Advancing ISRU Through Terrestrial Ice Resource Modeling: A Case Study from Galena Creek Rock Glacier.

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Introduction: Under the NASA SSERVI Resource Exploration and Science of OUR Cosmic Environment (RESOURCE) Project, we conducted geophysical sounding experiments in the Absaroka Mountains of Wyoming to support planetary in situ resource utilization (ISRU). The Galena Creek Rock Glacier (Fig. 1) serves as an analog to buried ices on planetary bodies such as the Moon, Mars, and other airless bodies in the Solar System. Using results from the field work, we model the volume of minable ice in order to assess the feasibility of further exploration and extraction.

Figure 1. The Galena Creek Rock Glacier as seen from an adjacent ridgeline. Credit: C.A. Walter.

Study Site Background: Galena Creek Rock Glacier is an ice-cored rock glacier (i.e., debris-covered glacier) located in the Absaroka Mountains, Wyoming [1] at 44.641° N, 109.791° W. About two thirds of the landform is composed of high purity glacial ice buried under 1-1.5 m of debris at the higher elevations, while the lower third is composed of lower purity interstitial ice underneath a debris layer 2-5 m thick [2-3]. “Debris” in this case is generally unsorted andesite clasts with sizes ranging from millimeters to meters [4]. The glacier is flowing downslope at a rate of up to 80 cm/yr [3,5].

We chose this site for our field efforts because (1) it is generally well characterized in terms of ice purity and depth to ice, (2) it offers a range of depth-to-ice and ice-purity scenarios to test, (3) members of our field team are familiar with the site and its logistical requirements, and (4) this work will additionally contribute to our understanding of the age, history, and health of the glacier.

Methods: We deployed a broad suite of non-invasive geophysical techniques at the ground surface and on drone-mounted operations, and we also tested shallow drilling technologies. Methods included both hand- and drone-operated ground penetrating radar (GPR), hand- and drone-operated electromagnetic sounding, hand- and drone-operated drilling, and passive seismic sounding.

We ingested the resulting datasets into the block modeling software LeapFrog Geo in order to interpolate the volume of ice and overburden within the framework of resource extraction.

Results: All block models require an important input, ascertained from extraction technologies, known as the selective mining unit (SMU). The SMU is the smallest volume (or block) that can be mined, and is further defined by the minimum mining width. We used predicted melt pool volumes and diameters of Rodwell extraction systems under terrestrial conditions for these inputs [6-7]). Our preliminary model (Fig. 2) uses 5m x 5m x 5m blocks. This corresponds roughly to the predicted melt cavities with a 5m diameter and 5m height. Our preliminary block model calculated just over 4 million tons of ice over 35,000 extractable blocks. We assumed a uniform 2m thick layer of overburden as well as 3m of ice. This choice is based upon the need to maintain roof stability and simple assumptions about the scale of extraction. We will also discuss how these assumptions may be incorrect when applied to ice on planetary bodies with zero or low surface pressure, specifically the Moon and Mars.

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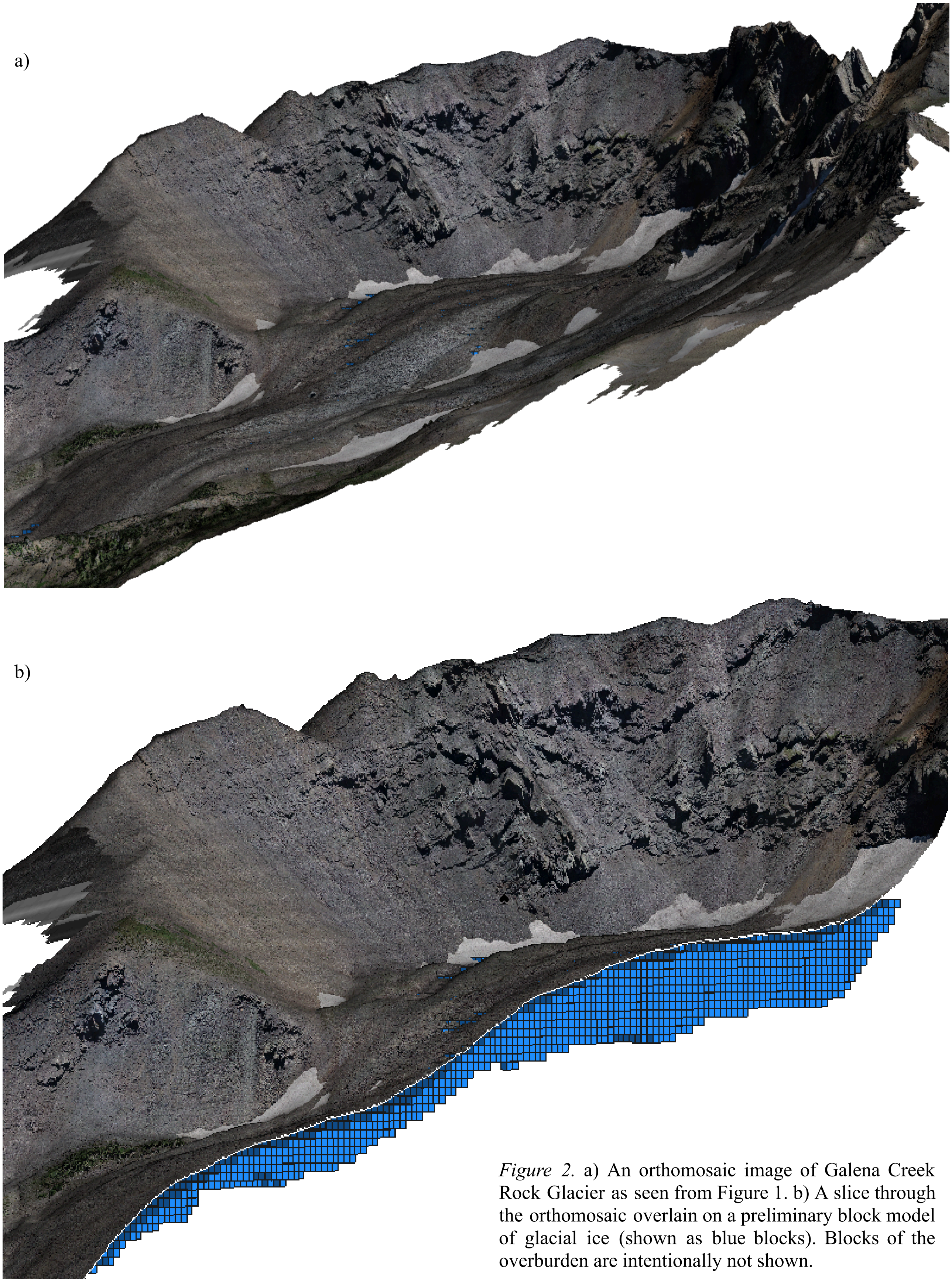

Figure 2. a) An orthomosaic image of Galena Creek Rock Glacier as seen from Figure 1. b) A slice through the orthomosaic overlain on a preliminary block model of glacial ice (shown as blue blocks). Blocks of the overburden are intentionally not shown.