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Äspö Hard Rock Laboratory

Preliminary selection of experimental sites for the Chemlab and TRUE-2 experiments

Select-2

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April 1999

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Abstract

Within the scope of SKB's program for RD&D 1995, SKB has decided to carry out an experiment with the designation the "Tracer Retention and Understanding Experiment (TRUE)". Another experiment is the "Radionuclide Retention (RNR, CHEMLAB) Experiment". The objective of the present report is to describe the basis for the selection of drilling sites for the localisation of the TRUE-2 and CHEMLAB sites. An important part of the selection of new sites is the compilation of the geological and hydrogeological characterisation data of the host rock at the possible sites.

The rock at the proposed sites for TRUE-2 or CHEMLAB consists of Äspö diorite with veins and inclusions of fine-grained granite. The main target fracture set is oriented in NW or WNW with steep dips. The most common fracture fillings are chlorite, calcite and epidote.

The proposed location for one borehole for SELECT-2 is within the niche located at 2375 m. The orientation of the borehole should be towards SW dipping slightly downwards. The length of the borehole is planned to be about 50-70 m. Other boreholes could be drilled from sections 2865 and 3065 m. These boreholes should be oriented in NE. The length of these boreholes should be about 50-70 m.

Another location of two core drilled boreholes is within the niche TASJ located at section 3505 m calculated along the main TASA tunnel. The orientation of the two boreholes should be towards N and NE respectively dipping slightly downwards. The length of the boreholes are planned to be about 50 m. Additional two boreholes are also planned to be drilled from this niche for microbiological studies.

Sammanfattning

Inom ramen för SKB´s program för FUD 1995 har SKB beslutat att genomföra ett projekt vid namn "Tracer Retention and Understanding Experiment (TRUE)". Ett annat experiment kallas "Radionuclide Retention (RNR, CHEMLAB) Experiment". Syftet med denna rapport är att beskriva underlaget för val av borrplatser för TRUE-2 experimentet och CHEMLAB. Ett underlag för att finna nya platser är att sammanställa geologisk och hydrogeologisk information från de tänkta platserna.

Bergarter vid de tänkta platserna för TRUE-2 och CHEMLAB består av Äspö diorit med gångar och inneslutningar av finkorning granit. Det huvudsakliga spricksetet som söks är orienterad i NW eller WNW med brant lutning. De huvudsakliga sprickmineralen är klorit, kalcit och epidot.

En föreslagen plats för lokaliseringen av ett borrhål för SELECT-2 är i nischen lokaliserad vid 2375 m. Borrhålet skall vara riktat mot SW med en lutning något nedåt. Längden av borrhålet planeras att bli ca 50-70 m. Andra borrhål kan placeras i sektionerna 2865 and 3065 m. Dessa borrhål orienteras i riktning mot NE. Längden av dessa borrhål planeras bli 50-70 m.

En annan lokalisering av två borrhål är i nischen TASJ. Borrhålen skall vara riktade mot N respektive NE med en lutning något nedåt. Längden av borrhålen planeras att bli omkring 50 m. Ytterligare två stycken borrhål planeras att borras från denna nisch för mikrobiologiska studier.

Summary

Within the scope of SKB's program for RD&D 1995, SKB has decided to carry out an experiment with the designation the "Tracer Retention and Understanding Experiment (TRUE)". The aim of the Tracer Retention and Understanding Experiment is to develop understanding of radionuclide migration (retention), increase confidence in models used, and to establish the methodology which will provide the necessary data through integrated laboratory tests, field experiments and modelling.

Another experiment is the "Radionuclide Retention (RNR, CHEMLAB) Experiment". The aim of the Radionuclide Retention Experiment is to validate the radionuclide retardation data which have been measured in laboratories by data from in situ experiments in the rock; to demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock and to decrease the uncertainty in the retardation properties of the relevant radionuclides. The construction of a second CHEMLAB probe necessitates a shift to a new experimental site.

The objective of the present report is to describe the basis for the selection of drilling sites for the localisation of the TRUE-2 and CHEMLAB sites. An important part of the selection of new sites is the characterisation of the geological and hydrogeological condition of the host rock at the possible sites.

The rock at the proposed TRUE-2 and CHEMLAB sites consists of Äspö diorite with veins and inclusions of fine-grained granite. The main target fracture set is oriented in NW or WNW with steep dips. The most common fracture fillings are chlorite, calcite and epidote. The proposed location for one borehole for SELECT-2 is within the niche located at 2375 m. The orientation of the borehole should be towards SW dipping slightly downwards. The length of the borehole is planned to be about 50-70 m. Other boreholes could be drilled from sections 2865 and 3065 m. These boreholes should be oriented in NE. The length of these boreholes should be about 50-70 m.

Another location of two core drilled boreholes is within the niche TASJ located at section 3505 m calculated along the main TASA tunnel. The orientation of the two boreholes should be towards N and NE respectively dipping sligthly downwards. The length of the boreholes are planned to be about 50 m. Additional two boreholes are planned to be drilled from this niche for microbiological studies.

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1 Introduction

1.1 General

The scientific investigations within SKB's research programme are part of the work conducted to develop and test methods for identification and characterisation of suitable repository sites and for design of a deep repository. This requires extensive field studies of the active processes and properties of the geological barrier and the interaction between different engineered barriers and host rock. The Äspö Hard Rock Laboratory provides an opportunity for research, development and demonstration of these issues in a realistic setting.

A set of Stage Goals has been defined for the work at the Äspö HRL. The Stage Goals were redefined in the SKB Research Development and Demonstration (RD&D) Programme 95 /SKB, 1995/. This programme is the basis for the planning and execution of the work.

The revised Stage Goals for the Operating Phase are defined as follows:

1 **Verify pre-investigation methods**

demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level.

2 **Finalise detailed investigation methodology**

refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

3 **Test models for description of the barrier function of the host rock**

further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration, and chemical conditions during operation of a repository and after closure.

4 **Demonstrate technology for and function of important parts of the repository system**

test, investigate and demonstrate on a full scale different components of importance for the long-term safety of a deep repository system and to show that high quality can be achieved in design, construction and operation of system components.

1.2 TRUE

1.2.1 Background

The safety of a KBS-3 type repository relies heavily on the engineered barrier system that contains the waste. In the case that the engineered barrier fails, the geosphere provides the remaining waste containment. Realistic estimates and predictions of transport times through the geosphere and release rates to the biosphere are thus critical for any safety assessment. Of particular interest in this regard is the rock adjacent to the canister holes and storage tunnels.

The plans for tracer experiments outlined in the SKB RD&D Programme 92 /SKB,1992/ comprised experiments in the Detailed and Block Scales. The experiments in the Detailed Scale consisted of three; Pore Volume Characterisation (PVC), Multiple-Well Tracer Experiment (MWTE) and the Matrix Diffusion Experiment (MDE). During 1994 detailed Test Plans were prepared for MWTE and MDE. Following review and evaluation the SKB HRL Project management decided to integrate the Detailed and Block Scale experiments within a common framework. This framework is described in a "Program for Tracer Retention Understanding Experiments (TRUE)"/Bäckblom and Olsson, 1994/. The basic idea is that tracer experiments will be performed in cycles with an approximate duration of 2 years /Winberg, 1994/. At the end of each tracer test cycle, results and experiences gained will be evaluated and the overall program for TRUE revised accordingly.

1.2.2 Objectives

The general objectives of the TRUE experiments /Bäckblom and Olsson 1994/ are;

- Develop the understanding of radionuclide migration and retention in fractured rock.
- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and if adequate data can be collected in site characterisation.
- Evaluate the usefulness and feasibility of different approaches to model radionuclide migration and retention.

1.2.3 Experimental concept

The experimental concept is to get an improved understanding of transport and retention processes in a singular feature through interactive use of site characterisation (including in situ tracer experiments in variable flow geometry and flow paths), conceptual and analytical/numerical modelling and supporting laboratory measurements.

The basic idea is to perform a series of tracer tests with progressively increasing complexity. In principle, each tracer experiment will consist of a cycle of activities beginning with geological characterisation of the selected site, followed by hydraulic and tracer tests, after which resin will be injected /Winberg, 1994/. Subsequently the tested rock volume will be excavated and analysed with regards to flow path geometry and tracer concentration.

The first tracer test cycle (TRUE-1) constituted a training exercise for tracer testing technology on a detailed scale using non-reactive tracers in a simple test. In addition, supporting technology development was performed for sampling and analysis techniques for matrix diffusion and for understanding of tracer transport through detailed aperture distributions obtained from resin injection. The TRUE-1 cycle was expected to contribute data and experience which would constitute the necessary platform for subsequent more elaborate experiments within TRUE-2.

In TRUE-2, which will constitute second tests in a detailed scale, the focus will be more on retention processes in a single fracture, their identification and discrimination. The time frames of the experiments will be such that diffusion into dead end pores and possibly also into the rock matrix will become a measurable process. A tantamount feat will be to locate and characterise yet another single fracture.

1.3 Radionuclide Retention (CHEMLAB)

1.3.1 Background

The retention of radionuclides in the rock is the most effective protection mechanism if the engineering barriers have failed and the radionuclides have been released from the waste form. The retention is mainly caused by the chemical character of the radionuclides themselves, the chemical composition of the groundwater and to some extent also by the conditions of the water conducting fractures and the groundwater flow.

Laboratory studies on solubility and migration of the long lived nuclides of e.g. Tc, Np, and Pu indicate that these elements are so strongly sorbed on the fracture surfaces and into the rock matrix that they will not be transported to the biosphere until they have decayed. Therefore these sorption processes could well be considered irreversible and thus the migration of the nuclides will stop as soon as the source term is ending. Natural analogue studies of an ancient reactor in Gabon have given results that show the mobility of plutonium to be within a few dm to m until it decayed.

Laboratory studies under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to be able to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, of organic matter, of bacteria etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. The CHEMLAB probe, has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions.

For the CHEMLAB experiment a second probe, CHEMLAB-2 has been developed. For the convenience of running both equipments simuntaneously, a new experimental site will be selected.

1.3.2 Objectives

The objectives of the Radionuclide Retention (CHEMLAB) experiments are:

- To validate the radionuclide retardation data which have been measured in laboratories by data from in situ experiments in the rock
- To demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock
- To decrease the uncertainty in the retardation properties of the relevant radionuclides

1.3.3 Experimental concept

CHEMLAB is a borehole laboratory built in a probe, in which migration experiments will be carried out under ambient conditions regarding pressure and temperature and with the use of the formation groundwater from the surrounding rock. The whole suite of experiments which are planned to be carried out are:

- Diffusion of radionuclides in bentonite clay
- Migration of redox sensitive radionuclides
- Radionuclide solubility and actinide speciation
- Desorption of radionuclides from the rock
- Migration from buffer to rock
- Radiolysis
- Batch sorption experiments
- Spent fuel leaching

1.4 Requirements set bye TRUE and CHEMLAB

The site requirements set up for TRUE are listed in Table 1-1 /Winberg, 1994/. The requirements for CHEMLAB are about the same Table 1-2 /Olsson, 1994/.

The size of the block needed is about 40x40x40 m. The target fractures should be located more than 10 m from the tunnel or niche. The fracture frequency should be

Table 1-1. Site requirements for TRUE /Winberg, 1994/ and /Olsson, 1994/.

Rock type and properties	
rock type	granite/diorite
mechanical properties of target rock	competent
Fracture system characteristics	
structural characteristics of target	Isolated fractured rock volume
fracture zones	
- location, orientation	far away (>20 m)
averagely fractured rock	
- fracture density	low
- fracture set orientation	well defined sets
Flow system	
average flow direction/hydraulic gradient	small natural gradient
groundwater pressure	>25 Bar
groundwater chemistry	deep natural, reducing
transmissivity (zones/average rock/target fracture)	target volume $T \approx 10^{-7}$ m^2/s average rock $K < 10^{-11}$ m/s
Rock stress	
magnitude	normal conditions
stress anisotropy	not important
stress orientation relative to experimental setup	irrelevant
Sensitivity to disturbances	safety zone: 30 m radius
possible interference from nearby experiments	not allowed
requirements on stability in groundwater pressure/head	virtually constant for periods of several weeks
groundwater chemistry	stable, deep natural
temperature	stable, ambient
ventilation	no
drilling	not allowed in safety zone
excavation activity (blasting)	not allowed within 50 m
grouting in nearby rock	not within 50 m (if possible)
Size of experimental volume	
size of excavations	experimental niche, 6x6x5 m
affected volume	40 m cube
need of nearby drifts for test holes	none
need for monitoring points	valuable
Transports	
size of access drifts	3.5x3 m
distance to shaft	irrelevant
Need for permanent installations	
electric power	uninterrupted supply, 10 kW (during drilling 40 kW).
ventilation	normal
pumping capacity	normal
instrument cabin	yes, 10 m^2
emergency facilities	rescue chamber
Legal issues	
permits to use radioactive materials	yes

Table 1-2. Site requirements for CHEMLAB /Olsson, 1994/.

Rock type and properties	
rock type	granite/diorite
mechanical properties of target rock	competent
Fracture system characteristics	
structural characteristics of target fracture zones	small steeply dipping fracture zone extent >40 m
- location, orientation	approximately 20 m from experimental drift, steep dip
averagely fractured rock	
- fracture density	moderate
- fracture set orientation	not important
Flow system	
average flow direction/hydraulic gradient	Moderate natural gradient
groundwater pressure	>25 Bar
groundwater chemistry	deep natural, reducing
transmissivity (zones/average rock/target fracture)	target zone $T \approx 10^{-7}$ m^2/s average rock $K<10^{-11}$ m/s
Rock stress	
magnitude	normal conditions
stress anisotropy	not important
stress orientation relative to experimental setup	irrelevant
Sensitivity to disturbances	safety zone: 20 m radius plus 50 m
possible interference from nearby experiments	minor variations in head allowed
requirements on stability in groundwater pressure/head	minor variations allowed during periods of several months
groundwater chemistry	stable, deep natural
temperature	stable, ambient
ventilation	no
drilling	not allowed in safety zone
excavation activity (blasting)	not allowed within 50 m after start of experiment
grouting in nearby rock	not within 50 m (if possible)
Size of experimental volume	
size of excavations	experimental drift, 20x6x3.5 m
affected volume	60 m cube
need of nearby drifts for test holes	none
need for monitoring points	valuable
Transports	
size of access drifts	5x3.5 m
distance to shaft	reasonable
Need for permanent installations	
electric power	uninterrupted supply, 30 kW (during drilling 40 kW).
ventilation	normal
pumping capacity	normal
instrument cabin	yes, 25 m^2
emergency facilities	rescue chamber

Legal issues permits to use radioactive materials	 yes, radioactive protection zone must be implemented

normal for granite/diorite, about 3-5 fractures/m. The vertical depth of the block should be from 320 m down to 450 m. The transmissivity of the target fractures should be about 10^{-7} m^2/s and the hydraulic conductivity of the rock mass about 10^{-11} m/s. The chemical condition of the water should be stable and reducing. The distance to disturbing activities should be more than 50 m.

The CHEMLAB probes needs two 50 m long boreholes with a diameter of 101 mm. This dimension can be reamed up from a pilot hole with a diameter of 76 mm. The target is a fracture or fracture zone with a low inflow ≈0.5 l/min. The niche must be large as a chemical laboratory trailer or container must be sited in the niche. A radiological control area must also be allocated in the niche.

The TRUE-2 site needs 50-70 m long boreholes with a diameter of 76 mm. These holes will be drilled with triple tube technique.

The objective of the present report is to describe the basis for the selection of the TRUE-2 and the CHEMLAB sites.

2 Overview of potential experimental sites

2.1 Location of potential experimental sites

The basic requirement for a suitable site within TRUE or CHEMLAB is that the experiments should be performed at depth so that they are made under conditions similar to what can be expected from transport in the vicinity of a future repository /Olsson, 1994, Olsson et al., 1994/. Based on these requirements a project for identification and localisation of suitable experimental sites has been defined /Olsson, 1993/.

In Figure 2-1 the location of sites already occupied by different experiments are shown. In the SW corner G, at a vertical depth of 335 m, the site for RNR-CHEMLAB is located. West of the corner the TRUE Block scale is localised. In the NW corner H, at a vertical depth of 358 m, the 2-phase flow experiment is localised. The REX experiment is localised in corner J, at a vertical depth of 378 m. Along the tunnel leg between corners J and K, the TRUE-1 experiment is localised at a vertical depth of 393 m. The ZEDEX tunnel, where the Backfill and Plug test will be performed, is localised south of the start of the TBM tunnel and the Assembly hall at a vertical depth of 420 m. South of the ZEDEX tunnel the demonstration of repository technology will be performed. South of the shaft at a level of 450 m, the long term test of buffer material has been performed. A new site for the long term test of buffer material is allocated to the tunnel north of the TBM tunnel in the western part of the HRL tunnel layout. The prototype repository will be localised in the inner part of the TBM tunnel at a vertical depth of 450 m.

In Figure 2-1 the possible locations for TRUE-2 and the new site for CHEMLAB are shown. The first possible location is in the corner F, site 2375, at a vertical depth of 320 m. The second location is north of the 2-phase flow site, site 2730, at a vertical depth of 360 m. The third possible location is east of the REX niche, site 2880, at a vertical depth of 380 m. The fourth possible location is east of the corner K, site 3067, at a vertical depth of 410 m. The fifth location is south of the assembly hall, site 3105, at a vertical depth of 415 m, where two boreholes KA3105A and KA3110A have been drilled in the first SELECT program /Winberg et al., 1996/. The sixth location is north of the assembly hall in the niche TASL at a vertical depth of 420 m. The seventh possible location is east of the elevator level at a vertical depth of 450 m positioned in the shaft niche, TASE. The eighth possible location is north of the niche TASJ at a vertical depth of 450 m.

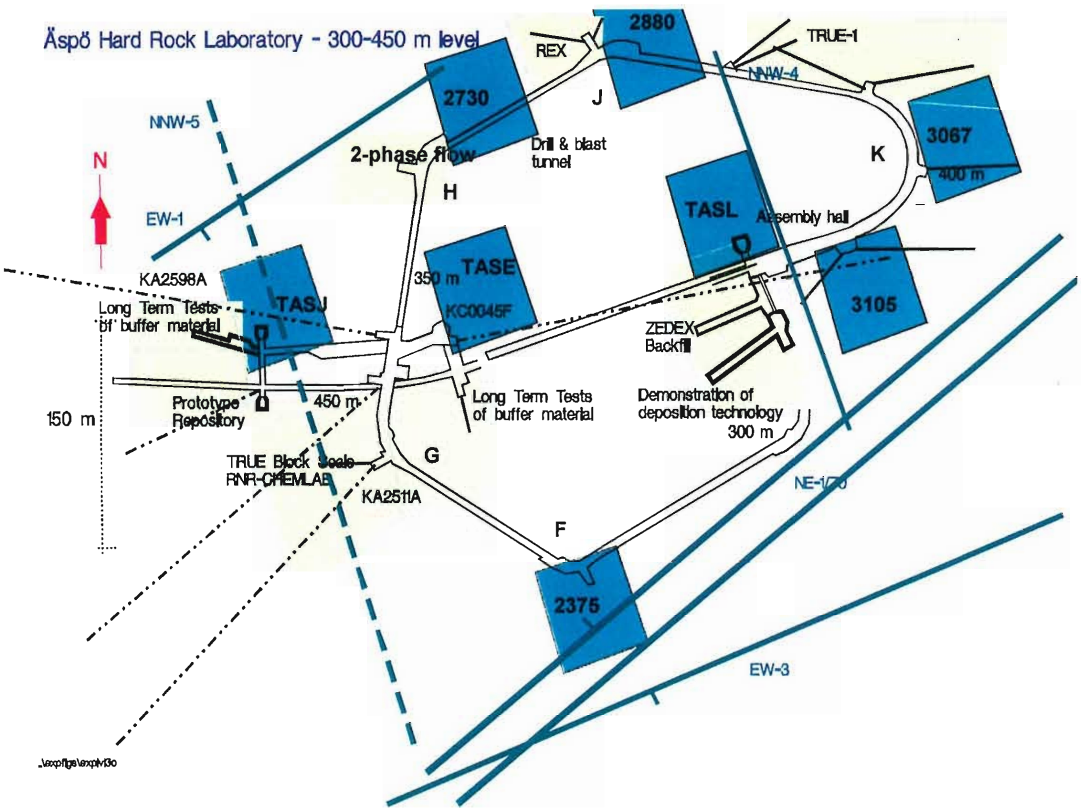


Figure 2-1. Proposed location of the SELECT-2 sites. Light green areas are sites occupied by different experiments. Light blue areas are possible sites for the location of TRUE-2 and CHEMLAB.

2.2 Screening of sites

2.2.1 Site 2375

Site 2375 is positioned at a vertical depth of 320 m and at a tunnel length of 2375 m. The requirement for the rock type is fulfilled. The fracture frequency is fulfilled. The location of fracture zone NE-1 is possible at a distance of 25-30 m south of the site, which could have influence on the site. Drilling of long holes southwards should be avoided. A water conductive fracture with a transmissivity of 0.28×10^{-7} m^2/s is located at a position of 2410 m in the tunnel /Markström et al., 1996/. The hydraulic gradient is moderate. The ground water chemistry is stable. No interference from other experiments is expected. The TRUE block scale is located 200 m up to 250 m from the site. A niche is located at 2375 m where drilling can be performed. Electricity for drilling can be arranged with a cored cable from a transformer located at a distance of 190 m from the site. The requirements for a site for TRUE-2 are fulfilled. CHEMLAB needs a site at a deeper location.

2.2.2 Site 2730

Site 2730 is positioned north of the 2-phase flow site at a vertical depth of 360 m and at a tunnel length of 2730 m. The requirements for the rock type is fulfilled north of 2730 m. The fracture frequency is fulfilled. A minor fracture zone is located at 2740 m /Markström et al., 1996/. The fracture zone has a transmissivity of 9.4 x 10^{-7} m^2/s. An inflow of 7.8 l/min was found in a percussion drilled probe hole HA2734A located at 2734 m. An inflow of 4.5 l/min was found in another drilled probe hole, HA2743A. In probe hole SA2751A an inflow of 24 l/min was observed. The hydraulic gradient is moderate. The ground water chemistry is stable. The REX site is located 130 m from the site 2730. Drilling can be performed from the wider part in the tunnel curve at 2730 m. Electricity for drilling can be arranged with a cored cable from a transformer located in a niche at 2567 m at a distance of 163 m from the site. Possible interference with 2-phase flow site can be expected. This has to be checked with drilling.

2.2.3 Site 2880

Site 2880 is positioned between the REX site and the TRUE-1 site at a vertical depth of 380 m and a tunnel length of 2880 m. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. A fracture zone, NNW4/NW3, is located 30 m east of 2880 m /Markström et al., 1996 and Winberg et al., 1996/. A transmissivity of 1.8 x 10^{-4} m^2/s was observed within this fracture zone. An inflow of 0.33 l/min was found in the percussion drilled probe hole SA2880A located at 2880 m. The hydraulic gradient is moderate. The ground water chemistry is stable but the most saline water in the earlier drilled SELECT boreholes was found in the REX boreholes /Winberg et al., 1996/. Drilling can be performed from the wider part in the tunnel curve at 2880 m or from the niche located at 2865 m. Electricity for drilling can be arranged with a cored cable from a transformer located in a niche at 2567 m at a distance of 313 m from the site. Possible interference with REX and TRUE-1 is expected. This has to be checked with drilling.

2.2.4 Site 3067

Site 3067 is positioned south of the TRUE-1 at a vertical depth of 410 m and at a tunnel length of 3067 m. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. A minor fracture zone is located at 3067 m /Markström et al., 1996/. The transmissivity of this fracture zone is 1.1 x 10^{-5} m^2/s. The hydraulic gradient is moderate. The ground water chemistry is stable. A chlorine content of 5650 mg/l was found in borehole KA3067A /Winberg et al., 1996/. An interference was observed during interference tests performed in the boreholes for TRUE-1 /Winberg et al., 1996/. A niche is located at 3067 m where drilling can be performed. Electricity for drilling can be arranged with a cored cable from a transformer located at 3106 m at a distance of 39 m from the site. Possible interference with REX and TRUE-1 is expected. This has to be checked with drilling.

2.2.5 Site 3105

Site 3105 is positioned at a vertical depth of 415 m and at a tunnel length of 3105 m. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. A minor fracture zone is located 15 m east of the niche at 3105 m /Markström et al., 1996/. A water conductive fracture with a transmissivity of 0.19 x 10^{-7} m^2/s is located at a position of 3090 m in the tunnel. The hydraulic gradient is moderate. The ground water chemistry is stable. A chlorine content of 3960 mg/l was found in borehole KA3105A /Winberg et al., 1996/. An interference was observed during interference tests performed in the boreholes for TRUE-1 /Winberg et al., 1996/. The TRUE-1 site is located 150 m from the site 3105. A niche is located at 3105 m where drilling can be performed. Electricity for drilling can be arranged with a cored cable from a transformer located at a distance of 5 m from the site. The requirements for a site for TRUE-2 or CHEMLAB are not fulfilled concerning the interference with TRUE-1.

2.2.6 Site TASL

Site TASL is positioned at a vertical depth of 420 m and at a tunnel length of 3170 m. The niche located at 3170 m, north of the assembly hall, is called niche TASL. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. One ductile fracture zone is located in the niche TASL, see Appendix 3. This fracture zone is oriented in NE (35°). Several fractures with an inflow of 0.3 lit/min up to 4.0 l/min were observed in the Assembly hall /Markström et al., 1996/. Inflow of water in the range from 0.009 up to 5.0 l/min were also observed in the niche TASL. The hydraulic gradient is moderate. The ground water chemistry is stable. The TRUE-1 site is located 125 m from the site TASL. Drilling can be performed from niche TASL. Electricity for drilling can be arranged with a cored cable from a transformer located at a distance of 80 m from the site. The niche TASL is planned to be used as a rescue chamber. The requirements for a site for TRUE-2 or CHEMLAB are not fulfilled concerning the planned usage of the niche as a rescue chamber.

2.2.7 Site TASE

Site TASE is positioned at a vertical depth of 450 m and at a tunnel length of 3385 m. The site is localised in a niche called TASE and is used as the deepest level for the elevator. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. No fracture zone is localised in the near vicinity of the site. Several fractures with an inflow of 0.6 l/min up to 1.5 l/min were observed in the TBM tunnel. The hydraulic gradient is moderate. The ground water chemistry is stable. A chlorine content of 6650 mg/l was found in borehole KA3385A localised in a niche opposite to the niche TASE /Winberg et al., 1996/. The TRUE-1 site is located 340 m from the site TASE. Drilling can be performed from niche TASE. Electricity for drilling can be arranged with a cored cable from a transformer located at a distance of 50 m from the niche. The niche is used as a level for the elevator and is also a separate fire protection cell. It can be a problem to find space for a container. The requirements for a site for TRUE-2 or CHEMLAB are not fulfilled concerning the needed space for a container and allocated spaces for radioactive protection.

2.2.8 Site TASJ

Site TASJ is positioned at a vertical depth of 450 m and at a tunnel length of 3505 m. The site is localised in a niche called TASJ. The requirements for the rock type is fulfilled. The fracture frequency is fulfilled. A minor fracture zone is localised in the near vicinity of the site. Several fractures with water inflow were observed in the side tunnel TASF. The hydraulic gradient is moderate. The ground water chemistry is stable. The site for long term tests of buffer material is planned to be localised 30-50 m from the site TASJ in tunnel TASG. Drilling can be performed from niche TASJ. Electricity for drilling can be arranged with a cored cable from a transformer located at a distance of 40 m from the niche. The requirements for a site for TRUE-2 or CHEMLAB are fulfilled.

2.2.9 List of possible sites

In Table 2-1 the accessibility and requirements of possible sites are listed.

Table 2-1. The accessibility and requirements of possible sites.

Site	Accessibility of site	Requirements fulfilled	Comments	Priority
2375	Yes	Yes	Fulfilled	1
2730	Yes	Yes	Possible interference with other experiments	1
2880	Yes	Yes	Possible interference with other experiments	1
3067	Yes	Yes	Possible interference with other experiments	1
3105	Yes	No	Interference with other experiments	2
TASL	No	Yes	Niche used as a rescue chamber	2
TASE	No	Yes	Space requirements not fulfilled	2
TASJ	Yes	Yes	Fulfilled	1

2.2.10 Characterisation of possible sites

The objectives with the characterisation work in the SELECT-2 for the localisation of sites for TRUE-2 and CHEMLAB experiments is to provide:

- data for determination of localisation of core holes
- data on boundary and rock conditions

Characterisation in the first stage is to summarise geological and hydrogeological data from the characterisation in the tunnel. In the following chapters 3 up to 7 only the sites with priority 1 are described.

3 Site 2375

3.1 Geology

3.1.1 Lithology

The following rock types have been identified in the vicinity of site 2375: Äspö diorite and fine-grained granite with Äspö diorite being the dominating rock. Fine-grained granite occur as inclusions, bands or veins.

Mineralogy and chemical composition of rocks and fracture minerals at Äspö have been described by /Wikman and Kornfält, 1995/ and compiled by /Tullborg E-L, 1995/. The following description is an excerpt of the latter. Characteristics for Äspö diorite and fine-grained granite are presented in Table 3-1.

Table 3-1. Characteristics of some rock types at Äspö /Tullborg E-L, 1995/.

	Äspö Diorite	Fine-grained granite
Texture	Medium grained, porphyritic	Fine grained
Age	Approx. 1800 Ma	Approx. 1800 Ma
Porosity (vol%)	0.5±0.2	0.3±0.2
Mineral composition (vol%)		
Quartz	14	31
K-feldspar	15	38
Plagioclase	45	23
Biotite	15	2.5
Muscovite	0.5	3
Epidote	6	1
Amphiboles	1	-
Sphene	2	0.5
Apatite	0.5	
Opaque minerals	1	1

3.1.2 Fracture fillings

The dominating fracture fillings at Äspö are chlorite and calcite. Epidote and quartz are also common. Clay minerals have been detected in some fracture zones and single fractures. The dominating clay minerals are illite and swelling mixed layer clay with a large illite component /Tullborg E-L, 1995/.

3.2 Geological Mapping

3.2.1 Standard tunnel mapping

Standard tunnel mapping from sections 2206 to 2526 m in the tunnel shows that the main rock type is Äspö diorite with veins and inclusions of fine-grained granite and greenstone. Plots from geological mapping are presented in Appendix 1, plots of geohydrology and groundwater chemistry are presented in Appendix 2 and plots of reinforcement and pregrouting are shown in Appendix 3.

3.2.2 Fractures

In the interval between 2350 and 2450 m totally 481 fractures have been observed. Fracture fillings from tunnel mapping between sections 2350 and 2450 m and niche at 2375 m are presented in Table 3-2. In the table two out of five observed mineral columns from the data base SICADA are shown. As can be seen, the most common fracture fillings are chlorite, calcite and epidote. A summary of the table below shows that 68% of the fractures have chlorite fillings, 48% calcite fillings and 10% epidote fillings. In the table also veins of fine-grained granite and pegmatite with a width less than 0.1 m are shown.

In Figure 3-1 the first mentioned mineral or vein (first mineral column in the data base) is shown in a structure log. The structure log consists of a tadpole presentation, a rose log and a polar log. In the tadpole the position of the dot represents the dip of the structure. The direction of the tale shows the azimuth direction where a tail directed upwards represent a strike towards north. The range of the azimuth is between 0 and 360° counted clockwise from north. The colour of the dots represent different minerals or veins observed in the first mineral column in the data base.

The rose and polar logs are divided into segments with a length of 25 m. The segments of the rose log have a width of 10°. Note that the dots in the polar log (Azimuth and Dip) represent the azimuth and dip of the structure. The dots do not represent poles to planes. As seen in the rose log strike directions in NW, NS and NE dominate. Also a semi-horizontal orientation of the structures are common.

Remark Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), All fractures (481 observations).

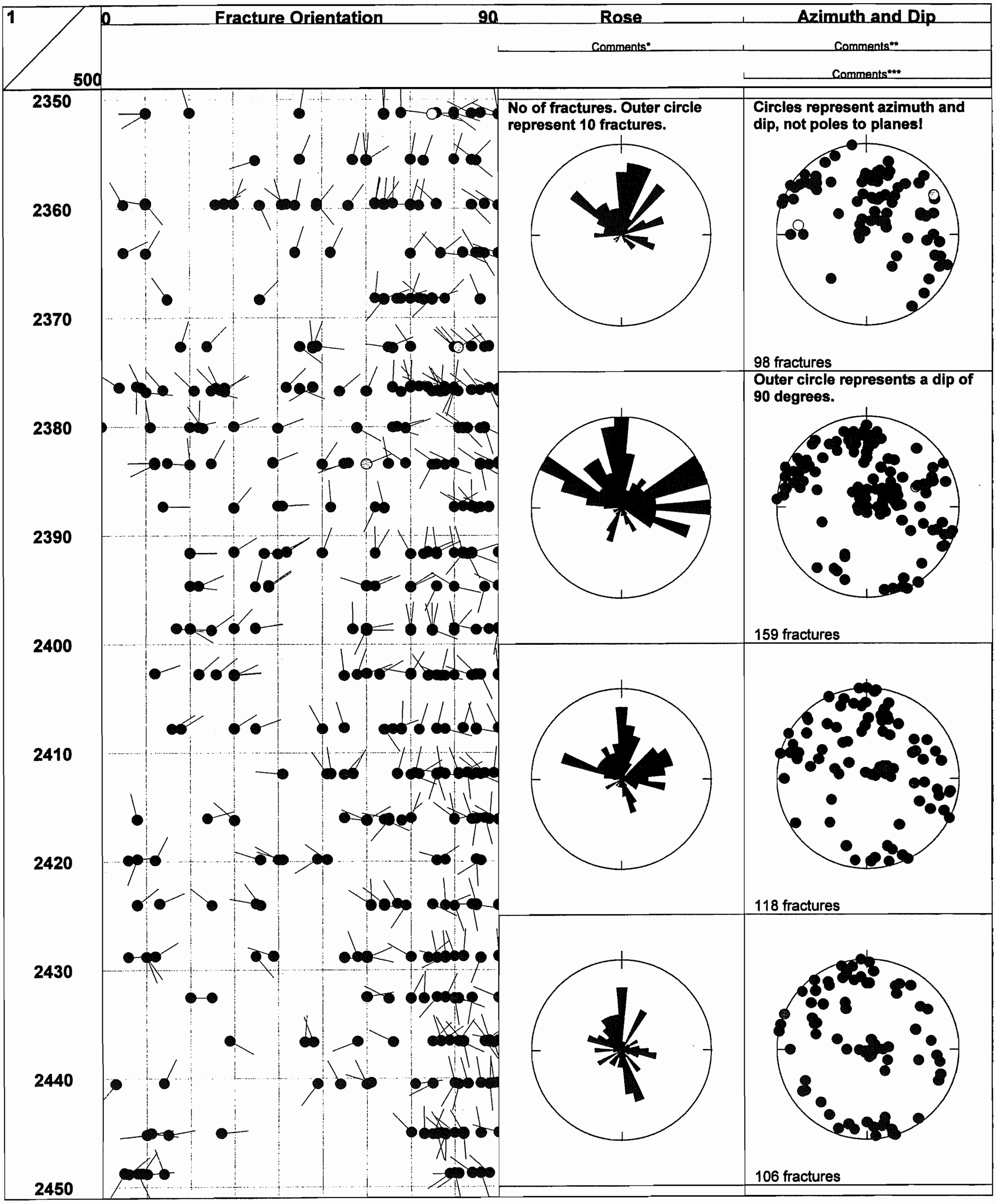


Figure 3-1. Structure log of fracture orientations for site 2375 (the first mineral column in the data base) presented as a tadpole presentation, a rose log and a polar log.

Table 3-2. Fracture fillings from tunnel mapping between 2350 - 2450 m.

Mineral 1	*Mineral 2*	*Fractures*	*%*
EP	KA	14	2,9%
EP	KL	22	4,6%
EP	MY	4	0,8%
EP	OX	3	0,6%
EP	PY	2	0,4%
EP	-	1	0,2%
FE	KA	1	0,2%
FE	KL	1	0,2%
FL	KA	2	0,4%
IJ	KA	2	0,4%
KA	BI	1	0,2%
KA	CY	2	0,4%
KA	KL	159	33,1%
KA	OX	9	1,9%
KA	-	45	9,4%
KL	BI	3	0,6%
KL	CY	1	0,2%
KL	OX	61	12,7%
KL	PY	1	0,2%
KL	-	77	16,0%
MY	OX	1	0,2%
OX	-	11	2,3%
QZ	FL	1	0,2%
QZ	KA	1	0,2%
QZ	OX	1	0,2%
-	-	23	4,8%
AT	-	22	4,6%
PG	-	10	2,1%
Total		481	100,0%

EP= epidote, KA= calcite, KL= chlorite, FE=ironoxide/hydroxide, FL=fluorite, IJ=grout, OX= oxidised, QZ= quartz, MY= mylonite, CY=clay, BI=biotite, "-"= no filling, AT=fine-grained granite and PG=pegmatite.

The corresponding plots for different minerals are presented in Appendix 5.All mineral columns in the data base are taken into account. Chlorite is the dominant fracture filling mineral. Chlorite occurs in 347 of 481 observations (72%). Orientations in NS and NE dominates. Calcite is the next common mineral and 262 of 481 observations were seen (54%). Orientations in NW and NS dominates. Epidote is the third common mineral and 69 of 481 observations were seen (14%). Orientations in NNW and NE dominates. Very few observations of mylonite were seen, 10 of 481 observations (2%). Orientations in NE and NW were observed. Water filled fractures or fractures with grout were observed in 8 occasions of 481 (1.7%). Orientations in NW, NS and EW were seen.

3.2.3 Fracture zones

Two observed fracture zones are located in the vicinity of site 2375. One is located at 2430 m and another at 2480 m, see the geological sheet in Appendix 1. The latter is named NE-2. The observed orientations of the different fracture groups within the fracture zones are presented in Figure 3-2.

The fracture zone at 2430 m has ductile precursors as mylonite is observed. The width of the fracture zone is about 0.5 m. The strike is towards NW (333°). Small amount of water inflow was observed within this fracture zone. The probe hole SA2420A gave however no inflow of water, see the geohydrological sheet in Appendix 2.

NE-2 has also ductile precursors as mylonite is observed. The width of the fracture zone NE-2 is 7 m. The strike is towards NE (28°). Small amount of water inflow of 0.73 l/min was observed within this fracture zone. The probe hole SA2453A gave an inflow of water of 0.245 l/min, see the geohydrological sheet in Appendix 2.

3.2.4 Water leakage

Eight fractures out of 481 have been marked as water bearing or containing grout. A total of 19 points of inflow of water are recorded in the data base in the range from 0.001 up to 0.3 l/min. Between 2350 and 2450 a total inflow of 0.468 l/min was observed.

3.2.5 RMR

In the tunnel between 2350 and 2450 m 25 mapping cells have been classified according to the RMR system /Bieniawski, 1988/. The ratings range from 60 to 84 with a median value of 73 corresponding to RMR classes I and II (see Table 3-3).

Classification of rock mass strength using RMR is the cumulative effect of weighted values given to specific parameters. The parameters considered in the RMR system are: intact rock uniaxial compressive strength (UCS), RQD, mean fracture spacing, fracture conditions, groundwater state and fracture orientation. The RMR value is the sum of these parameters which give an approximate guideline to values of rock parameters, as shown in Table 3-3 below.

Title	**SELECT-II. Fracture zones at 2420-2495.**		
Site	Tunnel section 2420-2495	**Coordinate System**	Azimuth relative to magnetic North
Borehole		**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture zone orientation, rose, azimuth and dip (note, not poles!)		

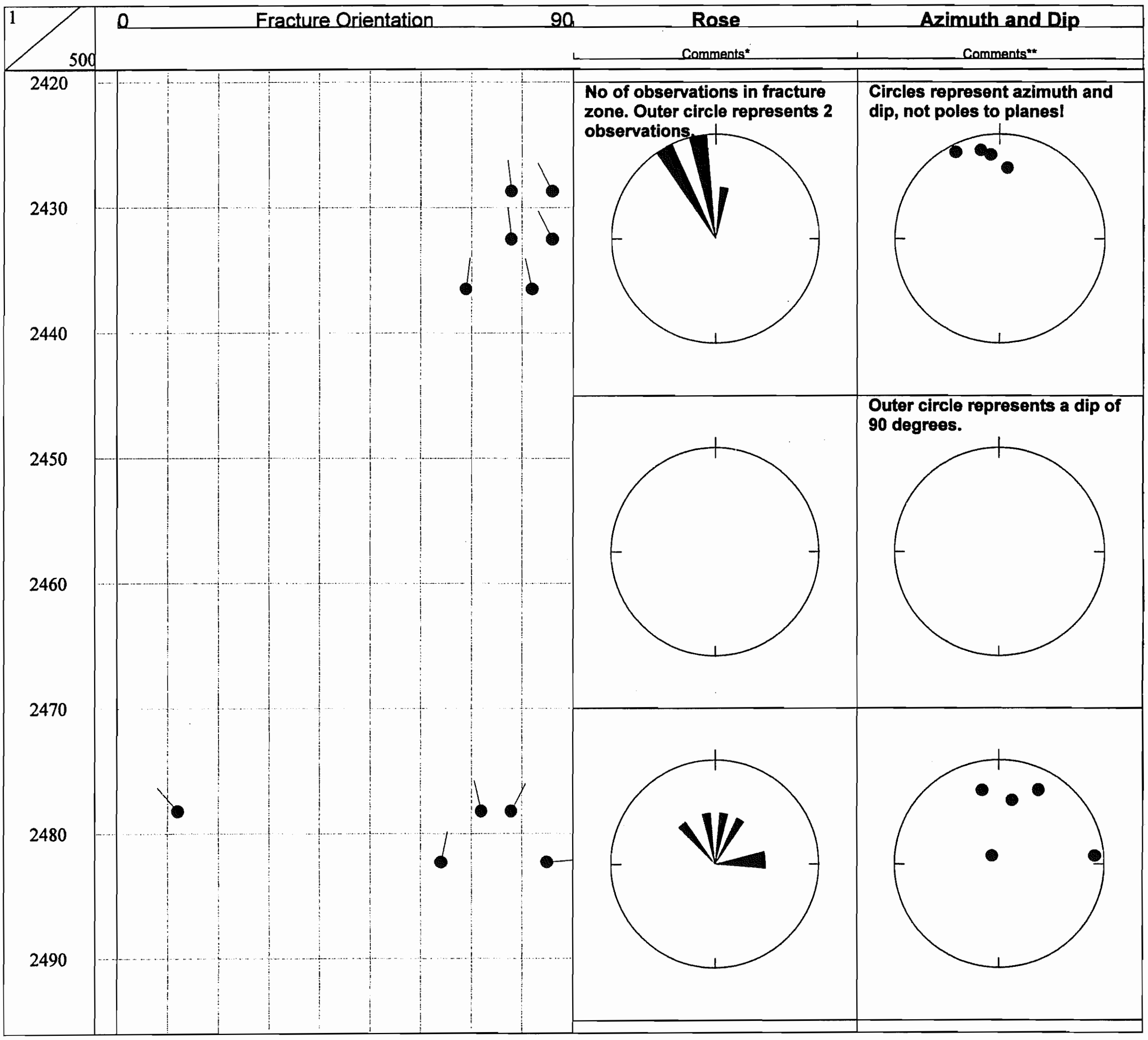


Figure 3-2. *The observed orientations of the different fracture groups within the fracture zones located at 2430 and 2480 m.*

Table 3-3. Guideline Properties Rock Mass Classes /Waltham A C, 1994/.

Class	I	II	III	IV	V
Description	Very Good Rock	Good Rock	Fair Rock	Poor Rock	Very Poor Rock
RMR	80-100	60-80	40-60	20-40	<20
Q Value	>40	10-40	4-10	1-4	<1
Friction angle Φ (°)	>45	34-45	25-35	15-25	<15
Cohesion (kPa)	>400	300-400	200-300	100-200	<100
SBP* (Mpa)	10	4-6	1-2	0.5	<0.2
Safe cut slope (°)	>70	65	55	45	<40
Tunnel support	None	Spot bolts	Pattern bolts	Bolts+shotcrete	Steel ribs
Stand up time, span	20 yr for 15 m	1 yr for 10 m	1 wk for 5 m	12 h for 2 m	30 min for 1 m

*) SBP= Safe Bearing Pressure

3.3 Inflow Measurements

Inflow measurements have been performed from March 1993 until October 1998 in the weir located at 2357 m and from April 1993 until October 1998 in the weir located at 2496 m. The aim of the measurements was to quantify the amounts of water inflow during the construction phase, see /Rhén et al., 1994/. The inflow at the two weirs are presented in Figure 3-3 and 3-4. The inflow into the weir located at 2357 varies between 59 up to 91 l/min with a median value of 76 l/min. In general the inflow decreases with time.

The main inflow into the weir positioned at 2357 m comes from a fracture located at 2230 m see Appendix 2, sheet geohydrology and groundwater chemistry. The inflow into the probe holes drilled at this position showed an inflow of 56 l/min and 513 l/min respectively. This fracture was grouted, see Appendix 3, sheet reinforcement and pregrouting. Three other sections at 2270, 2300 and 2350 m were also grouted.

The weir located at 2496 m show only a small inflow. The inflow in 2496 varies between 1.9 and 4.8 l/min with a median value of 3.0 l/min. The inflow comes mainly from the two observed fracture zones located at 2430 and 2480 m. The latter is in the structural model observed as NE-2 /Rhén et al., 1997/.

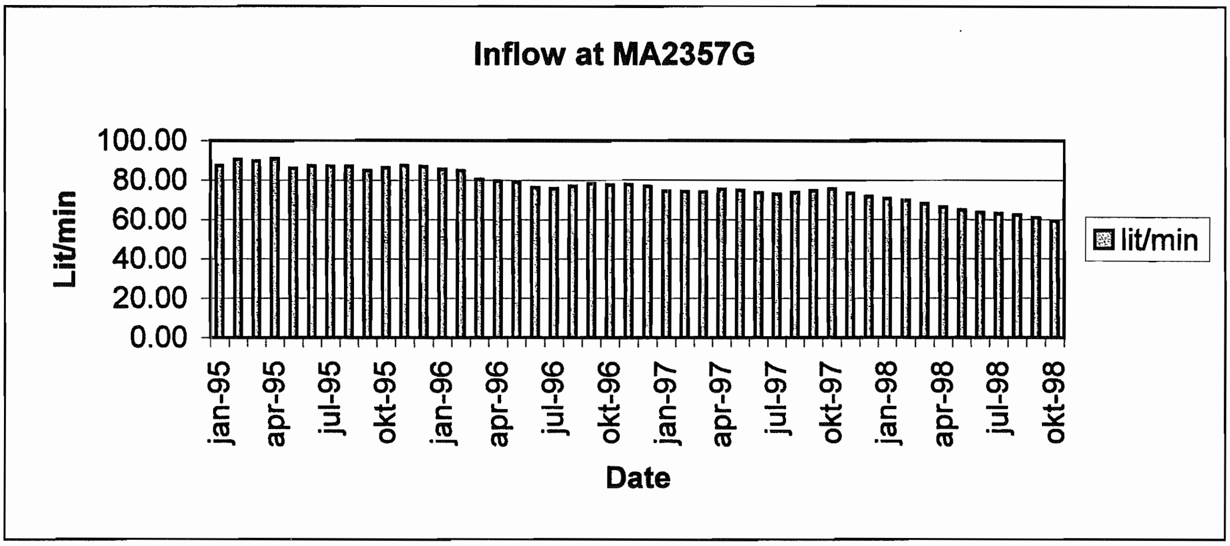


Figure 3-3. *Water inflow to the weir MA2357G located at section 2357 m.*

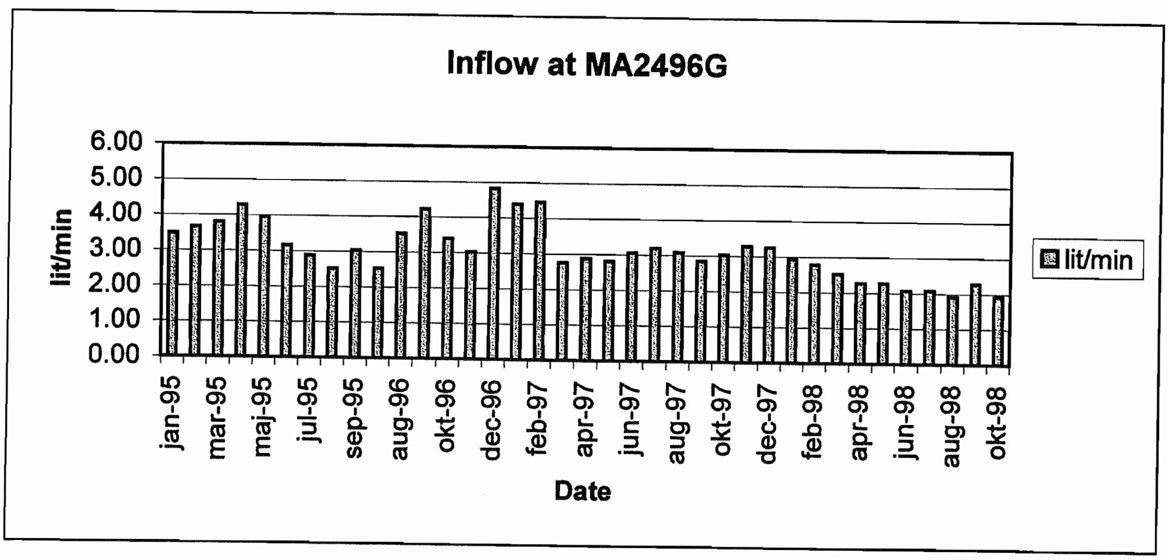


Figure 3-4. *Water inflow to the weir MA2496G located at section 2496 m.*

3.4 Chemistry

Electrical conductivity, pH and chlorine content have been measured from water samples taken in the weirs located at 2357 and 2496 m and are presented in Table 3-4. The electrical conductivity increases below 2357 m as well as the chlorine content.

Table 3-4 Electrical conductivity, pH and chlorine content taken on water samples from weirs.

Weir	Date	Electrical Conductivity (mS/m)	pH	Cl (mg/l)
MA2357G	950221	1453	7.4	
	950227	1431		
	950314	1420	7.8	4939
	950403	1380	7.7	4932
MA2496G	950227	1661		
	950314	1640		
	950403	1640	7.4	5804

4 Site 2730

4.1 Geology

4.1.1 Lithology

The following rock types have been identified in the vicinity of site 2730 corresponding to sections 2680 up to 2780 m in the main tunnel: Småland granite dominates the section (71%), see Appendix 1. Äspö diorite occur as inclusions (6%). Fine-grained granite occur as bands or veins (22%). Greenstone occur as inclusions (1%). Characteristics for Äspö diorite and fine-grained granite were presented in Table 3-1.

4.1.2 Fracture fillings

The dominating fracture fillings in the vicinity of site 2730 are chlorite and calcite. Epidote and quartz are also common. Clay minerals have been detected in some fracture zones and single fractures. The dominating clay minerals are illite and swelling mixed layer clay with a large illite component /Tullborg E-L, 1995/.

4.2 Geological Mapping

4.2.1 Standard tunnel mapping

Standard tunnel mapping from tunnel section 2680 up to 2780 m in the main TASA tunnel shows that the main rock type is Småland granite with veins and inclusions of Äspö diorite, fine-grained granite and greenstone. Plots from geological mapping, geohydrology and reinforcements are presented in Appendix 1 up to Appendix 3.

In the interval between 2680 and 2780 m totally 130 fractures have been observed. All fractures occuring in sections with increased fracturing, see Appendix 1, are not taken into account. Therefore very few fractures are observed in the first 25 m section in the structure log, Figure 4-1. Fracture fillings from tunnel mapping between sections 2680 and 2780 m are presented in Table 4-1. In the table two out of five observed mineral columns from the data base are shown. As can be seen, the most common fracture fillings are chlorite, calcite and epidote. A summary of the table below shows that 62% of the fractures have chlorite fillings, 47% calcite fillings and 12% epidote fillings. In the table also veins of fine-grained granite and pegmatite with a width less than 0.1 m are shown.

In Figure 4-1 the first mentioned mineral or vein (first mineral column in the data base) is shown in a structure log. The structure log consists of a tadpole presentation, a rose log and a polar log, see chapter 3.2. As seen in the polar and rose logs strike directions in NW, NS and NE dominate. Also a semi-horizontal orientation of the structures are common.

The corresponding plots for different minerals are presented in Appendix 6. All mineral columns in the data base are taken into account. Chlorite is the dominant fracture filling mineral. Chlorite occurs in 84 of 130 observations (64%). Orientations in NS and NW dominates. Calcite is the next common mineral and 68 of 130 observations were seen (52%). Orientations in NW and NS dominates. Epidote is the third common mineral and 19 of 130 observations were seen (15%). Orientations in NW and NS dominates.Very few observations of mylonite were seen, 2 of 130 observations (1.5%). Orientations in NE were observed. Water filled fractures or fractures with grout are presented in Appendix 6. A few observations, 18 of 130 were seen (14%). Orientations in NW and NS were seen.

4.2.2 Fracture zones

One observed fracture zone with a strike in NE and gently dipping towards SE is located at the section 2690 m. In the section between 2660 and 2720 m increased fracturing is observed in connection with fine-grained granite, see the geological sheet in Appendix 1. A fracture zone oriented in NE is located at 2740 m and another fracture zone is located at 2760 m. A section with increased fracturing is located between 2750 and 2770 m. The observed orientations of the different fracture groups within the fracture zones or zones with increased fracturing are presented in Figure 4-2.

The fracture zones at 2690 m and 2760 m has ductile precursors as mylonite is observed. The width of the fracture zones is from 0.2 up to 0.5 m. The strikes are towards NE (19°) and ENE (88°). Drops of water were observed within these two fracture zones. The probe hole SA2681A located at 2681 m gave an inflow of water of 2.25 l/min, see the geohydrological sheet in Appendix 2. The probe hole SA2734A located at 2734 m gave an inflow of 7.84 l/min and the probe hole SA2751A located at 2751 m gave an inflow of 24.0 l/min.

4.2.3 Leakage

18 fractures out of 130 have been marked as water bearing or containing grout. A total of 85 points of inflow of water are recorded in the data base in the range from 0.001 up to 5.0 l/min. Between 2680 and 2780 m a total inflow of 12.51 l/min was observed.

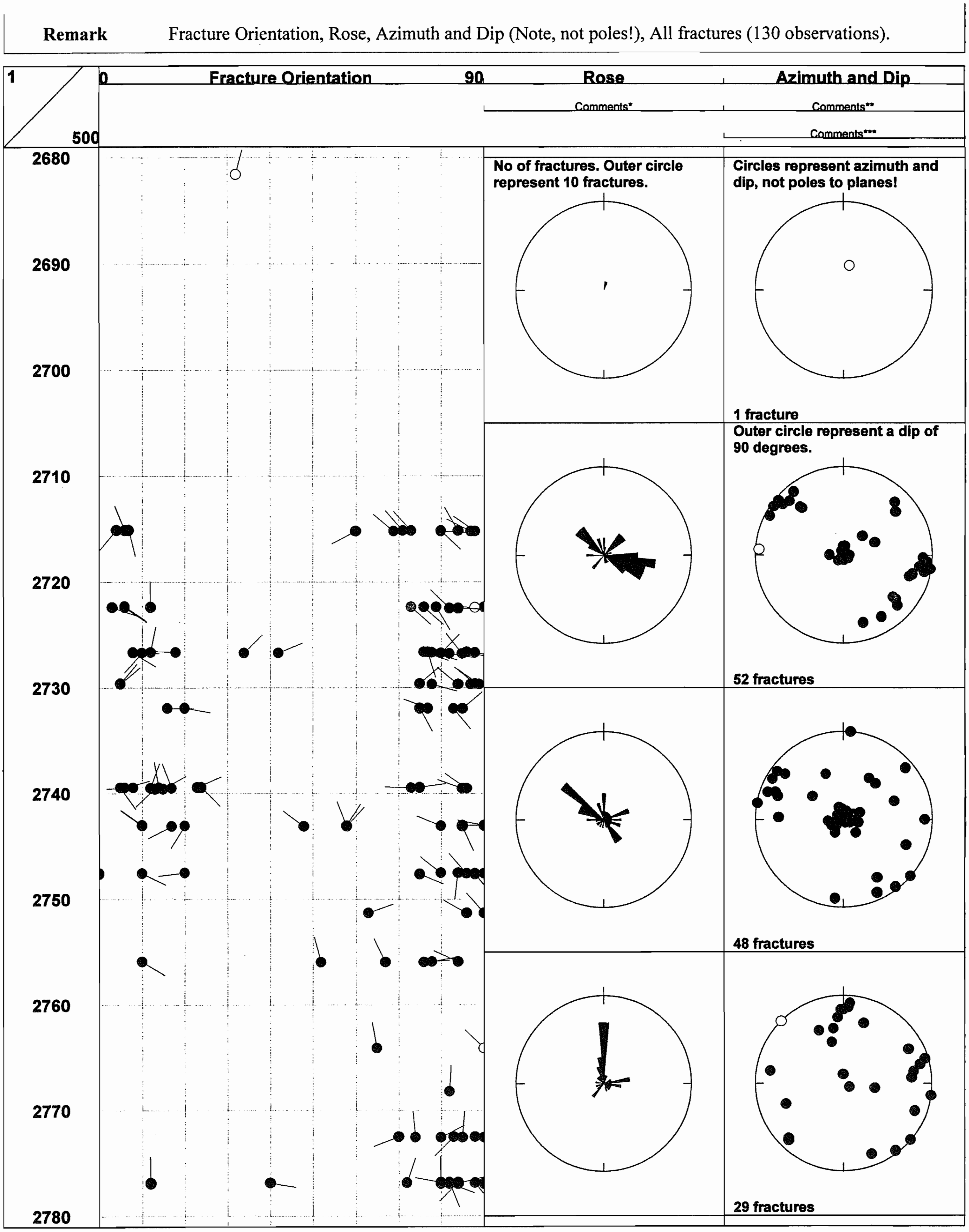


Figure 4-1. Structure log of fracture orientations for site 2730 (the first mineral column in the data base) presented as a tadpole presentation, a rose log and a polar log.

Table 4-1. Fracture fillings from tunnel mapping in the vicinity of site 2730.

Mineral 1	*Mineral 2*	*Fractures*	*%*
EP	KA	1	0,8%
EP	KL	8	6,2%
EP	OX	1	0,8%
EP	QZ	3	2,3%
EP	-	3	2,3%
IJ	FL	1	0,8%
IJ	KA	1	0,8%
IJ	KL	1	0,8%
IJ	-	1	0,8%
KA	FL	1	0,8%
KA	KL	37	28,5%
KA	OX	5	3,9%
KA	-	16	12,3%
FL	KL	1	0,8%
KL	FE	1	0,8%
KL	OX	4	3,1%
KL	-	26	20,0%
MY	-	1	0,8%
OX	-	1	0,8%
QZ	KL	2	1,5%
QZ	OX	1	0,8%
QZ	-	1	0,8%
-	-	11	8,5%
AT	-	1	0,8%
PG	-	1	0,8%
Total		130	100,0%

EP= epidote, KA= calcite, KL= chlorite, FE=ironoxide/hydroxide, FL=fluorite, IJ=grout, OX= oxidised, QZ= quartz, MY= mylonite, "-"= no filling, AT=fine grained granite and PG=pegmatite.

4.2.4 RMR

In the tunnel between 2680 and 2780 m 23 mapping cells have been classified according to the RMR system /Bieniawski, 1988/. The ratings range from 40 to 72 with a median value of 52 corresponding to RMR classes II and III (see Table 3-3).

Remark Fracture Zone Orientation, Rose, Azimuth and Dip (Note, not poles!).

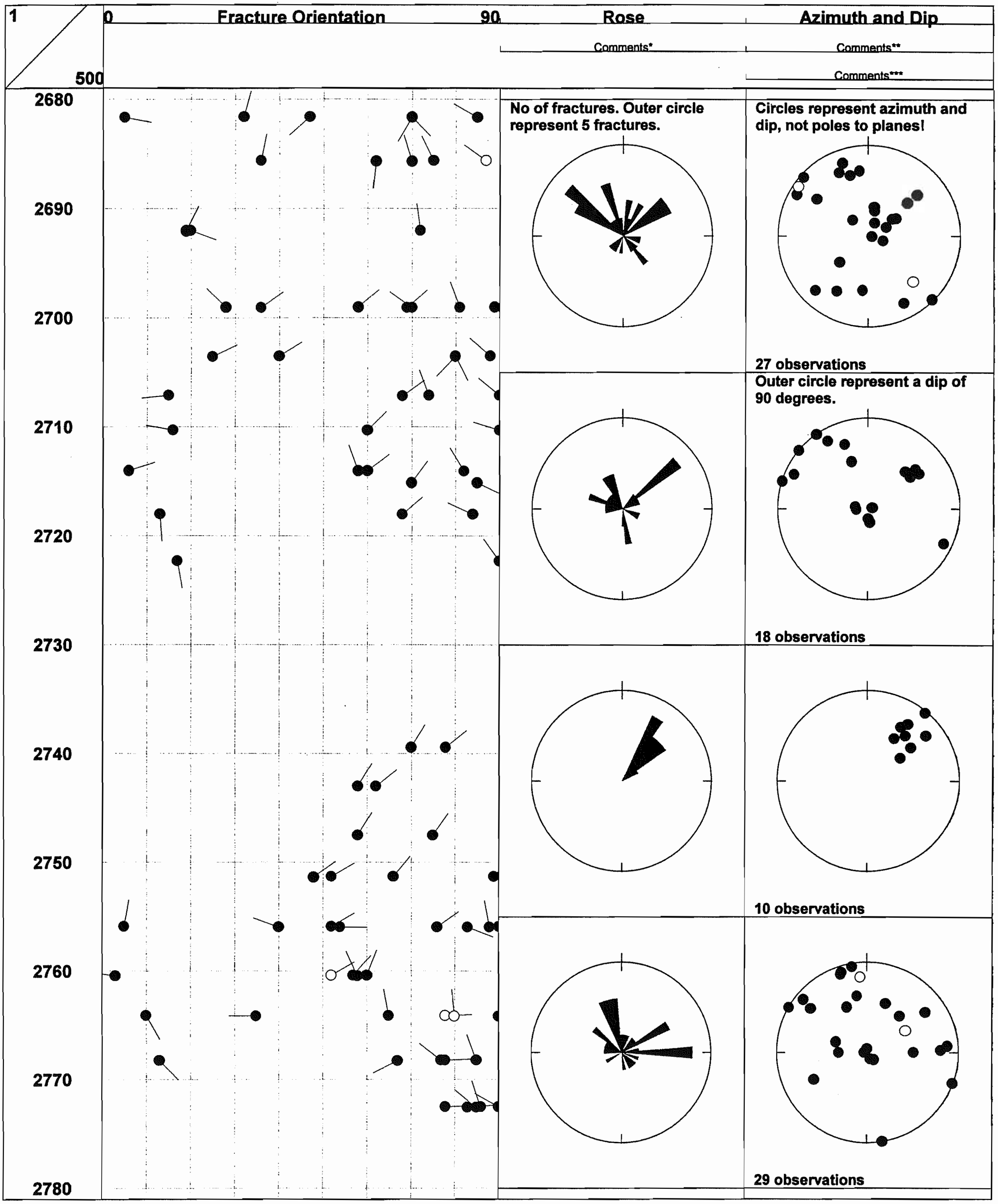


Figure 4-2. *The observed orientations of the different fracture groups within the fracture zones in the section between 2680 and 2780 m.*

4.3 Inflow Measurements

Inflow measurements have been performed from May 1993 until October 1998 in the weir located at 2699 m and from December 1993 until October 1998 in the weir located at 2840 m in the main tunnel TASA. The aim of the measurements was to quantify the amounts of water inflow during the construction phase, see /Rhén et al., 1994/. The inflow into the weirs are presented in Figures 4-3 and 4-4. The inflow into the weir located at 2699 m varies between 45 up to 98 l/min with a median value of 51 l/min. In general the inflow decreases a small amount with time. The main inflow into the weir positioned at 2699 m comes from a NE trending fracture zone located at 2690 m.

The inflow into the weir located at 2840 m varies between 23 up to 57 l/min with a median value of 25 l/min. In general the inflow decreases a small amount with time. The main inflow into the weir positioned at 2840 m comes from NE trending fracture zones located between 2740 m and 2760 m. A high inflow of 5 l/min was observed from a bolt hole located at 2743 m.

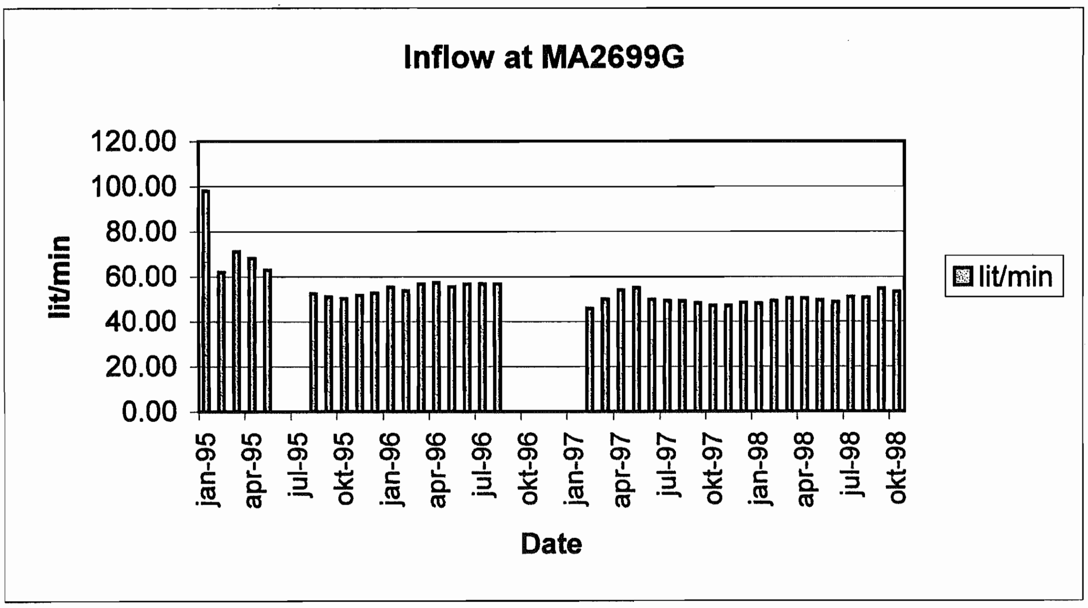


***Figure 4-3**. Water inflow to the weir MA2699G located at section 2699 m.*

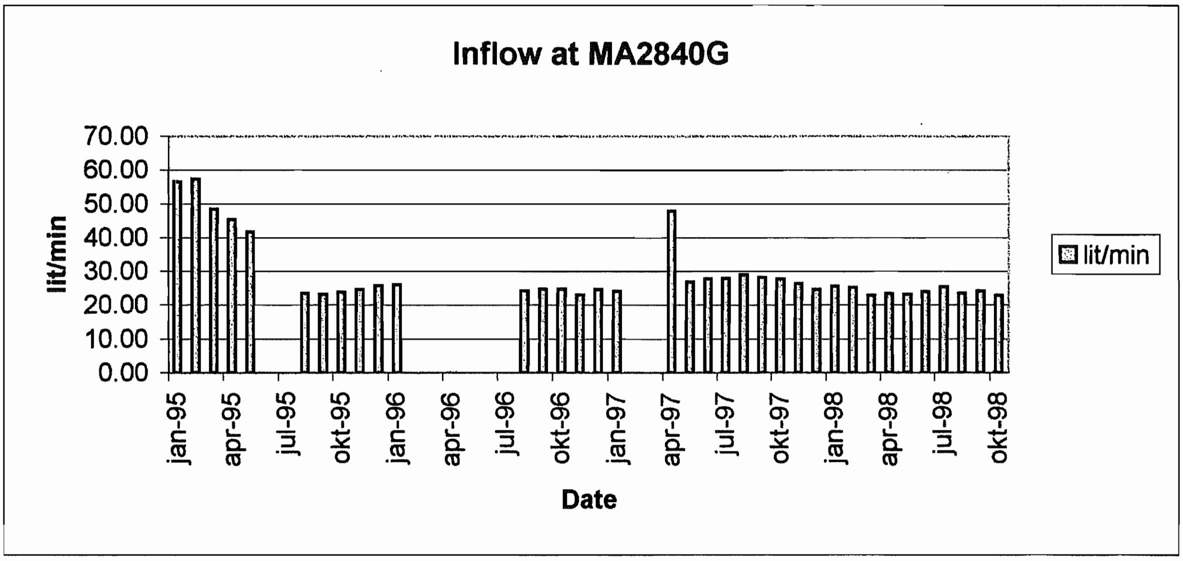


Figure 4-4. Water inflow to the weir MA2840G located at section 2840 m.

4.4 Chemistry

Electrical conductivity, pH and chlorine content have been measured from water samples taken in the weirs located at 2699 and 2840 m and are presented in Table 4-2. The electrical conductivity increases below 2699 m as well as the chlorine content.

Table 4-2 Electrical conductivity, pH and chlorine content taken on water samples from weirs.

Weir	Date	Electrical Conductivity (mS/m)	pH	Cl (mg/l)
MA2699G	950201	1659	6.9	
	950227	1703		
	950314	1740	7.6	6360
	950403	1740	7.4	6330
MA2840G	950201	2000	6.8	
	950227	2000		
	950314	2250	7.6	8707
	950403	2400		8977

5 Site 2880

5.1 Geology

5.1.1 Lithology

The following rock types have been identified in the vicinity of site 2880 corresponding to sections 2840 up to 2940 m in the main tunnel: Äspö diorite dominates the section (60%), see Appendix 1. Småland granite occur as inclusions (25%). Fine-grained granite occur as bands or veins (13%). Pegmatite occur also as bands or veins (1%). Greenstone occur as inclusions (1%). Characteristics for Äspö diorite and fine-grained granite were presented in Table 3-1.

5.1.2 Fracture fillings

The dominating fracture fillings in the vicinity of site 2880 are chlorite and calcite. Epidote and quartz are also common. Clay minerals have been detected in some fracture zones and single fractures. The dominating clay minerals are illite and swelling mixed layer clay with a large illite component /Tullborg E-L, 1995/.

5.2 Geological Mapping

5.2.1 Standard tunnel mapping

Standard tunnel mapping from tunnel section 2840 up to 2940 m in the main TASA tunnel shows that the main rock type is Äspö diorite with inclusions and veins of Småland granite, fine-grained granite and greenstone. Plots from geological mapping, geohydrology and reinforcements are presented in Appendix 1 up to Appendix 3.

In the interval between 2840 and 2940 m totally 259 fractures have been observed. Fracture fillings from tunnel mapping in the sections between 2840 and 2940 m are presented in Table 5-1. In the table two out of five observed mineral columns from the data base are shown. As can be seen, the most common fracture fillings are chlorite, calcite and epidote. A summary of the table below shows that 69% of the fractures have chlorite fillings, 48% calcite fillings and 14% epidote fillings. In the table also veins of fine-grained granite and pegmatite with a width less than 0.1 m are shown.

In Figure 5-1 the first mentioned mineral or vein (first mineral column in the data base) is shown in a structure log. The structure log consists of a tadpole presentation, a rose log and a polar log, see chapter 3.2. As seen in the polar and rose logs strike directions

in NW, NS and NE dominate. Also a semi-horizontal orientation of the structures are common.

The corresponding plots for different minerals are presented in Appendix 7. All mineral columns in the data base are taken into account. Chlorite is the dominant fracture filling mineral. Chlorite occurs in 188 of 259 observations (72%). Orientations in NS, NE and NW dominates. Calcite is the next common mineral and 138 of 259 observations were seen (53%). Orientations in NW and NS dominates. Epidote is the third common mineral and 40 of 259 observations were seen (15%). Orientations in NW, NE and NS dominates. Very few observations of mylonite were seen, 5 of 259 observations (2%). Orientations in NS and NE were observed. Water filled fractures or fractures with grout are presented in Appendix 7. A few observations, 18 of 259 were seen (7%). Orientations in NW and WNW were seen.

5.2.2 Fracture zones

One observed fracture zone with a strike in NNE (8°) and dipping towards E is located at the section 2865 m. In the section between 2855 and 2860 m increased fracturing is observed in the roof, see the geological sheet in Appendix 1. A fracture zone oriented in NW (128°) is located at 2920 m (NNW4 and NW3). The observed orientations of the different fracture groups within the fracture zones or zones with increased fracturing are presented in Figure 5-2.

The fracture zone at 2865 m has ductile precursors as mylonite is observed. The width of the fracture zone is 0.3 m. The strike is towards NNE (8°). Only sporadic drops of water were observed within this zone (0.04 l/min).The probe hole SA2850A located at 2850 m gave an inflow of water of 0.014 l/min, see the geohydrological sheet in Appendix 2. The fracture zone at 2920 m was observed as brittle. The width of the fracture zone is 15 m. The strike is towards NW (128°). Inflow of water was observed within this zone (21.5 l/min). The probe hole SA2897A located at 2897 m gave an inflow of 400 l/min and the probe hole SA2912A located at 2912 m gave an inflow of 73.2 l/min, see Appendix 2. The fracture zone located at 2920 m was grouted, see Appendix 3, sheet reinforcement and pregrouting.

5.2.3 Leakage

18 fractures out of 259 have been marked as water bearing or containing grout. A total of 36 points of inflow of water are recorded in the data base in the range from 0.002 up to 10.0 l/min. Between 2840 and 2940 m a total inflow of 26.5 l/min was observed.

Remark Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), All fractures (259 observations).

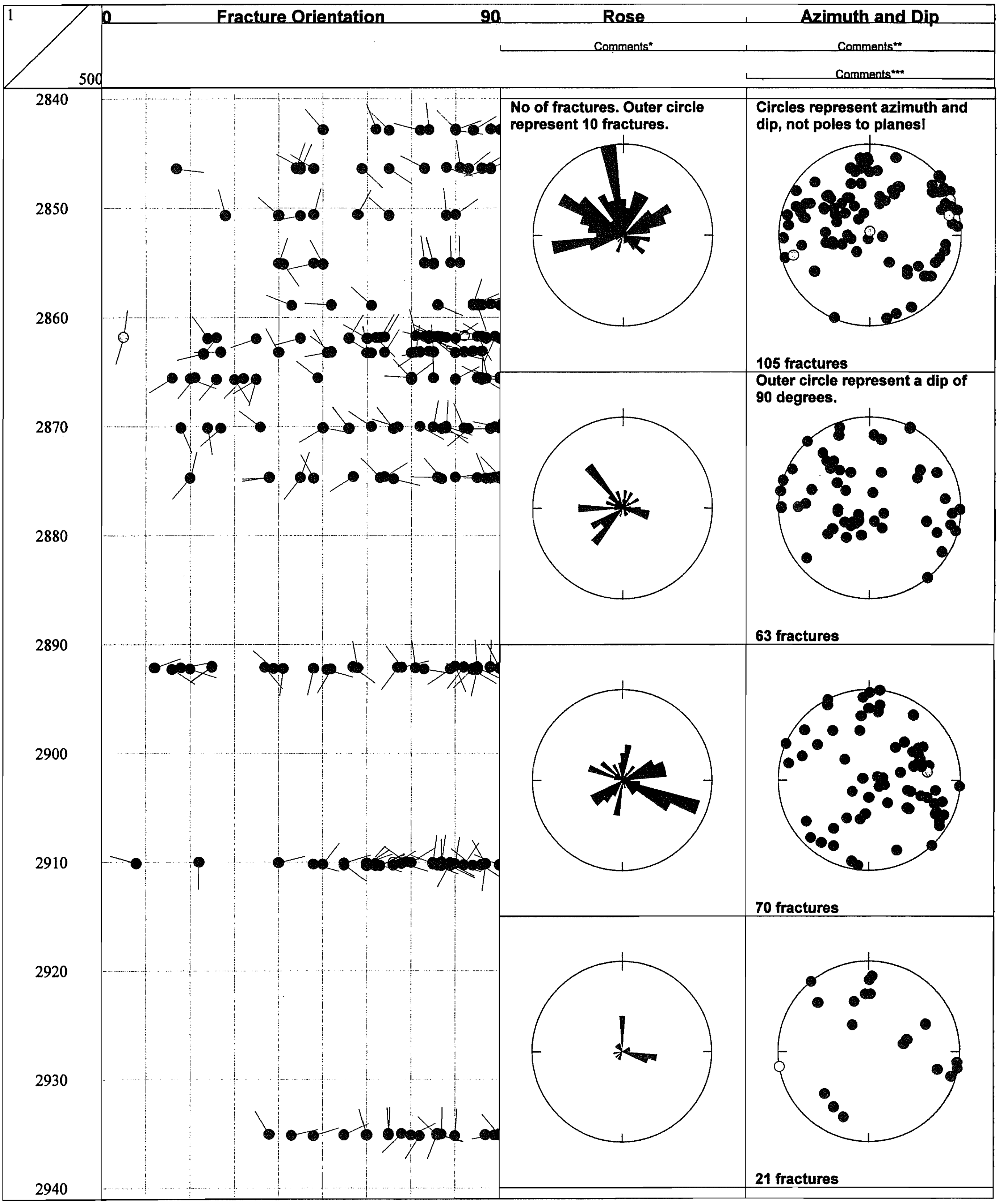


Figure 5-1. *Structure log of fracture orientations for site 2880 (the first mineral column in the data base) presented as a tadpole presentation, a rose log and a polar log.*

Table 5-1. Fracture fillings from tunnel mapping in the vicinity of site 2880.

Mineral 1	*Mineral 2*	*Fractures*	*%*
EP	KA	4	1,5%
EP	KL	15	5,8%
EP	MY	2	0,8%
EP	OX	2	0,8%
EP	QZ	3	1,2%
EP	-	10	3,9%
FE	KA	3	1,2%
FE	KL	2	0,8%
FE	-	1	0,4%
IJ	-	1	0,4%
KA	CY	1	0,4%
KA	FE	2	0,8%
KA	KL	83	32,0%
KA	OX	2	0,8%
KA	-	29	11,2%
KL	FE	7	2,7%
KL	OX	4	1,5%
KL	-	53	20,5%
MY	-	1	0,8%
QZ	KA	1	0,4%
QZ	KL	14	5,4%
QZ	-	2	0,8%
-	-	11	4,2%
AT	PG	1	0,4%
AT	-	3	1,2%
PG	-	2	0,8%
Total		259	100,0%

EP= epidote, KA= calcite, KL= chlorite, FE=ironoxide/hydroxide, IJ=grout, CY=clay, OX= oxidised, QZ= quartz, MY= mylonite, "-"= no filling, AT=fine grained granite and PG=pegmatite.

5.2.4 RMR

In the tunnel between 2840 and 2940 m 13 mapping cells have been classified according to the RMR system /Bieniawski, 1988/. The ratings range from 48 to 92 with a median value of 74 corresponding to RMR classes I to III (see Table 3-3).

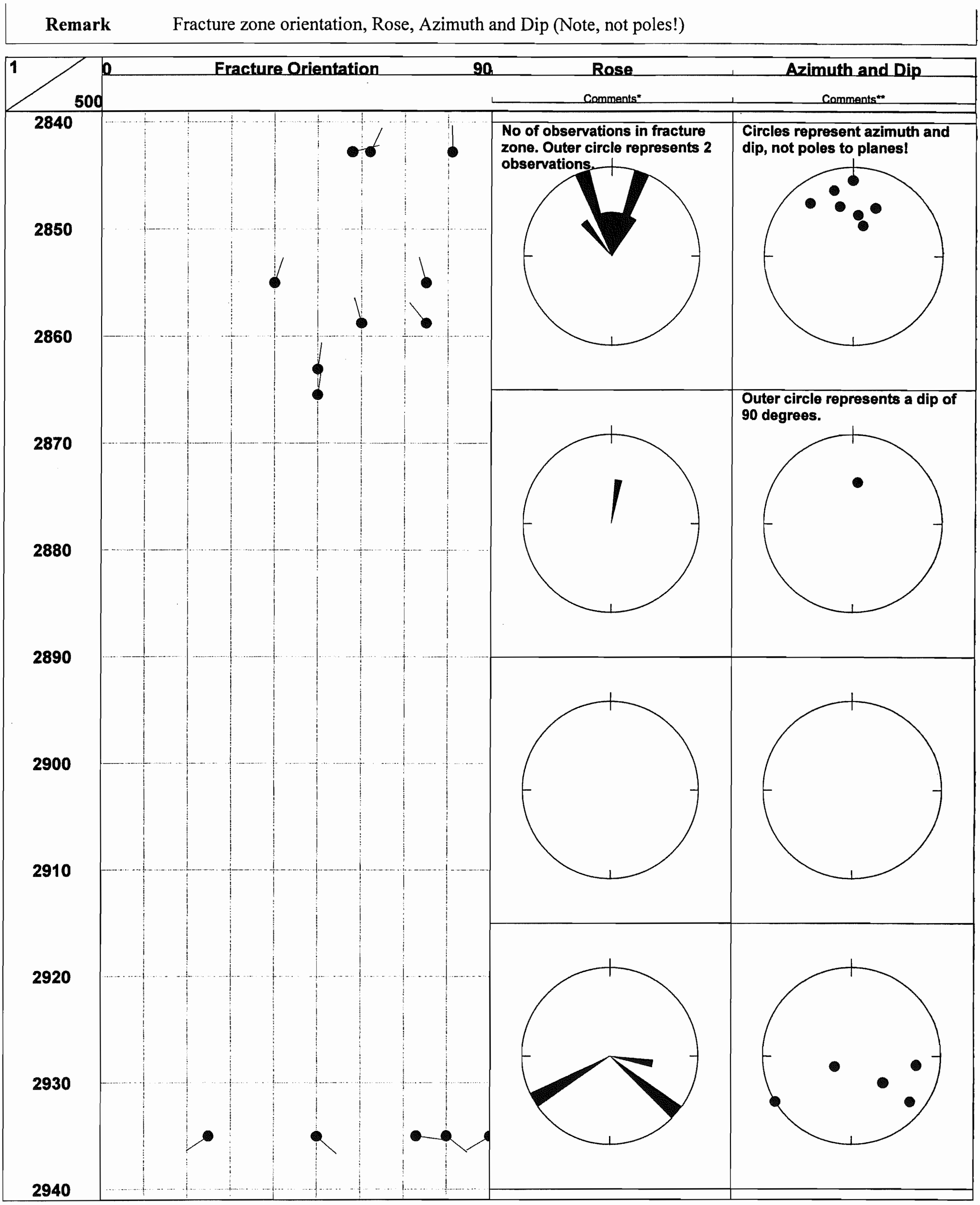


Figure 5-2. *The observed orientations of the different fracture groups within the fracture zones in the section between 2840 and 2940 m.*

5.3 Inflow Measurements

Inflow measurements have been performed from January 1994 until October 1998 in the weir located at 2994 m in the main tunnel TASA. The aim of the measurements was to quantify the amounts of water inflow during the construction phase, see /Rhén et al., 1994/. The inflow at the weir is presented in Figure 5-3. The inflow into the weir located at 2994 m varies between 50 up to 75 l/min with a median value of 63 l/min. In general the inflow decreases a small amount with time.

The main inflow into the weir positioned at 2994 m comes from the NW trending fracture zone located between 2920 and 2935 m (NNW4 and NW3), see Appendix 2.

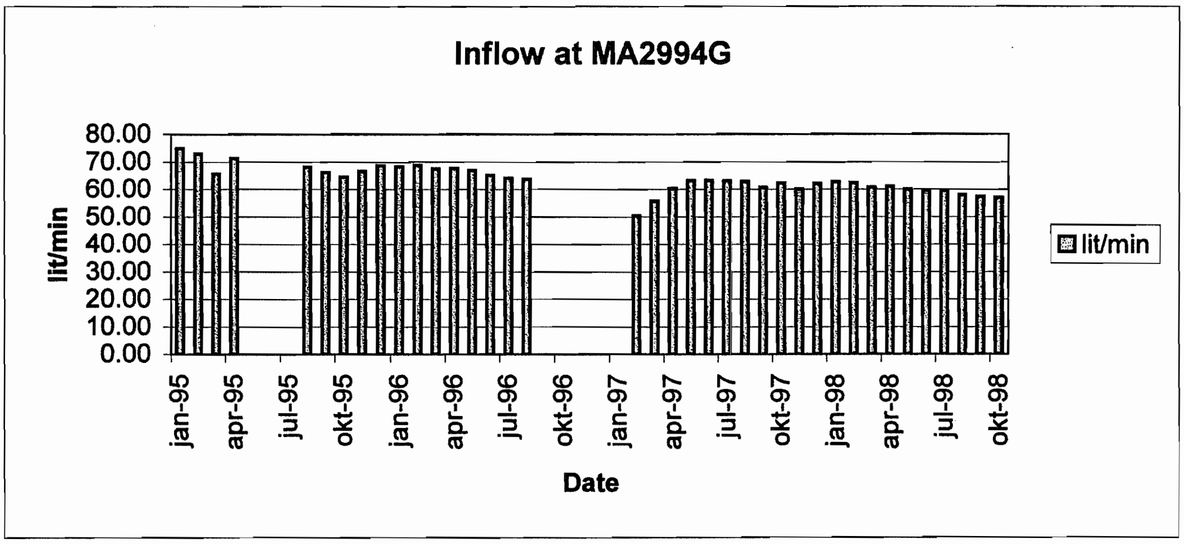


Figure 5-3. Water inflow to the weir MA2994G located at section 2994 m.

5.4 Chemistry

Electrical conductivity and pH have been measured in the weir MA2994G and are presented in Table 5-2 /Rhén et al., 1997/. The chlorine content (C) has not been measured. In Table 5-2 below the salinity (TDS) has been calculated according to the formula:

$TDS = 4.67 \cdot 10^{-3} / 0.741 \cdot C$ (g/l) /Wikberg, 1991/.

The estimated salinity (TDS) seems a little overestimated by comparison with the measured chlorine content in Table 4-2.

Table 5-2 Electrical conductivity, pH and salinity (TDS) taken on water samples from weirs.

Weir	Date	Electrical Conductivity (mS/m)	pH	TDS (mg/l)
MA2994G	950201	1744	6.8	10991
	950227	1707		10758
	950314	1720		10840
	950403	1740	7.5	10966

6 Site 3067

6.1 Geology

6.1.1 Lithology

The following rock types have been identified in the vicinity of site 3067 corresponding to sections 3040 up to 3140 m in the main tunnel: Äspö diorite dominates the section (65%), see Appendix 1. Småland granite occur as inclusions (20%). Fine-grained granite occur as bands or veins (8%). Pegmatite occur also as bands or veins (1%). Greenstone occur as inclusions (6%). Characteristics for Äspö diorite and fine-grained granite were presented in Table 3-1.

6.1.2 Fracture fillings

The dominating fracture fillings in the vicinity of site 3067 are chlorite and calcite. Epidote and quartz are also common. Clay minerals have been detected in some fracture zones and single fractures. The dominating clay minerals are illite and swelling mixed layer clay with a large illite component /Tullborg E-L, 1995/.

6.2 Geological Mapping

6.2.1 Standard tunnel mapping

Standard tunnel mapping from tunnel section 3040 up to 3140 m in the main TASA tunnel shows that the main rock type is Äspö diorite with inclusions and veins of Småland granite, fine-grained granite and greenstone. Plots from geological mapping, geohydrology and reinforcements are presented in Appendix 1 up to Appendix 3.

In the interval between 3040 and 3140 m totally 294 fractures have been observed. Fracture fillings from tunnel mapping between sections 3040 and 3140 m are presented in Table 6-1. In the table two out of five observed mineral columns from the data base are shown. As can be seen, the most common fracture fillings are chlorite, calcite and epidote. A summary of the table below shows that 79% of the fractures have chlorite fillings, 48% calcite fillings and 10% epidote fillings. In the table also veins of fine-grained granite and pegmatite with a width less than 0.1 m are shown.

In Figure 6-1 the first mentioned mineral or vein (first mineral column in the data base) is shown in a structure log. The structure log consists of a tadpole presentation, a rose log and a polar log, see chapter 3.2. As seen in the polar and rose logs strike directions

in NW and NE dominate. Also a semi-horizontal orientation of the structures are common.

The corresponding plots for different minerals are presented in Appendix 8. All mineral columns in the data base are taken into account. Chlorite is the dominant fracture filling mineral. Chlorite occurs in 239 of 294 observations (81%). Orientations in NW and NE dominates. Calcite is the next common mineral and 148 of 294 observations were seen (50%). Orientations in NW and NE dominates. Epidote is the third common mineral and 33 of 294 observations were seen (11%). Orientations in NW, NE and NS dominates. Only one observation of mylonite were seen, 1 of 294 observations. Orientation in NW was observed. Water filled fractures or fractures with grout are presented in Appendix 8. A few observations, 20 of 294 were seen (7%). Orientations in NW and WNW were seen.

6.2.2 Fracture zones

Three observed fracture zones with strike in NW (115° - 122°) are located at the sections 3070, 3085 and 3100 m, see Appendix 1. The observed orientations of the different fracture groups within the fracture zones are presented in Figure 6-2.

The fracture zone at 3085 m has ductile precursors. The width of the fracture zones are between 0.4 and 0.7 m. The strike is towards NW (115° - 122°). Drops and minor flow of water were observed from these fracture zones (0.04 - 0.95 l/min).The probe hole SA3045A located at 3045 m gave an inflow of water of 24.3 l/min, see the geohydrological sheet in Appendix 2. The probe hole SA3057A located at 3057 m gave an inflow of 0.012 l/min and the probe hole SA3075A located at 3075 m gave an inflow of 0.0012 l/min. Not any one of these fracture zones were grouted, see Appendix 3, sheet reinforcement and pregrouting.

6.2.3 Leakage

20 fractures out of 294 have been marked as water bearing or containing grout. A total of 38 points of inflow of water are recorded in the data base in the range from 0.002 up to 5.0 l/min. Between 3040 and 3140 m a total inflow of 16.4 l/min was observed.

Remark Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), All fractures (294 observations).

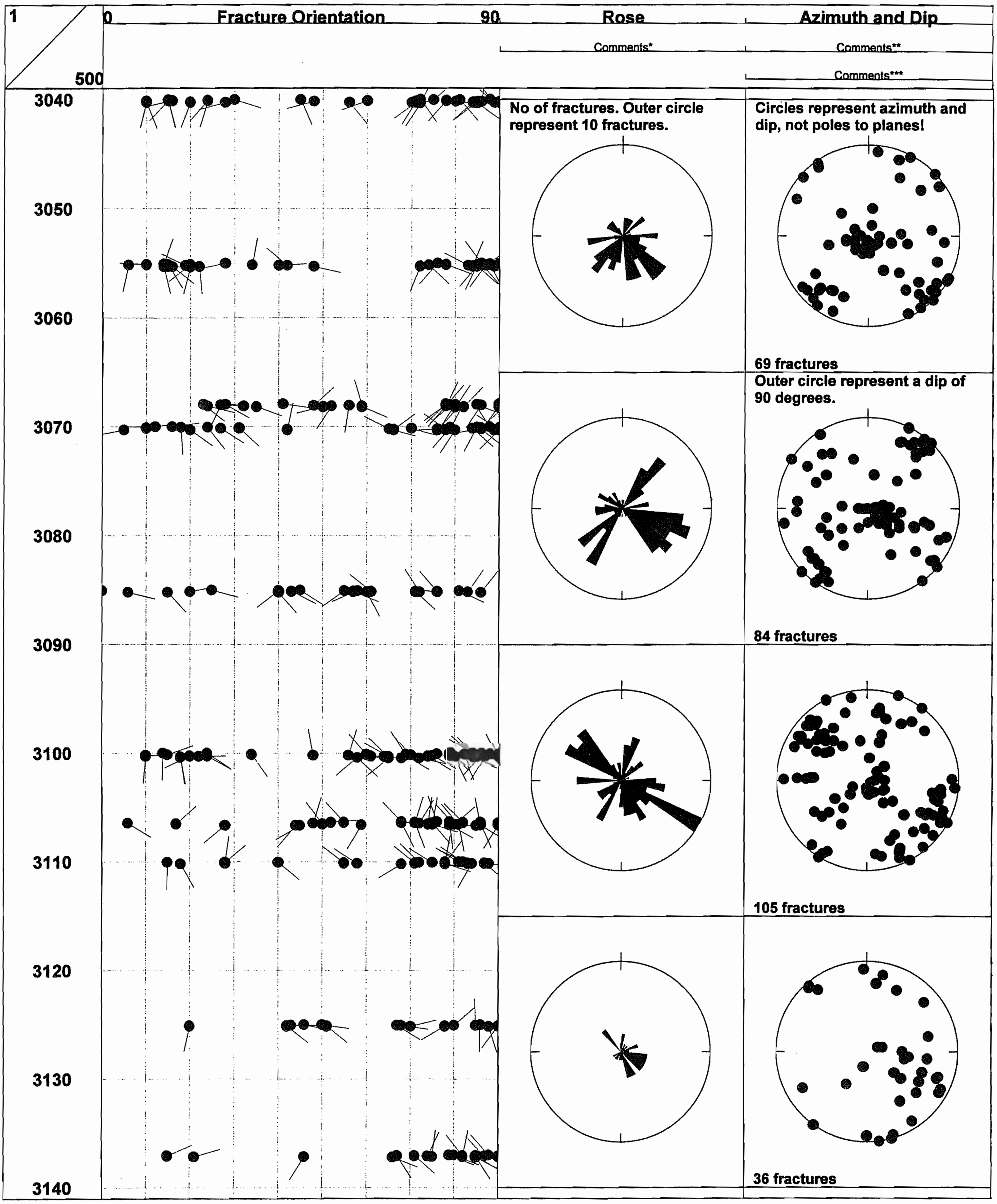


Figure 6-1. Structure log of fracture orientations for site 3067 (the first mineral column in the data base) presented as a tadpole presentation, a rose log and a polar log.

Table 6-1. Fracture fillings from tunnel mapping in the vicinity of site 3067.

Mineral 1	*Mineral 2*	*Fractures*	*%*
EP	KA	6	2,0%
EP	KL	12	4,1%
EP	OX	3	1,0%
EP	QZ	5	1,7%
EP	-	4	1,4%
KA	KL	109	37,1%
KA	OX	2	0,7%
KA	-	25	8,5%
KL	FE	1	0,3%
KL	IJ	1	0,3%
KL	OX	17	5,8%
KL	SU	2	0,7%
KL	-	87	29,6%
QZ	KL	3	1,0%
-	-	5	1,7%
AT	-	5	1,7%
PG	-	7	2,4%
Total		294	100,0%

EP= epidote, KA= calcite, KL= chlorite, FE=ironoxide/hydroxide, IJ=grout, SU=sulphide, OX= oxidised, QZ= quartz, "-"= no filling, AT=fine grained granite and PG=pegmatite.

6.2.4 RMR

In the tunnel between 2840 and 2940 m 10 mapping cells have been classified according to the RMR system /Bieniawski, 1988/. The ratings range from 63 to 86 with a median value of 70 corresponding to RMR classes I to II (see Table 3-3).

Remark Fracture Zone Orientation, Rose, Azimuth and Dip (Note, not poles!).

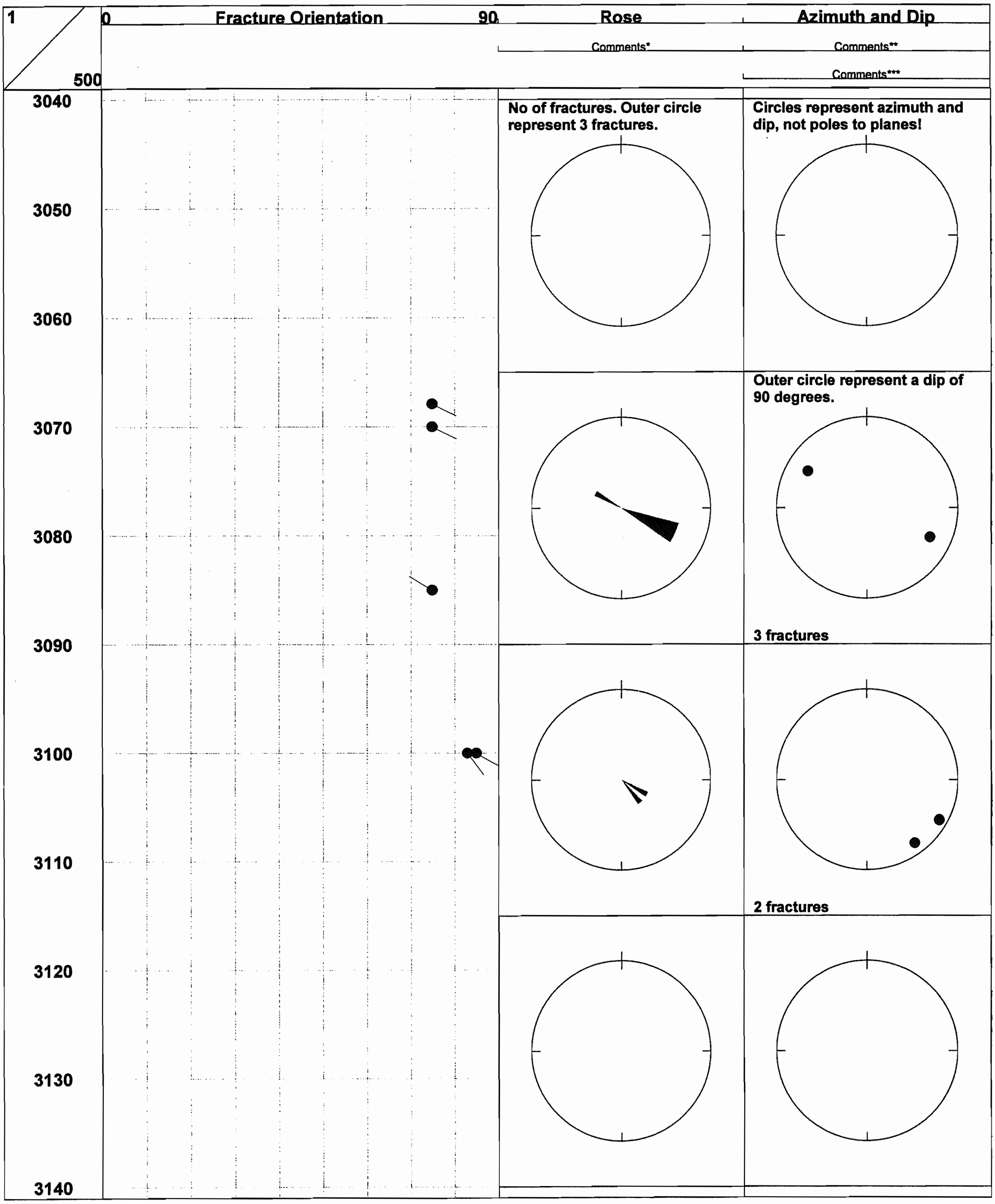


Figure 6-2. The observed orientations of the different fracture groups within the fracture zones in the section between 3040 and 3140 m.

6.3 Inflow Measurements

Inflow measurements have been performed from February 1994 until October1998 in the weir located at 3179 m in the main tunnel TASA. The aim of the measurements was to quantify the amounts of water inflow during the construction phase, see /Rhén et al., 1994/. The inflow at the weir is presented in Figure 6-3. The inflow into the weir located at 3179 m varies between 128 up to 187 l/min with a median value of 149 l/min. This weir collects water from the TBM assembly hall and from tunnels (TASD, TASK, TASL, TASO and TASZ) in the -420 m level. Increases in inflow occur after that new tunnels at the -420 m level have been excavated

The main inflow into the weir positioned at 3179 m comes from NW trending fracture zones and fractures located between 3040 and 3179 m, see Appendix 1.

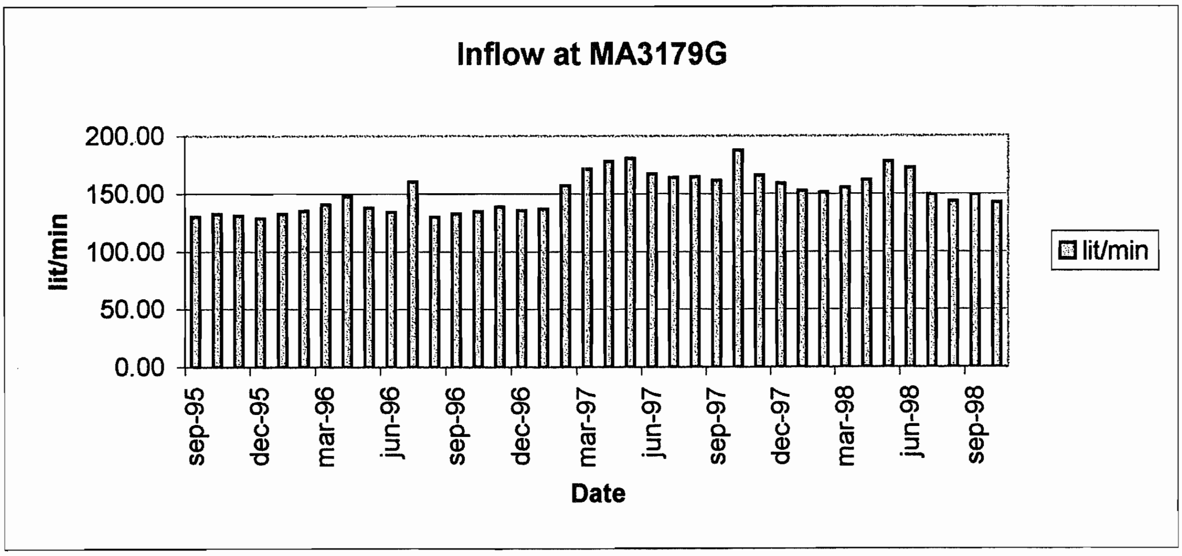


Figure 6-3. Water inflow to the weir MA3179G located at section 3179 m.

6.4 Chemistry

Electrical conductivity and pH have been measured in the weir MA3179G and are presented in Table 6-2. The chlorine content (C) has not been measured. In Table 6-2 below the salinity (TDS) has been calculated according to the formula:

$TDS = 4.67 \cdot 10^{-3} / 0.741 \cdot C$ (g/l) /Wikberg, 1991/.

The estimated salinity (TDS) seems a little overestimated by comparison with the measured chlorine content in Table 3-4.

Table 6-2 Electrical conductivity, pH and salinity (TDS) taken on water samples from weirs.

Weir	Date	Electrical Conductivity (mS/m)	pH	TDS (mg/l)
MA3179G	980302	1300	7.7	8193
	980929	1160	7.8	7310

7 Site TASJ

7.1 Geology

7.1.1 Lithology

The following rock types have been identified in the vicinity of site TASJ corresponding to section 3450 up to 3550 in the main tunnel: Äspö diorite and fine-grained granite with Äspö diorite being the dominating rock. Fine-grained granite occur as inclusions, bands or veins. Characteristics for Äspö diorite and fine-grained granite are presented in Table 3-1.

7.1.2 Fracture fillings

The dominating fracture fillings in the vicinity of site TASJ are chlorite and calcite. Epidote and quartz are also common. Clay minerals have been detected in some fracture zones and single fractures. The dominating clay minerals are illite and swelling mixed layer clay with a large illite component /Tullborg E-L, 1995/.

7.2 Geological Mapping

7.2.1 Standard tunnel mapping

Standard tunnel mapping from tunnels TASF, TASG and niche TASJ corresponding to sections 3450 up to 3550 m in the main TASA tunnel shows that the main rock type is Äspö diorite with veins and inclusions of fine-grained granite and pegmatite. Plots from geological mapping, geohydrology and reinforcements are presented in Appendix 4.

In the interval between 3450 and 3550 m totally 264 fractures have been observed. Fracture fillings from tunnel mapping between sections 3450 and 3550 m and niche TASJ are presented in Table 7-1. In the table two out of five observed mineral columns from the data base are shown. As can be seen, the most common fracture fillings are chlorite, calcite and epidote. A summary of the table below shows that 55% of the fractures have chlorite fillings, 23% calcite fillings and 9% epidote fillings. In the table also veins of pegmatite with a width less than 0.1 m are shown.

In Figure 7-1 the first mentioned mineral or vein (first mineral column in the data base) is shown in a structure log. The structure log consists of a tadpole presentation, a rose log and a polar log, see chapter 3.2. As seen in the polar and rose logs strike directions

in NW, NS and NE dominate. Also a semi-horizontal orientation of the structures are common.

The corresponding plots for different minerals are presented in Appendix 9. All mineral columns in the data base are taken into account. Chlorite is the dominant fracture filling mineral. Chlorite occurs in 208 of 264 observations (78%). Orientations in NS and NW dominates. Calcite is the next common mineral and 143 of 264 observations were seen (54%). Orientations in NW and NS dominates. Epidote is the third common mineral and 49 of 264 observations were seen (18%). Orientations in NS and NE dominates. Very few observations of mylonite were seen, 12 of 264 observations (4%). Orientations in NS, NE and NW were observed.Water filled fractures or fractures with grout are presented in Appendix 9. A few observations, 30 of 264 were seen (11%). Orientations in NW and WNW were seen.

7.2.2 Fracture zones

One observed fracture zone is located in the vicinity of the site TASJ. The fracture zone is located at 3500 m, the corresponding length of the main TASA tunnel, see the geological sheet in Appendix 4. This fracture zone is parallel to a fracture zone named NE-2. The observed orientations of the different fracture groups within the fracture zone are presented in Figure 7-2.

The fracture zone at 3500 m has ductile precursors as mylonite is observed. The width of the fracture zone is about 1.2 m. The strike is towards NE (24°). Small amount of water inflow (only sporadic drops) was observed within this fracture zone.

7.2.3 Leakage

30 fractures out of 264 have been marked as water bearing or containing grout. A total of 26 points of inflow of water are recorded in the data base in the range from 0.001 up to 3.0 l/min. Between 3450 and 3550 a total inflow of 4.85 l/min was observed.

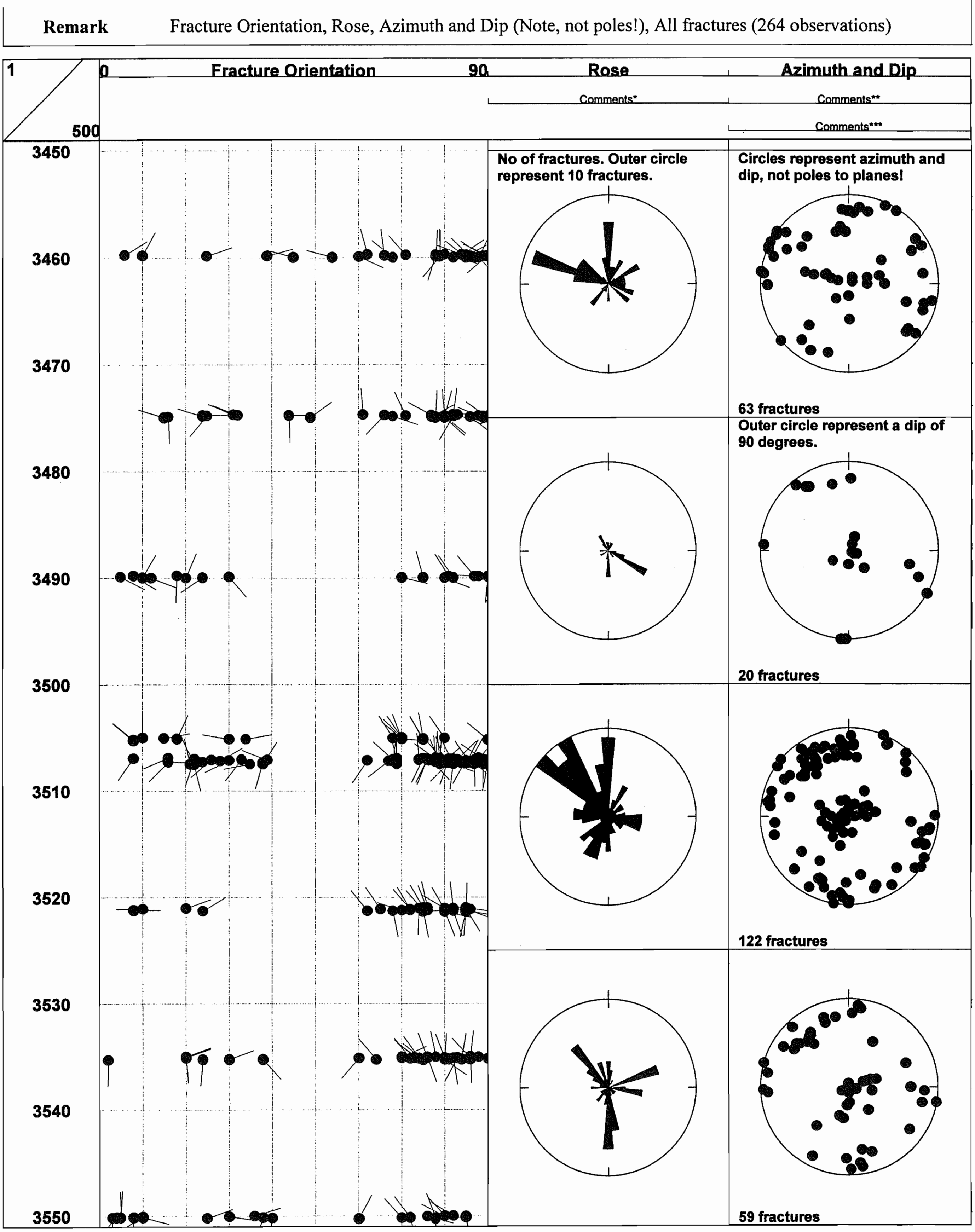


Figure 7-1. Structure log of fracture orientations for site TASJ (the first mineral column in the data base) presented as a tadpole presentation, a rose log and a polar log.

Table 7-1. Fracture fillings from tunnel mapping in the vicinity of niche TASJ.

Mineral 1	*Mineral 2*	*Fractures*	*%*
EP	KA	10	3,8%
EP	KL	15	5,6%
EP	OX	4	1,5%
EP	-	3	1,1%
KA	IJ	3	1,1%
KA	KL	94	35,6%
KA	-	24	9,1%
KL	FE	1	0,4%
KL	FL	2	0,8%
KL	HM	1	0,4%
KL	OX	13	4,9%
KL	PG	1	0,4%
KL	PY	4	1,5%
KL	QZ	3	1,1%
KL	-	51	19,3%
MY	EP	6	2,3%
MY	KL	5	1,9%
MY	QZ	1	0,4%
OX	-	1	0,4%
QZ	KA	1	0,4%
QZ	KL	4	1,5%
QZ	PY	3	1,1%
-	-	13	4,9%
PG	-	1	0,4%
Total		264	100,0%

EP= epidote, KA= calcite, KL= chlorite, FE=ironoxide/hydroxide, FL=fluorite, HM= hematite, IJ=grout, OX= oxidised, PY=pyrite, QZ= quartz, MY= mylonite, "-"= no filling and PG=pegmatite.

7.2.4 RMR

In the tunnel between 3450 and 3550 m 8 mapping cells have been classified according to the RMR system /Bieniawski, 1988/. The ratings range from 57 to 85 with a median value of 68 corresponding to RMR classes I and II (see Table 3-3).

7.3 Inflow Measurements

Inflow measurements have been performed from May 1996 until April 1998 in the weir located at 0061 m in the tunnel TASF. The aim of the measurements was to quantify the amounts of water inflow during the construction phase, see /Rhén et al., 1994/. The inflow at the weir is presented in Figure 7-3. The inflow into the weir located at 0061 m varies between 4 up to 23 l/min with a median value of 10 l/min. In

Title	SELECT-II. Site TASJ. Fracture zones at 3490-3510.		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3490-3510	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture zone orientation, Rose, Azimuth and Dip (Note, not poles!).		

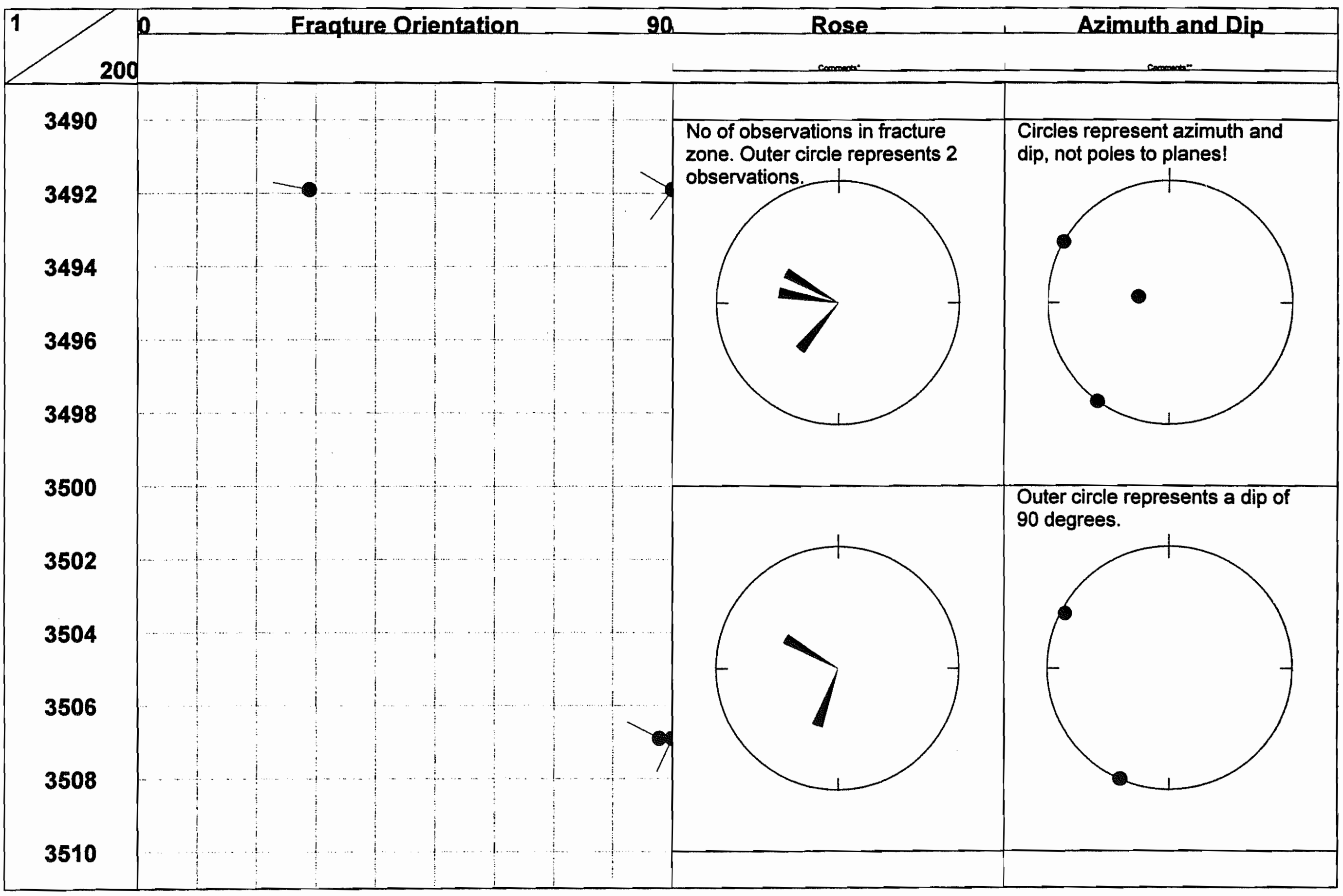


Figure 7-2. The observed orientations of the different fracture groups within the fracture zone located at 3500 m in the vicinity of site TASJ.

general the inflow increases a small amount with time. The high inflows might correspond to drilling activities at a location above the weir.

The main inflow into the weir positioned at 0061 m comes from NW trending fractures located between 3440 and 3500 and the fracture zone located at 3500 m, see Appendix 1 and Appendix 4, fractures and fracture zones.

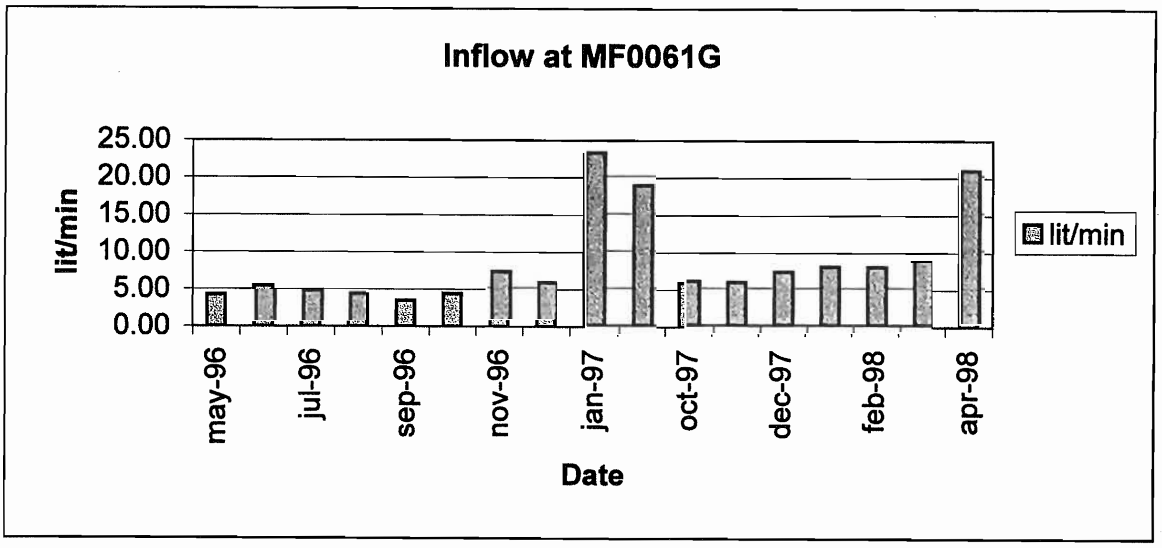


Figure 7-3. Water inflow to the weir MF0061G located at section 0061 m.

7.4 Chemistry

Electrical conductivity, pH and chlorine content have been measured from water samples taken in the weir located at 0061 m in tunnel TASF and are presented in Table 7-2.

Table 7-2. Electrical conductivity, pH and chlorine content taken on water samples from weir MF0061G.

Weir	Date	Electrical Conductivity (mS/m)	pH	Cl (mg/l)
MF0061G	951118	1717		
	951120	1661		
	980302	1752	8.2	5700
	980929	1503	7.2	5800

8 Structural geological model

The structural geological model for the proposed sites for TRUE-2 and CHEMLAB are more or less the same as for the TRUE block scale experiment because of that both sites are located in the vicinity of the TRUE block. In Figure 8-1 a top view of the structural geological model is presented /Olsson et al., 1997/. The model has been updated using data from borehole investigations and activities during drilling of boreholes KA2511A, KA2563A and KA3510A.

Fracture zone no.13 is fracture zone NE-2 and fracture zone no. 8 is the mentioned fracture zone located at 3500 m.

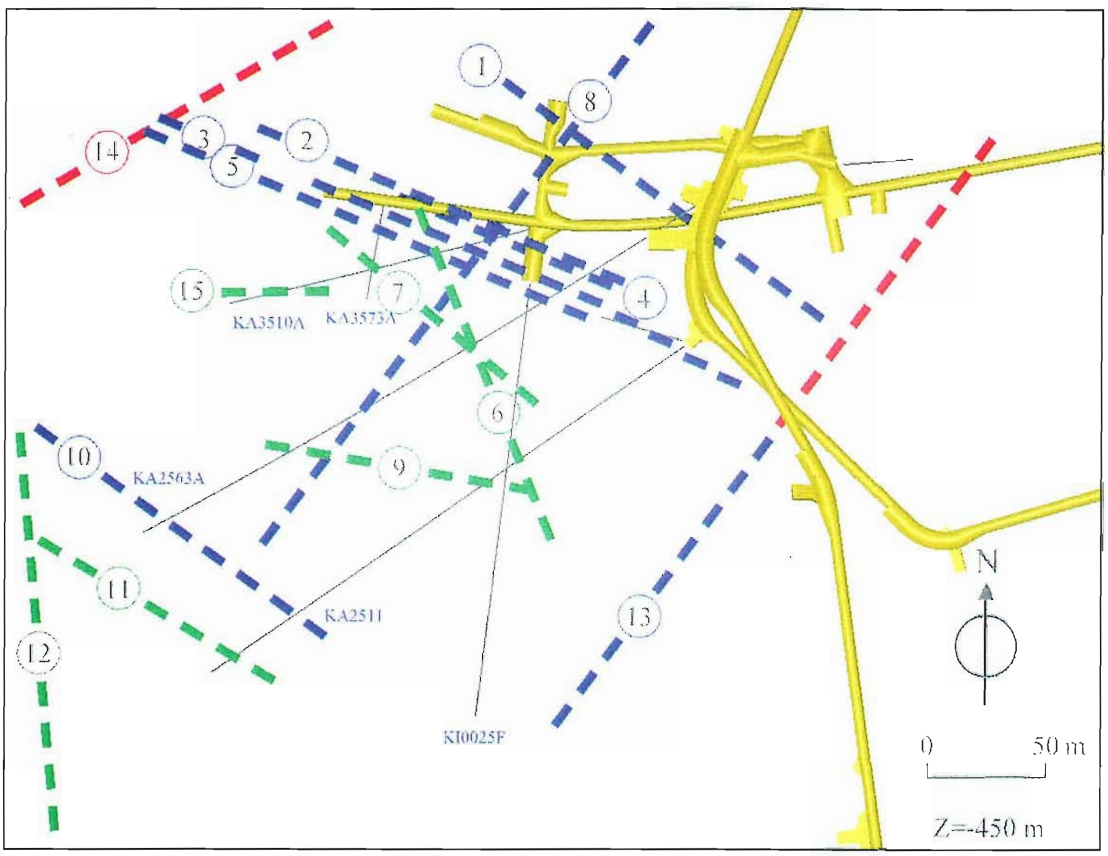


Figure 8-1. Structural model of the TRUE Block scale /Olsson et al., 1997/. Different colours represent different degrees of reliability. Red=certain, blue= probable and green= possible structures.

9 Localisation of boreholes for SELECT-2

The main targets for TRUE-2 and CHEMLAB are fractures oriented in NW or WNW filled with the minerals chlorite and calcite. The first borehole in SELECT-2 could be located in the niche located at 2375 m, Figure 9-1. The orientation of the borehole should be towards SW dipping slightly downwards. The length of the borehole is planned to be about 50 - 70 m. The outcome of the first borehole will give input to localisation of the other two or three boreholes. It might be necessary to excavate a niche at about 2390 m in the curve noted F, see Figure 9-1.

Another location for a borehole is in the wider part of the curve J at section 2880 or in the niche at 2865 m. The orientation of the borehole should be towards NE dipping slightly downwards. The length of the borehole is planned to be about 50 - 70 m.

A third location for a borehole is at section 3065. The orientation of the borehole should be towards NE dipping slightly downwards. The length of the borehole is planned to be about 50 - 70 m.

A fourth borehole for SELECT-2 could be drilled from the niche TASJ located at 3505 m, Figure 9-1. Two boreholes will be drilled and both will be sited in the niche. The orientation of the boreholes should be towards N and NE respectively dipping slightly downwards. The length of the boreholes are planned to be about 50 m. Another two boreholes could be drilled from this niche for microbiological studies.

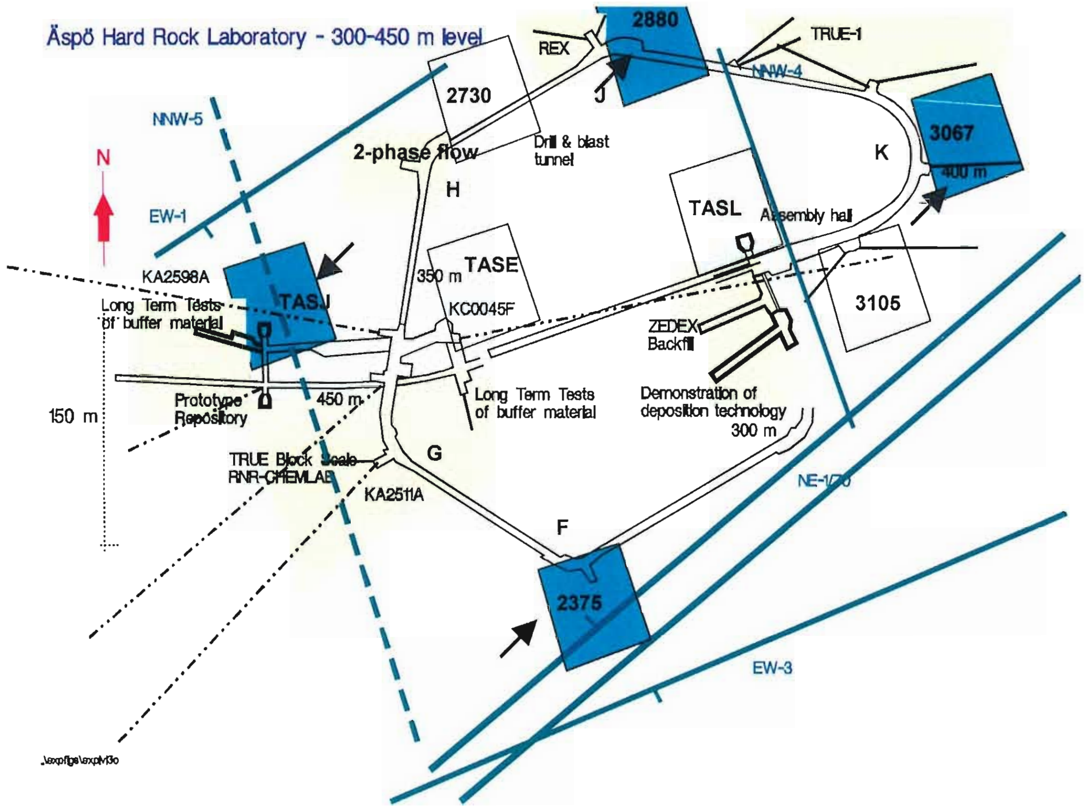


Figure 9-1. Proposed location of boreholes for SELECT-2. Proposed drilling sites are shaded with darker blue and marked with an arrow.

References

Bieniawski Z T, 1988. The rock Mass Rating (RMR) System (Geomechanics Classification) in Engineering Practice. Rock Classification System for Engineering Purposes, ASTM STM 984. Louise Kikaldie, Ed. American Society for Testing and Materials, Philadelphia, 1988, p. 17-34.

Bäckblom G and Olsson O, 1994. Program for Tracer Understanding Experiments. Äspö Hard Rock Laboratory. SKB Progress report 25-94-24.

Markström I and Erlström M, 1996. Overview of documentation of tunnel, niches and core boreholes. SKB Progress report HRL-96-19.

Olsson O, 1993. Task Plan for Localization of Experimental Sites and Layout of Turn 2. SKB, Äspö Hard Rock Laboratory Technical Document.

Olsson O (ed.), 1994. Localization of Experimental Sites and Layout of Turn 2 - Compilation of Technical Notes. SKB Progress report 25-94-03.

Olsson O, Stanfors R, Ranqvist G and Rhén I, 1994. Localization of Experimental Sites and Layout of Turn 2 - Results of investigations. SKB Progress report 25-94-14.

Olsson O (ed.) 1997. True Block Scale Project. Update of the structural model characterisation data from KA2563A, KA3510A and KA2511A. (performed by Hermanson J and Follin S, 1997). Äspö HRL status report, July-September, 1997. SKB Progress report HRL-97-21.

Rhén I (ed.), Gustafson G, Stanfors R and Wikberg P, 1997. Äspö HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995. SKB Technical report 97-06.

Rhén I, Danielsson P, Forsmark T, Gustafson G and Liedholm M, 1994. Geohydrological evaluation of the data from section 2265 - 2874 m. SKB Progress report 25-94-20.

Tullborg E-L, 1995. Mineralogical and chemical data on rocks and fracture minerals from Äspö. Technical note 25-95-07g. SKB, Stockholm, Sweden.

Waltham A C, 1994. Foundations of Engineering Geology. Blackie Academic & Professional, Glasgow, UK.

Wikberg P, Gustafson G, Rhén I and Stanfors R, 1991. Äspö Hard Rock Laboratory. Evaluation and conceptual modelling based on the pre-investigations 1986-1990. SKB Technical report 91-22.

Wikman H and Kornfält K-A, 1995. Updating of the geological model at Äspö. SKB Progress report 25-95-04. SKB, Stockholm, Sweden.

Winberg A, 1994. Tracer retention understanding experiments (TRUE). Test plan for the first TRUE stage. SKB Progress report 25-94-35. SKB, Stockholm, Sweden.

Winberg A, Andersson P, Hermanson J and Stenberg L, 1996. Results of the SELECT project. Investigation programme for selection of experimental sites for the operational phase. SKB Progress report HRL-96-01. SKB, Stockholm, Sweden.

SKB, 1992. FUD-program 92. Kärnkraftsavfallets behandling och slutförvaring. Underlagsrapport Äspölaboratoriet. SKB, Stockholm.

SKB, 1995. FUD-program 95. Kärnkraftsavfallets behandling och slutförvaring. Program för inkapsling, geologisk djupförvaring samt forskning, utveckling och demonstration. SKB, Stockholm.

Appendix 1

Presented in this appendix are plots of geology from the standard mapping performed within the interval between 2206 up to 3191 m. The projection is folded-out from the centreline of the roof.

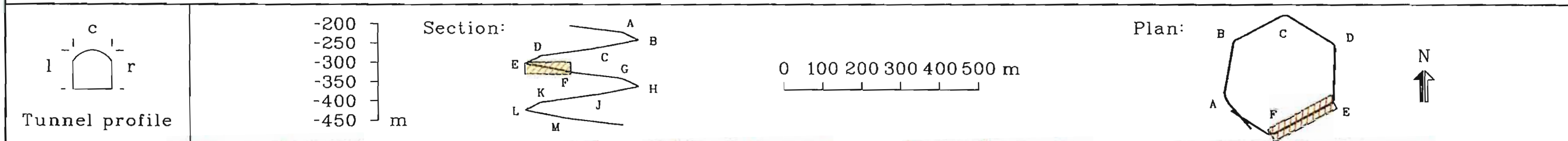
6 pages

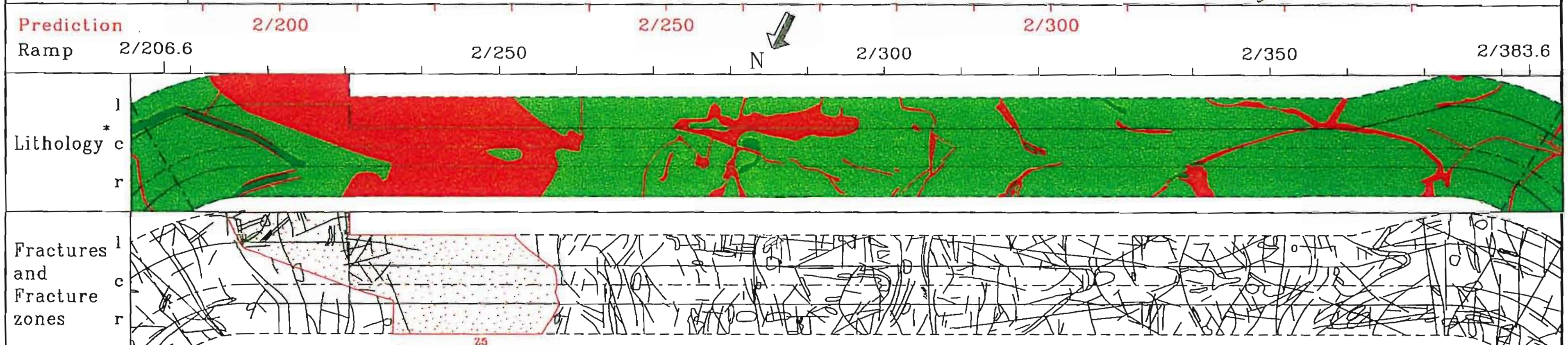
Äspö Hard Rock Laboratory

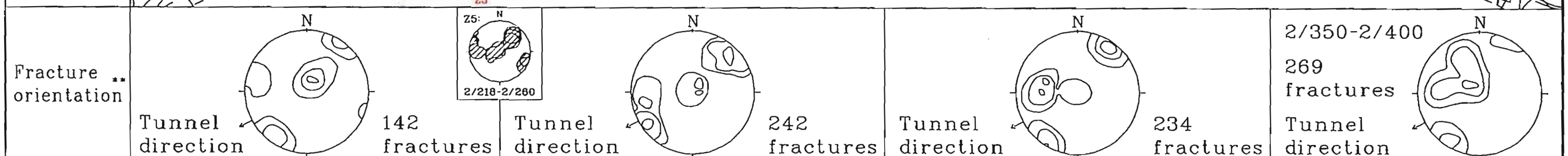
Overview of documentation

Loop 1, Leg E-F: 2/206.6-2/383.6

Geology







Fracture minerals ***	Cl: 75% Ca: 45% Ep: 18% Clay: 1%	Cl: 57% Ca: 54% Oxid: 24% Clay: 2%	Cl: 64% Ca: 39% Ep: 19% Clay: 3%	Cl: 77% Ca: 56% Oxid: 36% Clay: 1%
Sampling ****	□ □ □		□	
Experiments				

Notes

* Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Småland granite
- Fine-grained granite
- Mylonite
- Volcanite

** Incl. tunnel face

*** Dominating

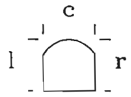
**** □ Rock Sample
○ Cored Borehole
✳ Clay Sample

960705

Äspö Hard Rock Laboratory — Overview of documentation

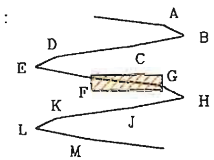
Loop 1, Leg F-G: 2/383.6-2/526.8 — Geology

Tunnel profile



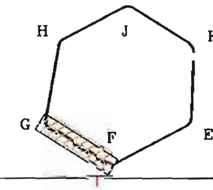
-200
-250
-300
-350
-400
-450 m

Section:



0 100 200 300 400 500 m

Plan:



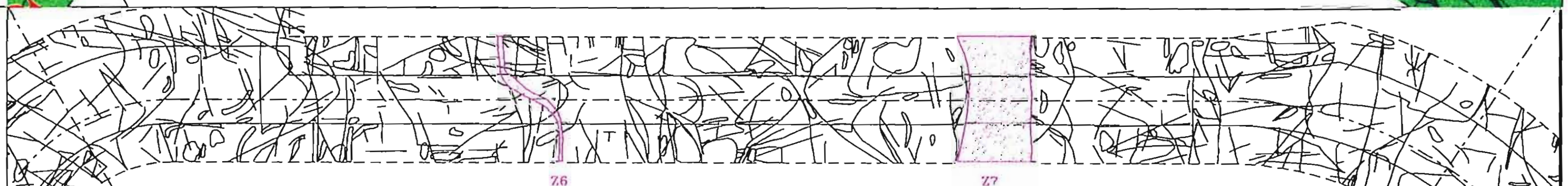
N

Prediction: 2/350, 2/400, 2/450

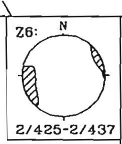
Ramp: 2/383.6, 2/400, 2/450, N, 2/500, 2/526.8

Lithology* (l, c, r)

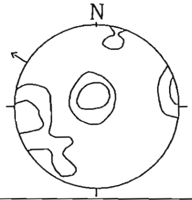
Fractures and Fracture zones (l, c, r)



Fracture orientation**

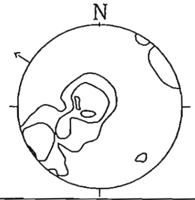


Tunnel direction

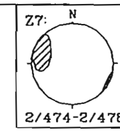


227 fractures

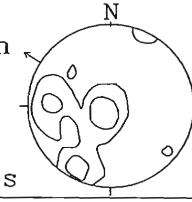
Tunnel direction



184 fractures



Tunnel direction



185 fractures

Fracture minerals***		Cl: 68% Ca: 50% Oxid: 30% Clay: 1%	Ca: 60% Cl: 57% Oxid: 18% Clay: 4%	Ca: 62% Cl: 55% Oxid: 23% Clay: 1%
Sampling****			□ □	□ ○○○
Experiments			Block P 50-05: 2/440-2/490	

Notes

960822

* Lithology:
  - Pegmatite
  - Greenstone
  - Äspö diorite
  - Småland granite
  - Fine-grained granite
  - Mylonite
  - Volcanite

** Incl. tunnel face

*** Dominating

**** □ Rock Sample
○ Cored Borehole
✳ Clay Sample

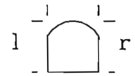
Äspö Hard Rock Laboratory

Overview of documentation

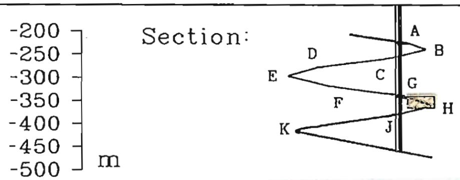
Loop 2, Leg G-H: 2/526.8-2/722.0

Geology

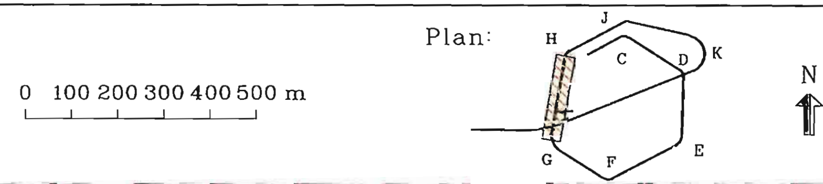
Tunnel profile

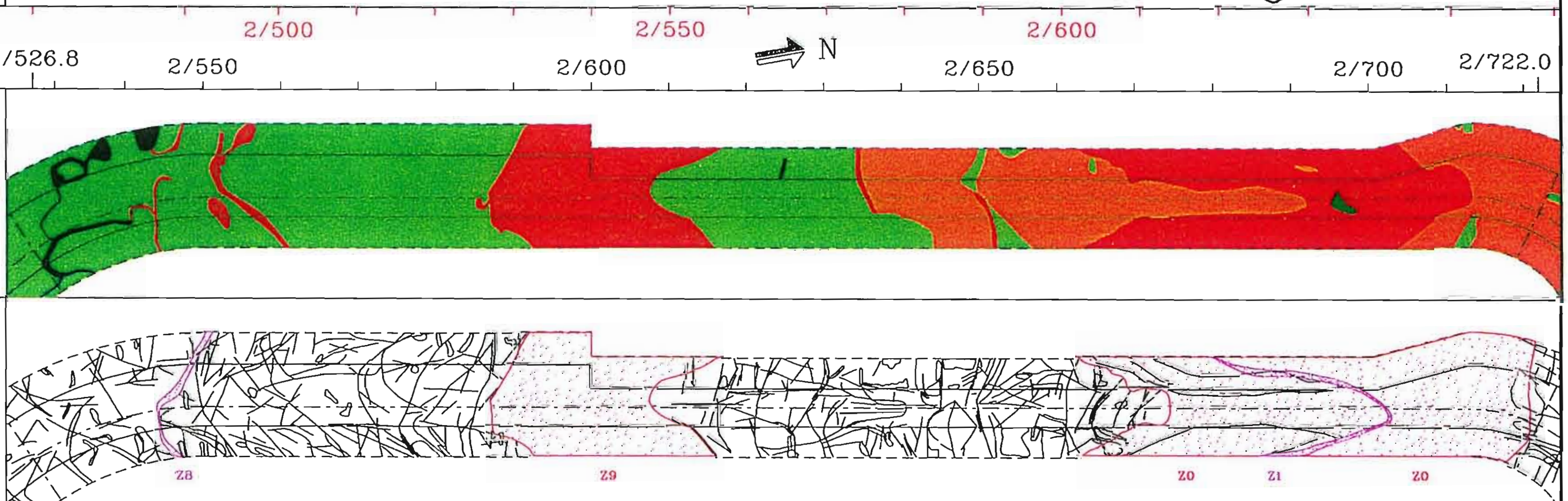


Section:



Plan:

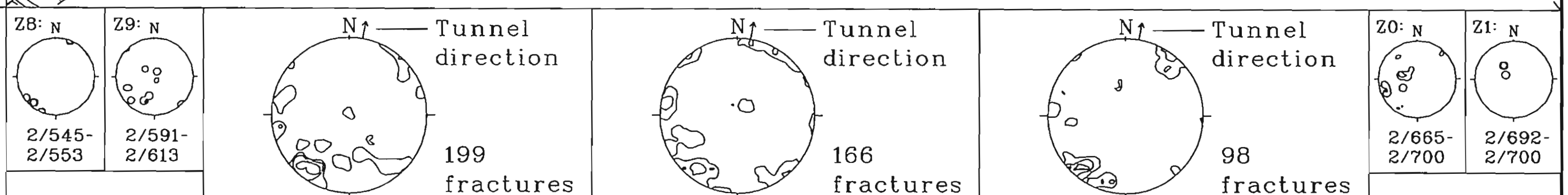




Lithology* (l, c, r)

Fractures and Fracture zones (l, c, r)

Fracture orientation**



Fracture minerals***		
Ca: 64% Ep: 17% Cl: 60% Clay: 1%	Ca: 66% Oxid: 32% Cl: 66% Clay: 3%	Ca: 68% Ep: 31% Cl: 68% Clay: 0%

Sampling**** ○ □ ✳ □ □

Notes

* Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Småland granite
- Fine-grained granite
- Mylonite
- Volcanite

** Incl. tunnel face

*** Dominating

**** □ Rock Sample ○ Cored Borehole ✳ Clay Sample

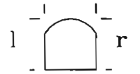
960705

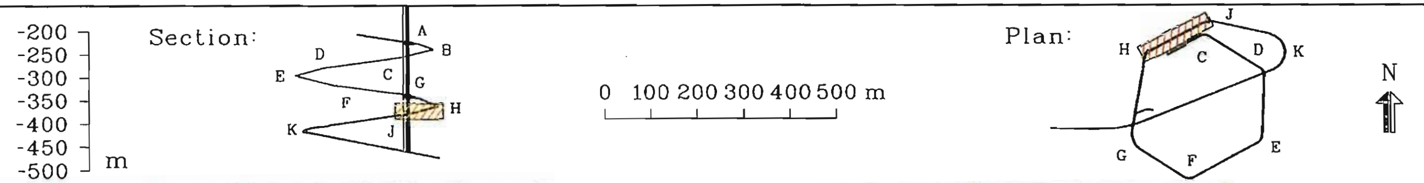
Äspö Hard Rock Laboratory

Overview of documentation

Loop 2, Leg H-J: 2/722.0-2/867.1 — **Geology**

Tunnel profile

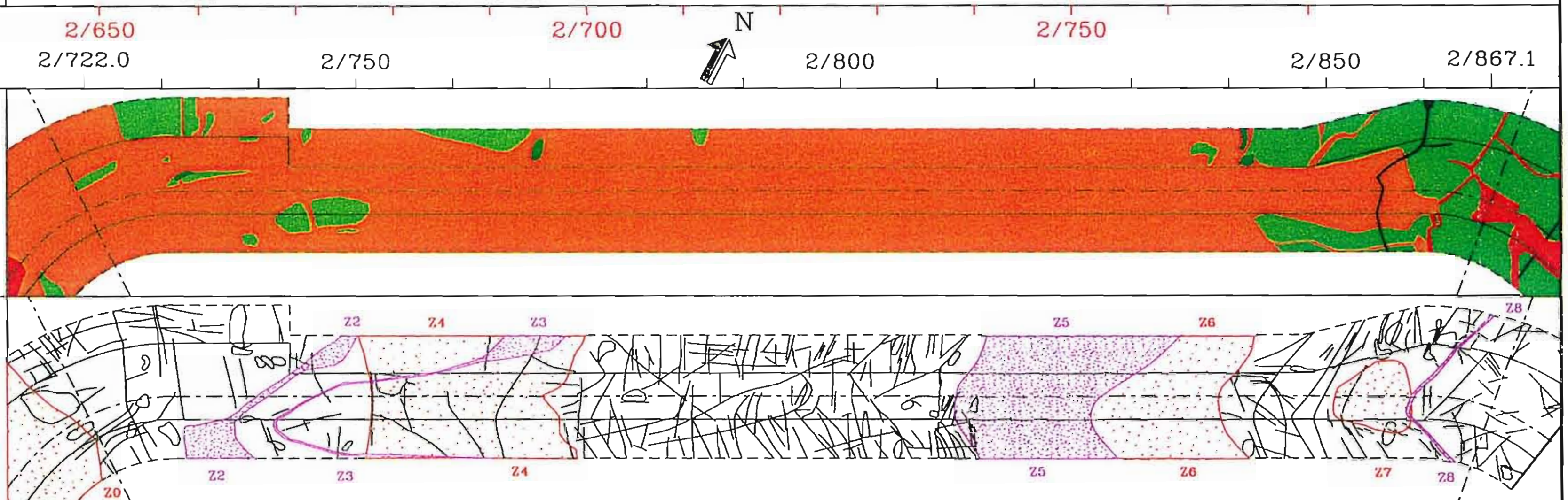




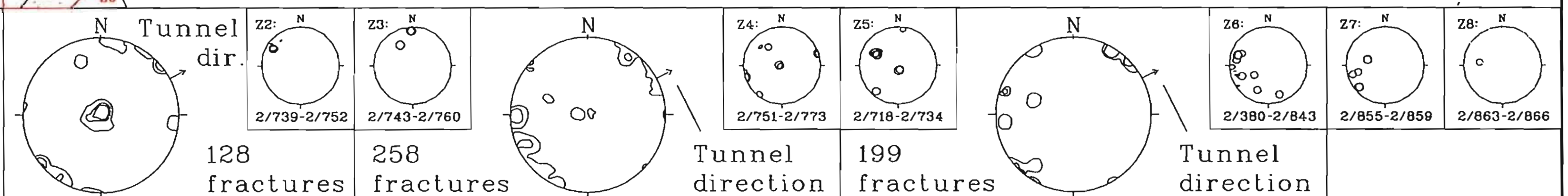
Prediction / Ramp

Lithology* (l, c, r)

Fractures and Fracture zones (l, c, r)



Fracture orientation**



Fracture minerals***	Ca: 66% Oxid: 10% Cl: 63% Clay: 0%	Cl: 76% Oxid: 33% Ca: 32% Clay: 0%	Cl: 82% Oxid: 9% Ca: 49% Clay: 5%
Sampling****	□		○○○ □
Experiments		Block P 50-04: 1/610 - 1/660	REX

Notes

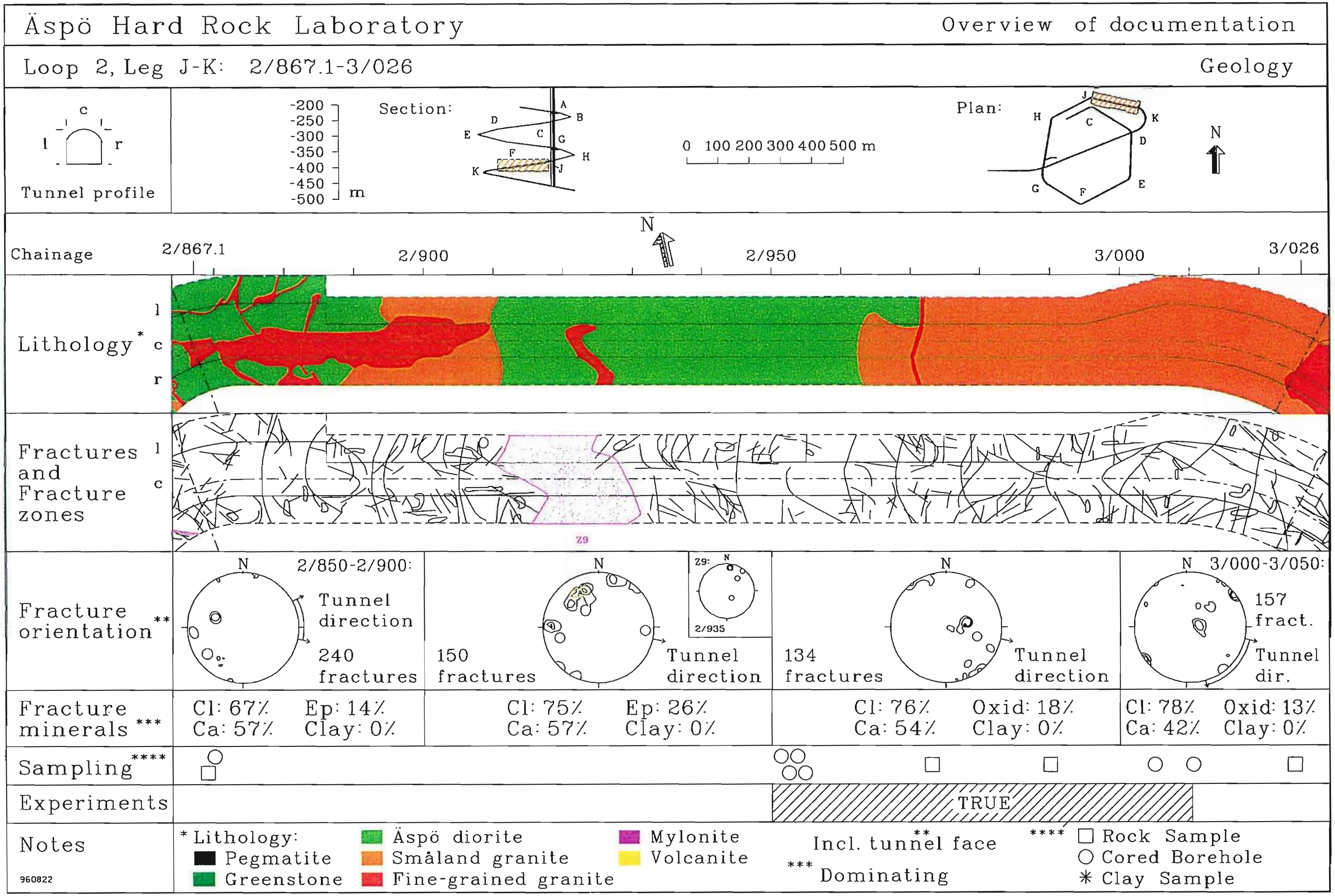
960819

* ■ Pegmatite ■ Småland granite ■ Äspö diorite
■ Greenstone ■ Fine-grained granite ■ Mylonite

** Incl. tunnel face

*** Dominating

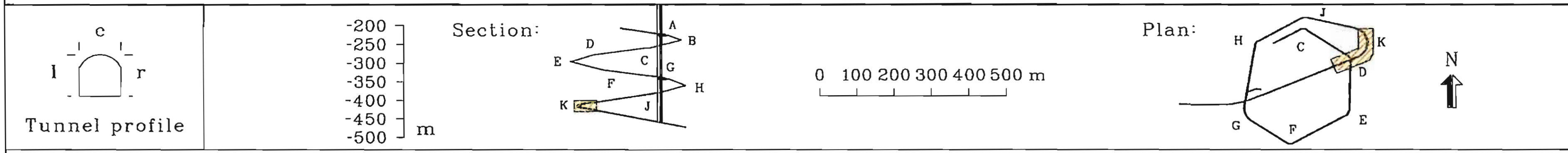
**** □ Rock Sample
○ Cored Borehole



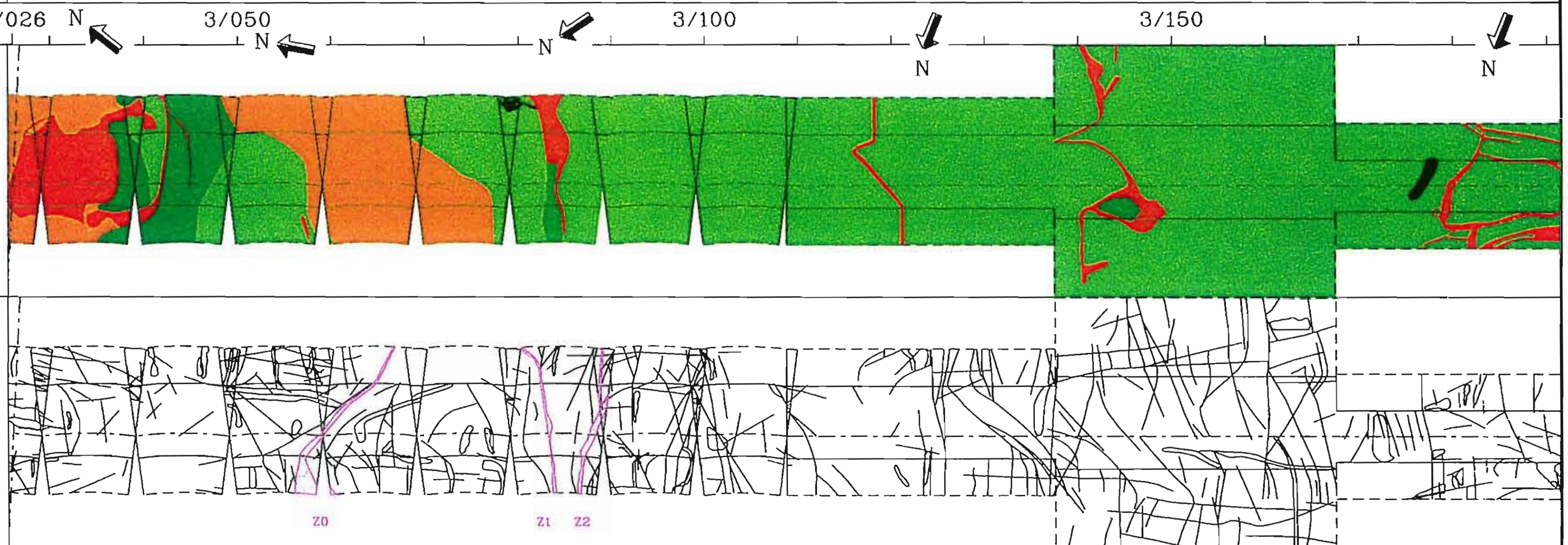
Äspö Hard Rock Laboratory
Overview of documentation
Loop 2, Leg J-K: 2/867.1-3/026
Geology
Tunnel profile
c
l
r
-200
-250
-300
-350
-400
-450
-500
m
Section:
A
B
C
D
E
F
G
H
J
K
0 100 200 300 400 500 m
Plan:
H
J
C
K
D
G
F
E
N
Chainage
2/867.1
2/900
2/950
3/000
3/026
Lithology *
l
c
r
Fractures and Fracture zones
l
c
Z9
Fracture orientation **
N
2/850-2/900:
Tunnel direction
240 fractures
150 fractures
Tunnel direction
Z9:
2/935
134 fractures
Tunnel direction
3/000-3/050:
157 fract.
Tunnel dir.
Fracture minerals ***
Cl: 67% Ep: 14%
Ca: 57% Clay: 0%
Cl: 75% Ep: 26%
Ca: 57% Clay: 0%
Cl: 76% Oxid: 18%
Ca: 54% Clay: 0%
Cl: 78% Oxid: 13%
Ca: 42% Clay: 0%
Sampling****
Experiments
TRUE
Notes
960822
* Lithology:
Pegmatite
Greenstone
Äspö diorite
Småland granite
Fine-grained granite
Mylonite
Volcanite
** Incl. tunnel face
*** Dominating
**** Rock Sample
Cored Borehole
Clay Sample

Äspö Hard Rock Laboratory — Overview of documentation

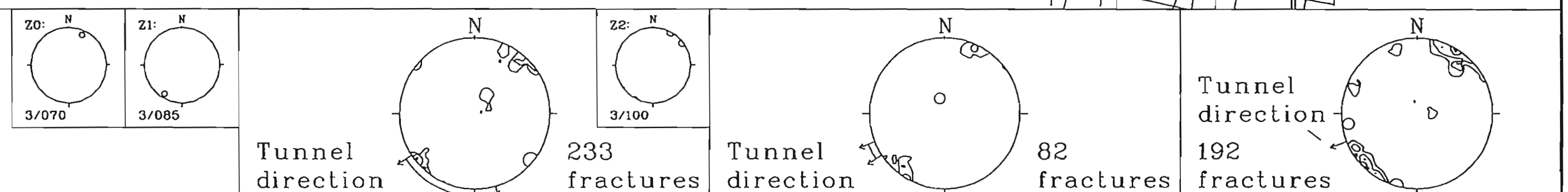
Loop 2, Curve K and TBM hall: 3/026-3/191.3 — Geology



Chainage



Fracture orientation**



Fracture minerals***		Cl: 87% Oxid: 15% Ca: 53% Clay: 0%	Cl: 88% Oxid: 18% Ca: 44% Clay: 4%	Cl: 70% Oxid: 19% Ca: 52% Clay: 2%
Sampling****	□ ○○		○○	7x○
Experiments				ZEDEX

Notes

* Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Småland granite
- Fine-grained granite
- Mylonite
- Volcanite

** Incl. tunnel face

*** Dominating

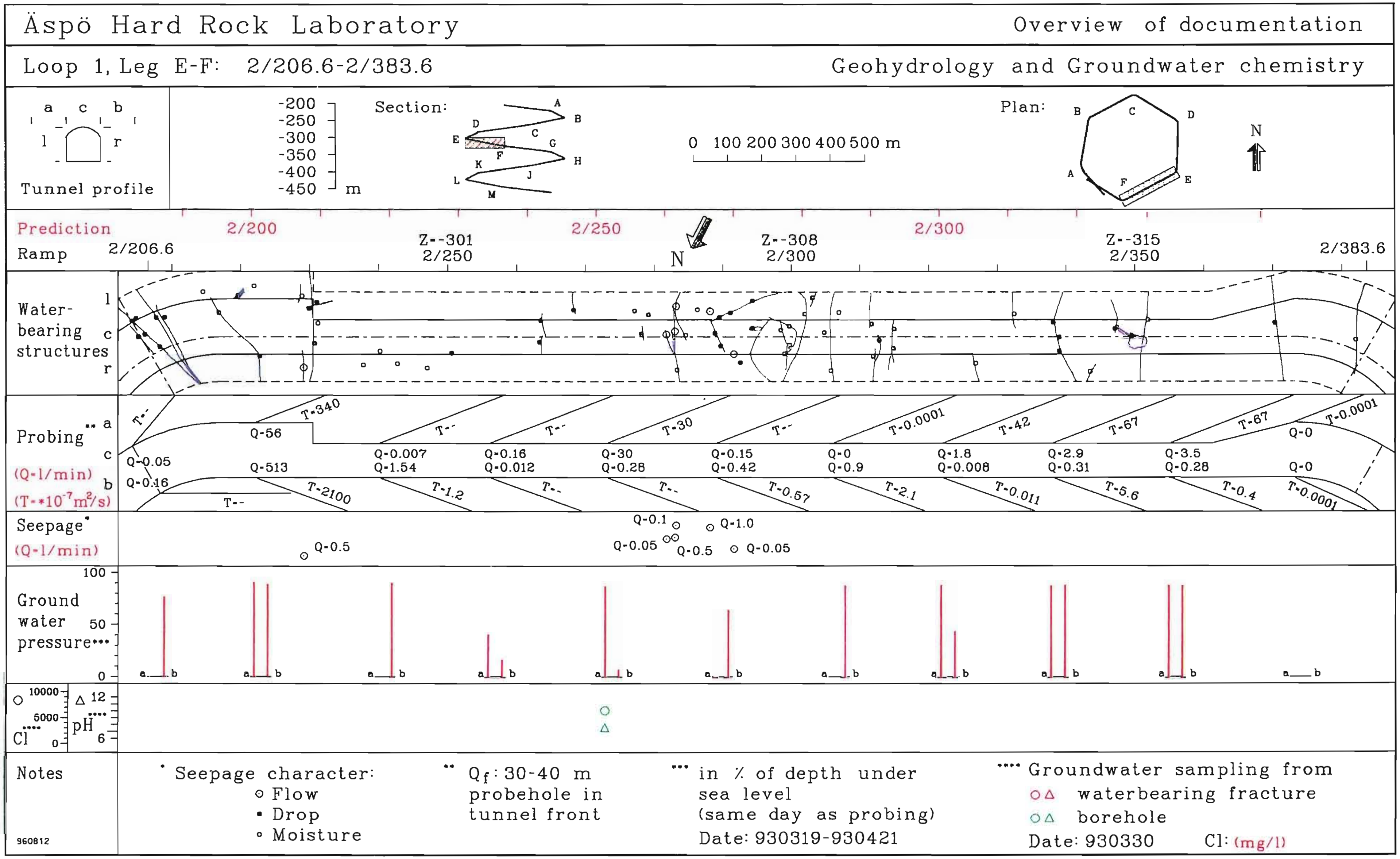
**** □ Rock Sample ○ Cored Borehole ✳ Clay Sample

960822

Appendix 2

Presented in this appendix are plots of geohydrology and groundwater chemistry from the standard mapping performed within the interval between 2206 up to 3191 m. The projection is folded-out from the centreline of the roof.

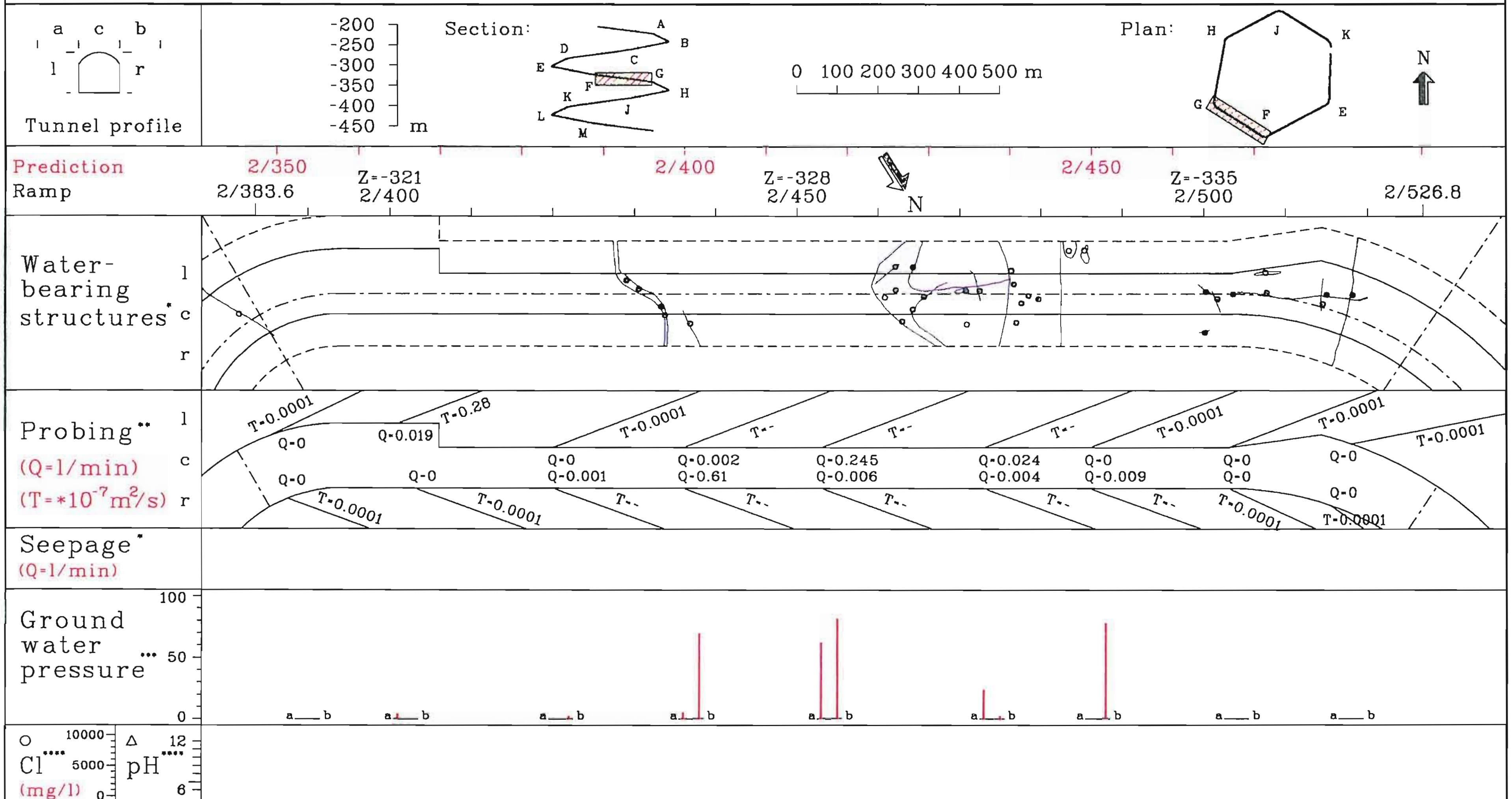
6 pages



Äspö Hard Rock Laboratory
Overview of documentation
Loop 1, Leg E-F: 2/206.6-2/383.6
Geohydrology and Groundwater chemistry
a c b
l r
Tunnel profile
-200 -250 -300 -350 -400 -450 m
Section:
A B C D E F G H J K L M
0 100 200 300 400 500 m
Plan:
N
Prediction
2/200
2/250
2/300
Ramp
2/206.6
Z--301
2/250
N
Z--308
2/300
Z--315
2/350
2/383.6
Water-bearing structures
l c r
Probing** a c b
(Q-l/min)
(T-*10^-7 m²/s)
T--
T-340
Q-56
T--
T--
T-30
T--
T-0.0001
T-42
T-67
T-67
T-0.0001
Q-0
Q-0.05
Q-0.16
Q-513
Q-0.007
Q-1.54
Q-0.16
Q-0.012
Q-30
Q-0.28
Q-0.15
Q-0.42
Q-0
Q-0.9
Q-1.8
Q-0.008
Q-2.9
Q-0.31
Q-3.5
Q-0.28
Q-0
T--
T-2100
T-1.2
T--
T--
T-0.57
T-2.1
T-0.011
T-5.6
T-0.4
T-0.0001
Seepage*
(Q-l/min)
Q-0.5
Q-0.1
Q-0.05
Q-0.5
Q-1.0
Q-0.05
Ground water pressure***
100
50
0
a b
Cl****
10000
5000
0
pH
12
6
Notes
* Seepage character:
○ Flow
● Drop
∘ Moisture
** Q_f: 30-40 m probehole in tunnel front
*** in % of depth under sea level (same day as probing)
Date: 930319-930421
**** Groundwater sampling from
○△ waterbearing fracture
○△ borehole
Date: 930330
Cl: (mg/l)
960812

Äspö Hard Rock Laboratory — Overview of documentation

Loop 1, Leg F-G: 2/383.6-2/526.8 — Geohydrology and Groundwater chemistry



Notes

960812

* Seepage character:
- Flow
- Drop
- Moisture

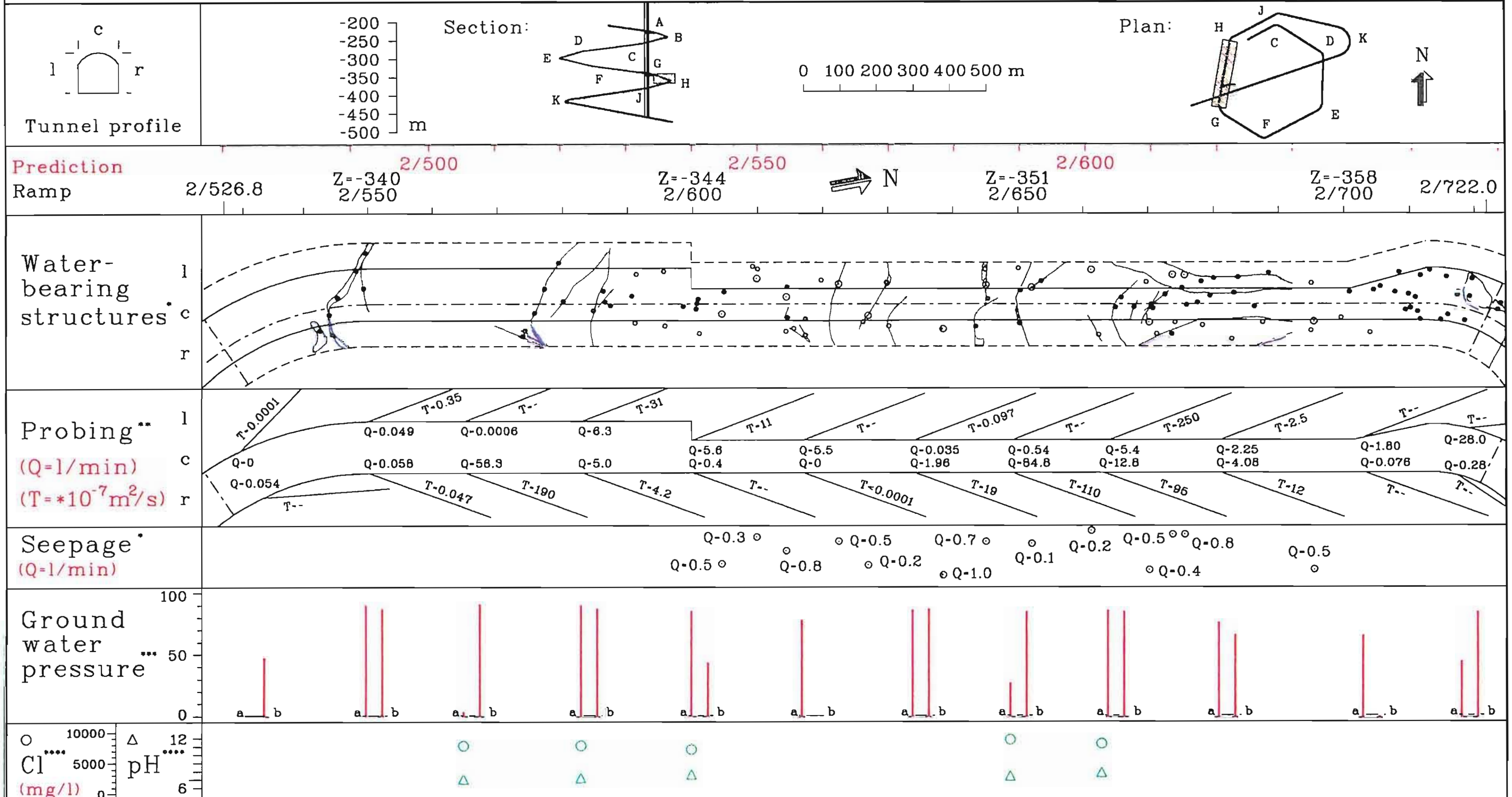
** Q_f: 30-40 m probehole in tunnel front

*** in % of depth under sea level (same day as probing)
Date: 930426-930514

**** Groundwater sampling from
○△ waterbearing fracture
○△ borehole

Äspö Hard Rock Laboratory — Overview of documentation

Loop 2, Leg G-H: 2/526.8-2/722.0 — Geohydrology and Groundwater chemistry



Notes

* Seepage character:
- ○ Flow
- ∘ Drop
- ∘ Moisture

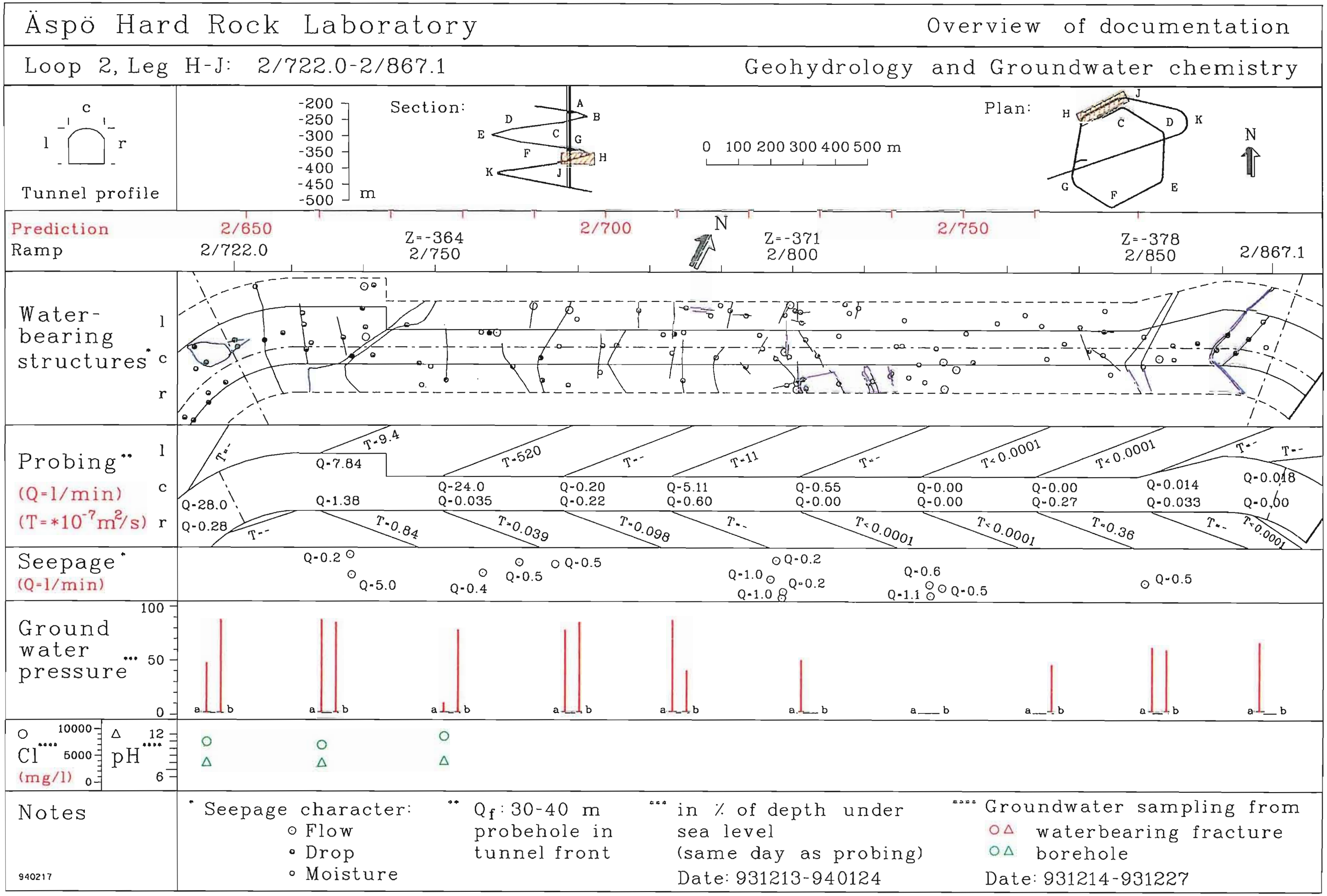
** Q_f: 30-40 m probehole in tunnel front

*** in % of depth under sea level (same day as probing) Date: 930518-931213

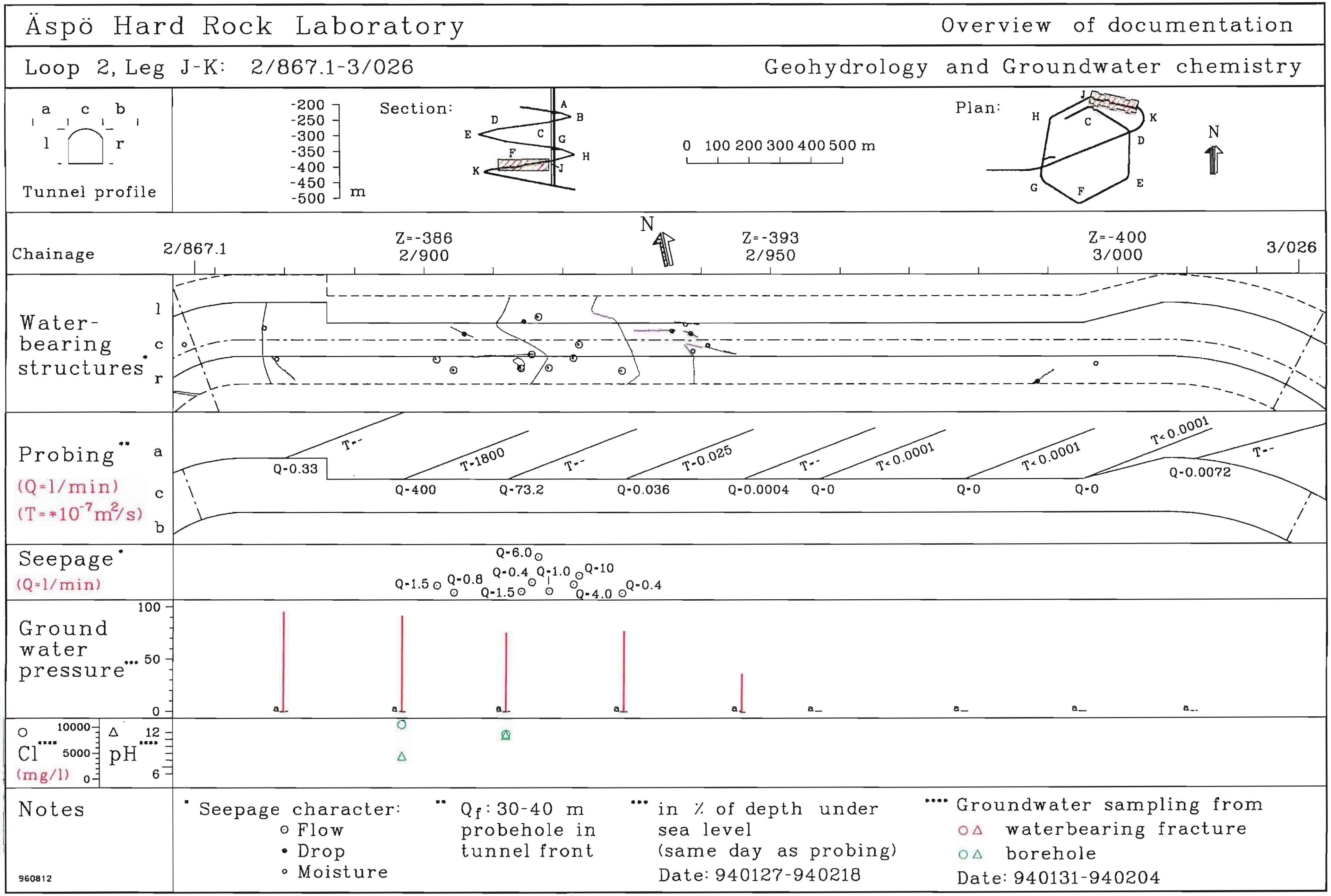
**** Groundwater sampling from
- ○△ waterbearing fracture
- ○△ borehole

Date: 930526-931125

960812

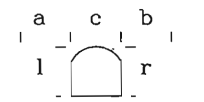


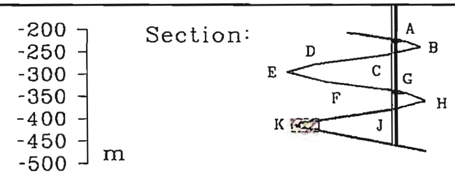
Äspö Hard Rock Laboratory
Overview of documentation
Loop 2, Leg H-J: 2/722.0-2/867.1
Geohydrology and Groundwater chemistry
Tunnel profile
c
l
r
Section:
-200
-250
-300
-350
-400
-450
-500
m
0 100 200 300 400 500 m
Plan:
N
Prediction
Ramp
2/650
2/700
2/750
2/722.0
Z=-364
2/750
Z=-371
2/800
Z=-378
2/850
2/867.1
Water-bearing structures*
Probing**
(Q=l/min)
(T=*10^{-7}m^2/s)
T=9.4
Q=7.84
T=520
T=11
T<0.0001
T=0.84
T=0.039
T=0.098
T=0.36
Q=28.0
Q=0.28
Q=1.38
Q=24.0
Q=0.035
Q=0.20
Q=0.22
Q=5.11
Q=0.60
Q=0.55
Q=0.00
Q=0.27
Q=0.014
Q=0.033
Q=0.018
Seepage*
(Q=l/min)
Q=0.2
Q=5.0
Q=0.4
Q=0.5
Q=1.0
Q=0.6
Q=1.1
Ground water pressure***
100
50
0
Cl****
(mg/l)
10000
5000
pH****
12
6
Notes
* Seepage character:
Flow
Drop
Moisture
** Q$_f$: 30-40 m probehole in tunnel front
*** in % of depth under sea level (same day as probing)
Date: 931213-940124
**** Groundwater sampling from
waterbearing fracture
borehole
Date: 931214-931227
940217

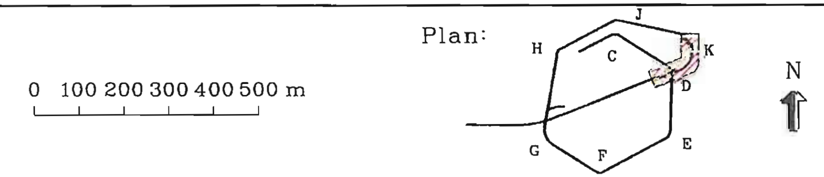

Äspö Hard Rock Laboratory
Overview of documentation
Loop 2, Leg J-K: 2/867.1-3/026
Geohydrology and Groundwater chemistry
a c b
l r
Tunnel profile
-200
-250
-300
-350
-400
-450
-500
m
Section:
A B C D E F G H J K
0 100 200 300 400 500 m
Plan:
H J C K D E F G
N
Chainage
2/867.1
Z=-386
2/900
Z=-393
2/950
Z=-400
3/000
3/026
Water-bearing structures*
l
c
r
Probing**
(Q=l/min)
(T=*10^-7 m²/s)
a
c
b
T=-
Q=0.33
T=1800
Q=400
T=-
Q=73.2
T=0.025
Q=0.036
T=-
Q=0.0004
T<0.0001
Q=0
T<0.0001
Q=0
T<0.0001
Q=0
T=-
Q=0.0072
Seepage*
(Q=l/min)
Q=6.0
Q=1.5
Q=0.8
Q=0.4
Q=1.0
Q=10
Q=1.5
Q=4.0
Q=0.4
Ground water pressure***
100
50
0
a
Cl****
(mg/l)
10000
5000
0
pH****
12
6
Notes
960812
* Seepage character:
Flow
Drop
Moisture
** Qf: 30-40 m probehole in tunnel front
*** in % of depth under sea level (same day as probing)
Date: 940127-940218
**** Groundwater sampling from
waterbearing fracture
borehole
Date: 940131-940204

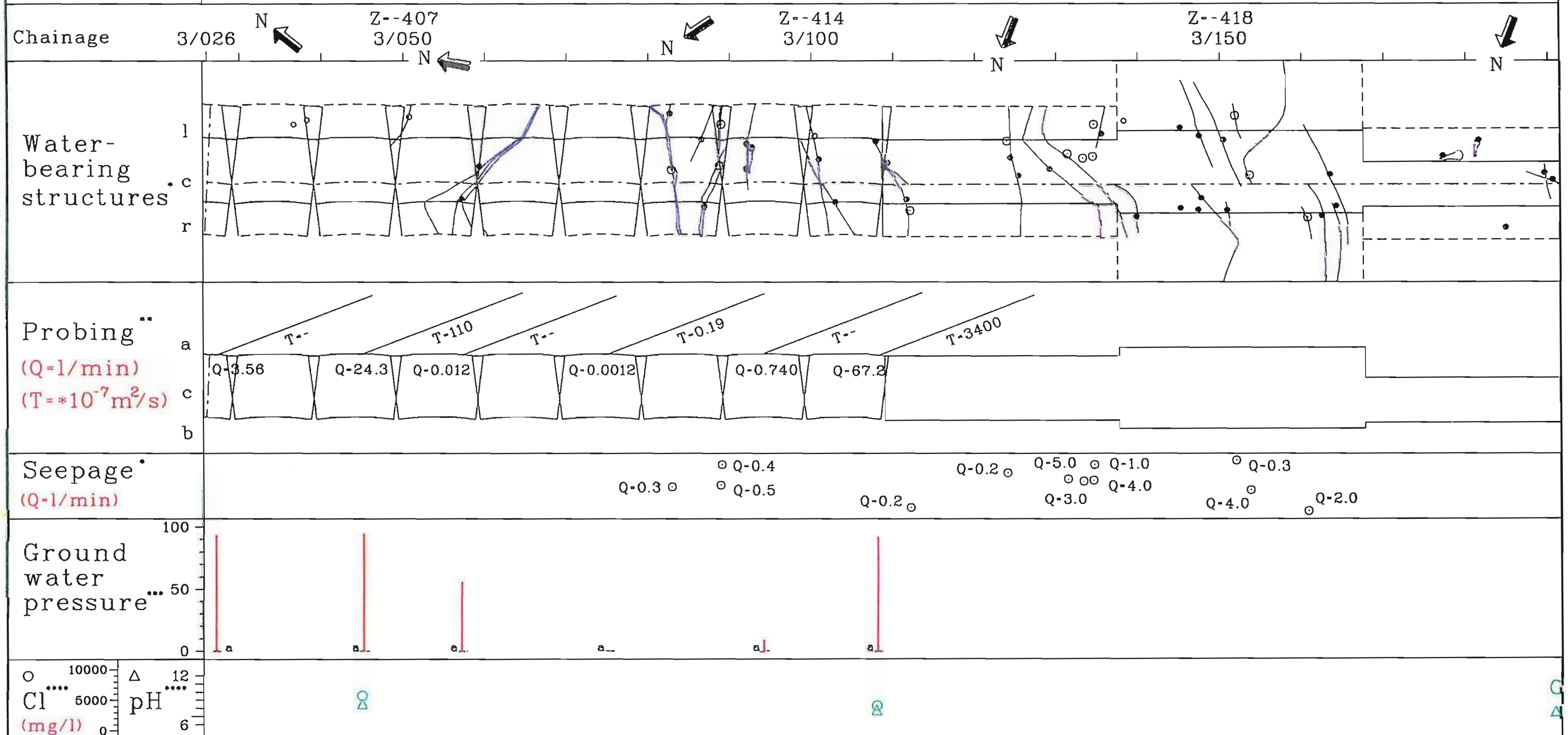
Äspö Hard Rock Laboratory — Overview of documentation

Loop 2, Curve K and TBM hall: 3/026-3/191.3 — Geohydrology and Groundwater chemistry









Notes

* Seepage character:
- ○ Flow
- • Drop
- ∘ Moisture

** Q_f: 30-40 m probehole in tunnel front

*** in % of depth under sea level (same day as probing)
Date: 940224-940308

**** Groundwater sampling from
- ○△ waterbearing fracture
- ○△ borehole

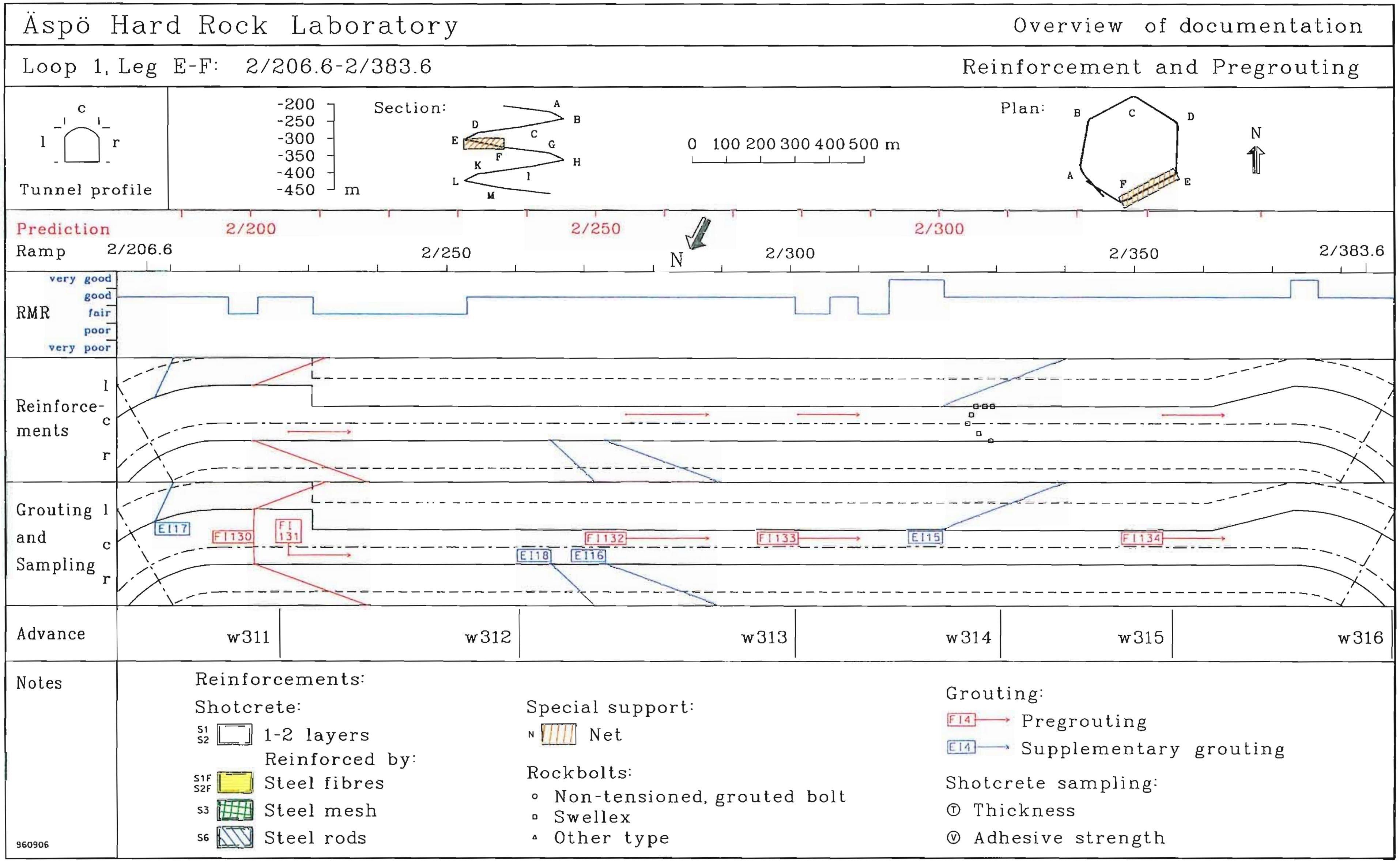
Date: 940227-940604

960812

Appendix 3

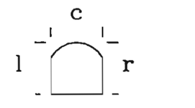
Presented in this appendix are plots of reinforcement and pregrouting from the standard mapping performed within the interval between 2206 up to 3191 m. The projection is folded-out from the centreline of the roof.

6 pages

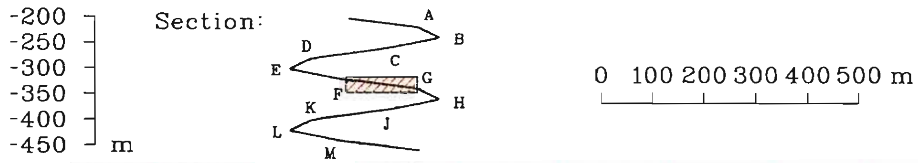

Äspö Hard Rock Laboratory
Overview of documentation
Loop 1, Leg E-F: 2/206.6-2/383.6
Reinforcement and Pregrouting
Tunnel profile
c
l
r
-200
-250
-300
-350
-400
-450
m
Section:
A
B
C
D
E
F
G
H
I
K
L
M
0 100 200 300 400 500 m
Plan:
N
Prediction
2/200
2/250
2/300
Ramp
2/206.6
2/250
2/300
2/350
2/383.6
RMR
very good
good
fair
poor
very poor
Reinforcements
Grouting and Sampling
E117
F1130
F1 131
F1132
F1133
E115
F1134
E118
E116
Advance
w311
w312
w313
w314
w315
w316
Notes
960906
Reinforcements:
Shotcrete:
S1 S2 1-2 layers
Reinforced by:
S1F S2F Steel fibres
S3 Steel mesh
S6 Steel rods
Special support:
N Net
Rockbolts:
Non-tensioned, grouted bolt
Swellex
Other type
Grouting:
F14 Pregrouting
E14 Supplementary grouting
Shotcrete sampling:
Ⓣ Thickness
Ⓥ Adhesive strength

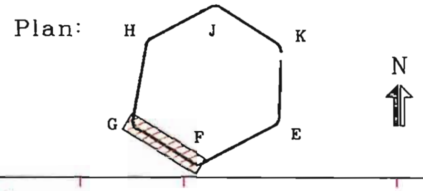
Äspö Hard Rock Laboratory | Overview of documentation

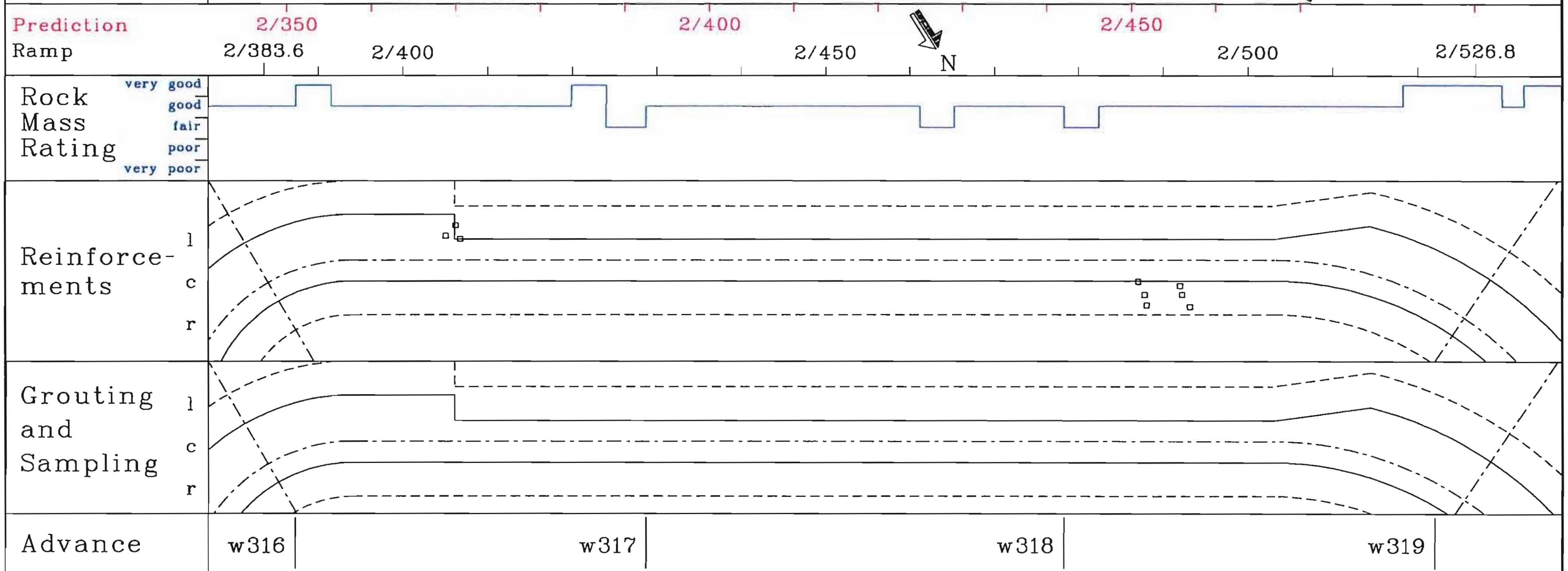
Loop 1, Leg F-G: 2/383.6-2/526.8 | Reinforcement and Pregrouting



Tunnel profile







Notes

Reinforcements:

Shotcrete:

S1 S2 1-2 layers

Reinforced by:

S1F S2F Steel fibres

S3 Steel mesh

S6 Steel rods

Special support:

N Net

Rockbolts:

- Non-tensioned, grouted bolt
- Swellex
- Other type

Grouting:

F14 Pregrouting

E14 Supplementary grouting

Shotcrete sampling:

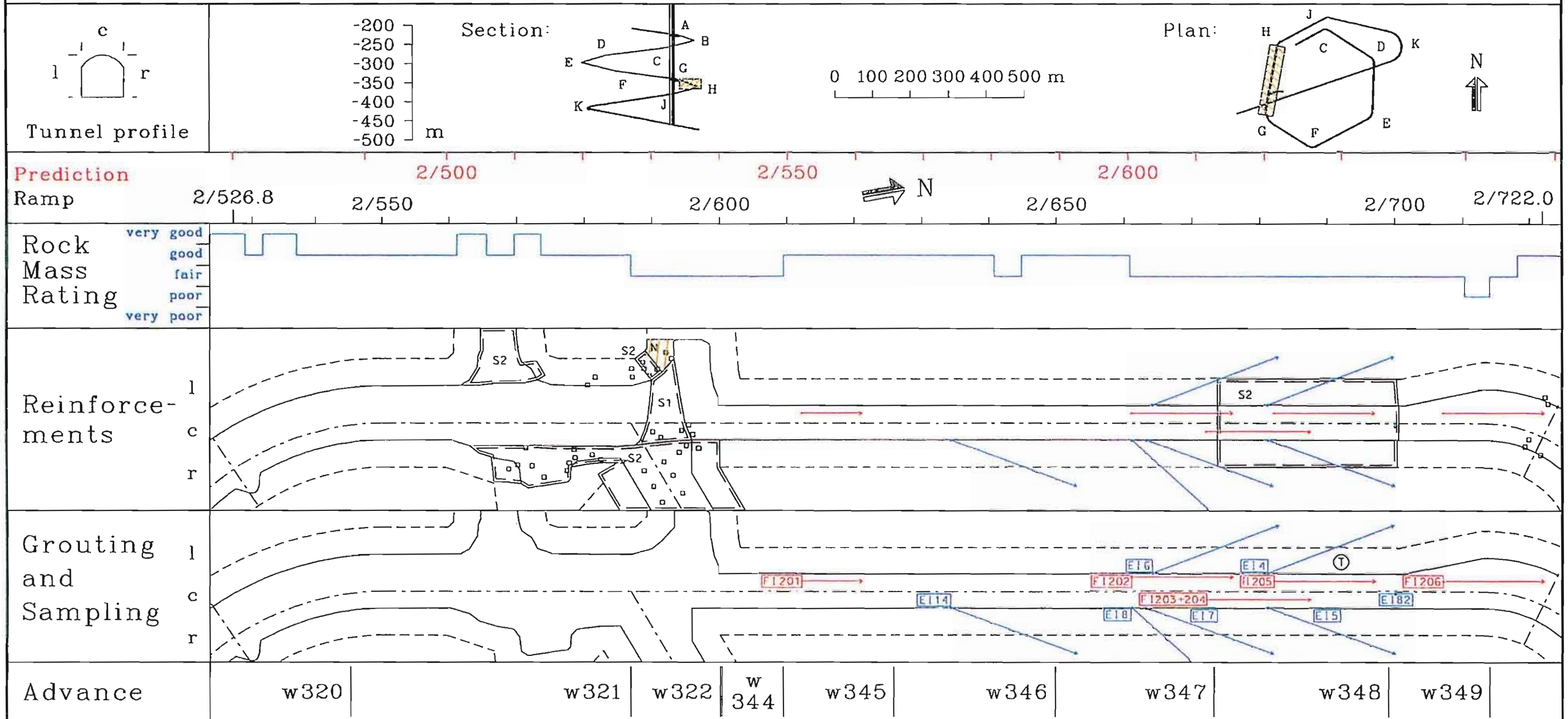
Ⓣ Thickness

Ⓥ Adhesive strength

960906

Äspö Hard Rock Laboratory — Overview of documentation

Loop 2, Leg G-H: 2/526.8-2/722.0 — Reinforcement and Pregrouting



Notes

Reinforcements:

Shotcrete:

- S1 S2 — 1-2 layers
- Reinforced by:
- S1F S2F — Steel fibres
- S3 — Steel mesh
- S6 — Steel rods

Special support:

- N — Net

Rockbolts:

- ∘ Non-tensioned, grouted bolt
- ▫ Swellex
- ▵ Other type

Grouting:

- F14 → Pregrouting
- E14 → Supplementary grouting

Shotcrete sampling:

- Ⓣ Thickness
- Ⓥ Adhesive strength

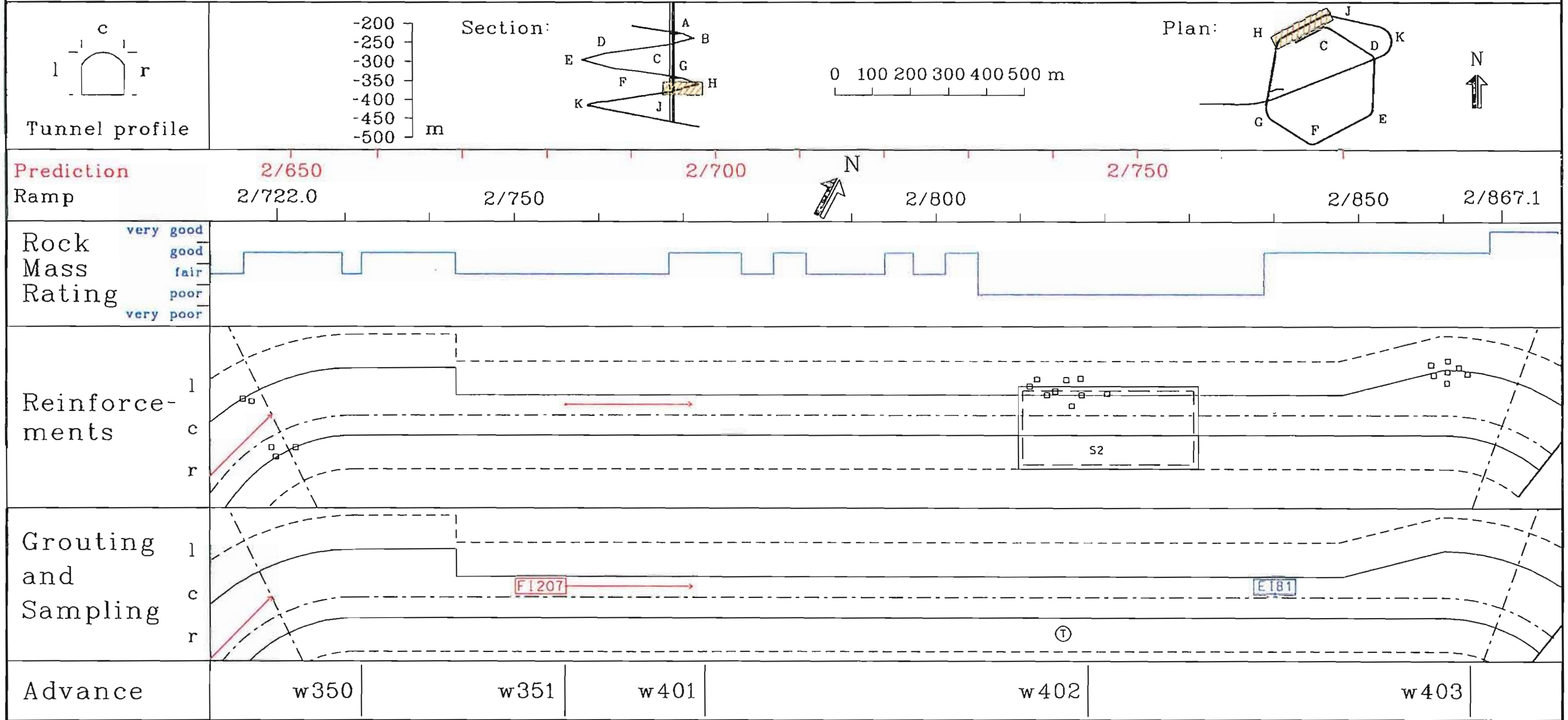
960920

Äspö Hard Rock Laboratory

Overview of documentation

Loop 2, Leg H-J: 2/722.0-2/867.1

Reinforcement and Pregrouting



Notes

Reinforcements:

Shotcrete:

S1 S2 1-2 layers

Reinforced by:

S1F S2F Steel fibres

S3 Steel mesh

S6 Steel rods

Special support:

N Net

Rockbolts:

- Non-tensioned, grouted bolt
- Swellex
- Other type

Grouting:

F14 Pregrouting

E14 Supplementary grouting

Shotcrete sampling:

Ⓣ Thickness

Ⓥ Adhesive strength

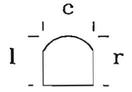
960920

Äspö Hard Rock Laboratory

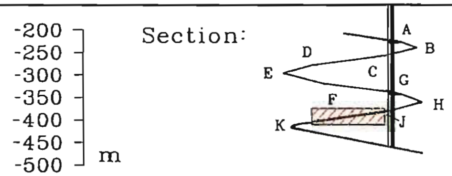
Overview of documentation

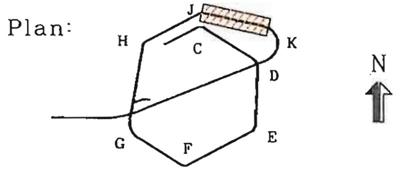
Loop 2, Leg J-K: 2/867.1-3/026

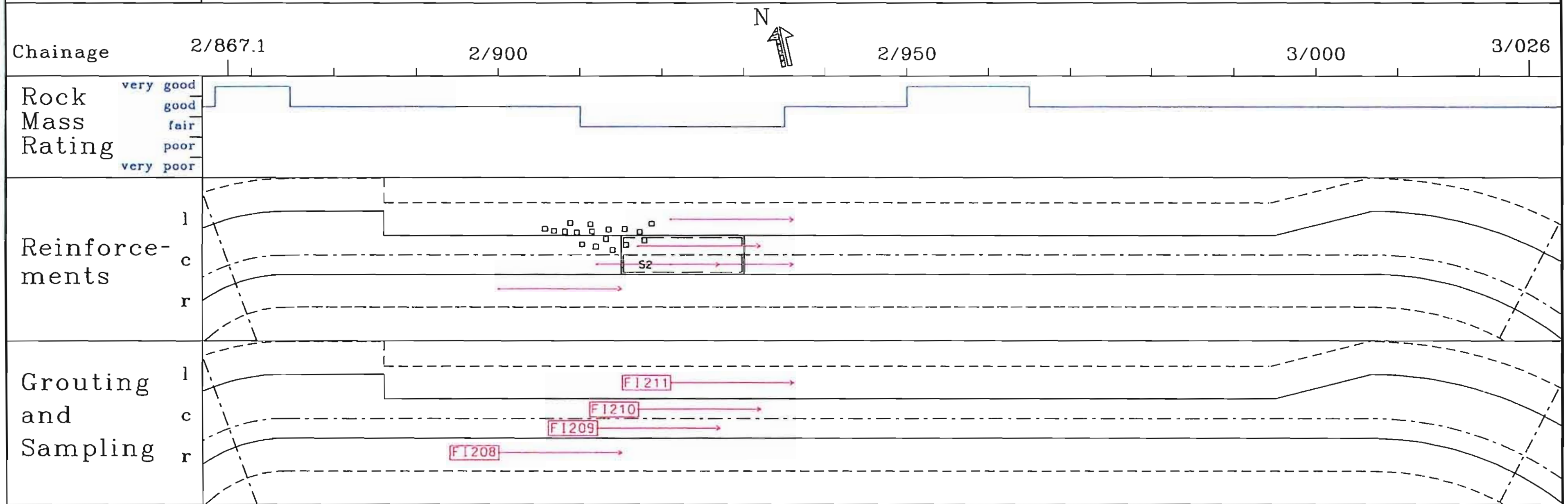
Reinforcement and Pregrouting



Tunnel profile







Advance	w404	w405	w406	w407

Notes

Reinforcements:

Shotcrete:
- S1 S2: 1-2 layers
- Reinforced by:
  - S1F S2F: Steel fibres
  - S3: Steel mesh
  - S6: Steel rods

Special support:
- N: Net

Rockbolts:
- ∘ Non-tensioned, grouted bolt
- ▫ Swellex
- ▵ Other type

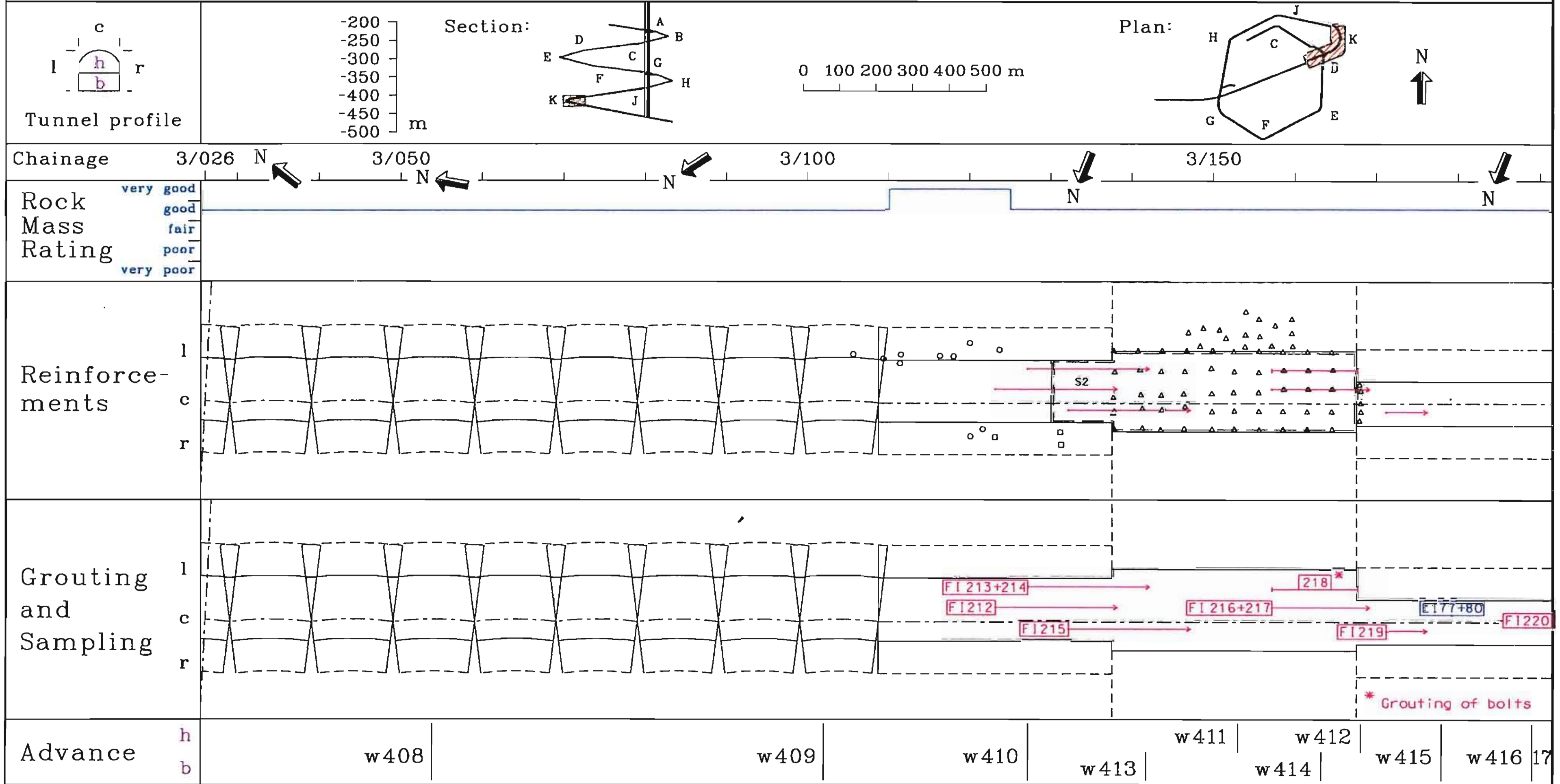
Grouting:
- F14 → Pregrouting
- E14 → Supplementary grouting

Shotcrete sampling:
- Ⓣ Thickness
- Ⓥ Adhesive strength

960906

Aspo Hard Rock Laboratory — Overview of documentation

Loop 2, Curve K and TBM hall: 3/026-3/191.3 — Reinforcement and Pregrouting



Notes

Reinforcements:

Shotcrete:

S1 S2 — 1-2 layers

Reinforced by:

S1F S2F — Steel fibres

S3 — Steel mesh

S6 — Steel rods

Special support:

N — Net

Rockbolts:

- ∘ Non-tensioned, grouted bolt
- ▫ Swellex
- ▵ Other type

Grouting:

FI4 → Pregrouting

EI4 → Supplementary grouting

Shotcrete sampling:

Ⓣ Thickness

Ⓥ Adhesive strength

Advance:

h = heading

b = bench

960906

Appendix 4

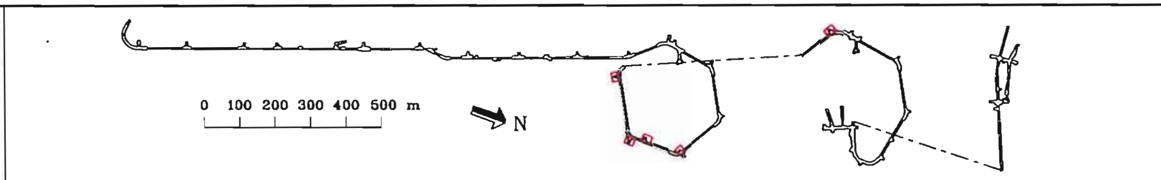
Presented in this appendix are plots of geology, geohydrology and reinforcements from the standard mapping performed in niches and side tunnels. The projection is folded-out from the centreline of the roof.

7 pages

Äspö Hard Rock Laboratory — Overview of documentation

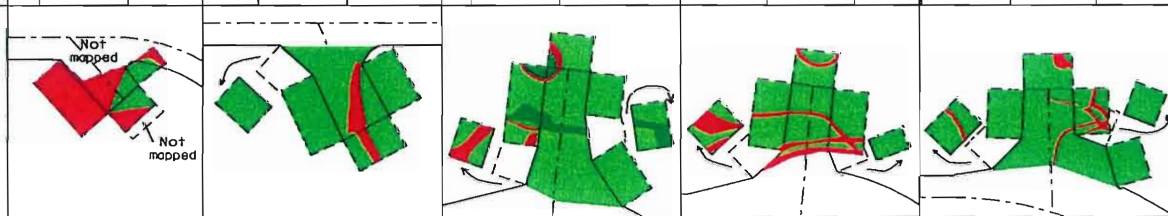
Niches: 2050-2550

Plan View



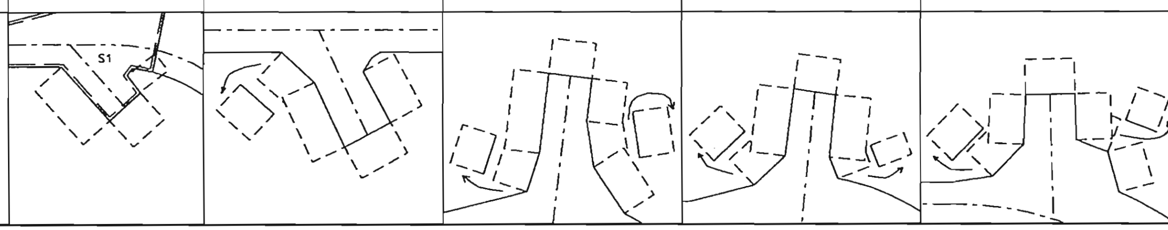
Chainage	2040 2050	2150 2160	2190 2200	2370 2380	2510 2520
Fracture minerals [4]	Cl: 56% Ep: 11% Ca: 56% Clay:0%	Ca: 47% Ep: 16% Cl: 38% Clay:0%	Cl: 54% Ep: 24% Ca: 41% Clay:0%	Cl: 70% Ep: 20% Ca: 55% Clay:0%	Cl: 56% Ep: 26% Ca: 35% Clay:0%
RMR	58	77	73	87	72

Lithology [1]



Fractures and Fracture zones [2] Seepage [3]

Reinforcements [5]



970528 RS_REDN1-05-4

[1] Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

[2] Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

[3] Seepage:
- Flow
- Drop
- Moisture

[4] Dominating

[5] Reinforcements:

Shotcrete:
- S1 S2 1-2 layers

Reinforced by:
- S1F S2F Steel fibres
- S3 Steel mesh
- S6 Steel rods

Special support:
- N Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- F14 Pregrouting
- E14 Supplementary

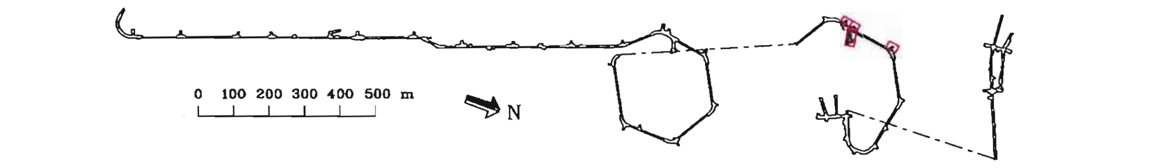
Shotcrete sampling:
- T Thickness
- V Adhesive strength

Äspö Hard Rock Laboratory

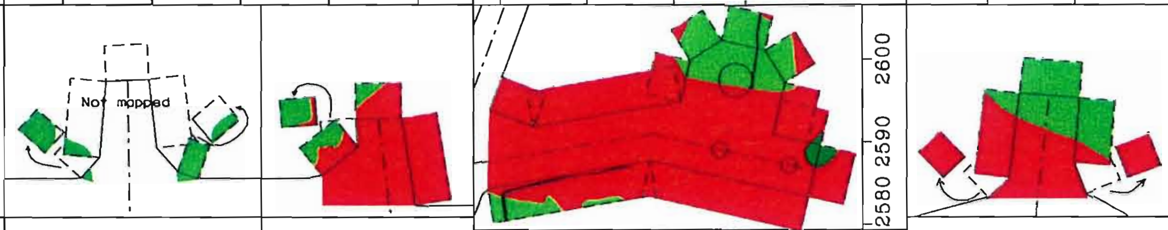
Overview of documentation

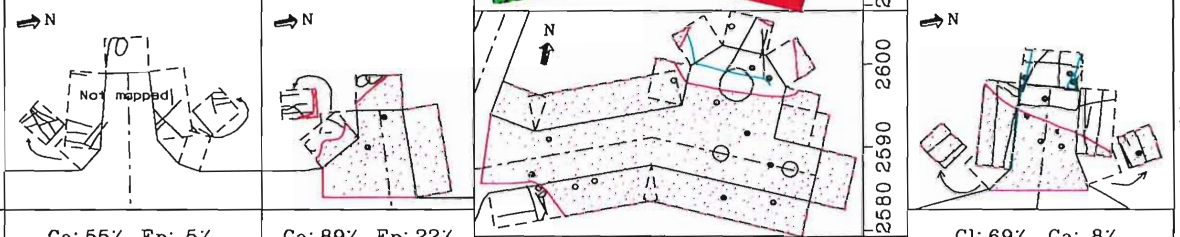
Niches: 2550-2800

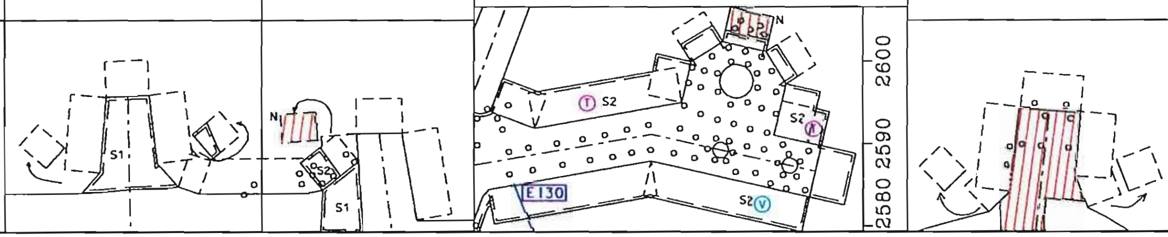
Plan View



Chainage	2560 2570 2580	2590 2600	000 010 020 030 Chainage	2710 2720
Lithology [1]				
Fractures and Fracture zones [2] Seepage [3]				
Fracture minerals [4]	Ca: 55% Ep: 5% Cl: 30% Clay:0%	Ca: 89% Ep: 22% Cl: 22% Clay:0%	Ca: 60% Ep: 20% Cl: 50% Clay: 0%	Cl: 69% Ca: 8% Ep: 54% Clay:0%
RMR	-	53	48	54
Reinforcements [5]				







970528 RS_REDN1-06-7

1 Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

2 Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

3 Seepage:
- Flow
- Drop
- Moisture

4 Dominating

5 Reinforcements:

Shotcrete:
- S1 S2: 1-2 layers

Reinforced by:
- S1F S2F: Steel fibres
- S3: Steel mesh
- S6: Steel rods

Special support:
- N: Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- F14 Pregrouting
- E14 Supplementary

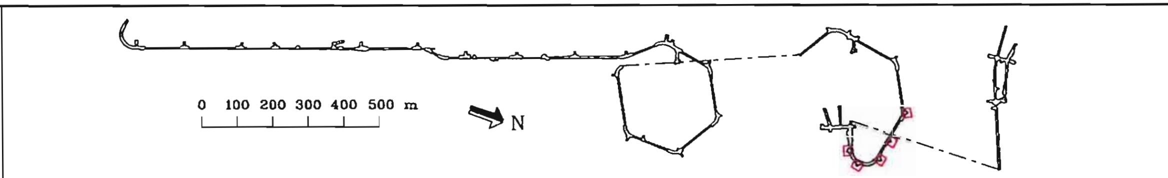
Shotcrete sampling:
- T Thickness
- V Adhesive strength

Äspö Hard Rock Laboratory

Overview of documentation

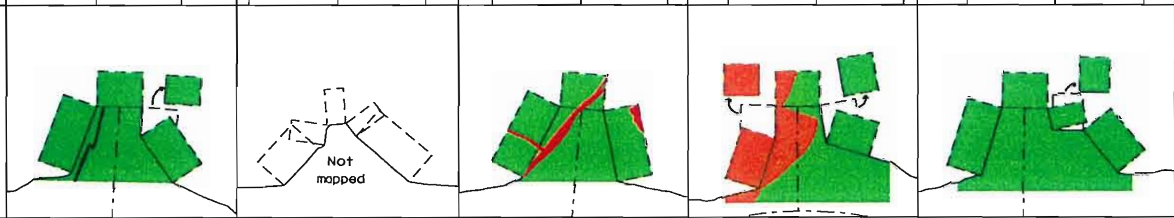
Niches: 2800-3150

Plan View

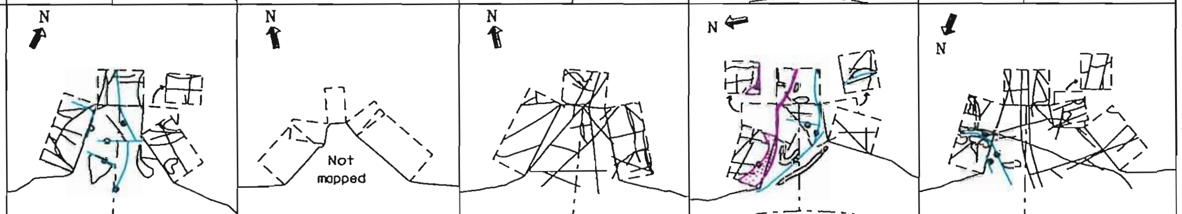


Chainage	2860 2870	2940 2950 2960	3000 3010 3020	3060 3070 3080	3100 3110 3120
Fracture minerals[4]	Cl: 78% Fe: 22% Ca: 56% Clay: 0%	No indications	Cl: 80% Ep: 33% Ca: 33% Clay: 0%	Ca: 72% Ep: 21% Cl: 52% Clay: 0%	Cl: 73% Oxid: 27% Ca: 57% Clay: 0%
RMR	71	-	70	63	67

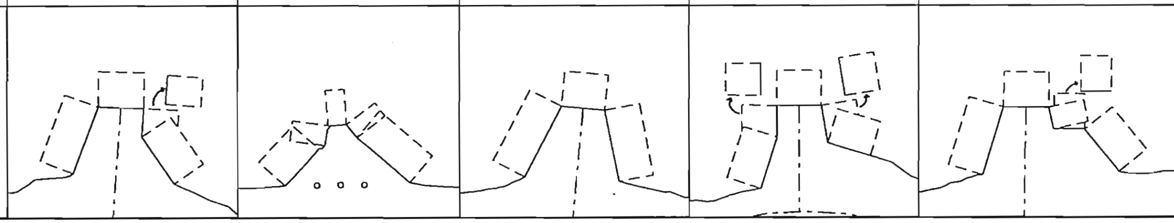
Lithology[1]



Fractures and Fracture zones[2] Seepage[3]



Reinforcements[5]



970818 RS_REDN1-11-2

[1] Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

[2] Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

[3] Seepage:
- ○ Flow
- • Drop
- ∘ Moisture

[4] Dominating

[5] Reinforcements:

Shotcrete:
- S1 S2 1-2 layers
- Reinforced by:
- S1F S2F Steel fibres
- S3 Steel mesh
- S6 Steel rods

Special support:
- N Net

Rockbolts:
- ∘ Non-tensioned, grouted
- ▫ Swellex
- ▵ Other type

Grouting:
- F14 Pregrouting
- E14 Supplementary

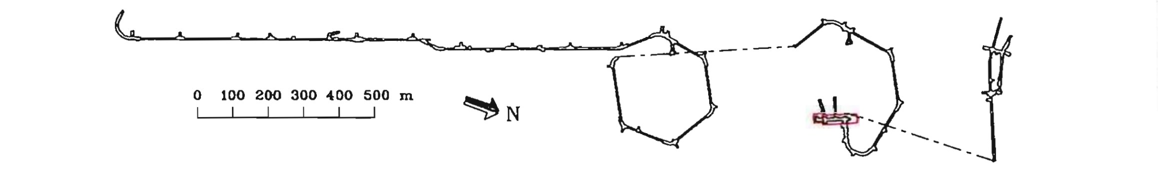
Shotcrete sampling:
- (T) Thickness
- (V) Adhesive strength

Äspö Hard Rock Laboratory

Overview of documentation

Niches: 3150-3180

Plan View

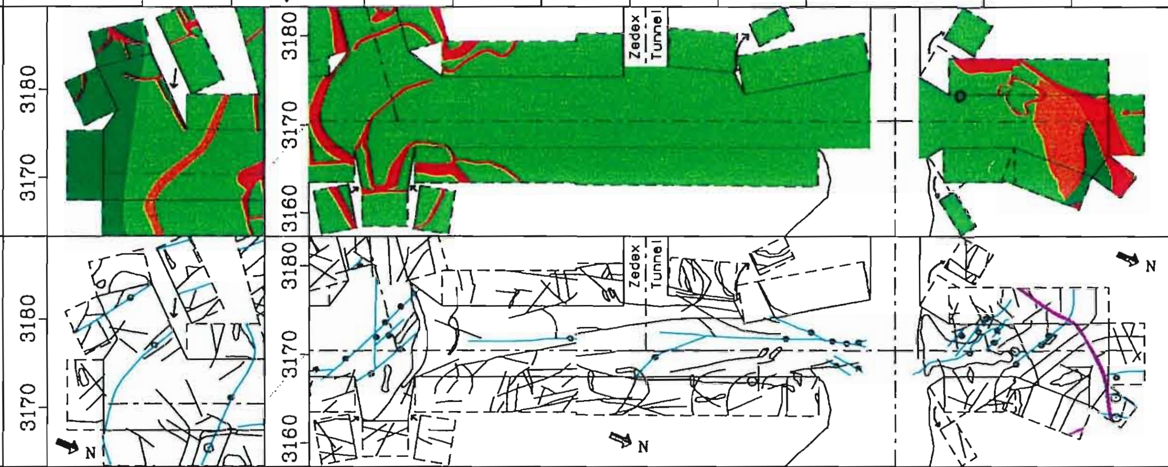


Chainage: Main 080 070 | Main 060 050 040 030 020 010 | 010 020

Lithology [1]

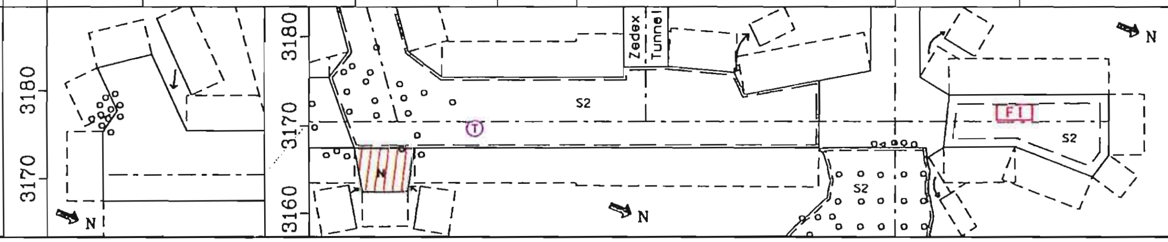
Fractures and Fracture zones [2]

Seepage [3]



Fracture minerals [4]	Cl: 84% Clay: 0%	Cl: 81% Ep:22% Ca: 70% Clay: 0%	Cl: 71% Oxid:11% Ca: 43% Clay: 0%	Cl: 71% Clay: 0%	Cl: 84% Oxid: 39% Ca: 53% Clay: 0%	Ca: 64% Oxid: 24% Cl: 58% Clay: 0%	Cl: 57% Ep:7% Ca: 32% Clay: 0%
RMR	68	79	54	70	69	70	65

Reinforcements [5]



970818 RS_REDNI-12-2

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1 Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

2 Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

3 Seepage:
- Flow
- Drop
- Moisture

4 Dominating

5 Reinforcements:

Shotcrete:
- S1 S2 1-2 layers

Reinforced by:
- S1F S2F Steel fibres
- S3 Steel mesh
- S6 Steel rods

Special support:
- N Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- F14 Pregrouting
- E14 Supplementary

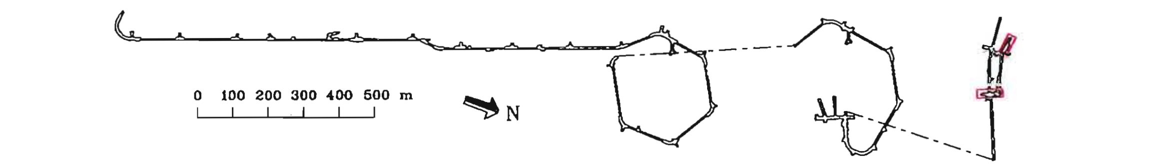
Shotcrete sampling:
- T Thickness
- V Adhesive strength

Äspö Hard Rock Laboratory

Overview of documentation

Niches: 3300-3540 (TBM tunnel)

Plan View



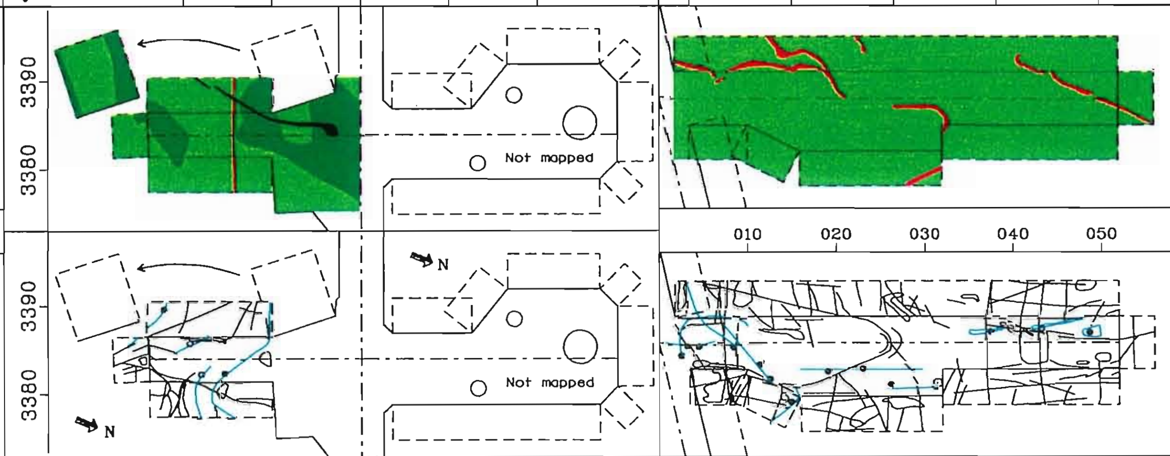
Chainage: Main 020 010 000 010 020 | 3500 3510 3520 3530 3540

Lithology [1]

Chainage: Side 010 020 030 040 050

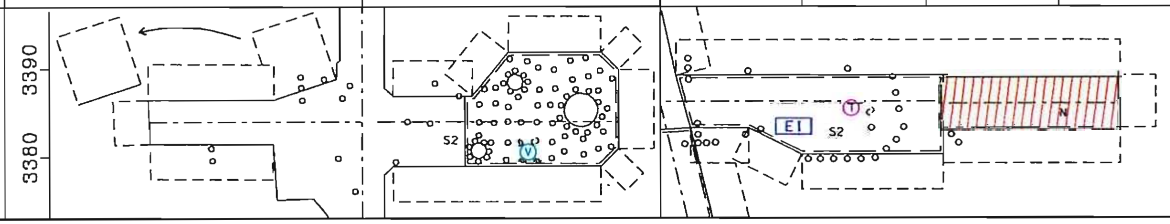
Fractures and Fracture zones [2]

Seepage [3]



Fracture minerals [4]	Ca: 85% Oxid: 27% Cl: 58% Clay: 0%	No indications	Cl: 79% Oxid: 26% Ca: 41% Clay: 0%	Cl: 88% Oxid: 21% Ca: 29% Clay: 0%	Cl: 72% Oxid: 44% Ca: 24% Clay: 0%	Cl: 61% Oxid: 17% Ca: 50% Clay: 0%
RMR	61	-	64	64	73	75

Reinforce-ments [5]



970528 RS_REDN1-14-1

[1] Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

[2] Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

[3] Seepage:
- ○ Flow
- • Drop
- ∘ Moisture

[4] Dominating

[5] Reinforcements:

Shotcrete:
- S1 S2 1-2 layers

Reinforced by:
- S1F S2F Steel fibres
- S3 Steel mesh
- S6 Steel rods

Special support:
- N Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- FI4 Pregrouting
- EI4 Supplementary

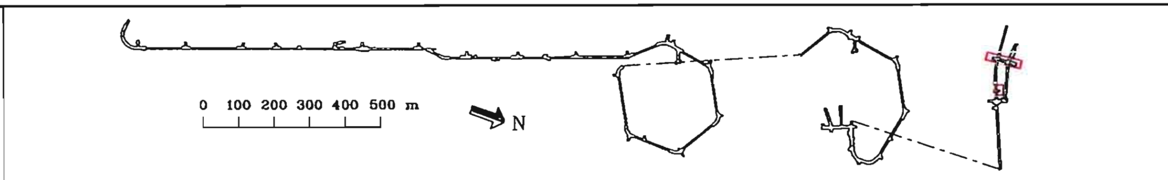
Shotcrete sampling:
- Ⓣ Thickness
- Ⓥ Adhesive strength

Äspö Hard Rock Laboratory

Overview of documentation

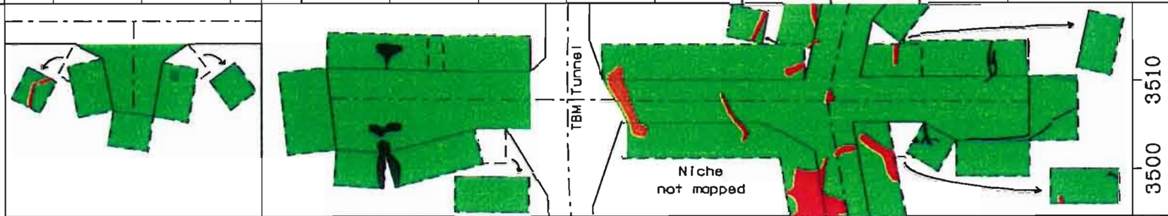
Niches: 3400-3520 (TBM tunnel)

Plan View

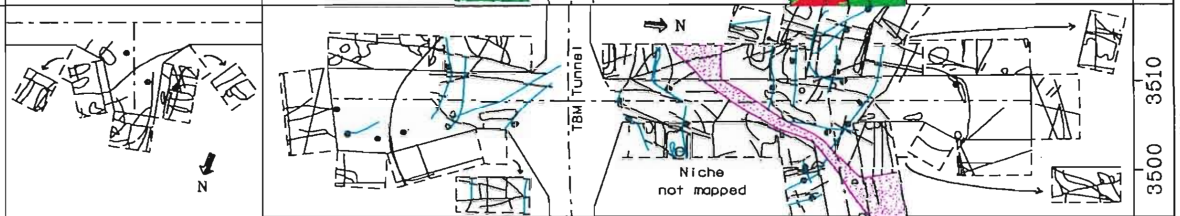


Chainage	3410	3420	3430	030	020	010	000	010	020	030	040	050	Chainage

Lithology [1]

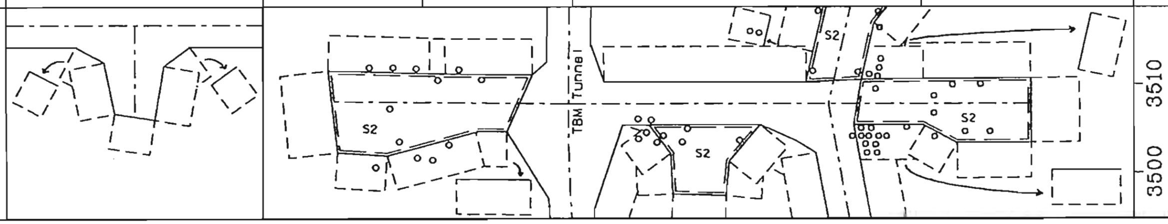


Fractures and Fracture zones [2] **Seepage** [3]



Fracture minerals [4]	Cl: 83% Ep: 44% Ca: 67% Clay:0%	Cl: 95% Ep:33% Ca: 52% Clay: 0%	Cl: 92% Oxid: 27% Ca: 69% Clay:0%	Cl: 89% Ep: 23% Ca: 70% Clay:0%	Cl: 93% Ep:18% Ca: 54% Clay: 4%
RMR	55	66	60	67	85

Reinforcements [5]



970818 RS_REDON1-15-2

1 Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Smål. granite
- Fine-grained granite
- Mylonite
- Volcanite

2 Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

3 Seepage:
- Flow
- Drop
- Moisture

4 Dominating

5 Reinforcements:

Shotcrete:
- S1 S2: 1-2 layers

Reinforced by:
- S1F S2F: Steel fibres
- S3: Steel mesh
- S6: Steel rods

Special support:
- N: Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- F14 Pregrouting
- E14 Supplementary

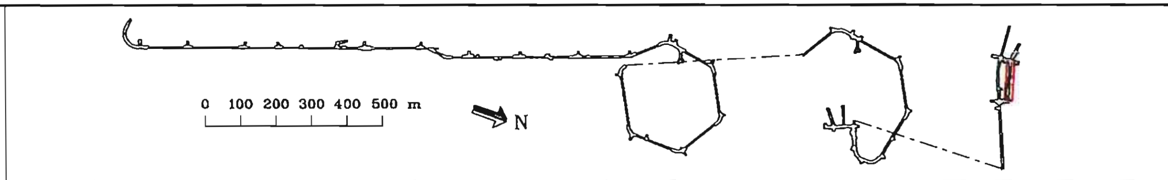
Shotcrete sampling:
- T Thickness
- V Adhesive strength

Äspö Hard Rock Laboratory

Overview of documentation

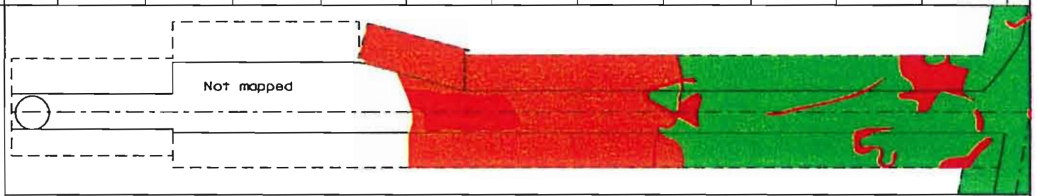
Niches: Parallel Tunnel at Z=-460 m

Plan View



Chainage (projected)	3400	3450	3500

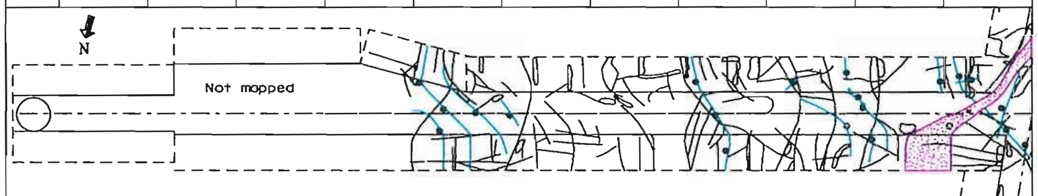
Lithology [1]



PARALLEL TUNNEL: 100 — 50 — 10

Fractures and Fracture zones [2]

Seepage [3]

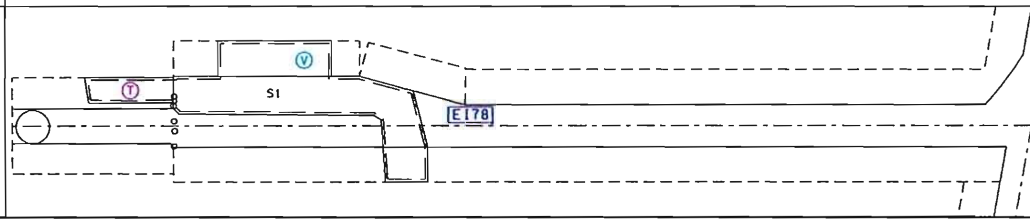


Fracture minerals [4]

Cl: 67% Ep: 23%
Ca: 56% Clay:1%

RMR	-	-	-	63	72	69	69	57

Reinforcements [5]



970818 RS_REDN1-10-7

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[1] Lithology:
- Pegmatite
- Greenstone
- Äspö diorite
- Småll. granite
- Fine-grained granite
- Mylonite
- Volcanite

[2] Fractures and zones:
- Fracture
- Water-bearing fracture
- Increased fracturing
- Fracture zone

[3] Seepage:
- Flow
- Drop
- Moisture

[4] Dominating

[5] Reinforcements:

Shotcrete:
- S1 S2 — 1-2 layers

Reinforced by:
- S1F S2F — Steel fibres
- S3 — Steel mesh
- S6 — Steel rods

Special support:
- N — Net

Rockbolts:
- Non-tensioned, grouted
- Swellex
- Other type

Grouting:
- F14 — Pregrouting
- E14 — Supplementary

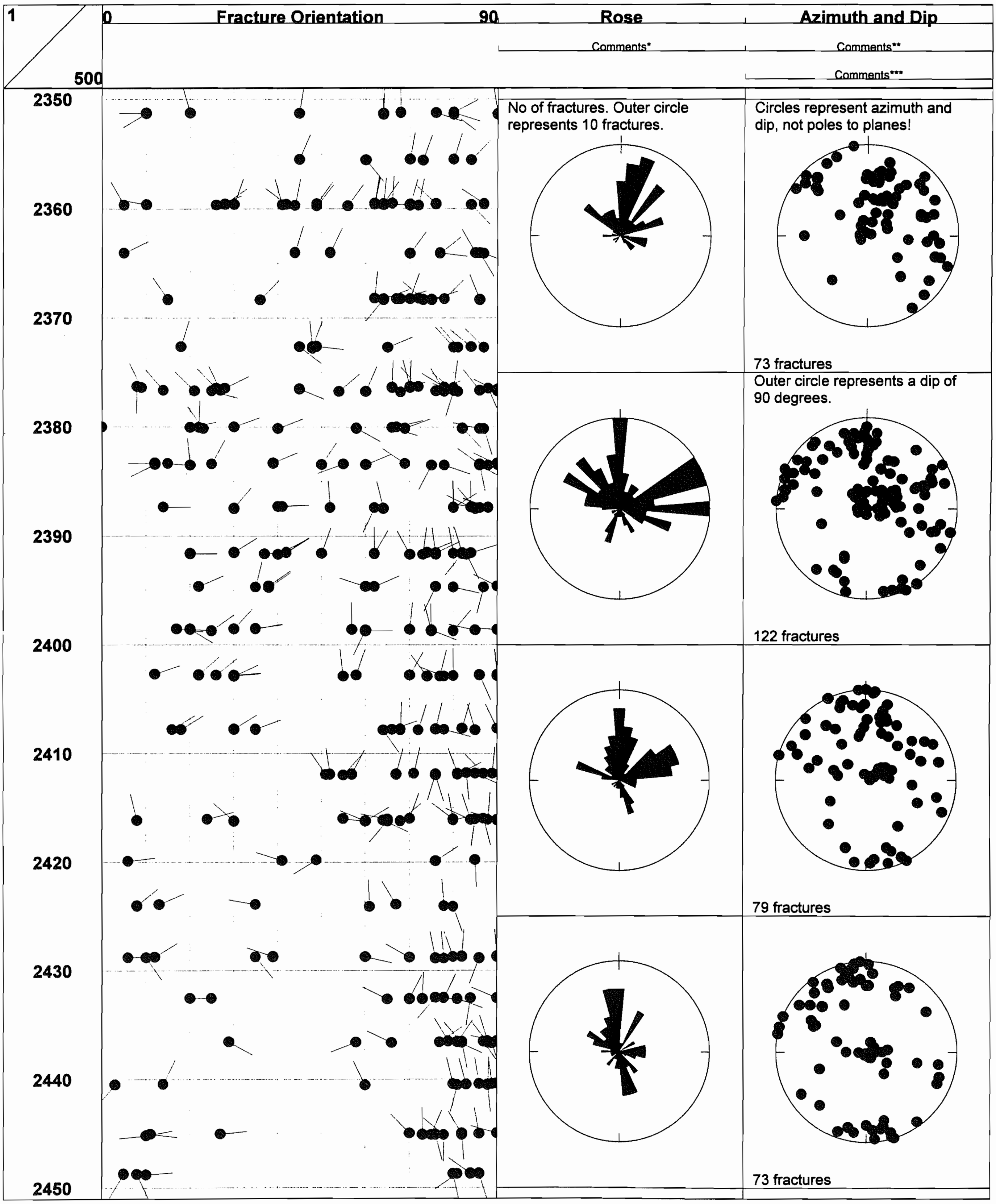
Shotcrete sampling:
- T — Thickness
- V — Adhesive strength

Appendix 5

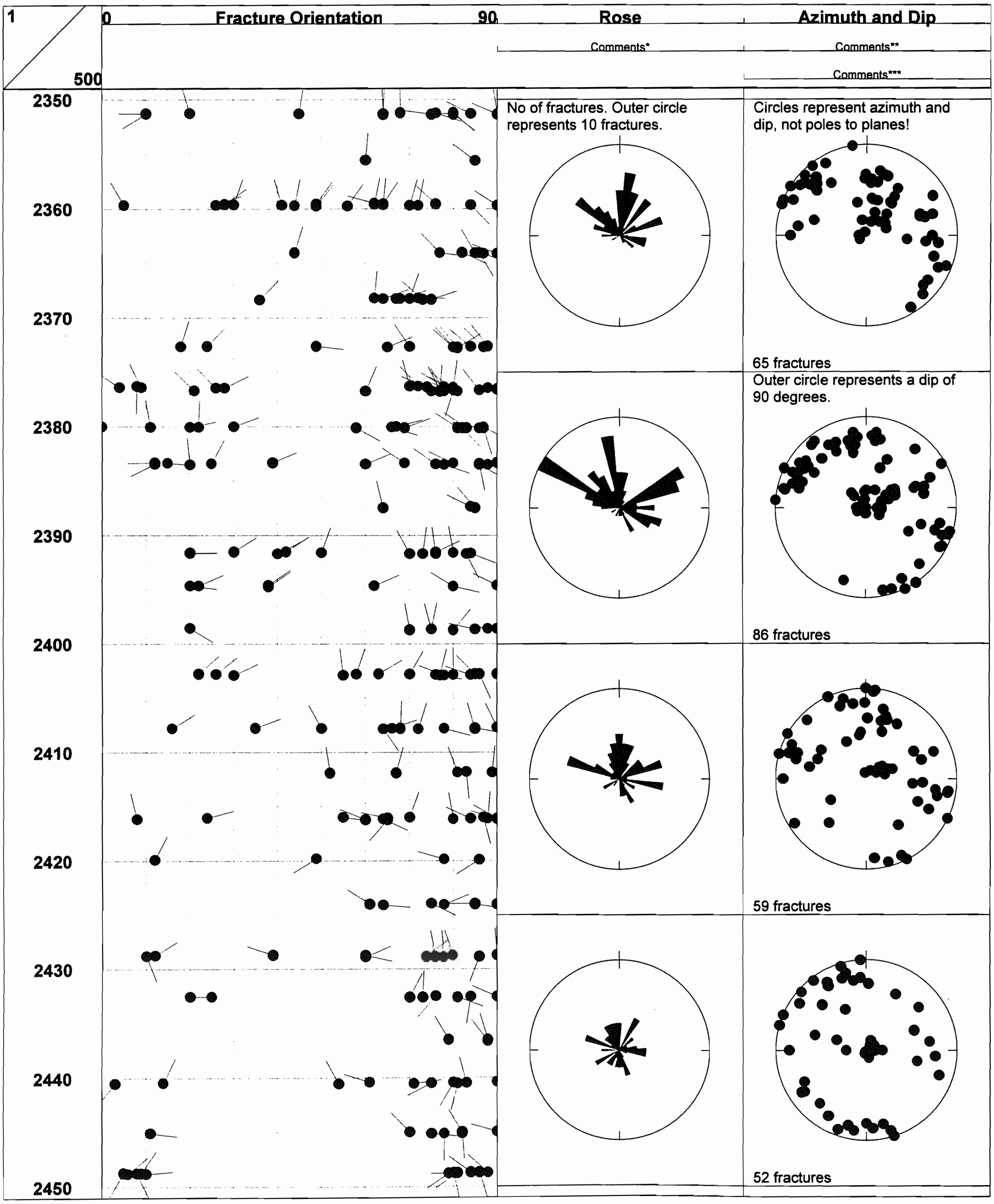
Presented in this appendix are plots of fracture orientations for chlorite, calcite, epidote, mylonite and waterfilled fractures for site 2375. The plot is a tadpole presentation, a rose plot and a plot of azimuth and dip.

5 pages

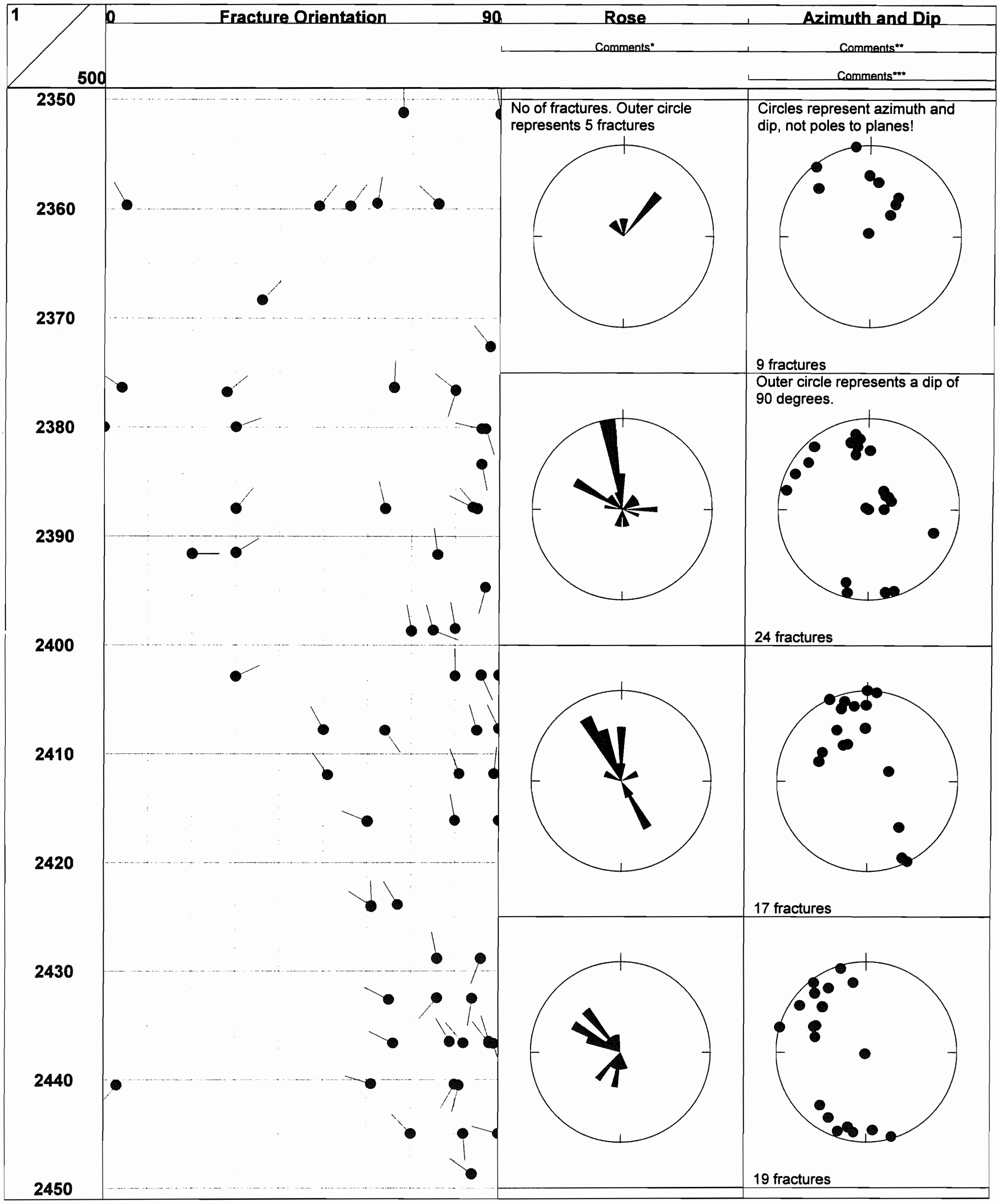
Title	SELECT-II. Site 2375. Chlorite.		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2350-2450	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, rose, azimuth and dip (note, not poles!), chlorite (347 of 481 obsevations).		



Title	**SELECT-II. Site 2375. Calcite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2350-2450	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture orientation, rose, azimuth and dip (note not poles!), calcite (262 of 481 observations).		

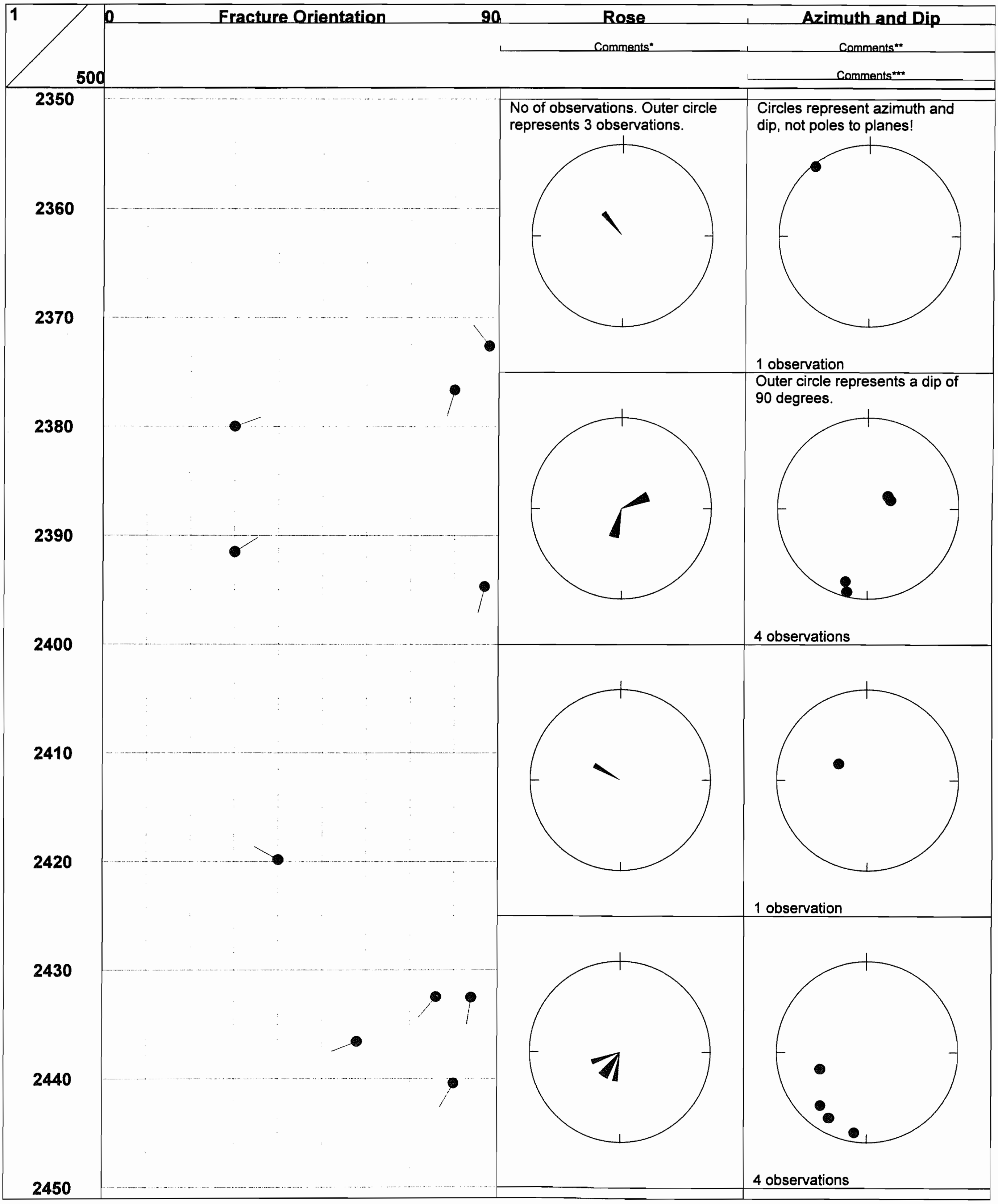


Title	**SELECT-II. Site 2375. Epidote.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2350-2450	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture orientation, rose, azimuth and dip (note not poles!), epidote (69 of 481 observations).		

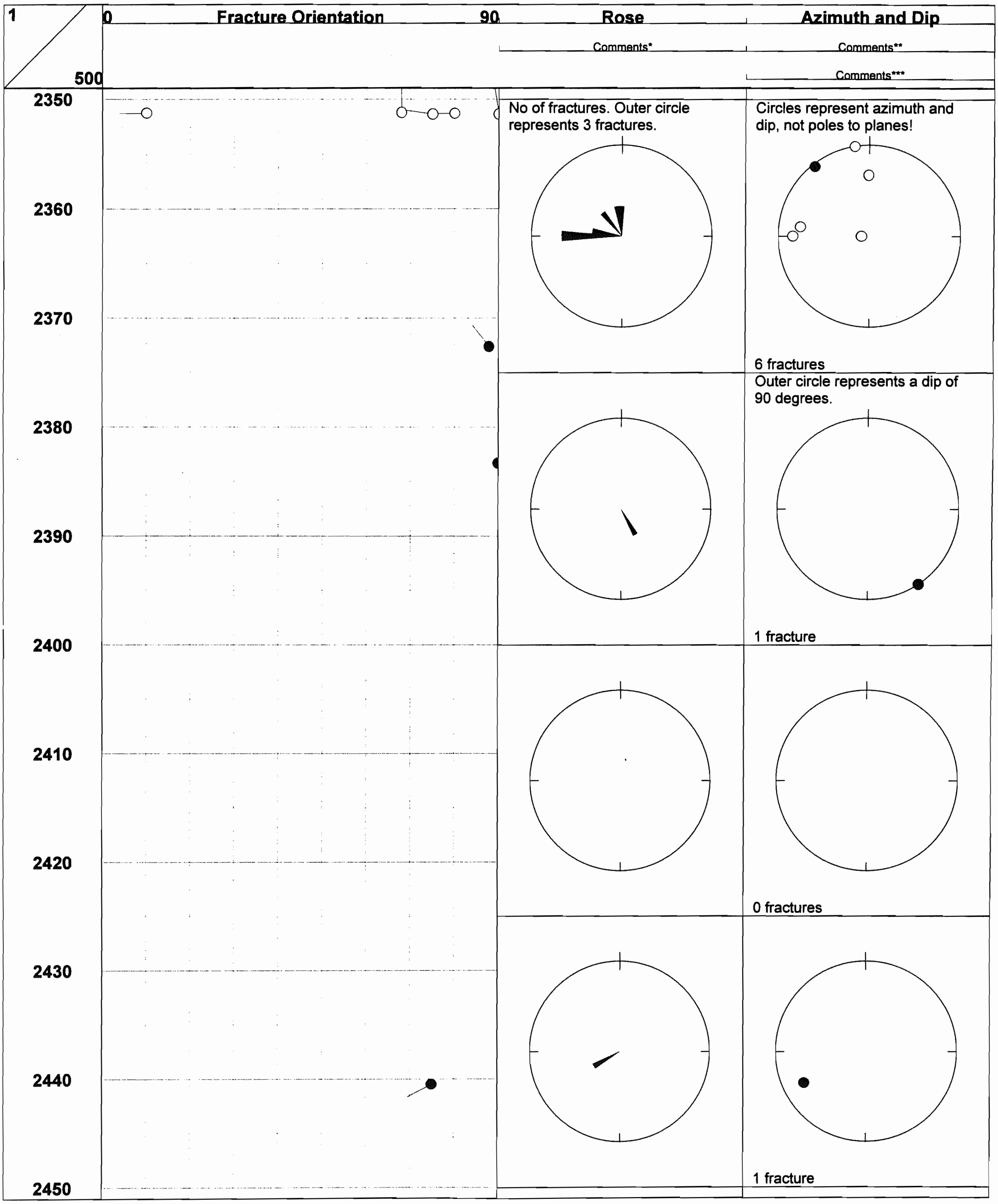


Title SELECT-II. Site 2375. Mylonite.

Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2350-2450	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture orientation, rose, azimuth and dip (note, not poles!), mylonite (10 of 481 observations).		



Title	**SELECT-II. Site 2375. Grout and water.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic Noth
Borehole	Tunnel section 2350-2450	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture orientation, rose, azimuth and dip (note not poles!), grout and water (8 of 481 obsevations).		



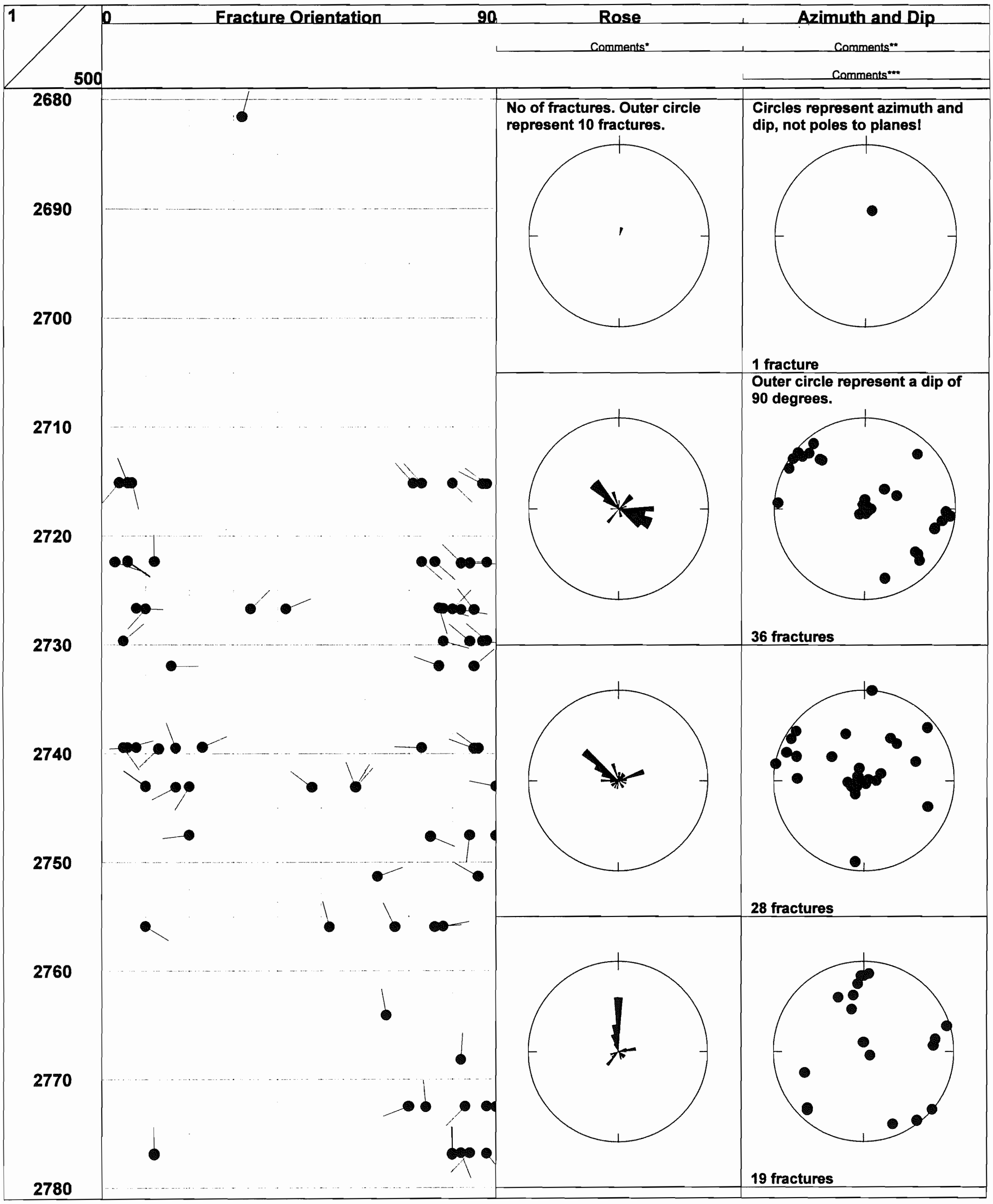
Appendix 6

Presented in this appendix are plots of fracture orientations for chlorite, calcite, epidote, mylonite and waterfilled fractures for site 2730. The plot is a tadpole presentation, a rose plot and a plot of azimuth and dip.

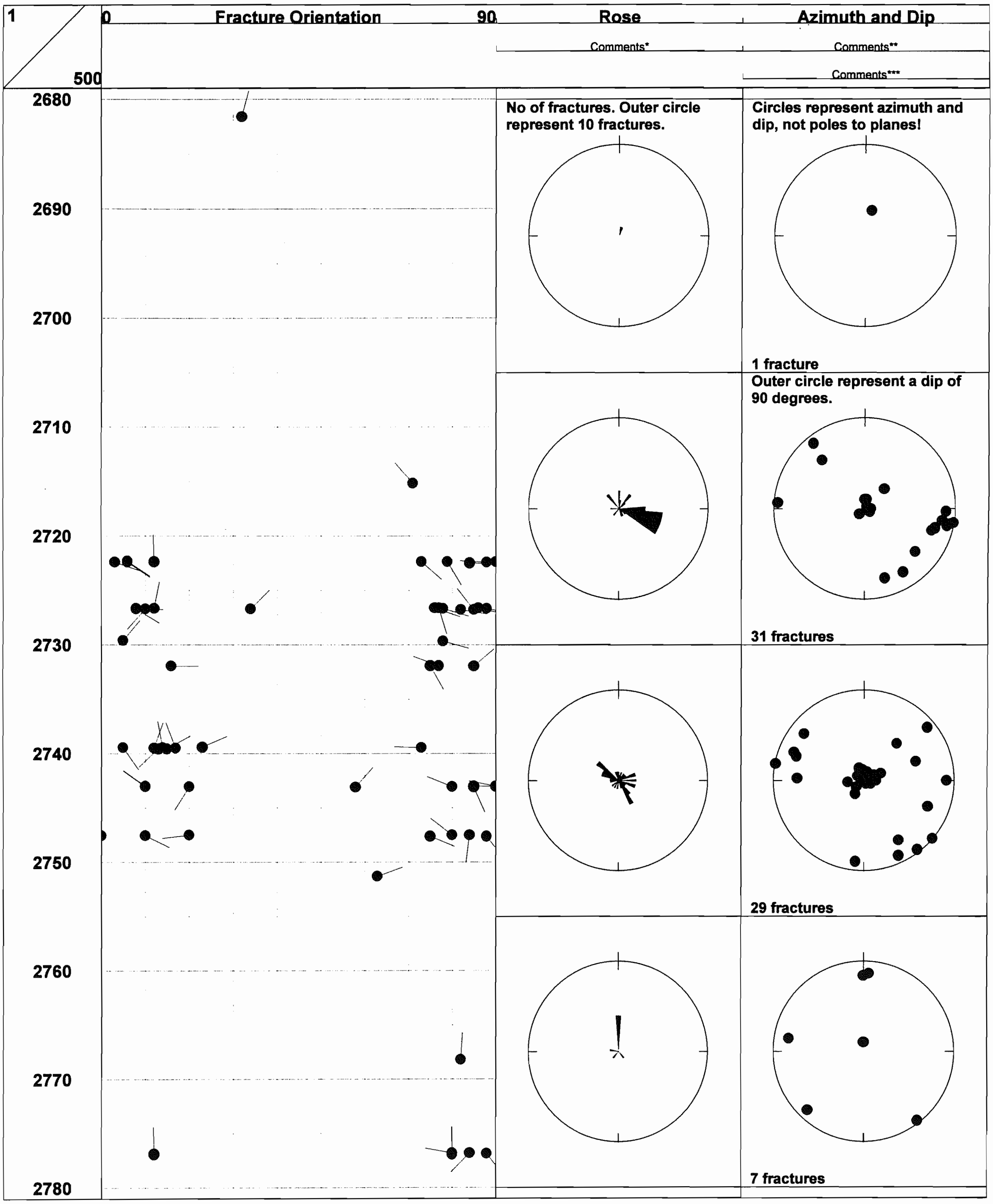
5 pages

Title SELECT-II. Site 2730. Chlorite.

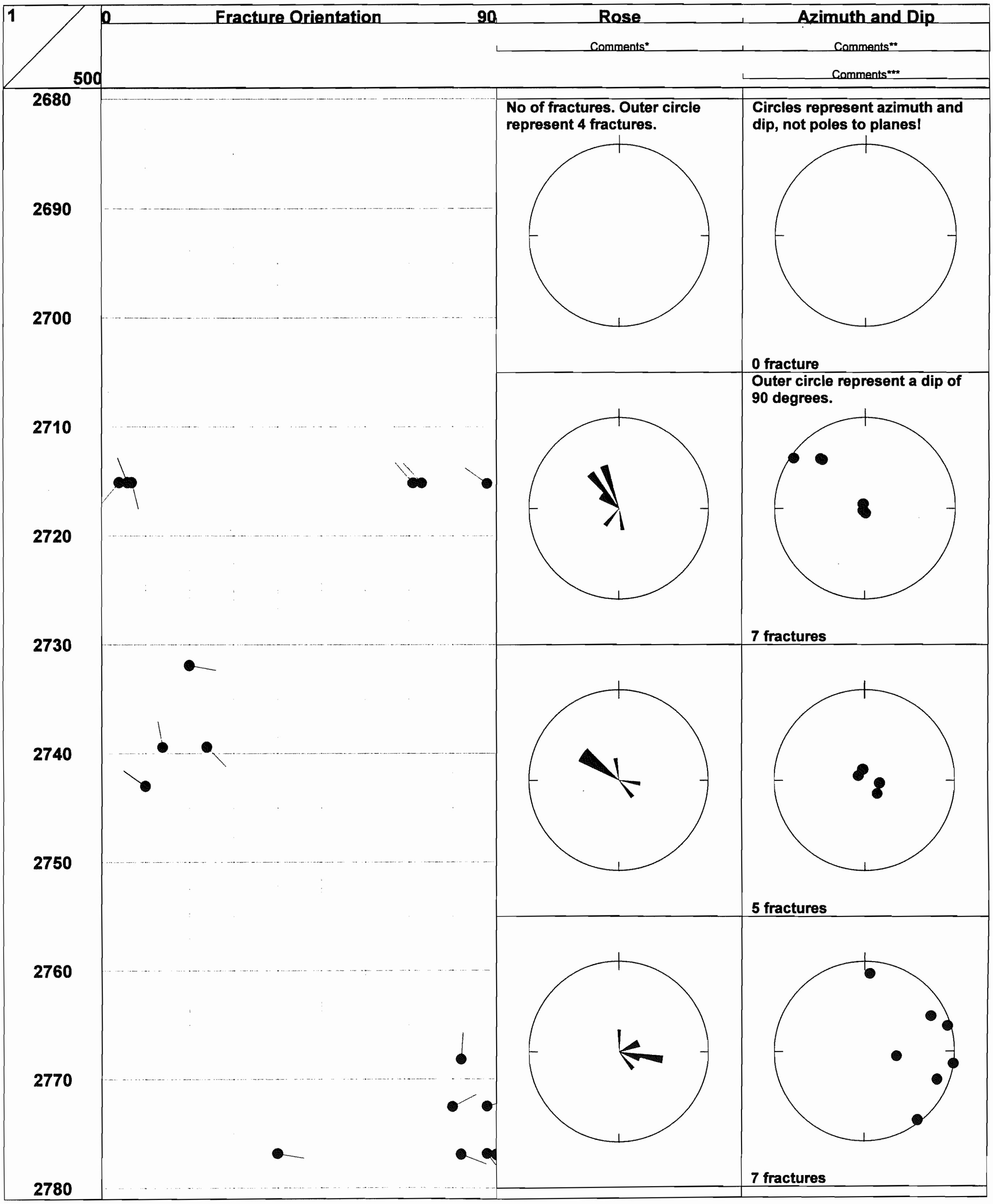
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2680-2780	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), chlorite (84 observations).		



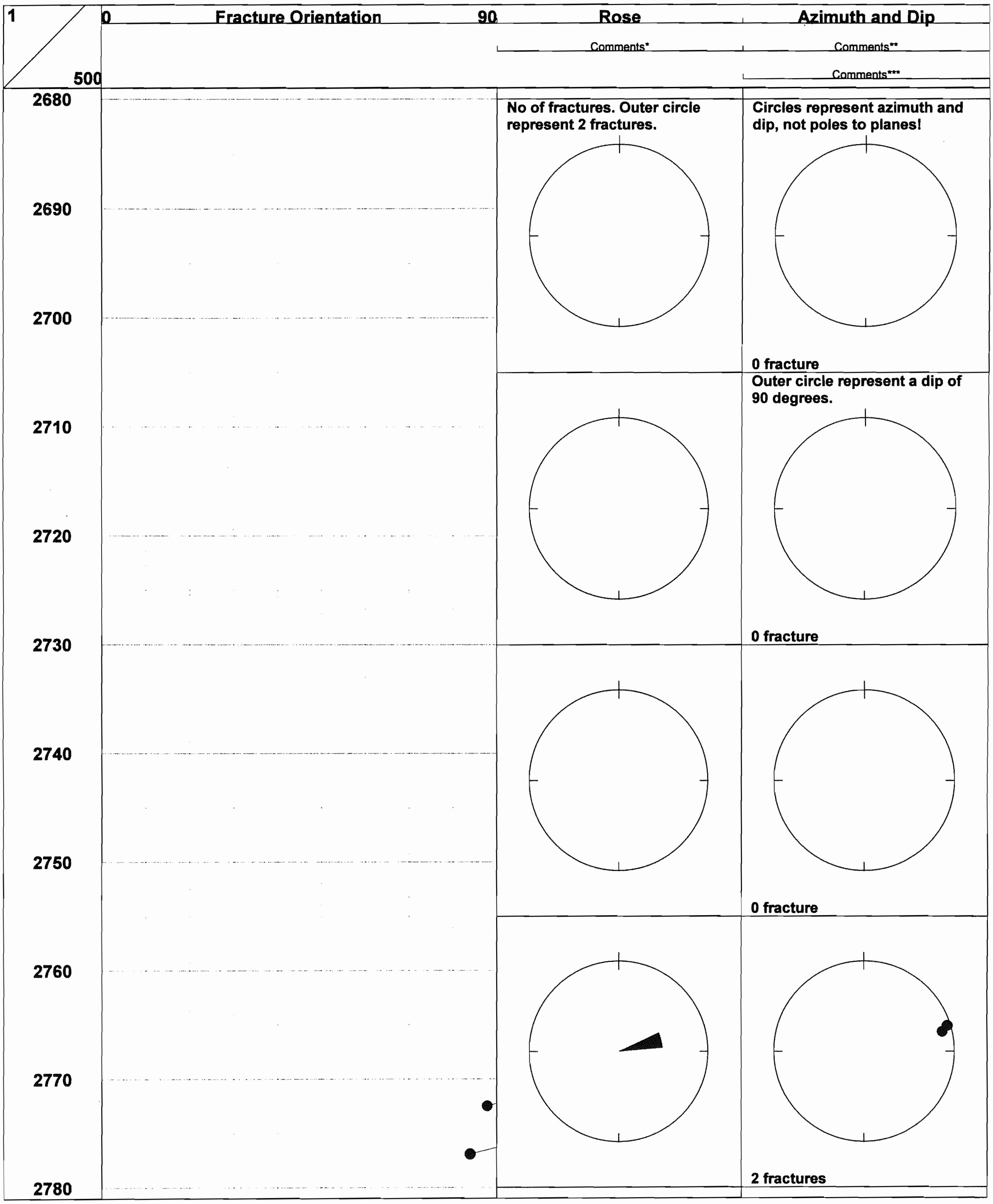
Title	**SELECT-II. Site 2730. Calcite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2680-2780	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990129
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), calcite (68 observations).		



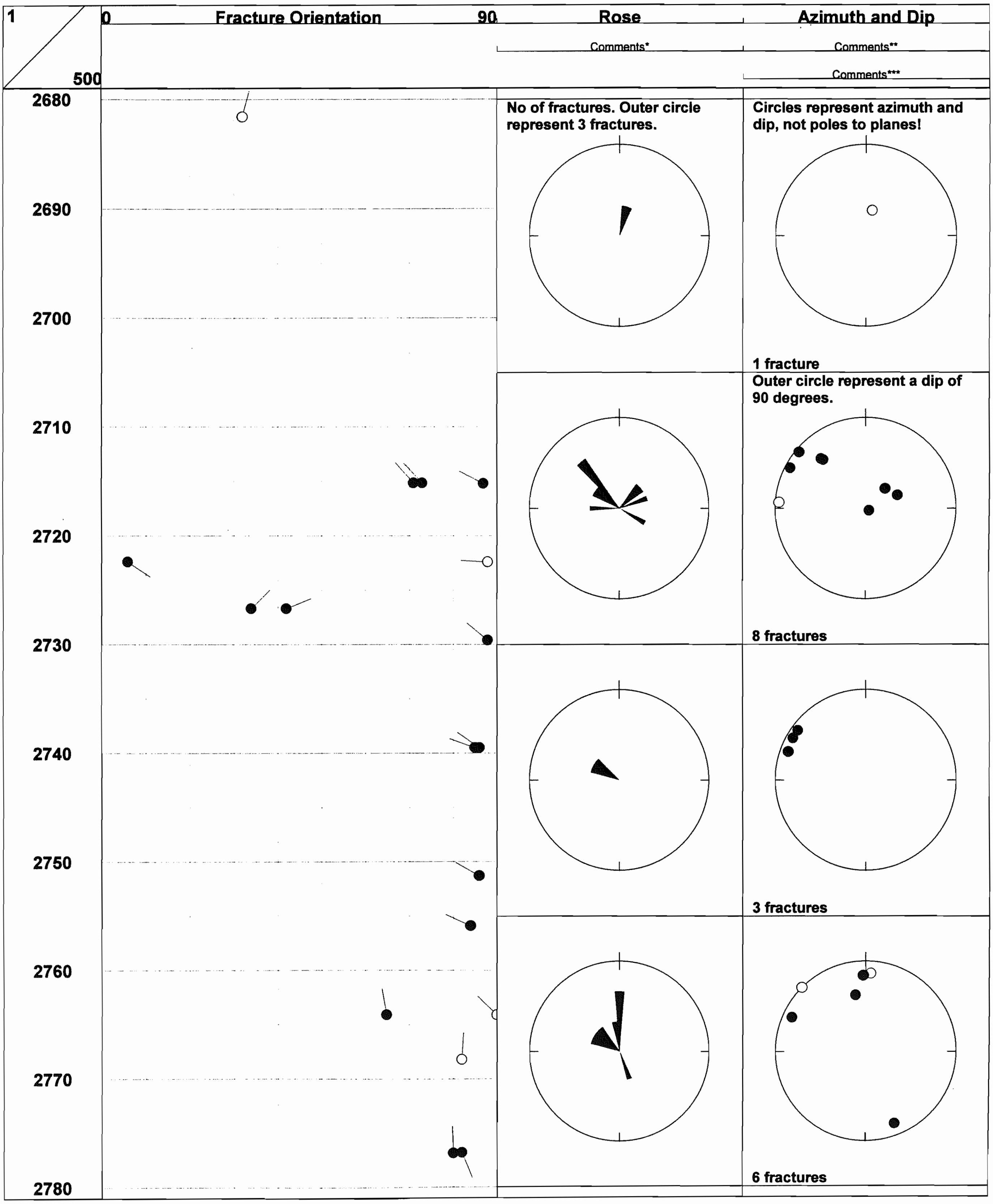
Title	**SELECT-II. Site 2730. Epidote.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2680-2780	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990129
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), epidote (19 observations).		



Title	**SELECT-II. Site 2730. Mylonite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2680-2780	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990129
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), mylonite (2 observations).		



Title	**SELECT-II. Site 2730. Water and grout.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2680-2780	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990129
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), water and grout (18 observations).		

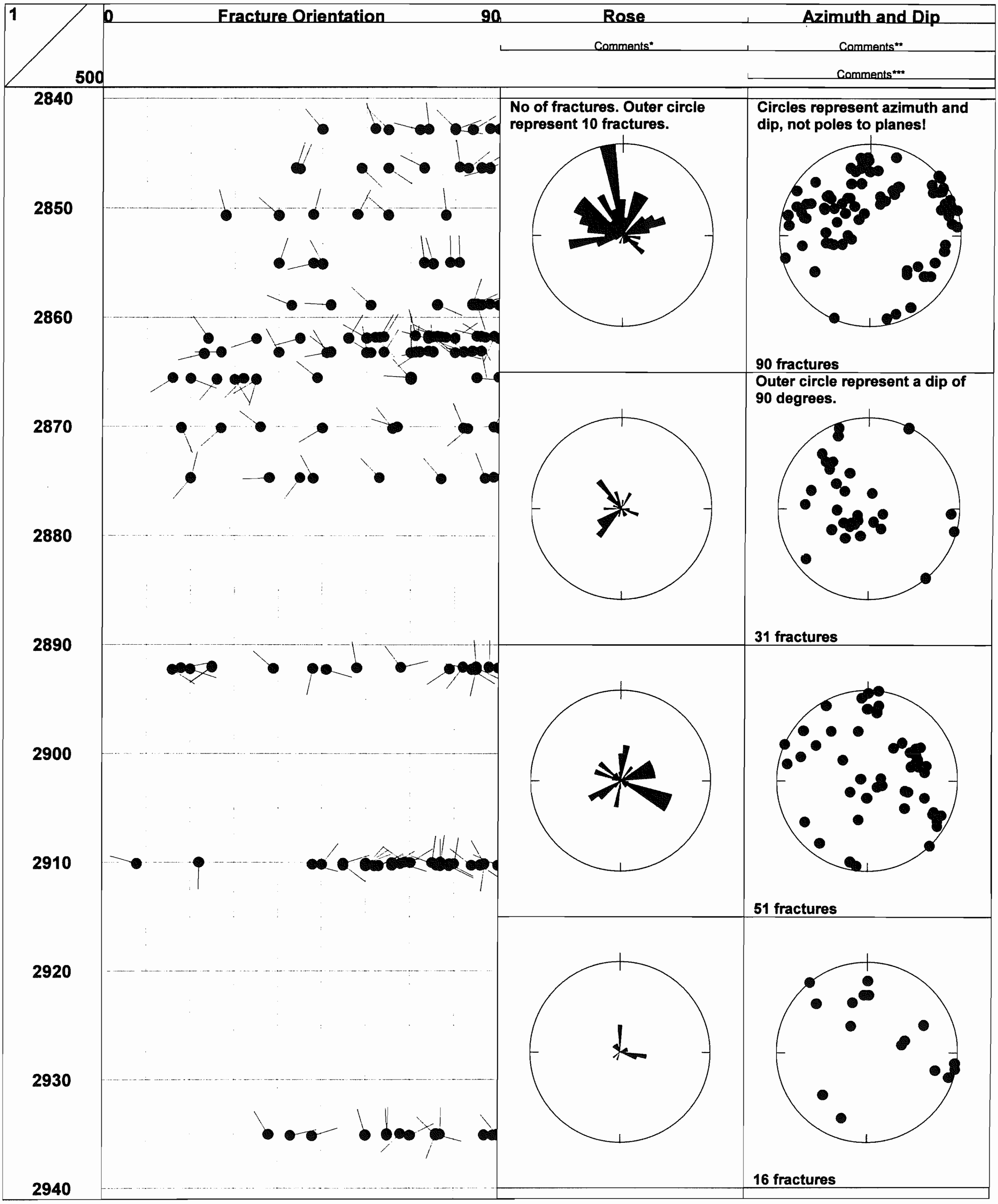


Appendix 7

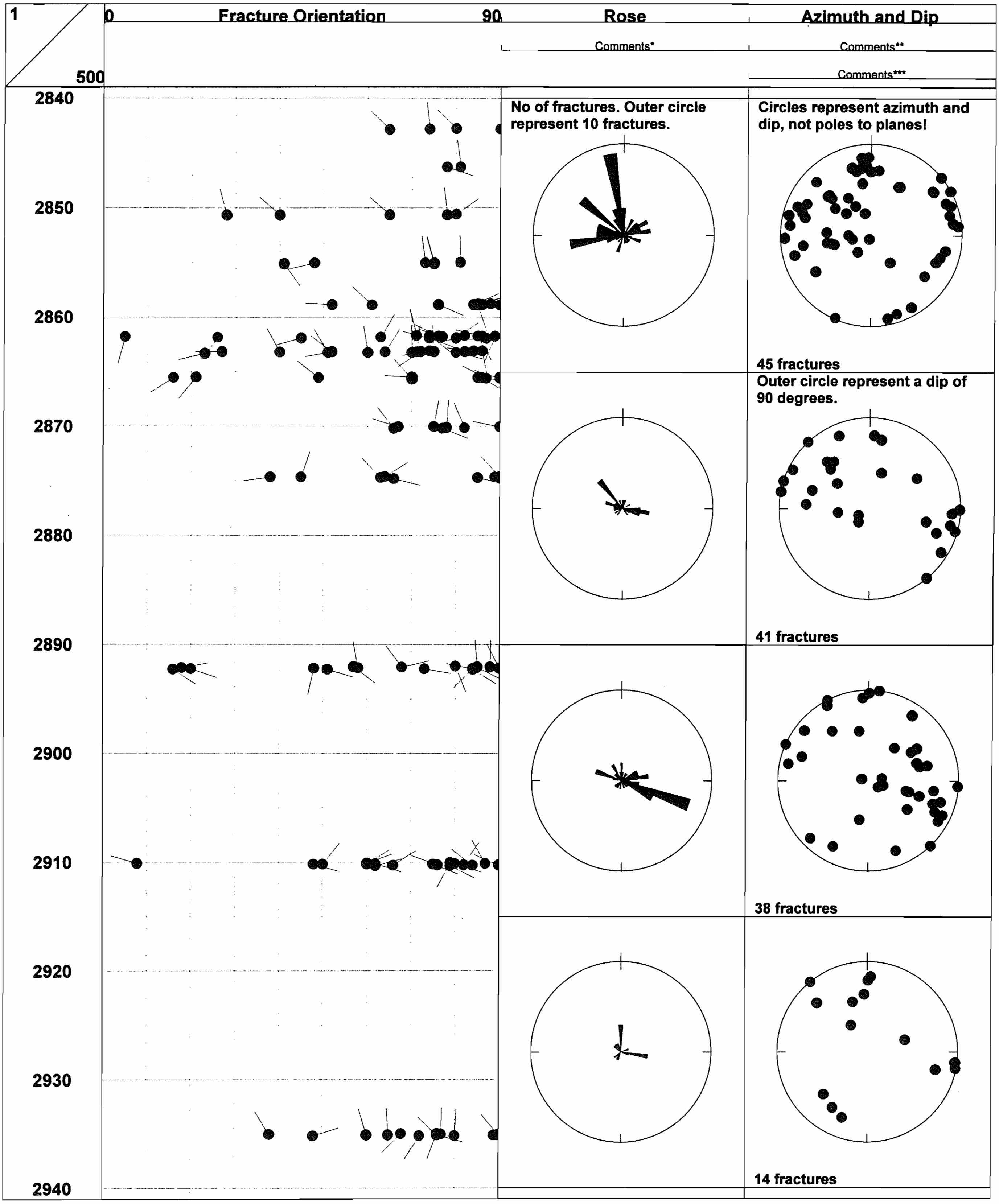
Presented in this appendix are plots of fracture orientations for chlorite, calcite, epidote, mylonite and waterfilled fractures for site 2880. The plot is a tadpole presentation, a rose plot and a plot of azimuth and dip.

5 pages

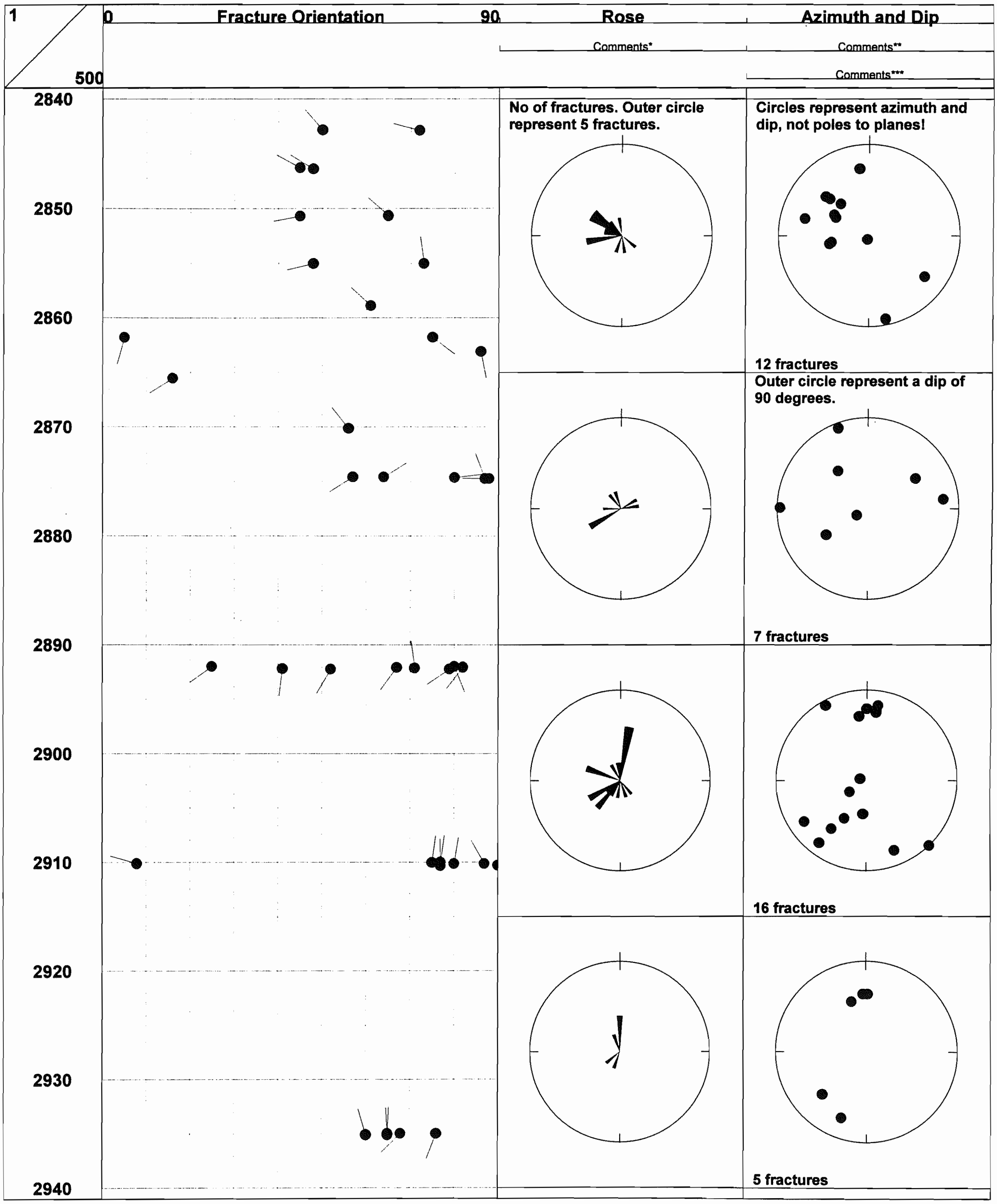
Title	SELECT-II. Site 2880. Chlorite.		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2840-2940	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990125
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!). chlorite (188 observations)		



Title	**SELECT-II. Site 2880. Calcite**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2840-2940	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990125
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), calcite (138 observations)		



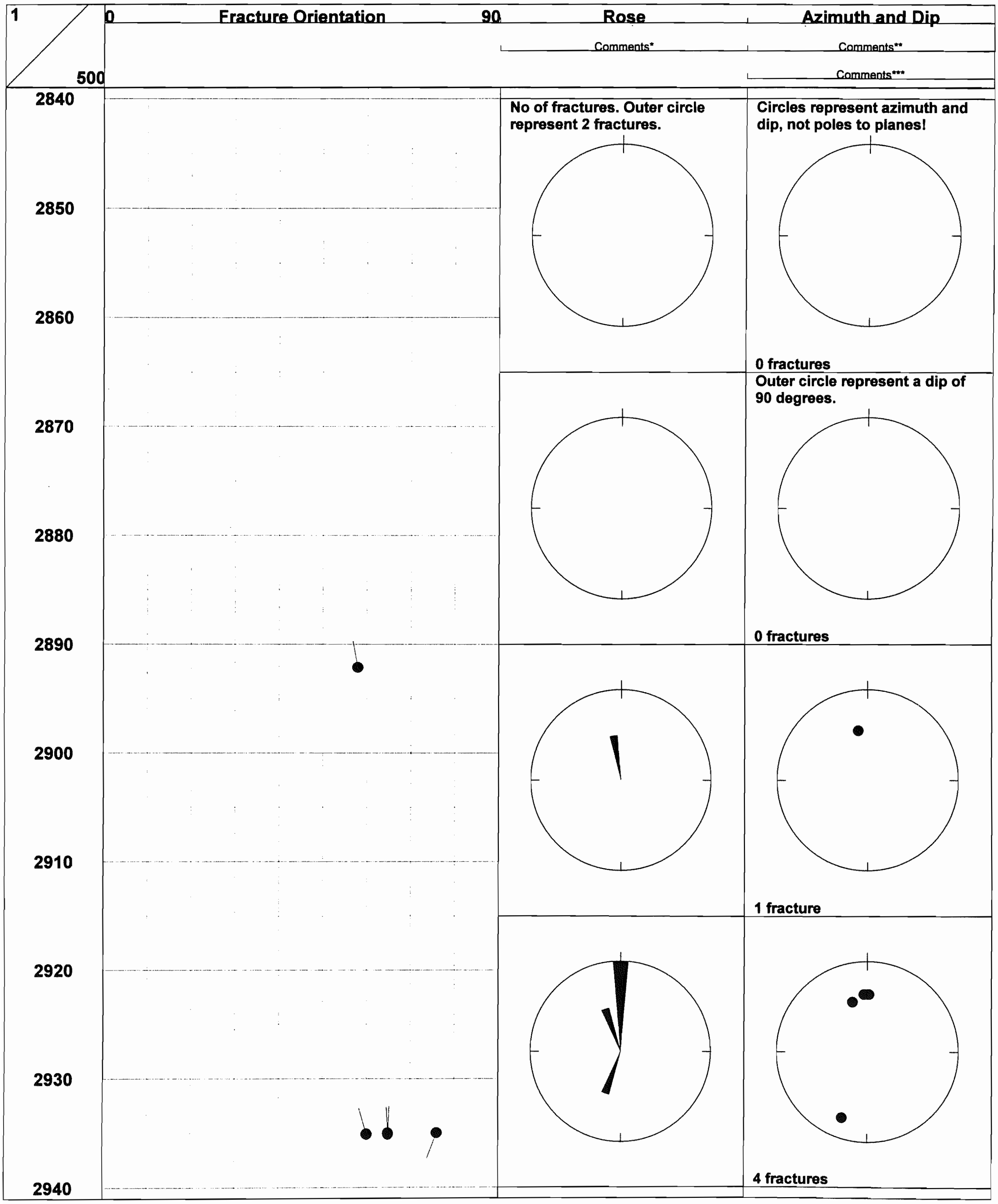
Title	**SELECT-II. Site 2880. Epidote.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North.
Borehole	Tunnel section 2840-2880	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990125
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), epidote (40 observations).		



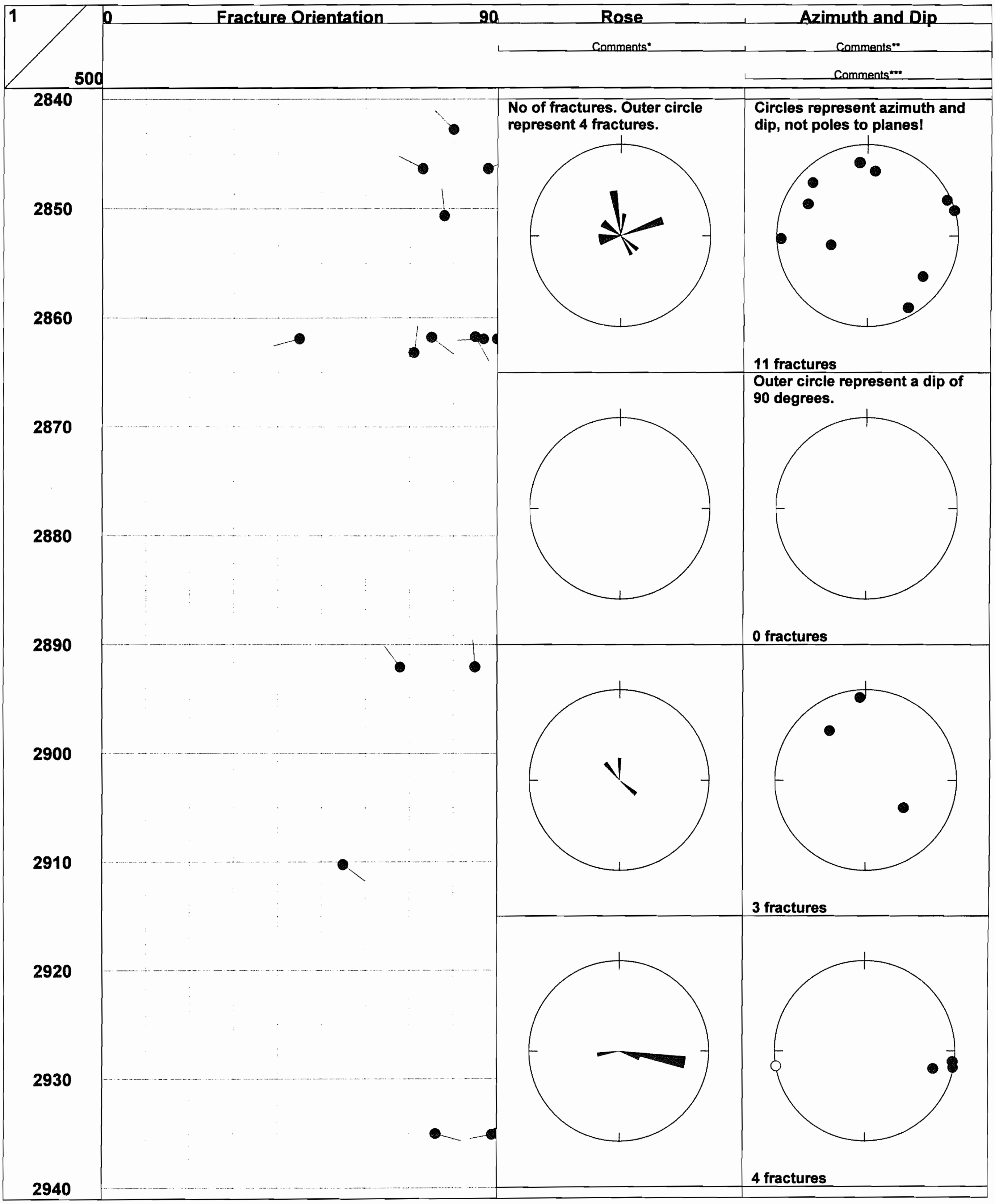
Title SELECT-II. Site 2880. Mylonite.

Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2840-2940	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990125
Inclination		**Mapping Date**	

Remark Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), mylonite (5 observations)



Title	**SELECT-II. Site 2880. Water and grout.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 2840-2940	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990125
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), water and grout (18 observations)		



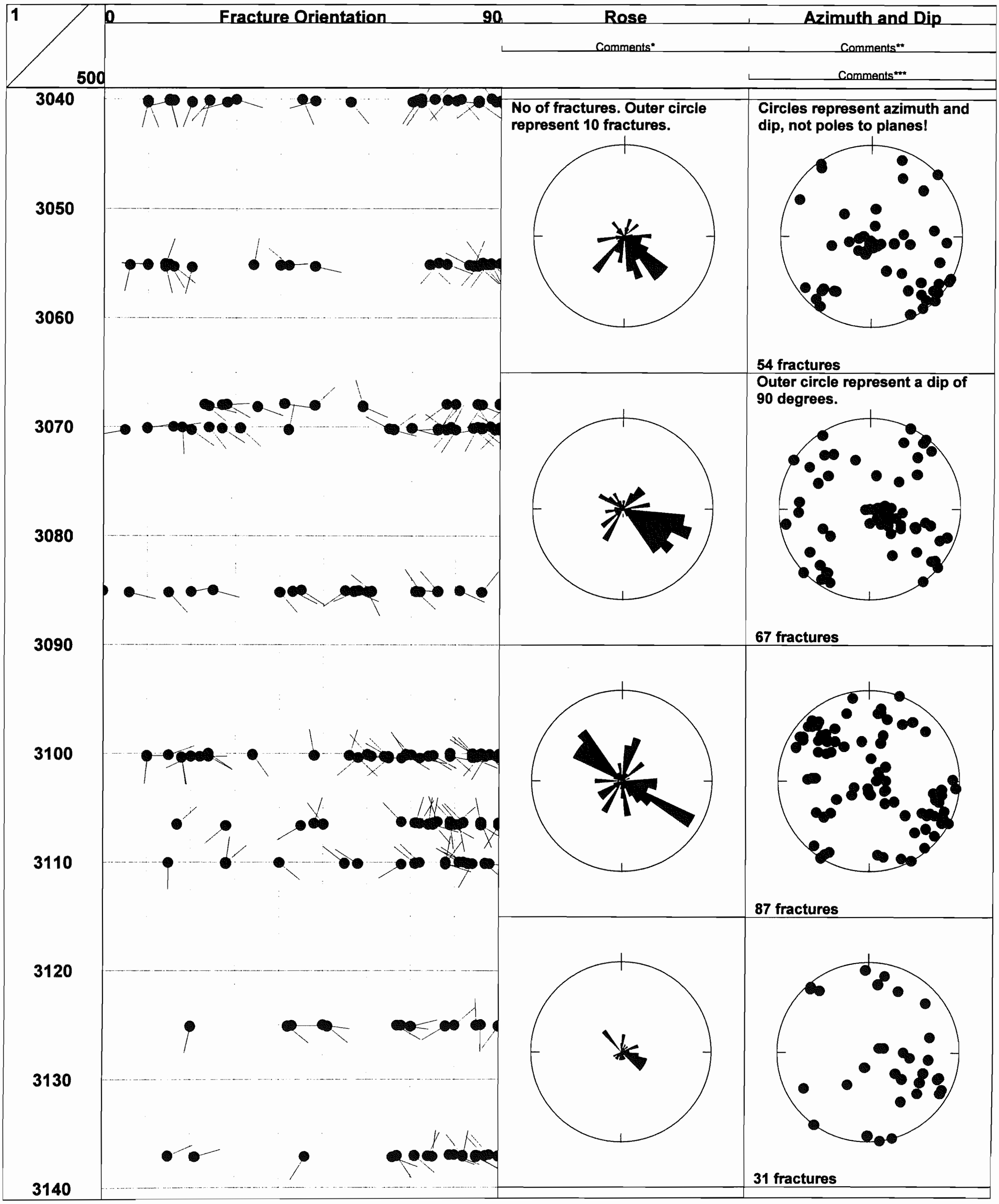
Appendix 8

Presented in this appendix are plots of fracture orientations for chlorite, calcite, epidote, mylonite and waterfilled fractures for site 3067. The plot is a tadpole presentation, a rose plot and a plot of azimuth and dip.

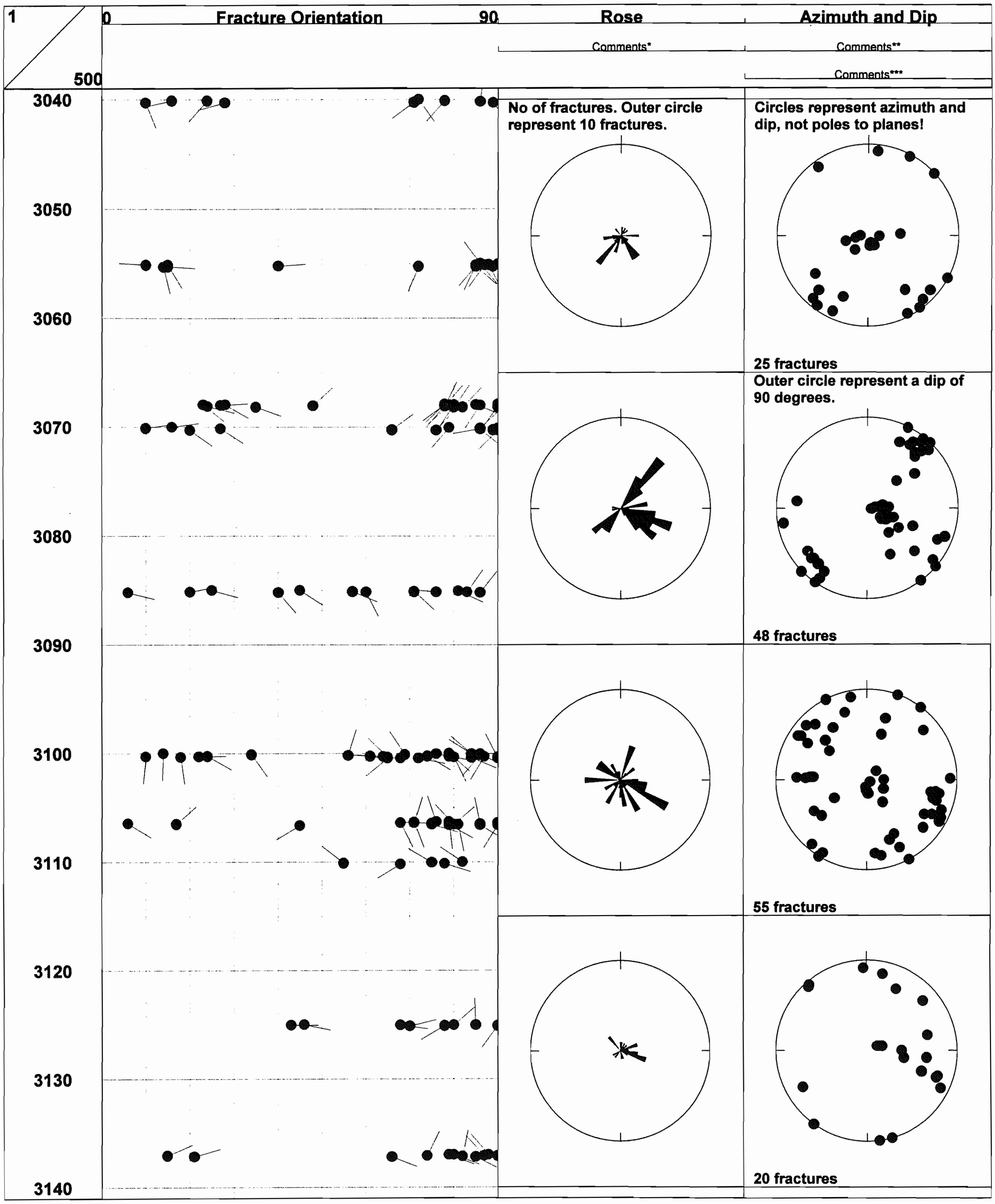
5 pages

Title **SELECT-II. Site 3067. Chlorite.**

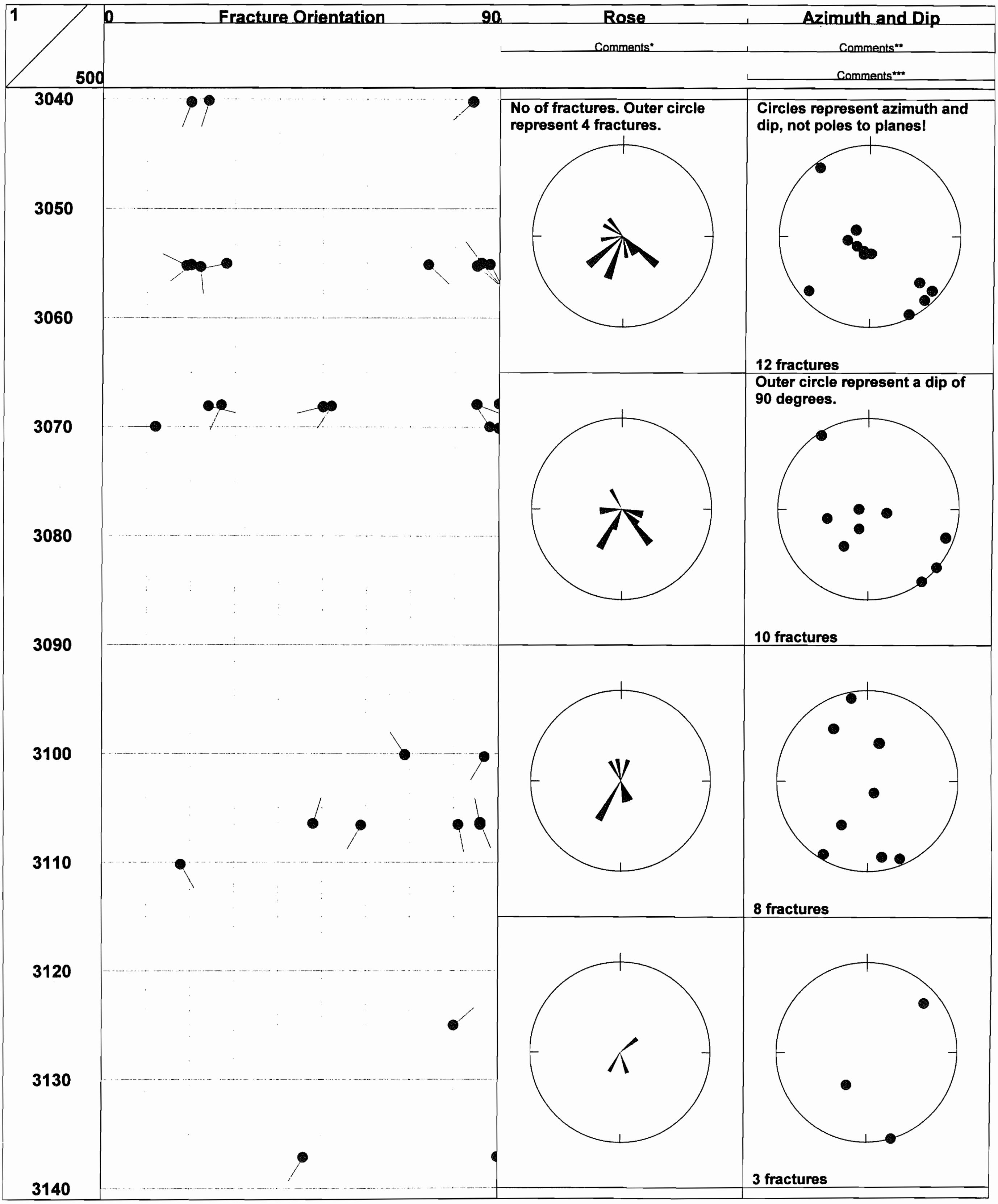
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3040-3140	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990127
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), chlorite (239 observations).		



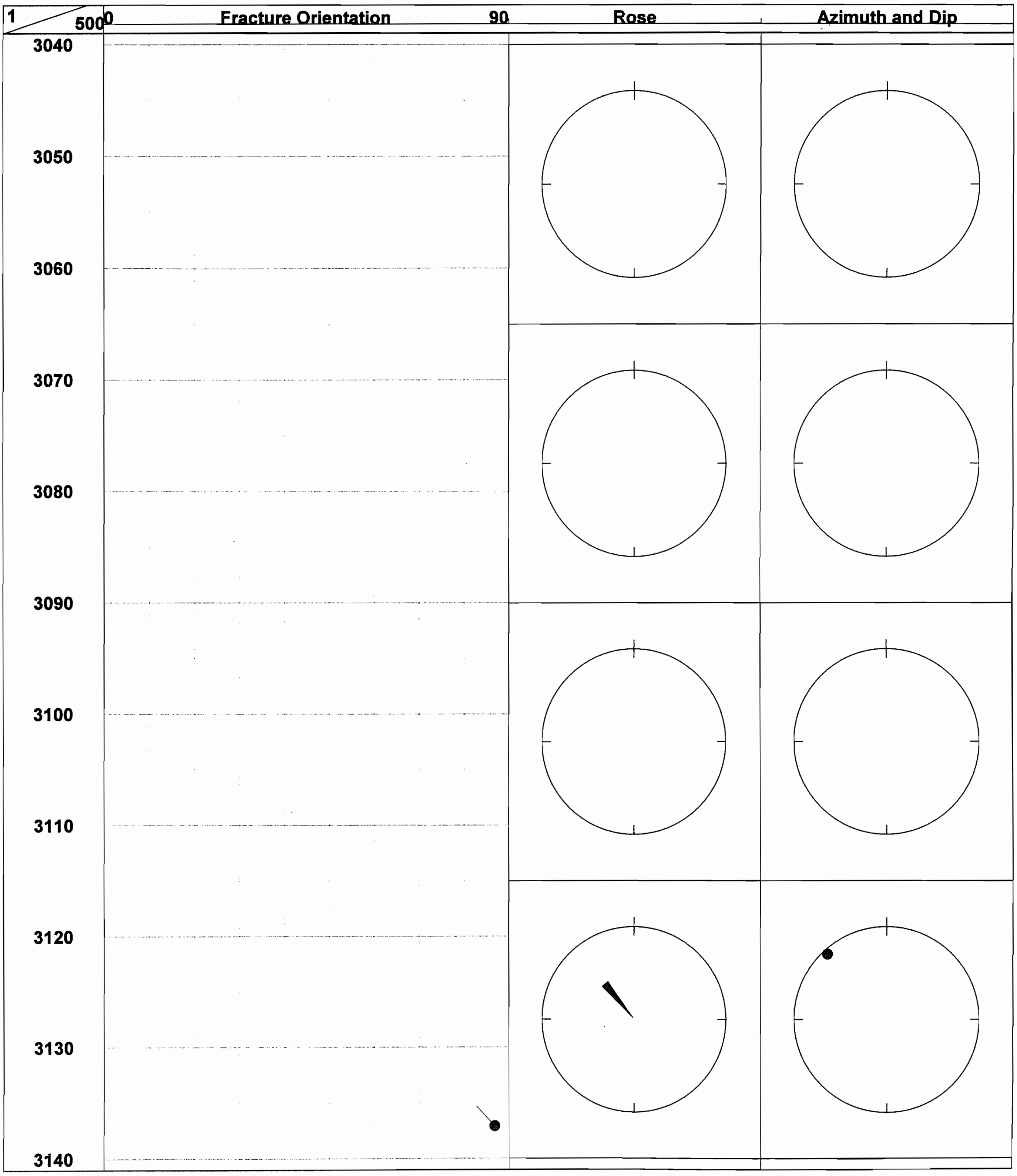
Title	SELECT-II. Site 3067. Calcite.		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3040-3140	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990127
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), calcite (148 observations).		



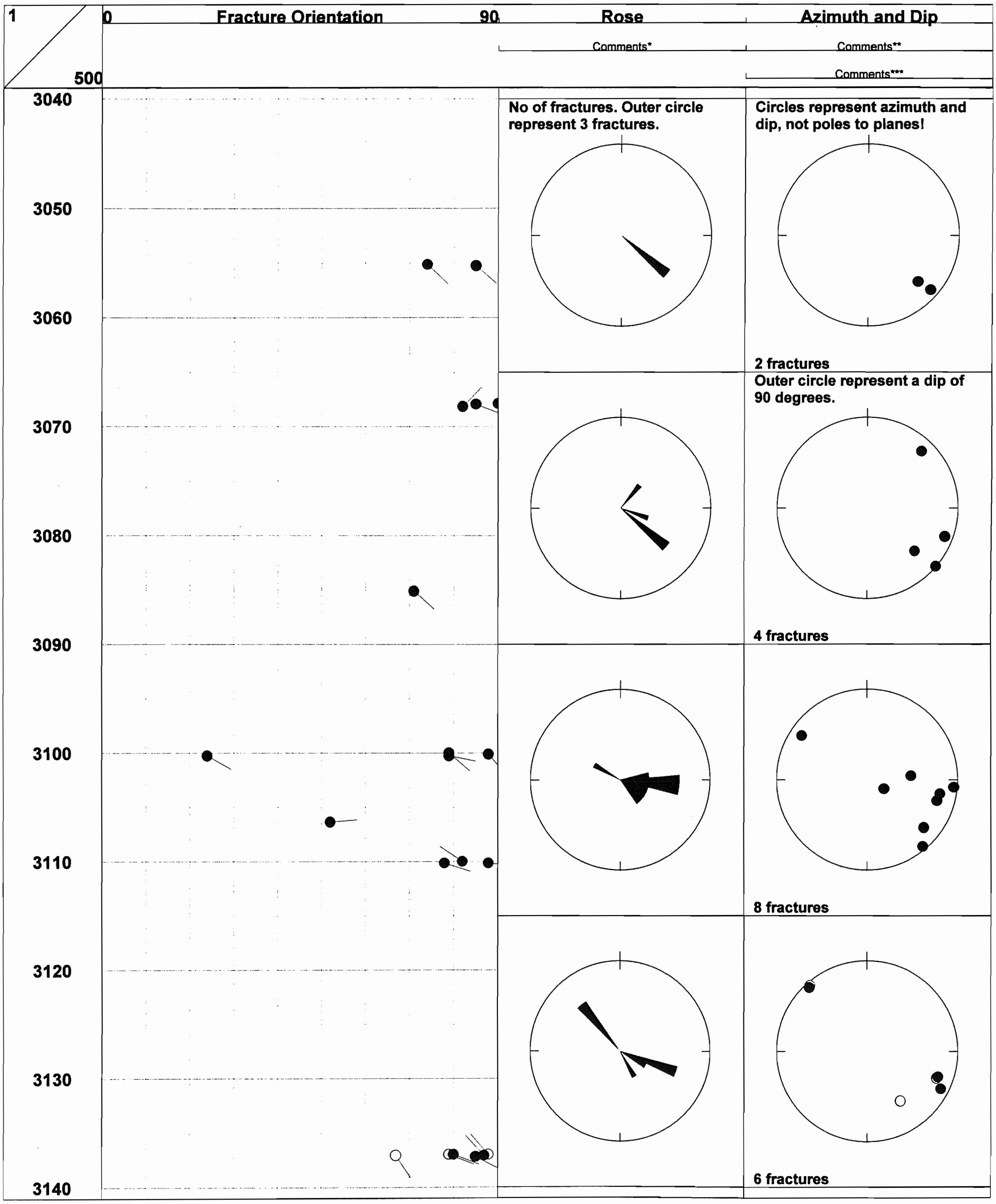
Title	**SELECT-II. Site 3067. Epidote.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3040-3140	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990127
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), epidote (33 observations).		



Title	**SELECT-II. Site 3067. Mylonite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3040-3140	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990127
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), mylonite (1 observation).		



Title	**SELECT-II. Site 3067. Water and grout.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3040-3140	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990127
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), water and grout (20 observations).		

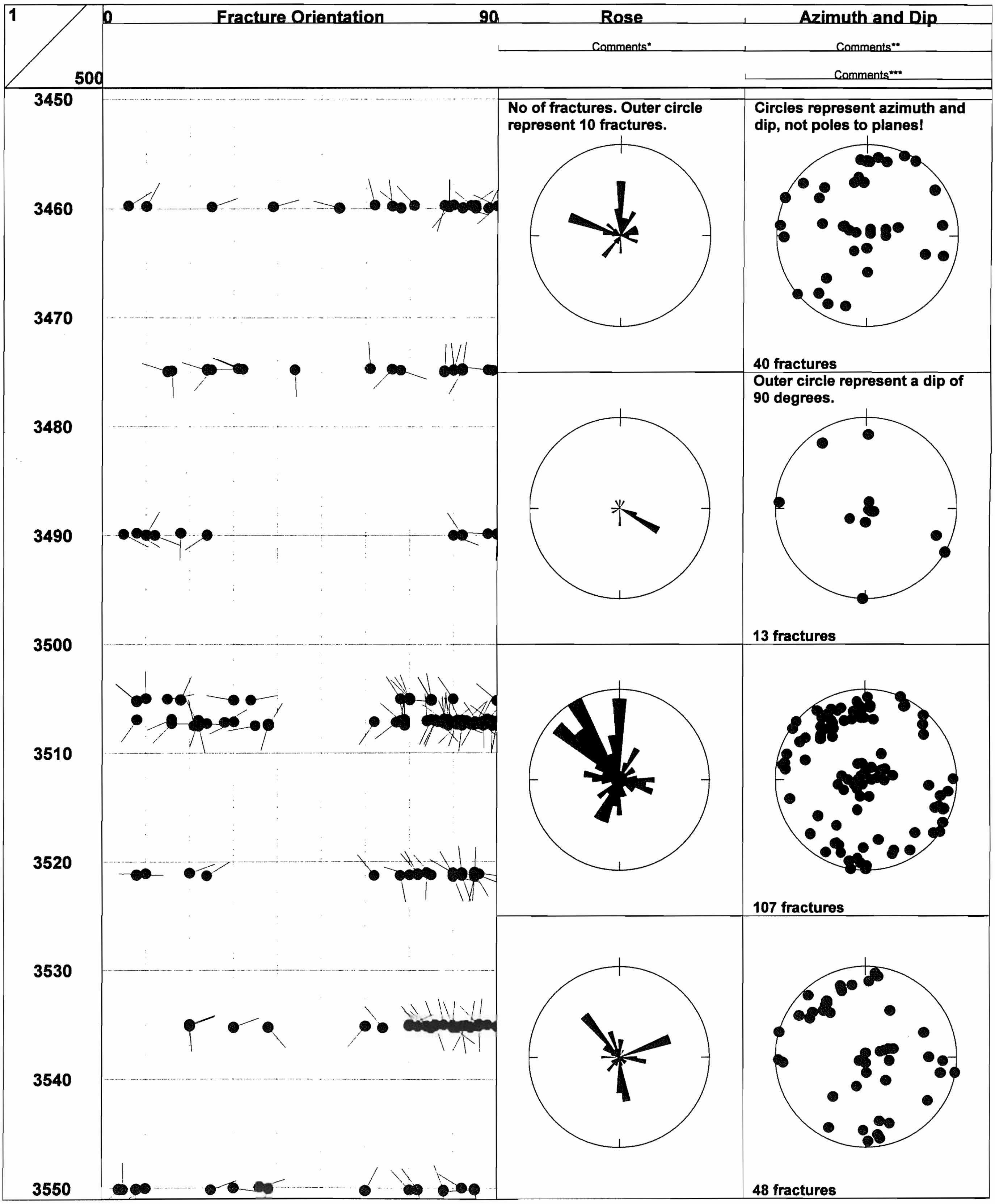


Appendix 9

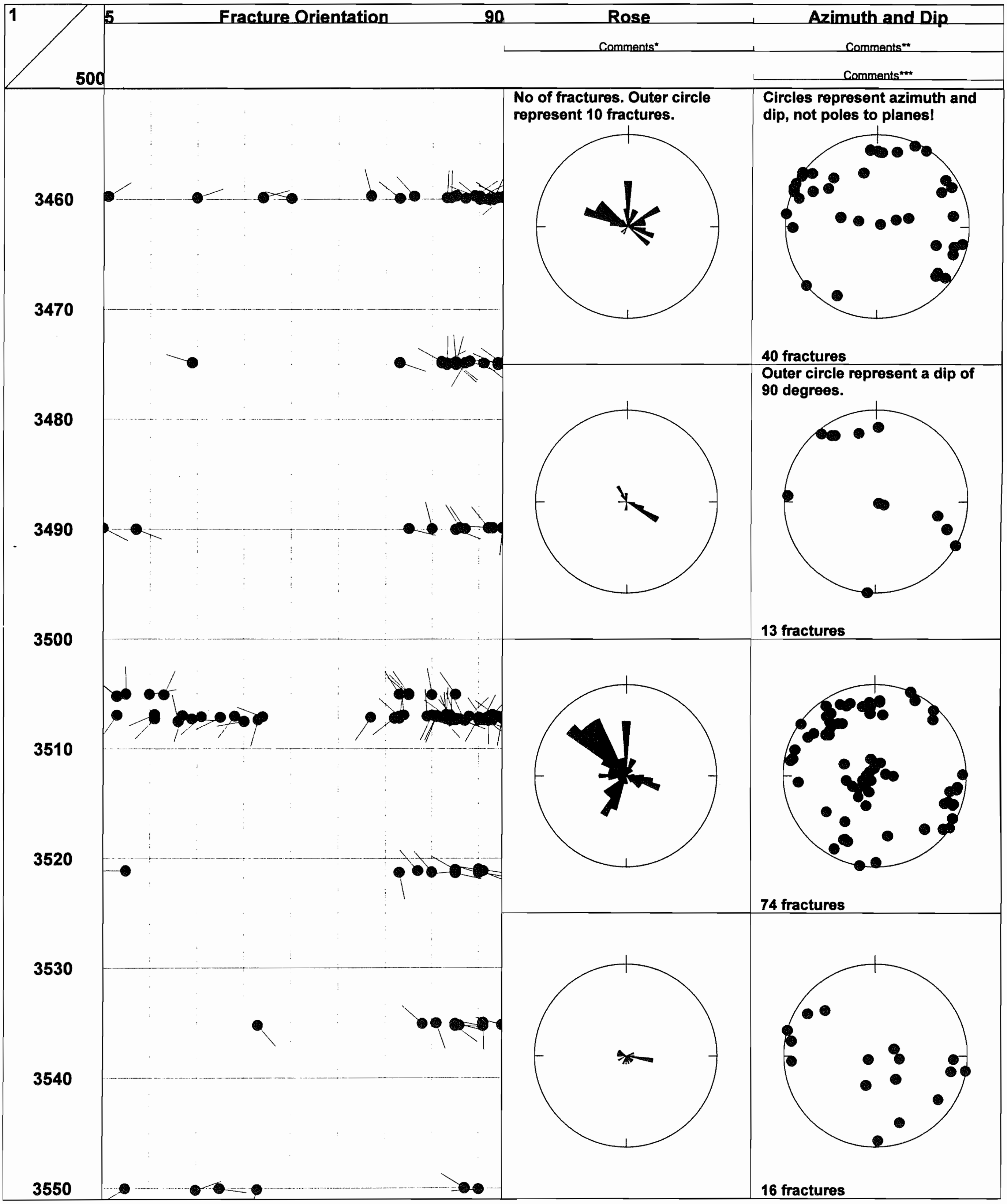
Presented in this appendix are plots of fracture orientations for chlorite, calcite, epidote, mylonite and waterfilled fractures for site TASJ. The plot is a tadpole presentation, a rose plot and a plot of azimuth and dip.

5 pages

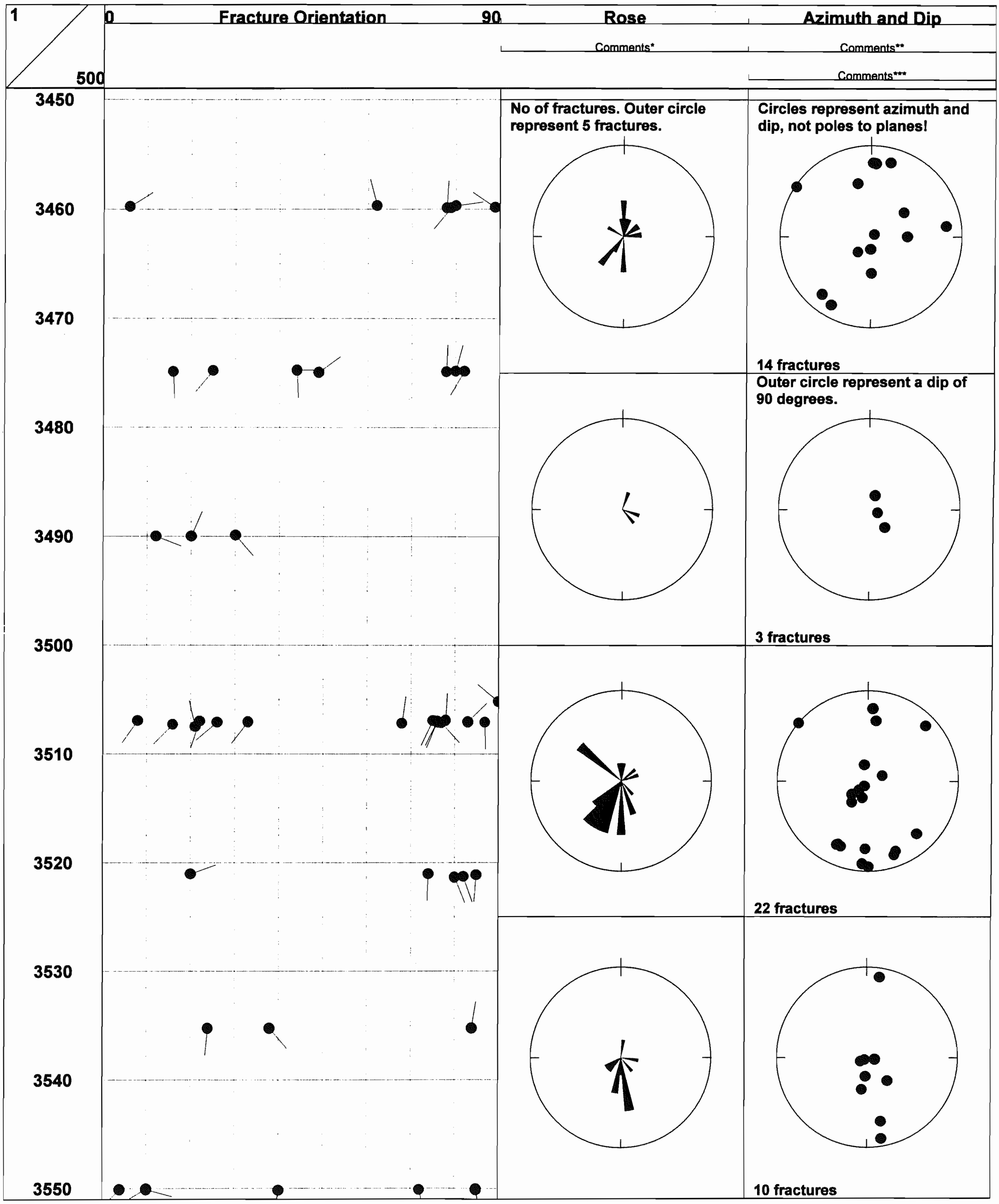
Title	SELECT-II. Site TASJ. Chlorite.		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3450-3550	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), Chlorite (208 observations)		



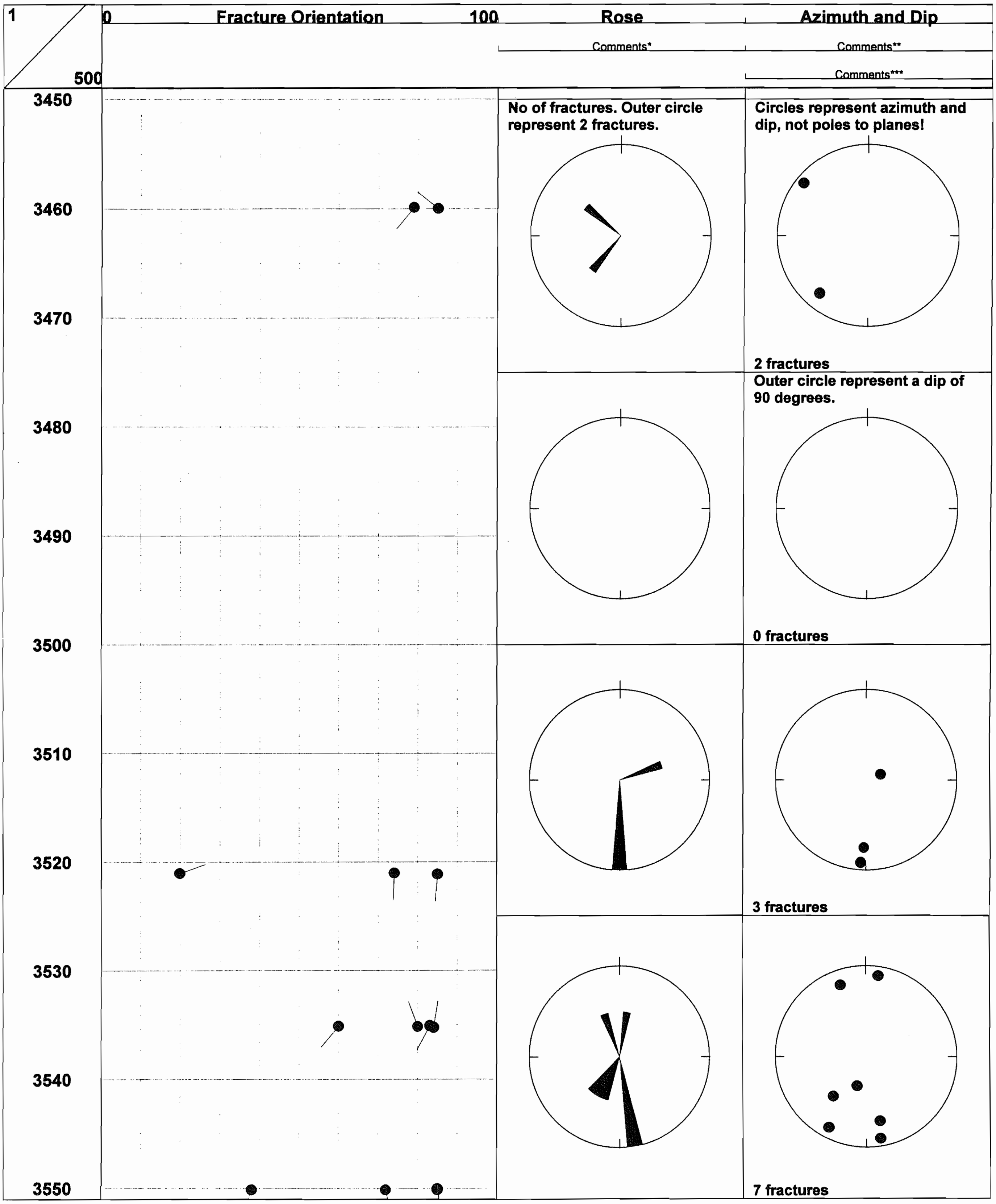
Title	**SELECT-II. Site TASJ. Calcite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3450-3550	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), calcite (143 observations).		



Title	**SELECT-II. TASJ. Epidote.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3450-3550	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), Epidote (49 observations)		



Title	**SELECT-II. Site TASJ. Mylonite.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3450-3550	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), Mylonite (12 observations)		



Title	**SELECT-II. Site TASJ. Water and grout.**		
Site	Äspö HRL	**Coordinate System**	Azimuth relative to Magnetic North
Borehole	Tunnel section 3450-3550	**Northing**	
Diameter		**Easting**	
Length		**Elevation**	
Bearing		**Completion Date**	990104
Inclination		**Mapping Date**	
Remark	Fracture Orientation, Rose, Azimuth and Dip (Note, not poles!), water and grout (30 observations).