Introduction to the Colloid Formation and Migration (CFM) Project at the Grimsel Test Site (GTS) Phase VI

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1. Grimsel Test Site

The Grimsel Test Site (GTS) is located at an altitude of 1730 meters in the granitic rock of the Aar Massif in the Alps, Switzerland. The GTS tunnel system is around 1 km long and was excavated in 1983 using a full-face tunneling machine (diameter 3.5m) [1]. The 6th phase of investigations was started in 2003 with a ten-year planning horizon. Numerous *in-situ* experiments with inactive tracers and radionuclides were successfully carried out over the past few years at the Grimsel Test Site. For the GTS Phase VI, major projects such as CFM (Colloid Formation and Migration), LCS (Long-Term Cement Studies), and LTD (Long-Term Diffusion) have been initiated to simulate the long-term behavior of contamination plumes in the repository near-field and the surrounding host rock [2].

2. CFM Project

2.1. Background

Compacted bentonite has been considered as a candidate buffer material in the underground repository for high-level radioactive waste disposal. It has been reported that bentonite colloids can be generated by erosion of bentonite particles caused by groundwater flow at the interface of compacted bentonite and surrounding fractured rock [3]. The generation of bentonite colloids can be important for the migration of radionuclides since most of the radionuclides are strongly sorbed onto the bentonite colloids. The basic concept of the CFM experiment is schematically illustrated in Fig. 1.

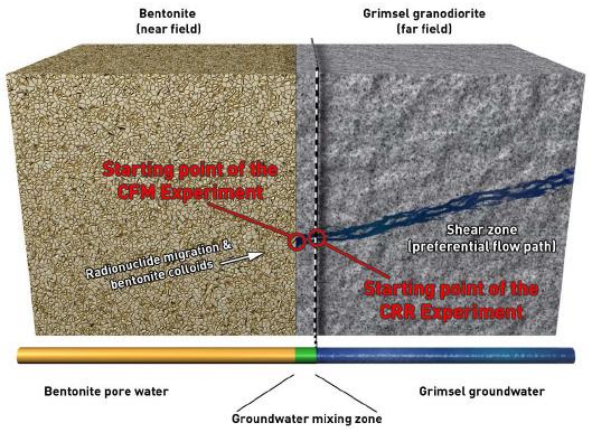

Fig. 1. Schematic illustration of the conceptual model for the CFM experiment.

The aims of the CFM long-term colloid project are listed in Table 1 [4]. They have been and will continue to be pursued with an integrated program of field testing, laboratory studies and modeling/interpretation. The contributions of the different aspects of the program to the aims are also included in the table.

Table 1: Aims and Methods of the CFM Project

Aim	Method
Examine colloid generation rates and mechanisms at the engineered barrier system (EBS) – host rock boundary under *in situ* conditions	Laboratory and *in situ* test
Evaluate the long-distance migration behavior of EBS-derived colloids in a water-conducting feature in a repository-relevant flow system	Colloid tracer tests and monitoring of release from in situ test
Study the long-term geochemical behavior of radionuclides at the EBS-host rock boundary	Laboratory tests including mockups and monitoring of *in situ* test
Examine reversibility of radionuclide uptake onto colloids	Laboratory, possibly mockups
Gain experience in long-term monitoring of radionuclide/colloid propagation near a repository	Design, development, implementation and "post-mortem" examination of in situ test monitoring system
Apply the results to improve repository performance assessments, optimize EBS design and contribute to the "monitoring" debate.	Post test interpretation and synthesis

2.2. Progress

The CFM project was initiated in 2004 by ANDRA (Agence nationale pour la gestion des déchets radioactifs, France), JAEA (Japan Atomic Energy Agency, Japan), FZK/INE (Forschungszentrum Karlsruhe/Institut für Nukleare Entsorgung, Germany), and Nagra (National Cooperative for the Disposal of Radioactive Waste, Switzerland). AIST (Advanced Industrial Science and Technology, Japan), SKB (Svensk Kärnbränslehantering AB, Sweden) and CRIEPI (Central Research Institute of the Electric Power Industry, Japan) joined the project at later stages in Phase 1. Phase 2 commenced in 2008 with active participation of seven partners: KAERI, Nagra, JAEA, CRIEPI, SKB, FZK/INE, and Posiva Oy. Phase 2 will continue until 2013.

2.3. Research Activities

2.3.1. Site selection, characterization and preparation

An early task of the CFM Phase 1 was focused on the site characterization and investigated the tunnel surface for the roughly 7 m marked by the shear zone of the former Migration Experiment (MI) at tunnel meter 96 of the radio-protection controlled tunnel of the GTS. Two boreholes CFM 06.001 and 06.002 were drilled and equipped for testing and observation in August 2006 (see Fig. 2).

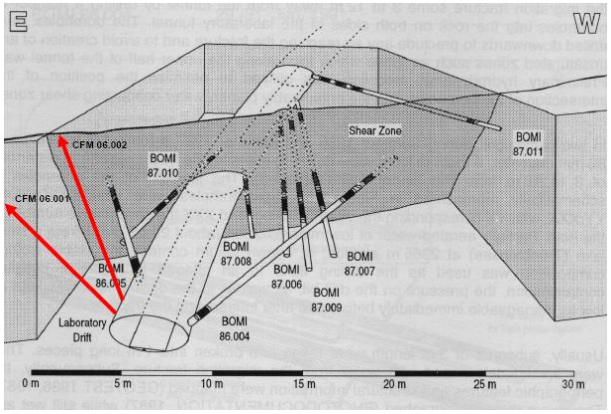

Fig. 2. Schematic block model of the site of the CFM *in situ* experiment, illustrating the boreholes from previous investigations and the newly drilled boreholes CFM 06.001 and CFM 06.002 (red arrows).

In order to fulfill the requirements for the *in situ* experiment, it was decided to install a 5 m long steel mechanical tunnel packer (referred to as mega packer or sub-mountain packer) to establish the natural saturation regime and to maintain high pressures in the MI shear zone.

2.3.2. Modeling and laboratory programs

A CFM modeling group was established with participants from the CFM partner organizations and beyond. The modeling group considers hydrogeological, radionuclide and colloid transport, as well as colloid generation models. A CFM laboratory group was established in 2005 and has held annual meetings. The group has recently completed a status report of the CFM laboratory program for Phase 1 with contributions from all participating laboratories. Data are available on the influence of the bentonite type, dry density, chemical composition of contact water, the fracture aperture and on the formation rate of colloids at the interface of bentonite and rock fracture.

2.3.3. Field tests

The basic concept of the CFM *in situ* experiment is shown in Fig. 3. Within Phase 1 field tests focused on:
- Characterization and preparation of the shear zone
- Development of an effective tunnel sealing system
- Drilling and testing of new boreholes
- Performance of conservative tracer tests
- Performance of colloid and homologue tracer tests

Within Phase 2, the field program will be focused on:
- Source zone selection and verification, monitoring system installation and the in situ test itself
- Colloid transport related tracer tests

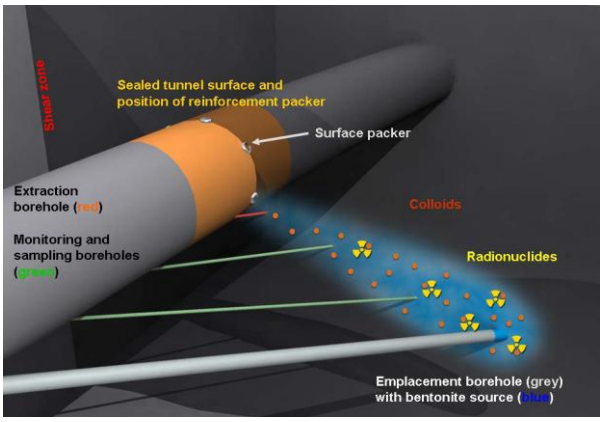

Fig. 3. Basic concept and tentative layout of the CFM *in situ* experiment.

3. Future Plans

In Phase 1, preparatory studies were carried out to define the project boundary conditions and supporting laboratory and modeling studies were initiated. The experimental site has now been prepared and equipped to allow the proposed long-term *in situ* experiment to be performed.

In 2008 and 2009, finalization of the experiment design, laboratory and mockup studies combined with field tests to characterize the source zone and consider colloid migration/filtration will be carried out. From mid 2009 onwards, the project is planning to perform long term emplacement and migration experiments with near-field/far-field monitoring followed by overcoring and detailed analysis of the source area and the flow field.

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