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The Yellowstone Hydrothermal System Reacting to Mantle Plume Progression

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More than 10,000 hot springs discharge from the Yellowstone caldera vapor-dominated hydrothermal system. Acid sulfate springs are dominant to the northeast and extend beyond the caldera margin, and circumneutral alkali chloride springs are concentrated in the southwestern half of the caldera. The 0.63 Ma caldera formed by eruption of the high-silica Lava Creek Tuff. Mantle basalts related to the Yellowstone-Snake River Plain hotspot (2.27 cm/yr) intrude the crust and provided the heat that creats the rhyolitic magmas and drives the hydrothermal engine. The deep hydrothermal boiling rate must equal or exceed the fluid recharge rate to maintain a vapor-dominated system. Projecting the O and H isotope ratios of the modern thermal fluids to the meteoric water line suggests that the source input has ratios lower than most modern precipitation in and around the caldera. A possible fluid source is older meteoric waters that recharged deeper aquifers during the Pleistocene glaciations when climate was cooler, or even older water, with lower bulk isotope ratios than modern precipitation. Boiling occurs deep in the system where the older water recharges the hydrothermal system and this steam then rises along fractures, flow contacts, and other permeable zones. Near the surface the steam condenses and forms a hot water carapace. This fluid rises and may boil a second time. Stable isotope data suggest that only minimal mixing occurs with near-surface modern groundwater. Boiling is an effective process for producing acid sulfate fluids, where the oxidation of sulfur species nearer the surface produces hydrogen ions. The water table would boil down as a vapor-dominated system develops, and residual boiled briny fluids would be able to rise to the surface as thermal input wanes. We propose that both scenarios are part of the modern Yellowstone hydrothermal system. The “bow” of the system, to the NE where basalt is most likely intruding deep in the crust, is now drawing down and is vapor-dominated with widespread acid sulfate springs. To the SW, where the “stern” is beginning to pass beyond basalt intrusion, residual boiled circumneutral alkali chloride fluids can reach the surface and discharge.