Seafloor Massive Sulphides: their post-formational fate

Lead supervisor: Professor Crispin Little, School of Earth and Environment, University of Leeds

Co-supervisors: Professor Christopher MacLeod, School of Earth and Environmental Sciences, Cardiff University; Dr Taija Torvela, University of Leeds

Project Highlights:

- Seafloor Massive Sulphides as a minerals resource
- Oxidative seafloor weathering as a process for the enrichment or loss of elements of economic interest
- Microbial interaction with Seafloor Massive Sulphides

Overview:

Hydrothermal seafloor massive sulphide (SMS) deposits are formed by seawater circulating through the hot rocks beneath the ocean floor at mid-ocean ridges, where they strip out various elements, particularly metals, which are then deposited at the seabed as they emerge and cool at hot water vent systems (Figure 1, top left). SMS are rich in minerals containing iron, copper and zinc, and also more valuable elements, such as gold, nickel and cobalt. As such they are potential targets for future seafloor mining activities. Active hydrothermal vents are widely spaced along active spreading ridges (kilometres to 100s of kilometres), but exploration has found that inactive (or extinct) seafloor massive sulphides are at least ten times more abundant on the seafloor. Both active and inactive SMS are affected by submarine weathering and alteration, largely through the interaction of oxygenated seawater. As oxidation penetrates an SMS deposit, copper and other base metals are re-mobilised, concentrated, and then re-precipitated at depth within the deposit. At the same time, supergene processes in the upper parts of the SMS also yield extreme enrichment of precious metals (including gold) in the altered zones, called gossans. Gossan are largely formed of insoluble oxides and oxyhydroxides of iron (Figure 1, top right, bottom left), which have a high adsorptive capacity economic elements, scavenged from seawater and pore fluids. Active and inactive SMS are host to abundant and diverse microbial communities, the activities of which may speed up the oxidative processes identified above, and also release precious metals such as gold and silver from their host minerals, leading to enrichment in the gossans.

Although the oxidative processes involved in the oxidative seafloor weathering of SMS are moderately well understood, the rates of weathering and the microbial involvement are not. In order to explore these issues an experiment was undertaken as part of the ULTRA project, where six replicate devices was deployed at active and inactive vent sites at the Semyenov Hydrothermal Field at the Mid-Atlantic Ridge (Figure 1, bottom right). These devices contained 45 resin blocks with pieces of polished sulphide minerals (Figure 2, left). After 18 months on the seafloor the devices were recovered, and preliminary observations show that there has been differential effects on the sulphide minerals (Figure 2, right). These polished blocks now await detailed study.

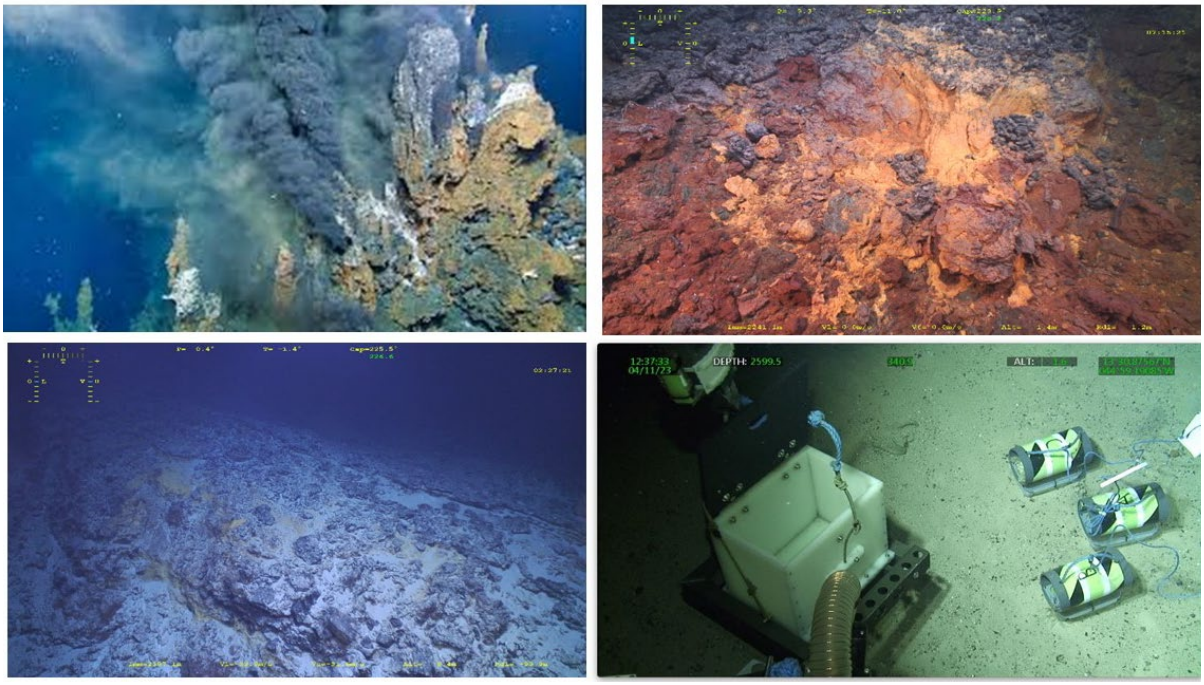

Figure 1: Top left, an active hydrothermal vent chimney complex (Okinawa Institute of Science and Technology). Top right and bottom left, inactive SMS, 14°N, Mid-Atlantic Ridge. Bottom right, experimental devices about to be recovered using a Remotely Operated Vehicle, from 2,400 metres water depth, 13°30'N, Mid-Atlantic Ridge, October 2023.

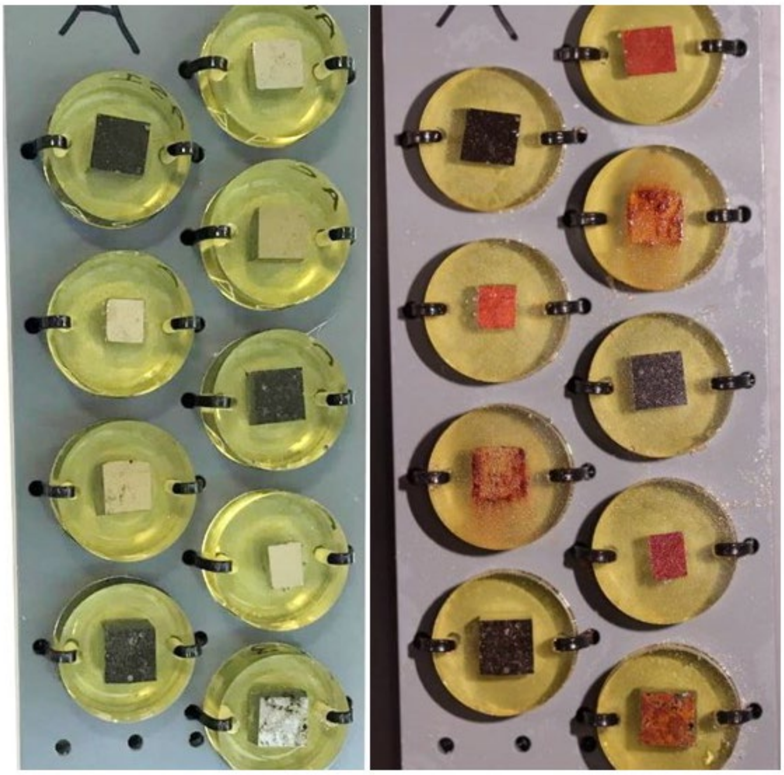

Figure 2: Left, resin blocks containing polished sulphides prior to seafloor deployment; from the top pyrite, sphalerite, chalcopyrite, repeated twice. Right, same resin blocks after 18 months on the seafloor, with chalcopyrites being considerably decayed and pyrites with a red oxidative layer; in contrast, sphalerites appear little altered.

Methodology:

The 45 polished blocks with the replicate sulphide minerals will be studied using a variety of microanalytical techniques to investigate the following questions:

1. How has the original sulphide mineralogy controlled the type and rate of oxidative weathering?
2. Have elements be concentrated or lost during the weathering process?
3. Is there a difference in the weathering types and rates between active and inactive vent sites?
4. Is there a microbial component to the sulphide weathering?

The techniques to be used will be Scanning Electron Microscopy (SEM), linked to Energy Dispersive Spectroscopy (EDS), and Electron Probe Micro Analyzer at the University of Leeds (LEMAS), and Analytical SEM and Laser Ablation ICP-MS at Cardiff University. Results from these analyses will be compared to mineralogical and textural data gained from nature seafloor sulphide samples from SMS, and lab-based oxidative experiments from the ULTRA project.

Possible Timeline

Year 1: Characterization of sulphide minerals in polished blocks at LEMAS, University of Leeds, including training in microanalytical techniques, and selection of samples for additional analysis at Cardiff.

Year 2: Continued data collection at Leeds and Cardiff; presentation of preliminary results at scientific conferences.

Year 3: Interpretation of collected data and comparison with results from analyses of natural seafloor samples and experimental materials; presentation of results at scientific conferences; preparation of scientific papers; writing PhD thesis.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- An annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences;
- use of microanalytical equipment (SEM, EDS, Microprobe, LA-ICP-MS) to generate qualitative and quantitative mineralogical data, and interpretation and visualization of that data.

Partners and collaboration (including CASE):

In addition to the Leeds supervision, the student will have regular contact with Professor MacLeod in the first year of study, mostly though virtual progress meetings. In their second year they will have a number of visits to Cardiff for training and to collect data using the analytical equipment there (see methodology). In their third year the student will have regular virtual meetings with Professor MacLeod as part of the supervisory team to discuss the use and significance of the collected data.

Further reading:

ULTRA project https://project-ultra.org/

Seafloor Massive Sulphides https://www.geomar.de/en/research/marine-resources/mmr/mineral-resources-2-1

Edwards, K. J., T. M. McCollom, H. Konishi, and P. R. Buseck. 2003. Seafloor bioalteration of sulphide minerals: results from in-situ incubation studies. Geochim. Cosmochim. Acta 67:2843–2856.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

Professor Crispin Little (https://environment.leeds.ac.uk/see/staff/1380/crispin-little)

Dr Taija Torvela, University of Leeds t.m.torvela@leeds.ac.uk

Professor Christopher MacLeod (https://profiles.cardiff.ac.uk/staff/macleod)

Leeds electron microscopy and spectroscopy centre (https://eps.leeds.ac.uk/chemical-engineering/dir-record/facilities/3865/leeds-electron-microscopy-and-spectroscopy-centre)