Ice Degradation and Boulder Size Frequency Distribution Analysis of the Fresh Martian Crater S1094b

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INTRODUCITON AND RATIONALE

S1094b is a fresh crater formed by an impact that occurred on 24 December 2021 and located in the northern part of Amazonis Planitia [1]. Its diameter is 155 m and its depth 20 m, but much more importantly, it exposes water ice among its ejecta. This ice is present under two forms: icy boulders and icy patches.

S1094b was repeatedly observed by HiRISE, giving us the opportunity to study its changings during time. In this work, we analyze two HiRISE images taken on February and December 2022, to perform a multi-temporal analysis of its ice-rich ejecta, and combining this analysis with the geologic mapping, the boulder SFD and thermal modeling. The objective is to provide a multidisciplinary characterization of both the impact and subsequent exposed ice sublimation processes.

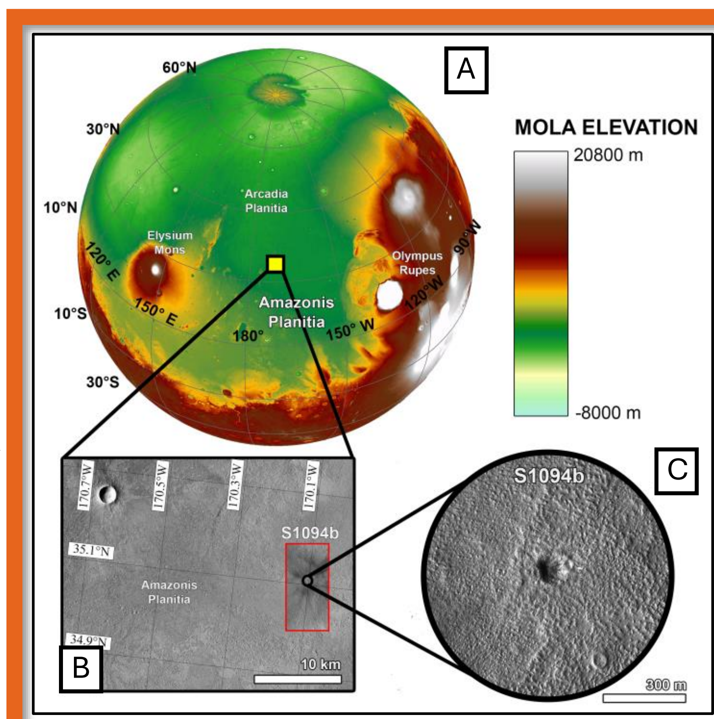


Fig. 1: Regional context image of S1094b. (A) MOLA elevation map, (B) Regional CTX , (C) HiRISE closeup.

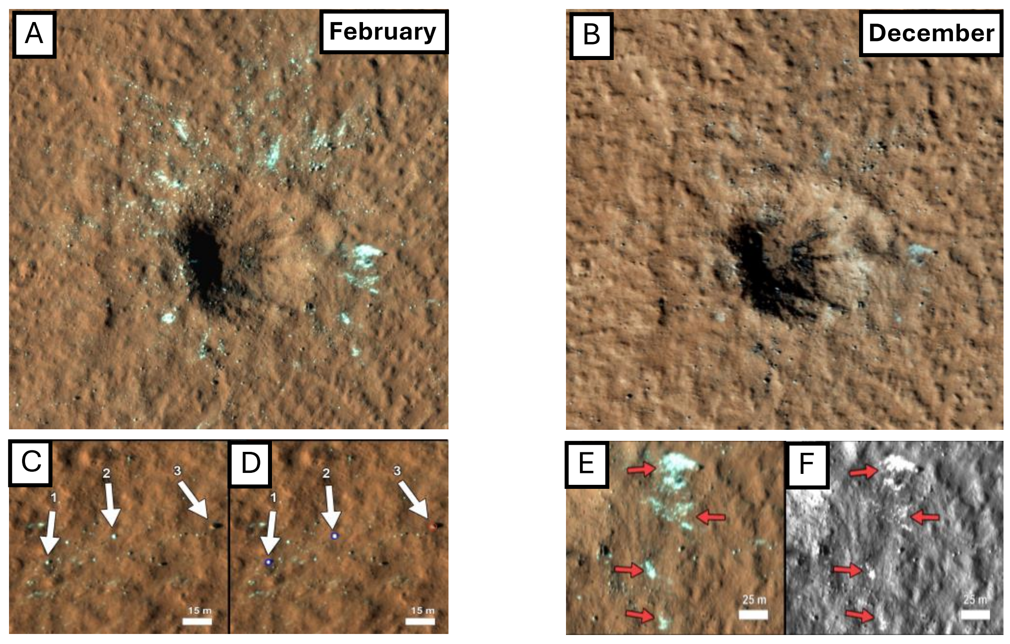
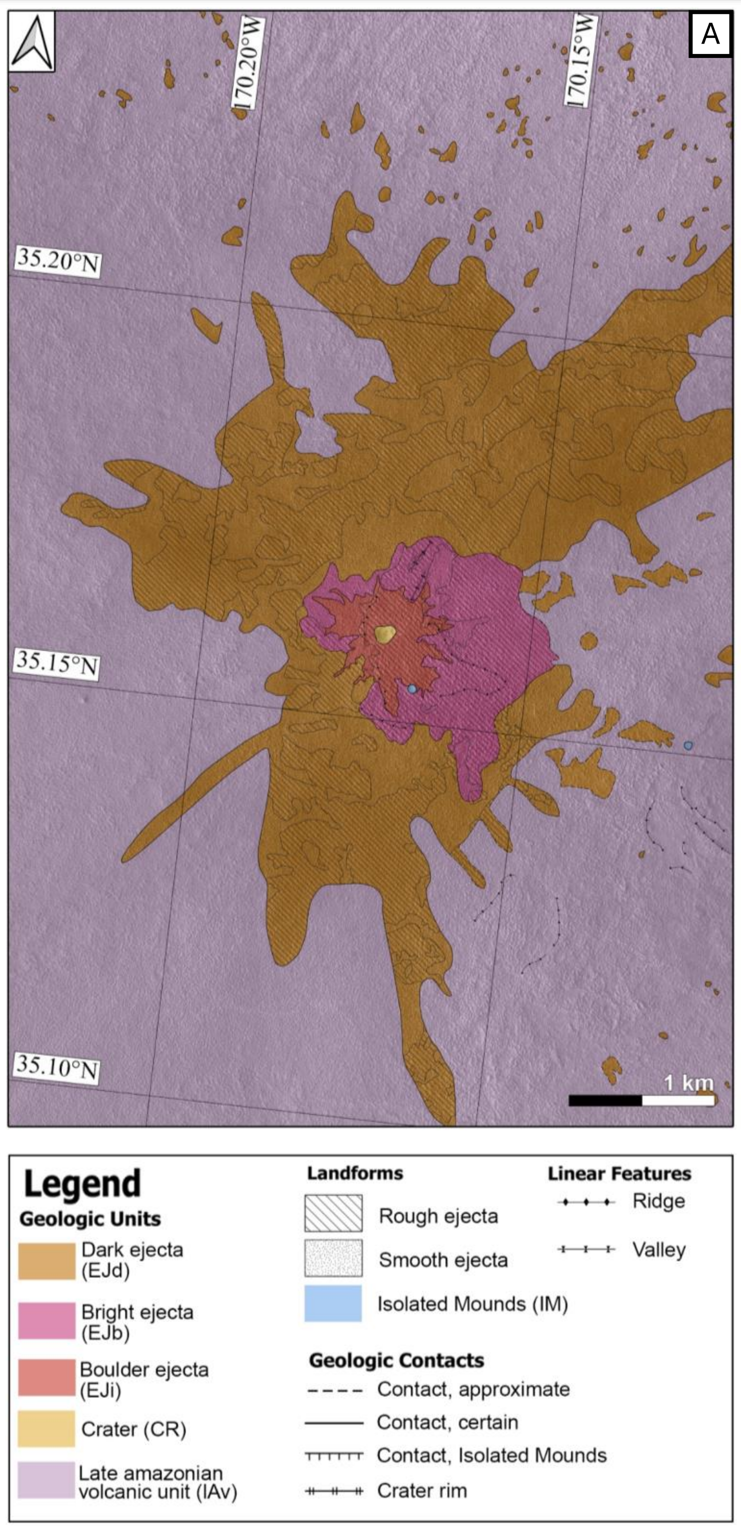


Fig. 2: (A) February and (B) December RGB images of S1094b. The blue-to-white features are water ice. (C,D) Closeups on icy (blue circle) and rocky (red circle) boulders. (E, F) BW and RGB Closeups on icy patches, indicated by the red arrows.

GEOLOGIC MAP

We produced the geologic map (1:10000 scale) by using both HiRISE DTM, RGB and RED channel images. The mapping scale ranged from 1:1000 to 1:5000.

5 geologic units and 4 landforms has been identified, focused on the different morphologies present in the study area like the different kinds of ejecta, the crater, and isolated mounds.



BOULDER SIZE FREQUENCY DISTRIBUTION

We manually identified each boulder present in the 1 km^2 study area for a total of 7989 on February image and 5138 on December image.

Both the February and December boulder SFD[2] statistics fit a power low, with an α index of -4.68 ± 0.15 and -3.47 ± 0.10 respectively. These distributions highlight a shallowing of the curve in 274 sols.

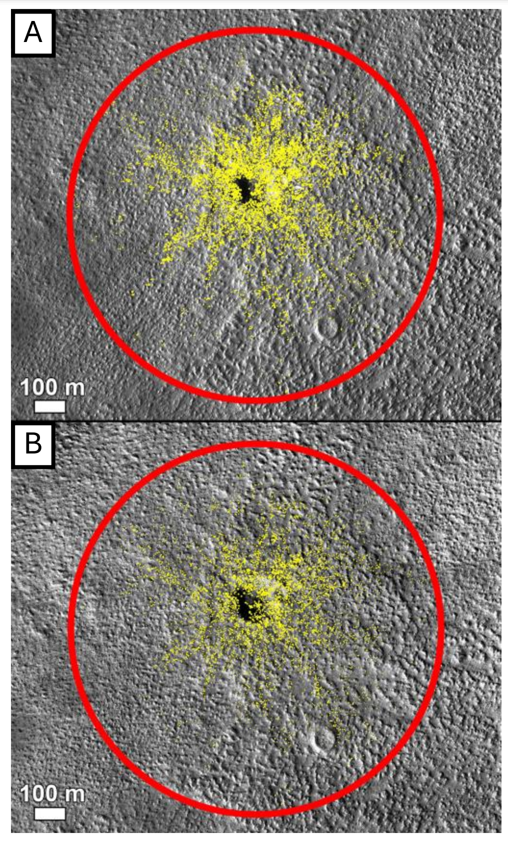


Fig. 4: Boulder mapping conducted on (A) February and (B) December 2022 images. Red circle is the 1 km^2 study area, boulders are yellow dots.

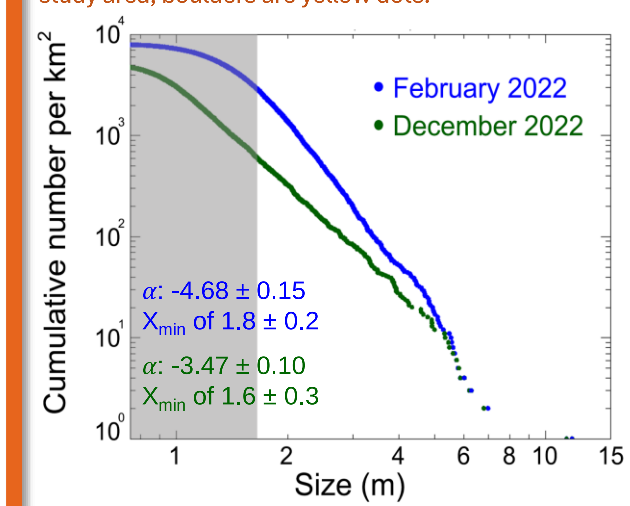
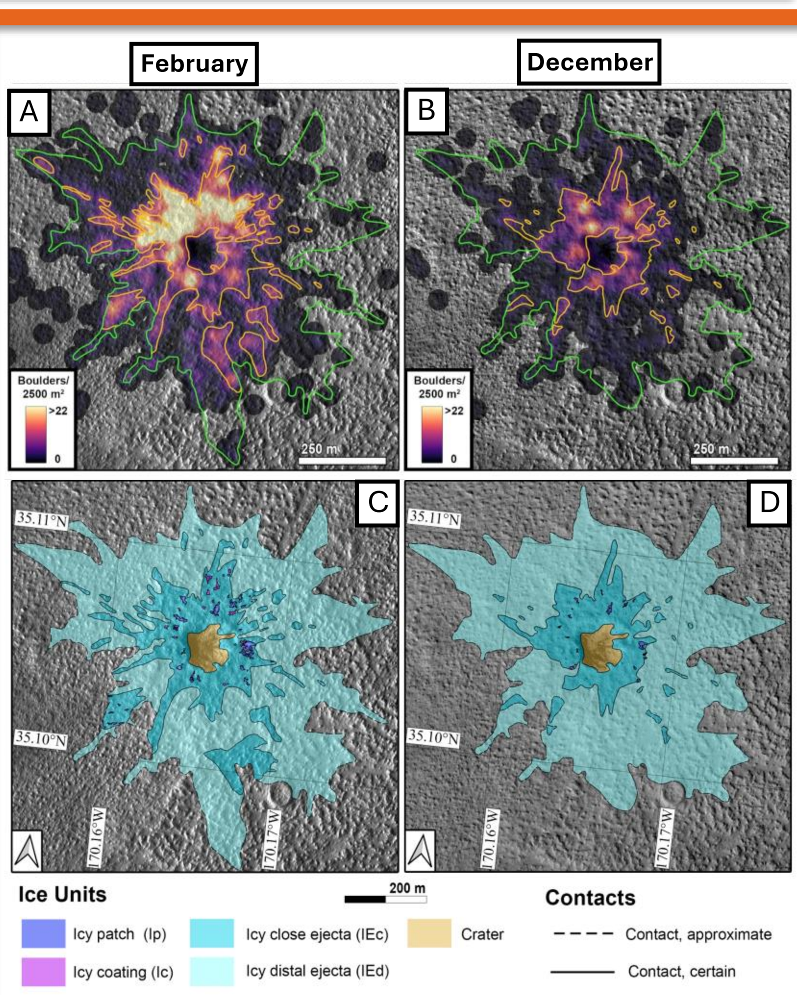


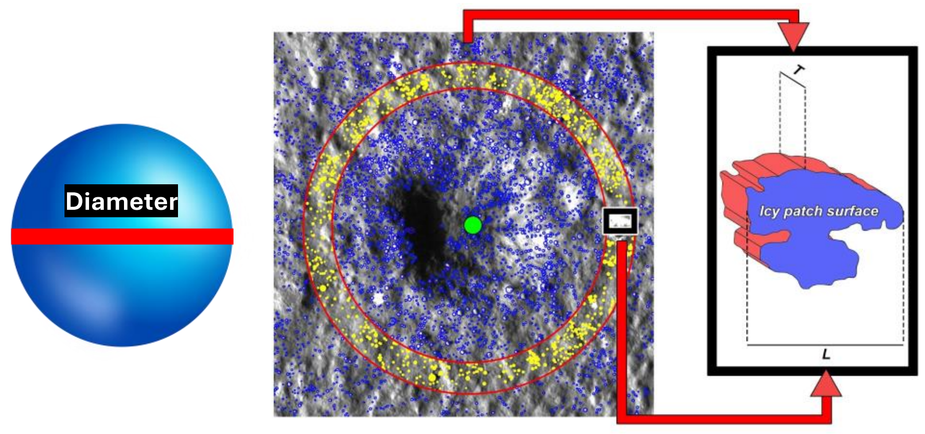
Fig. 5: Boulder mapping conducted on (A) February and (B) December 2022 images.

ICE ESTIMATION AND THERMAL MODELS

The estimation of the ice present in the area has been made through the sum of the areas and volumes of the manually mapped icy boulders and icy patches. Within the February 2022 dataset we identified a total of ~12276.85 ± 2165 m^2 of exposed ice and a total volume estimated to be 20274.44 ± 3997 m^3. Within the December 2022 dataset a total of ~4963.32 ± 642 m^2 of exposed ice and a total volume of 7951.53 ± 1117 m^3.

We then computed the thermal models of the area where S1094b was formed, basing on Clausius-Clayperon [3] equations. The climate condition in the timeframe between the first and las image, led the exposed ice to be almost continuously under sublimation condition, for a total of 6504.71 hours.





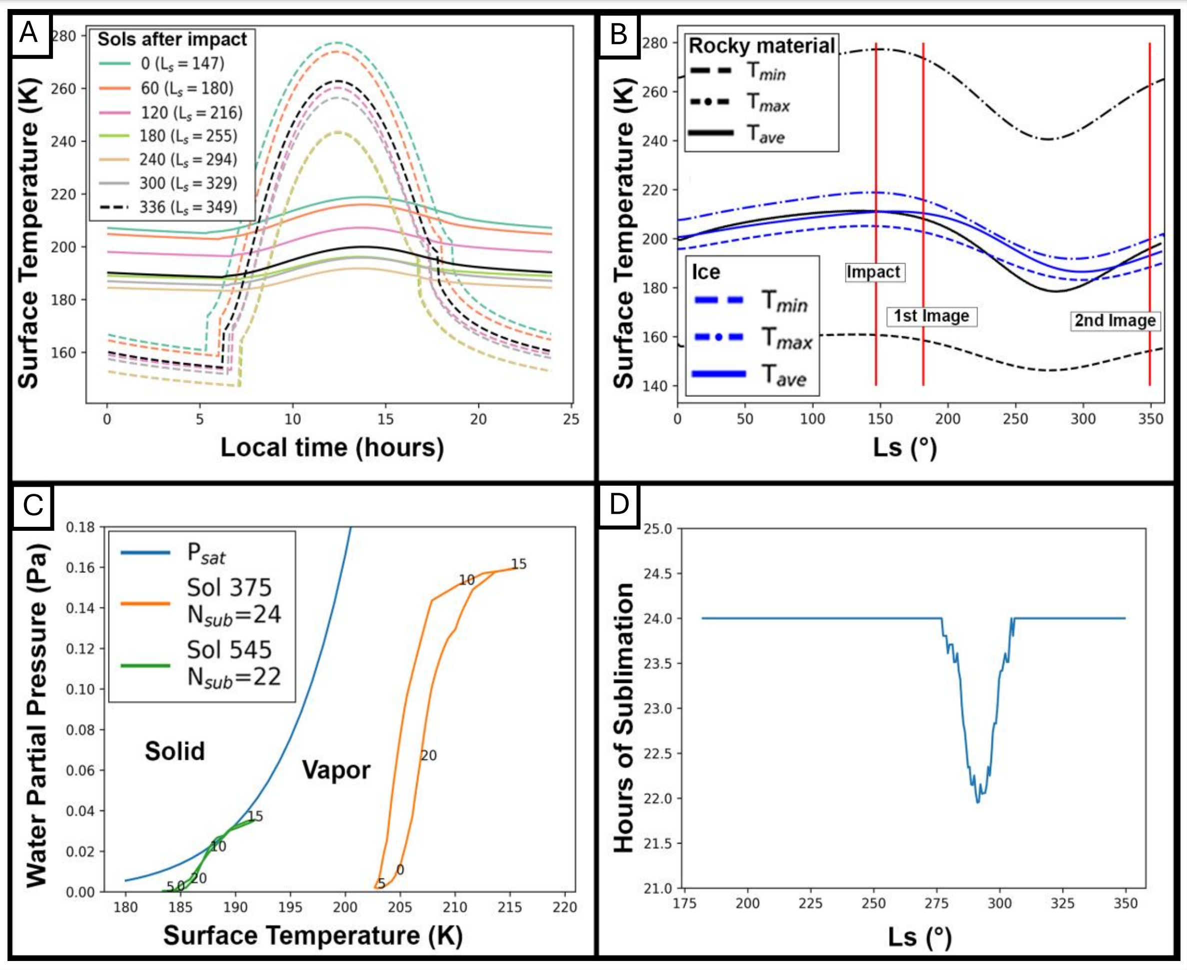


Fig. 6 (left): (A) Heatmaps of the ice present in February and (B) December. (C) Maps focusing on the different units characterized by different surface ice coverage, prepared both on February and (D) December images.

Fig. 7 (up): Image showing the workflow with wich we estimated the volume of the ice. We assumed the (left) boulders as spheres and the (right) patchest as irregular prisms with a thickness equal to the average diameter of the spherical boulders located at the same radial distances from the center of the crater as the considered icy patch

Fig. 8 (right): A) Diurnal surface temperature, computed for the rocky (dashed line) and icy (solid line) materials, at various sols after impact. B) Minimum (dashed line), Maximum (dot dashed line), and average (solid line) daily surface temperatures as a function of season (Ls) for the ice (blue) and rocky materials'. C) Water phase diagram showing the saturation partial pressure vs temperature curve (blue line) and ice diurnal temperatures and partial pressures for two selected Sols. D) Number of sublimation hours in the timeframe between the first and last image analyzed.

CONCLUSIONS

Despite a relatively small size of ~155 m, S1094b shows different geological features. In the timeframe between the two datasets, the power-law index decreased from -4.68± 0.15 to -3.47 ± 0.10. We interpreted this flattening of the cumulative distributions as the result of a loss of small-size boulders. This is consistent with the density per km^2 which shows a 80% reduction of the icy fraction with diameters ≥ 1.50 m. We also investigated the sublimation of the ice ejected from S1094b in the February and December timeframe. We mapped all the exposed ice in both datasets and estimated a loss of ice surface area of ~7313 m^2 and a decrease in ice volume of ~12322 m^3. Thanks to the thermal models we also calculated a total of 6504.71 sublimation hours from which we derived a sublimation rate of 1.96 m^3/h or 0.15 ± 0.04 mm/h. These results, are consistent with the loss of the smallest-size boulders due to the sublimation effect which occurred between February and December.

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