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Swiss Seismological Service

ETH zürich

Continuous measurements of radon and other dissolved gas species in groundwater: A crucial step in earthquake precursor research?

"ArtEmis" project

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ArtEmis: Awareness and Resilience Through European Multi-Sensor System



ArtEmis: Awareness and Resilience Through European Multi-Sensor System

Aims

- **European collaboration project** intended to design, build, and operate a multi-sensor system comprising of more than 100 sensors, which determine Radon (Rn) concentrations in groundwater.
- **Test if changes in radon concentrations can be used as potential precursors to earthquakes** by feeding measurement data into ML Algorithms and correlate them to seismic data

ArtEmis: Awareness and Resilience Through European Multi-Sensor System

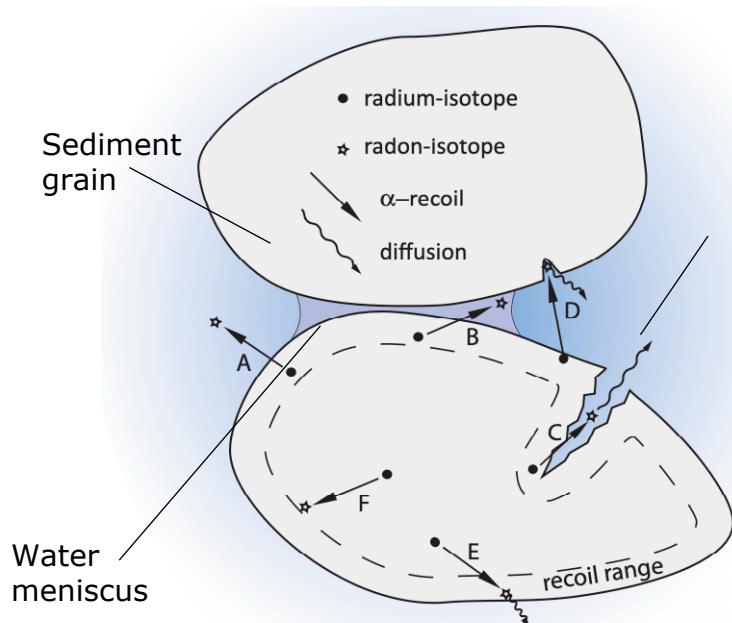
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→ **Can continuous long term measurements contribute to better earthquake forecasting?**

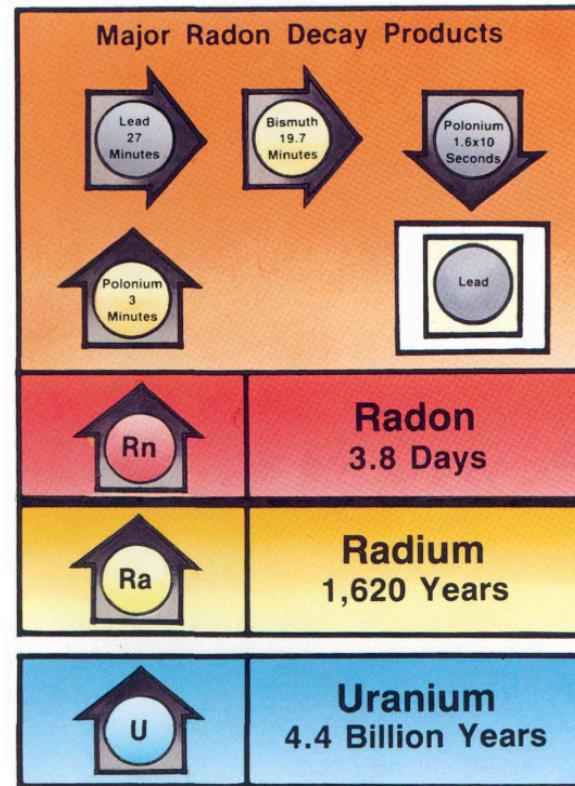
Background on Radon (Rn)

- Rn is a radioactive noble gas, decaying via alpha emission
- ^{222}Rn (half-life: 3.8d) is produced from the radioactive decay series of ^{238}U
- ^{222}Rn emanates from mineral grains



Emanation of Rn in the sediment pore space*

The decay chain of Uranium

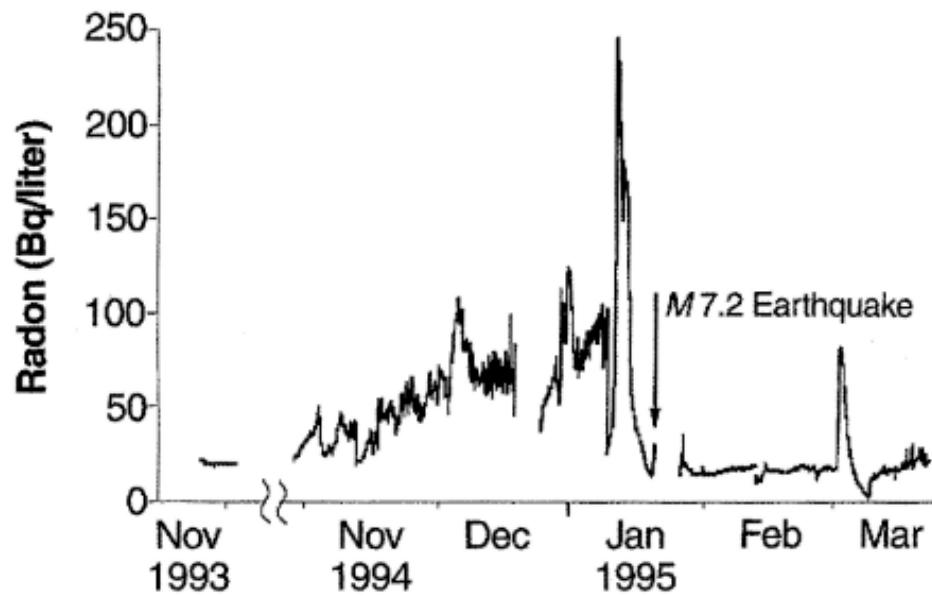


Background on Radon (Rn)

- Radon emission and variations in concentrations in air, soil air and groundwater is proposed as an earthquake precursor*.

Problems:

- Large distances between measurement sites and epicentre
- Uncertain time window
- Background variations



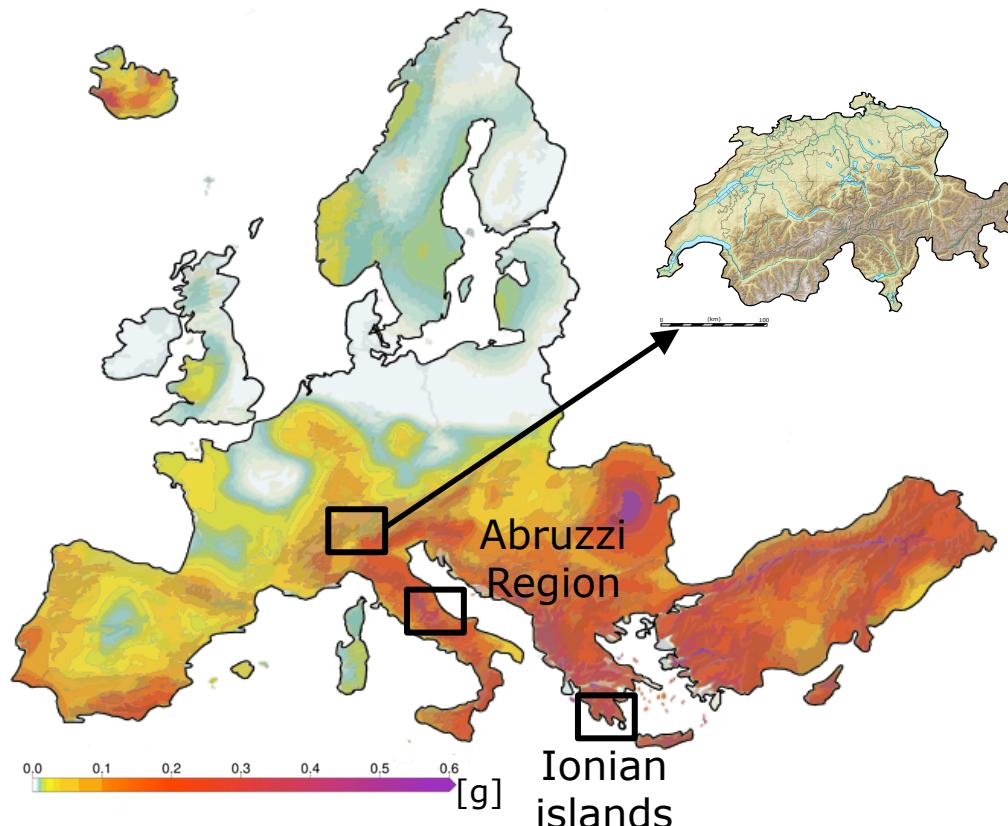
Rn anomaly in water recorded 5 days before the Izu-Oshima-kinkai EQ ($M=7.2$, Jan 17, '95; Igarashi et al., 1995)

Hypotheses:

Stress increase → larger number of cracks → increased radon emission

The larger the earthquake, the larger the radius where precursor phenomena can be observed**.

Interested Locations



Ground Acceleration Hazard Map*: Expected level of ground shaking at a specific location due to future potential earthquakes.

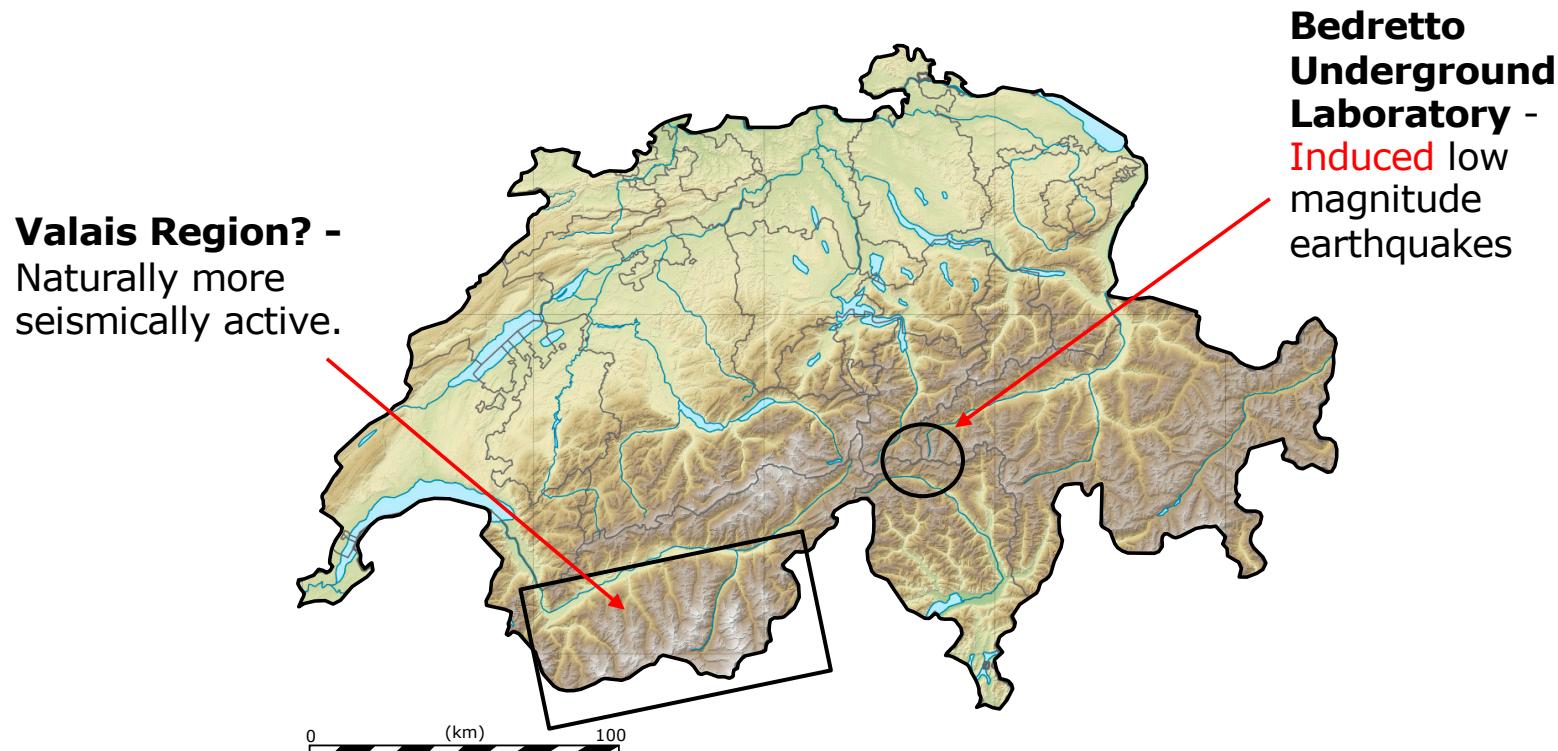
Sites

- Ionian islands and Gulf of Corinth, Greece
- Abruzzi region, Italy
- **Swiss Alps (Bedretto and Valais)**

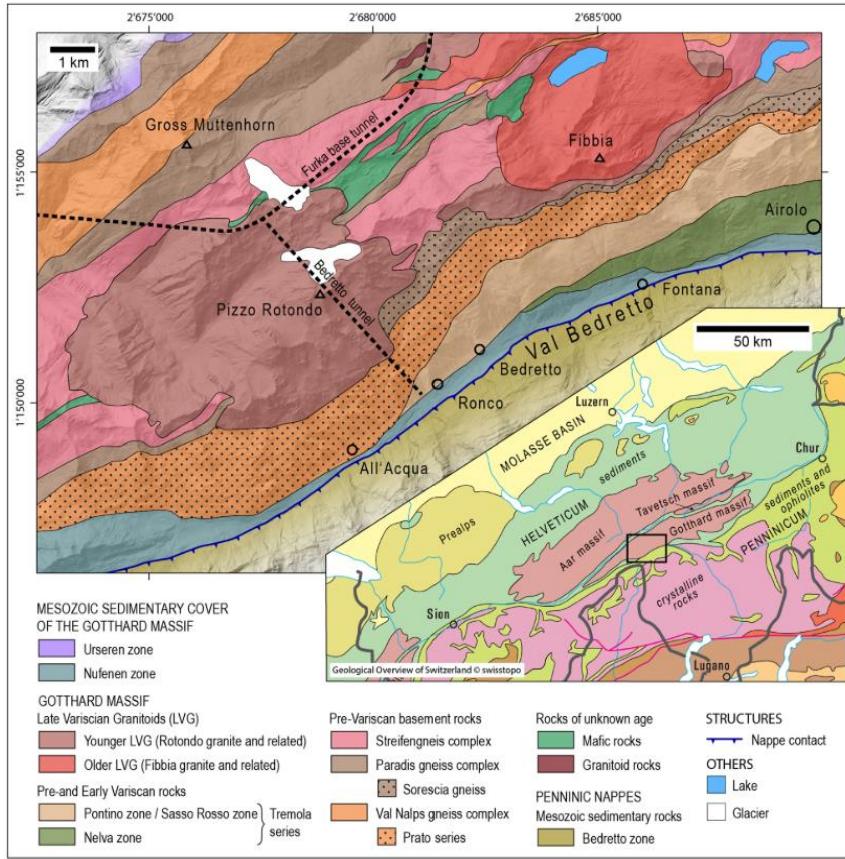
Site selection based on:

- Level of seismicity
- Different movement of the tectonic plates
- Good coverage of seismic stations
- Access to springs and wells

Interested Locations - Switzerland

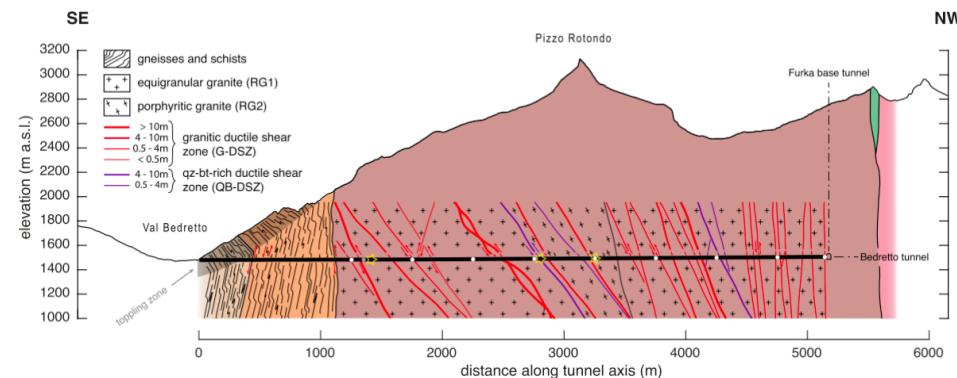


Swiss Alps – Bedretto (Ticino)



Tectonic map of the Bedretto and the Swiss Alps.

- The Bedretto tunnel is mostly located in Rotondo granite, a part of the Gotthard massif*.
- Various shear zones with thicknesses between few cm to > 10m.
- Compressional regime.
- Up to 1.5 km below surface.



Geology and shear zones along the Bedretto Tunnel.

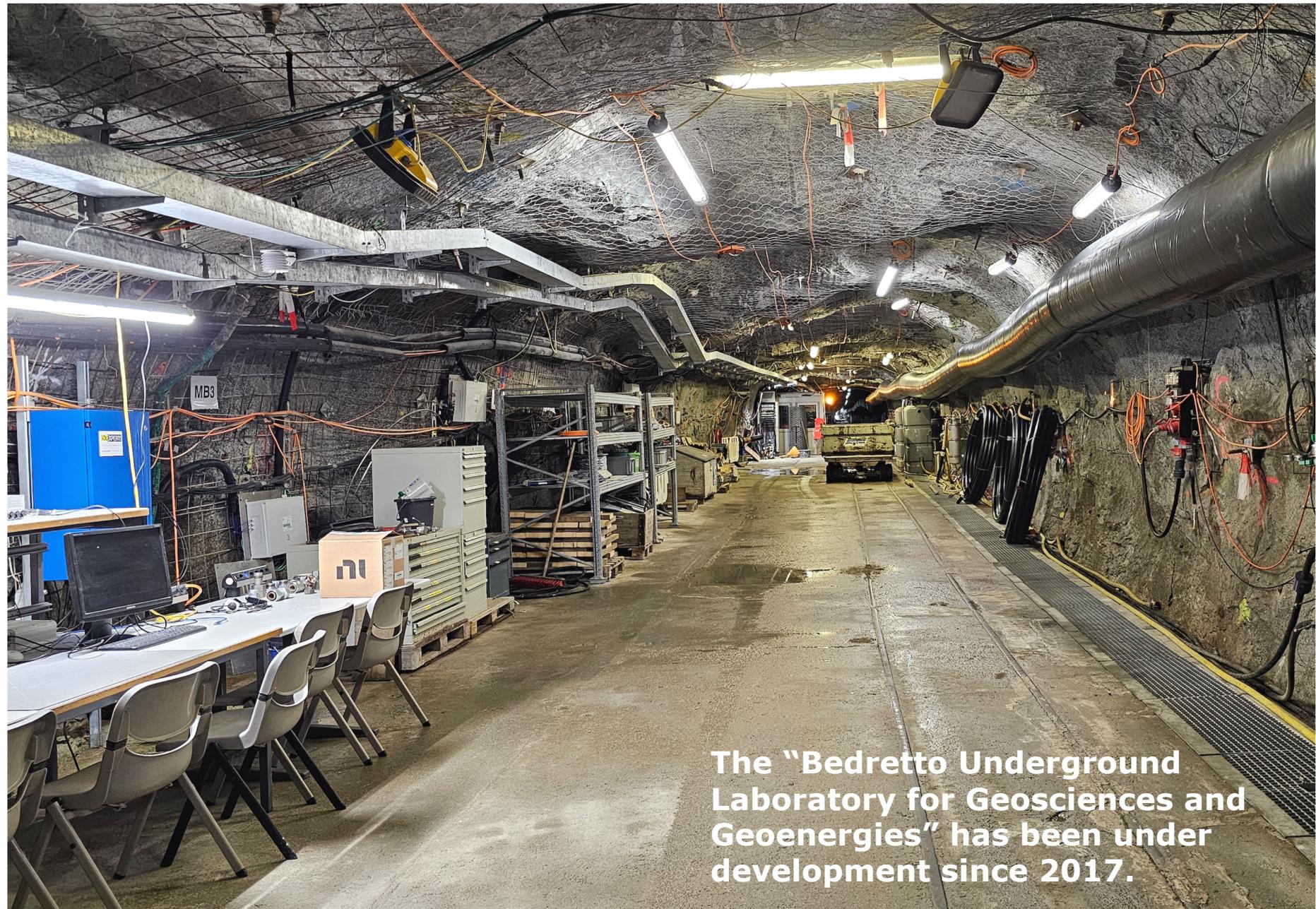
*(Rast et al., 2022)

Swiss Alps – Bedretto (Ticino)



Tunnel entrance

Tunnel was formed as an annex tunnel during the construction of the Furka Tunnel (1971 – 1982).



The “Bedretto Underground Laboratory for Geosciences and Geoenergies” has been under development since 2017.

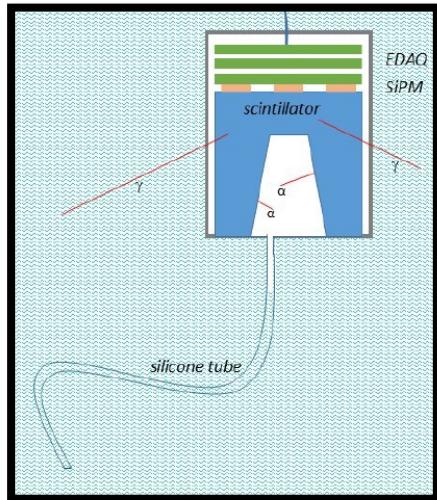
Swiss Alps – Bedretto (Ticino)



- Experiments planned with hydraulic stimulation to initiate small non-damaging earthquakes (up to M1).
- Ideal conditions for measuring Rn time series in groundwater (small temperature and pressure fluctuations).
- Outflows of water from drilled boreholes and fissures.

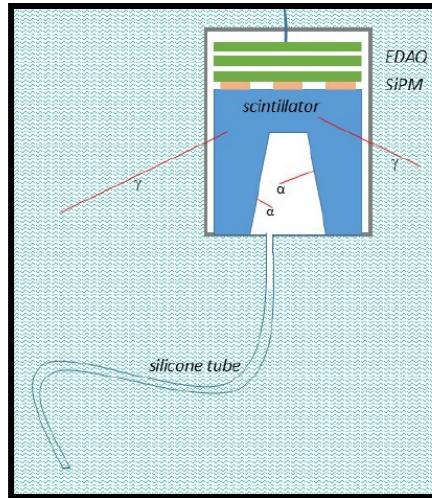
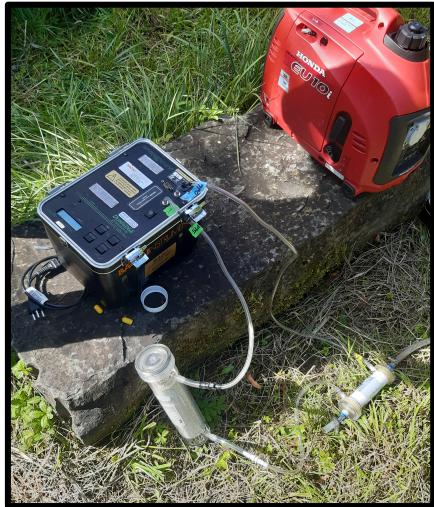
Rn sensor design

- Scintillation detector - CsI(Tl) crystal detecting γ radiation (and later additionally both α particles) from Rn decay progenies.



- Sensor additionally measures water temperature and acidity.

ST2 borehole installation/set-up



Rad8 –
commonly
employed Rn
detector

+

New ArtEmis
Rn Sensor

+

MiniRuedi

→ Correlate gas data with induced seismic stimulations in Bedretto

