A COMPARISON OF SAND-GRAIN SURFACE FEATURES ON TWO MARS ANALOGS FROM MAUNA KEA, HAWAI'I.

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Introduction: NASA's Mars Phoenix Lander (PHX) arrived at the northern plains of Mars with the objective of gathering evidence of the presence of water. The payload included an optical microscope which imaged regolith using a fixed-focus 6× optical apertures , the images were transferred in half of a 512×512 array. In this study, analogs are studied using SEM to observe grain surface features on an environmental gradient. HWMK600 and PH-07_CP are spectroscopic and magnetic analogs from two environments on Hawai'i, and surface feature inventories of the analogs show two distinct surface feature assemblages coinciding with the respective environments.

With the advent of the scanning electron microscope (SEM), considerable research was conducted relating grain surface features to environmental processes. Several works [e.g., 1] have compiled grain surface feature atlases that describe grain surface features and relate them to environmental processes. These studies examine quartz grains due to the durability of quartz on Earth and the consequent ubiquity of quartz in terrestrial sediments. These properties of quartz allow for the development of terrestrial environmental reconstructions. Later studies [2-5] examine basaltic tephra and volcanic ash to determine eruptive mechanisms, emplacement mechanics, and alteration of deposits. Using grain surface features, this study examines the correlation between process-specific grain surface features on volcanic tephra from two different environments along an environmental gradient.

Geologic Background:

Mars. For many years, the scientific strategy for Mars exploration was "Follow the Water". This strategy sought to determine (1) whether life exists or existed on Mars, by investigating how liquid water behaves on Mars through time, (2) the habitability of Mars, and (3) possibilities for future exploration [5]. Initial studies indicated that the planetary surface is composed largely of basaltic material and related alteration products. The soils at the multiple landing sites are very similar [6]. Recent studies, particularly the Phoenix Mission, have indicated the presence of H_2O ice near the planetary, and imaging of the planetary surface has also revealed polygonal-patterned ground which is associated with periglacial processes [7].

Hawai'i. Glaciation occurred in Hawaii during Pleistocene and early Holocene; the most recent interval, the Late Makanaka Glaciation, occurred 31-18 ka [8]. K-Ar dating of lava flows, radiocarbon dating of organic matter related stratigraphically to glacial deposits, and interstratification of glacial and volcanic units suggest sub-glacial eruptions occurred during the Makanaka Glaciation [9].

Samples and Methods: Two spectroscopic and magnetic analogs, HWMK600 and PH-07_CP [10] are used in this study. These samples are derived from iron-rich basaltic lavas and have similar elemental abundances to soils observed in previous Mars missions [10].

Sampling Sites. These samples were selected for this study based on their proximity to one another and the presence of an environmental gradient from emplacement to present. This allows for comparison of a cold, drier, high elevation environment to a warm, wetter, lower elevation environment through time. The sampling site of HWMK600 lies within the Waikahalulu Volcanic Formation which has sub-units that are coeval with the last glacial maximum on Mauna Kea, about 31-18 ka [8]. Currently, the sample site lies in a barren, relatively cold, and dry environment. The sampling site of PH-07_CP lies below the limit of the last glacial maximum; the current environment is grassland or shrubland, relatively warm, and wet [11,12]. The relative youth of the two samples permits the assumption that, although absolute environmental conditions may have varied over tens of thousands of years since tephra emplacement, the elevationally controlled environmental gradient between the sampling sites has been maintained.

HWMK600 was sampled from the south side of Very Large Baseline Array (VLBA) Rd, near the telescope, at an elevation of 3730 m; this site receives 220-260 mm of annual rainfall and the average temperature is 4°C. Sample PH-07_CP was sampled from Pu'u Huluhulu cinder cone at an elevation of 2000-2064 m; this site receives 508-762 mm of annual rainfall and the average temperature is 10°C to 14°C [10-12].

Sample Preparation. Size fractions for each sample were obtained initially by ultrasonication and sedimentation in water, both samples were later sieved to acquire <150-μm size fractions using a stainless steel sieve (Morris et al. 2000).

Analytical Methods. One hundred and fifty grains were imaged from each sample using a JEOL 6610LV SEM, and grain surface feature inventories for each grain were compiled using a binary system. The feature categories used are based on the type of process that causes each feature [13-]. Primary morphological features result from processes during the eruption that created the tephra; this often relates to eruptive conditions and mechanisms. Mechanical breakage features are features caused by compressional, shearing, or fracturing forces applied to grains that causes brittle deformation. Polygenetic features are often related to chemical alteration of grains; however, these features can also be produced either by eruptive processes or mechanical breakage.

Surface Feature Domains:

Results. The grain surface feature data was analyzed using relative frequency. Both samples are moderately vesiculated. A large fraction of grains in HWMK600 display mechanical breakage features, especially conchoidal fracture, relative to PH-07_CP. In general, more grains of HWMK600 display primary morphological features such as blocky shape, glassy material, and all categories that indicate vesicles are present. However, more grains of PH-07_CP are covered by adhering fine particles, and this sample contains more aggregate grains. Few grains in HWMK600 show polygenetic features relative to PH-07_CP; specifically, more grains from PH-07_CP show polygenetic features that are likely related to alteration. This trend is contrasted by the relatively high abundance of grains showing shallow and deep cracks, and V-shaped depressions in HWMK600 which may be related to mechanical breakage.

Discussion. The abundance of grains showing primary morphological features in HWMK600 is attributed to the cold temperature and relative lack of precipitation at the sampling site, which has restricted post-emplacement chemical weathering. The abundance of grains showing mechanical breakage features in HWMK600 is attributed to the glacial post-emplacement history at the sampling site. A larger fraction grains from PH-07_CP exhibit polygenetic features that are likely related to alteration. This is attributed to the relatively high temperature and rainfall at the sampling site, which would enable more extensive chemical weathering relative to the cooler, drier higher-elevation sampling site.

Conclusions:

Implications for Terrestrial Process-Product Relations. The two environments sampled by HWMK600 and PH-07_CP can be distinguished from one another based upon the grain surface feature inventories. A larger fraction of grains from HWMK600 display a higher abundance of mechanical breakage and primary morphological features; this correlates with the glacial history and cold, dry environmental conditions at the sampling site. A larger fraction of grains from PH-07_CP display surface features likely related to aqueous alteration; this correlates with the relatively high temperature and rainfall at the sampling site.

Generally, the high weathering and alteration rate of basaltic tephra prevents the use of grain features in environmental reconstructions. However, weathering effects in basalt are minimized in cold, dry environments; additionally, young deposits are likely to be less altered due to short cumulative exposure to water. This allows for primary grain surface features to be preserved and interpretations to be drawn from them. Post-emplacement environmentally driven alteration by water or other magmatic volatiles can cause overprinting of any primary (in this case, syn-eruptive) chemical features, thereby obscuring phenomena produced by previous environmental processes.

Implications for Mars. We hypothesize that Martian tephra exhibits grain surface features similar to the primary morphological mechanical breakage and features observed in HWMK600. Mars and the HWMK600 sample site both lack extensive liquid water at the surface. Periglacial processes on Mars (Baker, 2006) can produce mechanical breakage grain surface features similar to those produced by glaciers, and similar to those observed in this study. Additionlally, we expect an abundance of Martian grains showing aeolian abrasion features, particularly chipped edges and rounding, due to strong Martian winds,.

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