

## Analysis of nano-porosity in the St. Peter Sandstone Using (Ultra) Small Angle Neutron Scattering

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The evolution of porosity in time and space plays a critical role in many geologic processes. While this has long been recognized, the importance of nano-scale porosity has only recently begun to be understood. Such pores may act as throats, constraining overall flow, and confinement effects dramatically alter fluid thermodynamics in micropores, and thus rates and equilibria of local reaction processes. Small- and Ultra-Small Angle Neutron Scattering (SANS and USANS) provide powerful tools for quantitative analysis of porous rocks, yielding bulk statistical information over a wide range of length scales. Scattering contrast arises from the difference in scattering length density between the rock and the pores, and (U)SANS data show that pore-grain interfaces and structures are often best described as surface and mass fractals [1]. Understanding the evolution of these variables provides an important key to deciphering geologic processes.

In this study we used (U)SANS to characterize shallowly buried quartz arenites from the St. Peter Sandstone. Backscattered electron imaging was also used to extend the data to larger scales. These samples contain significant volumes of large-scale porosity, modified by quartz overgrowths, and neutron scattering results show significant sub-micron porosity. While previous scattering data from sandstones suggest scattering is dominated by surface fractal behavior over many orders of magnitude, careful analysis of our data shows both fractal and pseudo-fractal behavior. The scattering curves are composed of subtle steps, modeled as polydispersed assemblages of pores with log-normal distributions. However, in some samples an additional surface-fractal overprint is present, while in others there is no such structure, and scattering can be explained by summation of non-fractal structures. Combined with our work on other rock-types, these data suggest that microporosity is more prevalent, and may play a much more important role than previously thought in fluid/rock interactions.

[1] Anovitz *et al.* (2009) *GCA* **73**, 7303–7324.

## Oxygen isotope and cation chemistry: Evidence of multiple water sources influencing the alteration of Antarctic hyaloclastites

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Minna Bluff is a 45 km-long, up to 1100 meter-high volcanic peninsula in the southern Ross Sea, Antarctica. Thick successions of interbedded lavas, volcanic sediments, hyaloclastite breccias and evidence of glaciation were emplaced between 11.8 and 6.2 Ma [1]. ANDRILL core sediments of this age show evidence of cyclical changes in the Ross Ice Sheet [2].

Water-quenched hyaloclastites exhibit primary and secondary carbonate and zeolite alteration in vesicles, vugs, veins and interclast voids. Carbonates consist of complexly zoned calcite, dolomite and magnesite. Zeolites include phillipsite and chabazite. Their high cation ratios (Na+K/Ca) suggest marine water influence [3].  $\delta^{18}\text{O}_{\text{PDB}}$  values of carbonates show a wide range (-9.1 to -30.4‰). Using a conservative  $\leq 50^\circ\text{C}$  estimate for carbonate formation, the calculated  $\delta^{18}\text{O}$  for water in equilibrium ranges from -4 to -35‰. Overall,  $\delta^{18}\text{O}_{\text{water}}$  becomes lighter with elevation and age towards the top of the volcanic sequence. In some samples, carbonates in veins are lighter relative to those in vugs and vesicles. Increases in dolomite Mg/Ca ratios correlate with less depleted  $\delta^{18}\text{O}_{\text{dolomite}}$  values. Results suggest that seawater, meteoric water, and potentially, hydrothermal brines all influenced multiple episodes of hyaloclastite alteration.

[1] Wilch *et al.* (2008) *Eos Trans AGU* **89**(53). [2] Naish *et al.* (2007) *Terra Antarctica* **14**(3) 317–327. [3] Johnson & Smellie (2007) *Geochem. Geophys. Geosyst.* **8**(3), 1–19.