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Epithermal Alteration in the Yellowstone Hydrothermal System, Wyoming, USA

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The Yellowstone Caldera hydrothermal system, Yellowstone Park, Wyoming, USA, is found over an area greater than 6,000 km^2, includes more than 10,000 thermal features, and was active since at least 400,000 years ago. There are no reported ages of hydrothermal minerals in the interval between this age and caldera eruption at 640,000 years ago. Hydrothermal fluid flow is strongly controlled by permeable zones such as contacts between postcollapse flows and along faults and fractures. Drilling into the hydrothermal system in the past has shown that the modern hydrothermal fluids rise along the hydrostatic boiling curve. The Grand Canyon of the Yellowstone River incises into the older altered rocks in the caldera and exposes them over a cross section of more than 300 meters. Protoliths in the canyon are the postcollapse Tuff of Sulfur Creek and the Canyon Flow rhyolites that erupted about 470 ka. Glaciation has removed the upper part of this exposure. The canyon walls provide a unique opportunity to study the shallower part of an older phase of the Yellowstone hydrothermal system. Two alteration assemblages are exposed in the walls. A shallower assemblage has kaolinite as the dominant clay and includes silica either as quartz or opal and locally alunite, dickite, and barite. The deeper assemblage has illite as the dominant clay with quartz and in places hydrothermal feldspars (hyalophane, buddingtonite, and adularia). Coarse vuggy quartz crystals and meter-wide quartz veins are found in one area in the lower alteration assemblage. Pyrite and marcasite are widespread as disseminations or with opal or quartz in veins. Very minor fine-grained sphalerite was noted in only a few places. Significant K was lost from and Ba was added to the rocks during kaolinite alteration. Illite alteration produced losses in divalent cations such as Sr, Ba, and Pb. One alunite from the upper assemblage yielded a $^{40}Ar/^{39}Ar$ age of 154,000 years. This suggests the hydrothermal activity was ongoing during the Bull Lake-Pinedale interglaciation. The vertical variation in alteration mineralogy suggests that a thermal and geochemical gradient was present during alteration and is most likely related to temperature variations in a rising and boiling hydrothermal fluid, similar to modern hot springs at Yellowstone. Preliminary fluid inclusion homogenization temperatures in quartz range from 190° to 280°C, and mean temperatures show a vertical gradient over 250 meters that parallels the hydrostatic boiling temperatures found in the older drill holes. These data also suggest that several hundred meters of the shallowest altered rocks have been removed by Pinedale glaciation. Hot springs are now active at the base of the canyon, and the hydrothermal system may have been continuously active over the past several hundred thousand years and during canyon incision.