THE ROLE OF HYPOGENE SPELEOGENESIS IN THE EVOLUTION AND FUNCTION OF GEYSERS AND OTHER GEOTHERMAL FEATURES IN YELLOWSTONE NATIONAL PARK

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INTRODUCTION

- Evidence suggests that the geothermal features at Yellowstone are products of hypogene speleogenesis.
- The physical and chemical processes of hypogene speleogenesis are currently active in Geyser Basins.
- Reasonable to assume that morphogenetic features typical of hypogenic caves have formed within geyser and hot spring plumbing systems. Supported by geophysical studies.
- Such morphogenetic features play a vital role in geyser function, development, and evolution.

HYPOGENE SPELEOGENESIS

- Geologic Setting – Regional groundwater system. Local surface recharge not responsible for development of caves.

- Hydrogeology – Ascending fluids. Water that recharges the soluble formation from below, driven by hydrostatic pressure or other sources of energy.

- Geochemistry – Source of aggressiveness occurs at or below the water table or from interactions within the rocks themselves.

- Morphology – Rising shafts, cupolas and domes, irregular rooms, and isolated chambers.

Klimchouk 2007, Palmer 2009

YELLOWSTONE NATIONAL PARK

- Yellowstone National Park in northwestern Wyoming.

- Volcanic caldera underlain by a deep thermal plume.

- Contains approximately 10,000 geothermal features.

- Most active geyser region in the world.

- Old Faithful one of the most studied geysers in the world.

Rinehart 1980, NPS.GOV

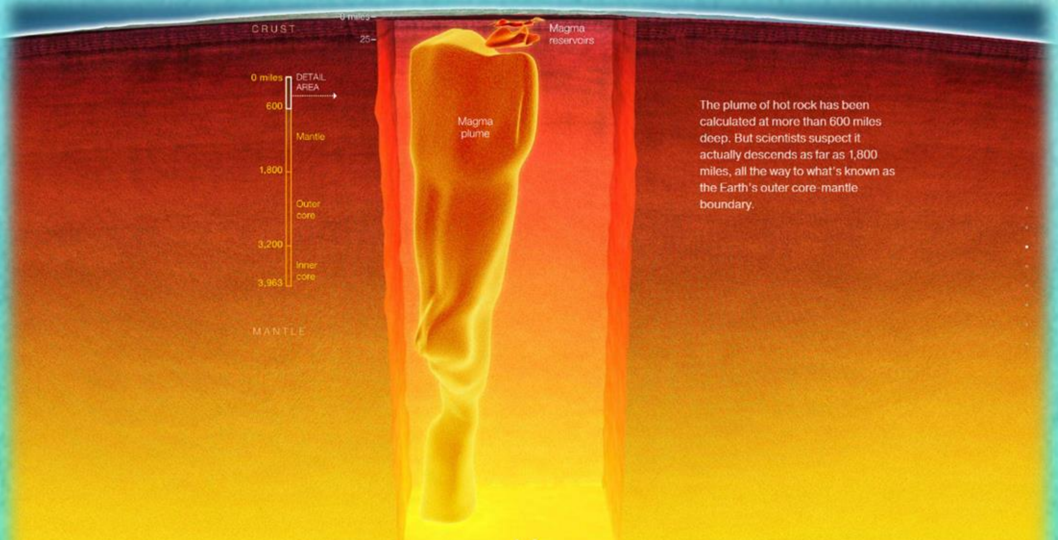
GEOLOGIC SETTING

- Volcanic Caldera – Massive eruptions produced 64km by 48km caldera about 640,000 years ago.

- Thermal Plume – Hot spot underlying the caldera, calculated to extend 970km deep, but may extend beyond 1,800km deep.

- Lithology / Stratigraphy (Upper Geyer Basin) – Top layer 6m sinter, 70m glacially emplaced gravels of rhyolite and obsidian and underlain by rhyolite.

- Altitude ~2,200 meters. Altitude boiling point 93 Celsius.

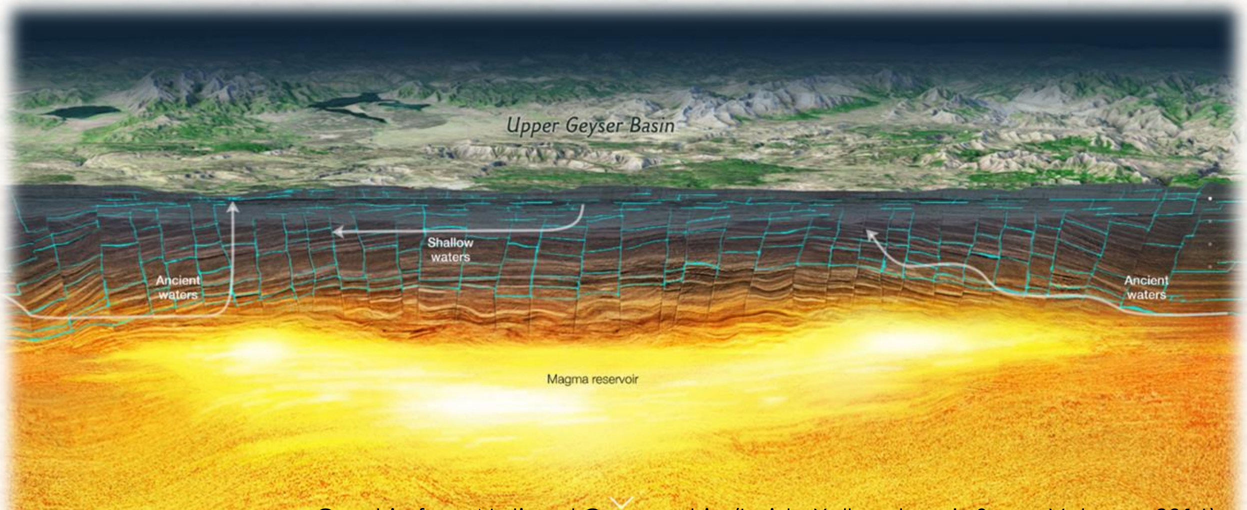


Graphic modified from National Geographic (Inside Yellowstone's Super Volcano 2016)

White et al. 1975, Keith et al. 1978, Rinehart 1980, Hendrix 2011

HYDROGEOLOGY

- Regional groundwater system driven by geothermal convection.
- Groundwater moves more/less vertically, but horizontal component exists, probably as top of a convection cell.
- Reduction of hydrostatic pressure causes underlying water to flash to steam. Under right conditions, may erupt.
- Disruptions of intervals between eruptions long attributed to earthquakes, earth tides, and barometric pressure. However, doesn't explain all changes (especially at Old Faithful).



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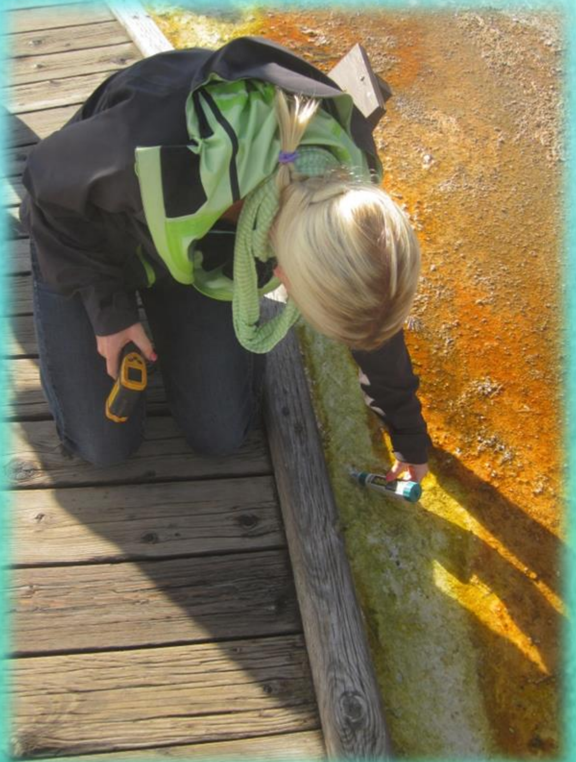
Rinehart 1980, Hurwitz et al. 2014

GEOCHEMISTRY

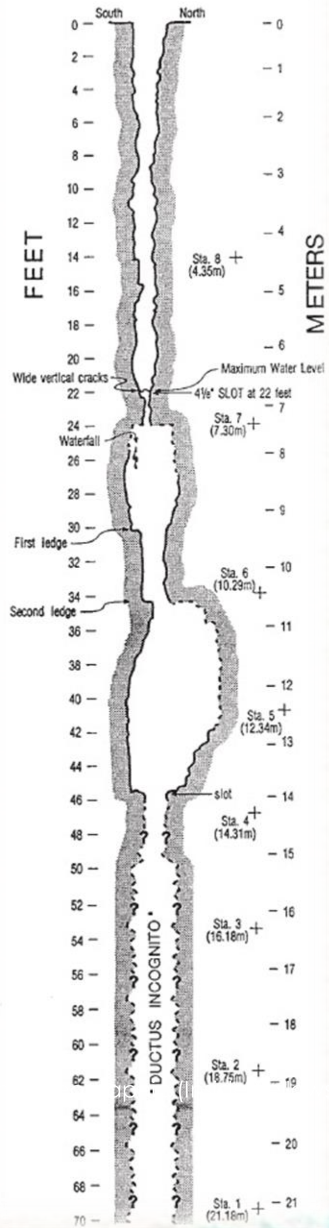
- Rhyolite is comprised of about 70% quartz and underlies all principal geyser basins.
- Quartz Solubility increases with increasing temperature and increasing pH. Levels off around 350 C then declines. Forms Silicic Acid (H4O4Si).
- Hot Water is a potent cave forming agent. Waters below geyser basins well above boiling point due to hydrostatic pressure.
- Alkaline Water discharges at all geyser basins. Sinter deposits only associated with alkaline springs. Clear-blue water with pH values >8.
- Brines – 340-370 Celsius brines as deep as 5,000 meters. Salinity increases quartz solubility.
- Opal / Geyserite deposited around geysers. Approximately 352,000 kg deposited daily (1.32 – 10g/L). Deposits as cools.



Rinehart 1980, Wood et al. 1986, Knauss et al. 1988, Bennett et al. 1991, Martini et al. 2000, Palmer 2009

MORPHOLOGY

- Geyser plumbing is mostly unknown since out of view.
- Contains vertical shafts, which waters rises and steam is ejected.
- Constriction plays an important role in geyser function.
- Cameras lowered into geysers have revealed caverns.
- Recent seismic studies have revealed presence of a large dome-like chamber in Old Faithful. Plays important role in geyser function. Similar findings at Lone Star geyser.



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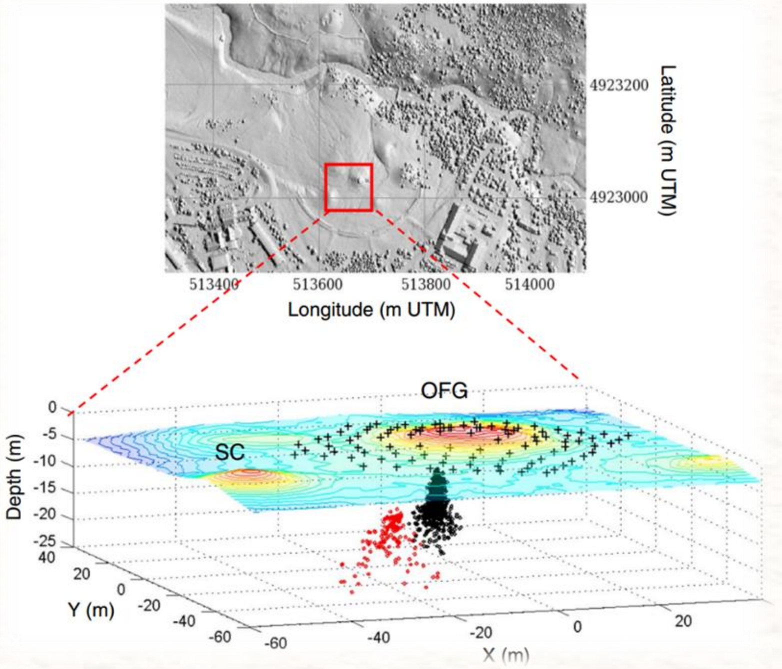
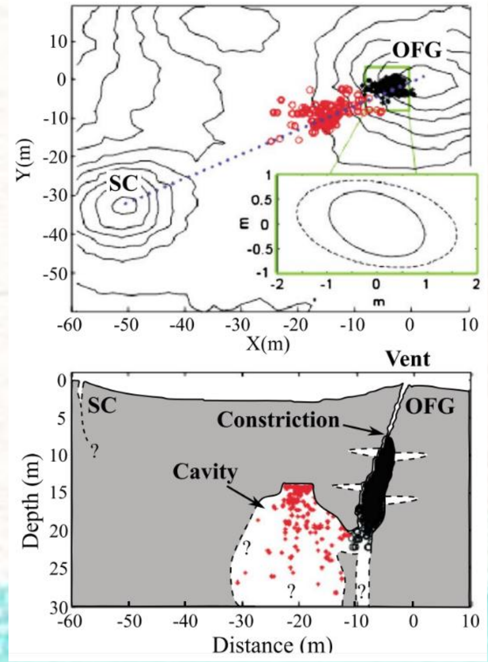


Graphic modified from Vandemeulebrouck 2013



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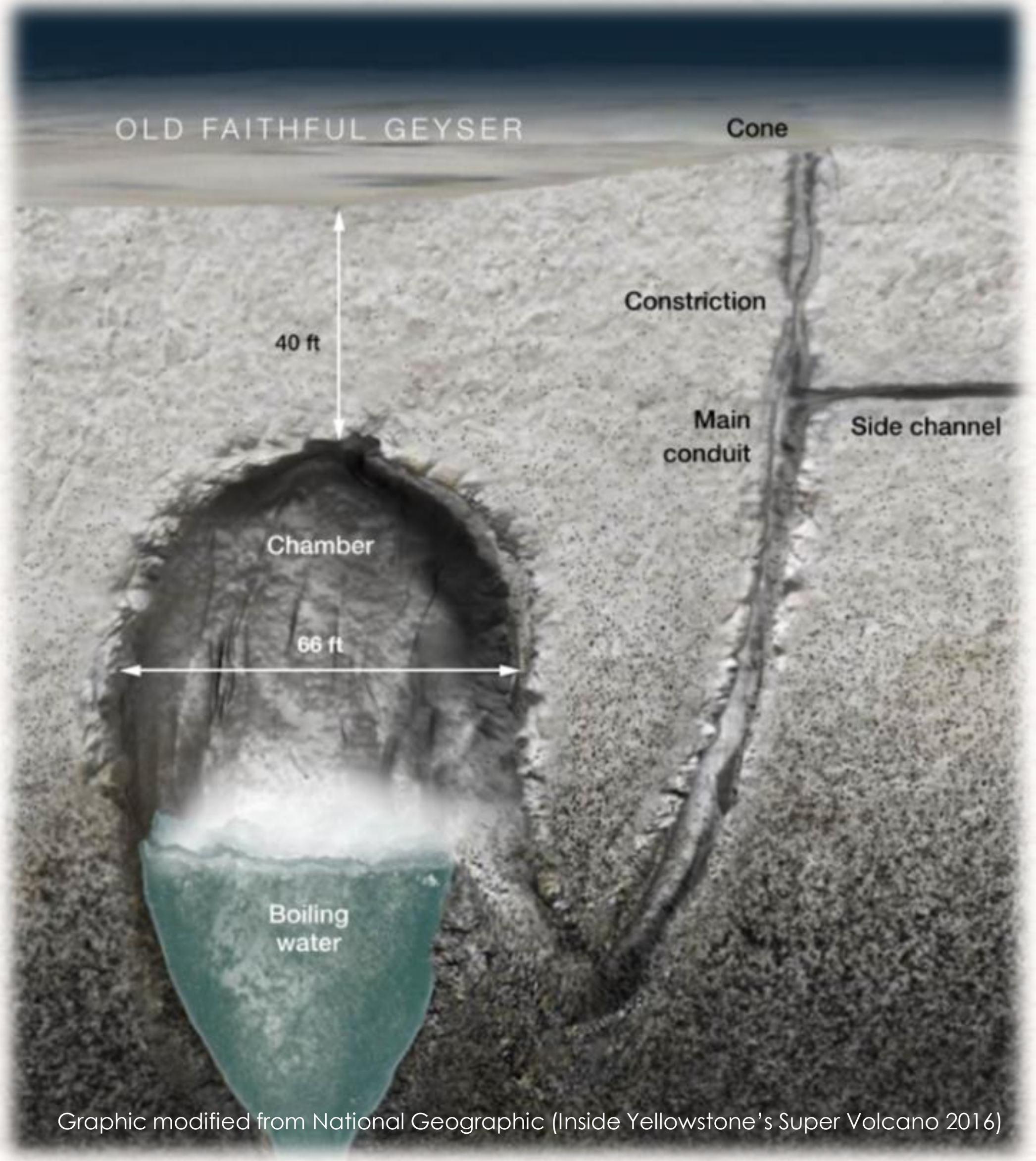

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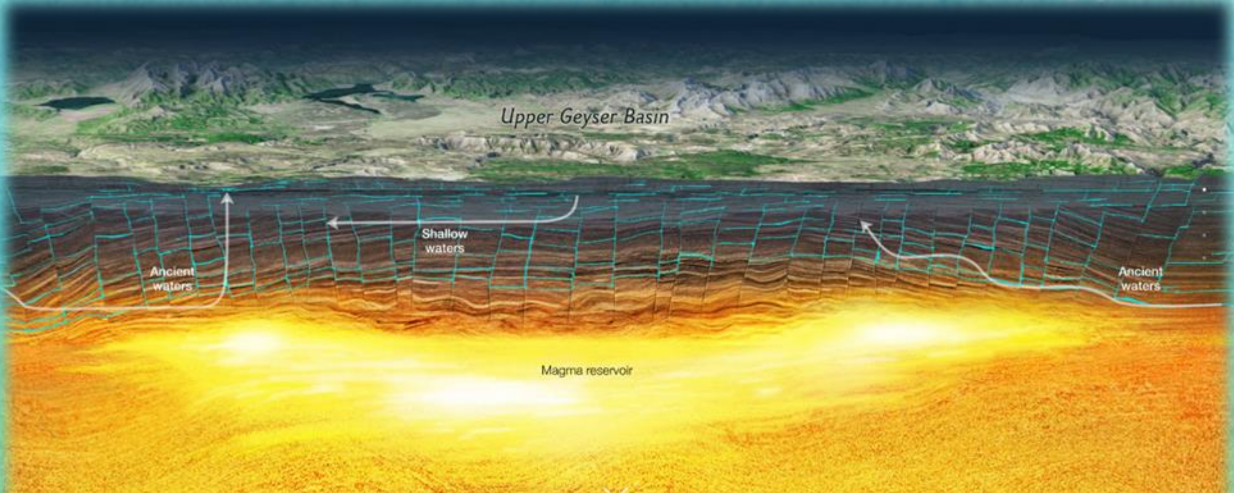
Rinehart 1980, Vandemeulebrouck 2013

CONCLUSIONS

- Many of the Yellowstone geysers and hot springs fit the criteria as products of hypogene speleogenesis.
- Evidence of caverns and conduits being formed by ascending fluids, which the source of aggressiveness occurs below the water table. Currently active.
- Seismic tomography reveals cavities with morphologies similar to those seen in hypogenic caves in carbonate rock.



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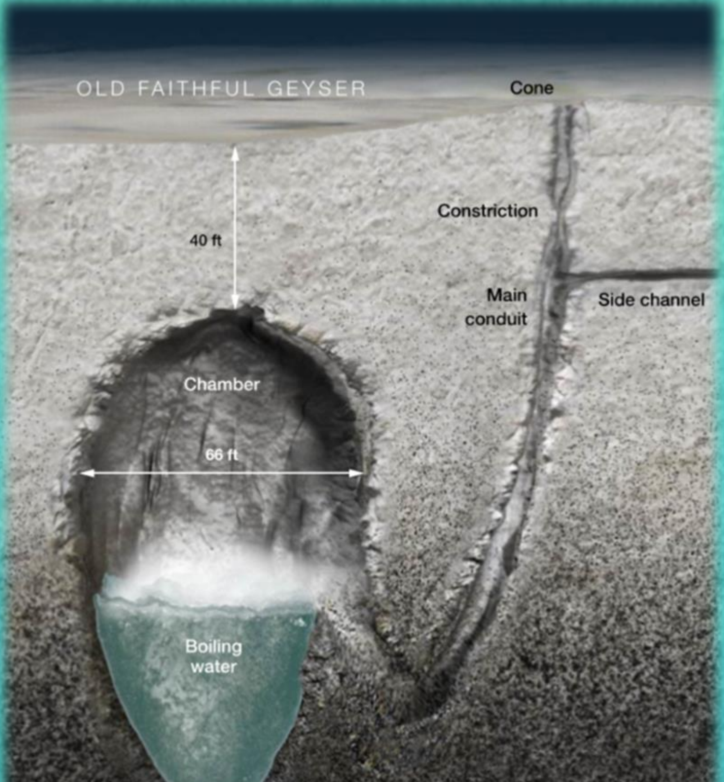

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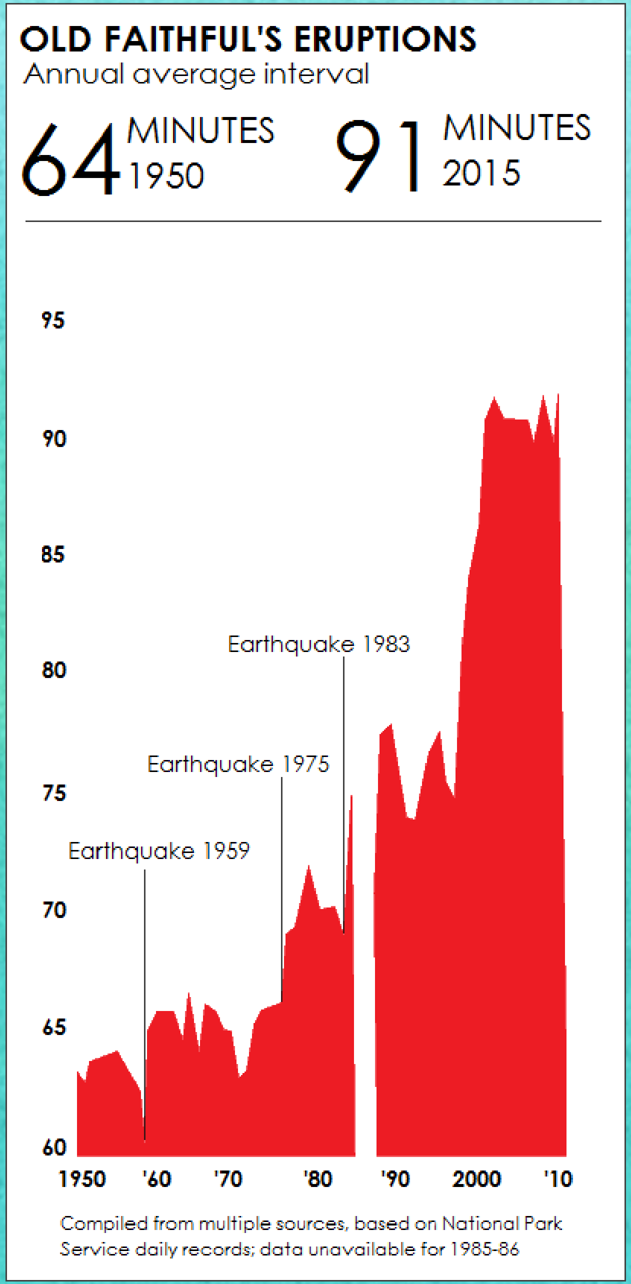
SPECULATIONS

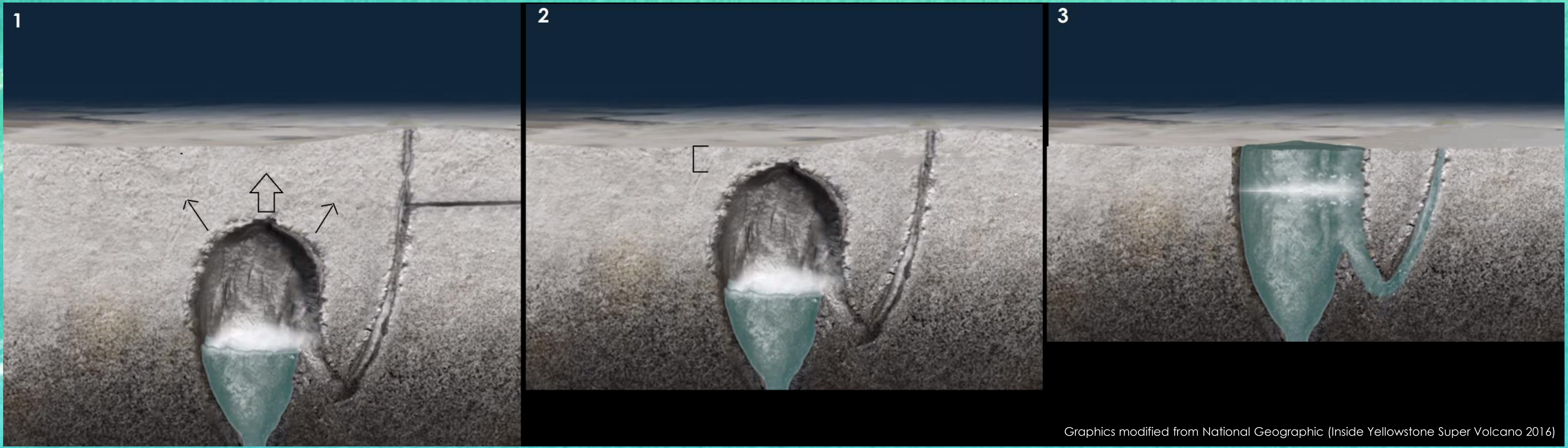
- Intervals between eruptions at Old Faithful are unaffected by barometric pressure, earth tides, or earthquakes. Only three earthquakes have had an affect on Old Faithful.
- Hurwitz et al. concluded that Response of intervals between eruptions to external forces is relatively small. Most geyser variability may be dominated by an interaction between "internal processes and interaction between other geysers".
- We speculate that the gradual change in intervals between eruptions is a result of hypogene speleogenesis as cupolas or "bubble traps" enlarges through dissolution. As cupolas expand, volume increases, requiring more steam to fill and more time to fill it.
- We think this is probably resulting in the gradual change in IBE.



Modified from National Geographic (Inside Yellowstone Super Volcano 2016).

SPECULATIONS

- Cupola formation by condensation corrosion and ceiling erosion from ascending fluids.
- If cavities migrate close enough to the surface, the build up of pressures could result in hydrothermal explosion as steam pressure over-comes gravitational pressure of overlying rock, unroofing the cupola forming a cratered or cavernous hot spring.



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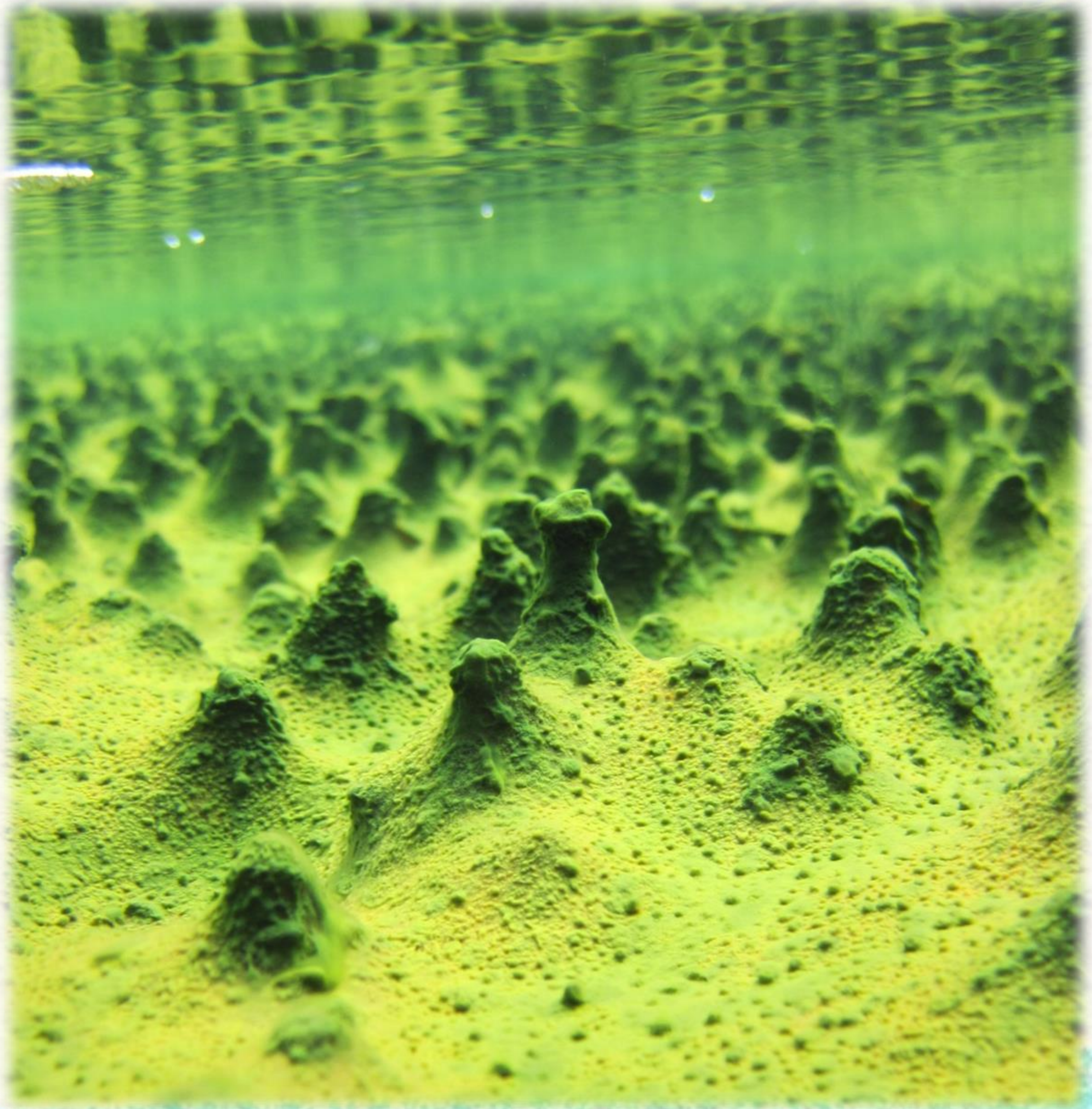
QUESTIONS?



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