MINERALOGICAL SIGNATURES OF MARS-ANALOG ESKERS IN ICELAND. E. B. Rampe[1] A. M. Rutledge[2], K. A. Bennett[3], L. A. Edgar[3], C. S. Edwards[2], H. Eifert[2], and A. Koeppel[2] [1]NASA JSC, Astromaterials Research and Exploration Science Division, Houston, TX 77058 (elizabeth.b.rampe@nasa.gov), [2]Northern Arizona University, Department of Astronomy and Planetary Science, Flagstaff, AZ 86011, [3]U.S. Geological Survey Astrogeology Science Center, Flagstaff, AZ 86001.

Introduction: Orbital geomorphic observations of the martian surface suggest glaciers were present during much of Mars' history. Amazonian- and Hesperian-aged lobate and viscous flow features and moraines, some of which retain remnant ice deposits, are typically interpreted as evidence for cold-based glaciation [e.g., 1-2]. There is some morphological evidence for wet-based glaciation [e.g., 3-5], however, and the Late Noachian Icy Highlands model, in which melting of glaciers is hypothesized to create valley networks [e.g., 6], would have generated features characteristic of wet-based glaciers, like eskers. Furthermore, recent work suggests lower gravity on Mars promoted subglacial water drainage, leading to channels and eskers [7]. There is a paucity of morphological and compositional measurements of subglacial landforms on Earth to provide comparison to putative subglacial features on the martian surface, like eskers. Our group is studying the morphology, sedimentology, and composition of eskers formed in Iceland to identify characteristics of these features that will help determine whether sinuous ridges on Mars are ancient eskers [8]. Here, we report on the mineralogy of eskers that were sampled during our summer 2022 field campaign and evaluate whether there is a mineralogical signature of eskers that is distinct from surrounding glacial outwash plains.

2022 Field campaign and laboratory measurements: Our field site is in the proglacial plains and glacial margin of Breiðamerkurjökull in southeast Iceland (Figure 1). We collected morphological data (including Uncrewed Aerial Vehicle (UAV) thermal and visible maps and terrestrial laser scans), made sedimentological observations (including descriptions of stratigraphic sections and trenches through eskers), and collected samples from eight eskers. These eskers have different exposure ages (i.e., when the glacier margin retreated to reveal the features), which allows us to evaluate how exposure age may affect morphological and compositional characteristics. In this abstract, we report on the bulk mineralogy of three of the eskers: one that was exposed ~60-80 years ago [e.g., 9] (nicknamed "Elves Labyrinth"), one that was exposed ~4-8 years ago (nicknamed "Pristine Baby" because of its characteristic esker appearance), and one that was first exposed ~5 years ago and is in the process of being fully exposed (nicknamed "Emerging Esker"). Elves Labyrinth is complex and the largest of the eskers studied, measuring up to 10 m tall. Samples were collected from the top, flank, and base of the esker at three different locations along its length. Pristine Baby was much smaller, measuring up to 2 m tall, and was sufficiently unconsolidated such that we dug two trenches through it and collected samples from different distinct sedimentary layers, distinguished by differences in color, grain size, and sedimentary structures. Emerging Esker was up to ~3 m tall and still had ice at its core, so we sampled distinct sedimentary facies observed on the top and the flank of this esker. Samples were collected in Whirl-Pak bags and transferred to 50 mL centrifuge tubes for laboratory analyses.

Samples were dried in a 50 ºC oven. For bulk mineralogy, samples were sieved to <2 mm then powdered with ethanol in a micronizing mill using agate beads. Powders were spiked with 20 wt.% corundum as an internal standard to quantify X-ray amorphous content. Powder X-ray diffraction (XRD) was performed on a Rigaku MiniFlex 6G using a Co X-ray source. We performed Rietveld refinement using the JADE program to quantify mineral and amorphous abundances and mineral unit-cell parameters.

Bulk mineralogy: Major phases identified in eskers and surrounding plains sediments include plagioclase feldspar and clinopyroxene (augite) (Figure 1). Quartz, amphibole, and chlorite are typically present as minor phases (~3-10 wt.%), and magnetite, ilmenite, and zeolite are typically present as trace phases (<3 wt.%). X-ray amorphous abundance varies from ~10 to ~80 wt.%.

Elves Labyrinth. There is very little variation in mineralogy between the proximal and distal sampling sites; between the sampling sites on the top, flank, and base of the esker; and between the sediments on the surrounding plains. The most significant variation is in the abundance of X-ray amorphous content (from ~10-30 wt.%), but there is no clear correlation between amorphous abundance and sampling location.

Pristine Baby. The very poorly sorted surface sediment and the sand and granule layers within the trench had similar mineralogy to the Elves Labyrinth samples, with ~20-30 wt.% amorphous materials. The silt and clay layer within the trench, however, had ~50 wt.% amorphous material and lacked magnetite.

Emerging Esker. Facies that contained abundant cobbles had a similar mineralogical composition to the Elves Labyrinth samples and the coarse layers (coarse sand and coarser) in Pristine Baby. The silt and clay layers were mineralogically like the finer-grained layers (silt and clay) within Pristine Baby, with ~50-60 wt.% amorphous material. A sample of a dark medium sand to silt on a dirt cone at the glacier margin was mineralogically distinct from all other samples analyzed, with ~10 wt.% plagioclase, ~10 wt.% clinopyroxene, and ~80 wt.% X-ray amorphous materials.

Interpretations: The major and minor phases identified (plagioclase, clinopyroxene, quartz, and amphibole) are consistent with a quartz-tholeiitic gabbroic source, which has been identified in the nearby Tertiary-aged Thverartindur volcano [10]. The high abundance of X-ray amorphous materials in small mounds of relatively fine-grained dark sediment that form near the glacier margin suggests that this material is glass-rich tephra.

Bulk mineralogical changes appear to be related to grain size. The coarse-grained layers within eskers typically have little X-ray amorphous materials, whereas fine-grained layers (dominated by silt and clay) have abundant X-ray amorphous materials. We hypothesize that the fine fraction is enriched in volcanic ash, contributing to the larger X-ray amorphous content. Future work will examine mineralogical changes within different grain size classes.

One of our hypotheses was that the water associated with the formation of the esker while it is under ice and the continued melting of the ice in its core would cause enhanced aqueous alteration of the sediment within the esker compared to sediment in the surrounding proglacial plains. To test this hypothesis, we will analyze the mineralogy of the clay-size fraction in which secondary phases are concentrated [e.g., 11] to see if esker sediments contain more secondary phases than the surrounding plains sediments. If eskers show a mineralogical distinction from surrounding plains sediments, then we may be able to use orbital infrared reflectance spectroscopy to help identify eskers on the martian surface.

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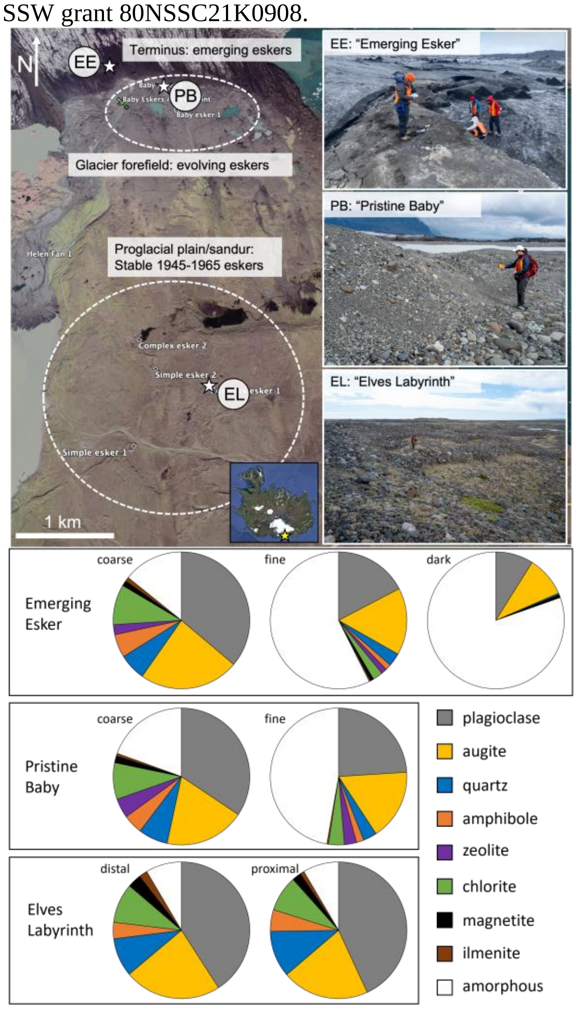

Figure 1. (Top left) Satellite image showing locations of the three sampled eskers (EE = Emerging Esker, PB = Pristine Baby, EL = Elves Labyrinth). (Top right) Field photos from each sampled esker. (Bottom) Pie diagrams showing mineral and amorphous abundances for select samples from Emerging Esker, Pristine Baby, and Elves Labyrinth. Emerging Esker: (left) Clast-supported layer, (middle) clay- and silt-dominated layer, (right) dark sand and silt on ice mound near esker. Pristine Baby: (left) sand- and granule-dominated layer, (right) silt- and clay-dominated layer. Elves Labyrinth: (left) sample from the crest of the distal (i.e., farthest from the glacier terminus) portion of the esker, (right) sample from the flank of the proximal portion of the esker.