SEDIMENTATION AND DIAGENESIS IN THE BASALTIC TERRAINS OF ICELAND, AN UPDATE FROM THE DIGMARS TEAM. M. T. Thorpe[1,2], E. B. Rampe[3], J. J. Tamborski[4], K. L. Siebach[4], A. Putnam[4], M.C. Raith[1], C.N. Achilles[2], D.P. Archer[3], P. Higley[6], D. Leeb[7], G. Gundjonsson[7], V. M. Tu[3], C. C. Bedford[3,8], K. L. Lynch[8], J. Lopez[9], R. C. Ewing[10], and S. Rahman[11], R. Kovtun[4], [1]University of Maryland, [2]NASA GSFC, Greenbelt, MD USA (michael.t.thorpe@nasa.gov), [3]NASA JSC, [4]Old Dominion University, [5]Rice University, [6] Specialty Devices Inc., [7]Iceland Space Agency, [8]Lunar and Planetary Institute, [9]University of Houston, [10]Texas A&M University, [11]University of Colorado.

Introduction: The Digging Iceland Geology for Mars Analog Research Science (DIGMARS) project has two overarching goals, (i) characterize the compositional changes induced by early diagenesis in sediments from a basaltic dominated watershed and (ii) identify the influence of lacustrine groundwater discharge on alteration processes. The motivation behind the DIGMARS research is the rich sedimentary rock record of Mars, which preserves evidence for ancient fluvial, deltaic, and lacustrine environments [1]. Gale crater exemplifies these ancient environments and throughout *Curiosity's* extensive exploration, sequences of sandstones and mudstones have also provided hints of groundwater interaction [e.g., 2-6]. Moreover, the *Perseverance* rover continues to explore the remnants of a delta in Jezero crater, there is also evidence that points to a complex diagenetic story [e.g., 7-8] that bears significantly on the basin history and early martian environment. Here, we present the initial results for the 2021 and 2022 field campaigns and the laboratory analysis of aqueous and sediment samples.

Site Selection and Methods: The DIGMARS project targets Iceland because the source rock lithology is predominantly basalt, largely consistent with the sediment provenance on Mars, and the cold and icy climate of Iceland is a reasonable candidate for the paleoclimate of regions of Mars [9]. In the summer of 2021, the DIGMARS team conducted 10 days of field work in the Lake Sandvatn catchment in southwest Iceland, a proglacial lake system. Then in the summer of 2022, the DIGMARS team spent 16 days again in southwest Iceland. For this trip, the team revisited Lake Sandvatn with two new drilling techniques. A custom-built drill rig was designed by Specialty Devices Inc.© for the DIGMARS team and enabled drilling to occur further offshore targeting deeper lacustrine deposits in these remote field sites. Additionally, a handheld drill from Specialty Devices Inc.© was employed and allowed teammates to wade out in shallow waters to drill softer sediments, compared to last year's custom A-frame on the shoreline that was challenged by coarser-grained material. Additionally, in 2022, the DIGMARS team targeted Lake Apavatn, a geothermally influenced and fluvially sourced lake. The ratiaonale behind this additional field site stems from one of the DIGMARS's goal to investigate the implications of warm groundwater on early digenesis.

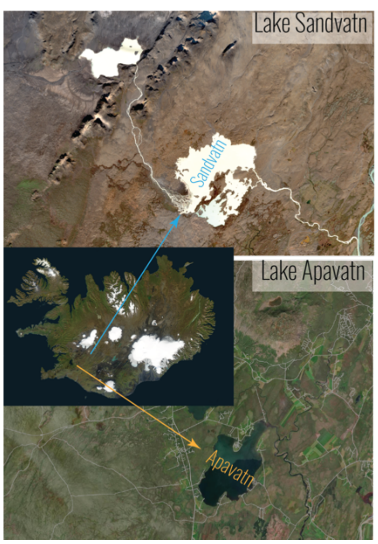

Figure 1. *The DIGMARS field sites for the 2021 and 2022 campaigns.*

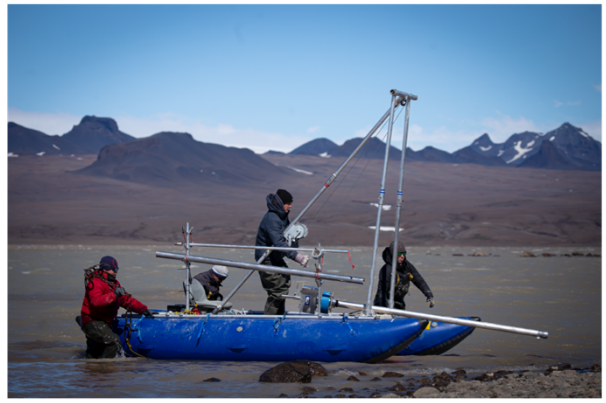

Figure 2. *The DIGMARS floating drill rig.*

During these two field campaigns, the team sampled source rocks in the upper reaches of the watershed, detritus from source to sink along stream inlets, sediments at the surface within the lake and along the shoreline, river water, lake water, and groundwaters, and buried sediments. The team also performed drone flights with a thermal attachment to detect temperature anomalies in the lake water and aid in identifying locations for potential groundwater discharge. To access sediments at depth, trenches were dug and logged, and we used two different vibracores for drilling sediments, a larger one for the custom-built floating rig and one smaller handheld drill. Sediment drilling locations were on the lake shoreline, adjacent to groundwater sampling locations, near hot water plumes, and further offshore at areas previously selected targets from historical imagery to aim for the oldest regions of the lake.

Groundwater was collected using a steel-tip drive-point piezometer, screened at various depths and equipped with a peristaltic pump.

Back in the lab, sediment and source rock samples were prepared for mineralogical and geochemical analysis. Laboratory methods following the field campaign for water and sediment analysis including: thin section analysis of source rocks [11], grain size and shape analysis, XRD, XRF, ICP-MS, TEM, and image processing and analysis.

Preliminary Results: In the field, four cores were successfully obtained with the 2021 A-frame and eight cores were obtained from Lake Sandvatn with the 2022 floating drill rig, while 4 cores were acquired at Lake Apavatn with a handheld drill. From Lake Sandvatn, the deepest sediment core was ~2.5 m and most cores display multiple transitions from fluvial to lacustrine sediments (Fig. 3). Importantly, in the lower lacustrine sediments of the deepest core, distinct layers are identified with variations in sediment color. From Lake Apavatn, the deepest sediment core (also ~ 2.5 m) displayed more subtle transitions in grain size and was consistent with predominately a lacustrine origin, as inferred from clay and silt the dominant grain size.

Preliminary laboratory analysis of Lake Sandvatn sediment samples suggests that the source rocks are largely consistent with basaltic progenitor [10-12]. The XRD results from lake surface sediments display a sediment mineralogy that is dominated by primary basaltic minerals (e.g., plagioclase and pyroxene) and little to no secondary clay minerals are observed in the bulk sediment. In comparison, the lacustrine sediments buried at depth display a similar mineral assemblage but also show an increase in X-ray amorphous materials and hints of clay minerals in some of the buried sediment XRD patterns. Moreover, the major element geochemistry of the buried sediments demonstrates mobilization of labile cations, consistent with an open system weathering regime (Fig. 4). On the other hand, the mineralogy of buried sediments at Lake Apavatn are significantly different and are abundant in secondary amorphous phases. Finally, the groundwater geochemistry from Lake Sandvatn and Lake Apavatn documents the contribution from distinct water reservoirs (e.g., metoric vs. groundwater) and can likely be linked to the overall sediment composition.

Figure 3. An *example of a sediment core segment*.

Implications: Early results from the 2021 and 2022 DIGMARS field campaign suggest that sediments generated and transported downstream can ultimately carry a mineralogical assemblage consistent with a pristine basaltic progenitor. It is not until these sediments are buried and interacting with groundwater that the mineralogy begins to show evidence for alteration. Early diagenesis in buried sediments from Lake Sandvatn suggests that groundwater discharge is the principal process preserved in the secondary mineralogical record of these sediments. Moreover, aqueous samples show that groundwater discharge and mixing lake waters creates a unique geochemical gradient in the subsurface. Compared to a geothermally influenced environment, the sediments at depth are fundamentally different and warm water significantly alter the sediment composition.

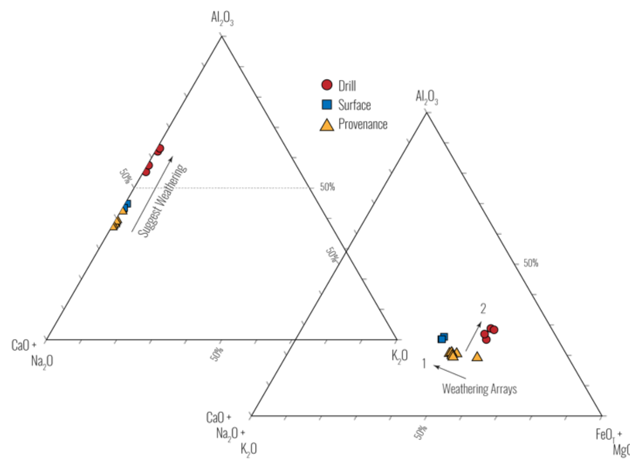

Figure 4. *Major element ternary diagrams documenting terrestrial weathering trends*.

When this terrestrial reference frame is applied to regions of Mars (e.g., Gale crater), it becomes clear how early diagenesis from sediments interacting with percolating groundwaters could have a profound impact on interpretations of the sedimentary history of lacustrine environments. Sediments from the ancient lake of Gale crater likely interacted with discharging groundwater and this unique subsurface mixing zone likely played a key role in shaping the sedimentary rock record.

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