THINKING LIKE A WILDCATTER – PROSPECTING FOR METHANE IN ARABIA TERRA, MARS.

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Introduction: Methane has been detected in the martian atmosphere at a concentration of approximately 10 ppb [1-4]. The lifetime of such methane against decomposition by solar radiation is approximately 300 years, strongly suggesting that methane is currently being released to the atmosphere. By analogy to Earth, possible methane sources on Mars include active volcanism, hot springs, frozen methane clathrates, thermally-matured sedimentary organic matter, and extant microbial metabolism. The discovery of any one of these sources would revolutionize our understanding of Mars.

The concentration of atmospheric methane is generally constant around the planet, reflecting effective mixing of the atmosphere. However, measurable variations have been observed by the Planetary Fourier Spectrometer (PFS) on Mars Express, suggesting localized sources of this gas [4]. The highest values have been measured over three large areas: Arabia Terra, Elysium Planum, and Arcadia-Memnonia. We are employing the extensive geological and geophysical datasets from Viking, Mars Odyssey, and Mars Global Surveyor in a search for possible methane sources in Arabia Terra. Arabia Terra was chosen for study as it contains indicators of sedimentary processes and water that are unique and thus may augur for the presence of biogenic methane.

Study Area: Arabia Terra, the northernmost extension of the cratered highlands, is approximately bounded by 0^o - 40^oN latitude and 20^oW - 60^oE longitude. The area is dominated by a regional slope, descending from +4000 m in the SE to -2000 m in the NW [5]. Arabia Terra is mapped predominantly as Noachian plains with minor Hesperian ridged units [6,7].

High-resolution Mars Orbiter Camera (MOC) images reveal distinct mappable layers, generally concentrated within impact craters, in western Arabia Terra [8]. This area exhibits some of the most prominent examples of widespread layering, interpreted as Noachian-age sedimentary rock [9]. Orbital images and Mars Orbiter Laser Altimeter (MOLA) mapping suggest that much of the layered rock originally present in this region has been removed by erosion [8,10].

Orbital gamma ray and neutron spectrometer measurements indicate that the near-surface of Arabia Terra contains abundant hydrogen, generally interpreted as water in either ice or hydrated minerals, relative to other parts of the martian highlands [11]. The cratering record suggests an enhanced and long-lasting concentration of ground ice in the region [12].

Approach: Our study uses a "new ventures" approach common to the oil industry to optimize the search for sources of methane in Arabia Terra. This approach involves creating and superimposing several maps which capture spatial distributions of critical parameters for methane generation and localization. The confluence, or intersection, of these maps will provide graphic representation of "***sweet spots***;" that is, regions most likely to be releasing methane to the atmosphere.

For the current study, we are investigating possible surface indicators of methane, geological/geophysical indicators of basins and hydrothermal areas, and potential methane release paths to the atmosphere.

Possible Surface Indicators of Methane. On Earth, hydrocarbon-induced alteration of soils and sediments can be expressed in a variety of manners including microbial, mineralogical, electrochemical, and radiation anomalies and the bleaching of red beds [13]. By analogy to hydrocarbon exploration [14], we are searching high-resolution MOC images for evidence of localized bleaching of iron-bearing rock. The bright crater rims common in Meridiani Planum (Fig. 1), immediately southwest of Arabia Terra, may be related to hydrocarbon-related bleached zones on Earth [15].

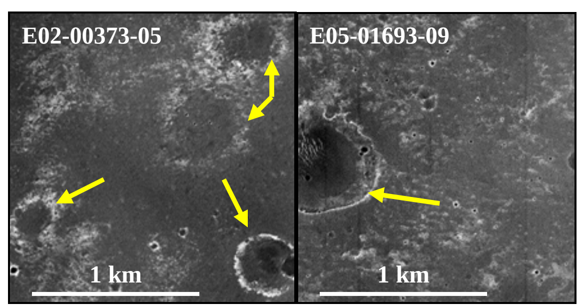

Figure 1. MOC images of bright crater rings (arrows) at Meridiani Planum [16].

Geological/Geophysical Indicators of Basins or Hydrothermal Areas. On Earth, methane commonly is found in sedimentary basins, being produced either by living microbes or from thermal alteration of buried organic matter. The possibility of a major sedimentary basin in southwest Arabia Terra is suggested by impressive layered sediments (Fig. 2) that are apparent remnants of much more extensive deposits [8-10]. We are examining high-resolution MOC and Thermal Emission Imaging System (THEMIS) images in order to estimate the full areal extent of this layered deposit. We are also searching for evidence of subsurface basins in Bouguer and Free-Air gravity data derived from tracking orbiting spacecraft [17], as gravity often reflects major sedimentary accumulations on Earth.

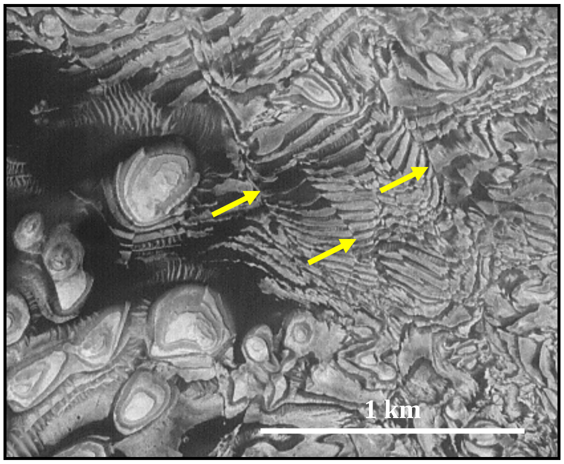

Figure 2. MOC image R14-01690 of Arabia Terra near 8°N, 7°W, showing layered deposits and NW-SE trending faults (arrows) offsetting layers [16].

Terrestrial volcanoes and hot springs can also release methane [1], but no young volcanics have been mapped in Arabia Terra at Viking orbiter resolution, though the Hesperian ridged units may be low-viscosity lava flows [6,7]. Similarly, no thermal anomalies suggestive of active hot springs have been recognized in orbital Thermal Emission Spectrometer (TES) data [18]. We are examining high-resolution MOC and THEMIS images for small-scale volcanic features and fossil hot springs that might have contributed to methane generation and release on the planet.

Potential Methane Release Paths to the Atmosphere. Gas accumulations on Earth often leak to the surface by way of faults and fissures, particularly in areas lacking seals such as permafrost or salt. Mapping at Viking resolution revealed a small number of 100 km-scale faults as well as a larger number of wrinkle ridges, almost all trending NW-SE [6,7]. We are examining high-resolution MOC and THEMIS images, as well as MOLA digital elevation models, for evidence of small-scale faults and fissures, to see if unsealed fracture systems might be coincident with concentrations of atmospheric methane.

Results: Initial examination of a subset of orbital data yields the following:

- Free-Air gravity maps show local lows up to hundreds of km across, some of which correspond to individual large craters. Work is continuing to determine the relevance of these gravity lows to potential sedimentary accumulations.
- As noted above, high-resolution MOC images show layering in craters of western Arabia Terra (Fig. 2) that has been interpreted as eroded sedimentary remnants. Further work will be aimed at determining the original extent of these layered deposits.
- High-resolution MOC images also show major faults displacing layers within craters (Fig. 2); this type of faulting, if in contact with subsurface methane, could provide conduits for methane leakage to the atmosphere.

New Data: Current and planned spacecraft have the potential to greatly improve our ability to prospect for methane. Further integration of the PFS data may refine the location of enhanced methane. The remote sensing suite on Mars Express is already producing maps of minerals, including clays and hydrates, that are often found in terrestrial localities affected by hydrocarbons. The 2005 Mars Reconnaissance Orbiter, with extremely high resolution and hyperspectral imaging, may permit confident identification of altered minerals and fossil hot springs. Finally, the gas chromatograph mass spectrometer selected for the Mars Science Laboratory should be able to confirm the detection of methane and, by stable isotope analyses, suggest whether or not the methane has a biogenic source.

References: [1] Krasnopolosky V.A. et al. (2004) *Icarus*, *172*, 537-547. [2] Krasnopolsky V.A. et al. (2004) *36th DPS Meeting*, Abs. [3] Mumma M.J. et al. (2004) *36th DPS Meeting*, Abs. [4] Formisano V. et al. (2004) *International Mars Conf.*, Abs. [5] Smith D.E. et al. (1999) *Science*, *284*, 1495-1503. [6] Scott D.H. & Tanaka K.L. (1986) *USGS Map I-1802-A*. [7] Greeley R. & Guest J.E. (1987) *USGS Map I-1802-B*. [8] Edgett K.S. & Malin M.C. (2002) *GRL*, *29*, 32-1 – 32-4. [9] Malin M.C. & Edgett K.S. (2000) *Science*, *290*, 1927-1937. [10] Hynek B.M. & Phillips R.J. (2001) *Geology*, *29*, 407-410. [11] Boynton W.V. et al. (2002) *Science*, *297*, 81-85. [12] Barlow N.G. & Dohm J.M. (2004) *LPSC XXXV*, Abs. [13] Schumacher D. (1996) *AAPG Mem. 66*, 71-89. [14] Oehler D.Z. & Sternberg B.K. (1984) *AAPG Bull.*, *68*, 1121-1145. [15] Oehler D.Z. et al. (2005) *LPSC XXXVI*, Abs. [16] NASA/JPL/Malin Space Science Systems. [17] Lemoine F.G. et al. (2001) *JGR*, *106*, 23-359-23-376. [18] Christensen P.R. et al. (2001) JGR, 106, 23,823-23,871.