Photonics for Deep Geothermal Energy Harvesting
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Electricity from deep geothermal resources in Switzerland: a challenge for 2030

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Content

- Geothermal activities at the University of Neuchâtel
- Geothermal conditions in Switzerland
- Geothermal power from hydrothermal systems
- Technology of the Enhanced Geothermal Systems (EGS)
- International situation of EGS projects
- Technology improvements needed for EGS
- Photonics and geothermal development
- Outlook

Milestones

1990 : Formation of the *Geothermal Group* of the CHYN (Dr. F.-D. Vuataz with MSc and PhD students): various studies on hydrogeology and geochemistry of deep fluids.

2004 : Founding of the *Centre for Geothermal Research - CREGE*, an association working as a competence centre. This Swiss network of 60 institutions had a core team of 5 persons based at the CHYN (President: Dr. J. Rognon; Director: Dr. F.-D. Vuataz).

2009 : Establishment of a *Chair in Geothermics* at the CHYN (Prof. Eva Schill). Since then, the CHYN is called *Centre for Hydrogeology and Geothermics*.

2010 : Creation of the *Laboratory for Geothermics – CREGE* (c/o CHYN) by merging the former CREGE team with the Geothermal Laboratory of Prof. E. Schill (10 collaborators).

Geothermal education at the University of Neuchâtel

- *Master of Science in Hydrogeology and Geothermics*
- *Certificate of advanced studies in Deep Geothermal Systems (CAS DEEGEOSYS)*

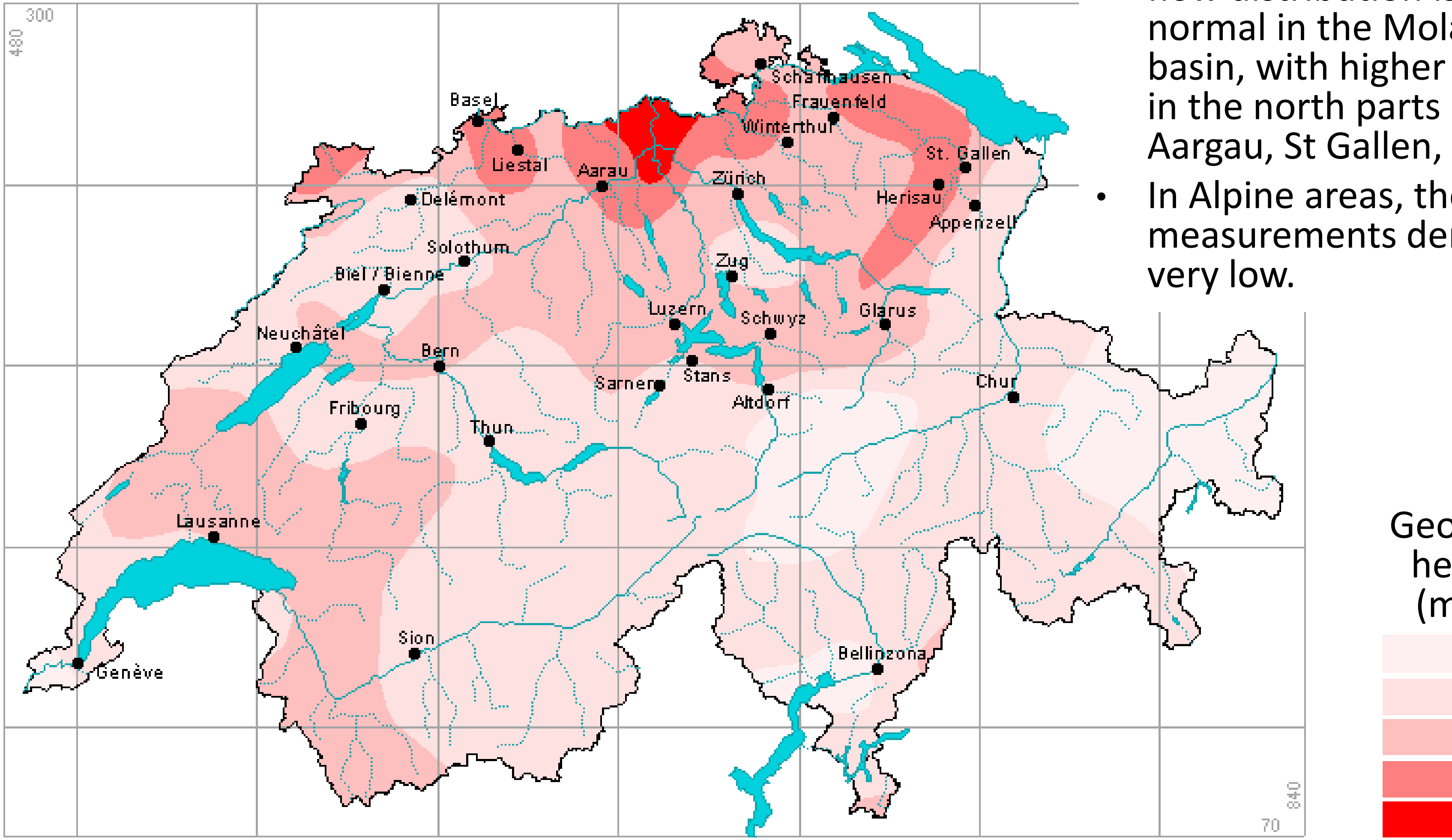
Scientific research

- Integrated 3D geology models combined with geophysical methods like gravity and cross-validation of the geological interpretation.
- Micro-gravity method to evaluate the porosity of the rocks at depth.
- Electromagnetic methods (Magnetotellurics-MT, Controlled Source Audio-frequency Magnetotellurics-CSAMT, Very Low Frequency-VLF).
- Fluid chemistry and isotopic methods.
- Modelling of coupled processes (thermal - hydraulic - chemical) to understand the resources formation and to help the reservoir management.

Applied studies on deep geothermal resources (cantons, cities, utilities, electric companies, Geo-Energie Suisse, NAGRA)

- Evaluation of regional geothermal potential and resource analysis.
- Optimisation of the resource exploitation.
- Simulation of chemical stimulation for EGS and hydrothermal systems.
- Exploration of Alpine hydrothermal systems.
- Corrosion and scaling in the installations

GEOTHERMAL CONDITIONS IN SWITZERLAND



- The Swiss geothermal heat flow distribution is quite normal in the Molasse basin, with higher values in the north parts (Basel, Aargau, St Gallen, etc.).
- In Alpine areas, the measurements density is very low.

Map of the geothermal heat flow in Switzerland (Medici & Rybach, 1995)

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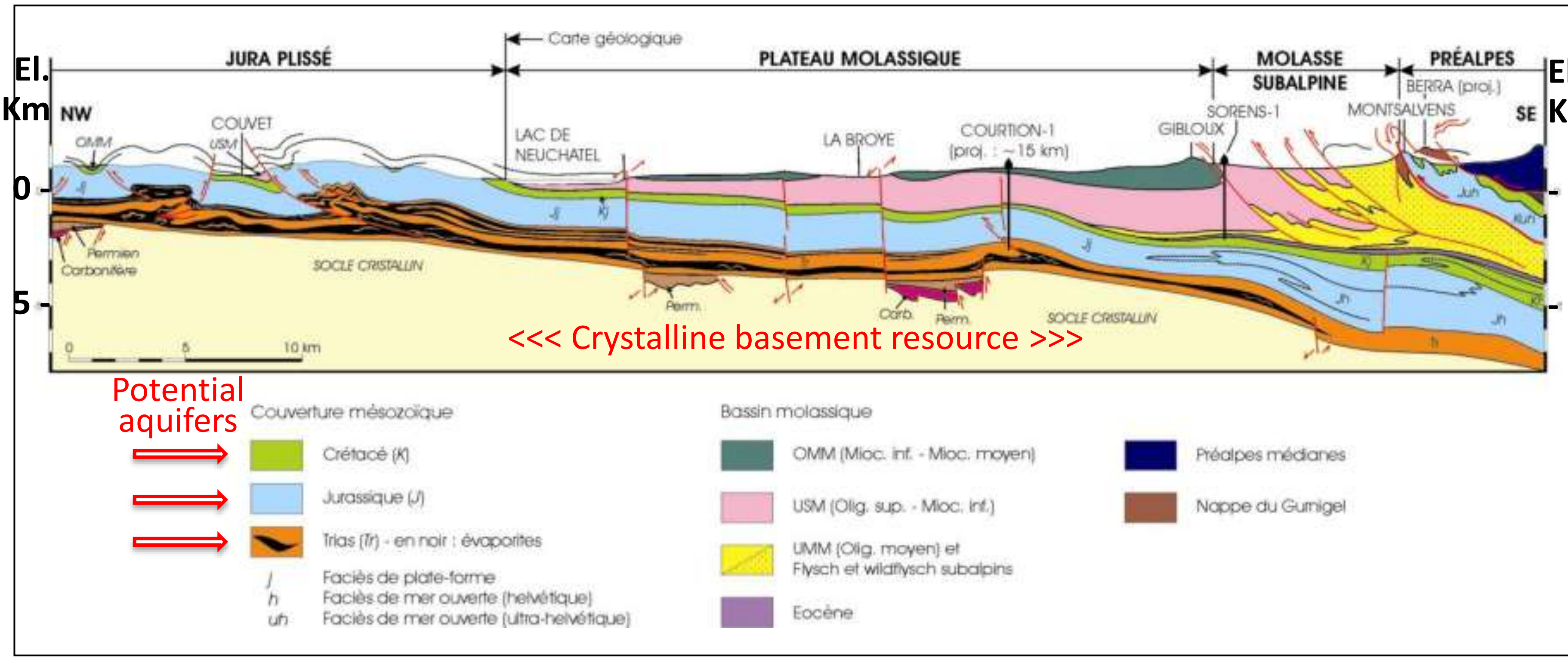
Temperatures and potential resources

- Average geothermal gradient in the Molasse Basin : 30 - 35° C km^{-1}.
- Potential geothermal resources for power production (> 100° C) : below a depth of 3 km.
- Resources: potential aquifers and stimulated geothermal systems.



NW-SE geological cross section between Jura and Prealps (PGF, 2005)

OPTIONS FOR SHORT-TERM GEOTHERMAL POWER IN SWITZERLAND

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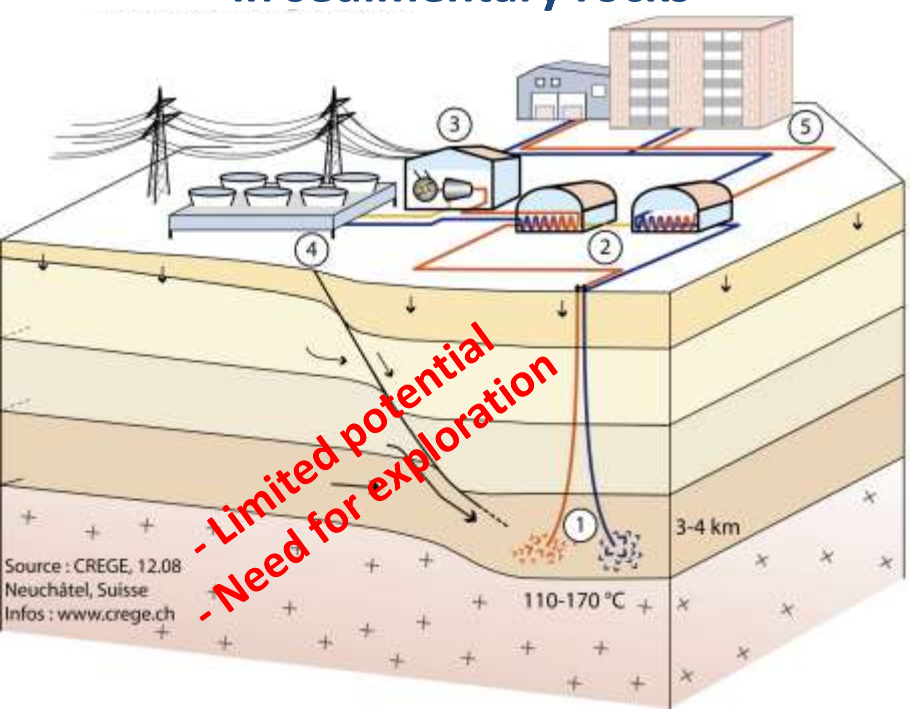
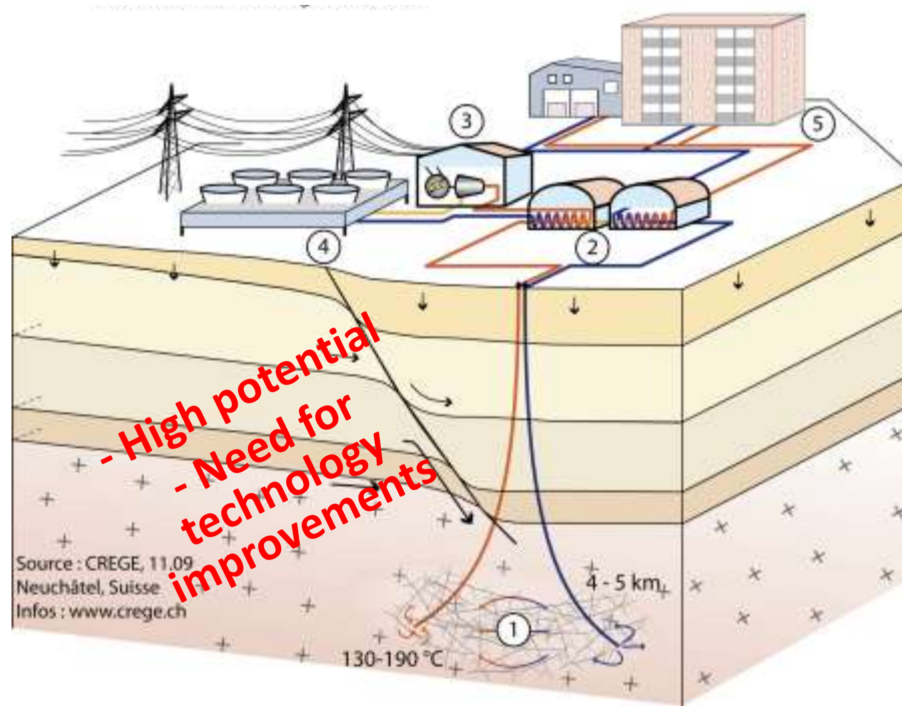
Geothermal installation for power and heat production

1. Production and injection wells.
2. Heat exchangers
3. Binary power plant: turbine and generator
4. Forced convection cooling systems
5. District heating system

Deep aquifer resources in sedimentary rocks



Enhanced Geothermal System in the crystalline basement



WORLDWIDE GEOTHERMAL POWER FROM HYDROTHERMAL SYSTEMS

Installed capacity and produced energy in 2010 for 11 countries with >100 MW el.

Country	MW el.	GWh/y	Nb. power plants
USA	3’093	16’603	209
Philippines	1’904	10’311	56
Indonesia	1’197	9’600	22
Mexico	958	7’047	37
Italy	843	5’520	33
New Zealand	628	4’055	43
Iceland	575	4’597	25
Japan	536	3’064	20
El Salvador	204	1’422	7
Kenya	167	1’430	10
Costa Rica	166	1’131	6

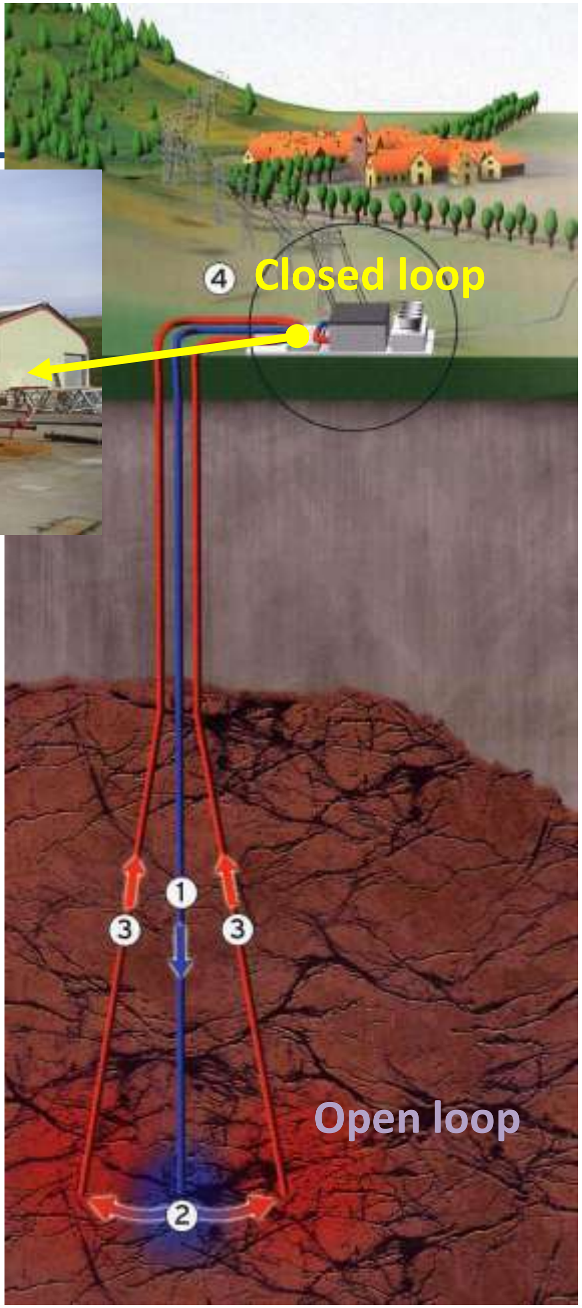
+ 13 other countries

Statistics of the geothermal power plants

- Total capacity: 11’000 MWe in 24 countries
- Total number of units: 526
- Capacity range per unit : 1 to 140 MWe
- Average capacity: 21 MWe
- Number of binary cycle plants: 236 units

Power plant in Tuscany (2x20 MWe)

TECHNOLOGY OF ENHANCED GEOTHERMAL SYSTEMS



Principles of EGS

Between 4 to 6 km depth, fractured granites reached 150 to 200° C. They all contain water, but permeability is low and a reservoir has to be created by hydraulic stimulation.

(**1**) High pressure injection of cold water in a deep hot rock enlarges existing fractures and creates a 3D heat exchanger.

(**2**) During exploitation, an open loop circulates fluid from surface to reservoir and back.

→ The surface of heat exchange is THE key parameter for an economic and sustainable energy production.

(**3**) Pumping the fluid heated at depth from production wells.

(**4**) Binary power plant: ORC turbine coupled to a generator.

International situation

Switzerland

- Deep Heat Mining Project in Basel: stopped since December 2006, following several seismic events up to M3.4 triggered by the hydraulic stimulation.
- Since 2011, the company *Geo-Energie Suisse* has started an EGS programme with a selection of best sites in the Molasse Basin.

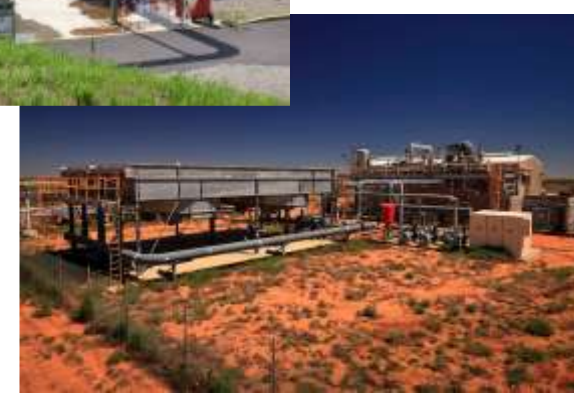
Rhine Graben

- 1st pilot plant at Soultz-sous-Forêts (Alsace)
- Small industrial plants at Landau & Insheim (D)
- More projects under way in France & Germany.

Australia

- Strong activity on EGS (> 30 companies).
- Very large potential discovered in granitic rocks.
- 1st pilot plant to be commissioned in 2013.

+ projects in Spain, GB, Norway, USA, China, …



TECHNOLOGY IMPROVEMENTS NEEDED FOR EGS

Operations	Methods, tools & conditions to improve or create
Site characterization	Geophysical methods to detect structures in the basement rocks (MT, Resistiv., Magnetics); Geological models to be adapted to EGS.
Deep drilling	Lowering drilling cost : penetration rate, new drilling methods, horizontal drilling, drilling tools, completion materials.
Well logging	High T-P logging tools; imaging tools (FMI, UBI, etc.), logging while drilling (LWD), fiber optics tools for physical and chemical param.
Reservoir stimulation	Mixed methods of hydraulic + chemical stimulation; proppants in fractures; decrease of induced seismicity; high T-P packers; limitation and control of induced seismicity.
Hydraulic tests	Smart tracers; long-term down-hole monitoring tools.
Well production pumps	Lifetime of ESP and LSP pumps (> 2 yr @> 300 m, > 150°C, > 50 ls^{-1})
Reservoir life-time	Geochemical methods to avoid plugging of the fractures.
Reservoir management	Monitoring, modelling of T-H-M-C processes; soft stimulation.
Commercial scale	Multiple directional drilling from same well pad. Increase reservoir volume and production flow (power plants from < 5 to > 25 MWe).

Examples of projects in innovative drilling, logging and monitoring

Stimulation with innovative fluid-placement methodology, production logging with fiber optic (FO) with a coiled tubing (Schlumberger)

- A new system enabling real-time and conventional temperature monitoring during acid stimulation of a reservoir using a specific coil tubing in which a FO cable is inserted.

Long-term temperature monitoring by fiber optic at Soultz EGS project (GTC)

- A FO cable was installed in the 2.2 km EPS-1 well at Soultz to measure temperature from 2006 to 2011. Important drift observed, but new solution found to compensate.

Projects of new drilling techniques for geothermal wells

- Since the 1980's, Sandia Laboratories did some research for geothermal drilling with DOE funds, and tried to investigate various technologies: jet-assisted, thermal-assisted, mud hammer, thermal spallation, spark drill, explosive, rock melters, pulsed-laser water-jet.
- Recently, Potter Drilling Co. (USA) manages a 7.5 million US$ project, trying to build and demonstrate a working prototype hydrothermal spallation drilling unit in the lab and on the field.
- Institute of Process Engineering (ETH-Z): on-going research on thermal spallation.
- + new results presented during this workshop.

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Conditions for significant development of geothermal power in Switzerland

- If geothermal power should be part of the Swiss energy mix in 2050 → **EGS technology** should turn soon from pilot to industrial phases.
- Temperature-depth relation: 150 to 200 ° C at 4.5 to 5.5 km.
- Reservoirs: mostly granitic rocks to be fractured for creation of a heat exchanger.
- Power plants:
  - ✓ 2014-2020: 2-3 pilot plants of 1-3 MWe (1 production well);
  - ✓ 2020-2030: 2-3 industrial plants of 20 MWe (7-8 production wells).
- Swiss EGS potential is high, but development has been slow, due to limited means up to now: **50** MWe for 2030 and **250** MWe until 2050 (OFEN/BFE, 2012).

Main progresses required for the EGS technology

- Drilling: lowering the costs and increasing the availability.
- Stimulation: placed and quantitative reservoir; control of induced seismicity.
- High T-P logging tools; robust production pumps; sustainable reservoir management.

Photonics technology can help the development deep geothermal resources

- Innovative drilling technology.
- Development of logging tools in high T-P environments.
- Equipment for long-term monitoring of reservoir and wells.

Thank you for your attention !

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