GRIMSEL TEST SITE (GTS)

NEWSLETTER

JULY 2022 YEAR 4, VOL. 7

ISCO 2022

Annual ISCO meeting

Participants from North America, Asia and Europe.

NEW CHAIRPERSON

GAST

GAs-permeable Seal Test

Final experiment phase with the main gas flow test (GFT).

ANDREAS REINICKE

GUEST

Editorial contribution

New active partner of the Grimsel Test Site: BGE, Germany.

AXEL LIEBSCHER

UPDATES

GTS Projects Updates

Updates and upcoming courses of the Grimsel Training Centre (GTC).

GRIMSEL TEST SITE

ISCO 2022 participants in front of Lake Brienz, Bern, Switzerland. © Comet Photoshopping GmbH, Dieter Enz.

▷ I. BLECHSCHMIDT

Dear colleagues and partners,

The first half of the year is already over and, at least with regard to COVID 19, there are signs of normalisation. Activities at the Grimsel Test Site have returned to pre-Corona levels in terms of the onsite presence of partners, contractors and guests, and after two years of online meetings we were finally able to hold another physical ISCO (International Steering COmmittee) meeting with the Grimsel partner organisations in the Bernese Oberland at the beginning of June.

The two-day ISCO meeting was divided into technical sessions (focus: update on ongoing projects and presentation of new project ideas) and an executive session with the FLG partner organisations (focus: organisation and operation of GTS, financial status and planning of the next project phase), complemented by a visit to the Grimsel Test Site. With more than 30 participants from North America, Asia and Europe it was a very intensive and successful meeting (cover image).

Left to right: Section Head of GTS Dr. Ingo Blechschmidt, new ISCO-chair Dr. Irina Gaus and former ISCO-chair Dr. Stratis Vomvoris (ISCO 2022). © Comet Photoshopping GmbH, Dieter Enz.

A special highlight of this year's ISCO meeting was the handing over of the function as chairperson of the ISCO meeting. Due to his upcoming planned retirement, Stratis Vomvoris (formerly Division Head International Services & Projects, Nagra) handed over this function to Irina Gaus (Head of Research and Development, Nagra) after 25 years. Stratis was thanked for his outstanding support of the Grimsel Programme in this function and his personal commitment over the past decades. Irina was warmly welcomed as the new Chair and we are convinced that, as Nagra's Head of R&D and with her international experience and reputation, she will be very successful in this important leadership role.

In this newsletter, we want to highlight the most important events in the projects and inform you about what else is going on. Concerning projects: (i) Gas-Permeable Seal Test (GAST) - after the many years of preparation and testing, the final experiment phase with the main "gas flow test" (GFT) started at the beginning of May 2022 successfully. (ii) Much has already been shown about the implementation of the HotBENT project, in this issue we want to inform you about the status of the "hot phase".

On the GTS website www.grimsel.com you will of course find more information about the activities in the laboratory.

We would also like to take this opportunity to thank Dr. Axel Liebscher (BGE, Germany) for his editorial guest contribution in this issue. As a relatively new representative in the GTS Executive Group, he and his colleagues have shown great commitment and dedication to the projects at the Grimsel Test Site from the very beginning, and we look forward to the coming years with great pleasure and anticipation.

We hope that you will find the content of the current newsletter interesting and enjoy reading it. And as always, we are looking forward to your feedback.

Yours sincerely,

INGO BLECHSCHMIDT
Head of Grimsel Test Site (GTS)

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Guest Editorial

NEW ACTIVE PARTNER OF THE GRIMSEL TEST SITE

▷ A. LIEBSCHER

With progression of the site selection process and later in the licensing and construction phases, site-specific data and research become increasingly important. However, R&D activities in generic underground research laboratories will play an important role for BGE* throughout the entire lifetime of the disposal programme. Here, fundamental scientific and technical questions can be studied and technical solutions tested, building confidence in the feasibility of geological disposal. It also will aid in process transparency, and foster knowledge management by international cooperation, training of scientific-technical personnel in multidisciplinary, repository-related projects, and preservation of technical and scientific know-how.

The Grimsel Test Site provides an excellent research infrastructure to address the above-mentioned objectives. Representing almost 40 years of cooperative research, BGE and all other GTS partners and research groups benefit from completed, on-going and coming state-of-the-art experiments and stimulating scientific exchange and discussions between experts, representing various scientific and technical disciplines and different national disposal programmes. BGE´s participation in the Grimsel Test Site focusses on: i) investigation and modelling of the behaviour of EBS components under repository conditions and their coupling and interaction with the geosphere (e.g., HotBENT), ii) determination of quantitative data for numerical modelling and safety analyses (e.g., CFM), and iii) testing and improvement of exploration methods.

BGE plans to expand its activity portfolio at GTS in the coming years by participation in further experiments and joint elaboration and designing of new experiments.

Yours Sincerely,
Axel Liebscher

**BGE: The Federal Company for Radioactive Waste Disposal (German: Bundesgesellschaft für Endlagerung mbH) implements the German radioactive waste disposal programme. BGE only recently joined the Grimsel Test Site GTS in 2021. Participation in international activities and especially underground research laboratories is one corner stone of BGE´s R&D strategy.*

Dr. Axel Liebscher (BGE-Germany). © A. Liebscher.

DR. AXEL LIEBSCHER

Axel Liebscher holds a Ph.D. in geology awarded by the Technical University of Berlin. He has a background in petrology, geochemistry and on fluid-rock interactions in metamorphic and hydrothermal systems. He also worked in the field of underground CO_2-storage. From 2018 to 2020, he was Head of the R&D Division at the German Federal Office for the Safety of Nuclear Waste Management (BASE). Since 2021, Axel is Head of the Repository R&D / Research Planning Division at Federal Company for Radioactive Waste Disposal (BGE).

Axel Liebscher is member of the Steering Committees for the Mont Terri Project and the Grimsel Test Site (GTS).

EXTENDED GAST - HIGHLIGHTS - 01

▷ A. REINICKE

The degradation of organic substances and metals leads to gas production and accumulation in the emplacement caverns of radioactive-waste repositories. A concept for gas-permeable plugs and seals was developed by Nagra to enhance and guide transport of this repository generated gas without compromising the hydraulic barrier function or the radionuclide retention capacity of the engineered barrier system. The GAs permeable Seal Test (GAST) at Grimsel Test Site has the main objective to demonstrate the functionality of this specific seal concept at full scale and realistic boundary conditions (see for more general information GTS Newsletter No. 5 or www.grimsel.com). The main sealing element is constructed from a sand/bentonite (S/B) mixture, which allows relatively fast transport of gas while it maintains a low hydraulic conductivity. With this functionality, the seals can release potential gas overpressures from a geological repository for low/intermediate-level waste (L/ILW) while the retention of radionuclides is maintained. A schematic of the GAST construction including the instrumented sections and layers containing the sensors is shown in Fig. 1.

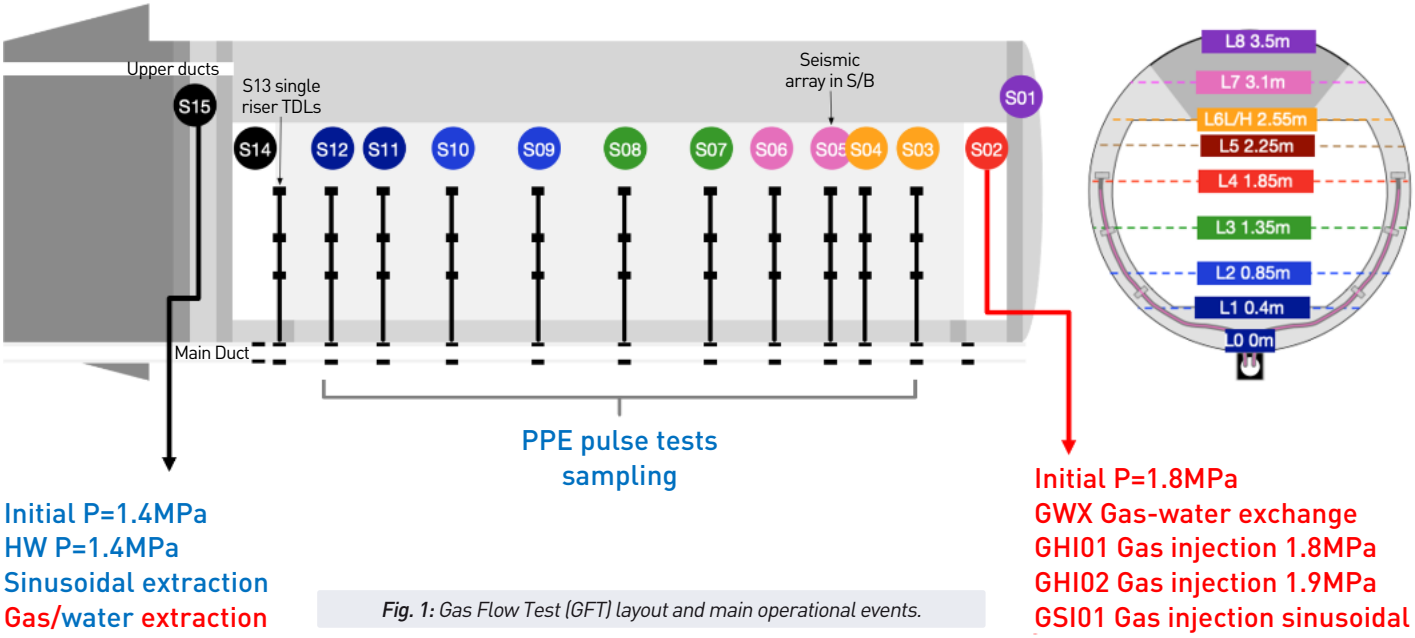


Fig. 1: Gas Flow Test (GFT) layout and main operational events.

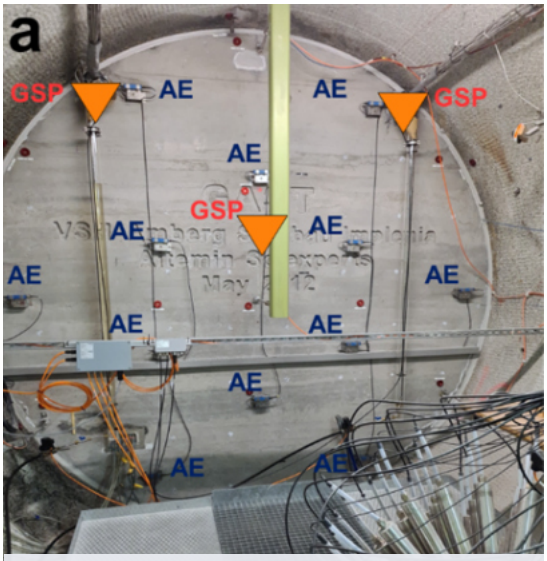


***Fig. 2 a)** front view of the GAST plug with installed acoustic emission (AE) sensors and gas sniffing ports (GSP)*

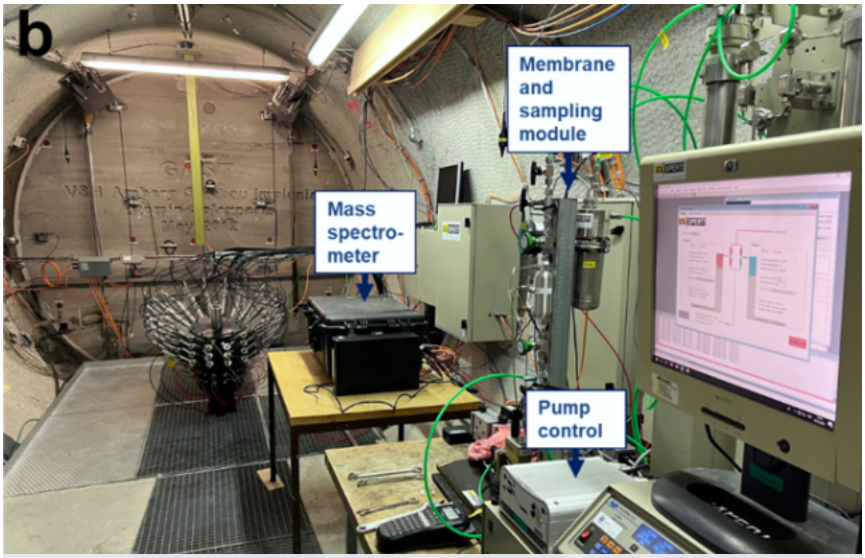


***Fig. 2 b)** Installation for outflow analysis containing pump equipment, the membrane module, and a mass spectrometer.*

Following the first set of experiments to characterise the gas transport properties of GAST in 2019, the further saturation and pressure homogenisation of the system was continued in 2020; at the same time the re-calibration of the GAST modelling tools occurred as a basis for the development and documentation of the Gas Flow Test (GFT) strategy. In 2021 and earlier this year, the GAST experimental system was updated by several components in preparation for GFT, in particular:

EXTENDED GAST - HIGHLIGHTS - 02

▷ A. REINICKE

- The acoustic emission (AE) detection system (Fig. 2 a) was extended with additional sensors, and the software was updated to allow for the automatic localization of events, filtering of human-made activities, automated reporting and an alarm system that warns if unusual AE activity is recorded.
- A gas extraction system was installed that can operate for the expected 2-phase flow conditions at constant rate or constant pressure, while allowing for outflow sampling under pressure.
- A custom-made module with a mass spectrometer (Fig 2 b) that can analyse the outflowing gas continuously. The same system was also conceived and tested to sniff close to the plug for gas leakage (the ports for leakage detection at the plug are indicated in Fig. 2 a).
- A fully automated safety control that can stop the gas supply to the experiment and release fluid from the experiment in case of a critical event or if monitored parameters exceeded pre-defined values.

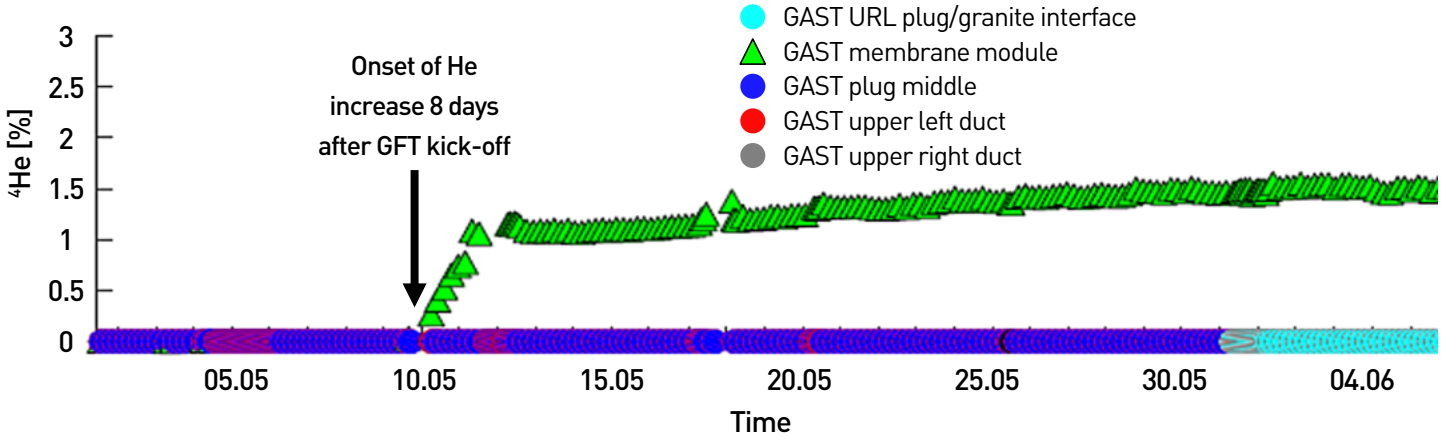


Fig. 3: Development of the tracer gas (He) concentration in the outflow from S14 filter.

A special focus of the component upgrade was to ensure the safe execution of the experiments, when high gas pressures of up to 2 MPa and large gas volumes were reached. A rigorous external safety review and assessment of the experimental system including the plug and implementation of safety relevant procedures, complemented these activities and confirmed the operational safety throughout all phases of the GFT.

The GFT started on 2 May 2022. The objective of the GFT is to simulate the transport of gas through a highly saturated sand/bentonite (S/B) body. This test will give insights into the conceptual understanding of transport though this special sealing element as well as reveal influences of seal construction such as heterogeneity material. The GFT consists of various phases described hereafter:

Phase 1: Water-Gas Exchange

The S02 (see Fig. 1) filter was partly drained. About 300 L of gas (98% Nitrogen, 2% Helium) at slight overpressure (~1.85 MPa) were placed in the filter. Helium is used as tracer gas as the atmospheric concentration is very low.

Phase 2: Stepwise increase of gas pressure in S02 filter

The gas pressure in the S02 filter was increased stepwise starting from 1.8 MPa. The maximum gas pressure for safe operation is 2.4 MPa. The aim of the stepwise increase is to identify the gas entry value (GEV) of the sand/bentonite mixture and allow for stable system conditions.

Phase 3: Stable gas injection

During phase 3 the gas starts to migrate into the sand/bentonite body and to form a stable gas pathway. It is expected that this process takes place in a controlled manner and reaches pseudo steady state conditions.

The inflow of gas into the S/B body was already recorded in phase 1, i.e. at a very low GEV of maximum 0.05 MPa and before phase 2 had started. The early reaction was mainly measured in the L4 layer of the S/B body and a little later in the L6 layer (see Fig. 1 for the location of the layers).

A stable gas flow was established within several days and the transition from Phase 1 to Phase 2 was very quick. Tracer gas (He) was detected in the water produced from S14 filter 8 days after the GFT kick-off (Fig. 3). The pressure signal was recorded even earlier.

On May 12 the pressure in S02 was increased to 1.9 MPa. Stable conditions were re-established quickly with inflow and outflow rates of about 10 mL/min, indicating a very good connection between the two filters. For diagnostic purposes, the injection in S02 and extraction from S14 was changed to sinusoidal rate (May 18) and pulse tests were performed to identify potential free gas phases in the S/B body.

EXTENDED GAST - HIGHLIGHTS - 03

▷ A. REINICKE

In this period a continuous increase of He gas concentration in the outflow was recorded by the mass spectrometer (Fig. 3). Finally, on June 8 a free gas phase was produced from S14 filter, and since then the free gas production continues. Currently the GAST team has started to take water/gas samples directly from the S/B body to identify and trace the injected gas from the centre of the sand/bentonite.

The Gas Flow Test, as part of the final phase of the GAST experiment has been very successful to date. A large volume of gas could be placed in the S02 filter, a low gas entry pressure was recorded, and the gas transport appeared to take place through the S/B body. The gas was traced early in the outflow form S14 and finally a free gas phase was produced. The development of the gas transport path was faster than expected from earlier model predictions and the existing numerical model of GAST will be updated with the latest data. The updated model will be utilized in near future to understand the nature and location of the fast gas transport in detail and diagnostic tests are planned to investigate the gas migration path.

HotBENT – REACHING THE "HOT PHASE"

▷ F. KOBER

The emplacement activities of the HotBENT experiment and the early low-temperature heating phase was the focus of the last GTS Newsletter No. 6. Since then, the four heaters have now reached the planned target temperatures of 175°C and 200°C (Fig. 4). While heaters 2 through 4 reached 175°C in early May, heater 1, set at 200°C, reached that temperature on May 30, 2022.

The evolution of the buffer and geosphere is continuously monitored – patience is required from now on. Partial dismantling is planned in 5 years, while full dismantling is planned after 20 years of heating and hydration. In the meantime, more emphasis will be placed on monitoring data and laboratory and modelling work. Reporting of the "As built status" and "Initial trends in monitoring" data are underway.

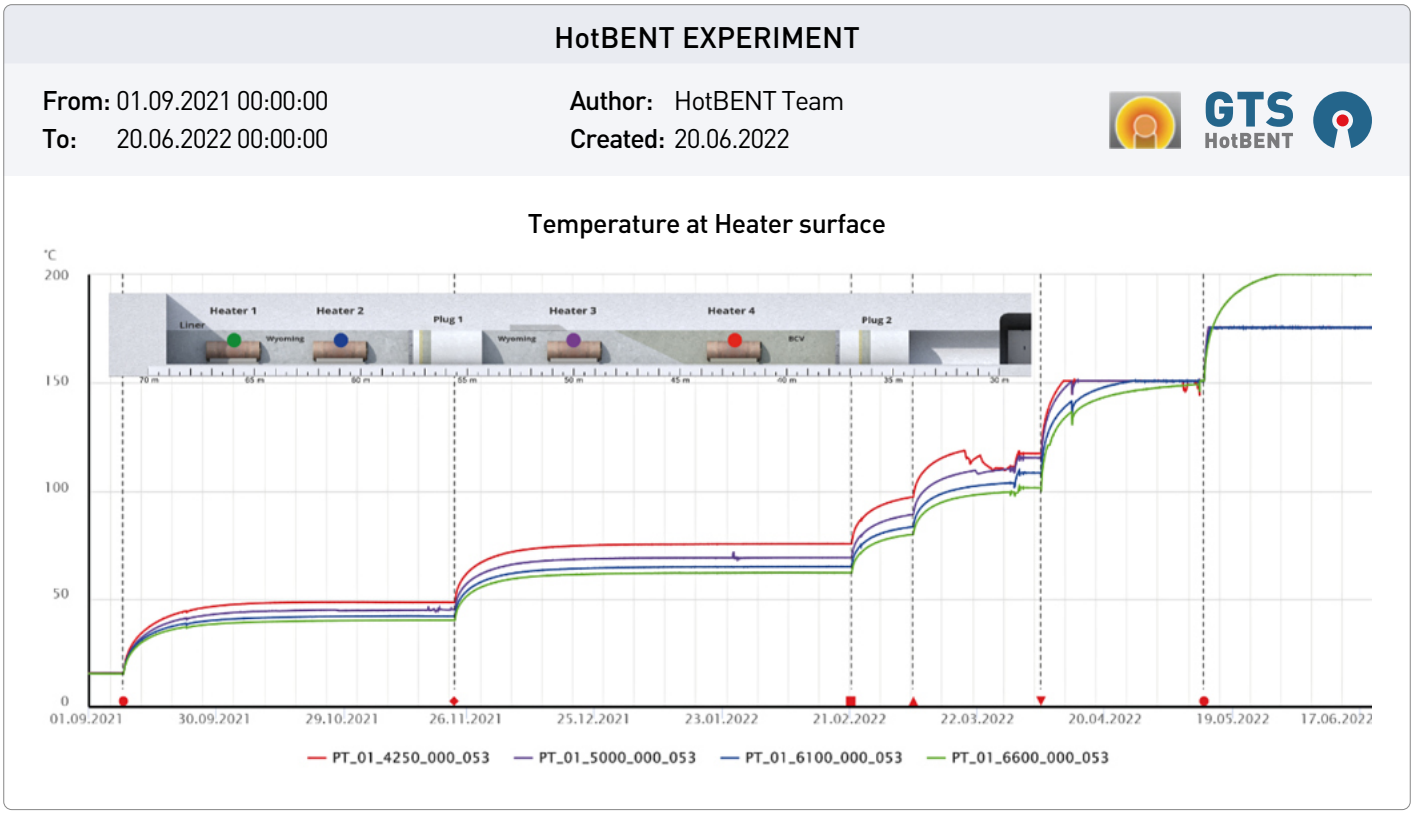


Fig. 4: HotBENT Heating – The layout of the HotBENT Experiments and the evolution of the temperature at the heaters surface central position for the four heaters.

PROJECT	DESCRIPTION
CFM i-BET **CFM LIT** Colloid Formation and Migration **I. Blechschmidt**	The long-term in situ test after running for 4.5 years (radionuclide-spiked bentonite source intersecting a shear zone) was successfully overcored in early 2019 and subsampled to achieve samples sizes that are feasible for laboratories. The subsampling was carried out so that samples could be shipped to KIT-INE as well as Ciemat. The sample analyses started and will be reported in the next newsletter. Onsite at GTS a tracer test run 22-01 was conducted to evaluate the hydraulic conditions prevailing in the MI shear zone after the overcoring. The tracer test has highlighted the suitability of the MI shear zone for future intermediate residence time tracer tests. The second on-site experiment associated with the CFM, the i-BET, is currently being further monitored. Since emplacement (over 1250 days ago), the degree of saturation has greatly increased, whereupon the pore pressure has continued to develop, which is, however, heterogeneous within the bentonite. The bentonite source is surrounded by three near-field monitoring boreholes, which are connected to onsite measurement of selected physical parameters such as pH, or turbidity as well as an automatic sampler. Detailed analyses of the water samples using nanoparticle tracking analysis (NTA) showed a slightly increased concentration of colloids in the groundwater compared to the background. Erosion estimation based on colloid assessment in the ground water sampled in the vicinity indicate very small erosion rates below 50 mg/a for the 50 kg source bentonite under the given hydraulic boundaries, which might be influenced by the short distance (approx. 3.5 m from the tunnel wall).
CIM ^{14}C and ^{129}I Migration **A. Martin**	Circulation and monitoring of HTO, C-14, I-129, Cl-36, Cs-134 and Ba-133 has continued since the start of injection in September 2021. Radionuclide circulation will be continued for at least another two years. The CIM partners have already started designing an overcoring concept in order to extract and analyse cement-mortar and granite matrix samples impregnated with radionuclides at the end of circulation. In parallel to the in-situ experiment, laboratory based studies were initiated to characterise the marginal zone of the cement-mortar in contact with granite matrix using interface samples previously removed and preserved in resin (during drilling of the circulation and observation boreholes) at the University of Helsinki (C-14 PMMA mapping combined with SEM element mapping), EMPA (SEM element mapping of hydrous phases) and the University of Strathclyde (development of novel, spatially resolved techniques to understand Portland cement alteration).
LTD Long Term Diffusion **A. Martin**	The surface and downhole equipment for performing a radionuclide migration test through the GAM shear zone was installed at the beginning of the year. After testing the flow and circulation in the target dipole within the shear zone, the first injection of HTO and Na-22 will be started in August. Based on the results of this first injection, a second injection test involving HTO and possibly also Cl-36 will be carried out later in the year. Both injections will provide information on the hydraulic and channelling characteristics of the target fracture. A third and final injection of sorbing radionuclides (Ni-63, Cs-134 and Ba-133) is planned to be carried out a few weeks prior to overcoring at the end of 2023.
MaCoTe Material Corrosion Test **A. Martin**	The detailed analysis of the 4.5-year modules has been completed, while the analysis of the 7-year modules retrieved in November 2021 is still ongoing. Microbial communities were identified using rRNA gene profiles in bentonite and swabs of metal coupons from both modules at the University of Waterloo. In the heated experiment, the 7-year (final) module will be retrieved later this year. Throughout the year water samples were taken for microbial analysis by the Technical University of Liberec from all five boreholes of the heated experiment.
SET Borehole Sealing Test **T. Kunimaru (R. Schneeberger)**	The SET project aims at the characterisation of a Kunigel V1 based borehole seal at intermediate scale between laboratory and real implementation. Two vertical boreholes were sealed in June with bentonite pellets in between two hydraulic packers mechanically confining the seal and allowing for later hydraulic characterisation of the seal. In addition, one borehole is equipped with fibre optical cable to assess the saturation within the bentonite seal through the evolution of the thermal conductivity. The saturation is expected to last for approximately 1 year as it is artificially enhanced by water injection from the top packers.
HotBENT High Temperature BENTonite **F. Kober**	See highlight section.
FEBEX-DP Full-scale Engineered Barrier EXperiment	See miscellaneous section.
GAST GAs-permeable Seal Test **A. Reinicke**	See highlight section.

After two years with a reduced course programme (Fig. 5), we are organizing three workshops again this year in August and September as part of the Grimsel Training Centre on the following topics:

DATE	DESCRIPTION
30.08.2022 to 01.09.2022 at the GTS 3 days	**FROM RD&D REQUIREMENTS TO IN-SITU EXPERIMENTS** How to design and setup URL experiment.
06.09.2022 to 09.09.2022 Nagra, Wettingen 4 days	**SITE SELECTION OF DEEP GEOLOGICAL REPOSITORIES** Module 1: Processes and Methodologies, Module 2: Geological and Geophysical Data Collection.
12.09.2022 to 14.09.2022 Nagra, Wettingen 3 days	**DATA MANAGEMENT** Making Geoscientific Data FAIR (Findable, Accessible, Interoperable and Reusable)

You can find more information in the course brochures on our website GTC Training Centre www.grimsel.com or contact us directly as usual. Even though the registration deadline was already at the end of June, **there are still a few places available** - but don't wait too long to register if you want to take part.

We look forward to physically meeting some of you again in the workshops to learn and discuss with you. Please note that the tentative course programme for 2023 will be announced in December this year already.

Fig. 5: Impressions from the last GTC courses.

In addition to maintaining a smooth and safe flow of GTS activities and providing technical support for the projects, the Grimsel team has also acquired extensive know-how and experience in the field of scientific sampling over the past decades. This includes, for example, high-precision core sampling, the stabilisation and extraction of sample material of different training or the sampling of radioactive rock samples. As a result, we are frequently asked to support colleagues outside our laboratory.

In February of this year, for example, we were able to support the team from ETH Zurich's Bedretto underground laboratory in drilling for the installation of monitoring equipment.

Fig. 6: *Sampling of altered clay zones at 1100 m depth in the Kiruna mine (left), specially designed drill bits for sampling (to prevent exposure of the material until it reaches the laboratory) (right).*

In May we were supporting colleagues from the EPFL's Laboratory of Environmental Microbiology in collecting samples deep underground in Kiruna (SE) at LKAB's world's largest underground iron ore mine (Fig. 6). Special drill bits and equipment were developed by the Grimsel team for a very challenging sampling campaign in clays at about 1100 m depth.

The sampling of the altered clay zones was carried out under unusual conditions, which nevertheless had to meet the high requirements for microbiological sampling. The sampling campaign and subsequent analysis are part of the Kiruna Natural Analogue Project (KiNa) of the IGD-TP www.igdtp.eu. The objective of the KiNa project is to investigate the long-term behavior of clay in contact with iron oxides as an analog for the very long-term development of a deep geological repository.

Kiruna, Sweden.
Snowy landscapes still prevailed at the surface at the end of May.

GTS OUTREACH - IMPORTANT PUBLICATIONS AND CONFERENCE PARTICIPATION

8th Clay Conference, June 12-16, 2022, Nancy, France

The GTS projects were prominently represented at the conference in the form of talks and posters on the experiments: HotBENT, GAST, CFM/iBET; in addition to presentations on the Nagra site selection process, the deep drilling campaign and related investigations, and the numerous investigations on the Mont Terri URL experiments. The discussion and feedback on experiments as well as the personal exchange with many colleagues and GTS partner delegates were highly appreciated → Programme.

5th Crystalline Club Meeting, June 28-30, 2022, Dresden, Germany

Nagra with its GTS URL is partner in the Crystalline Club of NEA → More Information on the NEA Website. Within this frame work the 5th meeting focused on: "The identification of requirements for the development of safety documentation concerning crystalline host rock environments".

FEBEX-Dismantling Project - Synthesis report NTB 17-01 is published

We are pleased to announce that after some long preparation times, that the final synthesis report on the FEBEX-DP project has been published. This 18-year long heater experiment and EBS investigations is summarised in NTB 17-01 jointly compiled by a multi-author team (Fig. 7). The report can be downloaded from → Grimsel Website.

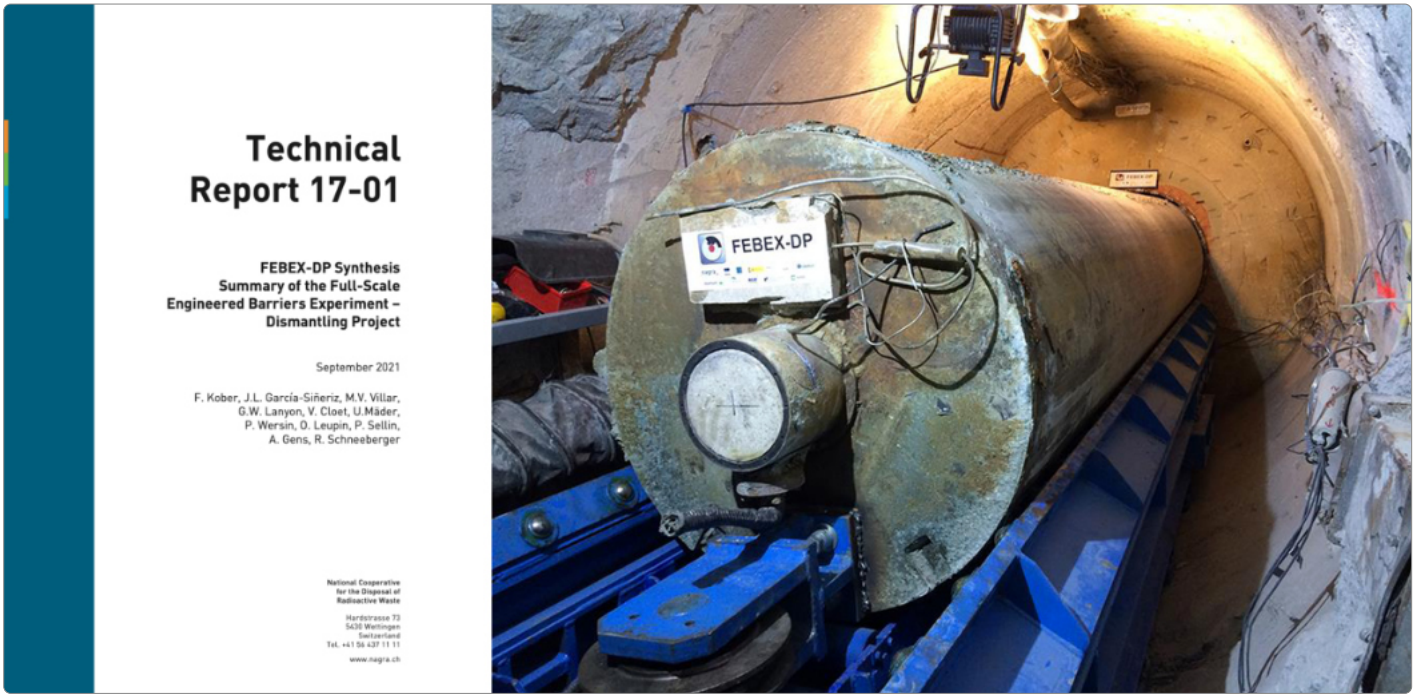
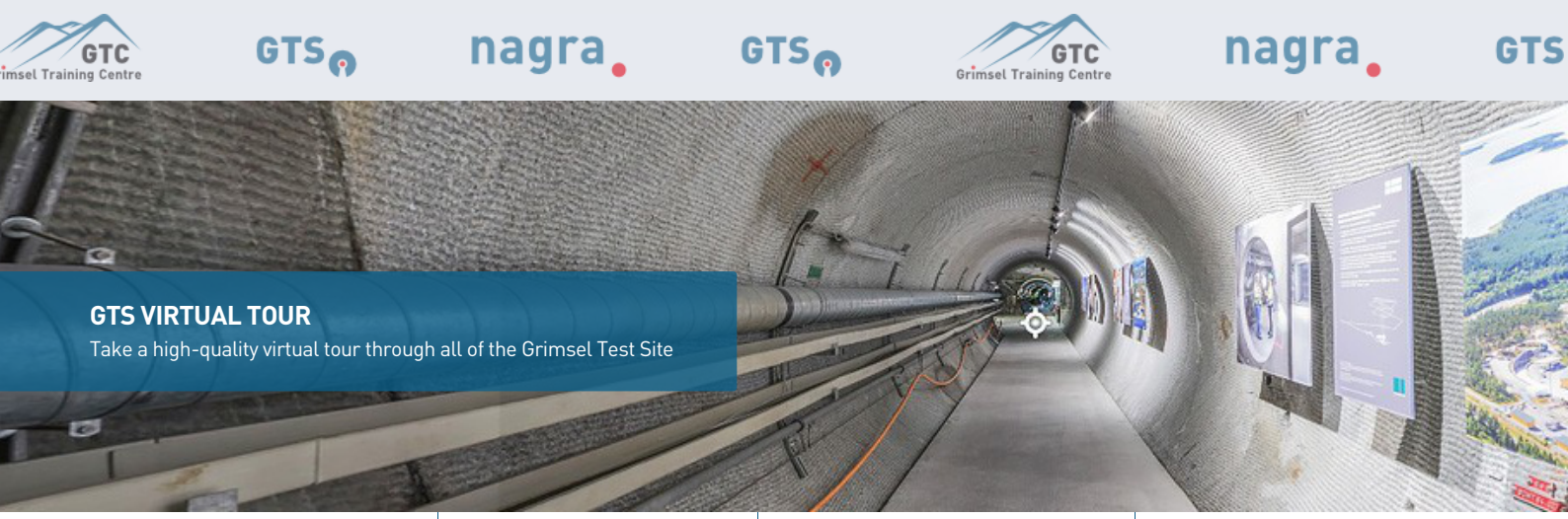


Fig. 7: Synthesis report NTB 17-01, cover page.

GTS Information . MISCELLANEOUS

GTS Website	The GTS virtual tour was recently extended: www.grimsel.com/Virtual_Tours/
GTS Publications	Please visit our GTS publication area to find the most recent updates on reports and publications: www.grimsel.com/media-and-downloads/grimsel-test-site-publications-list
GTS Meetings	Planned upcoming GTS project meetings and GTC activities are online now.
GTS Links	News from the Swiss national programme: www.nagra.ch/en/
GTC Programme	The GTC programme is available under: www.grimsel.com/grimsel-training-centre-gtc



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