Importance of Sulfur for Phosphorus Mobility on the Martian Surface

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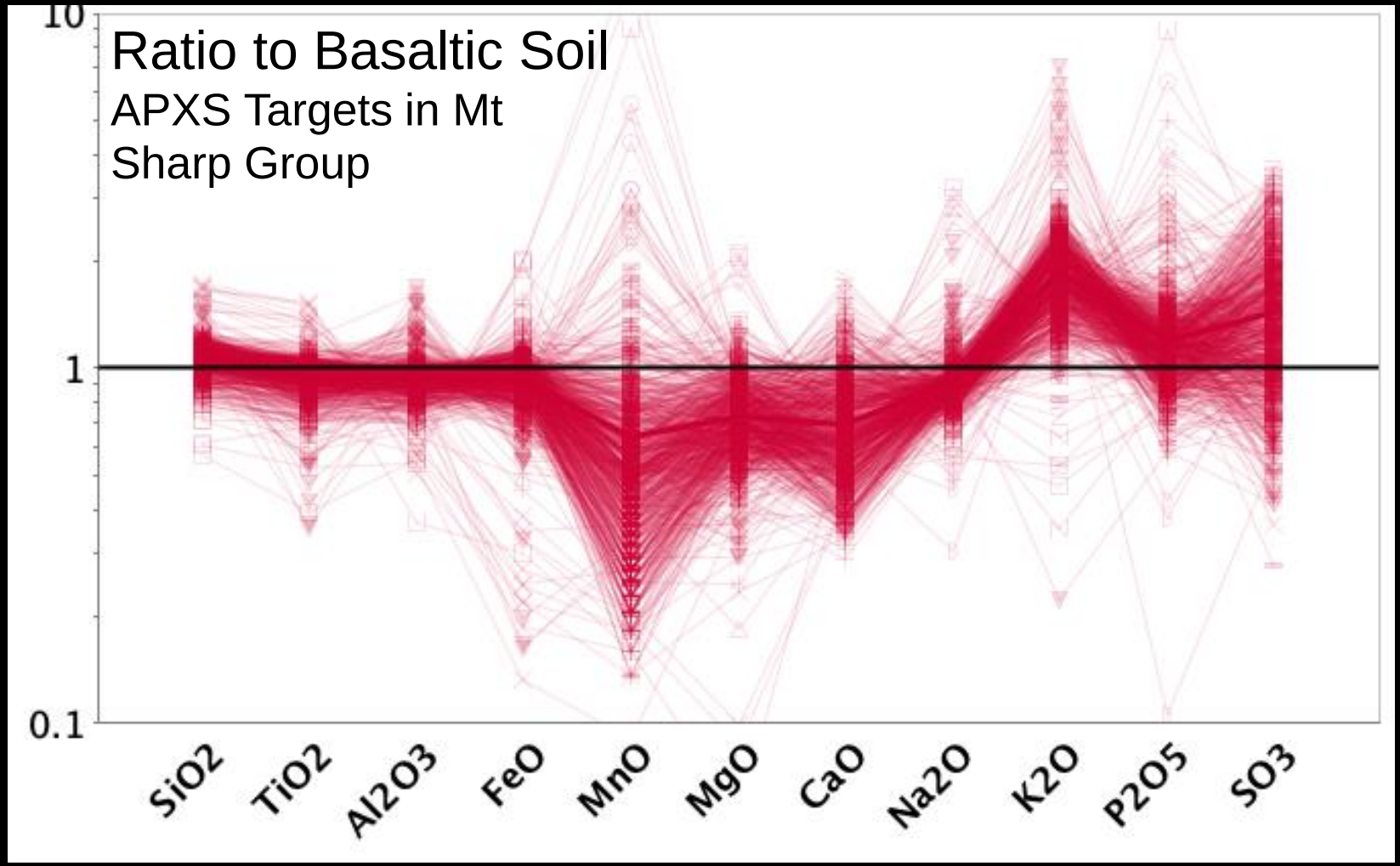
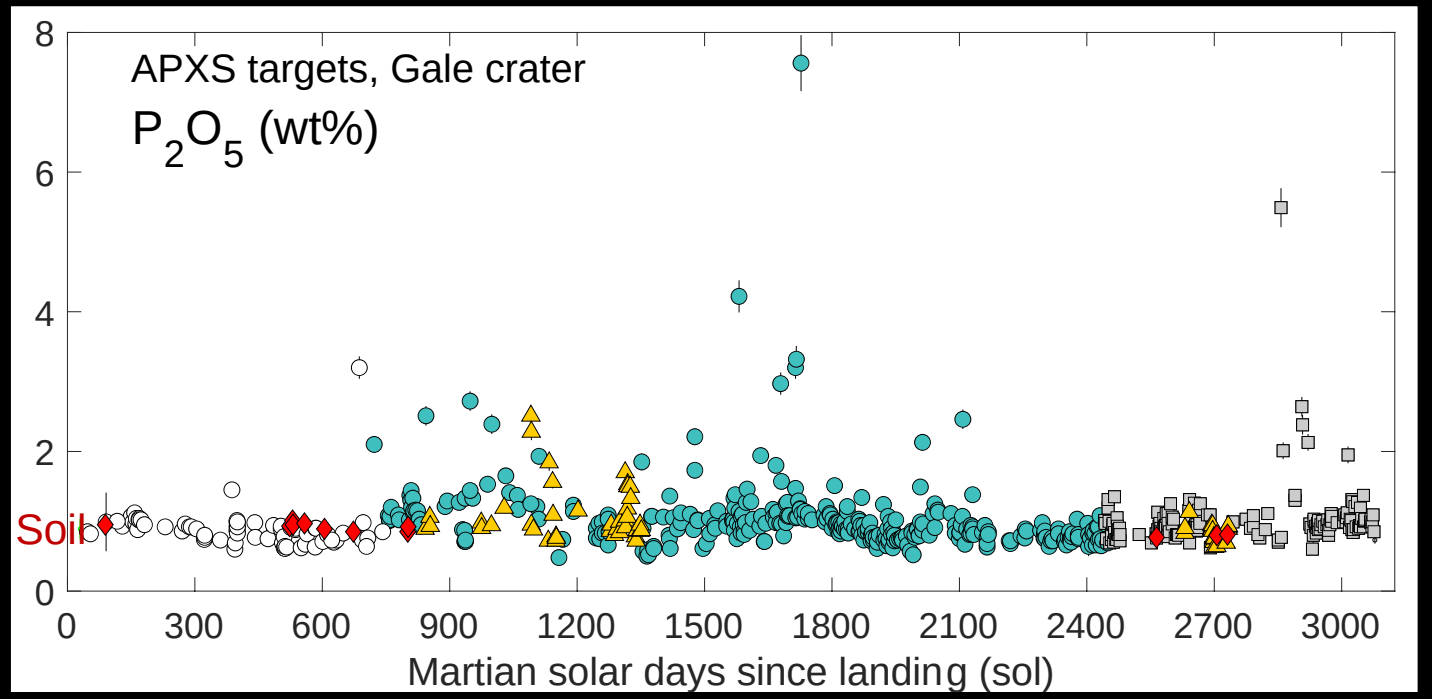
Phosphorus in Gale Crater: APXS Results

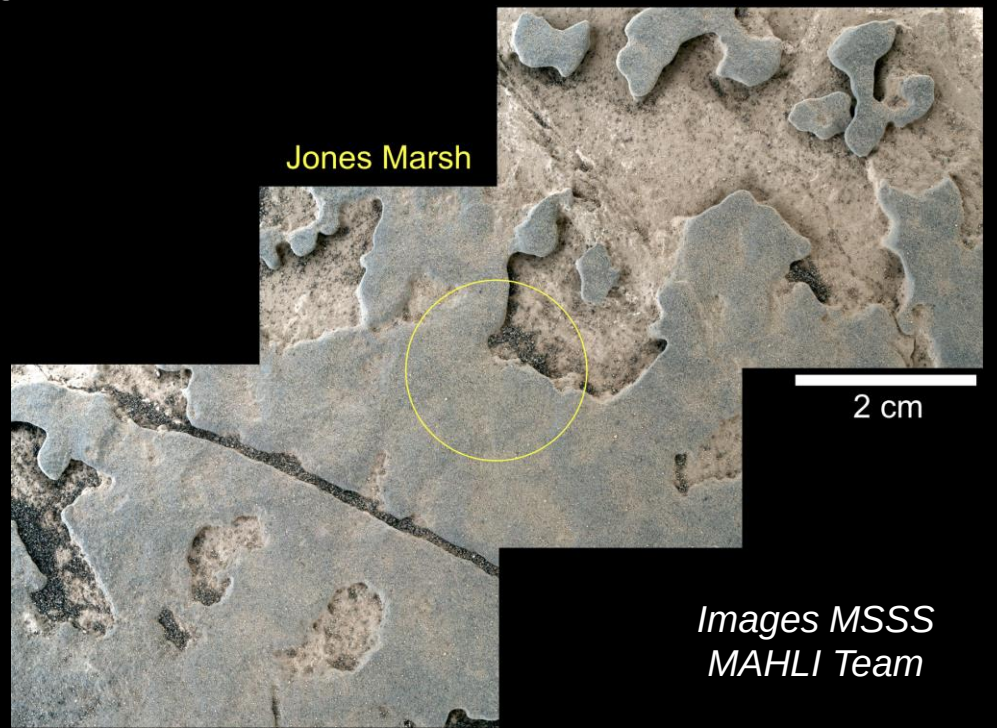
- Mt Sharp group bedrock has a mean P_2O_5 concentration (1.0 ± 0.4 wt%)
- This is roughly the same as the soil-like basaltic provenance (0.9 ± 0.1 wt%)
- Suggests that open-system mobility of P may have been relatively low
- Contrasts with leached Mn, Mg, and Ca
- Fluorapatite in CheMin XRD does not account for most of the P (Rampe et al., 2020)

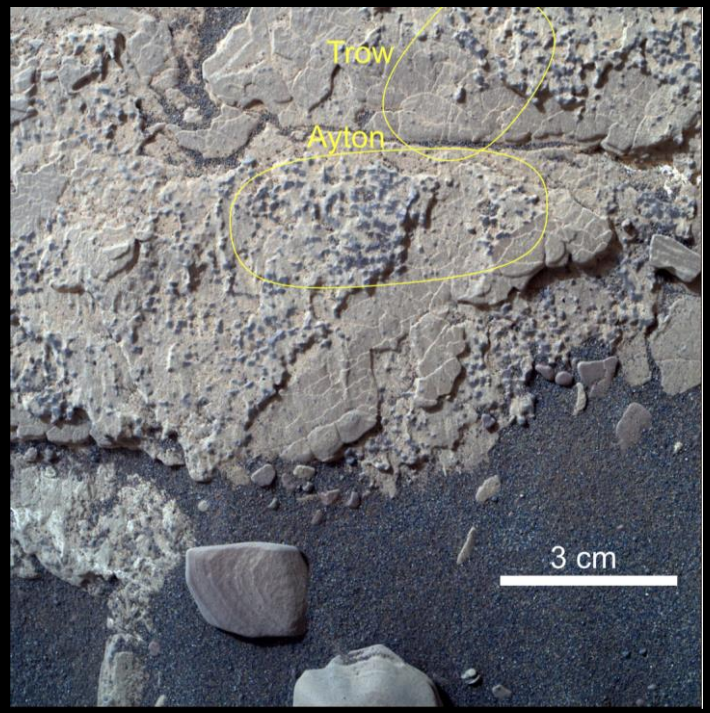


Phosphorus in Gale Crater: APXS Results

- Clear evidence that phosphorus was mobile in Gale crater
  - Enrichments associated with veins, nodules, and haloes
  - Co-enriched with Fe, Mn, and/or Cl
  - No consistent correlation with sulfur







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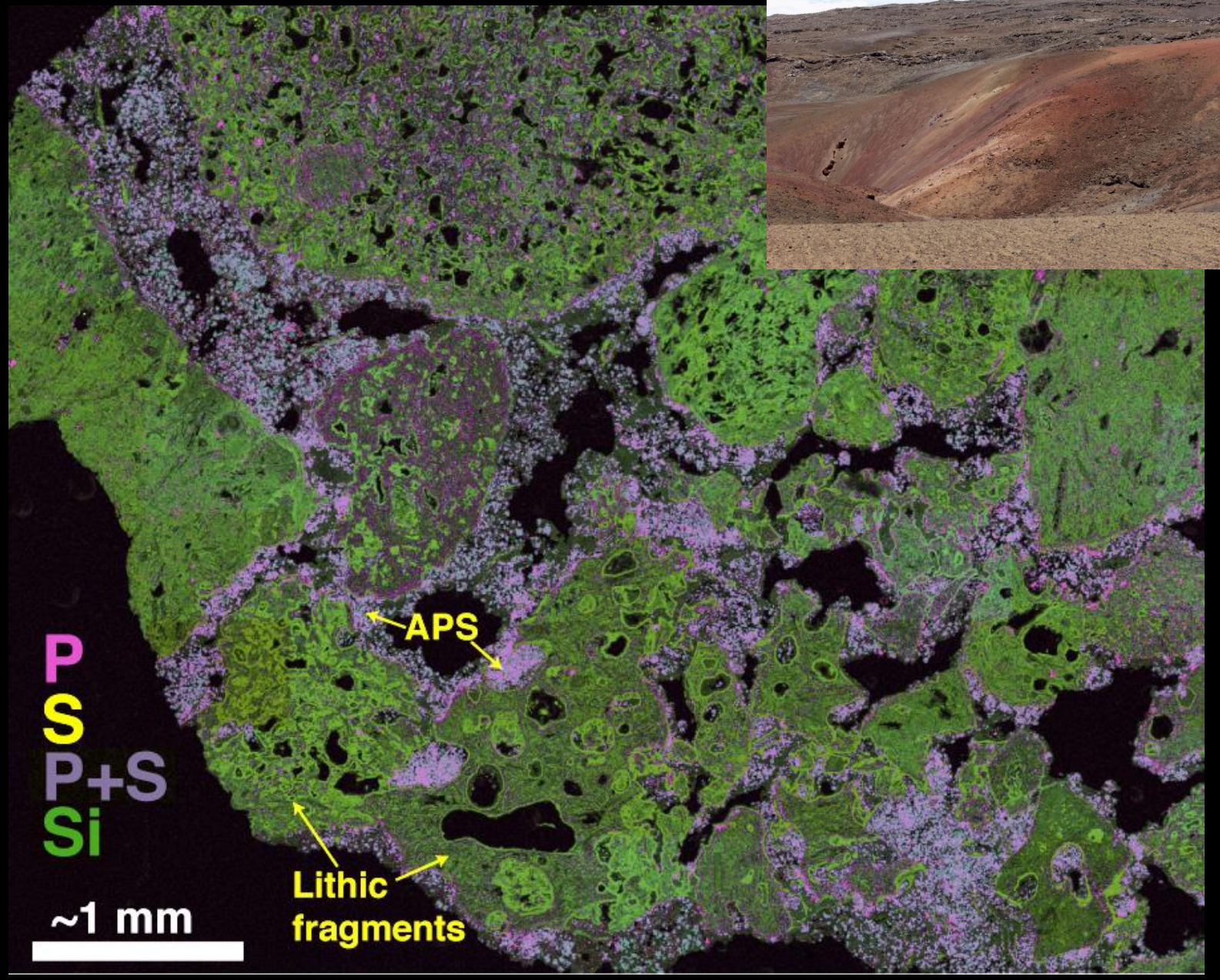
Phosphorus in Gale Crater: Open Questions

- Phosphorus history on the martian surface is largely unconstrained
  - Most of the phosphorus measured by APXS is not associated with crystalline material
  - Phosphorus does not have any consistent geochemical trends that indicate phase(s)
- Questions
  - What phase(s) is(are) phosphorus associated with in Mars-relevant sulfur-rich systems?
  - What were the conditions under which phosphorus was mobilized?

Mauna Kea Analogues

- Acid-sulfate altered samples:
  - P is leached entirely from the tephra and is deposited in sulfate-rich cement
  - The bulk P/Ti stays the same or higher than the tephra
  - XRD results indicate alunite/jarosite and no secondary P minerals
  - SEM results show ~5% P is substituted in sulfates

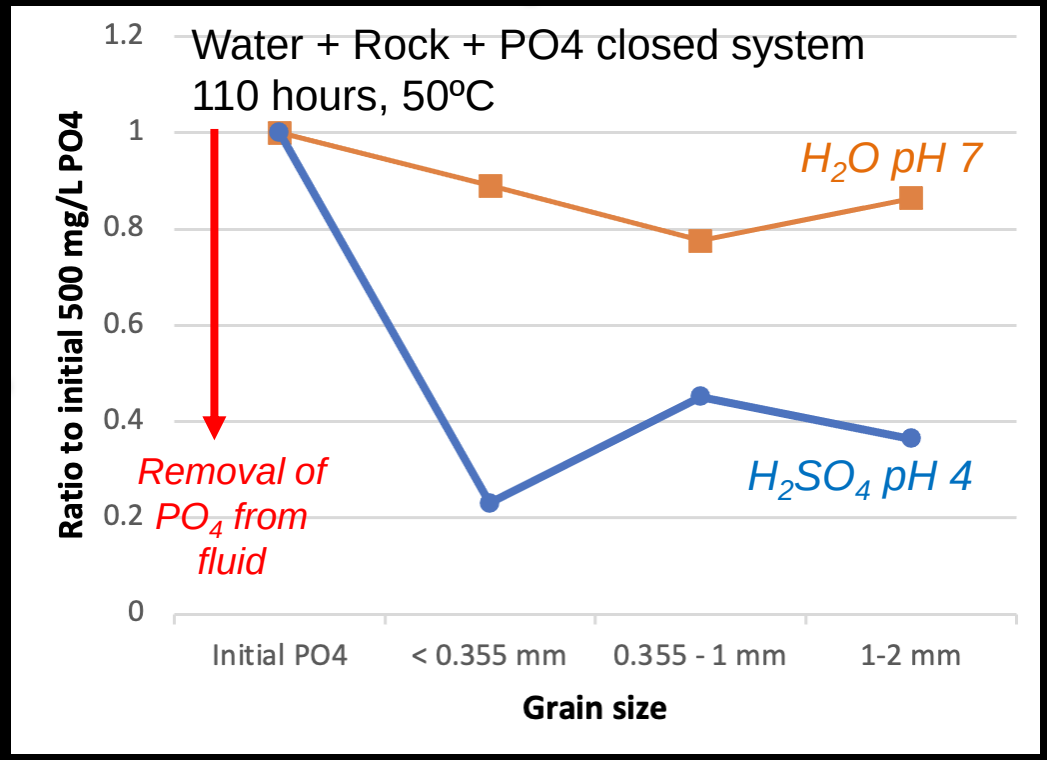


Experiments Testing Sulfur Control on Phosphorus Mobility

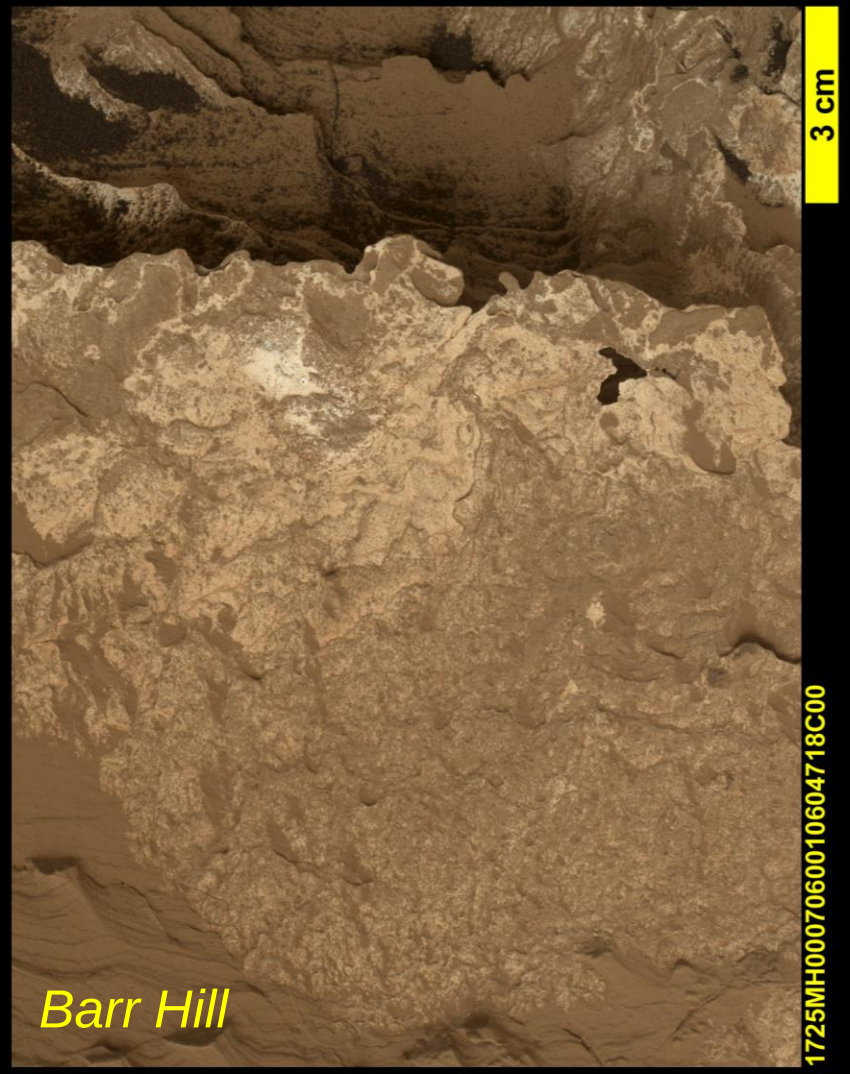
- Experiments with closed reactors and ion chromatography:
  - Powdered Hawaiite (50-500 mg)
  - Phosphate standard (10-500 mg/L)
  - Fluids (variable)
    - Pure water pH 7
    - HCl pH 4
    - H_2SO_4 pH 2-4

- Experiments with H_2SO_4 increase the rate of PO_4 uptake from the fluid (hours-days)

- Experiment runs >1 month with rock and doped PO_4 all end up with very low PO_4 (n.d. to ~1-2 mg/L)
  - Adsorption capacity t.b.d.



Evidence of P in Ca-sulfate Veins in Gale Crater



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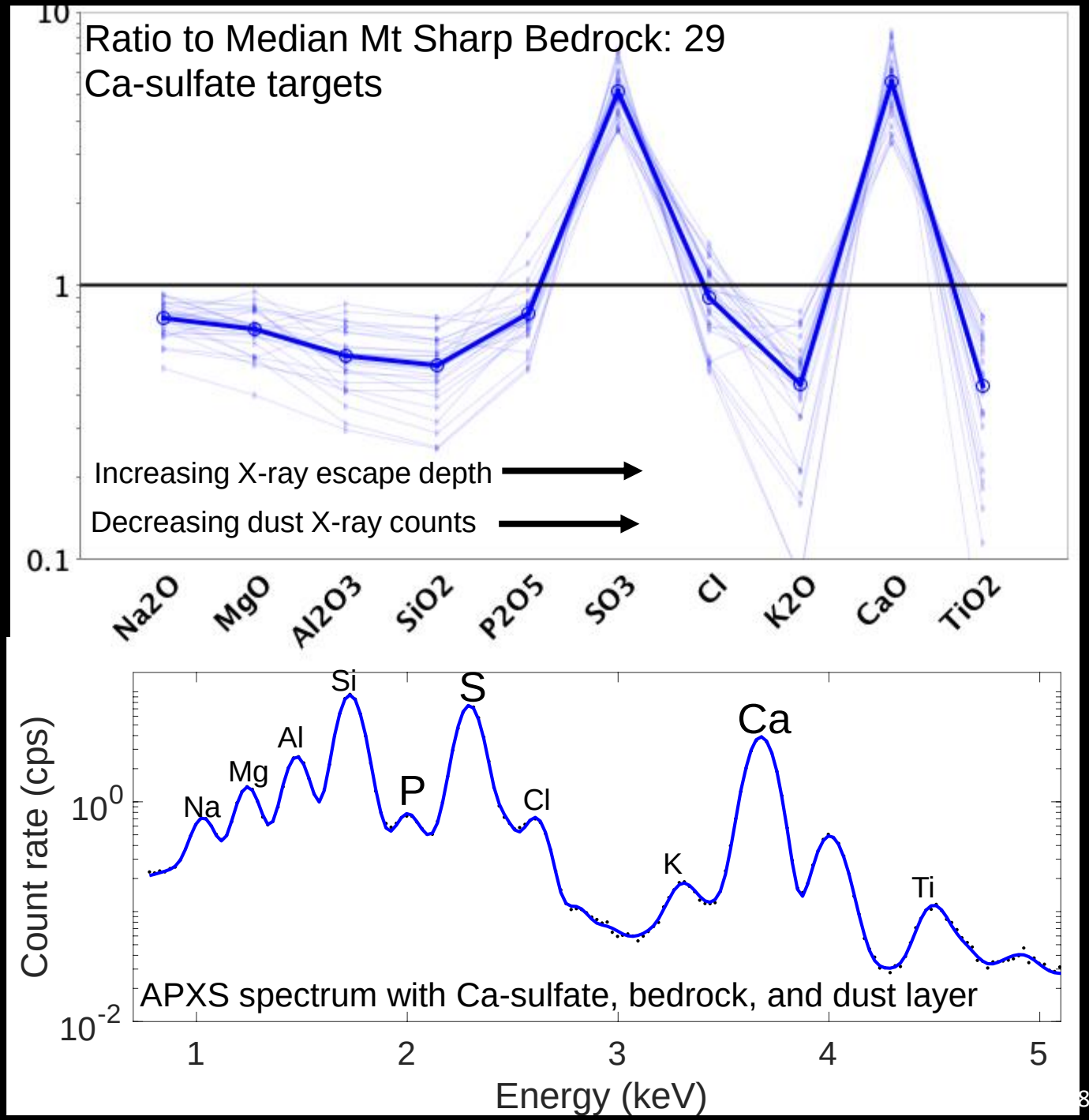
Evidence of P in Ca-sulfate Veins in Gale Crater

- Ratio of Ca-sulfate targets to background bedrock reveals P and Cl are not diluted to the same degree as predicted for pure Ca-sulfate
- Spectral modeling of bedrock, dust, and Ca-sulfate endmembers indicates that the Ca-sulfate veins contain ~1 wt% P_2O_5



Implications

- The potential for phosphate incorporation in martian sulfates is suggested by:
  - ~1 wt% phosphate in Gale crater Ca-sulfate veins
  - ~5 wt% phosphate in analogue sulfates
- The apparent retention of secondary phosphorus in Mt Sharp sedimentary bedrock could be associated with the ~5-10% Ca-sulfate in the matrix
- Phosphorus solubility may have been significantly controlled by sulfate solubility on the martian surface
- Was the sulfur cycle a control on the phosphorus cycle on Mars?