MUD VOLCANOES IN THE MARTIAN LOWLANDS: POTENTIAL WINDOWS TO FLUID-RICH SAMPLES FROM DEPTH. Dorothy Z. Oehler[1] and Carlton C. Allen.[1] [1]Astromaterials Research and Exploration Science, NASA-JSC, Houston, TX 77058. dorothy.z.oehler@nasa.gov; carlton.c.allen@nasa.gov.

Introduction: There is a growing awareness of potential, widespread mud volcanism in the lowlands of Mars. Structures likened to mud volcanoes have now been described from Utopia [1-2], Isidis [3], northern Borealis [4], Acidalia Planitia [5-7], southern Chryse Planitia [8], and we add central Chryse Planitia (Fig. 1).

On Earth, mud volcanoes form when overpressured gases and liquids in the subsurface erupt to the surface, carrying slurries of fluid, mud, and millimeter-to-meter sized rocks [12-14]. The driving force is generally a combination of overpressure and compression. These conditions often occur in orogenic belts and involve hydrocarbon generation, but other mechanisms (*e.g.* rapid sedimentation with gas hydrate destabilization or clay dewatering) have been suggested as well [12, 14]. 3-D seismic data illustrate the subsurface conduits through which the slurries ascend [15], and these data, coupled with downhole geological, geochemical and biostratigraphic analyses [16-18], demonstrate that rock and mud within surface exposures of mud volcanoes can originate from depths of several kilometers.

On Mars, occurrences of mud volcanoes would be important, as they would signal subsurface localities previously, or even presently, rich in volatiles. Of even greater consequence is the possibility that martian mud volcanoes may have transported rocks and sediment from deep, fluid-rich zones to the surface where they could be accessible to future rovers. In this way, mud volcanoes on Mars could provide access to samples from considerable depths that would otherwise be unreachable.

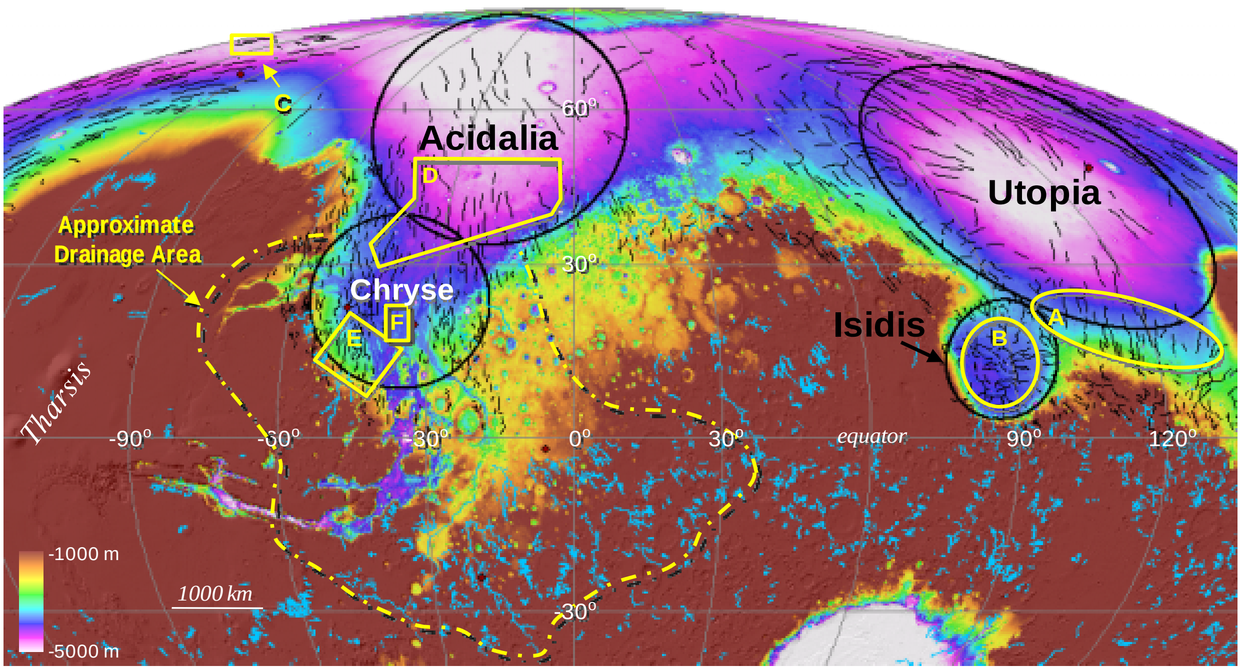

Fig. 1. MOLA topography illustrating regional setting of potential mud volcanoes (yellow polygons and ovals) in the martian lowlands. A, [1-2]; B, [3]; C, [4]; D, [5-7]; E, [8]; F, this study. Proposed ancient impact basins (black circles/ovals) [9]. Channels in the highlands (light blue lines) mapped by M. Carr [10]. Ridges (black straight lines) from [11]. Mollweide projection.

Observations: Features described as potential martian mud volcanoes include sub-circular domes, cones, and nearly flat features, hundreds of meters to several kilometers in size, with variable numbers of summit pits (or none at all) [1-8]. They occur in irregular clusters and occasional chains. Their sub-circular morphology, diversity of form, and clustered occurrence are characteristics typical of mud volcanoes on Earth. In Acidalia Planitia, hundreds of such structures have been described [5]; many are bright in THEMIS Daytime IR and dark in THEMIS Nighttime IR, suggesting that they are composed of fine grained and/or unconsolidated materials. Dozens of similar features occur in central Chryse Planitia (Fig. 2), and both groups are relatively young in that they overlie/intrude units mapped by Tanaka *et al.* [11] as late Hesperian to early Amazonian.

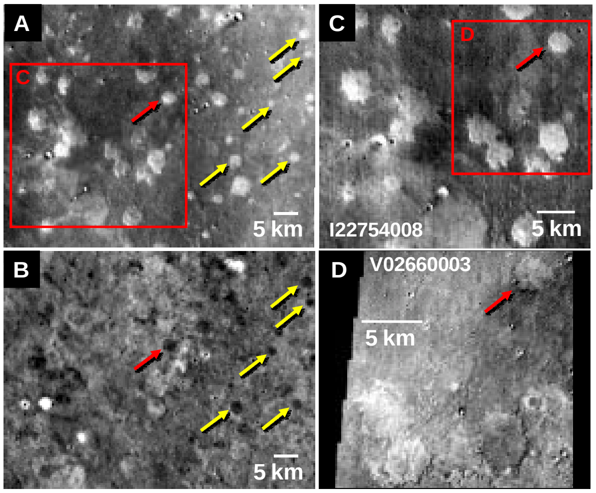

Fig. 2. Potential mud volcanoes, central Chryse Planitia. **A-B**, Same area; **A**, THEMIS Daytime IR; **B**, THEMIS Nighttime IR. **C**, Detail of rectangle in A. **D**, Detail of rectangle in C, THEMIS Visible Image. A-B from IR mosaics in [10]. Colored arrows point to same features in A-D.

Discussion: Of all the regions with potential mud volcanoes, the Chryse-Acidalia area is remarkable in having received extraordinary amounts of sediment and fluid from both the Hesperian circum-Chryse outflows and runoff through channels mapped by M. Carr (Fig. 1) in the highlands [10]. Moreover, accumulation of great thicknesses of those inflowing materials may have been facilitated by the embayment-like geometry of this area (Fig. 3) and by trapping in ancient impact basins, such as those proposed for Chryse and Acidalia (Figs. 1, 3) from quasi-circular-depressions [9]. On Earth, rapid and massive sedimentary accumulation often results in overpressure and this may have occurred in the Chryse-Acidalia region, as well.

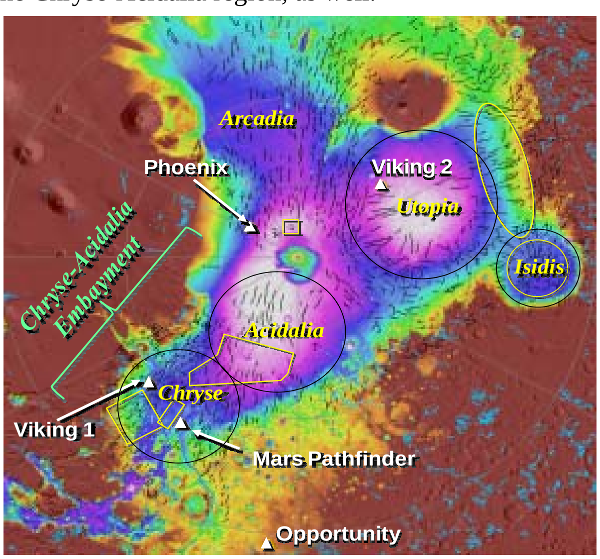

Fig. 3. MOLA topography of martian lowlands in polar stereographic projection. Previous landing sites indicated by triangles. Color scale and symbols as in Fig. 1.

In the accumulating martian deposits, pore waters in the shallowest strata eventually would have frozen and sublimed. The remaining lag could have provided protection for sediments below, minimizing sublimation and perhaps preserving subsurface ice and possibly even liquid water in deeper pore spaces. Since the rivers flowing into the Chryse-Acidalia embayment would have drained a large area of the highlands (Fig. 1), microbial life forms that might have been present anywhere in that catchment area could have been transported with the sediments to the embayment and may have persisted in the liquid or icy pore waters at depth. Subsequent compression (perhaps from Tharsis-related thrusting, hydrothermal pulses, clathrate destabilization, or local impacts) might have initiated late Hesperian to Amazonian mud volcanism in the potentially overpressured, thick sediment piles. Finally, remains of any martian life that may have existed at depth may have been brought to the surface with the ascending slurries of mud and rock.

Conclusions: The regional setting of the Chryse-Acidalia area augurs well for a fluid-rich subsurface, accumulation of diverse rock types reflecting the wide catchment area, astrobiological prospectivity, and mud volcanism. This latter provides a mechanism for transporting samples from relatively great depth to the surface. Since mud volcanoes are not associated with extreme heat or shock pressures, materials they transport to the surface are likely to be relatively unaltered; thus such materials could contain interpretable remnants of potential martian life (*e.g.*, organic chemical biomarkers, mineral biosignatures, or structural remains) as well as unmetamorphosed rock samples. None of the previous landings on Mars was located in an area with features identified as potential mud volcanoes (Fig. 3), but some of these features may offer targets for future missions aimed at sampling deep fluid-rich strata with potential habitable zones.

References: [1] Skinner J.A. & Tanaka K.L. (2007) Icarus *186*, 41-59. [2] Skinner J.A. *et al.* (2008) *LPS XXXIX*, Abs. 2418. [3] Tanaka K.L. *et al.* (2000) *LPS XXXI*, Abs. 2023. [4] Kite E.S. *et al.* (2007) *Europ. Mars Sci. Expl. Conf.*, Noordwijk. [5] Farrand W.H. *et al.* (2005) *JGR 110*, E05005:1-14. [6] Allen C.C. *et al*. (2008) *AGU 89* (53), Abs. P34A-05. [7] Allen, C.C. *et al.* (2009) *LPS XXXX*. [8] Rodriguez J.A.P. *et al.* (2007) *Icarus 191*, 545-567. [9] Frey H.V. (2006) JGR 111, E08S91. [10] MarsGIS DVD v. 1.4 (2008), prepared by T. Hare, USGS, Flagstaff. [11] Tanaka, K.L. *et al.* (2005) *USGS Scientific Investigations Map 2888*. [12] Kvenvolden K.A. & Rogers B.W. (2005) *Marine & Petrol Geol. 22*, 579-590. [13] Steward S.A. & Davies R.J. (2006) *AAPG Bull. 90*, 771-786. [14] Hovland M. *et al.* (2006) *AAPG Hedberg Conf.*, Trinidad. [15] Davies R.J. & Steward S. (2005) *J. Geol. Soc. London 162*, 1-4. [16] Deville E. *et al.*, (2003) *AAPG Ann. Meet.* Abs. 30017. [17] Deville E. *et al.* (2003) *Geol. Soc. (London.) Sp. Pub. 216, 475-490. [18] Barvalina O. (2003) Intergov. Oceanog. Comm. Wkshp. Rept. 187.*