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IMGS 2002 REPORT

The geological and structural characterization of the Olkiluoto site in a critical perspective

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In STUK this review process was co-ordinated by Kai Jakobsson

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Abstract

The proposed nuclear waste repository is to be constructed at Olkiluoto which is situated on the Precambrian rocks of the Fennoscandian shield. The rocks are made up of a complex mix of meta-sediments and meta-igneous units that have undergone several episodes of metamorphism and tectonic deformation. The latter have resulted in the formation of a variety of planar features including a regional fabric, ductile shear zones, fracture zones and discrete fractures. It is within this poly-metamorphosed foliated and fractured rock mass that the repository is to be sited.

In order to position the repository appropriately it is necessary to determine the geometry, spatial organization and properties of these zones of weakness and the properties of the intact rock.

This report critically examines the procedures and techniques used to determine these various parameters and the rational behind the proposed location of the underground rock characterization facility (ONKALO) and its access tunnels and shafts.

Particular attention is given to understanding the current stress field operating in the rock, the effect of the zones of weakness on the stress orientation and the confidence levels with which the position, geometry and properties of the major planar zones are known at the depth of the proposed repository.

Preface

Spent nuclear fuel from the Finnish nuclear power plants will, in accordance with the Nuclear Energy Act, be disposed of in domestic bedrock. The Finnish Government has made a decision in principle (the decision in principle by the Government on 21 December 2000 concerning Posiva Oy's application for the construction of a final disposal facility for spent nuclear fuel produced in Finland), which Parliament ratified in 2001, on the disposal facility to be located at Olkiluoto in the municipality of Eurajoki. The next milestones for the Research and Development program are attaining the preparedness for the submittal of a construction licence application in 2010.

Posiva has carried out field investigations in Olkiluoto since 1988 and the outcome of these investigations in essentially summarized in a structural bedrock model. The construction of Underground Rock Characterization Facility (URCF, known as ONKALO) in Olkiluoto is the final phase in the long sequence of site selection work. Parts of the URCF can later be used as part of the auxiliary space of the repository itself, if appropriate.

General guidelines and decisions on the regulatory aspects concerning the final disposal are given in STUK's Guides YVL 8.5 (STUK, 2002) and YVL 8.4 (STUK, 2001). Also the 'Decision in Principle' (DiP) contains (in its arguments) some general views on the repository itself, repository depth for example.

The research work and scientific investigations at Olkiluoto by Posiva have been evaluated and criticized recently by groups of international experts (1999 and 2001).

In STUK this review process was co-ordinated by Kai Jakobsson.

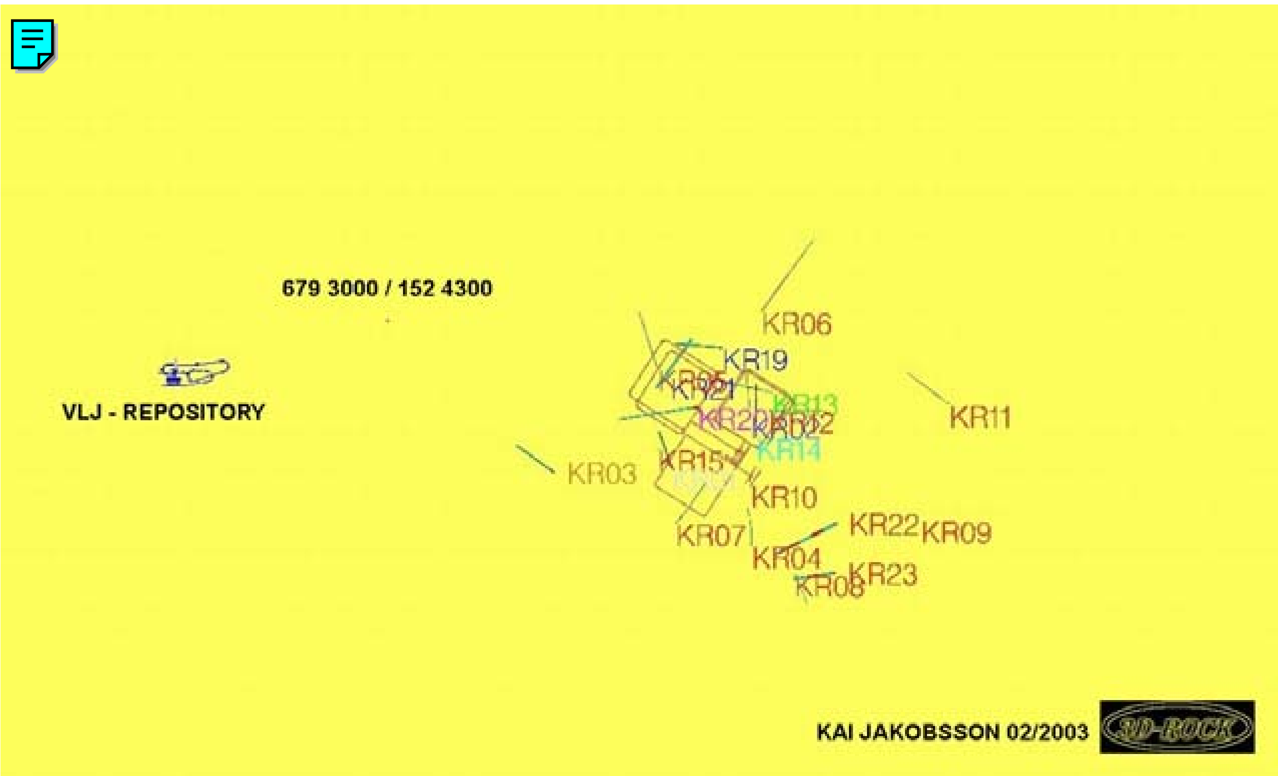

Figure 1. Location map showing the Island of Olkiluoto, the power plant and the cluster of borehole localities at the proposed repository site.

Contents

1 Background of IMGS group

The Support group for the Investigations and Modelling of Geological Structures, (IMGS) is one of four support groups set up by the Radiation and Nuclear Safety Authority (STUK) in connection with its regulatory activities related to the underground rock characterization facility to be constructed in Olkiluoto. The group was formed in the spring of 2002 and the first meeting was held in Turku in June 2002. The second meeting took place at the same venue in December 2002.

The interests and concerns of the IMGS group are, in practice, divided into two main areas. The first relates to the geological modelling and investigation of the Olkiluoto area, the proposed site for the construction of a nuclear waste repository. This covers the approach used and methods adopted to study the site at Olkiluoto. The second and related area of interest relates to the planning of the ONKALO facility including the locations of access ways, the preliminary design and the need for complementary investigations with respect to the existing structural model.

The group's working plan for the year 2002 included two meetings in Finland, a review of reports submitted by Posiva, and the writing of a review report before the end of the 2002 for STUK. In the request for an offer sent to the group members, specific requirements were itemised. These included a study of the updated bedrock model of Olkiluoto and of the optional access ways.

The group members are expected to evaluate the results of the investigations with respect to the structural model and to discuss and report their findings in a working meeting to be arranged during the last quarter of the year 2002. The group is unhappy that only a few of Posiva's reports are in English with the result that only these are accessible to foreign members of the group. In addition, the timing of the delivery of the reports is not well organised. Information often arrives too late for feedback from the ISGM group (or STUK) to have any impact on decisions.

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2 Introduction

As a result of discussions between members of the group at the group meetings in June and December 2002 at Turku, the review of various Posiva documents and the attendance of the group at two presentations by Posiva at Olkiluoto, a variety of topics relating to the construction of a repository have been considered. As a result of these deliberations nine main areas of concern were identified:

1. Homogeneity
2. Sampling problems
3. Geometric control of structures
4. Characterization system
5. Geological and Structural evolution – Stress State
6. Variability versus uncertainty in data
7. Baseline problems
8. Design and Modelling of ONKALO
9. Structural model

From a structural geology point of view the problem of building a repository at Olkiluoto is one of constructing an underground facility in a stressed rock mass containing important features which are likely to locally modify the stress field. The better the understanding of the stress state in the rock the better will be the modelling of the effect of constructing the underground repository and of predicting the behaviour and modified properties of planar features which either cut or bound the proposed repository volume.

It is reasonable to assume that the current state of stress in the rock is the combined result of the current regional stresses effecting the Fennoscandian Shield, the residual stress left in the rock as the result of previous tectonic events and the stress generated as a result of uplift of the crust in response to the removal of the glacial overburden.

The current stress field will be modified by local structures, particularly fractures and fracture zones and an understanding of how these structures influence the magnitude and orientation of the stress at Olkiluoto is an essential prerequisite to the design and lay- out of any underground facility.

Posiva's site characterisation program contains efforts to assess the intrinsic rock properties and the properties of the fractures and fracture zones. Key properties such as the bulk shear strength of a fracture zone are notoriously difficult to measure directly but they can be accurately deduced from the effect that the structure has on the stress field. We would therefore recommend that a detailed study of the stresses in the rock mass at Olkiluoto be carried out.

3 Bedrock model of Olkiluoto

The Fintact Company has developed for Posiva a structural bedrock model of the proposed repository site to represent the spatial organisation of the geological, geophysical and hydrological data collected from the boreholes drilled in the study area at Olkiluoto. The data is presented in Posiva's working reports. The structural model is presented in 3D and in selected cross-sections.

The simulated designs of ONKALO, used as reference in the IMGS-group's work have been created by Kai Jakobsson using STUK's 3D-ROCK modelling tool. The rock structures presented in the model originate from Fintact's structural model, versions 2001/1 and 2001/2. This model has the capacity to include all the structural and borehole data available and for exploring the implications of the various possible positions for ONKALO and the various options of access tunnels and shafts.

Collaboration between Kai Jakobsson and Jarkko Jokinen in a project entitles 'Focused Modelling' has enabled us to maximize the use of this model in our attempt to understand the structure at Olkiluoto. This modelling approach has the advantage of being relatively simple and quick to use. New information coming from the program of research related to the construction of the repository can be feed into the model and results regarding its implications quickly obtained. These can then be compared with the results from Posiva's model to see if there is agreement and if not to explore the reasons for the discrepancies. This modelling facility has been an invaluable help to the group and is an essential check on the model used by Posiva. However, it is a disadvantage for the IMGS group not to have access to the original Posiva model in a digital format.

Posiva have initiated research programs relating to, amongst other things, the lithological structures, the regional lineaments, the geological structure and the geological evolution of the area. However, all these data have not yet been incorporated into the Posiva bedrock model which relates to only a small area in the immediate vicinity of the proposed repository site. For example the study of lineaments using aerial photographs has identified important lineaments close to but not within the modelled region.

The modelling is focused on major fracture structures and weakness zones. The location of these structures will enable intervening areas of relatively homogeneous rock to be identified. It is planned to locate the ONKALO facility and, later, the repository for nuclear waste within these structure-free zones, but to retain the possibility of perforating any of the major planar weakness zones should it be safe to do so in order to characterise them. The main idea is to locate the repository tunnels in the intact rock in between the weakness zones. The volumes of 'homogeneous' rock bounded by the interpreted zones of weakness are not presented in the model.

Inspection of the bedrock model shows an almost random positioning of the boreholes. The planning of the borehole program is not obvious. In order to obtain a good understanding of the geometry, orientation, location and lateral extent of the major planar zones of weakness a systematic borehole program should be planned.

The Bedrock model is based on borehole and surface data. All data have a degree of uncertainty and natural structural discontinuities are characterised by variations in both dip and strike. It follows that the model presented is only one of a range of possible geometries. The level of confidence of the model relates directly to the accuracy with which the data are known. The accuracy of the dip readings of fractures and fracture zones is not given, and it follows therefore that the accuracy of the model is not known.

4 Comments regarding bedrock modelling of the Olkiluoto site

4.1 Homogeneity

The group have questions and comments relating to the homogeneity of the bedrock.

i) Homogeneity on a regional scale

- Is it possible to outline the borders of a 'homogeneous' area (i.e. an area similar in tectonic style and rock types [especially when considering ductile to semi-ductile deformation]) to which the Olkiluoto island belongs?
- A regional lineament interpretation is based on topographical data. Dip values of tectonic structures corresponding to the lineaments are given in working reports printed in Finnish (e.g. Posiva Working Report 96-28).
- Are some brittle structures related to the ductile deformation structures and is the overprinting of brittle structures evenly distributed in the immediate surroundings of Olkiluoto?

The structures that are most important from the point of view of designing a repository are the brittle structures ,some of which started as ductile structures. An understanding of the evolution of the fracture network that occurs in the bedrock at Olkiluoto and of the way these fractures and fracture zones interact to modify the local strength and stress state within the proposed repository volume is of key importance.

Events that may have contributed to the brittle structural pattern at Olkiluoto include:

- Intrusions of the rapakivi granites
- Large scale block faulting
- Reactivation of WNW-ESE to NW-SE trending faults
- Glacial and post-glacial adjustments

There could be a need for the use of an intermediate scale model of the site. Such a model proved very useful in the study of the relation between regional and local structures at Äspö, southeastern Sweden. However the group note that Posiva's 'Regional Model' approximates well to an intermediate scale model and that what is really needed is a better integration between the large-scale geology and the tectonic structures and the geology of the repository volume.

ii) Homogeneity on site scale

Site-scale homogeneity impacts directly on the problem of the location of the ONKALO facility within the proposed repository volume on Olkiluoto Island. If the rock in this volume is homogeneous then the location of the underground facility at its centre would seem reasonable. However, discussions at Olkiluoto during the presentations and the data made available to the group in the various Posiva publications, indicate clearly that the proposed repository volume is unlikely to be homogeneous. Nevertheless it is still planned to place the ONKALO facility at the centre of the volume. The arguments supporting this decision were not made clear. In addition it was noted that if the inhomogeneity of the volume has not been quantified then it will be difficult to assess whether the rock outside the ONKALO will have similar properties to those that at the ONKALO site.

Knowledge of the detailed internal variations within the repository volume depends upon:

- Information density (Sampling performance should be considered in relation to the geometrical framework of the structures in the rock.).

In addition attention should be paid to:

- Resolution and scale (What type of structures will have an influence on the layout of the repository?).

A comparison of the local structural pattern and the regional structural framework of a study area is often fruitful. However, this conformity apparently does not hold at Olkiluoto. The fracture pattern outside the mapped blocks (in sound rock) and the geometry of fracture zones are different.

4.2 Sampling problems

A clear understanding of the geological and structural history of an area gives information about the probable geometry and orientation of structures (both ductile and brittle) likely to be encountered. However, the precise location of a structure can not usually be predicted from the structural history. In order to determine this, detailed observations and data collection (e.g. field measurements, remote sensing, borehole core and borehole wall analysis) are required. The group have tried to determine whether these data are representative or biased.

The following comments and recommendations relate to sampling on both a regional and local scale.

i) Regional to local scale

The regional structural pattern is described in Posiva's Working Report 96-28 (in Finnish). Some ductile shear zones (ENE-WSW) are shown but other weakness zones may not have been recorded (i.e. sampled) if for example they are not made apparent by the offsets of some marker and where there are only minor differences in the geophysical properties between the zone of weakness and the wall rock.

ii) Local scale

The group notes that the borehole configuration of the site is dominated by boreholes trending approximately N-S /various plunges (N and S). There are only a few boreholes oblique to the general N-S borehole orientation. The drilling program seems not to have been linked to or constrained by the expected structure in the area.

The majority of the structures at the Olkiluoto site are only penetrated by a single borehole and only a few structures are found in two or more boreholes. The latter are the moderate to gently dipping zones. The formers are more steeply inclined and may hydraulically connect the low angle zones. The present borehole configuration may result in an underestimation of the importance and character of the steep structures and a low density of information on their properties. The boreholes are consistently steeply inclined. A future borehole programme should be planned in relation to the structural framework of the site to optimize the usage of further borehole investigation.

In view of the importance of understanding the internal structure of the proposed repository volume the group asks for a systematic detailed characterization of structures by mapping. This can be done along a sequence of trenches transecting the structures. This information is important when attempting to correlate structures from surface to boreholes and between boreholes.

The bedrock could also be exposed along two orthogonal trenches intersecting at the boreholes. Together with the borehole the trenches will represent a tri-axial mapping configuration that will enable the construction of a 3D representation of the structural pattern in the bedrock adjacent to the borehole. Of special interest are structures in the bedrock adjacent to the identified zones of weakness and the structural patterns within these zones. This information might help in understanding the hydraulic character of these extensive zones.

At the presentations in Olkiluoto the hydraulic character of the modelled structures (planar zones of weakness) was not discussed in any detail. The modelled structures were detected and classified primarily on the basis of fracture density and geophysical logs rather than on the basis of their hydraulic characteristics.

It would be worth carrying out tests to identify the water conductive structures (i.e. discrete fractures and fracture zones) and present a model showing the groundwater pathways in the bedrock. All structures could be included within the same model (structural database) and structures of certain characteristics could be selected and shown.

The geology of an area represents the combined effects of burial, diagenesis, tectonic deformation (often several separate events) and finally uplift and erosion/denudation. Geological data collected in the field may relate to any of these events. It follows from this that a good understanding of the geological and structural evolution of the region would be of great help (i) in organising the structures (and their associated data) chronologically and (ii) in the processing and analysing of these data.

4.3 Variability versus uncertainty in data

At the presentations in Olkiluoto the natural variation in appearance of structures was not well considered. A control on the natural variation in geometry and mechanical properties of a structure, (in the present example a fracture or fracture zone), improves the accuracy with which it can be modelled.

The group note that the uncertainty of recorded and delivered data can be large and that this needs to be recognised and quantified as much as possible.

The uncertainties are related to:

- Method limitations (e.g. the detection of a structure by the borehole radar is related to the angle between the structure and the borehole. What are the uncertainties in the measuring procedures?) and,
- Circumstances influencing the data recording and data treatment (e.g. the absolute orientation of a structure detected by borehole radar is mainly related to the skill of the interpreter of the radar data, the accuracy of the applied velocity of the radar ray and the accuracy in the location and orientation of the borehole).

With regard to uncertainties related to structural data, there are two parameters that are of particular interest, namely:

- Orientation
- Location

Uncertainties in these parameters markedly influence the accuracy linked to the extrapolation of structures.

The treatment of uncertainties was not presented at the meetings.

Extensive work has clearly been carried out in order to depict the fractures bordering the rock volume needed for the disposal site. The modelling is based on the different types of data collected continuously over a period of several years using a variety of geophysical methods. Geological data collected in boreholes is also included. Without knowing the reliability of the various techniques used to measure and gather the data it is difficult to know how reliable the results of the different models are. Since the data have been gathered over a long period of time, it is very unlikely that the results are directly comparable with each other. The models show that some of the structures are only cut by one borehole and there are examples of 'blind' structures i.e. structures that are not penetrated by any borehole.

STUK's 3D modelling tool (see section 3) has been used to look at the predicted orientation, position and geometry of the important planar structures (R structures) and to see how this is modified as new data become available (e.g. Fig. 2). The changes that occur are a direct indication of the confidence level that can be attributed to these parameters.

In short the group was concerned with the confidence levels of the data used in the modelling. We did not receive any estimate on the accuracy of the measurements and/or observations of the original data. The question of reliability and repeatability of the data used is of high importance.

4.4 Geometric control of structures

A description of the regional distribution of rock types and structural pattern has recently been reported (Paulamäki et al., 2002; Posiva 2002-04). The regional structural map they present is however a little too course to enable a useful comparison to be made between the regional pattern and the structural pattern within the Olkiluoto site. The group would recommend that the resolution of the regional map be increased and asks:

- How has the context of the regional geological and structural setting influenced the modelling of the Olkiluoto area?
- Why have the geometrical forms (the internal pattern of fracture zones and the geometry of the adjacent damage zones) not been used as 'structural indicators' in the local modelling of structures?

Detailed information concerning the geometry of structures (patterns within the various 'planar structures' and within the adjacent damage zones) and the geometric variations along strike and down dip are of fundamental importance when planning the location and orientation of the ONKALO. This is particularly true of structures which either lie within the repository volume or act as boundaries to it.

One of the most important structures is the low angle planar structure R21 which acts as the lower boundary of the repository volume. This structure outcrops outside the site and it is recommended that a detailed field examination is made of this in order to better understand the basic geometry and variations in geometry that occur along this feature. This knowledge is important when attempting to confirm the position and the geometry of the structure in both the 3D bedrock model and especially directly beneath the repository volume.

4.5 Characterization system

The characterisation of the rock mass and particularly the R-structures is based on a 30 year old system. This does not provide the key parameters (i.e. the rock properties) necessary to give the model a predictive capability or provide the data needed to push the study of the proposed site forward by numerical modelling. (See also section 4.9)

4.6 Geological and Structural evolution – Stress state

The general geology of the Olkiluoto area is quite well known, a result of several years of active field and laboratory work. The rock types, their age of formation and metamorphic history have been established and the tectonic and structural features have been mapped.

A dynamic geological and structural evolution of the bedrock in SW Finland has very recently become available (Posiva 2002-04). A number of comments, requests, questions and recommendations arise regarding this paper and its conclusions:

- The relationship between the ductile structures (folds and shear-zones), dykes/veins and the fracture system could be more clearly expressed.
- The group would appreciate a better subdivision of the post-ductile fracture system.

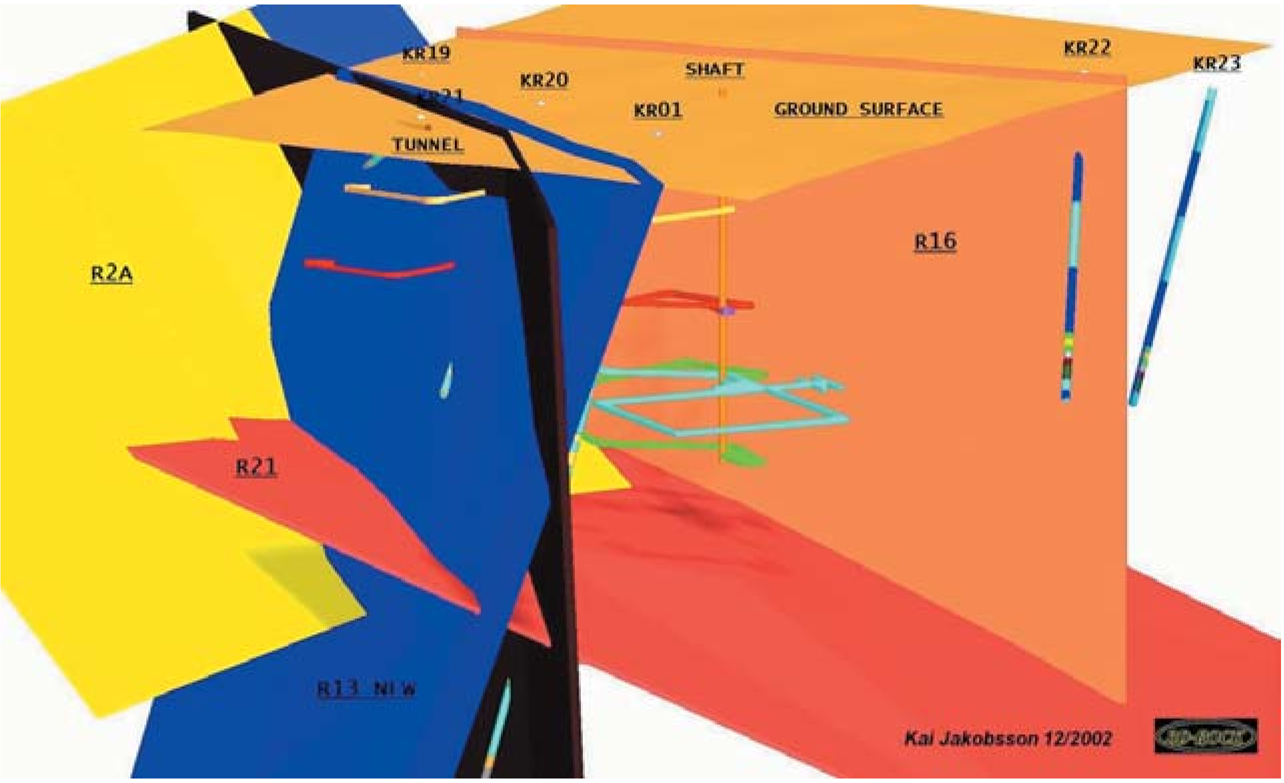

Figure 2. An illustration of how the understanding of the position, orientation and geometry of one of the major planar zones of weakness (R13) changes as the data base improves The Black plane shows the structure as predicted from the bedrock model 2001/1 and Cyan plane shows its position, orientation and geometry in a later bedrock model (2001/2).

It is argued that late potassium granites were emplaced during D3, a phase of regional folding:

- Did the intrusions occur along the axial plane fabric of these folds?
- Could the D3 shears have been exploited by subsequent intrusions?

The group feel that we should capitalise on the geological studies already carried out and attempt to use it to determine the stress history of the repository site. This should act as the foundation on which to build a better understanding of the distribution of stress at Olkiluoto and more specifically within the proposed repository site.

As noted earlier the state of stress in the rock at present will be a combination of:

- The current regional stress
- The residual stress
- The stresses induced as a result of glacial rebound.

This stress field will be locally modified by the 'major planar structures' in the rock and the amount of modification will be determined by the difference between their shear strength and that of the host rock.

There are several types of planar structures in the vicinity of Olkiluoto. These include:

1. The large-scale fractures which are clearly delineated on the lineation map. These fractures control the present shape of the Island and the coastline in general.
2. The 'pervasive' regional foliation.
3. The 'fracture zones' (the R-structures) recognised in the site investigation, which have been used to define the boundaries of the 'homogeneous' block at the centre of Olkiluoto Island in which the proposed repository is to be built.

An understanding of how these structures influence the magnitude and orientation of the stress at Olkiluoto is an essential prerequisite to the construction of any underground facility. The influence that these structures have on the local stress field is determined primarily by the difference in shear strength of the rock and of the fracture zone. A study of the stress distribution in and around these structures will therefore help quantify these important properties.

It is also important to recognise that the presence of fluids and fluid pressures in the rock are

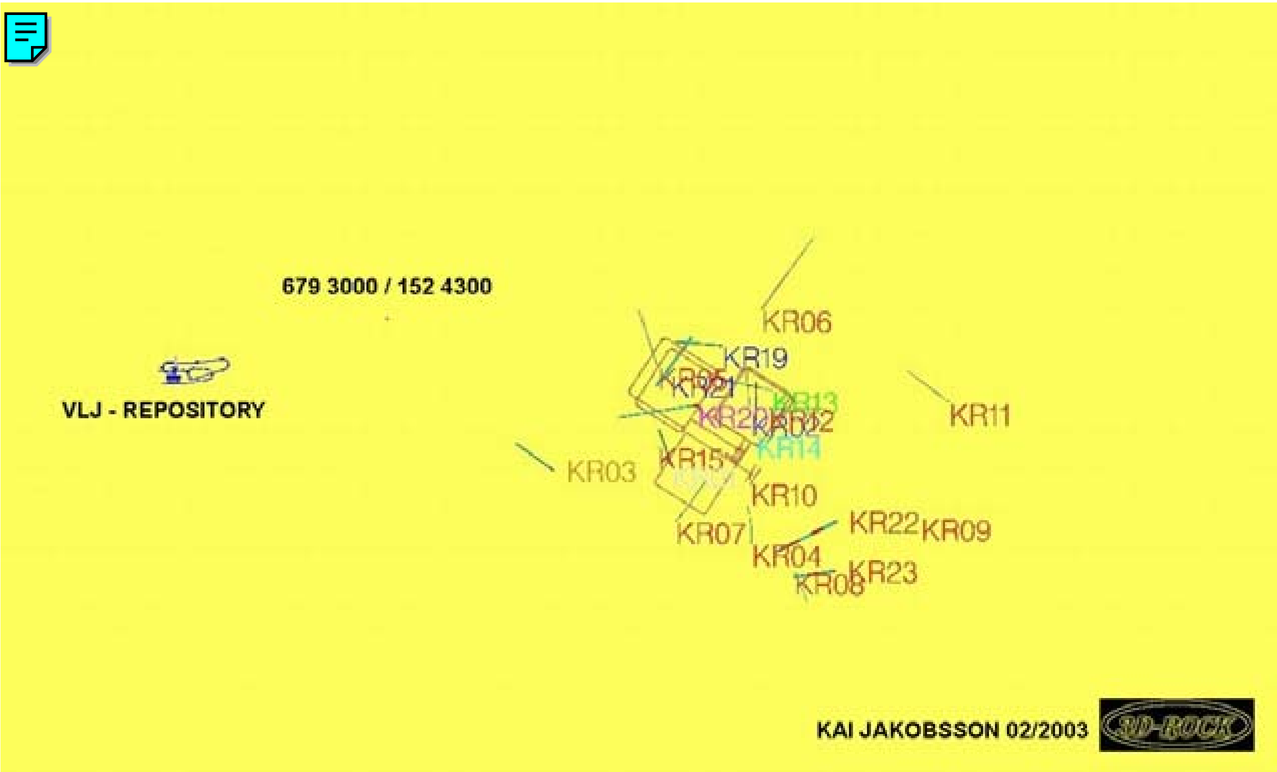

Figure 3. Land-use map with the tentative lay-out of ONKALO.

likely to dramatically affect the properties (particularly shear strength and permeability) of these structures.

4.7 Design and Modelling of ONKALO

During the first presentation at Olkiluoto the group were only shown one alternative of the design for the ONKALO facility. We were told that several different alternatives were developed and studied; some involving shafts and others tunnels. It has become apparent that a particular layout had already been chosen by early 2002.

The group are keen to know the criteria used to choose the selected design from these various, unspecified possibilities. What are considered to be the relative advantages and disadvantages of shafts and tunnels and what criteria were used to determine the position of the proposed shaft and tunnel? The group is concerned that cost effectiveness and an over optimistic time schedule may be overriding safety considerations.

The selected site of the ONKALO and the access to it is in the proposed repository area and it is planned that the ONKALO will become an integral part of the repository. What are Posiva's reasons for not having the access tunnel in a position mainly outside the repository area? This would have the advantage of minimising the disturbance of the site. Is the argument that the tunnel should be positioned in an area where the rock properties and the distribution of structures are known and is this reasoning acceptable? It appears that very little study of the geology of the surrounding areas has taken place and the group are keen to know why this is so.

This discussion leads on to the related topic of 'land use'. There is a very limited area in Olkiluoto for the repository. Figure 3 shows the proposed use of the various blocks of land making up the Island. The yellow area, reserved for ONKALO and the proposed repository, seem artificially constrained. Why not explore the regions to the west and south–east? The group is unhappy with the reasons why these adjacent areas are not being considered.

Is the chosen position the only position? Does Posiva's timetable justify omitting the geological research work on the surrounding areas? Does the fact that the surrounding areas are less examined justify Posiva concentrating only to the better known "central block, main volume" of the Olkiluoto repository site? Discussions at Olkiluoto gave the impression that the basic layout of ONKALO had already been decided. We are concerned that all possible options be considered before a final decision is made. Posiva need to justify the choice of location and design of ONKALO.

The group note that the major structures in and around the rock volume have been put into the structural model. How do Posiva justify avoiding some of these structures and not others in their design for ONKALO and its access? By examining their extent, orientation and geometry it is possible to establish those likely to result in the flow of ground water into and out of the repository site.

In designing the access to the ONKALO it is recommended that the repository site be disturbed as little as possible and that in addition, the access tunnels penetrate and therefore accurately characterize those structures (mentioned above) that are most likely to result in leakage. Once characterized it will be possible to plan boreholes to explore their flow properties.

The group would like to understand the rational behind the decision to located ONKALO in the centre of the best-investigated area i.e. an area which should be reserved for the repository. They note also that during a considerable part of the long research period used for the site investigations, the final disposal depth discussed has varied. Originally it was to have been between 500m to 700m. There has been a gradual decrease in the depth proposed for the repository. In papers, reports and even in the DiP, it has gradually become accepted that the final disposal depth will be between 400–700m. Posiva seems to have decided that the main research level of the ONKALO will be at –400m, as well as the preliminary lay-out design of the repository.

The structural model is constantly being updated as new data have become available. The group would like to know which one of the publicised models (or unpublished?) was used when the tentative location of the ONKALO facility was decided?

Visual inspection of cores shows several fracture zones in KR19, which is centrally located with respect to the modelled area and planned

ONKALO tunnels. Boreholes KR-19 and KR-20 were drilled about one or two months before the model version 2001/2 was published. Similarly, the new boreholes KR22 and KR23 penetrate structure R16 (see Figure 4) and might call for modification of its position within the model. The information from these boreholes has not however been utilized in the modelling work. The group would like to know why the new results from the boreholes have not been used

At the December (2002) seminar at Olkiluoto a memorandum was delivered by Posiva. In this document the principal requirements for the location of the access way to ONKALO were summarized as follows (Posiva Memorandum Tu-M-58/02. J. Vira and A. Ikonen, 29.11.2022; Principal requirements for the location of the access way to ONKALO):

The underground rock characterization facility ONKALO must:

1. Enable detailed underground characterization of a rock volume representative of the actual host rock for the repository before submission of the application for the construction licence.
2. Should be designed, built and operated in a way that preserves the conditions in the repository host rock as close to natural as possible.
3. Should be designed and constructed in a way that allows it to become a part of the actual repository.
4. Should preserve flexibility as regards the design, construction and operation of the actual repository.
5. Must comply with relevant standards, official guidelines and existing legislation.

Why have these five items been considered as rules? How do these requirements limit the position, depth and layout of other possibilities of ONKALO and the repository itself in Olkiluoto's bedrock?

A clarification of the use of 'variable respect distances' from classified fracture zones is needed. This item may be of relevance here.

4.8 Baseline problems

There is confusion regarding the baseline. We were informed that the baseline report would be ready in June 2003, but that it was planned to start work on ONKALO tunnels in 2004. Can this tight timetabling be justified?

Over what period has baseline data been recorded – 20 year? Is the reliability and accuracy of the data acceptable? There was an internal group discussion of the meaning of the term 'baseline'. According to common use in Swedish site investigation programs, baseline data is used to identify the impact the site investigation program (including all surface-based investigation, e.g. drilling) and construction of the repository will have on the environment (i.e. everything from small insects to mammal and from small pods of water to groundwater in the bedrock, including fluid flow and chemistry). What is Posiva's concept of a baseline? Do they see it as a set of conditions fixed in space and time or is it evolving?

What is the actual date set for defining the baseline data, prior to the construction of power plant and the intermediate storage?

The groups understanding of "Base Line" is that it represents a historical record of the natural site conditions – prior to the initiation of the site investigation, i.e. the data that will indicate the affect that the site investigation and construction of a deep bedrock repository will have on the environment.

The baseline report should establish the current surface and underground conditions, including natural fluctuation, at Olkiluoto. The surface conditions are relatively easy to establish but to get control of the underground conditions at depth, could prove to be more difficult, because the system will be affected by the investigations.

The Baseline will be more like a site characterization report than a description of the "untouched" original conditions. Posiva has recently presented the term "prevailing conditions" as a synonym for "baseline".

4.9 Structural model

During the long study time of the Olkiluoto area, the study methods and interpretation systems have developed and conclusions reached are not always compatible. It is very difficult to compare information from two datasets if for example the data acquisition involves a subjective element as in the recognition and counting of fractures to determine fracture density or fracture directions.

Similar problems could also occur when using the seismic VSP method where the interpretation system is under continuous developing.

There is also some concern regarding the linking of surface and borehole data, a process that is critical in determining the accuracy of locations and orientations of structures within and around the proposed rock volume. (This point relates to the accuracy of data such as the dip values of important structures and the errors generated when these are extrapolated to the ONKALO depths)

The process of developing the bedrock model is in the hands of a few experts and the group is concerned that large data sets from various researchers are not efficiently taken into account and integrated into the model. For example despite the fact that the geological surface data were available much earlier than the drilling of borehole OL-KR22, it was located (accidentally) exactly in the fracture zone R24, (Fig. 4). This information, together with many other geological or lithological details, is not included in the model and therefore the details or shapes of the geological units in the published cross-sections are not very reliable.

The group understands the difficulties often encountered in recognizing fracture zones either in outcrop or in cores. This problem links to the problem of characterizing fracture zones and we would suggest some classification be adopted to help address this problem. A simple and fast method for classifying the fracture structures is needed especially for further excavation period (see also section 4). In the excavation phase the speed of tunnelling work is high and drilling and excavation cannot wait for long time periods of interpretation of measured borehole data. For this reason the modelling method used cannot be used during the active tunnelling work.

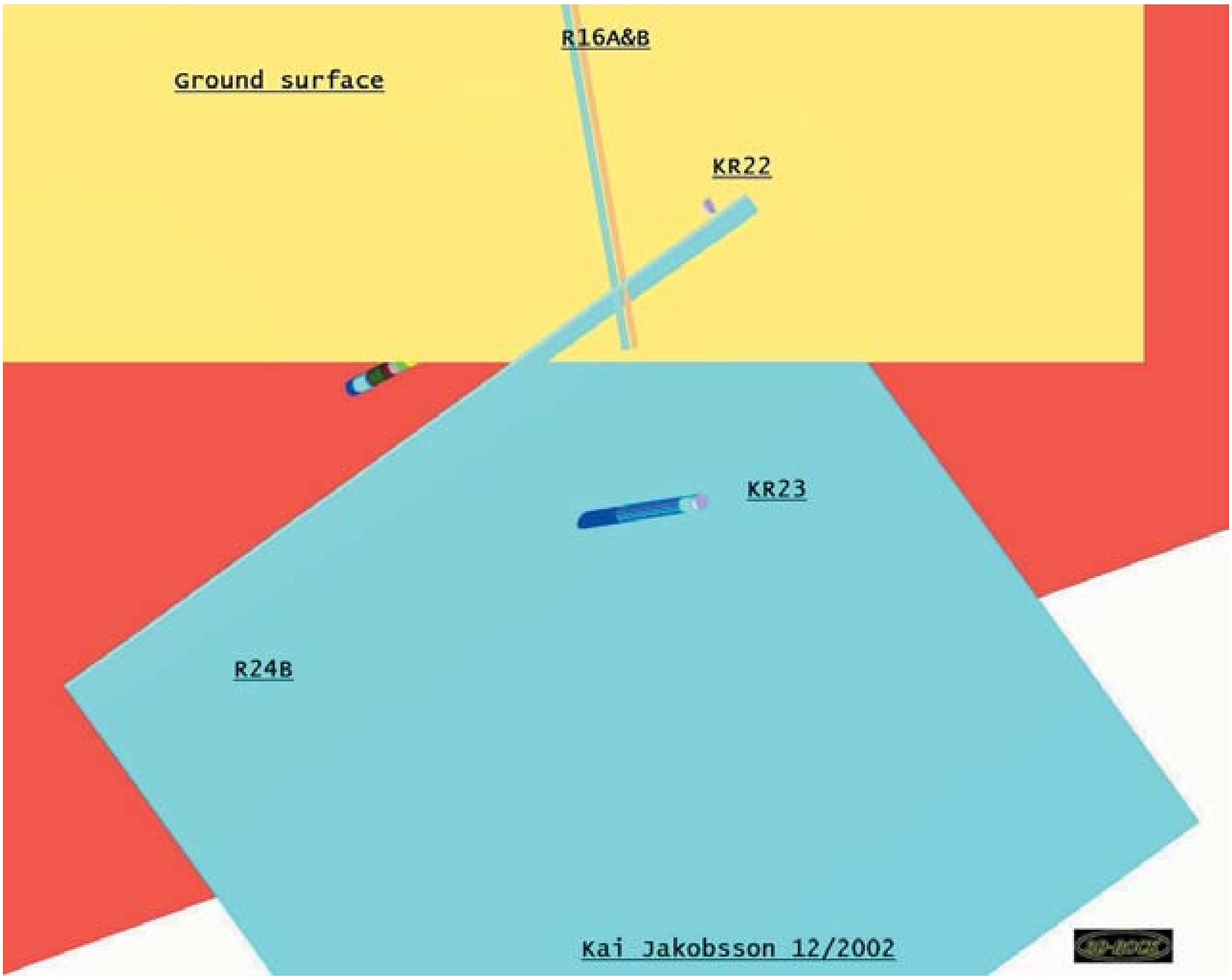

Figure 4. Structure R24B & R16A & B and the new boreholes KR22 and KR23. Plan view, north up.

Concerning the structural model the following points can be set forth:

- Lithological data has not had a major impact on the model. More lithological data should be included in the 3D models.
- Rock types are presented only in boreholes and on the surface (What are their 3D geometries and locations?).
- Do the different groups of researchers have the facility to interact with and modify the model (i.e. to change the orientation/position/properties of a structure) and explore the results?
- What criteria are used to determine how and which parts of any new data and interpretation are incorporated into the model?
- Once the model is updated are all users informed and if so how?

Source material

Posiva reports:

- Posiva 2000-14; Disposal of spent fuel in Olkiluoto bedrock
- Posiva 2000-15; The site selection process for a spent fuel repository in Finland – Summary report (Tim McEwen et al.)
- Posiva 2002-04; Structure and geological evolution of the bedrock of southern Satakunta, SW Finland (Seppo Paulamäki et al.)
- Posiva 2002-07; Establishing baseline conditions and monitoring during construction of the Olkiluoto URCF access ramp (Bill Miller et al.)

Posiva working reports:

- Posiva WR 2001-32; Bedrock model of Olkiluoto, version 2001/1 (Tiina Vaittinen et al.) (in Finnish)
- Posiva WR 2002-36, Host rock classification. Phase 1: The factors that determine the location and lay- out of a repository – a review. (Tim McEwen)
- Posiva WR 2002-46; Complementary bedrock model of Olkiluoto, version 2001/2 (Pauli Saksa et al.) (in Finnish)
- Posiva WR 2002-49, Core drilling of deep borehole OL-KR19 at Olkiluoto in Eurajoki 2002 (Risto Niinimäki)
- Posiva WR 2002-50, Core drilling of deep borehole OL-KR20 at Olkiluoto in Eurajoki 2002 (Risto Niinimäki)
- Evaluation of the access routes to the “ONKALO” facility (in Finnish), Posiva 19.6.2002 (Antti Ikonen et al.)
- Posiva Memorandum Tu-M-58/02. J. Vira and A. Ikonen, 29.11.2022; Principal requirements for the location of the access way to ONKALO

Others:

- STUK’s Guide YVL 8.4; Long-term safety of disposal of spent nuclear fuel, 23.5.2001.
- STUK’s Guide YVL 8.5; Operational safety of a disposal facility for spent nuclear fuel, 23.12.2002 (in Finnish)
- The decision in principle by the Government on 21 December 2000 concerning Posiva Oy’s application for the construction of a final disposal facility for spent nuclear fuel produced in Finland
- GSF report YST-111, Focused modelling of bedrock fracture zones in Olkiluoto (Jarkko Jokinen & Kai Jakobsson, 2002)
- STUK’s 3D- model of Posiva’s structures, boreholes and alternative simulations of the ONKALO-concept IMGS-group’s meeting discussions
- Posiva seminars 8.6., 26.11. and 13.12.2002
- In addition, the material contains different reports, statements, opinions etc. in which the actual problems have been discussed.