P-03-76

Forsmark site investigation

Searching for evidence of late- or post-glacial faulting in the Forsmark region

Results from 2002

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Geological Survey of Sweden (SGU)

July 2003

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Keywords: P-03-76, late- or post-glacial faulting, earthquake, Quaternary deposits, seismically induced deformations.

Contents

1 Introduction

SKB is performing site investigations for localisation of a deep repository for high level radioactive waste. The site investigations are performed at two sites; Forsmark and Oskarshamn. This document reports the data gained in *Searching for evidence of late- or post-glacial faulting in the Forsmark region*. The activities were performed according to the Activity Plan PF 400-02-13, version 1.0 (SKB internal controlling document) and the methods used are described in SKB MD 133.001. The area under investigation is shown in Figure 1-1.

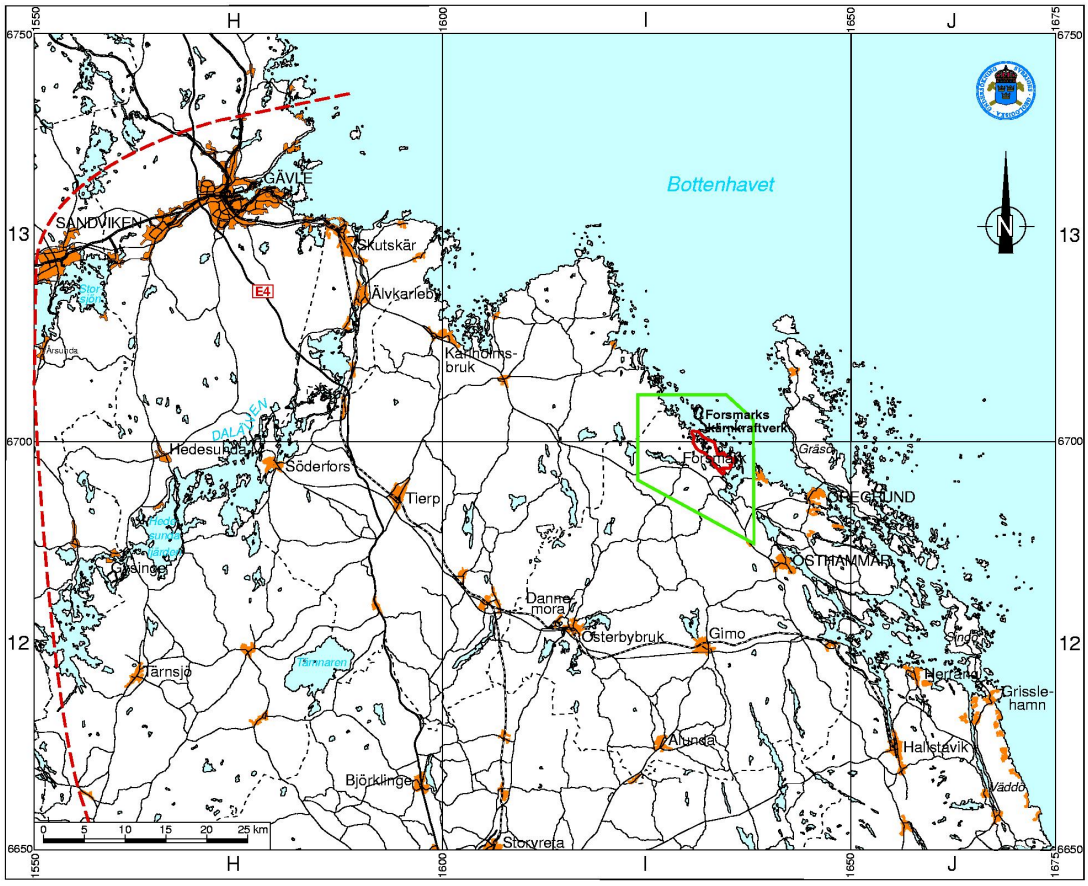

Figure 1-1. *Map of the investigation area in north-eastern Uppland (mainland areas to the east of the stippled red line). A continuous red line marks the candidate area for detailed site investigations and the green line marks the area covered by low-altitude aerial photographs.*

2 Objective and scope

The study aims to elucidate whether any major late- or post-glacial faulting has occurred in the proposed repository area in Forsmark or in its vicinity. “Major faulting” in this context means dislocations in the order of several metres along faults of several kilometres length. Faults of these dimensions may, if conditions are favourable, be detected by means of air-photo interpretation. The process of dislocation may have been associated with high magnitude earthquakes which may produce characteristic distortions in water-saturated sandy or silty sediments. Thus, fault movements may be indicated either directly by distinct dislocations manifested in the bedrock surface or covering regolith, or indirectly, by seismically derived deformations of certain types of Quaternary sediments. If late- or post-glacial fault movement is indicated and assigned to a specific fault or fault zone, the event should, as far as possible, be dated and fault displacement be quantified.

3 Equipment

3.1 Description of equipment

Air-photo interpretation is performed in a Wild Aviopret stereoscope (Figure 3-1) using IR-images at the scale of 1:30 000 (1:15 000 within the site-investigation area).

Excavators capable of cutting trenches to a depth of about 5 m are used for stratigraphical work (Figure 3-2). Trench walls are cleaned manually by shovels, scrapers, etc and are then documented in sketches and photographs.

GPS (hand-held) is used for positioning in terrain where orientation by map is difficult.

Figures 3-1 and 3-2. *Air-photo interpretation and stratigraphical investigations in achine-cut trenches are the most important steps in the investigation.*

4 Execution

The study includes several steps according to SKB MD 133.001.

- A brief review of geological literature and other relevant information from the investigation area. Any information that may indicate recent faulting or earthquakes is recorded for later following-up in the field.
- Air-photo interpretation. Any indications of recent faulting or earthquakes (landslides etc) are recorded for later following-up in the field. Gravel- and sand-pits are marked out on maps for later examination in the field.
- Field reconnaissance. Any indications of recent faulting or earthquakes recorded during the literature study or air photo interpretation are checked. Stratigraphies in gravel- and sand-pits in operation, temporary road cuttings etc are examined for any seismically induced distortions. Bedrock exposures in parts of the coastal areas are inspected for any fault-related displacements in the glacially polished rock surface (Figure 4-1).
- Stratigraphical investigations in machine-cut trenches, mainly dug in sediments of favourable composition for developing earthquake-induced liquefaction phenomena.

Figure 4-1. *Reconnaissance by boat in the archipelago offers good possibilities for detecting minor post-glacial displacements in the glacially polished bedrock surface. As the outcrops along the shores are recently raised above the sea they are not significantly weathered and they are often free from lichens, mosses or any other vegetation.*

4.1 Preparations

Not applicable.

4.2 Execution of tests/measurements

Not applicable.

4.3 Data handling

The positions of stratigraphical observations, geological observations, photos, etc were determined by GPS or topographical maps. The dates of the observations were notified and they were all given PFM numbers. All points and dates were later stored in SICADA under field note nr 38. The geological information connected to the PFM numbers was stored in SGUs database (Jorddagboken version 5.4.3). Data from the SGU database was exported to Excel files and JPG files (see CD).

The deliverance to SKB from the investigations carried-out during 2002 consists of:

1. Data files with stratigraphical and other geological information.

   SKB_PFM_NEO030429.xls

2. Data files with photos and sketches.

   PFM003684_A–PFM003735_I (33 photos), Foton.jpg

   PFM003735_S1– PFM003735_S11 (11 sketches), Skisser.jpg

3. Topographical maps indicating routes and points of observation from the reconnaissance by boat in the archipelago.

4.4 Analyses and interpretation

Not applicable.

5 Results

In the reviewed literature, primarily descriptions relating to the maps of Quaternary Deposits in SGU series Ae and Aa, observations of disturbed Quaternary stratigraphies are described from about 10 localities. The types of disturbances described range from faulted deposits in the Börstil esker /Persson, 1985/ to more plastic deformational structures in glacial silt and clay /Ericsson and Lidén, 1988; Grånäs, 1985; Sandegren et al, 1939; Sandegren and Asklund, 1948, Sandegren and Lundegårdh, 1949/. However, the deformations described are not considered to be of seismic origin but caused by glaciotectonics or processes related to land-upheaval. Sandegren, for example, explained the abundance of contorted clay sequences along the eskers in the Gävle-Sandviken region as an effect of glaciotectonic deformation underneath a re-advancing ice sheet.

The gravel-pit with the fault described by /Persson, 1985/ is today restored (no longer in operation). However, in another gravel-pit situated ca 1 km to the south along the Börstil esker, a more or less vertical fault was encountered. The nature of the fault is uncertain, but is not regarded to be of seismic origin. Till overlaying glaciofluvial sediments were observed in the sequence and a glaciotectonic origin of the fault cannot be ruled out. No sections with contorted clay sequences similar to those described by Sandegren were encountered during the survey in 2002.

/Agrell, 1981/ and /Persson, 1990/ describe a so-called boulder-cave named Gillbergagrytet in the south-western part of map sheet 11J Grisslehamn SV. The authors have different opinions regarding the nature of the cave formation. Agrell suggests a neotectonic event while Persson favours a glaciotectonic origin. A field inspection showed that sharp-edged boulders were transported a short distance to the south-east of the cave, i.e. in the dominating ice flow direction. It therefore seems likely that the formation is of glaciotectonic origin, as suggested by Persson.

The entire investigation area (Figure 1-1) has been air-photo interpreted. A number (35) of fairly pregnant escarpments and crevasses were noted and most of them were later field-checked. These candidates for young fault movement turned out to be more or less strongly glacially eroded, i.e. not late- or post-glacial in age. No landslides were observed but are perhaps not either to be expected in the relatively flat terrain.

In all, about 40 gravel- and sandpits were visited. Of these, 11 displayed sandy-silty deposits regarded as susceptible to seismically induced liquefaction, but no major distortions were notified. Strongly contorted and folded sequences of glacial clay were encountered at several localities, but the deformations are interpreted as a result of sliding. A seismic origin of the sliding cannot be excluded but no conclusive evidence for this was found. At a few localities, thin sandy-gravelly beds with a tendency to graded bedding intercalated clay sequences. The origin of these sandy-gravelly beds is uncertain, but they may possibly represent deposits from short-lived currents at the bottom of the ancient sea.

In spite of a rather extensive surveying of glacially polished bedrock exposures in the archipelago, no dislocations indicating minor post-glacial fault movements were found.

An 80 m long trench in sandy, silty and clayey sediments was excavated on the eastern flank of the Börstil esker. Although the stratigraphy, including a several metre thick bed of coarse silt covered by glacial clay, offers favourable conditions for development of liquefaction if affected by earthquake vibrations in a water-saturated state, no signs of such features were found. On the other hand, deformations of the primary sedimentary structures caused by dropstones and sliding occurred frequently. The sliding of clay may hypothetically be seismically triggered, but might also be a result of purely gravitational forces as the trench was cut in slightly inclined ground.

5.1 Discussion

The nature of the investigations performed during 2002 was principally probing, but was brief and incomplete if compared with the intentions laid out in SKB MD 133.001.

Due to great difficulty in getting access to appropriate sites for excavation, only one trench of some length was dug instead of four or five according to the Activity plan. For 2003 about 10–15 trenches, distributed as evenly as possible over the investigation area, are planned.

As mentioned above, no distinct indications of late- or post-glacial faulting have appeared so far, but it should be strongly stressed that the investigations are still in their beginning, and the most crucial test, the search for seismically generated distortions in strategically located trenches, remains to be done. Until then, it is not possible to make any diagnosis of whether or not any major recent faulting has occurred within the region.

It should also be stressed that water-saturated deposits are a prerequisite for the development of liquefaction phenomena and, therefore, a sandy-silty stratigraphy cannot register an earthquake after it was raised above the sea or the ground-water table. This implicates that even major earthquakes may be very difficult to identify if they occurred very late in post-glacial times.

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