Field Observations: Spirit’s investigation of the cratered plains (exclusive of the Columbia Hills) in Gusev crater reveals a surface dominated by impact and to a lesser extent, eolian processes [1, 2]. The surfaces explored are generally low relief rocky plains dominated by shallow soil filled circular depressions, typically with rocky rims, called hollows. Rocks are dark, fine-grained basalts [3] that are angular, consistent with impact ejecta around craters.

Spirit’s investigation of Bonneville crater indicates that the upper 10 m of the cratered plains is an impact generated regolith that likely formed in basalt lava flows [2]. The largest rocks observed are in ejecta near the rims of the largest craters, suggesting they were excavated from relatively intact basalt flows at depth [1]. No outcrop has been seen anywhere in the craters or cratered plains. There is no evidence for rounded to subrounded boulders, imbricated rocks, or troughs that would argue for fluvial processes as expected from the morphologic setting inside Gusev crater or the possible young debris flow that emanates from Ma’adim Vallis revealed in THEMIS images that covers the western part of the landing ellipse [2].

Systematic field observations across Spirit’s traverse correspond to terrains mapped in MOC images [2, 4]. Vesicular clasts and delicate scoria similar to original lava flow tops have been found on low thermal inertia intercrater plains just east of Missoula crater ejecta. Spirit traversed “tabled terrain” (rough, generally higher thermal inertia terrain characterized by local elongate plateaus or tables) to the south, “whaleback terrain” (widely dispersed hummocks or whale-back-shaped swells) to the north, and transitional terrain in between [2]. A south to north topographic gradient of up to several degrees is apparent in Navcam panoramas and MOLA topography, consistent with an original lava flow surface emplaced from the south. The tabled terrain is consistent with an upper inflated surface of lava flows with adjacent collapse depressions that typically occur where the underlying surface gradient decreases and where basalt flows encounter obstacles (Columbia Hills).

Hollows: Hollows, tens of centimeters to tens of meters in diameter, show a range of preservation states consistent with old and small craters being filled in with sediment and nearby ejecta with time [1, 2]. Some are shallow circular depressions with slightly lower rock abundance without rocky rims. Others are relatively fresh with rocky rims, rocky ejecta and more relief. An increase in rock abundance of only 7% from subsequent crater ejecta would make a 5 m diameter hollow difficult to identify from the background plains [2].

The size frequency distribution of 58 hollows, 1-10 m in diameter mapped along the rover traverse during the first 90 sols exhibits a power law ~1.5 slope and forms a continuum with craters 10 m to 600 m in diameter mapped in MOC images with a ~2 power law slope [2]. This distribution along with their morphology (circular depressions with rocky rims) strongly argues that hollows are impact craters. The slightly lower power law slope of the hollows is likely produced by the preferential loss of smaller hollows due to resurfacing or erosion.

Craters: Craters larger than ~100 m diameter show a progression in degradation state from Bonneville (210 m diameter), with fresh ejecta, raised rim, and little fill; to Lahonton (90 m diameter), with less fresh ejecta, more fill, and lower wall slopes; to Missoula (163 m diameter), with less fresh ejecta, more fill, and low wall slopes; to Searles crater (~100 m in diameter), which possesses only ~2 m of relief, and is mainly filled by a mix of eolian sediments and ejecta blocks. The observed gradation sequence mostly involves the filling of craters with sediment and younger ejecta and there is no evidence for the characteristic pattern of crater erosion dominated by water that occurs on Earth [5].

Origin of Craters as Secondaries: Crater morphometry and degradation state argue that most or all of the craters and hollows are secondaries rather than primaries. The poorly-circular planforms, low depth-to-diameter ratios (~0.1) and wall gradients for the Gusev craters are more consistent
with fairly pristine secondary craters formed into unconsolidated rubble rather than primaries (which are twice as deep at formation) that have been heavily modified [2, 5]. Bonneville, the freshest large crater needs only a few meters of fill to account for the observed depth/diameter (d/D) ratio if it formed as a relatively pristine secondary. The d/D ratio of the freshest, deepest hollows is also close to that expected for secondaries, with more degraded and filled hollows having lower d/D ratios. The morphometry and form of the freshest small craters superposed on Bonneville (the freshest large crater) observed by Spirit also argues that they are secondaries with low d/D ratios, triplet clusters, and non-circular planforms [2].

**Rock Distribution:** The size-frequency distribution of rocks >0.1 m diameter measured in >70° sectors at Columbia Memorial Station (low inertia plains), Legacy (edge of continuous ejecta), and Bonneville crater rim panoramas out to 10 m distance generally follows the exponential model distribution based on Viking Lander and rocky locations on Earth used in landing site selection work for total rock abundances of 5%, 7%, and 35% at the three respective sites [6]. The rock distribution at CMS displays power law behavior from 0.1 to 0.03 m diameter with a total of about 11% of the surface covered by rocks at this site (about half is covered by pebbles). The rock abundance increases as the thermal inertia increases at the three sites.

Regular clast surveys in Navcam and Pancam images along the traverse also show a positive relationship between thermal inertia and total rock abundance and the exponential factor that controls how steeply the area covered by rocks decreases with increasing size [7]. Higher thermal inertia areas generally show more larger rocks and more area covered by larger rocks, which yields a flatter cumulative area versus diameter curve than areas of lower thermal inertia that have far fewer large rocks and a much more abrupt drop off in cumulative area versus diameter. Lower thermal inertia areas with lower overall rock abundance have more pebbles that are better sorted and more evenly spaced than higher thermal inertia locations with more, larger rocks. This argues that the pebble rich surface in the low thermal inertia plains is similar to a desert pavement or lag produced by deflation of fines, with wind drag or saltation induced traction on the pebbles producing their even spacing and sorting [8]. Conversely, rocky ejecta deposits and high thermal inertia plains tend to be dustier with higher aerodynamic roughness making it more difficult for the wind to effectively move eolian materials [9].

**Surficial Geology:** Eolian features identified by the Spirit rover include bedforms (mostly ripples), "drifts" of material found in association with rocks, called wind tails, and planar surfaces (facets) and grooves (ventifacts) cut into rocks by impacts of saltating sand [9, 10]. Ripples investigated have surfaces with a monolayer of coarse-grained sand and granules covered with dust and more poorly sorted, but generally finer grained interiors. The granule rich surface and dust cover suggest a lag deposit with saltation induced creep no longer occurring.

The Spirit observations are consistent with the formation of the cratered plains by a process in which excavation during impact deposits ejecta with widely varying grain sizes and fractured rocks that was in disequilibrium with the eolian regime. Deflation of ejected fines exposed the fractured rocks, and created a population of perched coarser fragments. Transported fines would be rapidly trapped within the craters creating the hollows, which would reduce the sand supply and lead to a surface that was in equilibrium with the eolian regime and thus generally inactive (except for dust cycling) [1, 2].

Deflation of the surface by ~5 to 25 cm is suggested by two-toned rocks with a redder patination along their bases, ventifacts that originate from a common horizon above the soil (suggesting that the lower part of the rock was shielded), rocks that appear to be perched on top of other rocks, and some undercut rocks, in which the soil has been removed from their bases [1, 7, 10]. The observed deflation of the surface thus represents the cumulative change of the surface since the Hesperian, or ~3.0 Ga, which provides a clue to the climate over this time. Extremely slow average erosion rates of ~0.03 mm/yr (between 0.02 mm/yr and 0.08 mm/yr) for the cratered plains are generally similar to those estimated in a similar manner at the Mars Pathfinder and Viking 1 landing sites and argue for very little long term net change of the surface implying a dry and desiccating environment similar to today’s has been active throughout the Hesperian and Amazonian (~3.7 Ga to present) [2].