Neutron imaging of fluids in plant-soil-rock systems using the ORNL/HFIR CG-1 beamline

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A collaborative science program has been initiated using the newly commissioned CG-1 development beamline at the Oak Ridge National Laboratory's (ORNL) High Flux Isotope Reactor (HFIR). Investigation and modeling of the phase structure and flow dynamics of fluids (water, brines, air, CO_2) within plants, soils and rocks using non-invasive, non-destructive neutron imaging techniques is ongoing. Although the theoretical treatment of fluids in porous media has improved substantially over the past few decades, model validation using time-resolved (seconds to minutes), high-resolution (10's of μm) measurements of fluid distributions in heterogeneous natural systems is still lacking. Compared to other imaging techniques (X-ray, magnetic resonance, etc.), neutron imaging provides high sensitivity to light elements in fluids (e.g. *H*) and deep penetration into plants and earth materials. Utilizing the HFIR CG-1 beamline, we have started to develop *in situ* measurement and modeling capabilities to investigate soil-plant-atmosphere water exchange dynamics, soil water retention, unsaturated flow and solute transport in the vadose zone, and multi-phase flow and transport in groundwater systems. The scientific objectives of this program are to: (1) develop quantitative imaging techniques to accurately measure 3D phase structures and 2D fluid flow in porous media, (2) test and refine imaging/modeling capabilities using homogenous model systems, and (3) apply imaging/modeling capabilities to identify fluid pathways, rates of flow, and interactions between porous media, fluids, and plants under dynamic and complex environmental drivers. This presentation will provide a progress update and some recent results.

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The limits of hydrosphere-lithosphere interaction: The origin of the lowest-known $\delta^{18}O$ silicate rock on Earth

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Geologic records of Earth's hydrosphere and precipitation older than two billion years ago are rare, although they provide insight into the past climate, rates of water-rock interaction, and intensity of plate tectonics. Here we report and describe in detail the lowest-known $\delta^{18}O$, –16 to –27‰ terrestrial silicate rocks on Earth, found in Paleoproterozoic plagiogneisses from the Belomorian complex (Karelia, Russia). Geochronologic and oxygen-isotopic data on ruby (-22-27‰), zircons (+8 to –27‰) and monazite (–17.5‰) imply that the protoliths of these rocks were 2.5 Ga metasediments and metavolcanics that were hydrothermally altered prior to 1.85 Ga within an intracontinental rift zone, and involved ultra-low-$\delta^{18}O$,<-25-30‰ meteoric water. Paleogeographic reconstructions indicate that Karelia was at low- to mid-latitudes throughout the Paleoproterozoic Era. Ultradepleted $\delta^{18}O$ waters outside of polar regions or the interiors of large landmasses provide independent evidence for a moderately glaciated, so called 'Slushball' Earth climate between 2.45 and 2.4 Ga, in which low-or mid-latitude mid-size continents were covered with glaciers while the ocean remained at least partially unfrozen to allow for intracontinental isotopic distillation in a large temperature gradient. In addition to these climatic inferences, the data are more readily explained by a depleted –10‰ seawater reservoir during Paleoproterozoic.

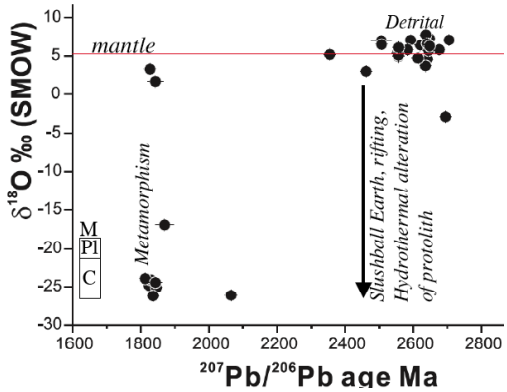

Figure 1: Extreme and 9‰ diverse on a cm-scale $\delta^{18}O$ values of minerals in Karelian plagiogneisses are recorded by corundum (C), Plag, Monazite (M), with only detrital zircon preserving normal-$\delta^{18}O$ values. The $\delta^{18}O$- D/H values of amphiboles and biotites (>-170‰) suggest retrogression and –30‰ initial water values.