Quantifying rates of CO$_2$ dissolution in U.S. natural CO$_2$ reservoirs through integration of noble gas and 3D reservoir modelling techniques

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This project will generate new knowledge relevant to the worldwide problem of engineering secure CO$_2$ storage. You will be trained in 3D reservoir modelling techniques and noble gas isotope and igneous rock geochemical interpretation. You will apply these techniques to provide a time-series of CO$_2$ dissolution rates across the series of natural CO$_2$ reservoirs found in the Colorado Plateau region of the USA. This aims to provide greater understanding of the key controls on CO$_2$ dissolution rates, determine if they can be enhanced through injection strategies and inform how they can be better incorporated into predictive models of CO$_2$ storage.

**Background:** CO$_2$ capture and storage (CCS) is the only industrial scale technology that can directly reduce the CO$_2$ emissions produced by the combustion of fossil fuels. Given global reliance on fossil fuels for energy and industrial manufacturing needs, CCS is an essential technology for the global drive to reduce anthropogenic CO$_2$ emissions to the atmosphere following the recent ratification of the Paris Agreement to combat climate change. CO$_2$ captured from various energy producing sources will be injected into depleted oil and gas reservoirs or deep saline formations for storage. For the safety of this storage to be assured it is essential that it can be shown that CO$_2$ can be retained safely in the subsurface over a minimum of 10,000 years. The only means to provide reassurance of storage over these timescales are to study natural CO$_2$ reservoirs, some of which have contained CO$_2$ for millions of years$^1$. Despite extensive research, the controls and timescales that each of these trapping mechanisms act on CO$_2$ contained in different reservoirs is still uncertain$^2$.

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**Fig. 1.** (L) Map of the Colorado Plateau illustrating the sites of major Cenozoic igneous provinces and location of natural CO$_2$ in the region from$^1$.  
**Fig. 2.** (R) **A** - Map showing the location of the Bravo Dome CO$_2$ field and extrusive products of volcanic activity. Colour map shows pressure distribution in the field in 1981.  
**B** - Down-dip cross section of the main section of the reservoir from B to B'.  
**C** - A cross section of the NE segment of the reservoir from C to C', from$^4$. 
Work by the principle supervisor has identified that solubility trapping is a key mechanism of CO₂ trapping in a number of natural CO₂ reservoirs across the Colorado Plateau area of the US³. This study also found limited geochemical evidence for significant mineral trapping in these reservoirs. Recent research has built on these findings by integrated noble gas measurements in the Bravo Dome natural CO₂ reservoir with 3D modelling of the reservoir structure to calculate the total amount of CO₂ dissolved and also identified the age of CO₂ charge into the reservoir.

**Proposed Research:** The initial phase of the project will construct 3D reservoir models in industry standard software of the individual CO₂ reservoirs using publically available well logs and geophysical data. These will be combined with discovery pressure data to calculate the amount of CO₂ stored in each reservoir prior to commercial extraction commencing.

The second stage will integrate noble gas measurements from each reservoir with well log records of the gas/water contact to calculate the amount of CO₂ lost to solubility trapping in each well, following the methods used in Bravo Dome³ and then interpolate this to obtain the total volume of CO₂ lost to solubility trapping across the entirety of each CO₂ reservoir. Thorough the interpretation of legacy pressure and measured noble gas data the likely CO₂ charge direction will be determined and combined with existing dates and geochemical compositions of nearby igneous rocks, to deduce age of CO₂ charge. Combining the charge timing and degree of CO₂ loss to solubility trapping for each reservoir to deduce the rate of CO₂ dissolution in each reservoir.

The final phase will compare and contrast the CO₂ dissolution rates in each reservoir with the reservoir geometry, properties and structure in order to deduce the key differences and similarities between each reservoir and identify the key controls on CO₂ dissolution rate. This knowledge will be used to ascertain how CO₂ dissolution can be enhanced through injection strategies and inform how they can be accurately incorporated into predictive models of CO₂ storage.

**Training:** Substantial foundation training will be provided in year one, with individually focused options available throughout the subsequent years. Gaps of knowledge can be filled by attending existing lecture courses. You will be supported in preparing posters and presentations of your work, aspiring to international conferences and academic publications.

You will benefit from peer support, seminars and social interaction in the multi-discipline research environment within the School of GeoSciences. You will be trained in integrated methods of geoscience evaluation, 3D reservoir modelling, well log and noble gas geochemical interpretation. The skills gained in this project will be applicable to diverse industries ranging from environmental, hydrocarbons to hydrogeology.

The successful applicant may have an opportunity to participate in geochemical sample collection and sample analysis, however the primary focus of the project will be interpretation and modelling existing data rather than analytical or field technique development.

**Requirements:** Applicants are invited from UK/EU citizens who should have, or expect to gain, a 2:1 BSc or MSc in the GeoSciences, Physical Sciences, or Mathematical Sciences. It is not expected that you will arrive with all the skills.

**References:**
1. Gilfillan et al., 2008, GCA, 72, p1174-1198 DOI:10.1016/j.gca.2007.10.009;
2. Scott et al., Nature Climate Change 3 (2), p105-111 DOI:10.1038/nclimate1695