6 Geology

6.1 Introduction

Geological rock type mapping has been carried out across the project area at various scales. The bedrock geology relevant to the project area is presented in the following sequence:

Regional scale

The results of Regional scale mapping, included in the present report, are based on selected text and figures from SKB's recent site descriptive modelling work and have been extracted from the Simpevarp – site descriptive model version 0 report /SKB, 2002/.

Local Scale

The results of lithological mapping at a local scale, covering the Simpevarp peninsula and the island of Ävrö, are based on original work by /Kornfält and Wikman, 1987a,b/.

Site Scale

Lithological mapping has been carried out at a more detailed site scale. For example, mapping of the excavated caverns and tunnels of the O1–O3 power plants and CLAB storage site. Whilst this mapping work provides an incomplete coverage of the project area, it does provide an indication of the variability within the rock mass that is inevitably masked when only considering the regional scale. The graphical results from lithological mapping of CLAB 2 are included in the present report as an example. Complete mapping results from CLAB 2 can be found in TP-01-02 (ID14).

6.2 Regional – the Simpevarp regional model area

The Simpevarp regional model area in southeastern Sweden forms part of an area of Precambrian crystalline rocks, referred to as the Fennoscandian Shield. Simpevarp lies within a major geological province within the shield, which extends from the Loftahammar area in the north to Blekinge in the south, and from coastal areas in the east to the area south of lake Vättern in the west. Deformation zones with NW to E-W strike form the boundaries to this province, both to the north and to the south (see Figure 6-1). Furthermore, the western boundary of the province is defined by the network of deformation zones with N-S strike, which form the eastern, frontal part of the Sveconorwegian orogenic belt (Figure 6-1). Major deformation zones also occur within the province, in particular in the area west of Oskarshamn.

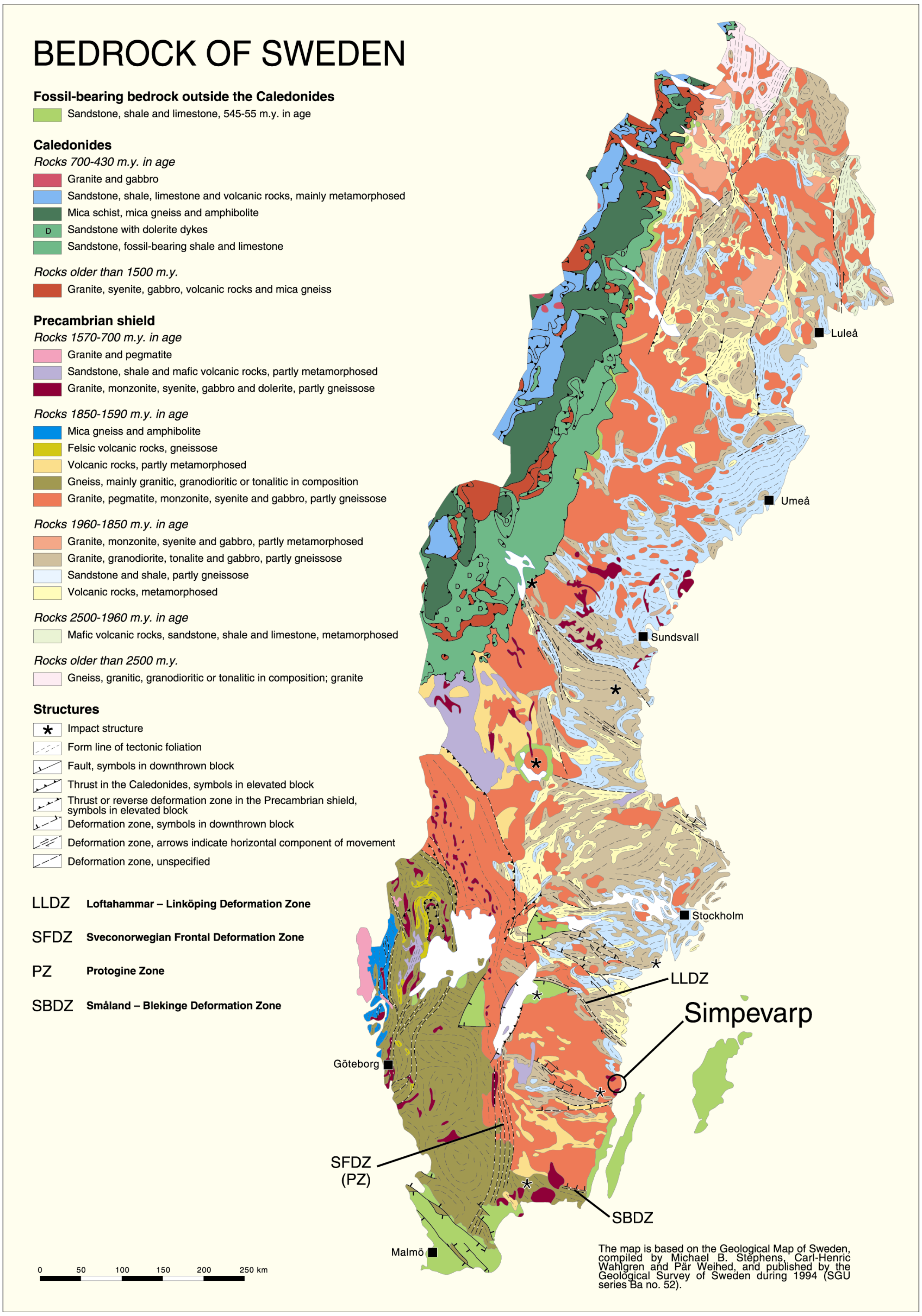

Figure 6-1. *Simplified map of the bedrock geology of Sweden. The position of the Simpevarp regional model area is shown. The geological province in which the Simpevarp area lies is bounded by major deformation zones along its northern (LLDZ), southern (SBDZ) and western (SFDZ) boundaries (for explanation, see text). TIB = Transscandinavian Igneous Belt. In southeastern Sweden, the TIB rocks vary in age from ca 1,850 to 1,770 million years. In the regional model area, the rocks belonging to this belt formed ca 1,800 million years ago.*

The province is dominated by volcanic and intrusive igneous rocks, which vary in age from ca 1,850 to 1,770 million years and which are included in the so-called Transscandinavian Igneous Belt (Figure 6-1).

In accordance with other Precambrian areas, the Fennoscandian Shield is transected, by a complex network of brittle-ductile and brittle fracture zones which initiated their development after ca 1,700 million years ago. Locally, it has been shown that individual zones were active at different times after ca 1,700 million years ago. The Simpevarp regional model area was affected by glacial activity during the Quaternary period (1,635–0 million years). Only the effects of the Weichselian glaciation, which started to affect Swedish latitudes ca 115,000 years ago, and the post-Weichselian development during the latest ca 12,500 years, are preserved in the Simpevarp area.

6.2.1 Rock type – distribution, description and age

The supracrustal rocks are dominated by a grey, fine-grained metavolcanic rock which displays an intermediate, dacitic to andesitic composition /Wikman and Kornfält, 1995/. Although being relatively pristine in character, the prefix "meta" is applied, since the rock is more or less recrystallized, presumably due to a thermal effect from surrounding intrusions. A thermal overprinting is also indicated by the local occurrence of small garnets. Apart from scattered occurrences, mainly as xenoliths of varying size, the extension of the metavolcanic rock is mainly restricted to the Simpevarp peninsula proper. However, this rock type is also present on the Ävrö and Äspö islands. It has not been radiometrically dated, but is interpreted to be more or less coeval with the surrounding intrusive rocks. Furthermore, field relationships as well as mineralogical and chemical compositions suggest that the metavolcanic rock is the extrusive equivalent of, i.e. comagmatic with, the granodioritic to quartz monzodioritic country rock (see below) on the Simpevarp peninsula.

On the Simpevarp peninsula, the metavolcanic rock seldomly forms any larger coherent bodies, but is more or less intimately mixed with the granodiorite to quartz monzodiorite. For this reason, and bearing in mind the scale of presentation in this study (Version 0), the occurrence of the metavolcanic rock has only been symbolized as point information (light green lenses) in Figure 6-2. Consequently, the percentage proportion of the metavolcanic rock throughout the regional model area is difficult to reckon. However, based on results from the field control in connection with the feasibility study, it is estimated to occupy ca 40–50% of the land area in the central parts of the Simpevarp peninsula. In the central part of Ävrö, metavolcanic rock is interpreted to constitute a coherent area, which is estimated to occupy ca 15–20% of the island. On Äspö, metavolcanic rock occupies two minor areas in the eastern central part.

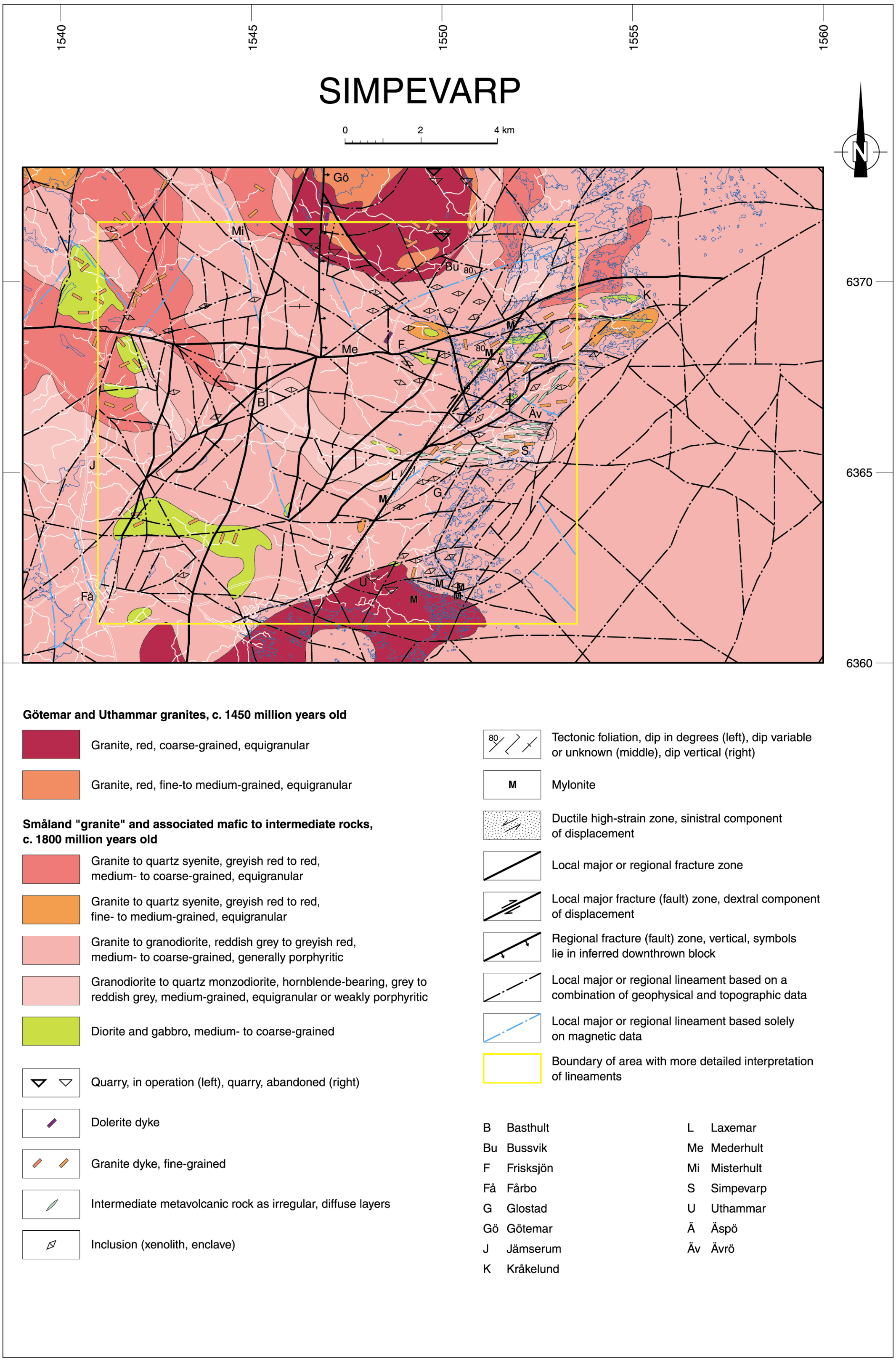

Figure 6-2. *Cartographic model of regional bedrock geology, both land and offshore /SKB, 2002/.*

On the Äspö island, greyish black, fine-grained mafic rocks ("greenstones") have been interpreted to constitute altered volcanic rocks, i.e. basalts /Kornfält and Wikman, 1988/. However, a supracrustal origin for these rocks was questioned by /Wikström, 1989/ who, based on the more or less intimate mixing with various granites, interpreted them as composite dykes which are genetically related to the numerous intrusions in the area. Diorite and gabbro comprise ca 4% of the land in the regional model area. These rock types have, together with unspecified mafic rocks, traditionally been called "greenstones".

The most conspicuous bodies occur in the western part of the area (Figure 6-2). Furthermore, there is a concentration of smaller bodies in the Äspö-Kråkelund area. Diorite and gabbro are usually relatively inhomogeneous in character, and granite dykes and veins occur within them quite frequently. They also display mixing phenomena with the surrounding, more felsic intrusive rocks, which indicate that they belong to the same magmatic generation. Apart from the bodies, which are marked in Figure 6-2, xenoliths, enclaves and minor bodies of diorite and gabbro, as well as unspecified mafic rocks, occur more or less commonly in the surrounding more felsic intrusive rocks. The locally complex and intimate mixture of these rock components is also evident from the documentation of rock types in, for example, the two cored boreholes KLX01 and KLX02 /Ekman, 2001/.

The dominant rock type in the regional model area is what has traditionally been called Småland "granite". In spite of this name, it comprises a variety of rock types (Figure 6-3), which together make up ca 85% of the land in the regional model area.

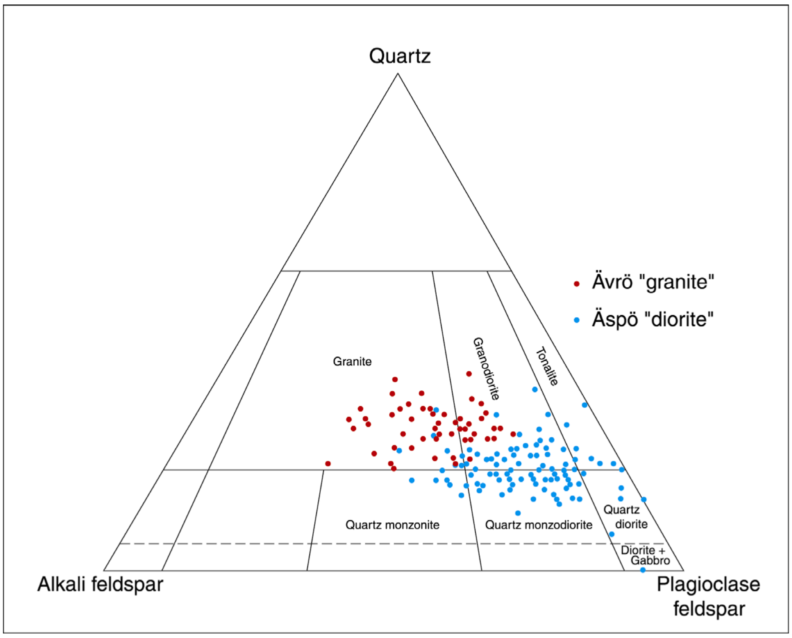

Figure 6-3. *Modal compositional variation of the Småland 'granites'. Based on Figures 3-13 and 3-14 in /Wikman and Kornfält, 1995/.*

6.2.2 Inhomogeneities including inclusions and dykes

Bedrock inhomogeneity can be assessed at different scales. Inspection of the cartographic 2D model for the surface distribution of rock types (Figure 6-2) indicates that, apart from the central coastal area, the regional model area is characterized by relatively large, homogeneous and uniform areas composed of different varieties of Småland "granite". However, it must be kept in mind that the major part of the regional model area is almost devoid of detailed bedrock information. Thus, the impression of differences in the degree of inhomogeneity within the model area is misleading. An attempt was made in the feasibility study to assess the variation in bedrock inhomogeneity on the more detailed, centimetre to several hundreds metre scale /Bergman et al, 2000/. Documentation of the occurrence of three types of bedrock inhomogeneity were carried out:

- Inclusions in intrusive rocks, including both xenoliths and enclaves.
- Granite, pegmatite and aplite dykes and minor intrusions.
- Dolerite dykes.

As mentioned above, inhomogeneous bedrock is indicated in the central coastal area, from the Simpevarp peninsula in the south to Bussvik in the north, including the Äspö and Ävrö islands (Figure 6-2). The inhomogeneity is based on the numerous, fine- to medium-grained granite dykes and/or inclusions of various rock types that have been documented /Kornfält and Wikman, 1987a,b, 1988/, and on the Simpevarp peninsula, also the high proportion of intermingled metavolcanic rock. However, results from the field control work revealed that granite dykes also constitute an equally important inhomogeneity factor in the remaining part of the area that was chosen for field control (cf Figure 10 in /Bergman et al, 2000/). Thus, the degree of inhomogeneity, where it concerns the amount of granite dykes, is inferred to be more or less similar throughout the regional model area. Apart from granite dykes, inclusions and lenses of diorite and gabbro, as well as unspecified rock types, have been documented during the field control work.

It is obvious from the detailed maps at the scale 1:10,000 that cover the Simpevarp peninsula, Ävrö, Äspö, etc /Kornfält and Wikman, 1987a,b, 1988/, that the high amount of inclusions and granite dykes is an important inhomogeneity factor that has to be seriously considered in future work. This phenomenon is also evident from the documentation of the rock types in, for example, the cored boreholes KLX01 and KLX02 /Ekman, 2001/.

Due to the necessary regional scale of the recent Version 0 modelling work neither the local minor to local major fracture zones in the Äspö-Ävrö area, nor the various tectonic models for these structures, e.g. /Markström et al, 2001/, were addressed and integrated.

6.2.3 Age of ductile deformation

There are no direct data available which determine the timing of the ductile deformation in the Simpevarp regional model area. However, the maximum age is ca 1,800 Ma, since the ductile high-strain zones have affected the different varieties of the Småland "granites". Deformation under ductile conditions is tentatively inferred to have waned gradually in the time interval ca 1,800–1,750 Ma, during the later part of the Svecokarelian orogeny.

6.2.4 Bedrock fractures

Detailed mapping of bedrock fractures in the eastern central part of the land area /Ericsson, 1987/ has shown that the bedrock is affected by different sets of fractures, the orientation of which resembles the orientation of the lineaments in the regional model area. This has also been confirmed within the Laxemar model area /Andersson et al, 2002b/ by a comparison between bedrock fracture orientations /Ericsson, 1987/ and local major and regional lineaments using discrete fracture network (DFN) analysis. These analyses provide support to the hypothesis that the lineaments presented here in Figure 6-2 are possible local major or regional fracture zones. The properties of fractures in different rock types are described in /Ericsson, 1987/ and /Munier, 1995/.

6.3 Local – the geology of Simpevarp peninsula

6.3.1 Quaternary deposits

The local topography is gently undulating with extensive rock outcrop with an elevation of ca 10 masl. The bedrock is exposed or, for the main part, only thinly covered by soil (< 0.5 m). However, in local depressions soil cover may reach a depth of 5–10 m. The dominating soil type is moraine.

6.3.2 Rock types

Figure 6-4 shows the distribution of lithologies over the Simpevarp peninsula. The rock types present are members of the so-called Småland-Värmland intrusions. The series is ca 1,700–1,800 million years old and dominated by granites and related metavolcanites (porfyr). As can be seen on the map, granite dominates the most northerly and southerly sections of the peninsula whilst the central section of the peninsula, where most of the excavation works have been carried out, is dominated by metavolcanite, with intrusions of fine grained granite (aplite) and greenstone.

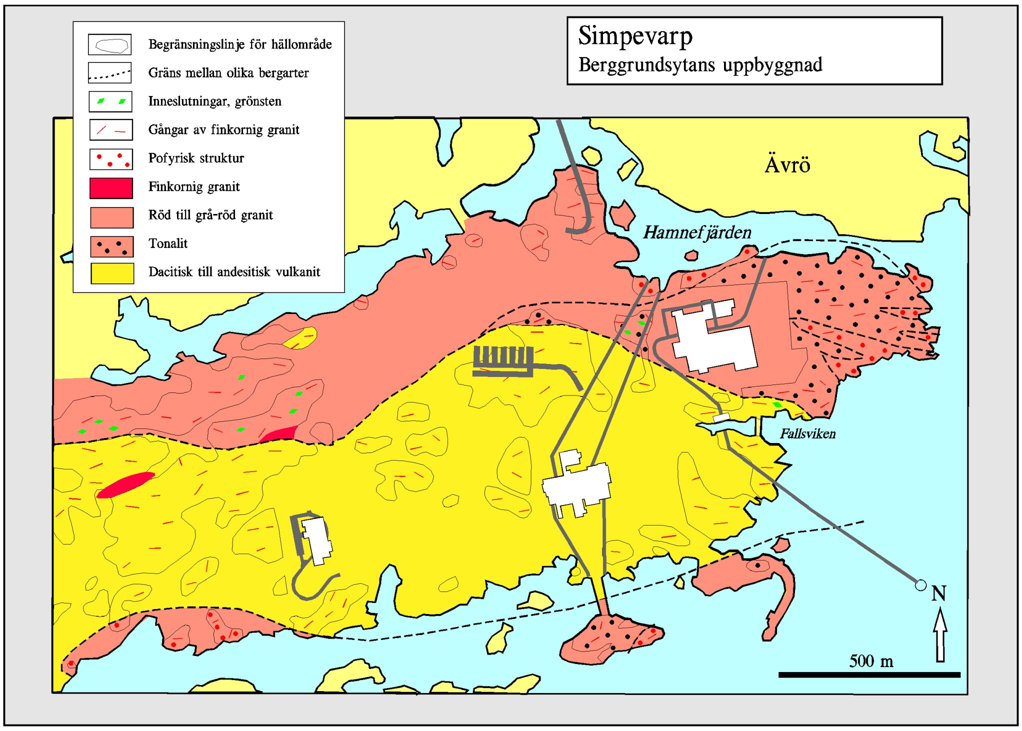

Figure 6-4. *Bedrock Geology on Simpevarp peninsula, after Kornfält and Wikman.*

Granite (Smålands granite)

This group contains a number of granitic rock types from typical granites to more basic granodiorites and tonalities. /Svedmark, 1904/ refers to the tonalitie as hornblendgranite on his map. The typical Småland granite present in the area can be described as medium grained, red-grey rock with a weak foliation. Porphyritic texture is common. In the NE part of the area the hornblende rich, grey tonalite is present. The tonalite often contains xenoliths (inclusions) of older rock fragments.

Metavolcanite

The metavolcanites found on the peninsula consist of altered grey to greyish black fine-grained rocks of volcanic origin that can be generally termed dacites and andesites. The metavolcanite has been intruded to such an extent by Småland granite that it has recrystalized and has itself developed a more granitic structure. For the most part the area identified as metavolcanite on the map can best be described as a mixed rock type of granite and metavolcanite.

Greenstone

This group contains a number of older basic rock types, which are rarely found on the peninsula as xenoliths (inclusions) in granite or tonalite.

Fine grained granite

Red-greyish red, fine-grained granite occurs throughout the peninsula, occasionally as small equidimensional bodies but more commonly as irregular dykes and veins in the older rockmass. The dykes and veins often run parallel with the foliation in a general E-W to NE direction.

6.4 Local – the geology of the island of Ävrö

Detailed field mapping of rock exposures was carried out in 1987 /Kornfält and Wikman, 1987a,b/.

The dominating rock type on the island is medium grained grey-red granite. Through the centre of the island runs a band of metavulcanite with a general NE strike. The metavolcanite is grey and in general finer grained than the surrounding granite. Along the island's SE and W coasts can be found smaller outcrops of greenstone. Associated with the main metavulcanite are found disk shaped xenoliths (inclusions) of fine-grained basic or volcanic rock types. These type of inclusions were also intercepted by drillhole KAV 01.

The youngest rock type on Ävrö, is pegmatite (coarse grained granitic rock type) and aplite (fine grained granitic rock type). These occur in the form of thin dykes striking NE to ENE.

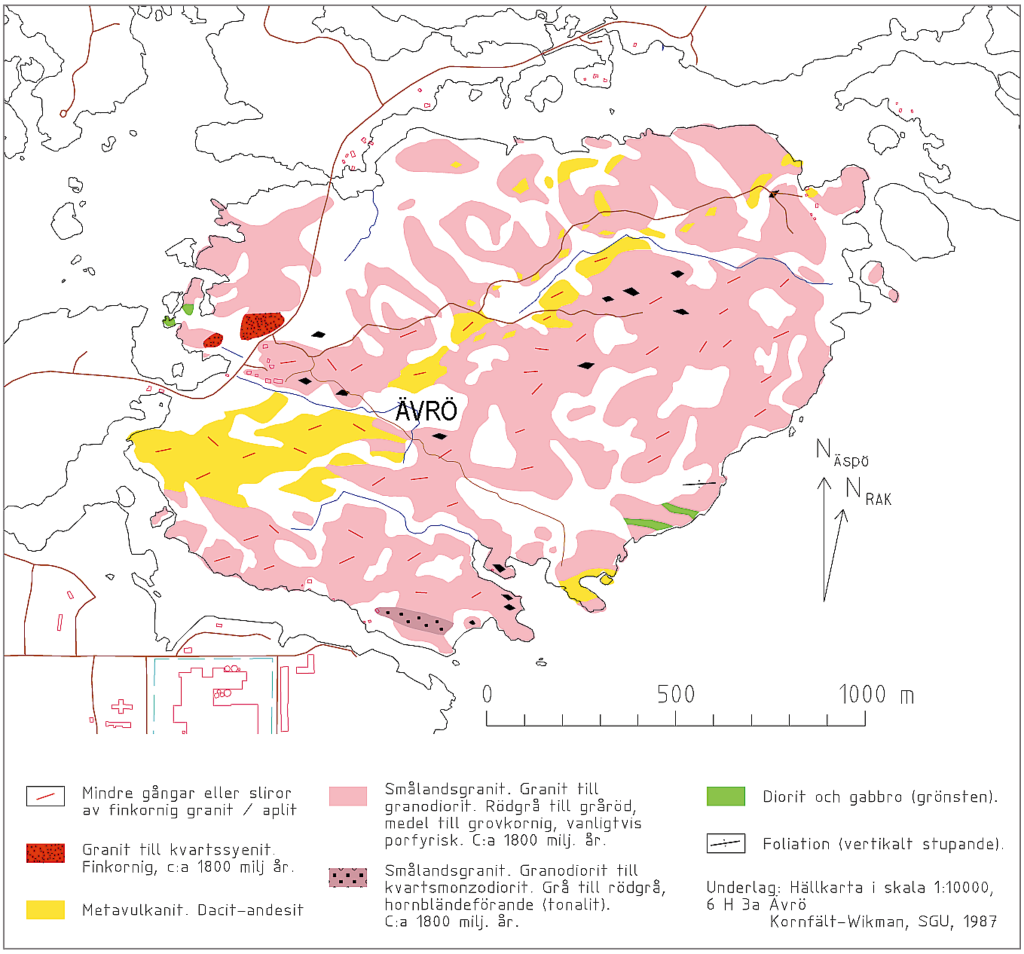

__Figure 6-5.__ Bedrock Geology on Ävrö island, after Kornfält and Wikman.

In summary it can be said that the rock mass in the area of Ävrö is relatively inhomogeneous. However, the bedrock can be described as fairly massive without any strongly developed foliation. The weak foliation when present is orientated ENE-NE, which coincides with the main foliation found across the Simpevarp region.

6.5 Site scale – CLAB 2 geology

The rock types in the area of the Simpevarp peninsula are generally homogenous over large areas, but locally around CLAB greater variation has been found with numerous dykes. The degree of schistosity is very variable and there have occurred numerous different types and generations of alteration.

The fracture frequency can in general terms be correlated with rock type. The granite, consisting of granite to quartz monzonite, has a typical block size of 1–3 m^3. Whereas the dyke rocks, principally the red granite dykes, aplite, pegmatite and fine-grained volcanite are more fractured having RQD values of ca 50% and a block size of ca 1 dm^3.

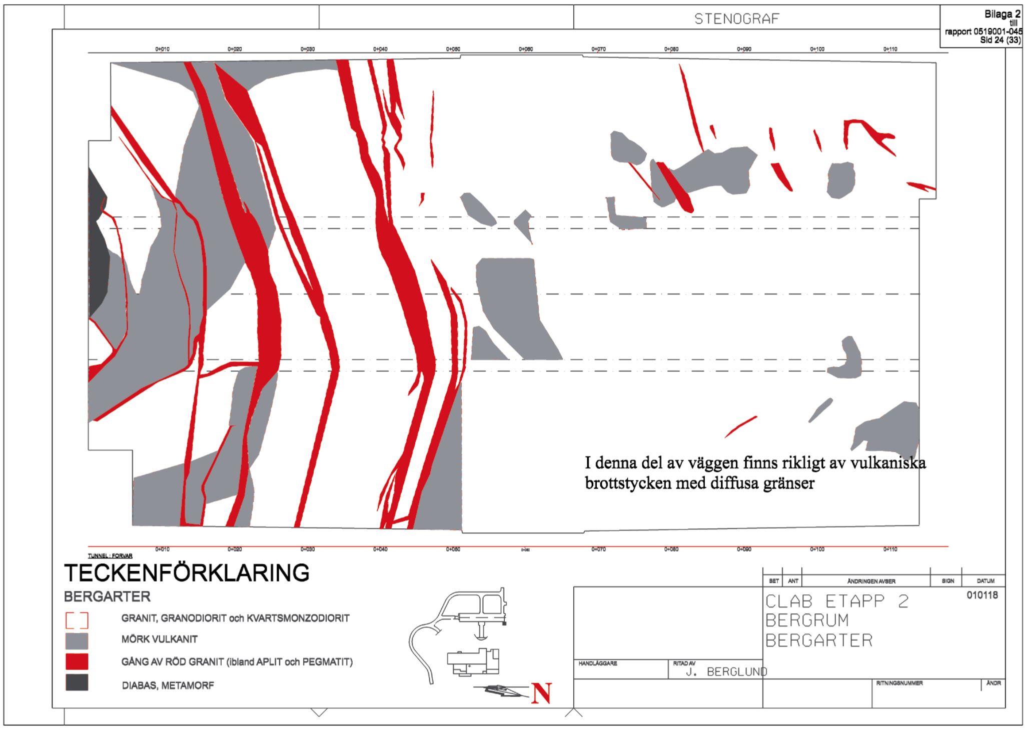

Figure 6-6. *Simplified lithological map of the CLAB 2 cavern. (Roof and walls) after /Berglund, 2001/.*

7 Construction experience

7.1 Oskarshamn nuclear power plant, construction of O1 and O2

The rock excavation work for O1 and O2 consisted of the cooling water tunnels, a number of surface excavations for foundations, culverts, roads and parking areas along with caverns for the intermediate storage of low and medium rated radioactive waste (BFA). The total excavated rock volume is ca 320,000 m^3 of which ca 50,000 m^3 is from the cooling water tunnels and 80,000 m^3 from BFA.

Compared with current standards only very limited documentation was kept during the construction phase as concerns geology and the rock conditions encountered. However, it can be said that no particular difficulties due to rock conditions were encountered during the tunnelling work. Rock support consisted of the installation of rockbolts when certain minor fracture zones were encountered and also occasional spot bolting for isolated blocks. Minor closely jointed or brecciated sections had their surfaces stabilised by shotcrete. The tunnel excavation encountered no significant inflows of water and it can be said that only very minor grouting work was carried out for either O1 or O2.

7.2 BFA

BFA consists of a transport tunnel from the ground surface to the storage level, a loading tunnel and set at right angles, seven short caverns for the storage of low grade radioactive waste and also, parallel with the loading tunnel a long cavern for medium level radioactive waste.

Geological and rock condition documentation from the construction phase of BFA was not maintained. However, it can be said that no problems were encountered with the rock excavation. Although rock conditions were good the storage caverns were supported by one or two layers of shotcrete. Ca 15 litres of water per minute are pumped from the underground facility.

7.3 Construction of O3

Rock excavation consisted of the cooling water tunnels, surface foundations and parking areas. Total rock excavation volume was ca 730,000 m^3, with ca 80,000 m^3 coming from the tunnels. Documentation from the excavation work is more complete than for O1 and O2.

A couple of minor brecciated zones were encountered in the area of the reactor building, however, there were not judged to be of significance for the foundation. Although surface excavation depths reached down to 15 m below sea level the rockmass showed itself to be tight with virtually no inflow of water to the foundation.

The coldwater intake is located ca 500 m off the coast where the water depth is ca 18 m. The advantages in the form of colder water and less chance of ice were judged to be worth the extra cost for the increased tunnel length and necessary intake structure. The intake tunnel consists of two parts; part one between the intake portal and Fallsviken and part two between Fallsviken and the reactor. The inner part of Fallsviken is isolated from the sea by a watertight dam in order to provide a surge basin effect.

The outfall is situated in Hammnefjärden ca 300 m east of the outfall from O2. An emergency coldwater tunnel links the reactor with the intake and tailrace tunnels.

Preliminary investigations for the tunnels consisted of seismic refraction surveys and spot checks on the rockhead depth at the intake area in order to identify any major fracture zones. No major fracture zones had been encountered during the previous O1 and O2 excavation work and none were identified by the seismic surveying.

7.3.1 Intake tunnel part 1

All blasting and rock support for the intake tunnel and preparation work for the deepwater intake itself was carried out in dry rock conditions from within the tunnel. Tunnel driving commenced from a portal site at Fallsviken protected by a cofferdam. The deepwater intake was excavated from within the tunnel. A ca 6 m rockplug was left to the seafloor. A ca 4 m thick sediment layer was removed from the seafloor. The rock plug was drilled and loaded from within the tunnel. The tunnel-shaft invert was over excavated to allow for the increased volume of rock from the final blast. The tunnel was flooded prior to blasting.

Out from the coastline investigation holes were drilled from the advancing tunnel face. The holes were drilled in pairs, 30 m long directed ahead and above the face with the aim of identifying potential weakness zones, allowing grouting ahead of the tunnel face if necessary and confirming minimum rock cover was available to the tunnel crown.

Advance grouting was carried out in three sections:

1. curtain grouting in a fracture zone ca 100 m from the coast.
2. curtain grouting in an area with gouge filled fractures ca 250 m from the coast.
3. a series of seven grout curtains from the tunnel’s last 100 m, towards the intake, as well as a further two after excavation.

The aim of the third series was to ensure a tight tunnel crown due to concerns about the limited rock cover in this section (ca 15 m) Investigations indicated a weakness zone occurred ca 400 m from the coastline. A 70 m long corehole was drilled from the face towards the intake. The fracture frequency was high to very high for the first 60 m with numerous, occasionally weathered, brecciated zones. However, the rock was generally fresh between such zones. In the last 10 m the rock quality was better.

Tunnel excavation through the zones was achieved without any special difficulty due to the pregrouting and the timely installation of temporary support in the form of shotcrete after every round. At a later stage ca 20 m length of the tunnel was given additional support of 150–250 mm thick layer of fibre-reinforced shotcrete. In the rest of the tunnel, including the section under the land, one or two layers of shotcrete were applied to ca 50% of the roof and 25% of the wall surfaces. The need for rock bolting was minimal, with a general frequency of 1 bolt per m of tunnel.

Towards the intake location, where there was less rock cover, additional grouting was carried out. Additionally, 10 vertical cored holes were drilled from the tunnel roof up to the rock surface in order to locate the best position for the shaft. The investigations led to the shaft position being moved some 20 m further from the coast.

An extensive grouting and rock support program was carried out to ensure the stability of the shaft. This included over 200 grouting holes and 50 tonnes of cement compared with a total figure of 85 tonnes for the entire tunnel grouting works. It should be noted that the majority of the grout injected around the shaft location was probably lost through surface fractures to the overlying sediment.

7.3.2 Other cooling water tunnels

The tunnelling work for O3 was carried out without any significant problems.
The tunnels were practically dry. Around 70% of the roof and 50% of the walls are reinforced with shotcrete, mainly at the portals and in connection to the reactor.

A steeply dipping chlorite-clay gouge filled fracture zone, with a width of up to 50 cm, runs along the tailrace tunnel roof from the turbine building until a change in the tunnel alignment. The zone has an east-west strike and cuts both the foundation of the turbine building and the intake tunnel (part two). Consequently it has a length of over 300 m but was too narrow to be identified by the seismic survey work. Along this section the tunnel roof was supported with fibre-reinforced shotcrete partly due to the presence of the fracture zone and partly due to the reduced rock cover over the crown and proximity to the buildings.

7.4 CLAB 1

Preliminary investigations were carried out in 1978 and 1979 in connection with the siting exercise for CLAB /Moberg, 1978, 1979/. The investigations confirmed the area’s suitability and formed a basis for the preliminary design work.

During the construction phase the following was carried out:

- drilling investigations ahead of the advancing face.
- lithological and fracture mapping.
- geohydrological measurements and assessments from both the excavations and surrounding area.
- drilling investigations in the excavation invert to assess foundation conditions for the cooling tanks.
- documentation of rock support and grouting works.

The majority of the above listed documentation has been compiled by /Eriksson, 1982/. Additional investigations for CLAB 2 were carried out during 1995–1997 /Stanfors et al, 1998/.

7.4.1 Rock excavation (CLAB 1)

The access tunnel connects with the cavern in three different places at three different levels. At the southern end at roof level, at the elevator shaft at midlevel and at the northern end at floor level. The cavern was excavated in four steps; a top heading followed by two side stopes and finally three benches down to the final invert level. Excavation of the cavern and crosscutting tunnel's roof section began at the southern end. The top bench was excavated via the crosscutting tunnel and the other two benches via the northern tunnel entrance to the cavern.

Dripping or running water was encountered at ca twenty locations along the access tunnel, pre-grouting was carried out at every location, ca 100 m south of the cavern's southern face and post-grouting was carried out in the zone immediately to the south of the same face. Continual pregrouting was carried out in the cavern and cross tunnel walls and roof. Water inflow to the finished tunnel and cavern was relatively low. At commissioning, 1985, total inflow was measured as 60 l/min, which after 12 years operation, had reduced to 40 l/min.

7.4.2 Rock reinforcement

The access tunnel's roof and 40% of the walls were reinforced with 50 mm shotcrete, partly to increase the factor of safety and partly to reduce the need for future maintenance scaling work. Pattern bolting was carried out in the roof at weakness zones and also occasional spot bolting. In total, 200 bolts were installed in a 500 m length of tunnel.

An extremely high factor of safety was set for the cavern rock support. The cavern roof is supported by 100 mm reinforced shotcrete and systematic bolting consisting of 26 mm threaded bolts with end plates and four bolts per square metre. The walls are reinforced with 50 mm unreinforced shotcrete. Cast in situ concrete pillars were constructed in each corner at the junction between the cavern and the cross cutting tunnel. In addition reinforced shotcrete and pattern bolting were used in the roof between the pillars. No such additional reinforcement was carried out in the remainder of the cavern roof since no weakness zones were identified. A large number of bolts were also installed in the walls since a large number of fractures were found to run parallel with the cavern walls. Due to the height of the walls 6 m bolts were used. Where unfavourable joint orientations were encountered 8 m bolts were used. In total ca 2,500 bolts were placed in the cavern and crosscutting tunnel.

7.5 CLAB 2

The excavation for CLAB 2 began in January 1999 and was completed in October 2000. The excavation work proceeded through to completion without any significant problems due rock conditions occurring. Fractures are common and are often filled by chlorite with a lower strength than the intact rock. This made blasting and mucking out straightforward. Two water bearing shear zones, identified on the ground surface, were penetrated by the excavation work. Both were foreseen and dealt with by pre and post grouting, and increased levels of temporary and permanent support. In the canal tunnel (east) towards CLAB 1 extra bolting was required in the northerly wall due to closely jointed rock with chlorite filled fractures dipping steeply towards the canal tunnel.

Water inflow to CLAB 2 amounts to approximately 10–15 l/min (winter 2000) with 40–50 l/min for the CLAB facility as a whole.

In general, the rockmass encountered in the excavation has a high density of fractures. This is most true along the boundaries of the volcanite where RQD values of 50% are common. In the granite RQD values are generally over 60% and normally as high as 80–90%. There are 3–5 joint groups. As well as the previously mentioned pair of water bearing shear zones, there also exist a number of thinner deformation zones, which were dry or nearly so. Joint infillings are dominated by chlorite followed by calcite. Quartz, epidote and other minerals are less common. Clay layers (ca 1–20 mm) occur in the two larger shear zones but otherwise are only very minor and rare.

The rock mass encountered in CLAB 2 is generally of good quality. Poor rock as defined by the Q system was only found in connection with the shear zones, which cross the cavern, canal tunnel and transport tunnels.

8 Data selection

8.1 Identification of objects among old data

SKB had conducted an inventory of old data from the Simpevarp peninsula during the early planning phase of the Site Investigation. This included 778 “objects”. Data have been produced during the investigation and construction of:

- Units O1 and O2.
- Unit 3.
- CLAB 1.
- CLAB 2.

In addition, data has been collected for other projects, especially early phases of the Swedish program for general understanding (70th, 80th), and for early screening of siting of the Final Repository for Low and Intermediate reactor waste. Many studies related to the Äspö HRL have also been carried out.

The following selection has been made:

- All data related from the Äspö program, testing of geophysical methods etc have been excluded. The results are all in SKB reports, and should be available elsewhere.
- The inventory list could after that be sorted on “Objects”, focus on the facilities, and the early screening investigation projects.
- The inventory had “Priority” and “Preliminary evaluation (of the value of the information)”. These where used for the next level of sorting data.

This sorting limited the total amount of data to 75 objects. After that a manual sorting was done, based on the given information. The priority ranking focused on during what phase of an investigation data was collected. There are two major sources of valuable information; the final summary of results before a decision on investment in any of the project, and the final documentation, especially from completed tunnels. In addition, it was noticed that there could be two additional types of site investigation reports with valuable information; early screening of an area, with for example seismic profiles and late additional investigations with focus of any tentative problem prior to, or during the site investigations. The list was sent on review to Hans Isaksson, who had carried out the inventory, Roy Stanfors and Carl-Henric Wahlgren. They added some objects. This resulted in a total of 28 objects.

The actual work started with collecting copies of all reports. During research in private files additional 18 reports of importance were identified. These were not on the original list with 778 objects.

A list including all the references referred to in the current project can be found in Appendix I at the end of this report as well as in the relevant data inventory tables presented in Appendices E to H.

The references were examined and drawings considered to contain key information were selected for inclusion in the project database and GIS visualisation. The working method for the processing of the drawings and data is described in Section 9 (description of data capture from figures in report archive hard copy format). However, in summary it can be said that from the drawings, the main lineaments and structures were selected, digitised, input to a GIS format and linked to an existing Excel table with cells that contained relevant descriptive data about the individual structures. Since the figures were to be included in a GIS format, only 2D plan views were selected for inclusion. It is possible to localise cross section views to a plan view but this was not considered worthwhile. However, information from such cross sections was input into the data table.

The selected figures present the position of interpreted deformation zones from a variety of data types either based solely on one type or in combination:

- Topographic indications.
- Marine geophysics.
- Land based geophysics.
- Aerial geophysics.
- Geological outcrop mapping.
- Geological excavation mapping (surface and underground).
- Drillhole indications.

The types of data selected were grouped and are represented with the following different line styles on the drawings.

1 solid red line = mapping on surface or underground

2 red dash dot line = topo and/or geophysical indications supported locally by borehole or mapping evidence

3 red dash thick line = topo and/or geophysical indications – regional scale from Version =0

4 red dash thin line = topo and/or geophysical indications

5 blue line = geophysical profile

6 blue square = geophysical low velocity location

7 green dash dot line = topo and/or geophysical indications supported locally by borehole or mapping evidence (RVS Ävrö model report R-01-06)

8 green dash thin line = topo and/or geophysical indications (RVS Ävrö model report R-01-06)

Line styles included in the figures and listed in the data compilation table Style column (Linked to GIS)

In addition to being differentiated solely on the basis of information type, the data was also further subdivided as follows on the basis of type and general geographical location:

ca,	CLAB, mapping underground
cb,	CLAB, topo and/or geophysical indications supported locally by borehole or mapping evidence
cc,	CLAB, topo and/or geophysical indications – regional scale from Version =0
cd,	CLAB, topo and/or geophysical indications
ce,	CLAB, geophysical profile
cf,	CLAB, geophysical low velocity location
cg,	CLAB, mapping on the surface
äa,	Ävrö-Hålö, mapping underground
äb,	Ävrö-Hålö, topo and/or geophysical indications supported locally by borehole or mapping evidence
äc,	Ävrö-Hålö, topo and/or geophysical indications – regional scale from Version =0
äd,	Ävrö-Hålö, topo and/or geophysical indications
äe,	Ävrö-Hålö, geophysical profile
äf,	Ävrö-Hålö, geophysical low velocity location
äg,	Ävrö-Hålö, topo and/or geophysical indications supported locally by borehole or mapping evidence, (RVS Ävrö model report R-01-06)
äh,	Ävrö-Hålö, topo and/or geophysical indications, (RVS Ävrö model report R-01-06)
äi,	Ävrö-Hålö, mapping on the surface
oa,	OI-III, mapping underground
ob,	OI-III, topo and/or geophysical indications supported locally by borehole or mapping evidence
oc,	OI-III, topo and/or geophysical indications – regional scale from Version =0
od,	OI-III, topo and/or geophysical indications
oe,	OI-III, geophysical profile
of,	OI-III, geophysical low seismic velocity locations
og,	OI-III, mapping on the surface

Codes for data types, data compilation table MI_SELECT column (Linked to GIS)

In this way it is possible to select interpreted deformation zones, based on mapping of underground structures, across the whole project area or only those associated with, for example, CLAB. The most obvious combinations, with consideration being taken to the limiting A4 paper format, have been included in this hard copy report (Figures 9-3 to 9-10).

8.1.1 Geophysical field surveys

Plan views showing the location of geophysical profile field measurements (not the results or interpreted structures themselves) were selected and digitised. However, this type of data has not been fully described and processed in the GIS system. Therefore, the drawings included in the current report, generally only represent 'geophysical survey coverage'. The details of the type of survey e.g. refraction, magnetic, VLF etc are not specified.

8.1.2 Borehole locations

Although borehole locations are included in many of the selected drawings their locations have not been digitised. Instead the borehole locations presented in Appendix A have been taken from SICADA via RVS and not input into the current GIS format. The drillhole logs included in Appendix A have been produced from SKB's WellCad system. Generally speaking the results from borehole data have not been directly examined in the current project since it was considered that such data should be studied in a 3D rather than a 2D environment.

8.2 Object selection and filtering

When all of the digitised objects from the initial set of figure selections were examined together it became clear that filtering of the data was required.

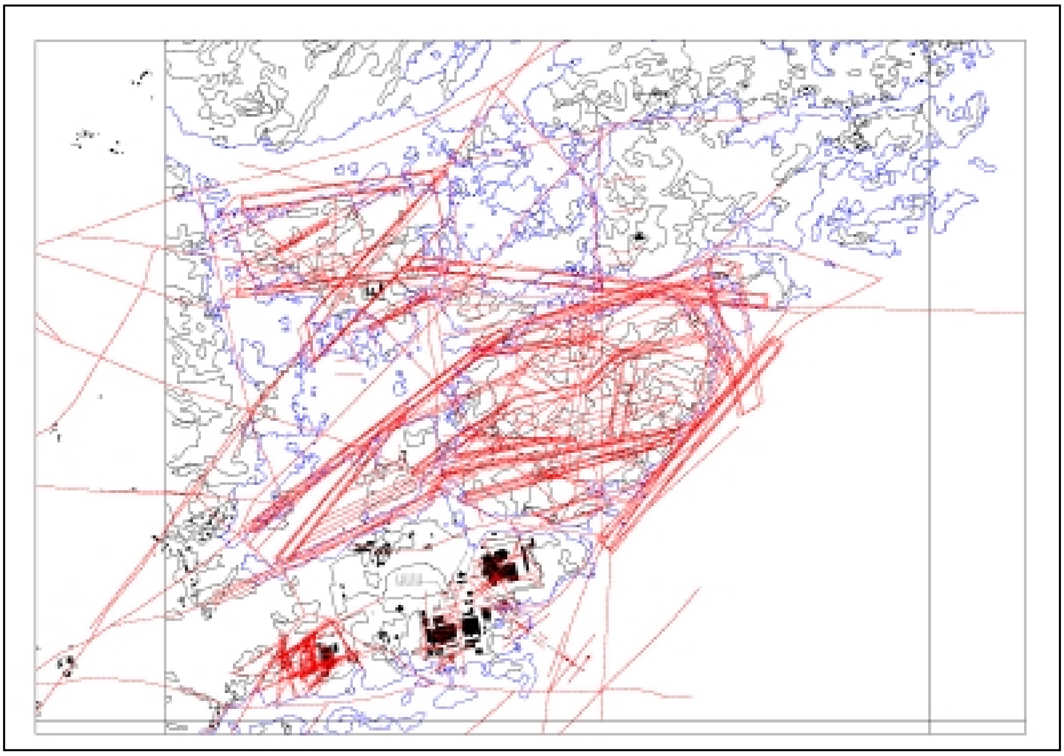

Figure 8-1. *Digitised objects covering the project area prior to filtering.*

The initial selection included a lot of double information with multiple lines having similar orientations and extent, representing the same zone. Some of this double information was clearly due to different degrees of accuracy and scale when plotting the exact same interpretations based on the same data. This meant that it was possible to simply remove some of the lines after checking their source and positional accuracy. In practice this was done by selecting the drawing that was closest to the source data, e.g. geological mapping drawings produced during or on completion, of the major excavation works. However, other apparently double information was due to similar interpretations or conclusions based on different source data, such as different geophysical surveys, tunnel information or drill hole data. In such cases the 'double lines' were left intact.

Only the more significant structures from the geological mapping of excavations were selected. For example, from the CLAB 2 excavation mapping, only the shear zones (marked in black on Figure 8-2) were selected for digitising. Individual fractures and 'fracture groups' were ignored.

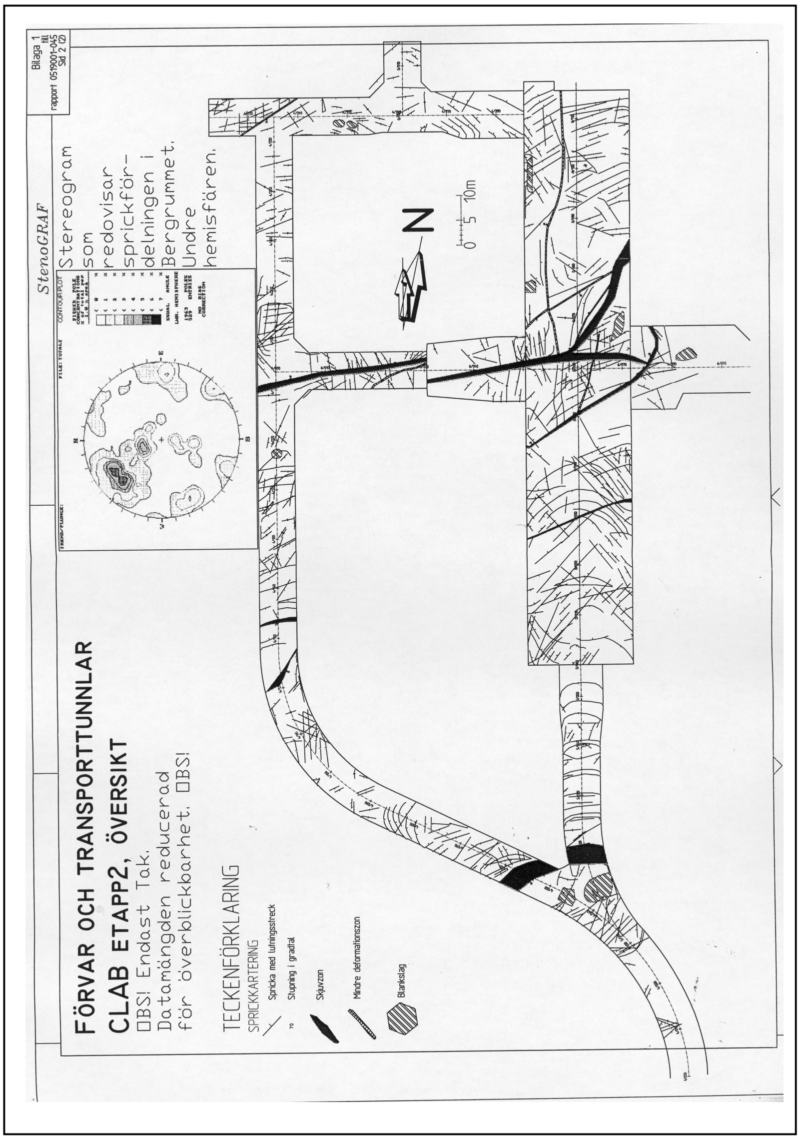

Figure 8-2. *CLAB 2, summary of geological mapping.*

8.3 Limitations and use of the compiled data format

One disadvantage with digitising the interpreted structures and transferring their geometry to another working environment is that they are no longer seen in the context of the data or time that they were produced. Interpreted structures from very different data sources and levels of certainty appear to have equal significance when viewed in a compilation drawing or on the computer screen. For this reason the digitised lines, areas and points representing the interpreted structures should not be used in isolation. In order to assist with a judgement of reliability concerning the original data, the differing types of data have been represented using different colours and lines styles, as previously described above.

In addition, the MapInfo system allows the original scanned images to be linked to the data table and viewed on the screen. The resolution is such that the user can zoom in and check details of the original drawing and maintain a feeling for the type and reliability of the original source data. Even if MapInfo is not available to a user, the scanned images, saved with the appropriate ID numbers, can be supplied on a CD and viewed by most standard viewers.

Figure 8-3. *Digitised figure with zoom window.*

9 Description of data capture from figures in report archive hard copy format

This section presents a short description of how data was captured from hard copy drawings, selected from the archive references, to unique objects in the GIS database. MapInfo Professional v6.5 was used as the GIS tool and Photoshop v7 used for the processing the original drawings. The work has subsequently been converted to SKB's standard ArcGIS V.8 format. The work can be described in the following four steps.

9.1 Scanning and figure processing

The source data for processing consisted of photocopied drawings in A3 or A4 format, which were scanned using an AGFA A3 flatbed scanner. Scanning was carried out using a grey scale with 300 dpi resolution. A number of the original drawings were in A2 or A1 formats and had been photocopied in sections. These sections were scanned and then merged to recreate the original complete drawings again. After such processing all the files were compressed to an ecw format. This format is particularly suitable for use in a GIS environment where both details and the figure as a whole can be handled at the same time while maintaining a reasonable degree of resolution. Every drawing file was given an identification name related to its source reference. Some of the drawings were available in digital format from the beginning.

9.2 Georeferencing

Each selected figure from the references was localised in the RT90 coordinate system by using identifiable location details available on each drawing. The type of available details varied depending on the nature of the original figure. For those figures, covering a major part of the project area, it was possible to use GSD data from the National Land Survey, where such features as the road network or coastline were clearly identifiable and gave a good fit with a high level of confidence. Figures showing geological mapping of the various major excavations on the peninsula were georeferenced using a combination of vector data from SICADA, known tunnel alignments, borehole locations and an existing OKG infrastructure CAD drawing. A number of these type of figures had various difficulties associated with them due to the paucity of clear control points available and were given a lower georeference rating of confidence.

9.3 Digitising

The georeferenced figures were opened in MapInfo and selected objects; lineaments, fracture zones, seismic profiles etc, were screen digitised in the RT90 coordinate system. In this way it was possible to compile all the data into a searchable database with the same master RT90 coordinate system, independent of the coordinate system,

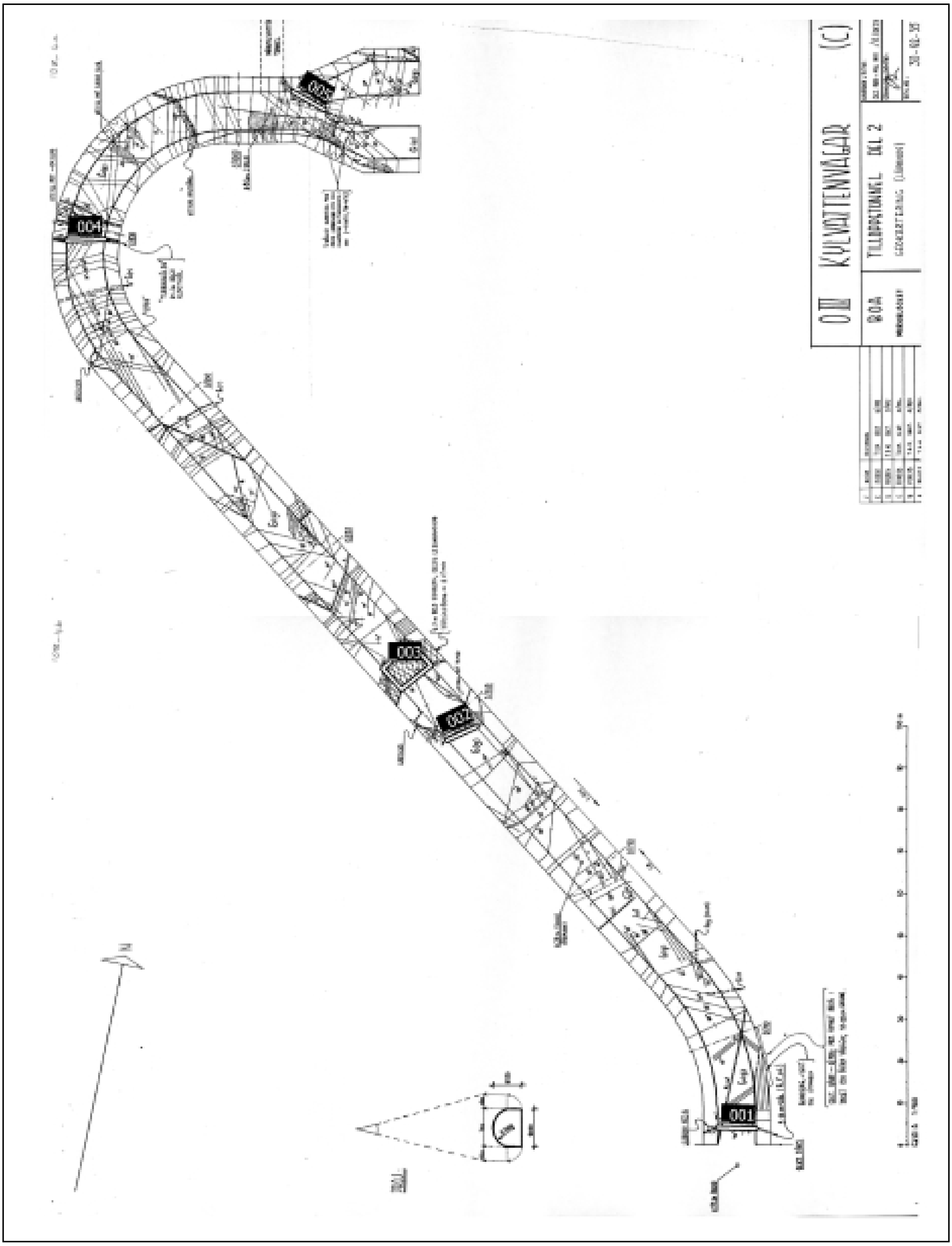

Figure 9-1. *Example: ID8-4, OIII, intake tunnel part 2 geomapping. OIII. Geomapping final report. This figure has been scanned, georeferenced and five structures have been selected and catalogued. These appear as ID 8_4_001 to 8_4_005 in the data tables, each such structure/object is allocated its own row in the datatable where additional information is input.*

scale or orientation of the original drawings. Every digitised object was allocated its own unique ID number linking it to a drawing and source reference. Other attributes which were included in the GIS database were the nature of the source material, geophysics or mapping, and a confidence rating for the georeferencing of the source drawing.

9.4 Linking of data

Key information taken from the source references was systematically organised into an Excel data table, with every object (lineament etc) given its own row and unique ID number. These same ID numbers being used in the MapInfo database. In this way the Excel file is linked to the MapInfo database so it is possible to 'click' on a MapInfo object and see all the information relevant to that object in the Excel file. The MapInfo database has subsequently been converted to ArcGIS V8 format.

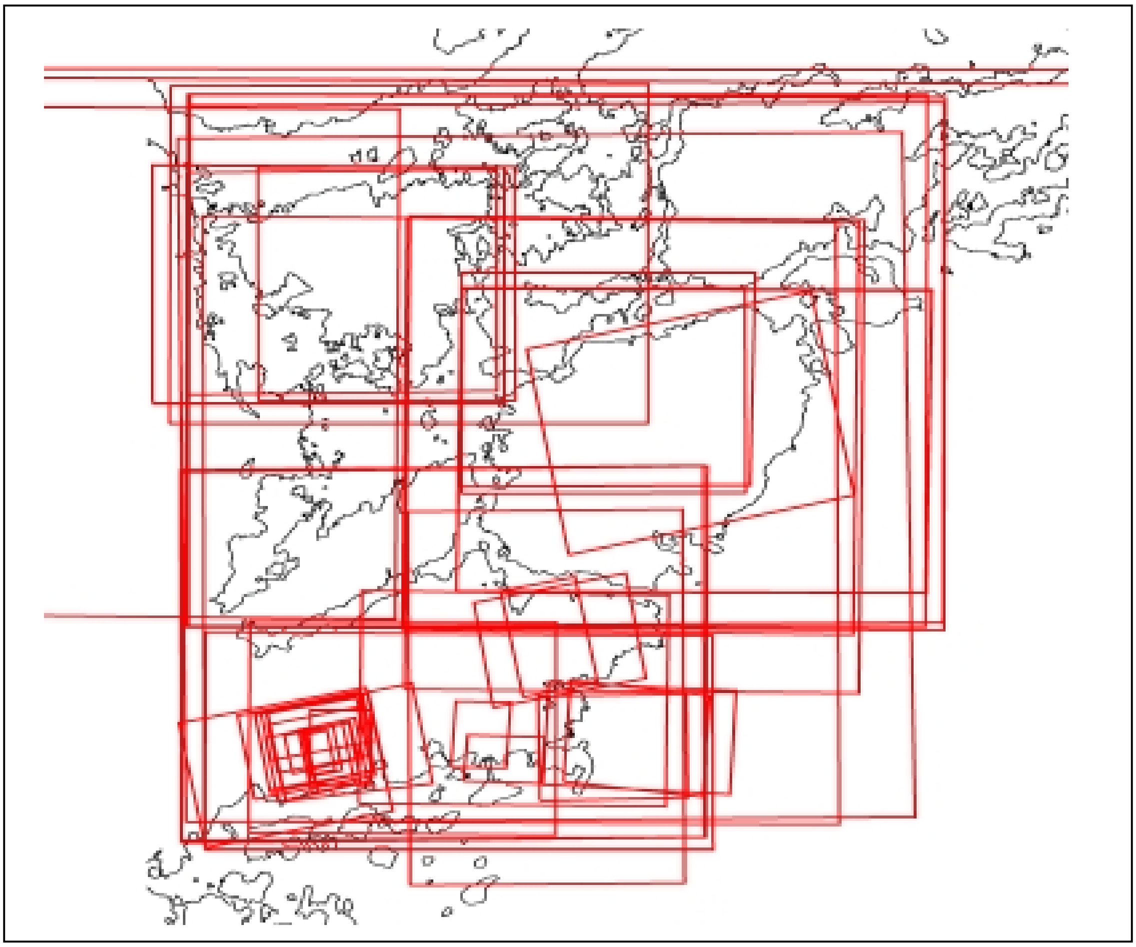

Figure 9-2. *The above figure shows a selection of rectangles representing the scanned images from the selected references. Each rectangle shows the extent and orientation of the image. All the outlines are labelled with the relevant ID and can be identified in ArcView or MapInfo. In MapInfo there is a link to the scanned images themselves, which allows the user to snap to any rectangle and view the original scanned image.*

The following eight figures give an indication of the distribution of interpreted structures and geophysical profiles across the project area. The digital data needs to be viewed with a GIS tool for the reader to obtain any specific information about the interpreted structures.

The data has been grouped as follows:

Figure 9-3 Interpreted potential geological structures – whole project area.

Figure 9-4 Geophysical profile locations – whole project area.

Figure 9-5 Interpreted potential geological structures – Ävrö + Hålö area.

Figure 9-6 Geophysical profile locations – Ävrö + Hålö area.

Figure 9-7 Interpreted potential geological structures – OI-OIII area.

Figure 9–8 Geophysical profile locations – OI-OIII area.

Figure 9-9 Interpreted potential geological structures – CLAB area.

Figure 9-10 Geophysical profile locations – CLAB area.

Legend: Line styles used in Figures 9-3 to 9-10

1 mapping on surface or underground
2 topo and/or geophysical indications supported locally by borehole or mapping evidence

3 topo and/or geophysical indications- regional scale from Version =0
4 topo and/or geophysical indications

5 geophysical profile
6 geophysical low velocity location

7 topo and/or geophysical indications supported locally by borehole or mapping evidence
8 topo and/or geophysical indications (Irms Ävrö report)

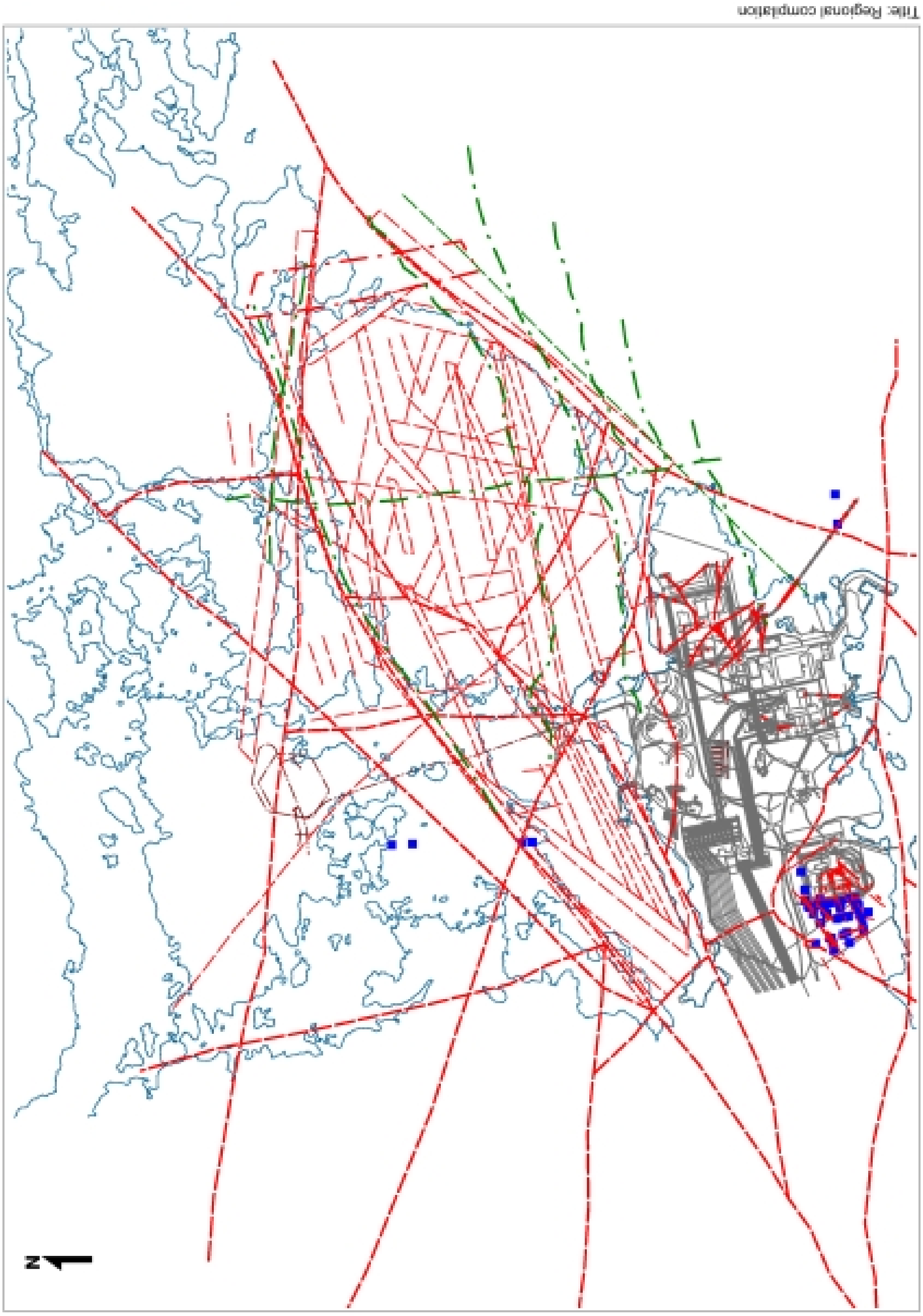

Figure 9-3. Interpreted potential geological structures – whole project area.

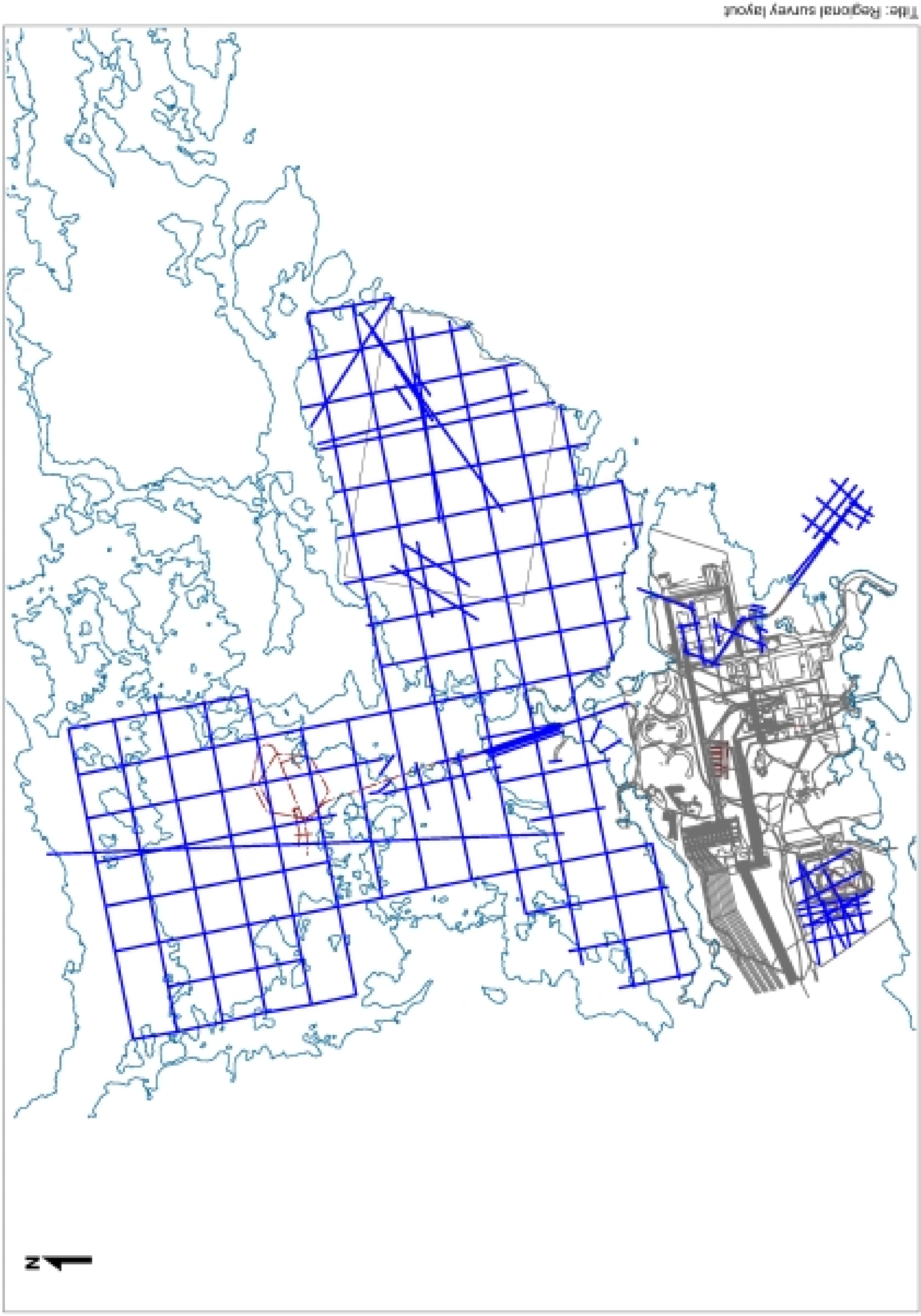

Figure 9-4. *Geophysical profile locations – whole project area.*

__Figure 9-5.__ Interpreted potential geological structures – Ävrö + Hålö area.

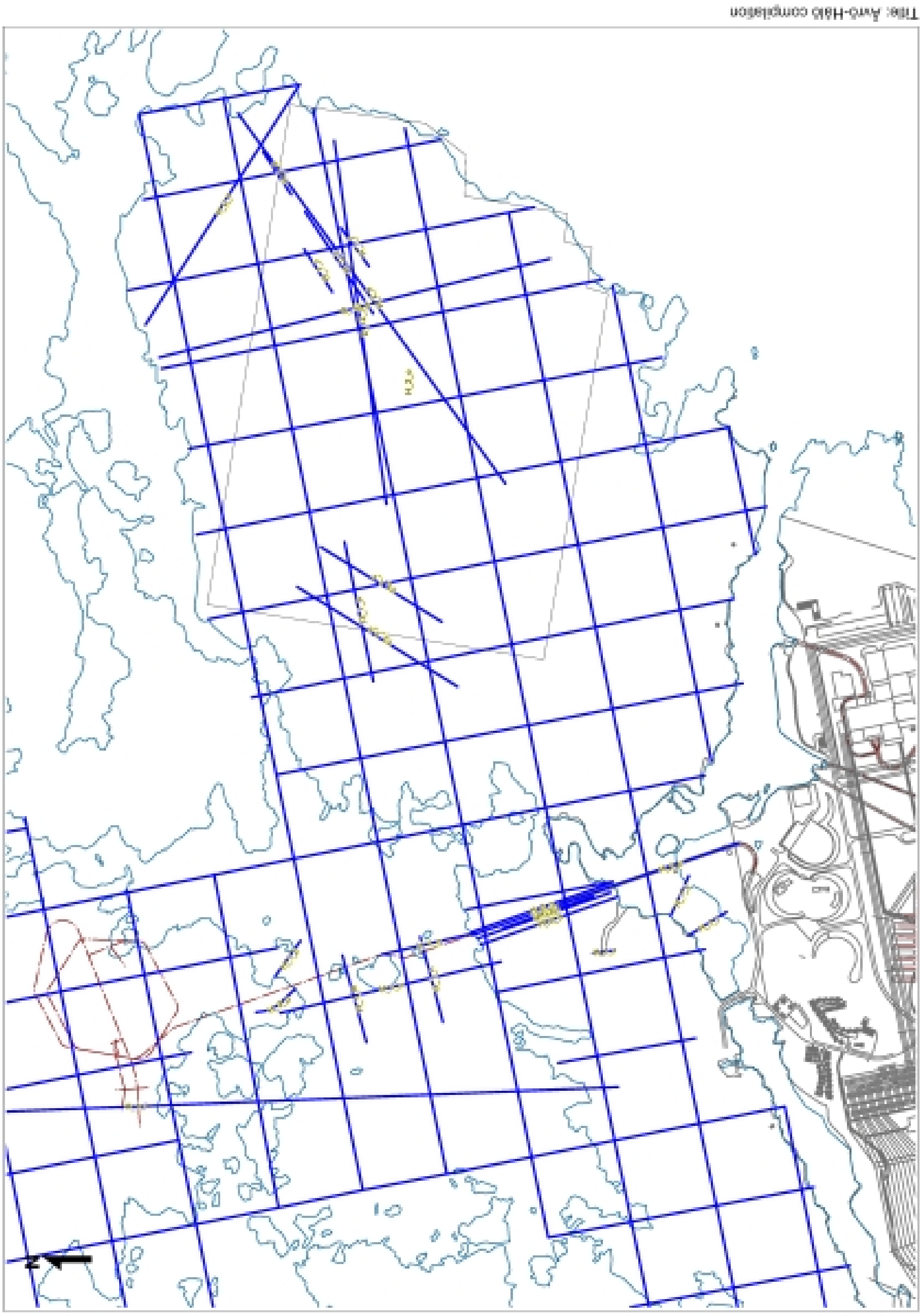

Figure 9-6. *Geophysical profile locations – Ävrö + Hålö area.*

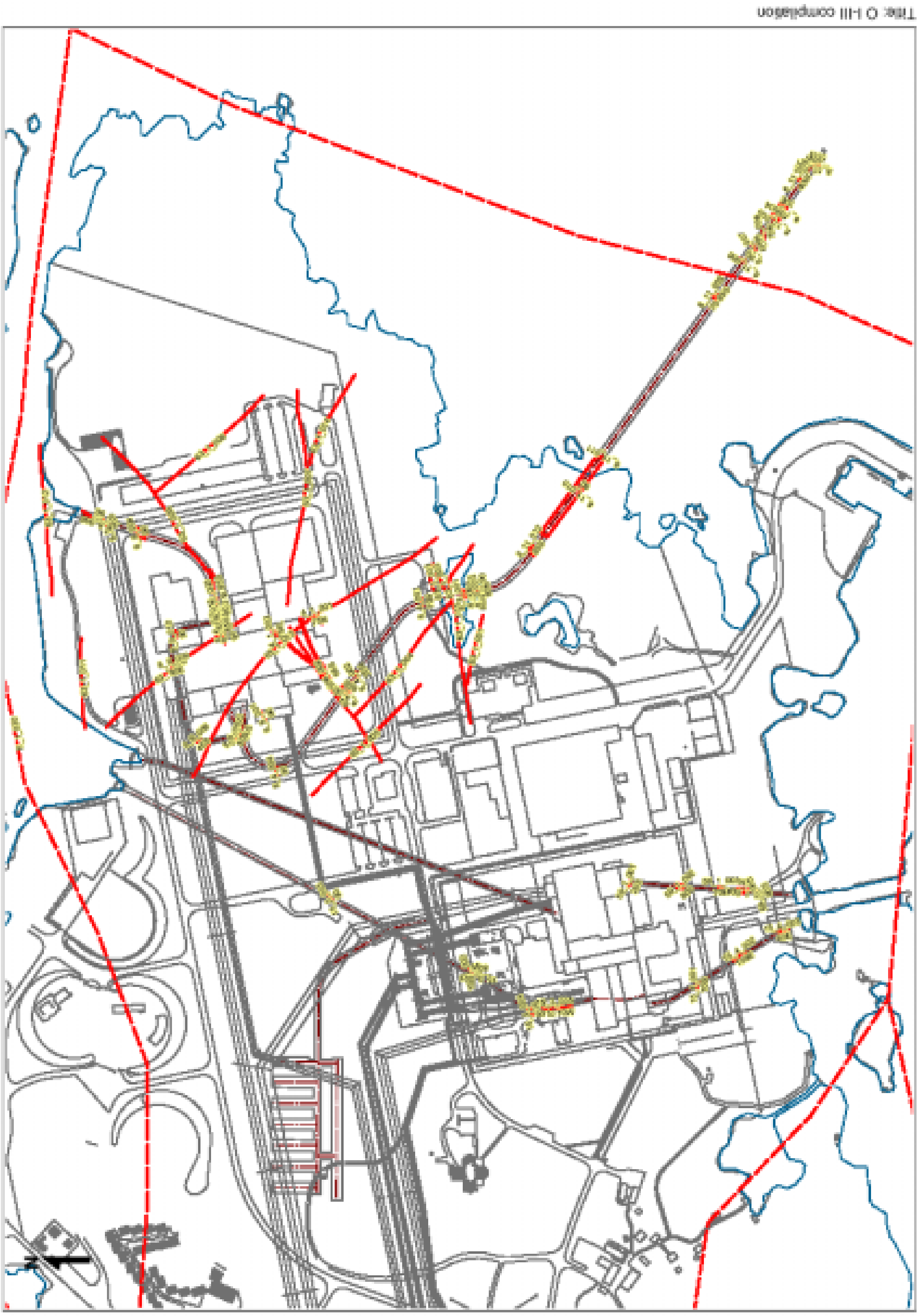

Figure 9-7. *Interpreted potential geological structures – OI-OIII area.*

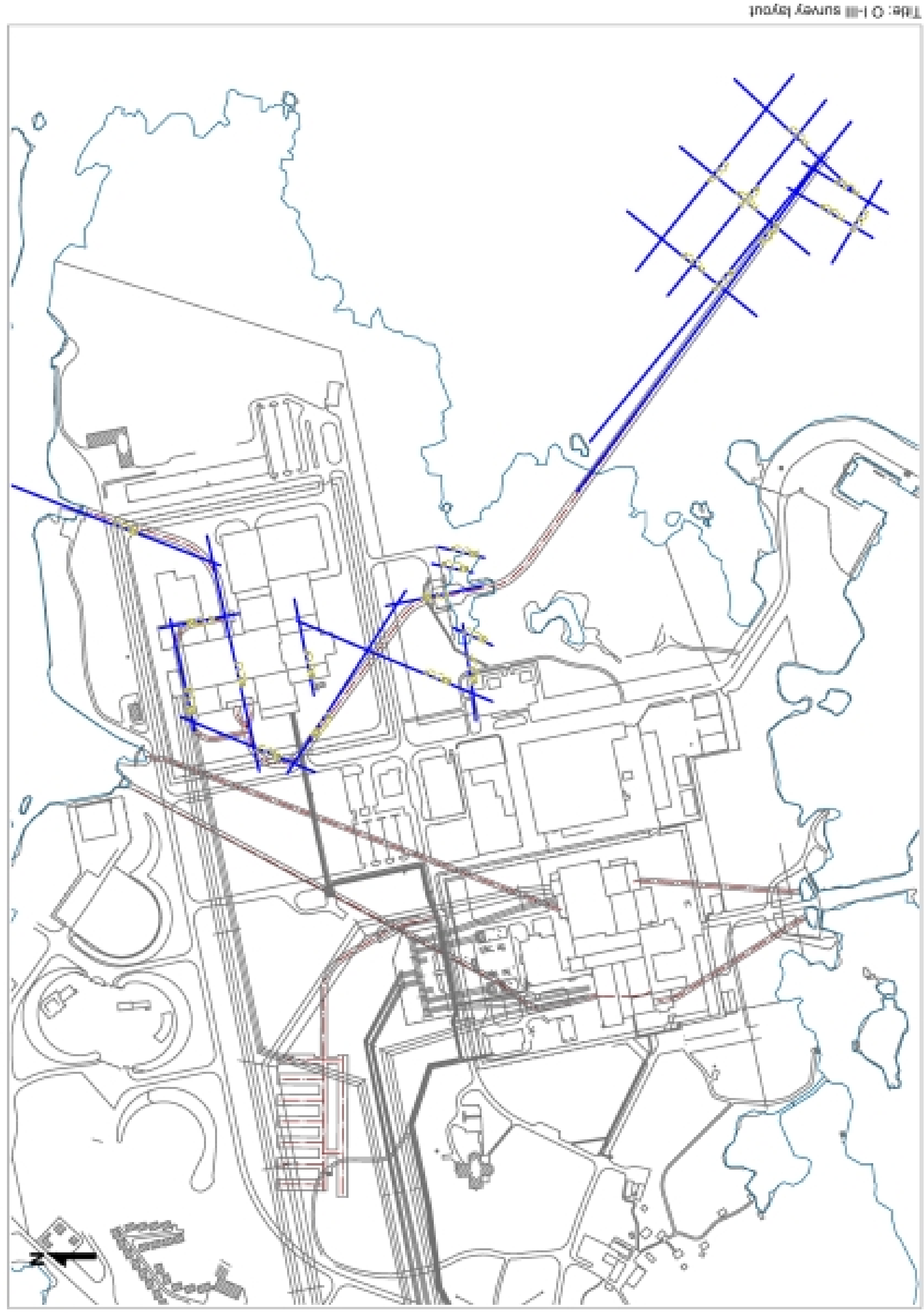

Figure 9-8. *Geophysical profile locations – OI-OIII area.*

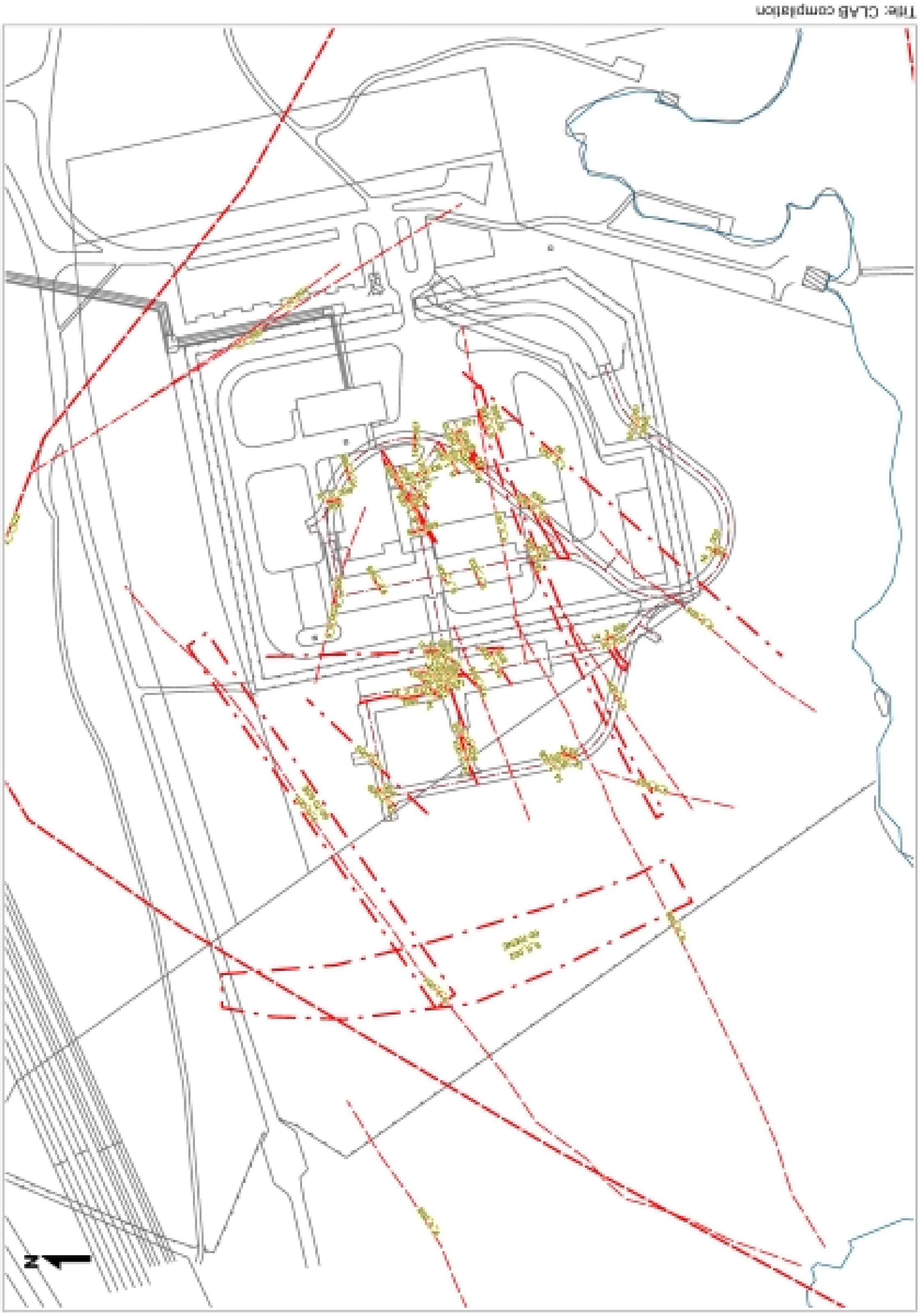

Figure 9-9. *Interpreted potential geological structures – CLAB area.*

Figure 9-10. *Geophysical profile location s – CLAB area.*

10 References

This list includes references referred to in the text of this report. Details of the references used to generate the GIS database are included in the datatables *(see attached CD)*.

Anderson J, Berglund J, Folin S, Hakami E, Halvarson E, Hermanson J, Laaksoharju M, Rhen I, Wahlgren C-H, 2002b. Testing the Methodology for site descriptive modelling. Application for the Laxemar area. SKB TR-02-19, Svensk Kärnbränslehantering AB.

Berglund J, 2001. Byggnadsgeologisk dokumentation, SKB TP-01-02, Svensk Kärnbränslehantering AB.

Bergman T, Isaksson H, Johansson R, Rudmark L, Stanfors R, Wahlgren C-H, 2000. Förstudie Oskarshamn. Kompletterande geologiska studier. SKB R-00-45. Svensk Kärnbränslehantering AB.

Ekman L, 2001. Project deep drilling KLX02-Phase 2. Methods, scope of activities and results. Summary report. SKB TR-01-11, Svensk Kärnbränslehantering AB.

Ericsson L O, 1987. Fracture mapping on outcrops. SKB PR 25-87-05. Svensk Kärnbränslehantering AB.

Eriksson K, 1982. Clab, Byggnadsgeologisk uppföljning av transport tunnlar och bergrum. Slutrapport, VIAK. SKB Inkapsling PM 95-3450-08.

Hagkonsult, 1976. Geologisk-bergteknisk utredning för centralt avfallslager i berg, Oskarshamnskraftverket 3, Simpevarp.

Kornfält K-A, Wikman H, 1987a. Description of the map of solid rocks around Simpevarp. SKB PR 25-87-02, Svensk Kärnbränslehantering AB.

Kornfält K-A, Wikman H, 1987b. Description to the map (No 4) of the solid rocks of 3 small areas around Simpevarp. SKB PR 25-87-02a, Svensk Kärnbränslehantering AB.

Kornfält K-A, Wikman H, 1988. The rocks of Äspö island. Description to the detailed maps of the solid rocks including maps of 3 uncovered trenches. SKB PR 25-88-12, Svensk Kärnbränslehantering AB.

Markström I, Stanfors R, Juhlin C, 2001. Äspölaboratoriet. RVS-modellering, Ävrö. Slutrapport. SKB R-01-06, Svensk Kärnbränslehantering AB.

Moberg M, 1978. Clab Simpevarp Berggrundsundersökning 1978, Vattenfall 1979-01-23. SKB, Inkapsling, Projekt-PM 95-3450-06.

Moberg M, 1979. Berggrundsundersökning 1979, Vattenfall 1979-04-10. SKB, Inkapsling, Projekt-PM 95-3450-07.

Munier R, 1995. Studies of geological structures at Äspö. Comprehensive summary of results. SKB PR 25-95-21, Svensk Kärnbränslehantering AB.

SKB, 2002. Simpevarp – site descriptive model version 0, SKB R-02-35, Svensk Kärnbränslehantering AB.

Stanfors R, 1981. Kartering av borrkärnor från kärnborrhål 1981-01 i tilloppstunnel. Del, sekt. 0/024. O:3, 81-09-05, OKG AB.

Stanfors R, Stille H, Rhen I, Larsson H, 1998. Berggrundsundersökningar 1995-1997, CLAB etapp 2. SKB PR 97-06, Svensk Kärnbränslehantering AB.

Svedmark E, 1904. Beskrivning till kartbladet Oskarshamn. Sveriges geologiska undersökning Ac 5.

Wikman H, Kornfält K-A, 1995. Updating of a lithological model of the bedrock of the Äspö area. SKB PR 25-95-04, Svensk Kärnbränslehantering AB.

Wikström A, 1989. General geological-tectonic study of the Simpevarp area with special attention to the Äspö island. SKB PR 25-89-06, Svensk Kärnbränslehantering AB.