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Insights from fumarole gas geochemistry on the origin of hydrothermal fluids on the Yellowstone Plateau

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The thermal fluids of Yellowstone have long prompted questions regarding their genesis, their relation to subsurface magmas, and the relation among geographically distant thermal areas. The water itself is essentially meteoric in origin, but the dissolved solutes and gases clearly reveal addition of crustal and mantle components. Most previous studies have focused solely on water chemistry and isotopes or on specific aspects of gas chemistry such as short-lived isotopes or noble-gas geochemistry, but as yet no comprehensive study synthesizing information on gas chemistry into a model for the origins and evolution of Yellowstone's diverse hydrothermal fluids has been proposed. In this frame, this contribution presents for the first time the results of a detailed sampling of fumarolic fluids, coupled with soil CO_2 degassing surveys, performed at Yellowstone in September 2007 by an international team. The fumarole gas compositions and isotopes, combined with those of a large database of chemical and isotopic compositions of Yellowstone fumarolic fluids (Bergfeld et al., 2011), were interpreted with thermodynamic models aimed to evaluate the chemistry and temperatures of magmatic, crustal and meteoric fluids and their mixtures in the Yellowstone hydrothermal system. Consideration of CO_2-CH4-CO-H_2O-H2 gas equilibria indicates temperatures from 170°C to 310°C. The estimated temperatures highly correlate with noble-gas variations, suggesting that the high-temperature geothermal waters at Yellowstone, particularly those within the Yellowstone Caldera, represent mixtures of a deep liquid having a magmatic signature at a temperature ~340°C with long-lived crustal waters at elevated but lower temperature around 170°C. The deep component is high in 3He/4He ratio (22 R/Ra) and low in 4He/40Ar ratio (~ 1), in agreement with a deep mantle origin. The crustal component is characterised by 4He concentrations 3-4 orders of magnitude higher than air-saturated meteoric water (ASMW). These high He concentrations may originate through long-lived circulation in Yellowstone tephras, and pre-Tertiary (including Archean) basement, all of which could be particularly rich in Uranium.
This model, derived from the study of fumaroles, is similar to models proposed by previous studies of thermal waters.