Challenges connected with experimental upscaling of flow and transport in porous media

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Column and sandbox experiments have a long and successful tradition in estimating flow and transport parameters of porous media. A recently developed methodology based on the combination of column and sandbox experiments might be even capable for upscaling flow and transport as follows: In a first step, a cubic Darcy cell of 0.1 m x 0.1 m x 0.1 m is used to experimentally estimate flow and transport characteristics of an unconsolidated sediment, means flow and transport is experimentally upscaled from the pore-scale to the 0.1 m- scale. In a second step, the sediment filled Darcy cell is frozen and the frozen sediment cube is extracted from the Darcy cell. In a third step, nine frozen sediment cubes are composed in a sandbox model such that a sediment body of 0.3 m x 0.3 m x 0.1 m is formed. Finally the flow and transport characteristics of the sediment body are estimated based on flow and transport experiments. Such procedure could allow for successive experimental upscaling from the pore- to the 0.1 m- to the 1 m-scale of flow and reactive transport.

First tests of the recently developed setup for experimental upscaling showed that it is feasible to form sediment cubes, extract them from the experimental apparatus and assemble them in a sandbox model. It could also be shown that the developed experimental set up is well suited to study flow and transport in single sediment cubes and sediment bodies consisting of assembled sediment cubes. Our ongoing experiments focus on improving the accuracy of the developed set up. So far, we found hydraulic conductivities (Ks) of fine gravel sediment cubes rather constant, and Ks of coarse and middle sand sediment cubes slightly changing pre- and post freezing. We also found from sandbox experiments that sediment bodies formed based on fine gravel or coarse sand sediment cubes to be rather insensitive, but sediment bodies formed based on middle sand cubes to be prone to the formation of preferential flowpath. Through procedures such like tuning of the sediment structure in sediment cubes and bodies, but also optimized drainage of sediment cubes before freezing, we are confident to enhance the developed methodology to reach an accuracy needed for proper experimental upscaling.

Cretaceous Large Igneous Provinces: the effects of submarine volcanism on calcareous nannoplankton

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During the Cretaceous the construction of Large Igneous Provinces (LIPs), forming gigantic oceanic plateaus, affected ecosystems at global scale. LIP volcanism was coeval with episodes of oxygen depletion in the oceans with consequent burial of massive amounts of organic matter known as Oceanic Anoxic Events (OAEs). Under these conditions, biota were forced to face excess CO_2 and global perturbations in the ocean-atmosphere system.

In the open ocean, coccolithophores are important carbonate rock-forming organisms, extremely sensitive to changes in physical-chemical parameters of surface waters. They are an ideal tracer for detecting the direct/indirect impacts of submarine volcanism on transient responses and evolution of calcifying biota.

We investigated calcareous nannoplankton assemblages across the early Aptian OAE1a and the latest Cenomanian OAE2, associated to the Ontong Java Plateau (OJP) and the Caribbean Plateau (CP), respectively. Massive submarine volcanism of OJP triggered a disruption in the oceanic carbonate system: excess CO_2 arguably induced ocean acidification that was detrimental to marine calcifiers, with temporary failure, but no extinctions, of rock-forming nannoconids and production of dwarf and malformed coccoliths. Similarly, during OAE2 the excess CO_2 from CP volcanism affected nannoplankton calcification inducing some coccolith dwarfism. Hydrothermal plumes during construction of both OJP and CP introduced biolimiting metals that fertilized the global ocean. However, some toxic metals might have disturbed the functioning of some intolerant coccolithophorid species.

There is a causal link between intervals of LIP submarine volcanism and changes in nannoplankton composition, abundance and biocalcification through OAE1a and OAE2. Changes in ocean chemistry, structure, and fertility during formation of oceanic plateaus might explain observed tempo and mode of nannoplankton evolution: major origination episodes might result from magmas especially enriched in biogeochemically important elements from the mantle.

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