Inverse modelling techniques to distinguish between different mechanisms of reservoir fluid migration to shallow aquifers

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Groundwater conservation and protection requires robust analytical techniques to identify unintended contamination from industrial activities. Surface and reservoir hydrocarbon fluids can potentially leak into shallow aquifers during production of conventional and unconventional systems. Concerns also exist about the leakage of fugitive fluids during subsurface fluid injection, such as enhanced oil recovery (EOR) and CO_2 sequestration. Noble gases are conservative tracers, unaffected by chemical processes, and are particularly powerful tools for tracing fluid miration in the subsurface.

Reservoir fluids may be introduced into the groundwater system by direct leakage from faulty wells, migration through reactivated or newly induced fractures in the stratigraphy or seepage into the water table from surface spillage. Importantly, hydrocarbon compounds and elevated CO_2 levels may also naturally occur in the groundwater due to microbial activity or tectonically driven migration. Recent studies have improved our understanding of noble gas signatures in unconventional petroleum systems [1], EOR sites [2] and CO_2 storage sites [3]. This allows us to construct a framework for modelling fluid comunication between surface, shallow and deep reservoirs.

Here we consider a variety of migration mechanisms, including simple mixing, diffusion and phase partitioning under open and closed system scenarios, taking into account fluid migration in a multiphase system and the extent to which dilution with groundwater overprints original noble gas signatures. We introduce an inverse modelling technique [e.g. 4] which allows us to statistically interogate the incursion of deep fluids into the shallow groundwater system. We test whether this approach provides a means to distinguish between various leakage scenarios, and the extent to which deep fluids can be definitively identified from background noble gas signatures in shallow groundwater.

[1] Byrne et al., 2018, GCA, 241. 240–254.
[2] Barry et al., 2018, EPSL, 496. 57–67.
[3] Györe et al., 2017, Appl. Geochem., 78. 116–12.
[4] Ballentine and Hall 1999, GCA 63, 2315-2336.