Putative Microbial Biosignatures in a Mars-Analogue Hydrovolcanic Environment – Fort Rock Volcanic Field, OR

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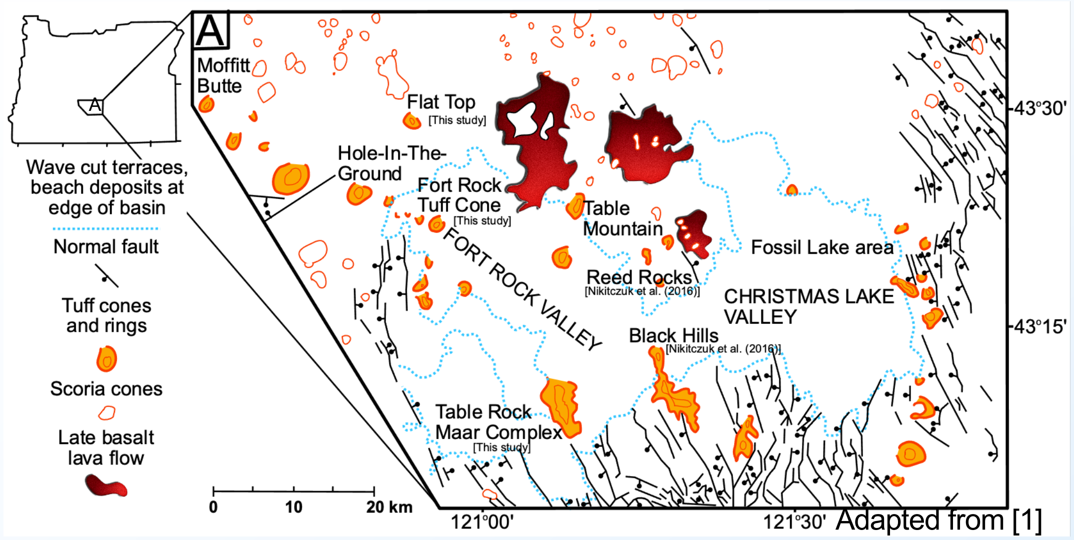


Adapted from [1]

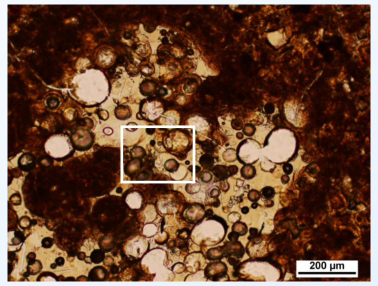
Fort Rock Volcanic Field

The Fort Rock Volcanic Field (FRVF) is a ~60 km * 40 km basin located in Oregon in the northwestern Basin-and-Range province, USA (see map, above) [1]. It hosted a **pluvial lake during the late Pliocene and into the Pleistocene**, which evolved through evaporation similarly to other Basin-and-Range pluvial lakes [2]. Widespread tabular diatomite beds underlying the basin floor and inter-bedded with volcanic deposits indicate a lacustrine environment that was **nutrient-poor with a neutral pH, evolving to alkaline/saline over time** [1, 2].
Mafic eruptions occurred during the Pliocene-Pleistocene along normal faults [1], creating **tuff cones, tuff rings,** maars, and cinder cones. Tuff cones and tuff rings are structures created by explosive magma-water interactions, and are found within and around the lake margins. Sedimentary structures such as inter-bedding with lacustrine mudstones, wave-cut terraces, bomb sags, and planar/cross/convolute bedding are indications of water-magma/lava interactions at different water levels during eruption and deposition [1].

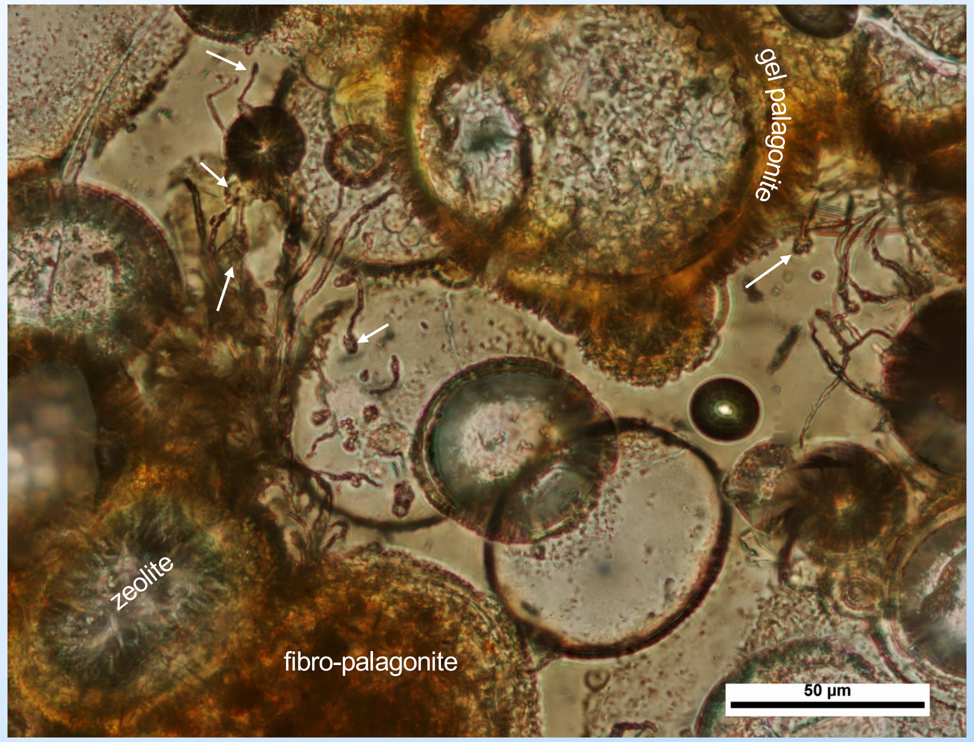
Mars Exploration

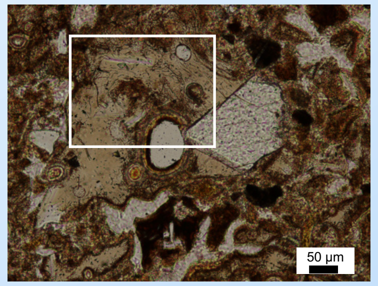
FRVF acts as a Mars-analogue environment on multiple levels:

- **Hydrovolcanic features:**
  - Potential tuff cones and tuff rings have been identified in the Nephentes Planum and Amanthes Cavi region along the dichotomy boundary on Mars [3]
  - Hydrovolcanism has been hypothesized as a source for a number of features found in Gusev Crater, including bomb sags, base-surge deposits, accretionary lapilli, and opaline/amorphous silica deposits [4-8]
- **Pluvial lake environment:**
  - Mineralogy and stratigraphy (inferred through both orbital and *in situ* data) from Gale Crater and Jezero Crater suggest the presence of ephemeral lacustrine environments [9, 10]
- **Mafic volcanism:**
  - The Martian crust and volcanic deposits are mafic in composition [11, 12]

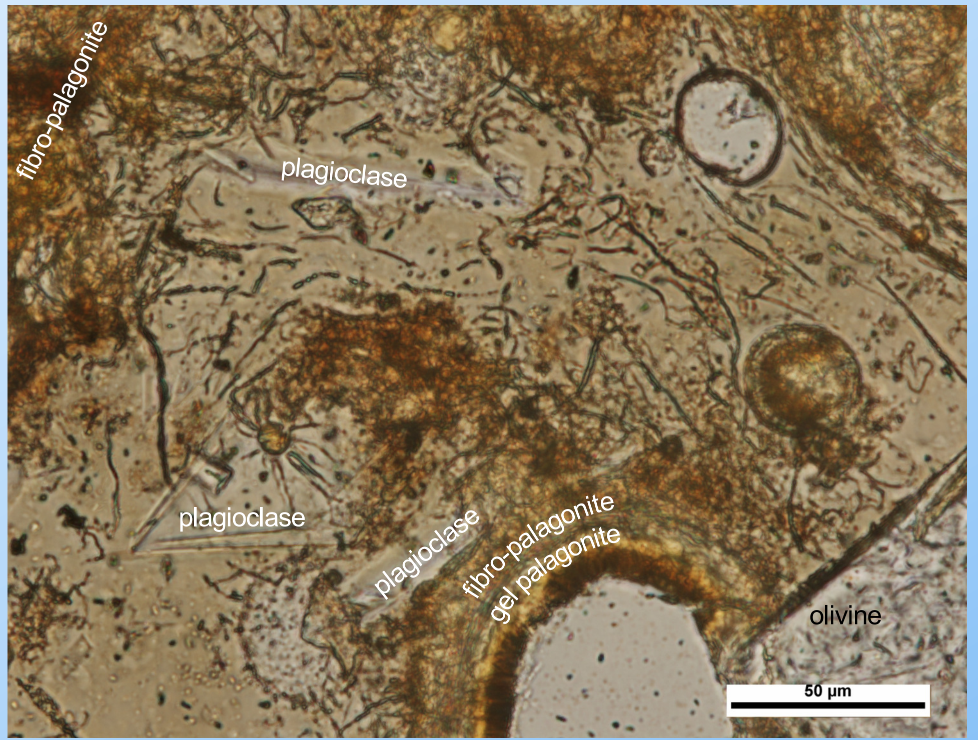


Flat Top sample shows curvilinear µts, some with terminal enlargements (arrows), emerging from gel– and fibro-palagonitized vesicles into glass. This slide also contains olivine phenocrysts, plagioclase microphenocrysts, and secondary zeolite.



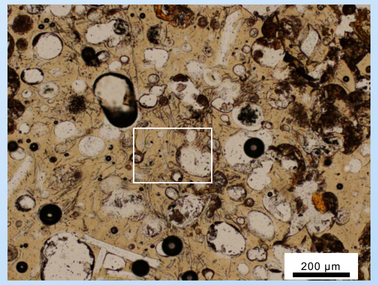


Fort Rock sample shows ubiquitous curvilinear µts associated primarily with fibro-palagonite/glass margins. This slide also contains olivine phenocrysts, plagioclase microphenocrysts, and secondary zeolite.

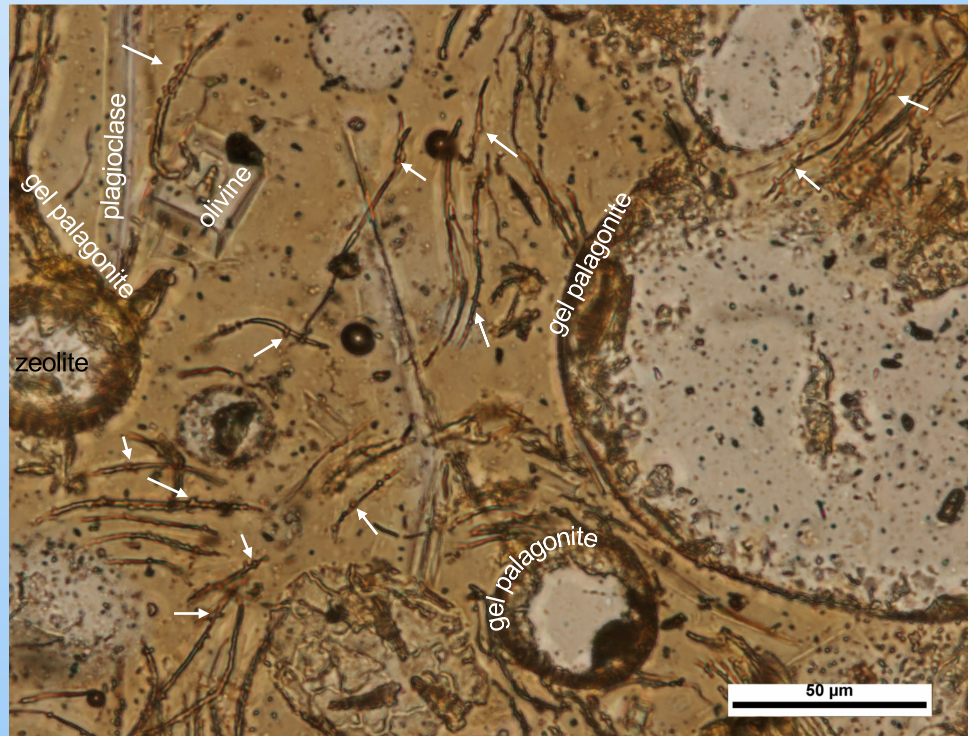


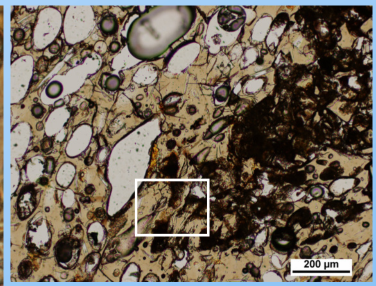
Microtubules in Volcanic Glass

Tuffs from the FRVF were initially examined in [2] and found to contain **putative microbial ichnofossils: microtubules** (µts) with a variety of morphologies that are indicative of biogenic formation [13]. These **µts are similar in morphology to µts found in sea-floor basalt and basaltic tuffs of a range of ages** [14-18], and are a **significant potential biosignature** as they would not be readily destroyed by the radiation environment on Mars. Our work continues that of [2] and examines further occurrences of these µts in other structures from the FRVF: Flat Top, Fort Rock, and Table Rock. Tubules have been found in sideromelane (mafic glass formed by water-mafic magma quenching) in association with gel- and fibro-palagonite, plagioclase and olivine microphenocrysts, and secondary calcite and zeolite. [2] suggested that µts formed during periods of **lower-temperature hydrothermal alteration.**

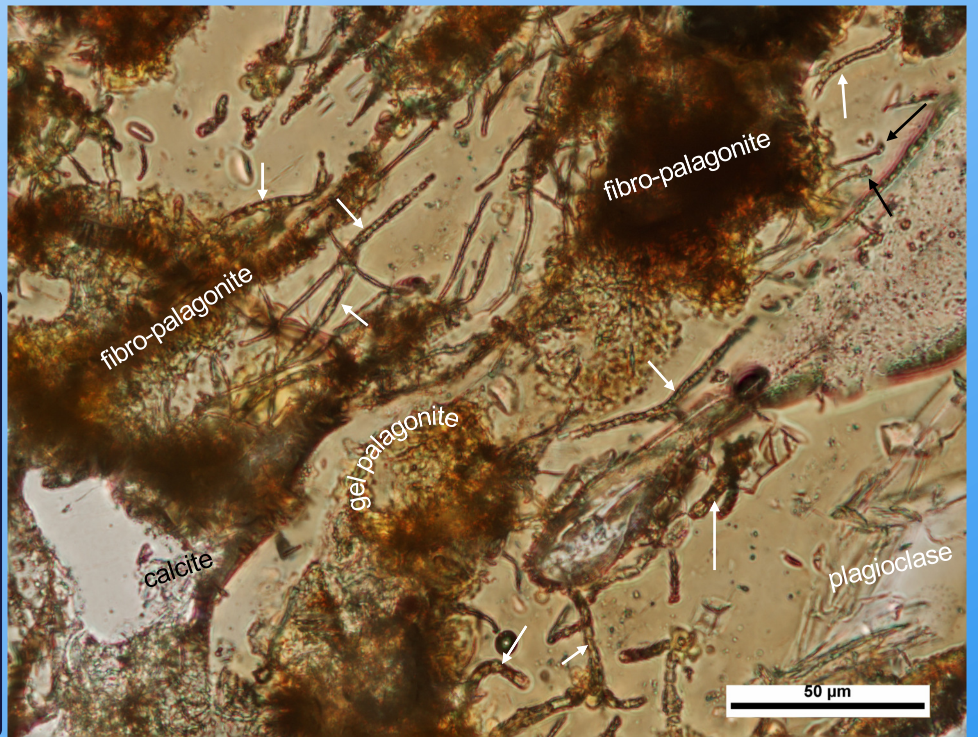


Fort Rock sample shows curvilinear µts with "bud-like" bumps along their lengths (arrows). This slide also contains gel- and fibro-palagonite, plagioclase microphenocrysts and secondary zeolite.





Fort Rock sample shows curvilinear µts, some empty, some with terminal enlargements (black arrows) and some containing septae or ovoid bodies (white arrows). This slide also contains gel- and fibro-palagonite, plagioclase microphenocrysts and secondary calcite.



[1] G.H. Heiken [1971] J.G.R., **76:**23, pp. 5615–5626. [2] M.P.C. Nikitczuk *et al.* [2016] G.S.A. Bull.,**128:**7–8, pp. 1270–1285. [3] P. Brož and E. Hauber [2013] J.G.R. Planets, **118:**8, pp. 1656–1675. [4] S.W. Squyres *et al.* [2007] Science, **316:**5825, p. 738–742. [5] D. Ming *et al.* [2008] J.G.R., **113:**E12S39, p. 1–28. [6] J.W. Rice *et al.* [2006] A.G.U. Fall Meeting, #P41B-1274. [7] A. Batista *et al.* [2010] 42nd D.P.S., #30.23. [8] L. Wilson and J.W. Head [2007] J. Volc. Geotherm. R. **163:**1-4, p. 83-97. [9] J.A. Hurowitz *et al.* [2017] Science, **356:**6341, p. 1-10. [10] B.H.N. Horgan *et al.* [2020] Icarus, **339,** p. 1-34. [11] M.H. Carr and J.W. Head [2010] E.P.S.L., **294,** p.185-203. [12] S.J. Robbins *et al.* [2011] Icarus, **221,** p.1179-1203. [13] M. Fisk and N. McLoughlin [2013] Geosphere, **9,** p. 317-341. [14] K.E. Metevier [2011] U. of Kansas Thesis. [15] N. McLoughlin *et al.* [2009] J. Geol. Soc. London., **166:**1, pp. 159–169. [16] N.R. Banerjee and K. Muehlenbachs [2003] Geochem., Geophys. Geosystems, **4:**4, p. 1037. [17] M.R.M. Izawa *et al.* [2010] P.S.S., **58:**4, pp. 583–591. [18] C.S. Cockell *et al.* [2009] Geobiology, **7:**1, pp. 50–65.