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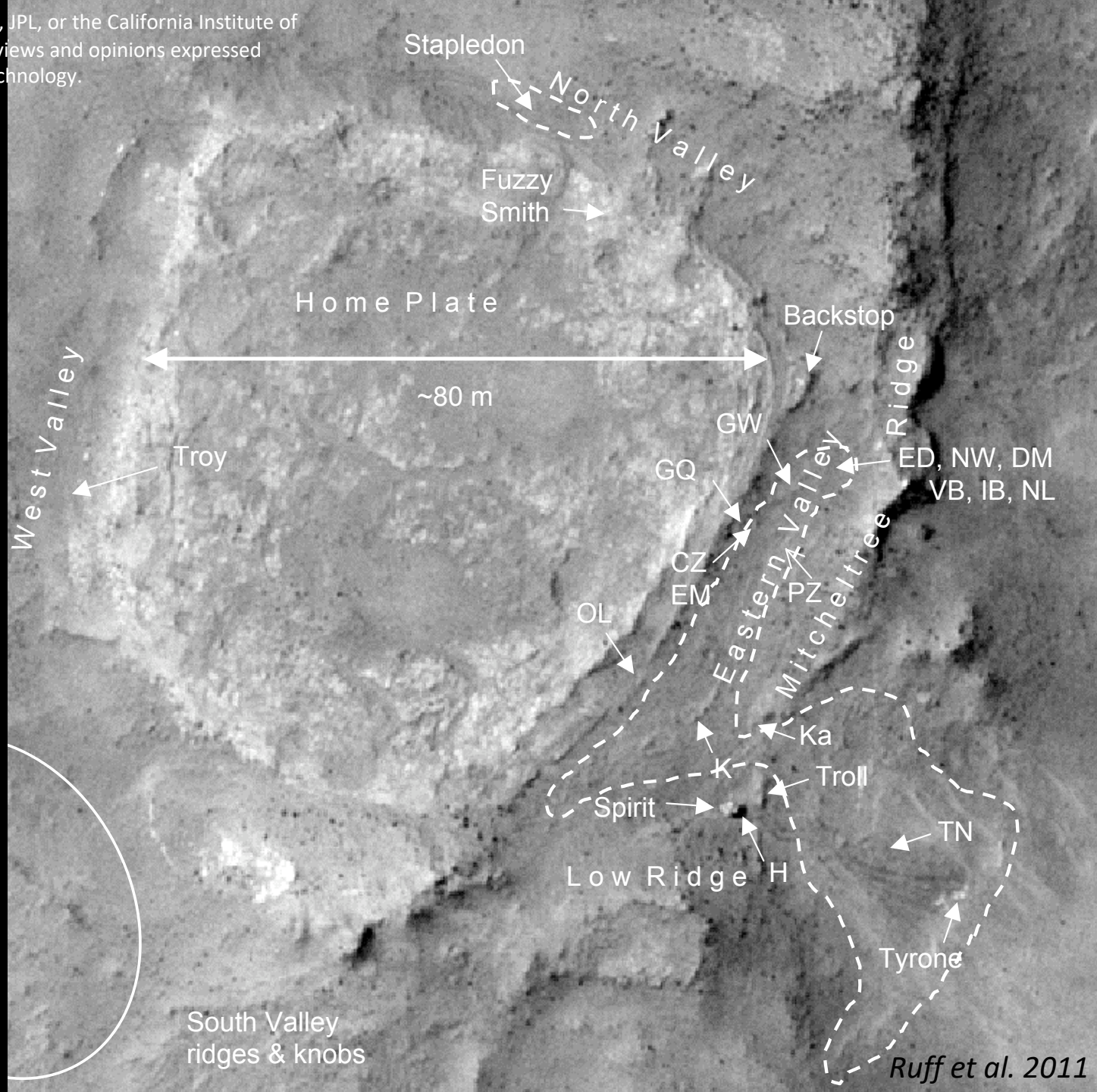
Origin and significance of opaline silica deposits at Columbia Hills

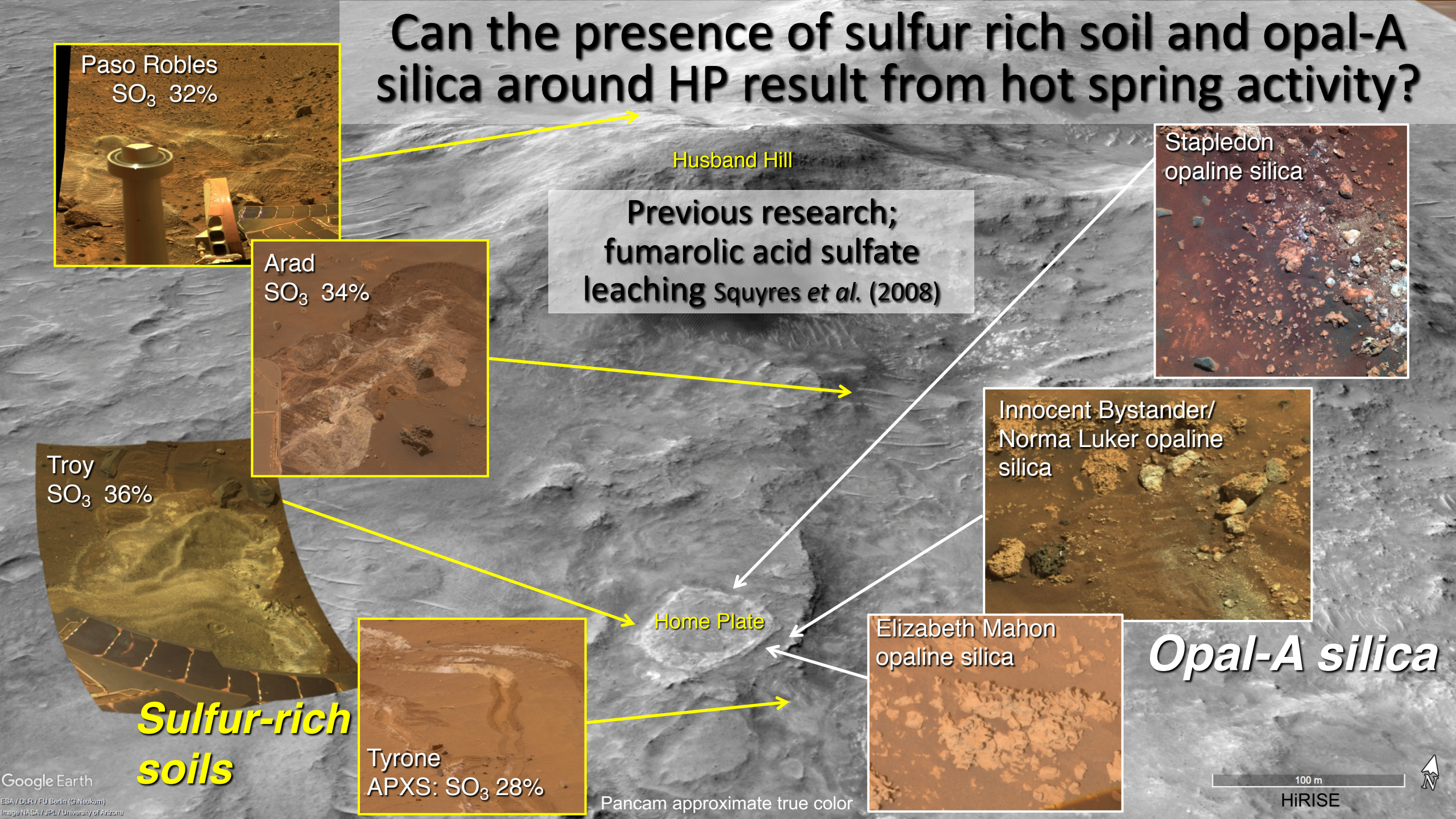
K. A. Campbell, T. Djokic,

S. W. Ruff, B. Teece, M. J. Van Kranendonk, J. D. Farmer, C. Sriaporn, K. M. Handley, M. Millan, D. M. Guido

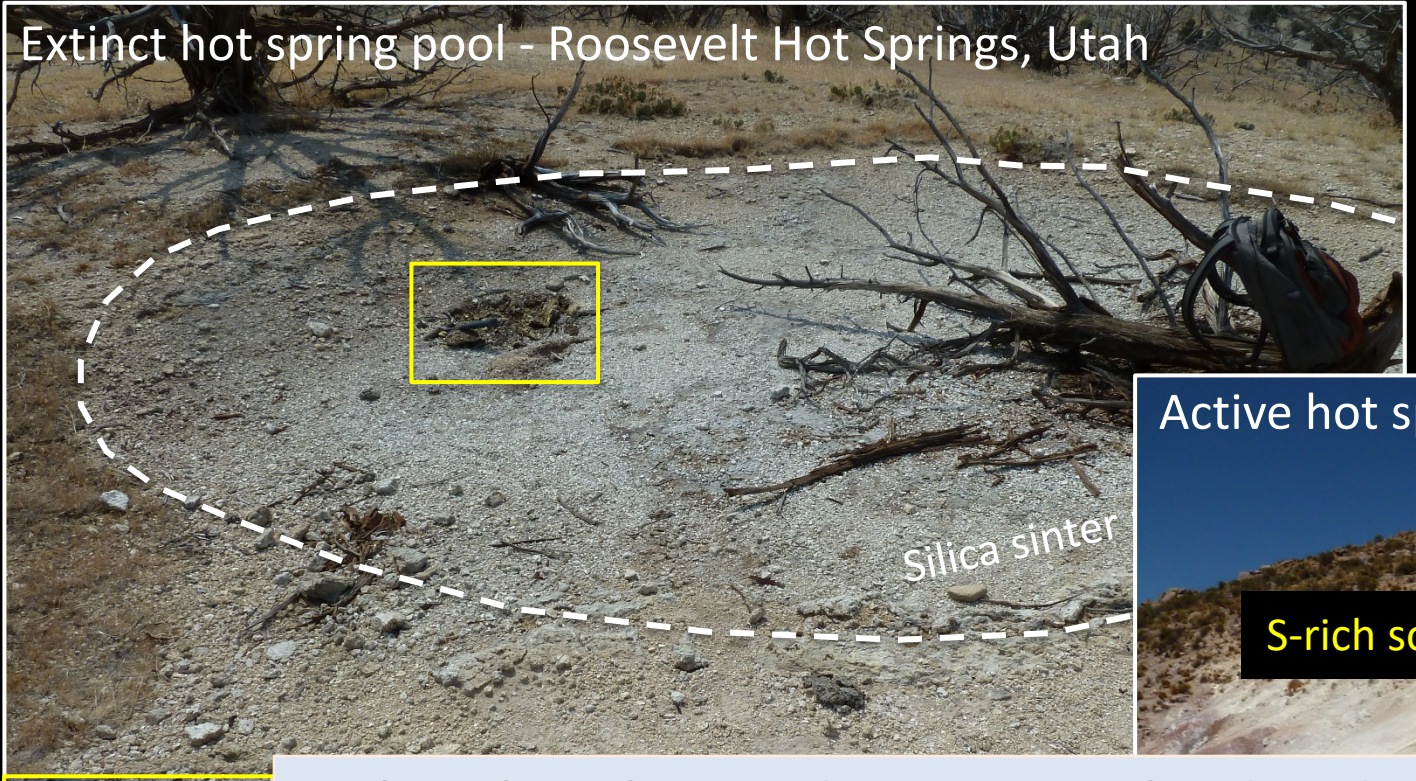


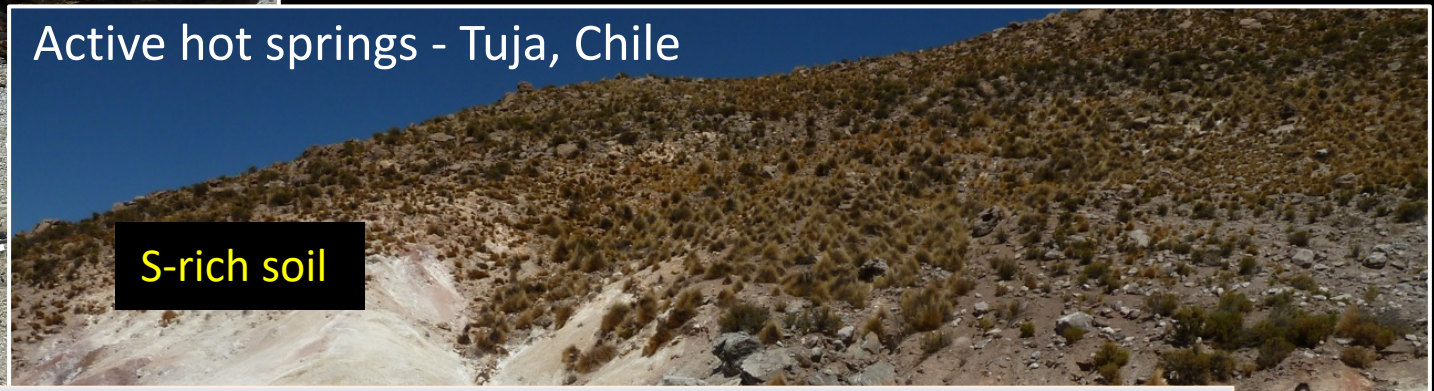
Ruff et al. 2011

Can the presence of sulfur rich soil and opal-A silica around HP result from hot spring activity?



Opaline silica *and* S-rich soil are common in terrestrial hot spring settings

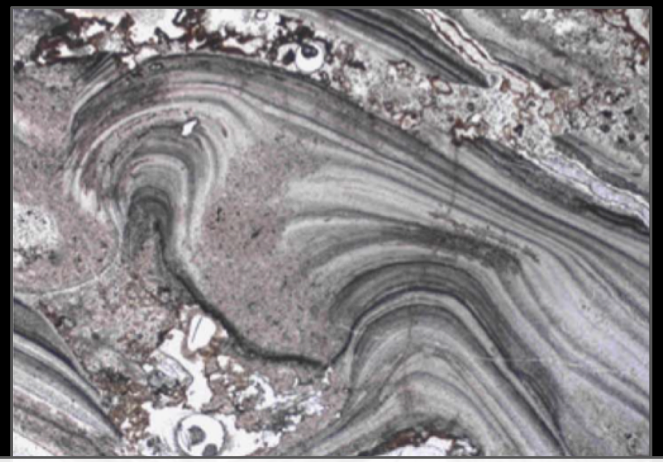




….this also observed in New Zealand and Yellowstone hydrothermal systems and is characteristic of continental hot springs….

The ~3.5 billion year old Dresser Formation – An ancient volcanic-hydrothermal system
- Also exhibits evidence for both
Steam-heated acid sulfate alteration and land-based silica hot springs

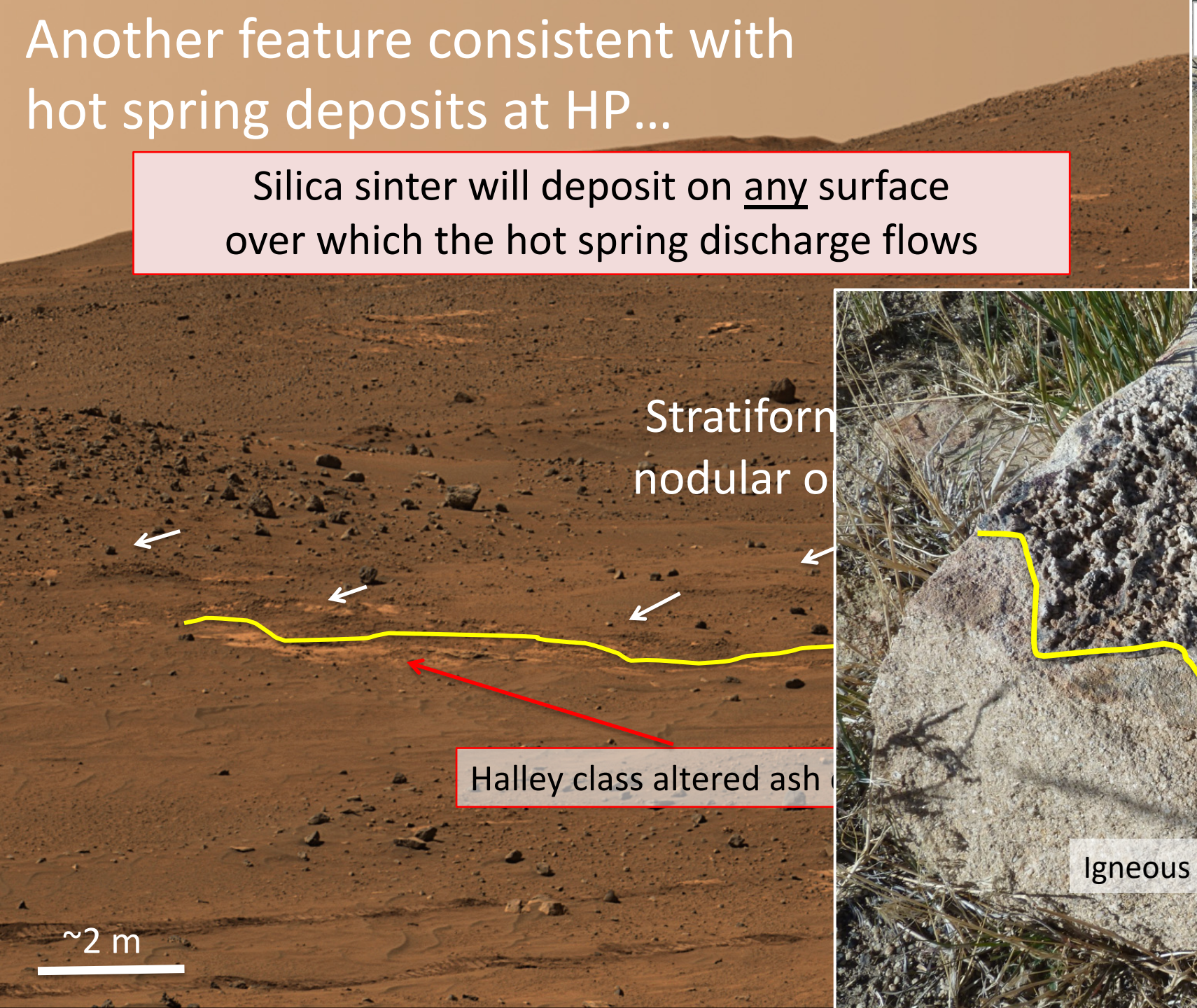
Kaolinized pillow basalts infer fumarolic vents
(Van Kranendonk & Pirajno, 2004; Van Kranendonk 2006)

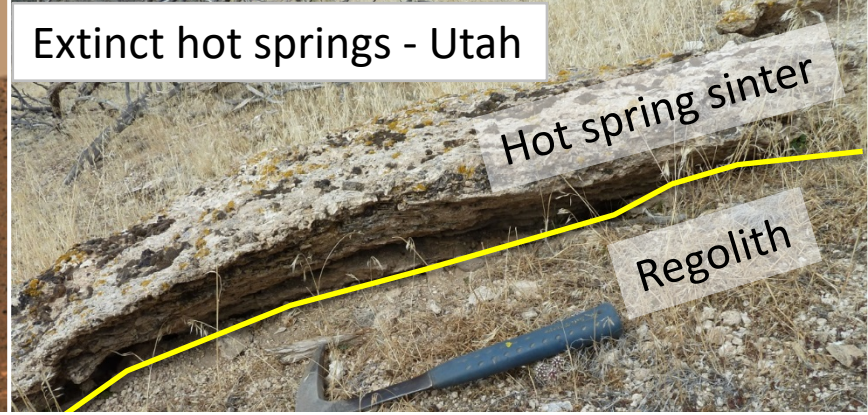


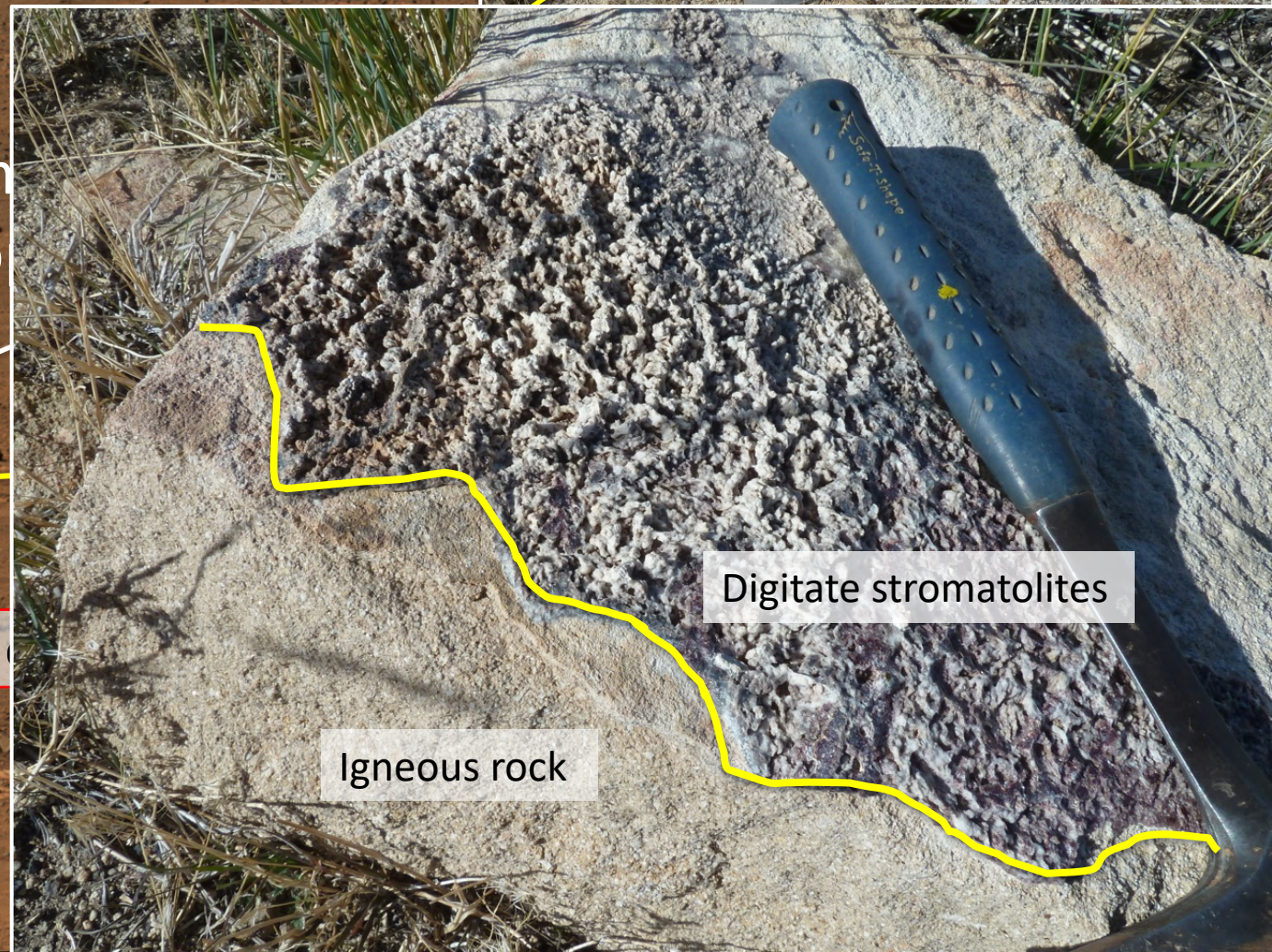
Geyserite (silica sinter) infer hot springs
(Djokic et al., 2017)

Another feature consistent with hot spring deposits at HP…

Silica sinter will deposit on <u>any</u> surface over which the hot spring discharge flows







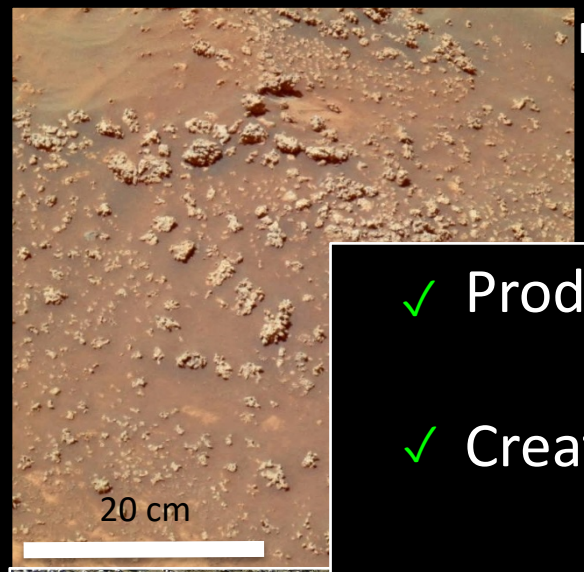
In addition, the Home Plate silica textures are comparable to hot spring sinters

Nodular and digitate features

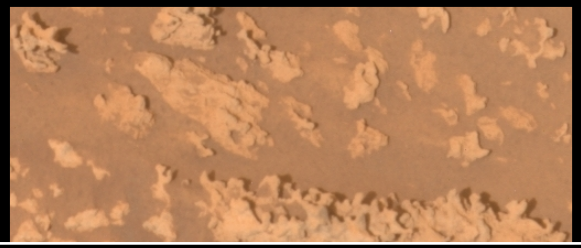
Breccia textures

Mars

Earth



Pancam



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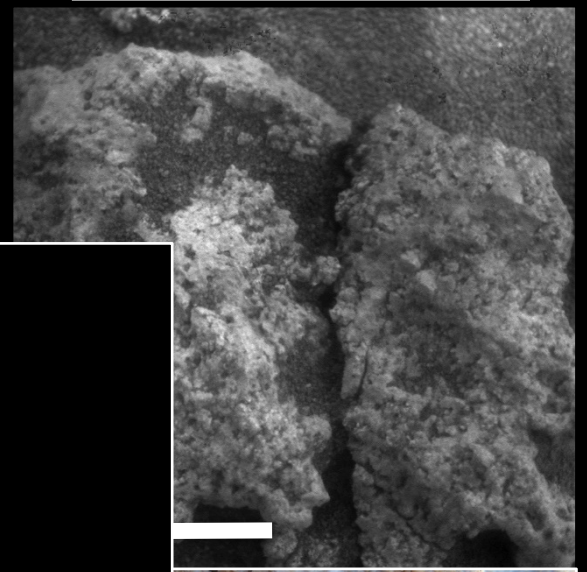
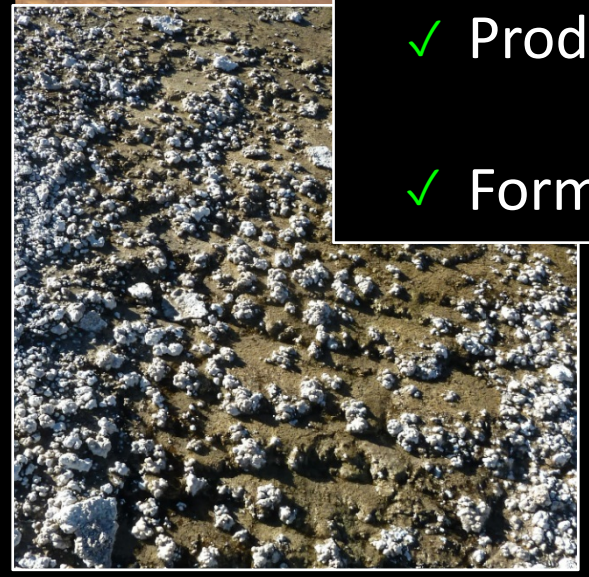


- ✓ Produce opaline silica and S-rich soils
- ✓ Create stratiform opaline silica deposits
- ✓ Produce sharp contact with any substrate
- ✓ Form digitate structures



Biomediated stromatolites

Ruff and Farmer (2016)

Alternative hypothesis: fumarolic acid sulfate leaching

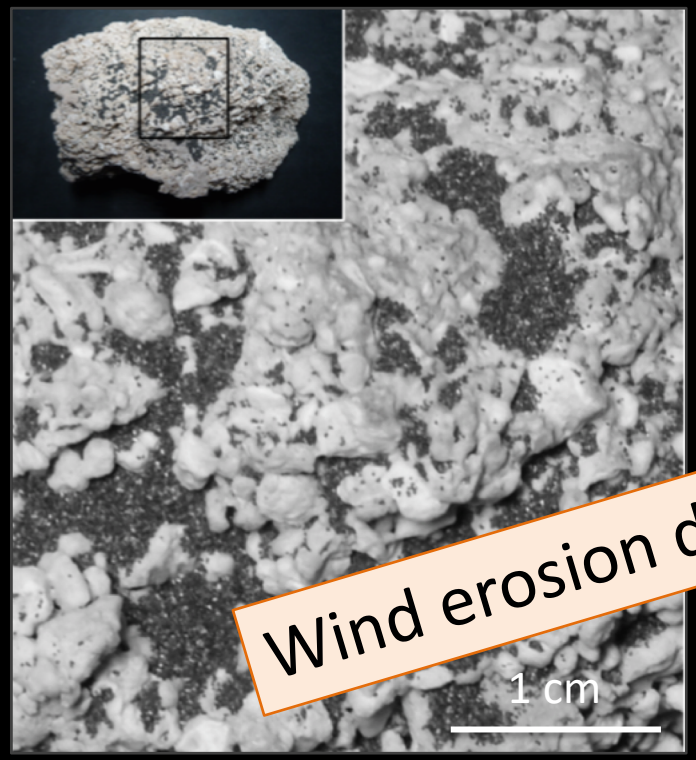
Acid-sulfate leaching does not explain the silica deposits at Home Plate

- ✓ D… …line silica – as *silica residue* …-rich soils
- ✗ Does not create stratiform opaline silica deposits
- ✗ Does not produce sharp contact with the substrate
- ✗ Does not form digitate structures

Type example of fumarolic acid sulfate leaching: Sulphur Banks, Hawaii (Squyres et al., 2008)

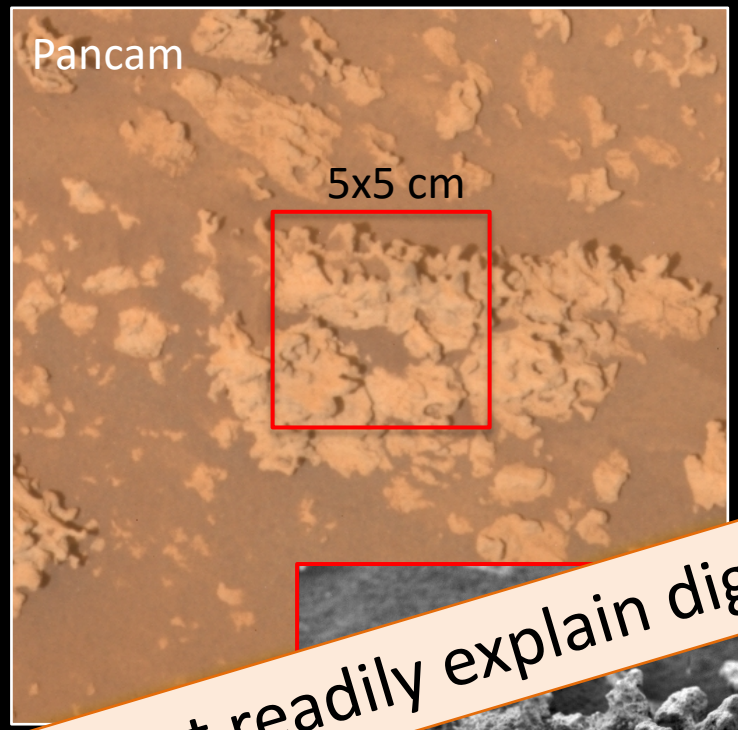
Are the digitate structures at Home Plate a result of wind erosion?

El Tatio hot spring sinter breccia exposed to sand-blasting
– Enhanced porosity and pitting

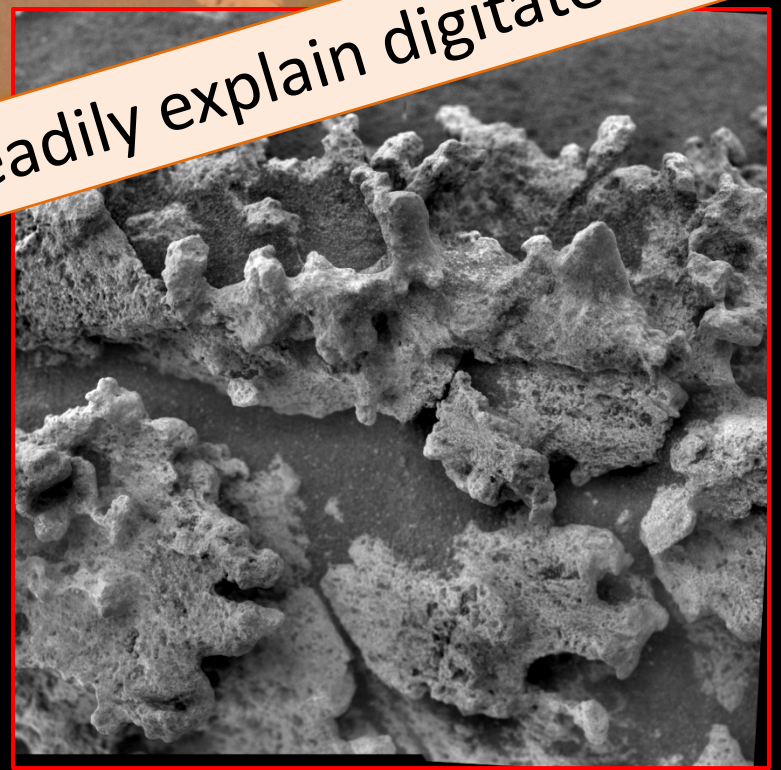


BUT, produced NO digitate structures

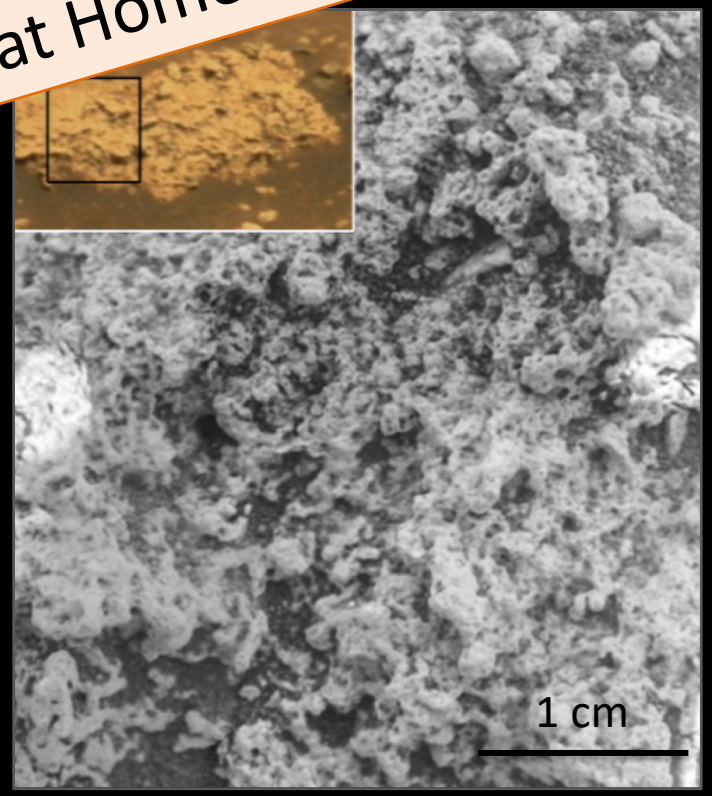
Ruff *et al.* 2017



Home Plate



INSTEAD, the product resembles other, non-digitate silica structures at Hom



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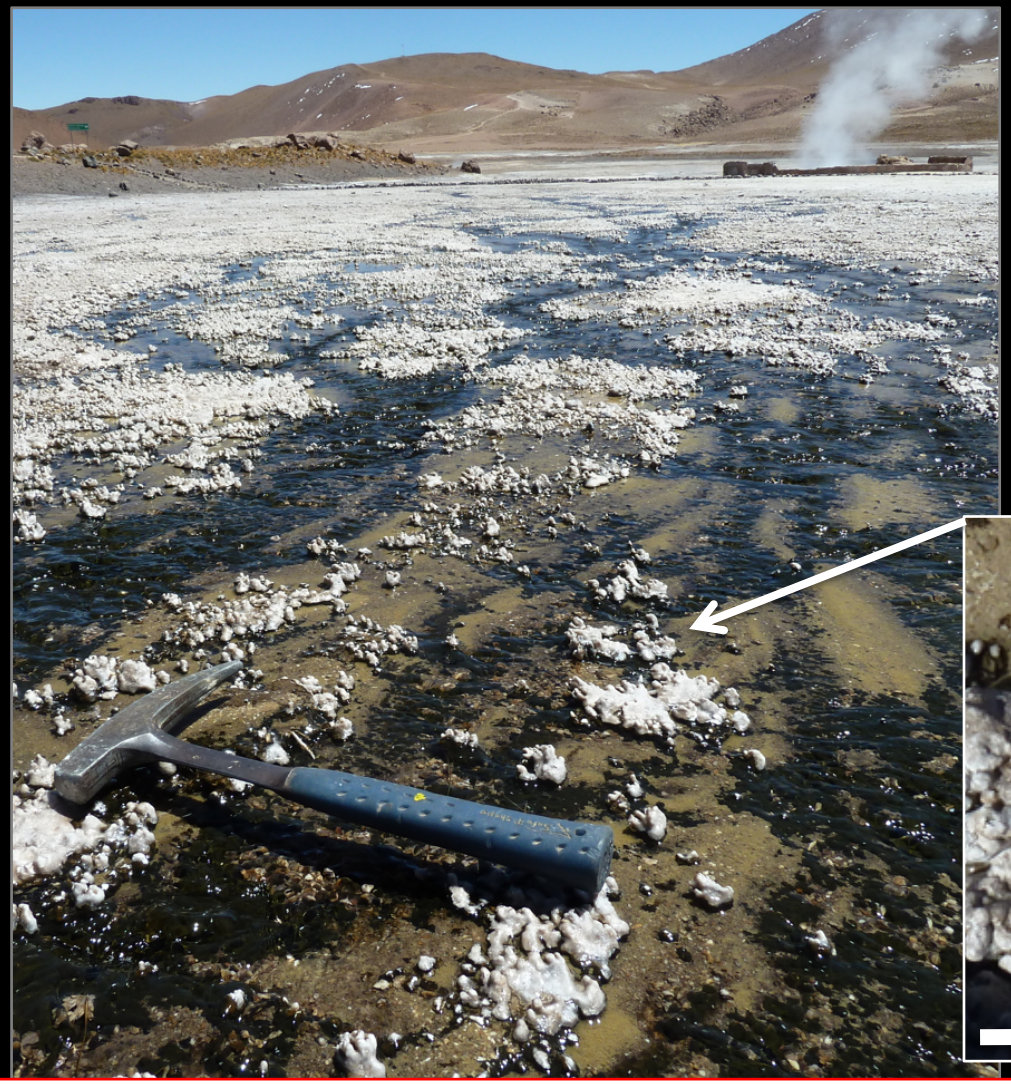
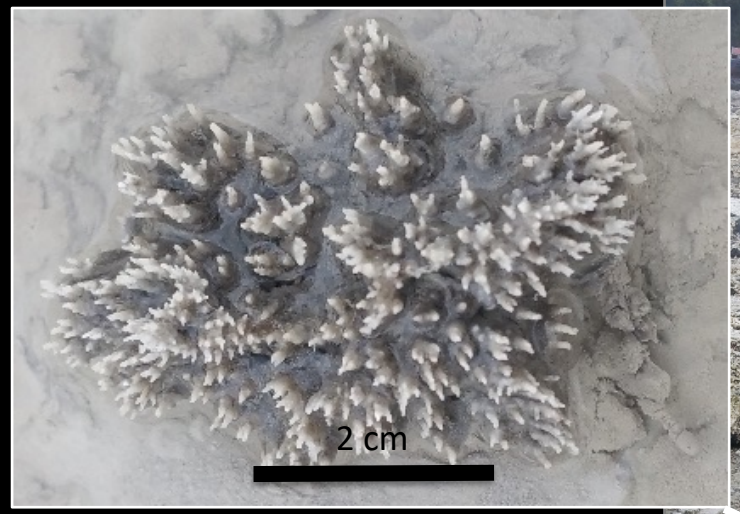
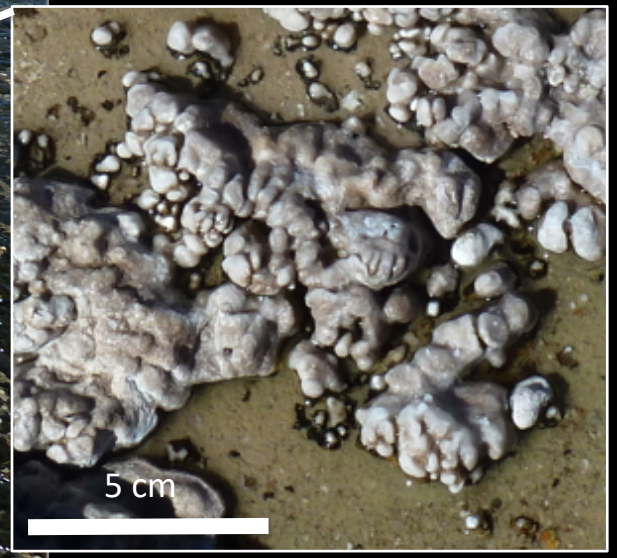
Wind erosion does not readily explain digitate silica at Home Plate

Where do digitate structures form in hot spring environments?



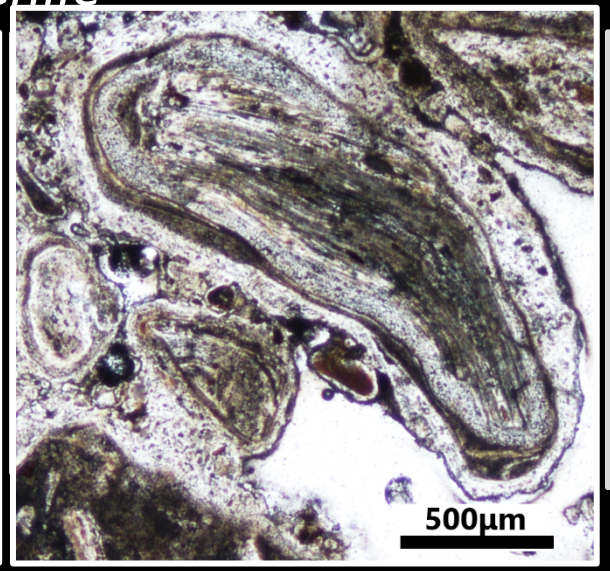


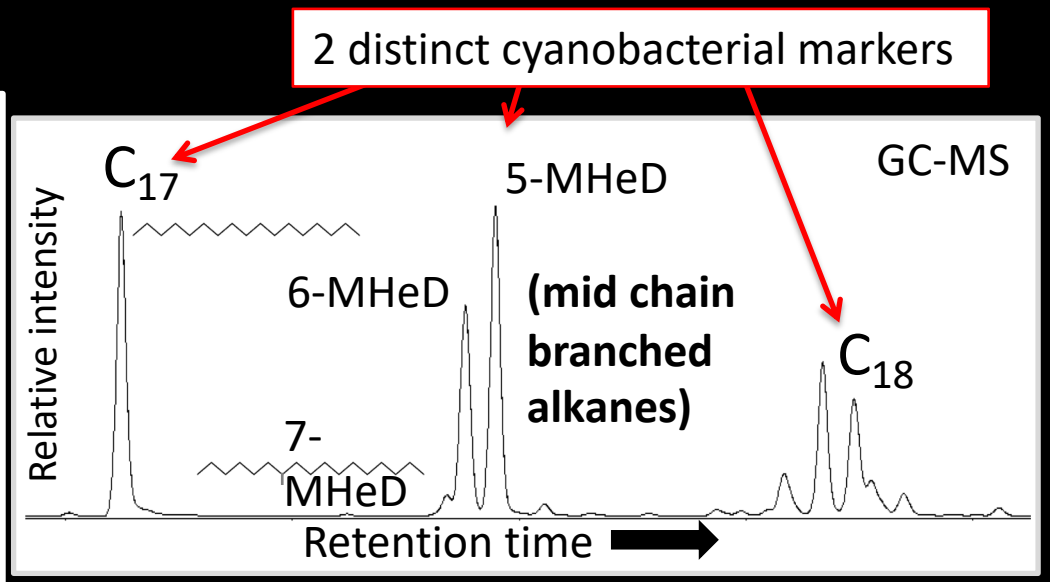


Textures may be strengthened as potential biosignatures by organic molecules...

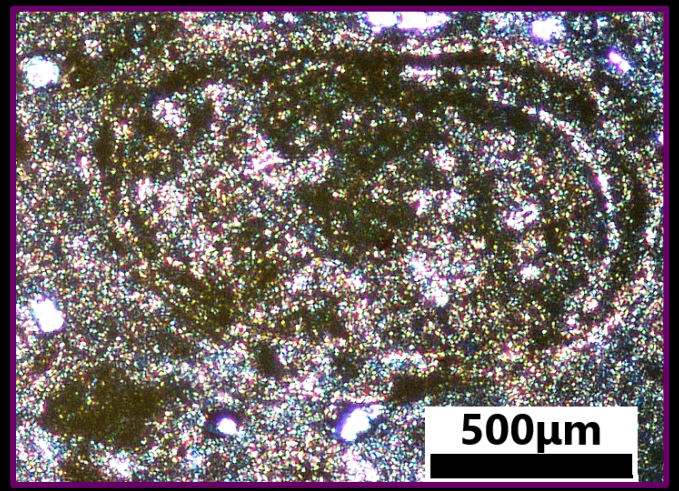
But… there is limited research available for organic biomolecules in fossil sinters… (currently oldest is ~900 years) – So what is their preservation potential?

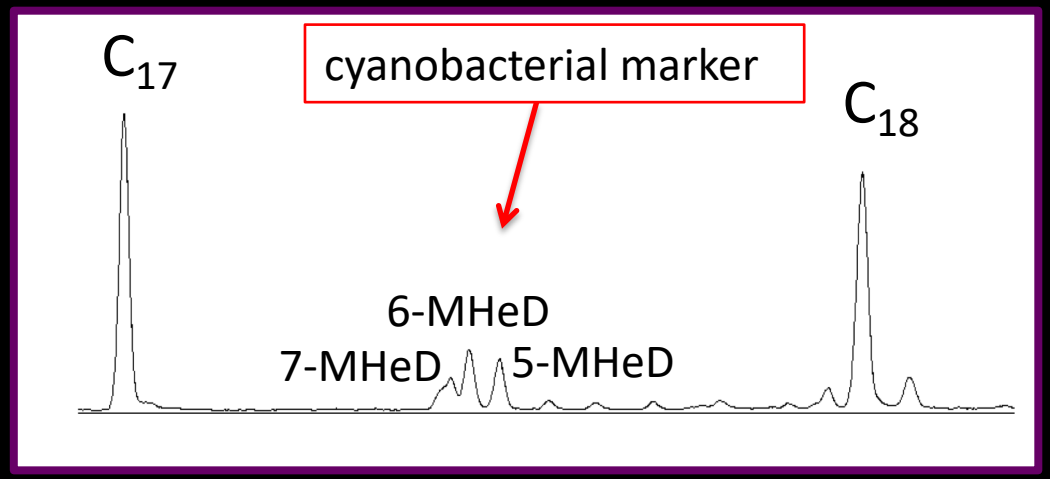
Active hot spring El Tatio, Chile





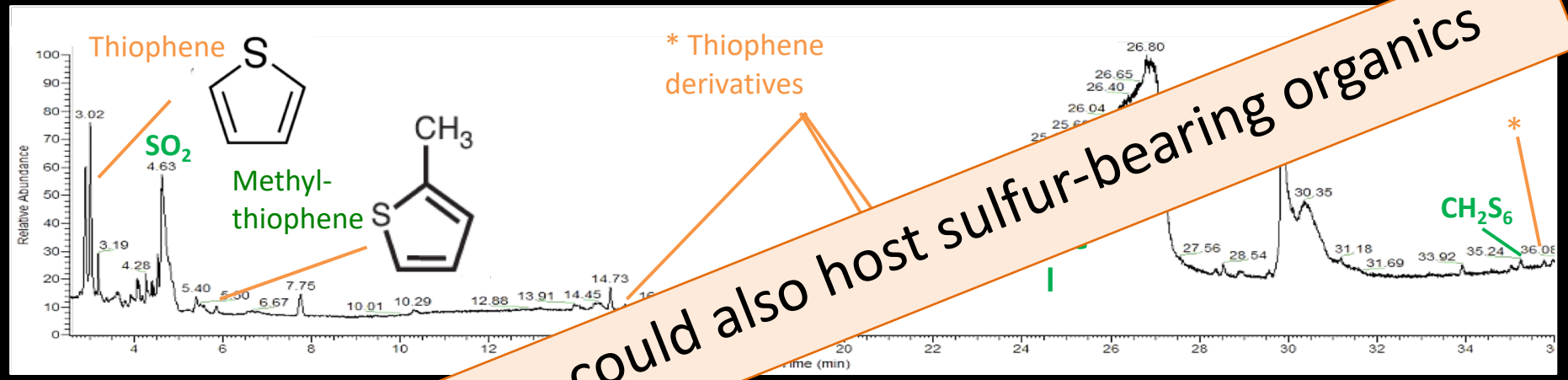
9,400 yrs; Mangatete, New Zealand, preserved as opal-A silica





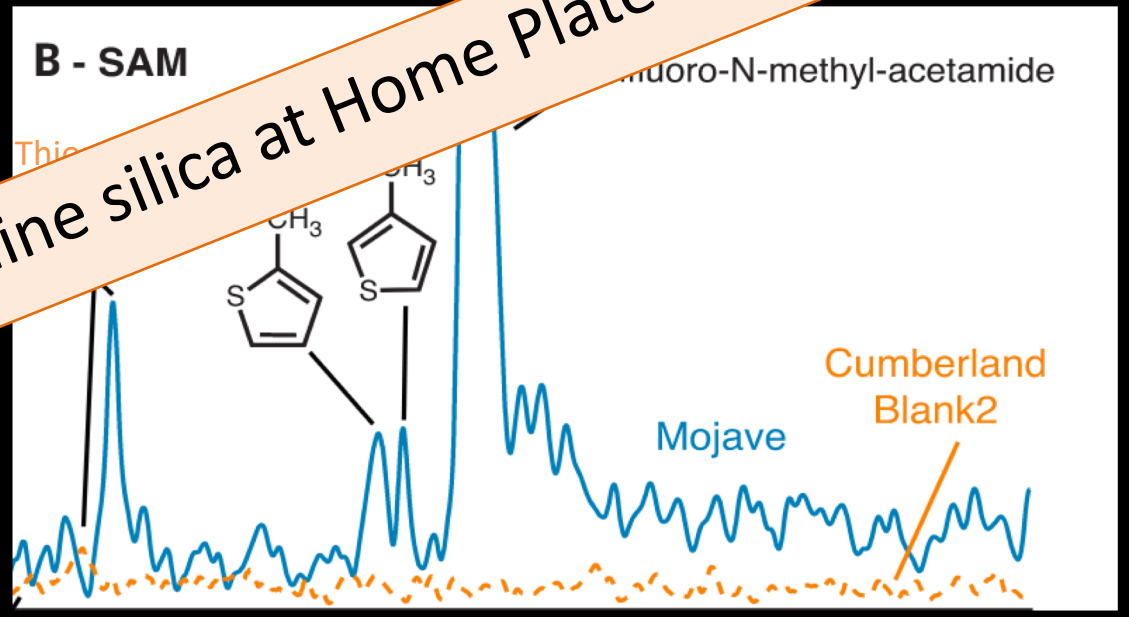
SAM-like experiment on digitate hot spring sinters

Hot spring digitate sinter, Rotokawa, NZ



This suggests opaline silica at Home Plate could also host sulfur-bearing organics

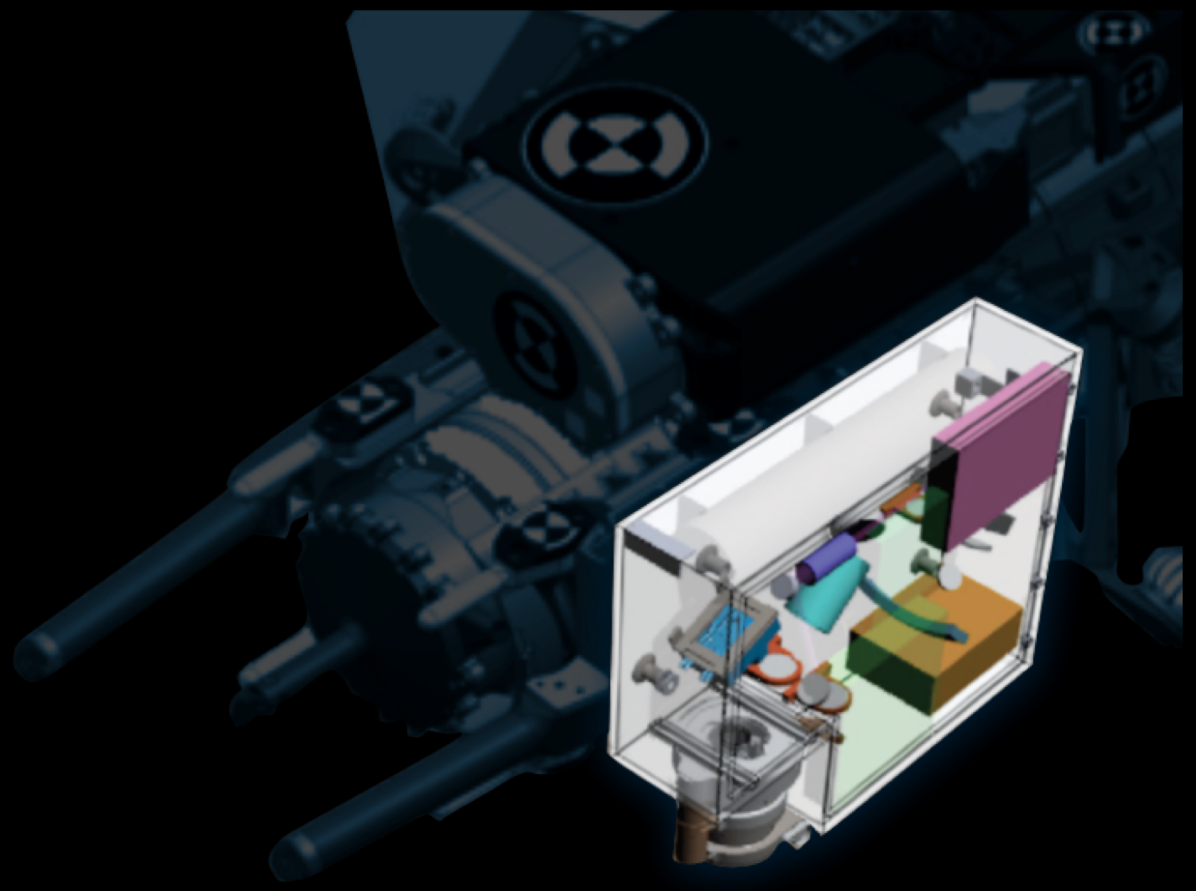
Organics detected at Rotokawa include heterocyclic sulfur-bearing organics in thiophene/ thio



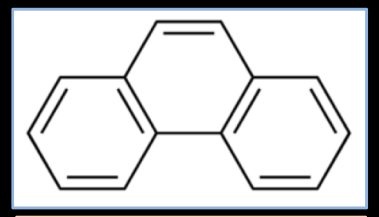
The same type of organics are also detected at Gale Crater by Curiosity

Eigenbrode *et al.* (2018)

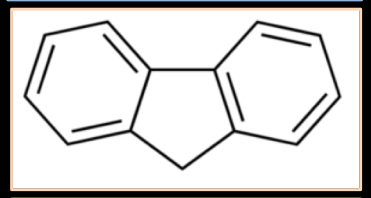
In addition to these aliphatic and heterocyclic aromatic compounds….



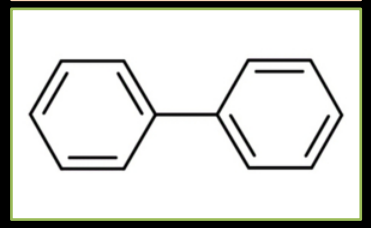
we also detected **polycyclic** aromatic compounds in modern and fossilized sinter, including:



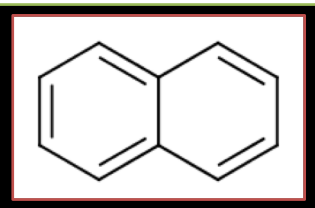
Phenanthrene



Fluorene



Biphenyl



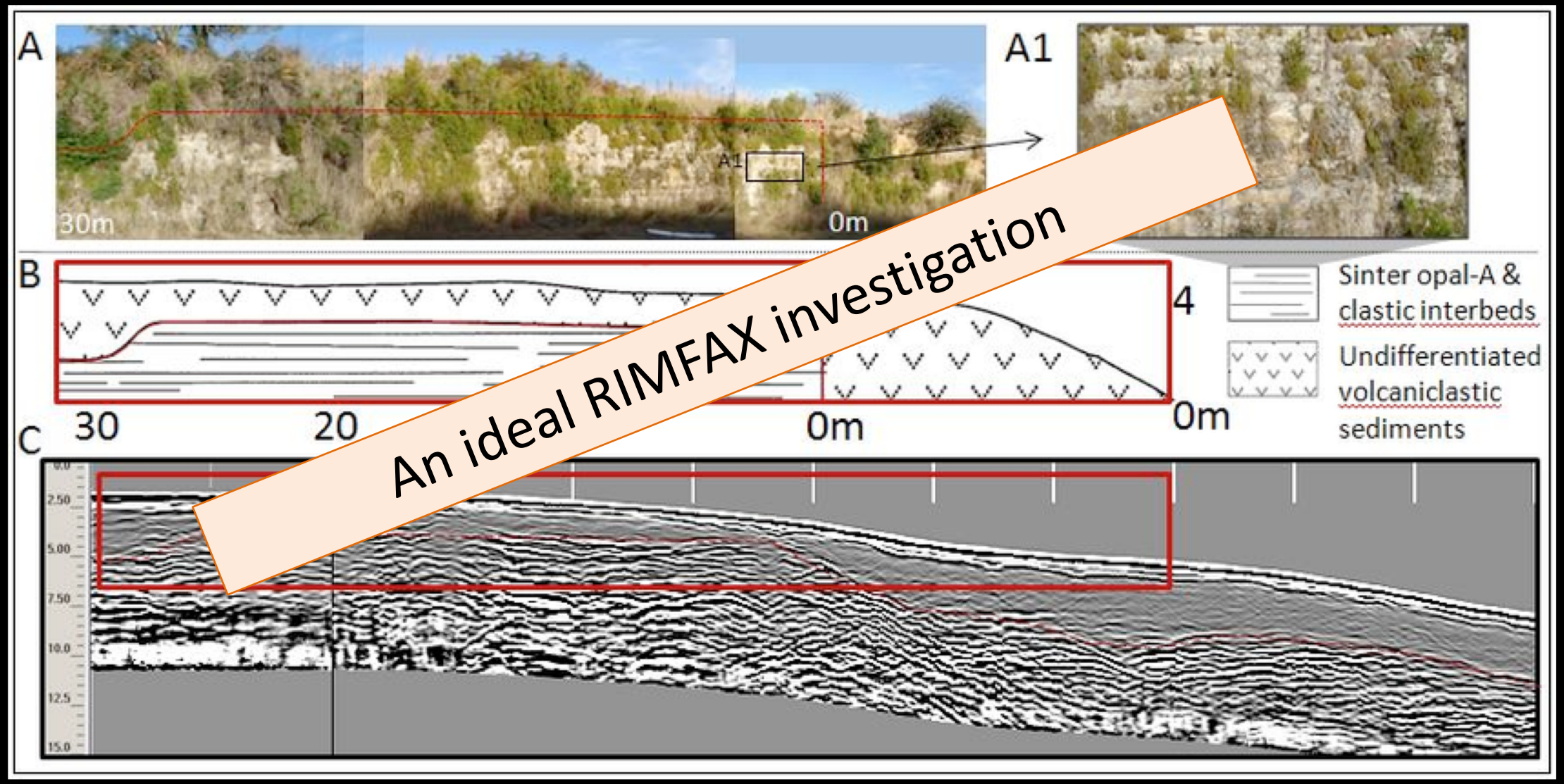
Naphthalene

Robust compounds detectable by SHERLOC

(NASA/JPL)

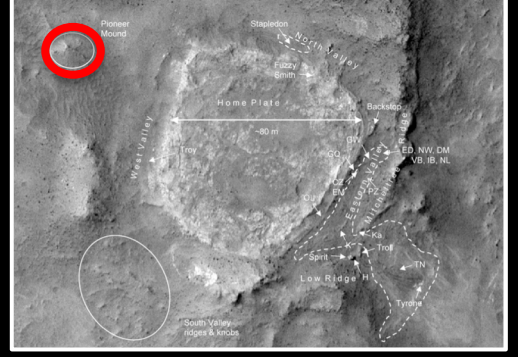
More to explore Is there silica sinter under Home Plate?

Ground Penetrating Radar Successful In Imaging Hot Spring Deposits: A New Geothermal Exploration Tool *Dougherty and Lynne,* 2010



More to explore

Are there any other hot spring features present at Home Plate?



Extinct hot spring sinter mound, Puchuldiza, Chile

El Tatio
active hot spring
sinter mound

t to
, Home Plate

In actively forming sinter vent mounds thick microbial mats are ubiquitous

Concluding remarks

Various features of the opaline silica deposit at HP are consistent with an origin in a hot spring setting:
- co-occurrence of silica and sulfur rich soils
- stratiform nature, sharp contact with underlying substrate
- silica textures (digitate, breccia) typical of hot spring sinter and unlikely erosional

GC-MS sinter study suggests high preservation potential of organic biomolecules in opal-A silica

Further investigation of silica at Home Plate:
- exploring the subsurface extent of silica
- exploring origin of Pioneer Mound