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Transformation of seawater into high-temperature hydrothermal fluids in an arc setting: evidence from Montserrat, Lesser Antilles

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Montserrat is an active andesitic island arc volcano in the Lesser Antilles, where recent geothermal exploration has drilled to ~2.5-3 km depth and encountered temperatures up to ~240 °C. Owing to its island setting, the system provides an opportunity to evaluate how infiltrating seawater is transformed into high-temperature geothermal fluid through magmatic gas input and water-rock interaction.

Hydrothermal reservoir fluids at depth are characterized by high salinity slightly above local seawater, indicating a dominantly seawater-derived parent fluid. However, major element systematics demonstrate substantial chemical modification. Compared to seawater, the hydrothermal fluids are strongly depleted in Mg and SO_4, consistent formation of Mg silicates and anhydrite. In contrast, Ca, K, and Si are markedly enriched, reflecting extensive silicate alteration and feldspar-chlorite-epidote buffering at depth. Sodium concentrations remain close to seawater values, suggesting partial control by residual seawater composition and possible albitization reactions. Moreover, the fluids are mildly acidic at *in-situ* conditions (pH ~4-5) and associated with CO_2-rich vapor consistent with a significant magmatic carbon contribution based on carbon isotope composition. Despite sulfate depletion, H_2S concentrations in vapor are modest, indicating redox conditions distinct from typical basalt-hosted seawater systems and potential magma gas addition.

Overall, the Montserrat hydrothermal fluids record progressive transformation of seawater by near-complete Mg and SO_4 removal and strong Ca-K-Si enrichment via high-temperature water-rock interaction, and acidification and carbon and sulfur addition from magmatic gases. These results highlight the contrasting evolution of arc-hosted seawater-derived systems relative to mid-ocean ridge analogues and constrain fluid-rock-gas interaction in subduction-related geothermal environments.