hazy atmosphere, conflicting elevations from different sources, and other factors.

A Viking Landing Site Working Group was convened in early 1972 to identify site-selection criteria compatible with landing safety, system capabilities, and science objectives [3]. Among numerous criteria were low elevation (for parachute performance), large separations of site pairs (for communications), and a "warm and wet" environment (favorable for life).

Eleven landing sites between 30°N and 30°S were selected and considered by the Landing Site Working Group [4,5]. Later, six sites from about 43° to 73°N were considered because of their relative abundance of water vapor [5]. Still later, four equatorial sites were added because of existing radar data on them and their accessibility to future radar observations. Most of the sites were rejected for various reasons.

Four landing sites were approved by NASA Headquarters: (1) Chryse (prime A1; 19°N, 34°W), (2) Tritonis Lacus (back-up A2; 20°N, 252°W), (3) Cydonia (prime B1; 43°N, 11°W), and (4) Alba (back-up B2; 43°N, 110°W). The northern B sites replaced earlier southern sites (Apollinares and Memnonia) because the B sites were thought to have higher atmospheric water contents. Two equatorial sites were retained because of their radar signatures: (1) Capri (C1; 6°S, 43°W) and (2) Meridiani Sinus (C2; 5°S, 5°W).

For mission operations, the Landing Site Working Group was augmented by the Viking Flight Team and renamed the Landing Site Staff [3]. This latter group was responsible for Site Certification when the first orbiter's instruments could observe the prime site (A1) and ongoing radar observations could be analyzed; its responsibilities included certification of the second landing site. Certification criteria were much the same as those for selection: (1) landing ellipse size, (2) elevation, (3) surface temperatures, (4) geology, (5) surface roughness (slopes), (6) protuberances (rocks), (7) "soil" properties (bulk density, etc.), (8) radar reflectivity, (9) density-temperature profile of atmosphere, (10) atmospheric composition, (11) dust storms, and (12) winds.

There was no landing at any preselected site. Plans to land the first spacecraft at the initial Chryse site on July 4, 1976, were discarded because the surface, which appeared to be smooth and nearly featureless in hazy Mariner 9 images, appeared extremely rough, complicated, and eroded (and probably rocky) in the Viking images [6–8]. Arecibo quasispecular radar echoes at 12.6 cm from the vicinity of the site suggested a rough surface (RMS slopes near 5°–7°) but near-average reflectivity [9]. Small signal-to-noise ratios of Goldstone echoes (3.5-cm wavelength) from the site were particularly worrisome because they contrasted with large signal-to-noise ratios from Tritonis Lacus [9], and scenarios to explain the small ratios were all unfavorable. Other criteria appeared to be satisfied.

Viking 1 then began a search for a new site to the northwest of the original site based on images and Arecibo quasispecular radar observations [6,9]. *A priori* selection and certification of the final site were satisfying and defensible, because the project could say (1) there is evidence for abundant soillike materials in the images, (2) the rms slopes (4.5°–5.5°) are like those of lunar maria where Surveyors had landed, and (3) the reflectivity (0.07) is average for Mars [6–9]. The Viking Project made a sincere effort to find a safe landing site and was rewarded with a successful landing.

After the first lander demonstrated Viking's capabilities for entry, descent, and landing, almost everyone wanted to explore to the north, where atmospheric water vapor abundances were high [3,10]. A new northern site, Utopia Planitia (B3), was added, and orbiter temperature observations replaced the radar as a tool to assess surface material properties. Both the Cydonia (B1) and Alba (B2) sites appeared unexpectedly rough; again, Mariner 9 images taken through hazy skies had suggested smooth and mantled surfaces. B1 was rejected because large areas appeared rough and eroded; extensive "mantles" and "dune fields" were not found. B3 was chosen over a western extension of B2 because of the operational complexity that would be introduced; the modest difference in water-vapor abundance and inferred thicknesses and extents of "mantles" and "dunes" did not warrant the increased risk engendered by the increased operational complexity [3,10]. Thermal inertia at the B3 site was judged to be about the same as that of the Lander 1 site, but it was not possible to distinguish between a surface of sand and a surface like that around Lander 1 [10]. The B2 site had a lower thermal inertia than the B3 site [10]. Lander 2 was a success, but those expecting to see extensive mantling deposits or abundant sand dunes were surprised by the rocky scene.

The problems that now confront Mars Pathfinder are much the same as those that confronted Viking, but more and better information exists today. Like Viking, Mars Pathfinder must select a landing site compatible with lander and rover designs as evidenced by available data (Viking images, radar and thermal observations, albedo and color observations, visible-infrared spectra, etc.). Most regions at low elevations probably contain favorable sites, but some sites at low elevations with weak quasispecular echoes and low thermal inertias may be unfavorable [11].

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TARTARUS COLLES: A SAMPLING OF THE MARTIAN HIGHLANDS. S. Murchie and A. Treiman, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058, USA.

Several of the most fundamental issues about the geology of Mars can be addressed using information on composition and structure of the plateau plains ("highlands") that cover approximately half the planet [1,2]. The units that compose the highlands are interpreted as a mixture of volcanic, fluvial, lacustrine, and impact ejecta deposits. A more precise inventory of differing of igneous and sedimentary lithologies in highland rock units would not only lead to a better understanding of how the plateau plains formed, but would also clarify the nature of the surface environment during the first 800 m.y. of martian history. Structural features including bedforms, joints, and small faults that are unresolved from orbit record a history of the emplacement and deformation of the highlands. In addition, weathering products present in this very ancient terrain represent a mineralogic record of past climate and of the pathways by which bedrock is altered chemically [3]. Their similarity or dissimilarity to bright soils observed spectroscopically and *in situ* at the Viking Lander sites [4–6] will be evidence for the relative roles of regional sources and global eolian transport in producing the widespread cover of "dust."

Unfortunately, these issues are difficult to address in the plateau plains proper, because bedrock is covered by mobile sand and weathering products, which dominate both surface composition and remotely measurable spectral properties [5]. However, the "Tartarus Colles" site (Fig. 1), located at 11.41°N, 197.69°W at an elevation of −1 km, provides an excellent opportunity to address the highland geology within the mission constraints of Mars Pathfinder. The site is mapped as unit HNu [7], and consists of knobby remnants of deeply eroded highlands. It contains rolling hills, but lacks steep escarpments and massifs common in most highland remnants, and is free of large channels that would have removed colluvium from eroded upper portions of the stratigraphic column. These characteristics indicate that a variety of bedrock types from thoughout the Noachian-Hesperian stratigraphic column may remain at the site.

Six characteristics of the site indicate that Mars Pathfinder can successfully be used here to address the fundamental issues outlined above:

Provenance of the Site is Known: This occurrence of unit HNu completely encompasses the landing ellipse, so that the geologic context of the landing site would be known independently of refinements in lander location.

Site Contains Locally Derived Material: The knobby morphology of the site, the lack of channels, and a measured block abundance of ~10–15% [5] are all consistent with the presence of decimeter-sized rock fragments derived from within several kilometers of their present locations.

Exposed Unit is of Global Import: The highlands bedrock accessible here contains a record of early martian history absent from the younger northern plains assemblage [1,2], which dominates most locations within the elevation and latitude range intended for Mars Pathfinder. Comparable exposures do occur in walls of outflow channels, the walls of Valles Marineris, and walls and massifs of large craters and basins, but these sites generally are characterized by very rough topography and/or they form targets much smaller than the Mars Pathfinder landing ellipse.

Site Contains Nearly Unaltered Material: The presence of relatively unaltered material is critical to an accurate compositional determination of the substrate. Visible color of the landing ellipse is dominated by "dark gray" materials, which are shown by near-infrared spectroscopic studies to consist of relatively unaltered, basaltic particles [4,5]. In addition, the thermal inertia of the site is ~8×10^{-3}, consistent with abundant sand [5]. Saltating sand may have partially abraded weathered rinds from locally derived blocks.

Site Also Contains Weathering Products: Albedo patterns at the site reveal the presence of segregated patches of bright red dust. Furthermore, the ancient origin of the block cover is consistent with substantial chemical alteration of at least portions of exposed rock particles.

Site Contains Evidence to Address Tractable Questions: The major issues about highland geology outlined above can be summarized in three questions, which can be meaningfully addressed using measurements from instruments on the Pathfinder lander and rover:

Fig. 1. Digital image model covering the Tartarus Colles region, showing the Pathfinder landing ellipse. Coordinates are latitudes and longitudes of image corners.

Bedrock lithology. The camera filters on the Imager for Mars Pathfinder (IMP) can discriminate major rock-forming minerals containing ferrous or ferric iron. IMP is thus able to distinguish different spectral types of blocks. Their elemental compositions can then be measured by the alpha-proton-X-ray spectrometer (APXS) on the rover, and their texures observed by the rover camera.

Nature of macrostructures. The stereo capability and spatial resolution of IMP will show fractures and bedforms in near-field blocks, and structurally influenced block and knob shapes in the far-field.

Composition and texture of weathering products. Spectral measurements of "dust" by IMP will provide a basis for comparison with telescopic and spacecraft spectral data and determinations of elemental composition by APXS will allow comparison with the Viking Lander sites. Both instruments and the rover camera, by observing fresh and weathered surfaces of the same blocks, can together determine the compositional and textural properties of weathered coatings. Finally, measurements of any indurated "duricrust" may be able to identify what phases are mobile and "enriched" in this material.

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