Application of X-Ray CT and high resolution modeling for elucidating multiphase flow phenomena in CO_2 sequestration

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Geological sequestration of CO_2 in deep geological formations has emerged as an important method for reducing CO_2 emissions. Options include oil and gas reservoirs, coal beds and saline aquifers. While much is known about multiphase flow of oil, water and natural gas, there is little direct experience with multiphase flow of CO_2 and brine. X-ray CT provides a unique opportunity for studying multiphase flow at realistic reservoir conditions—with spatial and temporal resolution that could never be observed in field-scale experiments. We use an X-ray CT scanner to obtain continuum scale images (~ mm^3) to study multiphase flow of CO_2 and brine—with a particular emphasis on understanding the influence of spatial heterogeneity, capillary pressure gradients and buoyancy driven flow. Here we present multiphase flow experiments on three different rocks—spanning a range of heterogeneity. We perform and compare high-resolution simulations of these experiments to develop a quantitative understanding of the factors that control observed spatial distributions of CO_2 and brine. One important conclusion is that the spatial distribution of CO_2 is highly variable, even in comparatively homogeneous rocks. These variations can only be explained by spatially variable capillary pressure curves. When the contrast in rock properties is large, low porosity layers act as capillary barriers, diverting flows along the high porosity/permeability pathways. Depending on the orientation of these layers, they can result in bypass of significant portions of the rock. Reasonable progress has been made towards quantitatively history matching observed CO_2 saturations, thus improving confidence in fundamental understanding of these processes—which is of course essential for developing reliable predictive models over the range of relevant spatial and temporal scales. Implications of these studies for reservoir scale sequestration projects are also discussed.

Petrological cooling rates from central Ribeira Belt (SE Brazil): New breakthroughs and developments

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Several authors have used mineral diffusion mechanisms in order to determine cooling rates (e.g. [1] and references therein). Garnet – biotite (inclusions) Fe-Mg diffusion based petrological cooling rates are amongst the most studied and applied to establish the thermal evolution of high grade terrains. However, several problems arise from the use of this methodology (see [2] and below).

Cooling rates based on Fe-Mg diffusion between garnet and respective biotite inclusions in migmatites and granulites from Ribeira Belt (SE Brazil) [3] show two contrasting situations: a) narrow temperature variation caused by garnet and biotite reequilibration at high temperatures followed by very fast cooling; b) high dispersion of results caused by compositional variations in garnet and biotite probably due to deformation and partial open-system behaviour [4]. Whereas the former allows a qualitative evaluation of the cooling pattern (e.g.: very slow vs. very fast), the latter are more difficult to interpret.

However, the use of garnets and biotites that show large Fe/Mg variation and a software that reduces result dispersion (due to deformation and open-system behaviour) provides ‘closure T vs. inclusion size’ trends which are solely resultant from compositional readjustment to thermal evolution during retrogression. Results show that: a) migmatites cooled rapidly from high temperatures, decreasing cooling rates through time (from 6 to 0.1 °C/Ma); b) granulites endured low cooling rates at high temperatures, being followed by fast cooling, increasing cooling rates during retrogression (from 1 to 120 °C/Ma). These results are in broad agreement with thermochronological results based on integration of multiple isotopic systems [5, 6].

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