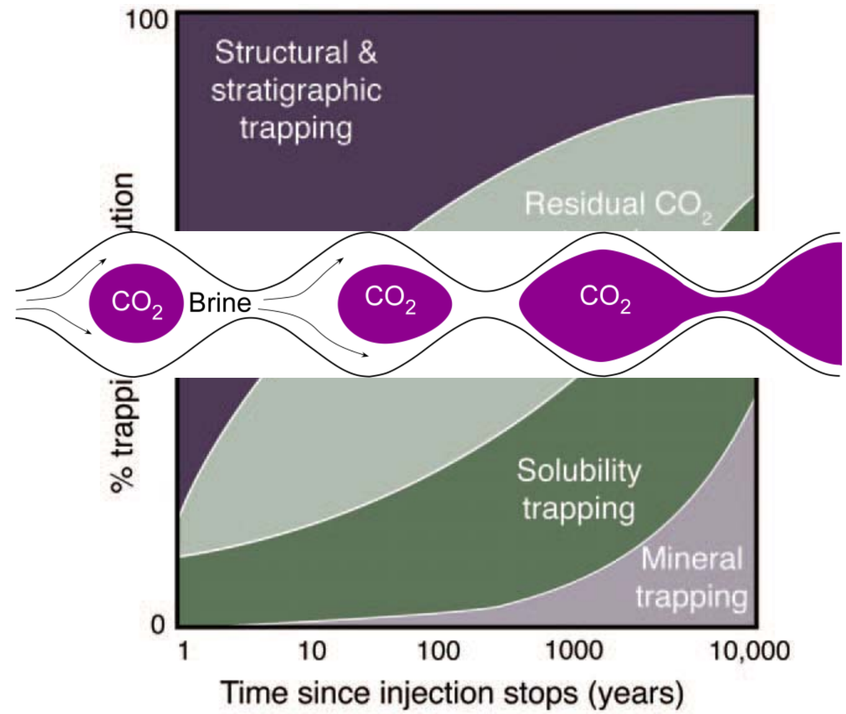
Modified theory for bubble formation from a CO_2 stream injected into pores

Scientific Achievement

A widely used theory for snap-off of a stream of injected fluid (e.g. supercritical CO_2) inside water-filled pores into bubbles was modified to be more comprehensive and realistic.

Significance and Impact

The modification to the classic theory more realistically represents the physics and therefore allows for better prediction of when snap-off into bubbles occurs. This is important for reservoir models of CO_2 injection since the new theory would better capture the propensity for capillary and dissolution trapping.



Research Details

- Dynamics of bubble formation or snap-off from a CO_2 plume is analyzed theoretically and computationally.
- Theoretical extension of widely used and accepted theory for bubble snap-off or plume break up.
- Extension achieved by adding additional terms in the snap-off threshold based on the Young-Laplace equation for capillary pressure across a fluid interface.
- The new theory is compared to computational fluid dynamics (numerical) simulations of multiphase flow (CO_2 and native formation water) showing snap-off.
- Residual or capillary trapping estimated ~50%!

Wen Deng, **M. Bayani Cardenas**, and Philip C. Bennett, Extended Roof snap-off for a continuous nonwetting fluid and an example case for supercritical CO_2, Advances in Water Resources, 64, 34-46, doi: 10.1016/j.advwatres.2013.12.001, 2014.

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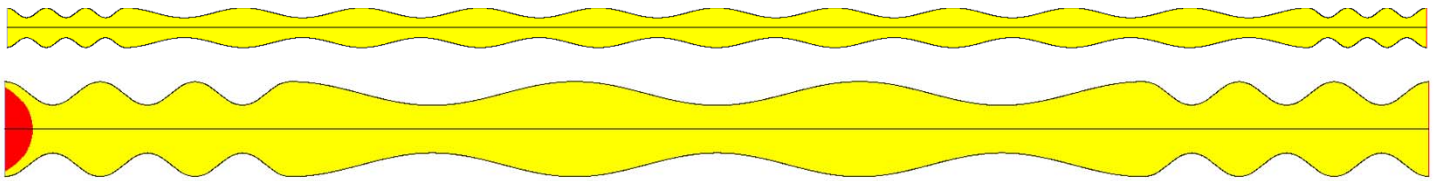
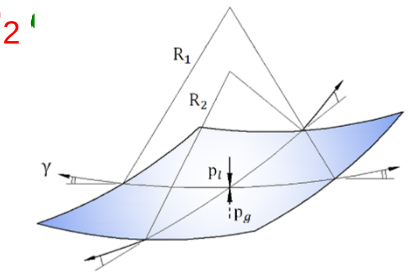
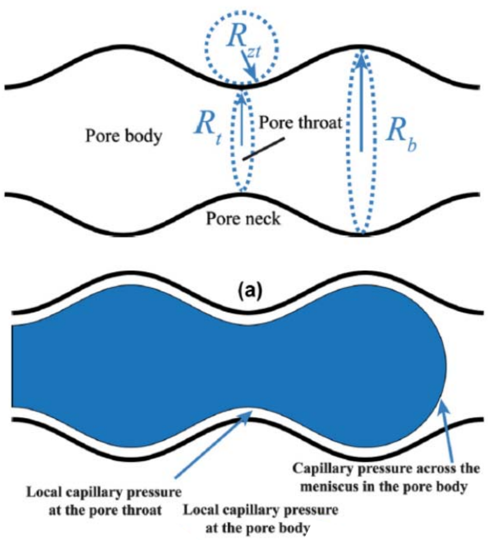
Computational fluid dynamics simulations of multiphase flow (sCO_2





Modification of the 1970 theory



Young-Laplace Eqn (pressure drop across a fluid interface)

Capillary pressure or p_c: $\Delta \boldsymbol{p} = \left(\frac{\mathbf{1}}{\boldsymbol{R_1}} + \frac{\mathbf{1}}{\boldsymbol{R_2}}\right)$, *R*'s are principal radii of curvature

Roof criterion or threshold (1970)

p_c at pore body, $\frac{\mathbf{2}}{\boldsymbol{R_b}} < \frac{\mathbf{1}}{\boldsymbol{R_t}} - \frac{\mathbf{1}}{\boldsymbol{R_{zt}}}$, p_c at pore throat

Our extension of Roof's theory (2014)

$$\frac{\mathbf{1}}{\boldsymbol{R_b}} + \frac{\mathbf{1}}{\boldsymbol{R_{zb}}} < \frac{\mathbf{1}}{\boldsymbol{R_t}} - \frac{\mathbf{1}}{\boldsymbol{R_{zt}}}$$

Future Work

Application in pore-network models of reservoir samples

p_c at pore body, $\frac{2}{R_b} < \frac{1}{R_t} - \frac{1}{R_{zt}}$, p_c at pore throat

Modified theory for bubble formation from a CO_2 stream injected into pores

Computational fluid dynamics simulations of multiphase flow (sCO_2 & water)