Can oil and gas migrate through rock?

Rock formations have sealed oil and gas reserves for millions of years. Professor Joe Cartwright identifies mechanisms by which oil and gas may bypass these seals. His work is important for the careful selection of drilling and CO2 storage sites.

Oil and gas exploration is inherently risky, and considerable efforts are put into research designed to mitigate the risk of failure, which can be highly costly. One of the major risks is linked to the natural tendency for oil and gas to migrate upwards through layers that are usually considered as seals. It is important to quantify the natural leakage of hydrocarbons ahead of drilling a prospect or potential oil/gas field. Professor Joe Cartwright has spent much of his career as a geologist studying the factors that influence the degree of leakage of hydrocarbons in the subsurface.

A key part of his research is focused on the identification and physical characterisation of geological features that facilitate leakage—what he calls ‘seal bypass systems’. They commonly occur in geological layers that have an intrinsically low permeability, such as claystones, and which are generally viewed by the petroleum exploration companies as good seals or ‘caprocks’. Examples of these features include geological faults, and various types of intrusions, where a more permeable layer has been injected upwards under high-pressure and crosses the low permeable seal layer. Professor Cartwright’s research has enabled petroleum companies to recognise some of these potential leakage pathways in advance of exploratory drilling.

In particular, Professor Cartwright has discovered a new type of geological fault network that he has termed ‘polygonal fault systems’. 3D seismic imaging reveals their characteristic appearance, which is reminiscent of the cracks on dried out mudflats, and can be kilometres in length. They have the potential to substantially alter the sealing potential of geological layers. His research helps to clarify under what conditions polygonal faults form and what their impact might be on bulk permeability of a layer.

Professor Cartwright and his U.S. colleague, Professor Carlos Santamarina, have developed a theory that these faults are the result of chemical causes. Unlike the usual mechanical causes, these faults are believed to have formed as a result of reactions taking place during the first tens of metres of burial of the sediments—a process known as sedimentary diagenesis. Now they are testing the hypothesis that other fracture systems also result from sediment diagenesis, but the tests are not conclusive yet.

This research will have far-reaching importance not just for the oil and gas industry, but also for future applications such as the underground storage of CO2, where the sealing properties of the caprocks are critical. This is arguably where this research could prove most beneficial.

For more information contact Joe.Cartwright@earth.ox.ac.uk or visit energy.ox.ac.uk/fossil-fuels/)