Highlights & Breakthroughs contribution for American Mineralogist on "Wishstone to Watchtower: Amorphous alteration of plagioclase-rich rocks in Gusev crater, Mars" by Stephen W. Ruff and Victoria E. Hamilton

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The Mars Exploration Rover "Spirit" provided us with a serendipitous opportunity to traverse a section of the ancient martian crust, acquiring a trove of imaging, geochemical, and mineralogical measurements along the way. This small window looking out on the Noachian period (>3.7 Ga), dubbed the Columbia Hills, pokes out from the younger, volcanically resurfaced floor of Gusev Crater. It was our first detailed look at early Mars, a time when liquid water appears to have played a much more prominent role in shaping and modifying the planet than later in its history.

The abundance of rocks that appear to be snapshots from early in the history of Mars are a luxury compared to the rarity and inevitable metamorphic overprinting of Hadean and early Archean samples from Earth. However, few planetary surfaces of this age anywhere in the solar system escape the disruption caused by impacts. In this sense, it is difficult to identify the geologic context of any given sample or series of samples. Although what appears to be an outcrop of a draping volcaniclastic unit in the Columbia Hills may still be in place, it is also possible for it to have been highly fractured, shocked, and overturned (perhaps multiple times) as part of the ejecta blanket from an impact event (e.g., McCoy et al., 2008).

It is in this context that Ruff and Hamilton investigate two series of rocks in the Columbia Hills; (1) Wishstone Class – plagioclase dominated rocks with volcaniclastic textures and elevated Al, Ca, Na, and P, and (2) Watchtower Class – containing fine veins, a large amorphous component, and relatively high Mg, Zn, S, Cl, and Br (Herkenhoff et al., 2006; Horowitz et al., 2006). Hurowitz et al. (2006) previously recognized a continuum between the relatively pristine Wishstone Class and the altered Watchtower rocks based on elemental chemistry measurements and variations in Fe^{3+}/Fe_{Total} (Morris et al., 2006). Despite these differences, MnO, FeO, and SiO_2 appear unchanged between the two rock classes.

What Ruff and Hamilton add to this story is a detailed look at the mineralogy of Wishstone and Watchtower Class rocks derived from Miniature Thermal Emission Spectrometer (Mini-TES) measurements acquired by the rover. This is an impressive example of perseverance in the face of what can be a challenging dataset, not least of which was a layer of dust deposited on the Mini-TES periscope mirror by a dust “event” and further dust deposited on the rocks themselves. I'll spare the reader from the obscure details of Mini-TES data reduction, except to note that Hamilton and Ruff manage to convincingly refine what initially appears to be a hopelessly complex set of spectra to a simple series that falls along a continuum between two end-members (See Figure 17 of Ruff and Hamilton).

The results show trends in mineralogical and amorphous phases that mimic the previously recognized trends in chemical composition and Fe-bearing mineralogy. The Wishstone class rocks contain a dominant intermediate to calcic plagioclase component with lesser olivine and phosphate components. By contrast, Watchtower class rocks have a dominant, relatively low Si amorphous silicate component that has spectral features resembling volcanic glass and maskelynite (an impact shocked plagioclase).

What Ruff and Hamilton pull together in their work is not just that water played a role in the geologic history of the Columbia Hills, but the details of how and under what conditions it played that role. Taking the full suite of measurements into account, it appears that the Watchtower rocks are Wishstone rocks that have been aqueously altered to varying degrees, yet again showing evidence of water early in martian history. What is new here is that this alteration appears to depolymerize silicate materials with

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extremely limited mobility of the major cations, forming nanophase oxides and a relatively low Si amorphous material. Exposure to water was extensive enough to alter a large proportion of the Watchtower class rocks, but limited enough to avoid creating large amounts of high Si amorphous materials and no detectable opaline silica, quartz, or phyllosilicate phases.

Ruff and Hamilton note just how unusual this style of weathering seems to be on Earth, but how it might be common on Mars. Even in the some of the driest and coldest places on Earth, such as the Antarctic Dry Valleys, high Si amorphous components dominate weathering products (Salvatore et al., 2013). Yet, analyses from the Mars Science Laboratory at Gale Crater, thousands of kilometers to the west, appear to show the same pattern of materials dominated by plagioclase and low Si amorphous materials, with no detectable phyllosilicates.

Is what we are seeing on Mars a globally predominant style of weathering, such as acid fog alteration (e.g., Tosca et al., 2004), that has little to no presence here on Earth? The evidence seems to point in that direction. Certainly, there is little evidence for globally widespread aqueous alteration processes that are more common to us here on Earth. Though the identification of aqueous phases on Mars, such as opaline silica and smectites have received much attention from the planetary science community, their occurrence is typically limited in both extent and concentration. The occurrence of diagenetic clays and quartz on Mars is even less common, suggesting that exposure to water was limited in duration and temperature (e.g., Tosca and Knoll, 2009).

Ruff and Hamilton add a new level of detail to a picture of Mars that is slowly coming into focus with each new spacecraft mission. While some locations on Mars certainly show evidence of exposure to large abundances of water, the results at Gusev Crater and elsewhere suggest that most regions have been influenced in a more limited way. Water may have played a large role, especially early in the history of Mars. However, it may have done so in a manner that still evokes an image of a cold and relatively dry planet that is difficult to reconcile with the presence of longstanding lakes, oceans, or precipitation.

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