GRIMSEL TEST SITE (GTS)

NEWSLETTER

DECEMBER 2025 • YEAR 7, VOL. 11

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WHEN LAKE GRIMSEL WENT DRY: A NATURAL EXPERIMENT IN ALPINE HYDROGEOLOGY

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EDITORIAL

The year 2025 marked the beginning of a new decade for the Grimsel Test Site after having celebrated its 40th anniversary in 2024. The numerous discussions and exchanges at the anniversary symposium led to renewed and new collaborations within the international RD&D programme at Grimsel, which we intensively followed up on this past year.

Important milestones in 2025 were the completion of the LTD – Long-term Diffusion – drilling and the CIM – Carbon14-Iodine-129 Migration – (over)core sampling (see details in the project updates). Both cores were intensively sampled and distributed to partner laboratories, where sample analysis is in full swing. In the radiation control zone of the GTS, the CFM – Colloid Formation & Migration – megapacker experiment setup was also completed after undergoing an overhaul. The site is now being prepared for upcoming migration and radionuclide tests in the famous MI shear zone (see section "GTS highlights").

Several other projects presented at this year's GTS ISCO Meeting are currently in the pipeline. On the one hand, TOUGH – a geothermal experiment led by RWTH Aachen University – recently completed the drilling phase for a couple of new boreholes, and on the other hand, iBET (part of CFM for bentonite mass loss studies in fractures) is being prepared for dismantling. The ACS project is at an advanced planning stage. It focuses on corrosion with different metals and their production processes as well as on in-situ corrosion monitoring with newly developed "corrosion sensors". Further information can be found in the project update section. This section also presents future projects that are still in an early preparatory phase.

Finally, a series of courses and workshops were organised by the Grimsel Training Centre (GTC) in 2025. These included tailor-made courses on request e.g. on safety and geological models as well as recurring generic courses on e.g., site selection, RD&D & URLs, and bentonites. Next year's GTC programme will be announced in early 2026 – please check our website www.grimsel.com.

With regard to Nagra's national programme, following the submission of the general licence applications at the end of 2024 (see online documentation at www.dRGB.ch), Nagra is now engaged in the review process of the submitted documents and reports, which will continue over the next few years. In the meantime, a restructuring of Nagra at the beginning of this year with a view to the realisation of the DGR at the proposed site has led to some changes within our AGIC Department (Applied Geosciences and International Cooperation). Beside extending our work tasks, we are pleased to welcome one or two new colleagues who will support us at the Grimsel Test Site in the future. Nagra's Head of the Communication and Public Affairs Department, Philipp Senn, refers to this in this issue's "Guest Editorial" for which he is acknowledged.

Last but not least, we would like to thank you for your continued cooperation and exchange in 2025 and look forward to the activities, partner meetings, challenges and further exchange opportunities in 2026! Season's greetings!

Florian Kober
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GUEST EDITORIAL

Philipp Senn, Head of Communication and Public Affairs, Nagra.

PIECING TOGETHER A HUGE PUZZLE FOR 40 YEARS

Forty years of research at the Grimsel Test Site have not only allowed us to deepen our expertise and knowledge, but also to engage in dialogue with countless interested visitors who came for a unique underground experience. Not many people are familiar with subsurface conditions, but you and I have often visited or worked in an underground research laboratory. Yet even as an "old hand", the descent from the picturesque Grimsel landscape into the Grimsel Test Site's subsurface tunnel world is special to me every time.

You can witness the reaction to this contrast when visitors first set foot in an underground research laboratory. Anyone who has the opportunity to walk through these tunnels will feel what "deep geological disposal" means. Experiencing the mountain from the inside makes a lasting impression.

This is not some abstract paper concept but real hands-on science.

As such, the Grimsel Test Site experience conveys more than a thousand words – also on another level. Being given the opportunity to watch researchers do their work from up close resonates and stimulates discussion, changes perspectives and reduces distrust: the researchers' commitment to this truly worthy cause is impressive.

However, while the importance and quality of our technical foundation and research results are beyond question, if we cannot communicate these to our fellow citizens, our efforts will have been of little value and the project will come to a standstill. That is why leading by example is crucial: transparency does not start when we share information in the form of a brochure, but already deep in the mountain, while the foundations are still being laid.

Our deep geological repository is nowhere near construction – there is nothing to see or touch just yet. This is where the Grimsel Test Site can help us make the project of the century of deep geological disposal literally tangible: visitors can touch a cool rock face, admire the structures in the rock, feel the humidity, smell the unique odour. Anyone entering a research laboratory will perceive this strange world with all their senses.

This is an opportunity for us to show visitors: 'This research benefits our society. We are doing this for you.' Our parents' generation and we have produced the waste. It is our duty to act now, so that we do not burden future generations with our waste legacy.

Speaking of generations: for 40 years, the Grimsel Test Site has contributed to piecing together a huge puzzle. With its experiments and findings, it played an important role in enabling us to submit the general licence application for the deep geological repository. We had been pursuing this goal for decades, and open communication with our research partners – you – was an important factor in reaching this milestone. We have several more milestones ahead of us. This should not discourage us. Quite the contrary: that is precisely what makes our work so important. We can be proud of our accomplishments.

Philipp Senn
Head of Communication and Public Affairs, Nagra, Switzerland.

Philipp Senn is a member of the Executive Board and Head of Communication and Public Affairs.

Philipp Senn studied earth sciences at the Swiss Federal Institute of Technology Zürich. He initially worked as an engineering geologist before taking on a position at Nagra, first in 2011 as project manager for regional participation where he was in charge of supporting various stakeholder groups. He left Nagra to pursue academic achievements: an Executive Master of Business Administration and further training in change and public affairs management. He then spent two years working at Roche in Basel as transformation and project manager, which involved supporting external stakeholders and other target groups. Philipp Senn returned to Nagra in 2018 and is now a member of the Executive Board and Head of Communication and Public Affairs.

GTS PROJECT HIGHLIGHT

Colloid Formation and Migration: The long journey continues.

CFM

Raphael Schneeberger / Andrew Martin

COLLOID FORMATION AND MIGRATION • The Colloid Formation and Migration (CFM) experiment has been active in the controlled area of the Grimsel Test Site (GTS) since 2004. Initially foreseen as one single experiment, CFM has evolved into a platform for numerous studies — including over 30 dipole tracer tests.

Until 2014, CFM focused on the well-known Migration shear zone (MI): a ductile shear zone that was later reactivated in a brittle manner, thereby significantly increasing its transmissivity. Alongside the MI studies, CFM was expanded to include other projects — such as the iBET erosion experiment (outside the controlled area) and, more recently, a new dipole designed to explore how lamprophyre mineralogy affects transport and sorption of radionuclides (CFM LAC).

Yet perhaps the most iconic element of CFM is the Megapacker — affectionately known as the "yellow submarine".

Constructed during the early phases of CFM, the Megapacker was designed to apply pressure to the rock matrix surrounding the MI shear zone. This reduces the hydraulic gradient within the zone, enabling more realistic estimates of flow velocities relevant for deep geological repository conditions.

How stable are these gradients? So stable, in fact, that we have to account for earth tides when interpreting tracer velocities.

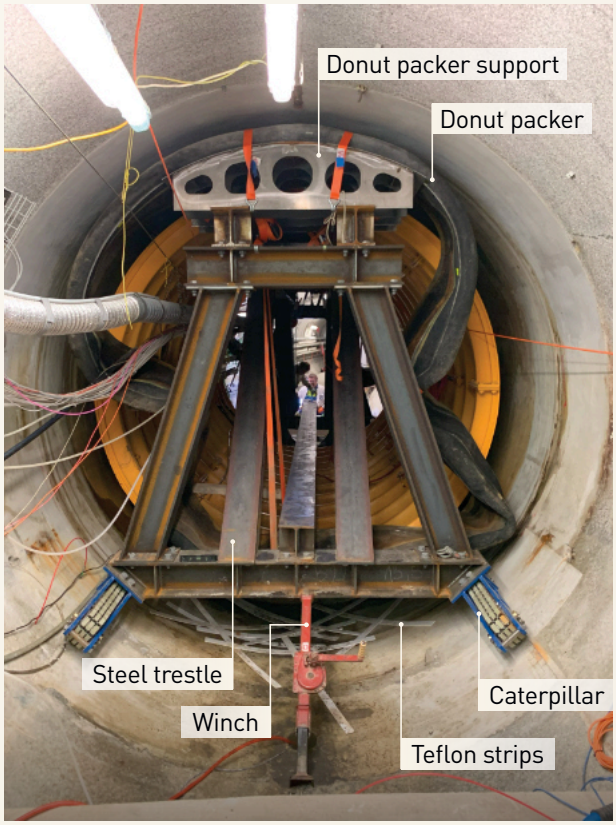
After years of faithful service, the Megapacker needed maintenance. This raised the question: how do you move a submarine inside an underground lab? The answer, surprisingly, is rowing — or at least the manual operation of pulleys connected to caterpillar trolleys.

Despite attempts to resolve the issue without major dismantling, we eventually had to partially disassemble the Megapacker. It was supported on a steel trestle mounted on caterpillars and carefully moved southward. Once relocated, we sanded the tunnel's resin-coated wall, replaced the surface packers on MI outflow points, and reapplied a fresh resin and foil layer.

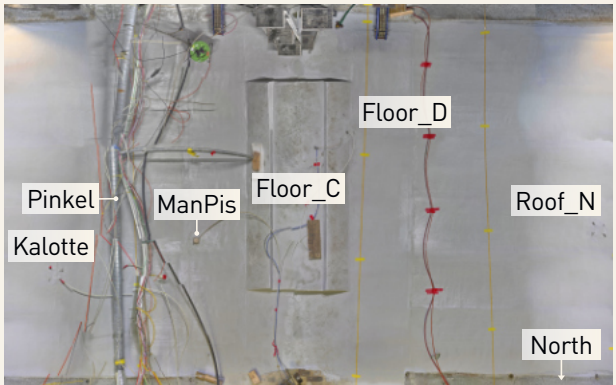
With that done, the Megapacker was shifted back to its original position. The annular space between the steel cylinder and tunnel wall was filled with water and repressurised to pre-maintenance levels. Now, we are allowing time for the near-field pressure to equilibrate.

Once equilibrium is confirmed, hydraulic tests will characterise selected dipoles such as those used previously — followed by a new series of dipole tracer tests, including radionuclide tracers, in the MI shear zone and possibly in new dipoles.

We are excited to see what insights lie ahead. As always, the journey continues.



Above: CFM Megapacker with crane device.
Below: Unwrapped 3D view of the completed resin seal.



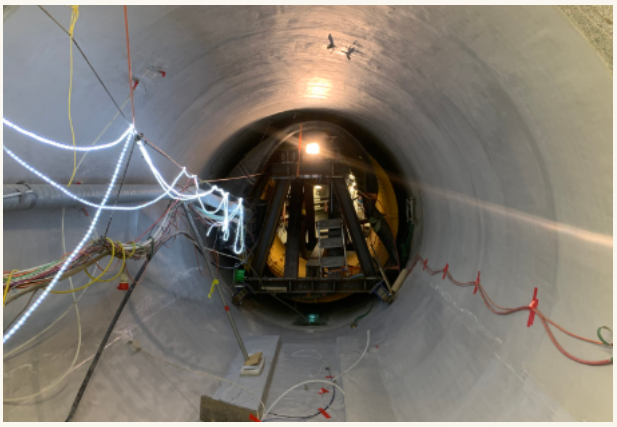
GTS MAIN PROJECTS OVERVIEW

Updates on ongoing Grimsel Test Site projects 1

CFM

Raphael Schneeberger / Andrew Martin

COLLOID FORMATION AND MIGRATION • For CFM, please see the GTS highlight section.on page 4.



Resin layer during curing before coverage by the steel cylinder.

CIM

Andrew Martin

C-14 AND I-129 MIGRATION • The CIM in-situ experiment was successfully overcored in May 2025 after circulating C-14, Cl-36, I-129, Cs-134, Ba-133 and HTO for more than three years in 15-year-old Portland cement in contact with granodiorite.

The overcore was immediately subsampled and vacuum-wrapped on site by a team from the University of Bern.

Subsampling, packaging and documenting of the CIM overcore.

The subsamples were then shipped to Helsinki University for C-14 PMMA and SEM (Scanning electron microscopy) element mapping as well as to UJV (Czech Nuclear Research Institute Rez/Ústav Jaderného Výzkumu Rez a.s), Czech Republic, and Tokyo Nuclear Service Ltd on behalf of NUMO for detailed analyses.

The purpose will be to characterise the distribution of the radionuclides in both the cement-mortar, granite and cement-granodiorite interface. From this, we should be able to confirm how much the cement-mortar retards C-14, Cl-36 and/or I-129 in situ, and how this compares with laboratory-based studies. Post-mortem modelling and final reporting will be carried out in 2026/27.

CIM "active" overcore showing the contact between cement and granodiorite.

Vacuum-wrapped CIM subsamples prepared in the BK cavern.

GTS MAIN PROJECTS OVERVIEW

Updates on ongoing Grimsel Test Site projects 2

LTD

Andrew Martin

LONG TERM DIFFUSION • The current focus of the LTD project is to study the sorption and diffusion of radionuclides flowing through channels in a natural shear zone and to compare the results with diffusion models developed from laboratory-based studies. Two in-situ migration tests were performed with radionuclides in the GAM shear zone within the radiation control zone at the GTS. The first of these tests was conducted with non- to weakly sorbing radionuclides (HTO and Na-22, 2022 – 2024), while the second migration test was conducted with strongly sorbing radionuclides (Ba-133 and Cs-134, fall 2024). Multiple radionuclide tracers were used to discriminate the influence of different transport and retention mechanisms within the shear zone. The first migration test started in October 2022 and ran until September 2024, with a constant injection and extraction rate of 1 mL/min for nearly two years. The target migration pathway within the GAM shear zone had an extremely stable flow field, having remained essentially unchanged for more than 20 years. The second migration test (Ba-133 and Cs-134) started three weeks prior to overcoring in October 2024. The purpose of the overcoring was to extract the main flow channels in the vicinity of the injection borehole interval. The extracted core was subsequently shipped to Helsinki University in December 2024 for subsampling, autoradiography and analysis. Subsamples were then distributed to the LTD partners for further detailed analysis, which has been ongoing throughout 2025.

LSP

Thomas Spillmann

LOW-PH SHOTCRETE PLUG • The LSP is intended to demonstrate the load-bearing capacity of a 4-metre-long frictional low-pH shotcrete plug. In 2006, a frictional low-pH shotcrete plug was emplaced at the GTS, sealing off a bentonite block wall. The current project plan foresees water injection into the 1-metre-thick bentonite block wall at the back of the plug to test the load-bearing capacity of the shotcrete plug. The injection pressure will be increased until cracking or movements indicate that the load capacity of the shotcrete plug has been reached. An accompanying modelling study simulated the final load capacity and supported scoping of the load test strategy until the end of 2025. The load test is planned to be performed in 2026. Current discussions focus on possible subsequent dismantling and sampling after the load test.

BOSSE

Patricia Hinterholzer-Reisegger

BOREHOLE SEALING SYSTEM EMPLACEMENT • NUMO and Nagra have collaborated in the development, testing and refinement of a deployment system for copper bridge plugs as part of the BOSSE project. This field-testing experiment is dedicated to the emplacement of copper bridge plugs using a prototype deployment tool, followed by the investigation of the mechanical and hydraulic behaviour of various sealing configurations at realistic scales in vertical boreholes within crystalline bedrock.

The BOSSE project focuses on testing under field conditions:

- AU Gallery Tests: In two short boreholes accessible from both ends, copper bridge plugs were emplaced using the prototype deployment tool. These tests aimed to validate the emplacement process under controlled field conditions, followed by mechanical and hydraulic testing of the bridge plugs.
- BK Cavern Tests: A more complex sealing system will be installed in 2026 in a deeper borehole to simulate realistic field conditions. The system includes multiple components – bentonite, cement, copper bridge plugs – which will be emplaced using the prototype deployment tool and a dump bailer. Wireless monitoring technology will be used to track the performance of the entire borehole seal over time.

GTS MAIN PROJECTS OVERVIEW

Updates on ongoing Grimsel Test Site projects 3

HOTBENT

Florian Kober / Raphael Schneeberger

HIGH-TEMPERATURE BENTONITE • HotBENT entered its fourth year of heating and saturation, as documented in Schneeberger et al. (2025; DOI: https://doi.org/10.1144/geoenergy2025-021). To improve the understanding of the specifications for electrical and thermal power consumption or average overall thermal conductivity (TC), a temperature shut-in test (TST) was conducted in March, during which the four electric heaters were turned off for two days, with the THM response being fully monitored by numerous sensors. These and other activities have been reported in various Nagra reports (bentonite baseline characterisation, heater test scoping calculation, muon tomography borehole at HotBENT). Outside the GTS, the characterisation of employed bentonites at elevated temperatures is continuing, while the calibration of the time-domain reflectometry (TDR) probes at the UPC/CIMNE are in full swing. In May, a partner meeting focusing on modelling took place in Berlin (organised by BGE), and the year was concluded with a HotBENT Partner and HotBENT Modelling Platform Meeting in Tokyo in November (organised by NUMO). There, the refinement of focused borehole drilling and sampling, prior to partial dismantling of HotBENT Sector 2, was also discussed in detail.

GAST

Thomas Spillmann

GAS-PERMEABLE SEAL TEST • After completion of the Gas Flow Test (GFT) that was performed in 2022-2023, two extensive reports were produced documenting the field data (NAB 23-15) and their preliminary interpretation (NAB 23-40). Both reports were part of Nagra's general licence application documentation (https://www.drbg.ch) and thus open for public download. Following the gas injections as part of the GFT, the GAST system in the GTS was smoothly resaturated using periodical water injections and finally shut in to facilitate pore pressure equilibration. Dismantling is planned for 2027 and planning is proceeding accordingly.

MACOTE

Andrew Martin

MATERIAL CORROSION TEST • To date, modules have been retrieved from the borehole 1 year, 3.5 years, 4.5 years, 7 years and 9 years after emplacement. Corrosion rates are determined by high-precision weight loss measurements. The chemical composition and microstructure of corrosion products are analysed using Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), combined scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). The roughness of the pristine and corroded metal surfaces is measured with profilometry. Mineralogical and micro-chemical analysis of the bentonite are also carried out to evaluate possible mineralogy changes in clay minerals in the altered bentonite zone next to corroded test coupons by comparison with clay minerals in unaltered zones. Microbial populations both in the bentonite and the borehole water are analysed using advanced cell counting and DNA analysis and gene-sequencing to determine microbial populations. Average corrosion rates were found to decrease from about 1.0 µm/yr down to 0.7 µm/yr for carbon steels and 0.10 µm/yr down to 0.02 µm/yr for copper and copper coatings over the 9-year period. There has been no significant impact of bentonite density on average corrosion rates so far. Based on analysis of 1-year- and 3.5-year-module testing of forged and cast steels, no significant difference in corrosion product chemistry and corrosion rates was detected. The test plan proceeds with the retrieval of modules once they reached their designed lifetime, and the corrosion rate database is continuously updated accordingly.

GTS MAIN PROJECTS OVERVIEW

Updates on ongoing Grimsel Test Site projects 4

TOUGH

Thomas Spillmann / RWTH Aachen

THMC-COUPLED PROCESSES IN FRACTURED GEOTHERMAL SYSTEMS WITH NON-ISOTHERMAL FLUID CIRCULATION • The TOUGH project aims at investigating THM processes during circulation of fluids and how these affect reservoir integrity. Furthermore, the influence of poroelastic and thermoelastic stress transfer on seismic or aseismic responses in the far field are monitored. To tackle these aims, which are part of a general aim to increase understanding of processes during geothermal energy production, the well-characterised BK site was chosen by RWTH Aachen as a test site to perform a series of iso- and non-isothermal fluid circulation experiments. Four boreholes have been drilled and logged to complement the existing array of test boreholes. The new and selected existing boreholes will be instrumented with packer systems, fibre-optical cables and seismics sensors to facilitate a detailed characterisation of the reservoir.

Status of new GTS projects

ACS

Andrew Martin

ADVANCED CORROSION STUDIES • The longevity of disposal canisters under anoxic conditions has been well assessed based on the corrosion behaviour of base metals such as carbon steel and copper in contact with bentonite (e.g., the MaCoTe project). Studies on canister sealing (welds) and corrosion under aerobic/thermal transient conditions are limited. Moreover, in order to measure corrosion under transient conditions (i.e., a changing environment), in-situ measuring techniques that allow continuous monitoring of the evolving corrosion rate need to be developed. The ACS project is a long-term project to develop and evaluate in-situ corrosion monitoring techniques for the purpose of investigating in-situ non-uniform corrosion of welds and corresponding base metals, and to study the effects of transient conditions. The project will be divided into three phases, moving from small scale to medium scale up to potentially 1:1 scale and including an increasing number of transients. This year, two physical meetings were held at Nagra in September 2025 and at NUMO, Tokyo, in November 2025 to plan the experiment in detail and to report on electrochemical impedance spectroscopy (EIS) and direct current potential drop (DCPD) sensors that have been developed and tested in Japan. Preparations for the field experiment will start in 2026, including drilling of boreholes and making a final design of the in-situ test.

MUT

Andrew Martin

MUON TOMOGRAPHY PROOF-OF-PRINCIPLE • A geological local digital twin of the Grimsel Test Site (GTS) in Switzerland was created and three primary scenarios were considered, all of which assume the deployment of existing muon planar and borehole detectors at typical repository depth (450 m to 500 m):

1. Detection of natural voids in the Grimsel geology within the digital twin. Detection times for voids ranging from 10 m to 25 m in diameter ranged from days to a year depending on the fraction of material infill within the void.

2. Detection of incomplete backfill in a tunnel. In this case, air voids within the bentonite backfill could be detected with high confidence. A near linear relationship was found between air gap size and detection rate.

3. Detection of plug damage. Cylindrical voids within the concrete containment plugs were modelled to assess potential damage detection. A 1-metre-diameter void was detectable within approximately 5 months with 20 borehole detector bundles. Detection times decreased exponentially with increasing detector array size.

A detailed proposal for a suite of in-situ experiments for testing both planar and borehole muon detectors is available for partners interested in joining the experiment or reading about it in more detail.

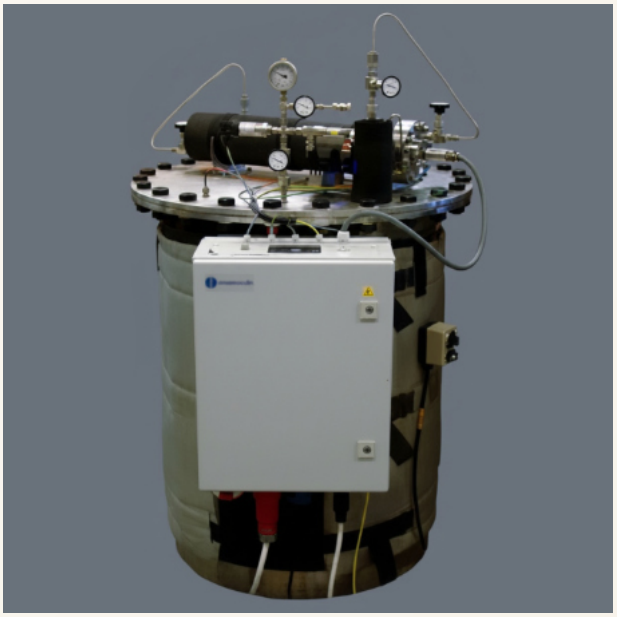
GTS PROJECTS & UPDATES

Status of new GTS projects

GME-2

Typhaine Guillemot

GAS MONITORING EXPERIMENT-2 • Gas production caused by chemical and microbiological activity after repository closure is a topic of relevance for safety and performance assessments of many deep geological repositories. For this reason, the Gas Monitoring Experiment (GME) has been performed by Nagra since 2015 to monitor gas production during the degradation of organic waste. This mock-up experiment hosted at Zwilag (interim storage facility in Switzerland), consists of five 200 l drums, each containing a single type of simulant organic waste (e.g., ion-exchange resins or PVC) in contact with Opalinus Clay porewater. Different types of ion-exchange resins and PVC where especially selected, as they are the main organics present in the Swiss waste inventory. An average of four samples per year allowed the measurements of gas rates for various gas species (i.e., H_2, N_2, O_2, CO_2, CH_4, C_2H_6 and other hydrocarbons) over a ten-year period. The GME will be decommissioned soon to study the geochemical and microbiological composition of the porewater, the degradation stage of the organics and the corrosion of the 200 l drums. A second version of this experiment is under preparation and would be, in case of partner interest, hosted at the Grimsel Test Site. The Gas Monitoring Experiment-2 will include both gas and solution sampling ports to monitor both the gas production rates, the chemical composition of the porewater, and the microbiological population. According to the interests of partners, different organics could be tested under various porewater compositions and pH conditions. This experiment is foreseen as a long-term experiment, with annual sampling campaigns after emplacement.



A picture of one GME drum. The 200 l drum is sealed in an outer hermetic container, surrounded by a heating jacket. Temperature and pressure sensors, as well as gas sampling ports, are positioned on the lid.

Experiments that are being developed

PINT

Porewater Intrusion Test

In an initial phase (on a laboratory scale), the project aims to simulate the flow of bentonite porewater through metals (i.e. breached canisters) and analyse the geochemical composition and evolution of the porewater over time. A subsequent upscaling to in-situ conditions is being considered.

POMO

Porous Mortar Emplacement Project

The project aims to test backfilling techniques and the performance of porous, gas-permeable mortars under realistic conditions. The formulation of a possible mortar (called M1) has now been developed under laboratory conditions, and simple applications and backfilling have already been performed.

TCTM

Testing of Chemical Thermodynamic Models

Chemical thermodynamic models assume chemical equilibrium, however, for environmental radiochemistry, equilibrium is an exception. TCTM aims to verify performance assessment (PA) models / databases through long-term (>10 years) experiments investigating the evolution of radionuclide concentration and speciation in solution within a contained volume representing the inside of a failed overpack.

GRIMSEL TRAINING CENTRE (GTC)

Grimsel Training Centre (GTC) course topics

GTC COURSE TOPICS 2025

In 2025, Grimsel Training Centre again offered a wide variety of generic and tailor-made workshops, after it reduced its activities in 2024 to focus on the submission of Nagra's general licence applications.

We are pleased and excited to have hosted more than 30 colleagues from 7 countries and 11 organisations in three courses held between 13.10.25 and 24.10.25 in Switzerland:

- Selection of a site for a deep geological repository, with a focus on drilling campaign processes and lessons learned
- From RD&D requirements to in-situ URL experiments
- Bentonites in radioactive waste disposal

Courses were held both at Nagra Headquarters and the Grimsel Test Site, with a marked focus on "hands-on" experience and lessons learned, and with the aim to maximise exchange among all participants.

In early 2026, we will propose a new set of generic workshops; feel welcome to follow all updates on our dedicated website: www.grimsel.com

TAILOR-MADE COURSES

In addition to generic workshops, we are always open to discussing tailor-made courses.

These can be held in Switzerland or in your country to meet your specific needs even better. Options for further topics could be:

- Performance and safety assessment
- Data management
- How to summarise geological information for site selection and the safety case
- Microbial studies in URL/EBS experiments and RD&D
- Corrosion / container material studies in URL/EBS experiments and RD&D
- Radionuclides in URL & RD&D
- Deep borehole exploration (planning, operation, testing, evaluation & reporting)
- NPP decommissioning and waste characterisation

In general, we gladly offer any tailor-made courses on any topics based on our experience and competences. Feel free to contact us anytime at international@nagra.ch

GTS ISCO MEETING 2025 & 2026

Operational aspects - International Steering Committee

TWENTY TWENTY FIVE

Following last year's major event when the GTS ISCO (International Steering Committee) meeting was held together with the celebrations marking the 40th anniversary of the GTS, this year we returned to the usual GTS ISCO meeting format.

Aside from detailed discussions on general GTS activities and specific projects, an additional focus was on new or planned projects, about which you can find more information in this newsletter. Partners who have already expressed their interest will be kept informed on the initial progress and follow-up steps of these new projects. All other interested parties are welcome to contact us, and we will gladly keep them updated, too.

TWENTY TWENTY SIX

Same procedure as every year

GTS ISCO 2026 will take place on 16 and 17 June 2026 – we look forward to welcoming the delegates back to the Haslital and Handeck!

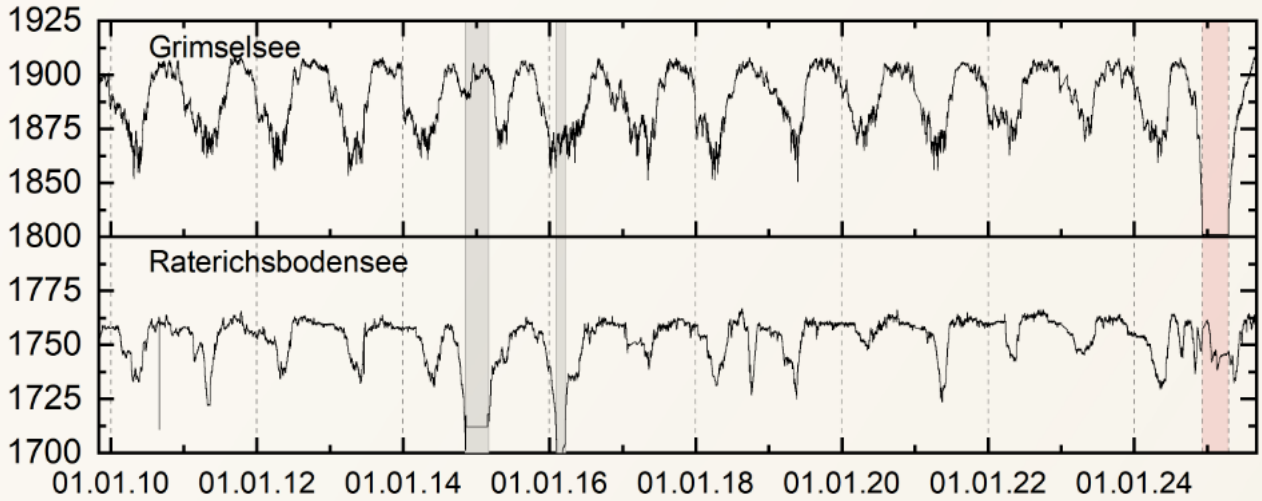
WHEN LAKE GRIMSEL WENT DRY

A Natural Experiment in Alpine Hydrogeology

Aerial view of the empty Lake Grimsel (Bild KWO, Foto © David Birri)

HYDROGEOLOGICAL COUPLING

Switzerland's Grimsel region serves as a national asset. Aside from the GTS, it hosts a major hydropower infrastructure that contributes significantly to the country's energy production. This coexistence of fundamental research and operational infrastructure provides a unique opportunity to study the hydrogeological coupling between surface reservoirs and deep fractured rock systems (see also the former GTS – LASMO project, www.grimsel.com).

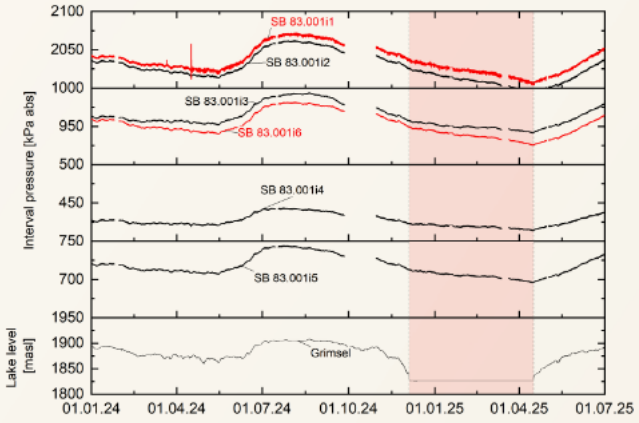


Seasonal variation of lake levels around the Grimsel Test Site over the last 15 years.

Operation of the KWO (local hydropower company) reservoir system results in changing lake levels over the year, with a roughly seasonal pattern of low levels in the early part of each year followed by refilling during the summer and early autumn. The level of Lake Grimsel normally varies between approximately 1,850 m a.s.l. (lowest) and slightly over 1,900 m a.s.l. (highest), representing a range of approximately 50 m.

In 2025, an exceptional circumstance arose: the complete drainage of Lake Grimsel for dam construction purposes (www.kwo.ch). During this operation, the lake level dropped to 1,826 m a.s.l. before refilling to over 1,900 m a.s.l. by late July 2025, representing a range of approximately 75 m. Although the magnitude of this change was only about 50% larger than during the normal annual cycle, the sustained rate of filling (approximately 1.5 m/day) from mid-April to mid-May was greater than in previous years. Furthermore, the period during which the level remained constant prior to refilling provided a stable baseline value for hydraulic heads before the change in lake level.

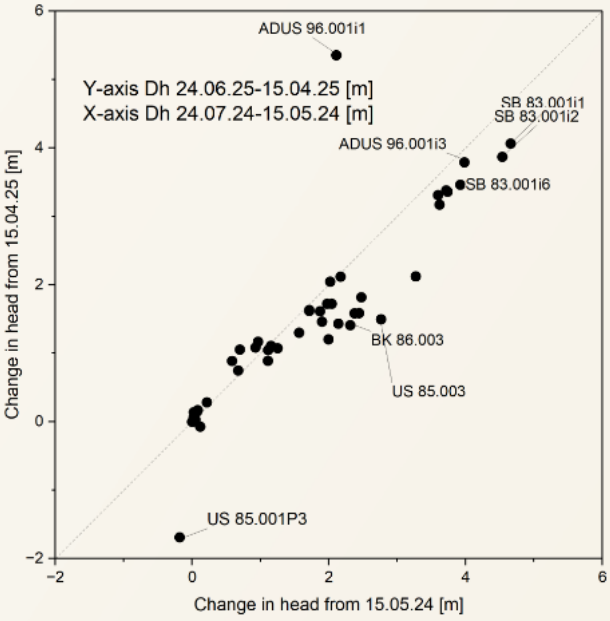
For the GTS, this presented a valuable opportunity to observe the hydraulic response of the underground facility to an extreme perturbation in surface boundary conditions. As anticipated, hydraulic pressures within the GTS responded to the lake drainage. Borehole SB 83.001, located at the southern extremity of the facility, exhibited a clear correlation with lake level variations, though with characteristic damping due to the hydraulic properties of the intervening fractured granite.



Pressure variation in SB 83.001.

The dependence of the subsurface hydraulic pressure on lake level is well-established from previous monitoring campaigns. The key question was whether the complete drainage would produce a significantly different response compared to normal seasonal variations associated with hydropower operations.

The analysis revealed that the magnitude of the pressure response was comparable to typical seasonal fluctuations. Similarly, the subsequent refilling of the reservoir produced hydraulic pressure evolution consistent with historical data – a comparison with 2024 operations at 70 days post-refilling shows no substantial differences.



Comparison of head changes.

SUMMARY

Continuous monitoring during the exceptional drainage and refilling of Lake Grimsel confirmed the hydraulic connection between the surface reservoir and the GTS. However, the pressure response to this complete drainage event remained within the range of variability observed during normal seasonal lake operations. This finding demonstrates the robustness of the natural hydraulic buffer provided by the fractured rock mass and validates existing models of the coupled surface-subsurface system.

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GTS MEETINGS
GTS project meetings and GTC activities: www.grimsel.com

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News from the Swiss national programme: www.nagra.ch/en/news/

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Navigate through the GTS tunnels using a point and click navigation: www.grimsel.com/Virtual_Tours/