Towards determining noble gas partitioning between supercirtcial CO_2 and water

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Geological storage of carbon dioxide within deep saline aquifers remains a solution to reduce global CO_2 emmisions [1]. However significant uncertainties remain in quantifying the rates of CO_2 dissolution into the water phase, rates of reaction with the aquifer minerals, and also in identifying techniques to trace reservoir leakage. Noble gas isotopes can play a key role in quantifying all of these areas [e.g. 2,3]. Nevertheless, the partitioning of noble gases between supercritcial CO_2 and water has never been determined, with studies to date assuming that noble gas partitioning between these phases can be approximated by data existing for gas/water systems. Indeed, the effect of significant volumes of CO_2 dissolved in the water phase on noble gas solubility in water has also not been determined and is presently neglected in modeling noble gases in natural systems.

We have taken an experimental and modeling approach to resolve this lack of information. We have constructed a Gibbs-Ensemble Monte Carlo (GEMC) model for calculating noble gas partitioning by simulating the molecular configurations of both the water-rich and carbon dioxide-rich phases. This model is currently at a stage where it reproduces carbon dioxide-water binary phase equilibria for the conditions of interest (40-140 Bars, 310-340 K) [4]. The model is now ready for input of noble gas atoms to determine their theoretical distribution between phases. Experimental work equilibrates noble gases between CO_2 and water in the British Geological Survey high-PT laboratory. We extract an aliquot of each phase at equilibrium and determine the noble gas concentration of each using a quadrupole mass spectrometer system developed at the Univeristy of Manchester.

Preliminary results from the experimental program suggest that noble gas solubilities are increased in the water phase when the water contains a high dissolved CO_2 content. In a sub-critical gas/water system at 50°C supporting a 37 bar CO_2 phase, an enhancement in noble gas solubility in water can be observed for Helium and Argon respectively. Confirmation of this increase in solubility is underway with an analytical program that expands the pressure and temperature range to includes the supercritical phase.

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Characterising exhumation of mid- and lower-orogenic crust during late-stage collision: a case history from NW Bhutan

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Abstract

Rare mafic rocks exposed in NW Bhutan, eastern Himalaya, preserve evidence for a granulite-facies event overprinting patchy evidence for precursor eclogite-facies conditions. These rocks yield U-Pb zircon ages of 15.3 ± 0.3 to 14.4 ± 0.3 Ma, interpreted as dating the timing of eclogite-facies metamorphism due to the trace element geochemistry of the zircons [1]. Monazite U-Th-Pb ages of 13.9 ± 0.3 Ma in leucosomes within associated pelitic opx-bearing granulites suggest that granulite-facies conditions were reached rapidly after eclogite-facies conditions [2]. Furthermore, U-Pb ages of rutile in both mafic and pelitic rocks of 10.1 ± 0.4 and 10.8 ± 0.1 Ma respectively, suggest that exhumation proceeded at rates of >40°C Ma^{-1} following the initiation of cooling [3]. These high grade rocks are exposed in the hanging wall of the Kakthang thrust system which emplaced them over older (21-17 Ma, U-Pb monazite) amphibolite-facies rocks which never reached eclogite or granulite facies conditions. Finally, 14.6 ± 1.2 Ma U-Pb ages of titanite in mafic rocks in the nearby Jhomolari Massif [3], which show textural evidence for eclogite-facies overprinted by an amphibolite event, suggest a third unit of high grade metamorphic rocks in Bhutan which experienced a distinct metamorphic history.

Taken together, these data show that rocks were exhumed from distinct middle and lower orogenic crustal levels at different times during the later stages of the India-Asia collision. Their exhumation raises questions about the mechanisms by which crustal material is transported in collision belts. Lower crustal eclogites have no inherent buoyancy, and therefore require a tectonic driver coupled with a lowering of viscosity to promote their exhumation. A strong, cold Indian plate indentor may have driven this hot weak material towards the surface. Multiple pulses of exhumation from different orogenic levels at different times are predicted by this “plunger” mechanism in numerical channel-flow models e.g. [4] which also predict the different PTt paths recorded in nature.

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