

A MARS PATHFINDER LANDING ON A RECENTLY DRAINED EPHEMERAL SEA: CERBERUS PLAINS, 6°N, 188°W. G. R. Brakenridge, Surficial Processes Laboratory, Department of Geography, Dartmouth College, Hanover NH 03755, USA.

Along a 500 km-wide belt extending between 202° and 180°W and lying astride the martian equator, moderately low-albedo, uncratered smooth plains exhibit low thermal inertia and potentially favorable conditions for the preservation of near-surface ice. The Cerberus Plains occupy a topographic trough as much as 2 km below the planetary datum [1,2], and the denser atmosphere at these altitudes would also favor long residence times for near-surface ice once emplaced [3]. The plains have previously been interpreted as the result of young (Late Amazonian) low-viscosity lava flows [4] or similarly youthful fluvial deposition [5,6]. However, the plains are also included in maps of possibly extensive martian paleoseas or paleolakes [7,8]. Ice emplaced as such seas dissipated could still be preserved under thin (a few tens of centimeters) sedimentary cover [9]. In any case, and if a sea once existed, aqueous-born interstitial cementation, probably including hydrated iron oxides and sulfate minerals, would have been favored and is now susceptible to investigation by the Pathfinder alpha proton X-ray spectrometer and multispectral imager.

There is interesting supporting evidence indicating an aqueous origin for the Cerberus Plains. On Viking Orbiter high-resolution images, some near-shoreline portions of the plains exhibit intersecting, very-low-relief linear or curvilinear ridges that may define ridge-interior, polygon-shaped, angular-to-rounded ice cakes and ice flows [10]. Lead- and pressure-ridge-like forms can be mapped, although local relief is very low. The shelf icelike pattern outlines flows that are similar in size to those that occur on Earth, and the general fragmental character is quite different from the smooth surface morphology imaged at Viking resolution on unmantled plains confidently known to have formed by lava flows. Finally, a suite of landforms elsewhere considered to be coastal in origin [11] occur along the southern margin of the plains: These are compatible with a marine or lacustral model but not with a lava flow origin. Such landforms include peninsulas and bays, spits, strandlines, and stepped massifs, and all are consistent with a maximum sea level reaching to ~-1000 m altitude.

For example, at 3°S, 197°W, the dark-albedo, low-thermal-inertia plains unit embays and overlaps the knobby terrains to the south along or very close to the -1000-m contour. Four hundred kilometers to the northeast, the "sea floor" plain reaches to below -2000 m, implying maximum stage water depths of at least 1000 m. In the deep region, two isolated massifs (Hibes Montes) extend to above -1000 m altitude, and both exhibit topographic steps at that altitude: These may be wave-cut or other coastal features. In contrast, if lava extrusions were instead centered in this deepest part of the basin and formed the Cerberus Plains [4], these lavas must have flowed uphill and at relatively steep gradients to reach the southern margin of the plains. Either the topography as now mapped is greatly in error (and there is no trough), or water is the more likely fluid to have formed the embayment features along the southern margin.

A 180-km-wide outflow channel typical in its morphology but unusual in its youthfulness (it too is uncratered) extends from the Cerberus Plain trough northeastward to a "spillway" at 24°N, 172°W. The spillway lies at -1000 m altitude and some 1100 km

from the Hibes Montes islands. In agreement with [4], streamlined interchannel islands indicate fluid flow to the northeast, from Cerberus and into Amazonis Planitia and the deeper (-3000 m altitude) basin therein. This could not have occurred unless fluid levels reached over the spillway; again, the basin must have once filled to ~-1000 m altitude, and this too suggests water and not lava as the fluid involved. The Cerberus Sea probably formed in much the same manner as did the outflow channels, but the surface discharge occurred within a topographic basin, and the basin itself was first filled before overtopping the lowest spillway and discharging excess water and ice into Amazonia Planitia. Slow filling, perhaps under a perennial ice cover, could instead have occurred if a global groundwater system exists [12] or if regional geothermal sources such as recently present at Elysium or Orcus Patera stimulated large-scale hydrothermal circulation [7] and water discharge along faults and fractures (in this case, at Cerberus Rupes). Whether filling was slow or rapid, much evidence indicates that an ice-covered sea recently existed at the location of the present-day Cerberus Plains, and this poses unique opportunities for a Pathfinder landing that would investigate the sedimentary and soil geochemical traces of the planet's water cycle.

At the suggested landing location, shelf ice may still exist, and be frozen together into extensive grounded composite flows and thinly mantled by cemented low-thermal-inertia eolian deposits. Alternatively, sediment-laden and perhaps mantled shelf ice existed here late in Mars history and has since sublimed or melted. In either event, the present sedimentary cover is resistant to wind erosion and thus probably cemented. There exists here the uncertain possibility of detecting near-surface ice, but the probable opportunity to analyze in detail chemically cemented fine sediment and thus learn much about interstitial water characteristics.

References: [1] *USGS Misc. Inv. Ser. Map I-2118* (1991). [2] *USGS Misc. Inv. Ser. Map I-2127* (1991). [3] Mellon M. T. and Jakosky B. M. (1993) *JGR*, 98, 3345-3364. [4] Plescia J. B. (1990) *Icarus*, 88, 465-490. [5] Greeley R. and Guest J. E. (1987) *USGS Map I-1802B*. [6] Tanaka K. L. (1986) *Proc. LPSC 17th*, in *JGR*, 91, E139-E158. [7] Baker V. R. et al. (1991) *Nature*, 352, 589-594. [8] Scott et al. (1991) *LPS XXII*, 1203-1204. [9] Paige D. A. (1992) *Nature*, 356, 43-45. [10] Brakenridge G. R. (1993) *LPS XXIV*, 175-176. [11] Parker T. J. et al. (1993) *JGR*, 98, 11061-11078. [12] Clifford S. M. (1993) *JGR*, 98, 10973-11016.

PHYSICAL PROPERTIES (PARTICLE SIZE, ROCK ABUNDANCE) FROM THERMAL INFRARED REMOTE OBSERVATIONS: IMPLICATIONS FOR MARS LANDING SITES. P. R. Christensen and K. S. Edgett, Department of Geology, Box 871404, Arizona State University, Tempe AZ 85287-1404, USA.

Critical to the assessment of potential sites for the 1997 Pathfinder landing is estimation of general physical properties of the martian surface. Surface properties have been studied using a variety of spacecraft and Earth-based remote sensing observations [1,2], plus *in situ* studies at the Viking lander sites [2,3]. Because of their value in identifying landing hazards and defining scientific objectives, we focus this discussion on thermal inertia and rock abundance derived from middle-infrared (6-30 μm) observations. Used in conjunction with other datasets, particularly albedo and Viking

orbiter images, thermal inertia and rock abundance provide clues about the properties of potential Mars landing sites.

Here we discuss the combined albedo [4], thermal inertia [2,5], and rock abundance [6] results [derived from Viking Infrared Thermal Mapper (IRTM) data collected 1976–1980] for regions that fit the Pathfinder landing constraints: areas below ~0 km elevation between 0° and 30°N latitude. Lately there has been considerable discussion of the uncertainty in thermal inertia derived under a relatively dusty martian atmosphere [7–11]. In particular, Hayashi et al. [8] suggest that the thermal inertias, which we describe below, are 50–100 (units of $\text{J m}^{-2} \text{s}^{-0.5} \text{K}^{-1}$, hereafter referred to as “units”), too high for regions with moderate and high inertias (>300 units) and 0–50 units high for regions of low inertia (<300 units). However, our interpretation of physical properties is general and accounts for uncertainty due to modeling of suspended dust.

Thermal inertia is related to average particle size of an assumed smooth, homogeneous surface to depths of 2–10 cm [12]. Rock abundance is derived from multiwavelength observations to resolve surface materials into fine (sub-centimeter-scale) and rocky (~10-cm) components, based on the fact that temperature of rocks and fines can differ by up to 60 K at night [6]. Low rock abundances generally indicate areas with dust or sand deposits, while areas of high rock abundance are commonly outflow channel deposits and/or regions deflated by wind [2,5,6].

Christensen and Moore (Fig. 11, [2]) identified four physical units that describe the general variation in surface properties on Mars. The data products used in this analysis include a 0.5°/bin-resolution thermal inertia map [5], a 1°/bin-resolution Viking-era albedo map [4], and the 1°/bin rock abundance map [6].

Unit 1 is defined by low thermal inertia (40–150 units), high albedo (0.26–0.40), and low rock abundance (<5%). Unit 1 surfaces are interpreted as being mantled by dust up to 1 m thick. Most of these surfaces are in the high-elevation Tharsis, Arabia, and Elysium regions; however, two regions lower than 0 km elevation between 0° and 30°N have similar deposits: Amazonis Planitia and Elysium Basin (150°W–210°W).

Unit 2 is characterized by high thermal inertia (300–850 units) and low albedo (0.1–0.2), with rock abundances high but variable. Southern Acidalia and Oxia Palus (0°–60°W) fit this description, and are considered to be regions of active sand transport and rocky lag deposits. Other Unit 2 surfaces include Syrtis Major (elevation >0 km) and Cerberus (elevation <0 km), which have lower rock abundances (<7%) and are probably more sandy and less rocky than Acidalia.

Unit 3 surfaces have moderate thermal inertias (150–350 units), average albedos (0.15–0.25), and moderate to low rock abundances. Parts of Western Arabia near Oxia Palus and parts of Xanthe Terra and Lunae Planum fit this description. These have been interpreted as possible surface exposures of indurated dust/soil deposits similar to the crusted materials seen a few centimeters beneath the surface at the Viking lander sites.

Unit 4 has moderate-to-high inertias (210–380 units), a relatively high albedo (0.25–0.30), and a high rock abundance (>7%). This unit includes the two Viking lander sites [13]. The Viking sites have elements of all the above Mars surface deposit types (dust, rocks, crust) except the low-albedo, sandy material of Unit 2 [2]. Much of Chryse Planitia and parts of Isidis Planitia and Elysium Planitia (210°W–250°W) can be described as possible Unit 4 surfaces.

Finally, there is some interest in landing sites in or at the mouths of outflow channels. Henry and Zimbelman [14] and Betts and Murray [15] have provided IRTM and Phobos 2 Termoskan evidence (respectively) that channel floors tend to have enhanced thermal inertias probably related, in part, to the presence of blocky material on the channel floors. Henry and Zimbelman saw a general “downstream” decrease in thermal inertia in Ares Vallis, consistent with a decrease in clast size down the channel. Surfaces at the mouths of major outflow channels, however, have enhanced rock abundances [6].

References: [1] Kieffer H. H. et al., eds. (1992) *Mars*, Univ. of Arizona, Tucson: Chapters by L. J. Martin et al., 34–70; R. A. Simpson et al., 652–685; L. A. Soderblom, 557–593. [2] Christensen P. R. and Moore H. J. (1992) in *Mars*, 686–729, Univ. of Arizona, Tucson. [3] Moore H. J. et al. (1987) *USGS Prof. Paper 1389*. [4] Pleskot L. K. and Miner E. D. (1981) *Icarus*, 45, 447–467. [5] Christensen P. R. and Malin M. C. (1993) *LPS XXIV*, 285–286. [6] Christensen P. R. (1986) *Icarus*, 68, 217–238. [7] Haberle R. M. and Jakosky B. M. (1991) *Icarus*, 90, 187–204. [8] Hayashi J. N. et al. (1994) *JGR*, submitted. [9] Bridges N. T. (1994) *GRL*, in press. [10] Edgett K. S. and Christensen P. R. (1994) *JGR*, 99, 1997–2018. [11] Paige D. A. et al. (1994) *JGR*, in press. [12] Kieffer H. H. et al. (1973) *JGR*, 78, 4291–4312. [13] Jakosky B. M. and Christensen (1986) *Icarus*, 66, 125–133. [14] Henry L. Y. and Zimbelman J. R. (1988) *LPS XIX*, 479–480. [15] Betts B. H. and Murray B. C. (1994) *JGR*, 99, 1983–1996.

RATIONALE FOR A MARS PATHFINDER MISSION TO CHRYSE PLANITIA AND THE VIKING 1 LANDER. R. A. Craddock, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington DC 20560, USA.

Presently the landing site for Mars Pathfinder will be constrained to latitudes between 0° and 30°N to facilitate communication with Earth and to allow the lander and rover solar arrays to generate the maximum possible power. The reference elevation of the site must also be below 0 km so that the descent parachute, a Viking derivative, has sufficient time to open and slow the lander to the correct terminal velocity. Although Mars has as much land surface area as the continental crust of the Earth, such engineering constraints immediately limit the number of possible landing sites to only three broad regions: Amazonis, Chryse, and Isidis Planitiae. Of these, both Chryse and Isidis Planitiae stand out as the sites offering the most information to address several broad scientific topics.

An immediate reaction to proposing Chryse Planitia as a potential landing site is, “Why go back to an area previously explored by the Viking 1 lander?” However, this question answers itself. Viking 1 landed successfully, proving that it is safe and providing us with valuable ground-truth observations of the martian surface. For example, Viking Lander 1 data have provided information useful in determining the physical properties of the martian surface materials [1]. Observations such as these have undoubtedly been incorporated into the Mars Pathfinder spacecraft and rover design, making them well equipped to successfully operate in the Chryse Planitia environment. We simply don’t know with any level of certainty what