ENI AWARD 2016

New Frontiers of Hydrocarbons - Upstream Prize

Christopher Ballentine

Winner

Novel Tracers for Determining the Fluid Processes Controlling Subsurface Gas Origin and Behaviour

Research Description

Fluids moving through the pore spaces and fractures in the rock beneath our feet have shaped much of the chemistry of the planet we live on. These fluids change the rock porosity by chemical erosion or mineral deposition, form microbial ecosystems, generated ore body resources and, in the form of hydrocarbons, give us the energy reserves that have formed the foundation of our society today. On geological timescales many fluids exist for only a fleeting moment. One of the greatest challenges we have in the study of subsurface fluids systems is determining the physical framework in which these fluids formed. To be able to reconstruct the driving processes we also need to identify the origin and amount of the different fluids that may no longer be present in a system. Chris Ballentine has shown that with 23 naturally occurring isotopes, the noble gases (helium, neon, argon, krypton, xenon) provide an inorganic Rosetta Stone with unprecedented capability to identify and quantify the processes controlling multi-phase (solid, gas, water, oil) systems and pioneered their application to critical subsurface settings.

For example noble gases dissolved in groundwater are isotopically distinct from almost any other subsurface source. When these are found in natural gas or oil the 'groundwater' noble gas concentration tells us how much water the gas or oil has contacted - even if the water is no longer present. This is critical when assessing mechanisms of chemical change in oil such as water washing or biodegradation, migration path lengths, and whether a gas field is present through exsolution of water or oil phases or has migrated to that point through buoyancy. A second level of detail is also retained by the noble gases because we know the elemental ratios of the fluid sources. When these are different in the hydrocarbon phase, because the noble gases are inert, this is because of the physical processes operating in the subsurface. Processes might include gas/water phase equilibration, gas cap formation, open system vs closed system behaviour or diffusional loss of gas. Identification of fluid sources, mass of fluid and reconstruction of physical processing of subsurface fluid systems is a major advance in predicting future resources, efficient extraction and environmental safe practice.

Highlights of Ballentine's work include showing how natural gas fields formed by basin scale groundwater flow and degassing can be distinguished from fields that filled through buoyant gas phase migration. He has shown how to discriminate between models of diagenetic mineral formation requiring regional vs local water contact, critical for understanding oil field filling in the North Sea. Study of noble gases in Coalbed methane in the San-Juan Basin, USA, provides the model foundation for determining the in-situ biogenic CH_4 production rate in this and a later study of the Albany shale, Michigan**.** He has shown the key role of regional groundwater in accumulating and concentrating N_2 and He to form commercially viable helium gas fields. Ballentine's team showed that mineralisation plays little if any role in removal of any separate CO_2 phase and even dissolution of CO_2 into groundwater will stop operating once saturation of the water phase is reached, no matter how old the CO_2 system**.** Future safety cases in both CO_2 enhanced oil recovery (EOR) and anthropogenic waste disposal must take the mobility of a separate CO_2 phase into consideration.

The future includes application of noble gases to understand how much oil and gas have migrated through systems, results that will be critical for calibration of basin scale hydrocarbon generation models; how we can use noble gases to more effectively predict the amount of hydrocarbon gas expelled from tight gas sources; and how using the same inert fingerprints of hydrocarbon phases we can track and monitor any leakage or incursion into shallower fluid systems.