EUROPEAN COMMISSION

Community research

CROCK

(Contract Number: 269658)

DELIVERABLE (D-N°:1.1)
Provision of new fracture bearing drill core samples obtained, handled, transported and stored under anoxic conditions, including first documentation.

Author(s): **KIT-INE**

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EURATOM

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Dissemination Level		
PU	Public	X
RE	Restricted to a group specified by the partners of the CROCK project	
CO	Confidential, only for partners of the CROCK project	

Objectives:

The objectives were to organize new samples of fracture crystalline rock drill-cores from the Äspö URL, sampled and handled under anoxic conditions.

A first planning meeting for the CP-CROCK drilling campaign was organized by Henrik Drake (Isochron) as consultant for SKB at Äspö on the 29.03.2011. Participants to this meeting were: Henrik Drake (Isochron), Thomas Rabung (INE), Volker Krepper (INE), Thorsten Schäfer (INE), Stellan Holgersson (CTH),Stefan Allard (CTH), Mikael Gustafsson (MiRo), Roger Jonsson (MiRo). The outcome of this meeting is documented in ANNEX 1.

Based on the outcome and action list fixed in this meeting the drilling locations have been agreed on and the drilling campaign was scheduled for the first week in May (2.-6.) 2011 including ground water sampling.

Sampling campaign CP-CROCK: 2.-6. May 2011 Äspö tunnel

Persons present:
Hendrik Drake (SKB consultant), Stellan Holgersson (CTH), Sebastian Büchner (KIT-INE), Thorsten Schäfer (KIT-INE); MiRo (Drilling company)

Drilling strategy:

- 1st borehole from tunnel surface parallel to water conducting feature: **KA2368A-01**.
- 2nd borehole from niche parallel to tunnel surface in a distance of approx. 7m slightly dipping (~5°) perpendicular to structural features: **KA2370A-01**.

2. May:
1st borehole **KA2368A-01**. 2m in total drilled on this day. In general, the sampling procedure of bore cores was as follows:

- After the end of drilling a section the core (~1m) was transferred from the core driller to the wooden sampling boxes under oxygen.
- After a short visual inspection (max. 5 min) the cores were transferred to a transparent LD-PE bag.
- The bag was three times evacuated (~-0.4bar) and purged with nitrogen gas before welding and therefore sealing the core from further oxygen contact.
- The same procedure was performed with an Al bag for the second confinement.

Sampling of drilling fluid tank (taken from borehole KA2598) before the start of the 1st borehole **KA2368A-01**.
Sample ID: CROCK-1 (gasmouse)
Sampling of groundwater from borehole KA3600-F-2. Valve of the borehole section opened 14:00h. Outflow ~2L/min. Sampling in 50l Teflon coated Al-barrel started 16:30h by continuously flushing the barrel.

(SKB chemistry file 2009-09: 5060mg/L Chloride, 0.196 mg/L Fe(II), 0.212 mg/L Fe(tot), pH: 7.35, elec. cond.: 1500mS/cm)

3. May:
Stopped groundwater flow through 50L barrel @ 7:45h (barrel volume exchanged ~ 40 times)

4. May:
Set single packer in borehole **KA2368A-01** at 9:00h, natural groundwater outflow observed.
Groundwater samples taken:
Sample ID: CROCK-2 (50mL PE) @ 10:30h and CROCK-2 (gasmouse) @12:20h

5. May:
Sampling of drilling fluid tank after the end of the drilling campaign finishing borehole borehole **KA2370A-01**.
Sample ID: CROCK-3 (50mL PE) and CROCK-3 (gasmouse)

A brief sample description can be found in ANNEX 2.

Partner CTH has received the following core section:
#1.11, #1.12, #1.20, #1.30a, #1.30b, #2.4, #2.5, #2.7, #2.10a, #2.10b, #2.19, #2.20, #2.23, #2.24, #2.26,# 2.27 and 2.37.

The wooden sample boxes with the remaining sealed core sections were transferred directly after the drilling campaign to KIT-INE and are currently stored under Ar atmosphere (slight overpressure) in a container.
A questionnaire will be send out to the project partners on sample requests based on the material available from the drilling campaign.

ANNEX 1:

CROCK
Meeting minutes 29. March 2011, Äspö, Sweden

Persons present: Hendrik Drake (SKB consultant), Stefan Allard (CTH), Stellan Holgersson (CTH), Thomas Rabung (KIT-INE), Volker Krepper (KIT-INE), Thorsten Schäfer (KIT-INE); two representatives from MiRo (Drilling company)

Important results on how to proceed:

- Time plan; start hopefully 1st week of May, and perhaps including 2nd week as well.
- Niche/Gallery NASA2376A will be used for drilling campaign.
- To ensure reducing conditions – non stop drilling is desired (hopefully allowed – HD will check with SKB coordinator); working in shifts.
- Packer available if borehole is left open for long time
- Number of boreholes: 2 (maximum 3)
- No drill core material will be left
- Double-tube, 42 mm core, flushing water under nitrogen gas pressure
- Length of drill cores: 15 m (a potential 3rd borehole can be shorter or one of the two first boreholes can be some meter longer if necessary)
- Samples needed:
    - KIT-INE: Some fractured drill-core samples from the first meters, 30-40 cm, fracture along the drill-core. 2-3 anoxic drill-core samples, 15-20 cm longitudinal fractures
    - CIEMAT: 1 drill-core sample without fracture, 40 cm
    - HZDR: 10 mm thick plates with and without fractures (+ crushed material)
    - CTH: Min. 3, max. 8 drill-core samples, 15-20 cm length, 1 fracture per drill-core sample (perpendicular fracture)
    - NRI: 10, 20 and 50 mm long intact matrix. Also oxidized material for testing
- Orientation of drill cores were decided (will be oriented by HD) and are roughly accordingly:
    - 1st priority – drill along water conducting fracture sub-parallel with gallery. Starting outside gallery (if permission to drill from main tunnel). This will provide material for KIT-INE and provide hopefully considerable amounts of fracture filling material.
    - 2nd priority (if "1" is not possible)
        - 2:1: Drilled into left wall in gallery, drilled at 90 degrees angle to left wall, aim is to follow one sub-horizontal fracture (KIT-INE) and to hit the water-conducting fracture in "1" (KIT-INE) and other fractures perpendicular to the borehole (CTH). If not sufficient fracture length along drill core for KIT-INE carry out 2:2. If not enough fractures perpendicular to drill core for CTH but enough material for KIT-INE - carry out 3.
        - 2:2, Drill in the inner wall of gallery and follow one or several sub-horizontal fractures (KIT-INE), and in the meantime probably at

several locations hit perpendicular fractures (CTH) and fresh rock (for other partners).
    - 3rd priority (if too few samples for CTH and perhaps other partners was achieved) is to drill in the inner wall of gallery at some distance to horizontal fractures, with aim to hit several perpendicular fractures to the borehole (CTH) and fresh rock in between (other partners)
- Water sample – yet undecided due to high salinity of SA2600 (12,000 mg/L). KA3600 was suggested instead (5,000 mg/L Cl). Decision pending, Ignasi contacted.
- Water sample will be taken from flushing water (KA2598 probably, which is anoxic); (one 250mL "gas mouse" sample of drilling water from tank before start of the drilling activity, one 250mL "gas mouse" sample of drilling water from tank after finishing drilling activities, one 250mL "gas mouse" sample of the groundwater near the niche)
- Tank for anoxic drilling fluid and nitrogen stripping has to be prepared in advance; HD?
    - KIT-INE provides barrel and related equipment for sampling
    - No filters needed
    - Based on the composition of the natural groundwater taken a synthetic groundwater composition/recipie will be provided to all CROCK partners (KIT-INE)
- Sampling procedure (same as Waber and Smellie, 2006 etc, involving nitrogen, vacuum pump and welding of plastic bags):
    - 1) sealing with plastic bag (ordered by HD), photography and documentation
    - 2) sealing with Alu-bag.
    - 3) placing in drill core box (ordered by HD)
- Sampling personnel, 2 persons working in shifts (if allowed); during drilling two persons form KIT-INE, one person from Chalmers, HD and two persons from MIRO are planned to be on-site.
- Table and chairs will be ordered to drill site (HD)
- KIT-INE brings one car (diesel, with two ABC 6kg fire extinguisher); appointment has to be arranged for car technical check and personal safety training HD?
- KIT-INE has to check for boarder controls (i.e. customs)
- Partners are responsible for proper clothing (safety shoes, helmet, light, etc.) and accommodation.
- SKB coordinator (Mats Lundqvist) will handle contracting of drilling company

ANNEX 2:

Brief sample descriptions of CROCK drill cores, as noted during sampling at the CROCK drill site

Note: all rock is Äspö diorite (ÄD), if nothing else is stated. Other rock types are mafic rock (as enclaves/xenoliths), fine-grained granite (FGG) and Ävrö granite (ÄG). Number of open fractures in each sample is noted in the sample protocols.

Drill core from KA2368A-01

#1.0 (0.00-0.47 m): Starts deformation zone in fine-grained granite (FGG). After a couple of decimetres the rock changes into intact rock (ÄD). High fracture frequency of open fractures in first dm.

#1.1 (0.47-0.97 m): There are three artificial fractures (FA) and three natural open fractures (FN) in this section.

#1.2 (0.97-1.47 m): At 0.97-1.20 , there is an epidote-dominated semi-ductile, sealed network (withbrittle re-activation) and with hydrothermally altered wall rock (red-stained). Rock is ÄD. At ~1.30-1.43 m, there is a similar epidote-fracture.

#1.3 (1.47-1.93 m): At 1.72, 1.915, and 1.93 m there are FA and at 1.92 there is a FN. At 1.76-1.86 m is a FGG dyke.

#1.4 (1.93-2.41 m): At 1.93, 2.26 and 2.41 there are FA:s.

#1.5 (2.41-2.92 m):

At 2.57 m is a sealed fracture with calcite (cc), K-feldspar (kfs), chlorite (chl), and quartz (qz).
At 2.67 m is a sealed fracture with cc, prehnite (pr), qz.
At 2.81 m AF
At 2.79-2.92 Sealed fracture at low angle to drill core, with slightly red-stained and hydrothermally altered wall rock (WR). Fracture minerals: epidote (epi), calcite (cc) and qz.

#1.6 (2.92-3.29 m):

At 2.93 m: sealed epi-fracture.
3.04 m sealed epi-fracture
3.25 m cc-qz fracture

#1.7 (3.29-3.62 m); Mafic xenolith at 3.35-3.44 cut by two thin sealed fractures.

3.60-3.62 m: sealed epi-cc-qz fracture.

#1.8 (3.62-3.93 m): Includes a epi-cc-qz-filled fracture at <45° to core at 3.62-3.72 cm.

#1.9 (3.93-4.28 m): At 4.08-4.28 is a sealed fracture/fracture network dominated by epidote, running at low angle to core.

#1.10 (4.28-4.77 m):

At 4.28-4.38 m: sealed epi-qz-cc fracture network (8 natural fractures) at low angle to core.
At 4.45-4.59 m and 4.71-4.74 m: Mafic enclaves
At 4.74-4.77 m: Sealed epi-chl-cc fracture

#1.11 (4.77-4.90 m): FN at lower end. Mafic parts (foliated) exist. Two sealed fractures exist and are aligned with foliation.

#1.12 (4.90-5.40 m): Samples starts with possible FN. 4.90-5.00 m comprises a very mafic variety of ÄD.

#1.13 (5.40-5.90 m): Sealed fracture at 5.84-5.87 m (cc, kfs, qz, chl). At 5.87-5.90 m is start of open fracture at low angle to core (epi, chl, euhedral cc). At 5.75 is a FN (possibly open before drilling).

#1.14 (5.90-6.31 m): At 5.90-6.10 m is a a sealed fracture at ~20° angle to drill core (and two at high angle). This is an old hydrothermal fracture which has been ra-activated and fracture minerals are epi, cc, chl. At 6.31 m is a FN.

#1.15 (6.31-6.51 m): FN at both ends. A sealed epidote-fracture is running along the drill core (in the centre of the drill core) at low angle through the whole sample.

#1.16 (6.51-6.85 m):

6.51 m: FN
6.52 m: FN
6.77 m: FN

#1.17 (6.85-7.31 m): At 7.14-7.31 is very fine-grained granite with very high amount of sealed epidote fractures (both perpendicular and sub-parallel to core).

#1.18 (7.31-7.64 m): At 7.32-7.47 is an open fracture with orientation ~30° to core with two related smaller fractures.

#1.19 (7.64-8.13 m): At 7.76-7.90 m: partly open fracture and hammer-induced fracture.

#1.20 (8.13-8.26 m): At 8.13 m: Sealed fracture opened during handling (running perpendicular to core).

#1.21 (8.26-8.56 m): Foliated granite. Start of natural fracture at ~8.50 m.

#1.22 (8.56-8.85 m): Foliated granite with an open fracture at ~20° angle to core (at 8.63-8.81 m).

#1.23 (8.85-9.26 m): At 9.14 m: FA. Long fracture along borehole through the whole 8.85-9.26 m section (with hydrothermal red-staining of wall rock). Main part of sample is granite. ÄD starts at 9.14-9.26 m.

#1.24 (9.26-9.74 m): Starts with fracture at ~20° to core (with related fracture) running with core for 9.26-9.53 m. At 9.70 m a fracture starts which has been fragmented into smaller pieces during drilling.

#1.25 (9.74-10.18 m): Starts with a drilling-altered FN. Rest of sample is not fractured except for a longer vein of qz-kfs (late-magmatic). Three veins7dykes of FGG (1-2 cm wide) exist.

#1.26 (10.18-10.65 m): ÄD-dominated with some FGG and some partly open fractures running along drill core.

#1.27 (10.65-11.12 m): Mainly unfractured granite. Diorite is included from 11.00 m and forward.

#1.28 (11.12-11.65 m): Fresh rock with a couple of sealed fractures. At 11.39-11.43 m is an epidote-dominated fracture.

#1.29 (11.65-12.11 m): Fresh ÄD rock.

#1.30 (12.11-12.66 m, a+b): Natural fracture re-opend during drilling handling (at 12.38 m). Sealed epi-fracture at 12.30 m. Mafic xenolith at 12.60-12.65 m.

#1.31 (12.66-13.04 m): 12.66-12.71 m: pegmatite dyke. 12.88 m FN (opened at drilling/handling). 13.02 m: FA.

#1.32 (13.04-13.52 m): Fresh rock. One fracture (sealed with epidote) at 13.27 m. Mafic enclave at 13.44 to 13.50 m.

#1.33 (13.52-14.00 m): At 13.96 m is an FA. Otherwise fresh rock dominates.

Drill core from KA2370A-01:

#2.1 (0.00-0.53 m): 0.00-0.15 m fractured excavation damage zone including at least one FN. 0.15-0.50 m: >3 sealed natural fractures running at 10° to core. One is partly open with "abundant" fracture coating (epi, chl).

#2.2 (0.53-0.97 m): At 0.70 m is a natural fracture that was opened during handling. At 0.96 m is a FA.

#2.3 (0.97-1.30 m): Sample used for bulk fracture coating material (INE). FN at 1.30 m, otherwise fresh ÄD. Thin sealed fracture at 1.28-1.30 m.

#2.4 (1.30-1.69 m): Natural fractures at both ends (~90° to core). A thin sealed fracture at 1.30-1.32 m.

#2.5 (1.69-1.93 m): FN at start. FA at low end (bottom). One thin sealed fracture at 1.78 m. One wider sealed fracture at 1.83-1.87 m. Otherwise fresh ÄD.

#2.6 (1.93-2.45 m): 3 FA in the sample. From 1.93-2.20 m is fresh ÄD. From 2.20 to 2-45 m is hydrothermally altered (red-stained) core.

#2.7 (2.45-2.89 m): Relatively fresh ÄD. FN at both ends and at 2.63-2.64 (with some crush in between). Indication of diffuse sealed fracture running along core at low angle.

#2.8 (2.89-3.38 m): FN at 3.36, 3.38 m (perpendicular to core), one or two of these may be induced. Two sealed fractures perpendicular to core exist, otherwise fresh rock dominates.

#2.9 (3.38-3.81 m): Fresh FGG-section (whole sample). At 3.61 m is a sealed fracture (~perpendicular to core). At 3.38 m is perhaps a FN (or FA, but there is indication of coating). At 3.81 is a FN (cc coating).

#2.10 (3.81-4.35 m):

At 3.81 m: FN (cc coating)
At 3.85 m: ÄD starts (first piece of sample is FGG).
At 3.95 m: Sealed fracture (5 mm thick 70° to core).
At 4.17 m: FN, which has re-activated 1) sealed epidote fracture, 2) partly open fracture at 4.16 m.
At 4.21, 4.22, 4.23, 4.24, 4.30, 4.33 m are thin sealed fractures (~perpendicular to core). At 4.35 is a FN (thin filling). This is probably the deformation zone sub-parallel with KA2368A-01.

#2.11 (4.35-4.68 m): ÄD with mafic inclusions (4.52-4.61 m, 4.63-4.68 m). 3 FN, perpendicular to core (including relatively abundant fracture coating). 8 parallel sealed fractures 4.35-4.49 m (perpendicular to core). At 4.55 ad 4.65 m are also sealed fractures. These fractures may be part of the deformation zone sub-parallel with KA2368A-01.

#2.12 (4.68-5.13 m): Mainly ÄD wich some mafic inclusions. Both ends are natural fractures. Sealed fractures are at 4.71, 4.73 and 4.80 m. At 5.01-5.07 m is a sealed epi-fracture (at ~20° to core). Fracture at 5.13 m has older filling material next to the fracture.

#2.13 (5.13-5.34 m): Quite fresh ÄD with FN at 5.13 m. FA at 5.34 m.

#2.14 (5.34-5.69 m): Fresh ÄD. Small mafic inclusions. FA at both ends. One diffuse hydrothermal alteration rim along sealed fracture (5.55-5.69 m, low angle to core).

#2.15 (5.69-6.03 m): Start of more hydrothermally altered ÄD at ~5.73 m and continues through the rest of the sample. Sealed fractures (mainly epidote) at 5.79-5.93 m (~20° to core).

#2.16 (6.03-6.33 m): Whole sample is hydrothermally altered ÄD. FA at both ends. At 6.22-6.28 m is a sealed network of epidote (and prehnite? +red-stained feldspar, with Fe-oxide inclusions) fractures (continues to 6.33 m).

#2.17 (6.33-6.84 m): FA at both ends. Fine-grained ÄD. Two diffuse sealed fractures with red-stained rims exist. At ~6.83 m the rock type changes to Ävrö granite (ÄG, mainly granodiorite to quartz monzodiorite) which is more coarse grained than ÄD.

#2.18 (6.84-7.30 m): Starts with FA. At 6.84-7.15 m there is a sealed fracture with prehnite running at 10-15° to core. At 7.17 m is a FA opened during hammering (perhaps sealed natural fractured re-activated). At 7.27, 7.29 and 7.30 m are FA which may have re-opened natural sealed fractures.

#2.19 (7.30-7.57 m): Fresh granite, except for mafic inclusions at 7.44-7.50 m. FA at 7.30 m and 7.57 m (FN?).

#2.20 (7.57-7.91 m): 3 FN perpendicular to core (At ends and 7.76 m). Thin sealed fracture at 7.89 m. Red-stained ÄG.

#2.21 (7.91-8.26 m): Red-stained ÄG. 6 FN at e.g. 7.91, 7.97, 8.02, 8.12 and 8.14 m (all perpendicular to core). At 7.91-8.05 m is a sealed fracture with abundant fracture coating (~10-15° to core).

#2.22 (8.26-8.47 m): Red-stained rock (ÄG) with a sealed fracture/fracture network (epi-dominated) at 8.30-8.40 m, which is partly open.

#2.23 (8.47-8.91 m): Quite fresh but diffusely red-stained ÄG. FN at both ends. Sealed fractures at 8.58 and 8.66 m.

#2.24 (8.91-9.24 m): FN at 8.91 m. FA at 9.20, 9.22 and 9.24 m. Red-stained ÄG with some hydrothermal alteration and micro-fracturing.

#2.25 (9.24-9.54 m): Open fracture at ~30° to drill core (from 9.24-9.42 m), intersected by fractures perpendicular to core at 9.32 m, 9.37 m (and 9.41 m). FA at both ends of sample.

#2.26 (9.54-9.81 m): Starts with FA and ends with FN (perpendicular to core). Small amount of sealed fractures (2 very diffuse).

#2.27 (9.81-10.20 m): Starts with FN (perpendicular to core). FA at 10.17 and 10.20 m. Otherwise quite un-fractured, red-stained granite (ÄG). Sealed fracture at 10.05-10.09 *(60° to core).

#2.28 (10.20-10.65 m): FA at ends and at 10.53 m. Fresh/un-fractured rock.

#2.29 (10.65-11.16 m): Starts with FA. At 10-73-10.85 m is an open fracture with small amounts of coating (~30° to core, with a perpendicular sealed fracture holding prehnite and calcite). At 10.90 m is a sealed fracture at 10° to core (epidte/prehnite+cc+kfs, partly a sealed network). This fracture continues to next sample.

#2.30 (11.16-11.63 m): Fresh ÄD. Sealed fracture at 11.16-11.27 m, with red-stained wall rock adjacent to it.

#2.31 (11.63-12.13 m): ÄD, red-stained around three fractures at 11.89-12.00 m dipping 45°, 45° and 15° to core (one with fracture coating; e.g. chl). 4 FA (ends and two re-activated sealed fractures during hammering).

#2.32 (12.13-12.50 m): ÄD with FGG-dyke at 12.26 m. Qz-vein at 12.28-12.33 m. At 12.50 m is FA which may be old sealed fracture, with red-stained wall rock.

#2.33 (12.50-12.82 m); FA at 12.50 m (may be old fracture). At 12.80 m are two cross-cutting open fractures (dip 45 and 40° to core). One of them has dark chlorite coating. At 12.55-12.68 m: sealed fracture sub-parallel to drill core.

#2.34 (12.82-13.08 m): At 12.82 m start of 40° and 45° oriented cross-cutting open fractures. FA at 13.08 m.

#2.35 (13.08-13.45 m): FA at 13.08 m. FN at 13.45 m. At 13.16 to 13.22 m is a sealed epidote-dominated fracture at 34° to core (+qz and chl) with breccia-features and hydrothermal rim of 2-4 cm into wall rock (diffuse gradual boundary to fresh rock).

#2.36 (13.45-13.69 m): Fresh ÄD with FN at both ends (dip 65° and 70° to core).

#2.37 (13.69-14.05 m): 3 open fractures (FN) at 13.69 to 13.79 m (dips to core: 74, 70 and 20°). Ends at 14.05 m with a FN with e.g. cc on the surface (dip to core ~70°).

#2.38 (14.05-14.60 m):

FN at 14.05 m (70° dip to core).
FN at 14.19 m (60° dip to core)
FN: 14.51-14.57 m (30° dip to core, slickensided with an additional perpendicular open fracture, at 80° to core)
Ends with FA at 14.60 m.