**Application of Buoyancy, Pressure Potential and Buoyancy Reversal to $CO_2$ Sequestration**

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Buoyancy plays a central role in carbon sequestration, be it in the determination of flow directions, or of the height of breakthrough columns for CO2. The general assumption is that fluids lighter than water (such as hydrocarbons and CO2) will rise vertically upwards and fluids heavier than water will sink to the bottom of the geologic layer packet. These opinions are based on the assumption of hydrostatic conditions (no-flow conditions) at sequestration sites. In reality the subsurface condition is one of flowing fluids under hydrodynamic conditions.

Hubbert (1953) showed the basic difference between hydrostatic and hydrodynamic conditions. In the hydrostatic case the gravitational force (-g) and the pressure potential force ($-1/\rho \times \text{grad } p$) are of exactly the same magnitude but point in opposite directions. The resultant force (-grad $\Phi$) is zero and no flow occurs. In the general hydrodynamic case the gravitational force and the pressure potential force do not assume opposite directions and equal magnitude. Thus the resultant force vector (-grad $\Phi$) is unequal to zero and flow occurs. In this case the 'buoyancy force' is not directed vertically upwards.

Low velocities or amounts of flow are irrelevant for the determination of hydrostatic conditions. The direction of the so-called 'buoyancy force' is determined by the force field, not by the flow field. In a low-permeable environment, the flow of groundwater may be slow and of minor amounts, but the associated pressure potential forces will be high and will determine the 'buoyancy force'.

Hubbert (1953) showed that force potentials (energy/unit mass) of fresh groundwater determine the flow behaviours of other fluids such as air, salt water, oil, or gas (including CO2 in any form). The direction of the fresh water pressure potential force determines the direction of the pressure potential forces for oil, gas and salt water. That is the reason why oil and gas float vertically upwards and saltwater vertically downward **under hydrostatic conditions**.

Under hydrodynamic conditions, the fresh water pressure potential force also determines the direction of the so-called 'buoyancy force', but can assume any direction in space including downward. This is the key observation for comprehending the behaviour such 'buoyancy forces'. The change in concept is of importance for successful CO2 sequestration and the reason for amending existing computer modelling programs for geological CO2 storage accordingly.