

Investigation of Magmatic Activities on Early Mars Using Igneous Mineral Chemistry in Gale Crater, Mars

Looking for
a postdoc! :)

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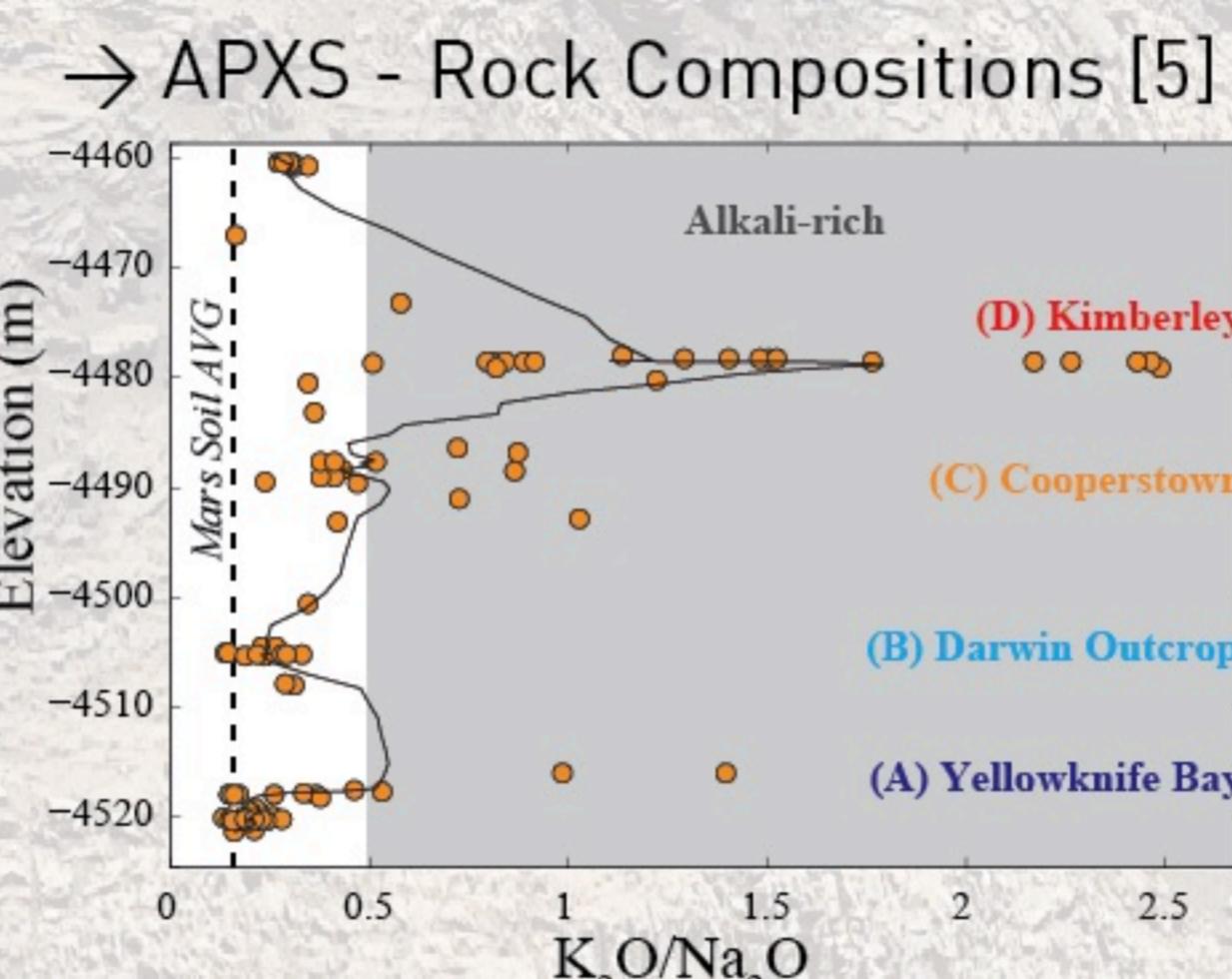
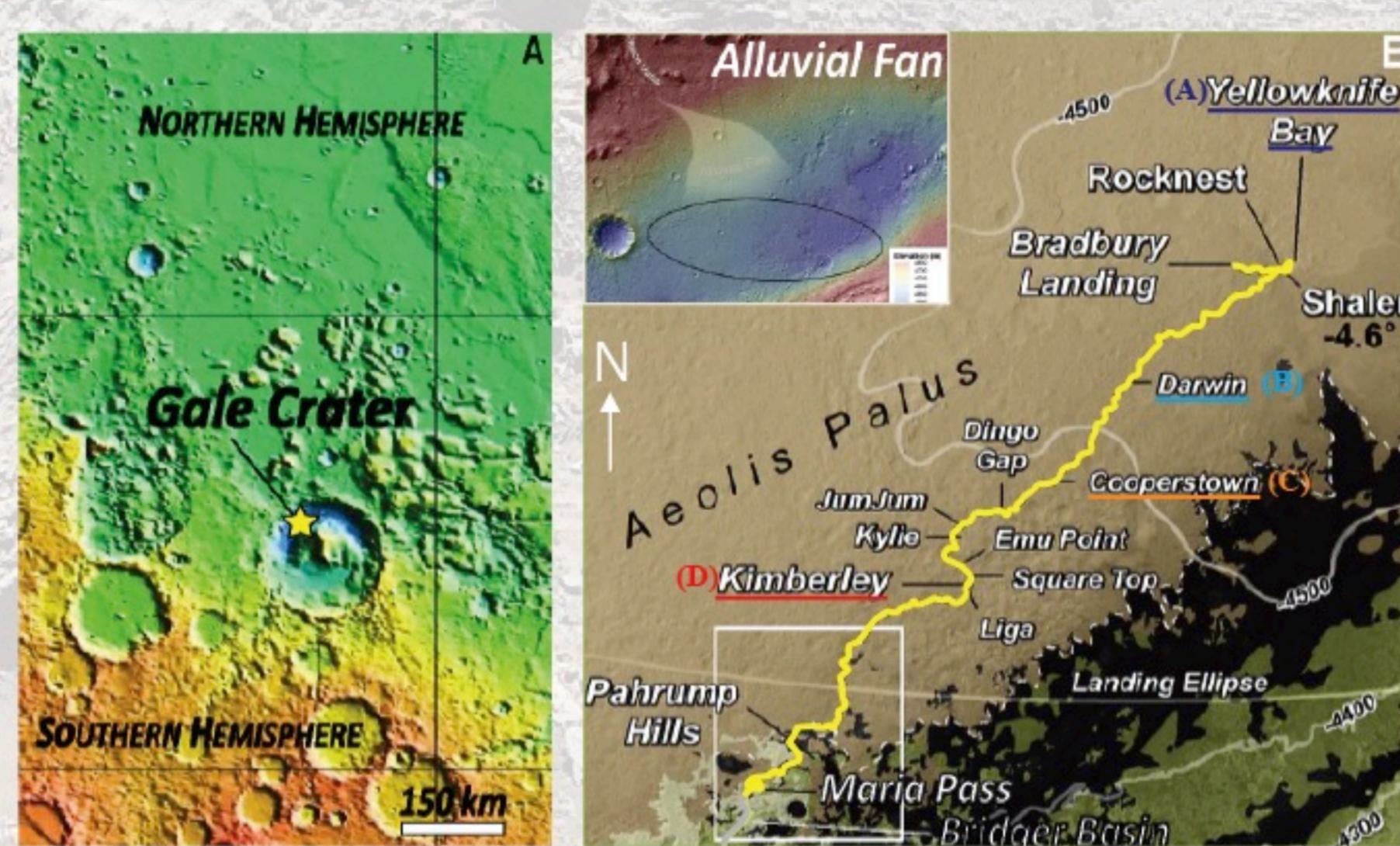
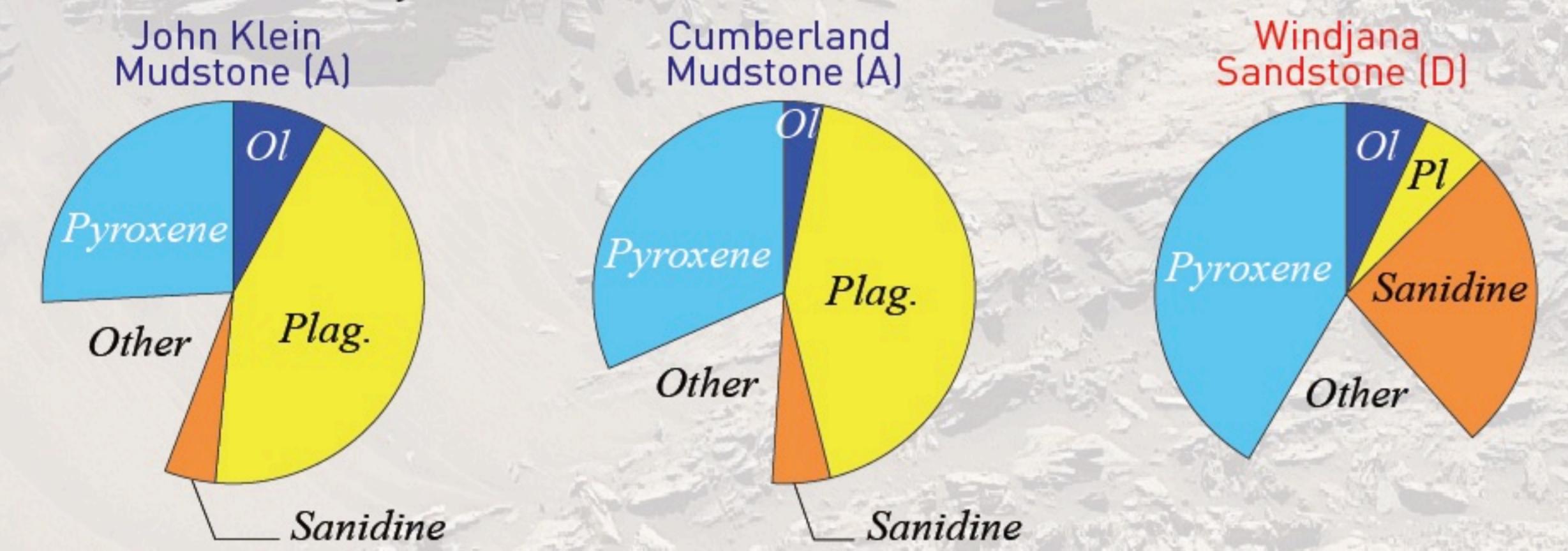
Gale Crater: a Sedimentary World

- ~3.5 Gyr impact crater
- Mainly sandstones and mudstones

Sedimentary Rocks

Bradbury group: rocks from the landing site to further Kimberley. Coherent sedimentary package with **sedimentary materials originated from one single provenance** (NW rim) [1]. Based on the mineral assemblage and chemical compositions, Bradbury sedimentary rocks come from at least 2 protoliths: one mafic (basalt), and one K-rich (trachytic) [2-5].

→ CheMin X-Ray Diffraction [2-4]



Sedimentary rocks contain **detrital igneous minerals** [2-4]. They are **poorly weathered** [5].

Igneous Rock

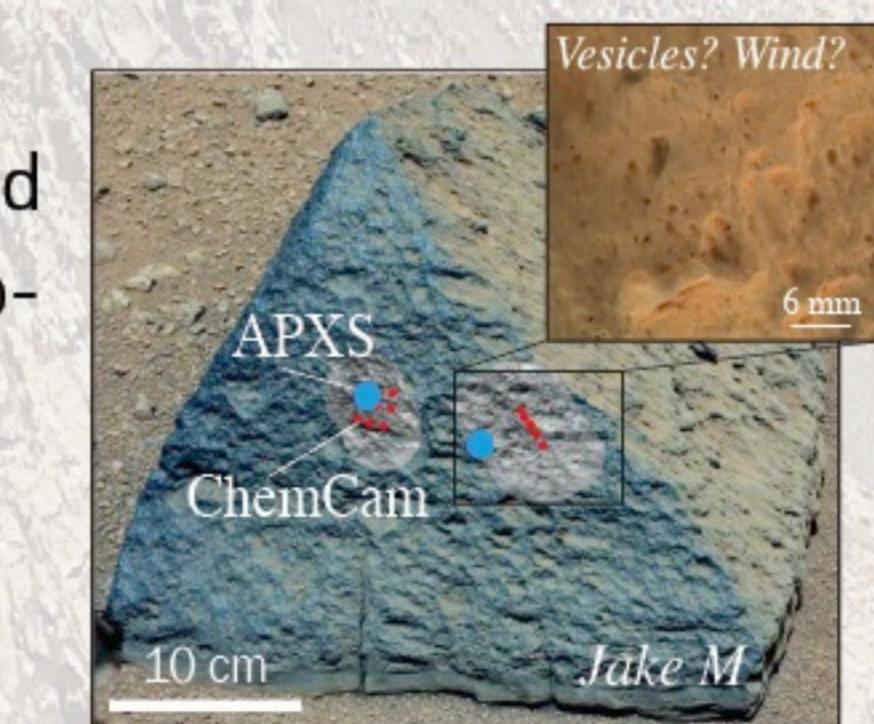
Various felsic igneous rocks analyzed by ChemCam instrument [6-7].

Igneous or sedimentary nature of a rock difficult to assess from rover observations, and bulk composition of heterogeneous rocks cannot be obtained: exploration of magmatic evolution from mineral chemistry of rocks using CheMin and ChemCam analyses [8].

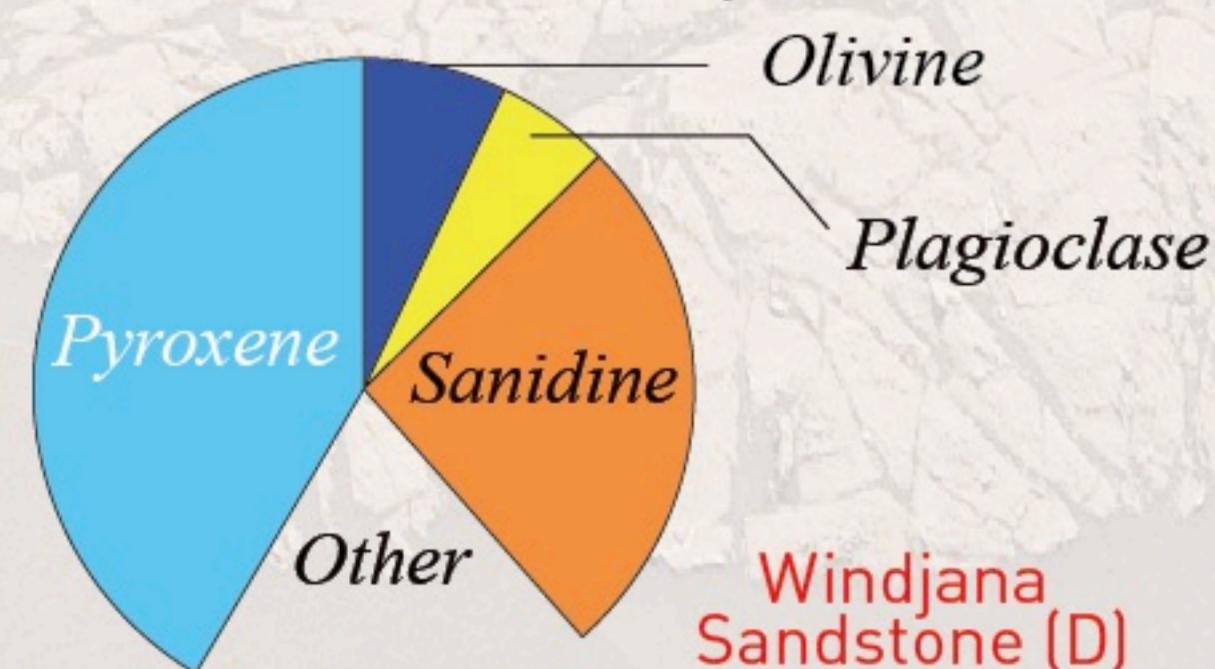
→ Are detrital igneous minerals from Bradbury coming from a similar igneous source?

→ What magmatic processes could have formed them?

Similar approach to what have been done for Gale float igneous rocks [9].



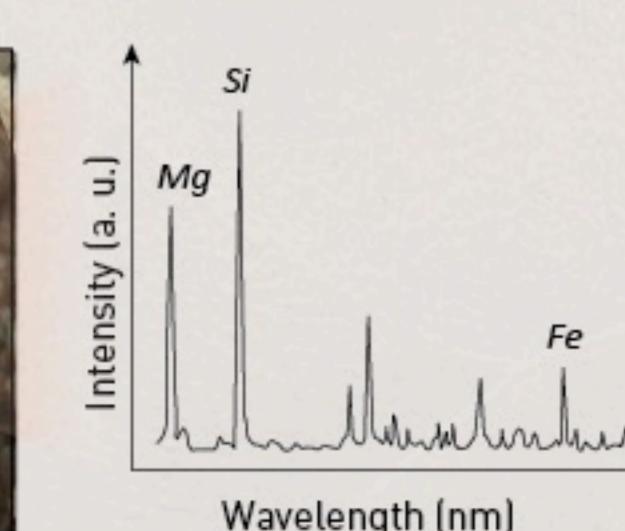
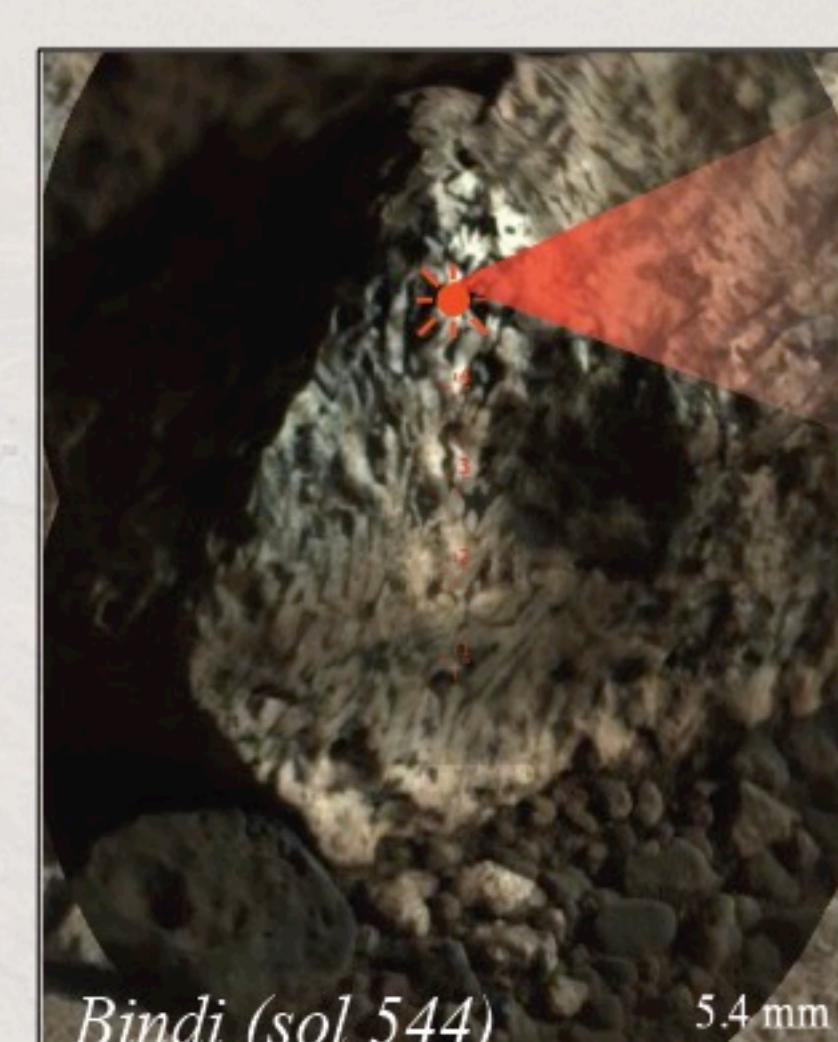
CheMin - X-Ray Diffraction (XRD)



- (1) Identification of each mineral using Rietveld refinement [4]
→ E.g., distinction between sanidine and plagioclase
- (2) Calculation of the chemistry of each mineral previously identified using refined unit-cell parameters [4]

→ Identification of igneous minerals (< 150 µm): feldspar, pyroxene and olivine

ChemCam - Laser Induced Breakdown Spectroscopy (LIBS)



Chemical analyses at a scale of 350 - 550 µm at distance (1.6-7m from the rover) [10]

Filtering based on feldspar, pyroxene and olivine stoichiometry among > 5000 LIBS measurements [8]

→ Identification of igneous minerals (> 1 mm): feldspar and pyroxene
→ No olivine evidenced: likely smaller than LIBS beam size

→ Good agreement between ChemCam and CheMin mineral composition except for alkali feldspar (cf. III.):
→ Sanidine too small relative to LIBS beam size?

III. Bradbury: Magmatic Processes

Fractional Crystallization (FC)

Occurrence of feldspar-cumulates
→ Fractional Crystallization (FC) [9]

Ⓐ AlphaMELTS Modeling (partial melting [PM] + FC)

- (1) Adiabatic ascent of a primitive mantle composition (PM) [10]
- (2) Extraction of one melt at a given degree of partial melting
- (3) FC at shallow pressures

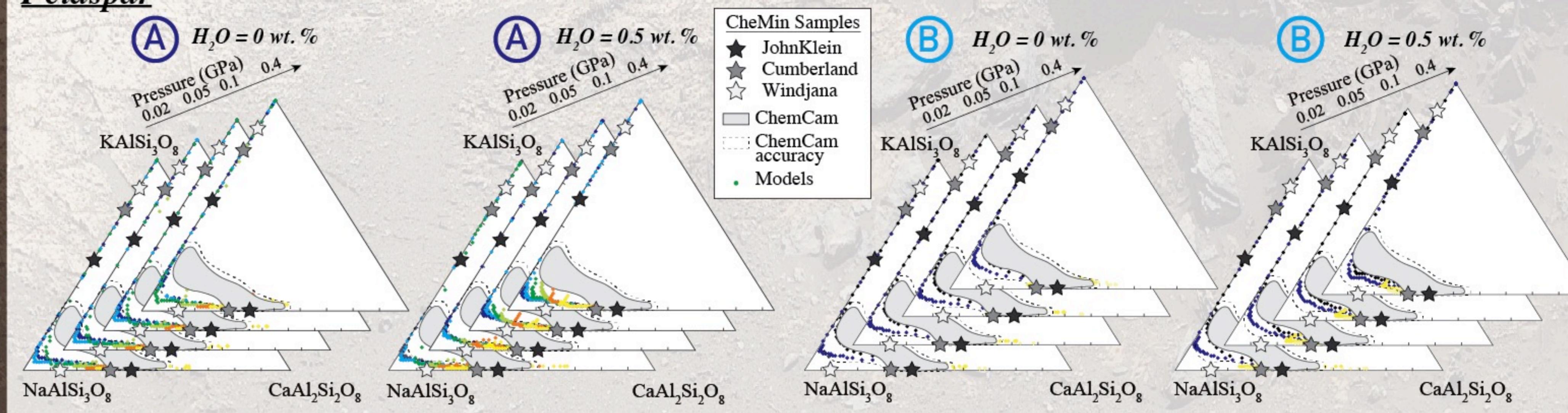
OR

Ⓑ Experiments (PM) + AlphaMELTS Modeling (FC)

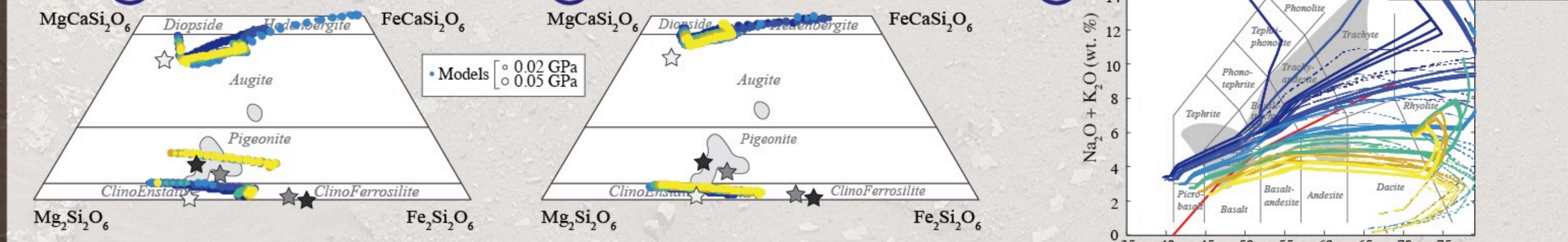
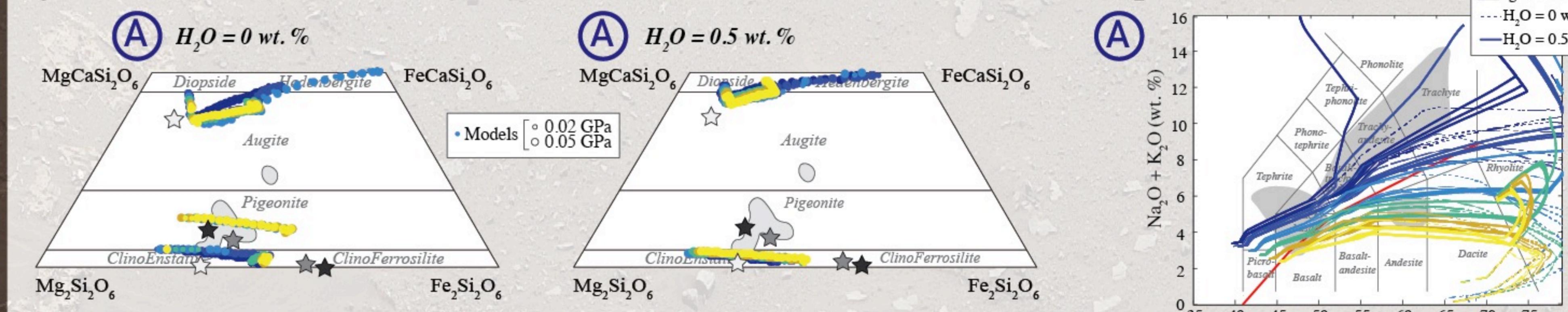
- (1) FC of various melting degree magmas obtained from lab experiments [11].

Melting degree of the starting melt that undergoes FC (%):

Feldspar



Pyroxene



→ Agreement between Ⓐ and Ⓑ

→ Two starting compositions are necessary to reproduce the whole range of feldspar compositions [8]:

- (1) FC of anhydrous high-degree melts (> 19%): Ca-plagioclase and pyroxene + basaltic to andesitic/dacitic melt
- (2) FC of hydrous low-degree melts (< 15%): Na-plagioclase and alkali-feldspar + trachytic to rhyolitic melt

IV. Conclusions

Magmatic Processes inferred from Igneous Mineral Chemistry:

→ Detrital igneous minerals from at least 2 distinct protoliths: basalt and trachyte (e.g., [2-3])

→ Crystallization of igneous minerals matching the whole compositional range analyzed in Bradbury rocks: use of MELTS models similar to those ran for understanding the formation of float igneous rocks from Gale crater [9]

→ Fractional crystallization of 2 melts coming from a single source is needed:

- plagioclase + pyroxene likely originated from an anhydrous basaltic - andesitic melt
- alkali feldspar crystallized from a potential hydrous trachytic - rhyolitic melt

→ Simple refilling of the crustal magma chamber

References: [1] Grotzinger et al. (2015), *Science*; [2] Vaniman et al. (2014), *Science*; [3] Treiman et al. (2016), *JGR*; [4] Morrison et al. (2018), *Am. Min.*; [5] Siebach et al. (2017), *JGR*; [6] Sautter et al. (2016), *Lithos*; [7] Cousin et al. (2017), *Icarus*; [8] Payré et al. (subm.), *JGR*; [9] Udry et al. (2018), *JGR*; [10] Clegg et al. (2017), *SAAB*; [11] Taylor (2013), *Chem. der erd.*; [11] Collinet et al. (2015) *EPSL*.

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