Diagenetic Concretions and Timing of Fluid Episodes in the Murray Formation, Gale Crater, Mars

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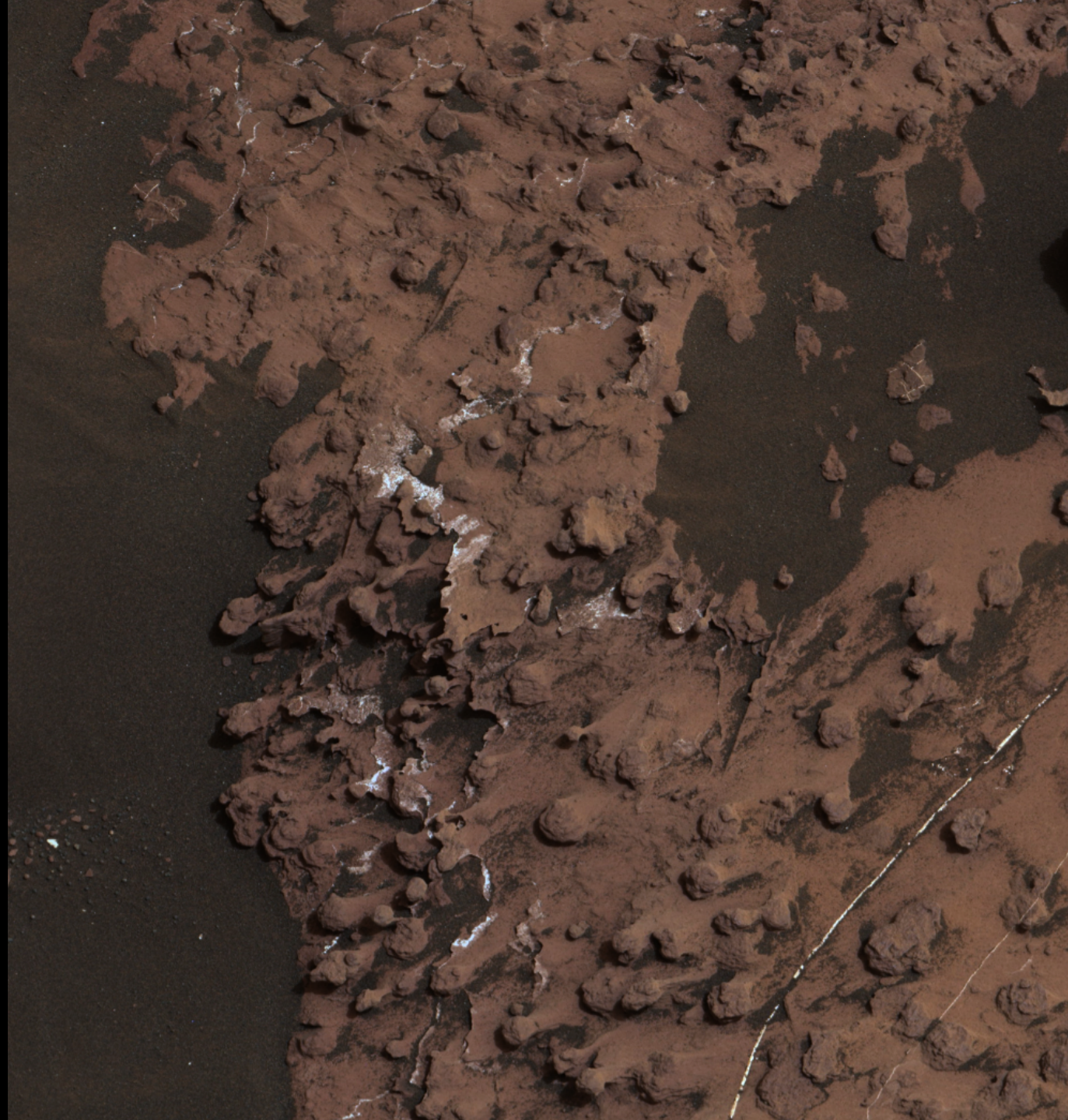
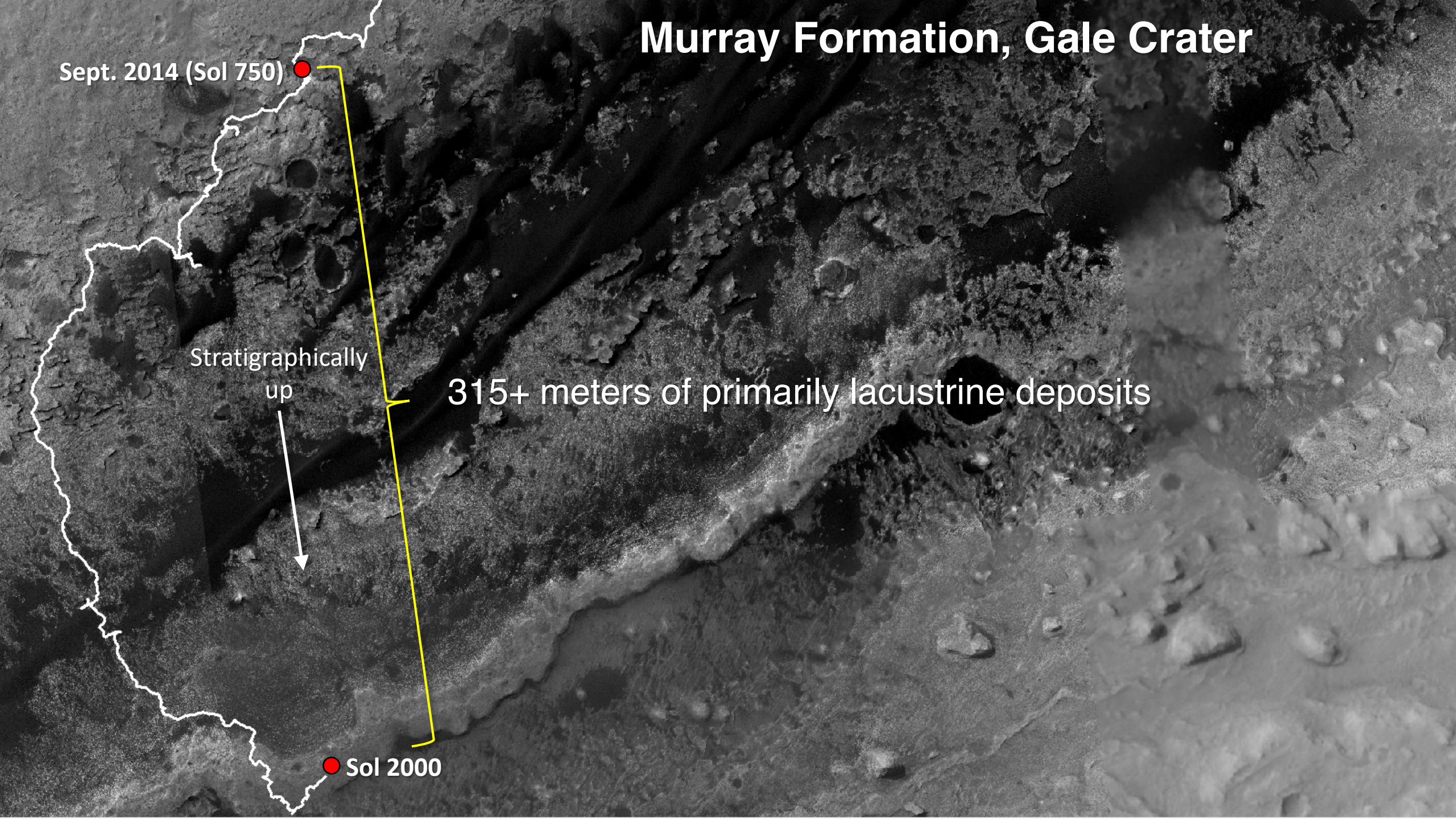
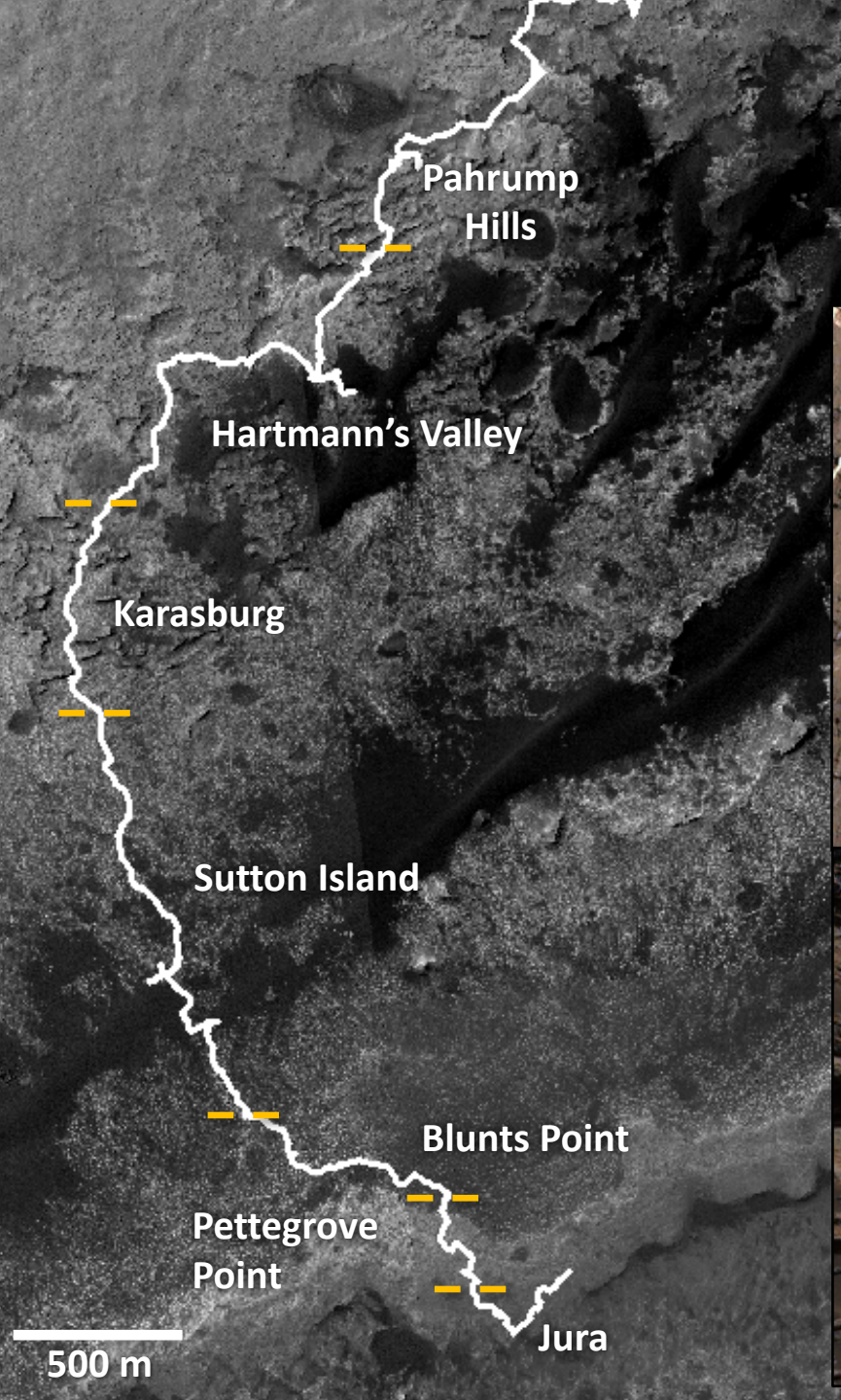
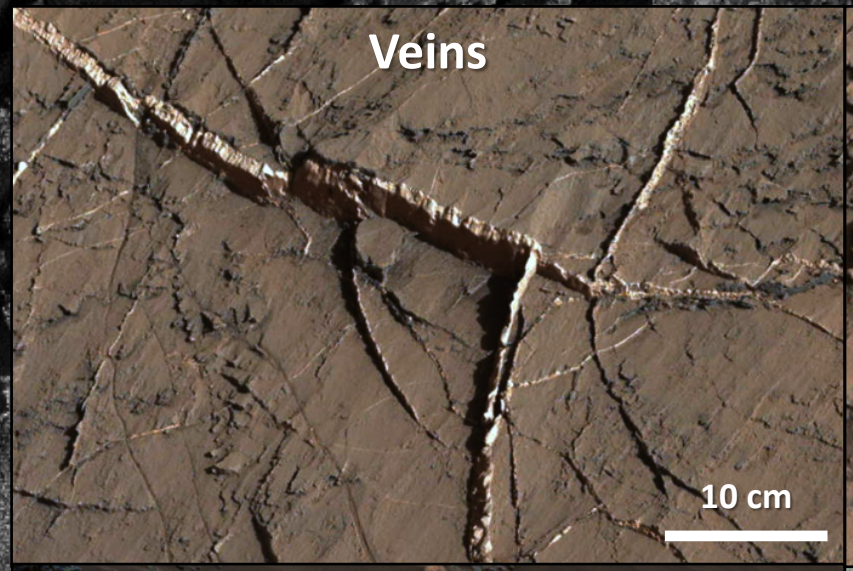


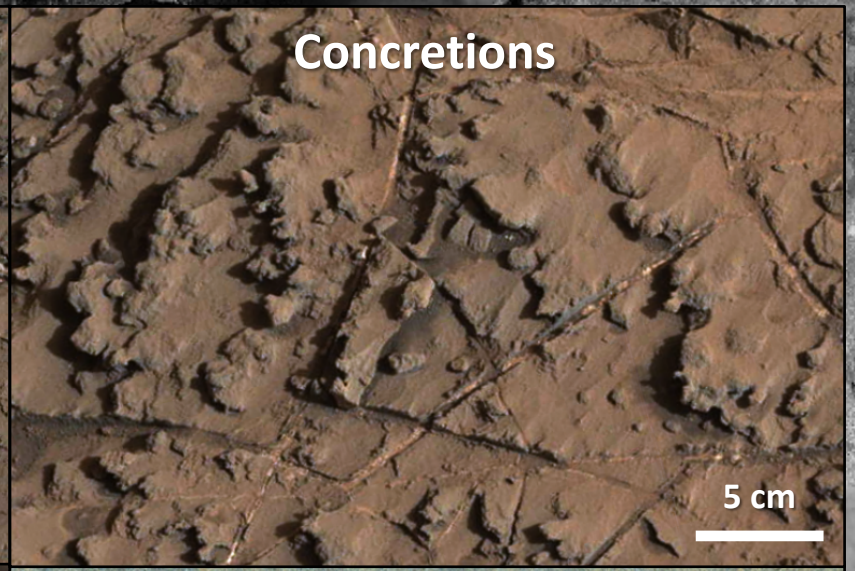

Murray Formation, Gale Crater
Sept. 2014 (Sol 750)
Stratigraphically up
315+ meters of primarily lacustrine deposits
Sol 2000

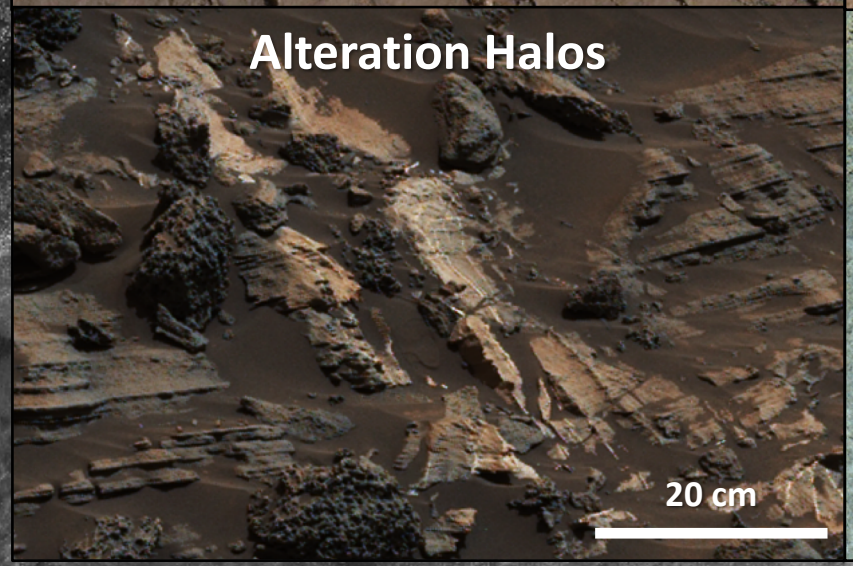
Diagenetic Features in the Murray Formation

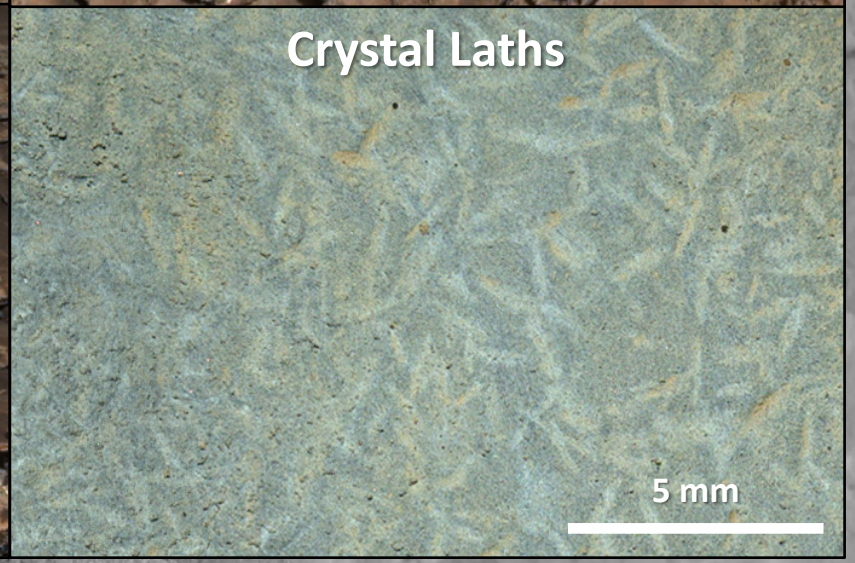
Variety of mineral alteration features suggest fluid events after the initial deposition of sediment.











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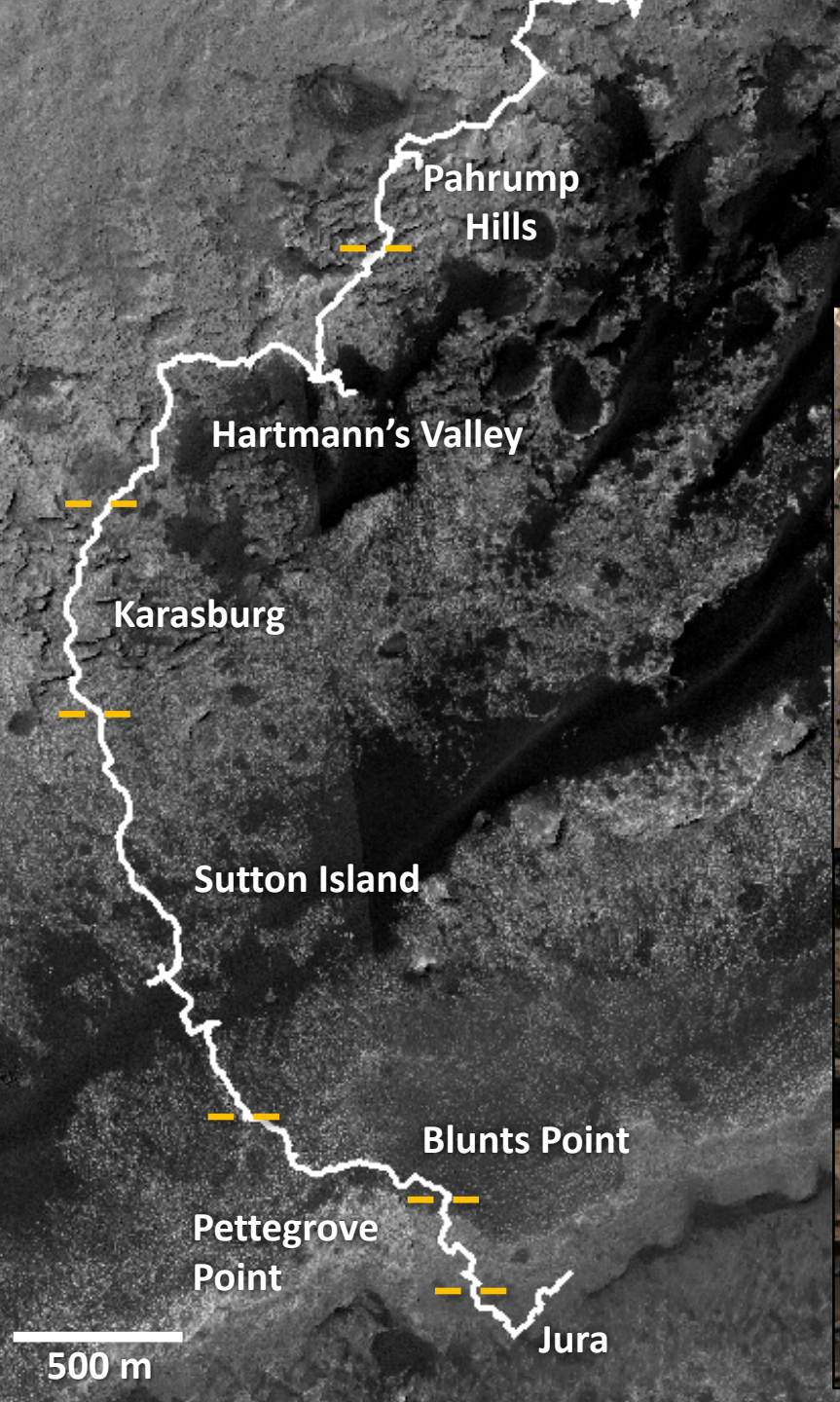
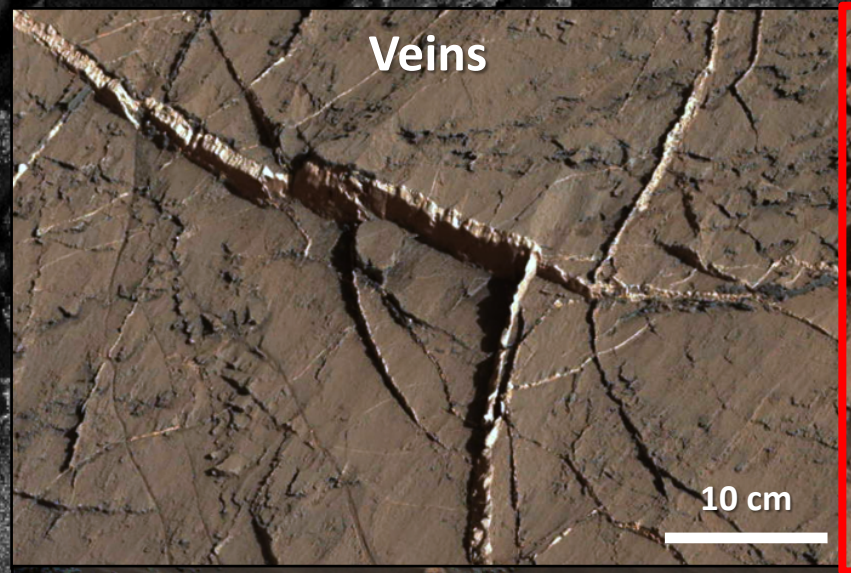
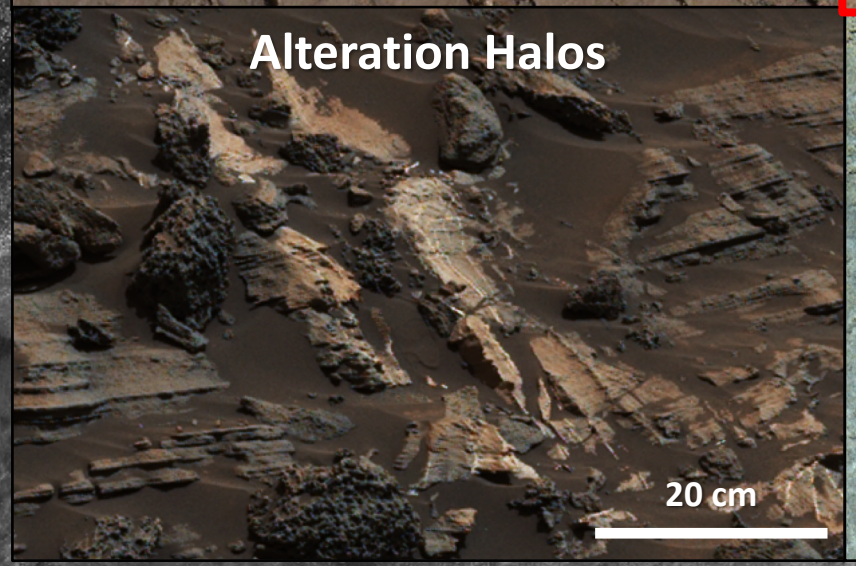
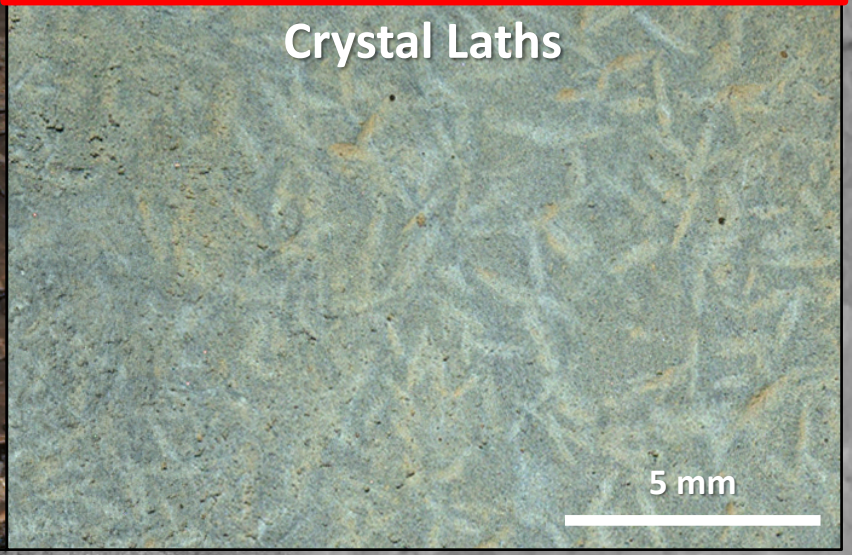
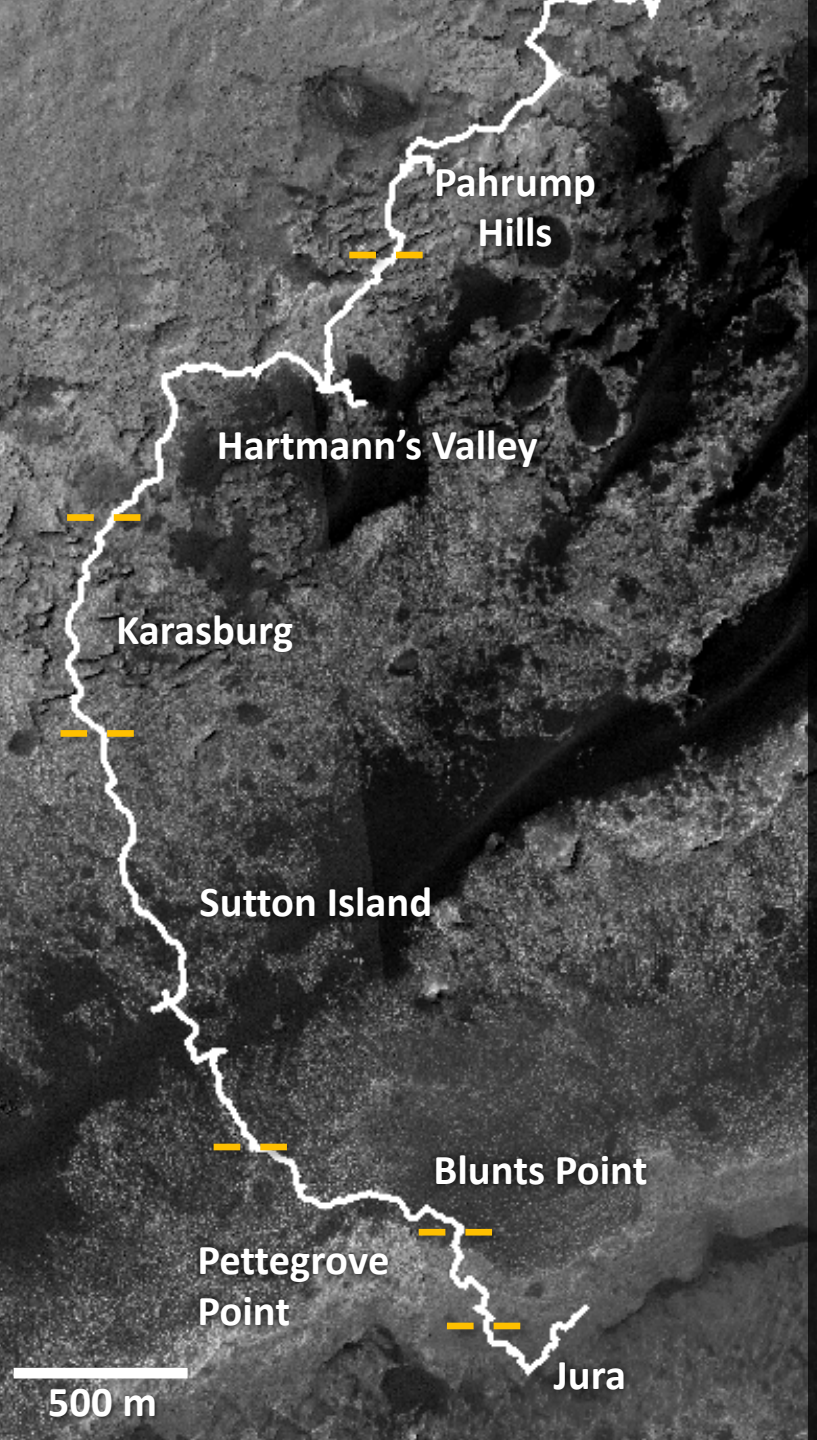










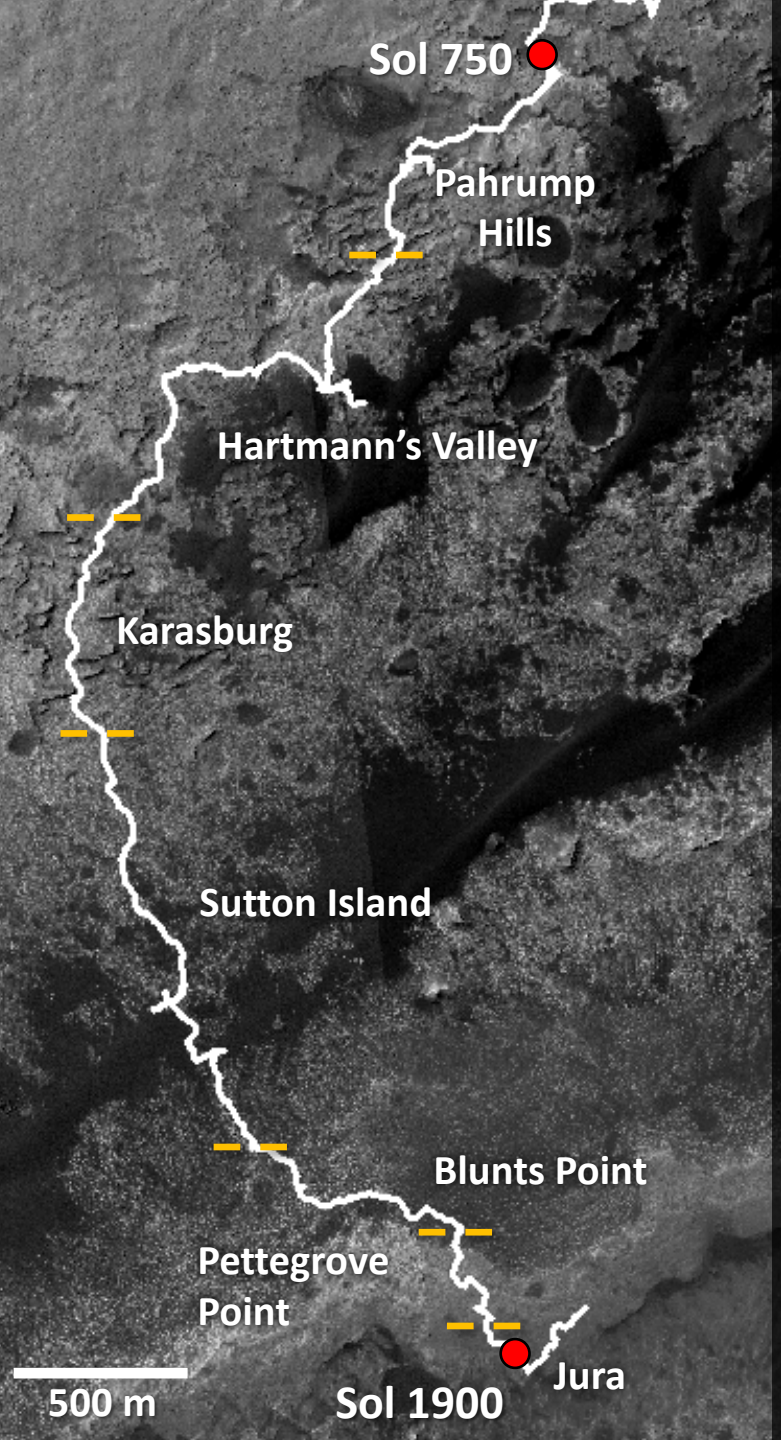
Motivating Questions

Concretions in the Murray Formation

- How many fluid episodes formed all of these concretions?
- What were the sediment conditions and fluid chemistries involved in concretion formation?
- Did these concretions form early or late relative to sediment deposition?

All Diagenetic Features in the Murray Formation

- How many fluid episodes formed all of the diagenetic features we see? Including veins, concretions, alteration halos, etc.



Methods
(Data from Sols 750-1900)

Concretion Physical Properties

- Shape, size, textures documented from image datasets
  - Mastcam
    - Provides broad coverage of our workspace
  - MAHLI (Mars Hand Lens Imager)
    - Provides high-resolution images of specific targets (up to 14 microns/pixel)

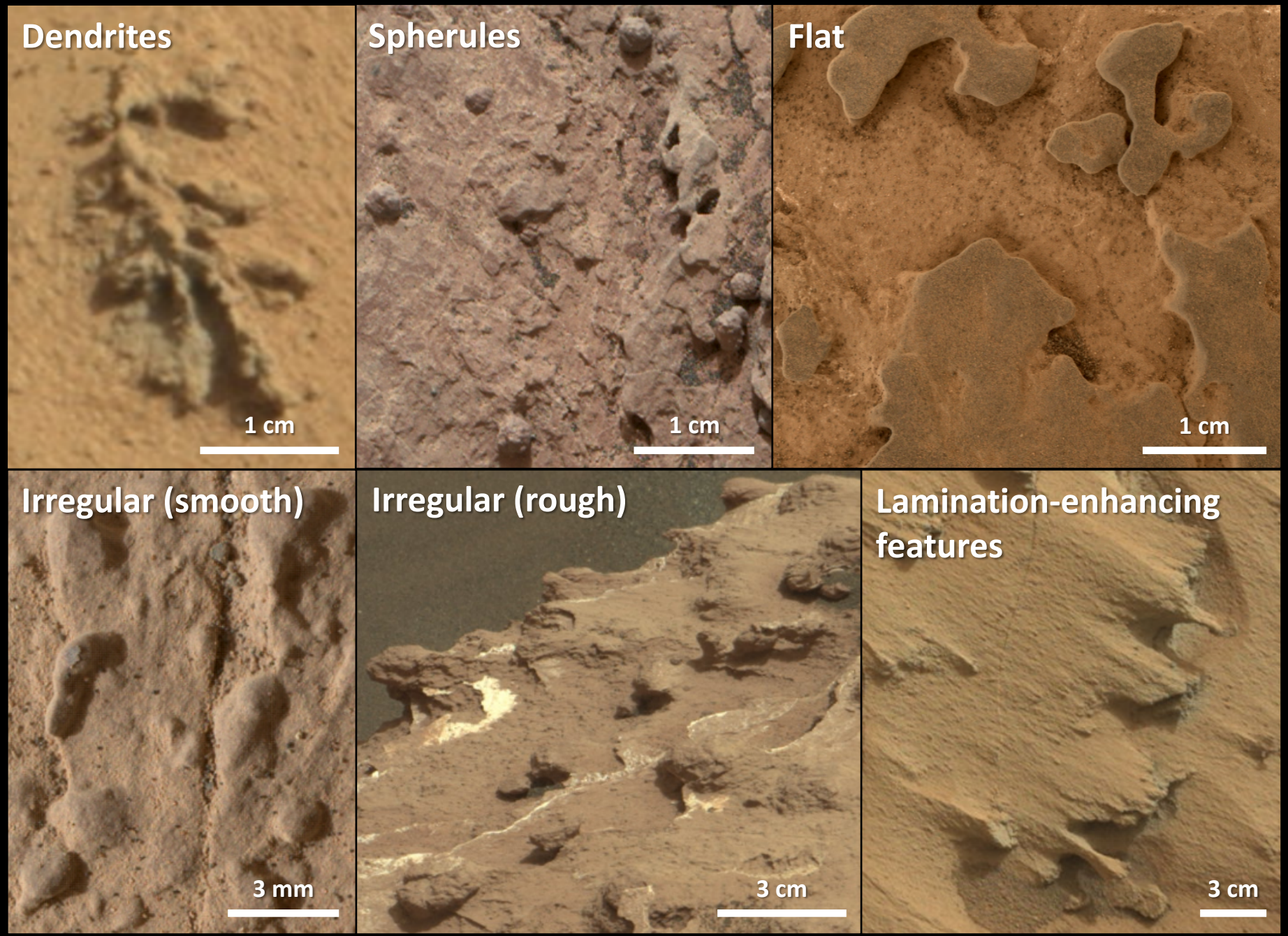
Concretion Composition

- Elemental composition documented from chemical datasets
  - ChemCam
    - Point measurements
  - APXS (Alpha Particle X-ray Spectrometer)
    - Bulk measurements of concretion + host rock

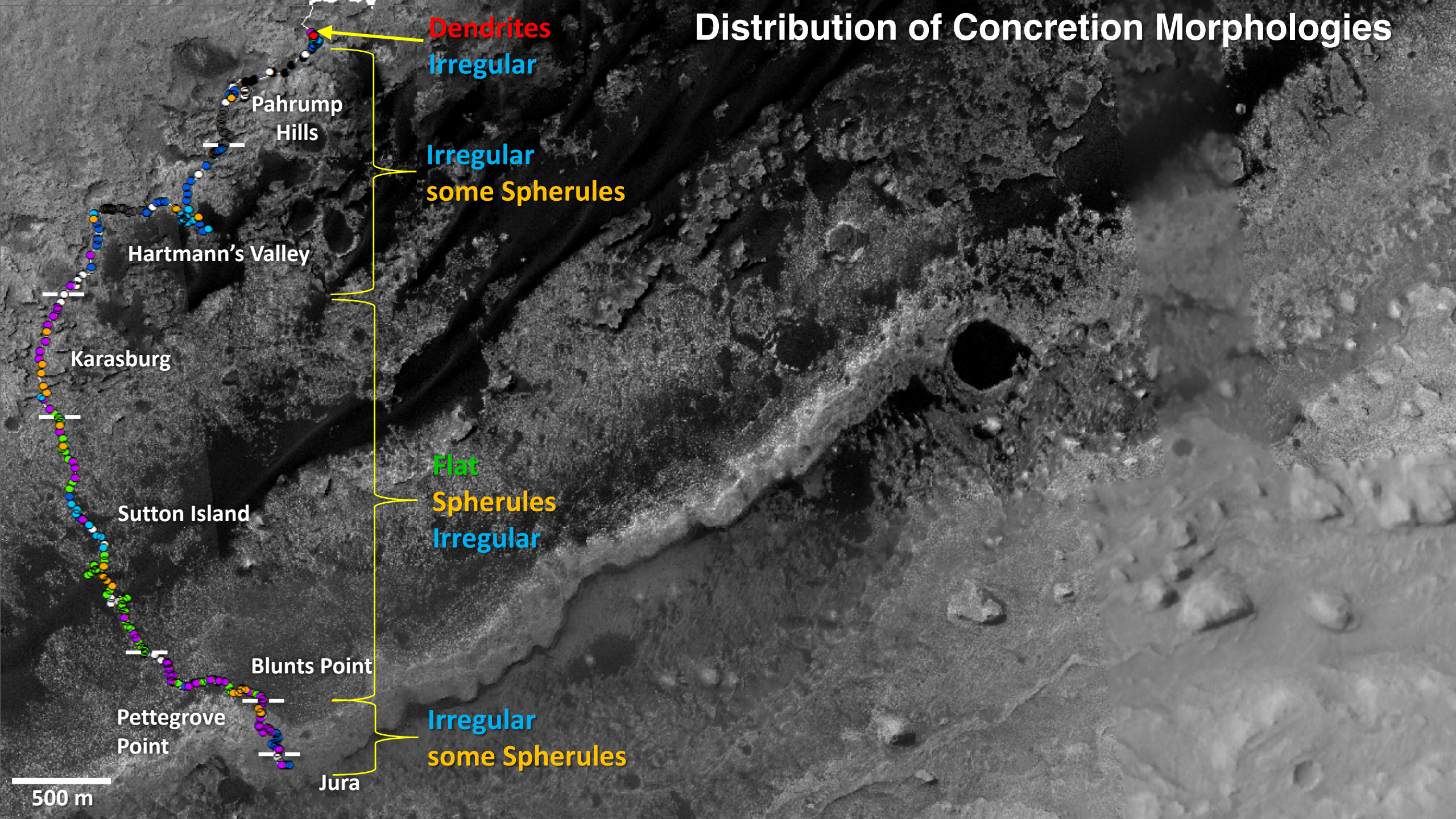
Concretion Morphologies in the Murray Fm.

Discrete concretions: higher cement-to-sediment ratio

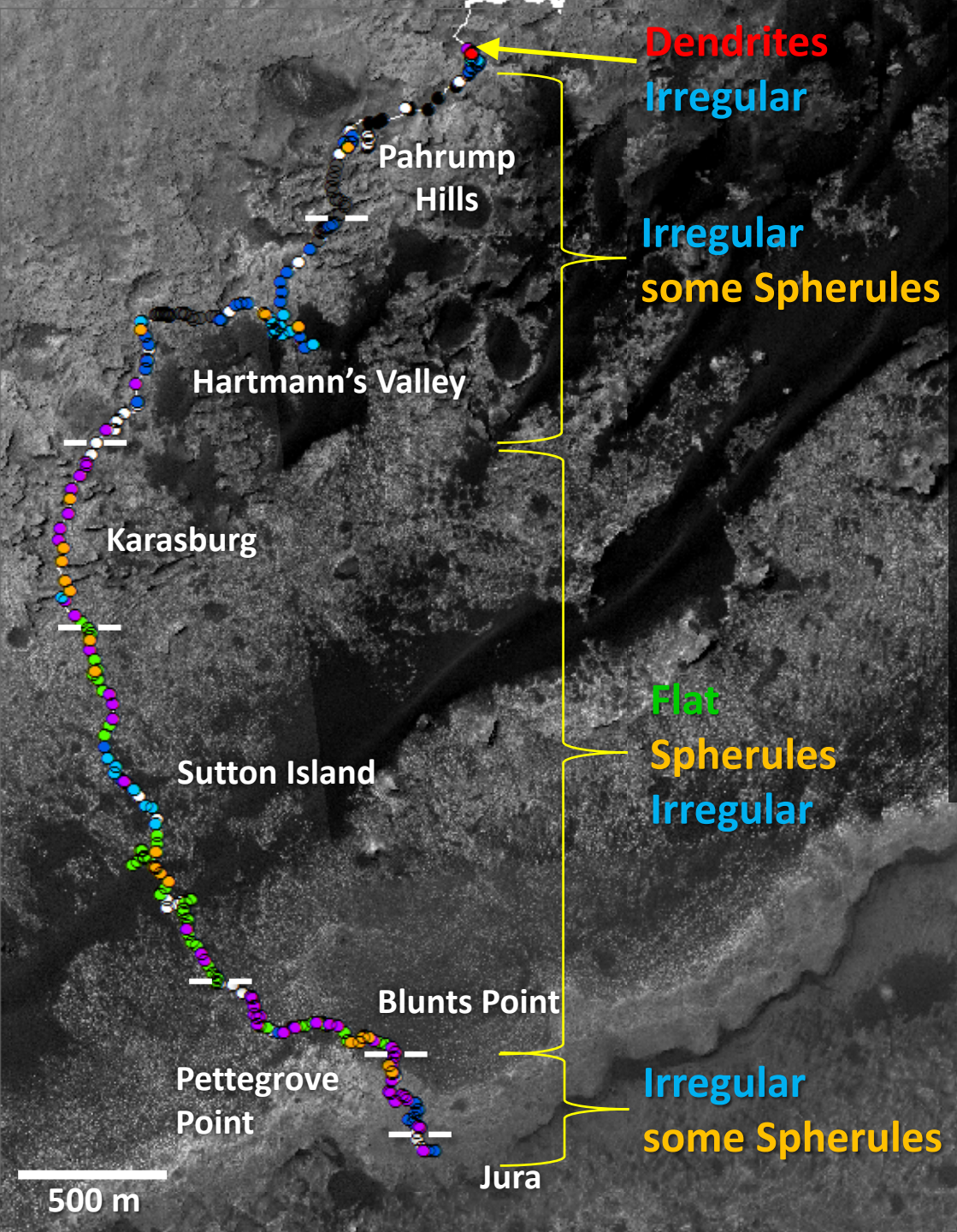
Lamination-enhancing features: lower cement-to-sediment ratio



mcam03304
Spider_Lake, MAHLI 25cm
Jones_Marsh, MAHLI 5cm
Quela postsieve, MAHLI 5cm
mcam07703
mcam03423


Distribution of Concretion Morphologies
Dendrites
Irregular
Pahrump Hills
Irregular
some Spherules
Hartmann's Valley
Karasburg
Flat
Spherules
Irregular
Sutton Island
Blunts Point
Pettegrove Point
Irregular
some Spherules
Jura
500 m

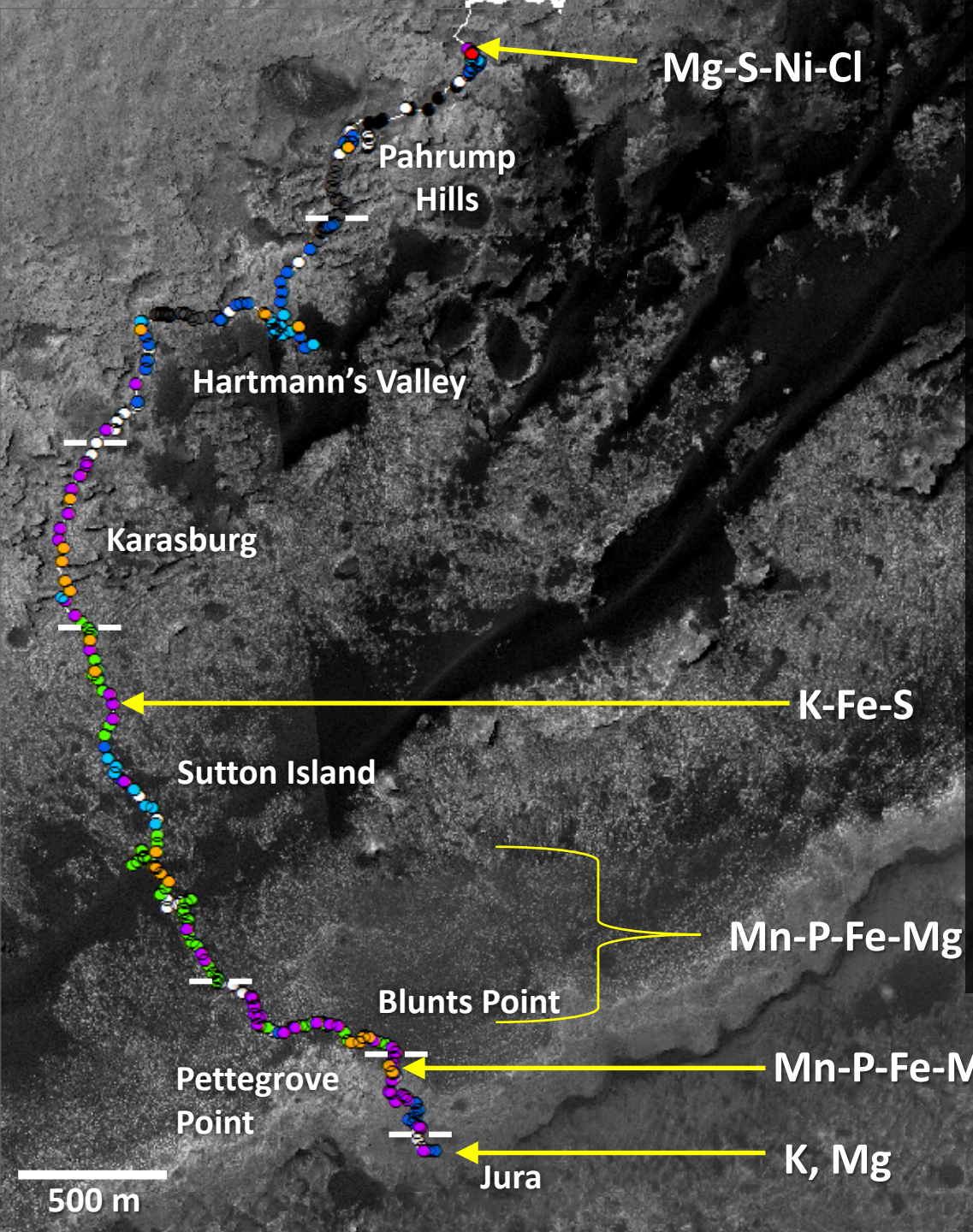
Distribution of Concretion Morphologies



Stratigraphic trends in concretion morphology result in <u>4 distinct concretion assemblages</u>.

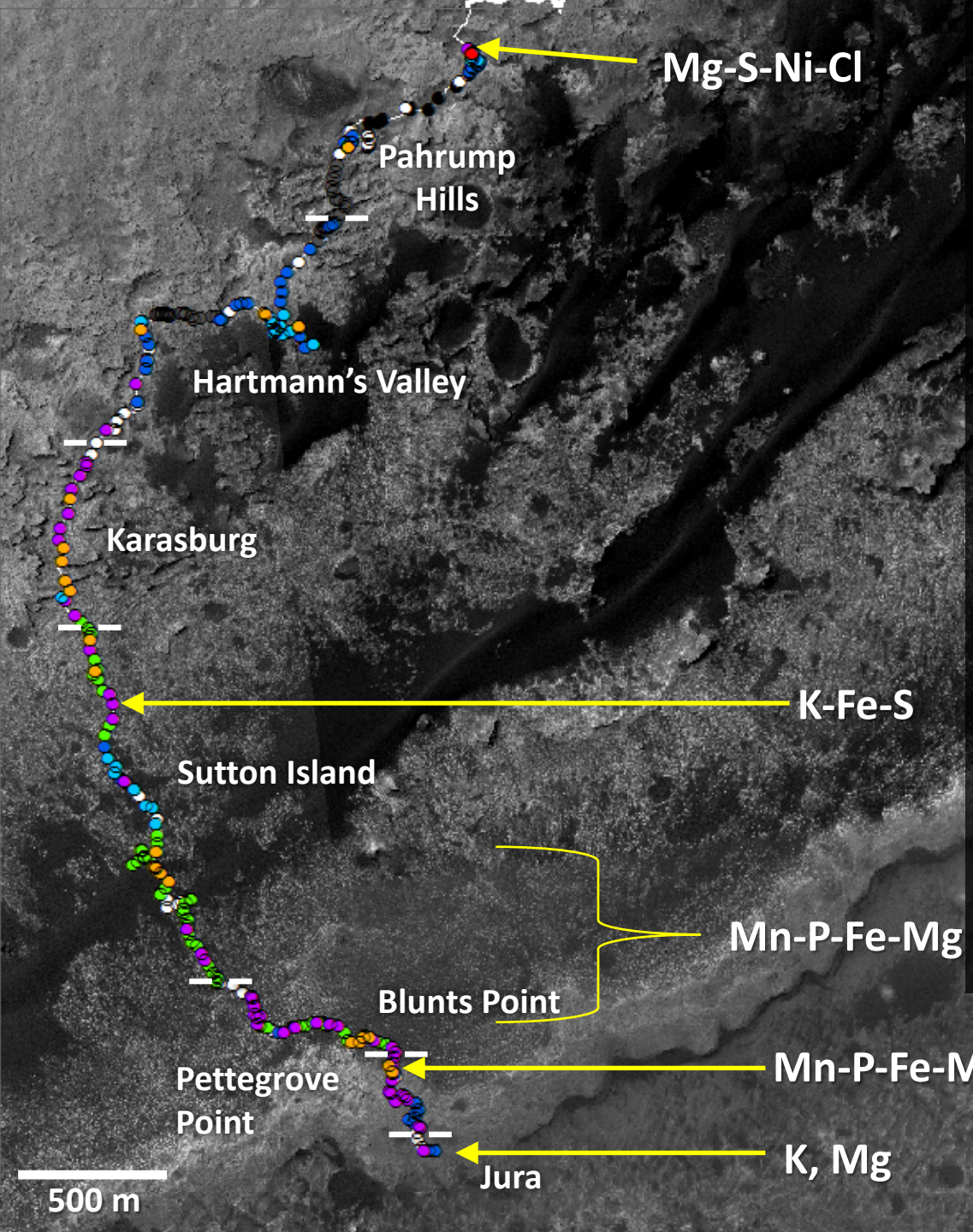
While some morphologic variation may be due to variations in the host rock, the overall diversity of concretion morphology in a single workspace suggests they formed in <u>multiple fluid episodes</u>.

Concretion Composition



Concretions are chemically enriched relative to the host rock at several distinct intervals.

Three enrichment types:
Mg-S-Ni-Cl
K-Fe-S
Mn-P-Fe-Mg



Concretion Composition

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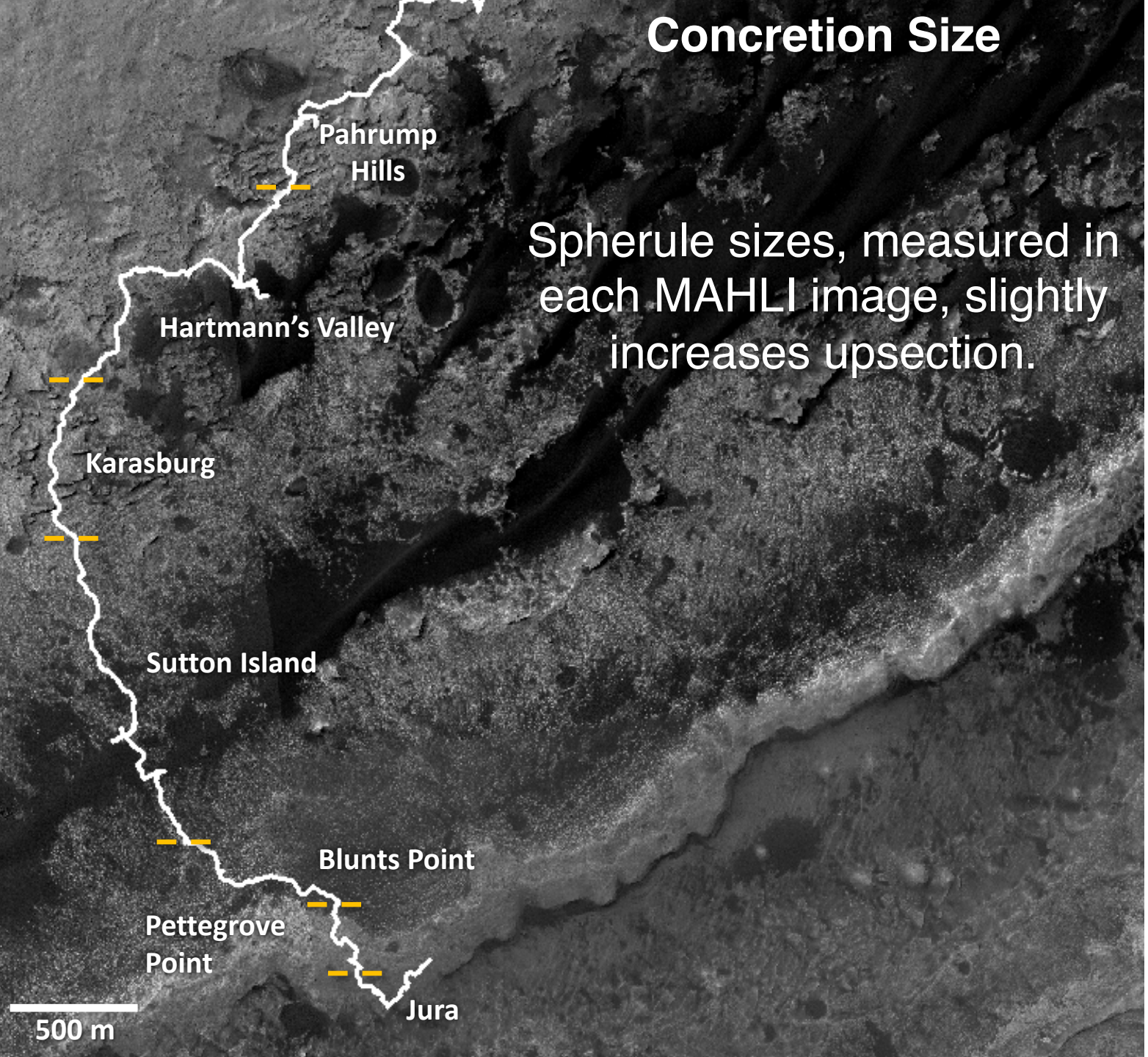
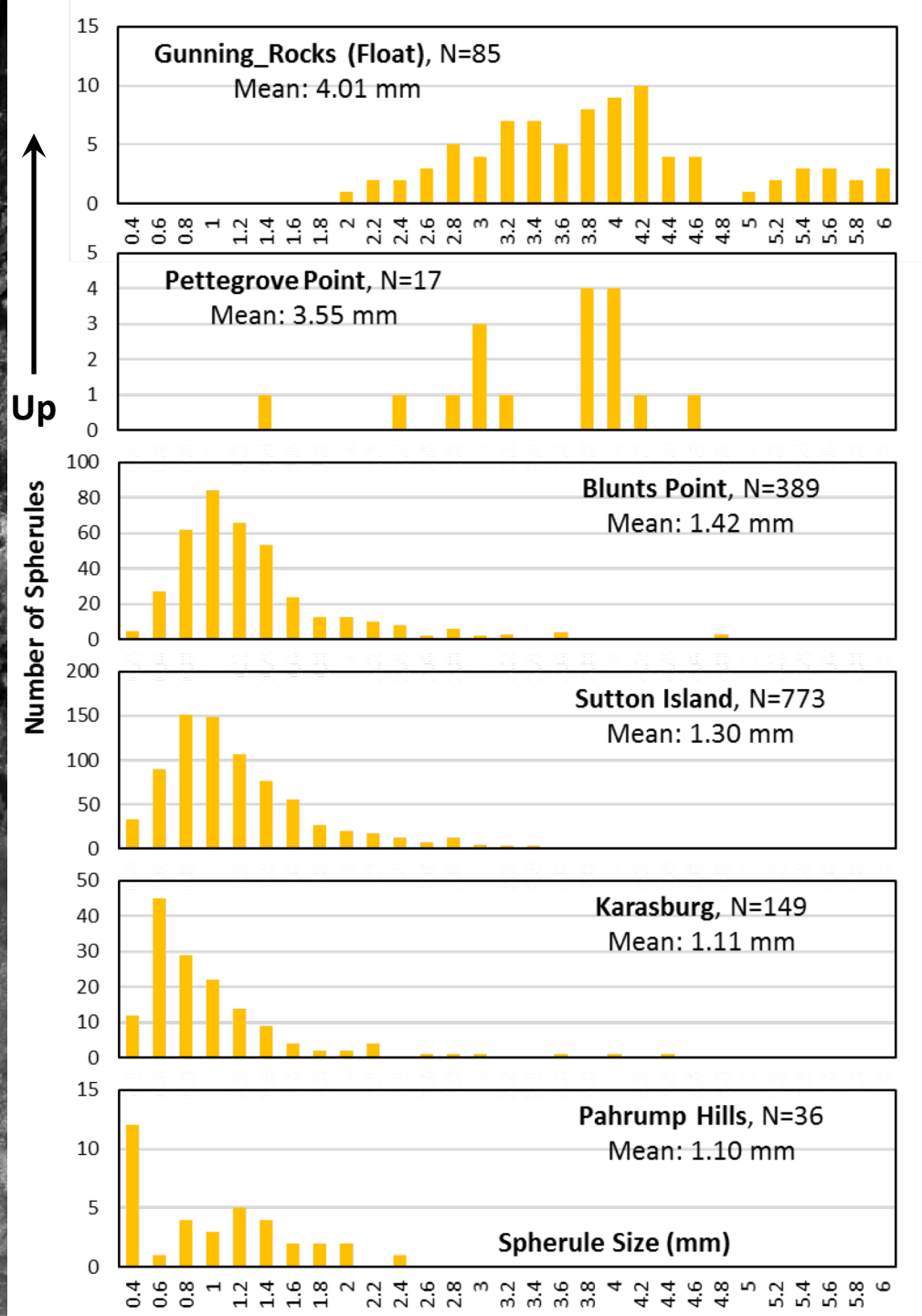
Mn-P-Fe-Mg

Varying compositions strongly suggest multiple precipitation episodes with different fluid chemistries.

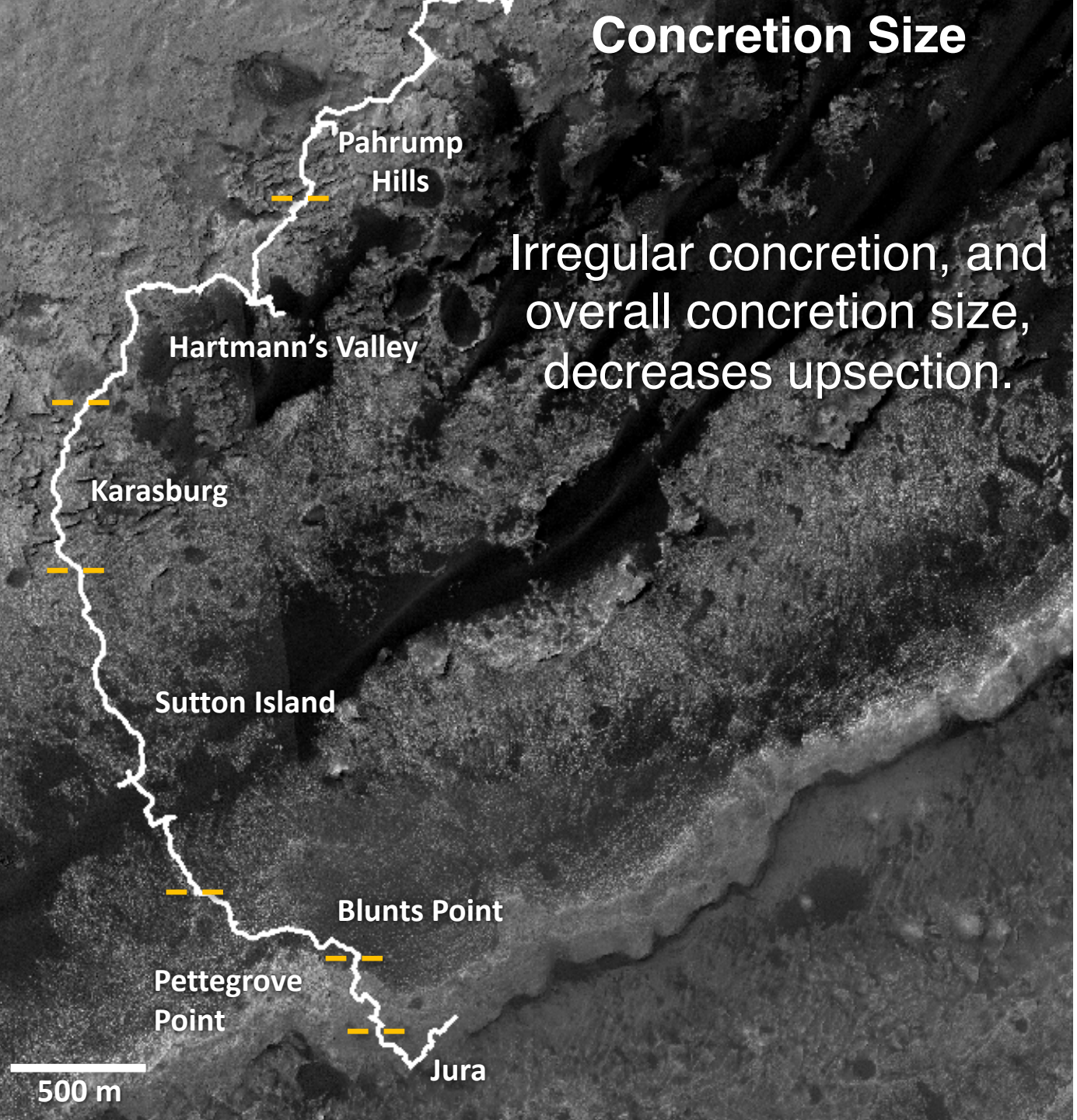
Concretion Size



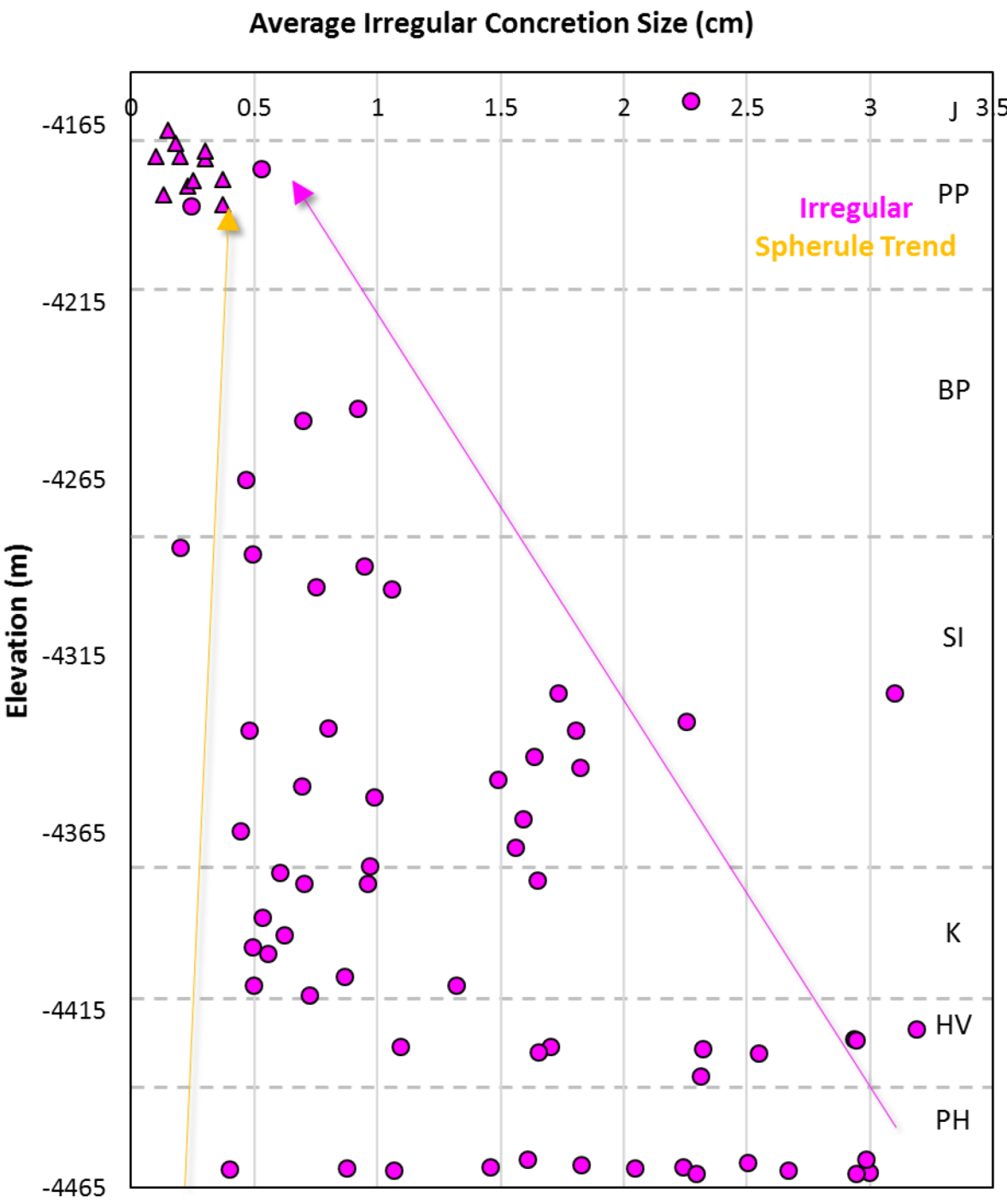
Spherule sizes, measured in each MAHLI image, slightly increases upsection.



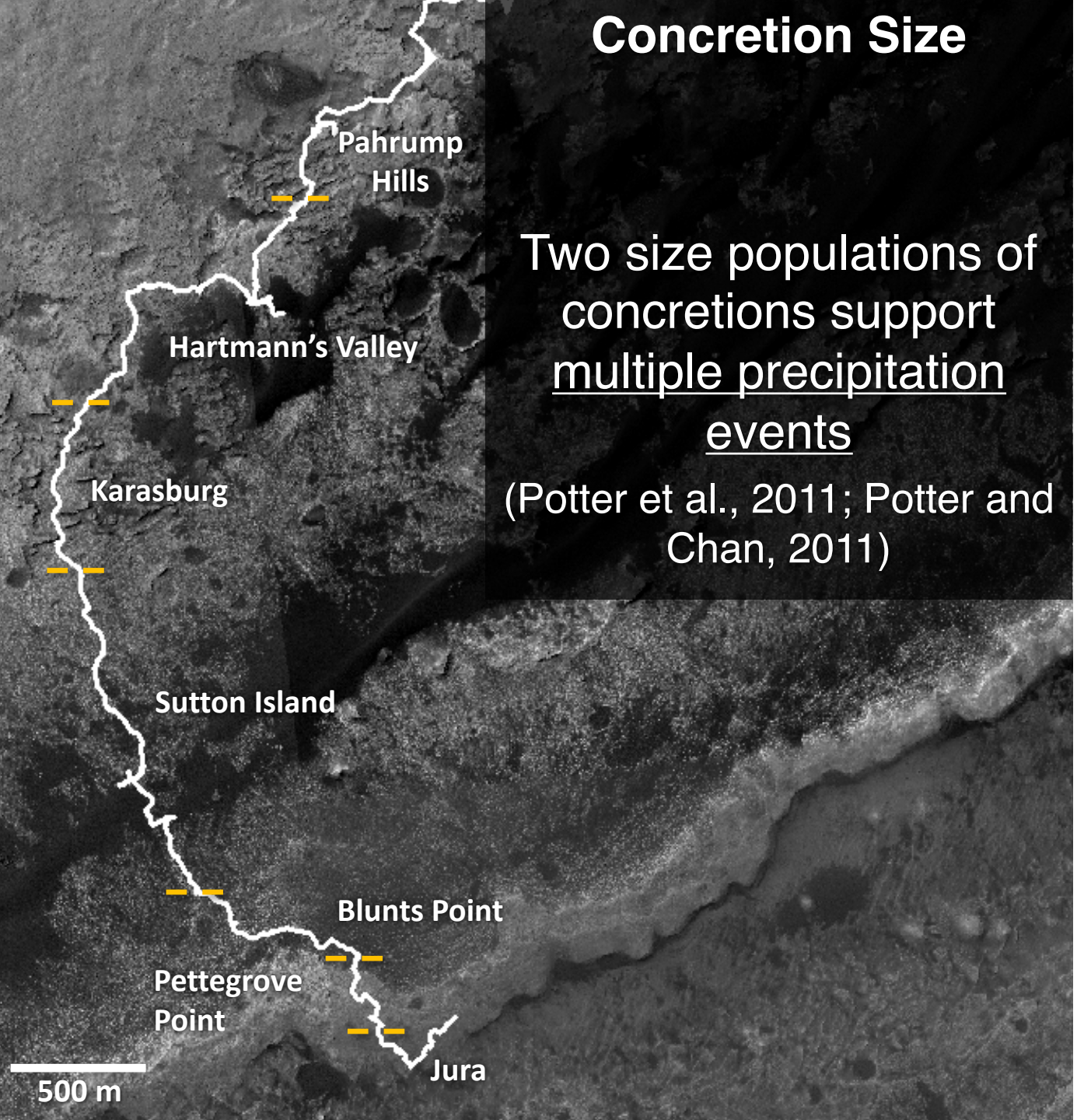
Concretion Size



Irregular concretion, and overall concretion size, decreases upsection.

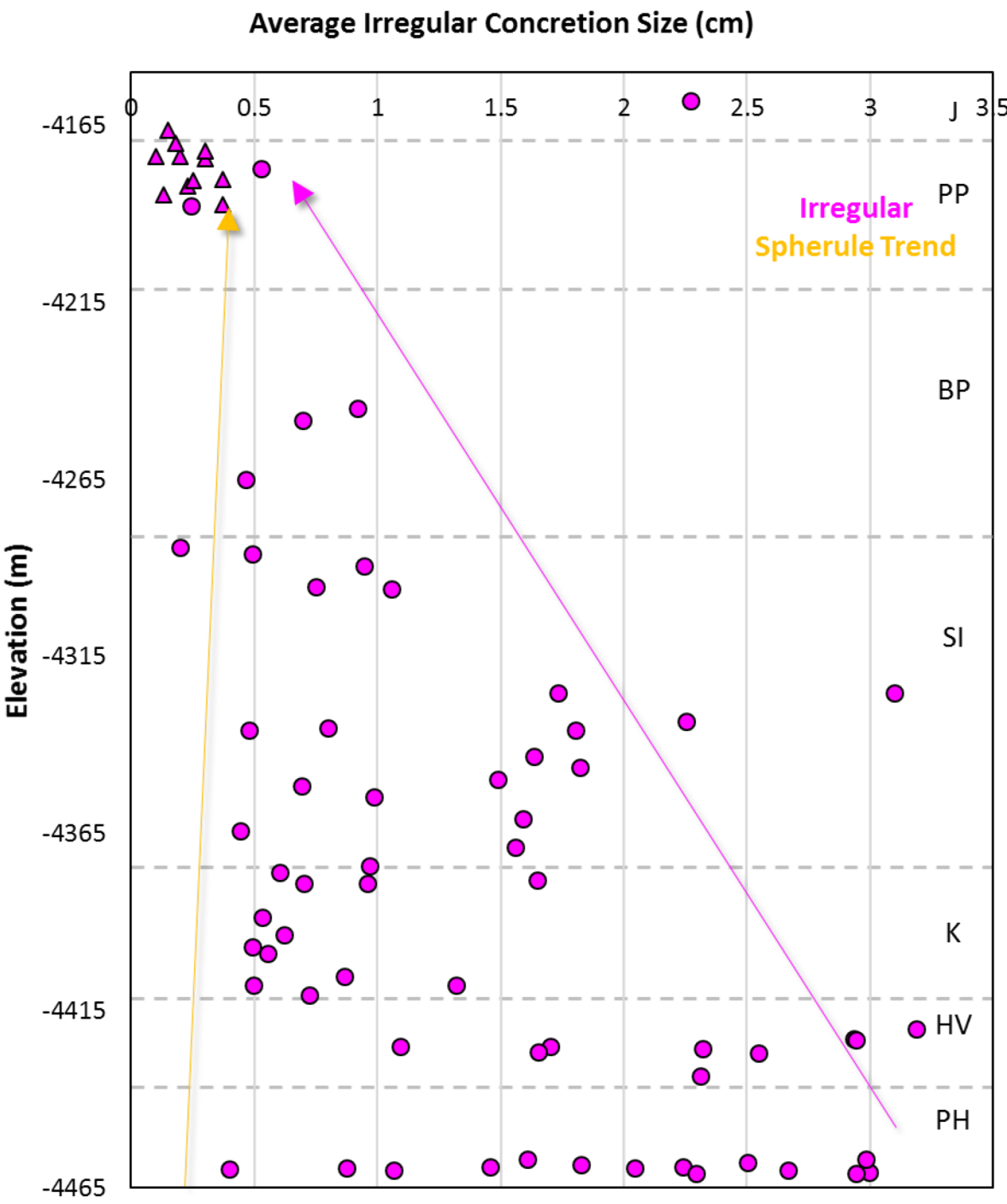


Concretion Size



Two size populations of concretions support <u>multiple precipitation events</u>

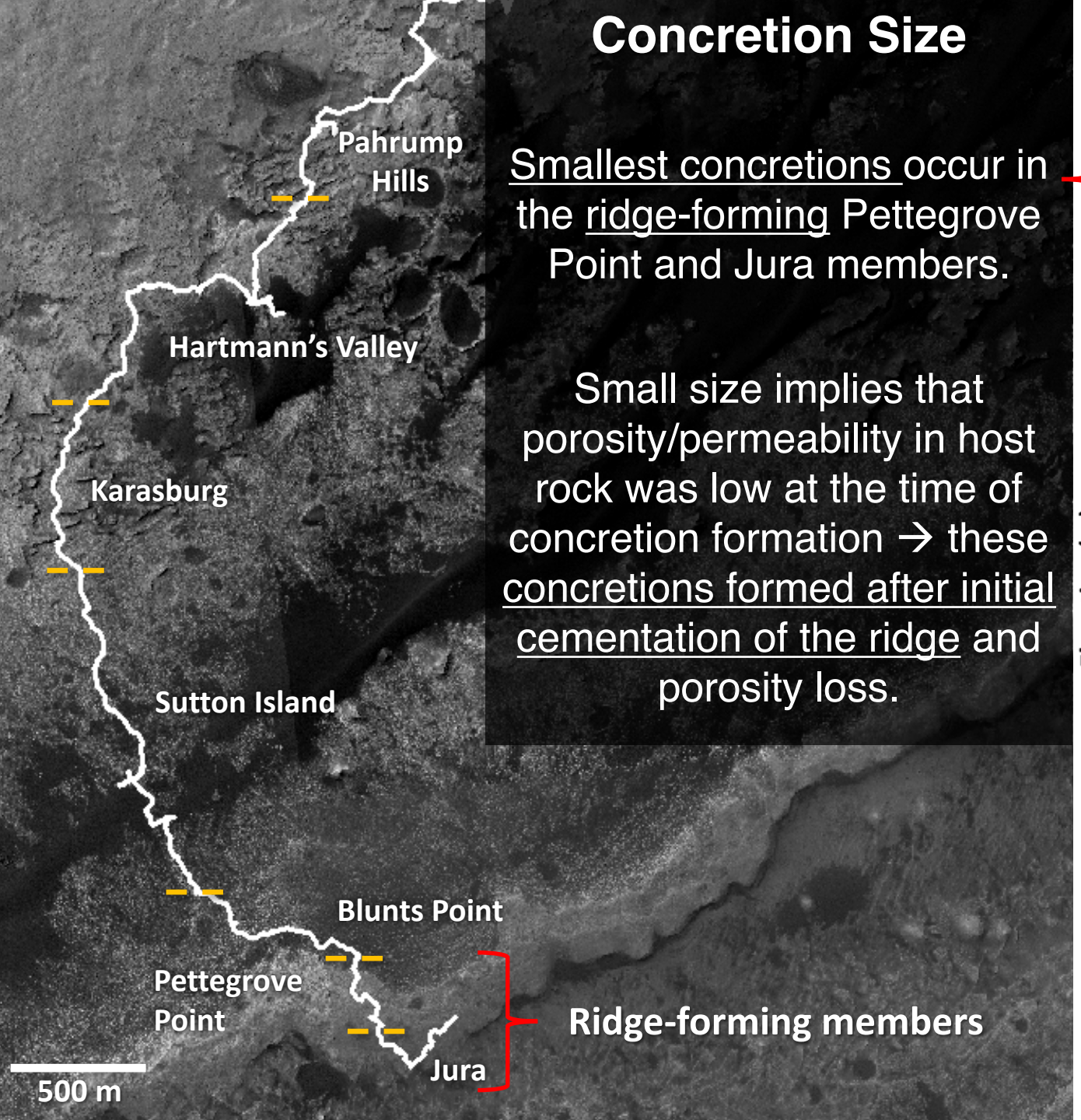
(Potter et al., 2011; Potter and Chan, 2011)

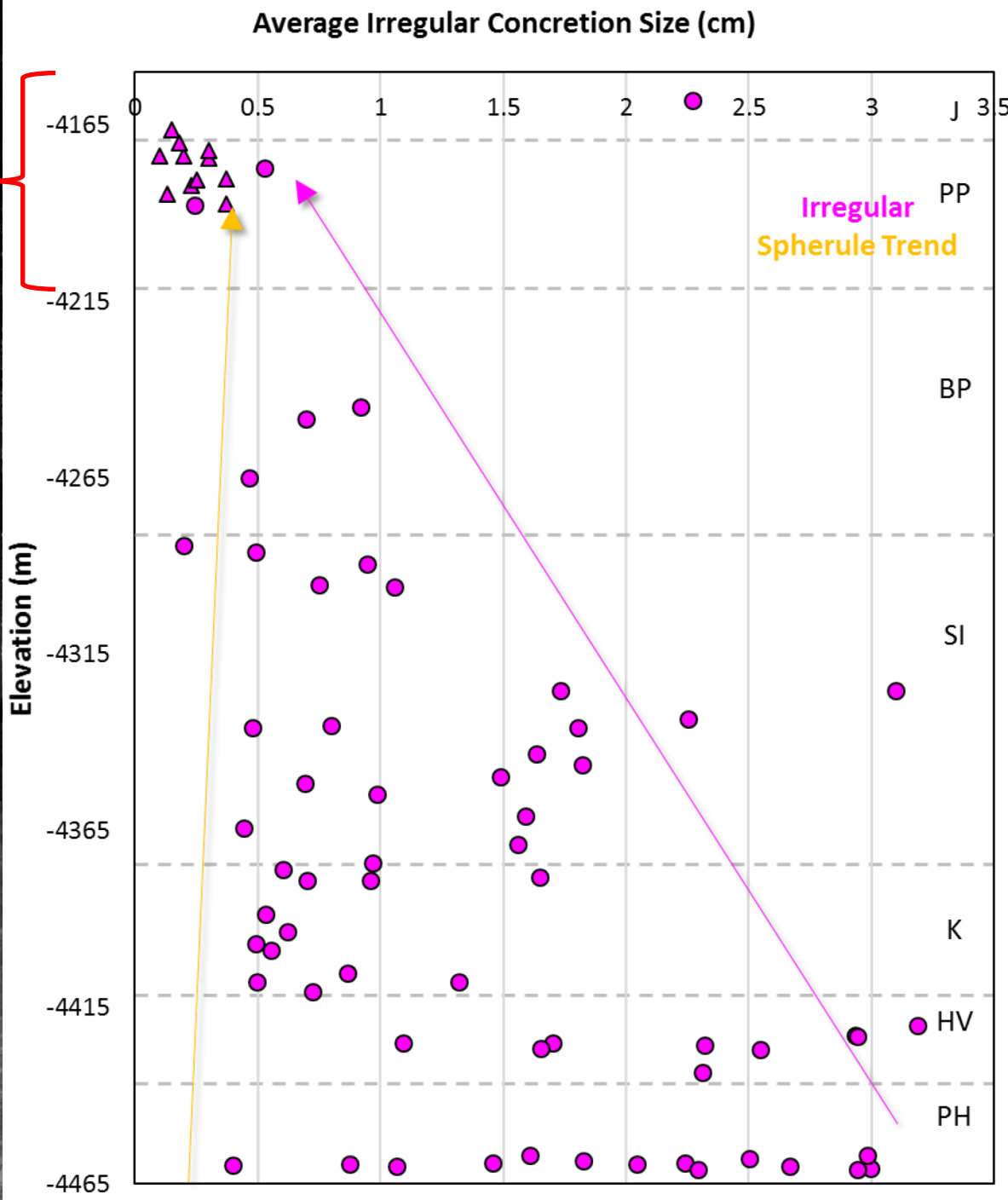


Concretion Size

Smallest concretions occur in the ridge-forming Pettegrove Point and Jura members.

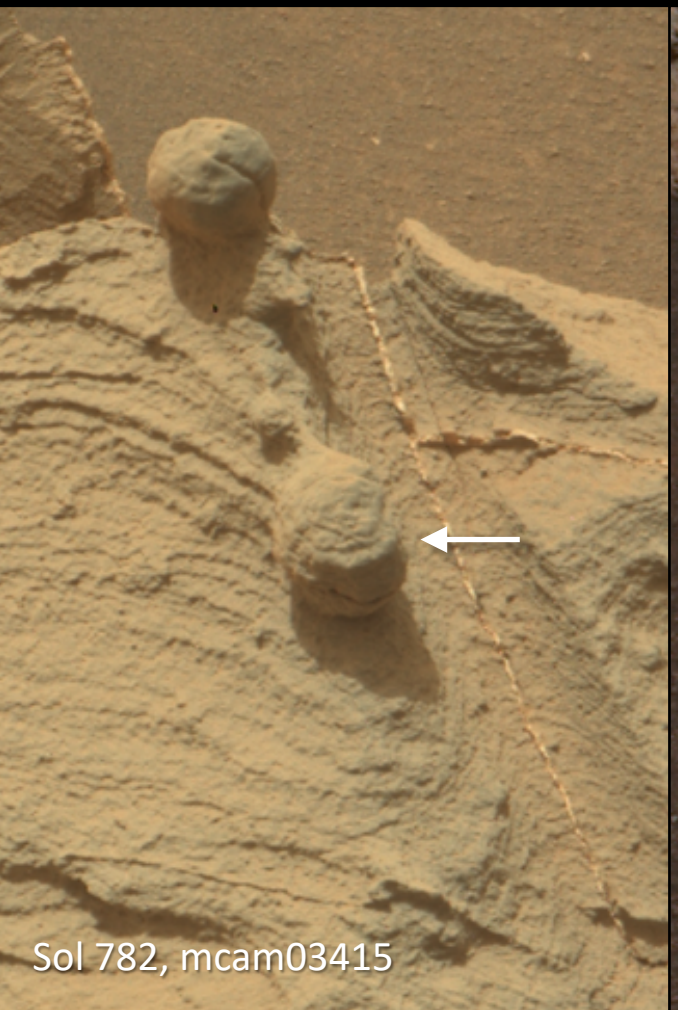
Small size implies that porosity/permeability in host rock was low at the time of concretion formation → these concretions formed after initial cementation of the ridge and porosity loss.



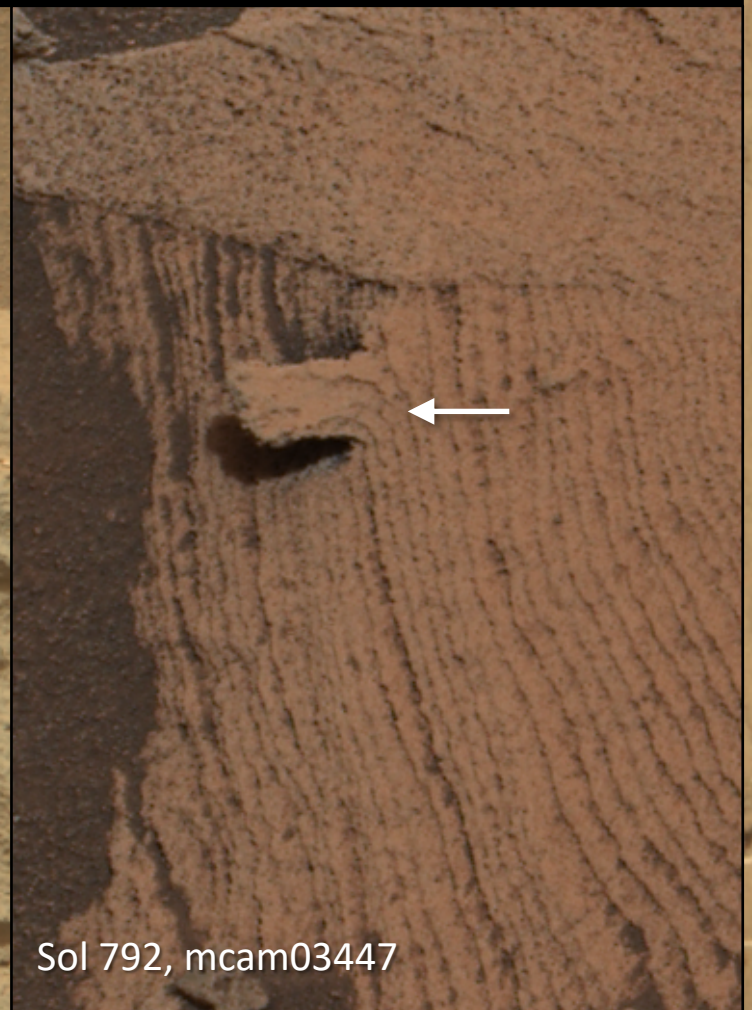


Evidence for Late-Stage Diagenesis

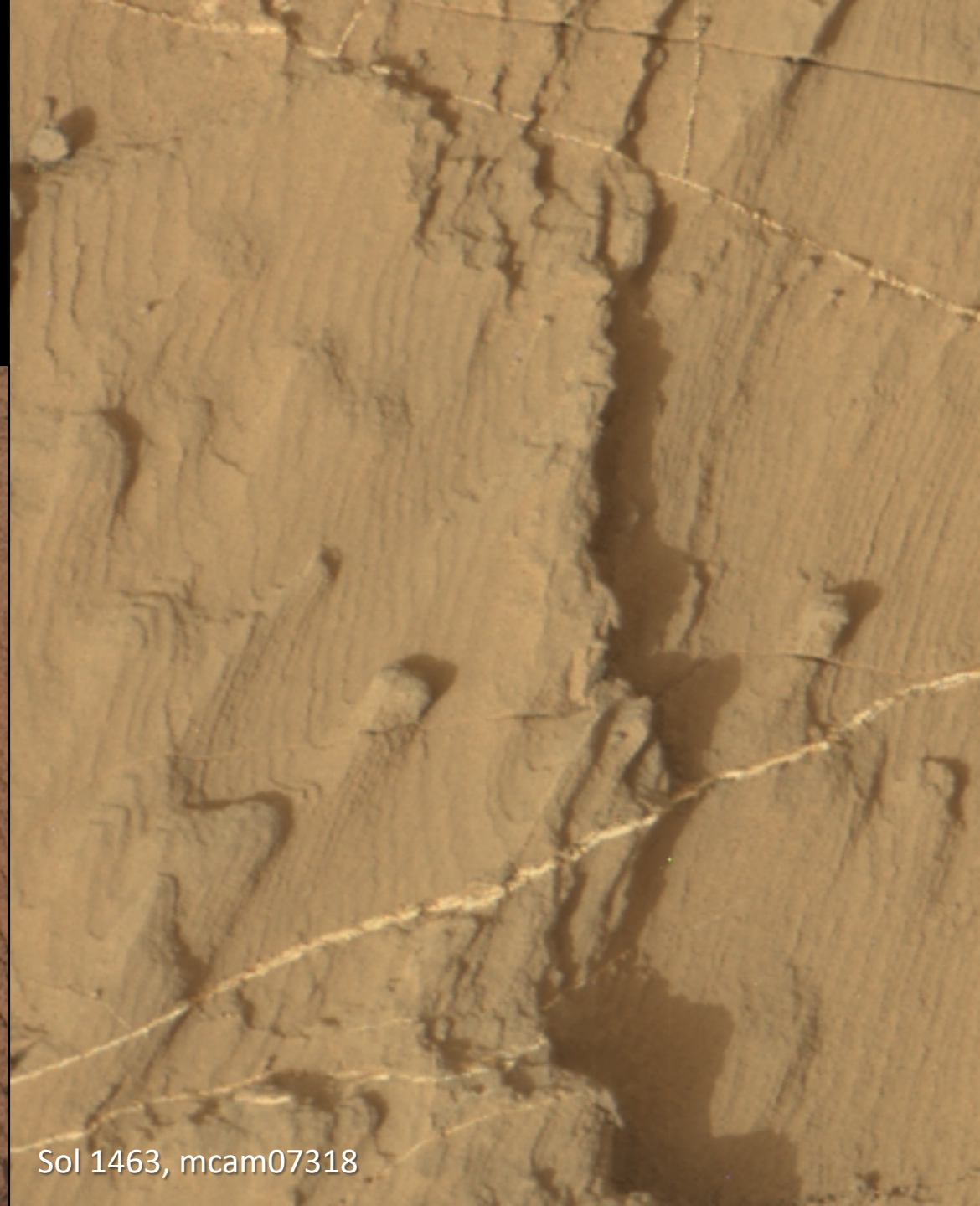
Some concretions preserve host rock laminations within the concretion body, without warping/deflection at concretion/host boundary.



Sol 782, mcam03415



Sol 792, mcam03447

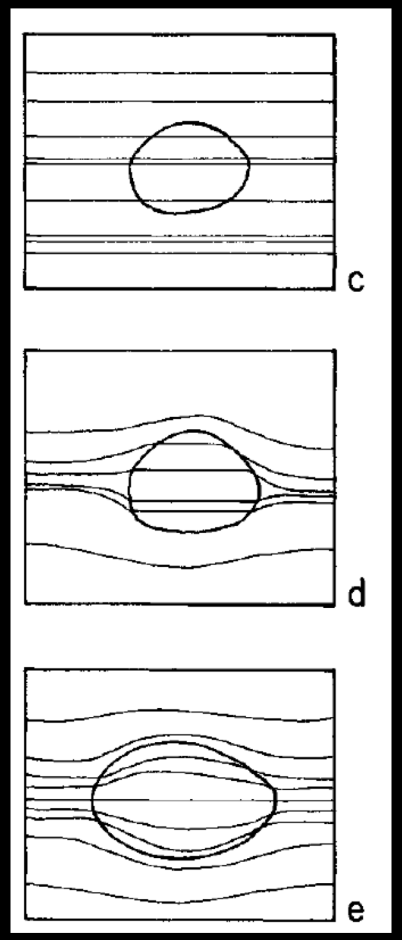


Sol 1463, mcam07318

Evidence for Late-Stage Diagenesis

No evidence for differential compaction (i.e. deflected/warped host rock laminations), implying concretion formation after the compaction and lithification of sediments.

Esp. in mudstones, would expect substantial reduction in laminae thickness during differential compaction.

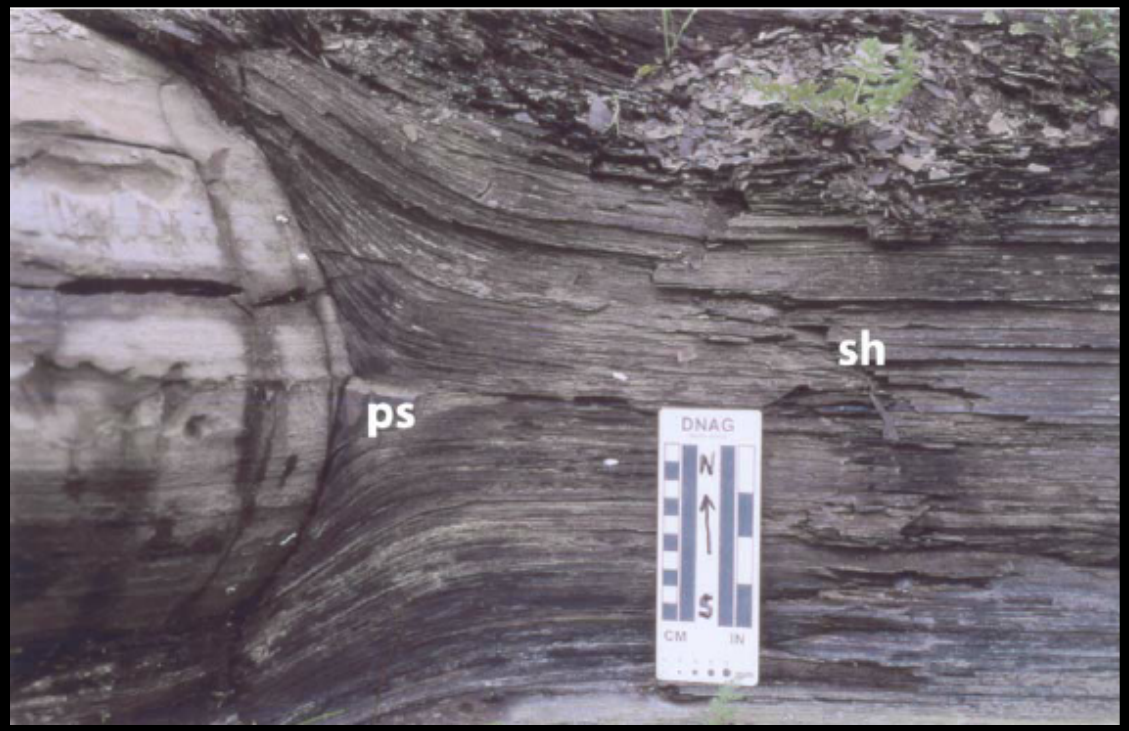


Late diagenesis, post compaction/lithification

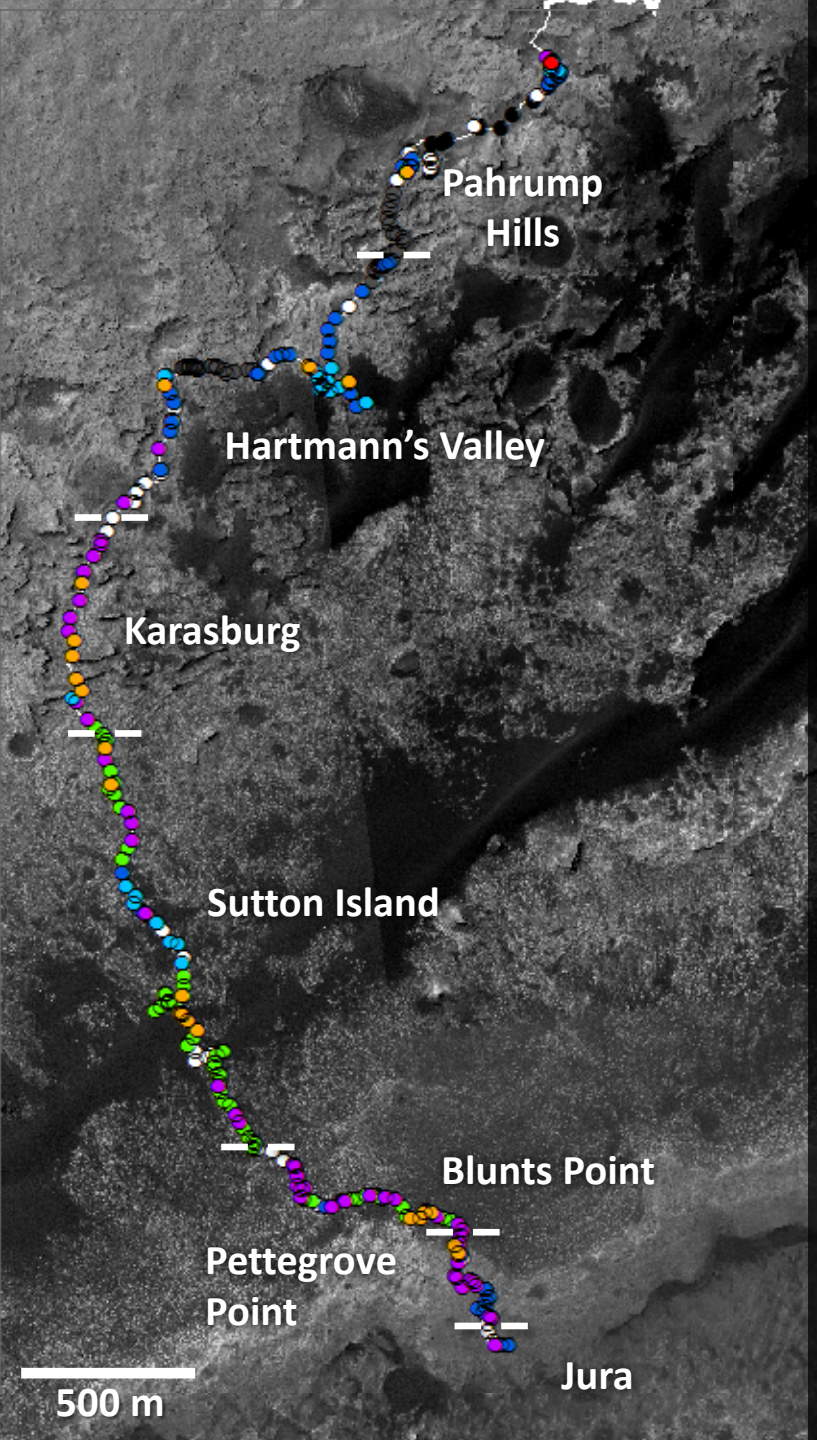
Concretion formed before compaction

Concretion formed during compaction

Figure 8, Selles-Martinez 2001



Lash and Blood, 2004 Chemical Geology

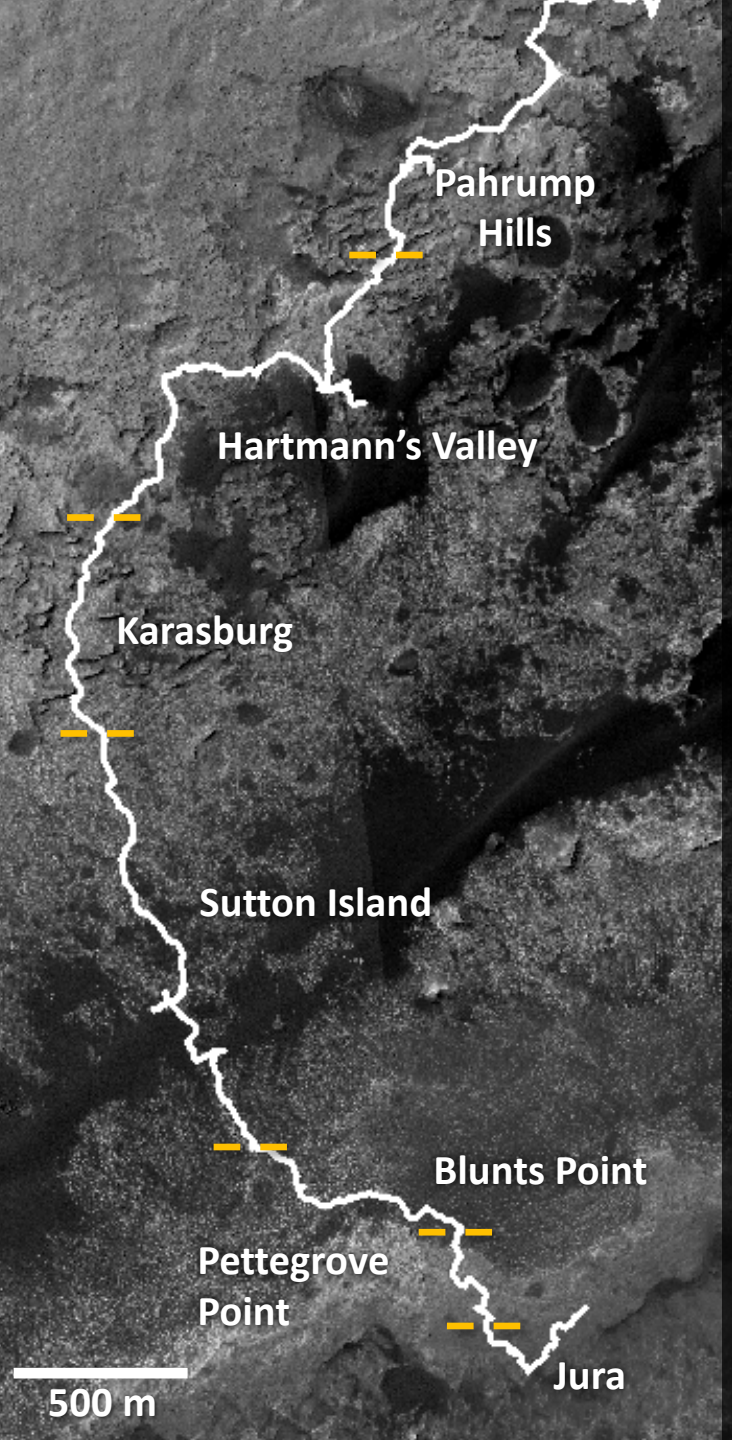


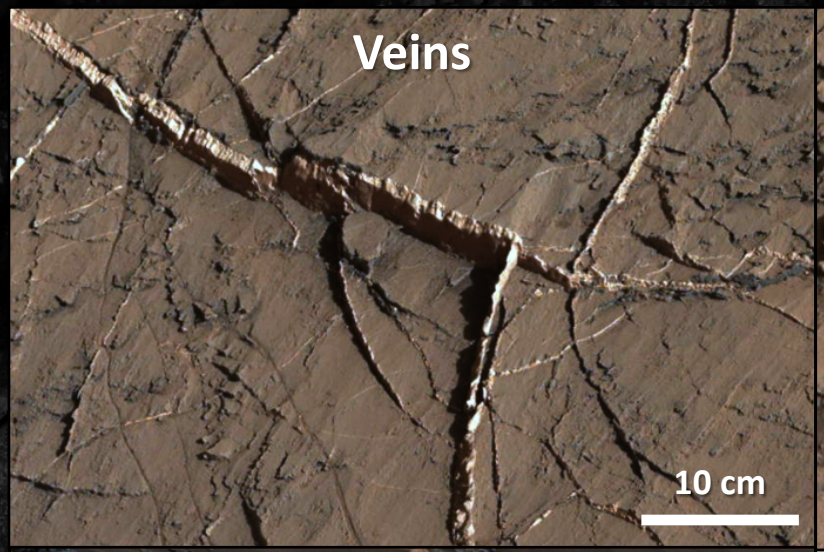
Summary of Concretion Results

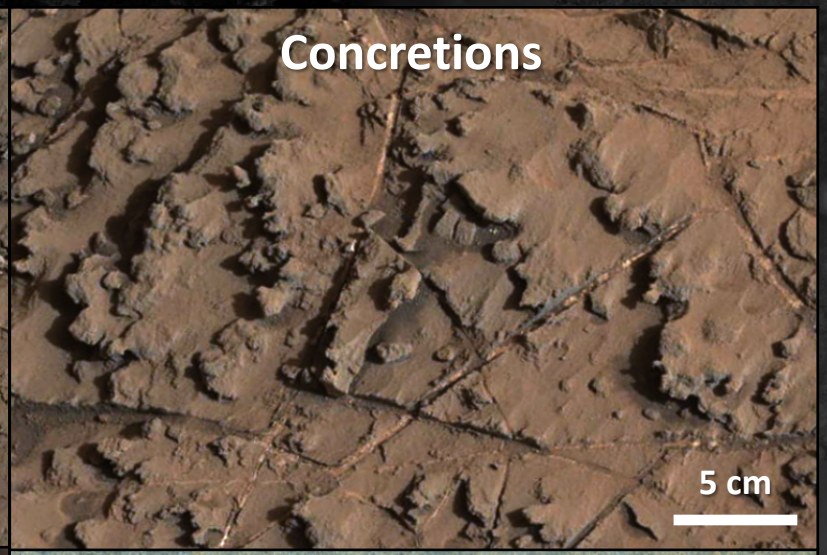
- 3+ fluid episodes formed these concretions, based on:
  - Morphologic diversity (varying sediment/rock conditions)
  - 3+ families of chemical enrichments
  - At least two distinct size populations
- Concretions formed during late diagenesis after compaction and lithification, based on:
  - Preservation of primary laminations; no differential compaction
  - Smallest concretions in ridge-forming units indicate formation after initial ridge cementation
- Late diagenetic concretions with chemical enrichments → allows constraints on late fluid chemistries:
  - Implications for extending potentially habitable conditions, perhaps even after Gale lake
  - Changes in chemistry might allow us to probe changes in martian climate/environment

Future Work

We see a lot of other diagenetic features in the Murray fm. How are they related in time? What is the full diagenetic history?







Murray Fm. Observations

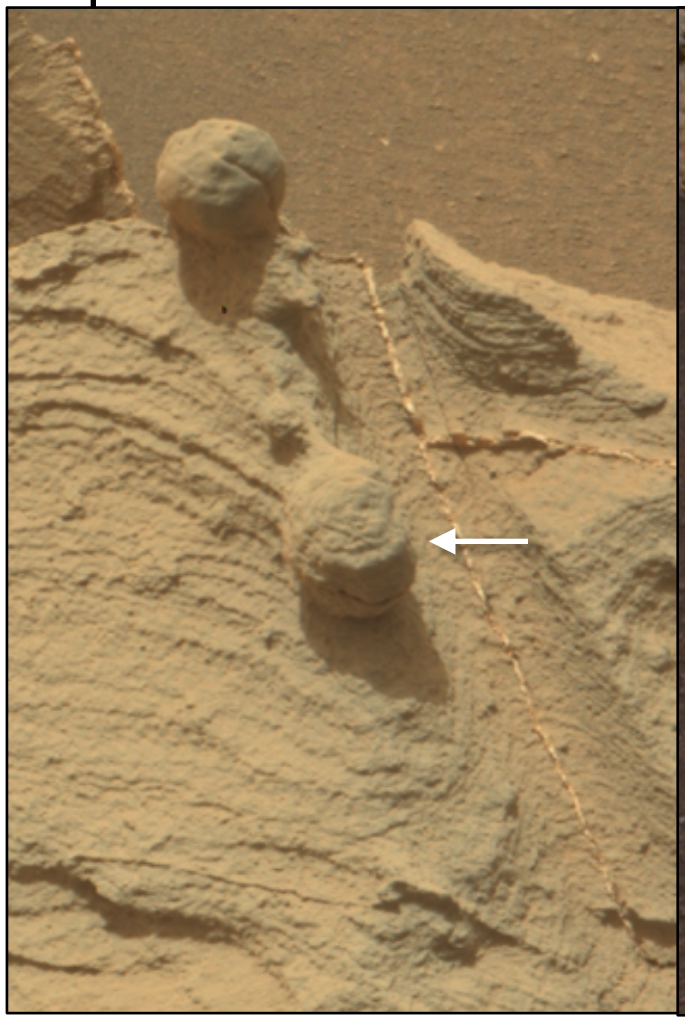
A. Initial ridge cementation

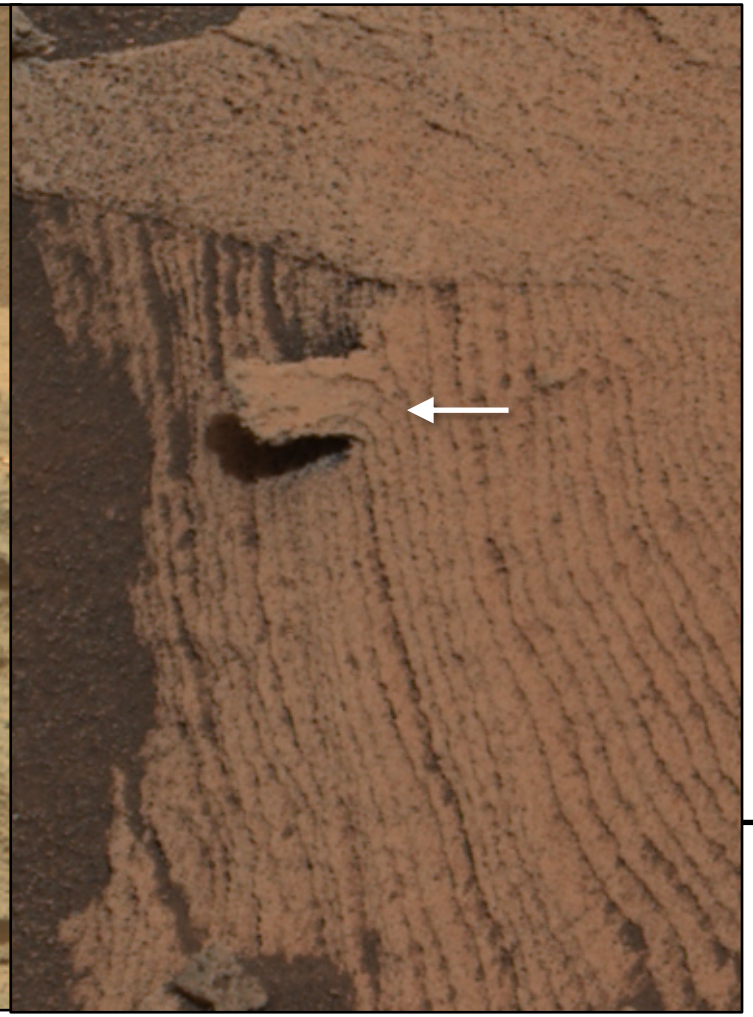
B. Late-diagenetic concretions

Possible Diagenetic Timeline →

? ?

? ← Multiple events → ?





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Stimson Fm. Observations

H. Alteration halos (Yen et al., 2017; Frydenvang et al., 2017)

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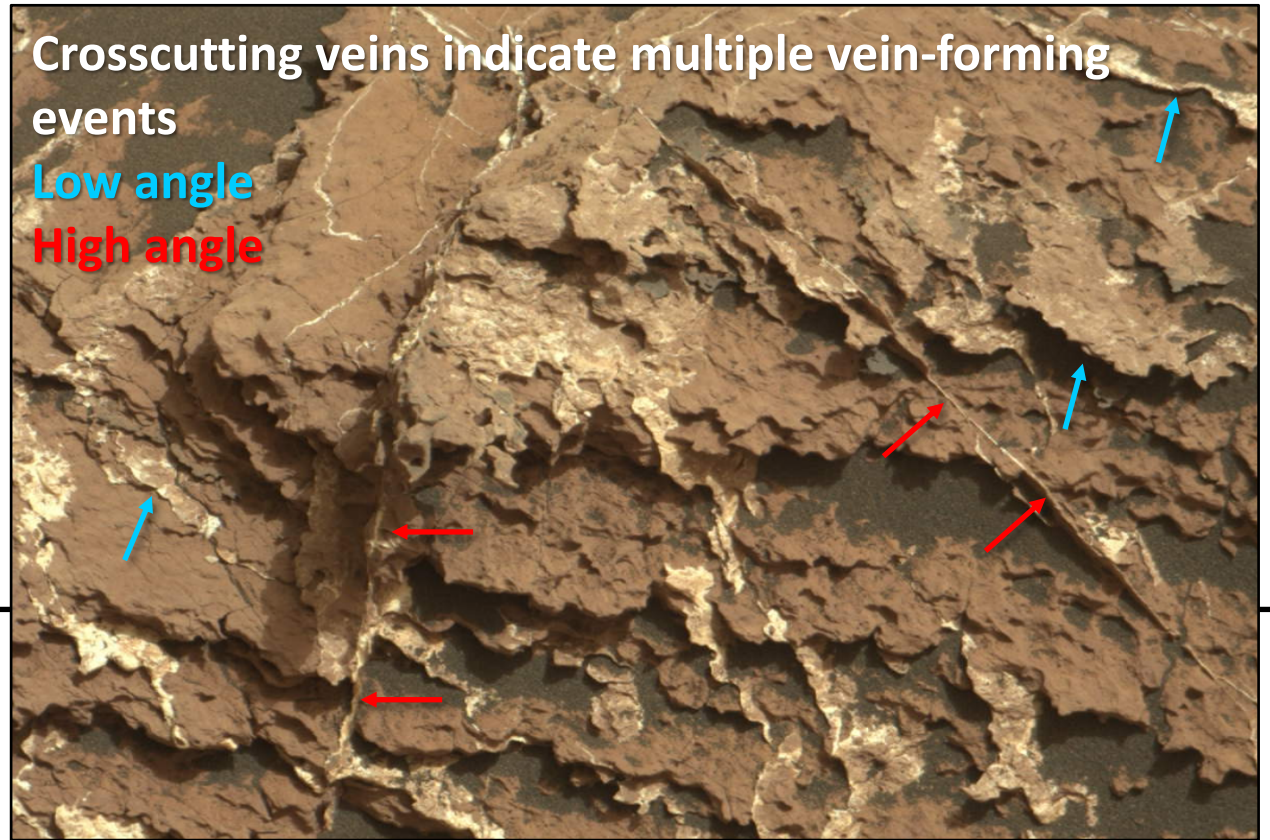

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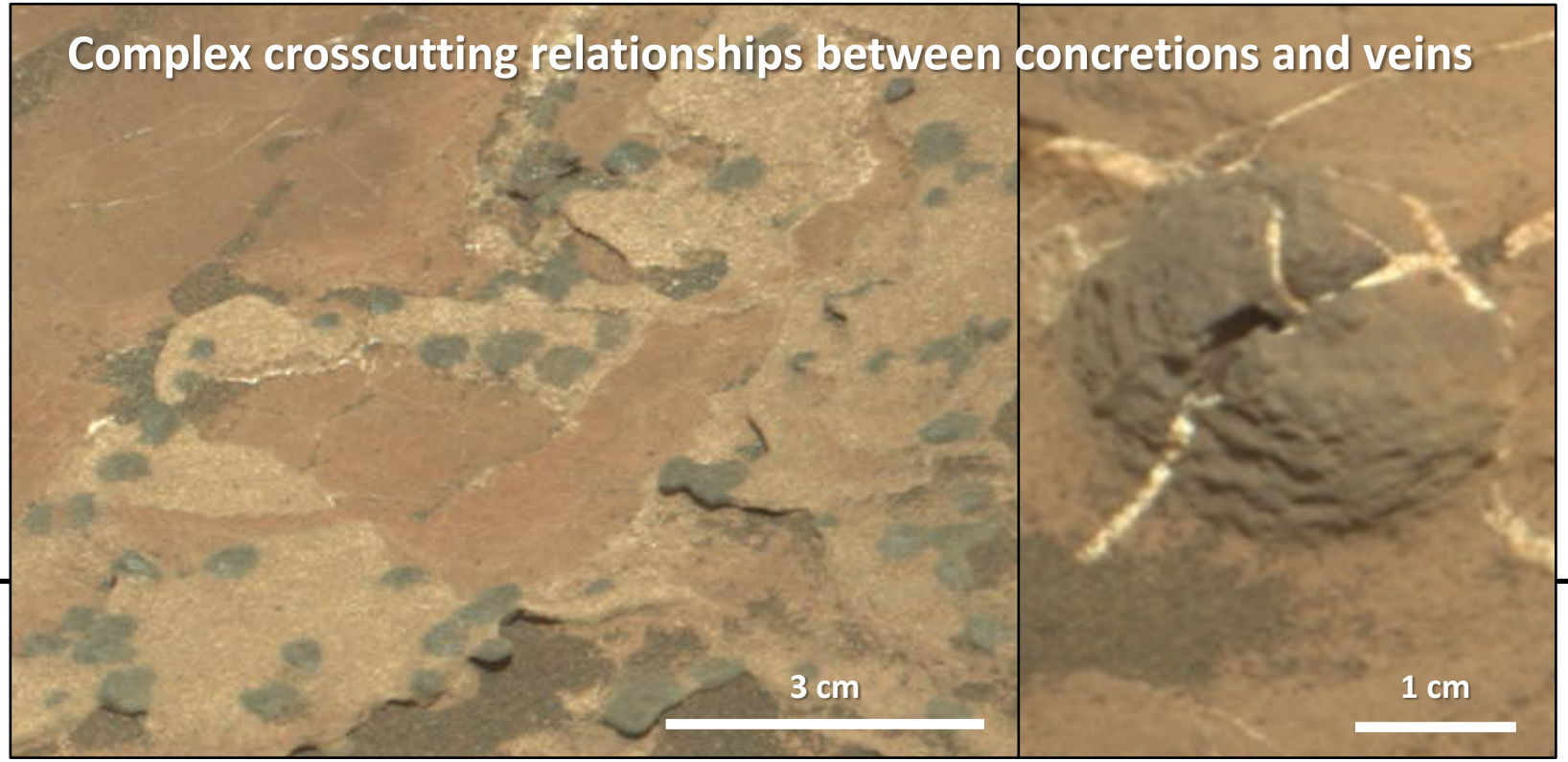

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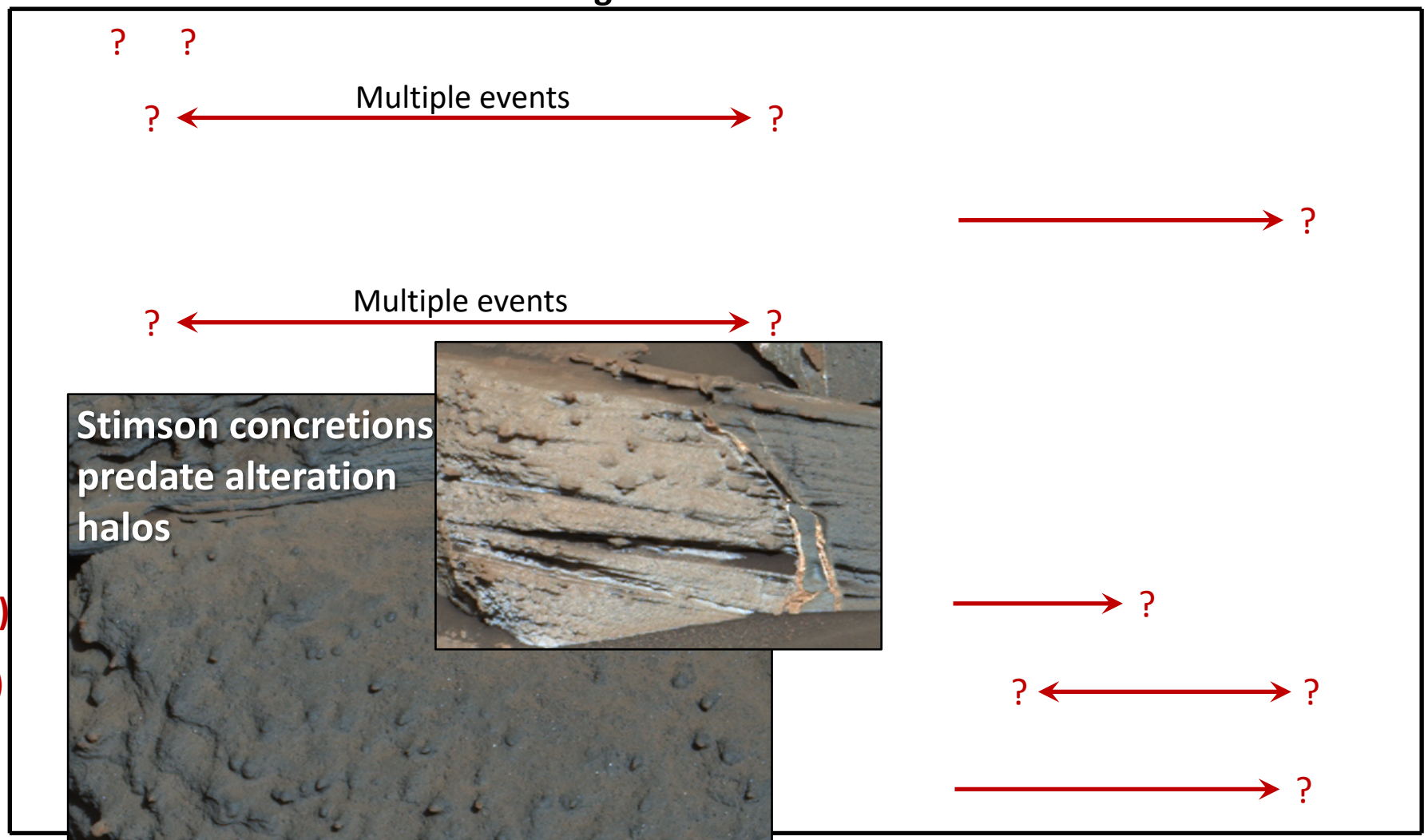
Stimson Fm. Observations

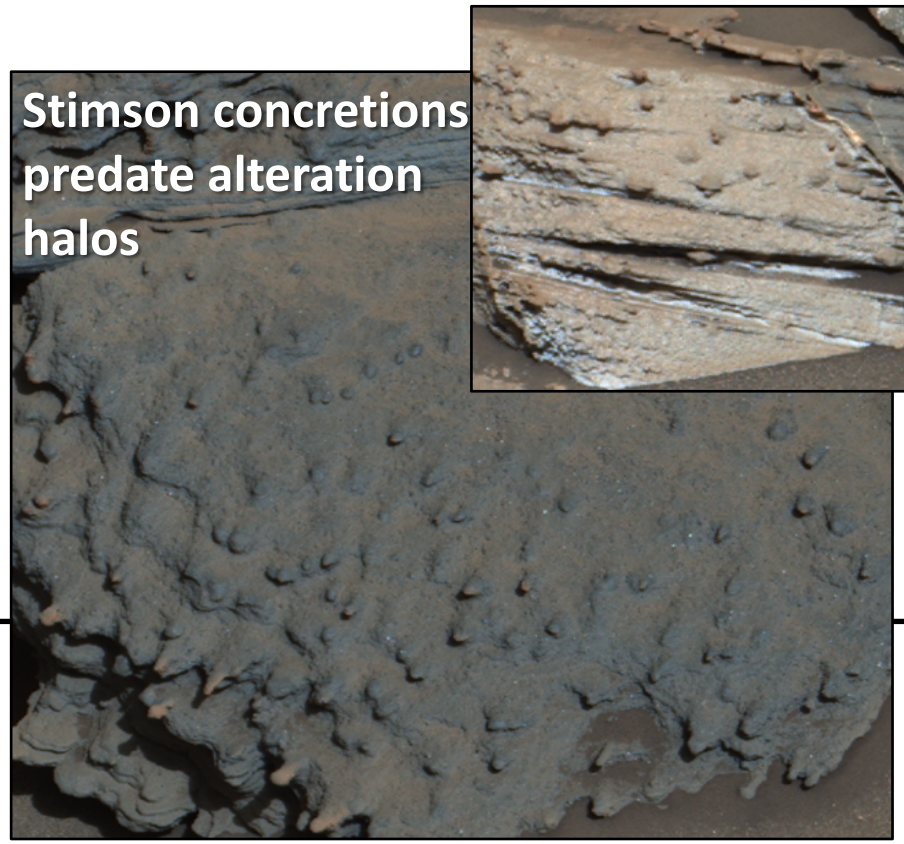
F. Concretions (Hurowitz et al., 2017)

G. Ca-sulfate veins (Nachon, in prep)

H. Alteration halos (Yen et al., 2017; Frydenvang et al., 2017)

Possible Diagenetic Timeline →





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Stimson Fm. Observations

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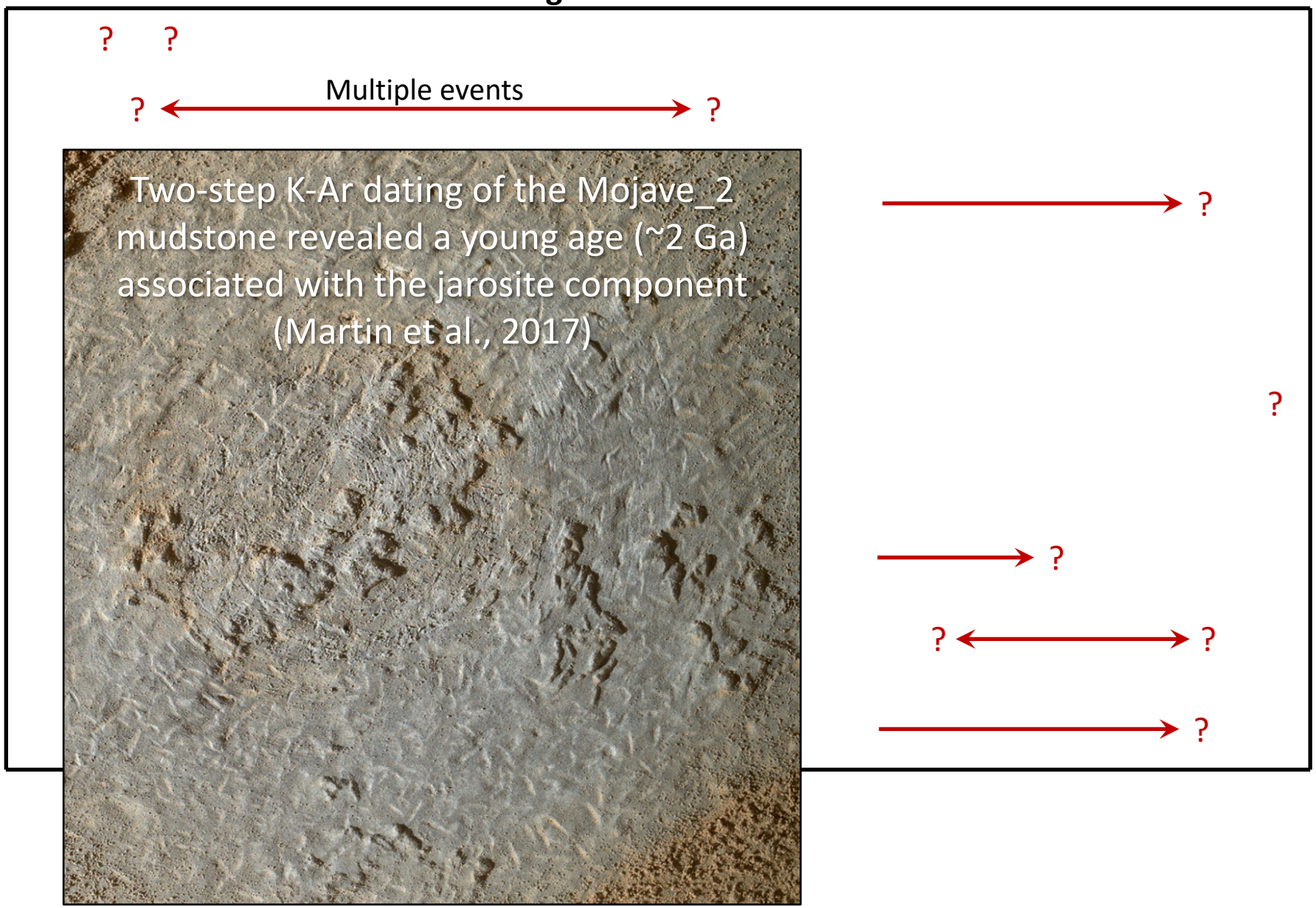

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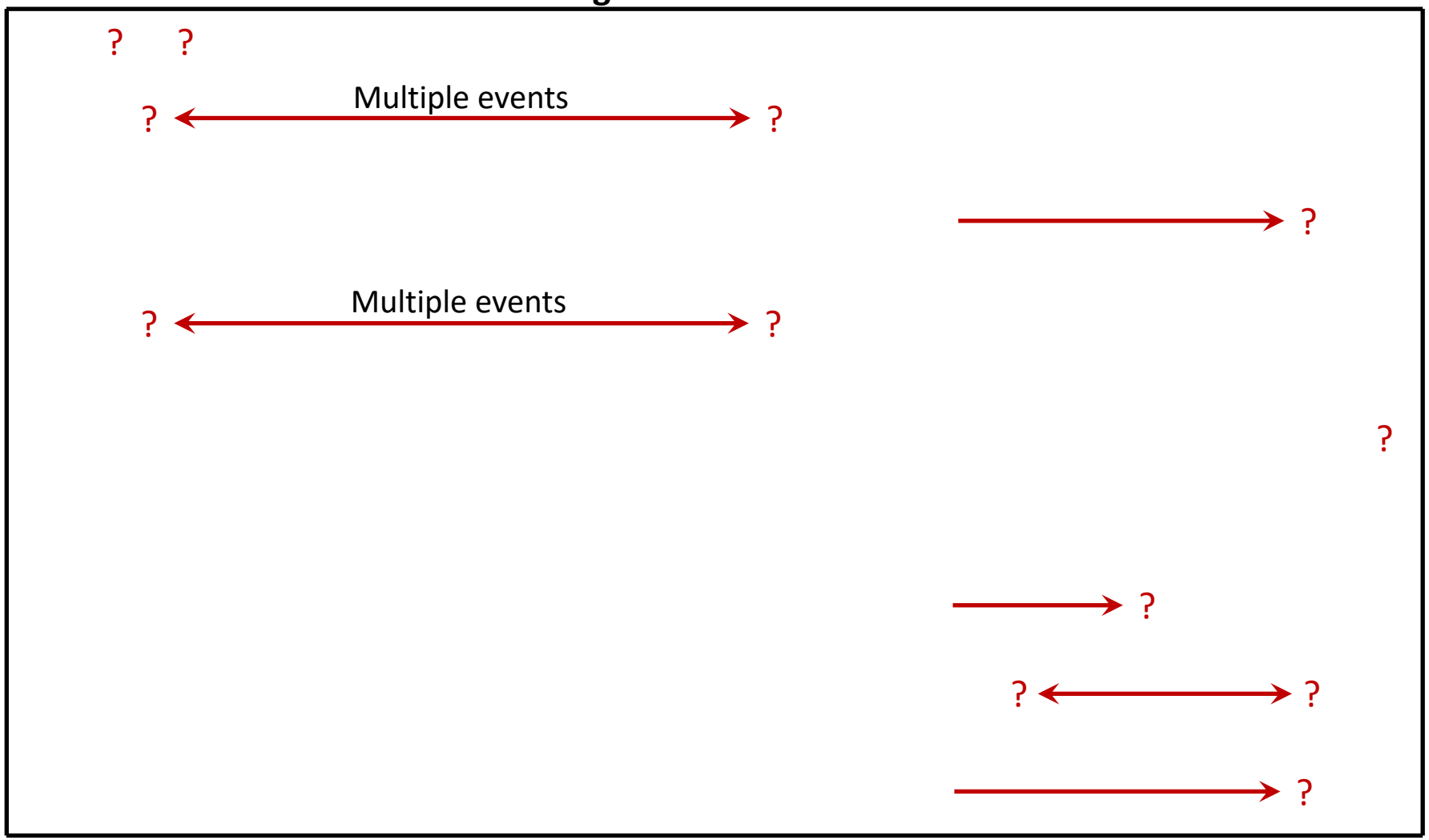

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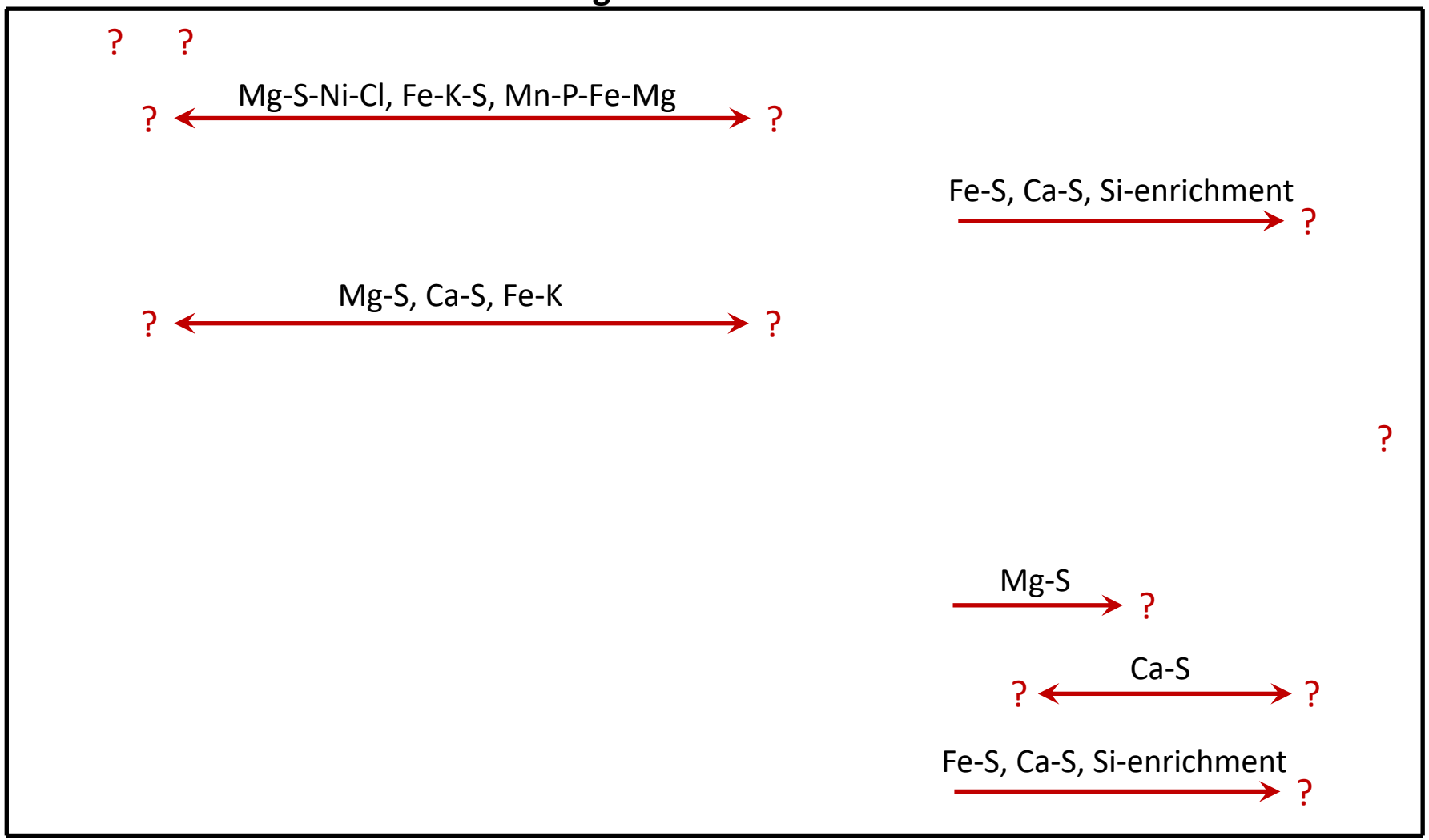
F. Concretions (Hurowitz et al., 2017)

G. Ca-sulfate veins (Nachon, in prep)

H. Alteration halos (Yen et al., 2017; Frydenvang et al., 2017)

Possible Diagenetic Timeline →



Thank you!

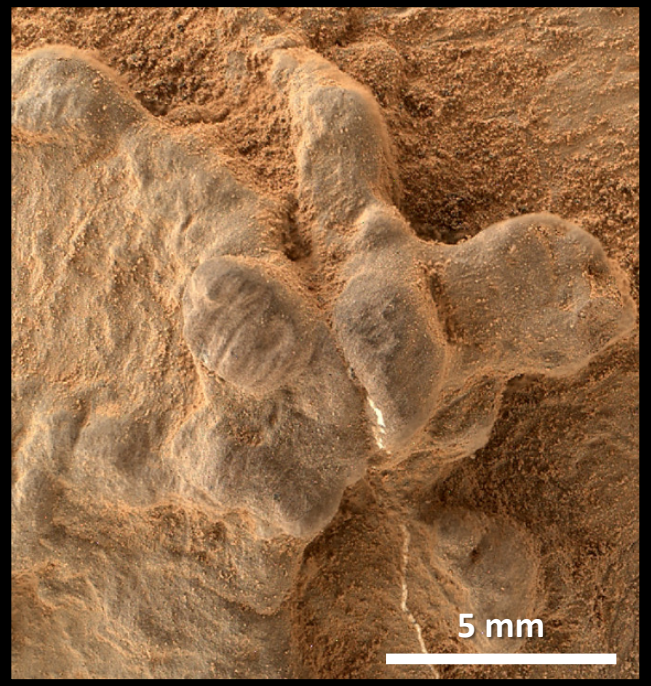
Questions?

Jet Propulsion Laboratory
California Institute of Technology

Backup Slides

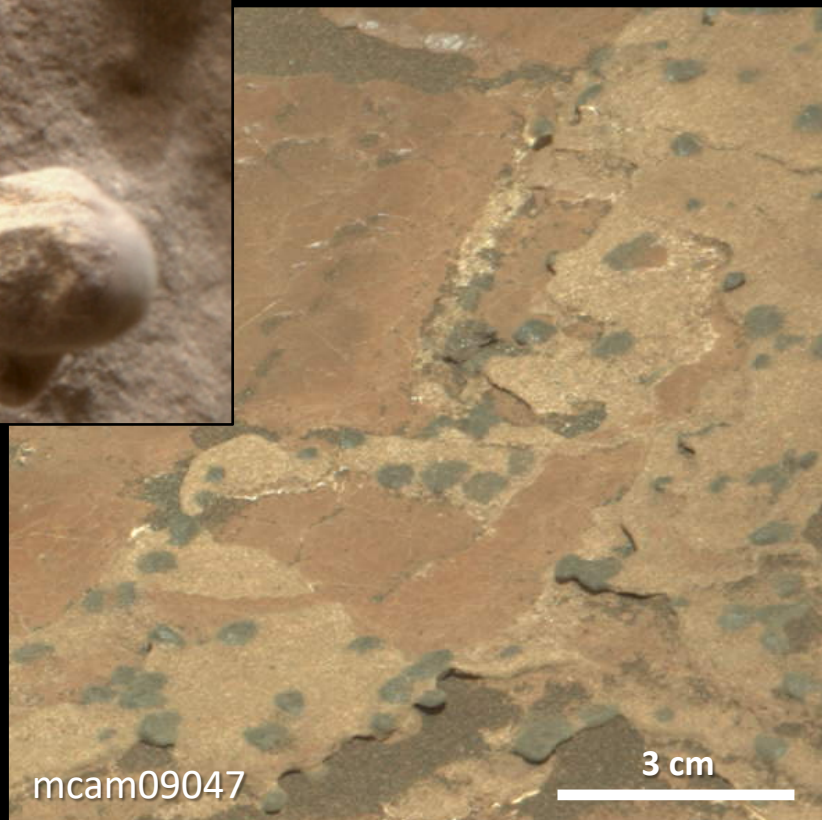
Evidence for Multiple Diagenetic Episodes

Concretions are sometimes positively correlated with veins and may have formed concurrently or postdate vein formation.



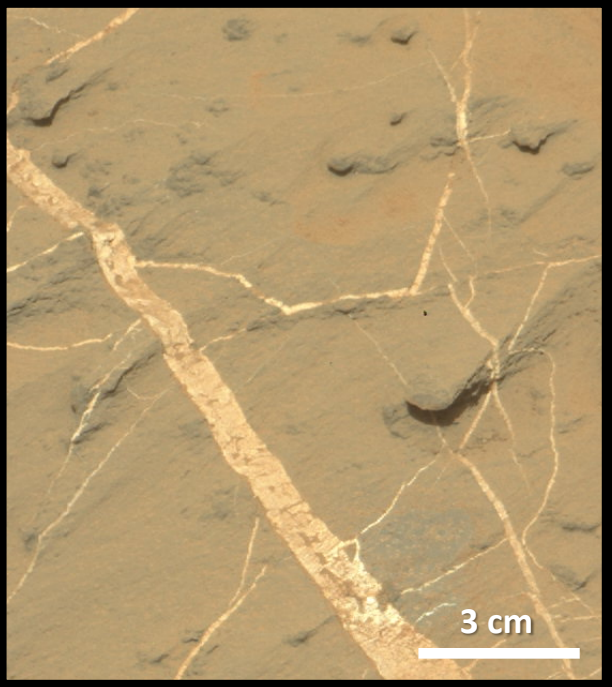
Moenkopi, MAHLI 2cm

Andulo, MAHLI 2cm



Evidence for Multiple Diagenetic Episodes

Concretions can also be crosscut by veins or antithetical with veins, suggesting vein formation after the concretions.



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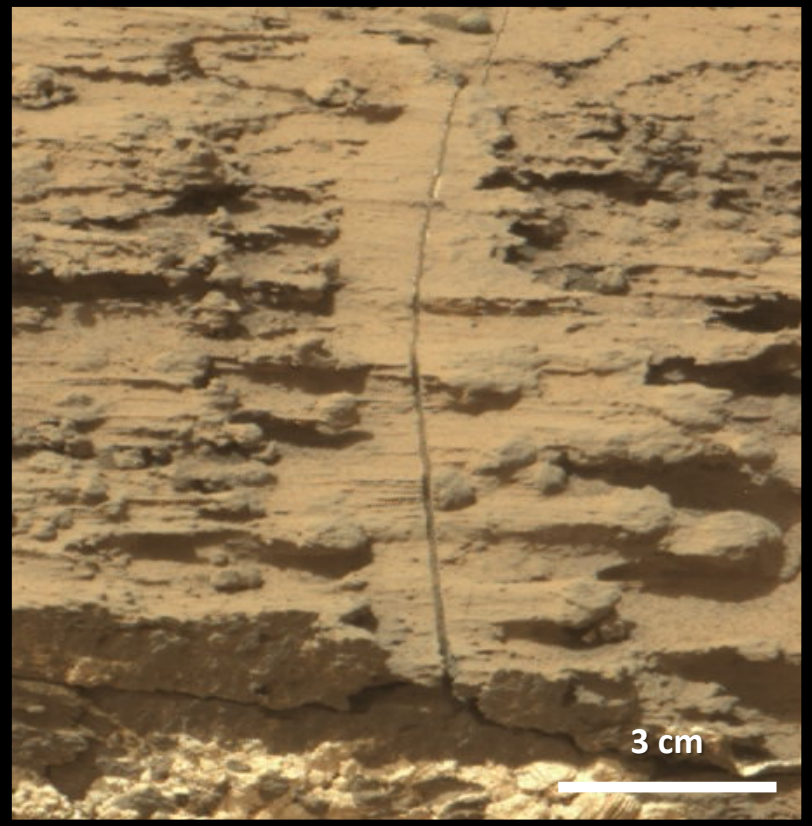

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