In-situ geochemical characterization of experimental partial melts

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Understanding partial melting of ancient gneiss terranes is crucial when considering crustal contamination in volcanic systems, for example, as these rocks are unlikely to melt completely at magmatic temperatures (900-1200 °C) and crustal pressures (<500 MPa). Variations in the bulk composition of the protolith, magma temperature, pressure (depth), the composition and abundance of any fluids present will produce a variety of melt compositions. This may range from partial melts enriched in incompatible elements to more complete melts, nearing the bulk chemistry of the parent gneiss.

We have used piston cylinder experiments to simulate partial melting in a suite of 10 gneisses from NW Scotland and Eastern Greenland at magma chamber temperatures and pressures (P = 200 MPa, T = 975 °C). These gneisses form the basement to much of the North Atlantic Igneous Province, where crustal contamination is frequently identified. However, the actual compositions of the crustal partial melts are poorly constrained. Partial melts were produced in all 10 experiments. The experimental charges were quenched so that partial melts were preserved as glass, making them suitable for in-situ microanalysis. Electron microprobe spot analyses of the glasses indicate they are compositionally heterogeneous and are significantly different to the bulk chemistry of the parent gneisses. The samples were mapped using energy-dispersive x-ray spectroscopy (EDX), which deciphered the spatial variation in melt chemistry and revealed evidence of intense mixing and mingling processes. Individual melt domains were microdrilled for Sr and Pb isotope ratios.

This novel petrological, experimental and in-situ geochemical approach allows quantification of partial melting in a volcanic context, providing accurate geochemical end-members for modelling crustal contamination processes.

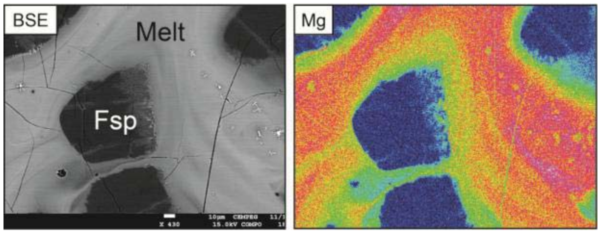

Figure 1: BSE image and EDX map of a partial melting experiment showing heterogeneous composition and mixing/mingling textures. Images and analyses were collected using the FE-EPMA facility at Uppsala University (http://www.geo.uu.se/mpt).

Pumping away: Impact of benthic macrofauna on flow, redox dynamics and sediment N cycling

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Burrowing organisms have long been recognized to play a major role in biogeochemical cycling in aquatic sediments. However, only recently have advances in sensor developments and computational capabilities provided the opportunity to detail the flow dynamics and oscillatory redox conditions driven by the pumping activity of benthic infauna. Here we present a coupled flow-reaction model analysis linked to observations in experimental microcosms.

While volumetric pumping rates are fairly well known and experimentally accessible, flow patterns in the subsurface are not. However, they are important to quantify location and extent of oxic-anoxic interfaces which are critical in determining the biogeochemical cycling of redox sensitive elements. We present the determination of such velocity fields using optical flow anlysis of fluorescent dye tracers in antfarm experiments.

Our work then focuses on the role of burrowing organisms on O_2 dynamics and nitrogen cycling in coastal sediment. We will present model analyses of the impacts of burrowing depth, irrigation intensity and activity patterns. Our results show a distinct role for all these factors on denitrification. Model simulations show a significant impact of volumetric water exchange on areal denitrifaction; notably, they also predict a different trajectory of total denitrification with increasing burrow depth for continuous vs. episodic biologically induced flow.

Our findings have significant implications for removal of N from shallow water environments, and the controls thereof. Initial results suggest that nitrate removal is controlled not only by spatial structuring of the sediment (e.g. concentration gradients), but also by temporal dynamics (duration and frequency) of anoxic conditions forming in the sediment domain. Our findings also suggest that bioirrigation models which depict organism activity as an averaged continuous, unidirectional process miss the temporally dynamic character of biologically active sediments that may profoundly affect sediment nitrogen cycling.