Geophysical Borehole Logging, Dummy-Sonding and Optical Imaging of the Borehole OL-KR24 at Olkiluoto 2005

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Suomen Malmi Oy

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Working Reports contain information on work in progress or pending completion.

The conclusions and viewpoints presented in the report are those of author(s) and do not necessarily coincide with those of Posiva.
ABSTRACT

Geophysical borehole logging, dummy -sonding and optical imaging of the borehole OL-KR24 at Olkiluoto 2005

4.1.2006

Johan Majapuro, Suomen Malmi Oy

Suomen Malmi Oy conducted geophysical borehole logging, dummy -sonding and optical imaging surveys of the borehole OL-KR24 at the Olkiluoto site in Eurajoki during 1.10.2005 – 4.10.2005. The survey is a part of Posiva Oy’s detailed investigation program for the final disposal of spent nuclear fuel. The methods applied are caliper survey and optical imaging. The assignment included the field work of surveys, interpretation and processing of the data. The report describes the field operation, equipment as well as processing procedures and shows the obtained results and their quality in the appendices. The raw and processed data are delivered digitally in WellCAD and Excel format.

Key words: Geophysics, borehole logging, structural geology, nuclear waste disposal
TIIVISTELMÄ

Kairanreiän OL-KR24 geofysikaaliset mittaukset, dummy –sondeeraus ja optinen kuvantaminen Olkiluodossa vuonna 2005

4.1.2006

Johan Majapuro, Suomen Malmi Oy


Avainsanat: Geofysiikka, reikämittaukset, rakenegeologia, ydinjätteen loppusijoitus
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Appendix on CD-ROM
1 INTRODUCTION

In 1999, Posiva Oy filed an application for a policy decision from the council of state for a construction permit to build a final disposal facility for spent fuel at the Olkiluoto area in the Eurajoki municipality. In December 2000, the Council of State made a positive policy decision and in May 2001, the Parliament ratified the decision.

The policy decision makes it possible to concentrate the research activities at Olkiluoto Eurajoki. The spent fuel of the Finnish nuclear power plants will be disposed into a rock repository. The site investigations at the Olkiluoto Site are culminating in the construction of an underground rock characterisation facility ONKALO. The construction of the ONKALO access tunnel started in June 2004.

Suomen Malmi Oy (Smoy) carried out geophysical borehole surveys of the borehole KR24 for Posiva Oy in October 2005. The assignment included dummy -sonding, caliper and optical imaging surveys and interpretation according to the purchase order 9837/05/TUAH.

The field surveys were coordinated by geophysical foreman Antero Saukko and the project management and reporting were conducted by survey engineer Johan Majapuro. Data integration was subcontracted by JP-Fintact Ltd (Eero Heikkinen).

This report describes the field operation of the borehole surveys and the data processing and interpretation. The quality of the results is shortly analysed and the data presented in the Appendices.
2 EQUIPMENT AND METHODS

The geophysical survey carried out in KR24 included dummy-sonding, caliper and optical imaging surveys. The borehole surveys were carried out using Advanced Logic Technology’s (ALT) OBI-40 optical televiewer, Mount Sopris 2PCA100 3-arm caliper and SKB’s dummy sondes. Applied control units was ALT Abox. All the electrical equipment is property of Smoy.

Cable was operated by a motorised winch. The depth measurement is triggered by pulses of sensitive depth encoder, installed on a pulley wheel. Optical imaging and caliper survey applied a Mount Sopris manufactured 1000 m long, 3/16” steel reinforced 4-conductor cable. The cable was marked with 10 m intervals for controlling the depth measurement to adjust any cable slip and stretch.

2.1 Optical televiewer

The borehole imaging was carried out using OBI40 optical televiewer manufactured by Advanced Logic Technology (ALT). Tool diameter is 42 mm. The maximum azimuthal resolution was 720 pixels and vertical resolution 0.5 mm. Smoy has prepared special centralisers for 76 mm boreholes. The tool configuration is shown in Figure 1 and optical assembly in Figure 2. The probe and logging control unit are also presented in Appendix 2.1.
Figure 1. The configuration of the OBI40-mk3, length 1.7 m (ALT, Optical Borehole Televiewer Operator Manual).

Figure 2. Optical assembly of the OBI40. The high sensitivity CCD digital camera with Pentax optics is located above a conical mirror. The light source is a ring of light bulbs located in the optical head (ALT, Optical Borehole Televiewer Operator Manual).
2.2 3-arm Caliper

The borehole caliper survey was carried out by Mount Sopris 2PCA1000 3-arm caliper tool. Tool diameter is 39 mm. Measurement applies three connected hard metal arms, for which the angle of opening produces the primary signal. The data was calibrated using measurements of four rings of different diameters in the measurement range 70 … 140 mm, performed before and after the logging run. The resolution of aperture is 0.08 mm.

2.3 Dummy-sonde

The dummy-sonding was done with SKB tool by using wire line cable of drill rig. The dummy-sonding was done to check that the borehole was completely open and it was straight enough. In addition the purpose of sonding was to check the openness of the borehole. The diameter of the tool was 73 mm. The used tool lengths were 3, 6, 9 and 12m.
3 FIELD WORK

The field work was carried out within 71 working hours 1.10.2005-4.10.2005. The assignment consisted of borehole survey of KR24 with estimated total survey amount of 550 m. The borehole specifications are listed in Table 1 and the duration of the field work in Table 2. Table 3 shows the survey parameters of each method.

Table 1. Specifications of the boreholes surveyed.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Azimuth</th>
<th>Dip</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KR24</td>
<td>76</td>
<td>-</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 2. Timing of the field work.

<table>
<thead>
<tr>
<th>Date</th>
<th>Actions</th>
<th>Surveyors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10.05 21:00 - 3.10.05 15:00</td>
<td>Borehole digital imaging, 190m – 550m</td>
<td>AS, JM, JK</td>
</tr>
<tr>
<td>3.10.05 15:00 - 3.10.05 24:00</td>
<td>Caliper survey 551m – 120m</td>
<td>AS, JM</td>
</tr>
<tr>
<td>4.10.05 06:00 - 4.10.05 17:00</td>
<td>Dummy -sonding</td>
<td>AS</td>
</tr>
</tbody>
</table>

Table 3. Survey parameters of the applied methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>Depth sampling</th>
<th>Settings</th>
<th>Survey speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole imaging</td>
<td>0.0005m</td>
<td>720 pixels / turn</td>
<td>0.18 m/min</td>
</tr>
<tr>
<td>Caliper</td>
<td>0.01 m</td>
<td>Calibrated with rings</td>
<td>1.0 m/min</td>
</tr>
<tr>
<td>Dummy -sonding</td>
<td>1.0 m</td>
<td>Length: 3m, 6m, 9m, 12m</td>
<td>2.0 m/min</td>
</tr>
</tbody>
</table>
4 PROCESSING AND RESULTS

The processing of the conventional geophysical results includes basic corrections and calibrations presented in Posiva’s Working report 2001-30 (Lahti et al., 2001). The depth adjustments as well as data integration were carried out by JP-Fintact Ltd.

The result of the caliper survey is presented in Appendix 1.1. The optical televiewer example of the image log is shown in Appendix 1.2 and in Appendix on CD-ROM.

Presented results, in Appendices, were joined with available geological data received from Posiva. These include lithology and fracture frequency, and location of fractures. Initial depth match is based on cable mark control. Images were oriented to North using simultaneous borehole deviation and tool orientation survey (3-component accelerometers and magnetometers). The depth encoder calibration shift (1% of borehole length) was matched using cable depth marks and geological depth references, e.g. previous gamma-gamma density log (report 2004-17, Julkunen et. al 2004). Current depth accuracy of image is 2-5 cm from the core sample and radial accuracy better than 1 degrees. Caliper data was depth matched to core sample and previous caliper record, with accuracy better than 2-5 cm to core. The image quality is very good, e.g. when compared to the image acquired immediately after drilling of the borehole in 2003.

4.1 Borehole image

The applied survey parameters of the borehole imaging were determined according to earlier optical televiewer works in the Olkiluoto Site (Lahti, 2004a, Lahti 2004b).

The quality of the image was controlled during survey by taking samples of the image and applying histogram analysis. Also the vertical resolution was checked using captured images. The data processing carried out after the field work consists of depth adjustment and image orientation of the raw image. The depth adjustment and image orientation methods are presented in the report Lahti 2004a. The images were produced to depth matched and oriented to north side presentations including a 3-D image. Images can be reviewed with WellCAD Reader and WellCAD software.
4.2 Caliper Survey

The results of caliper survey displays minor expansions in borehole diameter due to steering of borehole, e.g. at 245 and 315 m. These features are repeated in re-run. Narrow fracture zone originated expansions are seen at 299.15, 304.55, 331.80, 347.15, 380.75, 387.65 and 397.55 m. Usually these are clearly seen in the image, are associated with a clay or grain filled fracture, and indicate a density minimum.

Many of these occurrences have been levelled off during stabilization of upper part of the borehole (304.55, 331.80, 397.55), when comparing to the caliper data measured in 2003 (Julkunen et al. 2004). Significant remaining aperture was found at 380.65 m. This might have been further suppressed during subsequent stabilization.

4.3 Dummy -sonding

The dummy -sonding was done in two occasions. The first occasion was just before stabilisation and the other during plugging. During the first occasion all dummy tool lengths were used. The 3 m long tool went to the borehole to the depth of 223 m, the 6 m long tool went to the depth of 359 m. The 9 m and 12 m long tools went to the bottom of the borehole.

In the second occasion only 12 m long dummy tool was used. The tool went down to the bottom of the borehole. There were great problems to lift the tool from the borehole, because there was some very fine grained residue of the sand that was used in the plugging activity in the borehole.
5 CONCLUSIONS

The task of surveying the borehole KR24, was concluded within 71 hours in 1.10.2005-4.10.2005. The processed and interpreted data was delivered to the Client in digital format. The draft report was compiled in December 2005.

The quality of the data widely achieves the required level.
6 REFERENCES


Client: Posiva Oy
Site: Olkiluoto
Project no: Characterization

Hole no: KR24
Ø: 76
Length: 551.11
Dip: 90

Surveyed by: JM, AS
Survey date: 2.10. 2005
Reported by: JM
Report date: Dec 2005

Surveyed by: JM, AS
Survey date: 2.10. 2005
Reported by: JM
Report date: Dec 2005

Depth

Lith.  Fract. freq.

1m:500m  0  90

Orient. fract.

Gamma Gamma Density

Work Report 2004-17

2.6 3.2 g/cm3
Caliper 2003
Work Report 2004-17

KR24 Optical Image (Downsampled 1:10)
Oriented to North (0 degs), Depth Adjusted to Core

0°  90°  180°  270°  0°

0 10.00 20.00 30.00 40.00 50.00 60.00 70.00

11 Appendix 2.1
ALT’s family of acquisition system is based on modern electronic design in which software control techniques have been used to the best advantage. The hardware incorporates the latest electronic components with embedded systems controlled via the specially developed ALTlogger Windows interface program.

**Main features**

- High speed USB interface
- Self selecting AC power source from AC 100V to AC 240V
- Ruggedised system, heavy duty, fault tolerant
- Interfaces downhole probes from many manufacturer (not available on Abox system)
- Wireline and winch flexibility (runs on coax, mono, 4 or 7 conductor wireline)
- Compatible with most shaft encoder (runs on any 12V or 5V quadrature shaft encoder with any combination of wheel circumference/shaft pulse per revolution)
- Totally software controlled
- Very easy to use, with graphical user interface (dashboard), self diagnostic features, configurable through files and minimal technical knowledge needed from the user
- Runs on any notebook PC compatible Windows 2000 & windows XP
- Real time data display and printing
- Supports Windows supported printers and Printrex thermal printers
- Optional network enabled distributed architecture

**ALTlogger 19’’ rack and minirack**

The rack system has been designed to accommodate multivendor tool types. The modular and flexible design architecture of the system will allow virtually any logging tool to run on any winch supposed the required Tool Adapter and Depth Encoder Adapter is inserted into the ALTlogger Unit. Any new combination of logging tool and winch unit will just require selection of the proper ALTlog.ini File and the proper Tol-File.

The Tool Adapter is the software and hardware suitable to interface a specific family of tools. It provides the interface between a tool specific power, data protocol and wireline conductor format and the system core. When a logging tool is selected for use, the system automatically addresses the type of adapter associated with the tool.

The latest Digital Signal Processing (DSP) adapter adds even more flexibility to the system with expansion slots for future developments and upgrades, by implementing a 100% firmware based modem system.

<table>
<thead>
<tr>
<th></th>
<th>ALTlogger 19” rack mountable</th>
<th>ALTlogger minirack</th>
<th>ABOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>48.3 cm (19”)</td>
<td>37.6 cm (14.5”)</td>
<td>26 cm</td>
</tr>
<tr>
<td>L</td>
<td>50 cm (19.7”)</td>
<td>35 cm (13.8”)</td>
<td>16 cm</td>
</tr>
<tr>
<td>H</td>
<td>13.2 cm (3U)</td>
<td>13.2 cm (3U)</td>
<td>9 cm</td>
</tr>
<tr>
<td>W</td>
<td>16-20kgs without packaging</td>
<td>12-16kgs without packaging</td>
<td>3kgs</td>
</tr>
</tbody>
</table>

The specifications are not contractual and are subject to modification without notice.
The acquisition system ALTLoggers software runs on Windows OS and exploits the true pre-emptive multitasking ability of the Windows NT Kernel.

**Dashboard**

The heart of the graphical user interface is called the Dashboard and consists of multiple threads running concurrently and handling specific system tasks. The dashboard is also the operator’s control panel. It is used to select and control all systems functions and to monitor data acquisition. The dashboard contains seven sub windows:

- Depth (depth system)
- Tool (tool configuration & power)
- Communication (data flows and communication control)
- Acquisition (data sampling and replay controls)
- Browser and processors (data browser and processors controls)
- Status (self diagnostic system status indicators)
- Tension (tension gauge system)

**TOL file**

Information specific to a particular tool is contained in a unique tool configuration file which has the extension *.TOL. Information contained in the *.TOL file is used by different components of the system for initialising Dashboard components (tool power, data protocol, etc…), as well as setting parameters for client processes (browser & processors) handling data calibration, data processing, data display or printing. A copy of the TOL file is included in each data file acquired.

**Browser and processors (real time data monitoring)**

A Browser is a Client Process. The Browser offer the operator of the logging system a number of different on-line display facilities to present log data on the screen in a user-friendly, easy controllable, attractive layout. Depending on the tool category, different Browser are used to display log data such as conventional curves, full waveform sonics, borehole images …

Typical user screen with scrolling log display and data monitoring.
The tool generates a continuous oriented 360° image of the borehole wall using an optical imaging system. (downhole CCD camera which views a image of the borehole wall in a prism). The tool includes an orientation device consisting of a precision 3 axis magnetometer and 3 accelerometers thus allowing accurate borehole deviation data to be obtained during the same logging run (accurate and precise orientation of the image).

Optical and acoustic televiewer data are complimentary tools especially when the purpose of the survey is structural analysis.

A common data display option is the projection on a virtual core that can be rotated and viewed from any orientation. Actually, an optical televiewer image will complement and even replace coring survey and its associated problem of core recovery and orientation.

The optical televiewer is fully downhole digital and can be run on any standard wireline (mono, four-conductor, seven-conductor). Resolution is user definable (up to 0.5mm vertical resolution and 720 pixels azimuthal resolution)
**Applications:**

The purpose of the optical imaging tool is to provide detailed, oriented, structural information. Possible applications are:

- fracture detection and evaluation
- detection of thin beds
- bedding dip
- lithological characterization
- casing inspection

**Technical specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>40mm</td>
</tr>
<tr>
<td>Length</td>
<td>approx. 1.7m</td>
</tr>
<tr>
<td>Weight</td>
<td>approx 7 kgs</td>
</tr>
<tr>
<td>Max temp</td>
<td>50°C</td>
</tr>
<tr>
<td>Max pressure</td>
<td>200 bars</td>
</tr>
<tr>
<td>Borehole diameter</td>
<td>1 3/4&quot; to 24&quot; depending on borehole conditions</td>
</tr>
<tr>
<td>Logging speed</td>
<td>variable function of resolution and wireline</td>
</tr>
<tr>
<td>Cable:</td>
<td></td>
</tr>
<tr>
<td>Cable type</td>
<td>mono, four-conductor, seven-conductor</td>
</tr>
<tr>
<td>Digital data transmission</td>
<td>up to 500 Kbps depending on wireline, realtime compressed</td>
</tr>
<tr>
<td>Compatibility</td>
<td>ALTlogger- ALT-Abox- Mount Sopris MgXII (limited to 41 Kbps)</td>
</tr>
<tr>
<td>Sensor type</td>
<td>downhole DSP based digital CCD camera</td>
</tr>
<tr>
<td>Optics</td>
<td>plain polycarbonate conic prism system</td>
</tr>
<tr>
<td>Azimuthal resolution</td>
<td>user definable 90/180/360 or 720 pixels /360°</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>user definable, depth or time sampling rate</td>
</tr>
<tr>
<td>Color resolution</td>
<td>24 bit RGB value</td>
</tr>
<tr>
<td>White balance</td>
<td>automatic or user adjustable</td>
</tr>
<tr>
<td>Aperture &amp; Shutter</td>
<td>automatic or user adjustable</td>
</tr>
<tr>
<td>Special functions</td>
<td>User configurable real time digital edge enhancing User configurable ultra low light condition mode</td>
</tr>
<tr>
<td>Orientation</td>
<td>3 axis magnetometer and 3 accelerometers.</td>
</tr>
<tr>
<td>Inclination accuracy</td>
<td>0.5 degree</td>
</tr>
<tr>
<td>Azimuth accuracy:</td>
<td>1.0 degree</td>
</tr>
</tbody>
</table>

**Logging parameters:**

- 360° RGB orientated optical image
- Borehole azimuth and dip
- Tool internal Temperature

The specifications are not contractual and are subject to modification without notice.
MOUNT SOPRIS INSTRUMENT CO., INC.

Recognized World Leader for over 40 years manufacturing Borehole Geophysical Logging Systems

**2PCA-1000 3-Arm Caliper**
(can be operated with, or without 2PGA-1000)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>159 cm (62.6&quot;)</td>
</tr>
<tr>
<td>Diameter</td>
<td>39 mm (1.5&quot;)</td>
</tr>
<tr>
<td>Weight</td>
<td>7.3 Kg 16 lbs</td>
</tr>
<tr>
<td>Pressure Rating</td>
<td>13,790 kPa (2000 PSI)</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-20 - 80°C (6 - 176°F)</td>
</tr>
<tr>
<td>Sensor (Detector)</td>
<td>Micro-processor-controlled potentiometer</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>57 - 736 mm (2.25 - 29&quot;) with extensions</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.5 mm (0.02&quot;)</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.08 mm (0.003&quot;)</td>
</tr>
</tbody>
</table>

Operations Manual: [Click to view PDF operations manual for 3-Arm Caliper](#)

Send mail to [with questions or comments about this web site.](#)

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