IODP³ INTERNATIONAL OCEAN DRILLING PROGRAMME

PROPOSAL 1108-S

MEtal and Sulfur fluxes during Margin Evolution: from RIdge to Continent (MESMERIC)

IODP^3 Proposal Cover Sheet

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Project Abstract

Continental breakup and ocean opening are fundamental processes of the Earth system. They involve progressive thinning of the continental crust, upwelling of asthenospheric mantle and ultimately lead to the formation of new oceanic crust. Throughout this evolution a tight interplay occurs between tectonism, magmatism, sedimentation and hydrothermal fluid circulation, driving extensive geochemical exchanges between the asthenosphere, lithosphere, hydrosphere and biosphere. These geochemical fluxes at margins are closely intertwined with ore-forming processes and the S cycle. However, margins are highly diverse and complex, being classified as magma-poor, intermediate or magma-rich. Despite their global significance, the magnitude and nature of large-scale geochemical fluxes at margins remain poorly constrained. Fortunately, geological material recovered by the DSDP, ODP and IODP programs from numerous deep drill cores at continental margins provides unique insight and opportunity to understand geochemical fluxes at margins. With the MESMERIC project we want to re-investigate 20 legacy drill cores from: 1) the West Iberian margin and the conjugate Newfoundland margin, representative of magma-poor margins, 2) the South China Sea and the Red Sea margins, representative of intermediate margins, and 3) the Norwegian margin, representative of magma-rich margins. Study of deep drill cores at these margins will allow to gain in-depth insights into the geochemical fluxes of metals (Cu, Zn, Pb, Ni, Co, Au, Ag, Mo, As, Sb, Ge, Ga, In, Se, Te, Bi) and S at margins, especially across the basement-sedimentary interface, which has been little studied so far in this regard. The MESMERIC project focuses on three main research axes: 1) metal fluxes during margin evolution and the link to ore deposit formation, including Zn-Pb clastic dominated deposits, ultramafic-hosted volcanogenic massive sulfide (VMS) deposits and native Cu deposits, 2) S cycling throughout margin evolutions and the link to ore deposits, bacterial activity and biogenic-abiogenic sulfate-methane reactions, and 3) fluid-rock interactions and associated hydrothermal alterations. The approach of the MESMERIC project is multi-scale and multi-disciplinary combining geochemistry, tectonics, petrology, sedimentology, mineralogy, structural geology, hydrothermalism, geophysics, statistics and ore geology. Combination of state-of-the-art nondestructive and partly destructive methods will allow us to build a unique large database on metal and S concentration and speciation at margins. The project outcomes and deliverables will provide a unique holistic overview of large-scale processes associated with ore deposit formation as well as in-depth understanding of the S cycle at margins.

Scientific Objectives

Three main science objectives are defined in the MESMERIC project. First, **the metal fluxes during margin evolution and the link to ore deposit formation** . Margins are well-endowed in mineral resources and host diverse types of ore deposits including Pb-Zn clastic-dominated deposits, ultramafic-hosted volcanogenic massive sulfide deposits and the still poorly known native Cu deposits. Objective 1 will provide a holistic understanding of the mineral systems at crustal-scale which is still lacking within the frame of dynamic and evolving margin environments.

Second, **the S cycle at margins and the link to ore deposits, methane oxidation and bacterial activity** . Sulfur plays a paramount role in the formation of numerous ore deposits from the source to the sink. Additionally S buffers methane emissions from the seafloor via methane oxidation and sulfate reduction. Finally, microbial activity involving S-redox reactions and related to both ore-forming processes and methane oxidation, is common at margins. Objective 2 will provide a comprehensive understanding of the S cycle at margins.

Objective 3 focuses on **the hydrothermal alteration at margins and the link to the mobilization of metals and S** . Active hydrothermal fluid circulation at margins leads to widespread fluid-rock interactions. This results in extensive chemical and physical changes of both fluids and rocks recorded mainly as alteration zones in rocks. They provide evidences for the geochemical fluxes between the hydrosphere, lithosphere and asthenosphere. Hydrothermal alterations are extremely diverse, both in style and intensity.

Science Communication Plain Language Summary

The breakup of continents is a crucial step of tectonic plate evolution. During this geological process numerous and diverse types of ore deposit form. These deposits are enriched in a large suite of metals, such as copper, zinc, cobalt and nickel, which are needed for the energy transition away from fossil fuel. Additionally, the behavior of the element sulfur during continental breakup, known as the sulfur cycle, is extremely important. It is tightly linked to ore deposit formation, to life development deep in the Earth’s crust thanks to bacterial activity, and to oxidation and neutralization of methane, a potent greenhouse gas, emitted from the Earth’s crust.

In this project we look at rocks and sediments from the edges of continents to see how metals and sulfur move during continental breakup. When continents stretch and split, the tectonic movements, magma generation and sedimentary build-up drive fluid circulation and chemical exchanges between the mantle, the crust, the hydrosphere and the biosphere. Although this circulation is closely related to the formation of ore deposits and the global sulfur cycle, its diversity and magnitude at the margins of continents is yet poorly constrained. The deep drill cores collected by IODP programs provide crucial insights for understanding the mobility and behavior of metals and sulfur during continental breakup. The MESMERIC project aims at investigating 20 legacy deep drill cores form five key localities: the West Iberian, Newfoundland, South China Sea, Red Sea and Norwegian continental margins.

The project studies first on the distribution and behavior of metals during continent breakup and the link to the formation of ore deposits. Then, specific focus will be given to the sulfur cycle during continent breakup and its link to ore deposits, bacterial activity and methane oxidation. Finally, the interactions between fluids and rocks will be investigated for understanding chemical and mineralogical modifications associated with metal and sulfur mobility.

The MESMERIC project employs a multi-scale and multi-disciplinary approach combining expertise from geochemistry, tectonics, petrology, sedimentology, mineralogy, structural geology, hydrothermalism, geophysics, statistics and ore geology. We will use state-of-the-art methods that preserve legacy cores as much as possible allowing to build a unique large database on metal and sulfur concentration and chemical species at margins.