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# DOWNHOLE GEOPHYSICAL MONITORING FOR SHALLOW GEOTHERMAL OPERATIONS SAFETY, EFFICIENCY AND ACCEPTANCE

Ressources et usages du sous-sol dans la transition énergétique, Paris, 27-28 septembre 2022

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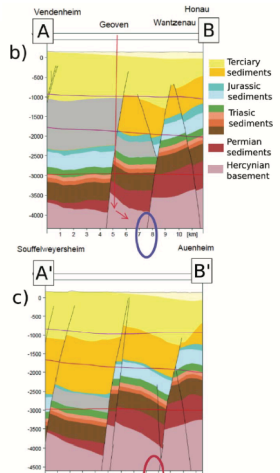
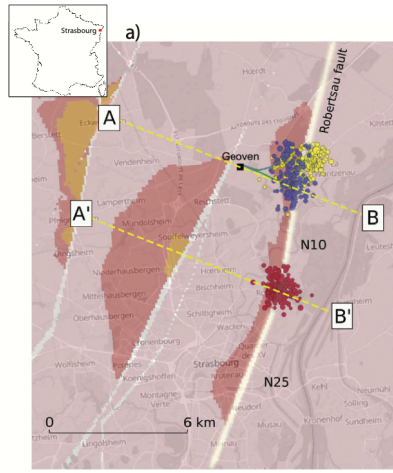
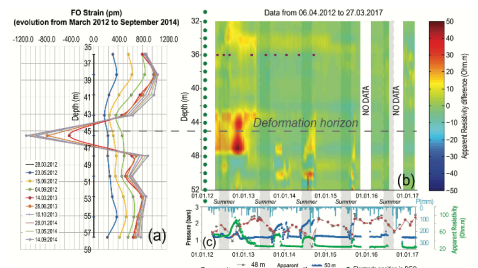
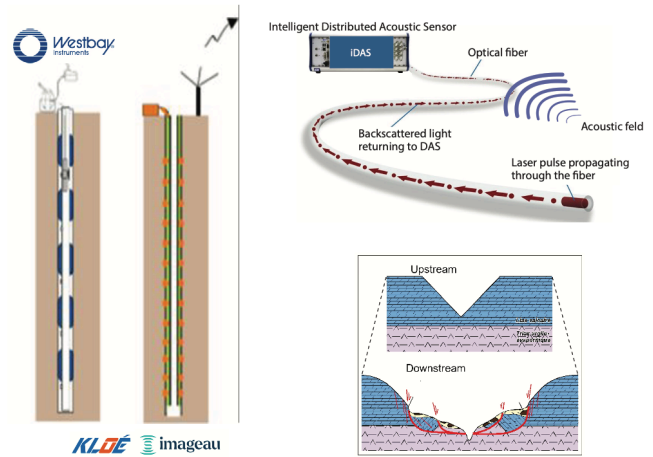
## Abstract

Geothermal exploitation is generally considered to be an environmentally friendly way of generating electricity in the context of the energy transition. However, subsurface drilling bears the environmental negative footprint of oil and gas exploration for more than a century. More recently, further difficulties associated with drilling were encountered with shale gas exploration, which lead to a ban of fracking and shale gas exploitation in numerous European countries (France, Germany, Denmark, Italy, Ireland, ...). Nowadays, CO<sub>2</sub> geological storage aimed at reducing the greenhouse gas effect is gradually being confronted to the same issue.

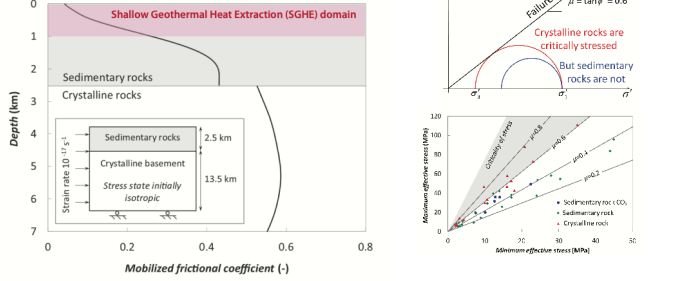
While reaching to less than a km, shallow geothermal heat extraction (SGHE) might consequently be facing the risk to be viewed as negative by the general public and the media for a series of reasons either justified from a scientific, technical or environmental point of view, or sometimes not at all. After the Basel earthquake in 2006, and the more recent ones in Alsace, both associated with deep geothermal project (at about 5 km depth), the latter appears as one of the main societal bottle neck in terms of public acceptance. In both cases, the induced seismic activity led to an operational shutdown, which actually extended for more than 10 years in the first case and spread all over Europe.

Fluid injection under pressure deep within the Earth crust often induces earthquakes (Zoback and Gorelick, 2012), as observed in Basel (2006) and Alsace (2019 and 2020). Vilarrasa and Carrera (2015) however argue that fluid injection is unlikely to trigger felt induced earthquakes because near surface sedimentary formations, which are softer than crystalline basement in the deeper crust, are less likely to be critically stressed by tectonic forces. Also, Vilarrasa and Carrera show that the least stable situation occurs at the beginning of injection, which makes it easier to control. There is consequently a need to design a coordinated injection strategy to minimized the societal impact of drilling and injection.

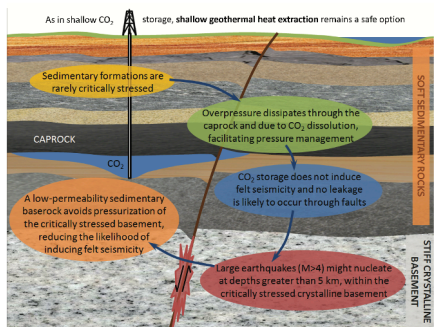
The operational success of shallow geothermal injection consequently implies both the set-up and modeling of fit-to-project injection strategies, and a real-time monitoring of downhole operations from surface and downhole with hydrogeophysical probes. The later necessarily includes temperature and pressure, but also a detailed follow up of seismic activity induced by subsurface fluid circulation. In particular, the surface monitoring should start long before injection operations to provide a record of natural ambient seismicity using commercial optical fibers. In short, to progress towards a safer, more reliable, integrative and cost-effective CO<sub>2</sub> storage management, priorities for R&D have been identified in recent reviews, ranging from sustained injectivity, large scale storage capacity and monitoring of the entire process at all scales in space and time.



There is a similarity between geothermal heat extraction and CO<sub>2</sub> storage in which, in both case, energy is being injected into the Earth crust. As advocated by G&Z (2012), this additional energy necessarily leads to earthquakes due to crustal weaknesses at depth, CO<sub>2</sub> storage at large scale appears impossible to them. This reasoning is directly applicable to deep geothermal heat extraction. To the contrary, V&C (2015) claim that CO<sub>2</sub> storage is possible at shallow depth and in sedimentary basins, which conversely applies to shallow heat extraction.



Multi-physics downhole observatories (MDPO) are progressively being deployed in several domains of subsurface geosciences, including CO<sub>2</sub> sequestration (Pezard et al., 2016), gas storage in general, salt-water intrusion in coastal aquifers (Petelet-Giraud et al., 2016; Folch et al., 2020) and slope instabilities monitoring (Denchik et al. (2019)). With the uprise of DAS monitoring, a possibility to monitor induced seismicity from downhole and surface spreads is now offered both in a very effective manner and at a reasonable cost. As a consequence, MDPO's provide a means to operate downhole geothermal heat extraction in real time, hence to minimise the tectonic impact while maximizing the energetic efficiency. Besides, the combined monitoring in a single hole, possibly the injection hole itself, is reducing the operational costs, improving the overall safety of the subsurface set-up and leading data integration scenarii serving as a base for real-time heat extraction management.



## Conclusion

As for CO<sub>2</sub> geological storage, and in spite of the repeated failure of deep geothermal projects at depth, and a general resentment for drilling operation across disciplines, the acceptability of safe geothermal heat extraction (SGHE) for stake holders, local authorities and the general public can be largely improved by real-time monitoring associated on that basis with appropriate injection management procedures. While SGHE monitoring methods are now within reach, the feasibility of long-term safe operations still remains to be demonstrated.

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