GTS Phase VI:
The Colloid Formation and Migration Project (CFM)

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Why colloids?

Comments from the swiss regulator HSK (memo of 24.3.98):

- “....the generation of colloids at the boundary of the bentonite package cannot be excluded....”
- “....colloid facilitated transport of strongly sorbing radionuclides at the near-field/far-field boundary remains very much an open question....”

1. Bentonite colloids
2. Radionuclides
3–6. Colloid interactions
7. RN matrix diffusion
8. e.g. organic colloids
CFM task list and time schedule

Phase I
1. Phase I
2. 1/ Preliminary studies
   a. 1.1. Definition of boundary conditions
   b. 1.2. FEs concept
   c. 1.3. FEs evaluation
   d. 1.4. Monitoring concept
   e. Milestone: Is the experimental concept feasible?
3. 2/ Predictive modelling & supporting lab programme
   a. 2.1. Hydraulic model
   b. 2.2. Critical area transport modelling
   c. 2.3. Supporting area flume programme
   d. Milestone: Is the experimental info appropriate?
4. Phase II
5. 3/ In situ experiment
   a. 3.1. Site preparation & validation of model predictions
   b. 3.2. Benthic transport & colonization
   c. 3.3. First monitoring phase
   d. 3.4. Second monitoring phase
   e. Milestone: Interim report of monitoring phase 1/2
   f. 3.5. Third monitoring phase
   g. Milestone: Decision for excavation
6. 4/ Excavation / Solid analysis
   a. 4.1. Excavation of collared source / flow field
   b. 4.2. Analysis of solid samples
7. Other activities (both phases)
   a. 5/ Modelling activities (see also above)
   b. 6/ Reporting (milestone- and progress reports)
   c. Milestone: End of project
Background

- Under certain conditions, it must be assumed that a limited amount of radionuclides will be released from the EBS of a potential repository.

- Bentonite colloids could be produced at the EBS/host-rock interface, preferentially near water conducting features.

- Natural analogue and field data: colloidal-mediated transport has been observed in certain systems but they are either non-relevant or not well enough characterised for clear PA statements to be made.

- CRR (Colloid and Radionuclide Retardation, 1997 - 2002) and CFM are dedicated to answering these open questions by studying the bentonite colloid formation and the influence of bentonite buffer-derived colloids on the migration behaviour of radionuclides (mainly actinides and fission products).
CFM – Initial aims

- Examine colloid generation rates and mechanisms at the EBS – host rock boundary under *in situ* conditions.
- Evaluate the long-distance migration behaviour of EBS-derived colloids in a water-conducting feature in a repository relevant flow system.
- Study the long-term geochemical behaviour (mobility, mineralisation, colloid formation, *etc*) of radionuclides at the EBS-host rock boundary.
- Examine reversibility of radionuclide uptake onto colloids.
- Gain experience in long-term monitoring of radionuclide/colloid propagation in the vicinity of a repository.
- Apply the results to improve repository performance assessments, optimise EBS design and contribute to the "monitoring" debate.
From CRR to CFM

Open points after CRR:

- Quantification of colloid formation and integration of source term into transport models
- Understanding of reversible or irreversible radionuclide binding to colloids and rock surfaces
- Need for improved filtration theories (colloid-mineral interaction)
- Characterisation of the bentonite porewater/groundwater mixing zone (formation of new colloids/immobilisation of colloids)

Answering these questions requires laboratory and field experiments at very low flow rates!!
Schematic illustration of the conceptual model for the CRR and CFM experiments

- Bentonite (near field)
- Grimsel granodiorite (far field)

Starting point of the CFM Experiment

Radionuclide migration & bentonite colloids

Shear zone (preferential flow path)

Bentonite pore water

Groundwater mixing zone

Grimsel groundwater
CFM - principle layout of the *in-situ* experiment

- Sealed tunnel surface and position of reinforcement packer
- Extraction borehole (red)
- Monitoring and sampling boreholes (green)
- Colloids
- Radionuclides
- Emplacement borehole (grey) with betonies/RN source (blue)
- Shear zone
The relevant surface for colloid formation and transportation will be the contact surface between the bentonite and the flow paths. Bentonite colloids are formed at the bentonite granite interface under static as well as under dynamic groundwater conditions (bentonite erosion).
The site – Where at the GTS are we?

- In the AU tunnel
- Encompassing a shear zone
- With several pre-existing boreholes
Field activities - Summary of the hydraulic testing (1)

⇒ Heterogeneous distribution of T-Values in the shear-zone

⇒ BOMI-7: Very tight zone (isolated)

⇒ CFM 06.001: Tight zone => end of shear zone?

⇒ CFM 06.001: Very well connected with Pinkel surface packer

⇒ BOMI-7: Very tight zone (isolated)
The site – The shear zone

- A zone with many discontinuities
- Signs of ductile and brittle deformation
- Some water inflow into the tunnel

Core sample for lab experiments
Field activities – Initial sealing

- Sealing the tunnel surface with Sikadur resin over a length of about 6 m with a complete sealing of the shear zone surface
- Installation of surface packers
Hydraulic testing (2)

- Hydraulic testing before and after sealing
- Long-term monitoring of pressure and groundwater flow from the shear zone into the tunnel
- Development of a hydrogeological model
Field activities – More sealing

- **Issue:** Surface sealing insufficient to sustain high water pressures along shear zone
- **Solution:** Installation of the Yellow Submarine = Mega tunnel packer

Water-filled space between tunnel surface and steel cylinder (pressure in annulus > pressure in shear zone)

- Steel cylinder
- “Bullflex” doughnut-shaped packer elements (inflated with concrete)
- Shear zone
- Reinforcement ring
Field activities – Installation of the
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Main activities during the years - *FIELD*

- Three short-term *tracer tests* were carried out in Nov. 05, Jan. 06 and May 07.
- Two boreholes were drilled and equipped for testing and observation (Aug. 06).
- The yellow *submarine* was born (Oct. 06).
- Tunnel packer and new boreholes have been *instrumented* and connected to the DAS (Feb. 07).
- *Saturation of tunnel packer* started in March 07 (groundwater inflow from the shear zone is monitored).
- *Additional sealing campaigns / final saturation of the packer* in Nov. 2007.
- Uranine *tracer tests* (Run 07-03/04/05) were carried out in Dec. 2007.
- Homologue / colloid *tracer test* and Uranine *tracer test* (Run 08-01/02) (February 2008).
First homologue / colloid tracer test (Run 08-01)

Simplified setup:
Laboratory programme – Objectives (1/2)

➢ Increase process understanding

➢ Investigate the bentonite porewater/groundwater mixing zone and define speciation of radionuclides / stability of bentonite colloids

➢ (formation of new colloids / immobilisation of bentonite colloids)

➢ Study the reversibility of radionuclide binding to colloids and rock surface (radionuclide-colloid & radionuclide-fracture infill mineral interaction)

➢ Perform flow-through experiments in the laboratory under low flow and anaerobic conditions with representative host rock material to investigate the colloid source term and colloid / radionuclide mobility (filtration, colloid-mineral surface interaction)
Laboratory programme (2/2)

- **Support of the *in situ* experiment**
  - Characterisation of tracer cocktails (*colloid formation, in situ* speciation)
  - Investigation of bentonite pre-saturation
  - Evaluate different forms of bentonite labelling and tracer release
  - Perform long term experiments for *colloid generation* at EBS-host rock interface with different bentonite / groundwater types
  - Test the applicability of new ‘passive’ *in situ* monitoring and sampling devices for colloids and radionuclides

- **Support the modelling group with base data for colloid transport modelling**
  - Deliver *process understanding* and parameters needed for conceptual models and to increase confidence in predictive modelling
Laboratory program – Issues to be studied

- Colloid generation (physical erosion, geochemical alteration etc.)
- Colloid transport/retardation and stability (filtration effects, sedimentation, groundwater chemistry)
- Radionuclide association (colloid-RN binding, reversibility / irreversibility, homogeneous radio-colloids)
- Bentonite inter-comparison (Febex, Kunigel, MX 80, …)
The Modelling Group – Objectives

- **Short-term objective:** Planning the *in-situ* experiment
  - Adjust the flow field
  - Decide where measurements should be taken
  - Test sensitivities of measuring devices

- **Longer-term objective:** Supporting repository safety studies
  - What initiates colloid facilitated radionuclide transport?
  - What is the possibility of mobile, stable colloids coupled with irreversible radionuclide uptake?
  - Is there matrix diffusion of colloids?
  - Is there buffer erosion/colloid generation? (of concern to some programs in conjunction with glaciation scenarios)

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**First transport modelling started (a)**

**and hydraulic modelling continued (b)**
Next activities

Finalise Phase I planning and initialisation of Phase II

- Finalise field work
  - Continue long-term monitoring
  - Additional sealing work of the Mega packer
  - Plan next homologue/colloid test with smaller flow rates

- Final Phase I reporting
  - Hydraulic interference between the CFM and LTD experiments (in prep.)
  - Modellers database (May 08)
  - Modelling report (May 08)
  - CFM Phase I report (lab/mod/field/as build)
  - Phase II planning document/design report (EBS/Monitoring concept/tracer evaluation/exp. setup...)

- Meetings
  - Phase II “Kick off meeting” May 08
  - Next modelling meeting October??
CFM Project - *Expected Output*

- Significant increase in the understanding of processes related to colloid formation at the bentonite/host rock interface
- Complement the currently available knowledge on colloid migration in water-conducting features (e.g. colloid stability, colloid filtration effects or the influence of colloids on the flow field) with “real time” data
- Provide PA relevant information on the influence of colloids on radionuclide migration and retardation
- Gain experiences in long term monitoring programmes for repository surveillance
thank you for your attention