Ground Penetrating Radar investigations into Iceland sinter deposits as martian analogs D. Susko[1], J.R. Skok[1,2], C. Muñoz[3], N. Lindsey[4] [1]Louisiana State University, [2]SETI Institute, [3]CEGA Institute, [4]University of California at Berkley (Davidsusko@gmail.com)

Introduction: The recent identification of amorphous silica in the Nili Patera region of the Syrtis Major Volcanic Province on Mars (1) makes possible the use of silica sinter deposits in Iceland as martian analogues. These silica deposits, which are effective at preserving microfossils in terrestrial settings (2, 3), have been proposed to be the product of high temperature hydrothermal processes in Syrtis Major. If this is the case, Nili Patera would not only represent a potentially habitable environment during the early Hesperian period, but could also represent one of the most likely locations to detect biosignatures on Mars(1).

The Mars2020 rover is equipped with an instrument suite designed to explore for signs of past life. Among these instruments is the Radar Imager for Mars' subsurface experiment (RIMFAX) which will use ground penetrating radar (GPR) to analyze the shallow subsurface of the rover's landing site(4). It will attempt to assess the depth of the regolith, provide information about the geological context of surface outcrops, and inform about subsurface compositions. GPR is an effective, non-destructive method for determining the physical properties of the subsurface (5). It utilizes high-frequency electromagnetic pulses which propagate through a target and reflect off of boundaries before returning to the surface to be detected by a receiver. The depth of penetration and resolution vary significantly, and are dependent on both the frequency of the antenna used and the type of material being analyzed. Generally, the lower the antenna frequency the greater the depth of penetration, but the weaker the resolution of the data (6).

We traveled to three Icelandic sinter sites (Gunnuhver, Hveravellir, and Lysuholl) to demonstrate the extent to which GPR can be used to analyze the structure of silica deposits and thus assess how effective components of the Mars2020 instrument suite will be for studying geologic settings on Mars where biosignatures could potentially be detected. Here, the methods, data and preliminary interpretations for GPR surveys conducted at these sites are described as a field debrief. Our work shows that silica deposits at Nili Patera are ideal targets for the Mars2020 RIMFAX instrument.

Instrumentation and methodology: For this study, we used a Sensors & Software PulseEkko Pro GPR. We utilized both a 100 and a 200 MHz antenna with a 1000 v transmitter. Due to the high voltage transmitter, we kept the antenna separated by a constant 1 m. We alternated between using the SmartCart configuration, where terrain was smooth enough to allow it, and a walker configuration where terrain was too rough. We collected data at 0.1 m intervals. We conducted multiple survey transects and grids with lines separated by 1 to 3m. We marked out the planned transects with flags and photographed the target prior to data acquisition. The data were then saved to a compact flash card and exported to the Pulse_Ekko Project software for processing.

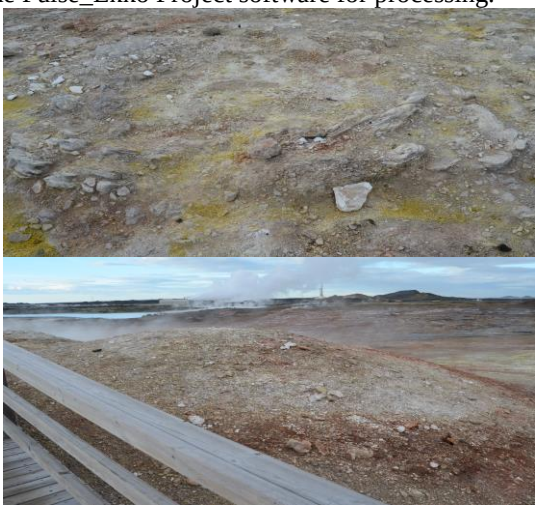

Figure 1: Images from Gunnuhver sinter site. Top picture shows a dormant vent with circular, downward slopping stratified sinter. This was the target of the first survey at Gunnuhver. Bottom image shows the secondary mound on which the second survey at the site was conducted.

Gunnuhver: Located on the Reykjanes Peninsula, southwest of Reykjavik, the Gunnuhver sinter has several active hydrothermal vents as well as several which are dormant. Other than the active vents, the primary feature of the site is a large mound which is covered in white stratified silica sinter and a blanket of yellow sulfur deposited from the surrounding active fumaroles. The mound is roughly 10m high and 100m wide, bearing a striking resemblance to a mound feature within Nili Patera, referred to as Nili Tholus, which is roughly the same width and 20m high (1). The mound at Gunnuhver sits atop basaltic lava flows, which have been locally altered by the hydrothermal system to a friable material, and covered with grassy vegetation at the base. The mound has several exposed vents, identifiable by concentric circles of inward dipping stratified sinter. There is also a secondary mound feature 3-4m tall on the eastern edge of the summit of the primary mound.

GPR surveys were conducted at two locations on the dormant mound using the 200MHz

antenna. The first survey was completed in a grid overlying the most prominent relict vent. 8 transects ran from east to west and were approximately 8 m in length and spaced 1 m apart. 3 additional transects ran north to south and were approximately 6m in length and spaced 3m apart. The second survey overlaid the secondary mound and consisted of ten transects, each approximately 10 m long and spaced 1m apart. Last, we ran a long, 40 m transect from the top of the mound down to the base and into the vegetation surrounding the mound in order to investigate whether or not the GPR could detect the boundary between the overburden and the underlying altered basalts.

Hveravellir: The second sinter site we investigated was Hveravellir in the Icelandic highlands. Hveravellir is considerably more active than Gunnuhver with several large active and dormant vents in the middle of the sinter field. Several hydrothermal pools are visible within the boundary of the deposit and there is a considerably higher volume of water at and near the surface of the Hveravellir site than at Gunnuhver. The water close to the vent and in the immediate subsurface was very high temperature, in excess of 100˚ C, making a comprehensive GPR analysis of this site dangerous, and analysis close to the main vents impossible.

We opted to conduct 5 GPR surveys at Hveravellir. First, we found an open, mostly flat segment of the distal apron, downstream of the main hydrothermal system. We used the Smart Cart configuration to survey grids using both the 100 and 200 MHz antenna in order to compare the results. 4 transects, 24 m in length, with 1m spacing were run southwest to northeast, and 5 transects, 10 to 14 m in length, with 2 m spacing were run perpendicular to these. We used the site's pedestrian boardwalk to run surveys using the Smart Cart with both 100 and 200 MHz antenna on a safe path through the center of the sinter field. Because the boardwalk rested roughly 0.6 m above the ground surface, special processing had to be conducted within Ekko_Project to mute the top 0.6m of the radargram. Last, we used the walker configuration with the 200 MHz to image the sinter field adjacent to the pedestrian boardwalk.

Lysuholl: The final site at which we conducted GPR surveys was Lysuholl on the western peninsula. Rather than the basalt found at Gunnuhver and Hveravellir, the bedrock at Lysholl is comprised of Rhyolite. This was by far the oldest sinter field, and it contains no active hydrothermal vents. The sinter was highly brecciated, but was still visibly stratified in many locations. This site contained a complex mineralogy, with some vents displaying a reddish color, likely due to the presence of iron-oxides. Also of considerable interest at Lysuholl, the stratified sinter contained plant material, such as grasses and stems, persevered as fossils locked within the silica. The sinter field had a high volume of water at the surface, but at much lower temperatures than at Hveravellir. The main sinter field is surrounded by vegetation with isolated pockets of sinter a few meters in diameter.

The most extensive GPR surveys were conducted at Lysuholl. We conducted a survey of a distal apron using the Smart Cart and 200 MHz antenna. We overlaid a pair of vents to the north of the field, one of which contained the reddish hue, with a grid using the same configuration. We then transitioned to using the walker configuration and conducted grid surveys for two additional, larger vents closer to the center of the field. Both of these grids were surveyed using the 200 MHz antenna. An additional, tight grid was shot using the 100 MHz antenna on the western vent. Last, we imaged a 37 m long transect from the center of the brecciated sinter field out across the vegetation to one of the sinter islands.

Discussion: The processed data reveal that using GPR is effective at distinguishing the boundary between the sinter deposit and other materials at each site, and thus could be effective at determining the extent, even where the deposit has been subject to burial processes. At Gunnuhver, the sloping sinter surrounding the exposed vent acted as strong reflectors, and these were detected beneath the surface at the adjacent secondary mound, indicating that over time, dormant vents may be buried by loosely consolidated material from Aeolian activity. At Hveravellir, transects with high volumes of water near the surface were easily distinguishable from drier terrains. At the distal apron survey at Hveravellir, a largely flat expanse away from the active vents, the float material is distinguishable from the underlying sinter topography. The survey reveals a mound structure less than a meter beneath the surface, which could represent original topography of the lava flow, or the remnants of now dormant vent, similar to the feature we investigated at Gunnuhver. This would suggest a migration of the active vents at Hveravellir over time. Even with the higher spatial resolution 200 MHz antenna, detecting the stratification of individual boundaries within each sinter deposit was impossible. A higher frequency, antenna, such as the maximum frequency of RIMFAX of 2500 MHz (4), may prove to be more effective, and may be able to help detect preserved biosignatures.

References: (1) Skok JR, et al. (2010), (2) Farmer JD, et al. (1999), (3) Squyres SW, et al. (2008), (4) Hamran S, et al. (2016), (5) Beauchamp M, et al. (2011), (6) Software & Software (2005)