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Craters of the Moon National Monument basalts as unshocked compositional and weathering analogs for martian rocks and meteorites

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Abstract

The availability of terrestrial sites that are martian analogs allows researchers to investigate Mars using knowledge gained on Earth. Among the terrestrial analog sites for Mars is Craters of the Moon National Monument (COTM) in Idaho, U.S.A. Craters of the Moon National Monument is home to over 60 basalt lava flows, many of which have been dated from 2050 to 18 340 years before present (y.b.p.). Following previous authors, we examined the chemistry and petrogenesis of COTM basalts compared to basaltic martian rocks, martian meteorites, and meteorite clasts, and then examined the results of chemical weathering of the basaltic flows. Results of our comparative chemical analysis suggest COTM basalts are generally more evolved than the martian materials, with a few notable exceptions. Several COTM flow basalts, including rocks of the >18 000 year old Kimama flow, have high FeO, TiO_2, and P_2O_5 contents similar to the Wishstone and Watchtower class rocks analyzed at Gusev Crater, Mars, by the Mars Exploration Rover Spirit. The youngest basalts of COTM, such as those of the Minidoka (3890 y.b.p.) and Blue Dragon (2050 y.b.p.) flows have similarities in SiO_2, alkali contents, and mineralogical norms with select clasts in meteorite Northwest Africa (NWA) 7034. These similarities over a range of flow ages therefore suggest that COTM basalts have the potential to shed important light on specific igneous processes occurring on Mars.

Many of the basaltic rocks measured by rovers on Mars are thought to have experienced chemical weathering during aqueous interactions; however, few basalt weathering rates exist for terrestrial Mars-relevant field environments to help interpret these processes. COTM, which has important similarities to some martian rocks discussed above, also represents a basalt flow chronosequence, and therefore allows for the investigation of basalt weathering as a function of time. We measured the depth of developed porosity in a suite of basalt flows ranging from 2050 to 18 340 y.b.p., and compared field weathering relationships at COTM to weathering rinds developed on the Gusev Crater martian rocks Humphrey, Champagne, Mazatzal, and Wooly Patch. Our results indicate that depths of incipient weathering in COTM rocks increase with time at a rate of 2.32×10^{-2} to 3.04×10^{-2} μm/yr, which is comparable to other terrestrial advance rates. Interestingly, this rate also indicates that chemical weathering strongly outpaces physical weathering even in this arid to semi arid environment. Weathering primarily of the matrix glass indicates that glass may be functioning as the profile-controlling mineral, which may have implications for chemical weathering in glass-rich rocks on Mars. Weathering rates of glass and other minerals can also help constrain the conditions (pH, temperature) of alteration on Mars. Of the altered martian rocks we compared to COTM (Humphrey, Champagne, Mazatzal, and Wooly Patch), altered surfaces of Mazatzal rock at Gusev Crater show the most similarities to weathered surfaces at COTM. Comparisons of chemical weathering in COTM basalts with altered surfaces of rocks in Gusev Crater, Mars, indicate Gusev Crater martian rocks have undergone significantly more aqueous alteration than that experienced by basaltic flows at COTM.

Keywords: Mars, analog, craters of the moon, basalt, martian meteorite, Gusev crater, weathering, age correlation; Earth Analogs for Martian Geological Materials and Processes