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Volcanic, CO_2-rich Brines in the Red Sea: Discovery of a Hydrothermal Endmember?

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Brine pools are among the most enigmatic and extreme environments in the deep sea, forming isolated, pycnoclinic water bodies characterized by hypersalinity, anoxia, and unique geochemical signatures. They represent natural laboratories for studying biogeochemical cycles, microbial extremophiles, and metalliferous sediment deposition. The Red Sea, a young ocean basin with its crust partially covered by thick Miocene evaporite sequences, hosts numerous deep-sea brines. While hydrothermal fluid input was recognized as an important contributor in several of the brines, e.g., at Atlantis II Deep, all these brines are close to evaporite deposits and are thought to result mainly from evaporite dissolution. In contrast, new data from recent expeditions to the Hatiba Mons and Mabahiss Mons volcanoes in the Red Sea revealed a previously unrecognized class of brine pools not associated with evaporites nearby. Unlike the other, well-studied brines that accumulate in deep rift depressions, these newly discovered brine pools are found at the summit areas of axial volcanoes, up to 1000 m above the surrounding seafloor at >5 km distance from the evaporites. AUV, ROV and CTD-based observations indicate that these pools directly emanate from the volcanic substrate and are closely related to hydrothermal vents that emit low-temperature fluids (60°C). Like the vents, the brines host abundant microbial communities. Further, they have a high CO_2 saturation, elevated temperatures, and distinct chemical compositions, indicating they represent a volcanic hydrothermal endmember within the spectrum of Red Sea brines. Our findings represent the first direct evidence of hypersaline gas-rich seafloor ponds produced by volcanic venting, shedding light on a previously unobserved mechanism of brine formation. This discovery has important implications for understanding the role of hydrothermalism in the global carbon cycle and for CO_2 sequestration in deep-sea environments. The presence of microbial communities further underscores the importance of brines for deep-sea biotechnology and for understanding life in extreme environments such as Earth's early oceans and extraterrestrial oceans. These results redefine our understanding of hydrothermal processes in active rift settings and provide a new perspective on the formation and evolution of deep-sea brines that may be more diverse and dynamic than previously thought.