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Discovery of high-temperature hydrothermal mineralization at Hatiba Mons volcano in the Red Sea

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Hatiba Mons, the largest axial volcano in the ultra-slow spreading Red Sea rift, hosts extensive hydrothermal activity discovered in 2022, expressed as widespread iron-rich mounds. In 2023 we examined some of these vent fields using ROV surveys and gravity coring, discovering the first massive sphalerite ± barite samples in the Red Sea underneath a metalliferous sediment cover. A multidisciplinary approach characterized the geochemical and mineralogical features of the system and integrated these with microbiological and pore-fluid analyses. Metagenomic analyses and scanning electron microscopy are used to determine whether microbial communities actively contribute to the formation, alteration or degradation of mineral deposits. Pore-fluid chemistry further constrains mound evolution and internal chemical heterogeneity.

This study presents the first detailed characterization of an active high-temperature mound-style hydrothermal system in the Red Sea. This is in contrast to the common metalliferous brine pools in basins such as those of the Atlantis-II Deep, which hosts the largest known hydrothermal metal deposit on the present-day seafloor. Although the mineralization at Hatiba Mons resembles basalt-hosted mid-ocean ridge deposits, hydrothermal circulation is strongly influenced by nearby Miocene evaporites. Brine-filled depressions at the volcano summit and near-halite-saturation fluid inclusions in barite indicate an evaporite-derived fluid component that enhances metal solubility, transport and precipitation, producing anomalously high Cd and Sb concentrations. Mineral paragenesis and microthermometry suggest a waning hydrothermal system that previously operated at 250-300°C despite recent in-situ temperatures of only 31-51°C. Sulfur isotope measurements indicate a strong contribution of seawater sulfur to the mound-style mineralization. The high-temperature mineralization at Hatiba Mons demonstrates that hydrothermal processes in the Red Sea are broadly comparable to other mid-ocean ridges. High fluid salinities at Hatiba Mons, however, indicate a geological setting of venting hot brines producing massive sulfides that has previously not been recognized in modern seafloor hydrothermal systems, yet is well documented in ancient volcanogenic massive sulfide (VMS) deposits.

Overall, these results advance our understanding of marine ore-forming processes, the life cycles of hydrothermal systems, and their geochemical and microbial implications, while emphasizing the Red Sea as a key target for further exploration of high-temperature vents and sulfide occurrences.