R-02-35

Simpevarp – site descriptive model version 0

Svensk Kärnbränslehantering AB

November 2002

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ISSN 1402-3091
SKB Rapport R-02-35

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Preface

During 2002, Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company) is starting investigations at two potential sites for a deep repository, Forsmark and Simpevarp. An important part of the necessary preparations concerns site descriptive modelling. SKB has conducted two parallel subprojects in this field. The first entailed the establishment of the first version ("version 0") of the site descriptive model of the two sites. An essential part of this work is the compilation of existing data and interpretations for each site at a regional scale. This report presents the version 0 regional site descriptive model of Simpevarp. The other subproject was aimed at testing the methodology for site descriptive modelling, by applying it to the existing data obtained from an earlier, detailed investigation of the Laxemar area, which is a part of the Simpevarp site.

The basic ambitions, content and principles for site descriptive modelling are described in the general execution programme for the site investigations /SKB, 2001a/. The site descriptive model, as developed during the site investigation stage, should be an integrated description of the site and its regional environments with respect to current state and naturally ongoing processes, covering geology, rock mechanics, thermal properties, hydrogeology, hydrogeochemistry, transport properties and surface ecosystems. The description should serve the needs for Safety Assessment and Design. The selection of parameters and the geometrical framework is based on an underlying conceptual model of the site. Estimations of geometry and parameter values for a full three-dimensional description rest on extrapolation of data measured at a few locations. The confidence in the description should be tested with simulations to the extent that these are useful.

The version 0 site descriptive model has obvious limitations, since it is solely based on knowledge before the start of the site investigations. Moreover, the report is quite a complex mixture of an inventory of the available data for the regional area surrounding Simpevarp, and a first attempt at descriptive modelling. The level of interpretation, or synthesis, of the site for each discipline is quite different. As an example of the kind of site descriptive model that is to be expected during the initial site investigation stage, the Laxemar subproject is to be preferred. Most of all, this report should serve as the natural starting point or platform for all forthcoming modelling work, as well as for the investigations to be performed at the site.

The work has been conducted by a project group with representatives from the main disciplines; geology, hydrogeology, hydrogeochemistry, rock mechanics and surface ecosystems. The different experts assessed and evaluated the data. The following participants contributed to the project and the report:

Hans Isaksson, Mikael Keisu, Carl-Axel Triumf	– data inventory
Tobias Lindborg, Sara Karlsson	– ecosystems
Carl-Henric Wahlgren, Michael Stephens, Philip Curtis	– geology, modelling
Eva Hakami	– rock mechanics
Sven Follin	– hydrogeology, hydrogeochemistry
Peter Wikberg, Ebbe Eriksson, Berit Lundqvist	

Rune Johansson acted as editor. Thanks are also due to Alan Geoffrey Milnes who proofread and scientifically reviewed the manuscript.

Anders Ström
Site Investigations – Analysis

Summary

During 2002, the Swedish Nuclear Fuel and Waste Management Company (SKB) is starting detailed investigations at two potential sites for a deep repository in the Precambrian rocks of the Fennoscandian Shield. The present report concerns one of those sites, Simpevarp, which lies in the municipality of Oskarshamn, on the southeast coast of Sweden, about 250 kilometres south of Stockholm.

Site description

The aim of the planned investigations at both sites is to produce a *site description*, i.e. a body of documentation which presents an integrated description of the site and its regional setting, covering the current state of both the geosphere and the biosphere, and the ongoing natural processes which affect their long-term evolution. The site description should present all collected data and interpreted parameters of importance for the overall scientific understanding of the site, for the technical design and environmental impact assessment of the deep repository, and for the assessment of long-term safety. The site description will have two main components: a written *synthesis* of the site, summarising the current state of knowledge, as documented in the *databases* containing the primary data from the site investigations, and one or several *site descriptive models*, in which the collected information is interpreted and presented in a form which can be used in numerical models for rock engineering, environmental impact and long-term safety assessments. SKB maintains two main databases at the present time, a site characterisation database called SICADA and a geographic information system called SKB GIS. The site descriptive model will be developed and presented with the aid of the SKB GIS capabilities, and with SKB's Rock Visualisation System (RVS), which is also linked to SICADA. RVS is an active instrument for interpreting and visualising the primary data in SICADA, and for building and representing deformation zones and other bedrock structures, in order to set up the geometrical lattice for the site descriptive models.

Site descriptive model, version 0

The site descriptive model is devised and stepwise updated as the site investigations proceed. The point of departure for this process is the *regional site descriptive model, version 0*, which is the subject of the present report. The version 0 model forms an important framework for subsequent model versions, which are developed successively, as new information from the site investigations becomes available. Version 0 is developed out of the information available at the start of the site investigation. In the case of Simpevarp, this is essentially the information which was compiled for the Oskarshamn feasibility study (/SKB, 2000b/ and related background reports), which led to the choice of that area as a favourable object for further study, together with information collected since its completion. This information, with the exception of the extensive data base from the nearby Äspö Hard Rock Laboratory, is mainly 2D in nature (surface data), and is general and regional, rather than site-specific, in content. For this reason, the Simpevarp site descriptive model, version 0, as detailed in the present report, has been developed at a regional scale. It covers a rectangular area, 21 km in an east-west and 13 km in a north-south direction, around the area identified in the feasibility study as favourable for further study. This rectangular area has now been designated the *Simpevarp regional model area.*

Against this background, the present report consists of the following components:

- an overview of the present content of the databases SICADA and SKB GIS, and an inventory and assessment of relevant data in other databases (Chapter 2),
- a systematic overview of data needs and availability for developing a site descriptive model for the surface ecosystems (biosphere) in the Simpevarp regional model area (Chapter 3),
- a more detailed treatment of the present data base for the geosphere in the Simpevarp regional model area, and its transformation into the format of a site descriptive model, version 0 (Chapters 4-7).

Databases

Version 0 modelling is based on data available before the start of site investigations, mostly collected for reasons not directly related to the deep disposal of spent nuclear fuel. An important component of the present work, therefore, is a *data inventory*, in which the location and scope of all potential sources of data is detailed and evaluated with respect to prospective usefulness for future site descriptive modelling for deep disposal (Chapter 2). This includes a general description of existing geographical data, of which most are stored in SKB GIS, a survey of data already stored in the SICADA database, and an inventory of other data sources, whose information content has not yet been evaluated and/or inserted in SICADA or SKB GIS (i.e. not yet converted to a digital form). Data sources relevant to the Simpevarp regional model area which still, to some degree, need to be evaluated/converted/inserted include the siting and construction of spent fuel interim storage facility, CLAB 1, and the siting, pre-investigation, predictive modelling and construction of the Äspö Hard Rock Laboratory. Other sources, such as earlier site investigations at Bussvik, Laxemar, Kråkemåla, Simpevarp and Ävrö, are only partially encompassed by SICADA at the present time.

The present version 0 report is above all at a regional scale, and the information identified as lacking in SICADA and/or SKB GIS is mainly very local and therefore not of crucial consequence in the present context. However, the information will be of potential interest when modelling different parts of the Simpevarp regional model area in more detail, and when establishing the variation ranges of model parameters. In this sense, the version 0 data inventory and the newly established inventory database will provide an important platform for future work.

Biosphere

The present report describes the current level of knowledge of the *surface ecosystems* in the Simpevarp regional model area, in a highly condensed form (Chapter 3). It refers to, and draws its examples from, a series of SKB background reports which have been produced since the completion of the Oskarshamn feasibility study, and a number of other sources of information which are gathered here for the first time. The data sources are outlined with reference to a series of functional ecosystem types: drainage areas, forest, wetland, agricultural land, lakes and rivers, and sea, each further subdivided into appropriate entities (topography, vegetation, fauna, soil characteristics, sediments, etc). A systematic approach has been used, even though, at the current level of knowledge, the information in many subdivisions is inadequate or lacking. In this way, the weaknesses of the data base are easily identified and priorities for future problem-oriented investigations can be set. The aims of biosphere studies within the site investigation programme are to define baseline (pre-construction) conditions, to provide the necessary database for the environmental impact statement, and to contribute to the dose estimations in the safety analysis. This version 0 compilation of data sources and contents is intended to provide guidelines for future site investigations, in order to achieve these aims.

Geosphere

The main emphasis of the report is on the preparation of a site descriptive model, version 0, for the *geosphere*, since data acquisition and processing in this area, in contrast to the biosphere, is sufficiently advanced for some initial modelling exercises. The available information on the geosphere in the Simpevarp regional model area is quite extensive, at least locally (especially Äspö). In order to develop and test the modelling procedures, this information has been collected and transformed into appropriate formats under four separate headings: Geology (Chapter 4), Rock mechanics (Chapter 5), Hydrogeology (Chapter 6), and Hydrogeochemistry (Chapter 7). As an example of the envisaged modelling process, geometrical modelling in RVS has been carried out in 3D using the presently available data on local major and regional fracture zones in the Simpevarp regional model area. The lithological model (Småland "granites" and associated mafic to intermediate rocks, in geometrically complex intrusive relationships) is still essentially 2D, but structural data allow a first 3D representation of the twelve most prominent deformation zones in the area, providing in turn an object for testing RVS procedures.

This first attempt to develop a 3D geological and geometrical framework for rock engineering and hydrogeological purposes (Chapter 4), is accompanied by a discussion of how best to assess uncertainty in relation to geological data, depending on the scale of compilation, the level of knowledge and the interpretation of surface geometry. In the areas of rock engineering, hydrogeology and hydrogeochemistry (Chapters 5-7), modelling activities were mainly confined to parameterisation exercises, using presently available data from the Simpevarp regional model area to put limits on, for instance, the *in situ* stress field, the mechanical properties of the rock mass, the hydraulic properties of the fracture zones and rock mass between them, and the hydrogeochemical evolution.

The site descriptive model, version 0, is intended as the basic platform and natural starting point for all groups involved in the site investigations at Simpevarp, especially for the regional model area. The main results of the present project were to focus attention on the strengths and weaknesses in the available data coverage and data storage and processing systems, and to provide a basis for developing and testing ways of transforming diverse types of geoscientific information into a form appropriate for modelling. At the same time, the project provided concrete guidelines for the planning of the initial site investigations at Simpevarp.

Contents

1 Introduction

1.1 The project "Site descriptive models v0"

A site investigation is an important step in the process of siting a deep repository for spent nuclear fuel. SKB aims at conducting thorough investigations in at least two municipalities and arriving at detailed proposals of how a deep repository can be built and operated. SKB has proposed site investigations to be conducted in Östhammar, Oskarshamn and Tierp /SKB, 2000a/ of which the two first-mentioned municipalities have consented to the proposal.

One of the necessary preparations for the planned site investigations is to collect and compile existing data and information for each area and their surroundings, and to transform this information into the format of a site descriptive model (version 0). This has been done in the project "Site descriptive models v0" during the period July 2001 to April 2002, and the results regarding Oskarshamn are described in this report. For further testing of the modelling methodology and tools, the project includes the setting up of a more detailed site descriptive model, approximately corresponding to model version 1.2 in /SKB, 2001a/ for an area in Oskarshamn /Andersson et al, 2002b/.

1.2 The site descriptive model version 0 as related to the site investigation process

The main product of the site investigations is a *site description* document. This document presents an integrated description of the site (geosphere and biosphere) and its regional environs with respect to current state and naturally ongoing processes. The description presents all collected data and interpreted parameters of importance for the overall *scientific understanding of the site*, for the *design of the deep repository* and, most important, for the *safety assessment*. The safety assessment is made with respect to the repository's layout and construction as well as its long-term performance and radiological safety.

The investigations provide primary data (measurement values and directly calculated values) that are collected in two databases, SICADA and GIS. In order for the collected (measured) information to be used for design and safety assessment, and to enable the reliability of the information to be judged, it must be interpreted and presented in a *site descriptive model*. The site-descriptive model consists of a description of the geometry and different properties of the site and comprises, together with the databases, the backbone of the site description (Figure 1-1).

The generalisations in a model that are necessary, depend on the scale of presentation and use. During the site investigation, a detailed descriptive model is devised, a *local model*, for the area within which the repository is expected to be placed, including the access routes and the immediate environs. In addition to a description on a local scale, a description is also devised for a much larger area, a *regional model*, in order to provide boundary conditions and to put the local model in a larger context.

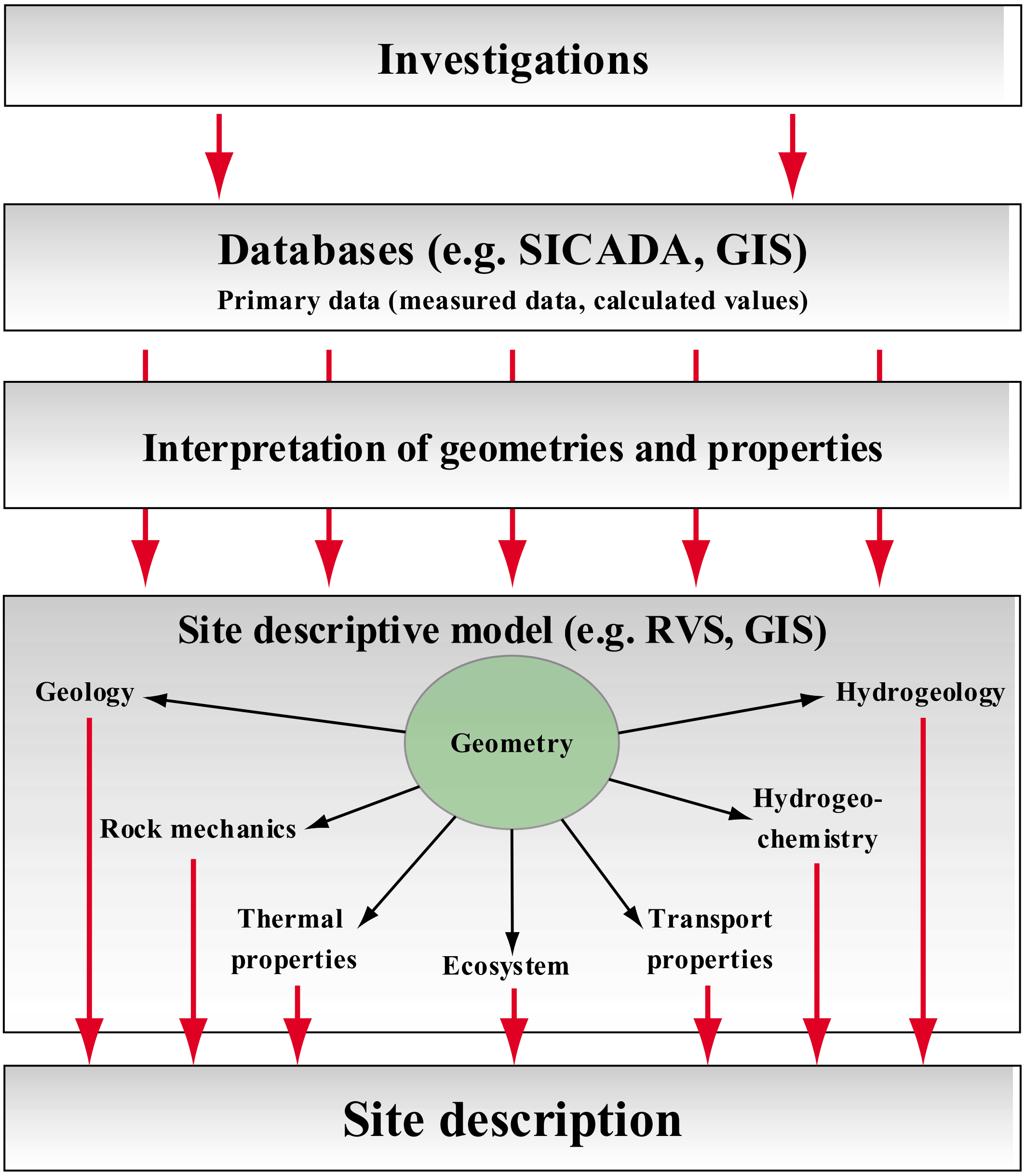


Figure 1-1. *The primary data from the investigations are collected in databases. Data are interpreted and presented in a site-descriptive model, which consists of a description of the geometry of the different units in the model and the corresponding properties of the site. The "site description" then consists of the site descriptive model together with the databases on which the model is based.*

Subdivision of the site investigation into stages and iterative investigation methodology have been applied by SKB in previous study site investigations and during the pre-investigation phase for the Äspö HRL /see e.g. Rhén et al, 1997a/. The site descriptive model is devised and stepwise updated as the site investigation progresses, see Table 1-1. The starting point for this process of model development is the *site descriptive model of version 0*. It forms the important framework for the new model versions, which are successively developed, as new information becomes available. Each discipline-specific model is developed progressively from general regional to more detailed local descriptions during the stepwise execution of the site investigation.

Table 1-1. Different versions of the site descriptive models that are developed during the site investigation. The first site descriptive model, version 0, is developed prior to the site investigation.

Phase	Basis	Coverage	Product/model
Prior to site investigation	Feasibility studies. Processing of existing data. Field checks.	Part of municipality and candidate area where priority site will be chosen.	General model, above all on regional scale (version 0).
Initial site investigation	General surveys from air, surface and short boreholes.	Area and priority site (regional and local scale).	Choice of priority site. General model (version 1.1).
	Investigations from surface and some deep boreholes.	Priority site. (regional environs).	Preliminary model on local and regional scales (version 1.2). Preliminary site description.
Complete site investigation	Investigations in several deep boreholes and supplementary ground surveys.	Priority site. Regional environs.	Model on regional and local scale (version 2.1).
	More deep boreholes and supplementary ground surveys.	Priority site. Regional environs.	Revised model on regional and local scale (version 2.2).
	More supplementary surveys.	Priority site. Regional environs.	Finished model on regional and local scale (version 2.x). Site description.

The site descriptive model version 0 is above all developed on a regional scale. Its prime merit is that it highlights the strengths and weaknesses in the data coverage and the knowledge of the present state, as well as of naturally ongoing processes in the regional environs of the potential site. It is furthermore expected to reflect the current view of the site-specific tasks to be addressed, especially at the initial stage of the site investigation. As such, it provides the necessary constraints for early survey design. This model, hereafter called the regional model v0, is based on the information available at the start of the site investigation, that is, mainly data from the feasibility studies, other existing data and field checks. Its character is predominantly two-dimensional

The geographic scope of the regional model depends on the local premises and is controlled by the need to achieve understanding of the conditions and processes that determine the conditions at the site. The regional model should encompass such a large area that all geoscientific conditions that can directly or indirectly influence the local conditions, or help in understanding the natural processes in the repository area, are included. In practical terms, this may entail a surface area of a few hundred square kilometres.

1.3 The Simpevarp regional model area

1.3.1 The Simpevarp candidate area

The Simpevarp candidate area, as defined in the feasibility study /SKB, 2000b/, is located in the province of Småland, within the municipality of Oskarshamn, adjacent to the Oskarshamn nuclear power station and the Central interim storage facility for spent nuclear fuel (CLAB), see Figure 1-2. The town Oskarshamn is located 20 km SSW of the candidate area.

Figure 1-2. *The Simpevarp candidate area and regional model area.*

The access to the Simpevarp candidate area is good. The European highway E22 runs to the west of the area, and at the village Fårbo a wide road runs east and then northeast, past the village Figeholm, to the Simpevarp peninsula, Äspö and Ävrö. From Simpevarp, there is a northwest running connection through the village Misterhult to the highway E22. The candidate area is in principle encircled by these major roads. In addition, the area is intersected by a number of local and minor roads. The area can be accessed from the sea via the Simpevarp harbour, located at the Oskarshamn nuclear power station and CLAB. Oskarshamn airport (flygplats), with domestic flights, is located approximately 10 km south of the Simpevarp area. There is no railway connection.

1.3.2 Extension of the Simpevarp regional model area

The Simpevarp candidate area is located near the shoreline of the Baltic Sea, see Figure 1-2. The easternmost part of this area includes the Simpevarp peninsula where the Oskarshamn nuclear power station is located, while the western limit is found approximately 9–10 km from the coast.

The Simpevarp regional model area includes land areas surrounding the candidate area and part of the offshore, and is defined by the co-ordinates in Table 1-2 (defined in RT90 2.5 gon V), as shown on Figure 1-2. The area covers 273 km^2, and extends 21 km in the E-W and 13 km in the N-S direction. The near-shore depressions in the Baltic Sea are included as well as most of the upstream drainage areas and the major nearby regional fracture zones.

1.3.3 Geomorphology

The Precambrian crystalline bedrock primarily determines the major features of the present relief of Småland, while the influence of overlying, in general thin glacial and postglacial deposits is less pronounced. Weathering and erosion processes have worn down an originally mountainous landscape to a low-lying peneplain, called the sub-Cambrian peneplain. The eroded bedrock surface is usually covered only by thin till deposits (see also Chapter 4, Geology). Some glaciofluvial formations, however, such as Tunaåsen, form basic elements of the relief.

The Simpevarp regional model area forms part of the sub-Cambrian peneplain. The model area may be classified as lowland and the peneplain has an overall gentle slope to the east. The highest point within the area is 54.8 m.a.s.l, located within the esker Tunaåsen, south of the village Jämserum. The terrain relief is low but pronounced due to the thin till cover, which results in a strong influence of the bedrock structure on the landforms. Valleys, which formed along regional fracture zones, are fairly common and easy to recognise on the terrain relief maps.

Table 1-2. Geographical definition of the Simpevarp regional model area. Co-ordinates given in meters (RAK RT 90 2.5 gon V).

RAK Y	RAK X
1539000	6360000
1539000	6373000
1560000	6373000
1560000	6360000

The waters of the Baltic Sea and Kalmarsund cover approximately 40% of the Simpevarp regional model area. Water depths are normally around 10–20 m. The deepest part is 46 m, in a local depression 1–2 km east of Kråkelund.

1.3.4 The Äspö Hard Rock Laboratory and the CLAB facility

Within the Simpevarp regional model area, there are two underground facilities of particular interest; the Äspö Hard Rock Laboratory (Äspö HRL) and the central interim storage facility for spent nuclear fuel (CLAB). The pre-investigations, construction and operation of these facilities, especially the Äspö HRL, have provided substantial information of importance to the understanding of how to design a deep repository for spent nuclear fuel.

Äspö HRL

The Äspö HRL was built to provide an opportunity for research, development and demonstration in a realistic and undisturbed rock environment down to the depth planned for a future repository for spent nuclear fuel. Geological investigations started in the region around Äspö in 1986, and Äspö was selected as the site for the laboratory in 1988. Construction of the underground facilities started in 1990, with the laboratory being completed in 1995.

The location and an overview of the layout of the Äspö HRL is shown in Figure 1-3. A 3.6 km long ramp has been excavated from the Simpevarp peninsula. The tunnel reaches Äspö at a depth of 200 m and then continues in a hexagonal spiral down to

Figure 1-3. *Location and general layout of the Äspö Hard Rock Laboratory. Modified after /Rhén et al, 1997a/.*

a depth of 450 m below sea level. The underground facilities are connected to the Äspö research village by a hoist shaft and two ventilation shafts. For a summary of activities during the pre-investigation and construction phases, the reader is referred to /Stanfors et al, 1997/ and references therein. A review of the achievements is presented in /SKB, 1996/.

CLAB

The central interim storage facility for spent nuclear fuel (CLAB) is located on the Simpevarp peninsula near the Oskarshamn nuclear power station. Construction work started in 1980 and operation started in 1985.

At CLAB, the fuel is stored in deep pools of water in underground caverns, 30 m below the ground surface (Figure 1-4). A second cavern, CLAB 2, is currently being built to increase capacity. Construction work is scheduled for completion in 2004.

Figure 1-4. *The central interim storage facility for spent nuclear fuel (CLAB 1 and 2). From /SKB, 2000b/.*

1.4 Regional model v0 – content and modelling tools

As described in Section 1.1 and shown in Figure 1-1, the site descriptive model, independently of scale, is expected to describe the geometry and properties of the site in terms of the seven different ”disciplines” (SKB terminology) Geology, Rock mechanics, Thermal properties, Surface ecosystems, Transport properties, Hydrogeochemistry and Hydrogeology. In this report all disciplines except ”Thermal properties” and ”Transport properties” are addressed. The two exceptions are motivated by the limited amount of data presently available.

The site-descriptive model is developed and presented with the aid of both geographic information systems (GIS) and SKB's CAD-based computer tool, Rock Visualization System (RVS), together with underlying databases. The GIS utilizes the programs ArcView® and ArcInfo®. RVS is based on a CAD program (Microstation®) and presents models in three dimensions. RVS, which is directly linked to SKB's database SICADA, is used as an active instrument for the interpretation of the database's primary data, especially for identification of deformation zones and their extent, i.e. for setting up the geometric lattice of the site-specific models.

At present, RVS is being refined such that interpreted properties for the geometric units can be entered and administrated in a given discipline-oriented structure /Munier and Hermanson, 2001/. The application will include standard procedures for version management to provide traceability and consistency between different disciplines.
It will also show what data underlie a given model version and who has performed the interpretation. Model version and other information on traceability are essential when site-descriptive models are used for design and safety assessment. Furthermore, conversion procedures are being developed so that the RVS model can be exported to other software.

2 Data inventory

The primary data from the Simpevarp regional model area is collected in a database, either SICADA or GIS. Specifically, version 0 differs from subsequent site description models in that the collection of new data is very limited. The major source of data for version 0 is information from the feasibility study together with other existing data sources. The preparatory work for the site investigation programme has also included some data collection and compilation not carried out during the feasibility studies, especially regarding the discipline "Ecosystems".

This chapter contains:

- A general description of existing geographical data, of which most is stored in GIS.
- An inventory of data already inserted into the databases SICADA or GIS at SKB, as well as data from other sources.

2.1 Geographical data

The major source of digital and analogue geographical data is Lantmäteriet (the National Land Survey of Sweden). Important digital information that has been acquired from Lantmäteriet and stored in the GIS database of SKB is briefly described below. The different areas in the region covered by digital maps, orthophoto and elevation data are presented in Figure 2-1. All data described are represented in the Swedish national grid. The co-ordinate system is for:

- X/Y (N/E): the national 2.5 gon V, RT 90 system ("RAK").
- Z (elevation): the national RH 70 levelling system.

The general map (previously called the red map) database provides a uniform national coverage regarding the presentation of area, line and point objects, adapted to the scale 1:250,000 and the database contains the following components:

- Public and private roads and railway lines.
- Sea, lakes, built-up areas, other concentrated building development, forest, open land, alvar, mountain areas above the tree line, glaciers and marshland.
- Watercourses.
- Administrative divisions (national, territorial, county, municipal and parish boundaries) and provincial boundaries.
- National parks, nature and private reserves.
- Nature conservancy areas and Crown Forest reserves.
- Bird and seal protection reserves.
- Military areas.

- Power transmission lines.
- Line symbols (dams, airports, mountain tracks, hiking trails, etc).
- Point symbols (elevation, points, mines, towers, houses etc).
- Names of buildings, natural features and explanatory text.

The topographic map (previously called the green map or version T5) represents a uniform national coverage regarding the presentation of area, line and point objects, adapted to the scale 1:50 000. The information is divided into separate layers that contain the following themes (according to the terminology of the ArcView software):

- Roads and railways, symbols for stations, bascule bridges and tunnels.
- Other line and point objects such as boundaries, power transmission lines, streams and various symbols.
- Depth contours.
- Land-use classification: bodies of water, forest (2 classes), arable land, fruit farms, clearings, built-up areas (5 classes), and open land (2 classes).
- Areas, which overlap the areas listed above: marshland (3 classes), rock outcrops and peat cutting areas.
- Areas with large boulders.
- Text.

The cadastral index map (previously called the economic map) provides presentation of area, line and point objects, adapted to the scale 1:10,000 – 20,000. The database contains:

- Administrative division and real estate boundaries.
- Hydrography.
- Land use.
- Communications.
- Developed areas.
- Restricted land-use.

The digital orthophoto is stored in a raster format produced by scanning, image processing and ortho-rectification of high-quality aerial photographs. When the database is created or updated, the latest aerial photography taken for the national mapping program is utilized and a national coverage is provided. Up-to-date raster databases are produced on a regular basis. The base comprises an 8-bit image for each 5x5 km grid and the spatial resolution is 1 metre. Thus, each file contains 5,000 x 5,000 pixels.

Elevation data, covering the land area, is available for the whole of Sweden from the GSD – Elevation database. The elevation data are produced as 50 m grid cells by means of stereo-model digitalisation of aerial photographs and automatic digitalisation of elevation curves from the cadastral index maps. The data have a maximum standard error of ± 2.5 metres, and are delivered with an accuracy of 0.1 metre. The latest revision of the database was completed in 1993. Complementary data in the sea area are *bathymetric data* from nautical charts, available from the Swedish Maritime Administration.

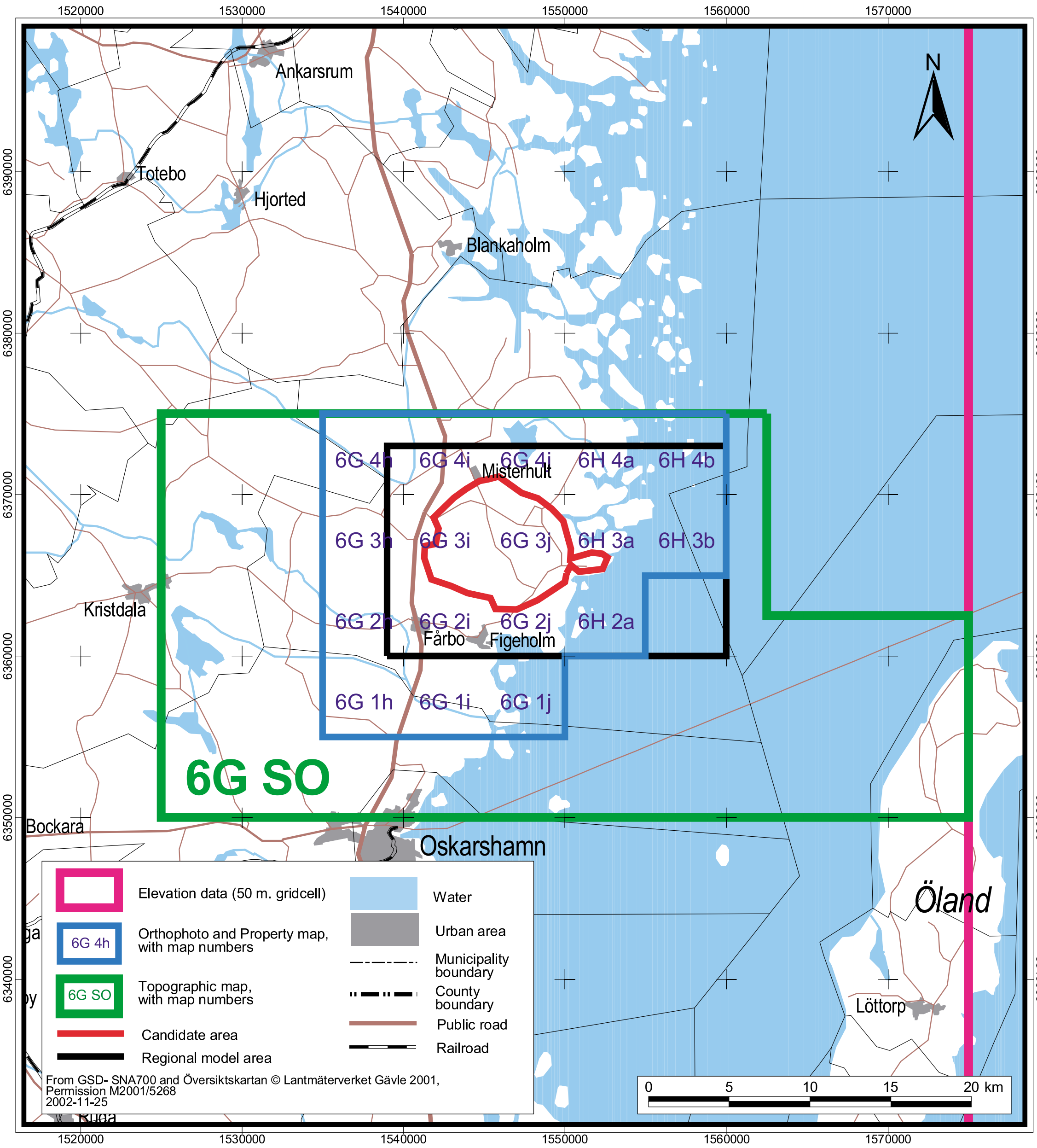


Figure 2-1. The distribution of maps, orthophotos and elevation data available in the GIS database of SKB over the northern part of the province Småland and the Simpevarp regional model area.

2.2 Inventory of data sources

The inventory of data aimed both at listing data, which were already included in the databases SICADA or GIS at SKB, as well as finding data from other sources. This subdivision is also noted in the presentation of the results where the general inventory of data sources is presented in Section 2.2.1 and the inventory of SICADA in Section 2.2.2. Conclusions on the results from both activities are presented in Section 2.2.3.

The overall aim of the inventory was to visualise and structure existing data in the Simpevarp regional model area in order to facilitate forthcoming modelling and planning of field investigations. The results also serve for planning of future data input. Some digitalisation has already started within the framework of the current project, such as collection of co-ordinate information on primary data, e.g. locations of drill-holes and tunnels. The major data insertion, however, remains the responsibility of the site investigation team at Simpevarp.

The results from the entire inventory work, including a complete listing of the inventory database (see Table 2-1), will be presented as a separate report.

2.2.1 Inventory of data sources other than SICADA

Methodology

The inventory covered data from the Simpevarp regional model area, as defined in Section 1.3, and was focused on complementary data sources containing information not fully evaluated in the Oskarshamn feasibility study. The work was adapted to the scale 1:50,000 – 1:100,000. Consideration of more detailed information was, in general, beyond the scope of the study.

The first step of the work consisted of making compilations and listings of different data sources followed by an inventory of these sources. The inventory was initially guided by interviewing key persons and, subsequently, follow-up inventories were made. A literature search was performed using selected keywords, map-sheet identities, co-ordinate windows, project and location names, etc, all specifically adapted to the area. The search criteria that revealed a hit were listed in the inventory database. The "Georegister" at SGU (Geological Survey of Sweden) and the register ”Bibas” at SKB were the main sources for the literature search.

In the next step, certain judgements regarding the data sets were made. The judgements were related to the importance of each data set for the site investigations and furthermore to the need for insertion of the data set into the GIS- and/or SICADA-databases of SKB.

Before the inventory started, a data base structure was designed. The structure was to a high degree dependent on the structure listed in /SKB, 2001a/. The structure was oriented towards the major disciplines, and the format was Microsoft Access. The database is constructed in Swedish and the structure is further explained in Table 2-1. Successively during the inventory, information found about each data set was inserted into the database. Some fields were compulsory (**bold text**) while others could be left blank.

The inventory was divided into a number of Inventory objects (major sources of information), see Table 2-2.

The sources of data that were identified have subsequently been catalogued into different information epochs, often related to a specific project, such as different phases of investigations, engineering or construction work. A compilation of the work performed during the development of the Äspö HRL is presented in /Stanfors et al, 1997/ and this work has formed the basis for dividing the information into different epochs. These epochs are often related to a specific geographic area and this information has been used to geographically describe the information source in an ArcView GIS presentation for the Simpevarp regional model area (see Figure 2-2 and 2-3). In some cases, it was difficult to decide to which epoch the information belonged. Also, some work within an epoch may have been performed at another locality.

Table 2-1. The structure of the database used for the inventory.

Field	Content
ID_nr	**10** ***<unique serial number together with the area name in the field ID_Plats>***
ID_Plats	**Area name: TN=Tierp norra; FM=Forsmark; SM=Simpevarp.**
Ämnesområde	**Discipline, according to nomenclature in /SKB, 2001a/.**
Parametergrupp	**Parameter group, according to nomenclature in /SKB, 2001a/.**
Informationsmängd_1	Type of information. General description. Heading or title in Report or Figure.
Informationsmängd_2	More detailed description of the information.
Parameter	Parameter, according to nomenclature in /SKB, 2001a/.
Referens	Report or Figure. Individual. Or other reference.
Geografisk beskrivning	Area, coverage and extension. Information density. Scale. Co-ordinate system. Type of coverage: area/line/point.
Datakälla	Data producer. Storage of data.
Aktualitet	Date of creation/revision of the data.
Dataform	Information state: Digital format, map, plan, report etc.
Sökväg	Data tracking. How to search for data.
Värdering	**Valuation of information.** **A. Necessary to examine the information in more detail for further prioritisation.** **B. No further inventory needed.**
Modell, Regional/Lokal	Significance for the regional or local model.
Prioritet	**Priority:** **1. Data insertion recommended.** **2. Data insertion may be considered.** **3. No data insertion necessary.** **4. Cannot judge (detailed examination needed).**
ÄA beslut	Recommendation by person responsible for each discipline.
SKB beslut	Decision by SKB.
Kommentar	Other information. Foreseen problems. Timing.
Inventeringsobjekt	**Inventory object. Source of inventory entry.**
Epok	**Epoch for which the information was collected.** ***<link to ArcView GIS>***
Datainlagring – status	Status of data storage.

Table 2-2. List of inventory objects.

Inventeringsobjekt	Inventory object
Basdata (stödjande data)	SKB GIS-data, support data in ongoing projects.
Bergsstaten	Mining Inspector register.
Litteratursökning FM	Literature search performed.
Geosigma AB	Geosigma AB's archives.
Mineralkontoret SGU	SGU Mineral Information Office, Malå.
SICADA	SICADA version valid 2001-11-01, see Section 2.2.2.
SGU	Delivery of "Förstudie Oskarshamn" data. Compilation valid 2001-11-01.
SKB GIS ver.5.0	Basic data from SKB GIS version 5.0. Valid: 2001-10-16.
FM Intervjuer och uppföljningar	Interview of key persons and subsequent inventories that were called to attention.
Ytnära ekosystem	Ecosystem. Data compilation, valid 2001-10-02.

The results are primarily presented with regard to the information epochs of the Simpevarp regional model area. In the database, the results are briefly described in a table format, with important comments highlighted in **bold** text. The data quantity and the extent of storage in the SKB GIS or SICADA systems have been summarised in general terms, as described in Table 2-4. The epochs for which the data to a major extent are already stored in GIS or SICADA are highlighted in **blue**.

A general appreciation on the "Valuation" and "Priority" of the full data-set is also added. The classification is the same as in Table 2-1;

A. Necessary to examine the information in more detail for further prioritisation.

B. No further inventory required.

1. Data insertion recommended.
2. Data insertion may be considered.
3. No data insertion necessary.
4. Cannot judge (detailed examination needed).

Table 2-3. Example of an epoch from the Simpevarp regional model area.

No	Epoch	Time Period	Information content Comments *No of entries, No of A-valuation and No of entries in priority class 1,2,3,4*	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Valuation ----- Priority
14	**Äspö HRL Semi-regional siting**	1987–89	Development of the Äspö HRL. Semiregional siting phase. Geology, hydrogeology and hydrogeochemistry. *No of Entries: 57 No of A-valuation: 47* *Priority class 1,2,3,4: 37,2,12,6*	Moderate ----- Low?	**A** ----- **2**

Table 2-4. Concepts used to describe data quantity and data storage.

	Data Quantity	Stored in SKB GIS/Sicada
None	No data available	No data stored
Low	Limited amount of data	Only a limited fraction of the available data stored
Moderate	Moderate amount of data	Moderate amount of available the data stored
High	Large amount of data *(Data collected at the Äspö HRL is regarded as a large amount)*	Most of the available data stored

Results

Table 2-5 describes the results in relation to the inventory object. This table gives an overview of how the data is distributed between different disciplines and inventory objects.

Table 2-5. Results distributed per inventory object.

Inventory object	Information content ***No of entries, No of A-valuation and No of entries in priority class 1,2,3,4***	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Summary Valuation ----- Priority
Basdata_ stödjande data Basic data Support data	Mainly data produced in the preparation for site investigations. Most of the data is in SKB GIS-format. No data noted in the Simpevarp model area. *No of entries: 0 No of A-valuation: 0 and No of entries in priority class 1,2,3,4: 0,0,0,0*	None ----- None	**B** ----- **3**
Bergsstaten The Mining Inspector	No data noted in the Simpevarp model area. *No of entries: 0 No of A-valuation: 0 and No of entries in priority class 1,2,3,4: 0,0,0,0*	None ----- None	**B** ----- **3**
Litteratursökning_SM Literature search	125 entries concern Geology and 50 entries concern Hydrogeology. No entry is directed towards Rock mechanics. No entry concerns the discipline Ecosystems. *No of entries: 175 No of A-valuation: 175 and No of entries in priority class 1,2,3,4: 104,62,1,8*	High ----- Low	**A** ----- **1(2)**
Mineralkontoret_SGU SGU Minerals Office	Limited surface geochemistry data. *No of entries: 4 No of A-valuation: 4 and No of entries in priority class 1,2,3,4: 0,0,1,3*	Low ----- None	**A** ----- **4**
Sicada	The Sicada entries represent "summary" entries from The Sicada inventory, further described in Chapter 2.2.2. 48 entries concern Geology and 60 entries concern Hydrogeology and Hydrogeochemistry. 21 entries are directed towards Rock mechanics. *No of entries: 137 No of A-valuation: 0 and No of entries in priority class 1,2,3,4: 0,0,137,0*	High ----- High	**B** ----- **3**
SGU	Delivery of "Förstudie Oskarshamn" geology data is ongoing. Most of the data will be delivered in SKB GIS-format. Remaining data from field follow up stages will need some data input. *No of entries: 31 No of A-valuation: 0 and No of entries in priority class 1,2,3,4: 0,10,21,0*	Moderate ----- High	**B** ----- **3(2)**
SKB_GIS_ver_5_0 GIS-stored data	Data stored in SKB GIS-database, version 5.0. Valid 2001-10-16. Hence all data in SKB GIS format. 55 entries concern Geology and 6 entries concern Hydrogeology. 1entry is directed towards Rock mechanics. 34 entries concern the discipline Ecosystems and 40 entries concern Support data. *No of entries: 140 No of A-valuation: 0 and No of entries in priority class 1,2,3,4: 0,0,140,0*	High ----- High	**B** ----- **3**

Inventory object	Information content ***No of entries, No of A-valuation and No of entries in priority class 1,2,3,4***	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Summary Valuation ----- Priority
SM_Intervjuer_ Uppföljningar Interviews and subsequent follow-up	64 entries concern Geology and 16 entries concern Hydrogeology and Hydrogeochemistry. 4 entries are directed towards Rock mechanics. *No of entries: 75 No of A-valuation: 69 and No of entries in priority class 1,2,3,4: 39,3,9,24*	Moderate ----- Low	**A** ----- **1(4)**
Ytnära_ekosystem Ecosystem	Most of the data collected in the preparation for site investigations. Mainly stored in SKB GIS-format. *No of entries: 100 No of A-valuation: 27 and No of entries in priority class 1,2,3,4: 0,0,73,27*	Moderate ----- High	**B(A)** ----- **3(4)**
SKB Reports TR-97-02 TR-01-11 R-01-06	Represents the work performed in the development of the Äspö Hard Rock Laboratory and later complementary work in the surrounding areas. 59 entries concern Geology and 64 entries concern Hydrogeology. 7entries is directed towards Rock mechanics. 3 entries concern the discipline Ecosystems. *No of entries: 116 No of A-valuation: 90 and No of entries in priority class 1,2,3,4: 70,4,26,16*	High ----- Moderate	**A** ---- **1**

The information content and different epochs, as identified in the Simpevarp regional model area, are presented in Table 2-6 and are linked to geographical areas presented in Figure 2-2 and 2-3.

Table 2-6. Information content and epochs identified in the Simpevarp regional model area. The epochs are linked to the geographical areas presented in Figure 2-2 and 2-3.

Nr	Epoch	Time Period	Information content Comments *No of entries, No of A-valuation and No of entries in priority class 1,2,3,4*	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Summary Valuation ----- Priority
1	**Lokaliserings-förutsättningar Ostkusten**	Late 1950's	Prerequisite for establishing a nuclear power plant on the Småland coast. No information found from this epoch. *No of Entries: 1 No of A-valuation: 0* *Priority class 1,2,3,4: 0,0,1,0*	None ----- None	**B** ----- **3**
2	**Förundersökningar Simpevarpshalvön**	1959–	Investigations for establishing nuclear power plants at Simpevarp. Geology and rock mechanics. *No of Entries: 4 No of A-valuation: 4* *Priority class 1,2,3,4: 4,0,0,0*	Low ----- None	**A** ----- **1**
3	**Förundersökningar O1-2, BFA**	1965–69	Site investigation for the Oskar 1&2, power plants and the BFA underground facility. Geology and geophysics. *No of Entries: 4 No of A-valuation: 4* *Priority class 1,2,3,4: 4,0,0,0*	Low/ Moderate? ----- None	**A** ----- **1**
4	**Byggnation O1-2, BFA**	1966–74	Construction of the Oskar 1&2, power plants and the BFA underground facility. Geology. *No of Entries: 1 No of A-valuation: 1* *Priority class 1,2,3,4: 1,0,0,0*	Low/ Moderate? ----- None	**A** ----- **1**
5	**Förundersökningar O3 (4)**	1974–76	Site investigation for the Oskar 3 (and 4) power plants. Geology and geophysics. *No of Entries: 3 No of A-valuation: 3* *Priority class 1,2,3,4: 3,0,0,0*	Moderate? ----- None	**A** ----- **1**
6	**Byggnation O3**	1976–85	Construction of the Oskar 3, power plant. Geology. *No of Entries: 3 No of A-valuation: 3* *Priority class 1,2,3,4: 3,0,0,0*	Moderate? ----- None	**A** ----- **1**
7	**KBS**	1976–77 and 1984, -94, -97	Initial work within the nuclear waste programme. Kråkemåla, Ävrö and Simpevarp. Geology and hydrogeology. *No of Entries: 22 No of A-valuation: 20* *Priority class 1,2,3,4: 7,10,2,3*	Moderate ----- Low	**A** ----- **1(2)**
8	**Förundersökningar CLAB1**	1976–79	Feasibility study for CLAB1. Geology and hydrogeology. *No of Entries: 14 No of A-valuation: 9* *Priority class 1,2,3,4: 2,1,5,6*	Moderate ----- Low	**A** ----- **4(3)**
9	**Förundersökningar ALMA (SFR)**	1979–80	Site investigation for SFR. Geology and hydrogeology. *No of Entries: 3 No of A-valuation: 3* *Priority class 1,2,3,4: 1,0,0,2*	Low ----- None	**A** ----- **4(1)**

Nr	Epoch	Time Period	Information content Comments *No of entries, No of A-valuation and No of entries in priority class 1,2,3,4*	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Summary Valuation ----- Priority
10	**Byggnation CLAB1**	1980–82	Construction of CLAB1. Geology, hydrogeochemistry and rock mechanical data. *No of Entries: 6 No of A-valuation: 3* *Priority class 1,2,3,4: 3,0,0,3*	Moderate ----- Moderate	**A(B)** ----- **1(4)**
11	**Hamn, inseglingsränna**	1970's (1988)	Harbour investigation and construction, bathymetry. Geotechnical data? *No of Entries: 1 No of A-valuation: 1* *Priority class 1,2,3,4: 0,0,0,1*	Low ----- None	**A** ----- **4**
12	**Förstudie kolkraftverk SM**	1980's ?	Feasibility study for a coal power plant. No information found from this epoch. *No of Entries: 1 No of A-valuation: 1* *Priority class 1,2,3,4: 0,0,0,4*	None ----- None	**A** ----- **4**
13	**Äspö HRL Regional siting**	1987–89	Development of the Äspö HRL. Regional siting phase. Geology and hydrogeology. *No of Entries: 33 No of A-valuation: 23* *Priority class 1,2,3,4: 18,4,10,1*	Moderate ----- Low?	**A** ----- **1**
14	**Äspö HRL Semiregional siting**	1987–89	Development of the Äspö HRL. Semiregional siting phase. Geology, hydrogeology and hydrogeochemistry. *No of Entries: 57 No of A-valuation: 47* *Priority class 1,2,3,4: 37,2,12,6*	Moderate ----- Low?	**A** ----- **2**
15	**Äspö HRL Siting**	1987–90	Development of the Äspö HRL. Siting phase. Geology and hydrogeology. *No of Entries: 54 No of A-valuation: 27* *Priority class 1,2,3,4: 22,5,27,0*	Moderate ----- Moderate?	**A(B)** ----- **1(3)**
16	**Äspö HRL Prediction stage**	1988–91	Development of the Äspö HRL. Prediction stage. Geology, hydrogeology and hydrogeochemistry. *No of Entries: 64 No of A-valuation: 34* *Priority class 1,2,3,4: 27,6,30,1*	Moderate ----- Moderate?	**A(B)** ----- **1(3)**
17	**Äspö HRL Construction**	1990–95	Development of the Äspö HRL. Construction stage. Geology, hydrogeochemistry and rock mechanics. *No of Entries: 38 No of A-valuation: 29* *Priority class 1,2,3,4: 22,4,9,3*	Moderate ----- Low?	**A** ----- **1**
18	**Äspö HRL R&D**	1995–	Development of the Äspö HRL. Research and development projects. Geology. *No of Entries: 24 No of A-valuation: 19* *Priority class 1,2,3,4: 5,12,5,2*	Moderate ----- Low?	**A** ----- **2**

Nr	Epoch	Time Period	Information content Comments ***No of entries, No of A-valuation and No of entries in priority class 1,2,3,4***	Data Quantity ----- Fraction stored in SKB GIS/Sicada	Summary Valuation ----- Priority
19	**Äspö HRL Complementary work**	1990–	Development of the Äspö HRL. Complementary work. Geology, hydrogeology, hydrogeochemistry and rock mechanics. *No of Entries: 123 No of A-valuation: 63* *Priority class 1,2,3,4: 34,14,60,15*	High ----- Moderate?	**A(B)** ----- **1(3)**
20	**Förundersökningar CLAB2**	1995–98	Feasibility study for CLAB2. Geology, hydrogeology and hydrogeochemistry. A lot of data stored in CAD-system. *No of Entries: 8 No of A-valuation: 6* *Priority class 1,2,3,4: 4,2,2,0*	Moderate ----- Moderate	**A** ----- **1**
21	**Förstudie Oskarshamn**	1998–99	Feasibility study of Oskarshamn municipality. **Important primary geology data.** Ongoing data delivery in SKB specified formats. Also ecosystems and support data. *No of Entries: 154 No of A-valuation: 2* *Priority class 1,2,3,4: 2,10,142,0*	High ----- High	**B** ----- **3**
22	**Förstudie Fältkontroll Oskarshamn**	2000	Feasibility study of Oskarshamn municipality. Field reconnaissance. **Some primary geology data.** Ongoing data delivery in SKB specified formats. *No of Entries: 23 No of A-valuation: 23* *Priority class 1,2,3,4: 0,0,23,0*	Low ----- High	**B** ----- **3**
23	**Byggnation CLAB2**	1998–2004	Construction of CLAB2. Geology. A lot of data stored in CAD-system. *No of Entries: 3 No of A-valuation: 3* *Priority class 1,2,3,4: 0,1,2,0*	Moderate ----- Moderate	**A** ----- **2**
24	**Ospecificerat och regionalt i SM-området**	xxxx	Unspecified sources and regional data. A considerable amount of the data is related to Ecosystems, already in SKB GIS-format. *No of Entries: 79 No of A-valuation: 62* *Priority class 1,2,3,4: 17,7,20,35*	Moderate ----- Moderate	**A** ----- **4(1)**
25	**PLU-förberedelser SM**	2001–	Most of the data collected in the preparation for site investigations. Mostly data is in SKB GIS-format. *No of Entries: 58 No of A-valuation: 0* *Priority class 1,2,3,4: 0,0,58,0*	Moderate ----- High	**B** ----- **3**

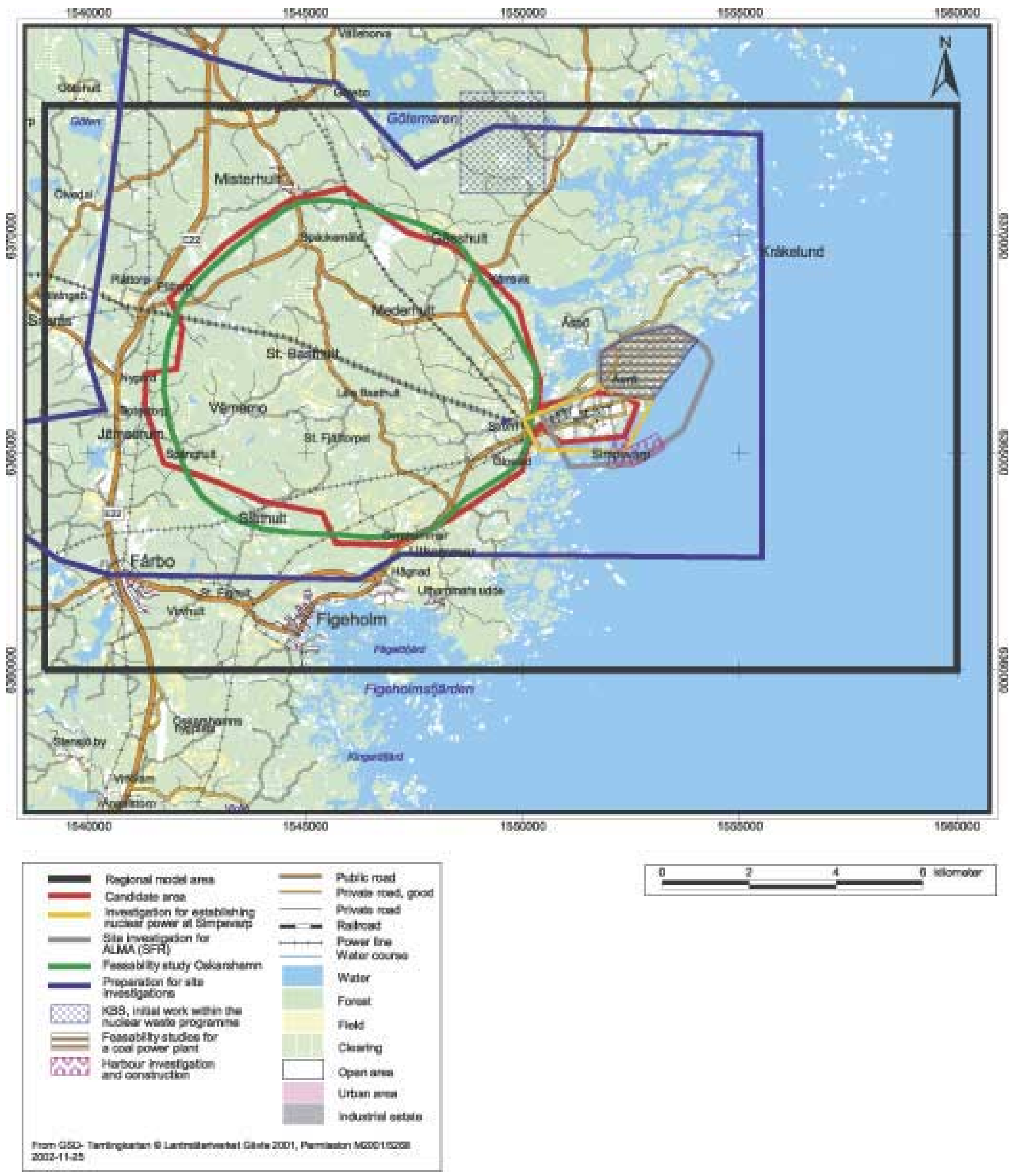


Figure 2-2. *Geographical areas investigated in connection with the feasibility study of the municipality of Oskarshamn and linked to information epochs in the data inventory.*

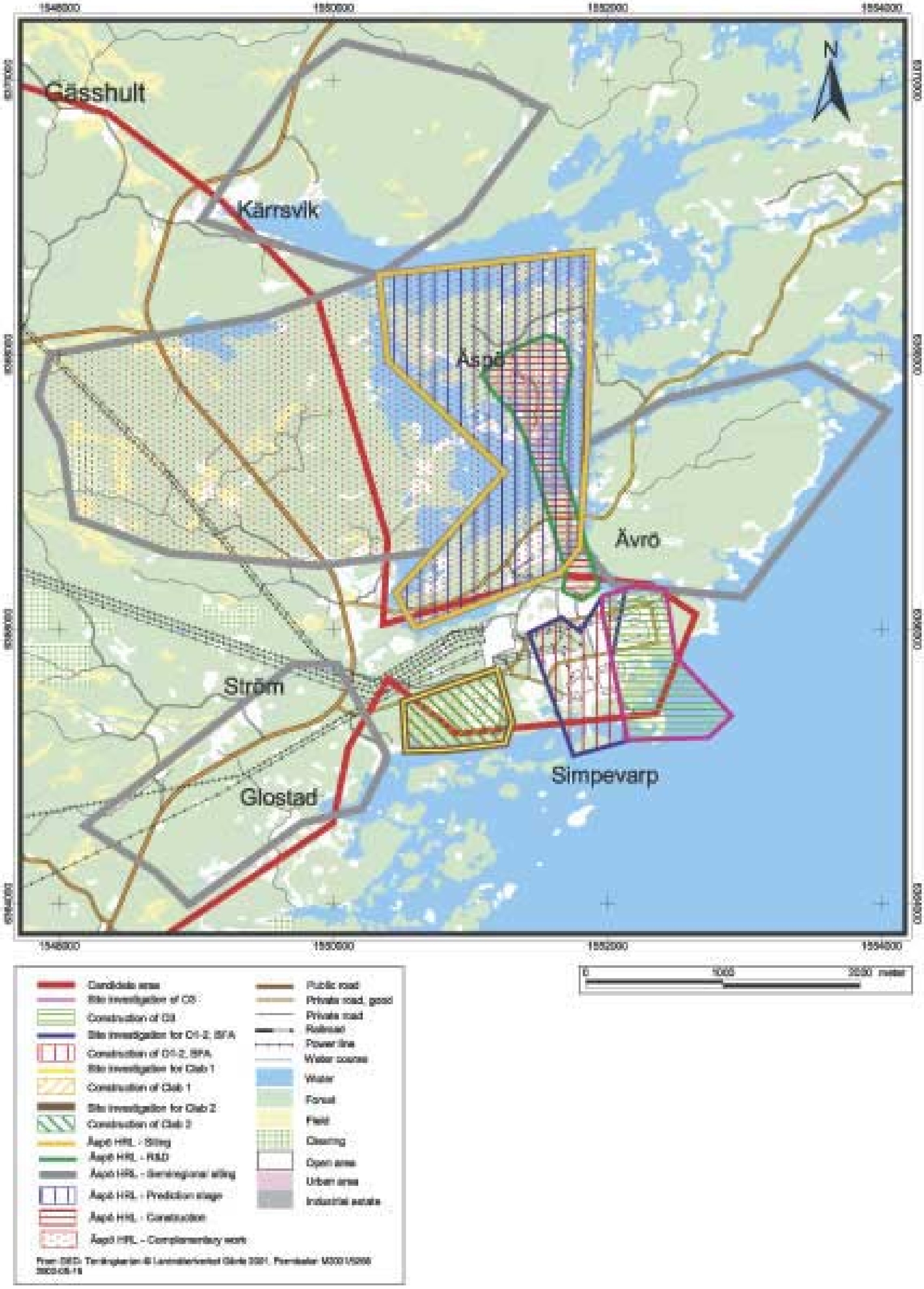


Figure 2-3. *Geographical areas in the vicinity of the Oskarshamn nuclear power station and CLAB and linked to information epochs in the data inventory.*

It is beyond the scope of this project to make a detailed comparison of data sets indicated in the inventory and the actual contents in the SICADA and GIS databases. This is especially valid for information collected during the development and operation of the Äspö HRL. However, Table 2-7 presents a summary of the number of entries for different information epochs in relation to concepts like; valuation, priority, discipline and SKB data storage. This presentation serves as a guideline in the subsequent prioritisation of what data that should be inserted into the SKB SICADA and/or GIS databases. The storage of data in SICADA is further described in Section 2.2.2.

All together 781 entries have been recorded. Of these, 367 entries have valuation A, i.e. should be examined in more detail, and 217 entries have priority 1, i.e. data inertion into SICADA and/or GIS is recommended. The majority of entries with valuation A (242) and priority 1 (165) relates to Äspö HRL (see above). 408 entries are already stored, or are currently in the process of being inserted, in SICADA and/or GIS.

Two data sources which need to be examined in more detail, can be identified; (1) the site investigations and constructions of CLAB I and II, and (2) those for the nuclear power plants, O 1-3. All these constructions are located on the Simpevarp peninsula and are of importance especially for the description of the local geology in this part of the regional model area. Some basic geological data and hydrogeological data, especially related to regional and semiregional areas surrounding the Äspö HRL, have probably not been utilised to their full extent during the feasibility studies.

Table 2-7. Summary of the number of entries in SICADA and/or GIS for different information epochs in relation to concepts such as valuation, priority, discipline and SKB data storage.

		No. of entries		Valuation		Priority				Discipline								SKB Data storage			
No	Epoch	Time period	Total	A	B	1	2	3	4	Geology	Rock mechanics	Hydrogeology	Hydrogeo-chemistry	Ecosystems	Support data	Transport properties	Thermal properties	Sicada	GIS	Eco-system (GIS)	SGU (GIS)
1	Lokaliseringsförutsättningar_Ostkusten	1950´s	1		1	**0**	0	1	0												
2	Förundersökningar_Simpevarpshalvön	1959-	4	**4**	0	**4**	0	0	0	3	1										
3	Förundersökningar_O1_O2_BFA	1965-69	4	**4**	0	**4**	0	0	0	4											
4	Byggnation_O1_O2_BFA	1966-74	1	**1**	0	**1**	0	0	0	1											
5	Förundersökningar_O3_(4)	1974-76	3	**3**	0	**3**	0	0	0	3											
6	Byggnation_O3	1976-85	3	**3**	0	**3**	0	0	0	3											
7	KBS_Kråkemåla_Ävrö_Simpevarp	1976-77(84, 94	22	**20**	2	**7**	10	2	3	13		9						2			
8	Förundersökningar_Clab1	1976-79	14	**9**	5	**2**	1	5	6	9		6						4			
9	Förundersökning_ALMA_(SFR)	1979-80	3	**3**	0	**1**	0	0	2	2		1									
10	Byggnation_Clab1	1980-82	6	**3**	3	**3**	0	0	3	2	3		1					3			
11	Hamn_inseglingsränna	1988	1	**1**	0	**0**	0	0	1	1											
12	Förstudie_kolkraftverk_SM	1980´s ?	1	**1**	0	**0**	0	0	1	1											
13	Äspö_HRL_Regional siting	1987-89	33	**23**	10	**18**	4	10	1	25		7	1								
14	Äspö_HRL_Semiregional siting	1987-89	57	**47**	10	**37**	2	12	6	48	1	9	1		1			9			
15	Äspö_HRL_Siting	1987-90	54	**27**	27	**22**	5	27	0	24	1	23	6					19			
16	Äspö_HRL_Prediction stage	1988-91	64	**34**	30	**27**	6	30	1	33	1	26	4					19			
17	Äspö_HRL_Construction	1990-95	38	**29**	9	**22**	4	9	3	23	6	1	11					9			
18	Äspö_HRL_R_D	1995-	24	**19**	5	**5**	12	5	2	19	1	2	1			1		5			
19	Äspö_HRL_Complementary_work	1990-	123	**63**	60	**34**	14	60	15	57	17	44	16		4	1	4	60			
20	Förundersökningar_Clab2	1995-98	8	**6**	2	**4**	2	2	0	5	1	2						2			
21	Förstudie_Oskarshamn	1998-99	154	**2**	152	**2**	10	142	0	64	1	5	2	38	40				125	4	23
22	Förstudie_Fältkontroll_Oskarshamn	2000	23	**0**	23	**0**	0	23	0	23									15		8
23	Byggnation_Clab2	1998-2004	3	**3**	0	**1**	2	0	0	3											
24	Ospecificerat_regionalt_SM	xxxx	79	**62**	17	**17**	7	20	35	22		17	1	41	1			5		38	
25	PLU_förberedelser_SM	2001-	58	**0**	58	**0**	0	58	0					58						58	
		Sum:	**781**	**367**	**414**	**217**	**79**	**406**	**79**	**388**	**33**	**152**	**44**	**137**	**46**	**2**	**4**	**137**	**140**	**100**	**31**

2.2.2 Inventory of SICADA

Within this project, an inventory of the database SICADA was carried out in order to describe its content of data from the Simpevarp regional model area.

SICADA database structure

The database SICADA contains descriptions of activities, such as investigations, constructions, installations etc. All activities are catalogued in the following structure:

- Biology
- Chemistry
- Engineering
- Geography
- Geophysics
- Geotechnics
- Hydrochemistry
- Hydrology
- Meteorology
- Rock mechanics

In SICADA, a series of tables are linked to the activities. The tables contain information about the activity and data from the activity. The number of tables typically varies between one and six, but some activities are linked to even more. The structure of SICADA also allows insertion of an activity without entering data into the associated table.

Methodology

At the time of the inventory, data from the Simpevarp regional model area had been stored in SICADA under the following sub-areas ("sites" in SICADA vocabulary):

- Bussvik
- CLAB
- Laxemar
- Kråkemåla
- Simpevarp
- Ävrö
- Äspö

The results from the inventory were stored in Microsoft Excel-files. As the area around Simpevarp has been studied by SKB over a long period of time, the number of activities is large (in total around 40,000). Hence, only approximately every fifth to every tenth (in the case of site Äspö every hundredth) activity was checked regarding data content in the corresponding tables.

The data content was judged in a fast and rather subjective manner in order to achieve the goal within the time available. This pragmatic method did not give a very detailed description of the content of SICADA but was, however, considered to provide a useful diagnostic description. The result was inserted into the data base structure developed for the general inventory work (see Section 2.2.1), where also a brief list of the objects for the activities is found.

It was not considered possible to rank the quality of the inserted data. However, it could be assumed that the quality would be a function of several factors, of which the most important are: year of activity, maturity of the investigation method applied, the skill of the entrepreneur and the type of equipment used.

Results

A compilation of the results is displayed graphically in Figure 2-4. The height of the column shows the amount of activities in every one of the ten groups (cp. SICADA database structure above). The colour of the column shows the proportion of data, which appear to have been inserted from the activities.

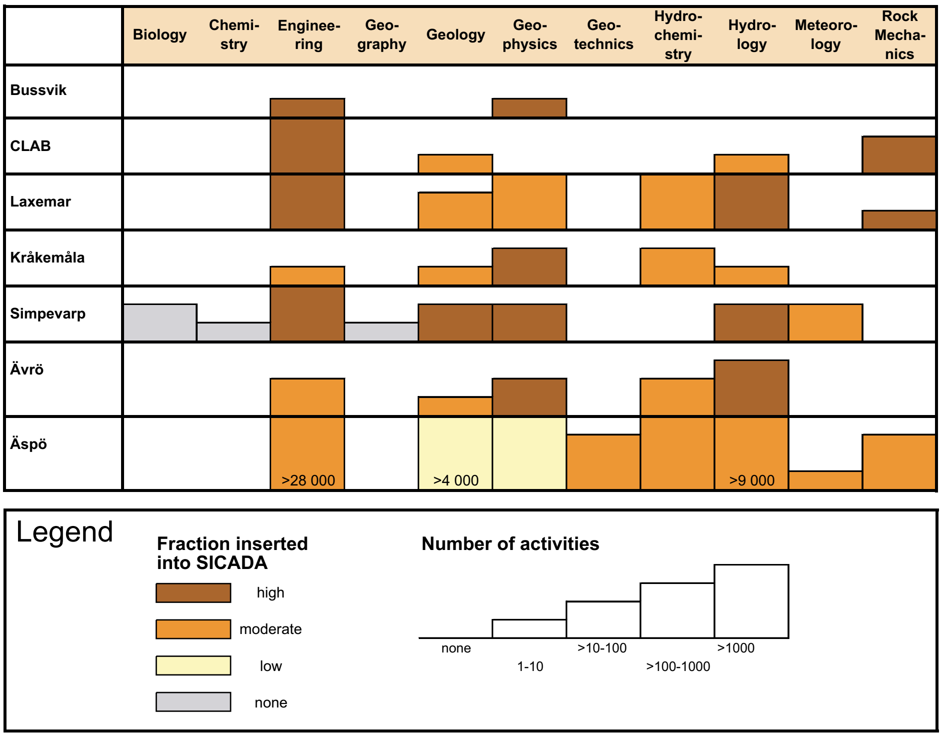


Figure 2-4. Data inventory for the area around Simpevarp. The number of activities, and an estimate of the fraction of data inserted from the activities, in SICADA, as of November 2001.

2.2.3 Conclusions

The inventory of data from the Simpevarp regional model area has shown a large amount of information from the site investigations and the construction phases of the Äspö Hard Rock Laboratory. The data from this large number of activities seem, in general, to have been inserted into SICADA in a systematic manner. However, this has to be further examined.

Three different data sources which need to be examined more in detail have been identified. The site investigations and construction phases of CLAB I and II, and those of the nuclear power plants, O 1-3, constitutes the first two sources. All the constructions are located on the Simpevarp peninsula and are of importance especially to describe the local geology in this part of the regional model area. The databases at SKB have mainly been used to store data from site investigations, and from scientific experiments, and not data from construction work. Hence, only limited parts of the construction-related data are stored in the databases at SKB. Furthermore, most of the data are not available in digital format (CLAB II is an exception). Most of the data can be classified as primary geological data, such as information from drillholes, ground constructions and tunnels, and seismic profiles.

The third data source to consider is basic geological data and some hydrogeological data from the immediate and wider surroundings of the Äspö HRL, which have not been utilised in full detail during the feasibility studies.

The site descriptive model version 0 is above all on a regional scale and most of the information necessary to obtain a model at this scale have been evaluated in the feasibility studies. Hence, most of the information described as lacking in SICADA and/or GIS is not of any crucial significance in this context. However, the information is of potential interest when modelling the geosphere in different parts of the Simpevarp regional model area in more detail.

An inventory database has been created which is expected to provide an overview of the information identified in this inventory. Furthermore, the results are displayed in a number of presentations in the ArcView GIS system.

3 Ecosystems

3.1 Introduction

This chapter describes the present (2001) status of knowledge of the ecosystems in the Simpevarp regional model area and is a compilation of selected reports and papers, which describe the ecosystems. The biosphere may be defined in slightly different ways /e.g. The Biosphere, 1970; Campbell, 1992/. In this report the biosphere has been defined as the ecosystem above the bedrock. This means that it includes the Quaternary deposits, surface water, groundwater in Quaternary deposits, humans and other biota as well as the surface hydrologic cycle and climate.

The intention has been to summarise all available data, but some sources of information may not have been recognised during the compilation. Upcoming versions of this report will remedy this defect. The information has been collected from different studies and therefore the investigated areas deviate. The definition of these areas is not of importance for this presentation as long as the data is relevant for the Simpevarp regional model area. In this chapter, the term "Simpevarp area" is used in a more general way, meaning different parts of the area close to the model area. For a definition of the different areas of investigation the reader is referred to the original references. No further synthesis has been made in this report, and the data and figures chosen only as illustrative examples.

The major discipline "Ecosystems" is divided into different functional ecosystem types, which will be investigated and described further during the site investigation.

The functional ecosystem types are:

- Drainage areas
- Forest
- Wetland
- Agricultural land
- Lakes and rivers
- Sea

These ecosystems are built up of different entities, as further discussed in Section 3.1.1. Data for the different functional ecosystems is presented in Sections 3.2–3.7.

3.1.1 Biosphere system and entities

During the last years, SKB has continuously adapted and developed tools for ecosystem modelling /SKB, 2001c/. To identify the interactions and flux pathways in different ecosystems, a general interaction matrix has been developed, reproduced here as Figure 3-1. The matrix contains all identified interactions and should be seen as a tool which will be used to ascertain that no important entities or pathways involved in the transport of radionuclides in ecosystems are neglected when the safety analysis of the area is performed.

GEOSPHERE (B.C.)	a)Erosion/weath. b)Change in rock surface location	NONE	NONE	NONE	NONE	NONE	a)Material supply b)Settlement
a) Mech. load b) Consolidation	**Quaternary deposits** a)Relocation	a)Settlement b)Deposition	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption	a)Settlement b)Consumption c)Material supply
Root penetration a) Rock b) Tunnels c) Biological	Root growth	**Primary producers** a)Stimul/Inhib.	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib.	a)Stimul./Inhib. b)Food supply d)Material supply
Potential intrusion	a)Decomposition b)Bioturbation	a)Stimul./Inhib.	**Decomposers** a)Stimul/Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply d)Material supply
Potential intrusion	Bioturbation	a)Stimul/Inhib. c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding	**Filter feeders** a)Stimul/Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply d)Material supply
Potential intrusion	Bioturbation	a)Stimul./Inhib. c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply	**Herbivores** a)Stimul/Inhib.	a)Stimul./Inhib. b)Food supply	a)Stimul./Inhib. b)Food supply d)Resource
Potential intrusion	Bioturbation	a)Stimul./Inhib.	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. c)Feeding	**Carnivores** a)Stimul/Inhib. b)Food supply c)Feeding	a)Stimul./Inhib. b)Food supply c)Feeding d)Resource
NONE	Disturbance *(dredging, digging)*	a)Stimul./Inhib. c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib. b)Food supply c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib. c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib. c)Feeding d)Dispersal/ Extermination	a)Stimul./Inhib. b)Food supply c)Feeding d)Dispersal/ Extermination e)Material use	**Humans** a)Stimul/Inhib.
a) Rech./disch. b) Press. change c) Mass flux d) Erosion/weath.	a)Erosion b)Water content change	a) Settlement b) Water uptake	a) Settlement b) Water uptake	NONE	a) Settlement b) Water uptake	a) Settlement b) Water uptake	a) Settlement b) Water use
a) Rech./disch. b) Press. change c) Mass flux d) Erosion/weath. e) Ice-load	Erosion *(icescoring)*	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water uptake	a)Settlement b)Relocation c)Water use
a) Mass flux b)Erosion/weath.	a) Sedimentation b) Precip./dissol. c) Erosion/weath.	a)Settlement b)Stimul./Inhib. c)Light attenu.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.
Gas transport	a)Erosion b)Deposition c)Oxidation	a)Settlement b)Stimul./Inhib. c)Relocation d)Depos./Remov.	a)Settlement b)Stimul./Inhib. c)Relocation d)Depos./Remov.	NONE	a)Settlement b)Stimul./Inhib. c)Relocation d)Depos./Remov.	a)Settlement b)Stimul./Inhib. c)Relocation d)Depos./Remov.	a)Settlement b)Stimul./Inhib. c)Relocation d)Depos./Remov.
a)Heat transport b)Erosion/weath.	a)Weathering b)Thermal expans/contr	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.	a)Settlement b)Stimul./Inhib.
Contaminant transport	a) Surface dep./uptake b) Irradiation	a) Int. exposure b) Ext. exposure	a) Int. exposure b) Ext. exposure	a) Int. exposure b) Ext. exposure	a) Int. exposure b) Ext. exposure	a) Int. exposure b) Ext. exposure	a) Int. exposure b) Ext. exposure
NONE	a) Import b) Land rise	a) Import b) Insolation	Import	Import	Import	Import	a)Import of energy b)Immigration

Figure 3-1. *The biosphere matrix, after /Kautsky et al, 2001/.*

	Discharge/ recharge	Discharge/ recharge	Mass flux	Gas transport	Heat transport	Contaminant transport	NONE
	a) Water transport b) Dehydration	a)Water transport b)Wave formation	a)Resuspension b)Leaching c)Sorpt./desorpt.	a)Resuspension b)Non-biol decomp c)Wind field changes d)Air pressure	a)Radiation b)Heat transport c)Heat storage	a)Sorption/desorpt. b)Dissolution	Export
	Root uptake	a)Interception b)Retard./Accel. c)Uptake/Excret. d)Covering	a)Uptake./Excret. b)Particle prod	a)Gas uptake/rel b)Part. trap/prod c)Wind retard.	a)Radiation b)Exo/Endo react. c)Heat transp.	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	Export *detached outflow of plankton*
	Decomposition	a)Decomposition b)Retard./Accel. c)Uptake/Excret. d)Movement	a)Uptake./Excret. b)Particle prod	a)Gas uptake/rel b)Part. trap/prod	a)Radiation b)Exo/Endo react. c)Heat transp.	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	Export
	NONE	a)Water-pumping b)Retard./Accel. c)Uptake/Excret.	a)Uptake./Excret. b)Particle prod	NONE	a)Radiation b)Exo/Endo react. c)Heat transp.	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	Export *detachment spawn*
	NONE	a)Movement b)Retard./Accel. c)Uptake/Excret.	a)Uptake./Excret. b)Particle prod	a)Gas uptake/rel b)Part. trap/prod	a)Radiation b)Exo/Endo react. c)Heat transp.	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	Export
	NONE	a)Movement b)Retard./Accel. c)Uptake/Excret.	a)Uptake./Excret. b)Particle prod	a)Gas uptake/rel b)Part. trap/prod	a)Radiation b)Exo/Endo react. c)Heat transp.	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	Export *swimming running*
	a)Water extraction b)Artific.infiltr.	a)Movement b)Retard./Accel. c)Uptake/Excret. d)Covering	a)Excretion b)Filtering c)Pollution	a)Gas uptake/rel b)Part. trap/prod c)Pollution d)Wind retard/acc.	a)Radiation b)Exo/Endo react. c)Heat transp. d)Antropogen eff	a) Uptake/sorpt. b) Excretion c) Degradation d) Growth	a)Export of energy b)Emigration?
NONE (former topography)							
	Water in quarternary deposits	Discharge (recharge)	a) Erosion b) Mixing c) Dens. effects	a)Evapo./Cond. b)Sublimation	a)Heat transp. b)Heat storage	Mixing	Export
	Recharge (discharge)	**Surface water**	a) Mixing b)Dens. effects	a)Evapo./Cond. b)Sublimation c)Erosion *(seaspray/snowdrift)*	a)Radiation b)Exo/Endo react. c)Heat transp. d)Heat storage e)Light reflection	Mixing	Export/import
	Water transport	Water transport	**Water composition**	a)Spray/Snowdrift b)Dissol./Degas.	a)Exo/Endo react. b)Light absorb. c)Light reflect./scatt. d)Adiab. compr.	a) Sorpt./desorpt. b) Dissol./precip. c) Sedimentation	Export
	a)Water transport b)Evapo./cond. c)Sublimation	a)Water transport b)Evapo./Cond. c)Precipitation d)Wind stress e)Sublimation	a)Precipitation b)Deposition c)Evapo./Cond. d)Dissol./Degas.	**Gas --------------- Atmosphere**	a)Radiation b)Exo/Endo react. c)Heat transp. d)Heat storage e)Adiab.temp.change f)Phase changes	a)Mixing b)Sorpt./desorpt. c)Photochem. reactions	Export
	Phase transitions	a)Phase transitions b)Convection	a)Kinetics & chem equil. b)Property changes c)Mixing	a)Pressure change b)Phase transitions	**Temperature**	a)Kinetics & chem equil. b)Phase transitions	Export of heat
	NONE	NONE	a) Radiolysis b) Stab. isotopes c) Chem. react.	Phase transition	Heat from decay	**Radionuclides and toxicants** a) Decay	Export
	Import	a) Sea level changes b) Sea currents	Import	a)Import b)Photochem-reactions	a) Import of heat b) Insolation	External load of contaminants	**External conditions (B.C.)**

The biosphere matrix displays interactions (processes) between the different physical and biological components in the local biosphere. Further, the interactions between the local biosphere and the global biosphere are also included. This means, in this case, that interactions with the geosphere as well as with the biosphere present outside the Simpevarp regional model area are also considered, representing different boundary conditions of the system.

Some of the interactions and flux pathways in the biosphere matrix represent the surface environment at the Simpevarp site, including:

- The parts of the surface environment that potentially may have an impact on a repository.
- Potential discharge areas and regions where any significant parts of potentially released radionuclides may migrate and give significant concentrations.

System state variables

The physical and biological components of the biosphere system are:

- Quaternary deposits
- Bedrock at the surface (outcrop)
- Buildings and structures such as roads, road-banks, bridges etc
- Vegetation
- Animal life
- Human life
- Water
- Gas and atmosphere
- Temperature
- Radionuclides and toxicants

These components are represented as diagonal elements in the biosphere matrix (Figure 3-1) and are numbered as element 1.1, 2.2, etc. The interactions between two components are numbered according to the lines of the components, e.g. the interactions between element 1.1 and 2.2 are shown as element 1.2 (influence of element 1.1 on element 2.2) and 2.1 (influence of element 2.2 on element 1.1).

For further definitions of the diagonal elements in the biosphere matrix and for a thorough description of the identified interactions, see /Kautsky et al, 2001/.

Variables

Using the biosphere matrix (Figure 3-1), a number of variables have been selected. These variables are to be studied during site investigations to describe the different ecosystems and fluxes at the site. The variables are presented in /Lindborg and Kautsky, 2000/. This chapter uses the same variable system to describe the present knowledge of the different ecosystems selected.

3.1.2 Availability of data

Data concerning ecosystems in the Simpevarp regional model area and its surroundings have been compiled and presented in a number of SKB reports. Important compilations, for other purposes and not focused on the Simpevarp regional model area, have also been made by other organisations, e.g. Länsstyrelsen i Kalmar län. In the present report, references are generally made to these compilations.

3.2 Drainage areas

Two major catchment areas, Virån and Marströmmen, are located within the Simpevarp area /Svensson, 1987/. The drainage areas of the Simpevarp regional model area are shown in Figure 3-2.

The bedrock in the catchment areas of the Simpevarp regional model area is dominated by Småland "granite" (see Chapter 4), with a high degree of exposed rock /Gustafson and Eriksson Nilsson, 1995; Hammarström and Olsson, 1996/. The catchment areas are dominated by forest. Coniferous forest with some contribution of deciduous trees is most common, with some small areas of arable land /Oskarshamns kommun, 1992/. The region contains few lakes. For more information about the lakes in the area, see Section 3.6.

The following entities will describe the drainage areas in Simpevarp regional model area:

- Meteorology
- Topography
- Surface hydrology
- Wells
- Pollutants

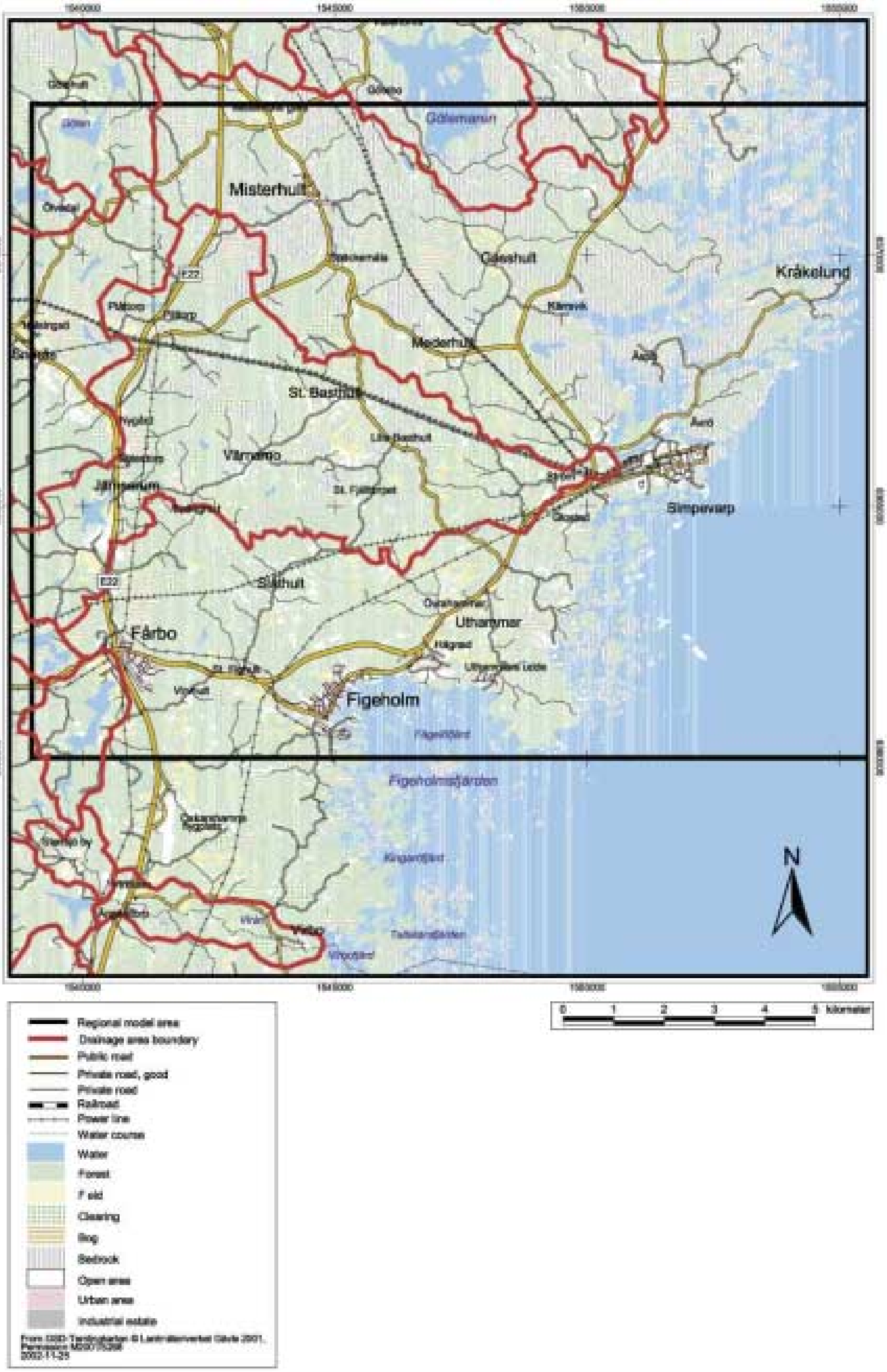


Figure 3-2. Drainage areas in the Simpevarp regional model area.

3.2.1 Meteorology

Data input

The variables describing the meteorological conditions at Simpevarp are: wind direction, precipitation, temperature, length of vegetative period, sunshine time, snow coverage and snow depth. Available data has been compiled by /Lindell et al, 1999/ and /Larsson-McCann et al, 2002/.

Distribution and character

Data from the Swedish Meteorological and Hydrological Institute (SMHI) are used for long term statistics. Data for the weather station "Ölands norra udde" are regarded as representative for coastal areas of Oskarshamn regarding most meteorological parameters. The weather station at Oskarshamn, which is located a few km inland from the coast, was chosen for precipitation and temperature /Larsson-McCann et al, 2002/.

On average, *winds* from south to west are the most frequent (Figure 3-3). In the spring, hard winds from north-east are not unusual. There is only a small proportion of calm (c. 1.5%), which is partly due to the position at the coast. A frequency of 5–10% of calm is not unusual for inland conditions also for open ground /Larsson-McCann et al, 2002/.

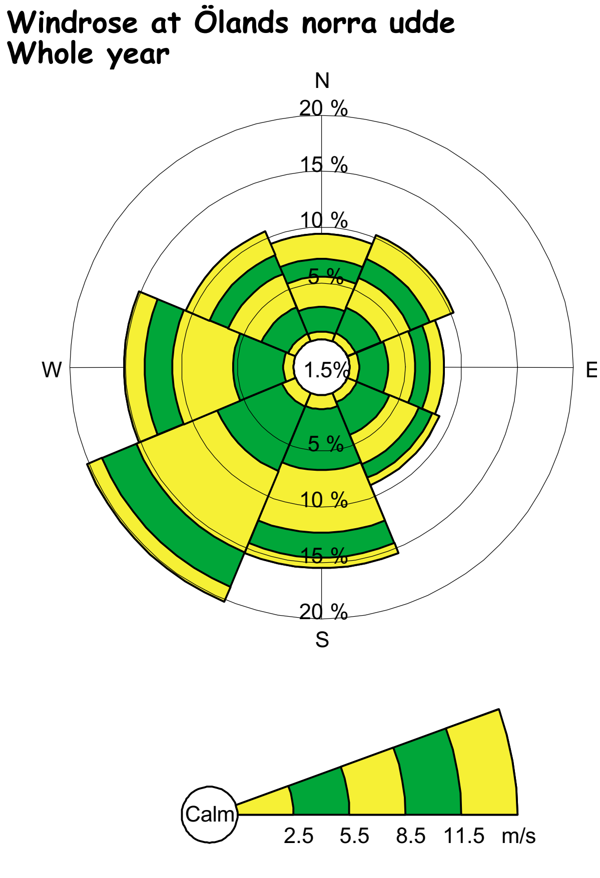


Figure 3-3. *Wind rose showing the average annual distribution of the wind direction and wind velocity for the weather station "Ölands norra udde". Frequencies (%) of wind (simultaneous direction and speed) are indicated with colours and percent of calm is noted in the centre of the windrose. Wind direction is grouped into 8 classes of 45° (N, NE, E, SE, S, SW, W and NW). Wind speed is classified in intervals of 3 m/s. After /Larsson-McCann et al, 2002/.*

In connection with precipitation, there is a much higher frequency of winds from north-east to east, especially with snowfall, when winds from these directions have a frequency of 60% and when the wind speed is beyond 12 m/s a great deal of that time /Larsson-McCann et al, 2002/.

Measured *precipitation* shows a great variation from place to place. The maximum usually occurs some km inland from the coast. The measured amount of precipitation is about 100 mm higher in Oskarshamn than at Ölands norra udde. The estimated true precipitation (adjusted for measuring losses) exceeds the gauged amounts by 100 mm or more, on an annual basis. About 20% of yearly precipitation fall as snow /Larsson-McCann et al, 2002/.

The annual mean *temperature* of the Simpevarp regional model area is 6–7°C, with a January mean of about –2°C and a July mean of 16–17°C. The annual mean could be compared to Stockholm (6.6°C), Malmö (8.2°C) and Östersund (2.5°C). The influence from the sea decreases inland and the average winter temperature is c. 2°C lower in Oskarshamn than at Ölands norra udde /Larsson-McCann et al, 2002/.

The temperature variation largely depends on the sea-land dualism, implying smaller annual variations over sea, i.e. higher winter and lower summer temperatures than over land. This is, combined with a similar day-night pattern, connected to the small diurnal variations over sea.

The *vegetative period* (daily mean temperature exceeding 5°C) has a duration of about 200 days /Larsson-McCann et al, 2002/.

The annual *sunshine time* is about 1,800 hours, a level typical for Swedish coastal sites, and near the highest Swedish values (about 1,900 hours). The values of sunshine time are lower inland, and in the interior of Götaland the values go down to 1,300 hours. The cloudiness percentage is 60–65%, slightly less in summer and slightly more in winter. In early summer the cloudiness tends to decrease near the coast compared to inland conditions /Larsson-McCann et al, 2002/.

The ground is covered by *snow* on an average 75 days a year, with an average annual maximum depth of snow of about 35–40 cm. The condition at the coast does not differ much from those 20–30 km inland /Larsson-McCann et al, 2002/.

A summary of the meteorological data for the Simpevarp regional model area is presented in Table 3-1.

Table 3-1. Meteorological data for the Simpevarp regional model area.

Parameter	Value for Simpevarp regional model area
Annual precipitation	c. 650 mm
Annual mean temperature	6–7°C
Mean temperature, January	–2°C
Mean temperature, July	16–17°C
Vegetation period	200 days
Sunshine time	1,800 hours
Snow coverage period	75 days
Maximum snow depth	35–40 cm

3.2.2 Topography

Data input

The key variable affecting topographical conditions in the Simpevarp regional model area is shoreline displacement. Important sources of information are /Gustafsson and Eriksson Nilsson, 1995/, /Hammarström and Olsson, 1996/, /Rhén et al, 1997a/, /Påsse, 1996/ and the digital elevation model (DEM) of Lantmäteriet (50 m resolution).

Distribution and character

The Simpevarp region is situated in a fissure valley landscape, which changes into an archipelago closer to the Baltic Sea. It is characterised by a relatively low topographical relief. The area rests on a bedrock dominated by Småland "granite", with a high degree of exposed rock /Gustafson and Eriksson Nilsson, 1995; Hammarström and Olsson, 1996/.

The ice of the latest glaciation melted in the area about 11,900 years ago and left deposits, mainly till but also silt, sand and clay /Rhén et al, 1997a/.

At present, the *shoreline displacement* in the area is about +1.5 mm/year relative to mean sea level /Påsse, 1996/. A calculation of the position of the shoreline in about 2,500 years is shown in Figure 3-4. As seen in the figure, the changes of the coastline are relatively small on this time perspective.

3.2.3 Surface hydrology

Data input

The variables describing conditions of surface hydrology in the Simpevarp regional model area are discharge and runoff area. Compilations and evaluations of exixsting data are presented by /Lindell et al, 1999/, /Losjö et al, 1999/ and /Larsson-McCann et al, 2002/.

Distribution and character

The hydrological station 1619 ("Forshultesjön nedre") has been chosen to represent the Oskarshamn area. It has a continuous record series with registrations since 1955, with an annual mean specific *discharge* of 5.7 l/s*km^2 and a *runoff area* of 103.2 km^2. The monthly discharge during the time period 1955–2000 is shown in Figure 3-5. The characteristics of discharge at a minimum of 50 years and a maximum of 50 and of 100 years were determined by frequency analysis. Moreover, the long term minimum and maximum as well as long term average has been determined by mean value calculation /Larsson-McCann et al, 2002/.

3.2.4 Wells

See Chapter 6 (Hydrogeology).

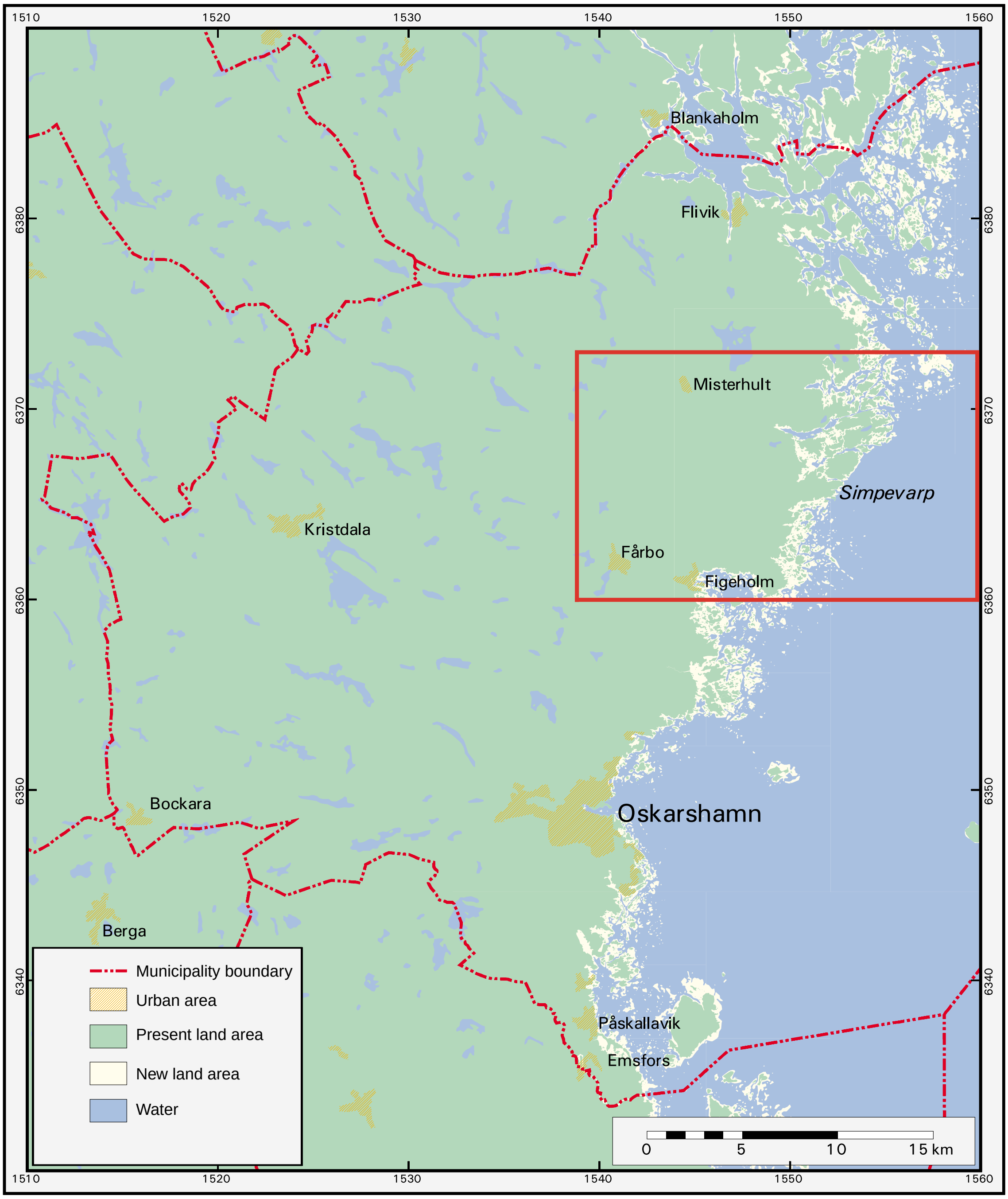


Figure 3-4. *The shoreline of the Simpevarp area at about 4,500 AD /after Follin et al, 1998a/. The Simpevarp regional model area is shown by a red line.*

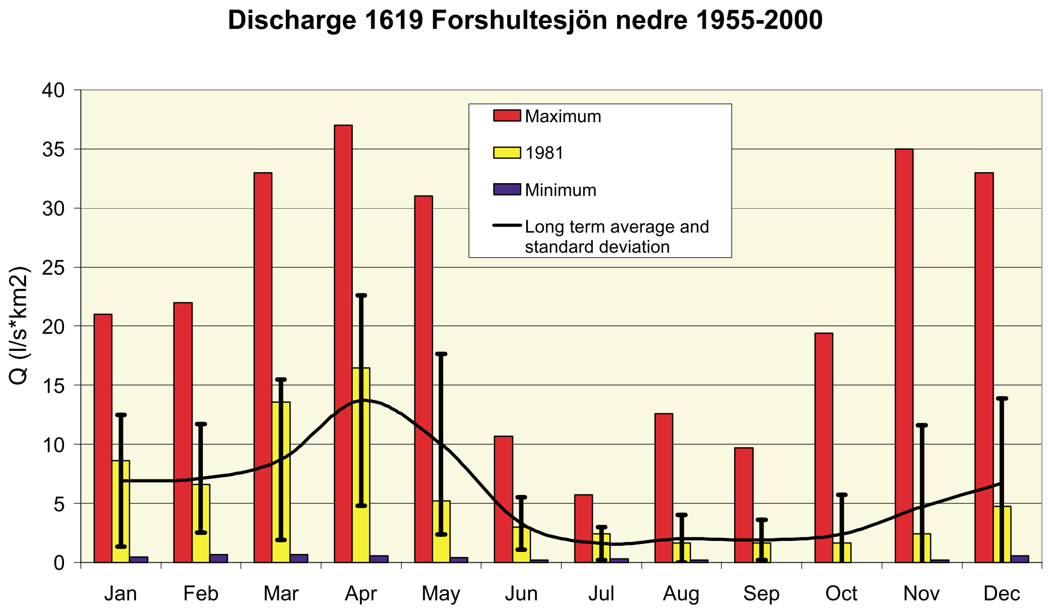


***Figure 3-5.** Monthly discharge at the hydrological station 1619 (Forshultesjön nedre) during the period /Larsson-McCann et al, 2002/.*

3.3 Forest

The following entities describe the forests in the Oskarshamn regional model area:

- Vegetation
- Fauna
- Soils
- Chemistry
- Land use
- Pollutants

3.3.1 Vegetation

Data input

The vareables describing conditions of the vegetation of forests in the Simpevarp regional model area are forest type, undergrowth and production. Information on these variables is found in /Berggren and Kyläkorpi, 2002/, /NMR, 1984/, /Gustafsson and Eriksson Nilsson, 1995/ and /Gustafsson and Ahlén, 1996/.

Distribution and character

The Simpevarp regional model area is situated within the Boreonemoral zone, which contains woodlands south of "Limes Norrlandicus", the biological Norrland boundary /Sjörs, 1967/. The northern limit of the boreonemoral zone coincides with the limit of oak and the area contains 750–900 species of vascular plants /NMR, 1984/. The region is part of the "Archipelagos of Södermanland and northern Götaland", a sub-region of the "Coast and archipelagos of the Baltic Sea" /NMR, 1984/. In this part of the archipelago, no birch (*Betula pendula*) occur and the annual temperature and the water deficit during the vegetation period is higher than in the main region /Gustafson and Eriksson Nilsson, 1995/.

The *categories of coniferous forest* compose 80% of the total forest area and is divided into: pine forest (c. 40%), spruce forest (c. 25%) and mixed forest (c. 15%) /Gustafsson and Ahlén, 1996/. Mixed deciduous forest also occurs, in addition to forests with one dominating species, for example oak (*Quercus robur*). The dominating vegetation type in the coastal area is pine forest on outcrops of bedrock /Gustafson and Eriksson Nilsson, 1995/.

The most common *undergrowth* is the grass type, which is considerably more common in southern Sweden. The beech (*Fagus sylvatica*), which is sensitive to frost in spring, has its northern limit in the Kalmar county /Gustafsson and Ahlén, 1996/.

In the National forestry inventory "riksskogstaxeringen", the following two variables describe the *production* (growth):

AVSTILLV 5 years of bark growth (1/10 m^3sk/ha)

KORTILLV 5 years of bark growth, corrected for weather (1/10 m^3sk/ha)

Both of these variables are calculated according to quite complicated methods. Growth and bark volume for coniferous trees have been estimated by /Svensson, 1988/. For deciduous trees, functions estimated by /Jacobsson, 1978/ have been used.

The difference between the two calculated variables is that AVSTILLV is an estimate of the actual growth rate which has been calculated for a sample area, whereas KORTILLV displays growth rate corrected for potential effects due to deviations in the local climate. For short, this is done by correcting the values for the latest five years with a "normal weather" which has been calculated for the latest 60-year time period. The result gives the growth which should have been gained if the weather had been "normal". In another inventory "ståndortskarteringen", only one variable, TILLVAX, is used for growth. This variable is gained through division of AVSTILLV with 50 /Berggren and Kyläkorpi, 2002/.

Production estimates, as average values for these parameters are given in /Berggren and Kyläkorpi, 2002/, see Table 3-2. The definition of "all sampling sites" in Table 3-2 is the area between 1530000 and 1555000 E and between 6350000 and 6380000 N (RAK).

Table 3-2. Forest growth rate variables, average values and standard deviation (Std), after /Berggren and Kyläkorpi, 2002/.

Variable	Average value, all sampling sites	Std	Average value, sampling sites within the Simpevarp regional model area	Std
AVSTILLV	23.06 m^3sk/ha/5 year	19.32	23.81 m^3sk/ha/5 year	17.10
KORTILLV	22.28 m^3sk/ha/5 year	18.55	22.75 m^3sk/ha/5 year	16.18
TILLVAX	4.11 m^3sk/ha/year	3.93	4.82 m^3sk/ha/year	3.43

3.3.2 Fauna

Data input

The sources of information available are outlined by /Berggren and Kyläkorpi, 2002/ and /Lindborg and Schüldt, 1998/.

Distribution and character

Hare (*Lepus sp.*) and roe deer (*Capreolus capreolus*) are frequent visitors in the Simpevarp regional model area. Mammals that are seen more seldom are moose (*Alces alces*), badger (*Meles meles*), and fox (*Vulpes vulpes*) /Lindborg and Schüldt, 1998/. The estimated population size for moose is 0.85 animals/km^2. Information about the number of animals hunted within the region has been compiled by /Berggren and Kyläkorpi, 2002/.

3.3.3 Soils

In this report, soil is used in the enginering geological sense, i.e. as synonymous with "regolith", which is defined as follows /Bates and Jackson, 1987/:

"A general term for the layer of fragmental and unconsolidated rock material, whether residual or transported and of highly varied character, that nearly everywhere forms the surface of the land and overlies or covers the bedrock. It includes rock debris of all kinds, volcanic ash, glacial drift, alluvium, loess and colian deposits, vegetal accumulations, and soil (*solum*)…"

The term soil, as used here, thus constitutes a subgroup to the more general term "unconsolidated deposits" which includes terrestrial, marine and lacustrine deposits.

Data input

The variables describing the soils of the forests in the Simpevarp regional model area are soil texture, soil depth and soil type. Information from various sources has been compiled by /Berggren and Kyläkorpi, 2002/.

Distribution and character

Information about forest soils in the area is presented in the National forestry inventory "Riksskogstaxeringen". 303 sampling sites are located within the region. Of those, 71 sampling sites are located within the Simpevarp regional model area. The data concerning soil texture and depth are presented in Table 3-3 and 3-4. The definition of "all sampling sites" is the region between 1530000 and 1555000 E and between 6350000 and 6380000 N, RAK.

Table 3-3. Textures of forest soils according to the National forestry inventory "Riksskogstaxeringen" /after Berggren and Kyläkorpi, 2002/.

Soil texture	All sampling sites		Simpevarp regional model area	
	Share	Nr	Share	Nr
Stony till/stone	2.64%	8	4.23%	3
Gravelly till/gravel	0.99%	3	1.41%	1
Sandy till/coarse sand	3.30%	10	4.23%	3
Sandy-silty till/medium sand	27.39%	83	35.21%	25
Sandy silty till/fine sand	45.21%	137	33.80%	24
Fine sand till/silt	15.84%	48	19.72%	14
Silty till/silt	2.64%	8	1.41%	1
Clayey till/clay	1.98%	6		
Sum	100.00%	303	100.00%	71

Table 3-4. Depth of forest soils according to the National forestry inventory "Riksskogstaxeringen" /after Berggren and Kyläkorpi, 2002/.

Soil depth	All sampling sites		Simpevarp regional model area	
	Share	Nr	Share	Nr
Thick (> 70 cm)	47.85%	156	34.25%	25
Moderately shallow (20–70 cm)	27.91%	91	39.73%	29
Shallow (< 20 cm)	15.64%	51	15.07%	11
Very variable	8.59%	28	10.96%	8
Sum	100.00%	326	100.00%	73

Another source of information is "Ståndortskarteringen". Only 20 sampling sites in this investigation are located within the region and, of those, 8 sampling sites are located within the Simpevarp area. Because of the small number of sampling sites, no statistical analysis has been performed /Berggren and Kyläkorpi, 2002/.

A third source of information is the forestry plan of AssiDomän (AssiDomäns skogsbruksplan) which covers about 20% of the Simpevarp regional model area.

The data presented above provide a relatively good estimate of the general situation within the area. The desire for data with high precision concerning site or position described in /Lindborg and Kautsky, 2000/, however, is far from fulfilled. Data from AssiDomän concerning this area could possibly offer higher resolution, but data with the desired precision is hard to acquire without further field investigations.

3.3.4 Chemistry

No data concerning the chemistry of forest soils has been found.

3.3.5 Land use

Data input

The variables describing the land use in the Simpevarp regional model area are share of forest, pasture and meadow, impediment, urban areas and power line areas. Sources of information are the forestry plan ("Skogsbruksplan") of AssiDomän and a compilation made by the municipality of Oskarshamn ("Översiktsplan 1990", revised 1992).

Distribution and character

The most common land class in the municipality of Oskarshamn is *forest* (75%) whereas *pasture and meadow* represent 7%, *impediment* 13%, *urban areas* 4% and 1% is *power line areas* /Oskarshamns kommun, 1992/. This distribution is assumed to be valid also for the Simpevarp regional model area.

3.3.6 Pollutants

Data input

Data on pollutants has been compiled by /Berggren and Kyläkorpi, 2002/.

Distribution and character

A study of the distribution of metals in roots of macrophytes in streams has been performed by SGU in order to quantify the variation of heavy metals in surface and groundwater. The metals analysed are As, Cd, Co, Cu, Cr, Hg, Mo, Ni, Pb, Se, U, V, W and Zn /Berggren and Kyläkorpi, 2002/. A survey of metals in mosses in Kalmar län has also been performed. Data can be found at the web-site of the county administrative board of Kalmar (http://www.h.lst.se/verk/milo/milomoss.pdf [Accessed 2001-06-18]). Data from 1995 is presented in /Berggren and Kyläkorpi, 2002/. For this description no data has been compiled.

3.4 Wetlands

There are no wetlands within the Simpevarp regional model area and its surroundings that can affect the hydrological conditions /Naturvårdsverket, 1984/.

3.5 Agricultural land

About 7,100 ha of the area in the Oskarshamn municipality is cultivated land and c. 2,400 ha is pastures and meadows /Birgersson et al, 1998/. The amount of arable land has decreased over the years.

The following entities describe the agricultural land in the Simpevarp regional model area:

- Vegetation
- Fauna
- Soils
- Chemistry
- Land use
- Pollutants

3.5.1 Vegetation

Data input

The variables describing the vegetation of agricultural land in the Simpevarp regional model area are land use and standard yield values for barley and oat. The information available has been compiled by /Berggren and Kyläkorpi, 2002/. Another source of information is Statistiscs Sweden (Statistiska Centralbyrån, SCB) /SCB, 1997/.

Distribution and character

The *different kind of agricultural land areas* in the Oskarshamn municipality are presented in Table 3-5. *Standard yield values* are calculated every year for all crops covered by the objective yield surveys /SCB, 1997/. Sweden is divided into 104 yield survey districts. Standard yield values (for year 2000) for the Oskarshamn municipality are shown in Table 3-6.

Table 3-5. Land use for land owners with more than 2 ha agricultural land in Oskarshamn /Berggren and Kyläkorpi, 2002/.

Geographical area	Year	Area (ha) Cultivated area	Pastures	Forest	Other land	Sum
Oskarshamn	1990	4,552	1,309	21,532	3,100	30,493
municipality	1995	4,223	1,728	17,923	2,534	26,409
	1999	3,980	1,898	16,957	2,319	25,154
Oskarshamn	1995	706	123	2,320	583	3,732
regional model area	1999	747	190	2,113	571	3,621

Table 3-6. Standard yields in the Oskarshamn municipality year 2000 /SCB, 1997/.

Geographical area	Standard yield (kilo/ha) Barley	Oats
Yield area 0814	3,349	3,381
Oskarshamn municipality*	2,874	2,498

* Yield area 0814 includes eastern part of Döderhult, Kristdala, Misterhult and Oskarshamn congregations.

3.5.2 Fauna

Data input

The variables describing the fauna of agricultural land in the Simpevarp regional model area are statistics concerning domestic animals (cattle, swine, sheep and poultry) in the Oskarshamn municipality. The information available has been compiled by /Berggren and Kyläkorpi, 2002/.

Distribution and character

The distribution of different kind of domestic animals in the Oskarshamn municipality is presented in Table 3-7.

Table 3-7. Domestic animals in the Oskarshamn municipality /Berggren and Kyläkorpi, 2002/.

Geographical area	Year	Cattle Milk-producing cattle	Breeding cattle	Heifers, bulls and bullocks 1 year or less	Calves less than 1 year	Sheep and lamb	Swine Boars and sows	Other swine	Laying hens and chickens
Oskarshamn municipality	1990	1,415	294	1,682	1,504	1,834	487	3,292	1,422
	1995	1,097	529	1,653	1,364	1,446	476	4,041	961
	1999	1,126	588	1,579	1,338	1,309	257	2,740	403
Simpevarp regional model area	1995	171	39	225	177	34	0	320	250
	1999	174	69	214	165	52	0	320	151

3.5.3 Soils

See Section 3.5.4.

3.5.4 Chemistry

The variable describing the soil chemistry of the agricultural land in the Simpevarp regional model area is soil type. The information available has been compiled by /Berggren and Kyläkorpi, 2002/, see also /Eriksson et al, 1997/.

Distribution and character

In a systematic investigation of Swedish agricultural land concerning humic content and the most important soil chemical characteristics /Eriksson et al, 1997/, about 3,100 samples of top-soil and 1,700 of sub-soil were taken from sampling sites randomly distributed over the cultivated area of Sweden. The top-soil samples (0–20 cm depth) were taken during 1988–1995, most of them during 1994–1995. The sub-soil samples (40–60 cm depth) were taken during 1995. In the Oskarshamn municipality, 5 sampling sites were located. The locations of the sampling sites have not been revealed by SCB, which was responsible for the selection of sites, and primary data has not been accessible. The statistics in Table 3-8 are based on data from these 5 sampling sites.

Table 3-8. Soil chemistry in the Oskarshamn municipality /Eriksson et al, 1997/.

	Nr	Average	Std	Median	Method	Unit
pH	5	5.84	0.416	5.8	pH-H_2O	
PAL	5	18.28	21.47	9.05	AL soluble P	mg/100 g TS
PHCl	5	94.31	55.53	104.1	HCl soluble P	mg/100 g TS
Ca	5	7.029	2.52	7.99	exchangeable	cmol(+)/kg TS
Mg	5	0.863	0.474	1.07	exchangeable	cmol(+)/kg TS
K	5	0.315	0.153	0.253	exchangeable	cmol(+)/kg TS
Na	5	0.0747	0.0378	0.0738	exchangeable	cmol(+)/kg TS
Utbacid	5	1.36	1.59	1.061	exchangeable acidity	cmol(+)/kg TS
Humus	5	6.50	6.75	3.61	(organic carbon)/0.58	% TS
N	5	0.263	0.207	0.162	tot N	% TS
S	5	0.0513	0.0445	0.0328	tot S	% TS
CaCO3	5	0	0	0	carbonate as $CaCO_3$ equivalents	% TS
CECeff	5	9.64	3.74	9.23	effective base saturation	cmol(+)/kg TS
Bseff	5	86.54	11.18	87.83	cation exchange capacity	% TS
C/N	5	12.87	2.48	12	ratio	
As	5	1.94	0.729	1.84	7M HNO_3	mg/kg TS
B	5	0.273	0.107	0.290	hotwater	mg/kg TS
Pb	5	16.43	8.21	13.94	7M HNO_3	mg/kg TS
Cs	5	2.18	1.05	2.49	7M HNO_3	mg/kg TS
Cd	5	0.182	0.050	0.183	7M HNO_3	mg/kg TS
Co	5	4.59	2.49	3.95	7M HNO_3	mg/kg TS
Cu	5	10.05	4.13	8.93	7M HNO_3	mg/kg TS
Cr	5	13.78	8.62	16.78	7M HNO_3	mg/kg TS
Hg	5	0.0403	0.0277	0.0342	7M HNO_3	mg/kg TS
Mn	5	303.8	223.4	205.8	7M HNO_3	mg/kg TS
Mo	5	0.612	0.198	0.577	7M HNO_3	mg/kg TS
Ni	5	6.93	4.14	8.08	7M HNO_3	mg/kg TS
Se	5	0.227	0.190	0.145	aqua regis	mg/kg TS
Sr	5	28.78	13.48	23.56	7M HNO_3	mg/kg TS
V	5	28.30	12.61	29.30	7M HNO_3	mg/kg TS
Zn	5	42.69	19.36	37.74	7M HNO_3	mg/kg TS

3.5.5 Land use

See Section 3.3.5.

3.5.6 Pollutants

See Section 3.5.4.

3.6 Lakes

A potential source of important data is the University of Agricultural Sciences (SLU) which performs different kinds of environmental monitoring. Data concerning lakes in the Simpevarp regional model area are presented in this section. For information about rivers the reader is referred to Section 3.2.3 which concerns surface hydrology of drainage areas in the Simpevarp regional model area.

The following entities describe the lakes in the Simpevarp regional model area:

- Physics
- Chemistry
- Biology
- Morphometry
- Sediments
- Human activities
- Pollutants

3.6.1 Physics

Data for one lake (Lake Götemaren) within the Simpevarp regional model area has been found. The physical characteristics of this lake are described by the following variables: ice period, lake depth and size, catchment area and water flow discharge. Data is presented by /Lindell et al, 1999/, /Johansson, 1991/ and /Larsson-McCann et al, 2002/, see Table 3-9.

Lake Götemaren is partly located within the Simpevarp regional model area. Data concerning water level in Lake Forshultesjön and ice period in Lake Gnötteln is presented in /Larsson-McCann et al, 2002/.

Table 3-9. Physical data for Lake Götemaren /Johansson, 1991/.

Depth (max)	17.8 m
Size	2.84 km^2
Catchment area	17.2 km^2
Water discharge	0.09 m^3/s

3.6.2 Chemistry

Data input

The variables describing the chemistry of lakes in the Simpevarp regional model area are pH, alkalinity, conductivity, colour, Ca + Mg, total phosphorous, total nitrogen. Information has been provided by the Municipality of Oskarshamn (Miljö- och hälsoskyddskontoret – see below).

Distribution and character

The Oskarshamn municipality has performed measurements at six sites within or near the Simpevarp regional model area (Marie Lindström, pers com, Miljö och hälsoskyddskontoret, Oskarshamns kommun, 2001-01-11), see Table 3-10.

Table 3-10. The number of water chemistry measurements performed by the Oskarshamn municipality (Marie Lindström, Miljö- och hälsoskyddskontoret, Oskarshamns kommun, 2001-01-11).

Variable	Fagersjön	Brobången	Plåttorpesjön	Götemaren	Frisksjön	Jämsen
pH	5	17	7	28	2	6
Alkalinity	4	17	7	28	2	6
Conductivity	4	12	3	23	2	6
Colour	4	16	7	28	2	6
Ca + Mg	3	11	3	23	2	6
TOT-P	3	10	3	7	1	5
TOT-N	2	10	3	7	1	4

3.6.3 Biology

Data input

Some aspects of the biology of lakes in the Simpevarp regional model area can be deduced from available data on the species of fish, crayfish and birds within and around the Lake Götemaren. Compilations of data have been made by /Berggren and Kyläkorpi, 2002/ and /Lindborg and Schüldt, 1998/.

Data about fish can be gained by electricity fishing. In the Simpevarp regional model area, no such investigation has been performed. Data from the discharge areas of Marströmmen and Virån is, however, available /Berggren and Kyläkorpi, 2002/.

Distribution and character

Benthic fauna in the county of Kalmar has been investigated at 14 sites in running waters and in 4 lakes. The only site within the municipality of Oskarshamn is "Videbäck vid Tålebo".

Fish species like pike (*Esox lucius*), perch (*Perca fluviatilis*), burbot (*Lota lota*), eel (*Anguilla anguilla*), bream (*Abramis brama*) and bleak (*Alburnus alburnus*) are common. Since 1979, the lake is a part of a research programme for eel performed by the freshwater laboratory of Drottningholm. The noble crayfish (*Astacus astacus*), was found earlier in the lake.

The lake has high ornithological values. Bird species that breed around the lake are e.g. mute swan (*Cygnus olor*), tufted duck (*Aythya fuligula*), crane (*Grus grus*), black-throated diver (*Garvia artica*) and osprey /Lindborg and Schüldt, 1998/.

3.6.4 Morphometry

See Section 3.6.1.

3.6.5 Sediments

No information on the sediments in the lakes of the Simpevarp regional model area has been found.

3.6.6 Human activities

Data input

Some data on human activities has been compiled by /Johansson, 1991/.

Distribution and character

The water level in the lake Götemaren was lowered during the 19th century to get more arable land. Since 1982, Oskarshamns Kraftgrupp (OKG) is allowed to dam the lake in order to use the water at Oskarshamn nuclear power plant as drinking water and cooling water /Johansson, 1991/. Data about other lakes in the area have not been compiled.

3.6.7 Pollutants

Data input

The variables describing the pollutants of the lakes in the Simpevarp regional model area are contents of Hg, Pb, Zn and Cd in lake water, nitrogen and phosphorous in river water and concentrations of Hg in pike. Data compilations are provided by /Carlsson et al, 1989/, /Ljungberg and Lönnbom, 1993/ and /Berggren and Kyläkorpi, 2002/.

Distribution and character

Most of the lakes within the Simpevarp regional model area are oligotrophic. The few eutrophic lakes in the region are affected by artificial nutrients. Toxic pollutants in the lakes are often bound to humus. High amounts of *Hg*, *Pb*, *Zn and Cd* have been noticed in the region. For specific values of metals in lakes, see /Carlsson et al, 1989/.

Data from an investigation of mercury in fish performed by the county administrative board of Kalmar is presented in Table 3-11 (data for 1996/1997).

Table 3-11. Hg in pike 1996/1997 in the area between 1530000–1560000 E and 6360000–6380000 N (RAK).

Lake name	Co-ordinates		Number of analysed pikes	Concentration of Hg (mg/kg)
Bussviken	637120	155150	6	0.12
Figeholms hamn	636100	154550	5	0.09
Gissjön	637897	153261	5	1.12
Glostad	636450	155100	5	0.10
Götemaren	637433	154830	5	0.46
Klintemåla	637720	155100	6	0.13
Långö	636850	155250	4	0.11

3.7 Sea

The following entities describe the sea in the Simpevarp regional model area:

- Physics
- Chemistry
- Biology
- Morphometry
- Sediments
- Human activities
- Pollutants

3.7.1 Physics

Data input

The variables describing the physical characteristics of the sea in the Simpevarp regional model area are hydrography, temperature, water exchange and water level. Information is found or referred to in /Lindell et al, 1999/, /Engqvist, 1997/ and /Larsson-McCann et al, 2002/.

Distribution and character

The area in the northern part of the strait Kalmarsund is part of the Baltic Sea basin where the *hydrography* is governed by salinity stratification with two haloclines at 50–60 m and about 70 m.

The *temperature* in the surface layer has the same seasonal variations that are found in the Baltic Sea. A warm surface layer is developed during spring due to the increased solar radiation. The temperature in this layer can exceed 20°C with a thermocline found at 20–25 m depth by the end of the summer. In the autumn, the temperature stratification breaks down due to increased cooling and wind mixing. Below the primary thermocline, the temperature is stable between 5–6°C all the year round. Temperature profiles are shown on Figure 3-6. The diagram shows a temperature stratification establishing in April. In June and August, the mean water column is completely stratified. The thermocline breaks down during autumn and in December the water is well mixed.

In the open waters around Simpevarp the hydrographical conditions are strongly affected by coastal processes with large variability in the surface temperature. This is due to the local wind conditions resulting in near shore upwelling. The salinity stratification is weak and the *water exchange* is good, as observed in measurements of high values of oxygen saturation in the water column. The currents in the near-shore area are weak and dominated by long shore directions. Water exchange for the basins surrounding Äspö island has been estimated by /Engqvist, 1997/.

Automatic registration of temperature was made in the sea outside Simpevarp at different stations between 1971–1983. The stations around Oskarshamn where SMHI has available data are described in Table 3-12.

Water level is measured hourly with an accuracy of 1 cm. Statistics concerning monthly water level of the sea at Oskarshamn can be seen in Figure 3-7 /Larsson-McCann et al, 2002/.

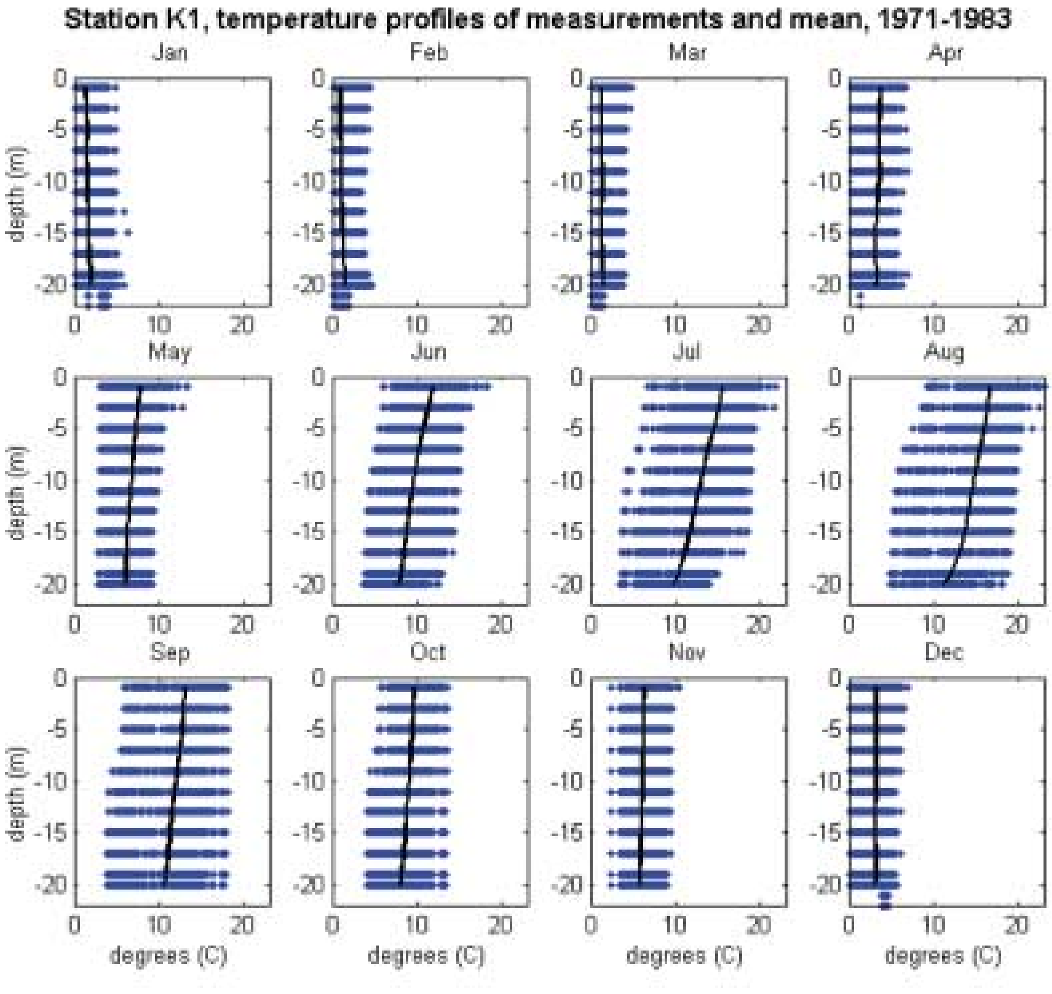


Figure 3-6. *Temperature profiles at station K1, 1971–1983. The daily mean of measurements (dots) and mean over depth (solid line) are plotted in the diagrams. After /Larsson-McCann et al, 2002/.*

Table 3-12. Stations in the Oskarshamn area where SMHI has available data. After /Larsson-McCann et al, 2002/.

Station	Co-ordinates, RT90		Parameter	Depth	Sampling year
K1	6365204	1554387	Temperature	c. 22 m	Parts of 1971–1983
BY 38	6333805	1612564	Temperature, nutrients, oxygen, pH, alkaline	c. 110 m	Monthly 1980–
TSNV	6365892	1550772	Temperature	c. 2 m	Parts of 1997–2000
OKG1-V	6365190	1553288	Temperature, nutrients, oxygen	c. 15 m	Every second month 1995–
O1-V	6360457	1546026	Temperature, nutrients, oxygen	c. 8 m	Every second month 1995–
Oskarshamn 2085	6349740	1540730	Water level	–	1976–2001

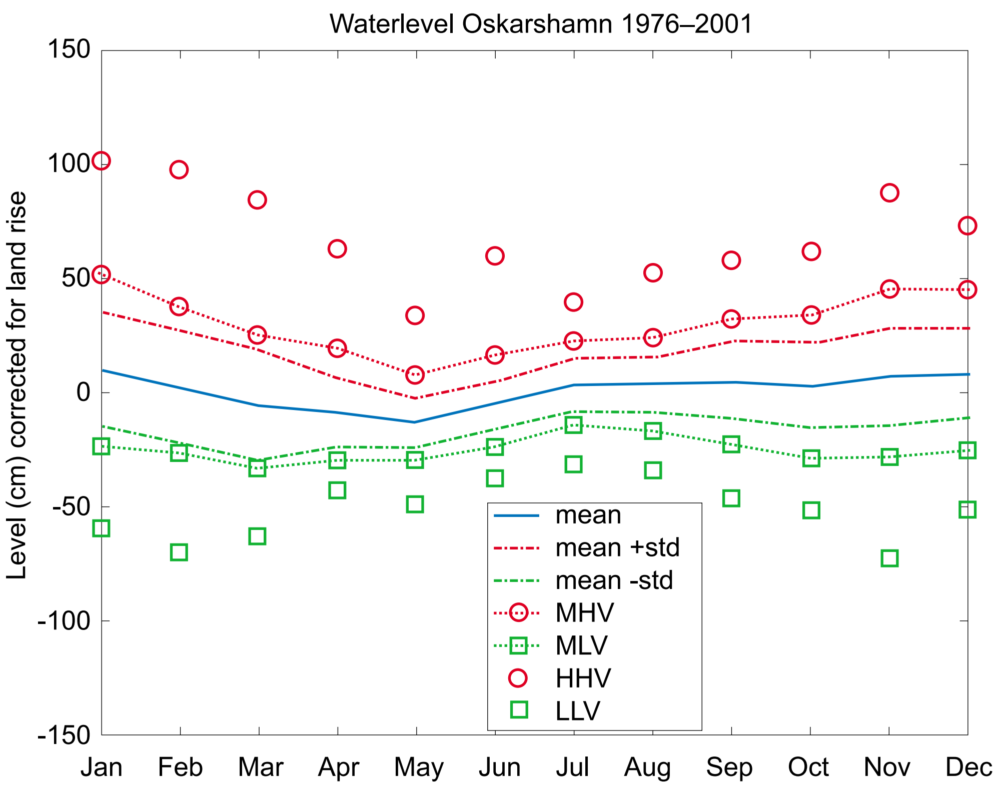


Figure 3-7. Monthly sea water level (cm) statistics at Oskarshamn 1976–2001. Monthly mean water level and one standard deviation are shown. MHV/MLV signifies mean high/low water level, i.e. mean of all years 1976–2001. HHV/LLV signifies highest/lowest water level ever during 1976–2001. Based on hourly measurements. After /Larsson-McCann et al, 2002/.

3.7.2 Chemistry

Data input

The variables describing the chemistry of the sea in the Simpevarp regional model area are salinity, oxygen saturation and contents of nutrients. Data has been compiled by /Larsson-McCann et al, 2002/. Information is also found on the SMHI Web site /SMHI, 2002/.

Distribution and character

The area in the northern part of the strait Kalmarsund is part of the Baltic Sea basin where the *hydrography* is governed by salinity stratification with two haloclines at 50–60 m and about 70 m. Between the surface and the primary halocline the salinity varies between 6–7 psu (practical salinity unit). Between the primary and the secondary halocline the salinity varies between 8–10 psu, whereas it varies between 11–13 psu below the secondary halocline.

The *oxygen* conditions in the Baltic Sea vary with depth and season. Above the primary halocline the water is saturated during autumn due to the thermohaline circulation. The uppermost layer, reaching down to 20–30 m, stays saturated all year. In the deeper layers, the oxygen supply is constricted by the strong salinity stratification. Oxygen can only be added by inflow of heavy salt water from the Öresund region through the Darsser threshold. Between such inflows, the oxygen concentration constantly diminishes in the deep water. This is a result of the biological degradation of organic matter sinking from the surface layer.

On the web site of SMHI /SMHI, 2002/ reports and data from the monitoring programme of coastal waters in the county of Kalmar is presented. At the station REF O3V (571590 E 162880 N, RT90), nutrients have been measured every month since 1995.

3.7.3 Biology

Data input

The variables describing the biology of the sea within the Simpevarp regional model area are data about benthic fauna and species composition of seabirds. Information has been provided by /Länsstyrelsen i Kalmar Län, 1989/. Data is also presented or referred to by /Lindborg and Schüldt, 1998/. Data concerning benthic fauna in the sea within the Simpevarp regional model area is available from Fiskeriverket.

Distribution and character

The bird fauna bound in the coastal environment includes goosander (*Mergus merganser*), red-breasted mergaster (*Mergus serrator*), eider and common sandpiper (*Tringa hypoleucos*). Rare species like Actica skua (*Stercorarius pomarinus*), raxorbill (*Alca torda*), white-tailed eagle (*Haliaeetus albicilla*) and eagle owl (*Bubo bubo*) occur, but do not breed /Länsstyrelsen i Kalmar län, 1989/. About 50 bird species breed on Äspö island, e.g. willow warbler (*Phylloscopus trochilus*), chaffich (*Fringilla coelebs*), robin (*Luscinia svecica*), great crested grebe and tufted duck, and osprey (*Pandion haliaetus*) and grey heron (*Ardea cinerea*) also occur /Lindborg and Schüldt, 1998/.

3.7.4 Morphometry

No data concerning morphometry of the coastal area within the Simpevarp regional model area has been compiled.

3.7.5 Sediment

Data input

Information from one sediment core from the Äspö area represents the information available on the sediment of the sea in the Simpevarp regional model area. The core is described by /Risberg, 2002/.

Data concerning the physical character of the sea bottoms is available from Fiskeriverket.

Distribution and character

A sediment core was collected in the archipelago above the tunnel from the Simpevarp peninsula to the Äspö Hard Rock Laboratory /Risberg, 2002/. The sediment consists of gyttja superimposed on gravel and two types of clay (bluish and brownish).

3.7.6 Human activities

One parameter describing the human activities in the sea of the Simpevarp regional model area is the number of professional fishermen who are active within the area. According to Jan Andersson at Fiskeriverket, two professional fishermen are operating within the Simpevarp regional model area.

3.7.7 Pollutants

Data input

Data on pollutants in the area has been compiled by /Berggren and Kyläkorpi, 2002/.

Distribution and character

Swedish Radiation Protection Authority, SSI, carries out environmental control programmes for radionuclides in the areas where the Swedish nuclear power plants are located. In these programmes the concentrations of radionuclides in the surroundings are measured continuously. The main target is biota but radionuclide concentrations in water, air and sediments are also measured. Data from this monitoring is available from SSI.

4 Geology

4.1 Introduction

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 (Figure 4-1). 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 4-1). Major deformation zones also occur within the province, in particular in the area west of Oskarshamn. The province is dominated by volcanic and intrusive igneous rocks which vary in age from c. 1,850 to 1,770 million years and which are included in the so-called Transscandinavian Igneous Belt (Figure 4-1).

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 c. 1,700 million years ago. Locally, it has been shown that individual zones were active at different times after c. 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 c. 115,000 years ago, and the post-Weichselian development during the latest c. 12,500 years, are preserved in the Simpevarp area.

The presentation of the geology begins with *a model for the geological evolution* (Section 4.2) in southeastern Sweden. This model focusses on the lithological and structural development in the bedrock. The Weichselian glacial deposits, the sediments deposited after this glaciation, and the possible effects of late- or post-glacial faulting in the regional model area, are all treated separately, and in more detail, under the section entitled "Quaternary geology". There follows a description of "parameter groups" /SKB, 2001a/, *Quaternary geology*, *bedrock – rock type* and *bedrock – structure* (Sections 4.3, 4.4 and 4.5, respectively). In Section 4.5, only regional and local major fracture zones (according to the definitions of /Stråhle, 2001/) are addressed. *A description of the 3D modelling* (Section 4.6), which has been carried out within the project, and *an assessment of the uncertainty in the geological data* (Section 4.7) complete this chapter.

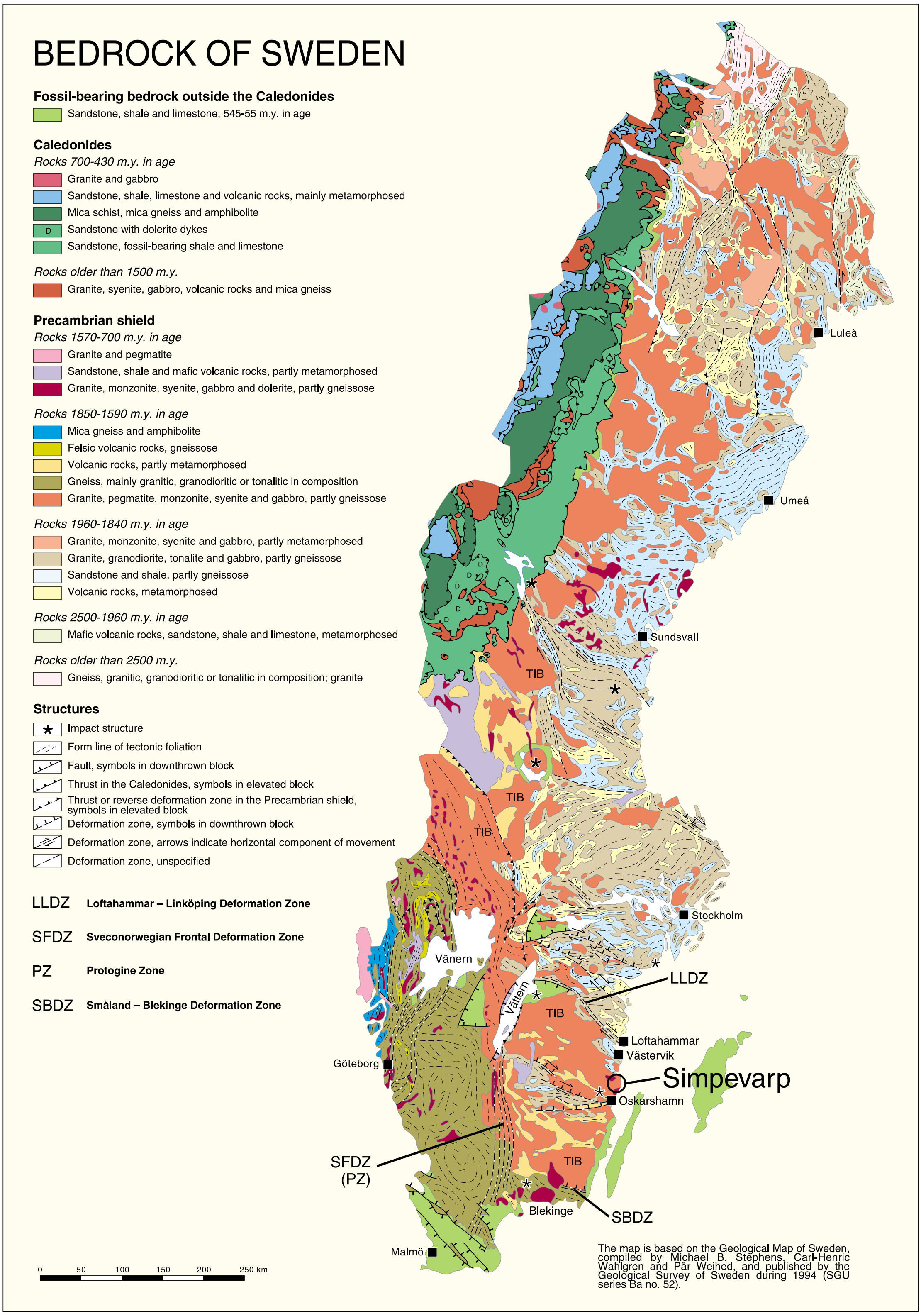


Figure 4-1. *Simplified map of the bedrock geology of Sweden. The position of the Simpevarp regional model area is shown. The geological province in which the Simpevarp area lies is bounded by major deformation zones along its northern (LLDZ), southern (SBDZ) and western (SFDZ) boundaries (for explanation, see text). TIB = Transscandinavian Igneous Belt. In southeastern Sweden, the TIB rocks vary in age from c. 1,850 to 1,770 million years. In the regional model area, the rocks belonging to this belt formed c. 1,800 million years ago.*

4.2 Model for the geological evolution

The geological province in southeastern Sweden, which hosts the Simpevarp regional model area, is delimited (Figure 4-1) to the north by the Loftahammar-Linköping Deformation Zone, to the south by the Småland-Blekinge Deformation Zone and to the west by the Sveconorwegian Frontal Deformation Zone (also known as the Protogine Zone). In this section, a model for the geological evolution of this geological province is presented for six main stages, which are related to different time periods. Each of these stages is described briefly in tabular format. The parts of the tables which are shaded in a grey colour refer specifically to the lithological or structural development of the geological province, during a particular stage in the geological evolution. Where the effects of geological events are of more limited character and, in general, less well understood (stages 3-6), attention has also been directed to areas further away, outside the geological province in southeastern Sweden.

The model has utilized the following information:

- A country-wide compilation of the bedrock geology /Stephens et al, 1997/.
- A review of tectonic regimes in the Fennoscandian Shield during the last 1,200 million years /Larson and Tullborg, 1993/.
- A reconstruction of the tectonic history of the Fennoscandian Shield during the last 100 million years, based on data available along its margins to the south and west /Muir Wood, 1995/.
- Summaries of the geology of southeastern Sweden in several county reports /Antal et al, 1998a,b; Gierup et al, 1999a,b/.
- An overview of the crustal structure and regional tectonics of southeastern Sweden and the Baltic Sea /Milnes et al, 1998/.
- Key references of more local interest which are referred to directly in the following tables.

Stage 1 – Time period 1,890 to 1,850 million years.

Infill of a marginal basin followed by deformation and metamorphism associated with basin closure (Svecokarelian orogeny, early stage).

Time period	Lithological development in southeastern Sweden
1,890 to 1,850 million years.	Sedimentation (mostly sandstone) and volcanic activity in the Västervik area.

Structural development in southeastern Sweden (ductile deformation)
Ductile deformation and metamorphism under medium- to high-grade conditions with development of a planar grain-shape fabric, including gneissosity in higher-grade rocks, prior to 1,850 million years /Gavelin, 1984; Bergström et al, 2002/. Uncertain tectonic regime in southeastern Sweden. A comparison with the Finnish segment of the Fennoscandian Shield suggests important, dextral transpressive deformation prior to c. 1,850 million years ago. The transpression was taken up in the Finnish segment by dextral displacement along ductile high-strain zones with NW strike, combined with shortening across an older continental margin which also strikes NW (thrusting to the NE). Oblique collision against the older continental margin, with a N-S to NNW-SSE movement direction, is inferred.

Stage 2 – Time period 1,850 to 1,750 million years.

Extensive igneous activity in the Transscandinavian Igneous Belt (TIB), deformation and metamorphism associated with crustal reworking (Svecokarelian orogeny, late stage). Exhumation of deeper crustal levels and erosion.

Time period	Lithological development in southeastern Sweden
1,850 million years.	1. Intrusion of granite, quartz monzonite, monzonite and associated mafic to intermediate rocks.
1,830–1,820 million years.	2. Intrusion of granitoids.
1,820–1,770 million years.	3. Intrusion of granite, quartz monzonite, monzonite and associated mafic to intermediate rocks. Sedimentation and volcanic activity.

Structural development in southeastern Sweden (ductile deformation)

Ductile deformation and metamorphism at mid-crustal depths with development of the following structures:

- Tectonic foliation in the intrusive rocks which are 1,850 million years in age.
- Major, regional-scale folding and minor folds which deform earlier planar fabrics.
- High-strain zones (e.g. Loftahammar-Linköping Deformation Zone), exhumation of deeper crustal levels and erosion.

This was followed by ductile deformation under lower-grade metamorphic conditions and at shallower depths after c. 1,800 million years.

The tectonic regime involved dextral transpressive deformation which was taken up by dextral displacement along ductile high-strain zones with NW strike, combined with shortening in a NE direction across the zones /Stephens and Wahlgren, 1996; Beunk and Page, 2001/. Continued oblique collision against the older continental margin to the NE, with a N-S to NNW-SSE movement direction, is inferred.

Stage 3 – Time period 1,750 to 850 million years.

Far-field effects of continued crustal growth and crustal reworking with deformation and metamorphism to the south and west (including Gothian, Hallandian and Sveconorwegian orogenies), which ultimately resulted in the assembly of the supercontinent Rodinia.

The tectonic scenario in southeastern Sweden was characterized by:

- **Exhumation of deeper crustal levels and erosion.**
- **Subsidence and formation of a foreland sedimentary basin to the east of the Sveconorwegian orogenic belt, related to the exhumation of deeper crustal levels and erosion within this belt.**

Time period	Lithological development to the south, west and north of southeastern Sweden	Lithological development in southeastern Sweden
1,700–1,660 million years.	Major igneous activity (intrusive/volcanic) and sedimentation (younger igneous activity in Transscandinavian Igneous Belt).	No lithologies exposed at the present-day Earth's surface.
1,660–1,100 million years.	Major igneous activity (intrusive/volcanic) and sedimentation.	1. Intrusion of alkaline rock (Norra Kärr; 1,545 million years old). 2. Intrusion of granite (Götemar, Uthammar and Jungfrun granites; 1,450 million years old).
1,000–900 million years.	Intrusion of granite, pegmatite, gabbro, anorthosite and mafic dykes.	Sedimentation (Almesåkra Group; uncertain age, possibly older) and intrusion of mafic dykes with c. N-S strike.

Time period	Structural development to the south, west and north of southeastern Sweden	Structural development in southeastern Sweden (brittle deformation)
1,700–1,660 million years.	Ductile deformation (Gothian orogeny – early stage). 1. A dextral transpressive high-strain zone with NNW strike in central Sweden displays dextral displacement along the zone, together with shortening in a ENE direction across the zone /Bergman and Sjöström, 1994/. An oblique collision with a NE-SW movement direction is inferred. 2. Regional deformation under amphibolite facies conditions in the Blekinge region; uncertain age between 1,770 and 1,450 million years.	Uncertain.
1,610–1,100 million years.	1. Ductile deformation during the time period 1,610–1,560 million years (Gothian orogeny). 2. Uncertain structural development during time-period 1,560–1,100 million years (including Hallandian orogeny, during the time period 1,460–1,420 million years).	Uncertain.
1,100–900 million years.	Ductile deformation (Sveconorwegian orogeny). A major, sinistral transpressive, high-strain zone with NW-SE to N-S strike displays variable amounts of sinistral strike-slip and reverse dip-slip deformation, respectively, depending on the strike of the zone /Stephens et al, 1996/. Inferred movement direction WNW-ESE to E-W. Extensional ductile deformation also identified along the same high-strain zone /Berglund, 1997/.	Uncertain. Ductile high-strain zones with N-S strike, referred to as the Sveconorwegian Frontal Deformation Zone (Protogine zone), are present along and south of lake Vättern (western border of geological province in southeastern Sweden). Subsidence related to the development of a Sveconorwegian foreland basin /Tullborg et al, 1996; Larson et al, 1999/.

Stage 4 – Time period 850 to 400 million years.

Far-field effects of:

- **The break-up of Rodinia with the formation of the ocean Iapetus and the continent Baltica.**
- **The rotation and drift of Baltica northwards over the globe.**
- **The destruction of Iapetus and the birth of the continent Laurussia (Caledonian orogeny).**

The tectonic scenario in southeastern Sweden was characterized by:

- **Rifting, erosion and final establishment of the sub-Cambrian peneplain.**
- **Marine transgression and deposition of sedimentary cover during the Early Palaeozoic.**
- **Subsidence and formation of an Upper Silurian to Devonian, foreland sedimentary basin to the east of the Caledonian orogenic belt, related to the exhumation of deeper crustal levels and erosion within this belt.**
- **Disturbance of the sub-Cambrian peneplain and Lower Palaeozoic rocks along some faults, during stage 4, stage 5 or both these stages.**

Time period	Lithological development to the south, west and north of southeastern Sweden	Lithological development in southeastern Sweden
800–520 million years.	1. Syn-rift sedimentation. 2. Glacial episode. 3. Intrusion of mafic dykes related to rifting in western areas and opening of the Iapetus Ocean. Alkaline intrusive rock near Sundsvall (Alnön). 4. Deposition of mature sandstone, siltstone and shale during the Vendian-Cambrian.	Syn-rift sedimentation, at least in the Vättern area (800–700 million years). Deposition of mature sandstone, siltstone and shale (Cambrian), preserved today along the Baltic sea coast south of Oskarshamn, in isolated, fault-controlled (Östergötland) outliers and in offshore areas.
520–400 million years.	1. Sedimentation on a shelf and in outboard basins. 2. Igneous activity associated with convergent plate margin setting in westernmost areas. 3. Syn-rift sedimentation.	Deposition of Cambrian to Silurian shale and limestone, preserved today on Öland and Gotland, in isolated, fault-controlled outliers (Östergötland) and in offshore areas.

Time period	Structural development to the south, west and north of southeastern Sweden	Structural development in southeastern Sweden (brittle deformation)
800–520 million years.	Rifting. Establishment of the sub-Cambrian peneplain and a marine transgression during the Vendian-Cambrian.	Rifting (Vättern area). Establishment of the sub-Cambrian peneplain and a marine transgression during the Cambrian.
510–400 million years.	1. Continent-arc and continent-continent collisions in connection with the Caledonian orogeny. Shortening in a WNW-ESE direction with major thrusting to the east. 2. Extensional collapse and sinistral strike-slip deformation.	Faults with NNE and WNW strike and uncertain kinematics steer the geometry of outliers with Lower Palaeozoic rocks. These faults disturb the sub-Cambrian peneplain and the Lower Palaeozoic rocks. They were active during stage 4 or stage 5 (or both). Subsidence related to the development of a Caledonian foreland basin /Tullborg et al, 1995, 1996; Larson et al, 1999/.

Stage 5 – Time period 400 to 250 million years.

Far-field effects of:

- **Hercynian-Variscan orogeny in central Europe and final assembly of the supercontinent Pangaea.**
- **Rifting along the southern margin of the Fennoscandian Shield.**

The tectonic scenario in southeastern Sweden was characterized by disturbance of the sub-Cambrian peneplain and Lower Palaeozoic rocks along some faults, during stage 4, stage 5 or both these stages.

Time period	Lithological development to the south, west and north of southeastern Sweden	Lithological development in southeastern Sweden
295–275 million years.	1. Main phase of volcanic and intrusive igneous activity in the Oslo graben, Norway. Mafic dykes and sills in southern Sweden. Alkaline intrusive rock near Särna, in the county of Dalarna. 2. Syn-rift sedimentation.	No lithologies exposed at the present-day Earth's surface.

Time period	Structural development to the south and west of southeastern Sweden	Structural development in southeastern Sweden (brittle deformation)
360–295 million years.	Hercynian-Variscan orogeny in central Europe.	Uncertain.
295–275 million years.	Extensional deformation along the Oslo Graben, Norway. Dextral transtensional deformation along the Sorgenfrei-Tornquist Zone in southernmost Sweden /Erlström and Sivhed, 2001/.	Faulting of the sub-Cambrian peneplain and Lower Palaeozoic rocks during stage 4, stage 5 or both these stages.
≥250 million years.		Latest fault movements on Äspö island /Maddock et al, 1993/?

Stage 6 – Time period 250 to 0 million years (excluding Quaternary developments, see Section 4.3).

Far-field effects of:

- **Rifting along the southern and western margins of the Fennoscandian Shield.**
- **Alpine orogeny in southern Europe.**
- **Opening and spreading of the North Atlantic Ocean.**

The tectonic scenario in southeastern Sweden is uncertain during this time period. A marine transgression during the Cretaceous (especially the Late Cretaceous) has been inferred. Minor disturbance of the sub-Cambrian peneplain along some faults may have occurred.

Time period	Lithological development to the south and west of southeastern Sweden	Lithological development in southeastern Sweden
250–60 million years.	Sedimentation and volcanic activity (Jurassic and Cretaceous).	No lithologies exposed at the present-day Earth's surface. Inferred cover of Cretaceous deposits eroded away during the Tertiary /Lidmar-Bergström, 1991/.

Time period	Structural development to the south and west of southeastern Sweden	Structural development in southeastern Sweden (brittle deformation)
250–95 million years.	Fault-controlled, differential subsidence along the Sorgenfrei-Tornquist Zone /Erlström and Sivhed, 2001/.	Uncertain.
95–60 million years.	Marine transgression increased during the Cretaceous.	Marine transgression during the Cretaceous.
	Inversion tectonics with dextral transpression along the Sorgenfrei-Tornquist Zone in southernmost Sweden /Erlström and Sivhed, 2001/. Inferred maximum principal stress (σ_1) in a NNE-SSW direction /Muir Wood, 1995/.	Uncertain.
60–0 million years.	Opening and spreading of the North Atlantic Ocean.	*In situ* stress measurements in the Simpevarp regional model area /Stille and Olsson, 1989; Ljunggren and Klasson, 1997/ indicate that the present day maximum principal compressive stress (σ_1) is almost horizontal and has a NW-SE orientation. This is consistent with the stress field expected to be generated by plate movements in the North Atlantic Ocean /Slunga, 1989; Gregersen et al, 1991; Gregersen, 1992/.

4.3 Quaternary geology

4.3.1 Data input

The distribution and description of Quaternary deposits in the Simpevarp regional model area as well as an assessment of late- or post-glacial crustal movement have been defined with the help of the cartographic database and the description of the Quaternary deposits which were compiled in connection with the Oskarshamn feasibility study /Bergman et al, 1998, 1999/. The cartographic data were extracted from SKB's GIS database (version 5.0). Details on data files, and references to corresponding reports and figures, are found in Appendix 1.

The compilation carried out during the feasibility study utilized a Quaternary deposit map of reconnaissance character at the scale 1:50,000 /SGAB, 1986/, which is mainly based on an interpretation of aerial photographs. No modern maps at the scale 1:50,000 which are based on extensive field investigations are available in the area. Thickness estimates are based only on general knowledge of the Quaternary deposits in the region. Information on soil texture and soil depth from specific sampling sites in the forest areas in the Simpevarp regional model area are summarized in Chapter 3.

An estimate of the present land rise relative to sea-level (shoreline displacement) is provided by /Ekman, 1996/.

A database from the University of Uppsala (Department of Earth Sciences), which is archived at SKB, was used as a source of information for seismic activity in Sweden during historical time (up to 1996).

On the basis of the geological data in the SKB GIS database (Appendix 1), a cartographic 2D model for the distribution of Quaternary deposits in the Simpevarp regional model area is presented in Figure 4-2. The map shows the distribution of deposits at the surface, whereby only the deposits on land are shown in this compilation. A generalized description of key geological "parameters" /SKB, 2001a/ for the different Quaternary deposits follows in Section 4.3.2. The deposits are described essentially in stratigraphic order from base to top.

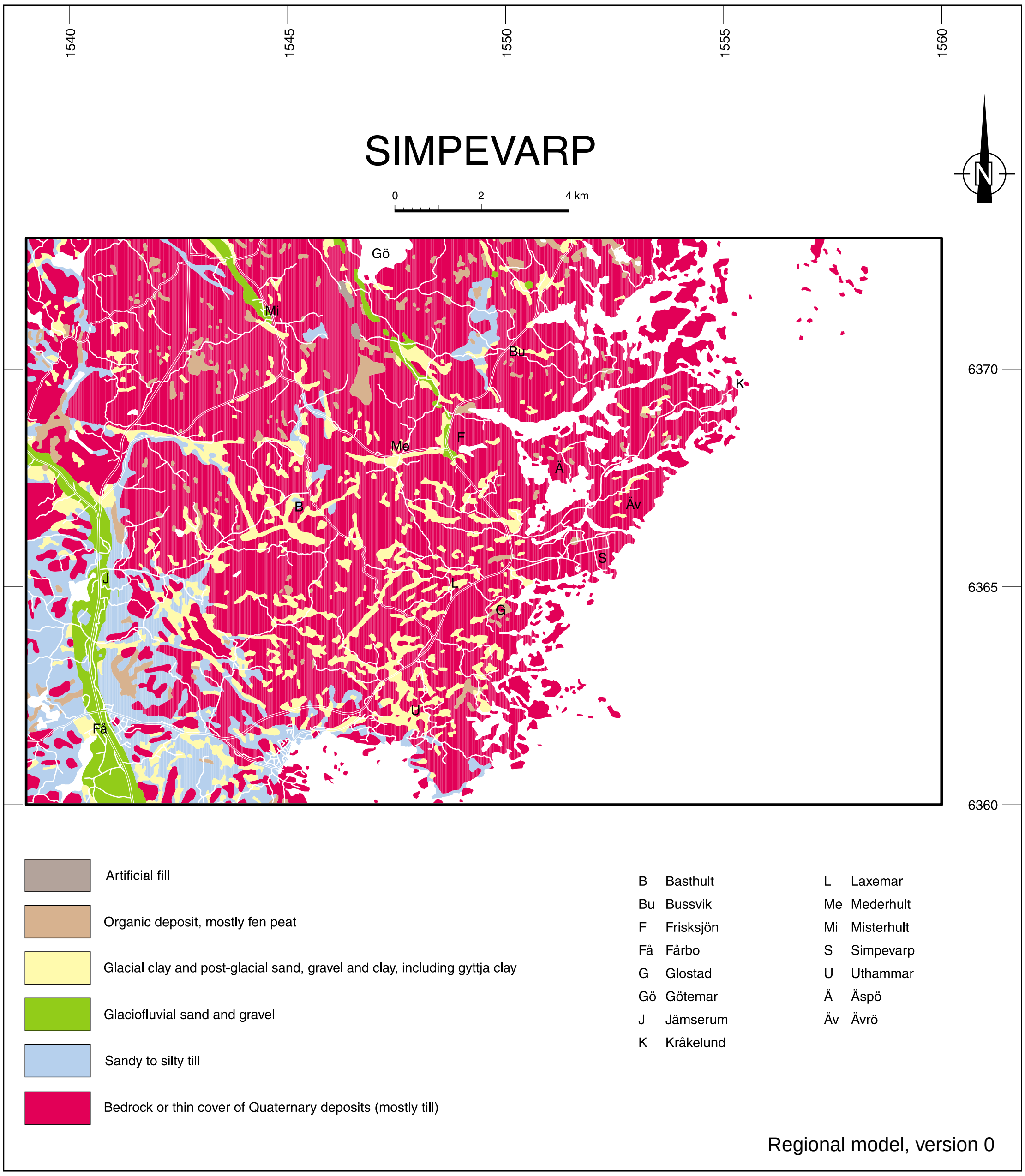


Figure 4-2. *2D cartographic model for the distribution of onshore Quaternary deposits in the Simpevarp regional model area.*

4.3.2 Quaternary deposits – distribution, description and thickness

The Quaternary deposits on land in the Simpevarp regional model area consist of two components:

- Glacial deposits which were deposited either directly from the inland ice or from the water derived from the melting of this ice. These deposits include till, glaciofluvial sand and gravel, and clay. Glacial striae on bedrock outcrops, as well as the orientation of moraine ridges and eskers, indicate an ice movement from the NW. A few observations indicate that older ice movements were both more westerly and more northerly.
- Post-glacial deposits which formed after the inland ice had melted and retreated from the area during the time period c. 12,500 to 12,300 years ago /Bergman et al, 1998, 1999/. The area lies beneath the highest shoreline which was established after retreat of the ice, and the older of these units were deposited when present land areas lay beneath the sea. Subsequently, following regression of the sea (see below), younger post-glacial sediments were deposited beneath lakes and on land. They include gravel, sand and clay deposits, and organic deposits dominated by fen peat.

Quaternary deposits, as defined above, occupy only c. 29% of the land in the regional model area (Figure 4-2). Exposed bedrock, or bedrock with only a thin (< 0.5 m) Quaternary cover, dominates the land area, occupying c. 71% of this area. However, in the southwesternmost part of the model area, around Fårbo, the percentage of exposed bedrock or bedrock with only a thin Quaternary cover is much less than in the remaining part of the area. Artificial fill occurs in two subordinate areas immediately southwest and southsouthwest of the lake Götemar.

In the percentage distribution of different Quaternary deposits, only deposits with an estimated thickness of more than 0.5 m are considered. Consequently, all numbers should be considered as minimum estimates. In particular, this is relevant for the percentage of till, which is the main constituent of the thin Quaternary cover. By consequence, the estimates of exposed bedrock are too high.

Sandy to silty till is the dominant glacial deposit and occupies c. 11% of the onshore area. Apart from scattered minor occurrences, the extension of till is strongly concentrated to the southwesternmost part of the model area, around Fårbo. In general, the till contains a normal boulder frequency but, c. 2.5 km northnorthwest of Fårbo, the boulder frequency is high. Locally, certain slopes display a high boulder frequency which, however, is commonly due to an enrichment caused by wave-wash. The thickness of the till, which lies directly on the crystalline bedrock, is generally up to c. 2 m.

Glaciofluvial sand and gravel deposits occupy only c. 4% of the onshore area and occur predominantly in three eskers. The most conspicuous of these can be followed from the area south of Fårbo in a northerly direction along the E 22 highway towards the area north of Jämserum where it swings into a northwesterly direction (Figure 4-2). Due to wave-washing and redeposition of the material, the esker is relatively flat within the model area. The other two eskers in the area are less prominent. One can be followed from Misterhult in a northwesterly direction, while the other has a discontinuous extension in a northwesterly direction from the western shore of the lake Frisksjön to the southwestern shore of the lake Götemar.

Glacial clay and post-glacial sediments occupy c. 11% of the onshore area. Due to the lack of detailed information, it has not been possible to distinguish these sediments in the Quaternary deposit map. The fine-grained glacial sediments are dominated by varved clay. The post-glacial sediments are composed of coarse, wave-washed material, dominated by gravel and sand, and fine-grained sediment dominated by clay and gyttja clay (clay with 2–6% organic material). The wave-washed sediments generally occur in connection with moraine ridges and eskers, while the clay and gyttja clay mainly occur in topographical depressions and valleys.

The thickness of glacial clay and post-glacial sediments varies but is, in general, ≤ 3–4 m. These sediments lie on top of till, glaciofluvial deposits and crystalline bedrock and probably occupy larger areas than what is shown on the map since they are generally hidden beneath post-glacial organic deposits.

Post-glacial organic deposits are dominated by peat and occupy c. 3% of the land in the regional model area (Figure 4-2). Fen peat dominates but bog peat is also present. These two varieties have not been distinguished in Figure 4-2. The thickness of the fen peat is usually 2–3 m, while the thickness of the bog peat varies between 0.5 and 2 m. The total thickness of peat where bog peat is underlain by fen peat is considered to be at the most 4–5 m.

4.3.3 Late- or post-glacial crustal movement including seismic activity in historical time

A major crustal phenomenon which has affected and continues to affect northern Europe, following the latest melting of inland ice, is the interplay between land rise (isostasy) on the one hand and sea-level rise or fall (eustasy) on the other. Shore level displacements in the Oskarshamn area during the last 12,000 years have been documented by /Svensson, 1989/. In the Oskarshamn municipality, shoreline regression prevails at the present time and the land is presently rising with respect to sea-level at the rate of c. 1 mm/year /Ekman, 1996/. Mathematical modelling of shoreline displacement in Fennoscandia permits predictions to be made concerning future developments /Påsse, 1996; Morén and Påsse, 2001/, including future shoreline positions (see Figure 3-4).

Evidence for the occurrence of late- or post-glacial faulting in the Simpevarp regional model area, as for the whole of southeastern Sweden, is lacking. A discussion of certain phenomena which have inspired some authors to speculate on the presence of such faulting was presented in /Bergman et al, 1998/. /Mörner, 1989/, for example, claimed that a large number of post-glacial faults occurs on the island Äspö. However, none of the speculated faults have been objectively verified /SKB, 1990/. It is apparent that further study of the significance of late- or post-glacial faulting in the regional model area will be necessary during the initial site investigation programme.

Southeastern Sweden is a seismically quiet area (Figure 4-3). Only a few earthquakes, with a magnitude of 2–3 or less on the Richter scale, have been registered in historical time. In the Oskarshamn municipality, no earthquakes have been registered during the last 600 years. However, an earthquake of magnitude 2.2 was recorded during March 1996 in the Västervik archipelago, immediately to the north. Furthermore, an earthquake of magnitude 1.0 and focal depth of c. 16 km was recorded c. 30 km south of Oskarshamn during September 1988 /Slunga and Nordgren, 1990/. Recent seismic activity in Sweden has been related to ongoing plate-tectonic processes including spreading of the North Atlantic Ocean /Slunga and Nordgren, 1990; Gregersen et al, 1991; Gregersen, 1992/. However, this activity may also be related to post-glacial rebound, i.e. there is no consensus that it is due to plate-tectonic processes alone.

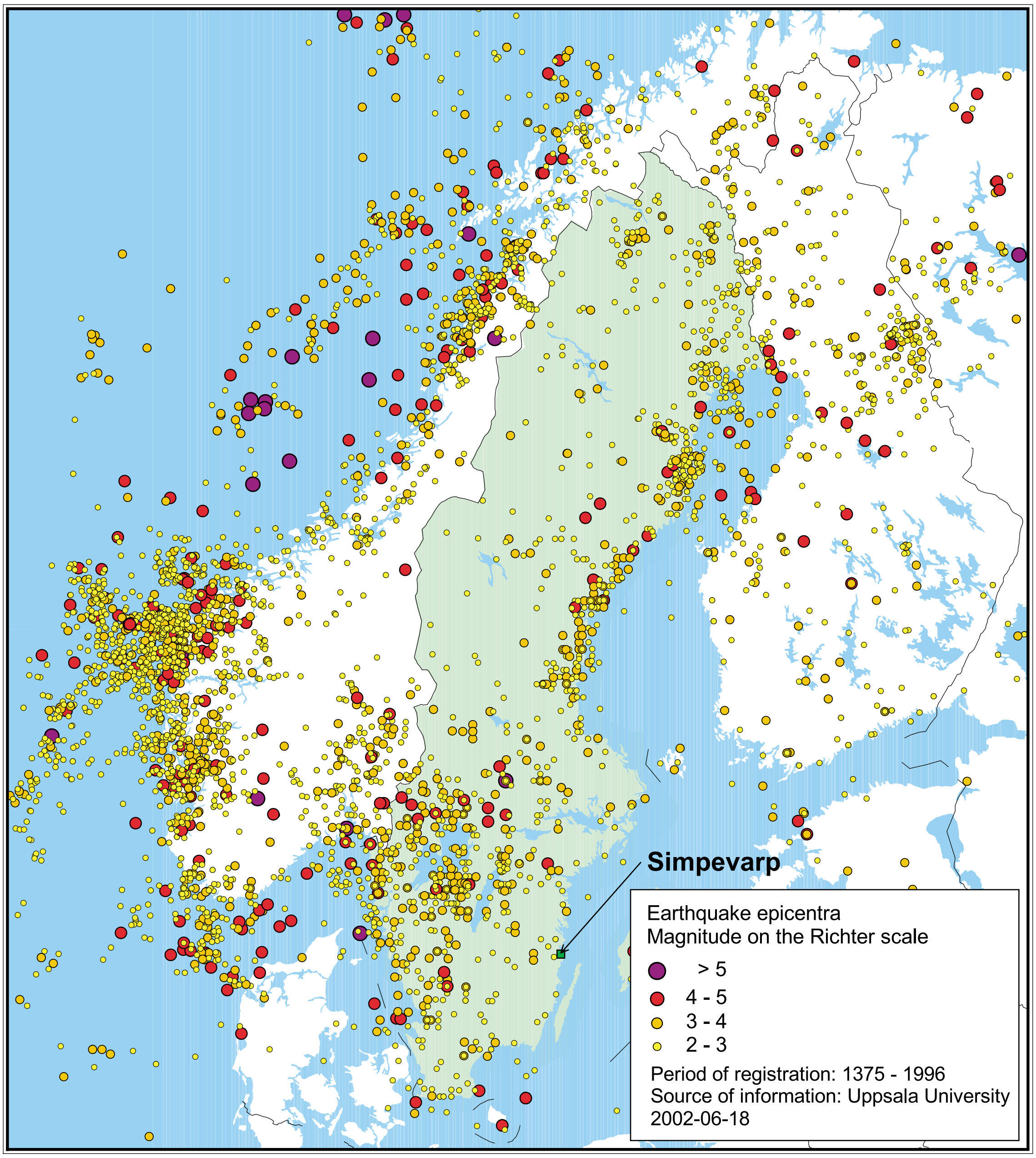


Figure 4-3. *Earthquake epicentra in Scandinavia and Finland 1375–1996. Data from the University of Uppsala.*

4.4 Bedrock – rock types and potential for ore deposits

4.4.1 Data input

The distribution, characteristics, inhomogeneity and age of the bedrock deposits in the Simpevarp regional model area have been defined primarily with the help of the cartographic database and the description of the bedrock geology which were compiled in connection with the early stage of the Oskarshamn feasibility study /Bergman et al, 1998, 1999/. These data were complemented and slightly modified in connection with the subsequent field control stage of the feasibility study in the Simpevarp-Laxemar area /Bergman et al, 2000/. Minor modifications outside the field control area have also been carried out in the present study. Furthermore, some new age-dating results /Åhäll, 2001/ are incorporated here. The cartographic data were extracted from SKB's GIS database 5.0 for Oskarshamn (Appendix 1).

The compilation carried out in the regional model area during the feasibility study was based on a bedrock map at the scale 1:50,000 which has been produced by SGU on a commission basis for SKB /Kornfält and Wikman, 1987a/. In connection with this mapping, more detailed bedrock maps at the scale 1:10,000 were also produced for the Simpevarp peninsula and its immediate surroundings including the Äspö-Ävrö-Kråkelund, Bussvik, Lilla Laxemar and Glostad areas /Kornfält and Wikman, 1987a,b, 1988/. The interpretation of the distribution of rock types in offshore areas was mainly based on the information from the land area and geophysical data.

The above-mentioned maps at the scale 1:10,000 were based on detailed geological field and analytical work, including optical microscopy and geochemistry. The investigations were carried out during 1987, with the exception of the mapping of the Äspö island which was carried out during 1988. The parts of the map at the scale 1:50,000 which are not covered by the detailed maps in the scale 1:10,000 are mainly a compilation of older cartographic material /Svedmark, 1904; Kresten and Chyssler, 1976/, supplemented by field examination along major roads. The regional model area is also covered by a reconnaissance geological map at the scale 1:250,000 /Lundegårdh et al, 1985/.

In order to allow cartographic presentation at the scale 1:100,000, some simplifications of the bedrock geology information collected from these sources were carried out in connection with the feasibility study bedrock compilation. Base data including, for example, field locality observations, have not been studied within the context of the present project.

On the basis of the GIS geological data, a cartographic 2D model for the bedrock geology in the Simpevarp regional model area is presented (Figure 4-4). This map includes the surface distribution of different rock types. A description of some key geological "parameters" /SKB, 2001a/ for the different rock types follows below. This description addresses predominantly the rock types observed onshore.

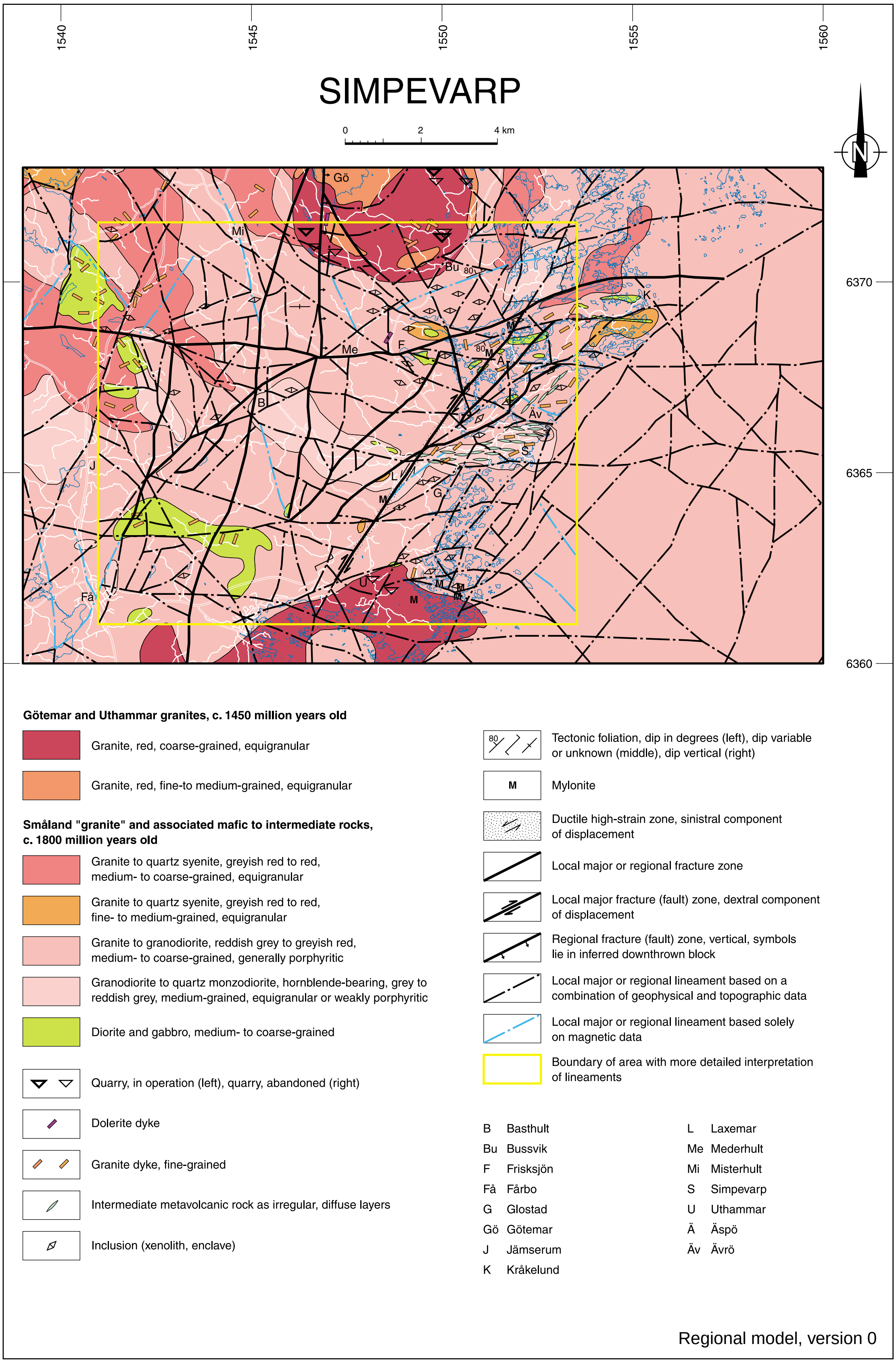


Figure 4-4. *2D cartographic model for the bedrock geology at the surface, both onshore and offshore, in the Simpevarp regional model area.*

4.4.2 Rock types – distribution, description and age

The Simpevarp regional model area is dominated by c. 1,800 Ma intrusive rocks that formed during stage 2 in the geological evolutionary model (see Section 4.2). These rocks belong to the c. 1,850–1,660 Ma so-called Transscandinavian Igneous Belt (TIB). Another conspicuous rock component is a younger, c. 1,450 Ma old granite which formed during stage 3 in the geological evolutionary model (see Section 4.2). Supracrustal rocks, which were originally deposited at or near the Earth's surface, constitute an extremely subordinate component in the area. A few dolerite dykes are also present. All existing rock types are post-tectonic in relation to the regional deformation that has affected the older rocks in the region (e.g. close to Västervik). With the exception of ductile and brittle, high-strain zones, all rocks are more or less undeformed.

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, the occurrence of the metavolcanic rock has only been symbolized as point information (light green lenses) in Figure 4-4. 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 c. 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 c. 15–20% of the island. On Äspö, metavolcanic rock occupies two minor areas in the eastern central part.

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 c. 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 4-4). 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 frequently within them. 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 4-4, 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 4-5), which together make up c. 85% of the land in the regional model area.

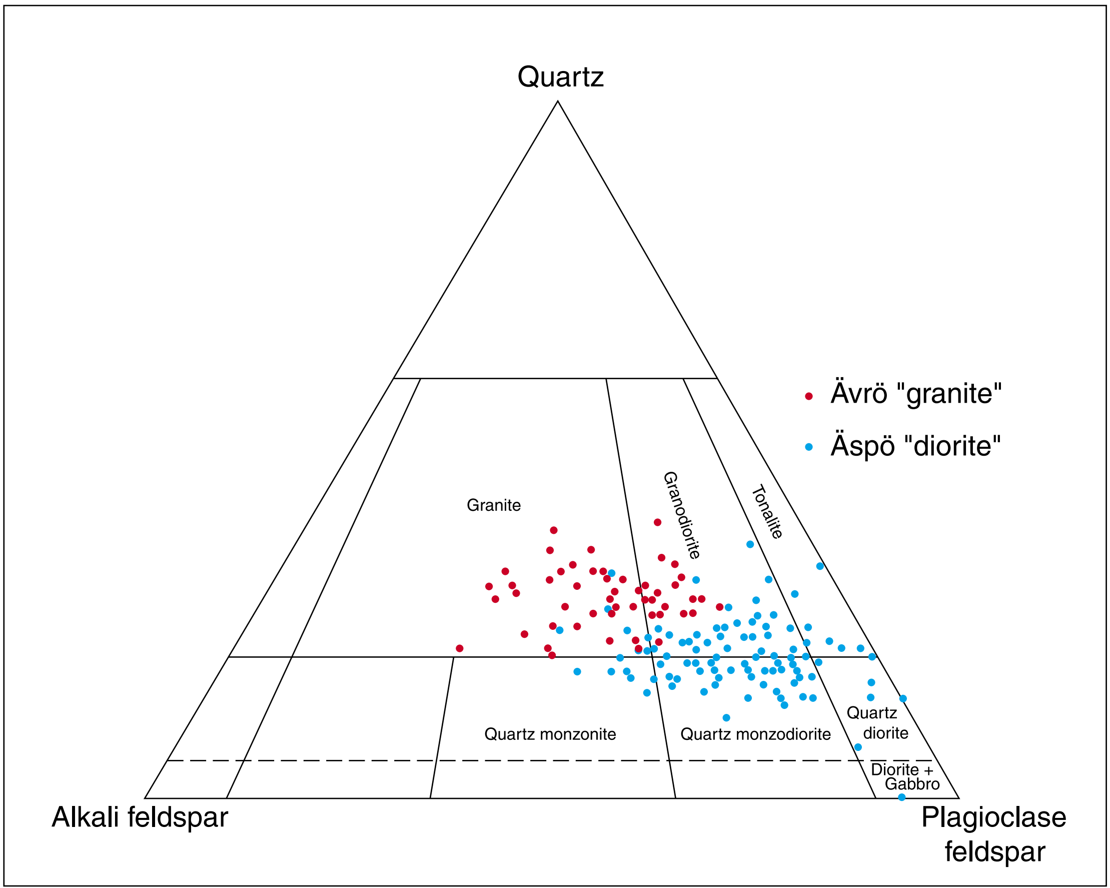


***Figure 4-5.** Modal compositional variation of the Småland "granites", based on Figures 3-13 and 3-14 in /Wikman and Kornfält, 1995/. Rock names according to /Le Maitre, 1989/.*

The varieties of the Småland "granite" that are displayed in Figure 4-4 are distinguished mainly on textural and compositional criteria. A description of the four main "granitic" rock types follows below in the order (from base to top) that they occur in the legend in Figure 4-4.

- *Grey to reddish grey, medium-grained, equigranular or weakly porphyritic granodiorite to quartz monzodiorite* constitutes an important rock type which occupies c. 9% of the land in the regional model area. This rock type is hornblende-bearing and appears to be both texturally and compositionally relatively homogeneous. Apart from two smaller bodies around Fårbo and a larger body on the mainland northeast of Äspö, it has its main extension in the central part of the land area (Figure 4-4). In this area, three specific bodies occur. The most conspicuous body extends from the Simpevarp peninsula in the east to Basthult in the west. As mentioned above, the granodiorite to quartz monzodiorite is intimately mixed with the presumed metavolcanic rock on the Simpevarp peninsula. Compositionally, this rock type is very similar to the so-called Äspö "diorite" (Figure 4-4). However, it differs in texture, since the Äspö "diorite" is generally porphyritic in character (cf. /Wikman and Kornfält, 1995/).

- The dominant type of Småland "granite" is a *reddish grey to greyish red, medium- to coarse-grained, generally porphyritic granite to granodiorite*, which comprises c. 61% of the land in the regional model area (Figure 4-4). Quartz monzonitic and quartz monzodioritic varieties are also present, which is exemplified by the Äspö "diorite" that belongs to this group (cf. Figure 4-4). An U-Pb zircon dating of the latter has yielded an age of 1,804 ±3 Ma /Wikman and Kornfält, 1995; Kornfält et al, 1997/. The feldspar phenocrysts are c. 1–3 cm in size and usually relatively sparsely distributed. Locally, more or less equigranular varieties occur. Consequently, this rock type is, both from a compositional and textural point of view, relatively inhomogeneous. It is commonly more or less isotropic, although locally, a foliation is developed. In places, it is difficult to decide whether the foliation is syn-intrusive or caused by a subsequent tectonic overprinting.

- *Greyish red to red, fine- to medium-grained, equigranular granite*, including subordinate quartz syenite, occupies c. 1% of the land in the regional model area. This estimate is based on the coherent bodies that are displayed in Figure 4-4. However, this type of granite primarily occurs as dykes in most rock types in the regional model area, and, consequently, the areal extent is underestimated. Apart from some minor bodies, the granite occupies three small areas, one south of Kråkelund, one north of lake Frisksjön, and one in the northwesternmost corner of the model area. The fine- to medium-grained granite north of lake Frisksjön envelops a small gabbro to diorite body. However, field control in connection with the feasibility study /Bergman et al, 2000/ revealed that the latter area constitutes a complex mixture of granite and gabbro to diorite /cf. Kornfält and Wikman, 1987b/. Two U-Pb zircon datings of the fine- to medium-grained granite have yielded ages of 1,794 +16/–12 Ma and 1,808 +33/–30 Ma /Wikman and Kornfält, 1995; Kornfält et al, 1997/. Although not well-defined, the ages indicate that this granite is coeval with and belongs to the same magmatic generation as the coarse-grained country rocks.

- *A greyish red to red, medium- to coarse-grained, equigranular granite*, including subordinate quartz syenite, occupies c. 14% of the land in the regional model area. It is distributed in four different bodies, two in the northeastern part close to the coast, and two in the northwestern part of the regional model area (Figure 4-4). The westernmost body is the largest and dominates the northwesternmost part of the area.

A second conspicuous rock type in the regional model area is a younger, c. 1,450 Ma granite /Bergman et al, 2000; Åhäll, 2001/, which occurs in two separate bodies, the so-called *Götemar and Uthammar granites*. Together they comprise c. 11% of the land in the regional model area.

Both the Götemar and Uthammar intrusions are composed of red, coarse-grained, equigranular, isotropic and homogeneous granite. However, in the Götemar granite, a fine- to medium-grained and equigranular variety is also present. Within the part of the Götemar granite that occurs in the regional model area, the coarse-grained and fine- to medium-grained varieties comprise c. 85 and 15%, respectively. The fine- to medium-grained granite also appears as dykes, which primarily occur within the granite body proper and in the immediate surroundings. According to /Kornfält et al, 1997/ and /Wikman and Kornfält, 1995/, the red granite dykes that belong to the Götemar intrusion are chemically distinct from the similar, c. 1,800 Ma dykes. Apart from red granite dykes, coarse-grained pegmatite and aplite also occur and some of the pegmatites contain beryl and topaz. Fluorite is a common accessory mineral in the Götemar granite and also occurs, together with pyrite, in fractures filled with Cambrian sandstone.

Both the Götemar and Uthammar granites (primarily the coarse-grained varieties) have been quarried for the production of dimension stone. Within the regional model area, five abandoned quarries, and three quarries which are in operation, are situated in the Götemar granite (Figure 4-4). No quarries are in operation in the Uthammar granite but two abandoned quarries are present.

Two *dolerite dykes* have been documented within the regional model area, one in the Götemar granite immediately south of the lake Götemar, and one c. 400 m northwest of the lake Frisksjön.

4.4.3 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 4-4) 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 may be 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, 1998, 1999, 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 4-4). 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/.

4.4.4 Potential for ore deposits

The Götemar granite has a mineralogical and chemical composition that is similar to granites which in other areas are associated with tungsten, tin and molybdenum mineralizations (see /Bergman et al, 1998, 1999/, and references therein). Furthermore, within a distance of 25 m from the western contact of the Götemar granite, the Småland "granite" displays alteration similar to greisening, which is an indicator of possible ore potential. Apart from this occurrence, data compilation within the Oskarshamn feasibility study /Bergman et al, 1998, 1999/ has led to the conclusion that the regional model area is devoid of any potential for ore deposits.

4.5 Bedrock – structure

4.5.1 Data input and integration

Field measurements of some *ductile structures* and the description of these structural features have been documented with the help of the cartographic database and the description of the structural geology which were completed in connection with the Oskarshamn feasibility study /Bergman et al, 1998, 1999, 2000/. These data have been extracted in the present study from SKB's GIS database 5.0 for Oskarshamn (Appendix 1).

During the feasibility study, a compilation of field measurements of ductile structures from the bedrock maps at the scale 1:10,000 and 1:50,000 that cover the regional model area /Kornfält and Wikman, 1987a,b, 1988/ was carried out. Field locality observations with exact measurements have not been analyzed within the context of the present project. For this reason, and bearing in mind the restricted number of field measurements, orientation data in stereographic plots have not been completed in this report. This will be of prime importance in connection with field activities during the initial site investigation programme.

Ductile structures are displayed in the maps presented in Figures 4-4 and 4-6.

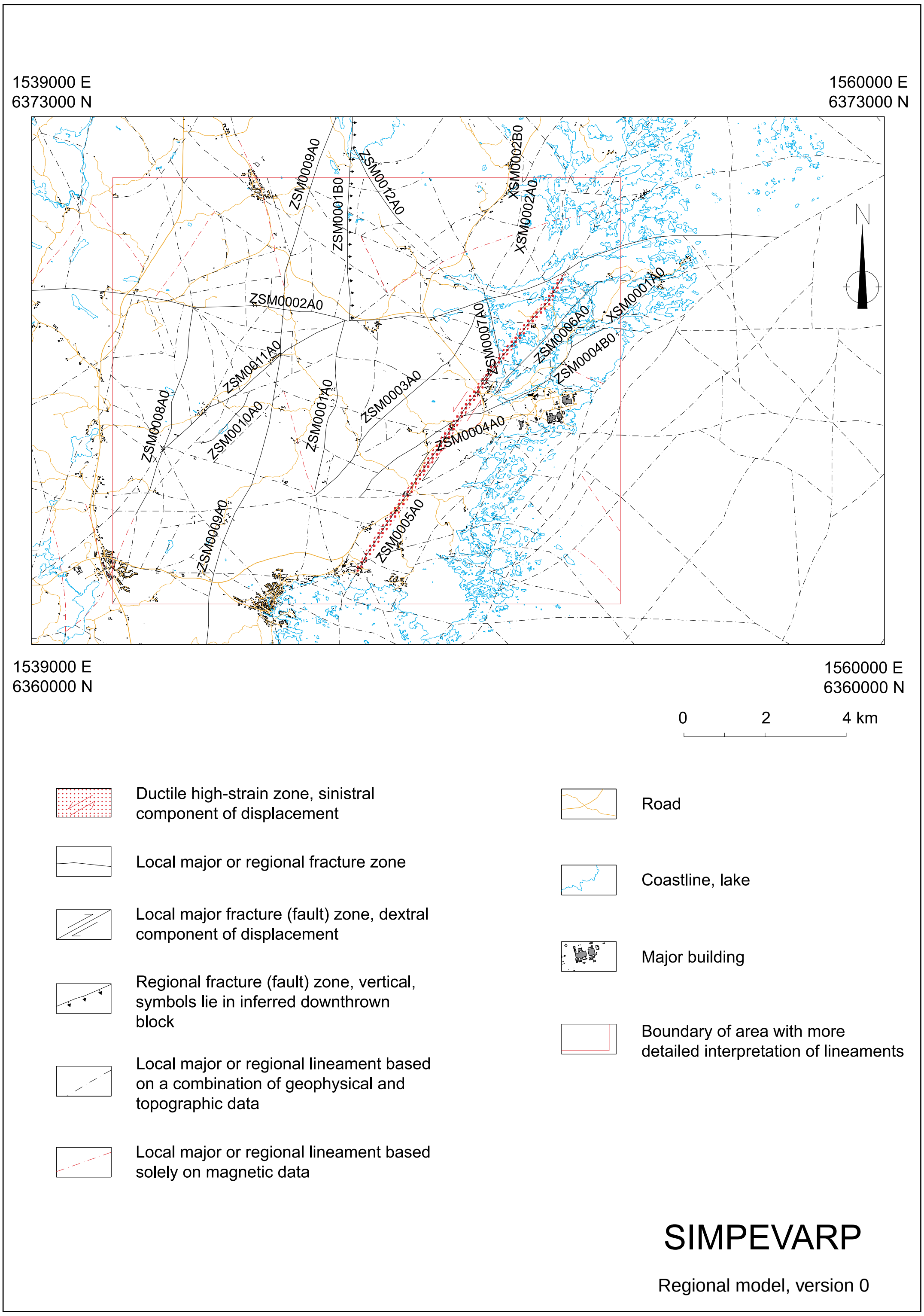


Figure 4-6. *Lineaments and deformation zones (local major and regional) at the surface. The lineaments with an identification number have been selected for communication purposes alone. The selection bears no relationship to their level of importance.*

Within the area defined by the coordinates 6361000–6371500 N and 1541000–1553500 E (RAK), the present study has utilized the compilation of *lineaments* that was completed during the field control stage during the Oskarshamn feasibility study /Bergman et al, 2000/. This more detailed compilation was based on the lineaments that had been identified in connection with the early stage of the feasibility study /Bergman et al, 1998, 1999/, but was complemented with lineaments with a length of at least 1–2 kilometres. Furthermore, the lineaments that had been identified during the early stage of the feasibility study were slightly adjusted due to the more detailed identification in connection with the field control study. All the lineaments reflect linear, low-magnetic features in the magnetic anomaly data and generally occur together with depressions in the digital topographic relief data. These data have been extracted from SKB's GIS database 5.0 for Oskarshamn (Appendix 1).

A comparison between the lineaments that were identified in the feasibility study and the lineaments (fracture zones) that were defined in /Stanfors and Erlström, 1995/ and /Rhén et al, 1997a,b/ displayed some minor discrepancies in the Äspö area. For this reason, a supplementary interpretation of topographical and magnetic data has been carried out in this area in the present study. Four new lineaments have been integrated into the present study and two of these have been upgraded to local major fracture zones (see below). This information is archived in a complementary GIS file (Appendix 1).

Outside the area defined by the coordinates 6361000–6371500 N and 1541000–1553500 E, the present study has utilized the interpretation of similar lineaments, with a minimum length of 5 km, which was completed in connection with the early stage of the Oskarshamn feasibility study /Bergman et al, 1998, 1999/. These data have been extracted from SKB's GIS 5.0 database for Oskarshamn (Appendix 1).

The lineaments are shown on Figure 4-4. For purposes of communication, the new lineaments recognized in this study are assigned the identification numbers XSM0001A0 and XSM0002B0 (Figure 4-6). The numbers are chosen according to the scheme recommended by SKB (see Appendix 2). The character and length of all the lineaments indicate that they are possible, local major or regional fracture zones.

Based on the presence of critical geological and/or geophysical information, twelve lineaments in the regional model area have been upgraded to highly probable to certain, *local major or regional fracture zones* (see Table 4-1). These have been assigned the identification numbers ZSM0001A0/B0, ZSM0002A0, ZSM0003A0, ZSM0004A0/B0, ZSM0005A0, ZSM0006A0, ZSM0007A0, ZSM0008A0, ZSM0009A0, ZSM0010A0, ZSM0011A0 and ZSM0012A0 (Figure 4-6), according to the scheme recommended by SKB (see Appendix 2). A comparison of the nomenclature presented in this study and in earlier SKB work can be seen in Table 4-2. The key sources of information which have formed the basis for the upgrading of a lineament to a local major or regional fracture zone are summarized in Table 4-3.

Due to the scale of study within the present 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/ have been addressed and integrated into the present study. Further work will be necessary during the initial site investigation programme to integrate these zones into the regional structural model.

The highly probable to certain, local major or regional fracture zones are displayed in the 2D cartographic model for the geology at the Earth's surface (Figure 4-4). The 3D modelling is described separately (see Section 4.6).

Table 4-1. Classification and naming of brittle structures, and ambition level for geometric description during site investigation (length and width measurements are approximate) /Andersson et al, 2000/.

Name	Length	Width	Ambition for geometric description
Regional fracture zones	> 10 km	> 100 m	Deterministic
Local major fracture zones	1–10 km	5–100 m	Deterministic (with uncertainties)
Local minor fracture zones	10 m–1 km	0.1–5 m	Statistical (some deterministic)
Fractures	< 10 m	< 0.1 m	Statistical

Table 4-2. Comparison of the nomenclature recommended by SKB for local major and regional deformation zones in this study and that used by SKB in earlier work.

Nomenclature of local major and regional deformation zones	
Earlier SKB work*	**Version 0**
SFZ02	ZSM0001A0/B0
SFZ03	ZSM0002A0
SFZ04	ZSM0003A0
SFZ05	ZSM0004A0/B0
SFZ07 (EW–1)	ZSM0005A0
SFZ12 (NE–1)	ZSM0006A0
SFZ14	ZSM0007A0

* Nomenclature in e.g. /Stanfors and Erlström, 1995/ and /Rhén et al, 1997a,b/.

Table 4-3. Key data sources for the local major or regional deformation zones.

Zone	Key data sources
ZSM0001A0	/Nisca, 1987; Tirén et al, 1987; Stenberg and Sehlstedt, 1989; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000/
ZSM0001B0	/Nisca, 1987; Tirén et al, 1987; Stenberg and Sehlstedt, 1989; Rydström and Gereben, 1989; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000/
ZSM0002A0	/Nisca, 1987; Tirén et al, 1987; Stenberg and Sehlstedt, 1989; Rydström and Gereben, 1989; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000, 2001/
ZSM0003A0	/Nisca, 1987; Tirén et al, 1987; Stanfors, 1988, 1995; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000, 2001; Ekman, 2001; this study/
ZSM0004A0	/Nisca, 1987; Tirén et al, 1987; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000/
ZSM0004B0	/Nisca, 1987; Tirén et al, 1987; Stanfors and Erlström, 1995; Gentzschein et al, 1987; Bergman et al, 1998, 2000/
ZSM0005A0	/Nisca, 1987; Tirén et al, 1987; Stanfors, 1988; Stenberg and Sehlstedt, 1989; Rydström and Gereben, 1989; Stanfors et al, 1991; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000/
ZSM0006A0	/Nisca, 1987; Tirén et al, 1987; Sehlstedt et al, 1990; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000; this study/
ZSM0007A0	/Nisca, 1987; Tirén et al, 1987; Stanfors and Erlström, 1995; Bergman et al, 1998, 2000/
ZSM0008A0	/Bergman et al, 1998, 2000/
ZSM0009A0	/Stenberg and Sehlstedt, 1989; Bergman et al, 1998, 2000/
ZSM0010A0	/Bergman et al, 2000/
ZSM0011A0	/Stenberg and Sehlstedt, 1989; Bergman et al, 1998, 2000/
ZSM0012A0	/Stenberg and Sehlstedt, 1989; Bergman et al, 1998, 2000/

4.5.2 Ductile structures

As mentioned above, all the rock types in the Simpevarp regional model area are post-tectonic with respect to the regional deformation that has affected the older rocks in the region (e.g. around Västervik). Hence, except for distinct ductile high-strain zones, the rocks are more or less isotropic. One local major, ductile high-strain zone has been recognized in the regional model area. This zone is referred to as ZSM0005A0 in this report (Figure 4-6). Mesoscopic ductile high-strain zones are also present in the area.

ZSM0005A0

The zone ZSM0005A0 corresponds to the so-called Äspö shear zone /Gustafsson et al, 1989; Bergman et al, 2000/ and constitutes a narrow structural belt, which is characterized by an increased concentration of separate, discontinuous high-strain zones. The shear zone is also distinctly seen in the airborne magnetic data. It has been verified with the help of ground magnetic measurements, in combination with borehole data, on Äspö island, and surface documentation at several places along its strike length. The southern part of the zone is also indicated in the topographic data. The positional accuracy of the zone is estimated to ±50 m.

In the south, it is bounded by the post-tectonic c. 1,450 Ma Uthammar granite and, in the north, by the fracture zone ZSM0002A0 (Figure 4-6). On this basis, the zone can be traced for c. 9 km. The zone strikes NE-SW and the ductile structures are vertical or steeply dipping to the SE. A dip of 80° SE and a width of 40 m have been adopted in the RVS modelling procedure (see Section 4.6).

Kinematically, the Äspö shear zone is characterized by a sinistral strike-slip component of movement. It developed during low-grade metamorphic conditions and is composed of strongly deformed to mylonitic varieties of the surrounding Småland "granites". In places, an enrichment in epidote and quartz, as seams, veins or dissemination in the rock matrix, is a characteristic feature.

Mesoscopic ductile high-strain zones

Low-grade, mesoscopic, ductile to brittle-ductile deformation zones of similar character as zone ZSM0005A0 have been described from the Äspö area (see e.g. /Munier, 1995/). Several were also observed during the field control work in connection with the feasibility study (see Figure 11 in /Bergman et al, 2000/). The mesoscopic shear zones are usually dm-m wide and are vertical or, occasionally, dip moderately. NE-SW and NW-SE orientations dominate; N-S- and E-W-trending zones also occur. Results from the field control work indicate that the frequency of mesoscopic, ductile deformation zones is much higher on the Simpevarp peninsula than in the remaining part of the regional model area (see Figure 11 in /Bergman et al, 2000/). On the Simpevarp peninsula, the orientation is dominantly NE-SW to ENE-WSW. Based on the structural and metamorphic similarities, as well as the spatial relations, the mesoscopic deformation zones and zone ZSM0005A0 (Äspö shear zone) are inferred to be temporally and genetically related to each other.

Since the mesoscopic, ductile deformation zones constitute important structural inhomogeneities, it is suggested that a detailed investigation of these zones needs to be completed during the initial site investigations in the Simpevarp candidate area, which was selected as a result of the Oskarshamn feasibility study /SKB, 2000b/.

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 c. 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 c. 1,800–1,750 Ma, during the later part of the Svecokarelian orogeny, i.e. during stage 2 in the geological evolutionary model (see Section 4.2).

4.5.3 Lineaments

Lineaments, which can be followed for at least 1–2 km and which are possible local major or regional fracture zones, appears to form an irregular, cross-cutting structural pattern in the Simpevarp regional model area (Figure 4-6). An inspection of the map pattern indicates that there are no distinctive orientation arrays. Lineaments with roughly N-S, E-W, NW-SE and NE-SW orientations are more or less equally represented. However, this is only a general judgement, since no quantitative work, with the help of, for example, rose diagrams, has been carried out in this study. Detailed investigations of at least some of the lineaments on the ground is deemed necessary during initial site investigations in the Simpevarp candidate area.

4.5.4 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 4-6 are possible local major or regional fracture zones. The properties of fractures in different rock types are described in /Ericsson, 1987/ and /Munier, 1995/.

4.5.5 Local major and regional fracture zones

The specific data which indicate and, to a variable extent, help to verify the occurrence of local major and regional fracture zones as well as the ductile deformation in ZSM0005A0 are summarized in Table 4-4. Estimated structural data, on which the appearance of these zones in various diagrams in this report and, most importantly, the geometric modelling in RVS (see Section 4.6) are based, are given in Table 4-5.

ZSM0001A0/B0

The regional fracture zone ZSM0001A0/B0 is divided into two segments by the fracture zone ZSM0002A0 (see below and Figure 4-6). The southern segment (ZSM0001A0) has a NNE (010°) strike and a somewhat more westerly position compared to the N-S-trending northern segment (ZSM0001B0).

Table 4-4. Indication and verification of local major or regional deformation zones. All are brittle fracture zones except ZSM0005A0 which dispays both ductile and brittle deformational components.

Zone	Indication	Verification	Comment
ZSM0001A0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geophysics,	
ZSM0001B0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geology, ground geophysics	
ZSM0002A0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geology, ground geophysics	
ZSM0003A0	Topographic data, airborne geophysics (magnetic data)	Boreholes KLX01, KLX02	
ZSM0004A0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geology, ground geophysics, tunnel (ÄHRL)	
ZSM0004B0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geology, ground geophysics, borehole KAV01 (Ä-1)*	
ZSM0005A0	Topographic data, airborne geophysics (magnetic data)	Ground geology, ground geophysics, borehole KAS04, KA1755A**	Ductile and brittle
ZSM0006A0	Topographic data, airborne geophysics (magnetic data)	Ground geophysics, borehole KAS09, KAS14, KAS16, KBH02, tunnel (Äspö HRL)	
ZSM0007A0	Topographic data, airborne geophysics (magnetic data, VLF data)	Ground geophysics	
ZSM0008A0	Airborne geophysics (magnetic data)	Ground geology	
ZSM0009A0	Topographic data, airborne geophysics (magnetic data)	Ground geology, ground geophysics	
ZSM0010A0	Topographic data, airborne geophysics (magnetic data)	Ground geology	
ZSM0011A0	Topographic data, airborne geophysics (magnetic data)	Ground geology, ground geophysics	
ZSM0012A0	Topographic data, airborne geophysics (magnetic data)	Ground geophysics	

* Cored drillhole on Ävrö island /Gentzschein et al, 1987/.
** Cored drillhole in Äspö HRL /Stanfors et al, 1994/.

All zones are judged to be highly probable to certain.

The two segments are indicated in both topographic and airborne geophysical data. The positional accuracy of segment ZSM0001A0 is ±50 m. South of coordinate 6371500, the positional accuracy of segment ZSM0001B0 is ±50 m; north of 6371500 it is ±50–100 m. The primary verification of both segments is based on ground magnetic and VLF measurements /Stenberg and Sehlstedt, 1989/. Furthermore, the northern segment has also been verified in a refraction seismic survey /Rydström and Gereben, 1989/ and by the documentation of increased small-scale fracturing, locally sealed by epidote, and mesoscopic brittle-ductile shear zones along or close to the marked fracture zone.
A steep to vertical dip is indicated by the results of the ground VLF measurements. Based on the anomalies visible in the ground VLF data, the width of the intensely fractured and/or altered part of the zone is estimated to c. 5–10 m. In the RVS modelling procedure (see Section 4.6), a dip of 90° and a width of 10 m have been adopted along the whole length of the fracture zone.

Table 4-5. Summary of estimated structural data on the local major or regional deformation zones.

Zone	Position (m)	Length (km)	Depth (m)	Strike	Dip	Width * (m)	Displacement
ZSM0001A0	+/– 50	c. 4.5		c. 010°	c. 90°	5–10 (150–250)	
ZSM0001B0	+/– 50–100	> 22		c. 360°	c. 90°	5–10 (150–250)	Eastern side downthrown
ZSM0002A0	+/– 50–100	c. 30	> 2000	070–280°	40–90° S	10–20 (30–300)	
ZSM0003A0	+/– 50	c. 6.5	> 1000	040–045°	60–90° SE	(50–300)	
ZSM0004A0	+/– 50	c. 6		035–080°	60–70° SE	(50–200)	
ZSM0004B0	+/– 50	c. 2		040–060°	60–70° SE	(50–200)	
ZSM0005A0	+/– 50	c. 9		c. 035°	70–90° NW, 60–90° SE	10–40 (70–200)	Ductile: sinistral Brittle: dextral
ZSM0006A0	+/– 50	c. 3.5	> 200	c. 040°	70° NW	5–10 (50–100)	
ZSM0007A0	+/– 50	c. 1.5		c. 345°	c. 90°	(50–100)	
ZSM0008A0	+/– 50	c. 5.5		360–030°			
ZSM0009A0	+/– 50–100	c. 25		360–020°		5–50 (85–120)	
ZSM0010A0	+/– 50	c. 2		025–080°			
ZSM0011A0	+/– 50	c. 5.6		050–065°		5–10 (100–200)	
ZSM0012A0	+/– 50–100	c. 2.3		320–330°		5–40	

* Estimated width of intense fracturing and/or alteration, indicated by ground VLF measurements and drillhole or tunnel documentation, is shown without brackets. Estimated width of alteration indicated by magnetic data, with or without increased fracturing, is shown in brackets. The length, strike, dip and width of ZSM0005A0 refer to the ductile deformational component.

On the basis of topographic and geophysical indications, the southern segment of this fracture zone (ZSM0001A0) can be traced for c. 4.5 km. The southern end of this segment connects to the southern end of fracture zone ZSM0003A0 (see below) and both are truncated by a lineament with E-W to WNW strike. The northern segment (ZSM0001B0) continues northwards outside the regional model area and, based on the interpretation in connection with the feasibility study, has a minimum length of c. 22 km. Hence, the total length of the two segments is > 26.5 km. The extrapolation of the fracture zone at depth is unknown due to lack of underground information.

Based on the fact that fractures filled with Cambrian sandstone only occur on the eastern side of segment ZSM0001B0 /Kresten and Chyssler, 1976/, it is inferred that the eastern block has been downthrown in relation to the western block. Kinematic data are absent along the southern segment. The timing of deformation along the zone, including its initial formation during the geological evolution, is unclear. However, the documentation of fractures filled with Cambrian sandstone, solely on the eastern side of the northern segment of the fracture zone, indicates that at least this segment of the zone has been active in post-Cambrian time, i.e. during the last 495 million years.

ZSM0002A0

The regional fracture zone ZSM0002A0 corresponds to a topographic depression and is also apparent in the airborne geophysical data. It is the trace of these anomalies which has been used to mark the fracture zone on the figures in this report. The positional accuracy of the zone is estimated to ±50 m between the coordinates 1541000–1553500 E, and ±50–100 m in the remaining part. The zone has been verified by ground magnetic and VLF measurements /Stenberg and Sehlstedt, 1989/, a refraction seismic survey /Rydström and Gereben, 1989/ and ground geology /Stanfors and Erlström, 1995/.

The strike of the zone varies between c. 070° and 280°, i.e. c. E-W. It can be traced from a NE-trending lineament in the sea area east of Kråkelund, westwards to the boundary of the regional model area, a distance of c. 19 km (Figure 4-6). In addition, the identification of lineaments during the feasibility study indicates that it extends further westwards for c. 11 km, where it turns or merges into a NW-trending regional lineament. Hence, the total length of this fracture zone is c. 30 km.

Results from the ground VLF measurements indicate that the zone has a steep southerly dip, while bedrock fractures in an outcrop close to the westernmost profile dip c. 40° towards the south. Based on an evaluation of the results from a reflection seismic survey /Bergman et al, 2001/, a dip of 52° towards the south /Andersson et al, 2002b/ has been used in the RVS modelling procedure (see Section 4.6). The anomalies indicated by the ground VLF measurements indicate a width of the intensely fractured and/or altered part of the zone of c. 10–20 m. A width of 20 m has been adopted in the RVS modelling procedure. On the basis of the interpretation of the reflection seismic data, this zone is inferred to extend to at least 2 km depth.

The configuration of the zones ZSM0001A0/B0 and ZSM0002A0 (Figure 4-6) suggests that ZSM0001A0/B0 may have been displaced by ZSM0002A0 with a dextral component of movement. However, there remains some uncertainty concerning this conclusion since field evidence is lacking. Movement along zone ZSM0002A0 during the Phanerozoic is consistent with the observation that the zone constitutes a break in the sub-Cambrian peneplain.

ZSM0003A0

The local major fracture zone ZSM0003A0 (Figure 4-6) is indicated on the basis of topographic and airborne magnetic data. It is the trace of these anomalies which has been used to mark the fracture zone on the figures in this report. On this basis, the zone is marked with a positional accuracy which is judged to be ±50 m. The zone has been verified in the two cored boreholes KLX01 and KLX02.

The fracture zone strikes c. 040–045° and can be traced for c. 6.5 km (Figure 4-6). The southwestern end of the zone connects to the southern end of the zone ZSM0001A0 and both are truncated by an E-W- to WNW-trending lineament. In the northeastern part, it is truncated by a lineament with an E-W to WNW trend. On the basis of the documentation of fractures in the cored boreholes KLX01 and KLX02, the dip of the zone is 60–90° to the SE. On the basis of seismic information /Bergman et al, 2001/, the dip of the zone is estimated to c. 87° in the same direction /Andersson et al, 2002b/. The maximum width is estimated at 50–300 m (Table 4-5). A dip of c. 87° to the SE and a width of 50 m were adopted in the RVS modelling procedure (see Section 4.6). Based on information from the cored borehole KLX02, the zone can be traced to a depth of at least c. 1,000 m below the Earth's surface. The direction, amount and timing of movement are not known.

ZSM0004A0/B0

The local major fracture zone ZSM0004A0/B0 is divided into two segments, a western segment and an eastern segment, referred to as ZSM0004A0 and ZSM0004B0, respectively (Figure 4-6). The "breaking point" is situated along a N-S lineament immediately north of the Simpevarp peninsula and west of the Ävrö island. Both segments of this fracture zone are indicated by topographic and airborne geophysical data. It is the trace of these anomalies which has been used to mark the fracture zone on the figures in this report. On this basis, the zone is marked with a positional accuracy which is judged to be ±50 m.

The zone has been verified by ground geology and ground geophysical measurements /Stanfors and Erlström, 1995/. Furthermore, segment ZSM0004A0 has been verified in the southernmost part of the Äspö access tunnel. /Stanfors and Erlström, 1995/ also indicate that segment ZSM0004B0 is transected in borehole KAV01 (Ä-1) on Ävrö. However, there remains some uncertainty whether this borehole transects segment ZSM0004B0 or another fracture zone /cf. Markström et al, 2001/.

The segment ZSM0004A0 can be traced for c. 6 km and varies in strike between c. 035° and 080°, while segment ZSM0004B0 extends for c. 2 km and strikes c. 40–60°. In total, the fracture zone is c. 8 km in length. It is bounded at both ends by c. E-W-trending lineaments (Figure 4-6). The extrapolation of this zone beneath the Earth's surface is uncertain. If segment ZSM0004B0 is transected in borehole KAV01 (Ä-1), then at least this segment of the zone can be traced to a depth of 578 m /Gentzschein et al, 1987/. The two segments have an estimated dip of c. 60–70° to the SE, and the maximum width is estimated to 50–200 m (Table 4-5). In the RVS modelling procedure (see Section 4.6), a width of 50 m and a dip of 70° are adopted. The amount and timing of movement along the fracture zone are not known.

ZSM0005A0

Following the ductile development (see above), the Äspö shear zone was reactivated in the brittle regime. On the basis of topographic and airborne magnetic data, the positional accuracy of the fracture zone is ±50 m.

Ground geophysics, including VLF and refraction seismic measurements, have verified brittle deformation along a profile across the southern extension of the ductile deformation zone, c. 1.5 km west of Uthammar /Stenberg and Sehlstedt, 1989; Rydström and Gereben, 1989/. Due to the low magnetic susceptibility of the rocks in the ductile deformation zone, the magnetic minima detected by the ground magnetic measurements cannot be used as a verification of the brittle reactivation. Furthermore, no VLF anomalies could be detected along three ground geophysical profiles further to the northeast along the zone /Stenberg and Sehlstedt, 1989/, due to the disturbance from power and telephone lines. On Äspö island, brittle reactivation with a dextral strike-slip component of movement has been documented /e.g. Munier, 1995/. During the field control work, which was carried out during the feasibility study, increased small-scale fracturing, indicative of brittle reactivation, was observed in outcrops along the ductile deformation zone. Furthermore, epidote-healed, mesoscopic fractures were also observed. However, due to the low-grade character of the ductile deformation, these could be related to a late stage of the ductile deformation and not to a later brittle overprinting.

The local major fracture zone ZSM0005A0 is at least 9 km long. However, the identification of lineaments in connection with the feasibility study indicates that this fracture zone possibly continues at least c. 4.5 km to the NNE, and c. 0.9 km to the SW.

Thus, the brittle deformation possibly extends for c. 14.4 km. The amount and timing of movement along the fracture zone are not known. However, to the south the presumed continuation of the fracture zone has been identified in the Uthammar granite, hence it is tentatively inferred that the zone was active after c. 1,450 Ma. The brittle component of deformation along zone ZSM0005A0 has not been modelled in 3D (see Section 4.6) due to the restricted amount of data.

Although not verified, a continuous brittle reactivation along the entire ductile deformation zone is inferred. However, a characterization of the Äspö shear zone with a focus on the degree and character of brittle reactivation is recommended to be carried out in the initial stages of the site investigation programme in the Simpevarp candidate area.

ZSM0006A0

The local major fracture zone ZSM0006A0 is indicated on the basis of both topographic and airborne magnetic data. These anomalies have been used to mark the fracture zone on the various figures in this report. Based on these anomalies, the zone has been marked with a positional accuracy of ±50 m. It is verified by ground geophysical measurements, in boreholes and in the Äspö tunnel /Stanfors and Erlström, 1995/. The zone extends for c. 3.5 km. It is bounded by a c. E-W-trending lineament in the northeastern part and it merges into a sub-parallel lineament in the southwestern part (Figure 4-6).

The zone strikes c. 040°, dips approximately 70° to the NW and the width of intense fracturing is estimated to c. 5–10 m. A dip of 70° to the NW and a width of 10 m have been adopted in the RVS modelling procedure (see Section 4.6). Based on its position in the Äspö tunnel, the zone can be traced at depth to at least 200 m below the Earth's surface. During the construction of the Äspö Hard Rock Laboratory, this fracture zone was found to have a very high hydraulic conductivity. The amount and timing of movement along the fracture zone are not known.

ZSM0007A0

The local major fracture zone ZSM0007A0 is recognized on the basis of topographic and airborne geophysical data. It is the trace of these anomalies which has been used to mark the fracture zone on the figures in this report. On this basis, the zone is marked with a positional accuracy which is judged to be ±50 m. The zone has been verified only by ground geophysical measurements /Stanfors and Erlström, 1995/. No geological data, either on the surface or in boreholes, are available which would help to verify the zone.

The zone strikes c. 345° and extends for c. 1.5 km between the zones ZSM0002A0 and ZSM0005A0 (Figure 4-6). The identification of lineaments in connection with the feasibility study indicates that this zone possibly continues at least c. 3.3 km to the north and c. 0.5 km to the south. Consequently, this zone possibly extends for at least c. 5.3 km. In the RVS modelling procedure (see Section 4.6), a dip of 90° and a width of c. 50 m (Table 4-5) is adopted. The extrapolation of the fracture zone at depth is unknown due to lack of information. The amount and timing of movement are not known.

ZSM0008A0

The local major fracture zone ZSM0008A0 is indicated solely by airborne magnetic data. This anomaly has been used to mark the fracture zone in this report. Based on the low-magnetic anomaly, the positional accuracy is ±50 m. It is verified by ground geological observations, such as increased small-scale fracturing and mesoscopic brittle-ductile deformation zones /Bergman et al, 2000/. The zone extends for c. 5.5 km, and is bounded in the north by the fracture zone ZSM0002A0 and in the south by a c. E-W-trending lineament (Figure 4-6). The identification of lineaments in connection with the feasibility study indicates that this zone possibly continues in a southerly direction for at least c. 2.4 km. Hence, this zone possibly extends for c. 7.9 km.

The strike of the zone varies between 360–030°, but the dip and width are unknown due to lack of information. A dip of 90° and a default width of 1 m have been assumed in the RVS modelling procedure (see Section 4.6). Furthermore, information about the extrapolation of the zone at depth and the amount and timing of movement are lacking. The documentation of brittle-ductile deformation tentatively suggests that the zone originally formed early in the geological evolution in the region, but observations of increased small-scale fracturing along the zone indicate that the zone was reactivated in the brittle regime.

ZSM0009A0

The regional fracture zone ZSM0009A0 is indicated on the basis of topographic and airborne magnetic data north of the fracture zone ZSM0002A0, but solely on magnetic data south of ZSM0002A0. These anomalies have been used to mark the extension of the fracture zone in the figures in this study. Between the coordinates 6361000–6371500 N, the positional accuracy of the zone is ±50 m, and ±50–100 m in the remaining part. It has been verified by ground magnetic and VLF measurements both north and south of ZSM0002A0 /Stenberg and Sehlstedt, 1989/. North of ZSM0002A0, this fracture zone was also verified during the field control work in connection with the feasibility study /Bergman et al, 2000/, by the documentation of increased small-scale fracturing, mesoscopic brittle and brittle-ductile deformation zones and epidote-healed fractures.

Fracture zone ZSM0009A0 strikes c. 360–020°. It extends for c. 13.5 km across the regional model area, but the lineament identification during the feasibility study indicates that it is traceable for c. 25 km, from the town of Oskarshamn in the south to the lake Götemar in the north. Based on the ground VLF measurements, the width of highly fractured bedrock along the zone is up to c. 50 m. This width has been adopted in the RVS modelling procedure (see Section 4.6). In one of the measured VLF profiles, south of ZSM0002A0, a steep dip to the west is indicated /Stenberg and Sehlstedt, 1989/. However, due to lack of more accurate information, the zone has been ascribed a dip of 90° in the modelling procedure.

The amount and timing of movement along the zone are not known. However, the documentation of brittle-ductile deformation suggests that the zone originally formed early in the geological evolution in the region, but was subsequently reactivated in the brittle regime.

ZSM0010A0

The fracture zone ZSM0010A0 is of local major character and is indicated on the basis of topographic and airborne magnetic data. These anomalies have been used to mark the fracture zone on the figures in this report. The positional accuracy of the zone is ±50 m. It is verified by the documentation of epidote-healed fractures during the field control work which was completed during the feasibility study /Bergman et al, 2000/.

The fracture zone strikes c. 025–080° but has a dominant NE trend. It extends for only c. 2 km and is bounded or merges into ENE- and NE-trending lineaments at its northeastern and southwestern ends, respectively (Figure 4-6). The dip and width of the fracture zone are unknown due to lack of information. The zone has been modelled with a dip of 90° and a default width of 1 m in the RVS modelling procedure (see Section 4.6). Furthermore, information which bears on the extrapolation of the zone at depth and the amount and timing of movement are lacking.

ZSM0011A0

The local major fracture zone ZSM0011A0 is indicated by both topographic and airborne magnetic data. These anomalies have been used to mark the fracture zone on the figures in this report. The positional accuracy of the zone is ±50 m. It is verified by ground magnetic and VLF measurements /Stenberg and Sehlstedt, 1989/, and by the documentation of increased small-scale fracturing, mesoscopic brittle and brittle-ductile deformation zones and epidote-healed fractures /Bergman et al, 2000/.

The fracture zone strikes 050–065° and extends for c. 5.6 km. The northeastern end of the zone connects to the junction between fracture zones ZSM0001A0 and ZSM0002A0, and in the southwestern part it is truncated by the zone ZSM0008A0 (Figure 4-6). However, the lineament identification during the feasibility study indicates that the fracture zone possibly continues c. 6.7 km to the southwest where it is truncated by a NW-trending lineament. Consequently, this zone is possibly of regional character and extends for c. 12 km. Based on the ground VLF measurements, the width of highly fractured bedrock along the zone is estimated to be c. 5–10 m. A width of 10 m has been adopted in the RVS modelling procedure (see Section 4.6). Since no information about the dip is available, the zone has been ascribed a dip of 90° in the modelling procedure. No information about the depth of the zone and amount and timing of movement exist.

ZSM0012A0

The local major fracture zone ZSM0012A0 is indicated on the basis of topographic and airborne magnetic data. On the basis of these anomalies, the fracture zone has been marked on the figures in this report. The positional accuracy of the zone is ±50 m south of coordinate 6371500 N and ±50–100 m north of this coordinate. It is verified solely by ground magnetic and VLF measurements /Stenberg and Sehlstedt, 1989/. The fracture zone is situated outside the area that was chosen for field control work in connection with the feasibility study.

The fracture zone strikes c. 320–330° and extends for c. 2.3 km. The northwestern end of the zone connects to the fracture zone ZSM0001B0, while the southeastern end connects to an intersection between a lineament which extends southeastwards in the same direction and a ENE-trending lineament (Figure 4-6). The southeastward continuation of the zone is regarded to be uncertain, mainly due to the position of the southeasternmost ground geophysical profile close to an intersection point between several lineaments. If the zone continues southeastwards along the lineament, the maximum length for the zone is c. 3.5 km.

Based on the ground VLF measurements, the width of highly fractured bedrock along the zone is estimated at c. 40 m (maximum). The latter has been adopted in the RVS modelling procedure (see Section 4.6). Since no information concerning the dip is available, the zone is modelled at a dip of 90°. No information about the extrapolation of the zone at depth nor the amount and timing of movement exist. However, since the zone affects the c. 1,450 Ma Götemar granite, it must have been formed and possibly also reactivated during the last 1,450 Ma.

Subhorizontal to horizontal fracture zones – regional importance?

It has not been possible to identify subhorizontal to horizontal structures in connection with the lineament identification work. However, gently dipping to subhorizontal fracture zones, described as thrusts, have been reported from the Oskarshamn region by /Nordenskjöld, 1944/. No local major or regional fracture zones of this character have so far been documented in the Simpevarp regional model area. However, in the reflection seismic studies at Ävrö and Laxemar, subhorizontal reflectors which were interpreted as fracture zones have been documented /Juhlin and Palm, 1997, 1999; Bergman et al, 2001/. Assessment of the regional importance of subhorizontal to horizontal fracture zones in the Simpevarp candidate area will be an important question which needs to be addressed during the initial site investigation programme.

4.6 Modelling process in 3D

4.6.1 General

The 3D modelling process begins with the definition of the model block volume, in this case within a region containing a potential disposal site. The process continues with the assembly of relevant 2D surface data which are imported into the model and allow the development of initial projections of 3D geometries. Initially, only structures relevant on a regional scale are considered. The process results in the generation of a regional model version 0 (v0), as presented in the current report. It should be emphasised that the v0 model in reality marks only the starting point of the modelling work. It helps to define what is not known about a site and provides a framework for the planning of relevant field investigations. The model is developed with the help of the RVS geometric rock modelling system.

Subsequent model versions, both at regional and local scale, will be produced as more data become available from the field investigations. The modelling process will ultimately result in the construction of a 3D block model with individual blocks being demarcated by structures, such as interpreted fracture zones and faults. This geometrical model will be used as the basis for further specialised modelling activities, such as rock mechanics and hydrogeology. Based on the results of the field investigations, as well as subsequent interpretations and modelling, the individual blocks and zones will then be assigned physical properties, such as density, strength and permeability.

A brief description of the procedures used and the results of the version 0 modelling in the Simpevarp regional model area are presented below.

4.6.2 Boundaries of the model block volume and data input

The Simpevarp regional model area, as described in Section 1.3, was defined in RVS. The top of the model volume was set at an elevation of +50 m to allow for the generation of a topographic surface. The base of the model volume was set at an arbitrarily chosen elevation of –2,200 m to allow for the future inclusion of deep structures from, for example, the interpretation of seismic and gravity data.

The Simpevarp regional model v0 has been based on data from the Earth's surface and an interpretation of how at least some of the geological features observed at the surface can be extrapolated towards depth. The following surface data have been imported into the model:

- Distribution of rock types.
- Local major and regional lineaments and deformation zones.
- Major infrastructure based on the National Land Survey's 1:50,000 map series.

The extrapolations which have been made with depth are based on the interpretation of available surface data. No 3D base data, for example from boreholes, have been imported into the model.

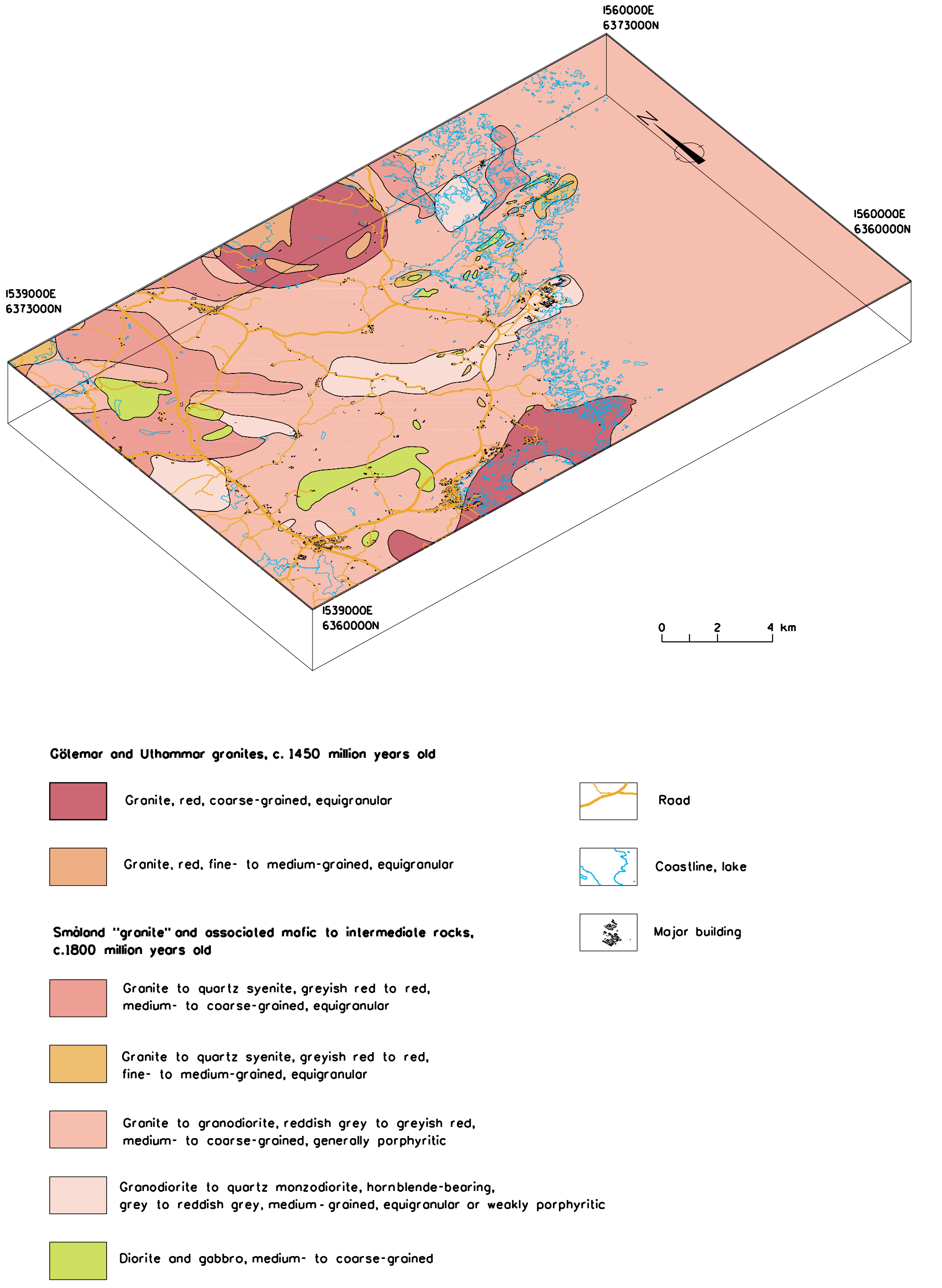
4.6.3 Lithological model

Data which directly confine the dip of the contacts between different rock types or groups of rock types (rock units) and, thereby, the extrapolation of these units at depth are lacking. For this reason, a 3D lithological model has not been constructed in this study. Only the distribution of rock types on the top surface of the block, i.e. the lithological part of the map shown in Figure 4-4, is presented (Figure 4-7).

4.6.4 Structural model

All the local major or regional lineaments addressed in this study (Figures 4-4 and 4-6) are considered to be possible fracture zones. They are displayed on the top surface of the block (Figure 4-8). The twelve lineaments which have been upgraded to highly probable to certain, local major or regional deformation zones have been modelled in a 3D format with the help of the RVS geometric rock modelling system (Figure 4-8). Details of all these zones and supporting data, especially the parameters dip and width of highly deformed bedrock, are presented in Table 4-5, as discussed in Section 4.5.5. Where there are no data pertaining to the dip and/or width of a particular zone, the zone has been modelled in 3D with a dip of 90° and with a default width (thickness) of 1 m.

The geometry of lineaments that had been identified during the early stage of the feasibility study was adjusted due to the more detailed identification in connection with the field control work, during the later stage of the feasibility study. The difference in the level of detail between these two stages is also responsible for the apparent termination of certain lineaments at the boundary of the field control study area (see Figure 4-4). These terminations at the boundary line mark the geographical limits of our knowledge from the field control work (the yellow box on Figure 4-4) rather than the interpreted terminations of the individual lineaments based on real evidence. This general principle should also be borne in mind when viewing the individual zone geometries in the 3D structural model. It is highly probable that certain of the zones have a greater geographical extent than has been modelled in 3D. For example, ZSM0007A0 probably extends northwards beyond the intersection with ZSM0002A0, following an identified lineament. The modelled termination of ZSM0007A0 at ZSM0002A0 marks the limit of our current knowledge rather than an active interpretation that this zone in reality terminates at this point.



SIMPEVARP

Regional model, version 0

Figure 4-7. Lithological model. 3D view from the southwest.

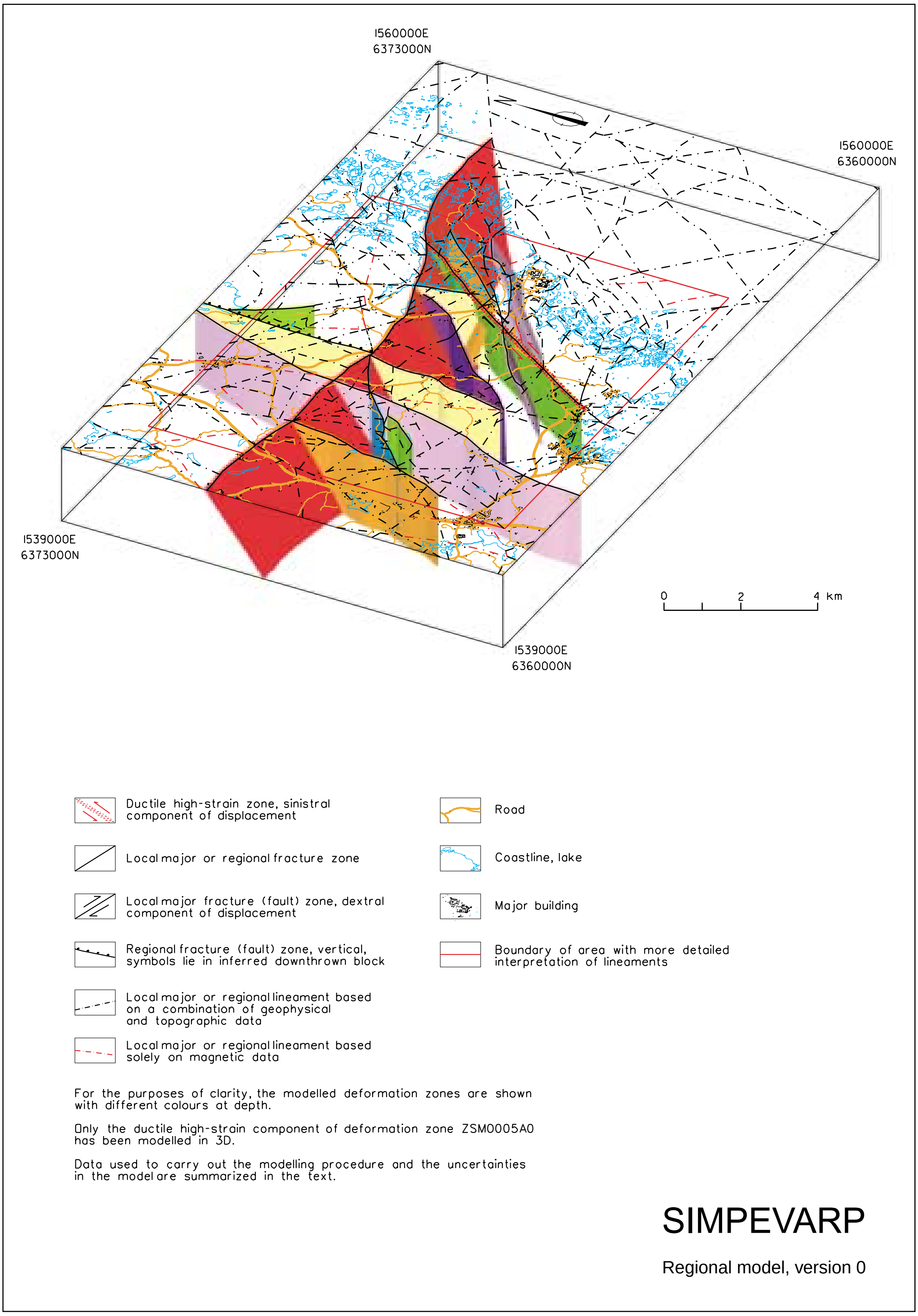


Figure 4-8. *Structural model – lineaments and deformation zones (local major and regional). 3D view from the southwest. The view direction is not the same as in Figure 4-7.*

When modelling the network of intersecting fracture (fault) zones, the geometry of certain zones is modified to reflect the interpreted tectonic sequence of their development. However, for much of the regional model area, little is known about the detailed evolution of individual zones. Where evidence is lacking, zones have been truncated at the potential intersection locations with the major zones (e.g. ZSM0002A0). Some apparent inconsistencies have been encountered which will require further investigation. For example, in the 3D model, ZSM0001A0 and ZSM0001B0 are represented with the same colour since they are considered to be two separate segments of the same vertically-dipping zone, with an apparent offset along ZSM0002A0. However, zone ZSM0009A0, which also strikes approximately N-S but across the entire regional model area, intersects ZSM0002A0 without an apparent geometrical offset. ZSM0004A0 and ZSM0004B0 are currently considered to be two separate segments of the same zone offset along a lineament with N-S strike. However, the detailed geometry of other lineaments effecting this offset need to be checked in order to arrive at a consistent solution for the tectonic sequence of the zone geometry.

Bearing in mind the character of the data which are available, only the broader, ductile high-strain component of the deformation zone ZSM0005A0 (Äspö shear zone), with its sinistral component of displacement, has been modelled in 3D. This zone also contains a brittle element with a suspected dextral component of displacement. The modelling of the compound nature of this zone needs to be further developed in future versions of the structural model for the Simpevarp area.

4.7 Assessment of uncertainty in the geological data

The geology of the Simpevarp regional model area is presented with the help of several compilations and some interpretations of primary data. These data are both observational and quantitative in character. The primary sources of information are:

- SKB's GIS database 5.0 which has been constructed in connection with the feasibility study work.
- Complementary GIS data summarized in this study.
- The description of the various "parameter groups" /SKB, 2001a/ in the feasibility study work.
- Key references included in the data inventory which is summarized in Chapter 2. These references are especially pertinent to the modelling of the local major and regional deformation zones in the regional model area.

An assessment of the uncertainty in this information needs to address:

- The scale at which the data have been compiled.
- The level of knowledge in different parts of the regional model area.
- Uncertainty in the definition of lineaments in the 2D model, and the extrapolation of inferred deformation zones to depth in the 3D model.

These aspects of uncertainty correspond to the factors *scale*, *level of knowledge* and *uncertainty in the interpretation of geometry or spatial variability*, respectively /Andersson et al, 2001; Munier and Hermanson, 2001/.

Quantitative assessment of uncertainty is provided here for some parameters. However, the assessment is generally qualitative in character and utilizes the terms "low", "high" and "variable" for level of knowledge and the terms "possible", "probable" and "highly probable to certain" for the uncertainties in the interpretation of geometry.

The level of knowledge in the model presented for the geological evolution of south-eastern Sweden is relatively high for stages 1 and 2, i.e. the older stages, and low for stages 3, 4, 5 and 6, i.e. the younger stages. The assessments of the data in the geological "parameter groups" /SKB, 2001a/ are presented in the form of three tables for Quaternary geology, bedrock – rock type and bedrock – structure (Tables 4-6, 4-7 and 4-8, respectively).

Table 4-6. Assessment of uncertainty. Quaternary geology.

	Scale of compilation	Level of knowledge	Comment
Distribution and description of Quaternary deposits	1:50,000	Low	No detailed surface mapping performed.
Thickness of Quaternary deposits		Low	
Land rise		High	
Late- or post-glacial crustal movement		Low	Conflicting interpretations exist.
Seismic activity in historical time		High	

Table 4-7. Assessment of uncertainty. Bedrock – rock type.

	Scale of compilation	Level of knowledge	Comment
Distribution, description and inhomogeneity	1:100,000	Variable	Information in 2D model generalized from 1:10,000 to 1:100,000 in the central coastal area. Information in the remaining part of the area is mainly based on older material. Interpretation in the offshore area is very uncertain.
Age of rocks		High	Five U-Pb zircon datings exist.

Table 4-8. Assessment of uncertainty. Bedrock – structure.

	Scale of compilation	Level of knowledge	Interpretation of geometry	Comment
LINEAMENTS (possible local major or regional fracture zones)	1:50,000 within the field control area (6361000–6371500 N/ 1541000–1553500 E); 1:100,000 outside this area.	High	Highly probable to certain. Position of lineaments: +/– 50 m in the field control area; +/– 50–100 m outside this area.	High-quality airborne geophysical data: 200 m flight line separation, ground clearance 30 m. Topographic relief data, 50 m grid.
ZSM0001A0 ZSM0004A0/B0 ZSM0005A0 ZSM0007A0 ZSM0008A0 ZSM0010A0 ZSM0011A0	1:50,000	Low	Highly probable to certain. Position of fracture zone: +/– 50 m. Uncertain extrapolation towards depth.	See verification criteria, Table 4-4.
ZSM0001B0 ZSM0009A0 ZSM0012A0	1:50,000 within the field control area (6361000–6371500 N/ 1541000–1553500 E); 1:100,000 outside this area.	Low	Highly probable to certain. Position of fracture zone: +/– 50 m in the field control area; +/– 50–100 m outside this area. Uncertain extrapolation towards depth.	See verification criteria, Table 4-4.
ZSM0002A0	1:50,000 within the field control area (6361000–6371500 N/ 1541000–1553500 E); 1:100,000 outside this area.	Low	Highly probable to certain. Position of fracture zone: +/– 50 m in the field control area; +/– 50–100 m outside this area. Extrapolation beneath c. 2,000 m depth uncertain.	See verification criteria, Table 4-4.
ZSM0003A0	1:50,000	Low	Highly probable to certain. Position of fracture zone: +/– 50 m. Extrapolation beneath c. 1,000 m depth uncertain.	See verification criteria, Table 4-4.
ZSM0006A0	1:50,000	High	Highly probable to certain. Position of fracture zone: +/– 50 m. Extrapolation beneath c. 200 m depth uncertain.	See verification criteria, Table 4-4.

5 Rock mechanics

To describe a site from a rock mechanics point of view, there are two aspects which need to be considered, the *in situ* stress and the mechanical properties of the rock. The combination of stress and strength determine the stability conditions of future repository excavations. The following sections, Sections 5.1 and 5.2, present the stress model and the mechanical property model, respectively.

5.1 *In situ* stress model

5.1.1 Available data

The Simpevarp regional model area includes the Äspö Hard Rock Laboratory and there exists a large number of stress measurements from the research performed by SKB in the area. Table 5-1 shows the sources of the available. Some data are stored in SICADA and some are presently only available in the cited reports.

Table 5-1. Stress measurement data from the Simpevarp regional model area.

Borehole	Method	Data source	Reference
KAS02	Hydraulic fracturing	SICADA	/Bjarnasson et al, 1989/
KAS03	Hydraulic fracturing	SICADA	/Bjarnasson et al, 1989/
KAS05	Overcoring	SICADA	/Bjarnasson et al, 1989/
KLX02	Hydraulic fracturing	SICADA	/Ljunggren and Klasson, 1997/
KOV01	Hydraulic fracturing	IPR-02-01	/Klee et al, 2002a/
KOV01	Overcoring	IPR-02-18	Data not available
KF0093A01	Hydraulic fracturing (horizontal hole)	IPR-02-02	/Klee et al, 2002b/ Data taken from /Janson and Stigsson, 2002/
KA2599G01	Hydraulic fracturing	IPR-02-02	/Klee et al, 2002b/ Data taken from /Janson and Stigsson, 2002/
KF0093A01	Overcoring	IPR-Report	Data taken from /Janson and Stigsson, 2002/
KA3579G	Overcoring	IPR-02-03	/Klasson et al, 2001/
KK0045G01	Overcoring	IPR-02-03	/Klasson et al, 2001/

5.1.2 Lithological and structural model implications

Two main factors may influence the *in situ* stress field, stiffness differences in fracture zones or the rock mass in between /Hakami et al, 2002/. For the conditions at Simpevarp, the second factor is expected to be minor because the difference in stiffness will not be sufficient to cause considerable stress differences (see Section 5.2.2). Fracture zones are expected to be the major cause for stress variations. "Stress variation" in this context mean stress differences apart from the stress increase with depth related to the gravitational forces (the load of the rock mass).

The structural model (Figure 4-8) indicates that the area is intersected by several fracture zones in different directions and that these deformation zones have been reactivated several times during the geological history. It is therefore reasonable to believe that the strength in the major zones is significantly lower than that of the rock mass between the zones, and that the zones may therefore have influenced the stress field. Weak zones will tend to deflect the stresses to become parallel and perpendicular to the fracture zone plane, since they cannot sustain shear forces.

The tectonic forces are the dominating source for the prevailing stress field in Sweden, resulting in a compressive horizontal stress clearly larger than the vertical stress. The regional stress field expected from the tectonic forces on the Fennoscandian shield suggests a NW orientation of the maximum horizontal compressive stress, /Slunga et al, 1984; Müller et al, 1992/. A major zone on the global scale, called the Tornquist zone, is located between Sweden and Denmark and has a NW-SE strike. It is possible that this zone influences the stress field orientation in the whole southern part of Sweden /Hakami et al, 2002/. Thus, both the primary stress sources and the global structure indicate that NW-SE should be the preferred maximum stress orientation in the Simpevarp regional model area.

Vertical stress magnitudes are normally related to the weight of overlying rocks /Amadei and Stephansson, 1997/ and this is assumed to be the case in the Simpevarp regional model area.

5.1.3 Stress model and uncertainties

The first step in modelling has been to study the available information on the minimum horizontal stress from hydraulic fracturing data (Figure 5-1). Five of the boreholes with measurements are located at Äspö and Laxemar, within the Simpevarp regional model area, but borehole KOV01 is located in Oskarshamn (20 km south of Simpevarp). The plotted data (Figure 5-1) show that the stress level has an increasing trend with depth, but also that the scatter in data is large, in particular at the deeper levels. However, at about 450 m depth, where several measurements have been made, the stress magnitudes from the different locations are all in the range of 9–13 MPa.

The selection of the equation for estimation of minimum horizontal stress was made by trial and error such that a good fit was obtained to the measurements. When no consistent depth dependency could be seen from the measurements the equation chosen was a linear trend. This does not mean that the stress along a borehole cannot have a non-linear increase (as shown in Figure 5-1). However, the local variation at a single borehole cannot be expected to necessarily represent the stress variation for the whole area, especially if the mechanism for the variation is judged to be due to local variations, such as a fracture zone. Therefore, an uncertainty span covering most of the results from all boreholes was adopted.

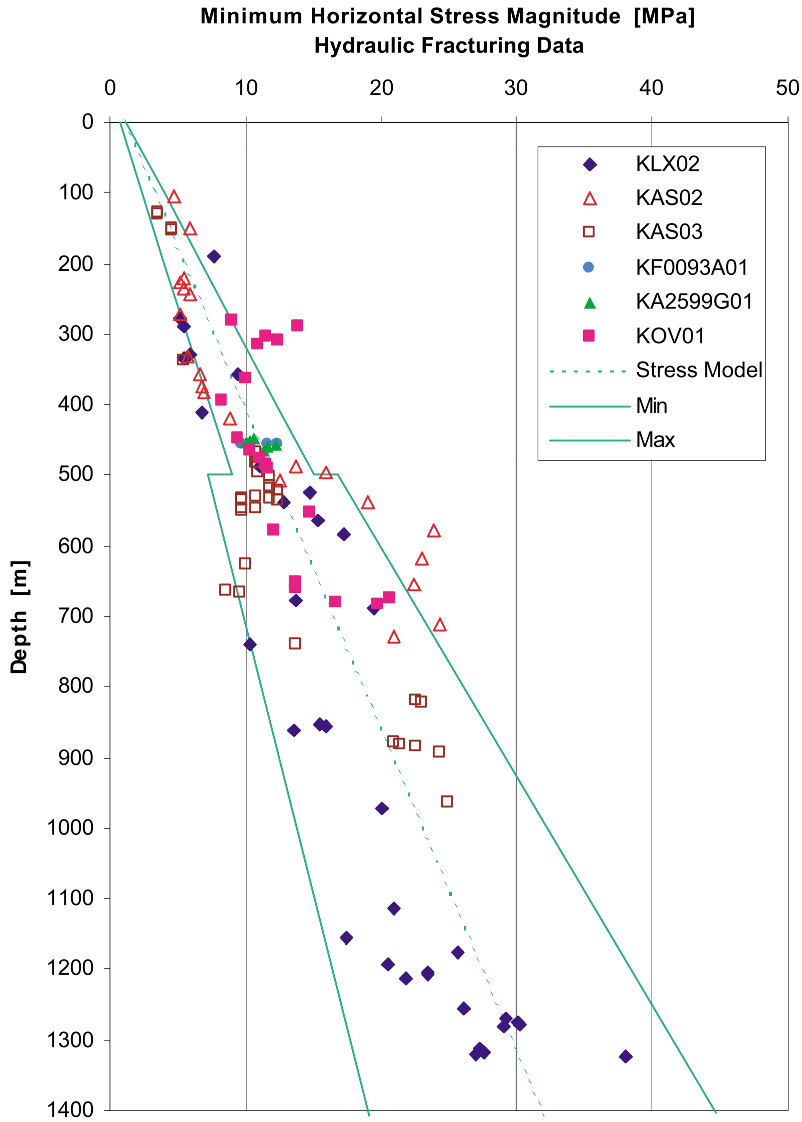


Figure 5-1. *The minimum horizontal stress magnitudes from hydraulic fracturing measurements in the Simpevarp regional model area. The model for the model area is shown with the green lines. The expected spatial variation around the mean stress, ±15%, is not shown in the diagram.*

Figure 5-2 shows the measurement results for the minimum principal stress magnitude, where overcoring techniques were used. The overcoring data are more scattered than the hydraulic fracturing data, which is often ascribed to the smaller scale of the overcoring method. It can also be seen that the measurement data mostly fall within the estimation for minimum principal stress level, which was based on the hydraulic fracturing data.

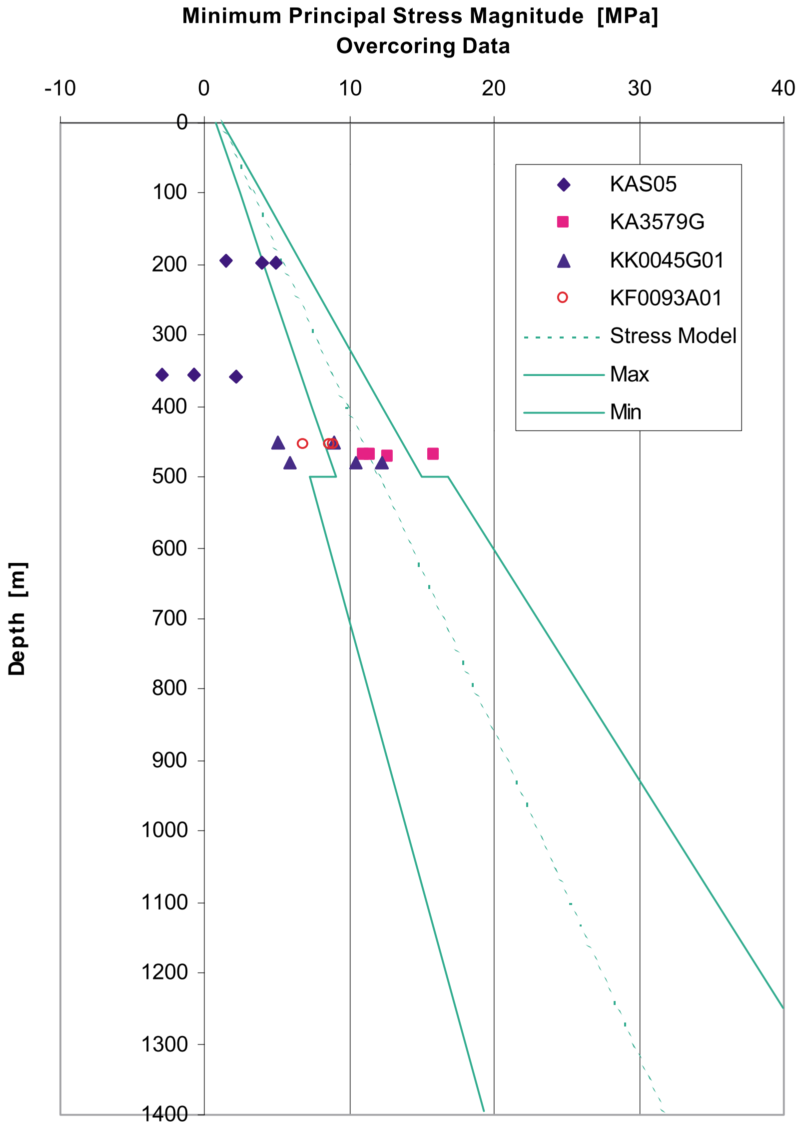


Figure 5-2. The minimum principal stress from overcoring measurements. The model for the Simpevarp regional model area based on data from hydraulic fracturing (Figure 5-1) is shown with the green lines. The increase in uncertainty span at 500 m depth reflects the fact that few measurements of stress exist at depth. The expected spatial variation around the mean stress, ±15%, is not shown in the diagram.

Figure 5-3 shows the maximum principal stress measured by the overcoring technique. The hydraulic fracturing measurements have not been used directly to estimate the maximum principal stress since it is believed that the traditional way of estimating maximum principal stress from hydraulic fracturing tests is not reliable /e.g. Rutqvist et al, 2000/. The estimation of the maximum stress was based instead solely on the overcoring test results. The ratio between the maximum and the minimum stress was studied and used for the estimation, although, in this case, the two measurement techniques were not used in the same bore holes, which would have been advantageous. The ratio $\sigma1/\sigma3$ for the four boreholes KAS05, KA3579G, KK0045G, KF0093A01 (Figure 5-2 and Figure 5-3) is 4.1 (lower level excluded), 2.7, 3.3 and 3.7, respectively. A $\sigma1/\sigma3$ ratio of 3 was selected for the model equations.

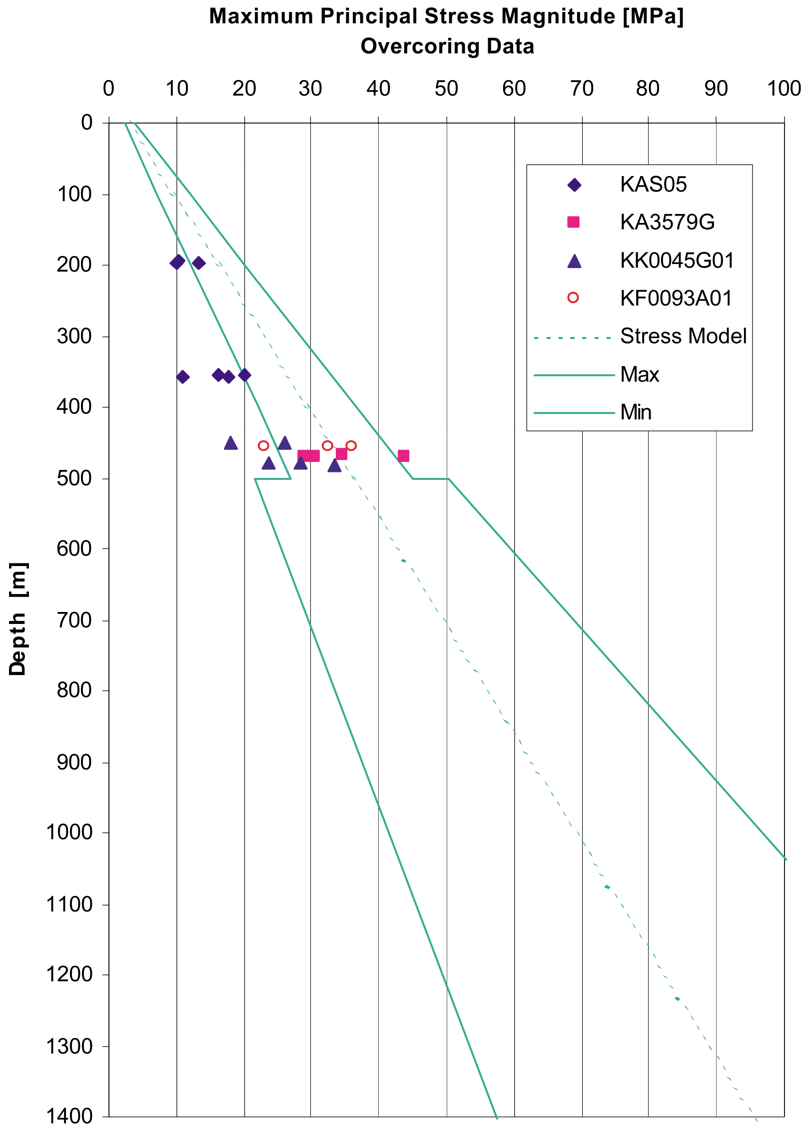


Figure 5-3. Maximum principal stress magnitudes measured by the overcoring technique. The stress estimation for the mean stress in the Simpevarp regional model is also depicted in the figure. The increase in uncertainty span at 500 m depth reflects the fact that few measurements of stress exist at depth. The measurements from KAS05 at 350 m depth are believed to be located inside a fracture zone /Hakami et al, 2002/.

The orientation of the maximum horizontal stress is based on data from both hydraulic fracturing and overcoring (Figure 5-4). The mean of the median values from 8 boreholes gave an orientation 132 degrees clockwise from north. It should be noted that this SE-NW direction fits well with the direction expected from the regional geological setting (Section 5.1.2).

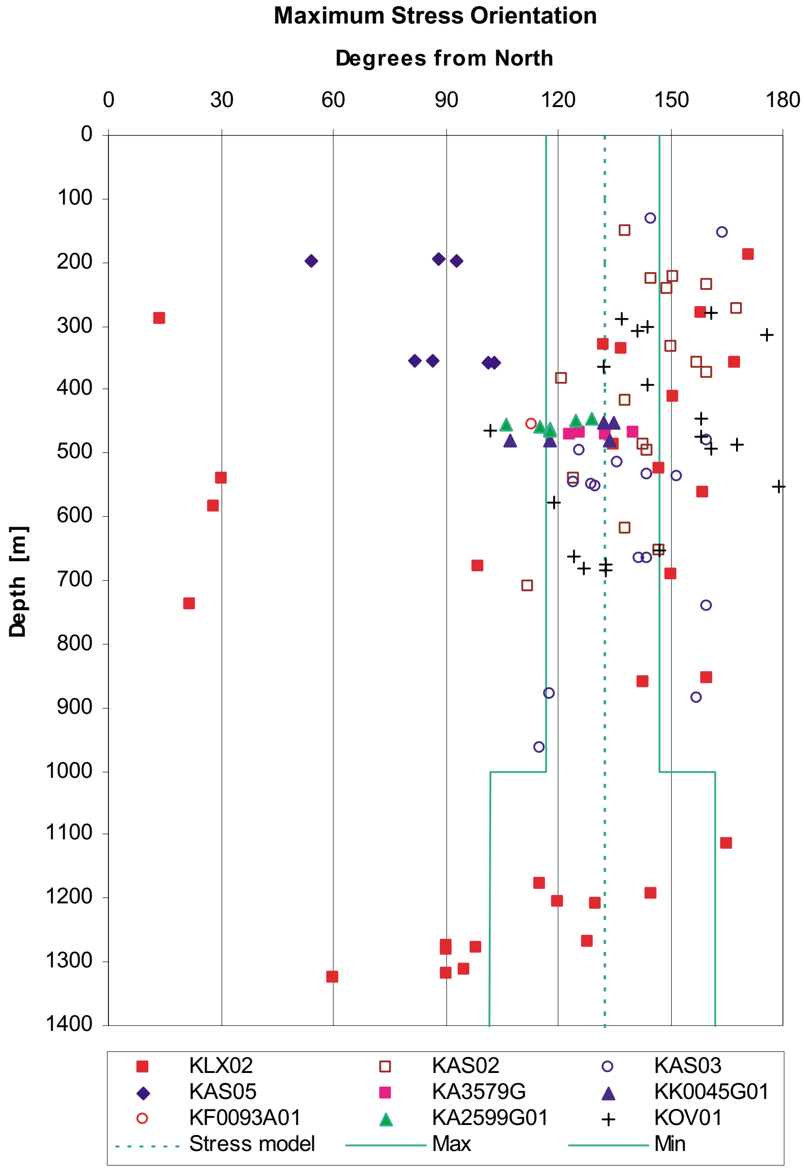


Figure 5-4. *Maximum stress orientation measured with overcoring and hydraulic fracturing methods from the Simpevarp regional model area and KOV01 in Oskarshamn. (Trend values larger than 180 degrees have been reduced by 180).*

In Tables 5-2 and 5-3, the stress estimations are presented for the Simpevarp regional model area. The change in the model at 500 depth should not be understood as an expected sudden change in stress at this depth but just as a way to describe the increased uncertainty. Also, inside the fairly intact rock mass between major fracture zones, the spatial variation of the stress is expected to be less than in the zones themselves. The rock volume involved in a single measurement is small, in the range 0.01–1 m^3 depending on the method applied. The mean stress values in Table 5-2 are meant to represent the mean stress level in a rock volume of 30x30x30 m.

Table 5-2. Model for *in situ* stress magnitudes in the Simpevarp regional model area.

Parameter	σ1	σ2	σ3
Mean stress magnitude, MPa	0.066·z+3	0.027·z	0.022·z+1
Uncertainty, 0–500 m	±25%	±25%	±25%
Uncertainty, 500–2,000 m	±40%	±25%	±40%
Spatial variation, rock mass	±15%	±15%	±15%
Spatial variation, fracture zones	±50%	±50%	±50%

Table 5-3. Predicted *in situ* stress orientations in the Simpevarp regional model area. The orientation of the second principal stress is determined form the orientation of the other two because principal stresses are in each point perpendicular to each other.

Parameter	σ1, trend	σ1, plunge	σ3, trend	σ3, plunge
Mean stress orientation	133°	0°	43°	0°
Uncertainty, 0–1,000 m	±15°	±10°	±15°	±15–45° *
Uncertainty, 1,000–2,000 m	±30°	±10°	±30°	±10°
Spatial variation, rock mass	±15°	±15°	±15°	±15°
Spatial variation, fracture zones	±25°	±30°	±25°	±30°

* At some level σ2 and σ3 may have similar magnitude and the dip can then become undefined.

5.1.4 Alternative stress model

As an alternative stress model for the Simpevarp regional model area, a model similar to the model presented by /Ask et al, 2001/ is shown in Figure 5-5. This model is based on measurement data from boreholes KAS02 and KAS03 at Äspö. It can be noted that the predicted stress levels are different in the two boreholes, which suggests that the two boreholes are exposed to different stress regimes /Ask et al, 2001/.

The model in Figure 5-5 predicts the stress to increase non-linearly with depth. If compared to the model presented in Section 5.1.3, the predicted minimum stress is higher for depths exceeding 600 m. For depths less than c. 500 m, the maximum stress is lower. Hence, the deviatoric stress (difference between highest and lowest principal stress) is predicted to be significantly lower at all depths with the model of /Ask et al, 2001/. The maximum stress level is similar for both models at depths below the inferred structure at 600 m depth.

The comparison between the model in Section 5.1.3 and the model presented by /Ask et al, 2001/ illustrates that the interpretation approach of measurement data, which is different for the two models, may result in different descriptive models (i.e. predictions).

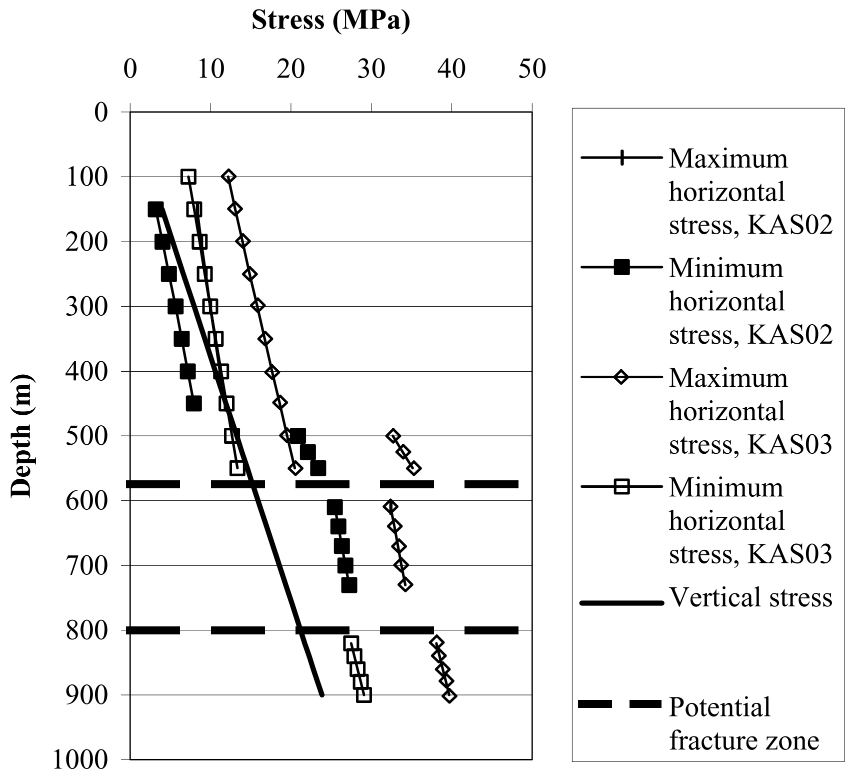


Figure 5-5. *Results from integrated stress analysis method (iterative inversion method) for boreholes KAS02 and KAS03 stress magnitudes. From /Ask et al, 2001/.*

5.2 Mechanical rock mass properties

5.2.1 Available data

Some laboratory tests on cores from the Simpevarp regional model area have been carried out and the results stored in SICADA. /Martin et al, 2001/ also present the results of laboratory tests on cores from the Äspö HRL. In the process of developing a strategy for rock mechanics descriptive modelling, a methodology test (the Test Case) was performed based on data from the Äspö HRL. The results from this study /Andersson et al, 2002a; Staub et al, 2002; Röshoff et al, 2002/, which are based on data from drill core mapping and laboratory tests, were used as a base for the estimation of properties. The experiences and analyses from the CLAB excavations were also considered /Fredriksson et al, 2001/.

5.2.2 Lithological and structural model implications

The lithological model (see Section 4.4) shows that the dominating rock types vary between diorite to granite (coarse and fine grained), with some mafic rocks ("greenstone"). From experience we know that these rock types all have a fairly high strength and high stiffness /e.g. Persson, 1998; Persson et al, 1998; Rhén et al, 1997b; Staub et al, 2002; Lama and Vutukuri, 1978/. The possible parameter ranges for deformation and strength for these rock types are to a large extent overlapping. This means that the mechanical property model, at this stage, will not be very sensitive to the lithological model. Instead, the mechanical properties on a larger scale will be dependent on the fractures in the rock, and the degree of fracturing will determine the expected mechanical properties of the rock mass between the zones.

On the other hand, the occurrence and location of *major fracture zones* (those included in the structural model, see Section 4.6.4) will directly determine the expected mechanical properties of the rock volume. Actually, the definition of fracture zones is connected to the fracture frequency and alteration. We also know from the Äspö HRL excavations and boreholes that much softer material, such as clay, exists in the major zone ZSM0006A0 (NE-1). The repeated reactivation of major fracture zones is a further indication that the strength of these zones cannot be high, and should certainly be much lower than the surrounding rock.

5.2.3 Mechanical property model and uncertainties

Rock strength tests on intact cores have been performed in the laboratory by SKB on drill cores from within the Simpevarp regional model area (Figure 5-6). A large spread in the obtained uniaxial compressive strength values can be observed. The lowest values are clearly lower than what is normally expected for this type of rock material, possibly due to some measurement errors. However, given the expected variation in rock type, even if some further scrutiny of data (not performed within this project) might narrow the span of reliable results, the expected variation in type of rock material would probably still cause the uniaxial strength for intact rock to vary over a fairly wide range.

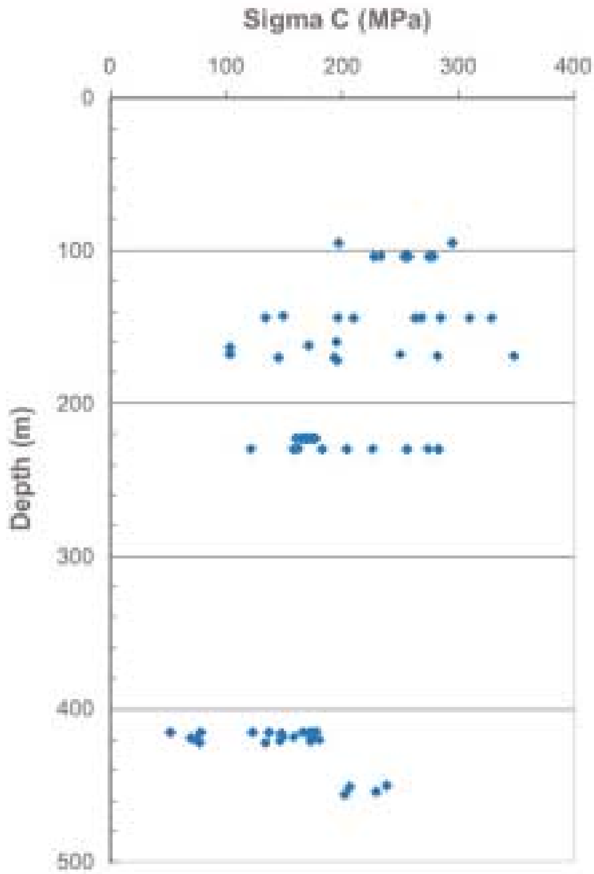


Figure 5-6. *Laboratory test results from uniaxial strength test on cores from Äspö. Not all these data were available in SICADA, therefore the figure was taken from /Martin et al, 2001/.*

Table 5-4 presents the parameters for the Simpevarp regional model area. The bedrock is divided into two categories; the "normally fractured" rock mass and the fracture zones. The estimation for a certain point will thus depend only on whether this point is expected to be located inside a fracture zone or in the rock mass between the zones.

The parameters used are (i) Young's modulus for intact rock, (ii) Poisson's ratio for intact rock, (iii) uniaxial strength for intact rock, (iv) tensile strength for intact rock, (v) Young's modulus for rock mass, (vi) Poisson's ratio for rock mass, (vii) uniaxial strength for rock mass at high confining stress, (viii) cohesion of rock mass (ix) internal friction angle of rock mass. The last five of these parameters, concerning "rock mass" are not regarded as standard parameters and the definitions should be considered carefully before use (the reader is referred to /Andersson et al, 2002a/ for a more detailed description and discussion). The scale of a 'rock mass unit' is taken as 30x30x30 m and the reference level for the confining stress is 10 MPa.

Table 5-4. Predicted rock mechanical properties in the Simpevarp regional model area. (Shaded areas correspond to parameters that will be estimated in later versions of the site descriptive models.)

Parameter for intact rock (drill core scale)	**All rock types**	**Rock type I**	**Rock type II**	**Rock type III**
Young´s Modulus	50–75 GPa			
Poisson's ratio	0.20–0.30			
Uniaxial strength	150–300 MPa			
Tensile strength	5–20 MPa			
Parameter for the rock mass * (30x30x30 m scale)**	**Rock Mass All depths**	**Rock Mass Certain depth interval**	**Fracture Zones All depths**	**Fracture Zones Certain depth interval**
Young´s Modulus*	30–65 GPa		10–40 GPa	
Poisson's ratio*	0.20–0.30		0.20–0.26	
Uniaxial strength*	100–160 MPa		55–85 MPa	
Friction angle**	35–50°		25–40°	
Cohesion**	10–30 MPa		5–20 MPa	

* Confining stress magnitude 10 MPa.

** Linear model between 10 and 20 MPa confining stress magnitude.

*** See /Andersson et al, 2002a/.

6 Hydrogeology

6.1 Introduction

Figure 6-1 illustrates SKB's systems approach to hydrogeological modelling of groundwater flow through fractured crystalline rocks. The division into hydraulic domains (HSD, HRD and HCD) is described in the general program for site investigations /SKB, 2001a/. This chapter describes the present knowledge of the hydrogeological setting of the Simpevarp regional model area. The hydrogeological setting is described by means of parameters, which detail:

- The *geometric and hydraulic properties* of the Quaternary deposits (HSD) and the crystalline bedrock (HRD and HCD).
- The *hydrological processes* that govern the hydraulic interplay between surface water and groundwater including groundwater flow at repository depth.

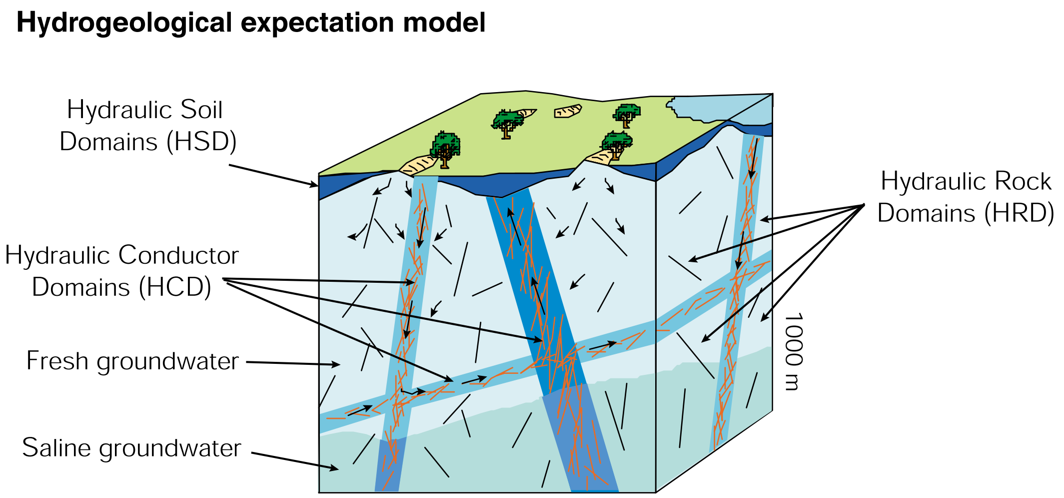


Figure 6-1. *The Quaternary deposits and the crystalline bedrock are divided into separate hydraulic domains denoted HSD, HRD and HCD. Within each domain, the hydraulic properties are represented by mean values or by spatially distributed statistical distributions (modified after /SKB, 2001a/).*

6.2 Sources of information

6.2.1 Data compilations and interpretations

The present knowledge of the hydrogeological setting of the Simpevarp regional model area is based on four different types and sources of information. The four sources are: (*i*) mapping of Quaternary deposits and bedrock geology (rock type, lineaments and deformation zones) (*ii*) meteorological and hydrological investigations, (*iii*) hydraulic borehole investigations and monitoring, and (*iv*) hydrogeological interpretation, analysis and modelling.

The existing investigations and documentation of the *Quaternary deposits and bedrock geology* are reviewed and scrutinised in Chapter 4 of the present report. From a hydrogeological perspective, the geological data and interpretations presented in Chapter 4 constitute the basis for the *geometric modelling* of the different hydraulic domains in the Simpevarp regional model area. Thus, Chapter 4 and its underlying references provide input to:

- The geometry of deterministic fracture zones and lineaments (HCD) and the rock mass in between (HRD).
- The distribution of Quaternary deposits (HSD), including genesis, composition, stratification, thickness and depth.

The existing investigations and documentation of the *meteorology* and *hydrology* presented in Chapter 3 constitute, from a hydrogeological perspective, the basis for the *hydrological process modelling*. In concrete terms, the references provide input to:

- The present-day interpretation of drainage areas, as well as mapping of springs, wetlands and streams, surveying of land use such as ditching and damming projects, water supply resources, nature conservation areas, etc.
- Mean estimates of the present-day specific runoff, lake water levels and flows in streams.
- An assessment of the relative impact of local topography, shoreline displacement and variable-density groundwater flow versus the role of inferred fracture zones for the definition of initial and boundary conditions and the numerical simulation of present-day and future recharge and discharge areas of groundwater flow.

Existing investigations and documentation of *hydraulic borehole investigations* and *monitoring* are of interest for the definition *of hydraulic properties* of the different hydraulic domains. There are basically three main sources of information:

- Data from hydraulic tests and hydrogeological monitoring in boreholes drilled in the coastal part of the model area, i.e. in and around the Äspö Hard Rock Laboratory.
- Data from hydraulic tests in boreholes drilled in the nearby Kråkemåla study site in the northern part of the model area.
- Data from the Archive of Wells at the Geological Survey of Sweden (SGU). This information, however, is generally restricted to the uppermost part of the bedrock (less than c. 100 metres). Concerning hydraulic properties of the Quaternary deposits, current knowledge is more or less confined to general hydrogeological information found in the literature.

During the feasibility study, it was suggested that there might exist differences between different types of granites from a hydrogeological point of view /Follin et al, 1998a/, an observation which supports previous findings of the Äspö HRL project /e.g. Rhén et al, 1997b/. Subsequently, it was recognised that the existing differences often coincide with particular structural orientations and/or lithological units /Follin et al, 1998b; Bergman et al, 1999; Rhén and Forsmark, 2000; Follin et al, 2000/. Among the more notable results are the following observations:

(i) highly permeable features in the vicinity of the Äspö HRL often have a NNW strike direction,

(ii) increased inflow to the Äspö tunnel often coincides with dykes of fine-grained granite,

(iii) a rose diagram analysis of the transmissivity determined by a large number of borehole tests in the Äspö tunnel indicate that the rock mass between major fracture zones is hydraulically anisotropic,

(iv) hydraulic borehole tests indicate that the c. 1,450 Ma old granite in the Kråkemåla area (Götemar granite) is more transmissive than the predominating c. 1,800 Ma old rocks (Småland "granite"),

(v) there is no indication of a depth dependence in the hydraulic conductivity below –100 m, and

(vi) the contrast in transmissivity between borehole test sections that contain fracture zones and those that do not is c. two orders of magnitude on the average.

In conclusion, the detailed knowledge about the hydrogeological properties of the hydraulic domains in the coastal part of the Simpevarp regional model area makes it possible to extrapolate to the west, provided that similar structural and lithological conditions can be assumed without too much uncertainty. However, experience shows that every extrapolation must be scrutinised and used with great care.

The region where the Simpevarp regional model area is located has been subjected to extensive *hydrogeological interpretations, analyses and modelling* during the past ten years. The main projects, predominantly focussed on the Äspö HRL, may be summarised as follows:

- A large body of work has been carried out in support of SKB's investigations and construction of the Äspö HRL. Condensed presentations of the descriptive and analytical/modelling work carried out are given by /Gustafson et al, 1989; Wikberg et al, 1991; Rhén et al, 1997b; Svensson, 1997a,b/.
- Another large body of work has been carried out on behalf of the safety demonstration project SR 97 /Walker et al, 1997; Dershowitz et al, 1999; Gylling et al, 1999; Widén and Walker, 1999; Walker and Gylling, 1998; SKB, 1999/.
- The detailed flow and tracer tests conducted in the Äspö HRL have been used in two international groundwater modelling projects, Äspö Task Force /e.g. Gustafson et al, 1997/ and TRUE /e.g. Winberg et al, 2000; Andersson et al, 2002c,d/.
- Finally, the Swedish Nuclear Power Inspectorate, SKI, has also modelled the hydrogeology of the Äspö HRL in their safety assessment project SITE–94 /SKI, 1996/.

Figure 6-2 shows the extent of the Simevarp regional model area together with the locations of the SR 97 regional and local model areas.

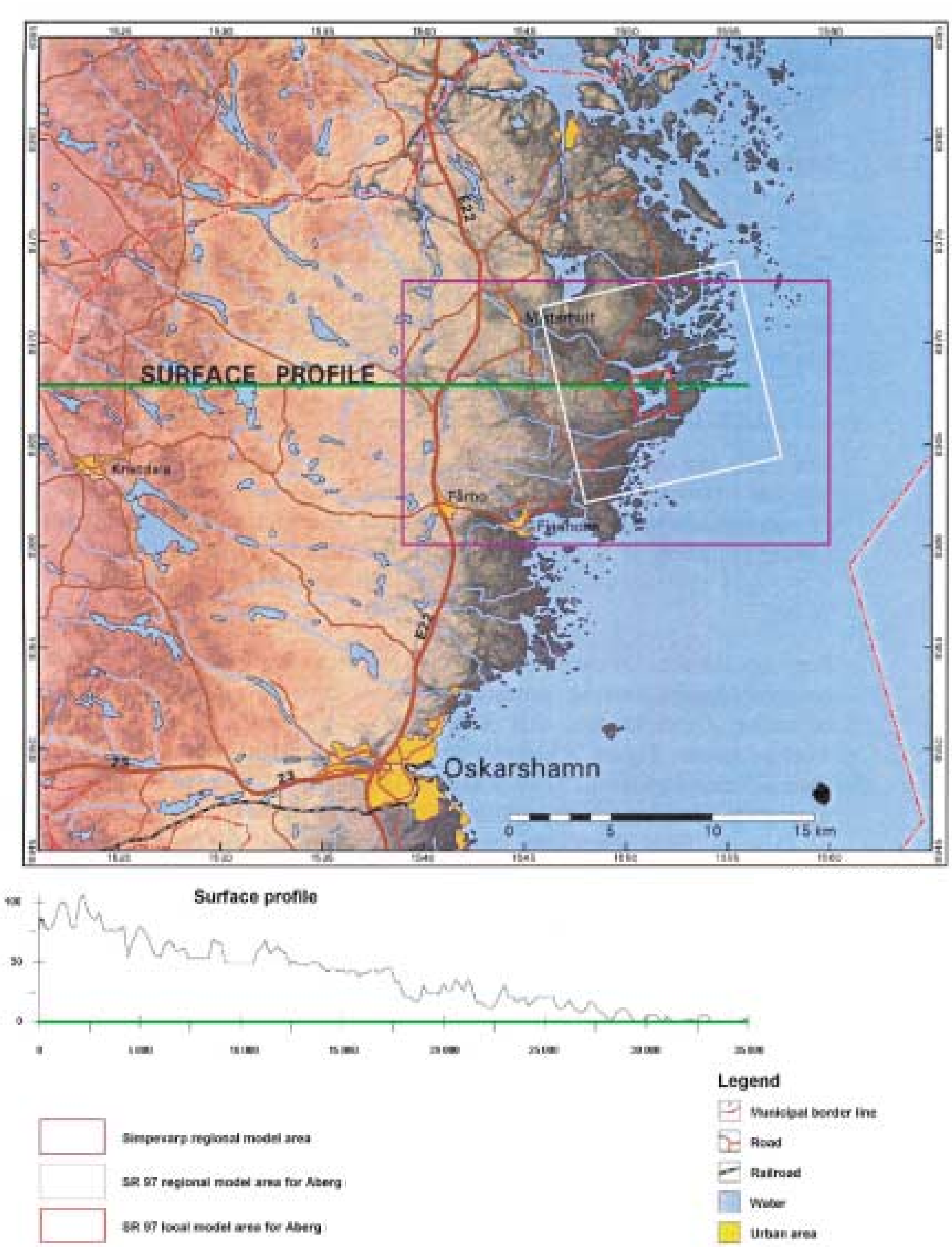


Figure 6-2. *Map showing the extent of the Simpevarp regional model area and the location of the regional model area for SR 97. The topography along the green, E-W trending, line is shown below the map. The topographic relief along the surface profile corresponds to a gradient of c. 3‰.*

6.2.2 Data in SKB's databases

Figure 6-3 shows the boundary of the Simpevarp regional model area together with the positions of the boreholes and wells currently recorded in SKB's databases (SICADA and GIS).

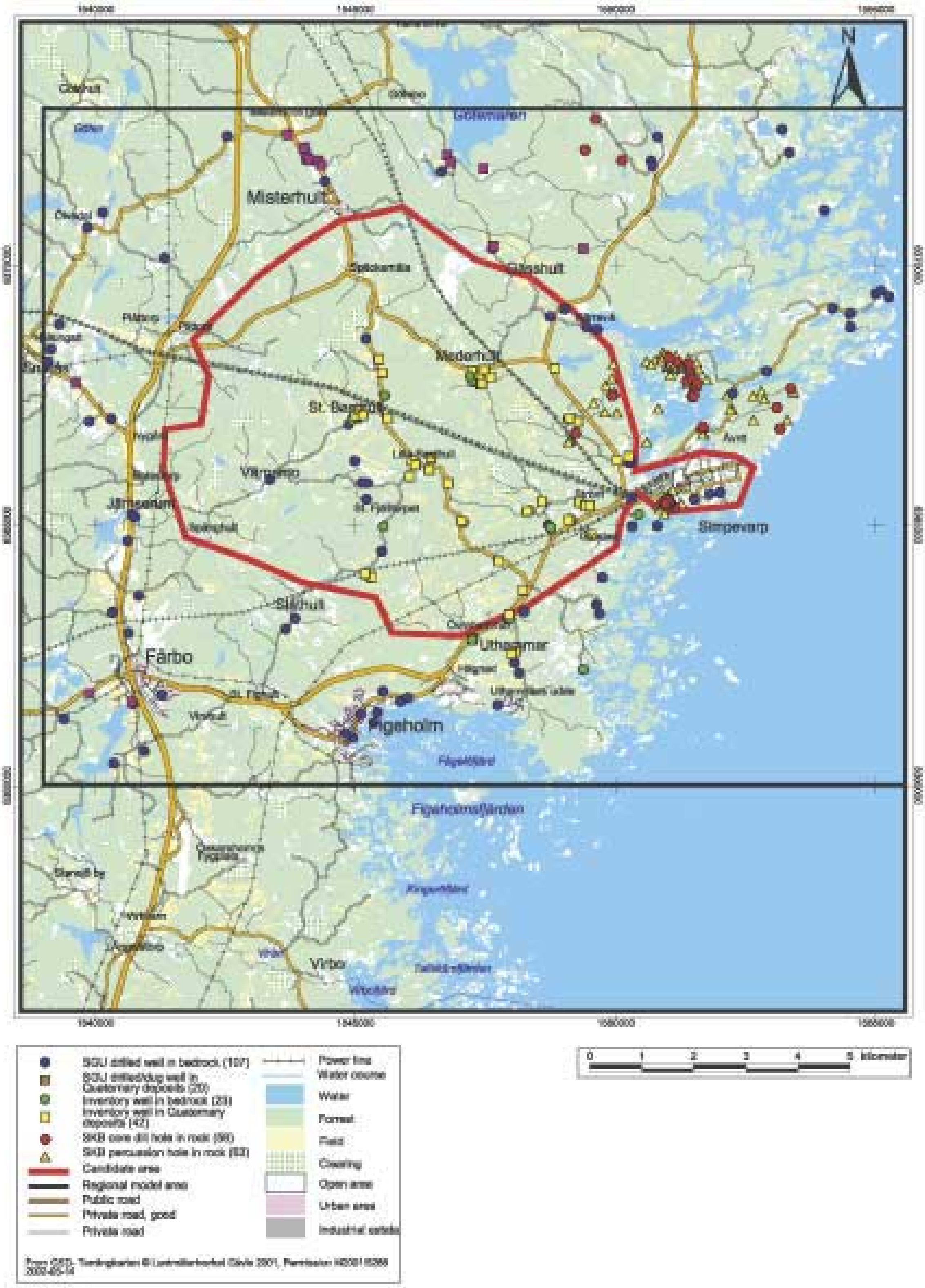


__Figure 6-3.__ Map of the Simpevarp regional model area, indicating the location of current private wells and SKB boreholes. For a detailed map and description of the SKB boreholes, the reader is referred to /Rhén et al, 1997a,b/.

Äspö HRL

The body of the current knowledge about the hydrogeology of the bedrock in the Simpevarp regional model area comes from the investigations prior to, and during, the construction of the Äspö Hard Rock Laboratory. The data are compiled and recorded in SKB's database SICADA. SICADA contains c. 10,000 hydrogeological activities at sites in the Simpevarp regional model area since 1978. The geographical distribution of the activities is shown in Table 6-1.

Archive of Wells at SGU

A total of c. 600 private wells in the municipality of Oskarshamn are recorded in the Archive of Wells at the Geological Survey of Sweden. 127 wells, of which 20 are dug wells, are located within the Simpevarp regional model area. Table 6-2 shows an overview of the contents of SKB's version of the Archive of Wells.

Well inventory

A well inventory was initiated in the eastern part of the Simpevarp regional model area during 2001. So far, the inventory has revealed 65 private wells of which 43 are dug wells (Figure 6-3). When completed, the inventory it will comprise hydrogeological and hydrogeochemical information such as well coordinates, total depth and water chemistry.

Table 6-1. Overview of the hydrogeological activities at sites in the Simpevarp regional model area recorded in SKB's database SICADA (as of 2001-01-11).

Area	Number of activities	Period
Kråkemåla	5	1978–1978
Laxemar	408	1987–Present
Äspö	9,194	1987–Present
CLAB	80	1976–Present
Ävrö	233	1987–1987

Table 6-2. Overview of the contents of SKB's GIS version of the Archive of Wells.

Parameter	Unit/Info
Yield (air-lifting/pumping)	L/h
Well diameter (drill bit)	mm
Total depth	m
Soil depth (if present)	m
Casing depth (steel/plastic)	m
Usage	Farming, Water Supply, Industry, Energy, etc

6.3 The Simpevarp regional structural model v0

The interpreted regional fracture zones of the Simpevarp version 0 structural model, both *probable and highly probable to certain*, are displayed in Figure 4-6. In addition, the length and character of the interpreted lineaments shown in this figure indicate that these are *possible candidates for local major or regional fracture zones*. From a modelling point of view, the Simpevarp version 0 structural model also constitutes the starting point for the assessment of the hydraulic rock domains (HRD) and the hydraulic conductor domains (HCD).

Figure 6-4 shows a 3D visualisation of the topography within the Simpevarp regional model area together with the *fracture zones* of the version 0 model presented in Figure 4-6. Figure 6-5 shows both the fracture zones and the lineaments of the version 0 model presented in Figure 4-6. The red surfaces indicate regional fracture zones (*probable and highly probable to certain*) and the blue surfaces indicate lineaments (*possible local major or regional fracture zones*). It should be noted that the planes are exaggerated above ground surface for clarity and that the dip angles of the inclined zones are not shown.

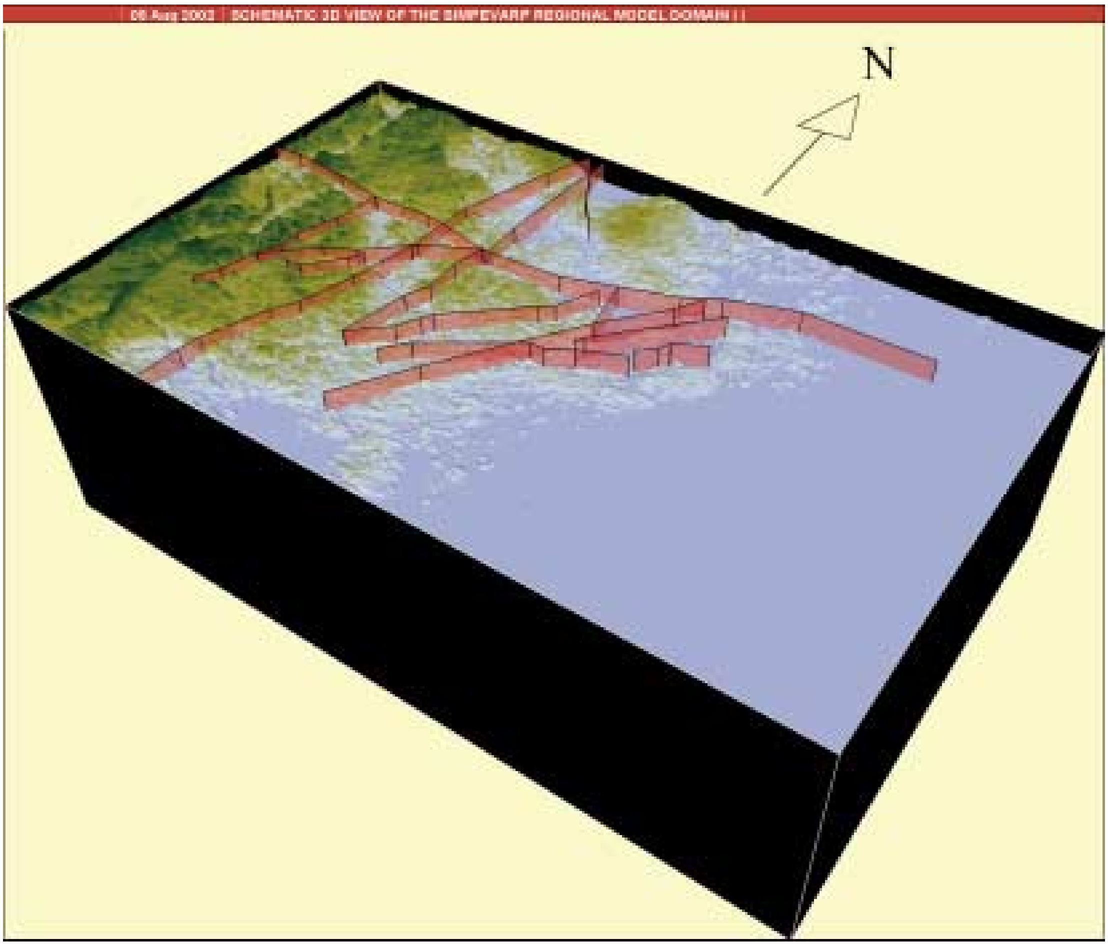


Figure 6-4. *Schematic 3D visualisation of the topography of the Simpevarp regional model area together with fracture zones of the Simpevarp version 0 structural model presented in Figure 4-6. The fracture zones are shown as red planes. It should be noted that the planes are exaggerated above ground surface for clarity and that the dip angels of inclined zones are not shown. The topography is taken from Lantmäteriverket's DEM, 50 m resolution. The border of the Simpevarp regional model domain is indicated with a black box.*

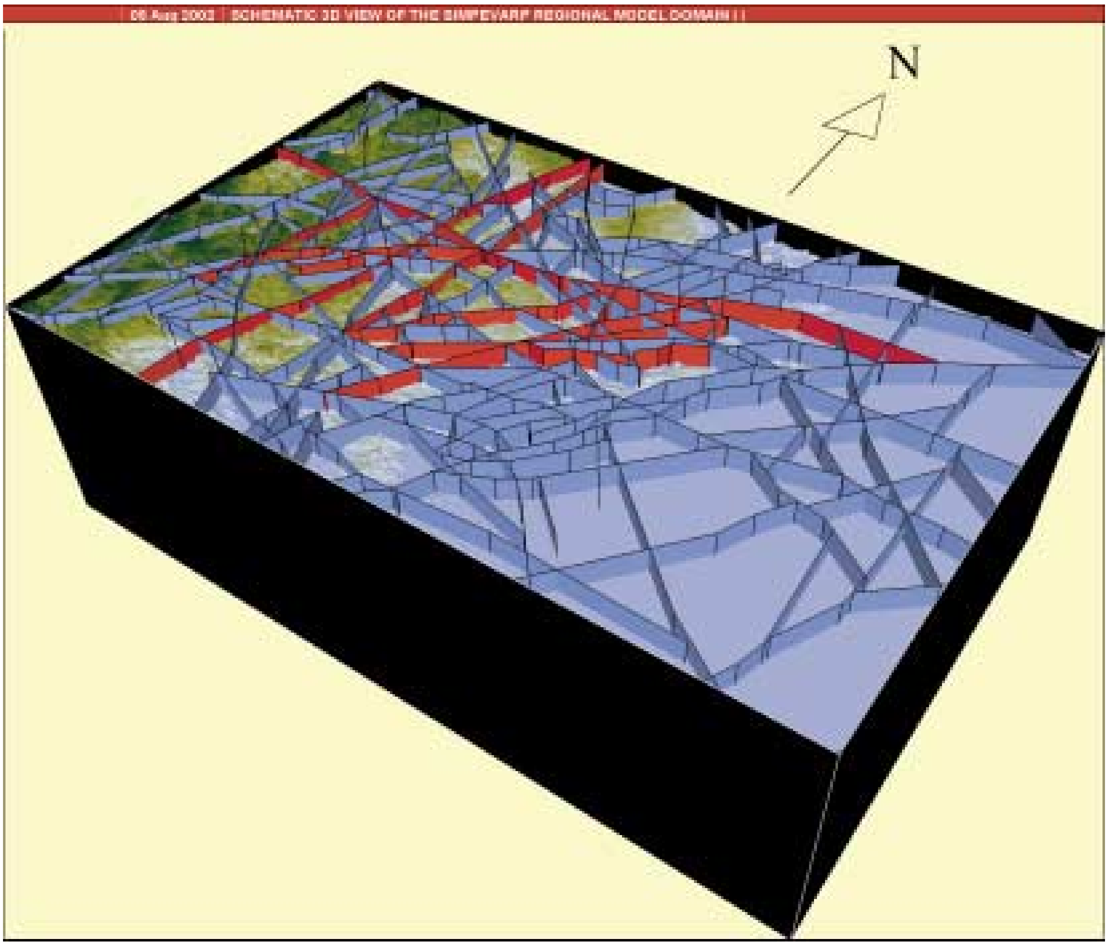


Figure 6-5. *Schematic 3D visualisation of the both the fracture zones and the lineaments of the Simpevarp version 0 structural model presented in Figure 4-6. The red surfaces indicate regional fracture zones (probable and highly probable to certain) and the blue surfaces indicate lineaments (possible local major or regional fracture zones). It should be noted that the planes are exaggerated above ground surface for clarity and that the dip angles of inclined zones are not shown.*

6.4 Geometric uncertainties and scale effects

The Simpevarp version 0 structural model is based on available geological and geophysical data on a fairly large scale. From a hydraulic modelling point of view, it is important to assess whether the mapped discrete fracture network (DFN) statistics is biased in any sense. For example, /La Pointe et al, 1999/ has advocated that the scale of the mapping window censors the identification of possible fault traces (lineaments). If an identified fault trace is large with regards to the size of the utilised mapping window, the estimated length of the perceived trace line will be censored. One way to treat this problem is to increase the size of the mapping window, although the problem of censoring can never be completely avoided in this manner. Since the resolution of the chosen mapping window is coupled to the map scale, there is a risk that short fault traces will be missed (or omitted for practical reasons) if the chosen scale of the mapping window is too small. In conclusion, both the size of the mapping window and the map scale may distort the length-frequency statistics of mapped fault traces.

/La Pointe et al, 1999/ have analysed the structural geology of Swedish crystalline rock from a statistical point of view at three different places, one of which was the Äspö island. According to their analyses of the trace maps reported by /Tirén and Beckholmen, 1990/ at the scale 1:1,000,000 and /Tirén et al, 1987/ at the scales 1:250,000, 1:150,000 and 1:7,000, the length-frequency statistics of possible fault traces in the province of Småland and, in particular, around Äspö island, scales in a fractal manner over a large range of scales. Moreover, the analyses suggest that a Poisson process is appropriate for generating fracture locations for the stochastic component of a discrete fracture network model of the Simpevarp regional model area. Based on the length-frequency analyses of the province of Småland and the Äspö island, /La Pointe et al, 1999/ also concluded that a power law exponent of –2.6 should be diagnostic for a 3D structural-hydraulic model of this region. Given this value and the size of the Simpevarp regional model area, it is feasible to compute preliminary estimates of the number of fracture zones of different sizes in 3D.

6.5 Hydraulic properties of bedrock

The geometric and hydraulic representation of a real fracture network in a numerical flow model depends on the conceptual approach. In the discrete fracture network (DFN) approach, each fracture maintains its geometric and hydraulic characteristics as inferred from the field investigations. In the continuum approach, the fractures' geometric and hydraulic properties may be approximately accounted for by means of an equivalent hydraulic conductivity tensor. For those parts of the bedrock that are not intersected by regional or local major fracture zones, the effective hydraulic conductivity tensor represents groundwater flow through the fracture network of the rock mass between the fracture zones. Due to the huge size of a regional model area, SKB's systems approach to hydrogeological modelling on a regional scale may entail a mixture of the two modelling approaches /e.g. Follin and Svensson, 2002/.

6.5.1 Fracture zones

The documentation of the extensive hydraulic testing within the Äspö HRL project /Rhén et al, 1997b/ constitutes the key document for assigning hydraulic properties to the Simpevarp version 0 structural model. A comparison between the Simpevarp version 0 model and the Äspö HRL/SR 97 regional structural model shows that there are several fracture zones that are common to the two models (Table 6-3).

Table 6-3 shows that the fracture zones ZSM0005A0 and ZSM0006A0 are also present in the Äspö HRL local structural model, and these zones have been subjected to hydraulic testing. However, none of the other zones or lineaments of the Simpevarp version 0 structural model have previously been subjected to hydraulic testing.

Table 6-3. Comparison between the Simpevarp version 0 regional structural model and the Äspö HRL/SR 97 regional structural model.

Simpevarp version 0 structural model	Äspö HRL / SR 97 regional structural model	Äspö HRL local structural model*
ZSM0001A0/B0	SFZ02	–
ZSM0002A	SFZ03	–
ZSM0003A0	SFZ04	–
ZSM0004A0/B0	SFZ05	–
ZSM0005A0	SFZ07	EW–1
ZSM0006A0	SFZ12	NE–1
ZSM0007A	SFZ14	–

* Nomeclature in e.g. /Stanfors and Erlström, 1995/ and /Rhén et al, 1997a,b/.

According to /Rhén et al, 1997b/, the definition of hydraulic width and transmissivity of a fracture zone often becomes more and more complex as the resolution is refined. For example, the width of zone ZSM0005A becomes quite wide on the Äspö island, c. 60 m, where the core of the zone has been found to be less transmissive than the edges. It is impossible without more information to be conclusive at this stage of the site investigations whether this observation of hydraulic heterogeneity is (*i*) valid on a regional scale as well, and (*ii*) applicable to the other fractures zones within the model area.

Based on the data compilation in /Rhén et al, 1997b/, it is suggested that the regional zone ZSM0005A0 is assigned a hydraulic width of 30–60 m and a median transmissivity of c. 2×10^{-5} m^2/s. The hydraulic heterogeneity of zone ZSM0005A0 is estimated to c. 1.4, defined as the standard deviation of the common logarithm of the transmissivity ($\log_{10}(m^2/s)$).

In contrast, zone ZSM0006A0 is found to be one of the more transmissive fracture zones on the Äspö island. Its hydraulic width is c. 30 m and its median transmissivity is c. 3×10^{-4} m^2/s. The hydraulic heterogeneity of zone ZSM0006A0 is according to /Rhén et al, 1997b/ c. 0.5, defined as the standard deviation of the common logarithm of the transmissivity.

For the remaining regional fracture zones of the Simpevarp version 0 structural model, it is suggested that both *probable and highly probable to certain* regional fracture zones are, as a first approximation, assigned similar hydraulic properties as zone ZSM0006A0

Concerning the lineaments, it is suggested that they are treated as fracture zones and the hydraulic width is set to c. 20 m and the median transmissivity to c. 3×10^{-6} m^2/s, in accordance with the data compilation of the local major zones identified on the Äspö island /Rhén et al, 1997b/. The assigned heterogeneity of the transmissivity is suggested to be c. 1.0, defined as the standard deviation of the common logarithm of the transmissivity.

6.5.2 Rock mass between fracture zones

The derivation of the equivalent hydraulic conductivity of the rock mass between the fracture zones from field data, and its subsequent use in regional flow modelling with the *continuum approach*, are two issues that need to be treated with great care. The reason for this concern is twofold:

- The inferred hydraulic conductivity from field tests are, among other things, dependent on the heterogeneity of the fracturing, the length of the test section and the duration of the hydraulic testing.
- The equivalent hydraulic conductivity of a heterogeneous medium is dependent on the direction of flow and the resolution (discretisation) of the mesh of the numerical model with regards to the nature of the heterogeneity.

The second issue means that the chosen resolution of the mesh can affect the result of regional groundwater flow simulations. That is, the larger the cell size, the greater the mean conductivity must be in order to account for the higher probability that the cell is intersected by unknown but existing fracture zones. /Rhén et al, 1997b/ have suggested that linear scaling laws should be used for the definition of a heterogeneous hydraulic conductivity field, whenever the continuum approach is used. It should be noted that the data behind the suggested scaling laws come from the Äspö HRL project. It is not known to what extent the conditions at the Äspö island with surroundings are representative also for the conditions within the Simpevarp regional model area in general. The scaling laws for the geometric mean (K_g) and the standard deviation ($s_{\log_{10} K}$) of a heterogeneous hydraulic conductivity field are given as follows /Rhén et al, 1997b/:

$$\log_{10}\left(K_g^{L_2}\right) = \log_{10}\left(K_g^{L_1}\right) + 0.817\ \left(\log_{10}[L_2] - \log_{10}[L_1]\right)$$

$$s_{\log_{10} K}^{L_2} = s_{\log_{10} K}^{L_1} \left(\frac{2.089 - 0.758\ \log_{10}[L_2]}{2.089 - 0.758\ \log_{10}[L_1]}\right)$$

where L_1 is the resolution of the supporting data (measurement scale) and L_2 is the desired resolution of the mesh of the numerical model.

In the *DFN approach* /e.g. Dershowitz et al, 1999/, the concept of a continuous hydraulic conductivity field is replaced by a computationally comprehensive and very detailed description of a large number of discrete fractures. Apart from the major fracture zones, which are generally treated deterministically, the DFN approach is also based on stochastic concepts. Detailed information about the statistical properties of the fracturing of the rock mass between major fracture zones within the Simpevarp regional model is quite sparse. However, a large amount of data exist from the investigations within the Äspö HRL project and the TRUE Block Scale project. The most recent example of a DFN analysis that treats data belonging to the Simpevarp regional model area outside Äspö is the methodology study by /Andersson et al, 2002b/. A brief summary of the analysis is given in Table 6-4. The statistics of the transmissivity field in Table 6-4 are inferred from a combined fracture frequency–transmissivity analysis of sequential packer tests in cored boreholes, using a constant packer spacing. Data from such analyses are reported also from the TRUE Block Scale.

Table 6-4. Example of geometric and hydraulic properties of the rock mass between the fractures zones in the Laxemar area /Andersson et al, 2002b/. *D* is the power law exponent of the fracture size and P_{32} is the fracture area per cubic metre, total and conductive.

Set	Orientation statistics of the mean normal vector (pole)				Fracture size	Spatial distribution	Fracture intensity	
No.	Type	Trend	Plunge	Dispersion	D	Type	P_{32}	P_{32c}
1	Fisher	262.0	3.8	8.52	–2.6	Baecher	0.78	0.12
2	Fisher	195.9	13.7	9.26	–2.6	Baecher	0.66	0.15
3	Fisher	135.9	7.9	9.36	–2.6	Baecher	0.76	0.12
4	Fisher	35.4	71.4	7.02	–2.6	Baecher	0.24	0.08
All	$T \in logN(4.2\times10^{-8}, 2\times10^{-7})$ m²/s [or $log_{10}T \in N(-8.06, 0.773)$ log_{10}(m²/s)]						2.44	0.48

In the *mixed DFN-continuum* approach /see, e.g. Svensson, 1997b/, the resolution of the mesh is not as crucial as for the aforementioned continuum approach, since the hydraulic conductivity field on the scale of the mesh is not statistically generated but hydraulically back calculated from the fracture network connectivity. That is, the mixed DFN-continuum approach is above all DFN based. The most recent example of a model study where the mixed DFN-continuum approach has been used is the methodology study by /Andersson et al, 2002b/.

6.6 Hydraulic properties of Quaternary deposits

6.6.1 Onshore deposits

Figure 4-2 shows a 2D cartographic model for the Quaternary deposits within the Simpevarp regional model area. From the data compilations provided in Chapter 4, it can be concluded that the total thickness of the onshore Quaternary deposits generally varies between 0–10 meters. Current knowledge of the hydraulic conductivity and the porosity of these deposits is more or less constrained to data found in the literature. Table 6-5 summarises the reported ranges in thickness together with suggested median values of the saturated hydraulic conductivity and the total porosity.

Table 6-5. Summary of the estimated ranges in thickness of the different types of Quaternary deposit (cf. Chapter 4), together with estimates of the median value of the saturated hydraulic conductivity and the median value of the total porosity /Todd, 1959; Carlsson and Gustafson, 1984; Knutsson and Morfeldt, 1993/.

Quaternary deposit	Thickness (m)	K_{50} (m/s)	n_{50} (–)
Glacial till, sandy silty	< 2	10^{-7}	0.30
Thin layers of flushed till	< 0.3	10^{-6}	0.20
Glacial till, clayey	0.5–2.5	10^{-9}	0.45
Glaciofluvial deposits, sand and gravel	< 10	10^{-4}	0.35
Glacial deposits, varved clay	< 2	10^{-10}	0.55
Post-glacial sediments, sand	< 2	10^{-5}	0.35
Post-glacial sediments, clay	< 2	10^{-9}	0.55
Post-glacial sediments, peat (bog, fen)	< 5	10^{-6}	0.60

6.6.2 Offshore deposits

No reports have been found on the seafloor sediments in the offshore part of the Simpevarp regional model area. However, investigations at other places along the coast of the Baltic Sea reveal that a thin layer of clay often rests on top of a thicker layer of glacial till /cf. Carlsson et al, 1986/. In areas where the currents are flushing the sea floor, the deposition of fine-grained sediments is less pronounced.

For the purpose of defining parameters for the Simpevarp version 0 regional model, the hydraulic properties of the offshore deposits in the harbour area of the final repository for radioactive operational waste (SFR) at Forsmark may serve as provisional parameter values. According to /Carlsson et al, 1986/, a hydraulic conductivity of 10^{-10}–10^{-9} m/s is reasonable for the clay and 10^{-8}–10^{-7} m/s for the till. The hydraulic conductivity of the glacial till at greater water depths has been estimated to be in the range 10^{-5}–10^{-8} m/s /Sigurdsson, 1987/.

6.7 Hydrological conditions and processes

The topography of the Simpevarp regional model area is indicated in Figure 6-2. The general trend of the topography in the region is towards the Baltic Sea, with a slope of c. 3‰.

The shore level displacement the area is moderate, presently c. 1.5 mm/year. At 11,900 BC, the shore level was c. 90 metres higher than the current shore level /Påsse, 1996; 1997/. Subsequently, the municipality of Oskarshamn has been covered by both freshwater stages (Baltic Ice Lake and Ancylus Lake) and seawater stages (Yoldia Sea and Litorina Sea) during the evolution of the Baltic Sea.

The Litorina Sea is the most important aquatic stage for the present-day groundwater composition within the Simpevarp regional model area. Between 5,200 BC – 3,200 BC the salinity in the Litorina Sea was 12–15‰ /Westman et al, 1999/. Since then the salinity has decreased to the present-day salt concentration of the Baltic Sea, c. 7‰.

Figures 6-6 and 6-7 shows how the shoreline displacement process has altered the looks of the coastline of the Simpevarp regional model area. Beginning around 10,400 BP, the Simpevarp regional model area has been subjected to freshwater flushing. The present-day specific runoff is c. 200 mm/year or c. 6 L/s, km^2 /Brandt et al, 1994/ (cf. Section 3.2.3).

Since the rate of the shore level displacement process is still declining and the water depths in the Baltic Sea close to the shoreline are quite deep (cf. Figure 3-4), the assessment above is considered sufficient for the definition of the initial and boundary conditions required for the numerical simulation of present-day and as well as future discharge areas of variable-density groundwater flow from repository depth (400–700 metres).

In addition, it should be noted that the upstream side of the model area is intersected by several local major to regional fracture zones, some of which are likely to reach extensive depths. The predominating strike direction for some of these zones is more or less orthogonal to the predominating runoff direction, which suggests that regional groundwater flow will not be a major characteristic of the flow system to be modelled.

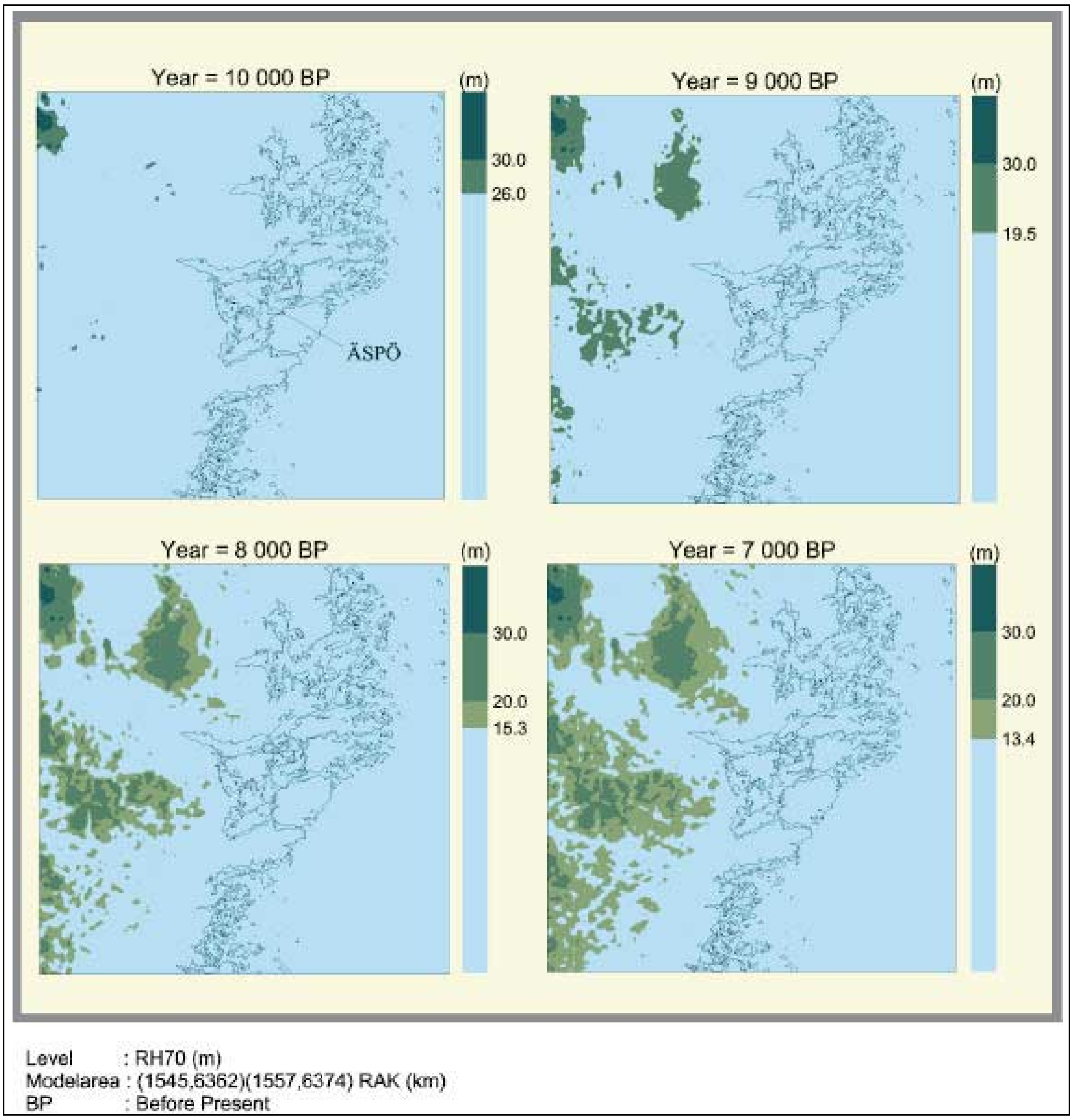


Figure 6-6. *Development of the shore level displacement in the Simpevarp regional model area, 10,000–7,000 BP. Reproduced from /Rhén et al, 1997b/.*

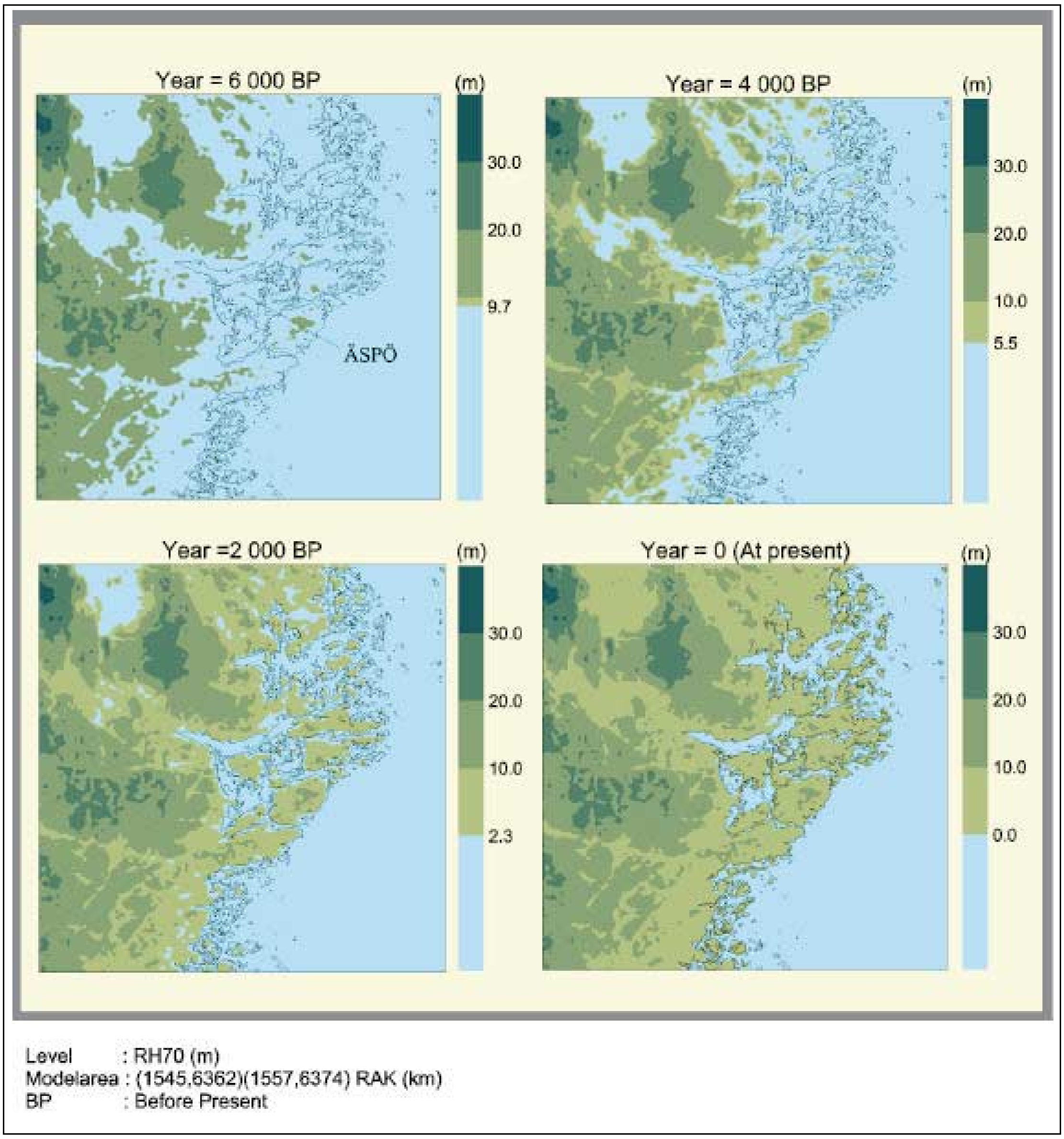


Figure 6-7. *Development of the shore level displacement in the Simpevarp regional model area, 6,000–present. Reproduced from /Rhén et al, 1997b/.*

7 Hydrogeochemistry

7.1 Introduction

A site's hydrogeochemical state is described by means of various parameters. The parameters detail the *chemical properties* of the groundwater in the Quaternary deposits and in the crystalline bedrock, and the *hydrogeochemical processes* that govern the chemical interplay between surface water and groundwater, including groundwater flow at repository depth. As stated in /SKB, 2001a/, hydrogeochemical evaluation should include the following tasks:

- Characterisation of the undisturbed groundwater chemistry, including the origin, depth/lateral distribution and the turnover time.
- Emphasised characterisation of those chemistry-related features of the groundwater which are of importance for the safety evaluation, such as pH, Eh, chloride, sulphide, colloids and microbes.
- Identification of possible dissolved oxygen at repository depth.

Currently, SKB is developing standard procedures for the hydrogeochemical modelling to be used to attain these goals. This chapter describes the present knowledge and uncertainties of the hydrogeochemical setting of the Simpevarp regional model area, as documented in the literature and SKB's report series.

7.2 Sources of information

The present knowledge of the hydrogeochemical setting of the Simpevarp regional model area is based on three different types/sources of information. The three sources are: (*i*) investigations of surface water and near-surface groundwater, e.g. sampling of water in lakes, sea, watercourses, springs, wells, percussion-drilled boreholes and observation holes, (*ii*) investigations and monitoring in deep boreholes, e.g. water and fracture-fill mineral investigations in core-drilled boreholes, and (*iii*) hydrogeochemical interpretation, analysis and modelling.

7.2.1 Surface water investigations

The Simpevarp regional model area has a low percentage of lakes and wetlands. The sources of information available have been presented earlier, in Chapter 3. The parameters describing the chemistry of lakes in the Simpevarp regional model area are pH, alkalinity, conductivity, colour, Ca + Mg, total phosphorous, total nitrogen. No data or published reports have been found on the chemistry of the precipitation within the model area, except for sulphate. According to /Naturvårdsverket, 1997/, the content of sulphate in surface water and groundwater corresponds to the current atmospheric deposistion, c. 14 mg /L.

7.2.2 Near-surface groundwater investigations

Current knowledge of the hydrogeochemistry of the near-surface groundwater in the Simpevarp regional model area comes from the evaluation of water samples from shallow groundwater wells.

Archive of Wells at SGU

Out of a total of the c. 600 wells in the municipality of Oskarshamn that are recorded in the Archive of Wells at the Geological Survey of Sweden, 127 wells are located within the Simpevarp regional model area and 20 of these are dug wells. SKB's version of the Archive of Wells contains information about the following chemical parameters: electrical conductivity, pH, Cl, HCO_3, SO_4, NH_4, NO_2, NO_3, F, PO_4, Fe, Mn and aggressive CO_2.

An overview of the spatial variations hydrogeochemical composition of the near-surface groundwater is given in /Aastrup et al, 1995/. The results of this overview lend support to the idea of a long period of flushing since the continental ice retreated. Only the most coastal wells indicate a slightly more pronounced marine water composition. Moreover, many wells have a water composition that is typical for thin soil layers with little or no calcareous content.

Well inventory

A well inventory was initiated in the eastern part of the Simpevarp regional model area during 2001. The inventory has so far resulted in 65 private wells out which 43 are dug wells (see Figure 6-3). The inventory is still going on, and once it is completed, at the end of 2003, it will comprise hydrogeological and hydrogeochemical information, such as well coordinates, total depth and water chemistry. The water samples will be analysed according to Swedish drinking water standard, which by and large coincides with SKB's chemical Class 3 /SKB, 2001a/.

/Laaksoharju, 1998/ made a reconnaissance study of the water chemistry in 13 shallow percussion-drilled boreholes close to the seashore. The water samples were analysed for pH, HCO^{3-}, Ca^{2+}, Mg^{2+}, Ca^{2+}, Na^{+}, Cl^{-}, $SO4^{2+}$ and Fe^{2+}. Later, /Follin et al, 1998a/ compared the sampled parameter values with similar data from the municipality of Oskarshamn and the Province of Småland. The authors conclude that the water samples collected by /Laaksoharju, 1998/ reflect the ongoing shore line displacement process.

7.2.3 Deep groundwater and fracture-filling mineral investigations

There are numerous deep water samples taken within the Simpevarp regional model area. The records from the greatest depth come from the two core-drilled boreholes in the Laxemar area, KLX01 and KLX02. Current knowledge about the hydrogeochemistry of the groundwater comes mainly from the investigations immediately prior to, and during, the construction of the Äspö Hard Rock Laboratory. The gathered data are compiled and recorded in SKB's database SICADA.

SICADA contains c. 4,000 hydrogeochemical activities at sites within the Simpevarp regional model area since 1978. The geographical distribution of the activities is shown in Table 7-1.

Table 7-1. Overview of the hydrogeochemical activities in the Simpevarp regional model area, as recorded in SICADA (as of 2001-01-11).

References	Area	Number of activities	Period
SKB/SICADA	Kråkemåla	17	1978–1978
SKB/SICADA	Laxemar	322	1987–Present
SKB/SICADA	Äspö	3,574	1987–Present
SKB/SICADA	Ävrö	71	1987–1987

According to the descriptions of, and comparisons between, seven bedrock sites in Fennoscandia compiled by /Puigdomenech, 2001/, it can be expected that the dominant fracture minerals in the Simpevarp regional model area are: chlorite, calcite, epidote, fluorite, quartz, hematite/FeOOH, pyrite and clay minerals. Moreover, according to the same author, the expected dominant hydrogeochemical processes are:

- Inorganic redox reactions
- Calcite precipitation/dilution
- Ion exchange
- Methanogenesis
- Microbial sulphate reduction
- Silicate dissolution

7.2.4 Hydrogeochemical interpretation, analysis and modelling

There are sufficient data from the Simpevarp regional model area to support detailed hydrogeochemical site-descriptive modelling. Also, all known post-glacial events in Fennoscandia are believed to have affected the groundwater composition in Simpevarp. Hence, the major post-glacial stages, which have all been identified at the Äspö, Finnsjön, Gideå, Hästholmen and Olkiluoto sites (Figure 7-1), are considered relevant for the hydrogeochemical evolution of the Simpevarp area (Figure 7-2):

1. The continental ice melted and retreated, and glacial melt water flushed the bedrock (> 13,000 BP). At depths greater than 800 m, glacial melt water was mixed with ancient brine groundwater in the bedrock. A saline groundwater with a glacial signature was formed at the interface. Fresh glacial water was present in the upper part of the bedrock.

2. The flushing on the mainland started directly after the deglaciation commenced. However, since the sites were below the prevailing sea level, the post-glacial marine water stages of the Baltic Sea, i.e. the Yoldia Sea and the Litorina Sea, affected the groundwater composition. The continuous land uplift elevated the site to its present-day altitude above the sea level (Figures 6-6 and 6-7). The increased hydraulic flushing created a mixture of existing groundwater types, i.e. glacial, brine, marine and meteoric groundwater.

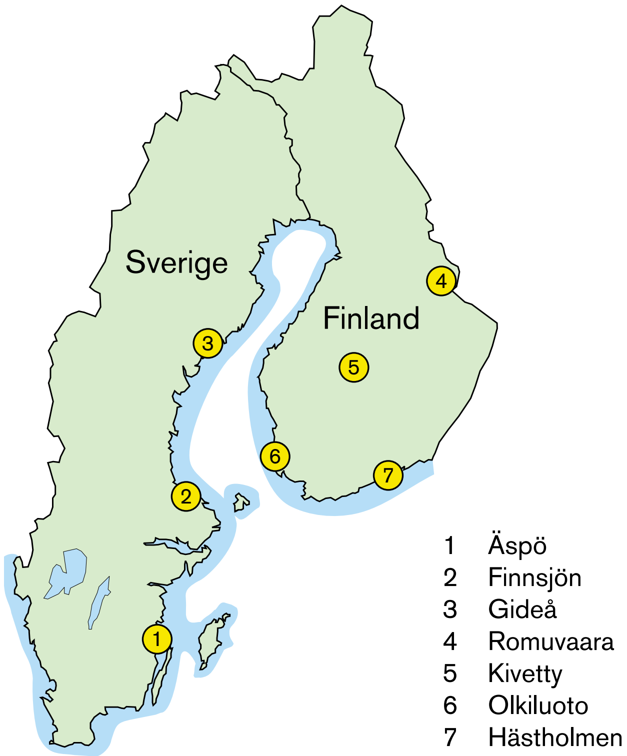


Figure 7-1. *Map showing the location of the seven hydrogeochemically evaluated sites in Finland and Sweden. Modified after /Puigdomenech, 2001/.*

The conceptual model describing these events is shown in Figure 7-2. The uncertainty of the model increases with modelled time, and the largest uncertainties are therefore associated with the stage showing the flushing of glacial melt water. The driving mechanism behind the flow lines in Figure 7-2, the shoreline displacement, is previously mentioned in Chapter 6.

/Laaksoharju et al, 1995/ and /Laaksoharju and Skårman, 1995/ have subjected the complex groundwater evolution in Figure 7-2 to an extensive analysis and developed a chemical calculation model, where the origin and evolution of a groundwater sample can be described. The calculation model consists of three steps; principal component analysis, mixing calculations and mass balance calculations. Figure 7-3 shows the result of applying the principal component analysis (PCA) method to borehole data from Äspö, Finnsjön and Gideå. The location of the Simpevarp regional model area in this context is not shown in Figure 7-3. However, given the extent of the Simpevarp regional model area, the condition in its eastern part may be estimated from the location of the data points from the Äspö site. Similarly, the condition in the western part may be estimated from the location of the data points from the Finnsjön site, which is hydrogeochemically further inland. Figure 7-4 is a PCA plot for all sites shown in Figure 7-2.

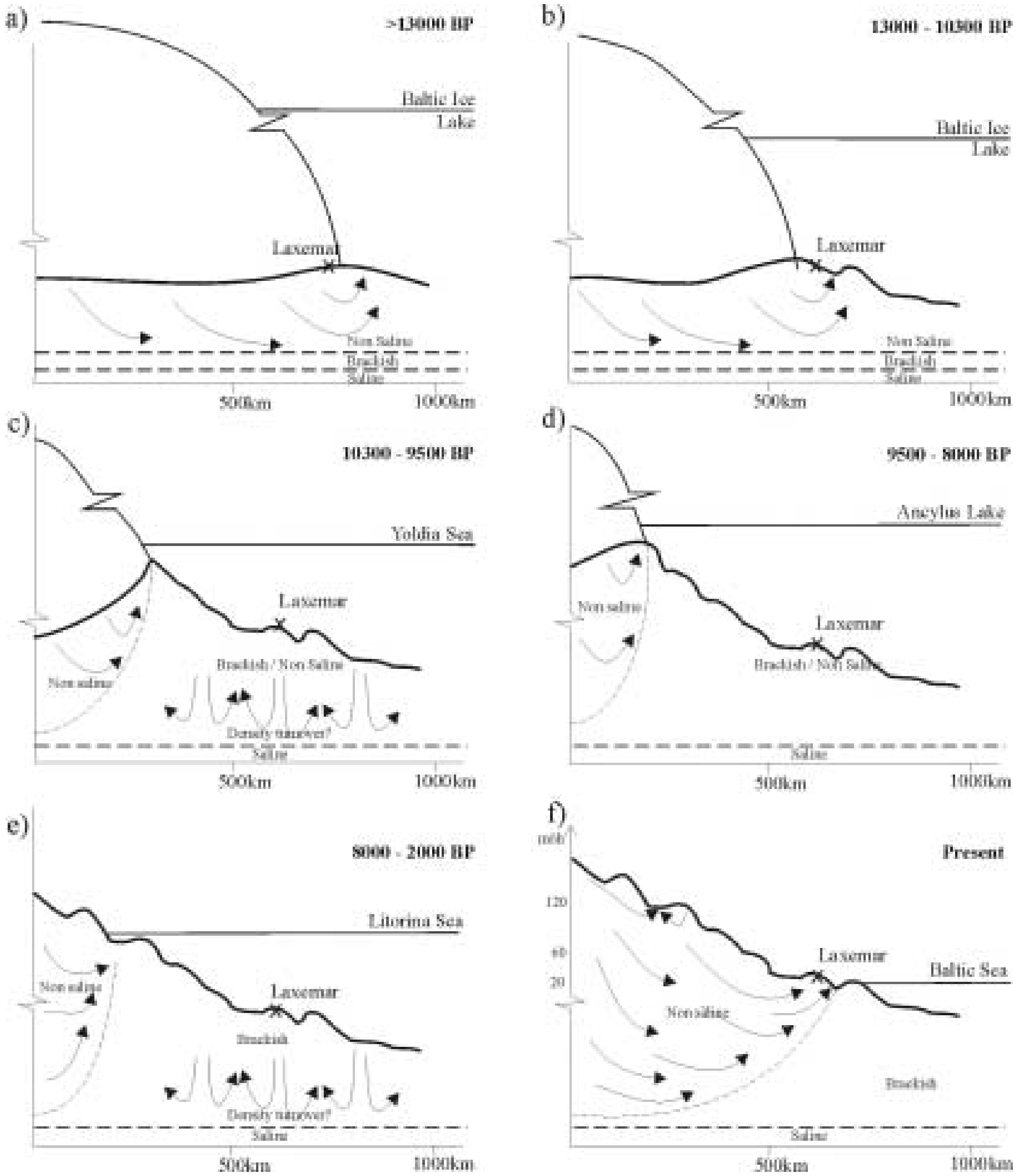


Figure 7-2. *A conceptual post-glacial scenario showing the hydrogeochemical evolution of the Äspö, Finnsjön, Gideå sites. The known post-glacial stages are: a) Injection of glacial melt water into the basement, b) Baltic Ice Lake, c) Yoldia Sea, d) Ancylus Lake, e) Litorina Sea, and f) Baltic Sea. The figures show possible flow lines, density driven turnover, non-saline, brackish and saline water interfaces. The cross indicates the position of Laxemar which is a subregion of the Simpevarp regional model area. Reproduced from /Puigdomenech, 2001/.*

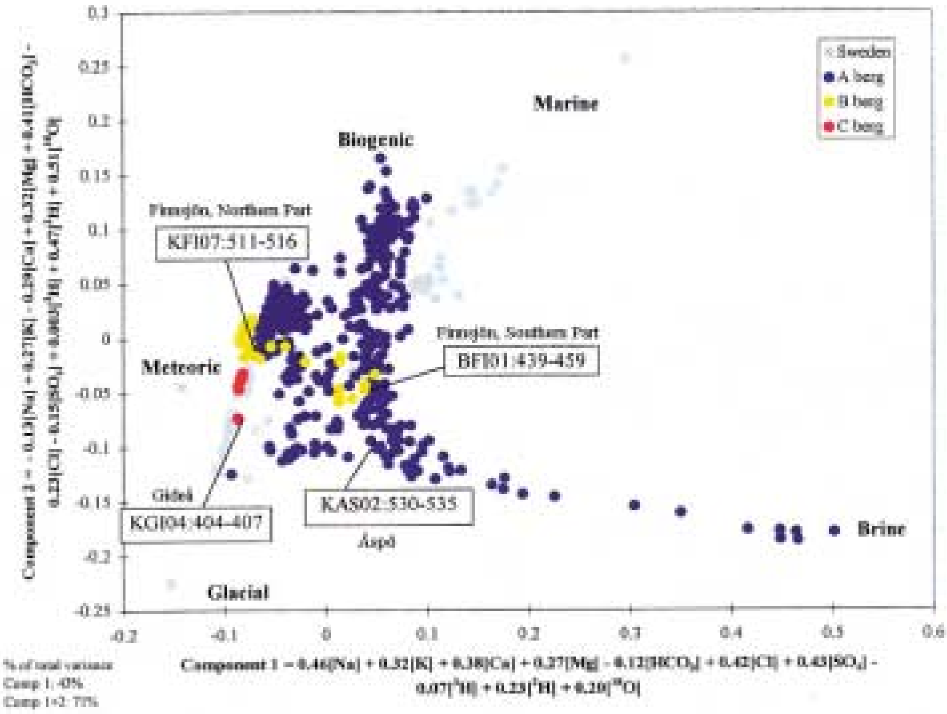


Figure 7-3. PCA-plot based on the major components, stable isotopes and tritium values from the SKB's study sites compared to data from Äspö, Finnsjön and Gideå. The groundwater chemistry of the eastern part of the Simpevarp regional model area is expected to correspond to that of Äspö, whereas the western part is expected to correspond to that of Finnsjön. Reference water samples at 500 ±100 meters depth from the three sites are tagged. Modified after /Laaksoharju et al, 1998/.

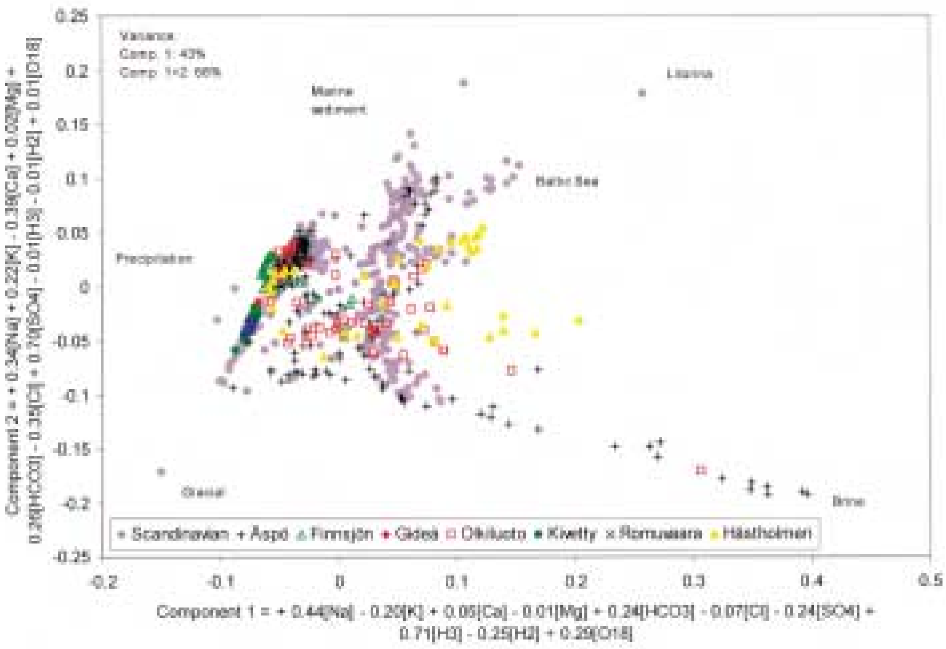


Figure 7-4. PCA-plot based on the major components, stable isotopes and tritium values from the sites shown in Figure 7-2. The position of the Simpevarp regional model area is not explicitly shown but may be estimated from the location of data points from the Olkiluoto and Hästholmen sites, since these are approximately equally far away from the shoreline as the Simpevarp regional model area. Reproduced from /Puigdomenech, 2001/.

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Appendix 1

Geology – data extraction from SKB GIS 5.0

Quaternary geology

Data input from SKB GIS 5.0

Catalogue	File name	Type	SKB report/figure	Geographic application
\fs_oskarshamn\sgu\jordart\	sgab_kns	Area	/Bergman et al, 1998/5-2	Whole regional model area

"Parameters" /SKB, 2001a/ addressed in the version 0, regional site descriptive model under section entitled, "Quaternary geology" and chapter entitled, "Ecosystems"

"Parameter group"	"Parameter"	
Soil cover	Thickness of soil cover	x
	Soil distribution	x
	Soil description	x
	Soil type	x
	Bottom sediment	
	Indication of neotectonics	x

Bedrock – rock types and potential for ore deposits

Data input from SKB GIS 5.0

Catalogue	File name	Type	SKB report/figure	Geographic application
\fs_oskarshamn\sgu\sgu_kartor\shape\	punktsymboler_r00_45fig6	Point	/Bergman et al, 2000/6	1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\berggr\	diabas	Point	/Bergman et al, 1998/6-1	Regional model area outside 1541000–155350/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\berggr\	gang	Point	/Bergman et al, 1998/6-1	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\berggr\	inneslut	Point	/Bergman et al, 1998/6-1	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\shape\	stenbrott_idrift_r98_56	Point	/Bergman et al, 1998/9-1	Whole regional model area
\fs_oskarshamn\sgu\sgu_kartor\shape\	stenbrott_nedlagda_r98_56	Point	/Bergman et al, 1998/9-1	Whole regional model area

Complementary data not previously submitted to SKB in digital format

Catalogue	File name (SGU)	Type	SKB report/figure	Geographic application
	berggrundsytor_simpevarp _version0	Area	Revised version after feasibility study	Whole regional model area

"Parameters" /SKB, 2001a/ addressed in the version 0, regional site descriptive model under section entitled, "Bedrock – rock types and potential for ore deposits"

"Parameter group"	"Parameter"	
Bedrock – rock types and potential for ore deposits. Occurring rock types	Rock type distribution (spatial and percentage)	x
	Xenoliths	x
	Dykes	x
	Contacts	
	Age	x
	Ore potential	x
Bedrock – rock types and potential for ore deposits. Rock type description	Mineralogical composition	x
	Grain size	x
	Mineral orientation	
	Microfractures	
	Density	
	Porosity	
	Susceptibility, gamma radiation etc	
	Mineralogical alteration/weathering	

Bedrock – structure

Data input from SKB GIS 5.0

Catalogue	File name	Type	SKB report/figure	Geographic application
\fs_oskarshamn\sgu\sgu_kartor\shape\	plastisk_skjuvzon_r00_45fig6	Area	/Bergman et al, 2000/6	1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\shape\	sprickzon_r00_45fig6	Line	/Bergman et al, 2000/6	1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\deform\	monly	Line	/Bergman et al, 1998/7-11	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\deform\	regh2	Line	/Bergman et al, 1998/7-11	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\deform\	regl2	Line	/Bergman et al, 1998/7-11	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\deform\	zonhav	Line	/Bergman et al, 1998/7-11	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\deform\	zonland	Line	/Bergman et al, 1998/7-11	Regional model area outside 1541000–1553500/ 6361000–6371500
\fs_oskarshamn\sgu\sgu_kartor\shape\	symboler_r98_56fig7_11	Point	/Bergman et al, 1998/7-11	Whole regional model area
\fs_oskarshamn\sgu\sgu_kartor\berggr\	streck	Point	/Bergman et al, 1998/7-11	Whole regional model area

Complementary data not previously submitted to SKB in digital format

Catalogue	File name (SGU)	Type	SKB report/figure	Geographic application
Reference: H Isaksson, GeoVista AB	Reference: H Isaksson, GeoVista AB	Line	None prior to version 0 project	Whole regional model area

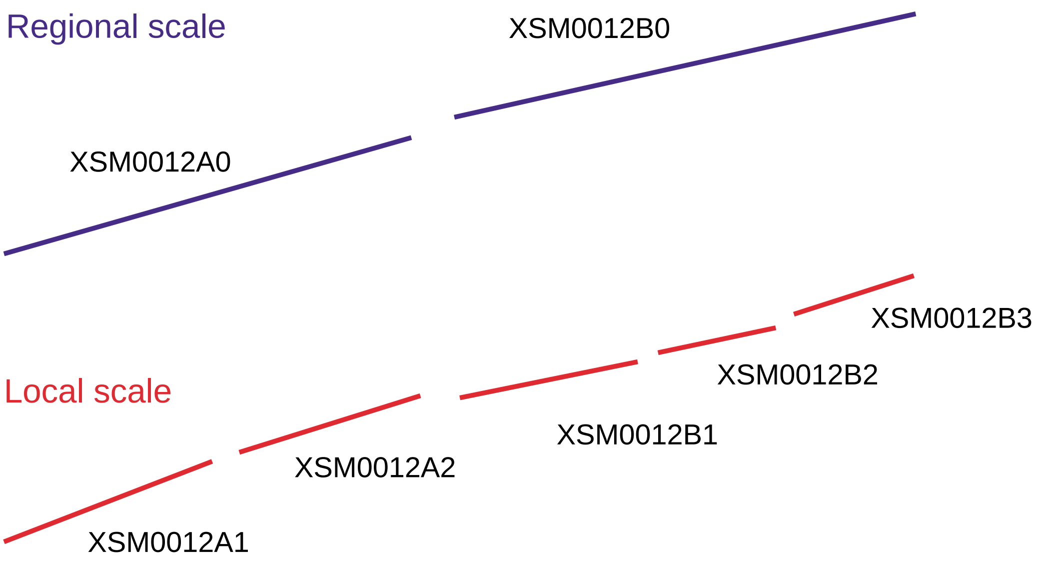
“Parameters” /SKB, 2001a/ addressed in the version 0, regional site descriptive model under section entitled, “Bedrock – structure”

“Parameter group”	“Parameter”	
Bedrock – structure. Ductile high-strain zones	Age	x
	Extent	x
	Properties	
Bedrock – structure. Local major and regional fracture zones	Location	x
	Orientation	x
	Length	x
	Width	x
	Movements (size, direction)	x
	Age	x
	Properties	

Denomination of lineaments and deformation zones

Lineaments and deformation zones are denominated according to the scheme **ABBCCCCDE**, where

A	=	Type of object; X for lineament, Z for deformation zone (including fracture zone)
BB	=	Area; SM for Simpevarp and FM for Forsmark
CCCC	=	Numeration of object; 0001–9999
D	=	Regional segment of object; A–Z
E	=	Local segment of object; 1–9 (E=0 for regional segments)



XSM0012A0, B0	Regional segments of lineament XSM0012
XSM0012A1, A2	Local segments of regional segment (XSM0012A0) of lineament XSM0012
XSM0012B1, B2, B3	Local segments of regional segment (XSM0012B0) of lineament XSM0012