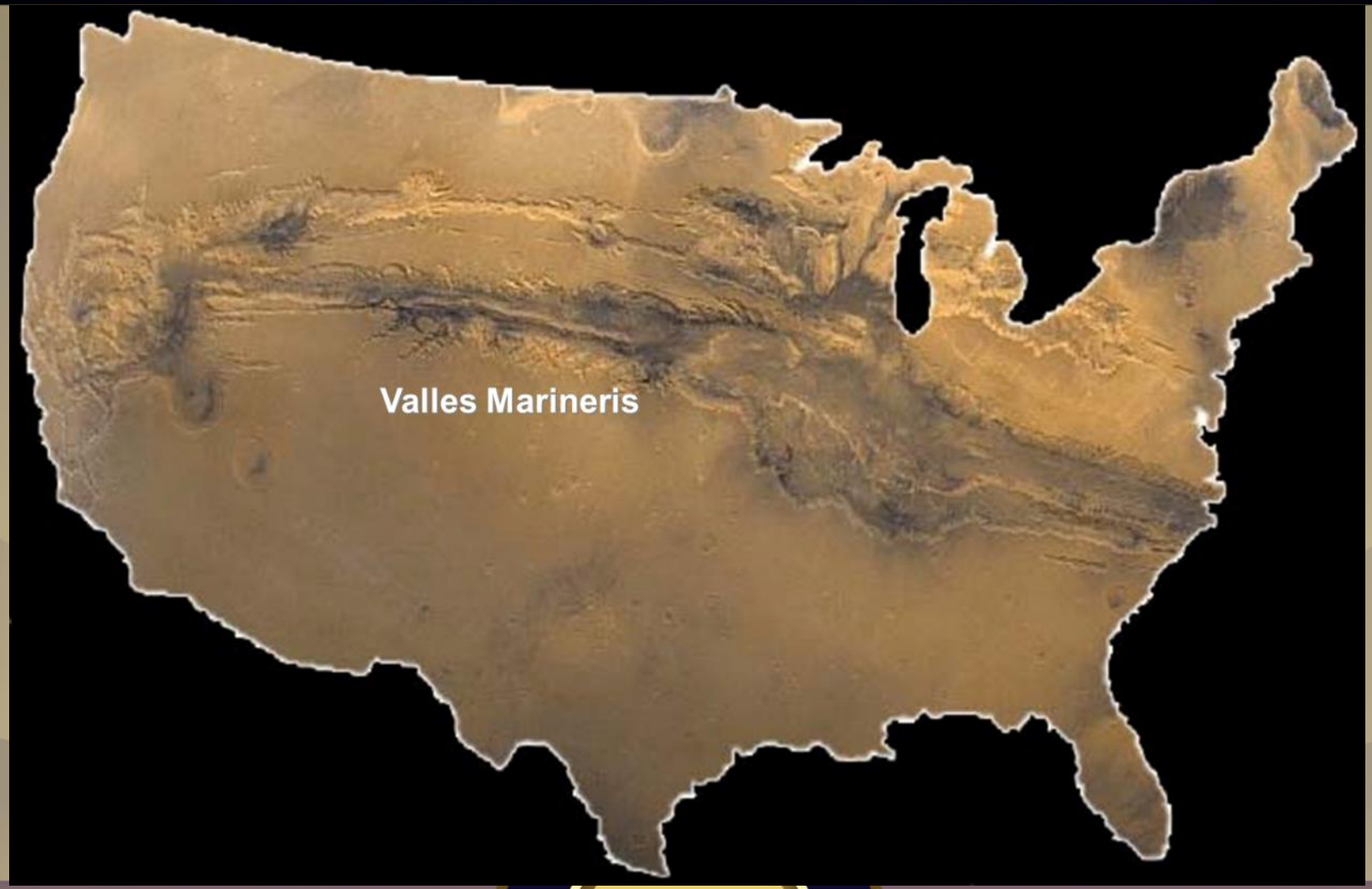
National Aeronautics and Space Administration

Robotic Missions: Trailblazing a Path for Humans

Doug Ming

NASA Johnson Space Center

Everything is Bigger on Mars!



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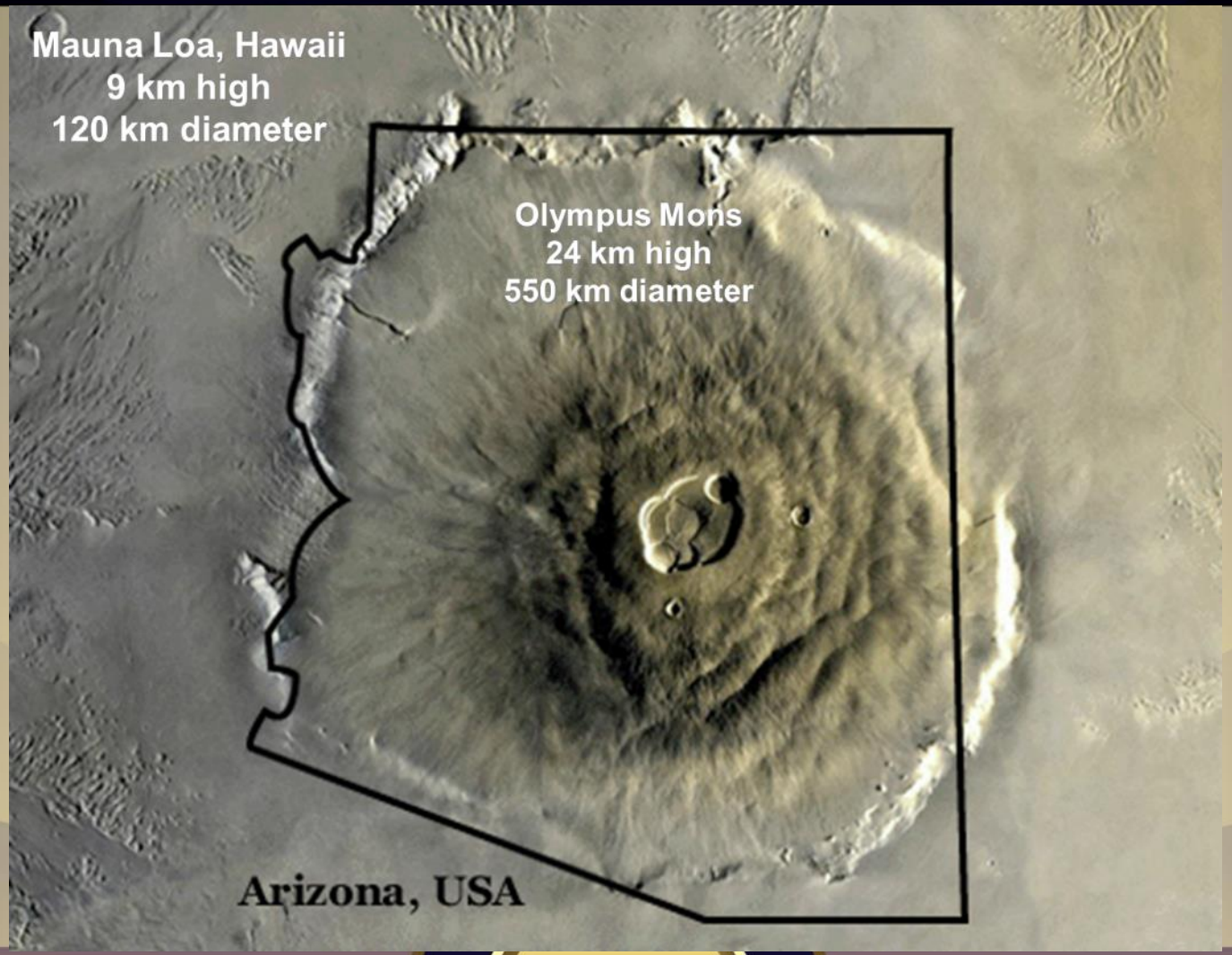
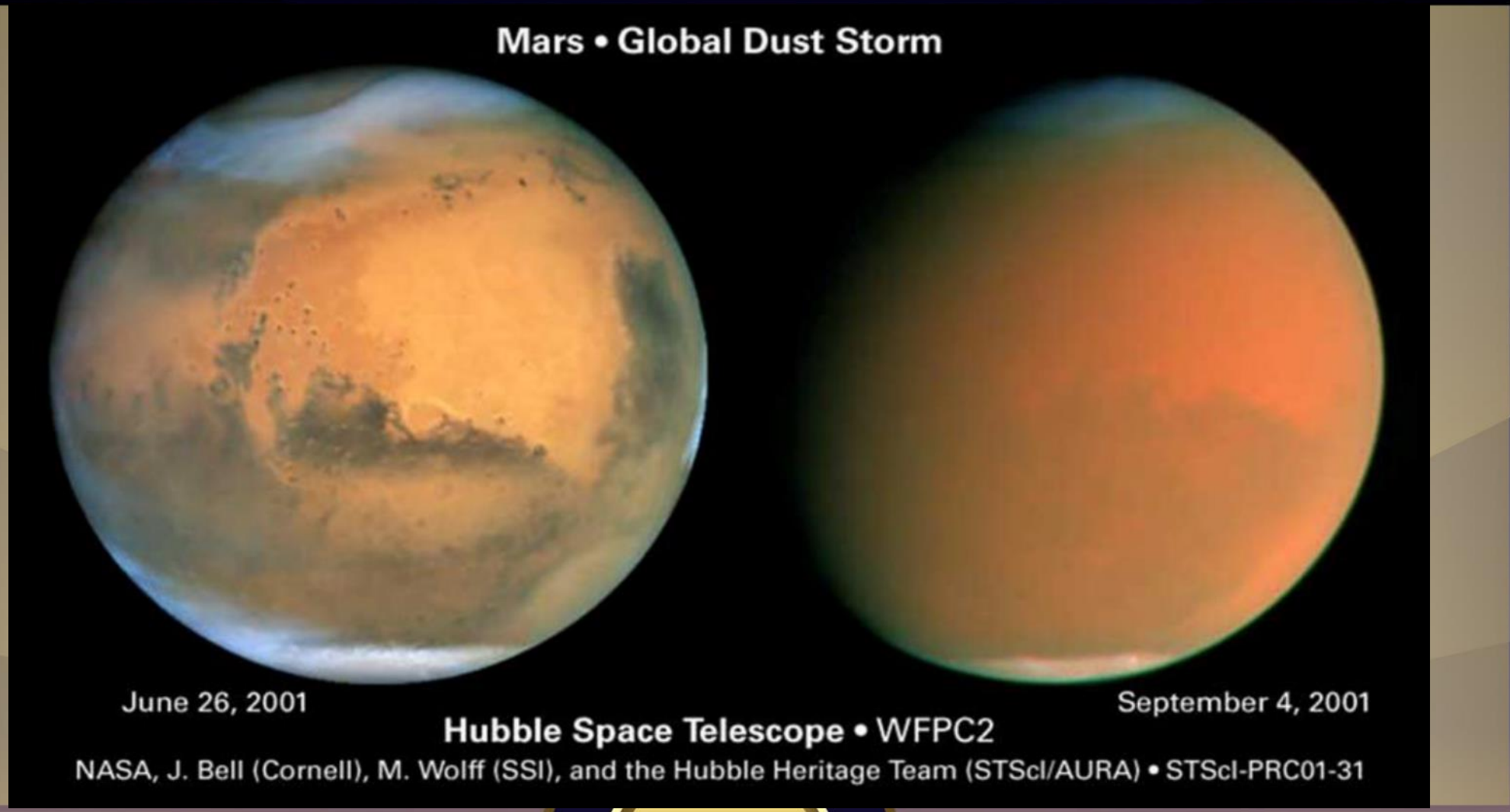
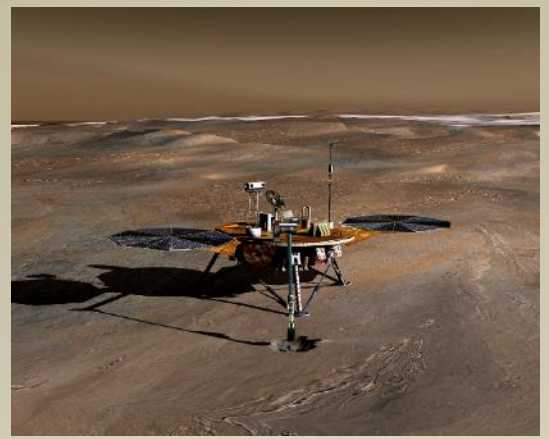


Global Dust Storms

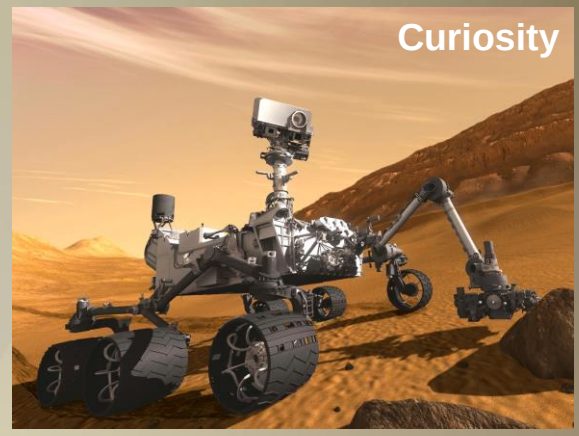


Recent Mars Robotic Missions

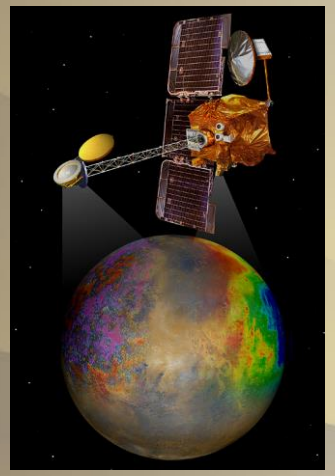
Mars Exploration Rovers



Mars Phoenix



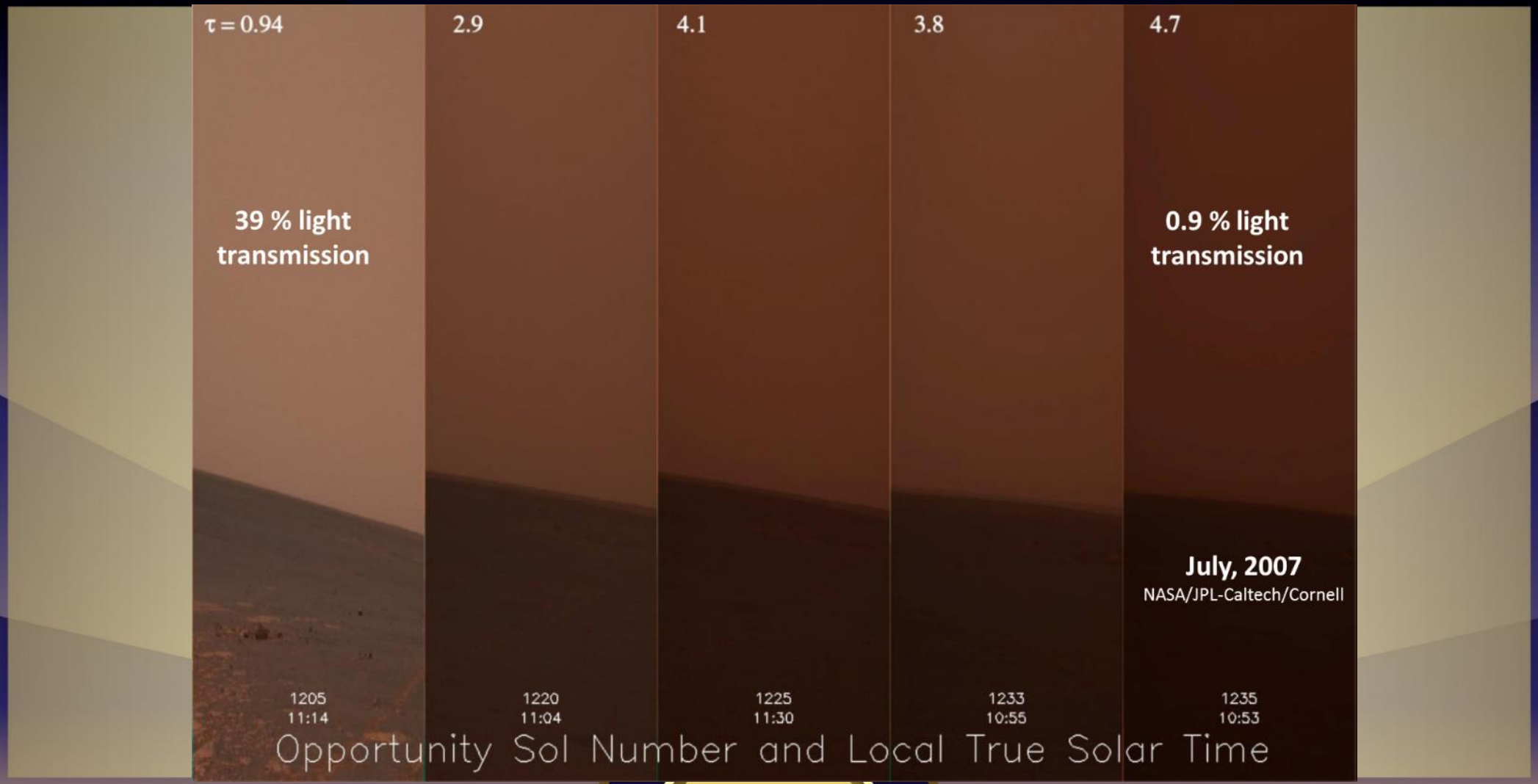
Mars Science Laboratory



Mars Odyssey

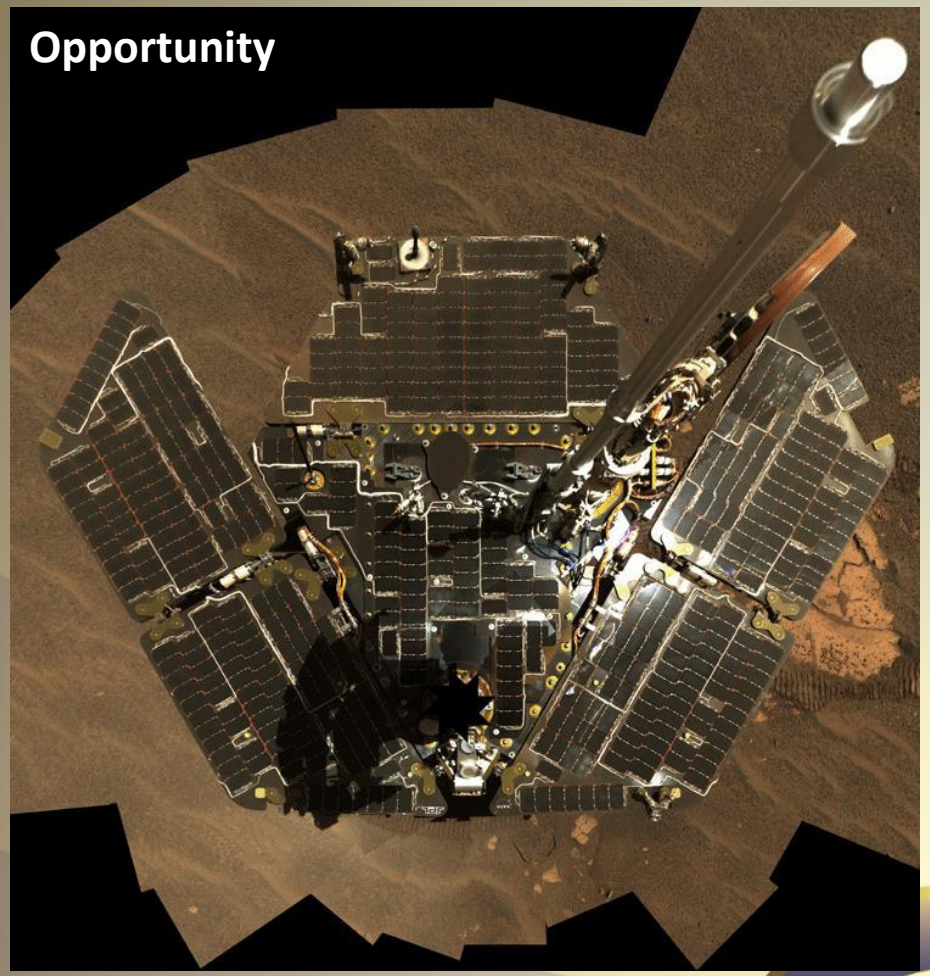
Mars Reconnaissance Orbiter

Dust Storm at the Opportunity Landing Site

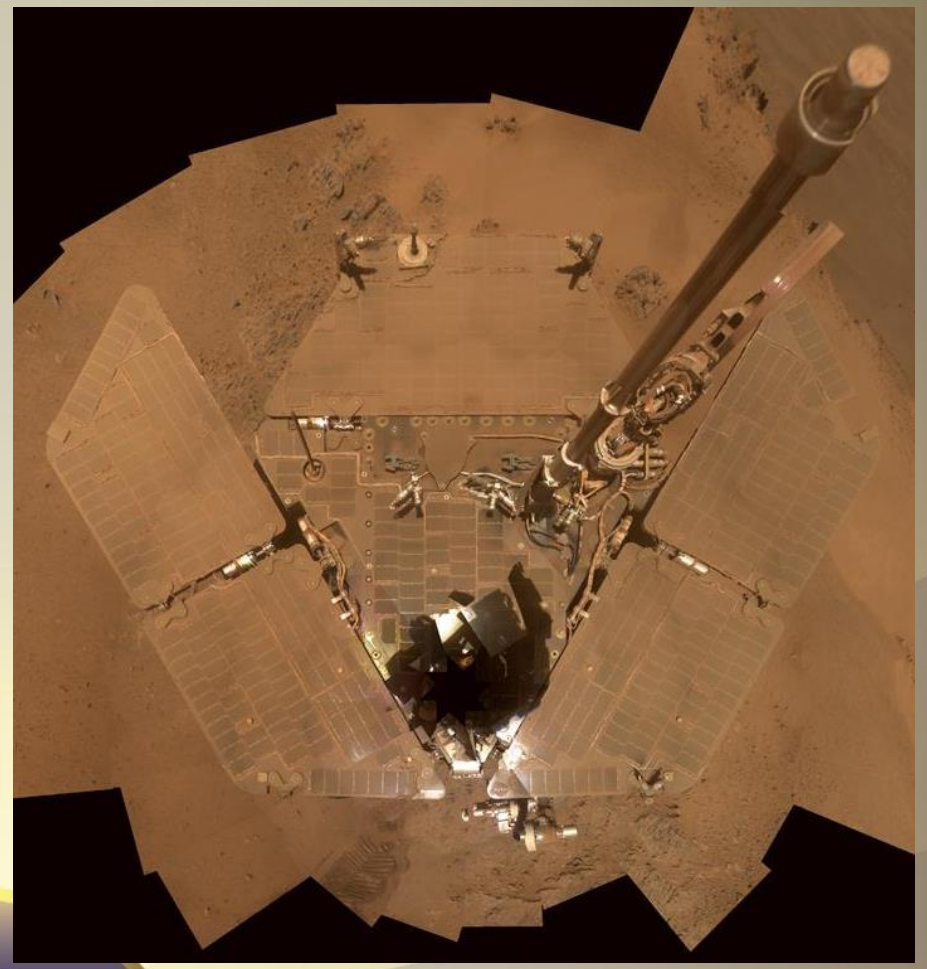


Dust Accumulation on Spacecraft

NASA/JPL-Caltech/Cornell



Sol 332 (December 2004)



Sol 2814 (December 2011)

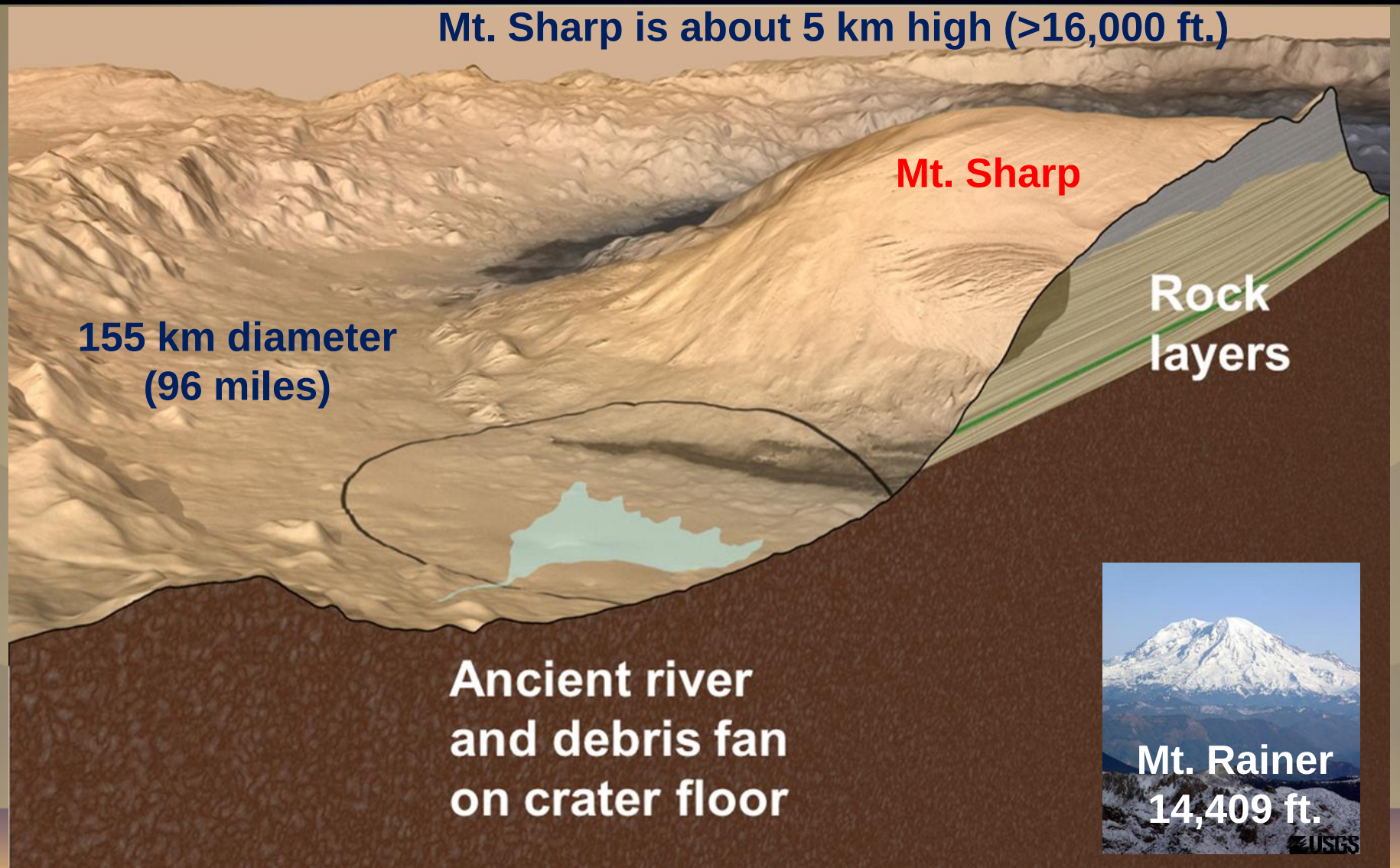
Dust Devils on Mars

NASA/JPL-Caltech

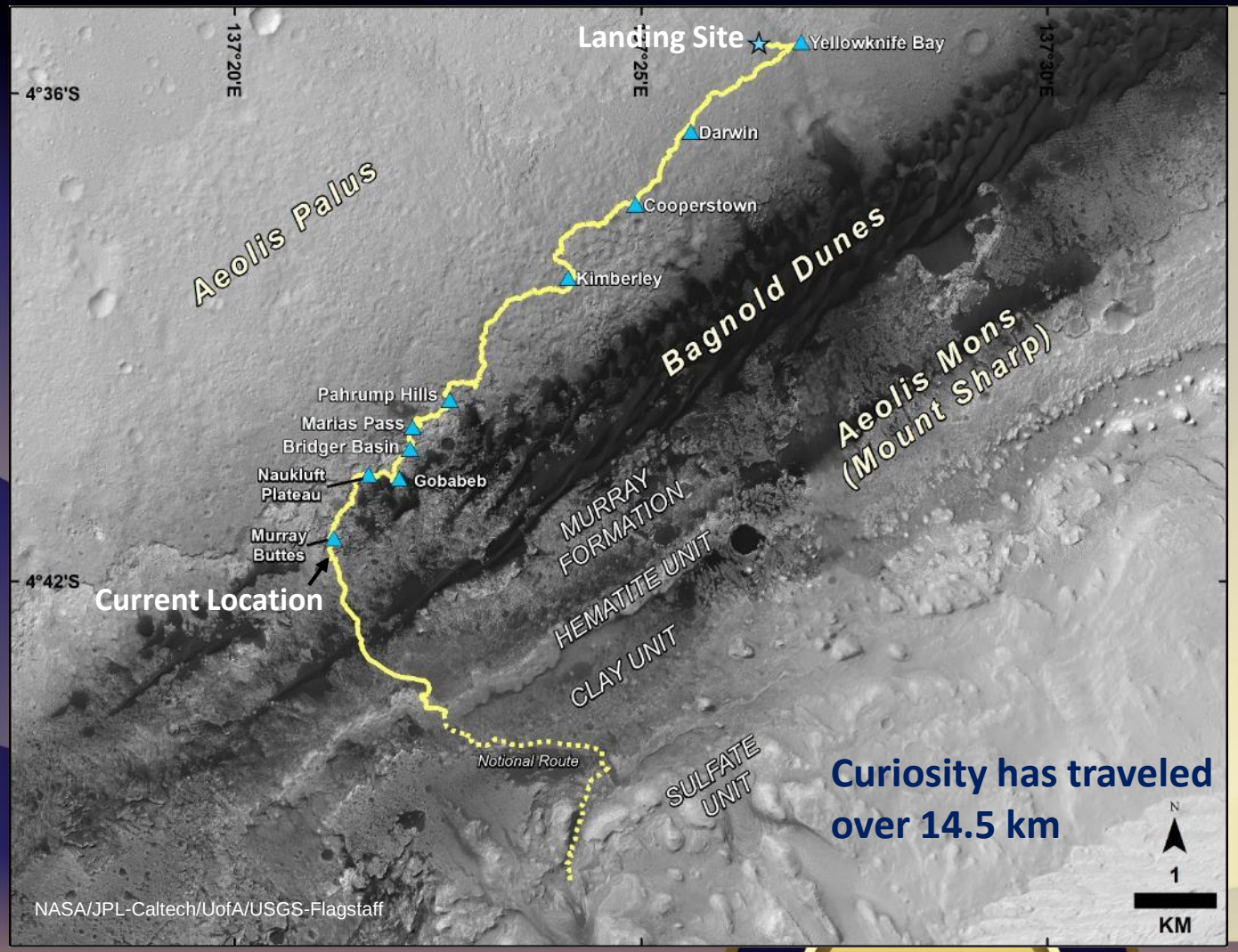
Dust Devils

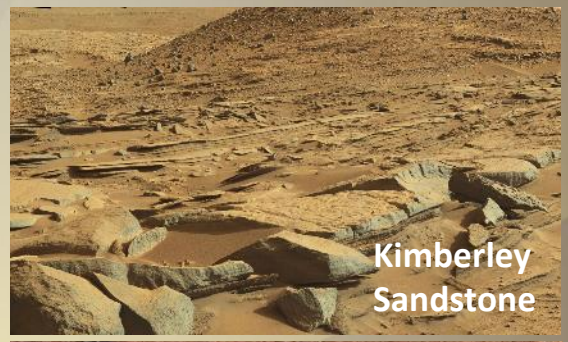
In Gusev Crater

Curiosity in Gale Crater



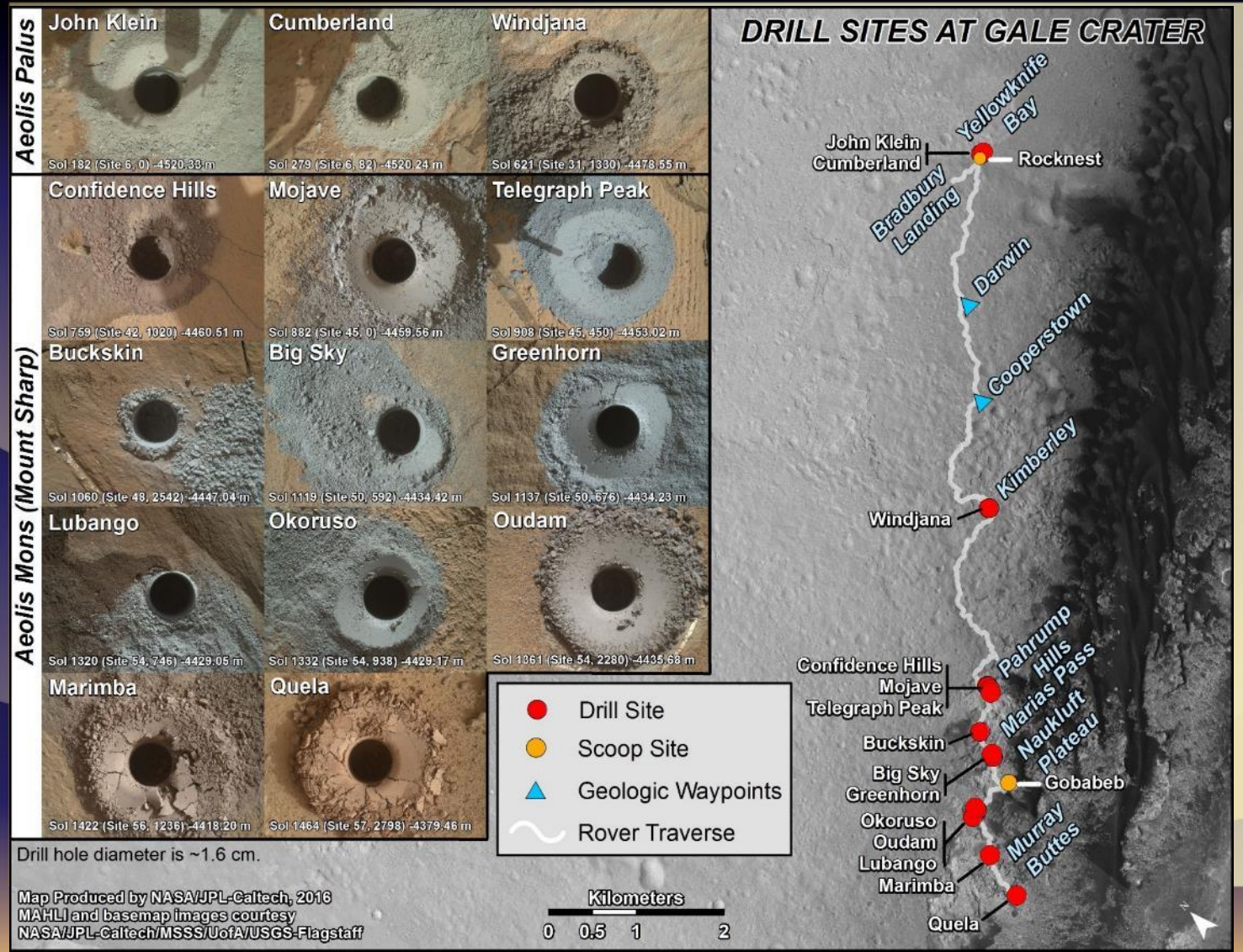
Curiosity's Journey



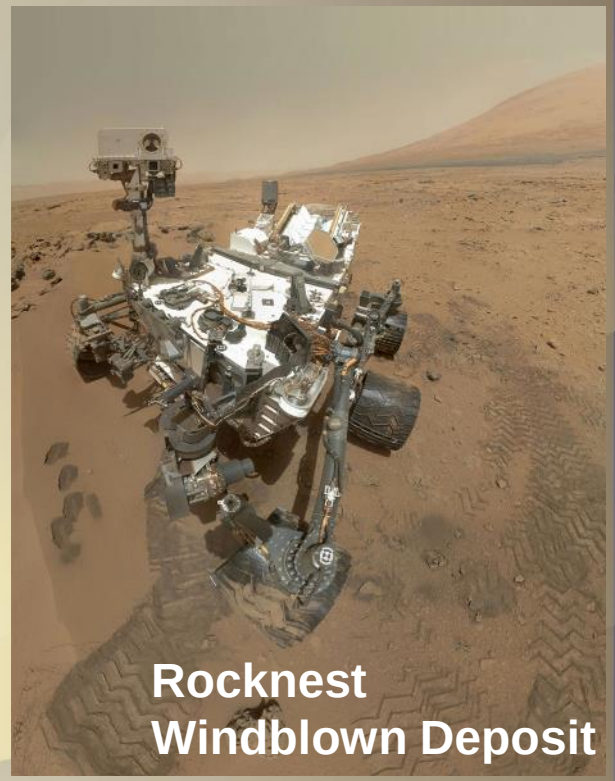


NASA/JPL-Caltech/MSSS

Samples Delivered to Instruments

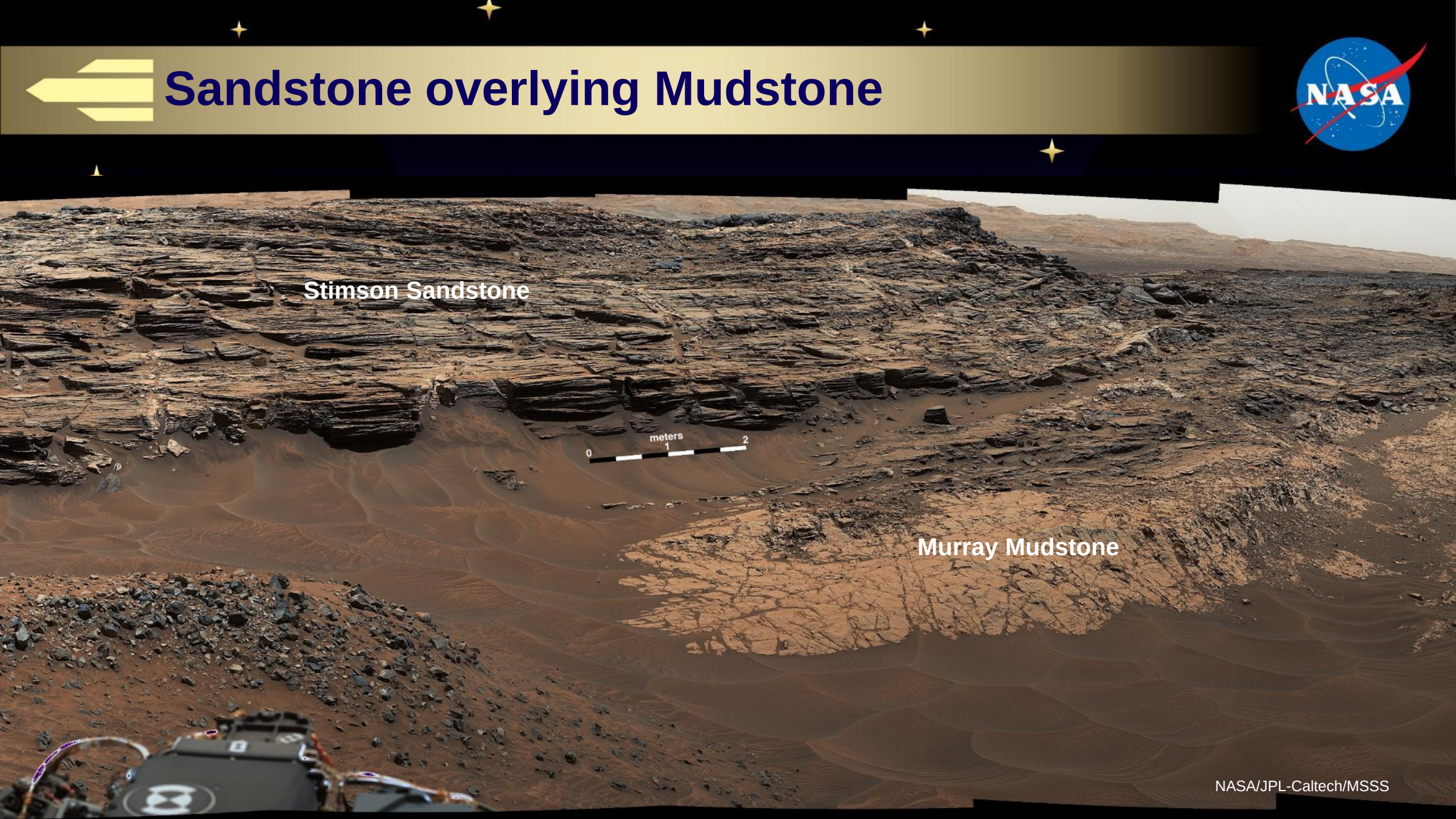


- 14 Drilled Samples
- 2 Scooped Samples

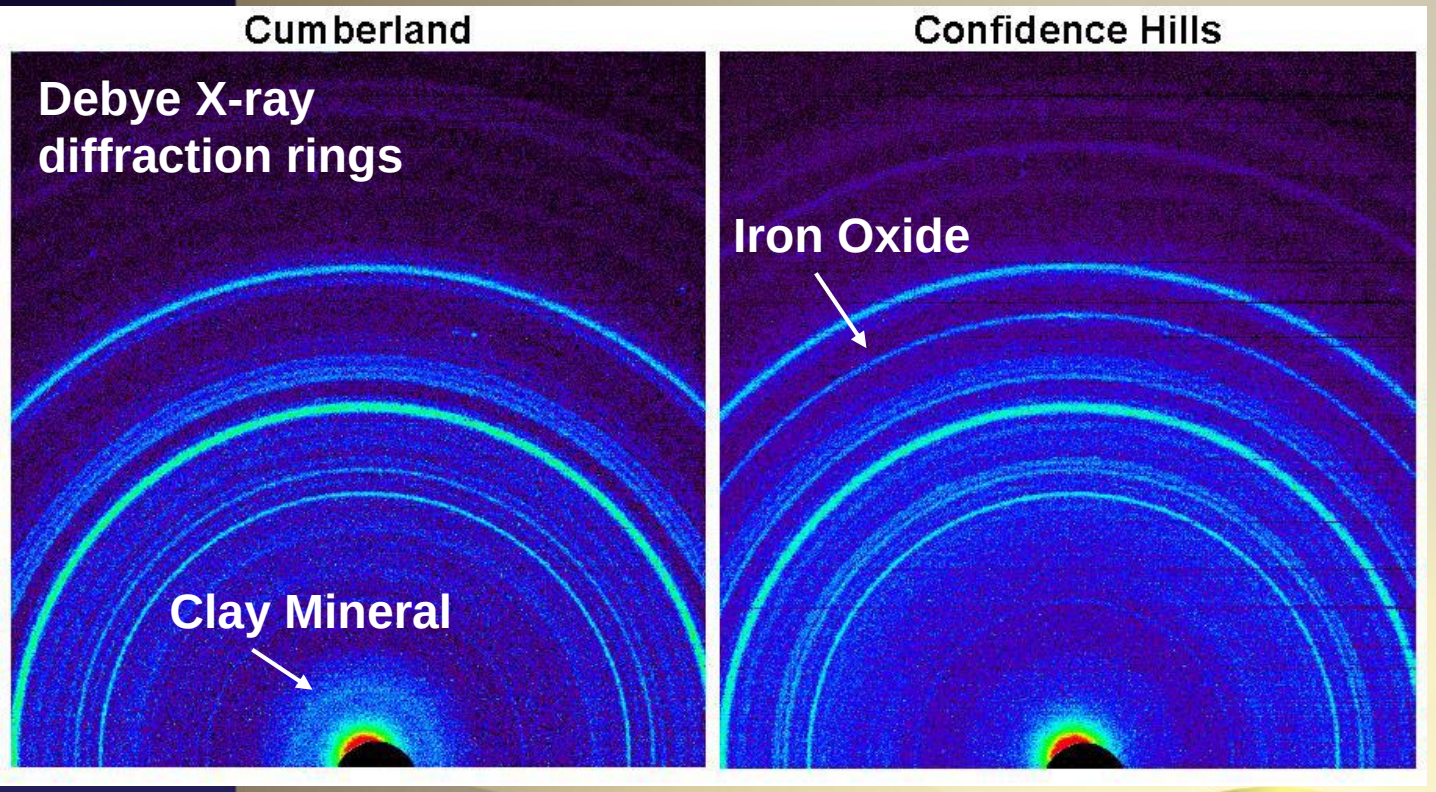


NASA/JPL-Caltech/MSSS

Sandstone overlying Mudstone

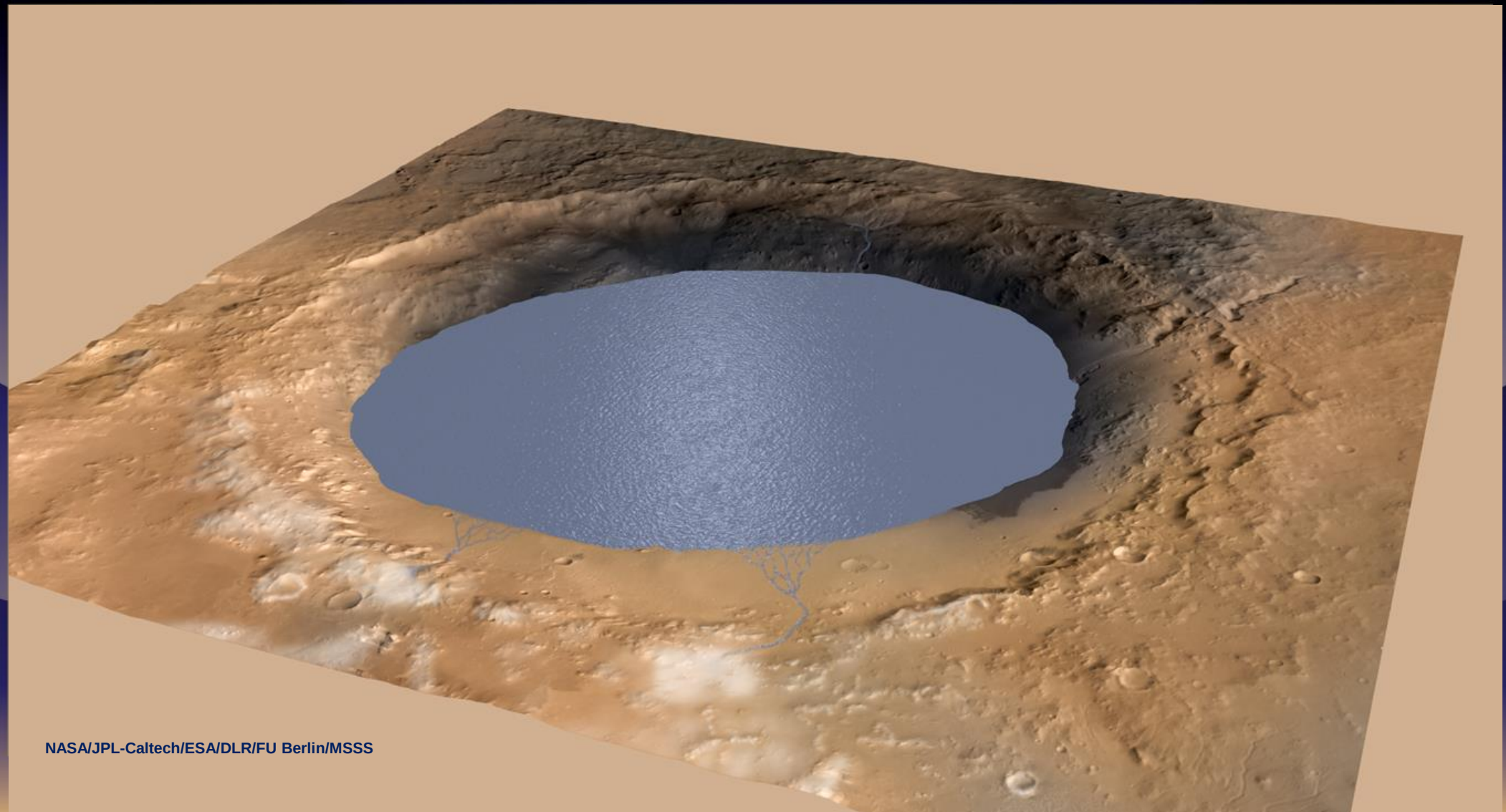


Mudstone Mineralogy



- Clay Minerals
- Iron oxides
  - Hematite (oxidized)
  - Magnetite (reduced)
- Sulfates
  - Calcium sulfates (neutral?)
  - Iron sulfates (acidic)
- X-ray amorphous materials

Ancient Lake in Gale Crater



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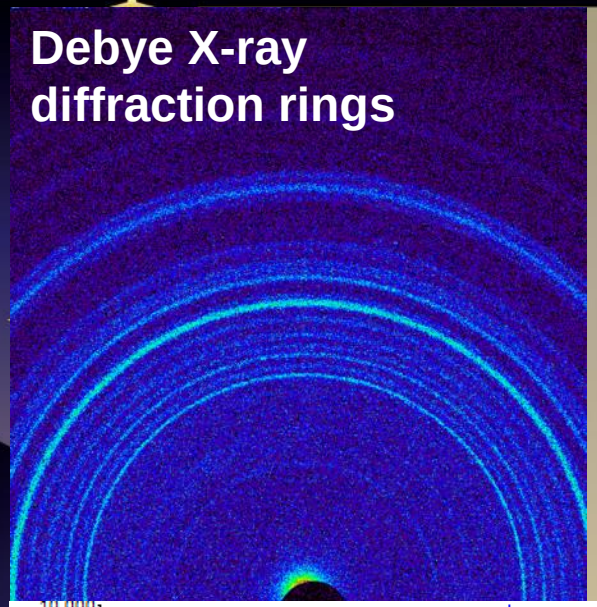
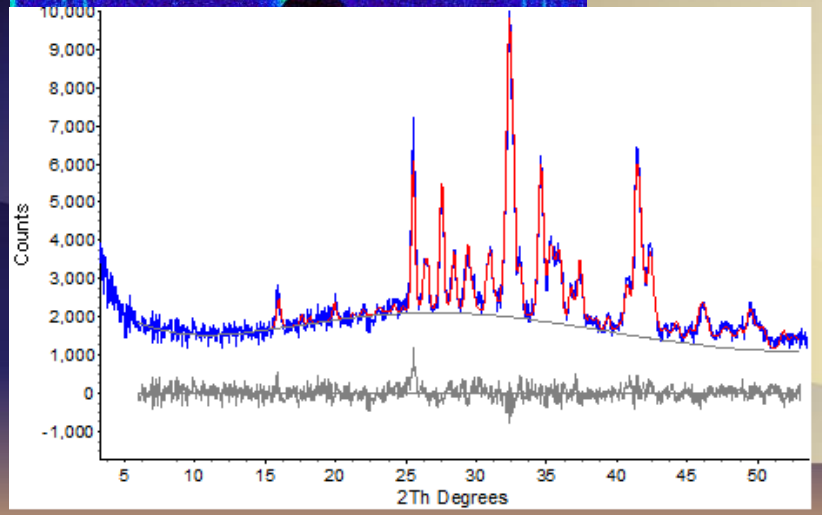
Windblown Deposit Mineralogy/Chemistry

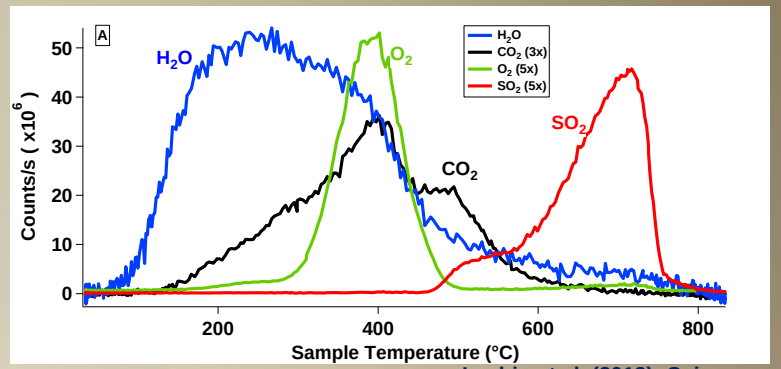




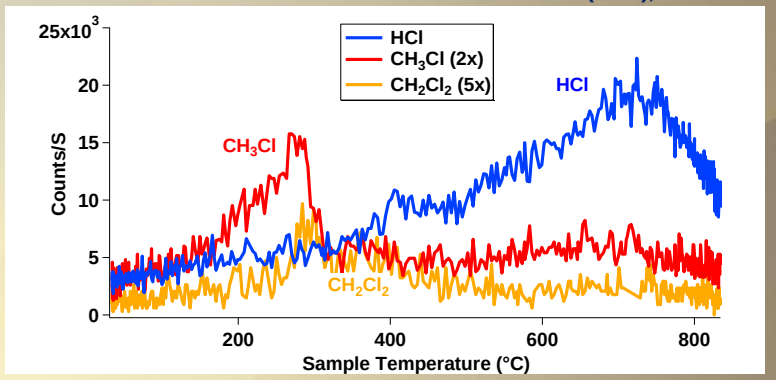
Bish et al. (2013), *Science*

- Basalt minerals
  - Feldspars
  - Olivine
  - Pyroxene
  - Magnetite
- Minor phases
  - Hematite (Fe-oxide)
  - Calcium sulfate
- X-ray amorphous materials

Evolved Gas Analysis

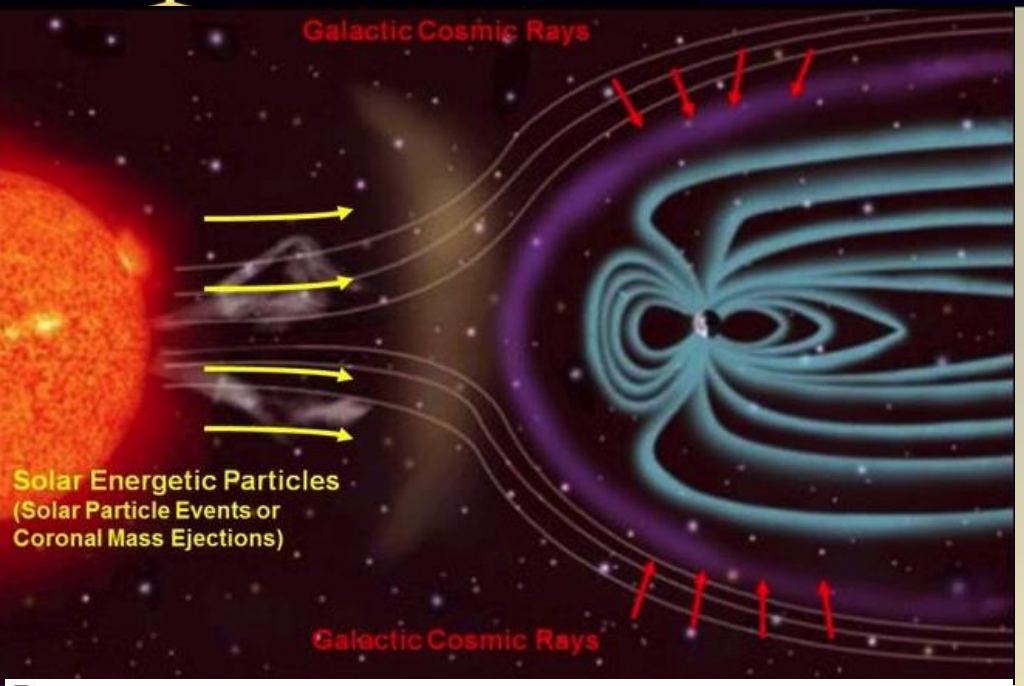


Leshin et al. (2013), *Science*



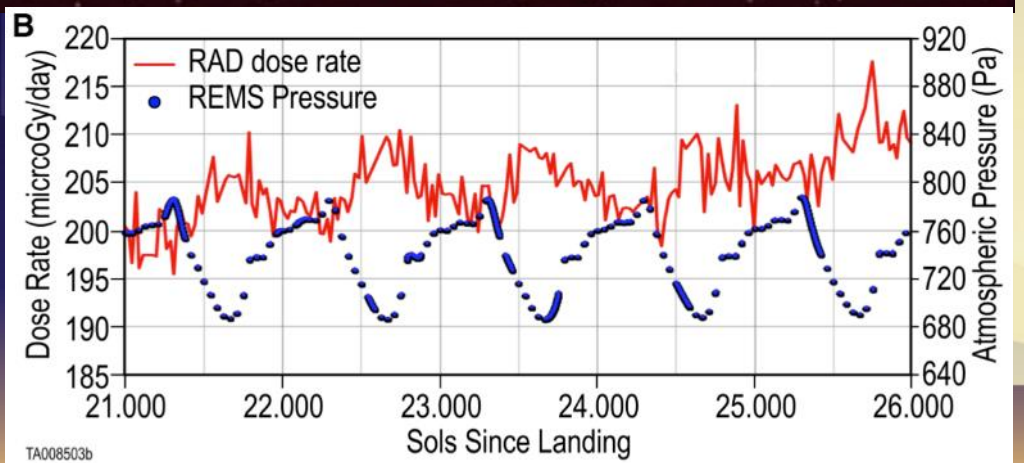
- 2-3 wt. % water release
- Oxygen, hydrochloric acid, and chlorinated hydrocarbon releases from decomposition of perchlorate salts

Radiation Environment on Mars

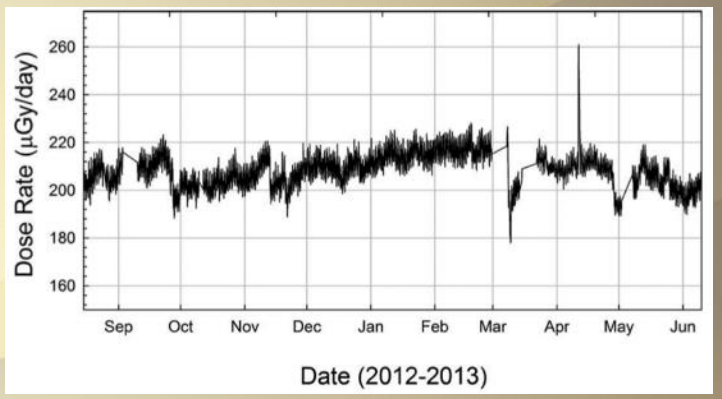


Radiation Assessment Detector (RAD)

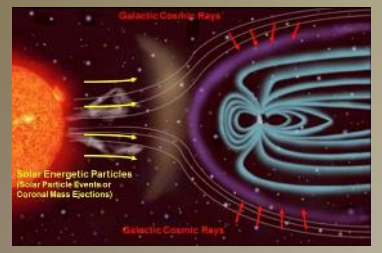
- RAD measured the radiation flux from galactic cosmic rays and solar energetic particles, in cruise and at Mars' surface
- The surface dose rate is about half that measured in cruise
- ~1000 millisievert of exposure on a trip to Mars with 500 sols on the surface (only about 75 millisievert dose during 6 months on ISS; 2-3 millisievert/year on Earth)



Hessler et al. (2014), *Science*



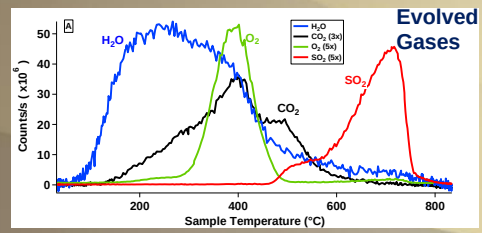
Technology Challenges/Benefits For Humans



- Radiation WILL be an issue (but not a “show stopper”)
  - Shielding (what materials should we use for shielding?)
  - Minimize exposure

NASA/JPL-Caltech/Cornell

- Martian dust must be addressed
  - Toxicology – e.g., perchlorates
  - Tribology – effects on seals, joints, airlocks, etc.
  - Minimize dust in living spaces and suits



Leshin et al. (2013), *Science*

- Extraction of resources (In Situ Resource Utilization)
  - Water extraction for propulsion, life support, etc.
    - Regolith, minerals with high water content, ice?
  - CO_2 atmosphere extraction and O_2 production
  - Other resources?

Can We Grow Plants in Martian Regolith?

- Regolith ("Soil") contains all essential plant growth nutrients.
  - N present but will likely have to fertilize.
  - Others?
- Perchlorates may be an issue collecting in plant tissue.
- Other salts? Other issues?
- As an agronomist by training – I think we CAN grow plants in Martian "soil."