Geomorphology of the Mars Exploration Rover (MER-A) Landing site from Observations by the *Spirit* rover

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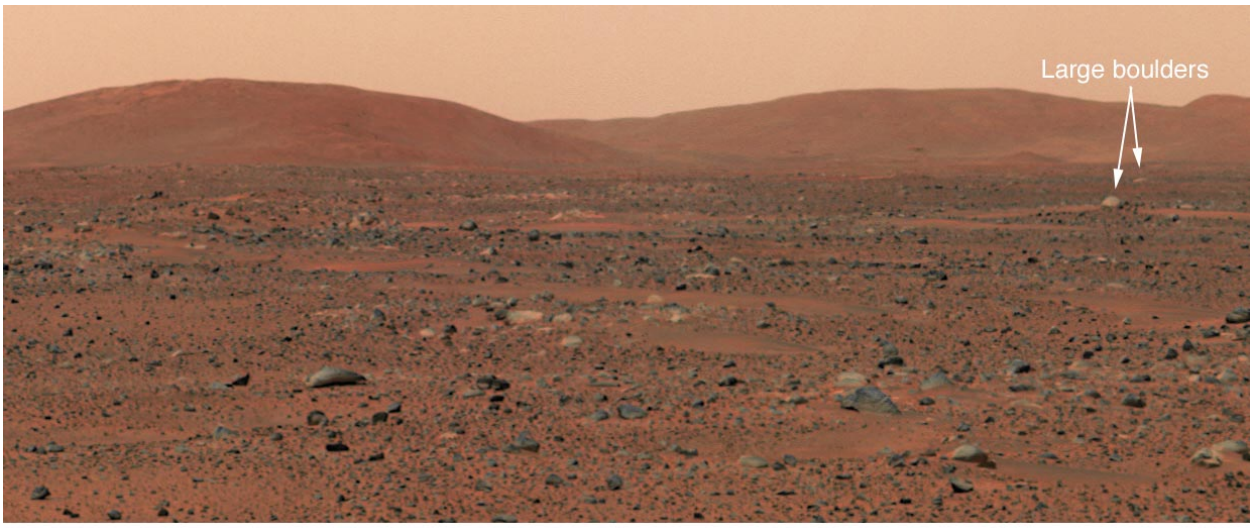
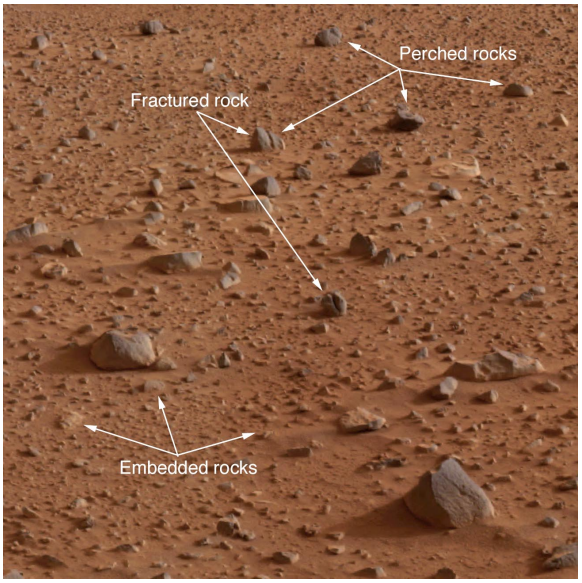


Introduction. MER-A, consisting of an entry, descent, and landing subsystem and the *Spirit* rover, successfully landed on Mars at 2034 PST on 3 January 2004. The landing location at 14.5692°S, 184.5271°W is within a variagated but generally low albedo zone that trends NW/SE across the center of Gusev Crater. Local relief is dominated by a cluster of well-defined, small (< 200 m diameter), low relief (< 15 m depth) impact craters and much smaller (~10's meters diameter) crudely circular swales and poorly-defined swells and ridges less than a few meters in relief. More distant features include a ridge of low-lying (<100 m high) hills 2-4 km east of the lander, and an isolated knob 7.6 km SW of the lander.

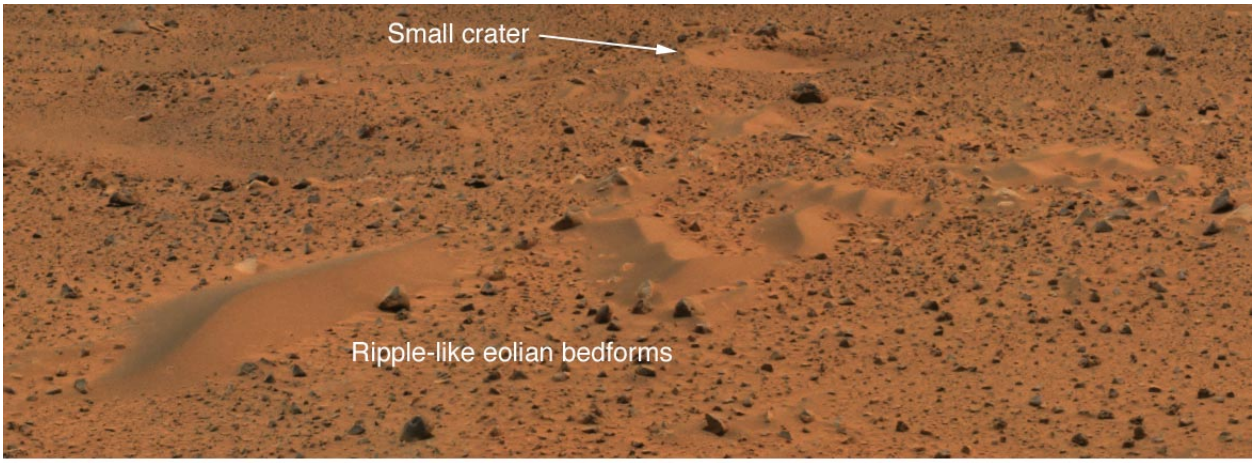
Geomorphology. The geomorphology of the landing site is defined by the interplay between processes and the native materials. Materials include silt, sand, granules, pebbles, cobbles and boulders. The primary transport agents are wind and potentially impact-related ballistic emplacement. No clear evidence of fluvial or lacustrine processes have been seen.

Boulder and cobbles are significantly less abundant at this site than at any of the previous landing locations—Chryse (Viking Lander 1 and Pathfinder) and Utopia (VL-2) Planitia. In the immediate vicinity of the lander, the largest stones are barely 50 cm in maximum dimension. Farfield views in Pancam and Navcam images suggest that occasional boulders to a few meters maximum dimension occur but are rare. Areal density of clasts 15 cm or larger is only a few percent, and stones larger than 1 cm only cover 5% of the surface.

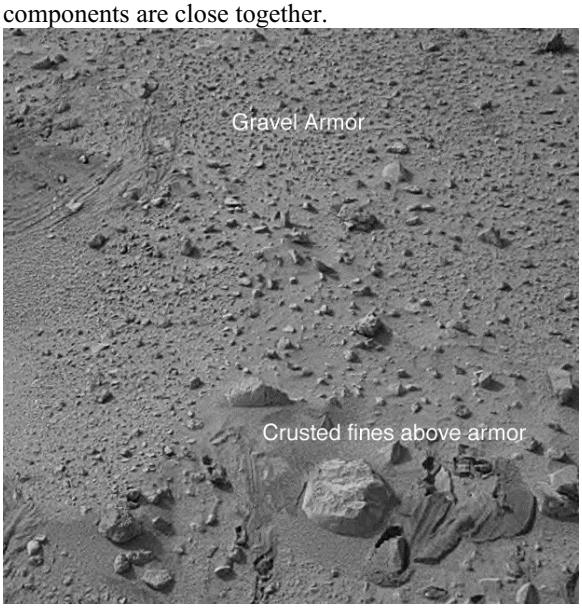
Stones can be distinguished on the basis of surface texture, surface brightness, shape, and position relative to the mean surface. Rocks of all



angularity are observed, with larger, more distant stones appearing somewhat more rounded than those in the near-field. This may in part reflect a resolution effect and oblique viewing. Typically, the best seen rocks are angular to sub-rounded. Two distinct populations are found relative to the mean surface: the majority of stones appear to be embedded within the surface material and a smaller population appears superimposed. Most rocks appear roughly equidimensional, but a small population of tabular stones is also present. Dark-toned rocks comprise fully 90% or more of the local population; light-toned stones are rare and do not comprise as well-defined a class as do the darker materials. Light-toned patination of the lower portions of near-vertical surfaces and occasionally of the upper surface of flat-lying, tabular rocks is attributed to weakly adhering



dust particles. Brushing ("zero force" grinding) by the Rock Abrasion Tool appears more than adequate to remove this surficial dusting. Roughly 20% of the rocks are pitted, some extremely so; most are massive with some evidence of etching. Essentially all stones show dull, matte or frosted reflections. Sharp edges are rare but do occur. More fractured/fragmented rocks are seen at this site than have been seen in the combined populations of the previous three landers. Most of the fractured rocks are small, and the components are close together.



The finer components of the regolith show a number of interesting attributes, some new or exclusive to this locale and some shared with previous landing sites. Among the attributes shared with the Viking and Pathfinder sites are a predominance on the uppermost surface of a light-toned, pink dust layer, surficial bedforms created by eolian transport of fine material, and a thin, distinctly cohesive upper layer or crust formed mostly of unresolved fine particles. Newly observed features include resolved sand- and granule-sized particles, and a well-delineated stratigraphy that includes a buried and occasionally exhumed gravel armor and a weakly cohesive layer 1-5 cm thick with embedded cobbles. Eolian drifts as seen at the VL-1 and Pathfinder sites are not seen in the immediate vicinity of the MER-A lander. Bedforms here more closely resemble the small ripple-forms seen at VL-2, but are significantly more abundant than at that site. The nature of the sand- and granule-sized particles is not clear: Cauliflower-form and indistinct boundaries when occurring as a surface as well as disappearance when subjected to external forces such as airbag impingement argue for aggregates held together by unknown mechanisms, while accumulation at the bases of larger rocks in subtle fillets suggest that the particles are strong enough to survive saltation and impact at the height of maximum energy deposition (~20-30 cm).