

## High-resolution X-ray tomography of fractionally-wet media: Drainage experiments

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Numerous lab- and field-scale experimental studies have shown the strong impact of wettability on constitutive relations and how increased water repellency can lead to preferential flow paths and a heterogeneous water distribution in the vadose zone. Advances in high-resolution X-ray computed tomography (XCT) techniques now make it possible to nondestructively image opaque materials providing previously hard-to-observe qualitative and quantitative data and information. Concurrent with these advances has been an effort to quantify structure within these materials. Of particular interest in porous media research is the ability to now extract granular packing details and pore network structure along with the capability to correlate fluid phases and distribution within the pore structure. This level of detail provides insights into that pore-scale processes that impact macroscopic behavior and are proving useful for pore-scale modelers.

Here we will discuss a series of experiments designed to obtain pore-scale details on the distribution of water in fractionally-wet media. A series of drainage experiments were conducted at the synchrotron-based tomography beamlines (i.e. APS/GSECARS and LSU/CAMD) where high-resolution XCT was used to image columns containing different fractions of water-repellant grains under similar capillary suction heads. A unique feature of these experiments was the ability to separate the water-wet from the water-repellant grains due to slight differences in their X-ray absorption properties. Following thresholding of the images (i.e. segmentation of the solid, water, and air phases), the granular packing and pore network structure were quantified along with the water volumetric content. In addition, the water distribution was correlated to the pore network structure and the individual water-wet and water-repellant grains providing valuable insights into the impact of pore-level wettability variations.

Results indicate that grain-level differences in wettability have a major impact on the connectivity of the water phase during drainage. This leads to large differences in the drainage pathways and ultimate distribution of irreducible water.

## Assessing capture of atmospheric CO<sub>2</sub> within mine tailings using stable isotopes and <sup>14</sup>C

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Ultramafic tailings produced by some mining operations are capable of capturing CO<sub>2</sub> directly from the atmosphere. Mineralization of CO<sub>2</sub> within Mg-carbonate minerals in mine tailings can occur on a scale that is significant relative to the greenhouse gas emissions of a mine, and therefore may represent an offsetting of greenhouse gas emissions

Stable C and O isotope data for secondary Mg-carbonate minerals within tailings from the Mount Keith Nickel Mine, Australia and the Diavik Diamond Mine, Canada fail to unambiguously fingerprint the source of CO<sub>2</sub> within these minerals. The fractionation of stable C isotopes during precipitation of a hydrated Mg-carbonate mineral, dypingite, was examined using analogue experiments that simulate conditions in mine tailings storage facilities. Experimental results demonstrate precipitation of <sup>13</sup>C-depleted dypingite from a dissolved inorganic carbon (DIC) pool that is out of C isotopic equilibrium with atmospheric CO<sub>2</sub>. These results provide a compelling explanation for the depleted, ambiguous stable C isotopic data for secondary Mg-carbonate minerals at Mount Keith. Furthermore, they suggest that equilibrium fractionation factors may fail to describe the δ<sup>13</sup>C signature of mine process water DIC and the secondary Mg-carbonate minerals that precipitate from this DIC pool.

Stable C and O isotope data for secondary Mg-carbonate minerals from mine tailings at Mount Keith and Diavik tend to reflect the processes by which C has been cycled rather than its provenance, making it difficult to fingerprint capture of atmospheric CO<sub>2</sub>. Alternatively, <sup>14</sup>C provides an unambiguous measure of the amount of modern atmospheric C trapped within carbonate minerals. Using this more robust tracer, we have determined that >90% of C mineralized in secondary Mg-carbonate minerals at Mount Keith and Diavik was trapped from the modern atmosphere.