Modeling the geologic processes that occur on Mars

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INTRODUCTION

- Martian meteorites are the only samples available on Earth to study Mars [1], and help us understand how processes such as magmatism and movement of volatiles, like water, have changed over time. Data from rovers, landers, and satellites can provide additional information on Mars' geologic history [2, 3, 4].
- The rocks observed on the surface of Mars at the Jezero crater (Fig. 1) by the Perseverance Rover have drastically different chemical compositions than the ones observed in martian meteorites [1-2]. Martian meteorites are Mg and Fe rich, while rocks at the martian surface are alkali-rich (Na and K) [1-2].

Research questions:
1. Why are the compositions of martian meteorites and surface rocks so different?
2. Can they be linked to one another via magmatic processes like fractional crystallization and assimilation?

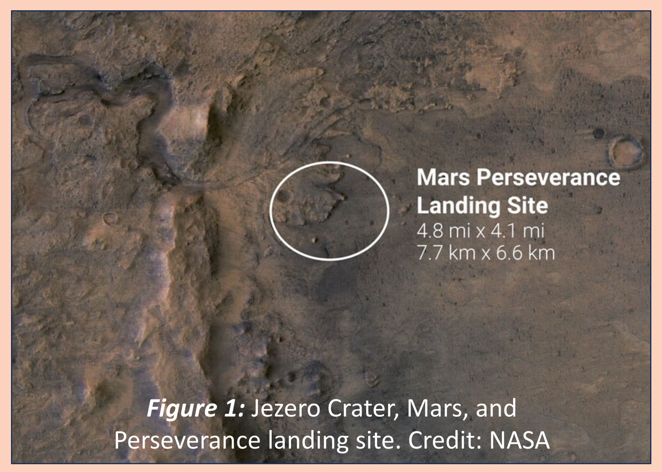

Figure 1: Jezero Crater, Mars, and Perseverance landing site. Credit: NASA

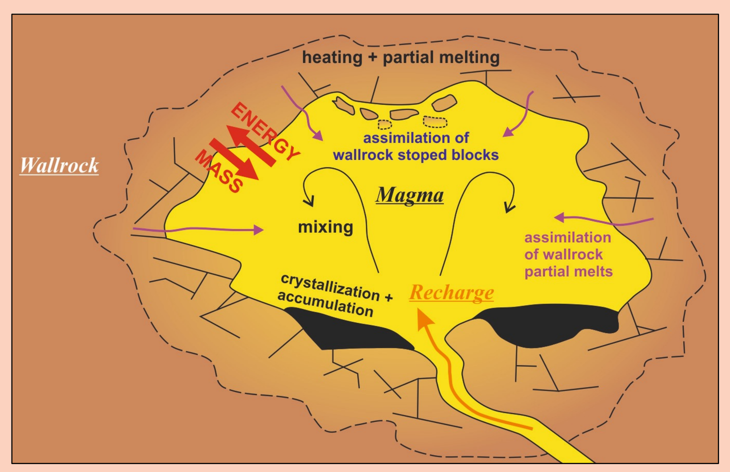

Figure 2: Assimilation and fractional crystallization processes in Magma Chamber Simulator. Credit: https://mcs.geol.ucsb.edu/about

OBJECTIVE: To attempt to replicate the chemistry at the surface of Mars, as measured by the NASA Perseverance rover mission at Jezero crater, Mars, with martian meteorites.

RESULTS

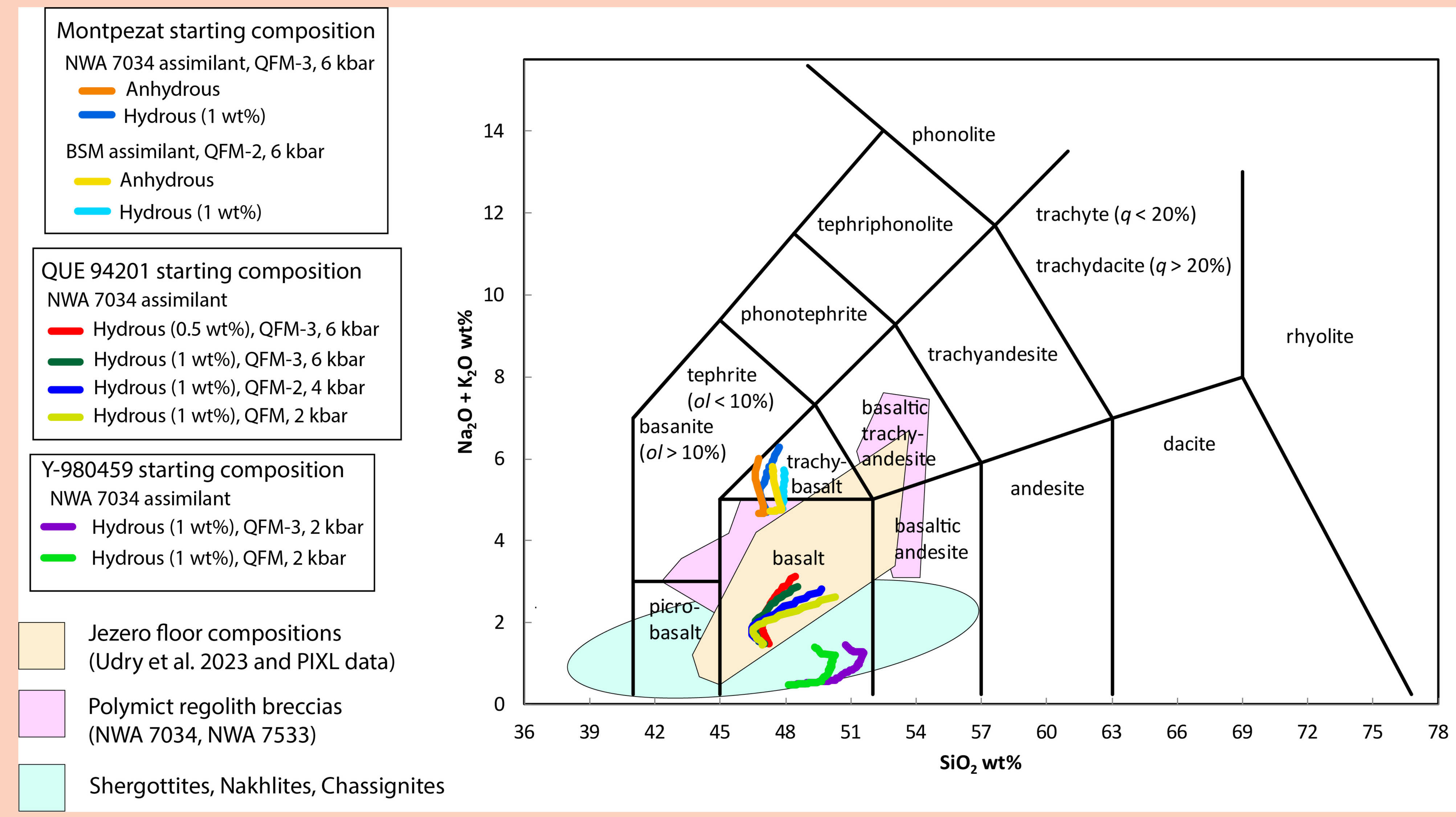

Figure 3: Total Alkali Silica (TAS) graph showing the data collected from MCS with the QUE 94201, Yamato 980459 and Montpezat compositions, and compositions envelopes of SNC meteorites, Jezero floor compositions, and polymict regolith breccias

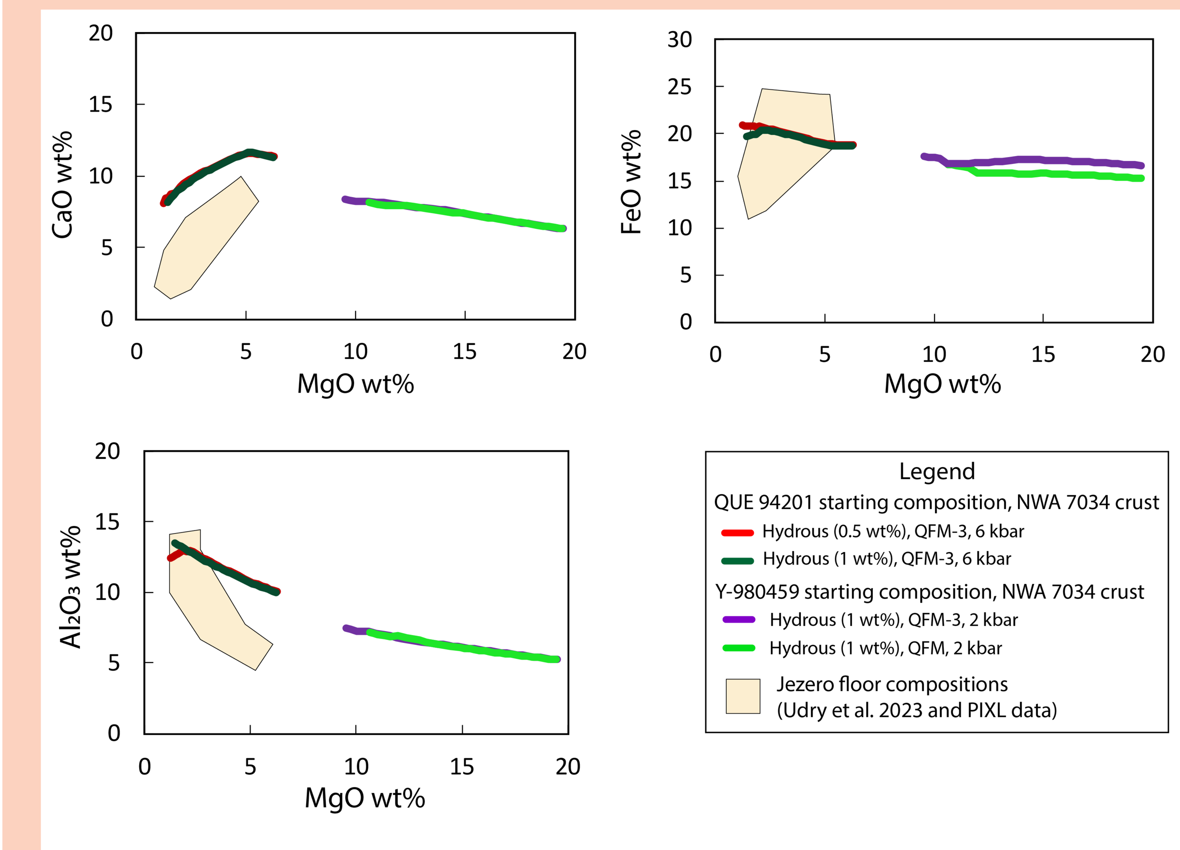

Figure 4: MgO graphs from MCS, with QUE 94201 and Yamato 980459 compositions

METHODS

Magma Chamber Simulator (MCS)

- The Magma Chamber Simulator [5] is a software that models open-system magmatic processes, providing a holistic view of how a magma body interacts with its surroundings, and how the chemistry evolves over time.
  - Components:
    - Magma composition
    - Wall rock composition
  - Acts as an input and output machine using Visual Basic in Microsoft Excel
  - Uses the MELTS family of algorithms [6-8]. We used Rhyolite-MELTS 1.2 MELTS as it works best for fluid-bearing magmas, and has successfully been used for martian compositions [9].
  - **Used the MCS to run models in order to observe how the compositions would change depending on certain variables** (and ultimately find a combination that would match the chemistry seen at the surface of Mars).
- **Variables considered when modeling**
  - Pressure: we used 1, 2, 4, and 6 kbars, representing the upper crust to the shallow subsurface [10].
  - Oxygen Fugacity (*f*O2) or Fe_2O_3 content, calculated separately using MELTS for Excel [11]. We used the Fe_2O_3 equivalent to a starting *f*O2 of 0 to 3 units below the Quartz-Fayalite-Magnetite buffer. These values are based on magmatic *f*O2 estimates of martian meteorites [1].
  - H_2O content (anhydrous to 1 wt% H_2O), based on literature values [12].
- **Magma compositions used**
  - Shergottite Yamato 980459 (Y98) [13], Mg-rich liquid composition
  - Shergottite QUE 94201 (QUE) [14], Fe-rich liquid composition
  - Calculated parental composition of surface rock Montpezat [M. Schmidt, pers comm]
- **Wall rock (assimilated part) compositions used**
  - Polymict regolith breccia NWA 7034 [15] whose composition is most similar to the average crust of Mars.
  - Bulk Silicate Mars (BSM) [16], a calculated average of the combined composition of the crust and mantle.

CONCLUSION

- In the TAS graph above, the QUE compositions overlap with the Jezero floor compositions (Fig. 3); thus, we were able to replicate the silica and alkali contents seen in the Jezero floor compositions.
- These results show us that the chemical compositions observed at the surface of Mars can be replicated with shergottites, but only with a good amount of water indicating that the martian interior may have more water than is currently suggested by martian meteorites [15], or the possibility of water-rich reservoirs closer to the surface.
- **Why didn't the other compositions work?**
  - BSM: Mg and Fe rich composition because it is an average of the mantle and crust of Mars [16]
  - Y98: when compared with the Montpezat and QUE compositions, Y98 has higher Mg (more primitive)
  - Montpezat: the composition was calculated, it is not a measured sample
- The sample that was best able to replicate the general composition of Jezero, in terms of its chemistry and chemical trends, was QUE which represents a direct sample from the mantle. However, it's far from a perfect match, which might indicate that the rocks from Jezero did not form from a mantle melt directly and perhaps required a more complex formation history.

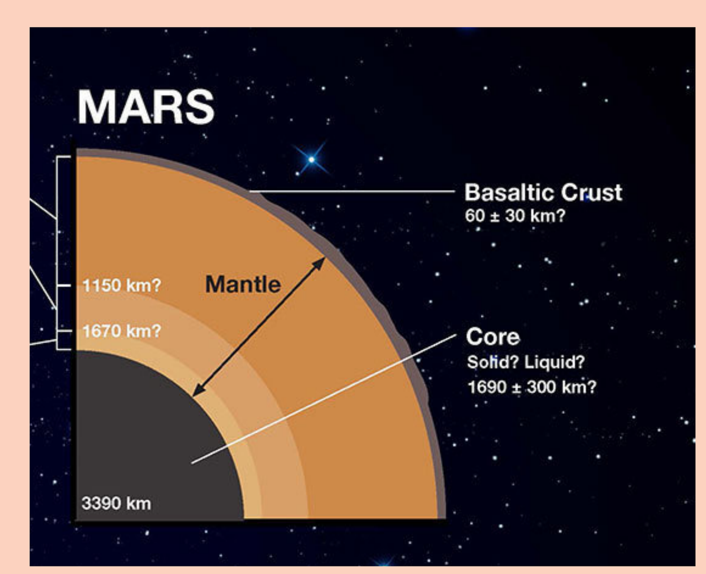

Figure 5: Diagram illustrating Mars' interior. Credit: NASA

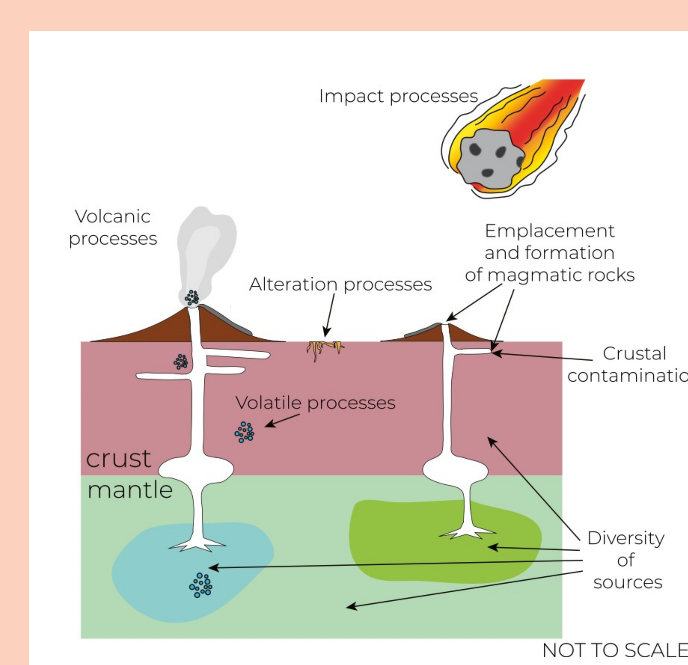

Figure 6: Magmatic processes on Mars [1]

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