Mechanical force fields as drivers of fluid migration at sequestration sites of carbon and other fluids.

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Abstract

The long term fate and leakage of CO_2 injected into geological formations depends on the mechanical force fields for fluid flow in the subsurface as much as on the geologic structure. These force fields (Hubbert, 1940) are created by gravitational energy omnipresent in the subsurface. Hubberts's force fields were applied in developing the Theory of Groundwater Flow Systems (Tóth, 1962). These flow systems penetrate into similar depth ranges as the injection of CO_2 and other fluids.

In general, under hydrodynamic conditions in the subsurface, the so-called 'buoyancy force' may be directed in any direction in space. Only under hydrostatic conditions is it always directed vertically-upwards. In areas of strong downward flow the groundwater flow systems may cause 'buoyancy reversal' in aquitards, a term created by Weyer (1978). 'Buoyancy reversal' means that under certain geologic and hydrodynamic conditions in the subsurface, the so-called 'buoyancy force' is directed downwards. These conditions have frequently been encountered in Alberta and in other areas.

The application of the principles of Hubbert's Potential Theory [energy is related to unit mass] to sequestration of carbon and other fluids is fundamental in achieving realistic results in any modeling attempt. For example, IPCC's (2005) attempt to determine a 1000 year buoyancy driven migration of CO_2 is seriously flawed as is IPCC's attempt to confine CO_2 migration to deep aquifers and to fault lines. Both cases ignored the mechanical vectors created by regional groundwater force fields. What is generally missing from the treatment of this topic is the consideration of deeply-penetrating force fields of fresh groundwater and its consequences for flow of fluids using the principals of Hubbert's Fluid Potential Theory. It will be shown that vectoral addition of the gravitational field and pressure potential force field of fresh groundwater determine the flow direction for all fluids in the subsurface. It is incorrect that fluids heavier than freshwater would sink to the bottom of the system and rest there.

The above points will be illustrated with examples from the literature, with field studies, and with the results of mathematical modeling. Any risk analysis of the sequestration of carbon and of other fluids and subsequent migration to aquifers or the surface needs to consider fluid flow analysis based on the principles of Fluid Potential Theory and the Theory of Groundwater Flow Systems.

The above principles naturally also apply to deep well injections in general and, in particular, to injections into oil or gas fields with abandoned wells.