Preparing for Mars Sample Return: Insights from Australian Analogue Samples

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INTRODUCTION

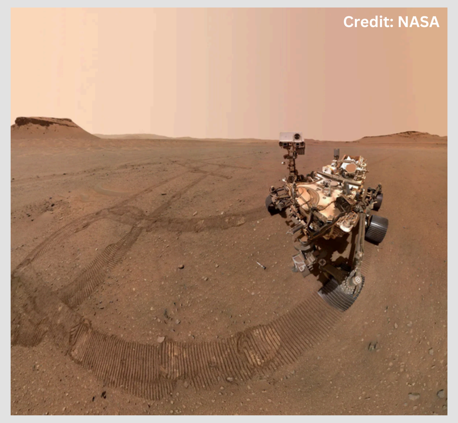


Figure 1. Perseverance rover on Mars with core sample

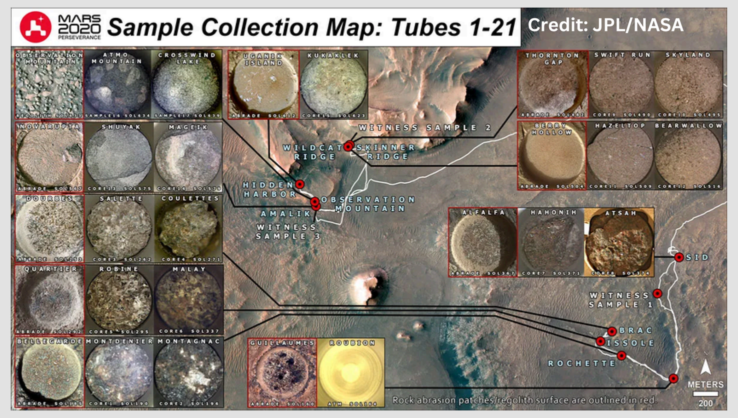


Figure 2. Mars Samples #1-21 from Perseverance rover

- The Perserverance rover is currently exploring Mars and collecting rock/regolith core samples to be returned to Earth for geological and astrobiological analysis as part of Mars Sample Return (MSR) (Fig. 1) (Fig. 2)
- The samples are small and precious, and to minimize Earth contamination scientists want to see inside the cores before opening them to figure out what they are working with in terms of signs of Mars' past climate, water, and potentially life.
- As a test-run, collaborators collected analogue samples from the Pilbara region in Australia (Fig. 3). The analogue samples were shared with the Herd Lab and NASA's Johnson Space Center. The Herd Lab received sedimentary and regolith core samples

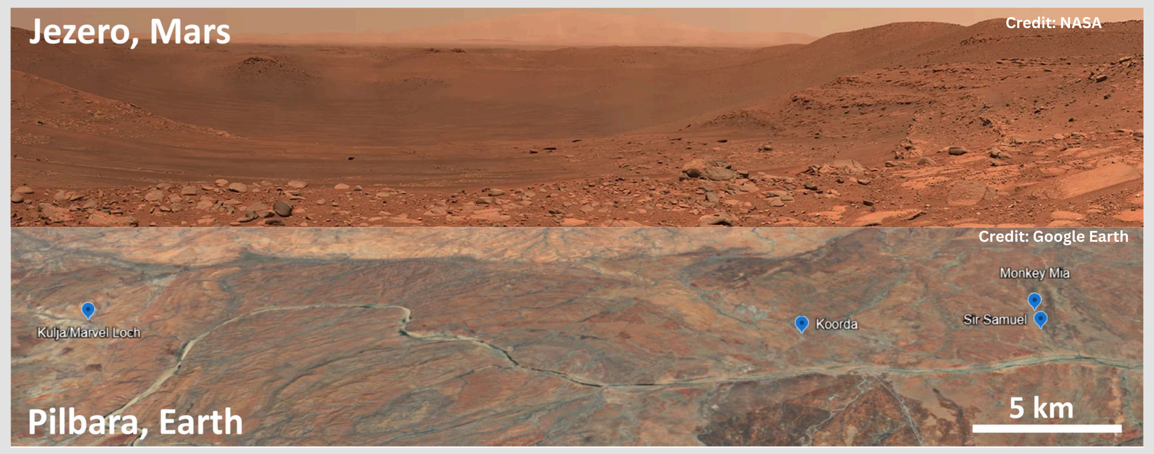


Figure 3. Rover image of Mars, and location of analogue samples in Pilbara Australia

METHODS

- This study looked at 5 core samples, 3 sedimentary rock samples, and 2 regolith samples.
- These samples were initially scanned using X-ray computed tomography at the University of Alberta PACS lab, using a Nikon XT H 225ST Industrial CT scanner with a voltage of 220 kV. We analyzed the XCT data of these samples through the use of Dragonfly software (Dragonfly, v2022.2) which interprets the 2000-4000 slices of data from XCT scans.
- In each sedimentary rock core (Kulja, Koorda, and Monkey Mia) we chose two fragments to rescan at 110 kV; one homogenous and one heterogenous fragment
- To determine the average fragment sizes of the regolith samples we tested different methods:
- S.S. #1a – Each fragment was fully segmented in 3D, and the max diameter was recorded for every fragment. All 200/200 slices were measured
- S.S. #1b – The max diameter of all fragments in 1 slice was measured using the ruler tool. 1/200 slices were measured.
- S.S. #1c – The max diameter of all fragments in 10 different slices (1 slice was measured every 25 slices) was measured using the ruler tool. 10/200 slices measured.
- M.L. #2a – Similar to method #1b, where the max diameter of all fragments in 10 slices using the ruler tool. 10/2000 slices measured.
- M.L. #2b – The max diameter of representative fragments of each size grouping (~10% of total fragments in each slice) was measured using the ruler tool. 20/2000 slices measured.

RESULTS AND CONCLUSIONS

Research Question 1: What are the sizes of the fragments in the regolith cores? What is the most time effective way to determine this ?

- S.S. #1a is the most accurate but takes 3000 hours to complete.
- S.S. #1b and #1c show a bias towards fine-sand-sized particles due to slice selection and possible underestimation of fragment max diameter.
- M.L. #2a and #2b show inconsistency in medium and coarse sand-sized fragments. M.L. #2b's higher coarse sand count is likely due to non-representative fragment measurement, making M.L. #2a more accurate despite M.L. #2b's faster processing.
- Use M.L. #2a for a quick, rough size distribution. For detailed analysis, segment the core sample fully with S.S. #1a if possible.

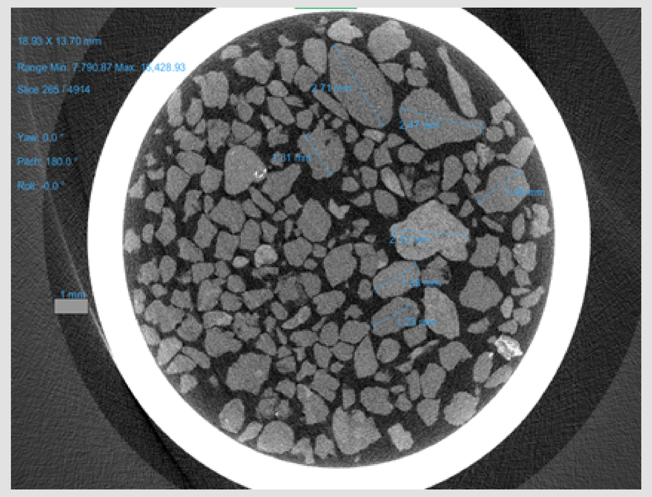


Figure 4. Measuring the maximum diameter in Method #1b, 1c, 2a, 2b

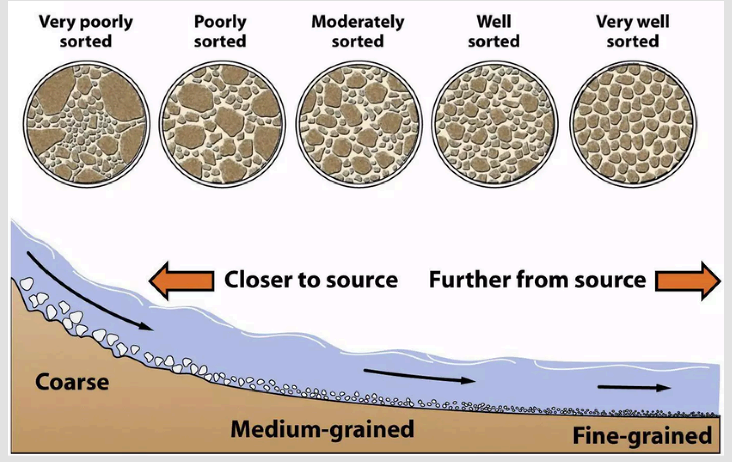


Figure 5. Fragment sorting size found in regolith samples

Image credit: B. Esrafili-Dizaji

Figure 6. Sir Samuel visual animation

Figure 7. Marvel Loch visual animation

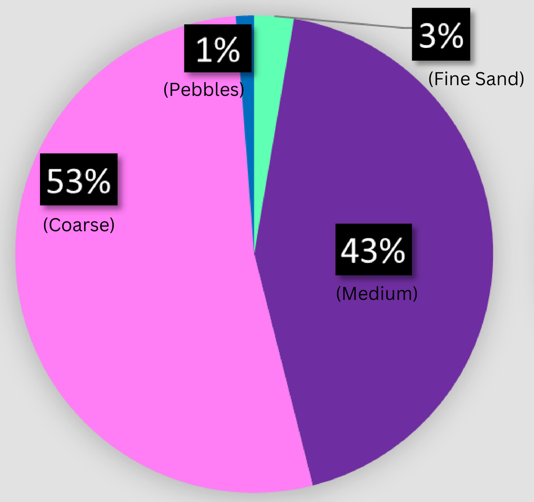


Figure 8. S.S. #1a. Duration: 30 hours

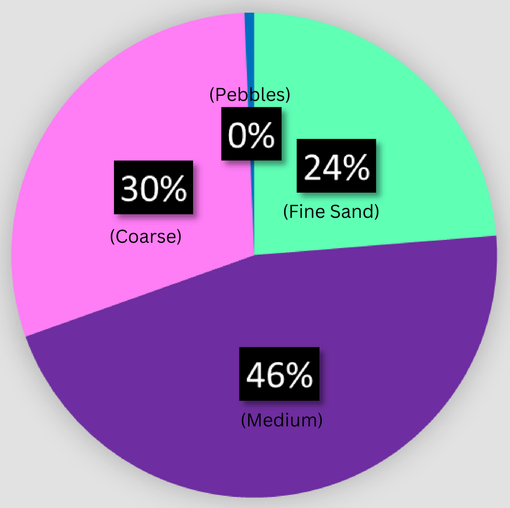


Figure 9. S.S. #1b. Duration: <3 hours

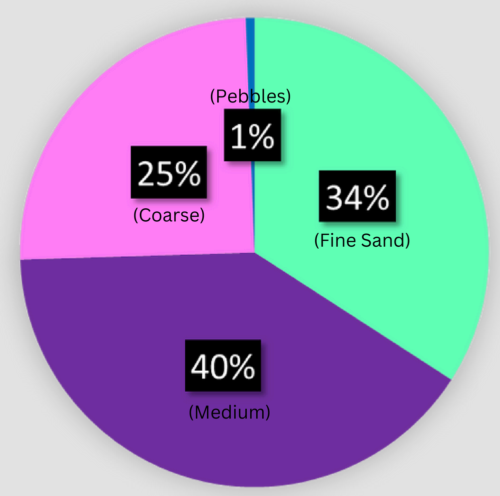
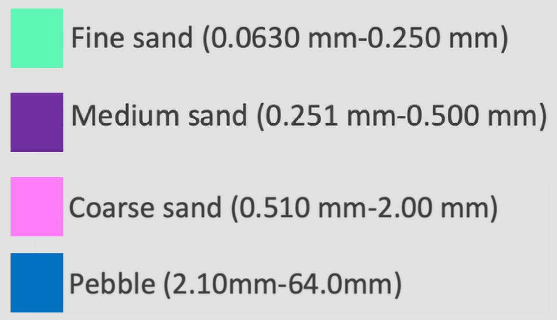


Figure 10. S.S. #1c. Duration: 9 hours



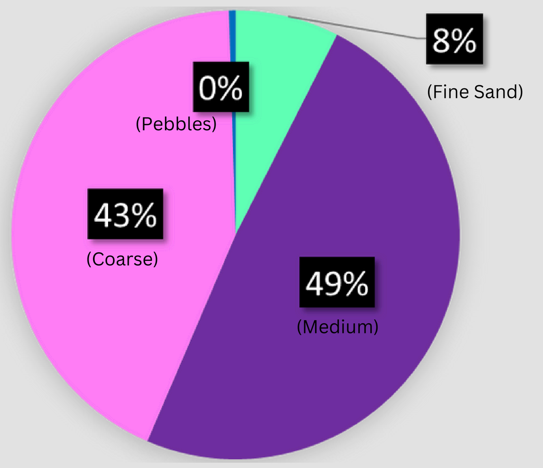


Figure 11. M.L. #2a. Duration: 9 hours

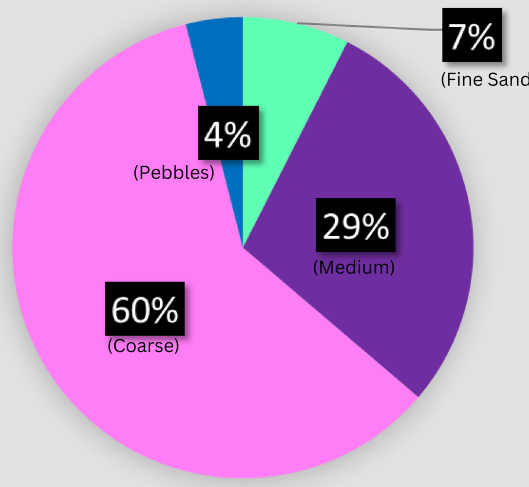


Figure 12. M.L.#2b. Duration: <6 hours

Research Question 2: What do these samples look like inside? Do they show any structures that are useful for the study of water or life?

Rescanning of Koorda, Kulja, and Monkey Mia and new resolution:

Koorda:

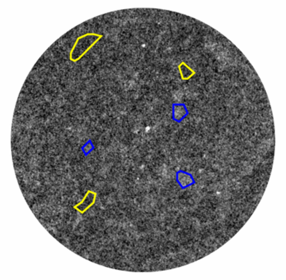


Figure 13. Heterogeneous fragment original scan

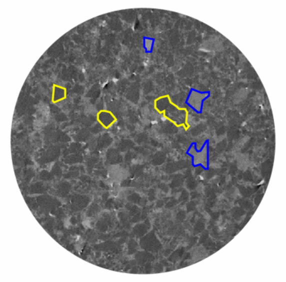


Figure 14. Heterogeneous fragment rescan

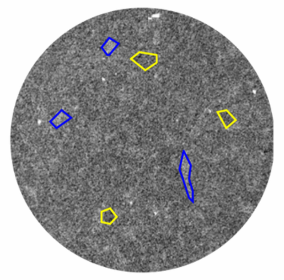


Figure 15. Homogeneous fragment original scan

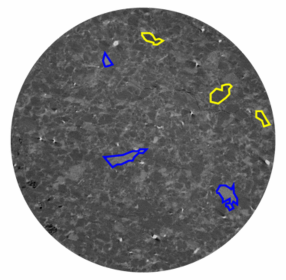


Figure 16. Homogeneous fragment rescan

Kulja:

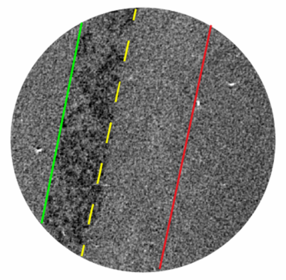


Figure 17. Heterogeneous fragment original scan

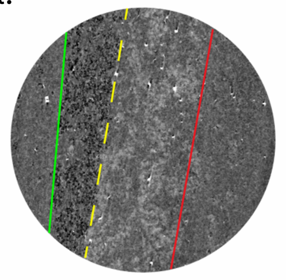


Figure 18. Heterogeneous fragment rescan

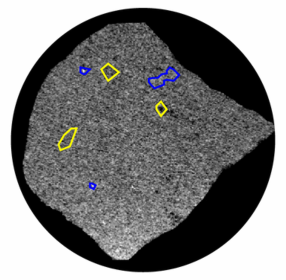


Figure 19. Homogeneous fragment original scan

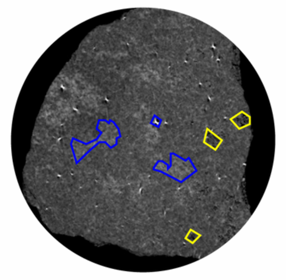


Figure 20. Homogeneous fragment rescan

Monkey Mia:

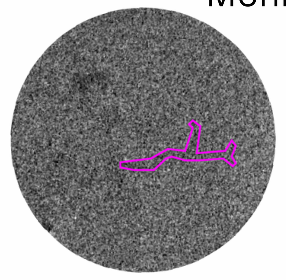


Figure 21. Heterogeneous fragment original scan

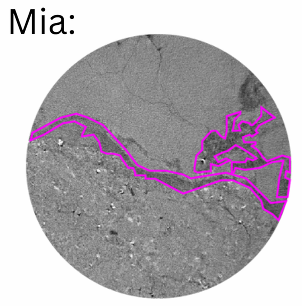


Figure 22. Heterogeneous fragment rescan

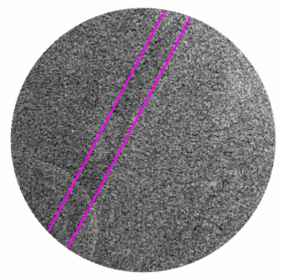


Figure 23. Homogeneous fragment original scan

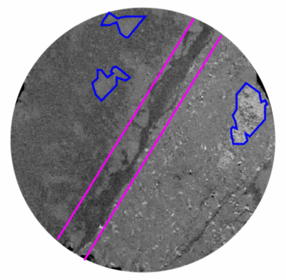


Figure 24. Homogeneous fragment rescan

1 mm

High density materials appear as brighter colors, and low density materials appear as darker colors

Figure 25. Koorda rescan animation

Figure 26. Kulja rescan animation

Figure 27. Monkey Mia rescan animation

- Rescanning at lower energy provides deeper insights into fragment composition, varying per rock core.
- Significant differences were observed in Monkey Mia and Koorda cores. Monkey Mia showed stromatolitic bands upon rescanning, crucial for astrobiology. Koorda revealed distinguishable grains, aiding mineralogy determination.
- Kulja scans showed minor differences, suggesting limited benefit of lower energy rescans for observable high-energy structures.
- To understand mineralogy, future work should involve cutting fragments and studying their mineralogy, so that insights gained from the analogue cores can be used to interpret the MSR cores.

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ACKNOWLEDGEMENTS

We acknowledge that this study was done on Treaty 6 territory the traditional meeting grounds and gathering places of the Cree, Salteaux, Blackfoot, Métis, and Inuit people. We strive to respect the land and living things that inhabit this land as it relates to our research. We strive to include indigenous knowledge into our studies.

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