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The impact of sedimentary basin architecture and gas phase formation on the transport of helium

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Helium is a crucial resource with various industrial, medical and scientific applications, but it faces a global supply crisis. However, helium reservoirs to date have only been discovered fortuitously. Recent advances have focused on addressing this critical gap. Combining observations and numerical modelling has enabled us to better understand mechanisms and rates of helium transport from the source rock to potential reservoir rocks and its distribution in the subsurface. Specifically, unique sampling campaigns in the Williston Basin, Canada [1], the Paradox Basin, USA [2], and the Southwest Ontario Basin have acquired helium samples from multiple units in the sedimentary basins, mapping vertical helium distribution. Helium concentrations higher than in-situ production are observed and can be explained by a diffusive transport of basement helium flux. Numerical modelling suggests constant helium loss to the atmosphere. However, tight sedimentary units (salt and shale) can allow efficient helium retention in all underlying units.

Nitrogen (N_2) is co-observed with helium in many wells and can provide a viable gas generation pathway in ancient intracratonic basins [4]. Once N_2 concentrations exceed its solubility, a separate gas phase forms into which, helium preferentially partitions from the groundwater, forming a distinct N_2-^4He reservoir, as observed in the Williston Basin [4]. The formed gas pool acts as a temporary repository of helium, reducing the diffusion-driven cross-formational transport of helium to shallower sedimentary units. The study suggests that this process can significantly re-distribute the helium budget in the subsurface. Therefore, the effect of gas phase formation is a critical component to consider in helium resource exploration strategies.

These studies lead to a more in-depth understanding of helium transport and distribution in sedimentary basins and demonstrate the significance of basin architecture, deposition timing, and freshwater recharge. These advances in understanding migration and accumulation are essential for strategic helium exploration strategies. Similar principles can be applied to other subsurface primary gases, e.g., unlocking the exploration potential of natural hydrogen.

[1] Cheng et al. (2021) *EPSL* 574: 117175.

[2] Tyne et al. (2022) *EPSL* 589: 117580.

[3] Cheng et al. (2018) *Goldschmidt Abstracts* 403

[4] Cheng et al. (2023) Nature **615**, 94–99