Organic Fingerprinting of Groundwater to Determine Surface Water Origins

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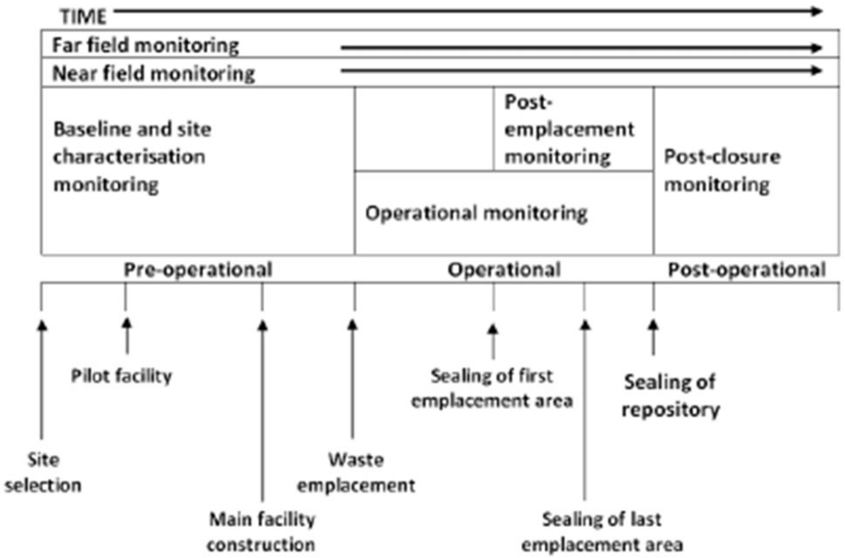
LArge **S**cale **Mo**nitoring **(LASMO)**

Aims

- Test monitoring systems, technologies or methods
- Collect monitoring data in order to identify baseline GW conditions and disturbing events.



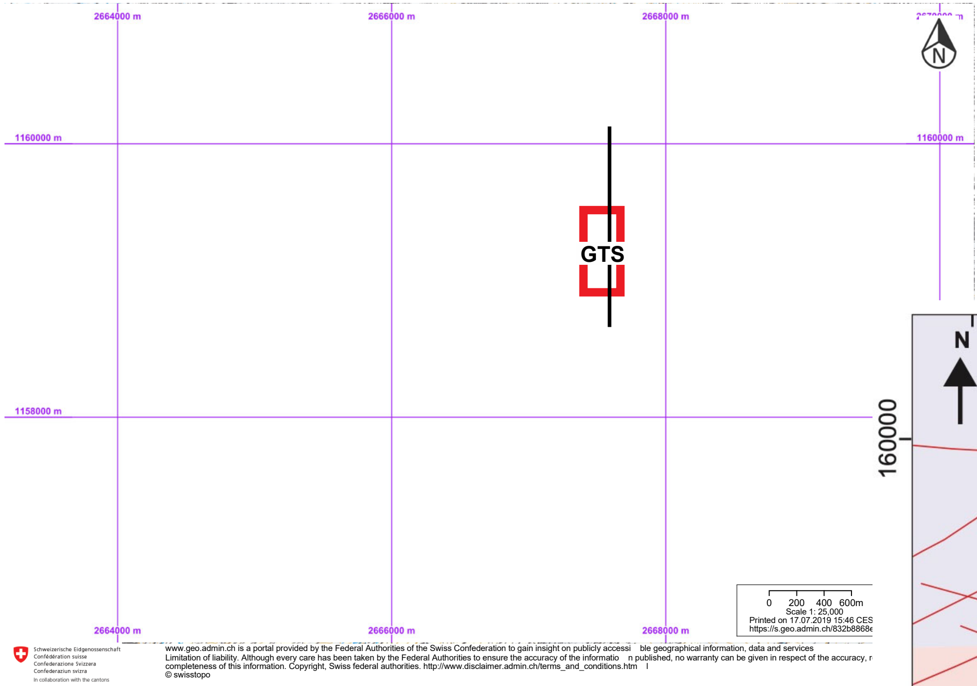
http://www.grimsel.com/gts-phase-vi/lasmo/lasmo-introduction

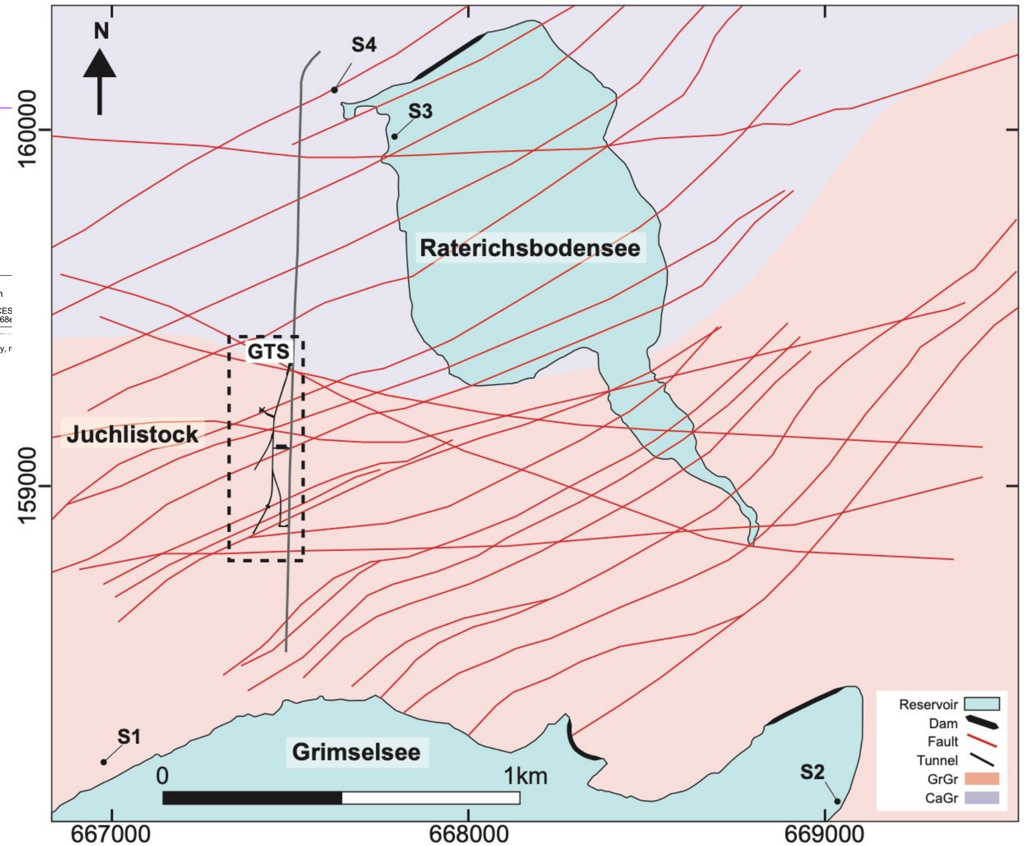
Groundwater Chemical background

Dissolved organics

Micro-seismic Monitoring

LArge Scale Monitoring (LASMO)





1. Monitoring to characterize baseline

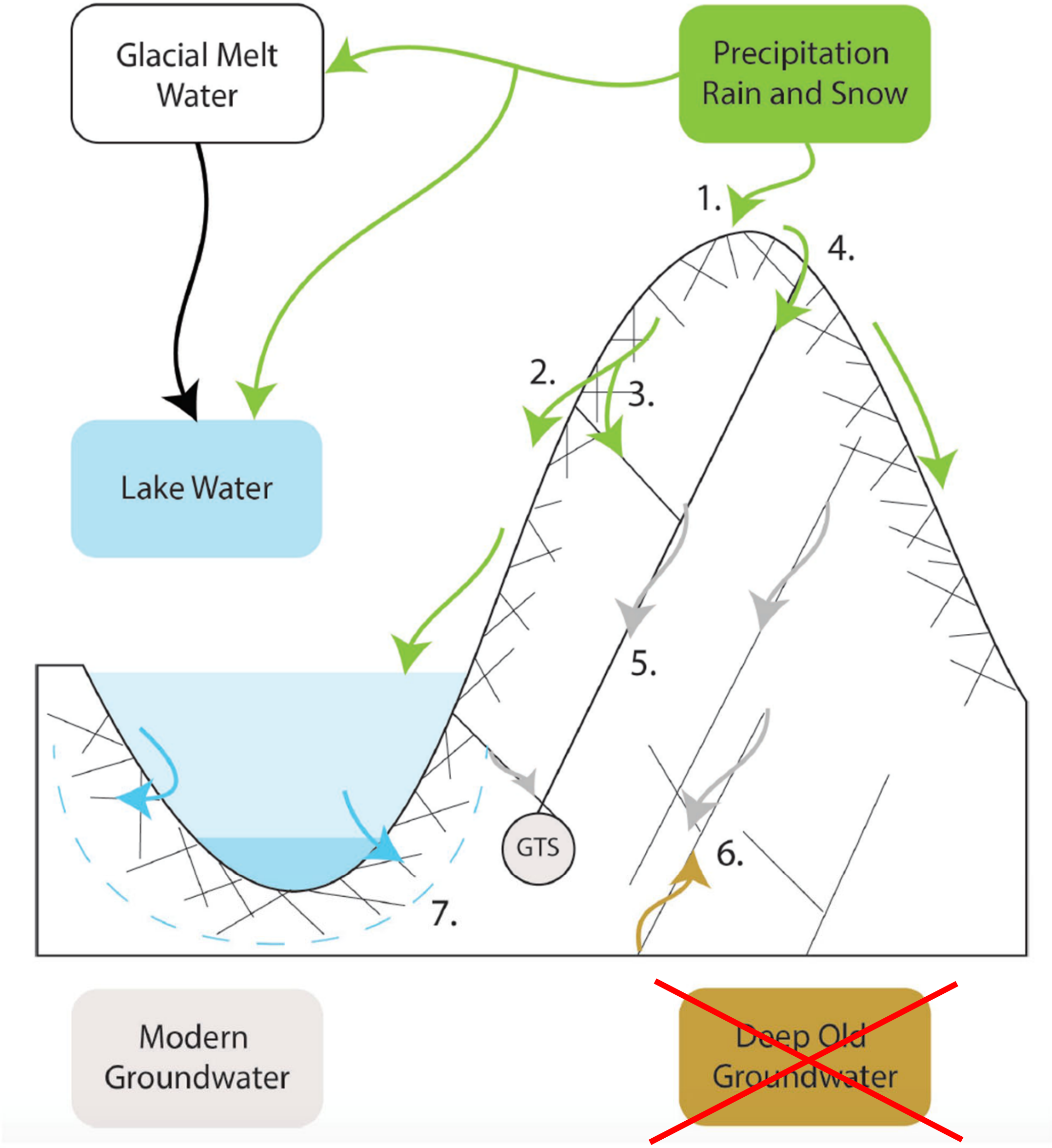
2. Surface water reservoir drained for maintenance – conditions perturbed

Strathclyde Contributions

1) Monitoring Background Groundwater chemistry
2) **Scrutinise and develop hydrogeological site investigation techniques**.
3) Examine whether surface load changes (due to lake drainage – as a glacial analogue) affect groundwater flow and geochemistry.

Developed 2 new site investigation techniques:

- **Organic fingerprinting**
- Baseline (nano-) microseismic event detection to
  - map subsurface fractures
  - Draw implications for glacial loading



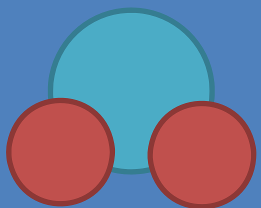
Deriving a flow model for the GTS

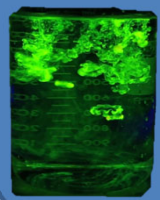
Can we distinguish components from the different surface water origins at depth?

- Glacial meltwater
- Lake water
- Rainwater/snow

What can distinguish groundwater sources?

$\delta^{18}O$, δD,



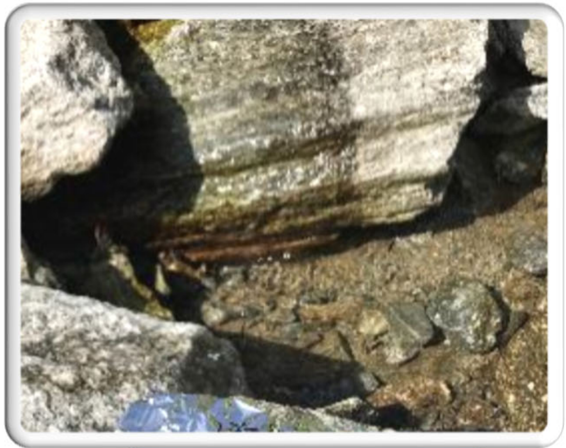


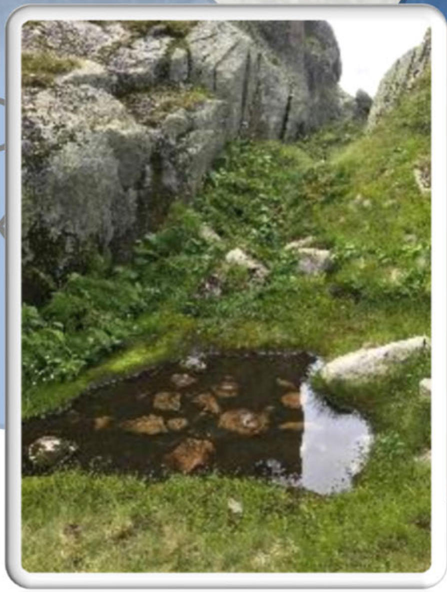
Traditional methods:
GTS groundwater is meteoric and > 65 years old

CFCs, ^{14}C, ^{85}Kr, ^{3}H

Major and Trace Ions

What can distinguish groundwater sources?



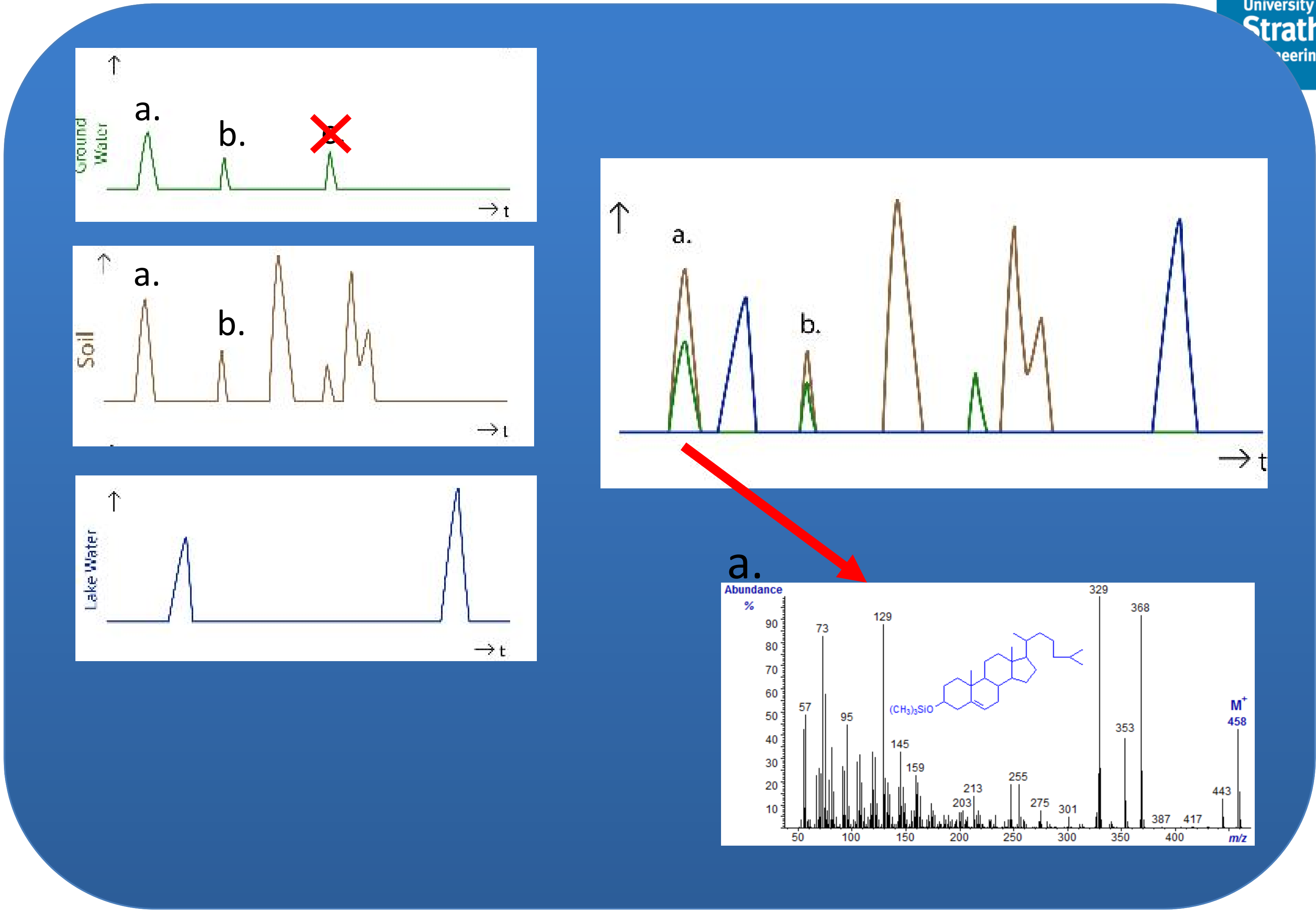


Traditional methods:
GTS groundwater is meteoric and > 65 years old

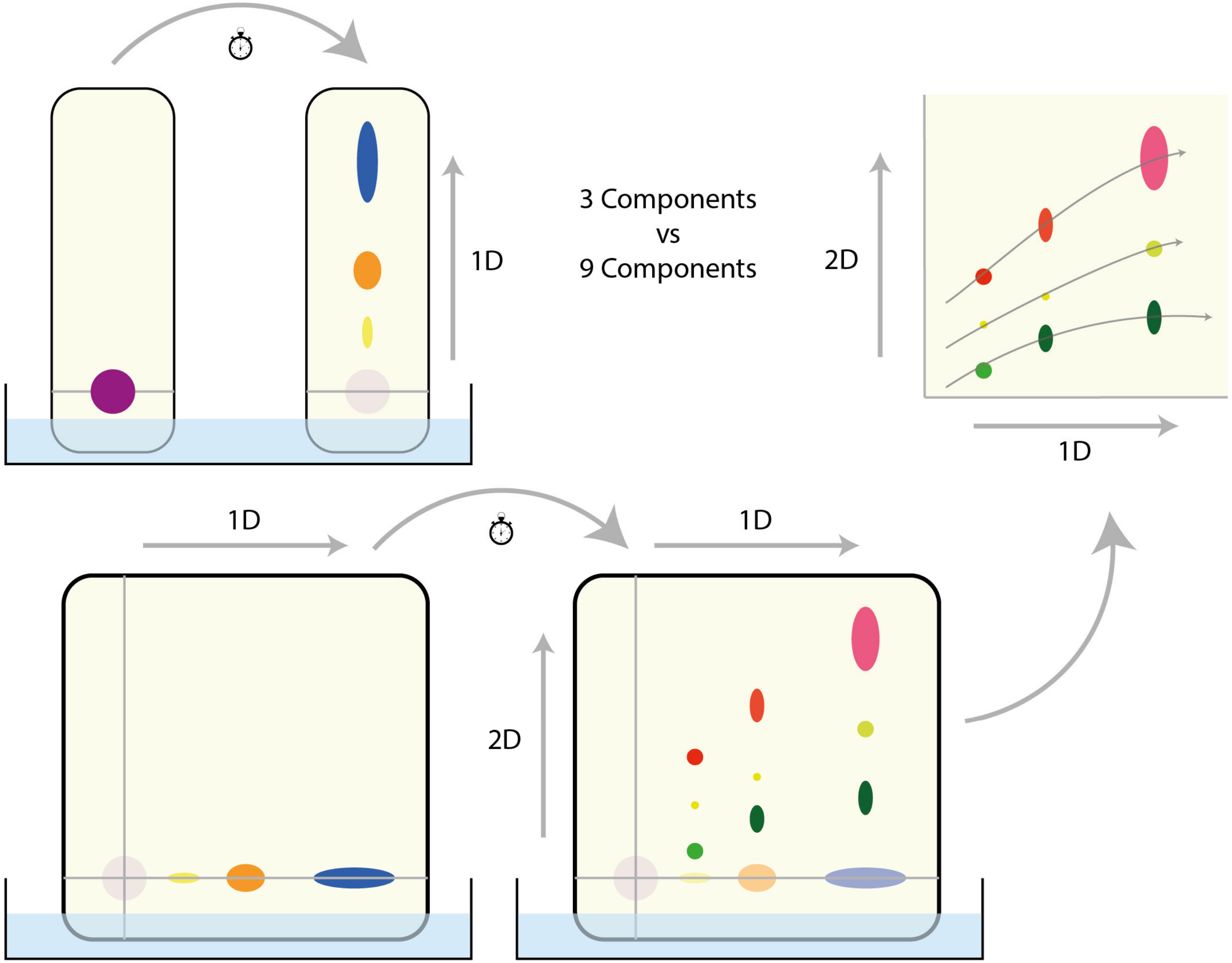
Biomarkers?

- Naturally Occurring
- Passive
- Spatial Discrimination
- Water soluble
- Detectable
- Long lasting

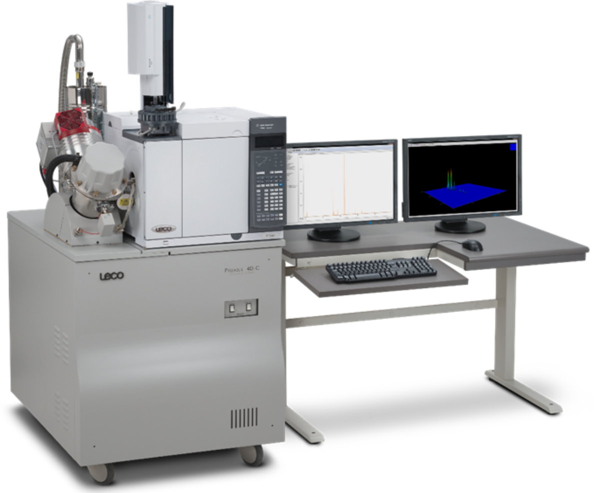
Concept – based on forensics

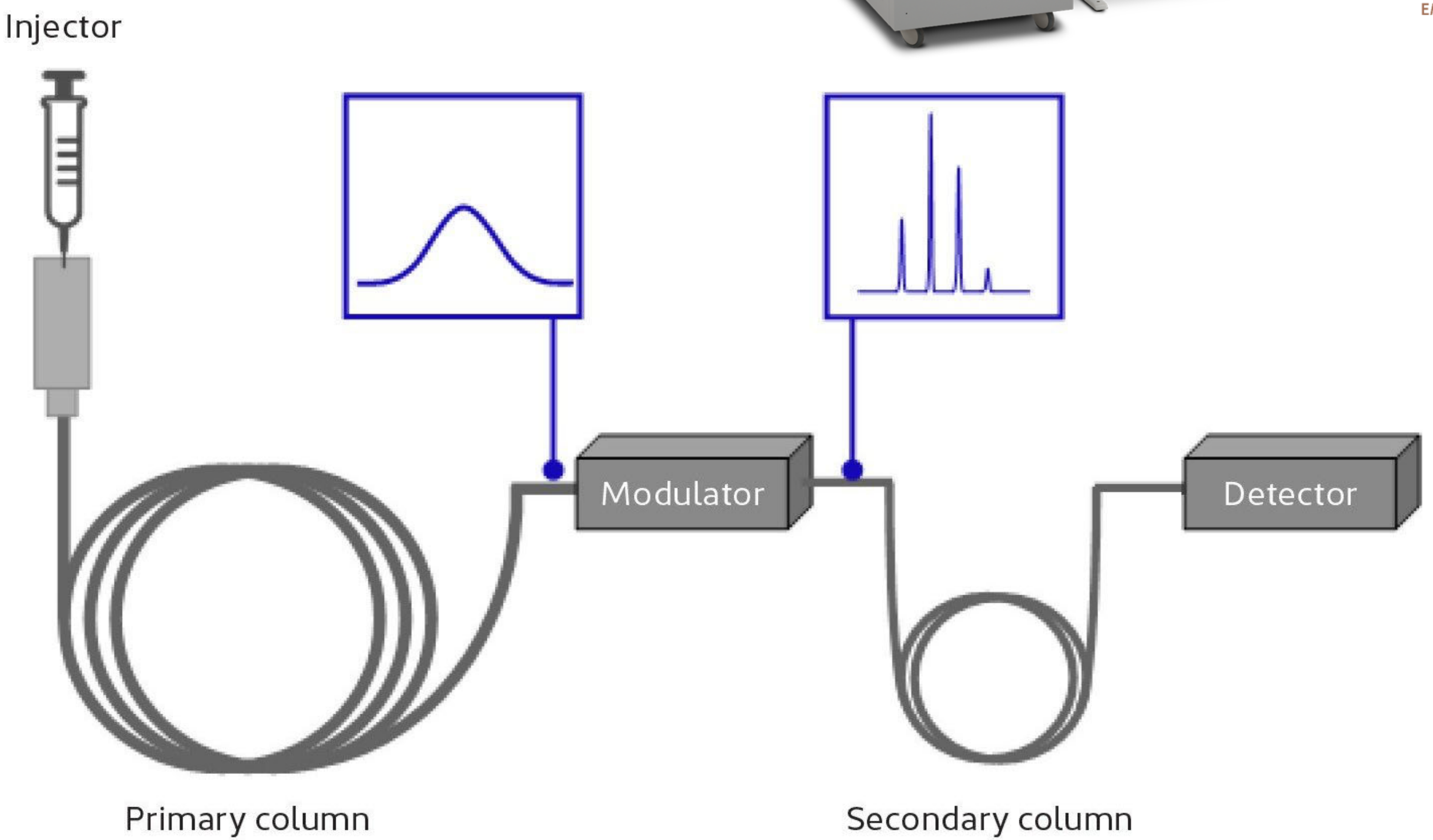


Detailed Organic Fingerprinting



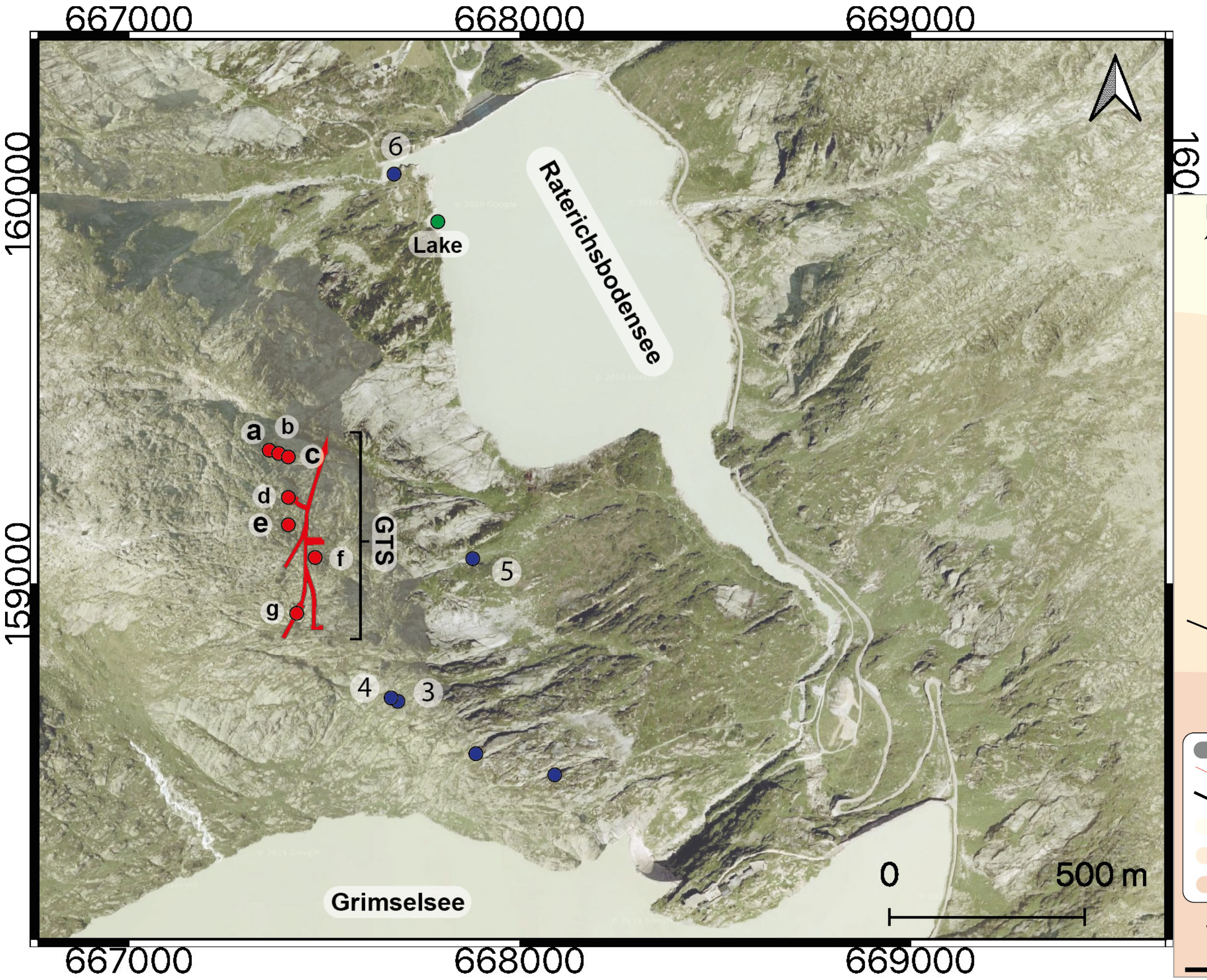
GC x GC

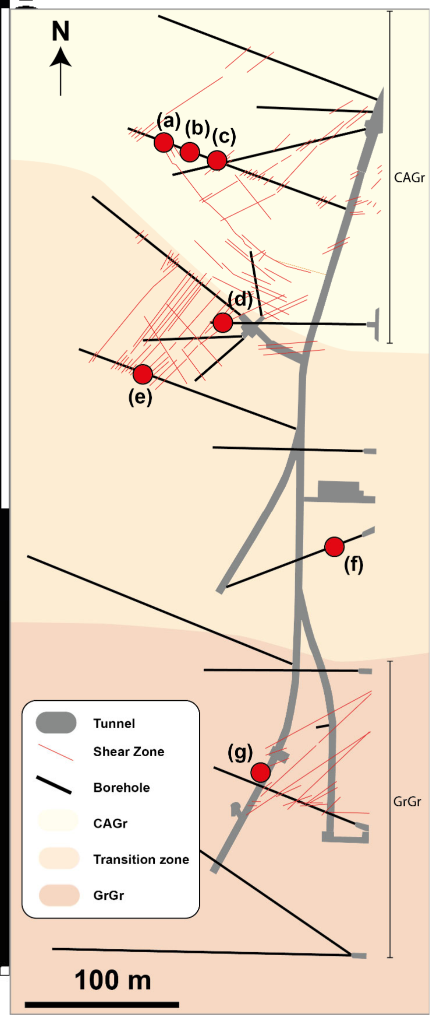




http://www.sepsolve.com/overview-of-gcgc/

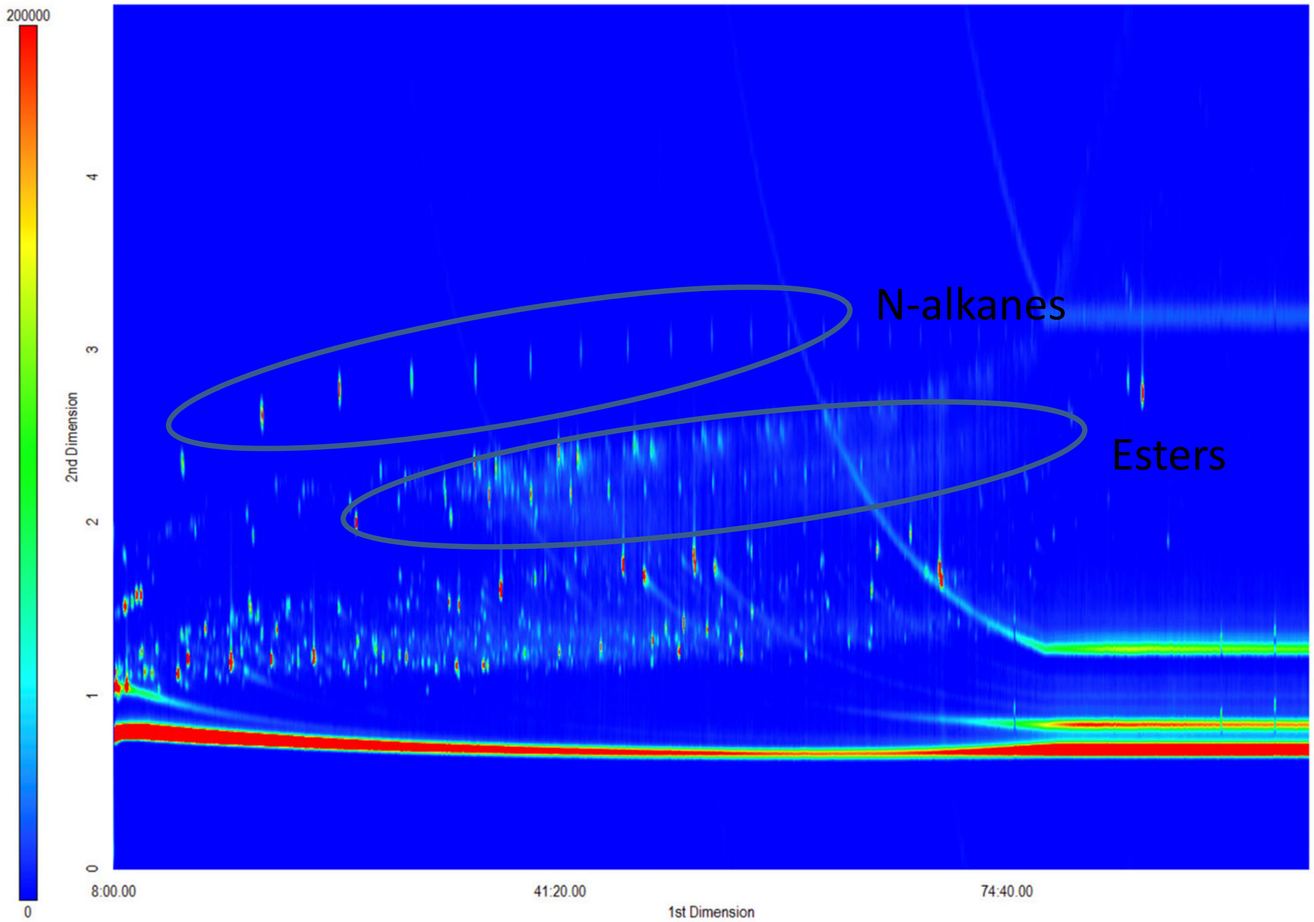
Sample locations





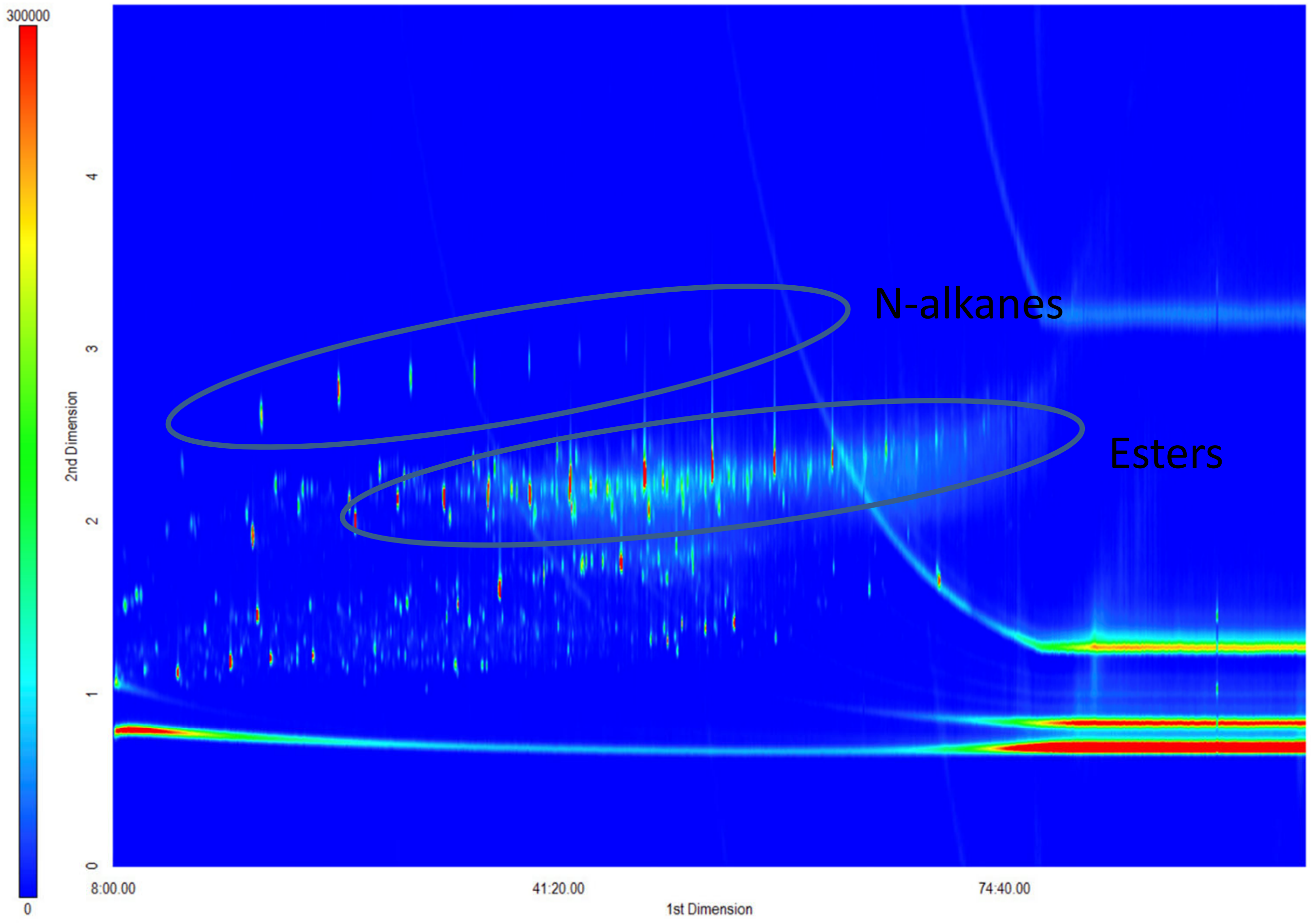
Organic Fingerprints

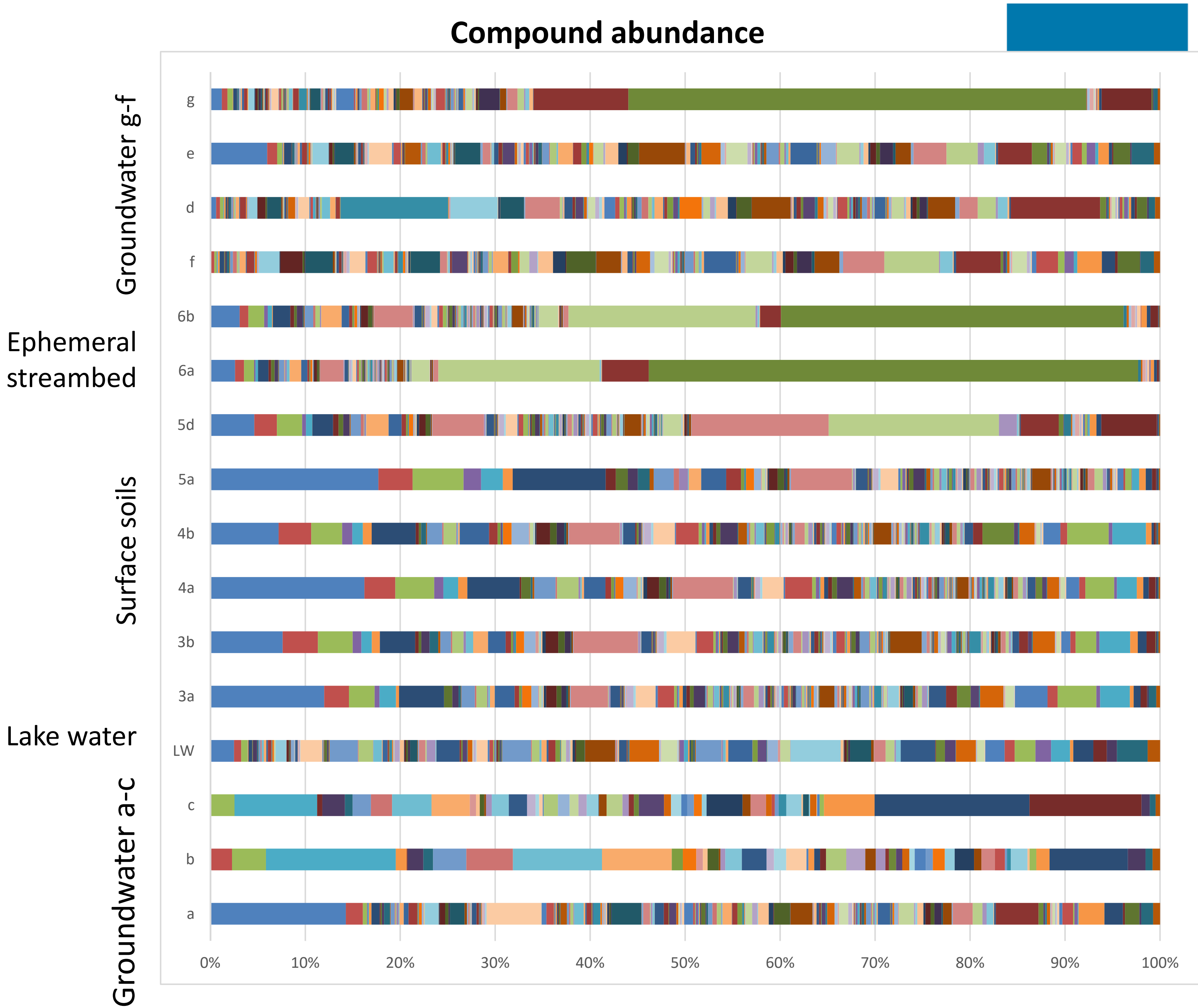
Groundwater



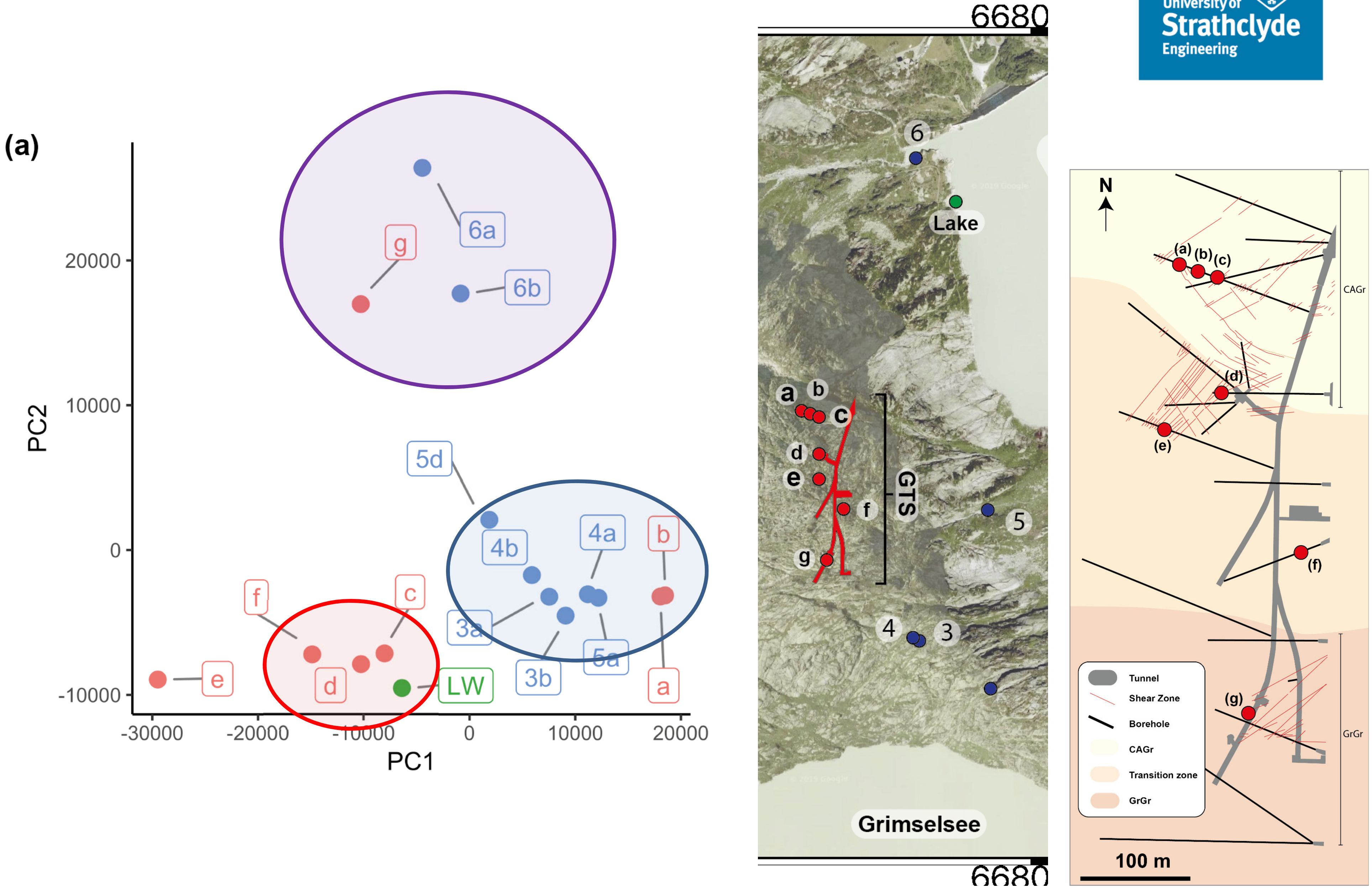
Organic Fingerprints

Lake Water

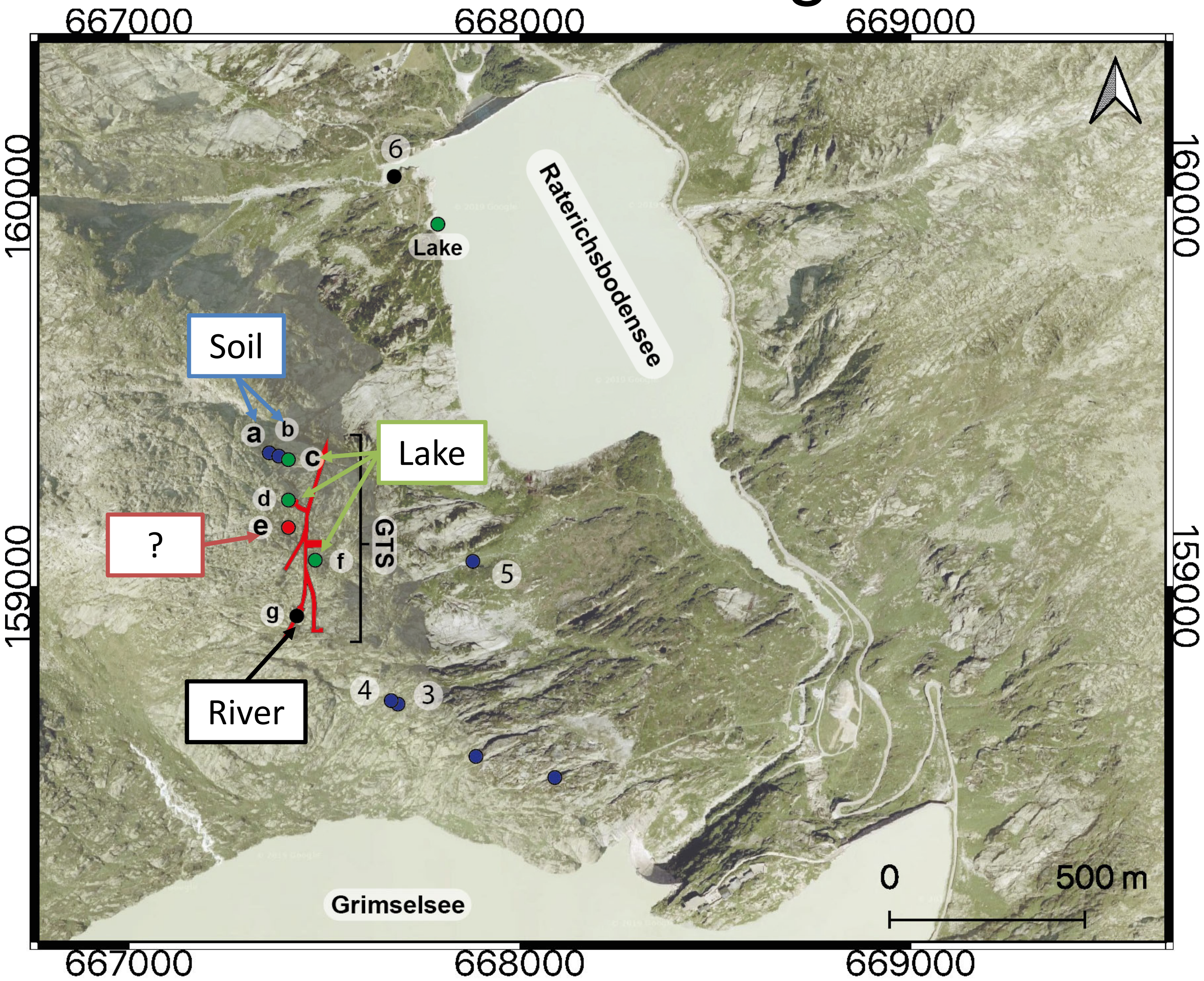



Compound abundance
Groundwater g-f
Ephemeral streambed
Surface soils
Lake water
Groundwater a-c
g
e
d
f
6b
6a
5d
5a
4b
4a
3b
3a
LW
c
b
a
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Principal component analysis

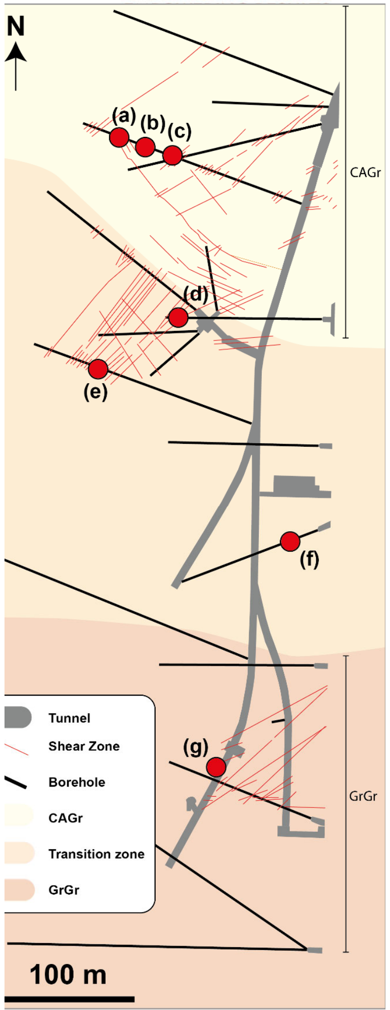


GC x GC Determining infiltration



University of Strathclyde Engineering

LECO



Implications for Groundwater Flow Model

- Lake and soil sources are different in composition
- Clear lake component in 3 groundwater sites
- Groundwater derives from lake, and two soil types
- Neighbouring fractures that cross the same borehole are extremely poorly connected (if at all)

– first ever use of organic fingerprinting as a groundwater tracing technique

Current Project:

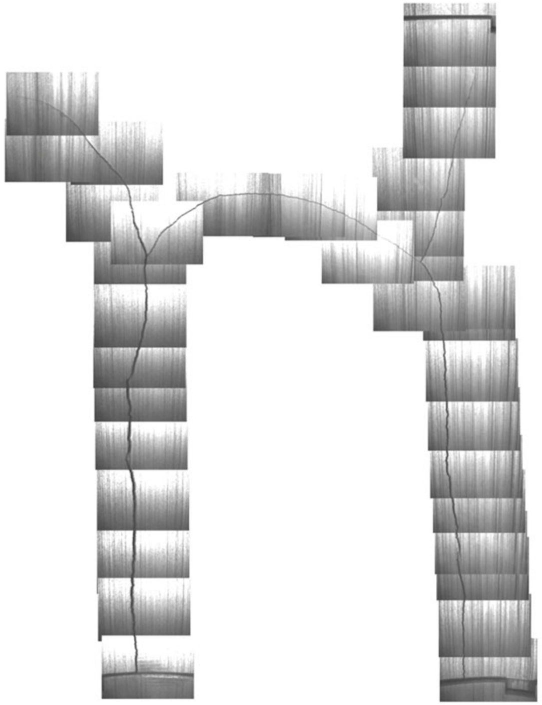
£197k – RWM *'Organic fingerprinting of groundwater to determine surface water origins'* (Jan 2020 - 2022)

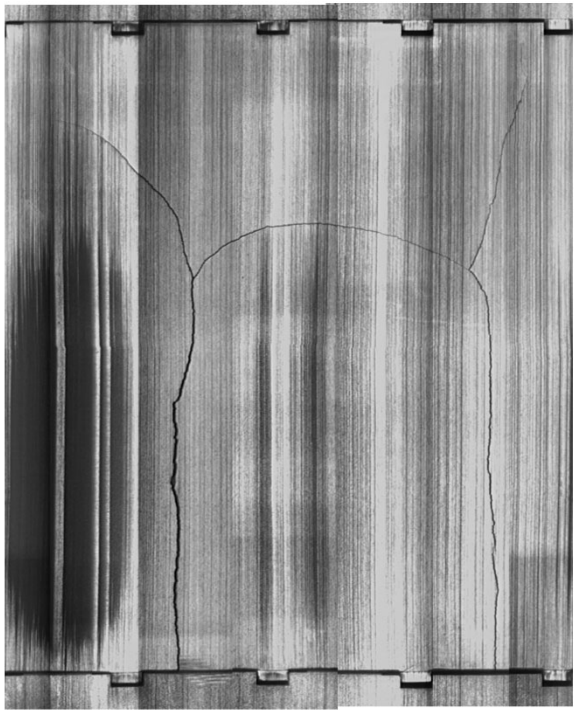
Test site: Mont Terri, Switzerland

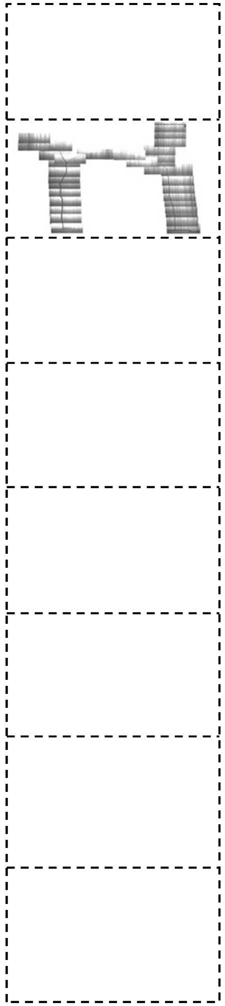
Exploring longevity, applicability to different clay sites, molecule decay etc.

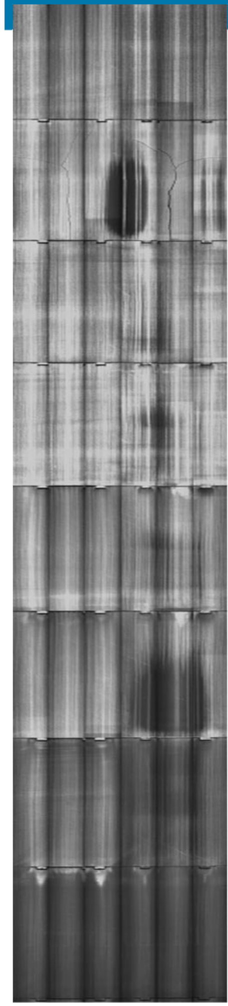
Advanced Image Processing Techniques

- Manual method: A full working day to produce approx. 3-4% of full channel image
- Automatic Artificial Intelligence-based method: Around 20 mins to produce 100% of 8 layers









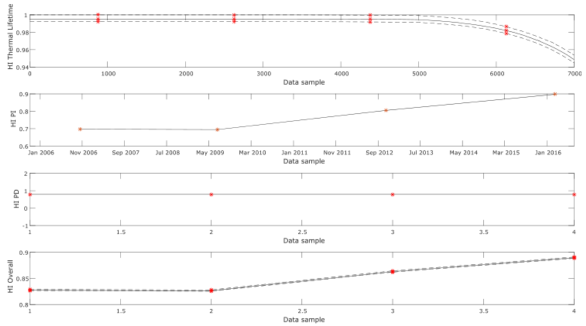
Develop similar AI-based inspection techniques for waste packages, cables etc?

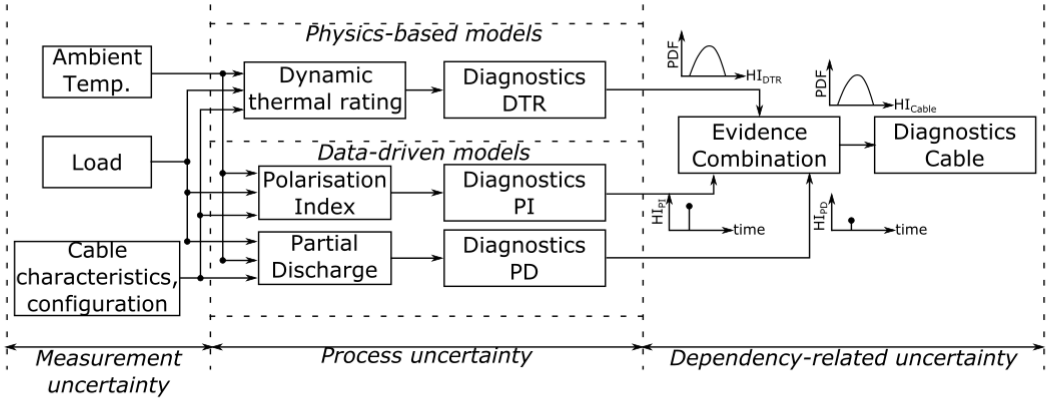
Diagnostic Life-time Asset Management Tools

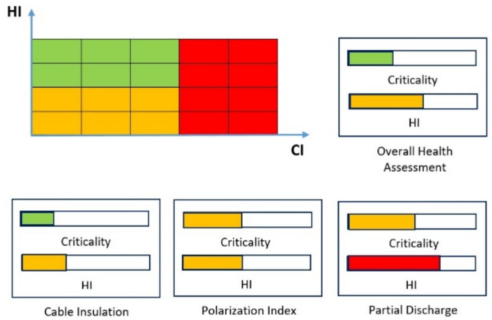
Cable Management

Combines monitoring measurements, data driven models and physics-based cable aging models to provide an overall trended **health index (HI)**

Integration into **engineering decision support systems** and cable asset management strategies







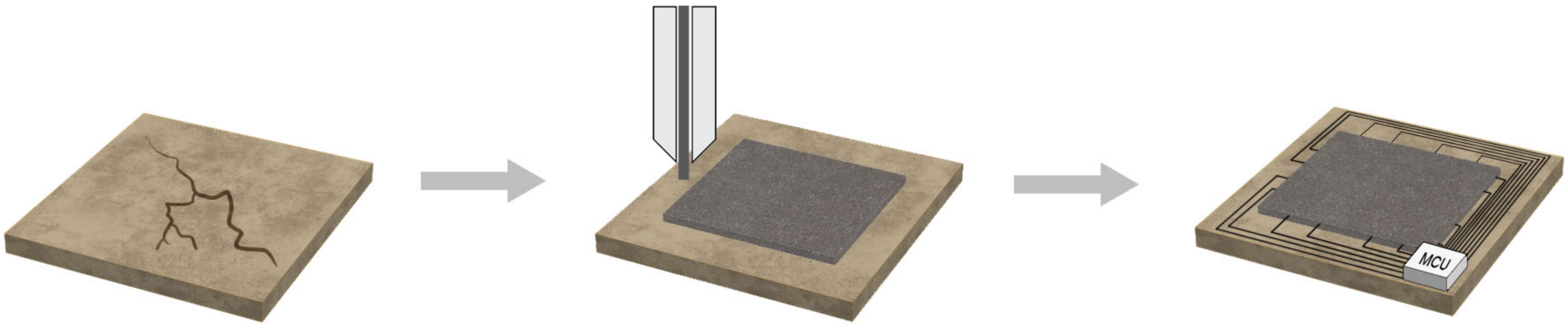
RWM - Public and operational assurance

Asset Management for Storage, Packaging, surface and subsurface GDF infrastructure?

Smart Cements for Crack / Leakage Detection

Remotely deployable, combined monitoring & maintenance for concrete

Continuous monitoring to detect cracks, moisture ingress, chloride content etc



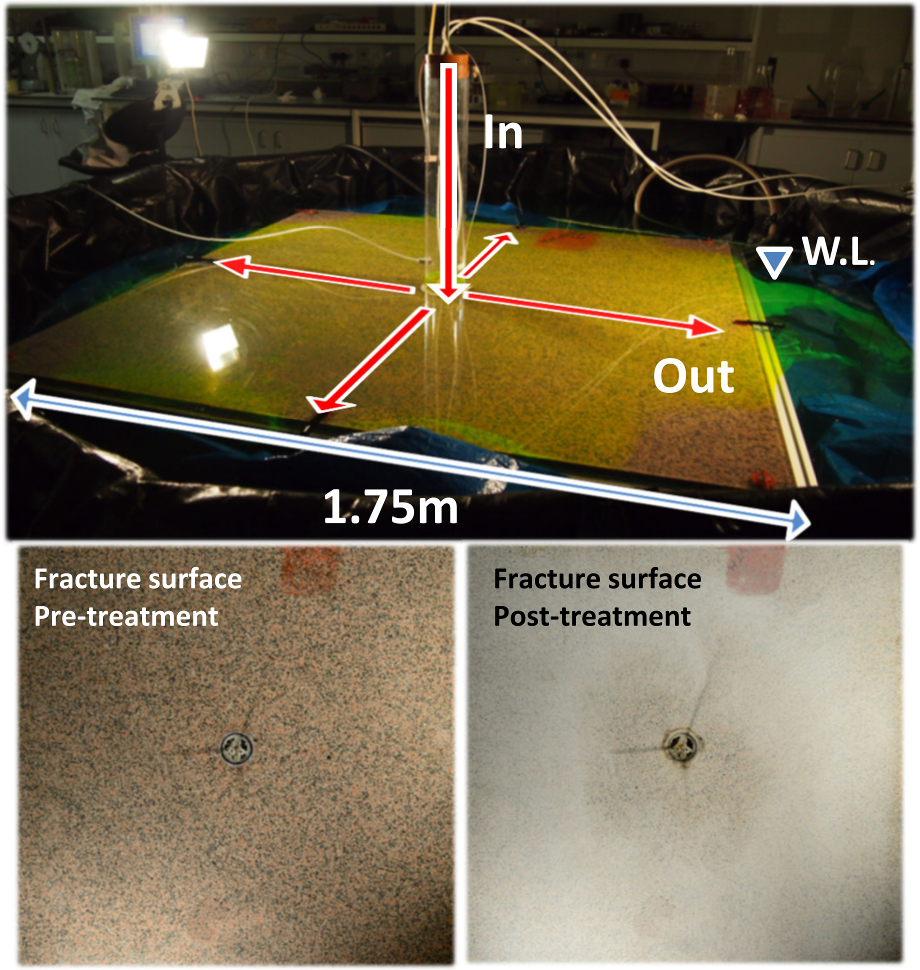
Concrete surface

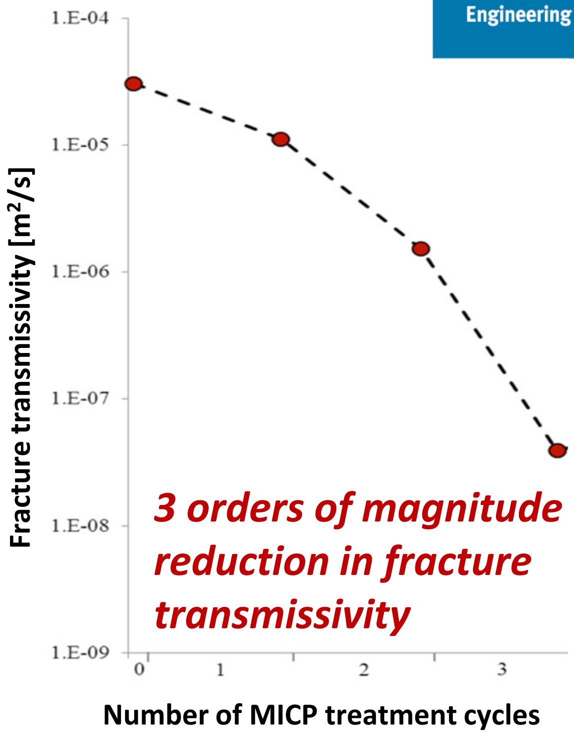
Self-sensing cement

Distributed sensor

RWM – Smart non-invasive monitoring of cement-based assets?

Crack sealing with microbially induced calcium carbonate precipitation





RWM: Rock fracture sealing in deposition holes, crack sealing in boreholes, concrete repair?

17 September 2020

In-situ analysis techniques to understand the behaviour of waste and backfill materials in a GDF environment

Professor Thomas B. Scott[1,2]

[1] Interface Analysis Centre, HH wills Physics Laboratory, University of Bristol, BS8 1TL, UK
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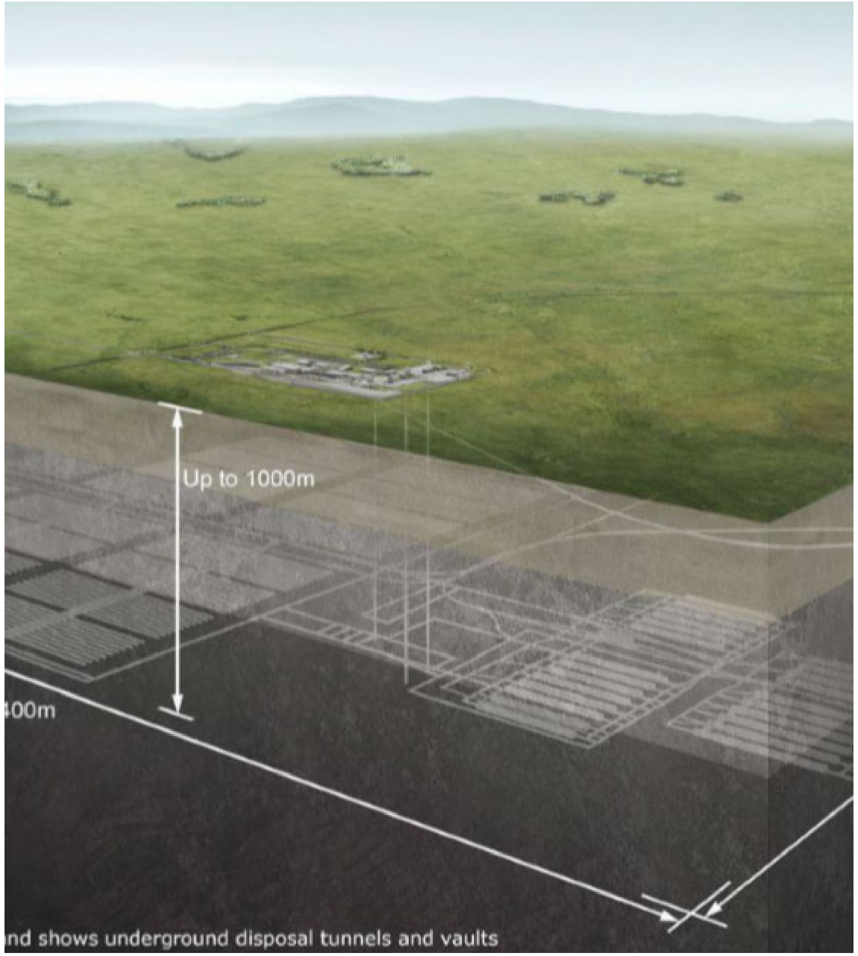
Dr Macarena Leal Olloqui, Dimitris Samaras, Dr Haris Parasevoulakos

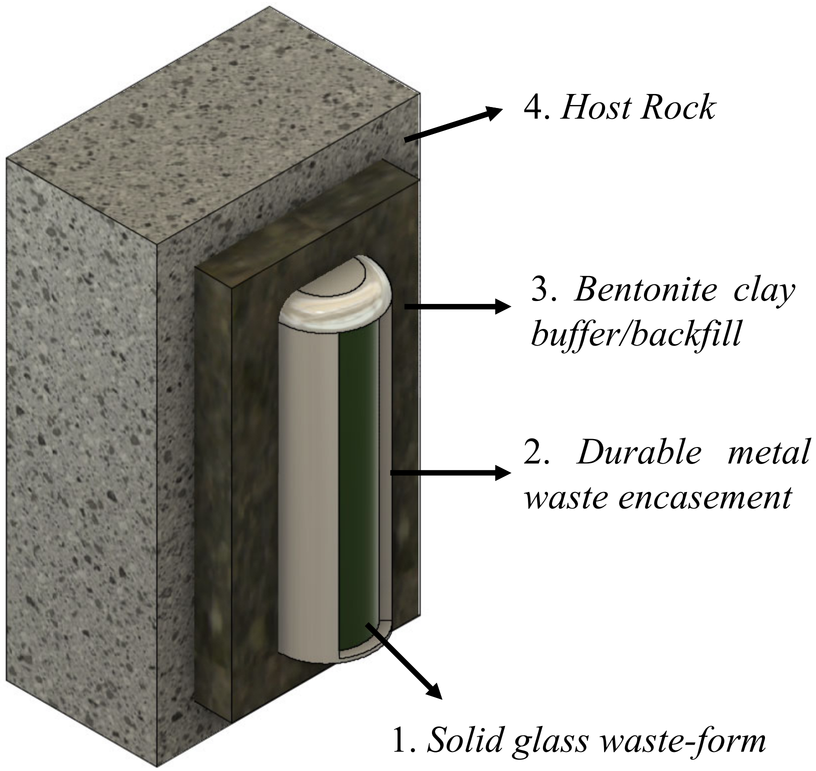
University of BRISTOL



Studying Materials in a Geological Disposal Facility setting is challenging!

- Time (lots of it!)
- Conditions (which vary)
- Radiation (which reduces)
- Microbes (good & bad!)

Engineered Barrier System (EBS) concept



The concept for an **Engineered Barrier System** (EBS), comprises:

1. *Solid glass waste-form*: To prevent the dissolution of radioactive waste into groundwater.

2.Durable metal encasement: Prevents the contact of groundwater with the HAW.

3.Bentonite clay buffer/backfill: Delays the migration of radioactive substances by slowing down the movement of groundwater and blocking microbes.

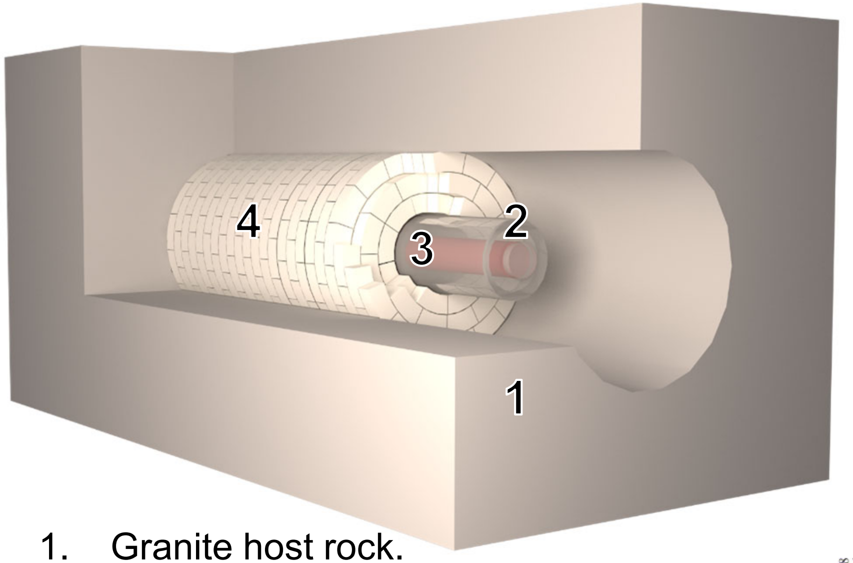
4.Host rock: To slow down the migration of radioactive nuclides to the surface.

Long-term experiments

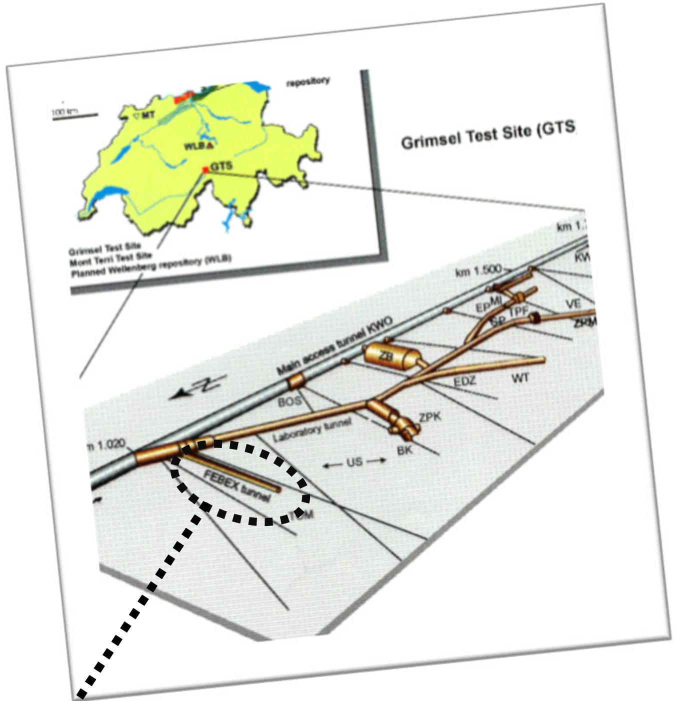
FEBEX in situ test

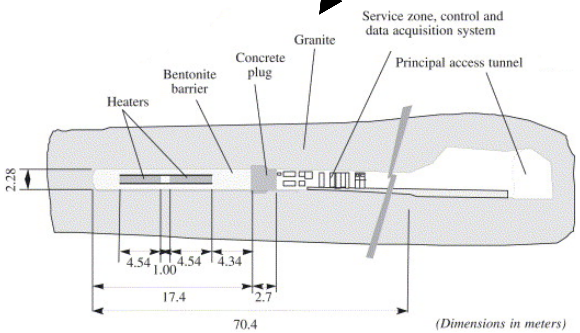
100°C for 18 years

Full-scale High Level Waste Engineered Barriers (FEBEX)



1. Granite host rock.
2. Heater.
3. Steel liner.
4. Compacted bentonite blocks.



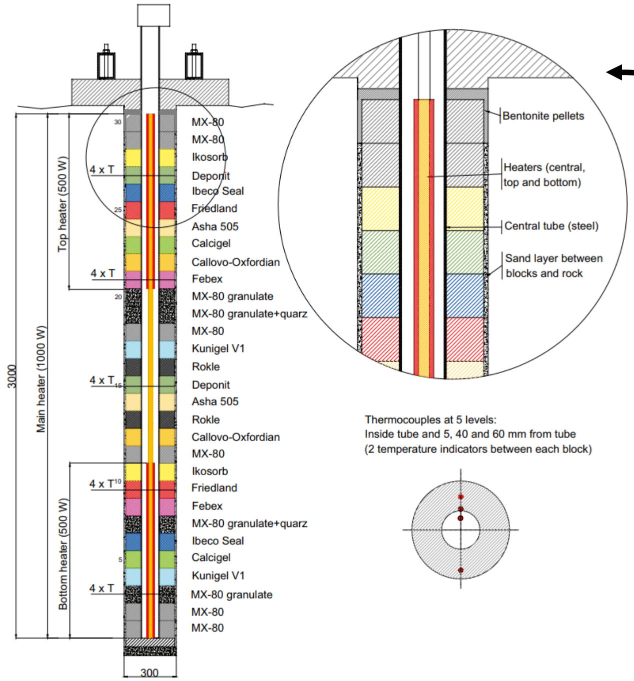


Grimsol test site in Switzerland

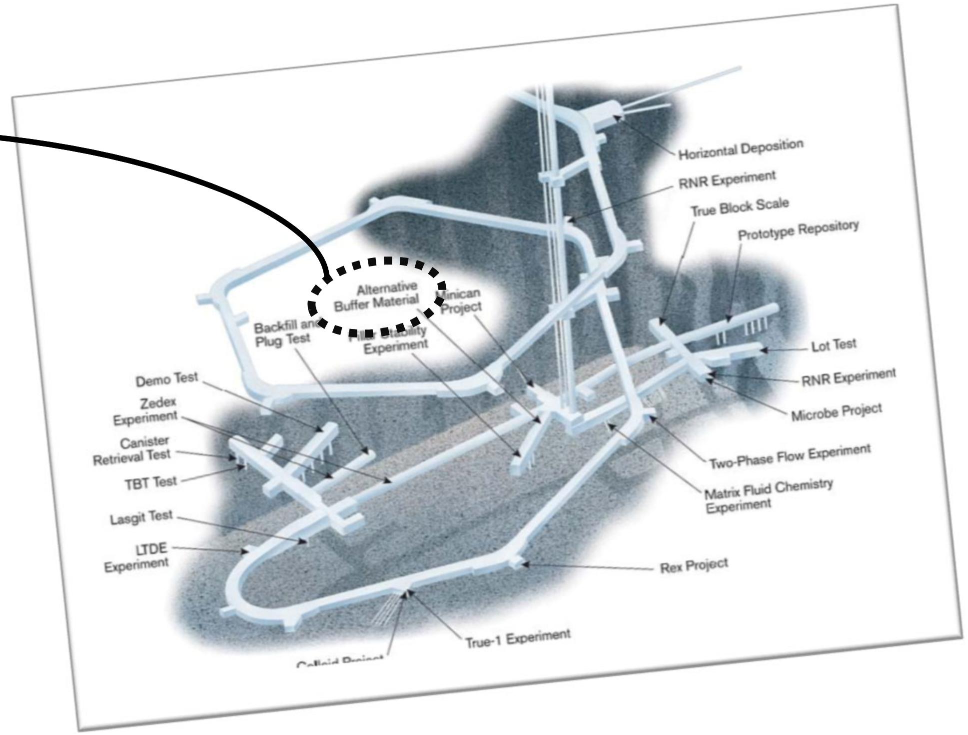
Long-term experiments

Alternative Buffer Material (ABM) project

130°C for 6.5 years



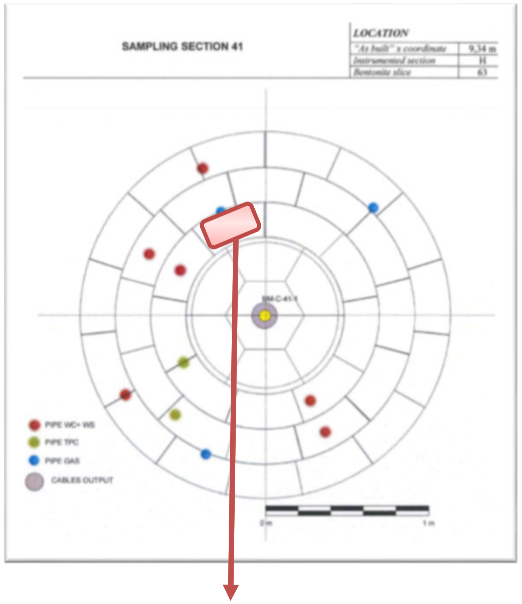
Schematic layout ABM experiment (test package 1)

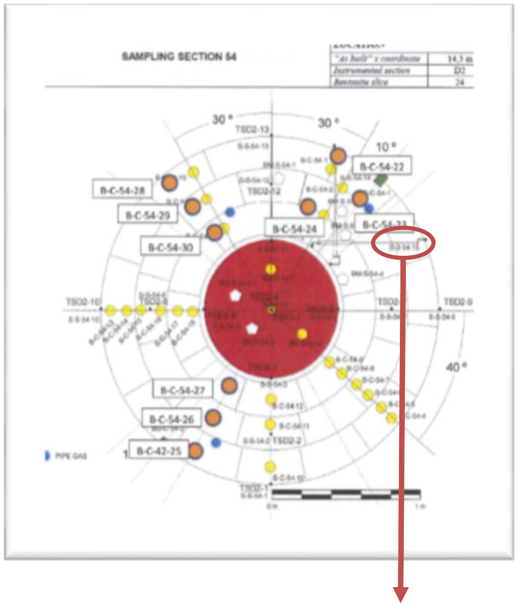


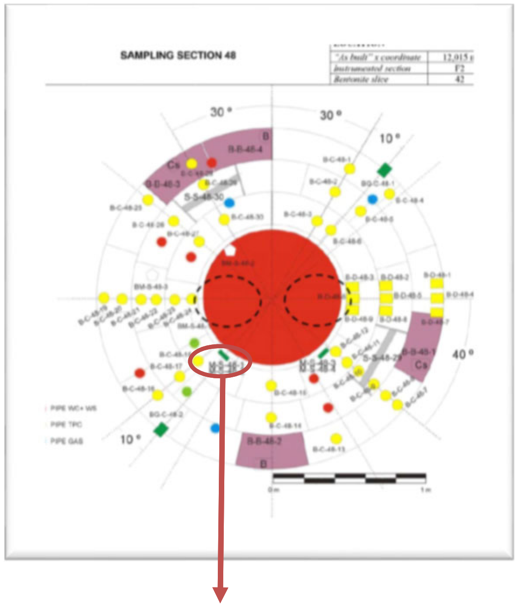
Äspö Hard Rock Laboratory, Sweden

A suite of incredibly important samples!

Example - Sampling the FEBEX in situ tests







Sample BM-B-41-1

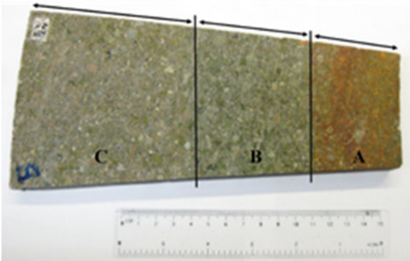
Samples S-S-54-15-A/B/C/D/E

Sample M-S-48-1

Important observations for alteration

Inspection FEBEX and ABM samples

Sometimes no result is a good result!



BM-B-41-1

S-S-54-15-A/B/C/D/E

Kunigel V1

MX-80

Deponit

Febex

- Sample BM-B-41-1 from the Febex experiment, displays a visual discolouration.
- Samples from ABM experiment, showed no appreciable differences detected.
- Also verified using advanced materials analysis techniques

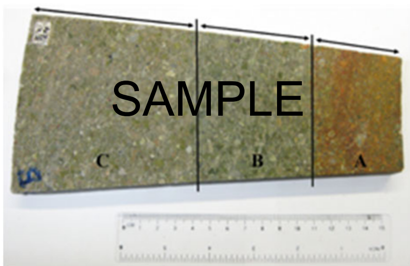
A multi-technique analysis approach

X-ray diffraction

Optical and Electron microscopy (inc. EDX)

Secondary ion mass spectrometry

X-ray tomography

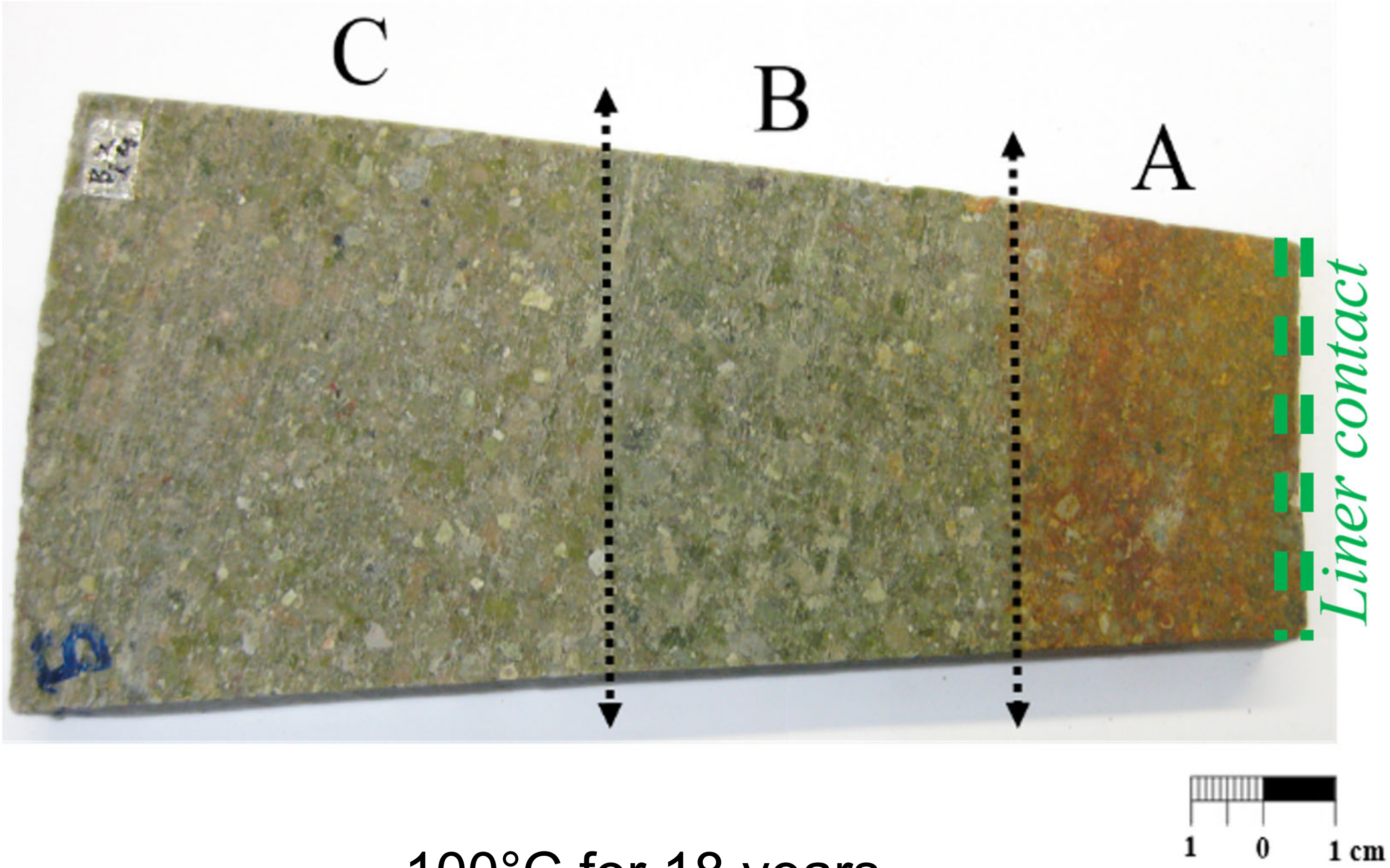


Cation Exchange Capacity

X-ray Fluorescence

FTIR and Raman

Example - Febex Bentonite alteration



100°C for 18 years

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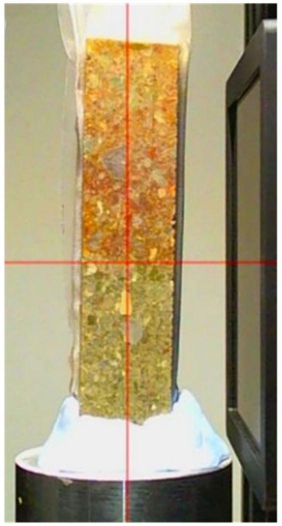
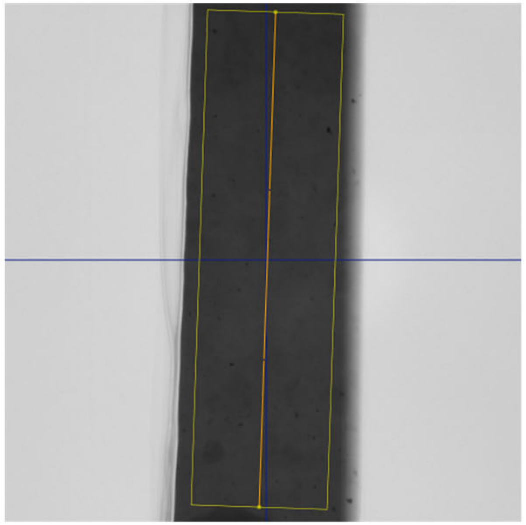
XRT

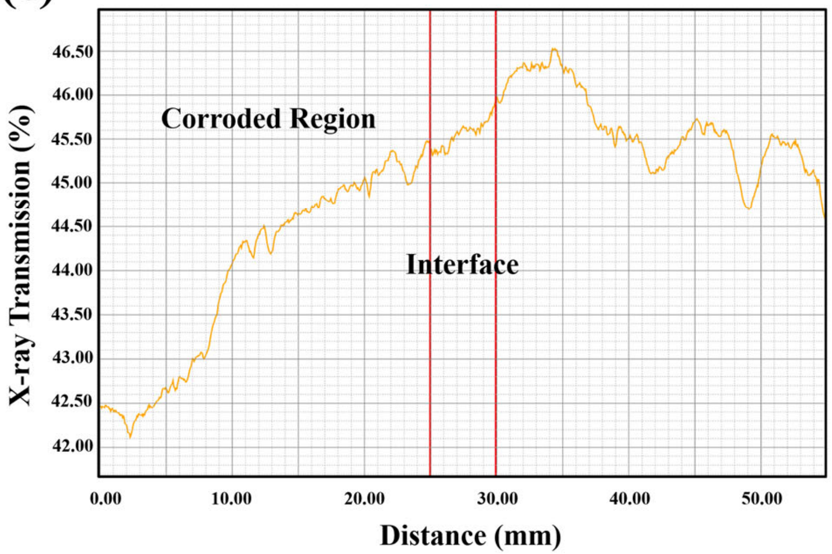
(a)

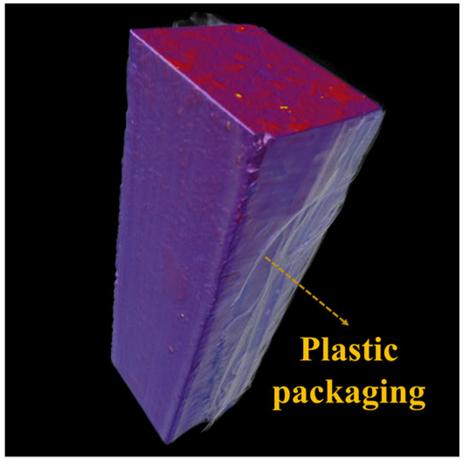


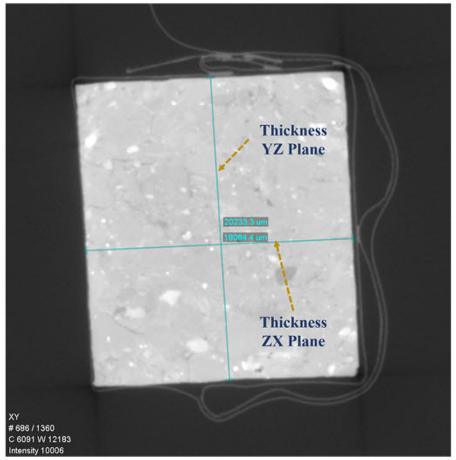
(b)

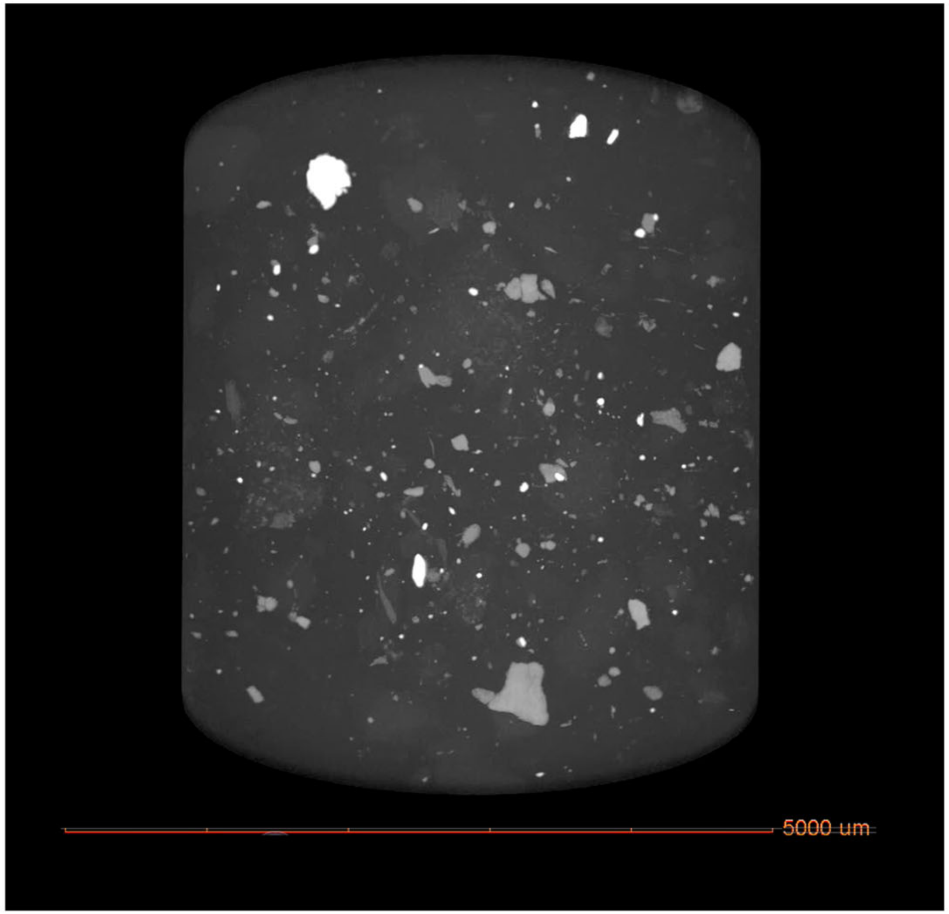


(c)

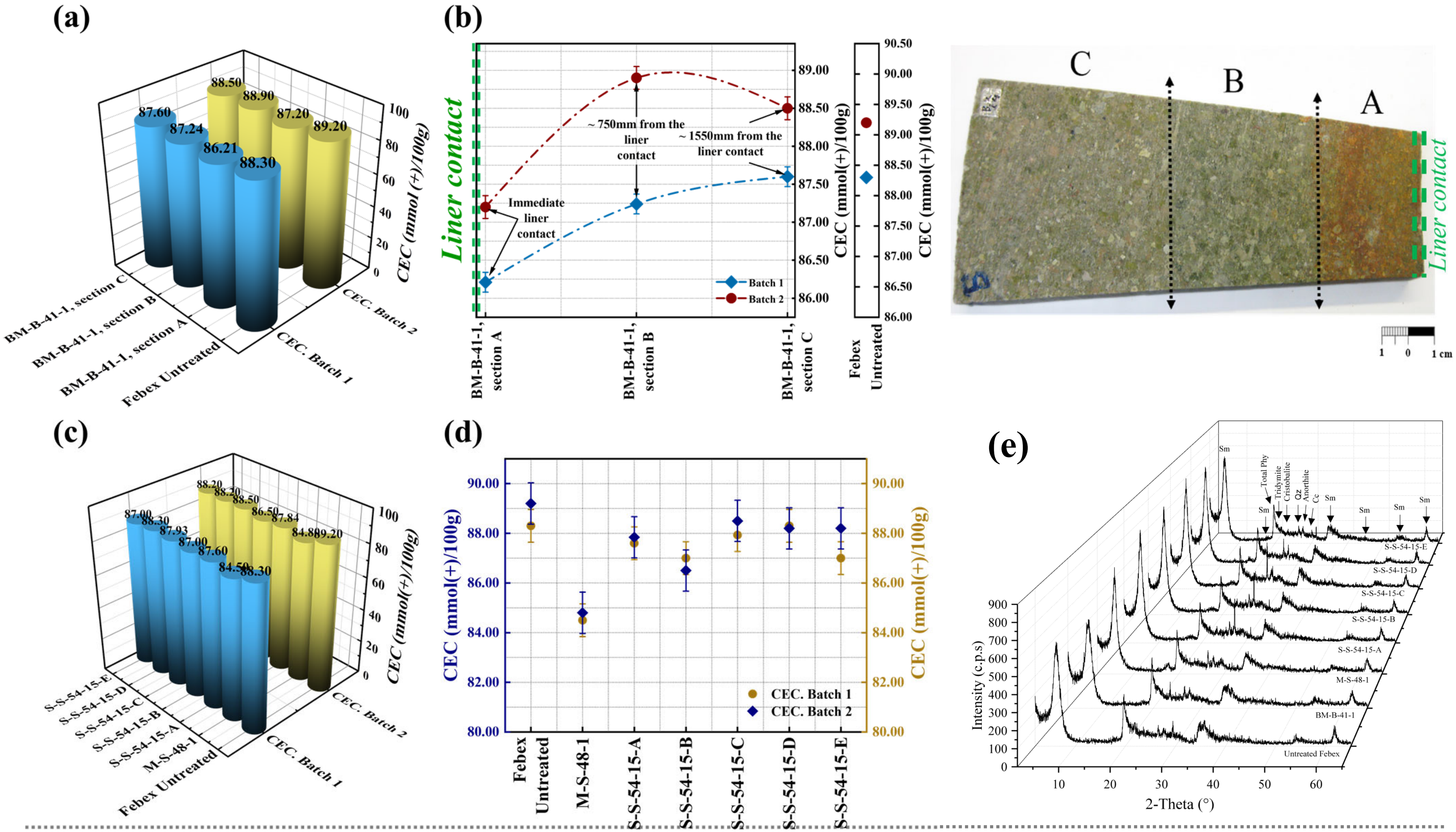




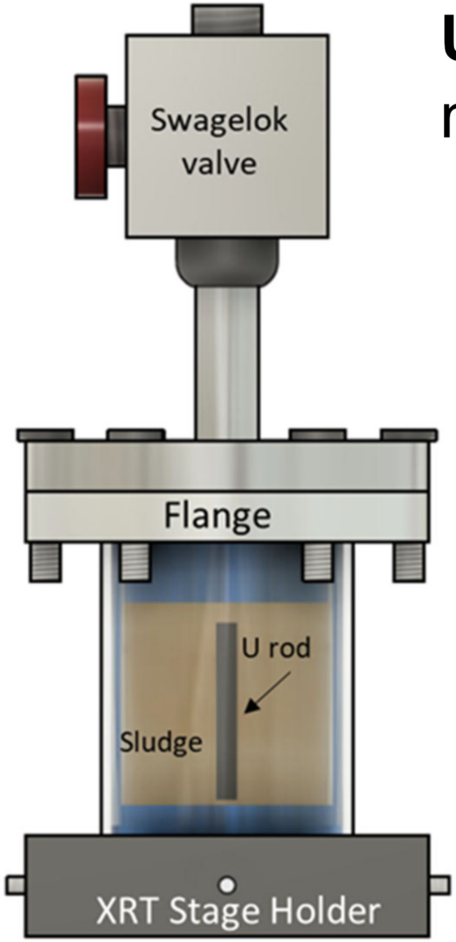




XRD and CEC results



Example – In situ analysis



Uranium and **Uranium Carbide** are fuel materials that will be emplaced in a UK GDF.

Should containment fail, both are **reactive materials** that can also be **leached** by contacting waters.

To study their GDF evolution you **must analyse them in situ!**

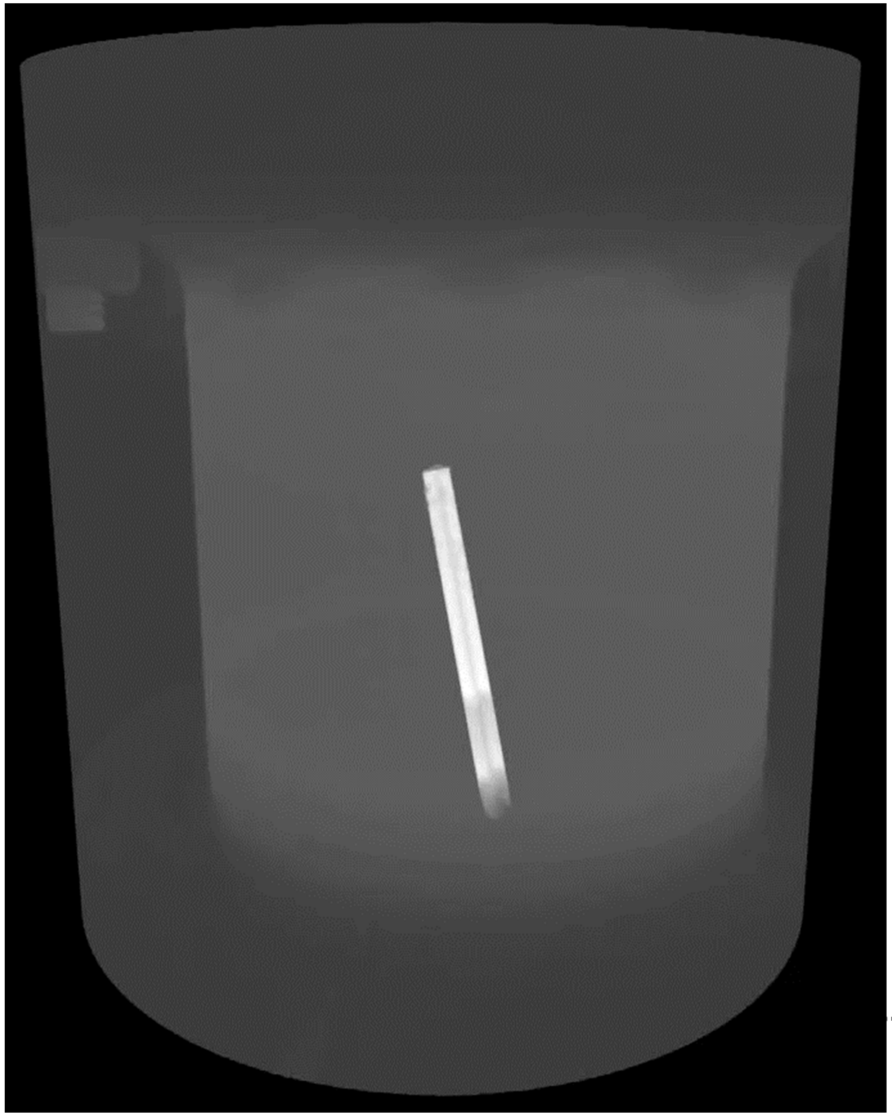
Data Collection

- 20 days after preparation
- 50 days after preparation
- 360 days after preparation

XRT Scans

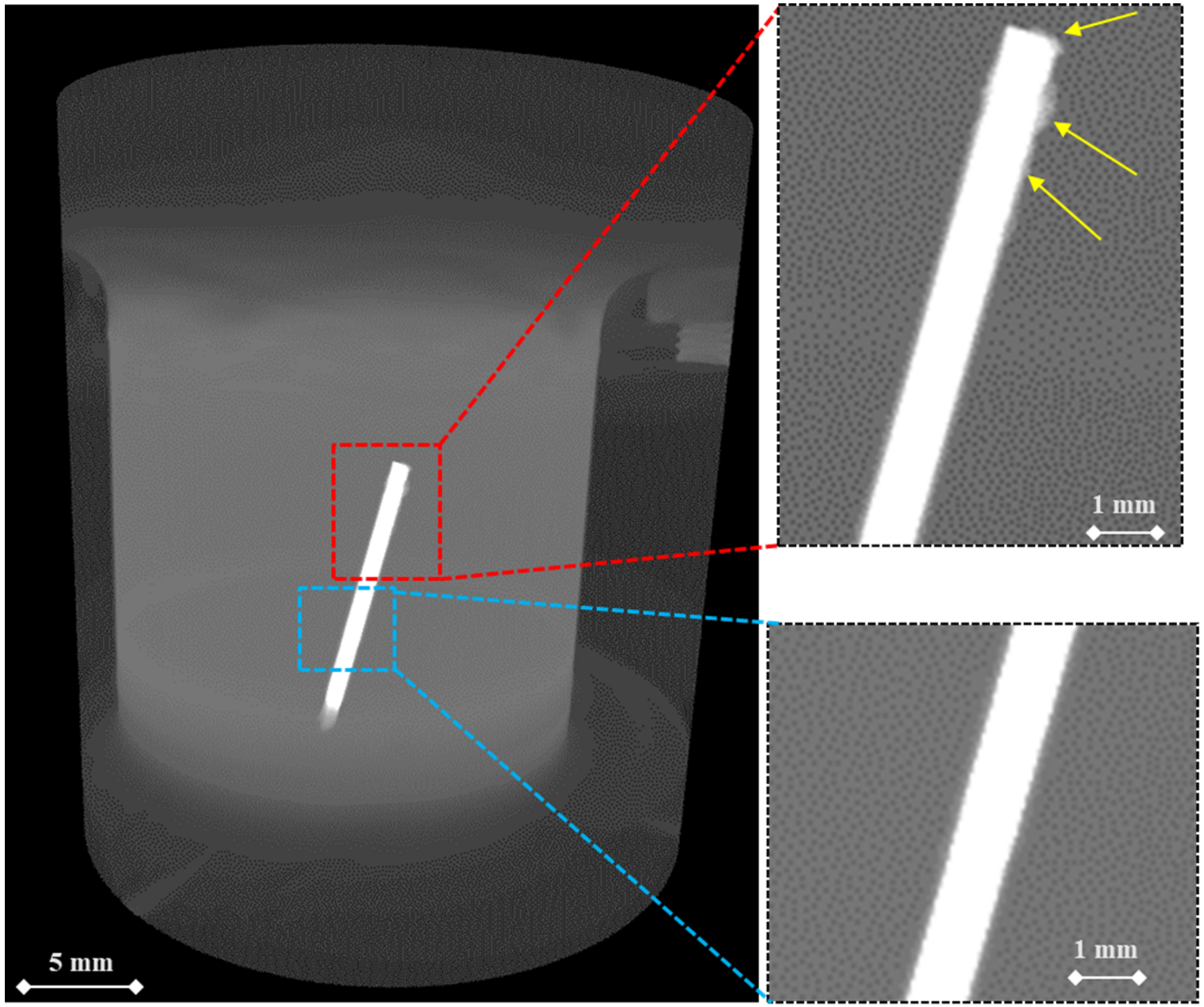
- Low-resolution, high FOV (~30µm/pixel, ~1 h 30 mins/scan)
- High-resolution, low FOV (~2.8µm/pixel, ~20 hours/scan)

In situ XRT analysis of U metal



- Both U metal and U carbide 'stick' samples have been placed in sealed X-ray transparent cells.
- Some are in water (different chemistries), some in Magnox sludge simulant (as shown).
- XRT analysis allows direct inspection of the samples without breaking containment.
- Doing so would disrupt the system and allow O_2 ingress.

20 days in-situ….



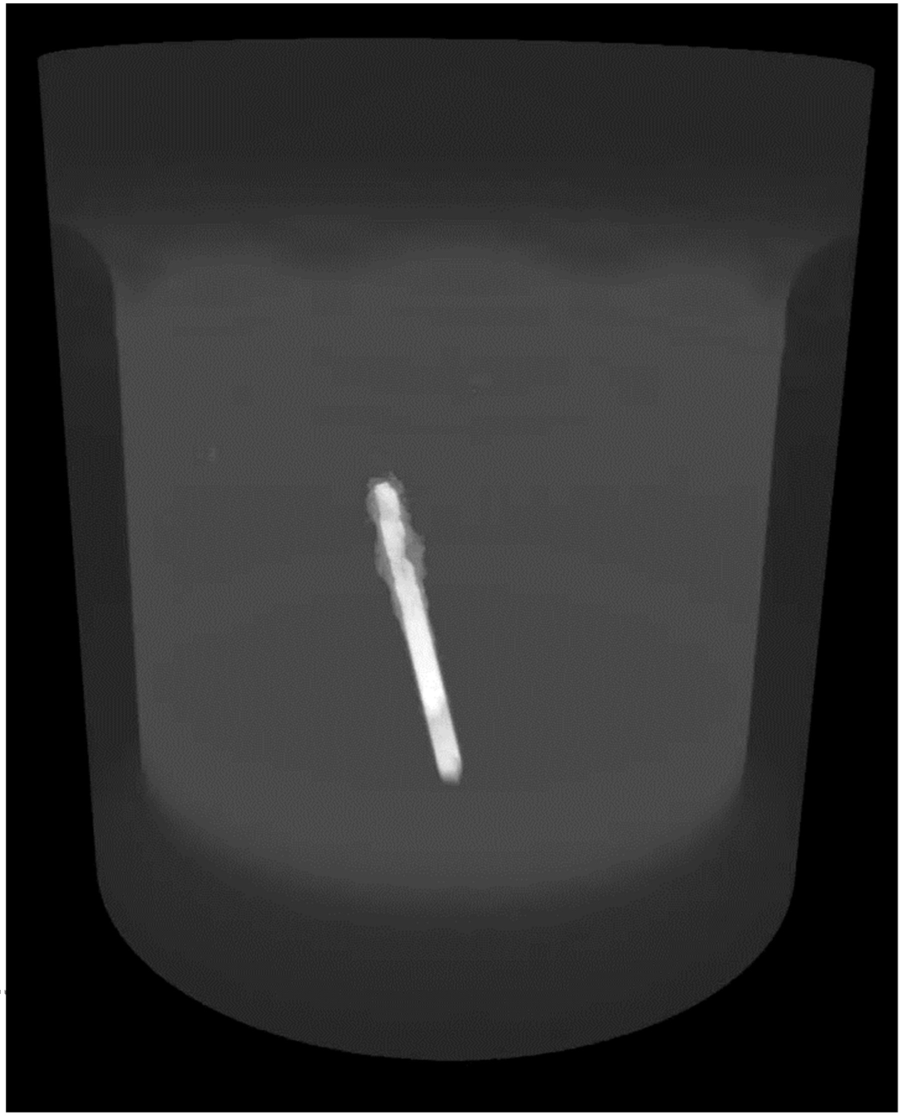
Key findings

- *First signs of corrosion*
- *Crater/blister type of morphology – No Layer*
- *No signs of corrosion across lower uranium*
- *No evidence of bubble formation in the sludge*

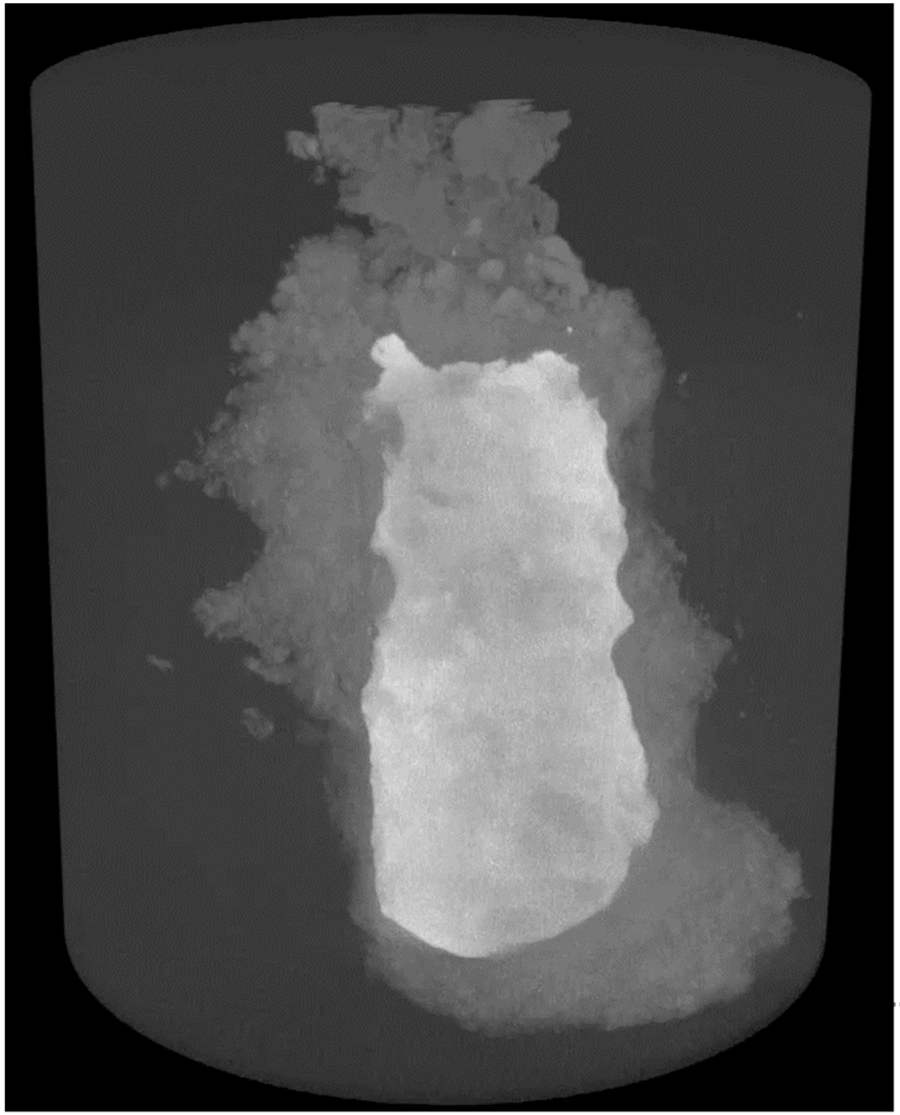
50 and 360 days in-situ….

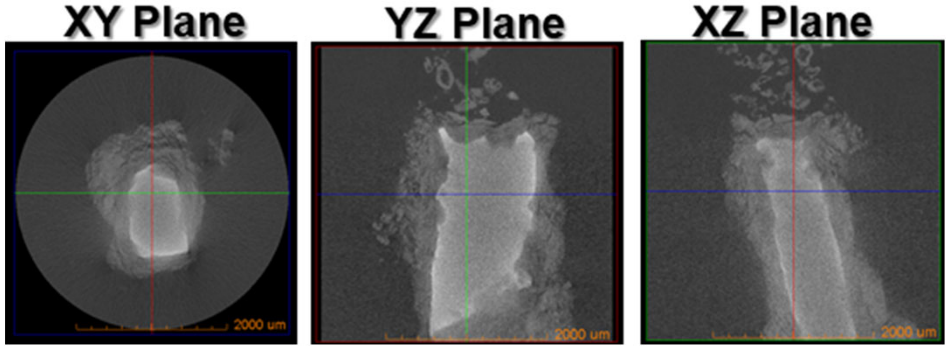
50 days

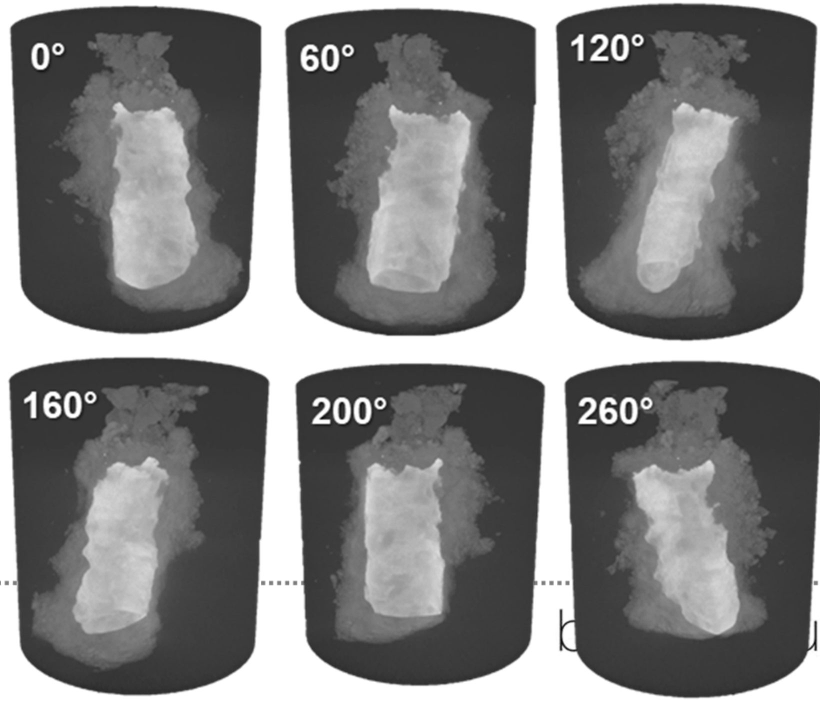
360 days



High Magnification Scan – 360 days



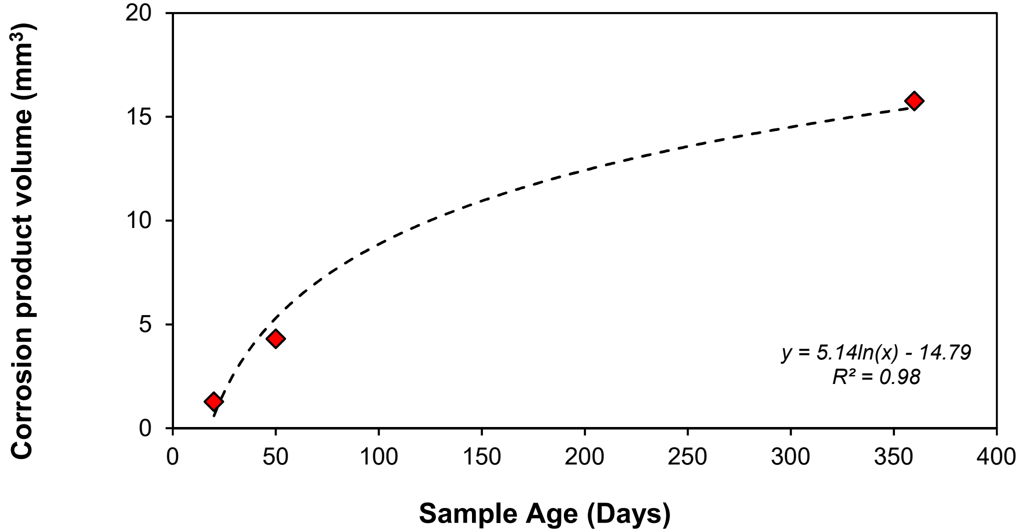


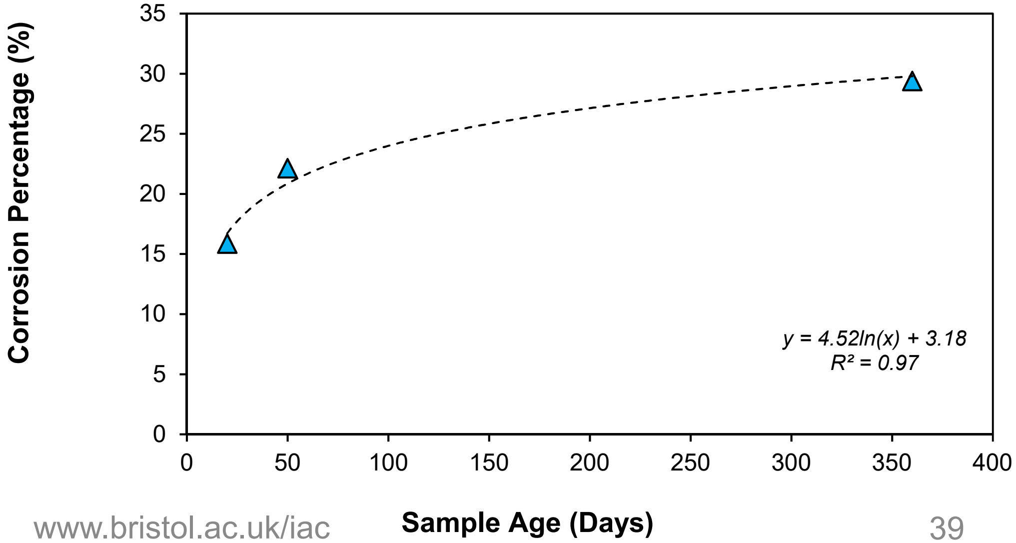


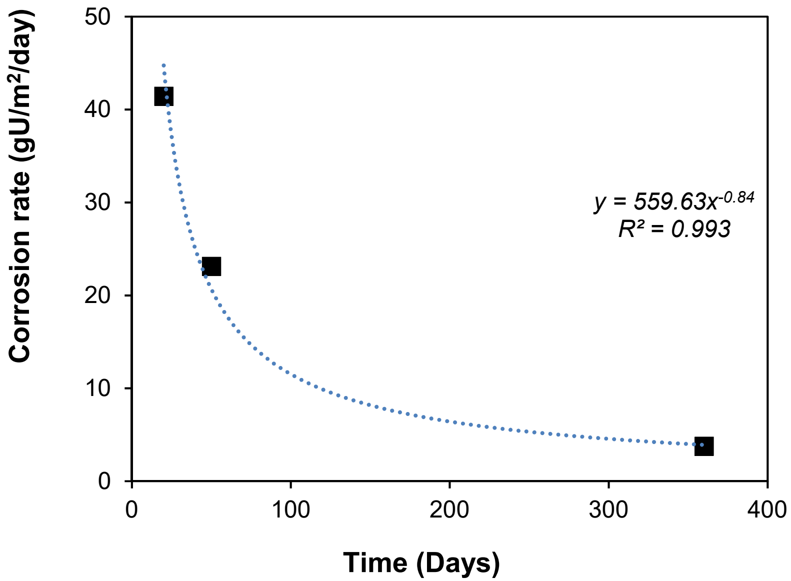
Quantitative analysis – rate data

Analysis

- *Image Segmentation*
- *Phase Separation*
- *Volume Calculations*
- *Corrosion Rate/Percentage*

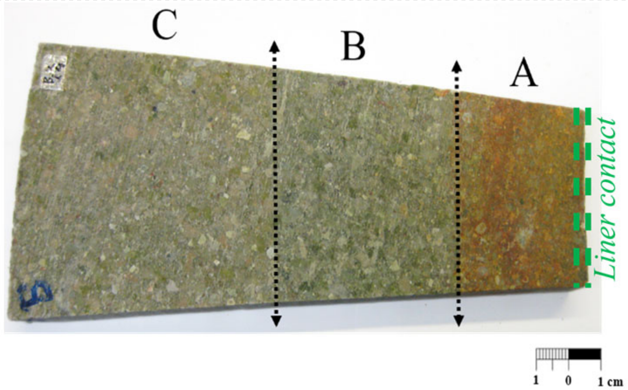


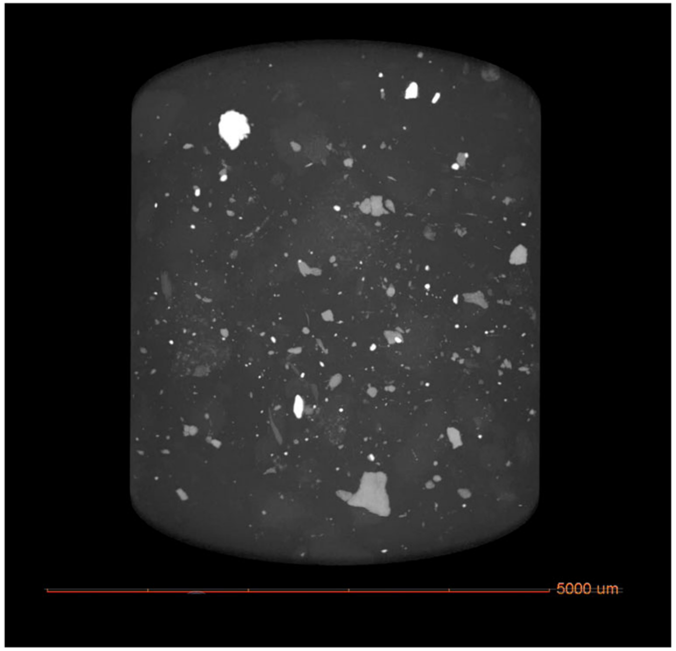




Summary and Conclusions

- Analysis of **long-duration test** samples is **incredibly valuable** for providing credible evidence for GDF performance.
- **In-situ analysis** of materials is challenging but highly-important for facilitating **time-resolved** studies of materials.
- A **multi-technique approach** for research on GDF materials is a necessity.
- We have the **experimental tools and methodologies ready** for site specific studies to commence in the UK.





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THANK YOU!

Research Support Office

Questions to the panel

Radioactive Waste Management

Ian Farnam
University of Cambridge

Becky Lunn
University of Strathclyde

Tom Scott
University of Bristol

Please post any questions into the chat.

You can message the chair, Katherine Morris, directly if preferred