P-03-19

Simpevarp site investigation

Measurements of petrophysical parameters on rock samples during autumn 2002

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ISSN 1651-4416
SKB P-03-19

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Keywords: magnetic susceptibility, remanent magnetization, anisotropy of magnetic susceptibility, density, porosity, electric resistivity, induced polarization.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

Contents

1 Introduction

This document reports the petrophysical data gained during autumn 2002 in connection to the selection of a preferred site for further investigations of the Simpevarp area.

All field sampling was conducted by GeoVista AB in accordance with the instructions and guidelines from SKB (activity plan AP PS 400-02-015 and method descriptions MD 132.001 and MD 230.001, SKB internal controlling documents) and under supervision of Leif Stenberg, SKB. The location of the sampling locations is shown in Figure 1-1.

178 bedrock samples were collected with a portable drill machine at 37 sampling locations (43 takings of specimens) and oriented with magnetic and sun compasses (Figure 1-1). Measurements of the magnetic susceptibility, remanent magnetization, anisotropy of magnetic susceptibility (AMS), density, porosity, electric resistivity and induced polarization were performed at the laboratory of the Division of Applied Geophysics, Luleå University of Technology.

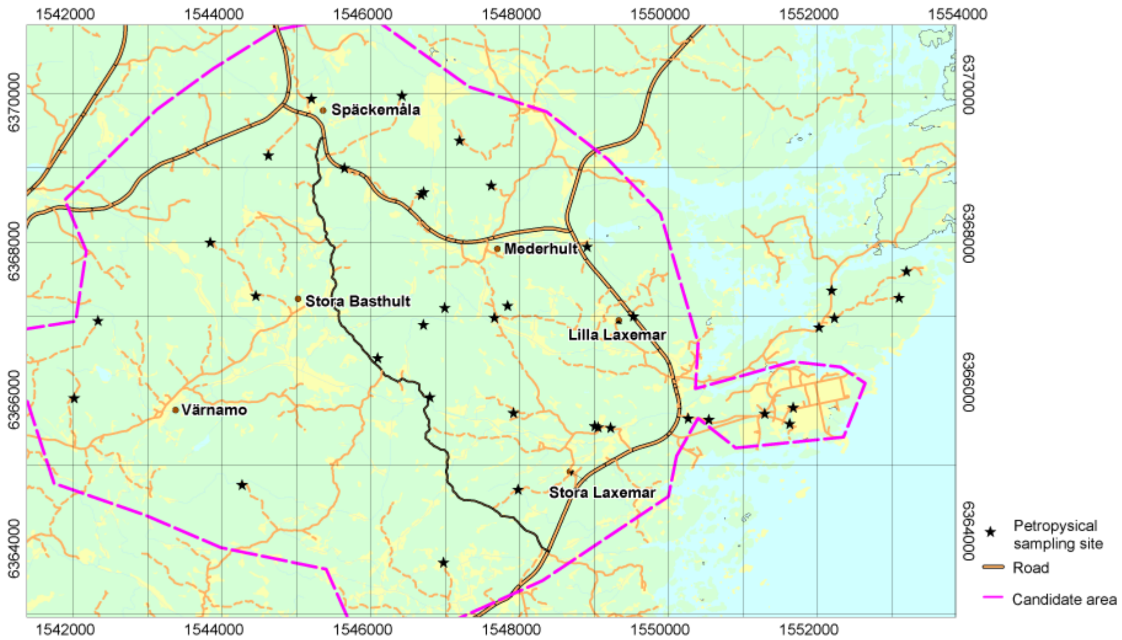

Figure 1-1. *Distribution of sampling locations for petrophysical sampling in the Simpevarp area.*

2 Objective and scope

The purpose of petrophysical measurements is to gain knowledge of the physical properties of different rock types. These data will mainly be used as supportive information for the interpretation of ground, borehole and airborne geophysical data. The petrophysical data help to correctly identify and interpret anomalies observed in geophysical data caused by e.g. deformation zones, dykes and contacts between rock units.

3 Equipment

3.1 Description of equipment

The field equipment for sampling consists of a portable, water-cooled drill machine and non-magnetic instruments for orienting the drill cores with both magnetic and sun compasses.

The measurements of magnetic remanence were performed with a cryogenic DC-SQUID magnetometer from 2G Enterprises and the anisotropy of magnetic susceptibility (AMS), including the magnetic volume susceptibility, was measured with a KLY-3 Kappabridge from Geofyzika Brno. Masses for the density and porosity determinations were measured with a digital Mettler Toledo PG 5002. The electric resistivity and induced polarization measurements were performed by use of a two-electrode in-house equipment (Luleå University of Technology) /1/.

4 Execution

In general the measurement procedures follows SKB method descriptions (MD 160.002 and MD 230.001, SKB internal controlling documents). The sampling procedure is described below.

4.1 Sampling

Four drill cores were generally collected at each sampling location, Figure 4-1. Occasionally two different rock types were sampled at one and the same location, and in those cases eight cores were collected. Each drill core is c. 8 cm long with a diameter of 25 mm. The strike and dip direction of each core was measured using the technique from traditional paleomagnetic sampling. A simple sketch of the sampled outcrop and the drill-hole positions was drawn and geological features such as contact zones, dykes and likewise were noted. The co-ordinates in the RT90 system were collected with a portable GPS instrument. All data were stored in a field diary.

Each sampling location was given a site code "PSM00XXXX" (id-code) followed by a rock type number (rock_no). The rock type number is followed by a specimen number (s_code), which separates the different drill cores (samples) selected at each sample location.

a)

b)

Figure 4-1. *a) Petrophysical sampling by use of water cooled drill machine. b) Orientation of drill core by use of sun compass.*

In order to produce a sample collection representing most of the rock types occurring in the area the selection of sampling locations was performed in co-operation with the geologist Carl-Henric Wahlgren (Geological Survey of Sweden) and by use of the geological map from the feasibility study of Oskarshamn /2/, see Table 4-1. The sampling locations will be geologically characterized in detail during the bedrock mapping planned later in the regional area of Simpevarp. Sample locations were also chosen to possibly explain some geophysical anomalies obtained by the airborne geophysical measurements.

Table 4-1. Rock types sampled for petrophysical measurements. The rock type names follow the updated nomenclature and is not exactly the same as used in the feasibility study /2/.

Rock type*	Number of sampling locations
Granite to quartz monzodiorite, generally porphyritic (Ävrö granite)	5
Intermediate volcanic rock (quartz latite to andesite), Simpevarp peninsula	5
Granite to quartz monzodiorite, generally porphyritic	11
Quartz monzonite to monzodiorite, equigranular to weakly porphyritic	5
Granite, fine to medium grained dykes	5
Granite, medium to coarse grained (red)	7
Diorite to gabbro	5

* The rock classification may be changed at some of the sampling locations as a result of the detailed bedrock mapping of the area.

4.2 Laboratory measurements

Preparations of the drill cores were performed by a technician at the laboratory of the Division of Applied Geophysics, Luleå University of Technology, according to the standard techniques used for example, in the preparation of samples for paleomagnetic analyses. Sun-strike directions of the drill cores were calculated at GeoVista AB by use of the DOS-software "sun.exe" (in-house software, Luleå University of Technology) and all orientation information was stored in a Microsoft Excel file.

The general measuring technique of the four samples from each sampling location was as follows. One long core was selected for electric and induced polarization measurements. Samples selected for measurements of electrical parameters were soaked in tap water according to MD 230.001. The surface of the sample was gently dried with a piece of paper before the sample was mounted in the two-electrode sample holder. Measurements were performed with a saw-tooth current wave-form with the frequencies 0.1, 0.6 and 4 Hz. All measurements were done in direct sequence to avoid drying of the sample. Harmonics of the lower frequencies were used to correct for possible drift due to drying. The electric resistivity of the soaking water was measured at regular intervals and recorded. The procedure was repeated after soaking the samples in water where 125 g of NaCl had been dissolved in 5 kg of water.

A 22 mm long specimen was then cut off from each drill core. AMS measurements were performed on all four specimens and a measurement of the remanent magnetization was performed on one specimen. A geological "reference specimen" was selected and saved for possible later use (e.g. thin section analysis). All specimens, plus the remains of all drill cores from the sample location, were then assembled and the density (wet and dry) and porosity measurements were performed. The samples were soaked in water for 48 hours (or more) and the mass was measured in air and in water, which allows a calculation of the wet density. The samples were dried in an oven at 107ºC for 48 hours and the mass was measured in air. The three mass measurements allow a calculation of the porosity. The sample volume was then calculated by the use of Archimedes principle, and the dry density was calculated by dividing the dry mass with the volume. The average sample volume for the density and porosity measurements is ca 100 cm^3.

Measurements of density and porosity were performed according to MD 160.002. The instruction is written to conform to rock mechanical measurements on drill cores from deep drillings, where the density and porosity determinations are parts of other types of measurements, not directly relevant for the bedrock mapping. The time to dry and soak the samples (48 hours in this investigation) is e.g. shorter than what is recommended in MD 160.002.

Calibration of instruments for measurements of petrophysical parameters were performed in accordance to the manual for each instrument respectively.

The petrophysical samples are stored in small core boxes. A box contains 5 rows and each sample location fills one row. A description on sample identification and a photographic documentation of the cores are available in Appendix 1.

4.3 Data handling

The laboratory measurements produce raw-data files in one of the formats ascii, binary or Microsoft Excel. All data files were delivered from the laboratory at the Luleå University of Technology to GeoVista AB. The data were then rearranged and placed in a Microsoft Excel file. Back-up files of all raw-data are stored both at GeoVista AB and at the laboratory.

5 Results

The laboratory measurements produced the following results for each sampling location, respectively, see Table 5-1 below.

Table 5-1. Petrophysical parameters gained from laboratory measurements.

Method	Resulting parameters
Remanent magnetization	Remanence intensity, remanence declination, remanence inclination
Anisotropy of magnetic susceptibility (AMS)	Volume susceptibility, declination/inclination of Kmax and Kmin, degree of anisotropy, degree of lineation, degree of foliation, shape parameter
Density	Wet density, dry density
Porosity	Porosity
Electric resistivity	Electric resistivity at 0.1, 0.6 and 4 Hz (in tap water and in tap water with 2.5 mass% salt)
Induced polarization	Phase angle between electric current and potential difference at 0.1, 0.6 and 4 Hz (in tap water and in tap water with 2.5 mass% salt)

Below follows a presentation of some of the parameters gained from the laboratory measurements for all the data, no rock type grouping has been performed (Figures 5-1, 5-2, 5-3 and 5-4). The majority of the sampled rocks appear to be able to classify as granite to quartz diorite, with the exception of the rocks at six sample locations that fall close to the gabbro curve, Figure 5-1. The magnetic susceptibility is generally fairly high and indicates a magnetite content ranging approximately from 0.1 vol.% to 1 vol.%. However, the Q-values are most often below 0.5 and the remanence directions show scattered orientations with moderate to steep dips, Figure 5-2. The AMS data are very consistent and clearly indicate significant groupings, in spite of the fact that a vast majority of the sampled rocks appear to be of primary origin and lack visible fabrics Figure 5-3. The poles to the foliation mainly cluster in the NE-SW, subhorizontal, direction, which indicates subvertical foliation planes with a NW-SE orientation. However, some samples also indicate NE-SW oriented foliations dipping toward SE. The magnetic lineations (maximum strain) cluster in a SE direction dipping moderate to steep. The AMS data most likely correspond to a magmatic fabric of the rocks. The electric resistivity is generally high (c. 10 000–20 000 Ωm) and all porosities are lower than 1%, Figure 5-4.

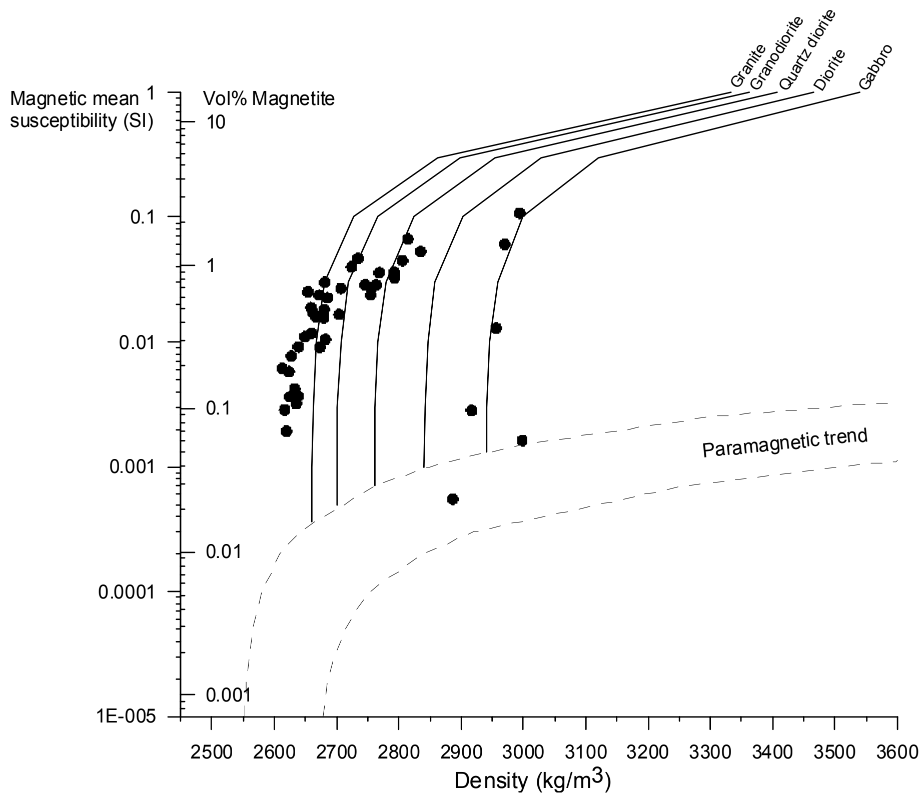

Figure 5-1. *Magnetic susceptibility versus density in a rock classification diagram. The classification curves are calculated from /3/ with average densities from /4/. The volume percent magnetite is estimated from /5/.*

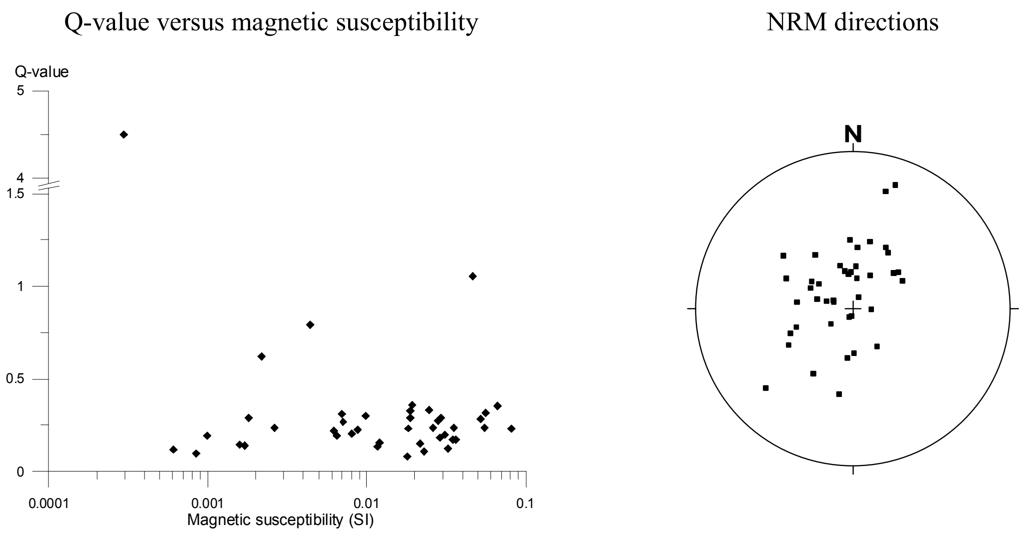

Figure 5-2. *Q-value (Koenigsberger ratio) versus magnetic susceptibility (left) and equal area projection plot of NRM-directions (right).*

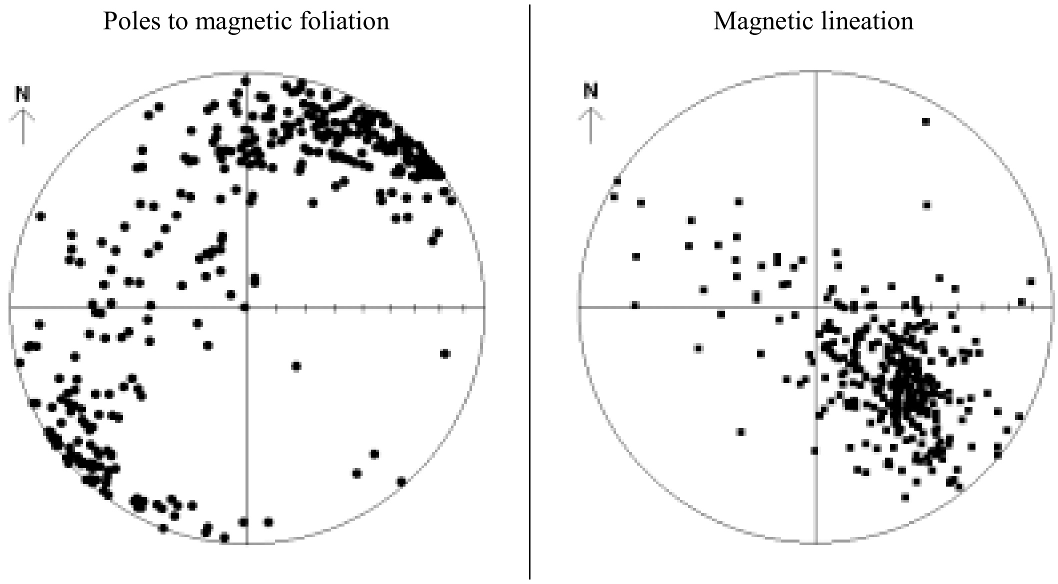

Figure 5-3. *Magnetic anisotropy of susceptibility (AMS). Equal area projection plot of the minimum principal susceptibility axes (poles to magnetic foliation) to the left and maximum principal susceptibility axes (magnetic lineation) to the right.*

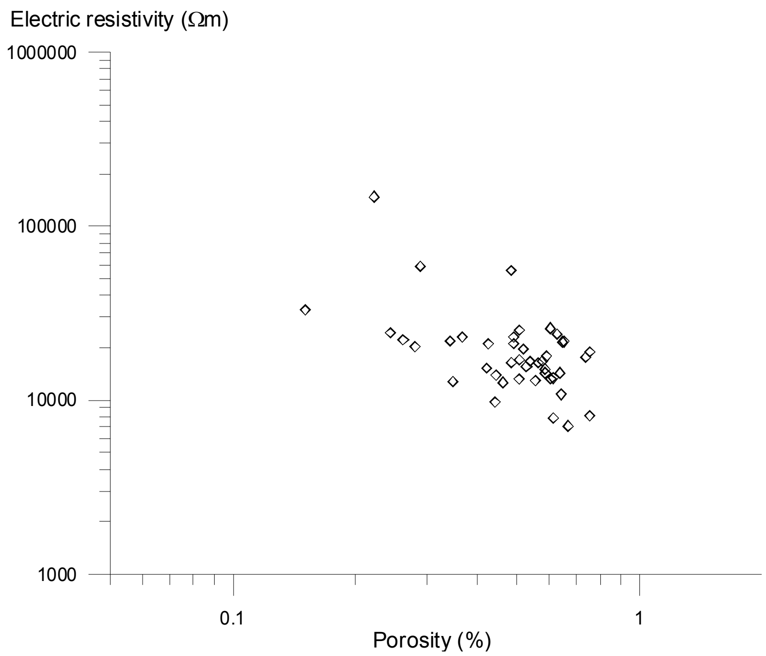

Figure 5-4. *Electric resistivity (f = 0.1 Hz, tap water) versus porosity.*

The delivered data have been inserted in the database (SICADA) of SKB. The SICADA reference to the present activity is Field note No. 21.

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Appendix 1

Storage of petrophysical samples

The petrophysical samples are stored in small core boxes. A box contains 5 rows and each sampling location (idcode) fills one row.

All boxes are marked with labels, showing information on:

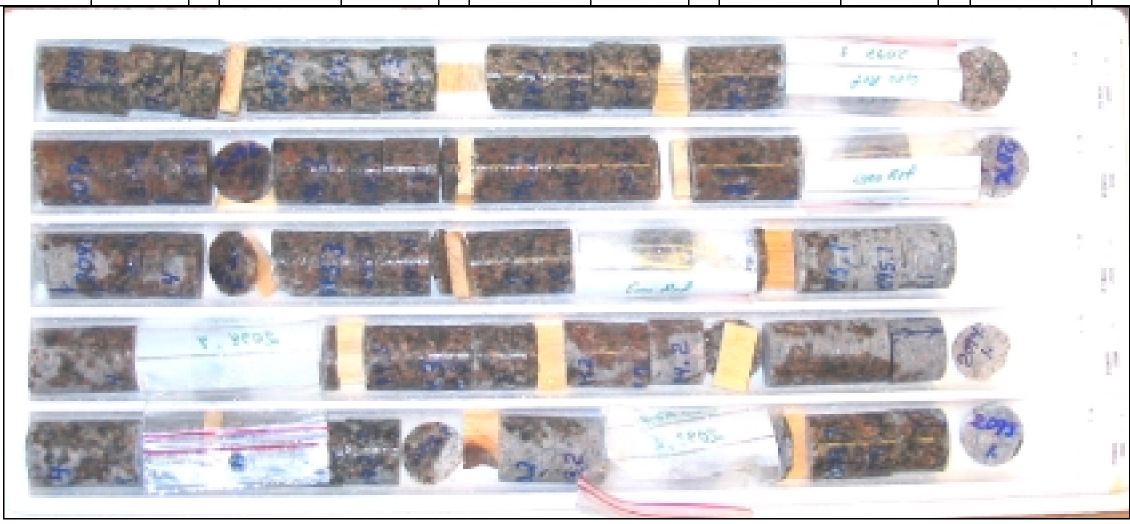
- **ID code**. Identity for geological observation (PSM…)
- **Scode**. Internal petrophysical sample numbers (löpnummer)
- **Rock no**. Link to rock type

The following pages show photographs of the core boxes and give a view of the rock type for each sample location. The caption specifies the idcode and rock_no for each sample location, in order from the bottom of the photograph to the top. The samples that are wrapped in plastic bags are geological reference specimens, see also chapter 4.2. The diameter of a sample is 25 mm.

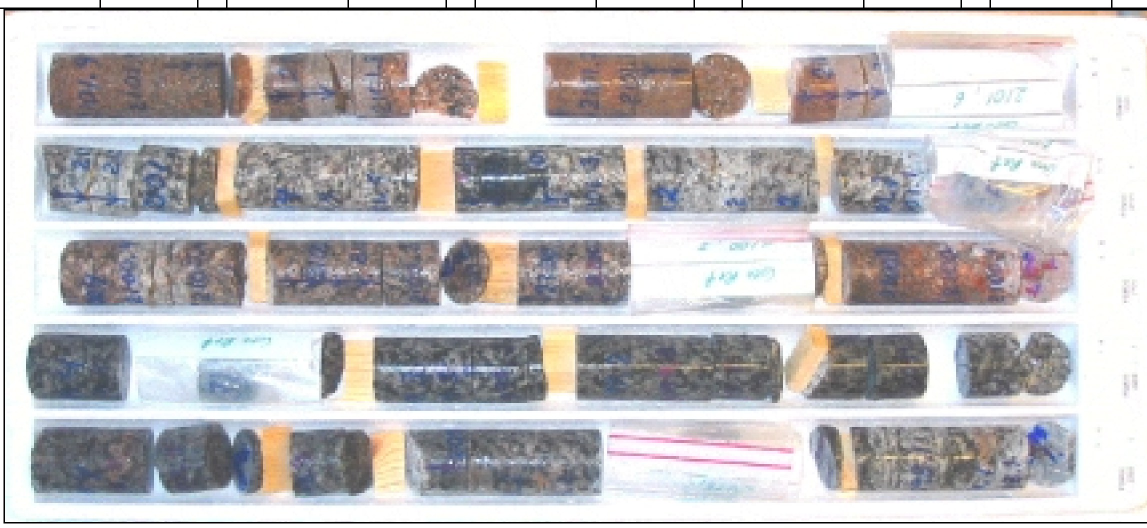
Bottom of photo Top of photo

PSM0002088	Rock_no:	1	**PSM002089**	Rock_no:	1	**PSM002090**	Rock_no:	1	**PSM002091**	Rock_no:	1	**PSM002092**	Rock_no:	1

PSM0002093	Rock_no:	1	**PSM002094**	Rock_no:	1	**PSM002095**	Rock_no:	1	**PSM002096**	Rock_no:	1	**PSM002097**	Rock_no:	1



PSM0002098	Rock_no:	1	**PSM002099**	Rock_no:	1	**PSM002100**	Rock_no:	1	**PSM002101**	Rock_no:	1	**PSM002101**	Rock_no:	2

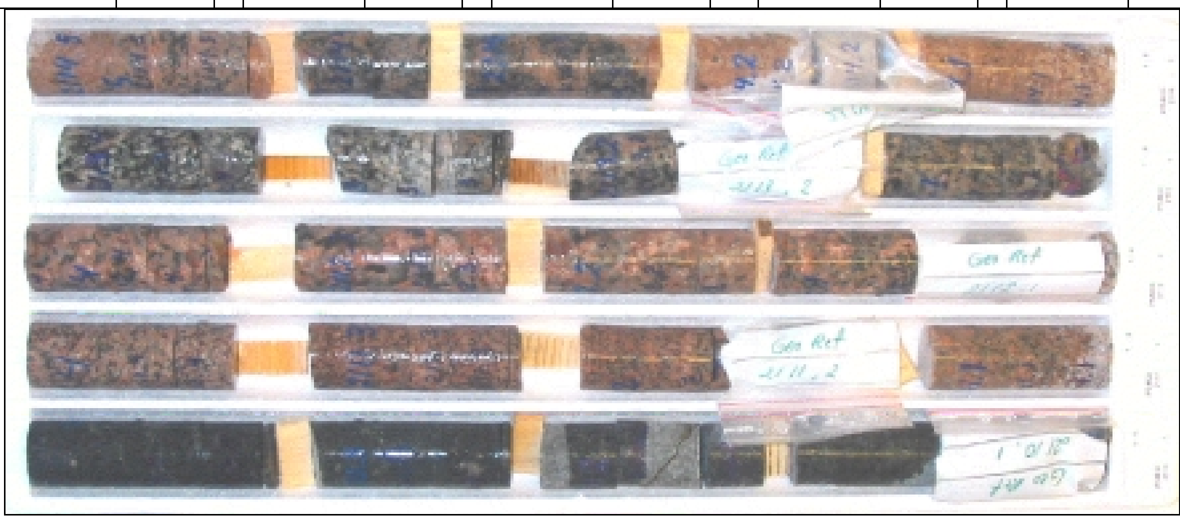


Bottom of photo Top of photo

PSM0002102	Rock_no:	1	**PSM002102**	Rock_no:	2	**PSM002103**	Rock_no:	1	**PSM002104**	Rock_no:	1	**PSM002105**	Rock_no:	1

PSM0002105	Rock_no:	2	**PSM002106**	Rock_no:	1	**PSM002107**	Rock_no:	1	**PSM002108**	Rock_no:	1	**PSM002109**	Rock_no:	1

PSM0002110	Rock_no:	1	**PSM002111**	Rock_no:	1	**PSM002112**	Rock_no:	1	**PSM002113**	Rock_no:	1	**PSM002114**	Rock_no:	1



Bottom of photo Top of photo

PSM0002114	Rock_no:	2	**PSM002115**	Rock_no:	2	**PSM002115**	Rock_no:	1	**PSM002116**	Rock_no:	1	**PSM002117**	Rock_no:	1

PSM0002118	Rock_no:	1	**PSM002119**	Rock_no:	1	**PSM002119**	Rock_no:	2	**PSM002120**	Rock_no:	1	**PSM002121**	Rock_no:	1

PSM0002122	Rock_no:	1	**PSM002123**	Rock_no:	1	**PSM002124**	Rock_no:	1