

**CONSTRAINING THE SURFACE WEATHERING FORMATION CONDITIONS OF THE OLIVINE-CARBONATE UNIT IN NORTHEAST SYRTIS REGION USING REACTIVE TRANSPORT MODELLING.** S. V. Kaufman<sup>1</sup> and J. F. Mustard<sup>1</sup> <sup>1</sup>Brown University, Department of Earth, Environmental, and Planetary Science. *Contact: sierra\_kaufman@brown.edu*

**Introduction:** The olivine-carbonate unit in NE Syrtis is the largest carbonate exposure found to date on Mars [1]. This Noachian-aged unit's carbonate presence indicates past conditions conducive to its formation, including liquid water of appropriate pH [1].

The abundant fluvial features [2,3] and alteration minerals [4,5] (such as in the olivine-carbonate unit) are thought to have formed during the Late Noachian/Early Hesperian, consistent with a warm and wet climate. However, the most robust 3D climate models cannot sustain liquid water on the surface for an extended period, given reasonable greenhouse gas estimates [6–8] due to the faint young sun paradox [9], implying a cold and icy background climate. Punctuated heating events, such as impacts [10–13], volcanism [14], and changes in eccentricity and obliquity [15], can cause the temperatures necessary to carve fluvial features. It is unknown if they can produce liquid water that would remain in contact with rock for the amount of time required to form hydrous mineralogy.

This study attempts to determine the resulting mineralogy from several alteration scenarios to constrain the climate, alteration duration, and parent material that resulted in the olivine-carbonate unit using reactive transport models (RTM). Specifically, we explore the hypothesis of surface alteration of the olivine to form carbonate. While these results may have some implications for hydrothermal or subsurface alteration, which has been suggested as a potential formation mechanism [16], it is not the goal of this model set up to discuss that hypothesis. Here, we compare our model results to previous work, which has constrained the unit's chemistry and mineralogy through remote sensing [17,18]. Our products can be compared to future Perseverance rover measurements, which will measure the chemistry at a much higher resolution than the currently available remote sensing data, to constrain further the possible formation scenarios. The rover will land on 2/18/2021 in Jezero Crater, which contains the olivine-carbonate unit [19,20], making the necessary measurements possible.

**Methods:** We use the RTM CrunchFlow [21–23] to react one-dimensional columns of varying parent mineralogy with water under a pure CO<sub>2</sub> atmosphere. The starting chemistry (Fo#) and mineralogy are varied to be within realistic parameters for the site based on previous remote sensing measurements [17,18] and parent unit hypotheses [20,24]. Water flows from the

top of the column down, implying precipitation (which motivated the chosen range of flow rates), but this **does not necessitate** it as the deliverance mechanism for these models to be relevant. We explore variations in atmospheric pressure, temperature, water availability, and pH (**Table 1**). Our models run for 100,000 years and have timesteps output every half order of magnitude and 10,000 years.

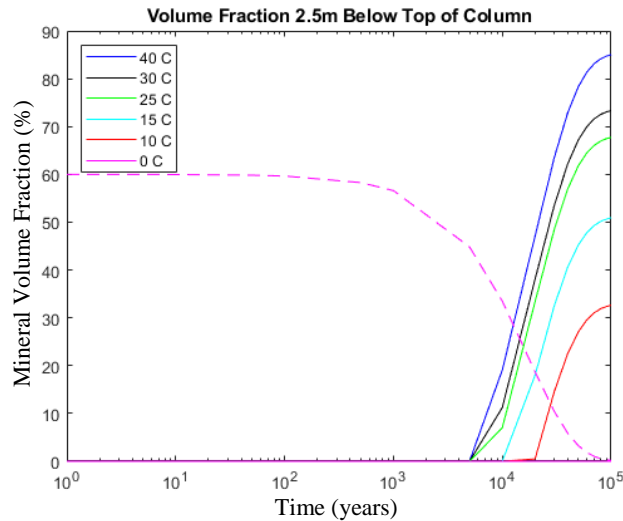
**Table 1.** The explored range for each RTM model variable of interest.

Variable	Minimum	Maximum
<i>Olivine Fo#</i>	40	100
<i>P<sub>CO2</sub></i>	0.5 bar	2 bar
<i>Temperature</i>	0 °C	40 °C
<i>Water flow rate</i>	0.01 m/yr.	2 m/yr.
<i>pH</i>	3	9

**Results:** Models for Fo<sub>100</sub> show alteration to magnesite in the presence of water and a CO<sub>2</sub> atmosphere regardless of temperature. The olivine dissolution occurs at a similar speed from 0 to 40 °C (shown overlain in **Figure 1**). However, the formation of magnesite is temperature-dependent, precipitating faster at higher temperatures. The column's top grid cells are completely dissolved in the pure olivine scenario; thus, a cell further down has been selected to show magnesite precipitation trends (**Figure 1**).

**Discussion:** Olivine is unstable at surface conditions on Earth as well as Mars [25]. Its presence on the Martian surface has been cited as evidence of low water availability after its deposition [26]. According to our model results, exposing olivine to abundant water at any temperature will cause it to start dissolving after 1,000 years of constant contact. The runs displayed here use a pure forsterite endmember. Fayalite is known to be ten times less stable than forsterite [26], and the carbonate in this unit is also not a pure Mg endmember, having some siderite component [27]. Thus, with the addition of each mineral's iron endmembers to our runs, we expect the olivine dissolution to start occurring earlier. Olivine is commonly associated with the carbonate [1], implying there is not total dissolution within the unit. The olivine's continued presence gives rise to two explanations assuming a surface weathering origin (1) the original layer was much thicker and what is present on the surface today is the remainder after dissolution of

the top of the column or (2) the water event which caused the alteration was quite short or sporadic.



**Figure 1.** The volume fraction of olivine and magnesite for runs of varying temperature 2.5 meters below the top of the column. Olivine fractions are denoted by the dashed lines (all are overlain), magnesite by the solid. Temperature variations are shown in different colors as in the legend.

The addition of other primary minerals will likely slow down olivine dissolution and stabilize the layer, allowing magnesite precipitation higher in the column. The runs with additional primary mineralogy should differentiate between the two above explanations based on the mineral distribution and observed layer morphology.

**Conclusions:** Based on our results, a pure forsterite endmember would begin dissolving after 1,000 years and be completely dissolved by 100,000 years (this assumes constant contact with water). Temperature mainly controls the magnesite precipitation but does not greatly affect olivine dissolution within this range. The top of the column is completely dissolved in most runs, which is expected to be mitigated with the inclusion of other primary mineralogy. We suggest the continued presence of olivine on the surface (under a surface alteration scenario) could be due to either (1) a thicker layer upon deposition which has since been partially dissolved, or (2) the water event which caused the alteration was very short or sporadic.

As the runs complete for the other variables, we will get a full picture of the resulting mineralogy from several surface alteration scenarios. These results can then be compared to the Perseverance rover measurements and data upon landing and contact with the olivine-carbonate unit within Jezero crater.

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