Laxemar – Sammanfattning av utförda undersökningar och aktuell status på pågående platsmodellering

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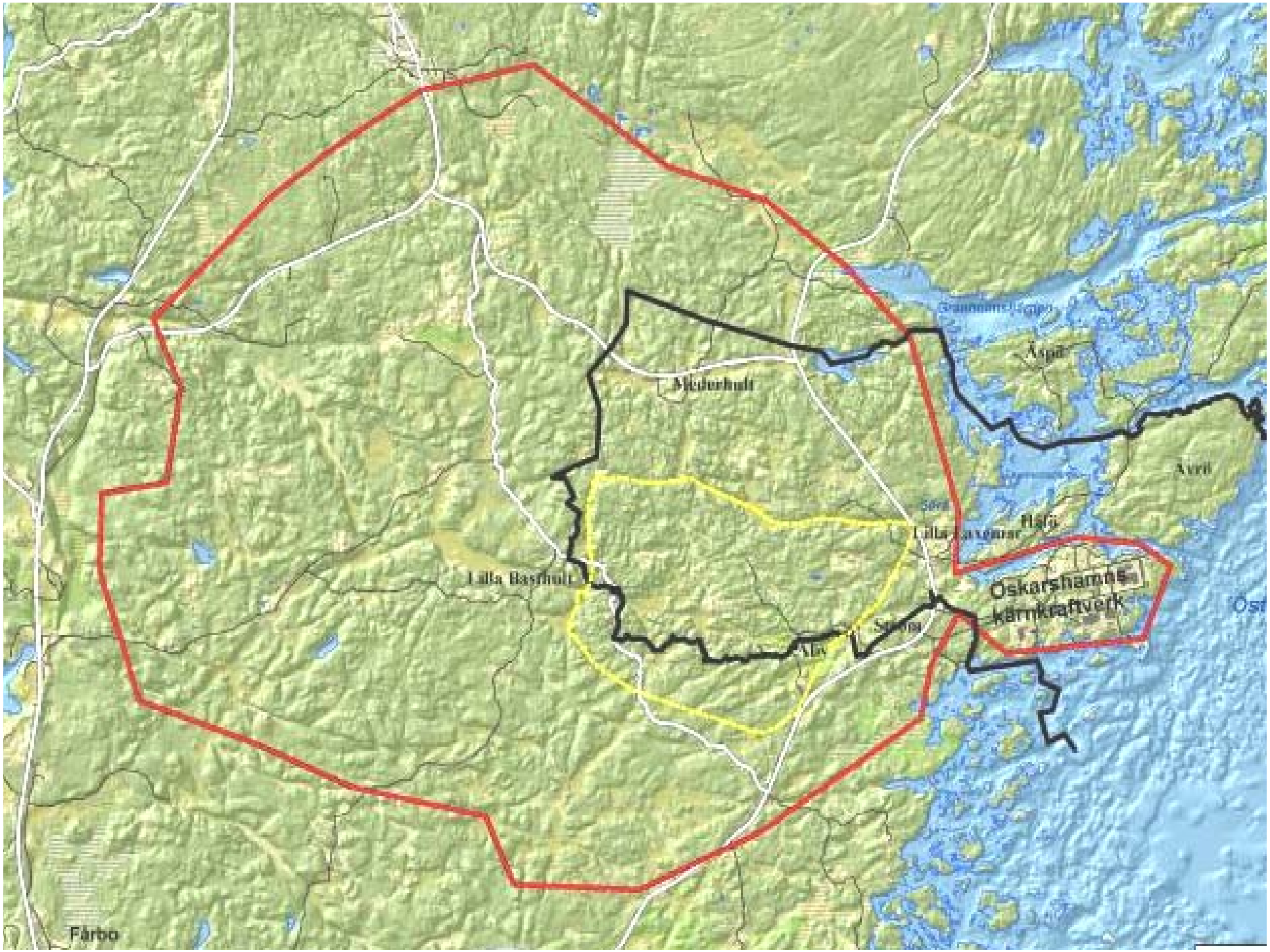
Samråd SKB/SKISSI, 19 Okober, 2007

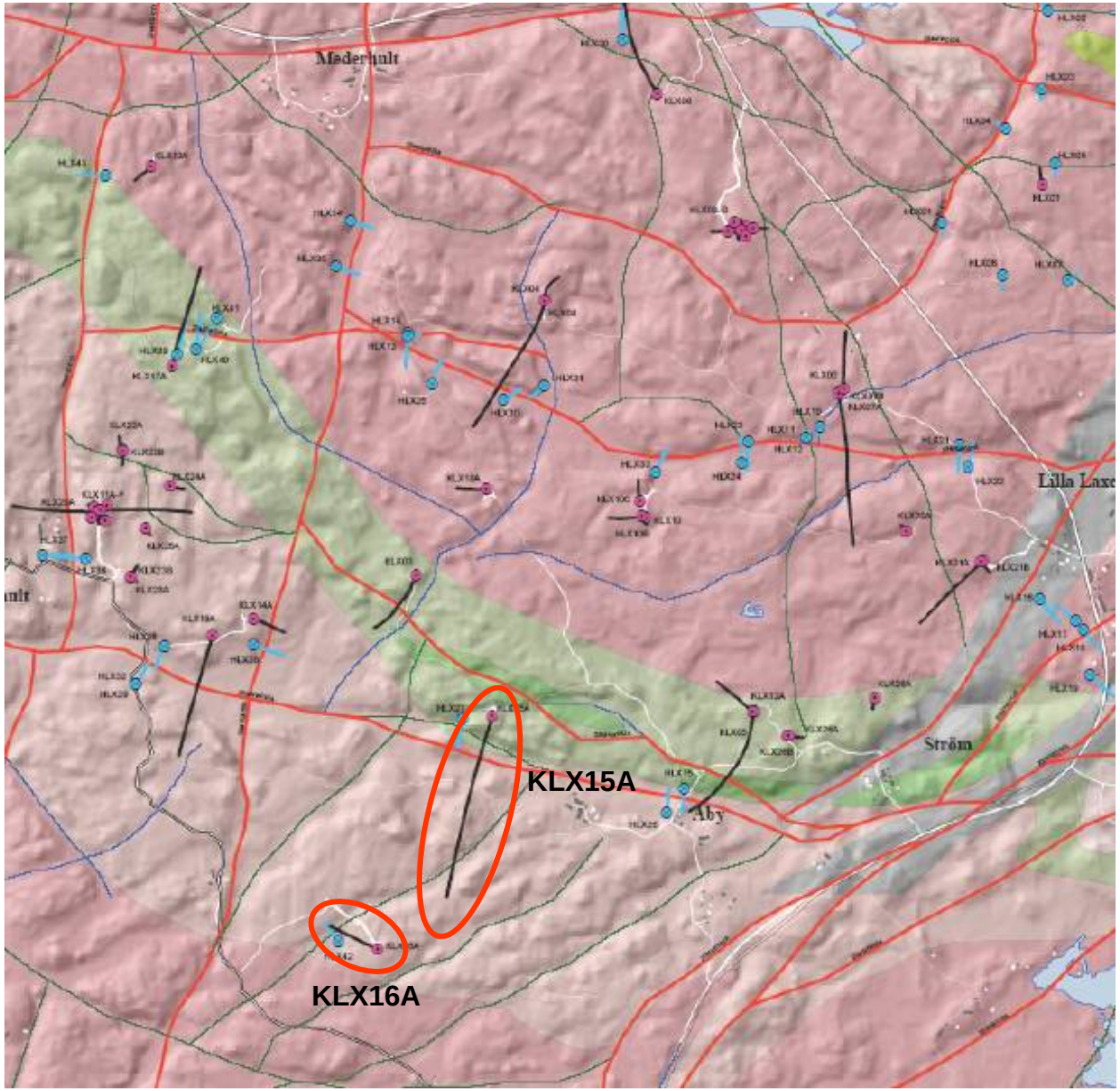
Disposition

- Slutförande av det ”kompletta platsundersökningsskedet” i Laxemar”.
  - Överblick av nya undersökningar
  - Tillägg till CSI-programmet (eg. KLX27A)
  - Sent inkommande data (eg. karakterisering i KLX27A)
  - Omformning av Oskarshams platsundersökningsprojekt
- Nuvarande förståelse av förhållandena i Laxemar
  - Speciellt fokus på geologi, hydrogeologi och hydrogeokemi
  - Är databaserna tillräckliga ?

Part 1

Completion of the complete site investigations at Laxemar.


Mederhult
Åsp
Lilla Basthult
Oskarshamns
kärnkraftverk
Färbo



Summary of CSI bore-holes in Laxemar:

Before the site investigation

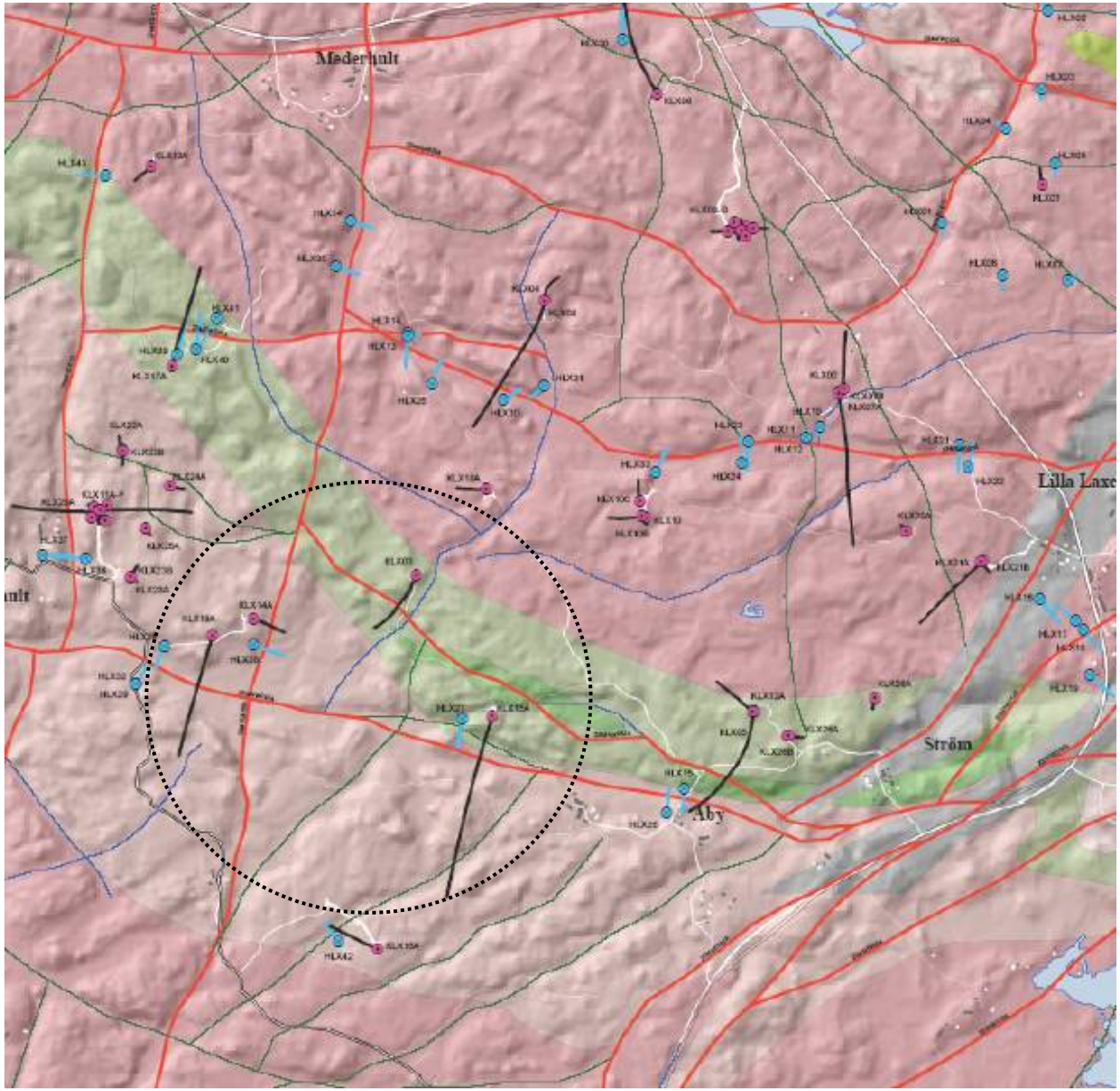
- **2 core drilled holes (1000-1700m)**
- **12 percussion drilled holes (100-200m)**

Drilled during the site investigation

- **18 core drilled holes (500-1000m). Last holes drilled were KLX15A and KLX16A**
- **25 core drilled holes (50-200m)**
- **31 percussion drilled holes (100-200m)**

Data freeze Laxemar 2.3

- 31 august 2007
- All CSI primary data stored in the Sicada data base, with a few exceptions
  - Supplementary hydrochemistry and transport laboratory analysis data will be stored by November 2007 (Extended DFL2.3)



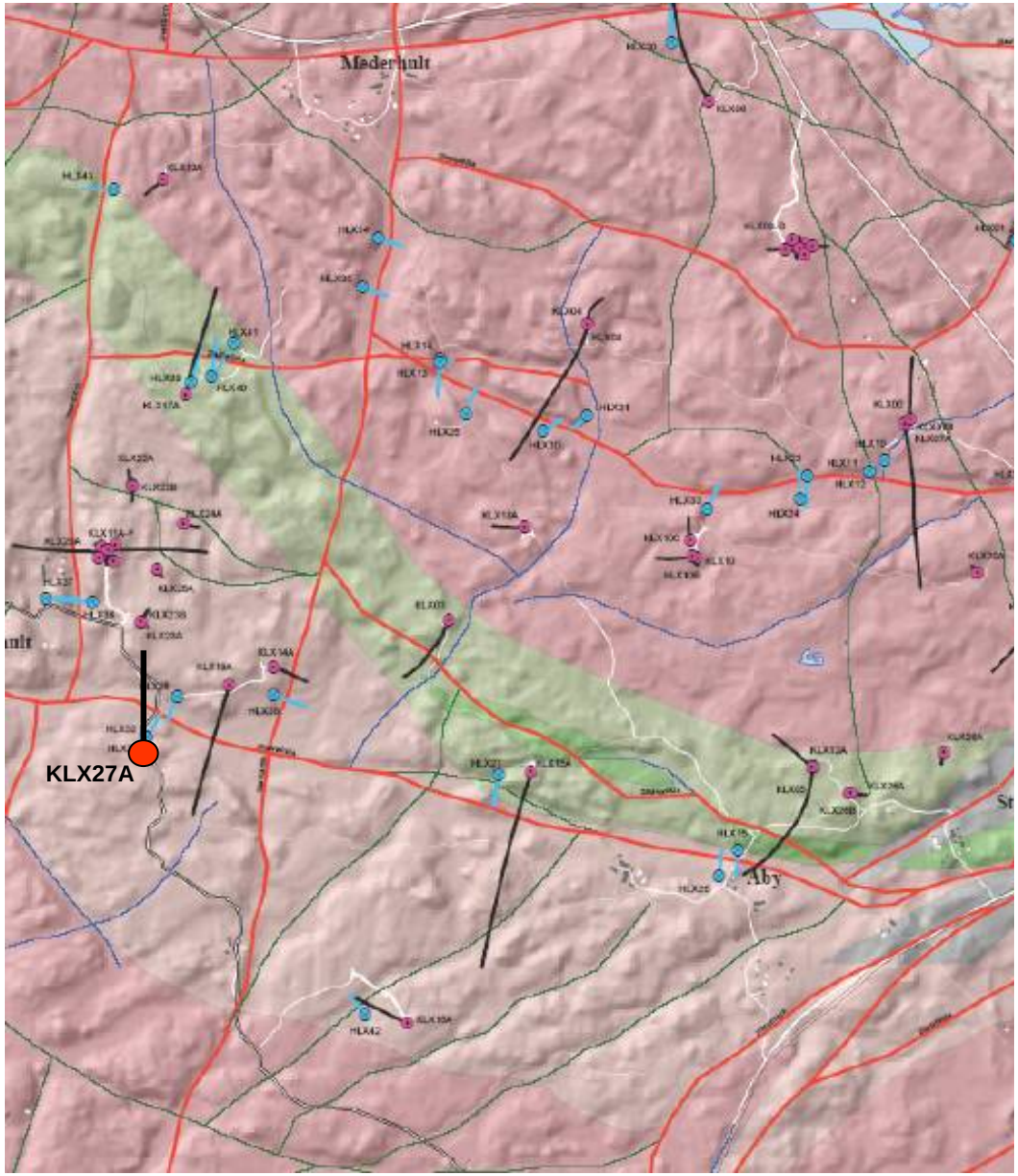
Work after DF2.3 according to the CSI programme

Large scale Pumping Test

- **Interference pumping and tracer test**
- **Postponed till spring 2008 due to the ongoing KLX27A programme**

Small scale tracer test

- Is considered in the same area



Supplementary work after ordinary CSI programme:

➢KLX27A

Main objective is to identify and characterise the modelled DZ NW042, in special the dip of the zone.

- **Azimuth 0º, Inclination 65º**
- **Planned length 700m**
- **Telescopic part (200mm) to 75m drilled in August.**
- **Core drilling at present 250 m**

Investigatiions planned

- **BIPS, Radar, geophysics, Boremap**
- **Hydraulic tests (PFL and PSS)**

The programme will be finnished in January 2008

Quantification of fracture minerals is ongoing;

Selected boreholes/fractures mostly PFL anomalies

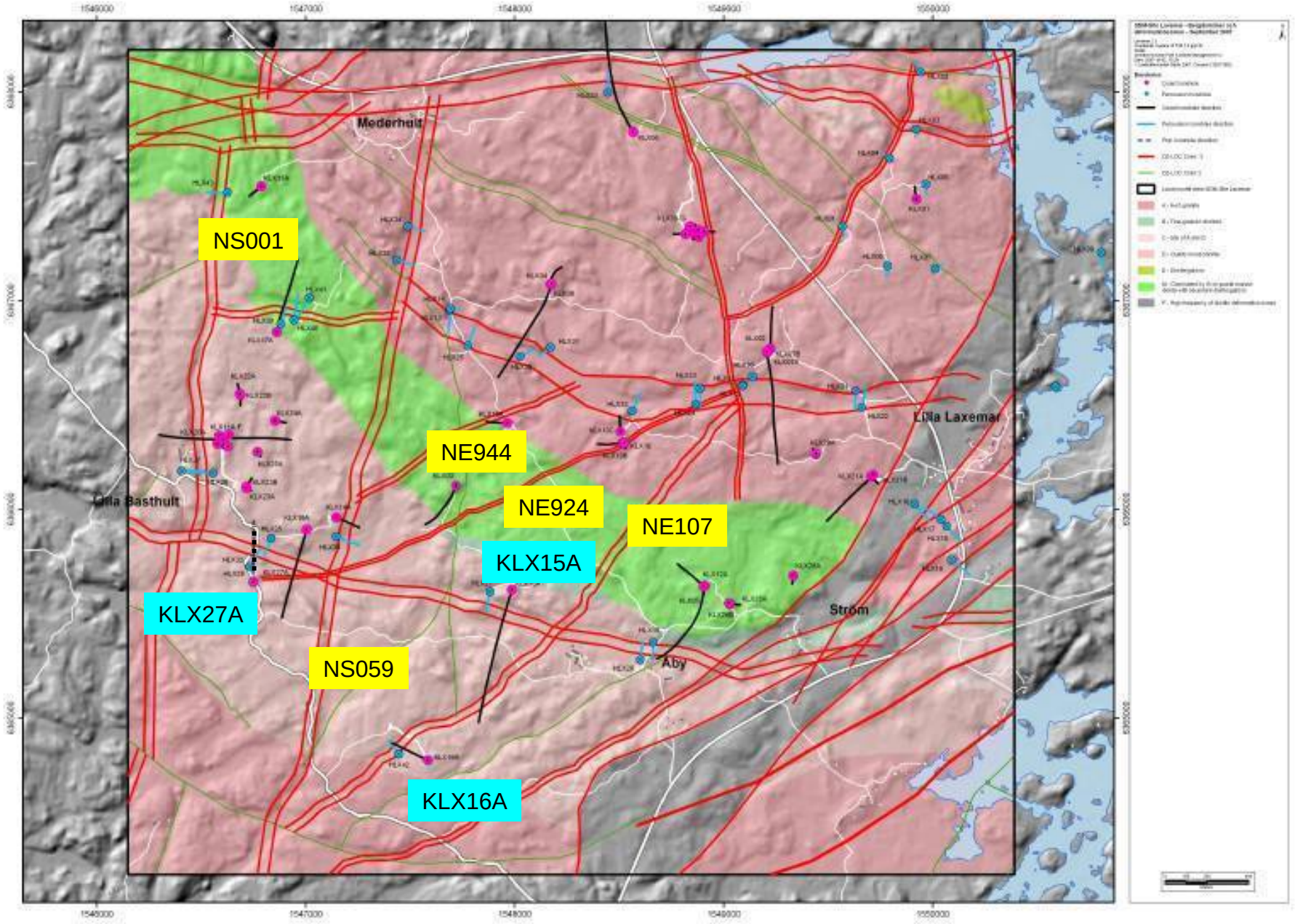
Work at the site from 2008 and onwards

- The ”Site Investigation Project” at Oskarshamn will finish at the end of 2007
- The ”Oskarshamn Site Project” will start January 1, 2008
- A limited numbers of the former activity leaders will remain in the new organisation
- The site organisation is responsible for the
  - monitoring programme
  - ongoing and possibly new supplementary investigations
  - quality support to the data base Sicada
  - support to the Site Modelling Project
  - continued contacts with land owners, munipicalities and politicians

Part 2
Current understanding of the Laxemar subarea

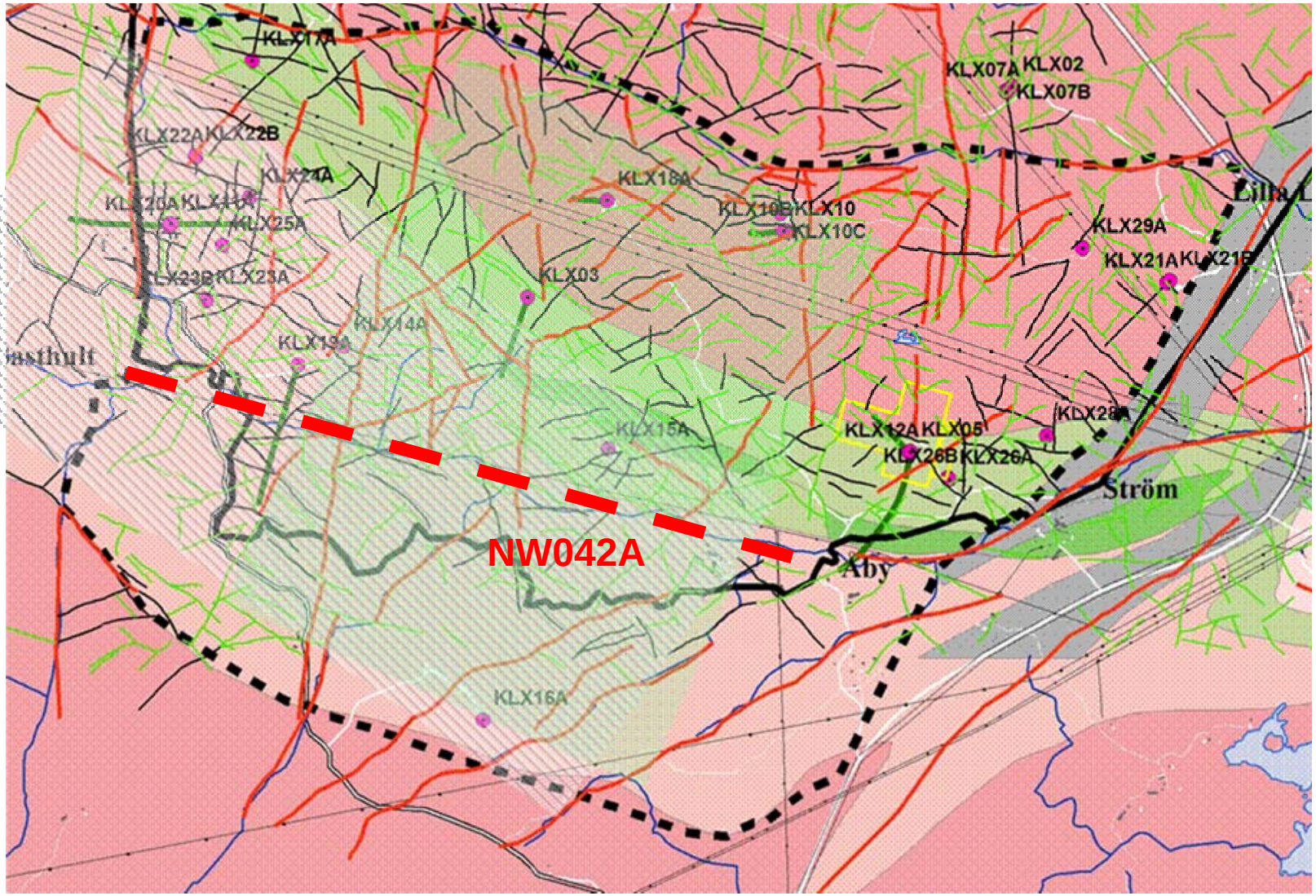
New premises for site modelling

- Extension of the investigation area to also **include the quartz monzodiorite (qmd) in its entirety**
- Drilling of KLX16A (geometry of southern boundary of qmd) and KLX15A (properties of qmd at depth)
- **DF L2.3 (Aug 31**, including data from new boreholes) **forms the basis for deliveries to both Design and Safety Assessment (SDM-Site Laxemar)**
- New time schedule - **SDM-Site Laxemar ready December 2008**
- Extension of detailed surface geophysical measure-ments in the south to cover quartzmonzodiorite
- **Intermittent deliveries to SER on properties of the Ävrö granite summer/early fall.**
- Problems with borehole orientation data has caused delays



SDM-Site Interim, June 2007

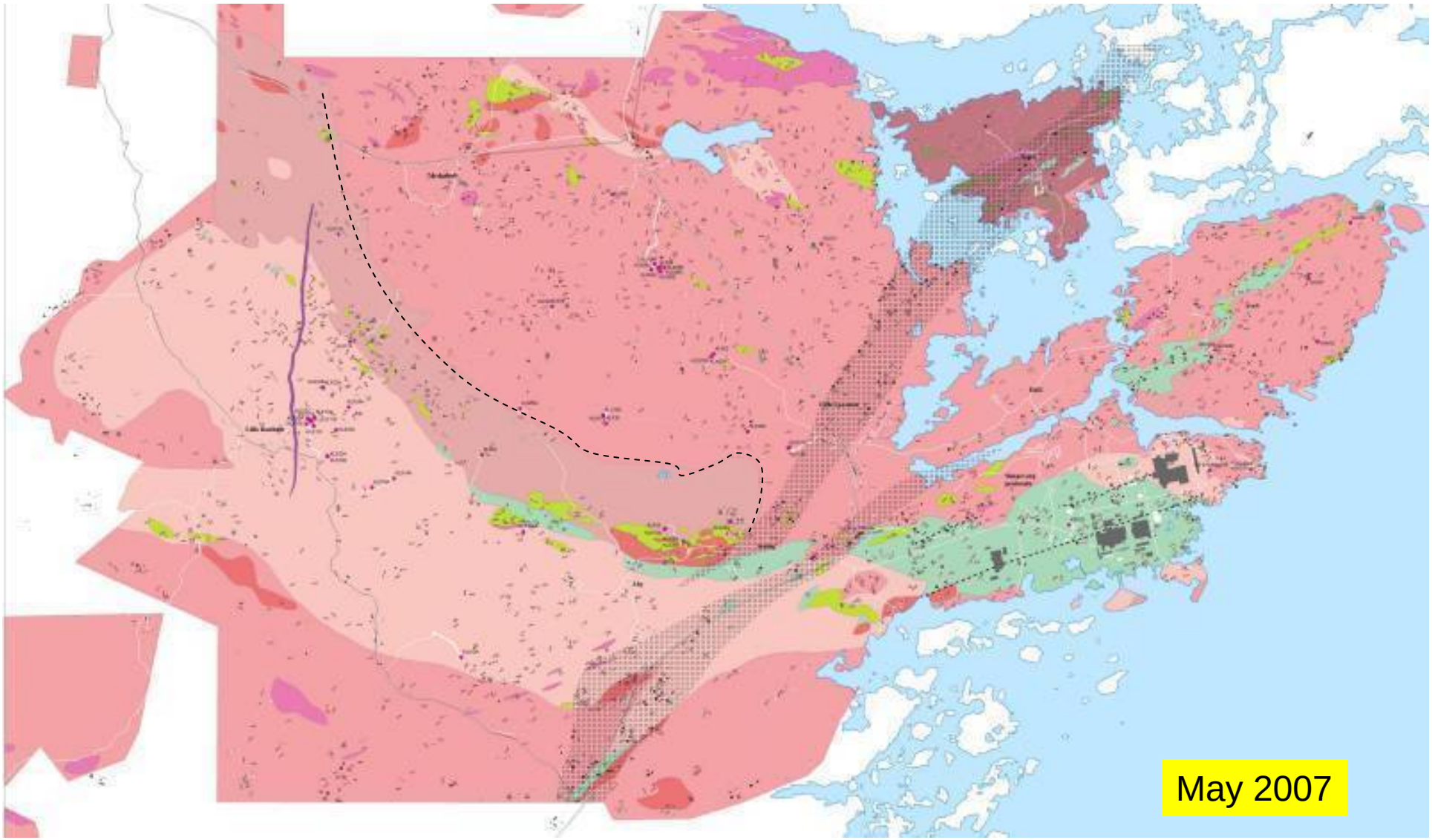
Principles for work on Layout D2



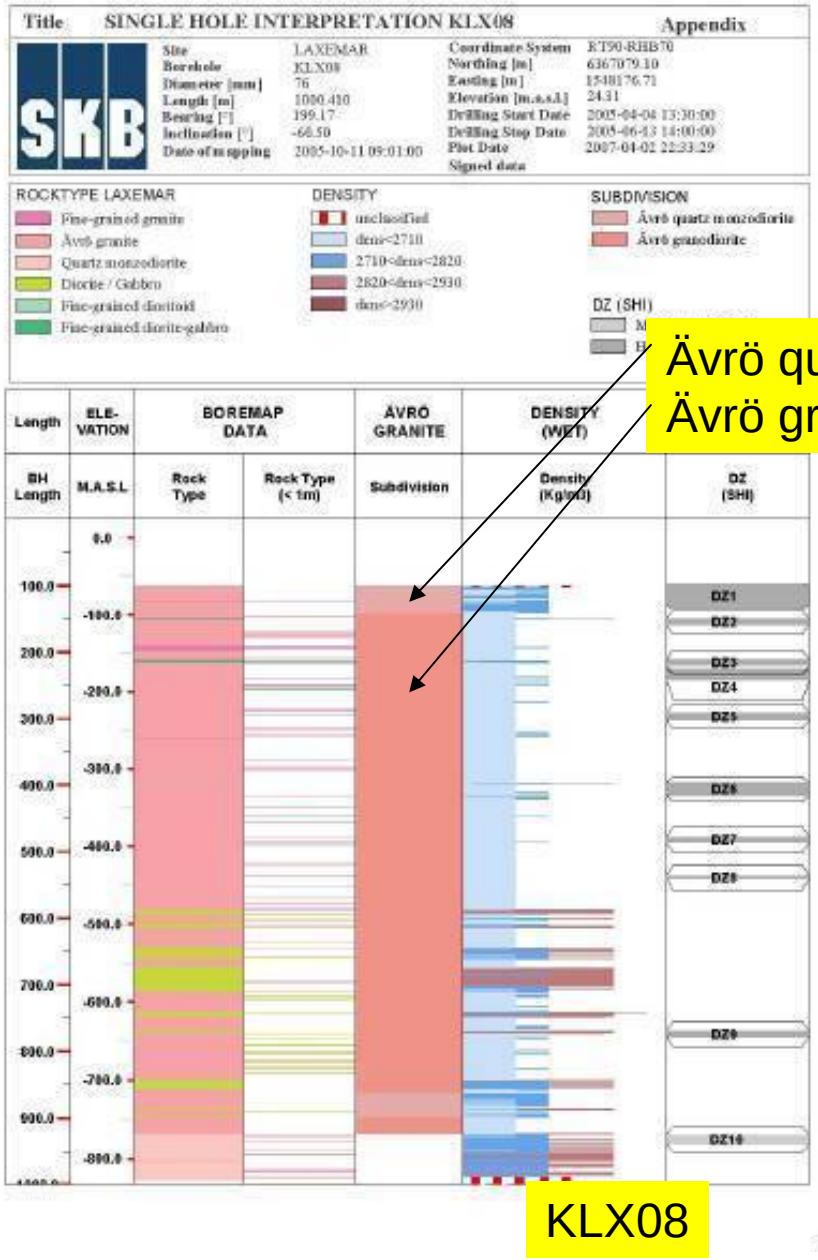
SDM-Site Laxemar – Rock domain modelling

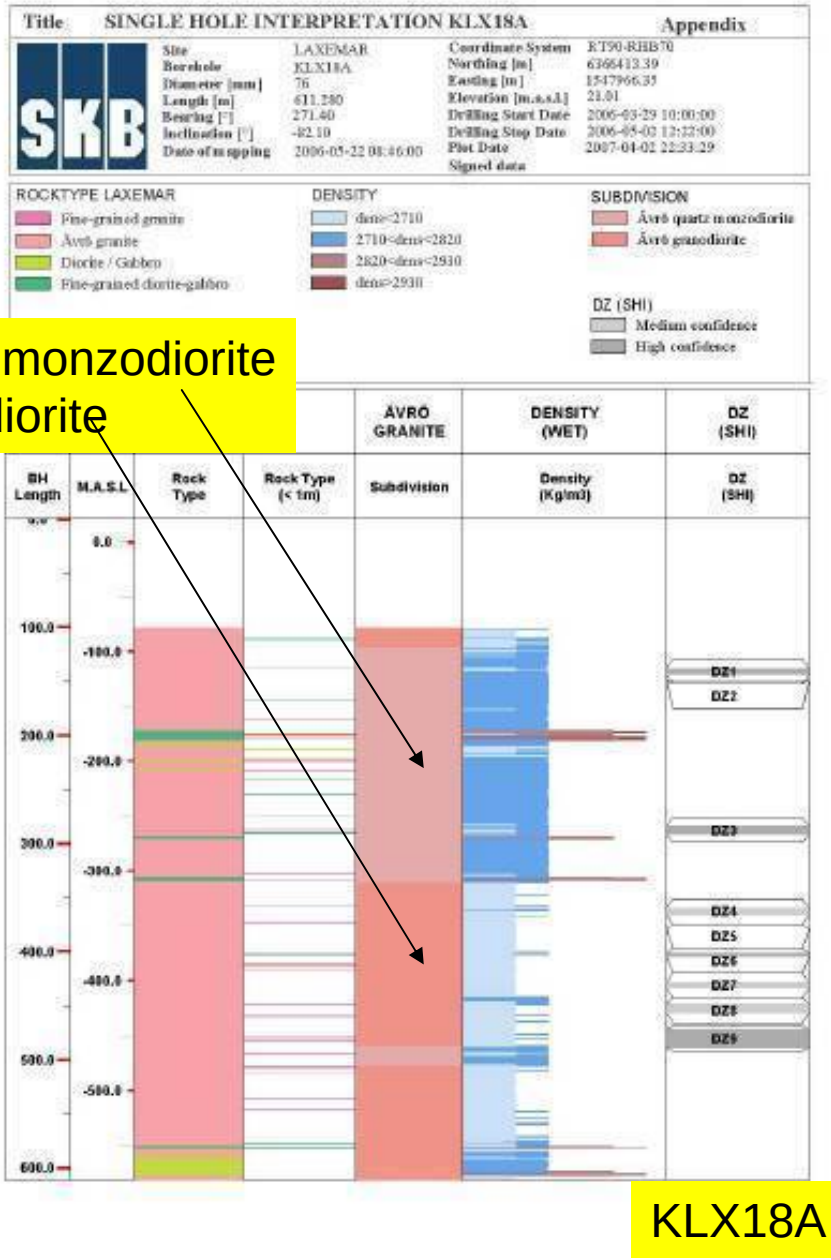
- Subdivision of the Ävrö granite in the two varieties Ävrö granodiorite and Ävrö quartz monzodiorite in boreholes (incorporated in SHI).
- RD model (3D) in RVS is based on definition of rock domains at the surface (2D – based on updated bedrock map) and RD definitions in boreholes.
- Various analytical work using Boremap data from cored boreholes in Laxemar (mainly subordinate rock types):
- Study of emplacement mechanism and influence of a younger granite in older country rock

Updated bedrock map of the Simpevarp area



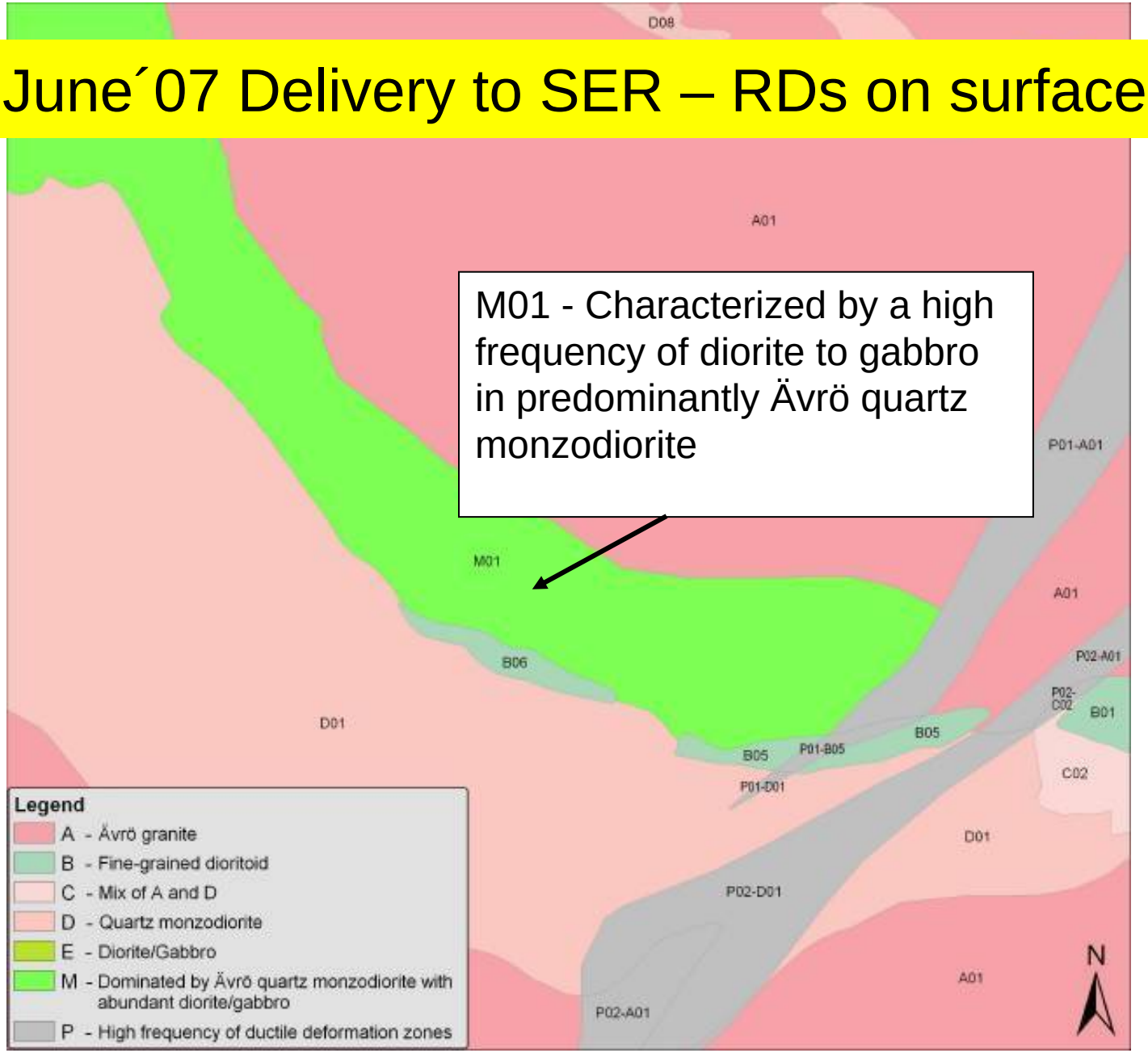
Example accounting of subdivision of Ävrö granite





Ävrö quartz monzodiorite
Ävrö granodiorite

June´07 Delivery to SER – RDs on surface



Rock domains
Confidence and issues (prel)

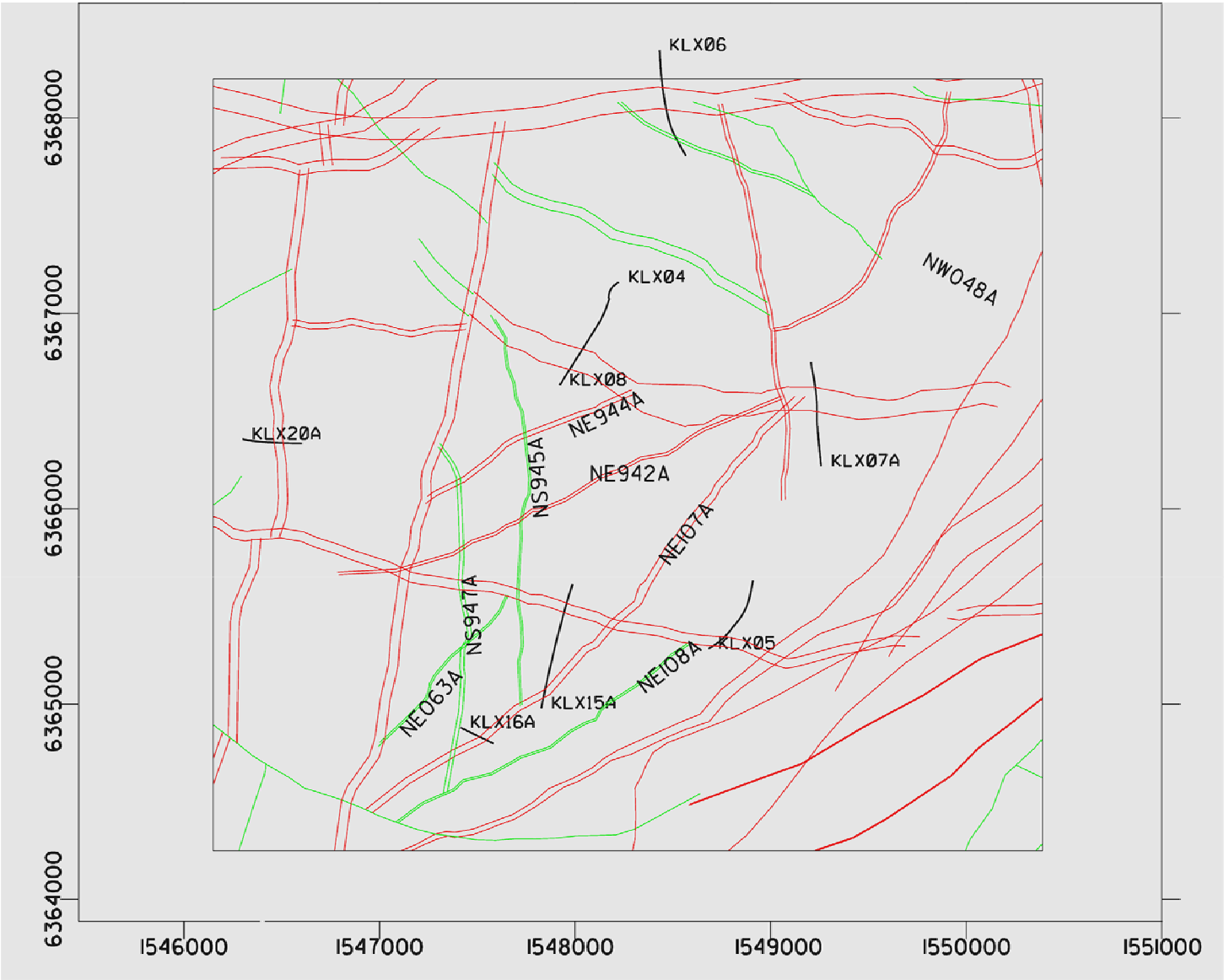
- The subdivision in rock domains is judged to be well established in the local modelled area, particularly in the focused area, both at surface and at depth.
- Properties/character of the dominant rock types in the rock domains are judged to be of high confidence in the focused area/volume. Uncertainties in assigned properties will be included in property tables.
- The remaining uncertainties relate to the location of the rock domain boundaries at depth between the fix points in boreholes, and particularly to the orientation and spatial distribution of subordinate rock types. Uncertainty in location of geometrical boundaries will be quantified.
- An analysis of the orientation and spatial distribution of subordinate rock types will be done.

Status of DZ modelling

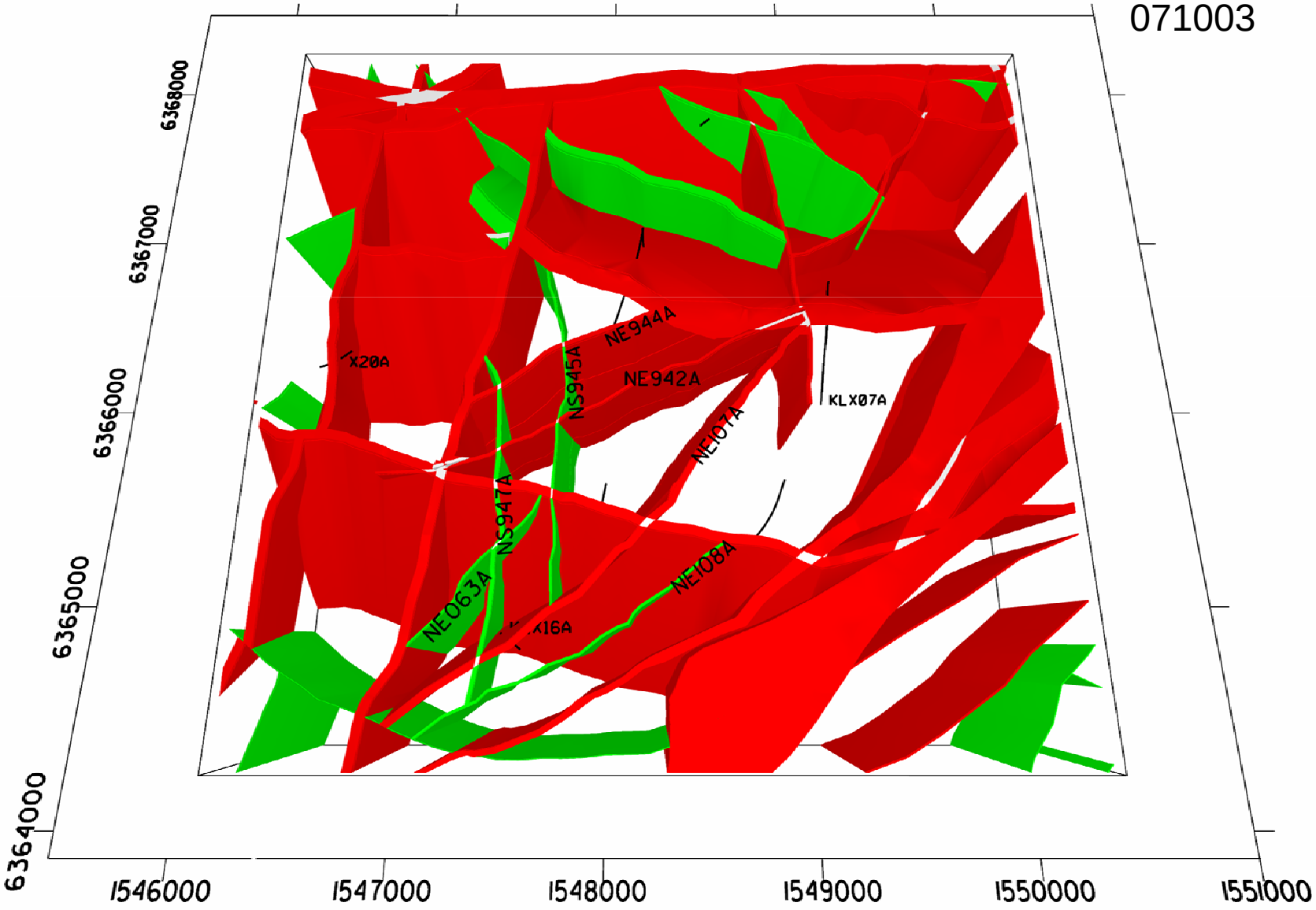
- Review and update of interpreted surface outcrops of zones. Results in part involve elimination of zones, alternatively adjusted geometries.
- Renewed evaluation DZs based on new data (detailed lineaments in the south).
  - Select zone by zone documentation
- Correlation of thicknesses and lengths of DZs
  - Enables ínclusion in the RVS model of select DZs seen only in boreholes

SDM-Site Interim (Oct 3)

Surface plan view DZ traces with modelled thicknesses



SDM-Site Interim
071003



Handling of DZs with thicknesses >10 m

For the SDM-Site Laxemar DZ model:

Major DZ : length >1000m, thickness >10m

MDZ : length < 1000m, thickness < 10m (**in GeoDFN**)

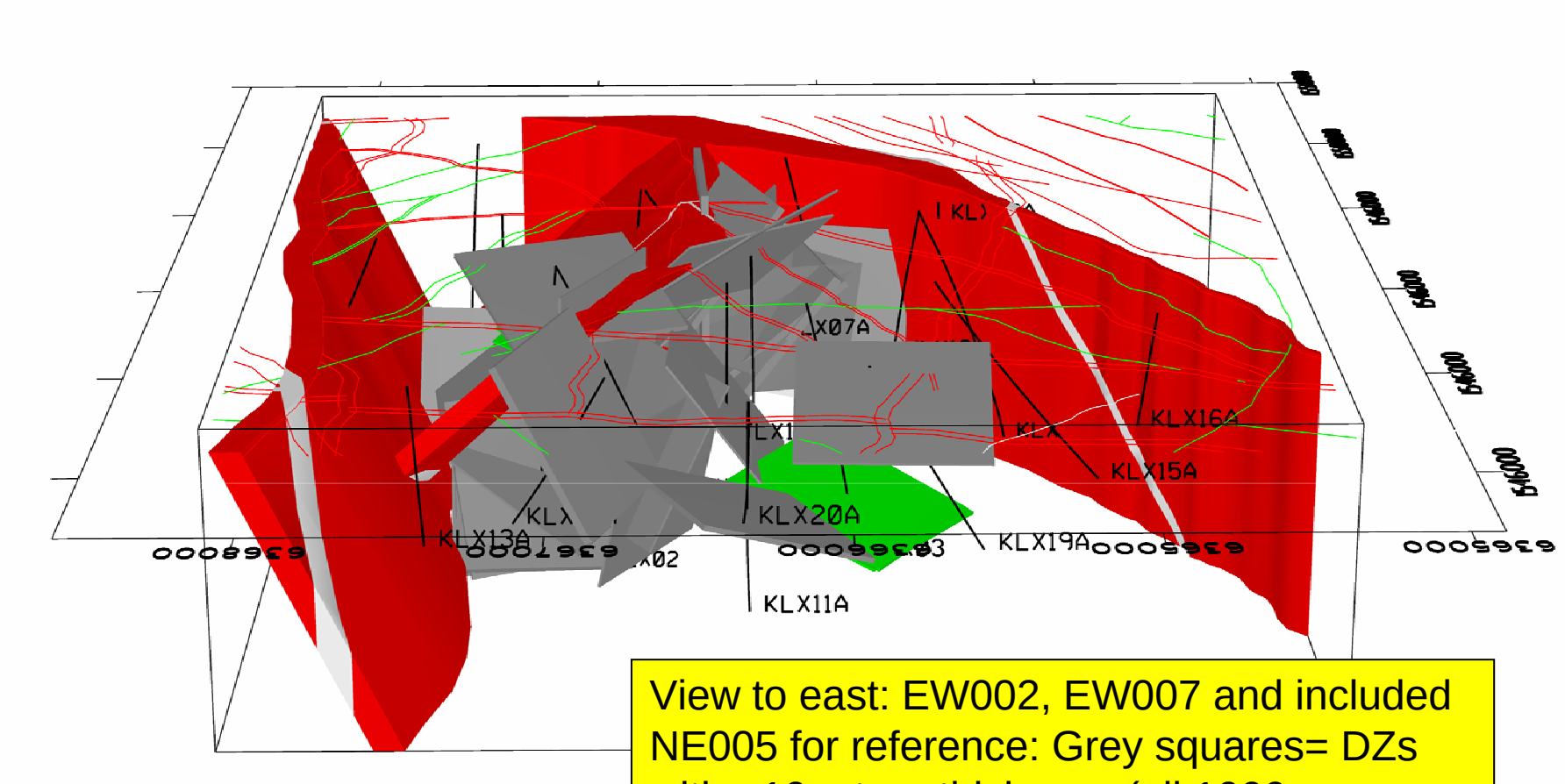
Procedure :

Give orientation and true thickness for all ESHI DZs. Any zone with a true thickness > 10m shall be included in the DZ model.

Any potential DZ from an ESHI, not already coupled to a lineament, will be modelled as a standard 1000m x 1000m square slab with applied orientation and true thickness.

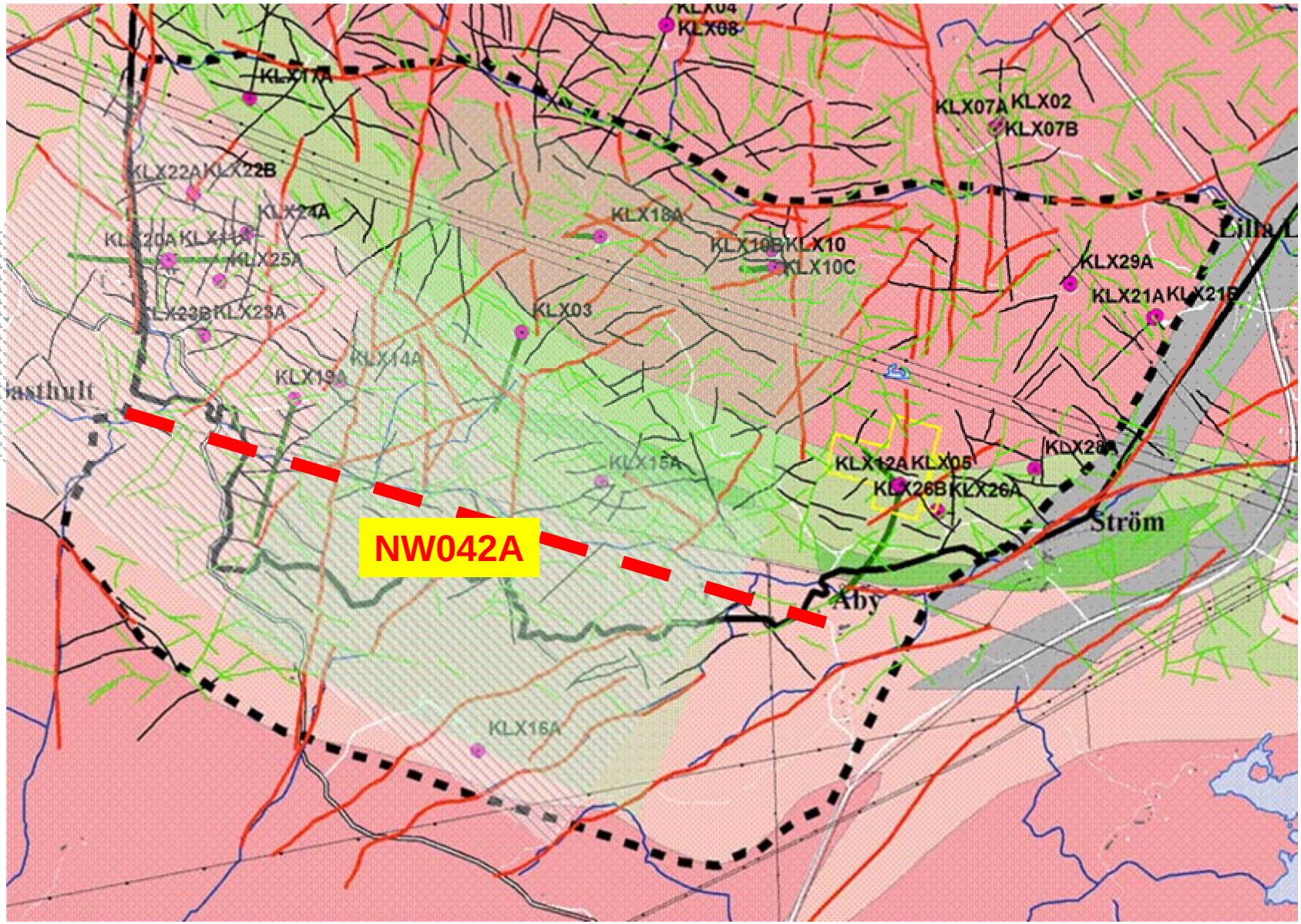
Generally, all such structures will have a high confidence in existence and low confidence for everything else.

L>1000 m DZs embedded in RVS



View to east: EW002, EW007 and included NE005 for reference: Grey squares= DZs with >10m true thickness (all 1000m x 1000m). Green = possibly part of M1 package

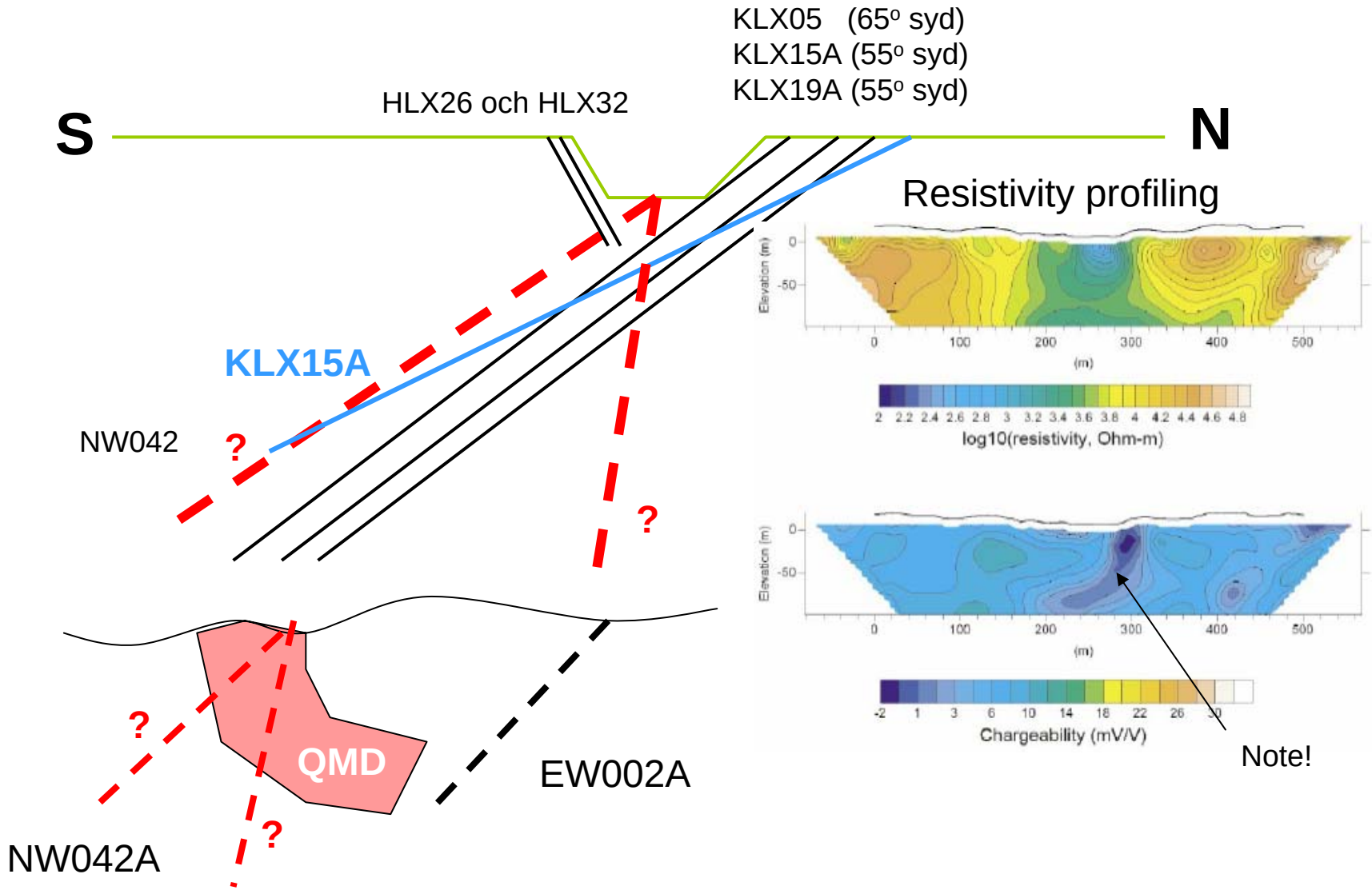
Principles for work on Layout D2



ZSMNW042A

Alternative geometrical models

KLX05 (65º syd)
KLX15A (55º syd)
KLX19A (55º syd)



Problem at hand and resolves

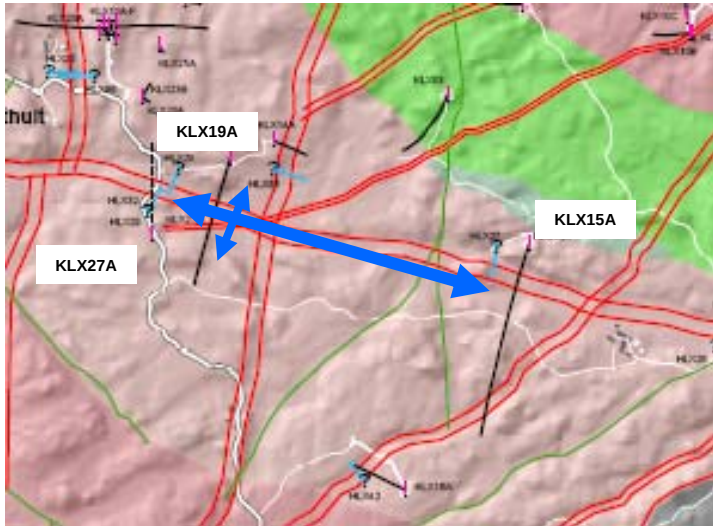
- Compilation and integration of available information show difficulties in establishing one well sustained geometrical model for zone ZSMNW042A.
- Two alternative models of the zone will be constructed and propagated through the modelling chain, including the hydrogeological flow modelling.
- The results from a well positioned verification borehole (KLX27A) can at a late stage be used to sustain preference of one of the model alternatives.

Deformation zones
Confidence and issues (prel)

- **Layout determining deformation zones**
  - High confidence in existence and location of larger (repository delimiting) DZs.
  - Area south of NW042A (new lineaments)
  - NW042A remains enigmatic! KLX27A!
  - Thickness-length relationship used to map out DZs of interest (L> 1000 m given by $2b_{lim}$ > ~10 m) in boreholes with associated geometry.
  - Relatively high uncertainty in properties (fracturing, alteration etc. (ie. heterogeneity) of DZs). Properties from ensemble statistics.

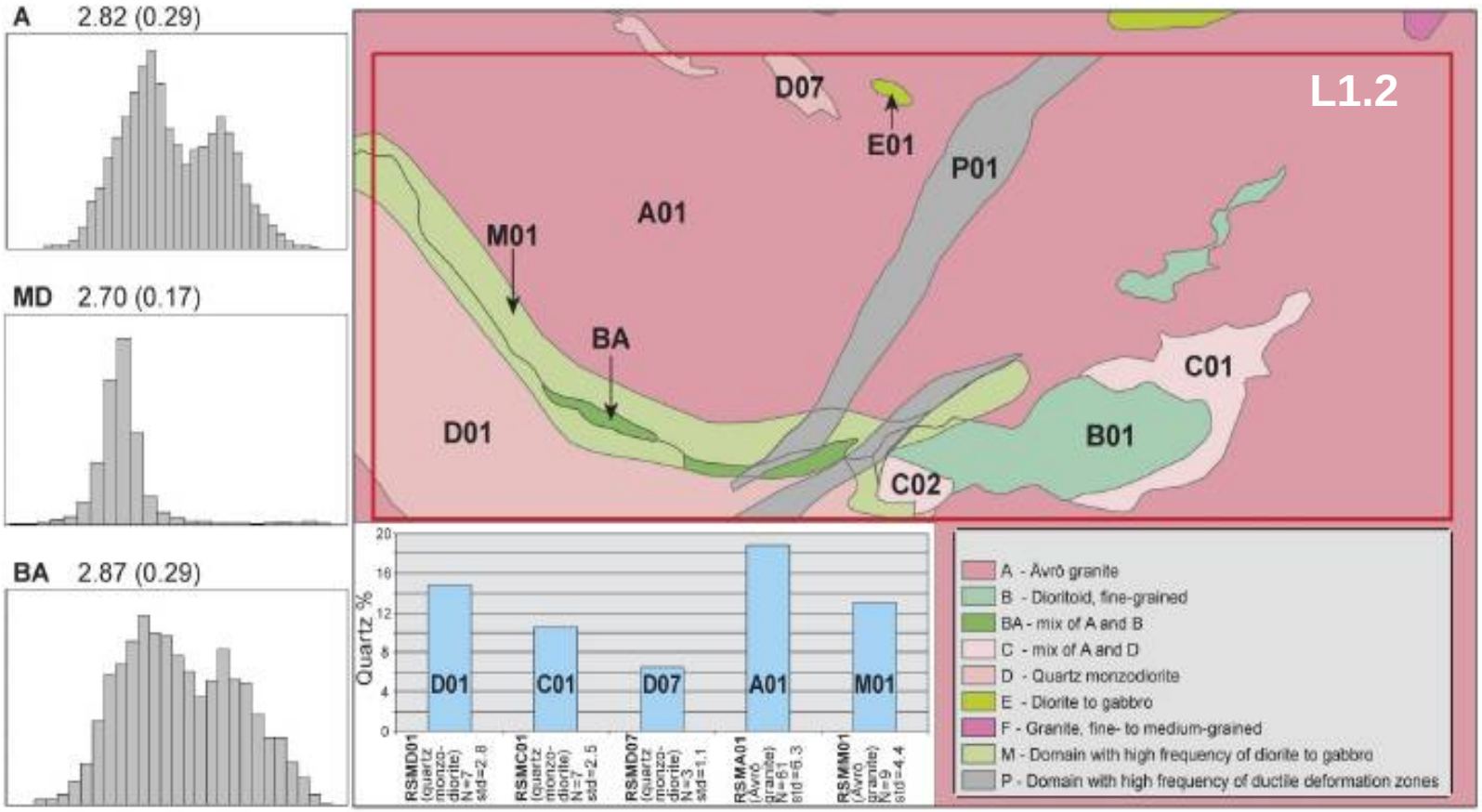
NEWS Flash! Oct 18

- Possible intercept with NW042A
  - Core of possible zone at c. 220-230 m (cf. photo).
  - POM prognosis based on interim DZ model is 157-203m (53 deg alternative)
- Drilling halted
- Intercepted zone currently subject to interference test!



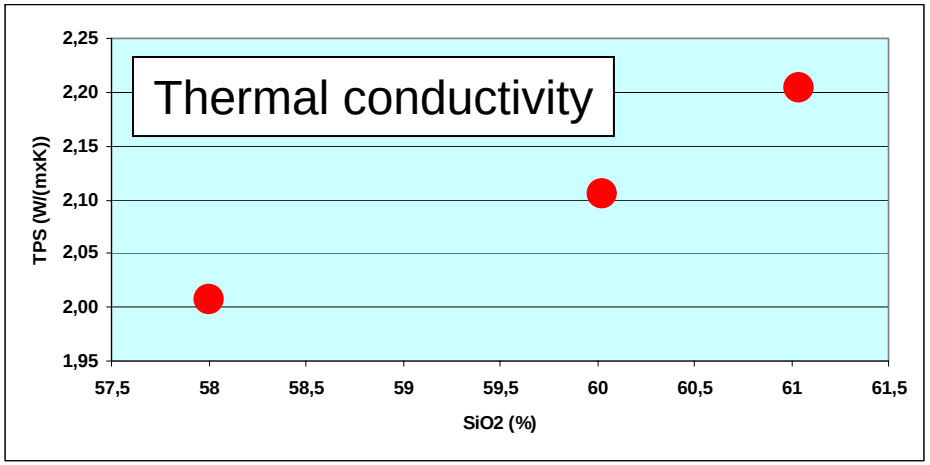
Thermal properties

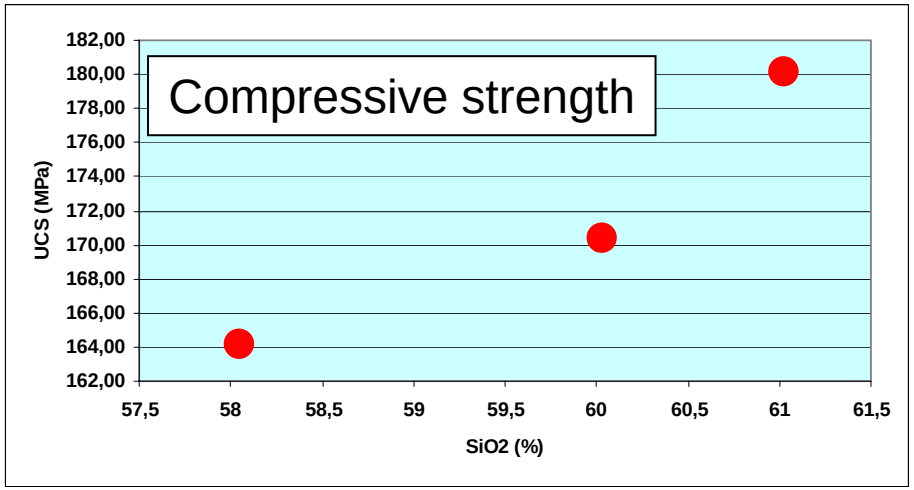
Rock domains with inter- and intra-variable quartz content and variable thermal conductivity



Mineralogy and its impact on rock strength and thermal properties

- A characteristic of the gabbroid-dioritoid-syenitoid-granite rocks of the Simpevarp area is their low quartz content
- The quartz content also shows a large variability with the lowest quartz content found in the diorite to gabbro (RSMBA) and quartz monzodiorite (RSMD) domains.
- The uniaxial compressive strength also depends on rock type and its quartz content.
- Likewise, thermal conductivity and heat capacity are closely related to mineralogical composition.





Data from KLX03

Thermal properties, Key issues

- 1. Uncertainty in thermal conductivity but possibly a bias in heat capacity data (inferred from Forsmark – to be explored!)
- 2. Representativeness of measurement data.
- 3. Uncertainties in the geological simulations, e.g. reproduction of typical length distributions for subordinate rocks: - related to the ability to model heterogeneity present. Representativeness of borehole data for domain M is also an important issue.
- 4. Uncertainties related to modelling spatial heterogeneity for thermal conductivity for certain rock types with large variability.
- 5. Suitable simulation scale / volume.
- 6. Anisotropy

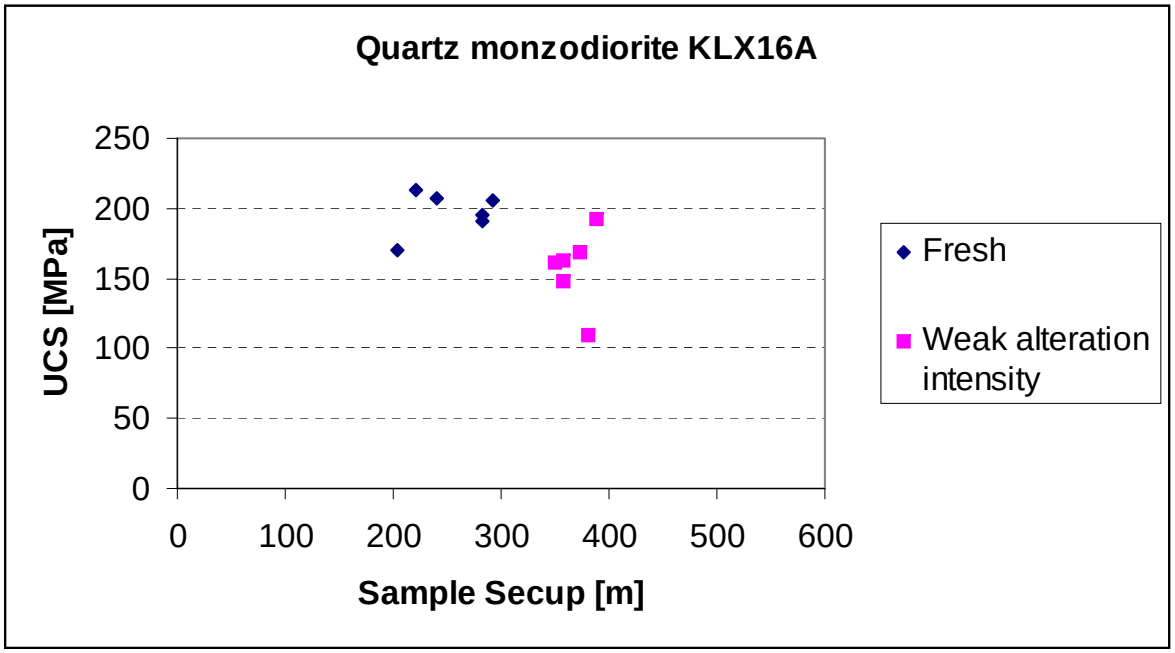
Provisional summary of rock strength

Summary of the results of the Uniaxial Compressive Strength tests (UCS) performed on intact rock samples from boreholes KSH01A, KSH02, KLX02, KLX03, KLX04, KLX08, KLX10, KLX11A, KLX12A, and KLX13A.

Rocktype	Number of samples	Minimum UCS (MPa)	Mean UCS (MPa)	Frequent UCS (MPa)	Maximum UCS (MPa)	UCS's Standard deviation (MPa)
Ävrö granite [1)]	46	151	186	184	239	19
Ävrö quartz monzodiorite [1)]	18	151	168	167	187	9
Ävrö granodiorite [1)]	28	175	198	196	239	15
Quarts monzodiorite[2)]	23	118	182	182	241	31

[1)] Ävrö granite (501044) is subdivided in Ävrö quartz monzodiorite (501046) and Ävrö granodiorite (501056).

Effect of alteration on rock strength

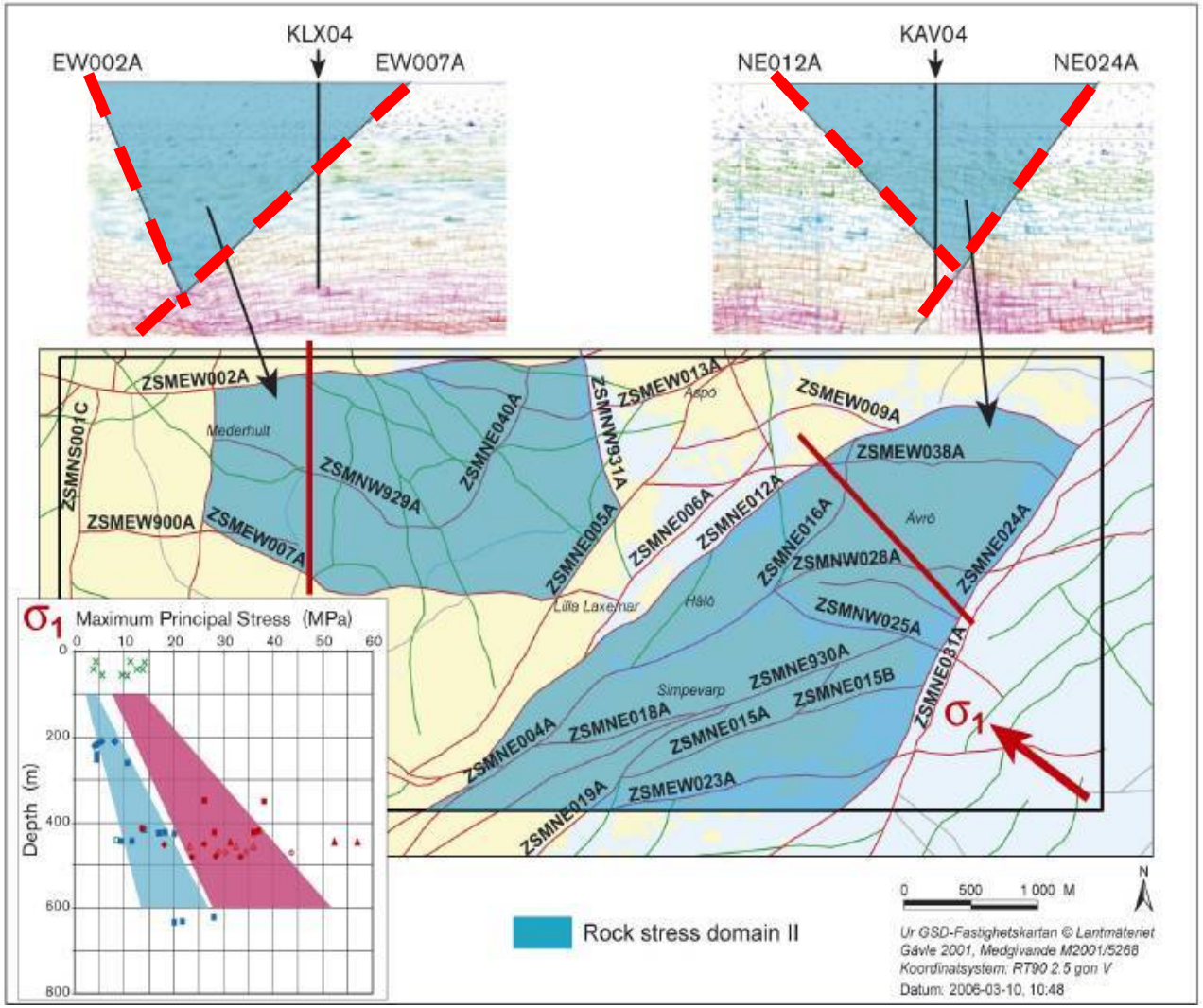


Uniaxial Compressive strength on Quartz monzodiorite (501036) based on samples from KLX16A

Mean for samples characterised by weak alteration is 80% (157 MPa) of the mean for fresh intact rock (197 MPa).

Occurence of weak alteration is not yet updated. Based on KLX03 (L 1.2) about 20% outside deformation zones.

Assessment of variable rock stress



Rock Mechanics
Key findings and issues (prel)

- **Stress**
  - Sigma-1 orientation is consistently oriented NW. Magnitudes are moderately high and increasing with depth. Stress magnitudes in KLX12 tentatively plot along the lower bound of L1.2 stress domain 1.
- **Intact rock mech. properties**
  - Depends on rock type and degree of alteration. Alteration gives reduced UCS and indirect tensile stress.
  - Low UCS of Ävrö quartz monzodiorite in relation to quartz monzodiorite is tentatively attributed to textural differences (larger grains in the former rock unit).

Overview of Hydrogeology modelling

- Primary data analysis for HydroDFN
  - Correlation of conductive features (PFL) with fractures mapped in Boremap
  - Statistics of conductive features, PFL transmissivity data (depth, rock domains)
  - Statistics of PFL data (5 m sections)
- Hydrogeological modelling
  - Effects of Äspö HRL on Laxemar situation
  - Sensitivity to chemical initial and boundary conditions
  - Surficial HydroDFN (KLX09x)
  - Assessment of regional scale boundary conditions
  - Preliminary HydroDFN SDM-Site (Ävrö granite)
    - Orientation distributions
    - Fracture transmissivity statistics

Hydrogeological data: Overview of boreholes contributing to analyses of hydraulic properties

Rock domain	Boreholes
RSMA01	KLX01, 02, 04, 07A, 07B, 08, 09. 09B-G, 10, 10B-C, 18A, 21B, 29A
RSMM01	KLX03, 05, 08, 10, 12A, 13A, 17A, 18A, 26A-B, 28A
RSMD01	KLX03, 05, 08, 10, 11A-F, 12A, 14A-16A, 19A, 20A, 21B, 22A-B, 23A-B, 24A, 25A

Total borehole ”meterages” of hydraulic testing in the rock domains defined by Geology:

RSMA01 : c. 5430 m (39 %)
RSMM01 : c. 2920 m (21 %)
RSMD01 : c. 5450 m (39 %)
Total : c.13800 m

NB. Lengths given include ESHI deformation zones.

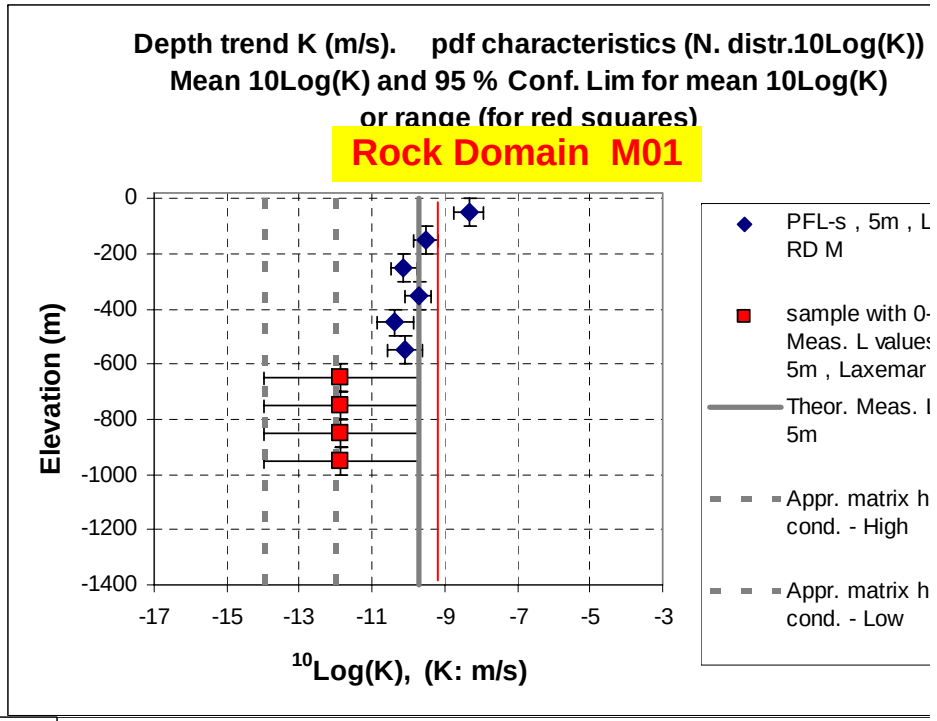
Long bh with PFL

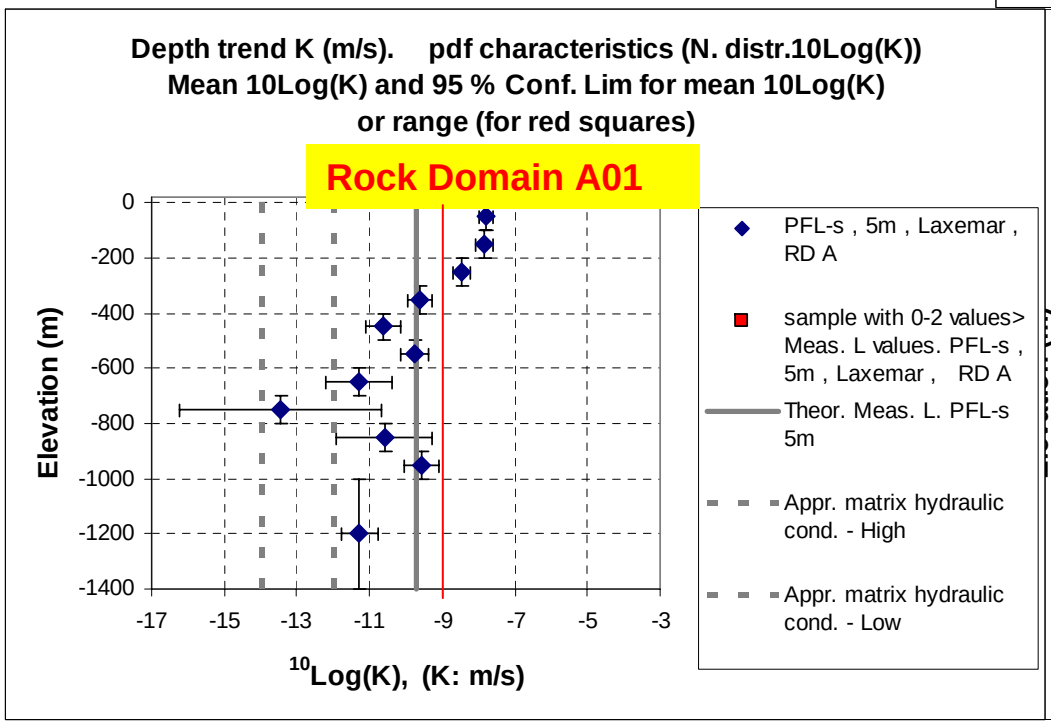
Long bh without PFL

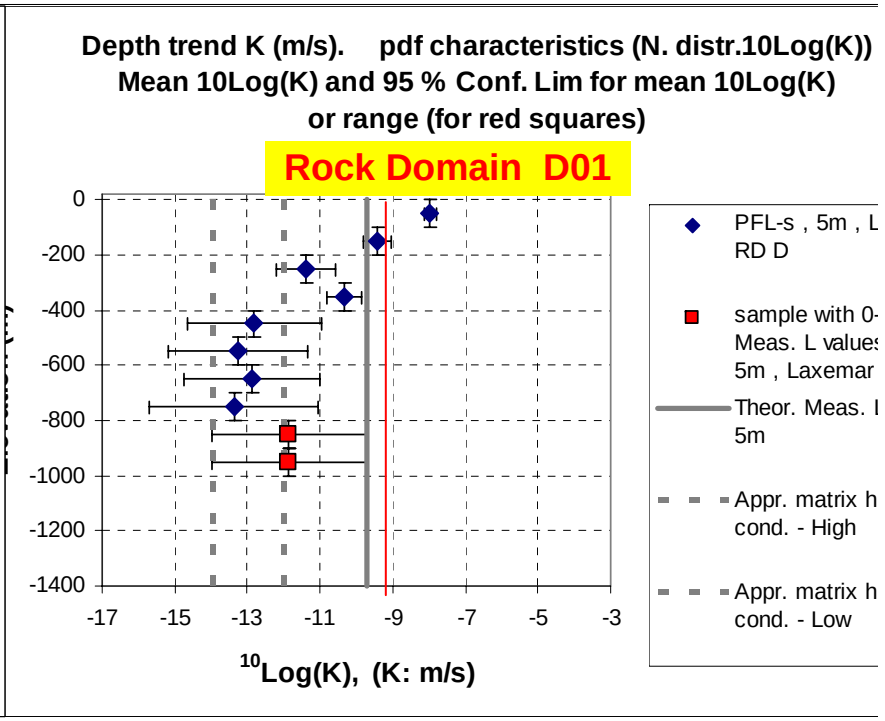
Short bh with PFL

Hydrogeological data: PFL-s (5m test sections)

- PFL-s data in the Laxemar subarea by depth
- Distribution Statistics for hydraulic conductivity presentd for 100 m depth intervals.



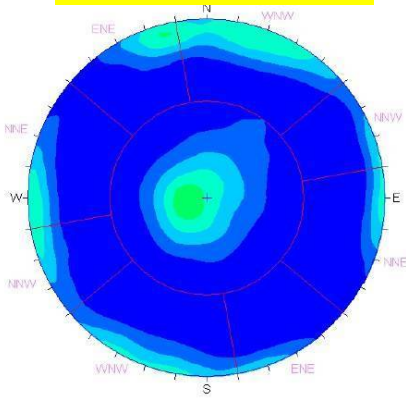




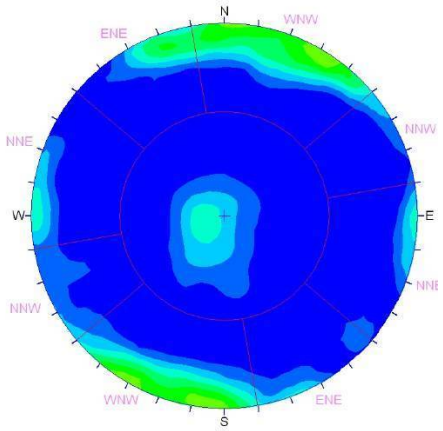
Prel. HydroDFN Ävrö granite

Terzaghi-corrected fracture intensity RSMA01

All fractures

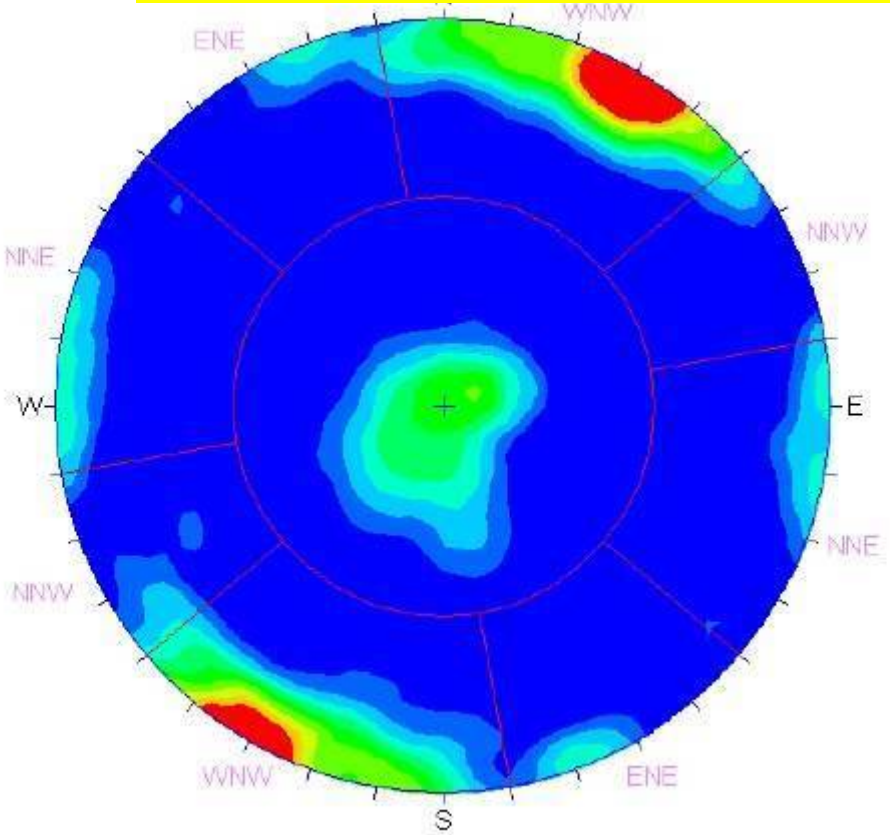


OPO-CP

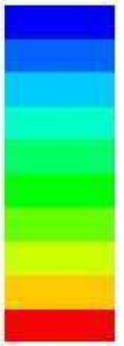


Equal Area
Lower Hemisphere
3444 Poles
3444 Entries

Conductive features identified from PFL



Fisher
Concentrations
% of total per 1.0 % area



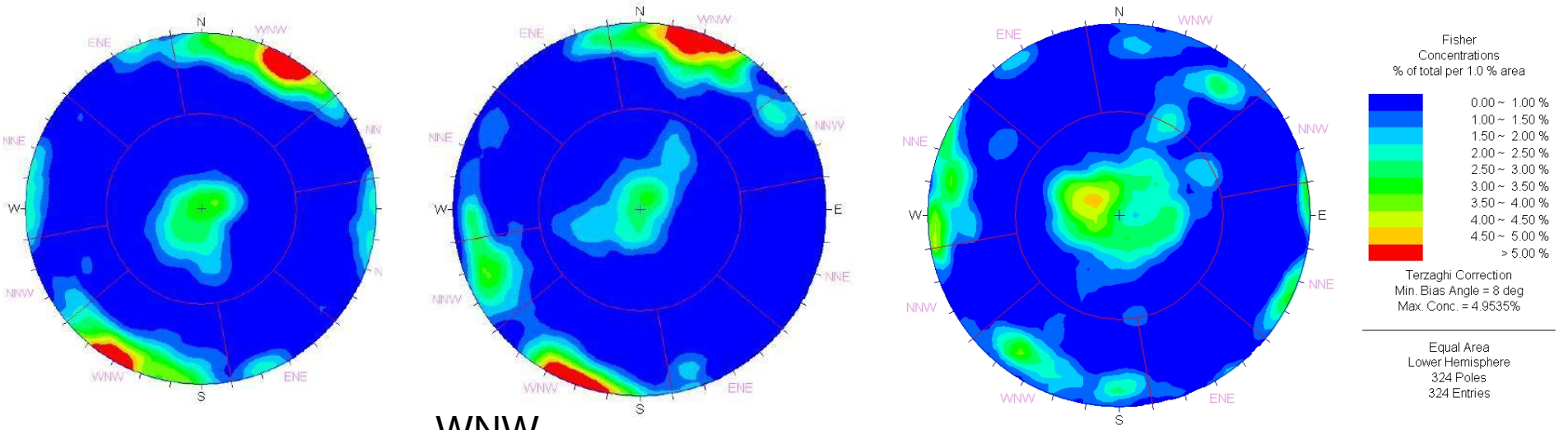
0.00 – 1.00 %
1.00 – 1.50 %
1.50 – 2.00 %
2.00 – 2.50 %
2.50 – 3.00 %
3.00 – 3.50 %
3.50 – 4.00 %
4.00 – 4.50 %
4.50 – 5.00 %
> 5.00 %

Terzaghi Correction
Min. Bias Angle = 8 deg
Max. Conc. = 7.8567%

Equal Area
Lower Hemisphere
996 Poles
996 Entries

Prel. HydroDFN Ävrö granite + QMD

Terzaghi-corrected fracture intensity
Conductive features identified from PFL



RSMA01

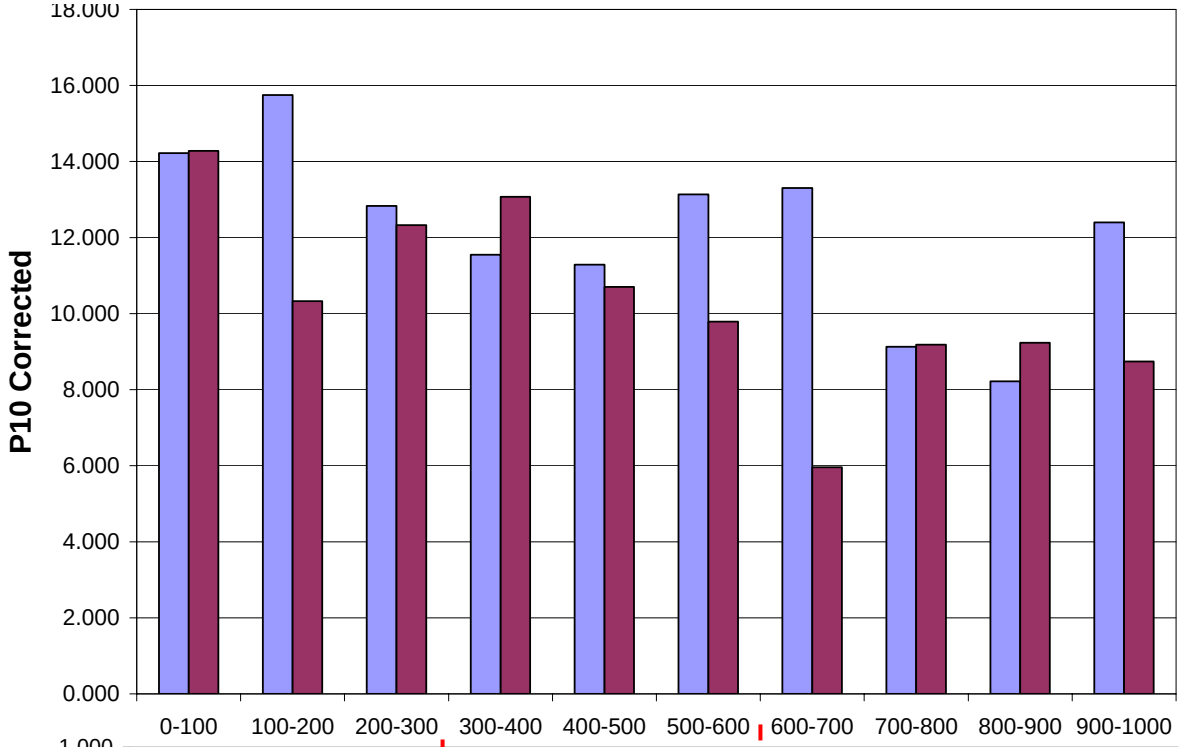
WNW
NNW
NNE
ENE
SubH

RSMM01

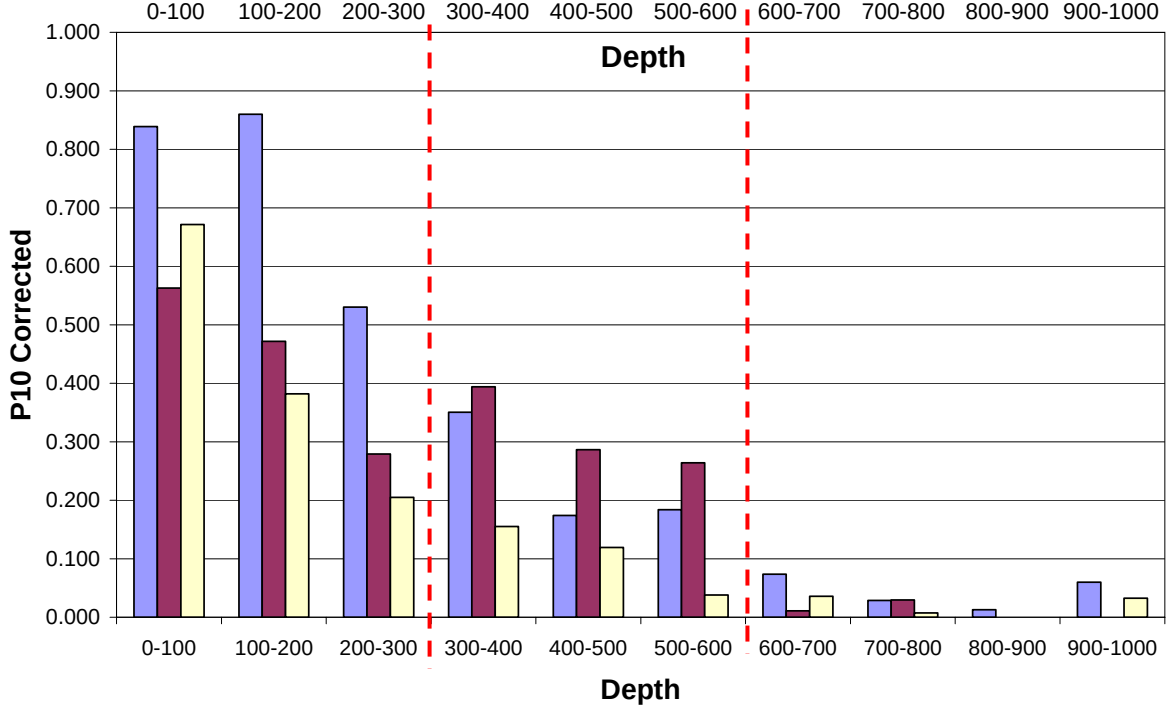
RSMD01

Provisional

Depth dependence in intensity



All fractures



RSMA01

RSMM01

RSMD01

Conductive features from PFL

Provisional

Summary of flowing fracture transmissivity statistics for the different rock domains. P10 corrected denotes the Terzaghi-corrected linear intensity [m-1]

Fracture Domain	Σ Borehole Length (m)	No. of flowing Features	Flowing feature frequency ($P_{10,PFL}$) (corrected)	ΣT/L (m/s)	Max T (m^2/s)	Min T (m^2/s)
RSMA01						
-200	1721	579	0.835	6.008E-07	6.760E-05	4.440E-10
200 - 600	3079	352	0.308	1.139E-07	9.860E-05	8.340E-10
600 -	1110	19	0.049	1.015E-08	7.836E-06	1.230E-09
RSMM01						
-200	951	215	0.501	5.957E-08	1.240E-05	3.140E-10
200 - 600	1987	257	0.313	1.836E-08	7.538E-06	3.310E-10
600 -	322	2	0.011	2.395E-10	7.400E-08	3.100E-09
RSMD01						
-200	1342	315	0.534	2.666E-07	4.240E-05	2.300E-10
200 - 600	1967	101	0.129	7.652E-08	7.791E-05	3.300E-10
600 -	1275	15	0.018	9.284E-10	4.380E-07	6.700E-10

Provisional

Provisional

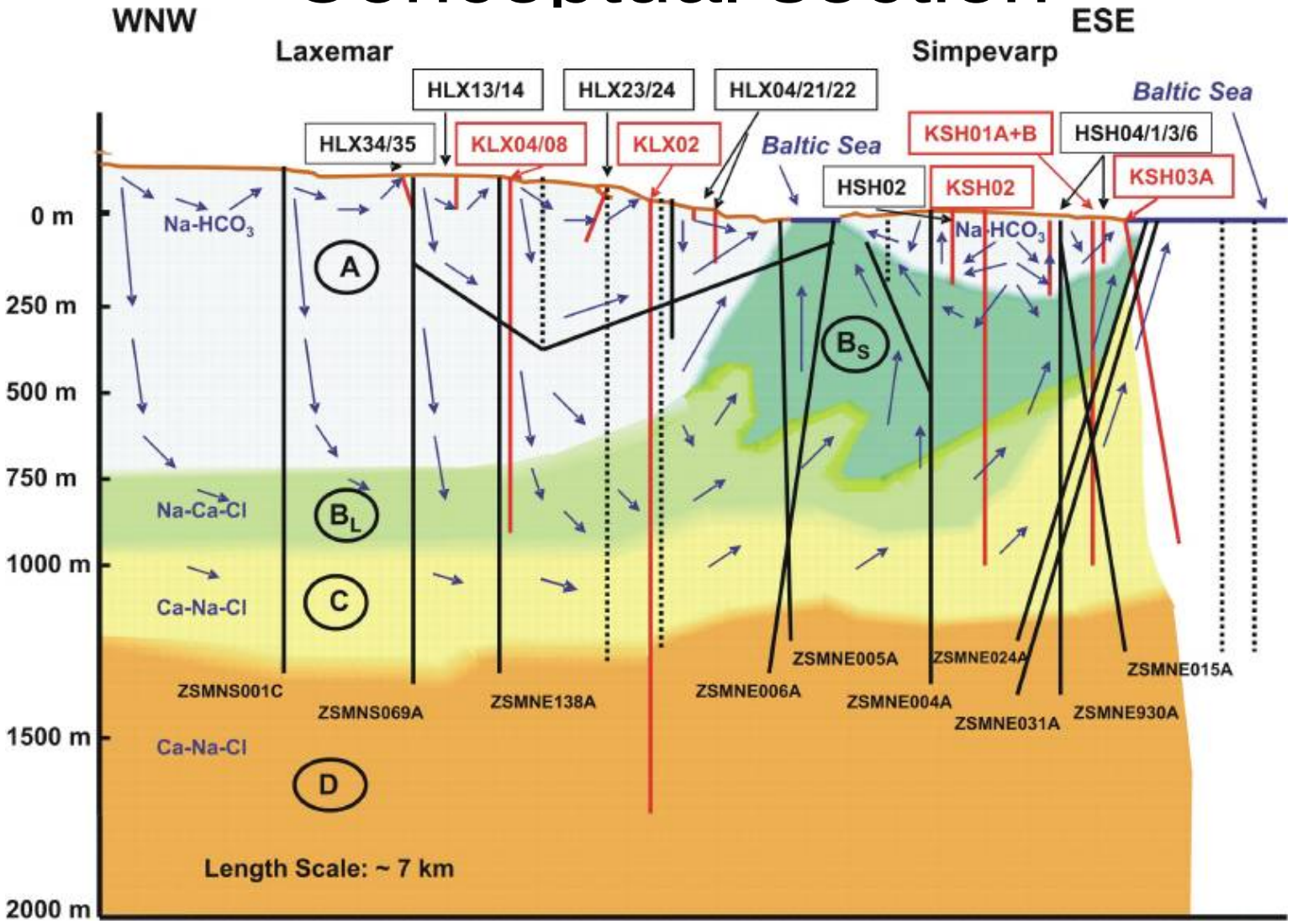
Summary of flowing fracture transmissivity statistics for the different rock domains. P10 corrected denotes the Terzaghi-corrected linear intensity [m-1]

Fracture Domain	ΣBH Length (m)	No. of flowing Features	Flowing feature frequency ($P_{10,PFL}$) (corrected)	ΣT/L (m/s)	Max T (m^2/s)	Min T (m^2/s)
RSMA01						
-200	1721	579	0.835	6.008E-07	6.760E-05	4.440E-10
200 - 400	1526	265	0.440	1.334E-07	3.985E-05	8.340E-10
400-600	1553	87	0.178	9.469E-08	9.860E-05	1.120E-09
600 -	1110	19	0.049	1.015E-08	7.836E-06	1.230E-09
RSMM01						
-200	951	215	0.501	5.957E-08	1.240E-05	3.140E-10
200 -400	1245	169	0.336	2.472E-08	7.538E-06	3.310E-10
400-600	742	88	0.276	7.679E-09	1.250E-06	3.890E-10
600 -	322	2	0.011	2.395E-10	7.400E-08	3.100E-09
RSMD01						
-200	1342	315	0.534	2.666E-07	4.240E-05	2.300E-10
200 - 400	947	66	0.187	1.342E-07	7.791E-05	7.190E-10
400-600	1021	35	0.076	2.298E-08	9.190E-06	3.300E-10
600 -	1275	15	0.018	9.284E-10	4.380E-07	6.700E-10

Hydrogeology
Confidence and issues (prel)

- Depth dependence and anisotropy seen (consistency with stress orientation).
- Differences in hydraulic properties between A, M and D noted! To be substantiated further!
- Possible fracture domains should be considered as an alternative to RD as a means of classifying data.
- Can hydrogeochemical support be established for less flow in D (southwest)?

Hydrogeochemistry
Conceptual section



Hydrogeochemistry
Confidence and issues

- Current distribution of groundwater composition
  - High confidence, many Class 3 samples
- Chemical processes
  - Clear evidence for redox reaction zone
  - More data (fracture fillings) - qualitative assessment of potential for ”non-dilute” waters
  - Essential to coordinate with surface system activities
  - Process controlled (thermal evolution) boundary conditions
- Detailed composition at repository depth
  - **Availability of Class 1 and 2 data – Is the database sufficient?!**
  - Are current uncertainties acceptable. Important to bound estimates given existing data and process understanding
- Pore water composition
  - Good data, also evidence of concentration profile in conjunction with conductive fracture (possible to assess matrix diffusion)

Bedrock transport properties
Key issues

- Effects of connectivity, complexity and channelling on distribution of flow (F-factor)
  - Scoping calculations show limited impact
  - Consider qualitative comparisons with tunnel data
- Matrix properties
  - Good data from all rock types (including altered rock)
  - Data may show whether important to distinguish (not likely)

Surface system
Interfacing rock and surface systems

- Upper bedrock hydraulic properties
  - Hydronet responsible – close interaction with Surface Net a must
  - Also a need for description to Repository Engineering to assess grouting designs
- Water flow in surface streams and brooks
  - Data quality problems
  - Needs to be resolved since water balance is a key calibration target

Overview of remaining critical issues

- **Ascertain sufficient description of hydraulic properties in deposition volumes**
  - T(RD), T(depth), T(L)
  - PFL(depth), PFL(RD)
- **Obtaining a satisfactory hydrogeochemical database (at depth in potential deposition volumes)**
- **Obtaining a better understanding of zone ZSM042A**
- **Confirmation of (hydraulic) properties of the quartz monzodiorite**

Summary comments on available databases at conclusion of CSI

- Databases for Geology, Hydrogeology, Rock mechanics, Thermal and Transport properties are deemed satisfactory
  - New data from KLX27A included to the extent possible. Possibility to a apply necessary weights on alternatives (NW042A)
- Hydrogeochemistry
  - Extended data freeze L2.3 (Nov 2007)
  - Additional sampling alternatives in existing installations being considered

End