# Evidence for Habitability in Gusev Crater

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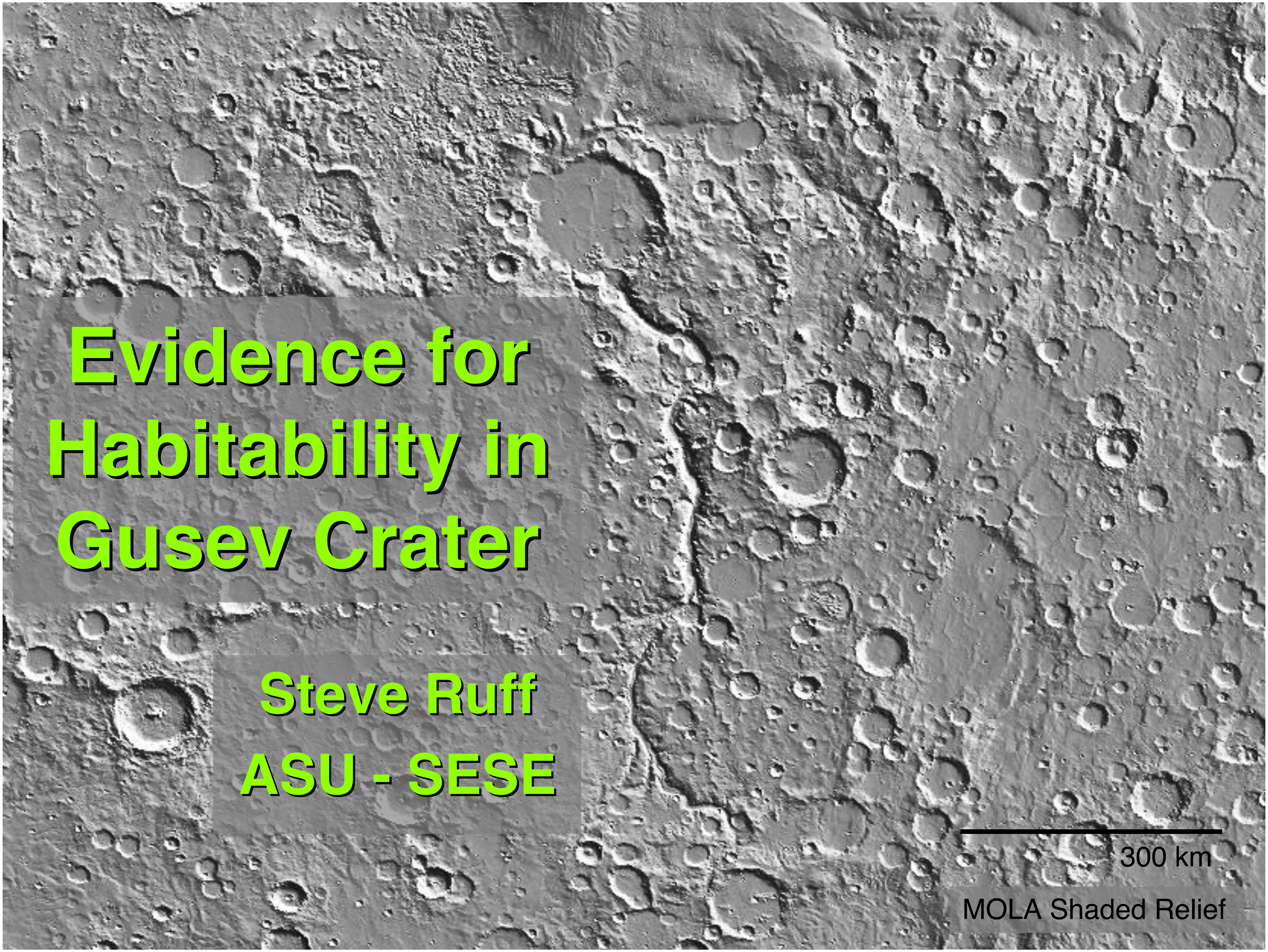
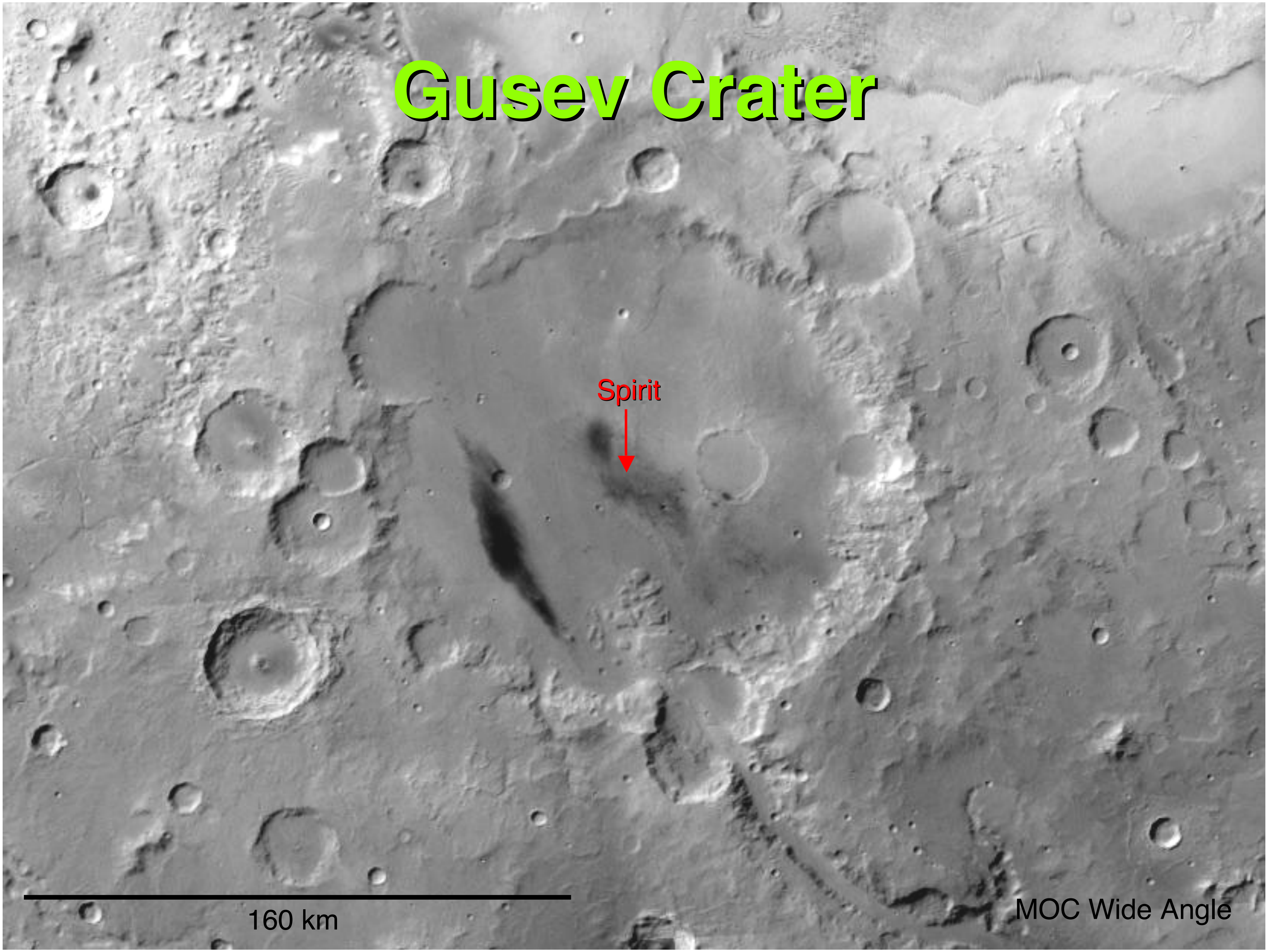
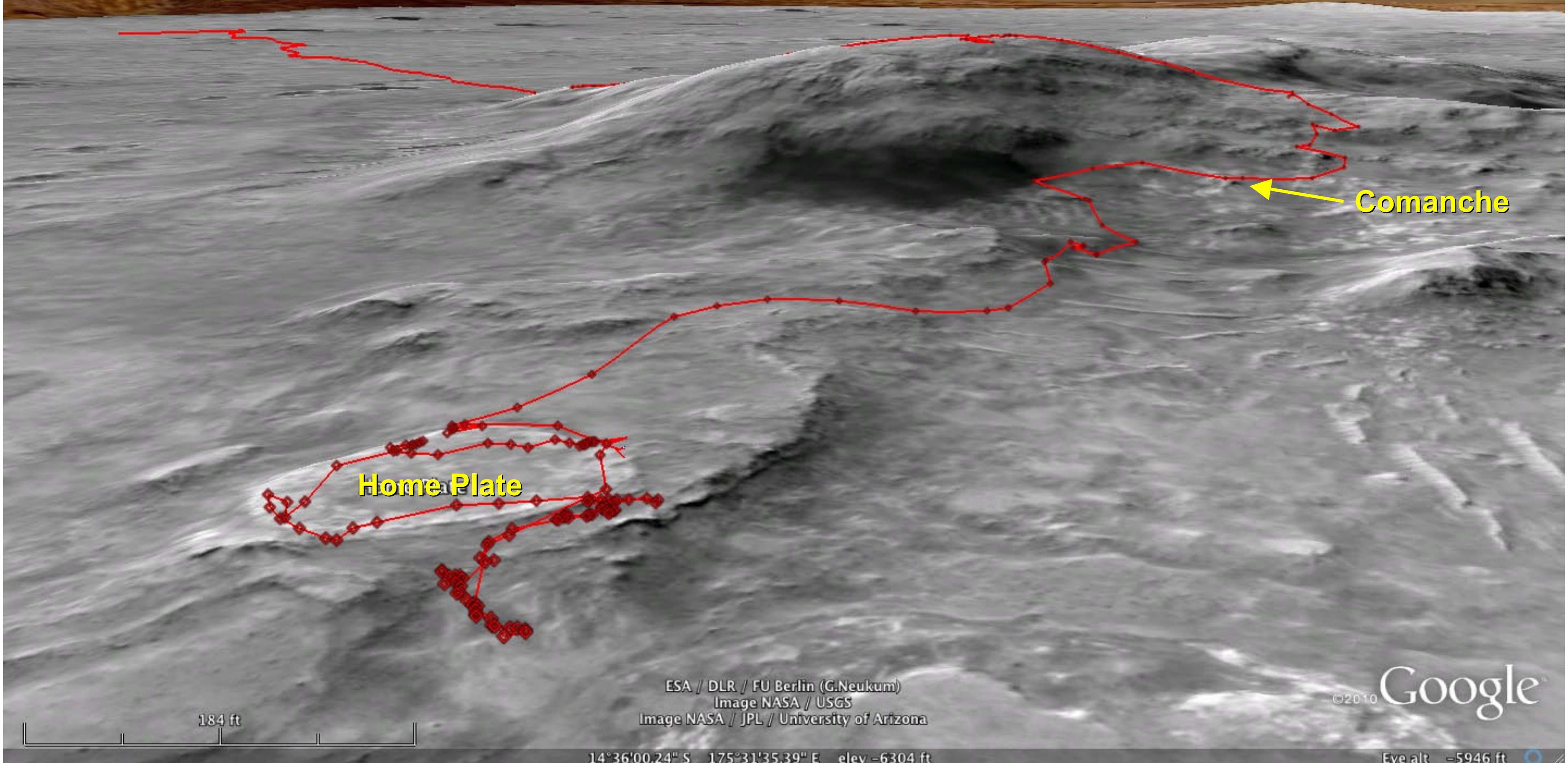
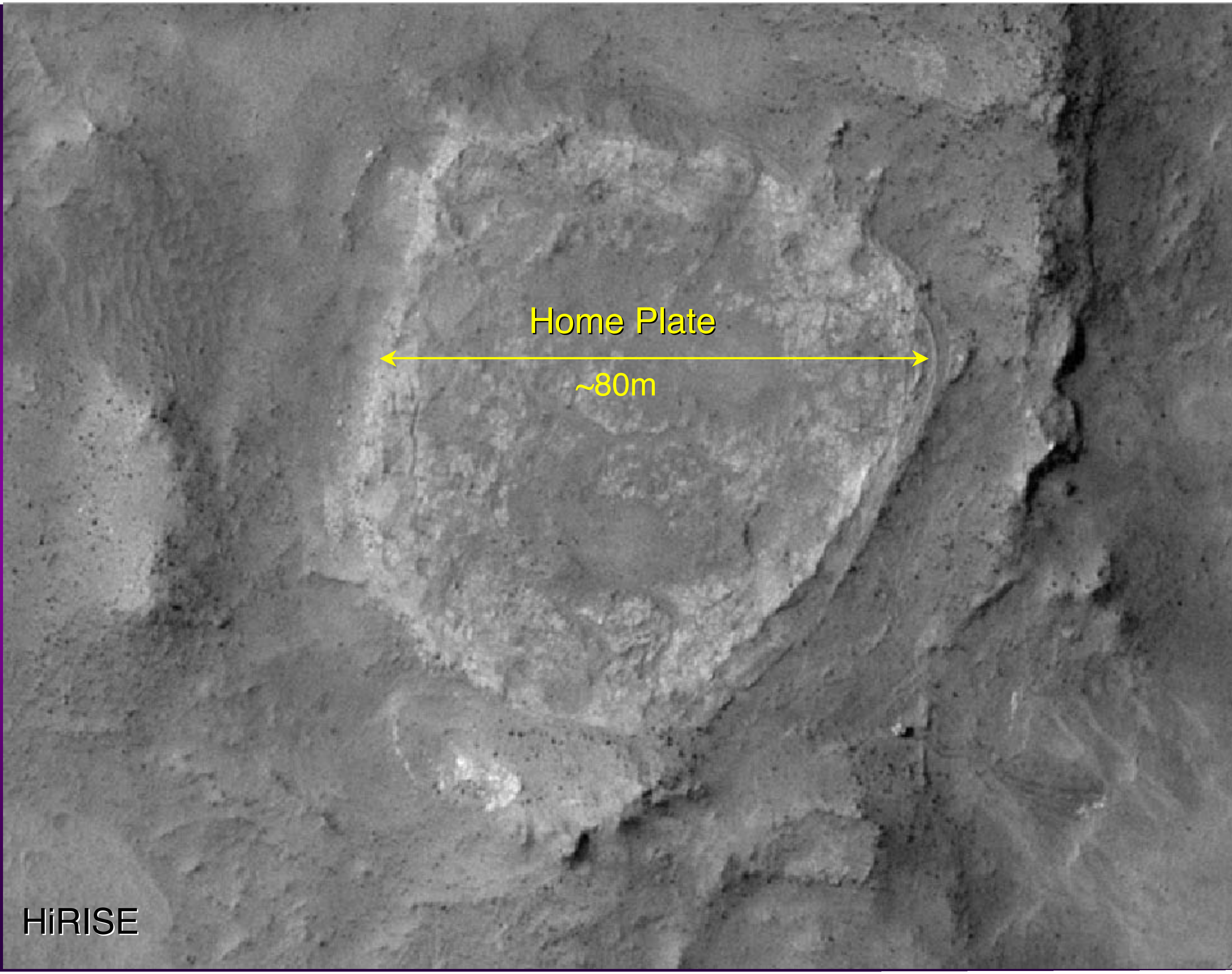



Gusev Crater
Spirit
160 km
MOC Wide Angle

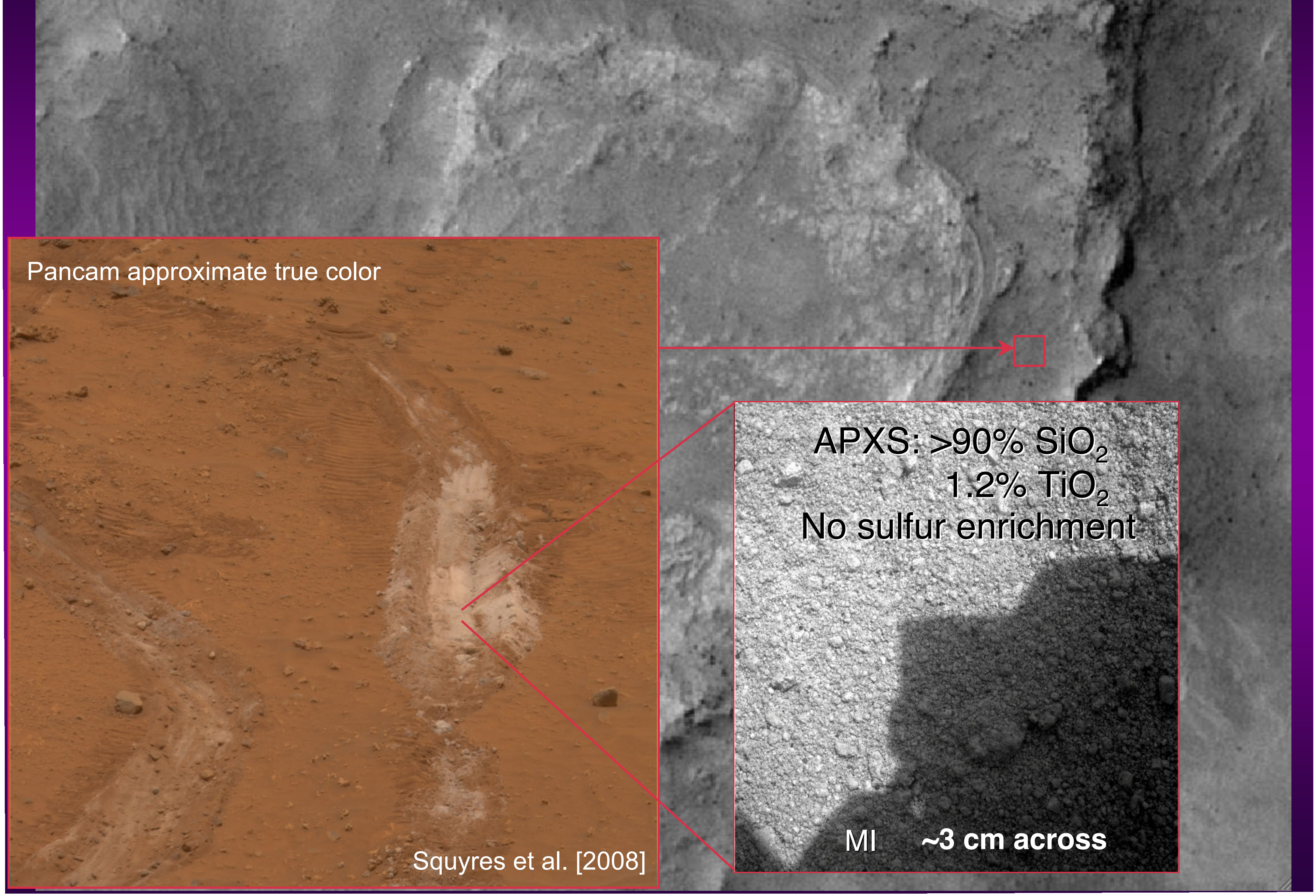
# Overview



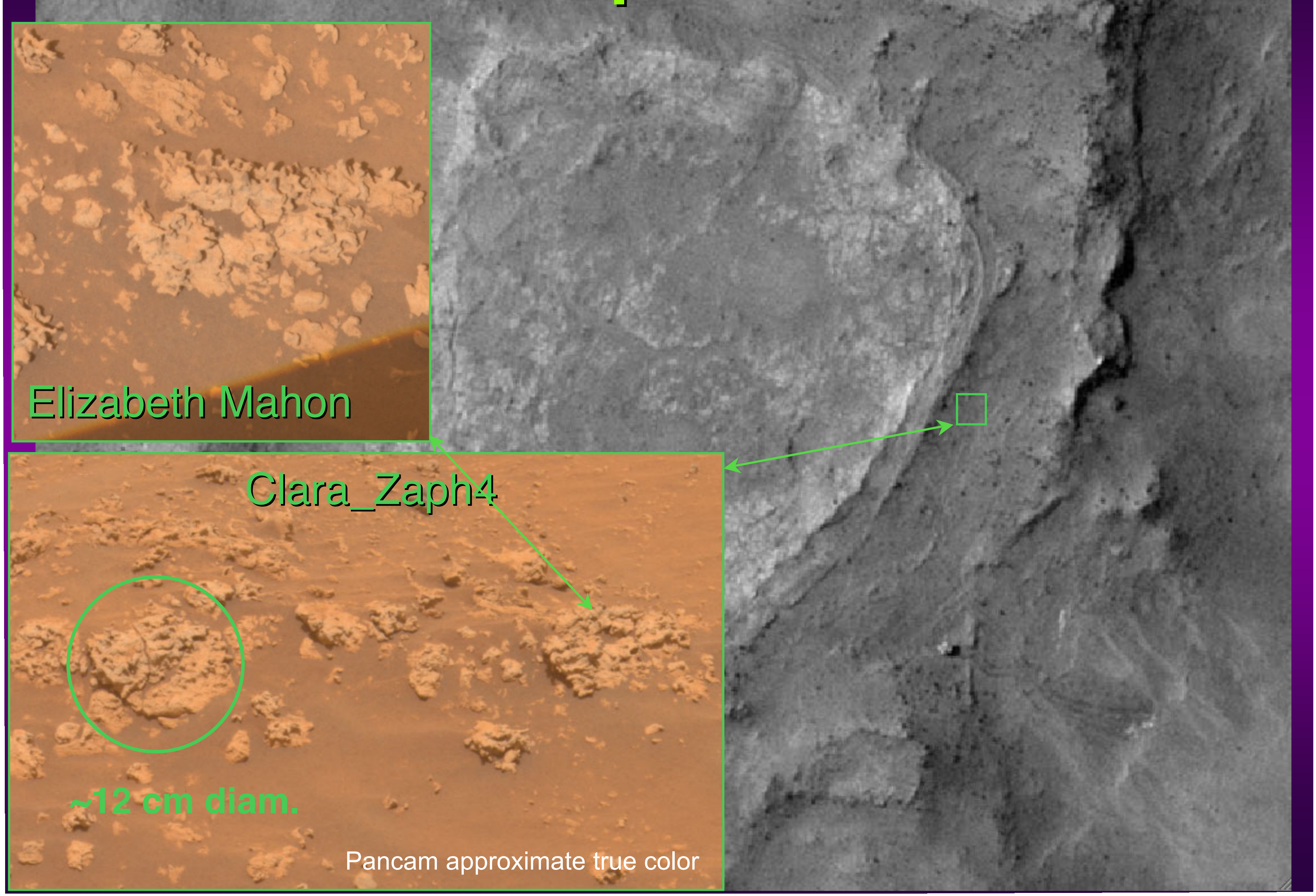

- Spirit identified two locations with clear evidence for abundant water
- Opaline silica (up to 92 wt%) occurs in outcrops and soil adjacent to "Home Plate"
- "Comanche" outcrops contain ~25 wt% Mg-Fe carbonate(s)


Home Plate
~80m
HiRISE

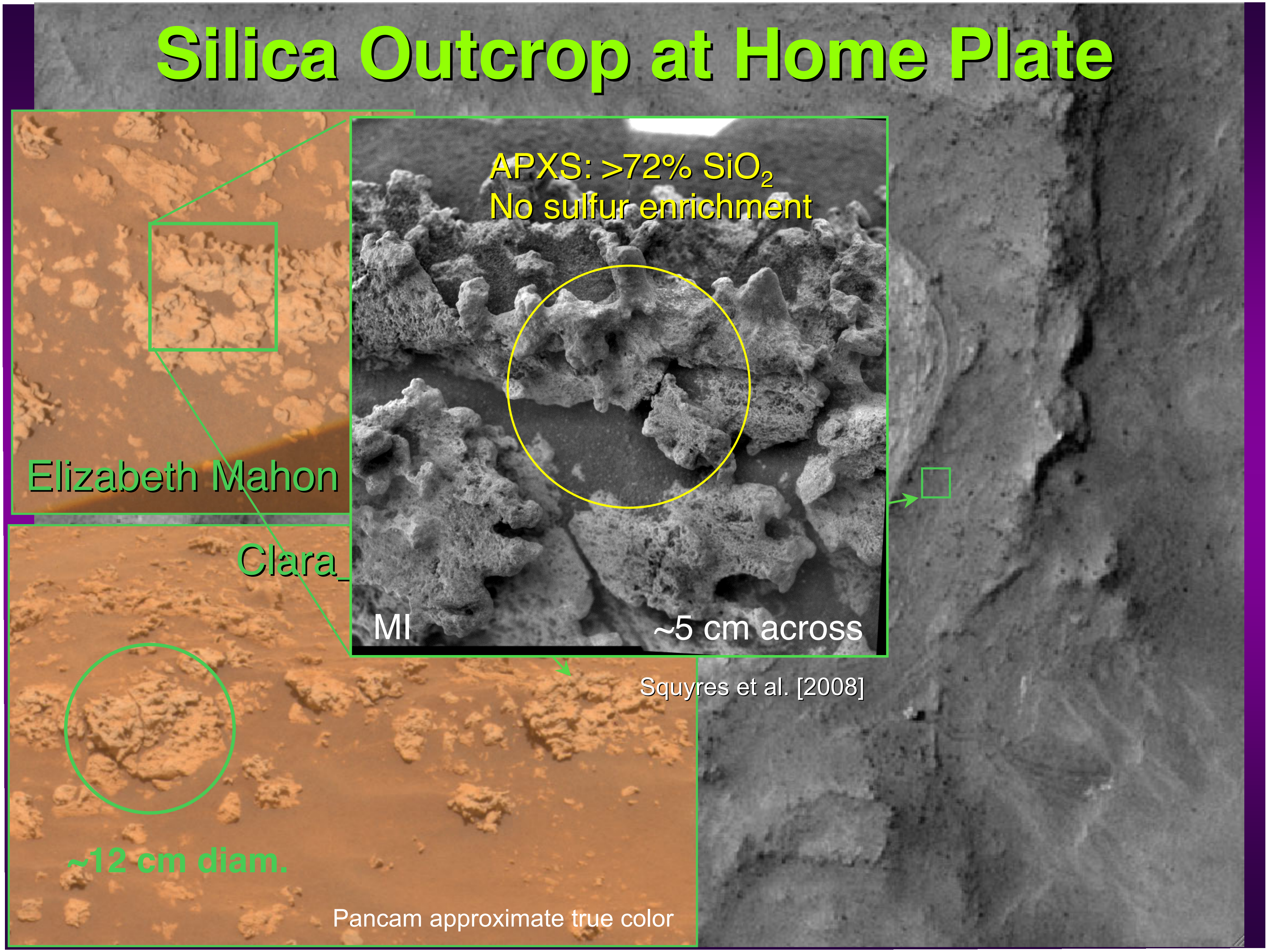
# Silica Soil at Home Plate



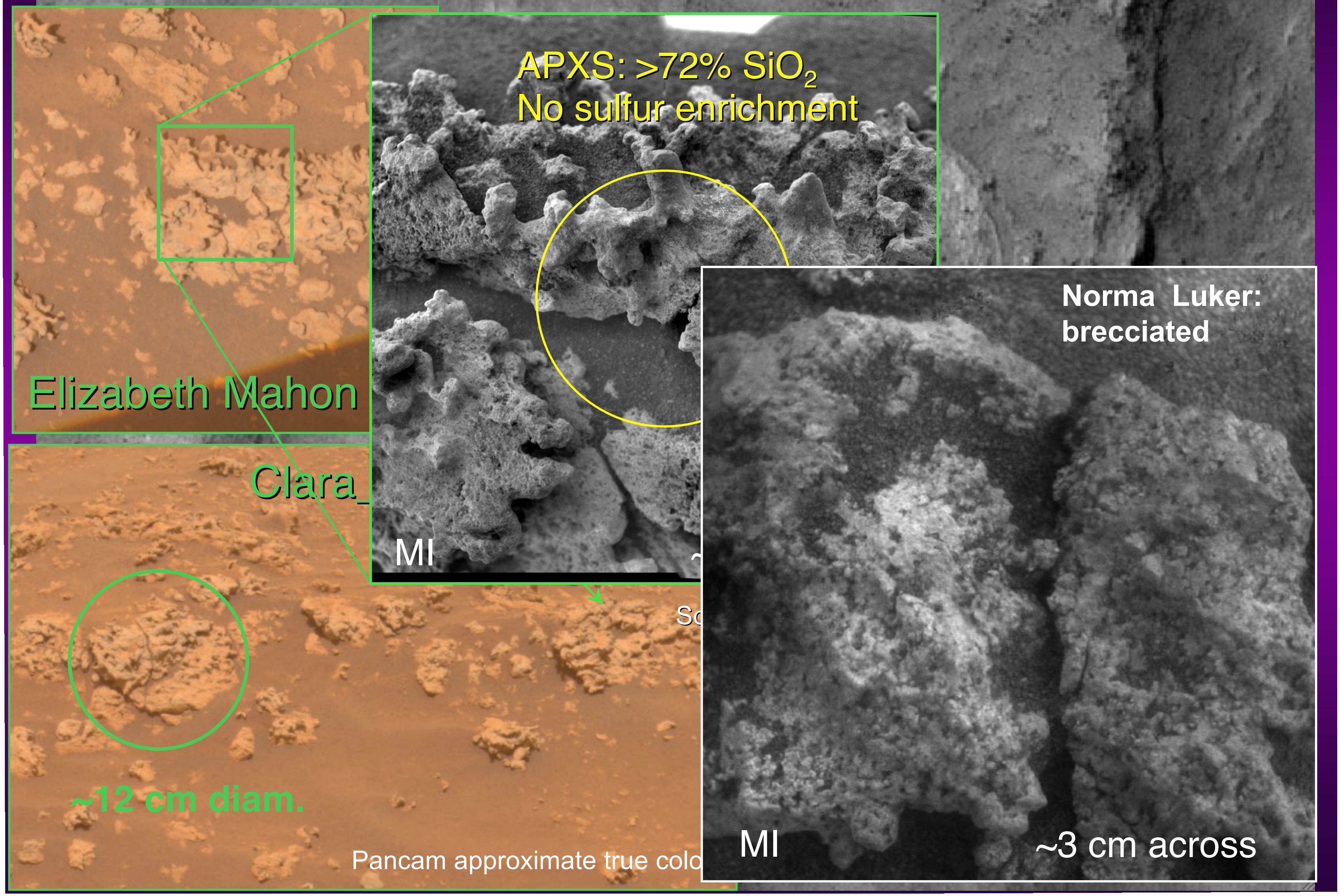
# Silica Outcrop at Home Plate



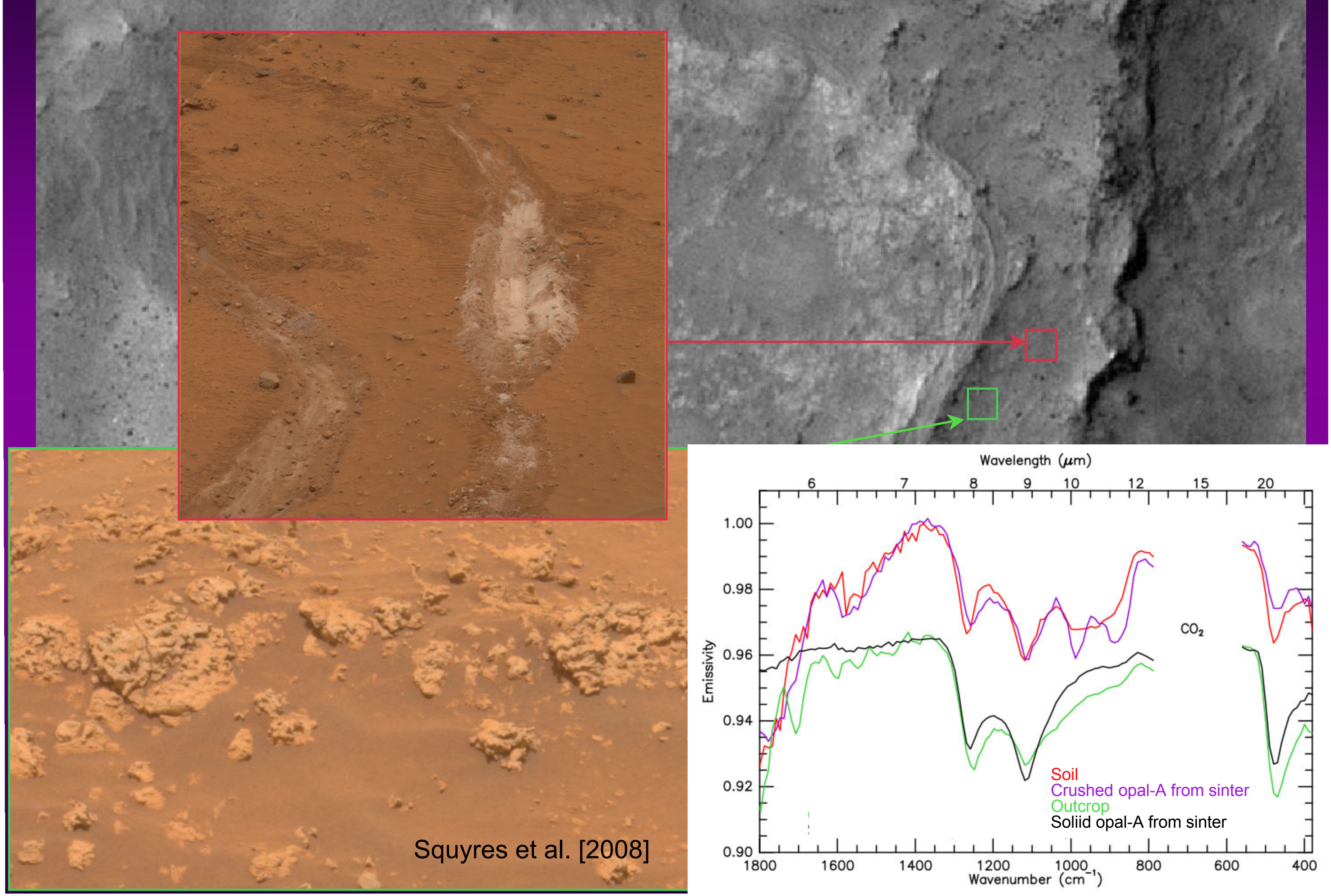
# Silica Outcrop at Home Plate



# Silica Outcrop at Home Plate

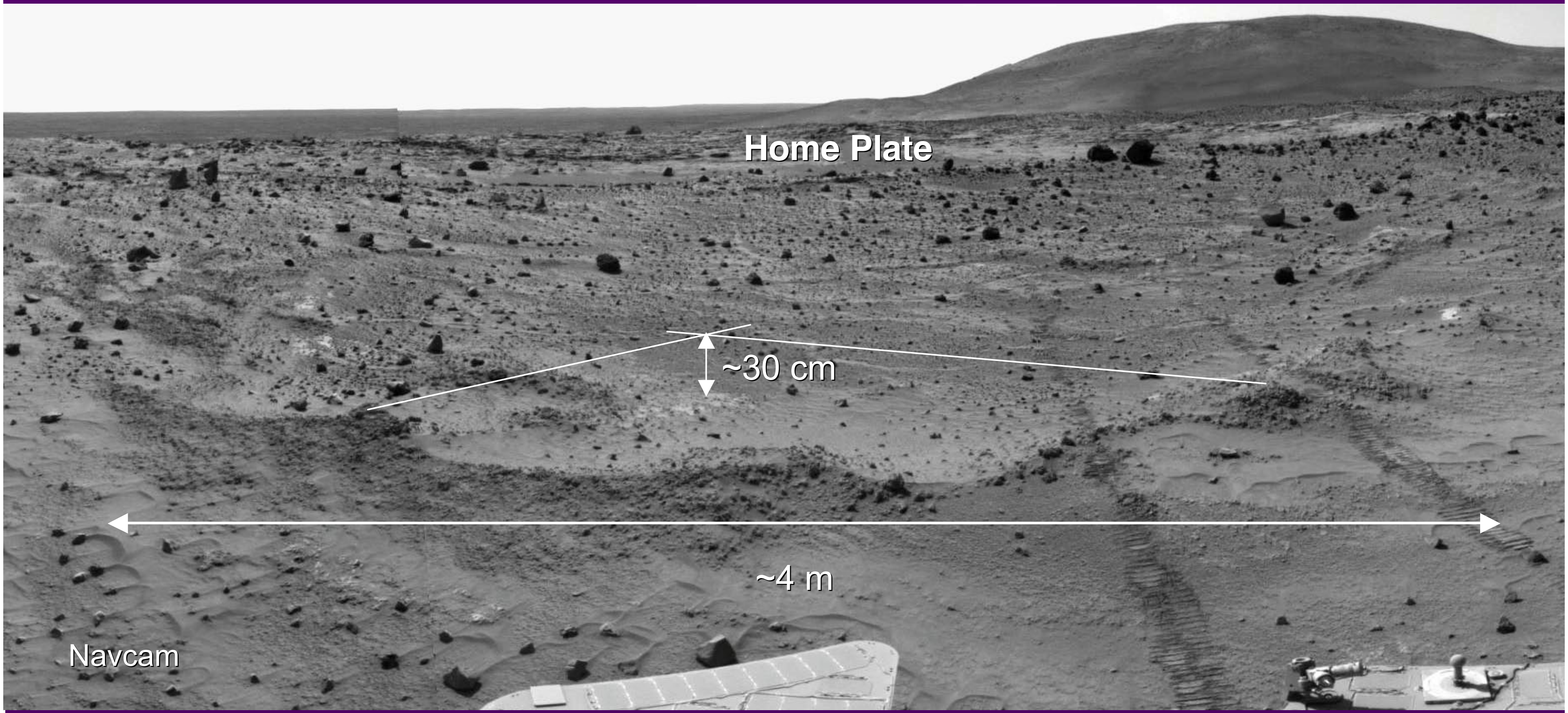


# *Opaline* Silica at Home Plate

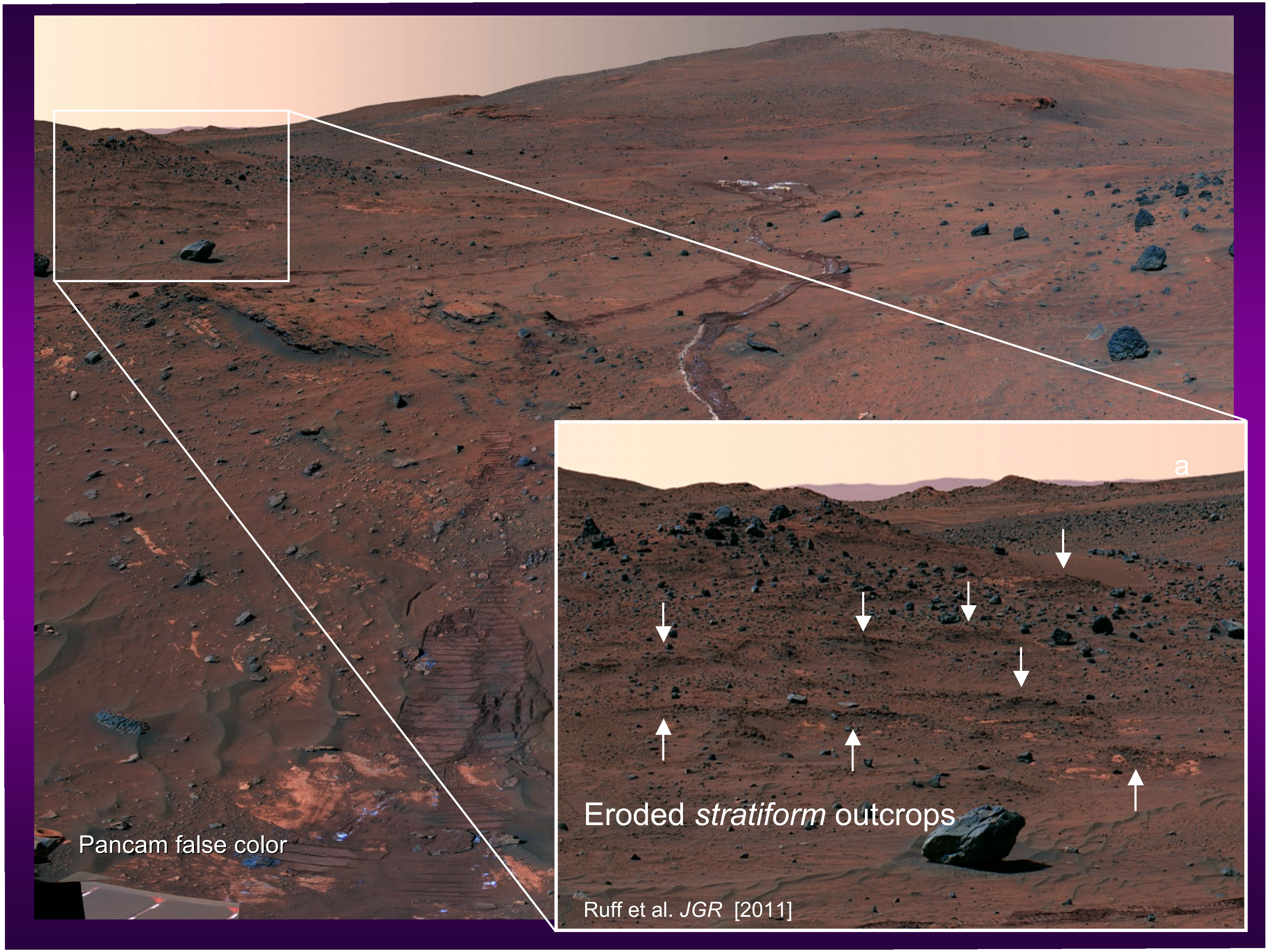



Squyres et al. [2008]

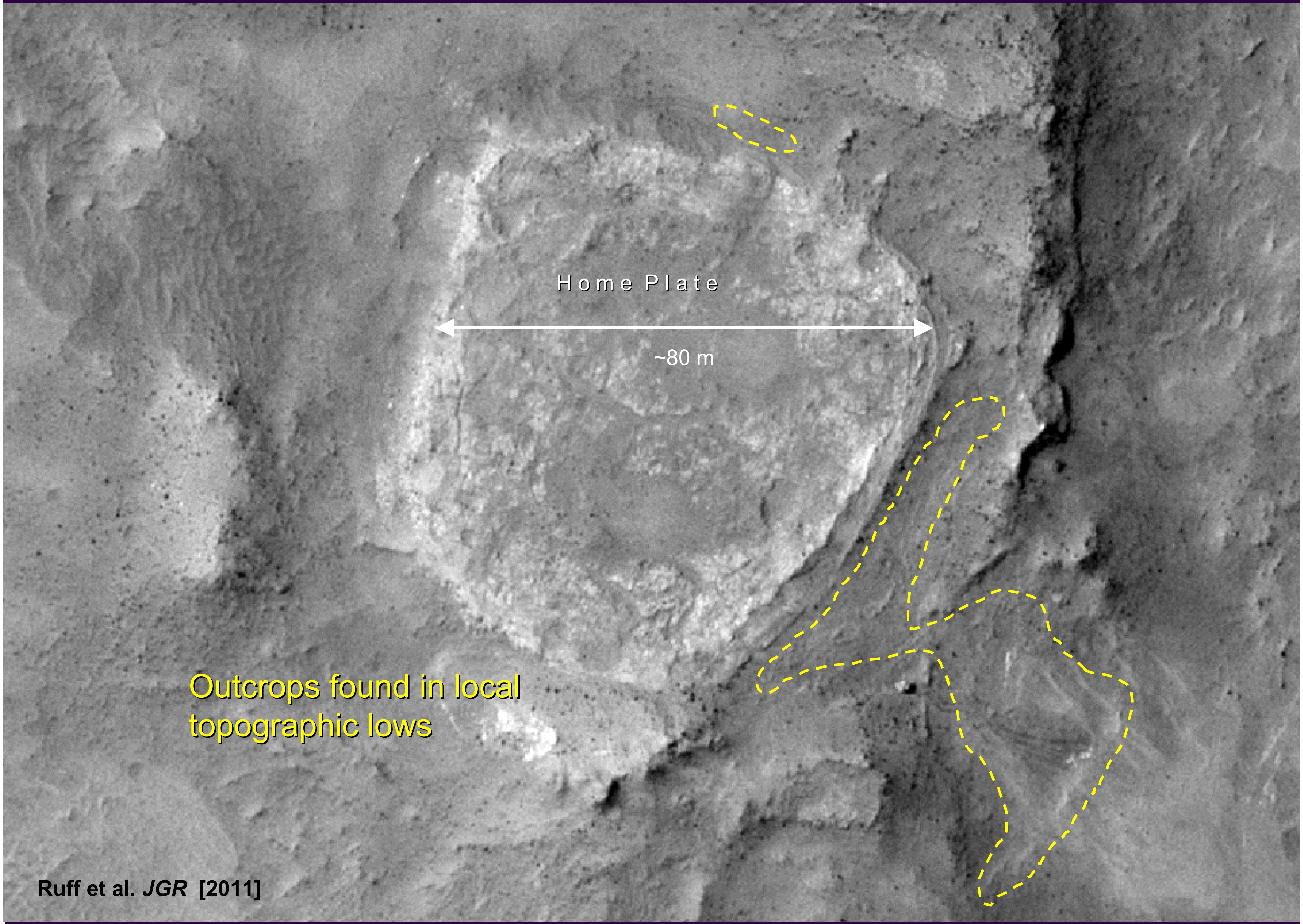
# *Outcrop* Characteristics




Ruff et al. *JGR* [2011]



Pancam false color
a
Eroded *stratiform* outcrops
Ruff et al. *JGR* [2011]



Home Plate
~80 m
Outcrops found in local topographic lows
Ruff et al. JGR [2011]

# Origin Hypotheses

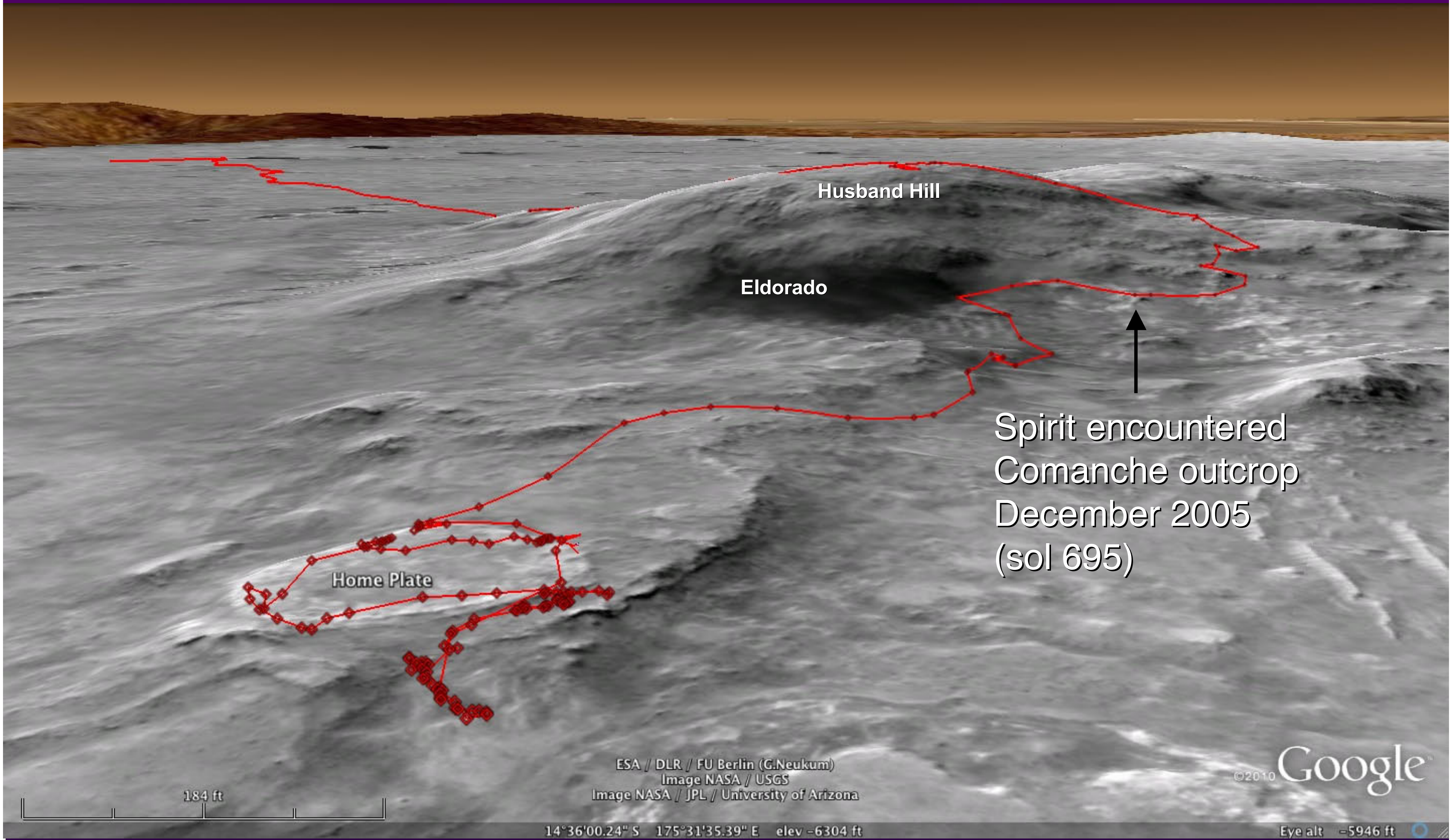

Hot spring sinter:
Consistent with stratiform outcrops, porous and brecciated textures, and lack of sulfur enrichment

**Both are habitable environments on Earth**

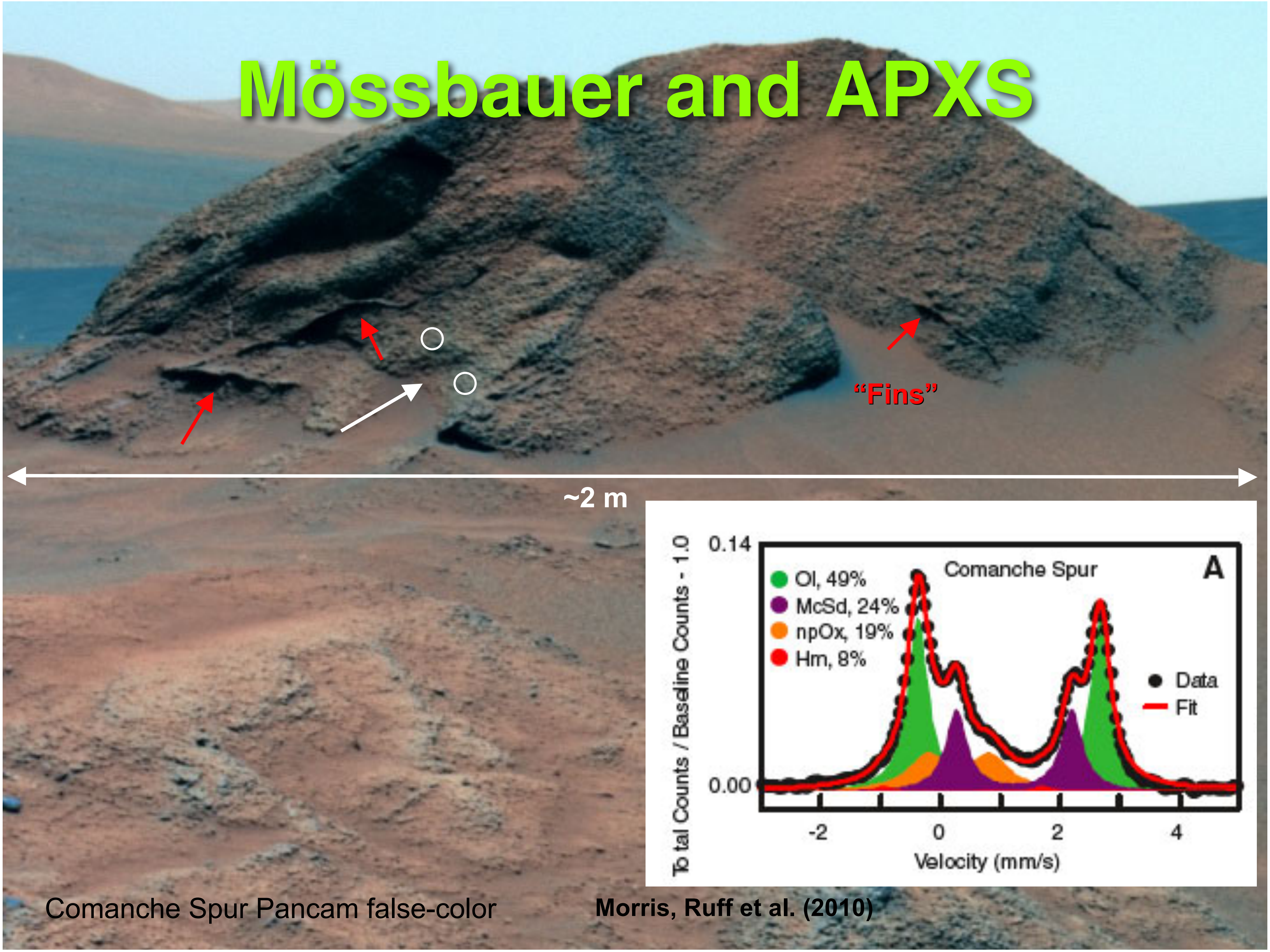

**Fumarolic silica residue**:
*Inconsistent* with stratiform outcrops and lack of sulfur enrichment

Ruff et al. *JGR* [2011]

# Comanche Carbonate

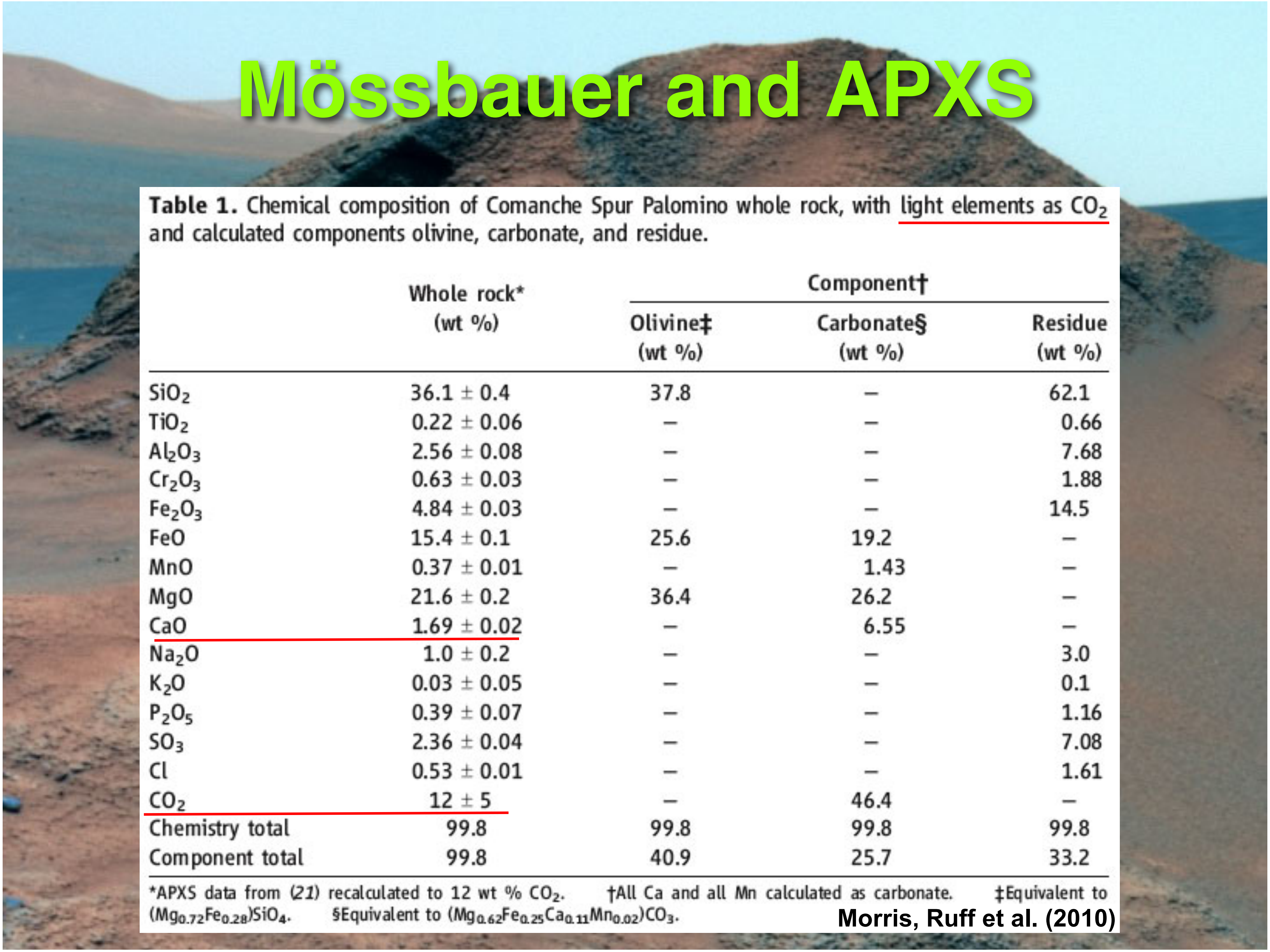


# Mössbauer and APXS




Comanche Spur Pancam false-color

**Morris, Ruff et al. (2010)**



# Mössbauer and APXS

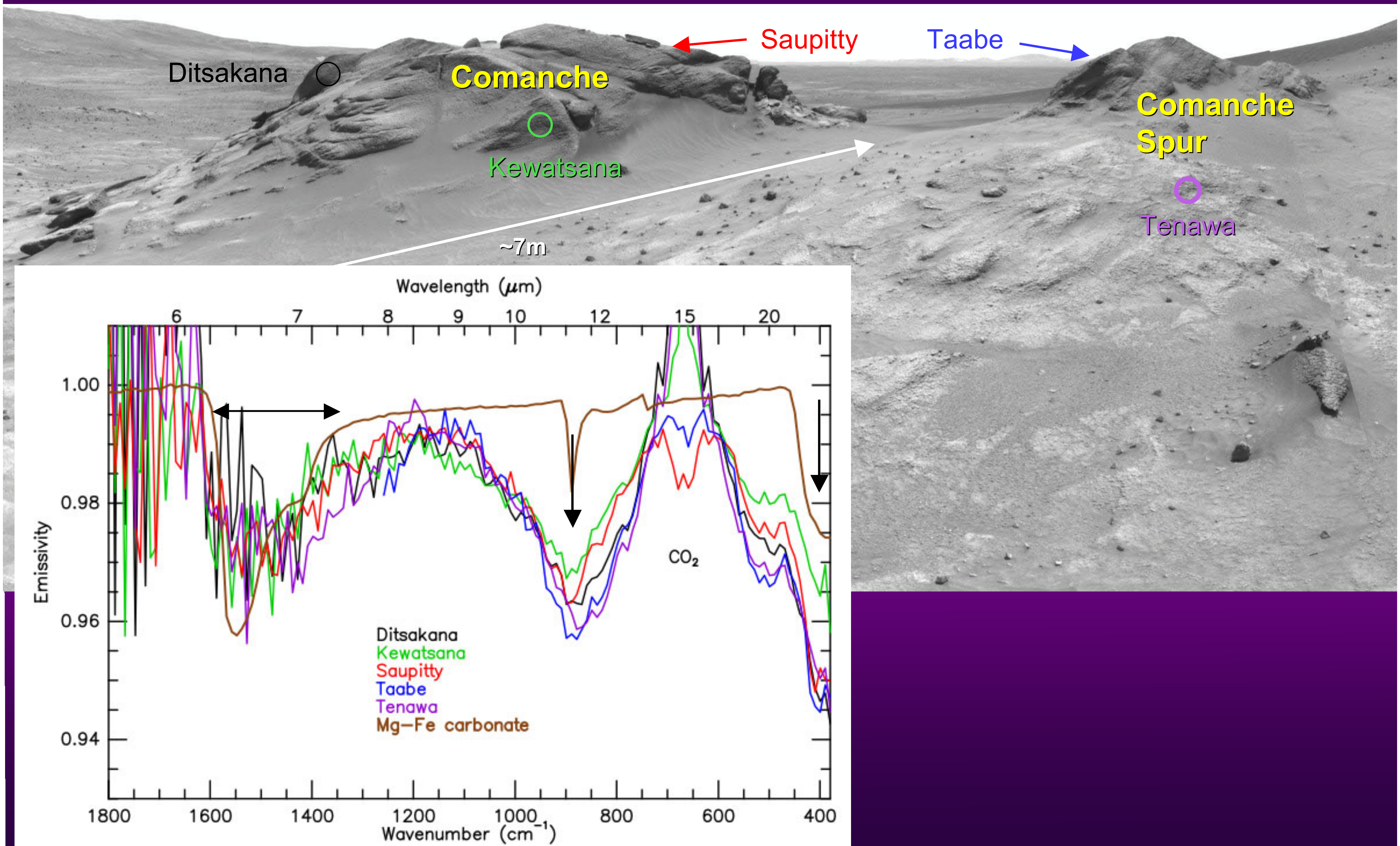
**Table 1.** Chemical composition of Comanche Spur Palomino whole rock, with light elements as $CO_2$ and calculated components olivine, carbonate, and residue.

| | Whole rock* (wt %) | Component† Olivine‡ (wt %) | Component† Carbonate§ (wt %) | Component† Residue (wt %) |
|---|---|---|---|---|
| $SiO_2$ | 36.1 ± 0.4 | 37.8 | – | 62.1 |
| $TiO_2$ | 0.22 ± 0.06 | – | – | 0.66 |
| $Al_2O_3$ | 2.56 ± 0.08 | – | – | 7.68 |
| $Cr_2O_3$ | 0.63 ± 0.03 | – | – | 1.88 |
| $Fe_2O_3$ | 4.84 ± 0.03 | – | – | 14.5 |
| FeO | 15.4 ± 0.1 | 25.6 | 19.2 | – |
| MnO | 0.37 ± 0.01 | – | 1.43 | – |
| MgO | 21.6 ± 0.2 | 36.4 | 26.2 | – |
| CaO | 1.69 ± 0.02 | – | 6.55 | – |
| $Na_2O$ | 1.0 ± 0.2 | – | – | 3.0 |
| $K_2O$ | 0.03 ± 0.05 | – | – | 0.1 |
| $P_2O_5$ | 0.39 ± 0.07 | – | – | 1.16 |
| $SO_3$ | 2.36 ± 0.04 | – | – | 7.08 |
| Cl | 0.53 ± 0.01 | – | – | 1.61 |
| $CO_2$ | 12 ± 5 | – | 46.4 | – |
| Chemistry total | 99.8 | 99.8 | 99.8 | 99.8 |
| Component total | 99.8 | 40.9 | 25.7 | 33.2 |

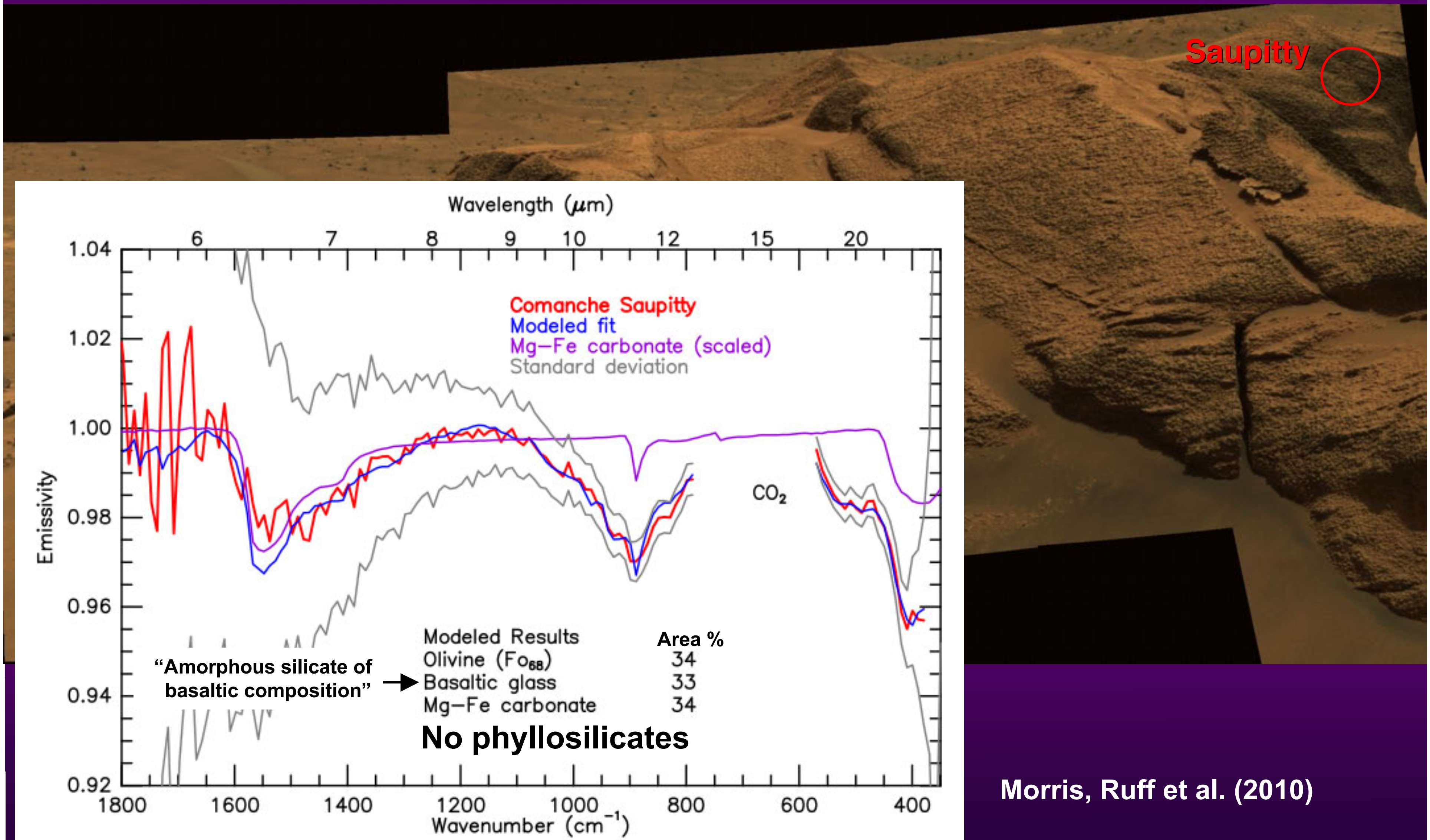
*APXS data from (*21*) recalculated to 12 wt % $CO_2$. †All Ca and all Mn calculated as carbonate. ‡Equivalent to $(Mg_{0.72}Fe_{0.28})SiO_4$. §Equivalent to $(Mg_{0.62}Fe_{0.25}Ca_{0.11}Mn_{0.02})CO_3$.

**Morris, Ruff et al. (2010)**

# Mini-TES on Comanche

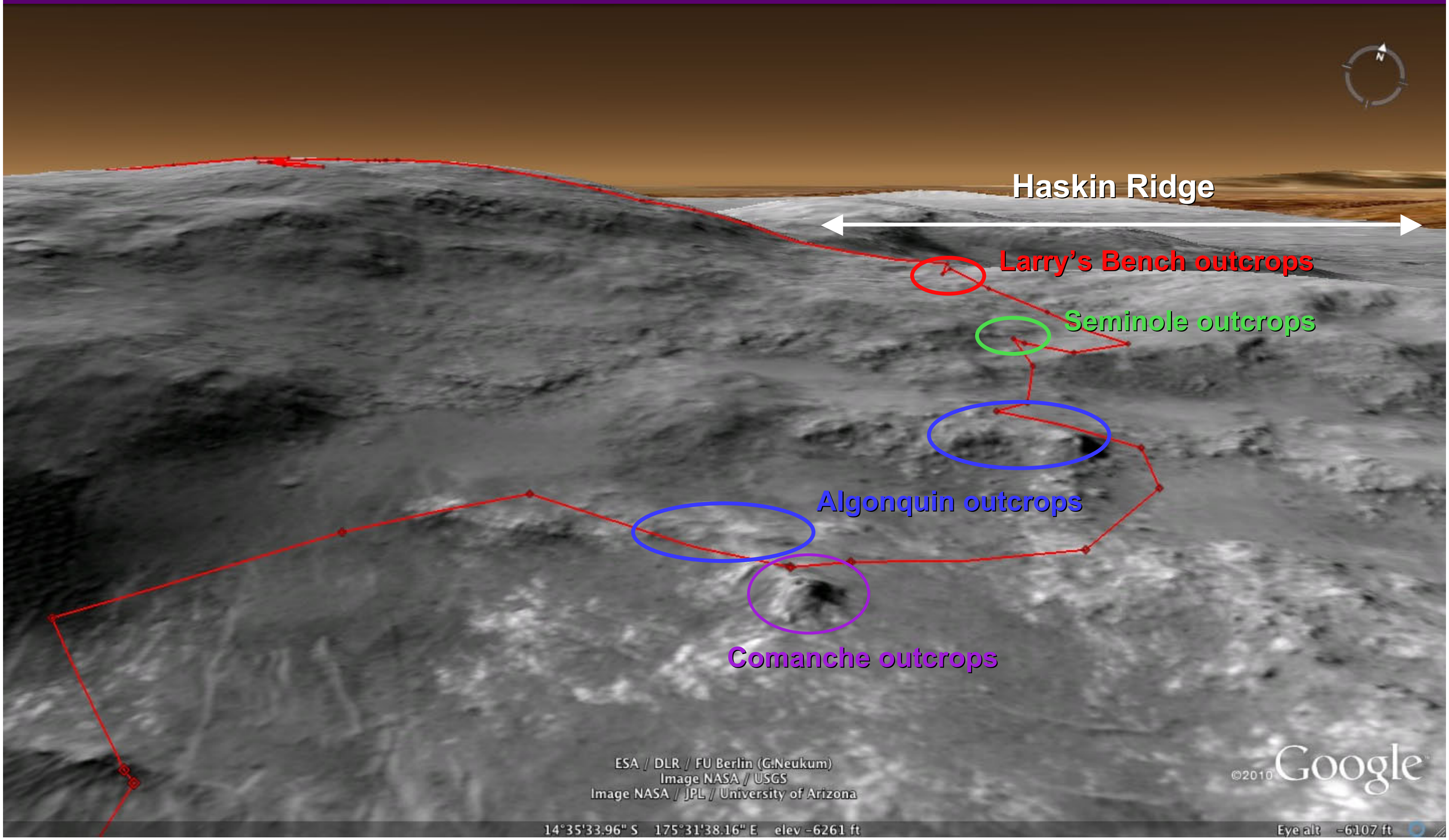


# Deconvolution of Saupitty Spectrum

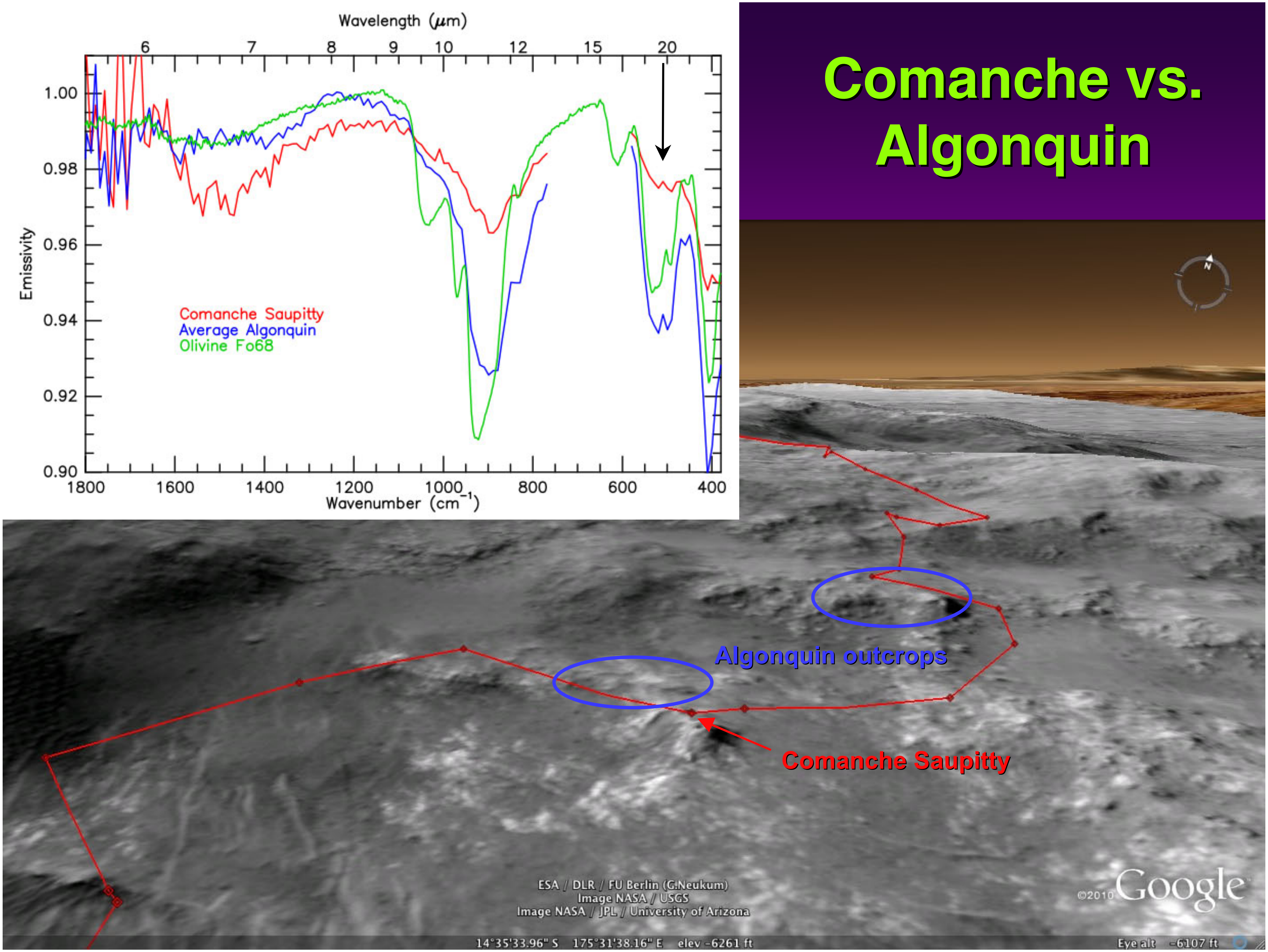



Morris, Ruff et al. (2010)

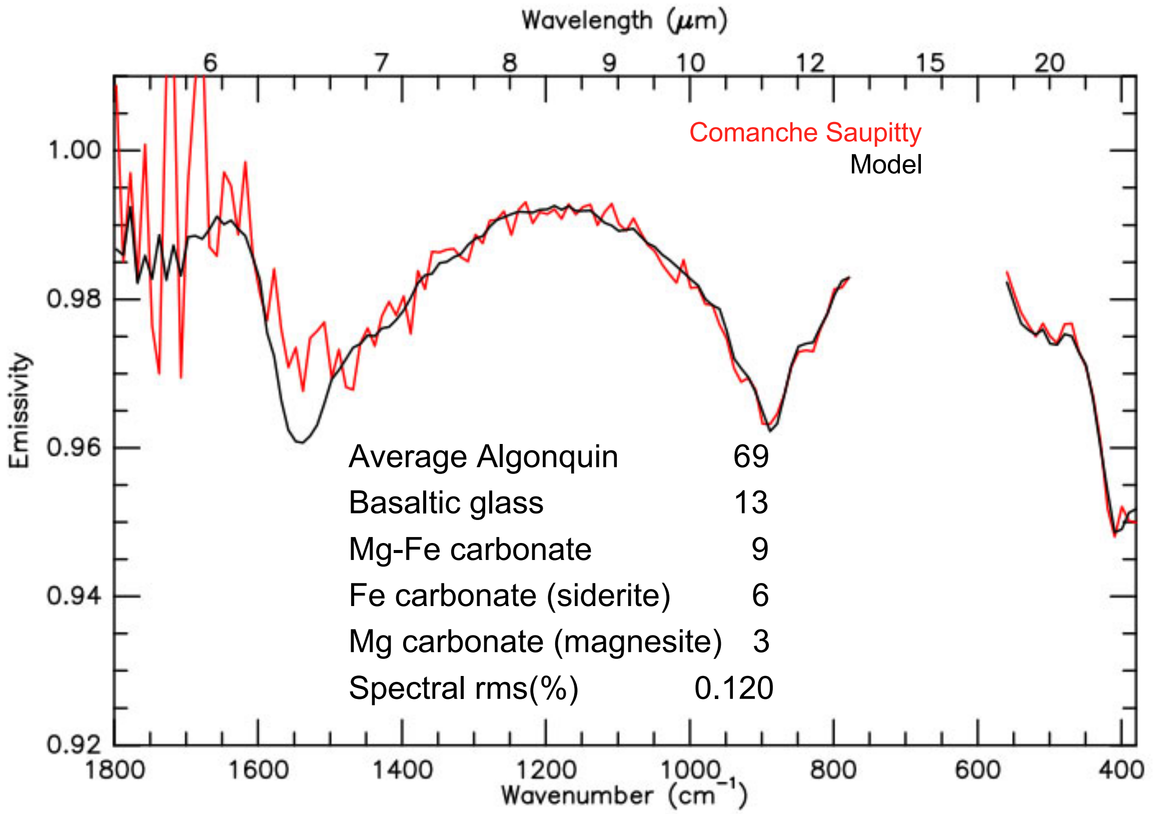
# Haskin Ridge Stratigraphy

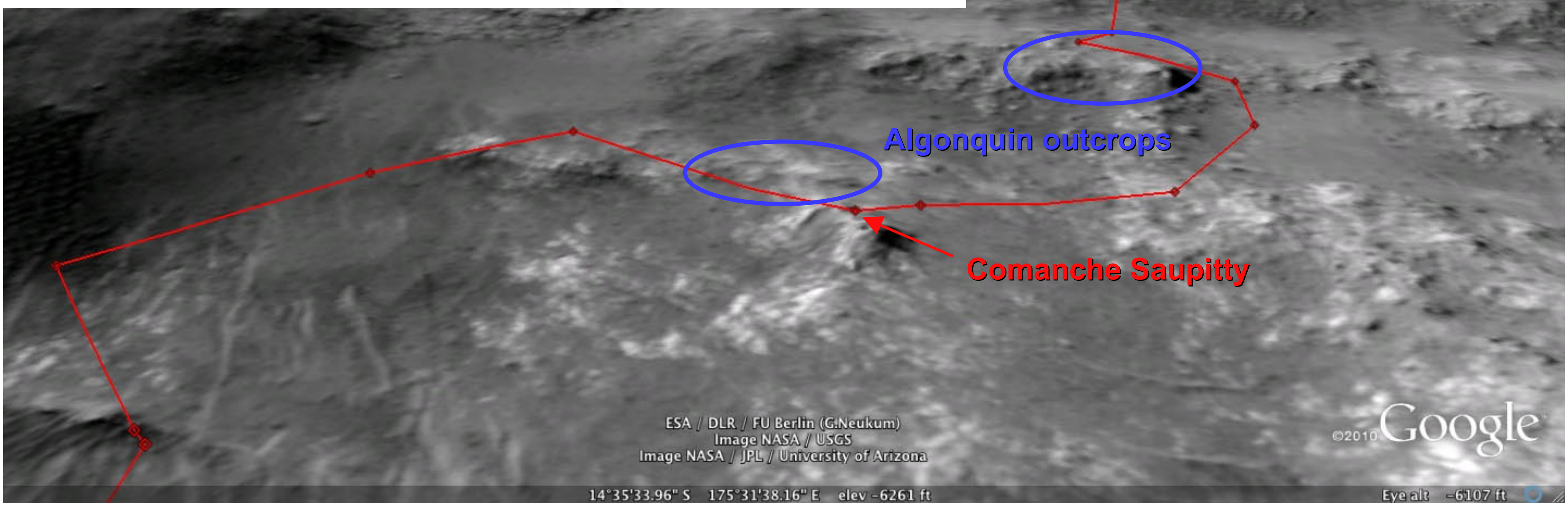


# Comanche vs. Algonquin



# Deconvolution of Comanche with Algonquin

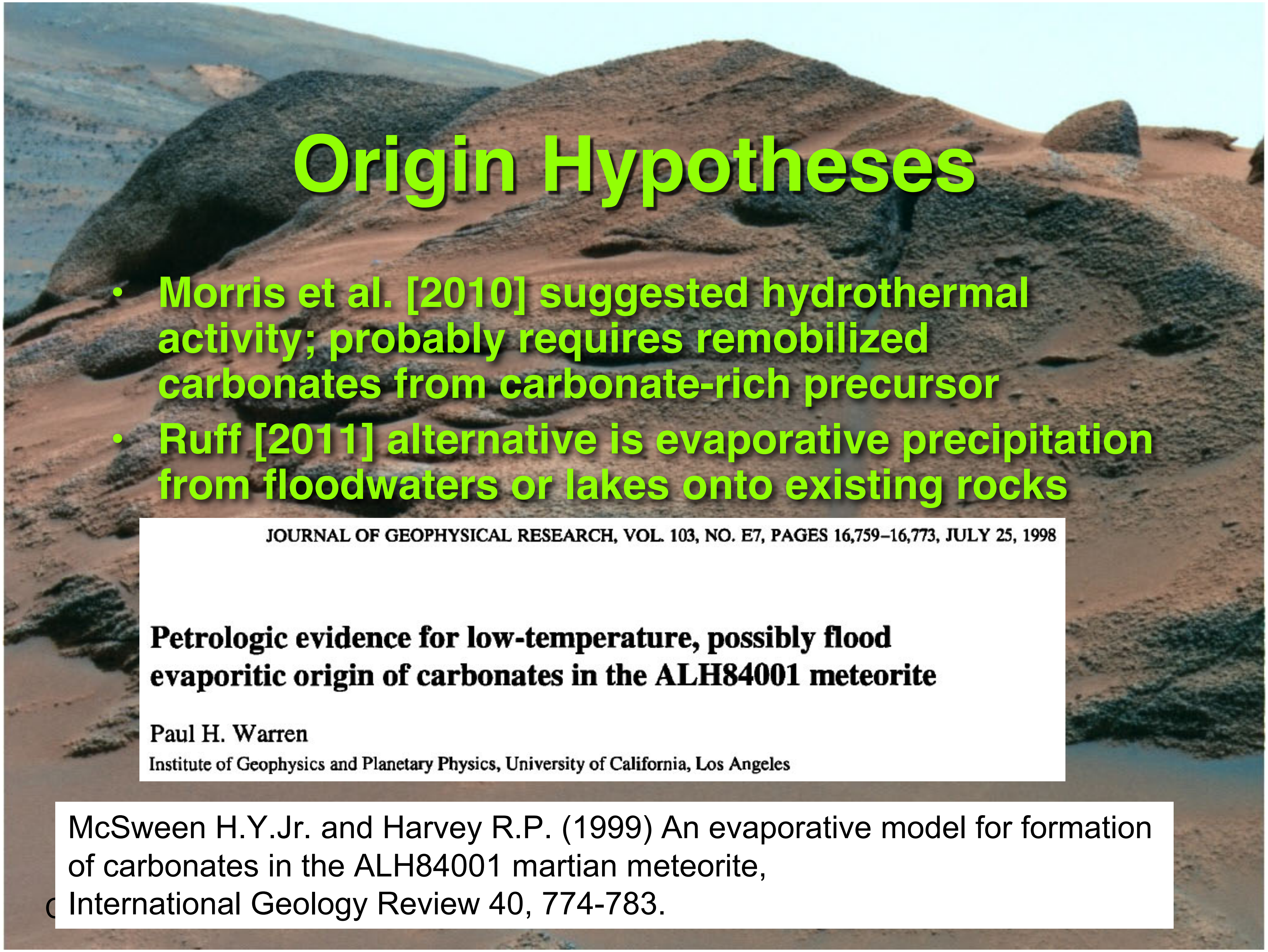


# Summary

- Abundant Mg-Fe carbonate is distributed homogeneously throughout the Comanche outcrops, not just in veins
- Carbonate possibly is zoned and appears to have formed in Algonquin class precursor rocks
- No crystalline mineral phases associated with alteration of mafic rocks are evident; olivine still abundant

Comanche Pancam false-color



# Origin Hypotheses

- Morris et al. [2010] suggested hydrothermal activity; probably requires remobilized carbonates from carbonate-rich precursor
- Ruff [2011] alternative is evaporative precipitation from floodwaters or lakes onto existing rocks

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**Petrologic evidence for low-temperature, possibly flood evaporitic origin of carbonates in the ALH84001 meteorite**

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Institute of Geophysics and Planetary Physics, University of California, Los Angeles

McSween H.Y.Jr. and Harvey R.P. (1999) An evaporative model for formation of carbonates in the ALH84001 martian meteorite, International Geology Review 40, 774-783.