



FUTURE CIRCULAR COLLIDER

FCC Subsurface Site Investigations for Areas of Geological Uncertainty

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Introduction

- Geology in the FCC Region
- Geological Studies since CDR
- Placement Considerations
- Definition of Areas of Geological Uncertainty
- Planned Subsurface Site Investigations
- Studies and Works after Subsurface Site Investigations
- Conclusions

Geology in the FCC region (i)

Main geological characteristics

Moraines (Quaternary Deposits)

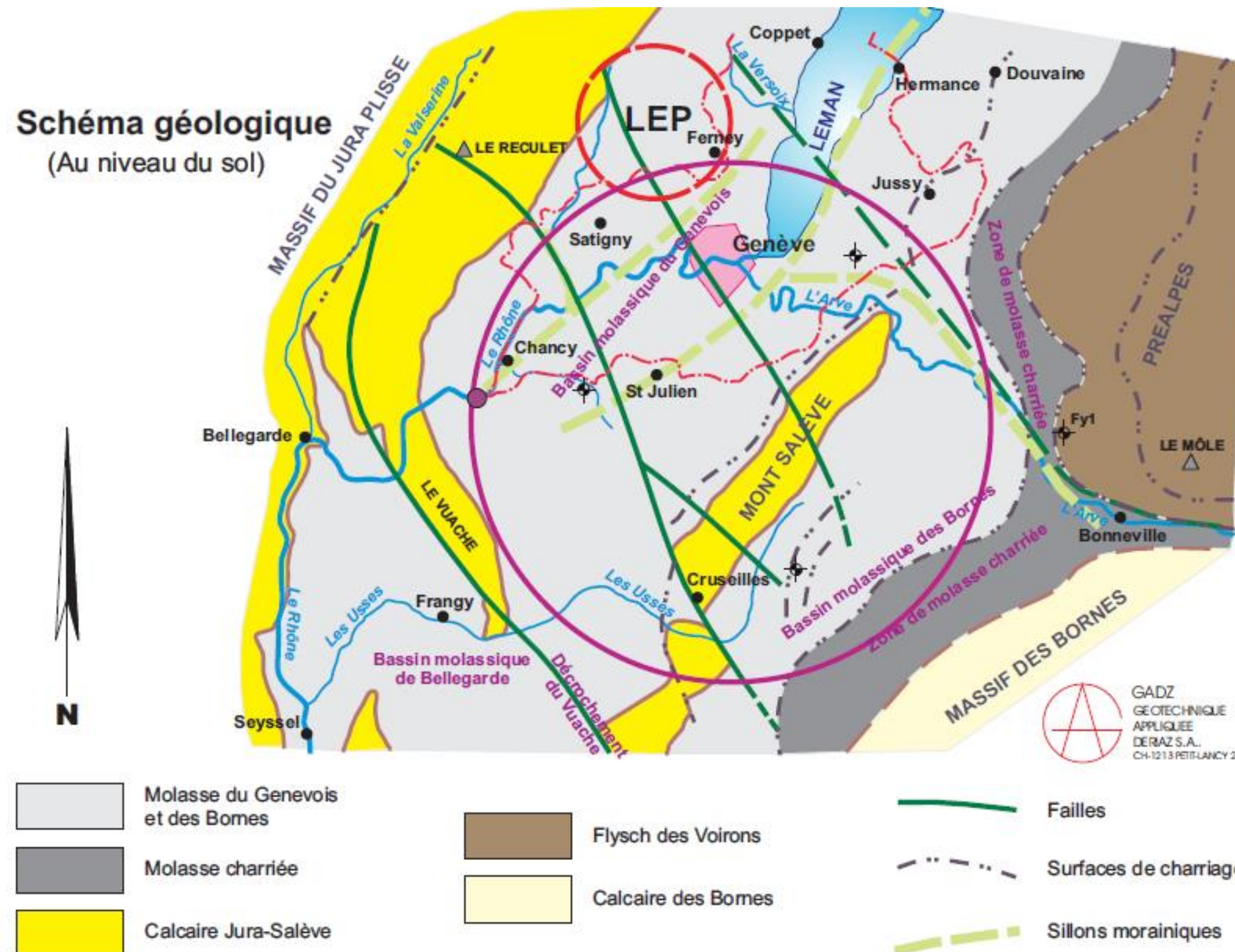
- Glacial deposits comprising gravel, sands silt and clay
- Water bearing

Molasse

- Mixture of sandstones, marls and formations of intermediate composition
- Relatively weak rock (Average compressive strength: 5.5-48 Mpa)
- Considered good excavation rock
- Relatively dry and stable
 - Faulting due to the redistribution of ground stresses

Limestone (Cretaceous)

- Hard rock
- Normally considered as good tunneling rock
- In this region fractures and karsts likely present
- High inflow rates measured during LEP construction (600L/sec)
- Clay-silt sediments in water
- Rockmass instabilities



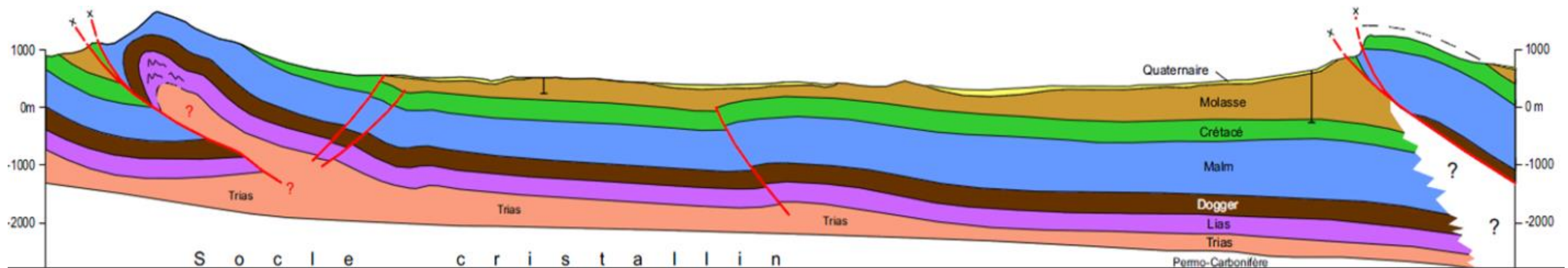
Geology in the FCC region (ii)

Moraines generally 50-150m

Molasse hosts the majority of the infrastructure

Limestone in the southern and western extents of the alignment

West-East geological section of Geneva region



Site Investigation Studies Since CDR (i)

ILF/GADZ 2020/21

Definition of 'Areas of Geological Uncertainty' for the preferred alignment scenario(s)
 Input into footprint exploration –comparison of scenarios and Geological Risks Assessment
 Initial proposals of site investigations in targeted areas to reduce the uncertainty of the geological model
 Cost estimates and schedule for target site investigation campaign
 ILF/GADZ study was focused on the construction risks for underground works



Université de Genève 2021-current

Updating 3D geological model
 Technical reporting on hydrogeological, tectonic and seismic characteristics of the Geneva region
 Data gathering of existing and new data from drilling and geophysics campaigns



Site Investigation Studies Since CDR (ii)

QUANTUM 2022-2025

Detailed analysis of 'Areas of Geological Uncertainty' for the amended alignment and updated geological models

Optimization of proposed SSI campaign scope of works

Preparation of Technical Specifications for SSI Contractor MS and IT

Cost estimates and schedule for SSI

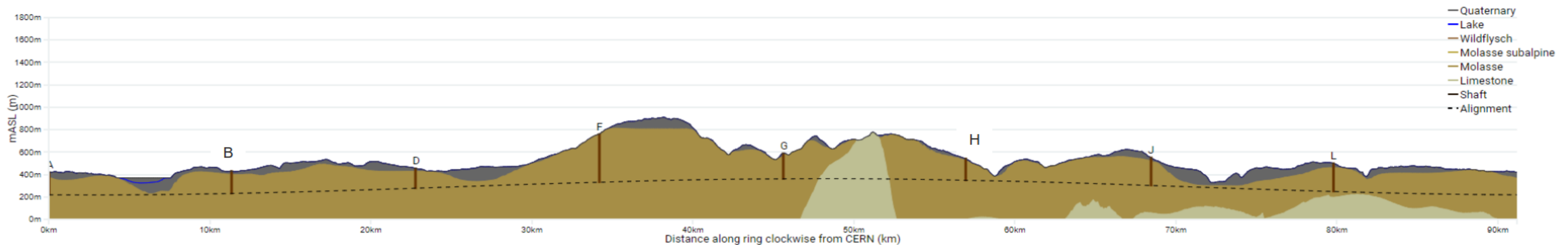
Site visits and preparation of site drawings, survey requirements and works schedules

Act in the role of Engineer during the execution of the Works



Placement Considerations

- Keep the tunnel and caverns in molasse wherever feasible
- Footprint of alignment fixed due to surface constraints
- Maintain a tilt of the alignment plane at around 0.5%
- Avoid water bearing moraines
- Avoid potentially karstic limestone wherever possible
- Keep overall depth of shafts as low as possible



Areas of Geological Uncertainty

- Good knowledge of the ground (e.g. information near to CERN from LEP/LHC projects)
- Good confidence that the tunnel alignment is in molasse

Jura

- Limestone/molasse interface uncertain.
- Risk of karts and high water pressures

Le Rhône

- Moraine/molasse interface not certain.
- Proximity to protected area

Vuache

- Limestone/molasse interface not certain.
- Risk of karts and high water pressures
- Proximity to main active fault

Les Usses

- Moraine/molasse interface not certain.
- Low tunnel rock cover

Lac Léman

- Moraine/molasse interface uncertain
- Soils and rock properties uncertain
- High uncertainty in the hydrogeological conditions and water pressure

Vallée de l'Arve

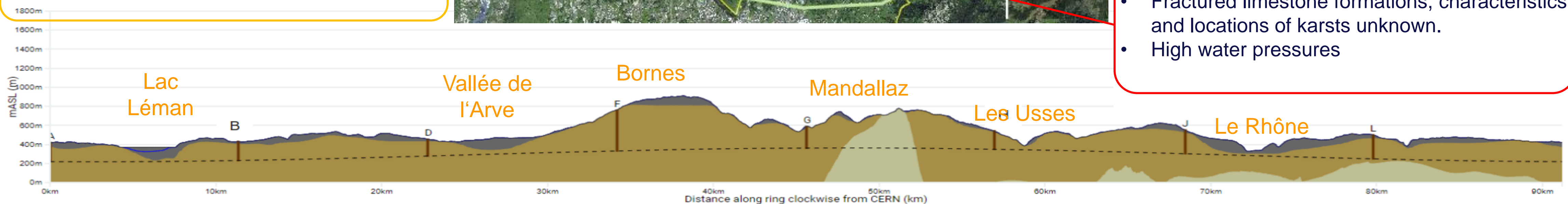
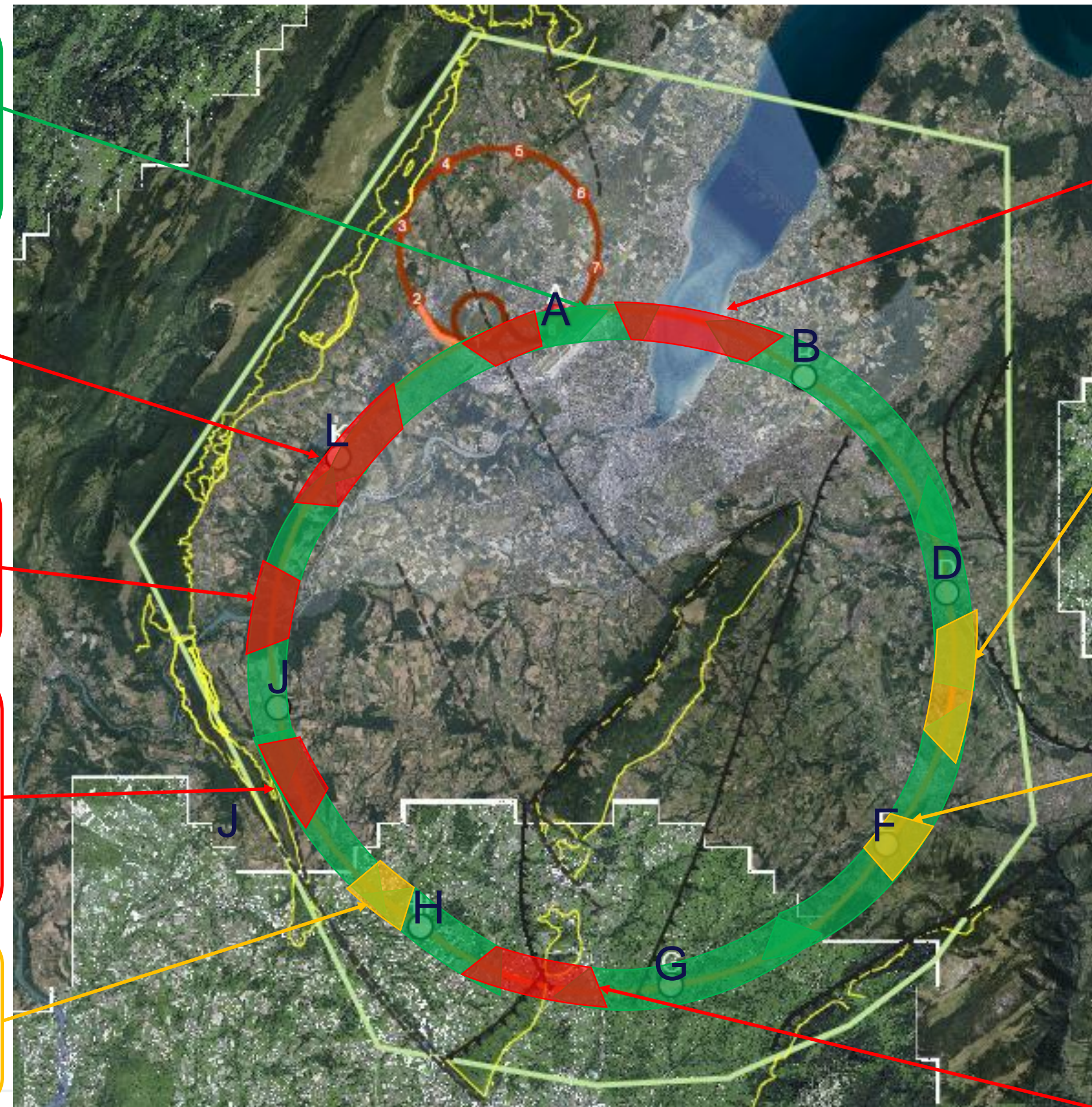
- Moraine/molasse interface uncertain.
- Lack of reliable boreholes

Bornes

- Insufficient deep boreholes information
- Complex faulted region, thrust zone.
- Quality of molasse is uncertain. High overburden. Large span experimental caverns should be constructed in good molasse.

Mandallaz

- Fractured limestone formations, characteristics and locations of karsts unknown.
- High water pressures



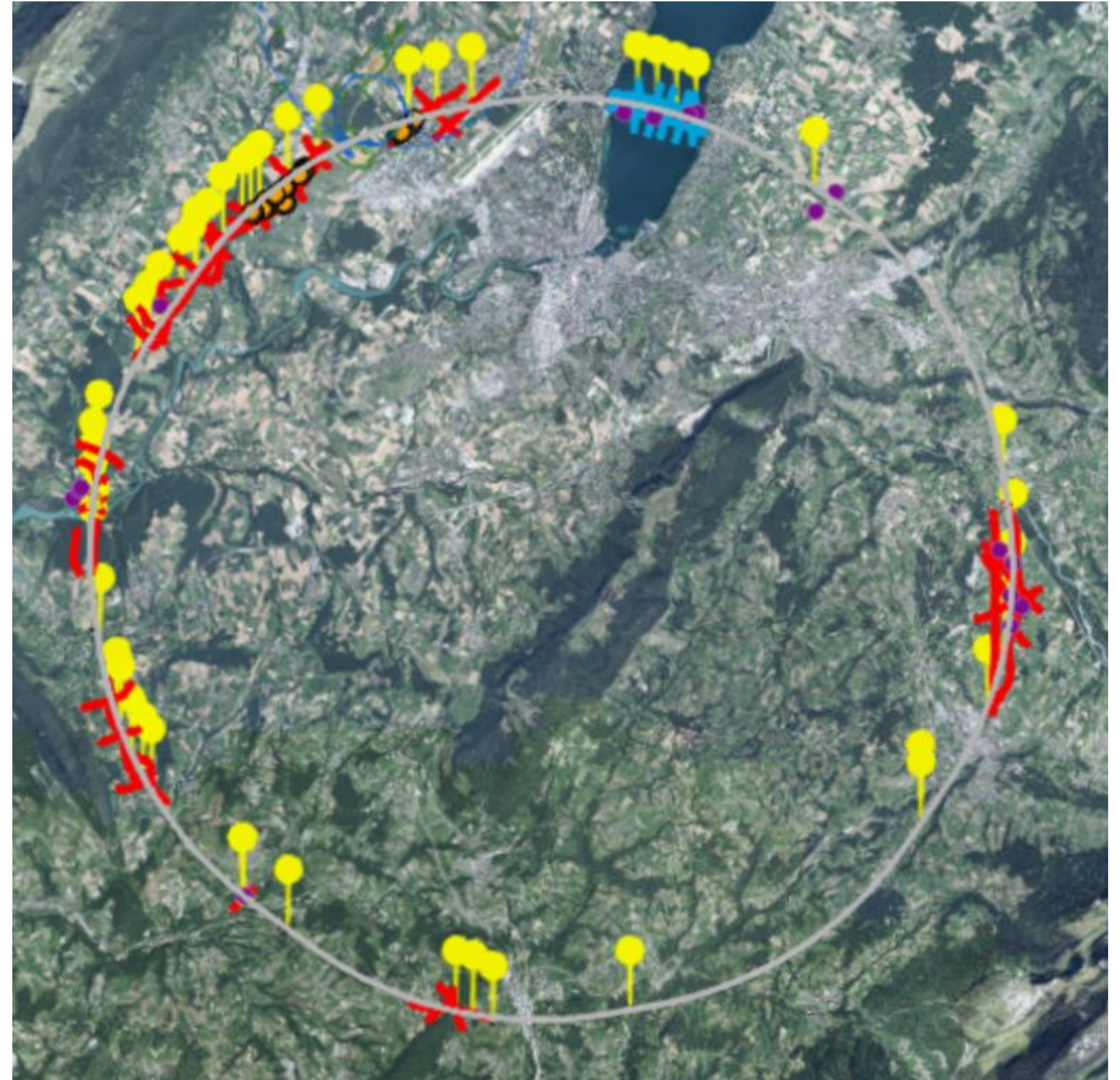
Site investigation campaign proposed

The site investigation campaign will fill in gaps in current 3D geological model and provide a better understanding of:

- The molasse-moraine interface in the area of the lake and the valleys (Arve, Rhone and Usses)
- The molasse-limestone interface and definition of karstic areas (Jura and Mandallaz)
- Vertical profiling of shafts at each point

The investigations consist of:

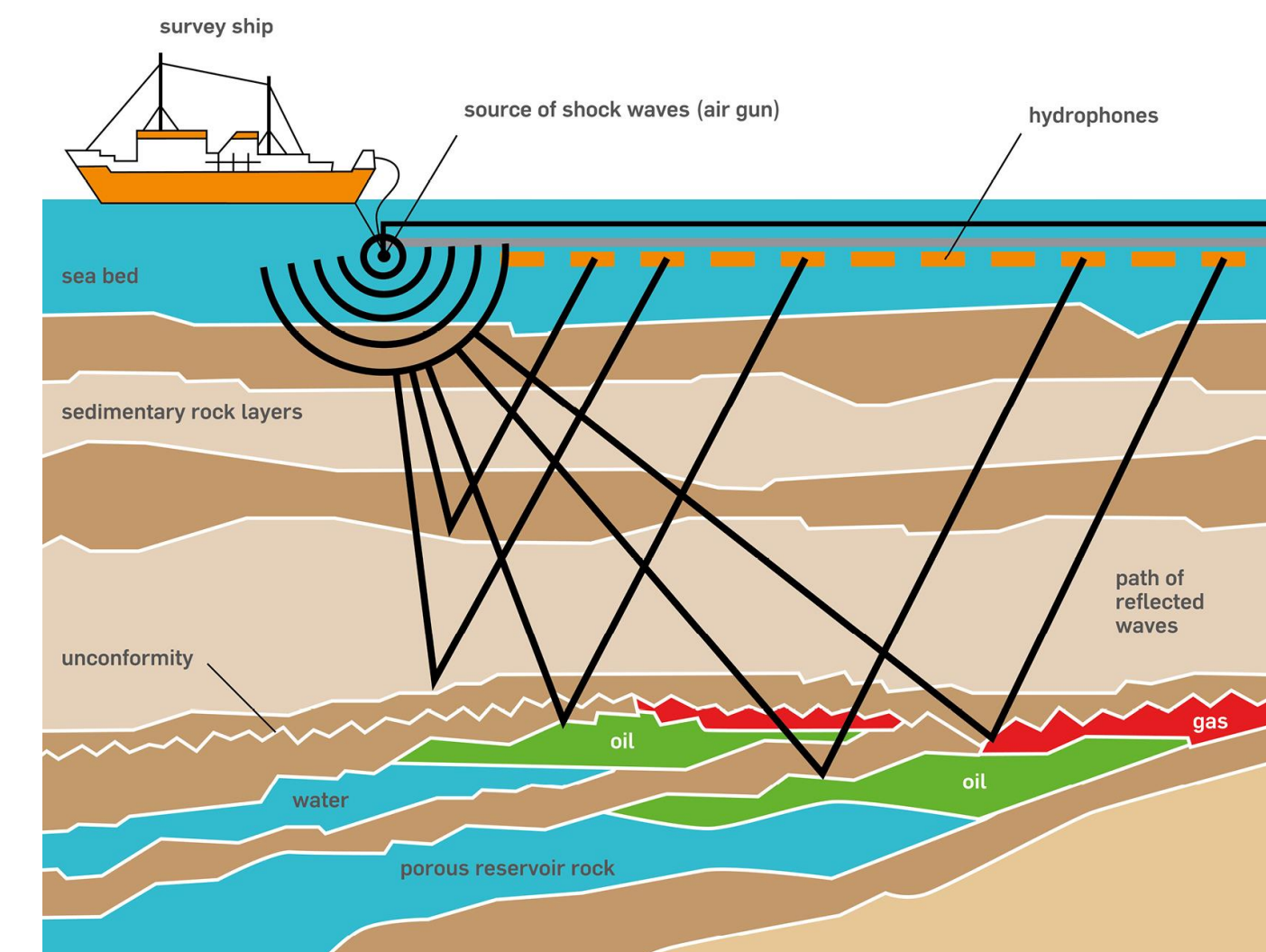
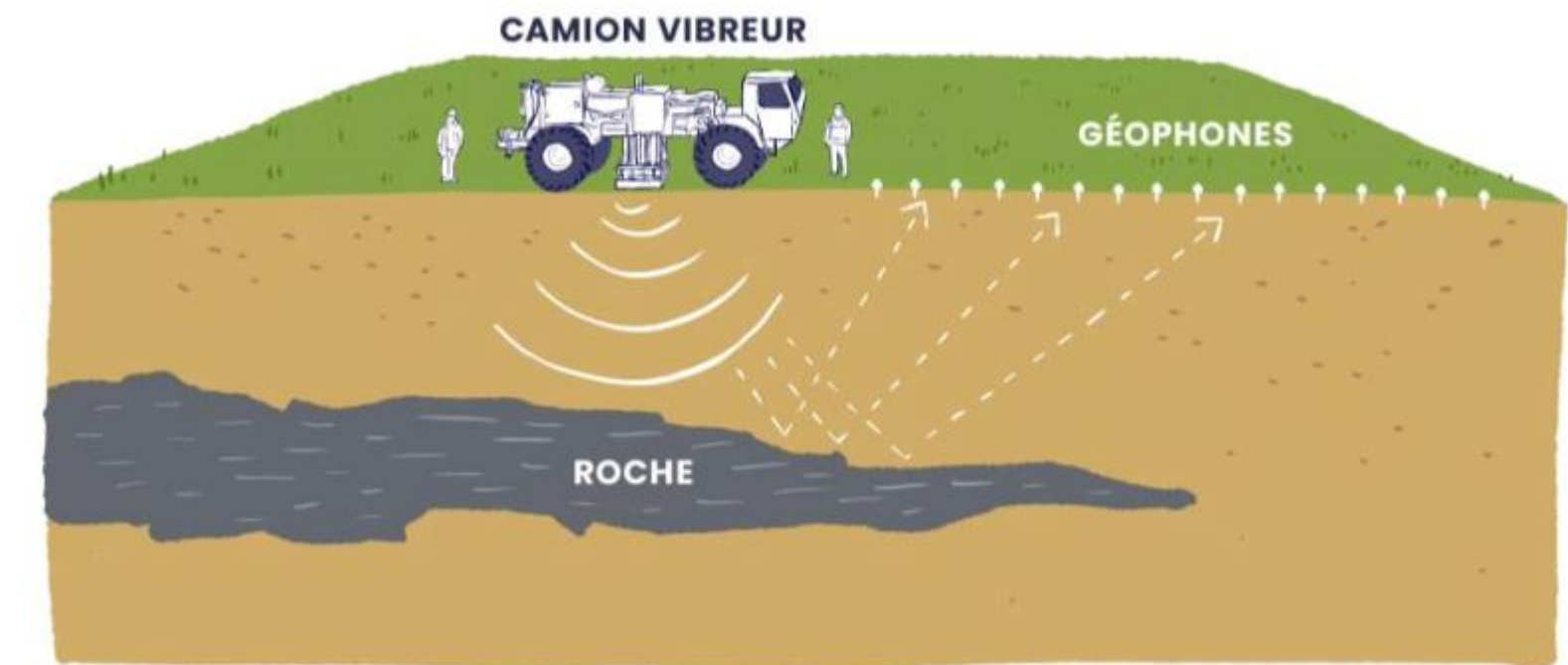
- 2D seismic geophysics
- Fully and partially cored boreholes



Types of Site Investigation: Geophysics

Use of different techniques depending on site constraints and the geological aim of the investigation:

- Seismic reflection
 - High resolution using vibratory truck (most common)
 - Very high resolution using a barrow
 - Offshore airgun for Lake Geneva
- Seismic refraction
 - Explosives or weight drop, depending on the sensitivity of the area (Usses and Rhône valleys only)
- Total of over 80km of seismic investigation

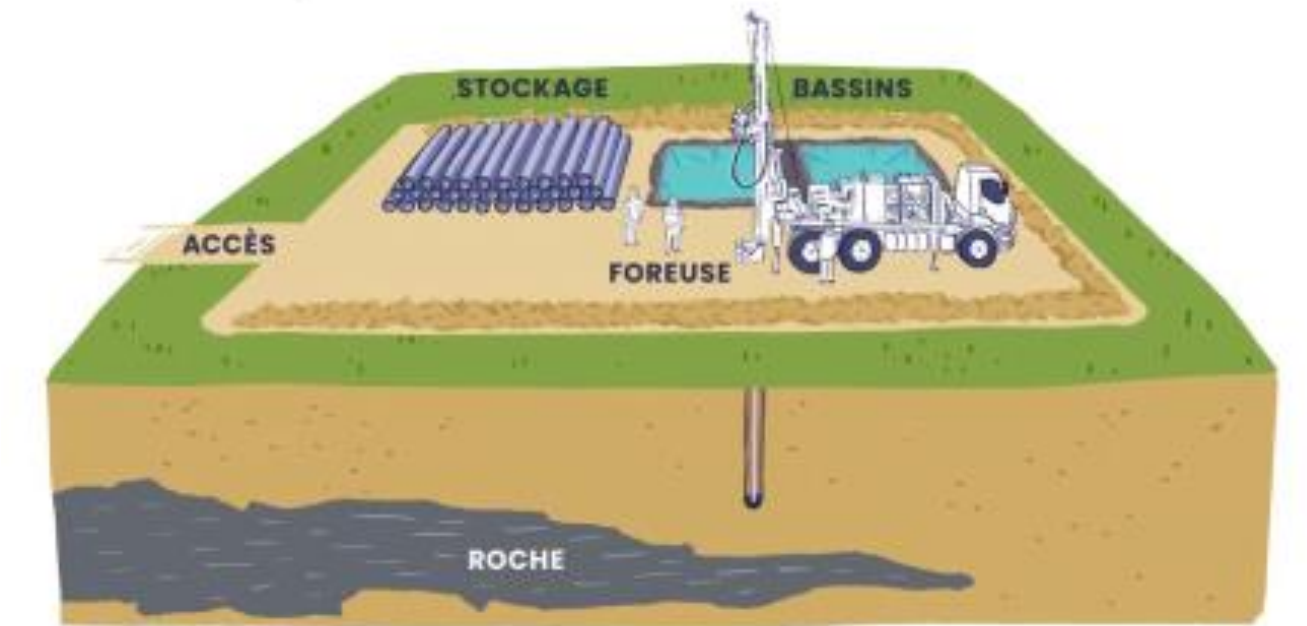


Types of Site Investigation: Boreholes

Geotechnical borehole drillings

- 48 boreholes (including 4 on Lake Geneva)
- Certain boreholes to be equipped with piezometers

Sector	Quantity	Depths (m)
Jura 1	13	230-275
Jura 2	3	240-250
Lake	4	130-185
Arve	5	185-210
Mandallaz	3	360-510
Usses	2	70-75
Vuache	5	210-295
Rhône	7	75-190



Drilling at Prevezin, CERN 2020



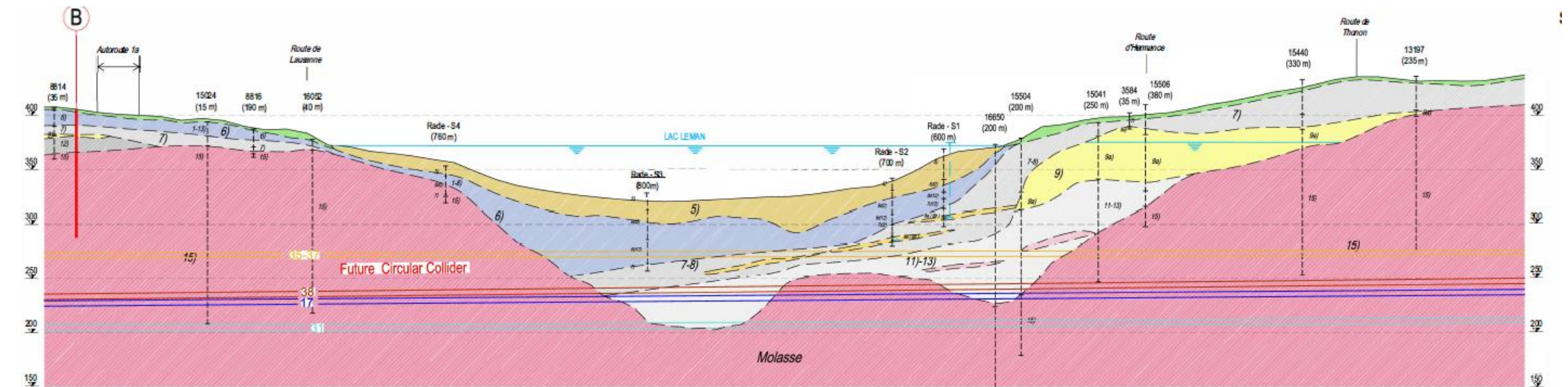
Drilling on Lake Geneva



Subsurface Investigation– Lake Geneva

Aims

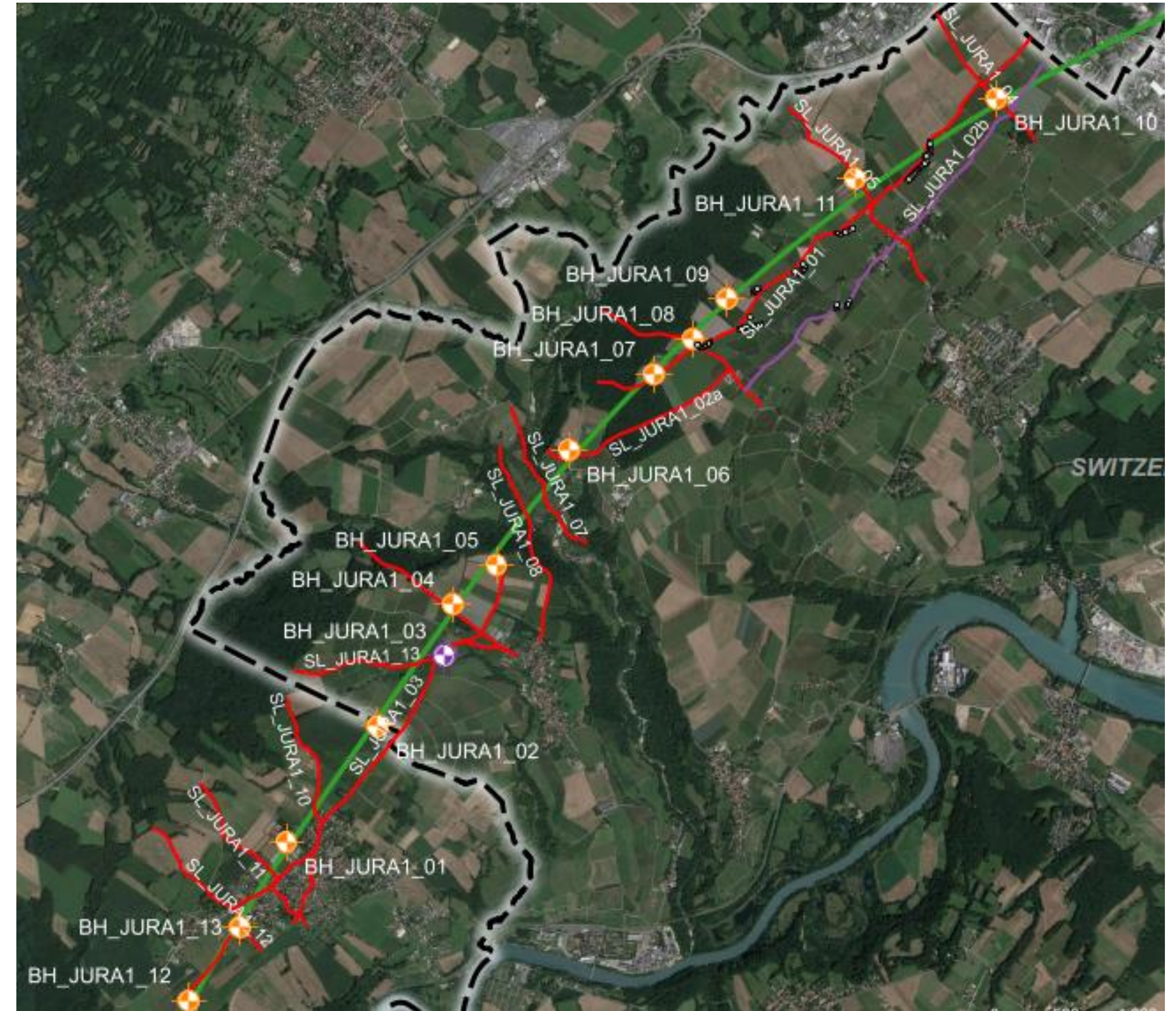
- Confirm the depth of the fluvio-glacial alluvial deposits
- Precise location of the molasse/moraine interface
- 4 boreholes
- 8 seismic lines



Subsurface Investigation– Jura 1

Aims

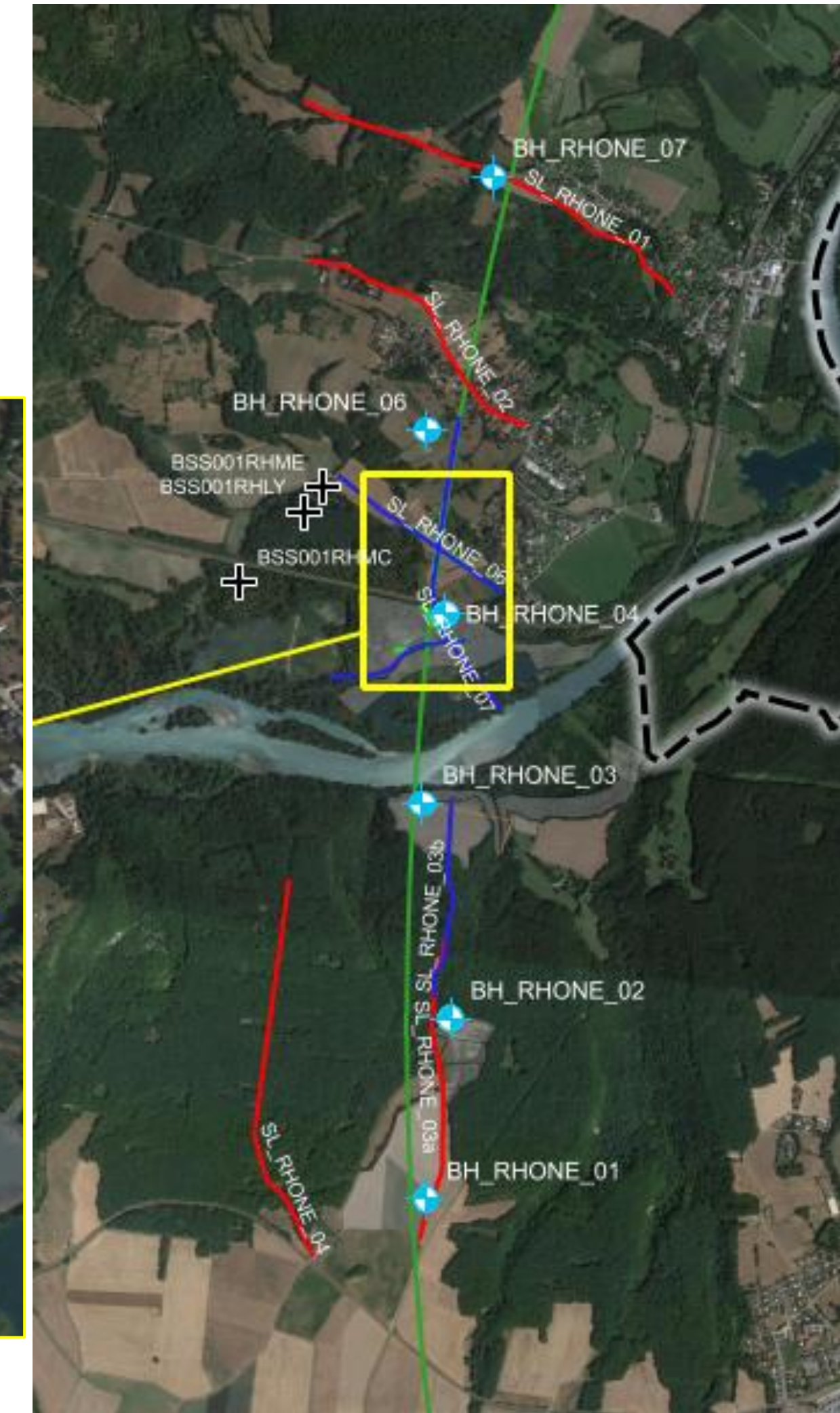
- Defining the molasse – limestone interface
- Characterise karstic features in limestone
- 13 boreholes
- 13 seismic lines



Subsurface Investigation– Rhône

Aims

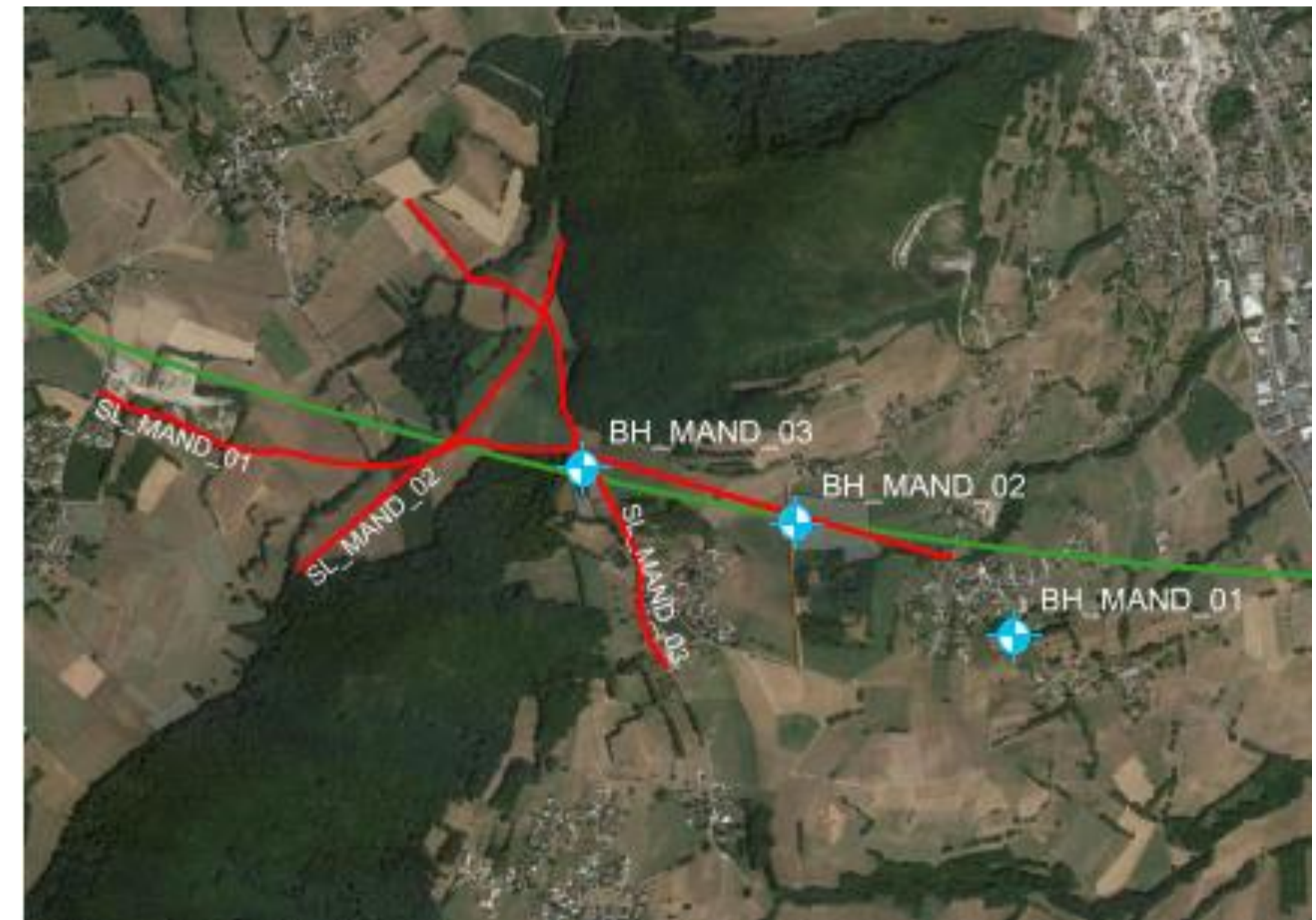
- Defining the molasse – moraine interface
- 7 boreholes
- 11 seismic lines using a mixture of techniques



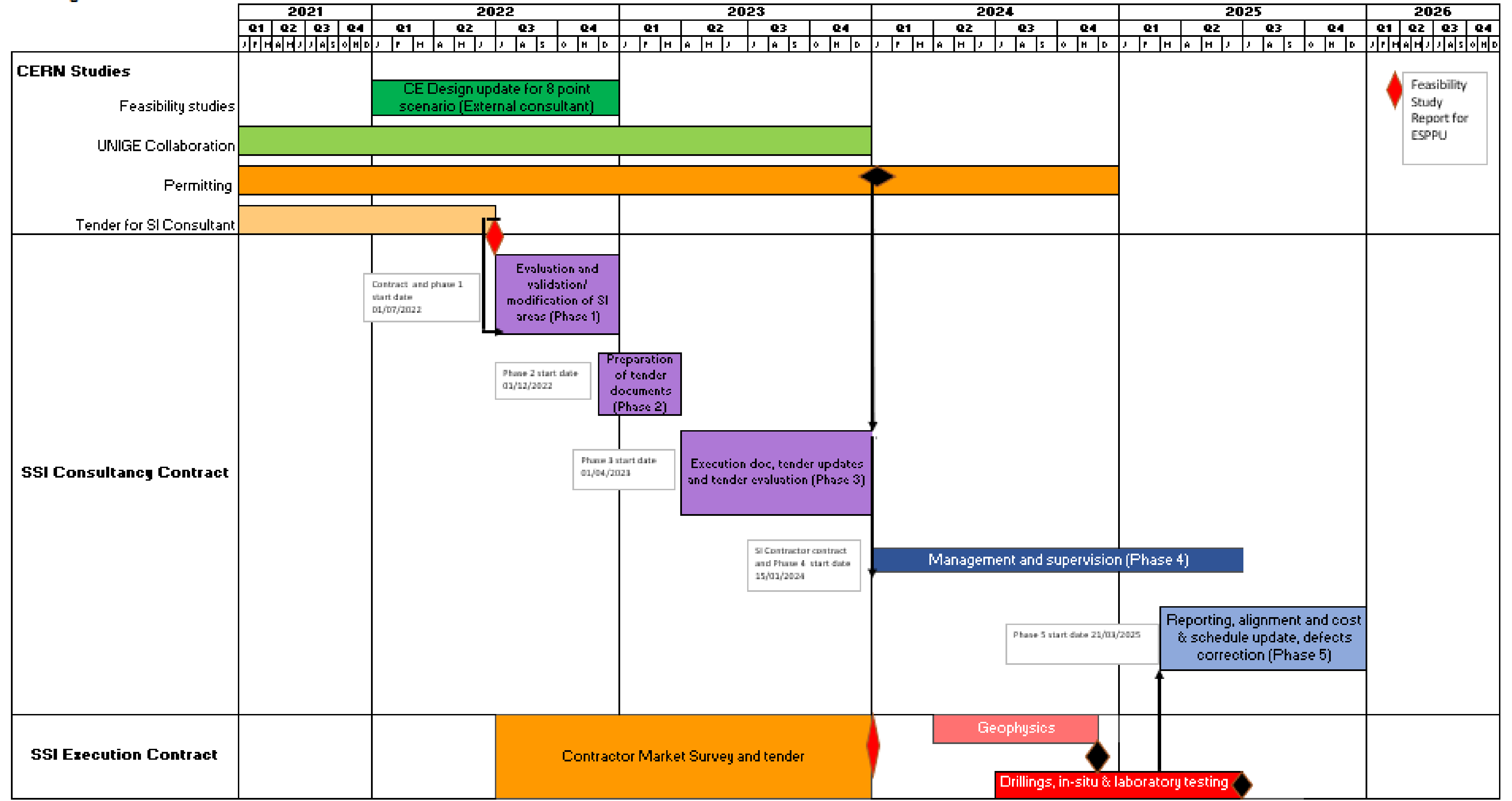
Subsurface Investigation– Mandallaz

Aims

- Characterising the limestone (which is unavoidable)
 - Understanding the extent of artesian water pressures
 - Confirming the presence of predicted thrust fault
-
- 3 fully cored boreholes
 - 3 seismic lines



SSI Programme

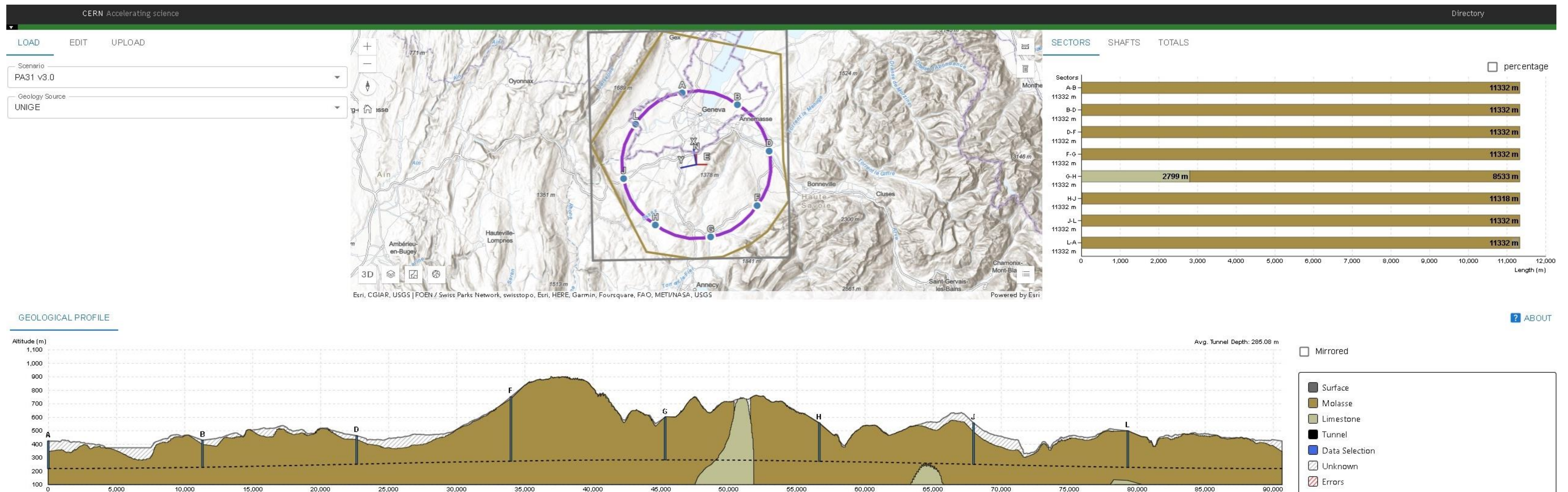


Studies and Works after Investigations(i)

Optimisation of the alignment using Geoprofiler

Change the tilt of the alignment in two axes

The depth of the overall alignment can be modified



Credit: Youri Robert, Nicolas Guilhaudin, Dominique Missiaen & Mehdi Daakir

Studies and Works after Investigations(ii)

Phase 5 Quantum Consultancy Contract

- Update of the current cost and schedule estimates before ESPPU
- Additional civil and structural design requirements

Post-feasibility Investigation Works (i)

- A more extensive campaign of ground investigations
- Geophysics and boreholes at regular intervals along the entire alignment
- Targeted additional investigations around key underground infrastructure such as caverns and shafts
- Sufficient in detail to allow for the tender of construction works packages.

Post-feasibility Investigation Works (ii)

- Additional supplementary investigations in areas where gaps still exist to be identified by design consultant
- These will allow the engineer to fully design the full scope of works

Conclusions

- Significant development of the subsurface site investigation works campaign has taken place since initial ILF/GADZ study in 2020/21
- Quantum have begun consultancy appointment and currently working on phase 3 to prepare works documentation and drawings
- Market survey for works Contractor has finished and Call for Tender due to be launched before July 2023
- Works due to commence in 2024 and last 18 months consisting of 48 boreholes and 80km+ geophysics
- Refinement of the alignment will be made using Geoprofiler in collaboration with SCE-SAM-TG team
- Update of cost and schedule estimates following site investigations before mid term review in 2025

Thanks to all collaborators

SCE-SAM-FS
SCE-SAM-TG
QUANTUM
ILF
UNIGE
GADZ