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Fundamentals of gas flow in shale; What the unconventional reservoir industry can learn from the radioactive waste industry

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Tight formations, such as shale, have a wide range of potential usage; this includes shale gas exploitation, hydrocarbon sealing, carbon capture & storage and radioactive waste disposal. Considerable research effort has been conducted over the last 20 years on the fundamental controls on gas flow in a range of clay-rich materials at the British Geological Survey (BGS) mainly focused on radioactive waste disposal; including French Callovo-Oxfordian claystone, Belgian Boom Clay, Swiss Opalinus Clay, British Oxford Clay, as well as engineered barrier material such as bentonite and concrete.

Recent work has concentrated on the underlying physics governing fluid flow, with evidence of dilatancy controlled advective flow demonstrated in Callovo-Oxfordian claystone. This has resulted in a review of how advective gas flow is dealt with in Performance Assessment and the applicability of numerical codes. Dilatancy flow has been shown in Boom clay using nano-particles and is seen in bentonite by the strong hydro-mechanical coupling displayed at the onset of gas flow. As well as observations made at BGS, dilatancy flow has been shown by other workers on shale (Cuss et al., 2012; Angeli et al. 2009).

As well as experimental studies using cores of intact material, fractured material has been investigated in bespoke shear apparatus. Experimental results have shown that the transmission of gas by fractures is highly localised, dependent on normal stress, varies with shear, is strongly linked with stress history, is highly temporal in nature, and shows a clear correlation with fracture angle. Several orders of magnitude variation in fracture transmissivity is seen during individual tests. Flow experiments have been conducted using gas and water, showing remarkably different behaviour.

The radioactive waste industry has also noted a number of important features related to sample preservation. Differences in gas entry pressure have been shown across many laboratories and these may be attributed to different core preparation techniques. Careful re-stressing of core barrels and sealing techniques also ensure that experiments are conducted on near in situ condition. The construction of tunnels within shale clearly aids our understanding of the interaction of engineered operations (borehole drilling or tunnelling) on the behaviour of the rock.

References:
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