

MINERALOGY OF ROCK FLOUR IN GLACIATED VOLCANIC TERRAINS: AN ANALOG FOR A COLD AND ICY EARLY MARS. E. B. Rampe¹, B. Horgan², N. Scudder², R. J. Smith², A. M. Rutledge² ¹NASA Johnson Space Center, Houston, TX 77058; elizabeth.b.rampe@nasa.gov, ²Purdue University.

Introduction: Geomorphological and mineralogical data from early martian surfaces indicate liquid water was present on ancient Mars [e.g., 1-2]. The relative surface temperatures, however, remain a subject of debate [e.g., 3]. Was early Mars warm and wet or cold and icy with punctuated periods of warmth and ice melt? By characterizing the mineralogy and geochemistry of modern icy mafic terrains on Earth, we can search for these characteristics in early martian terrains to better constrain the early martian climate. Here, we describe the mineralogy of glacial flour in a modern glaciated volcanic terrain in Oregon, USA. We are particularly interested in secondary phases that form in these environments, and we hypothesize that poorly crystalline phases may preferentially form in these terrains because of the low temperatures and the seasonality of melt water production. A description of the mineralogy of the moraines, the composition of the amorphous materials, and the geochemistry of the glacial melt waters are presented elsewhere [e.g., 4-7].

Glacial flour is made up of silt- and clay-sized particles that form from the physical weathering of rock underlying a wet-based glacier as the glacier slides over it. Flour is usually transported from underneath a glacier by melt water streams. The geochemistry of glacial melt water streams has been studied extensively and has been used to infer weathering reactions within glacial systems [e.g., 8-9]. However, the mineralogy of these environments, especially on mafic volcanic terrains, is not well studied [10]. Rock flour is a ubiquitous physical weathering product in glaciated terrains and, therefore, affects microbial habitats, stream and lake chemistry, and chemical weathering processes. and by studying the mineralogy of glacial flour, we can better understand geochemical and microbiological processes in subglacial and proglacial terrains.

Methods: Glacial flour samples were collected from the proglacial valleys and moraines of Collier and Diller Glaciers on North and Middle Sisters, respectively. Collier Glacier sits on top of basaltic andesite, andesite, and dacite flows that erupted ~15-30 ka and show evidence for oxidation and palagonitization [5,11], whereas Diller Glacier is predominantly on basaltic andesite that erupted ~17-20 ka [12]. Collier and Diller glaciers have retreated rapidly over the past century [13], revealing rocks and sediments that have been covered by ice for thousands of years.

Glacier flour samples were measured by X-ray diffraction (XRD) on a Panalytical X'Pert Pro instrument

with a Co-K α source on a traditional spinner stage. Mineral identifications and abundances were determined through Rietveld refinement of patterns in the MDI Jade program. The mineralogy reported here is from patterns of samples that were not spiked with a known abundance of a standard mineral (e.g., corundum). These data will be presented at the conference. Bulk samples were first sieved to <1 mm, then powdered to <10 μ m in an agate ball mill. Clay-sized (< 2 μ m) samples were separated by sonicating unsieved bulk sample in deionized water, then centrifuging the suspended sediment. Clay-sized samples were air dried in a 50 °C oven, then gently powdered in an agate mortar and pestle prior to analysis.

Results: The mineralogy of the glacial flour from the Collier proglacial valley (Figure 1) and the Diller proglacial valley (Figure 2) are very similar. Plagioclase (andesine) is the dominant mineral, followed by pyroxene (augite, pigeonite). Minor abundances of olivine, hematite, and magnetite are present. Both samples contain minor amounts of X-ray amorphous materials, and amorphous materials appear to be more abundant in the flour from Diller.

The clay-sized fraction of the Collier flour contains abundant plagioclase, pyroxene, and X-ray amorphous materials. Minor amounts of zeolite (chabazite), smectite (with a basal spacing of ~15 Å), maghemite, and hematite are present. The clay-sized fraction of the Diller flour has abundant plagioclase, pyroxene, and X-ray amorphous materials, with minor amounts of zeolite and hematite.

Discussion: The mineralogical similarities between the bulk glacial flour samples from Collier and Diller glacial valleys suggests that they are sourced from similar parent lithologies on North and Middle Sister, respectively, or that aeolian mixing of this fine-grained material has homogenized the glacial flour across multiple valleys. The mineralogical differences between the <2 μ m size fraction in the two samples implies that the glacial flour is locally derived, so the similarities in the bulk material may be a consequence of similar parent lithologies. The presence of both smectite and zeolite in the flour from Collier suggests a local, detrital source of hydrothermally altered volcanic material. This is supported by remote infrared measurements of the bedrock of North Sister, which shows evidence for oxidized and hydrated minerals [5]. The lack of phyllosilicate in the Diller sample indicates that alteration in glacial terrains is not a major source of phyllosilicates.

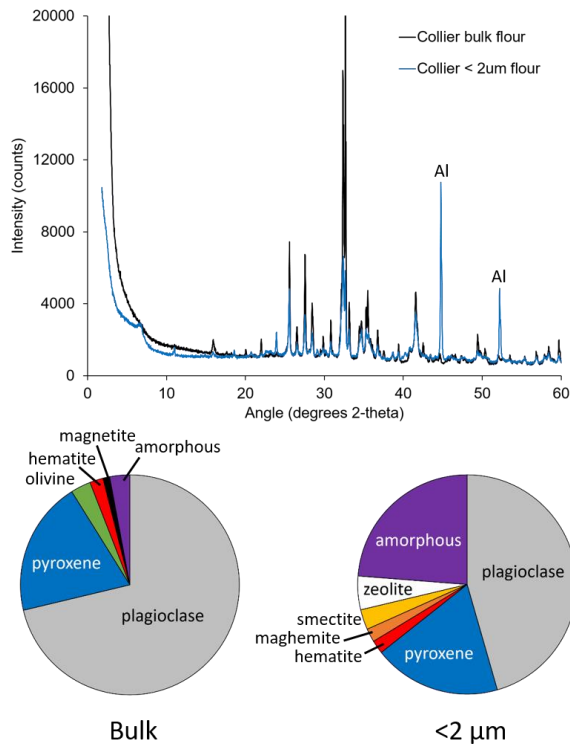


Figure 1. Top: XRD patterns of bulk (black) and clay-sized (blue) glacial flour from Collier Glacier. Peaks from the aluminum sample holder (Al) are apparent in the pattern of the clay-sized fraction. Bottom: Crystalline mineral and X-ray amorphous abundances for bulk (left) and clay-sized (right) glacial flour from Collier.

X-ray amorphous materials are concentrated in the clay-sized fraction. We hypothesize that these materials are secondary in nature and are a product of weathering in glacial environments. We expect poorly crystalline phases to form from rapid weathering of mafic minerals during the late spring and summer when melt water moves through the sediments [e.g., 4,14]. The lack of olivine in the $<2\ \mu\text{m}$ size fraction may indicate that this mineral is one of the phases altering to form X-ray amorphous materials. We will perform transmission electron microscopy with electron dispersive spectroscopy on these materials to investigate their crystallinity, morphology, and chemical composition to determine whether they are primary or secondary in nature. Calculations of the composition of the X-ray amorphous component of glacial sediments from Three Sisters, OR using XRD-derived mineralogy and bulk chemistry from X-ray fluorescence are ongoing and can also be used to infer the primary vs. secondary nature of X-ray amorphous materials in glaciated volcanic terrains [6].

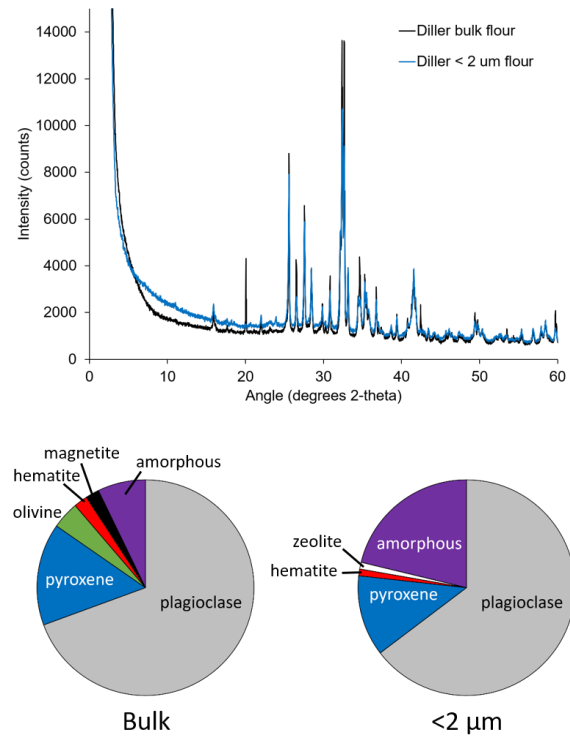


Figure 2. Top: XRD patterns of bulk (black) and clay-sized (blue) glacial flour from Diller Glacier. Bottom: Crystalline mineral and X-ray amorphous abundances for bulk (left) and clay-sized (right) glacial flour from Diller.

X-ray amorphous materials have been identified in all rocks and soils measured to date by the CheMin XRD on Mars Science Laboratory [e.g., 15,16]. By studying the formation and composition of amorphous materials in glacial flour, we can compare our data to those returned by MSL to better constrain the formation mechanisms of amorphous materials on Mars.

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