Glacial tillites reveal temporal evolution of upper continental crust

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Defining the absolute composition of the continental crust, and its lateral and vertical variations, are essential parameters needed in extracting the geoneutrino signal from the mantle and thereby place constraints on the Earth's present-day radioactive power. K, Th, and U are strongly concentrated in the upper continental crust (UCC) so refining its composition and deriving uncertainties is important to neutrino geoscience.

UCC estimates generally rely on reference suites of shales, pelites, and loess (e.g., Hu and Gao, 2008: HG08). Here we use modern to Archean glacial tills and tillites to determine the average UCC composition through time and then we compare them with HG08. Paleoproterozoic tillites are systematically enriched in transition metals (Sc, Cr, Co, Ni) relative to post-Archean tillites and average UCC, indicating more mafic contribution to the Archean upper crust (as previously documented in shales). However, in contrast to shale data, we find no systematic differences in Th/Sc as a function of age in tillites, implying that Th is not systematically depleted in Archean UCC as sampled by the glaciers. Th/U of the tillites correlates with their age: Th/U ~3 in modern tills, and Carboniferous and Paleoproterozoic tillites, whereas Neoproterozoic tillites and HG08 have Th/U ~6. The high Th/U of the Neoproterozoic tillites can be linked to intense weathering (and U leaching) attending the snowball Earth glaciations. The lack of a significant difference in the abundances of heat producing elements in Archean and post-Archean average UCC may imply that the lower surface heat flow in Archean cratons compared to post-Archean regions may be related to differences in Moho heat flux.

Resolving gas transport through compacted sand/bentonite material by using noble gases

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Gases (hydrogen, methane, carbon dioxide) may accumulate in the emplacement caverns of a geological repository for low/intermediate-level waste due to the corrosion and degradation of the wastes. Nagra is evaluating the concept of an engineered gas transport system (EGTS), aimed at providing an additional transport pathway for gas release if overpressures were to be developed. Gas permeable tunnel seals are among the main design elements of the EGTS, consisting of sand/bentonite (S/B) mixtures with a bentonite content of 20% to 30%.

It is expected that material heterogeneities at repository scales will, at least to some extent, lead to a water saturation and a gas invasion behaviour that differs from those observed in small-scale lab experiments. Past applications of probabilistic two-phase flow models tried to assess the influence of material heterogeneities on water and gas transport in clay material. The models revealed complex two-phase flow patterns during gas imbibition and after gas breakthrough. It is thought that these patterns are mainly driven by the material properties and associated heterogeneity. However, there is little experimental evidence to constrain the large number of possible model realisations.

In 2010, a laboratory column was filled with a S/B mixture (80% sand and 20% MX80 bentonite) and compacted to a density of 1.5 g/cm^3. The column was then saturated with distilled water for a few weeks and a hydro test was performed to determine the hydraulic permeability of the material and to confirm saturation. A gas test was performed by injecting N_2 at increasing pressures until breakthrough. After breakthrough the gas flow was kept constant and the N_2 gas was replaced by a gas mixture (N_2, He, Ar, Xe, SF_6) and the breakthrough pattern of the different gases was monitored continuously using a mass spectrometer. The choice of the gas tracers was made based on their different physical properties – i.e. solubility in water and diffusivity in both gas and liquid phases.

The observed partitioning of the different gas tracers provides unique experimental evidence for the determining the dominating transport processes within the partially saturated material and thus help constrain probabilistic models for two-phase flow and transport through S/B material.

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