PETROGENETIC INTERPRETATIONS OF ROCK TEXTURES AT THE PATHFINDER LANDING SITE T. J. Parker[1], H. J. Moore[2], J. A. Crisp[1], and M. P. Golombek[1], Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, tparker@jpl.nasa.gov, [2]United States Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025, moore@astmnl.wr.usgs.gov.

The cameras on the Mars Pathfinder Lander and Sojourner Rover enable detailed observation and analysis of rock textures that should be useful for corroborating inferences about petrogenesis based on results from the Alpha Proton X-ray Spectrometer) APXS. The rover's forward stereo cameras provided closeup images of rocks at a spatial resolution of 0.7 to 1 mm per pixel at closest range. For rocks further than 1.3 meters from the IMP lander camera, yet within 40 cm of the rover cameras, the spatial resolution of the rover cameras is better than that of the lander camera. However, super-resolution images prepared by coadding multiple single-frame IMP images can improve the resolution of IMP images by a factor of 2 to 3 (1).

A variety of surface textures are seen on the rocks at the landing site, including pitted, knobby, smooth, bumpy, and lineated. So far, none of the textures have proven to be diagnostic of a particular mode of formation.

Surface area abundance of pits on each rock is typically on the order of 5 to 10%. The pitted textures more closely resemble some of the rocks at Viking Lander 1 than the spongy-looking rocks common at Viking Lander 2. Pit sizes range from a few millimeters to a few centimeters across, and are similar to those seen in Viking lander images. On some rocks, such as Souffle' and the Dice, the pits resemble volcanic vesicles, although a nonvolcanic origin cannot be ruled out and aeolian processes probably have enlarged the original vesicles and changed their shapes.

One alternative to vesicles are chemically etched pits, such as those formed in the cold arid climate of Antarctica, during brief periods each year when the rock surfaces have thin films of snow melt. Allen and Conca (2) proposed this mechanism to explain the pits in rocks at the Viking landing sites. A second alternative is a "selective" etching out of softer minerals from within a matrix of harder minerals (3).

Yet a third alternative to vesicles are ventifact pits formed entirely by wind-blasting with dust and sand. On the surface of the rock Stimpy, it is not clear whether original volcanic vesicles have exerted control on wind abrasion or whether all of the pit formation could be due to weathering. The difference between the deep pits on most of Stimpy's surface and the curved, slotted grooves at the top of the rock could be due to the relationship between the impact angle of saltating particles and susceptibility to abrasion (4), and the less-affected zone at the very top could be a more resistant part of the rock.

One rock, Squash, exhibits an unusual knobby shape with lobes and protrusions roughly 10 cm in size, extending as far out as 12 cm. No other rocks at the site have similar protrusions. This texture could be an indicator that the rock is an autobrecciated lava, a pillow basalt, a sediment with rounded cobbles, an impact breccia, or a volcanic rock with lithic fragments. The protrusions are darker in albedo than the rest of the rock, much of which appears to be coated with dust. The other side of Squash facing IMP does not have these protrusions, and has a near-vertical fairly dust-free face and a dust-covered top.

Linear features, which could be layering, typically appearing as repeating subtle light-dark bands spaced 3 to 5 mm apart, are seen on many of the rocks at the landing site. The most striking examples are Chimp (Fig. 1) and Zebra. In some places the banding appears to be defined by thin subtle topographic ridges, but in most, it appears to be flush with the rock surface. Other rocks with these linear features include Mini-Matterhorn, Yogi, Half Dome, Ender, Squid, Flat Top, Stack, and Booboo. The banding is not a camera or image processing artifact. For example, the same lineations seen on the front face of Flat Top in rover images also shows up in super-resolution IMP images, at an orientation of about 40 degrees to its flat top. At times, the lineations are more easily seen in a super-resolution composite image or an anaglyph than in a single-frame image, but the features are also found in the single frame images. In some rocks, such as Barnacle Bill, multiple orientations of lineations may appear so faint and nonpervasive that the rock may not be layered at all. Nevertheless, similarly oriented linear features probably reflect something about the rock, either the orientation of stresses the rock has experienced; internal inhomogeneities such as alignments of bubbles or minerals, zones of weakness; or sedimentary layering.

Alignment of 1-3 cm vesicles in rocks at the Viking landing sites has been pointed out by McCauley et al. (5) and Carr (3), and gives some of the rocks a layered appearance. Alignment of pits in this size range is not common on rocks at the Pathfinder landing site, although Chimp (Fig. 1) is an exception. However, it is possible that the lineations are expressions of tiny vesicles that are aligned in planes. Such banding has been seen within inflated lava flows on Earth.

Only one rock at the landing site, Chimp, has been identified as having a texture resembling exfoliation (top left side of rock in Fig. 1). What may be an outer, probably more weathered, portion of the rock appears to have spalled off, exposing a rock surface underneath that either has a lighter albedo or perhaps is rougher and thus a better dust-collector than the dark outer surfaces of the rock. A large crack runs from top to bottom in this area. Freeze-thaw cycles over the past 2 billion years (± 2 Phanerozoics) may have contributed to cracking and exfoliation. On Earth, exfoliation is most commonly associated with decomposition of micas and hydration of feldspars in granite. However, it can also result in other rock types due to expansion and fracturing from temperature changes, mineral expansion due to chemical weathering, or through release of internal stresses when an overburden is removed. If exfoliation was a predominant weathering process at the landing site at some time in the past that has since ceased, some of the rounded boulders at the site may have been rounded by spheroidal weathering.

A bumpy texture, with rounded bumps on the scale of a few mm, is common on rocks at the Pathfinder site. Rocks with this texture include Wedge, Barnacle Bill, and Shark. Such bumpy textures could be the surface expression of something inside the rock that is more resistant to erosion (e.g., crystals, pebbles, cobbles, or lithic fragments), or could be a result of aeolian abrasion (6) or etching by chemical weathering. If chemical weathering is indicated, then Wedge's bumpy texture may be the most intensely altered surface of this type. Larger (2-4 cm) rounded lumps, like those seen on the base of Barnacle Bill and Bambam could be the surface expression of rounded cobbles in a conglomerate, rounded lithic fragments in a volcanic rock, or concretions.

Prince Charming and Shark are examples of several of the rocks that exhibit a bumpy texture with rounded pits and bumps. One possible explanation for the bumpy texture is that these rocks are conglomerates in which some pebbles and cobbles are still embedded in the rock while others have been plucked out by weathering to leave sockets. This process could be the source for the rounded pebbles and cobbles seen in the soil by the rover forward cameras. Rounded pebbles and cobbles were not found in the soil at the Viking Lander 1 and 2 sites, nor were rocks with similar pits and bumps, suggesting that if these rocks are conglomerates, they are unique to the Pathfinder site. However, although the bumpy textures could be indicative of conglomerates, they are not diagnostic, and might instead be the surface expression of other rock types such as poorly sorted sandstones or weathered volcanic rocks containing crystals and lithic fragments.

In the end, because of the equivocal nature of interpreting rock textures at the Pathfinder site, we cannot rule out a sedimentary origin for all the rocks (layering), a volcanic origin for all the rocks (aligned vesicles), a mixture of the two rock types, or even modification of such rocks by hydrothermal alteration, impact alteration, or metamorphism. In this case, our interpretation of the origin of the rocks is complicated by the fact that multiple processes were probably responsible for the final textures we see; the original rock textures have likely been overprinted by chemical weathering, aeolian abrasion, and dust coating. It may be possible to resolve this fundamental issue once more super resolution IMP images have been processed.

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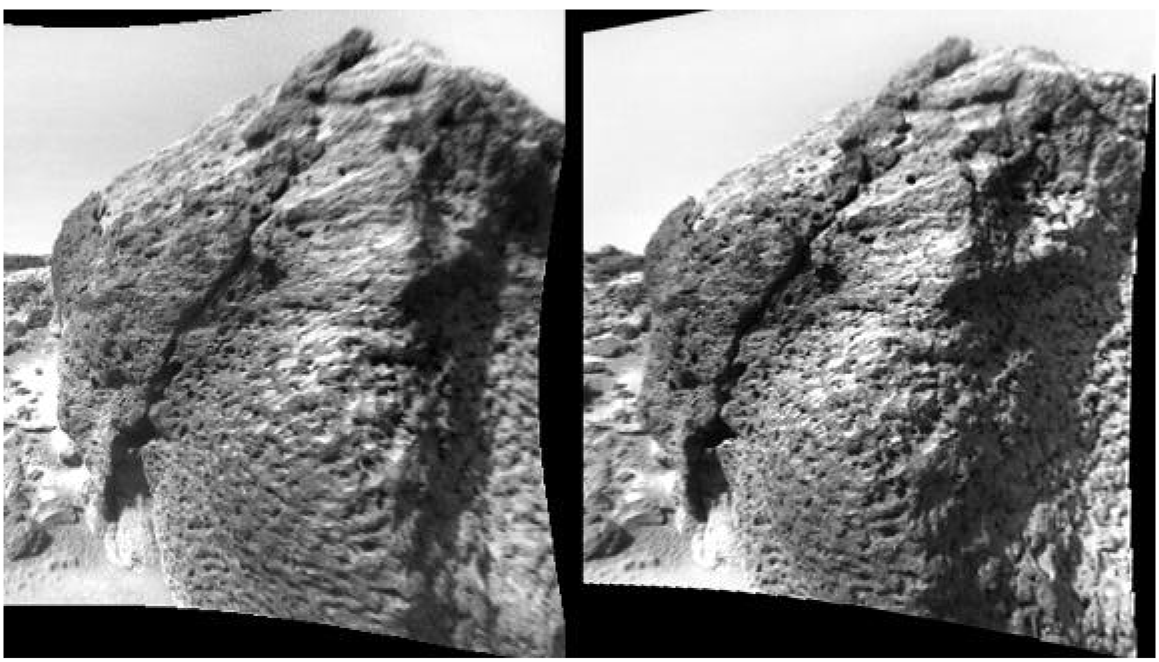

Figure 1: Rover forward camera stereo image of Chimp. Rock is 39 cm tall. Upper left texture resembles exfoliation. Prominent banding is roughly horizontal around the lower 2/3 of the rock, wrapping around the rounded nose closest to the camera, and continues around the left side of the rock.