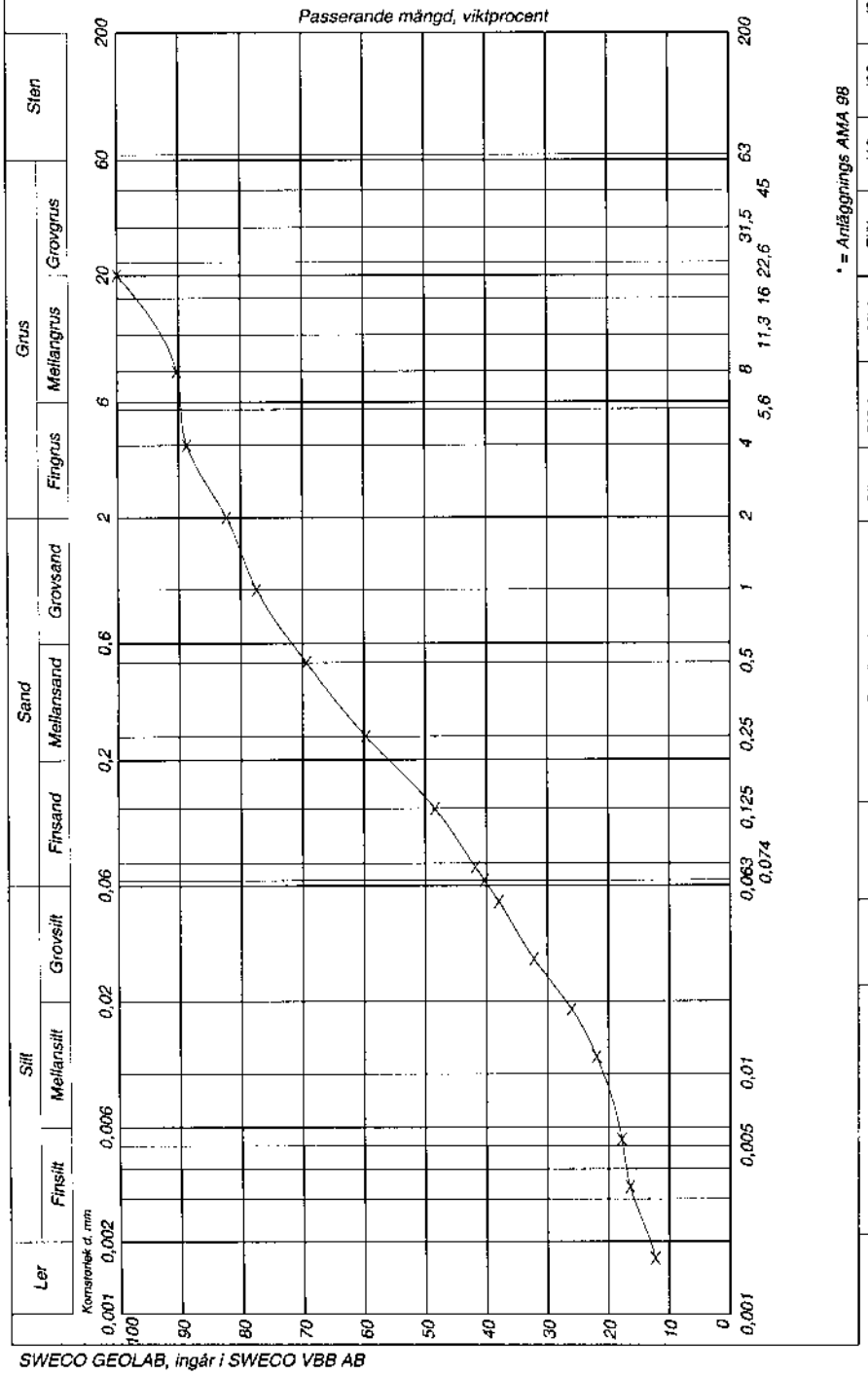

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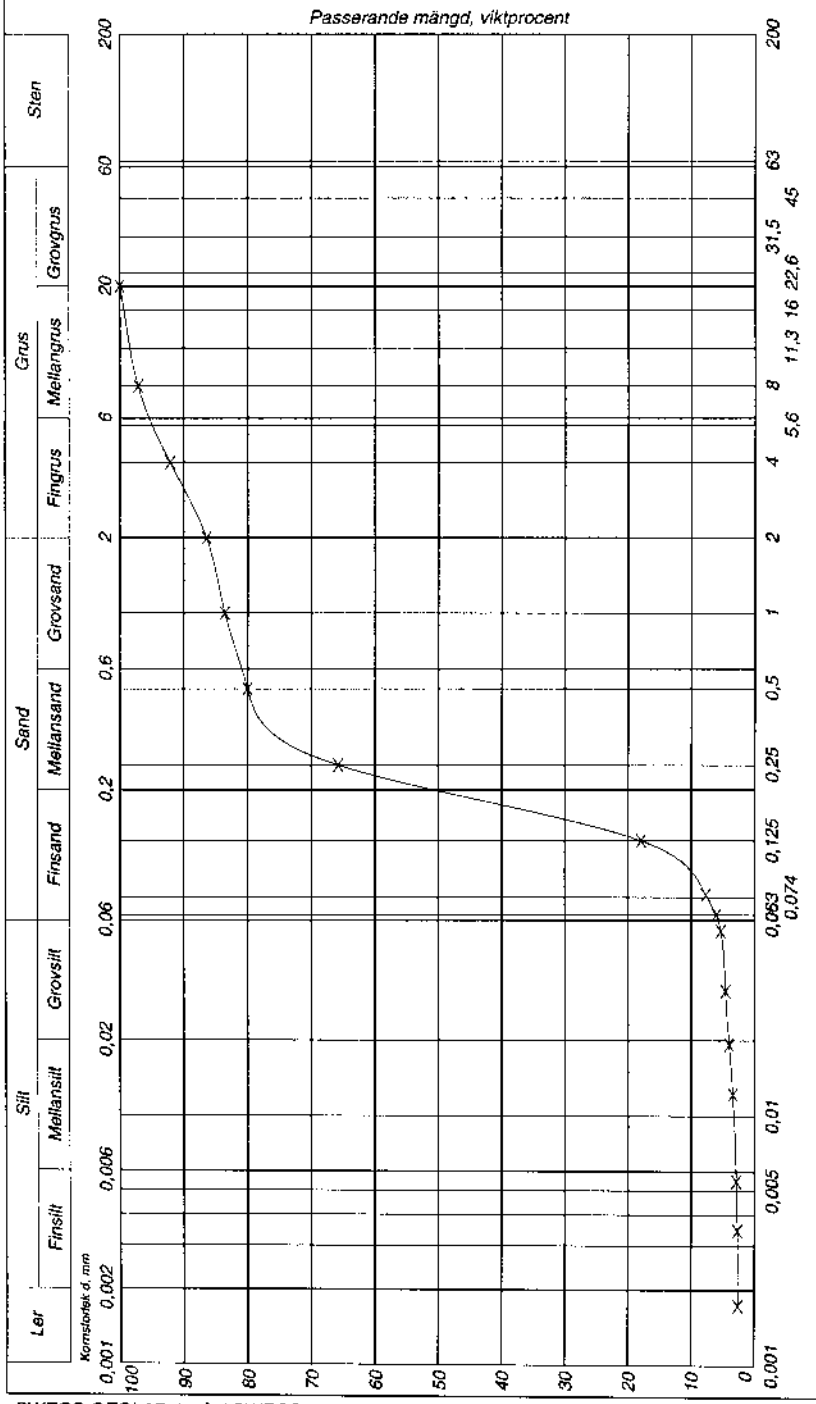

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PFM 006094 28195	--·X---		1,55-1,87	Sand (SGU serie Ae)	140			2/1*	0,085	0,23	3,084

* = Anläggnings AMA 98

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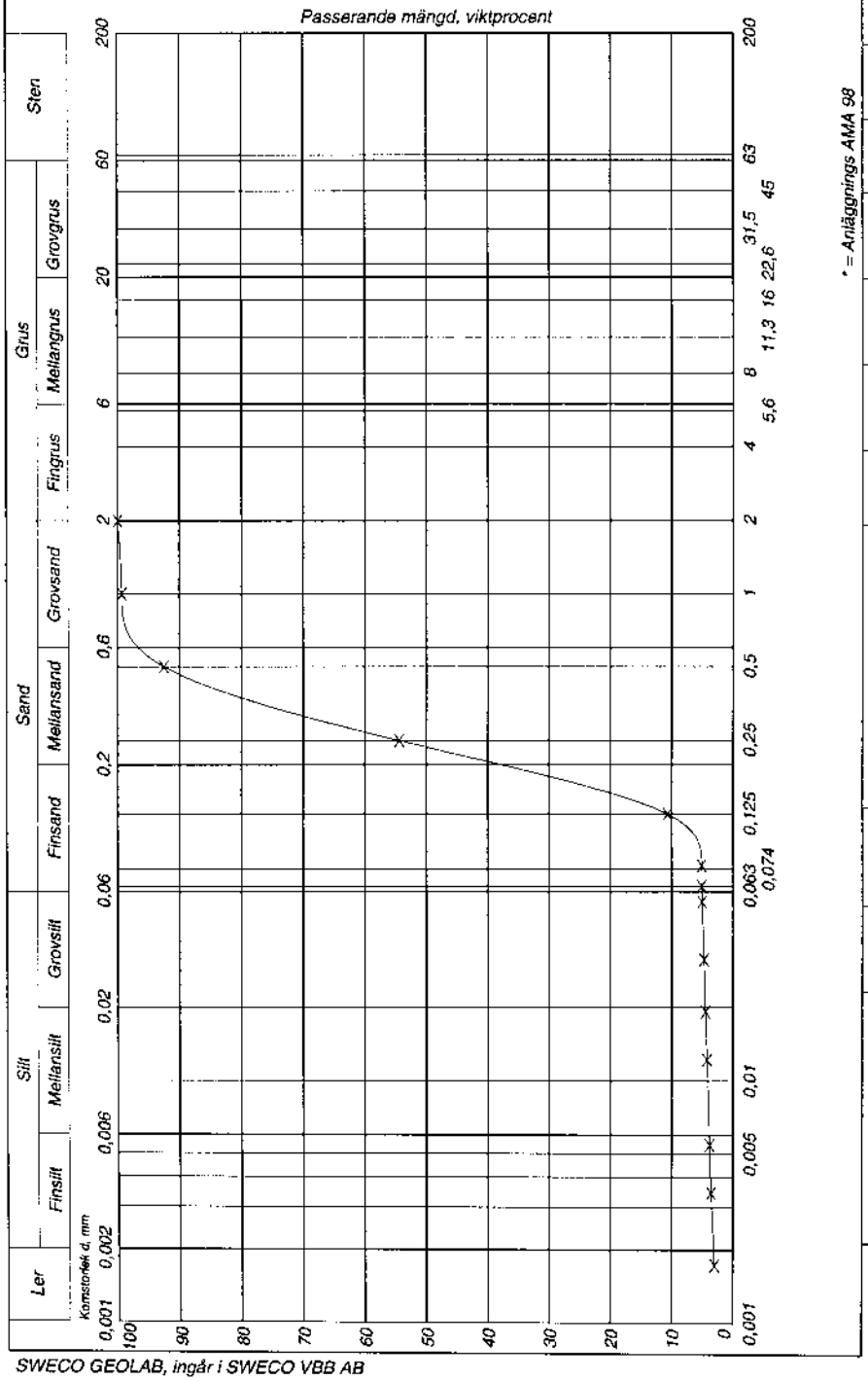

* = Anläggnings AMA 98

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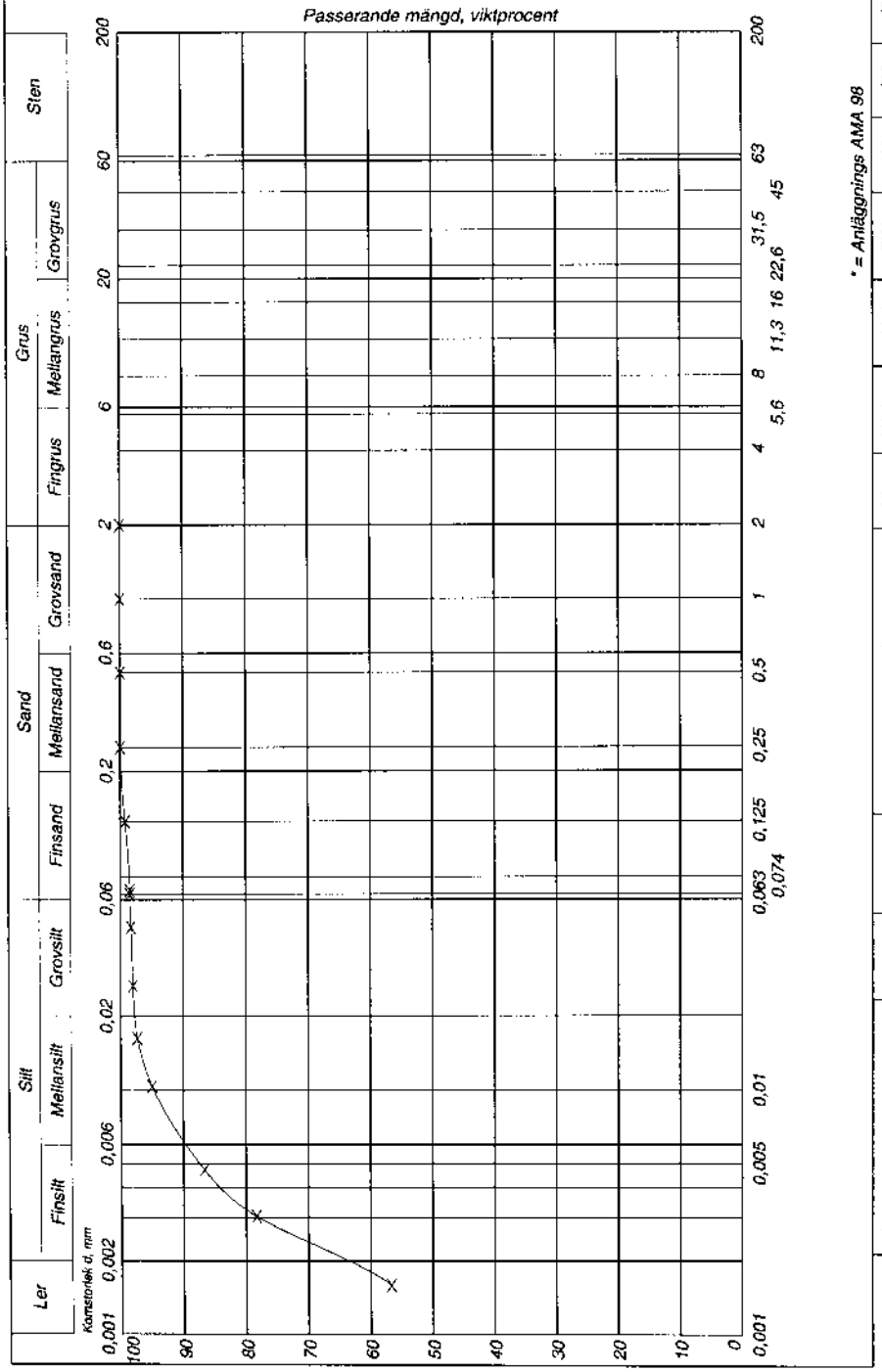

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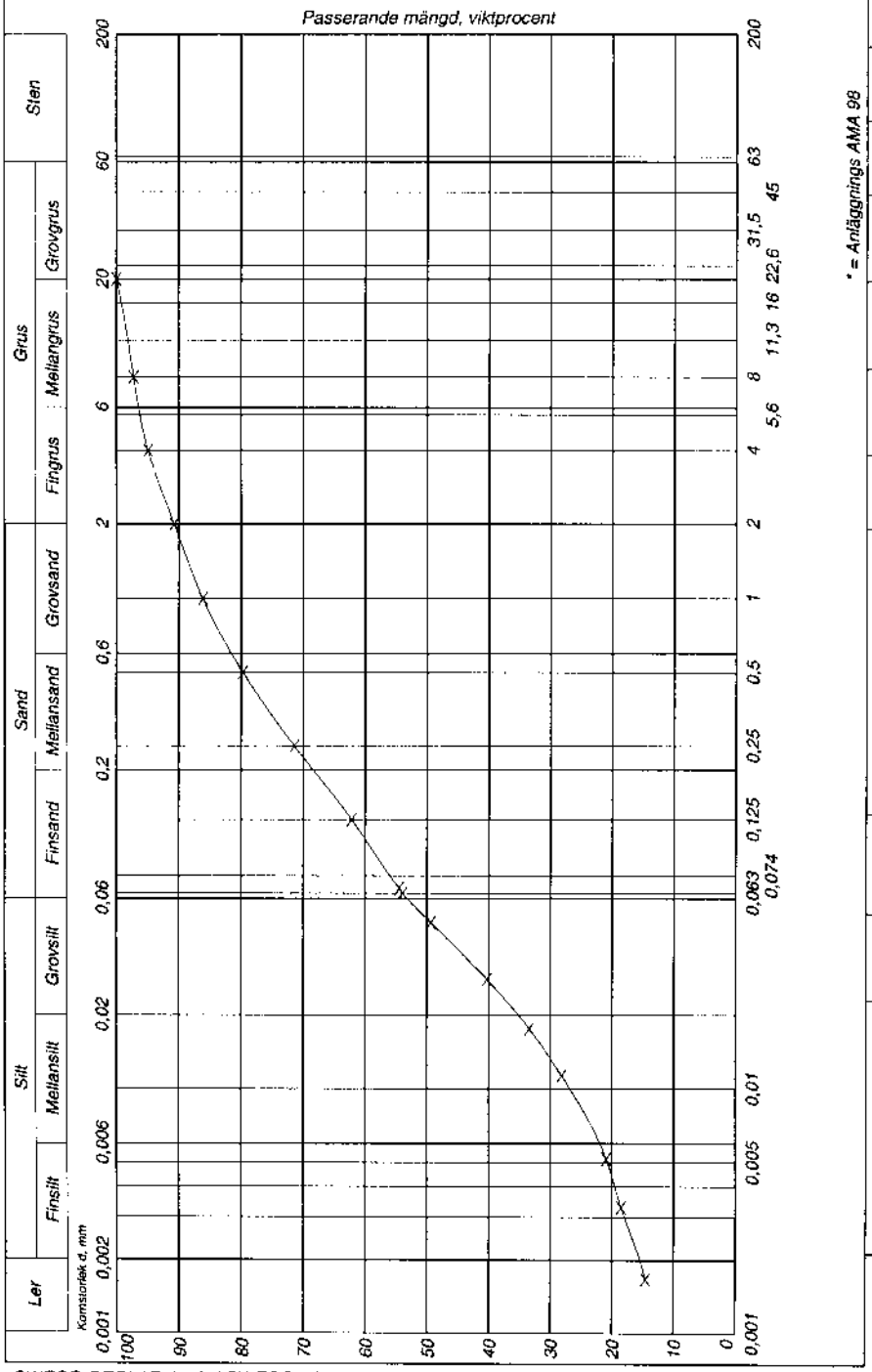

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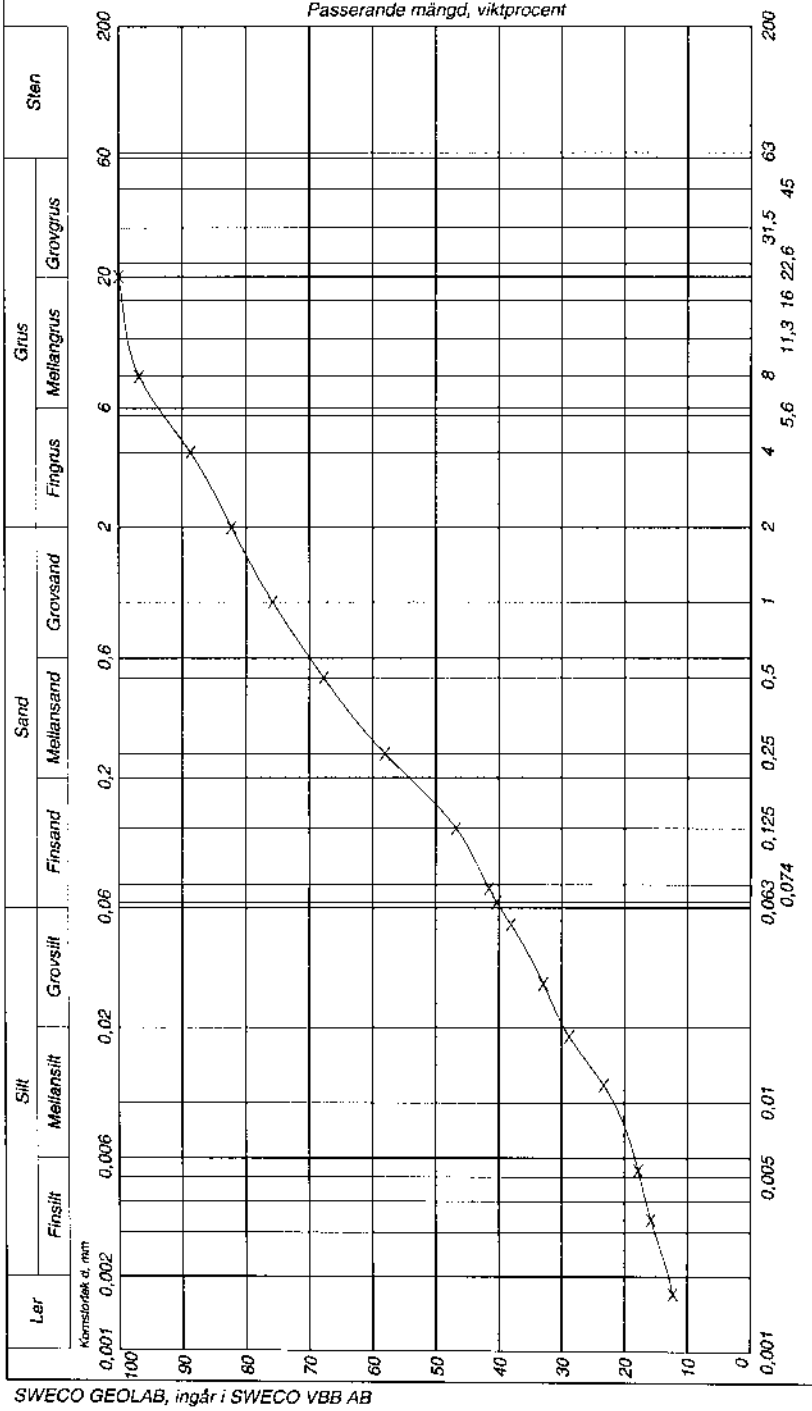
Uppdragsgivare:	SGU, Uppsala		*Gransk./Sign:*



Saktion Borrhål	Prov-beteckn.	Djup (m)	Gäller mellan (m)	Benämning	Siktat Prov (g)	Glödgn.-förlust %	Mtrl % > mm	Tjäl-farlighet	d10	d60	d90
PFM 006097 28199	—×—		3.55-3.67	Lerig sandig morän (SGU s. Ae)	62			4A/3*		0,287	4,469

* = Anläggnings AMA 98

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