What are the most important measurements, analyses, and modeling to better understand early Mars?

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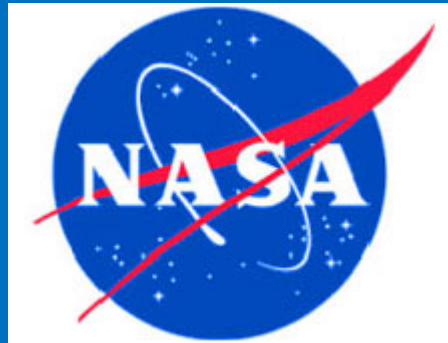
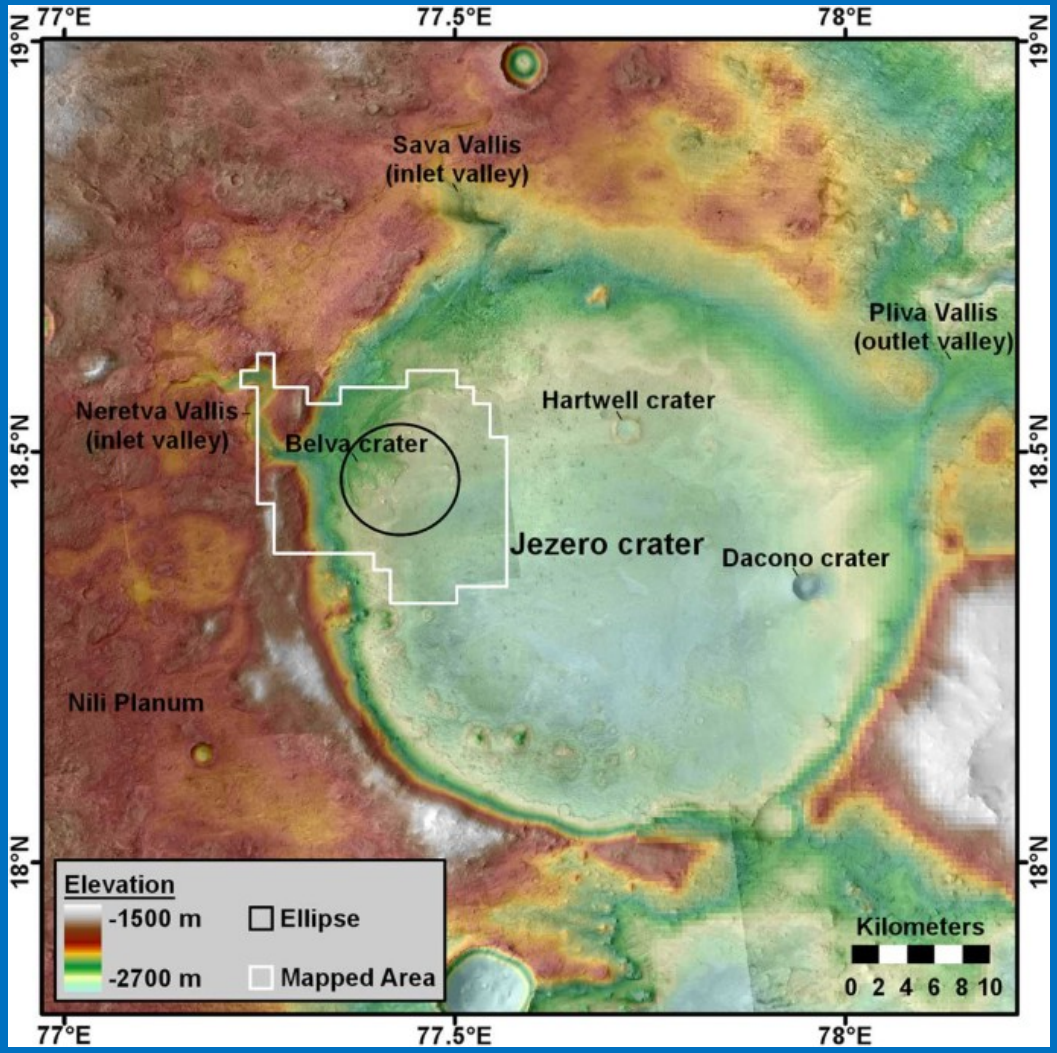
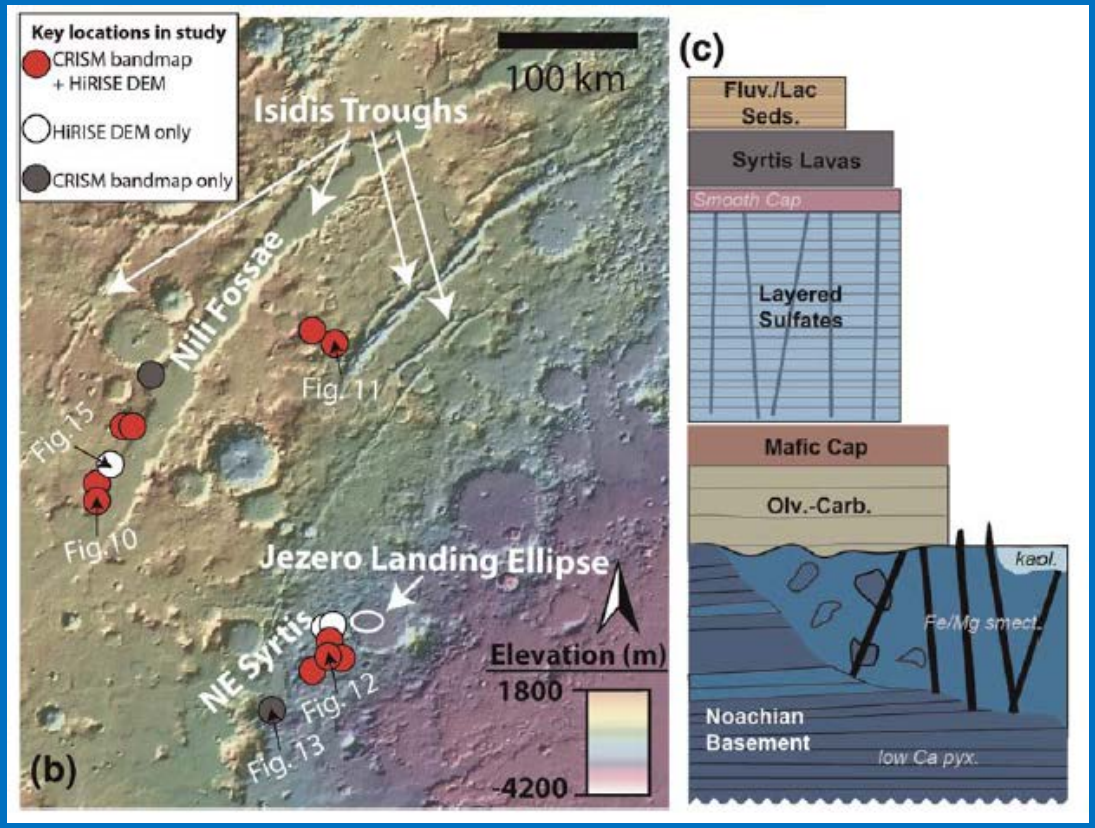


Secondary minerals on Mars can transform our understanding of Mars



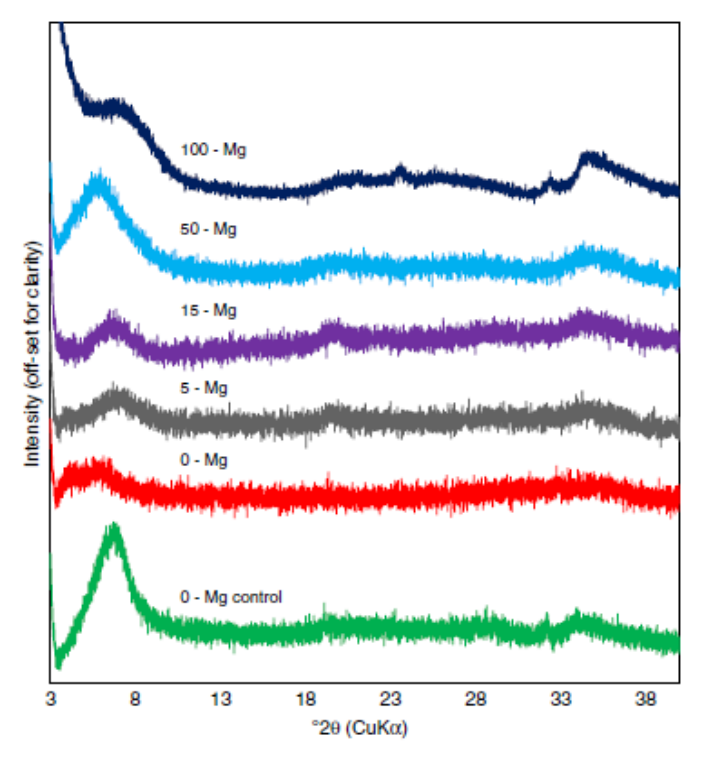
Stack et al. 2020

Clay minerals in Jezero crater and Nili Planum



Scheller and Ehlmann (2020)

These clay minerals carry within them a history of their formation



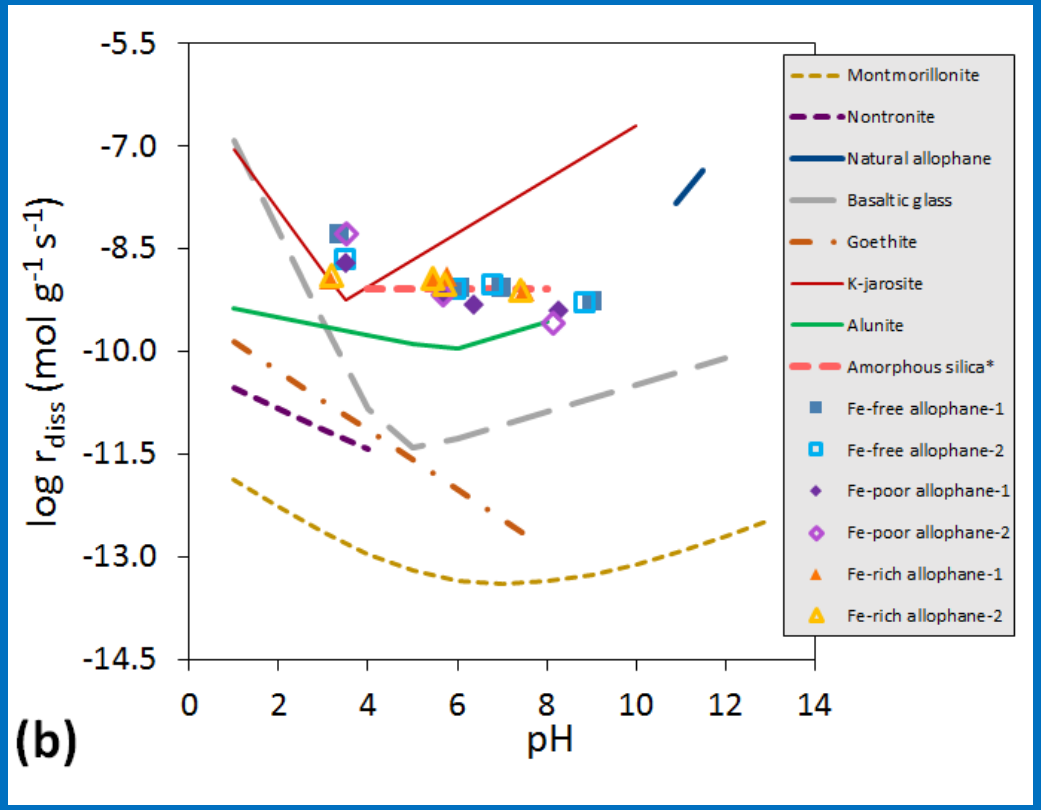
Sample	Site	Weight	δ (Isomer Shift)	Δ (Quadrupole Splitting)	χ^2	Source
*Nontronite NAu-1	Fe^{3+}	0.61	0.35	0.24	2.10	This study
	Fe^{3+}	0.39	0.60	0.68		
*Experiment 1 (100-Fe Control - Subsequently Oxidized)	Fe^{3+}	0.60	0.81	1.09	5.57	This study
	Fe^{3+}	0.40	0.67	0.46		
*Experiment 4 (15-Mg 85-Fe^{3+})	Fe^{3+}	0.60	0.45	0.24	4.63	This study
	Fe^{3+}	0.40	0.64	0.68		
*Experiment 5 (50-Mg 50-Fe3+)	Fe^{3+}	0.54	0.33	0.24	2.35	This study
	Fe^{3+}	0.46	0.58	0.68		

Gainey et al., 2017

X-ray amorphous material at Gale crater

NASA/JPL-Caltech

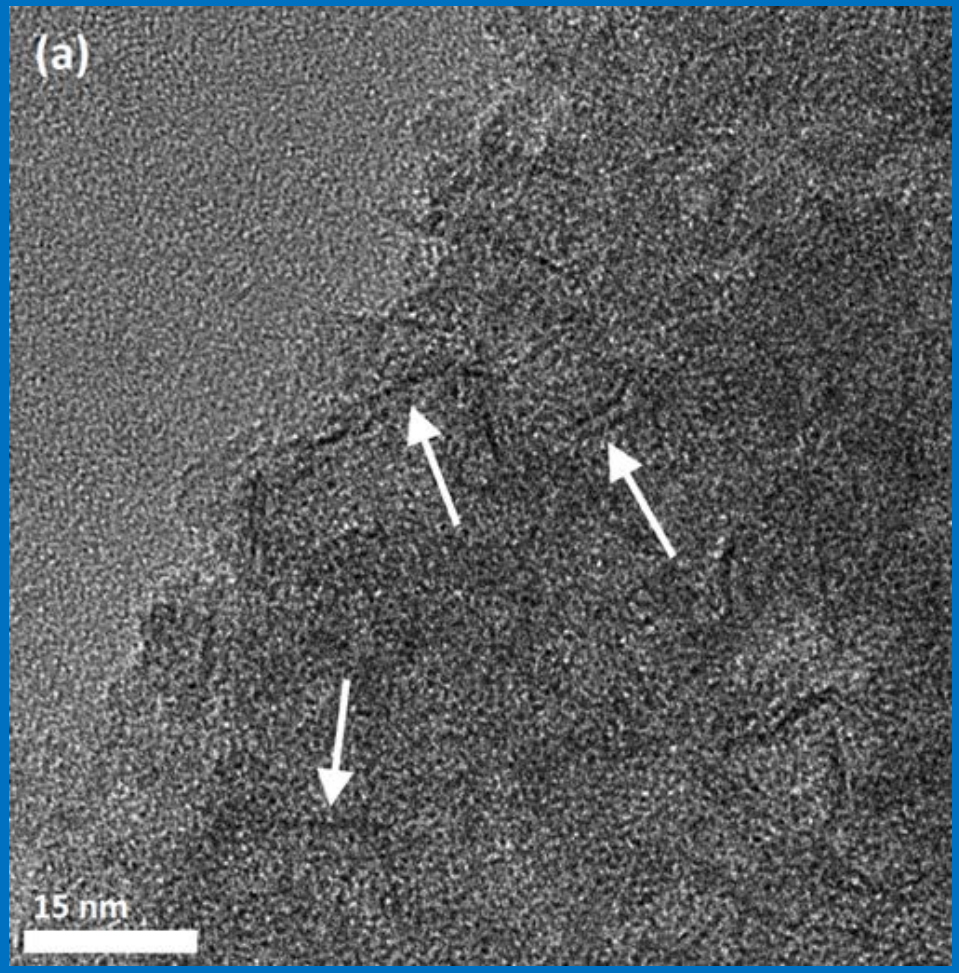
Contain history of alteration since formation



Ralston et al., in revision

Contain history of alteration since formation

- Fe-rich allophane
- pH ~8
- 57 days

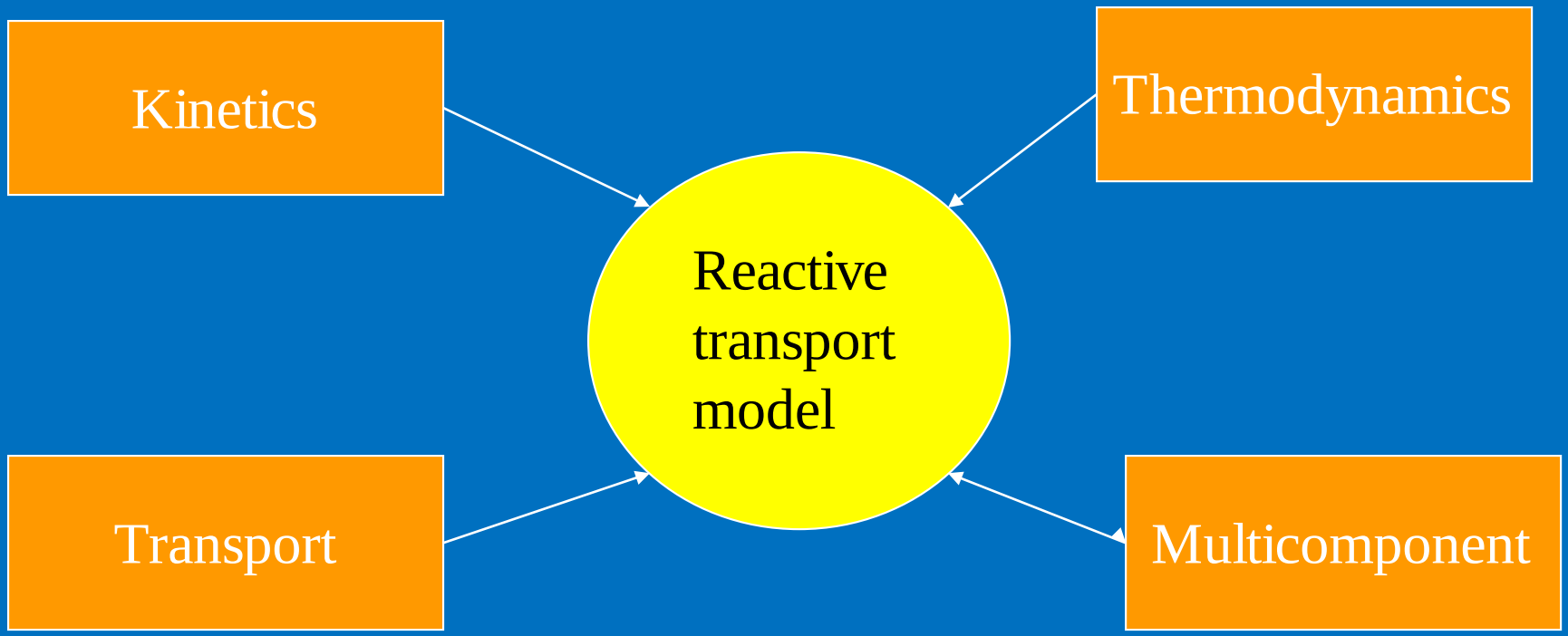


Ralston et al., in revision

These signatures can be examined in returned samples

Synthesis experiments to interpret these results

Modeling allows a quantitative analysis of field conditions



Modeling can address many questions about past aqueous conditions

- What was the pH and composition of the solutions?
- How long did they persist?
- How many different solutions were present?

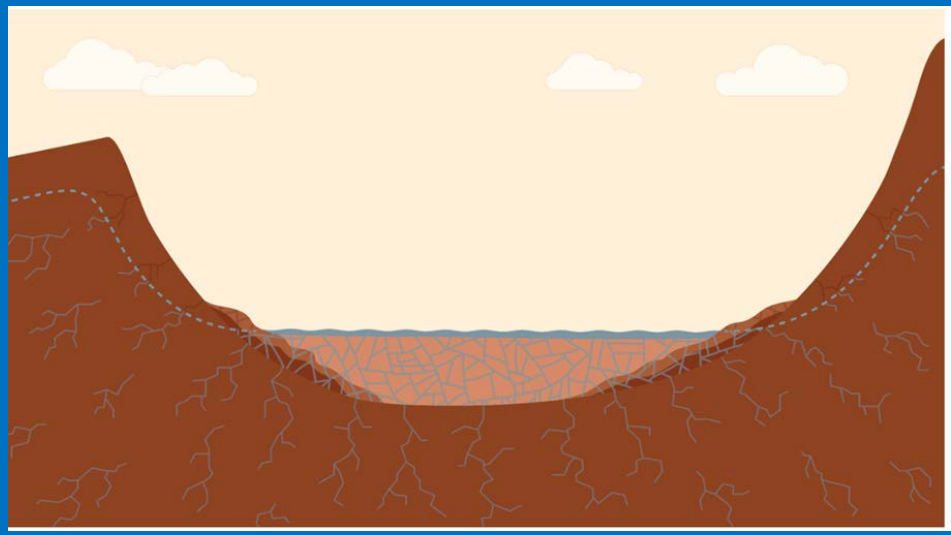


Image Credit: NASA/JPL-Caltech

Formation of bulk Stimson unit and fractured zones

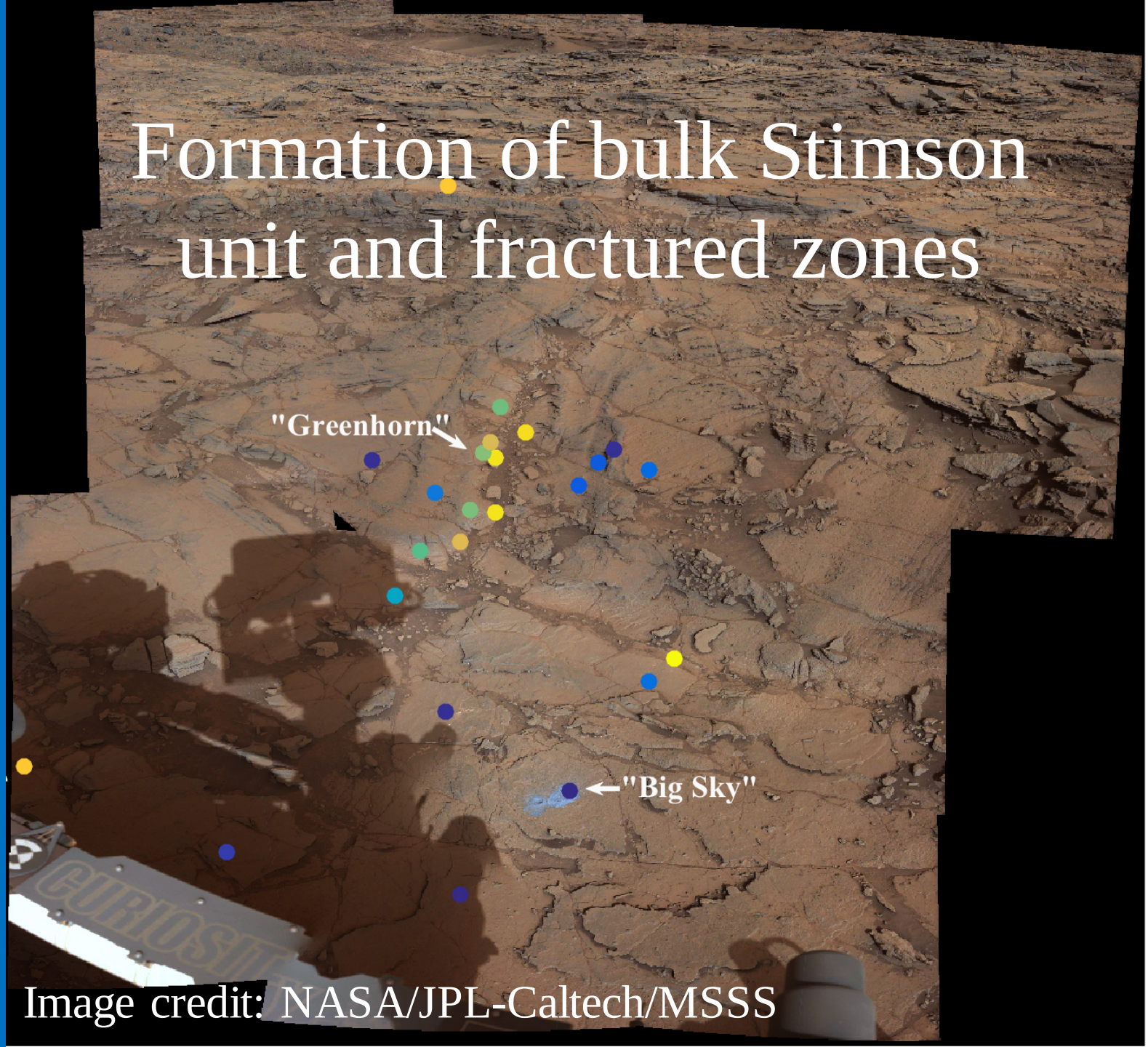
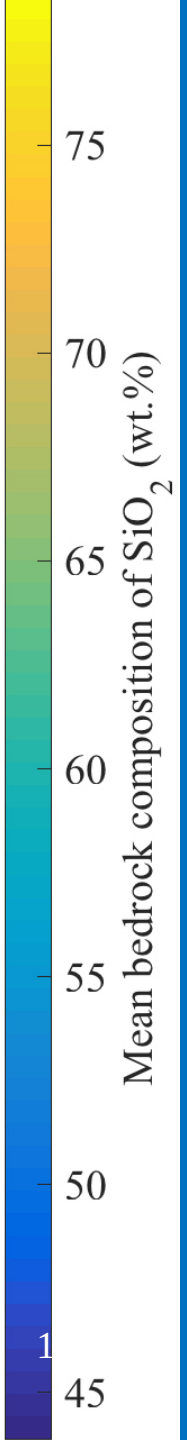
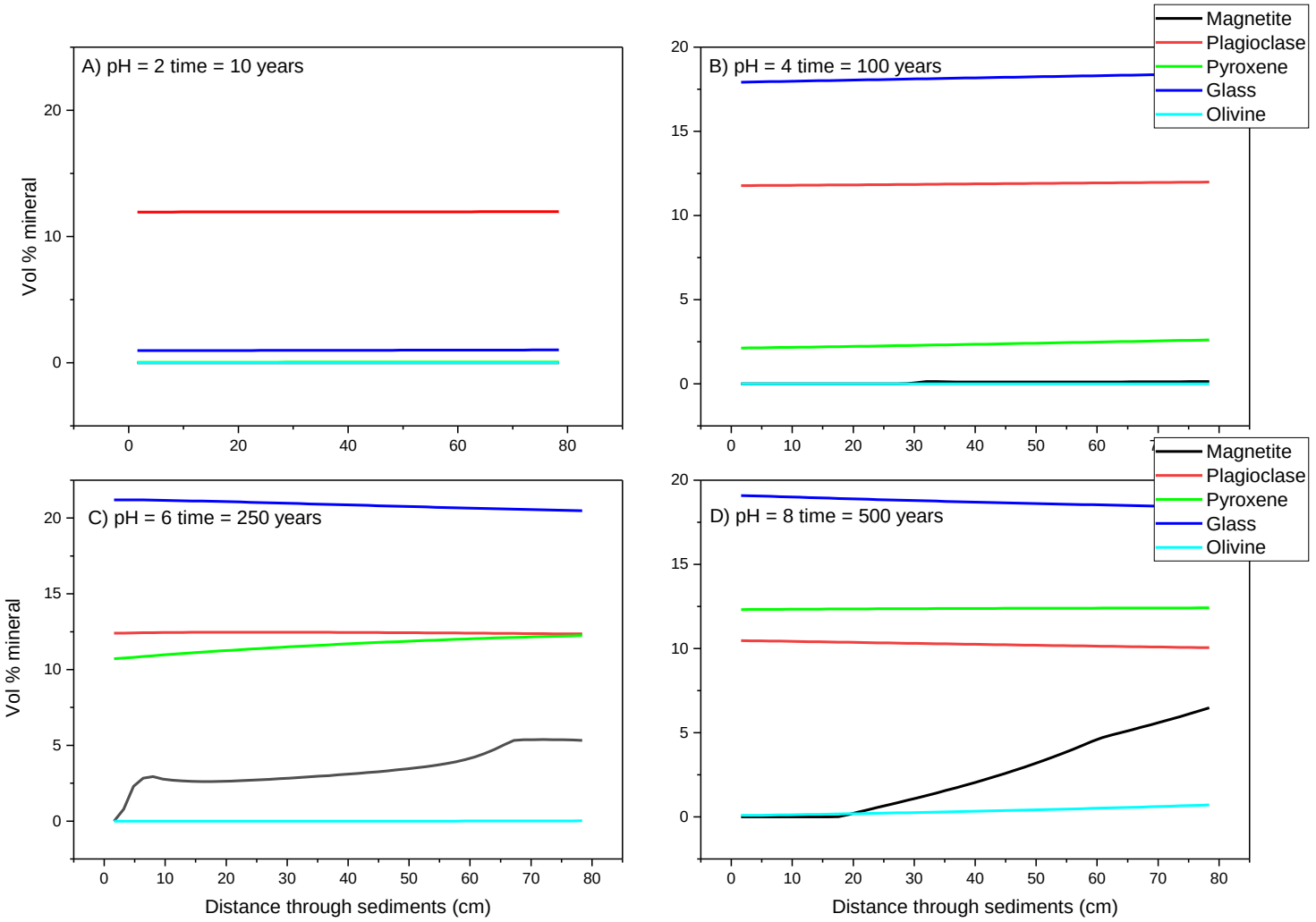


Image credit: NASA/JPL-Caltech/MSSS

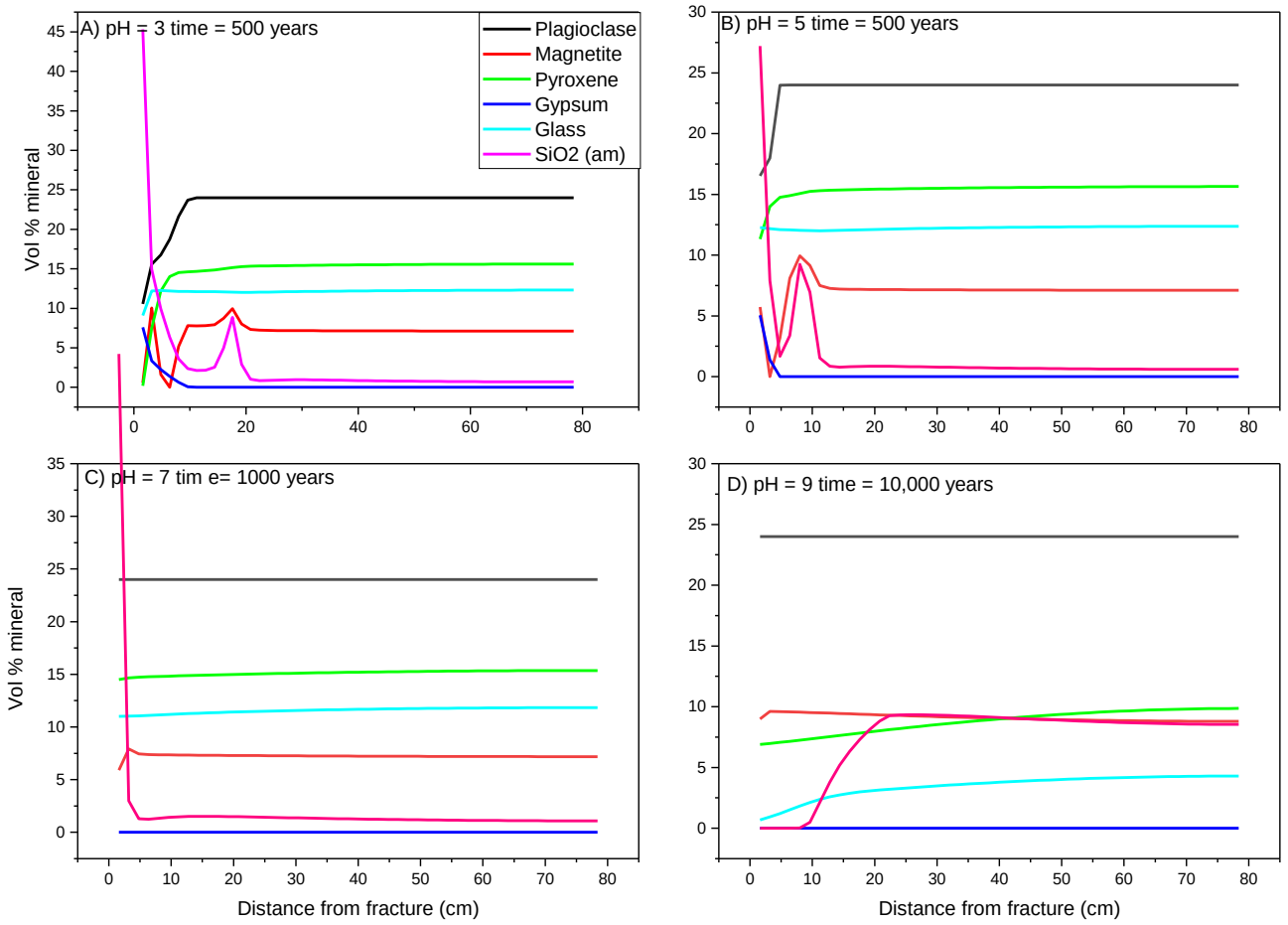


Formation of Big Sky from Bagnold



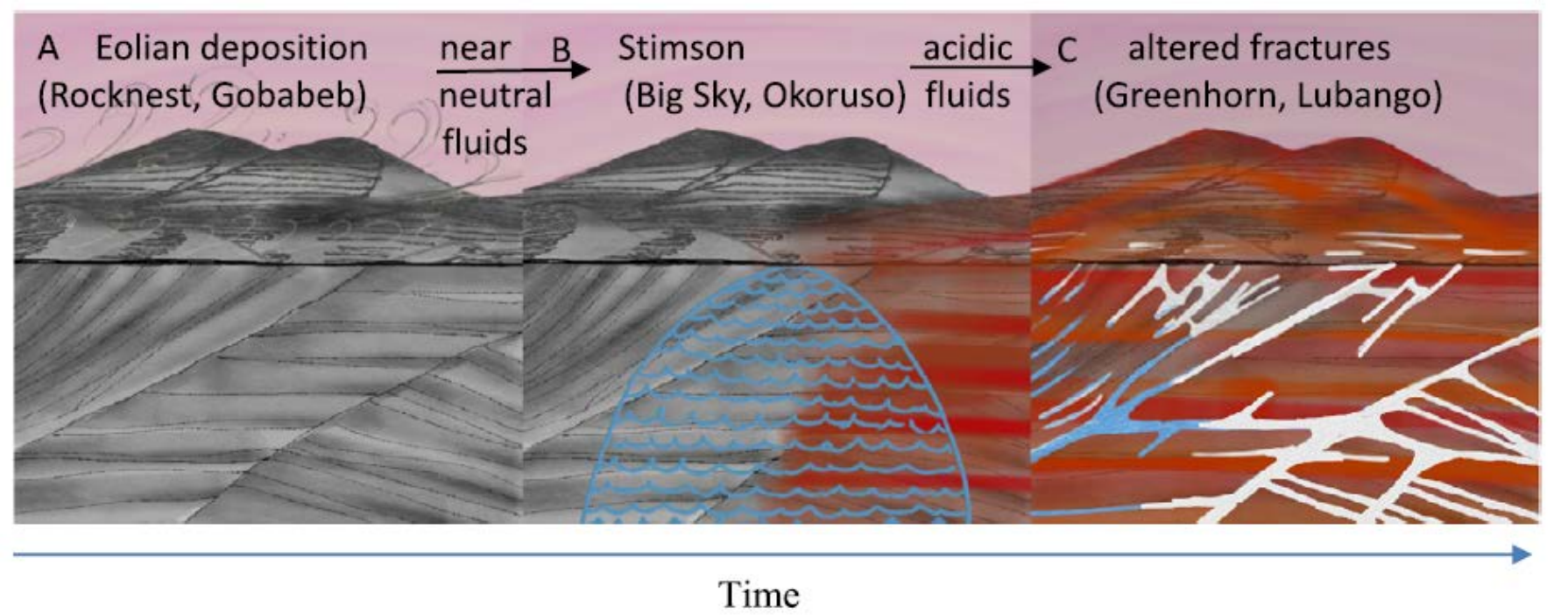
Hausrath et al, 2018

Formation of Greenhorn from Big Sky parent material



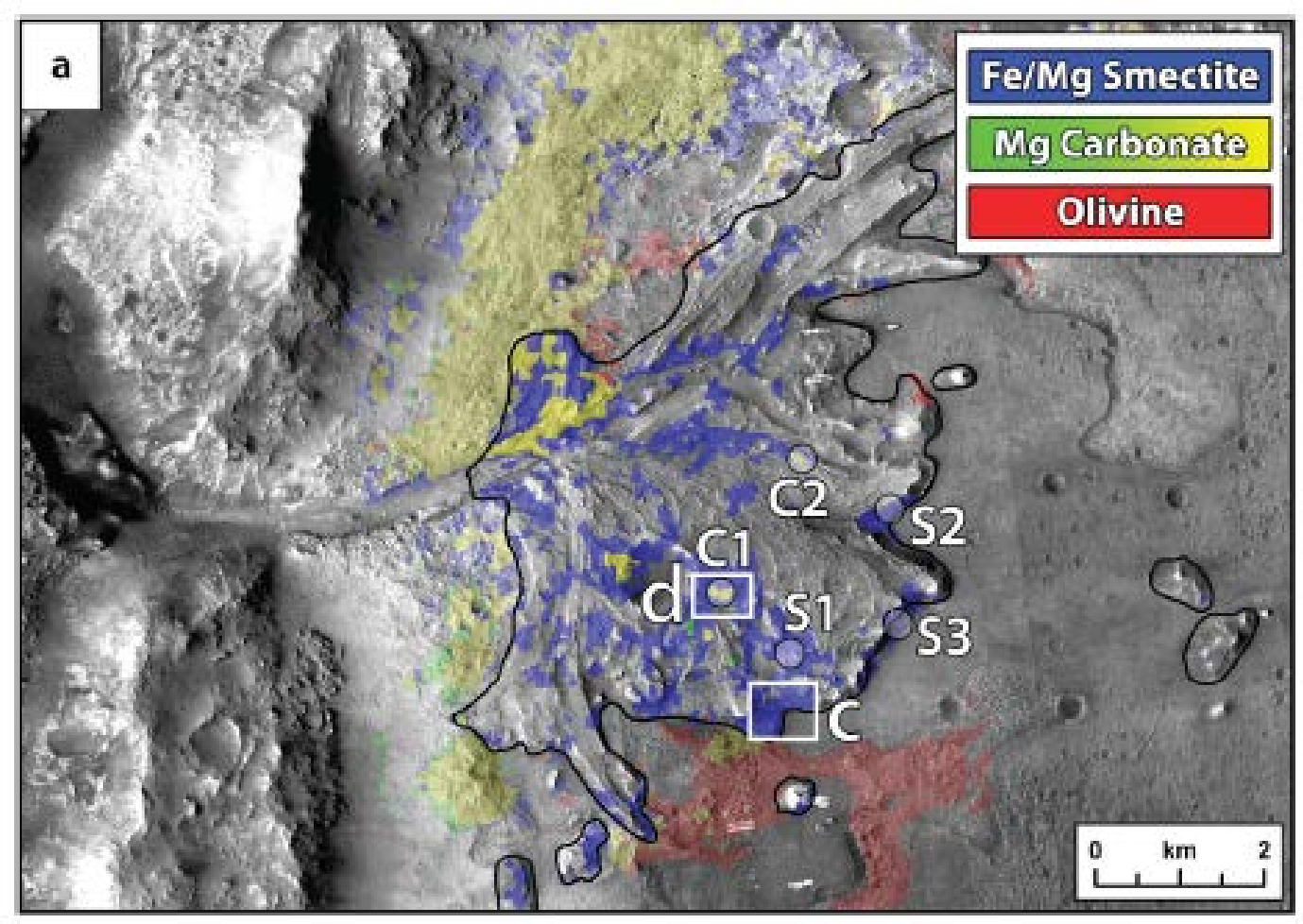
Hausrath et al, 2018

Long term water in Gale crater



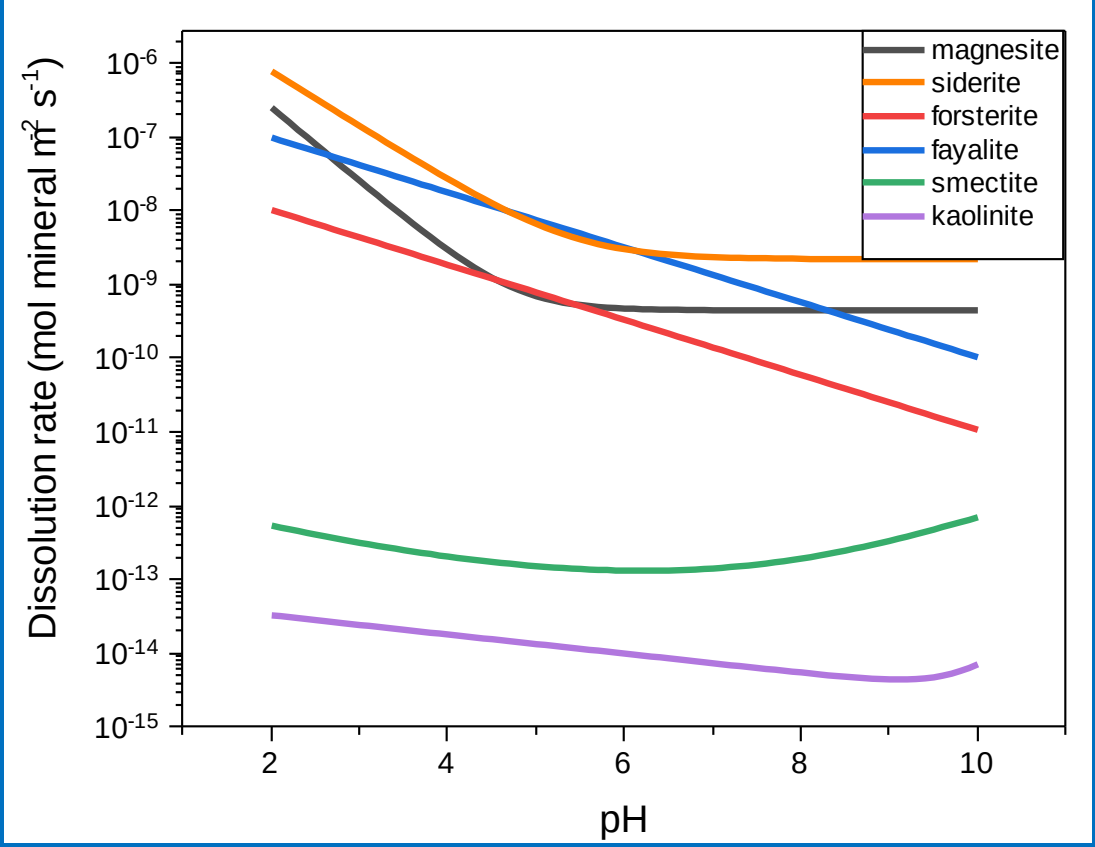
Hausrath et al. 2018

Carbonates in Jezero crater



Goudge et al. (2017)

Laboratory dissolution rate laws to support modeling



Hausrath (2019): dissolution rate laws from Saldi et al. (2009);Duckworth and Martin (2004);Bandstra and Brantley (2008); Gainey et al. (submitted); Palandri and Kharaka (2004); and Wogelius and Walther (1992)

Laboratory precipitation rates

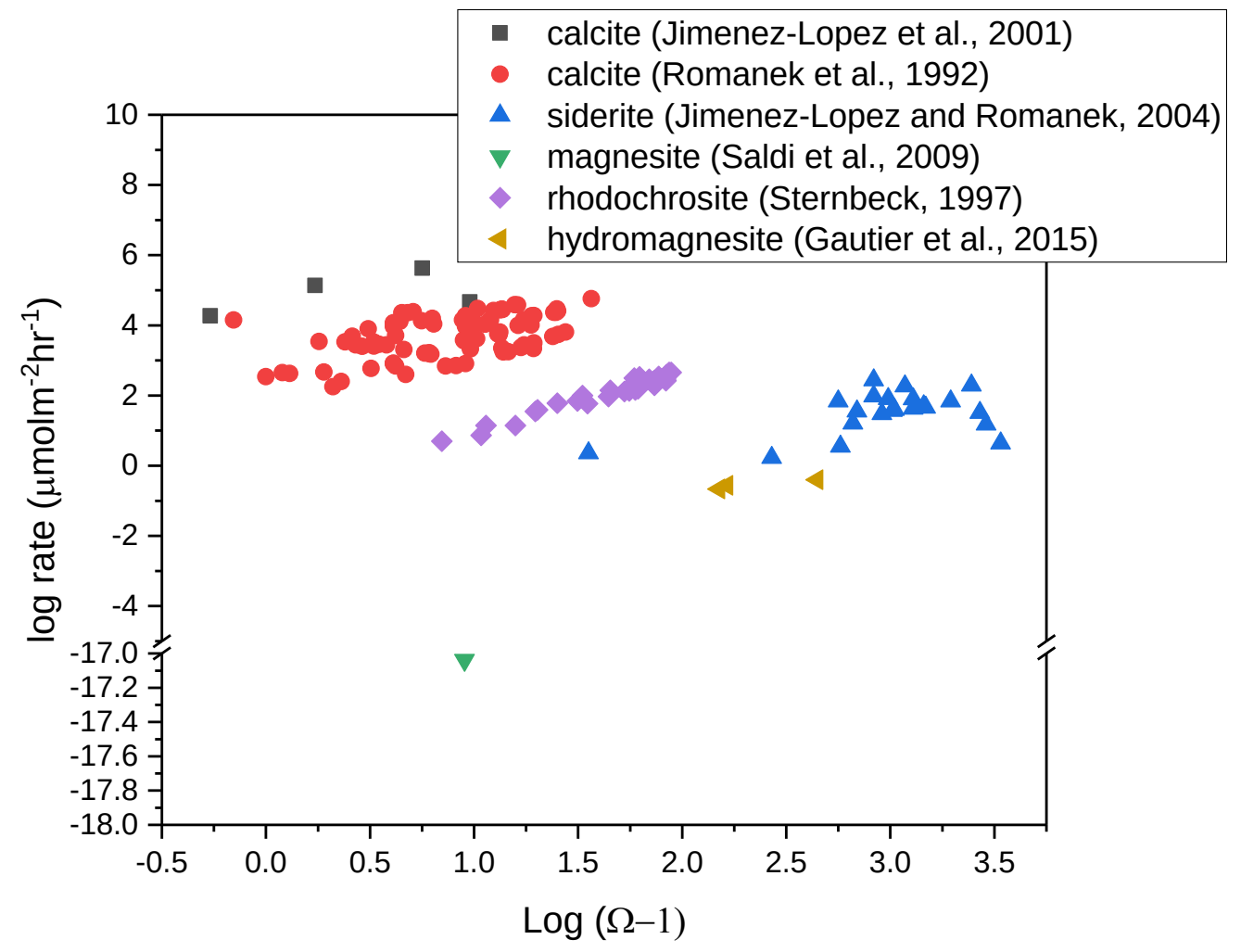


Figure after Hausrath and Albright Olsen (2013)

Conclusions:

- Fine scale analyses of returned samples (e.g. synchrotron, TEM) particularly of secondary phases will transform our understanding of Mars
- Synthesis experiments to interpret these measurements
- Numerical modeling to quantitatively interpret observations from Mars
- Dissolution and precipitation experiment to enable such modeling