

R-06-55

Comparative evaluation of core mapping results for KFM06C and KLX07B

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April 2006

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

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Summary

In order to ensure the same quality standards and working methods are applied at both the Forsmark and Laxemar sites, selected drill core from each site has been mapped independently by both site mapping teams. This report represents a comparative evaluation of the results.

Clear differences between the results have been identified though some differences are judged to be more significant than others; the interpretation is somewhat dependent on the particular end-user of the results.

Rock type, alteration and mineral identification, along with fracture frequency and fracture orientation appear consistent, after allowing for the influence of site specific experience and these differences are considered of minor importance. The difference in interpretation of shear zones and how they are recorded is considered significant and warrants further investigation. Certain fracture classifications, used as input data for Design rock mass classifications, can be better standardized.

There is a clear difference in the results of open vs sealed fractures that is of potential importance for hydrological modelling. It should be clearly understood that the open vs sealed fracture classification is not a parameter measured by the geologists but is determined by the Boremap system based on a combination of parameters. Thus the difference in the results is due to differences in more than one underlying parameter and is also related to site specific developed methodology.

Overall it is judged that some of these differences are exacerbated by the mapping system. There is potential to simplify the system, improve focus on important features and increase its relevance to the various end-users.

SKB have initiated a detailed review of current drill-core mapping routines and control documentation.

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1 Background

In order to ensure the same quality standards and working methods are applied at both the Forsmark and Laxemar sites, selected drill core from each site has been mapped independently by both site mapping teams. The mapping has subsequently been reported by SwedPower AB /Petersson et al. 2005ab/ and Geosigma AB /Ehrenborg and Dahlin 2005ab/. FB Engineering was assigned to carryout a comparative evaluation of the results.

2 Scope

The work is divided into the following three stages, with SKB reviewing the work after each stage:

ID1: identification of differences,

ID2: investigation of the differences,

ID3: review of SKB control documentation based on the results.

The current report concerns ID1 and ID2.

3 Definitions

The Boremap system of variables and parameters has been followed /Strähle and Stenberg 2002/ and /Larsson 2004/. Clarity, consistency and traceability of terminology between Boremap, SICADA (and RVS) have not been found to be completely straightforward. SKB have initiated a detailed review of current drillcore mapping routines and control documentation. The meaning of certain terms has been ‘assumed’ and absolute definitions still need to be confirmed. To a very limited extent the individual sites have developed their own work routines and interpretation of terminology to arrive at practical solutions. Such cases are highlighted in this report. The definitions according to /Larsson 2004/ of some important parameters are presented in Appendix D.

4 Execution

The execution of the work by each team is described in /Simeonov 2005/. It appears from inquiries that the usual 'home' site team has mapped each hole first at each site and then the visiting mapping team has performed their mapping. The mapping team of SwedPower normally works at Forsmark and the mapping team of Geosigma normally at Laxemar.

As a starting point the visiting team received a selected copy of the earlier mapping work. The copy was cleaned from mapped data along the comparative core length but was prepared with adjusted borehole position and orientation. In the case of KFM06C the copy included mapped data above the starting point of the comparative mapping.

The KFM06C BH logs present results from a depth of 102 m onwards though it should be noted that the comparative logging exercise does not begin until a depth of 176.5 m.

The core mapping of KFM06C by Geosigma (JEPD) stops at depth of 332.1 m rather than at 335 m as stated in the P report /Ehrenborg and Dahlin 2005a/. Similarly the core mapping of KLX07B by Geosigma (JEPD) /Ehrenborg and Dahlin 2005b/ stops at a depth of 131.9 m rather than the reported depth of 132.6 m.

In order to carryout a balanced comparison of the logging results from the two teams the data files have been adjusted to only cover those depths covered by both teams, see Table 4-1.

The mapping results are presented in the report for each borehole separately. The reporting is divided into parameters describing mapped lithology, fractures, sealed fracture networks and crush zones. Underlying values for the figures presented in the report referring to KFM06C are to be found in Appendix A and those concerning KLX07B in Appendix B. Strike and dip along with rosette plots for both boreholes are presented in Appendix C.

Table 4-1. Borehole orientation and diameter presented together with the depths and the corresponding length that is covered by the comparative evaluation.

Borehole	Orientation Bearing (deg)	Inclination(deg)	Diameter Hole (mm)	Core (mm)	Covered depth (m)	Mapped length (m)
KFM06C	N026	60	77	51	176.5–332.1	155.6
KLX07B	N171	85	76	51	9.6–132.0	122.4

5 Mapping results borehole KFM06C

5.1 Lithology

5.1.1 Rock type

Comparative quantities of the various rock types logged are presented in percentage of mapped core length in Figure 5-1.

The two mapping teams have reported the same rock type along approximately 80% of the mapped core length. The agreement in the results is considered to be acceptable, since the identification of rock types and selection of rock type codes is somewhat dependent on site specific experience. The reported differences are not judged to be significant.

5.1.2 Rock structure

The rock structure type and rock structure intensity versus percentage of mapped core length are presented in Figure 5-2 and Figure 5-3, respectively.

These two parameters are to a great extent influenced by subjective judgements linked to the geologists' experience of the 'normal' appearance of the common rock types found at the two different sites. Therefore, the significance of the reported differences should not be overemphasized.

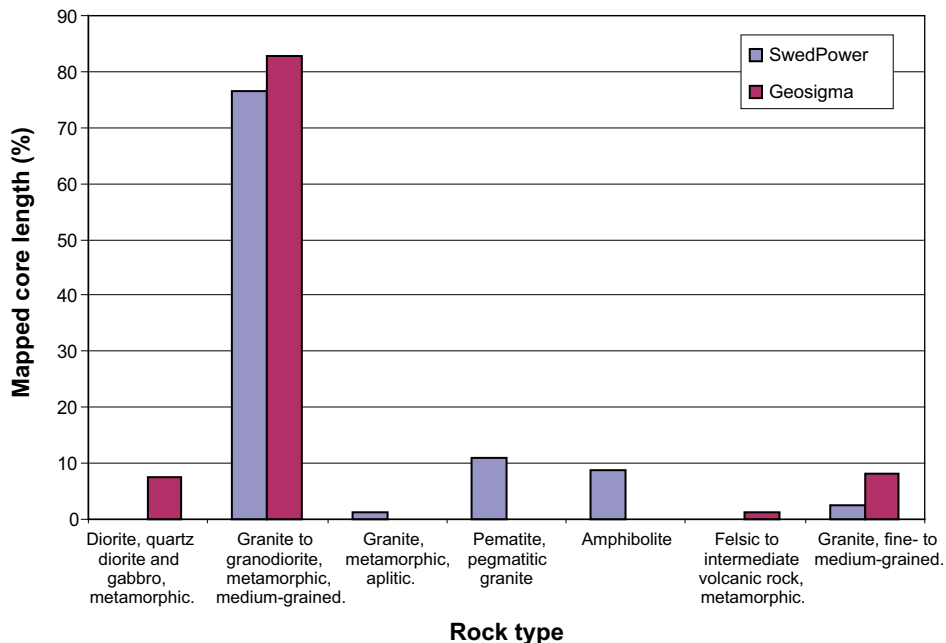


Figure 5-1. Rock type versus percentage of the mapped core length 155.6 m.

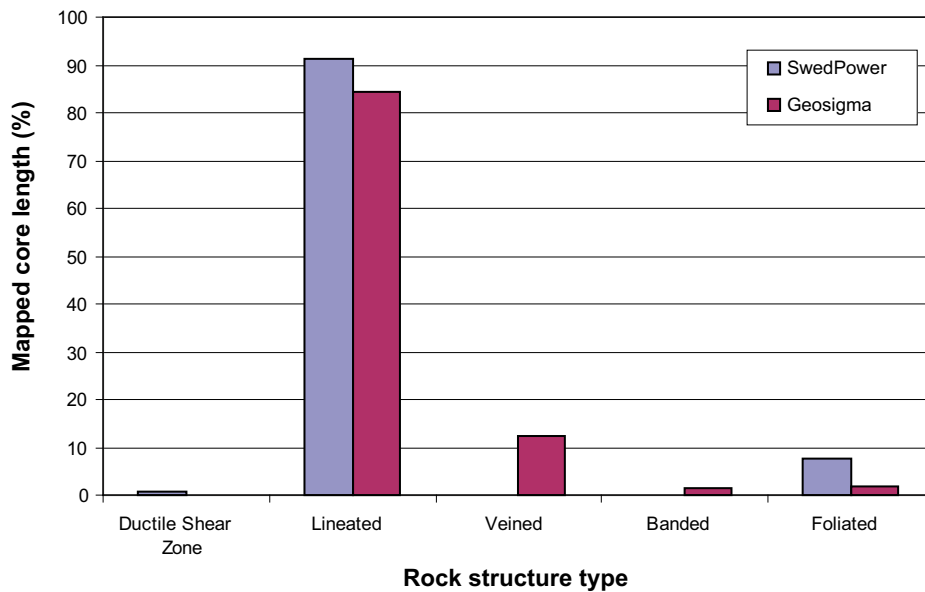


Figure 5-2. Rock structure type versus percentage of the mapped core length 155.6 m.

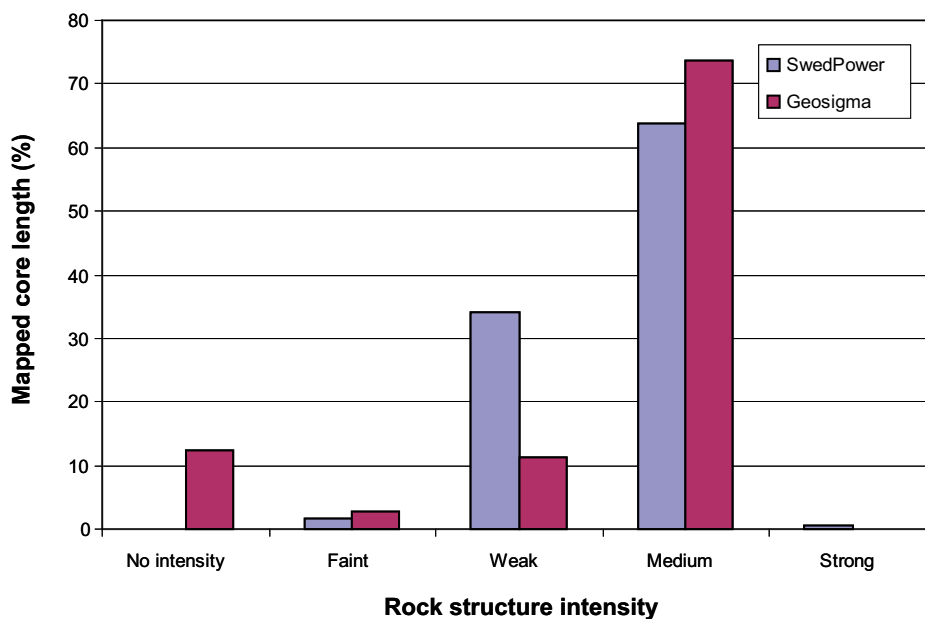


Figure 5-3. Rock structure intensity versus percentage of the mapped core length 155.6 m.

The two mapping teams have reported the same rock structure type along approximately 86% of the mapped core length and the same rock intensity along approximately 78%. The agreement in the results is judged to be acceptable. The most significant difference is considered to be how the two different teams interpret, record and describe the existence and extent of ductile and brittle-ductile shear zones. SwedPower have identified and recorded under rock type structure a single ductile shear zone with an intercept width of 1.4 m in the depth interval 223.6–225.0 m. This structure has not been identified by Geosigma. In addition SwedPower have identified a further 5 shear zones with intercept widths of less than 1 m. The difference in some cases may be associated with the differentiation between ductile shear zones and banding or foliation. This item is considered important and interpretation of deformation indicators needs to be as consistent as possible. There should be a follow up by a joint inspection of the core or BIPS image. This item is further discussed in Section 6.1.2.

5.1.3 Rock alteration

Figure 5-4 and 5-5 show the rock alteration type and the rock alteration intensity versus percentage of the mapped core length.

The mapping results are very similar. Both teams have principally mapped rock oxidation with faint or weak intensity, SwedPower mapped faint intensity along approximately 26% of the core length and Geosigma along approximately 18%. The differences are considered to be within an acceptable level and of minor importance. However, it is of interest to note that it is the “home team” SwedPower that is mapping the largest amount of rock alteration. This is considered to be related to the difference in the overall degree of alteration affecting the rock mass at the two different sites. The individual teams have perhaps developed their own ‘threshold’ judgements based on local indicators.

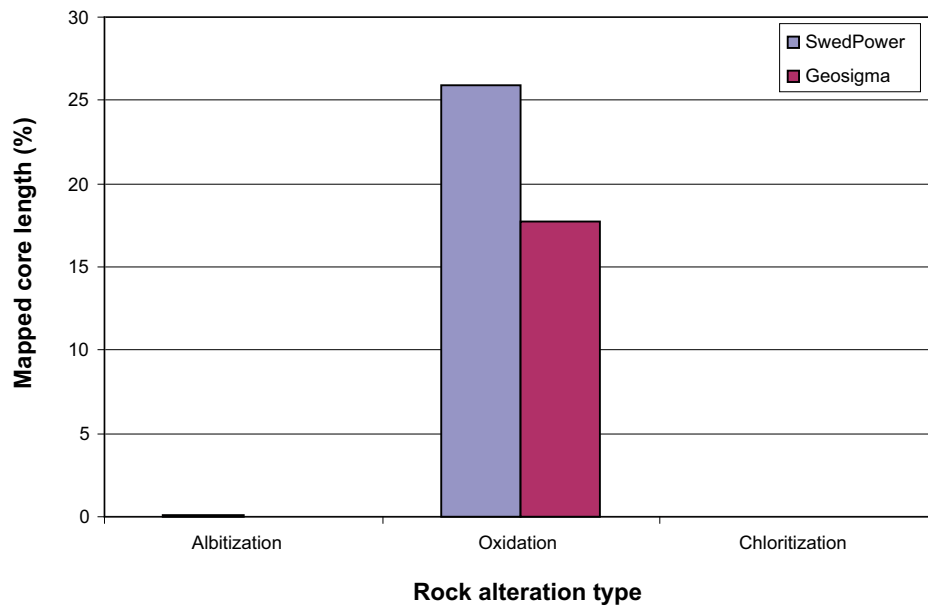


Figure 5-4. Rock alteration type versus percentage of the mapped core length 155.6 m.

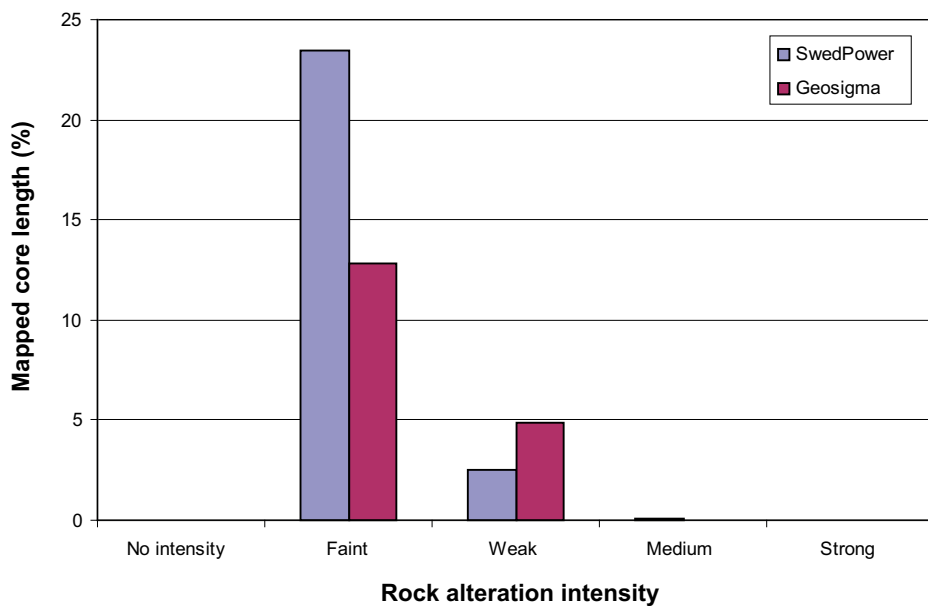


Figure 5-5. Rock alteration intensity versus percentage of the mapped core length 155.6 m.

5.1.4 Rock occurrence type

Figure 5-6 shows rock occurrence type versus frequency for the mapped core length. The mapped rock type associated with each occurrence is presented in Table A-4, Appendix A. The term “rock occurrence” refers to lithological sections of rock in the core that have an interception width of less than 1 m. Whilst the upper limit intercept width of 1 m is clearly followed there seems to be no clear Boremap definition of where the boundary between dyke and vein is established.

SwedPower have mapped a total of 279 such sections of rock occurrences and Geosigma a total of 209 sections. The total length of rock occurrences as a percentage of the core length, mapped by SwedPower, is approximately 16% and by Geosigma approximately 14%. SwedPower have consequently mapped about 35% more sections but of lesser width than Geosigma, which results in an equivalent total length of rock occurrence.

SwedPower classifies 66% of the rock occurrences mapped as ‘unspecified’ including all amphibolites and pegmatites that do not have sharp contacts, whereas Geosigma have 22% as unspecified. The classification of such amphibolites and pegmatites is not defined within Boremap and is specific to SwedPower. The difference between the two sets of quantities seems also to be related to the fact that the definition of veins and dykes, as well as mapping of quartz-rich “pieces” of the core, is rather subjective and the limits are not clearly defined in the mapping system.

The benefit of including rock occurrence type in its current format in the mapping sequence is not clear. The repeatable identification and differentiation between the different occurrence types in the drill core is questionable. The classification does not appear to have any practical application in any subsequent analysis. It is considered by the author that the systematic inclusion of this item is unnecessary and that if specific evidence exists for a particular occurrence type this could be noted in the comments field.

Concerning the rock name SwedPower have classified the main part, approximately 67% of the rock occurrences, as pegmatite to pegmatitic granite. Geosigma have on the other hand classified approximately 37% as pegmatite to pegmatitic granite and approximately 43% as granite, fine to medium grained.

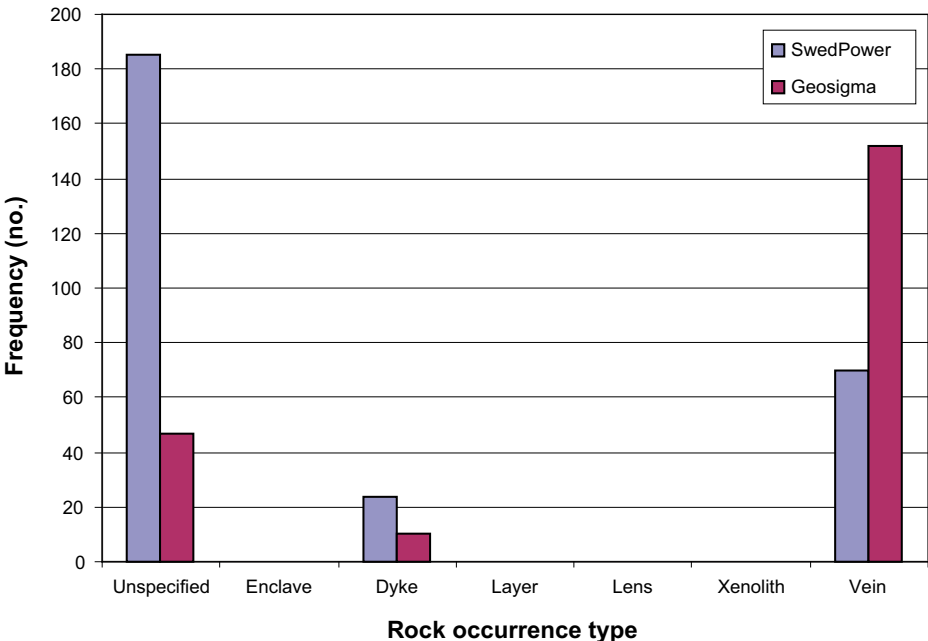


Figure 5-6. Rock occurrence type versus frequency of the mapped core.

5.2 Fractures

5.2.1 Fractures mapped

In the mapping process, fractures that split the core into physically separate pieces are mapped as “broken fractures” and fractures that do not split the core, as “unbroken fractures”. Core breaks which are judged not to be associated with natural fractures are not recorded. It is sometimes difficult to judge if the fracture was broken in situ, or if the core was broken during the drilling or later handling of the drill core. If the core is seen to be broken during handling the core is physically marked at that location with a letter ‘F’. If such a break coincides with a natural fracture then the fracture is mapped as unbroken. If the fracture is judged to be a simple unassociated mechanical break then it is not included in the mapping. The judgment of whether a fracture is drilling induced or not is made on the basis of how well the two fracture surfaces fit together and the condition of the surfaces with regards to alteration and weathering. In the case of uncertainty the fracture is classified as broken by default. Figure 5-7 presents the frequency of broken and unbroken fractures of the mapped core.

The total number of fractures logged is very similar, 582 fractures are logged by SwedPower and 593 fractures by Geosigma. However, there is a clear difference in the division between broken and unbroken fractures. This maybe related to the counting of broken fractures and whether particular fractured sections are visible in BIPS. If more highly fractured sections, with multiple fracture sets, are not clearly visible in BIPS then determining the absolute number of broken fractures in such a section must be problematical. Additionally when the BIPS photos are examined, along with the marked logged fracture traces, it is understandable that the number of fractures logged differs between the two teams particularly for highly fractured sections. In some cases Geosigma has mapped 2 fractures (1 broken and 1 unbroken) where SwedPower has only mapped one fracture with the additional note “partly broken” or “partly unbroken” appearing in the comments column. On a detailed level the two teams may not always be recording the exact same fractures in such sections of core. The identification and classification of an individual fracture should be repeatable for any clearly defined isolated fracture in the core.

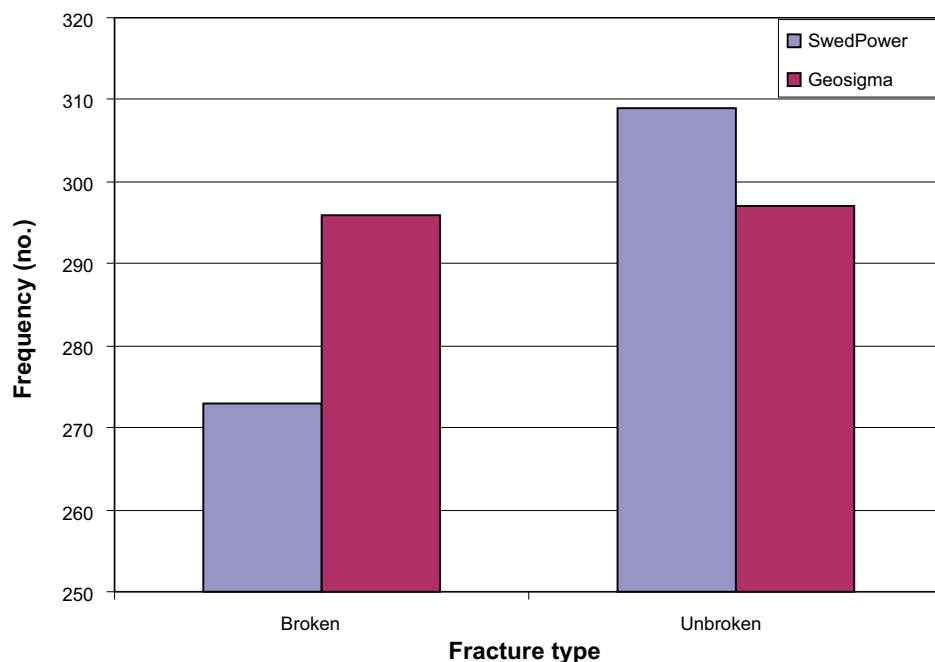


Figure 5-7. Frequency of broken and unbroken fractures of the mapped core.

However, the repeatability and reliability of even the total number of fractures recorded in a more highly fractured section of core, with cross cutting fracture sets, even with BIPS, must be more doubtful. This inevitably will affect the total number of fractures recorded. It is considered that it would be appropriate for both teams to make a joint inspection of the core to at least confirm that they have the same approach in practice when interpreting more fractured core sections and for the purposes of ‘calibration’ between the two teams.

It is considered that the practical limitations of the mapping must be taken into account even if sophisticated techniques are being used. It is considered that this should be borne in mind to ensure that the data is not over interpreted and over analysed.

5.2.2 Fracture recognition in BIPS

The fracture mapping is based jointly on information from the drill core and from the borehole BIPS-images. However, not all fractures are visible in the BIPS-image. The resolution of the BIPS camera is 0.6 mm. The reason could also be occurrence of suspended drilling cuttings, coatings on the borehole wall from the drill rods or disturbances in the movement of the BIPS-camera. The identification of thin fractures or fractures with low contrast minerals also makes the process more subjective than it may first appear /Petersson 2005a/. Fractures observed in the drill core that are not identified in the BIPS-image are therefore registered as “not visible in BIPS”. A plot of Frequency and Visibility in BIPS is included in Figure 5-8. There is a marked difference in the results from the two teams. SwedPower consistently mapped fractures that coincide with rock type contacts as “visible in BIPS” in that the orientation could be measured with confidence based on the orientation of the rock type contact whereas Geosigma mapped the same fractures as “not visible in BIPS”. Nevertheless the difference between the teams is of about 120 fractures and is difficult to explain only with this point. A joint inspection of the BIPS images is recommended.

5.2.3 Fracture aperture confidence

The aperture of the fractures is determined based on an inspection of the core and BIPS images (Aperture is further described in Section 5.2.9).

For all broken fractures the confidence in the actual existence of the aperture is settled as certain, probable or possible /Larsson 2004/. The stipulated predominant criterion for determining confidence according to the documentation is the observance of aperture in BIPS or not. If the aperture is visible in BIPS the confidence should be set to certain, if not the confidence is set as probable or possible based on the geometry and alteration of the fracture surfaces. However the application of the three confidence classes has not always followed the definition as given in /Larsson 2004/, thus leading to significant differences in the classification of fractures, see Figure 5-9. Both mapping teams state that they determine confidence level mainly based on the fitting of the core pieces and the alteration of the fracture plane (Dahlin 2006, Petersson 2006).

Confidence has also been determined for unbroken fractures following site specific interpretations, despite the fact that no definition is available in /Larsson 2004/. This implies that this parameter must be interpreted cautiously. This item is currently being reviewed.

5.2.4 Fracture type

Based on the aperture and the broken/unbroken division, fractures are classified by the database system as open, partly open or sealed according to the following rules:

Broken fractures with an aperture > 0 mm are classified automatically by the Boremap system as “open fractures”, unbroken fractures with an aperture > 0 mm as “partly open fractures”, broken and unbroken fractures with an aperture = 0 as “sealed fractures”, /Ehrenborg and Dahlin 2005a, Petersson et al. 2005a/.

It should be kept in mind that “open” and “sealed” is not a parameter that is directly mapped by the geologist but is a parameter generated by the Sicada database. Fracture type, confidence in the aperture classification (based on the openness of the fracture) and visibility in BIPS versus frequency of the mapped core are presented in Figure 5-8. Distribution in percentage between open, partly open and sealed fractures are presented in Figure 5-9.

As previously stated the total number of fractures logged is very similar, 582 fractures are logged by SwedPower and 593 fractures by Geosigma. However, there is a notable difference in the resulting division of the fractures between open and sealed. The difference in the proportion of open to sealed fractures is approximately 12% between the two teams, see Figure 5-9. The difference is consistent with the fact that SwedPower maps far more broken fractures with aperture 0 that are then classified as sealed by Sicada than Geosigma. It is also noticeable that “partly open” fractures have only been mapped by SwedPower.

In some cases it is difficult to judge if the fracture is broken in-situ or if it has broken up during the drilling. According to the determination criteria used for the mapping /Larsson 2004/, in the case of uncertainty a fracture should be classified as broken. This stipulation may be involved in the differences seen in the results.

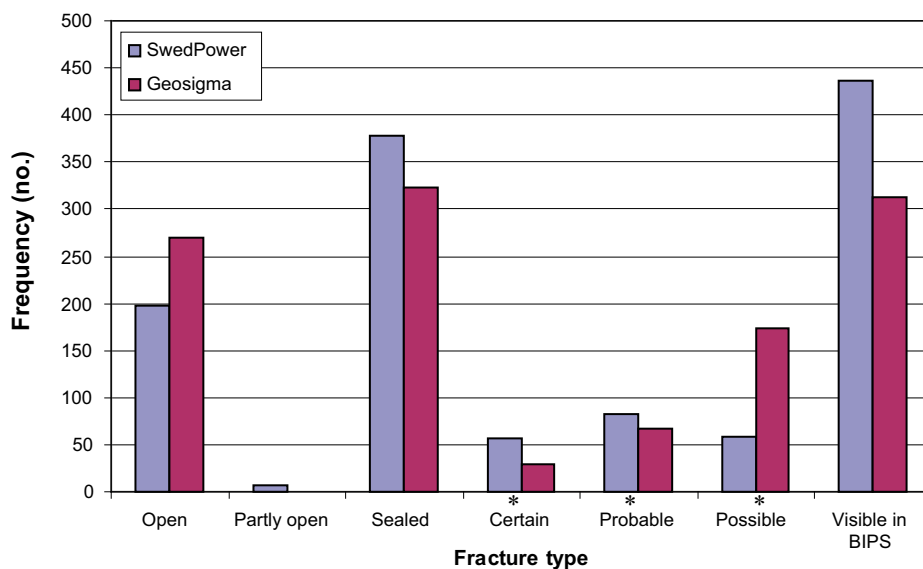
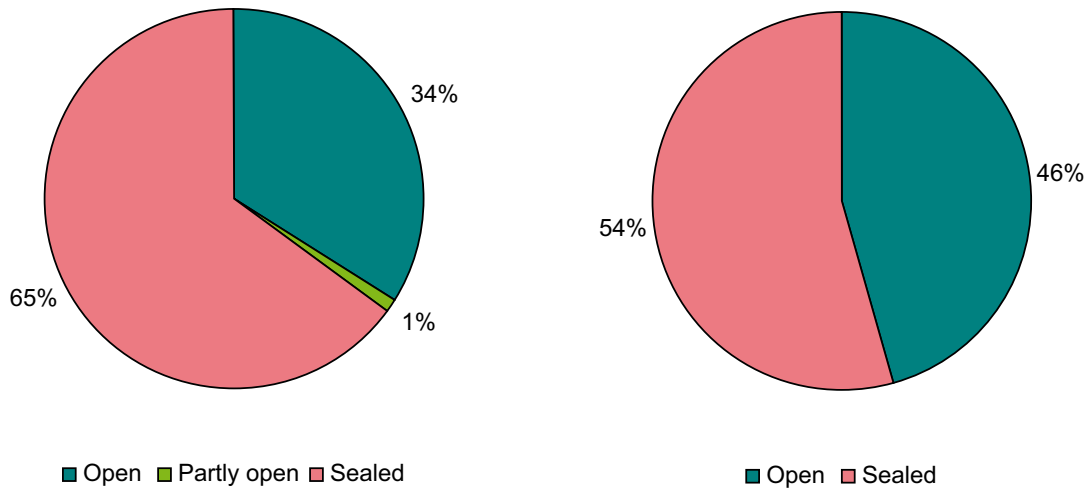


Figure 5-8. Fracture type, confidence and visibility versus frequency of the mapped core.
 * The degree of confidence (certain, probable and possible) only applies to open fractures. Sealed fractures are not classified by confidence.



SwedPower (JPGS). In total 582 fractures.

Geosigma (JEPD). In total 593 fractures.

Figure 5-9. Distribution in percentage amongst open, partly open and sealed fractures.

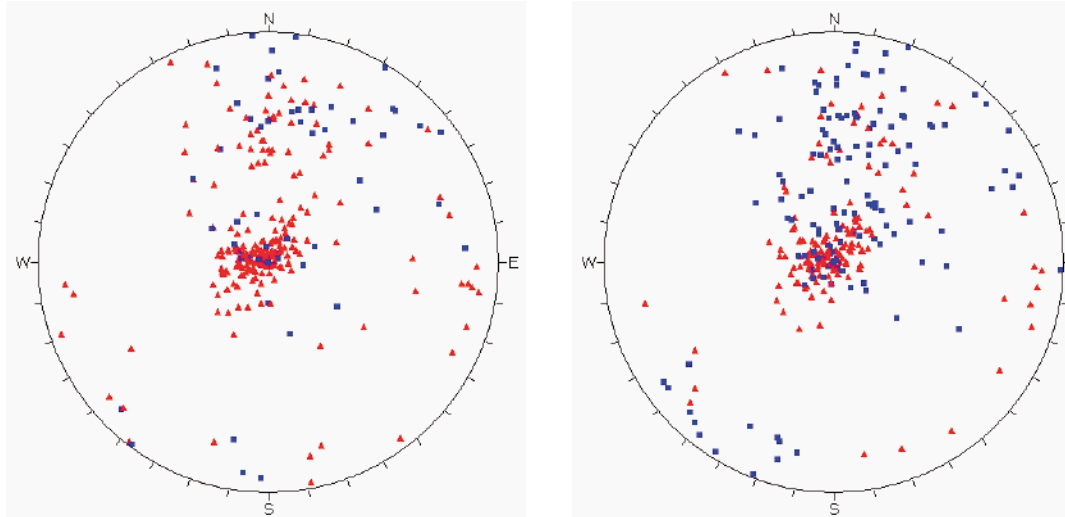
Overall, the interpretation of the resulting difference in the proportion of open and sealed fractures is not straight forward. The fact that open vs sealed is an indirect database parameter rather than parameter directly logged by the geologists has lacked transparency. It is considered that the differences are linked to the difficulty that exists in the decision as to whether a fracture should be classified as broken or unbroken, the judgement of aperture confidence and how the two teams classify fracture mineral alteration in different ways. Geosigma classifies the fracture filling minerals quartz, calcite, zeolites, sulphides and fluorite as “fresh” whilst chlorite, epidote, prehnite, clay minerals, adularia, hematite and “oxidized walls” are classified as “slightly altered”. SwedPower do not have the same direct link between mineral type and degree of alteration. The degree of alteration is involved in the open vs sealed classification. The differences must be of importance, since to our knowledge only open fractures are considered in the hydro modelling.

5.2.5 Orientation

Orientation of the fractures is normally performed by measuring in BIPS. However, some fractures are not visible in the BIPS-image. These fractures are oriented using the “guide-line method”, which implies that the fractures are oriented based on the absolute depth, the fracture amplitude and the relation between orientation of the fracture trace, measured on the drill core and a well defined structure visible in the BIPS-image /Ehrenborg and Dahlin 2005a/.

The orientations of fractures recorded by the two teams are presented by stereonet for broken fractures in Figure 5-10 and 5-11, and for unbroken fractures in Figure 5-13 and 5-14. To facilitate the comparison of the densities of the pole clusters these charts are supplemented by histograms, see Figure 5-12 and Figure 5-15. The histograms show the frequency of poles within a circle limited to a 60° plunge in the stereonet and 6 sectors of 60° outside this circle. The poles within the sectors and the inner circle are sorted into seven groups from A to G, starting with 0–60° and ending with the inner circle. Underlying values are presented in Table A-6 to A-7 in Appendix A.

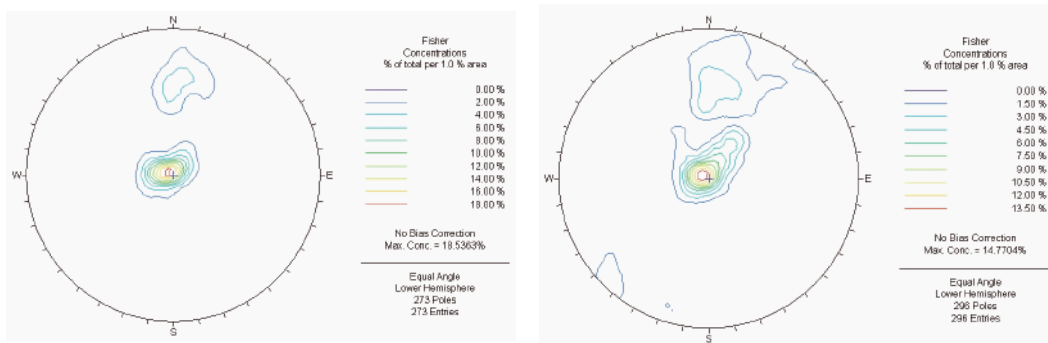
Both the pole plots and the histograms indicate, with few exceptions, good agreement between the fracture orientations recorded by the two teams. The difference in the pole density portion is normally less than 2%. However, greater divergences are found in group A (about 5%) of broken fractures and group B (about 7%) of unbroken fractures. The difference may be due to comparative differences in the records of non visible fractures in BIPS in these sectors between the mapping teams. This fact indicates greater uncertainty in the fracture orientation in this sector.



SwedPower (JPGS).
273 poles – 216 visible (red) and
57 not visible (blue) in BIPS.

Geosigma (JEPD).
296 poles – 156 visible (red) and
140 not visible (blue) in BIPS.

Figure 5-10. Strike and dip pole plot of broken fractures in KFM06C. Equal angle, lower hemisphere, no correction. Red triangular – fractures visible in BIPS. Blue square – fractures not visible in BIPS.



SwedPower (JPGS).
273 poles - Max concentration 18.5%.

Geosigma (JEPD).
296 poles - Max concentration 14.8%.

Figure 5-11. Strike and dip pole plot of broken fractures in KFM06C. Equal angle, lower hemisphere, Fisher distribution, no bias correction. Concentration in percent of total per 1.0% area.

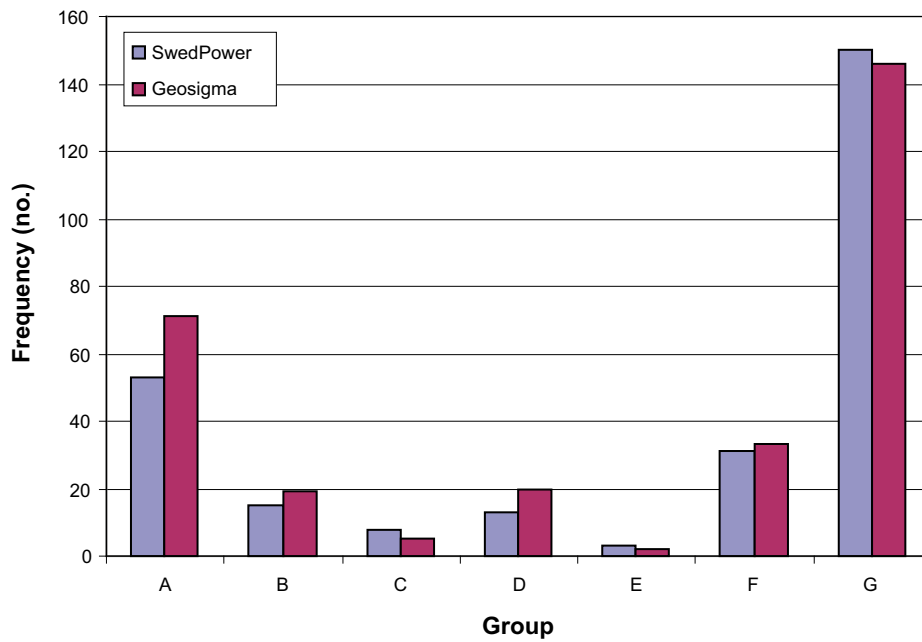
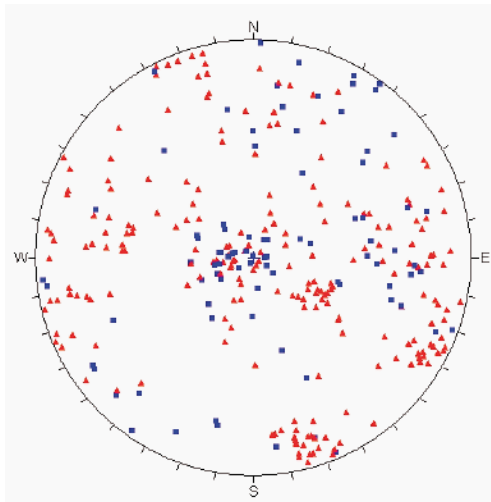
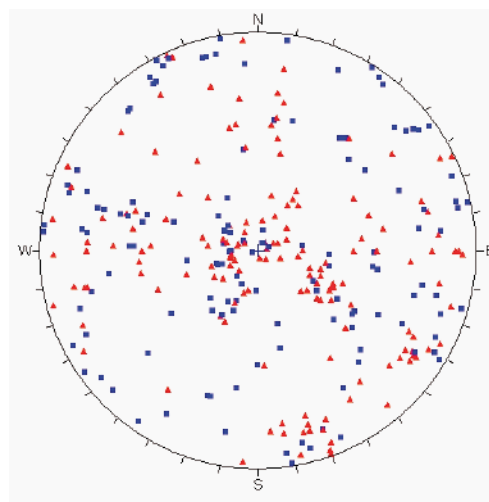


Figure 5-12. Frequency distributions for poles of broken fractures in KFM06C. The poles are sorted into seven groups from A to G based on a division of the stereonet into six sectors of 60° and an inner circle limited to 60° plunge.

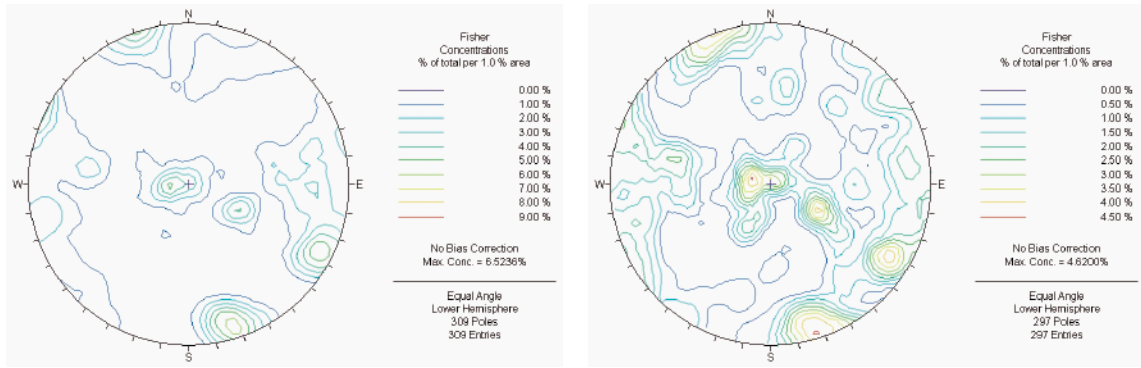


SwedPower (JPGS).
309 poles – 221 visible (red) and
88 not visible (blue) in BIPS.



Geosigma (JEPD).
297 poles – 156 visible (red) and
141 not visible (blue) in BIPS.

Figure 5-13. Strike and dip pole plot of unbroken fractures in KFM06C. Equal angle, lower hemisphere, no correction. Red triangular – fractures visible in BIPS. Blue square – fractures not visible in BIPS.



SwedPower (JPGS).
309 poles - Max concentration 6.5%.

Geosigma (JEPD).
297 poles - Max concentration 4.6%.

Figure 5-14. Contoured stereonet of poles to unbroken fractures in KFM06C. Equal angle, lower hemisphere, Fisher distribution, no bias correction. Concentration in percent of total per 1.0% area.

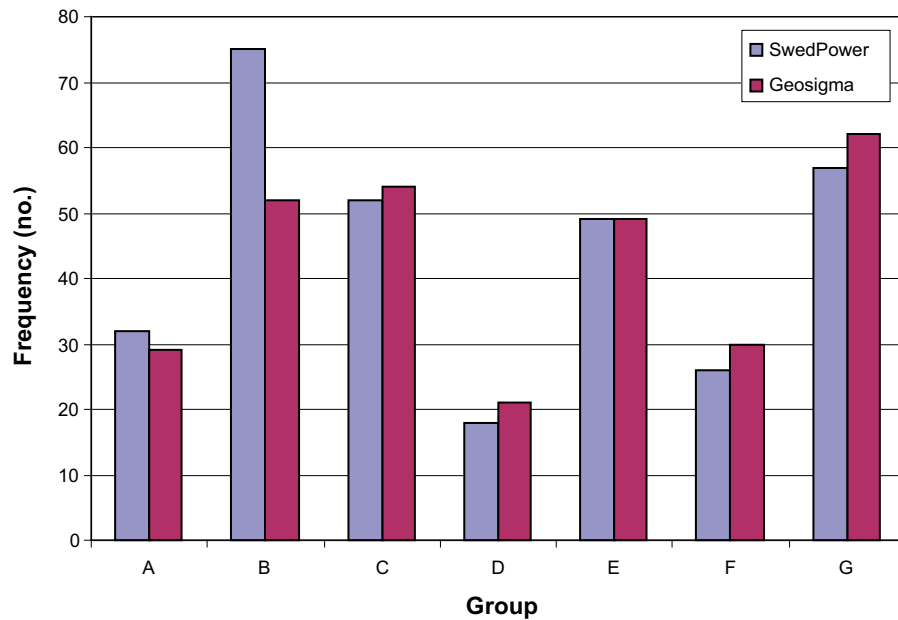


Figure 5-15. Frequency distributions for poles of unbroken fractures in KFM06C. The poles are sorted into seven groups from A to G based on a division of the stereonet into six sectors of 60° and an inner circle limited to 60° plunge.

5.2.6 Fracture mineralogy

Simple comparative frequency and percentages of the various mineral filling types logged are presented for broken fractures in Figure 5-16 and unbroken fractures in Figure 5-17.

Overall the pattern of identification between the two teams is very similar. There are differences, though to a certain degree accurate mineral type identification of uncommon minerals may require site specific experience. Whilst there is room for improved standardization between the two teams, for example in the use of ‘bleached walls’ as an identifier, the differences are not considered of major importance.

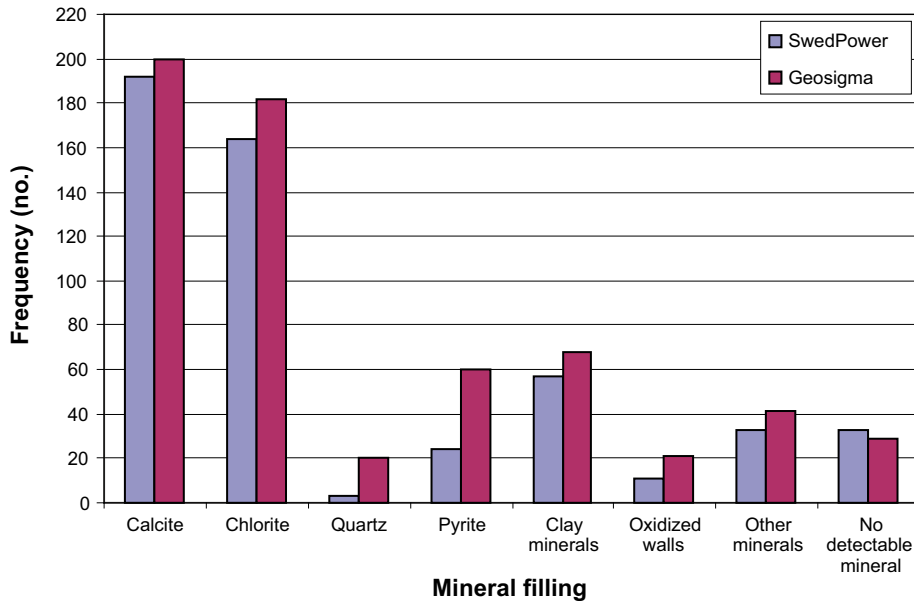


Figure 5-16. Mineral filling in broken fractures versus frequency of observations on the fracture planes.

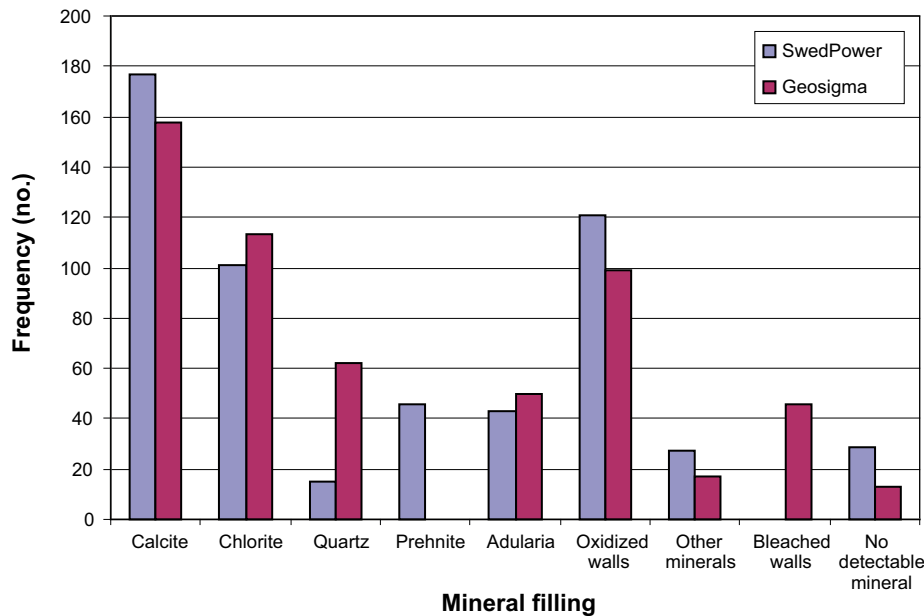


Figure 5-17. Mineral filling in unbroken fractures versus frequency of observations on the fracture planes.

5.2.7 Roughness and surface

Estimated fracture roughness profiles and surface conditions versus frequency for broken fractures are presented in Figure 5-18. The fracture surface classification uses standard terminology but this is not clearly linked to type profiles. Enquiries suggest that both roughness and surface estimations are somewhat general. Joint combs are not used and apparently no reference is made to ISRM standard profiles. It is considered that it is this degree of freedom and subjectivity in the interpretation that has led to the degree of difference in the results between the two teams. Differences will always be present but there are simple methods that can perhaps lead to this difference being reduced. Since it is assumed that both of these parameters are used as input to calculated rock mass quality Q estimates, a check could be made on their reliability and consistency.

5.2.8 Fracture mineral alteration

Estimated alteration intensity versus frequency in broken fractures is presented in Figure 5-19 and for unbroken fractures in Figure 5-20. There is basic difference how the two mapping teams are classifying fracture mineral alteration. Geosigma classifies the occurrence of fracture filling minerals, quartz, calcite, zeolites, sulphides, fluorite as “fresh” whilst chlorite, epidote, prehnite, clay minerals, adularia, hematite and “oxidized walls” are classified as “slightly altered”. However, SwedPower uses no such direct link and is using a combination of weathering and alteration as a criterion.

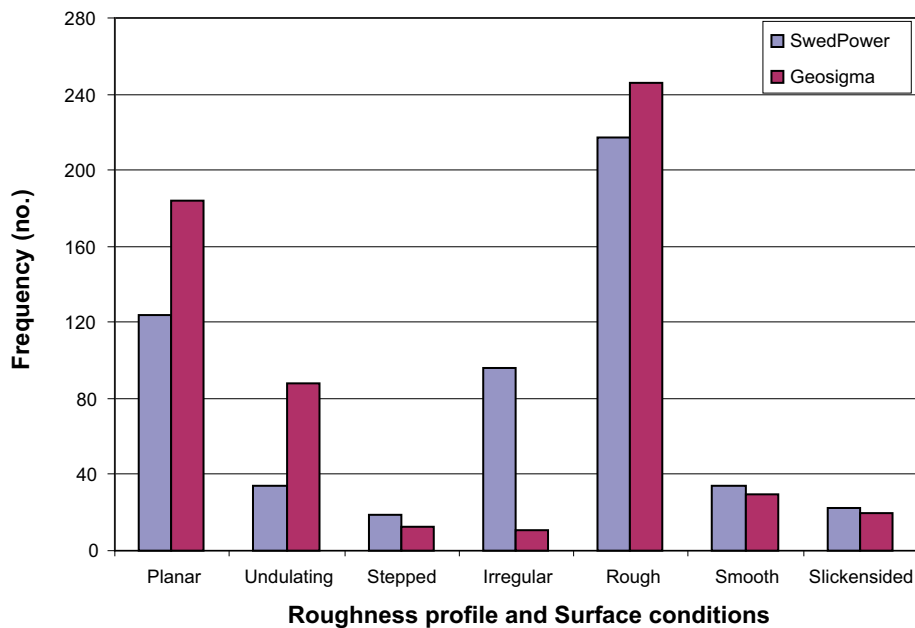


Figure 5-18. Estimated fracture roughness profile and surface conditions versus frequency for broken fractures. Roughness profile (large scale) surface conditions (small scale).

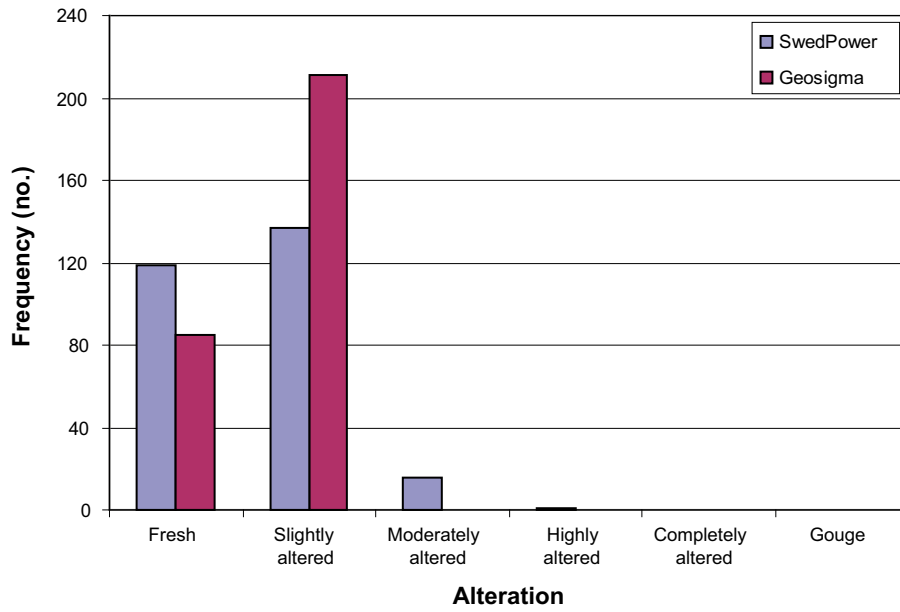


Figure 5-19. Estimated alteration versus frequency in broken fractures.

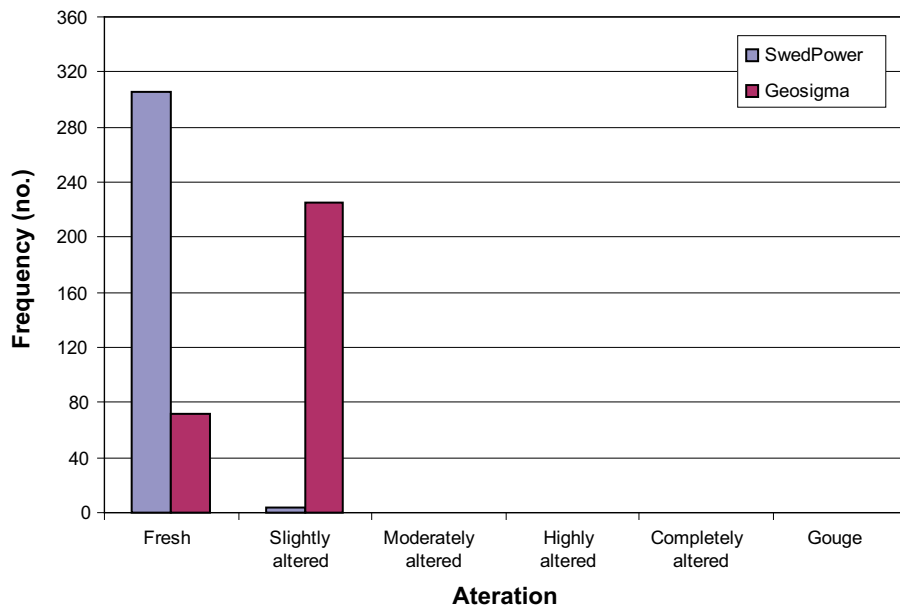


Figure 5-20. Estimated alteration versus frequency in unbroken fractures.

5.2.9 Aperture and width

Aperture versus frequency of broken fractures is presented in Figure 5-21 and in Figure 5-22 with subdivision dependent on confidence in aperture. Width versus frequency for unbroken fractures is presented in Figure 5-23. SwedPower record fracture apertures and widths in steps of 0.5 mm. However, Geosigma has systematically used a 0.1 mm interval for measuring width but used a 0.5 mm interval for measuring apertures up to 0.5 mm and occasionally 0.1 mm intervals for apertures greater than 0.5 mm. The site classifications should follow the 0.5 mm standard. The accepted minimum visible aperture in BIPS is 1 mm according to Boremap documentation. SwedPower have no fracture apertures of less than 1 mm that are judged as Certain, whereas this is not the case with Geosigma. The difference is most likely due to SwedPower relying on ‘supporting evidence’ from BIPS to define a fracture aperture as being Certain. This would be logical and be in agreement with the Boremap 1 mm limit. However, this is supposition and needs to be confirmed.

The difference in measurement classes between the teams may have a slight influence in the case of the differences in aperture measurements. However, it is the classification system itself which is considered to be the main reason for the differences. It is considered that even the subdivision into 0.5 mm classes is too detailed when considering how likely such measurements made on small core surfaces are representative the surrounding rock mass. When the manner of water movement and ‘channelling’ through the rock mass are considered the use of such detailed subdivisions appear even less relevant.

The frequency plot of width for unbroken fractures in Figure 5-23 shows a difference in the mapping of fractures wider than 5 mm. This is mainly due to the fact that SwedPower recorded such mineral filled fractures as “veins” in rock occurrences. This figure illustrates the difficulty in classifying some features.

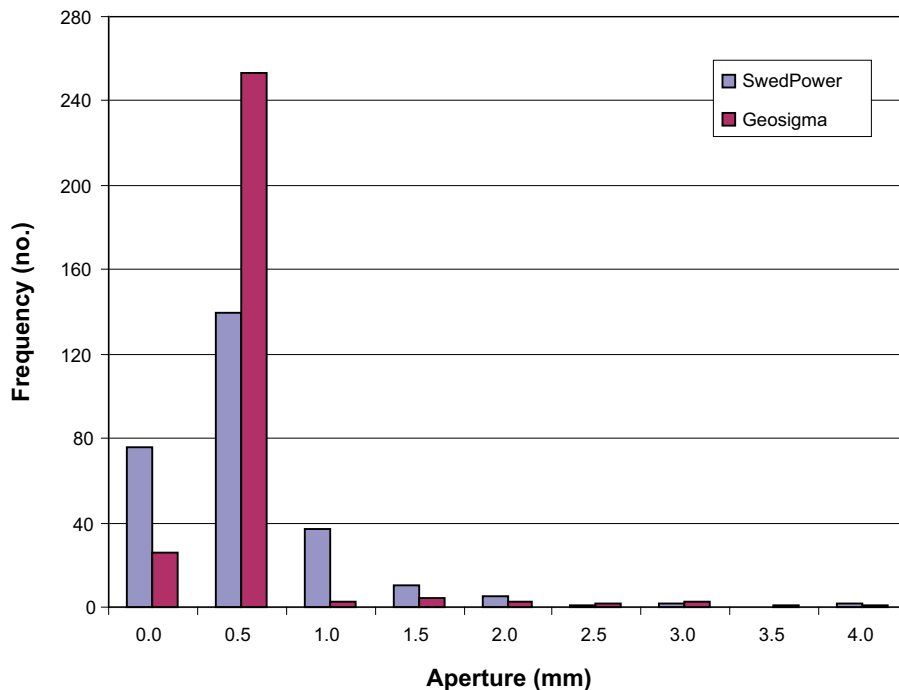


Figure 5-21. Aperture versus frequency of broken fractures. The aperture presented by Geosigma has been rounded to the closest half number.

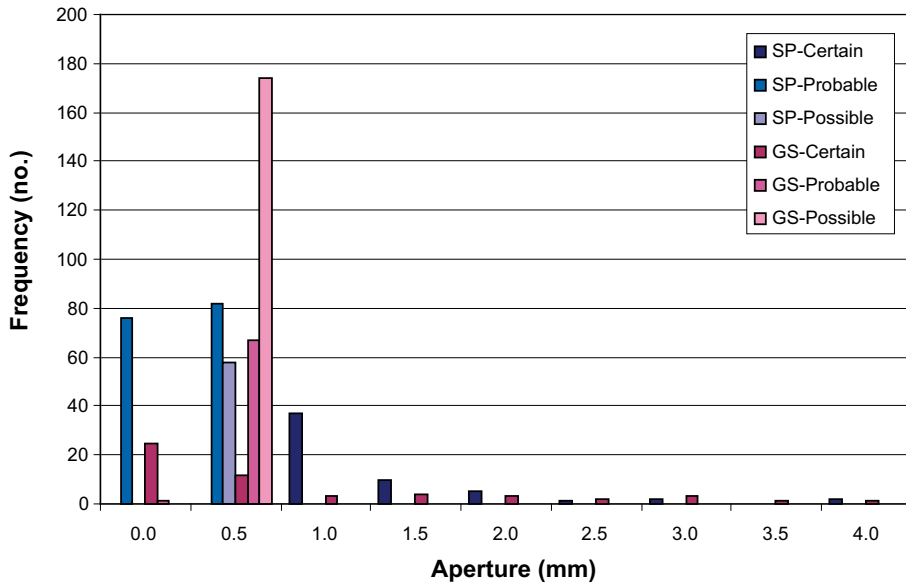


Figure 5-22. Aperture versus frequency of broken fractures with subdivision dependent on confidence in aperture. The aperture presented by Geosigma has been rounded to the closest half number.

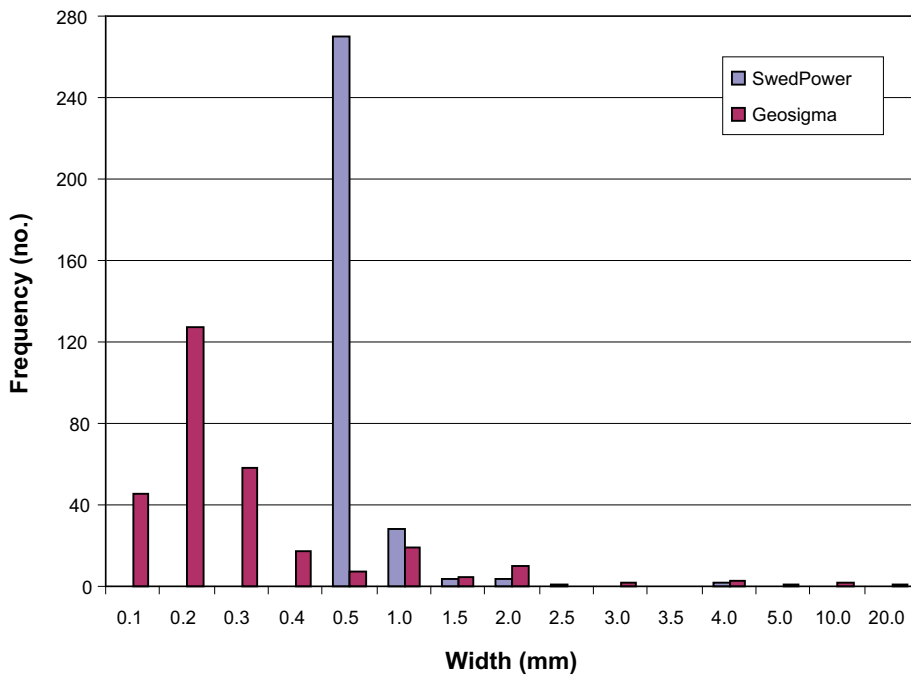


Figure 5-23. Width versus frequency for unbroken fractures.

5.3 Sealed fracture network

The position and extent of the sections of core interpreted as “sealed fracture networks” are presented in Table 5-1. It is reported that the two sites handle the mapping of sealed networks differently. Oskarshamn (Geosigma) report they have been instructed to identify a section of core containing a sealed network by defining a sec_up and sec_low depth interval. Within this interval they are to record no other individual sealed fractures or orientations. This leads to cases where clearly visible, well defined, sealed fractures are not recorded since they lie within a more diffuse sealed fracture network. Forsmark (SwedPower) have not been limited in this way. The methods should be standardized between the two sites. The difference in the number and extent of the sealed networks is clear. Whilst it is anticipated that local site experience plays a significant role in the identification and demarcation of such sealed networks a joint inspection of the core by both teams should be carried out to establish a clearer standard for this item.

Table 5-1. SecUp depth, core length and piece length for Sealed fracture network.

SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
–	–	–	187.1	0.11	4
–	–	–	188.6	1.11	10
207.9	0.10	10	207.9	0.06	5
228.9	0.16	20	228.7	0.45	10
–	–	–	242.4	0.18	10
–	–	–	247.8	0.30	10
249.0	0.20	20	249.0	0.24	10
–	–	–	281.0	0.00	10
282.6	0.13	20	283.0	0.28	10
–	–	–	293.8	0.00	3
–	–	–	329.8	0.83	40

5.4 Crush zones

SwedPower have found a small crush zone with 10 cm thickness in the depth interval 284.66–284.76 m while no such zone or even fracture is noted by Geosigma. Whilst this is not considered a major item, in terms of it being a single occurrence of minor extent, a joint inspection of the core at this location should be made. It is important that the interpretation of shear zones is standardized as far as possible.

6 Mapping results borehole KLX07B

6.1 Lithology

6.1.1 Rock type

Comparative quantities of the various rock types logged are presented as percentage of mapped core length in Figure 6-1.

The two mapping teams have reported the same rock type along approximately 99% of the mapped core length. The agreement in the results is consequently very good.

6.1.2 Rock structure

The rock structure type and rock structure intensity are presented in Figure 6-2 and Figure 6-3, respectively.

The two mapping teams have reported the same rock structure type along approximately 27% of the mapped core length and the same rock intensity along approximately 25%. The agreement in the mapping results is poor. Geosigma have on the whole mapped massive rock with no intensity where SwedPower have mapped foliated rock with faint intensity. Although the differences are very clear they are not considered to be of major significance or importance. The differences are considered to be closely related to local site experience and interpretation of the most common appearance of the main host granitic rocks. There is room for improved standardization but this is not of major concern. It is considered more realistic that these differences should be noted and appreciated when the sites are being compared.

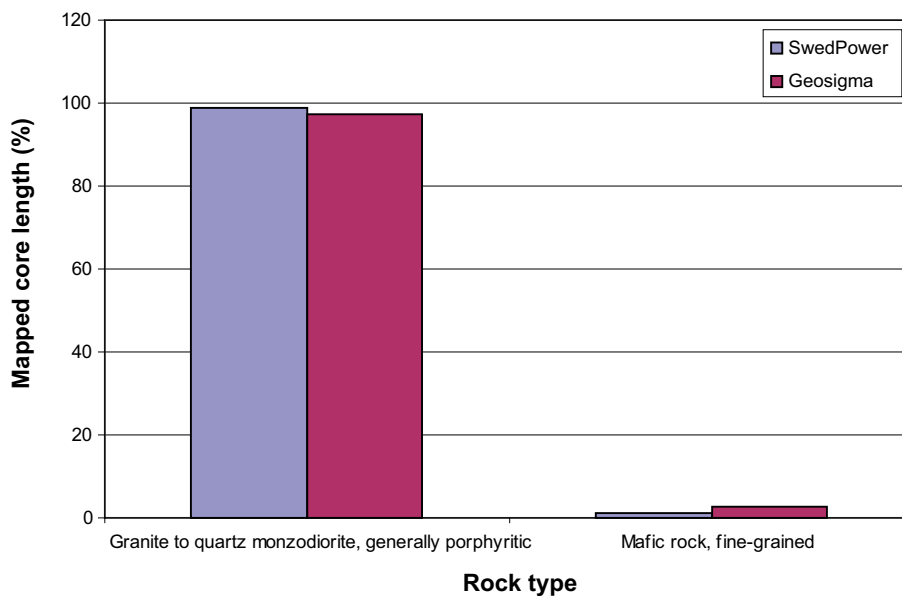


Figure 6-1. Rock type versus percentage of mapped core length 122.4 m.

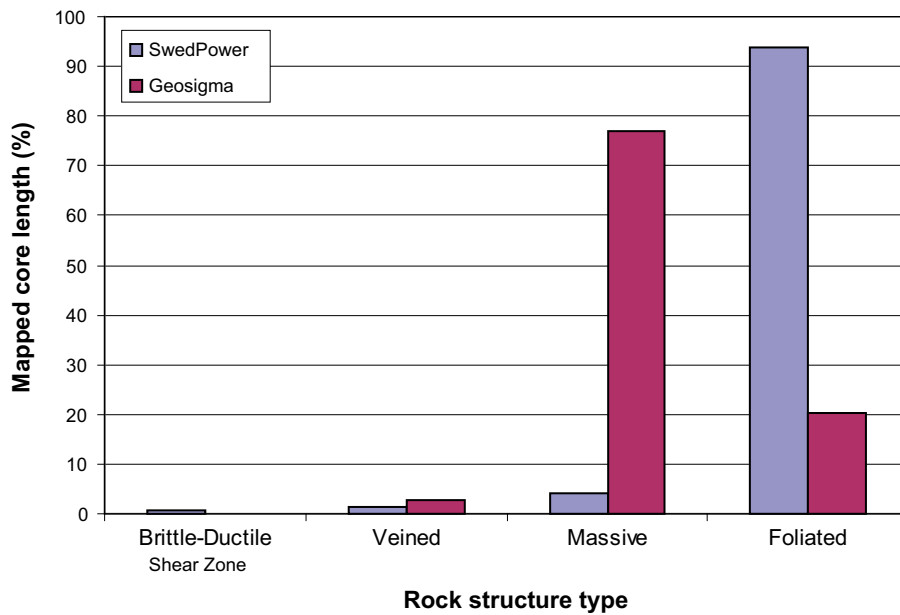


Figure 6-2. Rock structure type versus percentage of mapped core length 122.4 m.

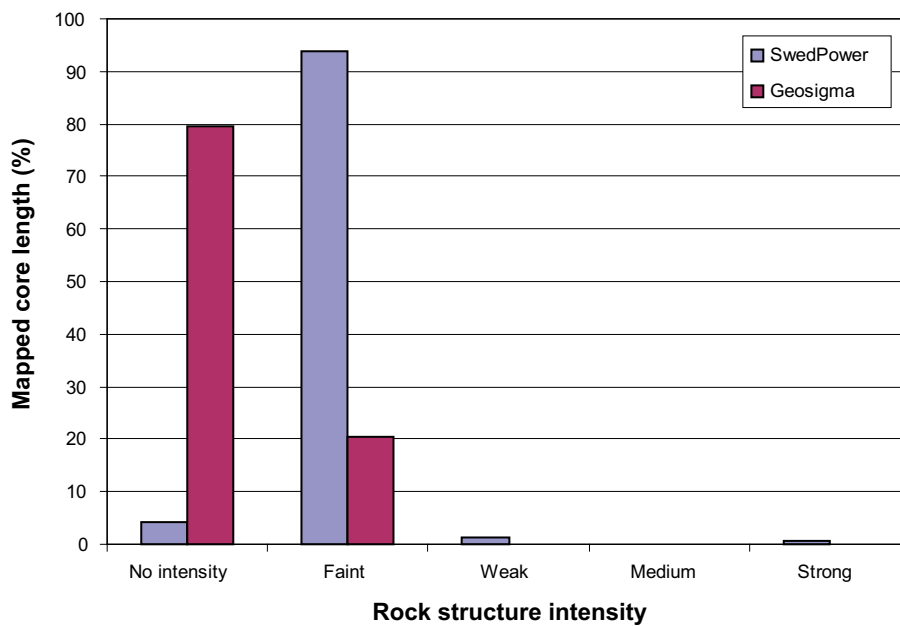


Figure 6-3. Rock structure intensity versus percentage of mapped core length 122.4 m.

A more significant difference is concerned with the identification and recording of shear zones. SwedPower have identified a total of 11 shear zones that are recorded as point information with generally no details other than structure orientations. These appear on the WellCAD log as point information but only one, with an intercept width of 0.9 m, is indicated in the rock structure field. According to current practice only a structure with an intercept width greater than 1 m should appear in this field. Geosigma have identified only 3 shear zones throughout the mapped section. Similarly none of these shear zones are demarcated in the rock structure field. Since the intercept widths of these zones are less than 1 m they fall within the rock occurrence group.

However, rock occurrence unlike rock type has no additional ‘rock structure’ descriptor that would give a clear indication of the presence and extent of a ductile or ductile-brittle shear zone. The practical result of this difference means that the mapped width of any shear zone with an intercept width of less than 1 m is not immediately apparent. It appears that one must assume that it corresponds to the full width of the recorded rock occurrence at a similar depth irrespective of the occurrence rock type. In reality the boundaries of a ductile-brittle zone are unlikely to always correspond to lithological boundaries. This issue is currently under investigation.

The significant difference in the number of interpreted shear zones, their intercept widths and character is a concern and needs further investigation. There should be a follow up joint inspection of the Boremap records, core and BIPS images to ensure that differences in interpretation are not more widespread and these structures are fully documented.

6.1.3 Rock alteration

Figure 6-4 and 6-5 show the rock alteration type and the rock alteration intensity versus percentage of the mapped core length.

The mapping results show a clear difference in the occurrence of oxidation. Geosigma have mapped oxidation along approximately 72% of the core length, while SwedPower only have mapped approximately 21%. Geosigma have mapped fewer but longer sections of alteration than SwedPower. Since the rock alteration type is linked to the rock alteration intensity this parameter also has poor agreement.

The differences are considered due to different ‘threshold levels’ for this item depending on local site experience. This is considered to be related to the difference in the overall degree of alteration affecting the rock mass at the two different sites. The individual teams have perhaps developed their own ‘threshold’ judgements based on local indicators.

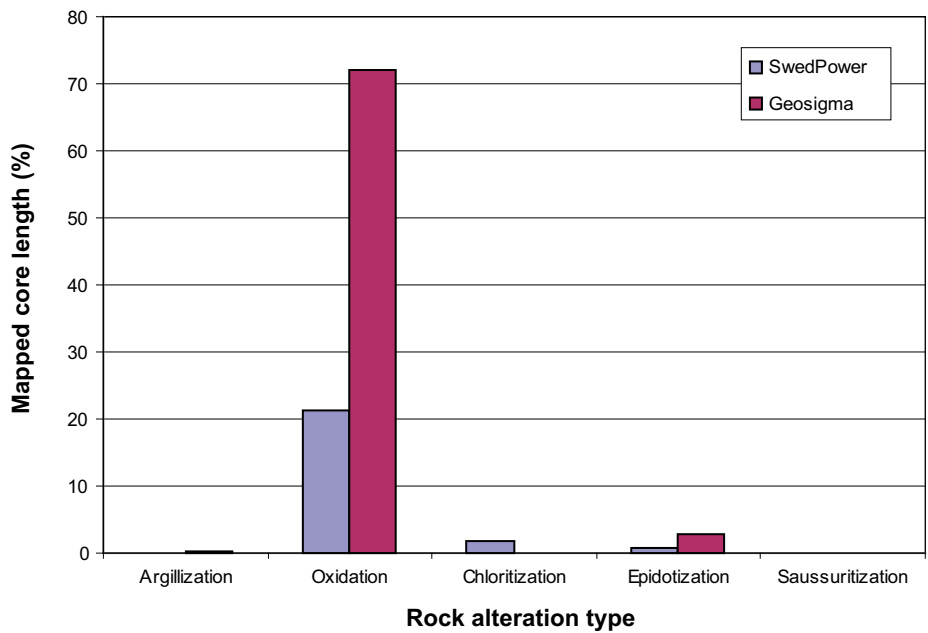


Figure 6-4. Rock alteration type versus percentage of mapped core length 122.4 m.

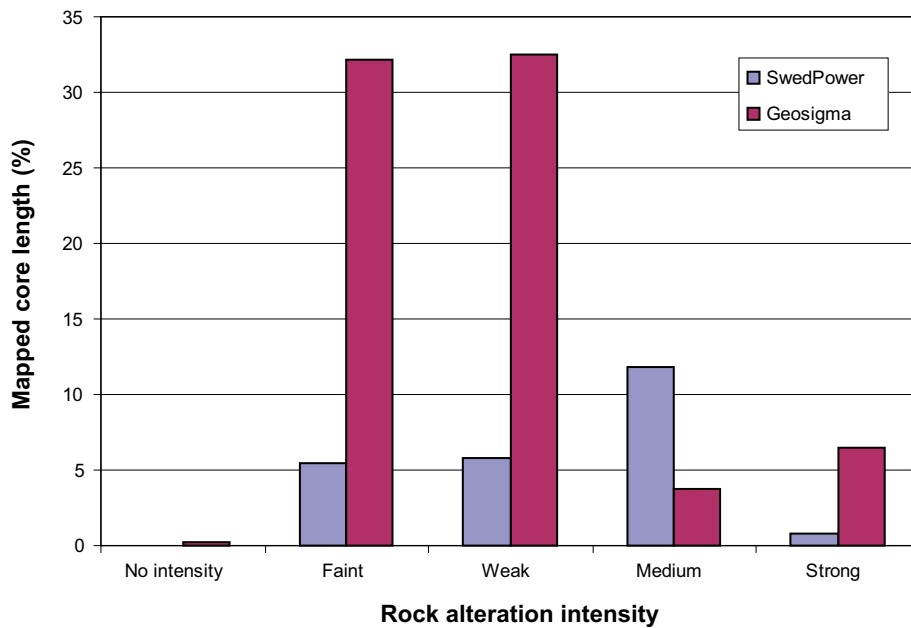


Figure 6-5. Rock alteration intensity versus percentage of mapped core length 122.4 m.

6.1.4 Rock occurrence

Figure 6-6 shows the rock occurrence type versus frequency of the mapped core length. The mapped rock type associated with each occurrence is presented in Table B-4, Appendix A. The term “rock occurrence” refers to elements of rock in the core that have an intercept width of less than 1 m.

SwedPower and Geosigma have mapped a total of 85 and 70 rock occurrences respectively. The total length of rock occurrences as a percentage of core length mapped is approximately 5% for SwedPower and 9% for Geosigma. SwedPower have consequently mapped about 20% more sections but of lesser width than Geosigma. Regarding the number to length proportion in the rock occurrences, the result is similar to mapping results from KFM06C. The differences between the two sets of quantities are most likely related to the thinner rock occurrences such as veins and familiarity with the local rock fabric of the main ‘host’ granites.

SwedPower have mapped approximately 40% of the rock occurrence as unspecified and 32% as veins. The proportion mapped by Geosigma is approximately 44% as unspecified and 50% as vein. This item is further discussed in Section 5.1.4. As stated previously the use and subdivision of the current rock occurrence type classification is considered to be of little practical value.

Both teams have classified about 50% of the rock occurrence as granite, fine to medium grained. The differences are clear however they are not considered to be of major significance.

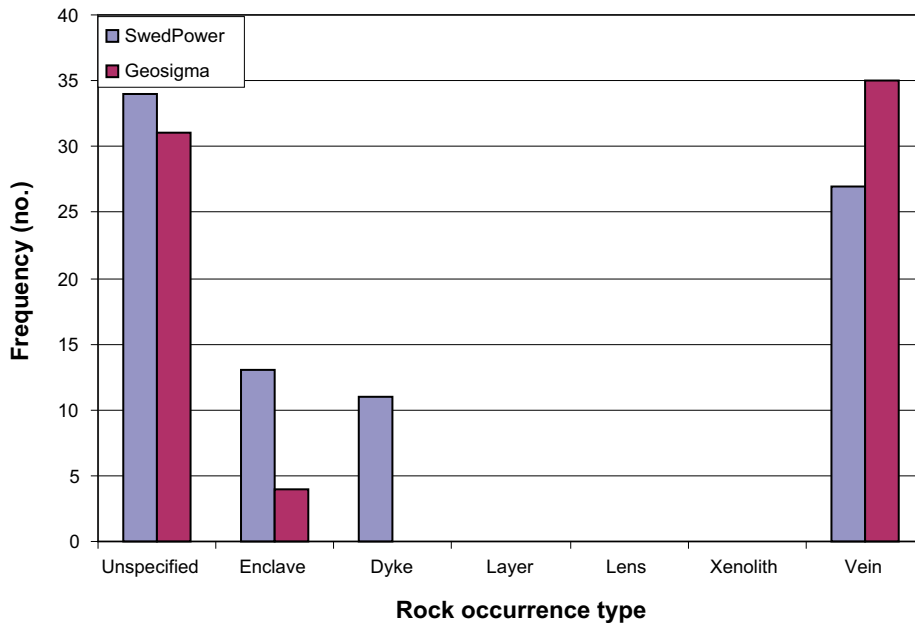


Figure 6-6. Rock occurrence type versus accumulated frequency along the mapped core.

6.2 Fractures

6.2.1 Fractures mapped

The procedure applied in the classification of mapped fractures is described in brief under Section 5.2.1. Further information is to be found in /Ehrenborg and Dahlin 2005b/ and /Pettersson et al. 2005b/. Figure 6-7 presents the frequency of broken and unbroken fractures of the mapped core. The total number of fractures logged by SwedPower is 699 fractures and 721 by Geosigma. Thus, the total number of fractures that were logged is similar.

6.2.2 Fracture recognition in BIPS

This procedure is outlined in Section 5.2.2. Visibility in BIPS versus frequency of the mapped core is presented in Figure 6-8.

6.2.3 Fracture aperture

This parameter is discussed in Section 5.2.3. Confidence in aperture versus frequency of the mapped core is presented in Figure 6-8.

6.2.4 Fracture type

This parameter is discussed in Section 5.2.4. Fracture type versus frequency of the mapped core is presented in Figure 6-8. The resulting Boremap distribution in percentage among open, partly open and sealed fractures is presented in Figure 6-9.

The total number of fractures logged by SwedPower is 699 fractures and 721 by Geosigma. Thus, the total number of fractures that were logged is similar. However, there is a notable difference in the number of fractures interpreted as open or sealed. The general picture of the results is on the whole similar to that logged in borehole KFM06C.

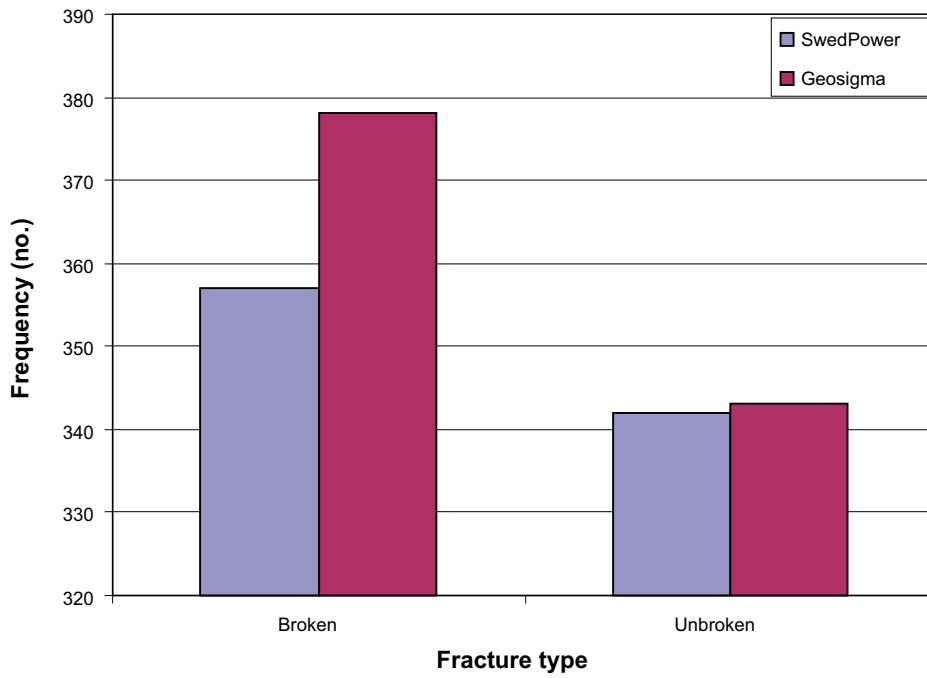


Figure 6-7. Frequency of broken and unbroken fractures of the mapped core.

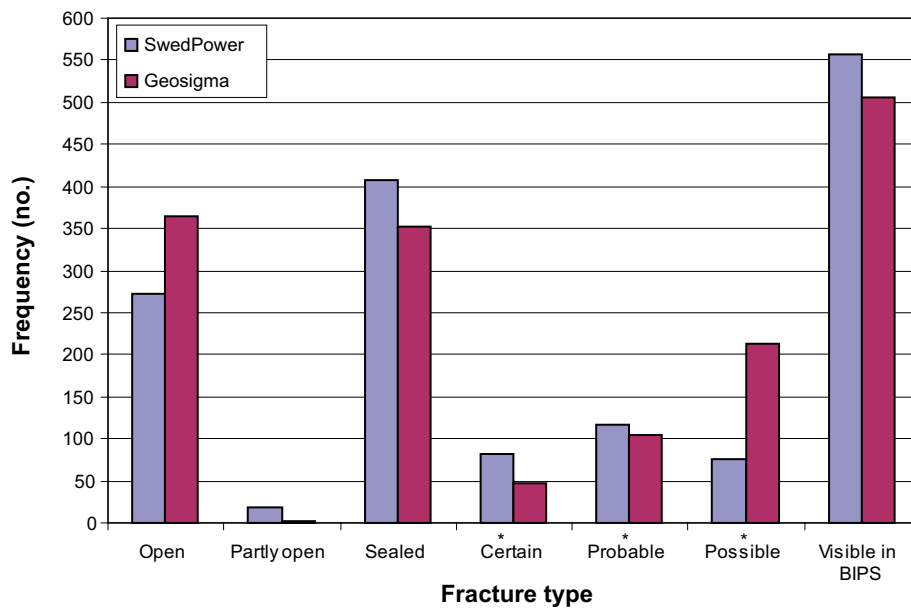
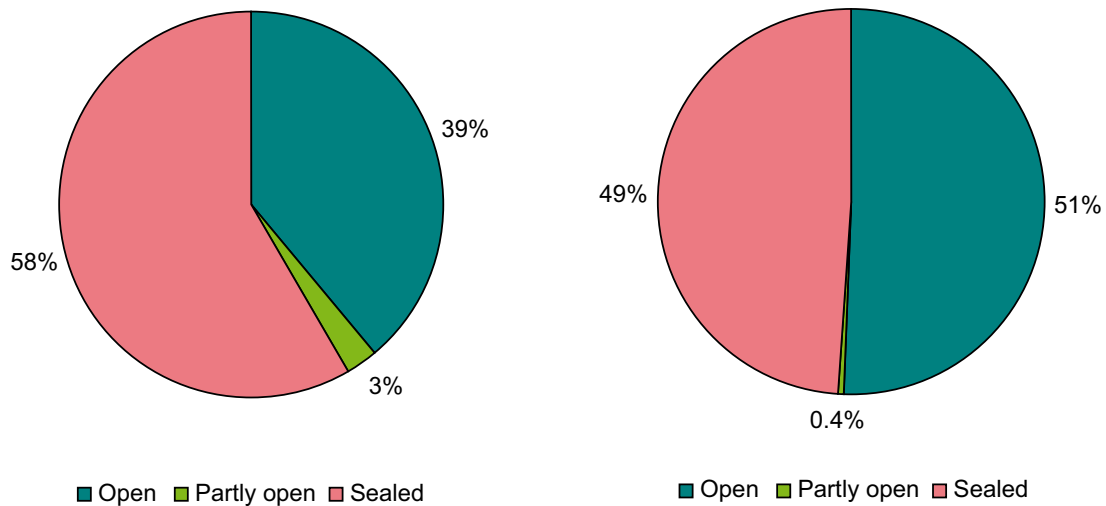


Figure 6-8. Fracture type, confidence and visibility versus frequency of the mapped core.
 * The degree of confidence (certain, probable and possible) only applies to open fractures.
 Sealed fractures are not classified by confidence.



SwedPower (JPGS). In total fractures.

Geosigma (JEPD). In total fractures.

Figure 6-9. Distribution in percentage amongst open, partly open and sealed fractures.

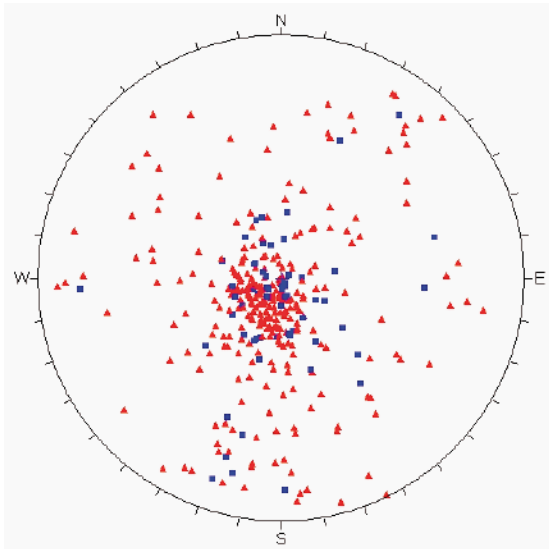
The difference in the proportion of open to sealed fractures is again approximately 12% between the two teams, see Figure 6-9. The identification and classification of an individual fracture should be repeatable for any clearly defined isolated fracture in the core. However, the repeatability and reliability of even the total number of fractures recorded in a more highly fractured section of core, with cross cutting fracture sets, even with BIPS, must be more doubtful. The difference in the number of crush zones recorded by the teams means that one team believes that they can piece the core together and determine the number of fractures involved, while the other team defines no such number and reports the section as a crush zone. This inevitably will affect the total number of fractures recorded.

6.2.5 Orientation

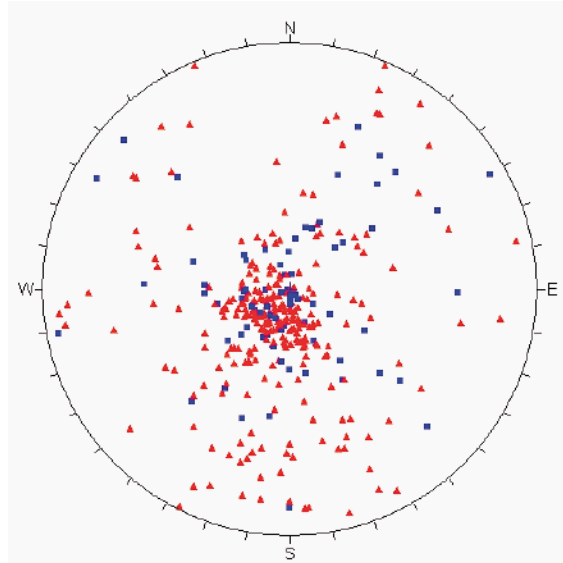
The procedure applied in the fracture orientation is described briefly in Section 5.2.5. Further information is to be found in /Ehrenborg and Dahlin 2005b/ and /Pettersson et al. 2005b/.

The recorded fracture orientations by the teams are presented in comparable stereonet for broken fractures in Figures 6-10 and 6-11, and for unbroken fractures in Figures 6-13 and 6-14. These charts, for comparison of the densities of the pole clusters, are supplemented by histograms in Figure 6-12 and Figure 6-15. The histograms show the frequency of poles within a circle limited to 60° plunge in the stereonet and 6 sectors of 60° outside this circle. The poles within the sectors and the inner circle are sorted into seven groups from A to G; starting with 0–60° and ending with the inner circle. Underlying values are presented in Tables B-6 to B-7, in Appendix B.

Both the stereonet and the histograms indicate good agreement between the fracture orientations recorded by the two teams. The difference in the pole density portion is generally less than 2%, similar to that for KFM06C. The greatest divergence is found in group B (about 4%) of unbroken fractures. As mentioned earlier the reason is assumed to be comparative differences in the records of non visible fractures in BIPS that cause uncertainties in the fracture orientation.

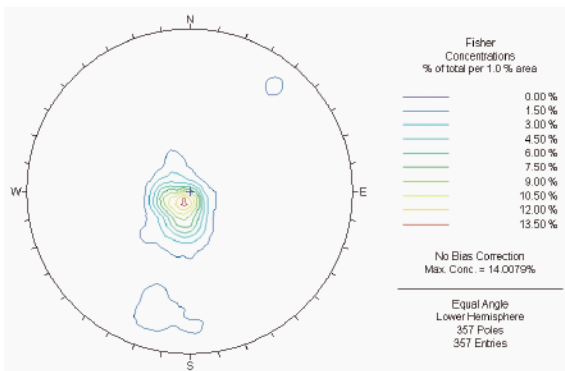


SwedPower (JPGS).
357 poles – 285 visible (red) and
72 not visible (blue) in BIPS.

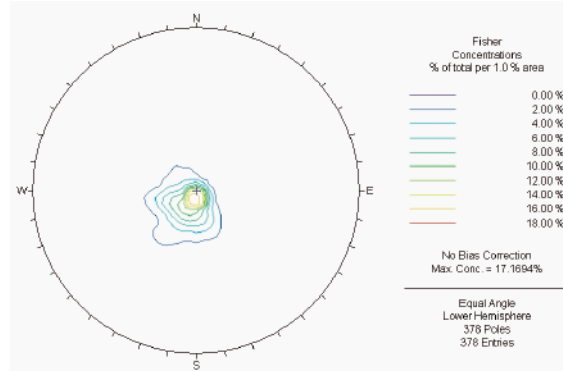


Geosigma (JEPD).
378 poles – 267 visible (red) and
111 not visible (blue) in BIPS.

Figure 6-10. Stereonets of poles to broken fractures in KLX07B. Equal angle, lower hemisphere, no correction. Red triangular – fractures visible in BIPS. Blue square – fractures not visible in BIPS.



SwedPower (JPGS).
357 poles - Max concentration 14.0%.



Geosigma (JEPD).
378 poles - Max concentration 17.2%.

Figure 6-11. Contoured stereonets of poles to broken fractures in KLX07B. Equal angle, lower hemisphere, Fisher distribution, no bias correction. Concentration in percent of total per 1.0% area.

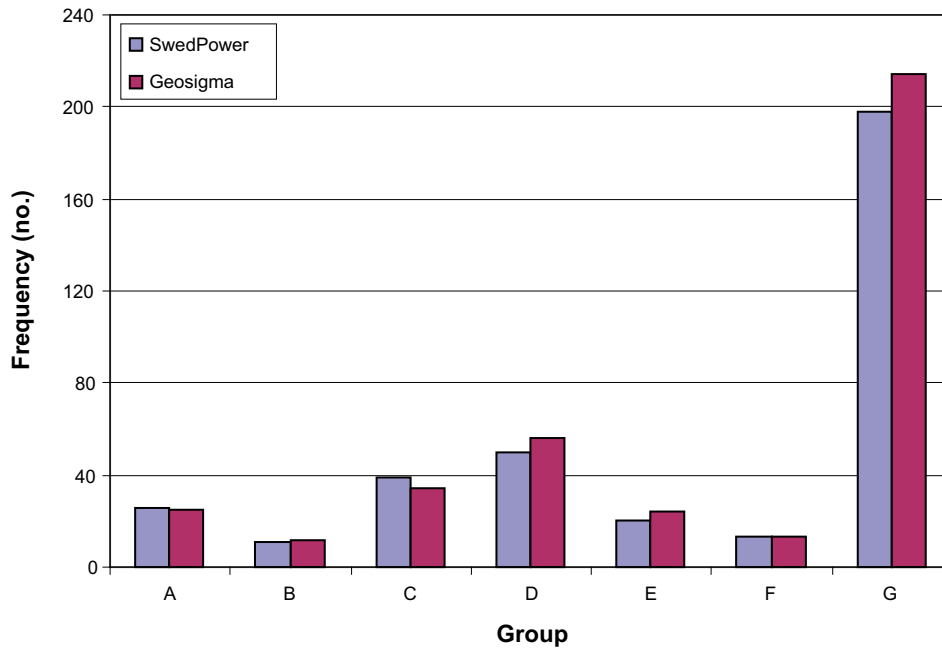
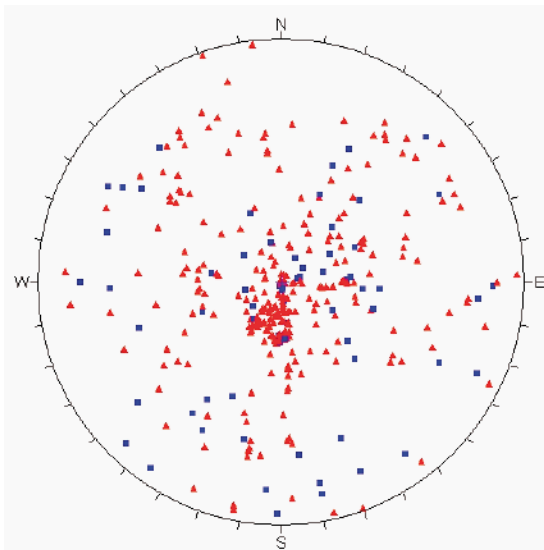
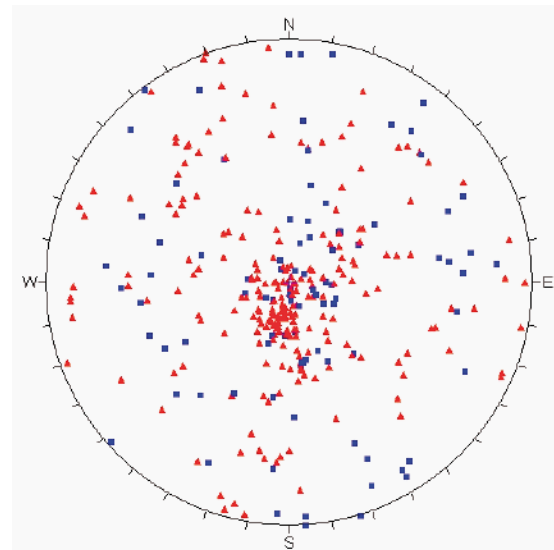


Figure 6-12. Frequency distributions for poles of broken fractures in KLX07B. The poles are sorted into seven groups from A to G based on a division of the stereonet into six sectors of 60° and an inner circle limited to 60° plunge.

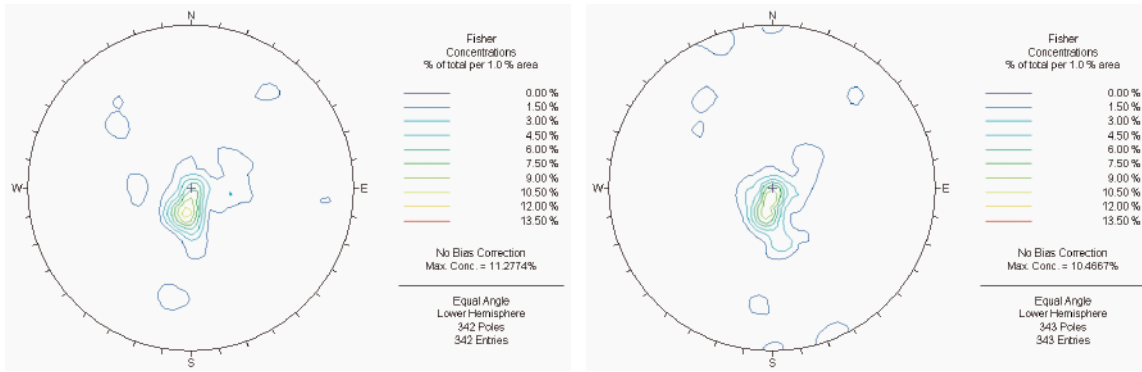


SwedPower (JPGS).
342 poles – 273 visible (red) and
69 not visible (blue) in BIPS.



Geosigma (JEPD).
343 poles – 238 visible (red) and
105 not visible (blue) in BIPS.

Figure 6-13. Stereonets of poles to unbroken fractures in KLX07B. Equal angle, lower hemisphere, no correction. Red triangular – fractures visible in BIPS. Blue square – fractures not visible in BIPS.



SwedPower (JPGS).
342 poles - Max concentration 11.3%.

Geosigma (JEPD).
343 poles - Max concentration 10.5%.

Figure 6-14. Contoured stereonets of poles to unbroken fractures in KLX07B. Equal angle, lower hemisphere, Fisher distribution, no bias correction. Concentration in percent of total per 1.0% area.

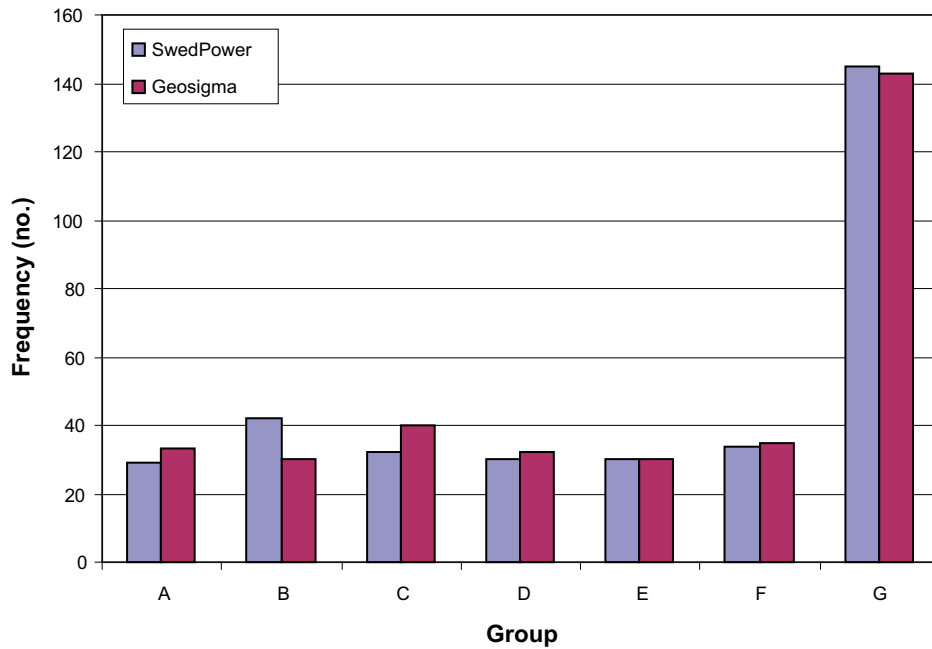


Figure 6-15. Frequency distributions for poles of unbroken fractures in KLX07B. The poles are sorted into seven groups from A to G based on a division of the stereonet into six sectors of 60° and an inner circle limited to 60° plunge.

6.2.6 Mineralogy

Simple comparative frequency and percentages of the various mineral filling types logged are presented for broken fractures in Figure 6-16 and unbroken fractures in Figure 6-17.

As for Forsmark (Section 5.2.6) the overall pattern of identification between the two teams is very similar. There are differences though they are not considered to be of major importance.

6.2.7 Roughness and surface

Estimated fracture roughness profiles and surface conditions versus frequency for broken fractures are presented in Figure 6-18. This issue is discussed in Section 5.2.7 of this report. The results for KLX07B are similar to those from KFM06C. It is considered there is room for greater standardization that will assist with the applicability of these results to engineering rock mass classifications.

6.2.8 Fracture mineral alteration

Estimated alteration intensity versus frequency of broken fractures is presented in Figure 6-19 and for unbroken fractures in Figure 6-20. There is a basic difference how the two mapping teams are classifying fracture mineral alteration. This item is discussed in Section 5.2.8.

6.2.9 Width and aperture

Aperture versus frequency of broken fractures is presented in Figure 6-21 and in Figure 6-22 with subdivision dependent on confidence in aperture. Width versus frequency for unbroken fractures is presented in Figure 6-23. SwedPower record fracture apertures and widths in steps of 0.5 mm. However, Geosigma has systematically used a 0.1 mm interval for measuring width but used a 0.5 mm interval for measuring apertures up to 0.5 mm and occasionally 0.1 mm intervals for apertures greater than 0.5 mm. The site classifications should follow the 0.5 mm standard. This item is discussed in Section 5.2.9.

The results for KLX07B are very similar to those from KFM06C. The distribution issue is discussed in Section 5.2.9 of this report.

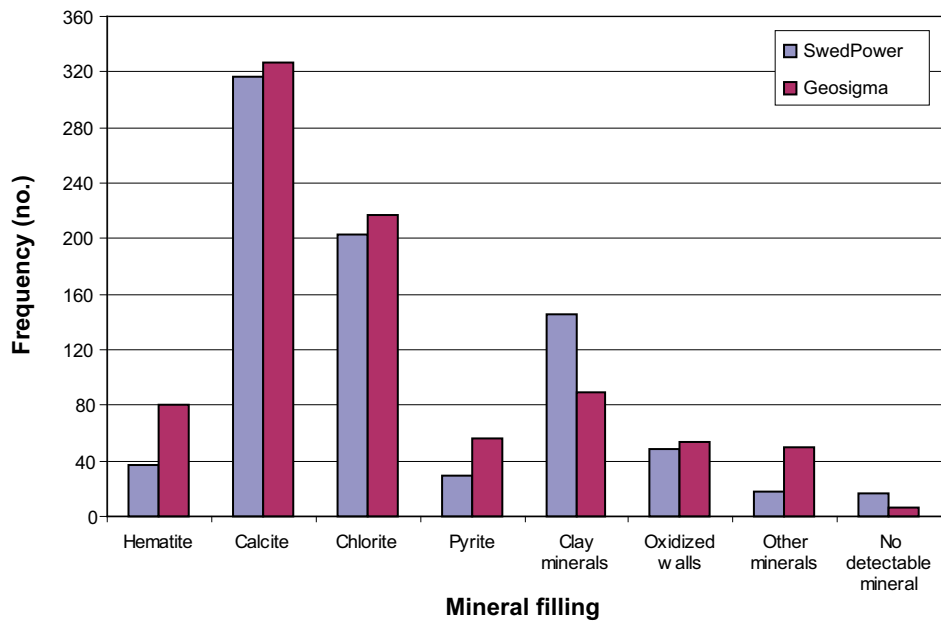


Figure 6-16. Mineral filling in broken fractures versus frequency of observation on the fracture planes.

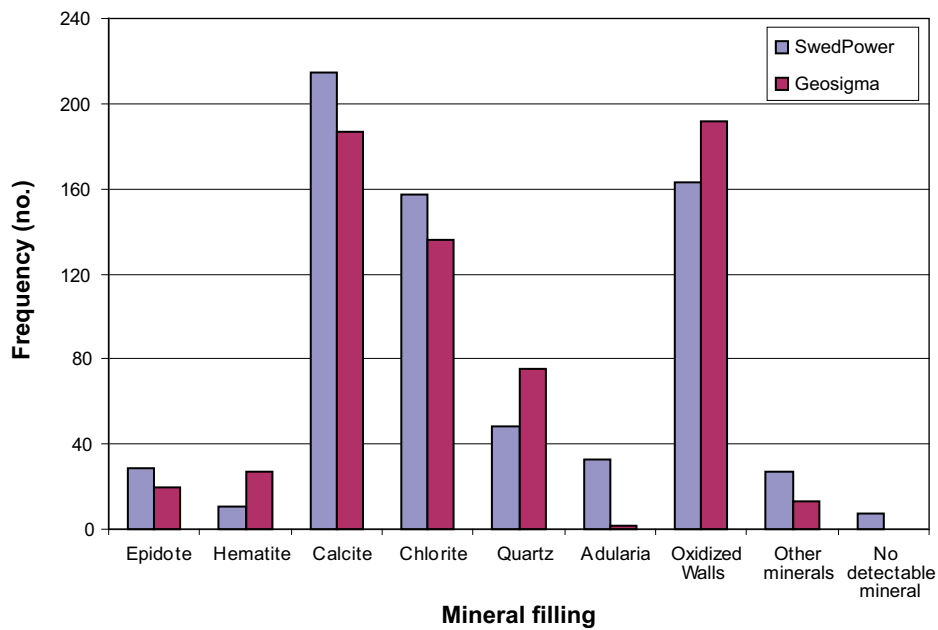


Figure 6-17. Mineral filling in unbroken fractures versus frequency of observation on the fracture planes.

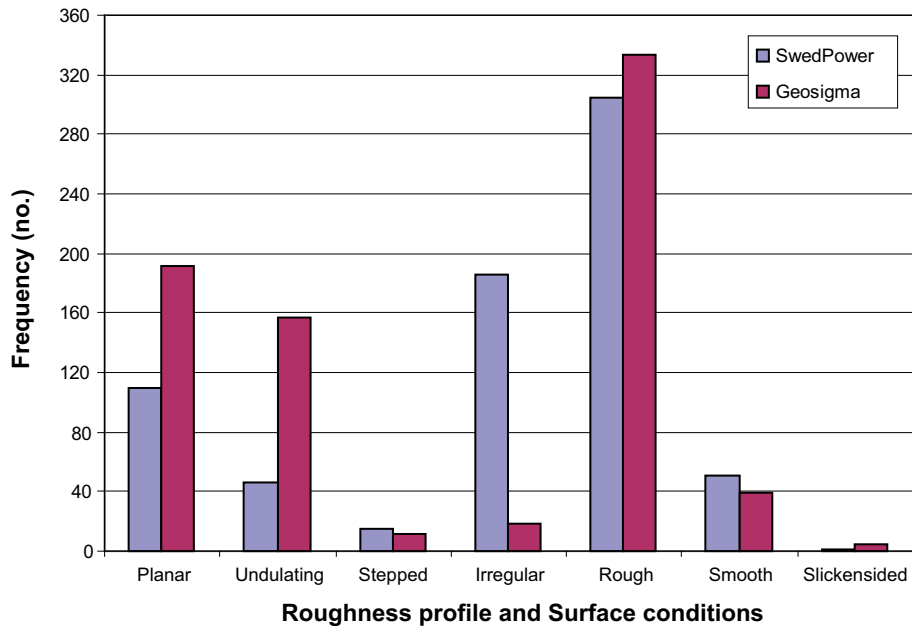


Figure 6-18. Estimated fracture roughness profile and surface conditions versus frequency for broken fractures. Roughness profile (large scale) and surface conditions (small scale) for broken fractures (small scale).

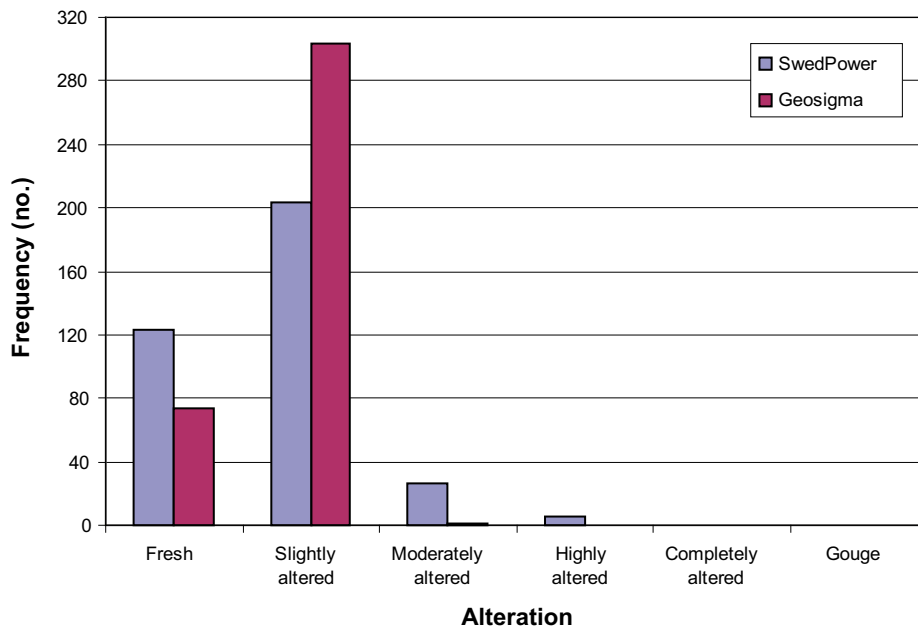


Figure 6-19. Estimated alteration versus frequency in broken fractures.

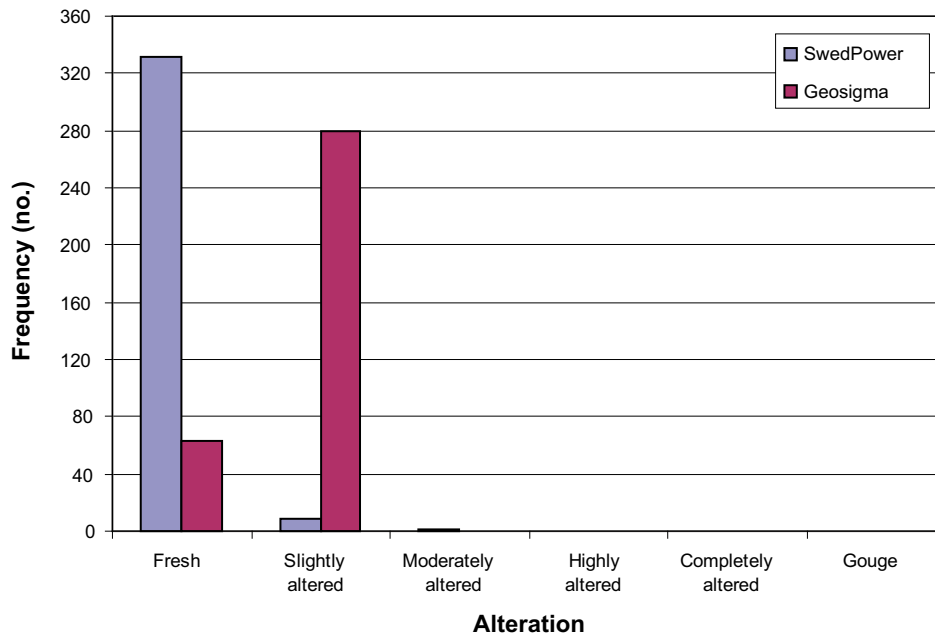


Figure 6-20. Estimated alteration versus frequency in unbroken fractures.

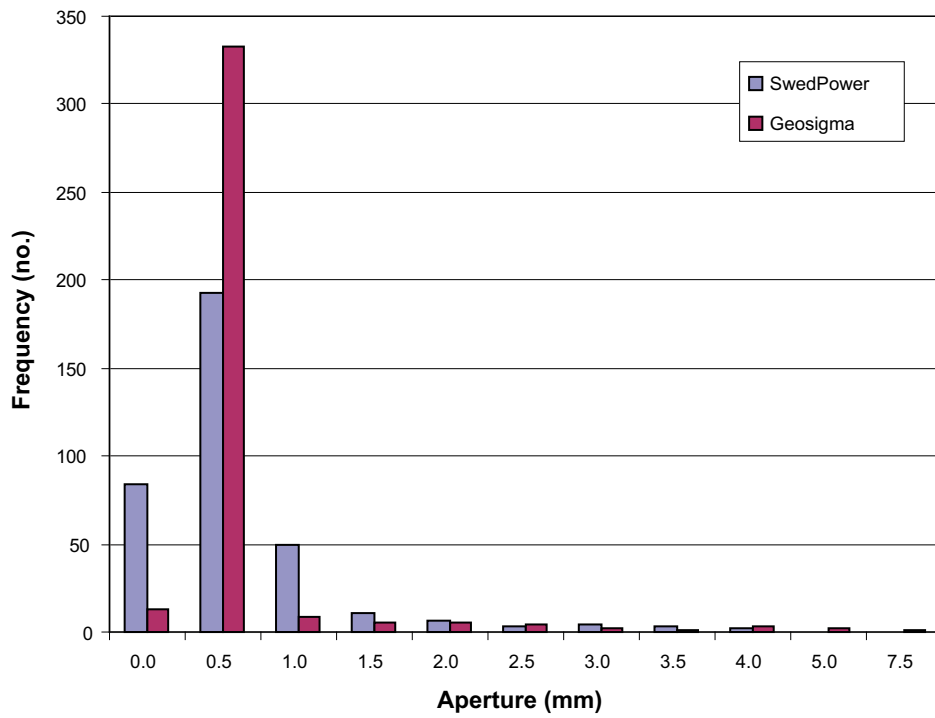


Figure 6-21. Aperture versus frequency for broken fractures. The aperture values presented by Geosigma have been rounded to the closest half number.

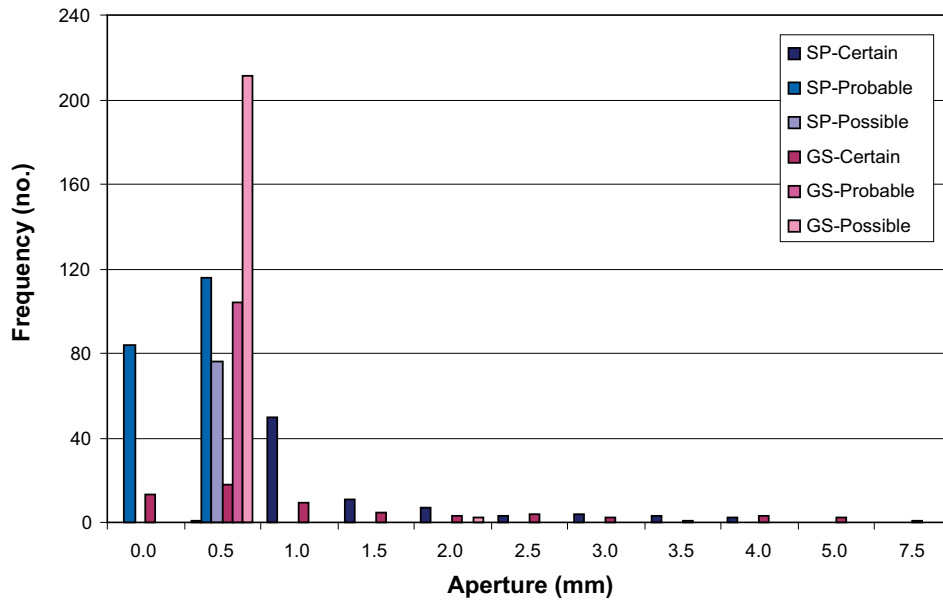


Figure 6-22. Aperture versus frequency for broken fractures with subdivision dependent on fracture type confidence. The aperture presented by Geosigma have been rounded to the closest half number.

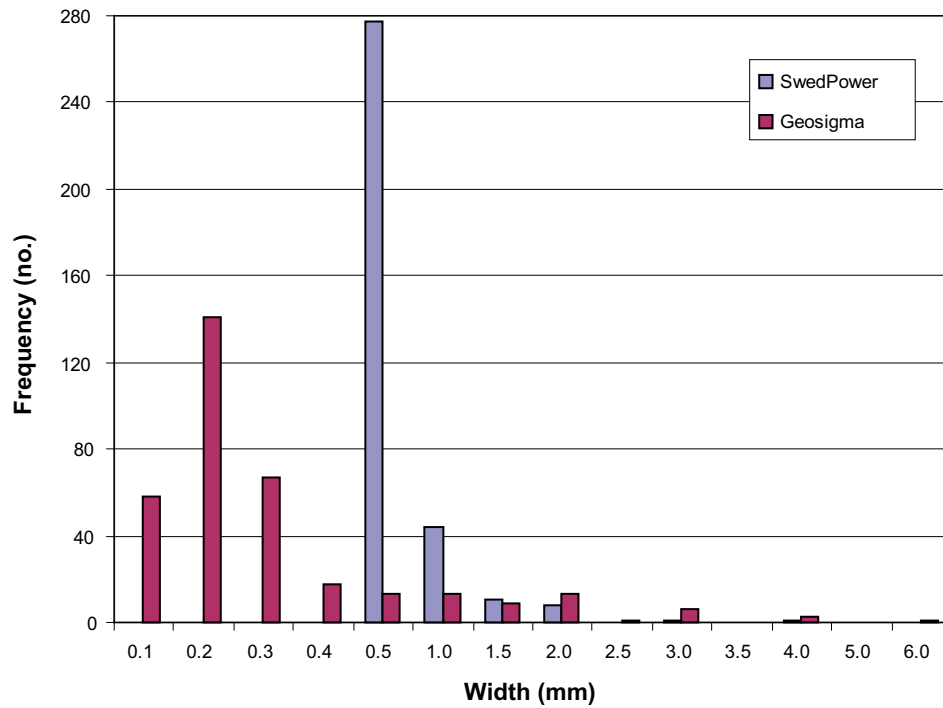


Figure 6-23. Width versus frequency for unbroken fractures.

6.3 Sealed fracture network

The position and extent of the sections of core interpreted as containing sealed fracture networks is presented in Table 6-1. This issue is discussed in Section 5.3 of this report. The difference in the number and extent of the sealed networks in KLX07B is very clear. In this respect the results are similar to those for KFM06C. However, in the case of KLX07B it is SwedPower who have identified significantly more core sections containing sealed networks. Whilst it is anticipated that local site experience plays a significant role in the identification and demarcation of such sealed networks a joint inspection of the core by both teams should be carried out to establish a clearer standard for this item.

Table 6-1. SecUp, core length and piece length of sealed fracture network.

SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
12.7	0.00	15	11.8	0.08	5
14.2	0.06	8	15.6	0.16	15
28.8	0.02	2	28.4	0.66	30
29.2	0.03	2	29.2	0.63	20
29.4	0.01	1	–	–	–
34.1	0.02	5	34.0	0.10	3
37.5	0.02	5	40.1	0.16	10
38.8	0.04	7	–	–	–
75.3	0.01	3	71.7	0.30	10
86.8	0.00	10	86.4	0.27	15
93.3	0.02	4	–	–	–
114.7	0.07	12	115.8	0.38	15
116.1	0.26	8	–	–	–
116.7	0.08	5	116.4	0.24	15
117.6	1.44	15	117.4	6.36	20
119.8	0.11	20	–	–	–
120.3	0.19	15	–	–	–
120.6	0.33	20	–	–	–
121.2	1.24	15	–	–	–
122.6	0.02	2	–	–	–
123.0	0.25	8	–	–	–
123.5	0.01	5	–	–	–
123.7	0.19	15	–	–	–
124.8	0.04	5	124.5	0.21	20
125.2	0.70	15	124.9	0.83	15
127.1	0.14	8	127.0	0.12	10
127.6	0.49	20	127.3	9.98	20
128.9	0.00	20	–	–	–
129.6	0.00	25	–	–	–
129.6	1.44	15	–	–	–
131.1	1.10	4	–	–	–

6.4 Crush zones

The number, position and extent of crush zones identified in the core by the two teams are presented in Table 6-2. SwedPower identify 13 zones with a total intercept width of 104 cm whilst Geosigma identify 6 such sections with a total width of 192 cm. These differences are considered significant and potentially linked to the interpretation of deformation zone indicators. As previously noted SwedPower and Geosigma have identified a significantly different number of ductile/ductile-brittle shear zones in both the Forsmark and Oskarshamn holes. A joint inspection would confirm whether or not these items are linked. It is important that the interpretation of shear zones is standardized as far as possible.

Table 6-2. SecUp, core length and piece length of crush zones.

SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
15.3	0.12	20	15.3	0.24	20
28.4	0.09	15	–	–	–
28.8	0.09	10	28.8	0.13	15
29.1	0.05	8	29.0	0.11	15
29.8	0.02	6	–	–	–
40.6	0.31	6	40.5	0.65	10
41.2	0.00	8	–	–	–
109.9	0.03	6	–	–	–
119.2	0.01	5	–	–	–
129.7	0.07	20	–	–	–
129.9	0.10	20	–	–	–
130.4	0.06	10	130.1	0.02	3
131.1	0.80	15	130.9	0.77	7

7 Conclusions

The interpretation of the significance of the differences identified from the comparative mapping exercise is somewhat dependent on the end-user of the particular type of data. However, a general interpretation and grouping of the results is given below.

Group 1: mapped parameters with very close agreement between teams requiring no further action. However, it should be noted that the total number of fractures are linked to the identification and demarcation of crush zones and sealed fracture networks:

total number of fractures measured and orientation of fractures.

Group 2: mapped parameters with minor to major differences identified but which are judged to be of relatively minor significance. There is certainly room for improved standardization and grounds for further internal review but these parameters are not prioritised for further action:

rock type, rock structure intensity, rock alteration type, rock alteration intensity, mineral fillings, fracture alteration type, fracture alteration intensity.

Group 3: mapped parameters which have differences or give clear indications that the underlying classifications, instructions, working methods need to be reviewed:

rock type structure/rock occurrence structure, crush zones- deformation zone indicators, fracture aperture, fracture width, broken-unbroken – confidence in aperture – fracture mineral alteration – open vs sealed, visibility in BIPS, roughness and surface conditions, and sealed fracture network.

Rock type structure/rock occurrence structure, crush zones- deformation zone indicators: SwedPower identified 11 ductile/ductile-brittle shear zones in KLX07B and 6 such zones in KFM06C, whereas Geosigma identified 3 and 0 respectively. These differences are considered significant. There are two aspects of concern. Firstly, the question of the inferred differences in interpretation, which needs to be inspected on a case by case basis. It is likely that site specific interpretation difficulties will be highlighted, related to the differentiation between plastic shear zone indicators and more general foliation and banding, that will explain at least some of the differences. Secondly, there is the question of how interpreted shear zones with intercept widths of less than 1 m are recorded in the Boremap system and presented on WellCAD logs. Rock occurrence unlike rock type has no additional ‘rock occurrence structure’ descriptor that would allow the use of a ‘ductile shear zone’ or ‘ductile-brittle shear zone.’ The practical result of this difference means that the character and mapped width of any shear zone with an intercept width of less than 1 m is not immediately apparent. It appears that one must assume that it corresponds to the full width of the recorded rock occurrence at a similar depth, irrespective of the occurrence rock type. In reality the boundaries of a shear zone are unlikely to always correspond to lithological boundaries. This issue is currently under investigation.

The significant difference in the number of interpreted shear zones, their intercept widths, character and how these are documented is a concern and needs further investigation. There should be a follow up joint inspection of the Boremap records, core and BIPS images to ensure that differences in interpretation are not more widespread.

The number and extent of crush zones identified in the core by the two teams is very different. These differences are considered significant and potentially linked to the interpretation of deformation zone indicators. A joint inspection would confirm whether or not these items are linked. It is important that the interpretation of shear zones is standardized as far as possible.

Fracture aperture and fracture width: the practical work routines and classification used by the two teams needs to be standardised. It is further recommended that the existing classification should be reviewed with the aim of simplification. It is considered the current number of subdivisions is too detailed and has no real practical application.

Broken-unbroken – confidence in aperture – fracture mineral alteration – open vs sealed: the work routines and classifications between the two teams that involve this string of parameters that leads to the open vs sealed classification must be standardized and made transparent. This is judged to be a key issue and should be given a high priority.

Current evidence suggests that there is a systematic difference between the two teams. It is for the end-users to judge how this added degree of uncertainty, due to differences between the team methodologies and judged weaknesses in the mapping system, compares with other uncertainties in their modelling work. It is judged that at least partly the differences are a result of the classification system currently being applied. It is considered that the current system involves over classification. Even the subdivision into 0.5 mm classes is too detailed when considering how likely such measurements made on small core surfaces are representative the surrounding rock mass. When the manner of water movement and “channelling” through the rock mass are considered the use of such detailed subdivisions appear even less relevant. It is recommended that the existing classification should be reviewed with the aim of simplification. It is considered the current number of subdivisions is too detailed, is unrealistic and has no real practical application.

Visibility in BIPS: there appears to be a clear difference in judgement. A joint inspection of the BIPS data should be able to resolve this issue and improve standardization.

Roughness and surface conditions: the fracture surface classification uses standard terminology but this is not clearly linked to type profiles. Enquiries suggest that both roughness and surface estimations are somewhat general. Joint combs are not used and apparently no reference is made to ISRM standard profiles. It is considered that it is this degree of freedom and subjectivity in the interpretation that has lead to the degree of difference in the results between the two teams. Differences will always be present but there are simple methods that can perhaps lead to this difference being reduced. Since it is assumed that both of these parameters are used as input to calculated rock mass quality Q estimates, a check could be made on there reliability and consistency.

Sealed fracture network: whilst this item is probably the least important of the Group 3 parameters the clear difference between the two teams is confusing and warrants further investigation. A joint inspection of the core data should be able to resolve this issue and improve standardization.

8 Discussion

This section describes various logging potential issues that have arisen during the current work but which are of a more general nature and not strictly involved with the comparison of the two results. It may well be that SKB has considered these issues and has reached their own conclusions.

The core is logged in great detail and the BIPS images and Boremap tool ensure that individual fractures can be accurately oriented. This is a very impressive set-up and it is difficult to imagine that anyone anywhere is doing anything better. However, it is considered that the mapping system itself has become too complicated and lacks focus. The concentration on what are considered unnecessary details is an unnecessary burden on the mapping teams and is seen to mask more important information- the reader gets 'lost in the details' and misses the bigger picture. To a certain extent the system is becoming divorced from its original aim i.e. a clear concise description of the rock mass. It is not the role of this report to review the Boremap system, however, it can be said that there is clearly potential to significantly simplify the system and increase the focus on what really matters.

It is surprising that the core is not physically oriented in the core boxes with the core 'top' or 'bottom' marked with a pen line with the aid of the BIPS images. While such orientation would not assist with the orientation of individual fractures it is thought that it would greatly assist with the Single hole interpretation process. It is considered that the viewer would get a better overall impression of the rock fabric and it would assist in the characterization and isolation of potential deformation zones, in complex core, where multiple zones have been identified. BIPS images do not give the same impression, as can be seen by comparing the standard core photos and BIPS images.

RQD and the more complicated rock mass Q values are both widely used by any Design team. Fracture surface and roughness are both input variables in any rock mass assessment. Enquiries suggest that both roughness and surface estimations are somewhat general. Joint combs are not used and apparently no reference is made to ISRM standard profiles. It is understood that both RQD and Q values are generated automatically based on existing Boremap data. Since such parameters are so basic to design it is considered beneficial that control sample measurements and assessments are manually performed on the actual core. This is possibly already being performed.

The geologists who carry out the detailed mapping of the core have spent a considerable period of time (and cost) in carrying out their work. It seems somewhat inconsistent that these same geologists do not take part in single hole interpretation meetings at both sites. It would seem sensible to have them present during such interpretation meetings if only for reference.

Both mapping teams feel there is definitely room for improvement in the documentation and the need for clearer work routines. Both teams would like to be given the opportunity for active input to link method descriptions and other documentation to the practicalities of the work.

Once the detailed review of the mapping documentation has been completed and any improved standardized work routines have been implemented it would seem both logical and valuable to repeat the comparative mapping exercise. The aims would be to demonstrate the effectiveness of the action taken and assist in assessing how generally comparable the mapping results are not only between the two teams but also before and after the implementation of the updated work routines.

9 References

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Tables borehole KFM06C

A1 – Lithology

Rock type

Table A-1. Rock type. Sum of mapped length and percentage of mapped core length.

Code	Rock name	SwedPower (JPGS)		Geosigma (JEPD)	
		(m)	(%)	(m)	(%)
101033	Diorite, quartz diorite and gabbro, metamorphic	–	–	11.7	7.5
101057	Granite to granodiorite, metamorphic, medium-grained	119.2	76.6	128.8	82.7
101058	Granite, metamorphic, aplitic	1.8	1.1	–	–
101061	Pematite, pegmatitic granite	17.2	11.1	–	–
102017	Amphibolite	13.6	8.7	–	–
103076	Felsic to intermediate volcanic rock, metamorphic	–	–	2.2	1.4
111058	Granite, fine- to medium-grained	3.8	2.5	12.9	8.3
Total		155.6	100.0	155.6	100.0

Rock structure

Table A-2. Rock structure type and intensity. Sum of mapped length and percentage of mapped core length.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(m)	(%)	(m)	(%)
Rock structure type				
Ductile Shear Zone	1.4	0.9	0	0
Lineated	142.2	91.4	131.0	84.2
Veined	0.0	0.0	19.3	12.4
Banded	0.0	0.0	2.2	1.4
Foliated	12.0	7.7	3.1	2.0
Total	155.6	100.0	155.6	100.0
Rock structure intensity				
No intensity	0.0	0.0	19.3	12.4
Faint	2.6	1.7	4.3	2.8
Weak	53.2	34.1	17.5	11.2
Medium	99.1	63.7	114.5	73.6
Strong	0.7	0.5	0.0	0.0
Total	155.6	100.0	155.6	100.0

Rock alteration

Table A-3. Rock alteration type and intensity. Sum of mapped length and percentage of mapped core length.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(m)	(%)	(m)	(%)
Rock alteration type				
Albitization	0.09	0.06	–	–
Oxidation	40.35	25.93	27.56	17.71
Chloritization	0.00	0.00	0.04	0.03
Total	40.4	26.0	27.6	17.7
Rock alteration intensity				
No intensity	0.00	0.00	0.00	0.00
Faint	36.47	23.44	19.99	12.85
Weak	3.88	2.50	7.58	4.87
Medium	0.09	0.06	0.04	0.03
Strong	0.00	0.00	0.00	0.00
Total	40.4	26.0	27.6	17.7

Rock occurrence

Table A-4. Rock occurrence and rock name. Frequency combined with sum of mapped rock type core length and percentage of mapped core length.

Code		SwedPower (JPGS)				Geosigma (JEPD)			
		Number (no.)	(%)	Length (m)	(%)	Number (no.)	(%)	Length (m)	(%)
Rock occurrence type									
0	Unspecified	185	66.3	21.0	13.5	47	22.5	9.5	6.1
1	Enclave	0	0	0	0	0	0	0	0.0
2	Dyke	24	8.6	2.3	1.5	10	4.8	4.9	3.2
6	Layer	0	0	0	0	0	0	0	0.0
8	Lens	0	0	0	0	0	0	0	0.0
13	Xenolith	0	0	0	0	0	0	0	0.0
18	Vein	70	25.1	1.2	0.8	152	72.7	6.9	4.5
Total		279	100.0	24.6	15.8	209	100.0	21.4	13.7
Rock name									
1053	Tonalite	1	0.4	0.09	0.06	–	–	–	–
1056	Granodiorite	2	0.7	0.10	0.07	–	–	–	–
1062	Aplite	2	0.7	0.05	0.03	–	–	–	–
8021	Quartz-dominated hydrothermal vein/ segregation	24	8.6	0.90	0.58	–	–	–	–
101033	Diorite, quartz diorite and gabbro, metamorphic	–	–	–	–	5	2.4	1.89	1.21
101057	Granite to granodiorite, metamorphic, medium-grained	23	8.2	4.56	2.93	19	9.1	5.18	3.33
101058	Granite, metamorphic, aplitic	21	7.5	2.27	1.46	7	3.3	0.31	0.20
101061	Pematite, pegmatitic granite	189	67.7	13.30	8.54	78	37.3	8.94	5.74
102017	Amphibolite	13	4.7	1.97	1.27	11	5.3	0.78	0.50
111058	Granite, fine- to medium-grained	4	1.4	1.38	0.89	89	42.6	4.31	2.77
Total		279	100.0	24.6	15.8	209	100.0	21.4	13.7

A2 – Fractures

Fracture type

Table A-5. Frequency of fracture type combined with confidence and visibility in BIPS.

	SwedPower(JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Open	197	33.9	270	45.5
Partly open	7	1.2	0	0
Sealed	378	64.9	323	54.5
Total	582	100.0	593	100.0
Certain	57	28.9	29	10.7
Probable	82	41.6	67	24.8
Possible	58	29.5	174	64.5
Visible in BIPS	437	75.1	312	52.6

Note: The degree of confidence only applies to open fractures.

Orientation

Table A-6. Frequency distribution of fracture orientation for broken fractures.

Group	Bearing (pole) (deg)	Plunge (pole) (deg)	SwedPower (JPGS)		Geosigma (JEPD)	
			(no.)	(%)	(no.)	(%)
A	0–60	0–60	53	19.4	71	24.0
B	60–120	0–60	15.0	5.5	19.0	6.4
C	120–180	0–60	8.0	2.9	5.0	1.7
D	180–240	0–60	13.0	4.8	20.0	6.8
E	240–300	0–60	3.0	1.1	2.0	0.7
F	300–360	0–60	31.0	11.4	33.0	11.1
G	0–360	60–90	150	54.9	146	49.3
Total			273	100	296	100

Table A-7. Frequency distribution of fracture orientation for unbroken fractures.

Group	Bearing (pole) (deg)	Plunge (pole) (deg)	SwedPower(JPGS)		Geosigma (JEPD)	
			(no.)	(%)	(no.)	(%)
A	0–60	0–60	32	10.4	29	9.8
B	60–120	0–60	75.0	24.3	52.0	17.5
C	120–180	0–60	52.0	16.8	54.0	18.2
D	180–240	0–60	18.0	5.8	21.0	7.1
E	240–300	0–60	49.0	15.9	49.0	16.5
F	300–360	0–60	26.0	8.4	30.0	10.1
G	0–360	60–90	57	18.4	62	20.9
Total			309	100	297	100

Fracture mineralogy

Table A-8. Frequency and percentage of fracture filling in broken fractures.

Mineral	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Biotite	1	0.2	0	0.0
Flourite	2	0.4	3	0.5
Hematite	8	1.5	7	1.1
Calcite	192	37.1	200	32.2
Chlorite	164	31.7	182	29.3
Quartz	3	0.6	20	3.2
Unknown	0	0.0	4	0.6
Pyrite	24	4.6	60	9.7
Sericite	5	1.0	8	1.3
Clay Minerals	57	11.0	68	11.0
Laumonite	4	0.8	2	0.3
Zeolite	0	0.0	4	0.6
Prehnite	6	1.2	0	0.0
Iron Hydroxide	0	0.0	1	0.2
Adularia	7	1.4	8	1.3
Oxidized Walls	11	2.1	21	3.4
X5, Bleached walls	0	0.0	3	0.5
X6, Polished fracture surface	0	0.0	1	0.2
X7, No detectable mineral	33a	6.4	29	4.7
Total	517	100	621	100

a) Logged with empty cells by SwedPower.

Table A-9. Frequency and percentage of fracture filling in unbroken fractures.

Mineral	SwedPower(JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Biotite	6	1.1	0	0.0
Epidote	2	0.2	0	0.0
Hematite	2	0.4	7	1.3
Calcite	177	31.7	158	28.3
Chlorite	101	18.1	113	20.3
Quartz	15	2.7	62	11.1
Unknown	1	0.2	1	0.2
Pyrite	5	0.9	4	0.7
Sulfides	1	0.2	0	0.0
Clay Minerals	1	0.2	0	0.0
Laumonite	9	1.6	5	0.9
Prehnite	46	8.2	0	0.0
Adularia	43	7.7	50	9.0
Oxidized Walls	121	21.4	99	17.7
X5, Bleached walls	0	0.0	46	8.2
X7, No detectable mineral	29a	5.2	13	2.3
Total	559	100	558	100

a) Logged with empty cells by SwedPower.

Roughness and surface

Table A-10. Frequency and percentage of estimated roughness profile (large scale) surface conditions (small scale) for broken fractures.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Roughness				
Planar	124	45.4	184	62.2
Undulating	34	12.4	88	29.7
Stepped	19	7.0	13	4.4
Irregular	96	35.2	11	3.7
Total	273	100.0	296	100
Surface				
Rough	217	79.5	246	83.1
Smooth	34	12.5	30	10.1
Slickensided	22	8.1	20	6.8
Total	273	100.0	296	100

Alteration

Table A-11. Frequency and percentage of estimated alteration in broken and unbroken fractures.

	SwedPower (JPGS)				Geosigma (JEPD)			
	Broken		Unbroken		Broken		Unbroken	
	(no.)	(%)	(no.)	(%)	(no.)	(%)	(no.)	(%)
Fresh	119	43.6	305	98.7	85	28.7	72	24.2
Slightly altered	137	50.2	4	1.3	211	71.3	225	75.8
Moderately altered	16	5.9	0	0.0	0	0.0	0	0.0
Highly altered	1	0.4	0	0.0	0	0.0	0	0.0
Completely altered	0	0.0	0	0.0	0	0.0	0	0.0
Gouge	0	0.0	0	0.0	0	0.0	0	0.0
Total	273	100	309	100	296	100	297	100

Width and aperture

Table A-12. Frequency and percentage of estimated aperture of broken fractures. The aperture presented by Geosigma have been rounded to the closest half number.

	SwedPower(JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
0	76	27.8	26	8.8
0.5	140	51.3	253	85.5
1.0	37	13.6	3	1.0
1.5	10	3.7	4	1.4
2.0	5	1.8	3	1.0
2.5	1	0.4	2	0.7
3.0	2	0.7	3	1.0
3.5	0	0	1	0.3
4.0	2	0.7	1	0.3
Total	273	100.0	296	100.0
Certain	57	20.9	54	18.2
Probable	158	57.9	68	23.0
Possible	58	21.2	174	58.8
Visible in BIPS	216	79.1	156	52.7

Table A-13. Frequency and percentage of estimated width of unbroken fractures.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
0.1	0	0	(45)	(15.1)
0.2	0	0	(127)	(42.8)
0.3	0	0	(58)	(19.5)
0.4	0	0	(17)	(5.7)
0.1–0.5	270	87.4	254 (7)	85.5 (2.4)
0.6–1.0	28	9.1	19	6.4
1.1–1.5	4	1.3	5	1.7
2.0	4	1.3	10	3.4
2.5	1	0.3	0	0
3.0	0	0	2	0.7
3.5	0	0	0	0
4.0	2	0.6	3	1.0
5.0	0	0	1	0.3
10.0	0	0	2	0.7
20.0	0	0	1	0.3
Total	309	100.0	297	100.0
Certain	259	83.8	297	100.0
Probable	44	14.2	0	0
Possible	6	2.0	0	0
Visible in BIPS	221	71.5	156	52.5

A3 – Sealed network

Table A-14. SecUp depth, core length and piece length for Sealed network.

SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
–	–	–	187.1	0.11	4
–	–	–	188.6	1.11	10
207.9	0.10	10	207.9	0.06	5
228.9	0.16	20	228.7	0.45	10
–	–	–	242.4	0.18	10
–	–	–	247.8	0.30	10
249.0	0.20	20	249.0	0.24	10
–	–	–	281.0	0.00	10
282.6	0.13	20	283.0	0.28	10
–	–	–	293.8	0.00	3
–	–	–	329.8	0.83	40

A4 – Crush zones

No tables

Tables borehole KLX07B

B1 – Lithology

Table B-1. Rock type. Sum of mapped core length and percentage of mapped core length.

Code	Rock name	SwedPower(JPGS)		Geosigma (JEPD)	
		(m)	(%)	(m)	(%)
501044	Granite to quartz monzodiorite, generally porphyritic	120.9	98.7	119.2	97.4
505102	Mafic rock, fine-grained	1.5	1.3	3.2	2.6
Total		122.4	100.0	122.4	100.0

Table B-2. Rock structure type and intensity. Sum of mapped core length and percentage of mapped core length.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(m)	(%)	(m)	(%)
Rock structure type				
Brittle-Ductile Shear Zone	0.9	0.7	0.0	0.0
Veined	1.5	1.3	3.2	2.6
Massive	5.0	4.1	94.3	77.0
Foliated	115.0	93.9	24.9	20.4
Total	122.4	100.0	122.4	100.0
Rock structure intensity				
No intensity	5.0	4.1	97.5	79.6
Faint	115.0	93.9	24.9	20.4
Weak	1.5	1.3	0.0	0.0
Medium	0.0	0.0	0.0	0.0
Strong	0.9	0.7	0.0	0.0
Total	122.4	100.0	122.4	100.0

Table B-3. Rock alteration type and intensity. Sum of mapped core length and percentage of mapped core length.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(m)	(%)	(m)	(%)
Rock alteration type				
Argillization	0.00	0.00	0.45	0.37
Oxidation	26.08	21.31	88.04	71.93
Chloritization	2.10	1.71	0.01	0.01
Epidotization	0.98	0.80	3.31	2.71
Saussuritization	0.00	0.00	0.02	0.02
Total	29.2	23.8	91.8	75.0
Rock alteration intensity				
No intensity	0.00	0.00	0.30	0.25
Faint	6.65	5.43	39.33	32.13
Weak	7.05	5.76	39.75	32.47
Medium	14.52	11.86	4.58	3.74
Strong	0.95	0.77	7.88	6.43
Total	29.2	23.8	91.8	75.0

Table B-4. Rock occurrence. Sum of mapped rock type core length and percentage of mapped core length.

Code	Rock name	SwedPower (JPGS)				Geosigma (JEPD)			
		Number (no.)	(%)	Length (m)	(%)	Number (no.)	(%)	Length (m)	(%)
Rock occurrence type									
0	Unspecified	34	40.0	3.6	2.9	31	44.3	7.6	6.2
1	Enclave	13	15.3	0.3	0.3	4	5.7	0.2	0.1
2	Dyke	11	12.9	1.3	1.0	0	0.0	0.0	0.0
6	Layer	0	0.0	0.0	0.0	0	0.0	0.0	0.0
8	Lens	0	0.0	0.0	0.0	0	0.0	0.0	0.0
13	Xenolith	0	0.0	0.0	0.0	0	0.0	0.0	0.0
18	Vein	27	31.8	0.9	0.7	35	50.0	2.8	2.3
Total		85	100.0	6.0	4.9	70	100.0	10.6	8.6
Rock name									
501044	Granite to quartz monzodiorite, generally porphyritic	14	16.5	1.66	1.36	20	28.6	4.20	3.43
501058	Granite, medium- to coarse-grained	4	4.7	0.13	0.11	2	2.9	0.11	0.09
501061	Pegmatite	3	3.5	0.08	0.07	1	1.4	0.02	0.02
505102	Mafic rock, fine-grained	23	27.1	0.86	0.70	14	20.0	3.34	2.73
511058	Granite, fine- to medium-grained	41	48.2	3.24	2.64	33	47.1	2.91	2.37
Total		85	100.0	6.0	4.9	70	100.0	10.6	8.6

B2 – Fractures

Frequency

Table B-5. Frequency of fracture type combined with confidence and visibility in BIPS.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Open	273	39.0	365	50.6
Partly open	18	2.6	3	0.4
Sealed	408	58.4	353	49.0
Total	699	100.0	721	100.0
Certain	81	29.7	48	13.1
Probable	116	42.5	104	28.5
Possible	76	27.8	213	58.4
Visible in BIPS	558	79.8	505	70.0

Note: The degree of confidence only applies to open fractures.

Orientation

Table B-6. Frequency distribution of fracture orientation for broken fractures.

Group	Bearing (pole) (deg)	Plunge (pole) (deg)	SwedPower(JPGS)		Geosigma (JEPD)	
			(no.)	(%)	(no.)	(%)
A	0–60	0–60	26	7.3	25	6.6
B	60–120	0–60	11.0	3.1	12.0	3.2
C	120–180	0–60	39.0	10.9	34.0	9.0
D	180–240	0–60	50.0	14.0	56.0	14.8
E	240–300	0–60	20.0	5.6	24.0	6.3
F	300–360	0–60	13.0	3.6	13.0	3.4
G	0–360	60–90	198	55.5	214	56.6
Total			357	100	378	100

Table B-7. Frequency distribution of fracture orientation for unbroken fractures.

Group	Bearing (pole) (deg)	Plunge (pole) (deg)	SwedPower(JPGS)		Geosigma (JEPD)	
			(no.)	(%)	(no.)	(%)
A	0–60	0–60	29	8.5	33	9.6
B	60–120	0–60	42.0	12.3	30.0	8.7
C	120–180	0–60	32.0	9.4	40.0	11.7
D	180–240	0–60	30.0	8.8	32.0	9.3
E	240–300	0–60	30.0	8.8	30.0	8.7
F	300–360	0–60	34.0	9.9	35.0	10.2
G	0–360	60–90	145	42.4	143	41.7
Total			342	100	343	100

Mineralogy

Table B-8. Frequency and percentage of fracture filling in broken fractures.

Mineral	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Epidote	4	0.5	23	2.6
Flourite	2	0.2	1	0.1
Hematite	37	4.5	80	8.9
Calcite	316	38.8	327	36.3
Chlorite	203	24.9	217	24.1
Chalcopyrite	0	0.0	3	0.3
Quartz	3	0.4	7	0.8
Muscovite	0	0.0	1	0.1
Unknown	0	0.0	5	0.6
Pyrite	30	3.7	56	6.2
Sericite	3	0.4	4	0.4
Sphalerite	0	0.0	1	0.1
Clay Minerals	145	17.8	90	10.0
Laumontite	1	0.1	2	0.2
Iron Hydroxide	1	0.1	1	0.1
Adularia	4	0.5	2	0.2
Oxidized Walls	48	5.9	54	6.0
X6, Polished fracture surface	0	0.0	20	2.2
X7, No detectable mineral	17a	2.1	7	0.8
Total	814	100.0	901	100.0

a) Logged with empty cells by SwedPower.

Table B-9. Frequency and percentage of fracture filling in unbroken fractures.

Mineral	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Epidote	29	4.2	20	3.0
Flourite	0	0.0	2	0.3
Hematite	11	1.6	27	4.1
Calcite	215	31.2	187	28.4
Chlorite	157	22.8	136	20.7
Quartz	48	7.0	75	11.4
Pyrite	3.0	0.4	4	0.6
Sericite	2	0.3	0	0.0
Clay Minerals	10	1.4	2	0.3
Laumontite	3	0.4	2	0.3
Prehnite	9	1.3	3	0.5
Adularia	33	4.8	2	0.3
Oxidized Walls	163	23.6	192	29.2
X4,	0	0.0	1	0.2
X7, No detectable mineral	7a	1.0	0	0.0
X8,	0	0.0	5	0.8
Total	690	100.0	658	100.0

a) Logged with empty cells by SwedPower.

Roughness and surface

Table B-10. Frequency and percentage of estimated roughness profile (large scale) and surface conditions (small scale) for broken fractures (small scale).

	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
Roughness				
Planar	110	30.8	191	50.5
Undulating	46	12.9	157	41.5
Stepped	15	4.2	12	3.2
Irregular	186	52.1	18	4.8
Total	357	100.0	378	100
Surface				
Rough	305	85.4	334	88.4
Smooth	51	14.3	39	10.3
Slickensided	1	0.3	5	1.3
Total	357	100.0	378	100.0

Alteration

Table B-11. Frequency and percentage of estimated alteration in broken and unbroken fractures.

	SwedPower (JPGS)				Geosigma (JEPD)			
	Broken		Unbroken		Broken		Unbroken	
	(no.)	(%)	(no.)	(%)	(no.)	(%)	(no.)	(%)
Fresh	123	34.4	332	97.1	74	19.6	63	18.4
Slightly altered	203	56.9	9	2.6	303	80.1	280	81.6
Moderately altered	26	7.3	1	0.3	1	0.3	0	0.0
Highly altered	5	1.4	0	0.0	0	0.0	0	0.0
Completely altered	0	0.0	0	0.0	0	0.0	0	0.0
Gouge	0	0.0	0	0.0	0	0.0	0	0.0
Total	357	100.0	342	100.0	378	100.0	343	100.0

Width and Aperture

Table B-12. Aperture of broken fractures. The aperture presented by Geosigma have been rounded to the closest half number.

	SwedPower(JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
0	84	23.5	13	3.4
0.5	193	54.1	333	88.1
1.0	50	14.0	9	2.4
1.5	11	3.1	5	1.3
2.0	7	2.0	5	1.3
2.5	3	0.8	4	1.1
3.0	4	1.1	2	0.5
3.5	3	0.8	1	0.3
4.0	2	0.6	3	0.8
5.0	0	0.0	2	0.5
7.5	0	0.0	1	0.3
Total	357	100.0	378	100.0
Certain	81	22.7	61	16.1
Probable	200	56.0	104	27.5
Possible	76	21.3	213	56.3
Visible in BIPS	285	79.8	267	70.6

Table B-13. Frequency and percentage of estimated width of unbroken fractures.

	SwedPower (JPGS)		Geosigma (JEPD)	
	(no.)	(%)	(no.)	(%)
0.1	0	0.0	(58)	16.9
0.2	0	0.0	(141)	41.1
0.3	0	0.0	(67)	19.5
0.4	0	0.0	(18)	5.2
0.1–0.5	277	81	297 (13)	86.5 (3.8)
0.6–1.0	44	12.9	13	3.8
1.1–1.5	11	3.2	9	2.6
1.6–2.0	8	2.3	13	3.8
2.5	0	0.0	1	0.3
3.0	1	0.3	6	1.8
3.5	0	0.0	0	0.0
4.0	1	0.3	3	0.9
5.0	0	0.0	0	0.0
6.0	0	0.0	1	0.3
Total	342	100.0	343	100.0
Certain	320	93.6	343	100.0
Probable	14	4.1	0	0.0
Possible	8	2.3	0	0.0
Visible in BIPS	273	79.8	238	69.4

B3 – Sealed network

Table B-14. SecUp, core length and piece length of sealed network.

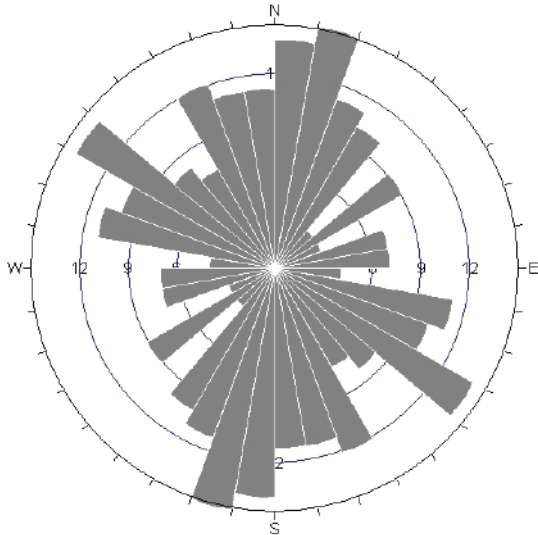
SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
12.7	0.00	15	11.8	0.08	5
14.2	0.06	8	15.6	0.16	15
28.8	0.02	2	28.4	0.66	30
29.2	0.03	2	29.2	0.63	20
29.4	0.01	1	–	–	–
34.1	0.02	5	34.0	0.10	3
37.5	0.02	5	40.1	0.16	10
38.8	0.04	7	–	–	–
75.3	0.01	3	71.7	0.30	10
86.8	0.00	10	86.4	0.27	15
93.3	0.02	4	–	–	–
114.7	0.07	12	115.8	0.38	15
116.1	0.26	8	–	–	–
116.7	0.08	5	116.4	0.24	15
117.6	1.44	15	117.4	6.36	20
119.8	0.11	20	–	–	–
120.3	0.19	15	–	–	–
120.6	0.33	20	–	–	–
121.2	1.24	15	–	–	–
122.6	0.02	2	–	–	–
123.0	0.25	8	–	–	–
123.5	0.01	5	–	–	–
123.7	0.19	15	–	–	–
124.8	0.04	5	124.5	0.21	20
125.2	0.70	15	124.9	0.83	15
127.1	0.14	8	127.0	0.12	10
127.6	0.49	20	127.3	9.98	20
128.9	0.00	20	–	–	–
129.6	0.00	25	–	–	–
129.6	1.44	15	–	–	–
131.1	1.10	4	–	–	–

B4 – Crush zones

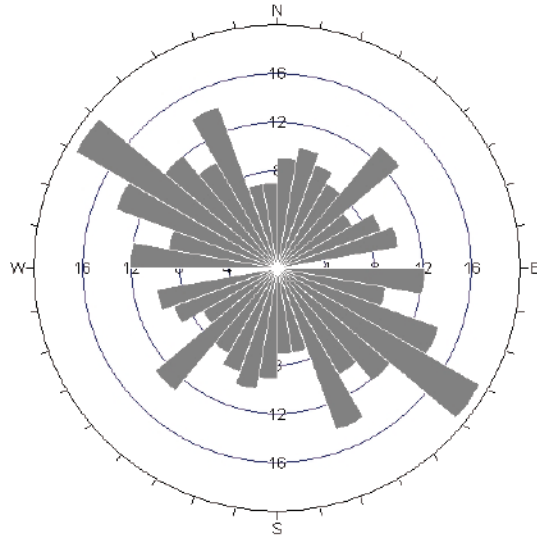
Table B-15. SecUp, core length and piece length of crush zones.

SwedPower (JPGS)			Geosigma (JEPD)		
SecUp depth (m)	Core length (m)	Piece length (mm)	SecUp depth (m)	Core length (m)	Piece length (mm)
15.3	0.12	20	15.3	0.24	20
28.4	0.09	15	–	–	–
28.8	0.09	10	28.8	0.13	15
29.1	0.05	8	29.0	0.11	15
29.8	0.02	6	–	–	–
40.6	0.31	6	40.5	0.65	10
41.2	0.00	8	–	–	–
109.9	0.03	6	–	–	–
119.2	0.01	5	–	–	–
129.7	0.07	20	–	–	–
129.9	0.10	20	–	–	–
130.4	0.06	10	130.1	0.02	3
131.1	0.80	15	130.9	0.77	7

Strike and dip rosette plots

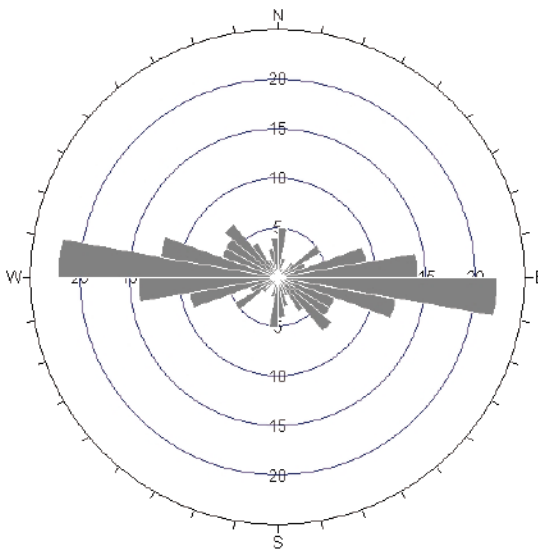


SwedPower (JPGS).
167 planes plotted. 15 planes at outer circle

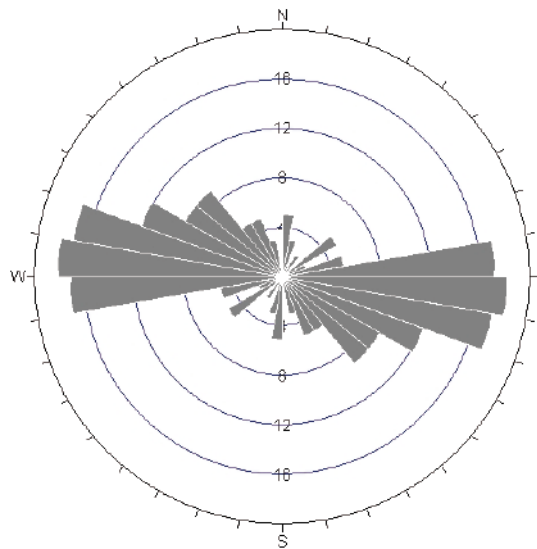


Geosigma (JEPD)
179 planes plotted. 20 planes at outer circle.

Figure C-1. Rosette plot of broken fractures in KFM06C. Apparent strike, face normal, no bias correction. 0–45° of viewing face.



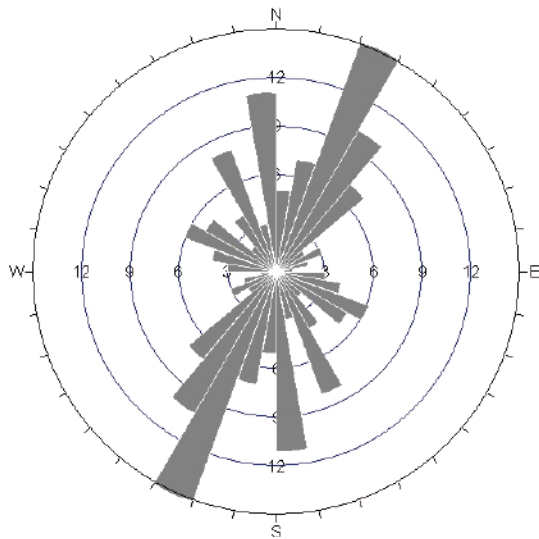
SwedPower (JPGS).
108 planes plotted. 25 planes at outer circle



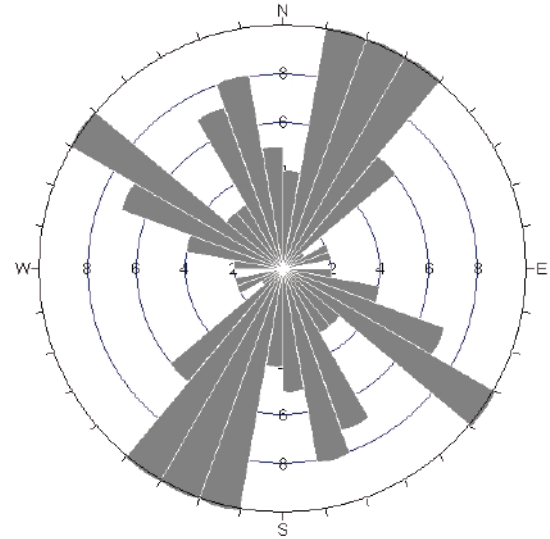
Geosigma (JEPD)
118 planes plotted. 20 planes at outer circle.

Figure C-2. Rosette plot of broken fractures in KFM06C. Apparent strike, face normal, no bias correction. 45–90° of viewing face.

(note: division of the fractures into two viewing planes leads to a minor number of fractures being represented in both views affecting the apparent total number of fractures plotted)

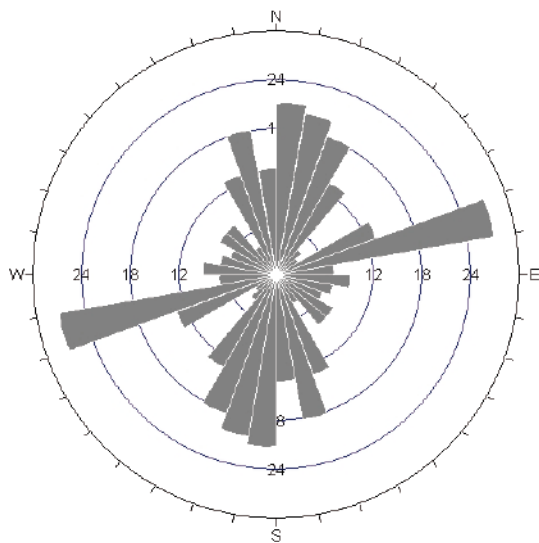


SwedPower (JPGS).
98 planes plotted. 15 planes at outer circle

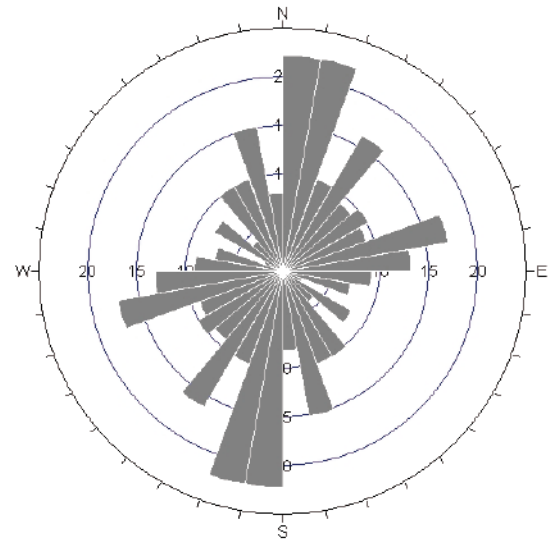


Geosigma (JEPD)
97 planes plotted. 10 planes at outer circle.

Figure C-3. Rosette plot of unbroken fractures in KFM06C. Apparent strike, face normal, no bias correction. 0–45° of viewing face.

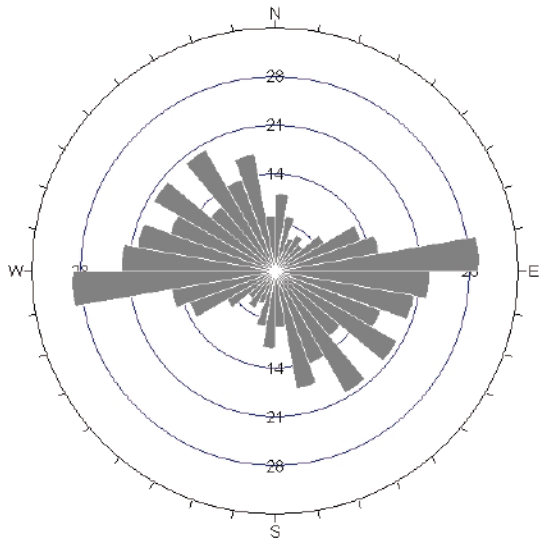


SwedPower (JPGS).
212 planes plotted. 30 planes at outer circle

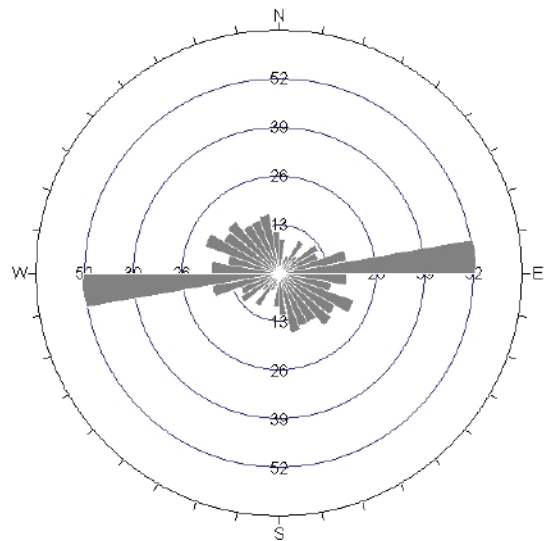


Geosigma (JEPD)
201 planes plotted. 25 planes at outer circle.

Figure C-4. Rosette plot of unbroken fractures in KFM06C. Apparent strike, face normal, no bias correction. 45–90° of viewing face.

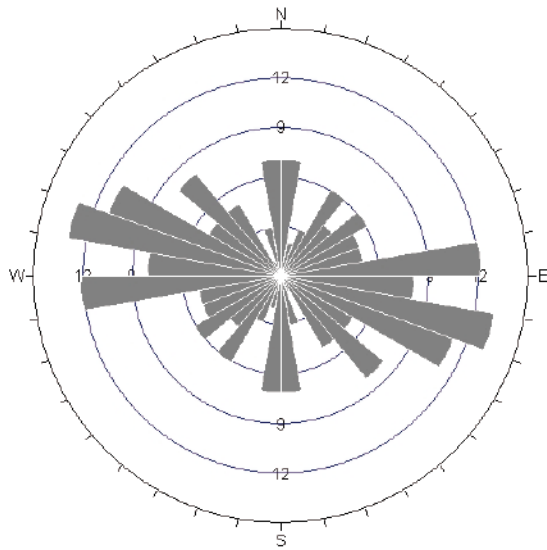


SwedPower (JPGS).
249 planes plotted. 35 planes at outer circle

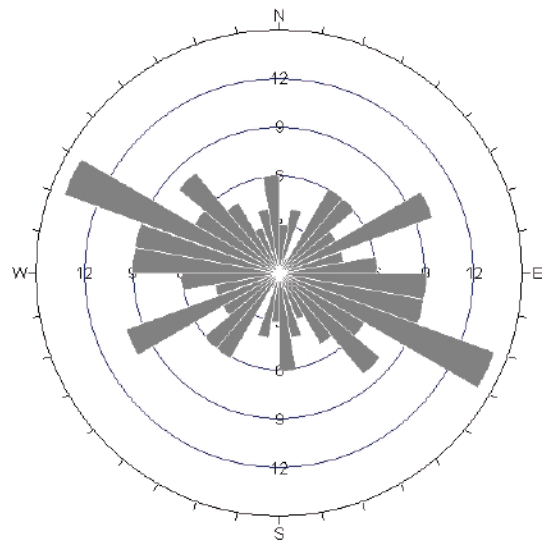


Geosigma (JEPD)
272 planes plotted. 65 planes at outer circle.

Figure C-5. Rosette plot of broken fractures in KLX07B. Apparent strike, face normal, no bias correction. 0–45° of viewing face.

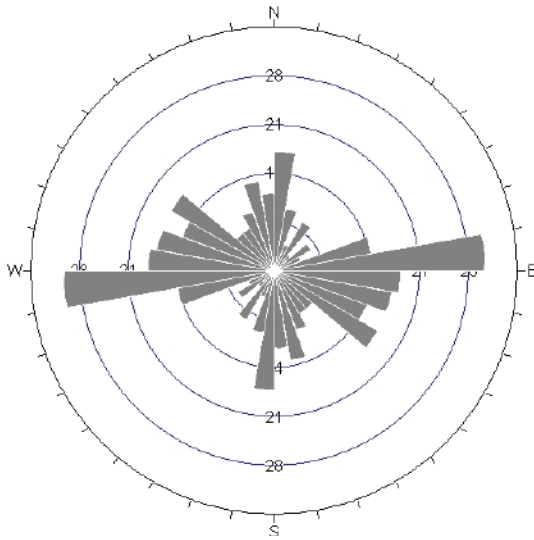


SwedPower (JPGS).
111 planes plotted. 15 planes at outer circle

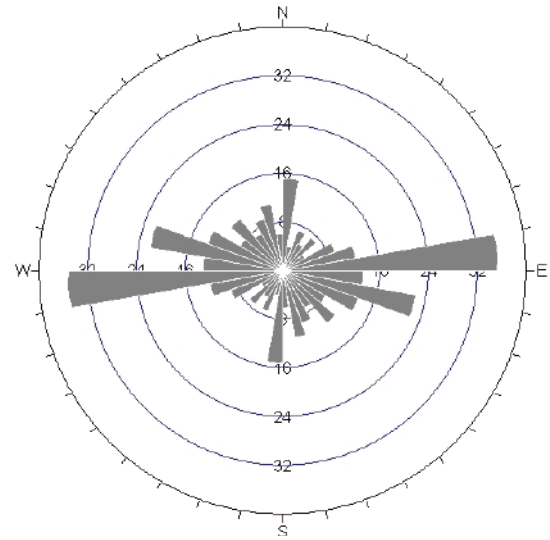


Geosigma (JEPD)
108 planes plotted. 15 planes at outer circle.

Figure C-6. Rosette plot of broken fractures in KLX07B. Apparent strike, face normal, no bias correction. 45–90° of viewing face.

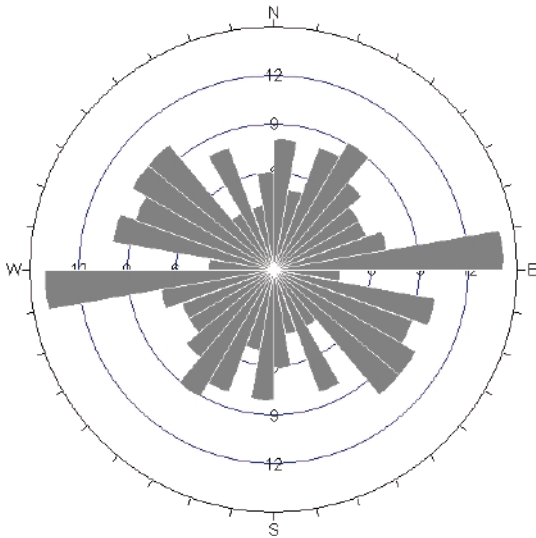


SwedPower (JPGS).
208 planes plotted. 35 planes at outer circle

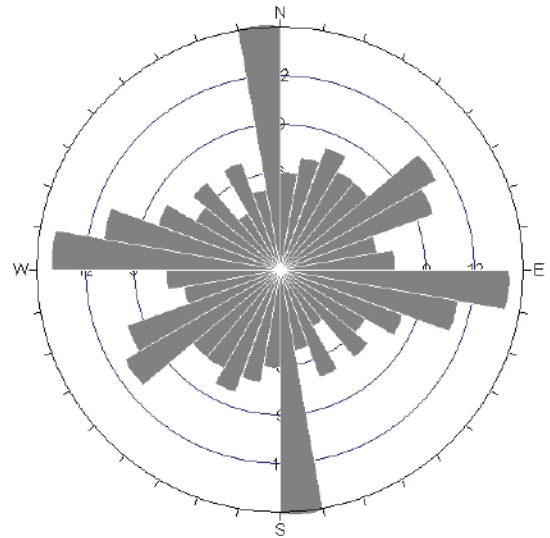


Geosigma (JEPD)
198 planes plotted. 40 planes at outer circle.

Figure C-7. Rosette plot of unbroken fractures in KLX07B. Apparent strike, face normal, no bias correction. 0–45° of viewing face.



SwedPower (JPGS).
135 planes plotted. 15 planes at outer circle



Geosigma (JEPD)
146 planes plotted. 15 planes at outer circle

Figure C-8. Rosette plot of unbroken fractures in KLX07B. Apparent strike, face normal, no bias correction. 45–90° of viewing face.

Definitions (boremap)

Fracture	General term that refers to all kinds of mechanical breaks in a rock mass
Fracture zone	A section within the bedrock with high fracture frequency
Sealed fracture	Fracture in the bedrock filled with consolidated fracture mineral such as quartz, epidote or calcite.
Sealed fracture network	Group of sealed fractures which are assigned average properties instead of individual.
Open fracture	Fracture in the bedrock filled with air, water or unconsolidated rock material.
Crush	Group of open fractures, which result in great difficulties to reconstruct the core or with a fracture spacing less than about 5 cm.
Break	A fracture with fresh planes originated for example from blasting or drilling.
