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Forsmark site investigation

Investigation of marine and lacustrine sediment in lakes

Field data 2003

Anna Hedenström, SGU

April 2003

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Contents

1 Introduction 5

2 Objective and scope 7

3 Equipment 9
3.1 Description of equipment 9

4 Execution 11
4.1 Preparations 11
4.2 Data handling 11

5 Results 13

6 References 17

Appendix 1 19

1 Introduction

SKB performs site investigations for location of a deep repository for high level radioactive waste. The site investigations are performed at two sites: Forsmark and Oskarshamn. This document reports field data gained within the activity *Investigation of marine and lacustrine sediment in lakes*, performed within the site investigation at Forsmark. The investigations were carried out according to the Activity Plan AP 400-02-49 (internal SKB controlling document). The working procedures followed the methods described in the SKB method description for mapping of unconsolidated Quaternary deposits, MD 131.002 (SKB internal controlling document) and the SKB method description for investigation of peat lands, MD 131.001, (SKB internal controlling document), with the principal difference in the type of sediments investigated.

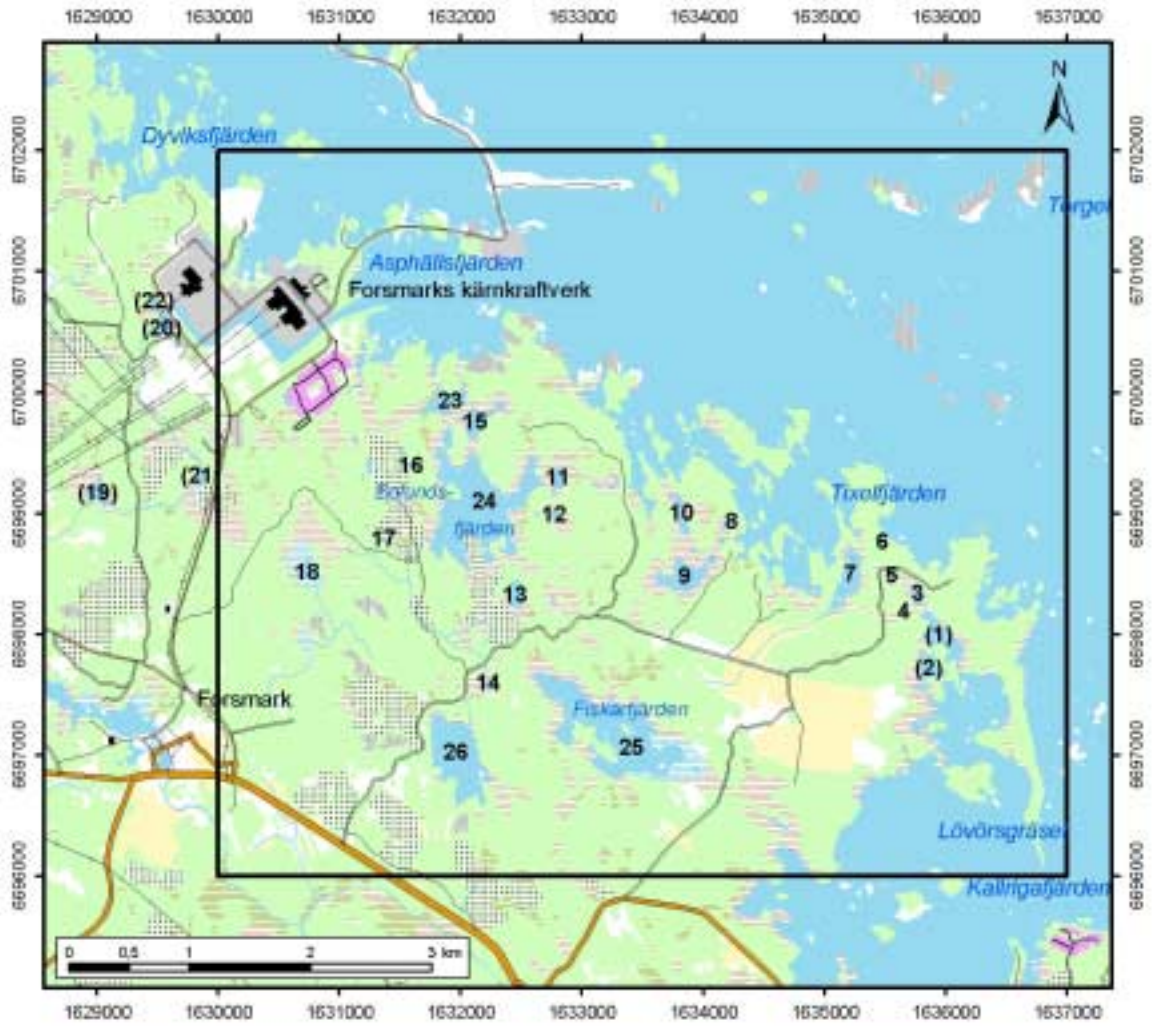


Figure 1-1. *Lakes included in the investigation are located within the black box, corresponding to the area where mapping of unconsolidated Quaternary deposits is presently carried out. The lake numbers are taken from the activity "Sjömätningar, identifiering av avrinningsområden samt habitatkartering av sjöar i områden aktuella för platsundersökningar", AP PF 400-02-05 (SKB internal controlling document). Lakes not included in the investigation are 1 & 2 (shallow coastal lagoons) and 19–22 (located outside the study area).*

2 Objective and scope

The aim of this activity is to describe the aerial and stratigraphical distribution of marine and lacustrine sediment i.e. sediment overlaying the glacial till and/or bedrock surface, in lakes in the Forsmark area. The investigation is carried out within areas where mapping of unconsolidated Quaternary deposits is presently carried out. Since small and shallow lakes cover a large part of the region, this work will give important information on the distribution and stratigraphy of sedimentary deposits not included in the regular mapping of unconsolidated Quaternary deposits within the site investigation programme.

Samples were also collected for laboratory analyses of grain size distribution, mineralogical composition as well as the total content of C, N and S and calcium carbonate. The analyses will be carried out on selected samples of representative sedimentary units in order to characterise the chemical and physical properties of the unconsolidated deposits.

The analytical data will be useful for the hydrogeological modelling and for models of the Quaternary evolution of the area. The mineralogical analyses of clay may provide information on the origin of the clay particles. One stratigraphic sequence from Lake Eckarfjärden will be stored for later analyses, e.g. pollen analysis.

This report includes field data from spring 2003. Together, the field data and the forthcoming results from the laboratory analyses will form the basis for construction of stratigraphical profiles to be presented in a following report in the fall 2003.

3 Equipment

3.1 Description of equipment

The stratigraphic distribution of marine and lacustrine sediment in lakes was investigated using a Russian peat corer, length 1 metre, width 5 cm supplied with rods of 1.5 m length. A probe was connected to the rods when the sediment was too coarse for the corer to penetrate.

Most photographs were taken using a Nikon Coolpix 4300 digital camera.

***Figure 3-1**. The coring equipment consists of a Russian peat corer, rods and a probe.*

***Figure 3-2**. The Ising plummet. The water depth was measured with a home made plummet, constructed by J. Ising.*

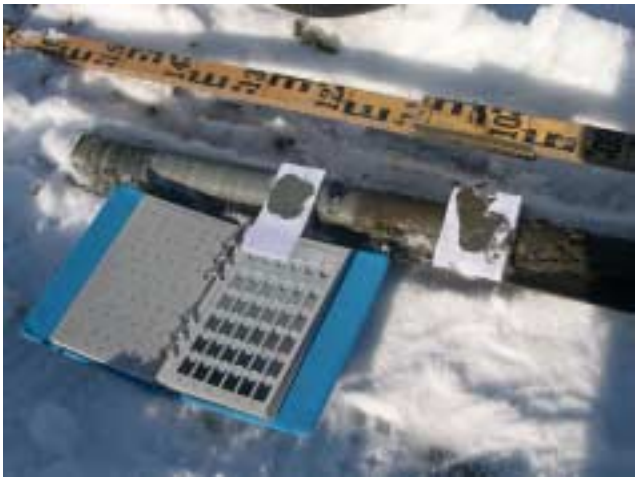


***Figure 3-3**. Munsell soil colour charts were used at selected sites /1/.*

4 Execution

The corings were performed from the ice of the lakes during one month in January and February, 2003. GPS (Garmin 12) and maps of the lakes were used for orientation and bathymetric maps were consulted to determine the exact location of the coring sites. The water depth at each coring site was checked with a plummet (Figure 3-2) and the litho-stratigraphy was investigated using a Russian peat corer (Figure 3-1). One metre long sequences were collected from the lake bottom/sediment surface and downwards until the sediment was to coarse for the corer. If the stratigraphical sequence was not complete, i.e. glacial clay or till was not reached, the rods were extended by a probe for further investigation.

4.1 Preparations

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

4.2 Data handling

Field data were noted in a notebook. The point observations were given PFM numbers. At each coring site, PFM number, co-ordinates and date for the observation was stored as a waypoint in the GPS. The information from the waypoints was subsequently transformed digitally to a PC computer and stored as an Excel file. This data was exported to the SKB SICADA database under field note Forsmark 98.

In lake basins where investigations of the uppermost unconsolidated sediments had been carried out within another activity, *Ytsedimenprovtagning i sjöar och grunda havsvikar*, AP 400-02-46 (SKB internal controlling document), the same coring spots were revisited, to obtain a complete sedimentary sequence from the lake-bottom down to the glacial till. At these sites, the site numbers (PFM) and coordinates were changed afterwards so that the same co-ordinates were used. The same procedure was applied at sites where pipes had been installed for groundwater investigations within the frame of another parallel running activity, *Jordborrnig och jordprovtagning samt installation av grundvattenrör och pegelrör*, AP 400-02-31 (SKB internal controlling document). These sites were assigned SFM numbers and a preliminary position was stored in the GPS as a waypoint. The original field coordinates and PFM numbers will also be archived at SKB.

After the field campaign, the field data (stratigraphical descriptions and geological observations) were stored in a database for mapping of unconsolidated Quaternary deposits at the Geological Survey of Sweden (Jorddagboken version 5.4.3). The data were subsequently converted to Excel format and exported to the SKB SICADA database where it was stored under field note Forsmark 98. Photographs of sediment cores are stored in the SKB file archive.

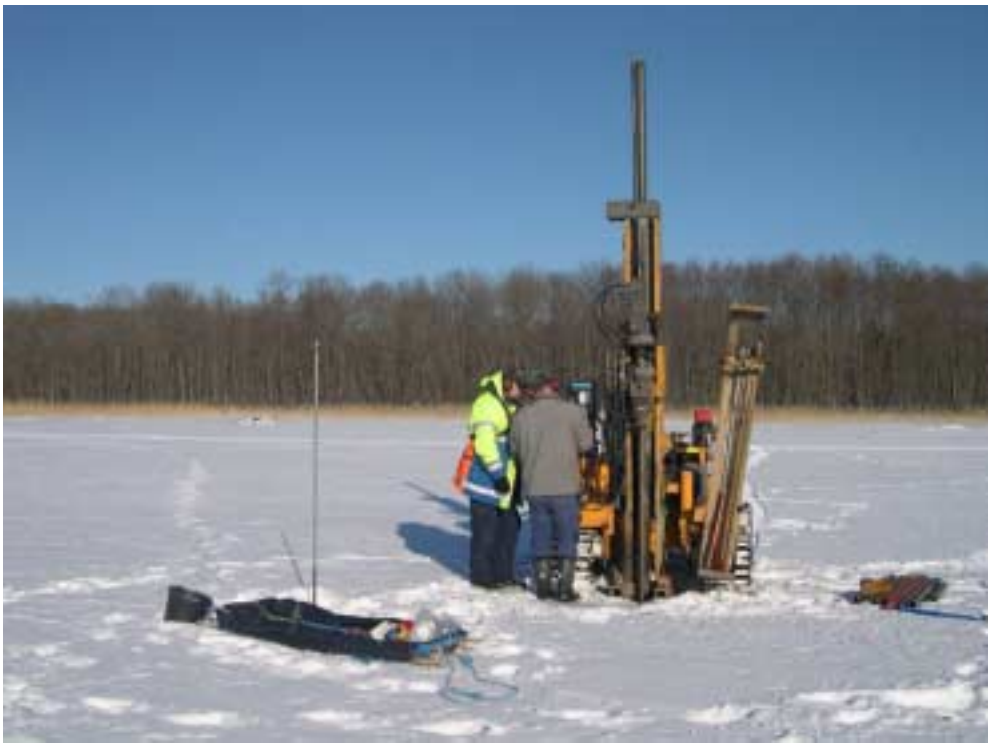


Figure 4-1*. Illustration of work with groundwater pipes, running parallel with ongoing investigation of the sedimentary sequence, at the drill site SFM0043/SFM0025. The rod on the left hand side of the drilling machine is located in the borehole to mark the position of the coring site.*

5 Results

19 of the 20 lakes in Figure 1-1 were investigated. Lake number 6 was excluded due to the restricted time schedule for field work at sites situated in areas hosting sensitive wildlife. This very small basin is in fact not yet an isolated lake and should therefore have been excluded from the investigations from the start, on the same ground as lake No 1 and 2 (commented on above).

In summary, the distribution of marine and lacustrine sediment in the Forsmark region is fairly consistent. The stratigraphy contains the following principal types of unconsolidated Quaternary deposits:

- glacial and postglacial clay,
- postglacial sand and gravel,
- clay gyttja/gyttja clay,
- algal gyttja,
- calcareous gyttja,
- lake marl.

The sedimentary sequences were generally thin. The depth from the lake ice, down to the glacial till, was often less than 3 m, including the water column generally less than one metre. Maximum coring depth in the area was 8.8 m, recorded at Lake Fiskarfjärden (coring site PFM004195; Appendix 1). In Table 5-1 the type of environment prevailing in the water column during the periods of sedimentation associated with the respective stratigraphical unit is described.

The detailed stratigraphical descriptions from each coring site are stored in SICADA under field note Forsmark 98. Maps showing the location of the coring sites are given in Appendix 1.

Table 5-1. Generalized outline of stratigraphical units in the investigated sediments at Forsmark and the environment in the water column during the time of deposition.

Environment	Lithology
Freshwater lake	Lake marl
Freshwater lake	Calcareous gyttja
Freshwater lake and coastal lagoons	Algal gyttja
Post glacial Baltic basin	Gyttja clay/clay gyttja
Shallow coast	Sand, gravel
Post glacial Baltic basin	Postglacial clay
Late glacial Baltic basin	Glacial clay

Varved glacial clay was observed at six lake basins. The varves were often well developed and distinct. Several localities contained thicker varves with a large silt content, interpreted to represent the bottom varves. The thickness of the layers was between ca 25 mm at the bottom to ca 1 mm at the upper part of the varved sequence. The sediment sequence in Figure 5-1 consists of 51 varves with a mean thickness of 10 mm for the summer layers (pale) and 9 mm for the winter layers (dark). The colour of the winter layer was bluish grey and the summer layers were pink. At several sites, visible fragments of limestone were discovered in the varved clay. On top of the varved glacial clay, and in basins where no varves could be seen, homogeneous blue-grey clay was observed. This unit was interpreted to represent late glacial deposition. The interpretation is based on the gradual transition from the varved glacial clay, thin sediment sequences and radiocarbon dates of the unit /3/.

Postglacial clay was observed only in Lake Fiskarfjärden (Lake number 25 in Figure 1-1 and Appendix 1). The clay appeared as homogeneous and grey. No reaction with HCl was recorded during later tests in the laboratory.

On top of the clay, a layer of postglacial sand (and gravel) was recorded in most of the stratigraphical sequences. The layer was often ca 10 cm thick. At coring site PFM004193, Lake Fiskarfjärden (lake No 25); the layer was 1.8 m thick. The contact between clay/sand is clearly erosive (Figure 5-2). The Forsmark region is exposed to a high-energy wave-action, and therefore erosion has affected the bottoms until only shortly before the isolation of the lakes. This is in agreement with models by Brydsten, 1999 /2/, as well as observations from the ongoing marine geological mapping outside of the coast of Forsmark (AP 400-02-27; SKB internal controlling document). Radiocarbon dates of samples collected from each side of the sand layer in sediment from Lake Eckarfjärden (lake No 26) indicates a hiatus representing the major part of the Holocene /3/. The postglacial sand gradually changes into gyttja clay/clay gyttja. This unit is not present at all sites and is usually not more than a few dm thick. The gyttja clay/clay gyttja was probably deposited in the Bothnian Sea, shortly prior to the isolation of the lake basins.

The various types of gyttja represent lacustrine and lagoonal sedimentation. Two main types of algal gyttja were observed, separated visually by colour. A greenish-grey algal gyttja often occurred on top of the gyttja clay/clay gyttja, commonly superposed by a reddish brown algal gyttja (Figure 5-3). In several lake basins, the greenish grey algal gyttja contained macroscopic remains of *Cladophora glomerata*. Gas was often released from the sediment when this unit was penetrated with the corer. *C. glomerata* is a brackish water algae, indicating that the unit was deposited on the bottoms of shallow bays during or shortly prior to the isolation of the lakes. Calcareous gyttja was observed in e.g. Lake Eckarfjärden and Lake Stocksjön (lake No 26 and 14 in Figure 1-1 and Appendix 1). The uppermost unconsolidated sediment was often not recovered in the corer.

***Figure 5-1**. In Lake No 5, coring site PFM004205, the sedimentary sequence between 1.27–2.27 m depth consists of varved glacial clay. Bottom is to the right in the picture.*

***Figure 5-2**. In Lake Eckarfjärden (lake No 26, coring site PFM004301), the typical erosive contact between the glacial clay and postglacial sand is recorded at 3.0 meter. Down is to the right in the picture.*

***Figure 5-3**. The lacustrine sediment in Lake Eckarfjärden, (lake No 26, coring site PFM004294) from 2.1–2.6 m depth, consists of greenish grey algal gyttja, calcareous gyttja, reddish brown algal gyttja and unconsolidated algal mat at the top. Down is to the left in the picture.*

6 References

/1/ Munsell Soil Color Charts, 1994. Macbeth Division of Kollmorgan Instruments Corporation, New Windsor.

/2/ Brydsten L, 1999. Change in coastal sedimentation conditions due to positive shore displacement in Öregrundsgrepen. SKB TR-99-37, 34 pp.

/3/ Hedenström A, Risberg J, in review. Shore displacement in northern Uppland during the last 6500 calendar years. SKB TR-report in review at SKB, Stockholm (Ulrik Kautsky).

Appendix 1

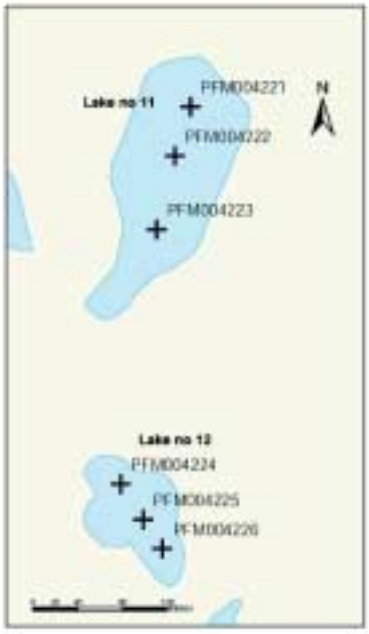
Maps showing the locations of coring sites in the investigated lakes. For locations of the lakes in the investigation area, refer to Figure 1-1. The geological descriptions to the coring sites are stored in the SKB SICADA database under field note Forsmark 98.

Lake No 3–5

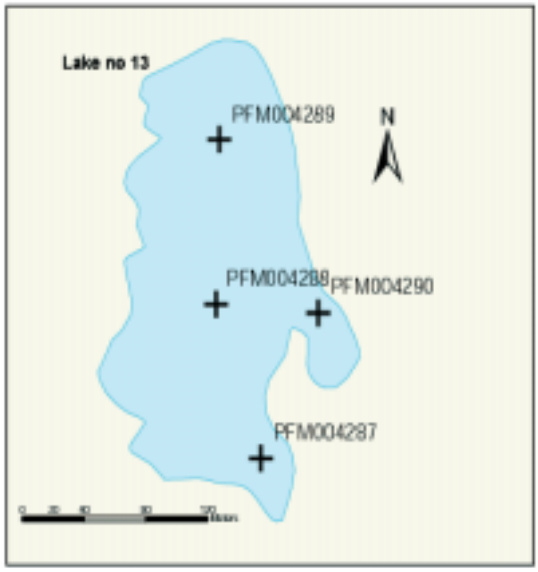
Lake No 7

Lake No 8–10

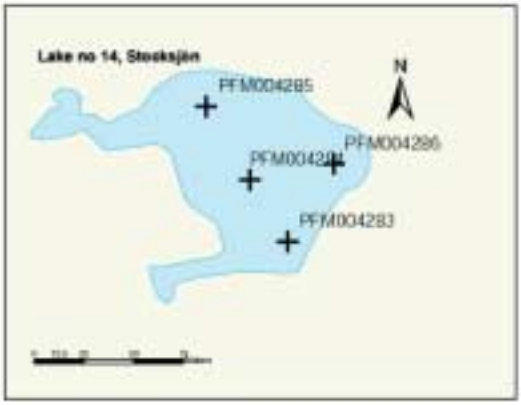
Lake No 11–12



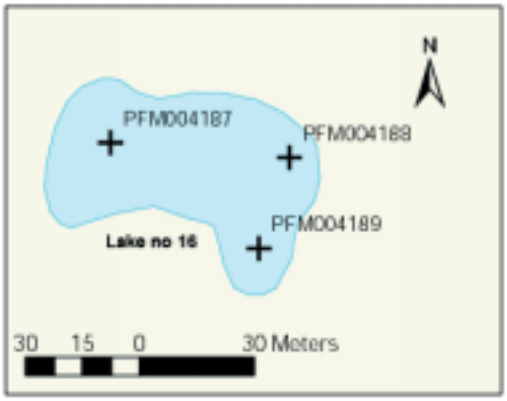
Lake No 13



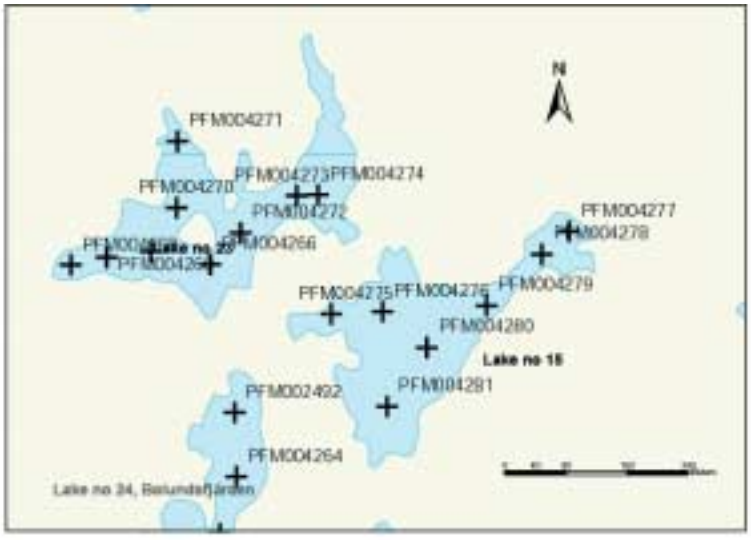
Lake No 14



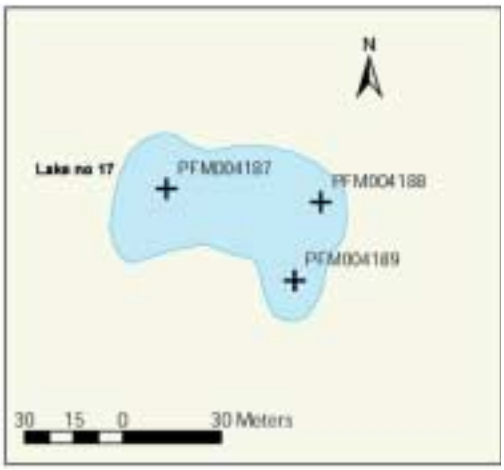
Lake No 16



Lake No 15 & 23



Lake No 17



Lake No 18

Lake No 24, Bolundsfjärden

Lake No 25, Fiskarfjärden

Lake No 26, Eckarfjärden