Sulfate-Rich Eolian and Wet Interdune Deposits, Erebus Crater, Meridiani Planum, Mars*

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Abstract

A long-standing goal of Mars environmental studies is to understand the role of water throughout its geologic history. The Mars Exploration Rover (MER) Opportunity has worked towards this goal by investigating bedrock exposures within craters in Meridiani Planum. Each crater provides an opportunity to test and refine models proposed for the formation of the Meridiani bedrock. The sulfate-rich bedrock exposed in crater walls at Eagle and Endurance has been interpreted by the MER team to have been deposited in an eolian dune-interdune environment. This study investigates three bedrock exposures at Erebus crater, located ~4 km south of Endurance crater. These outcrops, called Olympia, Payson and Yavapai, provide additional evidence in support of the dune-interdune model proposed for the formation of the deposits at the Opportunity landing site. There is evidence for the greater involvement of liquid water in the outcrop exposures of the Olympia outcrop than was observed in Eagle or Endurance craters. The Olympia outcrop likely formed in a wet interdune and sand sheet environment. The facies observed within the Payson outcrop, which is stratigraphically above the Olympia outcrop, indicates that it was deposited within a damp-wet interdune, sand sheet, and eolian dune environment. The Yavapai outcrop, which is stratigraphically above the Payson outcrop, indicates that it was deposited in primarily a sand sheet environment and also potentially within an eolian dune environment. These three outcrop exposures indicate an overall drying-upward trend spanning the stratigraphic section from its base at the Olympia outcrop to its top at the Yavapai outcrop. This contrasts with the wetting-upward trend seen within Endurance and Eagle craters. Thus, the series of outcrops seen at Meridiani by Opportunity may comprise a full climatic cycle, evolving from dry to wet to dry conditions.

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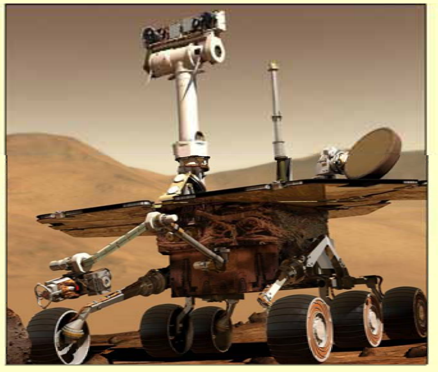
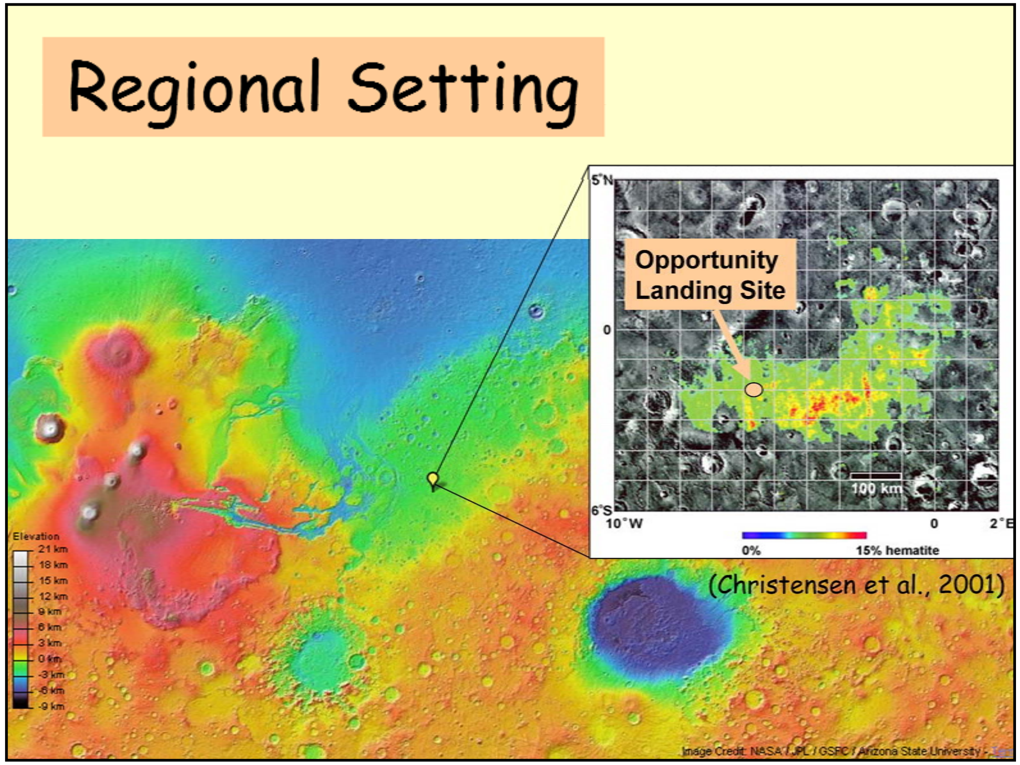
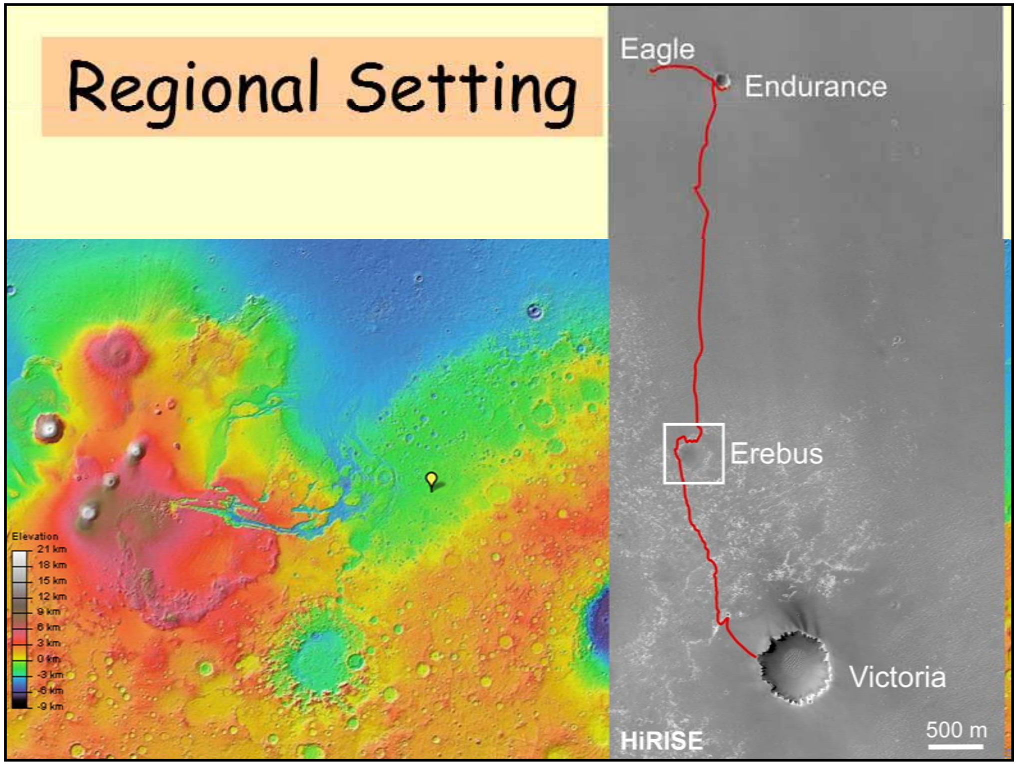


AAPG April 22, 2008

Rover camera height-my height, eye separation~human, resolution 20/20, MI~hand lens resolution

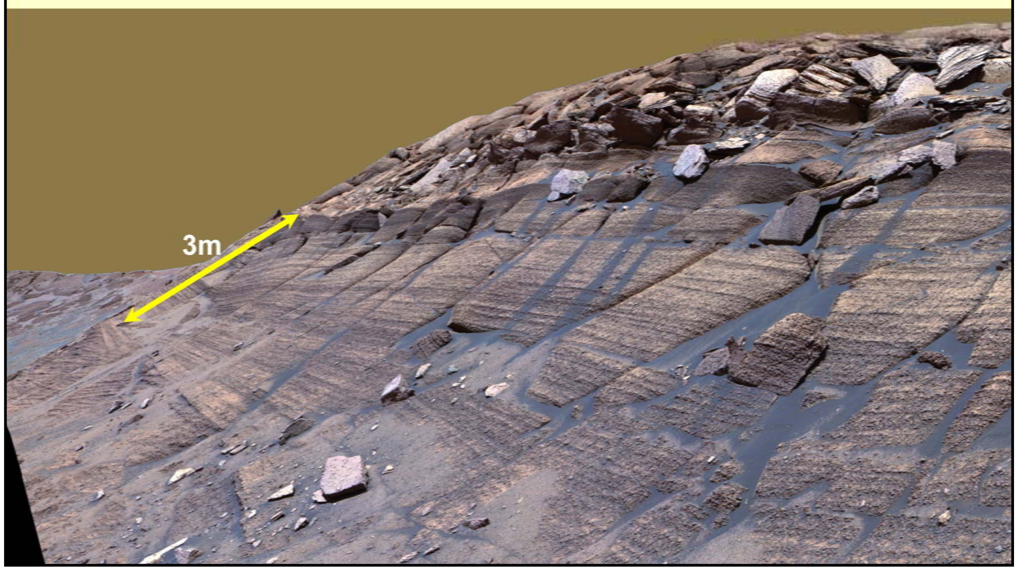


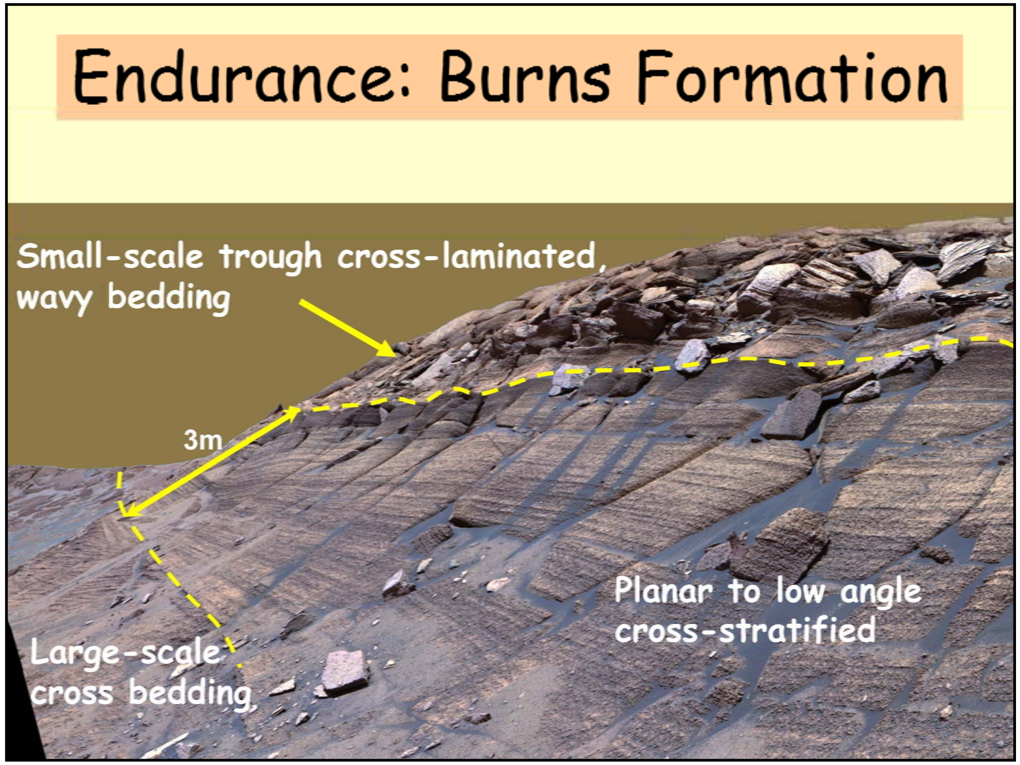
This is a mercator (Cylindrical) projection: + or – 55 deg. with a central meridian at 0° and latitude equal to the nominal scale at 0°. One of the primary goals of the Mars Exploration Rover mission was to search for sedimentary rocks that may contain clues as to the history of water on Mars. The Opportunity rover landing site in Meridiani Planum was chosen because the Mars Global Surveyor Thermal Emission Spectrometer showed a hematite signature of 15-20% hematite by fractional area (Christensen et al., 2000). Hematite can form by several processes, many of which involve liquid water (Squyres et al., 2004a). The hematite-bearing unit lies at the top of a 600 m thick layered sequence of rocks that overlies Noachian cratered terrain (Hynek and Phillips, 2001).



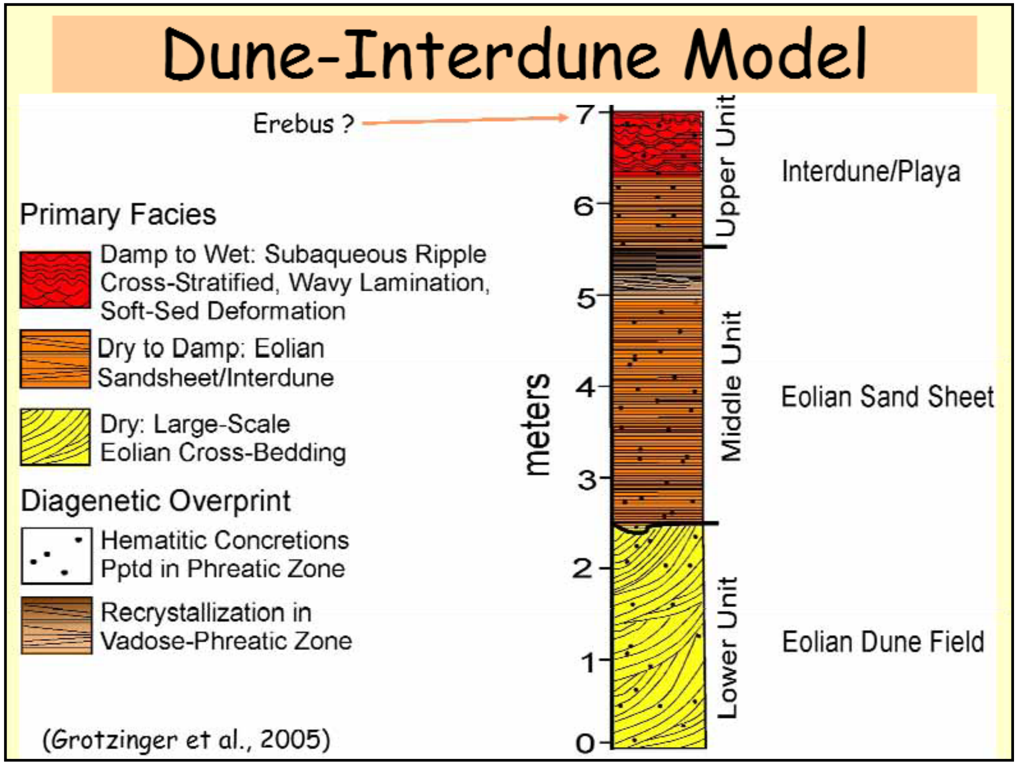
Erebus 300 m diameter, 4km south of Endurance

Endurance: Burns Formation

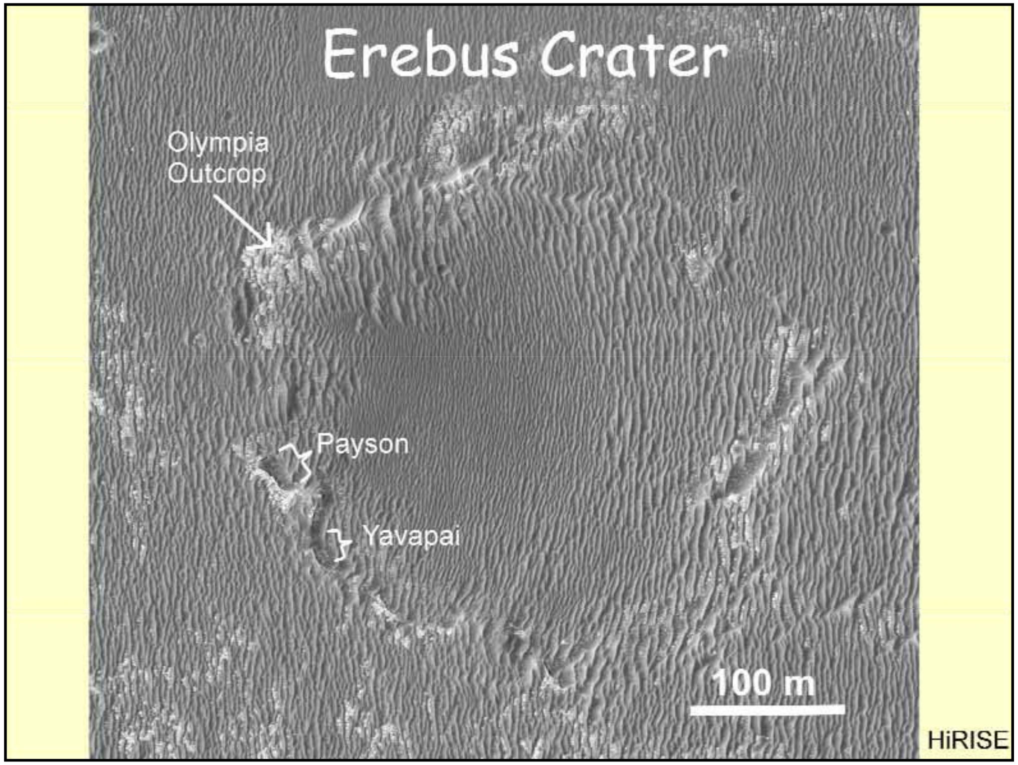




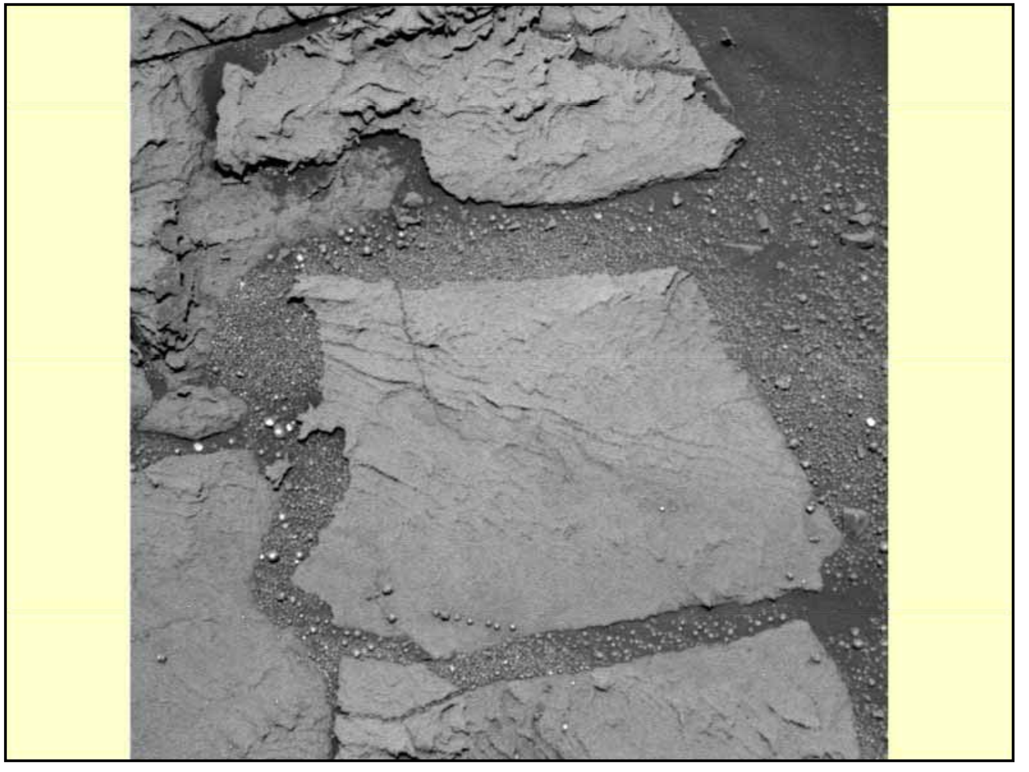
Fine- to medium-grained sandstones with well rounded and well sorted grains, bound together with intergranular cements; geochemical and mineralogic data show that the grains are composed of 50% fine-grained siliciclastic materials derived from the weathering of basaltic rock, 40% sulfate minerals, and 10% hematite (Clark et al. 2005; Squyres et al. 2004). The hematite is concentrated in diagenetic concretions



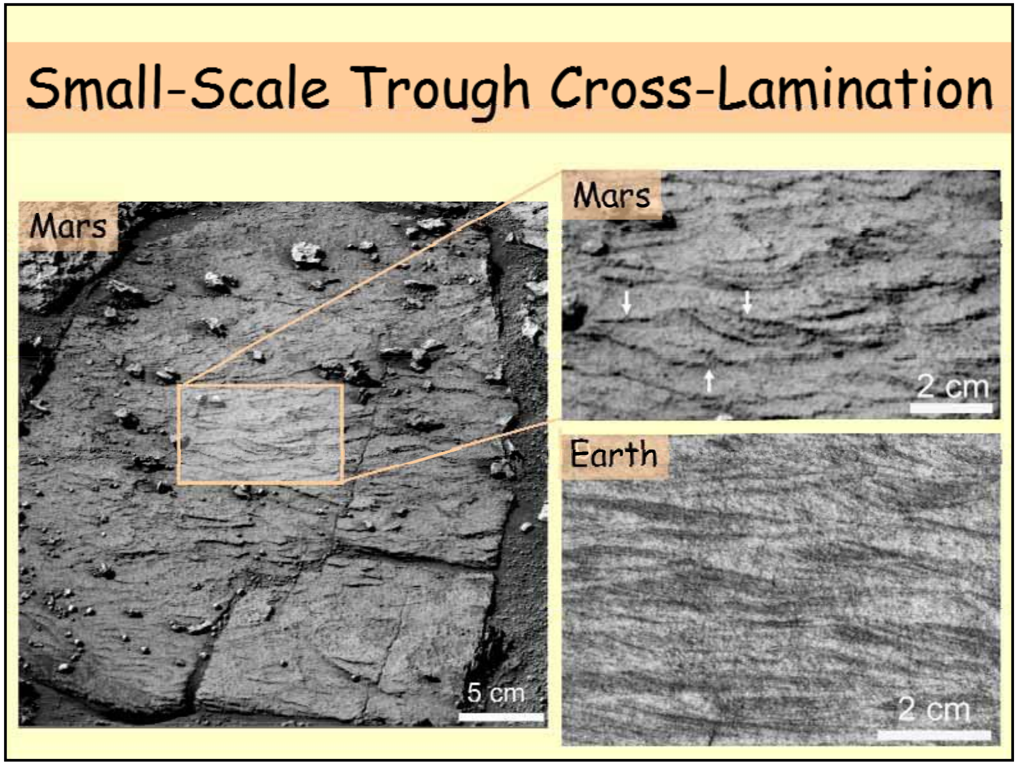
Sedimentary rocks can provide a high-resolution record of environmental conditions, clues to past aqueous environment on Mars


Erebus Crater
Olympia
Outcrop
Payson
Yavapai
100 m
HiRISE

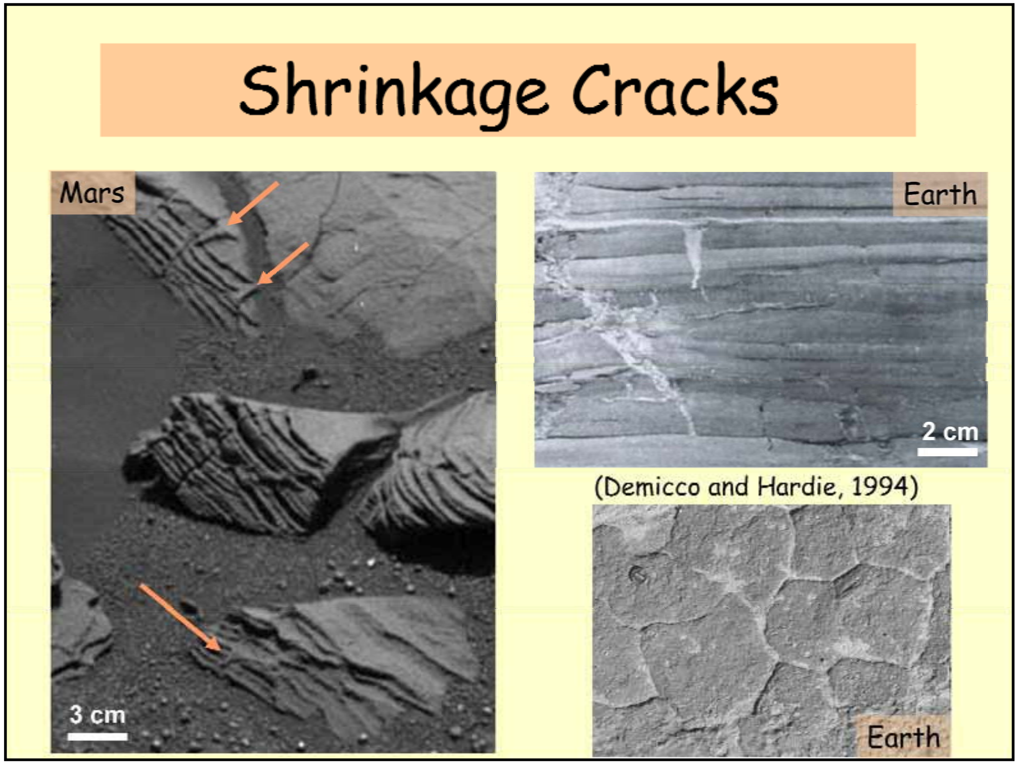
Payson Outcrop



Aperture –seismic array

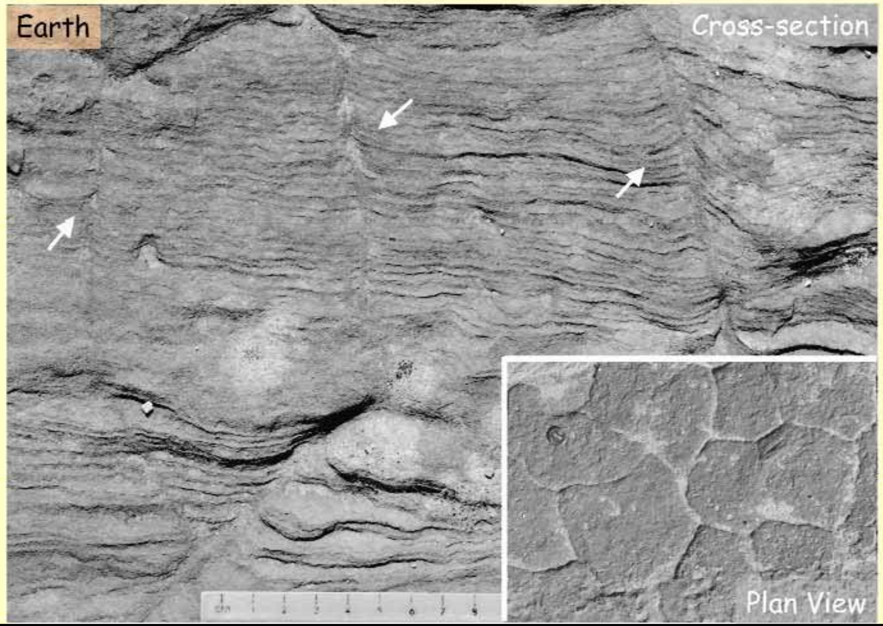


true stratigraphic thickness of close to 20-30 cm



Created by surface tension films of water that bridge the mineral grains at water contents less than complete saturation. These tensile stresses are large and cause haphazardly arranged grains to collapse on themselves generating tensional cracks. These stresses build up in the upper parts of a dewatering layer as it shrinks, declining downward from a max at the surface until they are replaced by compression related to the lithostatic force.

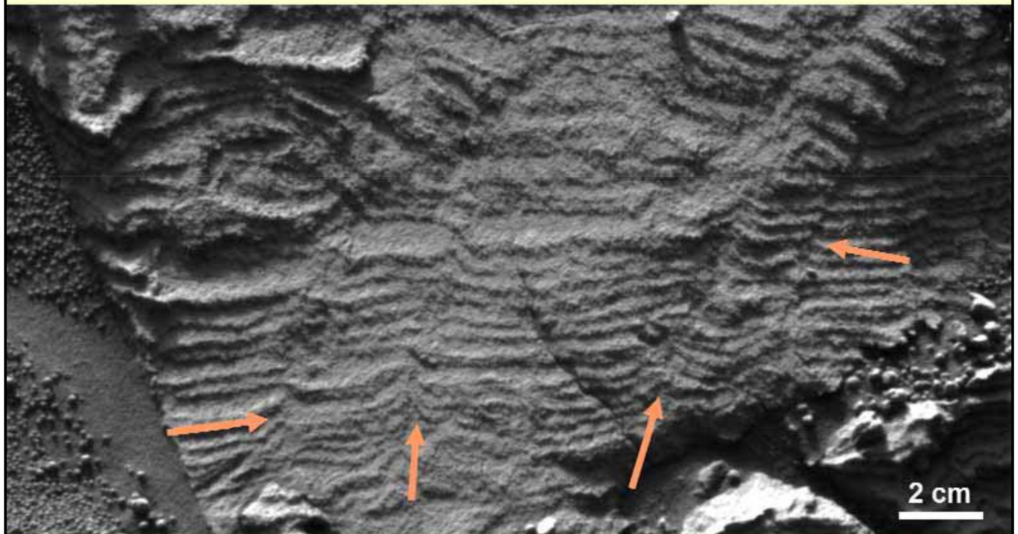
Prism Cracks on Earth



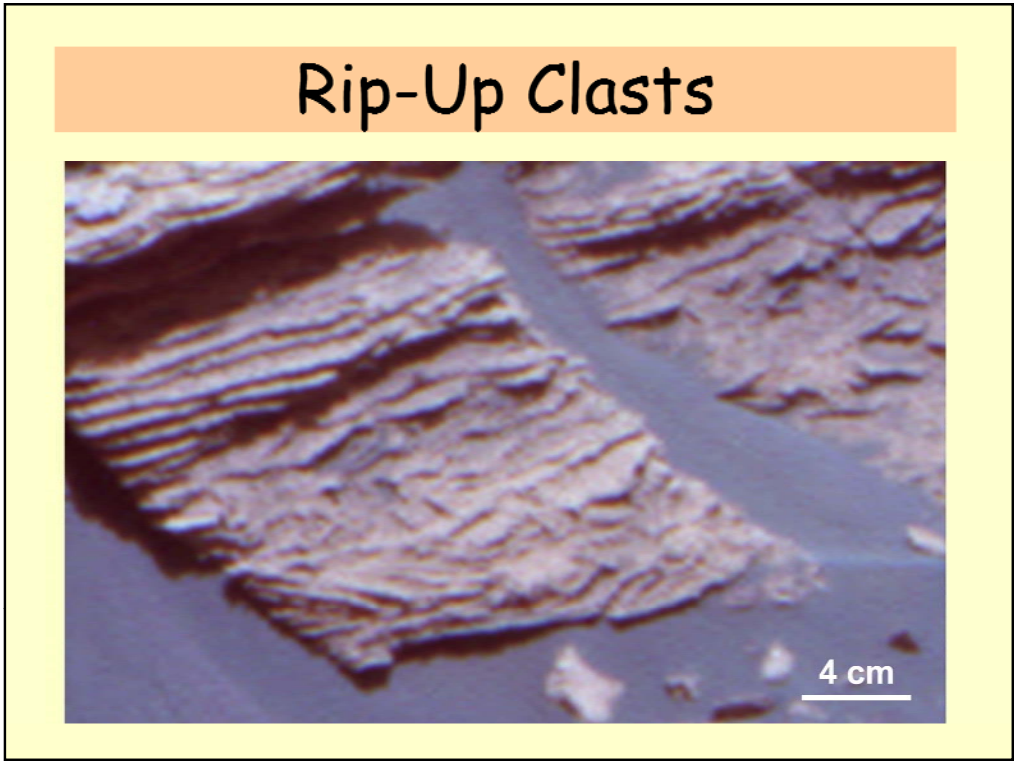
Truncated laminae commonly are deformed along crack margins; edges typically are rotated upward, forming “curl-up” structures

The terrestrial cracks are developed along an interdune bounding surface in the Jurassic Navajo Sandstone and form discrete prisms 10-15 cm wide extending to depths of up to 11 cm. These prism cracks formed by wetting-drying of a truncation surface that separates sets of eolian strata. Such surfaces are regarded to have formed during hiatuses in sedimention, followed by deflation to the water table

Prism Cracks on Mars

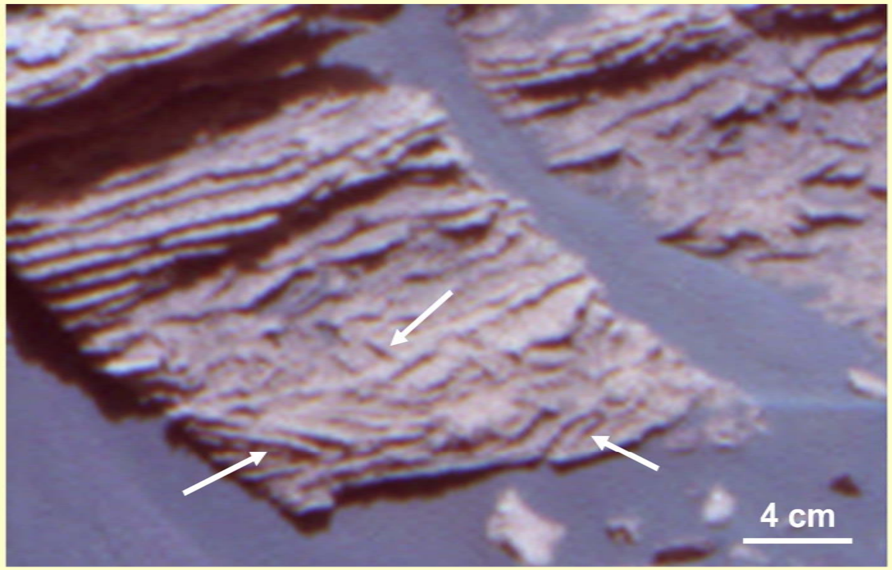


Martian strata in lower Overgaard and Skull Valley are interpreted to have become intermittently wet so that prism cracks could form along discrete surfaces. Minor oscillations of the water table would have been sufficient to accomplish this. The upward deflection of laminae to form curl-up structures is developed because a desiccating layer experiences more evaporation than the underside of the same layer, leading to differentially greater shortening – and thus curling – of the upper surface.

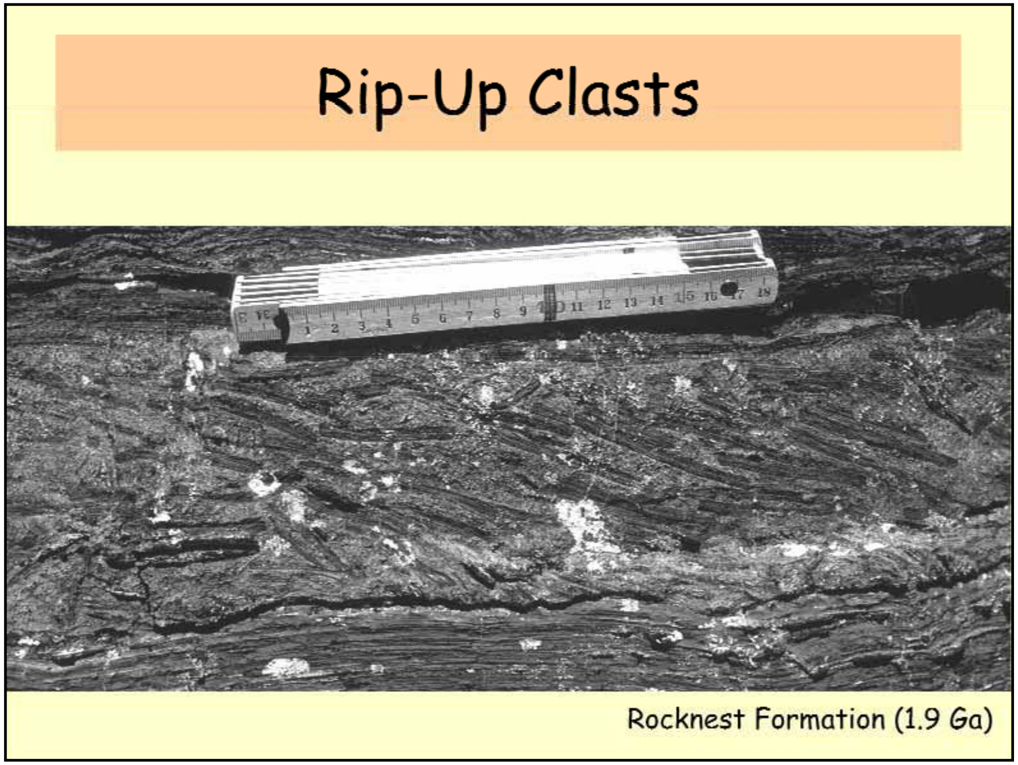


The rip-up clasts are interpreted to represent chips and pieces of former lamination that were cemented early and then broken up and reworked. Early cemented layers tend to undergo brittle deformation, whereas less-cemented, well-compacted layers undergo folding (Myrow et al. 2004). Clasts are often derived from desiccation-cracked ground and subaerial crusts (Demicco and Hardie 1994). Rip-up clasts are common on Earth in subaqueous environments where storms or strong currents can rework sediments (Demicco and Hardie 1994). Sediments tend to fail along planes of weakness, which in laminated deposits can result in mm-to-cm thick platy clasts (Myrow et al. 2004). This could have occurred in Erebus strata if a laminated deposited dried out and a crust formed over the surface; this crust then dried further and desiccation cracks developed, forming plates, which could then be reworked as clasts.

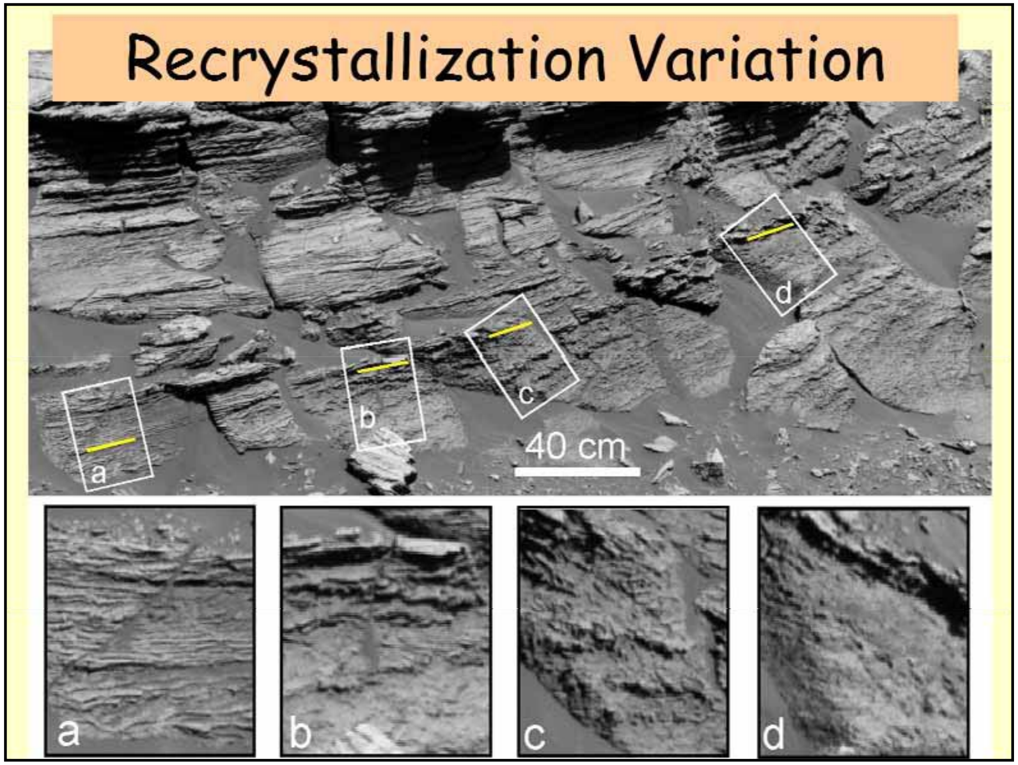
Rip-Up Clasts



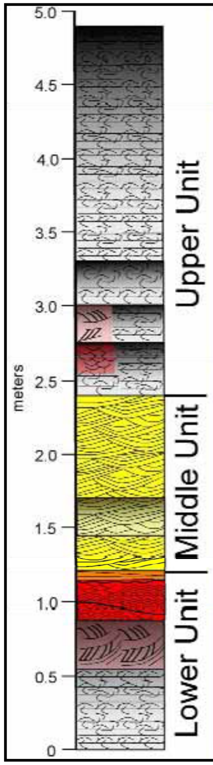
These rip-up clasts likely formed when the surface sediment became crusted over and was then later broken up, reworked, and deposited by a current. The clasts indicated by the left white arrow appear to be imbricated. One clast indicated by the white arrow appears to have broken into at least two pieces. There may also be a few more clasts imbricated in the same direction as those mentioned above in the block to the right, although they are more poorly defined. Clasts point vertically upward



Earth analog showing imbricated rip-up clasts from the Rocknest Formation (1.9 Ga), northern Canada. Scale is in centimeters.

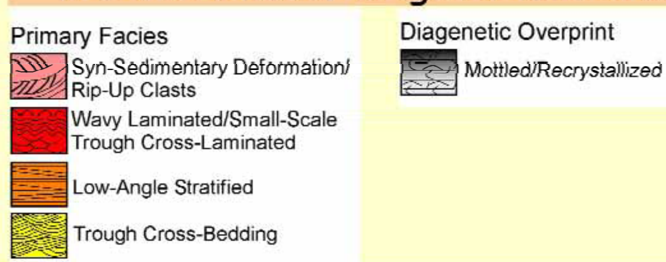


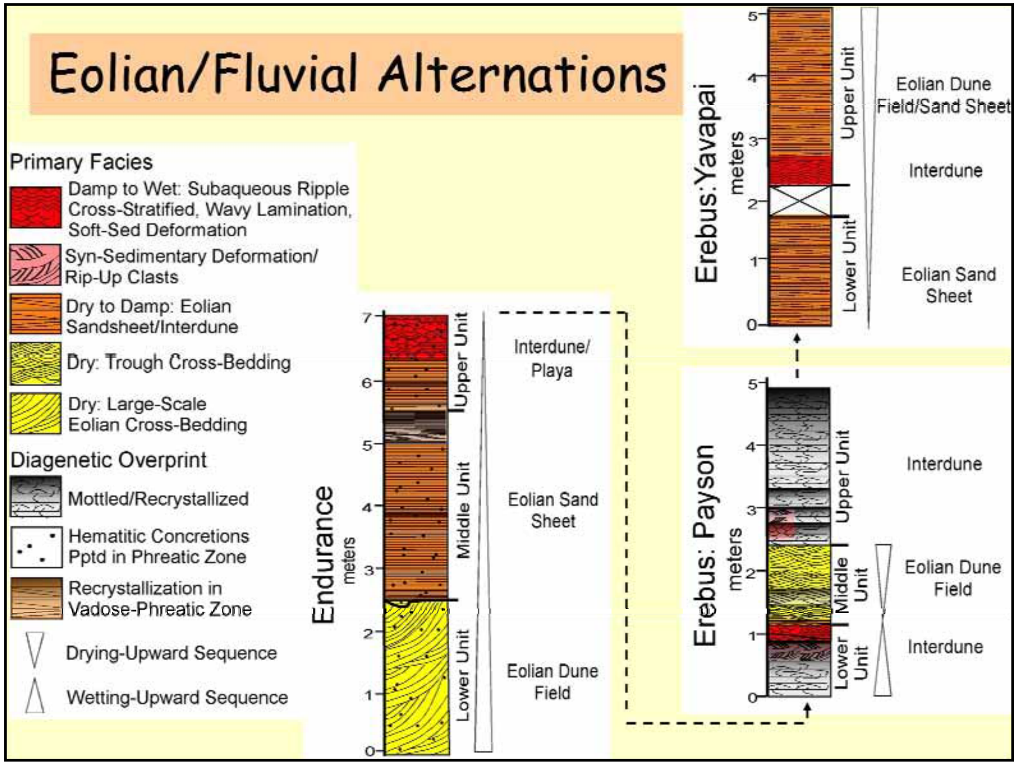
In box a, the original stratification is well preserved, but some of the original texture is lost farther along the same layer as shown in box b. In box c the recrystallization has been more intense with much of the original stratification lost, while farther to the right in box d the original stratification is almost completely lost. These images illustrate that although some areas of the outcrop may appear massive, they were all originally stratified at the cm-scale.



Environmental Interpretation

- Damp to wet interdune environment indicated by wavy lamination, syn-depositional reworking and cm-scale trough cross-lamination
- Later period of diagenesis results in some loss of original textures





Strata within Erebus crater, like those in the Burns formation in Endurance crater, record the interaction between eolian and fluvial processes. Repeated cycles of relative water table rise and fall within a dune-interdune system would be expected to form stacked deposits of dune-interdune facies (Grotzinger et al. 2005). The interactions between eolian and fluvial processes have been widely documented on Earth within both modern and ancient deposits, and these interactions can result in basin-wide drying or wetting-upward sequences

Conclusions

- Process sedimentology on Mars!
- New data from Erebus strengthens dune-interdune model
- Wetter facies at Erebus than seen in any previously investigated crater
- Facies extend over broad area, at least ~5km in N-S direction
- Only Eolian/Fluvial alternations seen
  - Wetting-upward at Endurance
  - Drying-upward at Erebus

On Earth, this would be a great reservoir rock; great as student to be able to do sedimentology on Mars similar to on earth

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