P-04-90

# Forsmark site investigation

# Detailed fracture mapping of excavated rock outcrop at drilling site 5, AFM100201

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Golder Associates AB

June 2004

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*Keywords:* Detailed fracture mapping, Drilling site 5, Forsmark, AP PF 400-03-75, Field note no Forsmark 222.

# Contents

# 1 Introduction

SKB performs site investigations for localisation of a deep repository for high level nuclear waste. The site investigations are performed at two sites; Forsmark, located some 120 km, as the crow flies, to the North of Stockholm and Simpevarp, located near the town of Oskarshamn, and 225 km to the South of Stockholm. This document reports the data gained during detailed fracture mapping of the outcrop drilling site 5, AFM100201, being one of the activities performed within the site investigation at Forsmark during September and October 2003.

Bedrock mapping of the site is presented in Appendix 1.

The detailed mapping campaign was conducted according to Activity Plan AP PF 400-03-75 (SKB internal controlling document).

# 2 Objective and scope

The activity aimed at collecting fracture data to be used in discrete fracture analysis and discrete fracture modelling in a regional as well as a local scale. The survey is expected to indicate geometric properties of fractures in the trace length interval between 0.5 m and 10 m at the mapped site. Mapped fractures comprise sealed fractures as well as open fractures. The results are indicative of the properties of the local fracture network and can provide important information of the variability of the fracturing over the whole site investigation area.

Rock boundaries were marked on the outcrop by Jesper Pettersson, SwedPower AB, on assignment by SKB. Golder's activities comprised a subsequent detailed survey of these boundaries, as described in Section 4.2. The resulting rock boundary map is shown in Appendix 1.

Location of the investigated outcrop is shown in Figure 2-1. The outcrop, drilling site 5, AFM100201 has been stripped from soil cover, prior to mapping. The outcrop area is 501 m$^2$.

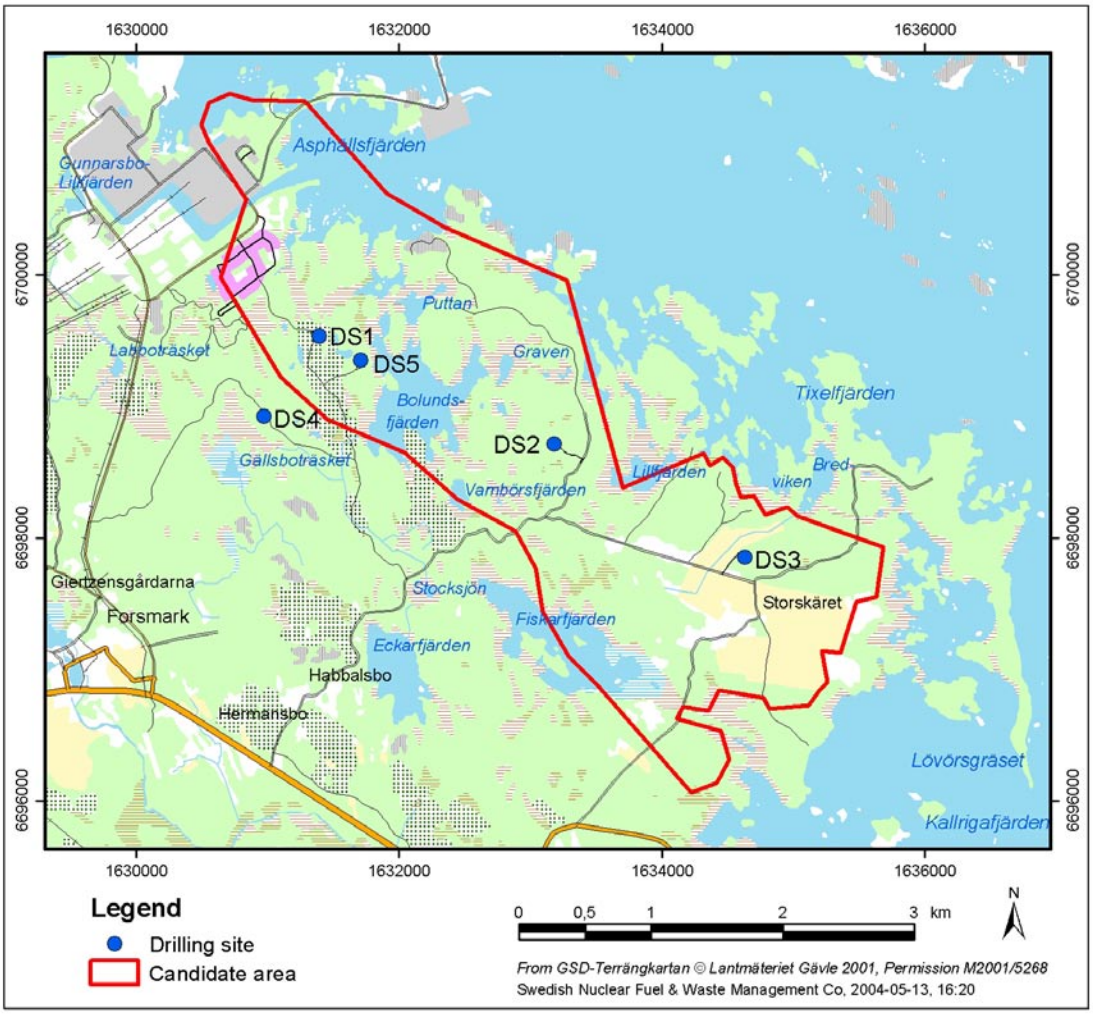



***Figure 2-1**. Location of AFM100201, drilling site 5 (DS5), in the Forsmark area.*

# 3 Equipment and methods

Fracture trace geometry was measured with a Geodimeter 640S Total Station. In theory, the survey instrument gives an accuracy of the position (x, y and z) of less than 3 mm. However, this accuracy is based on the assumption that the measuring lath is held in a perfectly vertical position. Since this is not always possible to achieve, the total error is larger. Each measurement is, therefore, estimated to be performed with a northing and easting accuracy of 1 cm. Elevation accuracy is estimated to be less than 5 mm.

Locations and trace lengths of fractures are based on the survey results of the fracture traces. The accuracy of the measurement depends on the number of measured points along the fracture trace as well as on the three dimensional spread of the data points. The number of points measured along each fracture trace varies from two to several points, depending on the complexity of the trace and the rock surface. More measurements result in a better definition of the trace. However, an increasing number of measurements substantially slow down the survey. The work was performed in such a way that there was a balance between mapping speed and degree of detail of the mapped fracture traces.

When the position of each point along a fracture trace was recorded, orientation and all other fracture parameters were mapped by hand, using a standard protocol, following methods described in method description for detailed fracture mapping at outcrops, SKB MD 132.003 (SKB internal controlling document).

# 4 Execution

## 4.1 Preparations

At drilling site 5, no regional survey point existed. The Golder Team established five fix points, with preliminary numbers 101, 102, 104, 106, and 107, to which the fracture survey was related. Later these five points were surveyed, and related to the regional point system, RT90 2.5g V RHB70 by the SKB Survey Team, as demonstrated in Table 4-1.

The survey instrument was positioned outside the outcrop and was calibrated against the fix points after each time data was downloaded from the instrument or at the beginning of each fieldwork session. The instrument was also recalibrated to reflect temperature changes during the day.

The survey results were converted to the RT90 2.5 grades V RHB70 system after completed survey by the SKB Survey Team.

**Table 4-1. Fix points at drilling site 5 with surveyed coordinates and Golder's preliminary as well as SKB's ID numbers.**

| Golder ID | SKB Pt ID | X (northing) | Y (Easting) | Z (elevation) |
|---|---|---|---|---|
| 106 | 3503 | 6 699 337.701 | 1 631 713.932 | 2.521 |
| 104 | 3511 | 6 699 318.356 | 1 631 676.785 | 4.563 |
| 101 | 3512 | 6 699 365.619 | 1 631 738.560 | 3.955 |
| 102 | 3513 | 6 699 312.340 | 1 631 743.862 | 3.797 |
| 107 | 3514 | 6 699 296.617 | 1 631 718.278 | 4.999 |

## 4.2 Execution of tests/survey

The methodology for mapping fractures follows the suggested method presented in SKB MD 132.003 (SKB internal controlling document). The work process was conducted as follows:

1. An approximately square shaped 5×5 m grid of plastic tape was applied over the outcrop as a help to divide the outcrop in sub-domains during the mapping campaign. These grid squares have no imprint on the collected data. Figure 4-1 shows the grid and the mapped area.
2. The survey instrument was calibrated against fix points in the vicinity of the outcrop, as specified in Section 4.1, above.
3. Each fracture trace was labelled with ID numbers at its start (A) and end (B) points on the outcrop, in order to keep track of surveyed fractures. The used truncation for fracture trace length for fracture mapping was 0.5 m.
4. Rock boundaries were marked on the rock surface by geologist Jesper Peterson, SwedPower.
5. Each fracture location and length was surveyed with two or more points with the survey instrument. The number of points on each fracture was controlled by its complexity. Special attention was given to the ends of certain fractures, in order to determine the fracture termination mode.
6. Rock boundaries were surveyed in a similar manner.
7. Each fracture was mapped with respect to the given geological parameters outlined in SKB MD 132-003, also given in Tables 5-2, 5-3, and 5-4.
8. Scan line measurements were performed along two 10 m long, approximately orthogonal scan lines. Scan line traces are shown in Figure 4-1.
9. Fracture locations were measured along the scan line. Used truncation for fracture trace length for scan line measurements was 0.2 m.
10. Each fracture was mapped with respect to geological parameters given in SKB MD 132-003.
11. The outcrop was cleared from labels.
12. Digital conversion of survey instrument data to RT90 2.5 grades V, RHB70 coordinate data.
13. Conversion to an AutoCAD DWG 14 file of fracture traces, square pattern and outcrop boundary.
14. Quality control of the survey data, using the auto-filter function in excel, and consistency check with survey instrument digital data with the mapping protocols.
15. Report production.

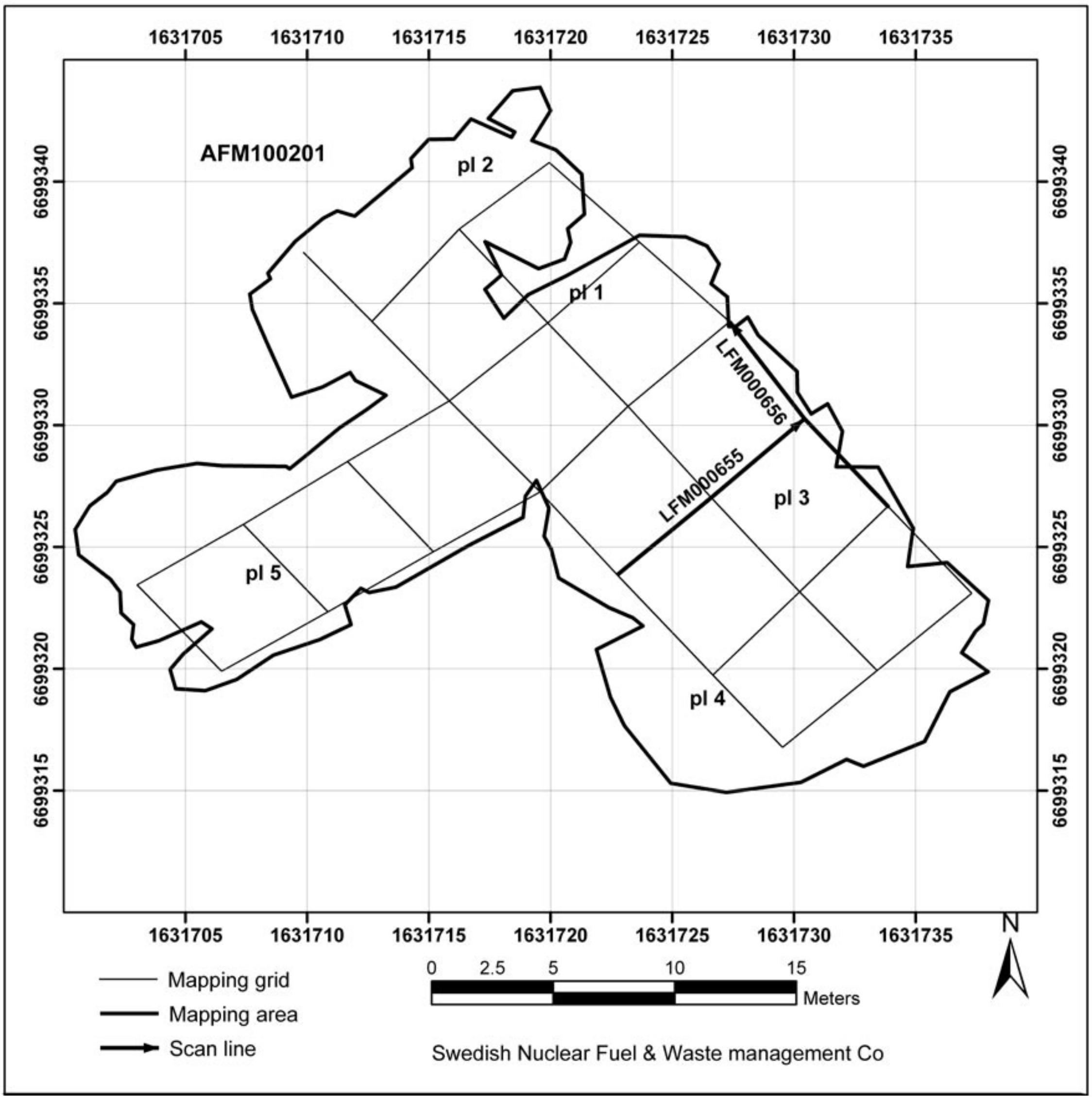



***Figure 4-1.*** *Drilling Site 5, AFM100201. Mapping grid, scan lines LFM000655 and LFM000656, and also photo of locations (pl 1, pl 2, etc).*

## 4.3 Data handling

Deliverables to SKB for mapping of drilling site 5, AFM100201 are listed in Appendix 2. Data from the detailed fracture mapping at drilling site 5 is stored in SICADA, field note no Forsmark 222.

# 5 Results

The results of the fracture mapping campaign include data tables of survey and mapping details of area fracture mapping, scan line fracture mapping, and also 3D GIS drawings of area fracture mapping and rock type mapping.

In addition to the method described in the activity plan, fractures have been surveyed directly by using survey results on several locations along each fracture trace, and not mapped by hand on a drawing. This method results in a very high degree of accuracy of the shape, location and length of each trace as compared to hand drawings. The method is also more time efficient as digital values are obtained immediately, while digital conversion of hand drawn data is time consuming.

Based on experience from previous work in crystalline basement outcrops, two fractures (truncation trace length more than 0.5 m) were expected in each square meter. At Drilling site 5 (AFM100201) has 1280 fractures been mapped. Of these, 913 had a trace length of 0.5 m or more giving an average of 1.8 fractures per square meter. Seven hundred and five fractures were assumed to be of late glacial age, of which 367 had a length of less than 0.5 m. The remaining, longer glacial induced fractures are assumed to be reactivated older fractures. All fracture types are shown in Table 5-1. The glacial induced fractures will be further treated in a separate report.

Scan line mapping was performed along two approximately perpendicular 10 m lines, one trending North-East and one trending North-West. Truncation length for fracture traces in the scan line survey was 0.2 m. The fracture frequency along the North-East trending line, LFM000655 is 1.1 fractures per metre. Along the North-West trending line, LFM000656, the figure is 2.6 fractures per metre.

Tables 5-2, 5-3, and 5-4 present the mapped geological parameters on the fracture traces. The parameters have been coded, according to a specified system that is appropriate for retrieving from SICADA, the SKB data base for the site investigations.

Figure 5-1 demonstrates the actual fracture trace map. Figure 5-2 shows stereographic scatter and contour plots for all fractures, Figure 5-3 shows corresponding diagrams for older (usually closed) fractures and Figure 5-4 for glacial (all of which are open) fractures. The result of the rock boundary survey is shown in Appendix 1.

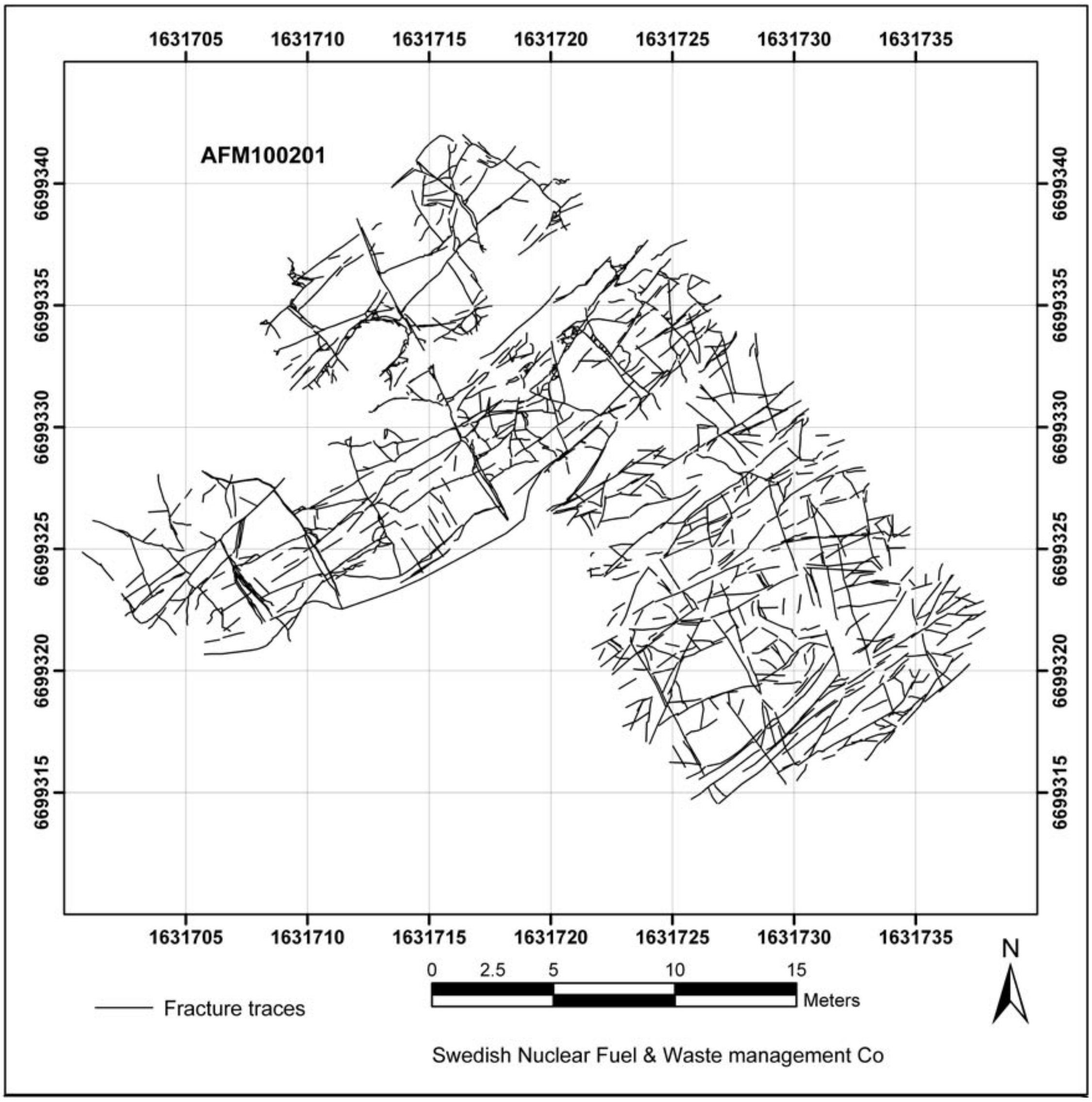



***Figure 5-1.*** *Fracture trace map of AFM100201, drilling site 5.*

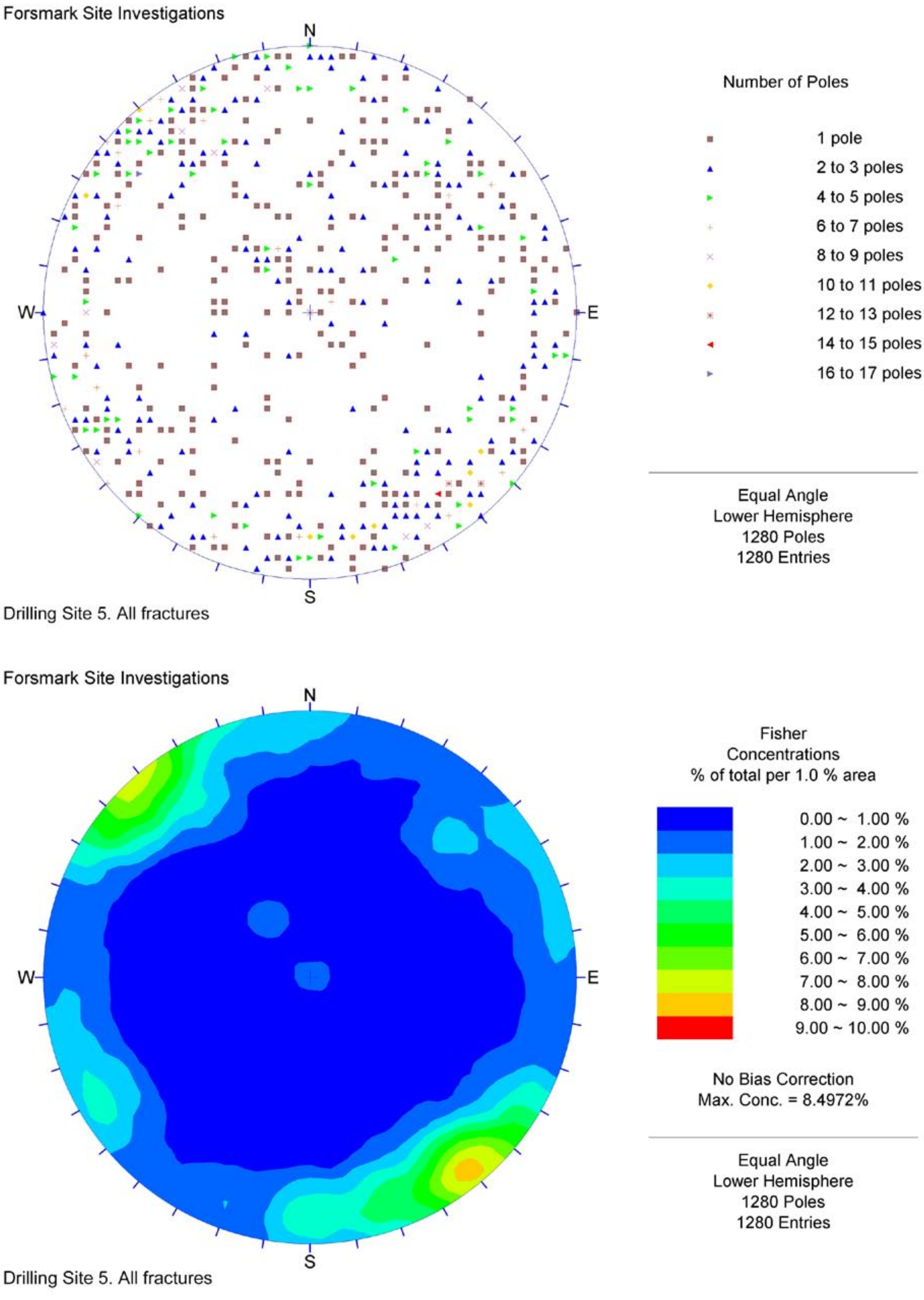



***Figure 5-2.*** *Stereographic scatter and contour plots of all fractures at AFM100201 drilling site 5.*

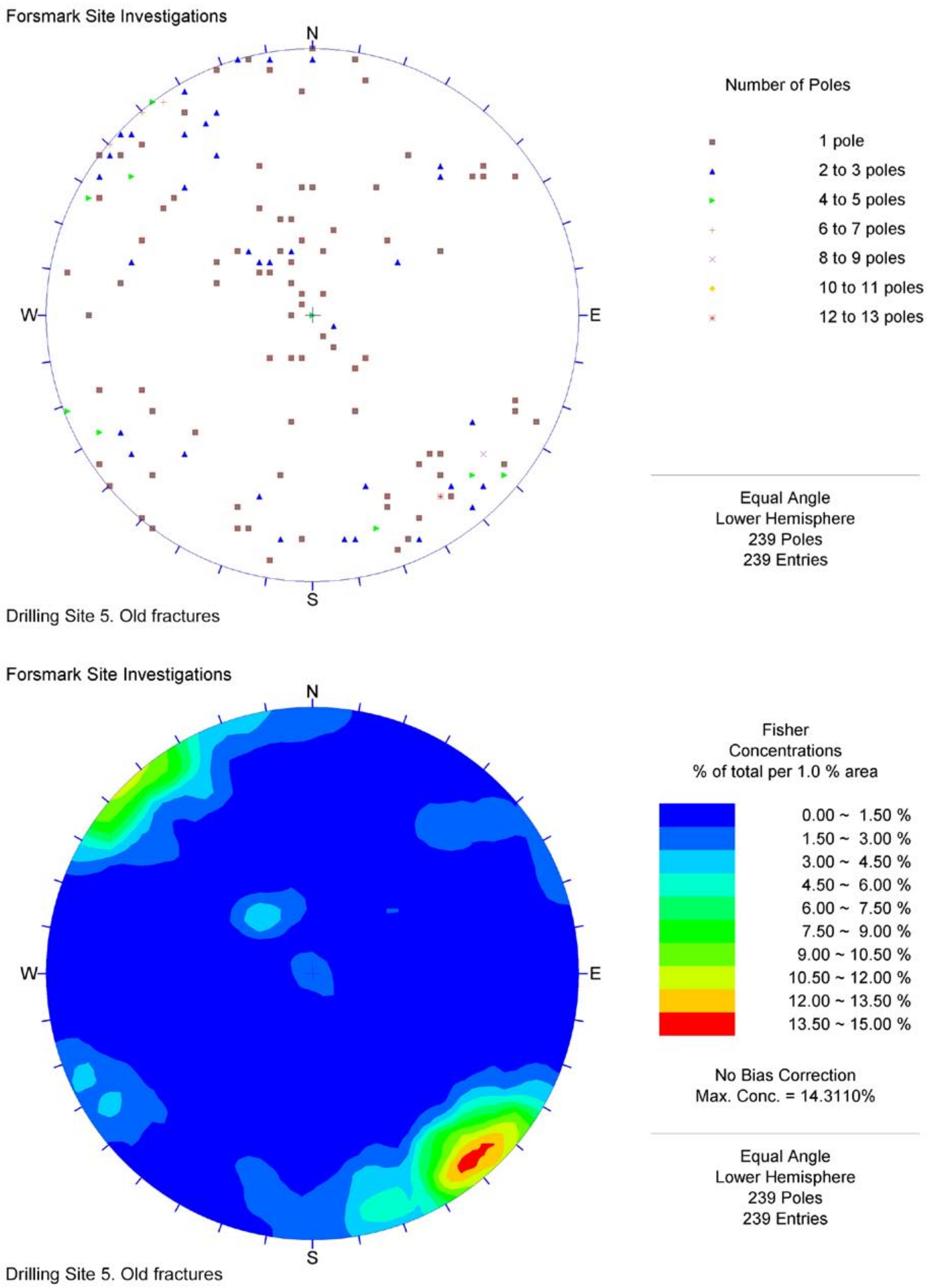
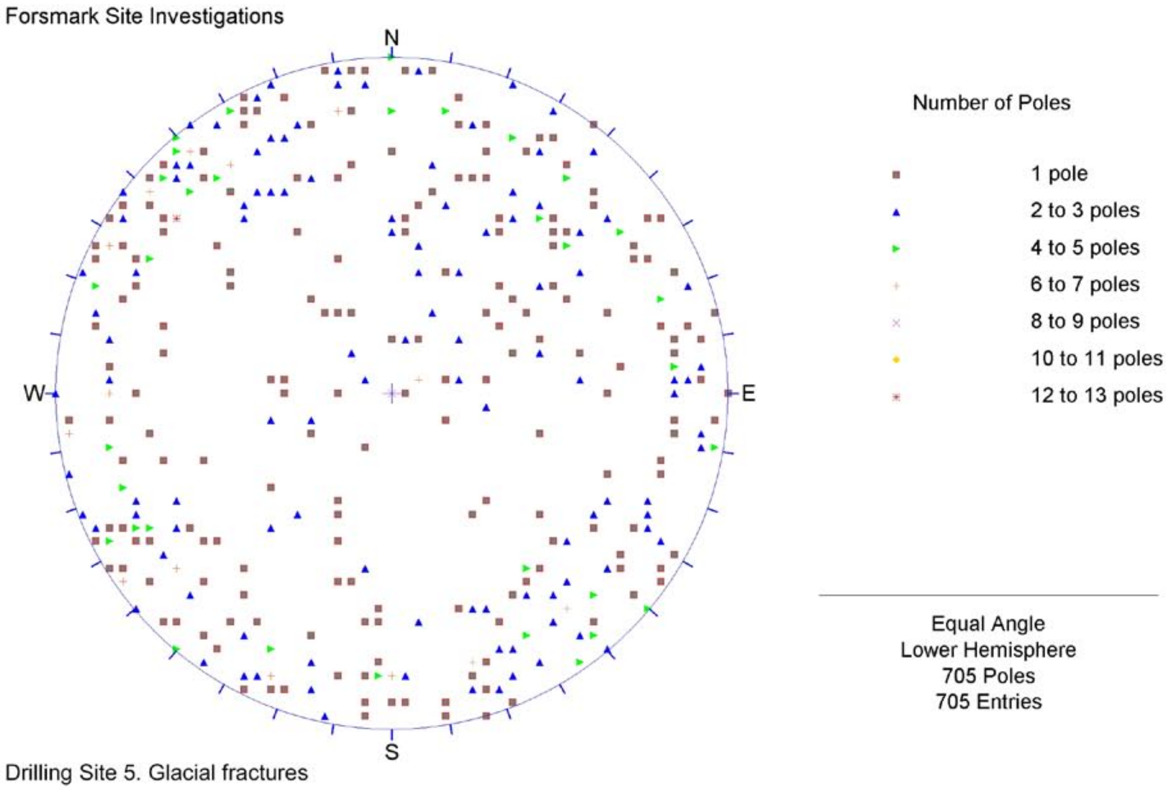



***Figure 5-3.*** *Stereographic scatter and contour plots of older fractures at AFM100201 drilling site 5.*



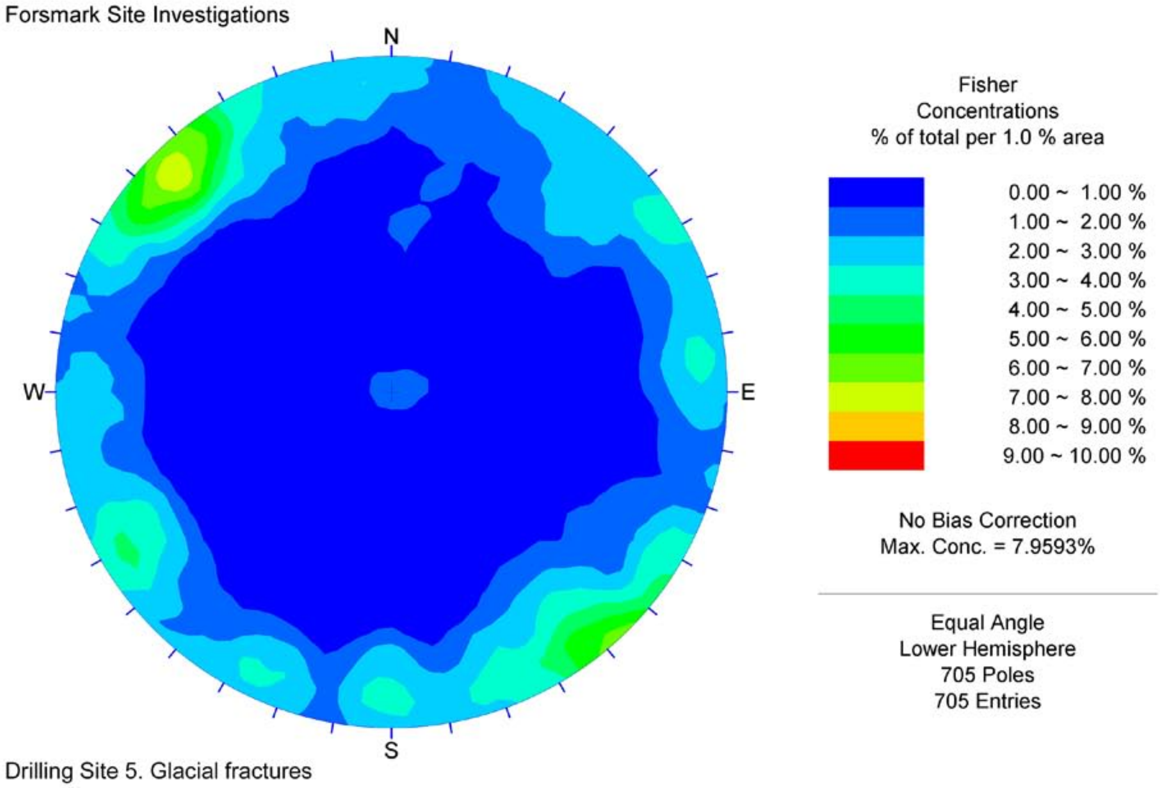




***Figure 5-4.*** *Stereographic scatter and contour plots of glacial fractures at AFM100201 drilling site 5.*

## 5.1 Tables

**Table 5-1. Specification of fractures with respect to fracture type.**

| Type | From no | To no | Quantity |
|---|---|---|---|
| Post or late glacial | 1 | 93 | 93 |
| Post or late glacial | 135 | 237 | 103 |
| Post or late glacial | 270 | 336 | 67 |
| Post or late glacial | 392 | 393 | 2 |
| Post or late glacial | 401 | 608 | 208 |
| Post or late glacial | 629 | 630 | 2 |
| Post or late glacial | 671 | 894 | 224 |
| Post or late glacial | 921 | 925 | 5 |
| Post or late glacial | 942 | 944 | 3 |
| Old | 94 | 134 | 41 |
| Old | 238 | 269 | 32 |
| Old | 337 | 391 | 55 |
| Old | 394 | 400 | 7 |
| Old | 609 | 628 | 20 |
| Old | 631 | 670 | 40 |
| Old | 895 | 920 | 26 |
| Old | 926 | 941 | 16 |
| Unspecified | 945 | 1280 | 336 |

**Table 5-2. Bedrock codes (two first digits relate to the Forsmark site) and description. SKB code system has been used to describe rock, structure, grain size and colour.**

| Code | Rock type (two first digits relate to the Forsmark site) |
|---|---|
| 111058 | Granite, fine- to medium-grained |
| 101061 | Pegmatite, pegmatitic granite |
| 101058 | Granite, metamorphic, aplitic |
| 101057 | Granite to granodiorite, metamorphic, medium-grained |
| 102017 | Amphibolite |
| **Code** | **Structure** |
| 45 | Lineation |
| 20 | Gneissic |
| 98 | Metamorphic, unspecified |
| **Code** | **Grain-size of matrix** |
| 2 | Fine-grained |
| 9 | Medium-grained |
| 4 | Coarse-grained |
| **Code** | **Colour** |
| 11 | Light red |
| 18 | Reddish grey |
| 13 | Black |
| | **Orientation (terminology applied on all structures in bedrock)** |
| | Strike/dip (used for all planar structures) |
| | Bearing/plunge (used for all linear structures) |

**Table 5-3. Physical properties of fractures with codes.**

| | Fracture trace = Visible length of the fracture in metres |
|---|---|
| **Code** | **Fracture Termination** |
| | Right-hand rule. Fracture termination A is starting point and B ending point. At vertical dip, the strike (B-direction) is against the northern hemisphere (271–90 degrees). Horizontal fractures are defined with strike = 0 |
| o | Termination outside outcrop (under soil cover, water or vegetation) |
| p | Termination within outcrop, not against any other fracture |
| t | Termination against another fracture |
| y | Fracture terminates in a y-shape (one or several times) |
| x | Fracture terminates against a rock boundary. Rock code is given in column for rock termination, respectively |
| | No data available |
| **Code** | **Fracture relation to rock boundary (except termination against, cf above)** |
| a | Fracture crosses no rock boundary |
| b | Fracture crosses one rock boundary |
| c | Fracture crosses several rock boundaries |
| d | Fracture is oriented in a rock boundary (rock types given in “comment” column) |
| | No data available |
| **Code** | **Fracture aperture** |
| o | Fracture appears to be open |
| s | Fracture appears to be closed |
| | No data available |
| **Code** | **Fracture width** |
| 0 | Fracture is open, but not measurable |
| 1 and up | Width in mm |
| **Code** | **Fracture shape** |
| t | Fracture is stepped up to approximately 1 cm (if the distance is greater, each part is mapped separately) |
| u | Fracture is undulating |
| p | Fracture is planar |
| | No data available |
| **Code** | **Fracture roughness** |
| r | Fracture surface is rough |
| s | Fracture surface is smooth |
| h | Fracture surface indicates movement (e.g. slickenside) |
| | No data available |
| **Code** | **Indication of movement** |
| 0 | There is an indication that movement has **not** occurred along the fracture (e.g. no displacement along a crossing rock boundary) |
| s | Sinistral |
| d | Dextral |
| ja | Indication of movement with unknown direction |
| | No data available |
| **Code** | **Indication of glacial reactivation of an older fracture** |
| r | Fracture appears to have been reactivated |
| | No data available |

**Table 5-4. Fracture mineralogy and chemistry with codes.**

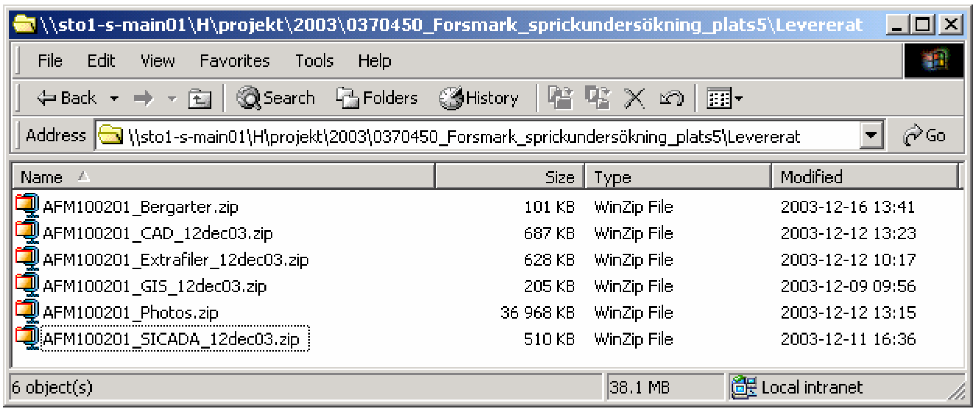
| Code | Fracture minerals |
|---|---|
| 30 | Calcite |
| 45 | Other or unidentified fill |
| **Code** | **Fracture fill** |
| | The coarsest loose material observed is given as text such as “silt”, “gravel”, etc |
| **Code** | **Alteration of side-rock** |
| r | The rock in the vicinity of the fracture is red coloured <1 cm on each side, unless otherwise indicated |
| rr | The rock in the vicinity of the fracture is deep red coloured <1 cm on each side, unless otherwise indicated |
| 0 | No alteration (equivalent to ISRM** weathering class I) |
| 1 | County rock is discoloured, not red (ISRM weathering class II) |

** International Society for Rock Mechanics Classification System

## Appendix 1

## Bedrock map of drilling site 5, AFM100201

# List of delivered files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| AFM100201_Extrafiler_12dec03.zip | 628 KB | WinZip File | 2003-12-12 10:17 |
| AFM100201_GIS_12dec03.zip | 205 KB | WinZip File | 2003-12-09 09:56 |
| AFM100201_Photos.zip | 36 968 KB | WinZip File | 2003-12-12 13:15 |
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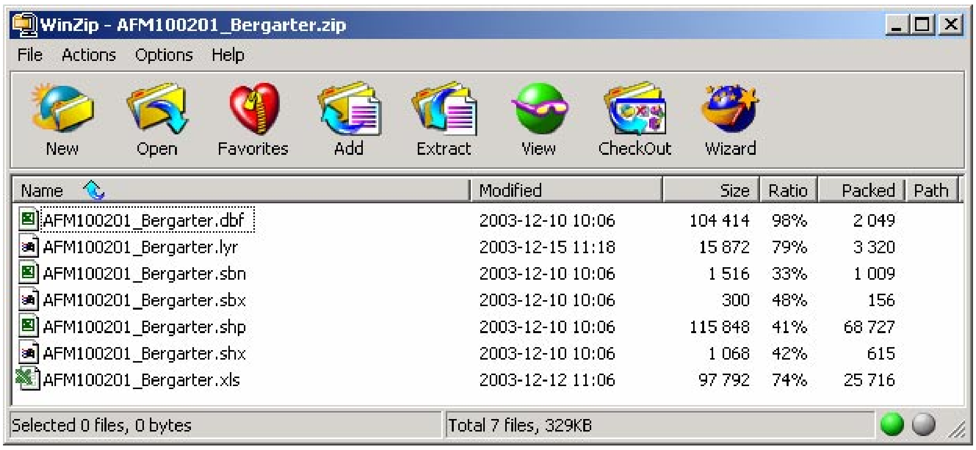
6 object(s) 38.1 MB Local intranet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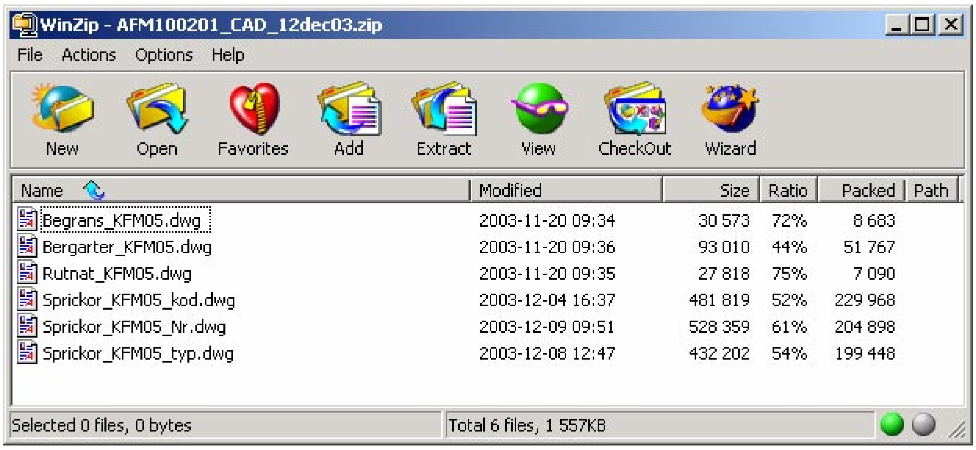
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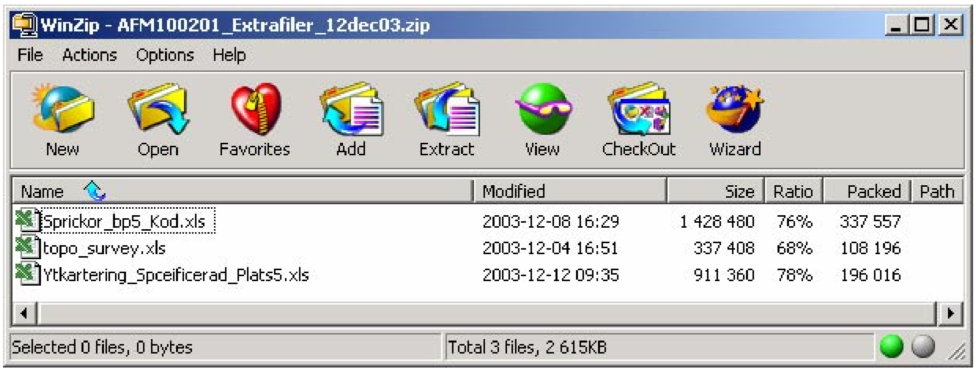


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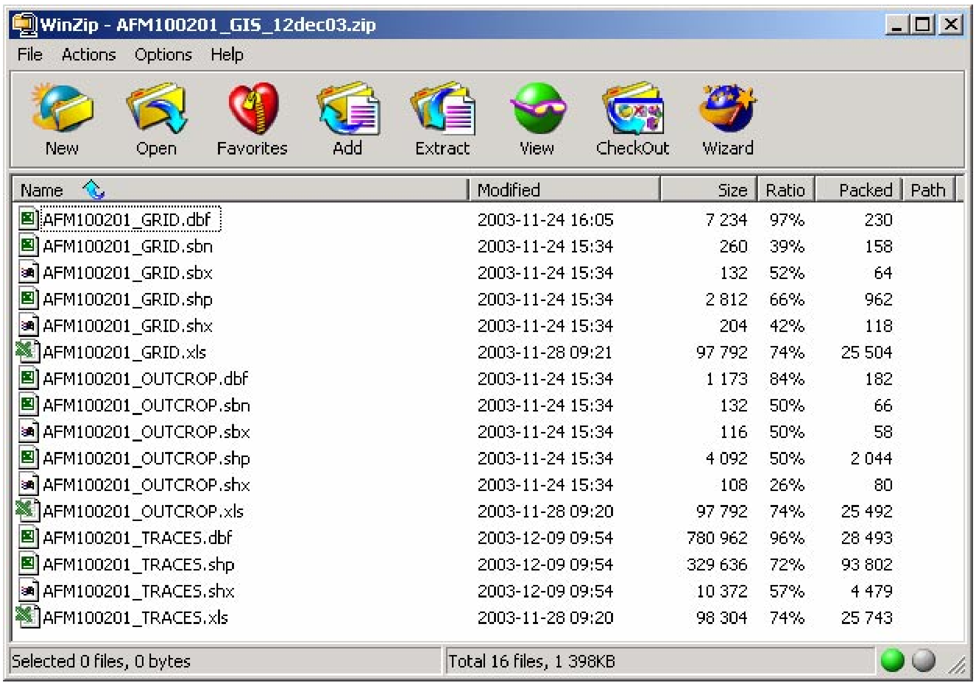


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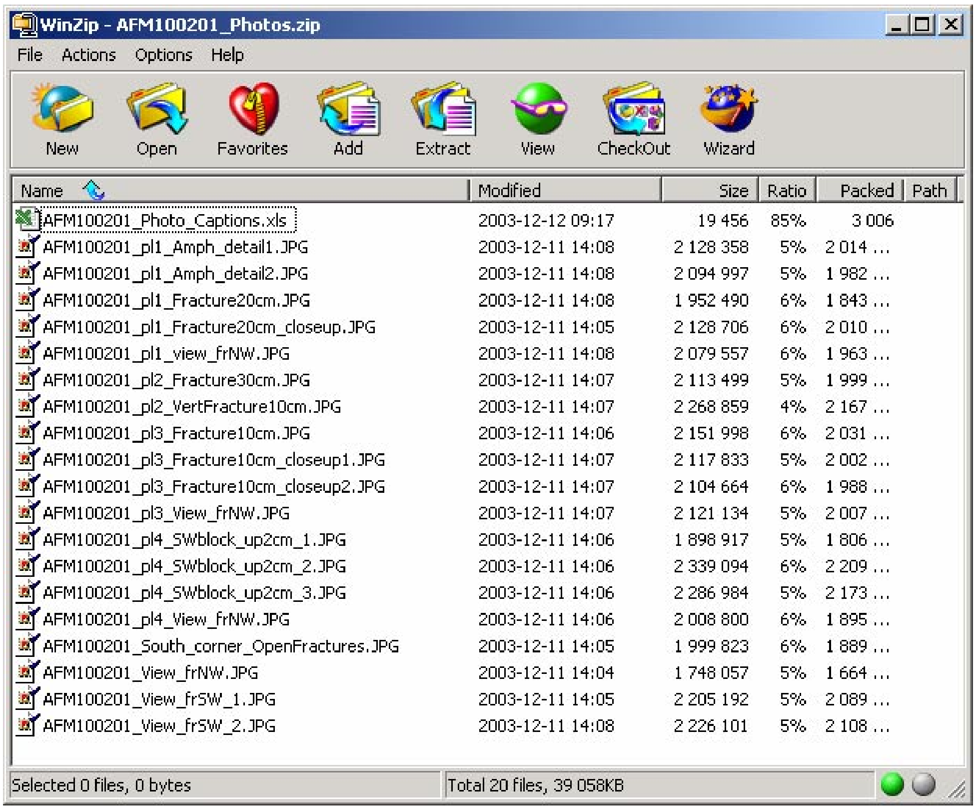


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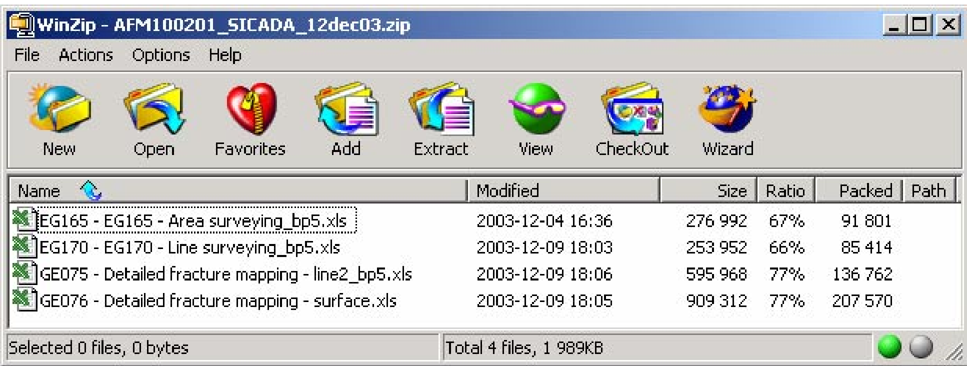


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