GeoNetZero Centre for Doctoral Training (CDT): Geoscience and its Role in the Low Carbon Energy Transition

(2022 start)

Project Title: Predicting CO2 permeation through shale rocks

Host institution: University of Nottingham
Supervisor 1: Sean Rigby
Supervisor 2: Joseph Wood

Project description (250 words max.):

The use of CO2 to displace methane from unconventional reservoirs, like gas shales, offers the potential for simultaneous improved methane recovery and CO2 storage. Understanding of the mass transport mechanisms is essential for predicting gas recovery and carbon storage efficiency, due to their impact on how far the CO2 will permeate throughout the reservoir. Shales are also a common caprock. Shales have complex void spaces, with various surface chemistries and pore types, corresponding to phases such as organic carbon and inorganic minerals. Due to the prevalence of microporosity and surface adsorption, the surface diffusion flux constitutes the largest component of mass transport. This work aims to predict surface diffusion rates, and thence overall mass transport fluxes, from the surface properties of typical reservoir rocks. The parameters thereby obtained are critical inputs for reservoir simulations to predict large-scale gas recovery, storage potential, and seal efficiency.

This work will develop a model for multi-mechanism mass transport in heterogeneous rocks using multi-fractal-based models. Pore-scale models will be incorporated into larger length-scale transport models, using percolation theory and critical path analysis to determine the particular void-space zones that control the overall flux. The model will be tested against experimental gas mass transport data for rock core samples.

Models of several different shale reservoirs with different petrophysical properties and geological heterogeneities will be generated to investigate the impact of surface diffusion of CO2 and CH4 on gas recovery and storage efficiency. Simulations will look at the impact of mass transport mechanisms on the efficiency of various injection scenarios.

Stated link to the overarching theme of the CDT i.e. The Role of Geoscience in the Energy Transition and the challenge to meet the net zero emission targets (NOTE: In order to qualify for NEO Energy CDT funding, there must be an explicit link to the Energy Transition with a clear application to the UK's Continental Shelf (UKCS). For projects supported by 100% matched funding from your University, links to the broader Energy Transition remit are sufficient):

This project relates to the topic of Safe Subsurface Storage (of carbon dioxide, hydrogen, methane and compressed air).

We currently have shale samples from several on-shore UK (eg Rempstone, Ratcliffe) and North Sea (eg Nordland) locations which we intend to use in this project. We plan to obtain others from BGS.

Details of mapping/fieldwork locations/data to be used by the project and confirmation of access to key data being secured (please attach map as an appendix if relevant):
N/A

Outline of planned work schedule for the 4-year research period:

Year 1: Background reading and literature review in rock core characterisation, mass transport in porous media, CCS, and shale caprocks and reservoirs. Training in operation of gas sorption/uptake rigs and other characterisation techniques (eg mercury porosimetry, CXT). Develop experimental protocols. Training in reservoir simulation software. Obtain additional rock core samples from BGS etc.

Year 2: Conduction of experimental rock core characterisation and mass transport measurements. Surface diffusion model development.

Year 3: Incorporation of mass transport model into reservoir simulator. Reservoir simulation of impact of surface diffusion on gas recovery and storage efficiency. Collect additional rock data as required.

Year 4: Finishing simulations. Write-up.

Any Additional Research Costs (NOTE: **Each CDT studentship includes an individual Research Training and Support Grant (RTSG) budget of £20k for the full 4-year study period)**
N/A

Supervisory arrangements and involvement of external partners (NOTE: Please indicate the area(s) of expertise covered by each supervisor. External collaboration is encouraged, but if proposed partner is not currently providing support to the CDT, please outline the extent of the partner's involvement with the project.)
Supervision will be by Profs Sean Rigby and Joseph Wood. We already have several UKCS shale samples but some further shale samples will be provided by British Geological Survey.

Likely graduate career routes:
The graduate will gain skills in reservoir rock core analysis and reservoir simulation which will be of use in several sectors, eg oil & gas, carbon sequestration, geothermal etc.