Surface expressions of potentially habitable subsurface environments on Mars: Sulfur alteration features at Borup Fiord Pass. G. E. Lau[1], C. B. Trivedi[2], S. E. Grasby[3], J. R. Spear[2], and A. S. Templeton[2], [1]University of Colorado Boulder (email: astrobiologist3@gmail.com), [2]Colorado School of Mines, [3]Geological Survey of Canada.

Introduction: Sulfate alteration features hosted in permafrost at Borup Fiord Pass, in the Canadian High Arctic, may represent key targets for the exploration of low-temperature subsurface fluid systems on Earth and Mars. Iron- and sulfur-rich minerals in these features are produced by subsurface fluids with a chemistry modified by *in-situ* biological activity. The features are typical of gossans, where oxidative leaching of pyritic ore in the near surface drives surface mineralogy toward oxidized sulfur and iron assemblages. We suggest such systems should be thoroughly investigated to assess their habitability and biosignature preservation potential.

Observations: At Borup Fiord Pass, sulfate alteration features are circular, up to 3 m in diameter, and stand out from the greyish carbonate rock units of the surrounding valley due to the red staining of the features from abundant iron oxide minerals. The two largest of these features have white central regions from abundant gypsum and lack of iron oxides (Figure 1).

The alteration features at Borup Fiord Pass were first discussed in detail by Grasby et al. [7], where the structures were termed "paleopipes" due to their possible origin as relict sulfide springs. A nearby glacier has been studied for the emergence of supraglacial sulfide springs and associated deposits rich in elemental sulfur [e.g., 5-8]. Sulfide in such springs is likely derived from biological sulfate reduction (BSR) in the subsurface at Borup Fiord Pass, as demonstrated from sulfur isotope data [6]. We report that the paleopipe alteration features preserve sulfide minerals, primarily pyrite, co-localized with elemental sulfur (S^0) and abundant sulfate minerals. We also show that isotopes of sulfides and sulfates from these paleopipes match those of reduced sulfur in the modern spring system on the glacier. We thus interpret the paleopipes to be remnants of spring conduits, where the low-termperature springs emplaced a large body of pyritic ore. The paleopipes also exhibit a surface mineralogy similar to terrestrial gossans, which develops as the pyrite has been oxidatively leached and altered to the diagnostic sulfur and iron mineralogy, which we detail through x-ray diffraction (XRD) and Raman microspectroscopy.

Gossans have developed in sulfur and iron rich systems across the Earth and may have developed on Mars. For instance, iron and sulfur are both enriched in the Martian crust [4], implying that iron sulfide ores may likely have formed and may still be present in the Martian subsurface [2]. Burns [1] and Burns and Fisher [2,3] have suggested that oxidative weathering of such pyritic ores on Mars may have established gossans. Although these authors have proposed a high temperature abiotic emplacement for such gossans, it is possible that similar system to the paleopipes at Borup Fiord Pass may exist on Mars [7]. For instance, a number of authors have considered the possibility of springs and subsurface hydrological systems on Mars [e.g., 7,9-10]. A subsurface fluid enriched in sulfide, potentially derived from Martian BSR, may have emplaced pyritic ores in the subsurface of Mars. Oxidative leaching of such ores may then leave behind diagnostic surface mienralizations reminiscent of these High Arctic paleopipes. Signatures of past or present biological processes within such surface expressions are thus be ideal targets for future astrobiological explorations of Mars.

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Figure 1. A Paleopipe Alteration Feature at Borup Fiord Pass. The white central region of gypsum and red stained rim are conspicuous among the rocks of the surrounding valley. Researchers are shown for scale.