A FRIGID TERRESTRIAL ANALOG FOR THE PALEOCLIMATE OF MARS. M. T. Thorpe[1], J. A. Hurowitz[1], and E. Dehouck[1,2], [1] Department of Geosciences, Stony Brook University, Stony Brook, NY 117794-2100, [2] Institut de Recherche en Astrophysique et Planétologie, UPS/CNRS/OMP, Toulous, France, michael.thorpe@stonybrook.edu.

Introduction: Climate plays a critical role in shaping the sedimentary rock record, influencing physical weathering processes and erosion rates, the kinetics of chemical weathering, and the mechanisms of sediment transportation [1]. On Earth, sediment is primarily derived from a granitic continental crust [2] and the effects of climate have been extensively explored [1]. However, on Mars, sediment generation is fundamentally different, owing to the basaltic nature of the sediment sources. Therefore, we lack an adequate terrestrial reference frame in which to place Martian sedimentary rocks, and reconstruct its paleoclimate record. Our work investigates basaltic sediment generation in the frigid climate of Iceland in an effort to fill a knowledge gap in our understanding of terrestrial sediment compositions, and provide the necessary context to understand the geochemistry and mineralogy of Martian sedimentary rocks.

Study Site and Methods: Iceland is dominated by volcanic rocks, with 80-85% of the terrain covered with Pleistocene flood basalts [3]. The study site for this work is based in the southwest portion of the island, with sampling locations targeting depositional sites along glacially-fed rivers and streams [**Fig. 1**]. Unconsolidated sediment was sieved into various grain size separates and major element geochemistry was analyzed using X-ray fluorescence (XRF) spectrometry. Mineralogy was determined using powder X-ray diffraction (XRD), including the use of aluminum oxide as an internal standard for quantitative mineralogy.

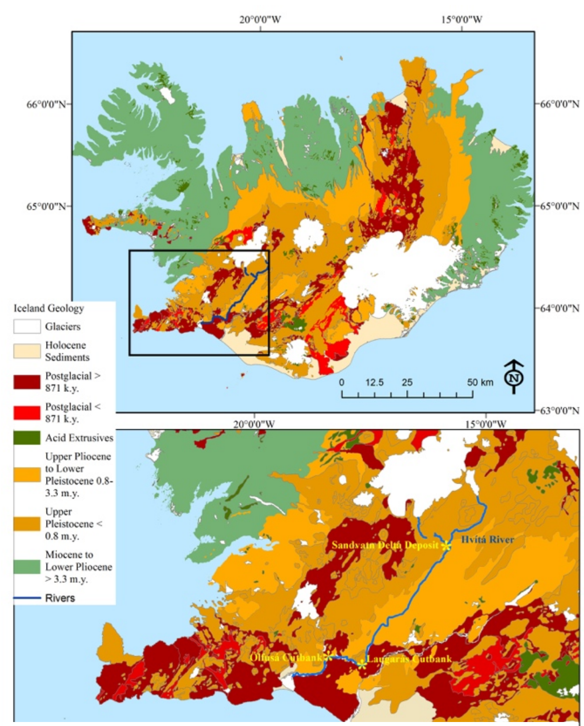

Figure 1 The surficial geology map of Iceland with units determined from ref [4] and GIS shapefiles obtained from ref [5] . An insert focuses on the extent of our field campaign with sampling locations identified with yellow stars.

Iceland Results: The geochemistry and mineralogy from Icelandic sediment displays limited evidence for chemical weathering. The Chemical Index of Alteration (CIA) is a tool used to quantify the degree of weathering [6]; an important finding for Iceland is that as grain size decreases in our samples, CIA values do increase as expected (CIA ranges from 38.1 to 48.8). However, even in the finest-grained sediment fraction from our samples (< 45μm), collected from the most distal depositional site, the maximum CIA value measured is 48.8, which suggests only very limited chemical weathering. The geochemical behavior of our samples as it relates to weathering is well illustrated on feldspar and mafic ternary diagrams, displayed on **Fig 2**. In the A-CN-K compositional space of the feldspar diagram, basalt weathering will generate a trend that is sub-parallel to the A-CN join. Icelandic sediments display such a trend with decreasing grain size, however, the trend never crosses the feldspar join (located at 50% Al_2O_3), and thus, limited chemical weathering is indicated. The mafics diagram is also useful for evaluating the chemical evolution of sediment generated from basaltic sources; once again, the geochemical behavior displayed by our samples expresses limited signs of chemical alteration.

X-ray diffraction of the < 45μm fraction from each sampling site indicates preservation of well crystalline mafic minerals (i.e., plagioclase and pyroxene) in **Fig 3**. We observe that primary minerals are retained in fine-grained materials at all depositional sites, and that there is also an increase in secondary minerals with distance from the source. Clay mineral reflections are absent from a near-source stream deposit, but are more abundant in downstream sites. Furthermore, an X-ray amorphous phase, present in the pattern as a broad hump extending from ~20-35 degrees two-theta, also increases in abundance with distance from source.

Comparison with Gale Crater, Mars: Early in *Curiosity's* traverse at Gale Crater, the Yellowknife Bay

(YKB) formation was extensively studied. The identification of smectites in the Sheepbed member mudstones [7] were taken as an indicator of olivine reaction with neutral-alkaline pH water under poorly-oxidizing conditions, possibly on 10^3-10^4 year timescales [8]. However, the elemental behavior displayed no evidence of chemical weathering and suggested a paleoclimate that was cold and/or arid [9]. As *Curiosity* continued to trek closer to Mt. Sharp, the rover began to sample lacustrine mudstones from the stratigraphically higher Pahrump Hills section of the Murray formation [10]. In contrast to YKB, the geochemistry from the mudstones at the Murray formation displayed more significant signs of element mobility, with CIA values as high as 53 [11]. This change in element behavior may be related to a change in climate, with more temperate and/or wetter conditions possible [11].

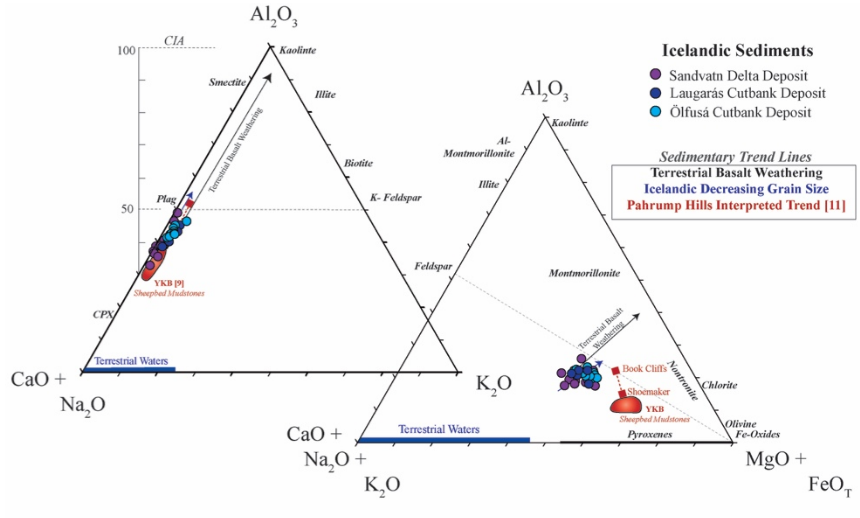

Figure 2. The geochemistry of Icelandic and Martin data plotted on a feldspar (left) and mafic (right) diagram. Elements are in molar proportions and there is no CaO* correction for the non-silicate fraction. See text for discussion of trends. YKB data from ref [9] and Pahrump Hills interpretation from ref [10]

The results from Gale Crater and Iceland allow us to draw on some similarities observed in sedimentary processes in basaltic terrains of both planets. On Mars, the Murray Hill mudstones illustrate the formation of a basaltic sedimentary rock with limited evidence of chemical weathering. Similarly, on Earth, we see that the generation of basaltic sediment in a frigid climate produces very fine-grained material with low CIA values. Furthermore, sediment from both planets largely preserves its igneous mineralogy with only minor abundances of secondary clay minerals and XRD amorphous material.

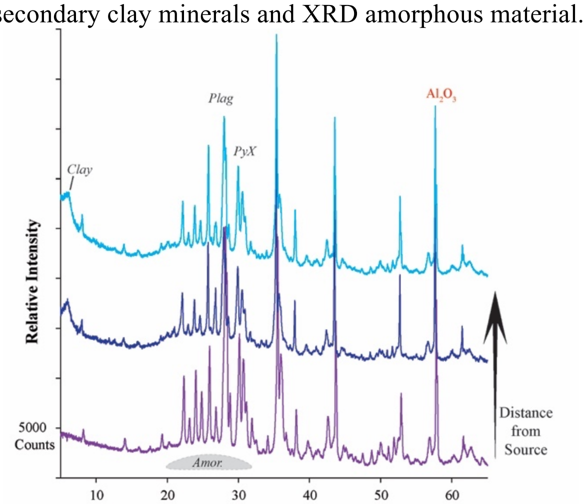

Figure 3. X-ray diffraction patterns of the < 45μmfraction of Icelandic sediments. Plag: plagioclase; PyX: pyroxene; Clay: smectites; Amor: XRD amorphous phases; Al_2O_3: corundum spike

However, the geochemical transformations that occur once this sediment is lithified on Earth remains to be answered.

Discussion and Future Work: Major element geochemistry and mineralogy of Icelandic sediments illustrates a unique weathering history that is far different from results in a more temperate climate [12]. With first order similarities to the Murray Hill formation, the continued investigation of terrestrial analogs will allow us to more confidently interpret the paleoenvironment of Mars. The next step in this work is to examine trace element behavior and investigate if these elements are transferred quantitatively from parent rock to weathered sediment. The insoluble nature of trace elements (e.g., REE, Sc, and Th) should serve as valuable tools to track any provenance signatures in the fine-grained sediment.

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