A more vast and accessible Martian sedimentary rock record

Ken Edgett – February 2017
We Build & Operate Space Cameras in San Diego

Mars Orbiter Camera

Mars Observer & Mars Global Surveyor

Mars Orbiter Camera

Mars Color Imager

Mars Reconnaissance Orbiter

Mars Context Imager

Lunar Reconnaissance Orbiter Cameras

JunoCam

OSIRIS-REx TAGCAMS

Psyche cameras

We Build & Operate Space Cameras in San Diego

Mast Camera, Mars Hand Lens Imager, Mars Descent Imager

Mars 2020 rover
- Mastcam-Z
- SHERLOC/WATSON
- descent cameras
sediment – example – windblown sand

8 February 2017
a week ago

2 mm
sedimentary rock – example – sandstone
sedimentary rock – records of past environment
Mars sedimentary rock record importance

Mars – sedimentary rock record (environment record) older than the oldest preserved on Earth (or Venus).

Physics the same but the “experiment” ran differently.
  - no plate tectonics, more mafic, different fluids, less(?) organics.
Mars heavily cratered terrain – very ancient

Schiaparelli (diameter ~460 km)
Mars sedimentary rock record importance

MARS

Sedimentary rocks in Gale (Curiosity)

Sedimentary rocks older than Earth’s oldest

4.5  4.0  3.5  3.0  2.5  2.0  1.5  1.0  0.5  0
billions of years

Mars

Noachian  Hesperian  Amazonian

Moon

Pre-Nectarian  Imbrian  Eratosthenian  Copernican

Earth

Hadean  Archean  Proterozoic  Phanerozoic

EARTH

Isua Greenstone Belt, Greenland  ~3.8 Ga

Warawoona Group, Western Australia  ~3.4 Ga

Barberton Greenstone Belt, South Africa
sedimentary rock – published December 2000

Malin and Edgett (2000)
typical – light-tone, layered, few impact craters

150 m

crater in northwest Schiaparelli 0.2°S, 345.7°W
typical – light-tone, layered, few impact craters

Opportunity rover
Sol 758 (12 March 2006)

solar panel for scale
typical – lavas are more resistant to erosion

- Here, the younger material is also the more heavily-cratered.
- This is a result of resistance to erosion.
fluvial transport and deposition of sediment

Eberswalde Crater
24.1°S, 33.7°W

Malin and Edgett (2003)
where not obscured by dust – some mineral info

CRISM mineral parameter maps on CTX mosaic

- olivine (dunes)
- clay (nontronite)
- sulfate/clay mix
- sulfates
- sulfates

5 km

White arrow = stratigraphic range of basic traverse

Gale crater figure from Ralph Milliken
but... there was this weird problem...

igneous extrusive rock

sedimentary rock

shield volcano in Arsia Mons caldera – 9.8°S, 120.9°W

west Candor Chasma – 6.3°S, 75.6°W
but... there was this weird problem...

a heavily-cratered dune field...
but... there was this weird problem...

a heavily-cratered dune field...
sedimentary rock that resists erosion like lava?

a heavily-cratered dune field...

cliff-forming & boulder-producing... it is rock
sed. rock occurrences – what we used to think

Identified from MGS MOC Images

One could spend the rest of one's career putting dots on the map!
Mars >99% mapped, 6 m per pixel and higher

MRO CTX Coverage through January 2017

MGS MOC + MRO HiRISE + MRO CTX

Edgett – Mars Sedimentary Rock – February 2017
+ Curiosity rover in Gale crater

Gale Crater
(155 km diam)

Robert Sharp

Knobel

Lasswitz

Wien

Herschel

Terra Cimmeria

MGS MOLA topography
Curiosity rover in Gale crater

Curiosity landed here

3 km
+ Curiosity rover in Gale crater
heat shield impact site on cratered surface
heat shield impact site on cratered surface

- descent stage crash site
- landing site
- Rover on 2 Sept 2012
- parachute
- Yellowknife Bay
- heat shield

300 m
that cratered surface – the rock is sandstone!
dark gray well-cemented sandstones common
... and erosion-resistant

sandstone

mudstone

40 cm
back to... Curiosity’s terminal descent...
descent engines exposed conglomerates

20 cm
conglomerate – erosional expression

Imaged at Sol 587 parking spot
conglomerate erosional expression from above

Sol 587 parking spot

Sol 597 parking spot

Curiosity at Kimberley – 11 April 2014

HiRISE ESP_036128_1755
the meaning of light tone

Opportunity rover
Sol 758 (12 March 2006)

solar panel for scale
the meaning of light tone

Mojave-2

0880MH0001970010302313C00

2 cm

100 m

rover

N

Pahrump Hills Site – HiRISE ESP_040770_1755 8 April 2015

Edgett – Mars Sedimentary Rock – February 2017
even more stuff learned from Curiosity…

- Bedrock always at or near the surface.
- Importance of wind erosion.
- Rock type and erosion resistance influence on landscape geomorphology.
- Fracture patterns, veins, halos in sedimentary rock.
depositional setting mimicry – fluvial delta

Eberswalde Crater
24.1°S, 33.7°W

Mosaic of MOC images
depositional setting mimicry – eolian dune field
Depositional setting mimicry – stream channel

This once was ~2x the size of Meteor Crater in Arizona, USA.

Western Arabia 8.2°N, 11.1°W
depositional setting mimicry – stream channel

in crater at 24.2°S, 13.4°W

boxwork

emergent inverted stream sediment bodies

400 m
depositional setting mimicry – impact ejecta

NE Arabia 27.9°N, 295.7°W

Huo Hsing Vallis

Auqakuh Vallis

60 km

from THEMIS IR day mosaic, Christensen, ASU
depositional setting mimicry – impact ejecta

- Ejecta is emergent from beneath layers of rock.
- The ejecta, too, has to be rock.
intercrater plains in heavily cratered terrain…

with these “wrinkle ridges,” ye olden times interpretation might say “volcanic”
intercrater plains in heavily cratered terrain...
examples abound in heavily-cratered terrain...

Terra Cimmeria (31.9°S, 184.6°W)
examples abound in heavily-cratered terrain...

Terra Cimmeria (31.9°S, 184.6°W)
examples abound in heavily-cratered terrain...

Terra Sabaea (23.4°S, 321.3°W)

2 km
finally… always have to ask “what is missing?”

Gale’s Neighbor, 4.3°S, 229.5°W

~2.5 km original depth
~1.8 km original depth

positive relief (ridge)
negative relief (valley)

15 km

From THEMIS day IR map; ASU – DNs inverted
“what is missing?”

and “how did it go missing?”

Gale’s Neighbor, 4.3°S, 229.5°W

15 km

~2.5 km original depth

~1.8 km original depth

positive relief (ridge)

negative relief (valley)

From THEMIS day IR map; ASU – DNs inverted
take-home messages

Mars sedimentary rock record –

• the last 16 years focused on most obvious sub-set
• new observations → new interpretation capabilities
• still building the foundation
  • how to recognize examples missed for 16+ years
  • role in landscape evolution
  • always ask, “what is missing?” – and how did stuff go missing?
  • Curiosity & Opportunity landscape observations suggest rocks are at and near the surface
• burden of proof may have shifted – what you see might be sedimentary until demonstrated otherwise
ADDITIONAL FIGURES / BACKUP
Northeast Arabia Terra – 29.7°N, 294.4°W

HiRISE image PSP_004091_1845

Edgett – Mars Sedimentary Rock – February 2017

Meridiani – 4.7°N, 1.3°W
Noachis Terra
26.8°S, 321.2°W

Edgett – Mars Sedimentary Rock – February 2017

from CTX B11_013781_1533_XI_26S321W & P15_007096_1536_XI_26S321W
Lipik Crater – 38.8°S, 248.7°W
typical – light-tone, layered, few impact craters

“dark mesa-forming”

“thin bedded”

“massive bedded”

200 m

Tithonium Chasma – 4.9°S, 89.8°W – HiRISE PSP_005281_1750
sedimentary rock – example – pebbly sandstone

19 mm diameter
Giant Boxwork on Mt. Sharp
Siebach and Grotzinger (2013)
Erosion-Resistant Vein Material - boxwork