Sources of reduced sulfur, early diagenesis, and fine laminae in the currently forming metalliferous sediment of the brine-covered Atlantis II Deep, Red Sea*

Corresponding author: Tea E. Laurila, 1) University of Ottawa, 2) Geomar - Helmholtz Centre for Ocean Research Kiel, laurilatea@gmail.com

Co-authors:
Mark D Hannington, 1) University of Ottawa 2) GEOMAR - Helmholtz Centre for Ocean Research Kiel, mark.hannington@uottawa.ca
Sven Petersen, GEOMAR Helmholtz Centre for Ocean Research Kiel, spetersen@geomar.de
Colin W. Devey, GEOMAR - Helmholtz Centre for Ocean Research Kiel, cdevey@geomar.de
Matthew Leybourne, ALS Geochemistry, Matthew.Leybourne@alsglobal.com
Dieter Garbe-Schönberg, Christian-Albrechts-Universität zu Kiel, dgs@gpi.uni-kiel.de
Simon Jost, GEOMAR - Helmholtz Centre for Ocean Research Kiel, sjost@geomar.de

The Atlantis II Deep is the only location on the modern seafloor where active formation of a stratiform ore deposit can be studied. Hydrothermal venting is localized in a brine pool that efficiently caps the system, causing most of the hydrothermal products to be deposited within the brine covered area, and resulting in the accumulation of 90 Mt of ore material. The high salinity in the brine pool (~28 wt.% NaCl) is due to dissolution of evaporites that outcrop on the flanks of the Atlantis II Deep. The hydrothermal fluids (up to 400°C) are also highly saline (15-32 wt.% NaCl) and contain >10 times more metal than sulfur on a molar basis. The brine pool is close to saturation with many metals, but devoid of reduced sulfur. Significant metal deposition in the brine pool results from precipitation with bacteriogenic sulfide or via adsorption onto surface active particles. This is a unique situation among modern seafloor hydrothermal systems but is interpreted to have been important in a number of ancient ore-forming systems (e.g., some ancient stratiform ore deposits including BIF, VMS, SEDEX and non-sulfide Zn-deposits).

The chemical variation in major and trace elements between individual laminae (representing ~annual precipitation) can be 100-fold and cannot be explained by large-scale changes in the configuration of the brine pool that have been responsible for the deposition of different stratigraphic units (1-12 m thick). As expected, proximal to the vents, hydrothermal sulfide (sphalerite and chalcopyrite) dominate, whereas distal to the vents bacteriogenic sulfide and pyrite are more common. High rates of Cu precipitation (as sulfide) occur during vigorous hydrothermal activity, when reduced sulfur is introduced into the brine pool; high rates of Zn precipitation (mainly by adsorption onto surface-active particles) occur during lower hydrothermal activity. Cu-sulfides also form by reaction with sulfide produced by bacteriogenic sulfate reduction at the chemocline overlying the brine pool. This precipitation accounts for a minor amount of total sulfide deposition, but causes the Cu/Zn ratio to increase away from the vent source. The chemocline also marks significant increase in oxygen content, which causes iron to precipitate as Fe-(oxy)hydroxides. During deposition Fe-(oxy)hydroxides adsorb metals, especially Zn, Cd, Ag, and Hg. Absorptive metal-deposition is most important in proximity to the known venting. During diagenesis the crystallinity of the deposited minerals increases, enhancing the fine lamination of the sediments, and metals that were deposited by adsorption onto surface-active particles are incorporated in sulfides, but also carbonates and clays. Mineral textures resulting from early
diagenesis (<5,000 yr), such as trace metal-enriched rims around pyrite, resemble those described in many ancient stratiform ore deposits that are also interpreted to have formed during diagenesis.