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Multi-Scale Photogrammetric 3D Reconstruction of Apollo 17 Station 7. S. Le Mouélic¹, G. Vaugeois¹, H. H. Schmitt², N. Mangold¹, G. Caravaca³, ¹LPG, CNRS UMR6112, Univ. Nantes, France. ²Dept of Engineering Physics, Univ. Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM 87199, USA. ³GET, Toulouse, France.

Introduction: The Apollo 17 manned mission landed in the Taurus Littrow valley on the Moon in December 1972. During three days spent at the lunar surface, a total of 111 kg of well-documented rock and soil samples were collected from geologic waypoints and brought back to Earth [1, 2].

In a previous study, we used scanned photographs taken *in situ* with astronaut's Hasselblad film cameras to reconstruct 3D models of boulders using Structure-from-Motion photogrammetry [3, 4]. In addition to the 3D reconstruction of the boulders, we have shown in [5] that the lunar rock samples retrieved from these boulders could also be reconstructed in 3D using photogrammetry applied on archived photographs, in addition to the 360° panoramas. This allowed to setup a comprehensive 3D model of Station 6, that can be explored in Virtual Reality (VR) [5]. The present work is focused on reconstructing the next waypoint, the "Station 7" geologic sampling site, also lying at the base of the North Massif.

The Station 7 geologic waypoint: Station 7 was selected during the third EVA of Apollo 17 in order to document a 3m size boulder (Fig. 1) which originated from ~500 meters higher on the North Massif and rolled downslope [2]. It was recognized after investigation to be a fine-grained impact melt-breccia, the west side of the boulder being a large noritic clast [2].

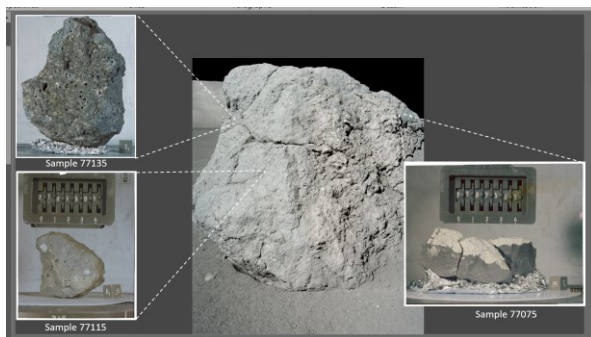


Fig. 1: The main boulder of Station 7 and location of 3 rock samples (out of 4) brought back to Earth.

The photographic records at Station 7 (85 images) includes two 360° panoramas and a series of 41 images of the boulder itself. Four rock samples were retrieved from this Station 7 location and brought back to Earth (Fig. 1). We were able to reconstruct 3 of these rock samples in 3D using the archived LPI images.

Photogrammetric processing of the surface data: We use the Structure-from-Motion technique in order

to integrate the photographic data set. Fig. 2 shows the result of the processing of the first 360° panorama images derived from a set of 25 images labeled AS17-146-22339 to AS17-146-22363. Parts of the Lunar Roving Vehicle (LRV) and the main Boulder are easily recognizable in the textured 3D mesh, in addition to rover tracks and astronaut footprints. This model will serve as a basis to add additional parts. The second panorama (a set of 19 images labeled AS17-141-21646 to AS17-141-21664) covered a smaller portion of soils and was not used at this stage.

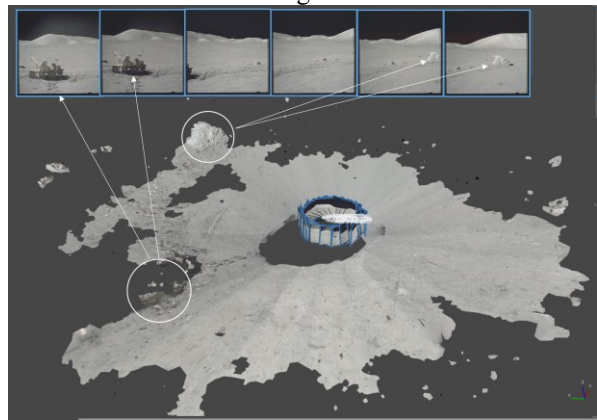


Figure 2 : Photogrammetric 3D reconstruction of the first 360° panorama, showing the location of the LRV and the main boulder. Individual images appear as blue rectangles.

The main boulder was documented using 41 images taken at two different distances. Fig. 3 shows the corresponding 3D reconstruction. This detailed model can be replaced at its location on the previous model of the locality derived from the 360° panorama.

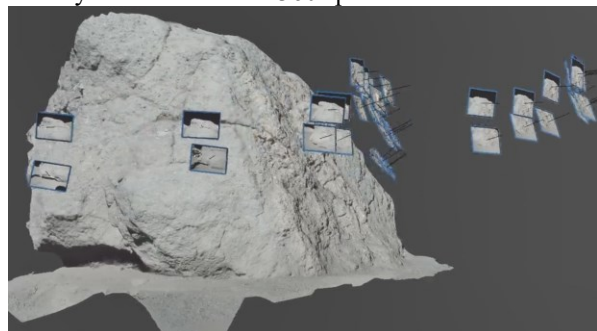


Fig. 3: The main boulder of Station 7 reconstructed in 3D.

Photogrammetric reconstruction of rock samples: Three rock samples (77115, 77075, 77135) taken at Station 7 had a sufficient photographic coverage, with

16 stereo pairs taken in two orthogonal directions, to allow their 3D reconstruction. These images are available on the LPI website. An example is given in Fig. 4 for sample 77035.

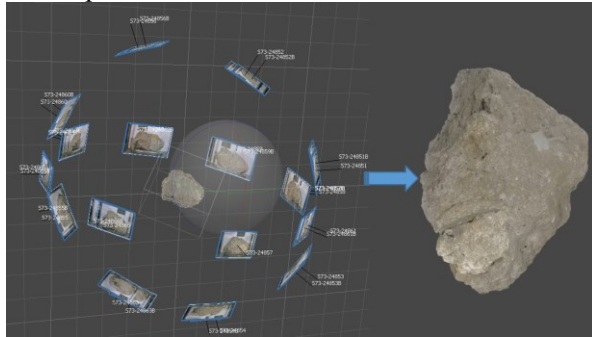


Fig. 4: 3D Reconstruction of sample 77035.

We have posted the 3D models of these samples on the Sketchfab web platform (<https://sketchfab.com/LPG-3D>) to allow their visual inspection. These 3D numerical reproduction have a potential value for conservation as the actual rock samples have been broken into multiple pieces after being photographed.

Integration into virtual reality and scientific implications: A complete 3D scene can be setup from the previous individual models using softwares such as Blender. LRO and Kaguya orbital imagery can be used to provide the context in the background. The 3D mesh derived from the 360° panorama (Fig. 2) is first tied to LRO. Then the close-up boulder model (Fig. 3) is placed at its location using the low resolution version derived from the panorama. Finally, the 3 rock samples (Fig. 4) can be replaced at their original location and orientation onto the boulder (Fig. 5).

This kind of multi-scale 3D reconstruction process theoretically opens new possibilities of scientific investigations. The precise location where each photograph has been taken can be derived from the automatic alignment in the photogrammetric software. Processes such as the space weathering can be further explored by looking at how the rock samples were exposed to the sky.

Using such a pipeline for the complete 3D reconstruction, it becomes also theoretically possible to derive the absolute position and orientation of the samples. This could be useful to enable measurements of the paleo-orientation of lunar magnetic fields. Such data could help to determine the geometry of the Moon's magnetic field and its reversal frequency, in addition to global-scale tectonic events [6]. Data from lunar samples indicate that the Moon generated a dynamo magnetic field from at least 4.2 to 3.56 Ga [6].

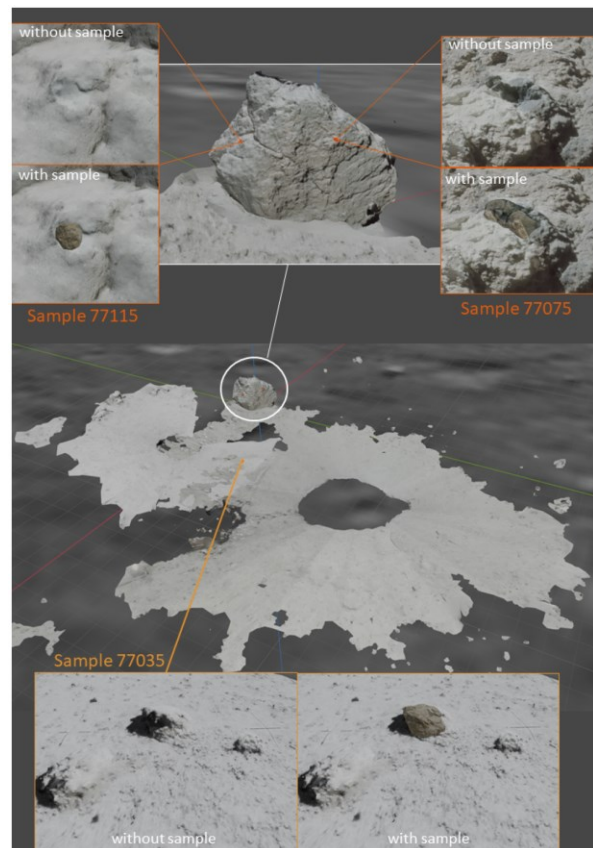


Fig. 5: Integration of multi-scale 3D models from panoramas, boulders, rock samples and orbital imagery at Station 7.

The age of samples from Station 7 is about ~3.8 billion years, which corresponds to the period where the lunar dynamo ended [6]. This kind of paleomagnetic study should preferably be applied to samples extracted from an in-place bedrock, which is unfortunately not the case of the main boulder of Station 7, which rolled down from North Massif about 28 million years ago [7].

Conclusion and Future Work: Following our previous work on Apollo 17 Station 6 [4-5], we have carried out a photogrammetric 3D reconstruction of the Station 7 outcrop including soil, boulder and rock samples replaced at their original location. Such 3D reconstruction techniques might be useful in the context of the forthcoming Artemis landing missions, provided that astronauts and robotic explorers acquire relevant sets of overlapping images.

References: [1] Wolfe, E.W. et al., U.S. Geol. Surv., 1080, 225–280, 1981. [2] Schmitt, H.H. et al., *Icarus*, 298, 2–33, 2017. [3] Ullman, 1979. [4] Le Mouélic et al., *Remote Sensing*, 12 (11), 2020. [5] Le Mouélic et al., *Planet. Space Sci.*, 2024. [6] Weiss, B. P. & S. M. Tikoo, *Science* 346 (6214), 1246753, 2014. [7] Crozaz et al., *LPSC 7th*, 2335-2378, 1974.