Contribution ID : **23** Type : **Poster**

Small and ultra small angle neutron scattering is useful for porosity analysis in fossil coral reef core

Monday, 4 November 2024 19:55 (20)

Small-angle neutron scattering (SANS) and ultra-small-angle neutron scattering (USANS) are useful methods that have been employed in many fields to investigate the micro-porous structure of rocks, ceramics, metals, polymers and even foods. These techniques provide statistical information on the distribution and structure of pores in a given sample from < 1 nm to ca. 60 μm (depending on the specific instrument). Neutrons with wavelengths typically in the 2 - 10 μm range are transmitted through a material non-destructively and the resultant scattering pattern generated by the interaction of the incident radiation with nano or micro-structures within the material: in 2D for SANS and smeared 1D for USANS. The intensity of the scattering depends on the number of scatterers at a given scale and the contrast between the solid matrix and whatever fills the pores (i.e., air, water, oil etc), and the scattering angle is given by Bragg's law. In this presentation the scattering contrast is compared to results at the micron to cm scale from previously measured fossil coral reef cores. This provides unique data for coral reef science due to the scale of measurement, the size of sample required, and the information that can be obtained. To date, however, this approach has not been applied to reefal limestones. This study, therefore, employed SANS and USANS to investigate porosity variations and nano-structural histories across two coral reef platforms: one from NW Australia and one from NE Australia of fossil coral reef core from the Mid Pleistocene Transition (MPT) ca. 0.8 Ma to the present. The porosity and pore anisotropy observed is a result of mechanical compaction caused by large-scale tectonic forces and gravitational loading by overlying sediments. By modelling the (U)SANS data, and comparing them to SEM images, we explore variations in compaction rates between these two coral reefs. Changes in pores sizes in sedimentary rocks due to heat stress and gravitational loading often first occur in the nano-fabric. Phase transformations produce micro-cracks that act as early fluid pathways. (U)SANS data can, therefore, contribute to the identification of diagenetic alteration in fossil coral reefs by assessing changes. Nano-scale identification of early alteration may help to avoid common pitfalls in coral reef age dating and contribute to understanding early structural and phase changes in reef mineralogy. Our data also show how the nanostructure of fossil coral reef material likely altered the rate of replacement of aragonite by calcite. Using these data, this study attempted to interpret the sea level history and episodes of subaerial exposure of carbonate platforms by analysing the variation in nano-porosity from the two boreholes. However, we determined that, for this to work, comparable samples of the same coral reef species must be available as a function of depth. We, therefore, here outline a method tailored to (U)SANS analysis of nanoscale mineral and porosity alteration of fossil coral reef materials to screen samples for age dating and subsidence rate and sea level history reconstruction.

Topics

Neutron Instruments and Techniques

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Session Classification : Posters