Synthesizing Mars: Advancements in Simulant Lithology for Astrobiological and ISRU Studies

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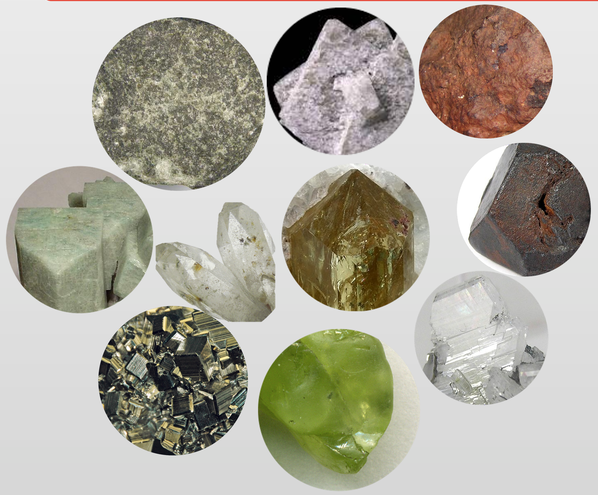
Abstract - Introduction

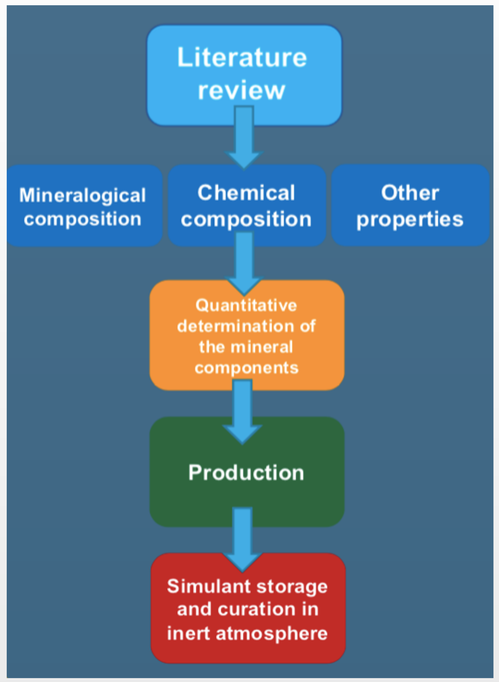
- **Mars is a planet with complex geology due to extensive past volcanism and water activity across its surface, resulting in the development of many different and unique surface lithologies and other structures.**
- **Simulant materials are being utilised to better understand and explore Mars, contributing to planetary evolution and habitability & astrobiological investigations, as well as, various aspects of ISRU research.**
- **Such materials need to boost both high resemblance to the composition (i.e. chemical, mineralogical), as well as, lithological to the Martian surface.**
- **Thus, our team is developing a series of Martian simulants aimed at enhancing fidelity to martian surface conditions and expanding available lithologies and compositions.**
- **The production of the simulants is done after a comprehensive analysis of martian surface datasets, including mineralogy and chemical composition, to inform simulant development, while verification of simulant accuracy is achieved through XRD, SEM-EDS, and LIBS analysis.**
- **Utilization of a Figure of Merit (FoM) system allow for standardized compositional comparison, achieving simulants exceeding 90% FoM.**

Materials



- **Collection of igneous rock samples, pure mineral phases and other required materials such as Basalt, Feldspars and other primary or secondary minerals.**
- **Quantitative calculation of required materials.**
- **Preparation of the materials.**

Methodology

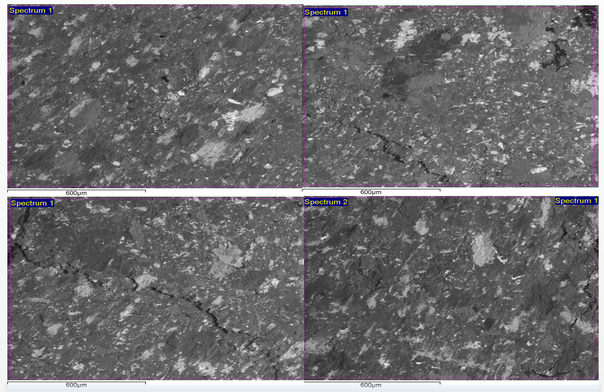


Production

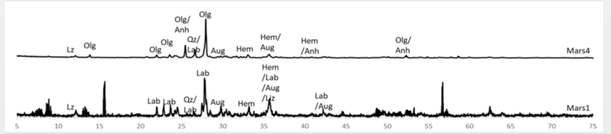
Steps

1. **Weighting**
2. **Mixing**
3. **Homogenisation/Grinding**
4. **Drying**
5. **Packing in inert atmosphere**

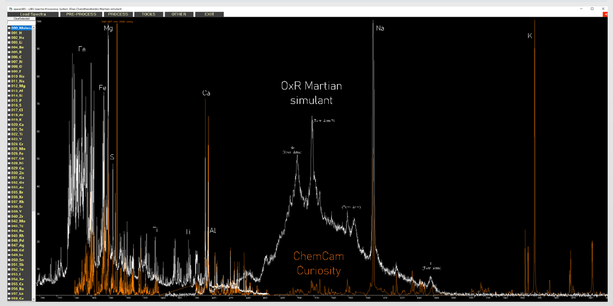
Analysis & Results

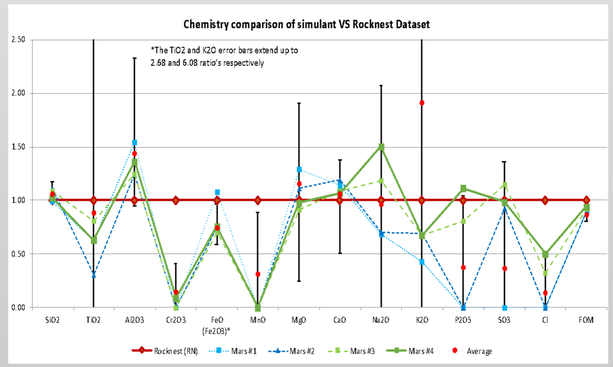


The above SEM images are of Mars Sulf #1 soil simulant. Respective grain size distribution was derived from those images. A grain size distribution analysis for the Mars Sulf #1 soil simulant suggest that the largest grains present of the order of 250µm, while the majority is smaller than 150µm.



XRD diagrams of the initial and final batch simulants, and the used basaltic core component are presented. Major mineralogical phases have been identified, as well as the complexity introduced in latter batches with the identification of further phases (e.g. Anhydrite). Thus, based in surface data the mineralogical accuracy is high.





Analysis & Results

Simulant Composition

- **As seen on the previous bottom chart Martian simulants developed had initially lower but aligned with literature fidelity, which was improved on further batches.**
- **Mars#4 exhibits the most consistent chemistry and FOM amongst Rocknest based simulants. See table below for the complete composition of each Martian simulant of each batch.**

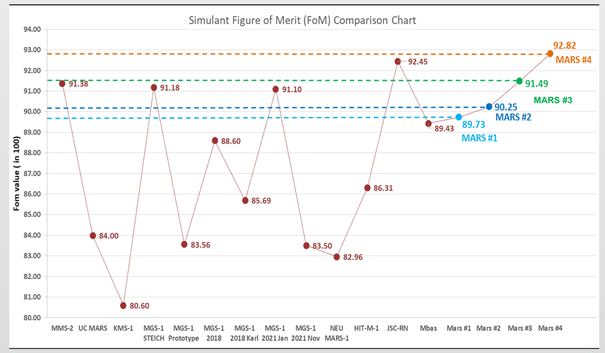
Element	Mars #1	Mars #2	Mars #3	Mars #4	Rocknest (RN)	Gobabeb (GB)	Mars Sulf #1	MER Opportunity
SiO_2	42.49	47.62	47.03	44.20	42.94	47.71	38.24	41.05
TiO_2	0.74	0.38	0.96	0.72	1.18	0.74	0.51	0.84
Al_2O_3	14.54	11.69	11.75	12.99	9.38	10.00	9.73	7.59
Cr_2O_3	0.00	0.00	0.00	0.07	0.48	0.33	0.58	0.00
FeO	20.61	14.43	13.47	14.23	19.08	17.70	15.71	18.87
MnO	0.00	0.00	0.00	0.00	0.42	0.31	0.00	0.31
MgO	11.30	10.32	8.00	8.41	8.76	8.41	8.69	7.45
CaO	8.28	8.43	7.88	7.68	7.24	7.77	5.48	5.44
Na_2O	1.84	2.05	3.20	4.13	2.69	2.56	3.08	1.57
K_2O	0.21	0.30	0.33	0.33	0.48	0.41	1.38	0.55
P_2O_5	0.00	0.00	0.76	0.96	0.94	0.67	0.40	1.00
SO_3	0.00	4.78	6.28	5.33	5.40	2.96	16.20	14.75
Cl	0.00	0.00	0.34	0.56	1.03	0.42	0.00	0.59
SUM	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
FOM	89.73	90.25	91.49	92.82	Rocknest (RN)		92.21	MER Opportunity
	89.16	93.91	93.87	92.24	Gobabeb (GB)			

FOM System – Quality assessment

The methodology used for fidelity estimation was based on the Figure of Merit (FOM) provided by (Schrader et al., 2009).

The Figure of Merit (FOM) system for comparisons is based on the sum of the minimum value between two analytical datasets.

Optimisation steps allowed the increase of FOM for each new simulant production batch, leading to finally achieving one of the highest FOM compared to simulants in the literature.



Conclusion - Current Applications & Future goals

- **Our team has achieved developing an array of simulants with high resemblance and fidelity to the Martian surface, including lithological variability.**
- **The current inventory of produced simulants include also a total of 5 Lunar Simulants, Lunar Dust simulants.**
- **Furthermore, a clay Martian simulant is under final analysis.**
- **A number of the currently produced quantities are been utilised for sensor system development, astrobiological investigations, and ISRU research.**
- **Future goals include the expansion of the array of simulated lithologies based on rover data, the enhancement of mineralogical variety and fidelity, as well as increasing the produced quantities.**

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