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Igneous lithologies at the Mars 2020 landing sites: Prospects for achieving MSR science goals

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Igneous Rocks and Mars 2020

Message #1

Igneous lithologies are likely to be present in some form at any of the candidate landing sites

Message #2

Careful selection of igneous samples will contribute significantly to addressing MSR objectives

iMOST Objectives

Objective #	Statement of Objective

Pre-Decisional - For planning and discussion purposes only

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Objective 1		Interpret the **primary geologic processes and history that formed the martian geologic record**, with an emphasis on the **role of water**.
	Sub-Obj. 1.1	Sedimentary System
	Sub-Obj. 1.2	Hydrothermal
	Sub-Obj. 1.3	Deep subsurface groundwater
	Sub-Obj. 1.4	Subaerial
	Sub-Obj. 1.5	Igneous terrane
Objective 2		Assess and interpret the **potential biological history of Mars**, including assaying returned samples for the evidence of life.
	Sub-Obj. 2.1	Carbon chemistry
	Sub-Obj. 2.2	Biosignatures-ancient
	Sub-Obj. 2.3	Biosignatures-modern
Objective 3		Determine the **evolutionary timeline of Mars**.
Objective 4		Constrain the **inventory of martian volatiles as a function of geologic time** and determine the ways in which these volatiles have interacted with Mars as a geologic system.
Objective 5		Reconstruct the **history of Mars as a planet**, elucidating those processes that have affected the **origin and modification of the crust, mantle and core**.
Objective 6		Understand and quantify the potential **martian environmental hazards to future human exploration** and the terrestrial biosphere.
Objective 7		Evaluate the **type and distribution of *in situ* resources** to support potential future Mars Exploration.

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Why igneous rocks? (*after iMOST*)

- Igneous rocks record the thermochemical evolution of a planet, and each rock type provides insights into the complexity of that history.

- Mars is a primarily basaltic planet; basaltic rocks are a direct window into the planetary interior.

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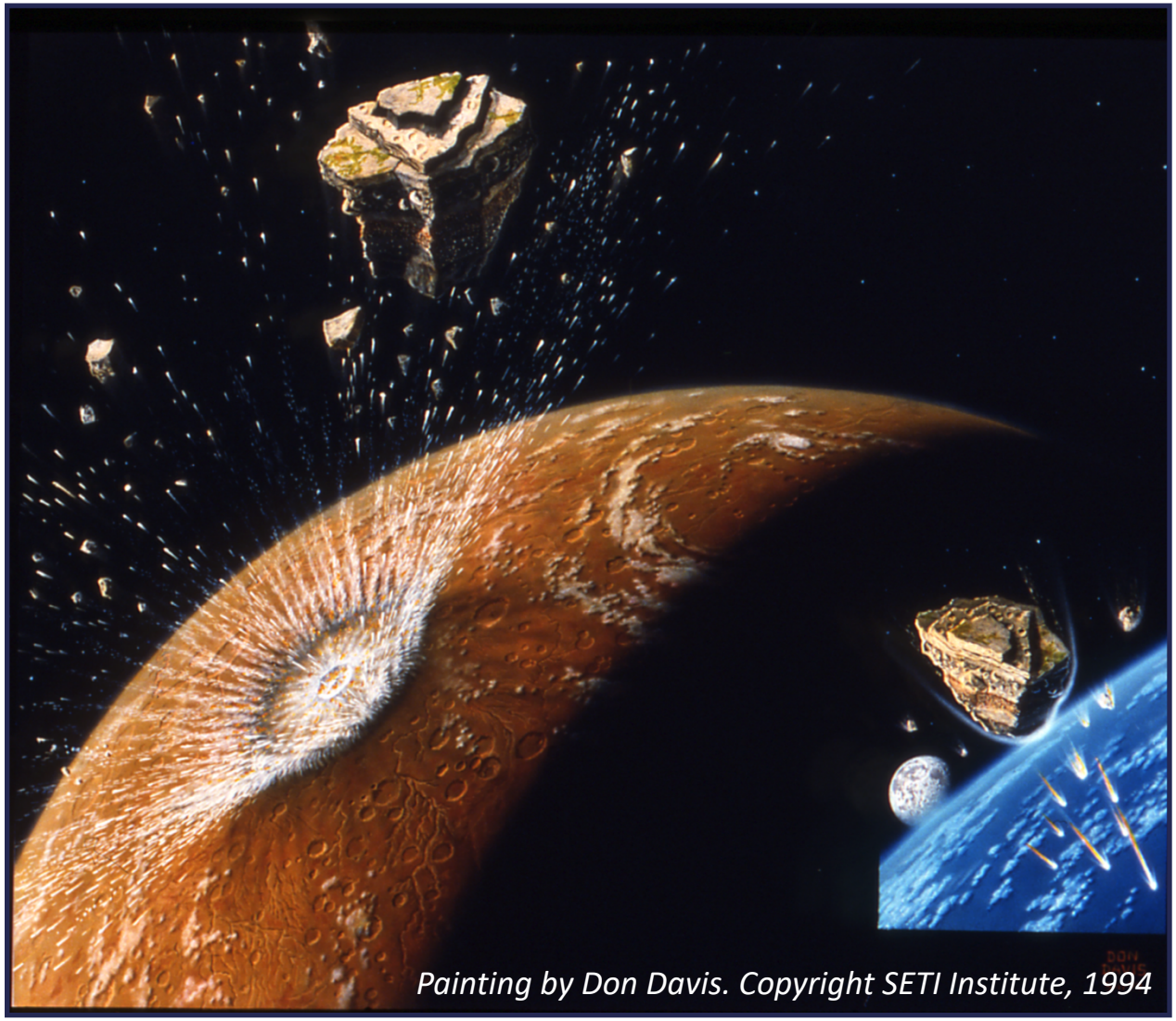
Why Returned Sample Studies are Important (*after iMOST*)



- Meteorites (~110) represent biased delivery of young igneous rocks from unknown locations/source units:
  - ***Amazonian*** (with one exception)
  - ***Shock metamorphosed*** (variably)
  - ***Not representative of crust*** (with one exception)

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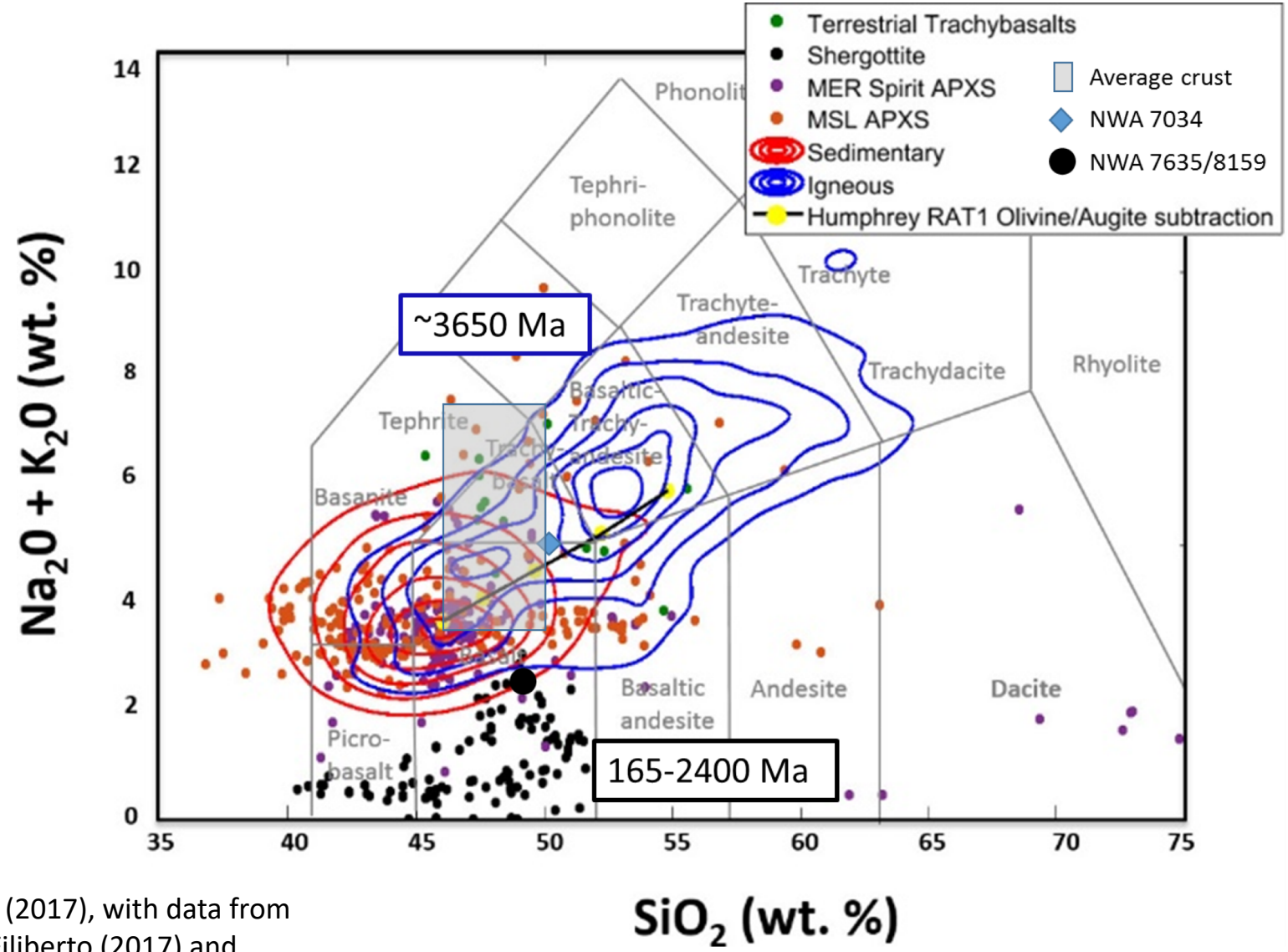
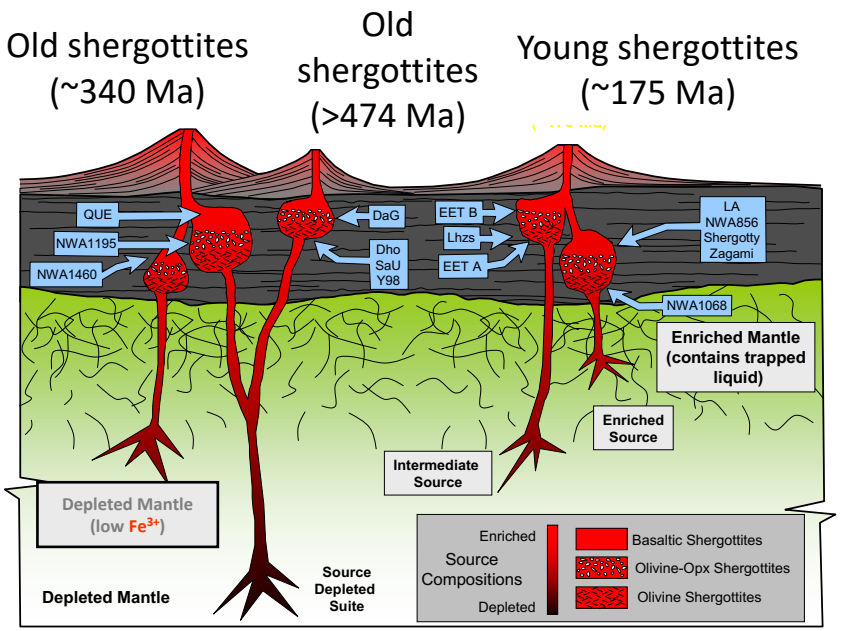
Meteorites vs. Igneous rocks of Mars (*after iMOST*)



After Edwards et al. (2017), with data from Agee et al. (2013), Filiberto (2017) and Herd et al. (2017)

Critical Open Questions (*after iMOST*)

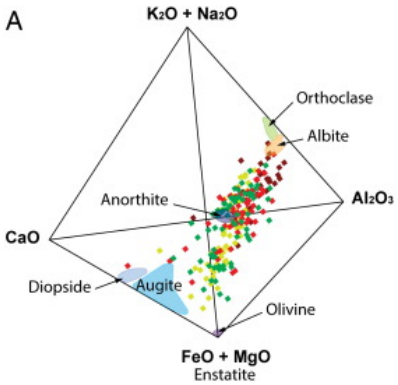
Is the mantle of Mars as viewed from the shergottite meteorites applicable to all of Mars?

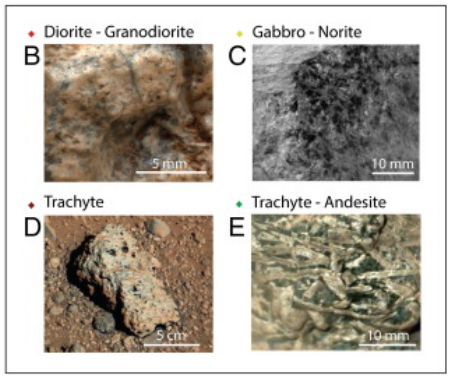


After Symes et al., 2008

What is the diversity of igneous rock compositions? Have they changed over time?

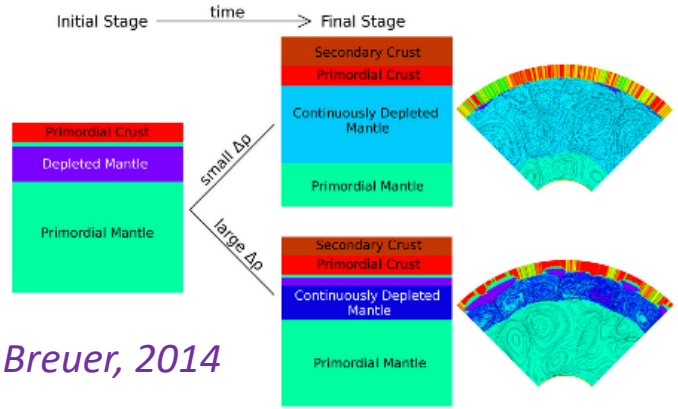
Sautter et al., 2016





the 4 main types of igneous rocks found around Bradbury landing site (Gale Crater)

What did the mantle of Mars look like > 3.5 Ga? Was metasomatism involved?



What is the nature of the original crust of Mars?

Plesa and Breuer, 2014

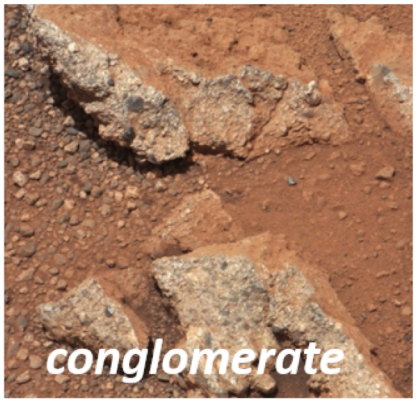
Where to expect igneous lithologies (*after iMOST*)

Any igneous lithology:
- Insights into magma genesis, properties, mantle source, timing/during, etc.

***In situ* (outcrop)**

***In situ* advantage**: all of the above, plus absolute age of emplacement

***Ex situ* (transported)**



***Ex situ* advantage**: all of the above, plus diversity

Ex situ Upper left: Low Ridge, Gusev (NASA/JPL-Caltech/Cornell/NMMNH)
Upper right: Gale Crater (NASA/JPL-Caltech/MSSS); All others public domain

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Provenance studies

Igneous emplacement

Host rocks/ nutrient sources

Interior/abiotic carbon

Host rocks/ nutrient sources

Interior volatiles

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Igneous lithologies are likely to be present in some form at any of the candidate landing sites

- Relative merit of *in situ* vs. *ex situ*
- Surface Operations

Message #2

Careful selection of igneous samples will contribute significantly to addressing MSR objectives

- A returnable cache should include igneous samples