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Core Drilling of Drillhole ONK-PVA8 in ONKALO at Olkiluoto 2010

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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.
Suomen Malmi Oy (Smoy) core drilled a drillhole for groundwater monitoring station in ONKALO at Eurajoki, Olkiluoto in July 2010. The groundwater monitoring stations are used for monitoring changes in groundwater conditions. The identification number of the hole is ONK-PVA8, and the length of the drillhole is 17.74 m. The drillhole is 75.7 mm by diameter. The drillhole was drilled in a niche of the access tunnel at chainage 2935.

The hydraulic DE 130 drilling rig was used. The drilling water was taken from the ONKALO drilling water pipeline and premixed sodium fluorescein was used as a label agent in the drilling water.

In addition to drilling the drillcores were logged and reported by geologist. Geological logging included the following parameters: lithology, foliation, fracture parameters, fractured zones, core loss, weathering, fracture frequency, RQD and rock quality.

The main rock types in the drillholes are diatexitic gneiss and pegmatitic granite. The average fracture frequency in drill core ONK-PVA8 is 1.7 pcs / m and the average RQD value 96.0 %.

**Keywords:** Olkiluoto, ONKALO, groundwater, core drilling, drillhole, diatexitic gneiss, pegmatite granite, fracture
TIIVISTELMÄ

Suomen Malmi Oy (Smoy) kairasi yhden pohjavesiasemaksi (PVA) tarkoitetun tutkimusreiän ONKALOsssa Eurajoen Olkiluodossa heinäkuussa 2010. Pohjavesiasemilla seurataan mahdollisia muutoksia pohjavedessä. Reiän tunnus ovat ONK-PVA8, ja sen pituus on 17,74 metriä. Kairareiän halkaisija on 75,7 mm. Reikä kairattiin ajotunnelin paalulla 2935 olevasta kuprikasta.

Reiän kairaustyössä käytettiin hydraulista DE 130 kairauskonetta. Reiän kairaukseen käytettiin natriumfluoresiinilla merkittyä huhteluvettä, joka otettiin ONKALO:n porausvesilinjasta.

Kairatuille kallionäytteille tehtiin geologinen kartoitus ja raportointi, joka sisälsi mm. kivilajit, suuntautuneisuuden, rakoparametrit, rakotiheyden ja RQD:n, rikkonaisuusvyöhykkeet, muuttuneisuuden, näytehukan ja kivilaadun.

Pääkivilajeina esiintyvät diateksiittinen gneissi ja pegmatiittinen graniitti. Kallion rakoluku oli reiässä ONK-PVA8 keskimäärin 1,7 kpl / m ja RQD-luku on keskimäärin 96,0 %.

Avainsanat: Olkiluoto, ONKALO, pohjavesi, kairaus, kairareikä, diateksiittinen gneissi, pegmatiittigraniitti, rako
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1 INTRODUCTION

1.1 Background


The policy decision made it possible to concentrate the research activities at Olkiluoto in Eurajoki. Construction of an underground rock characterisation facility (called “ONKALO”) is one part of the research. Construction of the access tunnel was started in autumn 2004.

Posiva Oy contracted (order number 9404-10) Suomen Malmi Oy (Smoy) to drill a drillhole for groundwater monitoring station in ONKALO. The identification number of the drillhole is ONK-PVA8, and its length is 17.74 metres. The groundwater monitoring stations are used to monitor possible changes in groundwater conditions. The ONK-PVA8 drillhole is part of the ReRoc campaign (WR2009-31).

The new drillhole ONK-PVA8 is located in a loading niche in the access tunnel at chainage 2935 (Figure 1). The initial azimuth of the drillhole is 150.8° and the initial dip is -9.3° from the horizontal. The diameter of the drillhole is 75.7 mm. Summary of the technical details of the drillhole is presented in Appendix 7.1.

1.2 Scope of the work

The aim of the work was to drill a drillhole and to document the geological conditions (continuity of rock units, fractured zones and rock quality) in the area. In addition to the drilling, the work included core logging and reporting. This report documents the work carried out during the drilling of the hole and geological logging of the drillcores.
Figure 1. Location of the drillhole ONK-PVA8 in ONKALO (short black line).
2 DRILLING WORK AND TECHNICAL DETAILS OF THE DRILLHOLE

2.1 Description of the drilling work

The diamond drill rig DE 130 was set up at the drilling site on the 7th of July in 2010. Drilling started on the 8th of July, and the drillhole was finished on the same day. The drill rig was moved to injection drillings at personnel shaft level -290.

The drilling of the ONK-PVA8 started from the tunnel shotcrete wall with no casing drilling. The thickness of the concrete was 0.06 metres. The drillhole was drilled using NQ2-double tube core barrel with NQ-drill rods. Drillhole diameter with NQ2 -core barrel is 75.7 mm and drill core diameter is 50.5 mm. Technical information of the drillhole is presented in Appendix 7.1.

The drilling was carried out as discontinuous shift work (one shift per day and the drilling team in each shift consisted of a driller and an assistant. Geologist Tauno Rautio was the project manager and Matti Alaverronen the drilling supervisor. Geological logging and compilation of the final report was done by geologist Vesa Toropainen.

The drill core samples were placed in wooden core boxes immediately after emptying the core barrel. In all, three core boxes were used. Start and end depths of the core in each core box are presented in Appendix 7.2. Wooden blocks separating the different lifts were placed to the core boxes to show the depth of each lift. The core drillings included seven lifts. The depths of the lifts are presented in Appendix 7.3.

2.2 Drilling and returning water and the use of label agent

The labelled drilling water for drillhole was taken from the water pipeline in ONKALO. The mixing of the label agent was done by Posiva Oy. The mixing was done before pumping water to the ONKALO pipeline. Practically all drilling water returned from the drillhole. Water leakage from the drillhole was so small that it couldn’t be measured.
2.3 Location surveys

Surveyed coordinates of the drillhole starting point and calculated coordinates at the end of the drillhole are presented in Table 1. The initial dip of the drillhole ONK-PVA8 is -9.3 degrees and the initial azimuth is 150.8 degrees (location surveyed by Prismarit Oy). The calculated end coordinates of the drillhole ONK-PVA8 are based on straight line calculation from the starting point of the drillhole.

Table 1. Coordinates of drillhole ONK-PVA8.

<table>
<thead>
<tr>
<th>Point location</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>Coordinate origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONK-PVA8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tunnel wall surface</td>
<td>6791907.23</td>
<td>1526030.24</td>
<td>-276.44</td>
<td>Location survey</td>
</tr>
<tr>
<td>End of drillhole (17.74 m)</td>
<td>6791891.95</td>
<td>1526038.78</td>
<td>-279.31</td>
<td>Calculated</td>
</tr>
</tbody>
</table>
3 GEOLOGICAL LOGGING

3.1 General

The handling of the core was based on the POSIVA work instructions POS-001427 "Core handling procedure with triple tube coring" (in Finnish). Drill core samples were placed into about one-metre long wooden core boxes immediately after emptying the core barrel.

The drill core was handled carefully during and after the drilling. The core was placed in the boxes avoiding any unnecessary breakage. Broken and clay rich parts of the core were wrapped in aluminium paper to avoid breaking them during storage and logging. If loose rock fragments from the drillhole walls were encountered during the logging, they were placed after the block marking the end of the previous sample run. Therefore, at the beginning of a sample run, there might be rock fragments not belonging to the sample run itself.

Geologist Vesa Toropainen logged the core in Posiva’s core logging facility at ONKALO site. The core logging of ONK-PVA8 followed the normal Posiva logging procedure, which has been used e.g. in pilot hole drilling programmes at Olkiluoto. The following parameters were logged: lithology, foliation, fracture parameters, fractured zones, weathering, core loss, artificial break, fracture frequency, RQD, rock quality and core discing. In addition, core orientation, the lifts and the core box numbers were documented.

All core boxes (Appendix 7.3) were digitally colour photographed, both dry and wet. The core photographs (wet) are presented at the end of the report.

The lift depths (Appendix 7.4) are given as they were marked on the wooden spacing blocks separating different sample runs in the core boxes. If the length of the core in the sample run indicated that sampling depth was different from the depth measured during drilling, the true sample depth was corrected on the spacing block. Therefore, the sample run depth equals the sample depth. The drilling depth might be deeper than the sampling depth, if the core lifter slips and part of the core is left in the drillhole and is retrieved by the next lift. The measured true sample depths were marked to the core sample with short red lines perpendicular to the core direction in one metre interval. Those depth values were marked to the upper dividing wall of the core box row. Posiva took a microbiological core sample from depth 13.15 – 14.20 m to be sent to laboratory in Sweden. The section of the core is replaced with wooden block in the core box.
3.2 Core orientation

Core orientation was carried out by using Ezy-Mark™ system. When utilized, the Ezy-Mark tool was locked into the core lifter case of the inner tube and set into the core barrel. Before drilling starts, the core barrel with the marking tool is lowered against the hole bottom. The pencil of the orientation head makes a mark on the hole bottom and the pins of the tool are pressed to record the profile of the hole bottom. When the tool reaches the bottom, the orientation balls of the tool are locked in their lowest position, indicating the bottom of the hole direction. During the drilling, the marking tool slides above the drilled core inside the core barrel. After the drilling is finished, the inner tube with the sample and the tool is pulled up from the hole by the wire line cable.

Core orientation can be done when the tool is twisted into Ezy-Mark Orientation Cradle (Figure 2) so that the orientation balls can be seen from the slot of the cradle. When the core sample is set into the cradle and the orientation head is aligned with the shape of the core face and pencil mark, orientation can be drawn on the outer surface of the core using the edge of the cradle (Figure 2). If a pencil mark does not exist, the core can still be orientated by using only the pins of the orientation head. The block marking “EM” is used with this method. The Ori-Block (Figure 3) is a separable pen and pin block of Ezy-Mark. The Ori-Block is used only once and then placed to the core box above the oriented lift. This allows the orientation marks to be audited afterwards.

![Figure 2](image-url). Drawing of the orientation line to the core sample with Ezy-Mark™ orientation tool (Photos 2iC Australia Pty Ltd).
The starting depths of the oriented lifts and the start and end depths and lengths of the oriented parts of the sample were recorded (Appendix 7.4). If the mark was rejected (not found, poor mark), a comment was written into the remarks column of the list.

One orientation was made during the drilling of ONK-PVA8, and 20.0 % (3.54 m) of the drill core was oriented. Orientation with Ori-Block™ was used in the drillhole.

The orientation bottom line drawn to the drill core sample on the basis of the orientation marks acted as a ground for direction measurements of fractures and other linear and planar features in the core. From the oriented drill core sections, core alpha and beta angles of every measurable fracture and chosen foliation measurement points were determined (Figure 4). Each alpha and beta value was recalculated to the real dip and dip directions using the drillhole orientation at the start of the drillhole, measured by Prismarit Oy.

*Figure 3. The Ori-Block™ separable orientation block (Photos 2iC Australia Pty Ltd).*
Figure 4. Fracture orientation measurements from orientated core. The core alpha (α) angle is measured relative to core axis. The core beta (β) angle is measured clockwise relative to a reference line, looking downward the core axis in direction of drilling. Figure modified from Rocscience Inc. Orientation Parameters for Borehole Data, Dips (v. 5.0) Features (Rocscience Inc., 2003).

3.3 Lithology

The rocks of Olkiluoto fall into four main groups: 1) gneisses, 2) migmatitic gneisses, 3) TGG-gneisses (TGG = tonalite-granodiorite-granite) and 4) pegmatitic granites (Kärki & Paulamäki 2006). In addition, narrow diabase dykes occur sporadically. The gneisses include homogeneous mica-bearing quartz gneisses, banded mica gneisses and hornblende or pyroxene-bearing mafic gneisses. The migmatitic gneisses, which typically contain 20 – 40 % leucosome, can be divided into three subgroups in terms of their migmatite structures: veined gneisses, stromatic gneisses and diatexitic gneisses. The leucosomes of the veined gneisses show vein-like, more or less elongated traces with some features similar to augen structures. Planar leucosome layers characterize the stromatic gneisses, whereas the migmatite structure of the diatexitic gneisses is asymmetric and irregular.

The lithological classification used in the mapping follows the classification by Mattila (2006). In this classification, the migmatitic metamorphic gneisses are divided into veined
gneisses (VGN), stromatic gneisses (SGN) and diatetic gneisses (DGN). The percentage of the leucosome proportion in gneisses is reported. The non-migmatitic metamorphic gneisses are separated into mica gneisses (MGN), mafic gneisses (MFGN), quartz gneisses (QGN) and tonalitic-granodioritic-granitic gneisses (TGG). The metamorphic rocks form a compositional series that can be separated by rock texture and the proportion of neosome. Igneous rock names used in the classification are coarse-grained pegmatitic granite (PGR), K-feldspar porphyry (KFP) and diabase (DB).

The TGG gneisses are medium-grained, relatively homogeneous rocks that can show a blastomylonitic foliation, but they can also resemble plutonic, unfoliated rocks. The pegmatitic granites are leucocratic, very coarse-grained rocks, which may contain large garnet, tourmaline and cordierite crystals. Mica gneiss enclaves are typical within the larger pegmatitic bodies. Gneisses, which are weakly or not at all migmatitic, make ca. 9 % of the bedrock. The migmatitic gneisses comprise over 64 % of the volume of the Olkiluoto bedrock, with the veined gneisses accounting for 43 %, the stromatic gneisses for 0.4 % and the diatetic gneisses for 21 %, based on drill core logging. Of the remaining lithologies, the TGG-gneisses constitute 8 % and the pegmatitic granites almost 20 % by volume (Kärki & Paulamäki 2006).

The ONK-PVA8 drillcore consists of diatetic gneiss (50.3 %) and pegmatitic granite (49.7 %) (Appendix 7.5). The DGN mostly has high leucosome content (~80 %) and it is irregular to weakly banded by foliation. The PGR is massive to locally weakly gneissic (almost TGG-like), light grey colored and contain some quartz-cordierite-muscovite-aggregates and ghostlike mica stripes.

### 3.4 Foliation

The classification of the foliation type and intensity used in this study is based on the characterization procedure introduced by Milnes et al. (2006). The foliation type was estimated macroscopically and classified into five categories:

- **MAS** = massive
- **GNE** = gneissic
- **BAN** = banded
- **SCH** = schistose
- **IRR** = irregular
The gneissic type (GNE) corresponds to a rock dominated by quartz and feldspars, with micas and amphiboles occurring only as minor constituents. The banded foliation type (BAN) consists of intercalated gneissic and schistose layers, which are either separated or discontinuous layers of micas or amphiboles. The schistose type (SCH) is dominated by micas or amphiboles, which have a strong orientation. Massive (MAS) corresponds to massive rock with no visible orientations and irregular (IRR) to folded or chaotic rock.

The intensity of the foliation is based on visual estimation and classified into the following four categories:

0 = massive or irregular
1 = weakly foliated
2 = moderately foliated
3 = strongly foliated

The type and intensity of the foliation was defined for every full metre. Measurements of foliation (Appendix 7.6) were carried out in one metre intervals from the core sample, if possible. Six measurements were made, and three of them were from oriented sample.

The diatexitic gneisses are mainly weakly banded, but irregular foliation is also common. The pegmatitic granite is massive or locally weakly gneissic. The main foliation direction in the core samples ONK-PVA8 is towards south-east (148°/48°).

### 3.5 Fracturing

Fractures were numbered sequentially from the beginning to the end of the drillcore (Appendix 7.7). Fracture depths were measured to the centre line of the core and given with an accuracy of 0.01 m. Each fracture was described individually with attributes including orientation, type, colour, fracture filling, surface shape and roughness. The abbreviations used to describe the fracture type are in accordance with the classification used by Suomen Malmi Oy (Niinimäki, 2004) (Table 2).

Fractures with a filling and an apparent colour were classified as filled, if the core was intact. The filled fractures with intact surfaces were described as closed or partly closed. In these cases, “closed” or “partly closed” has been written in the remarks column. The thickness of the filling was estimated with an accuracy of 0.1 mm.
The identification of fracture fillings was qualitative and made visually in accordance with the fracture mineral database developed by Kivitieto Oy and Posiva Oy (Table 3). Abbreviations were used during the logging. Where the recognition of a mineral was not possible, the mineral was described with a common mineral group name, such as clay, sulphide etc.

In addition to this, the morphology and alteration of fractures were also classified according to the Q-system (Grimstad & Barton 1993). The fracture morphology was described with the joint roughness number, Jr (Table 4) and the alteration with the joint alteration number, Ja (Table 5). The fracture shape and roughness of fracture surfaces were classified using a modification of Barton’s Q-classification (Barton et al. 1974) (Table 6).

**Table 2.** The abbreviations used to describe fracture type (Niinimäki 2004).

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Fracture type</th>
</tr>
</thead>
<tbody>
<tr>
<td>op</td>
<td>Open</td>
</tr>
<tr>
<td>ti</td>
<td>Tight, no filling material</td>
</tr>
<tr>
<td>fi</td>
<td>Filled</td>
</tr>
<tr>
<td>fisl</td>
<td>Filled slickensided</td>
</tr>
<tr>
<td>grfi</td>
<td>Grain filled</td>
</tr>
<tr>
<td>clfii</td>
<td>Clay filled</td>
</tr>
</tbody>
</table>

**Table 3.** Fracture filling mineral abbreviations.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Mineral</th>
<th>Abbreviation</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>= Calcite</td>
<td>SK</td>
<td>= Pyrite</td>
</tr>
<tr>
<td>SV</td>
<td>= Clay mineral</td>
<td>KA</td>
<td>= Kaolinite</td>
</tr>
<tr>
<td>KL</td>
<td>= Chlorite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Concise description of joint roughness number $J_r$ (Grimstad & Barton 1993).

<table>
<thead>
<tr>
<th>$J_r$</th>
<th>Profile</th>
<th>Rock wall contact, or rock wall contact before 10 cm shear.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>SRO</td>
<td>Discontinuous joint or rough and stepped</td>
</tr>
<tr>
<td>3</td>
<td>SSM</td>
<td>Stepped smooth</td>
</tr>
<tr>
<td>2</td>
<td>SSL</td>
<td>Stepped slickensided</td>
</tr>
<tr>
<td>3</td>
<td>URO</td>
<td>Rough and undulating</td>
</tr>
<tr>
<td>2</td>
<td>USM</td>
<td>Smooth and undulating</td>
</tr>
<tr>
<td>1.5</td>
<td>USL</td>
<td>Slickensided and undulating</td>
</tr>
<tr>
<td>1.5</td>
<td>PRO</td>
<td>Rough or irregular, planar</td>
</tr>
<tr>
<td>1</td>
<td>PSM</td>
<td>Smooth, planar</td>
</tr>
<tr>
<td>0.5</td>
<td>PSL</td>
<td>Slickensided, planar</td>
</tr>
</tbody>
</table>

Note
1. Descriptions refer to small-scale features and intermediate scale features, in that order.
2. $J_r = 0.5$ can be used for planar slickensided joints having lineation, provided the lineations are oriented for minimum strength.

Table 5. Concise description of joint alteration number $J_a$ (Grimstad & Barton 1993).

<table>
<thead>
<tr>
<th>$J_a$</th>
<th>Rock wall contact (no mineral filling, only coatings).</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75</td>
<td>Tightly healed, hard, non-softening impermeable filling, i.e. quartz, or epidote.</td>
</tr>
<tr>
<td>1</td>
<td>Unaltered joint walls, surface staining only.</td>
</tr>
<tr>
<td>2</td>
<td>Slightly altered joint walls. Non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.</td>
</tr>
<tr>
<td>3</td>
<td>Silty or sandy clay coatings, small clay fraction (non-softening).</td>
</tr>
<tr>
<td>4</td>
<td>Softening or low-friction clay mineral coatings, i.e. kaolinite, mica, chlorite, talc, gypsum, and graphite, etc., and small quantities of swelling clays (discontinuous coatings, 1-2 mm or less in thickness).</td>
</tr>
<tr>
<td>6</td>
<td>Rock wall contact before 10 cm shear (thin mineral fillings). Sandy particles, clay-free disintegrated rock, etc.</td>
</tr>
<tr>
<td>8</td>
<td>Medium or low over-consolidation, softening, clay mineral filling (continuous &lt;5 mm in thickness).</td>
</tr>
<tr>
<td>8-12</td>
<td>Swelling-clay fillings, i.e. montmorillonite (continuous, &lt;5 mm in thickness). Value of $J_a$ depends on percentage of swelling clay-sized particles, and access to water, etc.</td>
</tr>
</tbody>
</table>

| No rock-wall contact when sheared (thick mineral fillings).                                                                                           |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6-12  | Zones or bands of disintegrated or crushed rock and clay.                                                                                             |
| 5     | Zones or bands of silty- or sandy-clay, small clay fraction (non-softening).                                                                           |
| 10-20 | Thick, continuous zones or bands of clay.                                                                                                             |
Table 6. Fracture surface shapes and roughness (Barton et al. 1974).

<table>
<thead>
<tr>
<th>Fracture shape</th>
<th>Fracture roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar</td>
<td>Rough</td>
</tr>
<tr>
<td>Stepped</td>
<td>Smooth</td>
</tr>
<tr>
<td>Undulated</td>
<td>Slickensided</td>
</tr>
</tbody>
</table>

During the fracture logging, the surface colour was also registered. The colour is often caused by the dominating fracture filling mineral or minerals, e.g. chlorite (green) or kaolinite (white). Presence of minor filling minerals usually causes some variation in the colour of the fracture surface. These colour shades were described e.g. as dark or greenish. Tight fractures typically had only a slightly different shade from the host rock colour.

In the fracture logging, 30 separate fractures were recorded from drillcore ONK-PVA8 (Appendix 7.7). There are 12 filled fractures (40.0 %), nine filled slickensided fractures (30.0 %) eight tight fractures (26.7 %) and one grain filled fracture. In addition there is unknown number (few) of mainly slickensided fractures in depth section 12.00 – 12.06 m, where sample is crushed.

Most of the fractures are undulated or planar in shape, have a rough profile and high joint roughness number, indicating a high friction in the fracture surface. These fractures are usually filled or tight with low to low-moderate joint alteration numbers (0.75 – 3). The high friction fractures are mostly located scattered throughout the core. In the drillcore ONK-PVA8 the low friction fractures with smooth or slickensided shapes, planar or undulated surfaces and high joint alteration number (4 – 6) occur mostly within a fractured zone at depth section 11.75 – 12.13 m.

In the high-friction fractures, the fracture fillings are absent (tight fractures), or consist of hard, non-softening coatings or fillings, mainly calcite (filled fractures), often with small amounts of chlorite, kaolinite or other clay minerals. The low-friction fractures are mainly filled slickensided fractures. Slickensided fractures were mostly filled with chlorite, accompanied by one or several clay minerals, pyrite or calcite.

The identified fracture filling minerals of ONK-PVA8 according to the frequency of occurrence are: chlorite, calcite, pyrite, undefined clay minerals and kaolinite.

Only one fracture located in the oriented core section. Therefore the main fracture directions could not be defined.
3.6 Fracture frequency and RQD

The frequencies of natural fractures, RQD (Rock Quality Designator) (see Table 9) and mechanically induced breaks were all counted on one metre depth intervals (Appendix 7.10). The frequency of all fractures is the number of core breaks within one metre interval, including natural fractures and mechanically induced breaks. Mechanically induced breaks are caused by drilling, core handling and core discing. The natural fracture frequency is the number of natural fractures, open and closed, within one metre interval. If the frequency of all fractures is higher than the natural fracture frequency, the core must have been broken during the drilling. If the core was broken accidentally or by purpose during handling, it was marked to the core box with the letter F, and counted as a fracture or break depending on its nature. If the natural fracture frequency is higher than the frequency of all fractures, the fractures must be cohesive enough to keep the core together. The RQD gives the percentage of over 10 cm long core segments, separated by natural fractures, within one metre interval.

The average natural fracture frequency of the ONK-PVA8 core is 1.7 pcs/m and the average RQD value is 96.0 % (Appendix 7.8). There is one section with crushed sample in which the number of fractures is unknown, and the fractures in this section are not counted into the fracture frequency average.

3.7 Fractured zones and core loss

Fractured zones were classified according to Finnish engineering geological bedrock classification (Korhonen et al. 1974) (Table 7). In drillhole ONK-PVA8 there is one fractured zone (RiIV-Rk4) at depth of 11.75 – 12.13 m (Appendix 7.9).

Significant core loss due to non-cohesive rock was not observed. Core loss due to rock breaking or grinding is mainly insignificant in the drillhole.
Table 7. Classification of fractured rock (Korhonen et al. 1974).

<table>
<thead>
<tr>
<th>Broken rock mass</th>
<th>Zone class</th>
<th>Fractures / metre</th>
<th>Fracture filling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block structured</td>
<td>RiII</td>
<td>3 - 10</td>
<td>no fillings</td>
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<tr>
<td>Fracture structured</td>
<td>RiIII</td>
<td>&gt; 10</td>
<td>none or thin</td>
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<tr>
<td>Crush structured</td>
<td>RiIIV-Rk3</td>
<td>3 - 10</td>
<td>filled with clay minerals</td>
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<tr>
<td></td>
<td>RiIIV-Rk4</td>
<td>&gt; 10</td>
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<tr>
<td>Clay structured</td>
<td>RiV</td>
<td>-</td>
<td>abundant clay material in rock mass</td>
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</table>

3.8 Weathering

The weathering degree of the drill core was classified according to the method developed by Korhonen et al. (1974) and Gardemeister et al. (1976) (Table 8).

The drillcore is mostly unweathered (Rp0), having only very weak and mostly local alteration, or no visible alteration at all. There is weak silicification and epidotization related to the brittle deformation zone at the depth of 11.38 – 12.22 m. (Appendix 7.10).

Table 8. Abbreviations of the weathering degree.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description of weathering type</th>
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</thead>
<tbody>
<tr>
<td>Rp0</td>
<td>Unweathered</td>
</tr>
<tr>
<td>Rp1</td>
<td>Slightly weathered</td>
</tr>
<tr>
<td>Rp2</td>
<td>Strongly weathered</td>
</tr>
<tr>
<td>Rp3</td>
<td>Completely weathered</td>
</tr>
</tbody>
</table>

3.9 Core discing

In Posiva’s logging procedure, core discing is logged separately, and depth intervals where core discing occurs are documented. The number of breaks and core discs is logged. The geometry of the top and bottom surfaces of the discs is described separately using the following classification:

- Concave
- Convex
- Planar
- Saddle
- Incomplete.

No core discing was found in the drillcore ONK-PVA8.
4 ROCK MECHANICS

4.1 The rock quality

Rock quality was classified during the core logging using Barton’s Q-classification (Rock Tunneling Quality Index; Barton, 1974 and Grimstad & Barton, 1993). The core is divided into sections, which can vary from less than a metre to several metres in length. In each section, the rock quality is as homogenous as possible. The roughness and alteration numbers are estimated for each fracture surface (Appendix 7.7). The roughness and alteration numbers (average, median and lower and higher quartiles) are then calculated for each section, and the median value is used in the rock quality calculations.

The Q-value is calculated by Equation 1 (Barton, 1974 and Grimstad & Barton, 1993):

\[ Q = \frac{RQD \cdot J_a \cdot J_w}{J_n \cdot SRF} \]  

(1)

The RQD (Table 9) is defined as the cumulative length of core pieces longer than 10 cm in a run divided by the total length of the core run. Closed fractures are also counted in the RQD value. Some constant values are used in the calculations. All closed fractures are given joint alteration (Ja) number of 0.75 (see Table 5). If the fracture interval of the relevant joint set is over one metre, the value of 1 is given to Jn (Table 9). If the fracture interval of the relevant joint set is over three metres, the value of 1 is added to the value of Jn, and Jn is given the value of 0.5. For rock sections with no fractures, the value of 5 for Jr and the value of 0.75 for Ja are used. In the calculations, joint water (Jw) and stress reduction factors (SRF) are assumed as 1, so the result of the calculation is the Q’-value.

The core sample of ONK-PVA8 was divided to four units of variable lengths, the Q’-values of which were then calculated separately. The results of Q’-classification are presented in Appendix 7.11. The rock quality (see Table 9) of ONK-PVA8 is mainly “very good” (9.16 m, 51.8 %), “extremely good” (5.60 m, 31.7 %), “good” (2.52 m, 14.3 %). The fractured zone (RiIV-Rk4) in the drillhole at depth of 11.74 – 12.13 m (0.39 m) is classified as “very poor”.
Table 9. Description of RQD and joint set number $J_n$ (Grimstad & Barton 1993).

<table>
<thead>
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<th>1. Rock Quality Designation</th>
<th>RQD</th>
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<tr>
<td>A Very poor</td>
<td>0 - 25</td>
</tr>
<tr>
<td>B Poor</td>
<td>25 - 50</td>
</tr>
<tr>
<td>C Fair</td>
<td>50 - 75</td>
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<td>D Good</td>
<td>75 - 90</td>
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<tr>
<td>E Excellent</td>
<td>90 - 100</td>
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</table>

Note: i) Where RQD is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate $Q$.
ii) RQD intervals of 5, i.e., 100, 85, 80, etc., are sufficiently accurate.

<table>
<thead>
<tr>
<th>2. Joint Set Number</th>
<th>$J_n$</th>
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<tbody>
<tr>
<td>A Massive, no or few joints</td>
<td>0.5 - 1.0</td>
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<tr>
<td>B One joint set</td>
<td>2</td>
</tr>
<tr>
<td>C One joint set plus random joints</td>
<td>3</td>
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<tr>
<td>D Two joint sets</td>
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<tr>
<td>E Two joint sets plus random joints</td>
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<tr>
<td>F Three joint sets</td>
<td>9</td>
</tr>
<tr>
<td>G Three joint sets plus random joints</td>
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<tr>
<td>H Four or more joint sets, random, heavily jointed, &quot;sugar cube&quot;, etc.</td>
<td>16</td>
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<tr>
<td>J Crushed rock, earthlike</td>
<td>20</td>
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</table>

Note: i) For intersections, use $(2.0 \times J_n)$
ii) For portals, use $(2.0 \times J_n)$
5 SUMMARY

As a part of the groundwater monitoring program in ONKALO, Suomen Malmi Oy core drilled a drillhole (ONK-PVA8) for groundwater monitoring station. The length of the drillhole is 17.74 m. The drillhole was drilled in a niche of the access tunnel at chainage 2935. The drilling was started from the tunnel wall with no casing drilling.

The drill rig was DE 130. The core was drilled using a NQ2 double tube core barrel. The drillhole diameter is 75.7 mm and the sample diameter is 50.5 mm. The drilling water was taken from ONKALO pipeline and marked with sodium fluorescein.

The main rock types intersected by the drillhole are diatexitic gneiss and pegmatitic granite. The rock samples are mostly unweathered or slightly weathered.

The average fracture frequency in drillhole is 1.7 (ONK-PVA8) and the mean RQD value is 96.0 %. One fractured zone was intersected. In the drillhole ONK-PVA8 20.0 % of the core was oriented.
6 REFERENCES


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