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Bedrock mapping 2004 – Laxemar subarea and regional model area

Outcrop data and description of rock types

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Abstract

This project presents an outcrop database for the Laxemar subarea and its immediate surroundings as well as for selected parts of the regional model area. At a later stage, the outcrop database will be evaluated and integrated with results from geochemical and mineralogical analysis of rock samples and geophysical data, in order to generate a bedrock map at scale 1:10,000 for the Laxemar-subarea and its immediate surroundings. A total of 1,350 outcrop observation points have been documented. Out of these observation points, 1,169 are within Laxemar subarea and its immediate surroundings and 181 are within the remaining part of regional model area.

The bedrock information that was documented in the selected areas outside the Laxemar subarea and its immediate surroundings, demonstrates that the model version 0 bedrock map, with respect to the scale in which it originally was compiled (1:100,000), reasonably well reflects the extension of different rock types. However, significant discrepancies from the version 0 bedrock map were observed locally. The scattered bedrock information, including the documented discrepancies, that has been gained outside the Laxemar subarea and its immediate surroundings is to sparse to form the basis for an updated version of the version 0 bedrock map to the scale 1:50,000 in the overall regional model area.

Sammanfattning

Detta projekt presenterar en hälldatabas för delområde Laxemar och dess närmaste omgivning och utvalda delar av det regionala modellområdet. I ett senare skede kommer denna databas att integreras med analyser av insamlade bergartsprover och tillgänglig geofysiska data för att generera en berggrundskarta i skala 1:10 000 för delområde Laxemar och dess närmaste omgivning samt för de utvalda delarna av det regionala modellområdet. Totalt har 1 350 hällobservationer dokumenterats. Av dessa är 1 169 observationer i databasen från delområde Laxemar och dess närmaste omgivningar. 181 observationer i databasen är från den resterande delen av regionala modellområdet.

Det geologiska fältarbetet inom de utvalda områdena utanför delområde Laxemar och dess närmaste omgivningar visar att berggrundskartan i version 0, med hänsyn till presentationsskalan 1:100 000, relativt väl visar bergarternas utbredning inom området. Det bör dock påpekas att vissa signifikanta avvikelser från berggrundskartan i version 0 noterats inom vissa av de utvalda områdena. Då ny berggrundsinformation bara dokumenterats inom vissa utvalda områden utanför delområde Laxemar och dess närmaste omgivningar, och under beaktande av de avvikelser från berggrundskartan i version 0 som observerats, utgör inte den insamlade berggrundsinformationen ett tillräckligt underlag för en uppdatering till skala 1:50 000 av berggrundskartan i det regionala modellområdet.

Contents

1 Introduction

This document report data gained in connection with the bedrock mapping of Laxemar subarea and the regional model area, which is one of the activities performed within the site investigation at Oskarshamn during the summer of 2004. The work was carried out in accordance with activity plan SKB PS 400-04-001 with a few changes further explained in section 4.5. In Table 1-1 controlling documents for the performance of this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Berggrundskartering i delområde Laxemar och regionalt modellområde, 2004-Hällkartering	AP PS 400-04-001	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för berggrundskartering	SKB MD 132.001	1.0

The aim of the project was to collect outcrop data from Laxemar subarea as well as from the Simpevarp regional model area (Figure 1-1). The outcrop data within Laxemar subarea is aimed for use in production of a bedrock map at the scale of 1:10,000. The frequency of outcrop observations within this area was set to approximately 65 observation points per km^2 and an area of nearly 0.2 km^2 was covered per person and day. The distribution of observation points is however also dependent on the frequency of outcrops.

In mapping the regional model area a set of priorities were made. The first was to map the immediate surroundings of the Laxemar subarea in detail (Figure 1-1) to receive a better understanding of its boundary conditions. Secondly, a number of target areas were selected in order to explain the cause of geophysical anomalies within the regional model area.

Sampling of rocks for geochemical and mineralogical characterization of rock types was also carried out within the project. All the bedrock outcrop data documented during the fieldwork has been delivered to SKB and is stored in the SICADA database under field note no Simpevarp 485 (Table 1-2).

Table 1-2. Data references.

Subactivity	Database	Identity number
Outcrop database	SICADA	Field note no Simpevarp 485

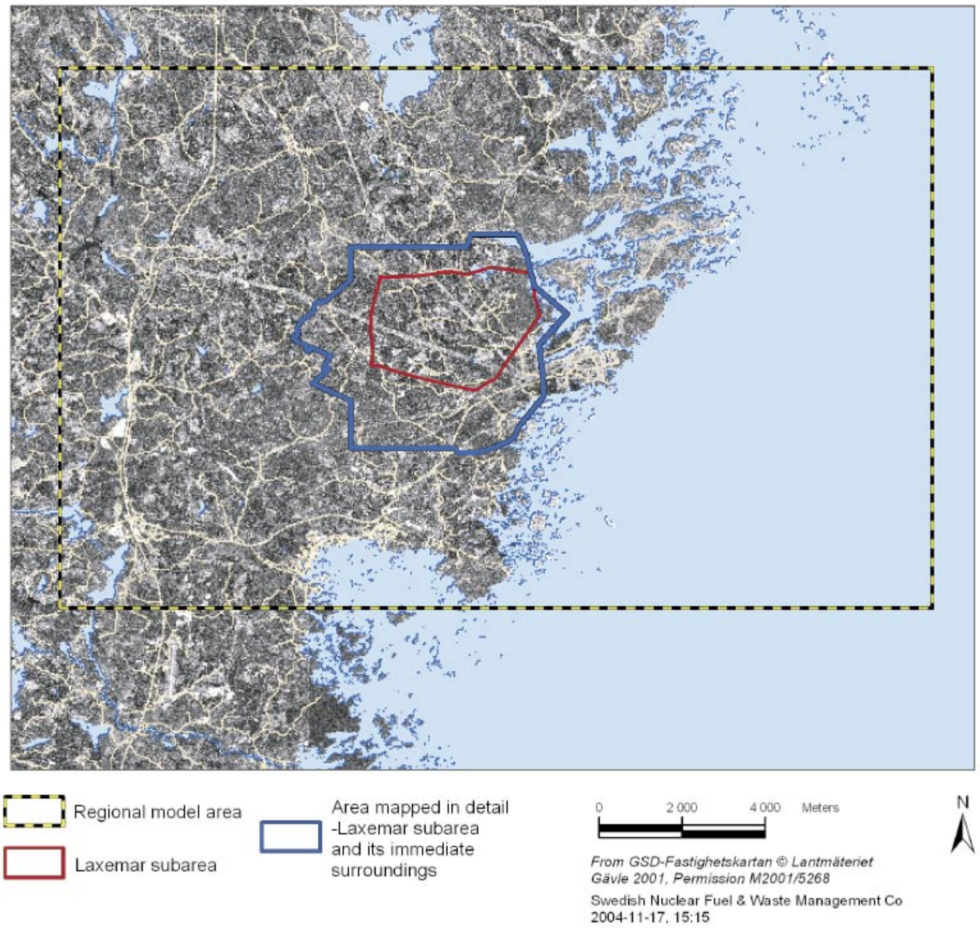

Figure 1-1. *Map of the Laxemar subarea and its immediate surroundings as well as the entire regional model area.*

2 Objective and scope

The mapping within Laxemar subarea aimed to document all outcrops in order to generate a detailed basis for the subsequent construction of a bedrock map at the scale 1:10,000. Many of the individual outcrops extend over large areas and have therefore been documented with more than one observation point. At each observation point the different rock types, as well as their texture, structure and relation to each other were documented. A further description of the documented data is presented in section 5. 1,169 observation points were documented within Laxemar subarea and its immediate surroundings (Figure 2-1).

The mapping within the regional model area, outside the Laxemar subarea and its immediate surroundings, focused on specific target areas that were defined in collaboration with SKB and Carl-Axel Triumf, GeoVista AB. The areas were chosen in order to try to explain geophysical anomalies that could not be explained by the regional bedrock geology presented in the Version 0 site descriptive model for Simpevarp /SKB, 2002/. The same documentation as described above, and further described in section 5, was collected at each observation. 181 observation points were documented in the regional model area outside the Laxemar subarea and its immediate surroundings (Figure 2-1).

A total of 135 rock samples were collected for reference. 19 rock samples were collected for geochemical analysis and 52 rock samples were collected for mineralogical analysis.

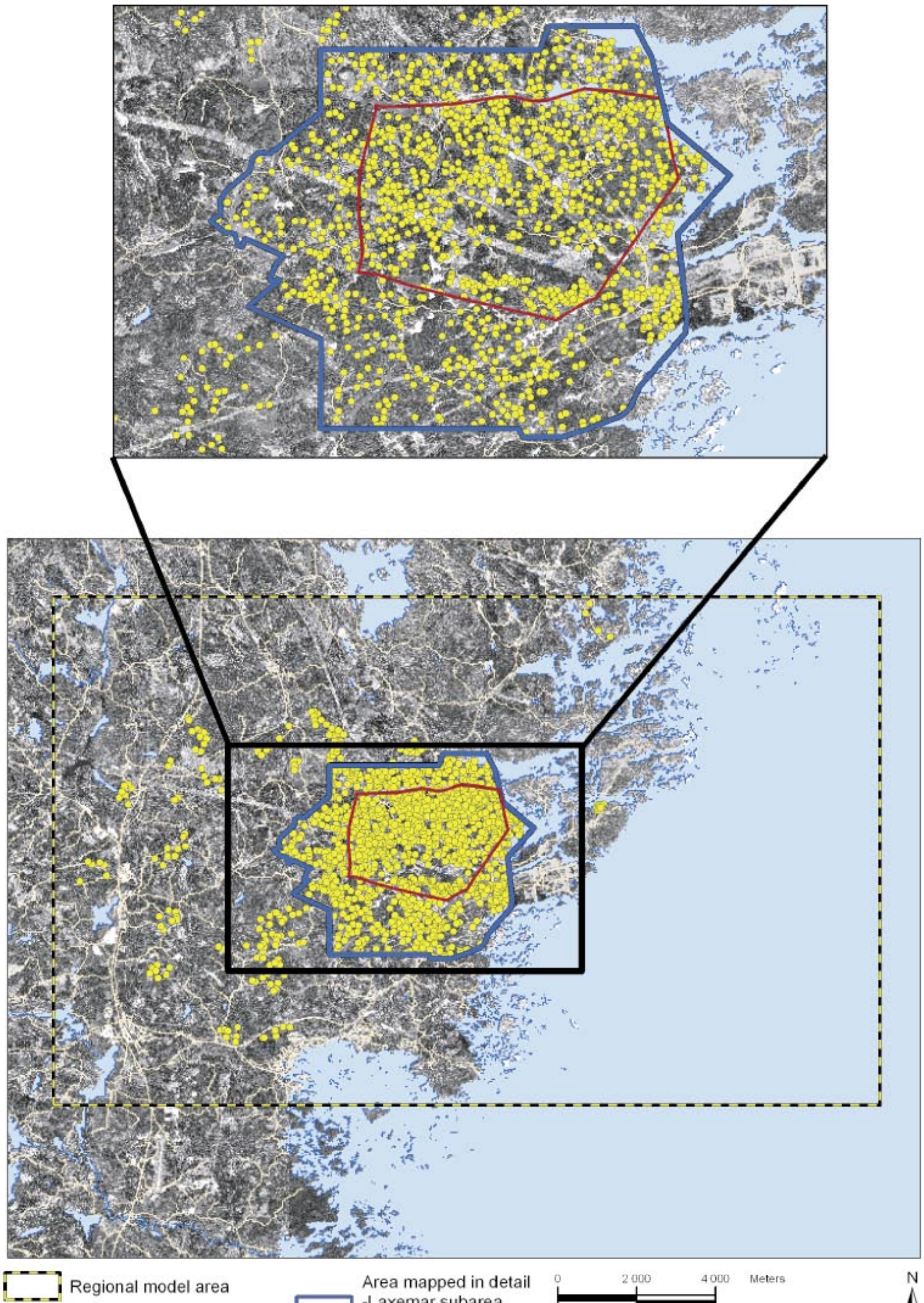

Figure 2-1. *All observation points where outcrop data have been documented.*

3 Equipment

3.1 Description of equipment/interpretation tools

The following equipment was used during the bedrock mapping:

- Topographic field maps at the scale of 1:10,000 generated from orthorectified aerial photographic data, with addition of identified outcrops from the interpretation of infrared aerial photographs. Added to the maps were also linked lineaments from geophysical interpretations /Triumf, 2004/, roads, lakes, buildings and bedrock contacts from older maps /Kornfält and Wikman, 1987a,b; 1988/.
- Geophysical maps (aeromagnetic- and radiometric maps).
- Garmin GPS 12.
- Hammer.
- Silva compass with clinometer.
- Instrument to measure magnetic susceptibility (GF Instruments, Chech Republic).
- Digital camera.
- Brush.
- Magnifying lens.
- Magnet.
- Sample bags.
- Field notebook with standard observation protocol.
- Drawing materials (pencils, pens, erasers etc).
- Safety equipment.

Transport to the field area was carried out with hired cars.

4 Execution

4.1 Preparations

Preparations involved documentation of previous works, assembly of field maps and equipment as well as other practical arrangement for field activities (housing, preparatory field excursion and meetings etc).

Key descriptions of the geology has been compiled in connection with the early stage of the Oskarshamn feasibility study /Bergman et al. 1998; 1999/. A complementary field study has also been carried out in the Simpevarp–Laxemar area /Bergman et al. 2000/. The bedrock compilation during the feasibility study was based on a bedrock map at the scale of 1:50,000 produced by the Geological Survey of Sweden (SGU) on a commission basis for SKB /Kornfält and Wikman, 1987a/. More detailed maps at the scale of 1:10,000 have also been produced for the Simpevarp peninsula, Äspö–Ävrö–Kråkelund, Bussvik, Lilla Laxemar and Glostad areas /Kornfält and Wikman, 1987a,b; 1988/. Information from these detailed maps, such as contacts between different rock types, has been followed up within this study. Older cartographic material from the area include /Svedmark, 1904/, /Kresten and Chyssler, 1976/ and /Lundegård et al. 1985/. Much of the documentation of previous work carried out in the area has been summarized in Simpevarp site descriptive model version 0 /SKB, 2002/.

4.2 Execution of field work

The fieldwork was carried out following the methodology presented in Metodbeskrivning för berggrundskartering (SKB MD 132.001, SKB internal document).

At the start of each day's field activities, the geologists visited one of two fixed points to test the drift in the coordinate values (RT 90, 2.5 gon V) obtained from the Garmin GPS 12 instrument. The average coordinate values for the points were registered after a few minutes. The results of this test were delivered to SKB in connection with the completion of the field activity diaries (aktivitetsdagbok).

During the bedrock mapping, each observation point was designated an ID-code (PSM-number) and the date of observation and the GPS-coordinates were documented in a standard observation protocol. The dominant rock type at each observation point was marked on the topographic field map at the scale 1:10,000. Different pen colours were used in order to distinguish different rock types. In areas with well exposed, large outcrops, several observation points were documented within the same outcrop. If a specific object in an outcrop was regarded important, an additional observation point was made and documented in the standard protocol.

Table 4-1 presents the different descriptive and numerical data documented in the standard protocol for the different observation points (database delivered in Swedish). Note that not all types of data were documented for every observation point. ID-number, date, location, object, rock type and measurements of magnetic susceptibility is compulsory for each observation point, whereas the completion of remaining types of documented data varies depending on the character of the bedrock at each outcrop.

Table 4-1. The different descriptive and numerical data documented in the standard protocol for the different observation points.

Documented data	Example or comment
ID-number	PSM00XXXX
Date	Ex 2004-05-06 (date of the observation)
Location (in RT 90 2.5 gon V)	Ex. N-S 6367277 and E-W 1548322
Object	Outcrop, excavation etc.
Rock type	The different rock types (granite, quartz monzodiorite etc) are listed according to their spatial importance in the outcrop
Occurrence of rock type	Ex. enclave, dyke, xenolith etc.
Texture	Ex. equigranular, porphyritic, alterated etc.
Structure	Ex. foliated, lineated, mylonitic etc.
Grain size (groundmass)	Fine-grained (0.05-1 mm)
	Medium-grained (1-5 mm)
	Coarse-grained (>5 mm)
Grain size (megacryst)	Finely porphyritic
	Coarsely porphyritic
	Or in mm
Colour	Ex. red, reddish grey, greyish red, dark grey etc.
Key mineral	Ex. Microcline, plagioclase, garnet, epidote etc.
Occurrence of key mineral	Ex. Megacrysts, fracture infill etc.
Stratigraphic position	Igneous rock GSDG ca 1,81-1,76 Ga
Measurements of mesoscopic structures	Measurements of foliation, lineation, bedrock contacts, fracture zones, shear zones etc (applying the right-hand rule).
Measurements of magnetic susceptibility	8 measurements were carried out on each rock type at each observation point.
Reference sample number	PSM00XXXXA, PSM00XXXXB etc.
Sketch	Drawings in observation protocol
Photograph/Photographs	PSM00XXXX_01, PSM00XXXX_02 etc
Comments	Comments in free text form to explain the general geology and complexity at each observation point.

Following each day's field activities, key information for all the observation points, predominantly rock type and structural measurements, were plotted on a clean outcrop map at the scale of 1:10,000 at the field office. This process was necessary in order to plan carefully the following day's field activities.

4.3 Data handling/post processing

All the bedrock outcrop data that were registered during the fieldwork was transferred into an Access database by using a programme developed by the Geological Survey of Sweden (BGDATA, version 1.7.3). The outcrop data were organised in this Access file into key groups (see section 5.1) in order to facilitate the transfer of the data into an Excel file in the delivery format needed for the data to be stored in the SICADA database. The outcrop data is stored under the field note no Simpevarp 485 in the SICADA database. Note that all data are in Swedish.

4.4 Analyses and interpretations

No analyses of bedrock samples were carried out in connection with the activities described in this report. However, the rock samples collected within this project aim to generate analytical data such as petrographic properties, including modal analyses in order to classify the rocks according to the nomenclature by /Streckeisen, 1976/, and geochemical properties (major, minor and trace elements including REE). The analytical data listed above will be documented in a separate P-report.

4.5 Nonconformities

The bedrock information that was documented in the selected areas outside the Laxemar subarea and its immediate surroundings, demonstrates that the model version 0 bedrock map, with respect to the scale in which it originally was compiled (1:100,000), reasonably well reflects the extension of different rock types. However, significant discrepancies have locally been documented in the minor areas that have been visited (see Figure 2-1), and similar discrepancies are likely to occur also in those parts of the regional model area that have not been visited during the field work. Consequently, the scattered bedrock information, including the documented discrepancies, that has been gained outside the Laxemar subarea and its immediate surroundings, is to sparse to form the basis for an overall updated version of the version 0 bedrock map to the scale 1:50,000 (cf AP PS 400-04-001).

5 Results

5.1 Outcrop database

5.1.1 General

The outcrop data at the 1,350 observation points (Figure 2-1) that were documented during the bedrock mapping project have been organized into the following groups:

- Outcrop coordinates and date.
- Outcrop rock type, occurrence, stratigraphic position, photographs and samples.
- Outcrop rock type, texture.
- Outcrop rock type, structure.
- Outcrop rock type, groundmass grain size.
- Outcrop rock type, megacryst grain size.
- Outcrop rock type, key minerals.
- Outcrop rock type, structure orientation.
- Outcrop rock type, magnetic susceptibility.
- Observation comment (in free text form)

1,169 observation points in the database are from the Laxemar subarea and its immediate surroundings that are mapped in detail, and 181 observation points are from the remaining part of the regional model area (Figure 2-1). The outcrop database is stored in the SICADA database under field note no Simpevarp 485.

5.1.2 Rock types

The rock types observed during the field mapping, both within Laxemar subarea as well as in the regional model area, have been organized into the following groups:

- Ävrö granite.
- Quartz monzodiorite.
- Fine-grained dioritoid.
- Diorite to gabbro.
- Fine-grained diorite to gabbro.
- Medium- to coarse-grained granite.
- Fine- to medium-grained granite.

The Ävrö granite (Figure 5-1) dominates and covers approximately 80% of Laxemar subarea. The Ävrö granite is a collective name for a suite of more or less porphyritic rocks that vary in composition from quartz monzodiorite to granite, including quartz dioritic and quartz monzonitic varieties. The Ävrö granite is reddish grey to greyish red, medium-grained with megacrysts of microcline usually 1-2 cm in size. As in the Simpevarp subarea /Wahlgren et al. 2004/, a characteristic feature in the Ävrö granite is the occurrence of enclaves of intermediate to mafic composition. The Ävrö granite has been observed to intimately mix and mingle with the equigranular quartz monzodiorite and gradual contact relationships indicate that the two rock types formed more or less synchronously, an observation also described by /Wahlgren et al. 2004/ for Simpevarp subarea.

The quartz monzodiorite (Figure 5-2) covers approximately 14% of Laxemar subarea. It is grey, medium grained, commonly equigranular and has a relatively restricted compositional range, which is similar to that of the fine-grained dioritoid /Wahlgren et al. 2004/. As in Simpevarp subarea /cf Wahlgren et al. 2004/, transitional varieties between typical quartz monzodiorite and fine-grained dioritoid occur.

Figure 5-1. *Medium-grained Ävrö granite with megacrysts of microcline.*

Figure 5-2. *Equigranular quartz monzodiorite.*

The fine-grained dioritoid (Figure 5-3) is grey and commonly porphyritic with 3 to 5 mm large megacrysts of hornblende and plagioclase. Patches with inhomogeneous coarsening in cm–m scale have been observed.

At several places bodies of diorite to gabbro (Figure 5-4) have been observed. These bodies often display mixing and mingling relationships with the country rock. Larger bodies are often medium-grained in its central part whereas they tend to be finer-grained and associated with fine- to medium-grained granites towards their edges. Fine-grained diorite to gabbro also occurs as composite dykes or minor bodies together with fine- to medium-grained granite. The fine-grained diorite to gabbro is generally porphyritic with larger (2–5 mm) megacrysts of hornblende and plagioclase. Except their occurrence with the diorite and gabbro, the fine- to medium grained granite also occurs as dykes of various sizes and as larger intrusion (the latter mainly outside Laxemar subarea).

The red to greyish red, medium- to coarse-grained granite occurs as sheets and bodies within most rock types, but also as diffusely delimited small occurrences in the Ävrö granite. Within Laxemar subarea, these granites are mainly observed along the southern- and northern boundaries. The pegmatites observed in the area are usually less than 0.3 m thick and are not as frequently occurring as the fine- to medium grained granitic dykes.

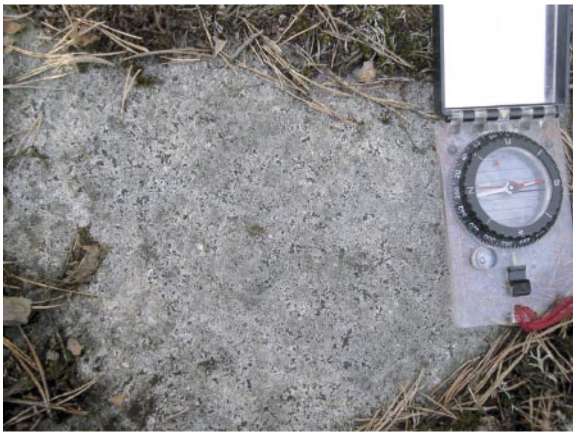

Figure 5-3. *Fine-grained dioritoid.*

Figure 5-4. *Diorite to gabbro.*

5.1.3 Structures

The rocks in the Laxemar subarea, as well as in the regional model area, are generally well preserved and more or less isotropic. Locally a week foliation is developed. It is commonly observed in the Ävrö granite that this foliation affects the matrix whereas the megacrysts of microcline show no or weak preferred orientation.

Even though the main part of the mapped area is well preserved, several localized shear zones have been observed. Both mylonitic, ductile shear zones and brittle-ductile shear zones are common. At several places it appears that the ductile zones have undergone a later reactivation. The width of these zones varies between a decimetre to several tens of metres. The alignment of some of the shear zones implies that they form part of one and the same zone of local major character.

Some of the linked lineaments /Triumf, 2004/ are known to constitute deformation zones /cf SKB, 2002/. During the mapping special care has been taken to verify if the remaining linked lineaments are deformation zones or not. However, many of the lineaments were not exposed and could not be verified. In many places, nearby exposed outcrops showed a high frequency of fractures and alteration indicating that the linked lineament could be a deformation zone. Observations of ductile- and brittle deformation zones as well as fractures, fracture infilling and alterations are stored in the outcrop database.

5.1.4 Alteration

A characteristic phenomena in the Simpevarp subarea is an extensive, inhomogenous, red staining (oxidation) of the bedrock /Wahlgren et al. 2004/. The same phenomenon appears within Laxemar subarea but is not observed to be of the same extent. In Laxemar subarea as well as in the mapped parts of the regional model area, the red staining mainly occurs along fractures or around fracture zones. The red staining is caused by hydrothermal processes of secondary nature /Eliasson, 1993; Drake et al. 2004; Wahlgren et al. 2004/. Areas with red staining (oxidation) is noted in the database. Many of these areas are around or close to interpreted linked lineaments.

6 Discussion

In the outcrop database, a lot of the information is of descriptive character and is based on an interpretation of what the geologist can see in the outcrop. This in contrast to for example results from geochemical analysis, structural measurements in the outcrop and measurements of magnetic susceptibility. All the different data sets in the database has to be evaluated and integrated with geophysical data, geochemical analysis etc. before the compilation of a bedrock map.

The mixing and mingling relationships and diffuse contacts between dominant rock types observed during the field observations suggests that they formed more or less synchronously. The following chronostratigraphy based on field observations was established by /Wahlgren et al. 2004/ during the mapping of Simpevarp subarea:

- Fine- to medium-grained granite and pegmatite. Youngest
- Fine-grained mafic rock (i. e. fine-grained diorite to gabbro).
- Medium- to coarse grained granite.
- Ävrö granite.
- Quartz monzodiorite.
- Diorite to gabbro.
- Fine-grained dioritoid. Oldest

Field observations during this project have not changed the above chronostratigraphy.

The kinematics and history of the deformation zones in the area is not well known and was not in the scope of this project. To get a better understanding of the deformation zones and their character a detailed study is needed including sampling of the rocks for studies of their microstructures in thin-sections.

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