The Rayleigh-Taylor instability and its impact on CO_2 mixing in saline aquifers

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Overview:

This project will involve developing numerical models to study the Rayleigh-Taylor instability in porous media and methods to upscale it. It would suit anyone who has or is willing to learn a scientific computing and fluid dynamics background.

More background

One way to mitigate anthropogenic climate change due to carbon oxide emissions into the atmosphere is to store the CO_2 in underground saline aquifers rather than release it into the atmosphere. The expectation is that the CO_2 will then remain trapped underground for millennia, similar to the way that hydrocarbons have been trapped in underground reservoirs.

After the CO_2 is injected it will begin to dissolve into the upper part of the saline water of the aquifer. This is a relatively slow process but it reduces the mobility of the CO_2 and thus increases the storage security. As the CO_2 saturated brine is denser than the unsaturated brine it will want to sink through the aquifer towards the bottom. This leads to an instability, known as the Rayleigh Taylor instability, which results in the dense CO_2 saturated water forming fingers that descend downwards into the brine, increasing the rate of mixing of CO_2 int the water (see Figure 1, e.g. Riaz et al., 2006; Neufeld et al., 2010).

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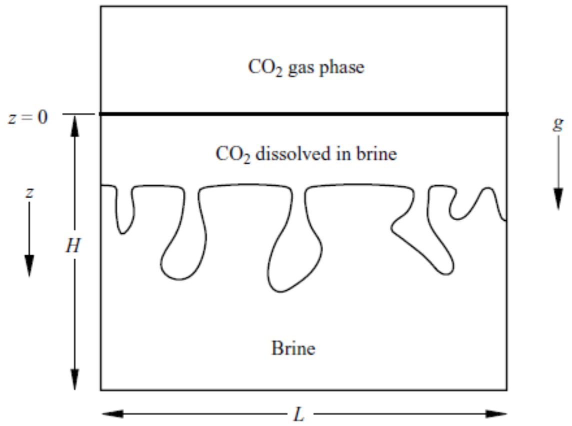

FIGURE 1. Sketch of the CO_2 sequestration process in a simple geometry. A CO_2 gas phase accumulates along the impermeable top boundary. It slowly dissolves into the underlying brine, forming a heavier boundary layer. The resulting gravitational instability leads to the convective transport of CO_2-saturated brine plumes.

Figure 1: After Riaz et al. (2006).

Numerical flow simulation is typically used by reservoir engineers to estimate the likely performance of alternative development plans for CO_2 storage. One aspect of this performance is storage security including how quickly the CO_2 will dissolve into the aquifer. The problem is that the Rayleigh Taylor instability depends on the mass diffusion as well as the reservoir rock properties. This makes the numerical modelling of the Rayleigh instability challenging because very fine grids are needed to ensure that physical diffusion dominates over numerical diffusion.

The student will be working with an existing research code in C++, increasing its functionality and applying it to the modelling of the Rayleigh-Taylor instability. If interested they could also complement this research with mathematical analysis and applied reservoir simulation using commercial simulation software. There may also be an opportunity to undertake complementary beadpack experiments using a beadpack or Hele-Shaw cell

Research Environment: The researcher will be based within the Subsurface CO_2 Research Group https://www.imperial.ac.uk/subsurface-co2/ We are a diverse group of individuals with background in geology, geochemistry, reservoir engineering, environmental engineering, applied mathematics, and numerical modelling. Researchers from the group have gone on to highly successful careers in academia, industry (CO_2 storage and otherwise), consulting, law, finance, and government. The researcher will be supported to participate in international conferences and encouraged to participate in internships and secondments as per their professional interests.

References

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