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News

Fundamental Research

Renewable energies Geothermal energy Hydrogen Energy storage

Geochemistry

In the context of the energy transition, it is vital to study underground biogeochemical cycles given the pivotal role they play in H_2 storage, geothermal energy, the extraction of critical metals and CO_2 burial. Resident microbial communities have a significant influence on these environments, modifying permeability, for example, and rendering geothermal energy, gas storage and other such operations complex. Their metabolic activity can also cause damage, notably by corroding infrastructure and producing hydrogen sulfide.

Intense biogeochemical activity in the underground environment

Numerous research questions relating to the biogeochemical cycles governing the workings of the underground environment are now of fundamental importance in the context of the energy transition. From H2 storage to geothermal energy production, from the extraction of critical materials to CO2 burial, the underground carries with it some crucial challenges for our short- and medium-term future.

It is now acknowledged that **subsurface environments can be greatly influenced by resident** (prokaryotic) **microbial communities** [1]. In particular, the presence of bacteria and archaea[1] organized in biofilms alters **the permeability of the porous medium**, hindering the operation of many applications, such as geothermal energy and geological gas storage [2]. Other studies indicate that 80% of injection wells in aquifers display **clogging problems** associated with bubble formation, suspended particles, microbial biofilm growth and induced mineral precipitation [3, 4]. In addition, the metabolic activity of bacteria and archaea present in the underground environment can **consume and/or produce gases** [5], thereby altering reservoir rocks [6] and, consequently, sometimes leading to major operational complications such as **infrastructure corrosion, clogging of injection sites** [7] and **hydrogen sulfide production** in gas storage facilities [8].

[1] Single-celled microorganisms that are genetically distinct from bacteria

Impact of mineralogy and temperature on hydrogen consumption by subsoil microbial communities

For example, initial IFPEN research described in the source below focused on assessing **the influence of mineralogy and temperature on hydrogen consumption by microbial communities** typically found underground (methanogenic archaea, sulfate-reducing and homoacetogenic bacteria[2]). The research highlighted the importance of taking mineralogy and temperature into account **when assessing potential underground hydrogen storage** (UHS) **reservoirs**, as they can have a significant impact on indigenous microbial populations and their consumption dynamics with respect to this molecule. For example, the presence of gypsum favors sulfate reduction over methanogenesis and homoacetogenesis, especially at low temperatures, whereas methanogenesis is dominant at 34 and 40°C in the absence of sulfate (see Figure). At 25°C, homoacetogenic bacteria are favored over methanogenic archaea, and acetate production varies depending on the mineralogy of the rocks present. This suggests **interactions between the microbial community and rocks, which can serve as substrates for biofilm formation**. These metabolic changes are associated with radical shifts in microbial populations, highlighting the fact that ecosystem plasticity with respect to hydrogen also depends on the mineralogical composition of the reservoir.

[2] Bacteria that use hydrogen and carbon dioxide to produce acetate

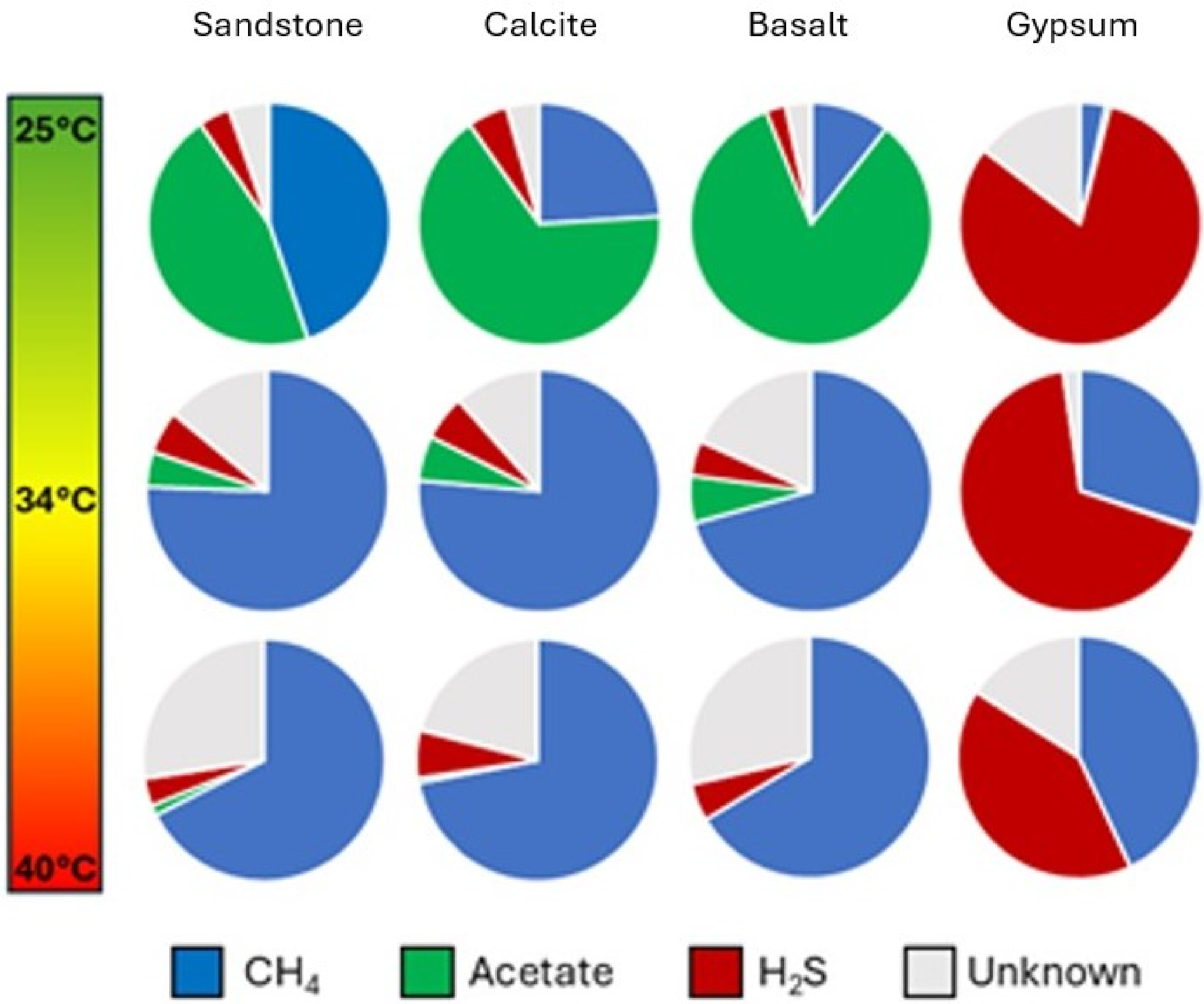

Figure: Influence of temperature and mineralogy on the proportions of hydrogen (in %) converted by various metabolic processes

Experimental data for use in future modeling research

To further advance this research, IFPEN teams are carrying out a project aimed at developing multidisciplinary methodological approaches in order to gain a better understanding of **the biogeochemical cycles** at work underground and in the facilities operating there. New experimental set-ups are being developed, ranging from micromodels to coreflood[3] via high-pressure reactors and calorimetry, to study **biofilm dynamics and microbial and geochemical reactivity in porous media**, at various scales and under conditions representative of the underground environment (temperature, pressure, flow). The data generated from this set of experiments will then be fed into modeling tools in order to improve the prediction of reactive phenomena in the underground environments studied.
Pour aller plus loin, les équipes d'IFPEN conduisent un projet visant à développer des approches méthodologiques multidisciplinaires pour mieux comprendre **les cycles biogéochimiques** ayant lieu dans les sous-sols et les installations qui y sont opérées. De nouveaux dispositifs expérimentaux sont développés, allant du micromodèle au coreflood[3] en passant par les réacteurs haute pression et la calorimétrie, afin d'étudier **la dynamique des biofilms et la réactivité microbienne et géochimique dans des milieux poreux**, à différentes échelles et dans des conditions représentatives du sous-sol

(température, pression, écoulement). Les données générées à partir de cet ensemble d'expérimentations alimenteront ensuite des outils de modélisation permettant d'améliorer la prédiction des phénomènes réactifs dans les environnements souterrains étudiés.

[3] Experimental set-up for injecting a fluid or combination of fluids through a rock sample

Source:

Muller, E., Guélard, J., Sissmann, O., Tafit, A., & Poirier, S. (2024). Evidencing the influence of temperature and mineralogy on microbial competition for hydrogen consumption: Implications for underground hydrogen storage (UHS). International Journal of Hydrogen Energy, 82, 1101-1113.
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