The mechanisms of hydrothermal faulting, fluid-rock interactions and fluid flow in the Wadi Gideah crustal section of the Samail ophiolite, Oman

Supervisors: Dr Elisabetta Mariani (SOES); Dr Karl Dawson (School of Engineering)

External supervisors and institution: Prof. Laura Crispini, University of Genova (IT); Prof. Damon Teagle, University of Southampton (UK)

Primary Contact Name and Email: Dr Elisabetta Mariani, mariani@liverpool.ac.uk

Introduction:

The Samail ophiolite in Oman is the greatest section of oceanic lithosphere exposed on land and its characteristic sequence of mantle peridotites, cumulate gabbros, sheeted dikes, lavas and continuous layers of sediments is comparable to rock sequences found at fast-spreading mid-ocean ridges (Nicolas et al. 2000). Through the years, this has motivated numerous scientists to work in the natural laboratory of the Samail ophiolite in order to test some of the key hypothesis proposed for spreading systems. Considerable progress has been made, however a number of important questions remain unanswered (e.g. Kelemen et al. 2013). Despite ongoing discussions, the processes that control transport of heat and mass from the mantle to the Earth's surface into the oceans, and their interplay, are not yet understood. Hydrothermal faults in the lower oceanic crust, their history and timing in relation to the gabbro host-rock and to later, shallower structures, and fluid-rock interactions at these sites (mechanical and chemical) are all factors that influence and feed back into the pathways of fluids, and therefore into cooling processes at spreading centres (Coogan et al. 2006). To test hypotheses at the cutting edge of research, including the factors highlighted above, the Oman Drilling Project (OmanDP) initiative (www.omandrilling.ac.uk), funded by the International Continental Scientific Drilling Program (ICDP) and numerous partner, is currently drilling in the deserts of Oman to core and geophysically log key sections of the Samail ophiolite (Kelemen et al. 2013). In the Wadi Gideah area two boreholes, through the gabbros of the middle and lower crust and a major hydrothermal fault zone, have been successfully completed yielding >800 m of core. This represents an excellent, continuous and well preserved section, unaffected by present day surface weathering, into the lower oceanic crust and into the lower reaches of an ocean floor hydrothermal system. Carefully selected samples from this core give us the unique opportunity to study and unravel the mechanical and chemical processes on hydrothermal faults, their timing and the implications for fluid flow.

Project Summary (max 700 words inc introduction):

This project will entail: 1) structural and petrologic characterisation of the brittle structures described and sampled by L.C. (University of Genova) from the OmanDP drill core, from the Samail ophiolite, during the logging operations of July-August2017, 2) this will be integrated with extensive laboratory analyses using complex techniques at the cutting edge of research (these are detailed below), 3) detailed fieldwork in the Wadi Gideah area of Oman, focussed on hydrothermal faults at scales of mm to 10s of m to compare with core samples and fill the scale gap with microstructures studied in the laboratory.
Specific objectives are:

- To map all brittle fault lithologies (gouges, cataclasites, breccias, veins, pseudotachylytes if present) and their microstructures at the nano- to meso-scales and determine spatial and temporal relationships between them and with the host-rock;

- To determine spatially resolved and bulk rock mineralogies and micro-chemistry as well as ppm chemical variations in fault rocks and the host-rock, for a full characterisation of hydrothermal alteration processes and their conditions and timing;
- To establish the importance of viscous microstructures and their chemical, spatial and temporal relationships with the host-rock and the brittle (frictional) microstructures identified. This will allow us to characterise the frictional-viscous (also known as brittle-ductile) transition if present in this hydrothermal fault system;
- To determine which structures and alterations may be associated with ocean detachment faulting versus obduction or more recent uplift-related deformations.

Structural and petrologic investigations at the macro- and micro-scale (University of Genova) will be combined with the analysis of selected samples using the EBSD/EDS SEM systems in Liverpool, to quantify fabrics, textures, chemical changes, and their spatial and temporal relationships. Fine grained samples will be studied using FIB-SEM equipped for 3D EBSD and EDS, and TEM.

Minerals from specific phases of deformation and hydrothermal alteration will be separated or analysed in situ for elemental concentrations and stable (D, O, C, S) and Sr-isotopic compositions, using mass spectrometry in Southampton, to determine the physical conditions and fluid chemistries, as well as the time of deformation and fluid flow.

The correlation and interpretation of all data will provide the framework upon which the hydrothermal fault system history will be reconstructed.

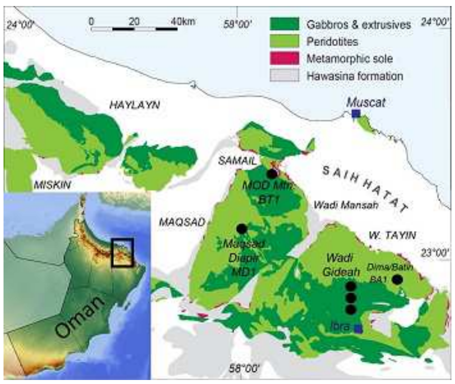

Image 1 - Geological map of the Samail ophiolite, Oman (after Nicolas and Boudier 2000). Black dots show drill site locations.

Image 2 - Breccia and localised zone of shear from core recovered during the ongoing Oman Drilling Project operations.

References

Coogan, L. A., et al. (2006). "Chemical and thermal constraints on focussed fluid flow in the lower oceanic crust." American Journal of Science **306**(6): 389-427.

Kelemen, P., et al. (2013). "Scientific drilling and related research in the samail ophiolite, sultanate of Oman." Scientific Drilling(15): 64-71.

Nicolas, A. and F. Boudier (2000). " Large Mantle Upwellings and Related Crustal Thickness in the Oman Ophiolite." Geological Society of America Bulletin **Special Paper 349**.

Nicolas, A., et al. (2000). "Accretion of Oman and United Arab Emirates ophiolite - Discussion of a new structural map." Marine Geophysical Researches **21**(3-4): 147-179.