

The Chemistry and Mineralogy of Sinter Deposits From two Large Geysers in the Upper Geyser Basin, Yellowstone National Park

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November 24, 2022

Abstract

We report the radiocarbon age, chemistry, and mineralogy of sinter deposits from Castle and Giant Geyser in the Upper Geyser Basin of Yellowstone National Park. At each geyser, we sampled following the stratigraphy of the older terrace and younger cone. We analyzed 15 samples with x-ray diffraction, x-ray tomography, x-ray fluorescence, scanning electron microscopy, thin section microscopy, 3D imaging, and loss on ignition. Castle Geyser's terrace and Giant Geyser's cone are composed of more increasingly more mature sinter. The concentrations of Na, K, Cs, and Ga decrease in the sinter with decreasing H₂O and increasing SiO₂, therefore water and trace element concentrations correlate with stratigraphic position, and sinters exhibit progressive dehydration with increasing age. However, radiocarbon dates resulted in stratigraphically out-of-sequence ages. This suggests both physical mixing and the influence of magmatically dead carbon. By isolating and dating individual pieces of externally sourced organic material, we report ages as upper bounds—increasing the known age of Castle Geyser cone to 2,000 yr BP. Additionally, we demonstrate that Castle Geyser's shield is mineralogically distinct from and at least 1,000 years older than its cone.

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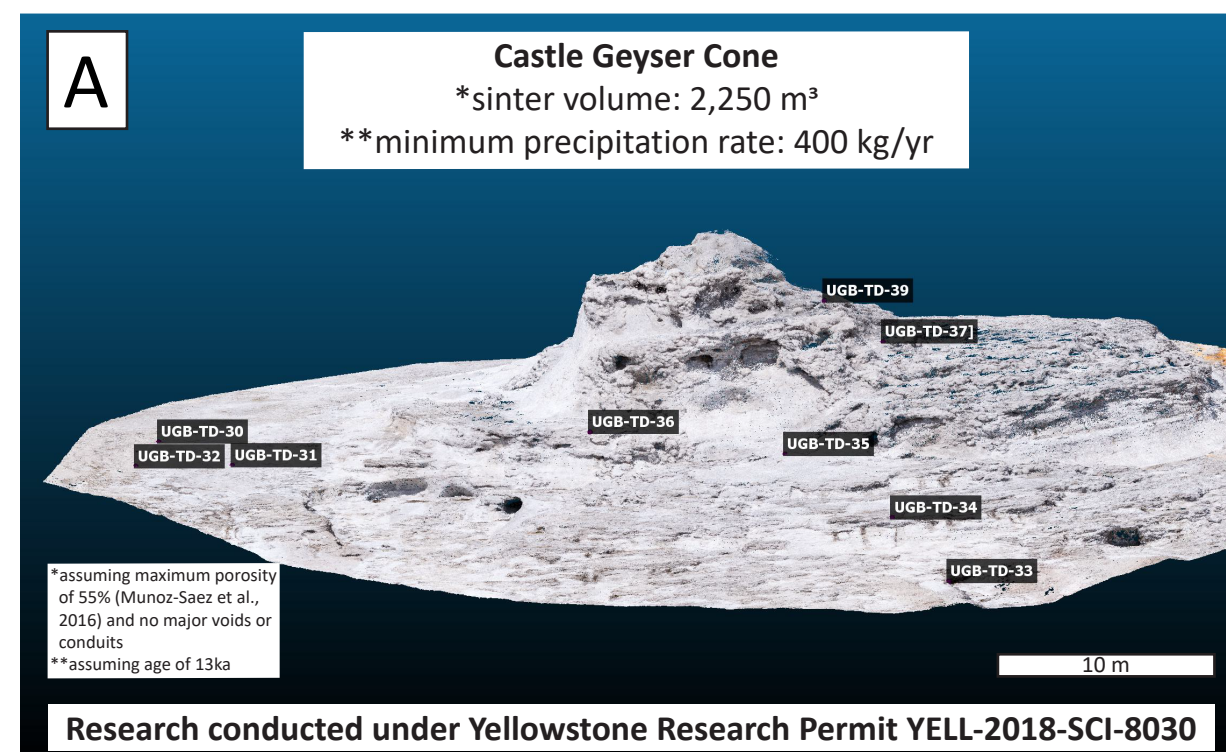
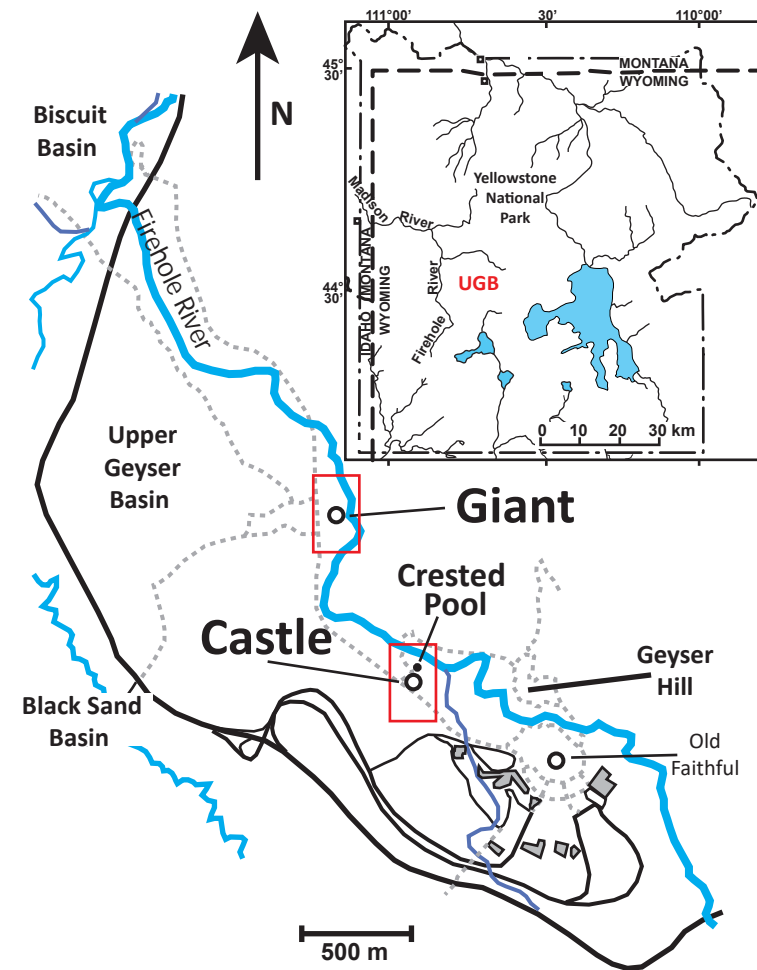
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Questions

- How long does it take to build large geyser cones?
- What are the volumes of large geyser cones and the minimum precipitation rates?
- Was hydrothermal activity continuous in the park since deglaciation (~13 ka)?
- What are the timescales of mineralogical transformations and chemical changes of silica sinter deposits?

Background

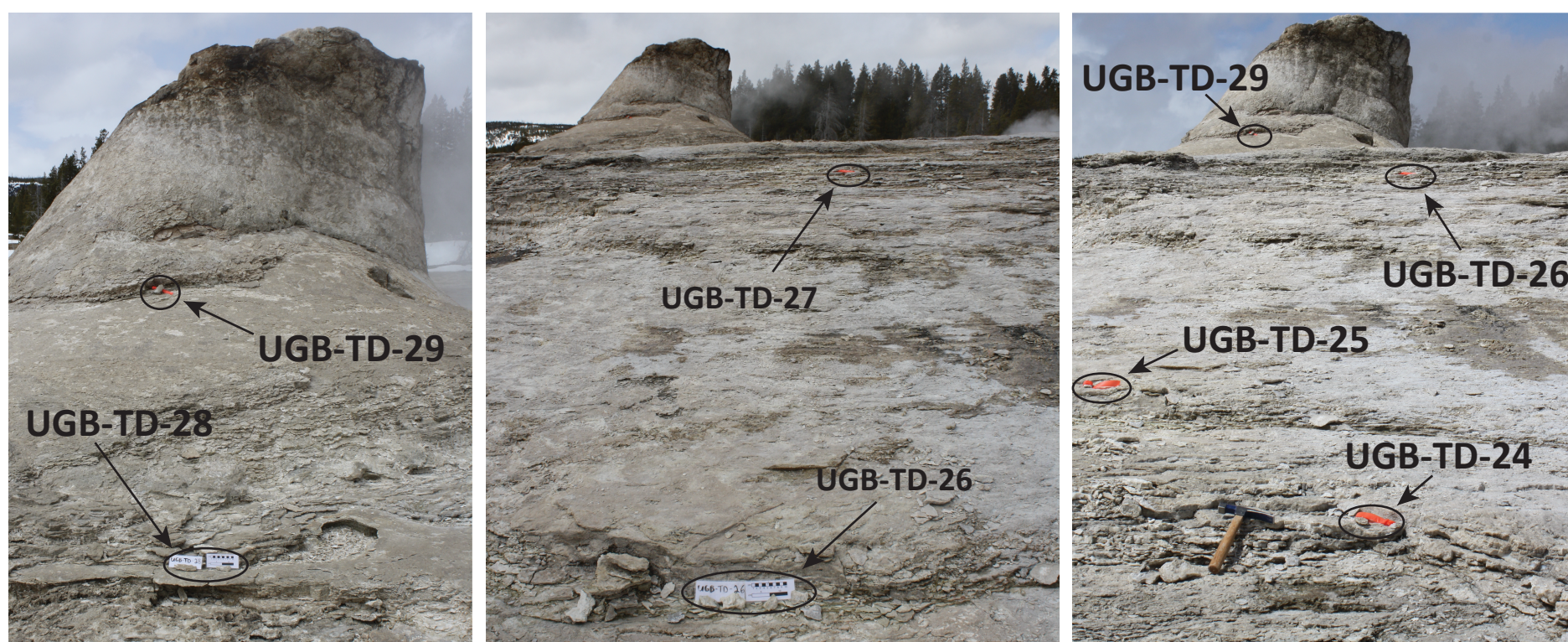
Yellowstone's Castle (A) and Giant (B) geysers were stratigraphically sampled in 2018



Previously, old and young sinter units were mapped at Castle Geyser (Muffler, 1982) and dated by Foley (2006)

B

Giant Geyser had not been previously dated



Research conducted under Yellowstone Research Permit YELL-2018-SCI-8030

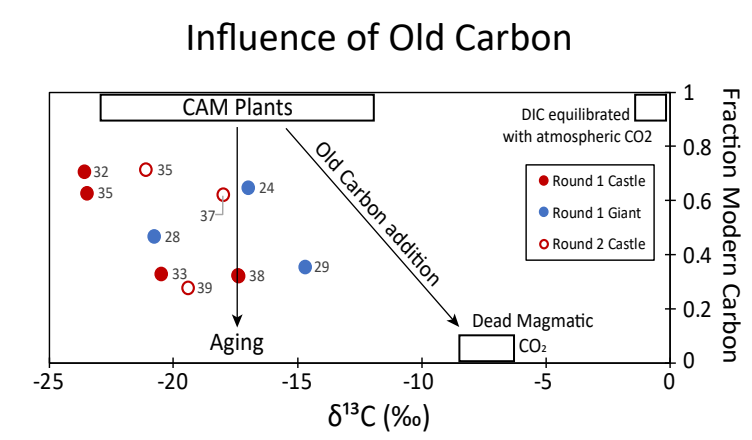
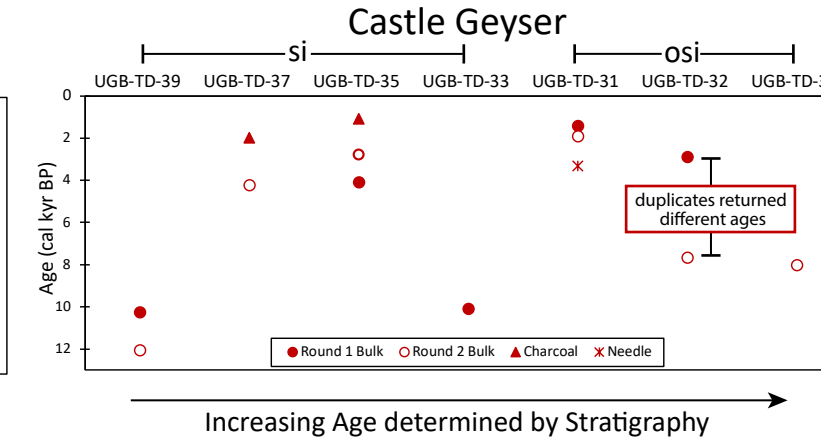
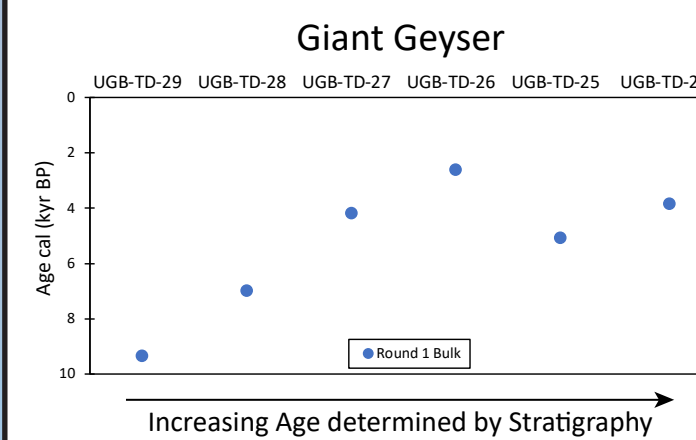
Results

Radiocarbon Dating

¹⁴C ages are stratigraphically out-of-sequence and imprecise

This may be attributed to:

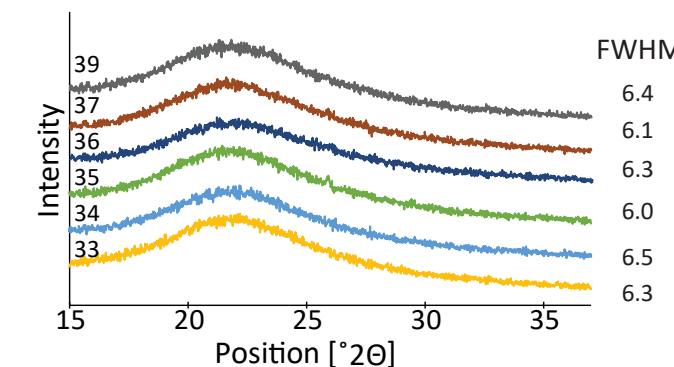
- 1) Physical mixing of sinter and recycling of organic material
- 2) Old carbon in thermal waters incorporated into microbial mats forming on the sinter



C - cristobalite
Q - quartz
T - tridimite

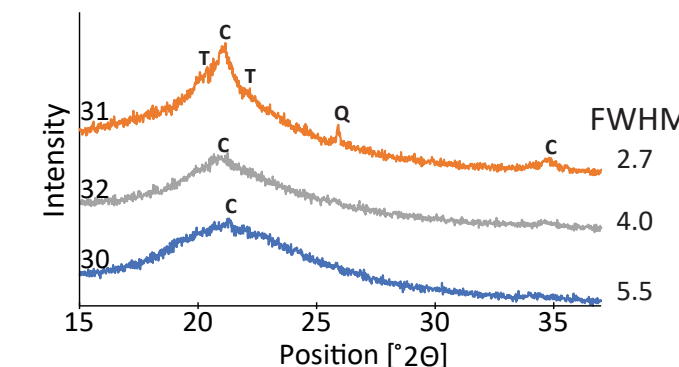
Mineralogy

The cone of Castle Geyser consists only of amorphous Opal A

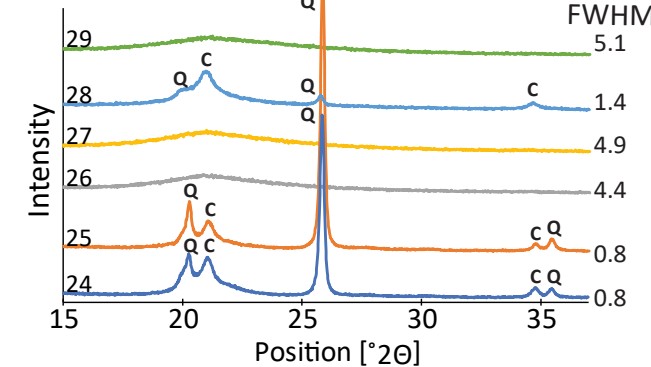


Least Mature

The shield of Castle Geyser contains Opal A/C and Opal CT + Quartz



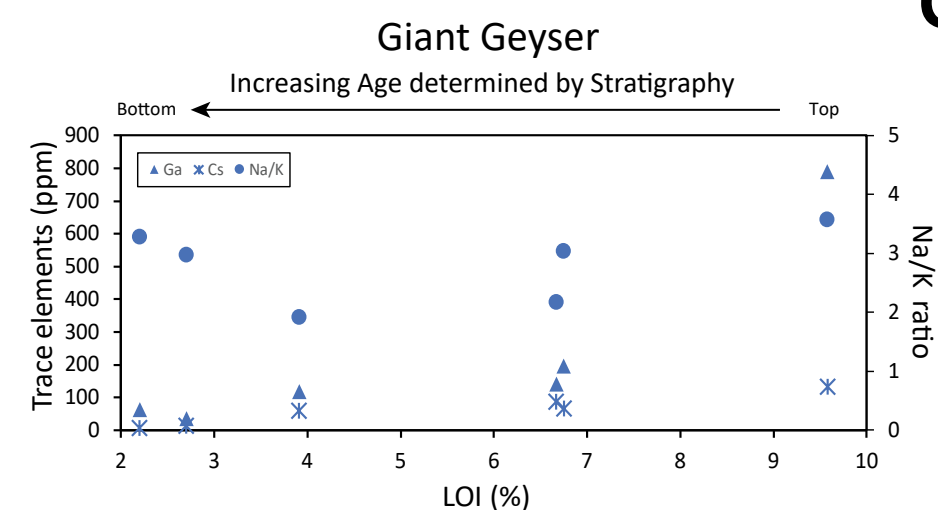
Giant Geyser contains Opal A/C, and Opal C/A + Quartz



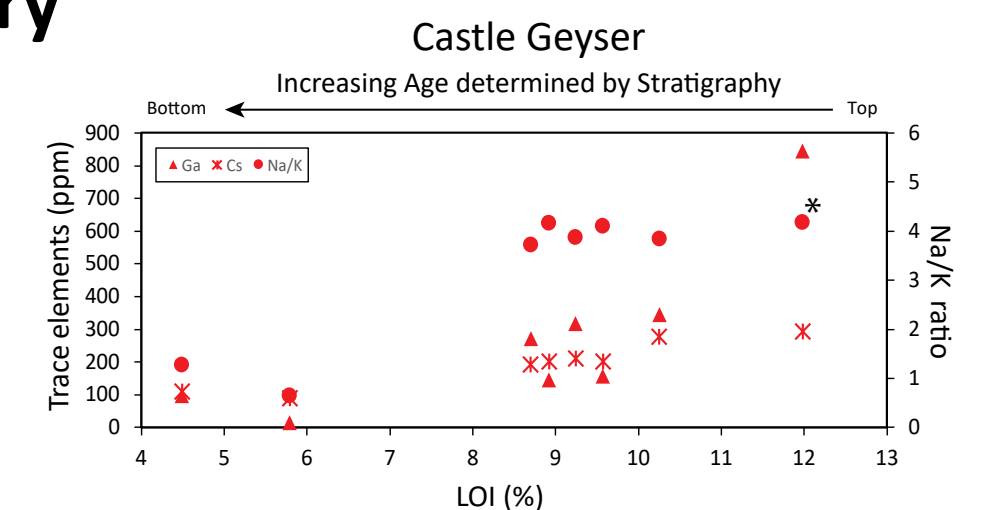
XRD

Increasing Age determined by Stratigraphy

Geochemistry



With increasing age, sinter dehydrates, the concentrations of most major and trace elements decrease, and the concentration of silica increases



*Water collected from nearby Crested Pool has a Na/K mass ratio of ~22, whereas the highest Na/K in sinter from Castle Geyser is ~4. This implies preferential incorporation of K in Opal A.

XRF

Conclusions

- Bulk radiocarbon ages of sinter do not accurately reflect deposition age
- Mineralogical, geochemical, and dehydration data can serve as an indicator for relative sinter age
- Castle Geyser cone is at least 2 ka and has a minimum precipitation rate of 400 kg/yr; its associated "old" shield is at least 3.3 ka and is mineralogically distinct from the cone
- Based on mineralogy Giant Geyser is older than Castle Geyser