GEOLOGIC SIGNATURE OF LIFE ON MARS: LOW-ALBEDO LAVA FLOWS AND THE SEARCH FOR WARM HAVENS .

K. S. Edgett[1] and J. W. Rice, Jr.[2], [1]Department of Geology, Arizona State University, Box 871404, Tempe, AZ 85287-1404, U.S.A. (edgett@esther.la.asu.edu), [2]Department of Geography, Arizona State University, Box 870104, Tempe, AZ 85287-0104, U.S.A. (asjwr@asuvm.inre.asu.edu).

INTRODUCTION. The possibility that Mars had living organisms in its past has become the focus of much attention in the wake of observations of the ALH84001 meteorite presented by McKay *et al.* [1]. Regardless of the final outcome of the vigorous debate which has ensued, the possibility that Mars had life in the past was already regaining interest and support prior to this announcement [2–4]. It is often argued that if Mars ever developed life, living organisms might still exist somewhere under the planet's surface. The focus of this paper is on the search for geologic settings for extant martian life.

A key component of the search for martian organisms is the search for credible evidence of geologically-young hydrothermal environments [4,5]. *Mars Global Surveyor*, scheduled to reach the planet on September 12, 1997, carries the Thermal Emission Spectrometer (TES). With 3 to 9 km/pixel resolution, TES data will play a major role in the search for minerals and geothermal heat associated with present and relatively recent hydrothermal systems [6]. Cameras on *Mars Global Surveyor* and the *Mars Surveyor 98* orbiter will also aid in this search; and instruments will surely be proposed for the *Mars Surveyor 01* orbiter that have higher spatial resolution for detecting hydrothermal environments. However, potential targets relevant to the search for young hydrothermal systems can already be identified. These are found on the basis of the presence of relatively young, low-albedo lava flows.

To date, the youngest features on Mars that are proposed to have a volcanic origin are dark, sandy spots associated with faults in the Valles Marineris, which B. K. Lucchitta suggested might be relatively young pyroclastic deposits [7, 8]. However, landing a spacecraft in these valleys to search for evidence of life might be difficult. A plain with hundreds of kilometers of relatively flat surface might make a more preferable future landing site. In this paper, we note the presence of two low-albedo lava flows that occur on vast plains that are large enough to consider a safe spacecraft landing, should either location prove (upon further examination by instruments such as TES) to be a viable place to look for extant life.

WHY LOW-ALBEDO LAVA FLOWS? Dark-hued surfaces on Mars tend to be sandy, aeolian environments, not lava flows [9]. Indeed, the surfaces with the lowest albedos are dune fields [*e.g,* 9–11]. The reason that dune fields and sandy surfaces tend to have low albedos is attributed to the probable mafic composition of the sand and the removal of fine dust via saltation [*e.g.,* 12]; a process that is well understood and documented in the terrestrial literature [*e.g.,* 13]. Thus, there is a general assumption about Mars that dark surfaces lack dust, while other surfaces have at least a thin coating of dust [*e.g.,* 14]. In this context, how would a low-albedo lava flow on Mars be explained? A low-albedo lava flow would be a surface that lacks an optically-thick coating of fine, bright dust. The lack of dust could be the result of sand saltating across the lava flow, or it could be explained if the flow is extremely young and has not had time to develop a thick enough mantle of dust. In either case, a dark lava flow would also be a surface that has not undergone significant chemical weathering. The lack of a dust coating and lack of weathering might indicate that the lava flow is extremely young.

DARK FLOW IN SYRIA PLANUM. The first low-albedo flow we describe is located in Syria Planum at 20.6°S, 98.6°W (see *Viking* orbiter image 643A64). Its presence was noted by Hodges and Moore [15], but they did not discuss the implication of its low albedo. The flow covers about 100 km^2 and appears to have erupted from a fissure that trends northwest-southeast. Many other lava flows are present in the region, and some of them also are associated with fissures. None of the other flows in the region are as dark as the low-albedo flow at 20.6°S, 98.6°W, but some flows in the region have dark margins. The flow is not entirely dark, however, as part of it has a bright surface. This bright patch could be caused by dust trapped on a small portion of the flow's presumably rough surface, but it could also be a local tephra deposit. Hodges and Moore [15] noted the similarity between this particular flow and the Kings Bowl Lava Field on the Snake River Plain in Idaho. The feature known as "Kings Bowl" is a small volcanic crater in the center of the lava field, from which a deposit of bright tephra was erupted about 2100 years ago [16].

The explosive phase of the Kings Bowl eruption was caused by magma interaction with groundwater. Could the flow in Syria Planum have also involved explosive interaction with groundwater? Higher-resolution images (*e.g.,* better than 20 m/pixel) would be helpful in determining the surface characteristics of this dark flow.

DARK FLOW IN CERBERUS. The second low-albedo lava flow lies at the northeastern end of the classical low-albedo feature, Cerberus. The flow originates at one of the Cerberus Rupes fissures at 16.1°N, 199.5°W [17]. The flow extends about 250 km to the southwest (see *Viking* orbiter images 883A 04, 06). The flow appears to have a lower albedo (*i.e.,* < 0.10) than the dark aeolian material in the same region. The Cerberus Rupes fissures might have been the source of other relatively young volcanic flows and possible pyroclastic deposits [15, 17], but this flow is the only one that appears to be dark. The Cerberus Rupes extend into the Elysium Basin. In addition to being sources of volcanism, the Cerberus Rupes might have been a source for water that carved streamlined islands located near 9°N, 204.8°W [17]. The Elysium Basin in general appears to have been both the site of an Amazonian sea [18] and very late Amazonian volcanism [19].

DISCUSSION. How did these two lava flow surfaces remain dark since the time of their eruption, when all other lava flows on Mars observed to date do not appear to be dark-hued? For some reason, they did not retain a coating of fine, bright dust following the major global dust storms (1973, 1977) observed in the same decade that the flows were imaged by the *Viking* orbiters.

The lava flow in Cerberus is associated with the dark Cerberus albedo feature, which might be a sandy aeolian environment [20]. It is therefore possible that abrasion by windblown sand could have helped keep the Cerberus flow dark. However, the dark Cerberus albedo feature overlies many other lava flows that are not dark and appear to be older than the dark flow described here. How could sand-blasting cause one lava flow to appear dark but not the others?

The lava flow in Syria Planum is not associated with any other low albedo surface features. Thus, the possibility of sand-blasting is difficult to invoke in the case of Syria Planum.

We conclude that both dark lava flows described here are very young relative to most other lava flows on Mars. The flow at Cerberus has a few small superposed craters (< 3 km diameter), suggesting that it might not be extremely young, however, all of the volcanic features associated with the Cerberus Rupes and Elysium Basin are very young relative to other volcanic landforms on Mars [19]. The lava flow in Syria Planum is too small relative to the available image resolution to determine if there are any superposed craters. It is entirely possible that this flow is less than 10^6 years old, perhaps less than 10^3 years if the low albedo is due to lack of net deposition of dust on its surface.

CONCLUSION. Low-albedo lava flows might be good indicators of the geographic locations of relatively recent martian volcanism. Places where volcanism was most recent have the highest potential for finding geothermal and hydrothermal processes that are active today. The association of volcanic, fluvial, and lacustrine features in the Cerberus and Elysium region [17–19] make this area more likely than Syria Planum to be a site of recent or active hydrothermal systems. However, both regions described here warrant additional examination using *Mars Global Surveyor* and future Mars Surveyor orbiter spectrometers and cameras.

ACKNOWLEDGMENTS. The term “Warm Havens” was borrowed, with respect, from B. M. Jakosky’s paper “Warm havens for life on Mars” [5].

REFERENCES: [1] McKay, D.S., *et al.* (1996) *Science, 273*, 924–930; [2] McKay, C.P., and C.R. Stoker (1989) *Rev. Geophys., 27*, 189–214; [3] Klein, H.P. (1996) *Icarus, 120*, 431-436; [4] An Exobiological Strategy for Mars Exploration (1995) *NASA SP-530*; [5] Jakosky, B.M. (1996) *New Scientist, 150*, 38–42; [6] Christensen, P.R. *et al.* (1992) *JGR, 97*, 7719–7734; [7] Lucchitta, B.K. (1987) *Science, 235*, 565–567; [8] Lucchitta, B.K. (1990) *Icarus, 86*, 476–509; [9] Edgett, K.S., and P.R. Christensen (1994) *JGR, 99*, 1997–2018; [10] Thomas, P., and C. Weitz (1989) *Icarus, 81*, 185–215; [11] Bell, J.F. III, *et al.* (1997) *LPS XXVIII*; [12] Thomas, P. (1984) *Icarus, 57*, 205–227; [13] Rice, M.A., *et al.* (1996) *Sedimentol., 43*, 21–31; [14] Christensen, P.R. (1986) *JGR, 91*, 3533–3545; [15] Hodges, C.A., and H.J. Moore (1994) *USGS Prof. Pap. 1534*; [16] King, J.S. (1977) in *Volcanism on the Snake River Plain, Idaho* (R. Greeley and J.S. King, eds.), NASA publ., pp. 153–163; [17] Edgett, K.S., and J.W. Rice, Jr. (1995) *LPS XXVI*, 357–358; [18] Scott, D.H., and M.G. Chapman (1991) *Proc. LPS, 21*, 669–677; [19] Plescia, J.B. (1990) *Icarus, 88*, 465–490; [20] Edgett, K.S. *et al.* (1994) *LPI Tech. Rept. 94-04*, 25.